MODULE 1: HISTORY AND PRESENT TRENDS IN CELL BIOLOGY

UNIT1: HISTORY OF CELL BIOLOGY

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1.0 INTRODUCTION

You may be wondering why we need to discuss the cell theory. The cell theory or cell doctrine states that all living organisms are composed of similar units of organization, called cells. A cell is the basic unit of a living organism. 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).

2.0 A: OBJECTIVES

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

- Discuss the history of cell biology.
- Itemize cell biology historical timeline.
- Discuss key events in scientific history.

2.0B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators

and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.
4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENTS

3.1 First Cells Seen in Cork

While the invention of the telescope made the Cosmos accessible to human observation, the microscope revealed the identities of microbes and shows what living forms were composed of. The cell was first discovered and named by Robert Hooke in 1665. He remarked that it looked strangely similar to cellular or small rooms which monks inhabited, thus depriving the name. However, what Hooke actually saw was the dead cell walls of plant cells called the cork as it appeared under the microscope. Hooke's description of these walls was published in Micrographia. The cell walls observed by Hooke gave no identification of the nucleus and other organelles found in most living cells. The first man to witness a live cell under a microscope was Anton van Leeuwenhoek, who in 1674 described the alga spirogyra.

Fig. 1 Electron Microscope of Cell(source: Dennis Kunkel Microscopy, 2009)

3.2 Formulation of the Cell Theory

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 next year, gave 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 in living things.
- The cell retains a dual existence as a distinct entity and a building block 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 cellular***……..** "All cells arise from pre-existing cells".

3.3 Modern Cell Theory

Let us examine the following statements that represent the modern cell theory:

- All known living things are made up of cells;
- The cell is the structural functional unit of all living things;
- All cells arise from pre-existing cells by division. (Spontaneous Generation does not occur);
- Cells contain hereditary information which is passed from cell to cell during cell division;
- All cells are basically the same in chemical composition;
- All energy flow (metabolism and biochemistry) of life occurs within cells.

As with the rapid growth of molecular biology in the mid-20th century, cell biology research exploded in the 1950's. It became possible to maintain, grow and manipulate cells outside of living organisms. The first continuous definition to be so cultured was in 1951 by George Otto Gey and coworkers, derived from cervical cancer cells taken from Henrietta Lacks, who died from the cancer in 1951. The cell line, which was eventually referred to as HeLa cells, have been the watershed in studying cell biology just as the structure of Deoxyribonucleic Acid (DNA) was significant breakthrough of molecular biology.

In an avalanche of progress in the study of cells, the coming decade included the characterization of the minimal media requirements for cells and development of sterile cell culture techniques. You should also know that the study of cells was also aided by the prior advances in electron microscopy, and later advances such as development of transfection methods, discovery of small interfering Ribonucleic Acid (siRNA), among others.

3.4 A Timeline

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

1595- Jansen credited with 1st compound microscope
1665- Hooke described 'cells' in cork
1674- Leeuwenhoek discovered protozoa. He observed bacteria some nine years later
1833- Brown described the cell nucleus in cells of the orchid
1838- Schleiden and Schwann proposed cell theory
1840- Albrecht von Roelliker realized that sperm cells and egg cells are also cell
1856- N. Pringsheim observed how a sperm cell penetrate an egg cell
1858- Rudolf Virchow (physician, pathologist and anthropologist) expounds his famous conclusion: omniscellulaecellula, which is cells develop only from pre-existing cells (cells come from pre-existing cells)
1857- Kolliker described mitochondria
1879- Flemming described chromosome behavior during mitosis
1883- Germ cells are haploid, chromosome theory of heredity
1898- Golgi described the Golgi apparatus
1938- Behrens used differential centrifugation to separate nuclei from cytoplasm
1939- Siemens produced the first commercial transmission electron microscope
1952- Gey and coworkers established a continuous human cell line
1955- Eagle systematically defined the nutritional needs of animal cells in culture
1957- Meselson, Stahl and Vinograd developed density gradient centrifugation in cesium chloride solutions for separating nucleic acids
1965- Ham introduced a defined serum-free medium. Cambridge Instruments produced the first commercial scanning electron microscope.
1976- Sato and colleagues published different cell line that required different mixtures of hormones and growth factors in serum-free media.
1981- Transgenic mice and fruit flies were produced. Mouse embryonic stem cell line was established.
1995- Tsien identified mutant GFP with enhanced spectral properties
1998- Mice were cloned from somatic cells
1999- Hamilton and Baulcombe discovered siRNA as part of post-transcriptional gene silencing (PTGS) in plants

4.0 CONCLUSION

The cell is the basic unit of all living organisms and all cells are derived from pre-existing cells by cell division.

