LECTURE NOTES : CELL BIOLOGY

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(BIOMEDICAL LABORATORY SCIENCE STUDENTS)

By

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Preface

Cell biology also known as cytology. It deals with cells and its organelles. Inside this document you find curious of yours about cells and how they act like independent livings within bodies of living organisms. Preparation of this lecture notes has took much effort as needs high understanding in science of biology. Cells are important parts of life and without them life can be impossible. Understanding sciences like cytology, histology, genetics, biochemistry, molecular biology, are essential sciences to know are linked to knowledge of cells. During preparation of this lecture notes, content of module of cell biology taught in biomedical sciences courses in INES-Ruhengeri at undergraduate level has been used. A part from this content different source has been used to study each topic with much attention. Books of cytology, molecular biology, medical genetics, biochemistry, and different journals related to this module have been contributed to produce this lecture notes. This lecture notes can be a good asset in different areas of biological and biomedical sciences. They can help biomedical laboratory scientists to understand the role of cell in life of living things.

Acknowledgement

Solidarity builds long-lasting life and creates confidence in social members. Striving to work with the community brings ways of producing products of good quantity and quality. I strongly thank members of community that I work with in INES-Ruhengeri who accepted working with me during hard times of producing this lecture notes. I firstly address my gratitude thanks to Dr. Francois NIYONZIMA, Vice Rector in charge of academic affairs, he provided advices and encouraged me during the period of writing this lecture notes, and has been in touch with me to know the progress of this document. I really appreciate his support despite much work he always does within the university to protect quality of education delivering within the university. I cannot forget thanking members of department of laboratory science, for guiding me to the content used while organizing topics of this lecture noted. I do acknowledge Ange Yvette Uwitonze to give us chance of participating in different activities of department including teaching and other activities; it is through her we get time of preparing this document. God protects all of you

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0. INTRODUCTION

0.1 Cell biology history

The discovery of the microscope influenced the discovery of cells. The microscopist and physicist from England Robert Hook (1635-1702) took the first description of cells in 1665. His scientific experiment conducted by making thin slices of cork and matched the boxy partitions he totally observed to the cells in a monastery. Hook observed open empty spaces but he and other scientists made their suggestions by saying that these spaces can be used to transport fluid in a living plant. They did not confirm that it is a basic unit of living organisms that they were observing.

Marcello Malpighi (1628–1694), and Hooke's colleague, Nehemiah Grew (1641–1712), continued making strong researches on plant cells, and put out the cellular structure in a plant body. Grew matched cellular empty spaces to the gas bubbles in rising bread and made his suggestions saying that they have the same process in their formation. Animals' cells were discovered later because it was essential for thin sections to facilitate viewing under the microscope but were difficulty to prepare.

Nowadays, scientists interested in biology were totally convinced that living things are made of fundamental units. It created curious to know what those units are. Microscope took its improvement to make their observation clearly and assisted to know more on cells and microscope chosen to be an important instrument to study life on the planet. The Dutch microscopist Antony van Leeuwenhoek (1632–1723) published his researches and observations in 1676 about single-cell organisms, or "little animalcules" the name given by him to these single celled animals. He has been respected first scientist observed red blood cells and even sperm cells in a microscope. Leeuwenhoek discovered and said many on his microorganisms, however, hundred years passed without guessing connection between cellular livings and cells that build plants and animals.

Researches continued developing and reach in 1824 where Frenchman Henri Milne-Edwards put out his suggestions on animal tissues, according him animal tissues are structured like an array of globules (the basic structure of all animal tissues was an array of "globules). Henri Dutrochet (1776–1847) identified the relationship between plant and animal cells explicit, and mentioned his proposition saying that a cell was both just a structural and physiological unit, and clearly defined that everything comes from cells.

Dutrochet in his proposal, he proposed that new cells come from old cells, and François Raspail (1794–1878) echoed this idea proposed by Dutrochet and said to be his contemporary, Raspail known as the first person who supported in mentioning one of the two main tenets of cell theory: **Omnis cellula e cellula**, which means "Every cell is derived from another cell." However, despite this ringing and famous phrase, the proposed mechanism on generation of cells has not been true. He contributed on chemical composition of cells and become the father and founder of cell biochemistry.

In 1832 Barthelemy Dumortier (1797–1878) French scientist entered his description on described on **binary fission** in plants and was the idea to cell division in common sense. He took his careful observation to the formation of a mid-line partition structure of both original and new cell, and Dumortier noted and took in considerations, it was as if he was going to provide clear understanding on the development of cells, “seems to us to provide a perfectly clear explanation of the origin and development of cells, which was still in obscurity explanations. His observation directed to rejection of the idea said that new cell comes from within old ones. Hugo von Mohl (1805–1872), is the one who discovered cell division despite Dumortier who preceded him. Von Mohl mentioned the word protoplasm as a material contained in the cell. **Cell nucleus** is also an important part of the cell and was discussed firstly by a Czech, Franz Bauer, in 1802 and was named in 1831 by Robert Brown (1773–1858) from Scotland, and also entered other parts of nucleus description. Schleiden and Schwann, took researches on cell theory and outlined their marks and contribution in 1838 and 1839. In 1838 Matthais Schleiden (1804–1881) clarified his proposition saying that each plant types or elements is made of cells.

In 1839 a fellow German, Theodor Schwann (1810–1882), came up with propositions on animals’ structure. His proposition was that all structural elements in animals are cell set products, which means that, are made by cells. Contribution of Schwann seems as imitating what

cell theory on plant has suggested. He declared that the laws governing cells were the same or identical in both animals and plants. The Czech Jan Purkyňe (1787–1869), or Purkinje, has also contributed on cell theory and was single cytologist in his day and known as one of the most important formulators of cell theory. He used Schwann theory to explain his contribution. His proposition was that animals were made of cells and cell products and this is applied to plants. Other scientists also contributed to cell theory but these are main ones.

0.2 Cell definition and overview

The **cell** is the smallest basic unit of all living organisms. They independently do their activities, they replicate to and divide. They are also known to be building blocks of life. The science dealing with cell study is known as cell biology or cytology. A human being is known to have more than 10 trillion of cells mathematically it is 10^{13}cells and seen by means a microscope, means that you cannot see them by a naked eye.

All living organisms are composed of cells. Cells have various forms and shapes, utilities and visibility. Cells have abilities of metabolic process and this give them ability of living independently and play a huge role in living things. Scientists and various researchers strove to understand how cell itself plays interesting functions in all livings things and how its absence leads to inexistence of living organisms. We better know that there are animal cells and plant cells, and these cells has high percentage of similarities, however, some few differences has already mentioned within their structures.

Cells are made of identical types of molecular building block and share some common characteristics. Even if cells have various common features, we take in consideration different and various cell types and this classification and categorization of cells is known as cellular diversity. This diversity of cells differs in kinds of organisms and within metazoan or multicellular livings themselves. Commonly known characteristics shared by cells are like using the same carbon in macromolecules which is the main component within cells. It includes carbohydrates, proteins, lipids and two nucleic acids found within nucleus of living cells. All cells have DNA in which genetic characters are located and known as a genetic material of living organisms. All living organisms use their genetic material (DNA) to make proteins where it decodes before making proteins and these proteins help in energy of a cell helping also in

metabolic activities of cells. Cells have ability to grow and divide despite some of cells found in multicellular organisms that lost their ability to divide and example can be given like on neurons that cannot divide.

Both animal and human cells possess different parts or organelles, and each connects with cell components by means of intracellular membrane. DNA separates from cytoplasm by nuclear membrane shaping an important large organelle called nucleus. Organelle like mitochondria which is important organelles that play a huge role in cell activities like generating Adenosine triphosphate (ATP) which a useful component in providing essential energy that facilitate various biochemical reactions that lead to formation molecules from smaller units and an example that can be taken is formation of protein through amino acids.

In multicellular organisms, cells are pointed to do and perform specific different functions. Those functions are like secretion and movements. Various molecules contribute in these functions talked above. Muscular cells of animals and humans themselves assured for synthesis of proteins that facilitate their contraction, but in non contractile cells these proteins are not synthesized. An example here is skin cells. Cells are different biochemically in multicellular livings, and also notification of shape difference is important as cells have different forms. Our look can be addressed to red blood cells that are small and disc in shape while neuron or nerve cells are long in shape, and all these forms and shapes are known as cell morphology

In organisms with many cells (multicellular) cells tend to be classified in different groups or tissues basing on their responsibilities and functions. You better know that cells and tissues organize to make organs and organs to organ systems that participate in performing different functions. Example is digestive and cardiovascular system. Living cells always work their activity; they always need energy and this allows them to make nutrients that will continue to facilitate cell activities in synthesis of new molecules. Remember that they make molecules and transport them in different parts of the cell and all need energy with this they also expulse waste . if the process is done in appropriate manner, cells get growing and enter division. Cell activities can allow a cell to take new shapes in terms of responding to environment and also in interacting with other cells in the process called cellular communication or cell signaling. This big process needs essentials movement of molecules to maintain and organize and coordinate in cell

1. CELL DIVERSITY AND CLASSIFICATION

1.1 Cell Diversity

Cells are found in different organisms, and each organisms has its special cells depending on its specie. However, cells are very diverse in size, shape and their internal structure and this applied to cells found in the same organisms. This diversity of cells is influenced by their roles and function within organism's body.

1.1.2 Cell Shape

Cells have different shapes due to appropriate function. Comparison can be found below where you find cells with long extensions like nerve cells that facilitate in sending and receiving impulses. You can find other cells which are flat or platlike, most of these cells are body cells and their function is protecting and covering body surface. Thus cells develop in size according recommended function within the body of a living.

Cells have different shapes. Nerve cells have long extensions. Skin cells have a shape which is flat and platelike. Egg cells have shape which is like sphere, and some bacteria are rod in shape. Some plant cells are rectangular.

Figure 1: Shape of cells

1.1.3 Cell Size

In all livings Cells are different both in shape and size. Some cell can be seen without using magnification instruments as they enough to be seen in size. One example that we say is a neuron cell of giraffe which is 2 meters in length.

1.2 Different types of animal cells

There are number of different kinds of animal cells and like skin, muscle, and blood.

1.2.1 Skin cells

The skin cells of animals are categorized in two and those are keratinocytes and melanocytes – and the suffix ‘cyte’ means a cell. Keratinocytes have a big number in all skin cells and have rate of 90% of all skin cells and is responsible in production of a protein known as ‘keratin’. Keratin is responsible in making effective layers of the skin in term of body protection. It can also participate in hair and nails formation.

Figure 2: Skin cells

Another important skin cell is Melanocyte which is responsible in melanin production and melanin is responsible in skin color determination. Melanocytes are located under keratinocytes in the part of lower layer of skin cells and after producing melanin, melanin gets transported up to the surface layers of the cells. The number of melanpocytes in the skin, determine how darker you are. Darker skinned means that you have thousands of melanocytes.

1.2.2 Muscle cells

Myocytes, muscle fibers or muscle cells are long tubular cells and have the responsibility of facilitating movement of an organism. Muscle cells are like cardiac muscles, smooth muscle cells, and skeletal muscle cells. In these cells, skeletal muscle cells are known to be the most common type of muscle cells with responsibilities of facilitating movements that are conscious in the body. Coming to cardiac muscle cells, they manage movement of contractions of the heart, and lastly, smooth muscle cells assist in managing subconscious movements of tissues including uterus, stomach, and the blood vessels

1.2.3 Blood cells

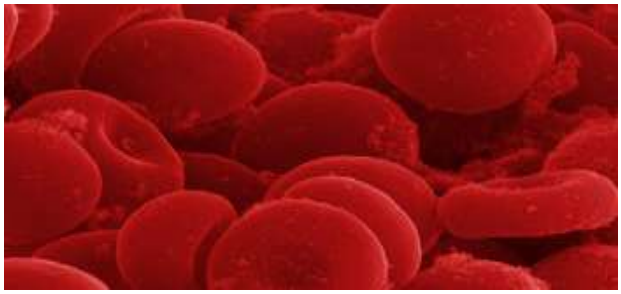

Figure 3: Blood cells

In the blood we find types of cells are classified in two categories: those are white blood cells and red blood cells. The estimations show that red blood cells occupy 99.9% of all blood cell found in the blood. Red blood cells help in facilitating distribution of oxygen in all parts of the body. It is also known that red blood cells have no nucleus and this make them different with other animal cells. White blood cells are known to be immunity of livings. They can kill invaders of our body and others that are harmful to the body.

1.2.4 Nerve cells

Nerve cells are also known as neurons, they are known as basic and main cells in the nervous system. Only human brain stores 100 billion nerve cells. They carry impulses of animal cells and responsible in delivering and receiving signals by means of their dendrites and axons.

1.2.5 Fat cells

Fat cells, also called adipocytes or lipocytes, and are responsible in storing fats and lipids which will facilitate energy store in animal's body. Fat cells are categorized in white fat cells and brown fat cells. The different is made from their ways of storing lipids. White fat cells store one large lipid drop while brown fat cells store smaller and multiple droplets of lipids spreading in the whole body of the cell.

Questions for evaluation

0. What do you understand by the term cell diversity?
1. Explain the difference between keratinocytes and melanocytes.
2. Explain the effects of low melanin production on human skin color
3. What are main shapes of cells
4. Fat cells are categorized in two classes. What are they? Mention their differences
5. Describe blood cells and give their proper functions. What makes difference on red blood cells to other types of cells of humans?

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2. ULTRA-STRUCTURE AND ORGANISATION OF CELL ORGANELLES

All living Organisms are made of cells, and cells have their appropriate structures which facilitate them to play their function within living cells. Cells structured in organelles, most of organelles of cells are seen by means of electron microscope leads to the term ultra structure. Numbers of organelles are found in cell structure and each one play its role independently and this refers to as division of labor.

