KHE 201

Human Anatomy, Physiology and Sports **1**

BY

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Module 1 Introduction to Human Anatomy, Physiology and Sports

Humans must necessarily engage in some processes that maintain life. Humans, therefore, possess certain characteristics that enable them carry on the process of living. Movement, a major characteristic of human life, is the cornerstone of human kinetics education and sports performance. In this module you will learn the rationale for studying anatomy and physiology in the improvement of human health and performance as found sports training and competition. You will also learn the terminologies used in the study of human anatomy and physiology, the life processes and general plan of the body according to levels of organisation.

Unit 1: Anatomy and Physiology in the study of Physical Activity in Human Kinetics and Sports.

1.0 Introduction

The aim of studying human kinetics education is the improvement of human health and performance of the human being's body in sports and dance performances. Anatomy and physiology, which studies the structure and function of the body, has a definite place in the study of human kinetics education in that it is the body that is being improved in health and performance. In this unit you will study the importance of studying anatomy and physiology in the study of physical activity in human kinetics and sports.

2.0 Intended Learning Outcome(s)

By the end of this unit, you would be able to

- Discuss Human Kinetics Education as the scientific study of human movement
- Explain the major objective of Human Kinetics Education
- Explain the importance of studying anatomy and physiology in human kinetics and sports.

3.0 Main Content

Importance of studying anatomy and physiology in human kinetics and sports

Human kinetics education is the scientific study of human movement and the movement brought about by the body of the human being. Physical activity, that movement which is brought about by contracting skeletal muscles, is guided in human kinetics education to produce improvements in human health and performances in dance and sports. Human kinetics education is therefore concerned with the scientific study of movements that is caused by the human being's body or its parts and the effects of movement on the body.

Everyone can benefit from guided physical activity. It should be noted that it is not all physical activities that are suitable to everybody. People have different anatomical build that makes them more suited to certain physical activities than others. People's physiological capacities also differ. Therefore, the amount of physical activities, in terms of quality and quantity, that people can cope with vary according to individual capacities. The rationale for studying anatomy and physiology in human kinetics education becomes more understandable given the fact that people's structural and functional capacities for any kind of physical activity can only be known through the study of human anatomy and physiology.

The objective of human kinetics education, as a discipline, is to improve human health and performance capacities. It is the knowledge acquired in the study of anatomy and physiology that makes it possible to find out whether the health and performance improvement objectives are being met. Therefore, anatomy and physiology makes it possible to find out whether participants are improving in health and/or performances.

Physical activities can be injurious if not done appropriately. Through the study of anatomy and physiology, it is possible to know the physical activities that are suitable and appropriate to different individuals. It is the knowledge obtained in anatomy and physiology that is used to teach people how to position themselves, during the physical activities of human kinetics education so that they can obtain maximal benefits and prevent injuries that could arise from inappropriate movement.

Man must necessarily engage in some processes that maintain life and enables performances in sports and dance. This he does by making use of the structures he is endowed with in the life process endeavour. Man possesses certain characteristics which enables him carry on the process of living. While anatomy studies the structures used by man in the life process, physiology studies how these structures studied in anatomy function in the sustenance of life.

4.0 Conclusion

The importance of anatomy and physiology in study of human kinetics and sports cannot be overemphasized. Anatomy provides an understanding of the structures used by man in life generally and sports performance specifically. It is physiology that enables us to know how the structures studied in anatomy function.

5.0 Summary

Knowing the rationale for studying anatomy and physiology in human kinetics and sports motivates one into serious effort in this scientific endeavour. You are now prepared to further your study by learning the functional processes in human life in the next unit.

Self Assessment Exercise

1. Discuss the meaning and objectives of Human Kinetics Education
2. How is the study of anatomy and physiology beneficial to the coach and athlete?

6.0 References/Further Readings

Ajiduah, A. O. (1998). *Basic theory of sports training.* Lagos: University of Lagos press

OpenStax College, *Anatomy & Physiology*. OpenStax College. 25 April 2013. *http://cnx.org/content/col11496/latest/*

Robergs, R. A. and Kateyian, S. J. (2003). *Fundamentals of exercise physiology for fitness, performance and health. (2nd ed)* New York. McGraw Hill.

Unit 2: Functional Processes of Human Life and Requirements for its Survival

1.0 Introduction

You learned the importance of studying anatomy and physiology in Human Kinetics and Health Education in the previous unit. You will further your study, in this unit, by looking briefly at the processes of human life that help him to sustain life on earth and participates in sports and dance.

2.0 Intended Learning Outcome(s)

By the end of this unit, you would be able to

- List and describe 10 functional processes of human life.
- Show how water, oxygen, food nutrients, heat, and pressure are essential to human existence.

3.0 Main Content

The following are the physiological processes of life.

Organization

The human body is made up of several billions of cells. Each of these cells has its own integrity. This enables it perform the function for which it is created. Some cells are made in such a way that they are able to function as a part of the nervous system, while others are made to perform the protective function of the skin. This cell formation right from the start that places cells into special tissues and organs for the purpose of special function performance is known as cell specialization. The process whereby specialized cells are joined together in such a way that they are placed in a position where they are capable of performing a special function for the human body is known as organization. All the cells in the human body are organized in such a way that there is division of labour. While the cells of the eye are used for seeing, the cells of the ear are for hearing, the cells of the muscles and bones are for movement, etc. Though there is division of labour, there must be cooperation among all the components of the human body if it is to be alive. The eye, the muscles and bones work in unison for movement to take place.

Metabolism

The human body interacts with the environment in several ways as it goes through the processes of life. It takes in substances from the environment, processes them into other substances useful to its life and releases energy for its life processes. These processes are generally known as metabolism. Metabolism is therefore a broad term which describes all the chemical reactions that occur in the body. Two phases can hence be identified in metabolism. The first phase of metabolism, catabolism is the phase in which complex substances are broken down into simpler building blocks and energy is released. The second phase of metabolism called anabolism makes use of energy in the processes of life. Cell formation and / or expansion for growth, movement, etc are examples of anabolism.

Irritability

This is also known as responsiveness. The internal and external environments of the human body are changing constantly. The act of sensing this change and responding to it is called irritability. Therefore irritability is concerned with detecting changes in the internal or external environments and reacting to that change.

Movement

This is the act of changing location or position. When molecules or blood cells move around the body, movement has taken place. The rise and fall of our chests as we breathe in and out is also movement. Thus there are many types of movement within the body. The act of leaving our homes to the school for lectures and the field for training are also movements.

Reproduction

The transmission of life from one generation to another through the birth of babies is reproduction. This however, is not the end of reproduction. The cells that make up the human body get worn out and / or die on a daily basis. These cells need replacement and repairs. The formation of new cells for the replacement and repairs of old and worn out cells is also known as reproduction. It would be very arguable to state that we are still retaining any of the cells we are born with some years ago in a functional state. This kind of reproduction is known as cellular reproduction. It should then be noted that the transmission of life from one generation to another is a necessary life process just as cellular reproduction is essential to the survival of the human being.

Growth

When we were born as babies, we were not as big as we are now. We have steadily increased in size from the miniature humans we were at birth to our present stage of maturity by the process known as growth. The number of cells we were born with has increased steadily till now. The individual cells too have increased in size. Thus growth refers to an increase in size either through an increase in the number of cells or through an increase in the size of each individual cell. In order for growth to occur, anabolic processes must occur at a faster rate than catabolic processes.

Differentiation

The human body, as big as it is, started its existence as a single cell. By the process of cellular reproduction, this single cell increased in number and size to produce the human being in his present state. At the early stage newly formed cells have similar structures that do not perform any special function. These cells at this stage of development are called unspecialized cells. These unspecialized cells now pass through some developmental processes which endow them with distinctive structural and functional characteristics. This developmental process is generally known as differentiation. Through the process of differentiation, cells develop as they combine to form tissues, tissues combine to form organs and several organs join to form systems.

Respiration

One of the substances needed by the body from the environment to survive is oxygen. As a man breathes in, he inhales air. Oxygen is extracted from the air and transported by the blood to every cell in all the tissues of the body. The cells make use of this oxygen for the life process known as metabolism for the production of energy for its activities. The end product of the utilization of oxygen in the cells is the production of carbon dioxide. The resultant carbon dioxide is transported back to the environment. This process of exchanging oxygen and carbon dioxide between the cells and the environment is called respiration. There are two phases in respiration. The first phase known as ventilation involve inhalation of air rich in oxygen and exhalation of carbon dioxide rich air. The oxygen rich air from the environment and carbon dioxide rich air from the cells are diffused into and transported in the blood. The second phase of respiration is called cellular respiration. Cellular respiration explains how the cells utilize oxygen and release of carbon dioxide and energy during metabolism.

Digestion

The body needs fuel for its numerous functions. This fuel is taken into the body in the form of food. The ingested food need to be broken down into simpler molecules before it can be absorbed into the blood and utilized by the body for its metabolic functions. This process is known as digestion.

Excretion

Digestion and metabolism are two life processes that produce lots of waste products. These waste products must be removed from the body. The process of removing waste products of digestion and metabolism from the body is known as excretion. Excretion removes the by-products of digestion and metabolism that the body is not able to use. Many of these by-products are toxic and incompatible with life and so must be removed from the body.

4.0 Conclusion

Humans need to undergo these life processes to remain alive and participate in physical activities such as sports and dance. Human life also depends on some other factors from the environment including oxygen, food nutrients, heat and pressure.

5.0 Summary

Now that you have known the importance of studying anatomy and physiology in Human Kinetics Education, and the functional processes of human life you should be motivated into serious effort in this scientific endeavour. The terminologies for describing the body and its structural organisation will therefore be the focus of the next unit.

Self Assessment Exercise

1. Name 10 functional processes of human life.
2. Describe 5 of the functional processes of life that are of utmost importance to Human Kinetics Education.
3. Discuss the life processes that require water, oxygen, food nutrients, heat or pressure to function properly.

6.0 References/Further Readings

Ajiduah, A. O. (1998). *Basic theory of sports training.* Lagos: University of Lagos press

OpenStax College, *Anatomy & Physiology*. OpenStax College. 25 April 2013. http://cnx.org/content/col11496/latest/

Robergs, R. A. and Kateyian, S. J. (2003). *Fundamentals of exercise physiology for fitness, performance and health. (2nd ed)* New York. McGraw Hill.

Unit 3: Terminologies for Describing the Body and Its Levels of Organisation

1.0 Introduction

You will now be introduced to the groups of terms used for describing anatomical structures of the body. These terms are used when describing body parts and areas, structural directions, body planes and cavities of the body.

2.0 Intended Learning Outcome(s)

By the end of this unit, you would be able to

- Learned the terminologies for describing the body.
- Explain the body's general plan
- Identify the different levels of organisation

3.0 Main Content

Body Parts and Areas are terms used to describe the well defined areas and parts of the body.

Body Parts and Areas

Anatomical position

Body parts and areas are described based on standardized map of the body generally referred to as anatomical position. It is a view of the body standing, in an upright position, on feet that are parallel with forward pointing toes and separated from each other by a distance that is the same as the width of the shoulder. The upper limbs, in the anatomical position view of the body, are on each side of the body with palms of the hands facing forward. The figure below shows the front and back view of the body in anatomical position on which the body parts and areas are properly labelled. Observe that "brachium" or "arm" is a term used for the "upper arm" while the lower arm is named "antebrachium" or "forearm". In a similar vein, the term "leg" or "crus" is used to describe the portion of the lower limb that is located between the knee and the ankle.

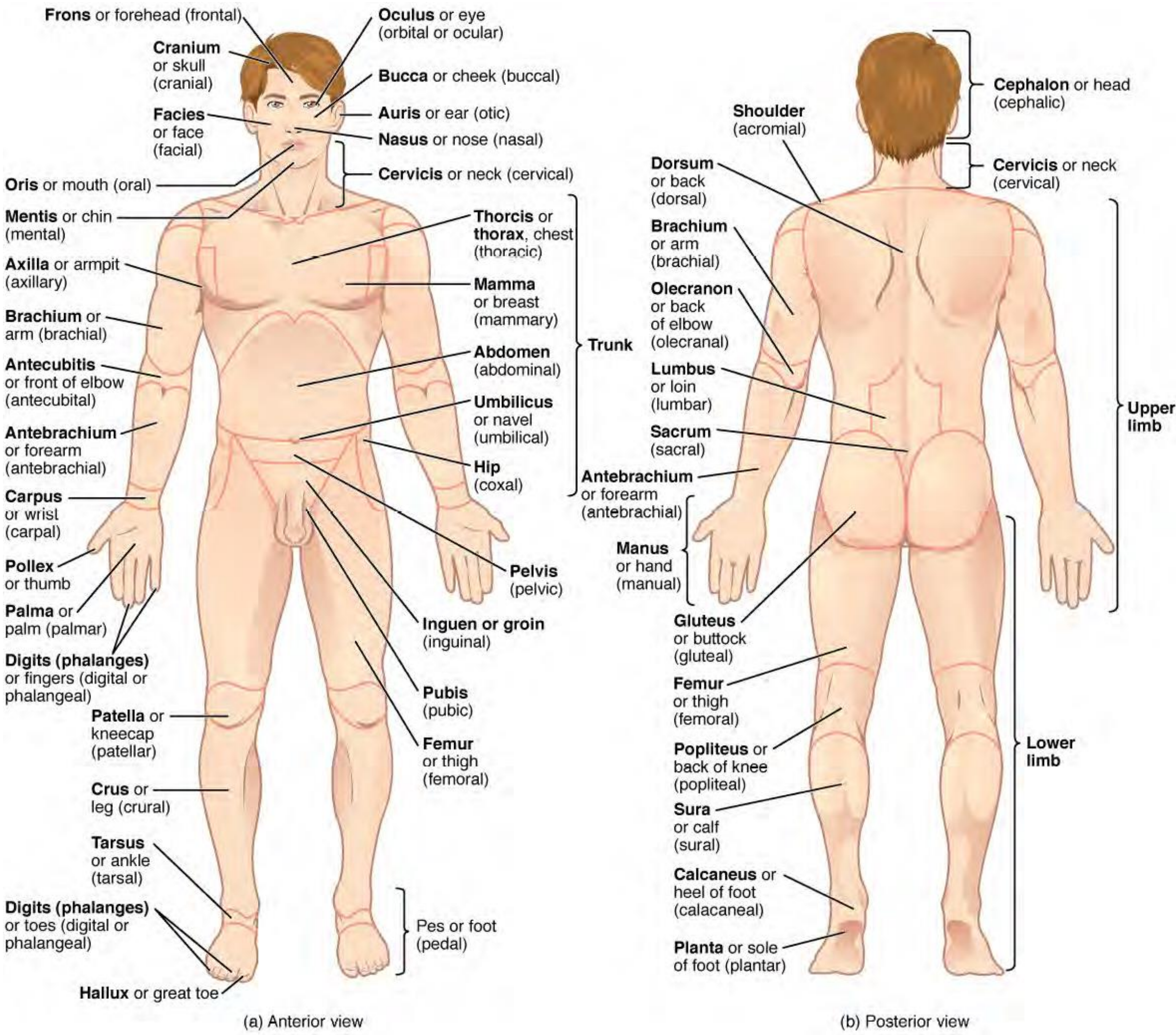


Figure 1.3.1: Body Parts and Areas shown on the Body in the Anatomical Position *(Body areas are labelled in bold face).*

Source: OpenStax College, *Anatomy & Physiology*. OpenStax College. 25 April 2013. *http://cnx.org/content/col11496/latest/ Page 25.*

Positional Terms

There are three basic positional terms used to describe a body that is lying down. These are supine, prone and lateral recumbent (which is either right or left). There are physical activities that can be performed from each of these positions in human kinetics education and sports.

Supine: This term is used to describe a body that is lying down horizontally with face looking upwards

Figure 1.3.2: Dumebi, a 400 Level Student of the Department of Human Kinetics and Health Education, Delta State University Demonstrating the Supine Position during Departmental Practicum at Abraka.

Figure 1.3.2: Dumebi is Performing Guided Physical Activities while in the Supine Position

Prone: When the body is lying down horizontally with the face looking downwards.

Figure 1.3.3: Sandra, a 200 Level Student of the Department of Human Kinetics and Health Education, Delta State University Demonstrating the Prone Position during Departmental Practicum at Abraka.

Figure 1.3.4: Sandra is Performing Guided Physical Activities while in the Prone Position

Lateral Recumbent: Describes a body that is lying down on its side. It is termed 'Right Lateral Recumbent' when the body is lying down on its right side and 'Left Lateral Recumbent' when it is lying down on its left side.

Figure 1.3 6: Victor, a 400 Level Student of the Department of Human Kinetics and Health Education, Delta State University Demonstrating the Lateral Recumbent Position during Departmental Practicum at Abraka.

Figure 1.3.7: Victor is Performing Guided Physical Activities while in the Lateral Recumbent Position

Directional Terms

The way cardinal points are used on a map in geography to describe locations, such as north, south, east, west, northeast, northwest, southwest, southeast and so on, so too are directional terms used in anatomy to describe areas of the body. The following are some directional terms used in anatomy to describe the positions of an organ or system in relation to some other structures' position or location in the body.

Superior or cranial

This term is used for describing a structure that is nearer the head or on the upper part of the body in relation to another specific structure(s). For example, when we say the hand is superior to the leg, we mean the hand is on the upper part of the body or the hand is nearer the head than the leg in its location on the body.

Inferior or caudal

This term is used to describe those structures that are positioned farther away from the head. For example, when we say that the foot is on the inferior extremity, we mean the foot is located at a position that is farthest from the head.

Anterior or ventral

This term describes a structure that is located in front of another structure on the front part of the organ or system. For example, the eyes are located on the anterior part of the head.

Posterior or dorsal

This term is used to describe the back position. For example, the buttocks are located on the posterior side of the body.

Medial

This is a term which describes a structure that is located towards the midline of the body. For example, the longest or middle finger is located medially on the hand.

Lateral

This is a term for describing a structure that is located away from the midline of the body. For example, the little finger is located at the lateral side of the hand.

Proximal

This is a term used for describing a structure that is located toward or nearest the trunk or the point of origin of the structure. For example, the proximal end of the femur joins with the pelvic bone.

Distal

Distal describes the structure that is located further away from or farthest from the trunk or the point or origin of the structure. For example, the foot is located at the distal end of the leg.

Superficial

This term is used for describing positions that nearer the body surface in relation to others. An example is when it is stated that skin is a superficial organ when compared to the bones.

Deep

This term is used for describing positions that are farther away from the body surface in relation to others. An example is when it is stated that skeletal muscles are deep when compared to the skin.

Planes of the Body

A plane is defined as an imagined flat surface that cuts across the body. There are three of these imaginary planes that run vertically or horizontally through an upright human body.

Coronal Plane (Frontal Plane)

This is a vertical plane that runs from side to side. The coronal or frontal plane divides the body or any structure into anterior and posterior portions.

Sagittal Plane (Lateral Plane)

This is a vertical plane that runs from front to back. The sagittal or lateral plane divides the body or any of the structures within it into right and left sides.

Axial Plane (Transverse Plane)

This is a horizontal plane that runs across the body or any of its structures. The axial or transverse plane divides the body or any of its structures into upper and lower parts.

Median plane

This is another term for describing the sagittal plane. The median plane runs through midline of the body or structure dividing it into right and left halves.

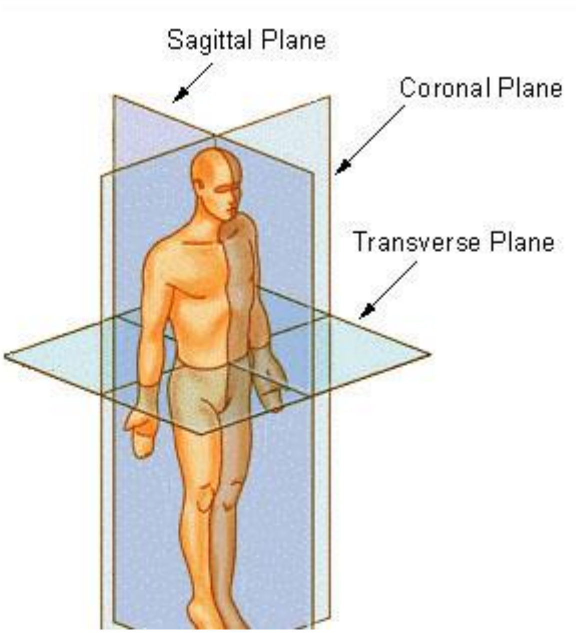


Figure 1.3.8: Planes of the body. **Source:** ICD-0-3 (2007)

Body Cavities

The internal organs of the body or viscera are placed in cavities within the body. There are two main cavities or spaces that house the internal organs in the body. These are the dorsal and ventral cavities.

Dorsal cavity

This is the smaller of the two main cavities containing organs which lie at the back or posterior end of the body. There are two portions in the dorsal cavity. The upper portion known as the cranial cavity contains the brain while the lower portion known as the vertebral canal contains the spinal cord.

Ventral cavity

The larger of the two main body cavities, the ventral is subdivided into two parts known as the thoracic and the abdominopelvic cavities. The dome-shaped respiratory muscle, the diaphragm, separates the thoracic cavity from the abdominopelvic cavity.

Thoracic cavity

This is the upper portion of the ventral cavity. The thoracic cavity also known as chest cavity houses the heart, lungs, trachea, oesophagus, large blood vessels, and nerves. Laterally, the thoracic cavity is bound by the ribs, and caudally by the diaphragm. In other words, the thoracic cavity is surrounded by the rib cage known as the costal pleura and the diaphragm known as the diaphragmatic pleura.

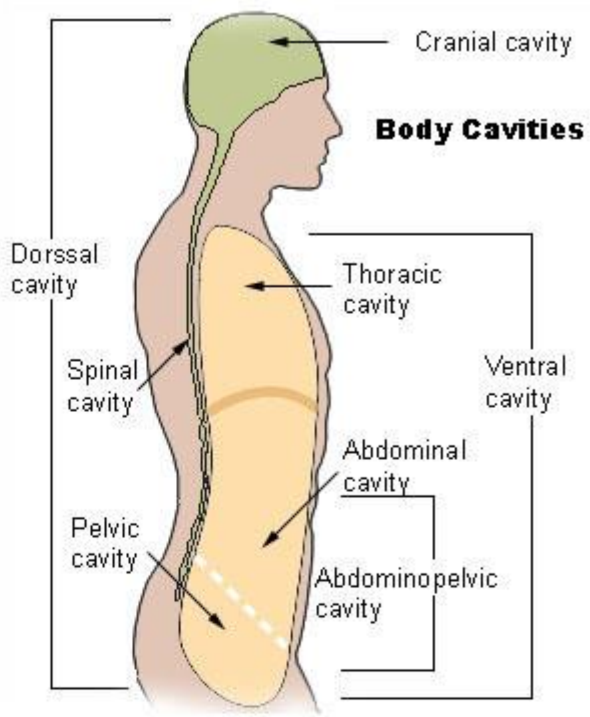


Figure 1.3.9: Body Cavities. Source: ICD-0-3 (2007)

Abdominopelvic Cavity (Abdominal and pelvic cavity)

This is a combination of the abdominal and pelvic cavities. The abdominal cavity which is bound on the superior end by the diaphragm, laterally by the body wall and inferiorly by the pelvic cavity houses most of the organs in the gastrointestinal tract as well as the kidneys and adrenal glands. Most of the urogenital system and the rectum are contained within the pelvic cavity. The pelvic cavity is bounded by the abdominal cavity on the superior end, by the sacrum on the end, and by the pelvis laterally.

Levels of Organisation

It is important you understand, right from this beginning, that there is an order in the structural and functional organization of the human body. This structural and organizational order shows how the smallest components of the body, that performs simple functions, are packaged into larger structures that perform more complex functions. There are six different levels of organization in the human body and these increases in structural and functional complexity. The levels are chemical, cell, tissue, organ, organ system and the whole human organism.

At the lowest level, chemicals combined to form and function in cells and their organelles. At the next level, the cell level, cells combine to form and function as tissues. At the tissues level, tissues combine to form and functions as organs. At the organ system level, organs are assembled in such a way that they can cooperatively perform the more complex functions of the organ systems. The final level is the organism level where all the organ systems are packaged together so that they can function harmoniously in the human organism.

The levels of organization of the human body is diagrammatically presented in the diagram below.

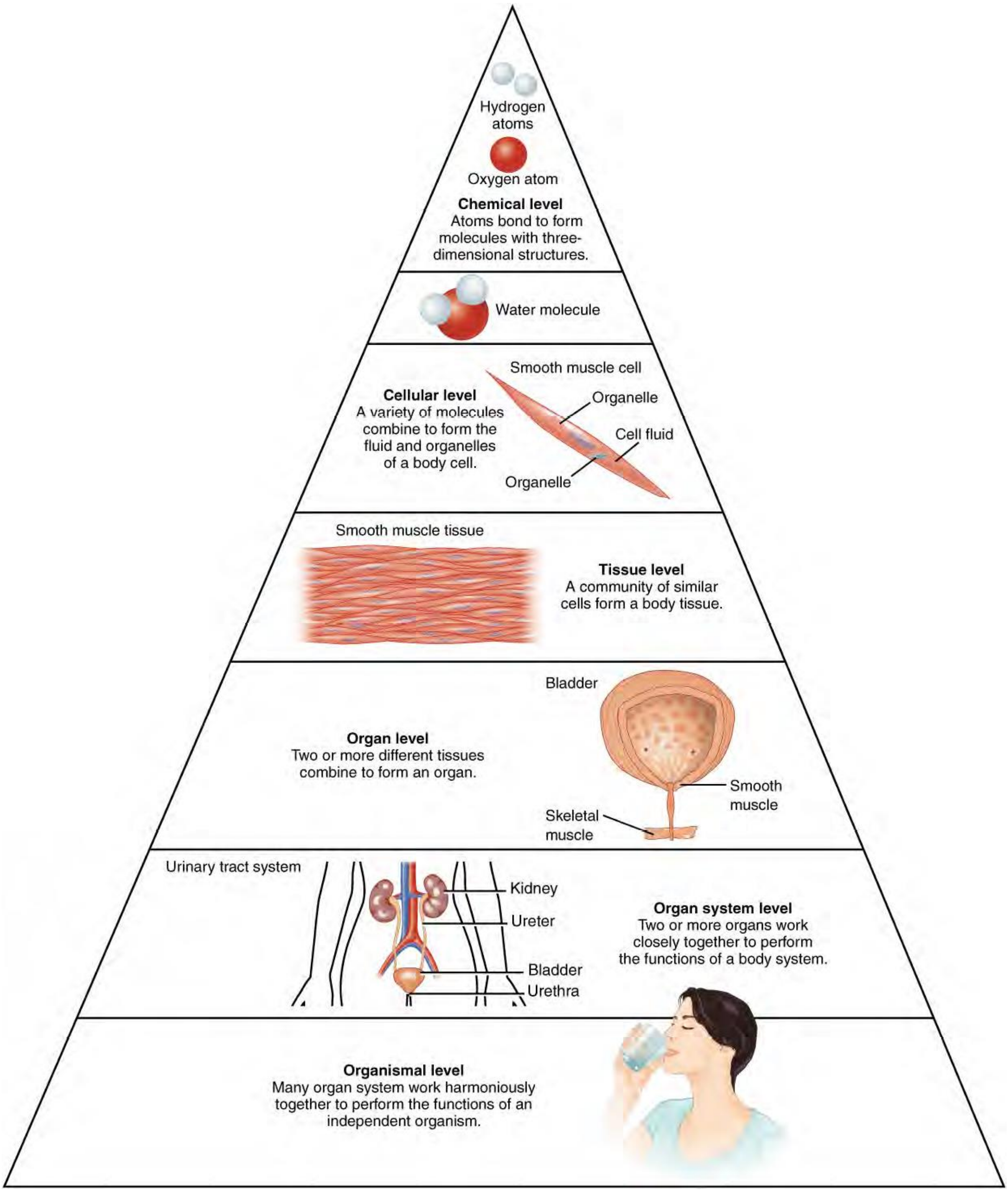


Figure 1.3.10: Levels of Organisation of the Human Body. Source: OpenStax College, *Anatomy & Physiology*. OpenStax College. 25 April 2013. *http://cnx.org/content/col11496/latest/ Page 12.*

4.0 Conclusion

There are terminologies used for describing the body and the body's general structural plan. These terms include those for describing body areas and parts, directional terms and cavities in the body. The levels of organisation the human body are also important in the understanding of the structure and function of the body.

