ESSENTIALS OF HUMAN ANATOMY

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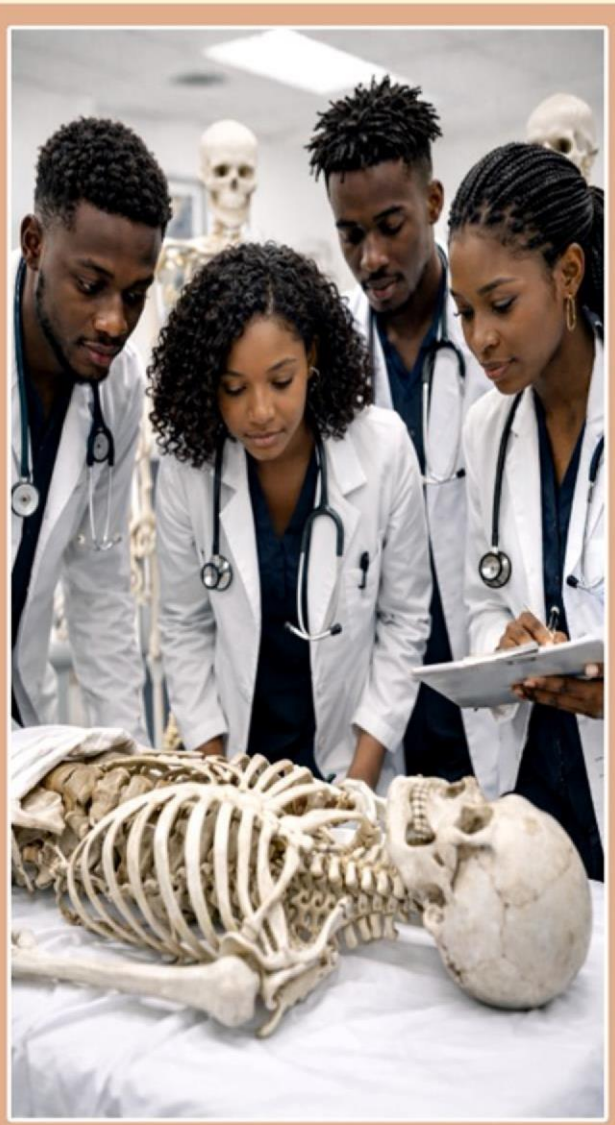
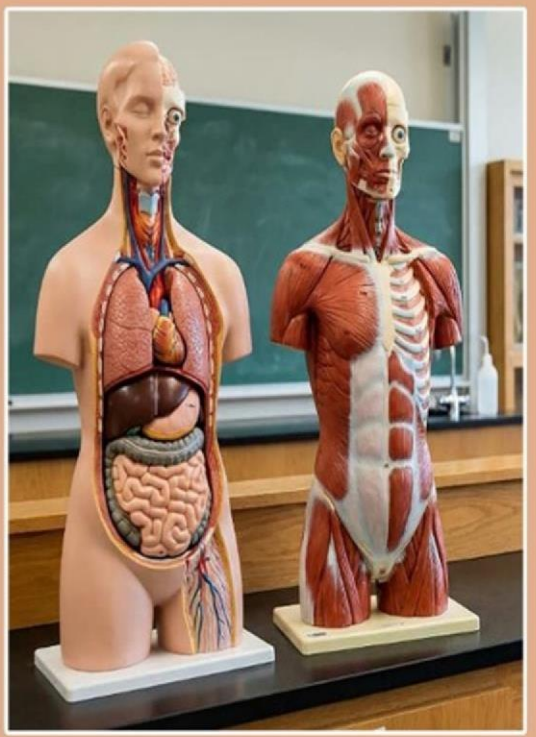
..... Lecture Notes for Beginners in Tropical Africa





Volume 1

DR. SAVIOUR ADJENTI

ESSENTIALS OF HUMAN ANATOMY

……. Lecture Notes for Beginners in Tropical Africa

Vol. 1

Saviour Adjenti

Design by DanGrace Services
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ISBN: 978 – 9988 – 41 – 097 – 1 EBOOK

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DEDICATION

I dedicate this book to God Almighty, my lovely family and friends.

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ACKNOWLEDGEMENT

Grateful to all my teachers who taught me this intriguing subject. Sincere gratitude also to all my students – present, past and future ones, from whom I have gained more in the learning of this fascinating subject than have given them. I‟m indebted to all the online sources and resources from which the illustrative images were obtained and used in this handbook. A big thanks to my colleagues in the Department of Physician Assistantship Studies, Central University School of Medical Sciences, especially to Ms. Gifty Amenya, a Clinical Psychologist and Ms. Gloria Aidoo, a Physician Assistant and Anatomist for taking time off their busy schedules to proofread the drafted materials independently, to Mr. Bright Tetteh Danyo (Opeemu) CEO of DanGrace Services – Printing and Publications. Finally, special thanks to my colleagues at the Department of Anatomy, University of Ghana Medical School for loaning out the study materials to me as a way of their support for the teaching and learning of our most cherished subject in a new and challenging environment.