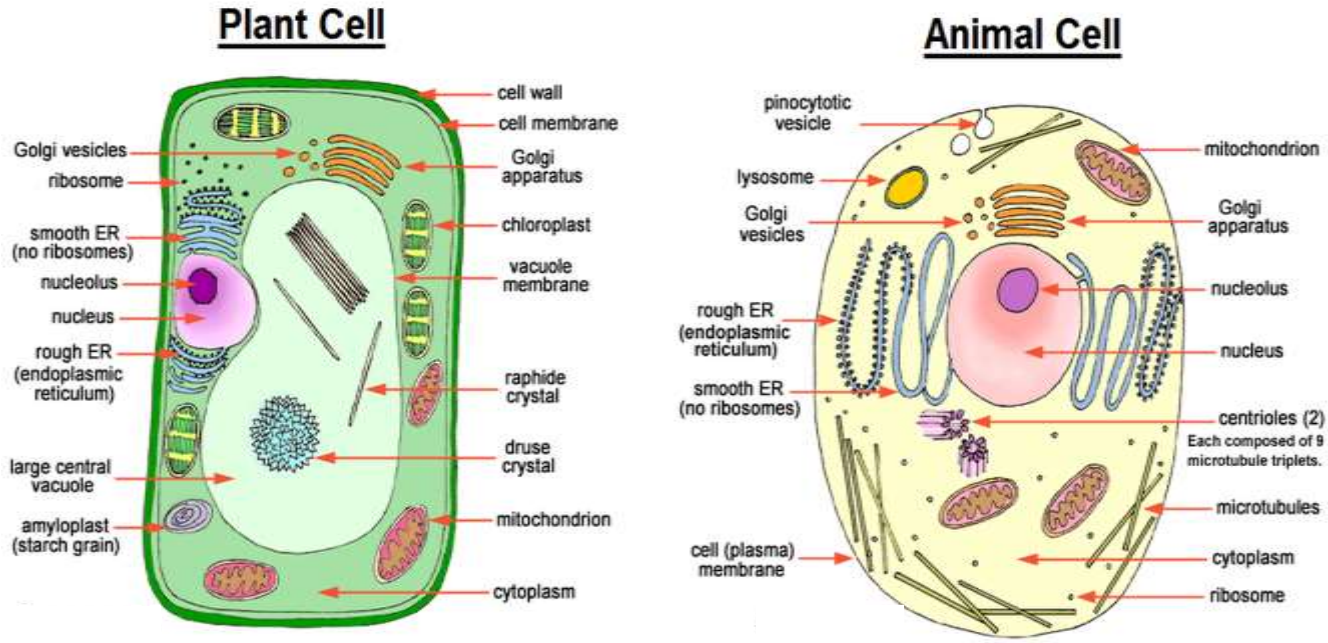

Figure 4: Structure of animal and plant cell

2.1 Descriptions of organelles and their function within cells.

2.1.1 The Nucleus

This is the largest organelle in a cell. Within cell nucleus, you find a dense structure known as Nucleolus covered and protected by nuclear membrane of envelope. This envelope has two membranes and their separation is done by means of a fluid in which nuclear pores that facilitate molecules to pass through are found. Nucleus stores genetic materials. Nucleolus is responsible for Ribonucleic acid production as well as involving in Ribosome protection which later takes journey through nuclear pore to cytoplasm and participate in protein synthesis process.

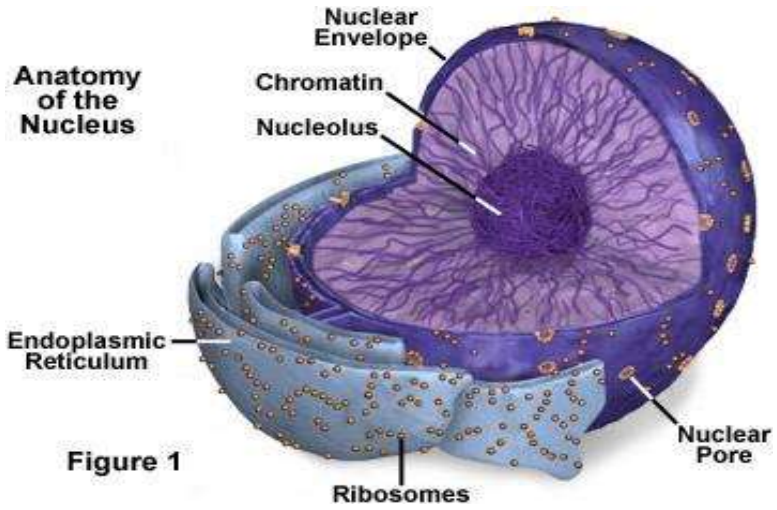

Figure 5: Nucleus structure

2.1.2. The Endoplasmic Reticulum (ER)

This is an organelle located near and around nucleus and contained cisternae which are sacks that are flat in shape, and are with nuclear envelope. Endoplasmic Reticulum is categorized in two types and those are Rough Endoplasmic reticulum and smooth endoplasmic reticulum. Rough Endoplasmic Reticulum has many around its outer surfaces but smooth endoplasmic reticulum has no ribosomes. Rough endoplasmic reticulum is responsible in transporting proteins synthesized in ribosomes and smooth endoplasmic reticulum serves in lipids synthesis.

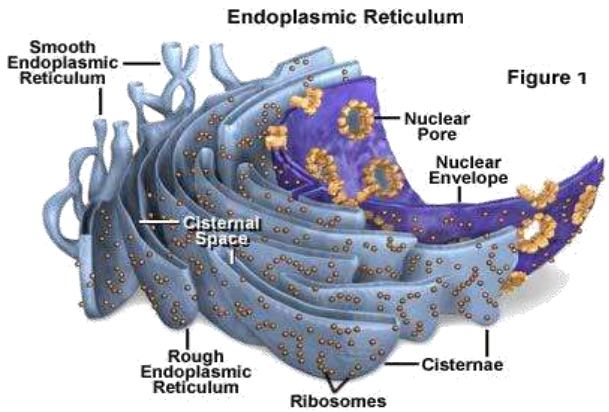

Figure 6: Structure of Endoplasmic reticulum

2.1.2. Golgi apparatus

The Golgi apparatus (GA) are also known as Golgi body. It resides in both plant and animal cells, it is composed by series of five to eight that are cup in shape, cisternae which seems as a

stack balloons. In some of flagella protozoan 60 cisternae put together and make Golgi apparatus. The amount of Golgi apparatus varies depending on their functions. Each cell of animals notified to contain 10 and 20. Golgi apparatus are responsible in modifying proteins brought by ER.

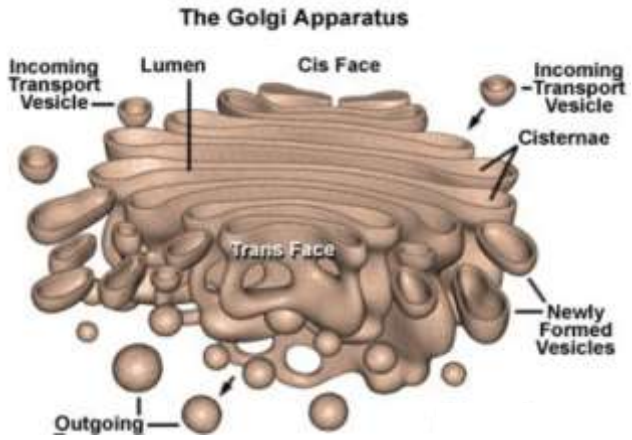

Figure 7: Structure of Golgi body

2.1.2.Lysosomes

Lysosomes are tiny sacs containing fluid in which enzymes are found. These enzymes are responsible in nutrients processing of the cell. Lysosomes are important sites of digestion; they break down heavy molecules in simple molecules that cannot harm the cell. A defining characteristic of lysosomes is that each one is bounded by only a single membrane. Alysosome size is a diameter of approx. 50nm to 1 μm[§], lysosomes possess a single outer membrane containing of a phospholipid bilayer and contain acid hydrolases which are enzymes capable of breaking-down macromolecules.

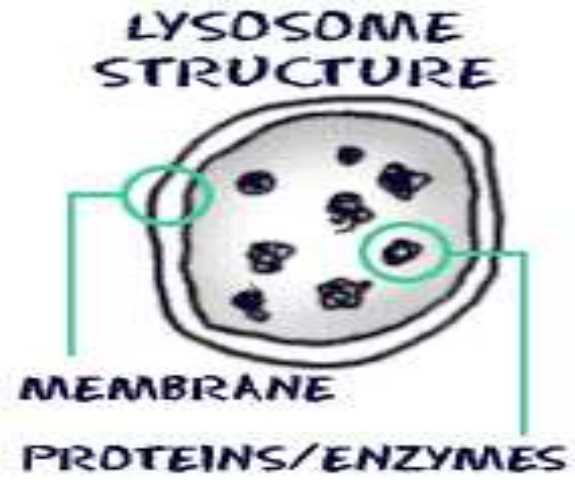

Figure 8:Structure of lysosome

Action of Lysosomes

Figure 9:Structure of action of lysosomes

Lysosomes are considered to be a digestion machines, they only work when the cell enters or absorbs or consumes a certain food. When a material located in the cell, lysosomes directly attach and produce their digestive enzymes. These enzymes are responsible in breaking down complex and heavy molecules that can give complex sugars and proteins. But what happens to lysosomes during the absence of food or starvation? The lysosomes continue their activity despite the absence of food in the cell. Here lysosomes can digest cell organelles to produce cell nutrients.

2.1.2.Mitochondria

Mitochondria are rod in shape and are known to be the power generator of the cell as it assist in converting oxygen and nutrient into ATP which is a chemical energy responsible in cell metabolic activities. the number mitochondria needed by a cell is based on metabolic activities required, and may be one or many depending on this condition.

Mitochondria are oblong shaped organelles, and their size is varied in the interval of 1 and 10 micrometer in length and number of them depends on metabolic activities that cells wish to accomplish. Different researches done on this organelle shows that it rapidly change the shape and has a constant movement in the cell.

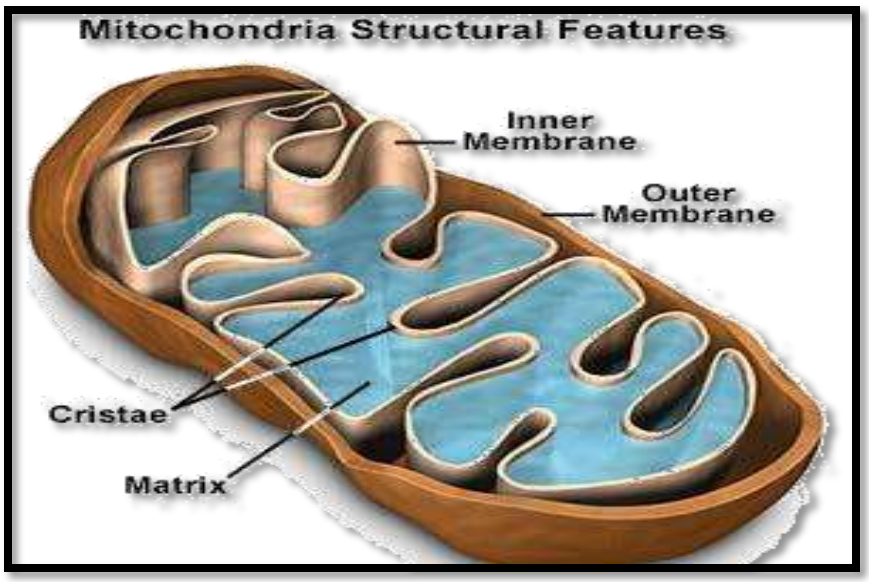

Figure 10: Mitochondrion structure

2.1.2. Chloroplasts

Chloroplasts are useful organelles among plastids as they highly participate in the process of photosynthesis which is a process by which plants synthesize their own food. They are located in outer surface of the cell to receive enough right. Chloroplasts are green colored due to pigment called chlorophyll found in its internal parts. Some of important characteristics of plant is its ability to do **photosynthesis** as the way they use in making their own food and pass through converting light energy in chemical energy. This pearl process take place in all plant kinds in the

organelle called chloroplast. All green plants are responsible to have chloroplasts within their structure and in most of plants, chloroplasts are found in the leaves.

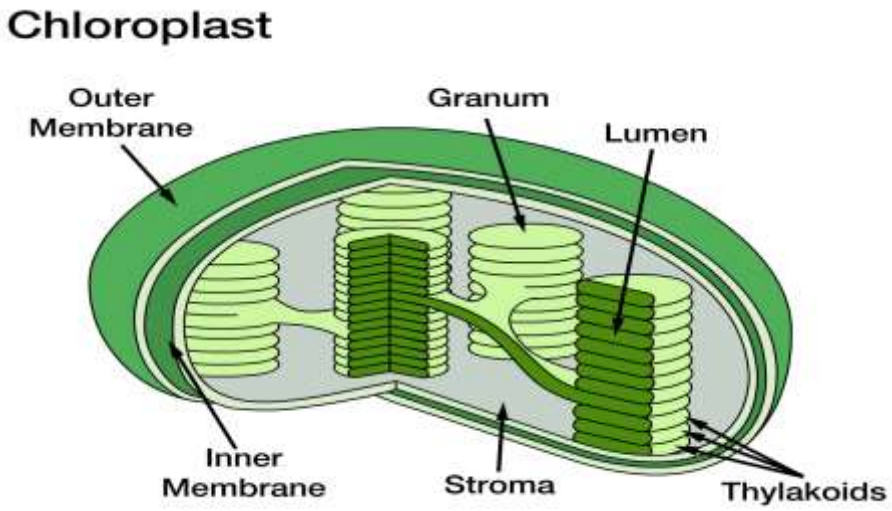

Figure 11: Chloroplast structure

2.1.2. Vacuoles

Vacuoles are storage bubbles that reside in cells. They are located in both plant animal cells despite their difference in size. Vacuoles in plant cell are larger than that of animal cells. Vacuoles play important roles in storing food and other nutrients essentially for a cell to be healthy. It also sometimes store wastes before sending them out to protect the cell. Vacuole has a very simple structure, only a mass of fluids surrounded by membrane are parts of vacuoles. This fluid might contain nutrient or wastes, plant can also profit occasions of storing water by means vacuoles found in plant cells.

As discussed early, plant cells have larger vacuoles comparing to that of animal cells. In their growth, plant cell may have one vacuole which is very large in plant cells, and probably occupy the half of the cell volume. Vacuoles are holders of much water in the cell, but also can store plant waste products, and break those wastes in small particles that cannot harm the cell. Vacuoles assure for structure of plants as plant uses cell wall in terms providing support and surround. Cell volume may change according to the presence or absence of water within vacuole. Shrinking of plant cells is not a result of cytoplasm amount but depends on amount of materials found in the vacuole

Gaining or losing water for the vacuole depends on water amount within plant.

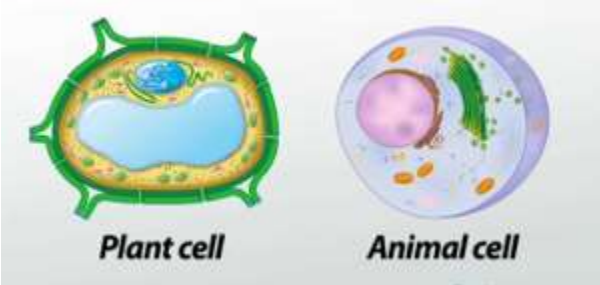

Figure 12: Animal and plant vacuole

2.1.2. Ribosomes

Cells always need **proteins** production**.** Enzymes that facilitate in speeding biological process with cells are made of proteins. Other proteins that play important roles in cell function are found in membranes. When a cell enters its way of making proteins it directly search for ribosomes as these organelles known to be proteins synthesizers or builders for the cell. The specialty of Ribosomes is their presence in both prokaryotic and eukaryotic cells. Some organelles like nucleus are found only in eukaryotic cells.

In eukaryotic cells Ribosomes are found in different places and are seen floating in cytosol. The important role of these proteins floating within the cell is the production of proteins to be used inside the cell. There are other ribosomes located on endoplasmic reticulum, and are responsible in activities inside the cell and proteins made for export out of the cell. We need to notify when these ribosomes participate in proteins synthesis. When living cells enter protein making, messenger RNA have to be synthesized in the nucleus.