5.0 Summary

You have learned that body areas and parts, cavities within the body directions are used to show the body's general plan. The knowledge you obtained, in this unit, that the body is organised in structural levels has prepared you for a more detailed study of the body's structure and function at the chemical level in the next unit.

Self-Assessment Exercise

1. What do you understand by the phrase "anatomic position"?
2. Name an organ that is superior to the mouth and one that is inferior to it (mouth).
3. The nose is located on the ………..part of the head. (a) anterior (b) posterior (c) lateral (d) medial.
4. The ears are located on the ………..parts of the head. (a) anterior (b) posterior (c) lateral (d) medial.
5. There are two major cavities in the body within which there are five minor cavities. Describe these cavities with the aid a diagram.
6. An imaginary section that cuts the body into two equal right and left halves is known as ……
7. An imaginary section that cuts the body into two equal anterior and posterior halves is known as ……….
8. An imaginary section that cuts the body into two equal superior and inferior halves is known as ……
9. Name the structure that is formed when similar cells combine to perform a simple function for the body.
10. Name the structure that is formed when a group of organs are linked and cooperate to perform a complex function for the body.
11. The two major cavities in the body are
    a. Cranial cavity and spinal cavity
    b. Dorsal cavity and thoracic cavity
    c. Ventral cavity and dorsal cavity
    d. Abdominal cavity and pelvic cavity
12. The following cavities in the body are completely surrounded by bone
    a. Cranial cavity and spinal cavity
    b. Dorsal cavity and thoracic cavity
    c. Ventral cavity and dorsal cavity
    d. Abdominal cavity and pelvic cavity
13. The following cavities in the body are lined by meninges
    a. Cranial cavity and spinal cavity
    b. Dorsal cavity and thoracic cavity
    c. Ventral cavity and dorsal cavity
    d. Abdominal cavity and pelvic cavity
14. The section through the body that would result in equal right and left halves is called ------
    a. Sagittal plane
    b. Transverse plane
    c. Coronal plane

d. Longitudinal plane

15. The section through the body that would result in equal superior and inferior parts is called ----
    a. Sagittal plane
    b. Transverse plane
    c. Coronal plane
    d. Longitudinal plane

6.0 References/Further Readings

Ajiduah, A. O. (1998). *Basic theory of sports training.* Lagos: University of Lagos press

OpenStax College, *Anatomy & Physiology*. OpenStax College. 25 April 2013. *http://cnx.org/content/col11496/latest/*

Robergs, R. A. and Kateyian, S. J. (2003). *Fundamentals of exercise physiology for fitness, performance and health. (2nd ed)* New York. McGraw Hill.

Module 2 Chemical and Cellular Composition of the Body

You learnt, in the last unit of Module 1, that the body is organised in six different levels that increases in structural and functional complexity from chemical, cellular, tissue, organ, and organ systems to the whole human organism level. You had also learnt that it is chemicals that react in the body to form cells, cells combine to form tissues, tissues combine to form organs, while organs combine to form systems that are packaged into the integumentary system to form the whole body. In this module you will be introduced to how chemicals combine/react to form the cells of the body. This module will also introduce you to the basic structure and function of the human cell and its organelles.

Unit 1 Basic Chemical Composition and Chemical Reactions in the Body

1.0 Introduction

The study of the structure of the body (anatomy) should start with the study of the basic chemicals that make up the body. It is because basic chemicals are the smallest materials that comprise the human body. In fact there are carbon-based (organic) molecules, inorganic molecules and bio-chemicals (those chemicals produced by the body) that participates in different types of chemical reactions in the body as it carry out its life's functional processes (physiology). In this unit you will examine the basic structural units of matter (atoms) and how the number of their subatomic particles (protons, neutrons, and electrons) determines the characteristics of the elements they combine to form and how these function in the sustenance of life.

2.0 Intended Learning Outcome(s)

By the end of this unit, you would be able to

- Describe an atom, element, molecule and compound.
- Explain how atoms combine to form molecules and compounds of matter.
- Show how the number of electrons in an atom is related to the stability of the chemicals they form.
- Identify the most common elements found in the human body
- Describe the different types of chemical bonds in the formation of matter
- Explain chemical reactions and distinguish between decomposition and synthesis reactions in the formation of matter

3.0 Main Content

The Basic Components of Matter: Atoms, Elements, Molecules and Compounds

Atoms

Everything, living and nonliving, in the whole world is made up of matter. Matter is defined as anything that has weight and occupies space. The atom is the smallest particle of matter in that it cannot be created nor easily broken down into simpler substances. When an atom happens to be broken up by very severe means or viewed under a high resolution electron microscope, it becomes possible to identify three subatomic particles known as protons, neutrons, and electrons. At the centre (scientifically called the nucleus) of an atom is the positively charged subatomic particle, proton, and the neutron that has no electrical charge and so it is described as being electrically neutral. Orbiting around the nucleus of the atom is the electron that is negatively charged. Every atom is neural in charge because it usually has an equal number of protons and electron.

There are different types of atoms in nature that are distinguishable by their atomic number and atomic weight. Atomic number is described as the number of protons that is equal to the number of electrons in an atom while atomic weight is described as the combined weight of the protons and neutrons in the atom. Electrons are considered to be weightless and move or whiz around the nucleus of the atom in an orbit of shells or energy levels that are specifically arranged. The arrangement is such that the shell which is closest to the nucleus can contain at most two electrons while others are capable of containing eight or a multiple of eight electrons. When an electron shell contains the maximum number of electrons it is capable of containing, the shell is considered stable. Thus, the first shell is said to be stable when it contains its maximum number of two electrons while the second is stable only when there are eight electrons in it. The other shells which are further away from the nucleus are also stable when they contain eight electrons, or a multiple of eight. An atom's outermost shell is known as its valence shell while the number of electrons in the atom's outermost shell is known as the atom's valency. An atom that has its valence shell full with the maximum number of electrons it is capable of containing is a stable or inert atom.

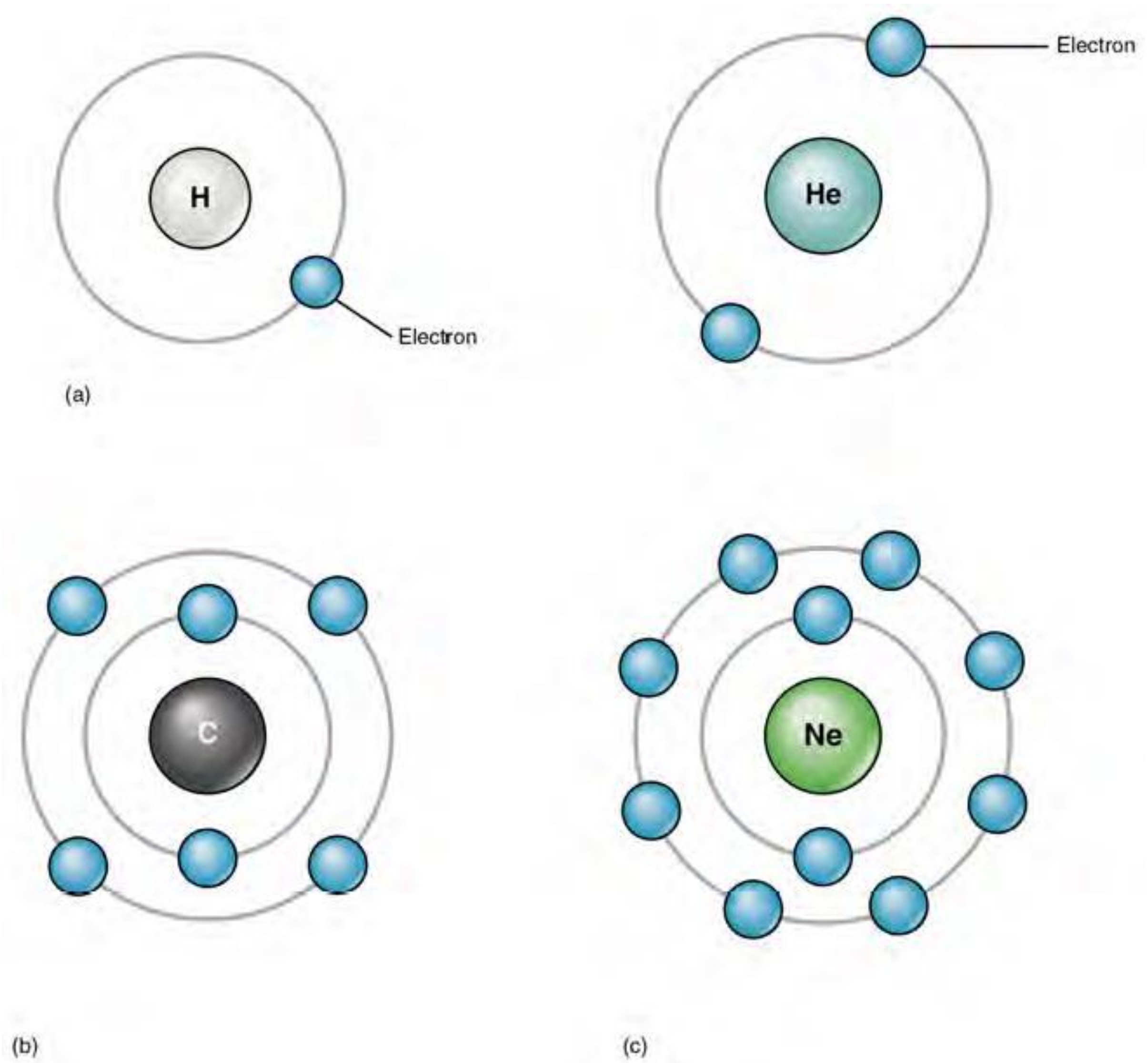


Figure 2.1.1: Atoms with Stable and Unstable Valence Shells. **Source:** OpenStax College (2013, *Page 48).*

The figure shows that: (a) hydrogen atom has only one electron shell with just one electron occupying it. It is unstable because its valence shell is not completely filled. The helium atom also has one electron shell with two electrons in it. It is stable because its valence shell is completely filled

(b)The carbon atom has two electron shells with six electrons occupying them. It is unstable because its valence shell has just four electrons and so it is not completely filled.

(c) The neon atom also has two electron shells with ten electrons occupying them. It is stable because its valence shell is completely filled with eight electrons.

Elements

Atoms do not exist on their own in nature. They exist as elements of several atoms joined together by very strong chemical bonds. An element is the resulting pure substance that is formed when the same type of atoms combine to exist in nature. It is for this reason that an atom is said to be the smallest unit of an element or matter. A total of 92 naturally occurring elements have been discovered. Among the discovered elements are carbon (C), calcium (Ca), hydrogen (H), nitrogen (N), and oxygen (O). Observe that one or two letters are placed in a bracket in front of each of these elements. These letters, first or first and second, of the name of the element is its standard chemical symbol. When two letters are used, the second letter is in lower case. Sometimes, the first or first and second letter of an element's Latin name is used as its standard symbol. For example, the standard chemical symbol of iron and sodium and 'Fe' and 'Na' because the Latin name of these elements are Ferous and Natrium respectively. It is important that you become familiar with these symbols because most textbooks, scholarly writings and laboratory reports among others, which you may come across or consult during the course of your study, make use of these symbols.

Over 99% of every human being's body is made up of carbon, hydrogen, oxygen, nitrogen, phosphorus, sulfur and calcium. To be precise, 65% of the body is made up of Oxygen (O) followed by Carbon (C, 18.5%), Hydrogen (H, 9.5%), Nitrogen (N, 3.3%), Calcium (Ca,1.5%),Phosphorus (P, 1.0), Potassium (K, 0.4%), Sulphur (S, 0.3), Chlorine (Cl, 0.2%), Sodium (Na, 0.2), Magnesium (Mg, 0.1%). The following elements exist as trace elements because all them combined account for less than one percent of the body: Boron (B), Chromium (Cr), Fluorine (F), Manganese (Mn), Molybdenum (Mo), Selenium (Se), Silicon (Si), Tin (Sn), Vanadium (V), Iron (Fe), Cobalt (Co) Copper (Cu), Zinc (Zn) and Iodine (I).

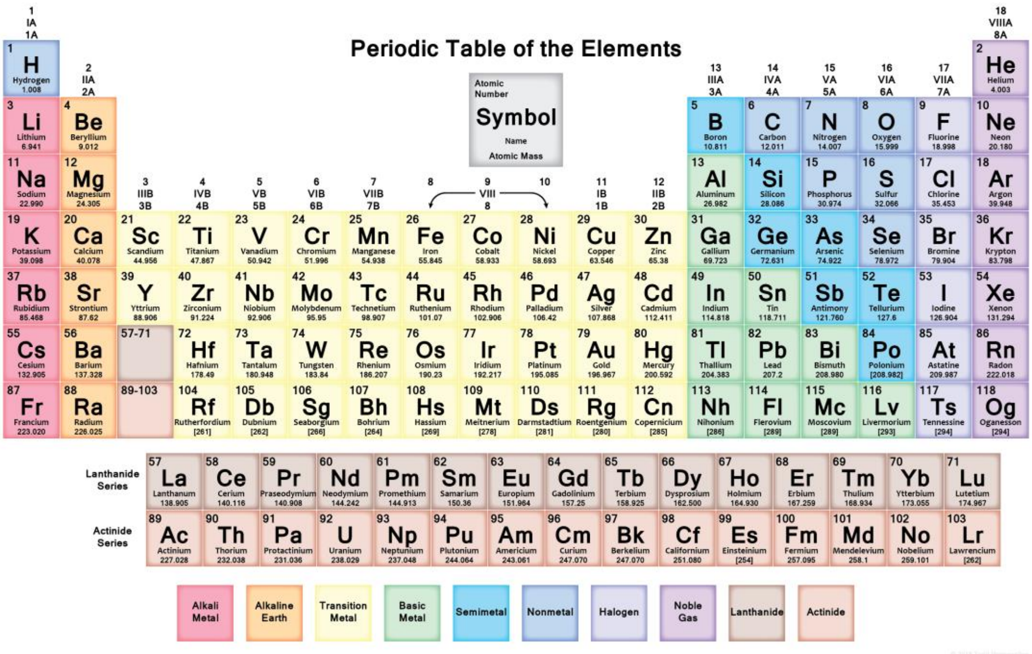


Figure 2.1.2: Periodic Table of Elements. **Source:** https://sciencenotes.org/printable-periodic-table/)

Molecules and Compounds

All the 92 elements found in nature do not normally exist by themselves alone. The atoms in them are joined with the atoms of other elements through chemical bonds and exist as chemical compounds. The smallest unit of a compound is known as the molecule. For example, water (H_2O) is a chemical compound whose molecule has two atoms of hydrogen chemically joined to one atom of oxygen. Glucose ($C_6H_{12}O_6$) is another compound that has six atoms of carbon chemically joined with six atoms of oxygen atoms and 12 atoms of hydrogen. The important thing to note is that every compound has specific types and amounts of atoms of different elements that are joined chemically in a specific way. Another important point to note is that while it is relatively easy to separate the elements in a compound by simple chemical means, it is a very difficult task to separate the atoms in an element. It needs to be pointed out too that while elements retain the physical characteristics of the atoms that form them, those of molecules are usually different from those elements whose atoms were bonded to form them. For instance, the atoms of the gaseous elements, hydrogen and oxygen, can be chemically bonded to form molecules of water that can exist as a liquid, solid or gas (steam).

Chemical Bonds and Chemical Reactions

There are only a few naturally occurring elements whose atoms have their valence shell filled with electrons. Helium and neon are gases that seldom react with other elements because the valence shells of their atoms are completely filled and so they are referred to as stable or inert elements. Whenever, the valence shells of the atoms that make up an element are not filled, such atoms are said to be reactive in accordance with the octet rule. The octet rule states that a reactive atom usually gives, collect, or share electrons with another atom in the effort to make its own valence shell to be completely full. The fact is that majority of the naturally existing elements have atoms that are not stable. They obey the octet rule as they form chemical bonds with atoms of other elements and become stable naturally existing chemical compounds. The chemical bonds known as ionic bonds, covalent bonds and hydrogen bonds are about the most important chemical bonds in the physiology of the human body.

Ions and Ionic Bonds

An atom that has its valence shell less than half filled with electrons has a tendency to empty it by releasing the electrons therein so as to become stable. Such an atom is no longer neutral in charge as it would then have more positively charged protons in its nucleus than electrons that orbit it. Conversely, atoms whose valence shells are more than half-filled tend to gain electrons to fill them up and become stable. Any atom that has become either more positive or negative in a manner like this is known as an ion. A positively charged ion is called a cation while a negatively charged ion is called an anion. For instance, an atom of sodium (Na) has the tendency lose the single electron that occupies its valence shell so as to become stable. The number of protons in the sodium atom would become more that of its electrons and so it becomes positively charged electrically with a valency of +1 and is named a sodium ion (Na^+). Also, an atom of chlorine (Cl) has the tendency gain one electron to fill its valence shell that already has seven electrons so as to become stable. The number of electrons in the sodium atom would become more that of its protons and so it becomes negatively charged electrically with a valency of -1 and is named a chloride ion (Cl^-). The unlike charges in these two ions of sodium and chlorine becomes attracted to one another and forms the molecule called sodium chloride (NaCl) generally known as the common table salt. The bond that makes it possible for the sodium and chloride ions to stay together as common salt is known as an ionic bond.

$$Na \quad + \quad Cl \quad = \quad NaCl$$

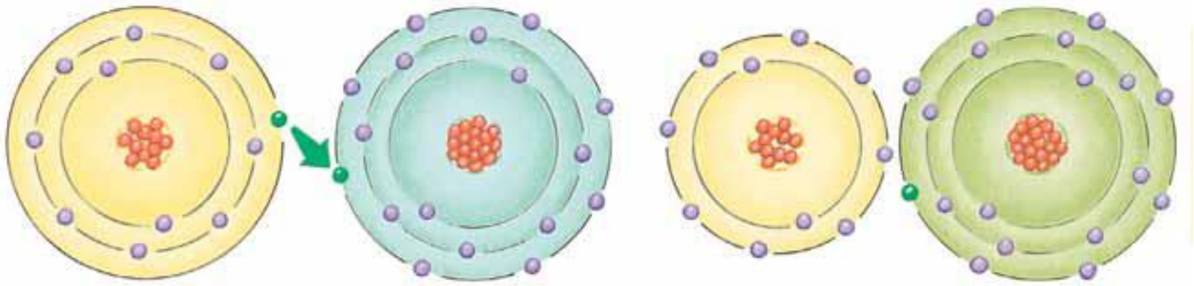


Figure 2.1.3: Ionic bonding of Sodium and Chlorine to for Sodium Chloride (NaCl), Common Salt. **Source:** Scanlon & Sanders (2007, page 26).

In Figure 2.1.3, an atom of sodium loses an electron to an atom of chlorine with the resulting positively charged sodium ion (cation) and negatively charged chloride ion (anion) remaining attached by the force of attraction of the opposite electrical charges to form a sodium chloride compound.

Ionic bonds, chemical bonds are readily broken by water. It is why atoms are mostly found as ions in body fluids. The separated ions of ionic bonds dissolved in the water of body fluids behave in such a manner that makes the body to become electrically charged and body fluids are generally referred to as electrolytes. It is this behaviour of dissolved ions in body fluids that makes it possible to trace heart and brain functions with the aid of electrocardiography (EKG or ECG) and electroencephalography (EEG).

Covalent Bonds

When two atoms decide to share their valence shell electrons so as to become stable, the chemical bond formed is known as covalent bond. Valence shell electrons of two or more atoms are mutually shared in covalent bonding unlike the situation in ionic bonding in which electrons are permanently donated or gained by atoms. For the reason of the intimate sharing of electrons, covalent bonds are relatively stronger in that they are not readily separated in the water of body fluids. Covalent bonds are described as single, double or triple covalent bonds and are so reflected in the writing of structural formulae of molecules. A single covalent bond results when a pair of electrons is shared by two different atoms. A single covalent bond is shown by a single line. A double or triple covalent bond results when two or three pairs of electrons are respectively shared by two different atoms. A double or triple covalent bond is shown by two or three lines respectively.

Covalent bonds exist as either polar or non-polar covalent bonds that produce polar or non-polar molecules. When the atoms that are involved in a covalent bond are not equal in size, there is a tendency for the shared electrons in such a molecule to be pulled more towards the heavier atom. The portion of the heavier atom in the molecule becomes relatively more negative while region of the smaller atom becomes more positive. Such molecules are described as polar molecules. Conversely, when the atoms that are involved in a covalent bond are equal in size, the tendency is for the shared electrons to be pulled equally in such a molecule by the two atoms. Such molecules are therefore described as non-polar molecules because the resulting molecules are electrically balanced.

Examples:

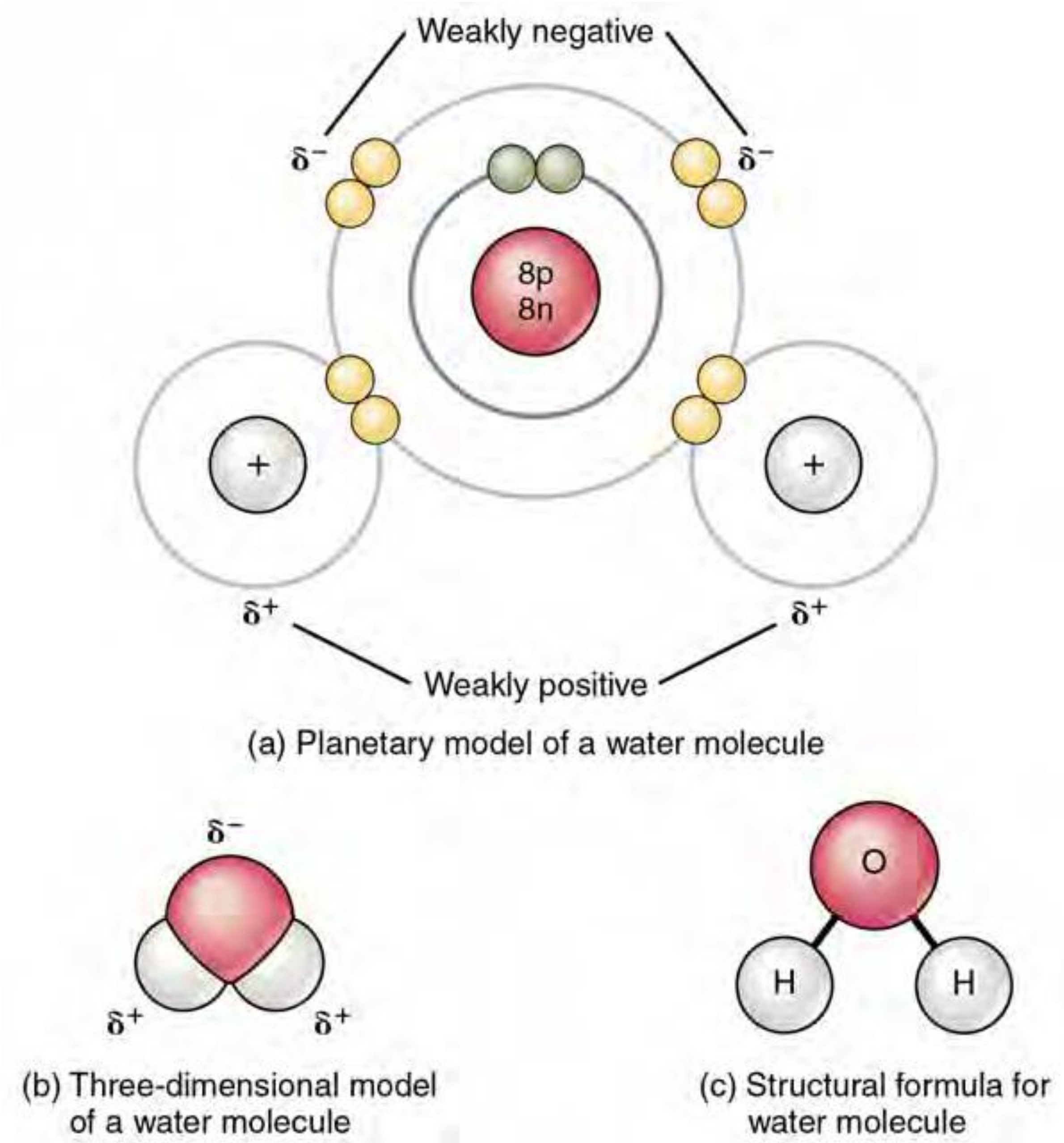


Figure 2.1.4: Polar Covalent Bonds in a Water Molecule. **Source:** OpenStax College (2013, *Page 53).*

Figure 2.1.4 shows a molecule of water (H2O) formed when an atom of oxygen share two of its valence shell electrons with two different atoms of hydrogen that has just one valence shell electron each to share. The bonds between the oxygen and hydrogen atoms are two single covalent bonds as shown in the structural formula. The water molecule has a region, the oxygen part of the molecule that is slightly positive in charge. The regions of the water molecule containing the two hydrogen atoms are slightly positively charged. Please note that the regional charges in this kind of polar molecule is referred to as "partial charges" because the charge is not as strong as the charge of one full electron in an ionic bond. The Greek letter delta (∂) and a plus (+) or minus (–) sign is used to show regions of the partial charged polarities.

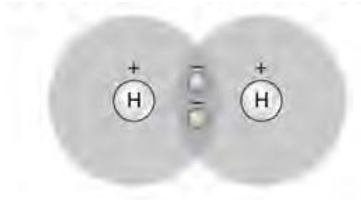


Figure 2.1.5: Single Non-Polar Covalent Bond in the Hydrogen Gas Element. **Source:** OpenStax College (2013, *Page 52).*
In Figure 2.1.5, two hydrogen atoms are shown sharing the lone electron in their valence shell in a single non-polar covalent bond. Hydrogen gas exists in its pure state as H_2 or H=H.

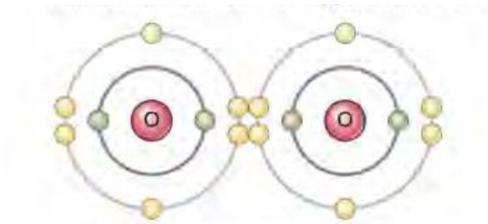


Figure 2.1.6: A Double Non-Polar Covalent Bond in the Oxygen Gas Element. **Source:** OpenStax College (2013, *Page 52).*
In Figure 2.1.6, two oxygen atoms are shown sharing two of valence shell electrons in a single non-polar covalent bond. Since there are six electrons in the valence shell of an oxygen atom, two atoms of oxygen decide to share two of their valence shell electrons so as to become stable so that the element, oxygen gas (O2 or O=O) can exists in nature as atmospheric oxygen.

