COURSE GUIDE

PHS 201
ANATOMY

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INTRODUCTION

PHS 201: Anatomy is a first semester two-credit course. It will be available to all students to take toward the course module of their B.Sc. programme. This course will give you a better understanding of the anatomy of the human body. The course guide tells you briefly what the course is about, what course materials you will be using, and how you can work your way through these materials. It suggests some general guidelines for the amount of time you are likely to spend on each unit of the course in order to complete it successfully. It also gives you some guidance on your tutor-marked assignments. Detailed information on tutor-marked assignments is similarly made available. There are regular tutorial classes that are linked to the course. You are advised to attend these sessions.

WHATYOU WILLLEARNINTHISCOURSE

The overall aim of PHS 201: Anatomy is to enable you to learn and understand the basic structure and function of the human body, which include: the human skin, the skeletal system, the nervous system, the endocrine system, there productive system, and the circulatory system.

COURSEOBJECTIVES

In order to achieve the aims set out above, the course sets overall objectives. In addition, each unit also has specific objectives. The unit objectives are always included at the beginning of each unit and these should be read before you start working through the unit. You may need to refer to them during your study of the unit in order to check on your progress. You should always look at the unit objectives again after completing each unit. In this way, you can be sure that you have done what was required of you by the unit. Set out below are the wider objectives of the course as a whole. By meeting these objectives, you should have achieved the aims of the course as a whole. On successful completion of the course, you should be able to:

- **define** the concept of anatomy and physiology
- **describe** levels of organisation in the body
- **describe** the skin and skeletal system
- **explain** the digestive, respiratory and circulatory systems
- **discuss** the nervous and endocrine system
- **explain** the constituents and role of the immune system and
- **describe** the sexual organs.

WORKINGTHROUGHTHISCOURSE

To complete this course, you are required to read the study units and books, and other materials provided by the National Open University of Nigeria(NOUN). Each unit contains self-assessment exercises. At the end of the course is a final examination. The course should take you about 14 weeks to complete. Below you will find listed all the components of the course, what you have to do, and how you should allocate your time to each unit in order to complete the course successfully and on time.

COURSEMATERIALS

Major components of the course are:

1. The Course Guide
2. Study Units
3. References
4. The Presentation Schedule

STUDYUNITS

Each study unit consists of some work, and includes introduction, specific objectives, reading materials, conclusion, summary, tutor marked assignments(TMAs), references and further readings. The units direct you to work on exercises related to the required readings. In general, these exercises are on the material you have just covered. Together with tutor-marked assignments, these exercises will assist you in achieving the stated learning objectives of the individual units and of the course.

THEASSIGNMENTFILE

The course assignment will cover:

Basic anatomy of the human body; concept, meaning and the relationship between these subspecialties of basic biology
Levels of organisation of the human body and basic organic chemistry
The organs and the regulatory roles of the nervous and endocrine systems The skeletal, circulatory, digestive, nervous systems, etc. and their functions.

ASSESSMENT

There are two aspects to the assessment of the course:

a. Tutor-marked assignments,
b. Written examination.

TUTOR-MARKEDASSIGNMENT

There are some tutor-marked assignments. You are encouraged, however, to submit the assignments to be given to you at the Study Centre for this course. In tackling the assignments, you are expected to apply information, knowledge and strategies gathered from the relevant study units. However, it is desirable to demonstrate that you have read and researched more widely than the required minimum. Using other references will give you a broader viewpoint and may provide a deeper understanding of the subject.

The assignments must be submitted together with a TMA (tutor-marked assignment) form, to your tutor for formal assessment in accordance with the deadlines stated in the Presentation Schedule and 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. Extensions will not be granted after the due date unless there are exceptional circumstances. The work you submit to your tutor for assessment will countfor40%ofyour course mark.

FINALEXAMINATIONANDGRADING

The final examination for PHS201 will be for 2 hours and its result will contribute 60% to the total course grade. The examination will consist of questions which reflect the types of self-testing, practice exercises and tutor-marked problems you have previously encountered. All are as of the course will be similarly assessed.

Use the time between finishing the last unit and sitting for the examination to revise the entire course. You might find it useful to review yourself-assessment questions, tutor-marked assignments and comments on them before the examination.

COURSEMARKINGSCHEME

The following table lays out how the actual course marking is broken down.

ASSESSMENTMARKS

Assignments:4TMAsof10markseach=40%of course marks
Final Examination =60%ofoverall course marks
Total course marks = 100%

COURSEOVERVIEW

This table brings together the units, the number of weeks you should take to complete them, and the assignments that follow them. These specially designed study materials should be used at your pace, and at a time and place that suit you best. Think of it as reading the lecture instead of listening to a lecturer. The study units tell you when to read your course material. Just as a lecturer might give you an in-class exercise, your study units provide exercises for you to do at appropriate points.

Each of the study units follows a common format:

1. Introduction to the subject matter of the unit and how a particular unit is integrated with the other units and the course as a whole.
2. A set of learning objectives. These objectives let you know what you should be able to do by the time you have completed the unit. You should use these objectives to guide your study. When you have finished the unit you must go back and check whether you have achieved the objectives. If you make a habit of doing this, you will significantly improve your chances of passing the course
3. The main body of the unit guides you through the required reading from other sources. This will usually be either from a reading section or some other courses.
4. Self-tests are interspersed throughout the units, and answers are given at the end of units. Working through these tests will help you to achieve the objectives of the units and prepare you for the assignments and the examination. You should do each self-test as you encounter it in the study unit. There will also be numerous examples given in the study units; work through these when you come across them too.

If you run into any trouble, telephone your tutor. Remember that your tutor’s job is to help you; so when you need help, don’t hesitate at all to ask your tutor to provide it.

HOW TO GET THE MOST FROM THIS COURSE

The following is a practical strategy for working through the course.

1. Read this **Course Guide** thoroughly.
2. Organise a study schedule: Refer to the “course overview” for more details. Note the time you are expected to spend on each unit and how the assignments relate to the units. Important information, e.g. details of your tutorials, and the date of the first day of the semester, is available. You need to gather all this information in one place, such as your diary or a wall calendar. Whatever method you choose to use, you should decide on and write in your own dates for working on each unit.
3. Once you have created your own study schedule, do everything you can to stick to it. The major reason that students fail is that they get behind with their course work. If you get in to difficulty with your schedule, please let your tutor know before it is too late for help.
4. Turn to Unit 1 and read the introduction and the objectives for the unit.
5. Assemble the study materials: Information about what you need for a unit is given on the contents page at the beginning of each unit. You will almost always need both the study unit you are working on and one of the materials for further reading on your desk at the same time.
6. Work through the unit: The content of the unit itself has been arranged to provide a sequence for you to follow. As you work through the unit you will be instructed to read sections from other sources. Use the unit to guide your reading.
7. Keep in mind that you will learn a lot by doing all your assignments carefully. They have been designed to help you to meet the objectives of the
   Course and, therefore will help you pass the exam. Submit all assignments not later than the due date.
8. Review the objectives for each study unit to confirm that you achieved them. If you feel unsure about any of the objectives, review the study materials or consult your tutor.
9. When you are confident that you have achieved a unit’s objectives, you may then start on the next unit. Proceed unit by unit through the course and try to pace your study so that you keep yourself on schedule.
10. When you have submitted an assignment to your tutor for making do not wait for its return before starting on the next unit. Keep to your schedule. When the assignment is returned, pay particular

attention to your tutor's comments, both on the Tutor-Marked Assignment form and also on the written assignment. Consult your tutor as soon as possible if you have any question or problems.

11. After completing the last unit, review the Course and prepare yourself for the final examination. Check that you have achieved the unit objectives. (Listed at the beginning of each unit) and the Course objectives (listed in the **Course Guide).**

FACILITATORS/TUTORSANDTUTORIALS

There are 8hours 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 numbers of your tutor, as soon as you are allocated a tutorial group. Your tutor will mark and comment on your assignment, 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 tutor marked assignments 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 hesitate to contact your tutor by telephone, e-mail for discussion. Contact your tutor if:

- You do not understand any part of the study units or the assignment
- You have difficulty with the self-tests or exercises
- You have a question or problem 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 for face to face contact with your tutor and to ask questions which are answered instantly. You can raise any problem you encounter in the course of your study. To gain maximum benefit from course tutorials, prepare a question list before attending them. You will learn a lot from participating and discussing actively. Best wishes.

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MODULE 1 INTRODUCTION TO ANATOMY

Unit 1 Basic concepts of Anatomy and Physiology
Unit 2 Structure of the Cell
Unit 3 Levels of organization of the Human Body Systems
Unit 4 Anatomy of the Skin, Ear and Eyes

UNIT 1 BASIC CONCEPTS OF ANATOMY AND PHYSIOLOGY

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1.0 Introduction
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3.2 Relationship between Anatomy and Physiology
3.3 Divisions of Anatomy
3.4 Divisions of Physiology
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 INTRODUCTION

You have gone through the basic biology course where you learnt that all living things share basic characteristics, some of which include the following: Movement, Reproduction, Nutrition, Irritability, Growth, Excretion and Respiration. The basic Biology includes Anatomy and Physiology as sub-specialties. These are biological subjects with slightly different perspectives, which we shall study in this unit.

2.0 OBJECTIVES

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

- Define Anatomy
- Define Physiology
- Describe the various specialties of each discipline
- Explain the relationship between Anatomy & Physiology.

3.0 MAIN CONTENT

3.1 Definition of Anatomy and Physiology

Anatomy is the science that deals with the structure of the body. It is derived from a Greek word meaning “cutting up” or “taking apart.” Anatomy is the oldest basic medical science. “The nature of the body is the beginning of medical science.” (Keith L. Moore) A literal translation would be “a cutting open” (of the body) for the purpose of studying the internal and external structure of the body. Anatomy is, therefore, the study of internal and external structures of the body and the physical relationships of one part to the other for example how a particular muscle attaches to the skeleton. Physiology, which also has Greek origin, on the other hand, is the study of how organisms make use of different parts of the body to perform their vital functions, which are for the overall benefit of the body. An example is the study of how a muscle uses the fact of its leverage on the skeleton to contract and move that part of the body. Physiology also examines the kind of forces that contracting muscles exert on the skeleton.

3.2 Relationship between Anatomy and Physiology

Anatomy and physiology are closely integrated both theoretically and practically. Anatomical information provides clues about probable functions, and physiological mechanisms can be explained only in terms of the underlying anatomy. This observation leads to a very important concept: All specific functions are performed by specific structures. Anatomists and physiologists approach the relationship between structure and function from different perspectives.

Carefully read through this simple non-biological analogy.

Assume that this class is made up of anatomists and physiologists, and we are asked to consider an electric bulb. The anatomists may begin by describing and measuring the shape of the bulb and, if possible, take it apart (“dissect it”) and put it back together. The physiologist could then explain its key structural relationships.

3.3 Divisions of Anatomy

Anatomy can be divided into different specialties based on:

- Degree of structural detail under consideration
- Specific processes
- Medical application

On the basis of structural detail we have:

- Microscopic Anatomy
- Gross (Macroscopic) Anatomy

Microscopic Anatomy

Microscopic anatomy deals with structures that cannot be seen without magnification. The limits of the equipment used determine the boundaries of microscopic anatomy. For example, with a light microscope, you can see basic details of cell structure; with an electron microscope, you can see individual molecules that are only a few nanometres across. Microscopic Anatomy includes cytology and histology. As we go through the course, we will consider details at all levels, from macroscopic to microscopic.

Cytology is the analysis of the structure of individual **cells,** the simplest units of life. Cells are composed of chemical substances in various combinations, and our lives depend on the chemical processes occurring in the trillion cells in the body.

Histology is the examination of tissues, which are groups of specialized cells and cell products, that work together to perform specific functions. Tissues combine to form organs, such as the heart, kidney, liver or brain. Many organs are easily examined without microscopic anatomy, by using gross anatomy.

Gross Anatomy (Macroscopic Anatomy) is the examination of relatively large structures and features usually visible with the unaided eye. There are many ways to approach gross anatomy:

Surface anatomy: Study of general form and superficial markings. Surface Anatomy begins when the physician, dentist, or other health professionals first examine a patient. It is the basis for the physical examination of the body that forms a part of physical diagnosis.

Regional anatomy: Focuses on anatomical organization of specific areas of the body, such as the head, neck or trunk

Systemic anatomy: Study of the structure of organ systems, such as the skeletal system or the muscular system. Organ systems are groups of organs that function together in a co-ordinated manner. For example the heart, blood and blood vessels form the cardiovascular system, which distributes oxygen and nutrients throughout the body. The human body has 11 organ systems, and they will be introduced later in this course.

Developmental anatomy: This deals with the changes in forms that occur during the period between conception and physical maturity. The study of these early developmental processes is called **Embryology.** Developmental Anatomy, which includes embryology, is the study of human growth and development. Much can be learned about the structure and function of adults by studying changes that occur during development (Moore, 1988).

Other anatomical specialties with focus on clinical settings include:

Mechanical anatomy (anatomical features that change during illness).

Radiographic anatomy (anatomical structures as seen by using specialised imaging techniques. Radiological Anatomy is the study of the structure and function of the body using radiographic techniques.

Surgical anatomy (anatomical landmarks important in surgery).

3.4 Divisions of Physiology

As earlier stated, physiology is the study of the function of anatomical structures. Human physiology is the study of the functions of the human body. These functions are complex and much more difficult to examine than most anatomical structures. As a result, there are even more specialties in Physiology than in Anatomy, which include the following:

Cell physiology: This is the cornerstone of human physiology; it is the study of the functions of cells. It deals with events at the chemical and molecular levels.

Special physiology: This is the study of the physiology of special organs. For example, renal physiology is the study of kidney function.

Systemic physiology: This includes all aspects of the functions of specific organ systems. Cardiovascular physiology, respiratory physiology and reproductive physiology are examples of systemic physiology.

Patho-physiology: This is the study of the effects of diseases on organ or system functions (*pathos* is the Greek word for “disease”). It may also be defined as the derangement in normal function that leads to development of disease. Modern medicine depends on an understanding of both normal physiology and patho- physiology.

4.0 CONCLUSION

Physicians normally use a combination of anatomical and psychological information when they evaluate patients. Full details in relation to physiology shall be discussed in Physiology lectures.

5.0 SUMMARY

This unit teaches that:

- Human beings share basic characteristics of living things.
- Human anatomy is the study of body structures and the physical relationship among body parts of human beings.
- Human physiology is the study of the normal functions of the human body.
- Anatomy and physiology are closely integrated, both theoretically and practically.
- Modern medicine depends on an understanding of physiology and anatomy.

SELF ASSESSMENT EXERCISE 1

1. Recap the basic functions of all living things.
2. Define anatomy.
3. Define physiology.

ANSWER TO SELF ASSESSMENT EXERCISE 1

Basic functions of living things include Movement, Respiration, Nutrition, Irritability, Growth, and Reproduction.

SELF ASSESSMENT EXERCISE 2

Name the factors that determine the divisions of anatomy.

ANSWER TO SELF ASSESSMENT EXERCISE 2

Factors that determine divisions in anatomy are:

- Degree of structural detail under consideration
- Specific processes
- Medical application

6.0 TUTOR-MARKED ASSIGNMENT

Briefly describe the following:

a. Microscopic anatomy.
b. Macroscopic anatomy.

7.0 REFERENCES/FURTHER READINGS

Martini, F.C; Ober, W.C; Garrison, C.W; Welch, K & Hutchings, R.T. (2001). Fundamentals of Anatomy and Physiology (5th ed.), New Jersey: Prentice-Hall, Inc.

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UNIT 2 STRUCTURE OF THE CELL

1.0 Introduction
2.0 Objectives
3.0 Main Content
    3.1 Cell structure and function
    3.2 Cell structure (Animacules and the first microscope)
    3.3 Organelles and cell structure (Eukaryotics and Prokaryotics)
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 INTRODUCTION

All living things are composed of cells. Cells are the basic units of life and all tissues and organs are composed of cells. They are so small that they must be viewed with a microscope. There are different types of cells. Cells can either be eukaryotic or prokaryotic. Eukaryotic cells have a nucleus and membrane bound organelles. Plant and animal cells are eukaryotes. Plant cells are generally a square shape while animal cells are usually circular. Plant cells and animal cells have evolved different organelles to perform specific functions. Plant cells have chloroplasts, a cell wall and a central vacuole. Animal cells lack these three organelles. Plant cells have chloroplasts because they make their own food. Plant cells have a cell wall so that they do not burst when the central vacuole fills up with water. Prokaryotes do not have a nucleus, and lack membrane bound organelles. They are the oldest cells on earth. Bacteria are prokaryotes. Prokaryotes often move using special structures such as flagella or cilia.

2.0 OBJECTIVES

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

- Describe cell structure
- State the functions of the cell
- State the parts of a cell and their functions

3.0 MAIN CONTENT

3.1 Cell Structure and Function

Cells were first described by Robert Hooke in his book Micrographia, published in 1665. Using a microscope, he described the structure of cork as closely resembling prison chambers or monks' quarters (there is some debate about this). He used the term "cell" to describe these hollow chambers. The Cell Theory was first described in 1839. While the Cell Theory has been altered and revised, most biologists today list three or four general characteristics shared by all cells:

1. The cell is the basic unit of life. By definition, anything that is smaller than a cell is not alive.
2. All organisms are composed of one or more cells.
3. Cells arise from pre-existing cells.
4. All cells, at some point in their life cycle, contain the genetic material for the entire organism.

The first two characteristics are definitions. The third characteristic was demonstrated in part by Louis Pasteur's work through 1862. The fourth point is subject to controversy; advocates point to the fact that organisms begin as a single cell with all of the genetic information for the organism and most divide by mitosis. Opponents point to the loss of genetic material that occurs during meiosis, although the loss is of copies of genes. The cells still have all of the genetic information.

3.1.1 Different Types of Cells

While cells do share many traits in common, there are differences. The cells that make up a tree are not the same as the ones that make up a dog. Even within the same organism, there are different types of cells. Your skin cells are different from muscle cells, or bone cells, or blood cells. Like organisms, cells can be characterized by their traits. Two common methods of distinguishing cells are by their feeding mechanisms and internal structure.

3.1.2 Cell Feeding Mechanisms

Cells must acquire nutrients and eliminate waste products. This can be done in different ways. Some cells are capable of producing food from the raw materials in the cell. This type of cell is called an autotrophic cell. The word Autotroph literally translates as "self-feeding". Most autotrophic cells on earth are photosynthetic, although in areas where light is not available (ocean bottoms, deep caves underground, etc.) autotrophs carry out chemosynthesis. Some examples of autotrophic cells are plants, algae, and some bacteria. Other cells must acquire their nutrients from other cells. This type of cell is called a heterotrophic cell. Heterotroph literally means “other feeding”. These cells must be able to capture and take in other food stuffs. Some examples of heterotrophic cells include animals, fungi, and some bacteria. There are a few groups of organisms which are mixotrophs. These organisms, such as protists like Euglena, have the capability to photosynthesize when light is available and switch to predation when light is not available.

3.2 Cell Structure

Cells also vary based on complexity and structure. The first cells were relatively simple in structure and complexity. They are still present and actually outnumber the more complex cells you may be more familiar with. The first cells are termed prokaryotic (literally “before kernel”, meaning before the nucleus). These cells are generally smaller and less active. Usually, prokaryotic cells utilize some form of anaerobic respiration. They have no nucleus or membrane-bound organelles. Their single loop of DNA is termed a nucleoid, but is not isolated from the cytoplasm by a membrane. Prokaryotic cells do have cytoplasm, ribosomes, cell walls, cell membranes and their associated materials. Today, two of the three domains of life are prokaryotic: Archaea and Bacteria (some scientists term this group Eubacter or Eubacteria). The second type of cell is termed eukaryotic (literally “true kernel” or having a true nucleus). These cells are larger and more complex. Membrane-bound organelles “compartmentalize” parts of the cell for specific functions. These cells can carry out anaerobic respiration, but most also carry out aerobic respiration due to the greater energy yield per molecule of glucose. Eukaryotic cells are found in the domain Eukarya. Remember though, while eukaryotic cells are larger and more complex, they are not “better” than prokaryotic, just different. Today, there is more prokaryotic biomass on earth than eukaryotic biomass.

These are two different ways to distinguish cell types. They are not related to each other. So do not fall into the trap some students succumb to by linking autotroph/heterotroph with prokaryotic/eukaryotic cells. There are cells that are prokaryotic and autotrophic (some primitive algae), prokaryotic and heterotrophic (bacteria), eukaryotic and autotrophic (most plants), eukaryotic and heterotrophic (animals). Additionally, there are other ways to distinguish cell types that your instructor may discuss.
Current theory is that eukaryotic cells arose from prokaryotic ancestors. Lynn Margulis worked on this concept. Her Endosymbiotic Theory is one

of the mainstays of cell biology. The Endosymbiotic Theory is an attempt to explain how a prokaryotic cell could have evolved into a eukaryotic cell. Most textbooks have a discussion on this; look in your index for “Lynn Margulis” or “endosymbiosis”. Basically, a prokaryotic heterotroph ingests a prokaryotic autotroph and does not immediately digest it (there is a lag time between ingestion and digestion, which is why you may feel uncomfortable for a short time after a large meal). During this time, the autotroph will continue to function close to normal. Food poisoning works in a similar manner: the bacteria keep producing toxins until they are destroyed by the digestive system. If the autotroph produced nutrients that leaked into the heterotrophic host, the digestive processes could have been delayed further and further, until a symbiotic relationship developed. The predator (heterotroph) is provided with nutrients, while the prey (autotroph) is provided with shelter and raw materials. There is some support for Margulis’ theory. Organelles such as chloroplasts and mitochondria are about the same size as modern day prokaryotes, have their own DNA, and are capable of dividing separately from the nucleus and rest of the cell.

3.2.1 *Animalcules* and the First Microscopes

A. Early Microscopists

1. Galileo saw details of insect eyes with two crude lenses.
2. Robert Hooke used simple lenses to observe cork in which he saw tiny compartments he called ***cells (cellulae)***.
3. van Leeuwenhoek saw protistans, sperm, and bacteria with his lenses and microscopes.

B. The Cell Theory

1. Schleiden (a botanist) and Schwann (a zoologist): believed that all plants and animals consist of cells.
2. Virchow: cells come from pre-existing cells.

C. The Cell Theory: three generalizations:

1. All organisms are composed of one or more cells.
2. The cell is the smallest unit having the properties of life.
3. The continuity of life arises directly from the growth and division of single cells.

3.2.2 Structural Organization of Cells

1. The cell is the smallest entity that still retains the characteristics of life.
2. All cells have three basic parts:
   a. A plasma membrane separates each cell from the environment, permits the flow of molecules across the membrane, and contains receptors that can affect the cell's activities.
   b. A DNA-containing region occupies a portion of the interior.
   c. The cytoplasm contains membrane-bound compartments (except bacteria), particles, and filaments & end ash; all bathed in a semifluid substance.

3. Eukaryotic cells are defined by their possession of a membrane-bound nucleus.
4. Prokaryotic cells have no defined nucleus; the only representatives are bacteria.

Fluid Mosaic Model of Cell Membranes

1. The "fluid" portion of the cell membrane is made of phospholipids.

a. A phospholipid molecule is composed of a hydrophilic head and two hydrophobic tails.
b. If phospholipid molecules are surrounded by water, their hydrophobic fatty acid tails cluster and a bilayer results; hydrophilic heads are at the outer faces of a two-layer sheet.
c. Bilayers of phospholipids are the structural foundation for all cell membranes.

2. Within a bilayer, phospholipids show quite a bit of movement; they diffuse sideways, spin, and flex their tails to prevent close packing and promote fluidity, which also results from short-tailed lipids and unsaturated tails (kink at double bonds).

Overview of Membrane Proteins

1. A variety of different proteins are embedded in the bilayer or positioned at its two surfaces.
2. Membrane proteins serve as transport proteins, receptor proteins, recognition proteins, and adhesion proteins.

Cell Size and Cell Shape

Because of their small size, most cells can only be seen by using light and electron microscopes. Cell size must be small; remember surface-to-volume ratio! A cell that is too large will not be able to move materials into and out of the cell.

3.3 Organelles and Cell Structures

Cells, especially eukaryotic ones, are complex structures made of smaller parts called organelles (literally – "little organ"). Most textbooks have a summary table or diagram at the end of the cell chapter covering these organelles. What follows is a brief overview of most of the major organelles and other structures found in cells as well as a brief description for each. This is not meant to be totally comprehensive (here all ribosomes treated together) or exclusive (there are a variety of different structures in the cell membrane)

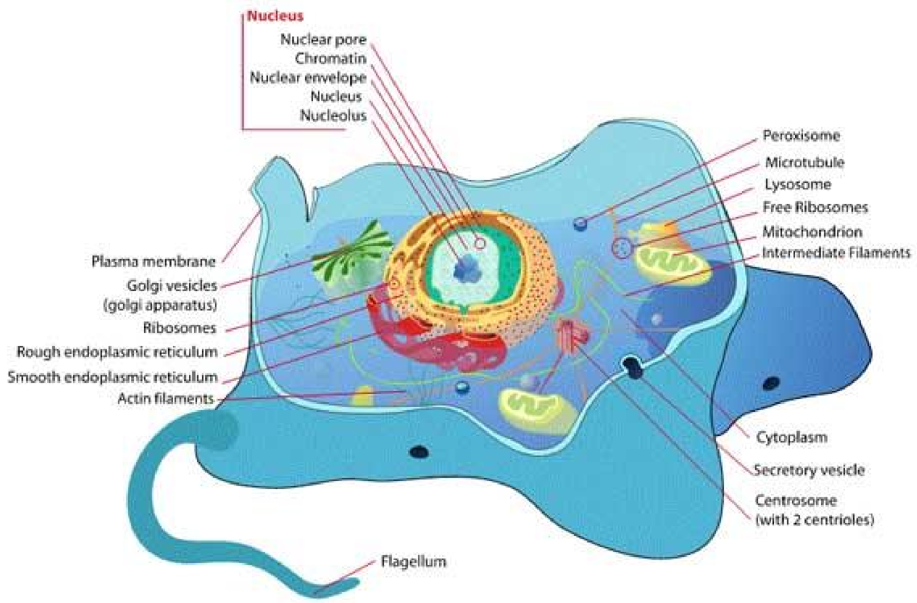

Figure 1: Organelles and Cell Structures

Cell Wall: Technically is not part of the living cell since it is outside the membrane. It provides rigid structural support in plant, fungi, some algae, and prokaryotic cells. The thickness and chemical composition of cell walls can vary between organisms.

Cell membrane: This is the barrier between the living part of the cell and the nonliving environment. It is a selective barrier, allowing some materials but not others to pass. Water and small particles can slip through the phospholipid bilayer while larger and more complex materials must pass through one of the protein channels embedded in the membrane. All cells have membranes.

Cytoplasm: The fluid matrix of the cell. The cytoplasm contains dissolved ions and other materials, allows for the movement of materials within the cell, and allow for movement of organelles during cyclosis. All living cells have cytoplasm.
Nucleus: The nucleus is the "control center" of the cell. The DNA is stored in the nucleus. The DNA is the set of instructions for the cell to function, not only for reproduction, but enzymes and other functions. Only eukaryotic cells have a nucleus.

Plastids: These are structures related to photosynthesis. Different pigments trigger different functions. Chloroplasts are the site of photosynthesis, chromoplasts may be photosynthetic and/or related to seed dispersal, leucoplasts store starch. All plastids begin as protoplasts before differentiation. Only autotrophs have plastids.

Mitochondrion: The powerhouse of the cell, the site of aerobic respiration. Pyruvate is broken down in the Krebs cycle and chemiosmosis then produces ATP from ADP and phosphate in the presence of oxygen. All eukaryotic cells contain mitochondria.

Vacuole: These membranous sacs have many functions. Material can be transported within the cell, from one organelle to another. Vacuoles can take materials to the membrane for expulsion, or can be formed at the membrane to bring materials into the cell. Plants and eukaryotic algae have a large central vacuole to store metabolic waste and water. Heterotrophs produce vacuoles containing digestive enzymes to break down food particles (called lysosomes). All cells can have vacuoles, but number and types can vary.

Endoplasmic reticulum: Endoplasmic reticulum is an organelle that extends throughout the cell. It may be smooth (no ribosomes) or rough (with ribosomes) and is associated with packaging, synthesis, and transport of materials in the cell. These are found in eukaryotic cells.

Golgi Bodies: Stacks of membranes within the cell. They package materials and form vesicles for transport out of the cell. Eukaryotic cells have Golgi Bodies.

Ribosomes: Ribosomes are not organelles, but structures of the cell. They are in the cytoplasm, on rough endoplasmic reticulum and in the nucleus. One of the primary roles of ribosomes is the location of protein synthesis. All cells possess ribosomes.

Cytoskeleton: The cytoskeleton is made of three different structures: microtubules, microfilaments, and intermediate filaments. They are responsible for maintaining the internal shape of the cell, acting as a framework for all the other parts. The cytoskeleton also assists in the movement of organelles and materials in cyclosis and they form the spindle structure during cell division. The cytoskeleton is present in all cells.

The largest cells are nerve cells. The giant squid has nerve cells over 12 meters in length while in humans the longest nerve cell is 1.5 meters. The smallest cell is a bacterium measuring 0.1 microns. The smallest human cells are sperm cells (40 microns). The most massive cell is the ostrich egg, weighing up to 1.4 kg.

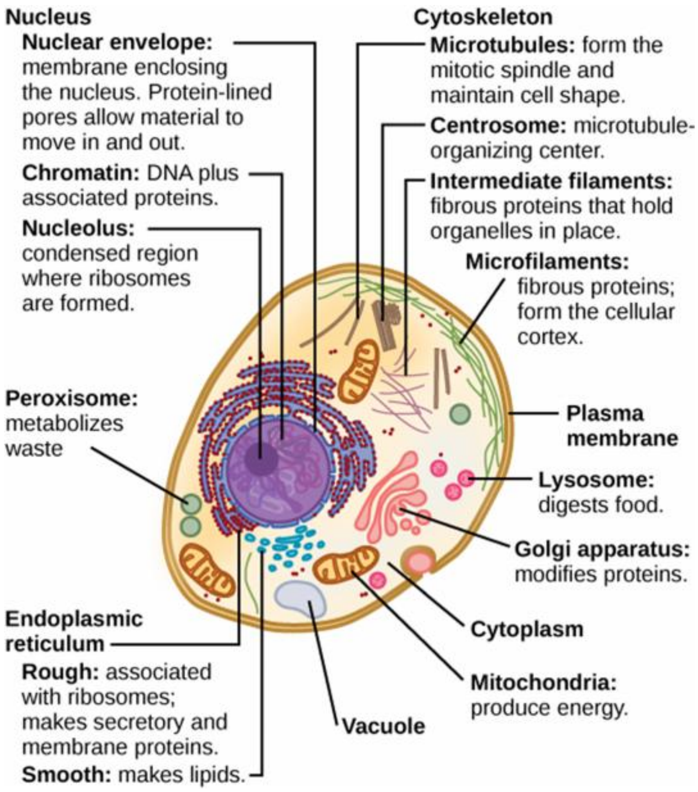

Figure 2: Cell Structure

3.3. 1 Cell Membrane

Cells have many structures inside of them called organelles. These organelles are like the organs in a human and they help the cell stay alive. Each organelle has its own specific function to help the cell survive. The nucleus of a eukaryotic cell directs the cell's activities and stores DNA. Eukaryotes also have a Golgi apparatus that packages and distributes proteins. Mitochondria are the power house of the cell and provide the cell with energy. Both plant and animal cells have mitochondria. Lysosomes are like the stomach of the cell. They contain enzymes that digest the cell's used parts. All of the cell's organelles must work together to keep the cell healthy.

The cell membrane is the protective barrier that surrounds the cell and prevents unwanted material from getting into it. The cell membrane has many functions, but one main function that it has is to transport materials (salts, electrolytes, glucose and other necessary molecules) into the cell to support necessary life functions. Not only does the membrane let molecules into the cell, but it also lets wastes such as carbon dioxide out of the cell. The cell membrane is made up of a phospholipid bilayer. Each phospholipid contains a hydrophilic, or water-loving head and a hydrophobic, or water-fearing tail. These properties that the phospholipids have and their specific orientation provide the cell with a selectively permeable barrier.

Table 1: **Cell Structure and Function**

Experiences	**Pattern**	**Explanations**
-a structure holds all of the parts of the factory in place (cytoplasm) -an outside wall gives a concrete area to the factory (cell wall) -metal beams keep the factory strong (cytoskeleton) -something takes out the trash and cleans up (lysosome) -a trash can collects the stuff until garbage day (vacuole) -assembly workers make a product (ribosomes) -other workers check the work and move it on (E.R.) -packagers box everything up and	-some cell structures are responsible for support of the cell (the physical building of the factory) -cell structures that are responsible for transport, disposal, and production (the workers of the factory) -allow movement in and out (the loading docks of the factory) -contain information vital to the cell (the foremen, or bosses in the factory	-The cell and its constituent parts are very small and difficult to grasp the concept of. A model of a factory is used to simulate the functions of the cell structures.

send it out (Golgi Body) -information goes to the workers from the bosses through the offices (nuclear membrane) -materials come in and products go out (cell membrane) -info. on how to make stuff is issued out (mitochondrion, chloroplast, nucleus)		

3.3.2 The Defining Features of Eukaryotic Cells

A. Major Cellular Components

1. Organelles form compartmentalized portions of the cytoplasm.
2. All **eukaryotic cells contain organelles.**

    a. The nucleus controls access to DNA and permits easier packing of DNA during cell division.
    b. The endoplasmic reticulum (ER) modifies newly formed polypeptide chains and is also involved with lipid synthesis.
    c. The Golgi body modifies, sorts, and ships proteins; they also play a role in the synthesis of lipids for secretion or internal use.
    d. Vesicles transport material between organelles and function in intracellular digestion.
    e. Mitochondria are efficient factories of ATP production.

3. Cells also contain non-membranous structures:

    a. Ribosomes, "free" or attached to membranes, participate in assembly of polypeptide chains.
    b. The cytoskeleton helps to determine cell shape, internal organization, and movements.

4. Organelles separate reactions with respect to time (allowing proper sequencing) and space (allowing incompatible reactions to occur in close proximity).

The Nucleus

A. Nucleus isolates DNA, which contains the code for protein assembly, from the sites (ribosomes in cytoplasm) where proteins will be assembled.

1. Localization of the DNA makes it easier to sort out hereditary instructions when the time comes for a cell to divide.
2. The membranous boundary of the nucleus helps control the exchange of signals and substances between the nucleus and the cytoplasm.

B. Nuclear Envelope

1. The *nuclear envelope* consists of two lipid bilayers with pores.
2. It surrounds the nucleoplasm within.
3. On the inner surface are attachment sites for protein filaments that anchor the DNA molecules and keep them organized.

C. Nucleolus

1. Located within the nucleus, the nucleolus appears as a darker globular mass.
2. It is a region where subunits of ribosomes are prefabricated before shipment out of the nucleus.

D. Chromosomes

1. *Chromatin* refers to the cell’s total collection of DNA and associated proteins.
2. A *chromosome* is an individual DNA molecule and its associated proteins.
3. DNA is duplicated and condensed before cell division occurs.

E. What Happens to the Proteins Specified by DNA?

1. Some of the polypeptide chains assembled on the ribosomes are stockpiled in the cytoplasm.

2. Others pass through the cytomembrane system, where they take on their final form and become packaged in vesicles for use within the cell or for export.

The Cytomembrane System

A. Endoplasmic Reticulum

1. The endoplasmic reticulum is a collection of interconnected tubes and flattened sacs that begin at the nucleus and ramble through the cytoplasm.
2. There are two types distinguished by the presence or absence of ribosomes:

   a. *Rough ER* consists of stacked, flattened sacs with many ribosomes attached; oligosaccharide groups are attached to polypeptides as they pass through on their way to other organelles or to secretory vesicles.
   b. *Smooth ER* has no ribosomes; it is the area from which vesicles carrying proteins and lipids are budded; it also inactivates harmful chemicals.

B. Golgi Bodies

1. In the *Golgi bodies*, proteins and lipids undergo final processing, sorting, and packaging.
2. The membranes of the Golgi are arranged in stacks of flattened sacs whose edges break away as vesicles.

C. Variety of Vesicles

1. *Lysosomes* are vesicles that bud from Golgi bodies; they carry powerful enzymes that can digest the contents of other vesicles, worn-out cell parts, or bacteria and foreign particles.
2. *Peroxisomes* are vesicles containing enzymes that break down fatty acids and amino acids; the hydrogen peroxide released is degraded by another enzyme.

Mitochondria

A. Mitochondria are the primary organelles for transferring the energy in carbohydrates to ATP under oxygen-plentiful conditions.

B. Hundreds of thousands of mitochondria occur in cells.

1. It has two membranes, an inner folded membrane (cristae) surrounded by a smooth outer membrane.
2. Inner and outer compartments formed by the membranes are important in energy transformations.
3. Mitochondria have their own DNA and some ribosomes, a fact which points to the possibility that they were once independent entities.

Specialized Plant Organelles

A. Chloroplasts and Other Plastids

1. *Chloroplasts* are oval or disk shaped, bounded by a double membrane and critical to the process of photosynthesis.

    a. In the stacked disks (grana), pigments and enzymes trap sunlight energy to form ATP.
    b. Sugars are formed in the fluid substance (stroma) surrounding the stacks.
    c. Pigments such as chlorophyll (green) confer distinctive colors to the chloroplasts.

2. *Chromoplasts* have carotenoids, which impart red-to-yellow colors to plant parts, but no chlorophyll.
3. *Amyloplasts* have no pigments; they store starch grains in plant parts such as potato tubers.

B. Central Vacuole

1. In the mature plant, the **central vacuole** may occupy **50 to 90%** of the cell interior!

    a. Stores amino acids, sugars, ions, and wastes.
    b. Enlarges during growth and greatly increases the cell's outer surface area.

2. The cytoplasm is forced into a very narrow zone between the central vacuole and the plasma membrane.

The Cytoskeleton

A. Main Components

1. The cytoskeleton is an interconnected system of fibers, threads, and lattices that extends between the nucleus and the plasma membrane.
2. It gives cells their internal organization, overall shape, and capacity to move.
3. The main components are **microtubules, microfilaments, and intermediate filaments:** all assembled from protein subunits.

4. Some portions are transient, such as the "spindle" microtubules used in chromosome movement during cell division; others are permanent, such as filaments operational in muscle contraction.

B. The Structural Basis of Cell Movements

1. Through the controlled assembly and disassembly of their subunits, microtubules and microfilaments grow or shrink in length (example: movement of chromosomes).
2. Microfilaments or microtubules actively slide past one another (example: muscle movement).
3. Microtubules or microfilaments shunt organelles from one location to another (example: cytoplasmic streaming).

C. Flagella and Cilia

1. *Flagella* are quite long, are usually not numerous, and are found on one-celled protistans and animal sperm cells.
2. *Cilia* are shorter and more numerous and can provide locomotion for free-living cells or may move surrounding water and particles if the ciliated cell is anchored.
3. Both of these extensions of the plasma membrane have a 9 + 2 cross-sectional array (arising from centrioles) and are useful in propulsion.

Cell Surface Specializations

A. Eukaryotic Cell Walls

1. Many single-celled eukaryotes have a cell wall, a supportive and protective structure outside the plasma membrane
2. Microscopic pores allow water and solute passage to and from underlying plasma membrane.

3. In plants, bundles of cellulose strands form the primary cell wall, which is more pliable than the more rigid secondary wall that is laid down inside it later.

4. Plasmodesmata are the channels that cross the adjacent walls to connect the cytoplasm of neighboring cells.

B. Matrices between Animal Cells

1. This is a meshwork that holds animal cells and tissues together and influences how the cells will divide and metabolize.
2. Cartilage consists of cells and proteins (collagen and elastin) scattered in a ground substance (modified polysaccharides).

C. Cell-to-Cell Junctions

1. At tissue surfaces, cells link together to form a barrier between the interior and exterior.
2. Three cell-to-cell junctions are common.
a. *Tight* junctions link cells of epithelial tissues to form seals.
b. *Adhering* junctions are like spot welds in tissues subject to stretching.
c. *Gap* junctions link the cytoplasm of adjacent cells; they form communication channels.

3.3.3 Prokaryotic Cells: The Bacteria

A. The term **prokaryotic** (literally, "before the nucleus") indicates existence of bacteria before evolution of cells with a nucleus; bacterial DNA is clustered in a distinct region of the cytoplasm.

B. Bacteria are some of the smallest and simplest cells.

1. A somewhat rigid cell wall supports the cell and surrounds the plasma membrane, which regulates transport into and out of the cell.
2. Ribosomes, protein assembly sites, are dispersed throughout the cytoplasm.
3. Bacterial flagella (without a 9+2 array) provide movement; pili on the cell surface help bacteria attach to surfaces and one another.

4.0 CONCLUSION

Cells also vary based on complexity and structure. The first cells were relatively simple in structure and complexity. They are still present and actually outnumber the more complex cells you may be more familiar with. The first cells are termed prokaryotic (literally "before kernel", meaning before the nucleus). These cells are generally smaller and less active. Usually, prokaryotic cells utilize some form of anaerobic respiration. They have no nucleus or membrane-bound organelles. Their single loop of DNA is termed a nucleoid, but is not isolated from the cytoplasm by a membrane. Prokaryotic cells do have cytoplasm, ribosomes, cell walls, cell membranes and their associated materials. Today, two of the three domains of life are prokaryotic: Archaea and Bacteria (some scientists term this group Eubacter or Eubacteria). The second type of cell is termed eukaryotic (literally "true kernel" or having a true nucleus). These cells are larger and more complex. Membrane-bound organelles "compartmentalize" parts of the cell for specific functions. These cells can carry out anaerobic respiration, but most also carry out aerobic respiration due to the greater energy yield per molecule of glucose.

5.0 SUMMARY

In this unit, we have described cell structure and functions in details. We learnt about the organelles, their functions, as well as the features of Prokaryotic and Eukaryotic cells.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define a cell with examples
2. Describe the functions of a cell
3. Compare and contrast Eukaryotics and Prokaryotics
4. Relate cell parts/organelles to their function.

7.0 REFERENCES/FURTHER READINGS

Martini, F.C; Ober, W.C; Garrison, C.W; Welch, K & Hutchings, R.T. (2001). Fundamentals of Anatomy and Physiology (5th ed), New Jersey: Prentice-Hall, Inc.

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UNIT 3 LEVELS OF ORGANIZATION OF THE HUMAN BODY

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
    3.1 Different Levels of Human Body Organization
    3.2 Interrelationships of Levels of Human Body Organization
    3.3 Organ Systems in the Body
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 INTRODUCTION

To study the chemical level of organization, scientists consider the simplest building blocks of matter: subatomic particles, atoms and molecules. All matter in the universe is composed of one or more unique pure substances called elements, familiar examples of which are hydrogen, oxygen, carbon, nitrogen, calcium, and iron. The smallest stable unit of any of these pure substances (elements) is an atom. Atoms are made up of subatomic particles such as the proton, electron and neutron. Two or more atoms combine to form a molecule, such as the water molecules, proteins, and sugars found in living things. Molecules are the chemical building blocks of all body structures.

2.0 OBJECTIVES

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

- Give an overview of the microscopic anatomy of the human body
- Describe the basic gross anatomy of each organ system in the body
- Describe the several independent levels of organization in the body
- Identify the six levels of organization of the body.