This messenger RNA gets out from nucleus to cytoplasm to meet ribosomes, where two subunits of ribosomes combine with messenger RNA and begin the process of synthesizing proteins. Simply protein synthesis needs amino acids. Transfer RNA is also located in the cell and simple gets bonding with amino acids floating around the cell. Due to instruction from messenger RNA, ribosomes connect to transfer RNA and break down the bonding structure between transfer RNA and amino acids, so they pull off amino acids. Transfer RNA also liberated to go back and

connects with amino acids. Ribosomes construct a chain of amino acid or polypeptide that will be broken in simple proteins.

Protein synthesis process is found below

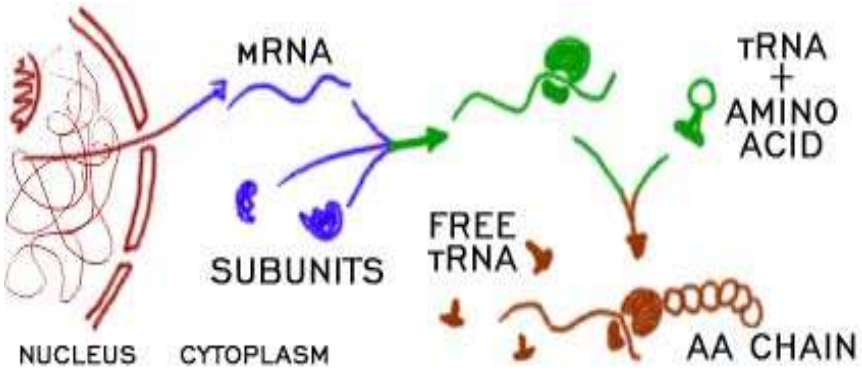

Figure 13: Structure of protein synthesis

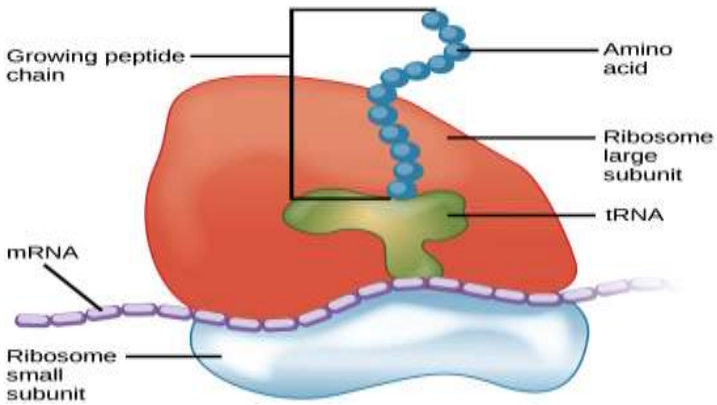

Figure 14: Amino acid chain in protein synthesis

2.1.2. Cell Wall

Cell wall is found only on plant cells. This is a non living part of the cell, and is known to be extra cytoplasmic product. Cell wall is more sized than plasma membranes. Its responsibility is to give a shape of the plant and manage plant cell growth. It protects the cell against the entry of unnecessary molecules and invading germs.

Cell walls have different layers. It has three basic layers, intracellular layer or middle lamella, primary and secondary layer. The middle lamella plays a role of cementing together the primary

walls of two contiguous cells and the secondary wall is laid over the primary. The middle lamella is mainly made of a pectic compound appearing to be calcium pectate. The primary wall is largely made of cellulose and the secondary wall may be of cellulose or cellulose whose inside found other substances.

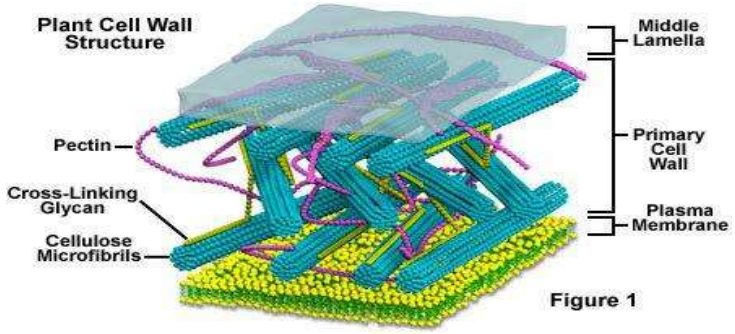

Figure 15: Cell wall structure

2.1.9.1 Primary cell wall

Cellulose is known to be the main chemical components of the primary cell wall, and made of organized microfibrils. Microfibrils is made of carbohydrate which is a cellulose component linked together. Cellulose has the bulk of material that cell walls are made in.

2.1.9.2 Secondary cell wall

The secondary cell wall is deposited inside the primary cell, and show cell maturity. This secondary part of cell wall can sometimes have the same components like that of primary cell wall. The specialty is that this part contains **lignin**. Lignin is aromatic alcohol group that build secondary cell wall. This important part helps in xylem formation, and gives strength and rigidity of the cell. In mature tissues this party is found.

2.1.9.3 Middle lamella

This is important part of a cell wall which is rich in pectins. It assures that two neighboring cell cemented together. The position of middle lamella facilitates neighbor cells to share their contents by means of special conduits. **plasmodesmata**, are small passages that penetrate and enter middle lamella and both primary and secondary cell wall, and support the exchange of transporting cytoplasmic contents from one cell to another.

2.1.10 Plasma Membrane

Plasma membrane is found in both prokaryotic and eukaryotic cells. It is cover that binds cell contents and known to semi-porous barrier to the external environment. It plays a role of boundary and holds the cell components together, without neglecting keeping other molecules from entering. Here it accepts for a substance to enter or not. Most of substance allowed by plasma membrane to enter include: oxygen, carbon dioxide, and water but also adding essential nutrients of the cell. However, waste materials are permitted to get out of the cell. Based on accepted principle known as fluid mosaic model, plasma membrane is made of two layers (bilayer) of lipids, oils and all found in all cells

2.1.11 Centrioles

The centrioles are cell organelles that are cylinders in shape. They can be found in most of cells having the real nucleus. Centrioles are composed of grouped microtubules and are responsible in organizing and fixing microtubules during cell division in animal cells. During replication, centrioles replicate in interphase of mitosis and meiosis.

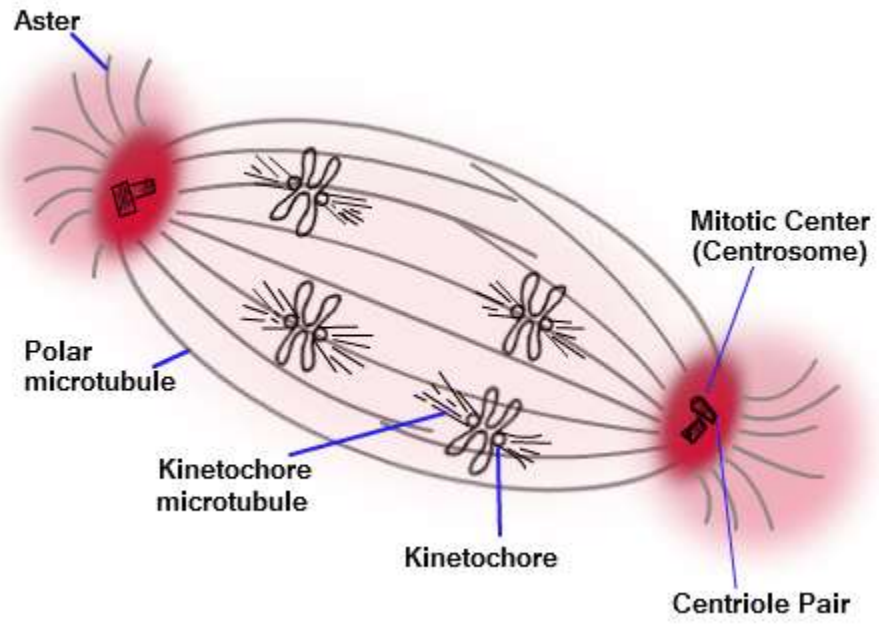

Figure 16: Structure of centrioles and spindle fibers

Centrioles in Plant and animal Cell

You better know that Plant cells do not possess centrioles. Its pole structure is different from that of animal cells. This difference in cell pole structure is due to absence of cellular organelles assisting in being focal point. Due to this issue, some spindles have no localization. In animal cells we found centrosomes containing two that are barrel in shape and are are called centrioles. The centrioles assist in organizing the mitotic spindle and in the completion stage of cytokinesis. The centrioles are essential in the formation of the mitotic spindle. These centrioles are useful part of the centrosomes, they contribute in coordination of organizing the microtubules in the cytoplasm.

They are other organelles of the cell that are not found here but these are main ones that everyone has to describe, and in further readings, you can read more about them.

Questions for evaluation

1. What is the difference between animal and plant cells?
2. Describe the process of protein synthesis by ribosomes
3. What is the difference between cell membrane and cell wall?
4. Centrioles facilitate cell division by fixing spindles fibers, and are not found in plant cell, explain how plant cells divide without centrioles.
5. Life is based on cells. What do you think on this statement?

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2. TYPES OF CELL DIVISION

All livings are made of great number of cells that we cannot estimate. Livings start as single cells and most of time people wonder on development of a living from a single cell to an organism with trillions of cells. The real response to fill their curious is cell division. Cells take their time to reach on maximum size and enter their division to give new cells. Released new cells are small but they grow rapidly and divide to release other new cells and this process continue by repeating in this way.

Cell division is made simple in prokaryotes but takes process in eukaryotes. Prokaryotic cells simple in their nature, they contain a circular chromosomes, and organelles like nucleus and some others are absent in prokaryotic cells. In contrast side Eukaryotic cells, have much number of chromosomes and located in important organelle called nucleus. All these organelles have to duplicate and separation occurs during cell division. Chromosomes are located and always reside in nucleus in eukaryotic cells. Cells are divided in two ways, one is mitosis and another one is meiosis. Mitosis is done on somatic cells while meiosis is done on reproductive cells that will enter gametes formation.

3.1 Mitosis

As discussed early in introductory part of this chapter, cell division is a sequence of process of steps by which living organisms are enabled to grow and have ability of reproduction. During cell division through mitosis, genetic material enters replication in a mature cell and is shared in equal way in two daughter new cells. Before a cell begin its division, it enters interphase state which is a period taken by the cell to grow. There important activities that take place during interphase, the replication of genetic material and organelles organization to be ready for cell division are all take place in interphase. Cell division through mitosis mature cell genome is carried into new formed daughter cells, and new cells are similar for themselves and to their mother cell. By the beginning of mitosis, the cell chromosomes enter condensation.

In most eukaryotic cells, the nuclear membrane separates genetic material (DNA) from the cytoplasm into membrane vesicles. The ribosome dissolves; the chromosomes arranged and align themselves. Microtubules are responsible in pulling apart of the sister chromatids of every chromosome. The homologous chromosomes (daughter chromosomes) are moved towards opposite sides. The formation of nuclear membrane takes place on separated daughter chromosomes. In animal cells, the pinching of cell membrane is done inwards, to create to form two daughter cells. In plant cells, the cell wall that is divided is built in between the daughter cells. The parent cell will split in half and produce to two daughter new cells.

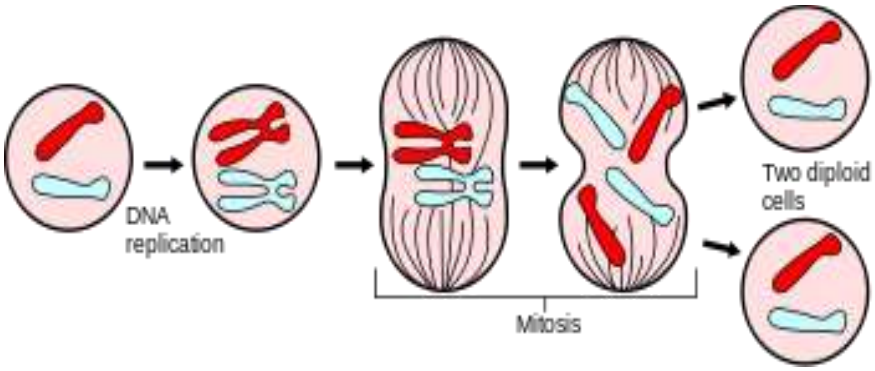

Figure 17: Mitosis summary

3.1.1 Phases of mitosis

Mitosis is a type of cell division that passes in four phases: prophase, metaphase, anaphase, and telophase. Because of long lasting time, prophase may have two phases prophase and prometaphase. Both Prophase and metaphase prepare the cell for division process. The real division is done on anaphase and telophase. Before it enters prophase, a cell creates a copy of its DNA. At this stage, the cell nucleus is contains chromatids, and two copies of the chromosomes in connection. On this phase, animal cells have already completed creating copies of their centrosome by this stage.

3.1.1.1 Prophase

In first stages of prophase, the cell organelles prepare for cell division and chromosomes begin condensation for facilitating its migration to poles when cell dividing. Formation of mitotic spindles takes place by this step of mitosis. Between two centromeres mitotic spindles are formed out microtubules. These spindles are responsible in organizing chromosomes when a cell dividing through mitosis.

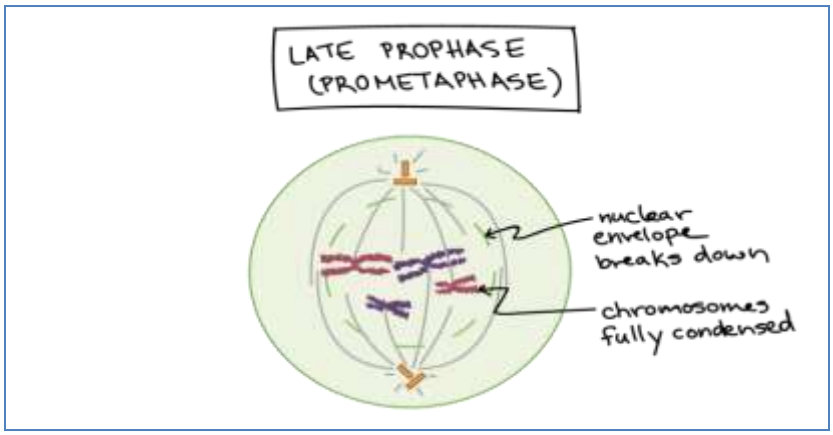

Figure 18: Prophase structure

During prophase, cells do not only create structures, but it enters in breaking down some structures. Ribosomes are created by nucleolus which always resides in cell nucleus. The nucleolus will disappear quickly as a cell ready for division. In later prophase, or prometaphase, the breaking of nuclear membrane take place at this stage and found as a second stage of prophase. As nuclear membrane breaks, chromosomes get of nucleus to cytoplasm. Between centrosomes, there are mitotic spindles and these spindles take their expansion and begin capturing chromosomes. After condensation of chromosomes, chromosomes get compacted. In mitotic spindles, microtubules are found and capture chromosomes and bind them kinetochore. The kinetochore is a structure located on the centromere of the sister chromatids, the region where the chromatids are the most tightly form their bonding and connection.

