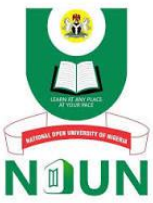
COURSE GUIDE

BIO205
INTRODUCTORY DEVELOPMENTAL BIOLOGY

Course Team Dr. (Mrs) O.O. Babalola- (Course Writer)-Olabisi Onabanjo University, Ogun State.
Prof. V. A Adisa- (Course Editor)
Dr. Kabir Mohammed Adamou- (Course Reviewer)-Ibrahim Badamasi Babangida University, Lapai, Niger State
Dr.MaureenN.Chukwu-(HOD) - (NOUN)



NATIONAL OPEN UNIVERSITY OF NIGERIA

National Open University of Nigeria
Headquarters
University Village
Plot 91, Cadastral Zone
Nnamdi Azikiwe Expressway
Jabi, Abuja

Lagos Office
14/16 Ahmadu Bello Way
Victoria Island, Lagos

E-mail : centralinfo@nou.edu.ng
URL: www.nou.edu.ng

Printed 2023

ISBN: 978-058-894-9

CONTENTS

BIO 205: INTRODUCTORY DEVELOPMENTAL CELL BIOLOGY

INTRODUCTION

Introductory Developmental Cell Biology is a three-unit course, available to students offering biology related courses. The course introduces students to the History and present trends in cell biology; cell as the fundamental unit of life. organelles and their basic structures and functions. mitosis and meiosis. cell differentiation and growth of cells. A brief study of the molecular basis of cell structure and development.

The Cell Cycle and Mitosis increase students understanding of the various events that occur in the cell cycle and the process of mitosis that divides the duplicated genetic material, creating two identical daughter cells. The meiosis session makes students understand the events that occurs in the process of meiosis that takes place to produce gametes during sexual reproduction. Students will get to know more on prokaryotic and eukaryotic cells that make up all living systems, as well as their organelles, and the differences between living cells. Learning Outcomes At the end of the lectures in this course, students should be able to:

- illustrate the detail structure of plant and animal cells and state the functions of the
- organelles;
- summarize and state the differences and similarities between mitosis and meiosis;
- describe cell differentiation and its growth; and
- explain the molecular basis of cell structure and development.

COURSE COMPETENCIES

The course will provide general overview of the course synopsis; this course material shall be divided into appropriate sections to help the learners understand and assimilate the contents of the course. The course guide will help students to understand how to go about Tutor-Marked-Assignment which will form part of the overall assessment at the end of the course.

Similarly, structured on-line facilitation classes in this course shall increase the comprehension of the course thus students are encouraged to activity participate. This course introduces students to the knowledge of cell (prokaryote and eukaryote), that will be helpful during in advance studies and biotechnology.

COURSE OBJECTIVES

This course is aimed at providing students the knowledge of the History and present trends in cell biology; cell as the fundamental unit of life. organelles and their basic structures and functions. mitosis and meiosis. cell differentiation and growth of cells. A brief study of the molecular basis of cell structure and development.

Thus, the course objectives are;

- discuss the history and present trends in cell biology.
- List and explain cells (prokaryotic and eukaryotic) as a fundamental unit of life.
- describe cell organelles and their basic functions.
- Elucidate the mechanisms of cell mitosis and meiosis divisions
- Elucidate the mechanisms of cell differentiation and growth.
- describe molecular basis of cell structure and development.

WORKING THROUGH THIS COURSE

The successful completion of this course entails the studying of the course guide and the reference textbooks/materials as well as other materials provided by the National Open University of Nigeria.

The course guide is divided into sections; each section has self-assessment exercise. The practice of the assessment will positively influence your academic performance in the course. The course is expected to cover a minimal period of 8 weeks to complete.

STUDY UNITS

The Modules of this course shall be in accordance with the course objectives thus;

Module 1: History and Present Trends in Cell Biology

Unit 1: History of Cell Biology
Unit 2: Historical Viewpoint
Unit 3: The Cell Theory
Unit 4: Types of Cells
Unit 5: Cell Organelles and Functions

Module 2: Cell Division, Differentiation and Growth

Unit 1: Cell Cycle

Unit 2: Cell Amitosis
Unit 3: Cell Mitosis
Unit 4: Cell Meiosis
Unit 5: Cell Differentiation

Module 3: Basis of Cell Structure and Molecular Development

Unit 1: Cell Growth
Unit 2: Cell Communication
Unit 3: Cell Signaling
Unit 4: Proteins structure and Synthesis
Unit 5: Nucleic Acids component and functions

REFERENCES AND FURTHER READINGS

In every section or Module, Reference materials shall be provided for further reading.

PRESENTATION SCHEDULE

Assignment	Marks
TMA 1-4	Four T M A s , best three marks of the four count at 10% each – 30% of course marks
End of course examination	70% of overall course marks
Total	100% of course materials

ASSESSMENT

In every section or Module, self-assessment questions shall be provided for further practice.

How to get the Most from the Course?

The course guide is designed in a simplified form to assist self comprehension. In addition, further references with web links are provided in each sectio/module or unit. Similarly, the course has facilitation session that will provide information on any grey areas.

ONLINE FACILITATION

Eight weeks is scheduled for online facilitation. This facilitation is divided into two session (synchronous and asynchronmous). The synchronous session is a live session that is provided by a facilitator

through University approved source (Zoom) for 1 hour. While the asynchronous session is an alternative interaction session that may not be live. In the facilitator dashboard, students have access to the course materials, recorded online facilitation, weblinks, virtual library and host of others that would improve the course comprehension.

COURSE INFORMATION

Course Code:	BIO 205
Course Title:	Introductory Developmental Cell Biology
Credit Unit:	3
Course Status:	Core
Course Blub:	http://elearn.nouedu2.net
Semester:	First
Course Duration:	3 hours per week (24 hours per semester)
Required Hours for Study:	3 x 3hours x 8 week (72hrs)

ICE BREAKER

Dr. Kabir Mohammed Adamu, is an Associate Professor of Hydrobiology, Fish Nutrition and Physiology, Department of Biology, Ibrahim Badamasi Babangida University, Lapai, (IBBUL) Niger State, Nigeria. He is an external Facilitator with the Department of Biological Sciences, National Open University of Nigeria (NOUN), where he facilitates the BIO 206 (Biostatistics) amongst other courses. He has been teaching/lecturing Introductory Developmental Cell Biology for the past ten (10) years. Dr. Kabir's research interest is in circular economy by understanding the interaction of freshwater fisheries with the environment, using both phenotypic and genotypic techniques in characterization of fisheries resources and their roles in healthy aquatic ecosystem.

Understanding the protein requirement of fish and seeking for protein (especially insect protein) resource fish growth, nutrition and physiology.

MAIN COURSE

MODULE 1 HISTORY AND PRESENT TRENDS IN CELL BIOLOGY

Unit 1 History of Cell Biology

Unit Structure

1.1 Introduction

The introduction to cell was dated back in the year **1655** when a revolutionary observation was made by an English scientist Robert Hooke. This observation made by him was so huge that it went on to change the basic biological theory and research forever. A cell is the basic unit of a living organism. Cell biology is a branch of biology that studies the structure and function of cells, from the most fundamental features to the most particular functions found only in specialized cells. It focuses primarily on the concept that the cell is the fundamental unit of life. The concept of cell theory was formally articulated in 1839 by Schleiden and Schwann and has remained as the foundation of modern biology. This unit buttresses the fact that the idea of cell theory predates other great paradigms (examples) of biology including Darwin's theory of evolution (1859), Mendel's laws of inheritance (1865), and the establishment of comparative biochemistry (1940).

1.2 Intended Learning Outcomes (ILOs)

By the end of this unit, students should be able to;

- describe the genesis of cell biology
- state the roles significant scientist played to the actualization of modern cell biology
- elucidate the historical timeline in cell biology

1.3 Main Content

1.3.1 Discovery of Cell

The term “cells” was first coined in 1665 by a British scientist Robert Hooke. He was a curator of instruments at the Royal Society of London, that was in touch with all new scientific developments and exhibited interest. He was the first person to study living things under a microscope and examined a thin slice of cork under a microscope and observed honeycomb-like structures. Robert Hooke called these structures as cells. In the year 1665 Hooke published his *Micrographia*, which was primarily a review of a series of observations that he had made while following the development and improvement of the microscope. The cell walls observed by Hooke gave no identification of the nucleus and other organelles found in most living cells.

Soon after this Antonie Van Leuwenhoek in 1674 made further discoveries by inventing his own microscope lenses that were more powerful than the microscopes of his time. He was the first person to observe human cells and bacteria under his microscope. With the advancements in microscopes, more discoveries were made about cells. However, with the help of a light microscope, it became difficult to visualize the minute structures inside the cells. As a result, a more powerful microscope, known as the electron microscope was invented that made it easier to observe objects smaller than cells. The first Scientist to discover cell was?

Self-Assessment Exercises 1

- In what year was the term cell discovered?
- The scientist that had the breakthrough in discovering cell in living

1.3.2 Formulation of the Cell Theory

Over a century later, many debates about cells began amongst scientists. Most of these debates involved the nature of cellular regeneration, and the idea of cells as a fundamental unit of life. Cell theory was eventually formulated in **1839**. This is usually credited to Matthias Schleiden and Theodor Schwann.

In 1838, Theodor Schwann and Matthias Schleiden were enjoying after-dinner coffee and talking about their studies on cells. It has been suggested that when Schwann heard Schleiden describe plant cells with nuclei, he was struck by similarity of these plant cells to cells he had observed in animal tissues. The two scientists went immediately to Schwann's lab to look at his slides. Schwann published his book on animal and plant cells Schwann (1839) the following, an account (a treatise) devoid of acknowledgements of anyone else's contributions, including that of Schleiden (1838).

He summarized his observations into three conclusions about cells:

- The cell is the unit of structure, physiology, and organization inliving things.
- The cell retains a dual existence as a distinct entity and a buildingblock in the construction of organisms.
- Cells form by free-cell formation, similar to the formation of crystals(spontaneous generation).

We know today that the first two principles (tenets) are correct, but the third is clearly wrong. The correct interpretation of cell formation by division was finally promoted by others and formally enunciated in Rudolph Virchow's powerful dictum, *Omnis cellula e cellula…* "All cells arise from pre-existing cells." The idea of cell theory was eventually formulated in year?

Self-Assessment Exercises 2

- The term *Omnis cellula e cellula* was credited to?
- The cell theory was credited to?

1.3.3 Modern Cell Theory

The **modern** version of the cell theory includes the ideas that: Energy flow occurs within cells.

Heredity information deoxyribonucleic acid (DNA) is passed on from cell to cell. All cells have the same basic chemical composition. Thus, it is a fundamental concept in biology that states that cells are the basic

unit of life and that all living organisms are composed of cells. The cell theory has evolved over time and is now widely accepted by the scientific community. The current version of the cell theory includes the following three main postulates:

- All living organisms are composed of cells. This means that cells are the fundamental unit of life, and that all living things are made up of one or more cells.
- Cells are the smallest unit of life that can perform all the functions necessary for life. This includes processes such as metabolism, growth, and reproduction.
- Cells arise from preexisting cells. This means that cells are produced through the process of cell division, in which a single cell divides into two daughter cells. The cells produced in this way are genetically identical to the parent cell.

The heredity information is called?

Self-Assessment Exercises 3

- State the current version of the cell theory.

1.3.4 Timeline in Cell Biology

The following historical events are important in discussing cells and cell theory.

Year	Scientist and activity(ies)
1595	Jansen credited with 1st compound microscope.
1665	Robert Hooke first observes cells while studying cork under a microscope. He coins the term "cell" to describe the small compartments he sees, likening them to the small rooms' monks lived in.
1838	Matthias Schleiden and Theodor Schwann propose the "cell theory," which states that all living organisms are composed of cells and that cells are the basic unit of life.
1855	Rudolf Virchow proposes the "law of cell growth," which states that cells can only arise from preexisting cells. This is known as the "biogenic law."
1875	Walther Flemming discovers the process of cell division, known as mitosis.
1882	Robert Remak proposes that cells can divide and differentiate to form tissues and organs.
1906	George Palade discovers the ribosomes, which are small, spherical structures within the cell that are involved in protein synthesis.
1952	James Watson and Francis Crick propose the double helix

	structure of DNA, which is the genetic material that carries the instructions for the development and function of living organisms.
1965	George Palade discovers the endoplasmic reticulum and the Golgi apparatus, which are organelles within the cell that are involved in the synthesis and transport of proteins and lipids.
1975	Christian de Duve discovers the lysosomes, which are organelles within the cell that contain enzymes that break down waste material and help to recycle cellular components.
1981	George Palade and colleagues discover the microtubules, which are long, thin structures within the cell that help to maintain the cell's shape and play a role in cell division.
1995	Tsien identifies mutant of GFP with enhanced spectral properties
1998	Mice are cloned from somatic cells.
1999	discover siRNA as part of post-transcriptional gene silencing (PTGS) in plants

In what year did Robert Remak proposed that cells can divide and differentiate to form tissues and organs?

Self-Assessment Exercises 4

- Who discovered the endoplasmic reticulum and the Golgi apparatus?
- Who discovered siRNA as part of post-transcriptional gene silencing (PTGS) in plants?

1.4 Summary

From the unit, it could be noted that the cell is the basic unit of all living organisms and all cells are derived from pre-existing cells by cell division. Similarly, the cell was first discovered and named by Robert Hooke in 1665; the cell is the structure, physiology, and organization in living things; the cell retains a dual existence as a distinct entity and a building block in the construction of organisms.

1.5 References/Further Reading/Web Sources

Pray, L. (2009). Discovery of DNA Structure and Function: Watson and Crick. *Nature Education, 100-101*

Landmark Papers in Cell Biology (2000): *Selected Research Articles Celebrating Forty Years of the American Society for Cell Biology*. Cold Spring Harbor Laboratory Press.

Mazzarello P. A. (1999). Unifying Concept: The History of Cell Theory. *Nat Cell Biology*. 1(1): E13-5.

https://www.bing.com/ck/a?!&&p=aebe00bbe995bea9JmltdHM9MTY3NTI5NjAwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTM3Mw&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=History+of+Cell+Biology&u=a1aHR0cHM6Ly93d3cuc2NyaWJkLmNvbS9kb2N1bWVudC82MTk5MjQ1ODYvSGlzdG9yeS1vZi1DZWxsLUJpb2xvZ3ktMQ&nA

https://www.bing.com/ck/a?!&&p=6f40db0d1cb87b2eJmltdHM9MTY3NTI5NjAwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTIzMQ&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=History+of+Cell+Biology&u=a1aHR0cHM6Ly93d3cucmVzZWFyY2hnYXRlLm5ldC9wdWJsaWNhdGlvbi8zMjUyNjk5MDFfQW5fT3ZlcnZpZXdfb2ZfQ2VsbF9CaW9sb2d5&ntb=1

https://www.bing.com/videos/search?q=History+of+Cell+Biology&&view=detail&mid=8179DE02825997283AB38179DE02825997283AB3&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3DHistory%2Bof%2BCell%2BBiology%26qs%3Dn%26form%3DQBVLPG%26sp%3D-1%26pq%3D%26sc%3D0-0%26sk%3D%26cvid%3D35B80D02CD4347F4847933A9B84F85C3%26ghsh%3D0%26ghacc%3D0%26ghpl%3D

https://www.bing.com/videos/search?q=History+of+Cell+Biology&&view=detail&mid=0D70EA8E188165ACC4770D70EA8E188165ACC477&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3DHistory%2Bof%2BCell%2BBiology%26qs%3Dn%26form%3DQBVLPG%26sp%3D-1%26pq%3D%26sc%3D0-0%26sk%3D%26cvid%3D35B80D02CD4347F4847933A9B84F85C3%26ghsh%3D0%26ghacc%3D0%26ghpl%3D

1.6: Possible Answers to Self-Assessment Exercises

SAE 1

- 1665
- Antonie Van Leuwenhoek

SAE 2

- Rudolph Virchow
- Theodor Schwann and Matthias Schleiden

SAE 3

- All living organisms are composed of cells. This means that cells are the fundamental unit of life, and that all living things are made up of one or more cells.
- Cells are the smallest unit of life that can perform all the functions necessary for life. This includes processes such as metabolism, growth, and reproduction.
- Cells arise from preexisting cells. This means that cells are produced through the process of cell division, in which a single cell divides into two daughter cells. The cells produced in this way are genetically identical to the parent cell.

SAE 4

- George Palade
- Hamilton and Baulcombe

Unit 2: Historical Viewpoint

Unit Structure

 2.1: Introduction

In the previous unit you should recollect that microscope was mentioned. With the invention of the microscope at the beginning of the seventeenth century, it became possible to take a first glimpse at the previously invisible world of microscopic life. A bewildering array of new structures appeared before the astonished eyes of the first microscopic scientists. You will come across the contributions of the microscope in revealing cellular structures andmicrobes.

 **2.2: Intended Learning Outcomes**

By the end of this unit, students should be able to:

- Discuss the historical development of science
- Describe the profiles of influential scientists and philosophers.

 **2.3: Main Body**

1.3.1: Histories of Cells Discoveries

After the first observations of life under the microscope, it took two centuries of research before the 'cell theory'; the idea that all living

things are composed of cells or their products were formulated. It proved even harder to accept that individual cells also make up nervous tissue.

The Jesuit priest Athanasius Kircher (1601−1680) showed, in 1658, that maggots and other living creatures developed in decaying tissues. In the same period, oval red-blood corpuscles were described by the Dutch naturalist Jan Swammerdam (1637−1680), who also discovered that a frog embryo consists of globular particles.

Another new world of extraordinary variety, that of microorganisms, was revealed by the exciting investigations of another Dutchman, Antoni van Leeuwenhoek (1632−1723). The particles that he saw under his microscope were motile (Fig 1) and, assuming that motility equates to life, he went on to conclude, in a letter of 9 October 1676 to the Royal Society, that these particles were indeed living organisms. In a long series of papers vanLeeuwenhoek then described many specific forms of these microorganisms (which he called “animalcules”), including protozoa and other unicellular organisms.

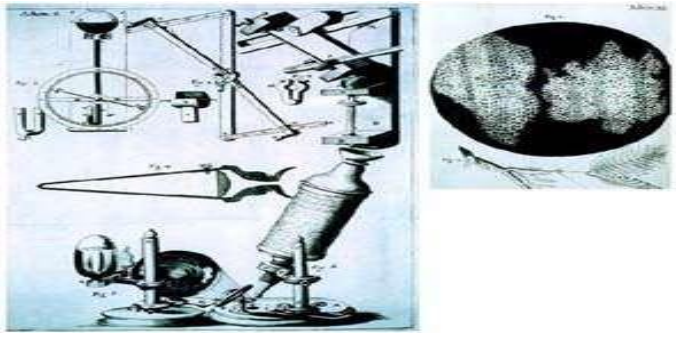


Fig. 1 Leeuwenhoek Microscope (*Source: Pelczar et al., (1986))*

Under the microscope: drawings of the instruments used by Robert Hooke (left) and the cellular structure of cork according to Hooke (right) (reproduced from Micrographia, 1665).

But the first description of the cell is generally attributed to Robert Hooke (1635−1702), an English physicist who was also a distinguished microscopic scientist. In 1665 Hooke published Micrographia, the first important work devoted to microscopical observation, and showed what the microscope could mean for naturalists. He described the microscopic units that made up the structure of a slice of cork and coined the term "cells" or "pores" to refer to these units. Cella is a Latin word meaning 'a small room' and Latin-speaking people applied the word Cellulae to the six-sided cells of the honeycomb. By analogy, Hooke applied the term "cells" to the thickened walls of the dead cells of the cork.

Although Hooke used the word differently to later cytologists (he thought of the cork cells as passages for fluids involved in plant growth), the modern term 'cell' comes directly from his book.

Please note that the following scientists have contributed to the knowledge of the discoveries of cells. Thus;

Hans and Zacharias Janssen (1595): Dutch lens grinders, father and son produced first compound microscope of two lenses.

Robert Hooke (1665): An English scientist looked at a thin slice of cork (oak cork) through a compoundmicroscope observed tiny, hollow, room-like structures called these structures 'cells' because they reminded him of the rooms that monks lived in only saw the outer walls (cell walls) because cork cells are notliving.

Anton van Leeuwenhoek (1674): Dutch fabric merchant and amateur scientist looked at blood, rainwater, scrapings from teeth through a simple microscope of one lens observed living cells; called some 'animalcules' some of the small 'animalcules' are now called bacteria.

Matthias Schleiden (1838): A German botanist viewed plant parts under a microscope discovered that plant parts are made of cells.

Theodor Schwann (1839): A German zoologist, viewed animal parts under a microscope, discovered that animal parts are made of cells

Rudolph Virchow (1855): A German physician stated that all living cells come only from other living cells. Who discovered that a frog embryo consists of globular particles?

Self-Assessment Exercises 1

- Who showed that maggots and other living creatures developed in decaying tissues?
- The scientist who used the words *'animalcules'* and *'animalcules'* is?

2.3.2: Bridge between Life and Non-life?

The existence of an entire world of microscopic living things (microbes) was seen as a bridge between inanimate matter and living organisms that are visible to the naked eye. This seemed to support the old Aristotelian doctrine of 'spontaneous generation', according to which water or land bears the potential to generate, 'spontaneously', different kinds of organism. This theory, which implied continuity between living and non-living matter, *natura non facit saltus*, was disproved by the masterful experiments of the Italian naturalist Lazzaro Spallanzani

(1729−1799). He and other researchers showed that an organism derives from another organism(s) and that a gap exists between inanimate matter and life. (But it was a century later before the idea of spontaneous generation was definitively refuted, by Louis Pasteur, 1822−1895) As a consequence, the search for the first elementary steps in the *scala naturae* was a motif in early-nineteenth- century biological thought: what could be the minimal unit carrying the potential for life?

There is a **scientific border** between life and non-life. From a historical point of view, things were first separated into organics and non-organics up until 1828 that a scientist, Wohler, made an organic compound called urea from some inorganic compounds. And today we know that all organic compounds are made up of inorganic ones.

To distinguish between life and non-life looks a bit harder because the definition of life is not that obvious. If life means living organic thing, then there is still a way to separate a live organic stuff from a dead one by their physical/thermodynamical state.

From the simplest organic compound, urea, to the most sophisticated organ on the planet earth, human brain, there are different borders that can also be considered as the border between life and non-life, for example some biologists believe that viruses are the smallest living things because they can reproduce and conserve their ribonucleic acid (RNA), most others believe that biological cells like bacteria are the first living things due to the reproduction of the whole cell using their DNA.

There are also other borders, for example living things are energy/mass consuming they must be constantly fed. Living things *do* or have the *potential* to undergo the process of Darwinian evolution thus;

- Living things are information processing 'machines' (if you will) whose causal capacities and downstream behavior are dependent both on stored prior information (DNA) and to the experiences manifest in their respective lives
- Living things are uniquely *intentional* homogeneous forms of matter which have the capacity for (some form of) representation, by which novel causal (possibilities) are made actual.
- Though there are many others, the most plausible involve information retaining and modifying capacity, which imply the possibility of alternative histories depending on the set of actualities which occur. These are dependent on the information processing mechanisms made possible by the existence and function of DNA and correlated gene expression, which are causally necessitated by the organism being involved in evolutionary processes.

In the year 1822-1895, ……. scientist refuted the idea of spontaneous generation.

Self-Assessment Exercises 2

- The theory which implied continuity between living and non-living matter, *natura n*
  facit saltus, was disproved by?

2.3.3: Protoplasmic Constituents

After Schleiden and Swann's formulation of cell theory, the basic constituents of the cell were considered to be a wall or a simple membrane and the nucleus. This simple membrane called "protoplasm" is a viscous substance. The word protoplasm is generally used to refer to the living parts of a cell, which comprises of different cellular organelles. It is a jelly-like, colourless, transparent and viscous living substances present within the cell wall. The term protoplasm was proposed in the year 1835 and is known as the primary substance, as it is responsible for various living processes.

The "living structure" present inside the cell referred to as protoplasm differentiates the living beings from the non-living beings. Huxley (1868) defined it as "Physical basis of life". First of all, Felix Dujardin (1835) described this homogenous jelly like mass of the cell and gave the name Sarcode. Later on, in 1839, Purkinje termed it as Protoplasm. Protoplasm is the ground substance of living matter found within membrane of a cell. Von Mohl (1946) emphasized its role in cell division including other metabolic processes of the cell.

The existence of similarities between the protoplasm of plants and animals was discovered by Max Schultz (1861) who proposed the famous "Protoplasm theory". According to this theory, protoplasm is the main part of the cells, performing all the physiological activity of the cell. It includes the ground substance cytoplasm having nucleus and limited by cell membrane. According to modern concept protoplasm is a colloidal substance exhibiting the presence of large number of minute particles held in suspension in the liquid portion. The organic substances which consist of proteins and carbohydrates in suspension may be hydrophilic or water loving. pH value of protoplasm is variable. It ranges between 5.8 to 6.8.

2.3.4 Physical Nature of Protoplasm

- It is optically homogenous, elastic, colourless, jelly like, semi-transparent to transparent and semi-viscous substance.
- There is about 80-90% of water in protoplasm.
- It appears granular containing many vacuoles.
- It responses well to external stimuli like electric shock, heat, cold, chemicals etc.
- Stimulation is its natural quality or distinct characteristics.
- Many soluble materials like salts, sugars and minerals are suspended in protoplasm in form of ions or molecules.
- Besides it, many-many organic substances like fats, proteins remain soluble which particles are bigger in size than molecules. Such type of solution is referred to as colloidal solution and the soluble particles are said as colloids.
- It is evident that protoplasm is a crystallocolloidal solution.
- Basically, the protoplasm is a polyphasic colloidal system. The colloidal structure of protoplasm was explained by Fisher and Hardy in 1894 and 1899 respectively.
- Viscosity of protoplasm has been found greater than that of water, because of this reason protoplasm exhibits Brownian and amoeboid movement including cytoplasmic streaming (cyclosis).
- The Brownian movement is characterized by the zigzag motion of the particles occurring due to the bombardment of one molecule or particle by other.
- The amoeboid movements are the result of viscosity and continued change of sol gel.
- The cytoplasmic streaming or cyclosis is the circulation of protoplasm within the cell. This streaming movement is of two types:
- Rotation: the movement of protoplasm is in one direction (clock-wise or anticlockwise) around vacuole inside a cell, e.g., leaf cells of the Hydrilla, Vallisneria etc.
- Circulation: the protoplasm moves in different directions around different vacuoles inside a cell e.g., staminal hairs of Tradescantia. The contractility of protoplasm is essential for various vital activities. The absorption and removal of water by the cells is due to the contractility of cytoplasm. The particles of protoplasm are adhered with each other by Vanderwaal's forces, that hold long chains of molecules together.

The various components give appearance of protoplasm of different kinds:

- Reticular Theory: According to this theory, particles form a network of fibrils in a liquid medium. It was proposed by Klein, Corno etc.
- Granular Theory: According to this theory, the protoplasm is composed by minute granules suspended in a fluid said as bioplast or elementary organism. It was proposed by Altmann (1893).
- Fibrillar Theory: According to this theory, the protoplasm consists of fibres embedded in the inner mass of matrix. The fibrillae are said as spongioplasm and the ground substance as hyaloplasm. It was proposed by Flemming.
- Alveolar Theory: According to this theory, the protoplasm consists of numerous suspended droplets or alveoli similar to foam or emulsion, also said as uritomes and inter-alveolar as mioplasma. This is also known as emulsion theory which states that the solid portion is in the form of foam and the liquid portion taking place in the bubbles of the foam.