3.0 MAIN CONTENT

3.1 Different Levels of Organization

1. The Chemical or Molecular Level:

Atoms, the smallest stable units of matter, can combine to form molecules with complex shapes. Even at this simplest level, the specialized shape of a molecule determines its function.

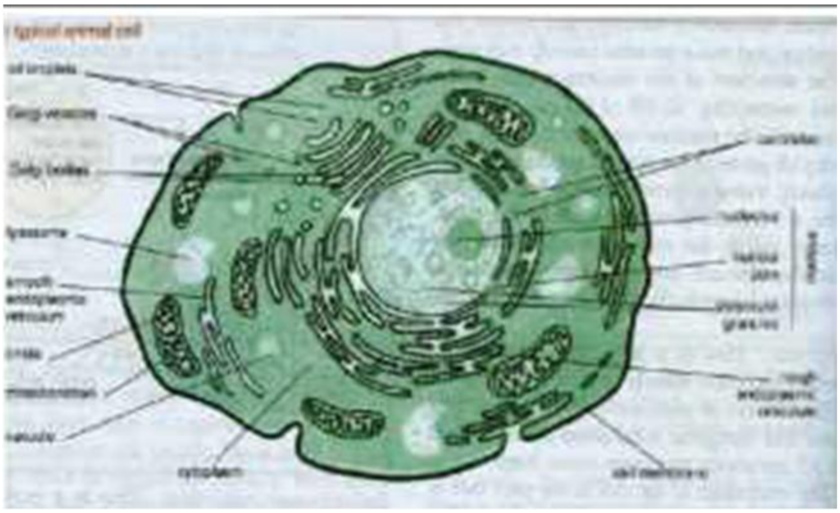

Figure 3: Typical Mammalian cell (Source: Encyclopaedia Britannica Inc. 1999)

2. The Cellular Level: Molecules can interact to form organelles such as the protein filaments found in muscle cells. Each type of organelle has specific functions. For example, interactions among protein filaments produce the contractions of muscle cells in the heart. Cells are the smallest living units in the body, and organelles are their structural and functional components.

3. The Tissue Level: A tissue is a group of cells working together to perform one or more specific functions. Heart muscle cells, or cardiac muscle cells, interact with other cell types and with extracellular materials to form muscle tissues.

4. The Organ Level: Organs consist of two or more tissues working in combination to perform several functions. Layers of cardiac muscle tissue, in combination with connective tissue, another tissue type, form the bulk of the wall of the heart, a hollow three-dimensional organ.

5. The Organ System Level: Organs interact in organ systems. Each time the heart contracts, it pushes blood into a network of blood vessels. Together the heart, blood and blood vessels form the cardiovascular system, one of 11 organ systems of the body.

6. The Organism Level: All organ systems of the body work together to maintain life and health. This brings us to the highest level of organization, that of the organism – in this case, the human being.

3.2 Interrelationships of the Levels of Organization

The organization at each level determines the characteristics and functions of higher levels. For example, the arrangement of atoms and molecules at the chemical level creates the protein filaments that, at the cellular level, give cardiac muscle cells the ability to contract powerfully. At the tissue level, these cells are linked, forming the cardiac muscle tissue. The structure of the tissue ensures that the contractions are coordinated, producing a heart-beat. When that beat occurs, the internal anatomy of the heart, an organ, enables it to function as a pump. The heart is filled with blood and connected to the blood vessels and the pumping action circulates to the blood vessels, of the cardiovascular system. By interacting with the respiratory, digestive, urinary, and other systems, the cardiovascular system performs a variety of functions essential to the survival of the organism. Something that affects a system will ultimately affect each component. For example, the heart cannot pump blood effectively after a massive blood loss. If the heart cannot pump and blood cannot flow, oxygen and nutrients cannot be distributed. Very soon, the cardiac muscle tissue begins to break down as individual muscle tissue cells die from oxygen and nutrient starvation. All cells, tissues, and organs in the body will be damaged.

3.3 Organs/Systems in the Body

This is an introduction to the organ systems in the human body. These organ systems are interdependent, interconnected, and packaged together in a relatively small space. The cells, tissues, organs, and organ systems of the body live together in a shared environment, like the inhabitants of a large city. Just as city dwellers breathe the city air and drink the water provided by the local water company, cells in the human body absorb oxygen and nutrients from the fluids that surround them. If a city is blanketed in smog or its water supply is contaminated, the inhabitants will become ill. Similarly, if body fluid composition becomes abnormal, cells will be injured or destroyed. Suppose the temperature or salt content of the blood changes, the effect on the heart could range from a minor adjustment (heart muscle tissue contracts more often, so the heart rate goes up) to a total disaster (the heart stops beating, so the individual dies). Various physiological mechanisms act to prevent potentially damaging changes in the composition of body fluid and the environment inside our cells.

Homeostasis

(*homeo*, unchanging + *stasis*, standing) refers to the existence of a stable internal environment. To survive, every organism must maintain homeostasis.

Table 2: Organ/System and functions

Organs/Systems		Functions
Integumentary System		Protects against environmental hazards
	Epidermis	Covers surfaces and protects deeper structures
	Dermis	Nourishes epidermis; provides strength for skin
	Hair follicles	Produce hair, innervation and sensation; protection for head
	Sebaceous glands	Secretes lipid coating that lubricates hair shaft and epidermis
	Sweat glands	Provides perspiration for evaporative cooling
	Nails	Protect and stiffen distal tips of digits
	Sensory receptors	Provide sensation of touch, pressure, temperature, pain. Store lipid; attach skin to deeper structures
Skeletal System		Protects tissues, stores minerals, forms blood, provides support for the body
	Bones and cartilages and joints	Support and protect soft tissues and store minerals
	Axial skeleton (Skull, Vertebrae, Sacrum, Ribs, Sternum,	Protects brain, spinal cord, sense organs and soft tissues of thoracic cavity; supports weight.

	sacrum, cartilages and ligaments)	
	Appendicular skeleton (Limbs and supporting bones and ligaments)	Provides internal support and positioning of the limbs; support and move axial skeleton
	Bone marrow	Acts as primary site of blood cell production (red and white cells)
	Skeletal muscles	Produces skeletal movement; control entrances and exits of digestive tract; produce heat; supports skeletal positioning; protects soft tissues
Central nervous system		Acts as control centre for the nervous system; processes information; provides short-term control over activities of other systems
	Brain	Perform complex integrative functions; controls both voluntary and involuntary (autonomic) activities
	Spinal cord	Relays information to and from the brain; performs less complex integrative functions and directs man's simple involuntary activities
Peripheral nervous system		Takes impulses from peripheral parts of the body to the spinal cord and takes responses back to other parts of the body
Pineal gland		May control timing of reproduction and set day-night rhythms
Pituitary gland		Controls other endocrine glands; regulates growth and fluid balance
Thyroid gland		Controls tissue metabolic rate
Parathyroid glands		Regulates calcium metabolism and levels
Thymus gland		Adjusts water balance, tissue metabolism, cardiovascular and respiratory activities

Adrenal glands			Control red blood cell production and elevates blood pressure
Kidneys			Transport cells and dissolved materials including nutrients, wastes and gases
Pancreas			Regulates blood glucose levels
Testes			Support male sexual characteristics and reproductive functions
Ovaries			Support female sexual characteristics and reproductive functions
Cardiovascular System			Responsible for circulation of blood throughout the body
	Heart		Propels blood and maintains blood pressure
	Blood vessels		Distribute blood around the body
		Arteries	Carry blood from the heart to the capillaries
		Capillaries	Permit diffusion between blood and interstitial fluids
		Veins	Returns blood from capillaries to the heart
		Blood	Transport oxygen, carbon dioxide and blood cells; delivers nutrients and hormones to tissues; removes waste products; assists in temperature regulation and defence against disease.

4.0 CONCLUSION

The relationship at each level determines the characteristics and functions of different organs in the human body.

5.0 SUMMARY

This unit shows that there are six (6) levels of organization of the body, with certain levels of relationships among these various levels of organization. It also shows the structure and functions of the systems in the body as well as homeostasis.

SELF ASSESSMENT EXERCISE 1

List the six levels of organization in the human body.

ANSWER TO SELF ASSESSMENT EXERCISE 1

The six levels are:

1. Chemical or molecular level
2. Cellular level
3. Tissue level
4. Organ level
5. Organ system level
6. Organism level

SELF ASSESSMENT EXERCISE 2

1. Define homeostasis.
2. Mention three characteristics of the organ system.

ANSWER TO SELF ASSESSMENT EXERCISE 2

1. Homeostasis refers to the existence of a stable internal environment. To survive, every organism must maintain homeostasis.
2. Three characteristics of organ systems
    i. Interdependent
    ii. Interconnected
    iii. Packaged together

6.0 TUTOR-MARKED ASSIGNMENT

Enumerate the levels of human body organization.

7.0 REFERENCES/FURTHER READINGS

Martini, F.C; Ober, W.C; Garrison, C.W; Welch, K & Hutchings, R.T. (2001). Fundamentals of Anatomy and Physiology (5th ed.), New Jersey: Prentice-Hall, Inc. Oxford Concise Medical Dictionary, E. A. Martins ed.

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UNIT 4 ANATOMY OF SKIN, EAR AND EYES

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
3.1 Anatomy of the skin
3.2 Anatomy of the ear
3.3 Anatomy of the eye
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 INTRODUCTION

The integumentary system consists of the skin, which is the largest organ of the body. Alterations in the skin will affect the overall wellbeing of an individual. The skin is a highly underestimated organ. It performs many vital functions, and has a complex structure. The ear is the organ of hearing and balance. The parts of the ear include the external or outer ear, consisting of the pinna or auricle and the external auditory canal or tube. This is the tube that connects the outer ear to the inside or middle ear. Hearing starts with the outer ear. The human eye is a specialised sense organ that is capable of receiving visual images, which are then carried to the brain.

2.0 OBJECTIVES

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

- Describe the anatomical structure and functions of human skin
- Describe the anatomical structure and functions of human ear
- Describe the anatomical structure and functions of human eyes

3.0 MAIN CONTENT

3.1 Anatomical structures of the skin

The skin is an organ because it consists of different tissues that are joined to perform specific activities. It is one of the largest organs of the body in surface area and weight. In adults, the skin covers an area of about 2 square meters, and weighs 4.5 to 5 kg. It ranges in thickness from 0.5 to 4.0 mm, depending on the location. The skin is not just a simple, thin coat that keeps the body together and provides protection, it performs several essential functions. Dermatology is the medical specialty that deals with diagnosing and treating skin disorders. Structurally, the skin consists of two principal parts. The outer thinner portion, which is composed of epithelium, is called the epidermis. The epidermis is attached to the inner, thicker, connective tissue part called the dermis. Beneath the dermis is a subcutaneous (subcut) layer. This layer, also called the superficial fascia or hypodermis, consists of areola and adipose tissues. Fibres from the dermis extend deep into the subcutaneous layer and anchor the skin to it. The subcutaneous layer, in turn, attaches to underlying tissues and organs.

3.2 Functions of the Skin

1. Regulation of body temperature

In response to high environmental temperature or strenuous exercise, the evaporation of sweat from the skin surface helps to lower an elevated body temperature to normal. In response to low environmental temperature, production of sweat is decreased, which helps to conserve heat. Changes in the flow of blood to the skin also help to regulate body temperature.

Temperature Homeostasis

Being the body’s outermost organ, the skin is able to regulate the body’s temperature by controlling how the body interacts with its environment. In the case of the body entering a state of hyperthermia, the skin is able to reduce body temperature through sweating and vasodilation. Sweat produced by sudoriferous glands delivers water to the surface of the body where it begins to evaporate. The sweat that is being evaporated absorbs heat from the body and so cools the body’s surface. Vasodilation is the process through which smooth muscle lining the blood vessels in the dermis relax and allow more blood to enter the skin. Blood transports heat through the body, pulling heat away from the body’s core and depositing it in the skin where it can radiate out of the body into the external environment.

2. Protection

The skin covers the body and provides a physical barrier that protects underlying tissues from shocks, physical abrasion, bacterial invasion, dehydration, and ultraviolet (UV) radiation. Hair and nails also have protective functions.

Keratinization

Keratinization, also known as cornification, is the process of keratin accumulating within keratinocytes. Keratinocytes begin their life as offspring of the stem cells of the stratum basale. Young keratinocytes have a cuboidal shape and contain almost no keratin protein at all. As the stem cells multiply, they push older keratinocytes towards the surface of the skin and into the superficial layers of the epidermis. By the time keratinocytes reach the stratum spinosum, they have begun to accumulate a significant amount of keratin and have become harder, flatter, and more water resistant. As the keratinocytes reach the stratum granulosum, they have become much flatter and are almost completely filled with keratin. At this point the cells are so far removed from the nutrients that diffuse from the blood vessels in the dermis that the cells go through the process of apoptosis. Apoptosis is programmed cell death where the cell digests its own nucleus and organelles, leaving only a tough, keratin-filled shell behind. Dead keratinocytes moving into the stratum lucidum and stratum corneum are very flat, hard, and tightly packed so as to form a keratin barrier to protect the underlying tissues.

Protection

The skin provides protection to its underlying tissues from pathogens, mechanical damage, and UV light. Pathogens, such as viruses and bacteria, are unable to enter the body through unbroken skin due to the outermost layers of epidermis containing an unending supply of tough, dead keratinocytes. This protection explains the necessity of cleaning and covering cuts and scrapes with bandages to prevent infection. Minor mechanical damage from rough or sharp objects is mostly absorbed by the skin before it can damage the underlying tissues. Epidermal cells reproduce constantly to quickly repair any damage to the skin. Melanocytes in the epidermis produce the pigment melanin, which absorbs UV light before it can pass through the skin. UV light can cause cells to become cancerous if not blocked from entering the body.

1. Skin Colour

Human skin colour is controlled by the interaction of 3 pigments: melanin, carotene, and haemoglobin. Melanin is a brown or black pigment produced by melanocytes to protect the skin from UV radiation. Melanin gives skin its tan or brown coloration and provides the colour of brown or black hair. Melanin production increases as the skin is exposed to higher levels of UV light resulting in tanning of the skin. Carotene is another pigment present in the skin that produces a yellow or orange cast to the skin and is most noticeable in people with low levels of melanin. Haemoglobin is another pigment most noticeable in people with little melanin. Haemoglobin is the red pigment found in red blood cells, but can be seen through the layers of the skin as a light red or pink colour. Haemoglobin is most noticeable in skin coloration during times of vasodilation when the capillaries of the dermis are open to carry more blood to the skin's surface.

2. Sensation

The skin contains abundant nerve endings and receptors that detect stimuli related to temperature, touch, pressure, and pain and relate the information to the nervous system.

3. Cutaneous Sensation

The skin allows the body to sense its external environment by picking up signals for touch, pressure, vibration, temperature, and pain. Merkel disks in the epidermis connect to nerve cells in the dermis to detect shapes and textures of objects contacting the skin. Corpuscles of touch are structures found in the dermal papillae of the dermis that also detect touch by objects contacting the skin. Lamellar corpuscles found deep in the dermis sense pressure and vibration of the skin. Throughout the dermis there are many free nerve endings that are simply neurons with their dendrites spread throughout the dermis. Free nerve endings may be sensitive to pain, warmth, or cold. The density of these sensory receptors in the skin varies throughout the body, resulting in some regions of the body being more sensitive to touch, temperature, or pain than other regions.

4. Excretion

Besides removing heat and some water from the body, sweat also is the vehicle for excretion of a small amount of salts and several organic compounds by integumentary glands.

In addition to secreting sweat to cool the body, eccrine sudoriferous glands of the skin also excrete waste products out of the body. Sweat produced by eccrine sudoriferous glands normally contains mostly water with many electrolytes and a few other trace chemicals. The most common electrolytes found in sweat are sodium and chloride, but potassium, calcium, and magnesium ions may be excreted as well. When these electrolytes reach high levels in the blood, their presence in sweat also increases, helping to reduce their presence within the body. In addition to electrolytes, sweat contains and helps to excrete small amounts of metabolic waste products such as lactic acid, urea, uric acid, and ammonia. Finally, eccrine sudoriferous glands can help to excrete alcohol from the body of someone who has been drinking alcoholic beverages. Alcohol causes vasodilation in the dermis, leading to increased perspiration as more blood reaches sweat glands. The alcohol in the blood is absorbed by the cells of the sweat glands, causing it to be excreted along with the other components of sweat.

5. Storage of nutrients

Lipids are stored in adipose tissues of the dermis and subcutaneous layer of the body. These are made available to the body when there is depletion which may be due to starvation.

6. Blood reservoir

The dermis of the skin houses extensive networks of blood vessels that carry 8 to 10% of the total blood flow in a resting adult. In moderate exercise, skin blood flow may increase, which helps to dissipate heat from the body. During strenuous exercise, however, skin blood vessels constrict (narrow) somewhat, and more blood is able to circulate to contracting muscles.

7. Synthesis of Vitamin D

Vitamin D is a group of closely related compounds. Synthesis of vitamin D begins with activation of a precursor molecule in the skin by ultraviolet (UV) rays in sunlight. The stratum basale and stratum spinosum layers of the epidermis contain a sterol molecule known as 7-dehydrocholesterol. Enzymes in the liver and kidneys then modify the molecule, first into vitamin D3 which is finally converted to calcitriol, the most active form of vitamin D. Calcitriol contributes to the homeostasis of body fluids by aiding absorption of calcium in foods. According to the synthesis sequence just described, vitamin D is a hormone, since it is produced in one location in the body, transported by the blood, and then exerts its effect in another location. In this respect, the skin may be considered an endocrine organ.

3.3 The Epidermis

The epidermis is composed of stratified squamous epithelium. It contains four principal types of cells:

i. Keratinocytes: About 90% of the epidermal cells are keratinocytes. They produce the protein keratin that helps waterproof and protect the skin and underlying tissues.
ii. Melanocytes: They produce the pigment melanin, which comprise about 8% of the epidermal cells. Their long, slender projections extend between and transfer granules of melanin to keratinocytes. Melanin (melan = black) is a brown-black pigment that contributes to skin colour and absorbs ultraviolet (UV) light.
iii. Langerhans: These are the third type of cell in the epidermis. These cells arise from bone marrow and migrate to the epidermis. They interact with white blood cells called helper T cells in immune responses and are easily damaged by UV radiation.
iv. A fourth type of cell found in the epidermis is called Merkel cells. These cells are located in the deepest layer (stratum basale) of the epidermis of hairless skin, where they are attached to keratinocytes by desmosomes. Merkel cells make contact with the flattened portion of the ending of a sensory neuron (nerve cell), called a tactile (Merkel) disc, and are thought to function in the sensation of touch.

Four or five distinct layers of cells form the epidermis. In most regions of the body the epidermis is about 0.1 mm thick and has four layers. Where exposure to friction is greatest, such as in the palms of the hand and soles of the foot, the epidermis is thicker (l to 2 mm) and has five layers. Constant exposure of thin or thick skin to friction or pressure stimulates formation of a callus, an abnormal thickening of the epidermis.

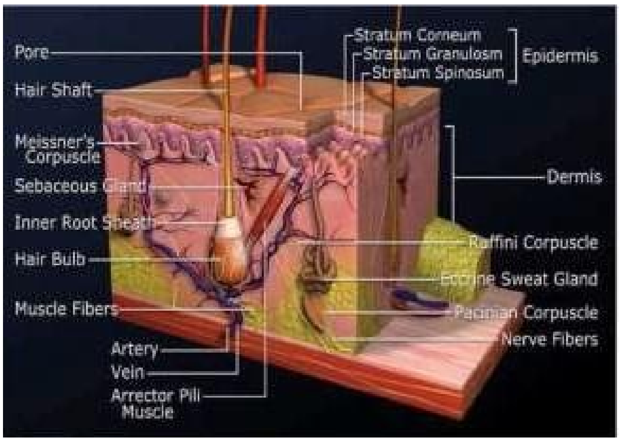

Fig. 4: Structure of Epidermis and Dermis
Source: http://en.wikipedia.org/wiki/commons/a/a5

The names of the five layers (strata), from the deepest to the most superficial are:

1. **Stratum Basale**: This single layer of cuboidal to columnar cells contains stem cells, which are capable of continued cell division, and Melanocytes. The stratum basale also contains tactile (Merkel) discs that are sensitive to touch.
2. **Stratum Spinosum**: This layer of the epidermis contains 8 to 10 rows (sheets) of polyhedral (many sided) cells that fit closely together. The cells here appear to be covered with prickly spines (spinosum = prickly) because the cells shrink and pull apart when the tissue is prepared for microscopic examination.

3. **Stratum Granulosum:** The third layer of the epidermis consists of three to five rows of flattened cells that develop darkly staining granules of a substance called keratohyalin. This compound is the precursor of keratin, a protein found in the outer layer of the epidermis. Keratin forms a barrier that protects deeper layers from injury and microbial invasion and makes the skin waterproof.

4. **Stratum Lucidum:** Normally, only the thick skin of the palms and soles has this layer. It consists of three to five rows of clear, flat, dead cells that contain droplets of an intermediate substance that is formed from keratohyalin and is eventually transformed to keratin.

5. **Stratum Corneum:** This layer consists of 25 to 30 rows of flat, dead cells completely filled with keratin. These cells are continuously shed and replaced by cells from deeper strata. The stratum corneum serves as an effective barrier against light and heat waves, bacteria, and many chemicals.

In the process of keratinisation, cells newly formed in the basal layers undergo a developmental process as they are pushed to the surface. As the cells relocate, they accumulate keratin. At the same time the cytoplasm, nucleus, and other organelles disappear, and the cells die. Eventually, the keratinised cells slough off and are replaced by underlying cells that, in turn, become keratinised. The whole process by which a cell forms in the basal layer, rises to the surface, becomes keratinised, and sloughs off takes two to four weeks. Epidermal growth factor (EGF) is a protein hormone that stimulates growth of epithelial and epidermal cells during tissue development, repair, and renewal.

3.4 The Dermis

The second principal part of the skin, the dermis, is composed of connective tissue containing collagen and elastic fibres. The few cells in the dermis include fibroblasts, macrophages, and adipocytes. The dermis is very thick in the palms and soles and very thin in the eyelids, penis, and scrotum. It also tends to be thicker on the dorsal than the ventral aspects of the body and thicker on the lateral than the medial aspects of the extremities. Blood vessels, nerves, glands, and hair follicles are embedded in the dermis.

The outer portion of the dermis, about one-fifth of the thickness of the total layer, is named the papillary region (layer). It consists of areola connective tissue containing fine elastic fibres. Its surface area is greatly increased by small, finger like projections called dermal papillae.

The deeper portion of the dermis is called the reticular region (layer). It consists of dense, irregular connective tissue containing interlacing bundles of collagen and coarse elastic fibres. Within the reticular region, bundles of collagen fibres interlace in a netlike manner. Spaces between the fibres are occupied by a small quantity of adipose tissue, hair follicles, nerves, oil glands, and the ducts of sweat glands. Varying thicknesses of the reticular region contribute to differences in the thickness of skin.

The combination of collagen and elastic fibres in the reticular region provides the skin with strength, extensibility, and elasticity. (Extensibility is the ability to stretch; elasticity is the ability to return to original shape after stretching.) The ability of the skin to stretch can readily be seen in pregnancy, obesity, and oedema. Small tears that occur in the dermis during extreme stretching are initially red and remain visible afterward as silvery white streaks called striae (STRI-e) or stretch marks.

The reticular region is attached to underlying organs, such as bone and muscle, by the subcutaneous layer, also called the hypodermis or superficial fascia. The subcutaneous layer also contains nerve endings called lamellated or Pacinian corpuscles that are sensitive to pressure. Nerve endings sensitive to cold are found in and just below the dermis, while those sensitive to heat are located in the middle and outer dermis.

Hypodermis

Deep to the dermis is a layer of loose connective tissues known as the hypodermis or subcutaneous tissue. The hypodermis serves as the flexible connection between the skin and the underlying muscles and bones as well as a fat storage area. Areolar connective tissue in the hypodermis contains elastin and collagen fibres loosely arranged to allow the skin to stretch and move independently of its underlying structures. Fatty adipose tissue in the hypodermis stores energy in the form of triglycerides. Adipose also helps to insulate the body by trapping body heat produced by the underlying muscles.

Hair

Hair is an accessory organ of the skin made of columns of tightly packed dead keratinocytes found in most regions of the body. The few hairless parts of the body include the palmar surface of the hands, plantar surface of the feet, **lips**, **labia minora**, and **glans penis**. Hair helps to protect the body from UV radiation by preventing sunlight from striking the skin. Hair also insulates the body by trapping warm air around the skin. The structure of hair can be broken down into 3 major parts: the follicle, root, and shaft.

Nails

Nails are accessory organs of the skin made of sheets of hardened keratinocytes and found on the distal ends of the fingers and toes. **Fingernails** and **toenails** reinforce and protect the end of the digits and are used for scraping and manipulating small objects. There are 3 main parts of a nail: the root, body, and free edge. The **nail root** is the portion of the nail found under the surface of the skin. The **nail body** is the visible external portion of the nail. The **free edge** is the distal end portion of the nail that has grown beyond the end of the finger or toe. Nails grow from a deep layer of epidermal tissue known as the nail matrix, which surrounds the nail root.

Sudoriferous Glands

Sudoriferous glands are exocrine glands found in the dermis of the skin and commonly known as sweat glands. There are 2 major types of sudoriferous glands: eccrine sweat glands and apocrine sweat glands. **Eccrine sweat glands** are found in almost every region of the skin and produce a secretion of water and sodium chloride. Eccrine sweat is delivered via a duct to the surface of the skin and is used to lower the body's temperature through evaporative cooling.

Apocrine sweat glands are found in mainly in the axillary and pubic regions of the body. The ducts of apocrine sweat glands extend into the follicles of hairs so that the sweat produced by these glands exits the body along the surface of the hair shaft. Apocrine sweat glands are inactive until puberty, at which point they produce a thick, oily liquid that is consumed by bacteria living on the skin. The digestion of apocrine sweat by bacteria produces body odor.

Sebaceous Glands

Sebaceous glands are exocrine glands found in the dermis of the skin that produce an oily secretion known as sebum. Sebaceous glands are found in every part of the skin except for the thick skin of the palms of the hands and soles of the feet. Sebum is produced in the sebaceous glands and carried through ducts to the surface of the skin or to hair follicles. Sebum acts to waterproof and increase the elasticity of the skin. Sebum also lubricates and protects the cuticles of hairs as they pass through the follicles to the exterior of the body.

Ceruminous Glands

Ceruminous glands are special exocrine glands found only in the dermis of the ear canals. Ceruminous glands produce a waxy secretion known as cerumen to protect the ear canals and lubricate the **eardrum**. Cerumen protects the ears by trapping foreign material such as dust and airborne pathogens that enter the **ear canal**. Cerumen is made continuously and slowly pushes older cerumen outward toward the exterior of the ear canal where it falls out of the ear or is manually removed. (Prepared by Tim Taylor, Anatomy and Physiology Instructor)

SELF ASSESSMENT EXERCISE

1. List five functions of the skin.
2. …………and……………..are two principal parts of the skin.

3.2 Anatomy of the ear

The ear is the organ of hearing and, in mammals, balance. In mammals, the ear is usually described as having three parts, namely the outer ear, middle ear and the inner ear. The outer ear consists of the pinna and the external auditory canal. Since the outer ear is the only visible portion of the ear in most animals, the word "ear" often refers to the external part alone.[1] The middle ear includes the tympanic cavity and the three bony ossicles. The inner ear sits in the bony labyrinth, and contains structures which are key to several senses: the semicircular canals, which enable balance and eye tracking when moving; the utricle and saccule, which enable balance when stationary; and the cochlea, which enables hearing. The ears of vertebrates are placed somewhat symmetrically on either side of the head, an arrangement that aids sound localisation. The ear develops from the first pharyngeal pouch and six small swellings that develop in the early embryo called otic placodes, which are derived from ectoderm. The ear may be affected by disease, including infection and traumatic damage. Diseases of the ear may lead to hearing loss, tinnitus (ringing sound in the ear) and balance disorders such as vertigo, although many of these conditions may also be affected by damage to the brain or neural pathways leading from the ear.

3.2.1 Anatomy of the Human Ear

Human ear, organ of hearing and equilibrium that detects and analyses sound by transduction (or the conversion of sound waves into electrochemical impulses) and maintains the sense of balance (equilibrium).

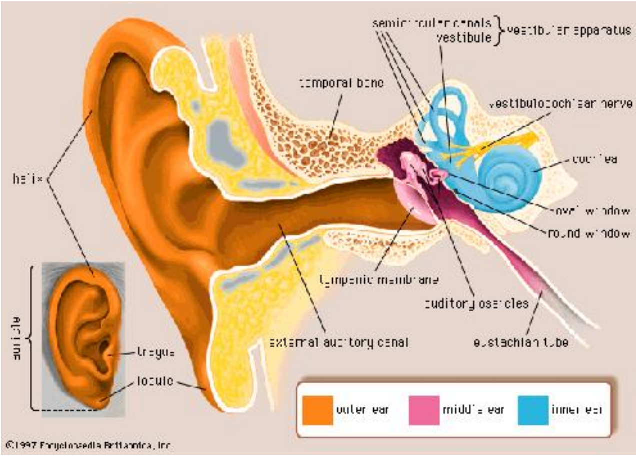

Figure 5: The Human ear

3.2.2 Structure of Human Ear

The human ear consists of three parts: the outer ear, middle ear and inner ear.[2] The ear canal of the outer ear is separated from the air-filled tympanic cavity of the middle ear by the eardrum (tympanic membrane). The middle ear contains the three small bones (ossicles) involved in the transmission of sound, and is connected to the throat (pharynx) at the nasopharynx, via the pharyngeal opening of the Eustachian tube. The inner ear contains the otolith organs: the utricle and saccule, and the semicircular canals belonging to the vestibular system, as well as the cochlea of the auditory system.

3.2.3 Function of Human Ear Hearing

The human ear can generally hear sounds with frequencies between 20 Hz and 20 kHz (the audio range). Sounds outside this range are considered infrasound (below 20 Hz)[10] or ultrasound (above 20 kHz)[11] Although hearing requires an intact and functioning auditory portion of the central nervous system as well as a working ear, human deafness (extreme insensitivity to sound) most commonly occurs because of abnormalities of the inner ear, rather than in the nerves or tracts of the central auditory system.

Balance

Providing balance, when moving or stationary is also a central function of the ear. The ear facilitates two types of balance: static balance, which allows a person to feel the effects of gravity, and dynamic balance, which allows a person to sense acceleration.

3.2.3 Hearing loss

Hearing loss may be either partial or total. This may be a result of injury or damage to the ear, congenital disease, or physiological causes. When hearing loss is a result of injury or damage to the outer ear or middle ear, it is known as conductive hearing loss. When deafness is a result of injury or damage to the inner ear, vestibulochoclear nerve, or brain, it is known as sensorineural hearing loss.

3.3 Anatomy of the Eye

The **human eye** is an organ which reacts to light and pressure. As a sense organ, the mammalian eye allows vision. Human eyes help to provide a three dimensional, moving image, normally coloured in daylight. Rod and cone cells in the retina allow conscious light perception and vision including colour differentiation and the perception of depth. The human eye can differentiate between about 10 million colours [1] and is possibly capable of detecting a single photon. The human eye's non-image-forming photosensitive ganglion cells in the retina receive light signals which affect adjustment of the size of the pupil, regulation and suppression of the hormone melatonin and entrainment of the body clock.

3.3.1 Structure of Human Eye

The eye is not shaped like a perfect sphere; rather it is a fused two-piece unit, composed of the anterior and the posterior segments. The anterior segment is made up of the cornea, iris and lens. The cornea is transparent and more curved, and is linked to the larger posterior segment, composed of the vitreous, retina, choroid and the outer white shell called the sclera. The cornea is typically about 11.5 mm (0.3 in) in diameter, and 1/2 mm (500 µm) in thickness near its center. The posterior chamber constitutes the remaining five-sixths; its diameter is typically about 24 mm. The cornea and sclera are connected by an area termed the limbus. The iris is the pigmented circular structure concentrically surrounding the center of the eye, the pupil, which appears to be black. The size of the pupil, which controls the amount of light entering the eye, is adjusted by the iris' dilator (dilator pupillae) and sphincter (sphincter pupillae) muscles.

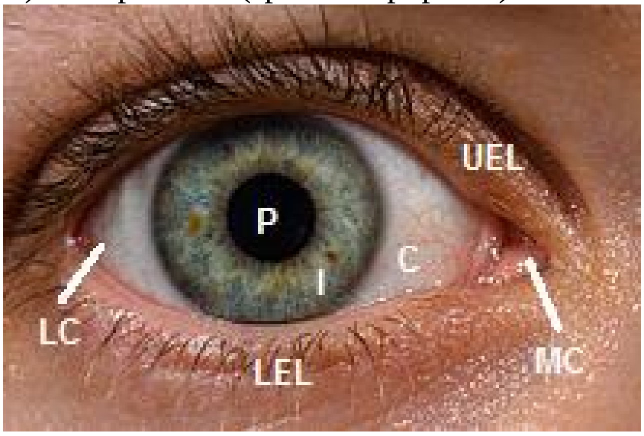

Figure 6: The Eye
P – Pupil, I – Iris, C – Cornea, UEL – Upper eye lid,
LEL – Lower eye lid, MC –

Medial canthus, LC – Lateral canthus

Light energy enters the eye through the cornea, the pupil and the lens. The ciliary muscle regulates the changes in the shape of the lens for near or distant vision (accommodation). Photons of light falling on the light-sensitive cells of the retina (photoreceptor cones and rods) are converted into electrical signals that are transmitted to the brain by the optic nerve and interpreted as sight and vision.

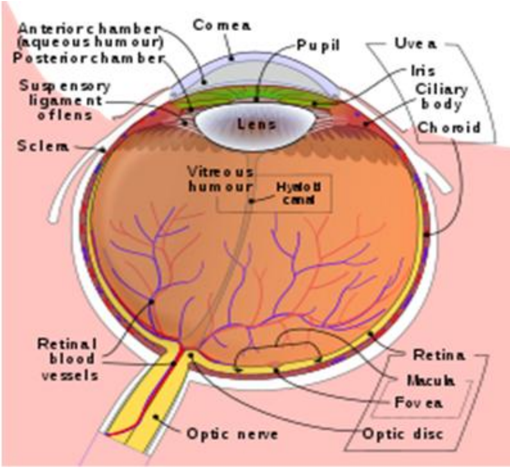

Figure 7: Schematic diagram of the human eye

3.3.2 Components of Human Eye

The eye is made up of three coats, or layers, enclosing various anatomical structures. The outermost layer, known as the fibrous tunic, is composed of the cornea and sclera. The middle layer, known as the vascular tunic or uvea, consists of the choroid, ciliary body, pigmented epithelium and iris. The innermost is the retina, which gets its oxygenation from the blood vessels of the choroid (posteriorly) as well as the retinal vessels (anteriorly).

The spaces of the eye are filled with the aqueous humour anteriorly, between the cornea and lens, and the vitreous body, a jelly-like substance, behind the lens, filling the entire posterior cavity. The aqueous humour is a clear watery fluid that is contained in two areas: the anterior chamber between the cornea and the iris, and the posterior chamber between the iris and the lens. The lens is suspended to the ciliary body by the suspensory ligament (Zonule of Zinn), made up of hundreds of fine transparent fibers which transmit muscular forces to change the shape of the lens for accommodation (focusing). The vitreous body is a clear substance composed of water and proteins, which give it a jelly-like and sticky composition

4.0 CONCLUSION

The skin, the ear and the eyes are vital organs in humans. They are all very important and have different functions in the body. It is hoped that you have gained a deeper understanding of the skin, ear and eye and understood the importance of taking care and maintaining the organs.

5.0 SUMMARY

In this unit, we have described the anatomical structure and functions of human skin, ear and eyes.

6.0 TUTOR-MARKED ASSIGNMENT

- Describe in details the functions of the skin
- What are the functions of human ear?
- Describe the structure of human eye

7.0 REFERENCES/FURTHER READINGS

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MODULE2 INTRODUCTION TO BODY SYSTEM

Unit 1 Overview of the skeletal system
Unit 2 Composition and types of bone
Unit 3 Axial skeleton and appendicular skeleton
Unit 4 The muscles as associate organ of the skeletal system

UNIT1 OVERVIEW OF THE SKELETAL SYSTEM

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 MainContent
3.1 General futures and surface markings
3.2 The Vertebral Column
3.3 FunctionsoftheSkeletalSystem
4.0 Conclusion
5.0 Summary
6.0 Tutor-MarkedAssignment
7.0 References/FurtherReadings

1.0INTRODUCTION

The skeletal system forms the rigid internal framework of the body. It consists of the bones, cartilages, and ligaments. Bones support the weight of the body, allow for body movements, and protect internal organs. Cartilage provides flexible strength and support for body structures such as the thoracic cage, the external ear, and the trachea and larynx. At joints of the body, cartilage can also unite adjacent bones or provide cushioning between them. Ligaments are the strong connective tissue bands that hold the bones at a moveable joint together and serve to prevent excessive movements of the joint that would result in injury. Providing movement of the skeleton are the muscles of the body, which are firmly attached to the skeleton via connective tissue structures called tendons. As muscles contract, they pull on the bones to produce movements of the body. Thus, without the skeleton, you would not be able to stand, run, or even feed yourself!

2.0OBJECTIVES

Attheendofthisunit,youshouldbeableto:

- Discuss the general futures and surface markings of skeletal system
- Discuss the Vertebral Column
- Discuss the functionsoftheSkeletalSystem

3.0 MAIN CONTENT

3.1General futures and surface markings

Looking to the bone reveals the surface is not smooth but scarred with bumps, holes and ridges. These are surface markings where muscles, tendons and ligaments are attached, and where blood & lymph vessels and nerves may leave their impression.

Depression and openings

Fissure narrow, cleft like opening between adjacent parts of bone. Example: Supra orbital fissure.
Foramen, a bigger, round opening. Example: Foramen magnum.
Meatus: a relatively narrow tubular canal. Example: External auditory meatus*Groves and sulcus*: are deep furrow on the surface of a bone or other structure.
Example: Inter-vertebral and radial groves of the humerus.
Fossa: shallow depressed area. Example: Mandibular fossa.

Processes that form joints

Condyle: knuckle-like process/ concave or convex. Example
Medial condyle of femur
Head: expanded, rounded surface at proximal end of a bone often joined to shaft by a narrowed neck. Example: Head of femur
Facet: small, flat surface. Example: Articular facet of ribs.

Process to which tendons, ligaments and other Connective tissue attach

Tubercle: it is *a* knob-like process. Example: Greater tubercle of humerus.

Tuberosity: it is large, round, roughened process. Example: ischial tuberosity.
Trochanter: it is a large, blunt projection found only on femur
Crest is a prominent ridge. Example: Iliac crest.
Line: it is a less prominent ridge than a crest.
Spinous process (spine) is a sharp, slender process. Example
Ischial spin*Epicondyle* is a prominence above condyle. Example medial Epicondyle of Femur

3.2The Vertebral Column

The vertebral column is also known as the spinal column or spine. (singular = vertebra), each of which is separated and united by an **intervertebral disc**. Together, the vertebrae and intervertebral discs form the vertebral column. It is a flexible column that supports the head, neck, and body and allows for their movements. It also protects the spinal cord, which passes down the back through openings in the vertebrae. The adult vertebral column consists of 24 vertebrae, plus the sacrum and coccyx.

The vertebrae are divided into three regions: cervical C1–C7 vertebrae, thoracic T1–T12 vertebrae, and lumbar L1–L5 vertebrae. The vertebral column is curved, with two primary curvatures (thoracic and sacrococcygeal curves) and two secondary curvatures (cervical and lumbar curves).

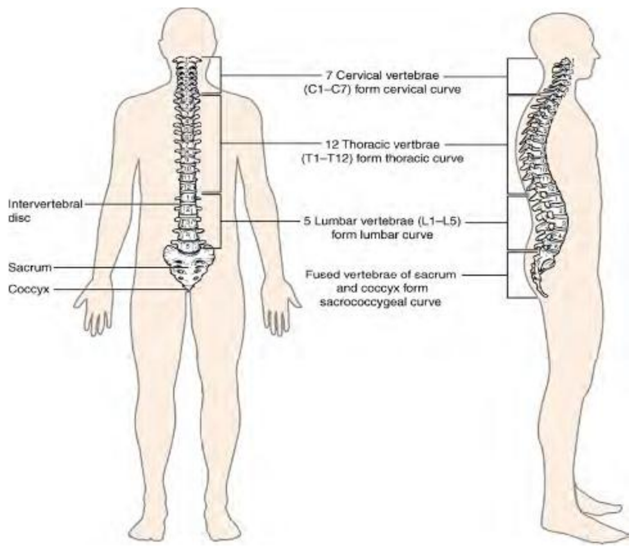

Figure 8: Vertebral Column

Regions of the Vertebral Column

The vertebral column originally develops as a series of 33 vertebrae, but this number is eventually reduced to 24 vertebrae, plus the sacrum and coccyx. The vertebral column is subdivided into five regions, with the vertebrae in each area named for that region and numbered in descending order. In the neck, there are seven cervical vertebrae, each designated with the letter “C” followed by its number. Superiorly, the C1 vertebra articulates (forms a joint) with the occipital condyles of the skull.

Inferiorly, C1 articulates with the C2 vertebra, and so on. Below these are the 12 thoracic vertebrae, designated T1–T12. The lower back contains the L1–L5 lumbar vertebrae. The single sacrum, which is also part of the pelvis, is formed by the fusion of five sacral vertebrae. Similarly, the coccyx, or tailbone, results from the fusion of four small coccygeal vertebrae. However, the sacral and coccygeal fusions do not start until age 20 and are not completed until middle age. An interesting anatomical fact is that almost all mammals have seven cervical vertebrae, regardless of body size.

Curvatures of the Vertebral Column

The adult vertebral column does not form a straight line, but instead has four curvatures along its length. These curves increase the vertebral column’s strength, flexibility, and ability to absorb shock. When the load on the spine is increased, by carrying a heavy backpack for example, the curvatures increase in depth (become more curved) to accommodate the extra weight. They then spring back when the weight is removed. The four adult curvatures are classified as either primary or secondary curvatures. Primary curves are retained from the original fetal curvature, while secondary curvatures develop after birth.

During fetal development, the body is flexed anteriorly into the fetal position, giving the entire vertebral column a single curvature that is concave anteriorly. In the adult, this fetal curvature is retained in two regions of the vertebral column as the **thoracic curve**, which involves the thoracic vertebrae, and the **sacrococcygeal curve**, formed by the sacrum and cocci. Each of these is thus called a **primary curve** because they are retained from the original fetal curvature of the vertebral column.

A **secondary curve** develops gradually after birth as the child learns to sit upright, stand, and walk. Secondary curves are concave posteriorly, opposite in direction to the original fetal curvature. The **cervical curve** of the neck region develops as the infant begins to hold his head upright when sitting. Later, as the child begins to stand and then to walk, the **lumbarcurve** of the lower back develops. In adults, the lumbar curve is generally deeper in females.