3.1.1.2 Metaphase

The beginning of metaphase, already started with bonding of mitotic spindles and chromosomes. And here they are found on line in the middle of the cell. At this stage, chromosomes have ability to divide. Each chromosome has two kinetochores and facilitate anchoring of chromosomes and microtubules. These are necessary for a cell to divide in proper manner.

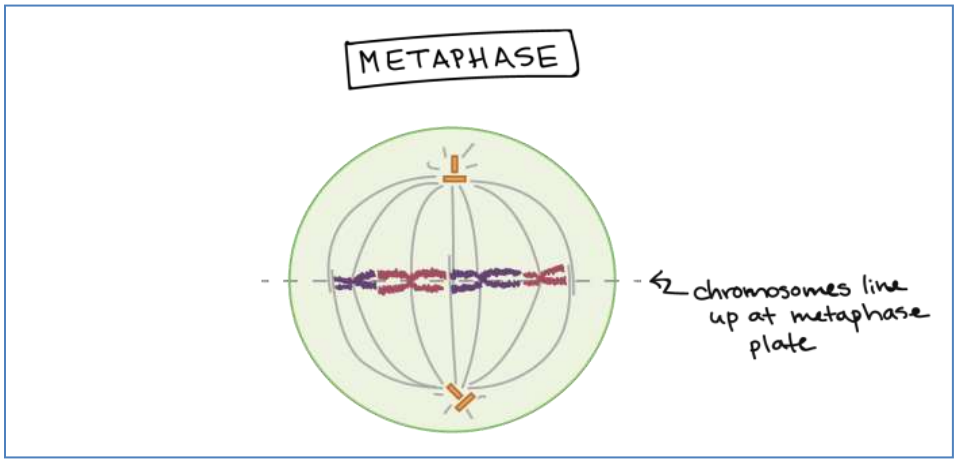

Figure 19: Metaphase structure

After chromosomes organization, the mature cell enters the process known as spindle checkpoint. Where spindles verify if chromatids are organized in proper way for cell division. Misalignments of chromatids can late cell division and in case cell division takes place with this problem of improperly attachment of chromatids, future problems in individual health.

3.1.1.3 Anaphase

Chromatids have already aligned in central part of the cell, in anaphase, the centrosomes begin pulling on chromatids. During this phase, sister chromatids are pulled by means spindles and leave central part to poles. They create daughter chromosomes separately. The microtubules, at this stage begin elongating and facilitate a cell to divide in two daughter cells.

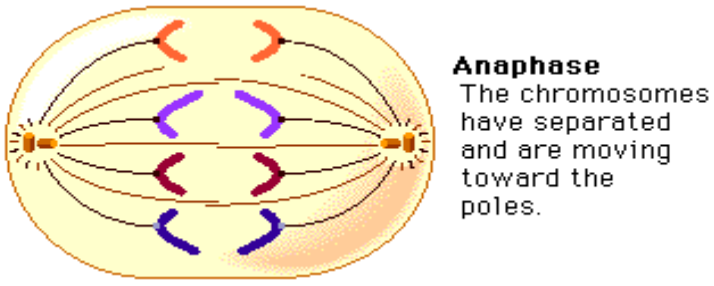

Figure 20: Anaphase structure

3.1.1.4 Telophase

Telophase is the last and final step of a cell to divide. When a cell finished dividing in two daughter cells, the formed cells enters the process of living independently and begins establishing new cell structure. Breaking down of mitotic spindles occurs at this stage and these spindles return back in the initial state in its constituents. Chromosomes get unwound and get their form like strings or chains. Nuclei are formed in both new cells already produced and formation of nuclear membrane renew on formed nucleoli. The complete cell division cannot take place until cytokinesis takes place and finishes

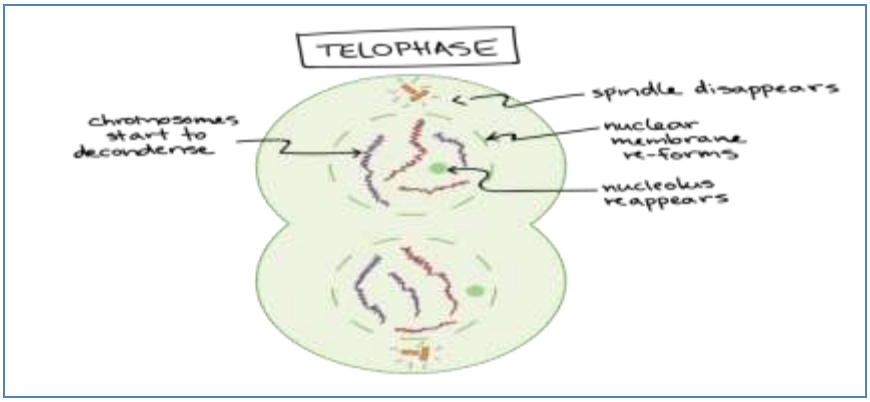

Figure 21: Telophase structure

3.1.1.5 Cytokinesis

Cytokinesis is the process that assures the division of mature cell into two new daughter cells with the same genome. It occurs in last phases of cell division. During cell division in animals, the cytoplasm is pinched and create cleavage furrow, and this continue up to the end of cytoplasm division. There is a difference on plant cells, they don't use the same process of division like that of animal cells, and one factor that makes difference is that their cell wall makes plant cells to be rigid. They easily make their new cell wall in central part of the cell. The four phases of mitosis are all integral to cell division and replication. Without mitosis, the cells in your body could not replicate, and life as we know it wouldn't exist.

3.2 Meiosis

Meiosis is type of cell division exist in cell responsible in gamete formation. Cells with haploid chromosomes enter nuclear division to produce four Haploid cells. It is also known as meiocytes to mean formation of sperms and eggs. Diploid cells enter in meiosis division for the purpose of creating gametes or meiocytes with half of ploidy of their parent cells, and are applied for organisms that reproduce sexually. It is known that the zygote gets half of ploidy of each parent and give a zygote ability to have ploidy information from both parents. Meiosis has no difference with mitosis in phases engaging cell division. The uniqueness that comes in meiosis is genetic recombination through crossing over of homologous chromosomes.

3.2.1 Meiosis I

All phases of meiosis seem to be the same as of that of mitosis. Replications of chromosomes are done in the same way in type one of meiosis. The amount of DNA in the cell has doubled, and the ploidy of the cell remains the same as before, at 2*n*. In meiosis I, the phases are analogous to mitosis: prophase I, metaphase I, anaphase I, and telophase I (below figure). Meiosis I proceeds directly to meiosis II without going through interphase.

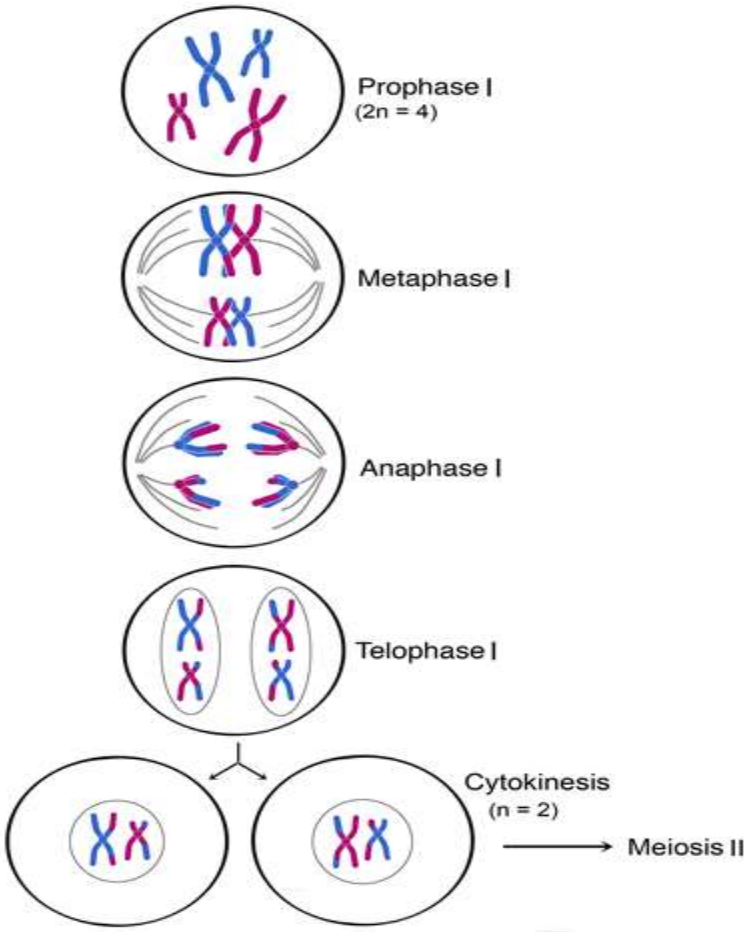

Figure 22: Meiosis 1 summary

3.2.1.1 Prophase I

This stage comes up with manifestation of chromosomes that are seen as solely bodies. Centrioles also get arranged in opposite sides of the nucleus. By this stage homologous chromosomes coiled and get zipped to form pairs known as bivalents in the process named synapsis. As chromosomes coiled around each other, chromatids remain connected in joining place known as Chiasmata. By the time of synapsis, chromosomes that are homologous enter an exchange of their genetic material between one another, and This exchange is known as crossing over.

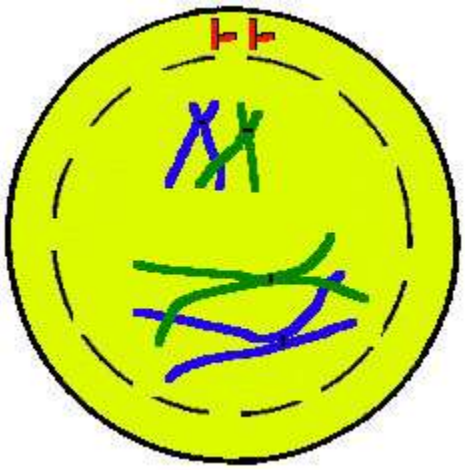

Figure 23: Prophase 1 structure

3.2.1.2 Metaphase 1

During this phase, Nuclear membrane gets disappeared to make freedom to chromosomes by entering cytoplasm. The formation of spindles already done in early stages. Chromosomes that are paired moves to equator and attachment on spindles facilitated by its centromere. During this time homologous chromosomes get orientation in opposite sides of poles.

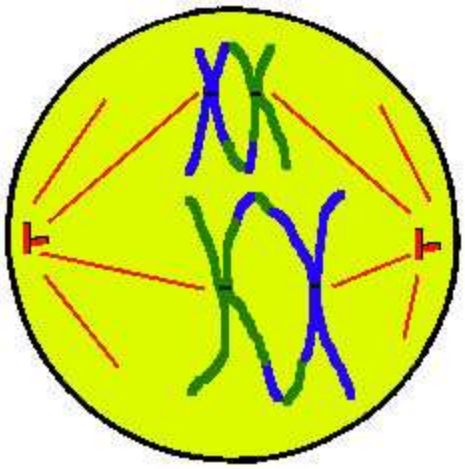

Figure 24: Metaphase 1

3.2.1.3 Anaphase 1

Chromosomes that are Homologous get separation and enter migration in opposite poles. The influence of this migration is facilitated by shortening of spindle fibres and chromosomes get pulled. However, sister chromatids still coiled at this stage.

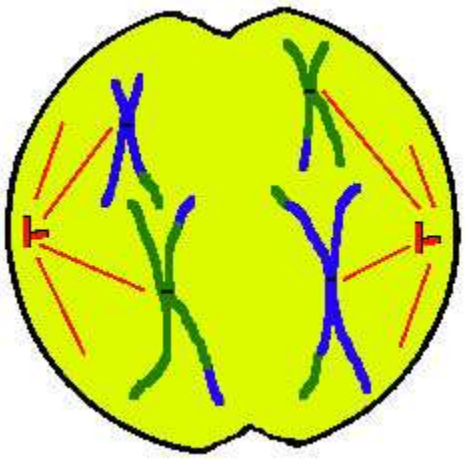

Figure 25: Anaphase 1

3.2.1.4 Telophase 1

When the journey of chromosomes from centre to poles finishes, they densely packed together. Spindles break down and formation of nuclear membrane takes place on each chromosomes and

the cell halved divides. However most of organisms do not enter telophase, and scientific evidences shows that they directly enter meiosis 2.

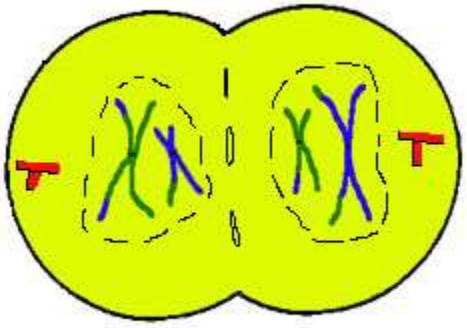

Figure 26: Telophase 1

3.2.1.5 Summary of meiosis 1

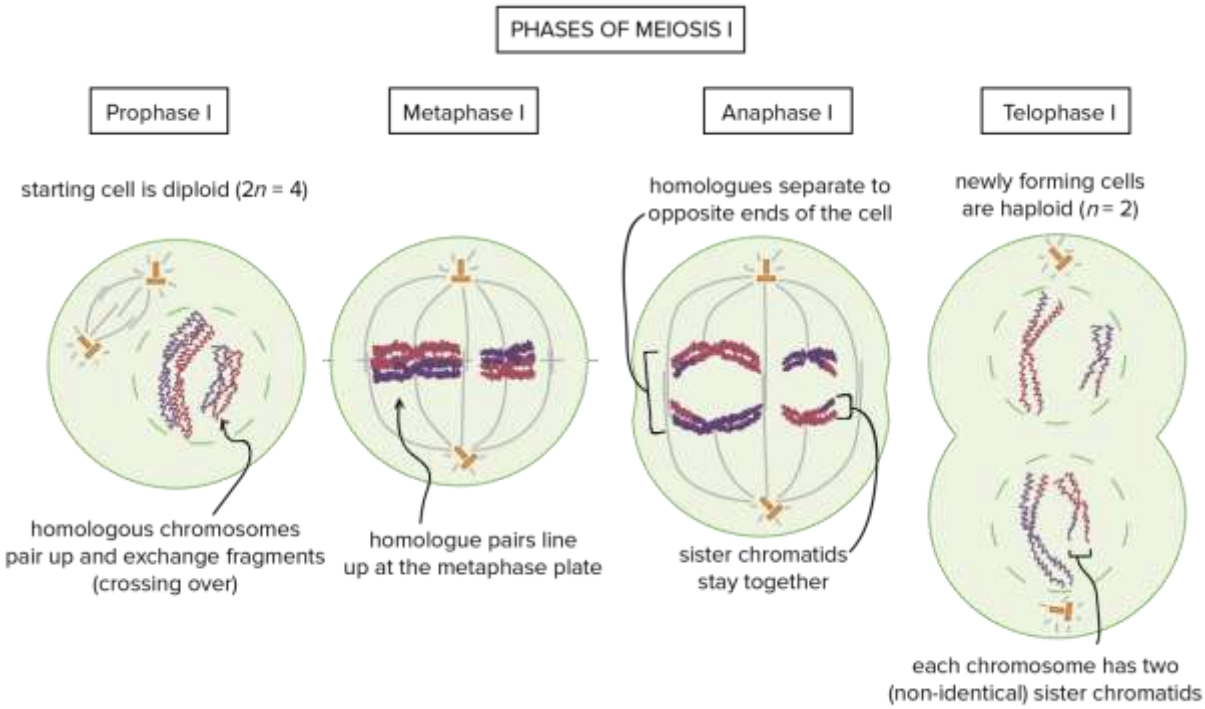

Figure 27: Meiosis 1 summary

3.2.2 Meiosis 2 Phases

3.2.2.1 Prophase 2

The thickenings of chromosomes take place at this point and new spindles formation place. You better know that dispersion of chromosomes already taken place in telophase I, thus, they will enter condensation in prophase II. At this early stage of meiosis II, sister chromatids continue coiling together.

