1.1 Introduction to cells

Understandings:

∑= IB Objectives

Cell Theory

The main part of cell theory consists of three main aspects:

- Cells are the basic unit of structure in all living things (smallest unit of life)
- All living organisms are composed of cells.
- New cells are formed from pre-existing cells.

- The two scientists given credit to the first two parts of cell theory are Theodor Schwann and Matthias Schlieden (1839).
- Rudolf Virchow came up with the 3rd aspect that all cells come from pre-existing cells.
- More recently, scientists have added another aspect of the cell theory that states "All cells contain hereditary information (DNA) which is passed on from cell to cell during cell division"

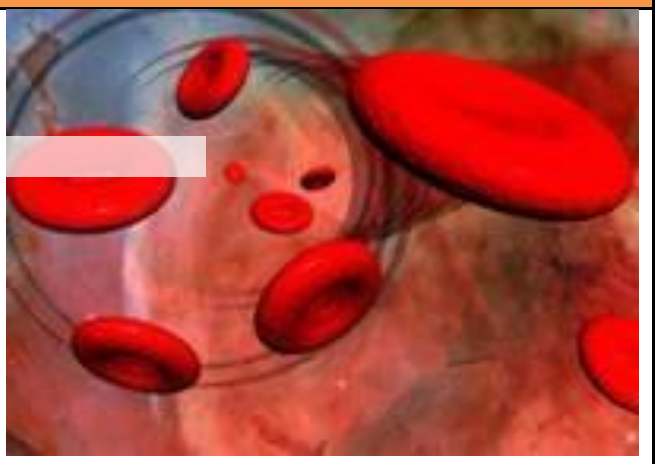
∑ According to the cell theory, living organisms are composed of cells.

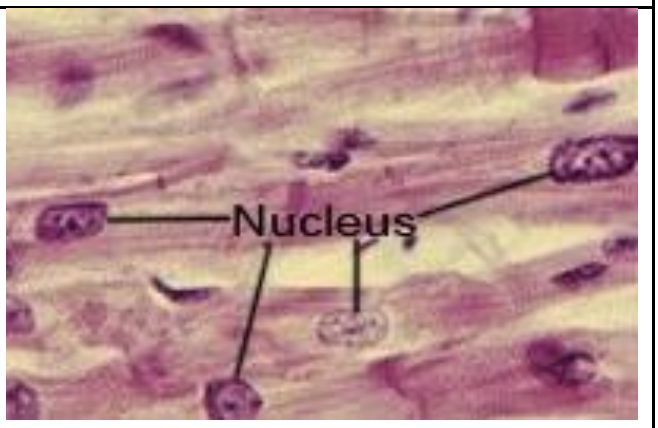
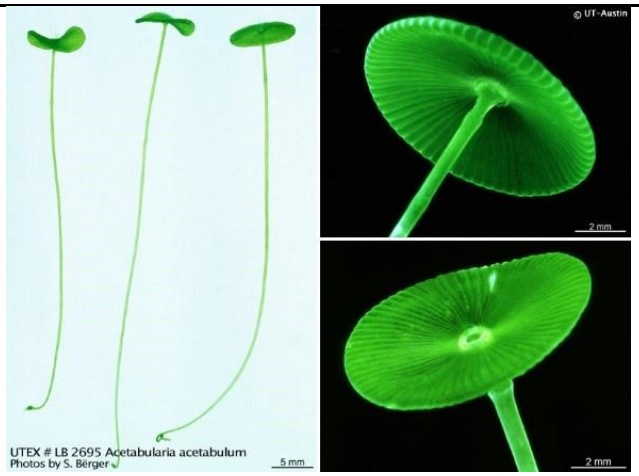
- Over the years many living organisms, both unicellular and multicellular, have been studied under microscopes and all have been found to be composed of cells.

- Cells vary extensively in size and shape, but contain certain commonalities such as a cell membrane, genetic material, chemical reactions catalysed by enzymes and the production of energy (ATP) through respiration.

Applications and skills: ß

ß Application: Questioning the cell theory using atypical examples, including striated muscle, giant algae and aseptate fungal hyphae.

Exceptions to General Cell Structure	Pictures
• Red Blood Cells are biconcave disks that carry oxygen to different tissues. • RBC lack a cell nucleus, cellular organelles and cannot synthesize protein Extra example	

• Fungal Cells can have multiple nuclei (multi-nucleated). • Fungi have cell walls made out of chitin surrounding threadlike structures called hyphae • Aseptate hyphae are one long continuous cell that are not separated by dividers called septa and therefore have many nuclei	
• Striated muscle cells are made up of contractile filaments that slide past each other. They have a single surrounding membrane, but can contain possibly 100's of nuclei.	
• Giant algae – Some uncommon algae exist that can actually grow up to approximately 1 cm. An example of this is Acetabularia, which is a genus of green algae. One would expect a cell of this size would consist of many cells, as it would have difficulty getting rid of metabolic waste.	 **http://arquivosilva.blogspot.ca/2012/08/acetabularia-desafia-genes.html**

ß - Skill: 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)

****This lab skill could be completed at the same time as the investigation of the paramecium and euglena.****

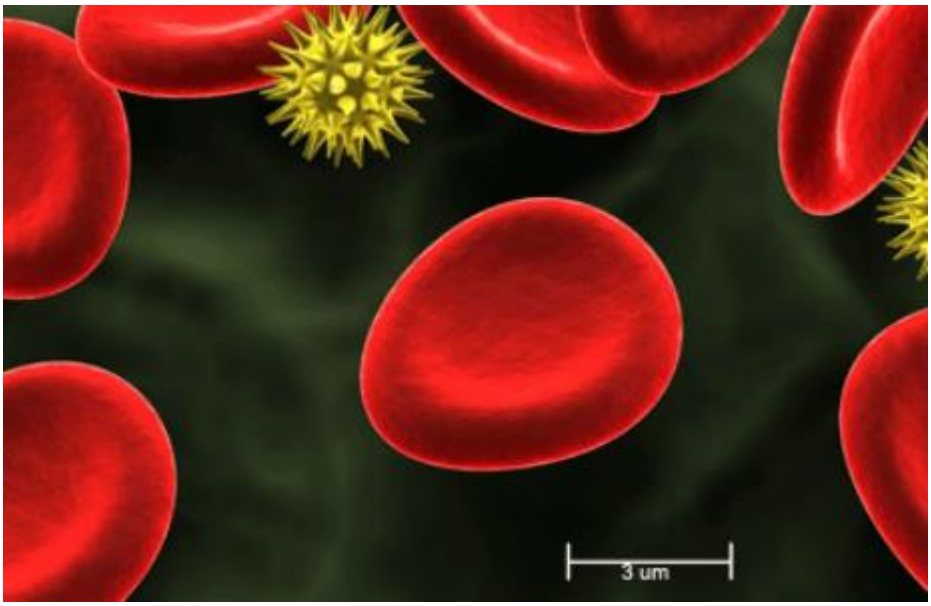
Using the formula Magnification = size of the image/actual size of the specimen

- Size of the image is how large a specimen appears in a photograph or a drawing.
- Actual size of the specimen simply means how big the specimen actually is.

Calculate magnification:

- Measure the actual specimen or a clear part of the specimen under a microscope using a clear ruler next to the specimen, so you can see the ruler under the microscope next to the specimen. This gives the actual size of the specimen value. In test questions, the actual specimen size can be given to you in order to calculate the magnification.
- Then measure the same specimen or part of the specimen represented in the drawing or photograph to get the value for size of the image.
- Make sure to convert the values to the same unit of measurement. For example if one value is mm and one value is µm, convert both to either µm or mm.
- Use the formula above to calculate magnification.

Scale bars are also used on many micrographs (photographs under a microscope), using a line to represent the actual scale or size of the image.



The scale shows that half of a red blood cell is about 3 µm

Actual image size is therefore based on the scale bar. You can then measure the size of the image with a ruler, convert the result into µm's and calculate magnification.

Note: The size of objects in digital images of microscope fields could be analysed using graticule baselines and image-processing software.

*****Complete introduction to microscope activity on the use of microscope, drawing cells and cell structure and calculating magnification*****

Complete data based questions on page 6 and 7 of your textbook.

∑ **Organisms consisting of only one cell carry out all functions of life in that cell.**

- Unicellular organisms carry out all the functions necessary for life including the following:

  a) Metabolism – the chemical reactions that occur in organisms in order for them to maintain life, such as the synthesis of ATP during cellular respiration.

  b) Response – organisms respond to their environment.

  c) Homeostasis – maintaining a stable internal environment within the cell.

  d) Growth – increase in size (volume and surface area) until the cell is too large to function efficiently.

  e) Reproduction – majority of prokaryotes reproduce through binary fission while single cell eukaryotes reproduce generally asexually, however some can also reproduce sexually through meiosis and then mitosis.

  f) Nutrition – creating or synthesizing their own organic molecules or consuming organic molecules.

- Unicellular organisms include Prokaryotes (bacteria) which lack a nucleus and membrane bound organelles, and most Protists which are Eukaryotes.

∑ **Surface area to volume ratio is important in the limitation of cell size.**

- 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 isproportional to the volume of the cell, while the exchange of these materials and heat energy is a function of the cell's surface area.
- As the size of an object or a cell increases, its volume increases faster in comparison to the surface area of that object because volume is **x^3(cubed),** while the surface area of an object or cell is only **x^2 (squared).**
- This means as a cell increases in size, its surface area to volume ratio (SA/V) will decrease.
- You can clearly see this by looking at cubes of varying sizes.