2.3.5 Chemical Nature of Protoplasm:

- Chemically, protoplasm consists of inorganic and organic matters.
- Among inorganic parts are included water, gas, salts etc.
- Organic matters are grouped into various proteins, carbohydrates, fats and other regulatory substances.
- The dry protoplasm shows 45% proteins, 25% carbohydrates, lipids 25% and 5% other substances.
- Protoplasm contains varying quantities of water in different parts of an organism. There is about 80%—90% of water which is about 3 parts of the total protoplasm. Water forms the main suspension medium in which various metabolic processes are carried on. Despite it, water acts as a best natural solvent. It helps in reactions through hydrolysis and dehydration.
- Proteins are the main components of protoplasm, made up of many complexes of physiological materials.

The two components that make up the protoplasm are?

Self-Assessment Exercises 3

- List and explain cytoplasmic streaming in protoplasm.

2.3.6 The Neuron Theory

The 'neuron theory' or 'neuron doctrine', which emerged at the end of the 19th century, asserts that **nerve tissue is composed of individual cells,** which are genetic, anatomic, functional and trophic units. The pioneers

of the neuron doctrine included neuroscientists, physicians, a polar explorer and three Nobel Laureates.

In 1865, Karl Deiters posthumously published work contains beautiful descriptions and drawings of nerve cells studied by using histological methods and microdissections made with thin needles under the microscope. These nerve cells were characterized by a soma, dendrites and a nerve prolongation (axon) which showed no branching. Kölliker, in the fifth edition of his important book on histology, published in 1867, proposed that sensory and motor cells of the right and left halves of the spinal cord were linked “by anastomoses” (direct fusion).

In 1872, the German histologist, Joseph Gerlach (1820−1896) expanded Kölliker's view and proposed that, in all of the central nervous system, nerve cells established anastomoses with each other through a network formed by the minute branching of their dendrites. According to this concept, the network or reticulum was an essential element of grey matter that provided a system for anatomical and functional communications, a protoplasmic continuum from which nerve fibres originated.

The most important breakthrough in neurocytology and neuroanatomy came in 1873 when Golgi developed the 'black reaction', which he announced to a friend with these few words, "I am delighted that I have found a new reaction to demonstrate, even to the blind, the structure of the interstitial stroma of the cerebral cortex. I let the silver nitrate react with pieces of brain hardened in potassium dichromate. I have obtained magnificent results and hope to do even better in the future." This reaction provided, for the first time, a full view of a single nerve cell and itsprocesses,
which could be followed and analysed even when they were at a great distance from the cell body.

The great advantage of this technique is that, for reasons that are still unknown, a precipitate of silver chromate randomly stains black only a few cells (usually from 1 to 5%), and completely spares the others, allowing individual elements to emerge from the nervous puzzle.

Aided by the black reaction, Golgi discovered the branching of the axon and found that, contrary to Gerlach's theory, dendrites are not fused in a network. Golgi, however, failed to go beyond the 'reticularistic paradigm'. He believed that the branched axons stained by his black reaction formed a gigantic continuous network along which the nervous impulse propagated. In fact, he was misled by an illusory network created by the superimposition and the interlocking of axons of separate cells. Golgi's network theory was, however, a substantial step forward

because it emphasized, for the first time, the function of branched axons in connectingnerve cells.

According to Gerlach and Golgi, the nervous system represented an exception to cell theory, being formed not by independent cells but rather by a gigantic syncytium. The unique structure and functions of the nerve cell could well justify an infringement of the general rule.

Matters changed quickly in the second half of the 1880s. In October 1886, the Swiss embryologist Wilhelm His (1831−1904) put forward the idea thatthe nerve-cell body and its prolongations form an independent unit. In discussing how the axons terminate at the motor plate and how sensory fibres originate at peripheral receptors such as the Pacinian corpuscles, he suggested that a separation of cell units might be true of the central nervous system. The nervous tissue began to be considered, like any other tissue, as a sum of anatomically and functionally independent cells, which interact bycontiguity rather than by continuity.

Similar conclusions were reached, at the beginning of 1887, by another Swiss scientist, the psychiatrist August Forel (1848−1931), and, in 1891, Waldeyer introduced the term "neurons" to indicate independent nerve cells. Thereafter, cell theory as applied to the nervous system became known as the 'neuron theory'.

Ironically, it was by using Golgi's black reaction that the Spanish neuroanatomist Santiago Ramón y Cajal (1852−1934) became the main supporter of the neuron theory. His neuroanatomical investigations contributed to the foundations of the basic concepts of modern neuroscience. However, definitive proof of the neuron theory was obtained only after the introduction of the electron microscope, which allowed identification of synapses between neurons.
The most important breakthrough in neurocytology and neuroanatomy came in the year?

Self-Assessment Exercises 4

- In the year 1891, the scientist that introduced the term "neurons" to indicate independent nerve cells is?
- What is neuron theory?

2.4: Summary

Cell theory obtained its final triumph when the nervous system was also found to be made up of independent units. Thus, the unit also discussed the idea of spontaneous generation that was refuted by Louis Pasteur.

2.5: References/Further Readings/Web Sources

Dutta, AC (1963). *Botany for Degree Students (5th Edition)*. Delhi OxfordUniversity Press.

Paolo, M (1999). *A Unifying Concept: the History of Cell Theory Nature Cell Biology* 1, E13 - E15.

Landmark Papers in Cell Biology (2000): *Selected Research Articles Celebrating Forty Years of the American Society for Cell Biology*. ColdSpring Harbor Laboratory Press.

https://www.bing.com/ck/a?!&&p=251b50d95683d3feJmltdHM9MTY3NTI5NjAwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTIzNA&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=textbook+on+constituents+of+protoplasm&u=a1aHR0cHM6Ly93d3cuYmlvbG9neWRpc2N1c3Npb24uY29tL2ludmVydGVicmF0ZS16b29sb2d5L3Byb3RvcGxhc20taW52ZXJ0ZWJyYXRlLXpvb2xvZ3kvcHJvdG9wbGFzbS1tZWFuaW5nLW5hdHVyZS1hbmQtcHJvcGVydGllcy1pbnZlcnRlYnJhdGUtem9vbG9neS8yNzk3Ng&ntb=1

https://www.bing.com/ck/a?!&&p=196c62037ca0092cJmltdHM9MTY3NTI5NjAwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTIzMQ&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=neuron+theory+in+cell+biology&u=a1aHR0cHM6Ly9saW5rLnNwcmluZ2VyLmNvbS9jaGFwdGVyLzEwLjEwMDcvOTc4LTEtNDYxMi0zNTQwLThfMQ&ntb=1

https://www.bing.com/videos/search?q=textbook+on+constituents+of+protoplasm&&view=detail&mid=CEB67F83681472B3923FCEB67F83681472B3923F&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3Dtextbook%2Bon%2Bconstituents%2Bof%2Bprotoplasm%26FORM%3DHDRSC4

https://www.bing.com/videos/search?q=neuron+theory+in+cell+biology&&view=detail&mid=F8301020586E762F3A37F8301020586E762F3A37&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3F

q%3Dneuron%2520theory%2520in%2520cell%2520biology%26qs%3Dn%26form%3DQBVR%26%3D%2525eManage%2520Your%2520Search%2520History%2525E%26sp%3D-1%26pq%3Dneuron%2520theory%2520in%2520cell%2520biology%26sc%3D10-29%26sk%3D%26cvid%3D0080FE8F4A9441D78C1A87CED9915C09%26ghsh%3D0%26ghacc%3D0%26ghpl%3D

2.6: Possible Answers to Self-Assessment Exercises

SAE 1

- Athanasius Kircher
- Anton van Leeuwenhoek

SAE 2

Lazzaro Spallanzani

SAE 3

- Rotation: the movement of protoplasm is in one direction (clockwise or anticlockwise) around vacuole inside a cell, e.g., leaf cells of the Hydrilla, Vallisneria etc.
- Circulation: the protoplasm moves in different directions around different vacuoles inside a cell e.g., staminal hairs of Tradescantia. The contractility of protoplasm is essential for various vital activities. The absorption and removal of water by the cells is due to the contractility of cytoplasm. The particles of protoplasm are adhered with each other by Vanderwaal's forces, that hold long chains of molecules together.

SAE 4

- Waldeyer
- The 'neuron theory' or 'neuron doctrine', asserts that **nerve tissue is composed of individual cells,** which are genetic, anatomic, functional and trophic units.

Unit 3 The Cell Theory

Unit Structure

3.1: Introduction

This unit will review the history of the development of the cell theory on the previous units. Throughout time, thoughts and ideas of life have been formed, stretching from abiogenesis and spontaneous generation to themodern cell theory. Here is an overview of the progression of thought that has contributed to today's cell theory.

3.2: Intended Learning Outcomes

By the end of this unit, students should be able to;

- analyze the modern cell theory
- evaluate evidence to support cell theory
- explain knowledge of basic historical science facts.

3.3: Main Body

3.3.1: People and Things that have made History

Anaximander

A member of the Greeks in the sixth century B.C. who resided on the Ionian Islands. He is credited with coming up with the primary thoughts of evolution. His perspective was that creatures from the sea were forced to come ashore, thereby evolving into land creatures.

Plato

Plato did not directly aid in the progress of biological thinking. His view was not experimental, but more philosophical. Many of his students wenton to influence the progression of biological studies in the field of classification.

The Atomists

The most noted of this group of Greek philosophers was Democritus (460 - 370 B.C.). He followed Anaximander's view of evolution. Democritus is credited as being the father of atomic theory which connects directly to biology. One important theory of his was simply that if you have nothing, nothing may be created out of it.

Aristotle

Aristotle (384 - 322 B.C.) was known for his experimental approach and numerous dissections. He was drawn to animal classification in order to discover aspects of connection between the soul and the human body. Some of his animal classifications still stand today. One of his famous thoughts is a foreshadowing of Mendelian genetic concepts:

"It is evident that there must be something or other really existing, corresponding to what we call by the name of Nature. For a given germ does not give rise to any random living being, nor spring from any chance one, but each germ springs from a definite parent and gives rise to a predictable progeny. And thus, it is the germ that is the ruling influence and fabricator of the offspring."

The Microscope

This instrument opened up new doors in the field of biology, by allowing scientists to gaze into a new world: the cellular world. Galileo is credited with the invention of the microscope. Two of the main pioneers in microscope usage were Athanasius Kircher and Antonie von Leeuwenhoek.

Robert Hooke

This English naturalist (1635 - 1703) coined the term "cell" after viewing slices of cork through a microscope. The term came from the Latin word cella which means "storeroom" or "small container". He documented his work in the Micrographia, written in 1665.

Jean-Baptiste De Lamarck

The majority of this Frenchman's work (1744 - 1829) dealt with animal classification and evolution. He is credited with taking steps towards the creation of the cell theory with this saying: “Every step which Nature takes when making her direct creations consists in organizing into cellular tissue the minute masses of viscous or mucous substances that he finds at his disposal under favorable circumstances.”

The Cell: An Individual Unit of Life

In 1824, Rene Dutrochet discovered that “the cell is the fundamental element in the structure of living bodies, forming both animals and plants through juxtaposition.” In Berlin, Johannes Muller created connections between biology and medicine, prompting the connective thinking of his students, such as those of Theodore Schwann. Schwann created the term “cell theory” and declared that plants consisted of cells. This declaration was made after that of Matthias Schlieden's (1804 - 1881) that animals are composed of cells.

Biogenesis

German pathologist Rudolf Virchow (1821 - 1902) altered the thought of cellular biology with his statement that “every cell comes from a cell”. Not even twenty years after this statement, processes of cell reproduction were being described. Virchow had completed the thought behind the basic cell theory.

The Scientist that is completely behind the basic cell theory is?

Self-Assessment Exercises 1

- Succinctly explain the role of Jean-Baptiste De Lamarck in the history of cell biology.

3.3.2: The Cell Theory

Hints at the idea that the cell is the basic component of living organisms emerged well before 1838−1839, which was when the cell theory was officially formulated. Cells were not seen as undifferentiated structures. Some cellular components, such as the nucleus, had been visualized, and the occurrence of these structures in cells of different tissues and organisms hinted at the possibility that cells of similar organization might underlie all living matter.

The abbot Felice Fontana (1730−1805) glimpsed the nucleus in epithelial cells in 1781, but this structure had probably been observed in animal and plant cells in the first decades of the eighteenth century. The

Scottish Botanist Robert Brown (1773−1858) was the first to recognize the nucleus (a term that he introduced) as an essential constituent of living cells (1831). In the leaves of orchids, Brown observed "a single circular areola, generally somewhat opaquer than the membrane of the cell. This areola, or nucleus of the cell as perhaps it might be termed, is not confined to the epidermis, being also found not only in the pubescence of the surface, but in many cases in the parenchyma or internal cells of the tissue". Brown recognized the general occurrence of the nucleus in these cells and apparently thought of the organization of the plant in terms of cellular constituents.

Meanwhile, technical improvements in microscopy were being made. The principal drawback of microscopes since van Leeuwenhoek's time was what we now call 'chromatic aberration', which diminishes the resolution power of the instrument at high magnifications. Only in the 1830s were achromatic microscopes introduced, allowing more precise histological observations.

Improvements were also made in tissue-preservation and - treating techniques.

In 1838, the botanist Matthias Jakob Schleiden (1804−1881) suggested that every structural element of plants is composed of cells or their products. The following year, a similar conclusion was elaborated for animals by the zoologist Theodor Schwann (1810−1882). He stated that "the elementary parts of all tissues are formed of cells" and that "there is one universal principle of development for the elementary parts of organisms and this principle is in the formation of cells." The conclusions of Schleiden and Schwann are considered to represent the official formulation of 'cell theory' and their names are almost as closely linked to cell theory as are those of Watson and Crick with the structure of DNA.

According to Schleiden, however, the first phase of the generation of cells was the formation of a nucleus of "crystallization" within the intracellular substance (which he called the "cytoblast"), with subsequent progressive enlargement of such condensed material to become a new cell. This theory of 'free cell formation' was reminiscent of the old 'spontaneous generation' doctrine (although as an intracellular variant), but was refuted in the 1850s by Robert Remak (1815−1865), Rudolf Virchow (1821−1902) and Albert Kölliker (1817−1905) who showed that cells are formed through scission of pre-existing cells. Virchow's aphorism *omnis cellula e cellula* (every cell from a pre-existing cell) thus became the basis of the theory of tissue formation, even if the mechanisms of nuclear division were not understood at the time.

Cell theory stimulated a reductionist approach to biological problems and became the most general structural paradigm in biology. It emphasized the concept of the unity of life and brought about the concept of organisms as "republics of living elementary units".

As well as being the fundamental unit of life, the cell was also seen as the basic element of pathological processes. Diseases came to be considered (irrespective of the causative agent) as an alteration of cells in the organism. Virchow's Cellular pathologies was the most important pathogenic concept until, in this century, the theory of molecular pathology was developed.
The Scientists that first reported on the structure of DNA are?

Self-Assessment Exercises 2

- Who recognized the general occurrence of the nucleus in these cells and apparently thought of the organization of the plant in terms of cellular constituents?

3.4: Summary

Cell is the structural unit of life, which is formed through studies of pre-existing cells. The unit took us through the profession of thought that has contributed to the cell theory. Similarly, the unit was able to discuss chromatic aberration is a principal drawback of microscopes since van Leeuwenhoek's time; cells are formed through scission of pre-existing cells; historical events leading to the development of the cell theory and contributions made by the following people/scientists -Robert Hooke, Hans and Zacharias Janssen, Anton van Leeuwenhoek, Matthias Schleiden, Theodor Schwann, Rudolph Virchow, etc. and dates of their contributions.

3.5: References/Further Readings/Web Sources

Alberts B, Johnson A, Lewis J, Raff M, Roberts K, & Walter P (2002). *Molecular Biology of the Cell* (4th edition). Garland Science, Taylor & Francis Group, New York.

Sweet D (2001). *Trends in Cell Biology*. A Trend Worth Following, Volume 11, Issue 12, 1 December, Page 536.

Wagner M. (2009). *Single-Cell Ecophysiology of Microbes* as Revealed by Raman Microspectroscopy or Secondary Ion Mass Spectrometry Imaging. Annu Rev Microbiol. Vol 63.

https://www.bing.com/ck/a?!&&p=88fd7044671faaf5JmltdHM9MTY3NTI5NjAwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTE3MQ&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=Cell+theory+textbook&u=a1aHR0cHM6Ly9iaW8ubGlicmV0ZXh0cy5vcmcvQm9va3NoZWx2ZXMvSW50cm9kdWN0b3J5X2FuZF9HZW5lcmFsX0Jpb2xvZ3kvQm9vayUzQV9HZW5lcmFsX0Jpb2xvZ3lfKEJvdW5kbGVzcykvMDQlM0FfQ2VsbF9TdHJ1Y3R1cmUvNC4wMyUzQV9TdHVkeWluZ19DZWxsc18tX0NlbGxfVGhlb3J5&ntb=1

https://www.bing.com/videos/search?q=Cell+theory+textbook&&view=detail&mid=E5B0C6AEFB6CC0D59E21E5B0C6AEFB6CC0D59E21&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3DCell%2Btheory%2Btextbook%26FORM%3DHDRSC4

3.6: Possible Answers to Self-Assessment Exercises

SAE 1

Jean-Baptiste De Lamarck is a Frenchman's (1744 - 1829) that dealt with animal classification and evolution. He is credited with taking steps towards the creation of the cell theory with this saying: “Every step which Nature takes when making her direct creations consists in organizing into cellular tissue the minute masses of viscous or mucous substances that he finds at his disposal under favorable circumstances.”

SAE 2

Robert Brown

Unit 4: Types of Cells

Unit Structure

4.1: Introduction

In the recent past, scientists grouped living things into five kingdoms—animals, plants, fungi, protists, and prokaryotes—based on several criteria, such as the absence or presence of a nucleus and other membrane-bound organelles, the absence or presence of cell walls, multicellularity, and so on. In the late 20th century, the pioneering work of Carl Woese and others compared sequences of small-subunit ribosomal RNA (SSU rRNA), which resulted in a more fundamental way to group organisms on Earth. Based on differences in the structure of cell membranes and in rRNA, Woese and his colleagues proposed that all life on Earth evolved along three lineages, called domains. The domain Bacteria comprises all organisms in the kingdom Bacteria, the domain Archaea comprises the rest of the prokaryotes, and the domain Eukarya comprises all eukaryotes—including organisms in the kingdoms Animalia, Plantae, Fungi, and Protista.

Two of the three domains—Bacteria and Archaea—are prokaryotic. Prokaryotes were the first inhabitants on Earth, appearing 3.5 to 3.8 billion years ago. These organisms are abundant and ubiquitous; that is, they are present everywhere. In addition to inhabiting moderate environments, they are found in extreme conditions: from boiling springs to permanently frozen environments in Antarctica; from salty environments like the Dead Sea to environments under tremendous pressure, such as the depths of the ocean; and from areas without oxygen, such as a waste management plant, to radioactively contaminated regions, such as Chernobyl. Prokaryotes reside in the human digestive system and on the skin, are responsible for certain illnesses, and serve an important role in the preparation of many foods.

4.2: Intended Learning Outcomes

By the end of this unit, students should be able to;

- Distinguish the different types of cells.
- Enumerate the characteristics of both prokaryotes and eukaryotes.
- Provide examples of the types of cells

4.3: Main Body

4.3.1: Prokaryotic Cell

"Prokaryotic cells are the cells that do not have a true nucleus and membrane-bound organelles." Prokaryotic cells have different characteristic features. The characteristics of the prokaryotic cells includes;

- They lack a nuclear membrane.
- Mitochondria, Golgi bodies, chloroplast, and lysosomes are absent.
- The genetic material is present on a single chromosome.
- The histone proteins, the important constituents of eukaryotic chromosomes, are lacking in them.
- The cell wall is made up of carbohydrates and amino acids.
- The plasma membrane acts as the mitochondrial membrane carrying respiratory enzymes.
- They divide asexually by binary fission. The sexual mode of reproduction involves conjugation.

Prokaryotic Cell Structure

A prokaryotic cell does not have a nuclear membrane. However, the genetic material is present in a region in the cytoplasm known as the nucleoid. They may be spherical, rod-shaped, or spiral. A prokaryotic cell lacks certain organelles like mitochondria, endoplasmic reticulum, and Golgi bodies. A prokaryotic cell structure is as follows:

- **Capsule**– It is an outer protective covering found in the bacterial cells, in addition to the cell wall. It helps in moisture retention, protects the cell when engulfed, and helps in the attachment of cells to nutrients and surfaces.

- **Cell Wall**– It is the outermost layer of the cell which gives shape to the cell.
- **Cytoplasm**– The cytoplasm is mainly composed of enzymes, salts, cell organelles and is a gel-like component.
- **Cell Membrane**– This layer surrounds the cytoplasm and regulates the entry and exit of substances in the cells.
- **Pili**– These are hair-like outgrowths that attach to the surface of other bacterial cells.
- **Flagella**– These are long structures in the form of a whip, that help in the locomotion of a cell.
- **Ribosomes**– These are involved in protein synthesis.
- **Plasmids**– Plasmids are non-chromosomal DNA structures. These are not involved in reproduction.
- **Nucleoid Region**– It is the region in the cytoplasm where the genetic material is present.

Prokaryotic Cell Diagram

The prokaryotic cell diagram (Fig 2) represents a bacterial cell. It depicts the absence of a true nucleus and the presence of a flagellum that differentiates it from a eukaryotic cell.

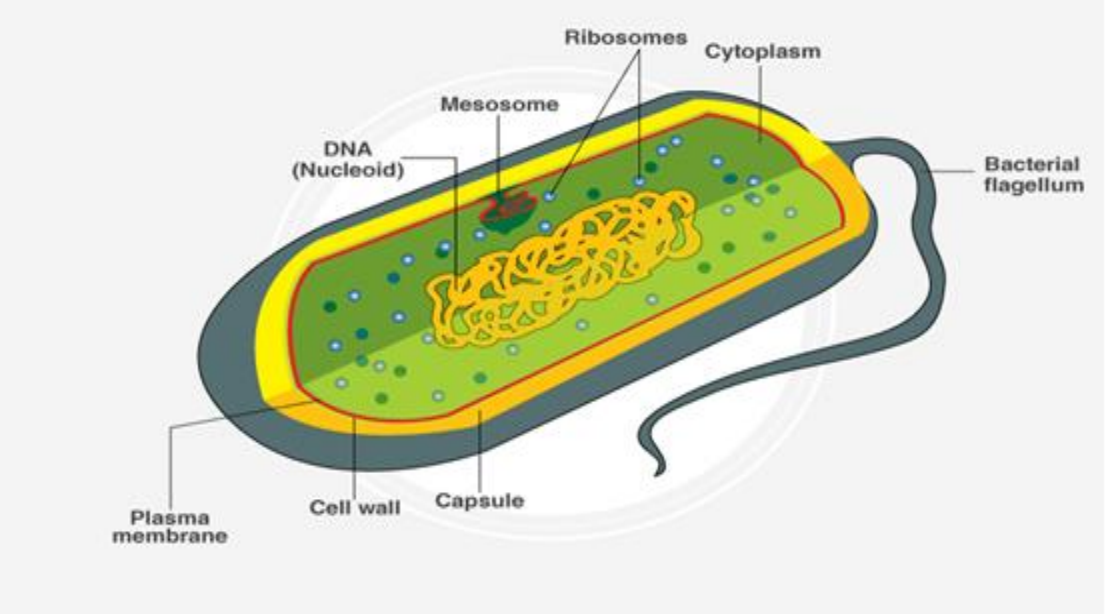


Fig 2: Representative of Prokaryotic Cell

Components of Prokaryotic Cells

The prokaryotic cells have four main components:

- **Plasma Membrane-** It is an outer protective covering of phospholipid molecules which separates the cell from the surrounding environment.
- **Cytoplasm-** It is a jelly-like substance present inside the cell. All the cell organelles are suspended in it.
- **DNA-** It is the genetic material of the cell. All the prokaryotes possess a circular DNA. It directs what proteins the cell creates. It also regulates the actions of the cell.
- **Ribosomes-** Protein synthesis occurs here.

Reproduction in Prokaryotes

A prokaryote reproduces in two ways:

- Asexually by binary fission

- The DNA of an organism replicates and the new copies attach to the cell membrane.
- The cell wall starts increasing in size and starts moving inwards.
- A cell wall is then formed between each DNA, dividing the cell into two daughter cells.
- Recombination: In this process, genes from one bacterium are transferred to the genome of other bacteria. It takes place in three ways-conjugation, transformation, transduction.

- Sexually by conjugation

- **Conjugation** is the process in which genes are transferred between two bacteria through a protein tube structure called a pilus.
- **Transformation** is the mode of sexual reproduction in which the DNA from the surroundings is taken by the bacterial cell and incorporated in its DNA.
- **Transduction** is the process in which the genetic material is transferred into the bacterial cell with the help of viruses. Bacteriophages are the virus that initiates the process.

Examples of Prokaryotic Cells

The examples of the prokaryotic cells are;

a. Bacterial Cells

- These are unicellular organisms found everywhere on earth from soil to the human body.

- They have different shapes and structures.
- The cell wall is composed of peptidoglycan that provides structure to the cell wall.
- Bacteria have some unique structures such as pili, flagella and capsule.
- They also possess extrachromosomal DNA known as plasmids.
- They have the ability to form tough, dormant structures known as endospores that helps them to survive under unfavourable conditions. The endospores become active when the conditions are favourable again.

b. Archaeal Cells

- Archaebacteria are unicellular organisms similar to bacteria in shape and size.
- They are found in extreme environments such as hot springs and other places such as soil, marshes, and even inside humans.
- They have a cell wall and flagella. The cell wall of archaea does not contain peptidoglycan.
- The membranes of the archaea have different lipids with a completely different stereochemistry.
- Just like bacteria, archaea have one circular chromosome. They also possess plasmids.

What are the structural features of prokaryotic cells?

Self-Assessment Exercises 1

- How does a prokaryotic cell divide?
- When did the prokaryotic cells evolve?

4.3.2: Eukaryotic Cell

Eukaryotic cells have a nucleus enclosed within the nuclear membrane and form large and complex organisms. Protozoa, fungi, plants, and animals all have eukaryotic cells. They are classified under the kingdom Eukaryota. They can maintain different environments in a single cell that allows them to carry out various metabolic reactions. This helps them grow many times larger than the prokaryotic cells. The characteristics of Eukaryotic Cells includes;

- Eukaryotic cells have the nucleus enclosed within the nuclear membrane.
- The cell has mitochondria.
- Flagella and cilia are the locomotory organs in a eukaryotic cell.

- A cell wall is the outermost layer of the eukaryotic cells.
- The cells divide by a process called mitosis.
- The eukaryotic cells contain a cytoskeletal structure.
- The nucleus contains a single, linear DNA, which carries all the genetic information.

Structure of Eukaryotic Cell

The eukaryotic cell structure comprises the following:

- Plasma Membrane: the plasma membrane separates the cell from the outside environment. It comprises specific embedded proteins, which help in the exchange of substances in and out of the cell.
- Cell Wall: A cell wall is a rigid structure present outside the plant cell. It is, however, absent in animal cells. It provides shape to the cell and helps in cell-to-cell interaction. It is a protective layer that protects the cell from any injury or pathogen attacks. It is composed of cellulose, hemicellulose, pectins, proteins, etc.
- Cytoskeleton: The cytoskeleton is present inside the cytoplasm, which consists of microfilaments, microtubules, and fibres to provide perfect shape to the cell, anchor the organelles, and stimulate the cell movement.
- Endoplasmic Reticulum: It is a network of small, tubular structures that divides the cell surface into two parts: luminal and extraluminal. It is of two types:
- Rough Endoplasmic Reticulum contains ribosomes.
- Smooth Endoplasmic Reticulum that lacks ribosomes and is therefore smooth.
- Nucleus: The nucleoplasm enclosed within the nucleus contains DNA and proteins. The nuclear envelop consists of two layers- the outer membrane and the inner membrane. Both the membranes are permeable to ions, molecules, and RNA material. Ribosome production also takes place inside the nucleus.
- Golgi Apparatus: It is made up of flat disc-shaped structures called cisternae. It is absent in red blood cells of humans and sieve cells of plants. They are arranged parallel and concentrically near the nucleus. It is an important site for the formation of glycoproteins and glycolipids.
- Ribosomes: These are the main site for protein synthesis and are composed of proteins and ribonucleic acids.
- Mitochondria: These are also known as “powerhouse of cells” because they produce energy. It consists of an outer membrane and an inner membrane. The inner membrane is divided into folds called cristae. They help in the regulation of cell metabolism.

