DELTA STATE UNIVERSITY ABRAKA, NIGERIA

CENTRE FOR DISTNACE LEARNING

General Physiology I

PHS 201

Course Material

DELTA STATE UNIVERSITY ABRAKA, NIGERIA
CENTRE FOR DISTANCE LEARNING

BACHELOR OF NURSING SCIENCE

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Vice Chancellor's Message

The Delta State University (DELSU), Abraka, was founded in April 1992. The dream of her founding fathers was to make the institution to not only cater for the higher education aspirations of young Nigerians, but to also ensure that in no time, the University will evolve and take her rightful place among other universities across the world. So far, despite the teething challenges confronting the world, DELSU has done well in her determination to realize her mission and vision. From the humble beginning of five faculties, DELSU has long come of age with thirteen faculties, a College of Health Sciences and a Postgraduate School. Our graduates are doing well in Nigeria and across the globe. The testimony to DELSU's sojourn so far attests to her realization of her vision as a centre for excellence in teaching, learning, research, and community service. This lofty vision has been well complemented with her mission of promotion of quality education, character and meeting the challenges of our time.

Three decades after, DELSU is once again taking on the challenge occasioned by the emergence of a New World Order by divesting from being a single mode university into a dual mode university as she is now set to run the Distance Learning system. What has confronted the university system in Nigeria in recent times is the inability of the conventional mode of learning to accommodate all qualified candidates. The Distance Learning mode has come in to fill the gap. What has now made it more compelling is the new role played by ICT in education in the world today. DELSU has taken on the challenge to provide learning opportunity for qualified candidates through the DL and also leverage on the use of ICT in learning. DELSU has thus come to harness the two factors for the good of humanity in promoting learning without borders.

DELSU is well placed to run a dual mode university in view of the phenomenal achievements we have recorded as among the best universities in Nigeria. Our array of courses, all fully accredited by the National Universities Commission, highly competent manpower, quality facilities, conducive environment and range of ICT facilities have combined to make DELSU the University of today and the future.

The course materials embedded here were authored by DELSU scholars after rigorous trainings in the technique of writing materials for DL. Remarkable efforts, quality time and rare expertise went into the production of the course materials in order for them to stand the test of global best practices. The content of the materials are lucid, interactive and up to date having been subjected to DELSU's quality assurance process. The course materials have been developed in multi-media formats which are available and accessible for use by learners.

It delightful to note that by running the DL, DELSU is offering those desirous of it an opportunity for lifelong learning. It is my pleasure to welcome our DL students to a new world of exciting learning.

Thank you.

Professor Andy Egwunyenga

Foreword

Delta State University has been committed to ensuring academic excellence in all her programmes for building knowledge, character and service among students. In consonance with this, the Centre for Distance Learning (CDL) is committed to the strive for excellence in the delivery of accessible, flexible and lifelong learning. Delta State University Centre for Distance Learning (DELSUCDL) is focused on the delivery of quality in all her academic and administrative activities. The centre is committed to providing quality learner support services to learners through provision of up-to-date information and guidance by the learner support unit.

Quality is entrenched in the admission process, development of course materials and appointment of facilitators and provision of learner support services. In consideration of the facts that learners are separated from their facilitators through space, the course materials have been developed in a manner that they are easily accessed by learners for their self-study and self-assessment at the approach of examination. In addition, the course materials are written as digestible bits that can be easily comprehended by learners.

As quality assurance measure in DELSU Distance Learning, the course materials were written by carefully selected brilliant and seasoned academics in their respective specialty and subjected to rigorous editorials by experts in English and open and distance learning to meet acceptable international standards. The course materials are learner-friendly, grouped into study sessions, with each study session having In-Text Questions (ITQs), In-Text Answers (ITAs), Self-Assessment Questions (SAQs), Self-Assessment Answers (SAAs), glossary of terms and references for learners' future study.

Learners are expected to take advantage of the worthy course materials and use them as guides in their study. In addition, learners are to source for other materials that are related and relevant to each course and use them as supplement. Some of these other course materials have been suggested by the course materials writers in each volume. Learners would find the direct Open Educational Resources (OERs) and references suggested by the course materials authors. You are advised to regularly be in touch with your e-tutors and e-facilitators assigned to you for help.

On behalf of the Vice Chancellor, Professor Andy Egwunyenga, I wish to appreciate all the course material writers and others for their contributions to the development of the course materials. To the learners, I wish you a treasurable ride as you read through the course materials and resounding progress as you navigate your academic journey.

Prof. (Mrs.) Romina I. Asiyai
Director, CDL

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INTRODUCTION

Welcome to PHS 201: General Physiology I. This course is a 2 credit unit course designed for 200 level Students in Basic Medical Sciences of Delta State University, Abraka. This course has 4 modules with 15 Study Sessions designed to help student understand basic knowledge of Physiology. General Physiology I is the first of two compulsory courses for students in the second year of the medical training programme. As a nursing student, PHS201 will provide you with the foundation about how the normal function of the body.

Physiology is an integrative science that studies the functions of complex living organisms at levels ranging from molecules and cells to organs and systems. The objective of this course is that student should acquire the terms and concepts of specific areas in physiology and also develop a conceptual framework to predict how one or more organ systems coordinate to maintain life in a constantly changing environment. It is this integrative approach and consideration of coordinated function among organs systems that is a special focus of physiology.

PHS201 will provide you with proper understanding of the course structure and requirements, course expectations**,** instructional materials needed for the course, how to attempt the computer-marked assignment, assess course assignment files and information relating to examination and grading of the course. This course guide provides you with better understanding of what to expect in general physiology. Happy reading through the lens.

AIM OF THE COURSE

The module one of this course will provide you with information on the definitions and meaning of Physiology, history, principles and importance of physiology, basic systems in physiology, blood and body fluids, and homeostasis. In other words, it covers the introduction to Physiology which you ought to know as a medical student.

The module two covers cell physiology with four Study sessions centered on the structure and function of cell, cell membrane: composition and function, transport across cell membrane, and levels of organization of the human system.

The module three centers on a solid foundation in understanding variations of normal and abnormal body physiology as it relates to biophysical principles. It has three Study sessions, namely; cardiac functioning, nerve and muscle functioning and respiratory functioning.

The module five is on the control systems and rhythms. It has three Study Sessions, namely; components of the control system, feedback system and biological rhythms.

LEARNING OUTCOMES FOR THE COURSE

After reading this course, student will be able to:

i. Demonstrate a depth of knowledge in Human Physiology
ii. Understand the various disciplines and core principles of Physiology
iii. Explain the structural and functional description of Cell
iv. Integrate their understanding across basic physiological systems and how they interact
v. Apply their understanding of physiological systems to novel scenarios
vi. Understand the biophysical principles surrounding cardiac, nerve, muscle and respiratory functioning
vii. Communicate their understanding to others in a meaningful and impactful way
viii. Develop and enhance skills related to problem solving, integration, and application of complex topics and processes in Physiology

COURSE EXPECTATIONS

The blended learning mode will be adopted in delivery of the course PHS201 such that 70% will be online and distance learning protocol whereas 30% will involve physical contact involving interactive sessions with facilitators and practical exposures with Laboratory technologists. You will be provided with soft copies accessible from the university e-courseware resources while the hard copies of course materials will be obtained from the ODL Directorate of Delta State University, Abraka. To access the online class sessions and this course material, you are required to register for this course online.

You can join the interactive online activities through the course link on the ODL website of the University. Endeavour to participate in scheduled activities and submit assignments were applicable for each Study Session as stipulated in the course schedule template before deadlines as grades will form part of the overall assessment for the course. You will be expected to carefully study the course module while attempting the assigned readings and the tutor-marked assessment provided at the end of every Study Sessions, to help you understand the course contents in detail and prepare adequately for the in-course computer-marked assessment and the end of course assessment/examination. Actively participating in the discussion will provide you with valuable information.

NSTRUCTIONAL MATERIALS FOR THE COURSE

The following are the instructional materials required for the course;

- Course Guide
- Study Sessions
- Text Books
- Presentation (Audio, visual or Slide)
- Assignment Files
- Tutorials

COMPUTER-MARKED ASSIGNMENT (CMA) PROCEDURE

The Computer Marked Assignment of the PHS201 will consist of continuous assessment structured into CMA-1, CMA-2 and CMA-3. Every Module has an activity that must be done by the student as spelt out in the course materials. These exercises are to aid you in understanding the concepts of the course and it is advisable that you attempt each of them.

COURSE ASSIGNMENT

To complete the course PHS201, you are required to read the Study Sessions for each module and related materials, thereafter, attempt the specific assignment as requested by each course facilitator. The CMA and assignment will account for 30% of the total course mark. Ensure that your assignments are submitted to your facilitator before the stipulated deadline. Request for extension of submission deadline by contacting the facilitator on time. Note that no extension will be granted after de due date except on exceptional conditions.

COURSE EXAMINATION AND GRADING

At the end of the course, you are expected to sit for the final written examination of PHS201 for 2-3 hours' duration at a stipulated examination venue within the university. This examination will account for 70% of the total course mark. The examination will cover every area of the course including questions related to the self-testing, practice exercise and tutor-marked assignment that you previously practiced in the Study Sessions of the course.

COURSE MARKING SCHEME

Table 1: Marking Scheme for PHS201

Category	**Marks**
Assignments and CMAs	CMA 1 – 10Marks CMA 2 – 10Marks CMA 3 – 10Marks Total: 30Marks
End of course examination	70% of overall course marks.
Total	100% of course materials.

COURSE SCHEDULE

Table 2: Course Schedule for PHS201

Course Guide	**Topics**	**Weekly Activity**	**Assignment**
Module One	**Introduction to Physiology**	**Week 1**	
Study Session 1	Definition of Physiology	Week 1	Assignment 1
Study Session 2	History, Principles and Importance of Physiology	Week 2	Assignment 2
Study Session 3	Basic Systems in Physiology	Week 3	Assignment 3
Study Session 4	Blood and Body Fluids	Week 4	Assignment 4

Study Session 5	Homeostasis	Week 5	Assignment 5
Module Two	**Cell Physiology**	**Week 6**	
Study Session 1	Structure and Function of Cell	Week 6	Assignment 6
Study Session 2	Cell Membrane: composition and Function	Week 7	Assignment 7
Study Session 3	Transport Across Cell Membrane	Week 8	Assignment 8
Study Session 4	Levels of organization of the human system	Week 9	Assignment 9
Module Three	**Biophysical Principles**	**Week 10**	
Study Session 1	Cardiac Functioning	Week 10	Assignment 10
Study Session 2	Nerve and Muscle Functioning	Week 11	Assignment 11
Study Session 3	Respiratory Functioning	Week 12	Assignment 12
Module Four	**Control Systems and Rhythms**	**Week 13**	
Study Session 1	Components of the Control system	Week 13	Assignment 13
Study Session 2	Feedback System	Week 14	Assignment 14
Study Session 3	Biological Rhythms	Week 15	Assignment 15
	Revision		
	Examination		
	Total	15 Weeks	

READERS GUIDE

i. Create a study schedule for yourself. Read the stipulated guide about registration of courses, and learn what is expected of you in terms of the course, participate in online discussion forum and practical sessions
ii. Strictly follow directives given by your facilitators and tutors for the course
iii. By reading this course guide, you may learn more about the context of the course. Endeavour to concentrate to details, knowing that prerequisites is necessary for success.
iv. Once you have established your personal study routine, make every effort to stick to it. The primary cause of student failure is falling behind on their course work. Please let your tutor know if you run across scheduling issues before it's too late to obtain assistance.
v. Attempt assignment files and tutor marked assessment provided at the end of every Study Session. Submit your assignments before deadlines
vi. Do not wait for an assignment to be returned from your facilitator before moving to the next Study Session; keenly stick to your reading timetable.

vii. Go through your assignments as soon as they are given to you, and don't wait until the day of the exam to address any issues you may be having with any Study Session or topic.
viii. Engage in active debate in online forums and keep in touch with the course facilita tor and exchange ideas with your study group.
ix. To be sure you have met the goal for each Study Session, go through the stipulated objectives and course outcome again. Consult your facilitator if you have questions about any of the goals.
x. Always make reference to the provided course materials. Watch the video clips, listen to audio files and consult other online reference textbooks.
xi. Work ahead of the interactive sessions.
xii. Remain in contact with the DELSU ODL Directorate and visit the university websites to get pertinent information because these sites will be updated often on this site.
xiii. Be focused and anticipate to achieve success. Don't forget, determination is the key to success.

COURSE FACILITATORS/TUTORS

You ought to make every effort to show up for the online. You will be duly notified of the dates, hours, and location of these tutorials or facilitation sessions, along with your facilitator name and contact information. Your facilitator will grade and provide feedbacks on your submitted assignments. Actively participating in online discussion groups can benefit you much. You will have an opportunity to speak with your facilitator directly and get immediate responses to your questions especially when you are having difficulty understanding any part of the Study Sessions or difficulty with any of the tutor-marked tests or assignment exercises. Prepare a list of questions before attending course tutorials to get the most out of them.

MODULE ONE

INTRODUCTION TO PHYSIOLOGY

Study Session 1: Definition of Physiology
Study Session 2: History, Principles and Importance of Physiology
Study Session 3: Basic Systems in Physiology
Study Session 4: Blood and Body Fluids
Study Session 5: Homeostasis

STUDY SESSION 1: DEFINITIONS AND MEANING OF PHYSIOLOGY

CONTENTS

1.0 Introduction

The study of Physiology helps in knowing the basic body functions, and to find the treatment of disease. It helps us comprehend what occurs in a healthy body and normal life in contrast to pathophysiology. This Study Session is designed to promote understanding of optimal health and factors that disturbs our physiological processes. The interplay of physiological mechanisms and principles and how they come together to result in human life being sustained. A basic knowledge of physiology whose professional careers will involve any aspects of health and patient care. This course cover definition and meaning of physiology, basic systems in physiology, cell physiology, homeostasis, muscle functioning, the nervous processes.

2.0 Learning Outcomes

After reading this course, student will be able to:

- Understand the definitions and meaning of Physiology
- Describe the basic Physiology terminologies
- Evaluate the core disciplines in Physiology

3.0 Main Content

3.1 Definitions of Physiology

Physiology is the study of proper function in living things and vital processes of living organisms, their parts and organs. Physiology is a sub-section of biology concerned with how the principal organ systems like; such as the endocrine, musculoskeletal and nervous systems interact to form a functional whole. Physiology focuses on mechanisms of action. The study of physiology covers a variety of topics like as cells, organs, systems, and biological chemicals, as well as how they all interact to promote life processes. Physiological study has altered our understanding of the components of our body, how they communicate, and how they keep us alive, from ancient theories to molecular laboratory techniques.

Human physiology is the scientific study of the physical and chemistry of the body structures and the mechanism in which these structure work together to support the functions of life. The Merrian-Webster defined physiology as: "that branch of biology which is concerned with the functioning and activities of life or living things such as tissues, cells, or organs, as well as the physical and chemical processes involved. "The Physiological Society of America sees Physiology as the branch of biology that aims towards understanding the mechanisms of living things from the basis of the function of cell at the molecular and ionic level to the integrated behaviour of the whole body in response to the external environment.

Physiology can also be viewed as the study of normal metabolism and functions of the human body and its parts. Considering that structure and function are inseparable, the study of physiology aims to understand many concepts such as the function of cells, mechanisms of living organisms, absorption and processing of nutrients, the functions of different tissues, to impact of the external environment. Why Human physiology aids the proper understanding of the integrated functioning of the human body, pathophysiology tries to grasp the inconsistencies that happen in human and animal infections.

3.2 Meaning of Physiology

The word "physiology" is derived from a Greek word 'physiologia' meaning 'study of nature'. It deals with the study of how the body and its part work or function. Physiology is the science of body function. Physiology revolves around understanding how the human body maintains a steady state while adapting to outside conditions, a process called homeostasis. The knowledge of physiology helps us to determine how the body works in health and how it responds and adapts to the perceived challenges of everyday life; it further helps us to understand what goes wrong in disease in contrast to the normal body function, facilitating the development of new treatments and guidelines for maintaining human and animal health.

Physiology is an experimental science. Numerous studies in physiology centers on the body's ability to maintain homeostasis that is the relatively stable conditions inside the body needed for survival. Human physiology in order words is the study of human life. In essence, physiology is the study of normal and abnormal functions and mechanisms of the human body. It addresses questions relating to how the internal structure of an organism functions and how they interact with the world around them. The difference between physiologies from other life sciences is that the formal emphasis on integrating molecular, cellular, systems and whole body function is what distinguishes.

Physiology studies the function of each structure, individually and in combination with other structures. Physiology tests explains how organs and systems communicates simultaneously, with a combine effort to bring about favorable conditions for survival. Research in physiology advances understanding of the detailed mechanisms that regulate and control the behaviour of living things. It elaborates on the fundamental processes, such as; the control of heart rate, respiratory volumes and capacities or the specific senses of taste, vision or olfaction through comprehensive exploration of the multiple processes involved.

Physiology also involves the sensible examination of the common limit in living structures. Its study aids in advancing our understanding of how the body functions. A sub-control of science that certainly includes observation, both with the naked eye and with microscopes, as well as manipulations and measurements of a living system. Physiologists study every aspect of the way the human and other animal bodies function. Similarly, physiologists equally investigate the behaviour of proteins in cells. Others are researching on the interaction of cells in tissues, organs and systems or study the integration of different systems to control the whole complex organism. This training provides the foundation for many clinical, biological and life sciences; including medicine and veterinary science.

3.3 Basic Physiology Terms

The following are basic glossary of terms in Physiology;

- **Autonomic Nervous System**, involuntary nervous system not subject to control by human will. It consists of two parts, namely; first, Parasympathetic: leaves the central nervous system in the cranial and sacral regions of the spine. It has a general calming effect on the body. Second, Sympathetic: leaves the central nervous system at the thoracolumbar region. It prepares the body for stressful situations
- **Alveoli,** very small air sacs in the lungs through which oxygen and carbon dioxide are exchanged.
- **Angiotensin I,** protein produced by the enzymatic action of renin on angiotensinogen; inactive precursor of angiotensin II
- **Angiotensin II,** protein produced by the enzymatic action of ACE on inactive angiotensin I; actively causes vasoconstriction and stimulates aldosterone release by the adrenal cortex

- **Alimentary Canal**, the continuous tract from mouth to anus through which food moves during the process of digestion.
- **Accessory Organs,** structures which aid in the digestive process – tongue, teeth, salivary glands, pancreas, liver and gall bladder
- **Bone,** dense connective tissue forming the skeleton
- **Bone Marrow,** substance contained in the medullary canal of long bone and in the cancellous tissue of all bone types.
- **Bile**, fluid secreted by the liver, stored in the gall bladder, and emptied into the small intestine where it assists in absorption of fats.
- **Bowel**, term covering the large and small intestines.
- **Blood**, fluid which circulates throughout the body carrying nutrients to cells and removing wastes from cells. It consists of **Venous blood** (with the exception of the pulmonary vein) contains carbon dioxide in large amounts and **Arterial blood** (with the exception of the pulmonary artery) contains a heavy concentration of oxygen.
- **Caecum**, first portion of the large intestine. The ileum joins the caecum at a right angle, and the appendix is attached to the caecum
- **Cell,** the smallest independently functioning unit of all organisms; in animals, a cell contains cytoplasm, composed of fluid and organelles
- **Control center,** compares values to their normal range; deviations cause the activation of an effector
- **Common Iliac Artery**, vessel which carries major blood supply to each leg
- **Chyme**, semi-liquid material resulting from action of digestive juices on food in the stomach.
- **Detrusor muscle,** smooth muscle in the bladder wall; fibers run in all directions to reduce the size of the organ when emptying it of urine
- **Digestion**, process by which ingested food is converted for absorption and use as nutrients for body cells.
- **Distal convoluted tubules,** distal regions of the nephron that receive hyposmotic filtrate from the loop of Henle and emptying into collecting ducts.
- **Diuretic,** compound that increases urine output, leading to decreased water conservation
- **Diastole,** the resting stage of the cardiac cycle.
- **Diaphysis**, shaft of the long bone.
- **Epiphysis**, end of the long bone
- **Endocrine System**, all the glands of internal secretion concerned with regulating and influencing organs and processes by the hormones they produce.
- **Endocrine Gland,** an organ which secretes hormones directly into the circulatory systems to influence and regulate numerous body processes.
- **Femur**, long bone of the thigh which extends from the hip to the knee.

- **Gall Bladder,** small sac in which bile made by the liver is stored until needed in the duodenum for fat digestion.
- **Glomerulus,** tuft of capillaries surrounded by Bowman's capsule; filters the blood based on size
- **Heart**, hollow, muscular organ which pumps blood to all parts of the body
- **Homeostasis,** steady state of body systems that living organisms maintain
- **Hormone,** chemical substance produced and secreted by an endocrine gland.
- **Ingestion,** the act of taking food into the body via the mouth.
- **Lymph**, substance continuously formed by the filtration from tissue fluids.
- **Lymph Nodes,** small bodies of lymphoid tissue arranged in chains to filter lymph and help prevent the spread of infection.
- **Lymph Circulatory System,** a drainage system which picks up fluids from tissues and returns them to the bloodstream
- **Larynx**, the organ of voice.
- **Lung**, major organ of respiration; consists of spongy, porous, elastic tissue.
- **Metabolism,** sum of all of the body's chemical reactions
- **Micturition,** also called urination or voiding
- **Mitral or Bicuspid Valve,** the two-leaflet heart valve between the left atrium and ventricle of the heart. Closure prevents reflux of blood into the left atrium.
- **Muscle,** tissue composed of fibres which have ability to contract or shorten.
- **Nasopharynx**, upper part of the back of the throat where the nasal cavity opens into the pharynx
- **Negative feedback,** homeostatic mechanism that tends to prevents or inhibit an excessive response to a stimulus, typically as the stimulus is removed
- **Nutrient,** chemical obtained from foods and beverages that is critical to human survival
- **Oliguria,** below normal urine production of 400–500 mL/day
- **Osteomalacia,** softening of bones due to a lack of mineralization with calcium and phosphate; most often due to lack of vitamin D;
- **Pharynx, -** area in the back of the mouth which serves as passageway for air from nasal cavity to larynx and for food from mouth to oesophagus
- **Physiology,** science that studies the chemistry, biochemistry, and physics of the body's functions
- **Positive feedback,** mechanism that intensifies or amplifies a change in the body's physiological condition in response to a stimulus
- **Pathological physiology**, the effects of diseases on organs and organ systems.
- **Pulmonary Artery**, vessel which carries venous blood from right ventricle of the heart to lung for oxygenation
  - **Pulmonary Circulation,** blood circulation from the right ventricle of the heart to the lungs and back to the left atrium.

- **Pulmonary Vein,** vessel which returns oxygenated blood from the lung to the left atrium of the heart.
- **Subclavian Artery,** large vessel which branches off the aortic arch on the left and the brachiocephalic trunk on the right to supply blood to areas of the trunk, head and upper extremities.
- **Systemic Circulation**, the circulation of blood flowing from the heart's left ventricle through the aorta to every parts of the body, there after returning back to the right atrium via the venae cavae.
- **Systole**, the contraction stage of the cardiac cycle
- **Spleen**, a large lymphoid organ located in the left upper abdomen behind the stomach that plays a significant role in lymphocyte production and in the destruction and storage of red blood cells.
- **Smooth Muscle**, involuntary muscle tissue without striation attached to visceral organs
- **Skeletal Muscle**, striated muscle which is attached to the bones
- **Trachea**, passageway for air between larynx and bronchi
- **Tendon**, fibrous tissue structure which serves to connect muscle to bone and other parts
- **Tricuspid Valve**, it is the valve with three fibrous tissue leaflets which open and close between the right atrium and ventricle of the heart. Closure prevents reflux of blood into the right atrium.
- **Vein**, vessel which carries blood in the direction toward the heart
- **Venule**, they are small vein.
- **Venae Cavae,** two large veins, inferior and superior, which return venous blood to the right atrium of the heart.

3.4 Disciplines in Physiology

Physiology is itself a branch of the larger discipline of biology. There are a great number of disciplines linked to Physiology. They are;

1. **Cell Physiology:** it concentrates on studying the physiological processes occurring within and among the cells and intracellular communication and behavior (membrane transport and neuron transmission).Cell physiology is also concerned with chemical and molecular processes that occur within and between cells.
2. **Evolutionary Physiology:** The study of how systems, or parts of systems, have adapted and altered across numerous generations. The role of behavior in evolution, sexual selection, and physiological changes in connection to geographic variance are all research issues.
3. **Comparative Physiology:** compares the physiology of multiple organisms, and may incorporate elements of developmental physiology to make the comparisons more complete. Comparative physiology can yield evidence for

evolution, aid scientists in determining the taxonomic relationships between organisms, and help researchers uncover how and when body structures such as wings or tails evolved.

4. **Developmental Physiology:** This discipline tracks the ways in which physiological systems change across the life span. For example, many animals are born with cartilage that later turns into bone, and human fetuses resemble other animals -- such as fish -- at various phases in their development. Developmental physiology may also examine the effects that both genetic and environmental influences have on an organism's development.
5. **Exercise Physiology:** This is the study of the physiology of physical activity, as the name suggests. This covers studies in bioenergetics, biochemistry, cardiopulmonary function, biomechanics, hematology, skeletal muscle physiology, neuroendocrine function, and nervous system function.
6. **Microscopic Physiology:** analyzes small organisms, and is usually subdivided into cellular physiology, bacterial physiology and viral physiology. This field of physiology has significant crossover with human and animal physiology, since bacteria and viruses so frequently affect larger living organisms. Because cells are the building blocks of organs and physiological systems, cellular physiology may be covered as a part of human or animal physiology.
7. **Systems Physiology:** this focuses on the functions of the body system. It attempts to define how individual cells or components of a system interact to produce a response as a whole. They frequently study metabolic networks and cell signaling. For example; neurophysiology is a sub-discipline of system physiology which involves the study of the brain, spinal cord, and nerves and how they work together to perform functions as complex and diverse as vision, movement, and thinking.
8. **Defense Physiology:** alterations that occur in response to a possible threat, such as the fight-or-flight response.

4.0 Conclusion

Physiology is an integrative study of the control of normal body function. Physiology as a discipline is the basis of health sciences that deals with understanding of how the body functions under normal conditions or good health. Basic physiology terminologies relating to understanding core aim of Physiology as it concerns the course PHS 201 were defined in this Study Sessions.

5.0 Summary

In this Study Session, Physiology was defined from different perspectives. Students have learnt that Physiology is an experimental and clinical science that deals with many key concepts arising from qualitative and quantitative observation and analysis of the normal function of living organisms. Some of the peculiar disciplines in Physiology

are; cell physiology, evolutionary physiology, developmental physiology, comparative physiology, microscopic physiology, systems physiology, defense physiology and exercise physiology

6.0 In-Text Questions

1. What is physiology all about?
2. What is the view of Physiological Society of America about the definition of Physiology?
3. What is the difference between Endocrine System and endocrine gland?
4. Lists 5 core disciplines of Physiology

7.0 In-Text Answers

Q1. Human physiology is the scientific study of the physical and chemistry of the body structures and the mechanism in which these structure work together to support the functions of life. Physiology also involves the sensible examination of the common limit in living structures. Its study aids in advancing our understanding of how the body functions. A sub-control of science that certainly includes observation, both with the naked eye and with microscopes, as well as manipulations and measurements of a living system.

Q2. The Physiological Society of America sees Physiology as the branch of biology that aims towards understanding the mechanisms of living things from the basis of the function of cell at the molecular and ionic level to the integrated behaviour of the whole body in response to the external environment.

Q3. Endocrine System refers to all the glands of internal secretion concerned with regulating and influencing organs and processes by the hormones they produce. While, **Endocrine Gland,** an organ which secretes hormones directly into the circulatory systems to influence and regulate numerous body processes.

Q4. The core disciplines of Physiology are;

- Systems Physiology
- Cell Physiology
- Evolutionary Physiology
- Developmental Physiology
- Comparative Physiology

8.0 References/ Further Reading

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STUDY SESSION 2: HISTORY, PRINCIPLES AND IMPORTANCE OF PHYSIOLOGY

CONTENTS

1.0 Introduction

Human physiology has its origins in ancient India and Egypt. It dates back to the time of Hippocrates, the legendary "father of medicine," circa 420 BC, as a medical field. Hippocrates popularized the four humors theory, which states that the body includes four separate physiological fluids: black bile, phlegm, blood, and yellow bile. According to the belief, any change in their ratios creates illness.

2.0 Learning Outcomes

After reading this course, student will be able to:

- Describe the historical origin of Physiology
- Explain the principles guiding the study of Physiology
- Identify the importance of the study of Physiology

3.0 Main Content

3.1 History of Physiology

The study of physiology traces its roots back to ancient India and Egypt. As a medical discipline, it goes back at least as far as the time of Hippocrates, the famous “father of medicine” – around 420 BC. Hippocrates coined the theory of the four humors, stating that the body contains four distinct bodily fluids: black bile, phlegm, blood, and yellow bile. Any disturbance in their ratios, as the theory goes, causes ill health.

- **laudius Galenus**(c.130-200 AD), generally known as Galen, revised Hippocrates' hypothesis and was the first to employ experimentation to learn about the body's systems. He is largely acknowledged as the father of experimental physiology.
- **Jean Fernel**(1497-1558), a French physician, was the first to use the term "physiology" from the Ancient Greek, which means "study of nature, origins."