5.0 SUMMARY

In this unit we have learnt that:

- 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.

6.0 TUTOR MARKED ASSIGNMENT

1. What is the important information that shapes the modern cell theory?
2. Write short notes on any five scientists on cell theory.

7.0 FURTHER READING AND OTHER RESOURCES

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

Mazzarello P. A. 1999. Unifying concept: the history of cell theory.Nat Cell Biology. 1(1):E13-5

UNIT 2: HISTORICAL VIEW POINT

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1.0 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 microscopists. You will come across the contributions of the microscope in revealing cellular structures and microbes.

2.0 A: OBJECTIVES

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

- Write on the historical development of Science.
- Explore profiles of influential scientists and philosophers.
- Discuss the contributions of each of the scientists/ Philosophers to the development of cell theory.

B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of

confirming what you have done.

4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENTS

3.1 Histories of cell 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 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 van Leeuwenhoek then described many specific forms of these microorganisms (which he called "animalcules"), including protozoa and other unicellular organisms.

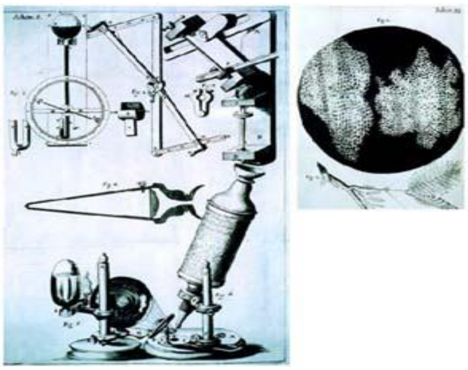

Fig. 2 **Leeuwenhoek Microscope**

Source: Pelczar M.J. et al.,1986. Microbiology McGraw-Hill International Editions

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 microscopist. 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. They are:

Hans and Zacharias Janssen (1595)

- Dutch lens grinders, father and son
- produced first compound microscope of two lenses

Robert Hooke (1665)

- English scientist
- looked at a thin slice of cork (oak cork) through a compound microscope
- observed tiny, hollow, roomlike 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 not living

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)

- German botanist
- viewed plant parts under a microscope
- discovered that plant parts are made of cells

Theodor Schwann (1839)

- German zoologist
- viewed animal parts under a microscope
- discovered that animal parts are made of cells

Rudolph Virchow (1855)

- German physician
- stated that all living cells come only from other living cells

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 facitsaltus*, was disproved by the masterful experiments of the Italian naturalist LazzaroSpallanzani (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 scalanaturae was a motive in early-nineteenth-century biological thought: what could be the minimal unit carrying the potential for life?

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. It soon became evident that the protoplasm was not a homogeneous fluid. Some biologists regarded its fine structure as fibrillary, whereas others described it as a reticular, alveolar or granular protoplasmic architecture. This discrepancy resulted partly from artefactual and illusory images due to fixation and staining procedures that caused a non-homogeneous precipitation of colloidal complexes.

Later, some staining of real cellular components led to the description of differentiated cellular elements, which were subsequently identified. The introduction of the oil-immersion lens in 1870, the development of the microtome technique and the use of new fixing methods and dyes greatly improved the identities of cellular components.

Towards the end of the nineteenth century, the principal organelles that are now considered to be parts of the cell were identified. The term "ergastoplasm" (endoplasmic reticulum) was introduced in 1897; mitochondria were observed by several authors and named by Carl Benda (1857−1933) in 1898. Camillo Golgi (1843−1926) discovered the intracellular apparatus, the golgi bodies in 1898.

The protoplasm was not the only structure to have a heterogeneous appearance. Within the nucleus, the nucleolus and a stainable substance could be seen. Moreover, a number of structures (ribbons, bands and threads) appeared during cell division. As these structures could be heavily stained, they were called "chromatin" by Walther Flemming (1843−1905), who also introduced the term "mitosis" in 1882 and gave a superb description of its various processes. Flemming observed the longitudinal splitting of salamander chromosomes during metaphase and established that each half-chromosome moves to the opposite pole of the mitotic nucleus. This process was also observed in plants, providing further evidence of the deep unity of the living world.

3.4 The neuron theory

There was, however, a tissue that seemed to belie the cell theory, the nervous tissue. Because of its softness and fragility, it was difficult to handle and susceptible to deterioration. But it was its structural complexity that prevented a simple reduction to models derived from the cell theory. Nerve-cell bodies, nervous prolongations and nervous fibres were observed in the first half of the nineteenth century. However, attempts at reconstructing a three-dimensional structure of the nervous system were frustrated by the impossibility of determining the exact relationships between cell bodies (somas), neuronal protoplasmic processes (dendrites) and nervous fibres.

