COURSE GUIDE

NSC 221

HUMAN PHYSIOLOGY I

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INTRODUCTION

Welcome to the first level course in Human Physiology, NSC 221 – Human Physiology I. This is a first year foundation life science course that you need to be knowledgable in as a nurse because it provides the foundation about how the body functions. It lays the foundation for a thorough understanding of the physiology and pathophysiology of body organs, hence this course is fundamental to nursing interventions that are evidence based.

COURSE AIM

The aim of this course is to build a solid foundation in understanding of body functions with the purpose of helping you as professionals that will develop care to meet variations in meeting normal and abnormal body physiology.

COURSE OBJECTIVES

At the end of this course, you should be able to:

- discuss the context of the cell as the functional unit of the body.
- apply the understanding of the mechanisms of dynamics of body fluids, homeostasis and the immune process in understanding changes and the control of the physiological body process of clients.

WORKING THROUGH THIS COURSE

The course will be delivered adopting the blended learning mode, 70% of online but interactive sessions and 30% of face-to-face during laboratory sessions. You are expected to register for this course online before you can have access to all the materials and have access to the class sessions online. You will have hard and soft copies of course materials, you will also have online interactive sessions, face-to-face sessions with instructors during practical sessions in the laboratory. The interactive online activities will be available to you on the course link on the Website of NOUN. There are activities and assignments online for every unit every week. It is important that you visit the course sites weekly and do all assignments to meet deadlines and to contribute to the topical issues that would be raised for everyone's contribution.

You will be expected to read every module along with all assigned readings to prepare you to have meaningful contributions to all sessions and to complete all activities. It is important that you attempt all the self-assessment exercise (SAE) at the end of every unit to help your understanding of the contents and to help you prepare for the in-course tests and the final examination. You will also be expected to keep a portfolio where you keep all your completed assignments.

COURSE MATERIALS

1. Course Guide
2. Study Units
3. Text Books
4. Assignment
5. Tutorials

STUDY UNITS

This course comprises 3 modules of 14 units.

MODULE 3- Respiratory Physiology

Unit 1: Components, muscles of respiration and mechanism of breathing

Unit 2: Surfactant and compliance of the lungs, the dead space, lung volumes and capacity

Unit 3: Transport and Exchange of Gases, Oxygen, Carbon dioxide and the Oxygen – haemoglobin dissociation curve

Unit 4: Control of Respiration and Respiratory Adaptations in Unusual Environment

Module 4 Heart and Circulatory Physiology

TEXTBOOKS AND REFERENCES

Fox, S.I. (2012). *Human Physiology.* (12th ed.). New York: Mc Graw Hill.

Ganong, W.F. (2019). *Review of Medical Physiology.* (26th ed.). New York: Mc Graw

Hill.

Guyton, A.C. & Hall, J.E. (2021*). Textbook of Medical Physiology*. (14th ed.). Philadelphia: Harcourt International Edition, W.B. Saunders.

Sembulingam K & Sembulingam P.(2012). *Essential Medical Physiology*. (6th ed.). new Delhi: Jaypee Brothers medical Publishers (P) Ltd

ASSIGNMENT FILE

In the assignment file, you will find all the details of the work you must submit to your tutor for marking. The marks you obtain for these assignments will count towards the final mark you obtain from this course. Further information on the assignments will be found in the assignment file itself and later in the section on assessment in this course guide. Each unit is loaded with a minimum of two assignments. In any way, there many assignments for this course and they cover every unit.

ASSESSMENT

There are two aspects to the assessment of this course. First are the tutor-marked assignments, second is a written examination. In doing the assignments, you are expected to apply information, knowledge and technique gathered during the course. The assignments must be submitted to your tutor for formal assessment in accordance with the deadline agreed upon in the assessment file. The work you submit to your tutor for assessment will count for 50% of your total course mark. At the end of the course, you will need to sit for final written examination of two hours duration. This examination will also count for 50% of your total course mark.

PRESENTATION SCHEDULE

Your course materials have important dates for the early and timely completion and submission of your TMAs and attending tutorials. You should remember that you are required to submit all you assignments by the stipulated time and date. You should guard against falling behind in your work.

TUTOR-MARKED ASSIGNMENTS (TMA)

There are marked assignments in this course. You are encouraged to submit all except any counter directive from your tutor, in which the best require number, will be counted. Make sure that each assignment reaches your tutor on or before the deadline given in the assignment file. If for any reason you cannot complete your work on time, contact your tutor before the assignment is due to discuss the possibility of an extension. Extension will not be granted after the due date unless there are exceptional circumstances.

FINAL EXAMINATION AND GRADING

The end- course- examination will be for three hours and it has a value of 70% of the total course work. The examination will consist of questions, which will reflect the type of self-testing, practice exercise and tutor-marked assignment problems you have previously encountered. All areas of the course will be assessed.

You are to use the time between finishing the last unit and sitting for the examination to revise the whole course. You might it useful to review your self-test, TMAs and comments on them before the examination. The end- of- course examination covers information from all parts of the course.

COURSE MARKING SCHEME

Table 1: Course Marking Scheme

Assignments	**Marks**
Assignments 1-4	Four TMAs, best three marks of the four count at 10% each 30% of course marks.
End of course examination	70% of overall course marks.

Total 100% of course materials.

COURSE OVERVIEW

Human Physiology (I)

Physiology is the scientific study of how the body works under normal conditions or in a state of good health. It describes how cells operate, how they combine their functions in specific organs, and how these organs work together to maintain a stable environment inside the body. Physiology is the functional basis of the health sciences, because most disease states are the result of disturbances of physiological processes. A basic knowledge of physiology is therefore essential for all students whose professional careers will involve aspects of health and patient care. Physiology is also one of the key subjects in biomedical science and continues to be at the forefront of biomedical research. Human Physiology (I) is the first of two courses that runs in the second year of your programme. This course covers the cell physiology, the maintenance of homeostasis, muscle functioning, the immune processes. Respiratory physiology, heart and circulatory physiology

HOW TO GET THE MOST FROM THIS COURSE

Read and understand the context of this course by reading through this course guide. Paying attention to details. You must know the requirements before you will do well.

Develop a study plan for yourself.

Follow instructions about registration and master expectations in terms of reading, participation in discussion forum, end of unit and module assignments, laboratory practical and other directives given by the course coordinator, facilitators and tutors.

Read your course texts and other reference textbooks.

Listen to audio files, watch the video clips and consult websites when given.

Participate actively in online discussion forum and make sure you are in touch with your study group and your course coordinator.

Submit your assignments as at when due.

Work ahead of the interactive sessions.

Work through your assignments when returned to you and do not wait until when examination is approaching before resolving any challenge you have with any unit or any topic.

Keep in touch with your study centre, the NOUN, School of Health Sciences websites as information will be provided continuously on these sites.

Be optimistic about doing well.

FACILITATORS/ TUTORS AND TUTORIALS

There are 12 hours of tutorials provided in support of this course. You will be notified of the dates, times and location of these tutorials, together with the name and phone number of your tutor, as soon as you are allocated a tutorial group. Your tutor will mark and comment on your assignments, keep a close watch on your progress and on any difficulties you might encounter and provide assistance to you during the course. You must mail your TMAs to your tutor well before the due date (at least two working days are required). They will be marked by your tutor and returned to you as soon as possible. Do not refuse to contact your tutor by telephone, e-mail or direct discussion if you need help. The following might be circumstances in which you would find help necessary. Contact your tutor in case:

1. You do not understand any part of the study units or the assigned readings
2. You have difficulty with the self-tests or exercises
3. You have a question or problems with an assignment, with your tutor's comments

You have a question or problems with an assignment, with your tutor's comments.

On an assignment or with the grading of an assignment you should try your best to attend the tutorials. This is the only chance to have face contact with your tutor and to ask questions which are answered instantly. You are free to raise any problem encountered in the course of your study. To maximise the benefit from course tutorials, prepare

question list before attending them. You will learn and gain a lot from participating in discussions group actively.

MAIN COURSE

CONTENTS PAGE

MODULE 1

INTRODUCTION

The human body is made of several cells that perform basic functions that sustain life. Different types of cells aggregate to form organs that ultimately perform different functions. While different organs perform different functions, the body must function in harmony. This module covers cell functioning and body's methods of achieving harmony through homeostasis.

MODULE OBJECTIVES

At the end of this module, you should be able to:

- discuss how the cell performs the various functions
- discuss how the plasma membrane performs its functions
- discuss how the body sustain homeostasis with contribution from the different body systems.

UNIT1 THE CELL

CONTENTS

1.0 INTRODUCTION

The basic living unit of the body is the cell. Each organ is an aggregate of many different cells held together by intercellular supporting structures. Each type of cell is specially adapted to perform one or a few particular functions. For instance, the red blood cells, numbering 25 trillion in each human being, transport oxygen from the lungs to the tissues.

2.0 OBJECTIVES

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

- explain the organisation of the cell
- explain 3 different substances that make up the cell
- give detailed explanation of the cell structure
- draw a typical cell showing the organelles in the cytoplasm and the nucleus.
- explain the functions following concepts- (a) Nucleus (b) Cytoplasm (c) Endoplasmic reticulum and Ribosomes (d) Golgi apparatus (e) Mitochondria (f) Centrosome (g) Lysosomes
- describe the cell or plasma membrane.

3.0 MAIN CONTENT

3.1 Organisation of the Cell

The cell has two major parts namely the nucleus and the cytoplasm. The nucleus is separated from the cytoplasm by a nuclear membrane, and the cytoplasm is separated from the surrounding fluids by a cell membrane, also called the plasma membrane. The different substances that make up the cell are collectively called protoplasm. Protoplasm is composed mainly of five basic substances: water, electrolytes, proteins, lipids, and carbohydrates.

The Protoplasm

Water

The principal fluid medium of the cell is water, which is present in most cells, except for fat cells, in a concentration of 70% to 85%. Many cellular chemicals are dissolved in the water. Others are suspended in the water as solid particulates. Chemical reactions take place among the

dissolved chemicals or at the surfaces of the suspended particles or membranes.

Electrolytes (Ions)
The most important ions in the cell are potassium, magnesium, phosphate, sulfate, bicarbonate, and smaller quantities of sodium, chloride, and calcium. The ions provide inorganic chemicals for cellular reactions. Also, they are necessary for operation of some of the cellular control mechanisms. For instance, ions acting at the cell membrane are required for transmission of electrochemical impulses in nerve and muscle fibers.

Proteins
After water, the most abundant substances in most cells are proteins, which normally constitute 10% to 20% of the cell mass. These can be divided into two types: structural proteins and functional proteins.

Lipids
The biologically important lipids are the fatty acids, triglycerides, phospholipids and sterols. Fatty acids can be saturated or unsaturated while phospholipids are found in cell membranes where they act as a structural component. Fatty acids also serve as an important source of energy in the body.

Carbohydrates
Carbohydrates are organic molecules made up of equal amounts carbon and water. They perform both structural and functional roles. They also help in cell signaling. They are a very important source of energy in the body.

3.2 Cell Structure

The cell is not merely a bag of fluid, enzymes, and chemicals; it also contains highly organised living structures, called intracellular organelles. The physical nature of each organelle is as important as the cell's chemical constituents for cell function. For instance, without one of the organelles, the mitochondria, more than 95% of the cell's energy release from nutrients would cease immediately. The most important organelles and other structures of the cell are shown in Figure 1.1.

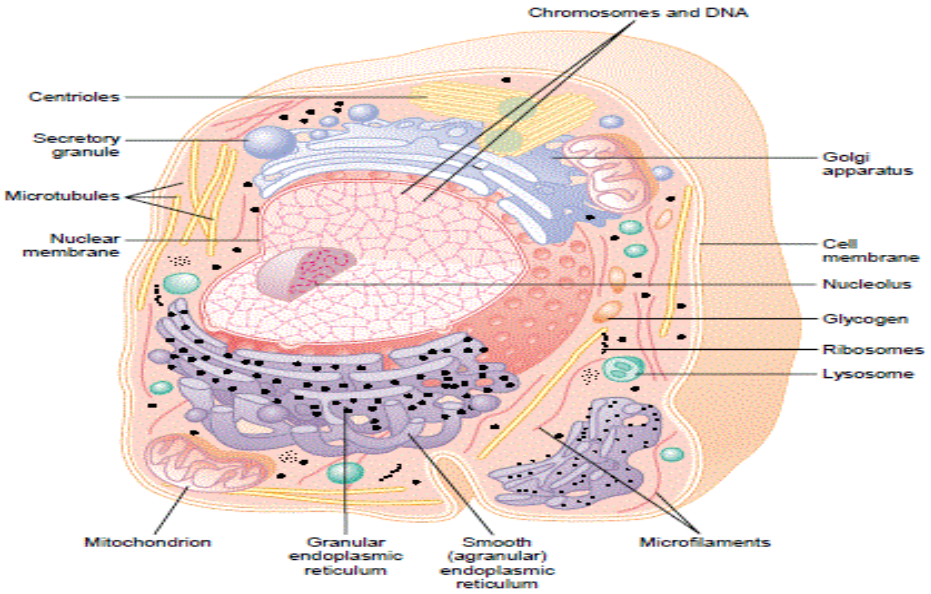

Fig.1.1: A Typical Cell, Showing the Organelles in the Cytoplasm and the Nucleus

Nucleus

The nucleus, shown in Figure 1-2, is usually a spherical organelle, though its shape may vary in some cells. It is surrounded by a membrane called nuclear membrane. The nuclear membrane has double layer and the two layers are fused at some points to produce nuclear pores which are thought to allow molecules pass between the nucleus and cytoplasm. There is a smaller spherical structure within the nucleus, the nucleolus. The fluid contained within the nucleus is called nucleoplasm to differentiate it from the fluid in the rest of the cell which is referred to as cytoplasm. The nucleus is best seen in a cell that has been stained because the chromatin within the nucleus stains vividly. In the unstained state, chromatin is colourless. Chromatin gives rise to the chromosomes when a cell divides. Chromosomes are primarily composed of deoxyribonucleic acid (DNA). DNA is the basic substance for inheritance. The second basic substance of inheritance is ribonucleic acid (RNA) which is generally contained within the nucleolus.

During cell division, genetic information contained in DNA is transferred to RNA, which carries the genetic information out of the nucleus into the cytoplasm where it directs the formation of protein. Thus, the nucleus is the repository of genetic information for the whole body.

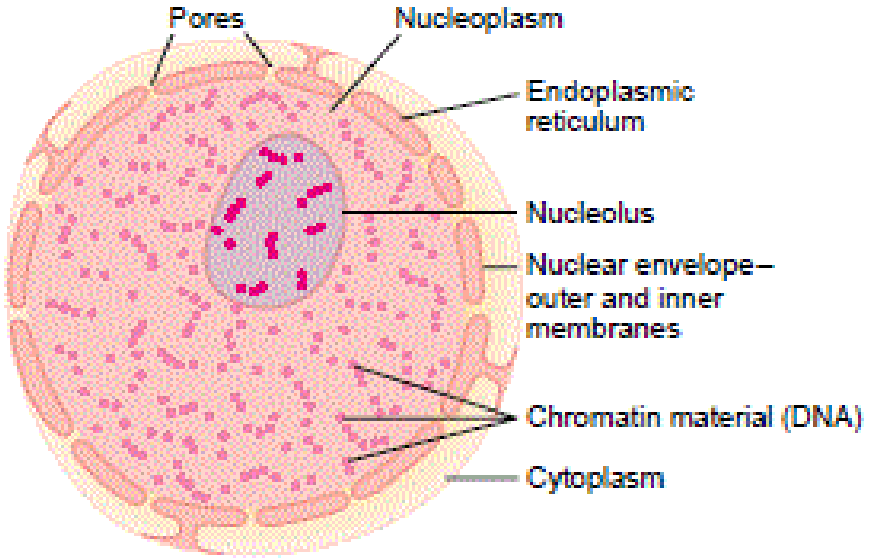

Fig. 1.2: Structure of the Nucleus

Cytoplasm

This is the jelly-like fluid between the nuclear membrane and the cell membrane inside which the cell organelles are suspended. The clear liquid portion in which the particles are suspended is called the cytosol. Cytoplasm is mostly water but it contains electrolyte and about 15% protein plus fat and carbohydrate. The cytoplasm comprises about 80% of the total weight of the cell.

Endoplasmic Reticulum and Ribosomes

There are small cytoplasmic tubules collectively called the endoplasmic reticulum. Some tubules of the endoplasmic reticulum have small, spherical structures called ribosomes attached to their membranes. Where these are present, the reticulum is called the granular or rough endoplasmic reticulum. Other tubules are free of ribosomes. This part is called the agranular, or smooth, endoplasmic reticulum, as shown in Figure 1.3.

The tubules of the granular, ribosome-containing endoplasmic reticulum are involved in the vital processes of protein synthesis and secretion in the cell. A molecule of RNA is formed from the DNA in the nucleus. This RNA is known as messenger RNA (mRNA) because it carries the genetic message from DNA in the nucleus and passes through the pores in the nuclear membrane to enter the cytoplasm. The mRNA then becomes attached to ribosomes, where it directs the formation of proteins. Once synthesised, protein enters the tubules of the endoplasmic reticulum. After the protein accumulates in the tubules, parts of the tubules break off to become spherical vesicles containing quantities of

protein. These vesicles then become part of the golgi apparatus and the protein is eventually secreted from the cell.

The agranular endoplasmic reticulum does seem to be involved in protein synthesis; yet many hormones are found stored in these tubules. In the cells of glands that secrete hormones, such as the thyroid gland, the agranular endoplasmic reticular tubules contain large quantities of the hormone. Smooth endoplasmic reticulum is involved in the synthesis of lipid steroid hormones and, in liver cells, contains the enzymes which catalyze glycogen breakdown.

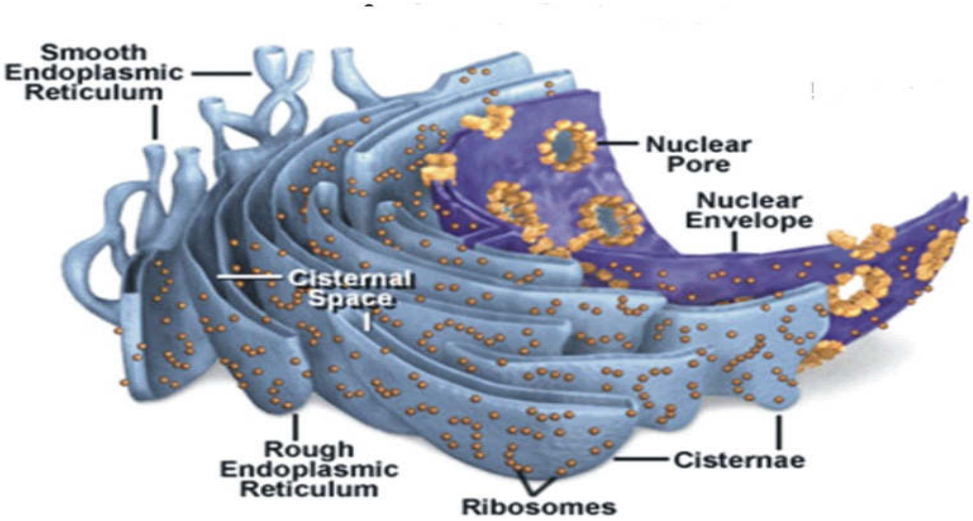

Fig. 1.3: Structure of the Endoplasmic Reticulum

Golgi Apparatus

The Golgi apparatus, also referred to as the Golgi complex or golgi body, shown in Figure 1–4, appears as a collection of tubules and vesicles. Secretory granules are formed in the Golgi apparatus. These granules are packages of highly concentrated protein. Once protein has been formed by the ribosomes, it accumulates in the Golgi apparatus where it is concentrated and may be modified and then packaged into vesicles of secretory granules. These vesicles fuse with the membrane and then open up to release the protein from the cell. Carbohydrate may be added to the protein within the Golgi body to form glycoproteins. Mucus is also formed in this area.

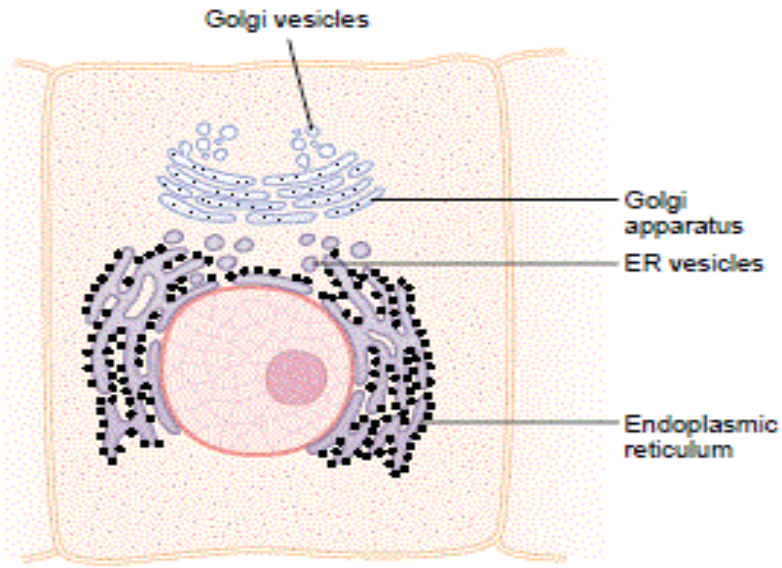

Fig. 1.4: A Typical Golgi Apparatus and its Relationship to the Endoplasmic Reticulum (ER) and the Nucleus

Mitochondria

The mitochondrion, shown in Figure 1.5, is called the "powerhouse" of the cell. Without the mitochondria, cells would be unable to extract enough energy from the nutrients, and essentially all cellular functions would cease. In the mitochondria, the very important compound adenosine triphosphate (ATP) is formed. ATP is said to be a high-energy phosphate compound because, when it splits off a phosphate molecule to become adenosine diphosphate (ADP), energy is made available to the cell. This energy is used for the various cellular processes, such as the contraction of a muscle cell.

Mitochondria are found in varying numbers in all nucleated cells. They may be distributed evenly throughout the cytoplasm or concentrated in areas of high energy requirement; for example they lie between the fibrils of muscle fibres where they produce energy for contraction.

Each mitochondria is bounded by a smooth outer membrane which is separated by a small space of about 8nm from a folded inner membrane. These folds are called cristae and they are studded with minute particles. The inner and outer membranes, the space between them, the membrane bound particles and the inner matrix contains enzymes. All of the enzymes which break down nutrient substances into carbon dioxide and water, together with the enzymes which enable the transfer of released energy to stable high-energy compounds are present within the mitochondrial structure. Virtually all of the cell's high-energy compounds are synthesised within the mitochondria.

Mitochondria can increase its own number by repeated self-replication. This occurs when there is need for increased amounts of ATP in the cell. Mitochondria contain deoxyribonucleic acid (DNA) similar to that found in the nucleus. The DNA of the mitochondrion, like that in the nucleus, controls its replication.

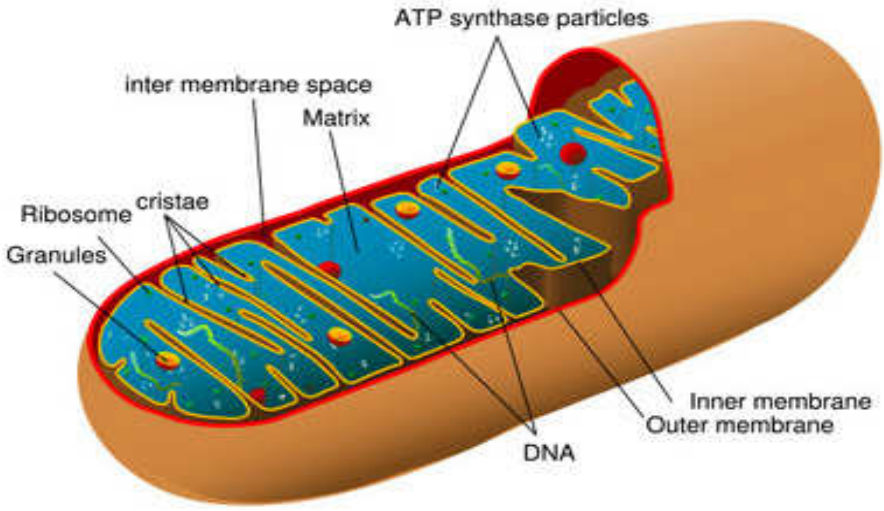

Fig. 1.5: Structure of Mitochondria

Centrosome

The centrosome contains two centrioles. They lie close to the nucleus. At the beginning of cell division, the two centrioles divide, thus forming four centrioles, one pair goes to one end of the cell and the other pair to the opposite end. The centrioles function to pull the chromosome pairs apart. In this way, one set of chromosomes goes to one side of the cell and the other set to the other. When the cell divides, each new cell has a complete set of chromosomes.

Lysosomes

Lysosomes are vesicular organelles that form by breaking off from the Golgi apparatus and then dispersing throughout the cytoplasm. When a cell engulfs bacteria, the bacteria come in contact with the lysosomal enzymes, which then destroy them. When a cell dies, the lysosomal membrane disintegrates and the enzymes are freed to act on the cellular debris to digest it. Hence, lysosomes are often referred to as suicide bags. Hence, lysosome functions as a form of digestive system for the cell. Each lysosome is filled with large numbers of small granules which are protein aggregates of hydrolytic (digestive) enzymes. The main substances liposomes digest are proteins, carbohydrates, lipids.

Peroxisomes
Peroxisomes are also small membrane-bound bodies which are similar in appearance to lysosomes. They contain catalase which causes the breakdown of hydrogen peroxide. The peroxisomes membrane contains some peroxisome – specific proteins that are concerned with the transport of substances into and out of the matrix of the peroxisome. The matrix contains more than 40 enzymes and these enzymes operate in concert with other enzymes outside the peroxidase to catalyze reactions, including the catabolism of very long chain fatty acids.

3.3 Cell or Plasma Membrane

The membrane that surrounds the cell is called the cell membrane. It is also referred to as the plasma membrane. Figure 6 shows the structure of the cell membrane. The cell membrane is composed primarily of membrane protein and lipid and is about 7.5 nm (75 Angstrom units) thick. They are semi permeable allowing some substances to pass through and excluding others. The major lipids are phospholipids and the approximate composition of the cell membrane is proteins, 55 per cent; phospholipids, 25 per cent; cholesterol, 13 per cent; other lipids, 4 per cent; and carbohydrates, 3 per cent. The accepted model concept of the structure of the cell membrane is that of a fluid mosaic model. According to this concept, the lipid bilayer is in form of a fluid and membrane protein mostly lipoprotein and glycoprotein, which are loosely attached and embedded in a bilayer matrix.

Figure 6 also shows globular masses floating in the lipid bilayer. These are membrane proteins, most of which are glycoprotein. The protein components of the cell membrane are of two main types- integral proteins and peripheral proteins. Integral protein pass all the way through the cell membrane, whereas, peripheral protein are attached to the outside or inside of the cell membrane. The integral protein provide pathway through which the water soluble substance diffuses through the extra and intracellular fluid. The peripheral protein functions almost entirely as enzyme. The membrane lipid makes up the matrix that give the shape and structure to the cell membrane and embedded in this matrix are the membrane proteins. All membrane contain phospholipid and glycolipid which are amphipathic in nature (possess two coat).

The lipids are characerised by having hydrophobic and hydrophilic ends. The hydrophilic end of the bi-lipid molecule are repel by water but attracted to each other, as shown in Figure 6. Membrane lipids are almost impermeable to water and water soluble substances such as ions,

glucose, urea, etc. while lipid soluble substances such as oxygen, carbon dioxide, alcohol can penetrate easily.
The proteins in the cell membrane carry out many functions. They serve as:

(1) Pumps which are actively involved in transporting ions across the membrane e.g. Na^+ - K^+ pump.
(2) Carriers transporting substances down the electrochemical gradient by a process called facilitated diffusion.
(3) Ion channels which when activated permit the passage of ions into or out of the cell.
(4) Receptors that bind neurotransmitter and hormone initiating physiological changes inside the cell.
(5) Enzyme catalysing reaction at the surface of the membrane
(6) Antigen and antibodies, the antigenic properties of the cell depend on the protein outside.

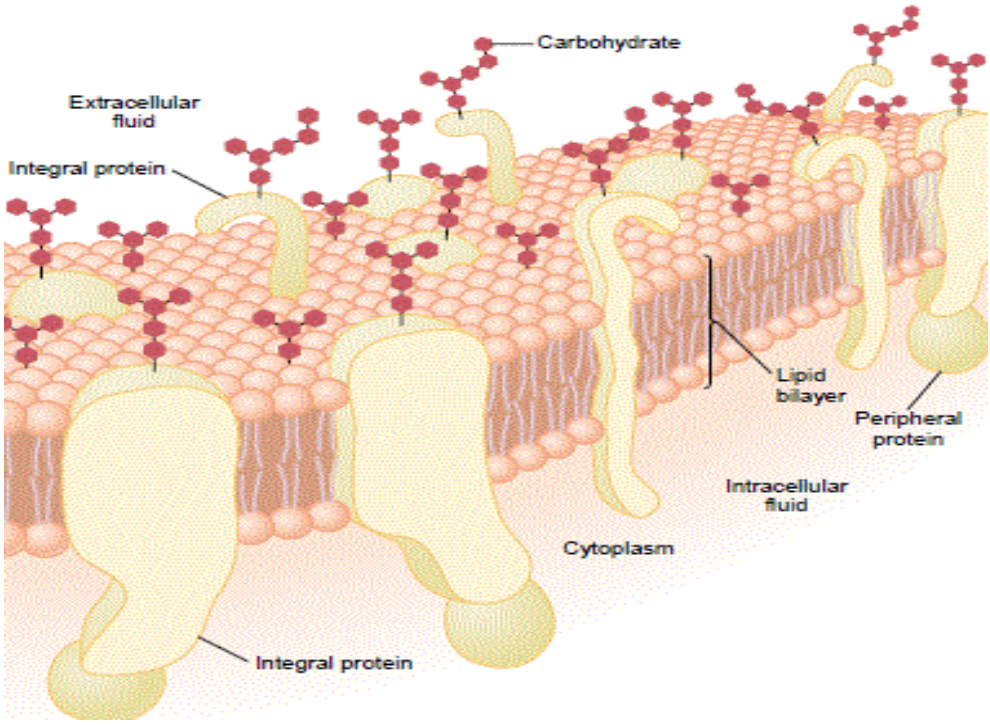

Fig. 1.6: Structure of the Cell Membrane

SAE:

Explain the organisation of the cell
2. Explain 3 different substances that make up the cell
3. Give detailed explanation of the cell structure
4. Draw a typical cell showing the organelles in the cytoplasm and the nucleus.

5. Explain the following concepts- (a) Nucleus (b) Cytoplasm (c) 6. Endoplasmic reticulum and Ribosomes (d) Golgi apparatus (e) 6. Mitochondria (f) Centrosome (g) Lysosomes
6. Describe the cell or plasma membrane

4.0 CONCLUSION

The cell is the basic unit of life with many structures organised to perform different functions that keep the cell alive.

5.0 SUMMARY

In this unit, you have learnt that:

The cell has two major parts, the nucleus and the cytoplasm with different substances all called protoplasm. The cell is made up of many structures and substances that perform diverse functions. The important parts of the cell that perform different functions include the Nucleus, the cytoplasm, the endoplasmic reticulum and Ribosomes, the Golgi apparatus, the Mitochondria, Centrosome, the Lysosomes to mention a few. You have also learnt that the cell or plasma membrane made up of protein and lipid perform about six listed functions.

6.0 TUTOR- MARKED ASSIGNMENT

Activity
Check this https://www.youtube.com/watch?v=kV1r2oVlHLI
Checking Youtube, pick the video that best helps you learn about the cell and its functions and share the information with your colleagues in the discussion forum online

7.0 REFERENCES/ FURTHER READING

Fox, S.I. (2012). *Human Physiology.* (12th ed.). New York: Mc Graw Hill.

Ganong, W.F. (2019). *Review of Medical Physiology.* (26th ed.). New York: Mc Graw Hill.

Guyton, A.C. & Hall, J.E. (2021*). Textbook of Medical Physiology*. (14th ed.). Philadelphia: Harcourt International Edition, W.B. Saunders.

Sembulingam K & Sembulingam P.(2012). *Essential Medical Physiology*. (6th ed.). new Delhi: Jaypee Brothers medical Publishers (P) Ltd

UNIT 2 TRANSPORT ACROSS CELL MEMBRANE

CONTENTS

1.0 INTRODUCTION

No cell is an island and life is only possible because several cells that make up the various organs of the body communicate. There is movement of substances across the cells and this is facilitated through various media. In this unit, you are going to learn about how solutes and solvents are transported across the cells.

2.0 OBJECTIVES

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

- explain the following concepts in details
- simple diffusion
- facilitated diffusion
- active transport
- secondary active transport
- osmosis
- endocytosis
- exocytosis
- solvent drag.

3.0 MAIN CONTENT

3.1 Simple Diffusion

This is the movement of the molecules of a substance from a region of higher concentration to that of lower concentration. This movement continues until the molecules are evenly distributed in the two regions, as demonstrated in Figure 1-9. It involves the movement of substances down their concentration gradient; it is a passive process that is it does not require energy. It is not carrier mediated. It does not display inhibition, either competitive or not. It is not saturable.