Fernel was also the first to describe the spinal canal (the space in the spine through which the spinal cord travels). For his efforts, a crater on the moon named Fernelius was named after him.

- **William Harvey** (1578–1657) made an important leap forward in physiological knowledge as reflected in his book titled: 'An anatomical exercise on the motion of the heart and blood in living beings' published in 1628.Harvey was the first to define systemic circulation and the flow of blood across the brain and body parts as it is pumped by the heart.
- **FranciscusSylvius** (1614–1672), a Dutch medical doctor, and professor at Leiden, as well as a scientist brought the concept of circulation of blood to the Netherlands. He was the first to distinguish between two nature of glands: **conglomerate** (made up of a number of smaller units, the excretory ducts of which combine to form ducts of progressively higher order) and **conglobate** (forming a rounded mass, or clump).
- **Johannes Walaeus** (1604–1649) is considered the founder of Dutch experimental physiology. He performed the so-called venous occlusion experiment to give support of the concept that blood returns to the heart, as part proof of the circulation.
- **William Beaumont** is the first American in 1822 to employ the application of practical physiology when a patient's gunshot wound healed with a window-like opening. This allows Beaumont to look directly into the stomach and study gastric function.
- **Joseph Lister** revealed in his study in 1858 the cause of coagulation of blood and inflammation following surgical wounds and/or injuries. Lister later discovered antiseptics and that through their use surgical mortality rates was lowered from 50 to 15 percent.
- **Matthias Schleiden & Theodor Schwann** in 1838 made a tremendous shift in thought relating to the cell theory, they theorized that the human body was made up of tiny units of cells.
- **Joseph Lister** in 1858 initially studied coagulation and inflammation following injury, he went on to discover and utilize lifesaving antiseptics.
- **Claude Bernard** in 1865 published his landmark text, "An Introduction to the Study of Experimental Medicine." It provided the first clear explanation of the theory and practice surrounding physiological and medical experiments.
- **Harvard University** around 1870's initiates a medical physiology program. **Henry Bowditch** serves as the first physiologist and first full-time faculty member.
- **Ivan Pavlov** in 1891 began an extensive research on "conditional reflexes" involving dogs' saliva production in relation to various sounds and other visual stimuli. He was awarded the 1904 Nobel Prize for his discoveries on the neural regulation of salivary, gastric, and pancreatic secretion.

- **John Jacob Abel** and **JokichiTakamine** in 1901 isolated and purified epinephrine (adrenaline) from the adrenal gland. It was the first hormone to be identified and synthesized.
- **Alexis Carrel** in 1904 performed the first mammalian heart transplant. He won the 1912 Nobel Prize for developing techniques to suture blood vessels, transfuse blood, and transplant organs.
- **Karl Landsteiner** in 1909 classified the basic human blood groups: A, B, AB, and O. He wins the Nobel Prize in 1930 for these discoveries. Ten years later, he discovered the Rh (+ or -) factor in blood, completing the current blood typing system used today.
- **August Krogh** in 1910 published his findings showing that fluid and oxygen exchange in the capillaries and lung membranes is mediated by diffusion. In 1920, he won the Nobel Prize for discovering how blood flow is regulated in capillaries.
- **Haldane J.S.** in 1911 led a group of respiratory physiologists on an expedition to Pike's Peak to study the effects of altitude on human breathing.
- **Anton Carlson** in 1916 studied the stomach and the relationship between hunger and digestion. In one of his experiments, Carlson went on a 15 day fast, using an inflated balloon in his stomach to measure the stomach contractions.
- **Frederick Banting** and **Charles Best** in 1922 isolated insulin, the central hormone involved in diabetes, in dogs. Their innovative use of insulin rapidly converts sufferer prognosis from a certain death sentence to a disease that can be managed while living a normal and active life. In 1923, Banting was awarded the Nobel Prize for these developments.
- **Eugene Landis** in 1926 published the first calculations of direct measurements of blood pressure within arteries, capillaries, and veins.
- **The Harvard Fatigue Laboratory** was formed in 1927 to study exercise and environmental physiology. The Laboratory Director, **David Dill**, conducted extensive research in extreme environmental conditions and often served as a test subject in his own experiments.
- **Walter Dandy** around the 1930's identified the cause of water on the brain (hydrocephalus), an often deadly condition affecting infants. A neurosurgeon by trade and a great baseball fan, Dandy went on to invent the baseball helmet.
- **Hodgkin Alan&HuxleyAndrew** in 1952 discovered the ionic mechanism by which nerve impulses are transmitted.
- **Welsh J.H.** 1953 discovered the neurotransmitter, serotonin. It is found to take part in many functions of the brain. Reduced levels of serotonin in the brain have been linked since to emotional conditions such as depression and obsessive compulsive disorder.
- **Huxley Andrew&HuxleyHugh** in 1954 made advances towards studies relating to muscles and found the sliding filaments are present in skeletal muscle.

- **James Watson** and **Francis Crick** won a Nobel Prize in 1962for their description of the double-helix structure of DNA.
- **Christiaan Barnard** of South Africa in 1967 performed the first human heart transplant. Advances in the physiological studies of the heart made this landmark surgery possible.
- **Earl Sutherland** in 1971 was awarded a Nobel Prize for identifying cyclic adenosine monophosphate (cyclic AMP), a chemical messenger that mobilizes blood sugar in response to epinephrine (adrenaline). This is the first discovery of a signaling system inside the cell.
- **Erwin Neher** and **Bert Sakmann** in 1974 developed the "patch-clamp" technique, which detects and measures the movement of small amounts of substances through cell membranes. This technique gives insight into diseases involving ion channels including diabetes, multiple sclerosis, and cystic fibrosis. Their research wins the 1991 Nobel Prize.
- **Leland Hartwell, Paul Nurse,** and **Timothy Hunt** won a Nobel Prize in2001for discovering the mechanism that regulates the cell growth, division and death. Their research will be applied to tumor diagnostics.
- **Peter Agre** in 2003, won part of the Nobel Prize in Chemistry for his discovery of water channels, the protein mechanism in cells that facilitates water exchange. Understanding these water channels allows scientists to study many organs, such as the kidneys that process high volumes of water every day, providing insight into diseases affecting the loss of water in the body including diabetes insipidus.
- **Elizabeth Blackburn, Carol Greider** and **Jack Szostak**in 2009 won the Nobel Prize in Physiology or Medicine for discovery of how chromosomes are protected by telomeres and the enzyme telomerase.
- **Bruce Beutler** and **Jules Hoffmann** won a Nobel Prize in Physiology or Medicine in 2011for activation of innate immunity and Ralph Steinman for role of dendritic cells in adaptive immunity.
- **Ralph Brinster**in 2011 received an award from National Medal of Science for his fundamental contributions to the development and use of transgenic mice and to **Shu Chien** for his pioneering work in cardiovascular physiology and bioengineering.
- **Sir John Gurdon&Shinya Yamanaka**2012 won a Nobel Prize in Physiology for the discovery that mature cells can be reprogrammed to become pluripotent.
- **Robert Lefkowitz&Brian Kobilka** in 2012 won a Nobel Prize in Chemistry for studies of G protein-coupled receptors.
- **James E. Rothman, Randy W. Schekman&Thomas C. Sudhof**won the Nobel Prize in Physiology/Medicine in2013for their discoveries of machinery regulating vesicle traffic, a major transport system in our cells.
- **John O'Keefe, May-Britt Moser &Edvard I. Moser**in 2014 Nobel Prize in Physiology or Medicine for their discoveries of cells that constitute a positioning system in the brain.

- **William C. Campbell&Satoshi Ōmura**in 2015 Nobel Prize in Physiology or Medicine for their discoveries concerning a novel therapy against infections caused by roundworm parasites.
- **YouyouTu**in 2015 won a Nobel Prize in Physiology or Medicine for her discoveries concerning a novel therapy against Malaria.

3.2 Principles of Physiology

The explosion of knowledge in all of the biological sciences, and specifically in physiology has been an issue of global concern. The "principles of physiology" stated below can serve as the core foundation for understanding physiology as an exciting and dynamic discipline which underpins translational and clinical medicine practice.

Principle 1: Evolution

- Evolution by means of natural selection provides an explanation for the origins of organisms and their physiological functions.
- Evolution describes the origin of the relationships between structure and function that are at the core of physiology. Its implications inform all of the biological sciences
- Evolution explains variations in protein structure that underlie physiological function at the molecular level are driven by evolutionary mechanisms.

Principle 2: Ecosystems and environments

- Life of every living organism exist within an ecosystem composed of the abiotic (physicochemical) environment and biotic environment (biological organisms).
- It is clear that the individual organism exists, and survives to reproduce or not, as part of an ecological system, as such, variations in both the abiotic environment (oxygen, temperature, DDT, etc.) and biotic factors (e.g., pathogens) can affect normal physiology and pathophysiology.
- Physiology arises from the action and interactions of cells and their interstitial "environment".

Principle 3: The Cell

- The cell membrane contains the contents of the cell and determines what can enter and leave the cell.
- The internal constituents and state of the cell are different than the extracellular environment.
- Although all cells have the same DNA, not all genes are expressed in every cell.
- As a consequence, cells have many common functions but also many specialized functions.

- The organism is a collection of cooperating cells, with each cell type contributing its special functions to the "economy" of the organism.

Principle 4: Body Fluids

- Body fluids can be divided into intracellular and extracellular fluid, depending on their location relative to the cell membrane
- Plasma is in dynamic equilibrium with the interstitial fluid through pores in the capillaries; the interstitial fluid serves as a reservoir from which water and electrolytes can be mobilized into the circulation.
- Interstitial fluid is present in the spaces between cells.
- The normal daily intake of water (drinks and internal product of food metabolism) by an adult averages 2.5 L of which about 1.5 L is excreted as urine, 100 mL is lost in sweat, and 100 mL is present in feces.

Principle 5: Structure/function relationships

- The three-dimensional structure of cells and tissues is a determinant of the functions of the cell and tissue.
- Surface area is a determinant of the movement of all substances; hence, the surface area (and the surface-to-volume ratio) is a determinant of function.
- All physiological systems are interdependent but are interconnected, as such, the interplay of organs and systems and how they affect each other
- All physical objects (cells, tissues, and organs) exhibit elastic recoil, which contributes to determining function.

Principle 6: Homeostasis

- The organism normally maintains a more or less constant internal environment that is different than the external environment.
- The stability of the internal environment occurs via information flow in the form of negative feedback.
- Some limited sets of internal system parameters are regulated (held more or less constant) by the manipulation of other parameters whose values are controlled.
- The "desired" value of a regulated parameter behaves like a "set point," and set points are often the products of natural selection.
- The value of the set point can change as the situation of the organism changes.
- The actual value of a regulated variable must be measured by the body (a parameter can only be regulated if it can be measured).
- The determinants of a regulated variable must be controlled by the body by altering matter/energy transformations.

Principle 7: Levels of organization

- Biological organisms function at many levels of organization (from atoms to the whole organism) that exist on different physical scales.
- Processes occurring on one level can often be explained by mechanisms occurring at lower levels (reductionism).
- Some phenomena at a particular level of organization cannot be fully explained by mechanisms occurring at lower levels; such emergent properties represent more than the "sum" of mechanisms at lower levels.

Principle 8: Causal Mechanisms

- The laws of physics and chemistry describe the functioning of the organism, and there are knowable physical causes for physiological phenomena.
- The organism is a "mechanism" in which changes in function arise from the behavior of the mechanism and in which changes "propagate" to affect other functions.
- States and functions of the organism are quantifiable, and the absolute magnitudes and changes in magnitude are important to understanding the system.

Principle 9: Information Flow

- Transmission of genetic information
    - Genetic information is coded in DNA, which make up the genes.
    - Expression of a gene (reading of the code) results in the cell producing a protein (enzyme).
    - Expression of genetic information can be turned on and off, leading to cell differentiation.
    - Expression of genetic information determines intracellular function.

- Information Processing

    - Neural information processing

        a. Information is encoded and transmitted by all-or-none action potentials generated in neurons and sensory receptors.
        b. Information is passed from neuron to neuron by chemical transmission at synapses, some of which are excitatory and some of which are inhibitory.
        c. The probability of a neuron firing is determined by the balance between excitatory and inhibitory inputs.
        d. Information is also passed from cell to cell via ion flow through the gap junctions that connect them.

- Chemical information processing

  a. Cells produce and release signaling molecules, which affect their own function and the function of other cells, some nearby and others quite distant.
  b. Endocrine cells produce and release hormones, which are carried to all cells in the body by the circulation.
  c. To respond to a signaling molecule, a cell must have a specific receptor for that molecule.
  d. When signal molecules bind to a receptor, they alter target cell function by opening membrane channels or altering intracellular enzymes.

Principle 10: Energy Transfer and Transformations

- Many physiological processes affect and are affected by changes in the equilibrium state of intra- and extracellular chemical reactions.
- Solutes move across a membrane either passively (down an electrochemical gradient) or actively (using metabolic energy to power a pump).
- The flow (bulk flow, diffusion, and osmosis) of a substance occurs as the result of an energy gradient.
- Energy is stored in high-energy bonds in the constituent molecules of biological systems.
- This energy is used in biosynthesis, moving solutes, and powering muscles

3.3 Importance of Studying Human Physiology

Understanding Life Processes

Physiology is the study of the life processes of a living being's mechanical, physical, and biochemical activities. The physiologist as teacher proffer trainings to improve understanding the function of the organs and organism.

Understanding Human Development

It's helpful to have an intimate knowledge of human development and how the body grows and changes throughout life. Working with children is very different from working with older adults, and a background in physiology can help towards better understanding of the individual needs.

Understanding System Interactions

Beyond the individual organs and systems, it is also important to understand how the various aspects of the human body work together. The circulatory system, the endocrine system, the respiratory system, the renal system, the lymphatic system, etc; all play a part in human health and the interactions can be healthy or unhealthy. By understanding how the systems interact, one can determine the proper care for each individual patient and their specific symptoms. With a foundation of physiology, one

will have the building blocks to make the proper decisions and provide accurate and quality care

Useful in Developing Precise Skills

Ultimately, medical career will be reliant on the ability to learn and execute tasks with precision. With a greater understanding of the way the systems of the body interact, a medical professional will be able to successfully determine the problem and conclude a more accurate solution. There is a range of potential career opportunities for someone with a strong background in physiology, from clinical work to laboratory research.

Useful in Medical Education:

Physiology is indispensable in the medical education as physicians must have a firm grounding in the biomedical sciences and understand their relation to the physical sciences. Physiology is represented in many disciplines, such as Medicine, and helps in other studies as well. It allows trained physicians to understand the location and function of organs and body systems. Physiologists should also keep in mind that their teaching may help in the education of physician scientists. Most often, physician-scientists either become pure clinicians or focus all of their energy on basic sciences, thus playing the same role as PhD-trained biomedical scientists, while they should form the core of the translational research effort.

4.0 Conclusion

Physiology is concerned with the functional processes that lead to the creation of life. Its significance cannot be over emphasized because it includes the study of how all the parts of the body communicate together and individually to allow an organism to function effectively. The history of Physiology as a discipline in medicine can be traced to several key domains, including anatomy, biochemistry, biophysics, genetics, and evolution.

5.0 Summary

In this study session we examined the history of Physiology, the principles guiding the study of Physiology and the importance to the study of Physiology

6.0 In-Text Questions

1. What is the contribution of William Harvey to the understanding of Physiology?
2. Enumerate the 10 principles guiding the study of Physiology
3. Identify 5 importance to the study of Physiology

7.0 In-Text Answers

Q1. William Harvey made an important leap forward in physiological knowledge as reflected in his book titled: 'An anatomical exercise on the motion of the heart and blood in living beings' published in 1628. Harvey was the first to describe systemic circulation and blood's journey through the brain and body, propelled by the heart.

Q2. The Principles of Physiology includes

- Principle of Evolution
- Principle of Ecosystems and environments
- Principle of The Cell
- Principle of Body Fluids
- Principle of Structure and function relationships
- Principle of Homeostasis
- Principle of Levels of organization
- Principle of Causal Mechanisms
- Principle of Information Flow
- Principle of Energy Transfer and Transformations

Q3. The importance to the study of Physiology includes;

- Useful in Medical Education
- Useful in Developing Precise Skills
- Understanding Life Processes
- Understanding Human Development
- Understanding System Interactions

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STUDY SESSION 3: BASIC SYSTEMS IN PHYSIOLOGY

CONTENTS

1.0 Introduction

The human body is a biological machine made of body systems made up of nearly 100 trillion cells (and contains at least 10 times as many bacteria). The human body is made up of eleven systems formed by different organs. Groups of cells forms organs that work together to produce and sustain life. This implies that the organ system is a group of tissues and organs that works together to perform one or complex function in humans. Of course, the human body represents the physical life form which has a great task to perform in order to keep its owner alive and operational. Hence, all body systems are necessary for a complex organism to be able to survive and live.

2.0 Learning Outcomes

After reading this course, student will be able to:

- Examine the concept the basic systems
- Types of basic systems in Physiology
- Clearly review the importance of basic systems in Physiology

3.0 Main Content

3.1 An Overview of the Basic Systems

The smallest unit that makes up an organism is the cell. Cells groups together to form the tissues which in turn groups together to form organs. These organs interact with each other to form systems. The different systems of the human body have a vast array of overlapping and complementary functions. Although, all systems are essential to keep the body alive, present a certain degree of hierarchy depending on the role they are designed to perform. Some organs belong to more than one organ system. For example, the pancreas can be considered a part of the digestive system because it secretes enzymes that help the body break down fat, protein, and starch. It is also forms

part of the endocrine system because it produces hormones that help regulates blood sugar. In all, there are eleven basic organ systems of humans. These systems and their functions are described in subsequent study sessions.

3.2 Types of Basic Systems in Physiology

The systems of the human body covered in Physiology are:

1. **Cardiovascular/Circulatory system** – The cardiovascular system consists of the heart (the muscular pump), and a closed system of arteries, capillaries and veins for the circulation of the blood. The cardiovascular system is comprised of the heart and the circulatory system of blood vessels. The heart is composed of four chambers; two atria and two ventricles. Blood enters the heart through the upper chambers of the left and right atria and exits via the left and right ventricles. Heart valves prevent the backflow of blood.
2. **Digestive/excretory system** – The major components of the system includes; alimentary canal like; moth, esophagus, stomach, large intestine, and small intestine, and anal canal; and accessory organ like; spleen, liver, gallbladder and pancreas.
3. **Endocrine system** – Some major organs of the endocrine system include; the pineal, adrenal, hypothalamus, thymus, pituitary, thyroid gland, pancreas, parathyroids, placenta and gonads (testicles and ovaries).
4. **Integumentary system** – This system is unique because it is the largest and only single-organ system in the body. Some organs of this system include; the skin, nails, sweat glands, hair and sebaceous glands (secretes oily or waxy substances).
5. **Immune/Lymphatic system** – acts as the body's natural defense system against microbial invasion. It is comprised of white blood cells, thymus and lymph systems. Major structures and organs of this system include the thymus, lymph nodes, the spleen, and lymphatic vessels.
6. **Muscular system:** The muscular system contains about 650 muscles, which include the large muscles in our legs, arms and buttocks but also tiny muscles in the eyes and ears. Muscles comes in three (3) main types. Skeletal muscles is attached to bones, the cardiac muscle forms the heart muscles and the smooth muscles is found within visceral organs.
7. **Skeletal system** – the bones, skeleton, tendons, ligaments, and cartilage are the major organs of this system. The skeletal system is made up of 206 bones connected by various tendons, ligaments and cartilage, and has many vital functions. The system consists of the axial skeleton and the appendicular skeleton. The axial skeleton is made up of 80 bones, including the vertebral column, the rib cage and the skull, and helps you maintain your upright posture. The appendicular skeleton consists of 126 bones that form the pectoral girdles, the upper limbs, the pelvic girdle and the lower limbs, making movement possible and protecting the vital organs.

8. **Nervous system** – consists of central nervous system (CNS) and peripheral nervous system (PNS). The central nervous system consists of brain (fore brain, mid brain and hind brain) and the spinal cord; while the peripheral nervous system consists of somatic nervous system (SNS) and autonomic nervous system (ANS).
9. **Respiratory system** – this system consists of the nasal cavity, pharynx, larynx, trachea, bronchi, bronchioles, lungs and alveoli. The nasal cavity and pharynx are together called the upper respiratory system, while other organs form the lower respiratory system.
10. **Reproductive system** – consists of the gonads and the sex organs. Organs of the male reproductive system include; testes, epididymis, scrotum, vas deferens, seminal vesicles, ejaculatory ducts, (prostate gland), urethra, bulbourethral glands, penis, external urethral meatus. Organs of the female reproductive system include; ovaries, pelvic cavity, fallopian tubes, uterus, cervical orifice, vagina, greater vestibular (Bartholin's) glands, vulva. Knowledge of the reproductive system also encompasses investigating the way a fetus is developed and nurtured for 9 months which is divided into 3 trimesters.
11. **Renal/urinary system** – components of this system includes; the kidneys, nephron (proximal convoluted tubules (PCT), Loop of Henle (descending and ascending), distal convoluted tubules (DCT), and collecting ducts) ureters, bladder, and urethra.

3.3 Importance of Basic Systems in Physiology

The functions of the systems in humans are:

1. **Cardiovascular/Circulatory system** – delivers oxygen and nutrients to tissues while also removing wastes, and helps to equalize temperature in the body. This is accomplished by the heart and blood vessels.
2. **Digestive/excretory system** –the excretory system takes care of eliminate from the body those substances that may be harmful, which have been introduced through food or are the result of metabolic processes. Digestive system aids mechanical and chemical degradation of food with purpose of absorbing into the body and used as energy (digestion and absorption) in the form of adenosine triphosphate (ATP) and its final exit from the body as waste products. Digestion begins in the mouth, where food is chewed and mixed with saliva. Then it passes into the esophagus to reach the stomach. There, through the actions of gastric acids, food is decomposed and reduced into simpler elements. Once the food has been spoiled it is passes to the intestines, first to the thin and then to the large**,** where the villi of these organs absorb the nutrients that pass into the bloodstream. It processes food for use by the body and removes wastes from undigested foods.
3. **Endocrine system** –This system is responsible for secreting hormones to regulate bodily processes. It equally regulates the internal environment of the organism via the dispersal of chemicals (hormones) that act at certain receptors throughout the body. It's generally considered one of the most complicated systems in the body.

4. **Integumentary system** – this system functions to enclose internal body structures and is the site of many sensory receptors (this physical barrier helps keep out microorganisms, regulates the moisture level of the organism and keeps temperature steady). The skin has the following function; body temperature regulation, protection, perception of stimuli, excretion, vitamin D synthesis (calcitriol), immunity and social function (makeup, piercing, tattoos, keloid scars).
5. **Immune/Lymphatic system** –The lymphatic system functions to return fluids back to the blood and defends the body against pathogens (draining of excess tissue fluid, immune defense of the body). A diverse array of receptors and chemicals work together to protect the host from pathogen attacks. Antibodies and cytokines play an important role in this. Immune cells help to combat foreign invaders.
6. **Muscular system:** The skeletal moves the body and perform other functions like voluntary contraction. Smooth muscle lines organs such as the gut and bladder and operates involuntarily allowing movement of substances. Cardiac muscle is a specialized kind of muscle in the myocardium of the heart for involuntary contractility allowing the transport of blood.
7. **Skeletal system** –This system provides a structural framework for the body and enables movement (with the help of the muscular system). The bones provide an internal frame work that supports and anchors all soft organs. It equally proffers protection (vertebrae around spinal cord, skull around brain, ribs around lungs, patella), act as levers moved by muscles attached to bones by tendons and the bone marrow in the middle of long bones makes immune cells.
8. **Nervous system** – this system functions to detects and processes sensory information and activates bodily responses. The Central nervous system (CNS) integrates, processes, co-ordinates sensory data & motor commands. Brain is seat of higher functions (intelligence, memory, learning, emotion, personality). Peripheral nervous system (PNS) neural tissue delivers sensory information to CNS and carries motor commands from CNS to peripheral tissues.
9. **Respiratory system** –This system participates in exchange of gases between the atmosphere and the blood in alveolar capillaries; it promotes inspiration of oxygen and expiration of carbon dioxide and water. The nasal cavity, trachea, and lungs all works together to carry out the functions of the respiratory system (internal and external exchange of gases). It also participates regulation of blood pH, vocalization, smell, and protection from inhaled pathogens & irritants (sneezing & coughing).
10. **Reproductive system** – The purpose of sexual reproduction is to produce offspring that are genetically different from each other and from their parents. The male reproductive system functions to deliver gametes to the female, while the female reproductive system supports an embryo/fetus until birth and produces milk for an infant. Both systems (gonads) participates in fertilization and propagation of genes into the next generation of organisms.
11. **Renal/urinary system** –This system aids the removal of excess water from blood in the form of urine formation, and excretes it as waste. It participates in regulates

blood pH, volume and osmolality. This system also controls water balance in the body and removes wastes from the blood and excretes them. It is the major excretory organs of the body (organic wastes, urea, uric acid, and creatinine). Conserves nutrients by reabsorbing them from filtrate (glucose, amino acids), it produces the enzyme renin (which catalyzes the formation of angiotensin I).

4.0 Conclusion

The human body has eleven different organ systems, namely; cardiovascular/ circulatory system, digestive/ excretory system, endocrine system, integumentary system, immune/ lymphatic system, muscular system, skeletal system, nervous system, respiratory system, reproductive system and renal/urinary system. Each group of organs has a different complex function, such as; movement, breathing, or digestion. In some cases, one system works closely with another on a particular task. For example, the endocrine system interacts with the gastrointestinal system to control digestion and metabolism.

5.0 Summary

In this study session, we focused on understanding the concept the basic systems in humans, the types of these basic systems in Physiology as well as their importance in promoting life.

6.0 In-Text Questions

1. Describe the role of basic systems in the structural complexity of humans
2. What are types of basic systems in Physiology?
3. What is the importance of cardiovascular system in the sustenance of life?

7.0 In-Text Answers

Q1. The human body is made up of eleven systems formed by different organs. Groups of cells forms organs that work together to produce and sustain life. The smallest unit that makes up an organism is the cell. Cells groups together to form the tissues which in turn groups together to form organs. These organs interact with each other to form systems. The different systems of the human body have a vast array of overlapping and complementary functions.

Q2. The types of basic systems in Physiology are

i. Cardiovascular/ circulatory system
ii. Digestive/ excretory system
iii. Endocrine system
iv. Integumentary system
v. Immune/ lymphatic system

vi. Muscular system
vii. Skeletal system
viii. Nervous system
ix. Respiratory system
x. Reproductive system; and
xi. Renal/urinary system.

Q3. The **Cardiovascular system** plays significant role in the exchange of gases (oxygen and carbon dioxide), nutrients and drugs to tissues while also removing wastes from the body. This system helps to equalize temperature in the body. This is accomplished by the heart and blood vessels.

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STUDY SESSION 4: BLOOD AND BODY FLUIDS

CONTENTS

1.0 Introduction

Blood is a liquid connective tissue that fills the heart and blood vessels. An average adult has about 5-6 liters, which accounts for about 8% of the body weight. Blood is known for many functions, namely; transport agent (gases, nutrient, hormones, waste product etc), defense (antibodies and phagocytic agents), coagulation (protein factors), regulatory functions (pH balance, thermoregulation, water balance), etc. Plasma is made up of water, plasma proteins and other substances. The water present in plasma serves as transport medium; carries heat. The three (3) plasma proteins are; albumins produced by liver and constitutes 60-80% of plasma proteins most important in maintenance of osmotic balance; globulins specifically alpha and beta globulins produced by liver and are important for transport of materials through the blood (e.g., thyroid hormone & iron), while some are clotting factors while some are gamma globulins are immunoglobulins (antibodies) produced by lymphocytes; and lastly, fibrinogen produced by liver and are important in clotting. Other substances present in plasma are; inorganic constituents (1% of plasma) - e.g., sodium, chloride, potassium, & calcium; nutrients such as; glucose, amino acids, lipids & vitamins; waste products like nitrogenous wastes like urea, dissolved gases (oxygen & carbon dioxide), enzymes and hormones

2.0 Learning Outcomes

After reading this course, student will be able to:

- To understand the concept of blood and its compositions
- To explore the meaning of blood formation
- To review the various function of blood
- To learn composition of body fluid and changes in body fluid compartments
- Explain the importance of water in the body

3.0 Main Content

3.1 Blood and its Compositions

1. Cell Fragments

a). Erythrocytes (Red Blood Cells): Erythropoiesis = formation of erythrocytes. The body must produce about 2.5 million new RBCs every second. In adults, erythropoiesis occurs mainly in the marrow of the sternum, ribs, vertebral processes, and skull bones. RBC formation begins with a cell called a hemocy to blast or stem cell. Biconcave discs. Diameter 7.2 μ. Thickness at sides 2 μ, at centre 1μ.RBC lack a nucleus and cannot reproduce (average lifespan = about 120 days)**.** RBC transport hemoglobin (each RBC has about 280 million hemoglobin molecules).Typically, the concentration of RBC is 4-6 million per cubic mm ([packed cell volume] of about 42% for females & 45% for males). About 1% of blood forms the buffy coat (present between plasma and red cell mass) that mainly contains WBC and platelets. RBC contains carbonic anhydrase (critical for transport of carbon dioxide).