- Lysosomes: They are known as “suicidal bags” because they possess hydrolytic enzymes to digest protein, lipids, carbohydrates, and nucleic acids.
- Plastids: These are double-membraned structures and are found only in plant. These are of three types:
- **Chloroplast** that contains chlorophyll and is involved in photosynthesis.
- **Chromoplast** that contains a pigment called carotene that provides the plants yellow, red, or orange colours.
- **Leucoplasts** that are colourless and store oil, fats, carbohydrates, or proteins.

Eukaryotic Cell Diagram

Eukaryotic cell diagram (Fig 3) mentioned below depicts different cell organelles present in eukaryotic cells. The nucleus, endoplasmic reticulum, cytoplasm, mitochondria, ribosomes, lysosomes are clearly mentioned in the diagram.

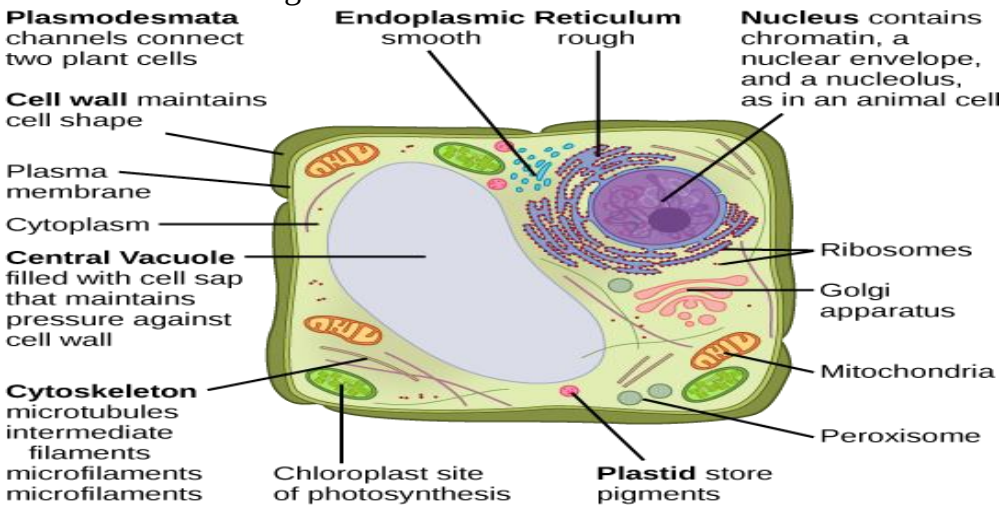


Fig 3: Typified Eukaryotic Cell

Examples of Eukaryotic Cells

Eukaryotic cells are exclusively found in plants, animals, fungi, protozoa, and other complex organisms. The examples of eukaryotic cells are;

- Plant Cells: the cell wall is made up of cellulose, which provides support to the plant. It has a large vacuole which maintains the turgor pressure. The plant cell contains chloroplast, which aids in the process of photosynthesis.

- Fungal Cells: the cell wall is made of chitin. Some fungi have holes known as septa which allow the organelles and cytoplasm to pass through them.
- Animal Cells: these do not have cell walls. Instead, they have a cell membrane. That is why animals have varied shapes. They have the ability to perform phagocytosis and pinocytosis.
- What is the most important characteristic of eukaryotic cells that distinguishes it from prokaryotic cells?

Self-Assessment Exercises 2

- Are virus's eukaryotes?
- What are the salient features of a eukaryotic cell?
- When did the first eukaryotic cell evolve?

4.4: Summary

This unit dealt with the two types of cells where Prokaryotic cells are cells without a nucleus.

Whereas Eukaryotic cells are cells that contain a nucleus. **Eukaryotic** cells have other organelles besides the nucleus. The only organelles in a prokaryotic cell are ribosomes.

4.5: References/Further Readings/Web Sources

Fancher, L.J (2015). *Prokaryotic and Eukaryotic Cells*. [online] Cod.edu. Available at: <http://www.cod.edu/people/faculty/fancher/prokeuk.htm> [Accessed 13 November 2015].

Cooper, G.M & Hausman, RE (2009). *The cell*, Washington, D.C.: ASM Press.

Prokaryotic and Eukaryotic Cells - Biology LibreTexts

https://www.bing.com/ck/a?!&&p=c108738d78b91397JmltdHM9MTY3NTI5NjAwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTE5Nw&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=lists+of+bibliography+of+prokaryotic+and+

eukaryotic+cells&u=a1aHR0cHM6Ly9iaW8ubGlcmV0ZXh0cy5vcmcvQm9va3NoZWx2ZXMvSW50cm9kdWN0b3J5X2FuZF9HZW5lcmFsX0Jpb2xvZ3kvQm9vayUzQV9JbnRyb2R1Y3RvcnlfQmlvbG9neV8oQ0stMTIpLzAyJTNBX0NlbGxfQmlvbG9neS8yLjAzJTNBX1Byb2thcnlvdGljX2FuZF9FdWthcnlvdGljX0NlbGxz&ntb=1

https://www.bing.com/ck/a?!&&p=bc2681da94f7d82bJmltdHM9MTY3NTI5NjAwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTI2Mw&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=lists+of+bibliography+of+prokaryotic+and+eukaryotic+cells&u=a1aHR0cHM6Ly9iaW8ubGlcmV0ZXh0cy5vcmcvQm9va3NoZWx2ZXMvSW50cm9kdWN0b3J5X2FuZF9HZW5lcmFsX0Jpb2xvZ3kvQm9vayUzQV9JbnRyb2R1Y3RvcnlfQmlvbG9neV8oQ0stMTIpLzAyJTNBX0NlbGxfQmlvbG9neS8yLjAzJTNBX1Byb2thcnlvdGljX2FuZF9FdWthcnlvdGljX0NlbGxz&ntb=1

https://www.bing.com/videos/search?q=lists+of+bibliography+of+prokaryotic+and+eukaryotic+cells&&view=detail&mid=A128BB13AC96923F933EA128BB13AC96923F933E&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3Dlists%2Bof%2Bbibliography%2Bof%2Bprokaryotic%2Band%2Beukaryotic%2Bcells%26FORM%3DHDRSC4

https://www.bing.com/videos/search?q=lists+of+bibliography+of+prokaryotic+and+eukaryotic+cells&&view=detail&mid=9D1A98789AC0243F38D09D1A98789AC0243F38D0&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3Dlists%2Bof%2Bbibliography%2Bof%2Bprokaryotic%2Band%2Beukaryotic%2Bcells%26FORM%3DHDRSC4

4.6: Possible Answers to Self-Assessment Exercises

SAE 1

- Prokaryotic cells undergo asexual reproduction. Most prokaryotic cells divide by binary fission, where the cells divide into two daughter cells.
- The first prokaryotic cells evolved around 3.5 billion years ago. The eukaryotic cells were formed after the prokaryotic cells and are believed to have evolved from them.

SAE 2

- Viruses are neither eukaryotes nor prokaryotes. Since viruses are a link between living and non-living they are not considered in either category.
- A eukaryotic cell has the following important features: A eukaryotic cell has a nuclear membrane; It has mitochondria, Golgi bodies, cell wall; It also contains locomotory organs such as cilia and flagella; The nucleus has a DNA that carries all the genetic information.
- The first eukaryotic cells evolved about 2 billion years ago. This is explained by the endosymbiotic theory that explains the origin of eukaryotic cells by the prokaryotic organisms. Mitochondria and chloroplasts are believed to have evolved from symbiotic bacteria.

Unit 5: Cell Organelles and Functions

Unit Structure

5.1: Introduction

Cells are one of two major classifications: eukaryotic and prokaryotic. Eukaryotic are more complex of the two. Eukaryotic cells include animal cells – including human cells – plant cells, fungal cells and algae. Eukaryotic cells are characterized by a membrane-bound nucleus. That's distinct from prokaryotic cells, which have a nucleoid – a region that's dense with cellular DNA – but don't actually have a separate membrane-bound compartment like the nucleus.

Eukaryotic cells also have organelles, which are membrane-bound structures found within the cell.

If you looked at eukaryotic cells under a microscope, you'd see distinct structures of all shapes and sizes. Prokaryotic cells, on the other hand, would look more uniform because they don't have those membrane-bound structures to break up the cell. Think of organelles like rooms in your home: your living room, bedrooms, bathrooms and so on. They're all separated by walls – in the cell, these would be the cell membranes – and each type of room has its own distinct use that, overall, make your home a comfy place to live. Organelles work a similar way; they all have distinct roles that help your cell’s function. All those organelles help eukaryotic cells carry out more complex functions. So, organisms with eukaryotic cells – like humans – are more complex than prokaryotic organisms, like bacteria.

5.2: Intended Learning Outcomes

By the end of this unit, students should be able to;

- Distinguish different types of cell organelles

- Describe the cell organelle structure
- Enumerate the functions of the cell organelles.

5.3: Main Body

Plasma (cell) membrane

The plasma membrane (Fig 4) is the outermost layer of the cell. The main function of the plasma membrane is to protect the cell from its environment. It is often referred to as a fluid mosaic phospholipid bilayer that is hydrophilic externally and internally, but hydrophobic at its core. The hydrophilic property arises from the charged phosphate molecule that forms the head of the phospholipid, and the hydrophobic nature is from the two lipid tails which forms the core. This feature allows the selective permeability of the membrane. For instance, particles that are hydrophilic (e.g. ions) are not able to pass through the hydrophobic core, and those that are hydrophobic (e.g. fats) are repelled from the outer surface. As a result, the cell is able to isolate its internal environment from the external environment.

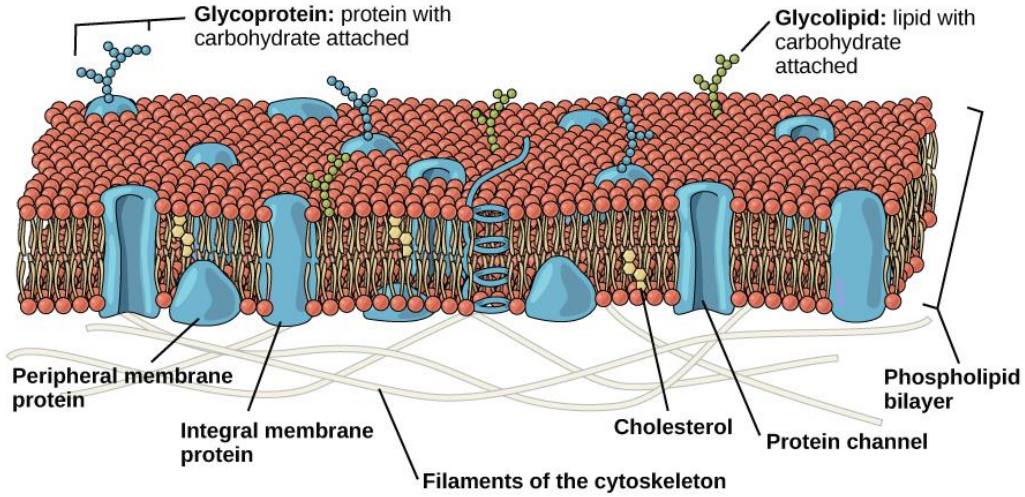


Fig 4: *The eukaryotic plasma membrane is a phospholipid bilayer with proteins and cholesterol embedded in it.*

Cytoplasm

The semi-solid medium that keeps the organelles suspended and nutrients dissolved within the internal cellular environment is the cytoplasm. In addition to the organelles, the cytoplasm also contains

microfilaments, microtubules and secretory granules. The microfilaments and microtubules are a part of the cellular architecture that helps give the cell its structure (cytoskeleton) and play a role in cell replication. They also contribute to the formation of cilia and flagella in some cell lines that require motility.

Ribosomes

In order for cells to grow and replicate, they must produce the necessary building blocks to achieve this feat. Additionally, some cells – like the β-cells of the pancreas – produce protein-based hormones to help maintain homeostasis. This process is achieved by ribosomes. Ribosomes (Fig 5) are complex ribonucleic acid-based molecules (i.e., ribosomal-ribonucleic acid; r-RNA) that are responsible for translating coded sequences of the messenger-RNA (m-RNA) to proteins. They are made up of a small and a large subunit which coordinate with each other to translate the m-RNA strand. Some ribosomes are membrane bound, while others float freely in the cytoplasm. While free ribosomes synthesize proteins that are used within the cell, the proteins synthesized by bound ribosomes are meant to be exported.

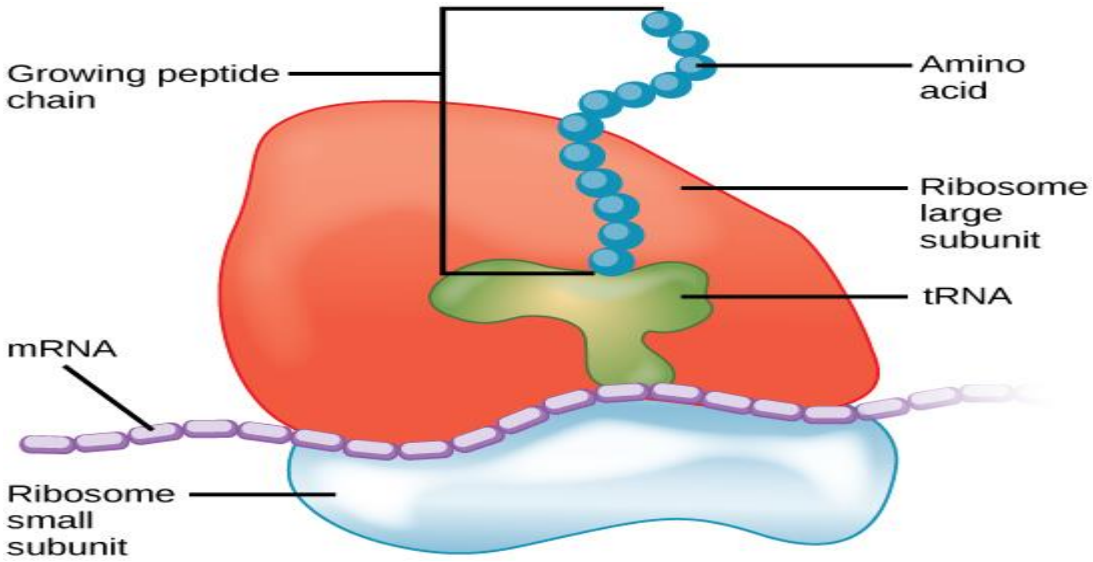


Fig 5. *Ribosomes are made up of a large subunit (top) and a small subunit (bottom). During protein synthesis, ribosomes assemble amino acids into proteins.*

Endoplasmic reticulum

There are clusters of sacs and vesicles that form cisternae (tubules) within the cytoplasm. These structures make the endoplasmic reticulum. There are two types of endoplasmic reticulum: one that has ribosomes

bound to its surface - rough endoplasmic reticulum (RER), while the other lacks ribosomes - smooth endoplasmic reticulum (SER).

Another distinguishing feature between rough and smooth endoplasmic reticulum is that rough endoplasmic reticulum is an extension of the nuclear membrane, while the smooth endoplasmic reticulum may either be an independent collection of sacs, or a continuation of the rough endoplasmic reticulum. As previously stated, the rough endoplasmic reticulum stores protein that was synthesized by the ribosomes on its surface. In contrast, the smooth endoplasmic reticulum synthesizes phospholipids, steroids, and lipids, which are subsequently used in steroid based hormone synthesis.

Golgi apparatus

Named after the Italian scientist that discovered it in 1898, Camillo Golgi, this organelle exists within the cytoplasm as a storage center for proteins that will be distributed to other sites. The Golgi apparatus (also referred to as the Golgi complex or Golgi body) is structurally subdivided into cis and trans components. The former represents flattened incoming vesicles from the endoplasmic reticulum that fuse to form cisternae. The trans aspect of the structure is the region from which vesicles bud off to join other vesicles, lysosome or the cell surface (to be exocytosed).

Vesicles and lysosomes

Some proteins synthesized within the cell are utilized by the cell, while others are intended for export to other areas of the body. To prevent these products from being activated and interacting unintentionally with the cell of origin, they are stored in membrane bound sacs called vesicles.

There are three general types of vesicles; exocytotic, lysosomal and secretory vesicles. The exocytotic vesicles contain proteins that will be expelled from the cell via exocytosis. This occurs when the vesicles fuse with the cytoplasmic membrane and expel its contents into the extracellular space. For example, the release of antibodies from activated B-cells during the humoral immune response.

Proteins housed in secretory vesicles are also for extracellular release but require a stimulus; the release of a neurotransmitter named acetylcholine (ACh) from the telodendria of neurons into the synaptic cleft following stimulation by an action potential.

Lysosome

On the other hand, proteases are enzymes designed to digest protein. These are special proteins that are involved in cellular degradation in an apoptotic (programmed cell death) fashion or as part of the defense mechanism against invading pathogens. In either case, these enzymes are stored in the lysosomes for subsequent release. When there is an organelle, cell or microorganism to be digested, a vesicle forms around the substance to be dissolved and subsequently fuses with the lysosome. This is done to prevent unintended damage to other cytoplasmic structures.

Mitochondria

Often referred to as the "powerhouse" of the cell, the mitochondria (s. mitochondrion) is an elongated, double membrane structure with numerous cristae within its inner membrane. In addition to the membrane bound ATP synthase proteins that facilitate ATP production, mitochondria are the only organelles that contain their own DNA material and is therefore capable of replication. The outer membrane that envelops the entire organelle is equipped with prion proteins that allow the selective uptake size of some substances. The inner membrane also has specific proteins such as ATP synthase (makes ATP), cytochrome C (performs oxidation-reduction reactions) and transport proteins (for selective uptake of material into the mitochondrial matrix).

The constituents of the intermembrane space (between the inner and outer membranes) are very similar to those in the cytoplasm of the cell. The matrix is the site at which the citric acid cycle (Krebs cycle - process in ATP formation) occurs. The number of mitochondria found within a particular cell is dependent on its function. For example, cardiac myocetes contain more mitochondria than epithelial cells of the skin because they require more ATP to make them resistant to fatigue.

Nucleus

The nucleus (Fig 6) is the largest structure within the cell. It is circumscribed by the nuclear envelope and contains a nucleolus, matrix, and most importantly, the hereditary genetic material known as deoxyribonucleic acid (DNA). There is approximately two meters of microscopic genetic material within each cell. This immense volume of DNA is able to be held within the cell by tightly coiling it around histones (proteinaceous scaffold) that are subsequently stacked as chromosomes.

However, DNA only exists as chromosomes during the active stages of cellular division. When the cell is in the growth phase, the DNA takes the form of either euchromatin or heterochromatin. DNA that takes the euchromatic form is usually more frequently transcribed and expressed by the cell.

Within the nucleus is a unique region known as the nucleolus. This is an area where DNA that codes for ribosomal RNA (or tandem repeats) is found. The primary function is to make and assimilate r-RNA that will be exported to the cytoplasm to translate m-RNA.

Nuclear envelope

There is another selectively permeable membrane that separates the nucleus cellular cytoplasm from the nuclear matrix. This structure is known as the nuclear envelope; like the plasma membrane, it is also made of a lipid bilayer. It is a double layered structure that encircles the nucleolus and the chromatin within the nuclear matrix. The nuclear envelope is continuous with the rough endoplasmic reticulum. In some areas of the envelope the inner and outer layers merge, forming openings known as nuclear pores. Not only do nuclear pores allow nucleotides and other materials to enter the nucleus, but they also allow m-RNA to leave the nucleus for translation in the cytoplasm.

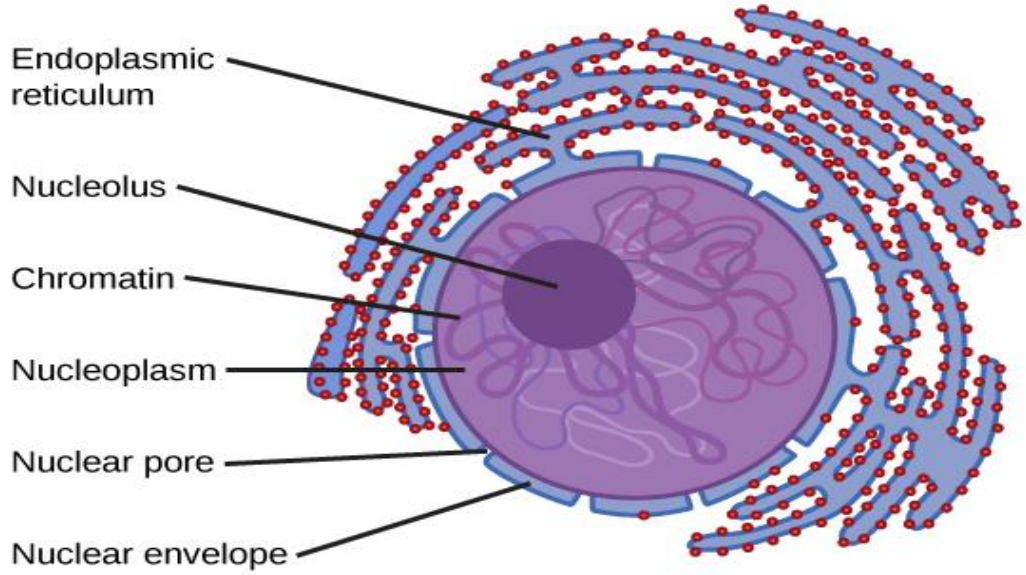


Fig 6. *The nucleus stores chromatin (DNA plus proteins) in a gel-like substance called the nucleoplasm. The nucleolus is a condensed region of chromatin where ribosome synthesis occurs.*

The boundary of the nucleus is called the nuclear envelope. It consists of two phospholipid bilayers: an outer membrane and an inner membrane. The nuclear membrane is continuous with the endoplasmic reticulum. Nuclear pores allow substances to enter and exit the nucleus.

Peroxisomes

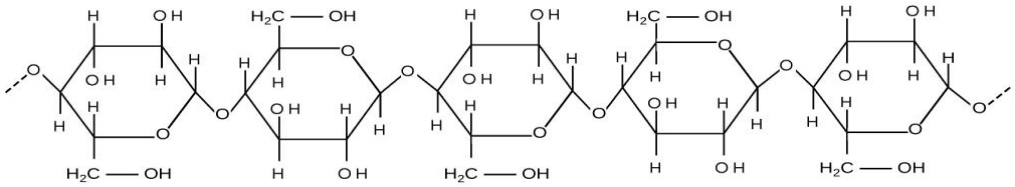
Peroxisomes are small, round organelles enclosed by single membranes. These organelles carry out redox reactions that oxidize and break down fatty acids and amino acids. They also help to detoxify many toxins that may enter the body. Many of these redox reactions release hydrogen peroxide, H_2O_2, which would be damaging to cells; however, when these reactions are confined to peroxisomes, enzymes safely break down the H_2O_2 into oxygen and water. For example, alcohol is detoxified by peroxisomes in liver cells. Glyoxysomes, which are specialized peroxisomes in plants, are responsible for converting stored fats into sugars.

Vesicles and vacuoles

Vesicles and *vacuoles* are membrane-bound sacs that function in storage and transport. Other than the fact that vacuoles are somewhat larger than vesicles, there is a very subtle distinction between them: the membranes of vesicles can fuse with either the plasma membrane or other membrane systems within the cell. Additionally, some agents such as enzymes within plant vacuoles break down macromolecules. The membrane of a vacuole does not fuse with the membranes of other cellular components.

The cell wall

The structure external to the plasma membrane in plant cell is called the *cell wall*. The cell wall is a rigid covering that protects the cell, provides structural support, and gives shape to the cell. Fungal and protistan cells also have cell walls. While the chief component of bacterial cell walls is peptidoglycan, the major organic molecule in the plant cell wall is cellulose (see structure below), a polysaccharide made up of glucose subunits.



Chloroplasts

Chloroplasts (Fig 7) are plant cell organelles that carry out photosynthesis. Like the mitochondria, chloroplasts have their own DNA and ribosomes, but chloroplasts have an entirely different function. Like mitochondria, chloroplasts have outer and inner membranes, but within the space enclosed by a chloroplast's inner membrane is a set of interconnected and stacked fluid-filled membrane sacs called thylakoids (figure below). Each stack of thylakoids is called a granum (plural = grana). The fluid enclosed by the inner membrane that surrounds the grana is called the stroma.

The chloroplasts contain a green pigment called *chlorophyll*, which captures the light energy that drives the reactions of photosynthesis. Like plant cells, photosynthetic protists also have chloroplasts. Some bacteria perform photosynthesis, but their chlorophyll is not relegated to an organelle.

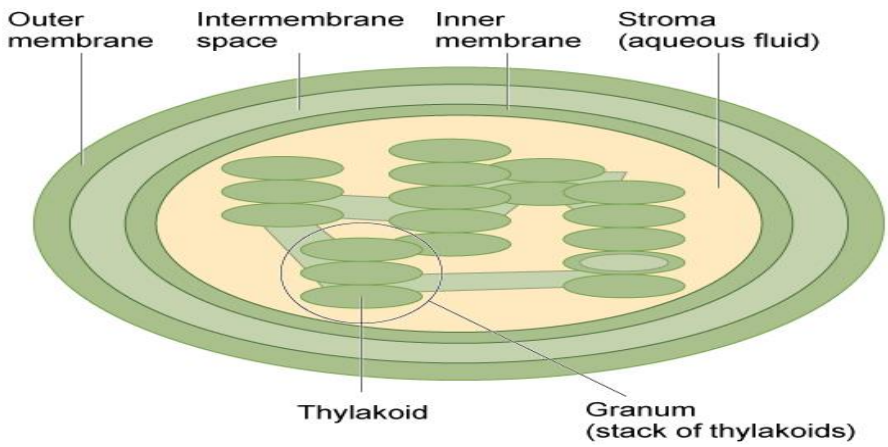


Fig 7. *The chloroplast has an outer membrane, an inner membrane, and membrane structures called thylakoids that are stacked into grana. The space inside the thylakoid membranes is called the thylakoid space. The light harvesting reactions take place in the thylakoid membranes, and the synthesis of sugar takes place in the fluid inside the inner membrane, which is called the stroma.*

Chloroplasts also have their own genome, which is contained on a single circular chromosome.

Define chloroplast?

Self-Assessment Exercises

- Which of the following is a single membrane-bound organelle?

- Vacuole
- Golgi Apparatus
- Endoplasmic Reticulum
- All of the options

- Which of the following cell organelles is present in animal cells and absent in plant cells?

- Nucleus
- Centrosome
- Golgi bodies
- All of the options

- Which of the following is not a double membrane-bound organelle?

- Chloroplast
- Mitochondria
- Endoplasmic Reticulum
- All of the options

- Which of the following statements is true about the Golgi bodies?

- It is a sac-like organelle
- It is located near the nucleus
- It helps in transporting the particles throughout the cell.
- All of the options

- Which of the following statements is true about the Nucleus?

- It is absent in prokaryotes
- It is called the brain of the cell

5.4: Summary

In this Unit, we are able to list, describe and state the functions of cell organelles.

5.5: References/Further Readings/Web Sources

Eroschenko, V. P & Mariano S. H (2008). di Fiore: Difiore's Atlas of Histology with Functional Correlations. 10th ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins, 2008. Print.

Hernandez-Verdun, D (2005). "Nucleolus: From Structure to Dynamics". *Histochemistry and Cell Biology* 125.1-2: 127-137.