Side Length	SA (cm^2)	Volume (cm^3)	SA/Volume Ratio
1	6	1	6 : 1
5	150	125	1.2 : 1
10	600	1000	3 : 5

100	60,000	1,000,000	3 : 50
1000	6,000,000	1,000,000,000	3 : 500

- 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 absorbedand 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.

ß - Application: Investigation of functions of life in Paramecium and one named photosynthetic unicellular organism.
(Paramecium and Euglena can be observed with a light microscope)

- Paramecium
  - Have a macronucleus and one or more micronuclei. The macronucleus expresses thegenes needed to carry out cell activities. The micronuclei contain the genetic material that is passed on asexually to the next generation through binary fission.
  - Have cilia used for movement
  - Contractile vacuole responsible for expelling water and waste
  - Metabolic reactions catalysed by enzymes take place in the cytoplasm
  - Consume food through an oral groove into the mouth opening ending up in vacuoles. These vacuoles digest the food using enzymes, passing on the nutrients back into the cytoplasm to be used for energy.
  - The outside is composed of a stiff but elastic membrane called a pellicle, which controls what enters and exits the cell. Excretion of waste through diffusion.

Showing paramecium movement, feeding and other life processes
https://www.youtube.com/watch?v=WFpBRfLtbIo

- Euglena
  - Contains chloroplasts surrounded by three membranes that carry out photosynthesis
  - Chloroplasts also contain pyrenoids which create a carbohydrate similar to starch called paramylon for periods of low light
  - Outer cell membrane consists of a stiff pellicle allowing the Euglena to maintain its shape
  - Have two flagella, one is quite long and is used for movement
  - Have an eyespot that is sensitive to light, which allows the euglena to sense sunlight or photosynthesis
  - Contain contractile vacuoles that excrete excess water and waste
  - DNA is contained within a nucleus, which controls cellular activities
  - Cell division through binary fission
  - Euglena are both autotrophic and heterotrophic organisms

Showing flagellum movement of the Euglena

https://www.youtube.com/watch?v=jl0TzaWUQWk&feature=endscreen

∑ Multicellular organisms have properties that emerge from the interaction of their cellular components.

- Emergent properties arise from the interaction of component parts, i.e. the whole is greater than the sum of its parts.
- Emergence in science and system theories is defined as how complex systems and patterns arise out of a multiplicity of relatively simple interactions. Basically, complex life systems involve millions of small simple interactions that work together to allow the complex system to function properly.
- For example, the cohesive properties of water are an emergent property that allows water to be "sticky" or a natural attraction to itself. Water therefore can easily move up trees from the roots to the cells involved in photosynthesis in the leaves. The component parts would be the interactions between the water molecules; more specifically the hydrogen bonding between oxygen and hydrogen molecules.

∑ Specialized tissues can develop by cell differentiation in multicellular organisms.

- Differentiation is basically the process where a less specialized cell becomes a more specialized cell.
- Large multi-cellular organisms need to have specialized cells in order to live and function efficiently
- Differentiation changes a cell's size, shape, membrane potential, metabolic activity, and responsiveness to signals.
- In development after the zygote divides to form the blastocyst (around 120-130 cells), and then the gastrula, which is differentiated into several dermal layers of cells (mesoderm, endoderm, ectoderm, and germ cells) that form into specific specialized cells.

∑ Differentiation involves the expression of some genes and not others in a cell's genome.

- Differentiation in cells is controlled by gene expression, which means some genes are turned on or turned off in specific cells that relates to their function.
- For example, a nerve cell will contain all genetic information that other cells have; however, the genes for the nerve cell are turned on or expressed while the genes for other cells, for example a pancreatic cell, are shut off.
- When a gene is turned on, it will produce specific proteins or products that allow that cell to function properly.
- Some cells when they differentiate lose their ability to reproduce such as nerve cells and muscle cells, while some cells retain this ability throughout their lives, like skin epithelial cells.

∑ 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 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)

Bone Marrow Transplants

- 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 marrowtissue.
- These cells will divide continually to form new red and white blood cells.
- 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.

Embryonic stem cells can also be used to **regenerate skin tissue** for people that have been badly burned or for healing diseases such as **type 1 diabetes** by **replacing the damaged insulin producing beta cells.**

Non-therapeutic uses include creating **meat (muscle fibres)** for human consumption that has been grown in a lab.
https://www.youtube.com/watch?v=2o0MCZwL_VE

ß - Application: Use of stem cells to treat Stargardt's disease and one other named condition.

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  - **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
  - More human trials are needed
  - http://www.bbc.co.uk/news/health-15025009
    https://www.youtube.com/watch?v=zPvaVLNrvrc

  - **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.

ß - Application: 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.

The sources of stem cells are as follows:

1. ***Embryonic stem cells*** – fertilize egg with sperm, fusion forms a zygote, the cell will now divide by mitosis till it is about 12-16 cells. These are all embryonic stem cells. They can differentiate into any cell type but have a higher risk of becoming tumour cells. There is also less chance that the cells have genetic damage as they are very new and don't have time to accumulate mutations like adult stem cells.
   Documentary on understanding embryonic stem cells
   https://www.youtube.com/watch?v=nYNBNZJ8Xck
2. ***Umbilical Cord Stem Cells*** – stem cells obtained from the cord, can be frozen and used later on in life. These are easily obtained and stored after birth.
   https://www.youtube.com/watch?v=C4rYL0frngM
   (Good video on cord stem stem cells)
3. ***Adult Stem Cells*** – obtained from some adult tissue such as bone marrow. They are difficult to obtain and have less growth potential and limited capacity to differentiate when compared to embryonic stem cells; however, they are fully compatible with adult's tissue (no rejection) and there is less chance for a malignant tumour to occur.
   https://www.youtube.com/watch?v=w9wIxe4WGFg
   (Adult Stem Cells cure blindness video)

Ethical Concerns

- The therapeutic use of stem cells involves the creation and the death of an embryo that 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.
- Also once a blastula is created, some people believe this might lead to reproductive cloning (the cloning of an entire human). This means that embryo would have to be implanted into a surrogate mother.
- Therapeutic cloning uses human eggs, which can only be obtained from a woman. The most common source of these eggs, are eggs that are produced in excess of the clinical need during IVF treatment. This also might create the problem of woman trying to sell their eggs for stemcell research. A human egg market might develop in the poorer countries in the world.
- Possible health risks involved in treating women with hormones to induce hyperovulation to provide eggs for research.
- Even though scientists argue that the embryos that are created by IVF (in vitro fertilization)wouldn't not have existed anyways unless they create them and no human that would have otherwise lived is denied a chance of living, others argue it is unethical to create human life for the sole purpose of harvesting stem cells.
- The arguments for stem cells is that it allows treatment for diseases that are currently incurable and reduces suffering in many sick and disabled people

1.2 Ultrastructure of cells

∑ = IB Objectives

Understandings:

The next two understandings point are basically asking to compare and contrast prokaryotes and eukaryotes (previous syllabus) but with a focus on compartmentalization. The following goes with the comparison in the table below.

∑ **Prokaryotes have a simple cell structure without compartmentalization.**

- 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.

∑ **Eukaryotes have a compartmentalized 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 bond organelles such as the nucleus and the mitochondria. Some advantages of compartmentalization are

    1) Enzymes that serve a specific function or catalyze a specific reaction can be concentrated within the compartment instead of being spread throughout the cytoplasm.

    2) Ideal conditions or particular processes can be maintained within the compartments such as pH

    3) Organelles with their content can be moved around the cell

    4) Damaging substances such as digestive enzymes (lysosome) can be contained within their organelle.

Prokaryotic Cells	Eukaryotic Cells
• Small - less than 10µm	• Larger cells – greater than 10 µm
• DNA free within the cytoplasm	• DNA contained within the nucleus
• DNA in a ring free of proteins (naked DNA)	• DNA associated with proteins
• No membrane bound organelles	• Membrane bound organelles
• No mitochondria	• Mitochondria present
• 70s ribosomes	• 80s ribosomes
• No internal compartmentalization to form organelles	• Internal membranes that compartmentalize their functions
• **Reproduction through binary**	• Reproduction through mitosis and

fission	meiosis

∑ Electron microscopes have a much higher resolution than light microscopes.