Physiological variation in RBC count:

- **Oxygen levels:** hypoxia (lower than normal oxygen levels) is detected by cells in the kidneys. Kidney cells release the hormone erythropoietin into the blood. Erythropoietin is the hormone that stimulates erythropoiesis by the bone marrow
- **Age:** RBC count is more in infants and children, less in adult, still decreases in old age. RBC count in a new born infant may be as high as 7–8 million/c.mm.
- **Sex:** RBC count is more in male than female. In adult male RBC count is 4.5–5.5 milliion/c.mm, average is 5 million/c.mm of blood, in adult female RBC count is 4–5 million/c.mm, and average is 4.5 million/c.mm of blood.
- **Altitude:** Altitude is the height of place of living. RBC count is more in people living at high altitude than those living at sea level. At high altitude places oxygen content in atmospheric air is less (hypoxia). To take up whatever oxygen is available, the number of RBC increases. This type of physiological adjustments with environmental factors is known as acclimatization**.**
- **Hormones:** Like androgens, thyroxine, corticoids, oestrogen, growth hormone and prolactin. Androgens, corticoids, thyroxine, growth hormone and prolactin increases the formation of erythropoietin, thereby stimulate bone marrow and increases the rate of cryotherapies. Oestrogen decreases erythropoiesis.
- **Pregnancy:** Total number of RBC in the blood increases during pregnancy, but RBC count per c.mm of blood decreases. This is because more increase in blood volume rather than increase in RBC count. This is known as haemodilution
- **Exercise:** RBC count increases during exercise.
- **Athlete:** RBC count is more in athletes.
- **Emotion:** RBC count increases during emotional states.

Pathological variation: Pathological increase (polycythemia) and pathological decrease (anemia).

Hemoglobin

It is a metallo protein present inside the RBC. It is an iron containing protein, ared colored pigment present inside the RBC. It is a conjugated protein. It has got two parts. Haemoglobin is a protein with 574 aminoacids and a molecular weight of 68,000.

Hb is composed of protein part called ***globin*** (made up of 4 highly folded polypeptide chains) and a non-protein part called ***heme***. (It has polypeptide chains, 2 α chains, 2 β chains, α chains contain 141 amino acids andβchain contains 146 amino acids). Haem consists of protoporphyrin ring with iron in the ferrous state. Protoporphyrin is made up of 4 pyrole rings. Haem contributes to 4% of weight of Hb, remaining 96% is by the globin part.

Types of haemoglobin are; Hb A – Hb α2 β2,Hb A2 – Hb α2 δ2,Hb F – Hb α2 γ2, and Hb S – Hb α2 β2. Normal range of haemoglobin concentration is 15gm/dl or 100 ml 15gm% Functions of haemoglobin are; transportation of oxygen, transportation of small quantity of CO_2. It acts as a chemical buffer, helps in the regulation of pH or acid base balance.Oxygenated haemoglobin gives red color to blood.

Physiological variations for Hb

i. **Age:** Haemoglobin concentration is more in new born and infants than adults. In new born infants Hb concentration is about 17 gm %.

ii. **Sex:** Haemoglobin concentration is more in male than female.

In Adult male, it is 14–17 gm % while Adult female is 12–15 gm %

iii. **Altitude:** Hb concentration is more in people living at high altitudes.

iv. **Emotion:** Hb concentration increases during emotional states.

v. **Exercise:** Hb concentration increases.

vi. **Pregnancy:** Total quantity of haemoglobin increases during pregnancy but haemoglobin concentration decreases due to haemodilution.

Pathological variation: Haemoglobinopathies (Hereditary disorders of haemoglobin; disorders of haemoglobin structure and synthesis).

b). Leukocytes (White Blood Cells): White blood cells have nuclei & do not contain hemoglobin. Typical concentration is 5,000 - 9,000 per cubic millimeter. There are two types of white blood cells, firstly; granular white blood cells contain numerous granules in the cytoplasm, & their nuclei are lobed. Secondly, a granular white blood cells have few or no granules in the cytoplasm & have a large spherical nucleus. Granular white blood cells are produced in the bone marrow, while a granular white blood cells are produced in lymph tissue.

- **Granular white blood cells:**thisinclude neutrophils (50 - 70% of WBCs); eosinophils (1 - 4%) and basophils (less than 1%)
- **Agranular (or non-granular) white blood cells:** this include lymphocytes (25 - 40%) and monocytes (2 - 8%)

The primary functions of the various white blood cells are:

- **Neutrophils** – phagocytosis (bacteria & cellular debris); very important in inflammation
- **Eosinophils** - help initiate and sustain inflammation and can activate T-cells (directly by serving as antigen-presenting cells and indirectly by secreting a variety of cytokines). Eosinophils can also kill bacteria by quickly releasing mitochondrial DNA and proteins. Eosinophils respond to diverse stimuli, including tissue injury, infections, allografts, allergens, and tumors. Eosinophils can also release a variety of cytokines, chemokines, lipid mediators, and neuromodulators. Eosinophils directly communicate with T cells and mast cells. Eosinophils activate T cells by serving as antigen-presenting cells.
- **Basophils** - along with mast cells, play a role in inflammation and allergic responses. Release of histamine (that contributes to the 'symptoms' of allergies) by mast cells requires the production of antibodies (IgE) by B-cells and that process is regulated, in part, by cytokines produced by basophils.
- **Monocytes** - phagocytosis (typically as macrophages in tissues of the liver, spleen, lungs, & lymph nodes) & also important antigen-presenting cells. Once distributed through the blood stream, monocytes enter other tissues of the body such as the liver (Kupffer cells), lungs (alveolar macrophages), skin (Langerhans cells), and central nervous system (microglia).
- **Lymphocytes** - immune response (including production of antibodies).

Some important characteristics of White Blood Cells are:

- **Phagocytic process**: this involves a process whereby certain living cells called phagocytes ingest or engulf other cells or particles
- **Capable of Diapedesis or extravasation:** involves the passage of blood cells through the intact walls of the capillaries, typically accompanying inflammation.
- **Capable of amoeboid movement:** the most common mode crawling-like type of movement.
- **Exhibit chemotaxis:** WBC are attracted to certain chemicals, such as those released by damaged cells
- **Opsonisation**: Neutrophils cannot efficiently recognize and attach to most microbes. By opsonisation some plasma factors like opsonones coat the bacteria and there by mark the microbes for ingestion and make them tasty for leukocytes.

Pathological variations of WBC:

- **Leukocytopenia or Leukopenia:** It is a clinical condition in which W.B.C. count is significantly below normal, *i.e.,* 2000 or 3000/c.mm

- **Leukocytosis:** It is a clinical condition in which there is a significant increase in W.B.C. count. It is seen in pathological conditions like allergy, tuberculosis, cold etc.
- **Leukemia:** It is a clinical condition in which there is a significant increase in immature nonfunctional W.B.C. due to carcinogenic reasons.
- **Leukopoiesis:** It is the process of production of leukocytes. All the types of leukocytes are produced in the bone marrow except lymphocytes. Lymphocytes are produced in the lymph node.

c). Thrombocytes (Platelets): These are the smallest non nucleated type of blood cells formed in the bone marrow from cells called megakaryocytes. They are round or oval in shape. Platelets have a Lifespan 8–10days Size of the cell is 2–5 μ diameter. Platelets lack a nucleus but can produce a variety of chemicals and contract (because to the presence of actin and myosin). Normal blood concentration is around 250,000 per cubic millimeter. They remain functional for about 7 - 10 days (after which they are removed from the blood by macrophages in the spleen & liver). Platelets play an important role in hemostasis (preventing blood loss).

Properties and Functions of Platelets

Platelets aggregate, or clump together, using fibrinogen and vWF as a connecting agent. The most abundant platelet aggregation receptor is glycoprotein (GP) IIb/IIIa; this is a calcium-dependent receptor for fibrinogen, fibronectin, vitronectin, thrombospondin, and von Willebr and factor (vWF). Activated platelets will adhere, via glycoprotein (GP) Ia, to the collagen that is exposed by endothelial damage. Aggregation and adhesion act together to form the platelet plug. Myosin and actin filaments in platelets are stimulated to contract during aggregation, further reinforcing the plug. Platelet aggregation is stimulated by Adenosine diphosphate (ADP), thromboxane, and α2 receptor activator, but inhibited by other inflammatory products like PPGI2 and PGD2, platelet aggregation at the site of injury act as a plug and block the flow of blood out of cut blood vessel. Platelet aggregation is enhanced by exogenous administration of anabolic steroids.

The aggregation of platelets releases vasoactive substances which assist in the vasospasm. Serotonin and thromboxane A2 are released at the site of the injury by the damaged platelets. These two local hormones produce vasoconstriction of damaged blood vessel. The narrowing down the flow of blood to the site of the injury and thereby minimizing the loss of blood out of blood vessel. The vasospasm lasts for about 30 minutes and is an important factor in the initial process in the arrest of hemorrhage. Vasoconstriction and plug formation are very important in rapid arrest of bleeding and together they form temporary or primary haemostasis. The platelets, release platelet factor III and help in blood coagulation. Due to their thrombos then in content, the platelets can retract and cause clot retraction, which is necessary for making the clot firm.

Platelets help in the coagulation of exudate which follows an acute invasion by bacteria. This coagulation helps to cordon off the bacteria and thus localize the

infection. Platelets also responsible in maintaining the integrity and health of vascular endothelium. Platelets help in the repair of damaged endothelium by being deposited on the damaged site and thus making a smooth layer on the intima. In addition to being the chief cellular effector of hemostasis, platelets are rapidly deployed to sites of injury or infection, and potentially modulate inflammatory processes by interacting with leukocytes and by secreting cytokines, chemokines, and other inflammatory mediators. Platelet also secrete platelet-derived growth factor (PDGF). This causes proliferation of endothelium and vascular smooth muscles. This helps in wound healing.

Pathological variations of Platelets:

- **Thrombocytopenia:** It is a clinical condition in which there is a significant reduction in the platelet count.
- **Thrombocytopenic purpura:** It is a clinical condition resulting from low platelet count.

2. Plasma

Blood plasma is a straw or light-yellowish colored fluid that forms the fluid base of whole blood. Plasma contains 91% to 92% of water and 8% to 9% of solid and gases. Removal of erythrocytes, leukocytes and thrombocytes from whole blood make results in plasma. It is important to note that serum differs from plasma because of the absence of fibrinogen (occurs when whole blood is placed in anticoagulant).

The origin of plasma, which constitutes 55% of total blood through the digestive tract, the reticuloendothelial cells of the liver which is in charge of plasma protein synthesis in adults. The bone marrow, degenerating blood cells, general body tissue cells, and the spleen that contributes to the formation of plasma proteins. Gamma globulins originates from B lymphocytes which in turn form immunoglobulins. The remaining 45% of blood mainly consists of red and white blood cells and platelets. Ideally, the component of plasma and their functions are as follows:

1. **Plasma proteins**: albumin and globulin helps in maintaining colloidal osmotic pressure at about 25 mmHg
2. **Fibrinogen**: a coagulant protein along with other procoagulants like thrombin and factor X aids in blood clotting (haemostasis).
3. **Dissolved gases***:* plasma also contains dissolved oxygen and carbon dioxide, in small amounts, as well as a significant amount of nitrogen.
4. **Immunoglobulins**: help fight infection and microorganisms such as; bacteria, viruses, fungi, and parasites.
5. **Hormones**: endocrine glands secrete chemicals called hormones into the blood which are transported to target organs.
6. **Electrolytes**: sodium is the most abundant ion carried in plasma and contributes most of the plasma osmolality. Others includes; chloride, potassium, bicarbonate, and calcium which contributes to maintenance of blood pH

7. **Amino acids**: plasma proteins may be broken down and the amino acids recycled for use in the synthesis of other biological structures. This may involve macrophages in the gut, the lymphatic system, and the lungs.
8. **Nitrogenous compounds**: waste compounds such as urea are produced by the breakdown of various substances in the body. These are carried in the plasma to the kidneys to be excreted.
9. **Nutrients:** act as a source of fuel for growth and development. Nutrients absorbed from the gut or from other organs of origin are carried in the plasma, such as glucose, fats, amino acids, minerals, and vitamins.

Each of these has a vital role to play in keeping the blood functioning effectively. Each of the above component of plasma can be separated using different techniques so that they form various blood products, which are used to treat different conditions. Although, Plasma can be separated from whole blood by centrifugation, i.e., spinning whole blood with an anticoagulant in a centrifuge.

Pathophysiology:

Clotting disorders: Deficiency of specific clotting factors cause hemophilia. Hemophilia A is due to factor VIII deficiency, while hemophilia B is due to deficiency of factor IX. Symptoms involve hem arthrosis and intramuscular hematomas.

Immunodeficiency: Antibodies or immunoglobulins play a critical role in the immune system to fight off infections. There are 5 classes of immunoglobulins which are IgM, IgG, IgA, IgD, and IgE. The deficiency of each of them can present with unique symptoms.

Thrombotic thrombocytopenic purpura (TTP): a type of micro angiopathic hemolytic anemia that manifests as fever, thrombocytopenia, hemolytic anemia, renal dysfunction, and neurologic dysfunction. All five criteria might not be present in all patients.

3.2 Formation of Blood Cells

Hemopoiesis (or hematopoiesis) describes the formation of blood cells, which is an active process that must maintain normal number of blood cells in peripheral blood and also should be able to respond to the increased demands in situations like hemorrhage or infections. During fetal life, hemopoiesis mainly occurs in the spleen and liver, and subsequently in red bone marrow present in the medullary cavity of all bones. From childhood, red marrow is progressively replaced by fat tissues (yellow marrow). Therefore, normal hemopoiesis in adults is restricted to vertebrae, sternum, ribs, clavicles, pelvic bones, skull and ends of humerus and femurs.

Bone marrow contains a range of hemopoietic precursor cells and a storage pool of mature cells for their release into peripheral circulation. All blood cells are derived

from the pluripotent stem cells, referred to as hemopoietic stem cells (HSCs). HSCs sustain life long production of all blood lineages. HSCs provide homeostasis of blood cells through their ability to generate the hundreds of millions of red cells, white cells and platelets needed every day

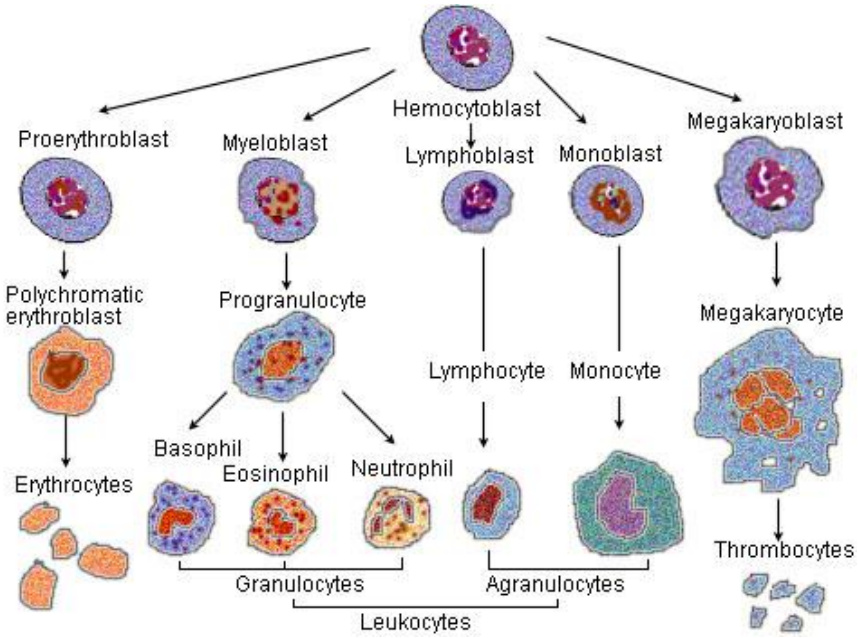

Figure 1.1: Pluripotent hematopoieticStem Cells

The mother hematopoietic stem cell is the pluripotent stem cells (PPSC), also called as hemocytoblast. PPSC is the *multilineage stem cell* capable of producing important groups of stem cells. Three main classifications of blood cells derive from haematopoietic stem cells (HSCs).

- ***Myeloid cells.*** This includes macrophages (monocytes) and granular white blood cells (or granulocytes; neutrophils, basophils and eosinophils). Macrophages have a role in adaptive immunity, cooperating with T and B cells through antigen presentation and the production of cytokines.
- ***Erythroid-megakaryocytes.*** Erythrocytes (red blood cells) carry oxygen through blood vessels, whereas platelets derived from megakaryocytes work to prevent blood loss.
- ***Lymphoid cells.*** This includes T-cells and B-cells. Natural killer (NK) cells are thought to be the prototype of T cells. Thymic, as well as pre-thymic, T-cell progenitors are able to generate dendritic cells. B cells secrete antibodies.

3.3 Functions of Blood

a- Transportation Functions: One of the important function of blood is transportation. Blood acts as the transporting agent of the body. Transportation functions of blood are described as follows:

Transportation of Oxygen transport: O_2 is transported from the lungs to the tissues by blood. It is needed to produce energy by metabolism. Of the oxygen entering the

body, only 1.5% is dissolved in blood plasma. In the lungs, the oxygen forms a weak bond with the iron portion of hemoglobin, creating **oxyhemoglobin.** Oxyhemoglobin travels through the circulatory system to the tissue cells. Once there, the difference in pH between the arterial and venous blood is enough to break the bond between the oxygen and the hemoglobin. The oxygen is then released to the tissues.

Transportation of Carbon dioxide: Carbon dioxide is transported from the tissues to the lungs via three (3) ways: About 10% is dissolved in the plasma. Another 20% is bound to hemoglobin, forming carbaminohemoglobin. The vast majority about 70% is carried in the form of bicarbonate ions (HCO_3^-). This occurs because when CO_2 dissolves in plasma, it reacts with the water in the plasma to form carbonic acid. Carbonic acid then dissociates into bicarbonate and hydrogen ions.

Transportation of Waste products (Excretory function): Blood is key in the transport of waste products of cell metabolism from various tissues away to the organs responsible for detoxifying and/or excreting them; like kidneys, lungs, G.I.T. and skin.

Transportation of nutrients: food like vitamins, minerals, water, fats and lipids, carbohydrates) from the gastrointestinal tract (G.I.T) to various parts of the body.

Transportation of hormones: Hormones are organic chemical substances secreted by ductless glands or endocrine glands and manifest their functions away from the site of secretion. Blood carries the hormones from the site of secretion to the site of action.

b – **Defense:** Blood helps in the defense of the body. Blood takes part in three types of defense.

Phagocytosis: WBC or leucocytes engulf foreign organisms, bacteria, fungus etc. and kill the microorganisms. So the microorganisms thereby do not get the chance of multiplication. The body is protected from the harmful effects of microorganisms.

Producing antibodies (formed from gama globulin): When a group of microorganisms enter the body for the first time they act as antigens. Against these antigens, antibodies are developed from gama globulins. When same group of microorganisms enter the body at a later date, they will be destroyed or killed by the antibody molecules already present in the body. This gives a long term protection to the body. This mechanism is known as immunity.

Blood shows the property of coagulation or clotting: This mechanism converts liquid blood into semisolid. This minimizes the loss of blood from a cut blood vessel.

c -Regulative functions:

Regulation of acid-base balance: this involves the maintenance of constant pH by the action of plasma proteins. pH of blood is maintained by the action of chemical buffers of the blood. There are different important groups of buffers in the blood that are key in this regulatory function.

Regulation of body temperature: Blood takes part in the distribution of thermal energy between different parts of the body. When the body temperature increases, blood vessels of the skin undergo dilatation. Because of this more blood may flow to the skin. Along with the blood more thermal energy flows to the skin and higher thermal energy is lost from the skin. This helps in the cooling of the body. When the body temperature is low, vasoconstriction of peripheral blood vessels takes place.

Because of this, less blood and less thermal energy will reach the skin. Less thermal energy is lost from the skin. This helps in the conservation of thermal energy.

Regulation of water balance: Blood acts as a buffer for water. It takes part in the distribution of water among the different compartments of the body (intra cellular, extra cellular etc).

3.4 Body Fluids and its Compartment

Humans are approximately 75% water by mass as infants and 50% to 60% water by mass as adults. Body fluid is the essence of life and it is the aqueous base solution in which all essential biochemical processes occur that produce life. The maintenance of a relatively constant volume and a stable composition of the body fluids is essential for homeostasis. Water content is by far the most abundant components in the different body organs & tissues. The total body weight (TBW) constitutes approximately 60% in young males and 40-50% in young women (lower level in fat, upper level in thin) and 73-80% in infants. The percentage of body water decreases with age primarily due to an increase of adipose tissue (old age 45%). The body water is distributed into two major fluid compartments in various fluid compartments: intracellular fluid (ICF) compartment constitutes 40% while extracellular fluid compartment (ECF) constitutes 20%. Water content varies in different body organs and tissues is represented in the figure below:

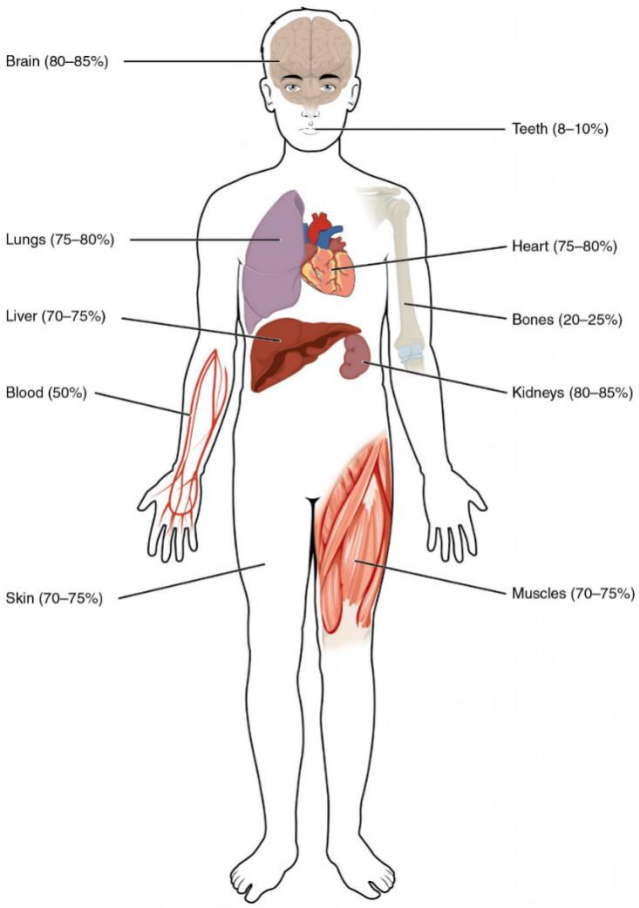

Figure 1.2: Organs and Tissues Content of Water in the Body

a. Extracellular fluid compartment: Extracellular fluid (ECF) surrounds all cells in the body and it constitutes approximately 20% of total body weight. They are divided into the following;

- **Interstitial fluid:** also known as intercellular fluid and tissue fluid. It represents the largest portion of the ECF compartment. The fluids between cells and in lymphatic of multi-cellular organisms which delivers materials to the cells, intercellular communication, and removal of metabolic waste. It constitutes about 15% of the TBW. Interstitial fluid consists of a water solvent containing amino acids, sugars, fatty acids, coenzymes, hormones, neurotransmitters, salts, as well as waste products from the cells.
- **Transcellular fluids**: constitutes about 1% of the TBW. Examples may include; fluid in the gastrointestinal, biliary and urinary tracts, the intraocular and cerebrospinal fluids, and fluid in serosal spaces like; the synovial, pleural, peritoneal, and pericardial fluid. Transcellular fluids are separated from blood plasma by a tight cellular barrier without large pores, and therefore may have a different composition from plasma
- **Plasma:** It is the fluid portion of the blood. This portion of blood aids in transport of oxygen from the lungs to the body cells and carbon dioxide from the body cells to the lungs. It also transports nutrients derived from food in the intestine to the body cells. Other nutrients between organs. It constitutes about 4% of the TBW.

b. Intracellular fluid compartment: the cytosol or intracellular fluids all the fluid enclosed in cells by the plasma membranes. Most of the water in the body is intracellular fluid constituting approximately 40% of the total body weight. This fluid volume tends to be very stable, because the amount of water in living cells is closely regulated. The cytosol is the site of multiple cell processes including; metabolic processes (such as glycolysis, gluconeogenesis etc). It is also involved in signal transduction from the cell membrane to sites within the cell.

4.0 Conclusion

Study of blood physiology includes the study of different components of blood, their formation, their role in different body functions and dysfunctions, and study of blood disorders. The components of blood are; formed element or cell fragments (45%) made up of red blood cells (or erythrocytes), white blood cells (or leucocytes) and platelets (or thrombocytes). Secondly, blood is made up of plasma (55%): a liquid portion of blood in which various types of blood cells are suspended. Plasma is made of solids, liquid and gases.

Human beings are creatures that are primarily composed of water. The distribution of this fluids can be categorized into intracellular fluid (ICF) which is the total space within cells primarily defined as the cytoplasm of cells and extracellular fluid (ECF) is made up of plasma and interstitial space. Fluid moves throughout cellular environments

in the body by passively crossing semipermeable membranes. Fluid is largely regulated through passive diffusion following the concentration gradients of osmotically active solutes; however, hydrostatic pressures can influence fluid movement between spaces.

5.0 Summary

Body fluids are aqueous solutions with differing concentrations of materials, called solutes. The percent of body water changes with development, because the proportions of the body given over to each organ and to muscles, fat, bone, and other tissues change from infancy to adulthood.

6.0 In-Text Questions

1. Write a brief note on composition of blood
2. Enumerates the function of blood in humans
3. Briefly describe the main classifications of haematopoietic stem cells
4. State the primary functions of the various white blood cells
5. State 5 physiological variations of haemoglobin
6. Describe the changes in body fluid compartments

7.0 In-Text Answers

Q1. Blood is divided into main parts, namely; cell fragments and plasma.
a. Cell Fragments: This is made of three parts namely;

- Erythrocytes (Red Blood Cells)
- Leukocytes (White Blood Cells)
- Thrombocytes (Platelets)

b. Blood plasma is a straw or light-yellowish colored fluid that forms the fluid base of whole blood. Plasma contains 91% to 92% of water and 8% to 9% of solid and gases.

Q2. Function of Blood includes;

- Transportation Functions eg transportation of gases, waste products, nutrients, and hormones
- Defense function eg phagocytosis, Production of antibodies and coagulation or clotting function
- Regulative functions eg Regulation of acid-base balance, body temperature and water balance

Q3. Three main classifications of blood cells derive from haematopoietic stem cells (HSCs).

- ***Myeloid cells.*** This includes macrophages (monocytes) and granular white blood cells (or granulocytes; neutrophils, basophils and eosinophils). Macrophages have a role in adaptive immunity, cooperating with T and B cells through antigen presentation and the production of cytokines.

- ***Erythroid-megakaryocytes.*** Erythrocytes (red blood cells) carry oxygen through blood vessels, whereas platelets derived from megakaryocytes work to prevent blood loss.
- ***Lymphoid cells.*** This includes T-cells and B-cells. Natural killer (NK) cells are thought to be the prototype of T cells. Thymic, as well as pre-thymic, T-cell progenitors are able to generate dendritic cells. B cells secrete antibodies.

Q4. The primary function of the 5 types of Leukocytes are

- **Neutrophils** – phagocytosis (bacteria & cellular debris); very important in inflammation
- **Eosinophils** - help initiate and sustain inflammation and can activate T-cells (directly by serving as antigen-presenting cells and indirectly by secreting a variety of cytokines). Eosinophils can also kill bacteria by quickly releasing mitochondrial DNA and proteins.
- **Basophils** - along with mast cells, play a role in inflammation and allergic responses. Release of histamine by mast cells requires the production of antibodies (IgE) by B-cells and that process is regulated, in part, by cytokines produced by basophils.
- **Monocytes** - phagocytosis (typically as macrophages in tissues of the liver, spleen, lungs, & lymph nodes) & also important antigen-presenting cells.
- **Lymphocytes** - immune response (including production of antibodies).

Q5. **Physiological variations for Hb**

- **Age:** Haemoglobin concentration is more in new born and infants than adults.
- **Sex:** Haemoglobin concentration is more in male than female.
- **Emotion:** Hb concentration increases during emotional states.
- **Exercise:** Hb concentration increases.
- **Pregnancy:** Total quantity of haemoglobin increases during pregnancy but haemoglobin concentration decreases due to haemodilution

Q6. Humans are approximately 75% water by mass as infants and 50% to 60% water by mass as adults. Body fluid is the essence of life and it is the aqueous base solution in which all essential biochemical processes occur that produce life. The maintenance of a relatively constant volume and a stable composition of the body fluids is essential for homeostasis. The body fluid compartment is divided into;

- **Extracellular fluid compartment:** Extracellular fluid (ECF) surrounds all cells in the body and it constitutes approximately 20% of total body weight. They are divided into the following; interstitial fluid, transcellular fluids and plasma.
- **Intracellular fluid compartment:** thecytosol or intracellular fluid is all the fluid enclosed in cells by the plasma membranes. Most of the water in the body is intracellular fluid constituting approximately 40% of the total body weight.