Lowe, S. W. (2000). "Apoptosis in Cancer". *Carcinogenesis* 21.3: 485-495.

https://www.bing.com/ck/a?!&&p=aed2b2b82b01f0cfJmltdHM9MTY3NTM4MjQwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTE2MA&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=cell+organelles&u=a1aHR0cHM6Ly9iaW8ubGlicmV0ZXh0cy5vcmcvQm9va3NoZWx2ZXMvSHVtYW5fQmlvbG9neS9Cb29rJTNBX0h1bWFuX0Jpb2xvZ3lfKFdha2ltX2FuZF9HcmV3YWwpLzA1JTNBX0NlbGxzLzUuMDYlM0FfQ2VsbF9PcmdhbmVsbGVz&ntb=1

https://www.bing.com/videos/search?q=cell+organelles&&view=detail&mid=E640D0AB68A9FB9CDA33E640D0AB68A9FB9CDA33&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3Dcell%2Borganelles%26FORM%3DHDRSC4

5.6: Possible Answers to Self-Assessment Exercises

- (d) All of the options
- (b) Centrosome.
- (c) Endoplasmic Reticulum
- (d) All of the options
- (d) All of the above. options

Glossary

- Animal Cells - eukaryotic cells that contain various membrane-bound organelles.
- Cell - the fundamental unit of life.
- Cell Membrane - a thin semi-permeable membrane that surrounds the cytoplasm of a cell.
- Cell theory - one of the five basic principles of biology, stating that the cell is the basic unit of life.
- Centrioles - cylindrical structures that are composed of groupings of microtubules arranged in a 9 + 3 pattern.
- Chromatid - one of two identical copies of a replicated chromosome.
- Chromatin - the mass of genetic material composed of DNA and protein that condense to form chromosomes during eukaryotic cell division.
- Chromosome - a long, stringy aggregate of genes that carries heredity information (DNA) and is formed from condensed chromatin.
- Cytoplasm - all of the contents outside of the nucleus and enclosed within the cell membrane of a cell.
- Cytosol - semi-fluid component of a cell's cytoplasm.
- Endoplasmic Reticulum - a network of tubules and flattened sacs that serve a variety of functions in the cell.
- Golgi complex - the cell organelle that is responsible for manufacturing, warehousing, and shipping certain cellular products.
- Lysosomes - the membranous sacs of enzymes that can digest cellular macromolecules.
- Mitochondria – cell organelles that convert energy into forms that are usable by the cell.
- Nucleus - a membrane-bound structure that contains the cell's hereditary information and controls the cell's growth and reproduction.

- Organelles - tiny cellular structures, that carry out specific functions necessary for normal cellular operation.
- Peroxisomes - cell structures that contain enzymes that produce hydrogen peroxide as a by-product.
- Plant Cells – eukaryotic cells that contain various membrane-bound organelles. They are distinct from animal cells, containing various structures not found in animal cells.
- Prokaryotes - single-celled organisms that are the earliest and most primitive forms of life on earth.

End of the module Questions

- What is a cell?

a) smallest and advanced unit of life
b) smallest and basic unit of life
c) largest and basic unit of life
d) largest and advanced unit of life

- Which of the following is a functional unit of a body?

a) Mitochondria
b) Cytoplasm
c) Spleen
d) Cell

- What is cell biology?

a) Study of cell division only
b) Study of cancerous cell
c) Study of cell structure and function
d) Study of metaphase of a cell

- Which of the following is known as the powerhouse of a cell?

a) Mitochondria
b) Cytoplasm
c) Lysosome
d) Nuclei

- Which of the following is known as the suicide bag of a cell?

a) Mitochondria

b) Golgi Complex
c) Lysosome
d) Nuclei

- Lysosomes are produced by which of the following cell organelles?

a) Mitochondria
b) Endoplasmic Reticulum
c) Golgi Complex
d) DNA

- Which of the following cell organelle is responsible for transporting, modifying, and packaging proteins and lipids?

a) Mitochondria
b) Endoplasmic Reticulum
c) Golgi Complex
d) DNA

- Which of the following cell doesn't contain a cell wall?

a) Plant cell
b) Bacteria
c) Fungi
d) Animal cell

- Who is the father of cell biology?

a) George N. Papanicolaou
b) George Emil Palade
c) Robert Hooke
d) None of the above

- DNA is stored in which of the following cell organelle?

a) Cell wall
b) Cell Membrane
c) Nucleus
d) Cytoplasm

- Which of the following organisms doesn't have a cell?

a) Virus
b) Bacteria
c) Fungi
d) Algae

- Who proposed the cell theory?

a) Theodor Schwann, Watson and Robert Hooke
b) Theodor Schwann, Matthias Schleiden and Robert Hooke
c) Theodor Schwann, Matthias Schleiden and Rudolf Virchow
d) Theodor Schwann, Rudolf Virchow and Robert Hooke

- RNA is present in which of the following cell organelles?

a) Cell wall
b) Ribosome
c) Nucleus
d) Cytoplasm
d) Golgi complex

- Protein synthesis takes place in which of the following cell organelle?

a) Cell wall
b) Ribosome
c) Nucleus
d) Cytoplasm

- Which of the following cell organelles is absent in animal cells and present in a plant cell?

- Cell wall
- Cytoplasm
- Vacuoles
- Mitochondria

- Which of the following cell organelles does not contain DNA?

- Nucleus
- Lysosomes
- Chloroplast
- Mitochondria

- Which of the following statements is true about the cell wall?
- The cell wall is mainly composed of lipid

- The cell wall is mainly composed of starch
- The cell wall is mainly composed of protein
- The cell wall is mainly composed of cellulose

- Which of the following statements is true about cell theory?
- The Cell theory does not apply to fungi
- The Cell theory does not apply to virus
- The Cell theory does not apply to algae
- The Cell theory does not apply to microbes

- _____ is a jellylike substance found floating inside the plasma membrane.
- Cell sap
- Cytoplasm
- Karyoplasm
- Mitochondria

- Which of the following cell organelles is called the powerhouse of the cell?
- Nucleus
- Lysosomes
- Chloroplast
- Mitochondria

- Which of the following cell organelles regulates the entry and exit of molecules to and from the cell?
- Lysosomes
- Golgi bodies
- Cell membrane
- Mitochondria

- _____is the study of the cell, its types, structure, functions and its organelles.
- Biology
- Cell Biology
- Microbiology
- Biotechnology

- _____ is involved in the synthesis of phospholipids.
- Mitochondria
- Cytoplasm
- Endoplasmic Reticulum
- Smooth Endoplasmic Reticulum

Answers

- **Answer:b**

- Explanation: A cell is the smallest and most fundamental unit of life, responsible for all of life's operations. All living beings have cells that serve as structural, functional, and biological units.
- Answer: d
  Explanation: Because all living beings are made up of cells, the cell is recognized as the structural and functional unit of life.
- Answer: c
  Explanation: The study of cell structure and function is known as cell biology, and it is based on the idea that the cell is the most basic unit of life. Concentrating on the cell allows for a more in-depth understanding of the tissues and organisms that cells make up.
- Answer: a
  Explanation: The mitochondria, also known as the "powerhouse of the cell," are the organelles that produce energy within the cell. The mitochondria are the major site for ATP generation and play a significant role in cellular respiration.
- Answer: c
  Explanation: The digesting enzymes are found in lysosomes. When lysosomes rupture, digestive enzymes are released, which begin digesting the body's own cells. That's why they're referred to as suicidal bags.
- Answer: c
  Explanation: They are produced by the Golgi body. The fusion of vesicles from the Golgi complex with endosomes produces lysosomes.
- Answer: c
  Explanation: The Golgi apparatus, also known as the Golgi complex, is a factory where proteins from the ER are further processed and sorted before being transported to their final destinations: secretion, lysosomes, or the plasma membrane.
- Answer: d
  Explanation: Plant cells require a cell wall, but animal cells do not, as plants require a stiff framework in order to grow up and out. Cell membranes are present in all cells and are flexible. Plant cells only have the shapes of their cell walls, but animal cells can have a variety of shapes.
- Answer: b
  Explanation: Dr. George Emil Palade, a Nobel Laureate, is known as the "Father of Cell Biology" for his pioneering work in the subject. He was a pioneer in the use of the electron microscope, which he used to discover ribosomes and secretory protein activity.

- Answer: c
  Explanation: DNA contains the blueprints for all of the proteins in our bodies, neatly packed in a double helix. Transcription and translation are the processes that turn DNA into proteins, and they take place in distinct parts of the cell. The first step, transcription, takes place in the nucleus, which is where the DNA is stored.
- Answer: a
  Explanation: Viruses aren't made up of cells. Their genetic material is protected by a protein covering (either DNA or RNA). However, they lack a cell membrane and other organelles seen in cells.
- Answer: c
  Explanation: Theodor Schwann proposed the classical cell hypothesis. This hypothesis is divided into three parts. All organisms are made up of cells, according to the first section. Cells are the basic units of life, according to the second portion. These sections were based on a conclusion reached by Schwann and Matthias Schleiden. Rudolf Virchow declared Omnis cellula e cellula, claiming that cells come from preexisting cells that had multiplied.
- Answer: b
  Explanation: Ribosomes are tiny organelles that contain RNA and specific proteins within the cytoplasm.
- Answer: b
  Explanation: Protein synthesis takes place on ribonucleoprotein particles called ribosomes in the cytoplasm. Ribosomes in the cytoplasm transform mRNA molecules exported from the nucleus into protein (which are RNA-protein complexes, not organelles).
- (a) Cell wall.
- (b) Lysosomes
- (d) The cell wall is mainly composed of cellulose.
- (b) The Cell theory does not apply to the virus.
- (b) Cytoplasm.
- (d) Mitochondria.
- (c) Cell membrane.
- (b) Cell Biology.
- (d) Smooth Endoplasmic Reticulum.

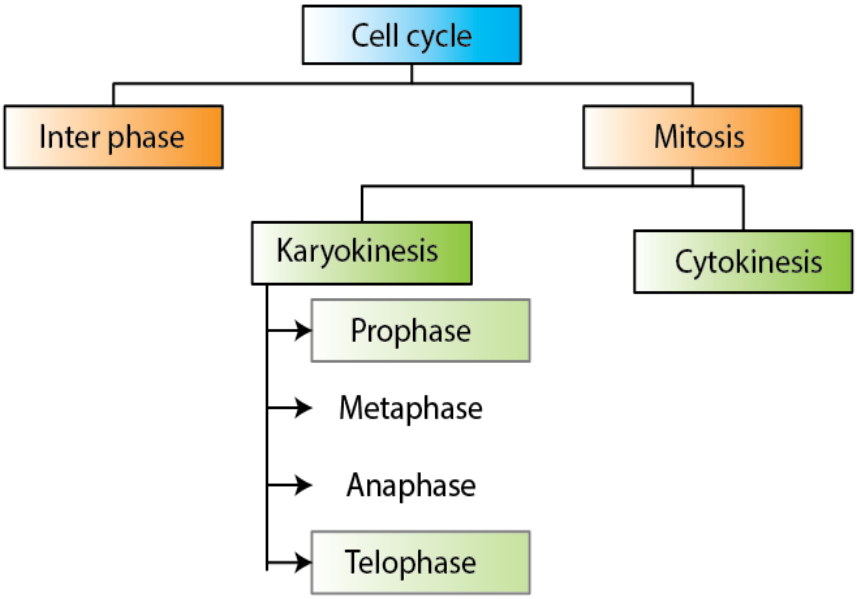
MODULE 2 CELL DIVISION, DIFFERENTIATION AND GROWTH

Unit 1: Cell Cycle

Unit Structure

1.1: Introduction

"Cell cycle refers to the series of events that take place in a cell, resulting in the duplication of DNA and division of cytoplasm and organelles to produce two daughter cells." **The cell cycle was discovered** by Prevost and Dumas (1824) while studying the cleavage of zygote of Frog. It is a series of stages a cell passes through, to divide and produce new cells. This entire process where with the help of one single parent cell a new cell population grows and develops is known as the cell cycle.



2.2: Intended Learning Outcomes

By the end of this unit, students should be able to;

- Distinguish the different stages of cell cycle.
- Enumerate the significance and importance of cell cycle.

1.3: Main Body

Phases of Cell Cycle

Cell division cycle or the cell cycle is a 4-stage process in a somatic cell during which two significant molecular processes occur – parent chromosome duplication (occurring in S phase) and equal detachment of the chromosome to the daughter cells (occurring during M phase). In eukaryotic cells, the cell cycle phases are split into two significant phases – interphase and the mitotic phase. While in interphase, the cell significantly grows and replicates a DNA copy, in the mitotic phase or the M phase, the cell splits its DNA into two sets and hence the division of the cytoplasm to form two daughter cells.

- **Interphase**: In Interphase, a newly formed cell and its nucleus enquiring a series of changes before it becomes capable of

division again. The interphase called the **resting phase**; in the meantime, the cell is preparing for division by undergoing both cell growth and **DNA replication** in an orderly manner. Interphase lasts quite 95% of the cell cycle. It is further divided into four phases:

- G0G0 **Phase (Quiescent Stage)**
- This is known as the **resting or inactive or quiescent stage,** as it neither **divides nor grows.**
- This phase can divide further as an extended G1G1 phase or a separate phase-out of the cell cycle.
- In this phase, cells remain metabolically active but do not undergo division.
- These cells can resume division as and when required.
- Nerve cells and muscle cells are examples of cells that enter the G0G0 phase when they reach maturity.
- Sometimes, cells might enter the G0G0 phase from the checkpoint in the G1G1 phase because of the lack of growth factors or nutrients.
- Some cells like the liver and kidneys' parenchymal cells enter the G0G0 phase semi-permanently and can be induced to divide.
- The G0G0 phase is often associated with senescence; the G0G0 phase is a reversible stage where a cell can enter the cell cycle again to divide.
- The cells in the G0G0 phase have different regulators that ensure the proper functioning of the cell.
- G1G1 **Phase (Gap** 11**)**
- G1G1 phase is a part of the interphase.
- This phase commences at the termination of the previous mitotic phase and continues till the starting of DNADNA replication, so it is known as **the first growth phase or post-mitotic gap phase.**
- Throughout this phase, the cell is metabolically active and continuously grows.
- In this phase, the transcriptions of all three sets of RNARNA (mRNA, tRNA and rRNA)(mRNA, tRNA and rRNA) and proteins are synthesized.
- The duration of the G1G1 phase is also highly variable among different cells.
- An important in the G1G1 phase is the G1/SG1/S checkpoint determining if the cell is ready to proceed into the division phase.
- At this point, events like detecting DNADNA damage and nutrient concentration are performed to make sure that the cell has enough machinery to undergo cell division.

- SS **Phase (Synthesis)**

- SS phase is known as the **synthesis** phase. It takes place in between G1G1 and G2G2 phases.
- In this phase, DNADNA replication takes place on the template of the existing DNADNA to form chromatin and chromatid.
- The formation of histone proteins and other proteins are important in this phase as the newly replicated DNADNA molecules need histone proteins to form nucleosomes.
- The entry into the SS phase is regulated by the G1/SG1/S checkpoint that only enables cells with enough nutrients and healthy DNADNA to enter the next phase.
- This phase is moderately long, occupying about 30%30% of the total cell cycle time.
- Each chromosome carries a duplicate set of genes; a haploid cell becomes diploid, and a diploid cell becomes tetraploid at the end of the SS phase.

- G2G2 **Phase (Gap** 22**)**

- G2G2 is also known as the **second growth** phase or **pre mitotic gap** phase because the cell collects nutrients and releases proteins to prepare the cell for the MM phase.
- This phase is also essential as it checks for DNADNA damage (during replication) to make sure that the cell is in proper condition to undergo division.
- In this phase, the synthesis of DNADNA stops, synthesis of RNAsRNAs and proteins continues.
- Organelles and spindle formation take place.
- The entry of the cell from the G2G2 phase to the MM phase is regulated by the G2G2 checkpoint, where different proteins and complexes are involved.
- In case of DNADNA damage or insufficient nutrients, the cell remains in the G2G2 phase and is not passed for cell division.

- **MM Phase (Mitotic Phase)**

MM **phase** is the most dramatic multi-step process in which actual cell division occurs. This phase starts with the **nuclear division**, corresponding to the separation of the **daughter chromosome** (Karyokinesis) and usually ends with the **division of cytoplasm** (Cytokinesis). It is also called an **equational division** because the number of chromosomes in parent and daughter cells remain the same.

Cell Cycle Importance

The importance of the Cell Cycle is given below:

- The cell cycle repairs and controls damages caused to the cells.
- The cell cycle helps in renewing damaged cells.
- The cycle is important for the survival and growth of living organisms.
- The cell cycle is essential to all organisms as if it is not present or stops suddenly, life on earth would completely stop.
- The cell cycle provides a greater number of cells for growth and development.
- The cell cycle helps in the replication and reproduction of cells in both prokaryotes and eukaryotes.

What is the shortest phase in a cell cycle? Why is the cell cycle important?

Self-Assessment Exercises

- Which is the most important stage of cell cycle?
- What is the significance of G1, S and G2 phases of the interphase?

1.4: Summary

Cell Cycle is a series of events in a cell at the time of its growth and division. These events include cell division, in which a parent cell divides into two or more daughter cells. The cell cycle consists of two stages interphase – the beginning of the cell division and the mitotic phase – which is the actual period of cell division. Further interphase is subdivided into G0G0, G1G1, SS and G2G2. The cell cycle is essential for all living organisms as it allows them to survive, replicate and reproduce. In brief, we can say that the cell cycle plays a significant role in the existence of life on earth.

1.5: References/Further Readings/Web Sources

Cooper, G. M. (1997). The cell: a molecular approach. Washington, DC: ASM Press.

Taylor, W. R., & Stark, G. R. (2001). Regulation of the G2/M transition by p53. Oncogene, 20(15), 1803-1815. doi: 10.1038/sj.onc.1204252

https://www.bing.com/ck/a?!&&p=1d903720d68214a9JmltdHM9MTY3NTU1NTIwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTE4Nw&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=cell+cycle+textbook&u=a1aHR0cHM6Ly93d3cubmNiaS5ubG0ubmloLmdvdi9ib29rcy9OQksyNjg2OS8&ntb=1

https://www.bing.com/ck/a?!&&p=f64e01ad9f349fb8JmltdHM9MTY3NTU1NTIwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTIzMg&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=cell+cycle+textbook&u=a1aHR0cHM6Ly9ib29rcy5nb29nbGUuY29tL2Jvb2tzL2Fib3V0L1RoZV9DZWxsX0N5Y2xlLmh0bWw_aWQ9Xzd5Z1FBT0sxRFVD&ntb=1

https://www.bing.com/videos/search?q=cell+cycle&&view=detail&mid=029D68758879282783BB029D68758879282783BB&&FORM=VRDGAR

https://www.bing.com/videos/search?q=cell+cycle&&view=detail&mid=20804A371ACA306DAC2F20804A371ACA306DAC2F&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3Dcell%2Bcycle%26go%3DSearch%26qs%3Dds%26form%3DQBVR

1.6: Possible Answers to Self-Assessment Exercises

- Interphase is the most important stage of cell cycle. The cell stays in the interphase for maximum periods. During this phase the cell prepares itself for division. The cell undergoes cell growth and replication during this phase.

- During the G1 phase the cell continues to grow but does not replicate. During the S phase the DNA of the cell replicates. During the G2 phase the RNA, proteins and other macromolecules required for mitotic division are produced by the cell.

Unit 2: Cell Amitosis

Unit Structure

2.1: Introduction

German botanist Hugo von Mohl in the year 1835, first observed cell division under the microscope. He worked over the green alga *Cladophora glomerata*. Neurons or nerve cells conduct nerve impulses. They are highly specialized and amitotic. So, if a neuron is destroyed, it cannot be replaced. Because neurons do not go through mitosis. The name 'Amitosis' was given by Remake and the explanation of amitosis was given by Walther Fleming in 1880 and others. Amitosis is also called Karyostenosis, which is a type of direct cell division. It is the most primitive type of cell division. He described the process as a 'simple' form of cell division and suggested that it involved the direct splitting of a cell into two daughter cells. At the time, it was thought that all cells were divided by mitosis, and Boveri's observations were met with disbelief.

2.2: Intended Learning Outcomes

By the end of this unit, students should be able to;

- describe the features/characteristics of amitosis.
- Explain the process of amitosis.
- State examples, advantages and disadvantages of amitosis.

2.3: Main Body

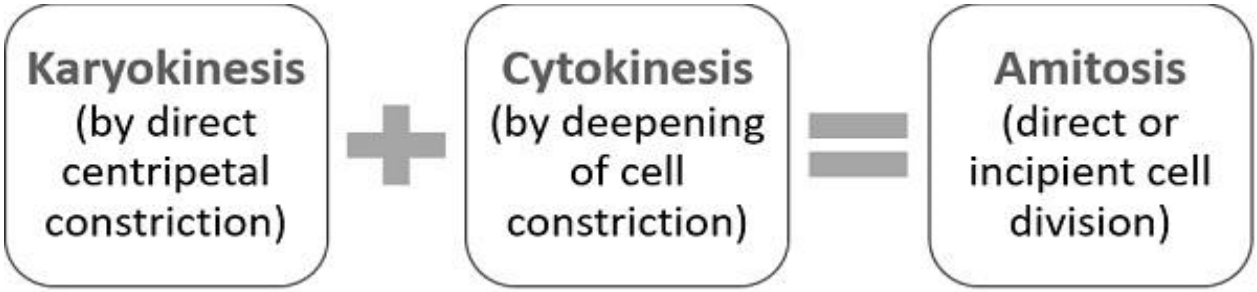
Amitosis cell division is a form of direct cell multiplication where the nuclear and cytoplasmic contents of parent cell split between the two daughter cells via a simple cell constriction. It is a kind of growth and

multiplication process that predominantly occurs in the acellular or unicellular organisms such as algae, bacteria, cyanobacteria, protozoans and yeasts.

The cytokinesis (cytoplasmic division) begins after the karyokinesis (nuclear division) due to deepening in the cell furrow during amitosis. Thus, amitosis is a kind of asexual growth and multiplication that does not involve events like chromatin condensation, chromatid separation, spindle formation etc. Remark and Kolliker were the two scientists who described the karyokinesis and cytokinesis.

Schleicher proposed a term karyokinesis and Whitman introduced term cytokinesis. A scientist named Robert Remak was the first to describe amitosis, and W. Flemming coined the term. We will discuss the meaning, examples, characteristic features, mechanism, significance, and drawback of the amitosis cell division in this context.

Amitosis is a type of direct cell division where a simple cell constriction partitions the nucleus and cytoplasmic content that eventually causes the splitting of a parent cell into two nascent cells. Firstly, a nucleus division occurs followed by cytoplasmic division during amitosis, like other cell divisions (mitosis and meiosis). The process of amitosis is characterized by the formation of cleavage furrow or cell constriction. In microbes, amitosis usually occurs horizontally or vertically.



Amitosis involves DNA replication and splitting of the cell. It is a primitive type of cell division where a simple mass division of a pre-existing cell occurs. A parent cell does not go through the stages like prophase, metaphase, anaphase and telophase, unlike mitosis. In amitosis, a nucleus form through segmentation or septum formation.

Examples

Amitosis cell division is carried out by many organisms and eukaryotic cells that are mentioned below:

- It predominantly exists in the unicellular organisms like algae, protozoans and bacteria.
- Amitosis is also carried out by the acellular group of fungi, i.e. yeast cells.
- It also occurs in the eukaryotic cells like cartilage cells, foetal cells and extra-embryonic cells.
- In plants, amitosis can be seen in the endosperm cells of the seed.
- Besides, diseased, degenerating and old cells also show the amitotic type of cell division.

Characteristics

- The spindle fibres formation cannot be observed in the amitosis cell division.
- There is no chromatin condensation.
- The chromosomes do not appear as chromatids or remain despiralized.
- Centromeres are not distinctly seen.
- Chromatin fibre does not replicate.
- The nuclear membrane and nucleolus appear or remain intact during the cell division, unlike the mitotic and meiotic cell division.
- A parent cell forms two daughter cells directly through the deepening of cell furrow.
- It facilitates a random or unequal distribution of the parental chromosomes.

Mechanism of Cell Division

Amitosis is a cellular division that occurs without any nuclear events or involves a simple mass division of a pre-existing cell via centripetal cell constriction. The events or stages of amitosis can be summarized in Fig 8.

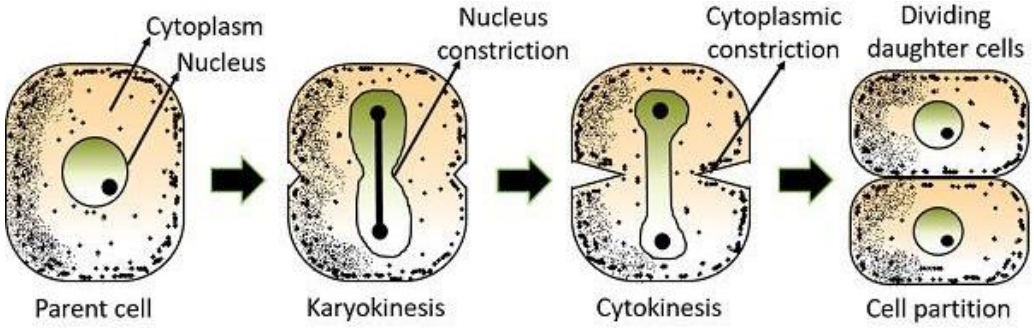


Fig 8: Stages in Amitosis Cell division

- Elongation of Parent Cell Nucleus: The nucleus of the parent cell elongates.
- Elongated nuclei form dumbbell like appearance due to the accumulation of nuclear material at both ends.
- Replication of DNA: DNA forms its copy by replication inside the nucleus. As a result, DNA doubles itself.
- Karyokinesis: The nucleus separates into two nuclei with unequal DNA content.
- Cytokinesis: After the separation of the nucleus, the cytoplasm starts to constrict centripetally, forming a furrow like structure. The gradual inward cytoplasmic constriction leads to the division of the cell.

Functions

- Amitosis can perform reproductive, developmental or physiological functions.
- Amitosis as Reproductive function: Reproduction in some organisms like algae, bacteria, cyanobacteria, protozoans, and yeasts occur through amitosis.
- Amitosis as Developmental function: In mammals like humans, adrenal cells and the placental tissue of rats are observed to divide by amitosis.
- Amitosis as Physiological function: It occurs in the hepato-pancreas of the crustacean Porcellio. Once the organ reaches maturity, the number of cells in it is never increased. All cells become binucleate when the nucleus undergoes amitotic division

Significance

- Amitosis is a cellular division required for acellular or unicellular organisms to continue their existence.
- Random distribution of genetic material leads to variation, which is an important tool for evolution.
- Amitosis is necessary for the production of new cells and bodies as well as the removal of old and damaged cells.
- It is necessary for the evolution of new species and cell renewal.

Advantages

- It is a faster process, as it does not require the formation of a mitotic spindle. It also does not require a high level of energy, making it a more efficient form of cell division.

- In addition, amitosis is a less precise form of cell division than mitosis. This means that the daughter cells are not identical to the parent cell, as they may contain different combinations of genetic material. This can be beneficial in certain circumstances, as it can lead to the development of new traits in the daughter cells.
- In organisms such as bacteria, amitosis can also be used to rapidly increase cell numbers. This can be beneficial in a variety of circumstances, such as when the organisms need to quickly adapt to a changing environment.

Disadvantages

- Amitosis is a less precise form of cell division than mitosis. This means that the daughter cells are not identical to the parent cell, as they may contain different combinations of genetic material. This can be detrimental in some circumstances, as it can lead to the development of deleterious traits in the daughter cells.
- In addition, amitosis is a random process, meaning that the daughter cells are not necessarily the same size as the parent cell. This can be problematic, as it can lead to the formation of cells with an abnormal size or shape.