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)

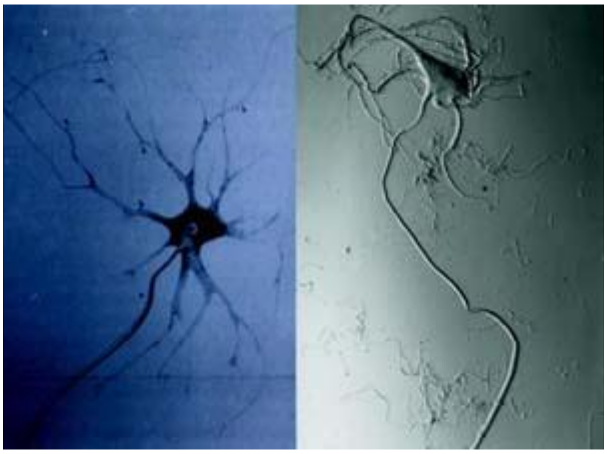

Fig. 3: ***The Neuron***

Source: Karl Deiters (reproduced from Deiters, O. F. K. (Braunschweig, Vieweg, 1865).). The long axon in both cases does not appear ramified because branchings were disrupted during the procedure.

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 its processes, 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 connecting nerve 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 that the 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 by contiguity 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 and 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.

4.0 CONCLUSION

Cell theory obtained its final triumph when the nervous system was also found to be made up of independent units.

5.0 SUMMARY

In this unit we have learnt that:

- The microscope means much to the naturalists.
- The idea of spontaneous generation was refuted by Louis Pasteur.

6.0 TUTOR MARKED ASSIGNMENT

Name and state the contributions of any five ancient scientists of Cell Biology.

7.0 FURTHER READING AND OTHER RESOURCES

Dutta, A. C. (1963).Botany for degree students 5th edition. Oxford University Press, Delhi.

Paolo M. (1999). A unifying concept: the history of cell theory Nature Cell Biology 1, E13 - E15.

UNIT 3: THE CELL THEORY

CONTENTS

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1.0 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 the modern cell theory. Here is an overview of the progression of thought that has contributed to today's cell theory.

2.0 A: OBJECTIVES

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

- Analyze the modern cell theory;
- Evaluate evidence to support cell theory;
- Have knowledge of basic historical science facts.

2.0 B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.

2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.

3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.

4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENTS

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 went on 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 she finds at her 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.

3.1 The cell theory

Hints at the idea that the cell is the basic component of living organisms emerged well before 1838−39, 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 more opaque 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 JakobSchleiden (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 omniscellula 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 Cellularpathologie was the most important pathogenic concept until, in this century, the theory of molecular pathology was developed.

Activity

1. What theory did these scientists provide evidence for?
2. What instrument was necessary before the cell theory could be developed?
3. Which three scientists directly contributed evidence for the cell theory?
4. How did the earlier scientists and their contributions directly affect the discoveries of later scientists (see #2)? For example, what had to come first?
5. List the three parts of the cell theory.

4.0 CONCLUSION

Cell is the structural unit of life

5.0 SUMMARY

In this unit we have learnt that:

- Chromatic aberration is a principal drawback of microscopes since van Leeuwenhoek's time.
- Cells are formed through scission of pre-existing cells.
- Mitosis observed in plants, provides further evidence of the deep unity of the living world.
- Historical events leading to the development of the cell theory.

- 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.
- Constructing a timeline showing the chronology of the historical events leading to the development of the cell theory.

6.0 TUTOR MARKED ASSIGNMENT

Research the following people: List some of their contributions to science and dates of these contributions.

- Robert Hooke
- Hans and Zacharias Janssen
- Anton van Leeuwenhoek
- Matthias Schleiden
- Theodor Schwann
- Rudolph Virchow.

Draw a timeline showing the chronological order of these scientists and their contributions.

Label the timeline with dates of the above scientists' discoveries.
The earliest date should be on the left of the timeline and the most recent date on the right.

Label each date with the corresponding scientist's name and contribution(s) in an organized and legible manner.

Be sure your spacing shows a reasonable approximation of the amount of time elapsed between dates.

7.0 FURTHER READING AND OTHER RESOURCES

Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, & Peter Walter(2002) Molecular Biology of the Cell 4th edition. Garland Science, Taylor & Francis Group, New York.ISBN 0-8153-3218-1 (hardbound) -- ISBN 0-8153-4072-9 (pbk.)

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