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STUDY SESSION 5: HOMEOSTASIS

CONTENTS

1.0 Introduction

Physiology as an integrative science studies the functions of complex living organisms at different structural complexity levels ranging from atoms, molecules and cells to tissue, organs and systems. The human body is an inter-dependent set of self-regulating systems whose primary function is to maintain an internal environment compatible with living cells and tissues (homeostasis). Considerably, every organ system in the body contributes to homeostasis. All organisms must maintain relatively stable internal conditions. A complex set of chemical, thermal, and neural factors interact in complex ways, both helping and hindering the body while it works to maintain homeostasis.

Homeostasis refers to the capacity of living things to maintain their internal composition constant despite changes in the external environment. Homeostasis can be considered in regards to a cell, tissue, organ, biological system, or environmental system. As such, homeostasis is the tendency to resist change in order to maintain a stable, relatively constant internal environment. The keys to maintaining stability of the ECF are self-regulatory mechanisms which allow us to adapt to a changing environment.

To understand the key notion behind homeostasis, it is important to consider the concepts of equilibrium and steady state. Steady state infers to the condition whereby the amount of a substance is constant within a compartment and does not change with time. A steady state is not necessarily an equilibrium state. Energy expenditure may be needed to maintain a steady state. When conditions outside of the body change (e.g., temperature), these changes are reflected in the composition of the ECF which surrounds the individual cells of the body. Equilibrium is a condition in which the opposing forces are balanced. There is no net transfer of a substance (or of energy) from one compartment to another.

2.0 Learning Outcomes

After reading this course, student will be able to:

- Define the terms homeostasis, steady state, and equilibrium.
- Explain the principles and mechanism of homeostasis.
- Explain homeostatic imbalance
- Identify the possible pathophysiology of homeostasis

3.0 Main Content

3.1 Homeostasis

Homeostasis is known as the process by which the body keeps the internal environment constant despite changes in the external environment. Homeostasis can also be defined as the tendency of an organism or cell to regulate its internal environment and maintain equilibrium, usually by a system of feedback controls, so as to stabilize health and functioning. To function optimally, the human body constantly maintains a relatively normalcy of the internal environment despite changes in external conditions. This constancy, equilibrium or balance, is termed homeostasis.

The word homeostasis is coined from two words; 'Homeo' meaning similar and 'Stasis' meaning state of equilibrium. Homeostasis is the maintenance of the ECF as a steady state. An equilibrium state will occur if there is sufficient time for exchange and if there is no barrier to movement from one compartment to the other. Hence, homeostasis refers to the ability of the body to as maintain a dynamic equilibrium. (Dynamic means "active" and equilibrium means "balanced."). Homeostasis is the state of dynamic equilibrium of the internal environment of the body. More so, homeostasis can be viewed as the state of internal harmony among the body systems.

Homeostasis means dynamic stability of conditions, e.g., biochemical variables, such as blood glucose level, and physiological variables, such as body temperature. Homeostasis can also be viewed as the body's ability to maintain a relatively constant internal environment in terms of body temperature, ion concentrations, blood and water balance, cardiac output, blood pH, hydration, dissolved CO_2 concentration in blood, blood glucose concentration, concentrations of wastes among others. This constancy of internal environment is maintained despite energy and molecules continuously entering and leaving the body. The values of these (and other) variables oscillate within a narrow range.

In the nineteenth century, Claude Bernard, a French physiologist, was first to introduce the concept of *milieu intérieur*, which means the internal environment of the body. In the absence of homeostasis in the human body, illness or even death will occur. A disease is an expression of functional disharmony of the systems that usually occurs due to prolonged disturbances of any kind. Understanding the nature of disturbance is critical to comprehend the pathophysiology of a disease and the physiological basis of

management of the disease. Every organ system is involved in helping the body maintain homeostasis. None works in isolation. The body depends on all organ systems nteracting together. In fact, a disruption in one body system usually has consequences in one or more other systems.

Basically, the body operates within a narrow range of temperature, fluids, and chemicals. This range of normal is called the set point or set point range. E.g, the body's internal temperature should remain between 97° and 99° F (36°– 37.2° C) despite the temperature outside the body. Likewise, blood glucose levels should remain between 65 and 99 mg/dl, even when you decide to indulge in an occasional sugar-laden dessert. Just as a gymnast must make constant physical adjustments to maintain balance on a balance beam, the body must make constant internal adjustments to maintain homeostasis.

3.2 Principles and Mechanisms of Homeostasis

In order to maintain homeostasis, systems must be controlled and regulated. Control refers to the organism or system's capacity to change the rate of a reaction or process whereas, regulation refers to the capacity to maintain a variable within specific limits. Homeostatic regulation is mainly achieved through the feedback mechanisms that operate to safeguard a set point already set for the physiological variable. Maintaining a stable environment requires constant monitoring and adjustment as conditions change. There are several different principles and mechanisms within the body that brings about homeostasis. These include negative feedback, positive feedback, feed forward, tonic control, antagonistic control and circadian rhythms.

3.2.1 Negative feedback loops

The response removes the stimulus. A critical consequence of negative feedback control is that it allows the system to resist deviation of a given parameter from a preset range (or set point). Negative feedback is the most common form of homeostatic control in biological systems. In physiological systems, we encounter two types of negative feedback systems namely: simple and complex negative feedback system. Simple negative feedback involves two cellular compartments whereas, the complex negative feedback involves more than two cellular components.

3.2.2 Positive feedback loops

The response reinforces the stimulus rather than decreasing or removing it and this is therefore an unstable condition. The consequence of positive feedback is not to maintain homeostasis but to elicit a change. Positive feedback loops are found during development or maturation. They are finite loops; often negative feedback will reduce or terminate these responses.

3.2.3 Feed-forward Control

This type of control enables the body to anticipate a change and start a reflex loop. For example, the sight, smell, or even the thought of food starts our mouths to water. The saliva lubricates the food particles during chewing.

3.2.4 Tonic Control

This control permits the activity of the organ system to be modulated (either up or down). This is like the volume control on a radio which enables you to make the sound louder or softer by turning a single knob. A moderate rate of signaling from the nerve results in a blood vessel of intermediate diameter. An increase in the rate of signaling by the nerve results in constriction of the vessel; a decrease in signaling leads to dilation.

3.2.5 Antagonistic Control

This control modulates the activity of an organ system by two separate regulators which act in opposition. For example; chemical signals (neurotransmitter) from a sympathetic neuron increase heart rate, whereas neurotransmitters from a parasympathetic neuron decrease it.

3.2.6 Circadian Rhythms

This control allows the biological systems to fluctuate in a predictable, timed manner over a 24hour cycle as their set points change. Circadian rhythms govern many biological functions, including blood pressure, body temperature, and metabolic processes. Circadian rhythms arise from special group of cells in the brain (suprachiamastic nucleus of the hypothalamus) which are programmed by either the light-dark, day-night cycle by input from the retina or our sleep (rest) -activity periods. When the circadian clock is altered (e.g., jet lag), temperature rhythms and the secretion of various hormones are also altered.

3.3 Homeostatic imbalance

Homeostasis is important for keeping a constant internal environment. Homeostatic imbalance is a fluctuation from equilibrium that changes the body's internal environment and prevents it from going back to equilibrium. Physiological imbalances occur when the cells have a structural issue or are not receiving the proper nutrition they need. Psychological imbalances are those that affect a person's mental health. Examples of homeostatic imbalances include but are not limited to thermoregulation, diabetes, cancer, dementia, and depression. Disruptions are any occurrences that affect a person's health from normal conditions. Such disruptions may include environmental factors, lifestyle factors, external toxins, and genetic mistakes. Similarly, disruptions to a person's psychological or physiological homeostasis are known as a drive states. The primary drive state includes components that affect both physiological and psychological imbalances such as food, water, and sex. The secondary drive state includes more psychological imbalances related to money and social interactions.

Aging is a general example of disease as a result of homeostatic imbalance. As an organism ages, weakening of feedback loops gradually results in an unstable internal environment. This lack of homeostasis increases the risk for illness and is responsible for the physical changes associated with aging. Heart failure is the result of negative feedback mechanisms that become overwhelmed, allowing destructive positive feedback mechanisms to compensate for the failed feedback mechanisms. This leads to

high blood pressure and enlargement of the heart, which eventually becomes too stiff to pump blood effectively, resulting in heart failure. A physical condition can be caused by many influences. One reason the body's cells experience a malfunction is due to age. As the body ages, there tends to be more mistakes in cell division which can lead to unwanted diseases and other complications. Another reason is there may be an imbalance that a person was born with. If the genetic code has a simple mistake when cells divide and include the mistake this could lead to a disorder.

Processes and stages in the life of the living organism, such as stress, disease and aging, are explained in terms of an ongoing change of homeostasis. A person's lifestyle can also affect their cells in a harmful way, such as drug and alcohol use and a fluctuation in nutrition intake. Another imbalance that can affect a person's health is external toxins. Since homeostatic imbalances can lead to disease states or even death, homeostasis has been identified as one of the eight core concepts of biology. Disease is any failure of normal physiological function that leads to negative symptoms. While disease is often a result of infection or injury, most diseases involve the disruption of normal homeostasis. Anything that prevents positive or negative feedback system from working correctly could lead to disease if the mechanisms of disruption become strong enough.

3.4 Pathophysiology of Homeostasis

Some of the factors that can interfere with homeostasis of the body at the cellular level, whether harmful or beneficial are described. They are described below;

Physical changes:

Physical maintenance is essential for our cells and bodies. Adequate rest, sunlight, and exercise are examples of physical mechanisms for influencing homeostasis. Lack of sleep is related to a number of ailments such as irregular cardiac rhythms, fatigue, anxiety and headaches.

Psychological changes:

The physical health and mental health of humans are inseparable. Thoughts and emotions cause chemical changes to take place either for better as with meditation, or worse as with stress.

Genetic changes:

Genes are sometimes turned off or on due to external factors which we can have some control over, but at other times little can be done to correct or improve genetic diseases. Inheriting strengths and weaknesses can be part of an individual’s genetic makeup. Beginning at the cellular level a variety of diseases come from mutated genes. For example, cancer can be genetically inherited or can be caused due to a mutation from an external source such as radiation or genes altered in a fetus when the mother uses drugs.

Excess toxins:

Too much toxicity also causes homeostatic imbalance, resulting in cellular malfunction. Any substance that interferes with cellular function, causing cellular malfunction is

termed toxin. This is done through a variety of ways; chemical, plant, insecticides, and/or bites. A commonly seen example of pathophysiology of homeostasis is consumption of overdoses of drug. When a person takes a drug above the therapeutic regime, such drugs begins to interfere with their vital signs; either by increasing or decreasing their set values, such fluctuations in vital signs could result to health problems like coma, brain damage and even death.

Nutritional factor:

Lack of adequate diet or balance diet containing the required nutrients affects the proper functioning of cells, possibly resulting in a disease condition. For example, a menstruating woman with inadequate dietary intake of iron will become anemic. Lack of hemoglobin, a molecule that requires iron, will result in reduced oxygen-carrying capacity. In mild cases symptoms may be vague (e.g. fatigue), but if the anemia is severe the body will try to compensate by increasing cardiac output, leading to palpitations and sweatiness, and possibly to heart failure.

4.0 Conclusion

The body is in a dynamic state of equilibrium because its internal conditions change and vary (oscillate) within relatively narrow limits. Receptors monitor changes in these physiological variables, that is, they receive a stimulus. This stimulus is transmitted via an afferent pathway to an integrating centre (e.g. the brain or a gland). The integrating centre compares the stimulus to the normal level of the variable – the "set point". If a response is required a message is sent via an efferent pathway to the effector organ. The effector produces a response that moves the value of the variable back towards the set point.

5.0 Summary

All living organisms, from cells upward, are in disequilibrium with their environment. Within the organism, and within individual cells, however, the milieu internal, the internal medium, has to be maintained within strict limits. Homeostasis refers to the body's ability to physiologically regulate its inner environment to ensure its stability in response to fluctuations in external or internal conditions. The body is a social order of many trillion of cells organized into various functional structures, the largest of which are called organs. Each functional structure, or organ, helps maintain a constant internal environment. As long as homeostasis is maintained, the cells of the body continue to live and function properly. Thus, each cell benefits from homeostasis, and in turn, each cell contributes its share toward maintaining homeostasis.

When this loss happens, all the cells of the body suffer. Extreme dysfunction leads to death, whereas moderate dysfunction leads to sickness (homeostatic imbalance). A state of homeostatic imbalance can affect a person physiologically as its hallmark is marked disruption of the function of cells in the body, a condition known as disturbance of homeostasis or the alteration of the body's normal internal equilibrium.

Successful compensatory mechanism helps to reestablish homeostasis as it is characterized by wellness, however, failure in such homeostatic compensation leads to pathophysiology characterized by illness or disease and when prolonged causes death.

6.0 In-Text Questions

1. What is homeostasis? Give 2 examples
2. Enumerate the principles and mechanism of homeostasis
3. What do you understand by homeostatic imbalance?
4. List 5 possible pathophysiology of homeostasis

7.0 In-Text Answers

Q1. Homeostasis is known as the process by which the body keeps the internal environment constant despite changes in the external environment. Homeostasis can also be defined as the tendency of an organism or cell to regulate its internal environment and maintain equilibrium, usually by a system of feedback controls, so as to stabilize health and functioning. To function optimally, the human body constantly maintains a relatively normalcy of the internal environment despite changes in external conditions. This constancy, equilibrium or balance, is termed homeostasis. An examples of homeostasis include changes in

- Biochemical variable like; blood glucose level
- Physiological variable like; body temperature

Q2. There are several different principles and mechanisms within the body that brings about homeostasis. These include negative feedback, positive feedback, feed forward, tonic control, antagonistic control and circadian rhythms.

Q3. Homeostatic imbalance is a fluctuation from equilibrium that changes the body's internal environment and prevents it from going back to equilibrium. Physiological imbalances occur when the cells have a structural issue or are not receiving the proper nutrition they need. Psychological imbalances are those that affect a person's mental health.

Q4. Some of the factors that can interfere with homeostasis of the body at the cellular level, whether harmful or beneficial are described. The pathophysiology of homeostasis includes;

- Physical changes
- Psychological changes
- Genetic changes
- Excess toxins
- Nutritional factor

8.0 References/ Further Reading

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MODULE TWO

CELL PHYSIOLOGY

Study Session 1: Structure and Function of Cell
Study Session 2: Cell Membrane: Composition and Function
Study Session 3: Transport Across Cell Membrane
Study Session 4: Levels of organization of the human system

STUDY SESSION 1: STRUCTURE AND FUNCTION OF CELL

CONTENTS

1.0 Introduction

The cell is the basic structural and functional unit of tissues. Over 100trillion cells make up the human body, each having a basic requirement to sustain it. Every living thing has cells: bacteria, protozoans, fungi, plants, and animals are the main groups (Kingdoms) of living things. Some organisms are made up of just one cell (e.g. bacteria and protozoans), but animals, including human beings, are multicellular. Perhaps, the body's organ systems are largely built around providing the cells with the required features like; oxygen, food, and waste removal.

There are about 200 different kinds of specialized cells in the human body. When many identical cells are organized together it is called a tissue (such as muscle tissue, nervous tissue, etc). Various tissues organized together for a common purpose are called organs (e.g. the stomach is an organ, and so is the skin, the brain, and the uterus). Major types of cells are nerve cell, muscle cell, red blood cell, gland cell and immune cell. It is important to note that groups of cell having similar function forms tissues. All physiological processes, disease, growth and development can be described at the cellular level.

There are many types of tissues in the body. All the tissues are classified into four major types which are called the primary tissues. The primary tissues include:

i. Muscle tissue (skeletal muscle, smooth muscle and cardiac muscle)
ii. Epithelial tissue (squamous, columnar and cuboidal epithelial cells)
iii. Nervous tissue (neurons and supporting cells)
iv. Connective tissue (connective tissue proper, cartilage, bone and blood).

The structure and function of the cell can be described under three components namely; cell membrane, cytoplasm and nucleus.

2.0 Learning Outcomes

After reading this course, student will be able to:

- Examine the structural composition of cell
- Describe the function of a typical cell
- Evaluate the theory of cell
- Evaluate the concept of cell inclusion

3.0 Main Content

3.1 Cell Structure

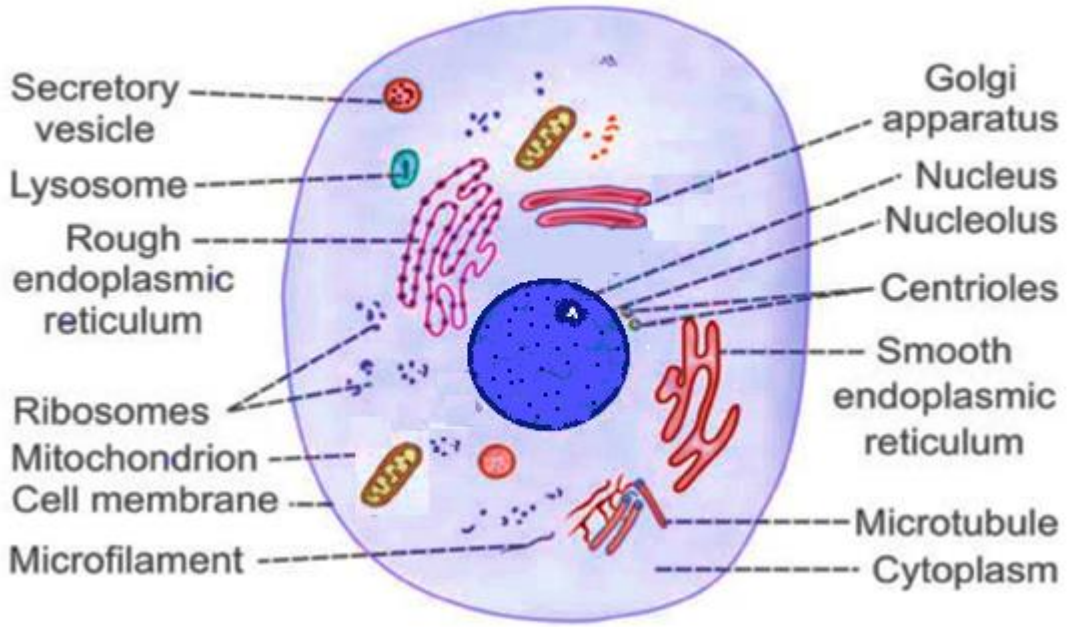

Figure2.1**:** A Typical Animal Cell

A cell consists of three fundamental structures, namely:

1. Cell Membrane

Cell membrane is a protective sheath, enveloping the cell body. It is also known as plasma membrane or plasmalemma. It is a thin, elastic semi-permeable membrane, enveloping the cell. Structurally, the cell membrane has a thickness of 7.5–10 nm. The boundary of the cell, sometimes called the plasma membrane, separates internal metabolic events from the external environment and controls the movement of

materials into and out of the cell. This membrane is very selective about what it allows to pass through; this characteristic is referred to as "selective permeability." Cell membrane is called a unit membrane or a three-layered membrane.

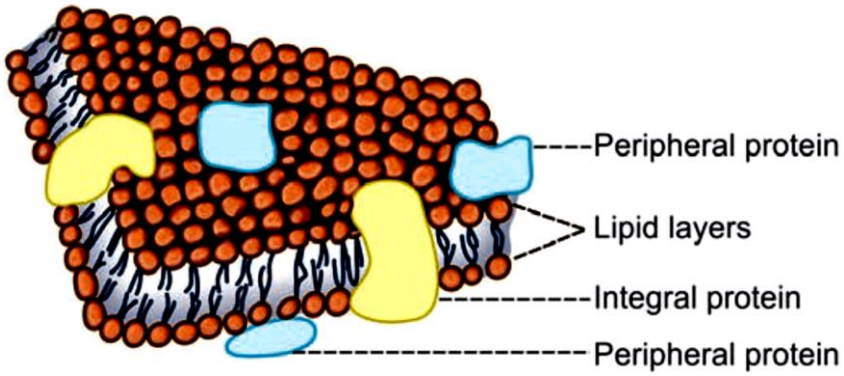

Figure2.2: Structure of a cell membrane

Cell membrane is a bilayer of lipids (double phospholipid membrane) that has a mosaic of proteins "floating" in a "sea" of lipids. The plasma membrane has two ends; the nonpolar hydrophobic tails pointing towards the inside of the membrane and the polar hydrophilic heads forming the inner and outer surfaces of the membrane. Structurally, the cell membrane is composed of three types of substances: Carbohydrates (5%), Proteins (55%) and Lipids (40%). Lipids are phospholipids (75%) which form a bilayer, and cholesterol (20%). Proteins are integral (one end in cell, other end out of cell) or peripheral.

2. Cytoplasm

Cytoplasm of the cell is a jellylike material formed by 80% of water. It contains a clear liquid portion called **cytosol** and various particles of different shape and size.The particles embedded in the cytoplasm are proteins, carbohydrates, lipids or electrolytes in nature. Several different molecules interact to form organelles with our body. Each type of organelle has a specific function. Organelles perform the vital functions that keep our cells alive. Organelles are considered as small organs of the cell. The organelles bound by limiting membrane and those that do not have limiting membrane are discussed as follows;

Membranous Organelles

i. Endoplasmic Reticulum (ER):

Endoplasmic reticulum is a network of tubular and microsomal vesicular structures which are interconnected with one another. The membranes of ER are continuous with the outer membrane of nucleus and are also connected with Golgi apparatus. It is covered by a limiting membrane which is forms networks of ***tubules***, ***vesicles***, and flattened ***cisternae***. ER is the site of the synthesis of proteins and lipids for the membrane of the cell and organelles, and secretory vesicles of the cytoplasm. Endoplasmic reticulum is of two types, namely **Rough Endoplasmic Reticulum (RER)** and **Smooth Endoplasmic Reticulum (SER)**. Both types are interconnected and continuous with one another. When the surface of ER is studded with ribosome, the organelle is called RER or *granular ER* but when ribosomes are not attached to the surface of ER, the organelle is called SER or *a granular ER.*

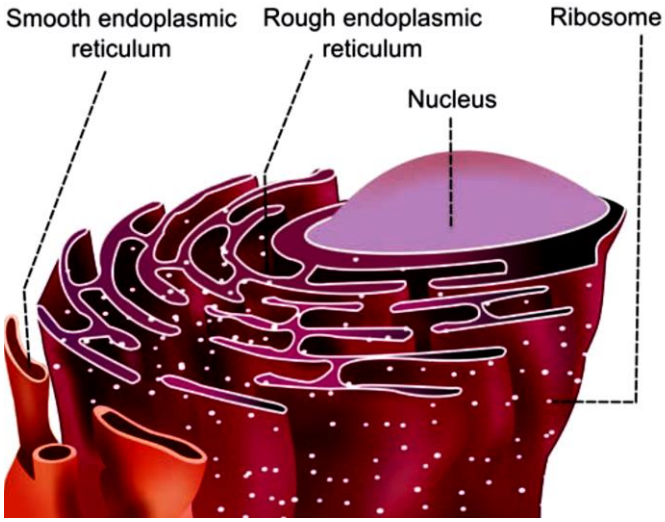

Figure2.3: Structure of endoplasmic reticulum (ER)

ii. Lysosomes

Lysosomes are the lipid membrane-bound vesicular organelles found throughout the cytoplasm. The lysosomes are formed by Golgi apparatus. The enzymes synthesized in rough endoplasmic reticulum are processed and packed in the form of small vesicles in the Golgi apparatus (membrane enclosed vesicles containing acidic environment with enzymes capable of digesting (lysing) a wide variety of molecules). Then, these vesicles are pinched off from Golgi apparatus and become the lysosomes. Lysosomes are of three types namely; **primary lysosome** (Golgi hydrolase vesicles), **secondary lysosome** (Endolysosome) and **tertiary lysosome** (Phagolysosome). Lysosomes are often called **'suicidal bag or garbage system'** of the cell because of their degradation activity.

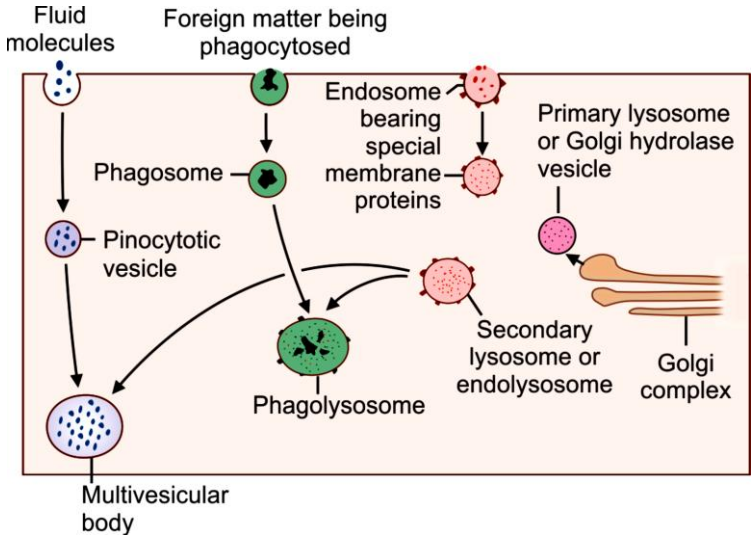

Figure 2.4: Formation of Primary, Secondary and Tertiary Lysosomes

iii. Golgi Apparatus:

Golgi apparatus or Golgi body or Golgi complex is a membrane-bound organelle involved in the processing of proteins. Golgi apparatus is situated close to the nucleus. It appears as flat discs that are dilated peripherally and stacked together in a bunch as **stack of cisternae**(4-6 flattened sacs stacked on top of each other).It has two ends or

faces, namely **cis face** and **trans face.** The cis face is positioned near the endoplasmic reticulum. Reticular vesicles from endoplasmic reticulum enter the Golgi apparatus through **cis** face. The **trans** face is situated near the cell membrane.

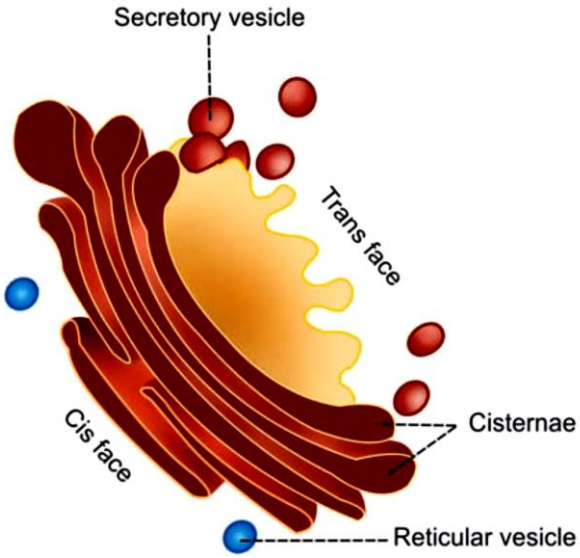

Figure 2.5: Structure of Golgi Apparatus

iv. Peroxisomes:

Peroxisomes are the membrane limited vesicles like the lysosomes. They are small spherical organelles having diameter of about 0.5 μ, and therefore denoted as **micro bodies**. Unlike lysosomes, peroxisomes are pinched off from endoplasmic reticulum and not from the Golgi apparatus. Peroxisomes contain some oxidative enzymes such as catalase, urate oxidase etc.

v. Secretory Vesicles

Secretory vesicles are the organelles with limiting membrane and contain the secretory substances. These vesicles are formed in the endoplasmic reticulum and are processed and packed in Golgi apparatus. Secretory vesicles are present throughout the cytoplasm.

vi. **Centrosome**

Centrosome is the membrane-bound cellular organelle situated almost in the center of cell, close to the nucleus. It consists of two cylindrical structures called centrioles which are made up of proteins. Centrioles are short cylindrical structures made up of microtubules placed in group of three (triplets) that run longitudinally in the wall of centrioles responsible for the movement of chromosomes during cell division. There are nine sets of triplets arranged at regular intervals in the wall of each centriole.

vii. Mitochondria

Mitochondria is a rod-shaped or oval-shaped structure with a diameter of 0.5 to 1 μ. It is covered by a bilayer membrane (inner membrane folded into cristae). The **outer membrane** is smooth and encloses the contents of mitochondrion (consists mostly of phospholipids and cholesterol, and contains a specific membrane protein that forms "*porin",* a channel that permit substances with molecular weight of less than 10,000 to

diffuse freely across the outer membrane) while the **inner membrane** is folded in the form of shelf-like inward projections called **cristae** which covers the inner matrix space (It is rich in many enzymes like cytochromes b, C_1, C, a and a_3, NADH dehydrogenase, succinate dehydrogenase, electron transferring flavoproteins). It is a membrane bound cytoplasmic organelle concerned with production of energy. That is, they are the "power house" of the cell.