Disorders associated with the curvature of the spine include **kyphosis** (an excessive posterior curvature of the thoracic region), **lordosis** (an excessive anterior curvature of the lumbar region), and **scoliosis** (an abnormal, lateral curvature, accompanied by twisting of the vertebral column).

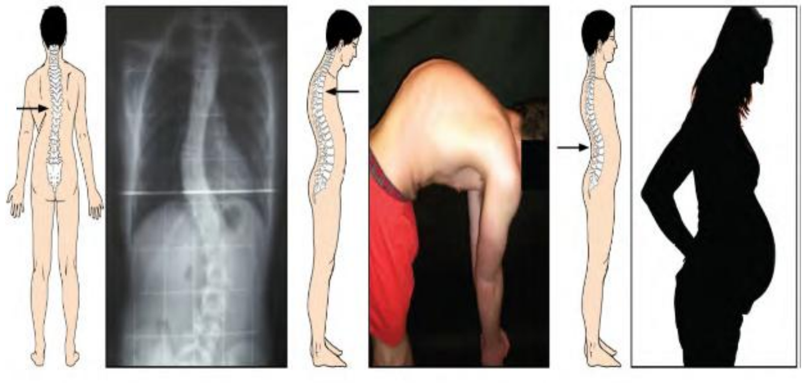

Figure 9: Abnormal Curvatures of the Vertebral Column

3.3 FunctionsoftheSkeletalSystem

The five main functions of bones are to provide:

1. Protection of vital structures: Vitalorgansare protectedbytheskeletalsystem.Thebrainis protectedbythesurroundingskullastheheartandlungsare encasedbythesternumandribcage.
2. Support for the body: e.g. the vertebral column forms the structural framework for the trunk.
3. A mechanical basis for movement: Bodilymovementiscarriedoutbytheinteractionofthemuscular andskeletalsystems.Forthisreason, theyareoftengrouped togetherasthemusculo-skeletalsystem.Musclesareconnected tobonesbytendons.Bonesareconnected toeachotherby ligaments.Where bonesmeetoneanotheristypicallycalleda *joint.*Muscleswhichcausemovementofajointareconnectedto twodifferentbonesandcontracttopullthemtogether.An examplewould bethecontractionof thebicepsandarelaxation

ofthetriceps.Thisproducesabendat theelbow.Thecontraction ofthetricepsandrelaxationofthebicepsproducetheeffectof straighteningthearm.

4. Blood cells, i.e. bloodcellsareproducedbythemarrowlocatedinsomebones. Anaverageof 2.6millionredbloodcells isproducedeachsecondbythebone marrowtoreplace thosewornoutanddestroyedbytheliver. Bonesserveasastorageareaformineralssuchascalciumandphosphorus. Whenanexcessispresentintheblood,abuild-upwilloccurwithinthebones.

Whenthesupplyofthesemineralswithin thebloodislow,itwillbewithdrawn fromthebonestoreplenishthesupply.

5. Storage for salts, i.e., the calcium, phosphorus, and magnesium salts in bones provide a mineral reservoir for the body.

4.0 CONCLUSION

The vertebral column together with the sternum & ribs constitutes the skeleton of the trunk of the body. It composes 2/5th of the height of the body and has average length of 71 cm in males and 61 cm in females. The adult vertebral column contains 26 vertebrae.

5.0 SUMMARY

Inthisunit,we have been abletodiscuss the general futures and surface markings of the skeletal system, the vertebral column and the functionsoftheSkeletalSystem.

6.0 TUTOR-MARKEDASSIGNMENT

1. Discuss the functions of the Skeletal System
2. Discuss the curvatures of the Vertebral Column
3. Discuss the regions of the Vertebral Column
4. List the parts of the sternum

ANSWERTOSELFASSESSMENTEXERCISE

1. Thefunctionsoftheskeletalsystemincludethefollowing:

- It providestheshapeandformforourbodies.
- It providessupportandprotectionfordelicatebodyorgans.

- It allowsbodilymovement.
- It producesbloodforthebodyandstoresminerals.

1. Primary curve
   a. Thoracic – Kyphosis, Scoliosis are abnormal thoracic curves
   b. Sacral

2. Secondary curve
   a. Cervical
   b. Lumbar – Lordosis is an abnormal lumbar curve

4. Thesternumis madeupofthemanubrium,thebodyandxiphoid process.

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UNIT 2 COMPOSITION AND TYPES OF BONE

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 MainContent
    3.1 Classification of Bones
    3.2 BoneComposition
    3.3 Types of bone
4.0 Conclusion
5.0 Summary
6.0 Tutor-MarkedAssignment
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1.0 INTRODUCTION

Bone, or **osseous tissue**, is a hard, dense connective tissue that forms most of the adult skeleton, the support structure of the body. In the areas of the skeleton where bones move (for example, the ribcage and joints), **cartilage**, a semi-rigid form of connective tissue, provides flexibility and smooth surfaces for movement. Thehumanskeletonisdividedintotwodistinctparts:Theaxialskeleton andtheappendicularskeleton.

2.0 OBJECTIVES

By the end of this section, you will be able to:

- Classify bones according to their shapes
- Describe the function of each category of bones

3.1 Classification of Bones

The 206 bones that make up the adult skeleton are divided into five categories based on their shapes. Their shapes and their functions are related such that each shape category of bone has a distinct function.

Long Bones

A **long bone** is one that is cylindrical in shape, being longer than it is wide. Keep in mind, however, that the term describes the shape of a bone, not its size. Long bones are found in the arms (humerus, ulna, radius) and legs (femur, tibia, fibula), as well as in the fingers (metacarpals, phalanges) and toes (metatarsals, phalanges). Long bones function as levers; they move when muscles attached to them contract.

Short Bones

A **short bone** is one that is cube-like in shape, being approximately equal in length, width, and thickness. The only short bones in the human skeleton are in the carpals

of the wrists and the tarsals of the ankles. Short bones provide stability and support as well as some limited motion.

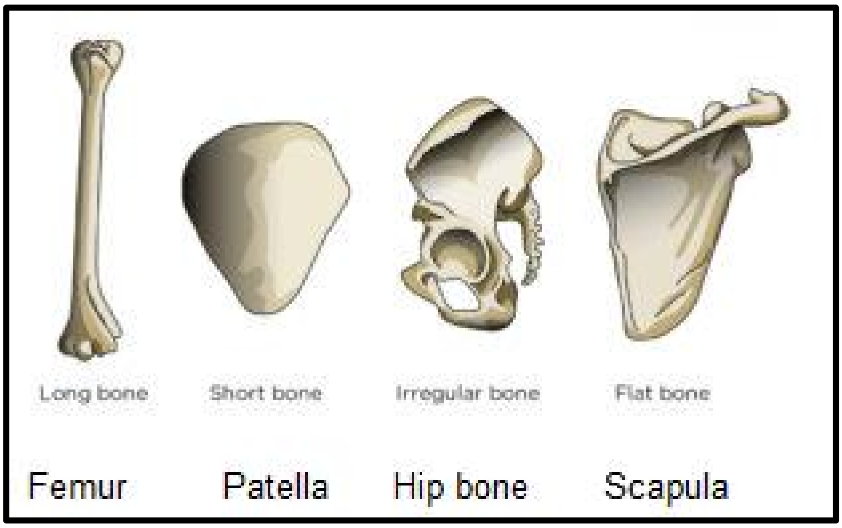

Figure 10: Classification of Bones

Bones may be classified according to their shape**:**

Flat Bones

The term "**flat bone**" is somewhat of a misnomer because, although a flat bone is typically thin, it is also often curved. Examples include the cranial (skull) bones, the scapulae (shoulder blades), the sternum (breastbone), and the ribs. Flat bones serve as points of attachment for muscles and often protect internal organs.

Irregular Bones

An **irregular bone** is one that does not have any easily characterisable shape and therefore does not fit any other classification. These bones tend to have more complex shapes, like the vertebrae that support and protect the spinal cord from compressive forces. Many facial bones, particularly the ones containing sinuses, are classified as irregular bones.

Sesamoid Bones

A **sesamoid bone** is a small, round bone that, as the name suggests, is shaped like a sesame seed. These bones form in tendons (the sheaths of tissue that connect bones to muscles) where a great deal of pressure is generated in a joint. The sesamoid bones protect tendons by helping them to overcome compressive forces. Sesamoid bones vary in number and placement from person to person but are typically found in tendons associated with the feet, hands, and knees. The patellae (singular = patella) are the only sesamoid bones found in common with every person, with their associated features, functions, and examples.

3.2 Typesof Bones

Thebonesofthebodyfallintofourgeneralcategories:longbones, short bones,flatbones,andirregularbones.Longbonesarelongerthanthey arewideandworkaslevers. Thebonesoftheupperandlower extremities(e.g. humerus,tibia,femur,ulna,metacarpals,etc.)areof thistype. Shortbonesareshort,cube-shaped,andfoundinthewrists andankles.Flatboneshavebroadsurfacesforprotectionoforgansand attachmentofmuscles(e.g. ribs,cranialbones,bonesofshoulder girdle).Irregularbonesareallothersthatdonotfallintotheprevious categories.Theyhavevariedshapes,sizes,andsurfacefeatures, and includethebonesofthevertebraeandafewintheskull.

3.3 Bonecomposition

Bonesarecomposedof tissuesthatmaytakeoneof twoforms in terms of their texture: Compact, (orDensebone),andspongy (or cancellousbone).Mostbones containboth types with no sharp boundaries between the two types because the differences between them depend on the relative amount of solid matter and the number and size of the spaces in each of them. All bones have an outer shell of compact bone around a central mass of spongy bone, except where the latter is replaced by a marrow or a medullary cavity, or an air space, such as maxillary sinus in the face. Compactboneisdense,hard,andformsthe protectiveexteriorportionofallbones.Spongyboneisinsidethe compactboneandisveryporous(fullof tinyholes).Spongybone occursinmostbones.Thebonetissueiscomposedofseveraltypesof bonecellsembeddedinawebofinorganicsalts(mostlycalciumand phosphorus)togivethebonestrength,andcollagenousfibresand groundsubstancetogivetheboneflexibility.

4.0CONCLUSION

Bonemassaccountsfor20percentofthebody weight.Thestrengthof bonecomesfromitsinorganiccomponentsof such durabilitythatthey resistdecompositionevenafterdeath.Theclavicleintheshoulderisthe mostcommonlybrokenboneinthebodybecauseittransmitsforces fromthearmtothe trunk.

5.0SUMMARY

Thisunitshowsthefollowing:

- Thedifferenttypesofbones
- Thecompositionofbones
- Thefunctionsoftheskeletalsystem
- Thedivisionsoftheskeletalsystem

SELF ASSESSMENTEXERCISE

1. Describethepatella.
2. Listthecategoriesofbonesinthehumanbody.

ANSWERTOSELFASSESSMENTEXERCISE

1. Thepatellaor kneecapisalarge,triangularsesamoidbone betweenthefemurandthetibia.
2. Thebonesof thebodyfallintofour generalcategories:long bones, shortbones,flatbones,andirregular bones.

6.0 TUTOR-MARKEDASSIGNMENT

Describethecranialandfacialbones.

7.0 REFERENCES/FURTHERREADINGS

Applegate,EdithJ.(1995).TheAnatomyandPhysiologyLearning System:Textbook.Philadelphia:W.B. SaundersCompany.

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UNIT 3AXIAL SKELETON AND APPENDICULAR SKELETON

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 MainContent
3.1 TheAxialSkeleton
3.2 The Appendicular skeleton
3.3 Sutures and Fontanelles
4.0 Conclusion
5.0 Summary
6.0 Tutor-MarkedAssignment
7.0 References/FurtherReadings

2.0 INTRODUCTION

The Adult human skeletons have 206 named bones that are grouped into two principal parts. These are the axial and appendicular skeleton. The Axial skeleton consist bones that lie around the axis of the body. And the appendicular skeleton consists of bones of the body outside of the axial group (associated with the limbs). These are appendages. Upper & lower extremities and bones of girdles are grouped under appendicular skeleton.

2.0OBJECTIVES

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

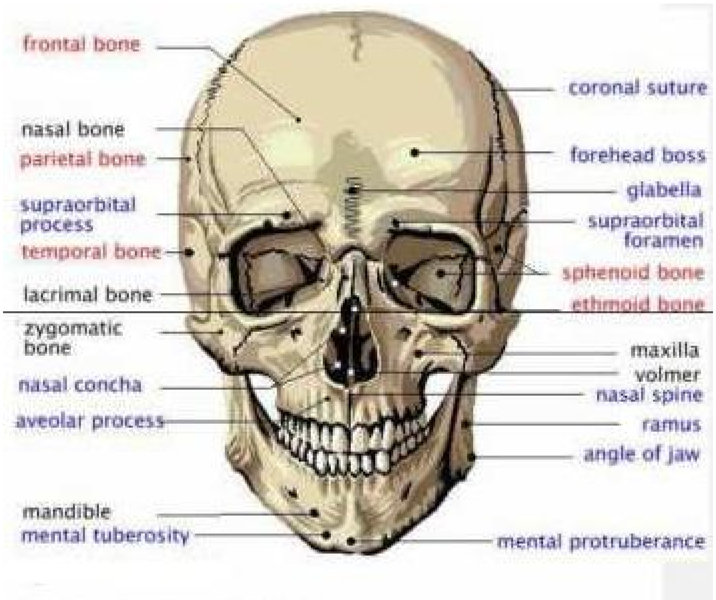
- Distinguish between the axial skeleton and appendicular skeleton
- Define the axial skeleton and its components
- Define the appendicular skeleton and its components

3.0MAINCONTENT

3.1TheAxialSkeleton

Theaxialskeletonconsistsof bonesthatform theaxisofthebodyand supportandprotecttheorgansofthehead,neck,andtrunk.It ismadeup ofthefollowing:

1.**TheSkull:**The skullisthebonyframeworkofthehead.It consistsofeightcranialandfourteenfacialbones.



(http://en.wikipedia.org/wiki/skull)

Figure 11: The Human Skull

(a) The cranialbonesmakeuptheprotectiveframeofbonearound the brain.Thecranialbonesareasfollows:

- Thefrontalformspartof thecranialcavityaswellasthe forehead,thebrowridgesandthenasalcavity.
- Theleftandrightparietalformsmuchofthesuperiorandlateral portionsofthecranium.
- Theleftandrighttemporalformthelateralwallsofthecranium aswellashousingtheexternalear.
- Theoccipitalformstheposteriorandinferiorportionsof the cranium.Manyneckmusclesattachhere, asthisisthepointof articulationwiththeneck.
- Thesphenoidformspart oftheeyeorbitandhelpstoformthe floorof thecranium.
- Theethmoidformsthemedialportionsoftheorbitsandtheroof ofthenasalcavity.

(b) Thefacialbonesmakeuptheupperandlowerjawandotherfacial structures.Thefacialbonesareasfollows:

- Themandibleisthelowerjawbone.It articulateswith the temporalbonesat thetemporomandibularjoints.Thisformsthe onlyfreelymoveablejointinthehead.Itprovidesthechewing motion.
- Theleftandrightmaxillaaretheupperjawbones.Theyform partofthenose,orbits,androofofthemouth.
- Theleftandrightpalatineformsaportionofthenasalcavityand theposteriorportionoftheroofofthemouth.
- Theleftandrightzygomaticarethecheekbones. Theyform portionsoftheorbitsaswell.
- Theleftandrightnasal bonesformthesuperiorpartofthebridge ofthenose.
- Theleftandrightlacrimal boneshelptoformtheorbits.
- Thevomerformspartofthenasalseptum(thedividerbetween thenostrils).

2.**TheSternum:**Thesternumisaflat,daggershapedbonelocated inthemiddleofthe chest.Alongwiththeribs, thesternumforms theribcagethatprotectstheheart,lungs,andmajorbloodvessels fromdamage. Thesternumiscomposedofthree parts:

- Themanubrium,alsocalledthe“handle”.
- Thebody,alsocalledthe“blade”or the“gladiolus”,islocatedin themiddleofthesternumandconnectsthethirdtoseventhribs directlyandtheeighththroughtenthribsindirectly.
- Thexiphoidprocess,alsocalledthe“tip”,islocatedonthe bottomofthesternum.It isoftencartilaginous(cartilage),but doesbecomebonyin later years. Thesethree segmentsofboneareusuallyfusedinadults.

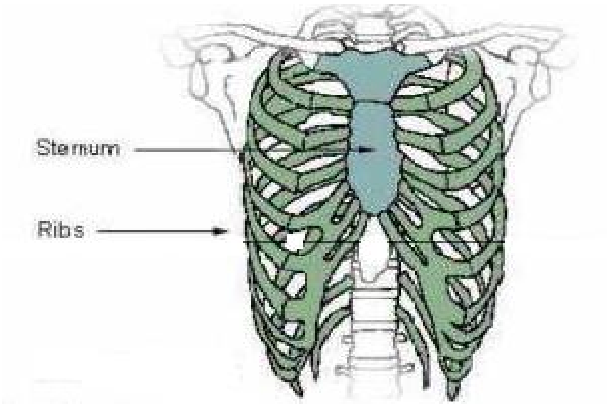


Figure 12: The Thoracic Cage

TheRibs: Theribsarethin,flat,curvedbonesthatforma protective cagearound theorgansintheupperbody.Theyare comprisedof24 bonesarrangedin12pairs.Thesebonesare dividedintothree categories:

- Thefirstsevenbonesarecalledthetrue ribs.
- Thenextthree pairsofbonesarecalledfalse ribs
- Thelasttwosetsofribbonesarecalledfloatingribs. Floating ribsaresmallerthanboththetrue ribsandthefalseribs.

Theribsformakindofcagethatenclosestheupperbody.Theygivethe chestitsfamiliarshape.

Theribsserve severalimportantpurposes:

- Theyprotecttheheartandlungsfrominjuriesandshocksthat mightdamagethem.
- Theyalsoprotectpartsofthestomach,spleen,andkidneys.
- Theribshelpyouto breathe.Asyouinhale,themusclesin betweentheribsliftheribcageup,allowingthelungsto expand.Whenyouexhale, theribcagemovesdownagain, squeezingtheairoutofyourlungs.

4.**TheVertebralColumn:**

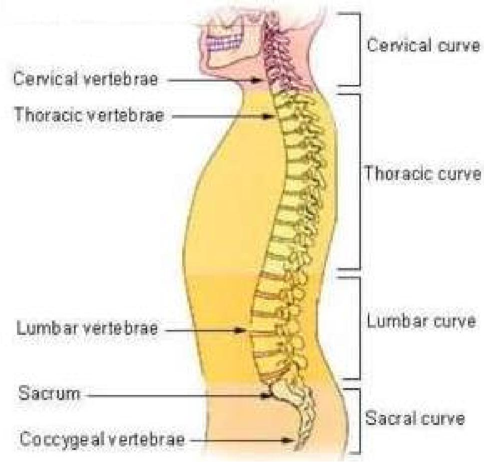


Figure 13: The Vertebral Column
Source: http://en.wikipedia.org/wiki/vertebralcolumn)

Thevertebralcolumn(alsocalledthebackbone,spine,or spinalcolumn) consistsofaseriesof 33irregularlyshaped bones,calledvertebrae. These33bonesaredividedintofivecategoriesdependingonwherethey arelocatedinthebackbone:

- Thefirstsevenvertebraearecalledthecervicalvertebrae. Locatedat thetopof thespinalcolumn,thesebonesforma flexibleframeworkfortheneckandsupportthehead.Thefirst cervicalvertebraiscalledtheatlasandthesecond iscalledthe axis.

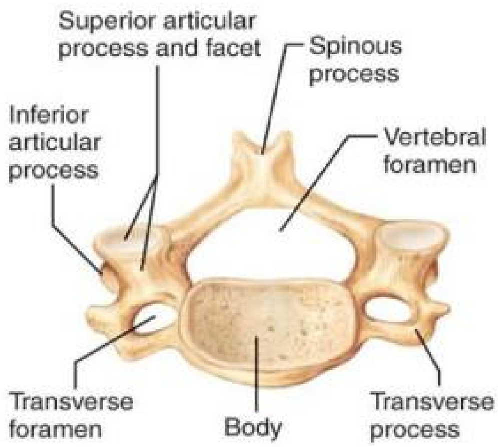


Figure 14: The cervical vertebra
Source: http://test.danstretton.com/the-anatomy-of-the-neck-part-one-the-cervical-vertebrae/

Thenexttwelvevertebraearecalledthethoracicvertebrae.These bonesmovewiththeribstoformtherearanchoroftheribcage.

- Afterthethoracicvertebrae,comethelumbarvertebrae.These fivebonesarethelargestvertebraeinthespinalcolumn.
- Thesacrumisatriangularbonelocatedjustbelowthelumbar vertebrae. It consistsof fourorfivesacralvertebraeinachild, whichbecomesfusedintoasingleboneafterage26. Thebottomofthespinalcolumnis calledthecoccyxor tailbone.It consistsof3-5bonesthatarefusedtogetherinanadult.Manymuscles connecttothecoccyx.

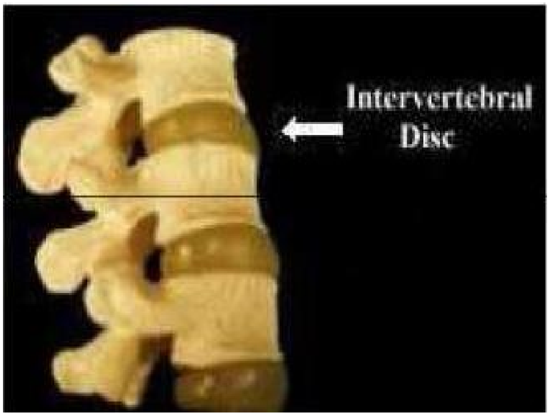


Fig.15:Theintervertebraldisc
http://en.wikipedia.org/wiki/disc

Thesebones make upthevertebralcolumn,resultinginatotalof26 movablepartsinanadult.Inbetween thevertebraeareintervertebral discsmadeof fibrouscartilagethatactasshockabsorbersandallowthe backtomove.Asaperson increases in age, thesediscscompressandshrink, resultinginadistinctlossofheight(generallybetween0.5and2.0cm) betweentheagesof50and55.

Whenlookedatfromtheside,thespineformsfourcurves.Thesecurves arecalledthecervical,thoracic,lumbar, andpelviccurves.Thecervical andlumbar curvesarenotpresentinaninfant.Thecervicalcurvesform around theage of3monthswhenaninfantbeginstoholditsheadup andthelumbarcurvedevelopswhenachildbeginstowalk.

Inadditionto allowinghumanstostanduprightandmaintaintheir balance,thevertebralcolumnservesseveralotherimportantfunctions. It helpstosupporttheheadandarms,whilepermittingfreedomof movement.Italso providesattachmentformanymuscles,theribs,and someoftheorgans,andprotectsthespinalcord, whichcontrolsmost bodilyfunctions.

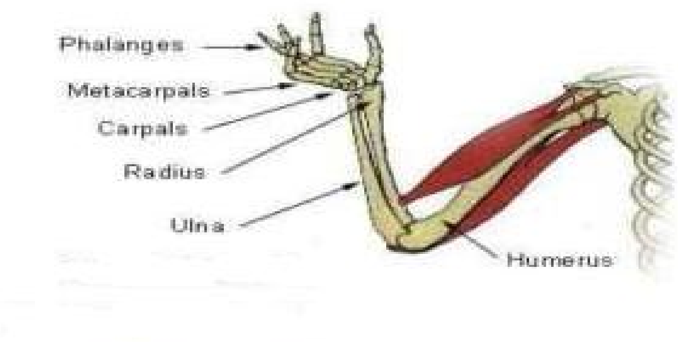
SELF ASSESSMENTEXERCISE1

1.Whatarethebasic functionsofthehumanskeleton?
2---------------,---------------------and----------------arethepartsof thesternum.

3.2 TheAppendicularSkeleton

Theappendicularskeletoniscomposedofbonesthatanchorthe appendagestotheaxialskeleton.

1. **TheUpperExtremities**



(http://en.wikipedia.org/wiki/upper extremity)

Figure 16: The Upper Extremity

Theupperextremityconsistsofthreeparts:thearm,theforearm,and thehand.Thearm,orbrachium,istechnicallyonlytheregionbetweenthe shoulderandelbow.Itconsistsofasinglelongbonecalledthehumerus. Thehumerusisthe longestbone intheupperextremity.Thetop,or head,islarge,smooth,androundedandfitsintothescapulainthe shoulder.Atthebottomofthehumerus,aretwodepressionswherethe humerusconnectstotheulnaandradiusoftheforearm.Together,the humerusandtheulnaformtheelbow joint.Thebottomofthehumerusprotectstheulnarnerveandiscommonlykno wn asthe"funnybone" becausestrikingtheelbowonahardsurfacestimulatestheulnarnerve andproducesatinglingsensation.

Theforearmisthe regionbetweentheelbowandthewrist.It isformed bytheradiusonthelateralsideandtheulnaonthemedialsidewhenthe forearmisviewedintheanatomicalposition.Theulnaislongerthanthe radiusandconnectedmore firmlytothehumerus.Theradius,however, contributesmoretothemovementofthewristandhandthantheulna. Thehandconsistsofthreeparts(thewrist,palm,andfivefingers)and 27bones.The wrist,or carpus,consistsof8smallbonescalledthecarpalbones thataretightlyboundbyligaments.Thesebonesarearranged intwo rowsoffourbones.

2. **TheLowerExtremities**

Thelowerextremityiscomposedofthebonesofthethigh,leg,foot, and thepatella (commonlyknownasthekneecap). Thethighistheregionbetweenthehipandthekneeandiscomposedof asinglebonecalledthefemuror thighbone.Thefemuristhelongest, largest,andstrongestboneinthebody. Thelegistechnicallyonlytheregionfromthekneetotheankle.Itis formedbythefibulaonthesideawayfromthebody(lateral side)and thetibia,alsocalledtheshinbone,onthesidenearestthebody(medial side).The tibiaconnectstothefemurtoformthekneejointandwiththe talus,afootbone,toallowtheankletoflexandextend.Thetibiais largerthanthefibulabecauseitbears mostoftheweight,whilethe fibulaservesasanareaformuscle attachment.

Thefoot,orpes,containsthe26bonesoftheankle,instep,andthefive toes.Theankle,ortarsus,iscomposedofthe7tarsalboneswhich correspondtothecarpalsinthewrist.Thelargesttarsalboneiscalled thecalcaneusor heelbone.Thetalus restsontopofthecalcaneusandis connectedtothetibia.Themetatarsalandphalangesbonesofthefoot aresimilarinnumberandpositiontothemetacarpalandphalanges bones ofthehand.

Thepatellaor kneecapisalarge,triangularsesamoidbonebetweenthe femurandthetibia. It isformedin responsetothestraininthetendon thatformstheknee.Thepatellaprotectsthekneejointandstrengthens thetendonthatformstheknee. Thebonesofthelowerextremitiesaretheheaviest,largest,and strongestbonesinthebodybecausetheymustbeartheentireweightof thebodywhenapersonisstandingintheuprightposition.

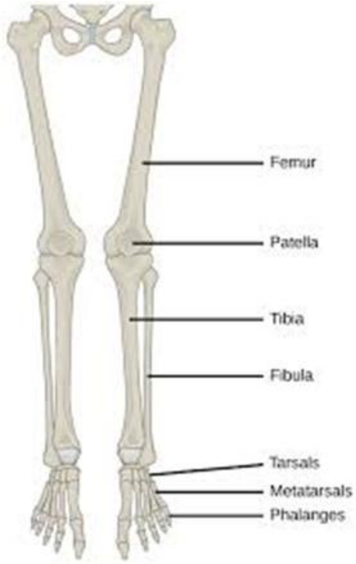


Figure 17: The lower extremities

3. TheShoulderGirdle

This is alsocalledthepectoralgirdle, and iscomposed of fourbones: twoclaviclesandtwoscapulae.

Theclavicle,commonlycalledthecollarbone,isaslenderS-shaped bonethatconnectstheupperarmtothetrunkofthebodyandholdsthe shoulderjointawayfromthebody to allowforgreaterfreedomof movement.

Thescapulaisalarge,triangular,flatboneonthebacksideoftherib cagecommonlycalledtheshoulderblade.It hasashallowdepression calledtheglenoidcavitythattheheadofthehumerus(upperarmbone) fitsinto.

Usually,a“girdle”referstosomethingthatencirclesor isacomplete ring. However,theshouldergirdleisanincompletering. Inthefront,the claviclesareseparatedbythesternum.Intheback,there isagap betweenthetwoscapulae.
Theprimaryfunctionofthepectoralgirdleis to provideanattachment pointforthenumerousmusclesthatallowtheshoulderandelbowjoints to move.It alsoprovidestheconnectionbetweentheupperextremities (thearms)andtheaxialskeleton.

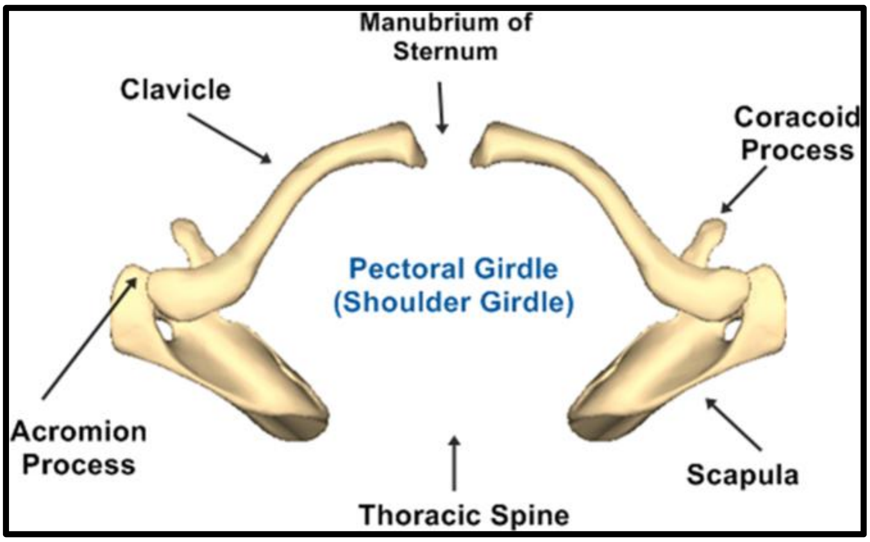


Figure 18: The Shoulder girdle

4. ThePelvicGirdle

It isalso calledthehipgirdle,andiscomposedoftwocoxal(hip)bones. Duringchildhood,eachcoxalboneconsistsofthreeseparateparts:the ilium,theischium,andthepubis.Inanadult,thesethree bonesare firmlyfusedintoasinglebone. Thepelvicgirdleservesseveralimportantfunctionsinthebody.It supportstheweightofthebodyfromthevertebralcolumn.Italso protectsandsupportsthelowerorgans,includingtheurinarybladder, thereproductiveorgans,andthedevelopingfoetusinapregnantwoman. Thepelvicgirdlediffersbetweenmenandwomen.Inaman,thepelvis ismoremassiveandtheiliaccrestsarecloser together.Inawoman,the pelvisismoredelicateandtheiliaccrestsarefartherapart.These differencesreflectthewoman'sroleinpregnancyanddeliveryofchildren. Whenachildisborn, itmustpassthroughitsmother'spelvis. Iftheopeningistoosmall,aCaesareansectionmaybe necessary.

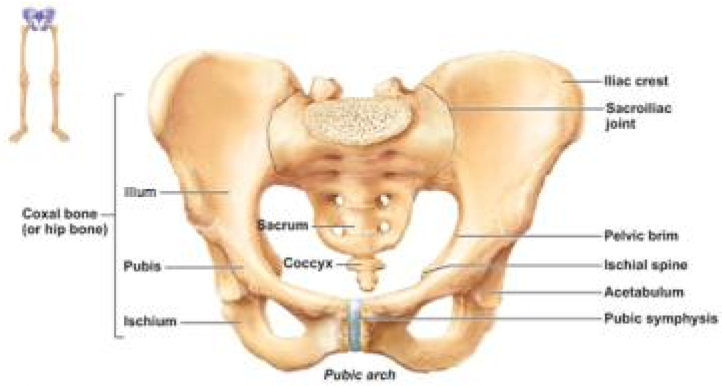


Figure 19: The Pelvic girdle

3.3 Sutures and Fontanelles

Sutures

Meaning to stitch, are immovable joints found between skull bones. There are four main sutures in the skull.

a) Coronal suture: between the frontal & the two-parietal bones.
b) Sagittal suture: between the two parietal bones.
c) Lambdoidal suture: between parietal & occipital bones.
d) Squamosal suture: between parietal bone and temporal bone.

Fontanels

The skeleton of a newly formed embryo consists of cartilage or fibrous membrane structures, which are gradually replaced by bone. The process is called ossification. At birth membrane filled spaces on the skull are called fontanel. They are found between cranial bones.

Function

- They enable the skull of the foetus to compress as it passes through the birth canal
- They permit the rapid growth and expansion of the brain before birth and during infancy
- They serve as landmark (anterior fontanel) for withdrawal of blood from the superior sagittal sinus
- They aid in the determination of fetal position prior to birth.

In the skull of the fetus there are 6 prominent fontanels:

a) One anterior fontanel, one posterior fontanel, two anteriolateral fontanels and two posterolateral fontanels.
b) The Anterior (frontal) fontanel, between angle of two parietal bones & segment of the frontal bone, is diamond in shape.

4.0CONCLUSION

The skeleton is subdivided into two major divisions: the axial and appendicular. The **axial skeleton** forms the vertical, central axis of the body and includes all bones of the head, neck, chest, and back. It serves to protect the brain, spinal cord, heart, and lungs. It also serves as the attachment site for muscles that move the head, neck, and back, and for muscles that act across the shoulder and hip joints to move their corresponding limbs. The axial skeleton of the adult consists of 80 bones, including the **skull**, the **vertebral column**, and the **thoracic cage**. The skull is formed by 22 bones. Also associated with the head are additional seven bones, including the **hyoid bone** and the **ear ossicles**(three small bones found in each middle ear). The vertebral column consists of 24 bones each of which is called a vertebra, plus the sacrum and coccyx. The thoracic cage includes the 12 pairs of ribs, and the sternum, the flattened bone of the anterior chest. The appendicular skeleton includes all bones of the upper and lower limbs, plus the bones that attach each limb to the axial skeleton. There are 126 bones in the appendicular skeleton of an adult.

5.0SUMMARY

In this unit, we have discussed the axial and appendicular skeleton, their composition and structures. Sutures and fontanelles have also been described.

6.0TUTOR-MARKEDASSIGNMENT

- Distinguish between the axial skeleton and appendicular skeleton
- Define the axial skeleton and its components
- Define the appendicular skeleton and its components

7.0REFERENCES/FURTHERREADINGS

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UNIT 4 THE MUSCLES AS ASSOCIATE ORGAN OF THE SKELETAL SYSTEM

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1.0 Introduction
2.0 Objectives
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  3.1 The muscular system
  3.2 Functions of muscle tissue
  3.3 Muscle structure
4.0 Conclusion
5.0 Summary
6.0 Tutor-MarkedAssignment
7.0 References/FurtherReadings

1.0INTRODUCTION

Think about the things that you do each day—talking, walking, sitting, standing, and running—all of these activities require movement of particular skeletal muscles. Skeletal muscles are even used during sleep. The diaphragm is a sheet of skeletal muscle that has to contract and relax for you to breathe day and night. If you recall from your study of the skeletal system and joints, body movement occurs around the joints in the body. The focus of this chapter is on skeletal muscle organization

2.0 OBJECTIVES

After studying this chapter, you will be able to:

- Identify the skeletal muscles and their actions on the skeleton and soft tissues of the body
- Identify the origins and insertions of skeletal muscles and the prime movements
- Explain the criteria used to name skeletal muscles

3.0MAINCONTENT

3.1The muscular system

The term muscle tissue refers to all the contractile tissues of the body: skeletal, cardiac, and smooth muscle. The muscular system, however, refers to the skeletal muscle system: the skeletal muscle tissue and connective tissues that makeup individual muscle organs, such as the biceps brachii muscle. Cardiac muscle tissue is located in the heart and is therefore considered part of the cardiovascular system. Smooth muscle tissue of the intestines is part of the digestive system, whereas smooth muscle tissue of the urinary bladder is part of the urinary system and so on.

3.2Functions of muscle tissue

Through sustained contraction or alternating contraction and relaxation, muscle tissue has three key functions: producing motion, providing stabilization, and generating heat.

1. **Motion**

Motion is obvious in movements such as walking and running, and in localized movements, such as grasping a pencil or nodding the head. These movements rely on the integrated functioning of bones, joints, and skeletal muscles.

2. **Stabilizing body positions and regulating the volume of cavities in the body:** Besides producing movements,skeletal muscle contractions maintain the body in stable positions, such as standing or sitting. Postural muscles display sustained contractions when a person is awake, for example, partially contracted neck muscles hold the head upright. In addition, the volumes of the body cavities are regulated through the contractions of skeletal muscles. For example muscles of respiration regulate the volume of the thoracic cavity during the process of breathing.

3. **Thermo genesis** (generation of heat). As skeletal muscle contracts to perform work, a by-product is heat. Much of the heat released by muscle is used to maintain normal body temperature. Muscle contractions are thought to generate as much as 85% of all body heat.

Physiologic Characteristics of muscle tissue

Muscle tissue has four principal characteristics that enable it to carry out its functions and thus contribute to homeostasis:

1. **Excitability** (**irritability**), a property of both muscle and nerve cells (neurons), is the ability to respond to certain stimuli by producing electrical signal called action potentials (impulses). For example, the stimuli that trigger action potentials are chemicals-neurotransmitters, released by neurons, and hormones distributed by the blood.

2. **Contractility** is the ability of muscle tissue to shorten and thicken (contract), thus generating force to do work. Muscles contract in response to one or more muscle action potentials.

3. **Extensibility** means that the muscle can be extended (stretched) without damaging the tissue. Most skeletal muscles are arranged in opposing pairs. While one is contracting, the other not only relaxed but also usually is being stretched.
4. **Elasticity** means that muscle tissue tends to return to its original shape after contraction or extension.

3.3 Muscle structure

A. Connective Tissue Component

A skeletal muscle is an organ that is composed mainly of striated muscle cells and connective tissue. Each skeletal muscle has two parts; the connective tissue sheath that extend to form specialized structures that aid in attaching the muscle to bone and the fleshy part called the **belly** or **gaster**. The extended specialized structure may take the form of a cord, called a **tendon**; alternatively, a broad sheet called an **aponeurosis** may attach muscles to bones or to other muscles, as in the abdomen or across the top (vault or vertex) of the skull. A connective tissue sheath called **fascia** surrounds and separates muscles. Connective tissue also extends into the muscle and divides it into numerous **muscle bundles** (fascicles). There are three connective tissue components that cover a skeletal muscle tissue. These are:

1. Epimysium─a connective tissue sheath that surrounds and separates muscles.
2. Perimysium─a connective tissue that surrounds and holds fascicles together.
3. Endomysium─a connective tissue that surrounds each muscle fibre.

B. Microscopic structures

The muscle bundles are composed of many elongated muscle cells called muscle fibres. Each **muscle fibre**is a cylindrical cell containing several nuclei located immediately beneath the cell membrane (**sarcolemma**). The cytoplasm of each muscle fibre (**sarcoplasm**) is filled with myofibrils. Each myofibril is a thread-like structure that extends from one end of the muscle fibre to the other. Myofibrils consist of two major kinds of protein fibres: **actins**or thin **myofilaments**, and **myosin** or thick **myofilaments**.

Muscle contractions

The thick myofilaments are composed of a protein called myosin. Each myosin filament has small regular projections known as **crossbridges**. The crossbridges lie in a radial fashion around the long axis of the myofilament. The rounded heads of the crossbridges lie in apposition to the thin myofilaments. The thin myofilaments are composed of a complex protein called actin, arranged in a double stranded coil. The actin filaments also contain two additional proteins called **troponin** and **tropomysin**.

Naming skeletal muscles

Most of the skeletal muscles are named according to one or more of the following basis:

1. **Direction** of muscle fibres relative to the midline of the body or longitudinal axis of a structure
Rectus means the fibres run parallel to the midline of the body or longitudinal axis of a structure. Example, rectus abdominis
Transverse means the fibres run perpendicular to the midline longitudinal axis of a structure. Example, transverse abdominis
Oblique means the fibres run diagonally to the midline longitudinal axis of a structure. Example, external oblique

2. **Location**−structure to which a muscle is found closely related. Example: **Frontal**, a muscle near the frontal bone. Tibialis anterior, a muscle near the front of tibia
3. **Size**−relative size of the muscle
   Maximus means largest. Example, Gluteus maximus
   Minimusmeans smallest. Example, Gluteus minimus
   Longus means longest. Example, Adductor longus
   Brevis means short. Example, Peroneous brevis
4. **Number of origins**−number of tendons of origin
   Biceps means two origins. Example, Biceps brachii
   Triceps means three origins. Example, Triceps brachii
   Quadriceps means four origins. Example, Quadriceps femoris
5. **Shape** − relative shape of the muscle
   Deltoid means triangular. Example, Deltoid
   Trapezius means trapezoid. Example, Trapezius
   Serratus means saw-toothed. Example, Serratus anterior
   Rhomboideusmeans rhomboid or diamond shape. Example, Rhomboideus major
6. **Origin and insertion**−sites where muscles originate and inserts. Example, Sternocleidomastoid−originates on sternum and clavicle and inserts on mastoid process of temporal bone.
7. **Action**−principal action of the muscle.
   Flexor: decrease the angle at a joint. Example, Flexor carpi radialis
   Extensor: increases the angle at a joint. Example, Extensor carpi ulnaris
   Abductor: moves a bone away from the midline. Example, Abductor pollicis brevis
   Adductor: moves a bone closer to the midline. Example, adductor longus
   Levator: produces an upward movement. Example, Levatorlabii superioris
   Depressor: produces a downward movement. Example, Depressor labiiinferioris
   Supinator: turns the palm upward or anteriorly. Example, Supinator
   Pronator: turns the palm downward or posteriorly. Example, Pronator teres
   Sphincter: control the size of an opening. Example, External anal sphincter
   Tensor: makes a body part more rigid. Example, Tensor fasciae latae

Rotator: moves a bone around its longitudinal axis. Example, Obturator externus.

4.0CONCLUSION

Think about the things that you do each day - talking, walking, sitting, standing, and running; all of these activities require movement of particular skeletal muscles. Skeletal muscles are even used during sleep. The diaphragm is a sheet of skeletal muscle that has to contract and relax for you to breathe day and night. If you recall from your study of the skeletal system and joints, body movement occurs around the joints in the body.

5.0 SUMMARY

In this unit, we have discussed the muscular system, the functions of muscle tissue and muscle structure. Naming of skeletal muscles was also discussed.