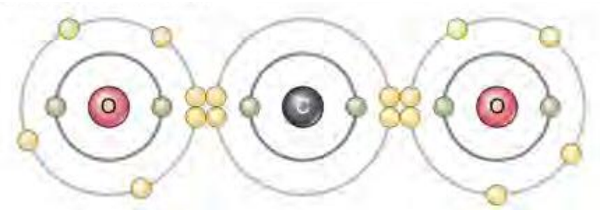


Figure 2.1.7: Two Double Non-Polar Covalent Bond Carbon Dioxide Molecule. **Source:** OpenStax College (2013, *Page 52).*
In Figure 2.1.7, two oxygen atoms are shown sharing two of valence shell electrons in double non-polar covalent bonds with one atom of carbon. Since there are four electrons in the valence shell of a carbon atom, four electrons would be needed to make it stable while oxygen requires two electrons more in its valence shell to make it stable. An atom of carbon is thus shown in Figure 2.1.7 sharing four of its valence shell electrons with four valence shell electrons of two different atoms of oxygen to form a stable molecule of the gas, carbon dioxide (CO_2 or O=C=O) that exists in nature as atmospheric carbon dioxide.

Hydrogen Bonds
Hydrogen atoms normally share their solitary electrons in covalent bonds. Anytime the bonding occurs with a heavier atom such oxygen, a polar covalent bond results with its proton having a slightly positive charge while heavier portion of the molecule remains slightly negatively charged. The slight positive charge of the hydrogen portion of such a molecule is attracted towards the heavier slightly negatively charged portions of other similar molecules. These kinds of week attractions involving hydrogen in a covalent bonding is known as hydrogen bond.

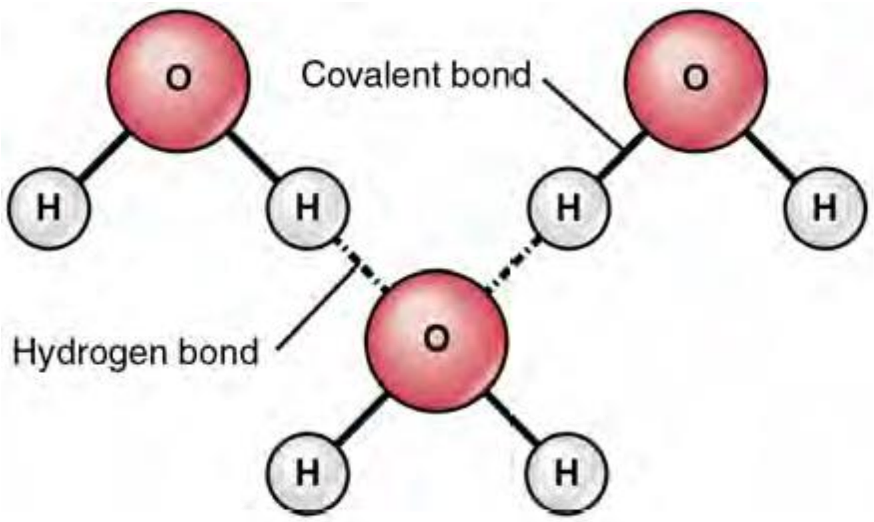


Figure 2.1.8: Hydrogen Bonds in Water Molecules. **Source:** OpenStax College (2013, *Page 54).*

In Figure 2.1.8, hydrogen bonds are shown as dotted lines between the hydrogen and oxygen of different water molecules while the covalent bonds that join hydrogen and oxygen in one molecule are shows as solid lines. Hydrogen bonds are important in human physiology in that they make water cohesive. It is the cohesiveness of water that makes blood to flow as a continuous stream in its flow inside blood vessels. It is also the cohesiveness of water help make intracellular and extracellular fluids, tissue fluid, maintain its consistent flow in and around the cells of the body.

Chemical Reactions

In the natural environment, atoms of elements and molecules of compounds interact on continuous basis. Any interaction that results to the breaking or formation of a chemical bond is known a chemical reaction. Chemical reactions bring about change in the physical and chemical characteristics of the reacting elements, molecules and/or compounds. There are two main types of chemical reactions. These are decomposition and synthesis reactions. A decomposition reaction takes place when a large molecule, upon interaction with other molecules or the environment, changes into two or more smaller ones as a result of a breakage of the chemical bonds holding it together. The digestive process that changes large molecules of carbohydrate into many smaller glucose molecules is a decomposition reaction. A synthesis reaction occurs when two or more interacting atoms or molecules form chemical bonds to a new compound. The processes that lead to the production of the protein haemoglobin of red blood cells is synthesis reaction. In fact every proteins is synthesized from a lot of amino acid molecules that are bonded

4.0 Conclusion

Atoms, the smallest unit of matter combines to form molecules while molecules combine, with the aid of ionic, covalent and hydrogen chemical bonds, to form the organic inorganic and the biochemical compounds that exist in nature and in humans. The breaking of chemical bonds within the body produces new set of chemicals through decomposition reactions while the combination of a group chemicals also produce a new chemicals for the body through synthesis reactions.

5.0 Summary

You have learnt that it is atoms, the smallest unit of matter that combines to form molecules and on to compounds of matter generally through ionic, covalent and hydrogen chemical bonding. You also learnt that it is the breaking (decomposition chemical reactions) or making (synthesis chemical reactions) of the chemical bonds that holds atoms together in a molecule and a compound that is referred to as the chemical reactions, which account for all physiological processes within the body. You are now ready to further your study, in the next unit, by learning the organic and inorganic compound that are important in the human being's body.

Self Assessment Exercise

1. With the aid of a well labelled diagram show the place of an atom in an element, a molecule and a compound.
2. What do you understand by the phrase 'Valency of an atom'? How is the valency of an atom related to the stability of the chemicals they form?
3. List and describe the different types of chemical bonds used in the formation of matter in the natural environment.
4. Explain chemical reactions and distinguish between decomposition and synthesis reactions in the formation of matter.
5. ________ is the smallest unit of an element that retains the distinctive characteristics of the element.
   a. electron
   b. atom
   c. elemental particle
   d. isotope
6. The characteristic that gives an element its distinctive properties is its number of ________.
   a. protons
   b. neutrons
   c. electrons
   d. atoms
7. How many electron shells are there in an atom of nitrogen with an atomic number of seven?
   a. one
   b. two
   c. three
   d. four
8. Which of the following is a molecule, but *not* a compound?
   a. H_2O
   b. 2H
   c. H_2
   d. H+
9. The type of chemical bonds that holds the one atom of nitrogen and three atoms of hydrogen in a molecule of ammonia are described as ________.
   a. ionic bonds
   b. nonpolar covalent bonds
   c. polar covalent bonds
   d. hydrogen bonds
10. Which of the following statements about chemical bonds is true?
    a. Covalent bonds are stronger than ionic bonds.
    b. Hydrogen bonds occur between two atoms of hydrogen.
    c. Bonding readily occurs between nonpolar and polar molecules.

d. A molecule of water is unlikely to bond with an ion.

6.0 Reference/Further Reading

OpenStax College, *Anatomy & Physiology*. OpenStax College. 25 April 2013. http://cnx.org/content/col11496/latest/

Scanlon, V. C. and Sanders, T. (2007): *Essentials of Anatomy and Physiology*. Philadelphia: F. A. Davis Company

Robergs, R. A. and Kateyian, S. J. (2003). *Fundamentals of exercise physiology for fitness, performance and health. (2nd ed)* New York. McGraw Hill.

Unit 2 Organic and Inorganic Compounds of Importance in the Human Body

1.0 Introduction

Organic compounds are substances whose molecules are made up of mainly carbon and hydrogen atoms, and are held together by covalent bonds. The structure of the human body is made up organic compounds. It is organic compound that provide energy for body functioning such as in provision of energy for sports performance. Although a lot of inorganic compounds do contain hydrogen atoms, as found in water (H_2O) and the hydrochloric acid (HCl) produced in the stomach, only a few inorganic compounds, such as carbon dioxide (CO_2), contain carbon atoms. You will study, in this unit, the structural organisation of organic and inorganic compounds in the human body and how they function in the sustenance of life.

2.0 Intended Learning Outcome(s)

By the end of this unit, you would be able to

- Describe the organic compounds that are necessary to the sustenance of life
- Describe the inorganic compounds that are important in human life

3.0 Main Content

Organic Compounds of Importance

Carbohydrates, lipids, proteins and nucleic acids are the major organic compounds that are important in the human body.

Carbohydrates

Carbohydrates are the primary sources of energy of energy for cell respiration. Carbohydrates are made up of carbon, hydrogen, and oxygen. Depending on the number sugar (saccharide) molecules in a given carbohydrate compound, it is classified either as a monosaccharide, a disaccharide, oligosaccharide or a polysaccharide. Any carbohydrate classified as a monosaccharide is made up of one sugar compound and is referred to as a simple sugar.

Monosaccharides

Pentose is a monosaccharide whose molecules contain five atoms of carbon each. Pentose compounds are structural components found in nucleic acids. For example, deoxyribose (C5H10O4), a pentose is a component of chromosomes, the genetic material known DNA. Ribose (C5H10O5) is another pentose that is a component of RNA, an essential compound in protein synthesis.

The hexoses are monosaccharides with six carbon atoms in each of its molecule. Glucose, the six-carbon sugar is a hexose with the formula C6H12O6. Fructose and galactose are also hexoses. The difference between glucose, fructose and galactose is that the atoms of carbon, hydrogen and oxygen are arranged differently. Glucose is the major source of energy for all body functions in that it is used in cell respiration for the production of ATP (Adenosine Triphosphate). Fructose and galactose are converted by the liver to glucose and so get used by cells to produce ATP, the energy rich compound that fuels all metabolic functions of the body.

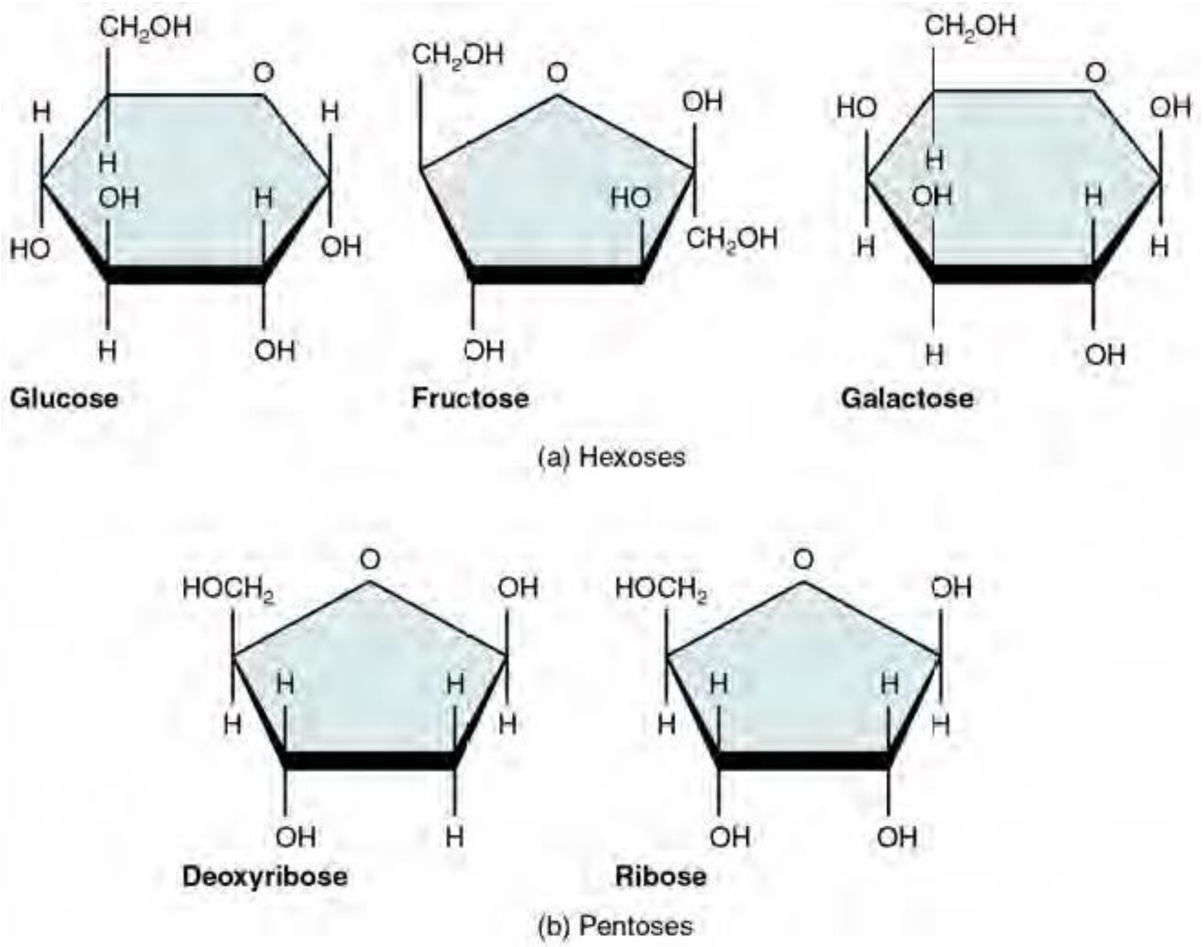


Figure 2.21: Five Important Monosaccharides. OpenStax College (2013, *Page 65).*

Disaccharides

Dissacharides are compounds whose molecules consist of two molecules of monosaccharides joined by covalent bonds. For this reason, disaccharides are known as double sugars. Examples of disaccharides that exist naturally are sucrose, lactose and maltose. Sucrose, found in sugar cane, has compounds whose molecules consist of one molecule of glucose and one of fructose each. Lactose is another naturally existing disaccharide whose compounds are made up molecules that are composed of one glucose and galactose molecules each. Maltose, made up of two glucose molecules is another naturally existing disaccharide found in food. Generally, all disaccharides found in food are digested into monosaccharides and then used for energy production.

Oligosaccharides

Oligosaccharides are made up few molecules of monosaccharide, between 3 and 20. Oligosaccharides are attached to the outer surface of cell membranes of human cells where they serve as antigens. Antigens are chemical markers used in identifying different kinds of cells. For example, the A, B, and AB blood types can be identified due to the presence of the oligosaccharide antigens found on the outer surfaces of red blood cell membranes. Every individual human being is made up cells that are peculiar to him. It is because each person's cells have antigens on the surfaces of their cell membrane that are capable of being used to identify cells that belong to him. For this reason, such antigens are referred to as "self" antigens that make it possible for our immune system to identify and reject/fight cells with antigens that are "non-self" as found in bacteria and viruses.

Polysaccharides
Polysaccharides consist of several thousand molecules of glucose held together by different types of complex covalent bond. Starches, produced in plant cells for the purpose of storing energy, are examples of polysaccharides. Starches several molecules of glucose bonded together by covalent bonds that make its molecule look like simple branched chains of glucose molecules. Starch molecules can be digested by enzymes in the stomach of human stomach by breaking the covalent bonds in the starch molecules to release its constituent glucose molecules. The released glucose molecules can then be absorbed and utilized for the production of energy for cell functioning and physical activities of sports.

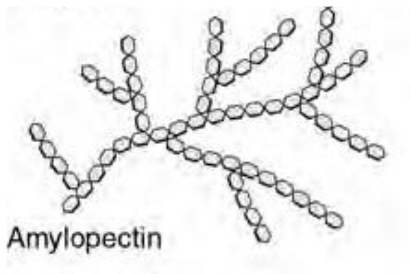


Figure 2.2.2: Starch molecule consisting of branched chains of several molecules of glucose. **Source:** OpenStax College (2013, *Page 67).*

Glycogen
Glycogen is another polysaccharide made up several chains of highly branched chain of glucose molecules. Glycogen is the form in which humans store excess glucose in the liver and skeletal muscles. A high carbohydrates' meal usually increases the glucose level circulating blood more than the required amounts. The extra glucose gets to glycogen which is stored in the liver and skeletal muscles. The stored glycogen gets broken down into glucose and released from its stores in the liver and skeletal muscles anytime there is a decrease of glucose circulating in the blood drops below required amounts for metabolic activities. Hormones such as insulin and glucagon determine when blood glucose should be converted into glycogen and when blood glucose is low enough for stored glycogen to be converted into glucose and released into the blood stream.

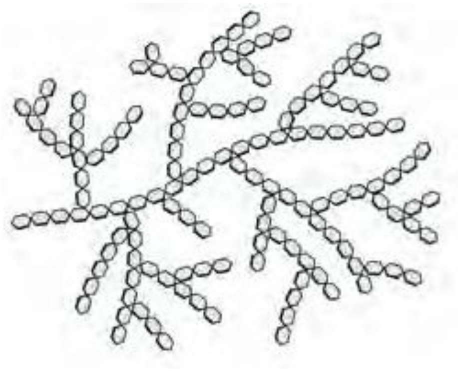


Figure 2.2.3: Gycogen. **Source:** OpenStax College (2013, *Page 67).*

Glycogen molecules are made up of several molecules of glucose bonded together by covalent bonds that make the molecule look like several and complex branched chains of glucose molecules.

Cellulose (Fibre)

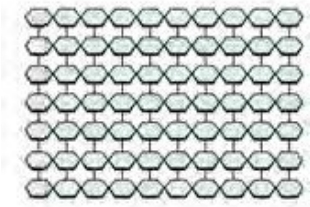


Figure 2.2.4: Cellulose (Fibre). **Source:** OpenStax College (2013, *Page 67).*

Cellulose is a nearly straight chain of glucose molecules produced by plant cells as part of their cell walls. We have no enzyme to digest the cellulose we consume as part of vegetables and grains, and it passes through the digestive tract unchanged. Another name for dietary cellulose is “fibre,” and although we cannot use its glucose for energy, it does have a function. Fibre provides bulk within the cavity of the large intestine. This promotes efficient peristalsis, the waves of contraction that propel undigested material through the colon. A diet low in fibre does not give the colon much exercise, and the muscle tissue of the colon will contract weakly, just as our skeletal muscles will become flabby without exercise. A diet high in fibre provides exercise for the colon muscle and may help prevent chronic constipation.

Fats/Lipids

Lipids are mostly hydrocarbon compounds that are made up of molecules that contain carbon, hydrogen, and a few oxygen atoms at the periphery. There are some lipids, however, which also contain phosphorus. Lipids are often described hydrophobic because the hydrocarbons in their molecules make them to be nonpolar and so cannot form true solutions with water. Lipids may, however form emulsions with water (emulsion is the word used for describing a combination of two or more substances that do not mix well). True fats, phospholipids and steroids are the three the groups of lipids that are important in human physiology.

True fats are sometimes referred to as neutral fats. True fats are composed of one molecule of glycerol and one, two, or three molecules of fatty acids. It is called a triglyceride if the one molecule of glycerol is covalently bonded to three fatty acid molecules. It is known as a diglyceride if the single glycerol molecule is bonded to two fatty acid molecules. In a similar manner, a monoglyceride would come to be when the single glycerol molecule is bonded to one fatty acid.

The fatty acid molecules in a true fat are either saturated or unsaturated. A fatty acid molecule is described as being saturated when all the carbon atoms have single covalent bonds. In other words, the carbon atoms in a saturated fatty acid molecule have their valence shells filled by sharing electrons with four different atoms. When the covalent bonds holding the carbon atoms are not all single but double or poly, the resulting fatty acid molecule is described as being an unsaturated fatty acid. At room temperature, saturated fats are often in solid form, while unsaturated fats are often (not always) in liquid form at room temperature. This is because saturated fat molecules have no double carbon bonds anywhere along their length and are arranged in such a way that they form straight, rigid chains of tightly packed molecules. Saturated fats tend to be found in animal foods such as beef, pork, eggs, and cheese, although palm oil and coconut oil are also saturated. Unsaturated fats tend to be liquid at room temperature. This is because unsaturated fat molecules have one or more double carbon bonds along its chain that make them kinked instead of the straight, rigid chains of tightly packed molecules found in saturated fats. Unsaturated fats are mostly found in other plant oils such as corn oil, sunflower oil, and safflower oil. Certain fish oils such as are also unsaturated, and even pork contains unsaturated fatty acids.

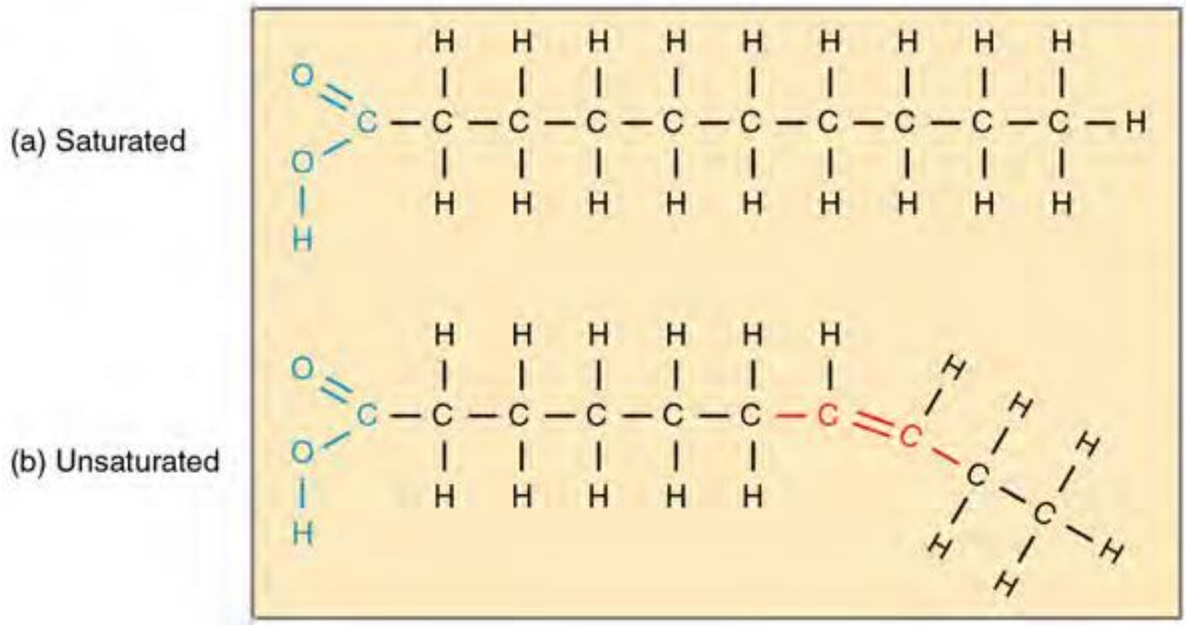


Figure 2.2 5: Shapes of Fatty Acid Molecules**. Source:** OpenStax College (2013, *Page 68). Note that in (a), the saturated fatty acid chains are straight while in (b), the unsaturated fatty acid chains are kinked.*

Triglycerides are the forms of true fats used for storage of excess food in the body. Any type of energy giving food such as carbohydrates, fats and oils, and protein consumed in excess of the body's caloric needs gets converted to fat and stored in adipose tissue. Adipose tissue is found in subcutaneous, the area between the skin and muscles, and around some organs such as the eyes and kidneys where it acts as a cushion to absorb shock.

Trans Fats

Hydrogen atoms may be chemically added to unsaturated fats to make them become saturated fats. Such chemically treated unsaturated fats are called Trans fat. Trans fats are usually added to packaged foods to make them more tasteful and allow them to be stored longer without refrigeration (a longer shelf life). Trans fats are also called hydrogenated fats because hydrogen atoms were chemically added to unsaturated fats to create them. Trans fats have been implicated in the abnormal deposit of cholesterol in the lumen of arteries especially the coronary arteries of the heart, which may become blocked or clogged leading a disease known as atherosclerosis.

Phospholipids

Phospholipids are compounds whose molecules consist of one molecule each of glycerol, two fatty acids and phosphorous. Although, phospholipids appear like triglyecrides in structure, they are in fact diglycerides with a phosphate group (PO4) in the third bonding site of the glycerol. There are two portions in a phospholipid molecule. The portion containing the fatty acids is hydrophobic, cannot mix with, the other portion, phosphate-containing group, is hydrophilic and so can mix with water. It is this chemical property of phospholipids that make it possible for it to blend with both fat and water. Phospholipids can disperse fats in watery liquids and so they are called emulsifiers. Phospholipids are able to act as components of the cell membrane because they can interact with both the fatty interior of cells and the watery solution outside of cells. Phospholipids are used as structural components of cells instead of for storing energy as found with triglycerides.

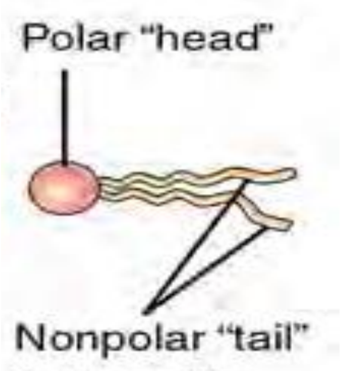


Figure 2.2.6: Schematic Diagram of a Phospholipid. **Source:** OpenStax College (2013, *Page 70).*

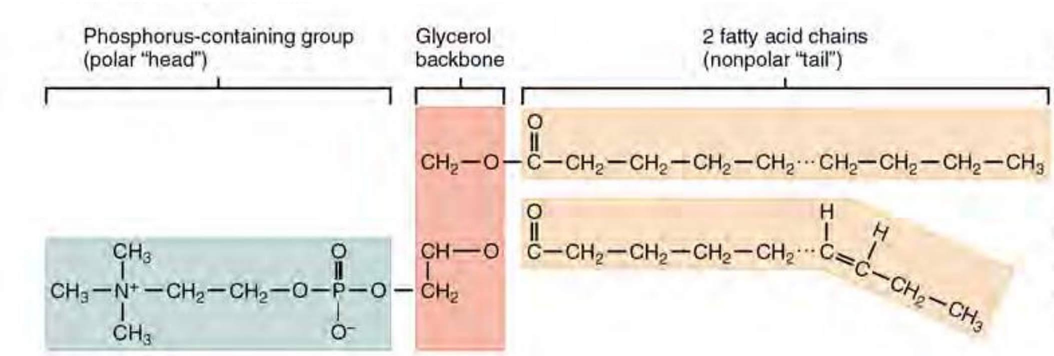


Figure 2.2.7: Phospholipids composed of two fatty acid chains and a phosphate group attached to a glycerol backbone. **Source:** OpenStax College (2013, *Page 70).*

Steroids

A steroid is compound made up of a set of four hydrocarbon rings bonded to a variety of other atoms and molecules. The chemical structure of steroids differentiates them from other lipids. Cholesterol is the most important steroid for human body structure and functioning. Cholesterol is composed of four rings of carbon and hydrogen instead of fatty acids and glycerol as found in other lipids. However, cholesterol also is like other lipids in that it has a hydrocarbon portion, like other lipids, that makes it hydrophobic and a polar hydroxyl head that makes it hydrophilic. Cholesterol is obtained from the food we eat and from the liver. Although, cholesterol is associated with development of coronary artery disease and heart attacks, it remain is very important to humans. Liver cells synthesize cholesterol and make use of it to create bile salts that fats to be digested via the process known as emulsification. It is also a component of cell membranes and a raw material (precursor) for tmaking of other steroids. It is used by the ovaries or testes to synthesize the steroid hormones estrogen or testosterone, respectively. There is a type of cholesterol that gets converted to vitamin D when the skin is exposed to sunlight.