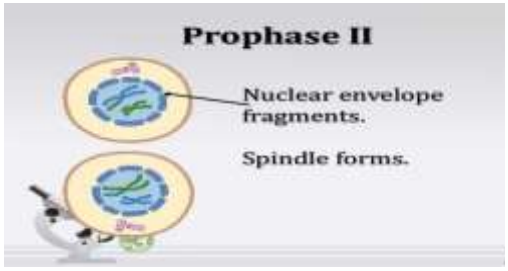

Figure 28: Prophase 2

3.2.2.2 Metaphase II

As usual, at this stage chromosomes get arranged in metaphase plate. And attached on new formed spindles. Each new formed cell, enters completion of spindles formation. Alignment of single chromosomes takes place in metaphase plate and seems different with metaphase I where paired chromosomes get alignment in metaphase plate. the kinetochores of each chromosome, of the sister chromatids face the opposite poles to be ready for migration, and each gets its attachment to a kinetochore microtubule that comes from that pole.

Figure 29: Metaphase 2

3.2.2.3 Anaphase II

At this stage separation of cetromeres take place as well as that of sister chromatids. Chromosomes take their trip toward opposite poles. This chromatids that are separated are known as chromosomes in their own right.

Figure 30: Anaphase 2

3.2.2.4 Telophase II

In second telophase, the formation of nuclear envelope take place on each part of chromosomes and time of cytokinesis arrives. Production of four daughter cells take place and diploid already changed to haploid. Crossing happened in meiosis I, allow chromosome to have some characters from parent chromosomes.

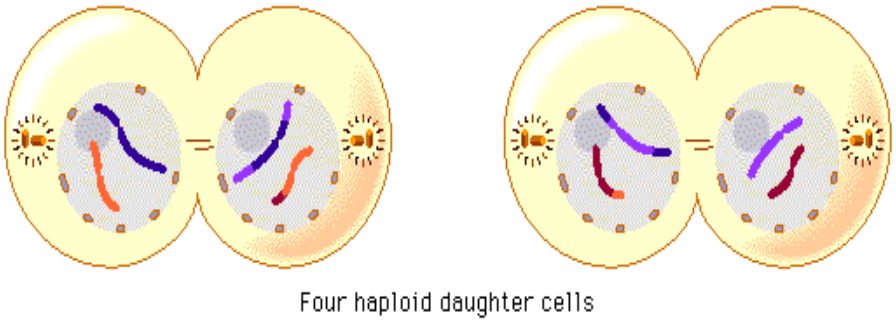

Figure 31: Telophase 2

3.2.2.5 Summary

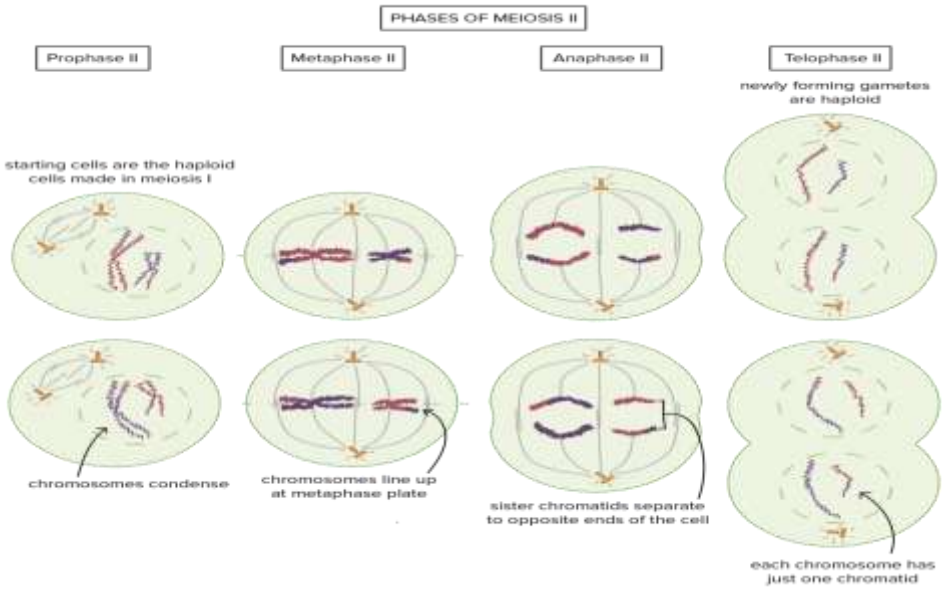

Figure 32: Summary of meiosis 2

Questions for evaluation

1. What the role of somatic cell division in living things?
2. Explain the process of mitotic division and explain clearly each step of this type of cell division.
3. Explain the process of crossing over and explain why this process play important role in living organisms
4. In which type and stage of cell division does crossing over take place?
5. What the difference between mitosis and meiosis?
6. Is meiosis different with gametogenesis? Explain your answer.
7. Meiosis is done in two principal parts, explain and mention all stages passes through in two parts.

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4. CYTO-SKELETON AND CELL MOTILITY

The cytoskeleton is a network of fibers that forms the "infrastructure" of eukaryotic cells, prokaryotic cells, and archaeans. Cytoskeleton was previously thought to be a feature only of eukaryotic cells, but homologues to all the major proteins of the eukaryotic cytoskeleton have recently been found in prokaryotes. Although the evolutionary relationships are so distant that they are not obvious from protein sequence comparisons alone, the similarity of their three-dimensional structures and similar functions in maintaining cell shape and polarity provides strong evidence that the eukaryotic and prokaryotic cytoskeletons are truly homologous unlike some structural differences in bacteria.

In eukaryotic cells, these fibers consist of a complex mesh of protein filaments and motor proteins that aid in cell movement and stabilize the cell. Cell motility is the extra cellular (cell itself) and intracellular movements of the cell which include moving along surfaces, through a tissue and the movement of inner cell components. Typical examples of cellular movement may include extracellular (cell movement) such as; movement of cells from one point to another in the embryo during embryonic development, movement of cells in to wound during wound healing, contraction of muscle cells, separation of cells during cell division (formation daughter cells) and intracellular movements (cell components) such as membrane-bound vesicles in to the cell during cell eating(phagocytosis or endocytosis) and chromosomal movement during cell division(mitosis).

The cytoskeleton is responsible for cell shape, motility (movement) of the cell as a whole, and motility of **organelles** within a cell. There are three types of filaments in the **cytoplasm** of most eukaryotic cells (vertebrate cells): microfilaments, microtubules, and intermediate filaments. All of these filament systems share a critical feature: They are composed of proteins that have the unique property of being able to self-assemble into a filamentous network. Imagine a pile of bricks that could assemble by themselves into a wall; the proteins that make up the fibers of the cytoskeleton are able to do just this. The proteins that make each of the three different filament systems assemble into only the structure characteristic of that filament.

Unlike the human skeleton, the cytoskeleton is extremely dynamic, meaning the filament systems are able to lengthen or shorten very rapidly. This dynamic nature of the cytoskeleton is necessary for cells to be able to change shape, complete cell division, or migrates, and represents one of the cytoskeleton's most important features. Each of the self-assembling proteins has a characteristic concentration, called the "critical concentration," below which the **monomer** state is favored and above which the **polymer** state is favored. Increasingly, the subunit concentration favors filament building, and decreasing it favors filament deconstruction. This property allows the cell to rapidly control cytoskeleton structure.

4.1.Microfilaments

The microfilament (actin) system is a network of filaments 6 **nanometers** (nm) in diameter that are important for anchoring plasma membrane proteins, for producing cell movement, and for cell division. The base filament is composed of a protein called actin that is 42 kilodaltons (kd) in weight. Actin is also the protein that forms the thin filaments found in muscle. When purified actin is incubated in a test tube, 6 **nm** filamentous structures are formed. These threads consist of side-by-side actin monomers that twist around each other in a helix. Inside cells, actin exists in two states, the monomeric protein, called G-actin (for globular actin) and the 6 nm filament, called F-actin (for filamentous actin). The factor that determines the relative proportions of F-actin and G-actin is the concentration of actin protein. Each microfilament has a fast-growing, or "plus," end, and a slow-growing, or "minus," end. In most cells the plus ends of the filaments are oriented toward the edge of the cell. In this way rapid polymerization of actin monomers onto the plus ends of microfilaments can produce protrusions on the cell surface called **pseudopods**. These extensions are critical for the ability of cells to migrate in a directional fashion.

Microfilaments exist in their highest concentration in association with the cell periphery, where they are believed to play an important role in anchoring membrane proteins. Microfilaments can also be organized into bundles, called stress fibers, which serve as contractile elements, somewhat like little muscles, within cells. These structures are important for maintaining connections between the cell and the surface on which it grows. In addition, these structures may be important for producing contractility to generate directional force during cell motility. A third microfilament-based structure, the contractile ring, is critical for the separation of a cell into its two **progeny** during cytokinesis.

In most cells the concentration of actin exceeds the critical concentration for microfilament assembly, yet the actin is not entirely assembled into filaments. This occurs because cells make a variety of "actin-associated" or "actin-binding" proteins. One example of an actin binding protein is the G-actin-binding protein profilin. When bound to profilin, actin monomers cannot assemble into filaments. Binding of actin by profilin can effectively reduce the concentration of free actin monomer to below the critical concentration. The actin-binding activity of profilin is regulated in cells. Certain stimuli will cause profilin molecules to release their bound actin monomers, effectively increasing the concentration of actin and thereby stimulating actin assembly. Thus cells can control the relative proportions of G-actin and F-actin.

In general, the functions of actin-associated proteins are to modify the properties of the microfilament network in cells. Some filament-associated proteins, for example the protein tropomyosin, bind along the length of the filament to stiffen it. There are also proteins such as villin or filamin that bind microfilaments together side by side to produce bundles of actin filaments. Other actin-binding proteins cross-link actin filaments to form meshlike structures such as those found in association with the cell membrane. Cells can also control the length of filaments through the action of proteins that can cut filaments to produce two shorter filaments. To keep the filaments a certain length, cells produce "capping" proteins that bind to the ends and prevent the addition of new actin subunits. By modulating the state of the microfilament network the cell can control the physical properties of the cytoplasm such as rigidity and viscosity. One of the most interesting types of actin-associated proteins is a family of **enzymes**, called myosins, which have the ability to convert chemical energy into movement. The characteristic property of these so-called myosin molecular motors is their ability to bind actin in an adenosine triphosphate–sensitive fashion and to produce movement of actin filaments. Over fifteen different types of myosin motors have been identified. Some of them, such as those involved in cytokinesis and cell motility, are two headed, meaning they have two actin-binding motor domains, while others have only one head. Some of these myosins are involved in the movement of membrane-bound **vesicles** along actin tracks. The best characterized of these molecular motors, myosin II, slides actin filaments past each other either to power contraction of the contractile ring or to produce cell migration. A different version of this myosin motor forms the thick filaments that are responsible for the contraction of muscle.

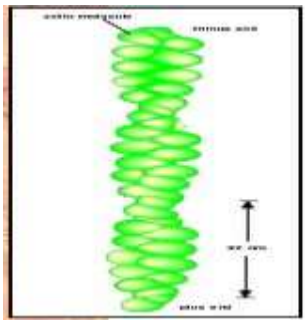
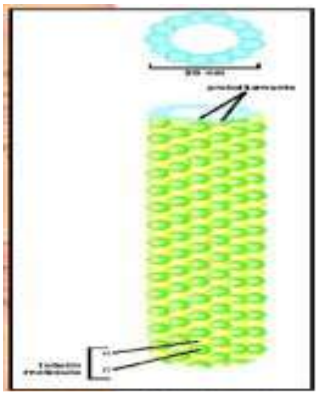


Figure 33:Actin molecule

4.2 Microtubules

Microtubules are the largest of the cytoskeletal filaments with a diameter of 25 nm. There are many parallels between the microfilament cytoskeletal system and the microtubule system. Like microfilaments, microtubules are produced by the self-assembly of a subunit, which in the case of microtubules is a **heterodimer** composed of one alpha tubulin and one beta tubulin bound together. Alpha and beta subunits alternate to form a protofilament. Thirteen protofilaments line up side by side, forming the hollow tube of the microtubule.



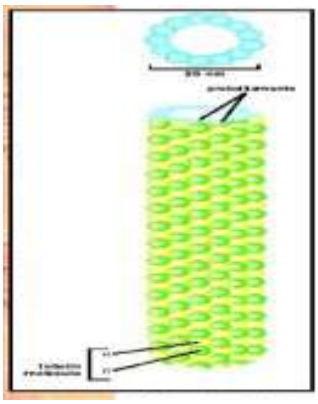


Figure 34: Microtubule molecule

Microtubule molecule: Illustration of the ring of 13 distinct subunits in a microtubule, each of which corresponds to a tubulin molecule. Bottom: A side view of a section of a microtubule, with the tubulin molecules in long, parallel rows called protofilaments.

Microtubules also have a fast-growing, or plus, end and a slow-growing, or minus, end. In most cells microtubules are organized in a radial array extending from a single site termed the microtubule organizing center (MTOC), generally positioned near the **nucleus** . This organization produces a network of microtubule tracks where the plus ends of the microtubules are near the cell surface and the minus ends are associated with the MTOC. This structure is well suited for the primary function of microtubules, which is to serve as tracks along which membrane-bound vesicles are moved. Vesicles transported include organelles such as **mitochondria,** as well as secretory vesicles destined for exocytosis. Another parallel with microfilaments is the highly dynamic nature of microtubules. Microtubules exhibit a phenomenon called "dynamic instability." Individual microtubules constantly grow and shorten, often shortening dramatically in a process called "catastrophe." This rapid turnover of microtubules allows cells to change shape quickly and facilitates reorganization of the tracks important for delivery of vesicles to sites throughout the cell. Like the microfilament cytoskeleton, the dynamics of microtubules can be modified by microtubule associated proteins, called MAPs. Some MAPs stabilize microtubules, while others cross-link microtubules, both

with other microtubules as well as with microfilaments and the third cytoskeleton system, intermediate filaments (see below).