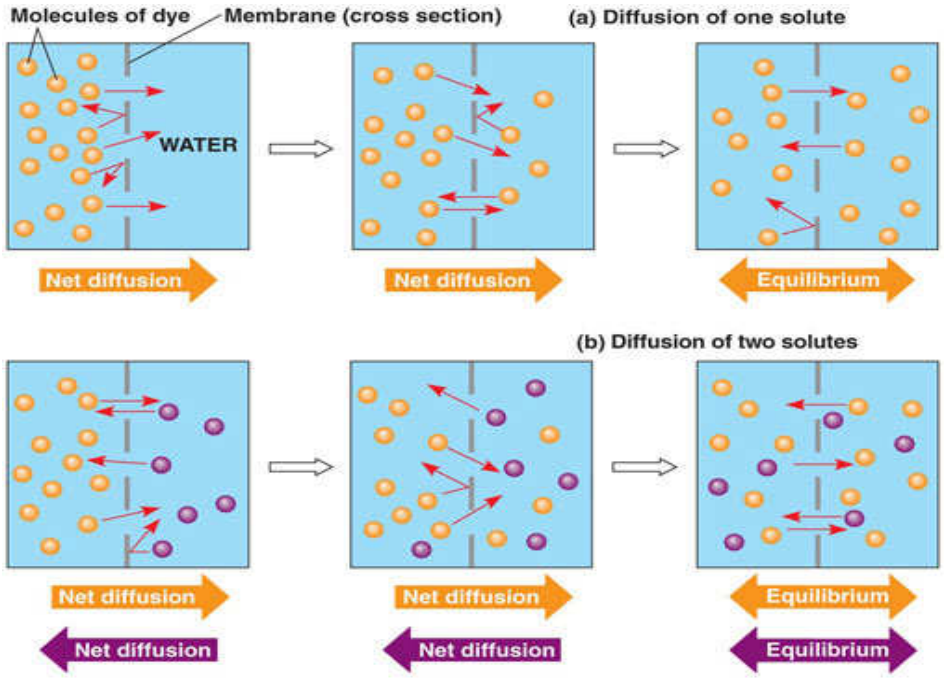

Fig. 2.1: Movement of Molecules by Simple Diffusion

3.2 Facilitated Diffusion

This is a carrier mediated transport and it involves some transport proteins that transport substances of larger molecules across the cell membrane. (Figure 1-10). It transports substances down their concentration gradients, thus it also is a passive process. It is saturable and exhibits the characteristics of inhibition either competitive or non-competitive. A typical example of facilitated diffusion is the glucose transport by glucose transporters which move glucose down the concentration gradient from extracellular fluid into cytoplasm of the cell.

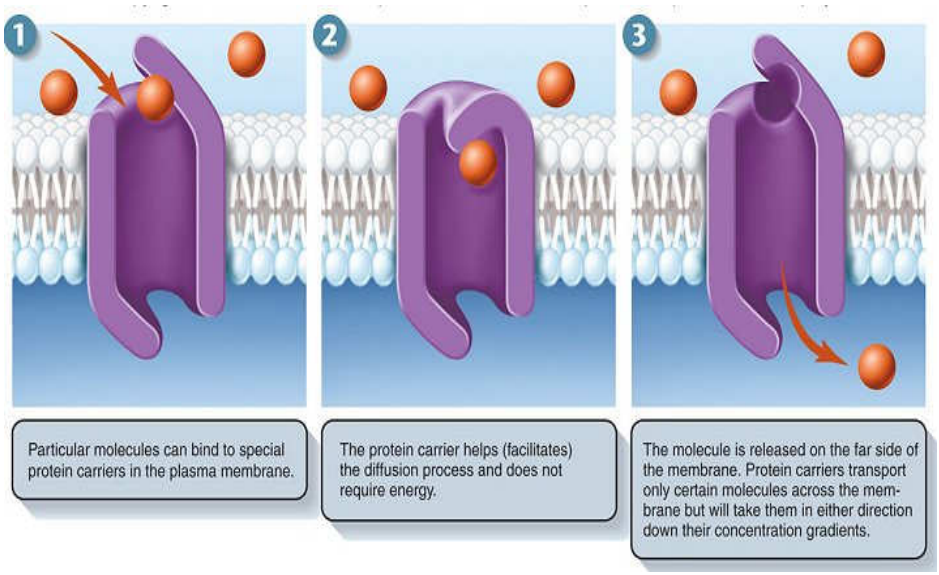

Fig. 2.2: Movement of Molecules by Facilitated Diffusion using Carrier Protein

3.3 Active Transport

As the name implies it is an active process that requires energy. It transports substances against the concentration gradient. It is also carrier mediated and saturable. It exhibits the characteristics of inhibition either competitive or non-competitive. Energy that is utilised for this transport is obtained from adenosine triphosphate (ATP) hydrolysis. A typical example of active transport is the transport of sodium ion out of the cell against its concentration gradient and the active transport of potassium ion into the cell against its own concentration gradient by the Na^+ - K^+ pump (Na^+- K^+ ATPase). For every, Na^+ pumped out by this pump, $2K^+$ is pump in.

Figure 1–11 shows the basic physical components of the Na^+-K^+ pump. The pump consists of a carrier protein which is a complex of two separate globular proteins, a larger one having a molecular weight of 100,000 and the small one has molecular weight of 45,000. Though, the function of the smaller one is not known. The larger protein has specific features that are very important for the pump.

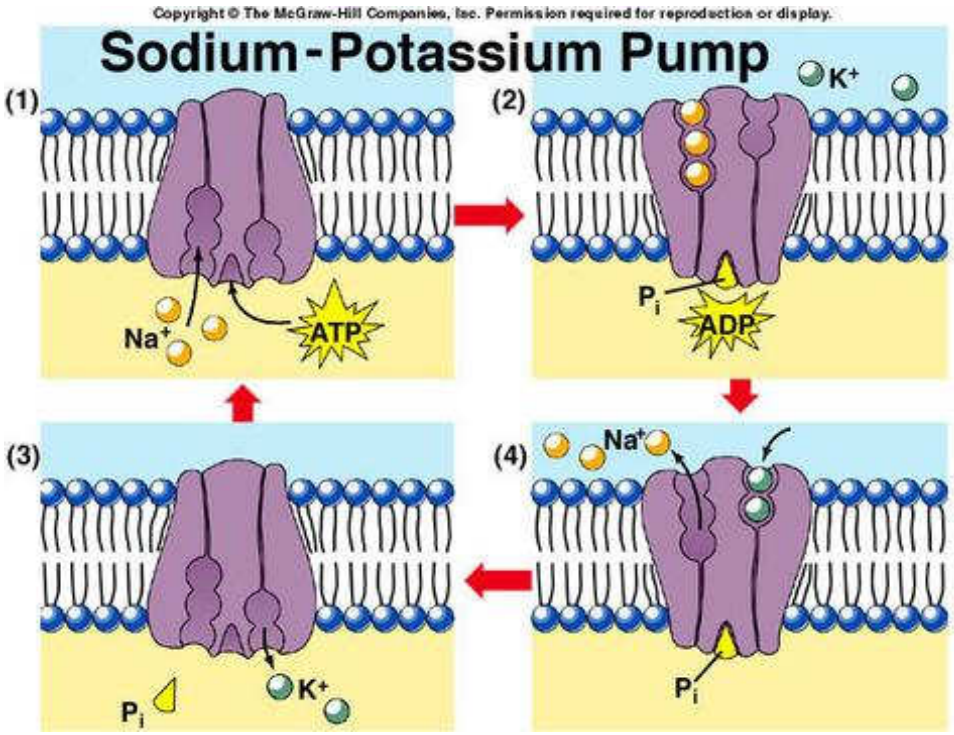

Fig. 2.3: Mechanism of the Sodium-Potassium Pump. ADP, Adenosine Diphosphate; ATP, Adenosine Triphosphate; Pi, Phosphate Ion.

3.4 Secondary Active Transport

Classes of Transport Protein

Some transport protein are uniport because they transport only one substance, others are called symport because the transport requires the binding of more than one substance to the transport protein and then the substances are transported across the membrane, example of symport, is a carrier protein in the intestinal mucosa that is responsible for the co-transport of sodium ion and glucose from the intestinal mucosa into the mucosa cells, other transporter are called antiport because they exchange one substance for the other. The Na^+ - K^+ ATPase is a typical example of an antiport. It moves three Na^+ out of the cell in exchange for each two K^+ that is moved into the cell.

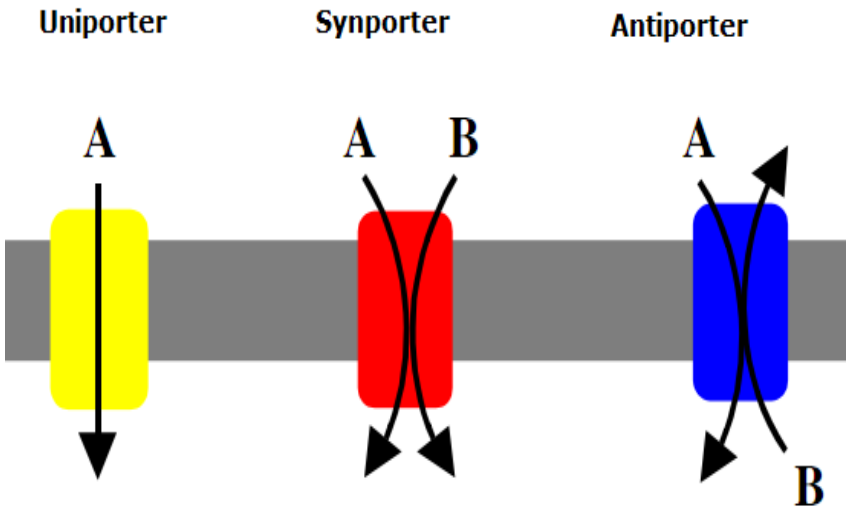

Fig. 2.4: Classes of Transport Protein

Secondary active transport is a carrier mediated transport that involves the binding of two types of substance to the binding site of the carrier. The carrier then transports both substances in or out of the cell as the case maybe. One of these substances is transported down its concentration gradient, while the other is transported against its concentration gradient. The latter substance is being dragged along by the former substance as it moves down its concentration gradient. The driving force for this type of transport is supply by the concentration gradient of one of the substances but not by ATP. This type of transport is also called Na co- transport.

Glucose and many amino acids are transported into most cells against large concentration gradients; the mechanism of this is entirely by co-transport, as shown in Figure 1–13. Sodium co-transport of glucose and amino acid occur especially in the epithelial cell of the intestinal tract and renal tubule to aid in the absorption of these substances into the blood. A typical example of sodium co-transport is demonstrated in the transport of glucose into the epithelial cells lining the small intestine by a synport. Present in the luminal brush border membrane of the small intestine is a synport that transport glucose into the cell following the binding of Na^+ to that carrier. The Na^+ is transported down its electrochemical gradient while the glucose is transported against its concentration gradient. The electrochemical gradient of sodium provides the driving force for the transport of glucose molecules. Thus, the sodium drags the glucose to transport across the brush border membrane. The electrochemical gradient of sodium is maintained by the Na^+ - K^+ pump.

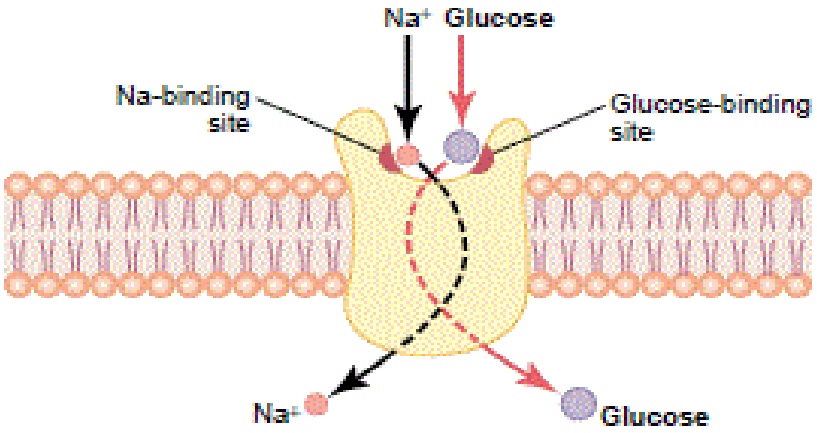

Fig. 2.5: Postulated Mechanism for Sodium Co-Transport of Glucose

3.5 Osmosis

This is process of diffusion of solvent molecule from a region where there is higher concentration (low solute concentration) to a region where there is lower concentration (higher solute concentration) across a semi-permeable or selectively permeable membrane. To give an example of osmosis, let us assume the conditions shown in Figures 1-14 & 1-15, with pure water on one side of the cell membrane and a solution of sugar and sodium chloride on the other side. When a substance is dissolve in water the concentration of water molecule in the solution is less than that of pure water of equal volume. If the solution is placed on one side of the membrane that is permeable to water and not to solute and an equal volume of water is placed on the other side, water molecule diffuse down their concentration gradient into the solution. This process of diffusion of solvent molecule to a region in which there is a higher concentration of solute to which the membrane is impermeable is called osmosis.

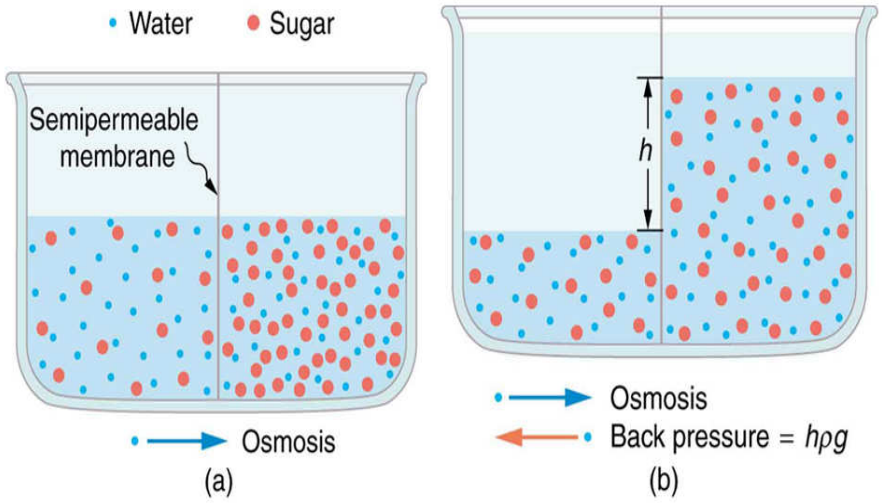

Fig. 2.6: Demonstration of Osmotic Pressure caused by Osmosis at a Semipermeable Membrane

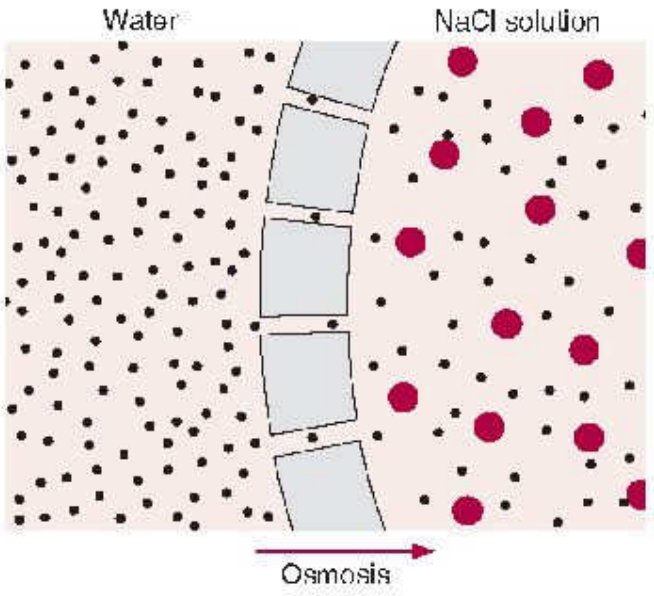

Fig. 2.7: Osmosis at a Cell Membrane when a Sodium Chloride Solution is placed on One Side of the Membrane and Water is placed on the Other Side

The tendency for movement of solvent molecule to a region of a greater solute concentration can be prevented by applying a pressure to the mole concentration solution. The pressure necessary to prevent solvent migration is the osmotic pressure of the solution. The osmotic pressure depends upon the number rather than the type of particle in solution.
The term tonicity is used to describe the osmolality of solution relating to plasma, solutions that have the same osmolality as plasma are said to

be isotonic, those with higher osmolality are called hypertonic, while those with lesser osmolality are said to be hypotonic. (Figure 1-16).

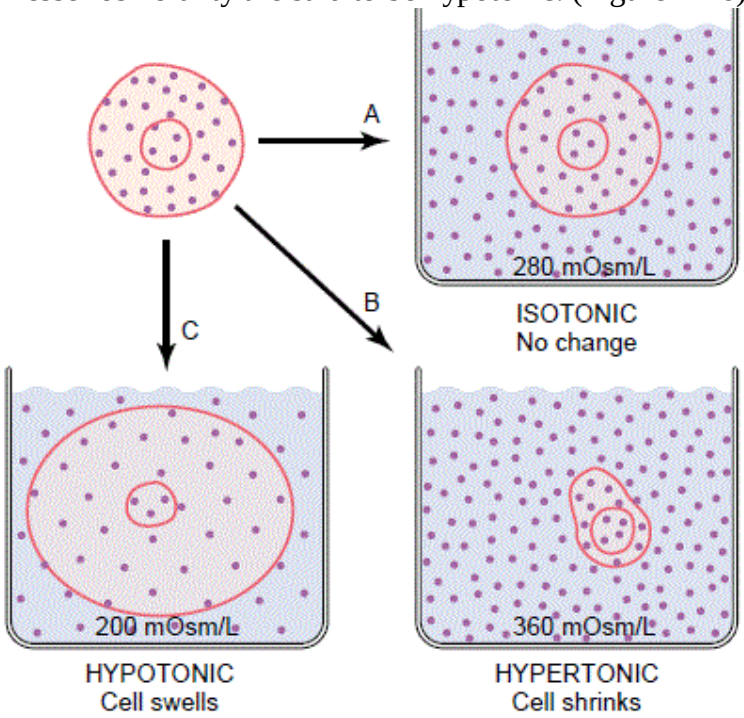

Fig. 2.8: Effects of Isotonic, Hypertonic, and Hypotonic Solutions on Cell Volume

3.6 Exocytosis

This is the process of extrusion of substances out of the cell. Proteins that are secreted by the cell moves from the endoplasmic reticulum to the Golgi apparatus, and from the trans-golgi they are extrude into secretory granules or vesicles. These granules move into cell membrane. Their membrane then fuses with the cell membrane and the area of fusion then breaks down. This leaves the content of the granules or vesicle outside the cell while the cell membrane remains intact. This extrusion process required calcium ion and energy.

3.7 Endocytosis

It is the process of ingestion of substances by the cell. It is the reverse of exocytosis. There are two types of endocytosis, these include phagocytosis and pinocytosis. Phagocytosis (cell eating) is the process by which bacteria, dead tissue or other particles visible under the microscope are engulfed by cells such as the polymorphonuclear leukocytes. The material makes contact with the cell membrane which then invaginate leaving the engulf material in the membrane enclosed vacuole while cell membrane remains intact.

Phagocytosis occurs in the following steps:

a. The cell membrane receptors attach to the surface ligands of the particle.
b. The edges of the membrane around the points of attachment evaginate outward within a fraction of a second to surround the entire particle; then, progressively more and more membrane receptors attach to the particle ligands.
c. Actin and other contractile fibrils in the cytoplasm surround the phagocytic vesicle and contract around its outer edge, pushing the vesicle to the interior.
d. The contractile proteins then pinch the stem of the vesicle so completely that the vesicle separates from the cell membrane, leaving the vesicle in the cell interior in the same way that pinocytotic vesicles are formed.

Pinocytosis means ingestion of minute particles that form vesicles of extracellular fluid and particulate constituents inside the cell cytoplasm. Pinocytosis is essentially the same process like phagocytosis, the only difference begin that the substances ingested are in solution and hence not visible under the microscope. Pinocytosis is the only means by which most large macromolecules, such as most protein molecules, can enter cells.

Figure 1–17 demonstrates the successive steps of pinocytosis, showing three molecules of protein attaching to the membrane. These molecules usually attach to specialised protein receptors on the surface of the membrane that are specific for the type of protein that is to be absorbed. The receptors generally are concentrated in small pits on the outer surface of the cell membrane, called coated pits. On the inside of the cell membrane beneath these pits is a latticework of fibrillar protein called clathrin, as well as other proteins, perhaps including contractile filaments of actin and myosin. Once the protein molecules have bound with the receptors, the surface properties of the local membrane change in such a way that the entire pit invaginates inward, and the fibrillar proteins surrounding the invaginating pit cause its borders to close over the attached proteins as well as over a small amount of extracellular fluid. Immediately thereafter, the invaginated portion of the membrane breaks away from the surface of the cell, forming a pinocytotic vesicle inside the cytoplasm of the cell.

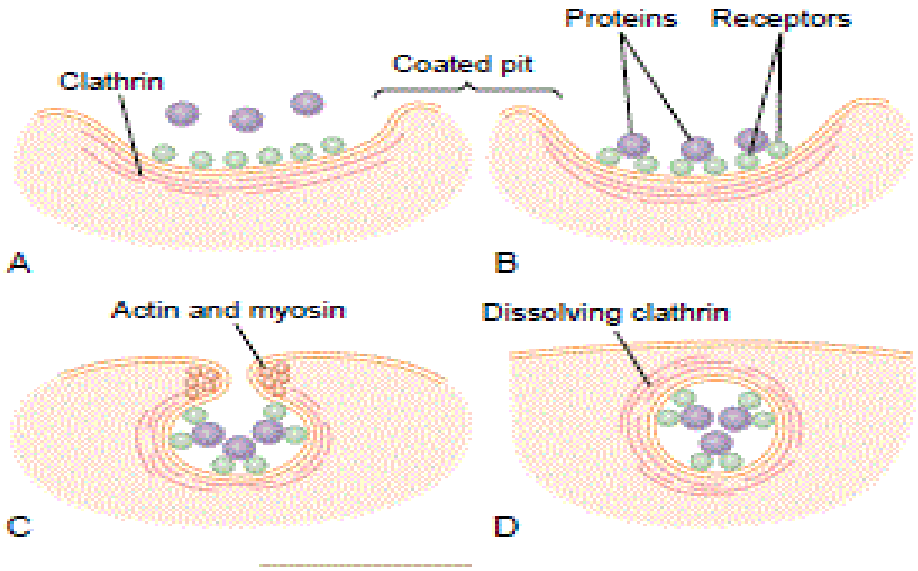

Fig. 2.9: Mechanism of Pinocytosis

Solvent Drag
When solvent is moving in one direction (bulk flow), the solvent tends to drag along some molecules or solutes in that direction, this force is called solvent drag. In most situations in the body, its effects are very small.

SAE
Distinguish between simple and facilitated diffusion.

a. Explain the Sodium-potassium pump
b. Explain the relevance of the knowledge of osmosis to the nurse.

4.0 CONCLUSION

Transportation of materials across cells is made possible through diffusion, osmosis and active transport using different media.

5.0 SUMMARY

In this unit you have learnt that the various mechanisms utilised by the body include simple diffusion, facilitated diffusion, active transport, secondary active transport, osmosis, endocytosis, exocytosis and solvent drag. The various mechanisms allow for exchange of fluid, minerals and molecules across cells.

a. Solvent drag

6.0 TUTOR- MARKED ASSIGNMENT

Activity – check these:

https://www.youtube.com/watch?v=w3_8FSrqc-I
https://www.youtube.com/watch?v=U9ZfowGuLfk
https://www.youtube.com/watch?v=zuNMVzTeCtw
https://www.youtube.com/watch?v=mzo_B5F7pk4
http://www.differencebetween.net/science/difference-between-exocytosis-and-endocytosis/
http://www.differencebetween.net/science/difference-between-pinocytosis-and-phagocytosis/
https://www.youtube.com/watch?v=SSS3EtKAzYc

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UNIT 3 BIOLOGICALLY IMPORTANT MOLECULES AND THEIR FUNCTIONS

CONTENTS

1.0 INTRODUCTION

The body needs digested nutrients to provide energy needed to perform functions and amino acids for body building and repairs. The nutrients in various forms are transported as small molecules of complex organic chemicals either as broken down carbohydrates, proteins, lipids and other forms. In this unit you will be introduced to the small molecules of these nutrients in the forms that they are absorbed.

2.0 OBJECTIVES

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

- describe carbohydrates
- explain the three main classes of carbohydrates
- discuss the major types of proteins
- describe lipids
- describe nucleic acids.

3.0 MAIN CONTENT

3.1 Carbohydrates

Carbohydrates are organic compounds made of carbon, hydrogen, and oxygen atoms. Carbohydrate are made of monosaccharide (simple sugars molecules) linked together. Their function is to provide a key

source of energy for cells. An example is starch, made of many linked glucose molecules. Carbohydrates are divided into three main classes: (i) monosaccharides (ii) disaccharides (iii) polysaccharides.

Monosaccharides
Monosaccharides are simple sugar unit with a general formula $(CH_2O)n$. The 'n' ranges between 3 and 9. Monosaccharides are all sweet, small crystalline molecules. They are readily soluble in water and are all reducing sugars. They are classified on the basis of the number of carbon atoms: trioses (3 carbons), tetroses (4 carbon), pentoses (5 carbons). The most common are pentoses and hexoses. Most monosaccharides are metabolic energy sources and serves as building blocks for the synthesis of other macromolecules.

Disaccharides
They are formed when two monosaccharides combine by condensation. The bonds formed between the two monosaccharides units as a result of condensation is called a glycosidic bond. There are several examples of disaccharide, but the most common are maltose, lactose and sucrose.

Polysaccharides
These are made by joining several monosaccharide units. They function mainly as food and energy stores e.g. starch and glycogen or as structural material e.g. cellulose. They are not sweet, non-crystalline, either slightly or insoluble in water.

3.2 Proteins

Proteins are macromolecules with molecular weight of several thousands. They are compounds containing carbon, hydrogen, oxygen, nitrogen, sulphur. There are two distinct types of protein: (1) Fibrous proteins (2) Globular proteins.

Fibrous Proteins
Fibrous proteins are insoluble in water and are physically tough. This property enables them to play a structural role in a cell. Major examples of fibrous proteins

(a) Collagen: This is found in bones, skin, tendon and cartilage. This is the most abundant protein in invertebrates and it usually contains three very long polypeptide chains, each with about 1,000 amino acids.
(b) Keratin: This is found in the outermost layer of the skin and hair, scales, hooves, nails and the feathers of animals. The main function is to protect the body against the environment.

(c) Fibrinogen: This is blood plasma protein, responsible for blood clotting. With the action of thrombin, fibrinogen is converted into molecules of insoluble protein called fibrin, which forms a network on the surface of wounds to trap blood cells and form clots.

Globular Proteins

These are proteins that are soluble in water. They have tertiary and sometimes quaternary structures. They are folded into spherical or globular shapes. They include immunoglobulin or antibodies in the blood, enzymes and some hormones, which are important in maintaining the structure of the cytoplasm.

3.3 Lipids

Lipids are non-polar molecules that are not soluble in water. They include fats, phospholipids, steroids, and waxes. Lipids functions are to provide energy and serve an important part in the structure and functioning of cell membranes. Some examples of lipids include butter (saturated fat), cholesterol (steroid) and ear wax (wax).

3.4 Nucleic Acids

Nucleic acids are long chains of smaller molecules called nucleotides. Nucleic acids mainly serve the purpose of providing the organism with its genetic blueprint and coding. Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are two types of nucleic acids.

SAE

a. Differentiate between the three main classes of carbohydrates
b. How is fibrous protein different from globular protein

4.0 CONCLUSION

In this unit, we have learnt that carbohydrates made of carbon, hydrogen and oxygen atoms metabolic energy sources and serve as building blocks for the synthesis of other macromolecules. Protein on the other hand are made up of carbon, hydrogen, oxygen, nitrogen, sulphur while lipids are not water soluble materials that include fats, phospholipids, steroids, and waxes. Nucleic acid provides basis for the genetic blueprint and coding of the DNA and RNA.

5.0 SUMMARY

In this unit, you have learnt that:

a. Carbohydrates are made up of three classes of monosacharides, disaccharides and polysacxharides depending
b. Proteins are mainly two types, fibrous and globular proteins
c. Lipids are non-polar molecules, insoluble in water and include fats, phospholipids, steroids and waxes and examples include saturated fats and cholesterol.
d. Nucleic acids

6.0 TUTOR -MARKED ASSIGNMENT

c. List two forms of lipids

Please answer the following questions:

7.0 REFERENCES/ FURTHER READING

Fox, S.I. (2012). *Human Physiology.* (12th ed.). New York: Mc Graw Hill.

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UNIT 4 HOMEOSTASIS

CONTENTS

1.0 INTRODUCTION

The human body has a remarkable capacity for self-restoration. The Greek physician Hippocrates (father of naturalism and rationalism) commented that human body usually returns to a state of equilibrium by itself and people recover from most illnesses even without the help of a physician. This tendency results from the body's ability to detect change and activate mechanisms that oppose it. In this unit, you will learn about the concept of homeostasis, how the body systems achieves physiological body maintenance through feedback mechanisms.

2.0 OBJECTIVES

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

- define homeostasis
- explain the different types of body systems that contribute to homeostasis
- explain the different types of feedback control systems that the body uses to maintain stability.

3.0 MAIN CONTENT

3.1 Homeostasis

Homeostasis is the maintenance of a constant internal environment in an ever changing external environment. It comes from the word homeo, which means the sameness, and stasis, that is, standing still. This is the maintenance of the constancy of the composition of the internal environment. The mechanisms which work towards its achievement are

called homeostatic mechanisms. Essentially all the organs and tissues of the body perform functions that help to maintain these constant conditions. For instance, the lungs provide oxygen to the extracellular fluid to continually replenish the oxygen that is being used by the cells, the kidneys maintain constant ion concentrations, and the gastrointestinal system provides nutrients. Each body system contributes to the homeostasis of other systems and of the entire being. No system of the body works in isolation, and the well-being of the person depends upon the well-being of all the interacting body systems. A disruption within one system generally has consequences for several additional body systems. Here are some brief explanations of how various body systems contribute to the maintenance of homeostasis.

3.2 The Body Systems and their Contributions to Homeostasis

Nervous System

This system is made of the brain, spinal cord, nerves and receptors. The nervous system, along with the endocrine system, serves as the primary control center of the body. It operates at a subconscious level and controls many functions of the internal organs, including the level of pumping activity by the heart, movements of the gastrointestinal tract, and secretion by many of the body's glands. For example, the hypothalamus of the brain is where the body's "thermostat" is found. The hypothalamus also stimulates the pituitary gland to release various hormones that control metabolism and development of the body. The sympathetic and parasympathetic divisions of the nervous system alternatively stimulate or inhibit various bodily responses (such as heart rate, breathing rate, etc.) to help maintain them at optimum levels. It also controls contraction of muscles like the erector pili muscles (involved in thermoregulation) and skeletal muscles. The nervous system also regulates various systems such as respiratory (controls rate and depth of breathing), cardiovascular system (controls heart rate and blood pressure), endocrine organs (causes secretion of ADH and oxytocin), the digestive system (regulates the digestive tract movement and secretion), and the urinary system (helps adjust renal blood flow and also controls voiding the bladder). The nervous system is also involved in sexual behaviours and functions.

Endocrine System

The endocrine system consists of glands hypothalamus, pituitary, thyroid, adrenal testes and ovaries which secrete hormones into the bloodstream. Each hormone has an effect on one or more target tissues. In this way the endocrine system regulates the metabolism and development of most body cells and body systems. Bone growth is

regulated by several hormones, and the endocrine system helps with the mobilization of calcium and phosphate into and out of the bones. In the muscular system hormones adjust muscle metabolism, energy production, and growth. In the nervous system, hormones affect neural metabolism, regulate fluid/electrolyte balance and help with reproductive hormones that influence central nervous system (CNS) development and behaviours. In the cardiovascular system hormones are needed in the regulation of RBC's production, and blood pressure. Hormones also have anti-inflammatory effects as well as stimulate the lymphatic system. In summary, the endocrine system has a regulatory effect on basically every other body systems.

Skeletal System

It consists of all bones in the body, cartilages and ligaments. The skeletal system serves as an important mineral reserve. For example, if blood levels of calcium or magnesium are low and the minerals are not available in the diet, they will be taken from the bones. On the other hand the skeletal system provides calcium needed for all muscle contractions. Lymphocytes and other cells relating to the immune response are produced and stored in the bone marrow. The skeletal system aids in protection of the nervous system, endocrine organs, chest and pelvic regions in which vital organs are housed.

Integumentary System

This system is composed of the skin that is the epidermis, dermis and adipose tissue, nails, hair, receptors, oil glands and sweat glands. The integumentary system is involved in protecting the body from invading microbes, regulating body temperature through sweating and vasodilation, or shivering and piloerection, and regulating ions balance in the blood. Stimulation of mast cells also produces changes in diameter of blood vessels and capillary permeability which can affect the blood flow in the body and how it is regulated. It also helps synthesise vitamin D which interacts with calcium and phosphorus absorption, a factor that is very important for bone growth and maintenance. Hair on the skin guards entrance into the nasal cavity or other orifices preventing invaders from getting further into the body. The skin also helps maintain balance by excretion of water and other solutes. The keratinised epidermis limits fluid loss through skin, thus providing mechanical protection against environmental hazards.