6.0 TUTOR-MARKEDASSIGNMENT

1. With good examples, name ten different muscles in the body
2. Describe the functions of muscular system

7.0REFERENCES/FURTHERREADINGS

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MODULE 3 NERVOUS AND ENDOCRINE SYSTEM

Unit 1 Overview of the nervous system
Unit 2 Structure of the brain and its blood supply
Unit 3 Spinal cord and spinal nerves
Unit 4 Integration of central nervous system with other systems
Unit 5 The endocrine gland and other secretory organs

UNIT1 OVERVIEW OF THE NERVOUS SYSTEM

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 MainContent
 3.1 Anoverviewofthenervoussystem
 3.2 Division of the Nervous System
 3.3 Anatomy of the Nervous System
4.0 Conclusion
5.0 Summary
6.0 Tutor-MarkedAssignment
7.0 References/FurtherReadings

1.0INTRODUCTION

The nervous system consists of the brain, spinal cord, sensory organs, and all of the nerves that connect these organs with the rest of the body. Together, these organs are responsible for the control of the body and communication among its parts. The brain and spinal cord form the control centre known as the central nervous system (CNS), where information is evaluated and decisions made. The sensory nerves and sense organs of the peripheral nervous system (PNS) monitor when you sit,stand,or walkbycontrollingmuscularactivities. Yourbody temperatureremainsstableonacoldwinter dayor inawarmkitchen becauseyourrateofheatgenerationandheatlossarecloselyregulated.

2.0OBJECTIVES

Attheendofthisunit,youshouldbeableto:

1. Explaintheactivitiesofthenervoussystem
2. Describeageneraloverviewofthenervoussystem
3. Describetheanatomicaldivisionsofthenervoussystemandtheir

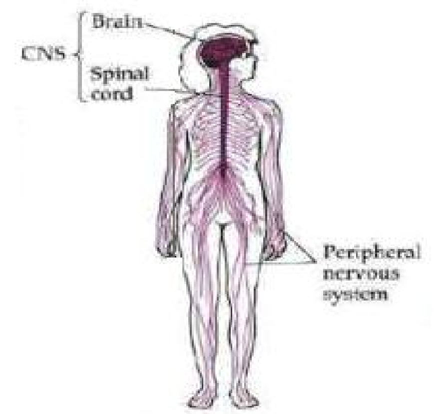
functions
4. Describethestructureofthebrain

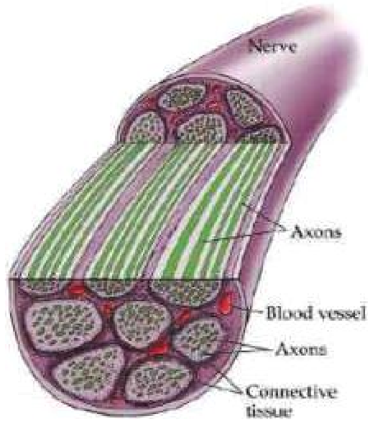
3.0MAINCONTENT

Thenervoussystem,whichaccountsforamere3percentofthetotal bodyweight,isthemostcomplexorgansystem.Itisvitalnotonlyto lifebutalsotoour appreciationoflife.Thisunitdetails withthe structureandfunctionofneuraltissueandintroducesprinciplesof neurophysiologythatarevitaltoanunderstandingof thenervous system'scapabilitiesandlimitations.

3.1AnOverviewoftheNervousSystem

(a)





(b) Parts of the nervous system (b) Composition of a peripheral nerve

Fig. 20:Thenervoussystemhttp://en.wikipedia.org/wiki/CNS

Thenervoussystemincludesalltheneuraltissuesinthebody.Thebasic anatomicalunitsofthenervoussystemareindividualcellscalled neurons.Supportingcellsor neuroglia separateandprotecttheneurons, provideasupportiveframeworkforneuraltissue,actasphagocytes, and help to regulatethecompositionoftheinterstitialfluid.Neuroglia,also calledglialcells,faroutnumberneurons,andaccountforroughlyhalf thevolumeofthenervoussystem.

Neuraltissue, withsupportingbloodvesselsandconnectivetissues, formstheorgansofthenervoussystem:the brain;thespinalcord;the receptorsincomplex senseorgans,suchastheeyeandear;andthe nervesthatinterconnectthese organsandlinkthenervoussystemwith othersystems. In Unit 2,weintroducedthetwomajoranatomical divisionsof thenervoussystem;(1)thecentral nervoussystemand(2) theperipheralnervoussystem.

The Nervoussystemofmanconsistsof2mainparts:

1. Thecentralnervoussystem.
2. Theperipheralnervoussystem

    a. Thesensorysystem. b.Themotorsystem.
    c. Thesomaticnervoussystem.
    d. Theautonomicnervoussystem,whichissubdividedinto the parasympatheticandsympatheticdivisions.

Thecentralnervoussystem:

- Consists of the brain and spinal cord
- Co-ordinatestheactivitiesofthenervoussystem
- Receivesconstantinputof impulsesrelatingtochangesin theinternalandexternalenvironments of the animal.
- Processesandintegratesinformationandsendsoutimpulseto relevanteffector cells, tissues and organsforaction.Impulsestransmittedalongsensory nervesarecalledsensoryimpulses while those transmitted along motor nerves are called motor impulses.

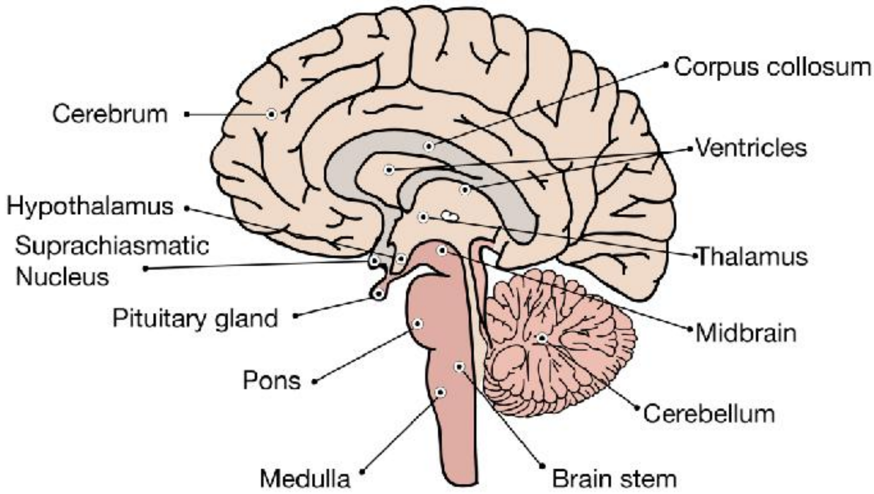


Figure 21: Vertical section of Human brain

3.2 Division of the Nervous System

Central Nervous System

The brain and spinal cord together form the central nervous system, or CNS. The CNS acts as the control center of the body by providing its processing, memory, and regulation systems. The CNS takes in all of the conscious and subconscious sensory information from the body's sensory receptors to stay aware of the body's internal and external conditions. Using this sensory information, it makes decisions about both conscious and subconscious actions to take to maintain the body's homeostasis and ensure its survival. The CNS is also responsible for the higher functions of the nervous system such as language, creativity, expression, emotions, and personality. The brain is the seat of consciousness and determines who we are as individuals.

Peripheral Nervous System

The peripheral nervous system (PNS) includes all of the parts of the nervous system outside of the brain and spinal cord. These parts include all of the cranial and spinal nerves, ganglia, and sensory receptors.

Somatic Nervous System

The somatic nervous system (SNS) is a division of the PNS that includes all of the voluntary efferent neurons. The SNS is the only consciously controlled part of the PNS and is responsible for stimulating skeletal muscles in the body.

Autonomic Nervous System

The autonomic nervous system (ANS) is a division of the PNS that includes all of the involuntary efferent neurons. The ANS controls subconscious effectors such as visceral muscle tissue, cardiac muscle tissue, and glandular tissue.

There are 2 divisions of the autonomic nervous system in the body: the sympathetic and parasympathetic divisions.

- *Sympathetic*. The sympathetic division forms the body's "fight or flight" response to stress, danger, excitement, exercise, emotions, and embarrassment. The sympathetic division increases respiration and heart rate, releases adrenaline and other stress hormones, and decreases digestion to cope with these situations.

- *Parasympathetic*. The parasympathetic division forms the body's "rest and digest" response when the body is relaxed, resting, or feeding. The parasympathetic works to undo the work of the sympathetic division after a stressful situation. Among other functions, the parasympathetic division works to decrease respiration and heart rate, increase digestion, and permit the elimination of wastes.

Enteric Nervous System

The enteric nervous system (ENS) is the division of the ANS that is responsible for regulating digestion and the function of the digestive organs. The ENS receives signals from the central nervous system through both the sympathetic and parasympathetic divisions of the autonomic nervous system to help regulate its functions. However, the ENS mostly works independently of the CNS and continues to function without any outside input. For this reason, the ENS is often called the "brain of the gut" or the body's "second brain." The ENS is an immense system—almost as many neurons exist in the ENS as in the spinal cord.

Action Potentials

Neurons function through the generation and propagation of electrochemical signals known as action potentials (APs). An AP is created by the movement of sodium and potassium ions through the membrane of neurons.

- *Resting Potential:* At rest, neurons maintain a concentration of sodium ions outside of the cell and potassium ions inside of the cell. This concentration is maintained by the sodium-potassium pump of the cell membrane which pumps 3 sodium ions out of the cell for every 2 potassium ions that are pumped into the cell. The ion concentration results in a resting electrical potential of -70 millivolts (mV), which means that the inside of the cell has a negative charge compared to its surroundings.
- *Threshold Potentia*l: If a stimulus permits enough positive ions to enter a region of the cell to cause it to reach -55 mV, that region of the cell will open its voltage-gated sodium channels and allow sodium ions to diffuse into the cell. -55 mV is the threshold potential for neurons as this is the "trigger" voltage that they must reach to cross the threshold into forming an action potential.
- *Depolarization:* Sodium carries a positive charge that causes the cell to become depolarized (positively charged) compared to its normal negative charge. The voltage for depolarization of all neurons is +30 mV. The depolarization of the cell is the AP that is transmitted by the neuron as a nerve signal. The positive ions spread into neighbouring regions of the cell, initiating a new AP in those regions as they reach -55 mV. The AP continues to spread down the cell membrane of the neuron until it reaches the end of an axon.
- *Repolarization:* After the depolarization voltage of +30 mV is reached, voltage-gated potassium ion channels open, allowing positive potassium ions to diffuse out of the cell. The loss of potassium along with the pumping of sodium ions back out of the cell through the sodium-potassium pump restores the cell to the -55 mV resting potential. At this point the neuron is ready to start a new action potential.

Synapses

A synapse is the junction between a neuron and another cell. Synapses may form between 2 neurons or between a neuron and an effector cell. There are two types of synapses found in the body: chemical synapses and electrical synapses.

- *Chemical synapses:* At the end of a neuron's axon is an enlarged region of the axon known as the axon terminal. The axon terminal is separated from the next cell by a small gap known as the synaptic cleft. When an AP reaches the axon terminal, it opens voltage-gated calcium ion channels. Calcium ions cause vesicles containing chemicals known as neurotransmitters (NT) to release their contents by exocytosis into the synaptic cleft. The NT molecules cross the synaptic cleft and bind to receptor molecules on the cell, forming a synapse with the neuron. These receptor molecules open ion channels that may either stimulate the receptor cell to form a new action potential or may inhibit the cell from forming an action potential when stimulated by another neuron.

- *Electrical synapses:* Electrical synapses are formed when 2 neurons are connected by small holes called gap junctions. The gap junctions allow electric current to pass from one neuron to the other, so that an AP in one cell is passed directly on to the other cell through the synapse.

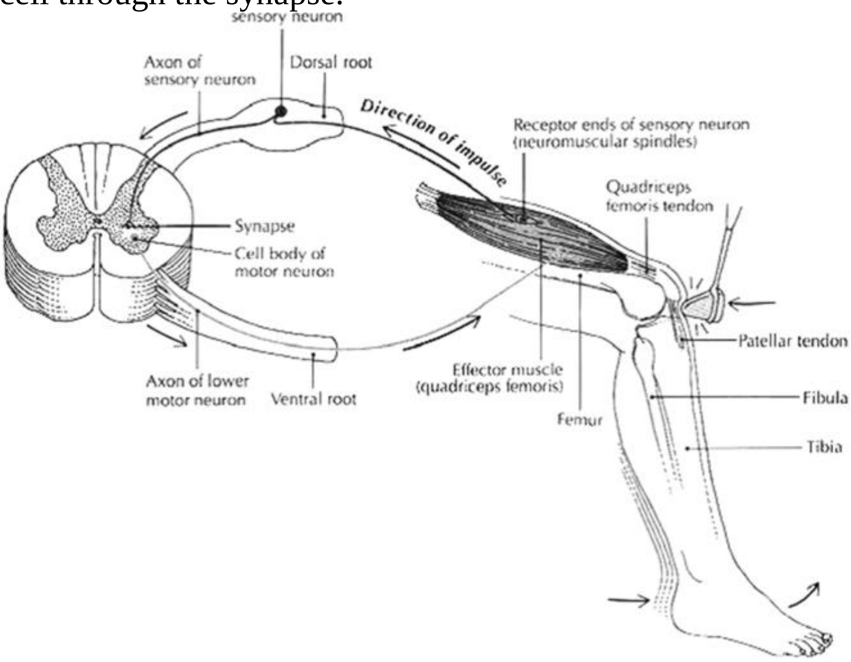


Figure 22: Reflex arc showing the pathway of impulses
Source: Carola, R., Harley,J.P., Noback R.C. (1992); Adapted from Assefa N & Tsige Y. (2003)

3.3 Anatomy of the Nervous Tissue

The majority of the nervous system is tissue made up of two classes of cells: neurons and neuroglia.

- **Neurons**. Neurons, also known as nerve cells, communicate within the body by transmitting electrochemical signals. Neurons are different from other cells in the body due to the many long cellular processes that extend from their cell body. The cell body is the roughly round part of a neuron that contains the nucleus, mitochondria, and most of the cellular organelles. Small tree-like structures called dendrites extend from the cell body to pick up stimuli from the environment, other neurons, or sensory receptor cells. Long transmitting processes called axons extend from the cell body to send signals to other neurons or effector cells in the body.

There are 3 basic classes of neurons: afferent neurons, efferent neurons, and interneurons.

1. *Afferent neurons:* Also known as sensory neurons, afferent neurons transmit sensory signals to the central nervous system from receptors in the body.

2. *Efferent neurons:* Also known as motor neurons, efferent neurons transmit signals from the central nervous system to effectors in the body such as muscles and glands.

3. *Interneurons:* Interneurons are neurons that have their components (cell body, axon and dendrite) entirely within the CNS and convey impulses between motor and sensory neurons. They especially function in reflex arcs.

Neuroglia

Neuroglia, also known as glial cells, act as the "helper" cells of the nervous system. Each neuron in the body is surrounded by 6 to 60 neuroglia cells that protect, feed, and insulate the neuron. Because neurons are extremely specialized cells that are essential to body function and almost never reproduce, neuroglia are vital to maintaining a functional nervous system.

Brain

The **brain**, a soft, wrinkled organ that weighs about 3 pounds, is located inside the cranial cavity, where the **bones of the skull** surround and protect it. The approximately 100 billion neurons of the brain form the main control centre of the body. The brain and spinal cord together form the central nervous system (CNS), where information is processed and responses originate. The brain, the seat of higher mental functions such as consciousness, memory, planning, and voluntary actions, also controls essential body functions such as the maintenance of respiration, heart rate, blood pressure, and digestion.

Spinal Cord

The **spinal cord** is a long, thin mass of bundled neurons that carries information through the vertebral cavity of the spine beginning at the lower border of the **medulla oblongata** of the brain on and ends inferiorly in the lumbar region of the spine. In the lumbar region, the spinal cord separates into a bundle of individual nerves called the **cauda equina** (due to its resemblance to the tail (cauda) of the horse (equina). This continues inferiorly to the levels of the **sacrum** and **coccyx**. The white matter of the spinal cord functions as the main conduit of nerve signals to the body from the brain. The grey matter of the spinal cord integrates reflexes to stimuli.

Nerves

Nerves are bundles of axons in the peripheral nervous system (PNS) that act as information highways to carry signals between the brain and spinal cord and the rest of the body. Each axon is wrapped in a connective tissue sheath called the endoneurium. Individual axons of the nerve are bundled into groups of axons called fascicles, wrapped in a sheath of connective tissue called the perineurium. Finally, many fascicles are wrapped together in another layer of connective tissue called the epineurium to form a whole nerve. The wrapping of nerves with connective tissue helps to protect the axons and to increase the speed of their communication within the body.

3.3.1Functions of the Nervous System

The nervous system has 3 main functions: sensory, integration, and motor.

- Sensory: The sensory function of the nervous system involves collecting information from sensory receptors that monitor the body's internal and external conditions. These signals are then passed on to the central nervous system (CNS) for integrated processing.

- Integration: The process of integration is the processing of the many sensory signals that are passed into the CNS at any given time. These signals are evaluated, compared, used for decision making, discarded or committed to memory as deemed appropriate. Integration takes place in the gray matter of the brain and spinal cord and is performed by interneurons. Many interneurons work together to form complex networks that provide this processing power.

- Motor: Once the networks of interneurons in the CNS evaluate sensory information and decide on an action, they stimulate efferent neurons. Efferent neurons (many of which are motor neurons) carry signals from the gray matter of the CNS through the nerves of the peripheral nervous system to effector cells. The effector may be smooth, cardiac, or skeletal muscle tissue or glandular tissue. The effector then releases a hormone or moves a part of the body to respond to the stimulus.

4.0CONCLUSION

The nervous system is unique in the vast complexity of thought processes and control of actions that it can perform. It receives each minute literally millions of bits of information from the different sensory nerves and sensory organs and then integrates all of these to determine the responses that are to be made by the body.

5.0SUMMARY

The study in this unit included anoverviewofthenervoussystem, divisions of the nervous system, the anatomy of the nervous system and the functions of the nervous system.

6.0TUTOR-MARKEDASSIGNMENT

1. Discuss in details the divisions of the nervous system
2. List and discuss the functions of the nervous system

7.0REFERENCES/FURTHERREADINGS

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UNIT2STRUCTURE OF THE BRAIN AND ITS BLOOD SUPPLY

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 MainContent
 3.1 Structureofthe Brain
 3.2 FunctionsoftheBrain
 3.3 Blood supply to the brain
4.0 Conclusion
5.0 Summary
6.0 Tutor-MarkedAssignment
7.0 References/FurtherReadings

1.0INTRODUCTION

The CNS, as its name implies, is centrally located in the core of the body. Its two major components, the brain and spinal cord, are found along the midsagittal plane of the body. The brain is protected in the cranial cavity of the skull. Protective membranes called **meninges** cover the brain and spinal cord.

2.0OBJECTIVES

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

- Describe the **structure**ofthe brain
- Describe the**functions**ofthebrain
- Describe the **blood supply** to the brain

3.0 MAIN CONTENT

3.1 Structureofthe Brain

TheBrain

- Thehumanbrainweighsabout1.2to1.4kg
- It consumes25%ofthebodyoxygensupplytogenerateenergy
- It iscoveredbyamembranecalledthemeninges
- It isenclosed inabonycasecalledtheskullor cranium
- It is madeupof2typesofnervoustissues,(nervescells,which form the grey matterandnervesfibres, which constitute the

whitematter.).

Divisions of the Brain

The brain, one of the largest organs in man, consists of the following major divisions, named in ascending order beginning with most inferior part:

I. Brain stem
   A. Medulla oblongata
   B. Pons
   C. Midbrain

II. Cerebellum

III. Diencephalon
   A. Hypothalamus
   B. Thalamus

IV. Cerebrum

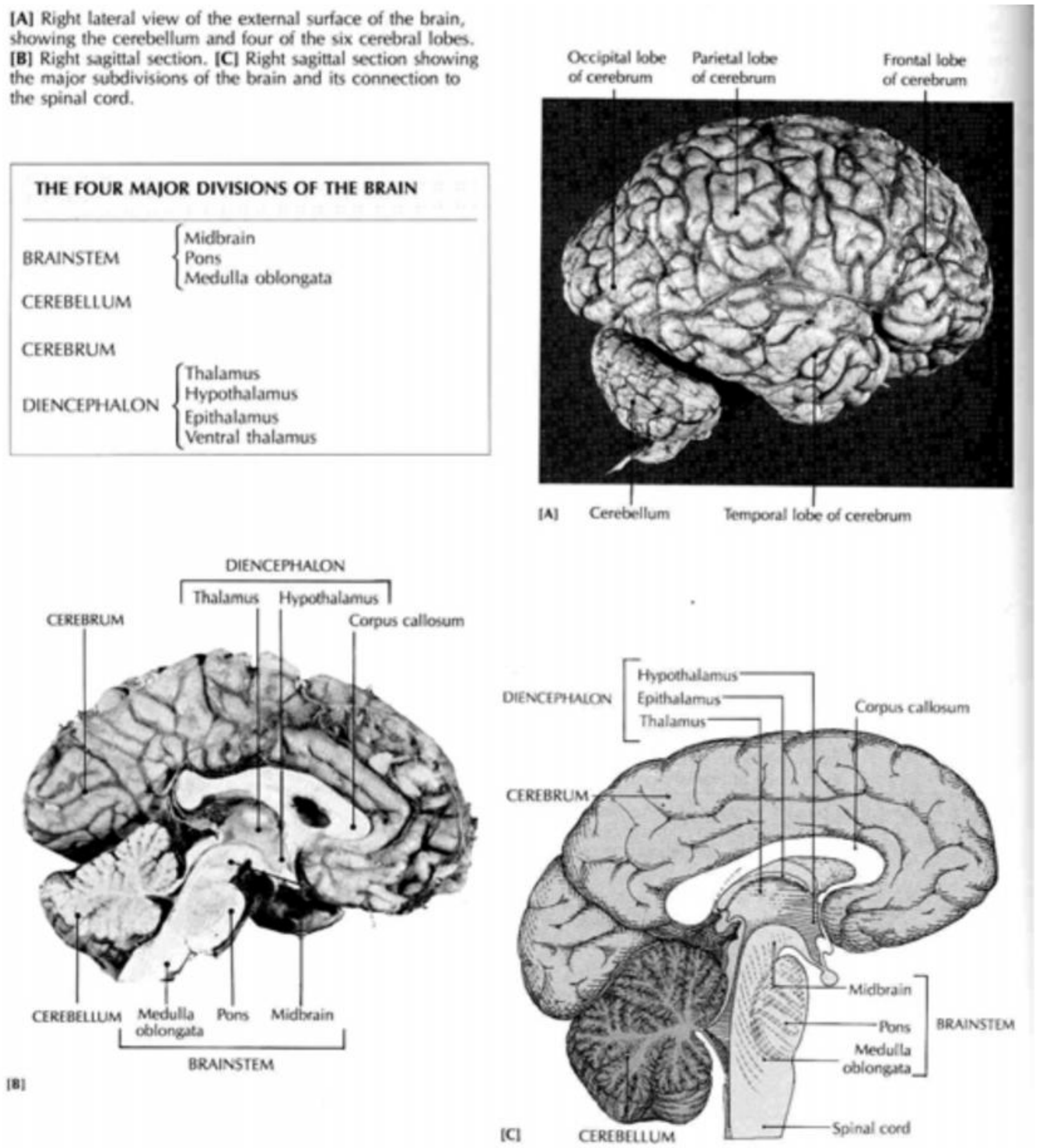


Figure 23: Major regions of the Central Nervous System. A, Sagital sections of the brain and spinal cord. B, Section of preserved brain (Source: Carola, R., Harley,J.P., Noback R.C., (1992)

Brain Stem

The lowest part of the brain stem is the medulla oblongata. Immediately superior to the medulla oblongata lies the pons and superior to that, the midbrain. Together these three structures are called the brain stem (Figure 23). The medulla oblongata is an enlarged, upward extension of the spinal cord. It lies just inside the cranial cavity superior to the large opening in the occipital bone called the foramen magnum. Like the spinal cord, the medulla consists of gray and white matter, but their arrangement differs in the two parts of the brain. In the medulla, bits of gray matter mix closely and intricately with white matter to form the reticular formation (reticular means "net-like"). In the spinal cord, gray matter and white matter do not intermingle; gray matter forms the core of the cord, and white matter surrounds it. The pons and midbrain, like the medulla, consist of white matter and scattered bits of gray matter.

Diencephalon

The diencephalon is a small but important part of the brain located between the midbrain inferiorly and the cerebrum superiorly. It consists of two major structures: the hypothalamus and the thalamus. The ventricle of the diencephalons is the 3rd ventricle.

Hypothalamus: The hypothalamus, as its name suggests, is located inferior to the thalamus. The posterior pituitary gland, the stalk that attaches it to the undersurface of the brain, and areas of gray matter located in the sidewalls of a fluid-filled space called the third ventricle are extensions of the hypothalamus. The **hypothalamus** is a crucial part of the mechanism for maintaining body temperature. Therefore a marked elevation in body temperature in the absence of disease frequently characterizes injuries or other abnormalities of the hypothalamus. In addition, this important center is involved in functions such as the regulation of water balance; sleep cycles, and the control of appetite and many emotions involved in pleasure, fear, anger, sexual arousal, and pain.

Thalamus: Immediately superior to the hypothalamus is a dumb bell shaped section or largely gray matter called the thalamus. Each enlarged end of the dumbbell lies in a lateral wall of the third ventricle. The medial surfaces of the thalamus are connected across the third ventricle by a thin white matter called the inter-thalamic adhesion. The thalamus is composed chiefly of dendrites and cell bodies of neurons that have axons extending up to the sensory areas of the cerebrum. It performs the following functions:

1. It helps to produce sensations. Its neurons relay impulses to the cerebral cortex from the sense organs of the body.
2. It associates sensations with emotions. Almost all sensations are accompanied by a feeling of some degree of pleasantness or unpleasantness. The way that these pleasant and unpleasant feelings are produced is unknown except that they seem to be associated with the arrival of sensory impulses in the thalamus.
3. It plays a part in the so-called arousal or alerting mechanism.

4. It contains important nuclei such as medial geniculate body, which is responsible for auditory sense and lateral geniculate body, which is responsible for vision.

Cerebellum

The cerebellum is the second largest part of the human brain. It lies under the occipital lobe of the cerebrum. In the cerebellum, gray matter composes the outer layer, and white matter composes the bulk of the interior.

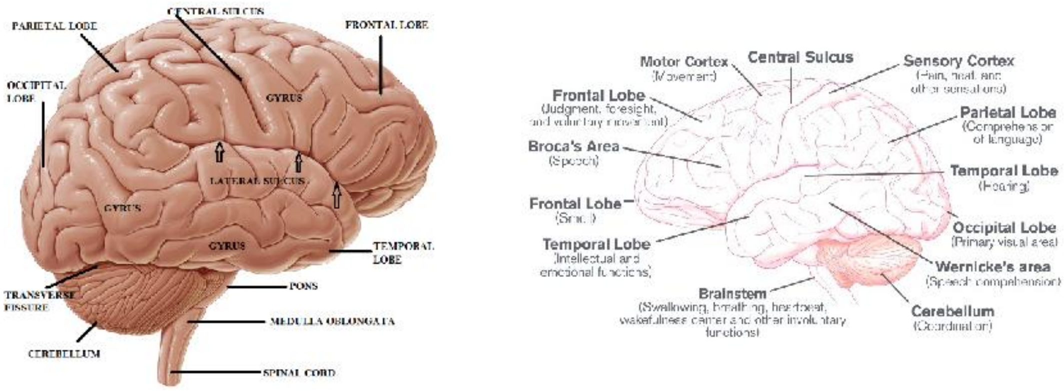
Function

The cerebellum plays an essential part in the production of normal movements. Perhaps a few examples will make this clear. A patient who has a tumor of the cerebellum frequently loses balance and may topple over and reel like a drunken person when walking. It may be impossible to coordinate muscles normally. Frequent complaints about being clumsy and unable to even drive a nail or draw a straight line are typical. With the loss of normal cerebellar function, the ability to make precise movements is lost. The general functions of the cerebellum, therefore, are to produce smooth coordinated movements, maintain equilibrium, and sustain normal postures.

Cerebrum

The cerebrum is the largest and uppermost part of the brain. If you were to look at the outer surface of the cerebrum, the first features you would notice might be its many ridges and grooves. The ridges are called convolutions or gyri, and the grooves are called sulci. The deepest sulci are called fissures; the longitudinal fissure divides the cerebrum into right and left halves or hemispheres. These halves are almost separate structures except for their lower mid-portions, which are connected by a structure called the corpus callosum (Figure 22c). Two deep sulci subdivide each cerebral hemisphere into four major lobes and each lobe into numerous convolutions.

The lobes are named after the bones that lie over them: the frontal lobe, the parietal lobe, the temporal lobe, and the occipital lobe. Identify these in Figure below.



a b

Figure 24: The cerebrum: a. Gyri, fissures and lobes; b. Functional areas

i. Functions of the cerebrum: The neurons of the cerebrum do not function alone. They function with many other neurons in many other parts of the brain and in the spinal cord. Neurons of these structures continually bring impulses to cerebral neurons and continually transmit impulses away from them. If all other neurons were functioning normally and only cerebral neurons were not functioning, here are some of the things that you could not do: You could not think or use your will.
ii. You could not remember anything that has ever happened to you.
iii. You could not decide to make the smallest movement, nor could you make it.
iv. You would not see or hear.
v. You could not experience any of the sensations that make life so rich and varied.
vi. Nothing would anger or frighten you, and nothing would bring you joy or sorrow.
vii. You would, in short, be unconscious.

These terms, then sum up cerebral functions: Consciousness, thinking, memory, sensations, emotions, and willed movements. Figure 23(b) above shows the areas of the cerebral cortex essential for willed movements, general sensations, vision, hearing, and normal speech. Specific areas of the cortex have very specific functions. For example, the temporal lobe's auditory areas interpret incoming nervous signals from the ear as very specific sounds. The visual area of the cortex in the occipital lobe helps you identify and understand specific images. Localized areas of the cortex are directly related to specific functions, as shown in Figure 23.

3.2FunctionsoftheBrain

- **Reasoning, a Definitive Characteristic of Human Nature**

Thinking or reasoning is performed by the frontal lobe of the cerebral cortex, and this is what distinguishes you as the most advanced and superior creature on the planet earth. Cognition or intellect is that capacity of human beings which enables them to challenge social or religious beliefs and verify facts. It is one of the amazing brain facts that the development of knowledge in various fields, such as science, art, philosophy, mathematics and language is solely owed to the marvelous potential of your reasoning.

- **Movements**

One of the important human brain functions is that of the production and coordination of miscellaneous body movements. The movements can be of two types, viz. voluntary and involuntary. They occur in various parts of your body, for example, arms, legs, and neck muscles are controlled by conscious actions, while beating of heart and breathing are the involuntary ones. The conscious activities are directed by cerebrum and originate from the motor areas of the frontal lobe and the primary motor cortex. Just imagine, if there were no movement in your body, there would be no life or soul in it!

- **Problem Solving and Emotions**

Humans, among all the advanced creatures on earth, have profound capability of understanding, evaluating, and offering a comprehensive and applicable solution to the critical issues of life. You also know that man is called the 'emotional beast' because of the variety of emotional attitudes in response to various real life situations. Both of these assignments fall under the domain of Frontal Lobe of the cerebral cortex. However, these problem solving characteristics are also found in some lower animals that simply follow the genetic programs already present in their brain, but are unable to reason (think over) and plan the tasks.

- **Memory and Learning**

The hippocampus is located in the temporal lobe of telencephalon and is considered as one of the major components of human brain that plays an important role in the process of learning and memory processing. Once information is received through the sensory organs, it is processed in the brain and temporarily stored in the short term memory. The function of the medial temporal lobe is to consolidate the information from short term memory to the long-term memory and carry out the spatial navigation.

- **Communication and Language**

Broca's and Wernicke's Areas are primarily associated with the production and comprehension of speech sounds, respectively. Broca's area is located in the Frontal Lobe, while Wernicke's area is found at the junction between the temporal and parietal lobe. So, this part of the brain assists you in communication with other members of the society. Non fluent and fluent aphasias are the disorders of language that are caused by any damage or injury to the areas that are responsible for the creation and perception of speech sounds.

- **Visual Processing**

Did you ever think how your brain creates a perfect visual image of the things you see in the world around you? Yes, this is the task assigned to the occipital lobe of the telencephalon region of your brain that receives the visual signals from the retina of your eye via the Optic Nerve, and after processing, converts it into the mirror image of the same object.

- **Auditory Processing**

The perception, recognition and interpretation of the stimuli, related to the sense of hearing, are accomplished by the assistance of the Temporal lobe that stretches across both the hemispheres of the cerebral cortex and is located beneath the lateral fissure. The function of this structurally and functionally specialized region of the brain is not just limited to auditory processing, it is also involved in the production of emotional attitudes, storage of new memories, processing sensory output and the retention of visual memories.

- **Sensory Perception**

All of the five traditional senses, namely, sight (vision), hearing (auditory), smell (olfactory), taste (gustation) and touch (somatosensory), are perceived, processed and controlled by one of the major parts of brain, i.e. cerebrum. It particularly involves the primary sensory areas. The perception of the world around man is developed by the sensory information that is synthesized by these regions of the cerebral cortex.

- **Breathing Control**

Can you breathe under your voluntary command or control and continue to control it while sleeping? The answer to the first part of the question is no and the reason is explained by the second phrase, i.e. if it were really under man's deliberate action, he wouldn't be able to breathe while sleeping, and consequently die! The posterior part of hindbrain, called medulla oblongata, controls involuntary tasks of the body, such as gaseous exchange. The alternative expansion and contraction or relaxation of lung muscles, lowering and elevation of diaphragm, and the similar activity of chest muscles are done quite automatically without even thinking about it.

- **Regulation of Heartbeat**

The heartbeat rate or regular pumping of blood by heart is vital to overall functioning of the body as it is responsible for the delivery and elimination of the respiratory gases and the products of metabolism across the smallest part of the body. If there is any delay in the supply of oxygen and essential nutrients, the deprived cells start dying, and an extended delay may even lead to death. Medulla oblongata is the organ associated with the regulation of heartbeat rate and is comprised of the lower part of brainstem or hindbrain.

- **Blood Pressure Control**

The maintenance and regulation of blood pressure is one of the involuntary human brain functions performed by the medullar region of the brain that connects the higher parts of Central Nervous System with the spinal cord. It keeps the diastolic (minimum) and systolic (maximum) pressure in the arteries under normal limits, and in case it rises beyond the bearable limits, heart-attack, brain haemorrhage or other critical circulatory disorders are very likely to be the result.

Table 3: Functions of Major Divisions of the Brain

BRAIN AREA	**FUNCTION**
Brain stem Medulla oblongata	Two-way conduction pathway between the spinal cord and higher brain centers; cardiac, respiratory,
Pons	and vasomotor control center
Midbrain	Two-way conduction pathway between areas of the brain and
Diencephalon Hypothalamus	other regions of the body; Influences respiration Two-way conduction pathway; relay
Thalamus	for visual and auditory Impulses
Cerebellum	
Cerebrum	Regulation of body temperature, water balance, sleep cycle control appetite, and sexual arousal Sensory relay station from various body areas to cerebral cortex; emotions and alerting or arousal mechanisms Muscle coordination; maintenance of equilibrium and posture Sensory perception, emotions willed

	movements, consciousness, and memory

SELF ASSESSMENTEXERCISE1

1.Theautonomicnervoussystemconsistsof --------------------and-------------------
2.Mentiontwoportionsofthehindbrain.

3.2 FunctionsofthePartsof theBrain

- Thecerebrumcontrolsallthebody’svoluntaryactionand consciousness.
- Thefrontallobeistheseat ofintelligence,memory, imagination, thought,judgment, emotionalreactionandmovementofskeletal muscles.
- Theparietallobereceivesandinterpretsthesensationsof pressure,temperatureandposition.
- Thetemporallobeisconcernedwithhearing,memoryand understandingofspeech.

3.3 Blood Supply of the Brain

Cerebral circulation is the movement of blood through the network of cerebral arteries and veins supplying the brain. The rate of the cerebral blood flow in the adult is typically 750 millilitres per minute, representing 15% of the cardiac output. The arteries deliver oxygenated blood, glucose and other nutrients to the brain, and the veins carry deoxygenated blood back to the heart, removing carbon dioxide, lactic acid, and other metabolic products. Since the brain is very vulnerable to compromises in its blood supply, the cerebral circulatory system has many safeguards including autoregulation of the blood vessels and the failure of these safeguards can result in a stroke. The amount of blood that the cerebral circulation carries is known as cerebral blood flow. The presence of gravitational fields or accelerations also determine variations in the movement and distribution of blood in the brain, such as when suspended upside-down.

Blood supply to the brain is normally divided into anterior and posterior segments, relating to the different arteries that supply the brain. The two main pairs of arteries are the Internal carotid arteries (supply the anterior brain) and vertebral arteries (supplying the brainstem and posterior brain).

The anterior and posterior cerebral circulations are interconnected via bilateral posterior communicating arteries. They are part of the Circle of Willis, which provides backup circulation to the brain. In case one of the supply arteries is occluded, the Circle of Willis provides interconnections between the anterior and the posterior cerebral circulation along the floor of the cerebral vault, providing blood to tissues that would otherwise become ischemic.

Anterior cerebral circulation

The Anterior cerebral circulation is the blood supply to the anterior portion of the brain. It is supplied by the following arteries:

- Internal carotid arteries: These large arteries are the medial branches of the Common carotid arteries in the neck which enter the skull, as opposed to the External carotid branches which supply the facial tissues. The Internal carotid artery branches into the Anterior cerebral artery and continues to form the Middle cerebral artery.
- Anterior cerebral artery (ACA)
  Anterior communicating artery: Connects both anterior cerebral arteries, within and along the floor of the cerebral vault.
- Middle cerebral artery (MCA)

Posterior cerebral circulation

The **posterior cerebral circulation** is the blood supply to the posterior portion of the brain, including the occipital lobes, cerebellum and brainstem. It is supplied by the following arteries:

- **Vertebral arteries**: These smaller arteries are branches of the Subclavian arteries which primarily supply the shoulders, lateral chest and arms. Within the cranium the two Vertebral arteries fuse into the Basilar artery.
  - Posterior inferior cerebellar artery (PICA)
- **Basilar artery**: Supplies the midbrain, cerebellum, and usually terminates as the:
  - Posterior cerebral artery; other branches are:
    - Anterior inferior cerebellar artery (AICA)
    - Pontine branches
    - Superior cerebellar artery (SCA)
  - Posterior cerebral artery (PCA)

- Posterior communicating artery

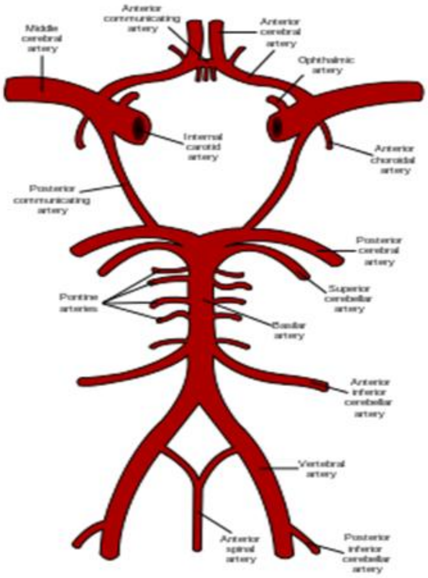


Figure 25: Blood supply of the Brain

Venous drainage

The venous drainage of the cerebrum can be separated into two subdivisions: superficial and deep.

The superficial system is composed of dural venous sinuses, which have walls composed of dura mater as opposed to a traditional vein. The dural sinuses are, therefore, located on the surface of the cerebrum. The most prominent of these sinuses is the superior sagittal sinus which flows in the sagittal plane under the midline of the cerebral vault, posteriorly and inferiorly to the confluence of sinuses, where the superficial drainage joins with the sinus that primarily drains the deep venous system. From here, two transverse sinuses bifurcate and travel laterally and inferiorly in an S-shaped curve that forms the sigmoid sinuses which go on to form the two Internal jugular veins. In the neck, the jugular veins parallel the upward course of the carotid arteries and drain blood into the superior vena cava.

The deep venous drainage is primarily composed of traditional veins inside the deep structures of the brain, which join behind the midbrain to form the vein of Galen. This vein merges with the inferior sagittal sinus to form the straight sinus which then joins the superficial venous system mentioned above at the confluence of sinuses.

4.0CONCLUSION

All three parts of the brain stem function as two-way conduction paths. Areas of the brain are supplied by different arteries. The major systems are divided into an anterior circulation (the anterior cerebral artery and middle cerebral artery) and a posterior circulation (posterior cerebral artery from the vertebral artery).

5.0SUMMARY

In this unit, we have learnt about the structure of the brain, the function and blood supply to the brain.

6.0 TUTOR-MARKEDASSIGNMENT

1. List and describe the functions of the brain
2. Describe the similarities and differences between cerebrum and cerebellum
3. Write a short note on the blood supply of the brain

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UNIT 3 SPINAL CORD AND NERVES

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 MainContent
  3.1 Anatomy and Function of Spinal cord
  3.2 Map of Dermatomes
  3.3 Spinal Nerves
4.0 Conclusion
5.0 Summary
6.0 Tutor-MarkedAssignment
7.0 References/FurtherReadings

1.0INTRODUCTION

The **spinal cord** is a long, thin, tubular bundle of nervous tissue and support cells that extends from the medulla oblongata in the brainstem to the lumbar region of the vertebral column. The brain and spinal cord together make up the central nervous system (CNS). In man, the spinal cord begins at the occipital bone where it passes through the foramen magnum, meets and enters the spinal canal at the beginning of the cervical vertebrae. The spinal cord extends down to between the first and second lumbar vertebrae where it ends. The enclosing bony vertebral column protects the relatively shorter spinal cord. It is around 45 cm (18 in) in men and around 43 cm (17 in) long in women. Also, the spinal cord has a varying width, ranging from 13 mm (½ in) thick in the cervical and lumbar regions to 6.4 mm (¼ in) thick in the thoracic area. The spinal cord functions primarily in the transmission of nerve signals from the motor cortex to the body, and from the afferent fibres of the sensory neurons to the sensory cortex. It is also a center for coordinating many reflexes and contains reflex arcs that can independently control reflexes and central pattern generators.

2.0 OBJECTIVES

At the end of this unit, you should be able to;
Discuss the anatomy and functions of the spinal cord

3.0MAINCONTENT

3.1 Anatomy and function of Spinal Cord

The spinal cord lies within the vertebral canal and extends from the foramen magnum to the level of the second lumbar vertebrae after which a fibrous remnant, the filum terminale, descends to be attached to the back of the coccyx. The cord is about 45 cm long. It is cylindrical in shape, flattened slightly anteroposteriorly, and has cervical and lumbar enlargements where the nerves supplying the upper and lower limb originate, the enlargements lie opposite the lower cervical and lower thoracic vertebrae. Since the spinal cord is shorter than the vertebral canal, the nerves descend with increasing obliquity before leaving the canal through the intervertebral foramina. The collection of lower lumbar, sacral and coccygeal nerves below the spinal cord, with the filum terminale, is known as the **cauda equina**. The cord has an **anterior median fissure** and a **posterior median sulcus**. On its sides the rootlets of the spinal nerves emerge from **anterolateral** and **posterolateral sulci**.

The spinal cord has a small, irregular shaped internal section that consists of gray matter (nerve cell bodies) and a larger area surrounding this gray part that consists of white matter (nerve cell fibers). The gray matter is so arranged that a column of cells extend up and down dorsally, one on each side; another column is found in the ventral region on each side. These two pairs of columns, called the dorsal and ventral horns, give the gray matter an H-shaped appearance in cross section. In the center of the gray matter is a small channel, central canal that contains cerebrospinal fluid, the liquid that circulates around the brain and spinal cord. The white matter consists of thousands of nerve cell fibers arranged in three areas external to the gray matter on each side.