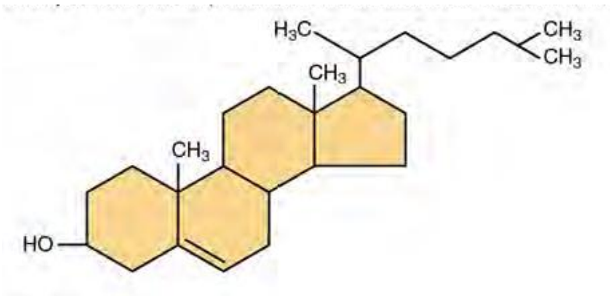


Figure 2.2.8: Four interlocking hydrocarbon rings of the steroid, cholesterol, the precursor of all steroids formed in the body. **Source:** OpenStax College (2013, *Page 70).*

Prostaglandin

Prostaglandins are similar in structure to hormone but they are derived from unsaturated fatty acids. In fact, Oomega-3 fatty acids found in fish stimulate the production of certain prostaglandins It is a sensitizing compound makes nerves to pain and helps to regulate some aspects of blood pressure, heart disease and inflammation, The group of drugs known as nonsteroidal anti-inflammatory drugs (NSAIDs) relieves pain by reducing the effects of prostaglandins.

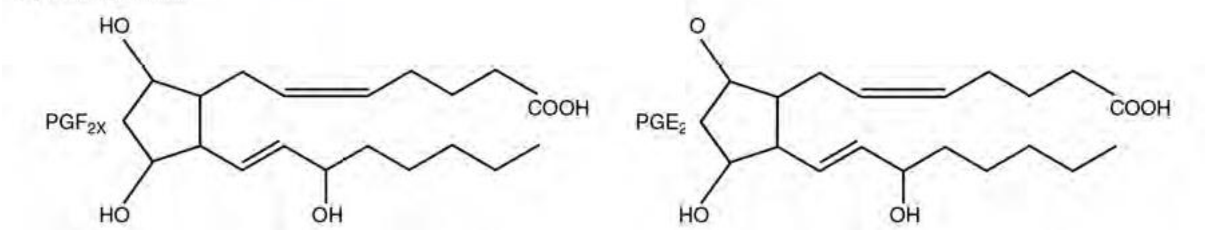


Figure 2.2.9: Prostaglandins. These are derived from unsaturated fatty acids and posses hydroxyl and carboxyl groups.

Proteins

Proteins are organic molecule compounds whose molecules are composed of amino acids linked by peptide bonds. Proteins are found as keratin in the epidermis of skin where its function is to protect underlying tissues, collagen in the dermis of skin, bones, and meninges that cover the brain and spinal cord. Many chemicals that perform important functions in the body are also made up proteins. For example, digestive enzymes, antibodies, neurotransmitters used by neurons to transfer information to other cells, peptide-based hormones that regulate certain body functions such as growth hormone are all composed of proteins.

Chemical Structure of Proteins

Proteins are made of up amino acid molecules. Every amino acid molecule is made up of carbon, hydrogen and oxygen atoms found in carbohydrates and lipids molecules plus nitrogen atoms and sometimes sulphur atoms. Every amino acid molecule has a central carbon atom covalently bonded to a hydrogen atom, an amino group (NH_2), a carboxyl group (COOH) and a variable side chain (R) as shown in the illustration below. The variable, R, could be an atom of hydrogen, a carbon-hydrogen group such as CH_3 or a more complex combination of carbon and hydrogen molecules. It is this variable, R, which makes each of these amino acid molecules distinct and different from every other one in physical shape.

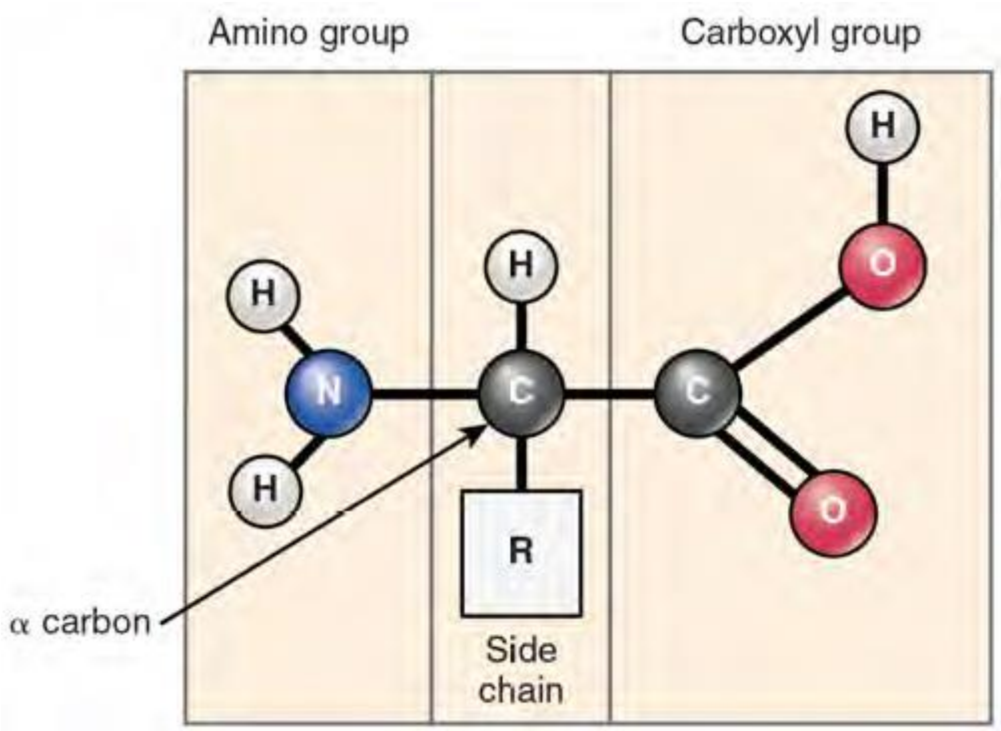


Figure 2.2.10: Basic Structure of an Amino Acid Molecule. **Source:** OpenStax College (2013, *Page 71).*

There are thousands of different types of proteins that are significantly used in the structuring and functioning of the human body. These thousands of proteins are made from only 20 different types of amino acid molecules that are joined by a type of covalent bond known as peptide bonds. The polypeptide is giant protein molecule by several amino acids joined by peptide bonds.

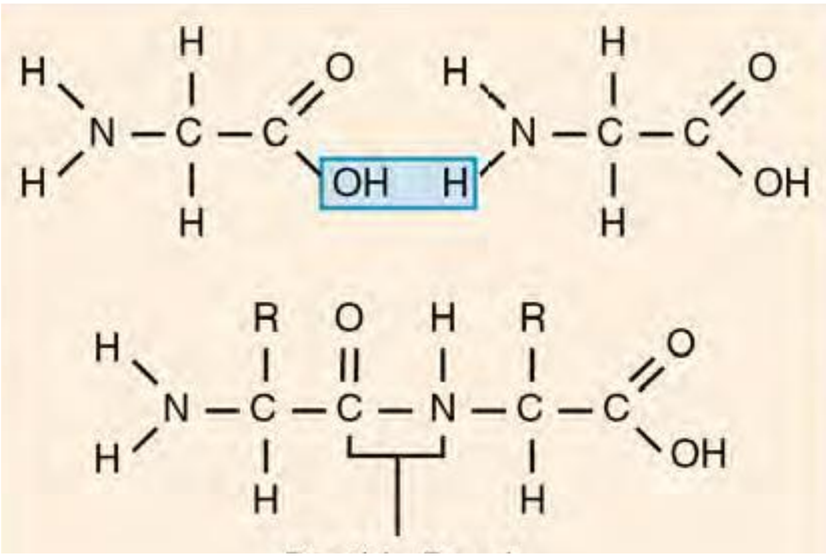


Figure 2.2.11: Peptide Bond. **Source:** OpenStax College (2013, *Page 72).*

Different amino acids join together to form peptides, polypeptides, or proteins. Eleven (11) of the 20 amino acids, that are important for body structuring and functioning, are synthesized within the body. The remaining nine (9) are obtained from food because they cannot be synthesized by the body. These nine amino acids are called essential amino acids. A protein can be made up of between 50 and several thousands of amino acids joined by peptide bonds. The amino acids in every protein are joined in a sequence that is unique and specific to it. This unique sequence, with which amino acids of a given protein, are joined is known as its primary structure.

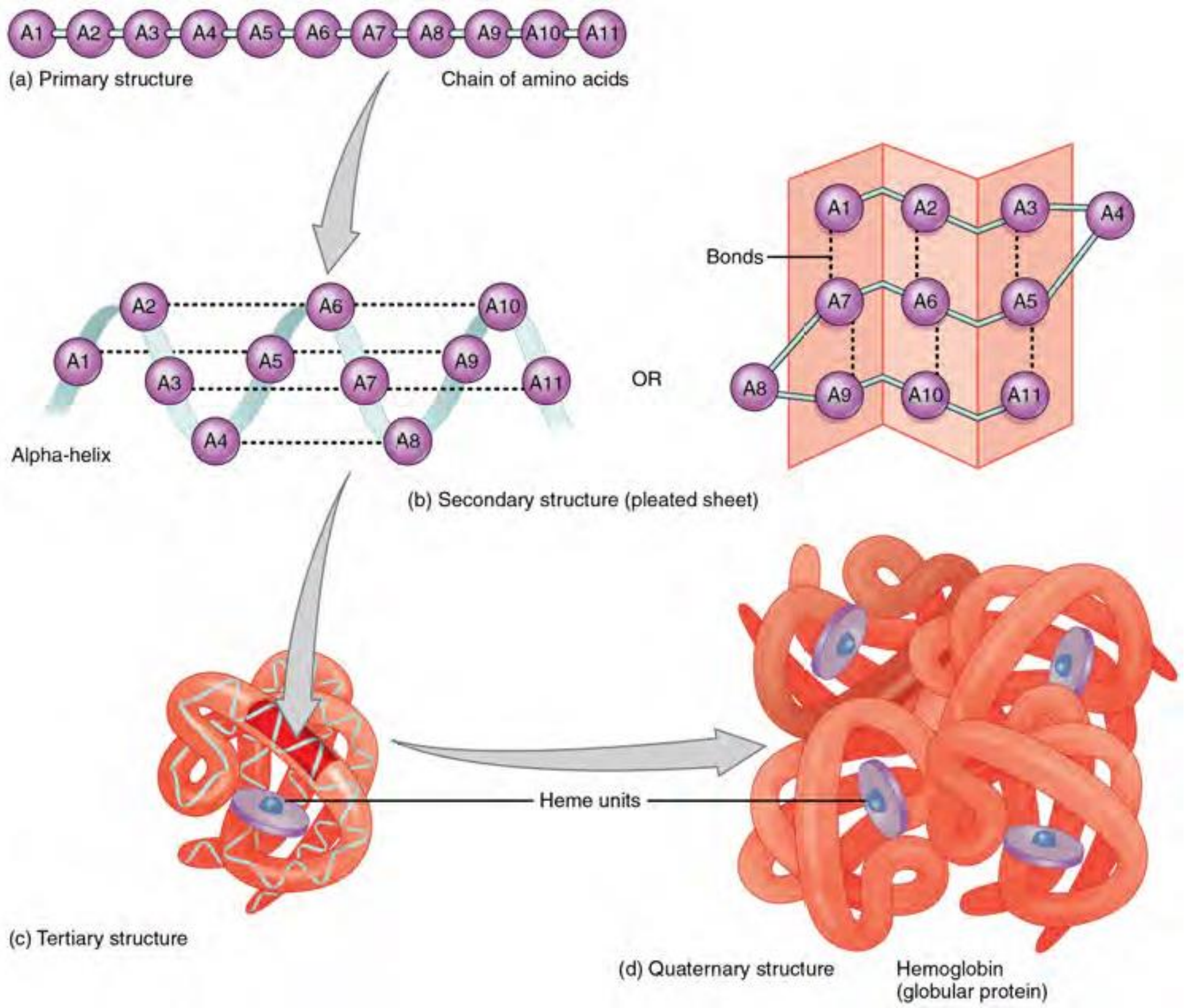


Figure 2.2.12: The sequence of amino acids in the polypeptide chains that constitute the primary, secondary, tertiary and quaternary structures of proteins. **Source:** OpenStax College (2013, *Page 73).*

The unique sequence of amino acids in the polypeptide chains of a protein may allow hydrogen bonds and disulphide bonds to be formed. These hydrogen and disulphide bonds bring about a folding of the resulting polypeptide of protein molecule. The folding may be simple, a helix (coil) or pleated sheet, and it is then called the secondary structure. The secondary structure is maintained by hydrogen bonds or disulphide bonds between amino acids in different regions of the original polypeptide strand. It can take the shape described as alpha-helix or beta-pleated sheet.

The folding can be more complex as found in a globular protein and it is called the tertiary structure of the protein. For example, myoglobin, found in muscles, is a globular protein. The tertiary structure occurs as a result of further folding and bonding of the secondary structure. Some proteins consist of more than one amino acid chain and are described as quaternary structured proteins. For example, haemoglobin found in blood has four amino acid chains. The quaternary structure occurs as a result of interactions between two or more tertiary subunits. The example shown above is haemoglobin, a protein in red blood cells which transports oxygen to body tissues.

Some proteins might need one or more trace elements such as iron and zinc so that it can perform its function properly. For example, myoglobin has an atom of iron while a haemoglobin molecule has four atoms of iron.

Functions of Proteins

Every protein has a characteristic three-dimensional shape determines its function. For this reason our body proteins have many functions.

1. The protein strands of skeletal muscle tissue have long and slender shapes, and so they can contract (shorten) and relax (lengthen).
2. The protein called collagen in bones has long threads that act as scaffolding upon which bone minerals are deposited. These are elongated proteins known as fibrous proteins which are strong and durable and are typically hydrophobic.
3. Globular proteins, on the other hand, are globes or spheres in shape that tend to be highly reactive and are hydrophilic. Globular proteins perform very critical functions all over the body since they exist in abundant quantities throughout the body including being packed as haemoglobin in red blood cells.
4. Proteins functions as enzymes. Enzymes are proteins with specific shapes that enable them to speed up chemical reactions in the body without getting changed and without a need for an external energy source. In other words, enzymes are proteins that function as catalysts. Enzymes have shapes that are specific that allow different molecules, known as substrates, to bind and react. The active site theory is used to explain how enzymes act as catalysts. Figure 2.2.13 is used to graphically explain this theory.

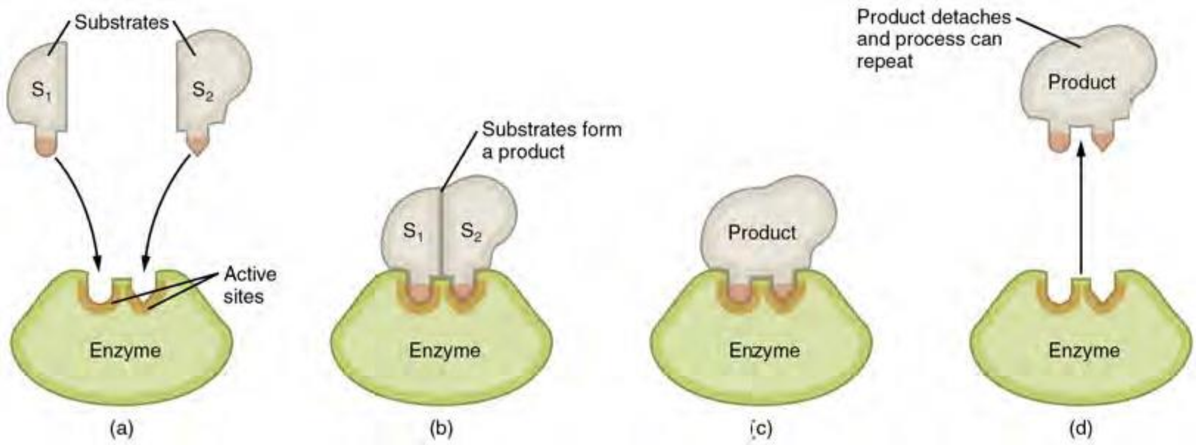


Figure 2.2.13: The Active Theory of Enzymatic Reaction. **Source:** OpenStax College (2013, *Page 74).*

(a) Substrates gets attracted to active sites on the protein, enzyme.
(b) Substrates get bound to the active sites and form an enzyme–substrate complex.
(c) The enzyme–substrates complex forces the substrates to interact; they break and/or make new chemical bonds with each other to create an entirely new molecule known as a product.
(d) Products formed do not have affinity for the enzyme and so are released returning the enzyme to its original state in which it can again enhance another enzymatic reaction.

The point to note is that;

i. There are many reactions within the body that are catalyzed by enzymes.
ii. Enzymatic reactions are specific. In other words an enzyme can facilitate only one reaction in that a substrate with a particular shape and electrical charge can bind only to an active site corresponding to that substrate. Thus the enzyme that can aid the digestion of starch cannot play any role in the digestion of meat.
iii. All enzymatic reactions occur only at specific body temperatures.

5. Protein is used for building, repairing, and maintaining muscle tissue, and every other body tissues, from the skin to the brain cells.
6. Some proteins function as hormones, chemical messengers, which help regulate body functions. Growth that is essential for bone growth is a protein.
7. Proteins act buffers that maintain the body's acid-base balance. This is possible because of their basic and acidic components.
8. Proteins help regulate fluid–electrolyte balance. Proteins attract fluid, and a healthy concentration of proteins in the blood, the cells, and the spaces between cells helps ensure a balance of fluids in these various "compartments."Proteins in the cell membrane help to transport electrolytes in and out of the cell, keeping these ions in a healthy balance.
9. Proteins can bind carbohydrates to produce glycoproteins that performs several functions in the body.
10. Anytime carbohydrate and fat intake are inadequate and there is a depletion of glycogen and adipose storage, protein becomes the source of energy for powering metabolic activities in the body.

Nucleotides

Nucleotides are the fourth type of organic compound that essential for human body structuring and functioning. A nucleotide is large molecule made up of three different types of organic molecules. These are:

• one or more phosphate groups
• a pentose sugar: either deoxyribose or ribose
• a nitrogen-containing base: adenine, cytosine, guanine, thymine, or uracil

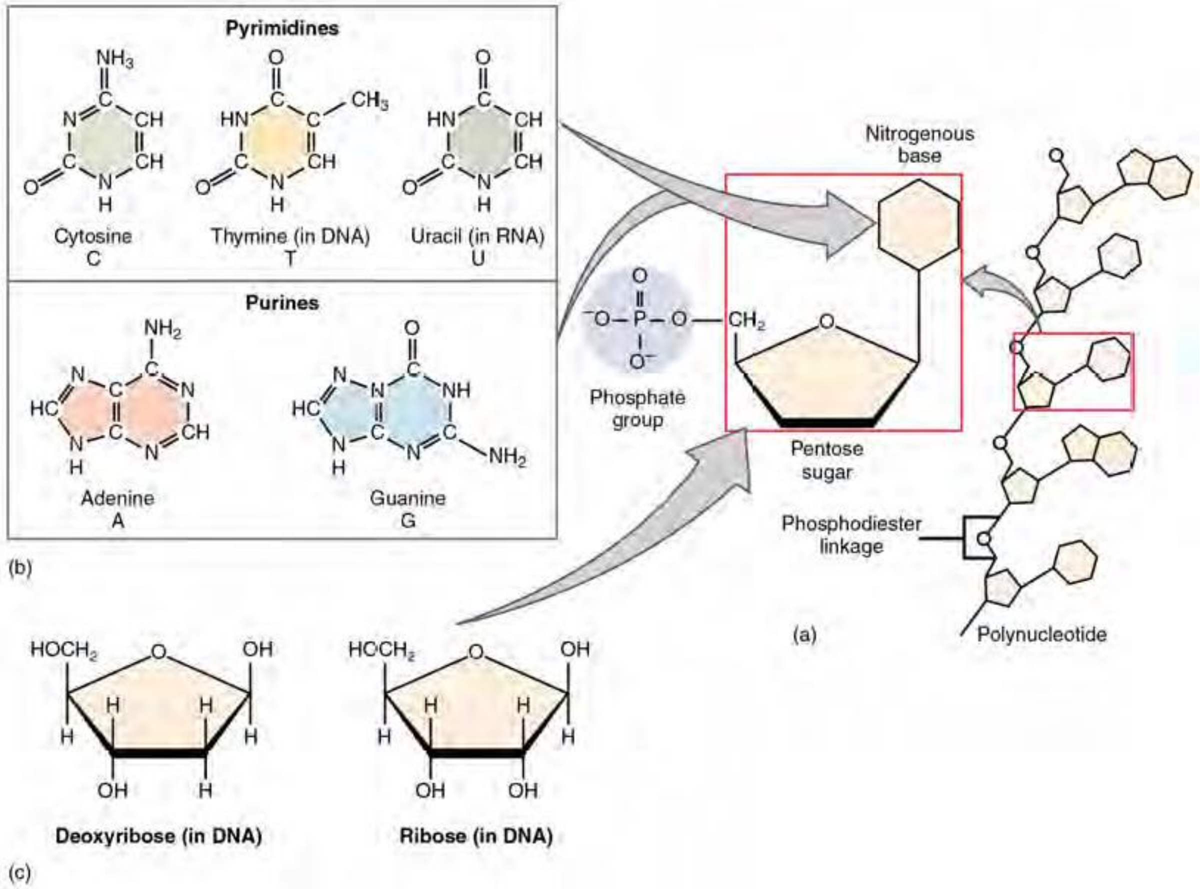


Figure 2.2.14: Structural Organisation of Nucleotides. **Source:** OpenStax College (2013, *Page 75).*

(a) Atypical nucleotide is composed one or more phosphate groups, a pentose sugar, and a nitrogen-containing base.
(b) nucleotides with their nitrogen-containing bases.
(c) The two pentose sugars found in DNA and RNA.

Nucleotides are used to compose nucleic acids (DNA or RNA) and adenosine triphosphate, the energy compound. Notice from Figure that the nitrogen-containing bases adenine and guanine are classified as purines while the bases cytosine, thymine (found in DNA only) and uracil (found in RNA only) are classified as pyramidines.

Nucleic Acids
The type of pentose sugar that constitutes a nucleic acid makes it different. For example, Deoxyribonucleic acid (DNA) contains the pentose sugar, deoxyribose, one phosphate group and one nitrogen-containing base. It is this nucleotide that transfers genetic information, The nitrogen containing bases in DNA can be adenine, cytosine, guanine or thymine.

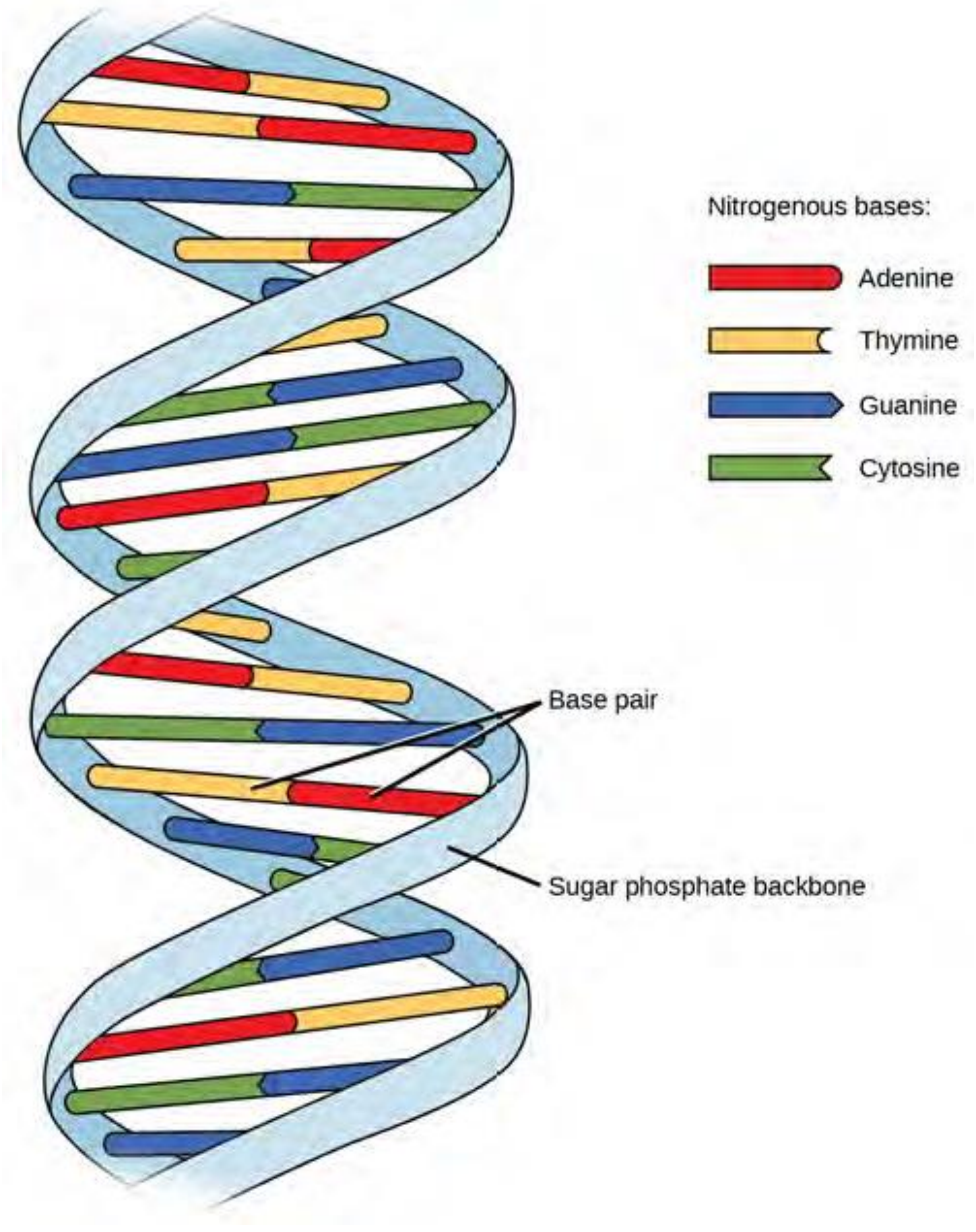


Figure 2.2.15: The Double Structure of DNA. **Source:** OpenStax College (2013, *Page 76).*

A DNA molecule looks like a twisted ladder made up two different coils or strands of nucleotides described as a double helix. The uprights of the ladder are composed of alternating phosphate and sugar molecules while its rungs consist of pairs of nitrogenous bases. Observe that the adenine in DNA is always paired with thymine with the aid of two hydrogen bonds while guanine is always paired with cytosine with the aid of three hydrogen bonds.

The sequence of the nucleotide bases in DNA strands specifies the code for protein synthesis in the many kinds of proteins produced by all living things. Every protein has a sequence of DNA bases that is specific to it. This specific sequence is termed a gene and it determines the type protein to be produced. Genes are, therefore, the codes for proteins synthesis. For this reason, DNA makes up the chromosomes of cells and is, therefore, the genetic code for hereditary characteristics of living things. In human DNA, there are about 22,000 genes within the 46 chromosomes inside the nucleus of each cell. It is these genes that carry the genetic code for build a person's body. Every person has a genetic code that specific to him or her except in the case of identical twins.

Ribonucleic acid (RNA) is another nucleotide. It contains the pentose sugar, ribose, one phosphate group, and one nitrogen-containing base. RNA is the nucleotide used in protein synthesis. The nitrogen bases in RNA can be adenine, cytosine, guanine or uracil.

RNA is synthesized from DNA in the nucleus of a cell for the purpose of protein synthesis in the cytoplasm. Every RNA is a single strand of nucleotides with uracil taking the place of thymine.

Adenosine Triphosphate

ATP (adenosine triphosphate) is a nucleotide. It is made of an adenine base, ribose, and three phosphate groups. There is a lot of potential energy stored by the two covalent bonds linking the three phosphates groups of ATP. It is the energy released when one of these covalent bonds is broken that is used to power our body's metabolic functions, including muscle contraction. ATP is therefore classified as a high energy compound.