Difference Between Amitosis and Mitosis

Amitosis	Mitosis
Absence of nuclear events like chromatin condensation.	Presence of nuclear events.
Random distribution of genetic material.	Equal distribution of genetic material.
Absence of spindle formation.	Presence of spindle formation.
Example: It occurs in unicellulars like bacteria, protozoa etc., and placental tissue of rats, adrenal tissue of humans, etc.	Example: It occurs in some bacteria, protozoa, skin cells of humans etc.

What is an amitosis example?

Self-Assessment Exercises

- What is the main difference between mitosis and amitosis?
- Is there DNA replication in amitosis?
- What is the importance of amitosis?
- Is amitosis *faster than mitosis?*

2.4: Summary

Amitosis is a kind of direct cell division in which the parent cell's nuclear and cytoplasmic contents are divided between two daughter cells by a simple cell constriction. It is a type of asexual reproduction among unicellular organisms like algae, bacteria, cyanobacteria, protozoans, and yeasts. It also has developmental and physiological functions. Amitosis can be characterized by features like the absence of formation of spindle fibres during cell division, absence of chromatin condensation etc. The mechanism is simpler than mitosis and involves simpler steps: elongation of the nucleus, replication, karyokinesis, followed by cytokinesis. It is a cellular division required for acellular or unicellular organisms to continue their existence.

Amitosis has certain disadvantages, such as unequal distribution of genetic material, which could result in irregular growth and metabolism. It occurs in acellular or unicellular microorganisms like bacteria, yeast etc., primarily, but it also occurs in some plant or animal cells.

2.5: References/Further Readings/Web Sources

Müller, W. (1936). Amitosis in Animal Cells. *British Journal of Experimental Biology,* 14, 369–378.

Bamforth, S., & Saffery, R. (2005). Amitosis: An alternative form of cell division. *Cell Division,* 1(1), 1-3.

Goncharov, A., & Gudkov, A. (2005). Amitosis: A mechanism of cell division in bacteria and other organisms. *Cell Cycle*, 4(9), 1234-1242.

https://www.bing.com/ck/a?!&&p=1f2de4415699e1bfJmltdHM9MTY3NTM4MjQwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTE3Mw&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=Cell+amitosis+textbook&u=a1aHR0cHM6Ly9vcGVuc3RheC5vcmcvYm9va3MvYmlvbG9neS0yZS9wYWdlcy8xMC0yLXRoZS1jZWxsLWN5Y2xl&ntb=1

https://www.youtube.com/watch?v=ELtpdGi3g88

https://www.youtube.com/watch?v=Gq2SQMkg4w4

2.6: Possible Answers to Self-Assessment Exercises

- The main difference between mitosis and amitosis is that mitosis involves equal division of cells and it performs reproductive and developmental functions, whereas amitosis involves unequal division of cells and it performs the physiological, reproductive and developmental functions.
- Yes! DNA replication in amitosis is not similar to mitosis.
- Amitosis allows random distribution of genetic material, which leads to variation.
- Yes! Based on studies, it has been observed that amitosis is faster than mitosis.

Unit 3: Cell Mitosis

Unit Structure

3.1: Introduction

Cell division is the driving process of reproduction at the cellular level. Most eukaryotic cells divide in a manner where the ploidy or the number of chromosomes remains the same, except in the case of germ cells where the number of chromosomes is halved. Mitosis is a process of **cell duplication**, in which one cell divides into two genetically identical daughter cells. In the various stages of mitosis, the cell's chromosomes are copied and then distributed equally between the two new nuclei of the daughter cells.

Mitosis is the step in the cell cycle that the newly duplicated DNA is separated, and two new cells are formed. This process is important in single-celled eukaryotes, as it is the process of asexual reproduction. In multi-celled eukaryotes, mitosis is how a single zygote can become an entire organism. Mitosis has several distinct stages, or phases, that will be discussed below. The other stages in the cell cycle include growth and the replication of DNA, both required for mitosis to take place.

***Thus, it* is that step in the cell cycle where the newly formed DNA is separated and two new cells are formed with the same number and kind of chromosomes as the parent nucleus."** Mitosis is a process of asexual reproduction observed in unicellular organisms. Mitosis is essential for the growth of the cells and the replacement of worn-out cells. Abnormalities during mitosis may alter the DNA, resulting in genetic disorders.

3.2: Intended Learning Outcomes

By the end of this unit, students should be able to;

- Describe the different mitotic division stages.

- Explain the features of mitotic division
- Enumerate the importance of mitotic division
- Explain the significance of mitotic division

3.3: Main Body

Features of Mitosis

- In each cycle of cell division, two daughter cells are formed from the parent cell.
- The cell is also known as equational cell division because the chromosome number in the parent cell and daughter cell is the same.
- In plants, mitosis leads to the growth of vegetative parts of the plant like root tip, stem tip, etc.
- Segregation and combination do not occur in this process.
- The processes occurring during mitosis have been divided into different stages.

Stages of Mitosis

Right before prophase, the cell spends most of its life in the interphase, where preparations are made before the beginning of mitosis (the DNA is copied). However, since the actual process involves the division of the nucleus, the prophase is technically the first stage of this process. The different stages of mitosis (Fig 9) occurring during cell division are given as follows-

- Interphase: before entering mitosis, a cell spends a period of its growth under interphase. It undergoes the following phases when in interphase:
- **G1 Phase:** This is the period before the synthesis of DNA.
- **S Phase:** This is the phase during which DNA synthesis takes place.
- **G2 Phase:** This is the phase between the end of DNA synthesis and the beginning of the prophase.
- Prophase: this immediately follows the S and G2 phases of the cycle and is marked by condensation of the genetic material to form compact mitotic chromosomes composed of two chromatids attached at the centromere. The completion of the prophase is characterized by the initiation of the assembly of the mitotic spindle, the microtubules and the proteinaceous components of the

cytoplasm that help in the process. The nuclear envelope starts disintegrating.

- Prometaphase: In this stage the nuclear envelop disintegrates. Now the microtubules are allowed to extend from the centromere to the chromosome. The microtubules attach to the kinetochores which allow the cell to move the chromosome around.
- Metaphase: At this stage, the microtubules start pulling the chromosomes with equal force and the chromosome ends up in the middle of the cell. This region is known as the metaphase plate. Thus, each cell gets an entire functioning genome.
- Anaphase: The splitting of the sister chromatids marks the onset of anaphase. These sister chromatids become the chromosome of the daughter nuclei. The chromosomes are then pulled towards the pole by the fibres attached to the kinetochores of each chromosome. The centromere of each chromosome leads at the edge while the arms trail behind it.
- Telophase: The chromosomes that cluster at the two poles start coalescing into an undifferentiated mass, as the nuclear envelope starts forming around it. The nucleolus, Golgi bodies and ER complex, which had disappeared after prophase start to reappear. Telophase is followed by cytokinesis, which denotes the division of the cytoplasm to form two daughter cells. Thus, it marks the completion of cell division.

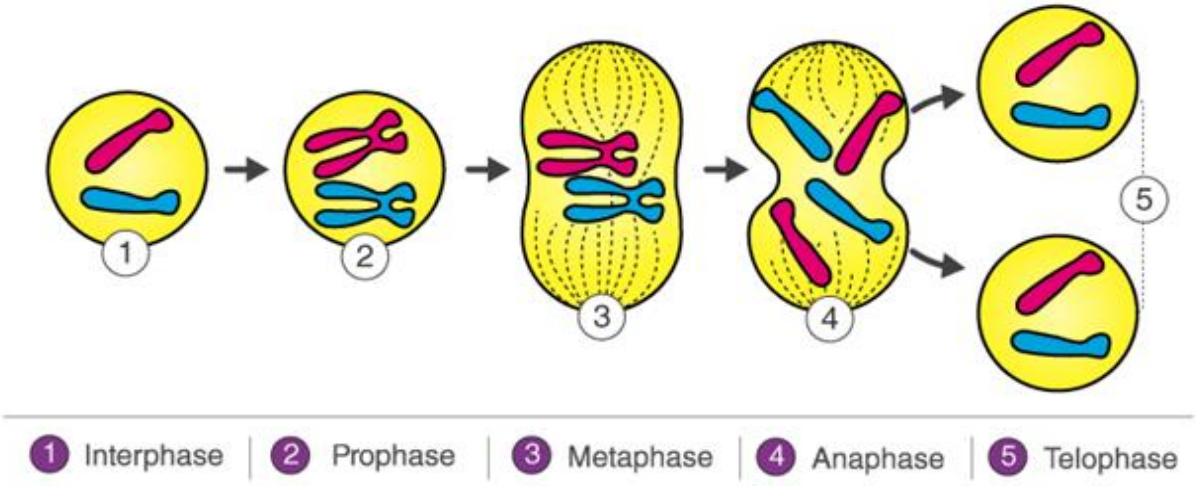


Fig 9: Mitosis Diagram showing the different stages of mitosis

Functions of Mitosis

- Mitosis helps in the development of an organism. In single-celled organisms, mitosis is the process of asexual reproduction.
- Mitosis helps in the replacement of damaged tissues. The cells near the damaged cells begin mitosis when they do not sense the

neighbouring cells. The dividing cells reach each other and cover the damaged cells.

Significance of Mitosis

- Mitosis is responsible for the development of the zygote into an adult.
- Equal distribution of chromosomes to each daughter cell.
- It is responsible for the growth and development of an individual.
- It maintains the constant number of chromosomes in all body cells of an organism.
- Mitosis is required for asexual reproduction, vegetative propagation in plants and is also responsible for the repair and regeneration of damaged tissues.
- Mitosis helps in maintaining the purity of the genome as no recombination or crossing over takes place.
- It is responsible for the repair and regeneration of old and damaged cells in animals e.g. gut epithelium, blood cells, etc.

List all the stages of mitosis.

Self-Assessment Exercises

- Define mitosis.
- Why is mitosis called equational division?
- What is prophase?
- What happens in metaphase?
- In what cells does mitosis occur?
- What is the primary function of mitosis?

3.4: Summary

Mitosis occurs exclusively in eukaryotic cells, but occurs in different ways in different species. The stages of mitosis proper are prophase, prometaphase, metaphase, anaphase and telophase. Mitosis occurs both in reproductive and vegetative cells. Mitosis is very important in several aspect of the cell and itsconstituents

3.5: References/Further Readings/Web Sources

Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K. & Walter, P. (2002). *"Chapter 17"*. *Molecular Biology of the Cell* (4th ed.). New York: Garland Science.

Krieger, M., Scott, M.P.; Matsudaira, P.T., Lodish, H.F., Darnell, J.E., Zipursky, L., Kaiser, C & Berk, A. (2004). *Molecular Cell Biology*. New York: W.H. Freeman and CO.

Morgan, D. L. (2007). *The Cell Cycle: Principles of Control*. London: Published by New Science Press in Association with Oxford University Press.

https://www.bing.com/ck/a?!&&p=5c182b5e7c829278JmltdHM9MTY3NTU1NTIwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTI2NA&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=mitosis&u=a1aHR0cHM6Ly93d3cucmVzZWFyY2hnYXRlLm5ldC9wdWJsaWNhdGlvbi8zMTQ4Mzg0NTdfV2hhdF9hcmVfdGhlX1N0YWdlc19vZl9NaXRvc2lz&ntb=1

https://www.bing.com/videos/search?q=mitosis&&view=detail&mid=976EB72F9EA63C74CA8D976EB72F9EA63C74CA8D&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3Dmitosis%26FORM%3DHDRSC4

3.6: Possible Answers to Self-Assessment Exercises

- Mitosis is the type of cell division by which a single cell divides in such a way as to produce two genetically identical “daughter cells”.
- Mitosis is the process of cell division wherein the chromosomes replicate and get equally distributed into two daughter cells. The chromosome number in each daughter cell is equal to that in the parent cell, i.e., diploid. Hence, mitosis is known as equational division.
- The process of mitosis begins with the prophase. In this stage, the chromatin condenses and the nucleolus disappears.
- Metaphase is the second stage of the process, chromosomes get condensed at the equator, before being split apart for each of the two daughter cells.
- Mitosis occurs in eukaryotic cells. Eukaryotic cells divide by both mitosis and meiosis. For e.g., skin cells divide by mitosis, whereas gametes divide by meiosis.
- Mitosis plays an important role in the life cycle of most living things. It helps in cell regeneration, asexual reproduction and growth.

Unit 4: Cell Meiosis

Unit Structure

4.1: Introduction

As a general rule, all cells come from pre-existing cell and the primary mode to how this happens is through the process of cell division. In this process, the parent cell divides into daughter cells while at the same time passing its genetic material across generations. In eukaryotic organisms, two kinds of cell division exist: mitosis and meiosis. On one hand, mitosis is concerned in the production of daughter cells that are mere copies of each other. On the other hand, meiosis involved the production of the reproductive cells that bear unique genetic characteristics. At the level of the genes, sexual reproduction is focused on the fusion of the paternal and maternal genes that result in a new combination of genes. And this is where the process of meiosis becomes important.

Meiosis is the process of cell division that results in the production of a haploid "*daughter*" cell with a *haploid* chromosomal number of a diploid "*parent*" ("original") cell. The resulting haploid cell after meiosis would have only one part of the various homologous chromosome pairs of the parent cell.

4.2: Intended Learning Outcomes

By the end of this unit, students should be able to;

- Describe the different stages of meiosis
- Enumerate the significance and importance of meiosis.

4.3: Main Body

Stages of Meiosis

The process of meiosis (Fig 10) is divided into 2 parts:

Meiosis I

Just like in mitosis, a cell must first undergo through the interphase before proceeding to meiosis proper. It increases in size during G1 phase, replicates all the chromosomes during S phase, and makes all the preparations during the G2 phase. Like the usual mitosis, the first meiotic division is divided into four different stages: prophase I, metaphase I, anaphase I, and telophase I.

This is the most complicated part of the meiotic division.

- Prophase I, in particular, occupies almost more than half the time taken for meiosis as it contains 5 substages: **leptotene, zygotene, pachytene, diplotene and diakinesis.** The behavior and organization of the chromosomes differ in each stage, which gives clues about the complexity of prophase I.
- **Leptotene:** Leptotene is the first stage of prophase during meiosis I. This phase is characterized by the condensation of the chromosomes wherein they become visible as chromatin. It comes from the two Greek words "*lepto*" and "*tene*" which mean "*thin*" and "*ribbon*" respectively.
- **Zygotene**: Coming from the Greek words "*zygo*" and "*tene*" which mean "*union*" and "*thread*", zygotene is the second phase of prophase I. During this stage, homologous chromosomes begin to form an association called a synapse which results to pairs of chromosomes that has four chromatids.
- **Pachytene**: This is the phase where the crossing over between pairs of homologous chromosomes occurs. The structure formed is referred to as the chiasmata. In contrast with leptotene ("*thin thread*"), the Greek word "*pachy*" means "*thick*"; thure referring to the characteristic of the chromosome in this stage.
- **Diplotene**: In this phase, the separation of the homologous chromosomes is starting but they remain attached through the chiasmata. The word "*diplo*" in diplotene means "*double*".
- **Diakinesis**: Following diplotene is the final phase called diakinesis, which comes from the Greek words "*dia*" which means "*across*" and "*kinesis*" which means "*motion*". This is when the homologous chromosomes continue to separate as the chiasmata move to the opposite ends of the chromosomes.
- Metaphase I: In this stage, the homologous pairs of chromosomes randomly align at the metaphase plate. Such configuration becomes the source of genetic material as the chromosomes from

the male and female parents appear similar but are not exactly identical.

- Anaphase I: The homologous chromosomes become separated as they are pulled toward the opposite ends of the cell. However, the sister chromatids remain attached to their pair and do not move apart.
- Telophase I: Like in the telophase of mitosis, the chromosomes finally are separated at the different sides of the cell. In addition, the chromosomes return to their uncondensed forms as the nuclear membrane is reformed. The division of the cytoplasm (referred to as cytokinesis) occurs simultaneously with telophase I, resulting to two haploid daughter cells.

- Meiosis I can be distinguished from mitosis by three main features:
- Meiosis I have reciprocal recombination (may also be called chiasma formation and crossing over)
- Meiosis I have the pairing of the homologous chromosome
- The release of the cohesion sister chromatids in a two-step process occurs in Meiosis
- These features allow the homologous segregation on the mitotic spindle. Then, the two sister chromatids separate during meiosis II.
- Moreover, it should be noted that these events are interdependent. This means that the different events during the pairing of chromosomes, such as the recombination of reciprocal, the crossing-over, and the formation of chiasma are connected; therefore, the only successful process of recombination at meiosis I prophase will be the one that produces the correct homologous chromosome segregation at meiosis I.
- The two succeeding chromosomal divisions result in the halving of the original number of chromosomes. After the completion of S phase and the production of identical chromatids from the replication of the parent chromosome, meiosis I commence. The chromosomes start to pair with each other and eventually segregate into two cells. The chromatids, though, remain together so each of the newly formed daughter cells will contain one of the homologous chromosomes with two chromatids by the end of meiosis I.

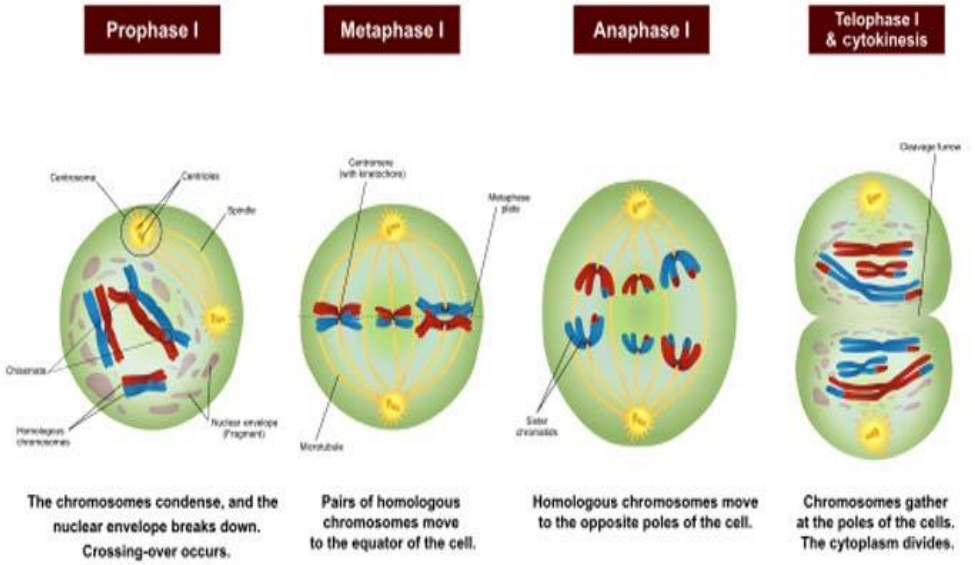


Fig 10: Description of Meiosis I

Meiosis II

The two chromatids will then separate and segregate to two daughter cells. Therefore, at the end of meiosis II, four daughter haploid cells are produced, each containing one copy of each chromosome.

After the replication of DNA, the pairing of the homologous chromosomes does not only allow for the segregation of meiotic chromosomes but also contributes to the recombination of maternal and paternal chromosomes. This pairing of chromosomes occurs during the prophase of meiosis I.

Cells undergo through meiosis I to meiosis II without the replication of the genetic material. It is important to note that the cells that undergo meiosis II are the daughter cells produced during meiosis I. Meiosis II is shorter than meiosis I but still is divided into four stages: prophase II, metaphase II, anaphase II, and telophase II (Fig 11).

- Prophase II: Prophase II is almost similar to mitotic prophase. In prophase II, the nuclear envelope disintegrates as the chromosomes condense. Aside from that, the centrosomes separate with each other while the spindle fibers try to catch the chromosomes.
- Metaphase II: Just like in meiosis I, meiosis II is when the chromosomes align at the metaphase plate because of the attachment of the spindle fibers to the centromeres of chromosomes. The segregation of different types of chromosome

is what creates the difference between the two metaphases of meiosis.

- Anaphase II: Unlike anaphase I, which involves the separation of homologous chromosomes, anaphase II is the separation of sister chromatids. In this stage, chromosomes (each with a chromatid) are separated from each other as they move toward the opposite poles of the cell.
- Telophase II: Just like the usual telophase, the cell cytoplasm divides equally and shortly after is reformed. The result of telophase II is the formation of four haploid cells (having each set of chromosomes). However, it is important to note that the four daughter cells are not identical with each other due to the events in meiosis I (i.e. random crossing over and random alignment of chromosomes.
-

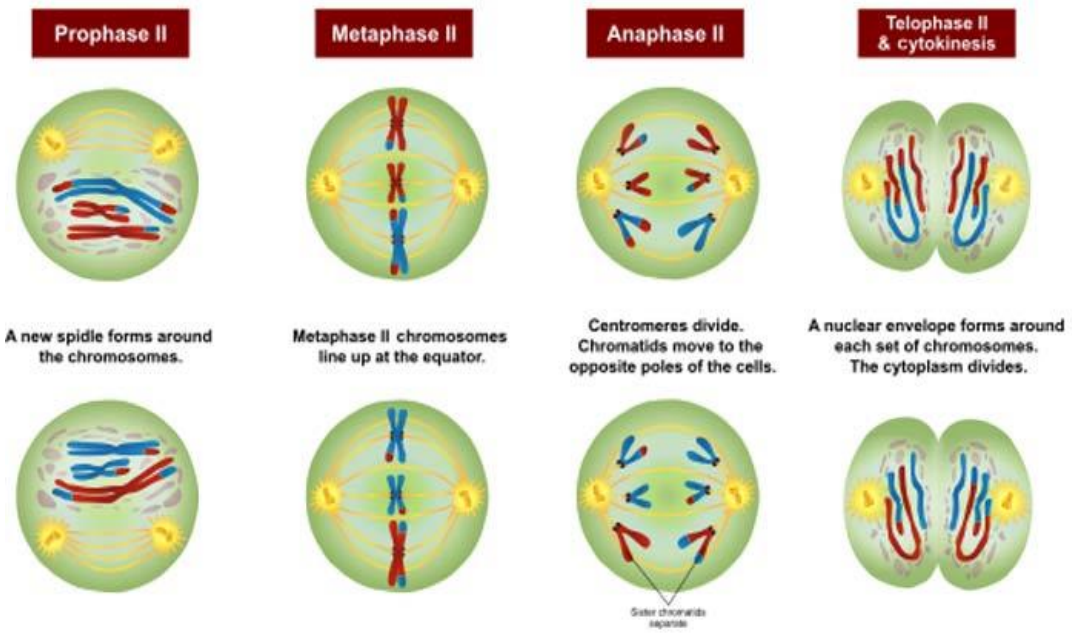


Fig 11: Description of Meiosis II

Features of Meiosis

- It results in the formation of four daughter cells in each cycle of cell division.
- The daughter cells are identical to the mother cell in shape and size but different in chromosome number.
- The daughter cells are haploid.
- Recombination and segregation take place in meiosis.
- The process occurs in the reproductive organs and results in the formation of gametes.

- The process is divided into two types-meiosis I reduces the chromosome number to half and is known as reductional division. Meiosis-II is just like the mitotic division.

Significance

- Meiosis is responsible for the formation of sex cells or gametes that are responsible for sexual reproduction.
- It activates the genetic information for the development of sex cells and deactivates the sporophytic information.
- It maintains the constant number of chromosomes by halving the same. This is important because the chromosome number doubles after fertilization.
- In this process independent assortment of maternal and paternal chromosomes takes place. Thus, the chromosomes and the traits controlled by them are reshuffled.
- The genetic mutation occurs due to irregularities in cell division by meiosis. The mutations that are beneficial are carried on by natural selection.
- Crossing over produces a new combination of traits and variations.

Functions

Production of gametes (egg cells or sperm cells) or spore. In the human body, the meiosis process takes place to decrease the number of chromosomes in a normal cell which is 46 chromosomes to 23 chromosomes in eggs and sperms. So, the number of chromosomes in meiosis decreases to half. Consequently, during fertilization when the two haploid cells fuse, the number of chromosomes in the produced cell is restored as somatic cells (each with 46 chromosomes).

Meiosis vs. Mitosis

Meiosis and mitosis are the two main forms of cell division. The differences between them are summarized in Table 1.

Table 1: Main differences between meiosis and mitosis

Meiosis	Mitosis
Produces haploid cells (n)	Produces diploid cells (2n)
Includes two nuclear divisions	Includes one nuclear division

The product is a gamete cell	The product is a somatic cell
Responsible for sexual reproduction	Responsible for asexual reproduction
Crossing over takes place	No crossing over
Four cells are produced	Two cells are produced

A cell is going through meiosis. The sister chromatids are lined up on the metaphase plate.

What phase of meiosis is this?

A. MetaphaseI
B. ProphaseII
C. Metaphase II

An adult organism has 60 chromosomes or 30 homologous chromosomes. 30 are maternally derived, 30 are paternally derived. How many chromosomes are in each cell after mitosis?

A. 60 chromosomes, 30 homologs.
B. 120 chromosomes, 60 homologs.
C. 30 chromosomes, no homologs.

Self-Assessment Exercises

- An adult organism has 60 chromosomes or 30 homologous pairs of chromosomes. 30 are maternally derived, 30 are paternally derived. How many chromosomes are in each cell after meiosis?
  A. 30 chromosomes, no homologous chromosomes.
  B. 60 chromosomes, 30 homologous chromosomes.
  C. 120 chromosomes, 60 homologous chromosomes.

- What do you understand by meiosis?

4.4: Summary

This unit discussed the different stages of meiosis (Meiosis I and Meiosis II). The importance, significance, features and functions.

4.5: References/Further Readings/Web Sources

Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K. & Walter, P. (2002). *"Chapter 17"*. *Molecular Biology of the Cell* (4th ed.). New York: Garland Science.

Krieger, M., Scott, M.P.; Matsudaira, P.T., Lodish, H.F., Darnell, J.E., Zipursky, L., Kaiser, C & Berk, A. (2004). *Molecular Cell Biology*. New York: W.H. Freeman and CO.

Morgan, D. L. (2007). *The Cell Cycle: Principles of Control*. London: Published by New Science Press in Association with Oxford University Press.

https://www.bing.com/ck/a?!&&p=5645b91a3fc32be8JmltdHM9MTY3NTU1NTIwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTM4MQ&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=Meiosis&u=a1aHR0cHM6Ly93d3cubmNiaS5ubG0ubmloLmdvdi9ib29rcy9OQksyNjg0MC8&ntb=1

https://www.bing.com/ck/a?!&&p=5165ebf2e64acae3JmltdHM9MTY3NTU1NTIwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTI0MA&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=Meiosis&u=a1aHR0cHM6Ly9vcGVub3JlZ29uLnByZXNzYm9va3MucHViL21oY2NtYWpvcnNiaW8vY2hhcHRlci9tZWlvc2lzLWkv&ntb=1

https://www.bing.com/videos/search?q=Meiosis&&view=detail&mid=56345FC95339EF90499456345FC95339EF904994&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3DMeiosis%26FORM%3DHDRSC4

https://www.bing.com/videos/search?q=Meiosis&&view=detail&mid=CD5EBFFB004251F6051BCD5EBFFB004251F6051B&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3DMeiosis%26FORM%3DHDRSC4

4.6: Possible Answers to Self-Assessment Exercises

- **A** is correct. Meiosis reduces the ploidy of each cell. Effectively, this means that only one copy of each chromosome, either the maternal or paternal copy, will be retained in each cell. The homologous copies of each chromosome are sorted on the metaphase plate in metaphase I. Each copy consists of two sister chromatids, which are separated after metaphase II. In this way, the final gamete will have 30 chromosomes, none of which will have a copy. Thus, when two gametes meet, they can create a zygote with 30 homologous pairs of chromosomes, or 60 total.

- Meiosis is the process in which a single cell divides twice to produce four cells with half the original amount of chromosomes.