The dynamics of microtubules are also important for **mitosis**. Each time the cell goes through division the microtubule network is completely disassembled and the tubulin subunits are reassembled into a new structure called the spindle. The spindle is responsible for the segregation of **chromosomes** into each daughter cell and also plays an important role in specifying the position of the cleavage plane that will separate the two daughter cells (during cytokinesis).

The functions of microtubules in vesicle transport and chromosome segregation are dependent on molecular motors that bind to and move along microtubule tracks. These motors are divided into two families, kinesin and cytoplasmic dynein. Kinesin was the first microtubule motor to be identified. It is responsible for moving vesicles (the cargo of the motor) toward the plus ends of microtubules, that is, from the center of the cell toward the plasma membrane. Since discovery of the first kinesin, the family has been shown to consist of many members, some of which are important for spindle function during mitosis. Some of these kinesins move toward the minus ends of microtubules. In contrast, the other type of microtubule motor, cytoplasmic dynein, appears to move cargo exclusively toward the minus ends of microtubules, that is, from the cell periphery back towards the center. The ability of these motors to move organelles around inside of cells is critical for processes such as **hormone secretion,** transmission of nerve impulses and recycling of membrane.

4.3 Intermediate Filaments

The third cytoskeletal system is called the intermediate filament system because the filaments, which are 10 nm in diameter, are intermediate in size between microfilaments and microtubules. There are many other features that set the intermediate filaments system apart from the other cytoskeletal systems. Unlike the other systems, which are composed of one or two different proteins, intermediate filaments can be formed by a relatively large number of different proteins. For example, the primary intermediate filaments found in epithelial cells (such as skin) are formed from pairs of **keratins**, one **basic** and one **acidic**. There are a large number of different keratin pairs, found in different tissues that produce 10-nm filaments. Wool, hair, and nails are

examples of structures formed from intermediate filaments. The different filament-forming keratins are developmentally regulated, and the keratins expressed early in embryos differ from those expressed later in development.

In contrast, a different cell type, **fibroblasts**, have intermediate filaments that are formed from a single protein, vimentin. In heart tissue, the intermediate filaments can be formed from a different single protein, desmin. In nervous tissue the intermediate filaments are formed from yet another family of **intermediate filament proteins** called neurofilament proteins. There are even structures in the nucleus formed from intermediate filament protein family members called nuclear lamins.

Although intermediate filaments can also self-assemble from their constituent subunits, the filaments differ from microtubules and microfilaments in that they do not have an obvious polarity. Structurally, intermediate filaments are formed from a bundle of subunit proteins which themselves are extended in structure, as compared to the more globular-shaped protein subunits that form microfilaments and microtubules. Intermediate filaments are generally more stable structures than the other cytoskeletal systems, although recently it has been shown that subunits are capable of exchanging in and out of the filament all across their length. Like other filament systems, intermediate filaments have associated proteins, but interestingly no molecular motors that use intermediate filaments as their track have been identified.

Intermediate filaments are organized within cells so that they link the cell surface and the nucleus. Intermediate filaments are believed to play an important role in cells by stabilizing structural integrity. Of all the cytoskeletal systems, intermediate filaments are best suited to play this structural role since they have the highest tensile strength (resistance to stretch). At the cell surface, intermediate filaments attach to specific junctions called desmosomes and hemidesmosomes. These junctions attach cells to neighboring cells or the extracellular **matrix** .

Mutations in intermediate filament subunit proteins have been shown to cause human diseases. For example, mutations in keratins cause blistering diseases that result from a loss of cellular integrity, causing cells to literally split in half. Similarly, mutations in the neurofilament proteins produce neurological diseases called neuropathies.

4.4 Cytoskeleton-Based Cellular Structures

Several cellular structures are built around a core of cytoskeletal proteins. Perhaps the best known examples are **cilia** and flagella. Flagella provide the motive force for sperm motility through their waving motion. Cilia line the surfaces of cells in the respiratory tract where their motion constantly moves mucus along the airway surface. The core of both flagella and cilia is composed of a highly organized bundle of specialized microtubules. Around a "central pair" of microtubules, there are nine pairs of modified microtubules called "doublet microtubules." The central pair and the outer doublet microtubules are connected by a number of different specialized proteins. The characteristic waving motion of cilia and flagella is generated by the action of a microtubule-based motor called axonemal dynein that moves the microtubules in the flagellum relative to each other. Axonemal dynein is related to the minus end directed motor cytoplasmic dynein that moves vesicles along microtubules. Dynein mutation causes cilia dysfunction, leading to respiratory illness and sperm immotility. Curiously, about half of the people with these mutations also have "situs inversus," in which the internal organs are reversed left for right.

Another microtubule-based cellular structure is the centriole. The centriole is a somewhat mysterious cylindrical structure containing vanes formed from microtubules that run the length of the cylinder. Centrioles together with the associated pericentriolar material form a somewhat larger structure called a centrosome. Centrosomes function as microtubule organizing centers during interphase of the **cell cycle**, and become the center of the spindle poles during mitosis.

4.4.1 Motor Proteins

A number of motor proteins are found in the cytoskeleton. As their name implies, these proteins actively move cytoskeleton fibers. As a result, molecules and organelles are transported around the cell. Motor proteins are powered by ATP, which is generated through cellular respiration. There are three types of motor proteins involved in cell movement.

Kinesins move along microtubules carrying cellular components along the way. They are typically used to pull organelles toward the cell membrane.

Dyneins are similar to kinesins and are used to pull cellular components inward toward the nucleus. Dyneins also work to slide microtubules relative to one another as observed in the movement of cilia and flagella.

Myosins interact with actin in order to perform muscle contractions. They are also involved in cytokinesis, endocytosis (endo-cyt-osis), and exocytosis (exo-cyt-osis).

Questions for evaluation

1. What is cell cytoskeleton?
2. What is the role of cell cytoskeleton?
3. Mention components of cell cytoskeleton.
4. What do you understand by cell motility

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5. THE RELATIONSHIP BETWEEN CELLS, TISSUES AND ORGANS

The relationship between cells, tissues and organs of the body best describes the architecture of the body through which all smaller parts get together and form bigger parts and then to system which makes a body. All matter in the universe is composed of one or more unique pure substances called elements, some which are commonly known include hydrogen, oxygen, carbon, nitrogen, calcium, and iron. The smallest unit of any of these pure substances (elements) is an atom. Atoms are made up of subatomic particles such as the proton, electron and neutron. Atoms form a molecule when combined in pairs of two or more atoms, molecules such as water molecules, proteins, and sugars found in living things are good examples of body molecules. Molecules are the chemical building blocks of all body structures, they build up to make a smallest independently functioning unit of a living organism called a **cell**. All living structures of human anatomy contain cells in which most of body functions are performed.

When a group of many similar cells get together forms a structure called **tissue** to perform a specific function in the body. An **organ** is an anatomically individual structure of the body composed of two or more types of tissues such as kidney. Each organ performs one or more specific physiological functions in the body of humans and other living organisms. Body organs form a **system** which performs major functions to meet physiological needs of the body, example of body system can include urinary composed of organs like kidneys and bladder.

Below is the schematic diagram showing the relationship between body structures from first level of atoms to the organism level.

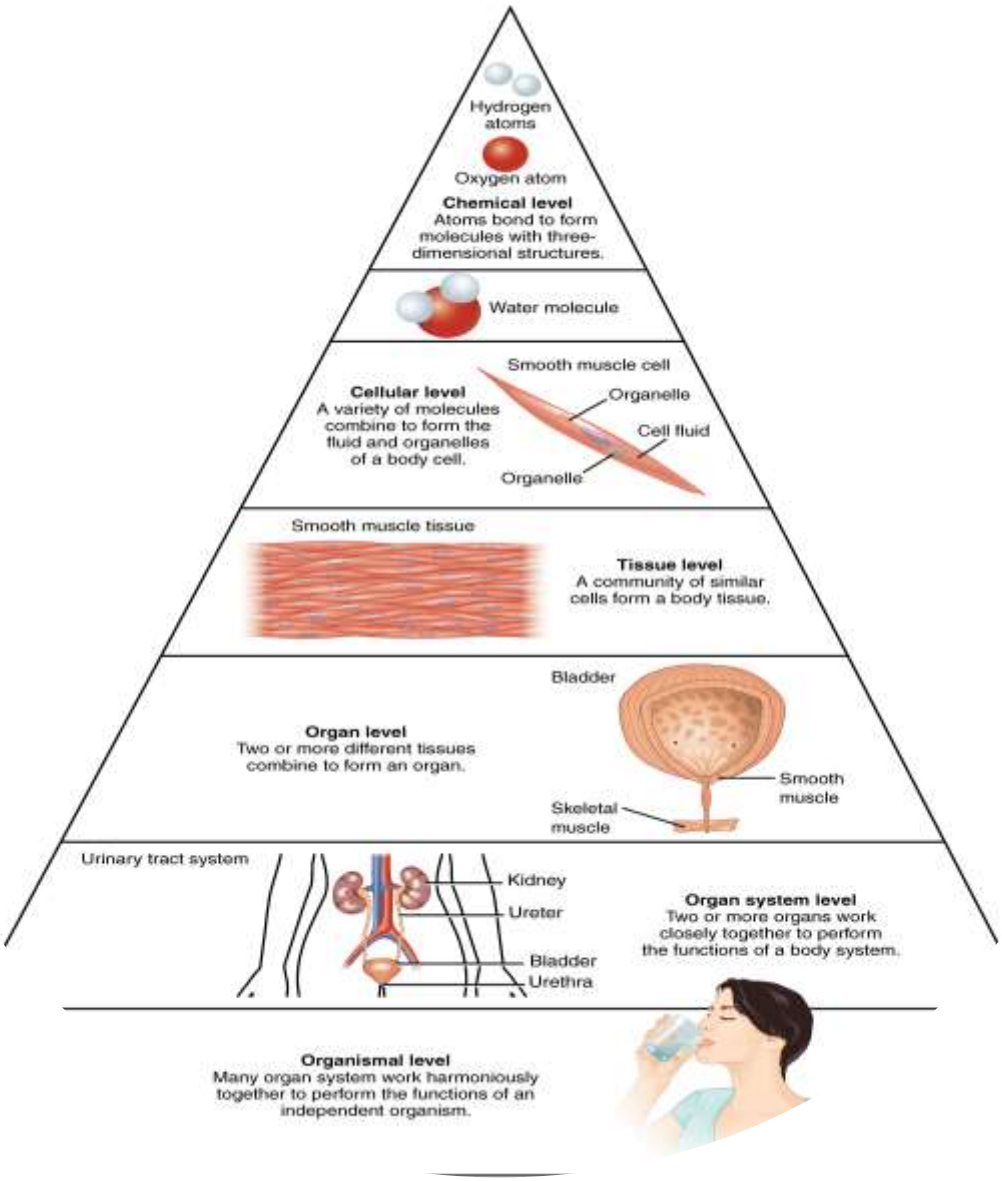

Figure 35: Description of relationship between cells, tissue and organs

During growth all levels in the above diagram are achieved to ensure that the human or any organism's body is established therefore any disruption at any level leads to abnormalities, sometimes leading to the absence of some body organs. For instance heart congenital heart defects detected during child birth.

Questions for evaluation

1. Briefly explain the relationship between cells, tissues and organs

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6. CELLULAR COMMUNICATION

Cells of the body communicate by sending and receiving signals, Cells communicate through their own language of chemical signals. Different compounds, such as hormones and neurotransmitters, work like words and phrases, telling a cell about the environment around it or communicating messages. There different sources of signals which include the environment, or they may even come from other cells (neighboring cells). Signals causes cellular response, after signals are must be transmitted across the cell membrane which triggers the cell to respond to specific signals (stimulus). Sometimes the signal itself can cross the membrane or other times the signal works by interacting with receptor proteins that contact both the outside and inside of the cell. Therefore, only cells that have the right receptors on their membranes can respond to the signal.

6.1 Types of signals

In multicellular organisms, cells use several types of extracellular molecules to transmit signals and communicate between each other. These means of cell signaling are group into four types as follows:

Endocrine: this is the major common type of cell signaling that involves conveying a signal throughout the whole body by secreting hormones into the bloodstream (circulatory system) of animals or the sap in plants (fig 1) .The cells that produce hormones in animals are called endocrine cells. For instance, the pancreas is an endocrine gland and produces the hormone insulin, which regulates the uptake of glucose in cells all over the body. Examples of hormones that function in an endocrine manner (via ducts) include testosterone, progesterone and gonadotropins

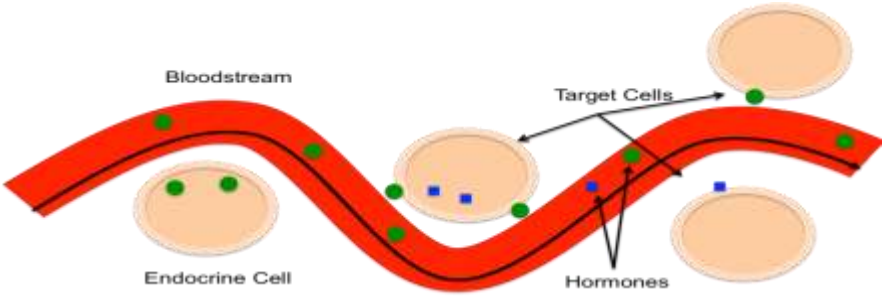

Figure 36: Endocrine signaling

In the figure above is illustrating endocrine signaling where endocrine cells release hormones (indicated in green) into the blood stream where they are able to move and bind to target cells located downstream. The binding of these hormones to target cells may lead to cellular responses such as the release of a second hormone for instance in line with body defense mechanisms (indicated in blue).

Paracrine: It can also be called local mediators signaling molecules. Molecules are released from paracrine cells and diffuse locally through the extracellular fluid, targeting cells that are nearby (fig 2). Many of the cells that are involved in inflammation during infection, or that regulate cell proliferation utilize this type of signaling. For example cancer cells sometimes enhance their own survival or proliferation in this way. Examples of signaling molecules that usually function in a paracrine manner may include transforming growth factor-β (TGF-β) and fibroblast growth factors (FGFs).

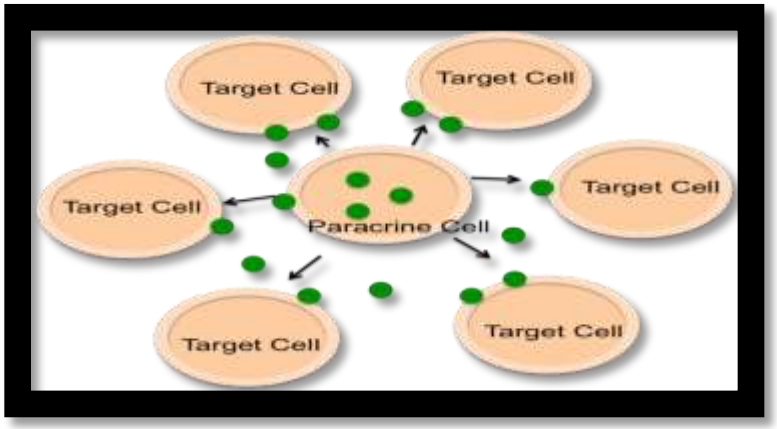

Figure 37: Paracrine signaling

Paracrine cells release signaling molecules (in green) into the immediate surrounding area, targeting nearby cells.