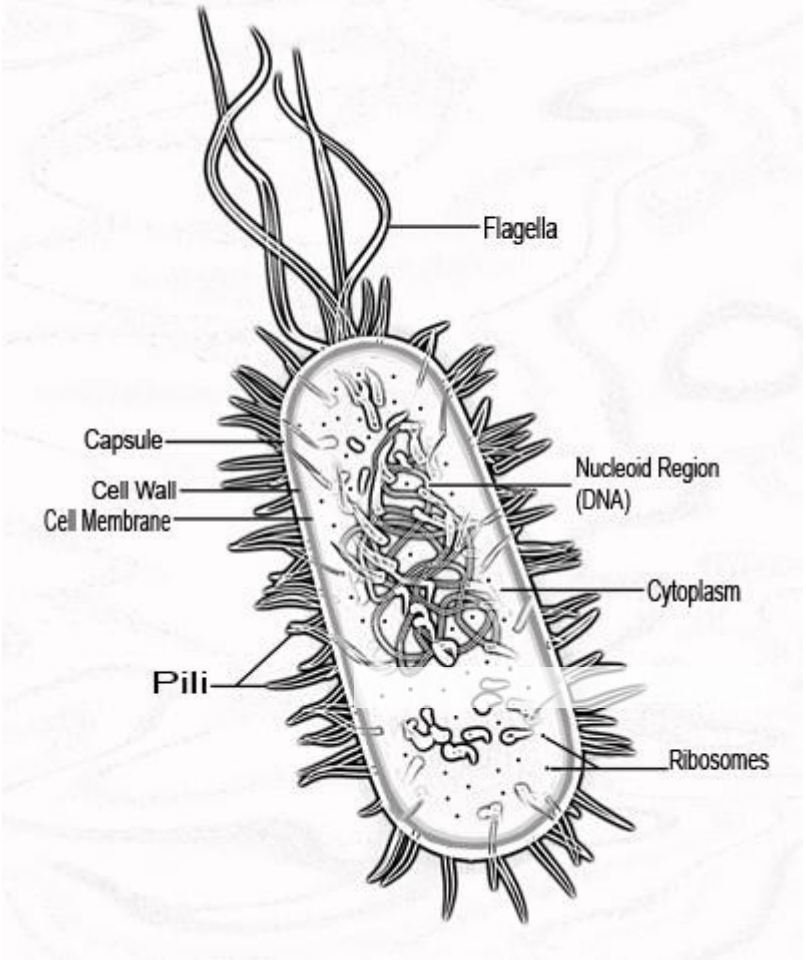
- The limit of resolution is the minimum distance that can be observed before two objects merge together to form one object. The smaller the limit of resolution the higher the resolving power.
- Electron microscopes have a greater resolution (about .001 μm) when compared to a light microscope (about 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)

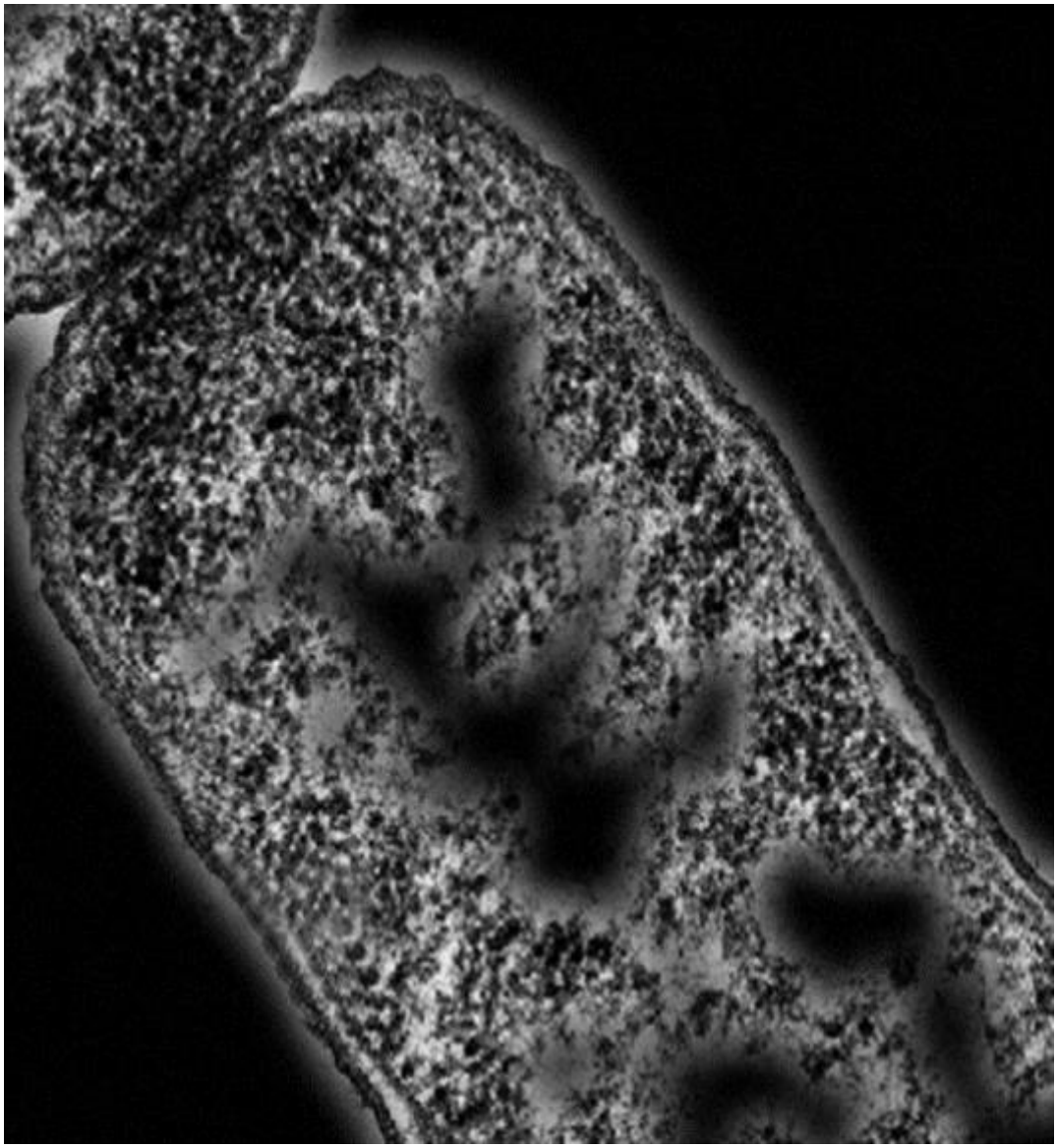
∑ Prokaryotes divide by binary fission.

- Binary fission is the form of asexual cell division that results in the reproduction of two genetically identical prokaryotic cells.

- All prokaryotic cells divide by binary fission.

ß - Skill: Drawing of the ultrastructure of prokaryotic cells based on electron micrographs





- The nucleoid region is the dark region in the middle (in other micrographs with a light background, the nucleoid region could possibly by a light region without ribosomes).
- You can see the cell wall surrounding the cell.
- Ribosomes are the black dots within the cytoplasm.
- The pili are not visible on this cell.

Applications and skills: ß

ß - Application: Structure and function of organelles within exocrine gland cells of the pancreas and within palisade mesophyll cells of the leaf.

Exocrine Gland Cells of the Pancreas

- These are animal cells that are specialized to secrete large quantities of digestive enzymes.
- They will have all the organelles of an animal cell but will have many ribosomes and rough ER to create the enzymes which are proteins and transport them outside the cell.
- They have many mitochondria to supply the ATP needed for these processes.

Here are the specific details of the functions of a eukaryotic animal cell

Ribosomes

- Produce proteins.
- Free ribosomes within the cytoplasm produce protein that will be used internally within the cell.
- Ribosomes attached to the rER produce proteins that will be secreted.

Golgi Apparatus

- Organelle found in most eukaryotic cells that processes and packages macromolecules such as proteins.
- Proteins are usually modified for secretion out of the cell.

Nucleus

- Known as the control center of the cell.
- The nucleus regulates cell activities through gene expression.
- Contains the majority of the cell's DNA.
- It is surrounded by a double membrane called the nuclear envelope, which has small nuclear pores to allow molecules to move in and out of the nucleus.

Mitochondria

- Membrane-bound organelles that carry out aerobic cellular respiration to create ATP.
- Contain highly folded inner membranes called cristae which increase the surface area to enhance the mitochondrion's ability to produce ATP (oxidative phosphorylation takes place here).
- Space enclosed by the inner membrane is called the matrix. This is where the Kreb's cycle takes place.
- Contain their own DNA genome.

Rough endoplasmic reticulum (rER)

- Site of protein synthesis (attached ribosomes) for secretion out of the cell.
- rER tubules are continuous with the outer layer of the nuclear envelope.

Lysosome

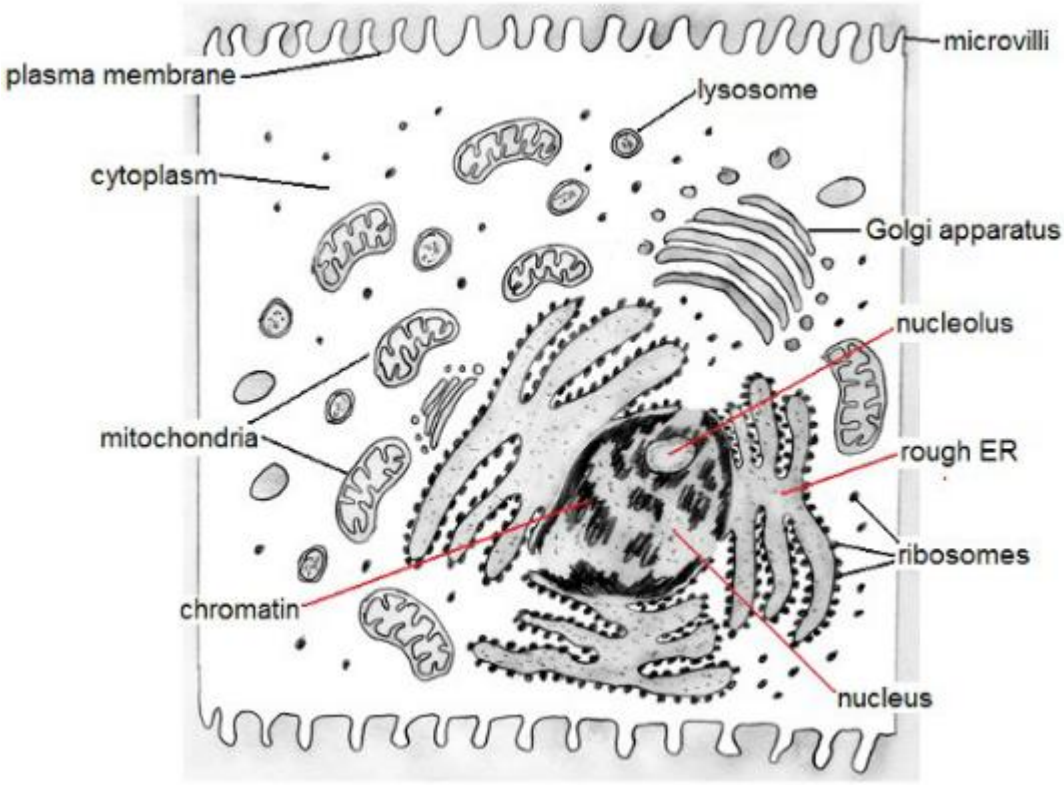
- Contains hydrolytic enzymes that digest worn-out organelles, food particles, and viruses or bacteria.
- Formed from the Golgi apparatus.
- Bounded by a single membrane.