Unit 5: Cell Differentiation

Unit Structure

5.1: Introduction

Cell differentiation refers to the process in which cells of the same source gradually produce cell groups with different morphological structures and functional characteristics. As a result, cells are spatially different, and the same cells differ in time from their previous state. The essence of cell differentiation is the selective expression of the genome in time and space. The expression of different genes is turned on or off, and finally, the iconic protein is produced. In general, the process of cell differentiation is irreversible. However, under certain conditions, the differentiated cells are also unstable, and their gene expression patterns can also undergo reversible changes and return to their undifferentiated state. This process is called dedifferentiation. Features of cell differentiation include: The potential of differentiation gradually appears with the development of the individual.

During embryonic development, the cells gradually change from "all-around" to "multi-energy", and finally to the "single-energy", which is the general rule of cell differentiation. In the process of individual development, multicellular biological cells have both temporal differentiation and spatial differentiation; cell differentiation is compatible with the state and speed of cell division, and differentiation must be based on division, that is, differentiation is inevitable with division, but the dividing cells do not necessarily need differentiate. The higher the degree of differentiation, the worse the ability to divide; the cell differentiation is highly stable. Under normal physiological conditions, cells that have differentiated into a specific, stable type are generally impossible to reverse to undifferentiated state or become other types. Cell differentiation is plastic, and the differentiated cells re-enter the undifferentiated state or transdifferentiate into another type of cell under special conditions.

5.2: Intended Learning Outcomes

By the end of this unit, students should be able to;

- describe the relevance of cell differentiation
- explain the process and significance of cell differentiation.

5.3: Main Body

Cellular differentiation, or simply cell differentiation, is the process through which a cell undergoes changes in gene expression to become a more specific type of cell. The process of cell differentiation allows multi-cellular organisms to create uniquely functional cell types and body plans. The process of cell differentiation is driven by genetics, and their interaction with the environment. Cell Differentiation ***is a biological process wherein cells gain specialized roles and switch from one cell type to another in an entity.*** In human development, a fertilized egg undergoes differentiation into other types of specialized cells present in the body such as muscle, neurons, etc.

Undifferentiated cells are known as stem cells (Fig 12). These stem cells are located in the embryos and in adults.

All organisms begin from a single cell. This single cell carries the DNA coding for all the proteins the adult organism will use. However, if this cell expressed all of these proteins at once it would not be functional. This cell must divide repeatedly, and the cells must begin the process of cell differentiation as they divide. The *cell lines* begin to emerge, and the cells get more and more specific. Eventually, an entire organism is formed with hundreds of different cell types from this process of cell differentiation.

The original mass of cells, which have not undergone differentiation, are known as *stem cells*.

Unlike normal cell division, which creates two identical daughter cells, the division of stem cells is *asymmetric cell division*. In this case, one of the cells remains identical to the parent stem cell. In the other cell, chemical triggers activate the process of cell differentiation, and the cell will start to express the DNA of a specific cell type. Stem cells which can differentiate into entire organisms are known as *embryonic stem cells* and are said to be *totipotent*.

By contrast, the body also has many cells which are only *pluripotent*. These cells have already undergone some cell differentiation. These stem cells can only divide into a narrow range of cell types. Bone marrow, for instance, contains *somatic stem cells* which can only become red blood cells. These cells are necessary for the constant replenishment of blood cells, which are mostly inactive besides their oxygen-carrying ability.

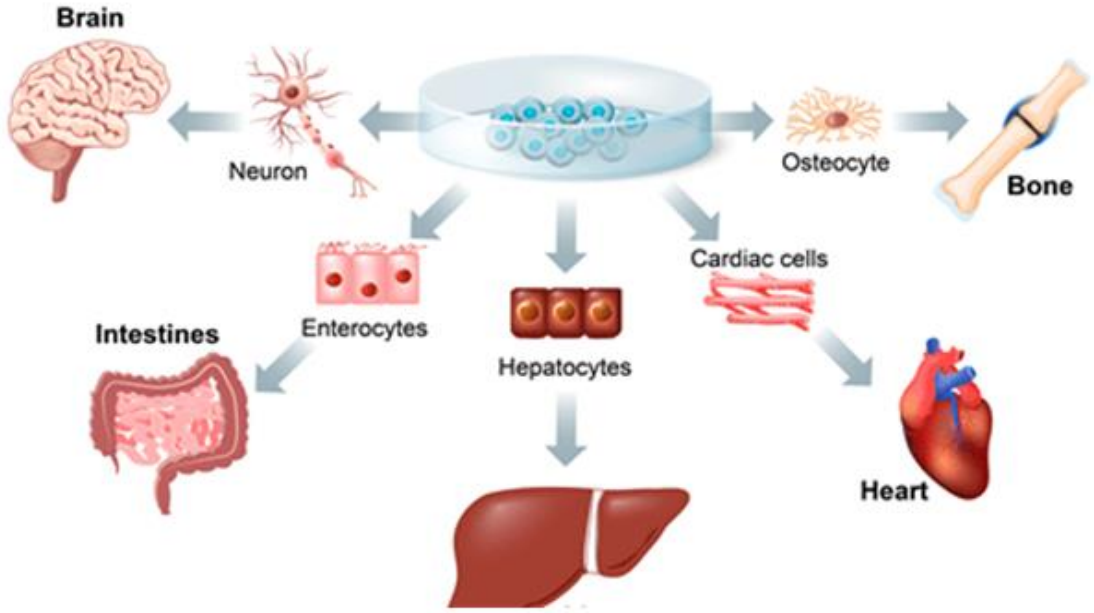


Fig 12. Cell differentiation: various cells arise from stem cells.

Function of cell differentiation

- The rapid development of stem cell biology has provided us with a strong support for further understanding of the precise molecular regulation mechanisms in the development of organisms, as well as new treatments for cancer, cardiovascular and cerebrovascular diseases, neurodegenerative diseases, diabetes, and other diseases.
- It brought hopes to neurological diseases. Therefore, before the therapeutic potential of stem cells is widely applied to the clinic, it is necessary to have a deeper understanding of the characteristics and regulatory mechanisms of stem cell proliferation and differentiation that determine the stem cell fate, to survive and proliferate through the endogenous cells.
- Differentiation and migration activate the organism's own regeneration mechanism to achieve the purpose of curing the disease. Although small molecules have been screened for new drug development and cell biology research on a cell basis for decades, the importance of these small molecules in stem cell research has just been recognized.

- The means of chemical genetics are controllable and reversible – small molecule compounds can be added or removed at any time to initiate or interrupt specific reactions.

Steps of Cell Differentiation

A cell capable of differentiating into any type of cell is known as "totipotent". For mammals, totipotent includes the zygote and products of the first few cell divisions. There are also certain types of cells that can differentiate into many types of cells. These cells are known as "pluripotent" or stem cells in animals (meristemic cells in higher plants). While this type of cell can divide to produce new differentiated generations, they retain the ability to divide and maintain the stem cell population making them some of the most important cells. Examples of stem and progenitor cells include:

- Hematopoietic stem cells: - These are from the bone marrow and are involved in the production of red and white blood cells as well as the platelets.
- Mesenchymal Stem Cells - Also from the bone marrow, these cells are involved in the production of fat cells, stromal cells as well as a given type of bone cell.
- Epithelial stem cells - These are progenitor cells and are involved in the production of certain skin cells.
- Muscle satellite cells - These are progenitor cells that contribute to differentiated muscle tissue.

The process of cell differentiation starts with the fertilization of the female egg. As soon as the egg is fertilized, cell multiplication is initiated resulting in the formation of a sphere of cells known as the blastocyst. It's this sphere of cells that attach to the uterine wall and continues to differentiate.
As the blastocyst differentiates, it divides and specializes to form a zygote that attaches to the womb for nutrients. As it continues to multiply and increase in size, the differentiation process results in the formation of different organs.

The Cell Differentiation Process

The process of differentiation occurs when different genes in the genome are expressed or repressed. This process occurs through the signal transduction pathway, a way of transmitting extracellular signals to cause changes in cell function. Signal transduction pathways start with an extracellular signal, such as a molecule released from another cell, contact with another cell, or changes in temperature, pressure or more. These **signaling molecules** activate receptor proteins in the

membrane of the cell. This in turn causes different proteins inside the cell to be activated or repressed. These changes ultimately lead to activation or repression of **transcription factors**.

Transcription factors are proteins that bind to the promoter sequence in DNA and help start gene expression. During gene expression RNA polymerase reads the DNA and creates a copy called mRNA. The mRNA is then used as a template by another organelle, called the ribosomes.

Ribosomes read the genetic code in the mRNA and create proteins. Those proteins will ultimately change the function of the cell and help it differentiate. For example, proteins may be created that change the size or shape of the cell, change its metabolism, permeability or more. Some of these proteins are **tissue-specific proteins**, which are proteins only expressed in a certain tissue type.

They are specialized for a certain function and only appear in certain types of cells. Creating tissue-specific proteins is an important step in cell differentiation.

Cell Differentiation Significance

- Cell differentiation is an important process through which a single cell gradually evolves allowing for development that not only results in various organs and tissues being formed, but also a fully functional animal.
- While it plays a significant role in embryonic development, the process of cell differentiation is also very important when it comes to complex organisms throughout their lives. This is because of the fact that it causes changes in size, shape, metabolic activities as well as signal responsiveness of cells.
- In cell differentiation, gene expression is particular important given that there are vital control systems that only ensure certain differentiation. Here, the process proves beneficial by controlling certain activities to guarantee both normal functioning tissues and organs, but also a full functional animal.
- Knowledge of cell differentiation has also influenced stem cell research. Today, scientists and researchers are working to determine the best way they can use stem cells for the purposes of regenerating and repairing cellular damage.
- As mentioned earlier, stem cells are important in that they can develop to any cell type. This makes them very special in that they can differentiate and be used for given treatment purposes. A good example of this is with cells among the older adults.

- Stem cells can continue differentiating into a number of specialized cells to renew and repair the tissue in question. In theory, it is supposed that there is no limit as to the type of diseases that can be treated using stem cell therapy. Research is still ongoing to ensure that this type of treatment is both safe and effective.

Primary Factors Influencing Cell Differentiation

- Gene structure: This is the most important factor when it comes to cell differentiation. Each of the viable genes contains important information that determine the cell type and physical attributes of the animal (host). Any problem in the genetic material ultimately affects cell differentiation and the development of the host.
- Environmental factors: - Various environmental factors as changes in temperature and supply of oxygen etc can affect the release and production of hormones given that various proteins are involved in the transmission of information as well as triggering of hormones. If these molecules are affected, then cell differentiation and development is also affected.
- At what stage does cell differentiation start?

Self-Assessment Exercises

- What are some examples of cell differentiation?
- What is cell differentiation and how is it controlled?

5.4: Summary

Cell differentiation is the process of stem cells becoming more specialized. Cell differentiation is important because it creates diversity in life on Earth, creates diversity within the cells of our body and allows cells to create unique structures that fit their individualized functions.

5.5: References/Further Readings/Web Sources

Cerdáesteban N & Spagnoli F M. (2014). Glimpse into Hox and tale regulation of cell differentiation and reprogramming. *Developmental Dynamics.* 2014, 243(1):76-87.

Regalo G & Leutz A. (2013). Hacking cell differentiation: transcriptional rerouting in reprogramming, lineage infidelity and metaplasia. *Embo Molecular Medicine.* 2013, 5(8):1154-1164.

Evans C M & Jenner R G. (2013). Transcription factor interplay in T helper cell differentiation. *Briefings in Functional Genomics.* 2013, 12(6):499-511.

Browder, L. W. 1996. Cell determination and differentiation: The muscle paradigm. In L. W. Browder (ed.), Advanced Developmental Biology. The University of Calgary. Retrieved November 15, 2007.

Berika, M., Elgayyar, M. E., & El-Hashash, A. H. K. (2014). Asymmetric cell division of stem cells in the lung and other systems. *Frontiers in Cell and Developmental Biology*, *2*. https://doi.org/10.3389/fcell.2014.00033

Kelly, A., Grabiec, A. M., & Travis, M. A. (2018). Culture of Human Monocyte-Derived Macrophages. Methods in Molecular Biology (Clifton, N.J.), 1784, 1–11. https://doi.org/10.1007/978-1-4939-7837-3_1

https://www.bing.com/ck/a?!&&p=bf5b0ad680680dc4JmltdHM9MTY3NTU1NTIwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTEzNA&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=Cell+Differentiation&u=a1aHR0cDovL3ByZXNzYm9va3MtZGV2Lm9lci5oYXdhaWkuZWR1L2FuYXRvbXlhbmRwaHlzaW9sb2d5L2NoYXB0ZXIvY2VsbHVsYXItZGlmZmVyZW50aWF0aW9uLw&ntb=1

https://www.bing.com/ck/a?!&&p=1937e6f5045fe9ebJmltdHM9MTY3NTU1NTIwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTE3NA&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=Cell+Differentiation&u=a1aHR0cHM6Ly9tZWQubGlicmV0ZXh0cy5vcmcvQm9va3NoZWx2ZXMvQW5hdG9teV9hbmRfUGh5c2lvbG9neS9Cb29rJTNBX0FuYXRvbXlfYW5kX1BoeXNpb2xvZ3lfMWVfKE9wZW5TdGF4KS9Vbml0XzElM0FfTGV2ZWxzX29mX09yZ2FuaXphdGlvbi8wMyUzQV9UaGVfQ2VsbHVsYXJfTGV2ZWxfb2ZfT3JnYW5pemF0aW9uLzMuMDYlM0FfQ2VsbHVsYXJfRGlmZmVyZW50aWF0aW9u&ntb=1

https://www.bing.com/videos/search?q=Cell+Differentiation&&view=detail&mid=F5374F7143C8BDAD56EFF5374F7143C8BDAD56EF&&FORM=VRDGAR

https://www.bing.com/videos/search?q=Cell+Differentiation&&view=detail&mid=BE89D210A369AA8E6CEABE89D210A369AA8E6CEA&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3DCell%2BDifferentiation%26FORM%3DHDRSC4

5.6: Possible Answers to Self-Assessment Exercises

1. Some examples of cell differentiation are stem cells turning into neurons, osteocytes or cardiomyocytes. All cells start from embryonic stem cells, which are undifferentiated. Through the process of embryonic development these cells start to express tissue-specific proteins and become highly specialized. Three examples of specialized cells that come from embryonic stem cells include:

Cardiomyocytes - heart cells
Osteocytes - bone cells
Neurons - brain cells

2. Cell differentiation is the process of cells becoming specialized in their structures and function and performing a certain job in the body. Cell differentiation is controlled through changes in gene expression.

Glossary

- Anaphase - a stage in mitosis where chromosomes begin moving to opposite ends (poles) of the cell.
- Allele - an alternative form of a gene (one member of a pair) that is located at a specific position on a specific chromosome.
- Apoptosis - a controlled sequence of steps in which cells signal self-termination.
- Asters - radial microtubule arrays found in animal cells that help to manipulate chromosomes during cell division.
- Cell Cycle - the life cycle of a dividing cell, including Interphase and the M phase or Mitotic phase (mitosis and cytokinesis).
- Centromere - a region on a chromosome that joins two sister chromatids.
- Cilia and Flagella - protrusions from some cells that aid in cellular locomotion.
- Cytokinesis - the division of the cytoplasm that produces distinct daughter cells.
- Daughter Cell - a cell resulting from the replication and division of a single parent cell.
- Daughter Chromosome - a chromosome that results from the separation of sister chromatids during cell division.
- Diploid Cell - a cell that contains two sets of chromosomes—one set of chromosomes is donated from each parent.
- Gametes - reproductive cells that unite during sexual reproduction to form a new cell called a zygote.

- Gene Theory - one of the five basic principles of biology, stating that traits are inherited through gene transmission.
- Genes - segments of DNA located on chromosomes that exist in alternative forms called alleles.
- Haploid Cell - a cell that contains one complete set of chromosomes.
- Interphase - the stage in the cell cycle where a cell doubles in size and synthesizes DNA in preparation for cell division.
- Meiosis - a two-part cell division process in organisms that sexually reproduce, resulting in gametes with one-half the number of chromosomes of the parent cell.
- Metaphase - the stage in cell division where chromosomes align along the metaphase plate in the center of the cell.
- Microtubules - fibrous, hollow rods that function primarily to help support and shape the cell.
- Mitosis - a phase of the cell cycle that involves the separation of nuclear chromosomes followed by cytokinesis.
- Polar Fibers - spindle fibers that extend from the two poles of a dividing cell.
- Prophase - the stage in cell division where chromatin condenses into discrete chromosomes.
- Ribosomes - cell organelles that are responsible for assembling proteins.
- Sister Chromatids - two identical copies of a single chromosome that are connected by a centromere.
- Spindle Fibers - aggregates of microtubules that move chromosomes during cell division.
- Telophase - the stage in cell division when the nucleus of one cell is divided equally into two nuclei.

End of the module Questions

- How is meiosis I different from meiosis II?
- Why is meiosis I also known as reductional division?
- What do you understand by crossing over in meiosis I?
- What are the different stages of meiosis I?
- A cell duplicates its DNA, divides into two cells, then divides into two cells again.
- Effectively, the cell reduces its DNA in half. Did this cell go through mitosis?

A. Yes, but only once.
B. Yes
C. No

1. During mitosis, the chromosomes have condensed, lined up on the metaphase plate, and the chromatids are being separated by an enzyme? Which phase of mitosis is this?

A. Prophase
B. Metaphase
C. Anaphase

Answers

1. In meiosis I the homologous chromosomes separate from each other, whereas, in meiosis II the sister chromatids separate. In meiosis I two diploid daughter cells are produced, whereas, in meiosis II four haploid daughter cells are produced
2. Meiosis 1 is known as reductional division because in this process the number of chromosomes is reduced to half, i.e., from diploid to haploid.
3. Crossing over is the process of meiosis in which two chromosomes of a homologous pair are exchanged between non-sister chromatids.
4. The different stages of meiosis I include:

Prophase
Metaphase
Anaphase
Telophase

5. C is correct. This process, although it starts like mitosis, is something completely different. This is known as meiosis, and is covered in a separate article. During mitosis, the DNA is maintained exactly, from parent to daughter cells. In meiosis, the number of alleles per gene is reduced, allowing gametes to form and create an organism with only two alleles per gene. Mitosis aims to create identical cells at the end of the process, needed for asexual reproduction and developing new organisms.
6. C is correct. When the chromatids are being separated, the cell is in anaphase of mitosis. After they are separated, the cell enters telophase. Also, in anaphase, the chromosomes become extremely condensed. This allows them to fit into a newly formed nucleus in the new cell.

MODULE 3: BASIS OF CELL STRUCTURE AND MOLECULAR DEVELOPMENT

Unit 1: Cell growth
Unit 2: Cell Communication
Unit 3: Cell Signaling
Unit 4: Proteins structure and Synthesis of Cell
Unit 5: Nucleic Acids component and functions of Cells

Unit 1: Cell growth

Unit Structure

1.1: Introduction
1.2: Intended Learning Outcomes
1.3: Main Body
1.4: Summary
1.5: References/Further Readings/Web Sources
1.6: Possible Answers to Self-Assessment Exercises

1.1: Introduction

The term cell growth is used in the contexts of cell development and cell division. When used in the context of cell division, it refers to growth ofcell populations, where one cell (the "mother cell") grows to maturity and divides to produce two "daughter cells". This unit describes in details the meaning of cell growth.

1.2: Intended Learning Outcomes

By the end of this unit, students should be able to;

- define cell growth
- distinguish between normal cell growth and cell growth disorder
- describe cell number, cell population and cell size.

1.3: Main Body

In most cases, living things grow by producing more cells. There are two main reasons why cells divide: (1) The larger a cell gets; the more

demands it places on its DNA. (2) As a cell gets bigger, it has more work moving enough nutrients (food) and wastes across its cell membrane. The rates at which materials move through the cell membrane depend on the cell's surface area the total area of its cell membrane. However, the rate at which food and oxygen are used up and formation of waste products depends on the cell's volume. As a cell grows, its internal volume increases faster than its surface area. That is, as a cell becomes bigger, its ratio of surface area to volume decreases.

Before a cell gets too large, it divides, forming two "daughter" cells. Cell division is the process by which a cell divides into two new daughter cells.

Cell Turnover

In higher vertebrates (birds and mammals), adult body size is relatively constant as compared with its size of organs. Nevertheless, in many tissues, cell birth continues throughout their life - thus, for body and organ size to remain stable, cells must also die. Cell number is therefore proportional to the rate of cell proliferation and the rate of cell death.

Renewing Cells

Mitosis is the process that brings about the renewing of cells. In most adult tissues, cell turnover continues throughout the animal's lifespan. In some tissues, cell turnover is very slow, and cell proliferation occurs primarily after injury - e.g., liver, blood vessels. In some adult tissues, cell turnover is rapid and occurs via the stem cells (a) hemopoietic system, (b) intestinal mucosa, and (c) skin epidermis

Cell Number

In higher vertebrates' cell birth continues throughout life. However, forbody and organ size to remain stable, cells must also die. Cell number is therefore proportional to the rate of cell proliferation and the rate of cell death. The processes of cell birth and cell death are termed cell turnover.

Cell Populations

Cell populations go through a type of exponential growth called doubling. Thus, each generation of cells should be twice as numerous as the previous generation. However, the number of generations only gives a maximum figure as not all cells survive in each generation. Cell

divisions bring about population of cells. For example, during mitosis, a parent cell divides to give two daughter cells.

Cell Size Regulation in Mammals

The cell size in mammals is regulated based on certain factors. Many of the signal molecules that convey information to cells during the control of cellular differentiation or growth are called growth factors. The protein that regulates translation and cell division is influenced by nutrient availability so that when cells are not able to grow to normal size, they will not undergo cell division. For example, the size of post-mitotic neurons depends on the size of the cell body, axon and dendrites.

In vertebrates, neuron size is oftena reflection of the number of synaptic contacts onto the neuron or from a neuron onto other cells. For example, the size of motor neurons usually reflects the size of the motor unit that is controlled by the motor neurons. Invertebrates often have giant neurons and axons that provide special functions such as rapid action potential propagation. Mammals also use this trick for increasing the speed of signals in the nervous system.

Types of Cell Division

For most of the constituents of the cell, growth is a steady, continuous process, interrupted only briefly at M phase when the nucleus and the cell divides to two. The process of cell division (e.g., mitosis), called cell cycle, has four major parts called phases. The first part, called G1 phase is marked by synthesis of various enzymes that are required for DNA replication. The second stage of the cell cycle is the S phase, where DNA replicationproduces two identical sets of chromosomes. The third part is the G2 phase where significant protein synthesis occurs. During this phase, it involves the production of microtubules, which are required during the process of division, called mitosis. The fourth stage, M phase, consists of nuclear division (karyokinesis) and cytoplasmic division (cytokinesis), accompanied by the formation of a new cell membrane. This is the physical division of "mother" and "daughter" cells. The M phase has been broken down into several distinct subphases, sequentially known as prophase, prometaphase, metaphase, anaphase and telophase leading to cytokinesis.

Cell division is more complex in eukaryotes than in other organisms. Prokaryotic cells such as bacterial cells reproduce by binary fission, a process that includes DNA replication, chromosome segregation, and cytokinesis. Eukaryotic cell division either involves mitosis or a more complex process called meiosis. Mitosis and meiosis are sometimes called the two "nuclear division" processes. Binary fission is similar to

eukaryotic cell division that involves mitosis. Both lead to the production of twodaughter cells with the same number of chromosomes as the parental cell.

Meiosis (a reduction division) is used for a special cell production process of diploid organisms. It produces four special daughter cells (gametes) eachhaving half the normal cellular amount of DNA.

A male and a female gamete can then combine to produce a fertilized cell now having normal number of chromosomes.

A cell must copy its genetic information before cell division begins. Each daughter cell then gets a complete copy of that information after cell division. In most prokaryotes, the cell division is a simple matter of separating the contents of the cell into two parts. In eukaryotes, cell division occurs in two main stages, mitosis and cytokinesis. Mitosis is the division of the nucleus.

Cytokinesis is the division of the cytoplasm. The cell cycle is a series of events cells go through as they grow and divide. During the cell cycle, a cell grows, prepares for division, and divides to form two daughter cells.

Why do Cells Divide?

Cells in a multicellular organism have different sizes, rates of growth and timing of cell division. Cells in a multicellular organisms divide to replace lost or damage cells and allow the organism to grow. Unicellular organismsdivide to reproduce. Cells must divide for two main reasons:

- Not enough DNA to provide the information a cell needs to survive.
- The surface area of a cell does not increase as fast as the volume ofthe cell.

Cellular Growth Disorders

A series of growth disorders can occur at the cellular level. A normal cell can become a cancer cell. Cancer is a disorder in which some of the body's cells lose the ability to control growth. Cancer cells do not respond to the signals that control the growth of normal cells. As a result, cancer cells divide uncontrollably. They form masses of cells called tumors, which can damage surrounding tissues. Cancer cells do not stop growing when they touch other cells. Instead, they continue to grow and divide until their supply of nutrients is used up. Cancer cells may break loose from tumors and spread throughout the body. Cancer

cells can invade other cells (invasion) and spread to other locations of the body, a process that is called metastasis.

State the reasons for cell division.

Self-Assessment Exercises

Write short note on;

- Cell turnover
- Renewing Cells
- Cell number
- Cell population

1.4: Summary

When cells grow and differentiate, they reach maturity and under certain conditions they undergo cell division to produce normal cells but sometimes cell disorders may occur. Cell number is proportional to the rate of cell proliferation and the rate of cell death. The process of cell birth and cell death is termed cell turnover. Cell turnover is very slow, and cell proliferation occurs primarily after injury. Cell division is more complex in eukaryotes than in other organisms. Binary fission, mitosis, and meiosis are types of cell division. There are reasons why cells divide. Cell disorders during cell division may occur.

1.5: References/Further Readings/Web Sources

Cooper, G. (2000). "*The Events of M Phase*". The Cell: A Molecular Approach. Sinaeur Associates, Inc.

Dornelas, M.C. (2003). 'Signal Transduction, Cell Division, Differentiation and Development: towards Unifying Mechanisms for Pattern Formation in Plants'. *Braz. J. Plant Physiol.*

Freeman, S (2002). "Cell Division". *Biological Science*. Upper Saddle River, NJ: Prentice Hall.

Morgan, D.O. (2007). "The Cell Cycle: *Principles of Control*" London: New Science Press.

The American Heritage® Dictionary of the English Language (2009). Fourth Edition copyright ©2000 by Houghton Mifflin Company. Published by Houghton Mifflin Company.

https://www.bing.com/ck/a?!&&p=bf5b0ad680680dc4JmltdHM9MTY3NTU1NTIwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTEzNA&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=Cell+Differentiation&u=a1aHR0cDovL3ByZXNzYm9va3MtZGV2Lm9lci5oYXdhaWkuZWR1L2FuYXRvbXlhbmRwaHlzaW9sb2d5L2NoYXB0ZXIvY2VsbHVsYXItZGlmZmVyZW50aWF0aW9uLw&ntb=1

https://www.bing.com/ck/a?!&&p=1937e6f5045fe9ebJmltdHM9MTY3NTU1NTIwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTE3NA&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=Cell+Differentiation&u=a1aHR0cHM6Ly9tZWQubGlicmV0ZXh0cy5vcmcvQm9va3NoZWx2ZXMvQW5hdG9teV9hbmRfUGh5c2lvbG9neS9Cb29rJTNBX0FuYXRvbXlfYW5kX1BoeXNpb2xvZ3lfMWVfKE9wZW5TdGF4KS9Vbml0XzElM0FfTGV2ZWxzX29mX09yZ2FuaXphdGlvbi8wMyUzQV9UaGVfQ2VsbHVsYXJfTGV2ZWxfb2ZfT3JnYW5pemF0aW9uLzMuMDYlM0FfQ2VsbHVsYXJfRGlmZmVyZW50aWF0aW9u&ntb=1

https://www.bing.com/videos/search?q=Cell+Differentiation&&view=detail&mid=F5374F7143C8BDAD56EFF5374F7143C8BDAD56EF&&FORM=VRDGAR

https://www.bing.com/videos/search?q=Cell+Differentiation&&view=detail&mid=BE89D210A369AA8E6CEABE89D210A369AA8E6CEA&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3DCell%2BDifferentiation%26FORM%3DHDRSC4

4.6: Possible Answers to Self-Assessment Exercises

Cell Turnover: In higher vertebrates (birds and mammals), adult body size is relatively constant as compared with its size of organs. Nevertheless, in many tissues, cell birth continues throughout their life - thus, for body and organ size to remain stable, cells must also die. Cell number is therefore proportional to the rate of cell proliferation and the rate of cell death.