Neuronal: Nerve cells (neurons) are specialized cells with a unique structure that can send signals very quickly in form of electrical impulses, over long distances and to specific target cells along their paths of interconnected cells (neurons) (fig 3). A signal is detected by receptors present on dendrites and then carried along the axon to a presynaptic terminal. When the signal reaches the presynaptic terminal, vesicles containing signaling molecules (neurotransmitters) fuse with the cell membrane, releasing the contents into the synaptic space. These neurotransmitters are detected by receptors on the postsynaptic membrane i.e. the cell membrane of the target cell, which may be another neuron or an effector cell. Common examples of neurotransmitters include acetylcholine, serotonin and histamine.

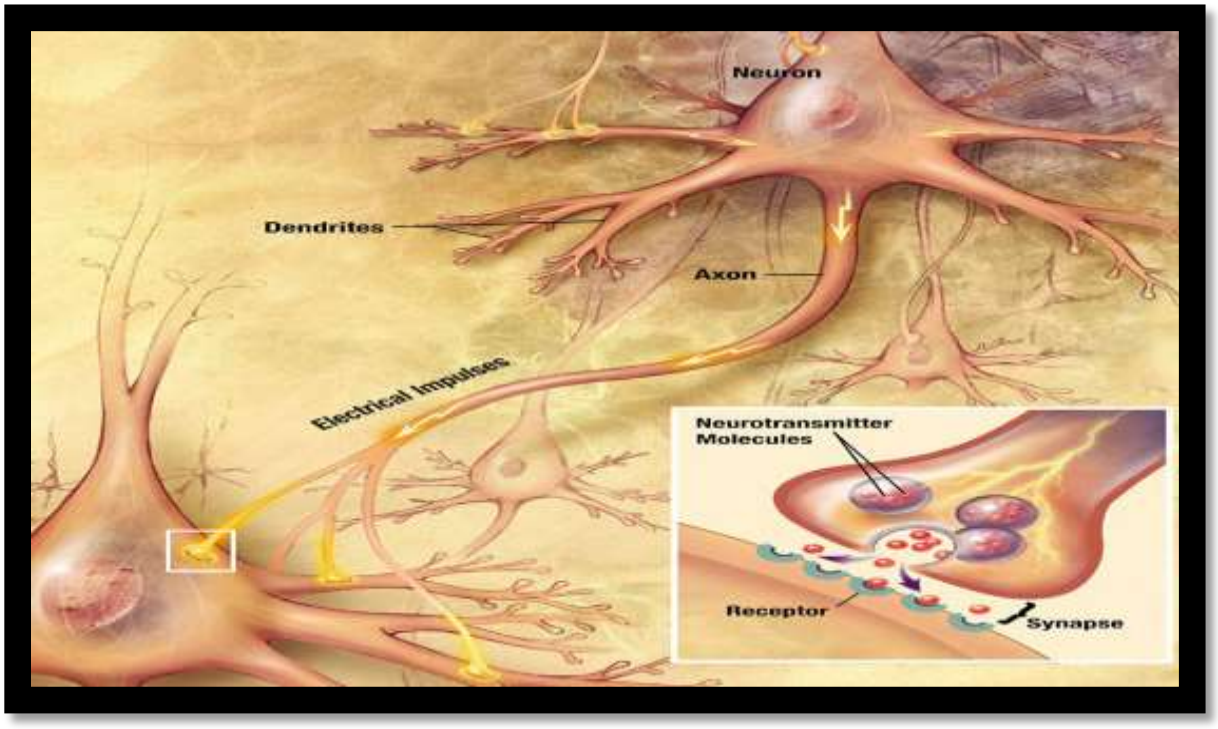

Figure 38: Neuron signaling

Neurons receive and send signals across long distances through thin, fragile extentions called axons, ultimately to effectors tissues such as muscles, or sensory organs.

Juxtacrine: This is often referred to as a contact-dependent signaling. In this signaling mode there is no release of secreted molecules it only occurs over short distances by cells direct physical contact through signal molecules found in the plasma membrane of the signaling cells and receptor proteins present in the plasma membrane of the target cell. This type of signaling is extremely important during embryonic development and cell-fate determination (when similar cells that are close to each other specialize to form a specific cell type). The Notch pathway mediates juxtacrine signaling between adjacent cells (Figure 4). Notch receptors are single Trans membrane proteins and they bind to specific ligands (e.g. Delta and Serrate ligands) on adjacent cells. Ligand binding results in proteolytic cleavage of the Notch receptor which releases an intracellular domain that is translocated to the nucleus where it regulates gene expression.

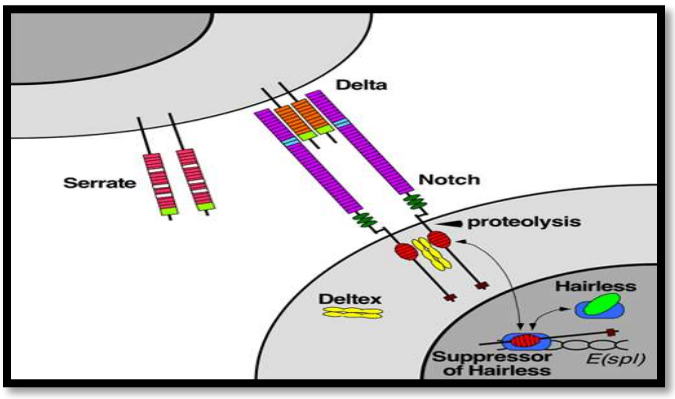

Figure 39: Juxtacrine signaling.

The binding of a Delta ligand (purple) to a Notch receptor (green) results in proteolysis and the release of an intracellular domain that regulates gene expression.

Questions for evaluation

1. Explain the process by which cell communicate on each other.
2. What are signals?
3. What are types of signals
4. What is the function of cell communication

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7. CELLULAR ABNORMALITIES

Cellular abnormality is defined as deviation or malformation during the occurrence of a certain phenomenon. Body cells can have abnormalities during cell multiplication or division and proliferations. One factor that can be a cause of this problem is gene mutations in cells.

7.1 Cellular abnormalities in cell division

This abnormality can happen at chromosomal level or gene level and this lead to serious genetic mutations which later cause different diseases and simply lead to death. Defects in chromosomes happen and seem to be surprising events. It was notified that 20% of mankind already experienced this problem of chromosome defects and abnormalities. Previous researches show that 1 out of 118 neonates get chromosomal abnormalities in United States of America. This issue is influenced by cell division through meiosis by which gamete formation gets place. Statistical estimation showed that among 5 sperm cells created by a men who are in a good health, 1 sperm can have defection.

We always observe spontaneous miscarriages in women and researchers have showed that half of them are due to gross chromosome errors and defects. Most of times this problem happens during early months of pregnancy may result from gross chromosomal errors.

Chromosomal abnormalities are categorized in two:

Irregular number of chromosomes and Modification in chromosome structure

Both these types of chromosomal abnormalities happen due to **nondisjunction errors** which are defined as errors that mechanic during cell division through meiosis. These kinds of errors take place in paired chromosomes that are homologous where they move in the same pole instead of moving toward poles that is in opposite sides.

7.1.1 Irregular Number of Chromosomes

These types of error are mostly found in karyotypes of human embryonic and fetal cells and is an error that leads to variation in number of chromosomes. Parents offer their contribution in offspring chromosomes. It is known that both parents participate in determination of offspring chromosomes which is 23 and come up on pair of 23 in their descendents. The complete multiple of sets can be among these errors. Example can be like 23 + 23 + 23), which is known as **polyploidy**. On the other hand, an addition or loss of chromosomes can be happen. Find some examples here 23 + 22 for loss of chromosomes and 23+24 when chromosomes added to normal number of chromosomes and this is known as **aneuploidy**. **Monosomy** is referred to the situation when there is one to few chromosomes. **Trisomy** is also used to mean homologous pairs with three chromosomes.

7.1.2 Structural Modification of a Chromosome

This kind of error occurs when we find that there is a breakage and loss of a part of chromatid, or added chromatid to to the same different or the same chromosome. The cause of chromosome breaking is still unknown however, medical geneticists and other related scientists are still analyzing and searching this causes. Remember that this breaking leads to genetic mutation which is influenced by radiation, chemicals and others, that is why they considered to be causes of chromosomes breaking.

7.1.2.1 Mosaicism

Chromosomal abnormalities are not always mentioned in all cells. They occur in some cells and tissues which mean that some cells are normal while others carry abnormalities. It is in this manner that symptoms can be less severe someone than when all cells have abnormalities. It is discussed and discovered that **mosaicism** comes as results from mutations occurring during mitosis in early period of development of an embryo. When mutation happens in The later the embryonic stage, some few cells can be abnormal.

The majority of chromosome abnormalities in humans take place in the autosomes. Monosomies and trisomies are mostly happen in the autosomes. During pregnancy, the presences of fetuses with autosomal monosomies will lead to spontaneous abortion in early in pregnancy. On the other hand, fetuses with autosomal trisomies have no chance of surviving as they die before parturition. When these babies get chances of surviving, they present number of physical defects mental retardation and other different problems that lead to early death of the newborn.

Down syndrome is an abnormality which is commonly and mostly known. This abnormality is mild to severe form of mental retardation escorted by different physical features and traits. People who suffered from Down syndrome show an irregularity with autosome pair having 21 chromosomes. People who suffered from Down syndrome have appearances of physical features like short and stocky bodies without forgetting thick hands and feet. It is also observed that people with this abnormality have **simian crease**, in their hands and this is a crease in the palm found in all sides of the hand and runs from one side to the other. Other feature like having broad, short heads with small low-set ears, small concave saddle-shaped or flattened noses, relatively large ridged tongues that roll over a protruding lower lip, loose joints, and low muscle tone that leads to poor motor skills. Frequently, their eyes have an East Asian-like its shape and appearance due to an **epicanthic fold**. People that suffered from Down syndrome can have other different problems of medical importance, and those problems we can say **epilepsy, hypothyroidism** , having eyes that are crossed, having problems in seeing that contributes to near-sightedness or far-sightedness, features like hearing impairment, defects of the heart, malformation of intestines, and low resistance to respiratory infections are seen on people suffering from Down syndrome. Leukemia in Childhood is seen 20 times in people with Down syndrome than those without it. Down syndrome can have its acceralation due to age, it was seen that at the age 35, the rate of 25% of people with non-mosaic Down syndrome begin developing **Alzheimer syndrome**. Actually, people with Down syndrome die in childhood, and in united states, they used dying at the age of 9 in 1929 but with development of medicine, they can reach the old age. But this is not applied to developing countries. Almost Down syndrome fetuses are not ready to survive and up to 85% get spontaneousl abortion. It was also noticed by researchers that 1/4 of all miscarriages are caused by **trisomy** which is a part of Down syndrome.

7.1.3 Abnormalities in Sex Chromosome

As abnormalities are found in somatic cells, it is also done in sex chromosomes. The frequency of chromosome abnormalities is less in sex chromosomes than somatic cells. Abnormalities in Sex chromosome are gender based. We better know that male who is Normal inherit X and Y chromosomes, and on the other hand females have XX which means two Xs in their chromosomes. Only single Y chromosome is enough to give maleness while X is responsible for femaleness. Abnormalities in female can occur due to any variation on chromosome number which chromosome X and for male abnormalities it can happen either to X or Y or can happen to both Y and X

7.1.3.1 Abnormalities in Female Sex Chromosome

Let's start on **Turner syndrome,** which takes place when a woman or females possesses X0, and directly inherit one X. chance of surviving to girls with this type of abnormalities is very low and if they get chance of surviving after birth, they seriously meet abnormal growth. These people are very short in stature, and averages of how short they vary from 4 foot to 7 inches on adult person. These people have webbed neck, small jaws and arched palates. These people can miss secondary sexual characters. Abnormalities in chest, breast, and other parts of the body can occur. Abnormal ovary development also is present which means that no ovulation for these people. They can produce children by implanted fertilized eggs. Women that have Turner syndrome are in high risk of getting thyroid disease, vision and hearing impairments, heart defects, diabetes, and some other autoimmune disorders. It can cause mental retardation in a small number of individuals and the good thing is that is rare within population.

Early detection and diagnosis of this abnormality in early childhood can be very fruitful. It can be done through regular injections of human hormone that are responsible for growth and can increase inches on the stature. During puberty, estrogen replacement can facilitate in the development of breast and also menstruation can occur regularly.

Another chromosomal abnormality for women is **Triple-X syndrome** occurring in women inheriting three X chromosomes and their genotype is structured like XXX. This brings as to "super-females" or "metafemales", in adults. They can be very tall with long legs, and have slender torsos. This condition is not common some women can stay in normal state with this abnormality. It does not matter on sexual characteristics and fertility; however, ovary abnormalities can take place and contribute to prematurity of ovary.

This abnormality leads to problems like having difficulties in learning, speaking, and have problems in language skills. You find them tall in childhood; the size of these individuals seems to be immature. Despite these problems that they face, their emotion give orient them to maturity like other girls of their generation, and these health traits cannot lead them to problems of being unaccepted as women like others. People with XX/XXX do not show number of symptoms. Triple-X syndrome is less common comparing to Turner syndrome.

7.1.3.2 Abnormalities in Male Sex Chromosome

One of male sex chromosomes abnormalities we can say is **Klinefelter syndrome** and is a condition where males inherit extra X chromosomes and you find their genotype in this form XXY or in other cases but rare you can find their genotype in this form XXXY. Males of this type of genotype may have very high pitched voices, very asexually women and can have big breasts. In many ways, they can be sterile or not, they are with very small testes as well as prostate glands, and this leads to low production of testosterone. During puberty, productions of testosterone can imbalance feminine effects.

As discussed early in women, in triple X females, men who suffered from Klinefelter syndrome can have abnormal height. These people also can suffer from abnormal weight, they can be overweighed. They have no capacity in learning during childhood and also have problems in speaking. This leads them to having low grading at schools and in different exams. Our consideration can confirm that these people with Klinefelter syndrome are not normal physically, but men suffered from this health condition are normal apparently and have all to live within society. Reproductive system of these people with Klinefelter syndrome, has ability of proper sexual functioning, they can have erections, ejaculations, in some most cases they can have

inability of producing sperms to conceive. In some cases, Klinefelter syndrome males, can have more than X chromosomes and in this case, they put out number of extreme features and symptoms and possess mental retardation. Men with mosaic genotype (XY/XXY) may have chance of having few problems.

Another second known abnormality in male sex chromosomes is **XYY syndrome,** it is a condition where males inherit extra Y chromosomes. The genotype formation of this condition is XYY. When gets to adult, super-males are apparently very tall and have more than 6 feet. This is not a condition that stops them to be normal, they have normal activities. due to genotype condition, they over produce testosterone, and this condition cause some secondary sexual characters that are different to other adolescents of the same age. Things like severe facial acne can be a problem and is hard to control due to this condition. Men with this condition have ability to reproduce and live in adult age like others. This condition (XYY syndrome) is also known on the name of Jacobs syndrome.