During digestion, all energy giving foods are broken down and absorbed and glucose or a form of glucose. During cell respiration, the glucose molecules are broken down into carbon dioxide and water with the release of energy. Energy released from the breakdown of glucose is used to synthesize ATP by loosely bonding ADP (adenosine diphosphate) and phosphate which are already present in the body. As cell respiration continues, ATP is resynthesized from ADP and phosphate. ATP can therefore be described as molecule created to trap energy from food and transfer same for powering cell processes.

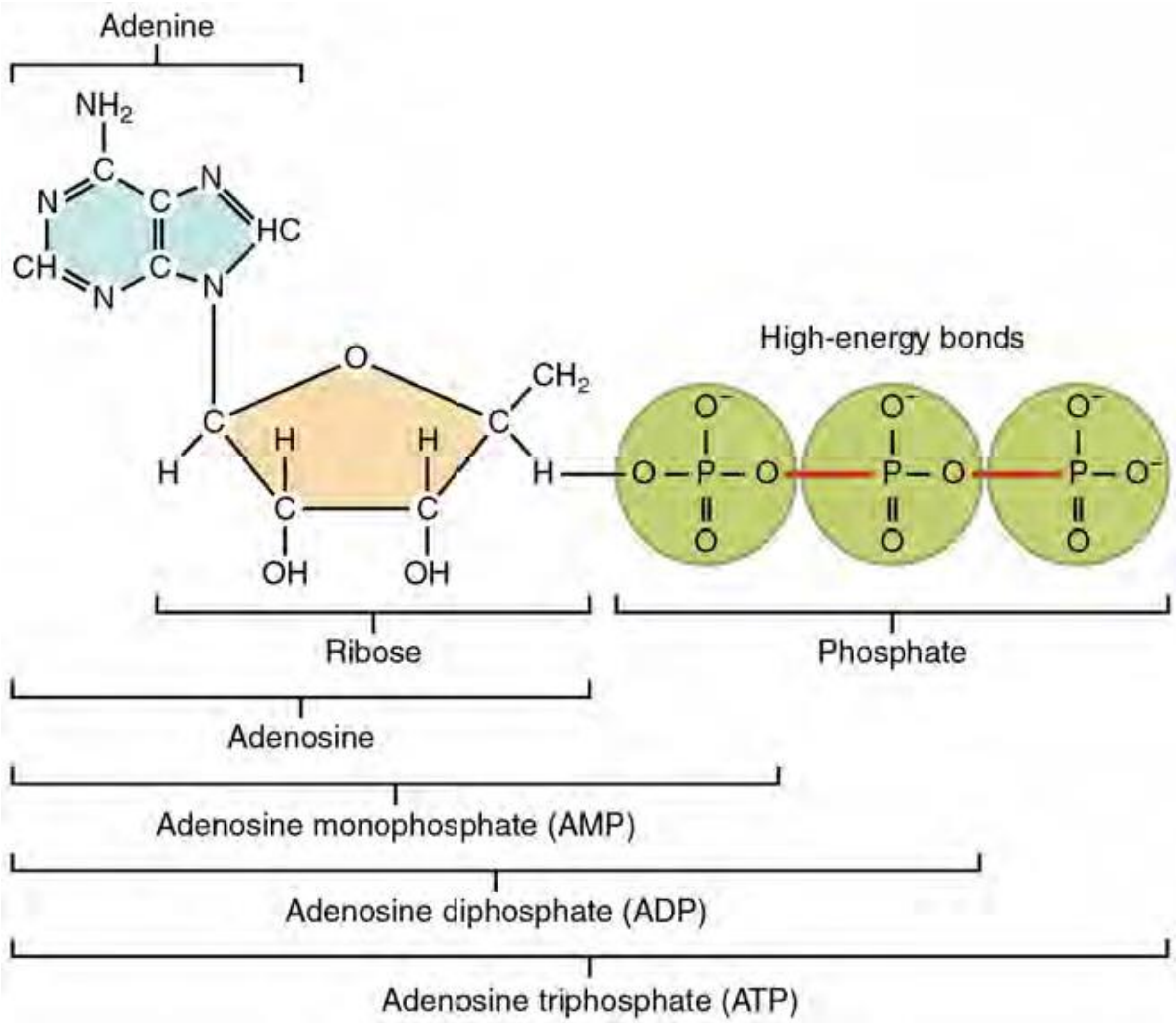


Figure 2.2.16: Structure of Adenosine Triphosphate (ATP).**Source:** OpenStax College (2013, *Page 77).*

Inorganic Compounds of Importance

The important inorganic compounds in the body are made up of molecules that do not contain both carbon and hydrogen. There are three groups of inorganic compounds that very important in human physiology. These are water, salts and acids and bases.

Water

About 70 percent of human body is composed of water. Water performs the following functions in the body:

1. Water is generally known as a universal solvent. A lot of substances (solutes) can dissolve in water. Plasma is essentially water with dissolved substances. Blood cells swim in plasma as they carry oxygen from the lungs to other cells and tissues of the body and carbon dioxide back to the lungs from the cells and tissues. Saliva is made up of water mostly. It is the dissolved food in saliva that makes it possible for receptors in taste buds to sense the taste of food. Urine is the body's waste products dissolved in water. Therefore, it is that makes it possible for the body to excrete waste products.

2. The lubricant property of water helps to prevent friction in most moving areas of the body. It is almost impossible for food to pass through the digestive tract during swallowing without the food being mixed with saliva. Also, it is the mucus, the watery and slippery fluid that covers the insides of the intestines that makes it possible for food to pass smoothly through

the intestines. Joints in the body are able reduce and increase their angles during movement without friction because of the water inside joint cavities known as synovial fluid.

3. Water helps the body to maintain a constant temperature. Water has the capacity to absorb or lose large quantities of heat before there is a significant rise or drop respectively in its temperature. It is due to this reason that water, which is about 70% of the body, is able to maintain a body temperature that nearly constant at all times. Water also has a high heat of vaporization, which is important for the process of sweating. Excess body heat evaporates sweat on the skin surfaces, rather than overheating the body's cells, and because of water's high heat of vaporization, a great deal of heat can be given off with the loss of a relatively small amount of water.

Water Compartments

Water compartments are specific locations in the body where water seem to aggregate. Although, water is always on the move within the body, it is known by different names when it appears in different compartments. The following are the known water compartments in the body:

Intracellular fluid (ICF) is the term used to describe the water that is found within the cells of the body. ICF constitute nearly 65% of the total body water.

Extracellular fluid (ECF) is the term used to describe the water that is found outside of the cells. ECF constitute about 35% of the total body water. Examples of ECF include plasma, the water found in blood vessels, lymph, water found in lymphatic vessels, tissue fluid or interstitial fluid, water found in the small spaces between cells, and specialized fluids, synovial fluid, cerebrospinal fluid and aqueous humour in the eye among others.

Oxygen

People breathe so as to obtain oxygen (O_2) from atmospheric. Oxygen is an essential element for cell respiration during which energy is released to power metabolic functions of the body. Oxygen is needed for the chemical break down of energy giving foods, such as glucose, during cell respiration for the release of energy.

Carbon Dioxide

Carbon dioxide (CO_2) is produced by cells as a waste product of cell respiration. Although carbon dioxide does not contribute to proper functioning of the body its presence in very high levels can cause harm. If the amount of carbon dioxide in the body fluids is not reduced by breathing, it could accumulate up to such a point that body fluids might become too acidic and cause serious ailments.

Trace Elements

Trace elements are those that are needed by the body in very small amounts. When they are present in food or nutritional supplements, we often call them minerals, and examples are iron, cobalt, and zinc. Although they may not be as abundant in the body as are carbon, hydrogen, or oxygen, they are nonetheless essential.

Acids, Bases, and pH

Any substance brings about the rise in concentration of hydrogen ions (H^-) and a fall in the concentration of hydroxyl ions (OH^-) in a water solution is defined as an acid. A base, on the other hand, is a substance that decreases the concentration of hydrogen ions (H^-) and increases the concentration of hydroxyl ions (OH^-) in a water solution.

The parts of hydrogen in any solution of water are described as the solution's acidity or alkalinity (sometimes referred to as basicity). A part of hydrogen in a solution of water is measured on a scale of values called pH scale. The values on the pH scale range from 0 to 14,

with 0 indicating the most acidic level and 14 the most alkaline. A solution with a pH of 7 is neutral because it contains the same number of H^- ions and OH^- ions. Pure water has a pH of 7. A solution with a higher concentration of H^- ions than OH^- ions is an acidic solution with a pH below 7. An alkaline solution, therefore, has a higher concentration of OH^- ions than H^- ions and has a pH above 7.
A one unit change in pH represents a 10 times change in the concentration of H^- ions. Therefore, a solution whose pH is 4 has 10 times as many H^- ions as a solution whose pH is 5, and 100 times as many H^- ions as a solution whose pH is 6.

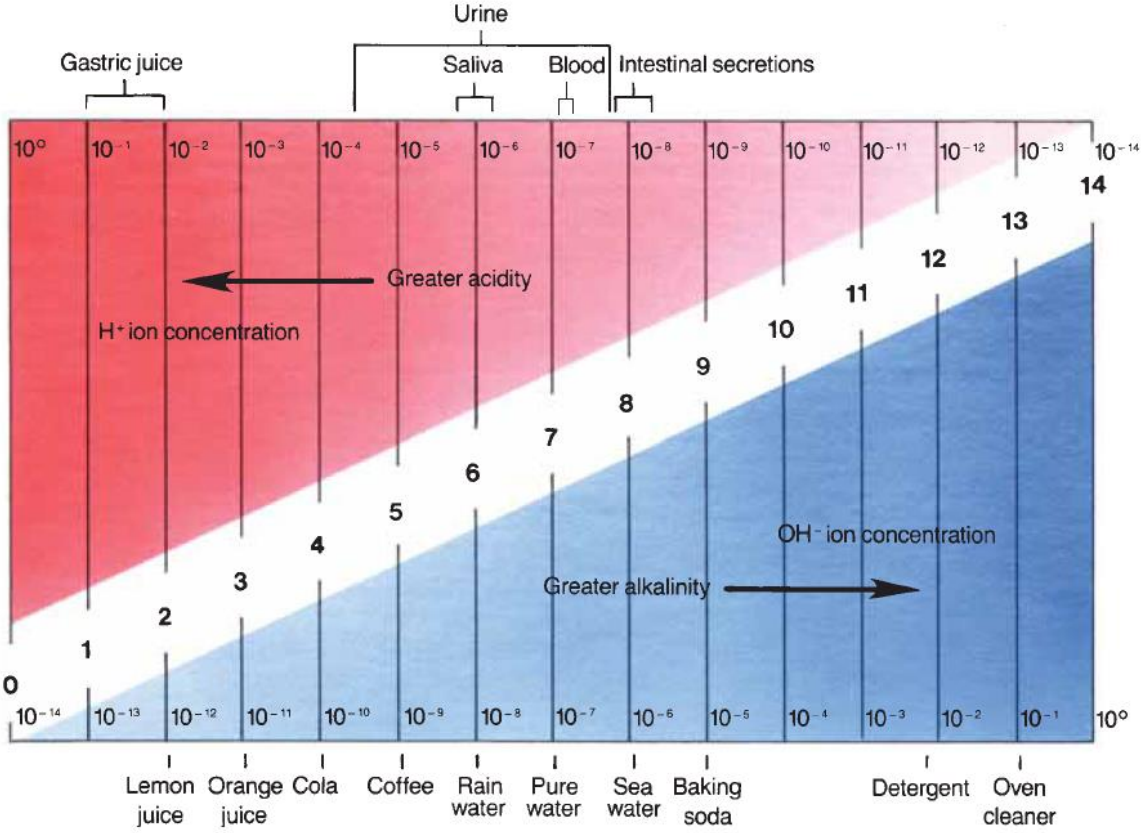


Figure 2.2.17: The pH Scale of some Body Fluids and some Common Chemicals. **Source:** Scanlon, V. C. and Sanders, T. (2007, page 32).
The pH of body fluids, within and outside cells of the human body is about neutral. The pH of Intracellular and extracellular fluid has a pH of value of about 6.8 while blood has a pH that ranges from 7.35 to 7.45. Gastric juice and urine, with pH values that are very acidic and alkaline respectively, do not harm the body because they are in body tracts that are open to the environment.

Buffers and Buffer Systems
There is a continuous entry of carbon dioxide and other inorganic chemicals into the blood stream by the metabolic actions of the several trillions of cells that make up the body. These dissolved chemicals have the tendency to affect the slightly alkaline nature of blood. Despite the tendency of these chemicals to make the blood either too acidic or to too alkaline, there are homeostatic mechanisms in the body that keep the pH of blood within the narrow range of between 7.35 and 7.45. These homeostatic mechanisms are described as the buffer systems of the body.
There are several mechanisms in the body that acts as buffer systems for maintaining acid-base balance of blood. These mechanisms include breathing that lowers blood pH by removing carbon dioxide in exhaled air, the excretion of chemicals in urine, and the internal

release of chemicals collectively called buffers into body fluids. A buffer is a solution of a weak acid and its conjugate base. A buffer can neutralize small amounts of acids or bases in body fluids. For example, if there is even a slight decrease below 7.35 in the pH of a bodily fluid, the buffer in the fluid, in this case acting as a weak base, will bind the excess hydrogen ions. In contrast, if pH rises above 7.45, the buffer will act as a weak acid and contribute hydrogen ions. For example, the bicarbonate buffer system consists of the weak acid, carbonic acid (H_2CO_3), and the weak base, sodium bicarbonate ($NaHCO_3$). The carbonic acid (H_2CO_3) of this buffer system, being a weak acid, does not contribute much to the H^- ions to blood and every other body fluid. Also, the sodium bicarbonate ($NaHCO_3$) being a weak base, does not contribute much OH^- to body fluids. Therefore, anytime a strong acid such hydrochloric acid (HCL) finds its way into the blood or any other body, it will drastically lower the pH far below the 7.35 minimum level and so is likely going cause serious adverse effects. What happens, however, is that the sodium bicarbonate of the bicarbonate buffer system will react with hydrochloric acid (HCL) to produce the salt, sodium chloride (NaCl) and carbonic acid (H_2CO_3), both of which affects pH minimally. Similarly, whenever, a strong base such sodium hydroxide finds its way into body fluids where it will cause an increase the pH level far above the maximum of 7.45, the carbonic acid (H_2CO_3) of the bicarbonate buffer system will react with it to produce water and sodium bicarbonate, both of which affects body fluids pH minimally.

In this manner, the bicarbonate buffer system prevents a drastic change in the pH of the extracellular fluids at rates that are less than a second. It has been found that body fluids have a tendency to become more acidic and so there is higher the need to correct acidosis more frequently. The implication is the body will always have a higher need of sodium bicarbonate in the bicarbonate buffer system that the carbonic acid in order for it to keep body fluids' pH within the narrow range of 7.35 and 7.45. The normal ratio of these compounds in this buffer system is usually 20:1 ($NaHCO_3$:H_2CO_3).

4.0 Conclusion

It is chemicals that came together to form the structural organisation of the body. There are important organic and inorganic compounds that contribute to human body structure and function. Most importantly, human body functions occur through the activities of several chemical reactions in the body.

5.0 Summary

Now that you have learned the chemical level of the body's general structure and function, you are now ready to go a little bit further by studying the second level of organisation, the basic structure and functions of cells and its organelles in the cellular level.

Self Assessment Exercise

1. Over 95 percent of the body's mass is composed of ________.
   a. calcium, magnesium, iron, and carbon
   b. oxygen, calcium, iron, and nitrogen
   c. sodium, chlorine, carbon, and hydrogen
   d. oxygen, carbon, hydrogen, and nitrogen
2. The compound, methane (CH_4) is ________.
   a. inorganic
   b. organic
   c. reactive
   d. a crystal

3. Which of the following is most likely to be found evenly distributed in water in a homogeneous solution?
   a. sodium ions and chloride ions
   b. NaCl molecules
   c. salt crystals
   d. red blood cells
4. A substance that dissociates into K+ and Cl– ions in a water solution is ________.
   a. acid
   b. base
   c. salt
   d. buffer
5. $C_6H_{12}O_6$ is the chemical formula for a ________.
   a. polymer of carbohydrate
   b. pentose monosaccharide
   c. hexose monosaccharide
   d. all of the above
6. Which of the following is a functional group that is part of a building block of proteins?
   a. phosphate
   b. adenine
   c. amino
   d. ribose
7. A pentose sugar is a part of the monomer used to build which type of macromolecule?
   a. polysaccharides
   b. nucleic acids
   c. phosphorylated glucose
   d. glycogen
8. A phospholipid ________.
   a. has both polar and nonpolar regions
   b. is made up of a triglyceride bonded to a phosphate group
   c. is a building block of ATP
   d. can donate both cations and anions in solution
9. In DNA, nucleotide bonding forms a compound with a characteristic shape known as a ________.
   a. beta chain
   b. pleated sheet
   c. alpha helix
   d. double helix
10. The ability of an enzyme's active sites to bind only substrates of compatible shape and charge is known as ________.
    a. selectivity
    b. specificity
    c. subjectivity
    d. specialty

6.0 Reference/Further Reading

OpenStax College, *Anatomy & Physiology*. OpenStax College. 25 April 2013. http://cnx.org/content/col11496/latest/

Scanlon, V. C. and Sanders, T. (2007): *Essentials of Anatomy and Physiology*. Philadelphia: F. A. Davis Company

Robergs, R. A. and Kateyian, S. J. (2003). *Fundamentals of exercise physiology for fitness, performance and health. (2nd ed)* New York. McGraw Hill.

Unit 3 Cell; the Basic Unit of Life

1.0 Introduction

We started the study of the structure of the body (anatomy) with the study of the basic chemicals that make up the body and they function in chemical reactions to keep the body active and alive (physiology). In this unit you will examine the cell and its organelles are formed from the chemicals studied earlier on in the previous unit. The cell will be studied in this unit as the basic structural unit of life and how the organelles that compose it function in the sustenance of life.

2.0 Intended Learning Outcome(s)

By the end of this unit, you would be able to

- Describe the basic structure and function of the human cell and its organelles.
- Describe the mechanisms by which materials are transported into and out of cells.
- Explain what genetic code means and how protein synthesis takes place
- Describe the process of cell division

3.0 Main Content

The Human Cell

The cell is the smallest and the simplest unit of living matter that is capable of maintaining life and reproducing itself. The cell is alive independently and lives in cooperation with other cells in the formation of complex living organisms. In fact the human body, which is made up of numerous cells, started as a single, newly fertilized cell known as the zygote. There are different kinds, sizes and shapes of cells.

Human cells are so minute that there is the need of a microscope for them to be seen. The human cell is able to keep itself alive by possessing a series of 'miniature machines' known as organelles. Presented here is the diagram of a generalized human cell showing all of the organelles the structural organisation and functions of which we are going to discuss shortly. It should be noted that a cell possesses these organelles to the extent that they are needed in the functioning of the cell. In other words, only the organelles needed by the cell to perform its function in the human organism, would be present in a given cell. Let us

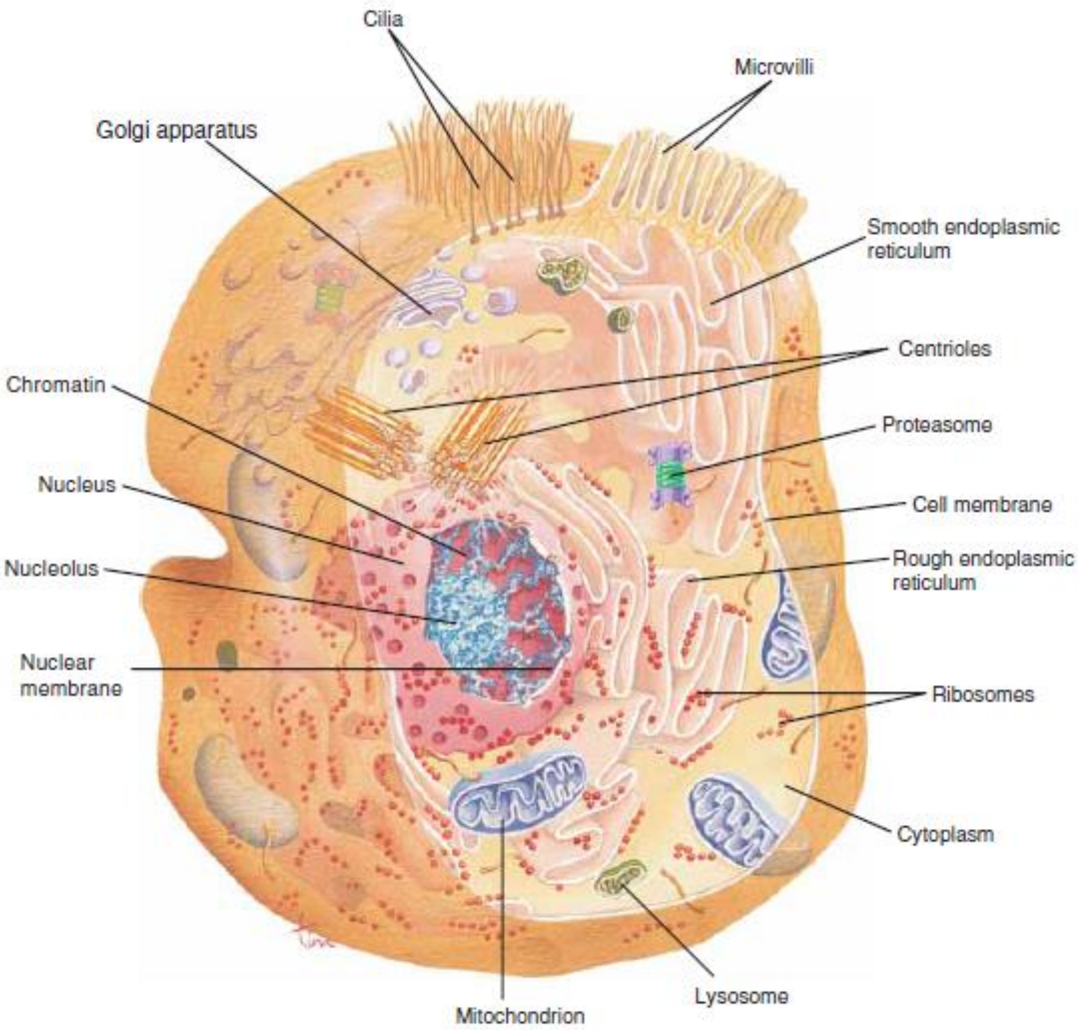


Figure 2.3.1: Generalised Human Cell showing Its Structural Components. **Source:** Scanlon, V. C. and Sanders, T. (2007, page 50).

Cell membrane (Plasma membrane)

This is a double layer of phospholipids, cholesterols and protein molecules which surrounds every cell in the body. The environment external to the cell known as the extra-cellular environment is separated from the cell's internal environment known as the intra-cellular environment by the cell membrane. The movement of materials into and out of a cell is controlled by the cell membrane. It is the cell membrane that gives a cell its characteristic shape and integrity. There are proteins in the cell membrane that provide structural support, form channels for passage of materials and act as receptor sites. These proteins also function as carrier molecules and provide identification markers.

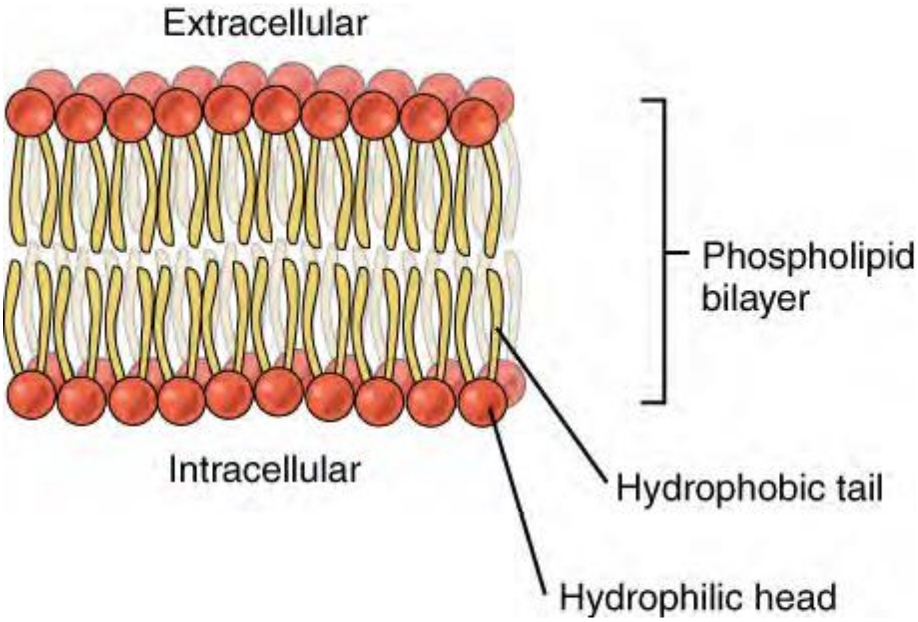


Figure 2.3.2: Phospolipids Bilayer of the Cell Membrane. Source: OpenStax College (2013, *Page 87).*

Notice the two adjacent sheets of phospholipids, arranged tail to tail. They are arranged in such a way that the hydrophobic tails are in contact with one another to form the interior of the membrane while their polar heads are in contact the fluids inside and outside of the cell.

The organic molecules, mostly phospholipids that are usually diglycerides that form the cell membrane are arranged in such a way that they form a double layer with their hydrophobic ends on the outside and inside of the cell.

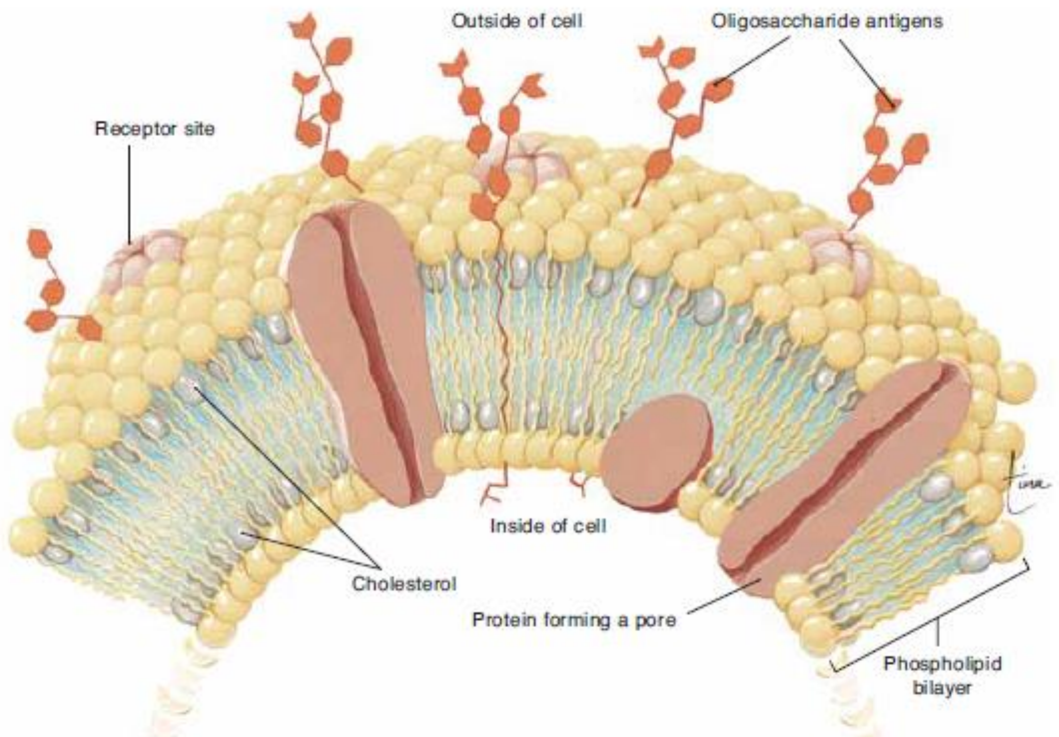


Figure 2.3.3: The cell (plasma) membrane depicting the types of molecules present. Source: **Scanlon, V. C. and Sanders, T. (2007, page 49).**

Nucleus and Nucleolus

The control centre or brain of a cell is called the nucleus. It is formed by a nuclear membrane surrounding a fluid called the nucleoplasm. Within the nucleus is the cell's genetic material called the chromatin. Threads of chromatin in the nucleus contain deoxyribonucleic acid (DNA). The region of the nucleus where the formation of ribosomes takes place is called the nucleolus. This is a dense region of ribonucleic acid (RNA). The function and the basic structure of any cell are determined by the nucleolus.