Functions of the Spinal Cord

The spinal cord is the link between the spinal nerves and the brain. It is also a place where simple responses, known as reflexes can be coordinated even without involving the brain.

The functions of the spinal cord may be divided into three categories:

1. Conduction of sensory impulses upward through ascending tracts to the brain

2. Conduction of motor impulses from the brain down through descending tracts to the efferent neurons that supply muscles or glands
3. Reflex activities. A reflex is a simple, rapid, and automatic response involving very few neurons.

When you fling out an arm or leg to catch your balance, withdraw from a painful stimulus, or blink to avoid an object approaching your eyes, you are experiencing reflex behaviour. A reflex pathway that passes through the spinal cord alone and does not involve the brain is termed a spinal reflex. The stretch reflex, in which a muscle is stretched and responds by contracting, is an example.

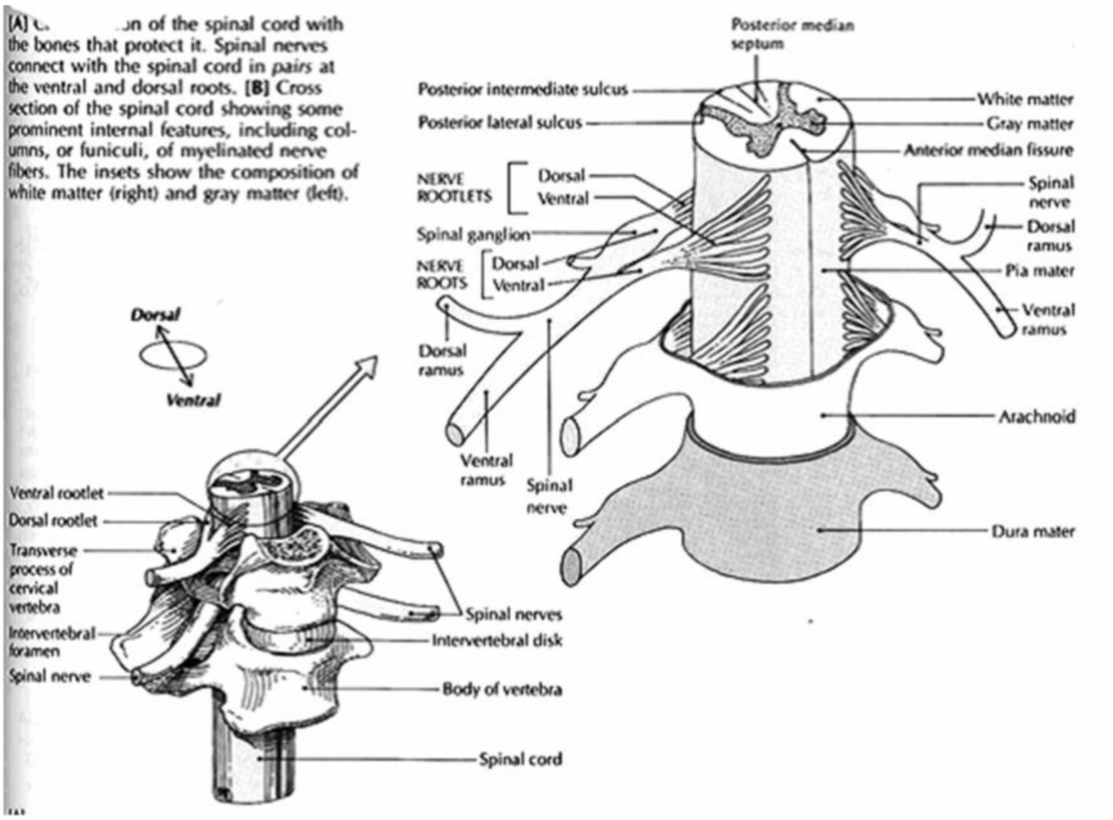

Figure 26: Spinal cord. The meninges, spinal nerves, and sympathetic trunk are visible in the illustration (Source: Carola, R., Harley,J.P., NobackR.C., (1992)

Peripheral Nervous System

The nerves connecting the brain and the spinal cord to other parts of the body constitute the peripheral nervous system (PNS). This system includes cranial and spinal nerves that connect the brain and spinal cord, respectively, to peripheral structures such as the skin surface and the skeletal muscles. In addition, other structures in the autonomic nervous system (ANS) are considered part of the PNS. These connect the brain and spinal cord to various glands in the body and to the cardiac and smooth muscle in the thorax and abdomen.

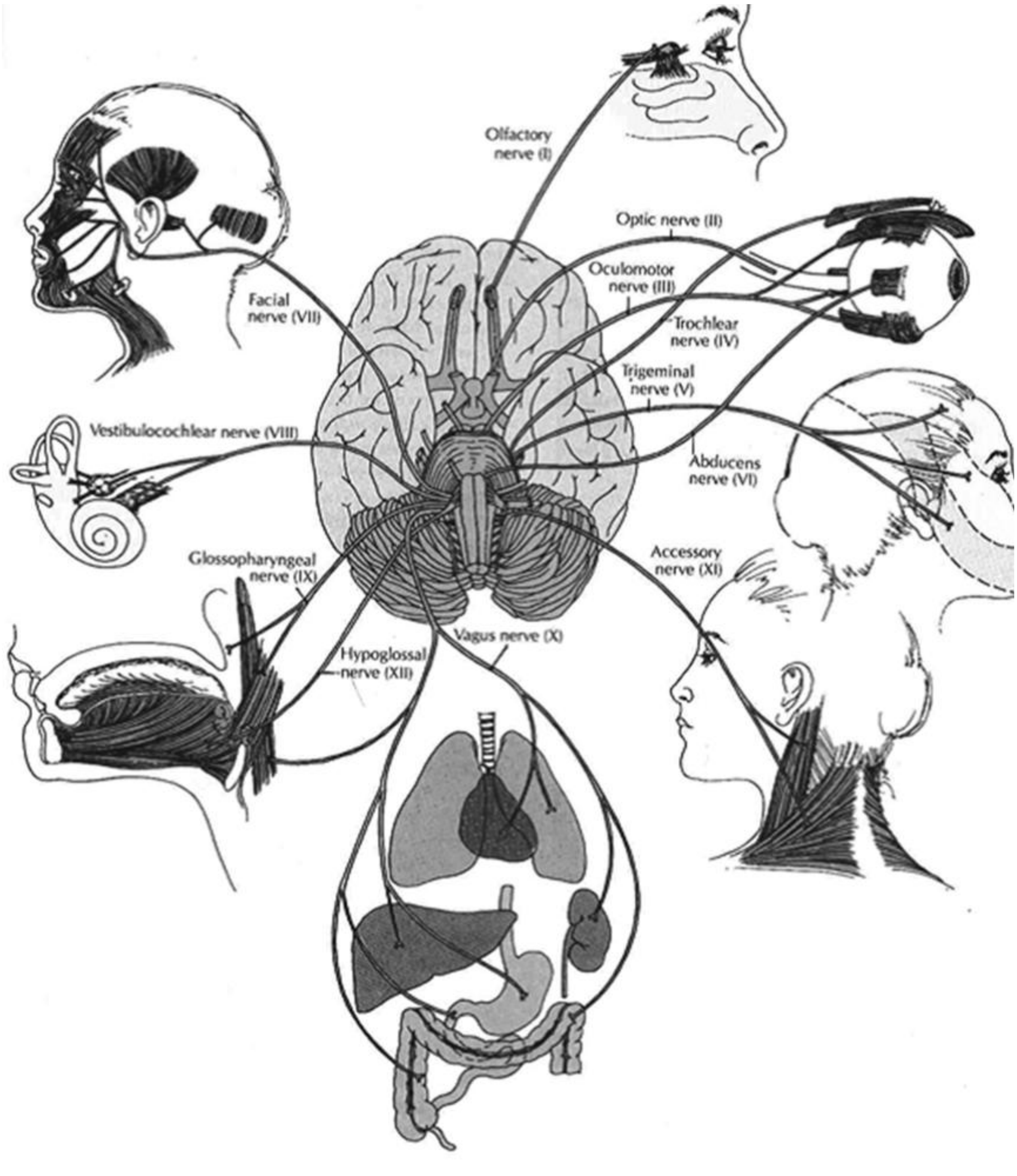

Figure 27: Base of the brain showing cranial nerves (Source: Carola, R., Harley,J.P., Noback R.C., (1992)

3.2 Nerves

A nerve is a bundle of nerve cell fibers located outside the CNS. Bundles of nerve cell fibers within the CNS are tracts. Tracts are located within the brain and also within the spinal cord to conduct impulses to and from the brain. A nerve or tract can be compared to an electric cable made up of many wires. As with muscles, the "wires," or nerve cell fibers in a nerve, are bound together with connective tissue.

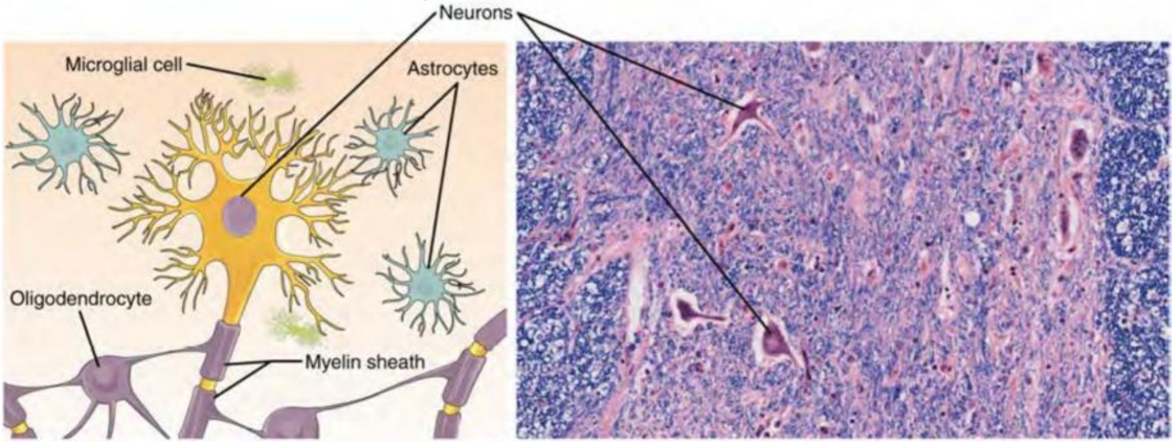

Figure 28: Nervous Tissue Mag. × 872. (Micrograph provided by the Regents of University of Michigan Medical School c 2012)

3.2 The Spinal Nerves

A spinal nerve is any of the 31 pairs of nerves that arise from the spinal cord. The spinal nerves correspond to where it emerges and passes through the spinal vertebrae: there are 8 cervical (neck), 12 thoracic (chest), 5 lumbar (lower back), 5 sacral (sacrum bone) and one coccygeal (tailbone) nerve(s). Each spinal nerve is attached to the spinal cord by two roots: a dorsal or posterior sensory root and a ventral or anterior motor root. The fibers of the sensory root carry sensory impulses to the spinal cord—pain, temperature, touch and position sense (proprioception)—from tendons, joints and body surfaces. The motor roots carry impulses from the spinal cord. The spinal nerves exit the spinal cord and pass through the intervertebral foramen, then divides into four branches.

Description

There are **thirty-one** pairs of **spinal nerves**. These nerves are mixed, having both sensory and motor aspects. Their motor fibers begin on the ventral part of the spinal cord at the **anterior horns** of the gray matter. The roots of their sensory fibers are located on the dorsal side of the spinal cord in the **posterior root ganglia**. When the motor and sensory fibers exit the column through the intervertebral foramina and pass through the meninges, they join together to form the spinal nerves.
Spinal nerves receive only contralateral innervation from first order neurons.

Eight pairs of spinal nerves are located in the uppermost, **cervical** region of the cord:

Twelve pairs are found in the **thoracic** region.
Five pairs are in the **lumbar** area.
Five pairs are in the **sacral** area.
One pair is found in the most inferior, **coccygeal** region.
Function

These second order lower motor neurons, the spinal nerves, form part of the final common pathway for information traveling from the central nervous system to the periphery. The spinal nerves provide innervation to body areas below the neck while cranial nerves (also second order neurons) carry impulses only to the head and neck, except for the vagus nerve. (You will understand shortly that cranial nerves can be sensory, motor or both).

The Autonomic (self-regulating) Nervous System

The autonomic nervous system is involved in the control of the heart, glands and smooth muscles of the body and plays a major role in regulating unconscious, vegetative functions. It works together with the endocrine system to control the secretion of hormones and is itself controlled by the **hypothalamus**.

Because motor fibers make up the bulk of the autonomic nervous system, some anatomists consider it to be purely motor, but it does include some afferent axons that carry information from the viscera.

Although the autonomic nervous system is considered to be one of the three main divisions of the human nervous system in its own right, parts of both the central nervous systems and the peripheral nervous systems play a role in its functions.

The autonomic nervous system has two components, the **sympatheticsystem** and the **parasympathetic system**. These two aspects have antagonistic functions.

Sympathetic System

The **sympathetic system** prepares the body for fight or flight reactions. Action of this system results in accelerated heart rate, increased blood pressure and blood flow away from the periphery and digestive system toward the brain, heart and skeletal muscles. It also causes **adrenaline** to be released, temporarily increasing physical strength.

Parasympathetic System

The **parasympathetic system** brings the body back to a state of equilibrium. It slows the heart rate and decreases the release of hormones into the blood stream. The activity of the parasympathetic system causes more localized reactions than does the sympathetic system as much of its output is to specific organs.

The autonomic nervous system consists of four chains of nuclei or ganglia, two of which are located on either side of the spinal cord. The outer chains of nuclei form the **parasympathetic** division of the system while those closest to the spinal cord make up its **sympathetic** element.

Rami communicantes

The rami of the autonomic nervous system are the axons of pre-ganglionic and ganglionic fibers. Most of the axons of pre-ganglionic neurons are myelinated. Their cell bodies are found in the gray matter of the brain stem and spinal cord. Their axons synapse with neurons within the two ganglionic chains.

Pre-ganglionic cells of the autonomic nervous system are neurons located in some of the cranial nerves of the brain stem and in some of the spinal nerves that project to the ganglionic chains of the autonomic nervous system. The autonomic nervous system is closely connected with the central and peripheral nervous systems.

Ganglionic cells originate within the ganglia. They project to post-ganglionic neurons.

Post-ganglionic cells are neurons that are located in the target organs and muscles of the autonomic nervous system.

It can be said that the motor pathways of the autonomic nervous system are made up of its pre-ganglionic and ganglionic cells.

The fibers of the ganglionic chain of the parasympathetic system are not as well-defined as those of the sympathetic chain. All pre-ganglionic neurons of the sympathetic system synapse with the sympathetic chain. This is not true of the parasympathetic pre-ganglionic cells, however. Some of them synapse with the chain, but others go directly to end organs or muscle

3.3 Map of Dermatomes

A dermatome is a band or region of skin supplied by a single sensory nerve. Sensory nerves carry sensory impulses to the spinal cord—pain, temperature, touch and position sense (proprioception)—from tendons, joints and body surfaces. The face is supplied by the cranial nerves.

Regions

Each pair of spinal nerves links to one of four regions of the body:

- **Cervical Region** (green): 8 pairs of nerves supply the skin covering the back of the head, the neck, shoulders, arms and hands.
- **Thoracic Region** (blue): 12 pairs of thoracic nerves supply the skin on the chest, back and under the arms
- **Lumbar Region** (pink): 5 pairs of lumbar nerves supply the skin on the lower abdomen, thighs and fronts of the legs
- **Sacral Region** (yellow): 6 pairs of sacral nerves supply the skin on the back of the legs, the feet and genial areas

Levels of principal dermatomes

- C5 — clavicles
- C5, C6, C7 — lateral parts of the upper limb
- C8, T1 — medial sides of the upper limb
- C6 — thumb
- C6, C7, C8 — hand
- C8 — ring and little fingers
- T4 — level of nipples
- T10 — level of umbilicus
- T12 — inguinal or groin regions
- L1 L2 L3 L4 — anterior and inner services of lower limb
- L4, L5, S1 — foot
- L4 — medial side of big toe
- S1. S2, L5 — posterior and outer surfaces of lower limbs
- S1 — lateral margin of foot and little toe
- S2, S3, S4 — perineum

Receptor Arc

Nerves can be divided into two types – motor nerves and sensory nerves. Motor nerves control movement by carrying messages from the brain to the muscles. Sensory nerves carry messages from the sensory receptors in the body to the brain. In many places the motor nerves and sensory nerves run in pairs alongside each other. There are 31 pairs of nerves that branch off the spinal cord.

Spinal nerve pairs

Cervical nerve – 8 pairs
Thoracic nerve – 12 pairs
Lumbar – 5 pairs
Sacral – 5 pairs
Coccyx – 1 pair

In the nervous system there is a "closed loop" system of sensation sensory), decision (brain), and reactions (motor). This process is carried out through the activity of afferent neurons (sensory), interneurons (spinal cord), and efferent (motor) neurons. Nerves are made of very specialized cells called neurons.

Afferent neurons (otherwise known as sensory or receptor neurons) are receptors that receive the stimulus then carry nerve impulses from receptors or sense organs towards the central nervous system communicating sensory information to the spinal cord and brain. Sensory neurons respond to the senses of touch, sound, light, smell and taste. An example of a sensory response is when your skin is stuck with a pin, the afferent neuron communicates pain or discomfort to the spinal cord and then to the brain. The brain processes the pain information, decides how your body should react and then sends information back through the efferent neuron to the muscle to contract which moves the area (finger, arm, etc.) away from the cause of the pain. This process is called a receptor or reflex arc.

The sensory and motor fibers of the spinal nerves form a **reflex arc**. This type of reflexive behavior occurs when a message from afferent fibers causes a motor reaction before going to the brain. For example, if you touch a hot burner on the stove, sensory information about the temperature of the burner travels along spinal nerves to your spinal cord and are carried directly to their motor nuclei by interneurons; the motor command goes out along the axons of the lower motor neuron causing you to move your hand away from the stove. As messages do not have to travel up to the brain to be processed, reactions mediated by this reflex arc can occur very rapidly. Of course you WILL feel pain shortly thereafter (milliseconds) as the information gets to the parietal lobe via the thalamus.

4.0CONCLUSION

The spinal cord begins below the medulla and ends just above the small of the back at the **conus medularis**. The area within the vertebral column beyond the end of the spinal cord is called the **cauda equina**. The spinal cord is protected by the vertebrae and the meninges. The dura mater, arachnoid mater and pia mater of the spinal cord are continuous with those of the brain. Cerebrospinal fluid is in the **subarachnoid space** that lies between the arachnoid and pia mater and in the **central canal**, a space in the middle of the gray matter of the cord. It provides a hydraulic cushion for the spinal cord.

5.0SUMMARY

This unit has discussed the anatomy of the spinal cord, Map of dermatomes and the spinal nerves including the reflex arc.

6.0 TUTOR-MARKEDASSIGNMENT

- Describe the functions of the spinal cord
- Write a short note on “Reflex Arc”
- Describe Dermatomes with examples

7.0REFERENCES/FURTHERREADINGS

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UNIT4 INTEGRATION OF CENTRAL NERVOUS WITH OTHER SYSTEMS

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 MainContent
3.1 IntegrationwithotherSystems
3.2 Nervous and Chemical Integration
3.3 Sensory Integration
4.0 Conclusion
5.0 Summary
6.0 Tutor-MarkedAssignment
7.0 References/FurtherReadings

1.0 INTRODUCTION

Integration is the process of combining information from many sources. The nervous system combines information from the different senses (vision, hearing touch, etc), and each part of the brain combines information from many other parts of the brain. This process is essential for the body and its parts to function smoothly and effectively. It is also essential for the ability of the brain to extract and organize information about the world. The nervous system can do this because neurons (nerve cells) have a part (called *dendrites*), which are designed to combine or integrate information. They form connections, called (*synapses*) with many other neurons and combine the signals from them.

2.0OBJECTIVES

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

- Discuss integrationof the nervous system withothersystems
- DescribeNervous and Chemical Integration
- Discuss Sensory Integration
- Discuss Sensory Integration Disorder (SID)

3.0MAINCONTENT

3.1Integrationwith OtherSystems

Tofunctioneffectively,everycellinthebodymustcommunicatewith itsneighboursandwithcellsandtissuesindistantpartsofthebody.

Inafewspecialisedcases,cellularactivitiesarecoordinatedbythe exchangeofionsandmoleculesfromonecelltothenextacrossgap junctions.Thisdirectcommunicationoccursbetweencellsofthesame type,andthetwocellsmustbe inextensivephysicalcontact.Thetwo cellscommunicatesocloselythattheyfunctionassingleentity.For example,gapjunctions(1)coordinateciliary movementamong epithelialcells, (2) coordinatethecontractionsofcardiacmusclecells, and(3)facilitate thepropagationofactionpotentialfromoneneuron to thenextat electricalsynapses.

Directcommunicationishighlyspecialisedandrelativelyrare. Mostof thecommunicationsbetweencellsinvolvetherelease andreceiptof chemicalmessages.Each cellcontinuously“talks”toitsneighboursby releasingchemicalsintotheextracellularfluid.Thesechemicalsspeak of whattheirneighboursaredoingat anymoment;theresultisthe coordinationoftissuefunctionat thelocallevel.The useofchemical messengerstotransferinformationfromcell to cellwithinasingletissue iscalledparacrine communications.Thechemicalsinvolvedarecalled paracrinefactors,alsoknownascytokines,or localhormones.Examples ofparacrinefactorsincludetheprostaglandins.

3.2 Nervous and Chemical Integration

Animals constantly monitor both their internal and external environment and make the necessary adjustments in order to maintain themselves optimally, develop and reproduce at the maximum rate. The adjustments they make may be immediate and obvious, for example, flight from predators, or longer-term, for example, entry into diapause to avoid impending adverse conditions. The nature of the response depends on the nature of the stimulus. Only very rarely does a stimulus act directly on the effector system; almost always a stimulus is received by an appropriate sensory structure and taken to the central nervous system, which “determines” an appropriate response under the circumstances. When a response is immediate, that is, achieved in a matter of seconds or less, it is the nervous system that transfers the message to the effector system. Such responses are usually temporary in nature. Delayed responses are achieved through the use of chemical messages (viz., hormones) and are generally longer-lasting. The nervous and endocrine systems of an individual are, then, the systems that coordinate the response with the stimulus. Pheromones, which constitute another chemical regulating system, coordinate the behaviour and development of a group of individuals of the same species. This system is intimately related to nervous and endocrine regulation

3.3 Sensory Integration

Sensory integration refers to how people use the information provided by all the sensations coming from within the body and from the external environment. We usually think of the senses as separate channels of information, but they actually work together to give us a reliable picture of the world and our place in it. Your senses integrate to form a complete understanding of who you are, where you are, and what is happening around you. Because your brain uses information about sights, sounds, textures, smells, tastes, and movement in an organized way, you assign meaning to your sensory experiences, and you know how to respond and behave accordingly. Walking through a shopping mall, if you smell a powerful, sweet scent, you are able to identify it as a candle or essential oil and realize that you're walking past an aromatherapy store.

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Sensory Integration Disorder

Sensory integration disorder or dysfunction (SID) is a neurological disorder that results from the brain's inability to integrate certain information received from the body's five basic sensory systems. These sensory systems are responsible for detecting sights, sounds, smell, tastes, temperatures, pain, and the position and movements of the body. The brain then forms a combined picture of this information in order for the body to make sense of its surroundings and react to them appropriately. The ongoing relationship between behavior and brain functioning is called sensory integration (SI).

The normal process of SI begins before birth and continues throughout life, with the majority of SI development occurring before the early teenage years. The ability for SI to become more refined and effective coincides with the aging process as it determines how well motor and speech skills, and emotional stability develops. The beginnings of the SI theory by Ayres instigated ongoing research that looks at the crucial foundation it provides for complex learning and behavior throughout life.

4.0 CONCLUSION

The nervous system has three main functions: sensory input, integration of data and motor output. Sensory input is when the body gathers information or data, by way of neurons, glia and synapses. The nervous system is composed of excitable nerve cells (neurons) and synapses that form between the neurons and connect them to centers throughout the body or to other neurons. These neurons operate on excitation or inhibition, and although nerve cells can vary in size and location, their communication with one another determines their function. These nerves conduct impulses from sensory receptors to the brain and spinal cord. The data is then processed by way of integration of data, which occurs only in the brain. After the brain has processed the information, impulses are conducted from the brain and spinal cord to muscles and glands, a path which is called motor output. Glia cells are found within tissues and are not excitable but help with myelination, ionic regulation and extracellular fluid.

1.0 SUMMARY

In this unit, we have discussed theIntegration of central nervous with other systems, Nervous and Chemical Integration and Sensory Integration. We also mentioned Sensory Integration Disorder.

5.0 TUTOR-MARKEDASSIGNMENT

- What is Sensory Integration?
- Discuss sensory Integration Disorder

7.0REFERENCES/FURTHERREADINGS

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UNIT5THEENDOCRINESYSTEM

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 MainContent
 3.1 AnOverviewoftheEndocrineSystem
 3.2 ComponentsoftheEndocrineSystem
 3.3 Hormones
 3.4 IntegrationbetweentheEndocrineSystemandthe Nervous System
4.0 Conclusion
5.0 Summary
6.0 Tutor-MarkedAssignment
7.0 References/FurtherReadings

1.0INTRODUCTION

Thisunitintroducesthecomponentsandfunctionsof theendocrine systemandexplorestheinteractionsbetweenthenervousandendocrine systems.Weshallconsiderspecificendocrineorgans,hormonesand functions.

2.0 OBJECTIVES

Attheendofthisunit,youshouldbeableto:

- describetheendocrinesystem
- identifythecomponentsoftheendocrinesystem
- describethethreecategoriesofhormones
- explaintheintegrationbetweentheendocrinesystem andthe nervoussystem.

3.0MAINCONTENT

3.1AnOverviewoftheEndocrineSystem

Theendocrinesystemincludesalltheendocrinecells,andtissuesofthe body.Endocrinecellsareglandularsecretorycellsthatreleasetheir secretionsintotheextracellularfluid.This characteristicdistinguishes themfromexocrinecells, whichsecretetheirproductsontoepithelial surfacesgenerallybywayofducts.Thechemicalsreleasedbyendocrine cellsmayaffectonlyadjacentcells,asinthecaseofmostparacrine factors,ortheymayaffectcellsthroughoutthebody.

Structures of the Endocrine System

The endocrine system consists of cells, tissues, and organs that secrete hormones as a primary or secondary function. The **endocrine gland** is the major player in this system. The primary function of these ductless glands is to secrete their hormones directly into the surrounding fluid. The interstitial fluid and the blood vessels then transport the hormones throughout the body. The endocrine system includes the pituitary, thyroid, parathyroid, adrenal, and pineal glands. Some of these glands have both endocrine and non-endocrine (exocrine) functions. For example, the pancreas contains cells that function in digestion as well as cells that secrete the hormones insulin and glucagon, which regulate blood glucose levels. The hypothalamus, thymus, heart, kidneys, stomach, small intestine, liver, skin, female ovaries, and male testes are other organs that contain cells with endocrine function. Moreover, adipose tissue has long been known to produce hormones, and recent research has revealed that even bone tissue has endocrine functions. The ductless endocrine glands are not to be confused with the body’s **exocrine system**, whose glands release their secretions through ducts. Examples of exocrine glands include the sebaceous and sweat glands of the skin. As just noted, the pancreas also has an exocrine function: most of its cells secrete pancreatic juice through the pancreatic and accessory ducts to the lumen of the small intestine.

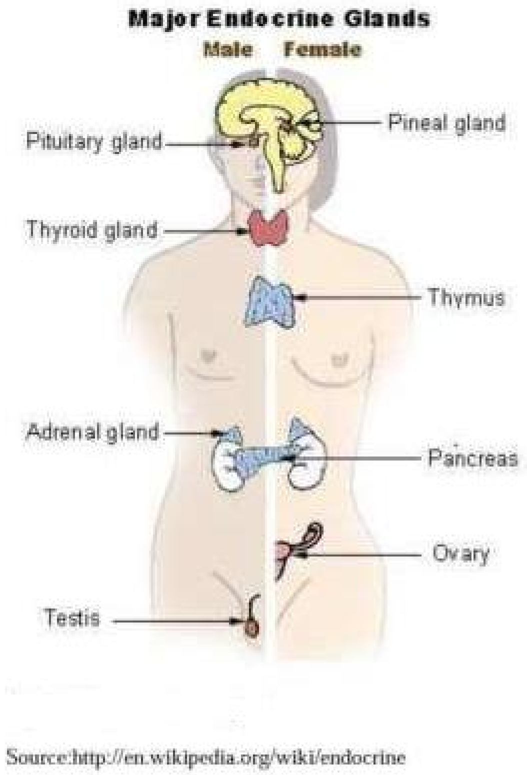

Figure 29: Major Endocrine glands

3.2ComponentsoftheEndocrineSystem

Thecomponentsoftheendocrinesystem areintroducedinFig.28.Some oftheseorgans,suchasthepituitarygland,haveendocrinesecretionasaprimar yfunction.Others,suchasthepancreashaveother functionsinadditiontoendocrinesecretion.Otherendocrineorgans includethe hypothalamus,theadrenalmedullae,theheart,thethymus, thepancreasanddigestivetract,thekidneys, thereproductiveorgans, andplacenta.

Paracrinefactorsenterthebloodstream,buttheconcentrationsare usuallysolowthatdistant cellsandtissuesarenotaffected.However, someparacrinefactors,includingseveraloftheprostaglandinsand relatedchemicals,haveprimaryeffectsintheirtissuesoforiginand secondaryeffectsinothertissuesandorgans.Whensecondaryeffects occur,theparacrinefactorsarealsoactingashormones.

SELF ASSESSMENTEXERCISE1

1. Whatareendocrinecells?
2. Listthefourendocrineorgansthatyouknow.

3.3Hormones

Hormonesarechemicalmessengersthatarereleasedinonetissueand transportedinthebloodstreamtoreachspecificcellsinothertissues.

Whereasmostcellsreleaseparacrinefactors,typicalhormonesare producedonlybyspecialisedcells. Inintercellularcommunications, hormonesarelettersandthecirculatorysystemis thepostalservice.A hormonereleasedintothebloodstreamwillbedistributedthroughoutthe body.Eachhormonehastargetcells orspecificcellsthatrespondtoits presence.Thesecellspossessthereceptorsneededtobindand“read”the hormonalmessage.Althougheverycellinthebodyisexposedtothe mixtureof hormonesincirculationat anymoment,eachindividualcell willrespondtoonlyafewofthehormonespresent.Theotherhormones aretreated likejunkmailandignored,becausethecelllacksthereceptorstoreadthemessagestheycontain.Theuseofhormonesto coordinatecellularactivitiesintissuesindistantpartsofthebodyis called*endocrinecommunications.*

Becausethetargetcellscanbe anywhereinthebody,asinglehormone canalterthemetabolicactivitiesofmultipletissuesandorgans simultaneously.Theseeffectsmaybeslowtoappear,buttheytypically persistfordays. Consequently,hormonesareeffectiveincoordinating cell,tissue,andorganactivitiesonasustained,long-termbasis.For example,circulatinghormoneskeepbodywatercontentandlevelsof electrolytesandorganicnutrientswithinnormallimits24hoursaday throughoutourentirelife time.

Whiletheeffectsof asinglehormonepersist, acellmayreceive additionalinstructionsfromotherhormones.Theresultwillbe afurther modificationofcellularoperations.Gradualchangesinthequantities andidentitiesof circulatinghormonescanproducecomplexchangesin physicalstructureandphysiologicalcapabilities.Examplesincludethe processesof embryologicalandfoetaldevelopment,growth,and puberty.Hormonescanbedividedintothree groupsonthebasisof chemicalstructure:(1)aminoacidderivatives,(2)peptidehormones, and(3)lipidderivatives.

Although a given hormone may travel throughout the body in the bloodstream, it will affect the activity only of its target cells; that is, cells with receptors for that particular hormone. Once the hormone binds to the receptor, a chain of events is initiated that leads to the target cell’s response. Hormones play a critical role in the regulation of physiological processes because of the target cell responses they regulate. These responses contribute to human reproduction, growth and development of body tissues, metabolism, fluid, and electrolyte balance, sleep, and many other body functions. The major hormones of the human body and their effects are identified in **Table below**.

Table 4: Endocrine Glands and Their Major Hormones

Endocrine Gland	**Associated Hormones**	**Chemical Class**	**Effect**
Pituitary (anterior)	Growth hormone (GH)	Protein	Promotes growth of body tissues
Pituitary (anterior)	Prolactin (PRL)	Peptide	Promotes milk production
Pituitary (anterior)	Thyroid-stimulating hormone (TSH)	Glycoprotein	Stimulates thyroid hormone release
Pituitary (anterior)	Adrenocorticotropic hormone (ACTH)	Peptide	Stimulates hormone release by adrenal cortex
Pituitary (anterior)	Follicle-stimulating hormone (FSH)	Glycoprotein	Stimulates gamete production
Pituitary (anterior)	Luteinizing hormone (LH)	Glycoprotein	Stimulates androgen production by gonads
Pituitary (posterior)	Antidiuretic hormone (ADH)	Peptide	Stimulates water reabsorption by kidneys
Pituitary (posterior)	Oxytocin	Peptide	Stimulates uterine contractions during childbirth
Thyroid	Thyroxine (T4), triiodothyronine (T3)	Amine	Stimulate basal metabolic rate
Thyroid	Calcitonin	Peptide	Reduces blood Ca2+ levels
Parathyroid	Parathyroid hormone (PTH)	Peptide	Increases blood Ca2+ levels
Adrenal (cortex)	Aldosterone	Steroid	Steroid Increases blood Na+ levels
Adrenal (cortex)	Cortisol, corticosterone, cortisone	Steroid	Increase blood glucose levels
Adrenal	Epinephrine,	Amine	Stimulate fight-or-

(medulla)	norepinephrine		flight response
Pineal	Melatonin	Amine	Regulates sleep cycles
Pancreas	Insulin	Protein	Reduces blood glucose levels
Pancreas	Glucagon	Protein	Increases blood glucose levels
Testes	Testosterone	Steroid	Stimulates development of male secondary sex characteristics and sperm production
Ovaries	Estrogens and progesterone	Steroid	Stimulate development of female secondary sex characteristics and prepare the body for childbirth

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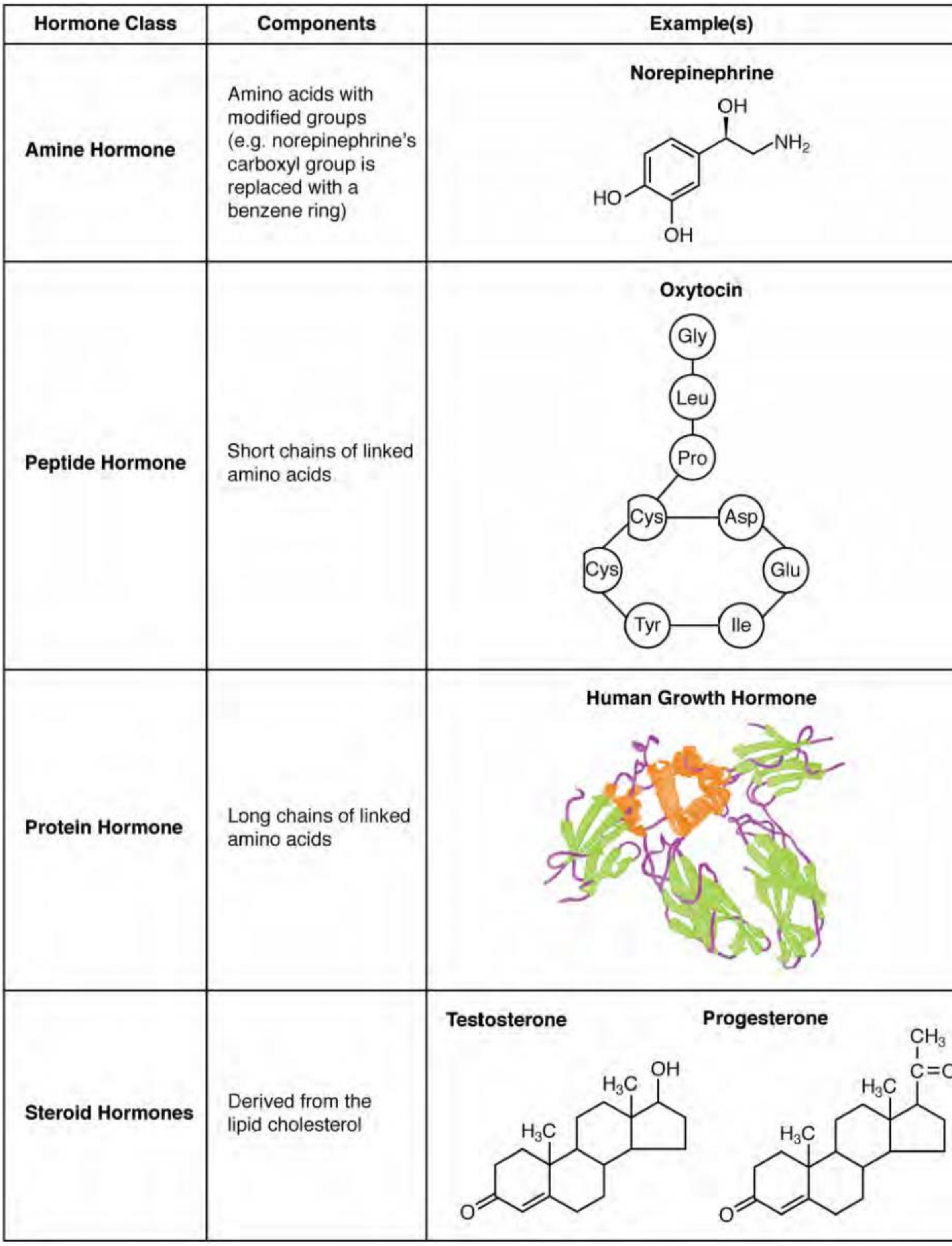
Types of Hormones

The hormones of the human body can be divided into two major groups on the basis of their chemical structure. Hormones derived from amino acids include amines, peptidesand proteins. Those derived from lipids include steroids. These chemical groups affect a hormone’s distribution, the type of receptors it binds to, and other aspects of its function.



Hormone Class	Components	Example(s)
Amine Hormone	Amino acids with modified groups (e.g. norepinephrine's carboxyl group is replaced with a benzene ring)	Norepinephrine
Peptide Hormone	Short chains of linked amino acids	Oxytocin
Protein Hormone	Long chains of linked amino acids	Human Growth Hormone
Steroid Hormones	Derived from the lipid cholesterol	Testosterone; Progesterone

Figure 30: Structure of Amine, Peptide, Protein, and Steroid hormones
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Functions of Hormones

1. Help regulate:

 • Chemical composition and volume of internal environment (interstitial fluid)
 • Metabolism and energy balance
 • Contraction of smooth and cardiac muscle fibers
 • Glandular secretions
 • Some immune system activities
2. Control growth and development.
3. Regulate operation of reproductive systems.
4. Help establish circadian rhythms.

3.4 IntegrationbetweentheEndocrineSystemandthe NervousSystem

Thenervoussystemalsoreliesprimarilyonchemicalcommunication, butitdoesnotusebloodstreamcommunicationsformessagedelivery liketheendocrinesystem.Instead,neuronsreleaseaneurotransmitterat asynapseveryclosetothetargetcellsthatbeartheappropriate receptors.The commandtoreleasetheneurotransmitterrapidlytravels fromonelocationtoanotherintheformofactionpotentialpropagated alongaxons.Thenervoussystem thusactslikeatelephonecompany, carryinghigh-speed“messages”fromonelocationinthebodyto another anddeliveringthemtoaspecificdestination.Theeffectsof neuralstimulationaregenerallyshortlived,andtendto berestrictedtospecifictargetcells–primarilybecausetheneurotransmitter israpidlybrokendownor recycled.Thisformofsynaptic communicationisidealforcrisismanagement:ifyouareindangerof beinghitbyaspeedingbus,thenervoussystemcancoordinateanddirectyou toleaptosafety.Oncethecrisisisoverandtheneuralcircuitquietensdown,thin gssoonreturntonormal.

Whenviewedfromageneralperspectivethedifferencesbetweenthe nervousandendocrinesystemsseemrelativelyclear.Infact,these broad organisationalandfunctionaldistinctionsarethebasisfortreatingthem astwoseparatesystems.Yet,whenweconsiderthemindetail,thetwo systemsareorganisedalongparallellines.Forexample:

- Bothsystemsrelyonthereleaseofchemicalsthatbind tospecific receptorsontheirtargetcells.
- Thetwosystemsshare manychemicalmessengers;forexample, norepinephrineandepinephrinearecalledhormoneswhen released

intothebloodstreambutneurotransmitterswhen released acrosssynapses.

- Bothsystemsare regulatedprimarilybynegativefeedback controlmechanisms.
- Thetwosystemsshareacommon goal:topreservehomeostasis bycoordinatingandregulating theactivitiesofothercells,tissues, organs,andsystems.

Table 5: Endocrine and Nervous Systems

Signaling mechanism(s)	Chemical	Chemical/electrical
Primary chemical signal	Hormones	Neurotransmitters
Distance traveled	Long or short	Always short
Response time	Fast or slow	Always fast
Environment targeted	Internal	Internal and external

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SELF ASSESSMENTEXERCISE2

Hormonescanbeclassifiedinto3groups:----------------------------------, ——---------------------------------and--------------------------------------.

4.0CONCLUSION

Youshouldhaveseenthattheendocrinesystemincludesallthe endocrinecellsandtissuesofthebody.Theyhaveglandularsecretorycellsthat releasetheirsecretionsintotheextracellularfluid.Themain functionof theendocrinesystemistopreservehomeostasisby coordinatingandregulatingtheactivitiesofothercells,tissues,organs, andsystems.

The endocrine system consists of cells, tissues, and organs that secrete hormones critical to homeostasis. The body coordinates its functions through two major types of communication: neural and endocrine. Neural communication includes both electrical and chemical signaling between neurons and target cells. Endocrine communication involves chemical signaling via the release of hormones into the extracellular fluid. From there, hormones diffuse into the bloodstream and may travel to distant body regions, where they elicit a response in target cells. Endocrine glands are ductless glands that secrete hormones. Many organs of the body with other primary functions—such as the heart, stomach, and kidneys—also have hormone-secreting cells. Hormones are derived from amino acids or lipids. Amine hormones originate from the amino acids tryptophan or tyrosine. Larger amino acid hormones include peptides and protein hormones. Steroid hormones are derived from cholesterol.

5.0SUMMARY

Inthisunitwehave consideredthefactthatendocrinecellsaredifferent fromexocrinecells;thelattersecretetheirproductsontoepithelia's surfacesgenerallybywayofducts.Also,thereareseveral similaritiesas wellasdistinctionsbetweentheendocrinesystem andthenervous system.

ANSWERTOSELFASSESSMENTEXERCISE1

Theendocrineorgansincludehypothalamus,theadrenalmedullae,the heart,thethymus,thepancreasanddigestivetract, thekidneys, the reproductiveorgans,andplacenta.