ß - Palisade Mesophyll cells carry out most of the photosynthesis in the leaf.

- They have many chloroplasts to allow the cell to carry out the maximum levels of photosynthesis.

- The cells are surrounded by a cell wall to hold the shape of and protect the cell and a plasma membrane to allow substances in and out of the cell.
- They also have mitochondria which are membrane-bound organelles that carry out aerobic cellular respiration to create ATP.
- They have vacuoles which are a large cavity in the middle of the cell that stores water and dissolved substances, e.g. sugars and metabolic by-products
- They are basically plant cells with many chloroplasts.

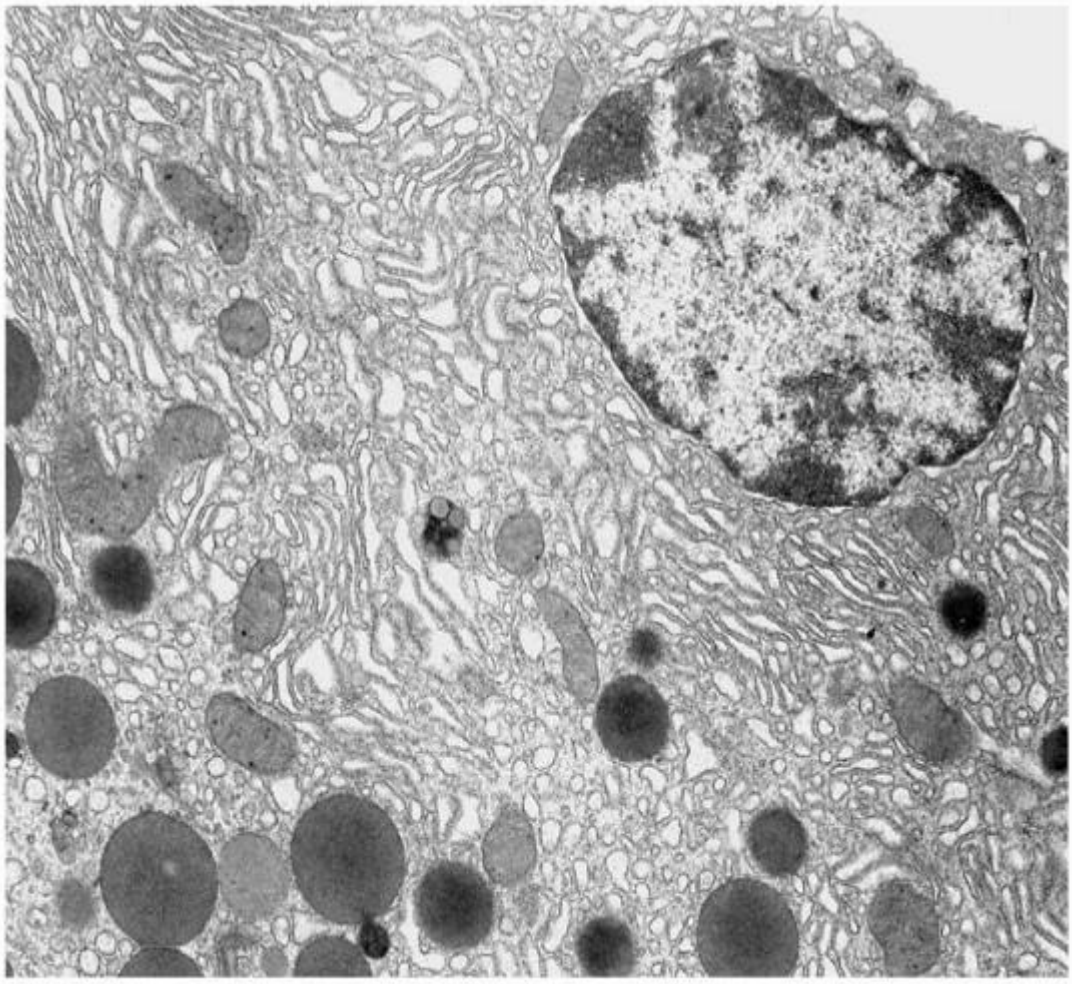
ß - Skill: Drawing of the ultrastructure of eukaryotic cells based on electron micrographs.



- The diagram above shows a animal cell like a liver cell which contains many ribosomes, rough endoplasmic reticulum (rER), lysosomes, Golgi apparatus, many mitochondria and the nucleus.
- Liver cells contain many mitochondria for energy and rough endoplasmic reticulum with ribosomes for secretion purposes.

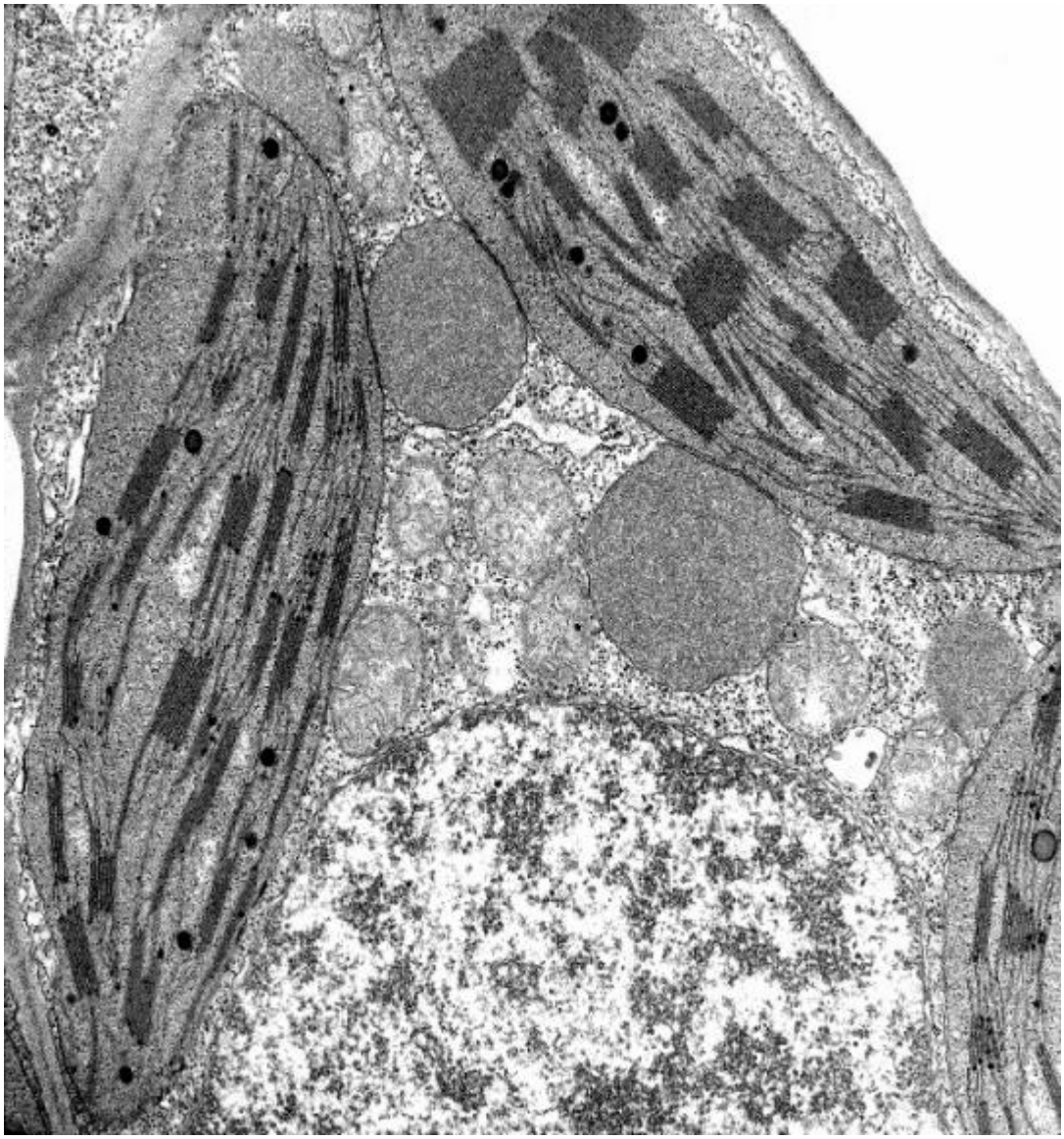
ß - Skill: Interpretation of electron micrographs to identify organelles and deduce the function of specialized cells.