Cytoplasm

This is a gel-like fluid in which the contents inside of a cell are submerged. All the chemical reactions that goes on within a cell for it to be able to maintain life occurs in the cytoplasm. The cytoplasm is the site of all the functions for cell expansion, growth and replication of a cell. It is the medium where other organelles can operate within the cell. Materials can move from one region of the cell to another within the cytoplasm by the process of diffusion.

Mitochondria

These structures are round or long cellular organelles that are suspended within the cytoplasm of a cell. The mitochondria are rich in fats, proteins and enzymes. They produce energy for the cell through cellular respiration.

Ribosome

These are RNA-rich granules suspended within the cytoplasm of a cell. Ribosomes are the sites of protein synthesis.

Endoplasmic Reticulum

These are systems of interconnected vesicular and lamellar membranes that are suspended within the cytoplasm. The endoplasmic reticulum is an important organelle said to be heavily involved in protein synthesis in that it is studded with ribosome in some places.

Golgi Apparatus

An organelle within the cytoplasm that is made up of a stack of smooth membranous saccules and associated vesicles. The golgi apparatus are active in the modification and transport of proteins.

Lysosome

This is a saclike organelle within the cytoplasm that contains various hydrolytic enzymes.

Cell Function

There are many types of cells within the human body. In the same vein, there are several functions that are attributable to the various kinds of cells. All cells despite the type and / or location, contains proteins. The nature of the proteins present in a cell determines its functional and structural characteristics. It is because a cell structure is very closely associated with its function. Therefore, a cell that is very thin may not be well suited for a protective function. In the same vein, cells that would serve the function of nerve impulse conduction, may not be not find a place in a bone tissue. Just as cells are many and varied in types and shapes, so also are cells many and varied in their functions. While we shall study the functions of cells along with the tissues they form, there are some functions that are general to all cells. The generalized cell functions include movement of substances across the cell membrane, cell division to make new cells, production and consumption of energy and protein synthesis.

Movement of substances across the cell membrane

The cell is a living entity surrounded by a cell membrane which is semi-permeable in that it selectively allows materials into and out of the cell. By selectively allowing materials into and out of the cell, it is able to maintain the difference between its extracellular and intracellular environment.

The Breakdown of Materials in a Cell

It might become necessary to breakdown more complex particles into simpler molecules in a cell. The simpler molecules derived from the digestion process are used as raw materials to build and/or repair by the cell. Some cells in the body such as the white blood cells have powerful digestive enzymes which are used to eliminate pathogens by breaking them down to the molecular level. One of such processes called 'Pinocytosis' involves the breaking down of structures, such as bacteria, into forms that are literarily said to be drinkable by the cell. These cells secretes powerful enzyme that dissolves the structure into such a form that could be absorbed by the cell for other purposes. Another of such processes is 'Phagocytosis'. In this case, foreign particles like bacteria are engulfed or eaten up whole by the cell, dissolved and used for other cell functions such being a source for energy production. This is how the cell takes in food as a living entity. The food thus eaten is then used for energy production or protein synthesis for cell reproduction or cell repair.

Energy Production within the Cell

All cells need energy to power its processes such as muscle contraction, hormonal secretion, nerve impulse conduction, etc. The high energy compound adenosine tri-phosphate releases the needed energy when it breaks off one of its phosphate groups as shown in the following reaction. ATP $\longrightarrow$ ADP + P + Energy. There is a limited quantity of ATP in the body. The cells have to continuously re-synthesize ATP if energy is to be made available for cellular functions. The phosphagen system (also known as the ATP-PC system), the lactic acid system (also known as anaerobic glycolysis) and the oxygen system (also known as the aerobic system) make energy available anaerobically and aerobically by re-synthesizing ATP on a regular basis. The re-synthesis of ATP through any of the above systems requires energy. The breakdown of one of the molecular bonds in the compound phosphocreatine to liberate the phosphate group from the creatine releases the energy needed to power the ATP – PC system in the re-synthesis of ATP. The end product of the metabolism of energy foods such as carbohydrates, fats and proteins is used to re-synthesize ATP in the other two systems of anaerobic glycolysis and the aerobic system. The use of the end products of energy foods metabolism in the re-synthesis of ATP occur through a series of enzyme controlled steps which allow energy to be released. This process, called cellular respiration, makes energy available for our existence.

Cell Division

One of the major processes of life is growth and the repair of worn out tissues in the maintenance of life. By the process of cell division, new cells are formed for the purposes of growth, repair, and replacement of worn out cells in the body. Cell division starts from the division of the nuclear material and proceeds to divide through the cytoplasm to the cell membrane to two daughter cells. Apart from gametes (cells that give rise to eggs and sperms), all cells in the body (somatic cells) undergo mitotic cell division. Gametes are produced by a special type of cell division called meiosis.

Mitotic cell division known as mitosis is the type of cell division that results in the production of two daughter cells which are identical to the parent cell. Mitosis occurs in stages. The stages are prophase, metaphase, anaphase, and telophase. The interval between these stages is known as interphase. The division of the cytoplasm which occurs during the telophase stage is called cytokinesis.

Meiosis is a special type of cell division that leads to the production of gametes. Gametes are the names given to sperm and egg cells. They have only half the number of chromosomes found in somatic cells. That is, while somatic cells have 46 chromosomes, gametes have only 23. They are made in such a way that after fertilization has taken place the resulting cell will again have 46 chromosomes, since both sperm and egg will each contribute 23 chromosomes.

Genetic Material

Chromosomes are made up deoxyribonucleic acid (DNA). It is therefore the DNA that is passed from one generation to another in cell replication. Since every organism including humans has specific characteristics that are peculiar to them and relates offspring to parents, it must be the DNA that contains the genetic information that is passed from one generation to another. Hence it is actually the DNA that makes us who we are.

Protein Synthesis

Protein synthesis, one of the most important cell functions, uses the genetic code in the DNA to create proteins that build, repair and operate the cells. Protein synthesis occurs in two stages called transcription and translation. During the transcription stage, genetic code is transferred from a molecule of DNA to an intermediary molecule called ribonucleic acid (RNA). The DNA double helix structure uncoils and one of the strands acts as a template to form the kind of RNA called messenger RNA (mRNA). This mRNA leaves the cell nucleus and attaches to the ribosomes, the cell organelles specialized as sites for protein synthesis. Another type of RNA known as transfer RNA (tRNA) then carries amino acids to the ribosomes. During the stage of protein synthesis called translation, the amino acids are linked together in a particular sequence, dictated by the mRNA, to form the desired protein. In this manner, all kinds of proteins are synthesized.

4.0 Conclusion

The cell and its organelles are formed from chemicals and how cells are organised as the basic structural unit of life. The organelles that compose the cell and how they function in the sustenance of life were studied.

5.0 Summary

Now that you have learned the cellular level of the body’s general structure and function, you are now ready to go a little bit further by studying the third level of organisation, the tissue level.

Self Assessment Exercise

1. State the functions of the following organic molecules of cell membranes: cholesterol, proteins, and phospholipids.
2. Describe the function of each of these cell organelles: mitochondria, lysosomes, Golgi apparatus, ribosomes, proteasomes, and endoplasmic reticulum.

3. Explain why the nucleus is the control center of the cell.
4. What part of the cell membrane is necessary for facilitated diffusion? Describe one way this process is important within the body.
5. Define osmosis, and describe one way this process is important within the body.
6. In what way are phagocytosis and pinocytosis similar? Describe one way each process is important within the body.
7. How many chromosomes does a human cell have? What are these chromosomes made of?
8. Name the stage of mitosis in which each of the following takes place:
    a. The two sets of chromosomes are pulled toward opposite poles of the cell
    b. The chromosomes become visible as short rods
    c. A nuclear membrane re-forms around each complete set of chromosomes
    d. The pairs of chromatids line up along the equator of the cell
    e. The centrioles organize the spindle fibers
    f. Cytokinesis takes place after this stage
9. Describe two specific ways mitosis is important within the body. Explain why meiosis is important.
10. Compare mitosis and meiosis in terms of:
    a. Number of divisions
    b. Number of cells formed
    c. Chromosome number of the cells formed
11. Facilitated diffusion
    a. Movement of molecules from an area of greater concentration to an area of lesser concentration through a selectively permeable membrane such as the absorption of water by the small intestine or kidneys.
    b. Carrier and transporter enzymes move molecules across cell membranes such as the intake of glucose by most cells.
    c. Movement of molecules from an area of greater concentration to an area of lesser concentration such as exchange of gases in the lungs or body tissues.
    d. Movement of molecules from an area of lesser concentration to an area of greater concentration that requires energy such as the absorption of amino acids and glucose from food by the cells of the small intestine.
12. Filtration
    a. Movement of water and dissolved substances from an area of higher pressure to an area of lower pressure such as the formation of tissue fluid found in the first step in the formation of urine.
    b. Movement of molecules from an area of greater concentration to an area of lesser concentration through a selectively permeable membrane such as the absorption of water by the small intestine or kidneys.
    c. Carrier and transporter enzymes move molecules across cell membranes such as the intake of glucose by most cells.
    d. Movement of molecules from an area of lesser concentration to an area of greater concentration that requires energy such as the absorption of amino acids and glucose from food by the cells of the small intestine.
13. The process whereby a moving cell engulfs something such as when a white blood cell engulfs a bacteria cell is described as --------
    a. Phagocytosis
    b. Negative feedback
    c. Pinocytosis
    d. Active transport

14. The process whereby a stationary cell engulfs something such as when cells of the kidney tubules reabsorb small proteins is described as --------
    a. Phagocytosis
    b. Negative feedback
    c. Pinocytosis
    d. Active transport
15. The process whereby molecules move from an area of lesser concentration to an area of greater concentration requiring energy such as when amino acids and glucose are absorbed from food by the cells of the small intestine. is described as --------
    a. Phagocytosis
    b. Negative feedback
    c. Pinocytosis
    d. Active transport
16. The process whereby a stimulus initiates a response that reverses or reduces the stimulus, thereby stopping the response until the stimulus occurs again and there is a need for the response is described as -------
    a. Mmm Phagocytosis
    b. Negative feedback
    c. Pinocytosis
    d. Active transport
17. Cholesterol in the cell membrane
    a. permit lipid-soluble materials to easily enter or leave the cell by diffusion through the cell membrane.
    b. decreases the fluidity of the membrane, thus making it more stable.
    c. have several functions including the forming of **channels** or **pores** to permit passage of materials such as water or ions
    d. triggers chemical reactions within the cell membrane or the interior of the cell
18. Proteins in the cell membrane
    a. permit lipid-soluble materials to easily enter or leave the cell by diffusion through the cell membrane.
    b. decreases the fluidity of the membrane, thus making it more stable.
    c. have several functions including the forming of **channels** or **pores** to permit passage of materials such as water or ions
    d. triggers chemical reactions within the cell membrane or the interior of the cell
19. Phospholipids
    a. permit lipid-soluble materials to easily enter or leave the cell by diffusion through the cell membrane.
    b. decreases the fluidity of the membrane, thus making it more stable.
    c. have several functions including the forming of **channels** or **pores** to permit passage of materials such as water or ions
    d. triggers chemical reactions within the cell membrane or the interior of the cell
20. The cell organelle, endoplasmic reticulum functions
    a. Site of aerobic cell respiration in energy production
    b. Passageway for transport of materials within the cell and in the synthesis of lipids
    c. Site of protein synthesis
    d. Synthesis of carbohydrates and the packaging of materials for secretions from the cell
21. The cell organelle, mitochondria functions
    a. Site of aerobic cell respiration in energy production

b. Passageway for transport of materials within the cell and in the synthesis of lipids
c. Site of protein synthesis
d. Synthesis of carbohydrates and the packaging of materials for secretions from the cell

22. The cell organelle, lysosomes functions as
    a. Site of destruction of old or damaged proteins
    b. Organize the spindle fibers during cell division
    c. Contain enzymes to digest ingested material or damaged tissue
    d. Sweep materials across the cell surface
23. The cell organelle, cilia functions as
    a. Site of destruction of old or damaged proteins
    b. Organize the spindle fibers during cell division
    c. Contain enzymes to digest ingested material or damaged tissue
    d. Sweep materials across the cell surface

6.0 Reference/Further Reading

OpenStax College, *Anatomy & Physiology*. OpenStax College. 25 April 2013. http://cnx.org/content/col11496/latest/

Scanlon, V. C. and Sanders, T. (2007): *Essentials of Anatomy and Physiology*. Philadelphia: F. A. Davis Company

Robergs, R. A. and Kateyian, S. J. (2003). *Fundamentals of exercise physiology for fitness, performance and health. (2nd ed)* New York. McGraw Hill.

Module 3 Tissue Level of the Body's Organisational Structure

Introduction

Cells become specialized to perform a particular function within the body as part of a larger tissue consisting of many cells with similar features working together as a unit. Therefore, the efforts of cells in these tissues are combined so that they can perform a common task. The task a cell will perform at maturity will determine in what way it is going to be specialized. This is because different cells are suited to different purposes. Let us now look at the structure and function of the different types of cells that make up the different types of tissues in the body.

A tissue can be defined as the organization of many cells which are similar in structure. The cells that combine to form a tissue have in between them varying amounts and kinds of nonliving, intercellular substance. This nonliving matter called intercellular matrix that fills the spaces between cells in a tissue, vary from tissue to tissue. Some substances like salts and fibres may be found in the intercellular matrix. In fact the types of cells, the size and nature of the intercellular matrix, and kinds of substances found in the intercellular matrix of any tissue makes it unique and so gives it its distinctive characteristics. Based on these characteristics, it is possible to identify four main types of tissues in the body. In other words, the human body is made up of four major types of tissues. The types of tissues found in the human body are epithelial, connective, muscle, and nervous tissues. Each of these tissues is designed for a specific function.

Unit 1: Epithelial Tissues

1.0 Introduction

The human being lives in and interacts with the environment and still maintains its internal consistency. The body is able to maintain its internal integrity because all the surfaces of the body that exposed to the outside and inside world are covered by a lining known as the epithelium. The skin including the hollow of the mouth and the digestive system, airways including inside of the nose and passages leading to the air sacs of the lungs, digestive tract, urinary and reproductive systems are surfaces of the body that are exposed to the outside world and so are covered by epithelia tissues. Glandular tissues of the body are also formed from epithelial tissues. The structural organization and function of the different types of tissues are to be studied in this unit.

2.0 Intended Learning Outcome(s)

By the end of this unit, you would be able to

- Describe the structure and function of epithelial tissue
- Distinguish between simple, stratified, squamous, cuboidal and columnar epithelia.
- Describe the structure and function of endocrine and exocrine glands and their respective secretions

3.0 Main Content

Epithelial tissue is the tissue designed for the specific function of providing cover for all the surfaces of the body. All body surfaces whether internal or external are covered by epithelial tissue. Epithelial tissue that lines the body cavities that opens to the outside is mucous membranes or mucosae. The membranes that line the entire gastro intestinal tract, respiratory tract, excretory tract and the reproductive tract are mucous membranes. On the other hand, epithelial tissue that lines the body cavities which do not open directly to the outside, are called serous membranes. Serous membranes also cover the organs that are located in those cavities that do not open directly to the outside. A thin layer of serous fluid covers the serous membranes for lubrication purposes. Movement of organs within the thorax and abdominopelvic cavity is frictionless and without abrasion by the action of the serous fluid.

Cells in epithelial tissue are closely packed with little or no intercellular spaces. The cells are arranged in one or more layers. A thin sheet of connective tissue called the basement membrane separates the epithelial tissues from its underlying structures. The basement membrane provides structural support for the epithelium and binds it to the underlying tissues.

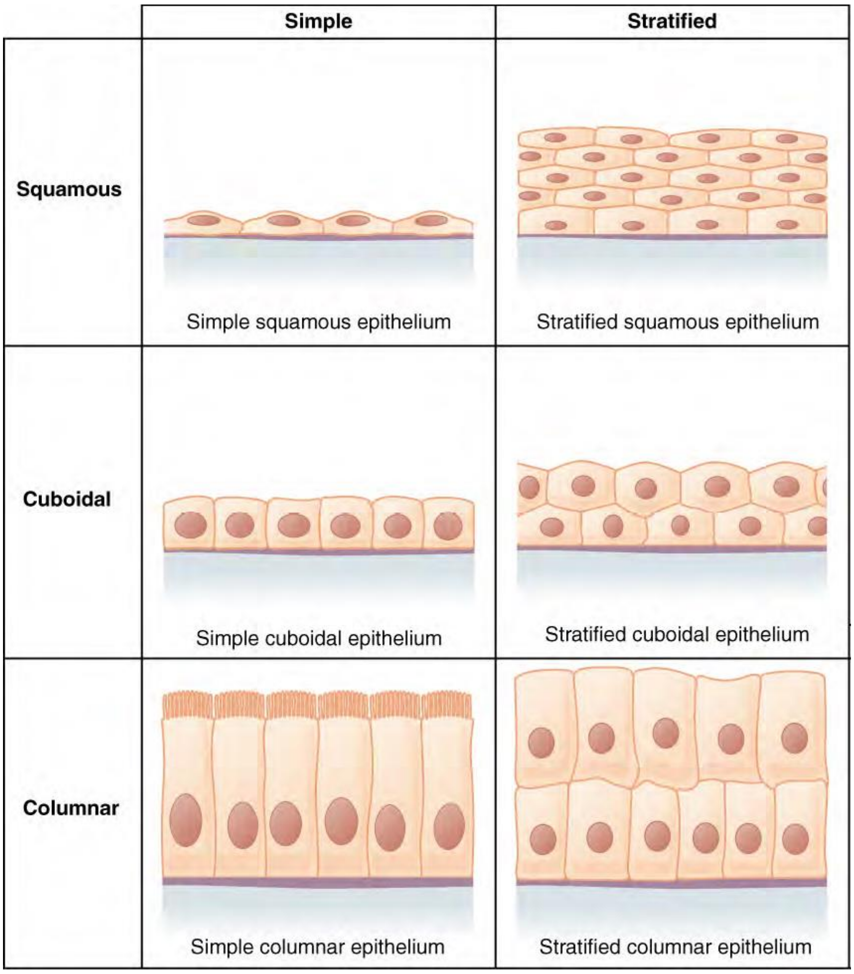


Figure 3.1.1: Cells of Epithelial Tissue. **Source:** OpenStax College (2013, *Page 139).*

An epithelial tissue is described as simple epithelial tissue if it is organized as a single layer of cells and stratified epithelial tissue if it is formed by several layers of cells. The shapes of the cells that form an epithelial tissue is used to name it. Thus, an epithelial tissue that is made up one layer of cells that appear squeezed is called a squamous epithelial tissue, the one made from a single layer of cells that are cubical in shape are called simple cuboidal epithelial tissue. The simple columnar epithelial tissue is made up of cells that appears as columns. When an epithelial tissue is made up of more than one layer of cells, it is called a stratified epithelial tissue. For this reason, we have stratified squamous, stratified cuboidal and stratified columnar epithelial tissues.

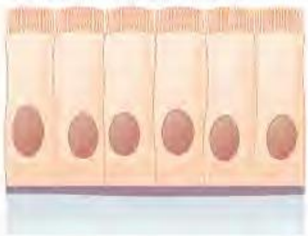
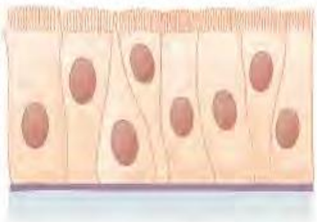
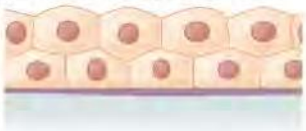
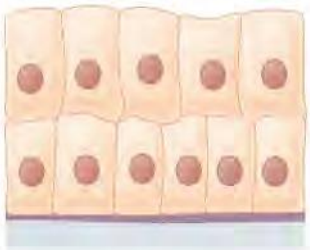
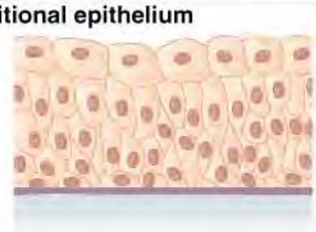
Cells	Location	Function
Simple squamous epithelium 	Air sacs of lungs and the lining of the heart, blood vessels, and lymphatic vessels	Allows materials to pass through by diffusion and filtration, and secretes lubricating substance
Simple cuboidal epithelium 	In ducts and secretory portions of small glands and in kidney tubules	Secretes and absorbs
Simple columnar epithelium 	Ciliated tissues are in bronchi, uterine tubes, and uterus; smooth (nonciliated tissues) are in the digestive tract, bladder	Absorbs; it also secretes mucous and enzymes
Pseudostratified columnar epithelium 	Ciliated tissue lines the trachea and much of the upper respiratory tract	Secretes mucus; ciliated tissue moves mucus
Stratified squamous epithelium 	Lines the esophagus, mouth, and vagina	Protects against abrasion
Stratified cuboidal epithelium 	Sweat glands, salivary glands, and the mammary glands	Protective tissue
Stratified columnar epithelium 	The male urethra and the ducts of some glands	Secretes and protects
Transitional epithelium 	Lines the bladder, uretha, and the ureters	Allows the urinary organs to expand and stretch

Figure 3.1.2: Specific Epithelial Tissues, their Location and Functions. **Source:** OpenStax College (2013, *Page 142).*

An epithelial tissue that is made up one or more cells which are specialized for synthesizing and secreting chemical substances is known as a glandular epithelial tissue or glandular epithelium. A gland is classified either as an endocrine gland which is a ductless gland that releases secretions directly into surrounding tissues and fluids or an exocrine gland that contains ducts through which its secretions leave into the external environment.

4.0 Conclusion

You learnt the structure and function of epithelial tissue and how to distinguish between simple, stratified, squamous, cuboidal and columnar epithelia tissues. You also learnt how the different types of epithelial tissues can be modified with or without ducts to function as glands or glandular tissues.

5.0 Summary

Now that you have learned how cells are organised into epithelial tissues at the cellular level of the body's general structure and function, you are now ready to go a little bit further by studying this third level of organisation deeper at the connective tissue level.

Self Assessment Exercise

24. Discuss the different types of epithelial tissues in relation to their location on the body and functions.
25. Stratified squamous epithelial tissue consists of
    a. many layers of flat surface cells that changed from rounded to flat at the surface such as found in lining of urinary bladder
    b. One layer of columnar cells with cilia on their free surfaces found in the Linings of trachea—and fallopian tube.
    c. many layers of flat surface and rounded lower cells as found in the epidermis and linings of the esophagus and vagina
    d. one layer of flat cells as found in the alveoli of the lungs and capillaries.
26. Transitional epithelial tissue consists of **__________**
    a. many layers of flat surface cells that change from rounded to flat at the surface such as found in lining of urinary bladder
    b. one layer of columnar cells with cilia on their free surfaces found in the Linings of trachea—and fallopian tube.
    c. many layers of flat surface and rounded lower cells as found in the epidermis and linings of the esophagus and vagina
    d. one layer of flat cells as found in the alveoli of the lungs and capillaries.
27. An group of epithelial tissue cells, when seen under a microscope, appear arranged in a single layer and look tall and narrow, with their nuclei located close to the base of the cells is identified as **_______________**
    a. Columnar
    b. Stratified
    c. Squamous
    d. transitional
28. Which of the following is the epithelial tissue that lines the interior of blood vessels?
    a. Columnar
    b. Pseudostratified
    c. simple squamous
    d. transitional
29. Which type of epithelial tissue specializes in moving particles across its surface and is

found in airways and lining of the oviduct?

a. Transitional
b. stratified columnar
c. pseudostratified ciliated columnar
d. stratified squamous

6.0 References/Further Readings

OpenStax College, *Anatomy & Physiology*. OpenStax College. 25 April 2013. *http://cnx.org/content/col11496/latest/*

Scanlon, V. C. and Sanders, T. (2007): *Essentials of Anatomy and Physiology*. Philadelphia: F. A. Davis Company

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Unit 2: Connective Tissue

1.0 Introduction

Connective tissues too are made up of cells. The cells in connective tissues secrete a lot of intercellular substance called ground matter or matrix. The intercellular ground substance which was secreted in the first place by the living cells, pushes apart the cells making the connective tissue to be characteristically made up of a relatively few number of cells which are widely separated. The matrix of a connective tissue is a nonliving substance which could be liquid as found in blood and synovial fluids, semi-solid as found in meninges of the brain and spinal cord or solid as found in bone and cartilage. The matrix contains different amount and types of supporting fibres. The type of fibre which is predominant in the matrix enables the connective tissue perform its characteristic function of binding or connecting together all types of tissue in the body. Connective tissues perform three main functions. Connective tissues are classified into three different categories in accordance with their primary structure, composition of their matrices and their basic function. The three classes of connective tissues are fluid or liquid connective tissue, the semisolid or loose connective tissue and the solid connective tissue.

2.0 Intended Learning Outcome(s)

By the end of this unit, you would be able to

- Describe the structure and functions of connective tissues
- Distinguish between fluid, loose or semisolid and dense connective tissues.
- Describe the structure and function of blood and lymph as fluid connective tissue, areolar and adipose tissues as loose connective tissues and cartilage and bone as dense or solid connective tissues.

3.0 Main Content

Fluid or Liquid Connective Tissues

There are two tissues in the body that are known as liquid or fluid connective tissues. These tissues are blood and lymph. Both of these tissues have cells that circulate freely in a liquid extracellular matrix.

Blood, a Fluid Connective Tissue

Blood is a connective that consists of cells and the liquid known as plasma. Blood cells are the living portion of liquid connective tissue called blood. Blood cells include red blood cells, white blood cells (neutrophils, eosinophils, basophils, monocytes and lymphocytes) and platelets. Together, all the blood cells make up 38% to 48% of the total blood volume. Each type of the blood cells has specific functions that they perform. Erythrocytes or red blood cells (RBCs) carry oxygen bonded to the iron in their haemoglobin. Leukocytes or White blood cells (WBCs) destroy pathogens by phagocytosis, the production of antibodies, or other chemical methods, and provide us with immunity to some diseases. Some white blood cells can cross the endothelial layer that of blood vessels and enter nearby tissues to perform their immunity functions. Platelets prevent blood loss; the process of blood clotting involves platelets.

Plasma is the matrix or liquid non-living component of blood. 52% to 62% of the total blood volume in the human body is composed of plasma. Plasma is made up water in which salts, nutrients, gases, and waste products are dissolved. The main function of the matrix, plasma, of the connective, blood, is transport of blood cells and dissolved materials, including nutrients, salts and wastes, within the body.