ANSWERTOSELFASSESSMENTEXERCISE2

Hormonescanbeclassifiedinto(a)amino acidderivatives,(b)peptide hormones,and(c) lipidderivatives.

6.0TUTOR-MARKEDASSIGNMENT

Discussthe synergisticrelationshipoftheendocrineandnervous systems.

7.0REFERENCES/FURTHERREADINGS

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MODULE 4 THE RESPIRATORY AND DIGESTIVE SYSTEMS

Unit 1 Overview of the respiratory system
Unit 2 The structure of the respiratory system
Unit 3 Overview of digestive system
Unit 4 The structure and function of the digestive system
Unit 5 Pelvic organs

UNIT 1 OVERVIEW OF THE RESPIRATORY SYSTEM

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
 3.1 General Function of respiratory system
 3.2 Physiology of Respiration
 3.3 Air Movement
 3.4 Pulmonary Ventilation
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 INTRODUCTION

The respiratory system extends from the breathing zone just outside of the nose and mouth through the conductive airways in the head and thorax to the alveoli, where respiratory gas exchange takes place between the alveoli and the capillary blood flowing around them. Its prime function is to deliver oxygen (O_2) to the gas-exchange region of the lung, where it can diffuse to and through the walls of the alveoli to oxygenate the blood passing through the alveolar capillaries as needed over a wide range of work or activity levels. In addition, the system must also: (1) remove an equal volume of carbon dioxide entering the lungs from the alveolar capillaries; (2) maintain body temperature and water vapour saturation within the lung airways (in order to maintain the viability and functional capacities of the surface fluids and cells); (3) maintain sterility (to prevent infections and their adverse consequences); and (4) eliminate excess surface fluids and debris, such as inhaled particles and senescent phagocytic and epithelial cells. It must accomplish all of these demanding tasks continuously over a lifetime, and do so with high efficiency in terms of performance and energy utilization. The system can be abused and overwhelmed by severe insults such as high concentrations of cigarette smoke and industrial dust, or by low concentrations of specific pathogens which attack or destroy its defence mechanisms, or cause them to malfunction. Its ability to overcome or compensate for such insults as competently as it usually does is a testament to its elegant combination of structure and function

2.0 OBJECTIVES

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

- Discuss the General Function of respiratory system
- Describe the Physiology of Respiration
- Discuss Air Movement
- Discuss Pulmonary Ventilation

3.0 MAIN CONTENT

3.1 General Function

A primary requirement for all body cell activities and growth is oxygen, which is needed to obtain energy from food. The fundamental purpose of the respiratory system is to supply oxygen to the individual tissue cells and to remove their gaseous waste product, carbon dioxide. Breathing or ventilation refers to the inhalation and exhalation of air. Air is a mixture of oxygen, nitrogen, carbondioxide and other gases; the pressure of these gases varies, depending on the elevation above sea level. The first, called external expiration, takes place only in the lungs, where oxygen from the outside air enters the blood and carbondioxide leaves the blood to be breathed into the outside air. In the second, called internal respiration, gas exchanges take place between the blood and the body cells, with oxygen leaving the blood and entering the cells at the same time that carbon dioxide leaves the cells and enters the blood.

The respiratory system is an intricate arrangement of spaces and passageways that conduct air into the lungs. These spaces include the nasal cavities; the pharynx, which is common to the digestive and respiratory systems; the voice box or larynx; the windpipe or trachea; and the lungs themselves, with their conducting tubes and air sacs. The entire system might be thought of as a pathway for air between the atmosphere and the blood.

3.2 Physiology of Respiration Pulmonary Ventilation

Ventilation is the movement of air into and out of the lungs, as in breathing. There are two phases of ventilation:

1. **Inhalation** is the drawing of air into the lungs.
2. **Exhalation** is the expulsion of air from the lungs.

In **inhalation,** the active phase of breathing, the respiratory muscles contract to enlarge the thoracic cavity. The diaphragm is a strong dome-shaped muscle attached around the base of the rib cage. The contraction and relaxation of the diaphragm cause a piston-like downward motion that result in an increase in the vertical dimension of the chest. The rib cage is also moved upward and outward by contraction of the external intercostal muscles and, during exertion, by contraction of other muscles of the neck and chest. During quiet breathing, the movement of the diaphragm accounts for most of the increase in thoracic volume. As the thoracic cavity increases in size, gas pressure within the cavity decreases. When the pressure drops to slightly below atmospheric pressure, air is drawn into the lungs.

In exhalation, the passive phase of breathing, the muscles of respiration relax, allowing the ribs and diaphragm to return to their original positions. The tissues of the lung, which are elastic, recoil during exhalation. During forced exhalation, the internal intercostal muscles and the muscles of the abdominal wall contracts, pulling the lower part of the rib cage in and down. The abdominal viscera are also pushed upward against the diaphragm.

3.3 Air Movement

Air enters the respiratory passages and flows through the ever-dividing tubes of the bronchial tree. As the air traverses this passage, it moves more and more slowly through the great number of bronchial tubes until there is virtually no forward flow as it reaches the alveoli. Here the air moves by diffusion, which soon equalizes any differences in the amounts of gases present. Each breath causes relatively little change in the gas composition of the alveoli, but normal continuous breathing ensures the presence of adequate oxygen and the removal of carbon dioxide.

Regulation of respiration

Regulation of respiration is a complex process that keeps pace with moment-to-moment changes in cellular oxygen requirements and carbon dioxide production. Regulation depends primarily on the respiratory control centers located in the medulla and pons of the brain stem. Nerve impulses from the medulla are modified by the centers in the pons. Respiration is regulated so that the levels of oxygen, carbon dioxide and acid are kept within certain limits. The control centers regulate the rate, depth, and rhythm of respiration.

4.0 CONCLUSION

Of vital importance in the control of respiration are the chemoreceptors. These receptors are found in structures called the carotid and aortic bodies, as well as outside the medulla of the brain stem. It is possible for a person to deliberately breathe more rapidly or more slowly or to hold his breath and not breath at all for a time. Usually we breathe without thinking about it, while the respiratory centers in the medulla and pons do the controlling.

5.0 SUMMARY

In this unit, we have discussed the **general function of the respiratory system,** the **physiology of respiration** and **air movement during respiration.**

6.0 TUTOR-MARKED ASSIGNMENT

- Discuss the functions of the respiratory system
- Discuss the physiology of respiration

7.0 REFERENCES/FURTHER READINGS

Martini, F.C; Ober, W.C; Garrison, C.W; Welch, K. & Hutchings, R.T. (2001). Fundamentals of Anatomy and Physiology, (5th ed), New Jersey: Prentice-Hall, Inc.

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UNIT 2 THE STRUCTURE OF THE RESPIRATORY SYSTEM

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
3.1 The Concept of the Respiration
3.2 Types of Respiration
3.3 The Respiratory System Anatomy
3.4 Pulmonary Ventilation
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 INTRODUCTION

The respiratory system is the combination of organs and tissues associated with breathing (gaseous exchange). It consists of a pair of lungs enclosed in the thorax and connected to the air outside by a series of branching air tubes (trachea, bronchi and bronchioles) and air pathways (nasal cavity, pharynx and larynx). The ribcage, intercostal muscles and diaphragm work together, to draw air into and out of the lungs.

2.0 OBJECTIVES

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

- explain the respiratory process
- describe the types of respiration
- explain the anatomy of the respiratory system
- describe pulmonary ventilation.

3.0 MAIN CONTENT

General Function of respiratory system

The major organs of the respiratory system function primarily to provide oxygen to body tissues for cellular respiration, remove the waste product carbon dioxide, and help to maintain acid-base balance. Portions of the respiratory system are also used for non-vital functions such as sensing odors, speech production, and for straining, such as during childbirth or coughing (Figure 30 below). Functionally, the respiratory system can be divided into a conducting zone and a respiratory zone. The **conducting zone** of the respiratory system includes the organs and structures not directly involved in gas exchange. The gas exchange occurs in the **respiratory zone**.

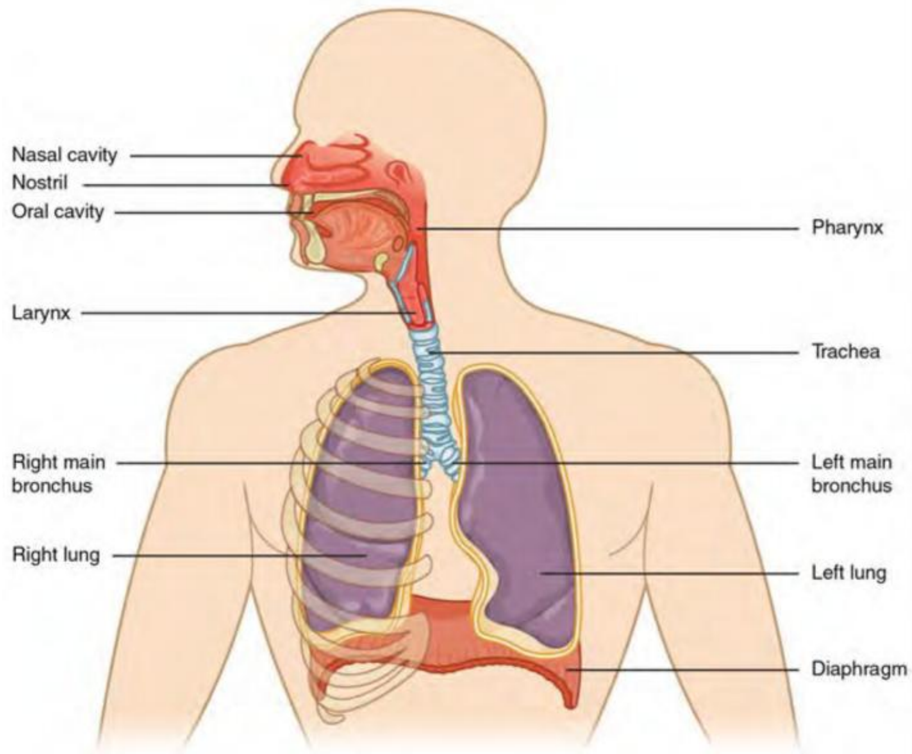


Figure 31: Major Respiratory Structures. (This content is available for free at http://cnx.org/content/col11496/1.6)

Breathing, or ventilation, refers to the inhalation and exhalation of air. Air is a mixture of oxygen, nitrogen, carbon dioxide and other gases; the pressure of these gases varies, depending on the elevation above sea level. The first, called external expiration, takes place only in the lungs, where oxygen from the outside air enters the blood and carbon dioxide leaves the blood to be breathed into the outside air. In the second, called internal respiration, gas exchanges take place between the blood and the body cells, with oxygen leaving the blood and entering the cells at the same time that carbon dioxide leaves the cells and enters the blood.

The respiratory system is an intricate arrangement of spaces and passageways that conduct air into the lungs. These spaces include the nasal cavities; the pharynx, which is common to the digestive and respiratory systems; the voice box, or larynx; the windpipe, or trachea; and the lungs themselves, with their conducting tubes and air sacs. The entire system might be thought of as a pathway for air between the atmosphere and the blood (Figure above).

Structure and Function of Respiratory Pathways

The Nasal Cavities

Several bones that help to form the walls of the nasal cavity have air-containing spaces called the paranasal sinuses, which serve to warm and humidify incoming air. Sinuses are lined with a mucosa. Each **paranasal sinus** is named after its associated bone: frontal sinus, maxillary sinus, sphenoidal sinus, and ethmoidal sinus. The sinuses produce mucus and lighten the weight of the skull. The nares and anterior portion of the nasal cavities are lined with mucous membranes containing sebaceous glands and hair follicles that serve to prevent the passage of large debris, such as dirt, through the nasal cavity. An olfactory epithelium used to detect odors is found deeper in the nasal cavity.

The Pharynx

The **pharynx** is a tube formed by skeletal muscle and lined by mucous membrane that is continuous with that of the nasal Cavities. The pharynx is divided into three major regions: the nasopharynx, the oropharynx, and the laryngopharynx.

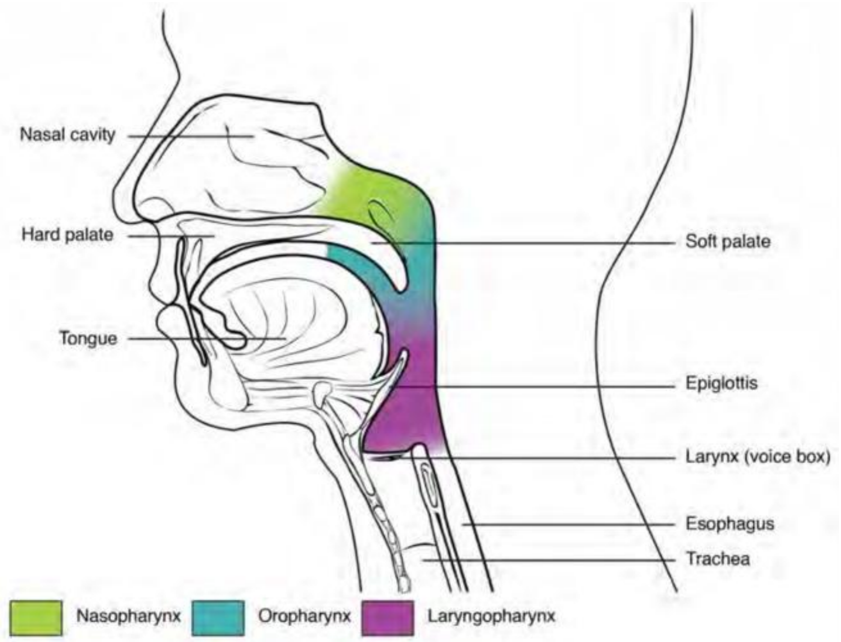


Figure 32: Divisions of the Pharynx (This content is available for free at http://cnx.org/content/col11496/1.6)

The Larynx

The larynx (voice box) is located between the pharynx and the trachea. The **larynx** is a cartilaginous structure inferior to the laryngopharynx that connects the pharynx to the trachea and helps regulate the volume of air that enters and leaves the lungs (Figure 32). The structure of the larynx is formed by several pieces of cartilage. Three large cartilage pieces—the thyroid cartilage (anterior), epiglottis (superior), and cricoid cartilage (inferior)—form the major structure of the larynx. The **thyroid cartilage** is the largest piece of cartilage that makes up the larynx. The thyroid cartilage consists of the **laryngeal prominence**, or “Adam’s apple,” which tends to be more prominent in males. The thick **cricoid cartilage** forms a ring, with a wide posterior region and a thinner anterior region. Three smaller, paired cartilages—the arytenoids, corniculates, and cuneiforms—attach to the epiglottis and the vocal cords and muscle that help move the vocal cords to produce speech. You can feel the larynx move upward toward the epiglottis during this process by placing the flat ends of your fingers on your larynx as you swallow.

The Trachea

The trachea (windpipe) extends from the larynx toward the lungs. The **trachea** is formed by 16 to 20 stacked, C-shaped pieces of hyaline cartilage that are connected by dense connective tissue. The **trachealis muscle** and elastic connective tissue together form the **fibroelastic membrane**, a flexible membrane that closes the posterior surface of the trachea, connecting the C-shaped cartilages. The fibroelastic membrane allows the trachea to stretch and expand slightly during inhalation and exhalation, whereas the rings of cartilage provide structural support and prevent the trachea from collapsing. In addition, the trachealis muscle can be contracted to force air through the trachea during exhalation. The trachea is lined with pseudostratified ciliated columnar epithelium, which is continuous with the larynx. The esophagus borders the trachea posteriorly.

Bronchial Tree

The trachea branches into the right and left primary **bronchi** at the carina. These bronchi are also lined by pseudostratified ciliated columnar epithelium containing mucus-producing goblet cells. The carina is a raised structure that contains specialized nervous tissue that induces violent coughing if a foreign body, such as food, is present. Rings of cartilage, similar to those of the trachea, support the structure of the bronchi and prevent their collapse. The primary bronchi enter the lungs at the hilum, a concave region where blood vessels, lymphatic vessels and nerves also enter the lungs.

The bronchi continue to branch into a bronchial tree. A **bronchial tree** (or respiratory tree) is the collective term used for these multiple-branched bronchi. The main function of the bronchi, like other conducting zone structures, is to provide a passageway for air to move into and out of each lung. In addition, the mucous membrane traps debris and pathogens.

A **bronchiole** branches from the tertiary bronchi. Bronchioles, which are about 1 mm in diameter, further branch until they become the tiny terminal bronchioles, which lead to the structures of gas exchange. There are more than 1000 terminal bronchioles in each lung. The muscular walls of the bronchioles do not contain cartilage like those of the bronchi. This muscular wall can change the size of the tubing to increase or decrease airflow through the tube.

3.1 The Concept of Respiration

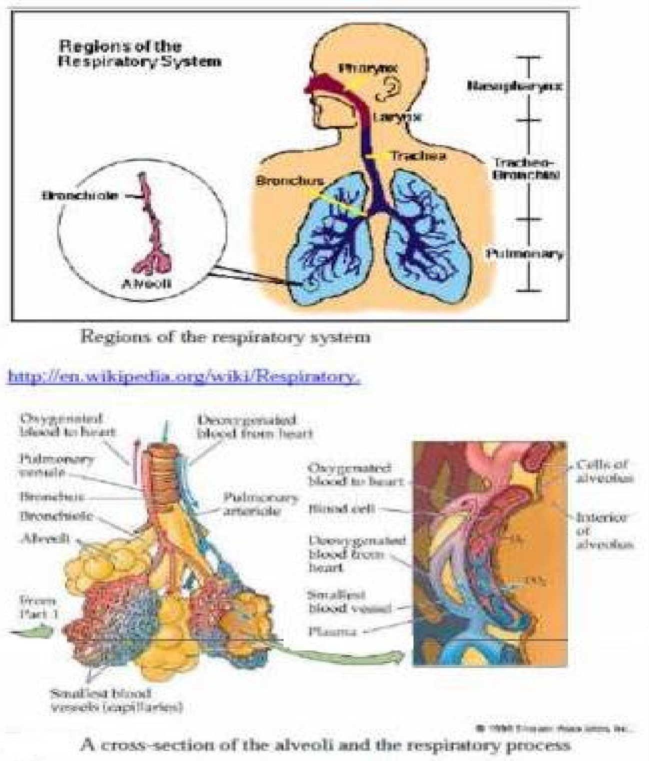
Respiration is the chemical breakdown of glucose, accelerated by enzymes inside the body cells to liberate energy. Carbon dioxide and water or alcohols are given off as waste products.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + H_2O + 674\ \text{Kcal}$$

Glucose Oxygen Carbon dioxide water Kinetic and heat energy

Respiration can also be described as:

- The intake and absorption of oxygen from the surrounding environment.
- The transport of oxygen to individual cells of the body.
- Using oxygen to release energy in the form of adenosine triphosphate (ATP).



Regions of the respiratory system

http://en.wikipedia.org/wiki/Respiratory.

A cross-section of the alveoli and the respiratory process

Figure 33: A cross section of the alveoli and the respiratory process

3.2 Types of Respiration

1. Internal respiration
2. External respiration

Internal or Tissues Respiration

Air (Oxygen) enters the body through the nostril where it is cleaned, moistened and heated to the body temperature and passes through: Trachea → bronchi → bronchioles → alveoli. Internal respiration involves two breathing processes or mechanisms. These are:

- Inhalation or Inspiration
- Exhalation or Expiration

- In the wall of the alveoli, the oxygen combines with the haemoglobin in the red blood corpuscles to form oxyhaemoglobin. This is carried away in the pulmonary vein to the heart and then distributed to all parts of the body. When the blood reaches an active organ the oxyhaemoglobin dissociates again, giving up its oxygen for respiration to produce energy.
- Carbon dioxide produced as one of the end products combines with sodium carbonates in the plasma to form bicarbonates.

- In the lungs the bicarbonates are broken down by the enzymes to liberate carbon dioxide.
- This diffuses into the alveoli and eventually expelled through the nostrils or the mouth.

Pulmonary Ventilation

The difference in pressures drives pulmonary ventilation because air flows down a pressure gradient, that is, air flows from an area of higher pressure to an area of lower pressure. Air flows into the lungs largely due to a difference in pressure; atmospheric pressure is greater than intra-alveolar pressure, and intra-alveolar pressure is greater than intrapleural pressure. Air flows out of the lungs during expiration based on the same principle; pressure within the lungs becomes greater than the atmospheric pressure.

Pulmonary ventilation comprises two major steps: inspiration and expiration. **Inspiration** is the process that causes air to enter the lungs, and **expiration** is the process that causes air to leave the lungs. A **respiratory cycle** is one sequence of inspiration and expiration. In general, two muscle groups are used during normal inspiration: the diaphragm and the external intercostal muscles. Additional muscles can be used if a bigger breath is required. When the diaphragm contracts, it moves inferiorly toward the abdominal cavity, creating a larger thoracic cavity and more space for the lungs.

Contraction of the external intercostal muscles moves the ribs upward and outward, causing the rib cage to expand, which increases the volume of the thoracic cavity. Due to the adhesive force of the pleural fluid, the expansion of the thoracic cavity forces the lungs to stretch and expand as well. This increase in volume leads to a decrease in intra-alveolar pressure, creating a pressure lower than atmospheric pressure. As a result, a pressure gradient is created that drives air into the lungs.

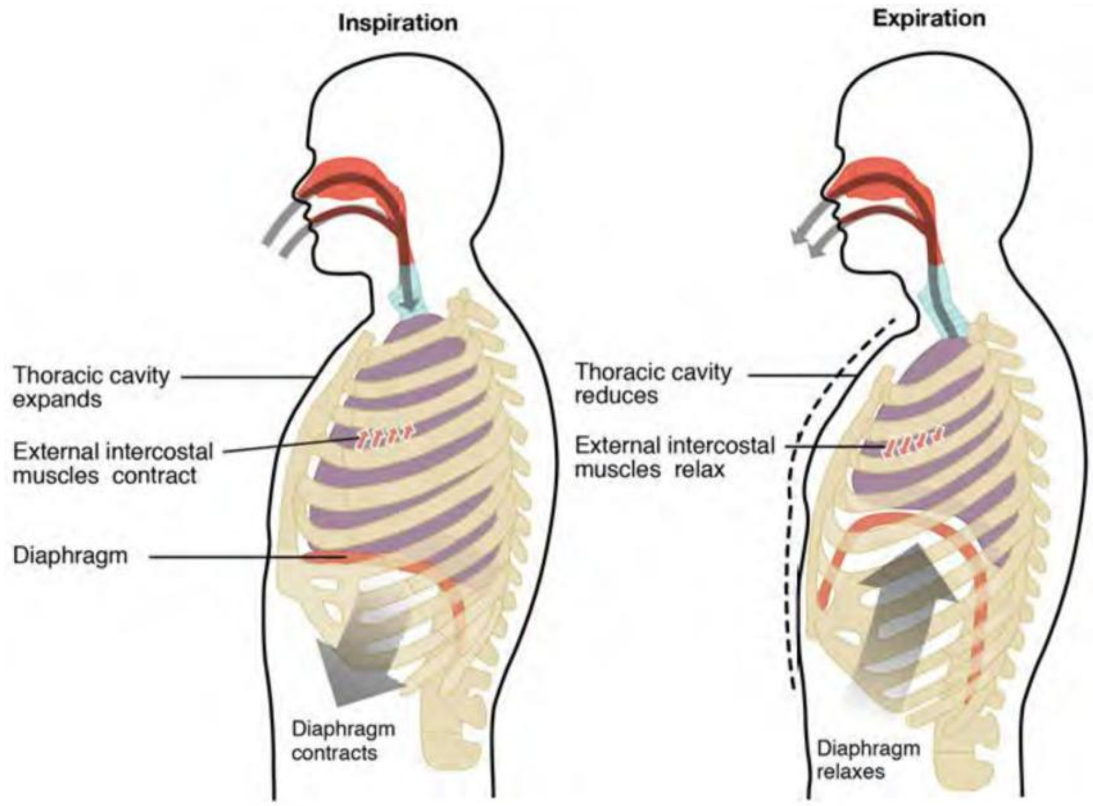


Figure 34: Inspiration and Expiration
(This content is available for free at http://cnx.org/content/col11496/1.6)

SELF ASSESSMENT EXERCISE 1

1. Internal respiration consists of ----------------------and-------------------.
2. What is respiration?

3.3 Respiratory System Anatomy

Upper Respiratory Tract (URT):

1. Paranasal structures like external nares, nasal cavity and septum, nasal conchae, nasal meatuses, olfactory epithelium, paranasal sinuses and ciliated pseudostratified epithelium.
2. Pharynx: Internal nares, auditory tubes, oropharynx and laryngopharynx.

Lower Respiratory Tract (LRT):

1. Larynx: Thyroid and cricoid cartilage, vocal box and hyoid
2. Trachea: Bronchi and other structures.
3. Lungs (right lung = three lobes; left lung = two lobes), consist of pleural membranes, bronchi, bronchioles, terminal bronchioles,

smooth muscles within bronchiole walls, alveolar ducts, alveolar sacs and alveoli.

3.4 Pulmonary Ventilation

Inspiration: This process is influenced by Boyle's Law (air pressure in closed space inversely correlate with volume). Increased volume = decreased pressure; decreased volume = increase pressure.

Differences in air pressure between air and lungs drive the movement of air into/out of lungs. Normal inspiration is an active process. Inspiratory muscles involved are:

1. Diaphragm (75% normal inspiratory action). It is activated by the phrenic nerve.
2. External intercostal muscles (25% normal inspiratory action). It is activated by intercostal nerves.
3. Accessory muscles can also enhance inspiration. Examples are sternocleidomastoid and scalenes. Normal breathing (“eupnoea”) consists of moving approx 0.5 L (tidal volume) into/out of lungs. Not all air inspired actually enters the lung because there is an anatomic “dead space” (approx 150 ml) which includes URT and trachea and bronchi. Only air within alveoli (approx 350ml) can exchange gases.

Expiration: This is a passive process; it involves the relaxation of the diaphragm and external intercostals. The ribs are depressed and the diaphragm curves upwards. Expiration can become an active process by contraction of abdominals and internal intercostals. Major factors driving expiration are elastic recoil of lungs and surface tension of alveolar fluid (lessened by surfactant) .These factors create high “compliance”, that is ease of lung expansion. Low compliance results from pulmonary scarring, oedema, surfactant deficiency (especially in premature babies). Compliance can become too high in conditions like emphysema. Intrapleural pressure: This is the pressure within the pleural cavity; it must stay approx 4 mmHg LESS than intrapulmonary pressure. Any condition that equalises Intrapleural and intrapulmonary pressures causes immediate lung collapse.

Certain terms associated with pulmonary ventilation include:

- Dyspnea – painful, difficult breathing;
- Hypoxia - decreased oxygen delivery to tissues;
- Hypercapnia - increased carbon dioxide levels in blood.

SELF ASSESSMENT EXERCISE 2

1 The upper respiratory tract consists of ---------------, -------------- and-----------------

2 -----------------------and-----------------------------are inspiratory muscles involved in normal inspiration.

4.0 CONCLUSION

We can conclude this study by emphasising that respiration is the exchange of gases (oxygen/carbon dioxide) from the atmosphere between blood and tissues. It is made up of many physical and chemical processes.

5.0 SUMMARY

This unit examines the organs of the respiratory tract, and the respiratory processes. Normal inspiration is an active process, while expiration is a passive process.

ANSWER TO SELF ASSESSMENT EXERCISE 1

1. Internal respiration consists of inhalation/inspiration and exhalation/expiration.
2. Respiration is the chemical breakdown of glucose, accelerated by enzymes inside the body cells to liberate energy. Carbon dioxide and water or alcohol are given off as waste products.

ANSWER TO SELF ASSESSMENT EXERCISE 2

1. The upper respiratory tract consists of: (a) Paranasal structures like external nares, nasal cavity and septum, nasal conchae, nasal meatuses, olfactory epithelium, paranasal sinuses and ciliated pseudostratified epithelium; (b) Pharynx: internal nares, auditory tubes, oropharynx and laryngopharynx
2. The diaphragm and external intercostals are muscles involved in normal inspiration.

6.0 TUTOR-MARKED ASSIGNMENT

Describe the internal and external respiration system.

7.0 REFERENCES/FURTHER READINGS

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UNIT 3 OVERVIEW OF DIGESTIVE SYSTEM

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
    3.1 Digestive System Organs
    3.2 General Function of digestive system
    3.3 The Walls of the Digestive Tract
    3.4 Nutrient Absorption
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 INTRODUCTION

The function of the digestive system is to break down the foods you eat, release their nutrients, and absorb those nutrients into the body. Although the small intestine is the workhorse of the system, where the majority of digestion occurs, and where most of the released nutrients are absorbed into the blood or lymph, each organ of the digestive system makes a vital contribution to this process (**Figure 35**).

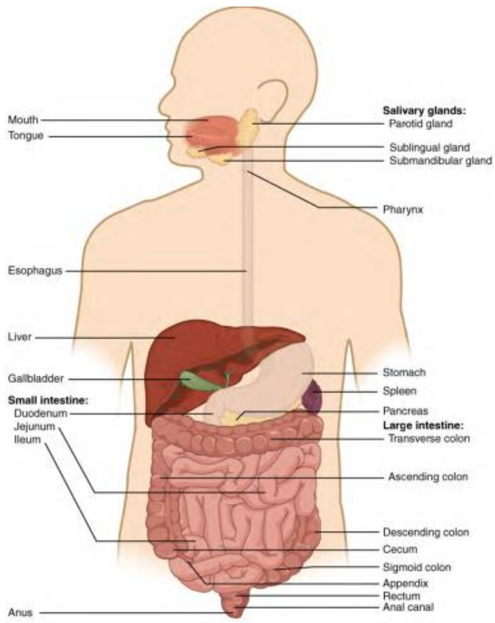

Figure 35: The digestive system

2.0 OBJECTIVES

By the end of this section, you will be able to:

- Describe the organs of the digestive system
- Discuss the general function of the digestive system
- Describe the walls of the digestive tract

3.0 MAIN CONTENT

3.1 Organs of the Digestive System

The easiest way to understand the digestive system is to divide its organs into two main categories. The first group is the organs that make up the alimentary canal. Accessory digestive organs comprise the second group and are critical for orchestrating the breakdown of food and the assimilation of its nutrients into the body. Accessory digestive organs, despite their name, are critical to the function of the digestive system.

Alimentary Canal Organs

Also called the gastrointestinal (GI) tract or gut, the **alimentary canal** (aliment- = "to nourish") is a one-way tube about 7.62 meters (25 feet) in length during life and closer to 10.67 meters (35 feet) in length when measured after death, the increase being due to loss of smooth muscle tone. The main function of the organs of the alimentary canal is to nourish the body. This tube begins at the mouth and terminates at the anus. Between those two points, the canal is modified as the pharynx, esophagus, stomach and large intestines to fit the functional needs of the body. Both the mouth and anus are open to the external environment; thus, food and wastes within the alimentary canal are technically considered to be outside the body. Only through the process of absorption do the nutrients in food enter into and nourish the body's "inner space."

Accessory Structures

Each **accessory digestive organ** aids in the breakdown of food. Within the mouth, the teeth and tongue begin mechanical digestion, whereas the salivary glands begin chemical digestion. Once food products enter the small intestine, the gallbladder, liver, and pancreas release secretions—such as bile and enzymes—essential for digestion to continue. Together, these are called accessory organs because they sprout from the lining cells of the developing gut (mucosa) and augment its function; indeed, you could not live without their vital contributions, and many significant diseases result from their malfunction. Even after development is complete, they maintain a connection to the gut by way of ducts.

3.2 General Function of digestive system

Every body cell needs a constant supply of nutrients to provide energy and building blocks for the manufacture of body substances. Food as we take it in, however, is too large to enter the cells. It must first be broken down into particles small enough to pass through the cell membrane. This process is known as **digestion**. After digestion, food must be carried to the cells in every part of the body by the circulation. The transfer of food into the circulation is called **absorption**. Digestion and absorption are the two chief functions of the digestive system.

3.3 The Walls of the Digestive Tract

The wall of the digestive tract, from the esophagus to the anus, is similar in structure throughout. First is the **mucous membrane**, so called because its epithelial layer contains many mucus-secreting cells. The type of epithelium is simple columnar. The layer of connective tissue beneath this, the **submucosa**, contains blood vessels and some of the nerves that help regulate digestive activity. Next are two layers of **smooth muscle**. The inner layer has circular fibers, and the outer layer has longitudinal fibers. The alternate contractions of these muscles create the wavelike movement that propels food through the digestive tract and mixes it with digestive juices. This movement is called **peristalsis**.

The outermost layer of the wall consists of fibrous connective tissue. Most of the abdominal organs have an additional layer of **serous membrane** that is part of the peritoneum.

The Peritoneum

The abdominal cavity is lined with a thin, shiny serous membrane that also covers most of the abdominal organs. The portion of this membrane that lines the abdomen is called the **parietal peritoneum**; that covering the organs is called the **visceral peritoneum**. In addition to these single layered portions of the peritoneum there are a number of double-layered structures that carry blood vessels, lymph vessels, and nerves, and sometimes act as ligaments supporting the organs. These are called mesentaries or, in some places, ligaments. The **mesentery** is a double-layered portion of the peritoneum shaped somewhat like a fan. The handle portion is attached to the back (posterior) wall of the abdomen, and the expanded long edge is attached to the small intestine. Between the two layers of membrane that form the mesentery are the blood vessels, lymphatic vessels, and nerves that supply the intestine. The section of the peritoneum that extends from the colon to the back wall is the mesocolon.

4.0 CONCLUSION

The digestive system is continually at work, yet people seldom appreciate the complex tasks it performs in a choreographed biologic symphony. Consider what happens when you eat an apple. Of course, you enjoy the apple's taste as you chew it, but in the hours that follow, unless something goes amiss and you get a stomachache, you don't notice that your digestive system is working. You may be taking a walk or studying or sleeping, having forgotten all about the apple, but your stomach and intestines are busy digesting it and absorbing its vitamins and other nutrients. By the time any waste material is excreted, the body has appropriated all it can use from the apple. In short, whether you pay attention or not, the organs of the digestive system perform their specific functions, allowing you to use the food you eat to keep you going.

5.0 SUMMARY

This unit discussed digestive system organs, the general function of digestive system and the walls of the digestive tract.

6.0 TUTOR-MARKED ASSIGNMENT

- Discuss the functions of digestive system
- Briefly describe peritoneum

7.0 REFERENCES/FURTHER READINGS

Martini, F.C; Ober, W.C; Garrison, C.W; Welch, K & Hutchings, R.T. (2001). Fundamentals of Anatomy and Physiology, (5th ed). New Jersey: Prentice-Hall, Inc.

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UNIT 4 THE STRUCTURE AND FUNCTION OF THE DIGESTIVE SYSTEM

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
    3.1 General Anatomy of the Digestive System
    3.2 Major Organs of Digestion and Absorption
    3.3 Roles of the Liver
    3.4 Nutrient Absorption
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 INTRODUCTION

The digestive system is a group of organs working together to convert food into energy and basic nutrients to feed the entire body. It is responsible for taking whole foods and turning them into energy and nutrients to allow the body to function, grow, and repair itself. Food passes through a long tube inside the body known as the alimentary canal or the gastrointestinal tract (GIT). The alimentary canal is made up of the oral cavity, pharynx, oesophagus, stomach, small intestines, and large intestines. In addition to the alimentary canal, there are several important accessory organs that help your body to digest food but do not have food pass through them. Accessory organs of the digestive system include the teeth, tongue, salivary glands, liver, gallbladder, and pancreas. In order to achieve the goal of providing energy and nutrients to the body, six primary functions take place in the digestive system. These are: ingestion of food, secretion of fluids and digestive enzymes, mixing and movement of food and wastes through the body, digestion of food into smaller pieces, absorption of nutrients and excretion of wastes. This chapter examines the structure and functions of these organs, and explores the mechanics of the digestive processes. This chapter examines the structure and functions of these organs, and explores the mechanics of the digestive processes.

2.0 OBJECTIVES

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

- describe the general anatomy of the digestive system
- describe the major organs of digestion and absorption
- explain the mechanism of digestion.

3.0 MAIN CONTENT

3.1 General Anatomy of the Digestive System

- The gastrointestinal tract, also known as the "alimentary canal" consists of all organs through which food passes (from the mouth to the anus)
- Accessory structures that assist in digestion include teeth, salivary glands, liver, gall bladder, and pancreas.

Four major layers of the gastrointestinal tract are:

1. Mucosa - innermost lining of the gastrointestinal tract
2. Submucosa - areolar connective tissue, blood vessels, autonomic nerves
3. Muscularis externa - circular and longitudinal smooth muscles
4. Serosa - outermost layer

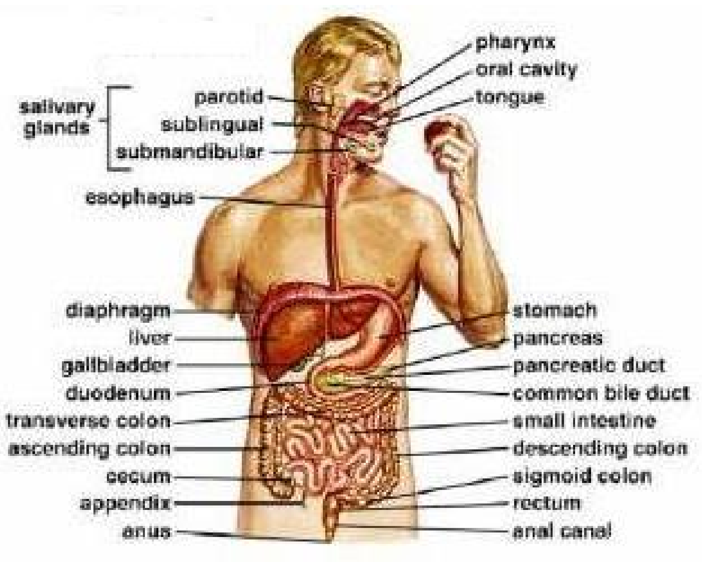

Fig. 36: The Human Digestive System

3.2 Major Organs of Digestion and Absorption in Man
The Stomach

1. General anatomic regions: Cardiac, fundus, body and pyloric region
2. The stomach is important in the process of physical digestion
3. Rugae are undulations in stomach wall to help grind
4. Gastric pits contain four major secretory cells:
   (a) Chief cells, which produce pepsinogen which is, in turn, activated by Hydrochloric acid into pepsin
   (b) Parietal cells which produces hydrochloric acid (HCl). The secretion is enhanced by histamine via H2 receptors,
   (c) G-cell which secretes gastrin hormone; gastrin activates gastric juice secretion and gastric smooth muscle “churning”. It also activates gastroileal reflex which moves chyme (liquefied digested material) from the ileum to colon,
   (d) Mucus cell which plays the protective role of mucus against acids and digestive enzymes.
5. Pyloric sphincter regulates entry of food into the duodenum.

The Small Intestine

This is the major site of chemical digestion and absorption. It has three major segments: duodenum, jejunum and the ileum. The histology is as follows:

(a) Mucosa has intestinal glands (cavities) for secretion of intestinal juice.
(b) Mucosa also has circular folds, villi and microvilli for increased surface area.

The Pancreas

The pancreas produces approximately 1.5 litres a day of pancreatic secretions, the secretions enter the duodenum via two pancreatic ducts and there are many different components in these secretions like $NaHCO_3$ (buffers pH of chyme), pancreatic amylase, trypsinogen, chymotrypsinogen and carboxypeptidase.

The Liver

The liver is the largest gland in the body. Its functions include:

- To “filter” and process nutrient-rich blood delivered to it.
- To receive nutrient-rich blood from the small intestine via the hepatic portal vein.
- To regulate carbohydrate metabolism.

The Large Intestine

The major function is to absorb water and eliminate indigestible matter. Major structures are:

(a) Caecum with vermiform appendix,
(b) Ascending, transverse, descending colon,
(c) Sigmoid colon, rectum,
(d) The haustra which are pouches in the wall of the large intestine.

Table 6: Functions of the Digestive Organs

Organ	Major functions	Other functions
Mouth	Ingests food Chews and mixes food Begins chemical breakdown of carbohydrates Moves food into the pharynx Begins breakdown of lipids via lingual lipase	Moistens and dissolves food, allowing you to taste it Cleans and lubricates the teeth and oral cavity Has some antimicrobial activity
Pharynx	Propels food from the oral cavity to the esophagus	Lubricates food and passageways
Esophagus	Propels food to the stomach	Lubricates food and passageways
Stomach	Mixes and churns food with gastric juices to form chyme Begins chemical breakdown of proteins Releases food into the duodenum as chyme Absorbs some fat-soluble substances (for example, alcohol, aspirin) Possesses antimicrobial functions	Stimulates protein-digesting enzymes Secretes intrinsic factor required for vitamin B12 absorption in small intestine
Small intestine	Mixes chyme with digestive juices	Provides optimal medium for enzymatic activity

	Propels food at a rate slow enough for digestion and absorption Absorbs breakdown products of carbohydrates, proteins, lipids, and nucleic acids, along with vitamins, minerals, and water Performs physical digestion via segmentation	
Accessory organs	Liver: produces bile salts, which emulsify lipids, aiding their digestion and absorption Gallbladder: stores, concentrates, and releases bile Pancreas: produces digestive enzymes and bicarbonate	Bicarbonate-rich pancreatic juices help neutralize acidic chyme and provide optimal environment for enzymatic activity
Large intestine	Further breaks down food residues Absorbs most residual water, electrolytes, and vitamins produced by enteric bacteria Propels feces toward rectum Eliminates feces	Food residue is concentrated and temporarily stored prior to defecation Mucus eases passage of feces through colon

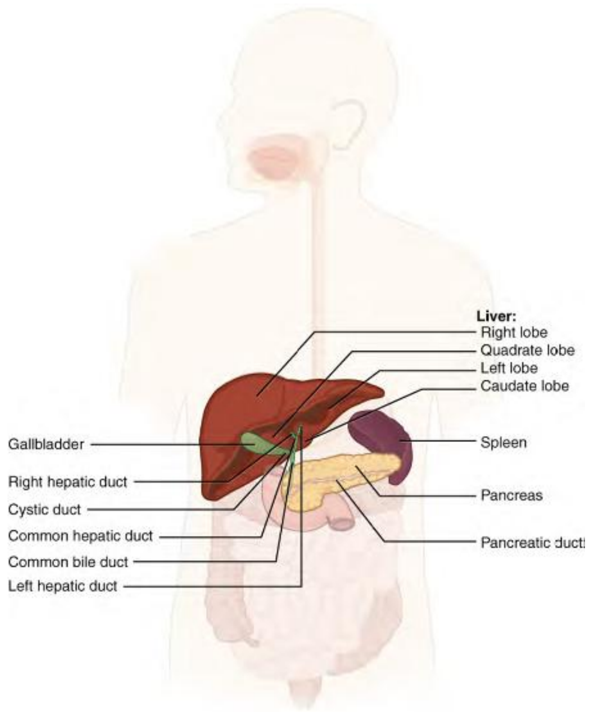

Figure 37: Accessory Organs The liver, pancreas, and gallbladder are considered accessory digestive organs, but their roles in the digestive system are vital. (This content is available for free at http://cnx.org/content/col11496/1.6)

SELF ASSESSMENT EXERCISE 1

1. ------------------, ------------------- and ---------------------- are accessory structures in human digestion.
2. ------------------ regulates entry of food into the duodenum. Fig. 22: The wall of the human digestive tract

3.3 The Process of Digestion

Digestion of food starts in the mouth. Saliva is secreted by the salivary gland. It contains an enzyme called ptyalin. Ptyalin acts on cooked starch, converting it into complex sugars. It also helps to increase the surface area of the food substance.