Lymphatic System

The lymphatic system is composed mainly of the lymphatic vessels, lymph nodes, thymus, spleen and the bone marrow. It has three principal roles. First is the maintenance of blood and other body fluid volumes. Excess fluid that leaves the capillaries when under pressure would build

up and cause edema, but for the role of the lymphatic system. Secondly, the lymphatic system absorbs fatty acids and triglycerides from fat digestion so that these components of digestion do not enter directly into the blood stream. Thirdly, the lymphatic system is involved in defending the body against invading microbes, and also in the immune response. This system assists in body maintenance such as bone and muscle repair after injuries. It also assists in maintaining the acid pH of urine required to fight infections in the urinary system. The tonsils are the body helpers that defend against infections and toxins absorbed from the digestive tract. The tonsils also protect against infections entering into the lungs.

Respiratory System

The components of the respiratory system are the nasal cavity, pharynx, larynx, glottis, epiglottis, bronchi, bronchioles, alveoli and the lungs. The respiratory system works in conjunction with the cardiovascular system to provide oxygen to cells within every body system for cellular metabolism. The respiratory system also removes carbon dioxide. Since CO_2 is mainly transported in the plasma as bicarbonate ions, which act as a chemical buffer, the respiratory system also helps maintain proper blood pH levels a fact that is very important for homeostasis. As a result of hyperventilation, the level of CO_2 is reduced. This causes the pH of body fluids to increase. If pH rises above 7.45, the results are respiratory alkalosis. On the other hand, too much CO_2 causes pH to fall below 7.35 which results in respiratory acidosis. The respiratory system also helps the lymphatic system by trapping pathogens and protecting deeper tissues from invading microorganisms.

Urinary System

Its main components are the kidneys, ureter, bladder and urethra. Toxic nitrogenous wastes accumulate as urea, uric acid and creatinine. The urinary system rids the body of these wastes. It is also involved in the maintenance of blood volume, blood pressure and electrolyte concentrations within the blood. The kidneys produce a hormone (erythropoietin) that stimulates red blood cell production. They also play an important role in maintaining the water content of the body and the level of salts in the extracellular fluid.

Cardiovascular System

It consists of the heart, blood vessels and the blood. The cardiovascular system ensures the normal functioning of other body systems by transporting hormones, oxygen and nutrients to them and taking away waste products from them thereby providing all living body cells with a fresh supply of oxygen and nutrients and also removing carbon dioxide and other toxic wastes from their surroundings. Homeostasis is disturbed if the cardiovascular or lymphatic systems are not functioning properly.

The cardiovascular system also contains sensors to monitor blood pressure. They are called baroreceptors. They detect the amount of stretch of the blood vessels and relay information via the nerves to the CNS which brings about the appropriate responses that regulate the blood pressure.

Muscular System
This system is made of skeletal muscles such as biceps, quadriceps, and gastrocnemius muscles and smooth or involuntary muscles such as cardiac muscle, intestinal muscles and muscles of the blood vessels. The muscular system is largely responsible for movement, posture, balance, gait, secretion by glands and maintenance of body temperature through heat production. It also contributes to blood glucose balance by storing glucose in form of glycogen. Muscles also aid in moving blood through veins, protect deep blood vessels and help the lymphatic system move lymph.

Digestive System
Its components include oral cavity, esophagus, stomach, intestines, liver and pancreas. The nutrients needed by the body are derived from the diet. Food is taken in by the mouth and broken down into its component parts by enzymes in the gastrointestinal tract (or gut). The digestive products are then absorbed into the blood across the wall of the intestine and pass to the liver via the portal vein. The digestive system absorbs organic substances, vitamins, ions, and water that are needed all over the body. The liver makes nutrients available to the tissues both for their growth and repair and for the production of energy.

Reproductive System
The main components of this system are the ovaries, testes, prostate, uterine tubes, uterus, vagina and penis. The reproductive system is responsible for the production of sperm cells and oval for the production of new offspring. The sex hormones do have various effects on other body systems, and an imbalance can lead to various disorders.

4.3 Feedback Control Systems

Negative Feedback Control
Negative feedback is the mechanism by which the body maintains conditions within particular limits. It is a control system that acts to maintain the level of some variable within a given range following a disturbance. Once equilibrium conditions are restored, the stimulus that activated the feedback loop is removed, so that the system ceases to function until an appropriate stimulus initiates the feedback process again; that is, negative feedback systems in the body normally are

reversible and they come into play on demand. The component of a simple negative feedback loop include (i) a regulated variable, (ii) sensor (or detector), (iii) controller (comparator), and (iv) effector. Each component controls the next component to it (Figure 1.1).

Various disturbances may arise within or outside the internal environment and caused undesirable changes in the regulated variable. The regulated variable is sensed by sensor, information about its level is fed back to a controller (comparator), which compares it to a desired value (set point). If there is a difference, signal is generated, which drives the effector to oppose the changes and bring the regulated variable closer to the desire

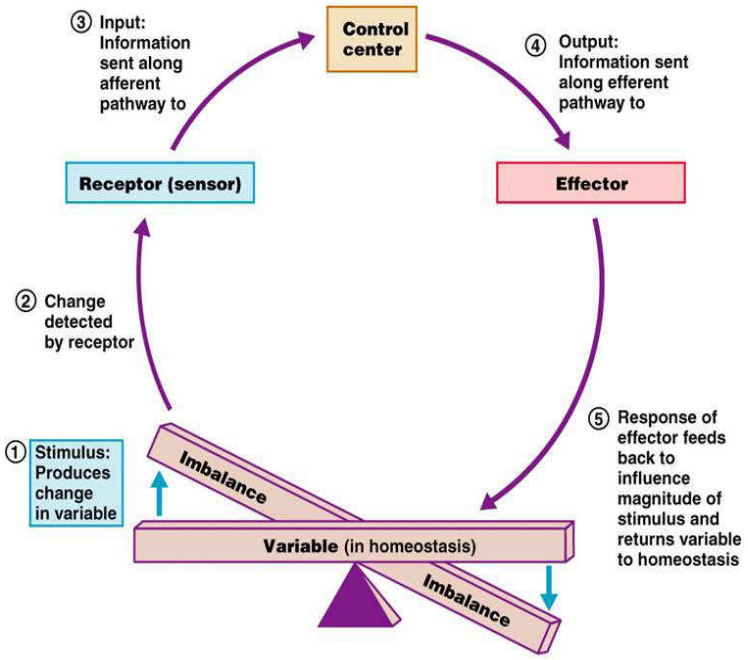

Fig. 4.1: Component of a Simple Negative Feedback Loop

A familiar example of a negative feedback control is the thermostatic control of room temperature. Room temperature (regulated variable) is subject to disturbance; on a cold day, room temperature falls. The room temperature is detected by a thermometer (sensor) in the thermostat (controller). The thermostat is set for a certain temperature (set point). The controller compares the actual temperature (feedback signal) to the set point temperature and signal is generated if the former falls below the latter. The signal activates the furnace (effector). The resulting change in temperature is monitored by the controller, and when temperature rises sufficiently the furnace is turned off. Such a negative feedback system allows some fluctuation in room temperature. Effective

communication between the sensor and effector is important in keeping these oscillations to a minimum.

Similar negative feedback systems maintain homeostasis in the body. One example is in arterial blood pressure regulation illustrated in Figure 1.2. These system sensors (arterial baroreceptors) are located in the carotid sinuses and aortic arch. Changes in stretch of the walls of the carotid sinus and aorta, which follow from changes in blood pressure, stimulate these sensors. Afferent nerve fibers transmit impulses to control centers in the medulla oblongata. Efferent nerve fibers send impulses from the medullar centre to the systems effectors, the heart and blood vessels. The output of blood by the heart and resistance to blood flow are altered in an appropriate direction to maintain blood pressure, as measured at the sensors within a given range values.

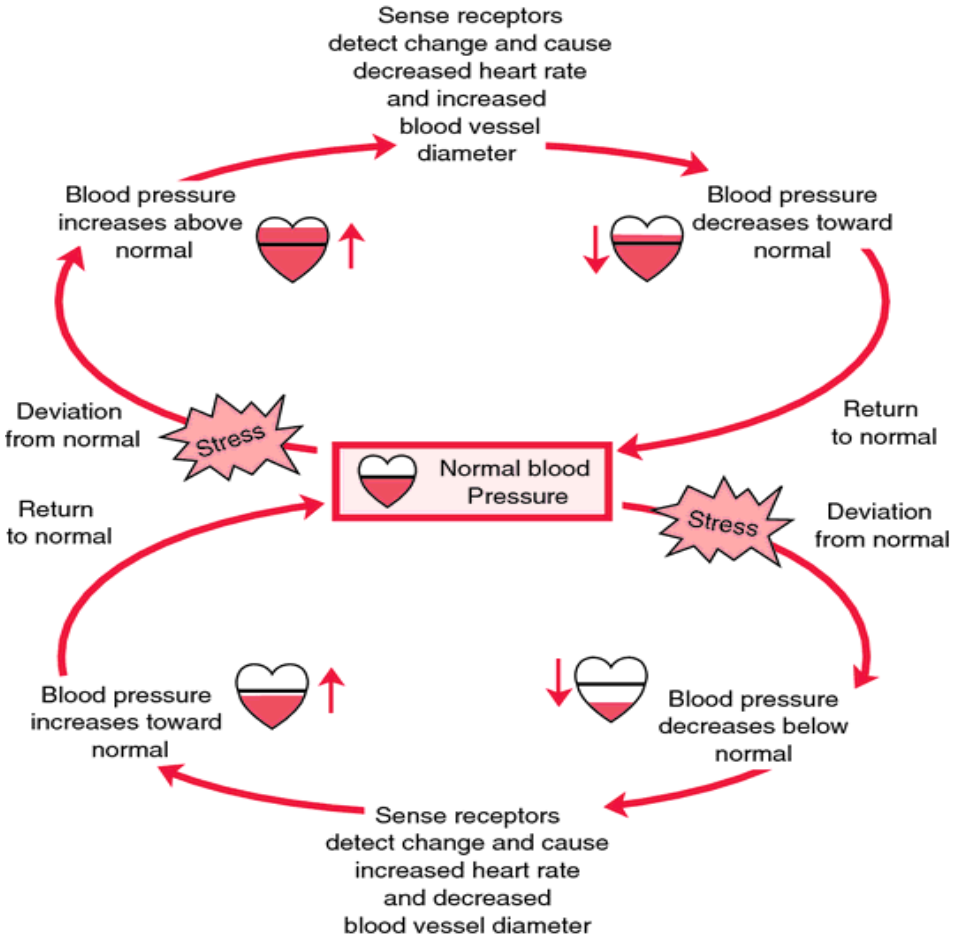

Fig. 4.2: Regulation of Arterial Blood Pressure

The control of testosterone secretion, control of calcium ions level in the blood, control of blood glucose by insulin and glucagon, control of

cortisol secretion by the adrenal cortex are other examples of the operation of such mechanisms.

Positive Feedback Control

Positive feedback is a self-amplifying cycle in which a physiological change leads to even greater changes in the same direction, rather than producing the corrective effects of negative feedback. Positive feedback promotes rapid change and it is often a normal way of producing rapid progressive change in one direction. For example, when a woman is giving birth, the head of the baby pushes against her cervix and stimulates nerve endings there. Nerve signals are sent to the brain, which, in turn, stimulates the pituitary gland to secrete the hormone oxytocin. Oxytocin travels in the blood and stimulates the uterus to contract. This pushes the baby downward, stimulating the cervix the more and causing the positive feedback loop to be repeated. Labor contractions therefore become more and more intense until the baby is expelled.

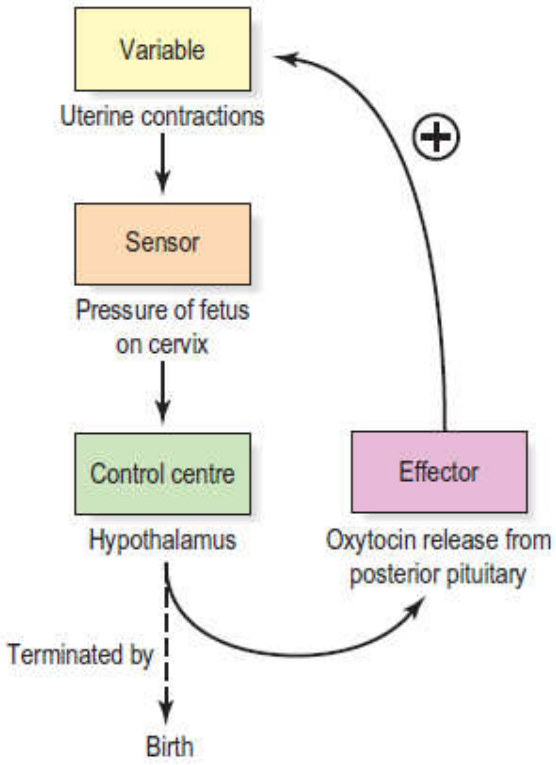

Fig. 4.3: Control of Childbirth by Positive Feedback Mechanism

It should be noted however that the overall process of childbirth is a negative feedback loop- it is a response to pregnancy that terminates the pregnancy. But within this negative feedback loop, there is a smaller positive feedback loop that has just been described. Beneficial positive

feedback loops are often part of larger negative feedback loops. Other examples of beneficial positive feedback includes: generation of nerve signals, blood clotting and the stomach digestion of protein. Frequently, however, positive feedback is a harmful and even life- threatening process. This is because its self-amplifying nature can quickly change the internal state of the body to something far from its homeostatic set point. Consider a high fever, for example. A fever triggered by infection is beneficial up to a point, but if the body temperature raises much above 42^{o}C, it may create a dangerous positive feedback loop. This high temperature raises the metabolic rate, which makes the body to produce heat faster than it gets rid of it. Thus temperature rises still further, increasing the metabolic rate and heat production still more. This "vicious circle" becomes fatal at approximately 45^{o}c such temperature are so high that they destroy the proteins that cells need to function. Convulsion and coma are some outward signs of this damage. Thus positive feedback loops often create dangerously out of control situations that require emergency medical treatment.

Feed Forward Control

Feed forward control is another strategy used to control systems in the body, particularly when a change with time is desired. It is anticipatory in nature. A feed forward controller generates commands without directly sensing the regulated variable. These commands specify the target or goals. Feed forward control often senses a disturbance and can therefore take corrective action that anticipates change. It often operates through the feedback controllers. The moment-to-moment operation of the feed forward controller is "open loop" (unlike closed loop in negative feedback) because the regulated variable itself is not sensed by sensor. Examples include increased heart rate and breathing rate even before a person has begun to exercise, flight reactions and others.

SAE

i. Define homeostasis, and identify the components of negative feedback loops.
ii. How do negative and positive feedbacks help to maintain the body homeostasis? Illustrate these with drawing and labeling of examples of negative and positive feedback?
iii. What is homeostatic imbalance? Write on two examples of how this contributes to illness?

4.0 CONCLUSION

The principle of homeostasis allows the body to maintain a state of balance. All the systems are involved in the complicated process of maintaining constancy. Homeostatic control is achieved within a

complex process involving the receptor, the control centre and the effector. Homeostatic imbalance results to diseases.

5.0 SUMMARY

In this unit, you have learnt that:

i. Homeostasis as the ability of the body to maintain relatively stable internal conditions even when the outside environment changes on a continuous basis.
ii. All the body systems are involved in the process of attainment of homeostasis.
iii. The body uses negative and positive feedbacks and the feed forward control of regulating homeostatic processes in the body.

6.0 TUTOR- MARKED ASSIGNMENT

Activity

Watch this video clips:

https://www.youtube.com/watch?v=XZxuQo3ylII
https://www.youtube.com/watch?v=IoU3lKrOYMY
Explore the use of thirst and sweat in achieving body's homeostasis, Explore other 5 other actions of the body that contribute to the maintenance of the body and how you can use them as guides in providing nursing care. Submit your findings to the tutor 2 weeks after the completion of this unit.

7.0 REFERENCES/ FURTHER READING

Fox, S.I. (2012). *Human Physiology.* (12th ed.). New York: Mc Graw Hill.

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John Campbell Homeostasis 1 https ://www. youtube. com/ watch? v=5HS66q OA8g accessed on June 30 2015.

John Campbell Homeostasis 2 https://www.youtube. com/ watch? v=IoU3lKrOYMY accessed on June 30, 2015.

UNIT 5 NERVE AND MUSCLE PHYSIOLOGY

CONTENTS

1.0 INTRODUCTION

We respond to our living environment through our senses. We are only able to do this because we have a master controlling and communicating systems, the nervous system. In this unit, you are going to learn more about the typical nerve cell and how the nerve cells perform their functions. You are also going to learn about how the nerve cells enables the body to engage in coordinated movement as it facilitates muscle contractions.

2.0 OBJECTIVES

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

- discuss the structure and functions of a typical nerve cell
- explain the functional unit of the muscle
- discuss the mechanisms involved in muscle contraction.

3.0 MAIN CONTENT

3.1 Nerves and the Functions

Nerves/Neurons are the basic structural and functional units of the nervous system. They are specialised to respond to physical and chemical stimuli, conduct electrochemical impulses, and release chemical regulators. Through these activities, neurons enable the perception of sensory stimuli, learning, memory, and the control of muscles and glands. Neurons have three principal regions: cell body, dendrites, and axon. They vary considerably in size and shape.

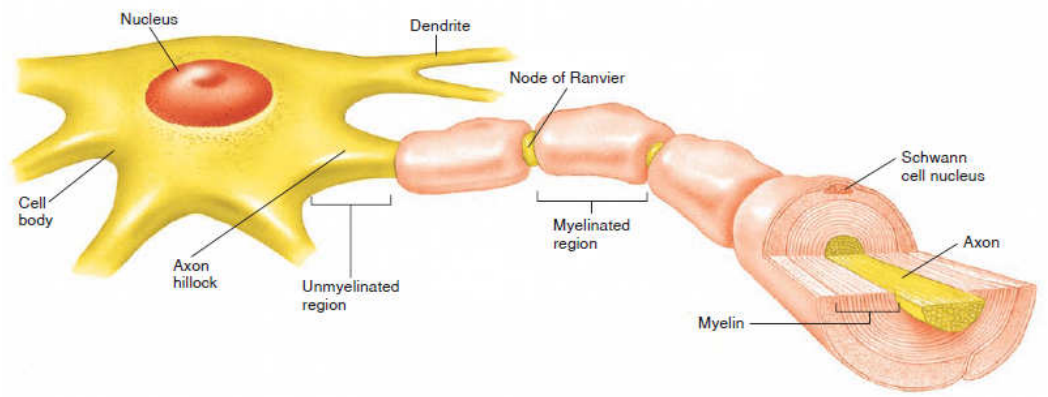

Fig. 5.1: Parts of a Neuron (Myelinated)

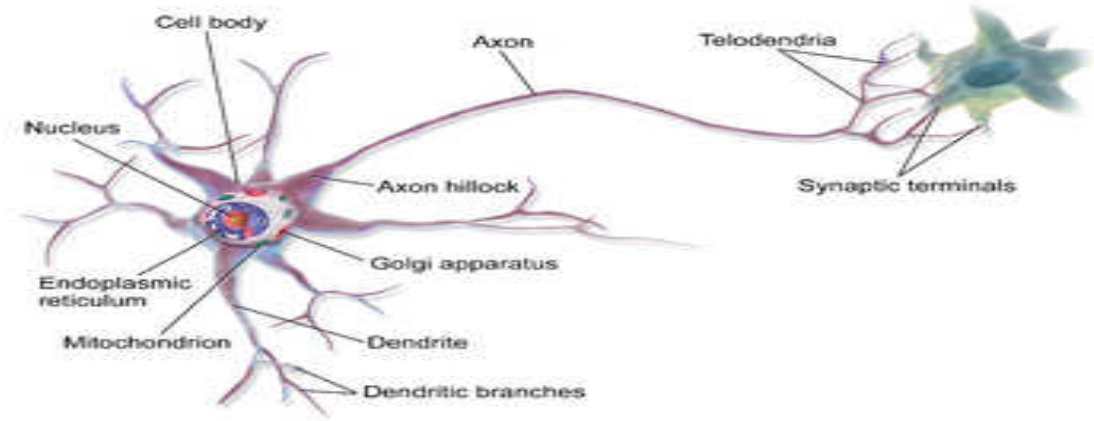

Fig. 5.2: Parts of a Neuron (Unmyelinated)

The cell body (Soma) is the enlarged portion of the neuron that contains the nucleus. Dendrites are thin, branched processes that extend from the cytoplasm of the cell body. Dendrites provide a receptive area that transmits graded electrochemical impulses to the cell body. The axon is a longer process that conducts impulses, called action potentials, away from the cell body. The origin of the axon near the cell body is an expanded region called the axon hillock; it is here that action potentials originate. Side branches called axon collaterals may extend from the axon.

The axon at its end is divided into terminal branches. Each terminal branch ends in synaptic knobs or terminal buttons. The axon of a neuron can either be myelinated or unmyelinated. The myelinated neuron is wrapped by Schwann cells, which form a myelin sheath (Figs 2-1 and 2-2). The myelin sheath envelops the axon except at the terminal endings and at the Nodes of Ranvier.

3.1.1 Resting and Action Membrane Potential

Resting Membrane Potential
When the cell is not transmitting an impulse, the trans-membrane potential is called the resting membrane potential (RMP). Also the RMP can be defined as the inside negative potential across the membrane of cells. A resting membrane potential is due to uneven distribution of ions between the inside and the outside of the membrane.

The following phenomena are involved in establishing the cell potential.

i. By means of active transport: sodium is actively pumped out of the cell and potassium is pumped into it. So the K^+ concentration in the cell is twenty times the concentration in the extracellular fluid.
ii. The membrane at rest is far more permeable to K^+ than Na^+. K^+ ions diffuse out of the cell with far greater ease than Na^+ diffuse into the cell.
iii. The interior of the cell contains a high concentration of non-diffusible ions. Of particular importance in this regard are proteins, organic phosphates and organic sulphate anions. Since the resting membrane is much more permeable to K^+ than to Na^+, the RMP is much closer to the K equilibrium potential than that of Na^+.

The chief determinants of the movement of substances across the cell membrane are the membrane permeability, electrical as well as chemical gradients of the ions. When the chemical and electrical forces acting on ions are equal and opposite there is no net flux and the system is in equilibrium.

Action Potential
This is the voltage of the cell membrane when the cell membrane is stimulated or activated. It can also be defined as the potential generated when excitable tissue (nerve and muscle) are stimulated resulting in the propagation of an impulse. The components of the action potential are: latent period, depolarisation, repolarisation and hyperpolarisation. (Figure 2-3).

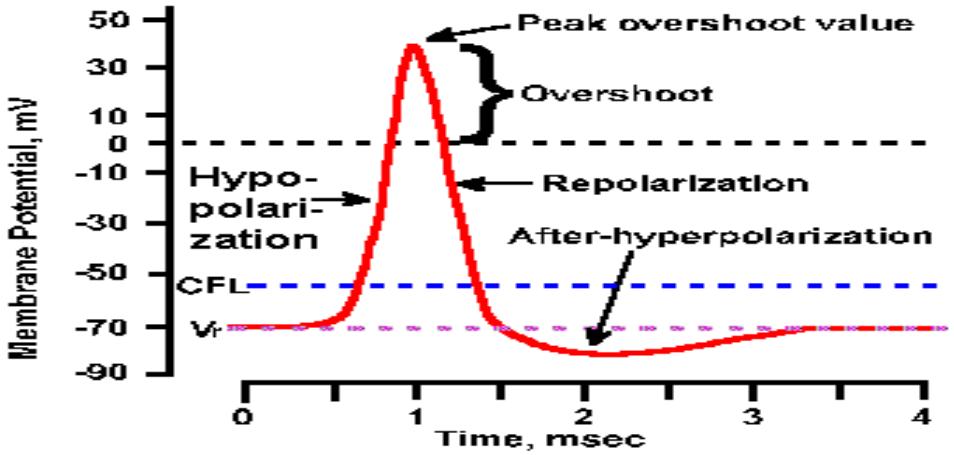

Fig. 5.3: Phases of Action Potential

When a stimulus is applied to an axon, there is a brief irregular deflection of the baseline, called stimulus artifact. The stimulus artifact is followed by isopotential interval (latent period) that ends with the start of action potential and corresponds to the time it takes the impulse to travel along the axon from the site of stimulation to the recording electrodes.

Depolarisation Stage

At this time, the membrane suddenly becomes very permeable to sodium ions, allowing tremendous numbers of positively charged sodium ions to diffuse to the interior of the axon. The normal "polarised" state of –90 millivolts is immediately neutralized by the inflowing positively charged sodium ions, with the potential rising rapidly in the positive direction. This is called depolarisation. In large nerve fibers, the great excess of positive sodium ions moving to the inside causes the membrane potential to actually "overshoot" beyond the zero level and to become somewhat positive. In some smaller fibers, as well as in many central nervous system neurons, the potential merely approaches the zero level and does not overshoot to the positive state.

Repolarisation Stage

Within a few milliseconds after the membrane becomes highly permeable to sodium ions, the sodium channels begin to close and the potassium channels open more than normal. Then, rapid diffusion of potassium ions to the exterior re-establishes the normal negative resting membrane potential. This is called repolarisation of the membrane.

The sharp rise and the rapid fall are the spike potential of the axon, and the slower fall at the end of the process is the after-depolarisation.

After the action potential, during the recovery period, Na^+ that came in during depolarisation and the K^+ that went out during repolarisation are

brought back to their original positions. Since this means moving sodium against its concentration gradient (i.e. from in to out) and vice-versa for K^+, the process involves active transport requiring energy.

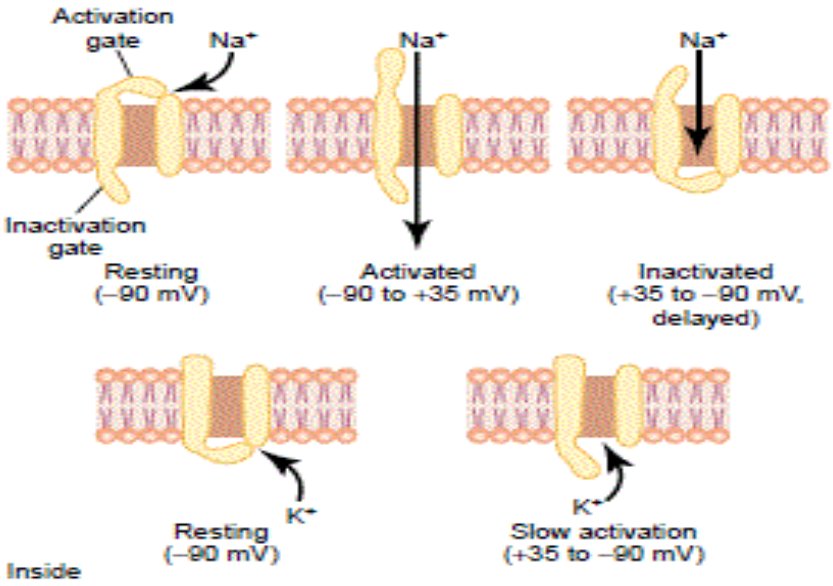

Fig. 5.4: Characteristics of the Voltage-Gated Sodium and Potassium Channels

Changes in Excitability during Action Potential

The refractory period is divided into an absolute refractory period, which corresponds to the period from the time the firing level is reached until repolarisation is about 1/3 complete, and a relative refractory period, lasting from this point to the start of after-depolarisation. During the absolute refractory period, no stimulus, no matter how strong will excite the nerve, but during the relative refractive period, stronger than normal stimuli can cause excitation. During after-depolarisation, the threshold is again decreased and during after-hyperpolarisation it is increased.

All-or-Nothing Principle

Once an action potential has been elicited at any point on the membrane of a normal fiber, the depolarisation process travels over the entire membrane if conditions are right, or it does not travel at all if conditions are not right. This is called the all-or-nothing principle, and it applies to all normal excitable tissues.

3.1.2 Conduction of Impulse along Nerve Fibers

Non-Myelinated Nerve

The nerve cell membrane is polarised at rest, positive charges lined up along the outside of the membrane and negative charges along the inside of the membrane. During the action potential (AP), this polarity is abolished and for a period is actually reversed. Positive charges from the membrane ahead of the AP and behind the AP flowing into the area of negativity represented by the AP it's called the current sink. By drawing off positive charges, this flow decreases the polarity of the membrane ahead of the AP. This type of electrotonic depolarisation initiates a local response, and when the firing level is reached, a propagated response occurs that in turn electrotonically depolarises the membrane in front of it. This sequence of event moves regularly along an unmyelinated axon to its end. Thus, the self-propagating nature of the nerve impulse is due to circular current flow and successive electrotonic depolarisation to the firing level of the membrane ahead of the action potential.

Myelinated Nerve

Conduction in myelinated axons depends upon a similar pattern of circular current flow. However, myelin is an effective insulator and current flow through it is negligible. Instead, depolarisation in myelinated axons jumps from one node of Ranvier to the next, the "current sink" at the active node serving to electrotonically depolarise to the firing level the node ahead of the AP. This jumping of depolarisation from node to node is called saltatory conduction, as shown in Figure 2-5. It is a rapid process, and myelinated axon conducts up to 50 times faster than the fastest unmyelinated fibers.

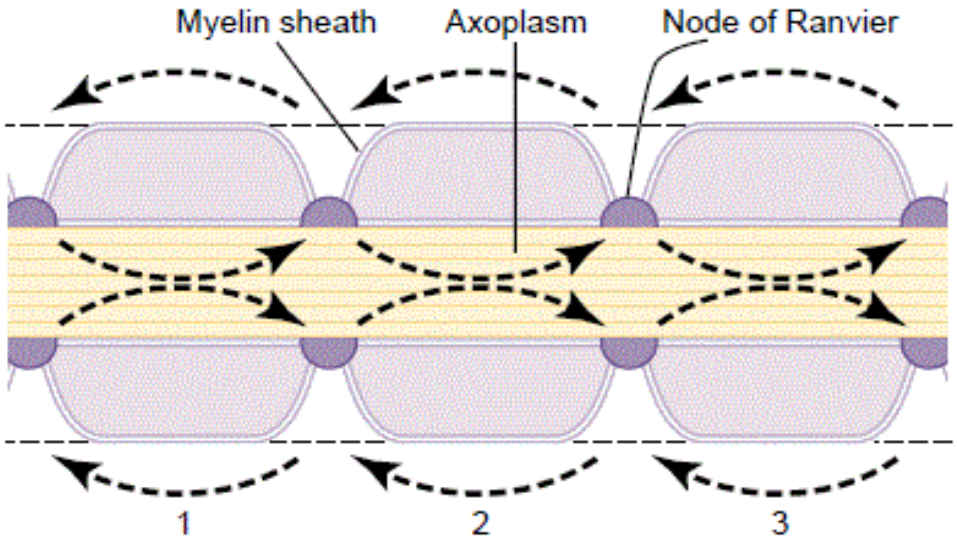

Fig. 5.5: Saltatory Conduction along a Myelinated Axon. Flow of Electrical Current from Node to Node is Illustrated by the Arrows

Neuromuscular Transmission

As the axon supplying the skeletal muscle fiber approaches its termination, it loses its myelin sheath and divides into a number of terminal buttons or end-feet. The end-feet contain many small, clear vesicles that contain acetylcholine, which is the transmitter at this junction. The endings fit into depressions in the motor end plate – which is the thickened portion of the muscle membrane of the junctions. The depression is called the synaptic gutter or synaptic trough, and the space between the terminal and the end plate is called the synaptic cleft or space.

At the bottom of the gutter are numerous smaller folds of the muscle membrane of the end plate called sub-neural clefts or functional folds, which greatly increase the surface area which the synaptic transmitter can act. The whole structure is known as the neuromuscular or myoneural junction (Figure 2.6).

In the axon terminal are many mitochondria that supply ATP, the energy source that is used mainly for synthesis of the excitatory transmitter called acetylcholine. The acetylcholine in turn excites muscle fiber membrane. Acetylcholine is synthesised in the cytoplasm of the terminal button, but it is absorbed rapidly into many small synaptic vesicles. In the synaptic space, a large quantity of the enzyme acetyl cholinesterase, which is capable of destroying acetylcholine after it has been released from the synaptic vesicles are present.