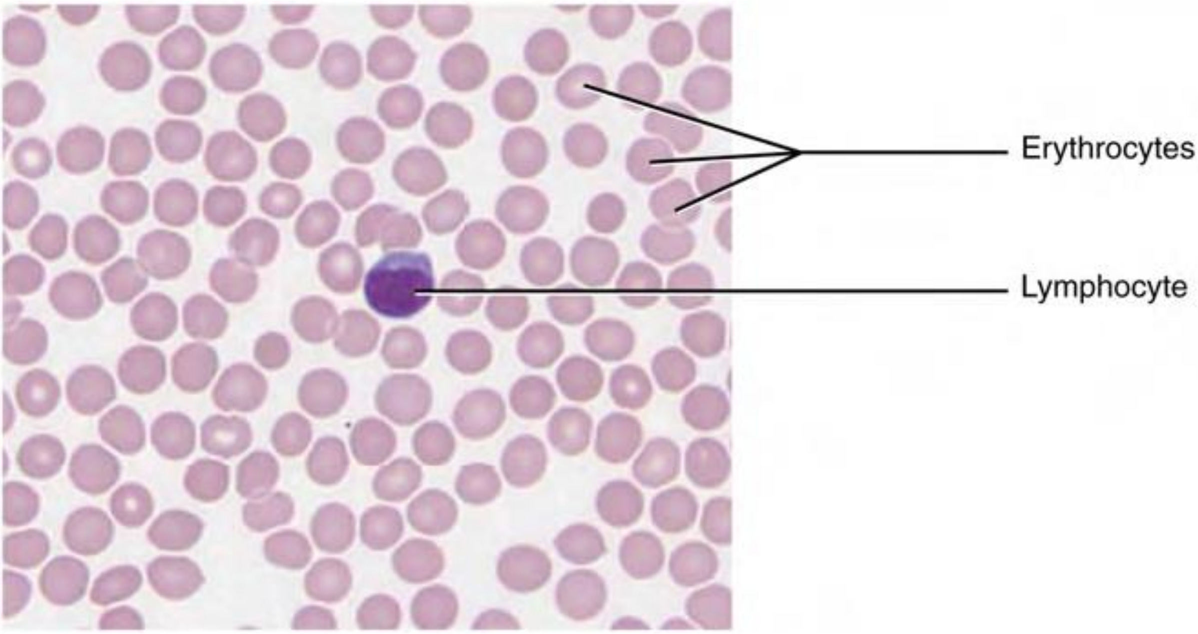

Figure 3.2.1: Blood, a Fluid Connective Tissue. **Source:** OpenStax College (2013, *Page 142). Blood seen here is a fluid connective tissue containing erythrocytes and various types of leukocytes that circulate in a liquid extracellular matrix.*

Lymph the Fluid Connective Tissue

Lymph is a connective tissue that contains a liquid matrix and white blood cells. Lymph is found in lymphatic capillaries which are extremely permeable, and so allows larger molecules and excess fluid from interstitial spaces to enter the lymphatic vessels. Lymph gets emptied into blood vessels, where it delivers molecules such as absorbed large fat molecules, to the bloodstream. It is in the form of the lymph, the liquid or fluid connective tissue, that those large molecules that could not be absorbed directly into the bloodstream, are transport from the intestine and delivered into the blood.

Soft or Semisolid Connective Tissues

These connective tissues are made up of living cells embedded in a matrix that is semisolid or soft in nature. Soft connective tissue, also known as proper connective tissue, has two types of cells; cells that remain within the tissue throughout its life span, and cells that move into and out of the tissue in response to chemical signals. Examples of fixed cells in soft connective tissues are fibroblasts, fibrocytes, adipocytes, and mesenchymal macrophages, mast cells, lymphocytes, plasma cells, and phagocytes are cells that move in and out. Fibroblasts and fibrocytes secrete polysaccharides and proteins which combine with extra-cellular fluids to produce a viscous ground substance. It is this extracellular ground substance in which fibrous proteins are embedded that forms the extra-cellular matrix of soft or proper connective tissue. Adipocytes are cells used for storing droplets of fat molecules. White and brown adipocytes are the two forms in which adipocytes exists in the body. Brown adipocytes store fat molecules, lipids, as many droplets, while white fat adipocytes store lipids as a one large drop of lipid. Mesenchymal macrophages occur as stem cells or fixed macrophages. The mesenchymal stem cell can differentiate into any type of connective tissue cells needed for repair and healing of a damaged tissue. The macrophage cells (fixed and roaming) are an essential component of the immune system. When the fixed macrophage cells are stimulated, they release cytokines that recruit other cells of the immune system, such as free or roaming macrophages, to infected sites. Mast cells have many cytoplasmic granules that signal the production of histamine and heparin. Histamine released from mast cells of

soft connective tissues causes vasodilation and increased blood flow to the site of injury or infection accompanied with itching, swelling, and redness.
The matrix of soft connective tissue is made up a viscous ground substance produced by fibroblasts and fibrocytes in which fibrous proteins are embedded. There are three major types of protein fibres in the matrix of all soft connective tissues. These protein fibres are collagen fibres, elastic fibres, and reticular fibres. Collagen fibres are flexible, very strong, do not stretch, and are found in ligaments and tendons which are characteristically resilient and tough. Ligaments hold bone to bones in joints of the human body while tendons attach muscles to bones. Collagen fibres that make the soft tissues of ligaments and tendons are thus very important in sports.
Reticular fibre is also made of the protein, collagen. The collagen proteins in reticular fibre are, however, narrow in shape and arranged in a greater array of branching network. Reticular fibres are found mostly in the liver and spleen.
Elastic fibre is mainly made up of protein elastin that has the property of being able to return to its original shape after being stretched or compressed. Elastic fibres are found mostly in the elastic tissues of the skin and the elastic ligaments of the vertebral column.
Soft or proper connective tissue, depending on how tightly packed the cells and matrix substances are, exist in two forms. These are loose soft connective tissues or dense soft connective tissues.

Loose Soft Connective Tissue
The cells and matrix of loose connective tissues are so loosely packed that they permit water, salts, and various nutrients to diffuse through them into adjoining or imbedded cells and tissues. Loose soft connective tissues are found between many organs of the body where they perform the function of binding tissues together and absorbing shock. Adipose, areolar and reticular tissues are the loose soft connective tissues in the body.

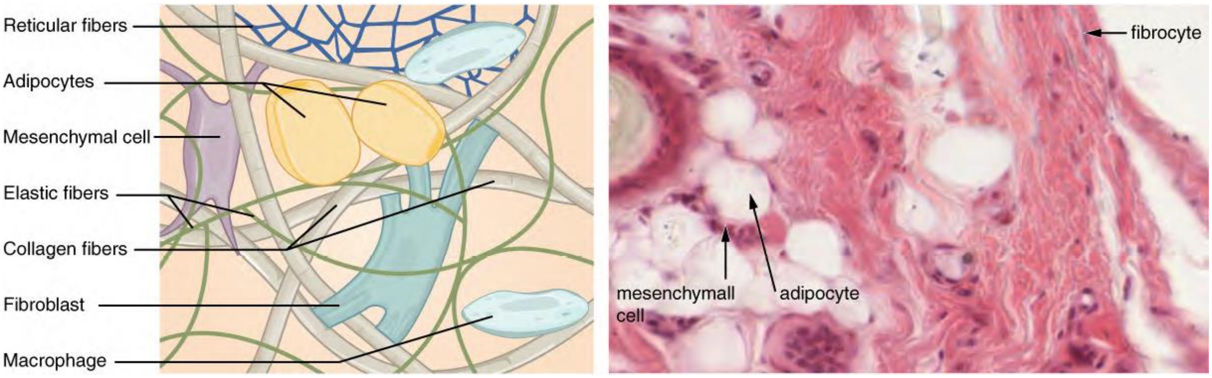

Figure 3.2.2: Loose Connective Tissue**. Source:** OpenStax College (2013, *Page 147).*

Adipose Tissue
The cells in adipose tissue are called adipocytes and are used for storage of fat. The extracellular matrix of adipose tissue is composed of a small amount of tissue fluids and collagen fibres. Adipose tissue exists as white and brown coloured fat in humans. These fat tissues functions distinctly because they are composed of adipocytes (fat cells) that are different in structure, type of protein fibres, and in developmental origin. White adipose tissue makes up the main mass of adipose tissue in human adults, and represents 10-20 percent of body weight in healthy individuals. White adipose tissue is located mainly under the skin (where it is known as subcutaneous fat) and surrounding internal organs (where it is known as visceral fat). White adipose tissue consists of white adipocytes that are specialised

for the storage of energy in the form of triglycerides or lipids, which can be released via lipolysis whenever energy is needed.
Structurally, white adipocytes contain one big lipid droplet that occupy most of its cytoplasm, and has a peripheral nucleus, which makes it to look like a signet ring. Brown adipose tissue is made up of adipocytes with unique thermogenic properties which are vital for maintaining body temperature without shivering. Structurally, brown adipocytes contain many small lipid droplets that make them have a multi-locular histological appearance. Brown adipose tissue has a lot of blood capillaries that pass through them and so appear brown in colour. Brown adipocytes contain densely packed mitochondria that are needed for generating heat without shivering. Brown adipose tissue in human adults is mainly found in the supraclavicular, neck, perirenal and mediastinal region.

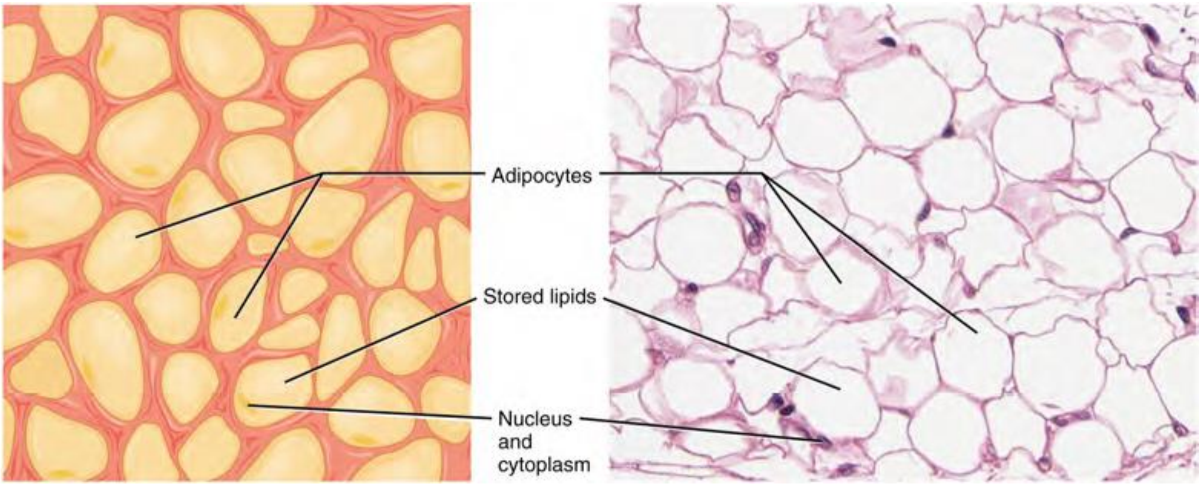

Figure 3.2.3: Adipose Tissue. **Source:** OpenStax College (2013, *Page 149).*

Areolar Tissue
It contains all the cell types and fibres previously described and are distributed in a random, web-like fashion. It fills the spaces between muscle fibres, surrounds blood and lymph vessels, and supports organs in the abdominal cavity. Areolar tissue underlies most epithelia and represents the connective tissue component of epithelial membranes, which are described further in a later section. The cells of areolar tissue are generally known as fibroblasts. Mast cells and white blood cells are also found in areolar tissue. The matrix of areolar tissue is made up of extracellular fluid and the protein fibres called collagen and elastin. Areolar tissue is found under the skin and beneath the epithelial tissue of all the body systems that have openings to the environment. It is this strategic location that makes it possible for the mast cells and white blood cells in areolar tissue to intercept pathogens before they get to the blood and circulate throughout the body.

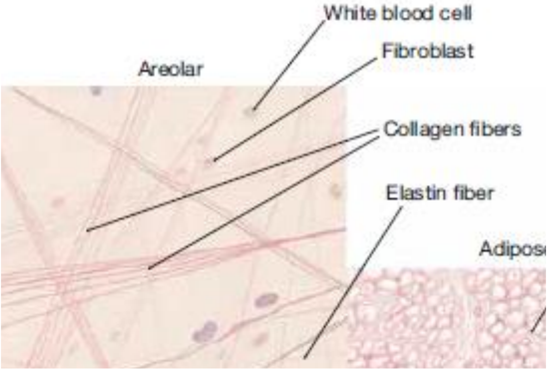

Figure 3.2.4: Areolar Connective Tissue. Source: Scanlon and Sanders (2007, page 75).

Reticular tissue
Reticular tissue looks like a mesh. It is used mainly to support soft organs of the body such as lymphatic vessels, the spleen, and the liver.

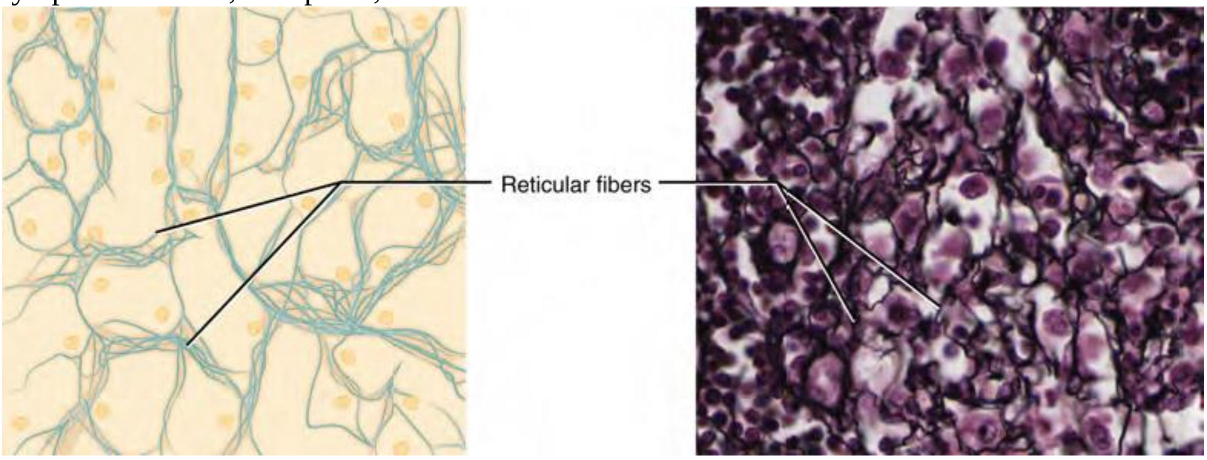

Figure 3.2.5: Reticular Tissue. **Source:** OpenStax College (2013, *Page 149).*

Dense Connective Tissue
There are more collagen fibres in dense connective tissue compared to loose connective tissue. For this reason, dense connective tissue does not stretch easily. Dense connective tissue appears in the body as regular dense connective tissue and irregular dense connective tissue. The collagen fibres in dense regular connective tissue are placed parallel to each other, thus making it to be very strong and difficult to stretch in the direction of orientation. Dense regular tissues are found in ligaments and tendons. Elastin fibres are also found in some dense regular tissue. It is the elastin in the ligaments of the vocal folds and between the vertebrae in the vertebral column that allows the ligament to return to its original length after stretching.
The protein fibres in dense irregular connective tissue are randomly arranged. The fibres in some dense irregular tissues crisscross one another to form a mesh. In other dense irregular connective tissues, the fibres are arranged in layers where they are aligned in one direction. These layers of protein fibres, which run in the same orientation, are however, stacked at an angle making the tissue to stretch in several directions. For this reason, dense irregular connective tissue is not as strong as dense regular connective tissue in a given direction but stronger in all directions. Dense irregular tissues are found in the dermis of the skin and in the walls of blood carrying arteries.

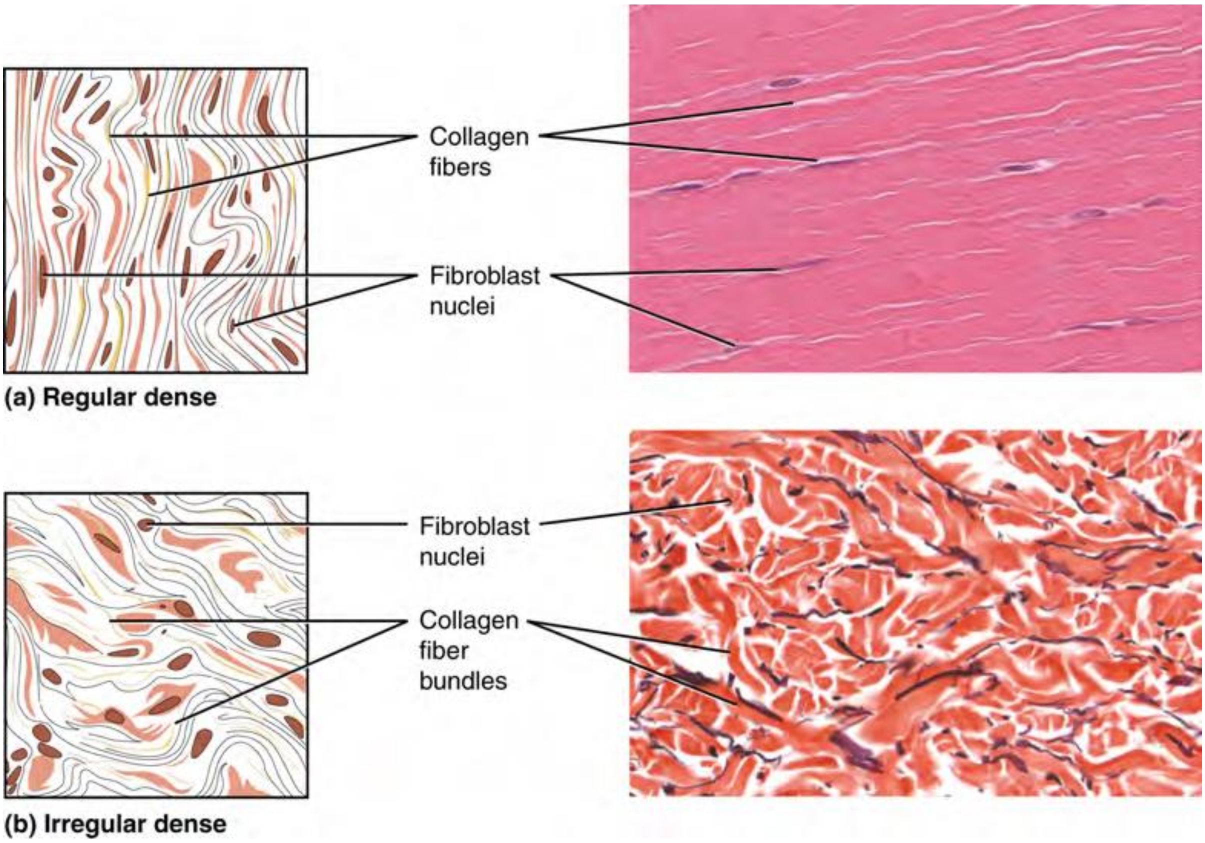

Figure 3.2.6: Dense Connective Tissue. **Source:** OpenStax College (2013, *Page 150).*
Note that in (a) the collagenous fibres are packed in parallel bundles; in (b) the collagenous fibres are interwoven into a mesh-like network.

Supportive Connective Tissue

There are two major forms of supportive connective tissue, cartilage and bone, that allow the body to maintain its posture and protect internal organs.

Cartilage

Cartilage is a special type of dense irregular connective tissue that is solid. Cartilage is used for supportive and purposes in addition to allowing the body to maintain its posture. The cells in cartilage are called chondrocytes. The matrix of cartilage is made up of proteoglycans, the firm substance formed from the binding of ground substance collagenous proteins with the polysaccharides known as chondroitin sulphate. The cells, chondrocytes, occupy the space called lacuna (plural = lacunae) in the solid matrix of cartilage. Every cartilage is covered by another layer of dense irregular connective tissue known as the perichondrium. Blood supply does not get to the tissue, cartilage. Therefore, all nutritional requirements of the chondrocytes have to diffuse through the matrix. For this reason, cartilage does not heal fast whenever it is injured.

There are three major types of cartilage. These are hyaline cartilage, fibrocartilage, and elastic cartilage.

Hyaline cartilage is made up of large quantities of proteoglycans in which are dispersed collagen fibres. Hyaline cartilage is strong and flexible and it has smooth surface. It is the most common type of cartilage in the human body found in the rib cage and nose and covers the ends or joining parts of the bones in all moveable joints. It is from a cartilage template that bone formation takes place in the embryo and allows bones to grow at their ends until adulthood.

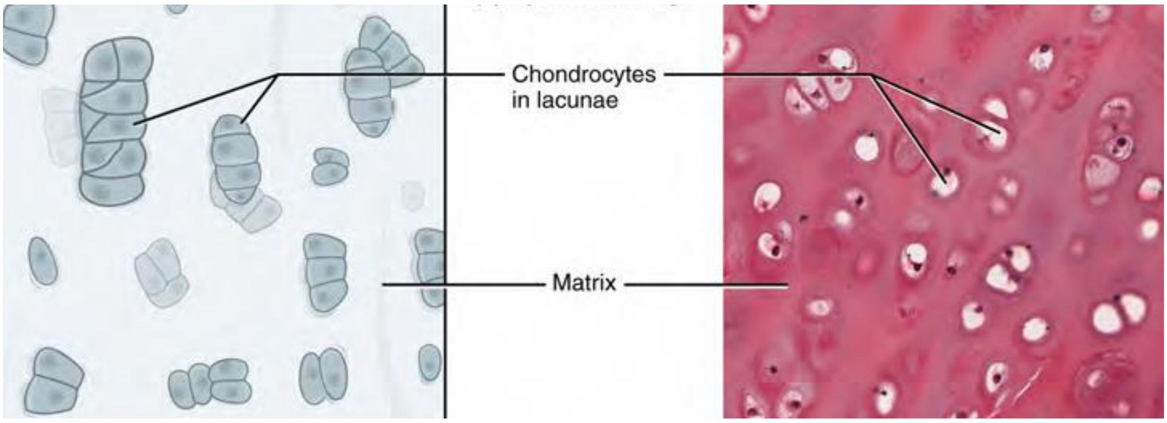

Figure 3.2.7**:** Hyaline Cartilage. **Source:** OpenStax College (2013, *Page 152).*

Fibrocartilage has thick bundles of collagen fibers dispersed in its proteoglycans matrix that enables it to provide some form of compressibility and to absorb shock and pressure. Fibrocartilage is tough and is found in the joints of the knee jaws and the intervertebral discs.

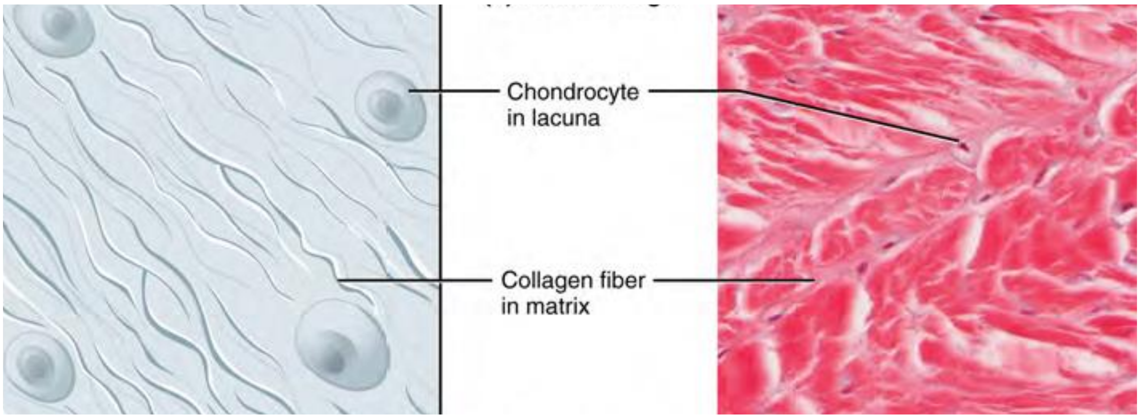

Figure 3.2.8: Fibrocartilage. **Source:** OpenStax College (2013, *Page 152).*

Elastic cartilage has a lot of elastic protein fibers and collagen protein fibres embedded in the proteoglycans ground substance. Elastic cartilage is found in lobes of the external ear where it provides a rigid support and elasticity.

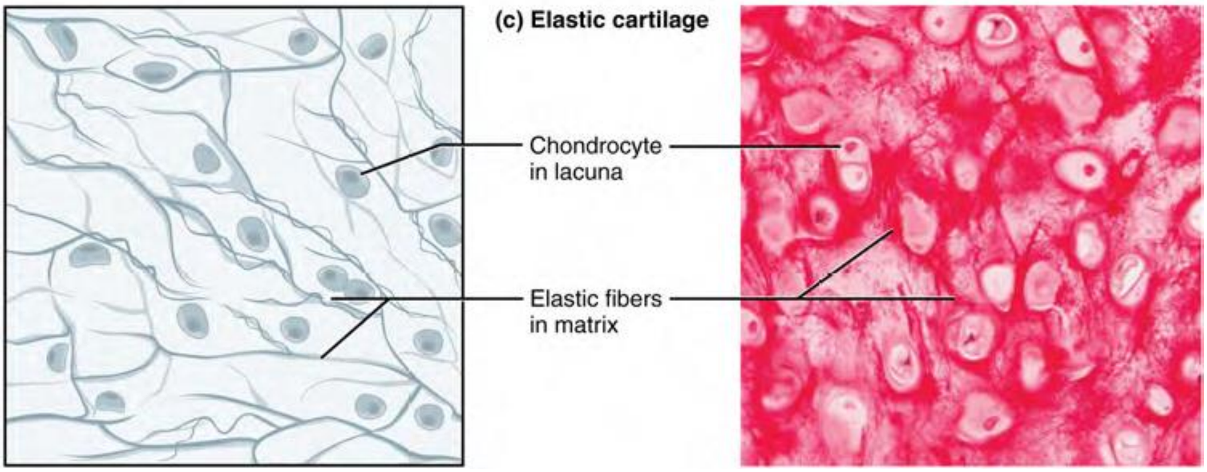

Figure 3.2.9: Elastic Cartilage. **Source:** OpenStax College (2013, *Page 152).*

Bone

The matrix of cartilage is made up of proteoglycans, the firm substance formed from the binding of ground substance collagenous proteins with the polysaccharides known as chondroitin sulphate. The cells, chondrocytes, occupy the space called lacuna (plural = lacunae) in the solid matrix of cartilage. Every cartilage is covered by another layer of dense irregular connective tissue known as the perichondrium. Blood supply does not get to the tissue, cartilage. Therefore, all nutritional requirements of the chondrocytes have to diffuse through the matrix. For this reason, cartilage does not heal fast whenever it is injured.

Bone is a very hard dense irregular connective tissue. The non-living matrix of bone is made up of a rigid ground substance that is very rich in minerals in which are embedded a lot of collagen fibres. The matrix of bone also contains a special type of calcium known as hydroxyapatite. In other words, the matrix of bone is composed of both organic and inorganic substances. The inorganic mineral crystals, which derive from the special form of calcium, in the matrix of bone make it to be a very dense connective hard. The mineral crystals in bone tissue make to be the hardest tissue in the body that does not bend nor flex. Mineral crystals, being brittle in property, could have made bone tissue to be brittle and so shatter easily. However, the organic substance, collagen fibres, embedded in the matrix of bone tissue maintains the hard and rigid consistency of bone tisuue. It it this hard and rigid property of bone tissue that enables bone to provide protection for internal organs and supports the body and systems of organs.