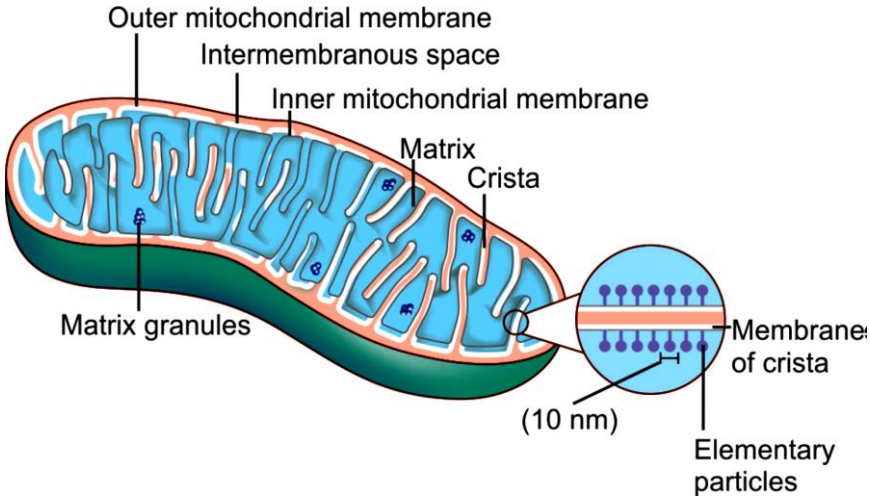

Figure 2.6: Structure of Mitochondria

Non-membranous Organelles:

i. Ribosomes

Ribosomes are the organelles without limiting membrane. These organelles are granular and small dot-like structures with a diameter of 15 nm. Though ribosomes are usually present on the surface of endoplasmic reticulum, they are also present as free organelles in the cytoplasm. Ribosomes are made up of 35% of proteins and 65% of ribonucleic acid (RNA) of the cell. RNA present in ribosomes is called ribosomal RNA (rRNA). Messenger RNA (mRNA) carries the **genetic code** for protein synthesis from nucleus to the ribosomes.

ii. Cytoskeleton

Cytoskeleton is the cellular organelle present throughout the cytoplasm that forms an intracellular system of fibers for structural integrity of the cell. It is a complex network of structures with varying sizes. These cytoskeletal elements are made up of different cell proteins. Cytoskeleton consists of three major protein components, namely: microtubules, intermediate filaments and microfilaments.

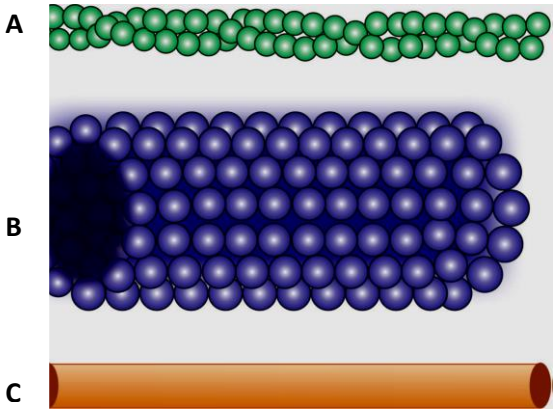

Figure 2.7: Structure of cytoskeleton
(A) micro filaments (B) Intermediate filaments (C) Microtubules

3. Nucleus

The nucleus is the most prominent and the largest cellular organelle. It has a diameter of 10 μ to 22 μ and occupies about 10% of total volume of the cell. Nucleus is present in all the cells in the body except the red blood cells. Nucleus is covered by a membrane called **nuclear membrane** and contains many components. Major components of nucleus are **nucleoplasm, chromatin** and nucleolus.

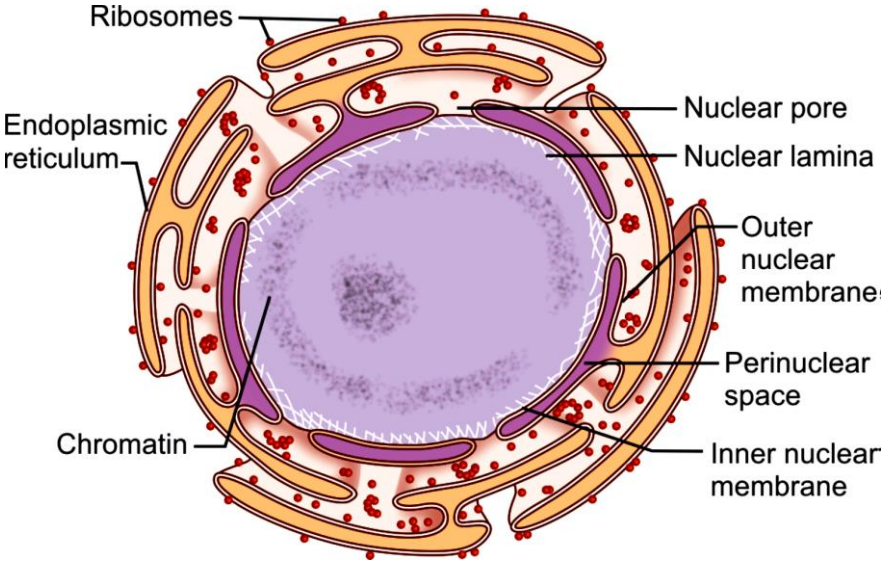

Figure 2.8: Structure of nucleus

i. ***Nuclear Membrane***

The nuclear membrane is a double-layered membrane. The space between the two membranes is called **perinuclear cisterns**. There are circular openings in the nuclear membrane known as **nuclear pores** that serve as passages for the exchange of materials between the cytoplasm and the nucleoplasm, especially for the transport of mRNA and proteins. There are two **special transport proteins** in the nuclear membrane, known as *importins* and *exportins.*

ii. ***Nucleolus***

The nucleus contains nucleolus, a patchwork of granules rich in RNA. There may be multiple nucleoli in a nucleus, especially in developing cells. Nucleoli synthesize ribosomes.

iii. ***Nucleoplasm***

The nucleoplasm is the nuclear matrix, which is a gel like substance that contains genetic material in the form of DNA. When cell is not dividing the genetic material is present in the form of tangled mass called **nuclear chromatin** and when cell division begins, the tangled mass unwinds and appears as distinct strands known as **chromosomes**.

3.2 Cell Function

1. Cell Membrane

Cell membrane maintains a constant and distinctive intracellular environment, which is essential for functioning of the organelles. For example, the intracellular fluid has lower concentration of sodium and chloride, low pH, but higher concentration of potassium, organic phosphates and magnesium.

2. Cytoplasm

The cytoplasm is vital in a cell because it acts as a "molecular soup" in which organelles are suspended and held together by a lipid membrane. The cytoplasm of a cell surrounds the nuclear envelope and cytoplasmic organelles within the plasma membrane. It plays a mechanical role by moving around inside the membrane and pushing against the cell membrane helping to maintain the shape and consistency of the cell and again, to provide suspension to the organelles. It is also a storage space for chemical substances indispensable to life, which are involved in vital metabolic reactions, such as anaerobic glycolysis and protein synthesis.

i. Endoplasmic Reticulum:

- **Functions of Rough Endoplasmic Reticulum included;** Synthesis of protein, degradation of worn-out organelles and conjugation of carbohydrates with proteins to form glycoproteins.
- **Functions of Smooth Endoplasmic Reticulum included;** cellular metabolism, intracellular transport, synthesis of lipids, Storage and metabolism of calcium, catabolism and detoxification of hormones and toxic substances.

ii. Mitochondrion:

- Aids production of energy, synthesis of ATP and apoptosis, other functions of mitochondria include storage of calcium and detoxification of ammonia in liver. The inner membrane contains the cytochromes of the electron transport system and the associated enzymes for oxidative phosphorylation (Krebs cycle occurs here).

iii. Golgi Apparatus:

- It is the site for the processing, packaging, labeling and delivery of secretory products into the secretory granules. Materials produced in rough ER travel through the lumen of smooth ER are packaged into the secretory vesicles.
- It is the site for the incorporation of carbohydrates into the newly synthesized proteins to form glycoproteins.
- Lysosomal enzymes are formed in GA.
- Transports material to other organelles and cell surface.

iv. Lysosomes:

- Lysosomal functions involve two mechanisms: Heterophagy (Digestion of extracellular materials or removal of infective organisms and foreign bodies via endocytosis) and Autophagy (Digestion of intracellular materials).
- Functions of lysosomes includes; degradation of macromolecules and worn-out organelles, removal of excess secretory products or removal intracellular products of metabolism from the cells as well as secretory functions.

v. Ribosomes:

- Ribosomes are concerned with protein synthesis in the cell; they arrange the amino acids into small units of proteins. Ribosomes are called **'protein factories'** because of their role in the synthesis of proteins.
- Ribosomes attached to rough endoplasmic reticulum are involved in the synthesis of proteins such as the enzymatic proteins, hormonal proteins, lysosomal proteins and the proteins of the cell membrane. Free ribosomes are responsible for the synthesis of proteins in hemoglobin, peroxisome and mitochondria.

vi. Peroxisomes:

- Peroxisomes contain **oxidases** that promote oxidation and many metabolic reactions of lipids. The membrane of peroxisome contains a number of specific proteins that transport substances between peroxisome matrix and cytosol.

vii. Centrosomes:

- Centrosomes regulate chromosome movement during cell division. They duplicate themselves and move apart from each other to the poles of mitotic spindle to monitor the process of cell division.

viii. Cytoskeleton:

- Cytoskeleton determines the shape of the cell and gives support to the cell. In addition to allowing appropriate change in cell shape for cell mobility and participation of cell in various physiological activities, it is also essential for the cellular movements and the response of the cell to external stimuli.

3. Nucleus

Several processes are involved in the nuclear functions such as: control of all the cell activities such as; cellular metabolism, growth and reproduction, synthesis of RNA for protein synthesis, formation of subunits of ribosomes, sending genetic instruction to the

cytoplasm for protein synthesis and control of the cell division, storage and transmission of hereditary features through genes.

3.3 Cell Theory

Basic Theory of Cell

- All living organisms are made up cell
- Cell is smallest structural and functional unit capable of carrying out life processes
- Cell give rise to pre-existing cells

Modern Theory of Cell

- Cells are living building blocks of all multicellular organisms
    - Size of cells same across different organisms
    - Difference in number and specific types of cells between species
    - 100 average-sized cells lined up would stretch a distance of 1mm
- Cells are composed of specific macromolecules that participate is similar chemical reactions or processes
    - Cells of all living organisms have genes stored as DNA written in chemical code
    - Functional activities of each cell depends on specific structural properties and protein content of the cell
    - Cells use the machinery of DNA transcription and RNA translation to produce protein molecules that make up and control the cell

3.4 Cell Inclusion

The plasma membranes of adjacent cells are usually separated by extracellular fluids that allow transport of nutrients and wastes to and from the bloodstream. In certain tissues, however, the membranes of adjacent cells may join and form a junction. Three kinds of cell junctions are recognized:

Desmosomes:

They are protein attachments between adjacent cells. Inside the plasma membrane, a desmosome bears a disk shaped structure from which protein fibers extend into the cytoplasm. Desmosomes act like spot welds to hold together tissues that undergo considerable stress, such as our skin or heart muscle.

Tight junctions:

They are tightly stitched seams between cells. The junction completely encircles each cell, preventing the movement of material between the cell. Tight junctions are characteristic of cells lining the digestive tract, where materials are required to pass through cells, rather than intercellular spaces, to penetrate the bloodstream.

Gap junctions:

They are narrow tunnels that directly connect the cytoplasm of two neighbouring cells, consisting of proteins called connexons. These proteins allow only the passage of ions

and small molecules. In this manner, gap junctions allow communication between cells through the exchange of materials or the transmission of electrical impulses.

4.0 Conclusion

Cells are the microscopic fundamental units of all living things. Cells of all living things are divided into two broad categories: prokaryotes and eukaryotes. Bacteria (and archea) are prokaryotes, which means they lack a nucleus or other membrane-bound organelles. Eukaryotes include all protozoans, fungi, plants, and animals (including humans), and these cells are characterized by a nucleus (which houses the chromosomes) as well as a variety of other organelles.
Organelles are bodies embedded in the cytoplasm that serve to physically separate the various metabolic activities that occur within cells. The organelles are each like separate little factories, each organelle is responsible for producing a certain product that is used elsewhere in the cell or body.

5.0 Summary

The smallest structure capable of performing activities essential for life. The structure and function of human cell can be understood on the basis of their membranous and non-membranous organelles which is described below;

- The **plasma membrane** is the outer lining of the cell. It separates the cell from its environment and allows materials to enter and leave the cell.
- Within cells, the **cytoplasm** is made up of a jelly-like fluid (called the cytosol) and other structures that surround the nucleus.
- **Mitochondria** is the powerhouse of the cell, plays a central role in producing adenosine triphosphate (ATP)
- **Endoplasmic reticulum** is a network of channels running through the cytoplasm. Helps process molecules created by the cell. Transports molecules to their specific destinations either inside or outside the cell.
- The **Golgi apparatus** packages molecules processed by the endoplasmic reticulum to be transported out of the cell.
- **Lysosomes** contain enzymes that break down molecules and digest bacteria that enter the cell. These organelles are the recycling centre of the cell. They digest foreign bacteria that invade the cell, rid the cell of toxic substances, and recycle worn-out cell components
- **Peroxisomes** are similar structure to lysosomes that are abundant in liver cells. They metabolise hydrogen peroxide, which is toxic to the cells of the body.
- The **nucleus** serves as the cell's command centre, sending directions to the cell to grow, mature, divide, or die. It also houses DNA (deoxyribonucleic acid), the cell's hereditary material. The nucleus is surrounded by a membrane called the nuclear envelope, which protects the DNA and separates the nucleus from the rest of the cell.

- **Ribosomes** are organelles that process the cell's genetic instructions to create proteins. These organelles can float freely in the cytoplasm or be connected to the endoplasmic reticulum. They are known as the protein factory of the cell.
- The **cytoskeleton** is a network of long fibres that make up the cell's structural framework. The cytoskeleton has several critical functions, including determining cell shape, participating in cell division and allowing cells to move. It also provides a track-like system that directs the movement of organelles and other substances within cells.

6.0 In-Text Questions

1. Briefly describe the structural organization of the cell
2. Describe the composition of cell membrane
3. List 3 membranous organellesand 2 non- membranous organelles
4. State the basic theory of cell

7.0 In-Text Answers

Q1. The structure and function of the cell can be described under three components namely;

- The **CELL MEMBRANE** or the plasma membrane which is the boundary in all animal cells that surrounds the *cytoplasm*, the fluid medium containing a variety of organelles.
- The **CYTOPLASM** which is the fluid matrix with two types of *organelles, namely* membrane bound organelles similar to the structure of cell membrane and non-membrane bound organelles.
- The **NUCLEUS** which is present at the center of the cell. In addition, there are many other proteins in the cells like actin and myosin that provide strength and mobility to the cell and also the mechanisms for adhesion to other cells.

Q2. Structurally, the cell membrane is composed of three types of substances: Carbohydrates (5%), Proteins (55%) and Lipids (40%). Lipids are phospholipids (75%) which form a bilayer, and cholesterol (20%).

Q3. Examples of membranous organelles include;

- Endoplasmic Reticulum (ER)
- Lysosomes
- Golgi Apparatus

Examples of non-membranous organelles include;

- Ribosomes
- Cytoskeleton

Q4. The basic theory of cell includes;

- All living organisms are made up cell
- Cell is smallest structural and functional unit capable of carrying out life processes

- Cell give rise to pre-existing cells

8.0 References/ Further Reading

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STUDY SESSION 2: CELL MEMBRANE: COMPOSITION AND FUNCTION

CONTENTS

1.0 Introduction

Plasma membrane also called the cell membrane surrounds every cell, separating the cell contents from its surroundings. That is, it separates ICF and ECF. It is a selectively permeable structure comprised of protein, lipid, and other macromolecules that controls movement of molecules into and out of cell and contains receptors for communication with other cells.

2.0 Learning Outcomes

After reading this course, student will be able to:

- Describe cell membrane and its compositions
- Understand the different plasma membrane models
- Clearly explain the functions of plasma membrane

3.0 Main Content

3.1 Cell Membrane

Plasma membrane separates the fluid outside the cell called extracellular fluid (ECF) from the fluid inside the cell called intracellular fluid (ICF). Thin (6-10 nm) barrier separating internal components of cell from exterior environment. It regulates passage of substances into and out of cell.

3.2 Compositions of Plasma Membrane

The plasma membrane is formed by three layers, namely; lipids, carbohydrates and proteins. These layers are described as follows;

1. Lipid Membrane Layer

The major lipids in the cell membrane are phospholipids, glycolipids and cholesterol.

a. **Phospholipids** present in cell membranes are; sphingomyelin, phosphatidylserine, phosphatidylcholine, and phosphatidyl ethanolamine
b. **Glycolipids** are generally found in the outer layer. Lipids are *amphipathic* molecules as their head or polar region is hydrophilic that are soluble in water and the tail or non-polar region is hydrophobic that are insoluble in water. The head end contains phosphate or hydroxyl moieties while the tail end contains two chains of fatty acids
c. **Cholesterol** is incorporated into the hydrophobic regions of the membrane, and serves to reinforce the lipid permeability barrier.

2. Protein Membrane Layer

Membrane proteins are of two types: Integral proteins and peripheral proteins.

a. ***Integral Proteins:*** Some membrane proteins that span the entire thickness of the membrane are known as integral proteins. They are also called transmembrane proteins. Some integral proteins penetrate only a portion of the membrane, so that they are exposed either to the external environment of the cell (interstitial fluid) or to the cytoplasmic surface of the membrane (intracellular fluid). Some membrane proteins also move laterally within the membrane (e.g. membrane receptors can move to sites of endocytosis). The types of integral membrane proteins and their functions are as follows:
    - **Channel proteins:** Proteins that provide passageways through the membranes for certain hydrophilic or water-soluble substances such as polar and charged molecules. No energy is used during transport, hence, this type of movement is called facilitated diffusion. Such proteins serve as channel proteins through which water-soluble substances like glucose and electrolytes can diffuse across the cell membrane.
    - **Transport proteins:** Proteins that spend energy (ATP) to transfer materials across the membrane. When energy is used to provide passageway for materials, the process is called active transport. Serve as ion pumps for active transport of ions across the membrane; e.g Na^+–K^+ ATPase that pumps K^+ into the cell and Na+ out of the cell against their concentration gradient. They equally serve as carrier protein to transport substances through cell membrane by facilitated diffusion; e.g transport of glucose through glucose transporter
    - **Receptor proteins:** Proteins that initiate specific cell responses once hormones or other trigger molecules bind to them. Such proteins serve as receptor (outer part) and enzyme proteins (inner part)

- **Recognition proteins:** Proteins that distinguish the identity of neighboring cells. These proteins have oligosaccharide or short polysaccharide chains extending out from their cell surface.
- **Complex membrane proteins:** Act as antigens on the surface of the cell (such as glycoproteins); e.g blood group antigens in the membrane of red cells.
- **Electron transfer proteins:** Proteins that are involved in moving electrons from one molecule to another during chemical reactions.

b. ***Peripheral Proteins:*** These are protein molecules are inserted lightly in the outer or inner border of the membrane or are just bound to the surface of the membrane. They are of two types, namely Intrinsic and extrinsic proteins:

- ***Intrinsic proteins***: They are present on the inner surface of the membrane. They usually serve as enzymes or anchor proteins for cytoskeleton and other microfilaments that maintain cell shape
- ***Extrinsic proteins***: They are present on the outer surface of the membrane. They serve as cell adhesion molecules for anchoring cells with basal lamina and with neighboring cells. They can be removed without disrupting the membrane.

3. Carbohydrate Membrane Layer

The external surface of the cell membrane is loosely covered by a carbohydrate layer known as the cell coat or **glycocalyx (**serves as a **protective coat)**. These carbohydrates are usually oligosaccharides that are covalently linked to membrane proteins forming transmembrane glycoproteins or lipids forming glycolipids (permit **temporary cell-to-cell adhesion)**. Some are also polysaccharide chains of proteoglycans, the integral membrane protein.

3.3 Plasma Membrane Models

The models that perfectly describes plasma membrane are;

i. ***Danielli-Davson model:*** proposed by James F Danielli and Hugh Davson in 1935. (On the basis of **sandwich of lipids'** covered by proteins on both sides).
ii. ***Unit membrane mode:*** proposed *by* JD Robertson in 1957 (On the basis of electron microscopic studies).
iii. ***Fluid mosaic model:*** proposed by SJ Singer and GL Nicolson in 1972 (On the basis that membrane is a fluid with mosaic of proteins which are found to float in the lipid layer instead of forming the layers of the sandwich-type model). This is the widely accepted model.

3.3 Functions of Plasma Membrane

Plasma membrane of cells performs the following functions

i. ***Protective function*****:** Cell membrane protects the cytoplasm and their surrounding organelles. Cell membrane helps in recognizing foreign cells or antigens so that they can be destroyed by phagocytes.

ii. ***Selective permeability:*** Cell membrane acts as a semipermeable membrane allowing only some substances to pass through it and acts as a barrier for other substances

iii. ***Maintenance of shape and size of the cell:*** Cell membrane is responsible for the maintenance of shape and size of the cell.

iv. ***Excretory function:*** Cell membrane aids excretion of metabolites and other waste products from the cell

v. ***Exchange of gases:*** Oxygen enters the cell from the blood and carbon dioxide leaves the cell and enters the blood through the cell membrane

vi. ***Absorptive function:*** Cell membrane aids nutrients absorption into the cell through the cell membrane

vii. **Membrane proteins act as:**

* Receptors (for signaling chemicals e.g hormones)
* Enzymes (catalyze reactions)
* Attachment (to cell's internal cytoskeleton & to extra cellular structures)
* Joiners (allow cells to adhere to each other)
* Recognizers (glycoproteins = identification tags)
* Transporters (selectively allow entry to some solutes via channels. (ATP-ases).

4.0 Conclusion

The plasma membrane exchanges materials between the cytoplasm and theexternal environment, facilitates interactions between cells and helps in anchoring the cells to each other.

5.0 Summary

This study session described cell membrane and its compositions, the different plasma membrane models and the functions of plasma membrane

6.0 In-Text Questions

1. Briefly describe the lipid layer of cell membrane
2. Write short note on the cell membrane model
3. List 5activities of membrane proteins
4. State the basic theory of cell

7.0 In-Text Answers

Q1. The lipid membrane layer is described below;

The major lipids in the cell membrane are phospholipids, glycolipids and cholesterol.

d. **Phospholipids** present in cell membranes are; sphingomyelin, phosphatidylserine, phosphatidylcholine, and phosphatidyl ethanolamine

e. **Glycolipids** are generally found in the outer layer. Lipids are *amphipathic* molecules as their head or polar region is hydrophilic that are soluble in water and the tail or non-polar region is hydrophobic that are insoluble in water. The head end contains phosphate or hydroxyl moieties while the tail end contains two chains of fatty acids

f. **Cholesterol** is incorporated into the hydrophobic regions of the membrane, and serves to reinforce the lipid permeability barrier.

Q2. The models that perfectly describes plasma membrane are;

iv. ***Danielli-Davson model:*** proposed by James F Danielli and Hugh Davson in 1935. (On the basis of **sandwich of lipids'** covered by proteins on both sides).

v. ***Unit membrane mode:*** proposed *by* JD Robertson in 1957 (On the basis of electron microscopic studies).

vi. ***Fluid mosaic model:*** proposed by SJ Singer and GL Nicolson in 1972 (On the basis that membrane is a fluid with mosaic of proteins which are found to float in the lipid layer instead of forming the layers of the sandwich-type model). This is the widely accepted model.

Q3. Membrane proteins act as:

* Receptors (for signaling chemicals e.g hormones)
* Enzymes (catalyze reactions)
* Joiners (allow cells to adhere to each other)
* Recognizers (glycoproteins = identification tags)
* Transporters (selectively allow entry to some solutes via channels. (ATP-ases).

Q4. The basic theory of cell includes;

- All living organisms are made up cell
- Cell is smallest structural and functional unit capable of carrying out life processes
- Cell give rise to pre-existing cells

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STUDY SESSION 3: TRANSPORT ACROSS CELL MEMBRANE

CONTENTS

1.0 Introduction

Biological membranes are selectively permeable, they allow some substances, and not others, to pass. Two types of transport process occur across cell membrane, namely; mediated transport and non-mediated transport. The mediated transport is classified into two categories depending on the thermodynamics of the system: In passive-mediated transport or facilitated diffusion a specific molecule flows from high concentration to low concentration. In active transport a specific molecule is transported from low concentration to high concentration, that is, against its concentration gradient. The non-mediated transport occurs through the simple diffusion process and the driving force for the transport of a substance through a medium depends on its chemical potential gradient. Whereas mediated transport requires specific carrier proteins. Thus, the substance diffuses in the direction that eliminates its concentration gradient; at a rate proportional to the magnitude of this gradient and also depends on its solubility in the membrane's non-polar core.

2.0 Learning Outcomes

After reading this course, student will be able to:

- To know different types of membrane transport
- To understand characteristic features of each
- Write the significance of vesicular transport
- Differentiate between clathrin and COP coated vesicles;
- Describe the molecular mechanism of vesicular transport;

3.0 Main Content

3.1 Passive transport

Substances that are too large or polar diffuse across the lipid bilayer on their own through membrane proteins called carriers, permeases, channels and transporters. Unlike active transport, this process does not involve chemical energy. So the passive mediated transport is totally dependent upon the permeability nature of cell membrane, which in turn, is function of organization and characteristics of membrane lipids and proteins. The different forms of passive transport are; diffusion, osmosis and filtration.

1. Diffusion

Diffusion is the spontaneous process of random movement of substance from a region of high concentration to a region of low concentration, eventually eliminating the concentration difference between the two regions towards equilibrium. The continual random movement of particles amongst each other is called diffusion. It is the way particles move about inside and around cells (in the absence of specific transport mechanisms). Diffusion occurs down the concentration gradient. Diffusion is a process of the net movement of solutes from a region of high concentration to a region of low concentration. All molecules and ions are in constant motion. In fluids these particles move quite separately, the higher the temperature, the faster is the motion. The differences of concentration between the two regions are termed as concentration gradient and the diffusion continues till the gradient has been vanished.

a. Simple Diffusion

Simple diffusion allows uniform distribution of molecules across the membrane and occurs through the lipid bilayer. In simple diffusion, transport of molecules of gases such as; carbon dioxide and oxygen, as well as small molecules like ethanol, fatty acids and steroids enter the cell by crossing the cell membrane across the plasma membrane occurs unaided. These molecules have similar permeability when different cells are compared. Simple diffusion takes place through the phospholipid bilayer. A small molecule in an aqueous solution dissolves into the phospholipid bilayer, crosses it, and then dissolves into the aqueous solution on the opposite side during simple diffusion. A molecule that is hydrophobic and soluble in lipids can pass through the membrane. Polar molecules do not pass through they are not soluble in the hydrophilic interior and form bonds instead in the aqueous environment near the membrane.

b. Facilitated diffusion

This is a type of passive transport in which molecules that cross the cell membrane move quickly due to the presence of specific permeases in the membrane. It allows for uniform distribution of molecules across the membrane. Occurs through Transmembrane carrier proteins. Facilitated diffusion or called carrier-mediated

diffusion is a process that involves the movement of molecules across the cell membrane via special transport proteins that are embedded within the cellular membrane. Typical molecules using pathway are ions like; Na^+, K^+, Cl-, Ca^{2+}; and polar molecules like glucose. Facilitated diffusion along a concentration gradient is assisted by specific protein carrier-molecules in membrane. The rate of molecule transport across the membrane is much faster than would be expected from simple diffusion.

2. Osmosis:

Osmosis is the type of diffusion of water molecules across a semi- permeable membrane, from a solution of high water potential to a region of low water potential or concentration. The movement of water molecules through the cell membrane is caused by differences in the concentration of the solute on its two sides. A cell with a less negative water potential will draw in water but this depends on other factors such as; solute potential (pressure in the cell e.g. net movement of water through pores ("aquaporins") in selectively permeable membrane along its concentration gradient) and pressure potential (external pressure e.g. cell wall).

The process by which water molecules enter the cell is known as **endosmosis**, whereas the process by which water molecules exit the cell is known as **exosmosis**. When two compartments of different solute concentrations are separated by a semipermeable membrane, the compartment with higher solute concentration is called **hypertonic** relative to the compartment of lower solute concentration, which is described as **hypotonic**. When the internal solute concentration equals the external solute concentration, it is said to be **isotonic**. Here, no net movement of water in or out of the cells occurs.

3. Filtration:

Filtration is a passive diffusion that involves the movement of water and solute molecules across the cell membrane due to hydrostatic pressure generated by the system. Depending on the size of the membrane pores, only solutes of a certain size may pass through it. The membrane pores of the Bowman's capsule in the kidneys are very small, and only albumins (smallest of the proteins) can filter through. Similarly, the membrane pores of liver cells are extremely large, to allow a variety of solutes to pass through and be metabolized.

3.2 Active Transport

Active transport is the movement of a substance against its concentration gradient (i.e. from low to high concentration). Active transport requires the input of chemical energy to move substances against their concentration gradients. Active transport is used to overcome concentration imbalances that are maintained by proteins in the membrane. It is an endergonic process that, in most cases, is coupled to the hydrolysis of ATP. This

form of transport requires ATP to move ions, amino acids & monosaccharides against their concentration gradient, or charge gradient. eg the "Na+ -K+ pump". The two forms of active transports are; Primary active transport and secondary active transport.

1. Primary active transport:

Primary active transport, also called direct active transport, directly uses energy to transport molecules across a membrane. Photon energy and redox energy are two sources of energy for primary active transport. Example: Sodium-potassium pump, which helps to maintain the cell potential. Primary active transport is demonstrated by glucose uptake in the human intestine.