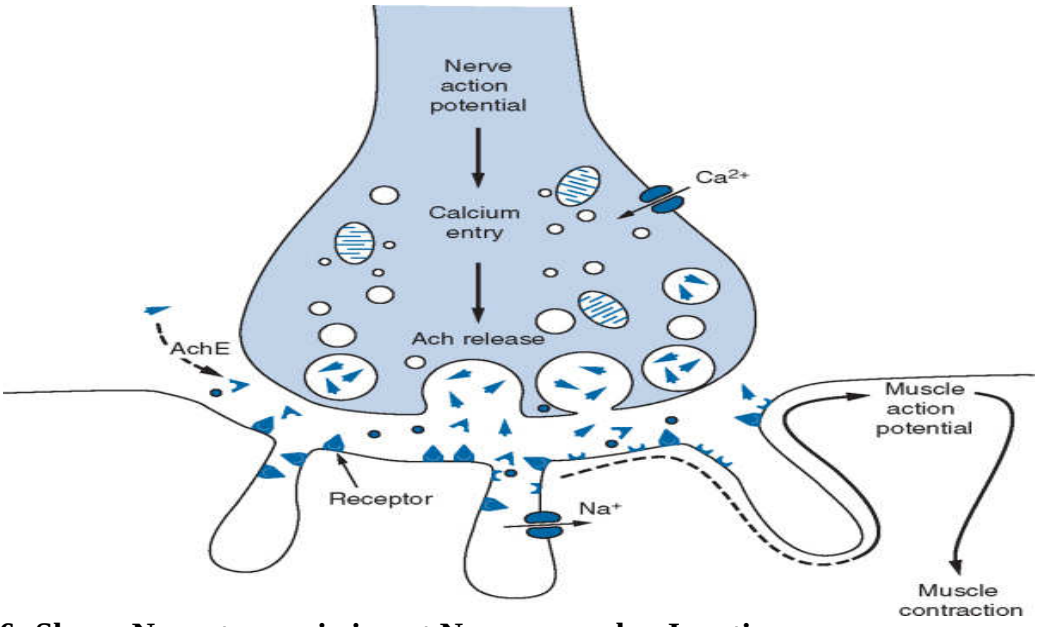

Fig. 5.6: Shows Neurotransmission at Neuromuscular Junction

3.2 Muscle Contraction

Three types of muscle cells can be identified on the basis of structure and contractile properties: (i) Skeletal muscle (ii) Smooth muscle (iii) Cardiac muscle

Most skeletal muscles as the name implies are attached to bones and their contraction is responsible for the movement of parts of the skeleton. Contraction of the skeletal muscle is controlled by the somatic nervous system and hence is under voluntary control. The movements produced by skeletal muscles are primarily involved with interactions between the body and external environment. Smooth muscles surround hollow organs and tubes-like stomach, intestinal tract, urinary bladder, uterus, blood vessels and air passages to the lungs. It is also found as single cells distributed throughout the organs (spleen) and the small group of cells attached to the hairs in the skin. The contraction of the smooth muscle may either propel the luminal content out of or through the hollow organs or it may regulate the flow of the contents through tubes by changing their diameters without itself initiating propulsion. Smooth muscle contraction is controlled by factors intrinsic to the muscle itself by the autonomic nervous system (ANS) and by hormones. Therefore, it is not normally under direct conscious control.

The third type of muscle; cardiac muscle is the muscle of the heart and its contraction propels blood through the circulatory system. Like smooth muscle, it is regulated by intrinsic factors and by ANS and hormones.

Skeletal Muscle

Figure 2-7 shows the organisation of skeletal muscle. Each skeletal muscle fiber is a cylinder with diameter of 10-100μm and length which may extend up to 300,000μm (1 foot). The term skeletal muscle refers to a number of muscle fibers bond together by connective tissue. From the light microscope, the most striking picture is series of transverse light and dark bands forming a regular pattern along each fiber. Most skeletal and cardiac muscle fibers have these characteristics banding and are known as striated muscles. Smooth muscle cells show no binding patterns. Although the pattern appears to be continuous across the entire cytoplasm of a single fiber, the bands are actually confined to a number of independent cylindrical elements, known as myofibrils. Each myofibril is about 1 to 2 micron (μm) in diameter and continues throughout the length of the muscle fiber. Myofibrils occupy about 80% of the fiber volume and vary in number from several hundred to several thousand per single fiber, depending on the fiber diameter.

The myofibrils consist of smaller filaments which are arranged in a repeating pattern along the length of the fibril. One unit of this repeating pattern is known as a sarcomere (little muscle), which is the functional unit of the contractile system in striated muscles. Each sarcomere contains two types of filaments: Thick filament composed of the contractile protein called myosin and thin filaments containing the contractile protein components; (i) Actin (ii) Tropomyosin (iii) Troponin.

Troponin is made up of three subunits: (i) Troponin I (ii) Troponin T (iii) Troponin C.

The thick filaments, 12-18nm in diameter are located in the central region of the sarcomere, where their orderly parallel arrangements gives rise to the dark bands known as A-bands, because they are anisotropic to polarised light. Thin filaments, 5-8nm in diameter are attached at either end of a sarcomere to a structure known as Z-line. Two successive Z-lines define the limits of the sarcomere. Z-lines are short fibrous structures, which interconnect the thin filaments from two adjoining sarcomeres thus, provide an anchoring point for the thin filaments, which extends from the Z-lines towards the centre of the sarcomere where they overlap with the thick filament.

Between the ends of the dark A-bands of two adjacent sarcomeres is the I-band (because it is isotropic to polarised light) forming the lighter region of the striated pattern.

One additional band called the H-zone appears as a thin lighter band in the centre of the A-band. It corresponds to the space between the ends of the thin filament. Thus, only thick filaments are found in the H-zone. Finally, a thin dark band can be seen in the center of the H-zone. This is known as the M-line and is produced by linkages between the thick filaments. The M-line by cross linking the thick-filaments keeps all these in a single sarcomere in parallel alignments. Thus, neither the thin nor thick filaments are free floating, each is linked either to Z-lines in the case of the thin filaments or to M-lines in the case of the thick filaments.

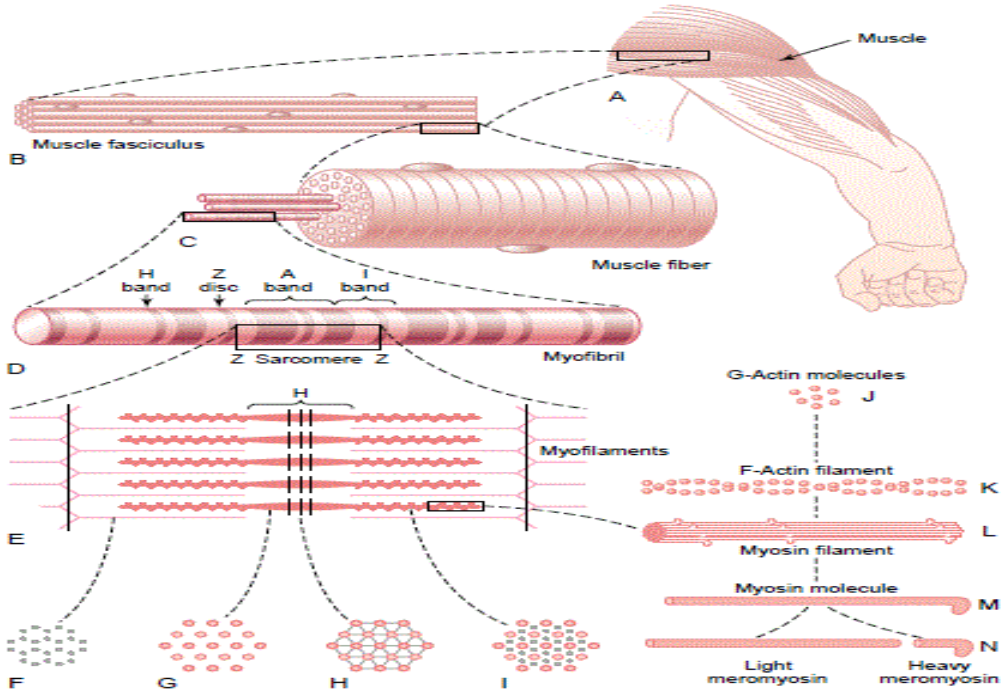

Fig. 5.7: Organisation of skeletal muscle from the gross to the molecular level

Smooth Muscle

Smooth muscles are distinguished anatomically from skeletal and cardiac muscles, because they lack physical cross striations. Actin and myosin are present and they slide on each other to produce contraction. However, they are not arranged in regular arrays as in skeletal muscle and cardiac muscles, and so the striations are absent. Instead of Z-lines, there are dense bodies in the cytoplasm attached to the cell membrane and these are bound by α – actinin to actin filament. Smooth muscles also contain tropomyosin, but troponin appears to be absent.

Smooth muscles can be generally divided into two major types, which are shown in Figure 2-8: multiunit smooth muscle and single unit or visceral muscle.

Multiunit Smooth Muscle

This type of smooth muscle is composed of discrete smooth muscle fibers. Each fiber operates entirely independently of the other fibers and is often innervated by a single nerve ending as occurred for skeletal muscle. Furthermore, the outer surfaces of these fibers, like those of skeletal muscle fibers are covered by a thin layer of glycoprotein that helps to insulate the separate fibers from each other. The most important characteristics of multi-unit smooth muscle fibers is that their control is exerted almost entirely by nerve fibers and very little by other stimuli, like local tissue factors. This is in contrast to a major share of the control of visceral smooth muscle by non-nervous stimuli. Some examples of multi-unit smooth muscle found in the body are smooth muscle fiber of the ciliary muscle of the eye, the iris of the eye, the nictitating membrane that covers the eye of some lower animals, the pilo-erector muscles that cause erection of the hairs when stimulated by the sympathetic nervous system and the smooth muscle of many of the larger blood vessels.

Visceral Smooth Muscle (Single unit)

Their fibers are similar to multi-unit fibers except that they are regularly or usually arranged in sheet or bundles and the cell membrane contact each other at multiple points to form many gap junctions. Thus, the fibers form a functional syncytium that usually contract large area at once. For this reason, this type of smooth muscle is also known as single unit or unitary smooth muscle. This type of muscle is found in most of the organs in the body, especially in the walls of the gut, the bile duct, ureters, uterus, etc.

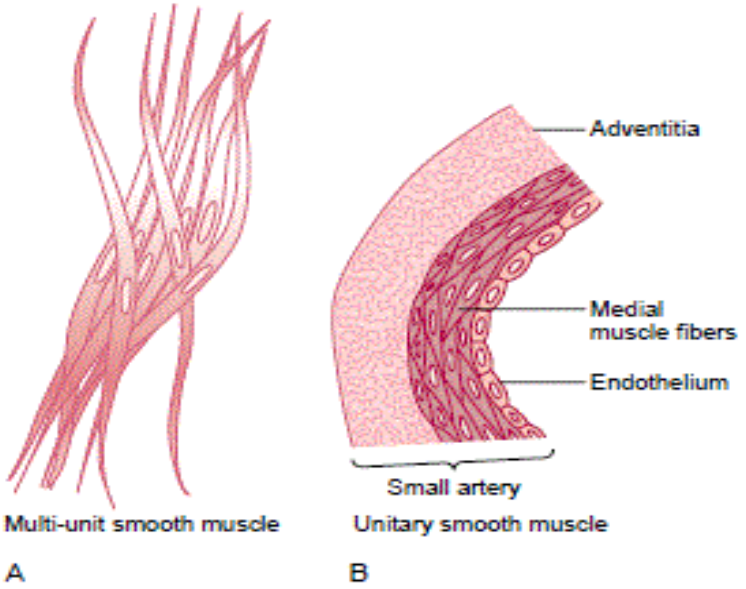

Fig. 5.8: Multi-Unit (A) and Unitary (B) Smooth Muscle

Cardiac Muscle

Striations in cardiac muscle are similar to those in skeletal muscle. There are large numbers of elongated mitochondria in close contacts to the muscle myofibrils and the muscle fibers branch and interdigitate. But each is a complete unit surrounded by a cell membrane. When the end of one muscle fiber joins on another, the membranes of both fibers parallel each other through an extensive series of folds. These areas which always occur as Z-lines and are called intercalated discs. They provide a strong union between fibers, maintaining cell-cell cohesion, so that the pull of one contractile unit can be transmitted along its axis to the next. Along the site of the muscle fibers next to the disks, the cell membranes of adjacent fibers fuse for considerable distances forming gap junctions. These junctions provide low-resistance bridges for the spread of excitation from one fiber to another.

Contractile Proteins

These are proteins which participate in the contractile processes. They include muscle proteins as well as those found in other cells and tissues. In the cells and tissues, these proteins participate in localised contractile events in the cytoplasm, in motile activity, and in cell aggregation phenomena. The two types of c*ontractile proteins* that are found within muscles are actin and myosin. Both proteins are responsible for muscle movement. The heads and necks of the myosin molecules forms cross-links to actin.

Excitation-Contraction Coupling

These are the events occurring between the excitation of a muscle fiber and the resulting contraction. The skeletal muscle fiber is so large that action potential (AP) spreads in along the surface membrane and causes almost no current flow deep within the fiber. However, to cause muscle contraction, this electrical current must penetrate deeply into the muscle fiber to the vicinity of all the separate myofibrils. This is achieved by transmission of APs along transverse tubules (T-tubules) that penetrate all the way through the muscle fiber from one side to the other. T-tubules action potential in turn causes release of Ca^{2+} in the immediate vicinity of all the myofibrils. This Ca^{2+} then causes contraction. This overall process is called excitation contraction- coupling (Figure 2-9).

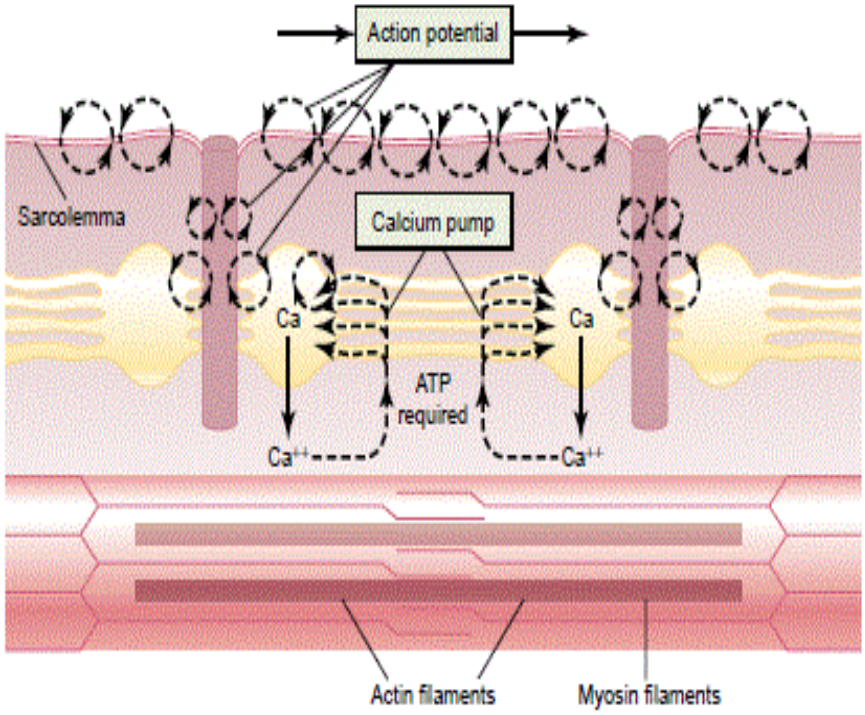

Fig. 5.9: Excitation-Contraction Coupling in the Muscle

Molecular Basis of Contraction

Figure 2.10 demonstrates the basic mechanism of muscle contraction. This is the process by which the shortening of the contractile elements in muscle is brought about by sliding of the thin filaments over the thick filaments. The width of the A-bands is constant, whereas the Z-lines move closer when contracts muscle and far apart when it is stretched (sliding filament mechanism).

Sliding during muscle contraction occurs when the myosin heads bind firmly to actin, bend at the junction of the head with the neck and then detach. “This power stroke” depends on the simultaneous hydrolysis of ATP.

Calcium ions initiate contraction by binding troponin C. In resting muscle, troponin I is tightly bound to actin and the tropomyosin covers the site, where myosin heads bind to actin. Thus, the troponin-tropomyosin complex constitutes a relaxing protein that inhibits the interaction between actin and myosin. When the Ca^{2+} is released from the terminal cisterna by the AP, it binds to troponin C, the binding of troponin I to actin is presumably weakened and this permits the tropomyosin to move laterally. This movement uncovers the active site of myosin heads. Adenosine triphosphate (ATP) is then split and contractions occur.

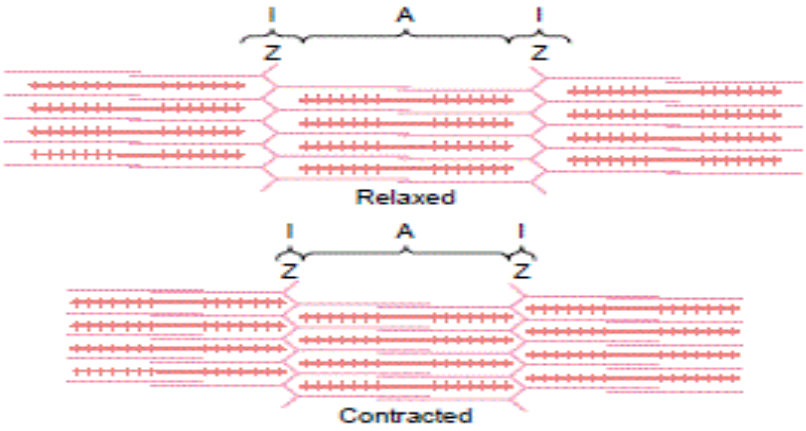

Fig. 5.10: Relaxed and Contracted States of a Myofibril Showing (top) Sliding of the Actin Filaments (Pink) into the Spaces between the Myosin Filaments (Red), and (Bottom) Pulling of The Z Membranes toward each Other

SAE

1. Discuss the structure and functions of a typical nerve cell.
2. Explain the functional unit of the muscle
3. Discuss the mechanisms involved in muscle contraction.

4.0 CONCLUSION

Nerve cells help the body to respond to various stimuli through the mediating effect of sodium, potassium and calcium ions. The three main muscle types are distinguishable by their structure and mode of contractions.

5.0 SUMMARY

In this unit, you have learnt about the following:

a. The structure and functions of a typical nerve cell.
b. The functional unit of the muscle
c. The various mechanisms involved in muscle contraction.

6.0 TUTOR MARKED ASSIGNMENT

Activity

As prescribed in the laboratory practical to be conducted by the Facilitator.

7.0 REFERENCES/ FURTHER READING

Fox, S.I. (2012). *Human Physiology.* (12th ed.). New York: Mc Graw Hill.

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MODULE 3 RESPIRATORY PHYSIOLOGY

Unit 1 Components, Muscles of Respiration and Mechanism of Breathing
Unit 2 Surfactant and Compliance of the Lungs, the Dead Space, Lung Volumes And Capacity
Unit 3 Transport and Exchange of Gases, Oxygen, Carbon Dioxide and The Oxygen – Haemoglobin Dissociation Curve
Unit 4 Control of Respiration and Respiratory Adaptations in Unusual Environment

UNIT 1 COMPONENTS, MUSCLES OF RESPIRATION AND MECHANISM OF BREATHING

CONTENTS

1.0 INTRODUCTION

A person is alive when he or she demonstrates the act of respiration. Several processes are involved in the exchange of gases at different levels of the organs involving diverse structures. Effective functioning of the organs of respiration, especially the lungs are measurable and this module provides you with the information about how the lungs perform the functions of gaseous exchange.

2.0 OBJECTIVES

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

- explain the component parts of the respiratory system
- explain the composition of the categories of muscles involved in respiration
- describe the mechanism of respiration.

3.0 MAIN CONTENT

3.1 Respiration

Respiration has two major components namely (a) the transport of oxygen from the outside air to the cells within tissues, and the transport of carbon dioxide from the cells to the outside air and (b) the utilisation of oxygen within the body cells for the liberation of energy from food substances. The former is known as external respiration or gaseous exchange while the latter is called internal or tissue respiration. The respiratory system functions in close collaboration with the circulatory system which acts as the transport system that conveys oxygen from the respiratory apparatus to the tissues and carbon-dioxide from the tissues to the respiratory apparatus for expulsion from the body. The respiratory system is thus an “air pump” while the cardiovascular system is a “blood pump”. This unit covers the n

3.1.1 The Pulmonary Circulation

Venous blood from tissues of the body is returned to the right atrium of the heart. From here, the blood enters the right ventricle. The right ventricle pumps the blood out of the heart through the pulmonary artery. The pulmonary arterial trunk divides into the right and left pulmonary arteries and these supply blood to the right and left lungs respectively. The pulmonary arteries divide several times just like the trachea until the pulmonary capillaries are formed. The pulmonary circulation is a low pressure circulation. Blood is pumped out of the right ventricle at a pressure of 25/0 mmHg. By the time blood reaches the pulmonary capillaries, the pressure has fallen to an average of 10mmHg. Since the plasma oncoti pressure is 25mmHg, no fluid moves out of the pulmonary capillaries into the interstitial space. This is important because if fluid moves out of the arterial end of the pulmonary capillaries as it does in the systemic circulation, then, the small diameter air sacs (alveoli) can become “flooded’’ with tissue fluid and this will adversely affect the transport of gases in the lungs. The blood pumped into the pulmonary circulation at rest is 5L/min, the same as that

pumped out of the left side of the heart per minute at rest. Blood from the pulmonary capillaries is returned to the left atrium of the heart through the pulmonary vein. The pulmonary artery carries deoxygenated blood while the pulmonary vein carries oxygenated blood.

About 2% of the blood flow to the lungs is through the bronchial arteries and veins. The left bronchial artery arises directly from the aorta while the right bronchial artery arises from the first right intercostal artery. The bronchial arteries run along the bronchi and follow them into the lung. They supply the air passages, their glands and sub pleural connective tissue. The bronchial veins, which carry deoxygenated blood join the pulmonary vein so that the latter which was 100% saturated with oxygen in the lungs is diluted by the addition of venous blood from the bronchial veins. The oxygen in the blood that is delivered to the left atrium is therefore about 97%. This mixing of deoxygenated bronchial venous blood with oxygenated pulmonary venous blood is called physiological shunting.

3.1.2 Capillary/alveolar membrane

The capillary/alveolar membrane (Figure 2-2) is very thin and this makes it easy for gases to diffuse across the membrane. The large surface area of the alveoli is matched by an even larger surface area presented by the capillaries. Since the capillaries are 10 micrometer in diameter and the red blood cells are 7.2 micrometer in their larger diameter, many of the red blood cells will cross the pulmonary capillaries in a "queue'' of single cells. This also exposes a large surface area of RBC for gaseous exchange.

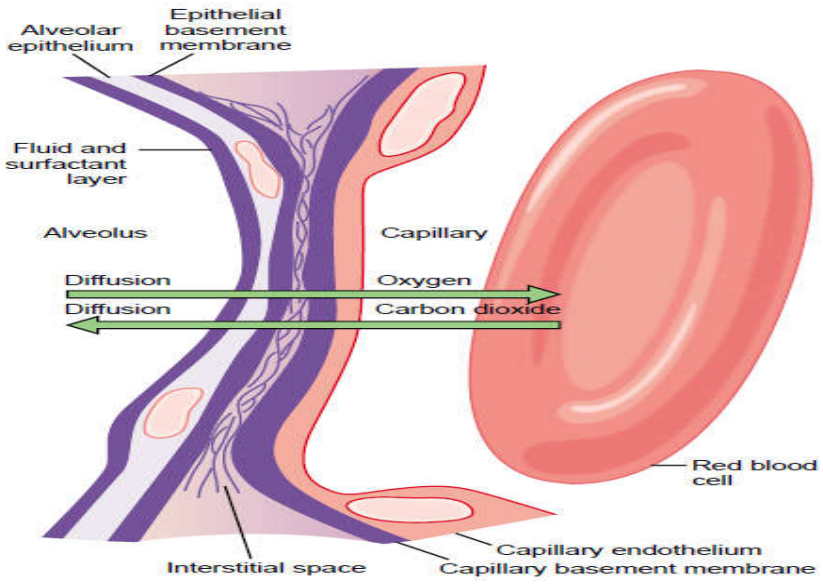

Fig. 1: Ultra-structure of the Respiratory Membrane

3.2 Muscles of Respiration

These can be divided into two broad groups:

i. Muscles of inspiration
ii. Muscles of expiration

The main muscles of inspiration are the diaphragm (innervated by the phrenic nerve, from C3, 4 and 5) and the external intercostal muscles. The accessory muscles of inspiration are sternocleido-mastoids, scalenes, serratus anterior, levator scapulae, erectus spinae and pectoralis major and minor. Expiration is normally a passive process under quiet breathing. But in strenuous exercise, when there is difficulty with breathing or in forced expiration as in sneezing, the internal intercostal muscles are used. The accessory muscles of expiration are the abdominal recti and posterior inferior serratus muscle.

There are two types of intercostal muscles in each of the eleven intercostal spaces, the internal and external intercostal muscles. They are supplied by intercostal nerves from adjacent intercostal nerve roots. The external intercostal run forwards and downwards and they pull the ribs forward and upward. The internal intercostal runs backwards and downwards and pulls the ribs backward and downward.

The diaphragm is the dome-shaped musculo-tendinous partition between the thorax and abdomen, forming the roof of the abdomen and the floor of the thorax. The bony thorax, the intercostal muscles and the diaphragm form a cone shaped structure, called the thoracic cavity (Figure 2.1).

The distance from the thoracic inlet to the diaphragm is the vertical diameter of the thorax. The vertical diameter can increase in size when the diaphragm contracts and moves downwards. The distance between the posterior surface of the sternum and the anterior surface of the vertebral column is the antero-posterior (AP) diameter. When the ribs are pulled upward and forward, the AP diameter increases.

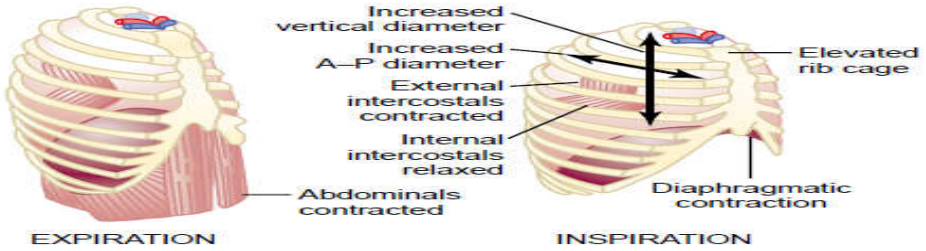

Fig. 2: Contraction and Expansion of the Thoracic Cage during Expiration and Inspiration.

3.3 Mechanism of Respiration

When the diaphragm contracts, it moves down, thereby increasing the vertical diameter of the thoracic cavity. The diaphragm is capable of vertical excursion of 2.5cm to 10cm depending on the depth of breathing. An increase in thoracic volume due to diaphragm causes the intrathoracic pressure to be 2 to 6 mmHg less than atmospheric pressure. Since pressure outside (atmospheric air) is higher than the pressure in the thoracic cavity, atmospheric air rushes into the lungs and fills the lungs. In deep breathing, contraction of the external intercostal muscles will pull the ribs upwards and move the sternum forward thereby increasing the AP diameter. This will increase the thoracic volume further and make the intrathoracic pressure more negative, so that more air will fill the lungs.

As air rushes in to fill the lungs, the lungs and the chest wall expand. This expansion stretches the elastic tissues of the lungs and the chest wall. At the end of inspiration, the stretched elastic tissues relax and this causes the lungs and the thoracic wall to recoil passively.

At the end of inspiration, the diaphragm relaxes and it is pushed up to a dome-shaped position by the abdominal viscera. This leads to a reduction of the vertical diameter of the thoracic cage. The thoracic cage and its elastic recoil and the lung tissues makes the thoracic volume to become smaller so that the pressure inside the thorax is now greater than the pressure outside (P_o). This higher pressure compresses the lungs so that air is expelled from the lungs. During quiet breathing expiration is a passive process, relying on the elastic recoil of the lung and chest wall. When ventilation is increased, such as during exercise, expiration becomes active with contraction of the muscles of the abdominal wall and the internal intercostals muscle.

SAE

Describe the mechanism of respiration.

4.0 CONCLUSION

The respiratory system serves as the air pump that allows for external and internal exchange of gases from the external environment and the internal environment of the body. The two groups of muscles are for inspiration and expiration. The mechanism of labour is facilitated by the movement of the diaphragm as it contracts, moves down or up, thereby increasing or decreasing the vertical diameter of the thoracic cavity to allow air entry or air push-out.

5.0 SUMMARY

In this unit, you have learnt that air exchange is facilitated through pulmonary circulation, and at the level of the capillary membrane/alveolar membrane. The main muscles of inspiration are the diaphragm and the external intercostal muscles and are supported by the accessory muscles of inspiration including the sternocleido-mastoids, scalenes, serratus anterior, levator scapulae, erectus spinae and pectoralis major and minor.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain how the structural makeup of the pulmonary circulation, the capillary and alveolar membranes facilitates exchange of gases from the outside of the body and within the body.
2. Enumerate the muscles in their groupings involved in respiration.

7.0 REFERENCES/FURTHER READING

Fox, S.I. (2012). *Human Physiology.* (12th ed.). New York: Mc Graw Hill,.

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UNIT 2 SURFACTANT AND COMPLIANCE OF THE LUNGS, THE DEAD SPACE, LUNG VOLUMES AND CAPACITY

CONTENTS

1.0 INTRODUCTION

The lung is able to perform its function of facilitating air intake and exchange by the presence of a special fluid and this helps in getting the lungs to hold some volume of air. The amount of air in the lungs can be measured using various measures. In this unit, you will cover these and how some of the measures are taken.

2.0 OBJECTIVES

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

- explain in detail the surfactant and compliance of the lungs
- describe the anatomic and physiologic dead space
- discuss the process of spirometry
- describe lung volumes and lung capacity as measures of pulmonary function.

3.0 MAIN CONTENT

3.1 Surfactant and Compliance of the Lungs

Surfactant is a surface acting agent that is responsible for lowering the surface tension of a fluid. The surfactant that lines the epithelium of the alveoli is the pulmonary surfactant and it decreases the surface tension

on the alveolar membrane. The pulmonary surfactant is secreted by the Type II alveolar epithelial cells in the lungs. Surfactant is a lipoprotein complex formed by lipids especially phospholipids, proteins and ions. In infants, lack or absence of surfactant causes Respiratory Distress Syndrome or Hyaline Membrane Disease.

Figure 4.1 is a diagram relating lung volume changes to changes in trans-pulmonary pressure. Compliance means the volume change in the lungs produced by a unit change of pressure. It is a measure of the distensibility (elasticity) of the lungs and thoracic structures. The extent to which the lungs expand for each unit increase in trans-pulmonary pressure is called their compliance. The total compliance of both lungs together in normal adult human being averages about 200 millimeters of air per centimeter of water trans-pulmonary pressure. That is, every time the trans-pulmonary pressure increases by 1 centimeter of water, the lung volume expands 200 millimeters.

Tissues of the lungs and thorax exhibit elastic properties so that when a force (pressure) is applied, the resulting volume change is proportional to the applied force within limits. Thus, under static conditions, when pressure is increased, volume is increased and the lungs and thoracic wall are stretched. When the increase in pressure is removed, the elastic properties of the tissue restore the original volume.

Compliance (C) is given by the ratio: $\frac{\text{Change in volume}}{\text{Change in pressure}}$

The unit of compliance is Liters/cmH_20.

3.2 Anatomic and Physiologic Dead Space

In the lungs, exchange of gases occurs only in the respiratory bronchioles and the alveoli. Air in the air passages does not take part in gaseous exchange. The anatomical structures that make up the air passages in which no gaseous exchange occurs are the nasal cavity, the pharynx, the larynx, the trachea, the bronchi and the bronchioles up to the terminal bronchioles. The volume of air inside this conduit is the anatomic dead space (ADS).

Physiologic dead space is the anatomic dead space plus the volume of areas of the lungs that are not taking part in gaseous exchange. Such non-functional areas result from poor or absent perfusion in a well-ventilated lung. In a perfectly healthy person, there is no such non-functional area in the lungs, so that the anatomic dead space is equal to the physiologic dead space.

Spirometry

The volume of air that moves into and out of the lungs under different conditions can be measured, using a spirometer. The process is called spirometry. A typical basic spirometer is shown in Figure 3-3. It consists of a drum containing air or oxygen inverted over a slightly bigger drum containing water. A string is attached to the inverted drum and this is passed over pulleys to a counter balancing weight. A writing point is attached to the device so that movements of the inverted drum can be recorded on a kymograph. The apparatus has a mouthpiece through which a subject breathes in and out. The end of the mouthpiece is above the water level. When the subject inspires from the spirometer, the volumes of air inside the inverted drum is reduced, the inverted drum sinks lower into the water and the writing point on the other side moves up. The reverse occurs during expiration. So an upward deflection is inspiration and a downward deflection is expiration.

During spirometry, many of the volumes are measured starting from the resting expiratory level. The resting expiratory level is the volume of air present in the lungs following quiet expiration. In the latter condition, elastic recoil of the lungs and thoracic cage causes the lungs to be passively compressed to a relaxed state.

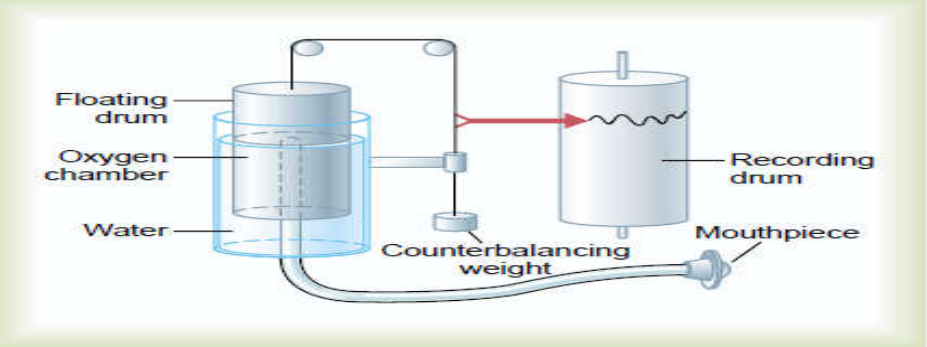

Fig.3: Spirometer

3.3 Lung Volumes

Lung volumes are the volumes of air breathed by an individual. There are four volumes;

i.) Tidal Volume (TV): This is the volume of air breathed in and out of the lungs during normal quiet respiration. It has a value of 500ml (0.5L)

ii) Inspiratory Reserve Volume (IRV): This is the volume of air that can be forcefully inspired after a normal inspiration. It has an average value of 3300ml (3.3L)

iii.) Expiratory Reserve Volume (ERV): This is volume of air that can be forcefully expired after normal expiration.

iv) Residual Volume: This is the volume of air remaining in the lungs even after a most forceful expiration. This volume of air cannot be emptied from the lungs. It has a value of 1200ml (1.2L).