The cells in bone are Osteoblasts, bone-forming cells, osteoclasts that reabsorb or break down bone tissue and osteocytes mature bone cells. These bone cells are found inside lacunae produced within the hard matrix of bone. The lacunae containing living osteocytes in bone tissue are transversely in concentric circles around its central canal. Bone is structured in such a manner that allows blood vessels to reach the lacucae and so supply blood to the living cells.

There are two types of bone tissue: compact and spongy. The names imply that the two types of differ in density, or how tightly the tissue is packed together. There are three types of cells that contribute to bone homeostasis. Osteoblasts are bone-forming cell, osteoclasts resorb or break down bone, and osteocytes are mature bone cells. An equilibrium between osteoblasts and osteoclasts maintains bone tissue.

Compact Bone

Compact bone consists of closely packed osteons or haversian systems. The osteon consists of a central canal called the osteonic (haversian) canal, which is surrounded by concentric rings (lamellae) of matrix. Between the rings of matrix, the bone cells (osteocytes) are located in spaces called lacunae. Small channels (canaliculi) radiate from the lacunae to the osteonic (haversian) canal to provide passageways through the hard matrix. In compact bone, the haversian systems are packed tightly together to form what appears to be a solid mass. The osteonic canals contain blood vessels that are parallel to the long axis of the bone. These blood vessels interconnect, by way of perforating canals, with vessels on the surface of the bone.

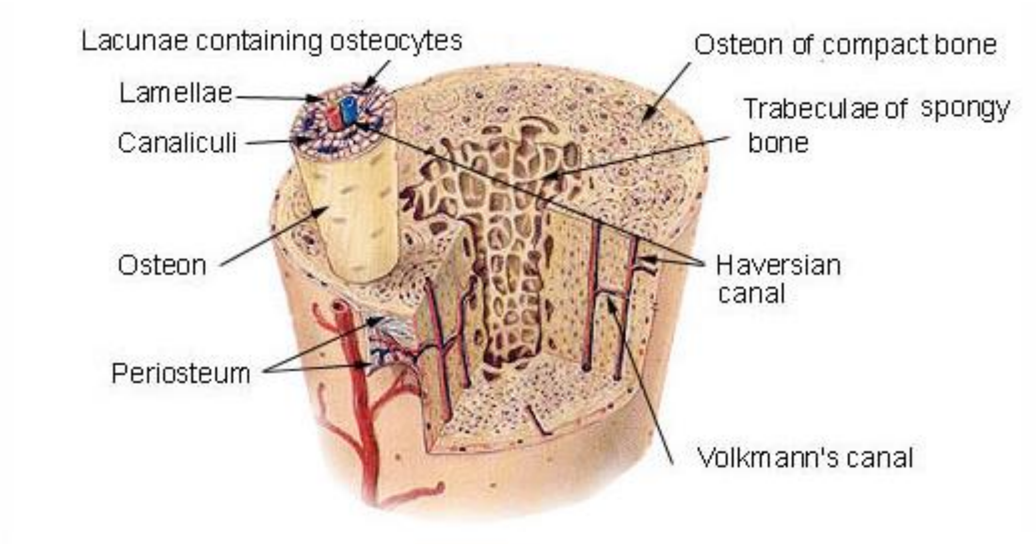

Figure 3.2.10: Spongy or Cancellous Bone**. Source:** ICD-0-3 (2007)**.**

Spongy (cancellous) bone is lighter and less dense than compact bone. Spongy bone consists of plates (trabeculae) and bars of bone adjacent to small, irregular cavities that contain red bone marrow. The canaliculi connect to the adjacent cavities, instead of a central haversian canal, to receive their blood supply. It may appear that the trabeculae are arranged in a haphazard manner, but they are organized to provide maximum strength similar to braces that are used to support a building. The trabeculae of spongy bone follow the lines of stress and can realign if the direction of stress changes.

Parts of the skeleton are formed during the first few weeks after conception. By the end of the eighth week after conception, the skeletal pattern is formed in cartilage and connective tissue membranes and ossification begins. Bone development continues throughout adulthood. Even after adult stature is attained, bone development continues for repair of fractures and for remodelling to meet changing lifestyles. All three types of bone cells, osteoblasts, osteocytes and osteoclasts, are involved in the development, growth and remodelling of bones. Osteoblasts are bone-forming cells, osteocytes are mature bone cells and osteoclasts break down and reabsorb bone.

The terms osteogenesis and ossification are often used synonymously to indicate the process of bone formation. There are two types of ossification: intramembranous and endochondral.

Intramembranous

Intramembranous ossification involves the replacement of sheet-like connective tissue membranes with bony tissue. Bones formed in this manner are called intramembranous bones. They include certain flat bones of the skull and some of the irregular bones. The future bones are first formed as loose connective tissue membranes. Osteoblasts migrate to the membranes and deposit bony matrix around themselves. When the osteoblasts are surrounded by matrix they are called osteocytes.

Endochondral Ossification

Endochondral ossification involves the replacement of hyaline cartilage with bony tissue. Most of the bones of the skeleton are formed in this manner. These bones are called endochondral bones. In this process, the future bones are first formed as hyaline cartilage models. During the third month after conception, the perichondrium that surrounds the hyaline cartilage "models" becomes infiltrated with blood vessels and osteoblasts and changes into a periosteum. The osteoblasts form a collar of compact bone around the diaphysis. At the same time, the cartilage in the centre of the diaphysis begins to disintegrate. Osteoblasts penetrate the disintegrating cartilage and replace it with spongy bone. This forms a primary ossification centre. Ossification continues from this centre toward the ends of the bones. After spongy bone is formed in the diaphysis, osteoclasts break down the newly formed bone to open up the medullary cavity.

The cartilage in the epiphyses continues to grow so the developing bone increases in length. Later, usually after birth, secondary ossification centres form in the epiphyses. Ossification in the epiphyses is similar to that in the diaphysis except that the spongy bone is retained instead of being broken down to form medullary cavities. When secondary ossification is complete, the hyaline cartilage is totally replaced by bone except in two areas. A region of hyaline cartilage remains over the surface of the epiphysis as the articular (joint-ends) cartilage and another area of cartilage remains between the epiphysis and diaphysis. This is the epiphyseal plate or growth region.

Bone Growth
Bones grow in length at the epiphyseal plate by a process that is similar to endochondral ossification. The cartilage in the region of the epiphyseal plate next to the epiphysis continues to grow by mitosis. The chondrocytes, in the region next to the diaphysis, age and degenerate. Osteoblasts move in and ossify the matrix to form bone. This process continues throughout childhood and the adolescent years until the cartilage growth slows and finally stops. When cartilage growth ceases, usually in the early twenties, the epiphyseal plate completely ossifies so that only a thin epiphyseal line remains and the bones can no longer grow in length. Bone growth is under the influence of growth hormone from the anterior pituitary gland and sex hormones from the ovaries and testes.

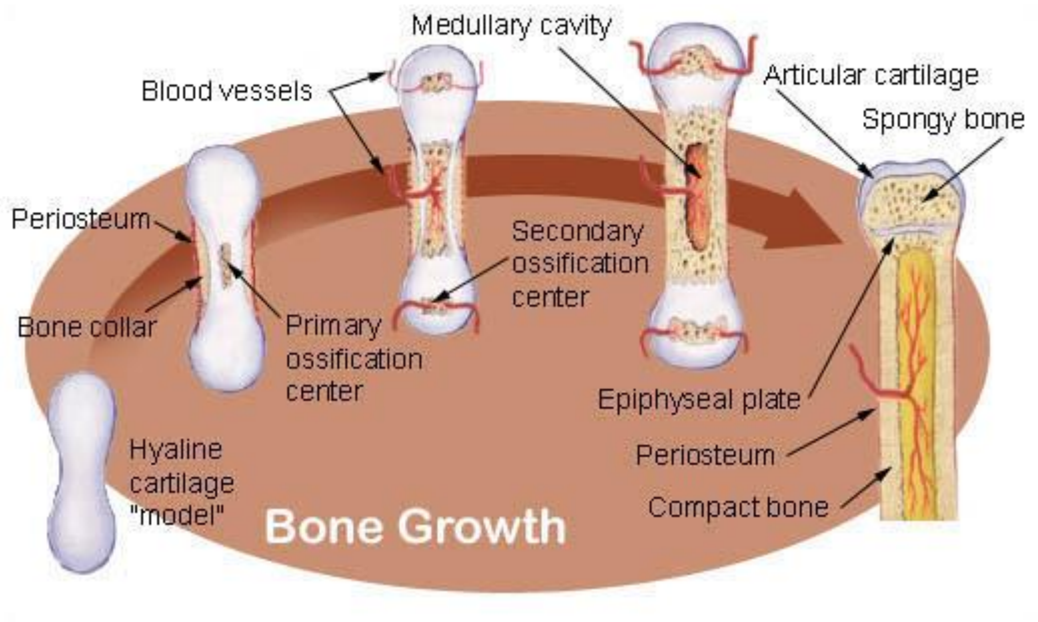

Figure 3.2.11: Bone Growth**. Source:** ICD-0-3 (2007)**.**

Even though bones stop growing in length in early adulthood, they can continue to increase in thickness or diameter throughout life in response to stress from increased muscle activity or to weight during sports performance. The increase in diameter is called appositional growth. Osteoblasts in the periosteum form compact bone around the external bone surface. At the same time, osteoclasts in the endosteum break down bone on the internal bone surface, around the medullary cavity. These two processes together increase the diameter of the bone and, at the same time, keep the bone from becoming excessively heavy and bulky.

Functions of Bone Tissue

The living cells in the bones in our bodies use oxygen and give off waste products in metabolism. They are thus active tissues that consume nutrients, require a blood supply and change shape or remodel in response to variations in mechanical stress.

Bones provide a rigid frame work, known as the skeleton, which support and protect the soft organs of the body. The skeleton supports the body against the pull of gravity. The large bones of the lower limbs support the trunk when standing.

The skeleton also protects the soft body parts. The fused bones of the cranium surround the brain to make it less vulnerable to injury. Vertebrae surround and protect the spinal cord and bones of the rib cage help protect the heart and lungs of the thorax.

Bones work together with muscles as simple mechanical lever systems to produce body movement.

The extracellular matrix of bone contains large amounts of calcium salts, the most important being calcium phosphate. When blood calcium levels decrease below normal, calcium is released from the bones so that there will be an adequate supply for metabolic needs. When blood calcium levels are increased, the excess calcium is stored in the bone matrix. The dynamic process of releasing and storing calcium goes on almost continuously.

Hematopoiesis, the formation of blood cells, mostly takes place in the red marrow of the bones. In infants, red marrow is found in the bone cavities. With age, it is largely replaced by yellow marrow for fat storage. In adults, red marrow is limited to the spongy bone in the skull, ribs, sternum, clavicles, vertebrae and pelvis. Red marrow functions in the formation of red blood cells, white blood cells and blood platelets.

4.0 Conclusion

There are loose and dense connective tissues in the body. The different types of connective tissues are structurally suited to their various functions.

5.0 Summary

Now that you have learned how connective tissues function in protecting and supporting every of the tissues and organs of the body systems, you are now ready to go a little bit further by studying the fourth level of organisation, the muscular tissue level that allows movement to take place.

Self Assessment Exercise

1. List and describe the different types of dense and loose connective tissues.
2. How are the structures of connective tissues related to their functions?
3. How is a compact bone different from a spongy bone? Show the location of each.
4. The three essential components found in every connective tissue __________
    a. cells, ground substance, and carbohydrate fibers
    b. cells, ground substance, and protein fibers
    c. collagen, ground substance, and protein fibers
    d. matrix, ground substance, and fluid
5. ____________ is the type of connective tissue in ligaments that holds bones strongly together in joints of the human skeleton.
    a. areolar tissue

   b. adipose tissue
   c. dense regular connective tissue
   d. dense irregular connective tissue
6. The matrix of the connective tissue, blood is made up of __________
   a. Fibroblasts and a matrix of tissue fluid, collagen, and elastin fibres.
   b. Adipocytes that store fat.
   c. Plasma
   d. Mostly elastin fibers (matrix) with few fibroblasts.
7. How would you describe a specimen obtained from one of the organs that is observed, under a microscope, to have cells located in spaces scattered in a transparent background?
   a. loose connective tissue
   b. tendon
   c. bone
   d. hyaline cartilage
8. The connective tissue that specializes in fat storage is called ___________
   a. a. tendon
   b. adipose tissue
   c. reticular tissue
   d. dense connective tissue
9. The matrix of the connective tissue, bone, consists of _________
   a. Chondrocytes in a flexible protein matrix
   b. Mostly collagen fibers (matrix) with few fibroblasts.
   c. Mostly elastin fibers (matrix) with few fibroblasts.
   d. Osteocytes in a matrix of calcium salts and collagen.
10. The matrix of the connective tissue, cartilage, consists of -----
   a. Chondrocytes in a flexible protein matrix
   b. Mostly collagen fibers (matrix) with few fibroblasts.
   c. Mostly elastin fibers (matrix) with few fibroblasts.
   d. Osteocytes in a matrix of calcium salts and collagen.

6.0 References/Further Readings

ICD-0-3 (2007). Body Structure and Function. Retrieved on May 10, 2007 from http://training.seer.gov/module_anatomy/unit1_body_structure.html

McArdle, D. Katch, F. I., Katch, V. L. (1999): *Exercise Physiology: Energy, Nutrition and Human Performance. (4th ed.)* U.S.A. Lippricot Williams and Wilkins.

McGlynn, G. (1999). *Dynamics of Fitness: A Practical Approach. (5th ed.).* The McGraw – Hill Company Inc.

OpenStax College, *Anatomy & Physiology*. OpenStax College. 25 April 2013. http://cnx.org/content/col11496/latest/

Robergs, R. A. and Kateyian, S. J. (2003). *Fundamentals of exercise physiology for fitness, performance and health. (2nd ed)* New York. McGraw Hill.

Scanlon, V. C. and Sanders, T. (2007): *Essentials of Anatomy and Physiology*. Philadelphia: F. A. Davis Company

Unit 3:Muscle and Nerve Tissues

1.0 Introduction

Muscle tissue is the most abundant tissue in the human body. Muscle tissues are made up of muscle cells with little or no intercellular ground matter. The muscles cells are called fibres because they are long and slender and usually arranged in bundles or sheets bounded by connective tissues. The fibres in a muscle are composed of protein filaments called actin and myosin, which are capable of sliding across each other. The sliding across each other by the protein filaments constituting a muscle fibre makes it possible for the muscle fibre to lengthen or shorten. This is what has given the property of contractility and elasticity to muscles. All forms of movement by the body or in the body are due to contracting or relaxing muscles. There three types of muscle tissues in the body. These are skeletal (striated), smooth, and cardiac.

Nerve tissue is made up of specialized cells for the purpose of transmitting impulses. These impulses enable us have a sense of both internal and external stimuli as well as make it possible for us to coordinate and control many of our bodies' activities. Three different types of cells make up nervous tissue. These are the neurons, glial cells and Schwann's cell.

2.0 Intended Learning Outcome(s)

By the end of this unit, you would be able to

- Describe the structure and function of skeletal, soft, and cardiac muscle tissues
- Describe the structure and functions of the cells in a nerve tissue.
- Distinguish between skeletal, soft and cardiac muscular tissues.
- Distinguish between neurons, glial cells and Schwann's cells.

3.0 Main Content

Skeletal Muscle Tissue

Skeletal muscles are attached to the various bones of the skeleton so that their contraction can result in movement of the body or its part(s). It is for this reason that skeletal muscles are so called. A skeletal muscle is made up of thin elongated cylindrical cells, called fibres and described as syncytium. The cells are described as syncytium because each of the cells has many nuclei. The nuclei in skeletal muscles are oval in shape and are located at the periphery of the cell just beneath the sarcolemma. The sarcolemma is the thin elastic plasma membrane which surrounds the muscle cell. Almost all of the cell's cytoplasm called sarcoplasm is occupied by striated, thread-like myofibrils. Each myofibril is made up of the small protein filaments, actin and myosin. The myosin and actin filaments are responsible for the striated appearance of the myofibril as shown shortly. The myosin filaments are thicker and are located towards the centre where they produce a dark band, called the A-band. The actin filaments are thin and are situated on either side of the A-band, where they make up the light bands, called the I-bands. This arrangement of actin and myosin filaments, known as a sarcomere, allows the filaments to slide across each other thereby contracting or shortening its length. The sarcomere is therefore the functional unit of a muscle since the contraction of the several sarcomeres in a muscle that contracts the muscle.

Figure 3.3.5: Skeletal Muscle Tissue. **Source:** ICD-03 (2007)

Smooth Muscle Tissue

Smooth muscle tissues are made up of thin-elongated muscle cells that have single, large, oval nuclei. Every one of the cells have many myofibrils which are arranged in such a way that they are parallel to one another in the direction of the long axis of the cell. The myofibrils, embedded in the sarcoplasm and surrounded by the sarcolemma just as in skeletal muscles, are however not arranged in any definite striped or striated pattern. Smooth muscles fibres therefore do not have any striations. The fibres are not bunched together to form bundles as found in skeletal muscles. Rather, the fibres interlace to form sheets or layers of tissue. The autonomic nervous system innervates the smooth muscles. Hence smooth muscles are not voluntarily controlled. Muscles in the walls of internal, hollow organs are smooth muscles. The walls of the digestive tract, bladder, uterus, various glands' ducts, blood vessels, etc., are made up of smooth muscles. Contractions of smooth are slow and involuntarily done when compared to the contractions of skeletal muscles which are fast and voluntarily controlled. The slow involuntary movements of the oesophagus, stomach and intestines during mechanical digestion of food, and the slow contraction and relaxation of arterial muscles in the regulation of blood flow and pressure, are accomplished by smooth muscles.

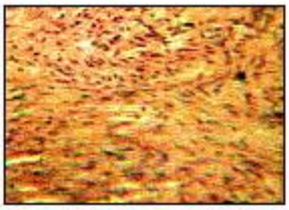

Figure 3.3.2: Smooth Muscle Tissue. **Source:** ICD-03 (2007)

Cardiac (Heart) Muscle Tissue

The muscles of the heart are of different kind of muscle tissue. This tissue is found only in the walls of the heart and it is called cardiac or heart muscle tissue. Cardiac muscle tissue possesses some of both skeletal and smooth muscle tissue properties. The fibres in cardiac muscle have both longitudinal and imperfect cross striations like skeletal muscle fibres but with a centrally located nucleus like smooth muscle fibres. Cardiac muscle fibres branches out and are connected to each other by specialized junctions known as intercalated disks. Aroelar connective tissue which contains blood capillaries fills the spaces between adjacent cardiac muscle fibres. This is because cardiac muscles get damaged in the absence or insufficient supply of blood and oxygen. It is the rhythmic and powerful contraction of cardiac muscles that pumps blood and its contents round the body.

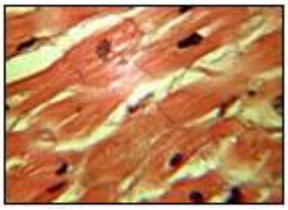

Figure 3.3.3: Cardiac Muscle Tissue. **Source:** ICD-03 (2007)

Neurons

Neurons, or nerve cells, are cells which are highly specialized for carrying out the functions of the nervous system. Neurons are so specialized that they are able to communicate with each other by way of electrical nerve impulses. In this manner, neurons are able to control and coordinate a lot of body activities such stimulation of muscle contractions, making us aware of our internal and external environments, our feelings, reasoning and memory. Neurons are located in the brain, spinal cord and nerves. One peculiar feature of neurons is that they are amitotic. By amitotic, we mean neurons do not undergo mitosis. Therefore a destroyed neuron cannot be replaced. The implication is that we live with the exact number of neurons we are born with till the end of our lives. A neuron may grow in size but it cannot be reproduced or repaired if destroyed. It is for this reason that neurons are heavily protected by the skull, spinal column and glial cells. The image by ICD-0-3 (2007) below illustrates the structure of a typical neuron.

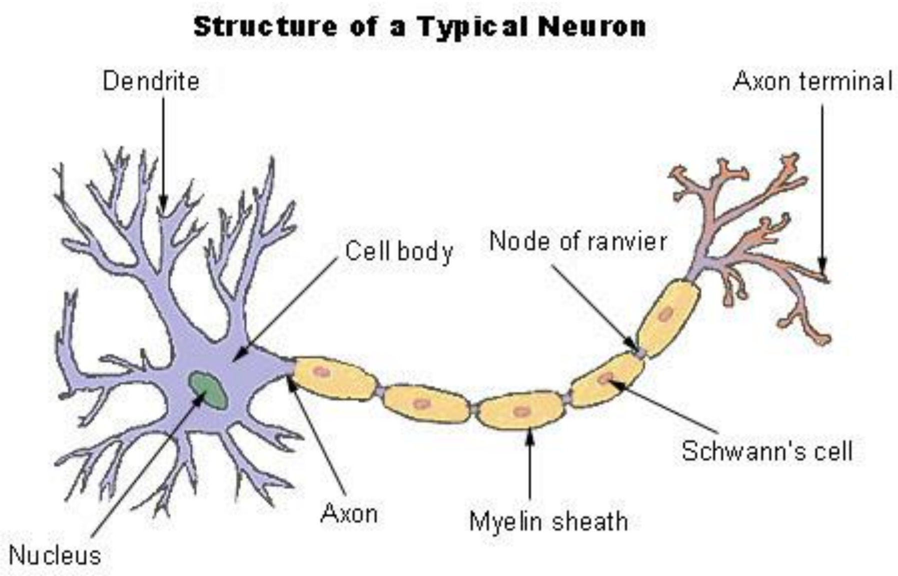

Figure 3.3.4: Neuron. **Source:** ICD-03 (2007)

From this illustration we can see that the basic parts of a neuron are cell body (soma), one or more dendrites, and a single axon.

Cell Body

Like most other cells, the cell body of a neuron has a nucleus and a minimum of one nucleolus with many of the typical cell organelles. Centrioles, the organelles used for cell division in a typical cell are however missing in the cell body of a neuron. The absence of centrioles from neurons is therefore quite consistent with the amitotic nature of neurons.

Neuronal Projection; Dendrites and Axon

Several fibres known as dendrites and one long shaft known as axon are cytoplasmic extensions, or processes, that project from the cell body. In most cases dendrites are short and branching. Dendrites increase the surface area which a neuron uses to receive signals from other neurons. Because dendrites transmit impulses to the cell body of a neuron, they are called afferent processes. Axon, the single elongated cytoplasmic projection from the cell body, on the other hand, is usually referred to as an efferent process. This is because it carries impulses away from the cell body. Branches known as axon collaterals may emanate from an axon. An axon or axon collateral terminates in whose distal ends enlarges to form synaptic bulbs. These branches that end an axon or axon collateral are known as telodendria.

Neuroglia

Neuroglia cells are more numerous than neurons. Neuroglia cells can reproduce through mitosis, therefore their number can always increase. They do not conduct nerve impulses the way neurons do. The work of neuroglia cells is to support, nourish, and protect the neurons. This is consistent with their name, neuroglia which literally means neurons gum, hence they gum neurons together thereby supporting and protecting them.

Myelin and Neurilemma

A white fatty substance called myelin or myelin sheet surrounds most axons of nerve fibres. Such nerve fibres are called myelinated fibres. The myelin sheet is not continuous. Rather it is segmented in myelinated fibres. The regions which are not covered by myelin in myelinated fibres are called the nodes of Ranvier. The white matter of the brain and the spinal cord is made up of myelinated fibres while the gray matter is made up of cell bodies and unmyelinated nerve fibres. In the peripheral nervous system, Schwann cells are found at the nodes of Ranvier. These Schwann cells whose nucleus, cytoplasm, and cell membranes forms tight coverings known as neurilemma around the axon, secretes the myelin covering of the nerve cell's axon. The neurilemma therefore separates the segmented layers of the myelin sheet. It is the neurilemma that makes the regeneration of peripheral nerve fibres possible. The myelin sheet in the central nervous system is however not produced by Schwann cells but by oligodendrocytes. Oligodendrocytes do not form neurilemma hence nerve regeneration can never occur in the central nervous system. Nerve cells do not actually touch one another. They lie in close proximity to each in a particular manner that allows the terminal branches of an axon and the dendrites of another neuron to almost touch at special junctions known as synapses.

4.0 Conclusion

You learnt the structure and function of muscular and nervous tissues and how to distinguish between the different types of muscle tissues and the different types of cells and their functions in a nervous tissue. You also learnt how the different types of muscle and nerve tissues are structurally suited to their various functions.

5.0 Summary

Now that you have learned how muscle and nerve tissues function in bringing about human movement, you are now ready to go a little bit further by studying the fifth level of organisation, where tissues are organised into organs and organ systems at the organ system levels.

Self Assessment Exercise

1. List and describe the different types of muscle tissues. State two functions of each of the identified muscle tissue types.
2. List and describe the three types of cells in a nervous tissue.
3. Skeletal muscles are

a. Small tapered cells with no striations and one nucleus each found in the walls of arteries, stomach and intestines.
b. Branched cells with faint striations and one nucleus each found in the walls of the chambers of the heart
c. Large cylindrical cells with striations and several nuclei each
d. Rectangular cells with little or no striations

4. Cardiac muscles are
    a. Small tapered cells with no striations and one nucleus each found in the walls of arteries, stomach and intestines.
    b. Branched cells with faint striations and one nucleus each found in the walls of the chambers of the heart
    c. Large cylindrical cells with striations and several nuclei each
    d. Rectangular cells with little or no striations
5. The cell body of a neuron contains----
    a. nerve processes that carry impulses within the cell body
    b. cellular processes that carry impulses toward the cell body
    c. the nucleus that regulates the functioning of the neuron
    d. Cellular processes that carries impulses away from the cell body
6. The dendrites of a neuron contains ----
    a. nerve processes that carry impulses within the cell body
    b. cellular processes that carry impulses toward the cell body
    c. the nucleus that regulates the functioning of the neuron
    d. Cellular processes that carries impulses away from the cell body
7. -------- between the axon of one neuron and the dendrite or cell body of the next neuron that enable it to transmits impulses from one neuron to others
    a. Synapse
    b. Melanin
    c. Stratum germinativum
    d. Stratum corneum
8. Striations, cylindrical cells, and multiple nuclei are observed in ________.
    a. skeletal muscle only
    b. cardiac muscle only
    c. smooth muscle only
    d. skeletal and cardiac muscles
9. The cells responsible for the transmission of the nerve impulse are ________
    a. Neurons
    b. Oligodendrocytes
    c. Astrocytes
    d. microglia
10. The nerve impulse travels down the ________, away from the cell body.
    a. Dendrite
    b. Axon
    c. Microglia
    d. collagen fiber

6.0 References/Further Readings

ICD-0-3 (2007). Body Structure and Function. Retrieved on May 10, 2007 from *http://training.seer.gov/module_anatomy/unit1_body_structure.html*

McArdle, D. Katch, F. I., Katch, V. L. (1999): *Exercise Physiology: Energy, Nutrition and Human Performance. (4th ed.)* U.S.A. Lippricot Williams and Wilkins.

McGlynn, G. (1999). *Dynamics of Fitness: A Practical Approach. (5th ed.).* The McGraw – Hill Company Inc.

OpenStax College, *Anatomy & Physiology*. OpenStax College. 25 April 2013. *http://cnx.org/content/col11496/latest/*

Robergs, R. A. and Kateyian, S. J. (2003). *Fundamentals of exercise physiology for fitness, performance and health. (2nd ed)* New York. McGraw Hill.

Scanlon, V. C. and Sanders, T. (2007): *Essentials of Anatomy and Physiology*. Philadelphia: F. A. Davis Company