2. Secondary active transport:

Secondary active transport or co-transport or coupled transport allows one solute to move downward (along its electrochemical potential gradient) in order to generate enough entropic energy to drive the transport of the other solute upward (from a low concentration region to a high concentration region). This type of transport uses energy to transport molecules across a membrane; however, in contrast to primary active transport, there is no direct coupling of ATP; instead, the electrochemical potential difference created by pumping ions out of the cell is instrumental. The two main forms of active transport are antiport and symport.

a. Antiport: In this secondary transport two species of ion or solutes are pumped in opposite directions across a membrane. One of these species is allowed to flow from high to low concentration which yields the entropic energy to drive the transport of the other solute from a low concentration region to a high one. Example: the sodium-calcium exchanger or antiporter, which allows three sodium ions into the cell to transport one calcium out.

b. Symport: this secondary transport uses the downhill movement of one solute species from high to low concentration to move another molecule uphill from low concentration to high concentration (against its electrochemical gradient). Example: glucose symporter SGLT1, which co-transports one glucose (or galactose) molecule into the cell for every two sodium ions it imports into the cell.

3.3 Bulk Transport

Plasma membrane engulfs the substance and the membrane enclosed vesicle moves through membrane.

1. Endocytosis:

Endocytosis is the process by which cells absorb larger molecules and particles from the surrounding by engulfing them. It is used by most of the cells because large and polar molecules cannot cross the plasma membrane. The material to be internalized is surrounded by plasma membrane, which then buds off inside the cell to form vesicles

containing ingested material. This form of bulk transport brings large substances (eg RBC, bacteria, proteins, polysaccharides) into cell. Types of endocytosis are phagocytosis, pinocytosis and receptor mediated edocytosis.

a. Phagocytosis: phagocytosis or "cell eating," is a mechanism whereby the cell can ingest solid particles. Phagocytosis is the process by which certain living cells called phagocytes engulf larger solid particles such as bacteria, debris or intact cells. A food vacuole (phagosome) forms and usually fuses with a lysosome, where contents are digested. Certain unicellular organisms, such as the protists, use this particular process as means of feeding. It provides them part or all of their nourishment. In amoeba, phagocytosis takes place by engulfing the nutrient with the help of pseudopods, that are present all over the cell, whereas, in ciliates, a specialized groove or chamber, known as the cytostome, is present, where the process takes place. During its maturation, some of the internalized membrane is recycled to plasma membrane by receptor mediated endocytosis.

b. Pinocytosis: pinocytosisor "cell drinking," allows the cell to consume solutions. The vesicles are smaller and bring in fluids and dissolved substances, as in the endothelium near blood vessels. An infant's intestinal lining ingests breast milk by pinocytosis, allowing the mother's protective antibodies to enter the baby's bloodstream.

c. Receptor–mediated endocytosis: this form of bulk transport depends on receptors to bind to specific molecules (their ligands). The receptors are integral membrane proteins. e.g. uptake of iron and insulin.

2. Exocytosis

Exocytosis is a process by which the cells direct the contents of secretory vesicles out of the cell membrane. The vesicle membrane fuses with the plasma membrane and the contents are released into the cellular environment. These vesicles contain soluble proteins to be secreted to the extracellular environment, as well as membrane proteins and lipids that are sent to become components of the cell membrane. This bulk transport takes large substances out of cell (eg at synapses, neurotransmitters are released from their vesicles by exocytosis). It is the final step in the secretory pathway that typically begins in the endoplasmic reticulum (ER), passes through the Golgi apparatus, and ends at the outside of the cell. Some of the examples include secretion of proteins like enzymes, peptide hormones and antibodies from cells and release of neurotransmitter from presynaptic neurons. Types of exocytosis are constitutive exocytosis and regulated exocytosis.

a. Constitutive exocytosis: Secretory materials are continuously released without requirement of any specific kind of signal.

b. Regulated exocytosis: Regulated exocytosis requires an external signal, a specific sorting signal on the vesicles for release of components. It contains a class of secretory

vesicles that fuse with plasma membrane following cell activation in presence of signal. Examples of regulated exocytosis are secretion of neurotransmitter, hormones and many other molecules.

3.4 Carrier Mediated transport

Transmembrane carrier proteins are of two types, name; channel mediated protein channels and carrier mediated proteins. Channel mediated protein channels allows ions to move through narrow water soluble pore while carrier mediated proteins Allows polar molecules (glucose) to move through specific carrier proteins

Examples of channel proteins are;

- **Leak channel**- this channel is continuously open
- **Ion channels:** are a type of channel protein; most are gated, and can be opened or closed to ion passage
- **Gated channel**: a gated channel opens when a stimulus causes the channel to change shape
- **Ligand-gated channel:** a stimulus may be a ligand which involves a chemical signal. A ligand-gated channel responds to its ligand.
- **Aquaporins:** are specific channels that allow large amounts of water to move along its concentration gradient

Examples of carrier proteins are;

- **Glucose transporters:** are carrier proteins in mammalian cells. Many large molecules, such as glucose, are insoluble in lipids and too large to fit into the porins, therefore, it will bind with its specific carrier proteins causing the protein to change shape and the complex will then be bonded to a receptor site and moved through the cellular membrane.

3.5 Vesicular transport

Vesicular transport deals with the soluble and membrane proteins i.e. proteins destined along the secretory route. The synthesis and their translocation between different organelles of cell are facilitated by small membrane bound structures known as transport vesicles. This is possible due to the presence of specific receptor proteins and signaling molecules present on both the vesicles and target sites. In eukaryotes, vesicular transport is crucial for growth, development and survival of organism because it maintains the correct balance and distribution of various moieties in specific cellular compartments. Vesicular transport mechanism helps in sorting and transport of protein to their correct address.

Proteins destined along the secretory route are transported from endoplasmic reticulum (ER) to Golgi complex for post translational modification as well as sorting. These vesicles then catch a ride on a molecular motor such as; kinesin or myosin, and travel along the cytoskeleton until they dock at the appropriate destination and fuse with the target membrane or organelle. The proteins are transported to lysosomes, secretory granules or plasma membrane according to the signal it bears which is encoded by their sequence. In general, the Golgi has been classified into: cis compartment closest to ER, medial compartment and trans compartment, which exports proteins to different destinations. Vesicles migrate from the ER to the cis Golgi, then to the medial Golgi, then to the trans Golgi, and finally to the plasma membrane or other compartments. Although, most movement is in this direction, there are also vesicles that move back from the Golgi to the ER, carrying proteins that were supposed to stay in the ER and were accidentally scooped up within a vesicle.

The vesicular transport is initiated after the formation of the transport vesicles. Vesicles are formed by detachment of a small portion of lipid bilayer. This process is also called budding. The initiation of membrane curvature required for vesicle formation requires energy. This process is mediated by proteins such as epsins. The newly formed vesicles contain the proteins that were present in the portion of membrane as well as soluble molecules. Fusion of the vesicle with a target membrane is generally a reversal of the process of its formation. The proteins that mediate targeting of the vesicle to the specific cellular location also mediate fusion, and in some systems regulate the precise time at which fusion occurs.

In vesicular transport, membrane symmetry is preserved i.e. the cytosolic face of a transport vesicle corresponds to the cytosolic face of donor compartment. After fusion, the cytosolic face of the transport vesicles becomes continuous with the cytosolic face of the target compartment. Accordingly, when a vesicle fuses with the plasma membrane, its luminal surface becomes part of the external side of the plasma membrane. The carbohydrate groups of glycoproteins in plasma membrane is always on the extracellular surface.

The formation of vesicles is dependent on coat proteins that will, under proper conditions, self-assemble into spherical cages. When associated with transmembrane proteins, they can pull the attached membrane along into a spherical shape. COPII, COPI, and clathrin are the three primary coat proteins involved in vesicle production. COPII coat proteins produce vesicles that go from the ER to the Golgi. COPI coat proteins are utilized to connect components of the Golgi apparatus and to generate vesicles that travel from the Golgi to the ER. The clathrin is used to form vesicles leaving the Golgi for the plasma membrane as well as for vesicles formed from the plasma membrane for endocytosis. All three types of vesicle coat proteins have the ability to spontaneously associate into a spherical construct, but only the COPI and COPII coated vesicle also spontaneously “pinch off” the membrane to release the vesicle from its originating membrane.

Clathrin-coated vesicles require an external mechanism to release the vesicle. Once the vesicle has almost completed, there is still a small stalk or neck of membrane that connects the vesicle to the membrane. Around this stalk, dynamic GTP molecules aggregate in a ring/spiral construction. Dynamin molecules are globular GTPases that contract upon hydrolysis of GTP. When they associate around the vesicle stalk, each dynamin protein contracts, with the combined effect of constricting the stalk enough that the membrane pinches together, sealing off and releasing the vesicle from the originating membrane.

4.0 Conclusion

Cell membrane is a phospholipid bilayer that regulates the entry and exit of molecules. Two processes of transport: Passive transport does not require metabolic energy (energy independent) and active transport requires input of metabolic energy (energy dependent). Passive transport involves a slow process and direction of net flux is high to low concentration. Passive transport occurs through the lipid bilayer or through carrier proteins. Examples include; simple diffusion, facilitated diffusion, osmosis and filtration. Active transport is directional and moves a substance against its concentration gradient. A substance moves in the direction of the cell's needs, usually by means of a specific carrier protein.

Two types of active transport: primary active transport involves hydrolysis of ATP for energy. Secondary active transport uses the energy from an ion concentration gradient, or an electrical gradient. Membrane transport proteins and various carrier molecules present in the cell membrane allow the movement of ions or molecules through semipermeable or selectively permeable biological membrane. Macromolecules are too large or too charged to pass through biological membranes and instead pass through vesicles. To take up or to secrete macromolecules, cells must use endocytosis or exocytosis.

Proteins are transported from endoplasmic reticulum (ER) to Golgi complex for post translational modification (addition and alteration) as well as sorting. x Vesicle formation requires deformation of the lipid bilayer, forming a gobletshaped invagination of the membrane that will eventually be pinched off to form the vesicle, a process called budding. x COP I-coated vesicles shuttle molecules from exit sites on the cis Golgi complex towards the ER, while COP II-coated vesicles shuttle them from the ER towards the Golgi.

5.0 Summary

Membrane transport processes are utilized by all living cells. Transport is required for the accumulation of nutrients and elimination of wastes. Membrane transport steps have been identified in most biological events. The contents of a cell are completely surrounded by its cell membrane or plasma membrane. Thus, any communication between the cell and the extracellular medium is mediated by the cell membranes.

6.0 In-Text Questions

1. Enumerate 4 types of membrane transport you know
2. Compare and contrast the two types of secondary active transport
3. What is Endocytosis? List 2 types
4. Describe 4 examples of channel proteins
5. Briefly describe vesicular transport

7.0 In-Text Answers

Q1. Types of membrane transport are

The major lipids in the cell membrane are phospholipids, glycolipids and cholesterol.

- Diffusion eg Simple Diffusion and Facilitated diffusion
- Osmosis
- Filtration
- Active Transport

Q2. **Antiport** involves a secondary transport two species of ion or solutes are pumped in opposite directions across a membrane. Example: the sodium-calcium exchanger or antiporter, which allows three sodium ions into the cell to transport one calcium out. On the contrary **Symport** is a secondary transport that uses the downhill movement of one solute species from high to low concentration to move another molecule uphill from low concentration to high concentration. Example: glucose symporter SGLT1, which co-transports one glucose molecule into the cell for every two sodium ions it imports into the cell.

Q3. Endocytosis is the process by which cells absorb larger molecules and particles from the surrounding by engulfing them. It is used by most of the cells because large and polar molecules cannot cross the plasma membrane. The material to be internalized is surrounded by plasma membrane, which then buds off inside the cell to form vesicles containing ingested material. Type of endocytosis include; phagocytosis and pinocytosis

Q4. Examples of channel proteins are;

- **Leak channel**- this channel is continuously open
- **Ion channels:** are a type of channel protein; most are gated, and can be opened or closed to ion passage
- **Gated channel**: a gated channel opens when a stimulus causes the channel to change shape
- **Ligand-gated channel:** a stimulus may be a ligand which involves a chemical signal. A ligand-gated channel responds to its ligand.

Q5. Vesicular transport deals with the soluble and membrane proteins i.e. proteins destined along the secretory route. Vesicular transport mechanism helps in sorting and

transport of protein to their correct address. Proteins destined along the secretory route are transported from endoplasmic reticulum (ER) to Golgi complex for post translational modification as well as sorting. These vesicles then catch a ride on a molecular motor such as; kinesin or myosin, and travel along the cytoskeleton until they dock at the appropriate destination and fuse with the target membrane or organelle. The proteins are transported to lysosomes, secretory granules or plasma membrane according to the signal it bears which is encoded by their sequence.

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STUDY SESSION 4: LEVEL OF STRUCTURAL ORGANIZATION OF THE BODY

CONTENTS

1.0 Introduction

Life in the human being relies on this total function, which is considerably more complex than the sum of the functions of the individual cells, tissues, organs, and system. Human physiology links the basic sciences with clinical medicine and integrates multiple functions of molecules and subcellular components, the cells, tissues, and organs into the functions of the living human being. This integration requires communication and coordination by a vast array of control systems that operate at every level, from the genes that program synthesis of molecules to the complex nervous and hormonal systems that coordinate functions of cells, tissues, and organs throughout the body. Life processes of the human body are maintained at several levels of structural organization. These include the chemical, cellular, tissue, organ, organ system, and the organism level. Higher levels of organization are built from lower levels. Therefore, molecules combine to form cells, cells combine to form tissues, tissues combine to form organs, organs combine to form organ systems, and organ systems combine to form organisms. All these components of organism by their physical and/or chemical interaction split up their work in a way that exhibits division of labour and contributes to the survival of the body as a whole.

2.0 Learning Outcomes

After reading this course, student will be able to:

- Describe the structure of the human body in terms of six levels of organization
- Highlight the eleven organ systems of the human body and identify at least one organ and one major function of each

3.0 Main Content

3.1 Chemical level

The body is made up of various chemicals. This is the lowest level of structural organization of humans consists of all the chemicals that are essential for maintaining life. The smallest unit of any of these pure substances (elements) is an atom. Atoms are made up of subatomic particles such as the proton, electron and neutron. Different chemicals such as; adenosine triphosphate, oxygen, carbon dioxide and hydrogen combines to form the various molecules found in the human body. Two or more atoms combine to form a molecule which are the chemical building blocks of all body structures. For example, hydrogen and oxygen atoms combine to from a molecule of water - H20, which is essential for survival of the body. Saliva, tears and many other body fluids are made of water.

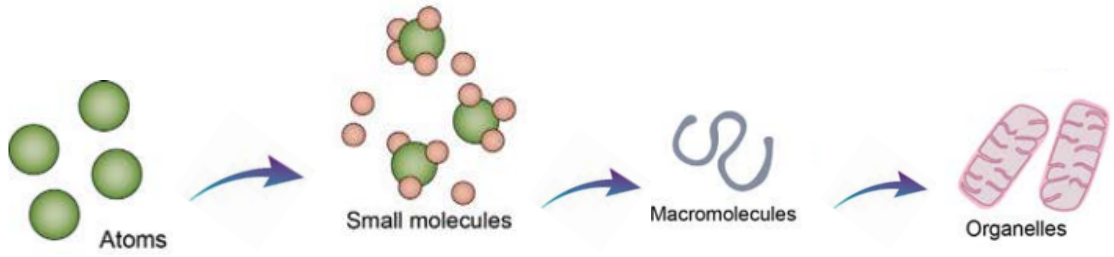

Figure 2.9: Chemical Level

3.2 Cellular level

Cell is the basic function and structural unit of every living organism and it forms the building blocks of the human body. Cells have many parts, each with a different function. Some of these parts, called organelles, are specialized structures that perform certain tasks within the cell. This smallest structure is capable of performing activities essential for life. They provide structure for the body, take in nutrients from food, convert those nutrients into energy and performs specific functions. Cells also contain the body's hereditary material and can make copies of themselves. The human body is composed of trillions of cells. There are many types of cell in the human body which vary in size, structure and function e.g muscle cells, nerve cells, Blood cells etc.

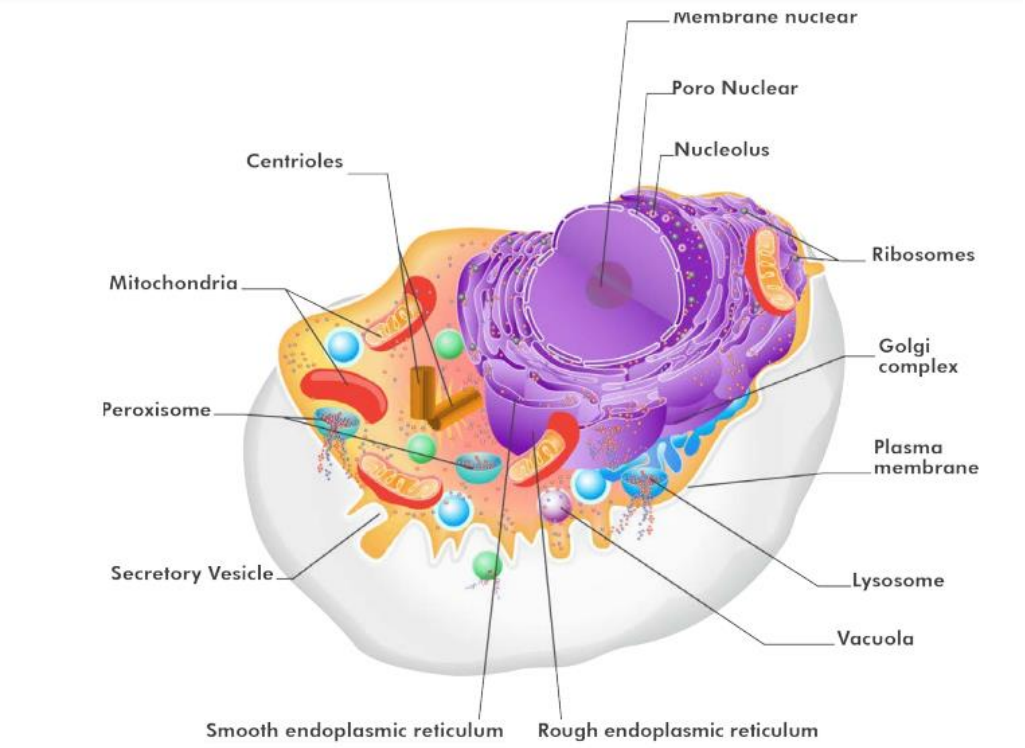

Figure 2.10: Cellular Level (A typical human cell)

3.3 Tissue level

Tissues are collections of similar cells grouped together to form body tissues which perform a specific function. Together, groups of specialized cells form tissue. There are four basic types of tissues in the body namely; nervous tissue, muscular tissue, epithelial tissue and connective tissue. The first two are excitable tissues, while the remaining two are non-excitable tissues.

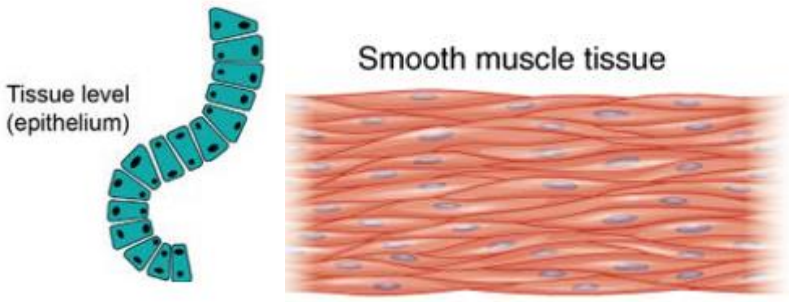

Figure 2.11: Tissue Level

3.4 Organ level

Tissues form specialized structures called organs. At the organ level of two or more types of tissue combine to form an organ which enable them to perform a specific role or function in the body. For example, the heart keeps blood flowing through its rhythmic contractions. Organs can be composed of any or all of the four basic tissue types. The heart, while mostly specialized muscle tissue, also contains nerve,

connective, and epithelial tissues. Examples of organs in the body include; heart, lungs, liver, kidneys, bladder, stomach and the skin.

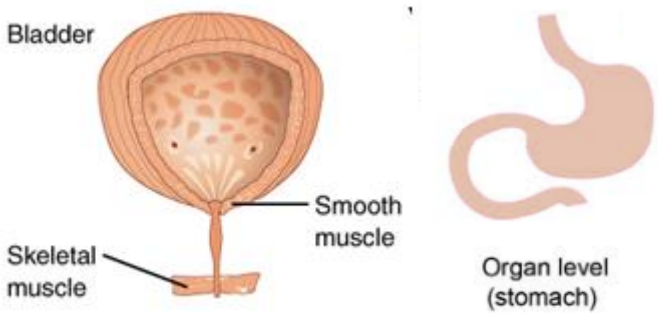

Figure 2.12: Organ Level (Bladder and Stomach)

3.5 System level

At the system level two or more organs work closely together to perform the functions of a body system. For example, the stomach, esophagus, and intestines are all part of the digestive system, which allows the human body to process and use nutrients. The basic systems of the body include; circulatory system, digestive system, endocrine system, integumentary system, immune system, skeletal system, muscular system, urinary system, respiratory system, nervous system, and reproductive system.

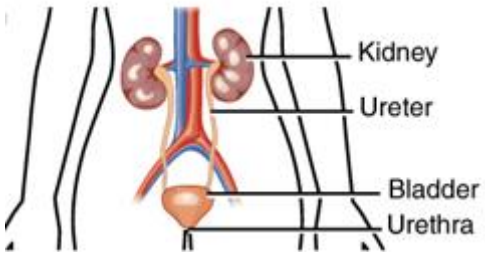

Figure2.13: System Level (E.g Urinary System)

3.6 Organismal level

All the other body structures function to bring life to the organism. The organism level is the highest level of organization. An organism is a living being that has a cellular structure and that can independently perform all physiologic functions necessary for life. In multicellular organisms, including humans, all cells, tissues, organs, and organ systems of the body work together to maintain the life and health of the organism. Examples of organisms are; humans, mammals and reptiles.

Figure 2.14: Organismal level

4.0 Conclusion

The human body consists of several layers of structural organization. The levels of structural complexity from the smallest to the largest as described below:

Chemical level: the smallest structure in the body, e.g. oxygen).

Cellular level: Cells are the basic building blocks of the human body. Although all human cells share some basic characteristics, they can vary greatly based on their specialized functions.

Tissue level- collections of similar cells grouped together to perform a specific function. There are four basic types of tissue in the human body, namely, connective tissue, muscle tissue, nervous tissue and epithelial tissue.

Organ level: structures that operate to perform a specific function. Consist of two or more types of tissue.

System level: a group of organs that work collaboratively to perform specific functions.

Organismal level: different systems groups to form organism. Many organ system works harmoniously together to perform the function of an independent organism. e.g. humans.

5.0 Summary

The human body is made up of a complex structure of systems that all work together. There are several levels of organization to this structure. The nervous system with each level more complex than the last. The structures of the body or structural complexity of the living organisms can be considered in terms of fundamental levels of organization that increase in complexity: subatomic particles, atoms, molecules, organelles, cells, tissues, organs, organ systems, organisms.

Chemicals are the smallest structure in the body formed from combination of atoms like oxygen, hydrogen, carbon to form water molecule and organelles found in cells. The cell is the smallest independently functioning unit of all organisms; in animals, a

cell contains cytoplasm, composed of fluid and organelles. The tissue is a group of similar or closely related cells that act together to perform a specific function. Organs are functionally distinct structure composed of two or more types of tissues. The organ system is group of organs that work together to carry out a particular function. The organism is the living being that has a cellular structure and that can independently perform all physiologic functions necessary for life.

6.0 In-Text Questions

1. Describe the structure of the human body on the basis of chemical composition
2. Describe the basic tissues of the body formed from boding of cells
3. State the basic systems of the body formed from different organs

7.0 In-Text Answers

Q1. The body is made up of various chemicals. This is the lowest level of structural organization of humans consists of all the chemicals that are essential for maintaining life. The smallest unit of any of these pure substances (elements) is an atom. Atoms are made up of subatomic particles such as the proton, electron and neutron. Different chemicals such as; adenosine triphosphate, oxygen, carbon dioxide and hydrogen combines to form the various molecules found in the human body. Two or more atoms combine to form a molecule which are the chemical building blocks of all body structures.

Q2. There are four basic types of tissues in the body described below;

- Connective tissue - binds and supports tissues and organs; provides protection and support to organs; stores energy as fat and provides immunity
- Muscle tissue - Produces motion or movement. The three types are; skeletal, cardiac or smooth.
- Nervous tissue - enables transmission of nerve impulses
- Epithelial tissue covers surfaces on both the inside and outside of the body; skin tissue is an epithelial tissue.

Q3. The basic systems of the body include; circulatory system, digestive system, endocrine system, integumentary system, immune system, skeletal system, muscular system, urinary system, respiratory system, nervous system, and reproductive system.

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MODULE THREE

BIOPHYSICAL PRINCIPLES

Study Session 1: Cardiac Functioning

Study Session 2: Nerve and Muscle Functioning

Study Session 3: Respiratory Functioning

STUDY SESSION 1: CARDIAC FUNCTIONING

CONTENTS

1.0 Introduction

The cardiovascular system is made up of the heart and blood vessels. It works to transport oxygen and other nutrients to all the organs and tissues of the body. The heart is a multiscale system that functions at the level of organ, tissue, cellular, and protein to transport blood alongside gases, nutrients, electrolytes, wastes, and hormones. Cardiac functioning helps to improve the knowledge on the need to have a healthy circulatory system as a vital component of human's health and well-being.

2.0 Learning Outcomes

After reading this course, student will be able to:

- Define Cardiac Output and its normal values.
- Define Stroke volume, end- systolic volume, and end- diastolic volume.
- Identify factors affecting and determining cardiac output, stroke volume and heart rate.

3.0 Main Content

3.1 Circulatory System

The cardiovascular system (CVS), also called the circulatory system consists of the pump and vessels that maintains the distribution of blood throughout the body. This system allows for the delivery of needed substances to the cells of the body as well as for the removal of wastes. The primary structures that comprise the cardiovascular system are: the heart (pumps blood through blood vessels) and the blood vessels such as; arteries (carries blood away from the heart), capillaries (exchange site between blood and tissues) and veins (carries blood toward the heart).

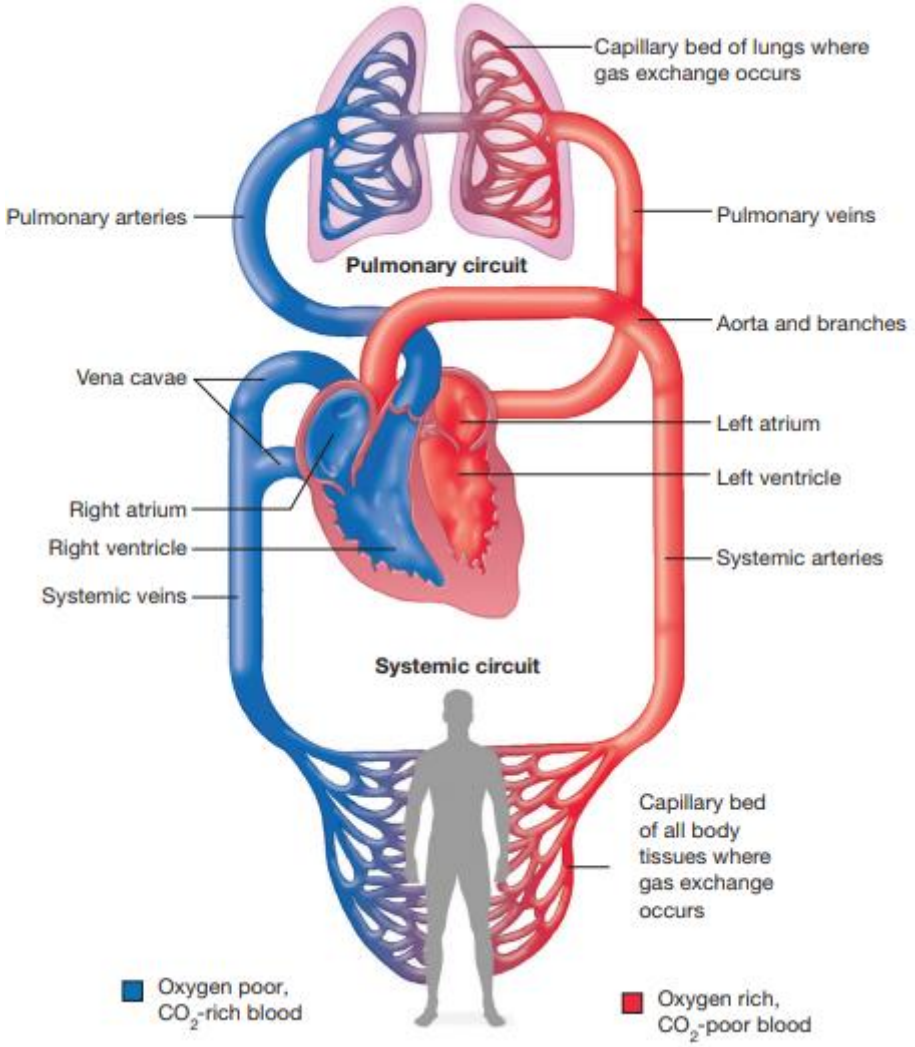

Fig 3.1: The Circulatory System

The circulatory system is composed of two parts: the systemic circulation and the pulmonary circulation. The systemic circulation carries oxygenated blood away from the heart to the tissues and cells, and then back to the heart while the pulmonary circulation transports deoxygenated blood to the lungs to get oxygen, and then back to the heart (between the heart and lungs). The cardiovascular system in addition to distributing oxygen and other nutrients like; as glucose and amino acids, also collects

waste products like carbon dioxide from the body's cells and other waste products produced by metabolic reaction are transported by the cardiovascular system to the lungs, kidneys and liver for possible elimination from the body.