3.4 Lung Capacities

Lung capacities are the combination of two or more lung volumes.

There are four types of lung capacities;

i. Inspiratory Capacity (IC): This is the maximum volume of air that is inspired after normal expiration. This is also TV + IRV. It has a value of about 3800ml (3.8L).

ii. Vital Capicity (VC): This is the maximum volume of air that can be forcefully expired after a maximal inspiratory effort. This is also TV + IRV + ERV. It has a value of about 4800ml (4.8L).

iii. Functional Residual Capacity (FRC): This is the volume of air remaining in the lungs after normal tidal expiration. This is also ERV + RV. It has a value of about 2200ml (2.2L).

iv. Total Lung Capacity (TLC): This is the volume of air present in the lungs after a inspiratory effort. This is also IRV + TV + ERV + RV. It has a value of about 6000ml (6.0L).
capacity plus the residual volume (VC + RV).

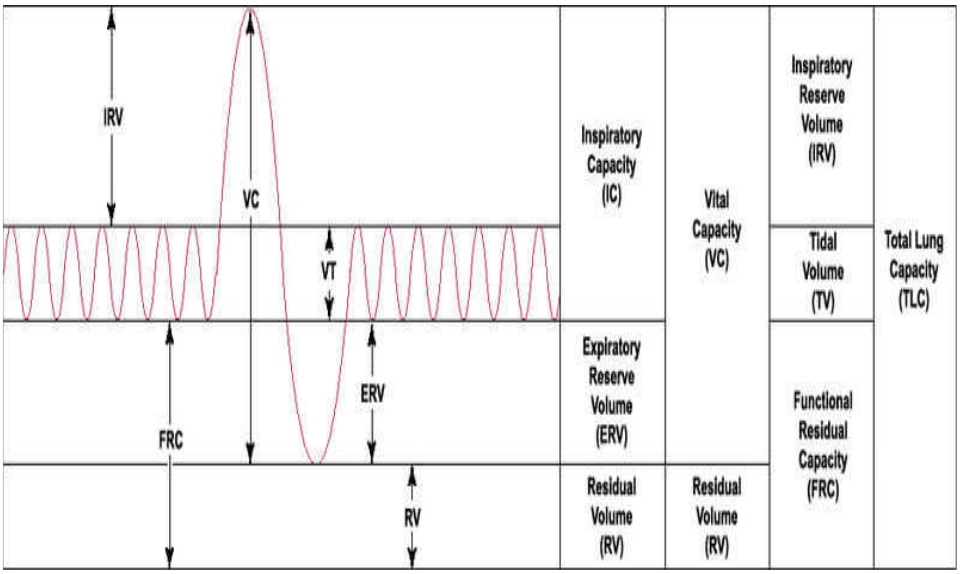

Fig.4: Diagram showing Respiratory Excursions during Normal Breathing and during Maximal Inspiration and Maximal Expiration

The most common parameters measured in spirometry are vital capacity (VC), forced vital capacity (FVC), forced expiratory volume (FEV) at timed intervals of 0.5, 1.0 (FEV_1), 2.0, and 3.0 seconds, forced expiratory flow 25–75% (FEF 25–75) and maximal voluntary ventilation (MVV), also known as maximum breathing capacity. Forced vital capacity (FVC) is the volume of air (measured in liters) that can forcibly be blown out after full inspiration. FVC is the most basic maneuver in spirometry tests.

Forced expiratory volume in 1 second (FEV_1): Average values for FEV_1 in healthy people depend mainly on sex and age. Values of between 80% and 120% of the average value are considered normal. FEV_1/FVC (FEV1%) is the ratio of FEV_1 to FVC. In healthy adults this should be approximately 75–80%. In obstructive diseases (asthma, COPD, chronic bronchitis, emphysema) FEV_1 is diminished because of increased airway resistance to expiratory flow; the FVC may be decreased as well, due to the premature closure of airway in expiration, just not in the same proportion as FEV_1 (for instance, both FEV_1 and FVC are reduced, but FEV_1 is more affected because of the increased airway resistance). This generates a reduced value (<80%, often ~45%).

In restrictive diseases (such as pulmonary fibrosis) the FEV_1 and FVC are both reduced proportionally and the value may be normal or even increased as a result of decreased lung compliance.

3.5 Minute Respiratory Volume and Alveolar Ventilation

The normal respiratory rate is 12 to 16 times per minute. The volume of fresh air moved into the respiratory system per minute is the minute respiratory volume or total ventilation. This volume is the product of the tidal volume (T.V.) and the respiratory rate (R.R.) i.e T.V x R.R
500ml/breath x 12 breaths/minute = 6000ml/min or 6L/min.

Alveolar ventilation is the volume of fresh air that enters the alveoli per minute. It is equal to the tidal volume minus the dead space volume (VD) multiplied by respiratory rate (RR). i.e. Alveolar ventilation= (TV-VD) x RR

Thus, if the TV is 500ml, and VD is 150ml and RR is 12/min,
Then, Alveolar ventilation = (500-150) x12
= 350 x 12 ml/min
= 4200ml/min.

SAE
What are the lung function tests that can be performed and what are the normal values of such measures?

4.0 CONCLUSION

The tissues of the lungs and thorax exhibit elastic properties that enables measurable amount of air to be inhaled and exhaled. These measurable volumes of air are determined to affirm the quality of functioning of the lungs.

5.0 SUMMARY

In this unit, you have leant about the use of surfactant in getting compliant lungs. You have also learnt about the structures of the respiratory system that are not actively involved in respiration. You have learnt about the various measures that can be used to measure lung functions.

6.0 TUTOR- MARKED ASSIGNMENTS

1. Compile the patients with respiratory disorders in you place of work. Share their diagnoses in your discussion forum and in groups as will be assigned to you, explain the homeostatic imbalance associated with their diseases. In your reference textbooks or from the Internet look for a diagram that shows compliance of the lungs in a healthy person.
2. What is the disease associated with the defect of surfactant and how will you explain what happens?
3. Describe how spirometry is conducted.

7.0 REFERENCES\FURTHER READING

Fox, S.I. (2012). *Human Physiology.* (12th ed.). New York: Mc Graw Hill,.

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UNIT 3 TRANSPORT AND EXCHANGE OF GASES - OXYGEN, CARBON DIOXIDE AND THE OXYGEN–HAEMOGLOBIN DISSOCIATION CURVE

CONTENTS

1.0 INTRODUCTION

The process of exchange of oxygen with carbon dioxide and vice-versa uses pressure gradients that are supported by some factors. The red blood also play important role in oxygen transport to tissues. In this unit the steps by step of the processes and the chemical reactions with the equations are explained in this unit.

2.0 OBJECTIVES

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

- explain the process of gaseous transport and exchange
- explain the process of oxygen transportation
- list various steps involved in oxygen transportation

- list the major forms through which oxygen can be transported in the blood.
- describe the give detailed explanation about oxygen dissociation curve
- enumerate the various factors that can cause oxygen- hemoglobin dissociation curve to shift to the left or shift to the right.
- explain the various steps involved in the transportation of the carbon-dioxide
- explain the ventilation – perfusion relationship citing relevant examples.

3.0 MAIN CONTENT

3.1 Transport and Exchange of Gases

Gaseous exchange is the process by which oxygen is transferred from the atmosphere to the tissue for use in metabolism; and the gas produced by metabolism, carbon dioxide, is transferred from tissues to the atmosphere. Gaseous exchange is divided into the processes of alveolar ventilation (bringing air into the lungs for transfer of oxygen and carbon dioxide) and pulmonary circulation (bringing blood to the lungs to take up oxygen and excrete carbon dioxide).

The process of gas exchange has several steps. The following is a summary of the steps:

i. Ventilation (breathing)
ii. Interchange of CO_2 and O_2 between air in the lungs' alveoli and blood in lung capillaries by diffusion
iii. Transport of CO_2 and O_2 through the bloodstream
iv. Interchange of CO_2 and O_2 between blood in lung capillaries and alveolar air by diffusion
v. Use of O_2 and production of CO_2 by cells through metabolism.

Upon inhalation, gas exchange occurs at the alveoli, the tiny sacs which are the basic functional component of the lungs. The alveolar walls are extremely thin (approximately 0.2 micrometers). These walls are composed of a single layer of epithelial cells (type I and type II epithelial cells) close to the pulmonary capillaries which are composed of a single layer of endothelial cells. The close proximity of these two cell types allows permeability to gases and, hence, gas exchange. This whole mechanism of gas exchange is carried by the simple phenomenon of pressure difference. Whenever the atmospheric pressure is lower than the pressure inside the lungs, the air from lungs flows out, but when the pressure in the lungs is lower than atmospheric, air rushes into the lungs.

To accomplish gas exchange the air that is inhale is delivered, via the mouth and nose, to tiny sacs, called alveoli, which are the terminal or end units of the airways. Oxygen from the air diffuses across a thin membrane into tiny blood capillaries surrounding the alveoli. At the same time CO_2 diffuses from the blood capillaries into the alveoli and out of the lungs with each exhalation. The combination of one alveolus (containing air) and its surrounding capillaries (containing blood) is called an alveolar-capillary unit. At the alveolar-capillary membrane, gas exchange takes place. Oxygen is delivered to, and carbon dioxide removed from, the capillary blood. This gas exchange converts the oxygen-poor blood entering the pulmonary capillary into oxygen-rich blood.

Partial pressures of O_2 and CO_2 in the body (normal, resting conditions):

PO_2 = 100 mm Hg
PCO_2 = 40 mm Hg

Alveolar capillaries

Entering the alveolar capillaries

PO_2 = 40 mm Hg (relatively low because this blood has just returned from the systemic circulation and has lost much of its oxygen)
PCO_2 = 45 mm Hg (relatively high because the blood returning from the systemic circulation has picked up carbon dioxide).

While in the alveolar capillaries, the diffusion of gasses occurs: oxygen diffuses from the alveoli into the blood and carbon dioxide from the blood into the alveoli.

Leaving the alveolar capillaries

PO_2 = 100 mm Hg
PCO_2 = 40 mm Hg

Blood leaving the alveolar capillaries returns to the left atrium and is pumped by the left ventricle into the systemic circulation. This blood travels through arteries and arterioles and into the systemic, or body, capillaries. As blood travels through arteries and arterioles, no gas exchange occurs.

Entering the systemic capillaries

PO_2 = 100 mm Hg
PCO_2 = 40 mm Hg

Body cells (resting conditions)

PO_2 = 40 mm Hg
PCO_2 = 45 mm Hg

Because of the differences in partial pressures of oxygen and carbon dioxide in the systemic capillaries and the body cells, oxygen diffuses from the blood and into the cells, while carbon dioxide diffuses from the cells into the blood.

Leaving the systemic capillaries

PO_2 = 40 mm Hg
PCO_2 = 45 mm Hg

Blood leaving the systemic capillaries returns to the heart (right atrium) via venules and veins (and no gas exchange occurs while blood is in venules and veins). This blood is then pumped to the lungs (and the alveolar capillaries) by the right ventricle.

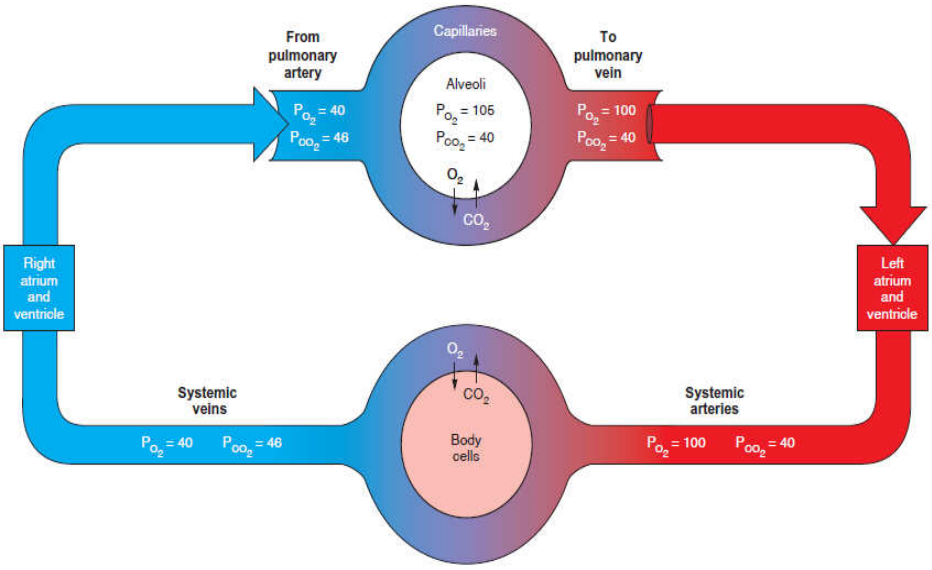

Fig. 5: Partial Pressures of Gases in Blood

3.1.1 Transport of Oxygen and Carbon-Dioxide Transport of oxygen

The process by which atmospheric oxygen gets to the tissues for use in metabolic processes is referred to as oxygen transport. Oxygen transport consists of four important steps:

i. Movement of oxygen from atmospheric air into the alveoli (inspiration)
ii. Diffusion of oxygen from the alveolar sac into the blood in the pulmonary capillaries
iii. Transport of oxygen in the blood from the lungs to the tissues.
iv. Delivery of oxygen from the systemic capillary blood to the tissues.

Fresh atmospheric air moves into the alveoli during inspiration. This is an active process involving contraction of the diaphragm with or without contraction of the external intercostal muscles.

In the alveoli, the PO_2 is 100mmHg, while PO_2 in pulmonary arterial capillaries is 40mmHg. There is therefore a gradient for oxygen to diffuse from the alveolar sacs into the pulmonary capillary blood. The capillary/alveolar membrane is very thin and the surface area of the alveolar sacs and pulmonary capillaries is very large. These factors favour rapid diffusion of oxygen from the alveoli into the capillaries.
Oxygen is transported in two forms in the blood, as shown in Figure 8.1:

(i) O_2 dissolved in plasma
(ii) O_2 carried in combination with hemoglobin in the red blood cell.

Dissolved O_2 in plasma

The plasma is a poor carrier of oxygen. At a PO_2 of 100 mmHg, 100 ml of plasma can carry only 0.3ml of oxygen, while at a PO_2 of 40 mmHg, dissolved oxygen is 0.13 ml/100ml. Nonetheless, oxygen diffuses from the region of high tension in the alveolar sacs (100 mmHg) into the region of low tension in the plasma (40mmHg). The oxygen that diffuses into the plasma dissolves in the plasma and the diffusion continues until the PO_2 in plasma rises to 100mmHg. At this point of equilibration, the plasma contains only 0.3ml of dissolved O_2 per 100ml. However, the saturation of plasma with oxygen exposes the red blood cells suspended in the plasma to a high oxygen tension. Oxygen diffuses rapidly from the plasma into the red blood cells and combines with hemoglobin.

3.2 Oxygen in Combination with Hemoglobin

The haem portion of the hemoglobin molecule contains four molecules of ferrous iron. This iron is capable of a reversible combination with oxygen, with the iron still remaining in the ferrous form. Since the iron is not converted to ferric iron, the reaction is not an oxidation, but an oxygenation. The normal hemoglobin concentration is about 14.5g/dl. Each gram of hemoglobin is capable of carrying 1.34ml of oxygen at full saturation. Then, 100ml of blood at full saturation will carry 19.7ml of oxygen (19.4ml combined with Hb and 0.3ml dissolved in plasma).
Each molecule of hemoglobin (which contains 4Hb units) combines with four molecules of oxygen. This can be written thus:

$$Hb_4 + 4O_2 \longrightarrow Hb_4O_8$$

The above reaction however occurs in stages, with one O_2 molecule combining with Hb at a time. The sequence of the reaction is as follows:

$$Hb_4 + O_2 \rightleftharpoons Hb_4O_2$$
$$Hb_4O_2 + O_2 \rightleftharpoons Hb_4O_4$$
$$Hb_4O_4 + O_2 \rightleftharpoons Hb_4O_6$$
$$Hb4O_6 + O_2 \rightleftharpoons Hb_4O_8$$

The above reaction is very rapid. It requires less than 0.01 second. The deoxygenation of Hb_4O_8 is also rapid. The combination of oxygen with hemoglobin is a self- catalytic reaction. The formation of Hb_4O_2 is relatively slow, but Hb_4O_2 catalyzes the combination of the next O_2 molecule with Hb_4O_2 so that Hb_4O_4 is formed at a faster rate than Hb_4O_2 and so on. This is why the oxygen- hemoglobin dissociation curve has a steep rise. The PO_2 of pulmonary capillary blood when fully oxygenated is 100mmHg, i.e. equal to alveolar PO_2. Before the blood gets to the left atrium, it mixes with venous blood from the bronchial vein (physiological shunting) so that the PO_2 of the blood entering the left atrium is about 97mmHg.

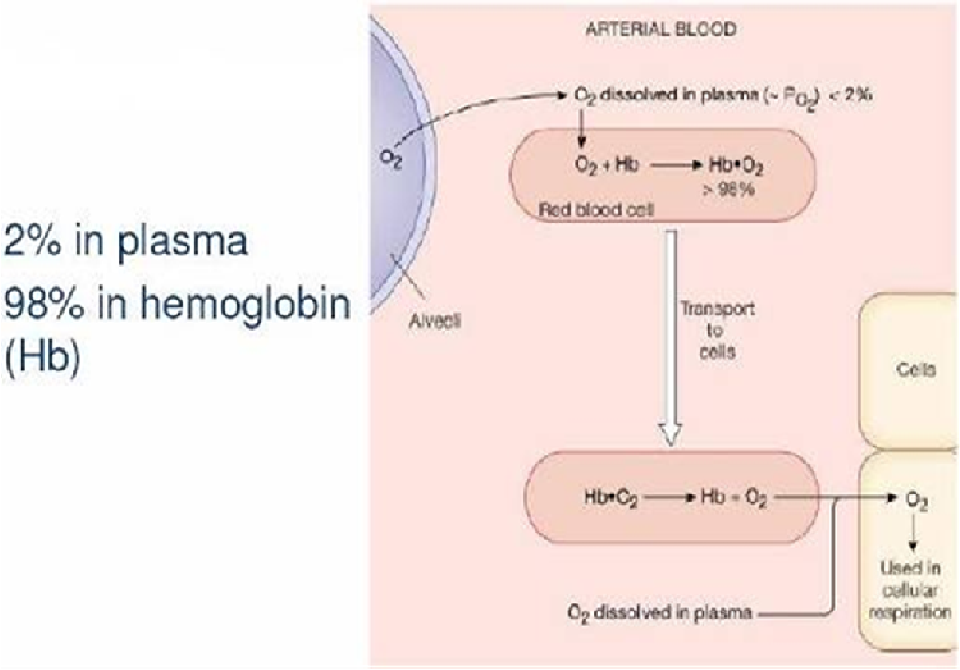

Fig. 6: Transport of Oxygen in the Blood

3.3 Oxygen Dissociation Curve

The oxygen dissociation curve is a graph that shows the percent saturation of hemoglobin at various partial pressures of oxygen (Figure 1-50). The oxygen–haemoglobin dissociation curve plots the proportion of haemoglobin in its saturated form on the vertical axis against the prevailing oxygen tension on the horizontal axis.

The oxyhemoglobin dissociation curve is an important tool for understanding how blood carries and releases oxygen. Specifically, the oxyhemoglobin dissociation curve relates oxygen saturation (SO_2) and partial pressure of oxygen in the blood (PO_2), and is determined by what is called "hemoglobin's affinity for oxygen"; that is, how readily haemoglobin acquires and releases oxygen molecules into the fluid that surrounds it.

The oxygen- hemoglobin dissociation curve can shift to the left or shift to the right. The factors that can cause a shift to the right are:

(a) increase in temperature
(b) increase PCO_2
(c) increased acidity (fall in pH)
(d) increase in 2,3 diphosphoglycerate (2,3 DPG)

A shift to the right due to increased acidity is called Bohr's effect.

The factors that can cause a shift to the left are the opposite of those that cause shift to the right. These are:

(a) decrease in temperature
(b) decrease PCO_2
(c) reduced acidity (increase in pH)
(d) decrease in 2,3- DPG
(e) presence of foetal hemoglobin

Variation of the hydrogen ion concentration

This changes the blood's pH. A decrease in pH shifts the standard curve to the right, while an increase shifts it to the left. This is known as the Bohr's effect. A reduction in the total binding capacity of haemoglobin to oxygen (i.e. shifting the curve down, not just to the right) due to reduced pH is called the root effect.

Effects of carbon dioxide

Carbon dioxide affects the curve in two ways: first, it influences intracellular pH (the Bohr's effect), and second, CO_2 accumulation causes carbamino compounds to be generated through chemical interactions, which bind to haemoglobin forming carbaminohaemoglobin. Low levels of carbamino compounds have the effect of shifting the curve to the right, while higher levels cause a leftward shift. However, this isn't the overriding effect of CO_2 accumulation. Only about 5–10% of the total CO_2 content of blood is transported as carbamino compounds. Most of the CO_2 content (80–90%) is transported as bicarbonate ions. The formation of a bicarbonate ion will release a proton into the plasma. Hence, the elevated CO_2 content creates a respiratory acidosis and shifts the oxygen–haemoglobin dissociation curve to the right.

Effects of 2, 3-D.P.G

2, 3-Disphosphoglycerate or 2,3-DPG is an organophosphate, which is created in erythrocytes during glycolysis. The production of 2,3-DPG is likely an important adaptive mechanism, because the production increases for several conditions in the presence of diminished peripheral tissue O_2 availability, such as hypoxaemia, chronic lung disease, anaemia, and congestive heart failure, among others. High levels of 2,3-DPG shift the curve to the right, while low levels of 2,3-DPG cause a

leftward shift, seen in states such as septic shock and hypophosphatemia.

Temperature

Temperature does not have such a dramatic effect compared to the previous factors, but hyperthermia causes a rightward shift, while hypothermia causes a leftward shift.

Carbon monoxide

Haemoglobin binds with carbon monoxide 200-250 times more readily than with oxygen. The presence of carbon monoxide on one of the 4 haem sites causes the oxygen on the other haem sites to bind with greater affinity. This makes it difficult for the haemoglobin to release oxygen to the tissues and has the effect of shifting the curve to the left (as well as downward, due to direct competitive effects of carbon monoxide). With an increased level of carbon monoxide, a person can suffer from severe tissue hypoxia while maintaining a normal PO_2.

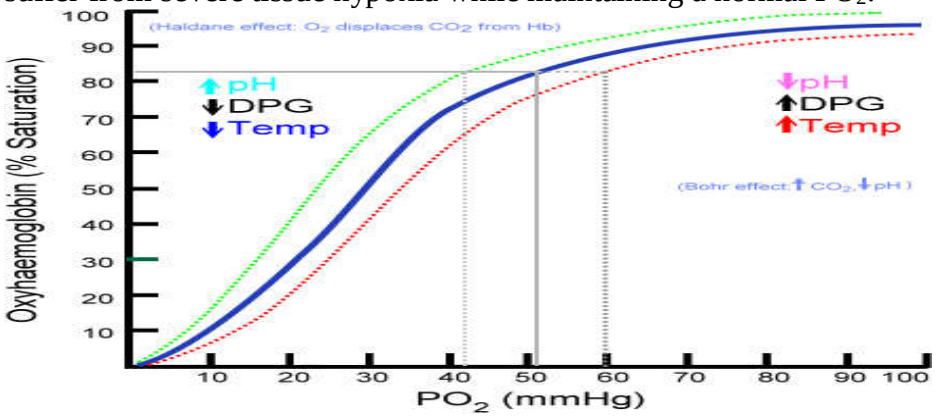

Fig. 7: Oxygen-haemoglobin Dissociation Curve

3.4 Carbon-Dioxide Transport

Since cellular (internal) respiration is a continuous process, carbondioxide is produced continuously in the body tissues. This CO_2 must be transported from the tissues to the lungs where it is expired.

The transport of CO_2 involves:

(a) diffusion of CO_2 from the tissues into the blood
(b) transport of CO_2 in the blood to the lungs
(c) diffusion of CO_2 from the pulmonary capillaries into the alveoli
(d) movement of CO_2 from the alveoli into atmospheric air

The PCO_2 in the tissues is 46mmHg and PCO_2 in the arterial blood is 40mmHg. Carbondioxide is about 20 times more diffusible than oxygen at body temperature. So, CO_2 diffuses rapidly from the tissues along its concentration gradient into the blood.

Transport of CO_2 in blood

Carbondioxide is transported in the blood in three forms

(a) as dissolved CO_2 -10%
(b) in combination with plasma protein and haemoglobin- carbamino compound- 30%
(c) as bicarbonate- 60%

CO_2 in solution

Since CO_2 is very soluble, about 10% of the CO_2 transported is in solution in the plasma.

CO_2 as Carbamino-compounds

Carbondioxide combines with the free NH_2 groups in plasma proteins and free NH_2 groups in haemoglobin inside the red blood cell to from carbamino compounds. Thus, CO_2 + protein-NH_2 = protein – NHCOOH= protein-$NHCOO^-$ + H^+

The H^+ produced in this reaction is buffered by plasma proteins and phosphates. Similarly, CO_2 + Hb - NH_2 = Hb- NHCOOH= $HbNHCOO^-$ + H^+

The H^+ produced is buffered by haemoglobin and phosphate esters in the red cells.

CO_2 as bicarbonate

In the plasma CO_2 combines with water to form carbonic acid.
$CO_2 + H_2O \longrightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$

The reaction is very slow unless the enzyme carbonic anhydrase which acts as a catalyst is present. Carbonic anhydrase is not found in the plasma, but it is abundant in the red cells.

Thus, when CO_2 diffuses into red blood cells, it is very rapidly converted to bicarbonate and hydrogen ions. Carbonic anhydrase

increases the speed of this reaction about 5000 times compared with that in the plasma. Because of the high rate of its formation, the concentration of bicarbonate in the red blood cell becomes higher than that in the plasma. Consequently, HCO_3^- diffuses from the red cell into the plasma. Since the H^+ produced by the same reaction has been buffered by intracellular haemoglobin and phosphate, H^+ cannot move out with the HCO_3^- . Also, neither Na^+ nor K^+ can move of the cell to accompany the HCO_3 so as to maintain electrical equilibrium. This is because the Na^+- K^+ ATPase pump maintains strictly the intra and extra-cellular Na^+ and K^+ concentrations. Chloride is the only free anion that can move. So, chloride moves from the plasma into the red cell to replace the HCO_3 that has moved out so as to maintain electrical neutrality. This movement of chloride into the red cells is called chloride shift or the Hamburger effect. As a result of this chloride shift, the concentration of chloride in venous blood is about 2% lower than in arterial blood. Also water moves into RBC so that red blood cell in venous blood is about 3% bigger than in arterial blood.

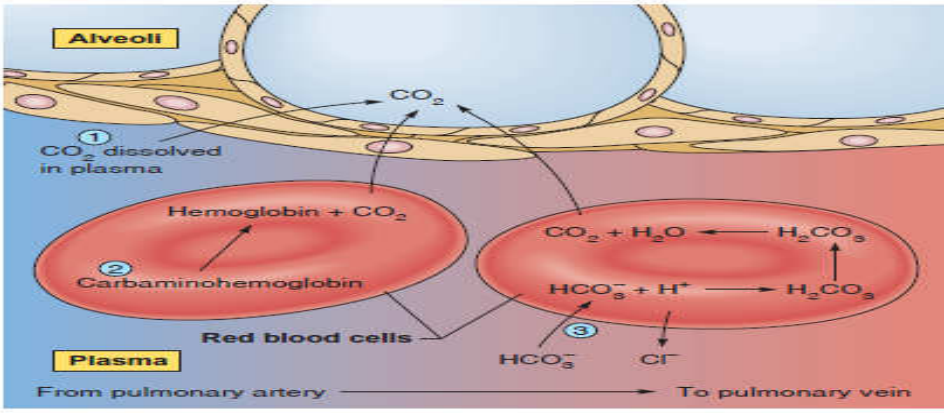

Fig. 8: Movement of Gases at Alveolar Level

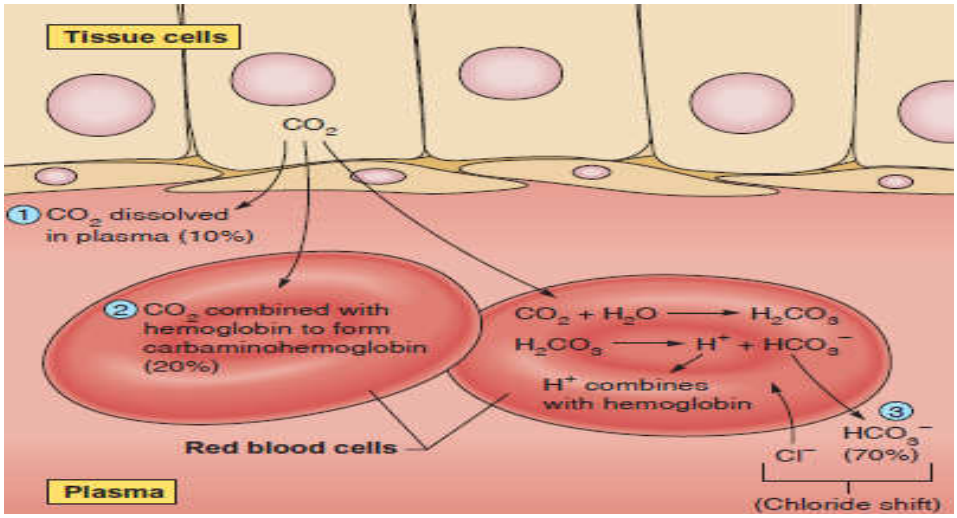

Fig. 9: Movement of Gases at Tissue Level

Carbon-dioxide dissociate curve

The volumes of CO_2 in 100 volumes of blood is plotted against the PCO_2 (Figure 1-53). A separate CO_2 dissociation curve is usually drawn from reduced whole blood and oxygenated whole blood. Carbon-dioxide in the three forms is carried in the venous blood (where the PCO_2 is 46mmHg, same as the in the tissues because of equilibration) to the right side of the heart and from there to the lungs. In the lungs, there is a reversal of the reactions at the tissue level so that CO_2 at a partial pressure of 46mmHg in the pulmonary arterial capillary diffuses into the alveoli where the PCO_2 is 40mmHg. From the alveoli, the CO_2 is expelled to the atmosphere during expiration.

Factors such as rate of tissue metabolism (which determines rate of CO_2 production), rate of blood flow, degree of deoxygenation of haemoglobin at the tissues level and the rate/ depth of pulmonary ventilation will affect the rate of CO_2 transport.

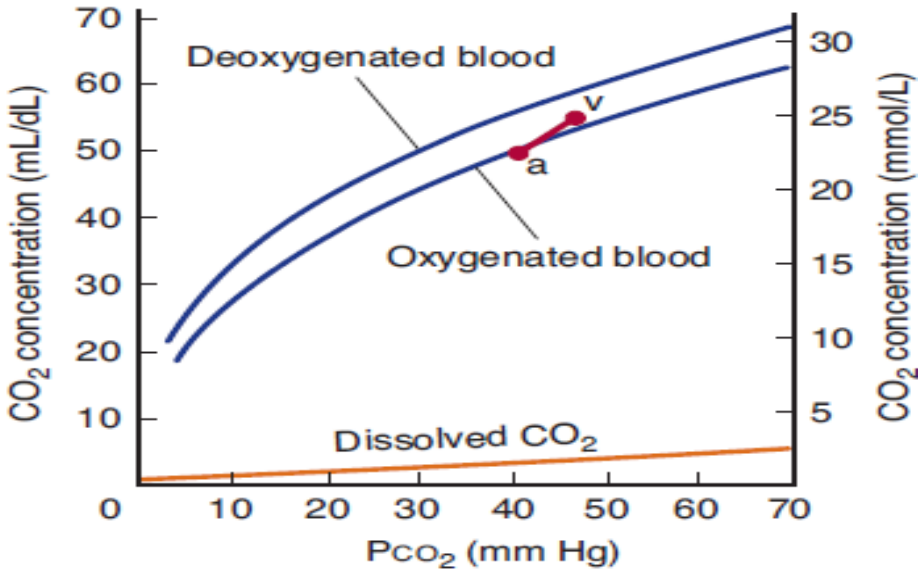

Fig.10: Carbon-dioxide Dissociation Curve

3.5 Ventilation – Perfusion Relationship

Ventilation is the movement of air into and out of the lungs; while perfusion is the flow of blood through the lungs. In the normal lung, in upright position, distribution of ventilation is greatest to the top and decreases slightly towards the bottom of the lung, while in a similar

position; distribution of perfusion is greatest at the bottom and decreases markedly towards the top of the lung.

For exchange of gases to occur normally in the lungs, a normal ratio of ventilation to perfusion must be maintained. Ventilation/perfusion imbalance is said to exist when this ratio is abnormal. An extreme example is a situation where a main bronchus is totally blocked by a foreign body that has been accidentally inhaled. In this situation, although there is an adequate blood flow to the affected lung, because there is no ventilation of the lung, there is no exchange of gases in that lung. Also, there could be obstruction to blood flow to a whole lung due to clot embolism. Although there will be adequate ventilation of the affected lung, because there is no perfusion of lung, no exchange of gases takes place in that lung. Very often, there are small areas in the lungs that may be underperfused. Such areas constitute physiologic dead spaces and increase the total dead space of the lung.