Renewing Cells: Mitosis is the process that brings about the renewing of cells. In most adult tissues, cell turnover continues throughout the animal's lifespan. In some tissues, cell turnover is very slow, and cell proliferation occurs primarily after injury - e.g., liver, blood vessels. In some adult tissues, cell turnover israpid and occurs via the stem cells (a) hemopoietic system, (b) intestinal mucosa, and (c) skin epidermis

Cell Number: In higher vertebrates' cell birth continues throughout life. However, forbody and organ size to remain stable, cells must also die. Cell number is therefore proportional to the rate of cell proliferation and the rate of cell death. The processes of cell birth and cell death are termed cell turnover.

Cell Populations: Cell populations go through a type of exponential growth called doubling. Thus, each generation of cells should be twice as numerous as the previous generation. However, the number of generations only gives a maximum figure as not all cells survive in each generation. Cell divisions bring about population of cells. For example, during mitosis, a parent cell divides to give two daughter cells

Unit 2: Cell Communication

Unit Structure

2.1: Introduction

Cell communication, or cellular communication, is a process where a cell is able to influence the behavior of other cells through signaling mechanisms. Cell communication is necessary for multicellular organisms like humans, though it does predate multicellular organisms. Multicellular organisms need their cells to communicate with each other to have their cells work together and coordinate their cellular activities. Cell communication between cells in a multicellular organism is necessary for cells to know when to assist in replicating and repairing damaged tissue, sensing pain, and informing the larger organism that it is hungry, thirsty, or tired.

The general principles of cell communication involve a sequence of processes by which a cell detects and responds to the signals in its surroundings or within itself. Here, let's learn more about the cell communication process.

2.2: Intended Learning Outcomes

By the end of this unit, students should be able to;

- Explain the principles of cell communication.
- State the importance, types and processes of cell communication.
- Describe the types and functions of cell junctions.

2.3: Main Body

Cells communicate along what is called a signal transduction pathway. This pathway is a series of molecular changes that allow a signaling cell to send a message that a target cell can receive and have an appropriate response. This process works by a signaling cell releasing a signaling molecule which is usually a volatile or soluble molecule called ligand. Once the signal molecule reaches a target cell, it binds to a receptor protein on the target cell's cellular membrane in a process called reception. After the signal molecule achieves reception, another step in the process begins called transduction. During this process, the target cell passes the signal molecule between its various receptors.

The signal molecule travels a path from the outside of the target cell to the inside. There are receptors such as the proteins on the cell's membrane, and there are internal receptors which are found in the cytoplasm or inside the cell. The signal molecule is relayed from the cell membrane receptor, then passes through the cell membrane and into the cytoplasm signal transduction.

Once the signal molecule reaches a certain protein within the cell, it binds to it and triggers a signaling response by the cell. The response from the target cell is simply the behavior that the signaling cell intended to entice. This response, of course, will vary and depend on the message which was received by the target cell. So, what things entice these cell-to-cell contacts or cell-to-cell communications? Or why do cells need to communicate?

Why Do Cells Need to Communicate?

Cells need to communicate with each other for numerous reasons. The communication between cells triggers many responses by cells. Responses to signals and therefore reasons for why signals are sent can include:

- Changes in gene expression or an increase or decrease in the production of a protein which is coded by a gene.
- Cell division and tissue repair. Cells within a multicellular organism usually do not divide until they have received signals from other cells telling them the reproduction is needed.
- Apoptosis is a process where a cell self-destructs. This process is signaled by other cells if the cell is damaged, or if it is infected by a virus or bacteria.

- Cells may need more energy and therefore cells might be signaled to increase their cellular metabolism in order to convert glucose to glycogen or the reverse.
- Cells also communicate with one another to send signals to the larger organism that they make up. Cells in the body and stomach signal the brain when nutrients and materials are needed, and therefore the larger organism feels hungry or thirsty. Nerve cells in an organism's body, will send signals to the brain when damage has occurred to tissues that nerve cells are attached to, and the organism will feel pain.

Importance of Cell Communication

- Cell communication is critical for nearly every aspect of cell structure and cell function.
- Cell signaling can help explain how many cells work together to perform a function. For example, cell signaling is intricately tied to the regulation of cell growth, cell division, and cell energetics.
- Dysregulation of cell signaling may cause a cell to lose its ability to regulate cell division, leading to the formation of a malignant tumor and cancer. Therefore, the study of cell signaling is crucial for understanding the basis of human disease and, ultimately, human health. Cancer is an outcome of dysregulated cell signaling. Typically, when cells are damaged, there is a signal to initiate controlled cell death called apoptosis. However, the cell does not respond to these cell death signals in a cancer cell, leading to uncontrolled growth.
- A cell that sends out a signal is called a **signaling cell.** The signal sent out by the signaling cell is called an *extracellular* **signaling molecule** or a **ligand**. The cell that receives the signal is called the **target cell,** and it contains proteins that bind to the ligand called **receptors**. Target cells can only respond to a signal if they express receptors that can bind to the ligand. A **ligand** or an **extracellular signaling molecule** is a chemical messenger that is released by the signaling cell. **A receptor** is a protein that is expressed on the target cell that recognizes and binds to the ligand.

Types of Cell Communication

- In **autocrine** signaling, a cell communicates with itself.
- In **paracrine** signaling, a signaling cell communicates to nearby target cells.
- In **endocrine** signaling, a signaling cell releases a ligand that enters the bloodstream to bind distant target cells.

- **Direct signaling** occurs when cells are in direct contact communicate with each other.

Cell junctions/Connections

There are many different ways that cells can connect to each other. Gap junctions are most commonly found in the skin, so mistakes in their functions can lead to a variety of diseases that make up ectodermal dysplasia, a series of genetic disorders affecting the development or function of the teeth, hair, nails and sweat glands. Additionally, errors in specific gap junction genes called, Cx43 and Cx56.6, can lead to the breakdown of some of our brain tissue called white matter which makes up 60% of our brain. Diseases that include the breakdown of white matter include multiple sclerosis and Huntington's disease! Mistakes in our genes that produce desmosomes cause skin blistering. The three main ways for cells to connect with each other are: gap junctions, tight junctions, and desmosomes. These types of junctions have different purposes, and are found in different places.

- Gap Junctions: Gap junctions are essentially tubes that join two cells together. These tubes create a connection that allows for the transport of water and ions to and from the connecting cells.
- The tubes also help to spread electrochemical signals that are produced by action potentials that occur in the nervous system (neurons) and in cardiac cells that make your heart beat. Gap Junction are specialized connections between cells. The presence of the Gap Junction directly connects the cytoplasm of adjacent cells. Their primary function is to allow the regulated passage of electrical impulses, molecules and ions from one cell to another. This communication is very important as Gap Junctions allow for complex functions to happen. For example, Gap Junctions perform a necessary function for the development of organs, embryos, and tissues. In the heart, the electrical impulses that order the muscles to contract pass through Gap Junctions. The signal for cellular death also passes through the Gap Junction. Sometimes, cells must die in order for tissue to evolve into its primary form and purpose. Gap Junctions also transmit "orders" for nearby and surrounding, healthy cells, to die, if and when a diseased cell is found to be dying. Gap Junction type cells are found in almost every kind of tissue within the body. The only exceptions to this are mobile cells such as erythrocytes, and fully matured skeletal muscle. Gap Junctions are not found in life forms like slime molds, sponges, and other simple organisms.
- Tight Junctions: Tight junctions are different from gap junctions because they are the connections that form when cells are squished

up against one another. In this case, the cell membranes are connected, but the contents of each cell are not connected in any way. There are no tubes here, but there is an impermeable layer in between the cells. These types of cell connections are useful in places that need to contain certain fluids, like in the bladder, the intestines or the kidneys. Tight junction directs the movement of solutes and water nestled between epithelia. This happens at that point where cells brush against each other. Tight Junctions can only be found in vertebrates. For invertebrates, junctions that match the functions of the Tight Junction are called Septate Junctions.

- Adherens Junction: Otherwise known as Zonula Adherens, it literally forms a continuous belt around a cell. The primary function of the Adherens Junction is to stick to an adjacent cell or surface. The junction is formed primarily with calcium. In certain parts of the body, Adherens Junctions perform a very important function. They help in binding the structure of the heart, keeping the heart together even as is it expands and contracts to supply oxygen throughout our body. Several proteins make up an Adherens Junction:

- Cadherin are floating adhesive substances located outside of the cell.
- There are anchor proteins inside the cell. They connect the cytoskeleton to Cadherin.
- The cytoskeleton of the cell itself, which has actin microfilaments.

A. Desmosomes: these are quite different from gap junctions and tight junctions. With
desmosomes, cell membranes are connected by thread like substances that connect the cells across the space in between cells. Much like tight junctions, desmosomes physically hold the cells together, but do not allow fluids or materials to pass from the inside of one cell to the next. These connections are also attached to the scaffolding of the cell, called the cytoskeleton, to help with structural support. The space in between the cells allows for water and solutes to flow freely between each cell without compromising the connection. Desmosome are similar in function to Adherens Junctions. Desmosomes are attached to the cytoskeleton of a cell via the demosplakin.

From there, the adhesion protein of the Desmosomes extends toward the cellular membrane, passes through the protective membrane, and attaches itself to another Desmosomes from another adjacent cell. The two Desmosomes intertwine to in an S, W, or A shaped manner. In muscular tissue, Desmosomes hold muscles together.

B. Hemidesmosome: are located in the basal lamina of a cell. They connect with other cells by extending filaments to reach other Hemidesmosomes of other adjacent cells. Like Desmosomes, the Hemidesmosome acts as an anchor between adjacent cells. The main difference lies in the fact that the Hemidesmosome is anchored to the basal lamina of the cell, while the Desmosome is anchored to the cytoskeleton of the cell.
Do cells communicate with each other?

Self-Assessment Exercises

- What is cell to cell communication called?
- Why do cells need to communicate?
- How does cell communication work in biology?
- What are the three types of cell communication?

2.4: Summary

They may be the smallest of particles within our bodies, but junctions are also the particles that compose and allow our bodies to function. The human body is a whole new universe open to exploration.

2.5: References/Further Readings/Web Sources

Davidson, M W. (2015-). "Plasmodesmata". *Molecular Expressions Cell Biology*. Retrieved 2017-04-13 from https://micro.magnet.fsu.edu/.

Evans, W.H. & Martin, P.E. (2002). "Gap junctions: structure and function (Review)". *Mol. Membr. Biol.* 19 (2): 121–36.

Kimball, J. W. (2015). "Junctions Between Cells". *Kimball's Biology Pages*. Retrieved 2017-04-12 from http://www.biology-pages.info/.

Wei, C.J., Xu, X., & Lo, C.W. (2004). "Connexins and cell signaling in development and disease". *Annu. Rev. Cell Dev. Biol.* 20: 811–38.

https://www.bing.com/ck/a?!&&p=117a34ccc2dda06eJmltdHM9MTY3NTY0MTYwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTI1OA&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=cell+communication&u=a1aHR0cHM6Ly93d3cubmNiaS5ubG0ubmloLmdvdi9ib29rcy9OQksyNjgxMy8&ntb=1

https://www.bing.com/ck/a?!&&p=165d2a0e43445c34JmltdHM9MTY3NTY0MTYwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTMxNw&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=cell+communication&u=a1aHR0cHM6Ly9vcGVub3JlZ29uLnByZXNzYm9va3MucHViL21oY2NtYWpvcnNiaW8vY2hhcHRlci9hLXN1bW1hcnktb2YtY2VsbC1jb21tdW5pY2F0aW9uLw&ntb=1

https://www.bing.com/videos/search?q=cell+communication&&view=detail&mid=DA2A981BF3CD3A16F5E6DA2A981BF3CD3A16F5E6&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3Dcell%2Bcommunication%26FORM%3DHDRSC4

https://www.bing.com/videos/search?q=cell+communication&&view=detail&mid=758A383A5ED437FD030D758A383A5ED437FD030D&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3Dcell%2Bcommunication%26FORM%3DHDRSC4

2.6: Possible Answers to Self-Assessment Exercises

1. Cell to cell communication is generally called cellular communication. It may also be referred to as cell to cell signaling.

2. Cell communication is critical for nearly every aspect of cell structure and cell function. Cells need to communicate to coordinate a large physiological process. If cells lose the ability to communicate, it can lead to the formation of malignant tumors and cancer.

3. Cell communication begins when a cell releases a signal called a ligand. A ligand binds to receptors in the target cell. Following binding, a signal transduction pathway is initiated leading to a cellular response.

4. The three main types of cell communication are autocrine, paracrine, and endocrine signaling. However, if cells are in direct contact with each other, direct signaling can also occur through gap junctions.

Unit 3: Cell Signaling

Unit Structure

3.1: Introduction

Cell communicates with each other using chemicals called signaling molecules. The cell secretes these molecules out. Other cells detect the presence of the signaling molecule through receptors present on their surface. Once signaling molecule is detected, the cells will make changes.

3.2: Intended Learning Outcomes

By the end of this unit, students should be able to;

- Describe the complications of cell signaling.
- Discuss the types of cells signaling.

3.3: Main Body

Cell Signaling: It's Complicated

Cell signaling is the process of communication between the cells of the body. It follows a 'simple' three-step sequence. Let's imagine that cell A wants to get a message to cell B. Cell A secretes molecules that carry this message or signal. These molecules are known as signaling molecules and function like a postman or messenger. Signaling molecules can be lipids, proteins or even gases.

Now, in order to receive the message, Cell B needs a receptor. A receptor is a protein that can bind to a signaling molecule. They are located either on the cell surface to bind to external molecules or they can be cytoplasmic receptors that bind to signaling molecules within the

cell. Each receptor is unique to a particular signaling molecule and only a cell that has the receptor for a signaling molecule will be able to receive its message. When the signaling molecule from Cell A binds to its receptor on Cell B, the first part of cell signaling is complete.

The binding of the molecule to its respective receptor on Cell B activates the receptor. This activation is brought about by a change in the shape of the receptor. The active receptor of Cell B can now launch a series of events in which the message gets amplified and spreads to other parts of the cells and sometimes even other molecules. This is the second step of cell signaling, called **transduction**, and the process is called a signal transduction pathway.

The third and final step is **response**. The signaling molecule has now successfully delivered Cell A's message to Cell B. Cell B must now decide how to respond to this message. The response will occur as a result of the signal transduction pathway initiated by the activation of Cell B's receptor. For example, if Cell A has alerted Cell B to an increased level of blood sugar, the resulting response will be ramping up insulin production.

Types of Cells Signaling

The sequence of cell signaling remains is the same for most cell but depending on the distance separating two communicating cells, cell signaling can be classified into several different categories. Cell signaling can be broadly classified into intracellular signaling and intercellular signaling.

- Intracellular signaling occurs within the cell in response to internal and external stimuli. In other words, it is simply when a cell is talking to itself and working independently.
- On the other hand, intercellular signaling is where a cell talks to the other cells of the body. In many cases, signaling might involve cells talking to themselves and to others in order to generate a response.

In the case of intercellular signaling, the type of signal can be further classified on the basis of the distance travelled (Fig 13)

- **Autocrine Signaling:** Sometimes cells can produce signaling molecules that bind to receptors on their own membrane. In this way, it's possible for cells to send messages to themselves! Although it sounds strange, autocrine signaling is essential during development, as it ensures correct cell division and maintenance of cell identity.

- **Direct-Contact Signaling:** Some cells lie very close to each other and are in direct contact. Such cells have passages that connect them. For example, gap junctions in animal cells and plasmodesmata in plant cells are such passages that connect neighbouring cells. Signaling molecules can easily pass through these passages. This feature enables a group of cells to respond to a signal received by just one cell.
- **Paracrine Signaling:** This form of communication takes place between cells that are near each other, but are not connected. In this case, the cells talk via the diffusion of chemical signaling molecules across short distances. Synaptic signaling between neurons (brain cells) is an example of paracrine signaling. Neurons release signaling molecules called neurotransmitters in the gap between themselves and the next neuron. This gap is known as a synapse. Hence, synaptic signaling allows our brain and central nervous system to work together by sending messages across multiple neurons.
- **Endocrine Signaling:** This is a method employed by cells that are far apart from each other. Like a package that is shipped internationally, signaling molecules may travel through the bloodstream to reach the target cell. Such molecules are called hormones. For example, the hormone adrenaline, released by the adrenal gland present atop the kidneys, is the fight or flight hormone. Adrenaline is released under stress and is responsible for increasing heart rate and blood pressure, redistributing blood to muscles, ramping up glucose production and much more. Hence, this hormone travels throughout the body from the adrenal gland via the bloodstream to the cardiac muscles to increase pumping, as well as to the liver for glucose production.

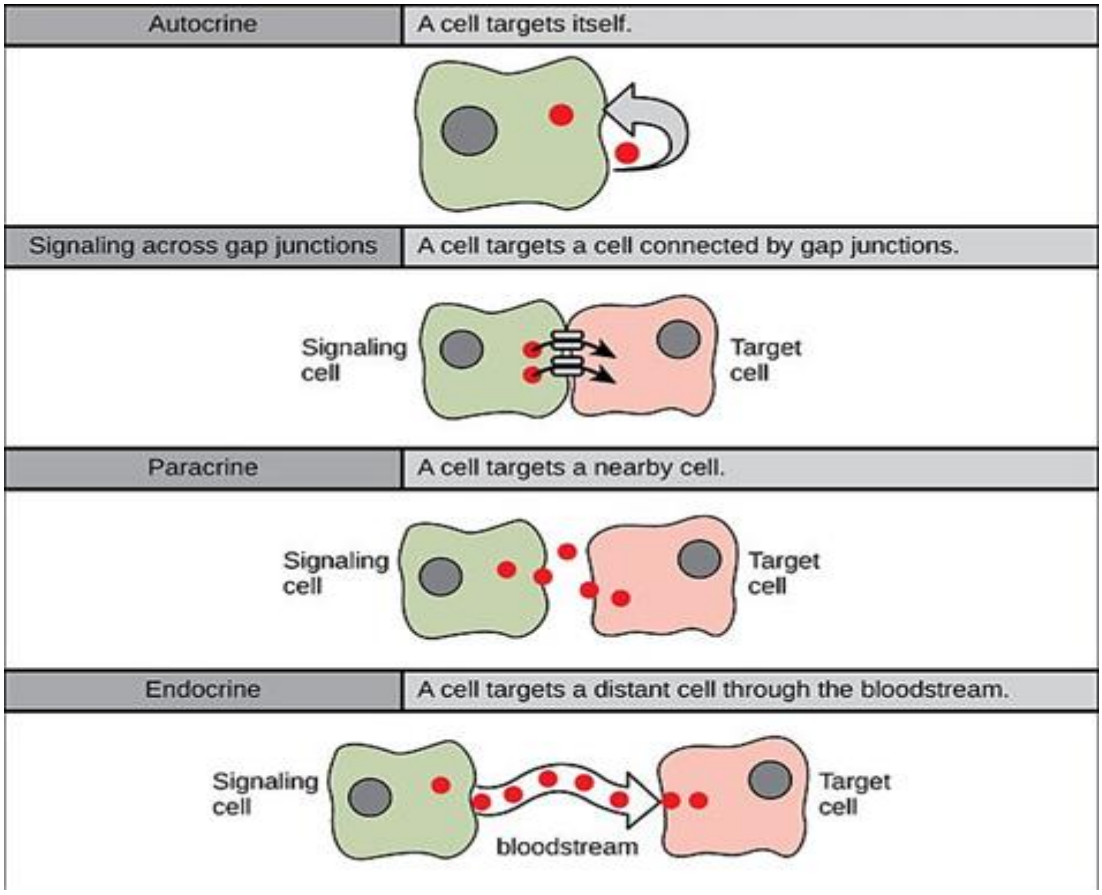


Fig 13: Forms of Chemical signaling

The Importance of Cell Signaling

Communication amongst the many cells of the body enables us to respond and adapt to our ever-changing environment. From a developmental aspect, cell signaling ensures that all body organs and tissues are on the same page. That is, it guarantees that things like cell functioning, size, location and number are kept in check. In this way, cells of different specialized tissues maintain their identities and functions. For example, cardiac cells are only present in the heart and hepatic cells are only found in the liver, and both perform their respective specialized role.

The second step of cell signaling is called?

Self-Assessment Exercises

- Enumerate the major types of cells signaling.

3.4: Summary

The cell signaling is an important form of cell communication that is required in the cell to effective performs its functions.

3.5: References/Further Readings/Web Sources

Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K. and Walter, P. (2002) *Molecular Biology of the Cell* (4th edn), Garland Science, New York.

Cowley, S., Paterson, H., Kemp, P. and Marshall, C. J.(1994) 'Activation of MAP kinase is necessary and sufficient for PC12 differentiation and for transformation of NIH 3T3 cells', *Cell*, vol. 77, no. 6, pp. 841–52.

Gomperts, B. D., Tatham, P. E. R. and Kramer, I. M. (2002) *Signal Transduction*, Academic Press, London.

Jhun, B. H., Rivnay, B., Price, D. and Abraham, H. (1995) 'The MATK tyrosine kinase interacts in a specific and SH2-dependent manner with c-Kit', *Journal of Biological Chemistry*, vol. 270, pp. 9661–6.

https://www.bing.com/ck/a?!&&p=c88922820998b0b7JmltdHM9MTY4MTYwMzIwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTIwNw&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=Cell+signaling&u=a1aHR0cHM6Ly93d3cua2hhbmFjYWRlbXkub3JnL3NjaWVuY2UvYXAtYmlvbG9neS9jZWxsLWNvbW11bmljYXRpb24tYW5kLWNlbGwtY3ljbGUvY2VsbC1jb21tdW5pY2F0aW9uL2EvaW50cm9kdWN0aW9uLXRvLWNlbGwtc2lnbmFsaW5n&ntb=1

https://www.bing.com/ck/a?!&&p=42e9944cd376a8c4JmltdHM9MTY4MTYwMzIwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTI4MQ&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=Cell+signaling&u=a1aHR0cHM6Ly9ieWp1cy5jb20vYmlvbG9neS9jZWxsLXNpZ25hbGxpbmcv&ntb=1

https://www.bing.com/videos/search?q=Cell+signaling&&view=detail&mid=415EA2A7E58AE7184AB3415EA2A7E58AE7184AB3&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3DCell%2Bsignaling%26FORM%3DHDRSC6

https://www.bing.com/videos/search?q=Cell+signaling&&view=detail&mid=3314A52E30ECAFF964D23314A52E30ECAFF964D2&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3DCell%2Bsignaling%26FORM%3DHDRSC6

3.6: Possible Answers to Self-Assessment Exercises

- Intercellular signaling
- Intracellular signaling

Unit 4: Proteins structure and Synthesis of Cell

Unit Structure

4.1: Introduction

Proteins are an essential macronutrient present in all living organisms. It is found throughout the body; in our muscles, bones, skin, hair, and basically every other body part or tissue. The term ‘Protein’ was invented by Swedish chemist Jöns Jacob Berzelius in 1838. It was derived from the Greek word ‘proteins’, which means "the first position". Proteins are responsible for making enzymes, which are extremely important to carry out certain chemical reactions in your body. The functioning and regulating of our body cells, tissues, and organs are also performed by proteins in our body. Proteins are made up of linear chains of smaller units called amino acids.

4.2: Intended Learning Outcomes

By the end of this unit, students should be able to;

- Discuss the roles of proteins in the body
- Provide schematic structure, classification, and synthesis of proteins.

4.3: Main Body

Proteins are essential part of every cell in our body, protein is one of the three macronutrients which is required by our body in larger amounts. Proteins are made up of linear chains of smaller units called amino acids. Every biochemical process that takes place inside our bodies is

possible because of these proteins. Proteins are 3-dimensional structures that are assembled with different amino acid sequences.

Sources of Proteins

- Both animal and plant products are excellent sources of proteins.
- Some of the strongest sources of protein are nuts, seafood, seeds, eggs, soy products, eggs, legumes, beans, pulses, milk, cheese, yogurt, meat, and poultry.
- Vegetables and whole grains also contain proteins, but not as much as other sources.

Protein Structure

A protein molecule is made from a long chain of amino acids, each linked to its neighbor through a covalent peptide bond. Hence, proteins are also known as polypeptides. Due to different rearrangements of amino acids, the structure of proteins is divided into four types (Fig 14):

- **Primary Structure:** In the primary structure of proteins, the proteins are linked through covalent bonds.
- **Secondary Structure:** It is a three-dimensional form of a local segment of proteins. They are formed by the linear peptide chains that fold either into an alpha-helical structure (coiled) or a beta-pleated structure (sheets) making hydrogen bonds between the atoms along the backbone of the polypeptide chain.
- **Tertiary Structure:** This structure is characterized by the arrangement of proteins into loops and bends. The tertiary structure contains hydrogen, ionic, and disulfide bonds. Many numbers of tertiary structures fold to form Quaternary Structure.
- **Quaternary Structure:** This structure is basically the arrangement of proteins containing more than one peptide chain.

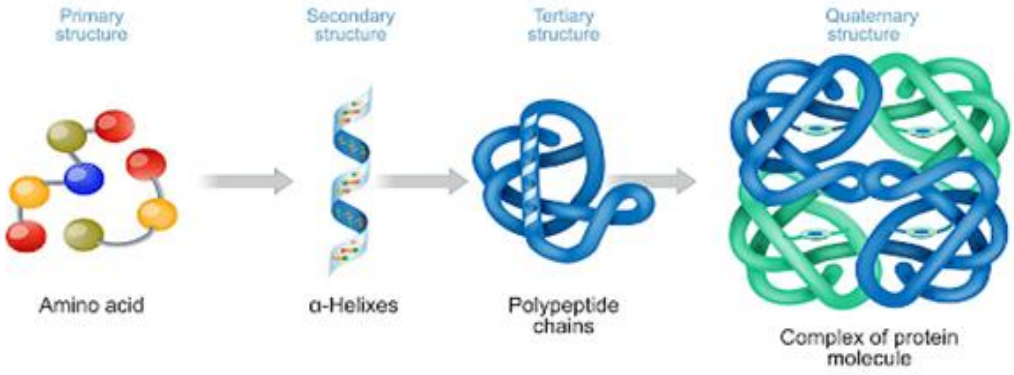


Fig 14: Protein Structures

Classification of Protein

Proteins are classified on the basis of:

a. **Shape**

- **Fibrous Proteins:** Usually long and elongated in structure, fibrous proteins help in maintaining and giving shape to the cell. They are insoluble in water and are less sensitive to factors such as changes in temperature and pH. Examples include keratin, collagen, elastin, and fibrin.
- **Globular Proteins:** Typically, spherical in shape. they are responsible for carrying out specific biological functions in the body. They are soluble in water and are more sensitive to temperature and pH. Examples include hemoglobin, myoglobin, insulin, enzymes.
- **Constitution**
- **Simple Proteins:** They are the combinations of only amino acids. Example: .g. albumins, globulins, prolamins, etc.
- **Conjugated Proteins:** These are combinations of complex proteins and non–amino acid substances called a prosthetic group. These are of the following types:
- **Nucleoproteins:** Combination of protein and nucleic acid
- **Mucoproteins:** Combination of proteins and carbohydrates
- **Glycoproteins:** Combination of proteins and carbohydrates
- **Chromoproteins:** Combination of proteins and colored pigments.
- **Lipoproteins:** Combination of proteins and lipids.
- **Metalloprotein:** Combination of proteins and metal ions.
- **Phosphoprotein**: Combination of proteins and phosphate group.
- **Derived Proteins:** These are the degradation products obtained when proteins are hydrolyzed by acids, alkalies, or enzymes.
- **Nature of Molecules**
- **Acidic Proteins:** These proteins contain acidic amino acids which exist as anions. E.g.: blood groups.
- **Basic proteins:** These proteins contain basic amino acids which exist as cations. Eg: lysine, arginine.