3.2 Cardiac Output

Cardiac output (CO) is the amount of blood pumped by each ventricle per minute. CO is a function of: Heart rate (HR) & Stroke volume. Cardiac output decides the rate of blood flow to the different parts of the body. This implies that a decrease in cardiac output implies a decrease in blood flow. For young, healthy men, resting cardiac output averages about 5.6l/min while for women, this value is about 4.9 L/min. Thus, CO (5 L/min) = SV (70 ml/beat) X HR (70-75 beat/min).Cardiac output may also be expressed in liters/minute in terms of stroke volume and heart rate Cardiac output is maintained by four factors: venous return, force of contraction, heart rate and peripheral resistance. CO is increased by exercise, gender (less in females more in males), age, eating, high environmental temperature, pregnancy, anxiety, sympathomimetic and epinephrine. CO is decreased by sitting or standing from lying position.

Stroke volume:

Stroke volume (SV) is the volume of blood ejected by each ventricle per beat SV x HR = CO. Stroke volume is expressed in ml/beat and heart rate in beats/minute. Stroke volume = end diastolic volume which is the amount of blood remaining in the heart by the end of diastole {140mL} – End Systolic Volume which is the amount of blood remaining in the heart by the end of systole {70mL}

i.e SV = EDV-ESV

Factors affecting stroke volume are; fitness level, contractility, duration of contraction, heart size, preload (EDV), and Afterload (resistance).

Heart rate:

When heart rate increases, cardiac output also increases. Any factor which changes heart rate will also change cardiac output. Under normal circumstances heart rate is 70 times/min. Increase in heart rate increases cardiac output but up to a limit after which it decreases due to decrease in cardiac filling. Factors affecting heart rate are; autonomic innervation, hormones, fitness, and age.

3.3 Electrocardiography

Electrocardiography is the technique involved in studying the conduction system of the heart; traces the path of the electrical impulse that stimulates the heart chambers to contract in the correct sequence. The electrocardiogram, referred to as an EKG or ECG, is a measurement of the electrical activity of the heart. It is the wave record of the electrical signal as it moves through the conduction system of the heart. This can give the physician information about the health of the heart, especially the myocardium.

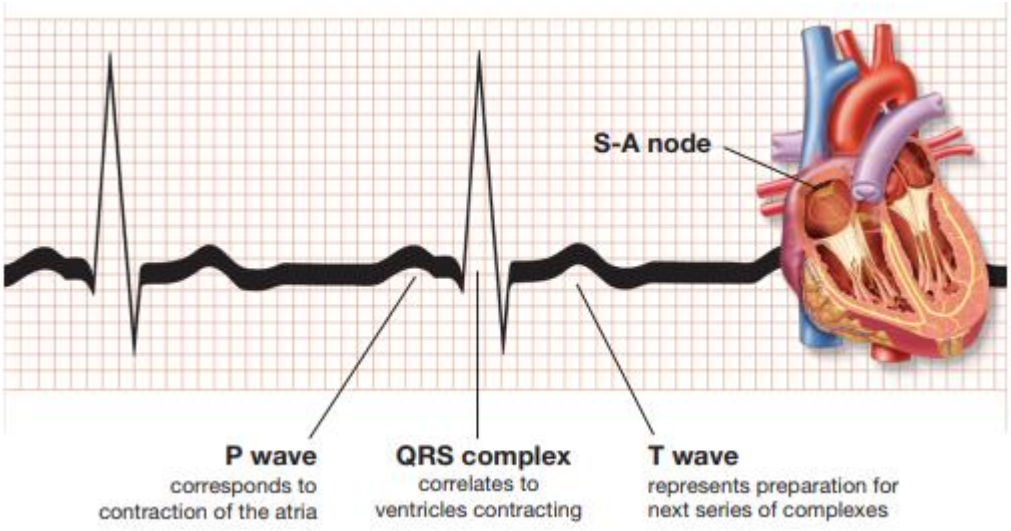

Figure 3.2: Electrocardiograph

3.4 Arterial Blood Pressure

Arterial blood pressure is a measurement of the force exerted by blood against the wall of a blood vessel. During ventricular systole, blood is under a lot of pressure from the ventricular contraction, giving the highest blood pressure reading the systolic pressure. During ventricular diastole, blood is not being pushed by the heart at all and the blood pressure reading drops to its lowest point the diastolic pressure. The pulse felt at the wrist or throat is the surge of blood caused by the heart contraction. This is why pulse rate is normally equal to heart rate. The instrument used to measure blood pressure is called a sphygmomanometer. A blood pressure reading is reported as two numbers, for example, 120/80 mmHg. The 120 is the systolic pressure and the 80 is the diastolic pressure. Blood pressure is affected by several other characteristics of the blood and the blood vessels. These include the elasticity of the arteries, the diameter of the blood vessels, the viscosity of the blood, the volume of blood flowing through the vessels, and the amount of resistance to blood flow.

4.0 Conclusion

The main function of the circulatory system is a network composed of the heart as a centralized pump and blood vessels (capillary, vein and artery) that helps to move blood throughout the body. The circulatory system also functions to provide oxygen, nutrients and hormones to muscles, tissues and organs throughout the body. Another part of the circulatory system is to remove waste from cells and organs.

5.0 Summary

The circulatory system (cardiovascular system) pumps blood from the heart to the lungs to get oxygen. The heart then sends oxygenated blood through arteries to the rest of the body. The veins carry oxygen-poor blood back to the heart to start the circulation

process over. The circulatory system is divided into two separate loops: pulmonary circuit that exchanges blood between the heart and the lungs for oxygenation; and the longer systemic circuit that distributes blood throughout all other systems and tissues of the body.

6.0 In-Text Questions

1. Define Cardiac Output. What is the normal value?
2. What is stroke volume? Enumerate the factors affecting stroke volume
3. What is Electrocardiography?

7.0 In-Text Answers

Q1. Cardiac output (CO) is the amount of blood pumped by each ventricle per minute. CO can also be defined as a function of: Heart rate (HR) and Stroke volume.For young, healthy men, resting cardiac output averages about 5.6l/min while for women, this value is about 4.9 L/min. Thus, CO (5 L/min) = SV (70 ml/beat) X HR (70-75 beat/min).

Q2. Stroke volume (SV) is the volume of blood ejected by each ventricle per beat SV x HR = CO. Stroke volume is expressed in ml/beat and heart rate in beats/minute. Stroke volume = end diastolic volume which is the amount of blood remaining in the heart by the end of diastole {140mL} – End Systolic Volume which is the amount of blood remaining in the heart by the end of systole {70mL. Factors affecting stroke volume are;

- Fitness level
- Contractility
- Duration of contraction
- Heart size
- Preload (EDV), and
- Afterload (resistance).

Q3. Electrocardiography is the technique involved in studying the conduction system of the heart; traces the path of the electrical impulse that stimulates the heart chambers to contract in the correct sequence.

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STUDY SESSION 2: NERVE AND MUSCLE FUNCTIONING

CONTENTS

1.0 Introduction

The human body is composed of billions of cells to perform various functions. The structure of the cells varies according to their function. In multicellular animals, a group of similar cells along with intercellular substances perform a specific function. Such an organization is called tissue. Four class of tissues have been broadly classified in this Study Session, namely: epithelial, connective, muscular and nervous tissues.

2.0 Learning Outcomes

After reading this course, student will be able to:

- Understand the concept of epithelial tissue and its types
- Explain the concept of connective tissue and its types
- Describe the concept of muscles as excitable tissue and its types
- Evaluate the concept of nerves as excitable tissue and its types

3.0 Main Content

3.1 Epithelial Tissue

Epithelial tissue covers or lines body surfaces; examples include the outer layer of the skin, the walls of capillaries, and kidney tubules. This tissue has a free surface that is exposed to either body fluids or the outside environment, and it serves as a covering or lining for specific parts of the body. The cells are densely packed and have little intercellular matrix. There are two types of epithelial tissues namely; simple epithelium and compound epithelium.

3.1.1 Simple Epithelium

Simple epithelium is composed of a single layer of cells and functions as a lining for body cavities, ducts, and tubes. Simple epithelium is further divided into three types, namely; squamous, columnar and cuboidal epithelium.

Squamous epithelium: it is made of a single thin layer of flattened cells with irregular boundaries. They are found in the walls of blood vessels and air sacs of lungs and are involved in functions like forming a diffusion boundary.

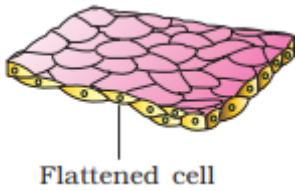


Figure3.3: Simple Squamous Epithelium

Columnar epithelium: it is composed of a single layer of tall and slender cells. Their nuclei are located at the base. Free surface may have microvilli. They are found in the lining of stomach and intestine and help in secretion and absorption. If the columnar or cuboidal cells bear cilia on their free surface they are called ciliated epithelium which aids to move particles or mucus in a specific direction over the epithelium found around the inner surface of hollow organs like bronchioles and fallopian tubes. Some of the columnar or cuboidal cells get specialized for secretion and are called glandular epithelium. They are mainly of two types: unicellular, consisting of isolated glandular cells (goblet cells of the alimentary canal), and multicellular, consisting of cluster of cells (salivary gland).

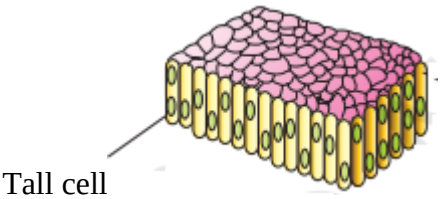
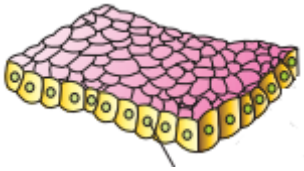


Figure 3.4: Simple Columnar Epithelium

Cuboidal epithelium: it is composed of a single layer of cube-like cells. This is commonly found in ducts of glands and tubular parts of nephrons in kidneys and its main functions are secretion and absorption. The epithelium of proximal convoluted tubule (PCT) of nephron in the kidney has microvilli.



Cube-like cell

Figure3.5: Simple Cuboidal Epithelium

3.1.2 Compound epithelium

Compound epithelium is made of more than one layer (multi-layered) of cells and thus has a limited role in secretion and absorption. Their main function is to provide protection against chemical and mechanical stresses. They cover the dry surface of the skin, the moist surface of buccal cavity, pharynx, inner lining of ducts of salivary glands and of pancreatic ducts.

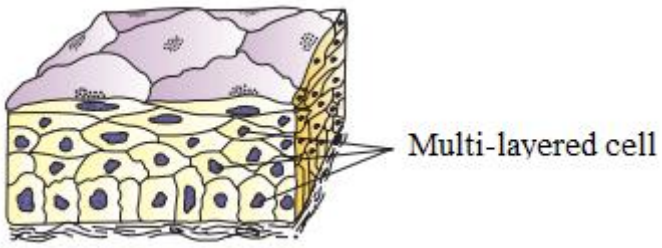


Figure3.6: Compound Epithelium

3.2 Connective tissues

Connective tissues are most abundant and widely distributed in the body of complex animals. They are named connective tissues because of their special function of linking and supporting other tissues/organs of the body. Connective tissue connects and supports parts of the body; some transport and store materials; examples include bone, cartilage, and adipose tissues. In all, the fibres provide strength, elasticity and flexibility to the tissue. Connective tissues are classified into three types: loose connective tissue, dense connective tissue and specialized connective tissue.

3.2.1 Loose Connective Tissue

Loose connective tissue has cells and fibres loosely arranged in a semi-fluid ground substance, for example, areolar tissue present beneath the skin. Often it serves as a support framework for epithelium. It contains fibroblasts (cells that produce and secrete fibres), macrophages and mast cells. Adipose tissue is another type of loose connective tissue located mainly beneath the skin. The cells of this tissue are specialized to store fats. The excess of nutrients which are not used immediately are converted into fats and are stored in this tissue.

3.2.2 Dense Connective Tissue

Fibres and fibroblasts are compactly packed in the dense connective tissues. Orientation of fibres show a regular or irregular pattern and are called dense regular and dense irregular tissues. In the dense regular connective tissues, the collagen fibres are present in rows between many parallel bundles of fibres e.g Tendons. Dense irregular

connective tissue has fibroblasts and many fibres (mostly collagen) that are oriented differently. This tissue is present in the skin.

3.2.3 Specialized Connective Tissues

There are three categories of specialized connective tissue, namely; blood, bones and cartilage. This are discussed as follows:

Blood:

Blood is a fluid connective tissue containing plasma, red blood cells (RBC), white blood cells (WBC) and platelets. It is the main circulating fluid that helps in the transport of various substances.

Figure 3.7: Fluid Connective Tissue (Blood cells)

Bones:

Bones have a hard and non-pliable ground substance rich in calcium salts and collagen fibres which give bone its strength. The bone cells (osteocytes) are present in the spaces called lacunae. The bone marrow in some bones is the site of production of blood cells. Bones are the main tissue that provides structural frame to the body. Bones support and protect softer tissues and organs. Limb bones, such as the long bones of the legs, serve weight-bearing functions. They also interact with skeletal muscles attached to them to bring about movements.

Cartilages:

The intercellular material of cartilage is solid and pliable and resists compression. Cells of this tissue (chondrocytes) are enclosed in small cavities within the matrix. Cartilage is present in the tip of nose, outer ear joints, between adjacent bones of the vertebral column, limbs and hands in adults. Most of the cartilages in vertebrate embryos are replaced by bones in adults.

3.3 Muscle Tissues

The Human body has more than 600 muscles. Muscles perform many useful functions and help us in doing everything in day-to-day life. In general, muscles play an active role in all the movements of the body. Muscle fibres contract (shorten) in response to stimulation, then relax (lengthen) and return to their uncontracted state in a coordinated pattern. Muscles are classified by three different methods, based on **striations (**Striated muscle eg*skeletal and cardiac* and Non-striated muscle eg*smooth*)**, control (**Voluntary muscle eg*skeletal* via somatic nerves and Involuntary muscle eg*cardiac and smooth* via autonomic nerves) and the **situation (**skeletal are situated in bones, cardiac are situated in the heart, smooth are situated in the visceral organs).

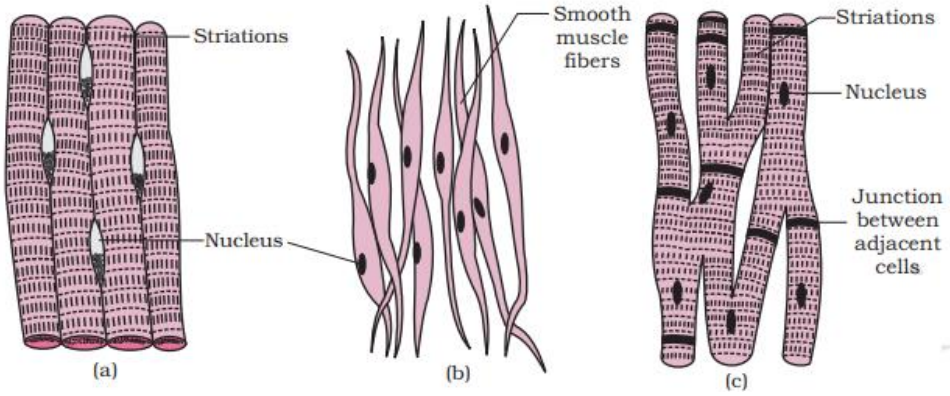


Figure 3.8: Muscle tissues: (a) Skeletal (striated) muscle tissue (b) Smooth muscle tissue (c) Cardiac muscle tissue

3.3.1 Smooth Muscle Tissue

Smooth muscles are **non-striated** (plain) and involuntary muscles. These muscles are present in almost all the organs in the form of sheets, bundles or sheaths around other tissues. Smooth muscles form the major contractile tissues of various organs such as;

- Iris and ciliary body of the eye.
- Ducts of digestive glands
- Arrectorpilorum of skin
- Wall of organs like esophagus, stomach and intestine in the gastrointestinal tract
- Ureter, urinary bladder and urethra in urinary system
- Wall of the blood vessels in circulatory system
- Trachea, bronchial tube and alveolar ducts of respiratory tract
- Uterus, genital ducts, prostate and mammary glands gland and scrotum in the reproductive system

Smooth muscle fibers are elongated or spindle-shaped cell. These fibers are generally very small, measuring 2-5 microns in diameter and 50 to 300 microns in length. Smooth muscle cells contain a single elongated nucleus at the center and few mitochondria, and two or more nucleoli are present in the nucleus.

3.3.2 Cardiac Muscle Tissue

Cardiac muscle tissue is a contractile tissue present only in the heart. Cell junctions fuse the plasma membranes of cardiac muscle cells and make them stick together. Communication junctions (intercalated discs) at some fusion points allow the cells to contract as a unit, i.e., when one cell receives a signal to contract, its neighbours are also stimulated to contract.

3.3.3 Skeletal muscle Tissue

Skeletal muscle tissue is closely attached to skeletal bones. In a typical muscle such as the biceps, striated (striped) skeletal muscle fibres are bundled together in a parallel fashion. A sheath of tough connective tissue encloses several bundles of muscle fibres

3.4 Nervous Tissues

Nervous system is a complex and well-organized **system of communication** that allows the individual to interact with his external environment. It is also a **system of integration** that coordinates functions of various internal organ systems of the body.

Neural connections between body parts provide the basis for anatomical and physiological communications that help in smooth execution of most of the systemic functions such as gastrointestinal functions, secretion of hormones, functions of heart, lungs and kidney, and musculoskeletal system etc. Nerve tissue generates and transmits impulses to regulate body function; examples include the brain and nerves. Neural tissue exerts the greatest control over the body's responsiveness to changing conditions.

3.4.1 Neurons

The building blocks of the nervous system are the ***nerve cells***, also called ***neurons***. A neuron is the structural and functional unit of the nervous system. Neurons, the unit of neural system are excitable cells. Its primary function is to receive the various stimuli and transmit the signals to other neurons and tissues (pain, touch, light, sound, cold and warmth). Neurons have evolved from primitive **neuroeffector** cells that respond to various stimuli by contracting. It is estimated that the human brain possesses 25 billion cells. In complex animal, integration and transmission of nerve impulses have become the specialized functions of neurons (action potentials, receptor potentials, and synaptic potentials).

3.4.2 Neuroglia

The nervous system aside the neurons contains several types of supporting cells called neuroglia. **Glial cells** of nervous system also called **neuroglia**constitute the rest of the neural system which support and protect the neurons and maintain homeostasis of fluids that bath the neurons. **Neurons** transmit impulses in the form of action potentials. Neuroglia are 10 – 30 times plentiful than neurons. They make up more than one-half the volume of neural tissue in the body. Glial cells **neither conduct action potential**nor form functional synapse with other cells. However, they can be passively polarized in response to nearby neural activity. Though glial cells generally provide support for neurons, their functions are complex and not completely understood.

4.0 Conclusion

Cells, tissues, organs and organ systems split up the work in a way that ensures the survival of the body as a whole and exhibit division of labour. A tissue is defined as group of cells along with intercellular substances performing one or more functions in the body. The body contains four types of tissues namely; epithelial tissue covers or lines body surfaces; examples include the outer layer of the skin, the walls of capillaries, and kidney tubules. Connective tissue which connects and supports parts of the body; some transport and store materials; examples include bone, cartilage, and adipose tissues. Muscle contracts to produce movement; examples include skeletal muscles and the heart and nerve tissue generates and transmits impulses to regulate body function; examples include the brain and nerves.

5.0 Summary

Four tissues were reviewed in this Study Session; epithelia, connective, muscular and nervous tissues. Epithelia are sheet like tissues lining the body's surface and its cavities, ducts and tubes. Epithelia have one free surface facing a body fluid or the outside environment. Their cells are structurally and functionally connected at junctions. Diverse types of connective tissues bind together, support, strengthen, protect, and insulate other tissue in the body. Soft connective tissues consist of protein fibres as well as a variety of cells arranged in a ground substance. Cartilage, bone, blood, and adipose tissue are specialized connective tissues. Cartilage and bone are both structural materials. Blood is a fluid tissue with transport functions. Adipose tissue is a reservoir of stored energy. Muscle tissue, which can contract (shorten) in response to stimulation, helps in movement of the body and specific body parts. Skeletal muscle is the muscle tissue attached to bones. Smooth muscle is a component of internal organs. Cardiac muscle makes up the contractile walls of the heart. Connective tissue covers all three types of tissues. Nervous tissue exerts greatest control over the response of body. Neurons are the basic units of nervous tissue.

6.0 In-Text Questions

1. What are epithelial tissues? List the 2 types
2. What are connective tissues? Enumerate the types
3. Briefly classify muscles based on known properties
4. List 6 major contractile smooth muscle tissues of various organs
5. Compare and contrast between nerve cell and neuroglia

7.0 In-Text Answers

Q1. Epithelial tissue covers or lines body surfaces like the outer layer of the skin, the walls of capillaries, and kidney tubules. This tissue has a free surface, which faces either a body fluid or the outside environment and thus provides a covering or a lining for some part of the body. There are two types of epithelial tissues namely; simple epithelium and compound epithelium.

Q2. Connective tissues are most abundant and widely distributed in the body of complex animals. They are named connective tissues because of their special function of linking and supporting other tissues/organs of the body. Connective tissue connects and supports parts of the body; some transport and store materials; examples include bone, cartilage, and adipose tissues.

Q3. Muscles are classified by three different methods, based on the following;

- **Striations:** Striated muscle eg*skeletal and cardiac* and Non-striated muscle eg*smooth*
- **Control:** Voluntary muscle eg*skeletal* via somatic nerves and Involuntary muscle eg*cardiac and smooth* via autonomic nerves

- **Situation:** skeletal are situated in bones, cardiac are situated in the heart, smooth are situated in the visceral organs.

Q4. Smooth muscles form the major contractile tissues of various organs such as;

- Ducts of digestive glands
- Iris and ciliary body of the eye.
- Arrectorpilorum of skin
- Ureter, urinary bladder and urethra in urinary system
- Wall of the blood vessels in circulatory system
- Trachea, bronchial tube and alveolar ducts of respiratory tract

Q5. The nervous system aside the neurons contains several types of supporting cells called neuroglia. **Glial cells** of nervous system also called **neuroglia** constitute the rest of the neural system which support and protect the neurons and maintain homeostasis of fluids that bath the neurons. **Neurons** transmit impulses in the form of action potentials. Neuroglia are 10 – 30 times plentiful than neurons. They make up more than one-half the volume of neural tissue in the body. Glial cells **neither conduct action potential** nor form functional synapse with other cells.

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STUDY SESSION 3: RESPIRATORY FUNCTIONING

CONTENTS

1.0 Introduction

Through breathing, inhalation and exhalation, the respiratory system facilitates the exchange of gases between the air and the blood and between the blood and the body's cells. The respiratory system also helps us to smell things and create sound. The key function of the respiratory system is to facilitates breathing mechanism or pulmonary ventilation such that; air is inhaled through the nasal and oral cavities to the pharynx, larynx, trachea and the lungs. Then air is exhaled, flowing back through the same pathway. Similarly, the respiratory system helps to filter inspired air, production of sound, contains receptors for smell, rids the body of some excess water and heat and to regulate blood pH.

2.0 Learning Outcomes

After reading this course, student will be able to:

- Understand the basic concepts of air movements and pressure
- Explain transport and exchange of gases within the respiratory system
- Describe the concept of pulmonary compliance
- Understand the role of pulmonary surfactant

3.0 Main Content

3.1 Respiratory System

Respiration refers to the exchange of gases either externally or internally. External respiration: involves the exchange of respiratory gases, i.e. oxygen and carbon dioxide between lungs and blood while internal respiration involves the exchange of gases between blood and tissues. The phases of respiration are; **inspiration or inhalation** which involves the entry of air into the lungs from atmosphere and **expiration or exhalation** that involves the removal of air through the lungs. During normal breathing, inspiration is an active process and expiration is a passive process. The functional anatomy of respiratory tract is described as follows;

Pleura or pleural sac: Each lung is enclosed by a bilayered serous membrane. Pleura has two layers namely **inner visceral layer** that is attached firmly to the surface of the lungs and **outer parietal layer** that is attached to the wall of thoracic cavity and is continuous at hilum.

Intrapleural Space or Pleural Cavity: Intrapleural space or pleural cavity is the narrow space in between the two layers of pleura. Pathological conditions of the pleural cavity include; expansion of the cavity with accumulation of water (hydrothorax), air (pneumothorax), blood (hemothorax) or pus (pyothorax).

Intrapleural Fluid: Within the intrapleural space is a thin film of serous fluid called intrapleural fluid secreted by the visceral layer of the pleura**.** It is involved in creating the negative pressure called intrapleural pressure. Also, it functions as the lubricant to prevent friction between two layers of pleura.

Tracheobronchial Tree: the combination of Trachea and bronchi gives rise to the tracheobronchial tree. It forms a part of air passage and is made up of the following components;

- Trachea bifurcates into two main or primary bronchi called right and left **bronchi**
- Each primary bronchus enters the lungs and divides into **secondary bronchi**.
- The secondary bronchi divide into tertiary bronchi. In left lung, there are eight tertiary bronchi while in right lung, there are 10 **tertiary bronchi**
- Tertiary bronchi divide several times with reduction in length and diameter into many generations of **bronchioles**
- When the diameter of bronchiole becomes 1 mm or less, it is called **terminal bronchiole**
- Terminal bronchiole continues or divides into **respiratory bronchioles**, which have a diameter of 0.5 mm.

Upper and Lower Respiratory Tracts: It is divided into two parts, namely; **Upper respiratory tract** that is comprised of all the structures from the nose up to vocal cords

(folds of mucous membrane within larynx that vibrates to produce the voice). **Lower respiratory tract** that is comprised of the trachea, bronchi and lungs

3.2 Basic Concepts of Air Movements and Pressure

Air moves through different parts of the respiratory system as follows:

- Air is inspired through the mouth or nose.
- The air travels down the trachea also called the windpipe.
- The air travels through airways called the bronchi into the lungs.
- The air is directed through smaller and smaller passages, called bronchioles.
- The air moves through a tiny duct called the alveolar duct and finally enters an individual alveolus, which is a tiny, balloon-shaped structure.
- At this point, the oxygen molecules move through a single layer of lung cells in the alveolus, then through a single cell layer in a capillary to enter the bloodstream.
- CO_2 is a byproduct of the process in cells that uses oxygen to produce energy. As oxygen moves out of the alveolus, CO_2 molecules pass into it. They are then breathed out of the body through the nose or mouth.
- Gas exchange occurs in the respiratory zone of the lung via Pleural pressure (the pressure of the fluid in the thin space between the lung pleura and the chest wall pleura) and Alveolar pressure (the pressures in all parts of the respiratory tree, all the way to the alveoli), where alveoli are present. The Difference between Alveolar and Pleural Pressures is known as Transpulmonary Pressure.

3.3 Transport and Exchange of Gases

The respiratory zone is where gas is exchanged. It consists of alveoli, alveolar sacs, alveolar ducts found within the lungs and the respiratory bronchioles. One of the major roles of the lungs is to facilitate gas exchange between the circulatory system and the external environment. Inside the lungs, oxygen is exchanged for carbon dioxide waste through the process called external respiration. This respiratory process takes place through hundreds of millions of microscopic sacs called alveoli. Oxygen from inhaled air diffuses from the alveoli into pulmonary capillaries surrounding them.

The bloodstream delivers oxygen to cells and removes waste carbon dioxide through internal respiration, another key function of the respiratory system. When oxygenated blood reaches the narrow capillaries, the red blood cells release the oxygen. It diffuses through the capillary walls into body tissues. Meanwhile, carbon dioxide diffuses from the tissues into red blood cells and plasma. The first breath takes place only after birth. Fetal lungs are non-functional. Hence, during intrauterine life the exchange of gases between fetal blood and mother's blood occurs through placenta. Permanent stoppage of respiration occurs only at death.

3.4 Pulmonary Compliance

Pulmonary or lung compliance is the ease with which lungs can be expanded. Specifically, it is the measure of the change in lung volume that occurs with a given change in transpulmonary pressure i.e a measurement of the elastic resistance of a system. The elastic properties of the lung enable it to recover its configuration and volume once the forces that distend it cease to act; this characteristic serves as the basis for studying its mechanical behavior. It is one of the most important concepts underpinning mechanical ventilation used to manage patient respiration in the operating room or intensive care unit environment. Pulmonary compliance is determined by two main factors; dispensability of the lung tissue surrounding thoracic cage and surface tension of the alveoli. Certain pulmonary diseases can influence changes in lung compliance such as; emphysema or Chronic Obstructive Pulmonary Disease (COPD), pulmonary fibrosis, atelectasis and Newborn Respiratory Distress Syndrome (NRDS).