SAE

1. Explain the process of gaseous exchange.

4.0 CONCLUSION

The process of exchange of oxygen with carbon dioxide and vice-versa uses pressure gradients that are supported by some factors.

5.0 SUMMARY

In this unit, you have leant about the process of Gaseous transport and exchange with emphasis on how the body receives oxygen and gives out carbon dioxide applying physical and chemical principles of pressure gradients and combining with haem and supported by some factors.

6.0 TUTOR- MARKED ASSIGNMENT

2. Explain the 4 steps of the Oxygen transport process
3. Describe the Oxygen-haemogobin combination and how this occurs in the vessels and the heart using appropriate equations.

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UNIT 4 CONTROL OF RESPIRATION AND RESPIRATORY ADAPTATIONS IN UNUSUAL ENVIRONMENT

CONTENTS

1.0 INTRODUCTION

Normal respiration has a rhythmic pattern, with inspiration alternating with expiration. It is unusual to find a normal person breathing in all the time without inspiring and expiring. The normal rhythmic pattern of breathing is possible because of precise control of breathing. The control of breathing can be divided into two broad groups, neural (nervous) control and chemical control. In this unit you will learn about control of breathing in usual and unusual environment.

2.0 OBJECTIVES

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

- explain the process of neural control of breathing
- explain the process of the chemical control of breathing
- describe different groups of chemo-receptors
- explain the ventilatory responses to changes in ph, carbon dioxide and oxygen lack.

3.0 MAIN CONTENT

3.1 Neural Control of Breathing

Neural control is the influence of nerve cells of the central nervous system and their efferent and afferent fibres on the regulation of breathing. The neural control can be sub-divided into two main types:

i. voluntary control;
ii. involuntary or autonomic control

Voluntary control

Voluntary control of respiration occurs when an individual decides to hold his breath or to hyper-ventilate. It is well known that when a swimmer wants to dive into the deep end of the swimming pool, he first takes a deep breath, dives into the water and holds his breath for the period he is under the water. If he breaths-in while under the pool, he will aspirate water into his lungs and may drown. Athletes are trained to consciously breathe in and out deeply before the start of a race. The acts of breath-holding and voluntary hyperventilation constitute voluntary control of breathing. It is carried out under the control of the motor cortex.

Involuntary control of breathing

The involuntary control of breathing is through the activities of collection of neurons referred as centres in the pons and the medulla and stretch receptors in the lung. The brain stem centres and the peripheral stretch receptors in the lungs are connected by afferent and efferent fibres into a network of functionally inter-related and well-connected neuronal circuit.

In the medulla oblongata, there are two centres, the inspiratory centre and the expiratory centres. In the pons, there are also two centres. In the lower part of the pons is the apneustic centre, while the pneumotaxic centre is located in the upper part of the pons. These brain stem respiratory centres are connected to each other and to the inspiratory muscles.

The inspiratory neurons (I neurons) at the inspiratory centre are capable of spontaneous discharge of nervous impulses. This impulse is transmitted in the spinal cord to the anterior horn cells of C3, 4 and 5 and efferent fibres that emerge from there is the phrenic nerve which supplies the diaphragm. Also, some of the impulses go to the anterior horn cells in the thoracic region and the efferent from these innervate the

intercostal muscles. Discharge of impulses from the inspiratory centre causes inspiration to occur, and this leads to expansion of the lungs. During inspiration, I-neurons inhibit the expiratory neurons (E-neurons) of the expiratory centre.

The depth of inspiration produced by the activity of the I-neurons is shallow. The apneustic centre in the lower pons send facilitatory impulses to the inspiratory centre and this leads to an increase in the depth of inspiration. At the same time as this increase in depth of respiration is going on, the following events are occurring

(i) Facilitatory impulses pass from the inspiratory centre to the pneumotaxic centre, causing its stimulation
(ii) Expansion of the lungs following inspiration causes the stretch receptors in the lungs to be stimulated. Afferent impulses from the stretch receptors are transmitted through the vagus nerve to the apneustic centre and cause its inhibition.
(iii) The pneumotaxic centre sends inhibitory impulses to the apneustic centre.
(iv) At the same time, the pneumotaxic centre sends facilitatory impulses to the expiratory centre.
(v) The inhibitory impulses reaching the apneustic centre from the pneumotaxic centre cause a reduction in the inspiratory drive of the apneustic centre on the inspiratory centre.
(vi) Also, the inhibitory impulses from the I-neurons to the E-neurons are removed.
(vii) As a result of inhibition of I-neurons and the stimulation of E-neurons, expiration occurs.

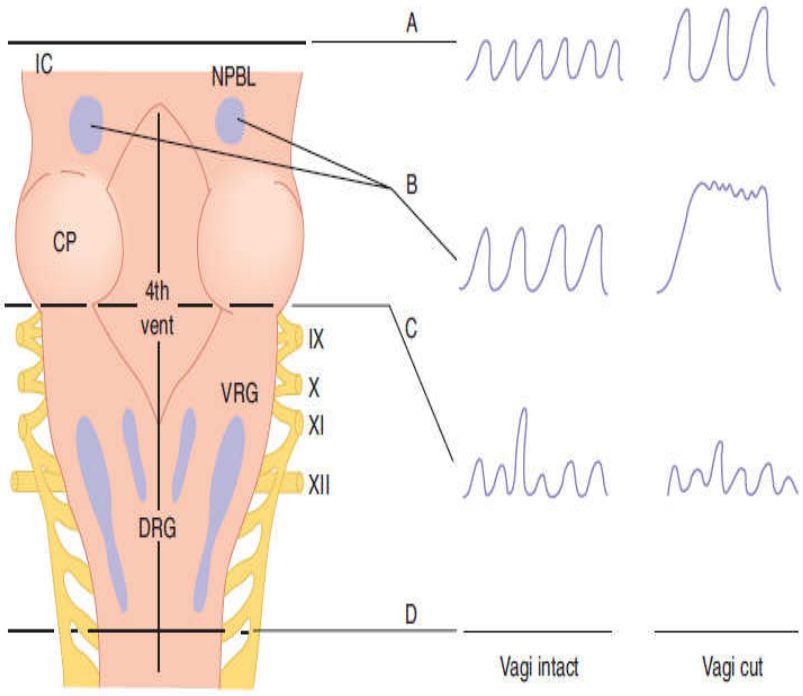

Fig.11: Respiratory Neurons in the Brain Stem

When expiration has occurred, the inhibitory impulses from the lungs on the apneustic centre are removed. The inhibition of the I-neurons during expiration removes the facilitatory impulses from the I-neurons to the pneumotaxic centre, which in turn stops inhibiting the apneustic centre. The apneustic centre is free once more to drive the inspiratory centre and the cycle starts all over again. This is how the alternating phases of inspiration and expiration occur.

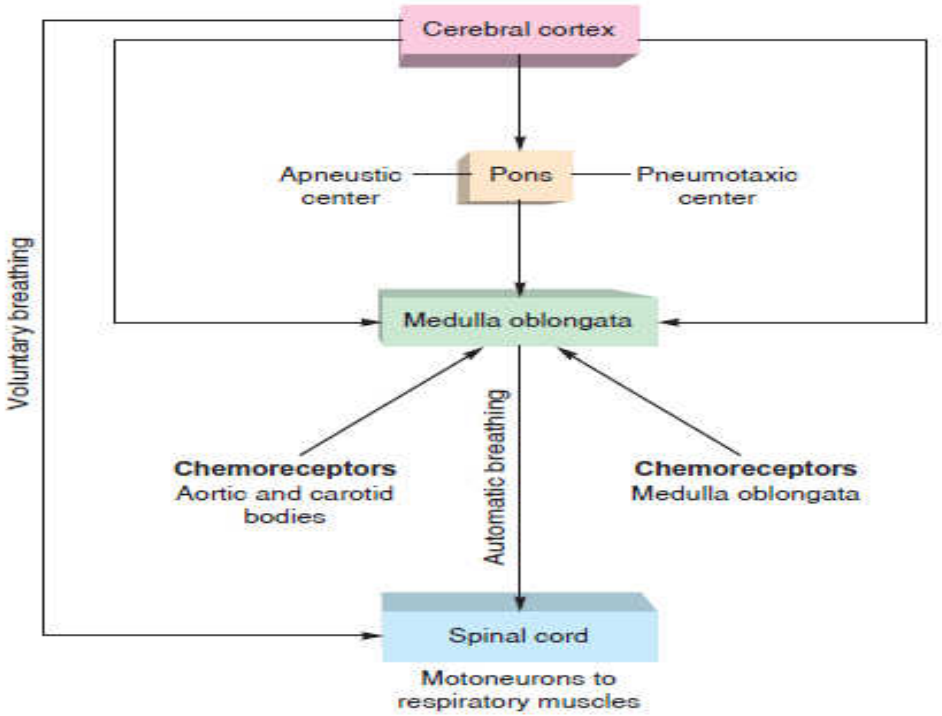

Fig.12: The Regulation of Ventilation by the Central Nervous System

3.2 Chemical Control of Breathing

Some chemical components of blood can affect respiration. The three main substances involved are CO_2, H^+ and O_2. A rise in PCO_2 or H^+ concentration of arterial blood or a fall in its PO_2 increases the activity of the respiratory centre, while a decrease in PCO_2 or H^+ concentration have inhibitory effect on respiratory centre activity. Increase in PO_2 has no effect on respiratory centre.

The changes in the chemical composition of blood are detected by chemoreceptors. There are two groups of chemoreceptors:

i. Peripheral chemoreceptors
ii. Central chemoreceptors

Peripheral chemoreceptors

The carotid and the aortic bodies are the peripheral chemoreceptors. The carotid body is located near the bifurcation of the common carotid artery into internal and external carotid arteries. There are usually two or more aortic bodies near the arch of the aorta. The carotid body has the glossopharyngeal nerve as its afferent fibre, while the vagus nerve in the afferent fibre from the aortic body.

The carotid bodies have a very high blood flow, about 2000 ml/100g of tissue per minute. Because of this large blood flow, the oxygen needs of the carotid bodies can be met by dissolved oxygen in plasma. For this reason, situations like anaemia or carbon monoxide poisoning which reduce the oxygen- carrying power of the blood do not cause stimulation of the carotid chemoreceptors. The peripheral chemoreceptors respond to decrease in PO_2 or increase in H^+.

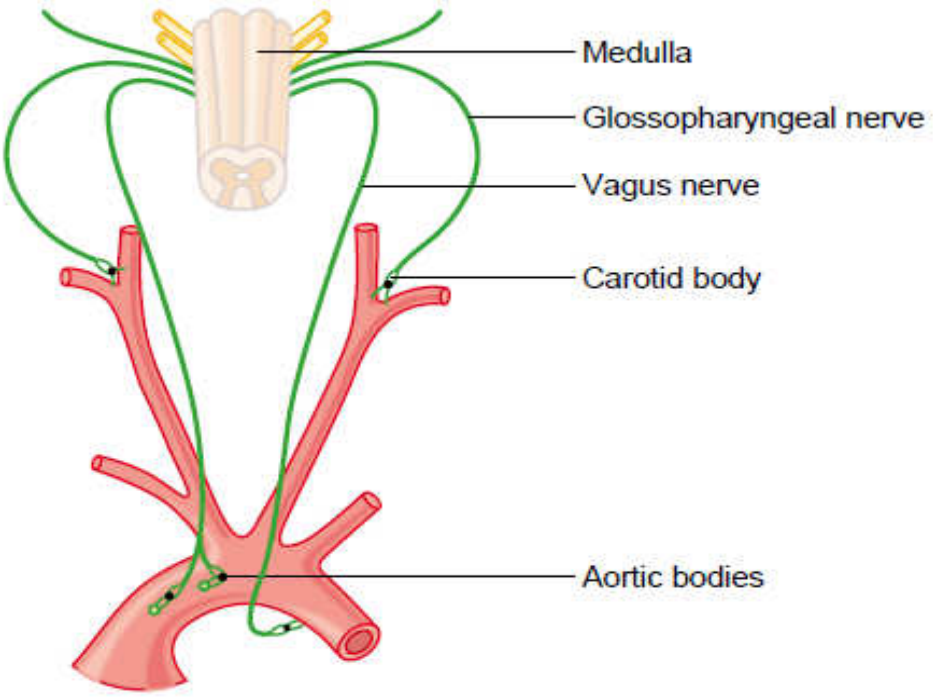

Fig. 13: Respiratory Control by in the Cand Aortic Bodies

Central chemoreceptors

The central chemoreceptors are located on the floor of the 4th ventricle in the medulla oblongata. They respond to changes in the H^+ concentration of the cerebrospinal fluid (CSF) or possibly, brain interstitial tissue. Hydrogen ion cannot penetrate the blood brain barrier easily; but CO_2 does. The CO_2 that enters the brain and CSF is hydrated to form H_2CO_3. The H_2CO_3 dissociates to H^+ and HCO_3. Therefore, the H^+ concentration in the CSF rises and this stimulates the central chemoreceptors. Chemoreceptor regulation of breathing in response to changes in PCO2 is illustrated in Figure 3-13.

Ventilatory responses to changes in pH

When there is an increase in the concentration of H^+ ions in the body, as may occur in uncontrolled diabetes mellitus which results in accumulation of acid ketone bodies, there is marked stimulation of respiration, mainly through the central chemoreceptors. The increased ventilation resulting from this leads to increased expulsion of CO_2 from the body and this leads to a compensatory fall in blood H^+ concentration. Conversely, when the H^+ concentration in blood falls, there is no stimulation of the central chemoreceptors leading to decreased ventilation and a consequent rise in arterial PCO_2. This leads to a rise in H^+ concentration. Thus, the blood concentration of H^+ is important in the regulation of respiration.

Persistent hyperventilation that is not secondary to an increase in H^+ concentration leads to a fall in blood H^+ concentration (due to excessive washing out of CO_2). This is respiratory alkalosis. Also, hypoventilation that is not secondary to a fall in plasma H^+ concentration leads to increase in H^+ concentration (due to accumulation of CO_2). This is respiratory acidosis.

Ventilatory responses to CO_2

When the arterial PCO_2 is increased, this stimulates the peripheral chemoreceptors (and indirectly, through increased H^+ concentration the central chemoreceptors are also stimulated) leading to increased pulmonary ventilation. The increased ventilation results in increased "washing out" of CO_2 from the body so that the PCO_2 is reduced. If the arterial PCO_2 falls too low, the CO_2 drive on the chemoreceptors is reduced or stopped. This leads to reduced excretion of CO_2. This allows CO_2 to accumulate in the body and causes a rise in PCO_2. The operation of this feed-back mechanism of respiratory control keeps CO_2 excretion and production in balance.

The normal arterial PCO_2 is 40 mmHg. Moderate increases in this concentration causes increased ventilation. If the arterial CO_2 level becomes too high, rather than stimulate respiration, it leads to depression of the central nervous system, including the respiratory centre, and it also produces headache, confusion and eventually coma. This is CO_2 narcosis.

Ventilatory responses to oxygen lack

When the arterial PO_2 is reduced, this causes stimulation of the peripheral chemoreceptors. The normal arterial PO_2 is 97 mm Hg and slight decreases in arterial PO_2 causes a slight stimulation of the

chemoreceptors. This slight reduction in PO_2 does not usually lead to an increase in ventilation for two reasons.

The first is that reduced arterial PO_2 means that haemoglobin is less saturated with oxygen. HbO_2 is more acidic than Hb. Therefore, less HbO_2 means that the blood will become slightly more alkaline and this will tend to inhibit respiration. This tends to cancel the stimulatory effect of the reduced PO_2.

Secondly, any increase in ventilation that may occur lowers PCO_2 and this tends to inhibit respiration.

Because of the two reasons above, the effect of fall in arterial PO_2 is not obvious until the O_2 falls to 60 mmHg or less. Under the latter condition, the rate and depth of respiration is increased. When PO_2 comes back to normal, this stimulus due to oxygen lack is removed and respiration comes back to normal.

The above account shows the importance of the three chemical substances, H^+, PCO_2 and PO_2, in the chemical control of respiration.

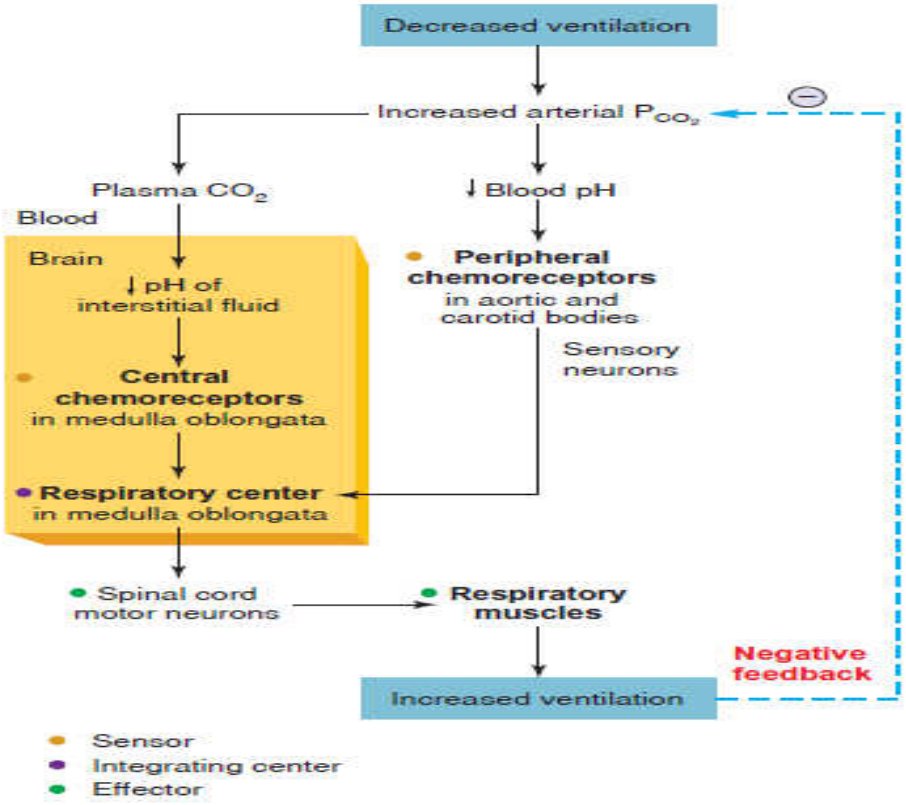

Fig.14: Chemoreceptor Control of Breathing

3.3 Respiration at High Altitude

The higher one goes into a high altitude, the lower the amount of air available in the environment. For example, the PO_2 in inspired air at sea-level is 159 mm Hg and alveolar PO_2 is 104 mm Hg, while at an altitude of about 10,000 meters, PO_2 in inspired air is 47 mm Hg and alveolar PO_2 is 21 mm Hg. There is a corresponding decrease in the total barometric pressure. The hypoxia at such an altitude stimulates the peripheral chemoreceptors in the carotid body leading to an increase in pulmonary ventilation. The resulting hyperventilation leads to a lot of CO_2 being expelled from the body and this produces respiratory alkalosis.

In order to be able to survive at such an altitude the body makes some adjustments, referred to as acclimatization.

Acclimatization to high altitude includes a great increase in pulmonary ventilation, an increase in red blood cell count brought about by stimulation of the bone marrow by erythropoietin, increase in 2, 3–DPG level which increases oxygen delivery to the tissues, excretion of alkaline urine to correct the alkalosis, an increase in the number of mitochondria in the cells and increased vascularity of the tissues.

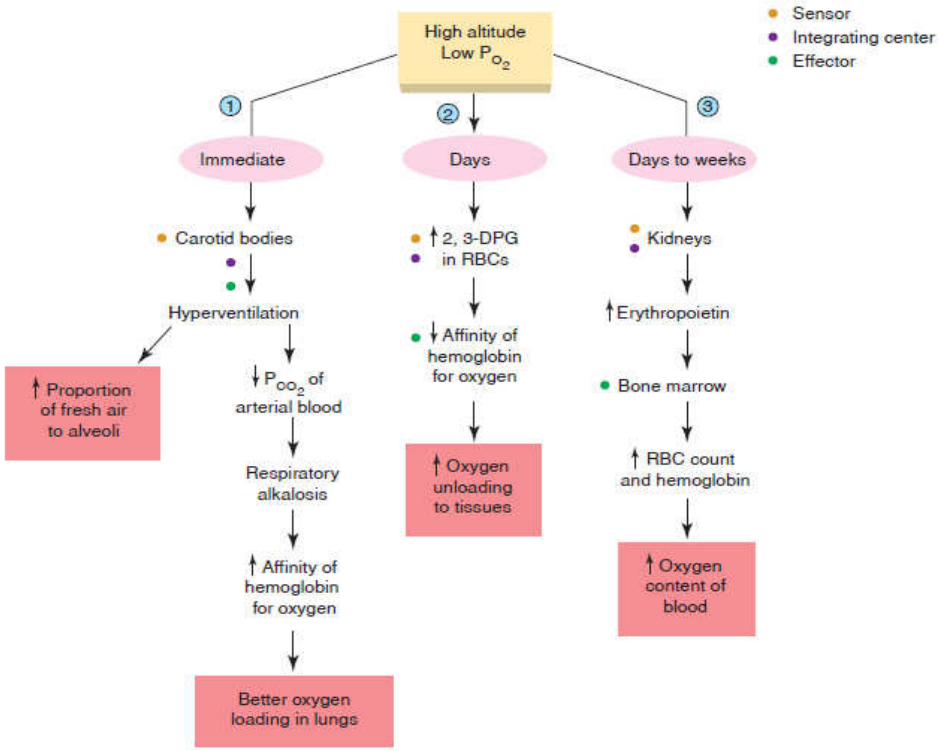

Fig.15: Respiratory Adaptations to a High Altitude

Cyanosis

This is a bluish discoloration of the skin and mucous membrane due to presence of a large quantity of deoxygenated haemoglobin in the blood. Blueness is not often easy to observe in the skin of black Africans except those who are very fair in complexion and in neonates. However, cyanosis can be observed in the tongue, nail bed and buccal mucosa of black Africans. Usually, cyanosis becomes noticeable when the arterial blood contains 5g or more of deoxygenated haemoglobin per 100ml (dl) of blood.

3.4 Deep Sea Diving

When human beings descend beneath the sea, the pressure around them increases tremendously. For every 10 meters of depth in sea-water, pressure on the diver increases by 1 atmosphere. So, at a depth of 31m (100ft) in the ocean, a diver is exposed to a pressure of 4 atmospheres (normal atmospheric pressure + 3 atmospheres due to 31m depth of sea water). In order to prevent the lungs from collapsing, the air breathed by the diver must be supplied under high pressure that is hyperbaric air and the condition of breathing air under high pressure is called hyperbarism. The gases present in the air the diver normally breathes are nitrogen, oxygen and carbon-dioxide. When these gases are breathed under high pressure, especially nitrogen and oxygen, serious physiological effects can result. CO_2 content of inspired air is very low and if there is no re-breathing, CO_2 does not create problems when breathed under high pressure. As the diver descends deeper into the sea, the increased pressure to which he is subjected causes compression of the gases being inspired, leading to a decrease in volume and an increase in pressure according to Boyle's law. The increased pressure causes a lot of nitrogen and oxygen to dissolve in the body fluids and in the tissues. As the depth of descent increases, the quantities of dissolved nitrogen and oxygen increase.

Nitrogen narcosis

At sea level, nitrogen has no effect on body functions, but nitrogen breathed at high pressures can cause varying degree of narcosis. When a diver remains beneath the sea for one hour or more, at about 120ft, the first symptoms of mild nitrogen narcosis appears. The diver becomes unduly jovial and loses many of his cares. At 150 to 200 feet, he becomes drowsy and at 200 to 250 feet, he becomes very weak and becomes too clumsy to perform the work he is supposed to do. At depths greater than 250 feet, the diver becomes almost useless as he can no longer perform any function. The features of nitrogen narcosis are

similar to those of alcoholic intoxication; hence it is often called "raptures of the depths". The mechanism of the narcotic effect of nitrogen is believed to be similar to that of anaesthetic gases.

Decompression sickness (also called bends, Caisson disease, Diver's paralysis).

If a diver stays beneath the sea for a long time, a large quantity of nitrogen will dissolve in his body. If the diver suddenly comes back to the surface of the sea, large quantities of the nitrogen that has been forced into solution will come out of solution and form gas bubbles in the body fluids, both in the intracellular and extracellular fluid compartments. Those bubbles that are in the plasma will flow along with the blood and block some of the small blood vessels (air embolism). These air bubbles can cause damage to any part of the body. The extent of the damage and the associated symptoms depend on the number and sizes of bubbles formed. The latter gives rise to "decompression sickness".

The symptoms of decompression sickness are due largely to the resultant air embolism. This leads to tissue ischaemia and sometimes, tissue death. About 90% of people suffering from decompression sickness develop pain in the joints and muscles of the legs or arms. The joint pain is the reason this condition is also called "bends". Various degrees of disorders of the nervous system such as dizziness, paralysis, collapse and unconsciousness may develop. A small percentage may develop massive pulmonary microembolism, with associated shortness of breath and later, pulmonary oedema. This can lead to death.

Decompression sickness can be avoided if the diver is made to ascend to the surface of the sea gradually over a period of 2 to 5 hours. If a diver is brought slowly to the surface, the dissolved nitrogen is exhaled rapidly enough through the lungs to prevent decompression. Slow ascents over one hour will elimination of about 70% of the dissolved nitrogen, while about 90% will have been eliminated if ascent is carried out in 6 hours.
Another method used to prevent decompression sickness is to bring the diver to the surface quickly and put him in pressurised tank and then lower the pressure inside the tank gradually back to normal atmospheric pressure over a couple of hours. Pressurized tank can also be used to treat the diver in whom the symptoms of decompression sickness have occurred. The diver is recompressed in the tank and then slowly decompressed over several hours.

The use of helium instead of nitrogen in the air mixture breathed by divers engaged in deep dives and stay underwater for long periods has minimised the problem of decompression sickness.

The introduction of SCUBA apparatus (self-contained underwater breathing apparatus) has turned diving into a popular sport. However, because of the limited amount of air a diver can carry in his SCUBA gear, the diver cannot remain for a long time under water, otherwise, he will run out of air.

SAE

1. Explain the process of Chemical control of breathing
2. Describe the chemoreceptors.

4.0 CONCLUSION

Breathing has voluntary, neural and chemical control with appropriate ventilatory responses to oxygen, carbon dioxide concentrations. Respiratory adaptations also occur appropriately in high altitude and in deep sea diving.

5.0 SUMMARY

In this unit, you have leant about the following voluntary and autonomic control of respiration. You also learn about peripheral and central chemoreceptors regulation and ventilatory responses to pH, oxygen lack and carbon dioxide.

i. Neural control of breathing
ii. Chemical control of breathing

6.0 TUTOR- MARKED ASSIGNMENT

1. Conduct the experiments on (1) respiratory movements and effects of various factors (2) measuring lung volumes and capacities.
2. Explain the process of neural control of breathing.
3. How do the body respond to changes in pH, carbon dioxide and oxygen lack?

7.0 REFERENCES/FURTHER READING

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MODULE 4 Heart and Circulatory Physiology

INTRODUCTION

The heart is the known life pump that sustains fluid circulation to all parts of the body for a lifetime. It is an important organ whose function is moderated by the special innervations. In this module, you are going to learn more about how the heart performs its functions and work in with the vessels to maintain the needed pressure for blood to flow round the body.

MODULE OBJECTIVES

At the end of this Module study session, you must be able to:

- describe the structure of the heart and its components
- describe the systemic and the pulmonary circulation
- describe the pacemaker potential and the myocardial action potential
- describe the components of the electrocardiogram (eg)
- describe the short-term and long-term regulation of arterial blood pressure
- describe circulatory shock.

CONTENTS

UNIT 1 THE CIRCULATORY SYSTEM

CONTENTS

1.0 INTRODUCTION

There is a mechanism of fluid movement through the body that allows for change of required nutrients and exchange of different types of wastes. This unit covers the coordinated circulation of blood to different parts of the body.

2.0 OBJECTIVES

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

- explain the concept of haemodynamics
- explain the functional parts of the circulation
- explain the functional divisions of the circulation.

3.0 MAIN CONTENT

3.1 Systemic and Pulmonary Circulation: Haemodynamics

The function of the circulation is to service the needs of the body tissues—to transport nutrients to the body tissues, waste products from the tissue to the excretory organs, hormones from one part of the body to another, and in general, to maintain an appropriate environment in all the tissue fluids of the body for optimal survival and function of the cells. The rate of blood flow through most tissues is controlled in response to tissues need for nutrients. The heart and circulation in turn are controlled to provide the necessary cardiac output and arterial pressure that are required for tissue blood flow.

The circulation is divided into the systemic circulation and the pulmonary circulation. The systemic circulation supplies blood to all the tissues of the body except the lungs, so it is also called the greater circulation or peripheral circulation.

3.2 Functional Parts of the Circulation

Arteries: Are blood vessels that carry blood away from the heart to the lungs and tissues. The arterioles are the last small branches of the arterial system; they act as control conduits through which blood is released into the capillaries and because of their small diameter, they play a key role in vasoconstriction and vasodilatation. Most arteries and arterioles carry oxygenated blood, except the pulmonary artery which transports deoxygenated blood from right ventricle to the lungs.

Capillaries: They are microscopic blood vessels that allow the exchange of fluid, nutrients, electrolytes, hormones, and other substances between the blood and the tissue. To serve this role, the capillary walls are very thin and have numerous minute capillary pores permeable to water and other small molecular substances.

Veins: These are blood vessels that carry blood to the heart, from the lungs and tissues. They serve as a major reservoir of extra blood. Blood pressure in veins is extremely low as a result, valves formed by the tunica internal layer are necessary to prevent backflow. Most veins carry deoxygenated blood, except the pulmonary vein which transports oxygenated blood from the lungs to the left atrium. The venules collect blood from the capillaries, and they gradually coalesce into progressively larger veins.

3.3 Functional Divisions of the Circulation

Systemic Circulation

Systemic circulation is a part of the cardiovascular system which is responsible for carrying oxygenated blood away from the heart to the body, and return deoxygenated blood back to the heart. Oxygen-rich blood from the lungs leaves the pulmonary circulation when it enters the left atrium through the pulmonary veins. The blood is then pumped through the mitral valve into the left ventricle. From the left ventricle, blood is pumped through the aortic valve and into the aorta, the body's largest artery. The aorta arches and branches into major arteries to the upper part of the body before passing through the diaphragm, where it branches further into arteries which supply the lower parts of the body. The arteries branch into smaller arteries, arterioles, and finally capillaries. Waste and carbon dioxide diffuse out of the cell into the blood, while oxygen and nutrients diffuses out of the blood into the interstitial fluid and then into the cell. The deoxygenated blood continues through the capillaries which merge into venules, then veins, and finally the venae cavae, which drain into the right atrium of the heart. From the right atrium, the blood travels through the pulmonary

circulation to be oxygenated before returning again to the system circulation. Coronary circulation, blood supply to the heart muscle itself, is also part of the systemic circulation.

Pulmonary Circulation

Pulmonary circulation is a part of the cardiovascular system which is responsible for carrying de-oxygenated from the heart to the lungs and then back to the heart for it to transfer the oxygenated blood to the rest of the body. Oxygen-depleted blood from the body leaves the systemic circulation when it enters the right atrium through the superior and inferior vena cavae. The blood is then pumped through the tricuspid valve into the right ventricle. From the right ventricle, blood is pumped through the pulmonary valve and into the pulmonary artery. The pulmonary artery splits into the right and left pulmonary arteries and travel to each lung. In the lungs, the blood travels through capillary beds on the alveoli where gaseous exchange occurs, removing carbon dioxide and adding oxygen to the blood. The alveoli are air sacs in the lungs that provide the surface for gas exchange during respiration. The oxygenated blood then leaves the lungs through pulmonary veins, which returns it to the left atrium, completing the pulmonary circuit.

After entering the left heart, the blood flows through the bicuspid valve into the left ventricle. From the left ventricle, the blood is pumped through the aortic valve into the aorta to travel through systemic circulation, delivering oxygenated blood to the body before returning again to the pulmonary circulation.

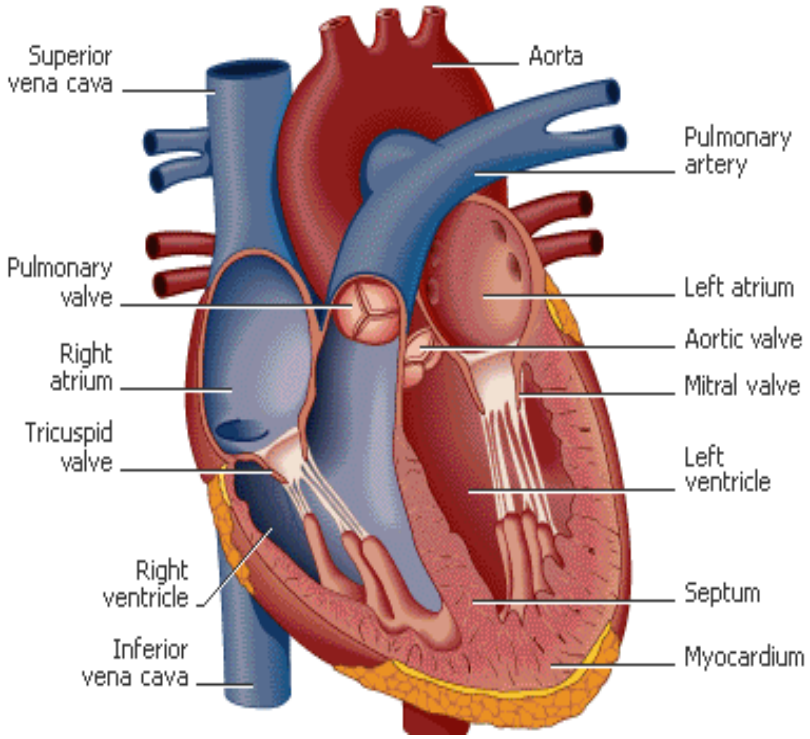

Fig.1.1: The Human Heart

SAE

Explain what happens in pulmonary and systemic circulation.