Food passes down from the mouth through the gullet (oesophagus) into the stomach. In the stomach, food is further broken down into smaller pieces by the action of enzymes mentioned above. Food is retained in the stomach for 3-4 hours.

Food passes down from the stomach to the small intestine where actual digestion, absorption and assimilation takes place by the action of some enzymes. From the small intestine, undigested food passes into the large intestine. Here water is absorbed. This concentrates the waste products and makes it semi-solid. In this state the waste products are called faeces. The faeces pass into the rectum and out of the body through the anus.

3.4 Nutrient Absorption

Carbohydrates are enzymatically digested to form monosaccharides (glucose, fructose, and galactose). They are absorbed in the small intestine by active transport or facilitated diffusion and enter the blood capillary in villi, then directed to the hepatic portal vein. Proteins are enzymatically digested to amino acids or di- and tripeptides, absorbed in the small intestine by active transport or facilitated diffusion, enter blood capillaries in villi, then directed to the hepatic portal vein. Lipids are enzymatically digested to short or long chain fatty acids; they are suspended in the small intestine in the form of micelles with bile salts, while inside the epithelial cells, lipids bind into chylomicrons for transport to lacteal villi; then into lymphatics, and then to venous circulation.

Table 7: Contribution of Other Body Systems to the Digestive System

Body system	**Benefits received by the digestive system**
Cardiovascular	Blood supplies digestive organs with oxygen and processed nutrients
Endocrine	Endocrine hormones help regulate secretion in digestive glands and accessory organs
Integumentary	Skin helps protect digestive organs and synthesizes vitamin D for calcium absorption
Lymphatic	Mucosa-associated lymphoid tissue and other lymphatic tissue defend against entry of pathogens; lacteals absorb lipids; and lymphatic vessels transport lipids to bloodstream
Muscular	Skeletal muscles support and protect abdominal organs
Nervous	Sensory and motor neurons help regulate secretions and muscle contractions in the digestive tract
Respiratory	Respiratory organs provide oxygen and remove carbon dioxide
Skeletal	Bones help protect and support digestive organs
Urinary	Kidneys convert vitamin D into its active form, allowing calcium absorption in the small intestine

SELF ASSESSMENT EXERCISE 2

1. Describe the role of the saliva in digestion.
2. Describe the absorption of lipids.

4.0 CONCLUSION

The digestive organs, tissues and enzymes are involved in the breaking down of ingested food in the alimentary canal into a form that can be absorbed and assimilated by the tissues of the body. Malfunctioning of any one of them will grossly affect the well-being of an individual. The digestive system includes the organs of the alimentary canal and accessory structures. The alimentary canal forms a continuous tube that is open to the outside environment at both ends. The organs of the alimentary canal are the mouth, pharynx, esophagus, stomach, small intestine, and large intestine. The accessory digestive structures include the teeth, tongue, salivary glands, liver, pancreas, and gallbladder. The wall of the alimentary canal is composed of four basic tissue layers: mucosa, submucosa, muscularis, and serosa. The enteric nervous system provides intrinsic innervation, and the autonomic nervous system provides extrinsic innervation.

5.0 SUMMARY

This unit has looked at the definition of digestion, the organs involved in digestion and the enzymes that are involved in the digestion and absorption of nutrients.

ANSWER TO SELF ASSESSMENT EXERCISE 1

1) Teeth, salivary glands, liver, gall bladder, and pancreas are the major accessory organs of digestion.
2) Pyloric sphincter regulates entry of food into the duodenum.

ANSWER TO SELF ASSESSMENT EXERCISE 2

Description of the absorption of lipids: It is enzymatically digested to short or long chain fatty acids. It is suspended in Small Intestine in the form of micelles with bile salts, while inside epithelial cells; lipids bind into chylomicrons for transport to *lacteal villi*; then into *lymphatics,* and then to venous circulation.

6.0 TUTOR-MARKED ASSIGNMENT

With a well labelled diagram, describe the stomach.

7.0 REFERENCES/FURTHER READINGS

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UNIT 5 PELVIC ORGANS

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1.0 INTRODUCTION

The **pelvic cavity** is a body cavity that is bounded by the bones of the pelvis. Its oblique roof is the pelvic inlet (the superior opening of the pelvis). Its lower boundary is the pelvic floor. The pelvic cavity primarily contains reproductive organs, the urinary bladder, the pelvic colon, and the rectum. The rectum is placed at the back of the pelvis, in the curve of the sacrum and coccyx; the bladder is in front, behind the pubic symphysis. In the female, the uterus and vagina occupy the interval between these viscera. The pelvic cavity also contains major arteries, veins, muscles, and nerves. These structures coexist in a crowded space, and disorders of one pelvic component may impact upon another; for example, constipation may overload the rectum and compress the urinary bladder, or childbirth might damage the pudendal nerves and later lead to anal weakness.

2.0 OBJECTIVES

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

- Understand pelvic anatomy
- Describe Organs and structures of the female pelvis organs
- Describe Organs and structures of the male pelvis organs
- Describe functional anatomy and relevant pathophysiology
- Describe Fertilization and Sex determination

3.0 MAIN CONTENT

3.1 Anatomy of Female Reproductive Organ

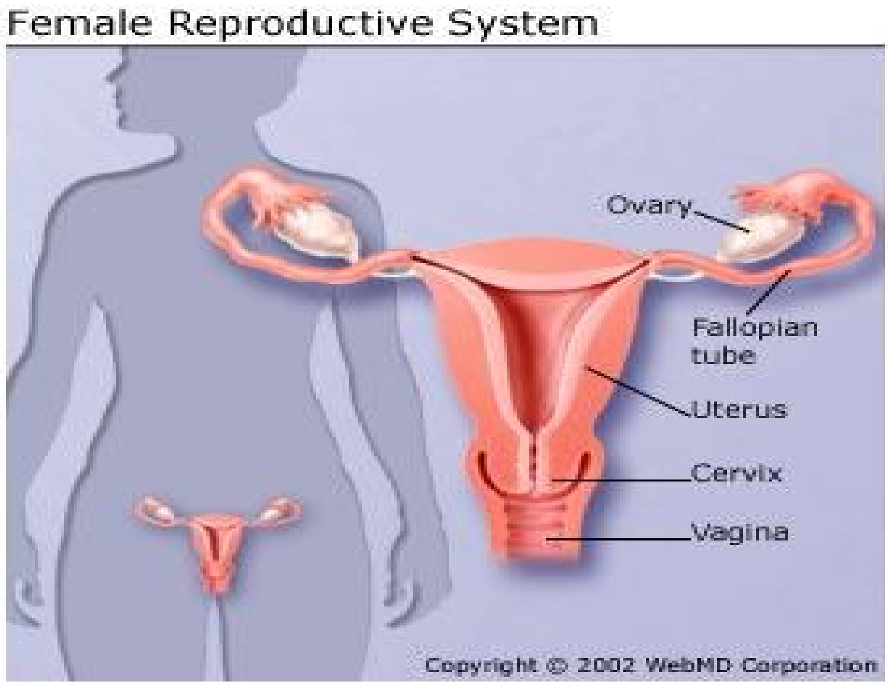

Figure 38: The female reproductive system (Internal Structures)

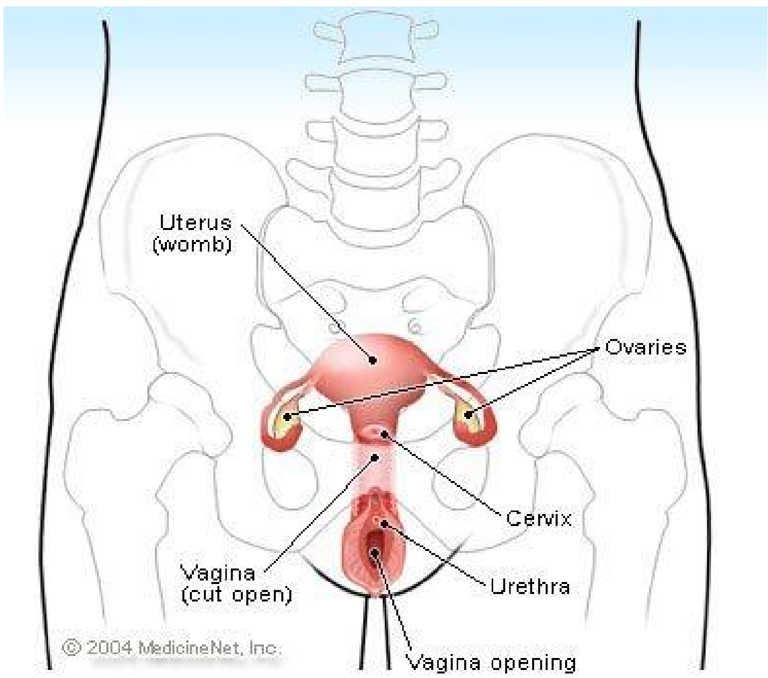

Figure 39: The female reproductive system (Gross Anatomy)

3.1.1 External Genitalia

The vulva, also known as the pudendum, is a term used to describe those external organs that may be visible in the perineal area. The vulva consists of the following organs: mons pubis, labia minora and majora, hymen, clitoris, vestibule, urethra, Skene glands, greater vestibular (Bartholin) glands, and vestibular bulbs. The boundaries include the mons pubis anteriorly, the rectum posteriorly, and the genitocrural folds (thigh folds) laterally.

Mons pubis

The mons pubis is the rounded portion of the vulva where sexual hair development occurs at the time of puberty. This area may be described as directly anterosuperior to the pubic symphysis.

Labia

The labia majora are 2 large, longitudinal folds of adipose and fibrous tissue. They vary in size and distribution from female to female, and the size is dependent upon adipose content. They extend from the mons anteriorly to the perineal body posteriorly. The labia majora have hair follicles.

The labia minora, also known as nymphae, are 2 small cutaneous folds that are found between the labia majora and the introitus or vaginal vestibule. Anteriorly, the labia minora join to form the frenulum of the clitoris.

Hymen

The hymen is a thin membrane found at the entrance to the vaginal orifice. Often, this membrane is perforated before the onset of menstruation, allowing flow of menses. The hymen varies greatly in shape.

Clitoris

The clitoris is an erectile structure found beneath the anterior joining of the labia minora. Its width in an adult female is approximately 1 cm, with an average length of 1.5-2.0 cm. The clitoris is made up of 2 crura, which attach to the periosteum of the ischiopubic rami. It is a very sensitive structure, analogous to the male penis. It is innervated by the dorsal nerve of the clitoris, a terminal branch of the pudendal nerve.

Vestibule and urethra

Between the clitoris and the vaginal introitus (opening) is a triangular area known as the vestibule, which extends to the posterior fourchette. The vestibule is where the urethral (urinary) meatus is found, approximately 1 cm anterior to the vaginal orifice, and it also gives rise to the opening of the Skene glands bilaterally. The urethra is composed of membranous connective tissue and links the urinary bladder to the vestibule externally. A female urethra ranges in length from 3.5 to 5.0 cm.

Skene and Bartholin glands

The Skene glands secrete lubrication at the opening of the urethra. The greater vestibular (Bartholin) glands are also responsible for secreting lubrication to the vagina, with openings just outside the hymen, bilaterally, at the posterior aspect of the vagina. Each gland is small, similar in shape to a kidney's bean shape.

Vestibular bulbs

Finally, the vestibular bulbs are 2 masses of erectile tissue that lie deep to the bulbocavernosus muscles bilaterally.

3.1.1 Internal Genitalia

Vagina

The vagina extends from the vulva externally to the uterine cervix internally. It is located within the pelvis, anterior to the rectum and posterior to the urinary bladder. The vagina lies at a 90º angle in relation to the uterus. The vagina is held in place by endopelvic fascia and ligaments. The vagina is lined by rugae, which are situated in folds throughout. These allow easy distention, especially during child bearing. The structure of the vagina is a network of connective, membranous, and erectile tissues.

The pelvic diaphragm, the sphincter urethrae and transverse perineal muscles, and the perineal membrane support the vagina. The sphincter urethrae and the transverse perineal muscle are innervated by perineal branches of the pudendal nerve. The pelvic diaphragm primarily refers to the levator ani and the coccygeus and is innervated by branches of sacral nerves S2-S4.

The vascular supply to the vagina is primarily from the vaginal artery, a branch of the anterior division of the internal iliac artery. Several of these arteries may be found on either side of the pelvis to richly supply the vagina.

The nerve supply to the vagina is primarily from the autonomic nervous system. Sensory fibers to the lower vagina arise from the pudendal nerve, and pain fibers are from sacral nerve roots. Lymphatic drainage of the vagina is generally to the external iliac nodes (upper third of the vagina), the common and internal iliac nodes (middle third), and the superficial inguinal nodes (lower third).

Uterus

The uterus is the inverted pear-shaped female reproductive organ that lies in the midline of the body, within the pelvis between the bladder and the rectum. It is thick-walled and muscular, with a lining that, during reproductive years, changes in response to hormone stimulation throughout a woman monthly cycle. The uterus can be divided into 2 parts: the most inferior aspect is the cervix, and the bulk of the organ is called the body of the uterus (corpus uteri). Between these 2 is the isthmus, a short area of constriction.

The body of the uterus is globe-shaped and is typically situated in an anteverted position, at a 90^o angle to the vagina. The upper aspect of the body is dome-shaped and is called the fundus; it is typically the most muscular part of the uterus. The body of the uterus is responsible for holding a pregnancy, and strong uterine wall contractions help to expel the fetus during labor and delivery.

The average weight of a non-pregnant, nulliparous uterus is approximately 40-50 g. A multiparous uterus may weigh slightly more than this, with an upper limit of approximately 110 g. A menopausal uterus is small and atrophied and typically weighs much less. The cavity of the uterus is flattened and triangular. The uterine tubes enter the uterine cavity bilaterally in the superolateral portion of the cavity.

The uterus is connected to its surrounding structures by a series of ligaments and connective tissue. The pelvic peritoneum is attached to the body and the cervix as the broad ligament, reflecting onto the bladder. The broad ligament attaches the uterus to the lateral pelvic side walls. Within the broad base of the broad ligament, between its anterior and posterior laminae, connective tissue strands associated with the uterine and vaginal vessels help to support the uterus and vagina. Together, these strands are referred to as the cardinal ligament.

Rectouterine ligaments, lying within peritoneal folds, stretch posteriorly from the cervix to reach the sacrum. The round ligaments of the uterus are much denser structures and connect the uterus to the anterolateral abdominal wall at the deep inguinal ring. They lie within the anterior lamina of the broad ligament. Within the round ligament is the artery of Sampson, a small artery that must be ligated during hysterectomy.

The vasculature of the uterus is derived from the uterine arteries and veins. The uterine vessels arise from the anterior division of the internal iliac, and branches of the uterine artery anastomose with the ovarian artery along the uterine tube.

The nerve supply and lymphatic drainage of the uterus are complex. Lymphatic drainage is primarily to the lateral aortic, pelvic, and iliac nodes that surround the iliac vessels. The nerve supply is attained through the sympathetic nervous system (by way of the hypogastric and ovarian plexuses) and the parasympathetic nervous system (by way of the pelvic splanchnic nerves from the second through fourth sacral nerves).

Cervix

The cervix is the inferior portion of the uterus, separating the body of the uterus from the vagina. The cervix is cylindrical in shape, with an endocervical canal located in the midline, allowing passage of semen into the uterus. The external opening into the vagina is termed the external os, and the internal opening into the endometrial cavity is termed the internal os. The internal os is the portion of a female cervix that dilates to allow delivery of the fetus during labor. The average length of the cervix is 3-5 cm.

The vasculature is supplied by descending branches of the uterine artery, which run bilaterally at the 3 o'clock and 9 o'clock position of the cervix. The nerve supply to the cervix is via the parasympathetic nervous system by way of the second through fourth sacral segments. Many pain nerve fibers run alongside these parasympathetics. Lymphatic drainage of the cervix is complex. The obturator, common iliac, internal iliac, external iliac, and visceral parametrial nodes are the main drainage points.

Uterine tubes

The uterine tubes (also referred to as oviducts or fallopian tubes) are uterine appendages located bilaterally at the superior portion of the cavity. Their primary function is to transport sperm toward the egg (ovum or oocyte), which is released by the ovary, and then to allow passage of the fertilized ovum back to the uterus for implantation.

The uterine tubes exit the uterus through an area known as the cornua and form a connection between the endometrial and peritoneal cavities. Each tube is approximately 10 cm in length and 1 cm in diameter and is situated within a portion of the broad ligament called the mesosalpinx. The distal portion of the uterine tube ends in an orientation encircling the ovary.

The uterine tube has 3 parts. The first segment, closest to the uterus, is called the isthmus. The second segment is the ampulla, which becomes more dilated in diameter and is the typical place of fertilization. The final segment, furthest from the uterus, is the infundibulum. The infundibulum gives rise to the fimbriae, finger-like projections that are responsible for catching the ovum that is released by the ovary.

The arterial supply to the uterine tubes is from branches of the uterine and ovarian arteries, small vessels that are located within the mesosalpinx. The nerve supply to the uterine tubes is via both sympathetic and parasympathetic fibers. Sensory fibers run from thoracic segments 11-12 and lumbar segment 1. Lymphatic drainage of the uterine tubes is through the iliac and aortic nodes.

Ovaries

The ovaries are paired organs located on either side of the uterus within the mesovarium portion of the broad ligament below the uterine tubes. The ovaries are responsible for producing, housing and releasing the ova, which are necessary for reproduction. At birth, a female has approximately 1-2 million ova, but only 300 of these ever mature and are released for the purpose of fertilization.

The ovaries are small and oval-shaped, exhibit a grayish color, and have an uneven surface. The actual size of an ovary depends on a woman’s age and hormonal status; the ovaries are approximately 3-5 cm in length during childbearing years and become much smaller and atrophic once menopause occurs. A cross-section of the ovary reveals many cystic structures that vary in size. These structures represent ovarian follicles at different stages of development and degeneration.

Pathophysiology of Female Reproductive System

Disorders of the female reproductive system can occur as a result of disease in one of the many varied reproductive organs: the ovaries, the fallopian tubes, the uterus, the cervix, the vagina, or the breast. During the reproductive years, these disorders often present as **altered menstruation, pelvic pain,** or **infertility.** Cancers arising in these tissues occur more often in the late reproductive or menopausal years. Unfortunately, for several reasons, they often have high mortality rates and a high incidence of metastases when they are diagnosed. Some organs are located deep and are relatively inaccessible to palpation (ovaries). Others have few sensory nerves (ovary, fallopian tubes) and hence remain asymptomatic. Additionally, the breasts have large amounts of adipose tissue, which can make early detection of breast cancer difficult. The one exception is the uterine cervix. It has easy access to surveillance with use of the Papanicolaou smear and human papillomavirus (HPV) screening, which have led to a dramatically reduced mortality rate of cervical cancer.

3.2 MALE REPRODUCTIVE ORGAN ANATOMY

3.2.1 External male genital organs Scrotum

The scrotum is a sac-like organ made of skin and muscles that houses the testes. It is located inferior to the penis in the pubic region. The scrotum is made up of 2 side-by-side pouches with a testis located in each pouch. The smooth muscles that make up the scrotum allow it to regulate the distance between the testes and the rest of the body. When the testes become too warm to support spermatogenesis, the scrotum relaxes to move the testes away from the body's heat. Conversely, the scrotum contracts to move the testes closer to the body's core heat when temperatures drop below the ideal range for spermatogenesis.

Penis

The penis is the male external sexual organ located superior to the scrotum and inferior to the umbilicus. The penis is roughly cylindrical in shape and contains the urethra and the external opening of the urethra. Large pockets of erectile tissue in the penis allow it to fill with blood and become erect. The erection of the penis causes it to increase in size and become turgid. The function of the penis is to deliver semen into the vagina during sexual intercourse. In addition to its reproductive function, the penis also allows for the excretion of urine through the urethra to the exterior of the body.

3.2.2 Internal genital organs

Testes

The 2 testes, also known as testicles, are the male gonads responsible for the production of sperm and testosterone. The testes are ellipsoid glandular organs around 3.5 to 5 cm long and 2.5 cm in diameter. Each testis is found inside its own pouch on one side of the scrotum and is connected to the abdomen by a spermatic cord and cremaster muscle. The cremaster muscles contract and relax along with the scrotum to regulate the temperature of the testes. The inside of the testes is divided into small compartments known as lobules. Each lobule contains a section of seminiferous tubule lined with epithelial cells. These epithelial cells contain many stem cells that divide and form sperm cells through the process of spermatogenesis.

Epididymis

The **epididymis** is a sperm storage area that wraps around the superior and posterior part of the testes. The epididymis is made up of several centimeters of long, thin tubules that are tightly coiled into a small mass. Sperm produced in the testes moves into the epididymis to mature before being passed on through the **male reproductive organs**. The length of the epididymis delays the release of the sperm and allows them time to mature.

Spermatic Cords and Ductus Deferens

Within the scrotum, a pair of spermatic cords connects the testes to the abdominal cavity. The spermatic cords contain the ductus deferens along with nerves, veins, arteries, and lymphatic vessels that support the function of the testes.

The **ductus deferens**, also known as the vas deferens, is a muscular tube that carries sperm superiorly from the epididymis into the abdominal cavity to the ejaculatory duct. The ductus deferens is wider in diameter than the epididymis and uses its internal space to store mature sperm. The smooth muscles of the walls of the ductus deferens are used to move sperm towards the ejaculatory duct through peristalsis.

Seminal Vesicles

The seminal vesicles are a pair of lumpy exocrine glands that store and produce some of the liquid portion of semen. The seminal vesicles are about 5 cm in length and located posterior to the urinary bladder and anterior to the rectum. The liquid produced by the seminal vesicles contains proteins and mucus and has an alkaline pH to help sperm survive in the acidic environment of the vagina. The liquid also contains fructose to feed sperm cells so that they survive long enough to fertilize the oocyte.

Ejaculatory Duct

The ductus deferens, while passing through the pelvis, is joined by the duct of the seminal vesicle to form the ejaculatory duct. This duct passes into the prostate gland to join the urethra. During ejaculation, the ejaculatory duct opens and expels sperm (from the testis) and the seminal fluid or secretions (from the seminal vesicles) into the urethra.

Urethra

Semen passes from the ejaculatory duct to the exterior of the body via the urethra, a 20 to 25 cm long muscular tube. The urethra passes through the prostate and ends at the external urethral orifice located at the tip of the penis. Urine exiting the body from the urinary bladder also passes through the urethra.

Prostate

The prostate is a walnut-sized exocrine gland that borders the inferior end of The urinary bladder and surrounds the urethra. The prostate produces a large portion of the fluid that makes up semen. This fluid is milky white in colour and contains enzymes, proteins, and other chemicals to support and protect sperm during and after ejaculation. The prostate also contains smooth muscle tissue that can constrict to prevent the flow of urine or semen.

Cowper's Glands

The Cowper's glands, also known as the bulbourethral glands, are a pair of pea-sized exocrine glands located inferior to the prostate and anterior to the anus. The Cowper's glands secrete a thin alkaline fluid into the urethra that lubricates the urethra and neutralizes acid from urine remaining in the urethra after urination. This fluid enters the urethra during sexual arousal prior to ejaculation to prepare the urethra for the flow of semen.

Semen

Semen is the fluid produced by males for sexual reproduction and is ejaculated out of the body during sexual intercourse. Semen contains sperm, the male reproductive gametes, along with a number of chemicals suspended in a liquid medium. The chemical composition of semen gives it a thick, sticky consistency and a slightly alkaline pH. These traits help semen to support reproduction by helping sperm to remain within the vagina after intercourse and to neutralize the acidic environment of the vagina. In healthy adult males, semen contains around 100 million sperm cells per millilitre. These sperm cells fertilize oocytes inside the female fallopian tubes.

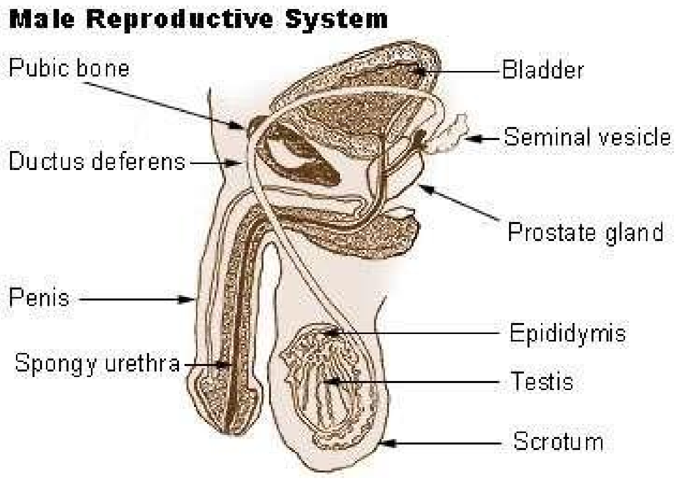

Figure 40: Male Reproductive system

3.3 Fertilization and Sex determination

3.3.1 Fertilization

Fertilization is the process by which a sperm combines with an oocyte, or egg cell, to produce a fertilized oocyte called a zygote. The sperm released during ejaculation must first swim through the vagina and uterus and into the fallopian tubes where they may find an oocyte. After encountering the oocyte, a sperm will have to penetrate the outer corona radiata and zona pellucida layers of the oocyte. Sperm contain enzymes in the acrosome region of the head that allow them to penetrate these layers. After penetrating the interior of the oocyte, the nuclei of these haploid cells fuse to form a diploid cell known as a zygote. The zygote cell begins cell division to form an embryo.

3.3.2 Sex determination

Sexual identity is determined at fertilization when the genetic sex of the zygote has been initialized by a sperm cell containing either an X or Y chromosome. If this sperm cell contains an X chromosome it will align with the X chromosome of the ovum and a female child will develop. A sperm cell carrying a Y chromosome results in an XY combination, and a male child will develop. Genetic sex determines whether the gonads will be testes or ovaries. In the developing embryo, if the testes are developed, it will produce and secrete male sex hormones during late embryonic development and cause the secondary sex organs of the male to develop.

4.0 CONCLUSION

The female reproductive system is a complicated but fascinating subject. It has the capability to function intimately with nearly every other body system for the purpose of reproduction. The female reproductive organs can be subdivided into the internal and external genitalia (see the images below). The internal genitalia are those organs that are within the true pelvis. These include the vagina, uterus, cervix, uterine tubes (oviducts or fallopian tubes), and ovaries. The external genitalia lie outside the true pelvis. These include the perineum, mons pubis, clitoris, urethral (urinary) meatus, labia majora and minora, vestibule, greater vestibular (Bartholin) glands, Skene glands, and periurethral area. The male reproductive system includes the scrotum, testes, spermatic ducts (epidiymis, ductus deferens, ejaculatory duct, urethra), sex glands, and penis. These organs work together to produce sperm, the male gamete, and the other components of semen and deliver semen out of the body and into the vagina where it can fertilize oocytes and produce offsprings.

Pathophysiology of Male Reproductive System

A man's reproductive system has many functions, including ensuring his fertility and providing sex hormones that support his sexual well-being. Although problems that arise in the system are often treatable, several disorders can have potentially serious consequences. The disorders of the male reproductive system include infection caused usually by bacteria (e.g. gonorrhoea which is a sexually transmitted disease) and virus including mumps, benign enlargement of the prostate, cancer, infertility and penile problems.

5.0 SUMMARY

In this unit, we have described the organs and structures of the male and female pelvis, the functional anatomy and relevant pathophysiology along with fertilization and sex determination.

6.0 TUTOR-MARKED ASSIGNMENT

- Discuss five Female internal reproductive organs
- What is fertilization?
- Briefly discuss sex determination
- Discuss two male external organs

7.0 REFERENCES/FURTHER READINGS

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MODULE 5 THE CIRCULATORY AND URINARY SYSTEM

Unit 1 Overview of the circulatory system
Unit 2 The heart, blood formation and blood vessels
Unit 3 Introduction to urinary system
Unit 4 The structure of the kidney
Unit 5 The organs responsible for urine formation, storage and elimination

UNIT 1 OVERVIEW OF THE CIRCULATORY SYSTEM

CONTENTS

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    3.2 Components of Blood
    3.3 Blood Groups and Blood Types
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 INTRODUCTION

Blood contributes to homeostasis by transporting oxygen, carbon dioxide, nutrients, and hormones to and from your body's cells. It helps regulate body pH and temperature, and provides protection against disease through phagocytosis and the production of antibodies. The cardiovascular system (*cardio* - heart; *vascular* - blood vessels) consists of three interrelated components: blood, the heart, and blood vessels. The focus of this chapter is blood; the next two chapters will examine the heart and blood vessels, respectively. Blood transports various substances, helps regulate several life processes, and affords protection against disease. For all of its similarities in origin, composition, and functions, blood is as unique from one person to another as are skin, bone, and hair. Health-care professionals routinely examine and analyze its differences through various blood tests when trying to determine the cause of different diseases.

In this unit, we will discuss how the composition of the interstitial fluid in tissues throughout the body is kept stable through continuous exchange between the peripheral tissues and the bloodstream. Blood can help to maintain homeostasis only if it stays in motion. Thus all the functions of the cardiovascular system ultimately depend on the heart which beats approximately 100,000 times each day, pumping roughly 8,000 litres of blood.

2.0 OBJECTIVES

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

- Describe the functions of blood.
- Describe the physical characteristics and principal components of blood.
- Structure and Function of Blood Vessels
- Discuss the Components of Blood
- Discuss Blood Groups and Blood Types

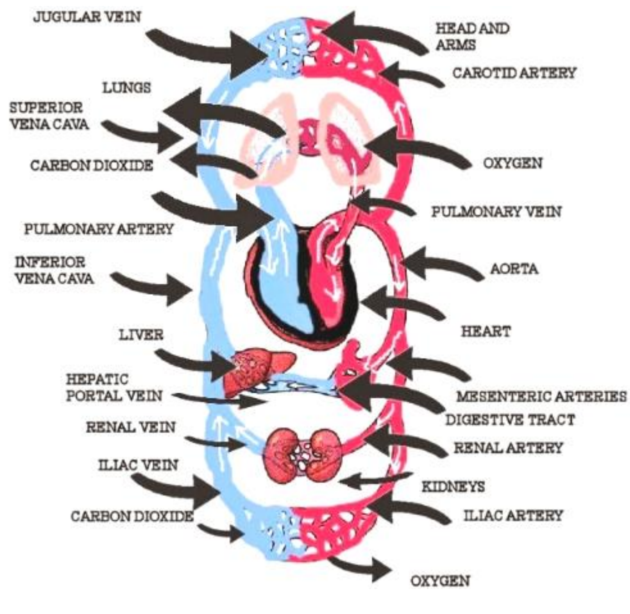

Figure 41: The circulatory system

3.0 MAIN CONTENT

3.1 Structure and Function of Blood Vessels

Blood is carried through the body via blood vessels. An artery is a blood vessel that carries blood away from the heart, where it branches into ever-smaller vessels. Eventually, the smallest arteries called arterioles, further branch into tiny capillaries, at which level nutrients and wastes are exchanged. Similar vessels called venules exit the capillary bed in continuity with the capillaries and carry blood to veins, which are larger blood vessel that return blood to the heart.

Arteries and veins transport blood in two distinct circuits: the systemic circuit and the pulmonary circuit. Systemic arteries provide blood rich in oxygen to the body's tissues. The blood returned to the heart through systemic veins has less oxygen, since much of the oxygen carried by the arteries has been delivered to the cells. In contrast, in the pulmonary circuit, arteries carry blood low in oxygen exclusively to the lungs for gas exchange. Pulmonary veins then return freshly oxygenated blood from the lungs to the heart to be pumped back into the systemic circulation. Although arteries and veins differ structurally and functionally, they share certain features.

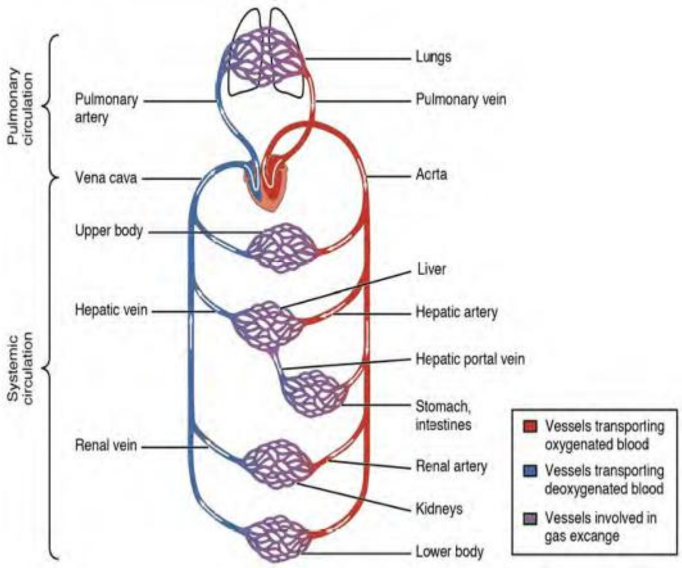

Figure 42: Cardiovascular Circulation

The pulmonary circuit moves blood from the right side of the heart to the lungs and back to the heart. The systemic circuit moves blood from the left side of the heart to the head and body and returns it to the right side of the heart to repeat the cycle. The arrows indicate the direction of blood flow, and the colors show the relative levels of oxygen concentration. Different types of blood vessels vary slightly in their structures, but they share the same general features. Arteries and arterioles have thicker walls than veins and venules because they are closer to the heart and receive blood that is surging at a far greater pressure. Each type of vessel has a **lumen -** a hollow passageway **-** through which blood flows. Arteries have smaller lumens than veins, a characteristic that helps to maintain the pressure of blood moving through the system. Together, their thicker walls and smaller diameters give arterial lumens a more rounded appearance in cross section than the lumens of veins.

3.1.1 Circulatory Loops

There are 2 primary circulatory loops in the human body: the *pulmonary circulation loop* and the *systemic circulation loop*.

1. Pulmonary circulation transports deoxygenated blood from the right side of the heart to the lungs, where the blood picks up oxygen and returns it to the left side of the heart. The pumping chambers of the heart that support the pulmonary circulation loop are the right atrium and right ventricle.
2. Systemic circulation carries highly oxygenated blood from the left side of the heart to all of the tissues of the body. Systemic circulation removes wastes from body tissues and returns deoxygenated blood to the right side of the heart. The left atrium and left ventricle of the heart are the pumping chambers for the systemic circulation loop.
3. **Blood Vessels:** These are the body's highways that allow blood to flow quickly and efficiently from the heart to every region of the body and back again. The size of blood vessels corresponds with the amount of blood that passes through the vessel. All blood vessels contain a hollow area called the lumen through which blood is able to flow. Around the lumen is the wall of the vessel, which may be thin in the case of capillaries or very thick in the case of arteries.
4. All blood vessels are lined with a thin layer of simple squamous epithelium known as the endothelium that keeps blood cells inside of the blood vessels and prevents clots from forming. The endothelium lines the entire circulatory system, all the way to the interior of the heart, where it is called the endocardium.
5. There are three major types of blood vessels: arteries, capillaries and veins. Blood vessels are often named after either the region of the body through which they carry blood or the nearby structures. For example, the brachiocephalic artery carries blood into the brachial (arm) and cephalic (head) regions. One of its branches, the subclavian artery, runs under the clavicle; hence the name subclavian. The subclavian artery runs into the axillary region where it becomes known as the axillary artery.
6. Arteries and Arterioles: Arteries are blood vessels that carry blood away from the heart. Blood carried by arteries is usually highly oxygenated, having just left the lungs on its way to the body's tissues. The pulmonary trunk and arteries of the pulmonary circulation loop provide an exception to this rule – these arteries carry deoxygenated blood from the heart to the lungs to be oxygenated.

Arteries face high levels of blood pressure as they carry blood being pushed from the heart under great force. To withstand this pressure, the walls of the arteries are thicker, more elastic, and more muscular than those of other vessels. The largest arteries of the body contain a high percentage of elastic tissue that allows them to stretch and accommodate the pressure of the heart.

Smaller arteries are more muscular in the structure of their walls. The smooth muscles of the arterial walls of these smaller arteries contract or expand to regulate the flow of blood through their lumen. In this way, the body controls how much blood flows to different parts of the body under varying circumstances. The regulation of blood flow also affects blood pressure, as smaller arteries give blood less area to flow through and therefore increase the pressure of the blood on arterial walls. Arterioles are narrower arteries that branch off from the ends of arteries and carry blood to capillaries. They face much lower blood pressures than arteries due to their greater number, decreased blood volume, and distance from the direct pressure of the heart. Thus arteriolar walls are much thinner than those of arteries. Arterioles, like arteries, are able to use smooth muscle to control their aperture and regulate blood flow and blood pressure.

7. *Capillaries*: Capillaries are the smallest and thinnest of the blood vessels in the body and also the most common. They can be found running throughout almost every tissue of the body and border the edges of the body's avascular tissues. Capillaries connect to arterioles on one end and venules on the other.

   Capillaries carry blood very close to the cells of the tissues of the body in order to exchange gases, nutrients, and waste products. The walls of capillaries consist of only a thin layer of endothelium so that there is minimum amount of structure possible between the blood and the tissues. The endothelium acts as a filter to keep blood cells inside of the vessels while allowing liquids, dissolved gases, and other chemicals to diffuse along their concentration gradients into or out of tissues.

   Precapillary sphincters are bands of smooth muscle found at the arteriole ends of capillaries. These sphincters regulate blood flow into the capillaries. Since there is a limited supply of blood, and not all tissues have the same energy and oxygen requirements, the precapillary sphincters reduce blood flow to inactive tissues and allow free flow into active tissues.

8. *Veins and Venules*: Veins are the large return vessels of the body and act as the blood return counterparts of arteries. Because the arteries, arterioles, and capillaries absorb most of the force of the heart's contractions, veins and venules are subjected to very low blood pressures. This lack of pressure allows the walls of veins to be much thinner, less elastic, and less muscular than the walls of arteries.

   Veins rely on gravity, inertia, and the force of skeletal muscle contractions to help push blood back to the heart. To facilitate the movement of blood, some veins contain many one-way valves that prevent blood from flowing away from the heart. As skeletal muscles in the body contract, they squeeze nearby veins and push blood through valves closer to the heart.

   When the muscle relaxes, the valve traps the blood until another contraction pushes the blood closer to the heart. Venules are similar to arterioles as they are small vessels that connect capillaries, but unlike arterioles, venules connect to veins instead of arteries. Venules pick up blood from many capillaries and deposit it into larger veins for transport back to the heart.

3.1.2 Coronary Circulation

The heart has its own set of blood vessels that provide the myocardium with the oxygen and nutrients necessary to pump blood throughout the body. The left and right coronary arteries branch off from the aorta and provide blood to the left and right sides of the heart. The coronary sinus is a vein on the posterior side of the heart that returns deoxygenated blood from the myocardium to the vena cava.

3.1.3 The Circulatory Pump

The heart is a four-chambered "double pump," where each side (left and right) operates as a separate pump. The left and right sides of the heart are separated by a muscular wall of tissue known as the septum of the heart. The right side of the heart receives deoxygenated blood from the systemic veins and pumps it to the lungs for oxygenation. The left side of the heart receives oxygenated blood from the lungs and pumps it through the systemic arteries to the tissues of the body. Each heartbeat results in the simultaneous pumping of both sides of the heart, making the heart a very efficient pump.

3.1.4 Regulation of Blood Pressure

Several functions of the cardiovascular system can control blood pressure. Certain hormones along with autonomic nerve signals from the brain affect the rate and strength of heart contractions. Greater contractile force and heart rate lead to an increase in blood pressure. Blood vessels can also affect blood pressure. Vasoconstriction decreases the diameter of an artery by contracting the smooth muscle in the arterial wall. The sympathetic (fight or flight) division of the autonomic nervous system causes vasoconstriction, which leads to increases in blood pressure and decreases in blood flow in the constricted region. Vasodilation is the expansion of an artery as the smooth muscle in the arterial wall relaxes after the fight-or-flight response wears off or under the effect of certain hormones or chemicals in the blood. The volume of blood in the body also affects blood pressure. A higher volume of blood in the body raises blood pressure by increasing the amount of blood pumped by each heartbeat. Thicker, more viscous blood from clotting disorders can also raise blood pressure.

3.1.5 Haemostasis

Haemostasis, or the clotting of blood and formation of scabs, is managed by the platelets of the blood. Platelets normally remain inactive in the blood until they reach damaged tissue or leak out of the blood vessels through a wound. Once active, platelets change into a spiny ball shape and become very sticky in order to latch on to damaged tissues. Platelets next release chemical clotting factors and begin to produce the protein fibrin to act as structure for the blood clot. Platelets also begin sticking together to form a platelet plug. The platelet plug will serve as a temporary seal to keep blood in the vessel and foreign material out of the vessel until the cells of the blood vessel can repair the damage to the vessel wall. (Tim Taylor, Anatomy and Physiology Instructor)

3.1.6 Structure of blood vessels

Arteries:

1. Outer coat (tunica external)
2. Middle coat (tunica media), usually the thickest and is made up of elastic fibres and smooth muscle which has sympathetic innervation.
3. Inner coat (tunica internal). It is made up of endothelium and basement membrane.
4. Large arteries (conducting) which have more elastic fibres.

5. Medium arteries (distributing) they have more smooth muscle and thicker and most vasodynamic.
6. Arterioles: regulate blood into capillaries.

Capillaries: These are endothelial sites of nutrient/gas/waste exchange.
Venules and veins: They have few smooth muscles

3.1.7 Movement of Materials across Capillaries

Diffusion: This is most important for solutes. It takes place through plasma membranes, fenestrations and clefts. It is concentration dependent.

Vesicular: This type of movement entails large hydrophilic molecules e.g. IgG.
Bulk flow: This regulates volume of plasma and interstitial fluid. Clinical implication of abnormal movement of material across capillaries is oedema. This is caused by:

1. Increased venous flow
2. Cardiac failure
3. Poor circulation
4. Increased fluid uptake
5. Plasma protein loss (kidney disease)
6. Increased capillary permeability due to toxins

3.1.8 Blood Circulation within the Heart

The contraction and relaxation of the heart to pump blood is called heartbeat. At rest the average heartbeat is about 70 times per minute. During exercise, this rate goes up to over 100 times, thereby increasing the supply of oxygen that goes to the body cells. Heartbeats occur in two stages: systole and diastole.

- At systole, the two ventricles contract, while at diastole they both relax.
- At systole, deoxygenated blood enters the right auricle (atrium) through the superior and inferior vena cavae.
- The tricuspid valve is closed.
- The right ventricles pump deoxygenated blood to the lungs through pulmonary artery.
- Oxygenated blood enters the left atrium from the lungs through the pulmonary veins.
- The bicuspid valve is closed.