3.5 Pulmonary Surfactant

Surfactant is an agent that decreases the surface tension between two media. The surface tension between gaseous-aqueous interphase in the lungs is decreased by the presence of a thin layer of fluid known as pulmonary surfactant. The pulmonary surfactant is produced by the alveolar type-II (AT-II) cells of the lungs. It is essential for efficient exchange of gases and for maintaining the structural integrity of alveoli. Surfactant is a secretory product, composed of lipids and proteins. It plays a very important role in aeration of the neonate's lungs. Pulmonary surfactant, which is inadequate in the premature infant, modifies surface tension during the act of breathing and is necessary for maintenance of alveolar stability.

4.0 Conclusion

Respiration is the process by which oxygen is taken in and carbon dioxide is given out. The respiratory system is to absorb oxygen and remove carbon dioxide. The four major components of respiration are;

- Pulmonary ventilation: The inflow and outflow of air between the atmosphere and the lung alveoli;
- Pulmonary circulation: Diffusion of oxygen and carbon dioxide between the alveoli and the blood;
- Transport of oxygen and carbon dioxide in the blood and body fluids to and from the body's tissue cells;
- Regulation of Ventilation, comprising of other aspects of respiration.

5.0 Summary

In this study session, we x-rayed the basic concepts of air movements and pressure, transport and exchange of gases within the respiratory system. In addition, the concept of pulmonary compliance and the role of pulmonary surfactant were evaluated.

6.0 In-Text Questions

1. What is respiration? List the phases
2. Describe the functional anatomy of the respiratory tract. Indicate the respiratory zones
3. What is pulmonary compliance?
4. What is pulmonary surfactant? Indicate how they are produced

7.0 In-Text Answers

Q1. Respiration refers to the exchange of gases either externally or internally. External respiration: involves the exchange of respiratory gases, i.e. oxygen and carbon dioxide between lungs and blood while internal respiration involves the exchange of gases between blood and tissues. The phases of respiration are; **inspiration or inhalation** which involves the entry of air into the lungs from atmosphere and **expiration or exhalation** that involves the removal of air through the lungs.

Q2. The functional anatomy of respiratory tract is described as follows;

- **Pleura or pleural sac**: Each lung is enclosed by a bilayered serous membrane. Pleura has two layers namely **inner visceral layer** and **outer parietal layer**
- **Intrapleural Space or Pleural Cavity:** Intrapleural space or pleural cavity is the narrow space in between the two layers of pleura.
- **Intrapleural Fluid**: Within the intrapleural space is a thin film of serous fluid called intrapleural fluid secreted by the visceral layer of the pleura**.**
- **Tracheobronchial Tree:** the combination of Trachea and bronchi gives rise to the tracheobronchial tree.

Respiratory zones: It is divided into two parts, namely; **Upper respiratory tract** that is comprised of all the structures from the nose up to vocal cords (folds of mucous membrane within larynx that vibrates to produce the voice). **Lower respiratory tract** that is comprised of the trachea, bronchi and lungs

Q3. Pulmonaryor lung compliance is the ease with which lungs can be expanded. Specifically, it is the measure of the change in lung volume that occurs with a given change in transpulmonary pressure i.e a measurement of the elastic resistance of a system. The elastic properties of the lung enable it to recover its configuration and volume once the forces that distend it cease to act; this characteristic serves as the basis for studying its mechanical behavior.

Q4.Surfactant is an agent that decreases the surface tension between two media. The surface tension between gaseous-aqueous interphase in the lungs is decreased by the

presence of a thin layer of fluid known as pulmonary surfactant. It modifies surface tension during the act of breathing and is necessary for maintenance of alveolar stability. The pulmonary surfactant is produced by the alveolar type-II (AT-II) cells of the lungs.

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MODULE FOUR

CONTROL SYSTEMS AND RHYTHMS

Study Session 1: Components of the Control system

Study Session 2: Feedback System

Study Session 3: Biological Rhythms

STUDY SESSION 1: COMPONENTS OF THE CONTROL SYSTEM

CONTENTS

1.0 Introduction

In order to maintain homeostasis, the control system must be able to detect deviations from normal in the internal environment that need to be held within narrow limits, integrate this information with other relevant information and make appropriate adjustments in order to restore factor to its desired value. This reciprocal interplay of the control system provides continuous automaticity of the body in maintaining homeostasis until one or more functional systems lose their ability to contribute their share of function. When this loss happens, all the cells of the body suffer. Extreme dysfunction leads to death, whereas moderate dysfunction leads to sickness.

2.0 Learning Outcomes

After reading this course, student will be able to:

- Understand the meaning of a control system
- Highlight the basic components of control system
- Explain the mechanism of the control system

3.0 Main Content

3.1 Control System

The human body has thousands of control systems that are essential for homeostasis. For example, genetic systems operate in all cells to control intracellular and extracellular functions. Other control systems operate within the organs or throughout the entire body to control interactions among the organs. The body maintains homeostasis by using homeostatic control system. Essentially all the functions of the body organs and tissues aim at keeping the internal environment at a nearly constant state. This means that the body constituents are normally regulated within a range rather than a fixed value by the control system.

The human body has thousands of control systems. Some of the most intricate of these systems are the genetic control systems that operate in all cells to help control intracellular and extracellular functions. Given for instance, the one or twoorgan systems contributes to helping the body in achieving the following functions:

A. Removal of Metabolic End Products

- **Liver:** eliminates certain waste products produced in the body, as well as toxic substances that are ingested.
- **Digestive system:** eliminates undigested materials and some waste products of metabolism in the feces.
- **Kidneys:** play a major role in regulating extracellular fluid composition by controlling excretion of salts, water, and waste products of the chemical reactions of the cells. The kidneys also regulate blood volume and blood pressure by controlling body fluid volumes and compositions as well as excrete most of the waste products other than carbon dioxide.
- **Respiratory system**: provides oxygen to the extracellular fluid and also removes carbon dioxide, which is produced by the cells, released from the blood into the alveoli, and then released to the external environment

B. Heat Generation:

- **Endocrine system:** Regulates the activities that requires thermoregulation. For example, the thyroid hormone production increases metabolism, which raises body temperature.
- **Nervous system:**Controls the body activities that requires rapid responses (speed). Detects and initiates reactions to changes in external environment (sensory input, central nervous system, motor output) e.g. the hypothalamus in the brain contains the body's "thermostat."
- **Cardiovascular system:** Blood vessels constrict to conserve heat.
- **Muscular system:** The muscles contract to cause shivering, which generates heat.
- **Integumentary system:** Sweat production stops and "goose bumps" form, which creates an insulating layer.

- **Digestive system:** The metabolism of food and stored fat generates heat.

C. Protection of the Body

- **Integumentary system:** provides protection against injury and defense against foreign invaders as well as protection of underlying tissues against dehydration. The skin also serves to regulate body temperature.
- **Immune system:** provides the body with a defense mechanism that protects against foreign invaders, such as bacteria and viruses, to which the body is exposed daily

D. Regulation of Body Functions

- **Endocrine system:** control many metabolic functions of the cells, such as growth, rate of metabolism, and special activities associated with reproduction. Hormones are secreted into the bloodstream and are carried to tissues throughout the body to help regulate cell functions.
- **Nervous system:** directs the activity of the muscular system, thereby providing locomotion. It also controls the function of many internal organs through the autonomic nervous system, and it allows us to sense our external and internal environment and to be intelligent beings so we can obtain the most advantageous conditions for survival

3.2 Components of Control system

Four (4) interdependent components of control mechanisms:

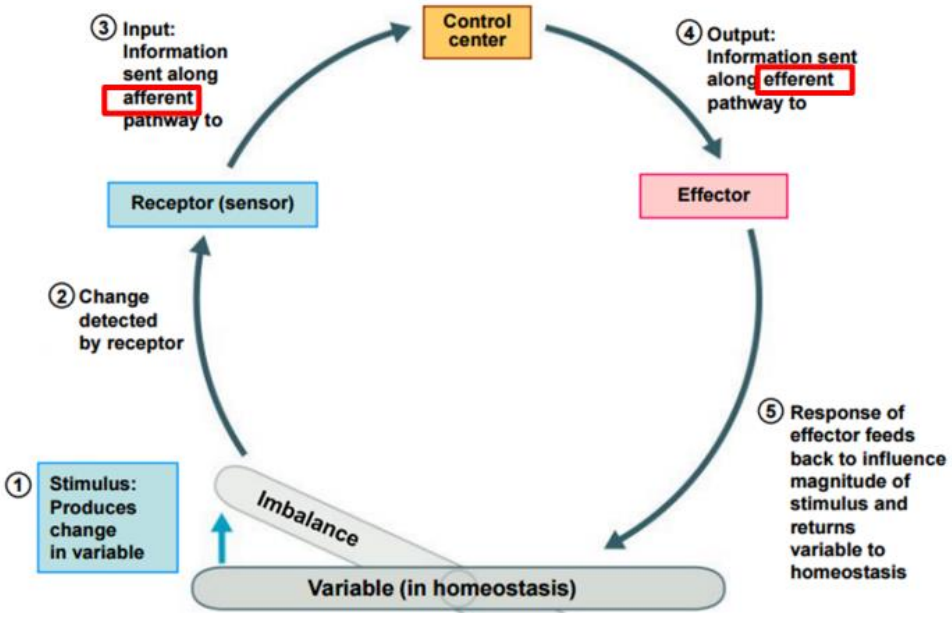

Fig 24: The Component of Control System

a. Controlled Variable:

This can be in the form of an error or a stimulus like; chemical, physical mechanical, thermal, electrical stressor (something a sensor can detect). The variable produces a change in the body.

b. Receptor:

Sometimes referred to as transducer or Sensor that monitors the environments and responds to changes or stimuli. (detects the amount of a controlled variable present in the environment). The stimulus for feedback control is a change in the level of the variable, which is detected by the sensor. That is, it receives information about a change in the environment. An example is peripheral chemoreceptors, which detect changes in blood pH.

c. Control center:

Determine the set point at which the variable is maintained or controlled (Compares sensor's input with a set point). Usually, control centers are located in the central nervous system, especially in the brain. That is, it receives and processes information from the receptor. The most important example is the hypothalamus, a region of the brain that controls everything from body temperature to heart rate, blood pressure, satiety (fullness), and circadian rhythms (including, sleep and wake cycles).

d. Effector:

Initiates a response that influences controlled variable or provides the means to respond to the stimulus e.g muscles and glands to bring about homeostasis. This is the target organ that carries out the command of the control center to achieve an effective response. That is, it responds to signals from the control center by either opposing or enhancing the stimulus (organ or tissue that receives information from the integrating center and acts to bring about the changes needed to maintain homeostasis. One example is the kidney, which retains water if blood pressure is too low).

3.3 Mechanism of the Control System

Control systems operated according to one of three main schemes; negative feedback, feed forward control and positive feedback control. However, the mechanism of the control systems is grouped into two classes:

a. **Intrinsic controls**
   This involves local controls that are inherent in an organ, tissue, or cell. Perhaps, act in and on local environment. For example; paracrine and autocrine chemical messengers never leave the local environment
b. **Extrinsic controls**
   This involves regulatory mechanisms initiated outside a cell, tissue, or organ. Accomplished by nervous and endocrine system chemical messengers. For example; hormones, neurotransmitters, neurohormones etc

4.0 Conclusion

The body is a social order of many trillions of cells organized into various functional structures, the largest of which are called organs. Each functional structure, or organ, helps maintain a constant internal environment. As long as homeostasis is maintained, the cells of the body continue to live and function properly. Thus, each cell benefits from homeostasis, and in turn, each cell contributes its share toward maintaining homeostasis. Although, some physiological variables, such as plasma concentrations of ions, are tightly regulated, others, such as body weight and adiposity, show wide variations among different individuals, at different stages of life, and even at different times of the day. Blood pressure, metabolic rate, nervous system activity, hormones, and other physiological variables change throughout the day as we move about and engage in normal daily activities.

5.0 Summary

The control system therefore aids the body to maintain physiological values at normal range by constantly reacting to perturbations and that variability may exist among different individuals depending on body weight and height, diet, age, sex, environment, genetics and other factors.

6.0 In-Text Questions

1. Describe the role of control system in homeostasis
2. Explain the components of the human control system
3. Explain the 2 mechanism of the control system

7.0 In-Text Answers

Q1. The human body has thousands of control systems that are essential for homeostasis. For example, genetic systems operate in all cells to control intracellular and extracellular functions. Other control systems operate within the organs or throughout the entire body to control interactions among the organs. The body maintains homeostasis by using homeostatic control system.
Q2.Four (4) interdependent components of control mechanisms, namely:

- **Controlled Variable:** This can be in the form of an error or a stimulus like; chemical, physical mechanical, thermal, electrical stressor (something a sensor can detect). The variable produces a change in the body.
- **Receptor:** referred to as transducer or Sensor that monitors the environments and responds to changes or stimuli. The stimulus for feedback control is a change in the level of the variable, which is detected by the sensor.
- **Control center:** Determine the set point at which the variable is maintained or controlled (Compares sensor's input with a set point). Usually, control centers

are located in the central nervous system, especially in the brain. That is, it receives and processes information from the receptor.

- **Effector:** Initiates a response that influences controlled variable or provides the means to respond to the stimulus e.g muscles and glands to bring about homeostasis. This is the target organ that carries out the command of the control center to achieve an effective response.

Q3. The mechanism of the control systems is grouped into two classes:

- **Intrinsic controls:** This involves local controls that are inherent in an organ, tissue, or cell. Perhaps, act in and on local environment.
- **Extrinsic controls:** This involves regulatory mechanisms initiated outside a cell, tissue, or organ. Accomplished by nervous and endocrine system chemical messengers.

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STUDY SESSION 2: FEEDBACK SYSTEM

CONTENTS

1.0 Introduction

A feedback mechanism is a process that uses the conditions of one component to regulate the function of the other. It is done to either increase or dampen the change in the system. When the process tends to increase the change in the system, the mechanism is known as positive feedback. Negative feedback is when the process seeks to counter the change and maintain equilibrium. Negative feedback helps to bring variable back to normal or opposes the initial change by taking it in opposite direction of original upset. If variable lower than normal, raise it to normal level. If variable higher than normal, decrease it to normal level. In contrast, keeps the change going in the direction it is already moving. Of course, produces more of the product that is accumulating. In all, positive feedback mechanisms enhance the original stimulus and negative feedback mechanisms inhibit it.

2.0 Learning Outcomes

After reading this course, student will be able to:

- Proper understanding of the feedback system
- Examine the types of the feedback system

3.0 Main Content

3.1 Overview of Feedback System

Life is maintained within a steady-state of internal environment. The internal environment must be kept constant in the face of an ever changing external environment. It separated from the external environment by the skin. The internal environment of the body is the extracellular fluid and all body cells live in this environment. Feedback mechanisms means the loop system in which the system responds to changes. Feedback system is a form of regulation that aids the body to

detect changes in internal environment & responds to such change. The system that controls these processes is the nervous system.

Feedback control mechanisms that provide this type of restraint work through homeostatic regulators that transmit information through the body. As such, the human system must be held relatively constant within carefully prescribed limits. Various basic system in the body operates within limits that ensues stability, competence and safety, while achieving some desired behavioral pattern.

3.2 Negative Feedback System Loop

This is a Self-limiting feedback. Most feedback system in the body acts by negative feedback loop. In this feedback system, original stimulus reversed (resulting action in the opposite direction of stimulus). This is a type of homeostatic control system that maintains the variable within a normal range. If stimulus increases, homeostatic control system activated to cause a decrease in the stimulus and vice versa. Variable maintained within a normal level, its set point fluctuates around the set point. The effector response of the system is in the opposite direction to stimulus that initiated the response. It is the primary mechanism through which your endocrine system maintains "homeostasis".

Negative feedback control system requires a sensor that detects the change in variable, a control center that receives input from the sensor and initiates command signal, and an effector that brings in responses according to the command signal directed from the control center. Examples of Negative Feedback;

a. ***Blood pressure regulation*****:** The normal systolic pressure in adult is kept constant between 100 and 140 mm Hg and diastolic pressure between 60 and 85 mm Hg. Sustained rise in pressure is called hypertension, and fall in pressure is called hypotension that initiates many neural and humoral mechanisms to restore blood pressure.
b. ***Regulation of hormone secretion*****:** Secretion of many hormones such as thyroxine, cortisol, etc. is regulated mainly by negative feedback mechanisms. Increase in hormone concentration in plasma inhibits their production and decrease in concentration facilitates their production mainly by altering the secretion of their regulating trophic hormones. This forms the basis of diagnosis of these hormonal disorders.
c. ***Blood glucose regulation:*** the control of blood sugar (glucose) by insulin is another good example of a negative feedback mechanism, that is, when blood sugar rises, receptors in the body sense the change, in turn, the control center (pancreas) secretes insulin into the blood effectively lowering blood sugar levels. Once blood sugar levels reach homeostasis, the pancreas stops releasing insulin (i.e when blood sugar is high: insulin is released into blood, cells absorbs glucose causing the liver to store excess glucose, then, blood sugar

level falls, insulin levels drop which causes liver to release glucose and causes insulin to be released into blood, etc).

d. ***Body temperature regulation*:** The temperature of the body is maintained within a narrow range of 96°F to 98.4°F. Increased temperature above normal is called as fever and below is called as hypothermia. When temperature is above normal, the body activates controlling mechanisms to increase heat loss through cutaneous vasodilation and sweating. When hypothermia develops, the body responds by decreasing heat loss through vasoconstriction and by increasing heat production through shivering (i.e when the body gets too warm: blood vessels dilate, sweat is produced, cools body, dilation and sweating stops).
e. ***Iron regulation:*** Iron is an essential element for human beings. The control of this necessary but potentially toxic substance is an important part of many aspects of human health and disease. Hematologists have been especially interested in the system of iron metabolism because iron is essential to red blood cells. In fact, most of the human body's iron is contained in red blood cells' hemoglobin protein where it aids in the binding and transport of oxygen for cellular respiration, and iron deficiency is the most common cause of anemia. When body levels of iron are too low, an iron-sensitive hormone called hepcidin is decreased in the duodenal epithelium (lining of the small intestine). This causes an increase in ferroportin activity, an iron-selective protein channel embedded in the membrane of intestinal cells. Activation of this channel stimulates iron uptake in the digestive system. An iron surplus will stimulate the reverse of this process.
f. ***Other examples of negative feedback:***A high level of in CO_2 in the ECF will increase pulmonary ventilation, increasing the amount of CO_2 expired will bring the level of CO_2 in ECF down, also, withdrawal reflex in response to injury, changing breathing rate in response to increased carbon dioxide, parathyroid hormone release in response to decreased calcium, pH balance, electrolyte composition of body fluids, and osmolarity of fluid compartments. The kidneys are important organ for the homeostasis of many physiological variables. Another, example is myotatic or stretch reflex that seeks to maintain muscle length.

3.3 Positive Feedback System

This is a self-perpetuating feedback. Increase in function in response to a stimulus, that is, resulting action on the same direction of the stimulus. If stimulus increases, homeostasis control system activated to cause increase in the stimulus. The effector response of the system is in the same direction to stimulus that initiated the response. Only few systems display positive feedback. In a positive feedback system, increase in the variable triggers processes that further increase the variable. Therefore, this control mechanism does not operate to provide homeostasis. Rather, positive feedback mechanism is a vicious cycle that terminates only when the stimulus applied to trigger

is withdrawn or the process itself is self-terminated.Examples of positive feedback regulations:

a. ***Parturition reflex initiated by Oxytocin during Child birth:*** Towards term, when the head of the matured fetus presses on the uterine cervix, the cervical distension sends signal to posterior pituitary to release oxytocin. Oxytocin increases the excitability of myometrium and causes uterine contraction. The increase in contraction of uterus further pushes the fetus onto the cervix, and cervical distension further increases oxytocin release that promotes uterine contraction, and the vicious cycle continues till the baby is delivered.
b. ***Hodgkin's cycle:*** In nerve signaling, entry of a small amount of Na^+ into the cell will open more Na^+ channels causing more Na^+ to enter the cell. This implies that sodium influx that causes upstroke (depolarization) of nerve or muscle action potential. Opening of few set of sodium channel provides positive feedback for opening of other sodium channels that results in massive sodium influx causing depolarization of cells
c. ***Blood clotting*****:** Once there is vessel injury, primary and secondary phases of hemostasis is initiated resulting in vasoconstriction, formation of platelets and coagulation plugs. In this feedback process, platelets start to cling to the injured site and release chemicals that attract more platelets. The platelets continue to pile up and release chemicals until a clot is formed.
d. ***LH surge:*** This is increased luteinizing hormone (LH) secretion that leads to ovulation. Normally, estrogen inhibits LH secretion. But, before ovulation, estrogen provides positive feedback to LH secretion, which results in LH surge.
e. ***Activation of digestive enzymes:*** The activation of digestive enzymes pepsinogen and trypsinogen by pepsin and trypsin respectively.

4.0 Conclusion

The stimulus, receptor, integrating center, and effectors are the basic components of every homeostatic response. Positive and negative feedback are more complicated mechanisms that enable these three basic components to maintain homeostasis for more complex physiological processes.

5.0 Summary

Negative feedback mechanisms use one of the products of the reaction to reduce the output or activity of the process for the purpose of returning an organ or system to its normal range of functioning. The **positive feedback** on the other hand is a mechanism in which an activated component enhances or further upregulates the process that gave rise to itself in order to create an even stronger response. Positive feedback mechanisms are designed to accelerate or enhance the output created by a stimulus that has already been activated.

6.0 In-Text Questions

1. Describe the Feedback System
2. Enumerate 5 examples of a negative feedback system
3. Explain the positive feedback loop

7.0 In-Text Answers

Q1. Life is maintained within a steady-state of internal environment. The internal environment must be kept constant in the face of an ever changing external environment. It separated from the external environment by the skin. A feedback mechanism is a process that uses the conditions of one component to regulate the function of the other. Feedback system is a form of regulation that aids the body to detect changes in internal environment & responds to such change. It is done to either increase or dampen the change in the system.

Q2.Examples of negative feedback;

- Blood pressure regulation
- Regulation of hormone secretion
- Blood glucose regulation
- Body temperature regulation
- Iron regulation

Q3. The positive feedback loop is a self-perpetuating feedback. Increase in function in response to a stimulus, that is, resulting action on the same direction of the stimulus. If stimulus increases, homeostasis control system activated to cause increase in the stimulus. The effector response of the system is in the same direction to stimulus that initiated the response. Only few systems display positive feedback. In a positive feedback system, increase in the variable triggers processes that further increase the variable.

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STUDY SESSION 3: BIOLOGICAL RHYTHMS

CONTENTS

1.0 Introduction

A biological system is a set of self-organized, differentiated components (elements) that interact pair-wise among themselves through various networks and media, isolated from other sets by boundaries called teguments and whose relation to other systems can be described as a closed loop in a steady-state. The mammalian organism maintains stable, efficient, and "near-optimal" performance and homeostasis in the face of external and internal perturbations via distinct biological systems ranging from the large-scale physiological (nervous, endocrine, immune, circulatory, respiratory, etc.), to the cellular (growth and proliferation regulation, DNA damage repair, etc.), and the sub-cellular (gene expression, protein synthesis, metabolite regulation, etc).

2.0 Learning Outcomes

After reading this course, student will be able to:

- Explain and understand the meaning of biological rhythm
- Enumerate the types of biological rhythm
- Highlight the significance of biological rhythm
- Identify the disorders of biological rhythm

3.0 Main Content

3.1 Overview of Biological Rhythm

Biological Control Systems is the application of control theory and practice to biological systems, arises from a control engineering perspective of the function, organization, and coordination of these multi-scale biological systems and the control mechanisms that enable them to carry out their functions effectively. Biological system or rhythms are the natural cycle of change in our body's chemicals or functions. It's

like an internal master "clock" that coordinates the other clocks in the body. The "clock" is located in the brain, right above the nerves where the eyes cross. It's made up of thousands of nerve cells that help sync body's functions and activities.

Every living organism can obviously be regarded as a biological system, including any individual organism within (i.e., a parasite) and the organs that constitute it, as well as their organization. The tiny suprachiasmatic nucleus (SCN) of the hypothalamus plays a central role in the daily programming of organismic functions by regulating day-to-day oscillations of the internal milieu and synchronizing them to the changing cycles of day and night and of body state. This biological clock drives the daily expression of vital homeostatic functions as diverse as feeding, drinking, body temperature, and neurohormone secretion. It adaptively organizes these body functions into near-24-hour oscillations termed circadian rhythms. The SCN imposes temporal order; through generating output signals that relay time-of-day information, and through gating its own sensitivity to incoming signals that adjust clock timing.

3.2 Types of Biological Rhythm

The circadian clock plays a physical, mental, and behavioral role that responds to light and dark. This clock helps regulate functions that include: sleep schedule, appetite, body temperature, hormone levels, alertness, daily performance, blood pressure and reaction times. External factors can influence your biological rhythms. For instance, exposure to sunlight, drugs, and caffeine can affect sleep schedules. There are four biological rhythms:

- **circadian rhythms**: the 24-hour cycle that includes physiological and behavioral rhythms like sleeping
- **diurnal rhythms**: the circadian rhythm synced with day and night
- **ultradian rhythms**: biological rhythms with a shorter period and higher frequency than circadian rhythms
- **infradian rhythms**: biological rhythms that last more than 24 hours, such as a menstrual cycle

3.3 Significance of Biological Rhythm

Physiological Control System

The mammalian system maintains homeostasis and desired physiological function in the face of constant perturbations with the aid of a collection of physiological systems, each with its dedicated function and objectives, and organized as follows:

The Master Regulators

- The Nervous System (for overall control and regulation, among other functions such as memory, behavior, etc.)

- The Endocrine System (for chemical regulation, among other functions such as growth and development, etc.)

The Defenders, Protectors & Supporters

- The Immune/Lymphatic System (for defense and internal protection, among other functions including fluid balance and fat absorption, etc.)
- The Integumentary System (for protection and heat transfer, among other functions such as Vitamin D production etc.)
- The Muscular/Skeletal System (for movement and mechanical support, among other functions such as minerals warehousing and blood cell production, etc.)

The Utilities

- The Cardiovascular System (for transport and supplies distribution)
- The Respiratory System (for oxygen supply and CO2 elimination, among other functions such as vice production and olfaction, etc.)
- The Digestive System (for nutrient processing and supply)
- The Urinary System (for waste extraction and elimination, among other functions such as Vitamin D synthesis, etc.)

The Species Propagator

- The Reproductive System (for species propagation from one generation to the next)
- Each of the eleven physiological systems noted above consists of exquisitely calibrated control systems that enable it carry out its functions efficiently.
- These control systems consist of the same functional components as the engineering control system: sensors, controllers, actuators, and the controlled process itself.

3.3 Disorders of Biological Rhythm

Disorders may develop when natural biological rhythms are disturbed. These disorders include:

- **Sleep Disorders**: The body is "wired" to sleep at night. Disruptions in the body's natural rhythms can lead to affected sleep, including insomnia.
- **Jet lag**: A disruption in circadian rhythms when traveling across time zones or overnight.
- **Mood Disorders**: Lack of exposure to sunlight can lead to conditions like depression, bipolar disorder, and seasonal affective disorder (SAD).
- **Shift work disorders**: When a person works outside the typical work day it causes changes in typical circadian rhythms.

4.0 Conclusion

The human body is a biological machine made of body systems; groups of organs that work together to produce and sustain life. A biological system is a complex network which connects several biologically relevant entities.

5.0 Summary

We focused on explaining the meaning of biological rhythm, the types of biological rhythm, significance of biological rhythm and the disorders of biological rhythm in this study session.

6.0 In-Text Questions

1. What is a biological clock? Describe the nucleus play significant role in rhythmicity
2. Using examples, explain the types of a biological control system
3. What are the disorders of a biological control system?

7.0 In-Text Answers

Q1. Biological clock is the application of control theory and practice to biological systems, arises from a control engineering perspective of the function, organization, and coordination of these multi-scale biological systems and the control mechanisms that enable them to carry out their functions effectively. Biological system or rhythms are the natural cycle of change in our body's chemicals or functions. It's like an internal master "clock" that coordinates the other clocks in the body. The tiny suprachiasmatic nucleus (SCN) of the hypothalamus plays a central role in the daily programming of organismic functions by regulating day-to-day oscillations of the internal milieu and synchronizing them to the changing cycles of day and night and of body state.

Q2. There are four biological rhythms:

- **Circadian rhythms**: the 24-hour cycle that includes physiological and behavioral rhythms like sleeping.
- **Diurnal rhythms**: the circadian rhythm synced with day and night
- **Ultradian rhythms**: biological rhythms with a shorter period and higher frequency than circadian rhythms
- **Infradian rhythms**: biological rhythms that last more than 24 hours, such as a menstrual cycle

Q3. The disorders of a biological system include:

- **Sleep Disorders**: The body is "wired" to sleep at night.
- **Jet lag**: A disruption in circadian rhythms when traveling across time zones or overnight.
- **Mood Disorders**: Lack of exposure to sunlight can lead to conditions like depression.
- **Shift work disorders**: When a person works outside the typical work day it causes changes in typical circadian rhythms.

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