4.0 CONCLUSION

With blood circulation through the arteries, veins and capillaries, circulation is divided into the systemic circulation and the pulmonary circulation. The systemic or greater circulation supplies blood to all the tissues of the body except the lungs, while the pulmonary circulation covers the movement of de-oxygenated blood from the heart to the lungs and then back to the heart for it to transfer the oxygenated blood to the rest of the body.

5.0 SUMMARY

In this unit, you have learnt about the concept of Haemodynamics, the functional parts of the circulation and the functional divisions of the circulation.

6.0 TUTOR -MARKED ASSIGNMENT

Activity – Laboratory assignment

Answer the following questions:

1. Explain the concept of Haemodynamics
2. Describe the functional parts of the circulation
3.

7.0 REFERENCES/ FURTHER READING

Fox, S.I. (2012). *Human Physiology.* (12th ed.). New York: Mc Graw Hill,.

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UNIT 2 CARDIAC FUNCTIONING

CONTENTS

1.0 INTRODUCTION

The heart is a life pump regulated by special innervations. In this unit, you are going to learn more about how the structuring of the heart supports its functions.

2.0 OBJECTIVES

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

- explain what in details the cardiac muscle
- discuss the cardiac muscle action potential
- explain in details the pacemaker cells
- discuss the cardiac cycle.

3.0 MAIN CONTENT

3.1 The Cardiac Muscle

The heart is a muscular organ which weighs about 250-350 gm in an adult. It has four chambers, two atria and two ventricles. The heart consists of a specialised muscle called cardiac muscle.

Cardiac muscle is similar in structure to skeletal muscle in many ways; however, there are several important differences that can be discerned at the structural level. The electrical activity of cardiac muscle is very different from that of skeletal muscle.

Like skeletal muscle, cardiac muscle is striated. It contains the same basic contractile proteins forming thick and thin filaments that are organised into sarcomeres as they are in skeletal muscle, and the same sliding filament mechanism applies. Cardiac muscle fibers or cardiac cells (i.e. myocytes) also contain myofibrils, a network of T-tubules, and sarcoplasmic reticulum (SR). Force generation and its control by Ca^{2+} are also very similar to skeletal muscle, although cardiac muscle is less dependent on the release of Ca^{2+} from the sarcoplasmic reticulum, and the mechanism of sarcoplasmic reticulum Ca^{2+} release is different (i.e., calcium-induced -calcium release).

Cardiac muscle cells are similar to type I (slow oxidative) skeletal muscle fibers. Cardiac muscle cells depend primarily on oxidative phosphorylation to generate ATP. They are highly resistant to fatigue, but are also highly dependent on a continuous supply of oxygen. Cardiac muscle cells are much shorter than skeletal muscle fibers and they are sometimes branched. A typical ventricular muscle cell is roughly 100 microns long and about 20 microns in diameter.

Individual cardiac muscle cells are joined together by structures called intercalated discs, as shown in Figure 1-2. This is a very important distinction between cardiac and skeletal muscle. There are two types of membrane junctions in the intercalated discs. These are:

(a) desmosomes, which are mechanical adhering junctions which hold the cells together.
(b) gap junctions, which are low resistance electrical connections between adjacent cells.

Gap junctions allow electrical activity (e.g., action potentials) of one cell to spread to adjacent cells. Cardiac muscle cells are electrically coupled to one another, which allow the heart to contract as a unit (a functional syncytium).

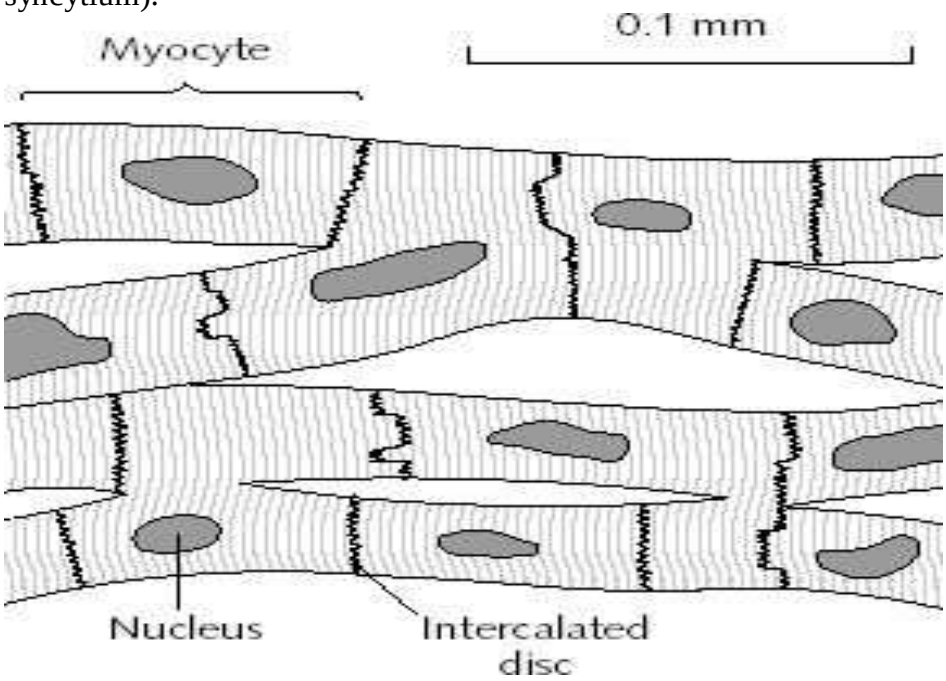

Fig. 2.1: Diagrammatic Section of Cardiac Muscle

3.2 The Cardiac Muscle action Potential

The cardiac muscle has a distinct action potential which is different from that seen in skeletal muscle and is an important adaptation for the functions of the heart.

The cardiac action potential has five phases, as shown in Figure 1-3. During phase 0, membrane permeability to potassium decreases and fast sodium channels open allowing the influx of Na^+, producing rapid depolarisation from −90 mV to +10 mV. During phase 1, there is partial repolarisation, because of a decrease in sodium permeability. Phase 2 is

the plateau phase of the cardiac action potential. Membrane permeability to calcium increases during this phase, maintaining depolarisation and prolonging the action potential. Membrane permeability to calcium decreases to some extent towards the end of phase 2, and the plateau is partially maintained by an inward sodium ion. Sodium flows into the cell through the sodium–calcium exchanger. The exchanger transfers three sodium ions into the cell in exchange for one calcium ion flowing out, and so produces a net inward flow of positive ions. As calcium channels inactivate towards the end of the plateau phase, an inward potassium ion produces repolarisation in phase 3. The resting membrane potential in phase 4 is approximately −90 mV.

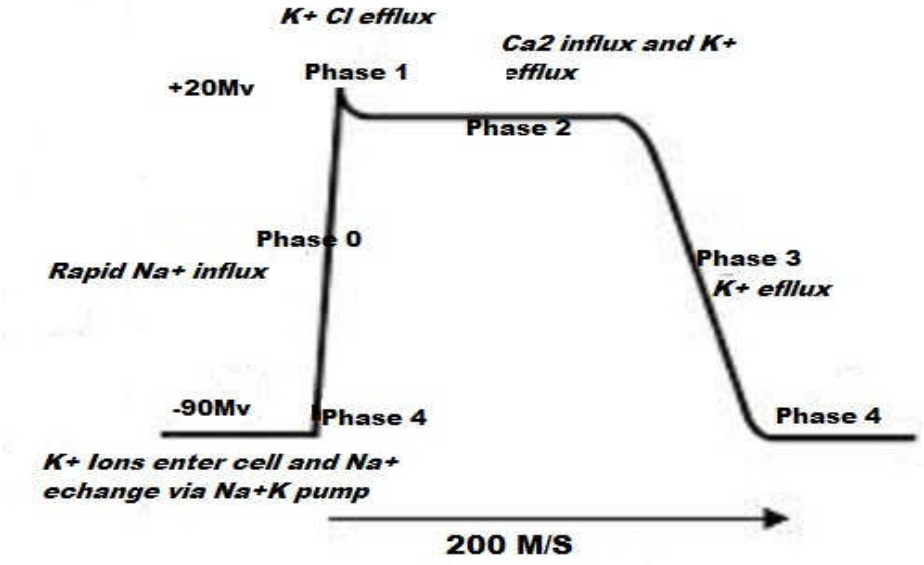

Fig. 2.2: Phases of the Action Potential of a Cardiac Muscle Fibre. 0, depolarisation; 1, rapid repolarisation; 2, plateau phase; 3, late repolarisation

3.3 The Pacemaker Cells

Pacemaker cells are found in the sinoatrial (SA) and atrioventricular (AV) nodes. However, the sinoatrial node has a faster rate of discharge and therefore ordinarily controls the rate of beat of the entire heart and is known as the cardiac pacemaker. The cells of the pacemaker have certain characteristics that enable it to exhibit automatic rhythmicity.

a. The resting membrane potential is -55 to -60 mV in sinoatrial node in comparison with -85 to -90mV in ventricular muscle fibers.

b. The cell membranes of the sinus fibers are naturally leaky to sodium ions and allow the influx of Na^+, thereby neutralizing much of the intracellular negativity.

Between heart beats, influx of Na^+ causes slowly rising membrane potential. When the membrane potential rises to a threshold voltage of about -40 mV, the calcium-sodium channels become activated, leading to rapid entry of both calcium and sodium ions thus eliciting the action potential. However the opening of the calcium and sodium channels is transient and they soon close and the simultaneous opening of K^+ channels leads to efflux of K^+ ions which causes repolarisation effectively terminating the action potential. As the resting membrane potential reaches -55mV to -60mV, the K^+ ions channels close. The inward leaking of Na^+ ions overbalance the efflux of K^+ ions and the resting membrane potential rises again towards the threshold level for discharge. This process is repeated over and over throughout the lifetime of the individual.

3.4 The Cardiac Cycle

The cardiac events that occur from the beginning of one heartbeat to the beginning of the next are called the cardiac cycle or the series of events that occur during one complete heartbeat. Cardiac cycle is divided into two main phases; (i) ventricular diastole (ii) ventricular systole
Figure 2.3 shows the different events during the cardiac cycle. Ventricular diastole refers to ventricular relaxation phase. Events occurring during the diastole include; isovolumetric (isovolumic) relaxation, rapid passive filling, slow filling (diastasis), rapid active filling (atrial contraction).

After the ventricles have ejected the blood into the arteries, the aortic and pulmonary valves close. As the ventricles relax there is isovolumetric relaxation i.e. no change in volume as the ventricles relax, because all the four valves are closed. This relaxation with no change in volume leads to a reduction in the pressure in the ventricle. Simultaneously blood flowing into atria from inferior and superior vena cavae and the pulmonary veins cause an increase in the pressure in the atria. When the pressure in the atria rises above that in the ventricles, the atrio-ventricular valves are forced open and blood rushes rapidly into the ventricles. About 75 percent of blood entering the ventricles does so by this passive means (rapid passive filling). The remaining 25 percent is forced into the ventricles by contraction of atria (rapid active filling). At this point the ventricles begin to contract and there is sudden closure of the atrioventricular valves. (This gives rise to the first heart sound).

Ventricular systole refers to period of ventricular contraction. Events occurring during ventricular systole include; isovolumetric (isovolumic) contraction, ventricular ejection.

The ventricles continue to contract with four valves again closed. This phase is called the isovolumetric contraction. During this phase the pressure in the ventricles rises rapidly until they exceed that in pulmonary artery and aorta. The aortic and pulmonary valves are pushed open and blood is ejected into the aorta and pulmonary arteries (ventricular ejection). The ejection continues leading to drop of pressure in the ventricles until the pressure in the aorta and pulmonary artery exceeds that in the ventricles. There is thus a tendency for the blood to flow back which is prevented by closure of the aortic and pulmonary valves. (This gives rise to the second heart sound). Once the pulmonary and aortic valves are closed, all four valves are again closed and isovolumetric relaxation of the ventricles begins thereby completing the cardiac cycles. On average, the cycle is repeated every 0.8 seconds i.e. 72 cycles per minute.

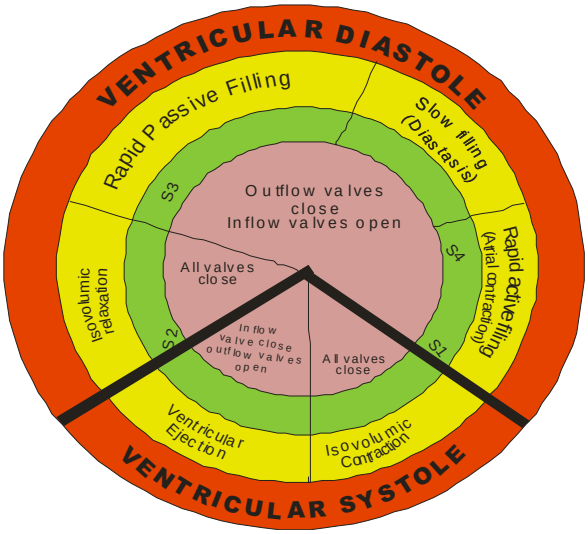

Fig. 2.3: Annotated Diagram of Cardiac Cycle

Wiggers diagram is a standard diagram in cardiovascular physiology to illustrate the haemodynamic consequences of cardiac cycle (Figure 1-5). The X-axis contains the time. The Y-axis contains; Blood pressure; ventricular pressure, aortic pressure and atrial pressure, Ventricular volume changes, Electrocardiogram, Phonocardiogram (optional).

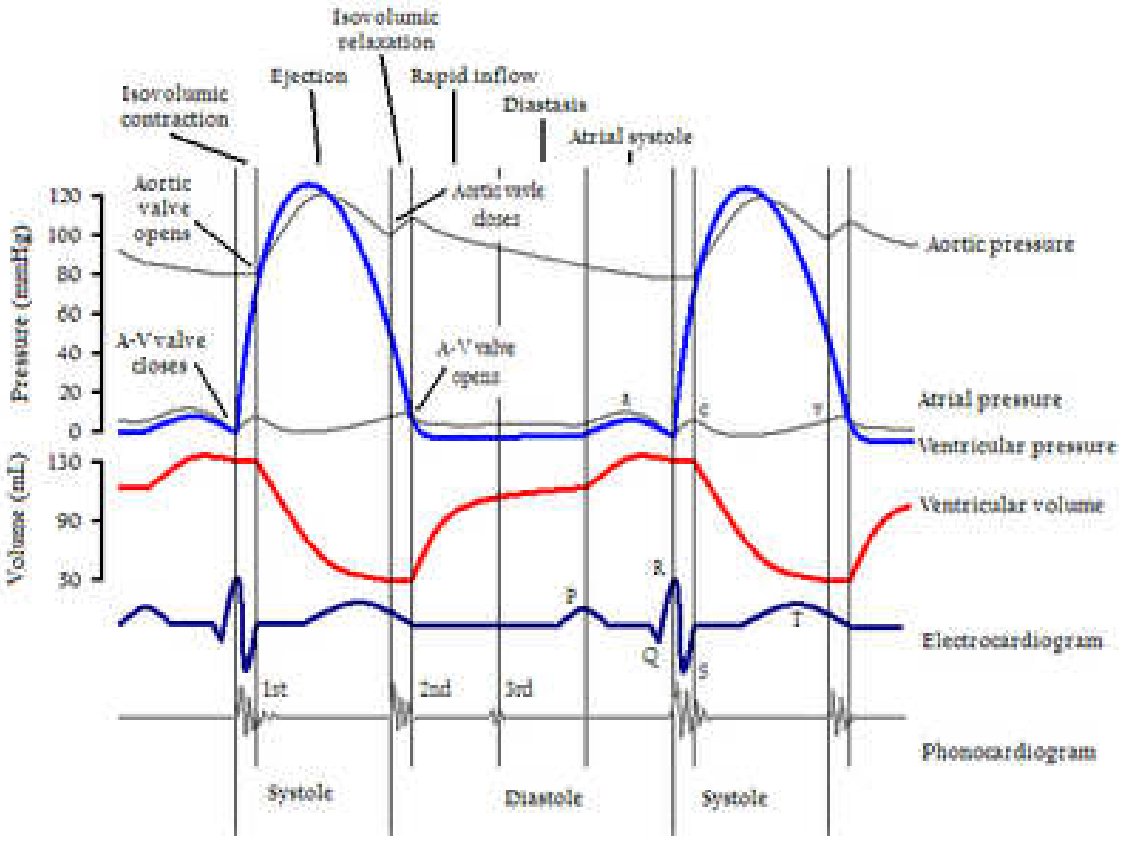

Fig. 2.4: Wiggers Diagram

SAE

Discuss the Cardiac Muscle Action Potential.

4.0 CONCLUSION

The heart is made of special cardiac muscles with a distinct action potential which is different from that seen in skeletal muscle and is an important adaptation for the functions of the heart.

5.0 SUMMARY

In this unit you have learnt about the Cardiac Muscle, the Cardiac Muscle Action Potential, the Pacemaker cells and the Cardiac Cycle and you should be able to explain the describe how the the cardiac muscle is specially made to perform its unique functions within these contexts.

6.0 TUTOR- MARKED ASSIGNMENT

Activity- See Laboratory instructions

Answer the following questions:

a. Explain in details the Cardiac Muscle.
b. Explain in details The Pacemaker cells.
c. Discuss the Cardiac Cycle.

7.0 REFERENCES/ FURTHER READING

Fox, S.I. (2012). *Human Physiology.* (12th ed.). New York: Mc Graw Hill.

Ganong, W.F. (2019). *Review of Medical Physiology.* (26th ed.). New York: Mc Graw Hill.

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UNIT 3 ELECTROCARDIOGRAPHY

CONTENTS

1.0 INTRODUCTION

The heart sustains some electrical charges that are measurable to explain the functioning of the heart. In this unit, you are going to learn about electrocardiography.

2.0 OBJECTIVES

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

- give detailed explanation about electrocardiography
- explain the different waves and complexes that electrocardiography is composed of
- define ECG and list different types of ECG leads used in ECG recording.

3.0 MAIN CONTENT

3.1 Electrocardiography

Electrocardiography is a trans thoracic (across the thorax or chest) interpretation of the electrical activity of the heart over a period of time, as detected by electrodes attached to the outer surface of the skin and recorded by a device external to the body. By placing electric contact points called electrodes at suitable locations on or within the body, the electrical impulses could be detected, amplified and transcribed into graphic record by the instrument called electrocardiograph (ECG Machine). The graphic record of the heart electrical activities recorded from the body surface constitutes what is known as electrocardiogram (ECG) while the graphic record obtained directly from heart muscle is called electrogram. Electrocardiogram (ECG) is the graphic record of

the electrical activities of the heart detected at the body surface by the aid of electrodes and lead system. The electrocardiogram (ECG) is simply a voltmeter that uses up to 12 different leads (electrodes) placed on designated areas of the body.

Electrical impulses of the heart are in form of waves of depolarisation and repolarisation. The waves represent the time-dependent electrical activities of the different regions of the heart that are transcribed on the graph paper as either upward (positive) or downward (negative) deflections separated by isoelectric lines. The pictogram formed from the deflections constitutes what is called electrocardiogram as denoted by PQRST complex, shown in Figure 1-6. The denotations can be measured in terms of magnitude, duration, orientation and shape. The various parameters had been standardised. Therefore, alterations in the standard pattern provide clues for the diagnosis of some cardiac lesions at a particular time.

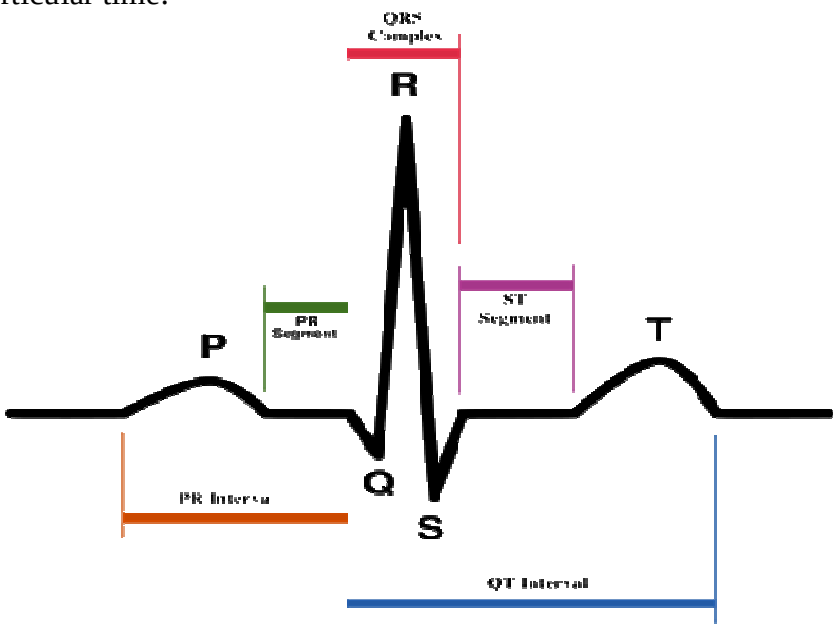

Fig. 3.1: A Normal Electrocardiogram

The electrocardiogram is composed of waves and complexes. Waves and complexes in the normal sinus rhythm are the P wave, PR interval, PR segment, QRS complex, ST segment, QT interval and T wave.

The P Wave

The P wave is caused by atrial Depolarisation. The P wave is usually smooth and positive. The P Wave duration is normally less than 0.12 Sec and the amplitude is normally less than 0.25 Mv. A negative P-wave can indicate depolarisation arising from the av node.

The P-R Segment
The PR segment is the portion on the ECG wave from the end of the P wave to the beginning of the QRS complex. The PR segment corresponds to the time between the ends of atrial depolarisation to the onset of ventricular depolarisation. It is an isoelectric segment, during which the impulse travels from the AV node through the conducting tissue (bundle branches, and Purkinje fibers) towards the ventricles.

The P-R Interval
The PR interval is the portion of the ECG wave from the beginning of the P wave (onset of atrial depolarisation) to the beginning of the QRS complex (onset of ventricular depolarisation). it is normally 0.12 - 0.20 seconds.

The Q Wave
This is the first negative deflection in ventricular depolarisation (QRS complex).

The R Wave
It is the first positive deflection in ventricular depolarisation.

The S Wave
This is the second negative deflection in ventricular depolarisation or the first negative deflection after R wave.

The QRS Complex
The QRS complex represents the time it takes for depolarisation of the ventricles to occur. The normal QRS interval range is from 0.04 sec - 0.12 sec measured from the first deflection to the end of the QRS complex.

The ST Segment
It is the isoelectric line from the end of ventricular depolarisation to the beginning of ventricular repolarisation. No electrical activity is recorded during this period.

The T Wave
The T wave is due to ventricular repolarisation .The wave is normally round and positive.

The QT Interval
The QT interval begins at the onset of the QRS complex and ends at the end of the T wave. It is the period from the onset of ventricular depolarisation to the end of ventricular repolarisation.

U Wave
It refers to any wave between T and P- waves.

3.2 ECG Leads

Lead may refer to the tracing of the voltage difference between two of the electrodes and is what is actually produced by the ECG recorder. Each will have a specific name. For example "Lead I" (lead one) is the voltage between the right arm electrode and the left arm electrode, whereas "Lead II" (lead two) is the voltage between the right limb and the feet. This rapidly becomes more complex as one of the "electrodes" may in fact be a composite of the electrical signal from a combination of the other electrodes. Twelve of these types of leads form a "12-lead" ECG.

There are three types of ECG leads used in ECG recording:

a. Standard limb leads
b. Augmented unipolar limb leads
c. Chest (precordial) leads

Standard Limb Leads
The leads are grouped depending on their anatomical placement on the body surface. These include:

Limb (Extremity) Leads
In both the 5- and 12-lead configuration, leads I, II and III are called limb leads. The electrodes that form these signals are located on the limbs—one on each arm and one on the left leg. The limb leads form the points of what is known as Einthoven's triangle (Figure 1-7).
Lead I is the voltage between the (positive) left arm (LA) electrode and right arm (RA) electrode: I = LA − RA.
Lead II is the voltage between the (positive) left leg (LL) electrode and the right arm (RA) electrode: II = LL − RA.
Lead III is the voltage between the (positive) left leg (LL) electrode and the left arm (LA) electrode: III = LL − LA.
In a 12-lead ECG, all leads besides the limb leads are unipolar (aVR, aVL, aVF, V1, V2, V3, V4, V5, and V6).

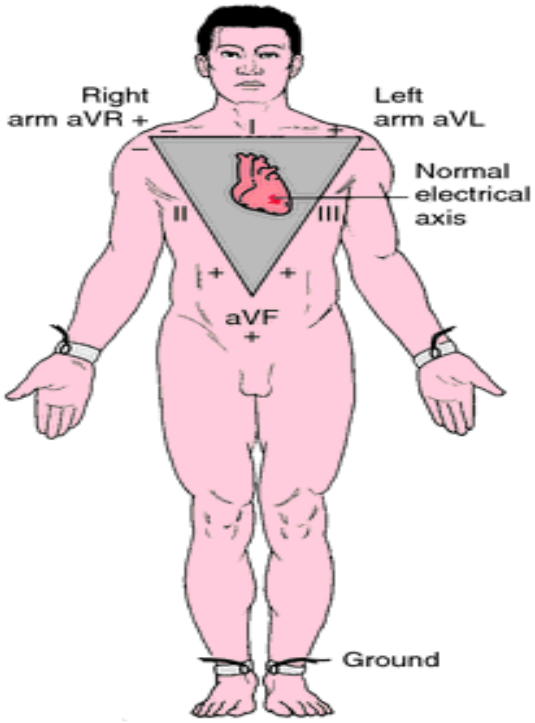

Fig. 3.2: Einthoven Triangle, Illustrating the Galvanometer Connections for Standard Limb Leads I, II and III

Augmented Unipolar Limb Leads

Augmented limb leads are aVF, aVL, aVR. They are described by Goldberger and are unipolar. The leads are connected by special mechanism, which allows for augmentation of the electrical activities of the heart. The positive pole of the augmented limb lead is at right arm for aVR, left arm for aVL and left leg for aVF. While recording from such a lead, the other limbs that are not used as the positive pole are connected to a central terminal or indifferent electrode which has zero potential. Thus, there is augmentation of the electrical activities by 50%. The lines of force of the augmented limb leads form an equilateral triangle.

Lead augmented vector right (aVR) has the positive electrode (white) on the right arm. The negative electrode is a combination of the left arm (black) electrode and the left leg (red) electrode, which "augments" the signal strength of the positive electrode on the right arm:

$$aV_R = RA - \tfrac{1}{2}(LA + LL).$$

Lead augmented vector left (aVL) has the positive (black) electrode on the left arm. The negative electrode is a combination of the right arm

(white) electrode and the left leg (red) electrode, which "augments" the signal strength of the positive electrode on the left arm:

$aV_{L} = LA - ½ (RA + LL)$

Lead augmented vector foot (aVF) has the positive (red) electrode on the left leg. The negative electrode is a combination of the right arm (white) electrode and the left arm (black) electrode, which "augments" the signal of the positive electrode on the left leg:

$aV_{F} = LL - ½ (RA + LA)$.

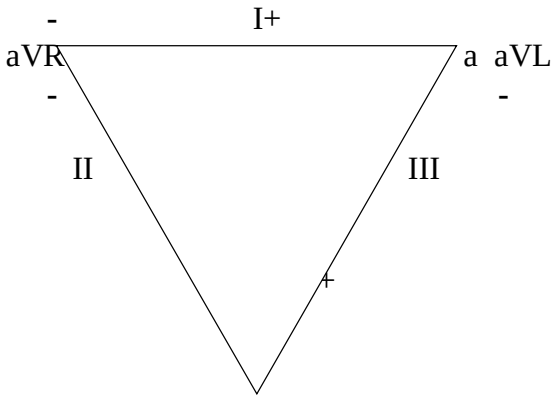

Fig. 3.3: The Standard ECG Leads Electrodes

Chest (Precordial) Leads

The electrodes for the precordial leads (V1, V2, V3, V4, V5 and V6) are placed directly on the chest (Figure 1-9). Because of their close proximity to the heart, they do not require augmentation. The precordial leads view the heart's electrical activity in the horizontal plane. The heart's electrical axis in the horizontal plane is referred to as the Z axis.
The chest leads are arranged on the chest wall in horizontal plane:

V_1 : 4^{th} intercostal space, right sternal edge
V_2 : 4^{th} intercostal space, left sternal edge
V_3 : mid-way between V_2 and V_4
V_4: 5^{th} intercostal space, midclavicular line
V_5: 5^{th} intercostal space, anterior axillary line
V_6: 5^{th} intercostal space, mid-axillary line

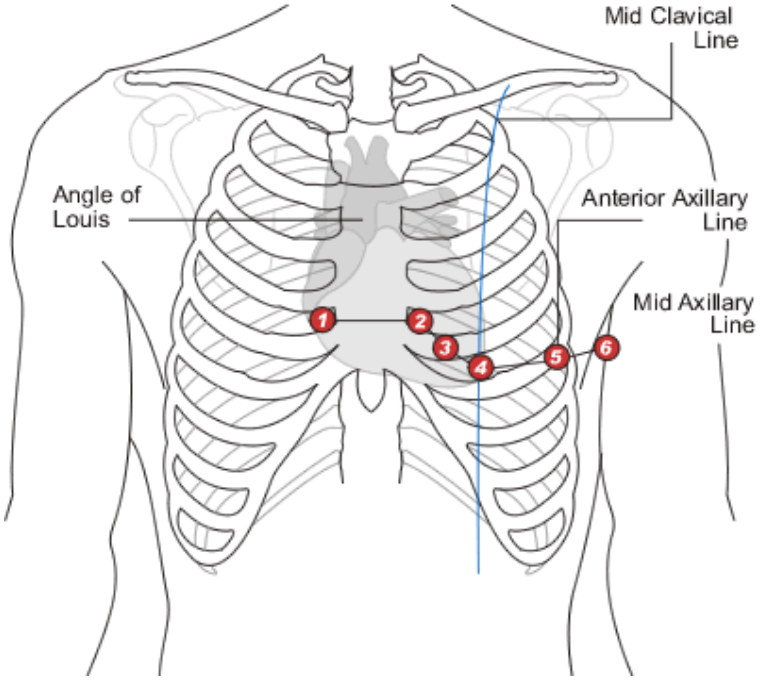

Fig. 3.4: Chest Lead Positions

SAE

Describe the different types of ECG leads used in ECG recording?

4.0 CONCLUSION

In this unit, we discussed about Electrocardiography, the different waves and complexes that Electrocardiography is composed of, ECG and different types of ECG leads used in ECG recording. Please determine how much you have learnt to see how much you can recollect about each of these.

5.0 SUMMARY

In this unit, you have learnt about Electrocardiography, the different waves and complexes that Electrocardiography is composed of, ECG and different types of ECG lead used in ECG recording. Please determine how much you have learnt to see how much you can recollect about each of these.

6.0 TUTOR -MARKED ASSIGNMENT

Activity – See Laboratory assignment as provided by the facilitator.

Answer the following questions:

1. What is electrocardiography?
2. Explain the different waves and complexes of Electrocardiography

7.0 REFERENCES /FURTHER READING

Fox, S.I. (2012). *Human Physiology.* (12th ed.). New York: Mc Graw Hill,.

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UNIT 4 CARDIAC OUTPUT AND CONTROL OF CARDIAC OUTPUT

CONTENTS

1.0 INTRODUCTION

The ability of the body to get the desirable nutrients are subject to high well the heart sends its output out for every act of pumping. In this unit, you are going to learn more about per minute functioning of the heart as such relates to some of the measures that you take to determine the health status of clients. In this unit, you will cover the concept of cardiac

output, regulation of the heart rate and the regulation of the stroke volume.

2.0 OBJECTIVES

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

- explain what cardiac output is
- discuss the control of cardiac output
- explain how heart rate is regulated
- explain regulation of stroke volume and its determinants.

3.0 MAIN CONTENT

3.1 Cardiac Output

Cardiac output is defined as the volume of blood ejected by each ventricle per minute. It is a function of heart rate and stroke volume. The heart rate is simply the number of heart beats per minute. The stroke volume is the volume of blood, in milliliters (mL), pumped out of the heart with each beat. Increasing either heart rate or stroke volume increases cardiac output.

Cardiac Output in mL/min = heart rate (beats/min) X stroke volume (mL/beat).

An average person has a resting heart rate of 70 beats/minute and a resting stroke volume of 70 mL/beat. The cardiac output for this person at rest is:

Cardiac Output = 70 (beats/min) X 70 (mL/beat) = 4900 mL/minute.
The average basal cardiac output is 5L per minute in adults. This can be increased tremendously in exercise or other conditions demanding increased blood supply to the body tissues.