- The left ventricle pumps oxygenated blood through the semilunar valve and the aorta to the body.
- The tricuspid and bicuspid valves auricles and ventricles (left and right) prevent the back flow of blood into the atria when the ventricles contract. The thick wall of left ventricles enables it to pump blood with sufficient pressure around the body.
- Ventricles relax at diastole.
- The tricuspid and bicuspid valves open.
- Deoxygenated blood enters the right ventricle from the right atrium.
- Oxygenated blood enters the left ventricle from the left atrium.
- Systole restarts when the ventricles are filled.
- Circulation is divided into systemic and pulmonary circulation

Directions of blood circulation

Blood from arteries → arteriole → capillaries
venules → veins → heart.

3.1.9 Functions and Properties of blood

Blood is a connective tissue composed of a liquid extracellular matrix called blood plasma that dissolves and suspends various cells and cell fragments. **Interstitial fluid** is the fluid that bathes body cells and is constantly renewed by the blood. Blood transports oxygen from the lungs and nutrients from the gastrointestinal tract, which diffuse from the blood into the interstitial fluid and then into body cells. Carbon dioxide and other wastes move in the reverse direction, from body cells to interstitial fluid to blood. Blood then transports the wastes to various organs—the lungs, kidneys, and skin—for elimination from the body. **Blood,** which is a liquid connective tissue, has three general functions:

1. Transportation. As you just learned, blood transports oxygen from the lungs to the cells of the body and carbon dioxide from the body cells to the lungs for exhalation. It carries nutrients from the gastrointestinal tract to body cells and hormones from endocrine glands to other body cells. Blood also transports heat and waste products to various organs for elimination from the body.

2. Regulation. Circulating blood helps to maintain homeostasis of all body fluids. Blood helps to regulate pH through the use of buffers. It also helps to adjust body temperature through the heat absorbing and coolant properties of the water (see page 40) in blood plasma and its variable rate of flow through the skin where excess heat can be lost from the blood to the environment. In addition, blood osmotic pressure influences the water content of cells, mainly through interactions of dissolved ions and proteins.

3. Protection. Blood can clot, which protects against its excessive loss from the cardiovascular system after an injury. In addition, its white blood cells protect against disease by carrying on phagocytosis. Several types of blood proteins, including antibodies, interferons, and complement, help to protect the body against disease in a variety of ways.

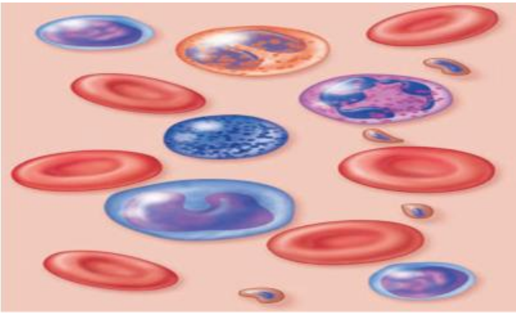

Figure 43: Blood Cells

3.1.10 Physical Characteristics of Blood

Blood is denser and more viscous (thicker) than water and feels slightly sticky. The temperature of blood is 38ºC (100.4ºF), about 1ºC higher than oral or rectal body temperature, and it has a slightly alkaline pH ranging from 7.35 to 7.45. The color of blood varies with its oxygen content. When it has a high oxygen content, it is bright red. When it has low oxygen content, it is dark red. Blood constitutes about 20% of extracellular fluid, amounting to 8% of the total body mass. The blood volume is 5 to 6 liters (1.5 gal) in an average-sized adult male and 4 to 5 liters (1.2 gal) in an average-sized adult female. The difference in volume is due to differences in body size.

3.2 Components of Blood

Blood has two components:

1. Blood plasma, a watery liquid extracellular matrix that contains dissolved substances, and
2. Formed elements, which are cells and cell fragments.

If a sample of blood is centrifuged (spun) in a small glass tube, the cells sink to the bottom of the tube while the lighter weight plasma forms a layer on top. Blood is about 45% formed elements and 55% blood plasma. Normally, more than 99% of the formed elements are cells named for their red color—red blood cells (RBCs).

3.2.1 Blood Plasma

When the formed elements are removed from blood, a straw-colored liquid called blood plasma (or simply plasma) is left. Blood plasma is about 91.5% water and 8.5% solutes, most of which (7% by weight) are proteins. Some of the proteins in blood plasma are also found elsewhere in the body, but those confined to blood are called plasma proteins.

3.2.2 Formed Elements

The formed elements of the blood include three principal components: red blood cells (RBCs), white blood cells (WBCs), and platelets. RBCs and WBCs are whole cells; platelets are cell fragments. RBCs and platelets have just a few roles, but WBCs have a number of specialized functions. Several distinct types of WBCs—neutrophils, lymphocytes, monocytes, eosinophils, and basophils—each with a unique microscopic appearance, carry out different functions.

I. Red blood cells
II. White blood cells

A. Granular leukocytes (contain conspicuous granules that are visible under a light microscope after staining)

1. Neutrophils
2. Eosinophils
3. Basophils

B. Agranular leukocytes (no granules are visible under a light microscope after staining)

1. T and B lymphocytes and natural killer (NK) cells
2. Monocytes

III. Platelets

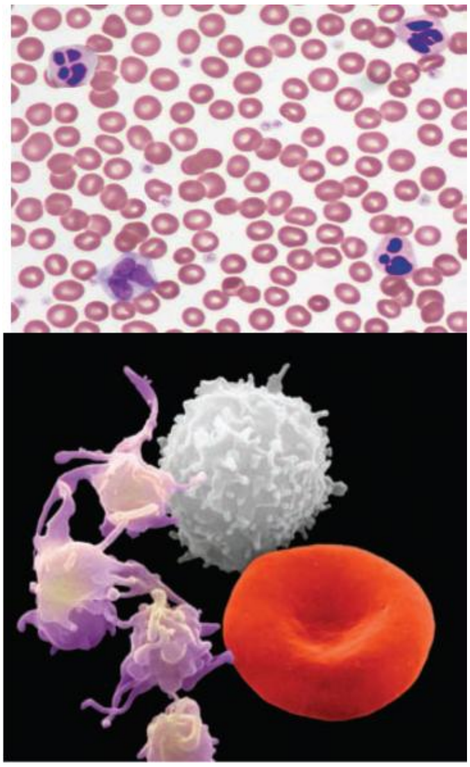

Figure 44: Photomicrograph and Scanning electron micrograph of the formed elements of blood.

3.2.3 Red Blood Cells

Red blood cells (RBCs) or **erythrocytes** (e-RITH-ro¯-sı¯ts; *erythro*-_ red; -*cyte* _ cell) contain the oxygen-carrying protein **hemoglobin,** which is a pigment that gives whole blood its red color. A healthy adult male has about 5.4 million red blood cells per microliter (μL) of blood,* and a healthy adult female has about 4.8 million. (One drop of blood is about 50 μL.) To maintain normal numbers of RBCs, new mature cells must enter the circulation at the astonishing rate of at least 2 million per second, a pace that balances the equally high rate of RBC destruction. These cells, like almost all the blood cells, live a much shorter time (120 days) than most other cells in the body, some of which last a lifetime. One purpose of the red cells is to carry oxygen from the lungs to the tissues. The oxygen is bound in the red cells to **haemoglobin**, a protein that contains iron. The erythrocytes are by far the most numerous of the corpuscles, averaging from 4.5 to 5 million per cubic millimeter of blood.

3.2.4 Leukocytes

The leukocytes, or white blood cells, are very different from the erythrocytes in appearance, quantity, and function. Unlike red blood cells, white blood cells or **leukocytes** have nuclei and do not contain hemoglobin. WBCs are classified as either granular or agranular, depending on whether they contain conspicuous chemical-filled cytoplasmic granules (vesicles) that are made visible by staining when viewed through a light microscope. Granular leukocytes include neutrophils, eosinophils, and basophils; agranular leukocytes include lymphocytes and mono-cytes.

3.2.5 Granular Leukocytes

After staining, each of the three types of granular leukocytes displays conspicuous granules with distinctive coloration that can be recognized under a light microscope. The large, uniform-sized granules within an **eosinophil** are eosinophilic, they stain red-orange with acidic dyes. The granules usually do not cover or obscure the nucleus, which most often has two lobes connected by a thick strand of chromatin. The round, variable-sized granules of a **basophil** are basophilic, they stain blue-purple with basic dyes. The granules commonly obscure the nucleus, which has two lobes. The granules of a **neutrophil** (NOO-tro-fil) are smaller, evenly distributed, and pale lilac in color, the nucleus has two to five lobes, connected by very thin strands of chromatin. As the cells age, the number of nuclear lobes increases. Because older neutrophils have several differently shaped nuclear lobes, they are often called polymorphonuclear leukocytes (PMNs), polymorphs, or "polys." Younger neutrophils are often called bands because their nucleus is more rod-shaped.

3.2.6 Agranular Leukocytes

Even though so-called agranular leukocytes possess cytoplasmic granules, the granules are not visible under a light microscope because of their small size and poor staining qualities. The nucleus of a **lymphocyte** is round or slightly indented and stains darkly. The cytoplasm stains sky blue and forms a rim around the nucleus. The larger the cell, the more cytoplasm is visible. Lymphocytes may be as small as 6 - 9 μm in diameter or as large as 10 - 14 μm in diameter. There are three types of lymphocytes: T lymphocytes (T cells), B lymphocytes (B cells), and natural killer (NK) cells.

3.2.7 Functions of WBC

The most important function of the leukocytes is to destroy pathogens. Whenever pathogens enter the tissues, for example through a wound, certain white blood cells (neutrophils and monocytes) are attracted to that area. They leave the blood vessels and proceed by **ameboid** or ameba-like motion to the area of infection. There they engulf the invaders by a process called **phagocytosis**. If the pathogens are extremely strong or numerous, they may destroy the leukocytes. The collection of dead and living leukocytes, forms **pus**. A collection of pus localized in one area is known as **abscess.** The Lymphocytes destroy foreign invaders by attacking the cells directly or by producing antibodies that circulate in the blood and help to destroy the cells.

3.2.8 Platelets

Of all the formed elements, the blood platelets (thrombocytes) are the smallest. Platelets help to stop blood loss from damaged blood vessels by forming a platelet plug. When, as a result of injury, blood comes in contact with any tissue other than the lining of the blood vessels, the platelets stick together and form a plug that seals the wound. Their granules also contain chemicals that, once released, promote blood clotting. Platelets have a short life span, normally just 5 to 9 days. Aged and dead platelets are removed by fixed macrophages in the spleen and liver

Plasma: Plasma is the non-cellular or liquid portion of the blood that makes up about 55% of the blood's volume. Plasma is a mixture of water, proteins, and dissolved substances. Around 90% of plasma is made of **water**, although the exact percentage varies depending upon the hydration levels of the individual. The **proteins** within plasma include antibodies and albumins. Antibodies are part of the immune system and bind to antigens on the surface of pathogens that infect the body. Albumins help to maintain the body's osmotic balance by providing an isotonic solution for the cells of the body. Many different substances can be found dissolved in the plasma, including glucose, oxygen, carbon dioxide, electrolytes, nutrients, and cellular waste products. The plasma functions as a transportation medium for these substances as they move throughout the body.

3.3 Blood Groups and Blood Types

The **ABO blood group** is based on two glycolipid antigens called A and B. People whose RBCs display only antigen A have **type A** blood. Those who have only antigen B are **type B.** Individuals who have both A and B antigens are **type AB;** those who have neither antigen A nor B are **type O.** Four blood types involving the A and B antigens have been recognized: A, B, AB, and O. These letters indicate the types of antigen present on the red cells, with O indicating that neither A nor B antigen is present. It is these antigens on the donor's red cells that react with the antibodies in the patient's plasma and cause a transfusion reaction. Blood serum containing antibodies that can agglutinate and destroy red cells that have A antigens on the surface is called **anti-A serum**; blood serum containing antibodies that can destroy red cells with B antigen on the surface is called **anti-B serum**. These sera are used to test for blood type. Persons with type O blood are said to be **universal donors** because they lack the AB red cell antigens and in an emergency their blood can be given to anyone. Type AB individuals are called **universal recipients**, since their blood contains no antibodies to agglutinate red cells and they can therefore receive blood from most donors.

3.3.1 The Rh Blood Group

Rh factor is another red cell antigen that determines the blood group. The **Rh blood group** is so named because the antigen was discovered in the blood of the Rhesus monkey. The alleles of three genes may code for the Rh antigen. People whose RBCs have Rh antigens are designated Rh+ve (Rh positive); those who lack Rh antigens are designated Rh-ve (Rh negative). Normally, blood plasma does not contain anti-Rh antibodies. If an Rh-ve person receives an Rh+blood transfusion, however, the immune system starts to make anti-Rh antibodies that will remain in the blood. If a second transfusion of Rh+ve blood is given later, the previously formed anti-Rh antibodies will cause agglutination and haemolysis of the RBCs in the donated blood, and a severe reaction may occur.

A pregnant woman who is Rh negative may become sensitized by proteins from her Rh positive fetus (this factor having been inherited from the father) if these proteins enter the mother's circulation before or during childbirth. During a subsequent pregnancy with an Rh positive fetus, some of the anti Rh antibodies may pass from the mother's blood in to the blood of her fetus and cause destruction of the fetus's red cells. This condition is called **erythroblastosis foetalis**, or **haemolytic disease of the newborn**.

Table 8: The ABO Blood Group System

Blood Type RBC	Antigen Plasma	Antibodies	Can take from	Can donate to
A	A	Anti-B	A, O	A, AB
B	B	Anti-A	B,O	B, AB
AB	A,B	None	AB, A, B, O	AB
O	NONE	Anti-A, Anti-B	O	O,A, B, AB

Source: Anatomy for Nurses

4.0 CONCLUSION

When blood flow needs to be redistributed to other parts of the body, the vasomotor center located in the medulla oblongata sends sympathetic stimulation to the smooth muscles in the walls of the veins, causing constriction—or in this case, venoconstriction. Less dramatic than the vasoconstriction seen in smaller arteries and arterioles, venoconstriction may be likened to a "stiffening" of the vessel wall. This increases pressure on the blood within the veins, speeding its return to the heart. Approximately 21 percent of the venous blood is located in venous networks within the liver, bone marrow, and integument. This volume of blood is referred to as **venous reserve**. Through venoconstriction, this "reserve" volume of blood can get back to the heart more quickly for redistribution to other parts of the circulation.

5.0 SUMMARY

This unit has described the Structure and Function of Blood Vessels, the functions of blood, the physical characteristics and principal components of blood, the Components of Blood, Blood Groups and Blood types.

6.0 TUTOR-MARKED ASSIGNMENT

- Discuss the functions of blood
- Discuss blood groups and blood types
- What are the components of blood

7.0 REFERENCES/FURTHER READINGS

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Tim Taylor, Anatomy and Physiology Instructor.

UNIT 2 THE HEART, BLOOD FORMATION AND BLOOD VESSELS

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
  3.1 Structure of the Heart
  3.2 The Four Chambers of the heart
  3.3 The Four Valves of the heart
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 INTRODUCTION

The heart is a muscular pump that drives the blood through the blood vessels. Slightly bigger than the owner's fist, this organ is located between the lungs in the center and a bit to the left of the midline of the body. The importance of the heart has been recognized for centuries. The fact that its rate of beating is affected by the emotions may be responsible for the very frequent references to the heart in song and poetry. However, the vital functions of the heart and its disorders are of more practical importance.

2.0 OBJECTIVES

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

- Describe the Structure of the heart
- Discuss the Four Chambers of the heart
- Discuss the Four Valves of the heart

3.0 MAIN CONTENT

3.1 Structure of the Heart

The heart is a hollow organ, the walls of which are formed of three different layers:

1. The **endocardium** is a very thin smooth layer of cells that resembles squamous epithelium. This membrane lines the interior

of the heart. The valves of the heart are formed by reinforced folds of this material.

2. The **myocardium**, the muscle of the heart, is the thickest layer.
3. The **epicardium** forms the thin outermost layer of the heart wall and is continuous with the serous lining of the fibrous sac that encloses the heart. These two membranes together make up the pericardium. The serous lining of the pericardial sac is separated from the epicardium on the heart surface by a thin fluid- filled space.

Two Hearts and a Partition

Physicians often refer to the right heart and the left heart. This is because the human heart is really a double pump. The two sides are completely separated from each other by a partition called the **septum**. The upper part of this partition is called **interatrial septum**; while the larger lower portion is called **interventricular septum**. The septum, like the heart wall, consists largely of myocardium.

3.2 The Four Chambers of the heart

On either side of the heart are two chambers, one a receiving chamber (atrium) and the other a pumping chamber (ventricle):

1. The **right atrium** is a thin-walled chamber that receives the blood that is
2. returning from the body tissues. This blood, which is low in oxygen, is carried in the veins, the blood vessels leading to the heart from the body tissues.
3. The **right ventricle** pumps the venous blood received from the right atrium and sends it to the lungs.
4. The **left atrium** receives blood high in oxygen content as it returns from the lungs.
5. The **left ventricle**, which has the thickest walls of all, pumps oxygenated blood to all parts of the body. This blood goes through the arteries, the vessels that take blood from the heart to the tissues.

3.3 The Four Valves of the heart

Since the ventricles are the pumping chambers, the valves, which are all one way, are located at the entrance and the exit of each ventricle. The entrance valves are the **atrioventricular valves**, while the exit valves are the **semilunar valves**. Semilunar means "resembling a half moon". Each valve has a specific name, as follows:

1. The **right atrioventricular valve** also is known as the **tricuspid valve**, since it has three cusps or flaps that open and close. When this valve is open, blood flows freely from the right atrium into the right ventricle. However, when the right ventricle begins to contract, the valve closes so that blood cannot return to the right atrium; this ensures forward flow into the pulmonary artery.

2. The **left atrioventricular valve** is the bicuspid valve, which is usually referred to as the **mirtal valve**. It has two rather heavy cusps that permit blood to flow freely from the left atrium into the left ventricle. However, the cusps close when the left ventricle begins to contract; this prevents blood from returning to the left atrium and ensures the forward flow of blood into the **aorta**. Both the tricuspid and mitral valves are attached by means of thin fibrous threads to the wall of the ventricles via bundles of muscular tissue called papillary muscles. The function of these threads, called the **chordae tendineae**, is to keep the valve flaps from flipping up into the atria when the ventricles contract and thus preventing a backflow of blood.

3. The **pulmonary** (semilunar) **valve** is located between the right ventricle and the pulmonary artery that leads to the lungs. As soon as the right ventricle has finished emptying itself, the valve closes in order to prevent blood on its way to the lungs from returning to the ventricle.

4. The **aortic** (semilunar) **valve** is located between the left ventricle and the aorta. Following contraction of the left ventricle, the aortic valve closes to prevent the flow of blood back from the aorta to the ventricle.

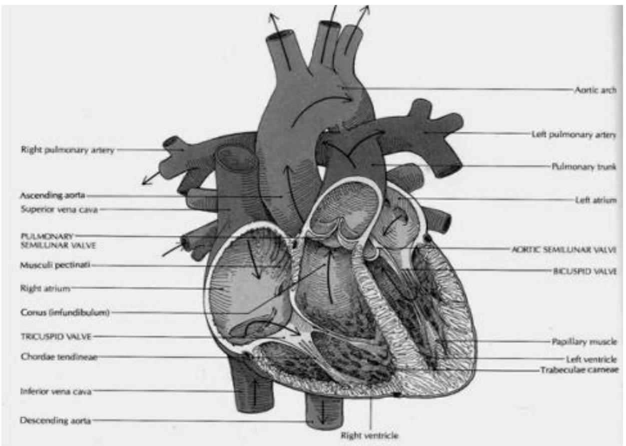

Figure 45: Heart and great vessels (Source: Carola, R., Harley,J.P., Noback R.C., (1992)

Blood Supply to the Myocardium

Although blood flows through the heart chambers, only the endocardium comes into contact with it. Therefore, the myocardium must have its own blood vessels to provide oxygen and nourishment and to remove waste products. The arteries that supply blood to the muscle of the heart are called the **right** and **left coronary arteries**. These arteries, which are the first branches of the aorta, arise just above the aortic semilunar valve. They receive blood when the heart relaxes. After passing through capillaries in the myocardium, blood drains into the cardiac veins and finally into the coronary (venous) sinus for return to the right atrium.

Capacity of the heart

The normal functional capacity of the heart includes the following:

(i) Approx. 100,000 heartbeats/day,
(ii) Approx. 2,760,000,000 heartbeats/lifetime
(iii) Approx. 4,000 gallons (15,000 litres) blood pumped/day.

Blood that leaves the heart is called oxygenated blood because it contains oxygen. Blood that comes back to the heart is called deoxygenated blood because it does not contain oxygen. The human heart works continuously throughout the life of a person. It weighs about 300 grams. It is divided into four chambers: two upper chambers, the left and right atria and two lower chambers, the left and right ventricles. The chambers are separated by walls called septum. The walls are thick and muscular. The ventricles have thicker walls than the atria to ensure that enough pressure is generated to pump the blood to the body and lungs. The left ventricle whose force of contraction pumps the blood to all parts of the body has the thickest wall compared to other chambers.

4.0 CONCLUSION

The **heart** is a muscular pumping organ located medial to the lungs along the body's midline in the thoracic region. The bottom tip of the heart, known as its apex, is turned to the left, so that about 2/3 of the heart is located on the body's left side with the other 1/3 on right. The top of the heart, known as the heart's base, connects to the great blood vessels of the body: the **aorta**, vena cava, pulmonary trunk, and pulmonary veins. We can see that all the functions of the cardiovascular system depend on the heart. The cardiovascular system is the most hardworking of all the systems in the body because, unlike other systems, its components do not rest. Not surprisingly, then, any substantial interruption or reduction in the flow of blood to this system has grave consequences: what we commonly call heart attack.

5.0 SUMMARY

This unit has described the structure of the Heart, the four Chambers of the heart and the four Valves of the heart.

6.0 TUTOR-MARKED ASSIGNMENT

- Describe the structure of the human heart showing clearly, the directions of blood circulation.
- Discuss the 4 chambers of the heart

7.0 REFERENCES/FURTHER READINGS

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UNIT 3 INTRODUCTION TO THE URINARY SYSTEM

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1.0 Introduction
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3.0 Main Content
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  3.2 The Structures and Functions of the Kidney
  3.3 An Overview of the Nephron
  3.4 Glomerular Filtration
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6.0 Tutor-Marked Assignment
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1.0 INTRODUCTION

The urinary system is the entire system of ducts and channels that conduct urine from the kidneys to the exterior. It includes the ureters, the urinary bladder and the urethra. The main function of the urinary system is to maintain homeostasis of blood composition, volume and pressure.

2.0 OBJECTIVES

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

- Discuss the overall function of the urinary system
- Identify the major organs of the urinary system and describe their functions
- Describe the mechanism of action of the urinary system.

3.0 MAIN CONTENT

3.1 Introduction to the Major Organs of the Urinary System

The major organs of the Urinary system are the:

- Kidneys
- Ureters
- Urinary bladder
- Urethra

They are located in the abdomen, pelvis and perineum and are responsible for the formation elimination of urine and other waste materials from the body.

3.2 Introduction to the Structure and Function of the Kidney

- Hilum –This is the entrance to renal sinus.
- Renal pelvis – An expansion of the ureter.
- Calyces (major and minor) – These are tubes emanating from renal pelvis.
- Inner medullary region – This contains renal columns and pyramids (site of nephrons).
- Outer cortex - Forms the outer cover and renal columns.
- Renal columns –This is the portion of cortex extending between renal pyramids
- Renal pyramids – The number is approximately 8-18 regions per kidney.

The Major Functions of the Kidney

The kidney:

- Regulates blood volume and composition
- Regulates blood pressure as it monitors renal blood pressure and the secretion of rennin
- Rregulates certain aspects of metabolism like gluconeogenesis.

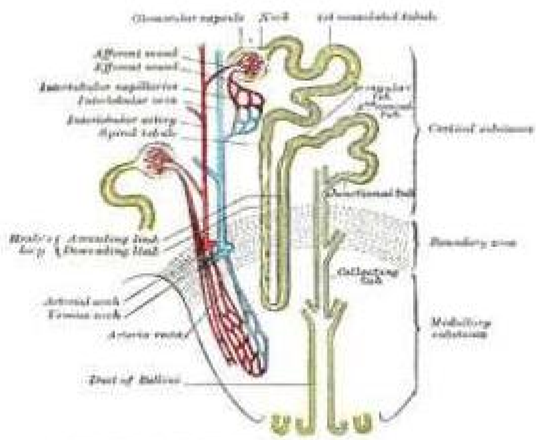
3.3 An Overview of the Nephron

There are two principal types of nephrons: cortical nephron and juxtamedullary nephron.

Each nephron has two major portions:

1. Renal corpuscle.
2. Renal tubule.

The basic function of the nephron is to filter blood and produce filtrate.



The nephron of the human kidney
http://en.wikipedia.org/wik

Figure 46: The nephron of human kidney

3.4 Filtrate Production

This is a three-step process:

1. Glomerular filtration: Filters fluid and waste solutes out of the blood.
2. Tubular reabsorption: Returns important solutes to the blood.
3. Tubular secretion: Selective secretion of more solutes into filtrates.

The one major factor affecting the glomerular filtration rate (GFR) is the glomerular hydrostatic pressure (HPg), which is determined by the diameter of afferent/efferent arterioles. The major mechanisms regulating GFR are:

1. Renal autoregulation
2. Hormonal regulation, like aldosterone and antidiuretic hormone (ADH)
3. Neuronal regulation

4.0 CONCLUSION

The kidney is very essential to life because it helps to get rid of substances that are toxic to the body, and also helps to maintain homeostasis.

5.0 SUMMARY

This unit has shown that the urinary system consists of the kidneys, the ureters, the urinary bladder and the urethra. The important role played by the nephron is the process of glomerular filtration.

SELF ASSESSMENT EXERCISE 1

1. What are the three major functions of the kidneys?
2. The four major organs of the urinary system are --------------------------------,
--------------------------------, -------------------------------- and ---------------------------.

SELF ASSESSMENT EXERCISE 2

1. What is the basic function of a nephron?
2. Write out the three steps of renal filtration.

ANSWER TO SELF ASSESSMENT EXERCISE 1

1. The major function of the urinary system is to maintain homeostasis of blood composition, volume and pressure.
2. The four major organs of the urinary system are kidneys, ureters, urinary bladder and urethra.

ANSWER TO SELF ASSESSMENT EXERCISE 2

1. The basic function of the nephron is to filter blood and produce filtrate.
2. The three steps of renal filtration are:

   - Glomerular filtration
   - Tubular reabsorption
   - Tubular secretion

6.0 TUTOR-MARKED ASSIGNMENT

Describe the process of filtrate production.

7.0 REFERENCES/FURTHER READINGS

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UNIT 4 THE STRUCTURE OF THE KIDNEY

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
    3.1 Structure and functions of the kidney
    3.2 Accessory excretory structures of the urinary system
    3.3 Urine and urination
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 INTRODUCTION

The urinary system is also called the excretory system of the body because one of its functions is to remove waste products from the blood and eliminate them from the body. The urinary system consists of two kidneys which are the organs that extract wastes from the blood, balance body fluids and form urine. The two ureters are tubes which conduct urine from the kidneys to the urinary bladder while the urinary bladder is a reservoir that receives and stores the urine brought to it by the two ureters. The urethra is a tube that conducts urine from the bladder to the outside of the body for elimination.

2.0 OBJECTIVES

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

- Discuss the structure & functions of the kidney
- Describe Accessory excretory structures of the urinary system
- Discuss Urine and urination

3.0 MAIN CONTENT

3.1 Structure and functions of the Kidney

This is a pair of reddish brown, bean shaped organ located in the posterior wall of the abdominal region, one in each side of the vertebral column. They usually span between T12 to L3. They are protected at least partially by the last pair of ribs and capped by the adrenal gland. The bean shape of the kidney is medially concave and laterally convex. On the medial concave border is the ***hilus*** (small indented area) where blood vessels, nerves & ureters enter and leave the kidney.

Covering and supporting each kidney are three layers of tissue:

- Renal capsule – innermost, tough, fibrous layer
- Adipose or fatty capsule – the middle layer composed of fat, giving the kidney protective cushion.
- Renal fascia – is outer sub-serous connective tissue layer.

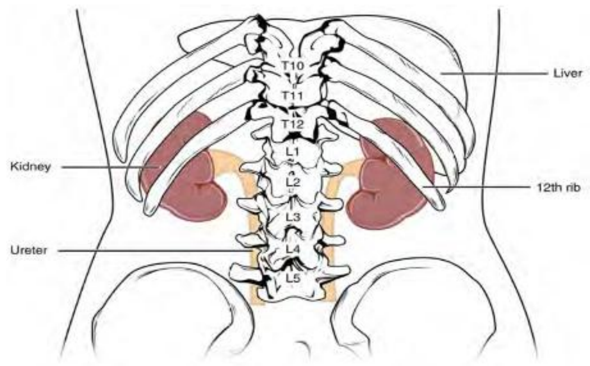

Figure 47: Human Kidneys

The kidneys are slightly protected by the ribs and are surrounded by fat for protection.

3.1.1 Internal Anatomy of the kidney

A sagittal section of the kidney reveals three distinct regions called pelvis, medulla and cortex from inside out (Figure 47).

The **renal pelvis** is the large collecting space within the kidney formed from the expanded upper portion of the ureters. The pelvis branches into two levels of cavities; these are 2-3 major calyces and 8 to 18 minor calyces.

The **Renal medulla** is the middle portion of the kidney. It consists of 8 to 18 renal pyramids, which are longitudinally striped, cone-shaped areas. The base of each pyramid is adjacent to the outer cortex. The apex of each renal pyramid ends in a papilla, which opens to a minor calyx. Pyramids contain tubules and collecting ducts of the nephron. The tubules are involved in transportation and re-absorption of filtered materials.

The **renal cortex** is the outermost portion of the kidney. It is divided into two regions: the outer cortical and the inner juxtamedullary region. The cortical tissue that penetrates between the pyramids forms ***Renal Columns***. The renal columns are
composed of mainly collecting tubules.

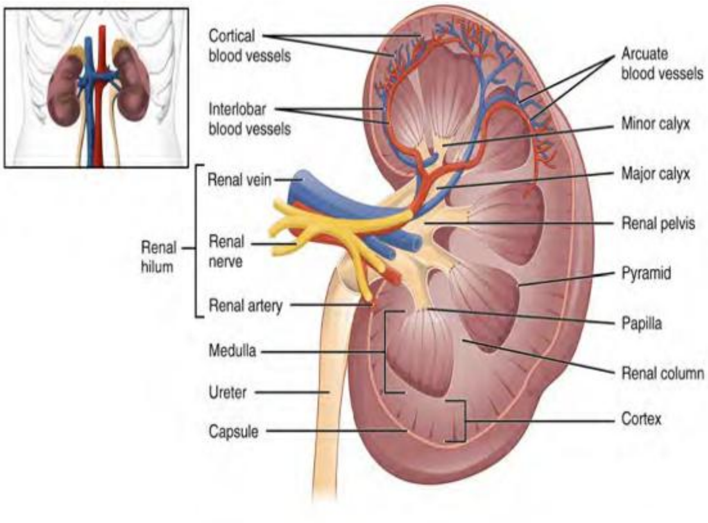

Figure 48: Internal structure of the Kidney

3.1.2 Functions of the Kidney

All the functions are directly or indirectly related to the formation of urine. The series of events leads to:

- Elimination of wastes
- Regulation of total body water balance.
- Control of the chemical composition of blood and other body fluids
- Control of acid base balance

The processes in urine formation are: -
1. Blood filtration; every day the kidneys filter 1700 liters of blood
2. Tubular re-absorption
3. Tubular secretion

The relative amounts of filtration, re-absorption and excretion in the kidney tubular system is influenced by daily diet, fluid intake, weather factors and exercise, all of which determine the composition of urine.

3.2 Accessory Excretory structures

Urine is formed in the kidney, but accessory structures are required to transfer, store and eventually eliminate urine from the body. These structures are the two ureters, urinary bladder and urethra.

3.2.1 Ureters

Attached to each kidney are two tubes called the ureters. Ureters transport urine from the renal pelvis to the urinary bladder. The ureters pass between the parietal peritoneum and the body wall to the pelvic cavity, where they enter the pelvic cavity. It is narrow at the kidney and widen near the bladder.

The wall of the ureters is composed of three layers:

- Innermost Tunica Mucosa
- The middle Tunica Muscularis (made of smooth muscle)
- The outer Tunica Adventitia

3.2.2 Urinary bladder

Urinary bladder is a hollow, muscular organ that collects urine from the ureters and store it until it is excreted. It usually accumulates 300 to 400 ml of urine but it can expand twice as much. It is located on the floor of the pelvic cavity like the kidneys and ureters. It is ***Retroperitoneal***. In males it is anterior to the rectum and above the prostate gland. In females, it is located somewhat lower, anterior to the uterus and upper vagina.

3.2.3 Urethra

Urethra is a tube of smooth muscle lined with mucosal layer. It leaves the bladder at its inferior surface (base) and transports urine outside the body during urination. It is an average of 4 cm long in females and 12 cm in length in males. In females it opens between the vagina and clitoris. In males, it passes through the prostate, membranous portion (pelvic diaphragm muscle), spongy portion (that passes through corpus spongiosus muscle) and open at the tip of penis. The spongy portion is joined by ducts from the bulbo-uretheral gland (Mucus secreting gland).

3.3 Urine & urination

Composition of urine varies depending on the diet, exercise, water consumption and other factors. However, it is composed of mainly water, urea, chloride, potassium, sodium, creatinin, phosphate, sulfates and uric acid. Proteins, glucose, casts (decomposed blood) and calculi from minerals are abnormal if present in urine. The PH of urine is 5.0 to 8.0 (mostly acidic) and has translucent (clear, not cloudy) color. To maintain the proper osmotic concentration of the extra cellular fluid to excrete wastes and to maintain proper kidney function the body must excrete at least 450ml of urine per day. A healthy person excretes 1000 to 1800 ml of urine daily. The volume and concentration of urine is controlled by:

- Antidiuretic hormone
- Aldestrone
- The Renin – angiotensin mechanism

3.3.1 Urination

Urination is emptying of the bladder; it is the process of conscious and unconscious nerve control. Steps of urination are:

- ➢ Conscious desire to urinate
- ➢ Pelvic diaphram muscles relax
- ➢ Urinary bladder neck moves down, outlet opens
- ➢ Wall stretches
- ➢ Receptors are stimulated
- ➢ Smooth muscle of Urinary bladder Contracts & urine ejects

4.0 CONCLUSION

Urine is a fluid of variable composition that requires specialized structures to remove it from the body safely and efficiently. Blood is filtered, and the filtrate is transformed into urine at a relatively constant rate throughout the day. This processed liquid is stored until a convenient time for excretion. All structures involved in the transport and storage of the urine are large enough to be visible to the naked eye. This transport and storage system not only stores the waste, but it protects the tissues from damage due to the wide range of pH and osmolarity of the urine, prevents infection by foreign organisms, and for the male, provides reproductive functions.

5.0 SUMMARY

- In this unit, we have discussed the structure & functions of the kidney, accessory excretory structures of the urinary system, Urine and urination.

6.0 TUTOR-MARKED ASSIGNMENT

- Discuss the external structures of kidney
- Briefly discuss the structures involved in removing urine from the body

7.0 REFERENCES/FURTHER READINGS

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UNIT 5 THE IMMUNE SYSTEM

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
   3.1 Cells of the Immune System
   3.2 Innate Immunity
   3.3 Types of Specific Immune Response
   3.4 Hypersensitivity Reactions
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.0 INTRODUCTION

The immune system consists of the organs responsible for the body's ability to resist infections, afforded by the help of circulating antibodies and white blood cells (mentioned in a previous unit on haematology).

2.0 OBJECTIVES

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

- describe the cells of the immune system
- define immunity and types of immunity
- define transplant immunology
- describe autoimmunity and related conditions.

3.0 MAIN CONTENT

3.1 Cells of the Immune System

1 Leukocytes: 5-10,000 cells/mm3 in blood; **and Granulocytes**:

a. **Neutrophils** (50-70%); 3-day lifespan: major phagocyte and granulocyte; attracted by inflammatory factors and complement; granules with hydrolytic enzymes; cell dies after degranulation/phagocytosis.

i) **"Band"** is immature neutrophil (band-shaped nucleus);
ii) **"Seg"** is mature neutrophil (segmented nucleus).
iii) **Neutrophilia**: increased percentage; common with acute bacterial infections
iv) **Neutropenia**: decreased percentage; common with anaemias, viral infections, radiation/chemotherapy.

b. Eosinophils (2-4%): major anti-helminthes protection (**myelin basic protein** released); it also contributes to some hypersensitivity reactions and phagocytosis of bacteria.
c. Basophils (<1%): granulocytic, nonphagocytic; major inflammatory cell, releases histamines, proteases and granulocyte-attracting factors.
d. Mast cells: non-circulating, reside in connective tissues, similar function as basophils; initiate inflammatory reactions.

2. **Monocytes** (2-8%): only last 8-12 hrs in circulation. then migrate to tissue = major function to become macrophage in tissue; play key role in "antigen presentation".
3. **Platelets** (240-400,000/mm3): crucial to help activate blood clot formation; spleen acts as reserve site.
4. **Lymphocytes** (20-30%) mononuclear cells: mediate/regulate specific immune responses (antibody formation, anti-viral and anti-tumor protection)

a. B-cells: produce immunoglobulins (mature in bone marrow).
b. T-cells: activate/regulate B-cells, major immune regulatory cells (mature in thymus).
c. NK cell: natural killer cell; non-specific anti-tumor cytolytic cell.

3.2 Innate Immunity

Innate immunity is genetically determined. It is present at birth and has no relationship to previous exposures to the antigen involved. For example, people do not get the same disease as fishes. Innate immunity only breaks down in the case of AIDS or other conditions that depress all aspects of specific resistance.

3.3 Types of Specific Immune Response

There are two types of specific immune response: Humoral and Cellular Immunity

Humoral Immunity

1. Immunoglobulin (Ig): Production by activated B-cells
2. Antigen (Ag): Any molecule capable of eliciting a specific immune response.
3. Antigen presentation: Macrophage (or B-cell) ingests antigen, degrades into fragments, and re-expresses antigen fragments on the surface in context of major histocompatibility complex II (MHC class II).
4. During this process, the macrophage releases Interleukin 1, a potent cytokine which acts as a pyrogen and activator of T-helper cells.

T-helper (CD4+) cell specific for that antigen binds to MHC-Ag using T-cell receptor (TCR) and is stimulated by binding and by Interleukin-1 released from antigen-presenting cell. This presentation usually occurs in lymph node or spleen. T-cell clone is activated, proliferates, and secretes Interleukin-2 which enhances T-cell activation. B-cell bearing Ig specific for that antigen binds antigen, and presents it to T-cell in the context of MHC-II. Binding of activated T-helper cell to B-cell and release of B-cell growth factors including Interleukins 4 and 6 from Tcells activate B-cells to proliferate and produce more Ig.

1. Clonal selection of Ag-specific T-cell (with TCR) and B-cell (with Ig) prospecific immune response.
   Memory B- and T-cells are also produced with the ability to be activated easily upon second exposure to Ag, provide long-term "immune protection", allows for very large and rapid response to second exposure (secondary immune response).

Immunoglobulins: "Y" shape monomer, two Ag-binding sites, one "tail" region (Fc region), made of two heavy chain proteins, two light chains proteins, produced only by B-cells. The immunoglobulins include:

a. IgG: most abundant Ig, long-lasting in serum, usually produced upon second exposure to Ag; can cross placenta.
b. IgM: second most abundant Ig, pentamer, produced upon first exposure to Ag.
c. IgA: most abundant Ig in secretions (saliva, tears and mucus). d. *IgE*: involved in allergic reactions by binding of mast cells and basophils and triggering to degranulate upon Ag exposure.
e. *IgD*: is seen on resting B-cells, not seen in serum (<0.1%). *Neutralisation:*

This is the binding of Ig to virus, toxins, and bacteria to block activity or infectivity.

Agglutination: clumping of cells by Ig binding, aids in phagocytosis.
Opsinisation = coating cell with Ig, enhances binding of macrophage by binding to the tail region of Ig (Fc region).

Precipitation: clumping of soluble molecules by Ig binding, aids in phagocytosis.

Complement activation: Ig bound to cell surfaces activates complement cascade to attack targeted cell.

Cellular Immunity

General Description: Specific anti-viral, anti-tumor immune response mediated by *cytolytic T-cells (CD8+).* All normal cells express major histocompatibility complex I *(MHC-I)* (only antigen presenting cells express MHC-II). MHC-I is your molecular "ID card" and is used to present antigens produced within the cell (not brought in from outside).
Virus-infected cells express viral antigens in the context of MHC-I Tcytotoxic (CD8+) bearing TCR specific for a particular antigen bind to Ag/MHC-I on virus-infected cells and are activated. T-cytotoxic cells release cytolytic molecules *(lymphotoxin, perforin*) to kill target cells.

Activation of T-cytotoxic cells is enhanced by cytokines released by T-helper cells (IL-2, *gamma interferon*). T-cytotoxic cells also act against tumour cells in similar way; tumour cells express tumor-Ag in the context of MHC-I and become targets for T-cytotoxic cells. The immune system constantly checks all tissues for "altered cells" (foreign, virus-infected, tumors) in a process called "*immune surveillance*". The use (necessity) of expressing most antigens in the context of MHC (class I or II) to initiate an immune response is termed *"MHC Restriction"*.

3.4 Hypersensitivity Reactions

Hypersensitivity reactions of the immune system include:

1. *Type I:* Anaphylactic Reactions (typical bee-sting or hay fever allergic responses).
2. *Type II:* Cytotoxic Reactions (as in mismatched ABO transfusion reaction).
3. *Type III:* Immune Complex Reactions (as in rheumatoid arthritis

or in "serum sickness").

1. *Type IV*: Cell-mediated Reactions (seen with positive tuberculin (TB)-skin test reaction).

Autoimmunity

This is "self/non-self" discrimination (**self-tolerance**) of the immune system developed during thymic maturation. It consists of positive and negative selection processes. Autoimmunity can occur in the following conditions:

1. Graves disease
2. Rheumatoid arthritis
3. Systemic lupus erythematosus (SLE)
4. Myasthenia gravis
5. Insulin-dependant diabetes: Auto-reactive T-cytotoxic cells destroy pancreatic beta-cells (the insulin producing cells).

SELF ASSESSMENT EXERCISE

1. What are the two arms of specific immune response?
2. List the four types of hypersensitive immune reactions of the immune system.

4.0 CONCLUSION

Cells of the immune system (Leucocytes and granulocytes) provide immunity that is resistant to injuries and diseases caused by foreign compounds, toxins or pathogens.

5.0 SUMMARY

In this unit we examined the cells of the immune system, immunity and types of immunity.

ANSWER TO SELF ASSESSMENT EXERCISE

1. The two arms of specific immune response are humoral and cellular immunity.
2. The four types of hypersensitive immune reactions of the immune system are:
   (a) Type I: Anaphylactic reactions (typical bee-sting or hay fever allergic responses).
   (b) Type II: Cytotoxic reactions (as in mismatched ABO

transfusion reaction)

(c) Type III: Immune Complex reactions (as in rheumatoid arthritis or in "serum sickness")

(d) Type IV: Cell-mediated reactions (seen with positive tuberculin (TB)-skin test reaction).

6.0 TUTOR-MARKED ASSIGNMENT

Enumerate the cells of the immune system.

7.0 REFERENCES/FURTHER READINGS

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