- Identify as many structures and organelles you can from the two micrographs below. Also, practice with the 3 micrographs in your book on page 25



Courtesy of T. Howard, Cold Spring Harbor. Noncommercial, educational use only.

Animal cell



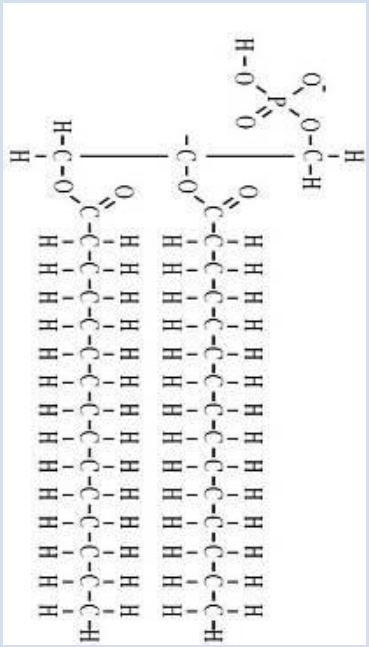
P lant Cell
Plant Cell
http://botit.botany.wisc.edu/Resources/Botany/Plant%20Cell/Electron%20Micrographs/General%20Cell/Nucleus%20microbodies%20chloroplasts.jpg

1.3 Membrane structure

Understandings: ∑

∑ - Phospholipids form bilayers in water due to the amphipathic properties of phospholipid molecules.

Hydrophilic and Hydrophobic Properties	Diagram of Phospholipid
• Cell membranes are composed of phospholipids that consist of **a hydrophilic (attracted to water) head**and a **hydrophobic (repelled by**	

water) tail • This property is described as**Amphipathic** • The phospholipid head contains anegatively charged phosphate group which because of its charge is attracted 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 • 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	

∑ - Membrane proteins are diverse in terms of structure, position in the membrane and function.

Hormone binding sites (receptor proteins)

- Proteins embedded in the membrane, which bind to specific hormones.
- When the hormone binds, it causes the receptor protein to undergo a conformational change, which signals the cell to perform a function.
- For example, insulin receptors.

Immobilized Enzymes

- Integral proteins that catalyze specific chemical reactions.
- Many of these enzymes catalyze metabolic reactions or are a part of a metabolic pathway, such as ATP Synthase in aerobic respiration.

Cell Adhesion

- Proteins that form tight bonds between adjacent cells in tissues and organs.
- For example, gap junctions.

Cell-to-cell communication

- Receptors for neurotransmitters at synapses between two nerve cells.
- Glycoproteins on the surface can also be used for cell identification purposes.

Channels for passive transport

- Integral proteins that span the membrane and provide a passageway for molecules to move from an area of high concentration to low concentration.
- Specific proteins are also used for facilitated diffusion.

Pumps for active transport

- Proteins that use ATP to move substances from a low concentration to a high concentration across the membrane.
- For example, Sodium/Potassium (Na+/K+) pumps and the proton (H+) pumps

∑ - Cholesterol is a component of animal cell membranes.

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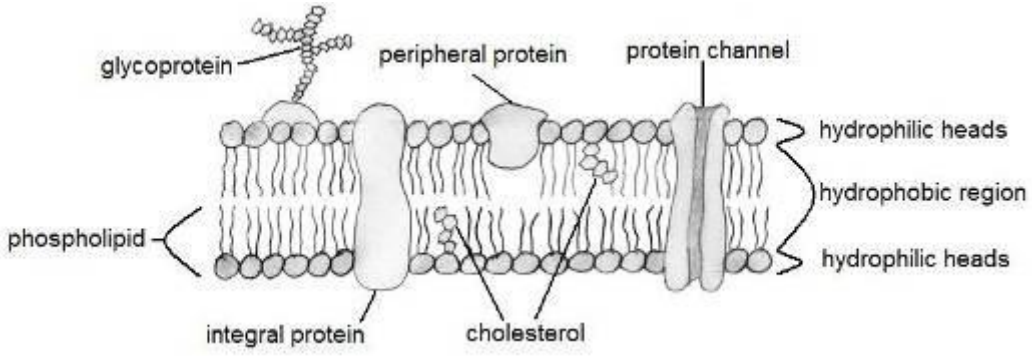
- Most of the cell membrane contains phospholipids and proteins
- Cholesterol is a lipid that belongs in the steroid group and is also a component of the cell membrane
- Most of the cholesterol molecule is hydrophobic and therefore embeds within the tails of the bilayer. A small portion (hydroxyl –OH group) is hydrophilic and is attracted to the phospholipid head

Applications and skills: ß

ß - Application: Cholesterol in mammalian membranes reduces membrane fluidity and permeability to some solutes.

- 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.
- At the high concentrations it is found in our cell's plasma membranes (close to 50 percent, molecule for molecule) cholesterol helps separate the phospholipids so that the fatty acid chains can't come together and crystallize.
- Therefore, cholesterol helps prevent extremes-- whether too fluid, or too firm-- in the consistency of the cell membrane

ß - Skill: Drawing of the fluid mosaic model.

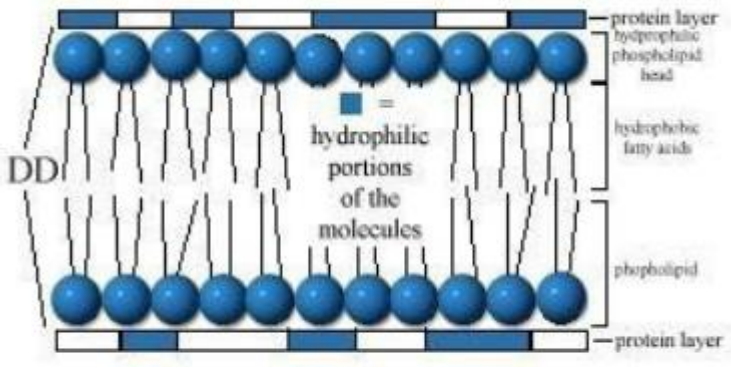


- The diagram of the plasma membrane above shows the phospholipid bilayer, cholesterol, glycoproteins, and integral (transmembrane) and peripheral proteins. Integral proteins are embedded in the phospholipid of the membrane, whereas peripheral proteins are attached to its surface. Glycoproteins are carbohydrates attached to surface proteins.

ß - Skill: Analysis of evidence from electron microscopy that led to the proposal of the Davson-Danielli model.

ß - Skill: Analysis of the falsification of the Davson-Danielli model that led to the Singer-Nicolson model.

- Davson and Danielli proposed a the theory that the lipid bilayer was coated on either side with a layer of globular proteins (as seen below)



Davson-Danielli-Modell

- Using your text, the web and the library analyze the evidence and the falsification of the Davson-Danielli model of the cell membrane by completing the analysis on page 26-27 in your text.

1.4 Membrane transport

∑ = **IB Objectives**

Understandings:

∑ - Particles move across membranes by simple diffusion, facilitated diffusion, osmosis and active transport.

- Diffusion is the passive movement (does not require energy) of particles from a region of high concentration to a region of low concentration.
- Passive transport means there is no expenditure of energy (ATP).
- Passive transport requires the substance to move from an area of high concentration to low concentration.

Osmosis is the passive movement of water molecules, across a semi-permeable membrane, from a region of lower solute concentration to a region of higher solute concentration.

Simple diffusion is the passive movement of particles from an area of high concentration to an area of low concentration (follows its concentration gradient).

- Simple diffusion across membranes occurs when substances other than water move across the phospholipid bilayer (between the phospholipids) or through protein channels.
- Substances that move across the membrane are usually small non-charged particles (i.e. Oxygen, Carbon Dioxide, and Nitrogen) or other lipids.

Facilitated Diffusion - Specific ions and other particles that cannot move through the phospholipid bilayer sometimes move across protein channels

- During facilitated diffusion the membrane protein changes its shape to allow a specific substance to move across the membrane.
- 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.

Active transport is movement of substances across membranes using energy from ATP.

- Active transport generally moves substances against their concentration gradient (low to high concentration).
- 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.

Good link for membrane transport
https://www.youtube.com/watch?v=svAAiKsJa-Y

∑The fluidity of membranes allows materials to be taken into cells by endocytosis or released by exocytosis. Vesicles move materials within cells.

- The phospholipids in the bilayer are loosely packed together creating fluidity and allowing movement along the horizontal plane.
- The hydrophilic properties of the phosphate heads and the hydrophobic properties of the hydrocarbon tails prevent flipping of the molecules across the vertical plane, maintaining the stable bilayer.
- Cholesterol embedded in the membrane will reduce the fluidity making the membrane more stable.