Functions of Protein

Proteins are used in many ways. Some of their functions are:

- **Enzymes:** Most of the important chemical reactions which take place inside a cell are mostly carried out by enzymes. They also play a role in regenerating and creating DNA molecules and carrying out complex processes.
- **Hormonal Regulation:** Proteins create various types of hormones that help in balancing the components of the body. For example, hormones like insulin help in regulating blood sugar and secretin. The formation of digestive juices essential for the whole digestion process is also possible because of hormones.
- **Protection:** Being the main constituent of antibodies, proteins protect our body against antigens and pathogens thus preventing infections.
- **Energy:** Proteins are one the most essential sources of energy required for our body movements. The right number of proteins should be consumed so that they can be turned into energy.
- **Structural functions:** Proteins are the building blocks of the body. They are required for the growth, development, healing, and repair of tissues. Proteins are essential in order to strengthen various structures like hair, skin, and muscles. It is also present in the outer membrane of all cells in the human body.

Protein Synthesis

Protein synthesis is an essential biological process that takes place inside a cell. The translation is a process by which protein synthesis takes place. Occurring in the cytoplasm of a cell, this process involves the rendering of genetic codes. Ribosomes present inside a cell are responsible for translating genetic codes into a polypeptide chain. These polypeptide chains become functioning proteins after undergoing certain modifications.

Importance of protein synthesis

- The process of protein synthesis serves as a method to produce proteins for the body.
- The process occurs in a few stages. First, the genetic code is copied from DNA in the nucleus to a molecule called mRNA.
- Then, transcription and translation will occur and with the help of a ribosome, a protein is created.

Purpose of Protein Synthesis

- Protein synthesis leads to the production of a vast number of proteins that play an integral role in cell function and structure alike.
- They serve many functions in the cell including animal cells using proteins for cell division, plants using proteins to produce sugars for food, and bacteria using protein as a defense against antibiotics.

Where Does the Protein Synthesis Take Place?

- Protein synthesis occurs in the cytoplasm of cells, specifically at the ribosome.
- Ribosomes are sub-units that are the site of protein synthesis. Before information is sent to the ribosome in the form of mRNA, it is stored in the nucleus as DNA.
- The process of transcriptions is responsible for copying the code from DNA to mRNA.
- This process allows the code from DNA to leave the nucleus and head to the ribosome.
- At the ribosome, tRNA will work with rRNA and mRNA in a process called translation.
- This process occurs at the ribosome and results in a chain of amino acids, linked by peptide bonds, which will become a protein.

Protein Synthesis Process

Protein synthesis occurs in two main steps: transcription and translation. Transcription is the first of overall two protein synthesis steps. During transcription, the information encoded in the DNA is copied to a RNA molecule as one strand of the DNA double helix is used as a template. The RNA molecule is sent to the cytoplasm, which helps to bring all components required for the actual protein synthesis together – amino acids, transport RNAs, ribosomes, etc. In the cytoplasm the protein polymers are actually "synthesized" through chemical reactions – that is why the process is known as "protein synthesis" or even more precisely – "protein biosynthesis". The RNA copy of the protein genetic information encoded in DNA molecule is produced in the nucleus and it is called messenger RNA (mRNA). Each mRNA encodes the information for a single protein and is much smaller in size compared to the DNA molecule. This makes possible for mRNA molecules to exit the nucleus through tiny openings called nuclear pores. Once it exits the nucleus and enters the cytoplasm, the mRNA could interact with a cellular structure known as a ribosome, which serves as the cell's assembler within the process of protein synthesis. The ribosome consists

of proteins and ribosome RNA molecules (rRNA), which are organized in two subunits. The mRNA initially binds to just one of the ribosome sub-units. When the mRNA interacts with the big ribosome sub-unit, this triggers the approach of another RNA molecule, called transfer RNA (tRNA). The tRNA molecule possess a specific sequence of 3-bases (anti-codon), which hast to complement a corresponding sequence (codon) within the mRNA sequence. When it finds it, it attaches to the mRNA, as the other end of the tRNA is "loaded" with an amino acid. At this point arrives the other sub-unit of the ribosome and a complete structure is formed. The first tRNA binds to a so called "start codon", which is one and the same for all proteins. As the complete ribosome structure is formed, another tRNA molecule approaches. The next tRNA differ from the first one and is carrying another amino acid. Again, the tRNA must have an anti-codon that matches complementary the second codon of the mRNA. The two amino acids carried by the first two tRNAs are bind together with help from the ribosome and using cellular energy in the form of adenosine triphosphate (ATP). The above steps repeats until there are uncoupled codon sequences on the mRNA – thus the chain of amino acids grows longer. Once the sequence of amino acids is successfully assembled in a protein, the two ribosome sub-units separate from each other, to be joined again for later use. The actual sequence of amino acids forms the so called primary structure of the proteins. Depending on the exact composition and order of the amino acids in the protein sequence, the chain folds into a three-dimensional shape. When this happens the protein is complete. The process of protein synthesis takes place in multiple ribosomes simultaneous and all throughout the cell cytoplasm. A living cell can synthesize hundreds of different proteins every single second.

The Role of Protein Synthesis in Biological Systems

Protein synthesis is the process that occurs in the body in two main stages known as transcription and translation that ultimately produces proteins. Proteins are molecules that help to do work in the body, and come in many forms, including enzymes. An example of an enzyme in humans is lactase, which aids in the breakdown of the sugar lactose, which is commonly found in dairy products.

Since lactase breaks down lactose, a person missing lactase is unable to digest the sugar lactose.

Proteins serve many functions in the cell including animal cells using proteins for cell division, plants using proteins to produce sugars for food, and bacteria using protein as a defense against antibiotics. In animals specifically, myostatin regulates muscle cells so they don't grow without control. Also, another protein called p53 aids in cell division

and ensures they don't divide out of control. A damaged p53 protein would result in an individual being at risk for uncontrolled cell division.

What is a protein?

What are the two main types of protein and what are their roles?

Self-Assessment Exercises

1. Describe the primary structure of a protein.
2. Describe the secondary structure of a protein.
3. Describe the tertiary structure of a protein.
4. Describe the quaternary structure of a protein.

3.4: Summary

Proteins are an essential macronutrient present in all living organisms. Proteins are made up of linear chains of smaller units called amino acids. The structure of proteins is divided into four types:

Primary, Secondary, Tertiary, and Quaternary. Protein synthesis is an essential biological process that takes place in the cytoplasm of a cell. The translation is a process by which protein synthesis takes place. Proteins are classified on the basis of their shape, constitution, and nature of molecules. Most of the important chemical reactions which take place inside a cell are mostly carried out by enzymes.

It is one of the most fundamental biological processes by which individual cells build their specific proteins. Within the process are involved both DNA (deoxyribonucleic acid) and different in their function ribonucleic acids (RNA). The process is initiated in the cell's nucleus, where specific enzymes unwind the needed section of DNA, which makes the DNA in this region accessible and a RNA copy can be made. This RNA molecule then moves from the nucleus to the cell cytoplasm, where the actual the process of protein synthesis take place.

4.5: References/Further Readings/Web Sources

Cooper, G. M. (1997). The cell: a molecular approach. Washington, DC: ASM Press.

Taylor, W. R., & Stark, G. R. (2001). Regulation of the G2/M transition by p53. Oncogene, 20(15), 1803-1815. doi: 10.1038/sj.onc.1204252

Pray, L. (2009). Discovery of DNA Structure and Function: Watson and Crick. *Nature Education, 100-101*

Landmark Papers in Cell Biology (2000): *Selected Research Articles Celebrating Forty Years of the American Society for Cell Biology*. ColdSpring Harbor Laboratory Press.

Mazzarello P. A. (1999). Unifying Concept: The History of Cell Theory. *Nat Cell Biology*. 1(1): E13-5.

https://www.bing.com/ck/a?!&&p=bbb2f940b048e63eJmltdHM9MTY3NTY0MTYwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTIyNg&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=protein+structure+and+synthesis+of+cell&u=a1aHR0cHM6Ly93d3cubmNiaS5ubG0ubmloLmdvdi9ib29rcy9OQks5OTE0Lw&ntb=1

https://www.bing.com/ck/a?!&&p=681ca6b24282753eJmltdHM9MTY3NTY0MTYwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTIwOQ&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=protein+structure+and+synthesis+of+cell&u=a1aHR0cHM6Ly9vcGVuYm9va3MubGliLm1zdS5lZHUvaXNiMjAyL2NoYXB0ZXIvcHJvdGVpbi1zdHJ1Y3R1cmUtYW5kLWZ1bmN0aW9uLw&ntb=1

https://www.bing.com/videos/search?q=protein+structure+and+synthesis+of+cell&&view=detail&mid=F45668A5896922A65A14F45668A5896922A65A14&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3Dprotein%2Bstructure%2Band%2Bsynthesis%2Bof%2Bcell%26FORM%3DHDRSC4

4.6: Possible Answers to Self-Assessment Exercises

1. The initial form of a protein; a singular polypeptide chain made up of a series of amino acids. This structure determines the ultimate shape, hence function, of the protein.

2. 'Folding' of the primary structure into local motifs, the α-helix and the β-sheet. The number, types of and extent of these motifs determines the secondary structure.

3. Further 'twisting' of secondary structure proteins into more complex shapes meaning that they have a 3D globular configuration.

4. The subunits of a molecular complex. Multiple quaternary structure proteins are combined together with non-protein prosthetic groups to produce large structures e.g. haemoglobin.

Unit 5: Nucleic Acids component and functions of Cells

Unit Structure

51: Introduction

In 1869, Friedrick Miescher discovered **nuclein** in eukaryotic cells. Nuclein is the material found in the nucleus, consisting mainly of nucleic acids, protein, and phosphoric acid. In 1889, Richard Altmann investigated the chemical properties of nuclein. He found it behaved as an acid, so the material was renamed **nucleic acid**. Nucleic acid refers to both DNA and RNA. In 1938, the first x-ray diffraction pattern of DNA was published by Astbury and Bell. In 1953, Watson and Crick described the structure of DNA. While discovered in eukaryotes, over time scientists realized a cell need not have a nucleus to possess nucleic acids. All true cells (e.g., from plants, animals, fungi) contain both DNA and RNA. The exceptions are some mature cells, such as human red blood cells.

A virus has either DNA or RNA, but rarely both molecules. While most DNA is double-stranded and most RNA is single-stranded, there are exceptions. Single-stranded DNA and double-stranded RNA exist in viruses. Even nucleic acids with three and four strands have been found.

5.2: Intended Learning Outcomes

By the end of this unit, students should be able to;

- Enumerate nucleic acid characteristics, types and functions.

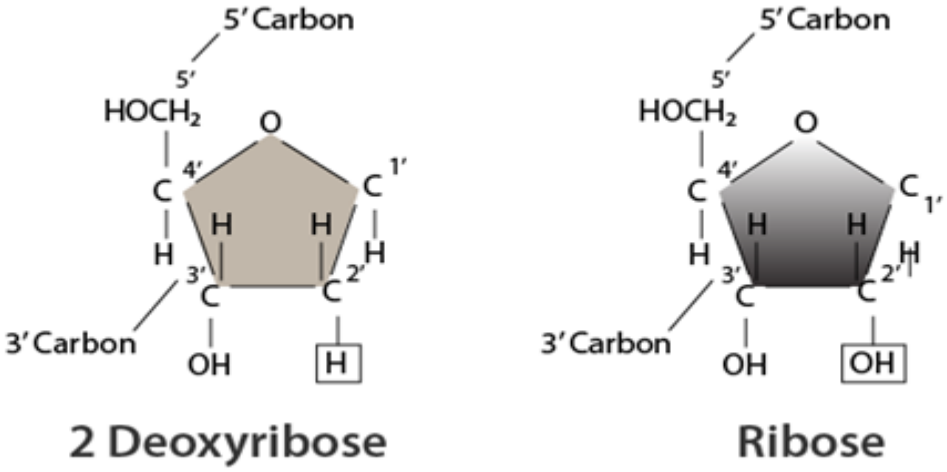
5.3: Main Body

Nucleotides

Nucleotides (backbone units of nucleic acids), consist of sugar, a nitrogenous base, and a phosphate. The sugars are either ribose or deoxyribose. They differ by the lack of one oxygen in deoxyribose. Both are pentoses usually in a ring form. Most of them, not just ATP, are the sources of energy that drive most of our reactions. ATP is the most commonly used source but GTP is used in protein synthesis as well as a few other reactions. UTP is the source of energy for activating glucose and galactose. CTP is an energy source in lipid metabolism. AMP is part of the structure of some of the **coenzymes like NAD and Coenzyme A**. And, of course, the nucleotides are part of nucleic acids.

Nucleic Acids

Nucleic acids are long-chain polymeric molecules. The monomer or the repeating unit is known as the nucleotides and hence sometimes nucleic acids are referred to as polynucleotides. Nucleic acids can be defined as organic molecules present in living cells. It plays a key factor in transferring genetic information from one generation to the next. Nucleic acids are composed of DNA-deoxyribonucleic acid and RNA-ribonucleic acid that form the polymer of nucleotides.



In the nucleus, nucleotide monomers are linked together comprising of distinct components namely a Phosphate Group, Nitrogenous Bases or Ribose and Deoxyribose. Pyrimidines and Purines are two types of nitrogenous bases. Pyrimidines are composed of cytosine and thymine. Purines are composed of guanine and adenine. Thymine is replaced by Uracil in ribonucleic acid whereas deoxyribonucleic acid comprises of all four bases.

Nucleic acids are molecules that allow organisms to transfer genetic information from one generation to the next. These macromolecules store the genetic information that determines traits and makes protein synthesis possible. Nucleic acids are macromolecules that store genetic information and enable protein production. Nucleic acids include DNA and RNA. These molecules are composed of long strands of nucleotides.

Nucleotides are composed of a nitrogenous base, a five-carbon sugar, and a phosphate group. DNA is composed of a phosphate-deoxyribose sugar backbone and the nitrogenous bases adenine (A), guanine (G), cytosine (C), and thymine (T). RNA has ribose sugar and the nitrogenous bases A, G, C, and uracil (U). Two examples of nucleic acids include deoxyribonucleic acid (better known as DNA) and ribonucleic acid (better known as RNA). These molecules are composed of long strands of nucleotides held together by covalent bonds. Nucleic acids can be found within the nucleus and cytoplasm of our cells.

Basic Components of Nucleic Acids

Nucleic acids consist of nucleotides. Nucleotides have three characteristic components. Thus;

- Nitrogenous Bases: the nitrogenous bases are the derivatives of two-parent compounds. They are PURINES & PYRIMIDINES
- Purines: Purine bases are found in nucleic acids and are heterocyclic compounds consisting of a pyrimidine ring and an imidazole ring fused. The two purine bases are;
- **Adenine** (6-Amino Purine): ($C_5H_5N_5$), found in both RNA and DNA, is a white crystalline purine base, with a molecular weight of 135.15 Dalton and a melting point of 360 to 365 C.
- Guanine (2-Amino-6-oxyPurine): ($C_5H_5ON_5$), also found in both DNA and RNA, is a colorless, insoluble crystalline substance, with MW=151.15 Dalton. It was first isolated from guano (bird manure), hence its name.

a) Pyrimidines: Pyrimidine bases consist of a six-membered ring with two nitrogen atoms. The pyrimidine bases are;

- **Cytosine** (2-Oxy-4-amino pyrimidine): ($C_5H_6O_2N_5$), found in both RNA and DNA, is a white crystalline substance, with an MW of 111.12 daltons and a melting point of 320 to 325 C.
- Thymine (2, 4-dioxy-5-methyl pyrimidine) ($C_5H_6O_2N_2$), found in DNA molecules only, has an MW of 126.13 Daltons. It was first isolated from the thymus, hence its name. Thymine is present in RNA only.
- Uracil (2, 4-dioxy pyrimidine) ($C_4H_4O_2N_2$), found in RNA molecules only, is a white, crystalline pyrimidine base with an

MW of 112.10 daltons and a melting point of 338 C. Uracil is present in DNA only.

- Sugar Moiety: Pentose sugar is present in DNA & RNA. It is present in their "β-furanose" (closed five number rings) and of β-configuration. Two types of pentose sugars are present in the nucleic acid. Ribose (present in RNA) and 2-Deoxyribose (present in DNA)
- Phosphorus acid: This is one of **the fundamental components of nucleic acids.** It contains the monovalent hydroxyl groups and one divalent oxygen atom, all of which are linked to the pentavalent phosphorus atom. The base is joined covalently (at N1 for pyrimidines and N9 for purines) and the phosphate is esterified to the 5'-carbon. The N-glycosyl bond is formed by the removal of the elements of water (hydroxyl groups from pentose and hydrogen atoms from the base). Adenosine triphosphate, better known as ATP, the energy currency or coin of the cell, transfers energy from chemical bonds to endergonic (energy absorbing) reactions within the cell. Structurally, ATP consists of the adenine nucleotide (ribose sugar, adenine base, and phosphate group, PO_4^{-2}) plus two other phosphate groups.

General Functions of Nucleic Acids

- Nucleic Acid is responsible for the synthesis of protein in our body.
- RNA is a vital component of protein synthesis.
- Loss of DNA content is linked to many diseases.
- DNA is an essential component required for transferring genes from parents to offspring.
- All the information of a cell is stored in DNA.
- DNA fingerprinting is a method used by forensic experts to determine paternity.
- It is also used for the identification of criminals.
- It has also played a major role in studies regarding biological evolution and genetics.

Ribonucleic Acid (RNA)

RNA was discovered after DNA. The RNA molecule is composed of phosphoric acid, a pentose sugar and some cyclic bases containing nitrogen. RNA has β-D-ribose in it as the sugar moiety.

The heterocyclic bases present in RNA are adenine (A), guanine (G), cytosine(C) and uracil (U).

In RNA the fourth base is different from that of DNA. The RNA generally consists of a single strand which sometimes folds back; that results in a double helix structure. DNA, with exceptions

in chloroplasts and mitochondria, is restricted to the nucleus (in eukaryotes, the nucleoid region in prokaryotes). There are three types of RNA:

- Messenger RNA (mRNA) is the blueprint for the construction of a protein.
- Ribosomal RNA (rRNA) is the construction site where the protein is made.
- Transfer RNA (tRNA) is the truck delivering the proper amino acid to the site at the right time.

Functions of RNA (Ribonucleic Acid)

- RNA is synthesized by DNA for the transportation of genetic information to the protein building apparatus in the cell.
- RNA also directs the synthesis of new proteins using the geneticinformation it has transported.
- mRNA (messenger ribonucleic acid) is used to transfer genetic information through plasma membranes

Deoxyribonucleic Acid (DNA)

Chemically, DNA is composed of a pentose sugar, phosphoric acid and some cyclic bases containing nitrogen. The sugar moiety present in DNA molecules is β-D-2-deoxyribose. The cyclic bases that have nitrogen in them are adenine (A), guanine (G), cytosine(C) and thymine (T). These bases and their arrangement in the molecules of DNA play an important role in the storage of information from one generation to the next one. DNA has a double-strand helical structure in which the strands are complementary to each other.

Functions of DNA (Deoxyribonucleic Acid)

- DNA is a permanent storage place for genetic information.
- DNA controls the synthesis of RNA (ribonucleic acid).
- The sequence of nitrogenous bases in DNA determines the protein development in new cells.
- The function of the double helix formation of DNA is to ensure that no disorders occur.

- This is because the second identical strand of DNA that runs anti-parallel to the first is a backup in case of lost or destroyed genetic information.

In what year did Watson and Crick describe the structure of DNA?

Self-Assessment Exercises

- Enumerate six functions of Nucleic Acids

5.4: Summary

The nucleic acids, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) consist of nitrogen bases, sugars and phosphate groups and carry out vital functions in the living cells of organisms.

5.5: References/Further Readings/Web Sources

Pelczar, M.J., Chan, E.C.S. & Krieg, N.R. (1986). *Microbiology*, International Edition, McGraw Hill International Editions.

Snyder, L. & Champness, W. (2003). *Molecular Genetics of Bacteria*, Second Edition, Washington, D.C.

https://www.bing.com/ck/a?!&&p=fff283c8b2b67416JmltdHM9MTY3NTY0MTYwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTE5Mw&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=nucleic+acids+components+and+functions+in+cell&u=a1aHR0cHM6Ly93d3cubmNiaS5ubG0ubmloLmdvdi9ib29rcy9OQks5ODc5Lw&ntb=1

https://www.bing.com/ck/a?!&&p=1012c3505692aa30JmltdHM9MTY3NTY0MTYwMCZpZ3VpZD0zNWJkZWU5MC0xOTQ1LTYyYjQtMzAzNi1mY2M1MTg1ODYzNGUmaW5zaWQ9NTIyNQ&ptn=3&hsh=3&fclid=35bdee90-1945-62b4-3036-fcc51858634e&psq=nucleic+acids+components+and+functions+in+cell&u=a1aHR0cDovL3d3dy5jaGVtLmxhdGVjaC5lZHUvfnVwYWxpL2NoZW0xMjEvTm90ZXMtQzIyLTEyMS5wZGY&ntb=1

https://www.bing.com/videos/search?q=nucleic+acids+components+and+functions+in+cell&&view=detail&mid=B82DE4693209923ACFB8B82DE4693209923ACFB8&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3Dnucleic%2Bacids%2Bcomponents%2Band%2Bfunctions%2Bin%2Bcell%26FORM%3DHDRSC4

https://www.bing.com/videos/search?q=nucleic+acids+components+and+functions+in+cell&&view=detail&mid=54F77CAC1E44A503F40C54F77CAC1E44A503F40C&&FORM=VRDGAR&ru=%2F

videos%2Fsearch%3Fq%3Dnucleic%2Bacids%2Bcomponents%2Band%2Bfunctions%2Bin%2Bcell%26FORM%3DHDRSC4

5.6: Possible Answers to Self-Assessment Exercises

- Nucleic Acid is responsible for the synthesis of protein in our body.
- RNA is a vital component of protein synthesis.
- Loss of DNA content is linked to many diseases.
- DNA is an essential component required for transferring genes from parents to offspring.
- All the information of a cell is stored in DNA.
- DNA fingerprinting is a method used by forensic experts to determine paternity.
- It is also used for the identification of criminals.
- It has also played a major role in studies regarding biological evolution and genetics.

Glossary

- Adenine - A purine that base-pairs with either thymine or uracil.
- Adherens junction: A region of cell-cell adhesion at which the actin cytoskeleton is anchored to the plasma membrane.
- Anaphase: the phase of mitosis during which sister chromatids separate and move to opposite poles of the spindle.
- Cell wall A rigid, porous structure forming an external layer that provides structural support to bacteria, fungi, and plant cells.
- Centriole - A cylindrical structure consisting of nine triplets of microtubules in the centrosomes of most animal cells.
- Centromere: A specialized chromosomal region that connects sister chromatids and attaches them to the mitotic spindle.
- Centrosome - The microtubule-organizing center in animal cells.
- Chromosomes - The carriers of genes, consisting of long DNA molecules and associated proteins.
- Deoxyribonucleic acid (DNA) - The genetic material of the cell.
- Desmosome - A region of contact between epithelial cells at which keratin filaments are anchored to the plasma membrane.
- Diakinesis: The final stage of the prophase of meiosis I during which the chromosomes fully condense and the cell progresses to metaphase.
- Diploid - An organism or cell that carries two copies of each chromosome.

- Diplotene - the stage of mieosis I during which homologous chromosomes separate along their length but remain associated at chiasmata.
- Endoplasmic reticulum (ER) - An extensive network of membrane-enclosed tubules and sacs involved in protein sorting and processing as well as in lipid synthesis.
- G_0 - A quiescent state in which cells remain metabolically active but do not proliferate.
- G_1 phase - The phase of the cell cycle between the end of mitosis and the beginning of DNA synthesis.
- G_2 phase: The phase of the cell cycle between the end of S phase and the beginning of mitosis.
- Gap junction - A plasma membrane channel forming a direct cytoplasmic connection between adjacent cells.
- Meiosis - The division of diploid cells to haploid progeny, consisting of two sequential rounds of nuclear and cellular division.
- messenger RNA (mRNA)- An RNA molecule that serves as a template for protein synthesis.
- Metaphase - The phase of mitosis during which the chromosomes are aligned on a metaphase plate in the center of the cell.
- Tight junction - A continuous network of protein strands around the circumference of epithelial cells, sealing the space between cells and forming a barrier between the apical and basolateral domains.

End of the module Questions

- What makes up protein structure?
- What are the 4 stages of protein structure?
- What is the process of protein folding?
- How proteins are formed?
- Is DNA a protein?
- What determines protein structure?
- What is the primary structure of a protein?
- **How many connexins are found in one gap junction channel?**
  A. 6
  B. 4
  C. 12
  D. 2

9. What is the "bystander effect" in relation to gap junctions?

A. Molecules can enter neighboring cells without passing through extracellular fluid.
B. Cells next to a cell that is undergoing cell death can also die.
C. Cells can transmit therapeutic compounds to one another.
D. Gap junctions are only found in cells that are located next to other cells.

10. Which is NOT a function of gap junctions?

A. Forming a barrier
B. Allowing molecules to pass between cells
C. Electrically coupling cells
D. Ensuring correct embryonic development

Answers

1. A protein's primary structure refers to the amino acid sequence in the polypeptide chain. Peptide bonds that are made during the protein biosynthesis process hold the primary structure together.
2. Four levels of structure of proteins. The principal, secondary, tertiary and quaternary levels of protein structure are the four stages. To fully understand how a protein functions, it is helpful to understand the purpose and role of each level of protein structure.
3. The folding of proteins is the mechanism through which a protein structure assumes its functional shape or conformation. Both molecules of protein are heterogeneous unbranched amino acid chains. They may perform their biological function by coiling and folding in a particular three-dimensional shape.
4. Amino acids form a polypeptide, In another words when amino acids bound by a sequence of peptide bonds, leads to formation of proteins. The polypeptide then folds into a particular conformation based on the interactions (strained lines) between its side chains of amino acids.
5. DNA is often associated with proteins in the nucleus called histones, but DNA itself is not a protein. No. DNA is a nucleic acid consisting of phosphate and sugar groups, bases (purines and pyrimidines), while proteins are large molecules made up of one or more long amino acid chains.
6. In the polypeptide chain, the main structure of a protein relates to the amino acid sequence. The primary structure is bound together by peptide bonds that are made during the phase of protein biosynthesis. The primary structure of a protein is determined by the gene corresponding to the protein.
7. The linear sequence of amino acids within a protein is called the primary structure of the protein. A sequence of just twenty amino

acids, each of which has a special side chain, is made up of proteins. The side chains of amino acids are chemically distinct.

8. **C** is correct. Six connexins form a unit called a connexon, which is half of a gap junction channel. Two connexons put together form a gap junction channel, so 12 total connexins make up one channel.
9. **B** is correct. All of these choices are true about gap junctions, but only choice B describes the bystander effect. When a diseased or injured cell dies, it sends out signals that reach adjacent cells, which can cause them to also die. This is called the bystander effect because the cells are like innocent bystanders that become victims at the scene of a crime.
10. **A** is correct. Gap junctions do not form a barrier; they have the opposite function. They connect adjacent cells together and have important roles in cell communication and embryonic development.