7.2 Some diseases that affect cells

Cells are made human body. These cells have number of genes, proteins and others that made cellular membrane. Cells act like independent livings; they respond to chemical signals, and also respond to environmental factors. Diseases come in cells as results of dysfunction of cells, this condition can lead to development of many cells, more than what are normal, some essential cells can be lost, and others. Some of diseases are listed below:

7.2.1 Cancer

Cancer is the most known diseases in United States and other developing countries. In 2009, researches in the cancer journal for clinicians, gave us estimation showing that cancer mortality rate was 562,340deaths and 1,479,350 new cases in United States. Cancer is term used to explain number of diseases occurring due to normal cells that develop mutations leading to abnormalities in cell proliferation and this facilitate formation of tumors. Cancer cells have ability to migrate in all parts of the body and lead formation of tumors in other body tissues and the tissue gets damaged and dies.

7.2.2 Sickle-cell Disease

Another known and common cell disease is sickle-cell disease, this is disorder of blood and characterized by defects in red blood cells. In Red blood cells, we know an important component called hemoglobin, which is responsible in transporting oxygen in all parts of the body by means bloodstreams. In the case of sickle cell diseases, this important part of red blood cell (hemoglobin) gets mutations and even changes its shape due to this mutation. This condition stops Hemoglobin to transport oxygen and cause problems in the blood. Clinical characteristics of patient suffering from sickle cell diseases are anemia, lack of oxygen, difficulties in breathing, cold hands and feet without forgetting pain.

7.2.3 Alzheimer's disease

Another known disease in cells is Alzheimer's, and affect nerve cells in the brain part known as neurons. Neurons are essential in communicating with other nerve cells in the brain, and facilitate transmission of information or signals to the whole body.

Patients suffering from Alzheimer's disease, have occurrence of developed harmful protein called protein plaques, and this protein participate in disrupting function of neurons that are neighbors. With this condition, we find neurons collapsing, and creation of neurofibrillary tangles takes place and this, seriously lead to death of neurons. Continuity in neurons loss is leading cause of dementia and memory loss, but also, defective motor function can develop. This condition is incurable, however some drugs can be used to facilitate patients having life.

Questions for evaluation

1. What do you understand by the term cellular abnormalities?
2. When do we say that there is abnormality within a cell?
3. Explain the process of chromosome abnormality in somatic cells
4. Explain and detail chromosome abnormality for both male and female chromosomes
5. Mention clinical features found on some with down syndrome
6. What is the cause of down syndrome?
7. Distinguish: a) monosomy and trisomy, b) super-male and super-female

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8. CELLULAR BIOLOGY MICROSCOPE (Laboratory part of the module)

In introduction of this module, it was mentioned that invention of microscope brought scientists to the discovery of cells. It is microscope that facilitated experiments on cells and also facilitated analysis on shape of cells and their components. Within this topic procedures of how microscope shows cells and their components are details. Before entering the use of microscope in cell biology, taking a look on types of microscopes and their parts is very essential. Microscopes are classified in different types but light and compound microscope are mostly used.

8.1 Microscope and its parts

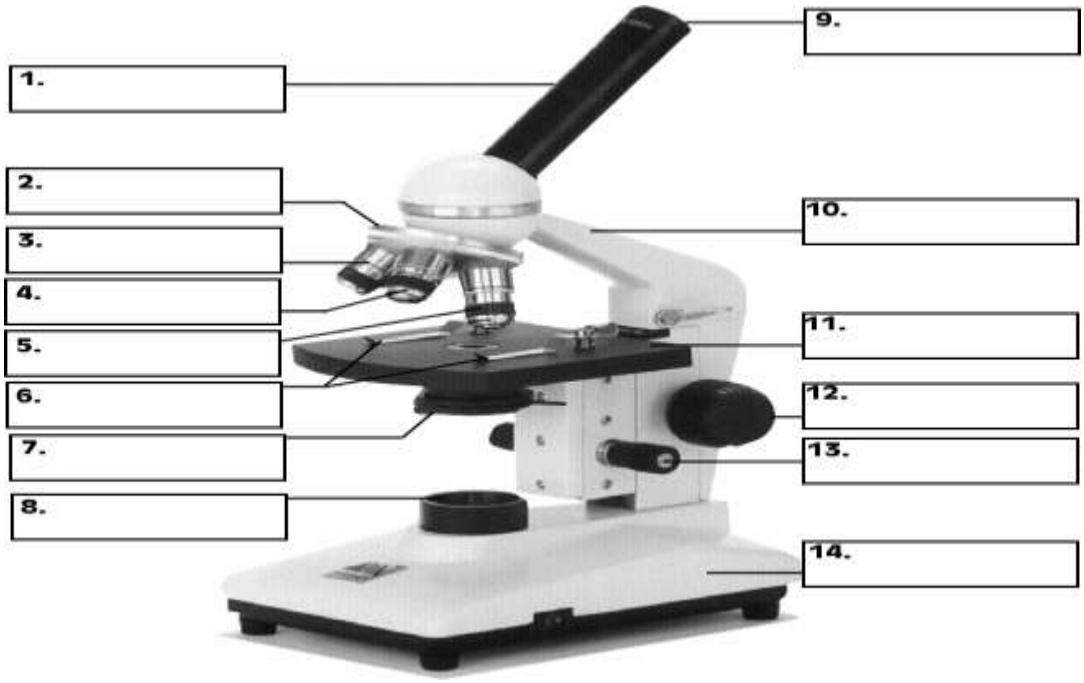

Figure 40: Microscope

1. Tube has a role Reflecting light up to the viewers eye
2. Rotating Objects facilitate a quick change of objectives
3. Low Power Objective: this is the first lens used when conducting proper use of microscope work. Usually 4 X
4. Medium Power Objective: this is the second lens used when doing proper microscope work. Usually 10 X
5. High Power Objective: this the highest magnification used. Usually 43 X and when using this lens, we do not need the course adjustment. However, this lens is not needed for observation.
6. Stage Clips: this helps in keeping the slide in its safe place
7. Diaphragm: this part is responsible in facilitating the amount of light passing through the slide.
8. Light Source: plays an important role in Sending light up through the diaphragm and through the slide for viewing
9. Eye Piece: this is the part you look at by means of your eye. Usually 10 X magnification
10. Neck: this is a part used in proper handling microscope. This is understandable when use transporting.
11. Stage: this is the place where slides are placed.
12. Coarse Adjustment: this part is used in making large changes in focus. But this part is not used while viewing on high power
13. Fine Adjustment : this part is used to small adjustments of focus
14. Base: this part is used to have safety in transporting and placing the microscope

Living things are made of cells. To observe cells we will use some parts of livings and describe our observations.

8.1.1 Human cells under microscope

Cheek cells are eukaryotic cells that are easily shed from the mouth lining. It is very simple to get them to make cell observation with microscope. It is therefore easy to obtain them for observation.

For human cells we can simply observe epithelial cells

8.1.2 Materials required running experiment

- Sterile cotton swab
- Clean, sterile microscope slides
- Microscope cover slips
- Methylene Blue solution (0.5% to 1%)
- A dropper
- Blotting paper/Tissue paper
- Microscope

8.1.2.1 How to Prepare a Wet Mount of Cheek Cells

At the beginning point, it is essential to control if the working area is clean and get ready for wearing clean gloves in terms of avoiding contaminants reaching and damaging your body

Cheek cells are simply found through gently scraping the inside of the mouth by means of a clean, sterile cotton swab.

8.1.2.1.1 Steps and procedures

1. place a drop of physiological saline on a clean microscopic slide in slide central area
2. The second step is smearing the cotton swab on to the center (part containing the saline drop) of the clean slide and wait 4 seconds for cells to migrate from cotton swab into the center of the slide

3. Adding a drop of methylene blue solution on to the smear and gently placing a cover slip on top for covering the stain and the cells.
4. When get a problem of excess solution, it can be removed by touching one side of the slide with a paper towel or blotting paper.
5. Placing the slide on the microscope for observation using 4 x or 10 x objective to observe cells
6. After noticing that cells are observed, they can be seen well through magnification which is high.

Figure 41:Cheek cells under microscope

8.1.2.1.2 Interpretations and observations

After applying all procedures and steps on microscope, the following will be observed under microscope.

- Large and irregular cells in shape with distinguished cell walls.
- Clear nucleus will be seen in the central part of the cell with blue which is dark in color.
- A cytoplasm of each cell will be seen.

8.1.2 Plant cells under microscope

8.1.2.1 Example of onion cells

The anion's bulb is made of modified leaves. Leaves of onion do photosynthesis like other leaves of different plants. This means that they have chloroplasts, and small part of glucose from this process is converted into starch, and this starch gets stored in the bulb. Chloroplasts and chlorophyll are located in leaves of onions and can't be found in the bulb.

Figure 42: Onion cell before staining

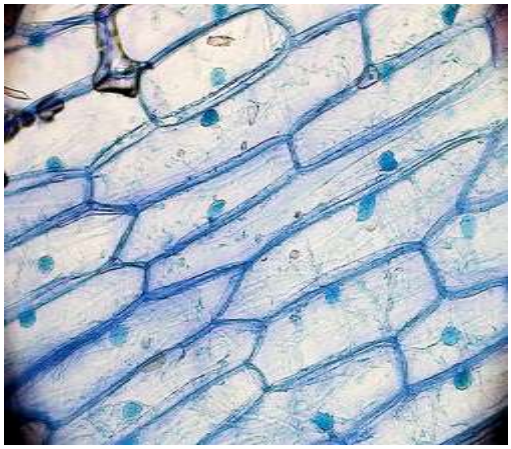

Figure 43: Onion cells after staining

An onion is composed of layers separated by a thin membrane. Considering this experiment, the thin membrane of the cell will be used in observing onion cells. It can simply be obtained after peeling it from any layer of the onion using tweezers.

8.1.2.2.Requirement for experiment

- A thin onion membrane,
- Microscopic glass slides,
- Microscopic cover slips,
- A needle,
- Blotting paper,
- Dropper,
- Iodine Solution,
- Water,
- Microscope

8.1.2.3 Procedures and steps

1. First step is adding a drop of water in the middle (the center of the microscopic slide)
2. Second steps, putting a thin membrane from the onion layer, have to lay in the center microscopic slide; here the drop of water plays an important role in flattening onion membrane.
3. Third step is adding a drop of iodine solution on this onion membrane; otherwise methylene blue can be used.
4. Kindly you to lay a microscopic cover slip on the membrane and pressing it down gently using a needle to remove air bubbles.
5. the other step is Touching a blotting paper on one side of the slide for draining excess iodine/water solution,
6. Placing the slide on the microscope stage under low power to observe.
7. Adjustment of focus for clarification of observation.

8.1.2.4 Interpretation and Observations

- Large, rectangular interlocking cells have to appear,
- Clarification of Clear visible distinctive cell walls surrounding cells are occurred ,
- Dark nucleus have to be occurred,
- vacuoles which large will occur in the center,
- Small granules have to be seen inside the cells specifically in cytoplasm.

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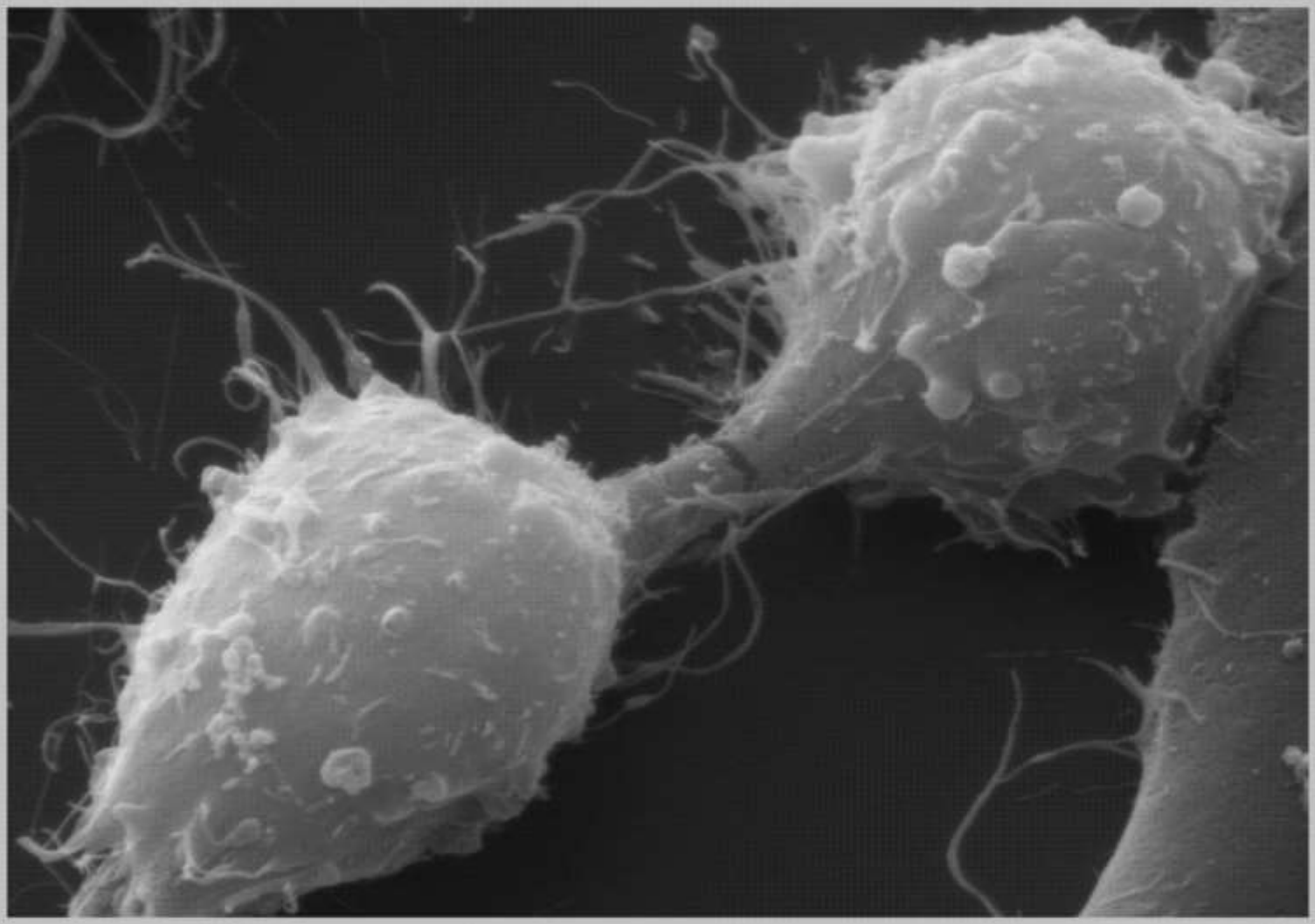

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