Endocytosis

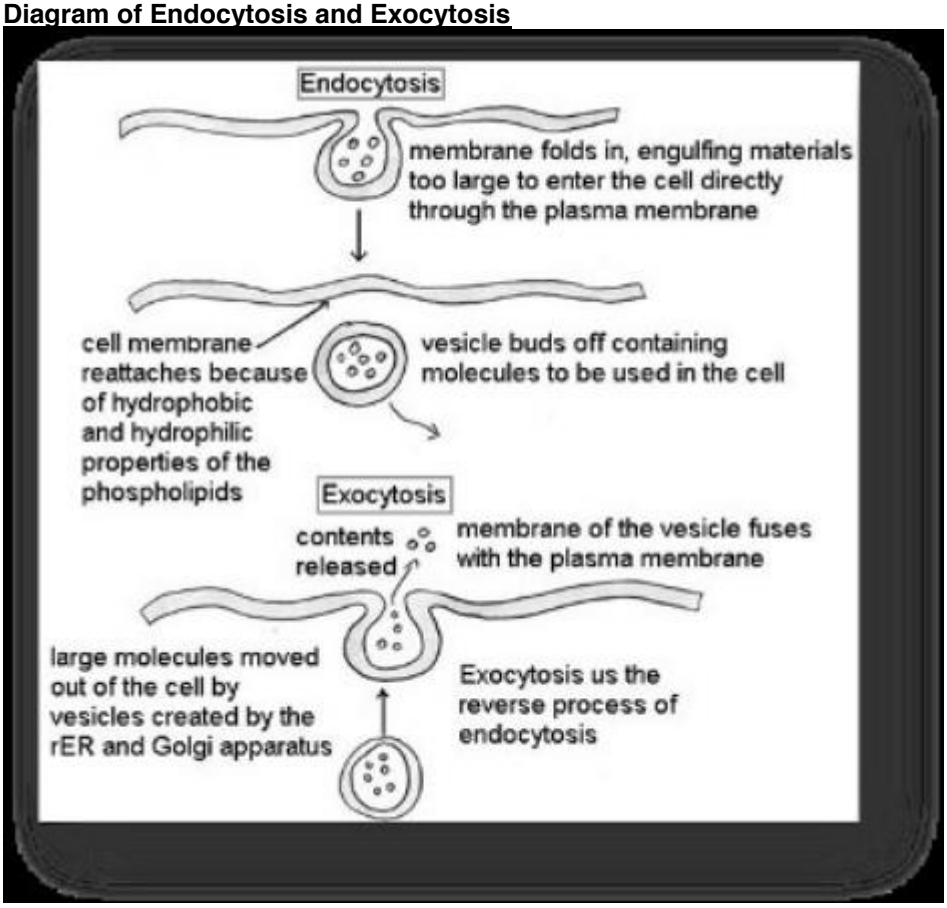
- Plasma membrane is pinched as a result of the membrane changing shape.
- External material (i.e. Fluid droplets) are engulfed and enclosed by the membrane.
- A vesicle is formed that contains the enclosed particles or fluid droplets, now moves into the cytoplasm.
- The plasma membrane easily reattaches 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.

Exocytosis

- 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.

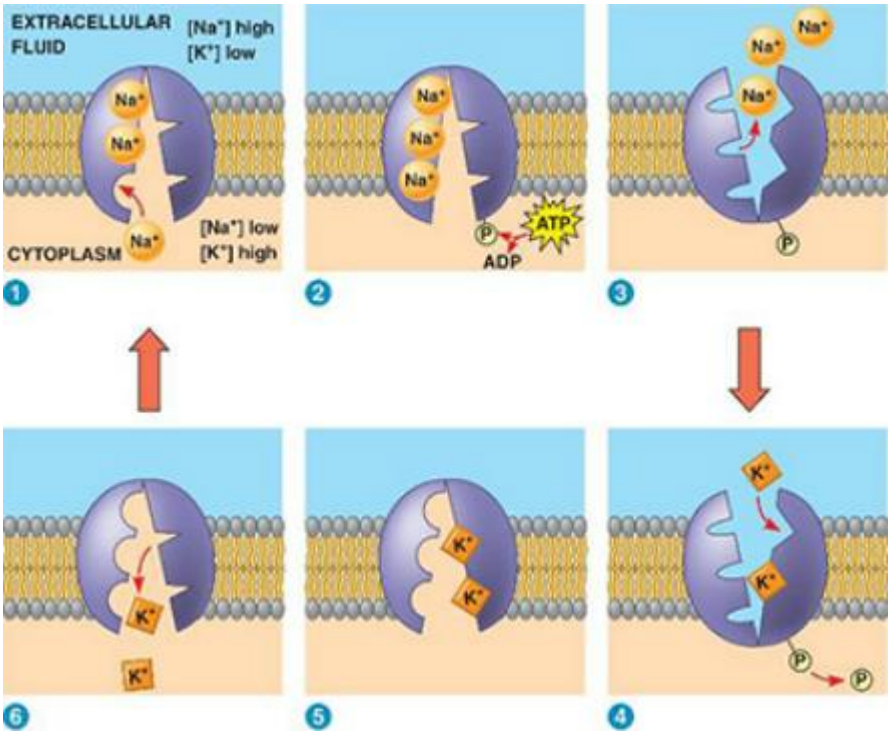
Video showing endocytosis and exocytosis
https://www.youtube.com/watch?v=K7yku3sa4Y8

Diagram of Endocytosis and Exocytosis



Applications and skills:

ß - Application: Structure and function of sodium–potassium pumps for active transport and potassium channels for facilitated diffusion in axons.



http://bio1151.nicerweb.com/Locked/media/ch07/pump.html

Watch the animation on McGraw-Hill to see how the sodium/potassium pumps are used pump ions in and out of neurons to facilitate the transmission of nerve impulses. Every cycle pumps three sodium ions out of the axon and two potassium ions into the axon.

http://highered.mheducation.com/sites/0072495855/student_view0/chapter14/animation__the_nerve_impulse.html

Using your textbook and the online resource, create a diagramexplaining the steps of active transport of sodium and potassium and the use of the facilitated diffusion of potassium ions in axons during nerve impulse transmission.

ß - Application: 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.

- Hypertonic solution – Is a solution with a higher osmolarity (higher solute concentration) then 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.
- Hypotonic solution – Is a solution with a lower osmolarity (lower solute concentration) then 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.
- 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.

In medical procedures, isotonic solutions are commonly used as

1) Intravenously infused fluids in hospitalized patients.
2) Used to rinse wounds and skin abrasions
3) Saline eye drops
4) Packing donor organs for transport (frozen to slush)
5) During skin grafts, used to keep damaged area moist
(normal saline is approx. 300 mOsm)

ß - Skill: Estimation of osmolarity in tissues by bathing samples in hypotonic and hypertonic solutions. (Practical 2)

-
  - Osmolarity of Potato or Yam Cores Lab

1.5 The origin of cells

∑ - Understandings:

∑ - Cells can only be formed by division of pre-existing cells.

-
- 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).
- Cell division to form new cells from pre-existing cells replaced the concept of spontaneous generation, where cells were formed from inanimate matter.

∑ - The first cells must have arisen from non-living material.

- Abiogenesis is the natural process of life arising from non-living matter such as simple organic compounds
- 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
- These are the hypothesized steps of how living cells possibly developed from non-living material over millions of years

1) Production of carbon compounds such amino acids and sugars. Miler and Urey's experiment showed how this could happen by passing water vapour through Ammonia, methane and hydrogen (early earth atmosphere). They added electricity to simulate lightening discharge. They found they could create amino acids and carbon compounds

2) Assembly of carbon compounds into polymers might have occurred at the deep sea hydrothermal vents, which could have supplied the inorganic compounds such as iron sulphide and thermal energy for the assembly

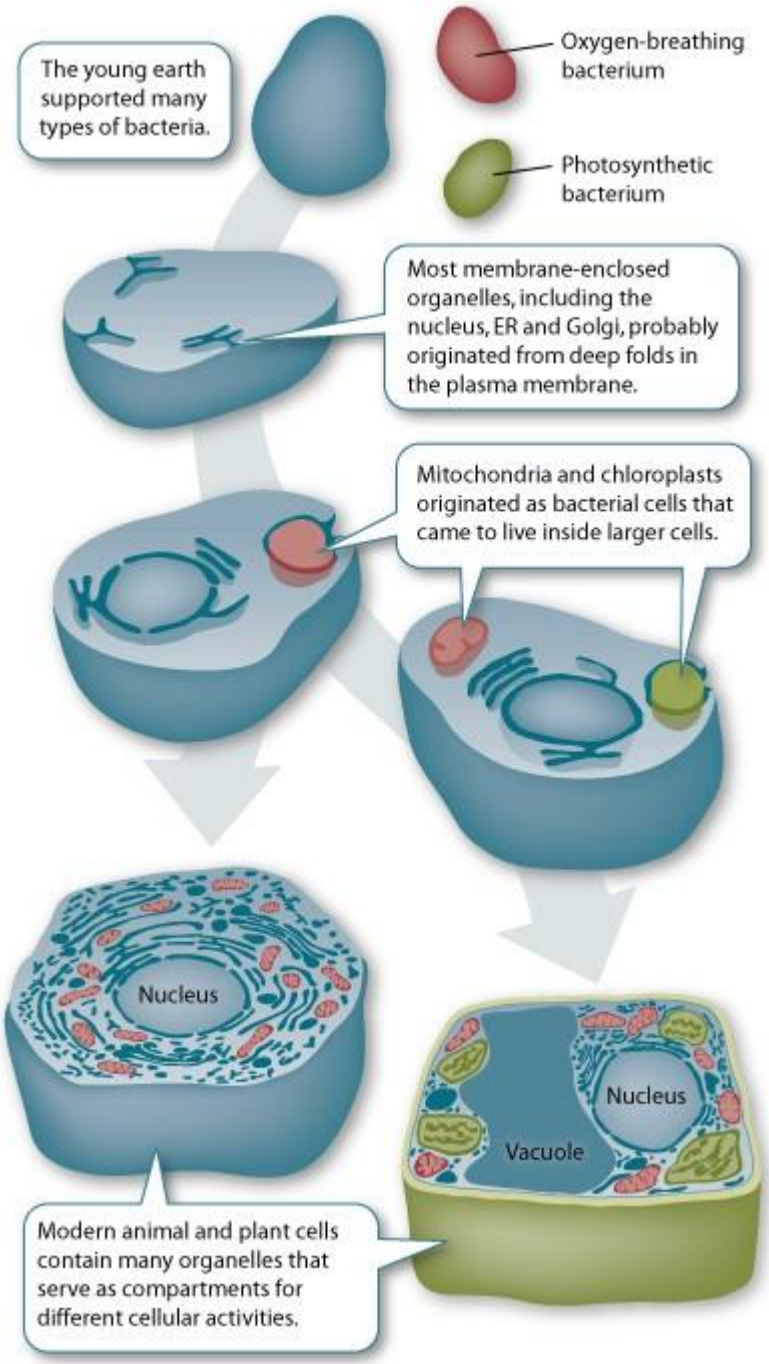
3) Formation of membranes would be possible if phospholipids were some of the first polymers created. These phospholipids would naturally form vesicles allowing for a different environment to exist inside compared to the surrounding water

4) Development of a mechanism for inheritance would be needed in order for the organism to replicate and pass its DNA on to the next generation. Current organisms need enzymes to replicate

DNA; however, enzymes are created by the genes on the DNA. A possible solution to this would be RNA being the first nucleic acid formed because it is self-replicating and can also act as a catalyst.