Thus, cardiac output can be increased either by increasing the heart rate or by increasing the stroke volume or by increasing both heart rate and stroke volume.

3.2 Control of Cardiac Output

Since cardiac output is a product of heart rate and stroke volume, variations in cardiac output can be produced by changes in heart rate or stroke volume or both stroke volume and heart rate.

3.3 Regulation of Heart Rate

The sinoatrial (SA) node of the heart is innervated by both sympathetic and parasympathetic nerve fibers. Under conditions of rest the parasympathetic fibers release acetylcholine, which acts to slow the pacemaker potential of the SA node and thus reduce heart rate. Under conditions of physical or emotional activity sympathetic nerve fibers release norepinephrine which acts to speed up the pacemaker potential of the SA node thus increasing heart rate. Sympathetic nervous system activity also causes the release of epinephrine from the adrenal medulla. Epinephrine enters the blood stream, and is delivered to the heart where it binds with SA node receptors leading to further increase in heart rate.

3.4 Regulation of Stroke Volume

Stroke volume (SV) is the volume of blood pumped from one ventricle of the heart with each beat. The stroke volume is determined by two main factors:

i. Nervous stimuli
ii. End – diastolic length of cardiac muscle fibers.

Sympathetic nerve stimulation makes the myocardial muscle fibres contract with greater strength, while parasympathetic nerve stimulation has the opposite effect. Increase in strength of contraction without a concomitant increase in length of muscle fibre leads to increased stroke volume and reduced end –systolic volume. Increase in heart rate caused by catecholamines released by sympathetic stimulation is referred to as their chronotropic action, while their effect on the force of contraction is called their inotropic action. Factors that increase the force of cardiac contraction are said to be positively inotropic and those that decrease it are said to be negatively inotropic.

The end-diastolic length of cardiac muscle fibres is also an important determinant of cardiac output. The length of the cardiac muscle fibres is determined by how much filling of blood the ventricles received during diastole. The degree to which the ventricular muscle is stretched before it contracts is called preload. It has been shown that the more the cardiac muscle fibres are stretched before they contract, the greater is the force of contraction. This relationship holds as long as the muscle is not over-stretched to cause damage to the contractile tissues. The relationship of muscle length to the tension developed is known as Starlings law of the heart or Frank-Starling law.

SAE

Explain the determinants and regulation of the stroke volume.

4.0 CONCLUSION

Cardiac output is the volume of blood ejected by each ventricle per minute and this is the function of heart rate and stroke volume. The heart rate is the number of heart beats per minute.

5.0 SUMMARY

In this unit, you have learnt about the cardiac output, the control of cardiac output, the regulation of heart rate and the regulation of stroke volume.

6.0 TUTOR- MARKED ASSIGNMENT

Activity – As given by the Facilitator

Answer the following questions:

1. Explain what Cardiac Output is
2. Discuss the Control of cardiac output
3. Explain how heart rate is regulated

7.0 REFERENCES/ FURTHER READING

Fox, S.I. (2012). *Human Physiology.* (12th ed.). New York: Mc Graw Hill.

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UNIT 5 ARTERIAL BLOOD PRESSURE

CONTENTS

1.0 INTRODUCTION

The nurse measures the arterial blood pressure of the clients as a basic assessment of the wellbeing of the person. In this unit, your knowledge of this procedure will be better enhanced.

2.0 OBJECTIVES

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

- explain the concept of arterial blood pressure
- explain the determinants of arterial pressure
- describe how to measure arterial blood pressure accurately
- explain the regulatory process of arterial blood pressure.

3.0 MAIN CONTENT

3.1 Arterial Blood Pressure

The force which the blood exerts on the walls of the blood vessels is called blood pressure. This is the force exerted when the blood flows through the arteries. Arterial pressure changes continuously throughout each cardiac cycle. The highest pressure reached during systole is termed systolic arterial pressure and the lowest pressure reached during diastole is called diastolic arterial pressure. The pulse pressure is the difference between these two values i.e. systolic pressure – diastolic pressure. Mean arterial pressure is the average pressure during the cardiac cycle. Mean arterial pressure is given by the formula:

Mean pressure = diastolic pressure + 1/3 of pulse pressure

Blood pressure is given by the formula: B.P = C.O x P.R. Where C.O is the cardiac output and P.R is the peripheral resistance.

Blood pressure can be varied by changing the cardiac output or by changing both PR and CO. Therefore, all factors affecting cardiac output and peripheral resistance will influence arterial pressure. The normal values of blood pressure for a given population show a fairly wide range in its distribution and also increase with age. The systolic blood pressure in person below 50 years of age ranges from 90 – 140 mm Hg, while the diastolic pressure ranges from 60-90 mm Hg. With increasing age, both systolic and diastolic pressures will increase.

Blood is pumped out of the heart at an average pressure of 120 mm Hg during systole.

3.2 Determinants of Arterial Pressure

There are some factors necessary for the maintenance of normal blood pressure, which are called local factors, mechanical factors or determinant of blood pressure. These factors are divided into two types called central factors and peripheral factors.

Central factors are related to the heart. These factors are (i) cardiac output and (ii) heart rate.

Peripheral factors are the factors pertaining to blood vessels. The following are the peripheral factors determining arterial blood pressure.

(1) Peripheral resistance
(2) Blood volume
(3) Venous return
(4) Elasticity of blood vessels
(5) Velocity of blood flow
(6) Diameter of blood vessels
(7) Viscosity of blood

Cardiac Output
Whenever the cardiac output is increased, the systolic blood pressure is increased and, when cardiac output is less, the systolic blood pressure is reduced. Cardiac output depends upon blood volume, venous return, heart rate and force of contraction. Cardiac output is directly proportional to blood volume. When blood volume increases, ventricular

filling is more, cardiac output is more and pressure rises. When the blood volume is reduced, the cardiac output is less and blood pressure falls.

Heart Rate
Moderate changes in heart rate do not affect arterial blood pressure much. However, marked alteration in the heart rate affects the blood pressure by altering diastolic period and stroke volume.

Peripheral Resistance
This is an important factor which maintains diastolic blood pressure. The diastolic blood pressure is directly proportional to peripheral resistance. When peripheral resistance is decreased, diastolic pressure is less and when peripheral resistance is more, the diastolic pressure rises.

Blood Volume
Blood pressure is directly proportional to blood volume. Blood volume maintains the blood pressure through the venous return and cardiac output. If the blood volume is more, there is increase in venous return and cardiac output resulting in elevation of blood pressure. Blood pressure is increased in polycythemia vera because of increased blood volume. The decrease in blood volume causes fall in blood pressure because of reduced cardiac output. This occurs in conditions like diarrhea, vomiting and other conditions of dehydration and hemorrhage.

Venous Return
Blood pressure is directly proportional to venous return. When venous return is more, there is increase in ventricular filling and cardiac output resulting in elevation of arterial blood pressure.

Elasticity of Blood Vessels
Blood pressure is inversely proportional to the elasticity of blood vessels. Due to the elastic property, the blood vessels are distensible and are able to maintain the pressure. When the elastic property is lost, the blood vessels become rigid and atherosclerosis causes elevated pressure. It occurs in old age. The deposition of cholesterol, fatty acids and calcium ions, produce rigidity of blood vessels and atherosclerosis leading to increased blood pressure.

Velocity of Blood Flow
The pressure in a blood vessel is directly proportional to the velocity of blood flow. If the velocity of the blood flow is more, the resistance is increased hence; the blood pressure is also increased.

Diameter of Blood Vessels
The arterial blood pressure is inversely proportional to the diameter of the blood vessels. If the diameter of arteries and arterioles decreases, the peripheral resistance is more and thereby, the blood pressure is elevated.

Viscosity of Blood
Arterial blood pressure is directly proportional to the viscosity of blood. When viscosity of blood is increased, the resistance is increased and thereby the blood pressure increases. In polycythemia and high content of plasma proteins, the viscosity of blood is increased causing increase in blood pressure. In anaemia, the reduced viscosity decreases the blood pressure.

3.3 Measurement of Arterial Blood Pressure

The first documented measurement of blood pressure was accomplished by Stephen Hales (1677–1761), an English clergyman and physiologist. Hales inserted a cannula into the artery of a horse and measured the heights to which blood would rise in the vertical tube. The height of this blood column bounced between the systolic pressure at its highest and the diastolic pressure at its lowest, as the heart went through its cycle of systole and diastole. This method is invasive in that it involves penetrating the body tissues to reach the artery. Although the invasive technique is used frequently in experimental animals, it is not often suitable for use in man. Clinically, arterial blood pressure is measured indirectly by using a sphygmomanometer. The sphygmomanometer comprises an inflatable rubber cuff covered by a layer of non-distensible fabric and this is attached to a mercury manometer. The rubber cuff is usually wrapped around the upper arm (about the middle third of the upper arm). There is a rubber hand-pump attached to the rubber cuff and pressure in the cuff can be altered by pumping air into the cuff to increase its pressure or releasing the air through a needle value to decrease the pressure (Figure 8-1).

Fig. 5.1: Measurement of Blood Pressure: Use of the Sphygmomanometer

There are two methods of measuring arterial blood pressure using the sphygmomanometer. These are:

i. By palpation
ii. By auscultation

The two methods are often combined during sphymomanometry (this is the process of measuring blood pressure using a sphygmomanometer). In the palpation method, the radial pulse is palpated and the palpating fingers are kept on the radial artery while the pressure in the sphygmomanometer cuff already wrapped round the arm is gradually increased. The reading of the mercury manometer at the point when the radial pulse can no longer be felt is the systolic pressure. The cuff pressure is increased further by about 50 mm Hg above the point of disappearance of the radial pulse. Then the second method, the auscultatory method, is carried out. At the peak of inflation of the cuff, a stethoscope is placed over the lower end of the branchial artery in the cubital fossa of the elbow joint (the artery is usually medial to the tendon of the biceps muscle at the cubital fossa). The pressure in the cuff is reduced gradually while the observer is listening with the stethoscope for any sound from the point of auscultation. When the cuff pressure has fallen to just below the systolic pressure, a clear, but often faint, tapping sound is suddenly heard. The cuff pressure at which the tapping sound is suddenly heard is the systolic pressure. As the cuff pressure is reduced further, the tapping sound becomes louder until it

gets to a point when the sound becomes muffled and rapidly grows fainter. Finally, the sound disappears. The diastolic pressure is the pressure at which muffling occurs.

The sound heard at the cubital fossa during auscultation is called Korotkoff sounds. It is named after a Russian physiologist who first described these sounds in 1905. Korotkoff sound is produced at the peak of each systole by the transient and turbulent blood flow through the partially occluded branchial artery. It is not the same as heart sounds and it is not heard in a fully opened artery, in which flow is non-turbulent. This is why the sound disappears at pressure below the diastolic pressure when blood flow is no longer turbulent.

3.4 Regulation of Arterial Blood Pressure

The maintenance of arterial blood pressure within a range of values consistent with health is mediated by two types of response. There are rapid, short-term adjustments and long-term adjustments.

Short-term adjustment are intended to correct temporary imbalances of pressure such as those caused by postural change, exercise or haemorrhage; short-term adjustment is usually a series of autonomic reflex responses mediated via the cardiovascular centres in the medulla i.e. baroreceptors reflex.

Long–term arterial blood pressure regulation is usually concerned with the balance between extracellular fluid and blood volume on the one hand and the renal mechanisms controlling urine output on the other hand. Renal urine output involves pituitary –adrenal cortical mechanisms which control water and sodium excretion by the kidney. Disturbances of this renal process may result in gradual increase in arterial blood pressure and if continued, it can lead to persistent elevation of blood pressure called hypertension.

Baroreceptor Reflex
The baroreceptor reflex is one of the body's homeostatic mechanisms for maintaining blood pressure. It provides a negative feedback loop in which an elevated blood pressure reflexively causes heart rate to decrease and also causing blood pressure to decrease; likewise, decreased blood pressure activates the baroreceptors, causing heart rate to increase, and also causing an increase in blood pressure.

The baroreceptors are stretch receptors located in the carotid sinuses (the slightly widened areas of the internal carotid arteries at their points of origin from the common carotid arteries) and in the aortic arch (Figure

1-41). Impulses arising in the carotid sinus travel up through afferent fibres in the sinus nerve, which is a branch of the glossopharyngeal nerve (IX^{th} cranial nerve) and synapse at the vasomotor center (VMC). Impulses arising from the aortic arch reach the VMC via afferent fibres in the vagus nerve (X^{th} cranial nerve).

When there is an increase in blood pressure, the baroreceptors are stretched, and this leads to increased discharge of afferent impulses through the IX and X cranial nerves to the VMC. These afferent impulses are inhibitory to the tonic activity of the VMC. Their effect is to reduce the sympathetic outflow to the arterioles.

This leads to vasodilatation and a reduction in blood pressure. In addition to the effects on the VMC, afferent impulses from the baroreceptors stimulate the cardioinhibitory centre, leading to a reduction in heart rate and force of contraction of the myocardium. The latter effects lead to a reduction in cardiac output and the combined effects of reduced peripheral resistance and cardiac output result in decrease of blood pressure.

When there is a fall in blood pressure, the reverse of the above responses occur. There is reduced stretching of the baroreceptors, less inhibitory afferent impulses are sent to the VMC and cardiac centre. As a result of this, there is increased sympathetic discharge to the blood vessels resulting in vasoconstriction and increased peripheral resistance. There is also reduced stimulation of the cardioinhibitory centre so that heart rate and force of cardiac contraction are increased leading to increased cardiac output. The combination of increased peripheral resistance and cardiac output result in increased of blood pressure. The response of the baroreceptors to increased or reduced blood pressure operate on a negative feedback mechanism and a careful adjustment of the responses to a rise or fall in blood pressure helps in maintaining a constant blood pressure.

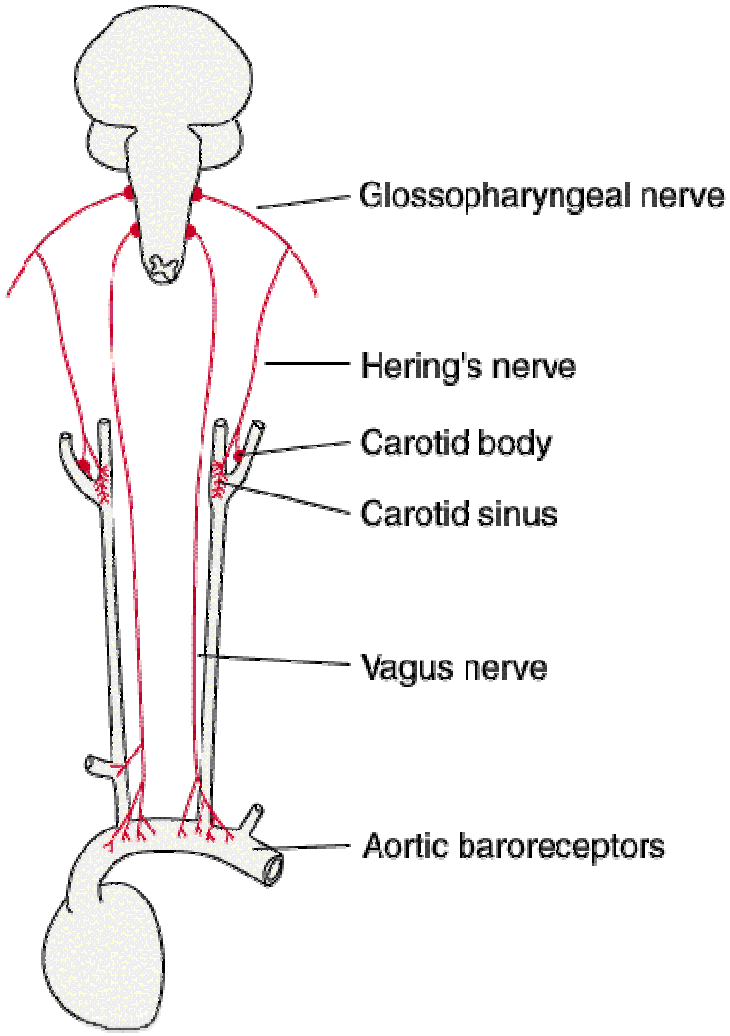

Fig. 5.2: The Baroreceptor System for Controlling Arterial Pressure

Renin – Angiotensin – Aldosterone System
The kidneys play an important role in the long term regulation of arterial blood pressure. Kidneys regulate arterial blood pressure in two ways:

(1) By regulation of extracellular fluid volume
(2) Through renin-angiotensin mechanism

By Regulation of Extracellular Fluid Volume
When the extracellular fluid volume increases, the blood volume also increases. This will tend to increase the arterial blood pressure.

However, when the pressure is increased, the kidneys excrete more water and salt, particularly sodium. This reduces extracellular fluid volume and, in turn the arterial blood pressure is reduced.

Even slight increases in blood pressure can double the water excretion which is known as pressure diuresis. Elevated blood pressure also leads to sodium excretion, which is called pressure natriuresis. When blood pressure falls due to decreased extracellular fluid volume, the reabsorption of water from renal tubules is increased and the volume of extracellular fluid is restored.

Through Renin – Angiotensin Mechanism
When there is a fall in blood pressure, special cells in the kidney collectively called juxtaglomerular apparatus detect the change and release renin into the bloodstream. Renin converts angiotensinogen the inactive forms of angiotensin, which is produced by the liver, to angiotensin I. Angiotensin I is converted to angiotensin II by angiotensin converting enzyme (ACE) in the lungs. Angiotensin II acts in two ways to increase arterial blood pressure.

(i) It causes constriction of arterioles in the body so that the peripheral resistance is increased, and blood pressure rises. Simultaneously, constriction of afferent arterioles in kidney causes retention of water and salts so that, the volume of extracellular fluid is increased. This in turn restores the normal blood pressure.
(ii) Angiotensin II also stimulates adrenal cortex to secrete aldosterone. This increases reabsorption of sodium from renal tubules. Sodium reabsorption is followed by water reabsorption and thereby extracellular fluid volume is increased and blood pressure becomes normal.

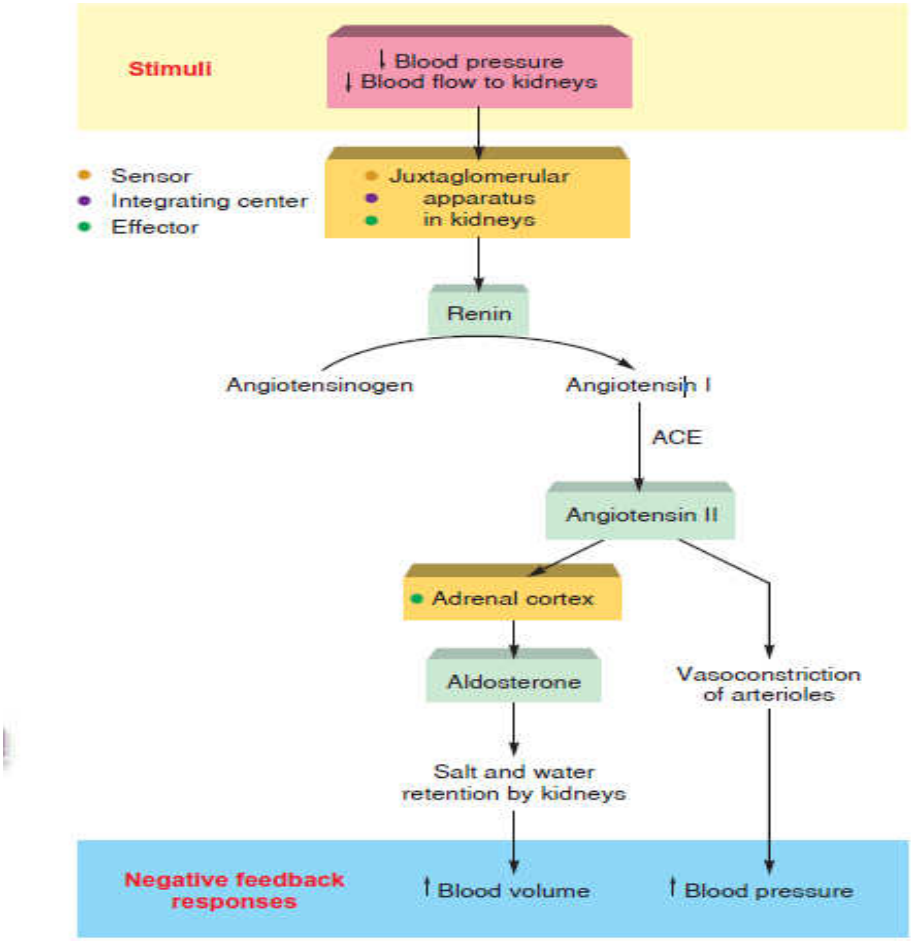

Fig. 5.3: Renal Regulation Of Blood Pressure By Renin - Angiotensin Mechanism

SAE

Explain the various factors that determine the arterial pressure.

4.0 CONCLUSION

The force which the blood exerts on the walls of the blood vessels is called blood pressure. This is the force exerted when the blood flows through the arteries. Arterial pressure changes continuously throughout each cardiac cycle. The pressure is determined by cardiac and peripheral factors and it is also regulated with short-term adjustments and long-term adjustments and controlled by baroreceptors reflex and the renal angio-tensin mechanisms.

5.0 SUMMARY

In this unit, you have learnt about the arterial blood pressure, determinants of arterial pressure, measurement of arterial blood pressure and the regulation of arterial blood pressure.

6.0 TUTOR- MARKED ASSIGNMENT

Activity – Laboratory and practical assignments as given by the Facilitator

Answer the following questions:

1. What is Arterial blood pressure?
2. Describe the process of measuring arterial blood pressure.
3. Explain how arterial blood pressure is regulated.

7.0 REFERENCES/FURTHER READING

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UNIT 6 CIRCULATORY SHOCK

CONTENTS

1.0 INTRODUCTION

Shock is a state of compromise to life. Circulatory shock threatens life and it if is not managed as an emergency, it could result to loss of life. In this unit, you will learn more about circulatory shock as for you to understand the physiological bases on intervention.

2.0 OBJECTIVES

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

- define circulatory shock
- explain the stages of shock
- explain different types of shock.

3.0 MAIN CONTENT

3.1 Circulatory Shock

Circulatory shock is a state of inadequate tissue perfusion associated with or due to relative or absolute inadequacy of cardiac output. The essential signs of shock are rapid heartbeat (tachycardia/tachypnoea, both compensatory mechanisms), low blood pressure (hypotension), and signs of poor end-organ perfusion or "decompensation" (such as low urine output, confusion or loss of consciousness).

3.2 Stages of Shock

There are four stages of shock

Compensatory (Compensating)
This stage is characerised by the body employing physiological mechanisms, including neural, hormonal and bio-chemical mechanisms in an attempt to reverse the condition. As a result of the acidosis, the person will begin to hyperventilate in order to rid the body of carbon dioxide (CO_2). CO_2 indirectly acts to acidify the blood and by removing it the body is attempting to raise the pH of the blood. The baroreceptors in the arteries detect the resulting hypotension, and cause the release of adrenaline and noradrenaline. Noradrenaline causes predominately vasoconstriction with a mild increase in heart rate, whereas adrenaline predominately causes an increase in heart rate with a small effect on the vascular tone; the combined effect results in an increase in blood pressure.

Renin-Angiotensin system is activated and anti-diuretic hormone (ADH) is released to conserve fluid via the kidneys. These hormones cause the vasoconstriction of the kidneys, gastrointestinal tract, and other organs to divert blood to the heart, lungs and brain. The lack of blood to the renal system causes the characteristic low urine production. However the effects of the renin-angiotensin system take time and are of little importance to the immediate homeostatic mediation of shock.

Progressive (Decompensating)
Should the cause of the crisis not be successfully treated, the shock will proceed to the progressive stage and the compensatory mechanisms begin to fail. Due to the decreased perfusion of the cells, sodium ions build up within while potassium ions leak out. As anaerobic metabolism continues, increasing the body's metabolic acidosis, the arteriolar smooth muscle and precapillary sphincters relax such that blood remains in the capillaries. Due to this, the hydrostatic pressure will increase and, combined with histamine release, this will lead to leakage of fluid and protein into the surrounding tissues. As this fluid is lost, the blood concentration and viscosity increase, causing sludging of the micro-circulation. The prolonged vasoconstriction will also cause the vital organs to be compromised due to reduced perfusion. If the bowel becomes sufficiently ischemic, bacteria may enter the blood stream, resulting in the increased complication of endotoxic shock.

Refractory (Irreversible)
At this stage, the vital organs have failed and the shock can no longer be reversed. Brain damage and cell death are occurring, and death will

occur imminently. One of the primary reasons that shock is irreversible at this point is that much cellular ATP has been degraded into adenosine in the absence of oxygen as an electron receptor in the mitochondrial matrix. Adenosine easily perfuses out of cellular membranes into extracellular fluid, furthering capillary vasodilation, and then is transformed into uric acid. Because cells can only produce adenosine at a rate of about 2% of the cell's total need per hour, even restoring oxygen is futile at this point because there is no adenosine to phosphorylate into ATP.

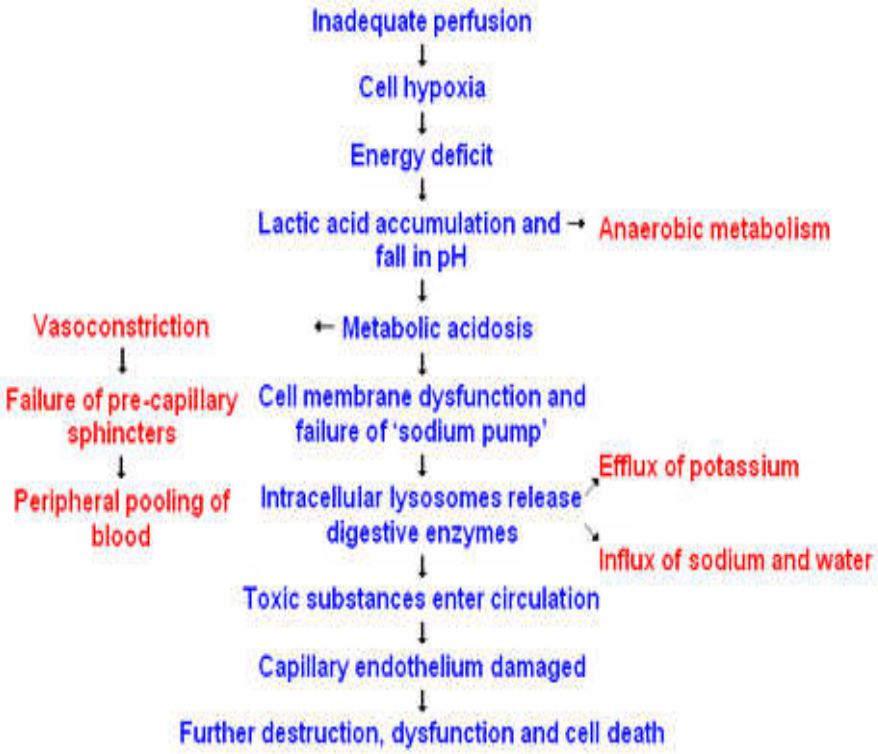

Fig. 6.1: Effects of inadequate perfusion on cell function

3.3 Types of Shock

There are four types of shock: hypovolemic, cardiogenic, distributive and obstructive shock

i. Hypovolemic shock e.g. hemorrhage, trauma, surgery, burns, fluid loss- diarrhoea, and vomiting
ii. Distributive shock/Vasogenic or low resistance shock e.g. fainting, anaphylaxis and sepsis .
iii. Cardiogenic shock e.g. myocardial infarction, congestive heart failure.

iv. Obstructive shock (obstruction to blood flow) e.g. tension pneumothorax, pulmonary embolism, cardiac tamponade.

Hypovolemic Shock

In this form of shock, there is an absolute reduction of the intravascular blood volume. Therefore the amount of blood available for the heart to pump to the tissues is greatly reduced. Venous return is reduced and therefore by Starlings law, the cardiac output is reduced. The symptoms of this shock is similar irrespective of the particular cause whether due to diarrhoea and vomiting, burns or haemorrhage. The symptoms are due to the body's attempts to compensate for the reduced blood volume.

These symptoms and signs include:

i. Cold skin particularly in the periphery, this is due to vasoconstriction of vessels to the skin in an attempt to shunt more blood to the heart and other vital tissues particularly the brain.
ii. Pallor and Clammyness of the skin are also caused by the above compensatory mechanism
iii. Thirst: The person feels an urge to drink. This is due to the stimulation of the thirst center located in the hypothalamus by hormones produced in response to depressed blood volume. The principal hormones involved are the antidiuretic hormone and angiotensin II.
iv. Rapid respiration or air hunger. The diminished tissue perfusion leads to hypoxia which is detected by the chemoreceptors which in turn send signals to the respiratory center to increase the rate of respiration in order to take in more oxygen. This increased respiration also helps to increase venous return and therefore cardiac output via the thoracic pump
v. A rapid thready (low volume) pulse. The pulse rate is greatly increased in order to compensate for the diminished stroke volume occasioned by the reduction of blood volume. Since cardiac output, CO = HR x SV, in order to increase CO, the heart rate must increase greatly, the threadiness of the pulse i.e. the low volume is due to the diminished stroke volume.
vi. The blood pressure is greatly reduced (hypotension). BP = CO x TPR. Since CO depends on blood volume, the reduction in blood volume causes a decrease in cardiac output leading to a fall in blood pressure.

Distributive Shock

In distributive shock there is a widespread vasodilatation which effectively increases the capacity of the circulation. Blood is trapped in non-essential areas of the body thereby being unavailable for circulation to the vital organs-heart, kidneys and brain. In these situations, the

cardiac output is normal. There is thus a relative inadequacy of cardiac output. These forms of widespread vasodilation are usually caused by toxins in sepsis, chemicals produced in anaphylactic shock. In neurogenic shock a sudden widespread vasodilation occurs with pooling of blood in the veins. This effectively reduces the venous return and cardiac output and results in fainting. This usually occurs in situations of profound grief or overwhelming fear.

Septic Shock

This refers to a bacterial infection widely disseminated to many areas of the body, with the infection being borne through the blood from one tissue to another and causing extensive damage.

Some of the typical causes of septic shock include the following:

i. Peritonitis caused by spread of infection from the uterus and fallopian tubes, sometimes resulting from instrumental abortion performed under unsterile conditions.
ii. Peritonitis resulting from rupture of the gastrointestinal system, sometimes caused by intestinal disease and sometimes by wounds.
iii. Generalised body infection resulting from spread of a skin infection such as streptococcal or staphylococcal infection.
iv. Generalised gangrenous infection resulting specifically from gas gangrene bacilli, spreading first through peripheral tissues and finally by way of the blood to the internal organs, especially the liver.
v. Infection spreading into the blood from the kidney or urinary tract, often caused by colon bacilli.

Some Features often Observed are:

i. High fever.
ii. Often marked vasodilation throughout the body, especially in the infected tissues.
iii. High cardiac output in perhaps half of patients, caused by arteriolar dilation in the infected tissues and by high metabolic rate and vasodilation elsewhere in the body, resulting from bacteria toxin stimulation of cellular metabolism and from high body temperature.
iv. Sludging of the blood, caused by red cell agglutination in response to degenerating tissues.

Cardiogenic Shock
This is shock arising from the heart inability to generate enough force or beat frequently enough to maintain the cardiac output. Therefore, heart rate is reduced as occurs in heart block and other arrhythmia.
Obstructive Shock
In this type of shock, the flow of blood is obstructed which impedes circulation and can result in circulatory arrest. Several conditions result in this form of shock.

Cardiac tamponade: In which fluid in the pericardium prevents inflow of blood into the heart (reduced venous return).

Constrictive pericarditis: The pericardium shrinks and hardens.

Tension pneumothorax: Through increased intrathoracic pressure, blood flow to the heart is prevented (decreased venous return).
Massive pulmonary embolism: It is the result of a thromboembolic incident in the blood vessels of the lungs and hinders the return of blood to the heart.

Aortic stenosis: This hinders circulation by obstructing the ventricular outflow tract.

SAE

Describe the compensatory mechanisms that act to raise blood volume during cardiovascular shock.

4.0 CONCLUSION

Circulatory shock is a state of inadequate tissue perfusion associated with or due to relative or absolute inadequacy of cardiac output that present in four stages. The essential signs of shock are rapid heartbeat (tachycardia/tachypnoea, both compensatory mechanisms), low blood pressure (hypotension), and signs of poor end-organ perfusion or "decompensation" (such as low urine output, confusion, or loss of consciousness). Hypovolemic shock e.g. hemorrhage, trauma, surgery, burns, fluid loss- diarrhoea, and vomiting, Shock can be hypovolumic, distributive shock/vasogenic, cardiogenic orbobstructive shock manifesting with varied signs and symptoms. The nurse is in a very high position to detect, respond appropriately and safe the life of a client in a state of shock by applying the knowledge of the pathology associated with shock.

5.0 SUMMARY

In this unit, you have learnt about circulatory shock, stages of shock, types of shock and the signs and symptoms that the nurse must be able to pick and respond to promptly to safe the client from loosing his/her life.

6.0 TUTOR- MARKED ASSIGNMENT

Activity

Answer the following questions:

i. What is Circulatory Shock?
ii. Describe the four stages of shock.
iii. Explain the different types of shock.
iv. Explain the physiological underpinnings of the signs and symptoms of shock.

7.0 REFERENCES/ FURTHER READING

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