∑ - The origin of eukaryotic cells can be explained by the 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.



http://learn.genetics.utah.edu/content/cells/organelles/

Applications and skills:

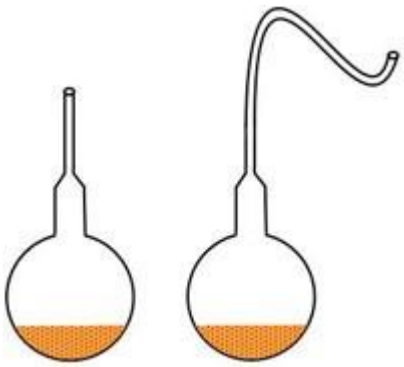
ß - Application: Evidence from Pasteur's experiments that spontaneous generation of cells and organisms does not now occur on Earth.

Pasteur's Experiment

The steps of Pasteur's experiment are outlined below:

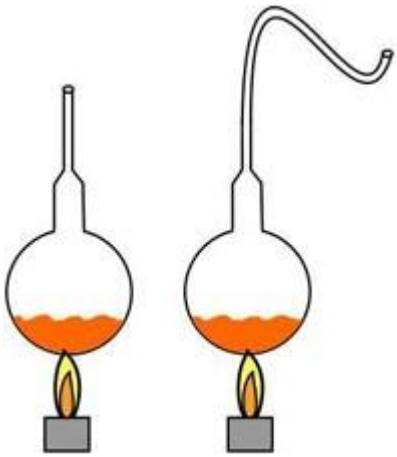
1. First, Pasteur prepared a nutrient broth similar to the broth one would use in soup.

2. Next, he placed equal amounts of the broth into two long-necked flasks. He left one flask with a straight neck. The other he bent to form an "S" shape.



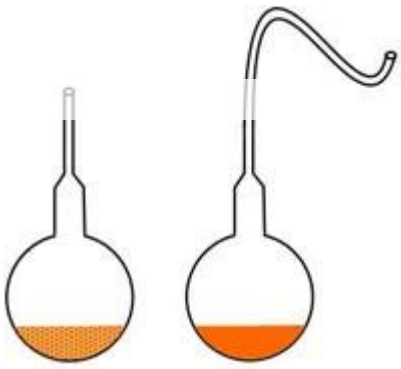
Images courtesy William Harris

3. Then he boiled the broth in each flask to kill any living matter in the liquid. The sterile broths were then left to sit, at room temperature and exposed to the air, in their open-mouthed flasks.



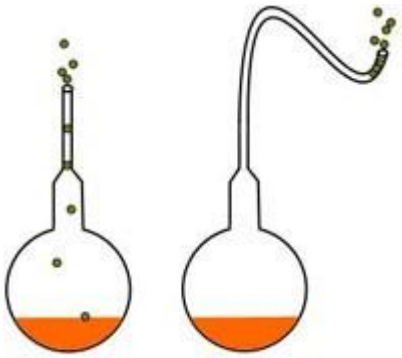
Images courtesy William Harris

4. After several weeks, Pasteur observed that the broth in the straight-neck flask was discolored and cloudy, while the broth in the curved-neck flask had not changed.



Images courtesy William Harris

5. He concluded that germs in the air were able to fall unobstructed down the straight-necked flask and contaminate the broth. The other flask, however, trapped germs in its curved neck, preventing them from reaching the broth, which never changed color or became cloudy.



Images courtesy William Harris

6. If spontaneous generation had been a real phenomenon, Pasteur argued, the broth in the curved-neck flask would have eventually become reinfected because the germs would have spontaneously generated. But the curved-neck flask never became infected, indicating that the germs could only come from other germs.

Taken from http://science.howstuffworks.com/innovation/scientific-experiments/scientific-method5.htm

1.6 Cell division

∑ - Understandings:

∑ - Mitosis is division of the nucleus into two genetically identical daughter nuclei.

- During cell division (mitosis and cytokinesis) the cell divides into two genetically identical daughter cells.
- During S phase in the cell cycle, the cell will replicate its chromosomes to create to identical sets of chromosomes (now called chromatids) attached in the middle by a centromere.
- Replication is semi-conservative, meaning that each strand of the original double-stranded DNA molecule serves as template for the production of the new complementary strand. Thereby insuring two identical copies of the DNA are created.
- Proofreading and error-checking mechanisms during replication ensure near perfect copies of DNA.
- Each chromosome now contains double the genetic material as it enters mitosis.
- During mitosis, the pairs of sister chromatids line up along the metaphase plate, where each chromatid is attached to a spindle fiber connected to opposite poles in the cell.
- During anaphase each identical chromatid is pulled towards opposite poles resulting in two genetically identical nuclei at opposite poles in the cell.

∑ - Chromosomes condense by supercoiling during mitosis.

-
- During mitosis chromosomes condense into visible structures due to a process called supercoiling

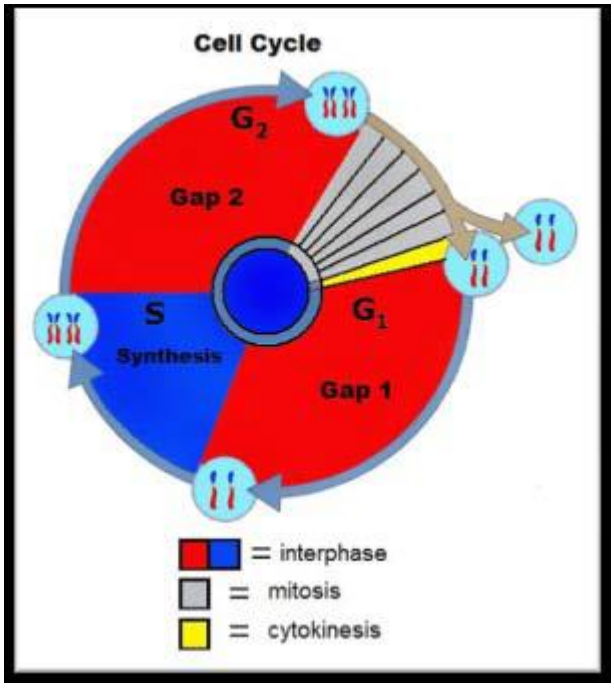
- Since a nucleus is generally less than 5 μm in diameter and some of the DNA molecules are over 50,000 μm in length. They have to condense and coil around histone proteins making the chromosome much shorter and fatter.
- The nucleosomes (made of histones) will interact further with each other causing the chromosomes to supercoil.
- This supercoiling helps regulate transcription because only certain areas of the DNA are accessible for the production of mRNA by transcription. This regulates the production of a polypeptide.

∑ - Cytokinesis occurs after mitosis and is different in plant and animal cells.

-
- Cytokinesis is the process in which the cytoplasm of a single eukaryotic cell is divided to form two daughter cells after mitosis is complete.
- 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 middle lamella
- Cellulose is then brought and deposited by exocytosis between the membranes as well, forming the new cell walls
- 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 to new cells are formed

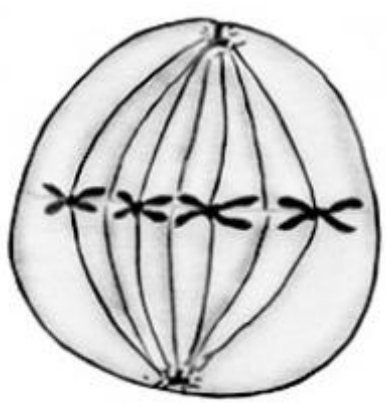
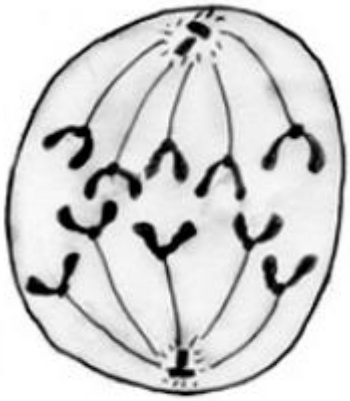
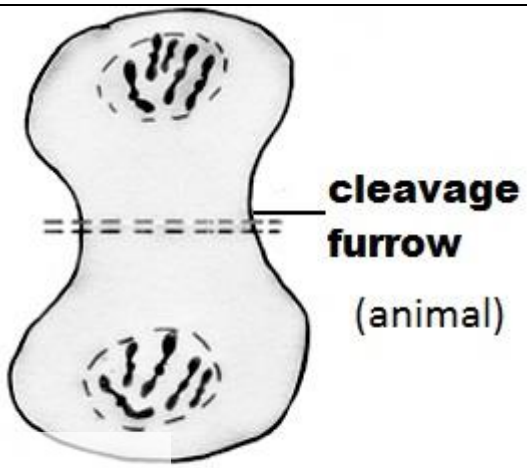
∑ - Interphase is a very active phase of the cell cycle with many processes occurring in the nucleus and cytoplasm.

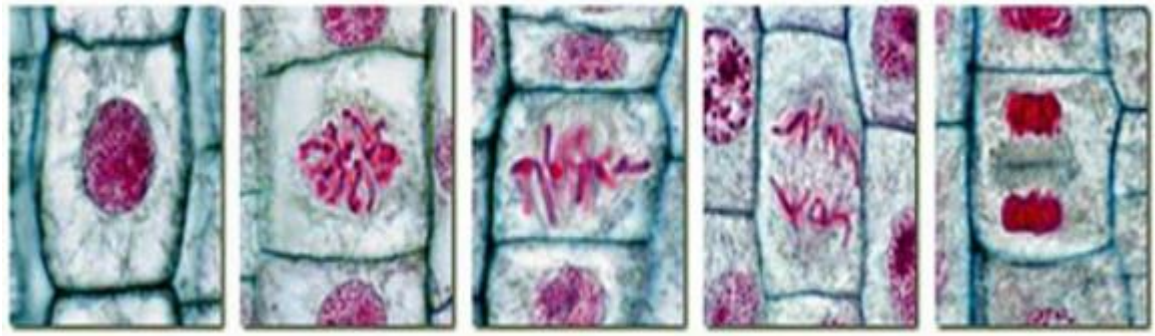
-
- Interphase - is the longest part of the cell cycle which consists of 3 stages G1, S, G2
- Interphase is an active period in the life of the cell in which many metabolic reactions occur, including protein synthesis, DNA replication and production or mitochondria and/or chloroplasts.
- Protein synthesis - synthesis of proteins and enzymes (Gap 1), many of which are required for the synthesis phase during DNA replication and the production of microtubules and proteins in Gap 2; needed for mitosis.
- DNA replication - Fundamental process in which the cell replicates its DNA before it divides (protein synthesis and transcription is low in the S phase.
- Mitochondria and/or chloroplasts number increases during interphase in preparation for division.
- Cellular respiration also takes place interphase and mitosis
- G1 – This stage is called Gap 1 in which the cell grows. After a checkup by the cell, if they are not ready to divide they go into G0



ß - Skill: Identification of phases of mitosis in cells viewed with a microscope or in a micrograph.

Mitosis Description	Diagrams
Prophase • **Chromosomes become shorter and more condensed in the process called supercoiling.** • **The nuclear envelope begins to break down and disintegrate.** • **Microtubules that form the mitotic spindle begin to develop from the centrosomes in the cell.** • **Centrosomes move towards the poles as the spindle grows and lengthens.**	 **Prophase**

Metaphase • **The spindle fibers are attached to the centromeres of the chromosomes.** • **Chromosomes move towards the equator of the cell and line up along the metaphase plate.** • **The other ends of the microtubules of the spindle are attached to poles of the cell.**	 **Metaphase**
Anaphase • **The pairs of sister chromatids are pulled apart by the spindle fibers towards the poles.** • **The chromatids are now considered chromosomes.** • **The chromosomes move to the poles as a result of the shortening of the microtubule.** • **After anaphase the cell now has two genetically identical nuclei at each end of the cell.**	 **Anaphase**
Telophase • **Nuclear membranes now begin to form around each set of chromosomes.** • **Chromosomes begin to uncoil to form chromatin again.** • **The spindle fibers break down and nucleoli reform in each nucleus.** • **The cell elongates and gets ready for cytokineis.**	 **cleavage furrow** (animal) **Telophase**



interphase prophase metaphase anaphase telophase

http://www.clt.astate.edu/mhuss/mitosis1.jpg

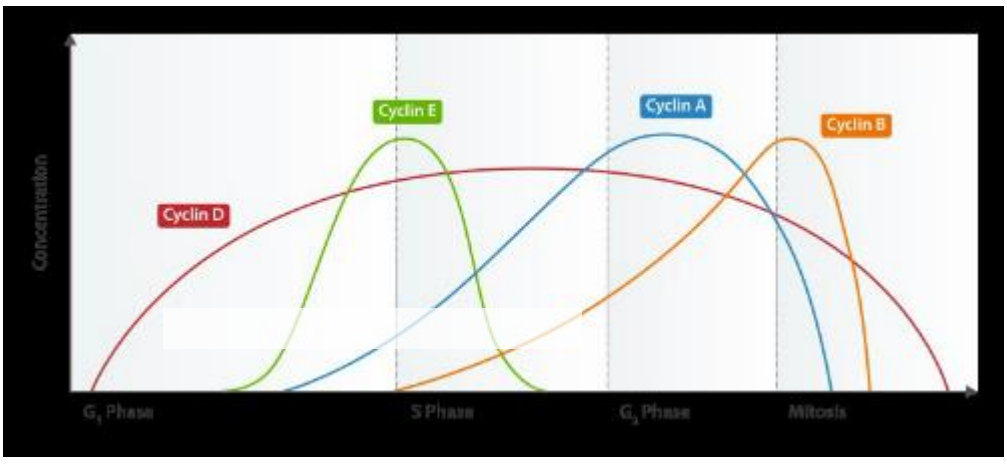
- **ß - Skill: Determination of a mitotic index from a micrograph.**

- The Mitotic index = number of cells containing visible chromosomes (in mitosis) divided by the total number of cells in field of view.

- **<u>Complete Lab Practical 1 on "Stages of Mitosis in a Garlic Bulb Root Tip"</u>**

∑ - Cyclins are involved in the control of the cell cycle.

- Cyclins are a family of proteins that help regulate the cell cycle
- They bind to enzymes called cyclin-dependent kinases, activating these cdk enzymes causing them to attach phosphates to other protein in the cell
- These proteins are also activated and carry out specific functions necessary to each phase of the cell cycle
- There are 4 main types of cyclin in human cells.



http://upload.wikimedia.org/wikipedia/commons/thumb/c/ce/Cyclin_Expression.svg/800px-Cyclin_Expression.svg.png

  - Cyclin D – causes G0 to move to G1 and G1 to move to S phase
  - Cyclin E – causes the cell to prepare for replication in S phase

- Cyclin A – activates DNA replication in S phase
- Cyclin B – causes the mitotic spindle to begin to form and other tasks needed in the preparation of mitosis

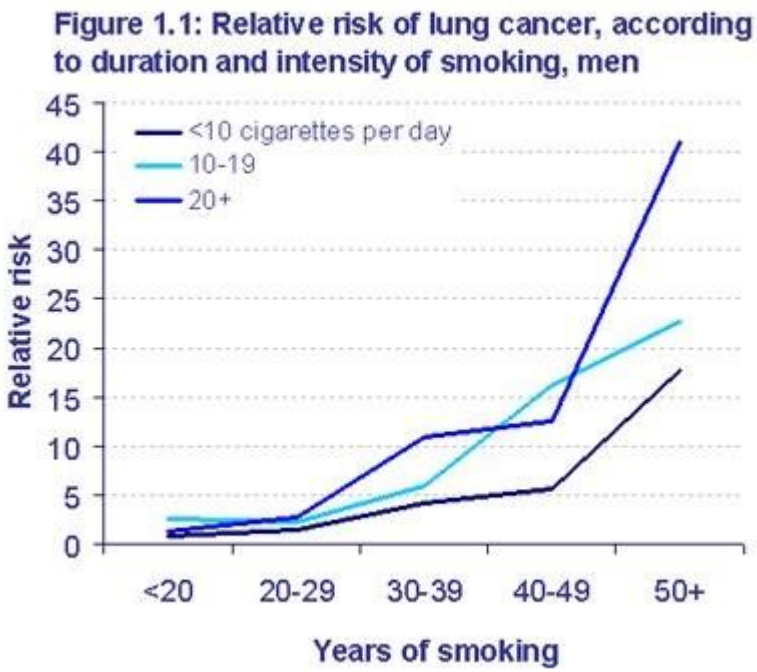
∑ - Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumours.

- Tumors 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
- Mutagens and carcinogens are strongly correlated and many mutagens can be carcinogens
- In cancer two types of genes are usually affected, oncogenes and tumor suppressor genes.
- Oncogenes are mutated forms of proto-oncogenes (which typically control synthesis of proteins involved in cell signaling or cell division). These cells with activated oncogenes cause uncontrolled growth and cell division, prevent the cancer cell from dying and allow them to invade other tissues.
- Tumor suppressor genes usually control replication and the cell cycle. In cancer cells these genes are generally inactivated causing a loss of normal function.

Applications and skills:

Application: The correlation between smoking and incidence of cancers.

- A correlation is a relationship between two variable factors
- There is a strong positive correlation between smoking and cancer
- Surveys have shown that the more cigarettes that one smokes per day, the higher the death rate due to cancer.
- The main cancers involved are cancer of the mouth, pharynx, larynx, esophagus and lungs



http://islaslab.blogspot.ca/2014_04_01_archive.html

More detailed tables in your text