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PREFACE

This handbook has been written primarily for undergraduate students studying Human Anatomy as *freshers* in all Health Science programmes across tropical African countries. Aptly referred to as *lecture notes,* it is not intended to replace the consultation and reading of standard Human Anatomy textbooks, but this handbook is made available to serve as an appealing, easy-to-read structured material for the curious student who is determined to have a head-start with the subject.

Essentials of Human Anatomy is born out of the author's enormous years of teaching experience, and out of personal observation that traditional textbooks of Human Anatomy tend to be voluminous, densely detailed and at times intimidating to many naïve beginners. The contents of this handbook are therefore designed to bring readers to a solid level of understanding of this fascinating subject while still leaving room for a desire to explore further knowledge. The themes of the book are presented as *units* rather than *chapters* to emphasize the fundamental and integrated nature of its contextual material. Whether a student is offering Anatomy as part of a multi-disciplinary modular course or as a stand-alone course requirement in their studies, a *unit* in this book would be found useful and relevant in its fundamental approach to every topic under consideration.

The simple and engaging presentation style adopted in *Essentials of Human Anatomy* are purported at discouraging rote learning by students. In both volumes 1 and 2, the contents are presented to underscore the importance of gaining a first-hand understanding of human anatomy for future healthcare professionals, portraying the subject as a practical tool in the hands of all healthcare professionals. Each *unit* of the book relates structure and function to what happens *when things go wrong* in the body, while also revealing the anatomical basis of clinical techniques and procedures. This approach allows

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readers to anticipate their clinical years with a clear and confident understanding of the human body.

From relating the biochemical activities in a cell to a bustling city, to describing blood as a specialized connective tissue, *Essentials of Human Anatomy* is rich in everyday examples, making the contents of the book easy to grasp. The contents of this handbook are best appreciated when read in conjunction with a standard human anatomy atlas; be it gross, embryology, histology or neuroanatomy atlas. Just as *Volume 1* of this handbook provides a foundation for the contents in *Volume 2*, each *unit* is carefully arranged to build logically on the previous one.

Essentials of Human Anatomy although designed as an abridged textbook for the beginner, its contents are presented in a clear and vivid manner, intended to inspire a lasting interest and curiosity in the subject. Enjoy this free ebook, and all comments and feedback are welcome.

S. Adjenti (*PhD, Cape Town; FWACMo***).**

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UNIT ONE

DESCRIPTIVE ANATOMY

Introduction

*Are you one of those who think **sciences** are dull, abstract or far removed from your everyday world? Perhaps you should put those thoughts away for a while. The study of human anatomy ought to be an exciting adventure, because it is your body that you are studying. The structures exist, and the processes are happening life in your own body!*

Anatomy, by definition, is the study of form and structure of organism. Currently it embraces physiology and biochemistry, and functions have grown faint. Full definitions of anatomy must therefore integrate these allied disciplines.

Anatomy: definition and description

What Anatomy is *NOT!*

The subject called Anatomy is not Medicine/Surgery; Nursing; Physiology; Physiotherapy/Radiography; Art/Biology; nor serving as Health and Prevention of diseases.

What is Anatomy?

Anatomy is a **tool** in the hands of the **practitioners** of **medicine** and related **allied health sciences.** It is a living subject/science; also can be described as a **visual science** and/or a **descriptive science**. Anatomy is the ***science*** that deals with the study of the ***structures*** of the body and the ***relationships*** between one structure and the other.

Anatomy is from the Greek word "***anatome"*** which means to cut open. Anatomy mainly deals with the **study of the structure of the body while its close "sibling" *physiology*** is a branch of *biological science* dealing with the ***function*** of ***organs*** and ***organ systems*** in the body.

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Importance of Anatomy

Anatomy as a subject or discipline is the bedrock of *medicine*. It forms the **basis** for a ***systematic approach*** to ***patient examination.*** It is useful for the ***recognition*** of **pathological changes,** for example a diagnosis of swollen eyes could only be made if and only if the normal structure of the human eye is fully known; forms the **basis** for ***surgical management*** of cases in surgical practice, for example removal of uterus (hysterectomy) requires a thorough knowledge of both the uterus and related structures in that region and Anatomy also serves as the principal knowledge **base** for ***radiological diagnosis,*** for example X-rays, CT scans etc.

Overview of Anatomy

The branches of Anatomy as a discipline include:

Gross Anatomy; Microscopic Anatomy (Histology); Developmental Anatomy (Embryology); Comparative Anatomy and Neuroanatomy

Anatomy: approaches to the study of the subject (methodology)

The study of Anatomy can be approached in different ways namely:

Regional Anatomy: studies regions of the human body, for example abdomen, leg, head and neck, thorax.

Systematic Anatomy: the body structure is studied by systems. For example, cardiovascular system etc. The main tool deployed in the regional and systemic approaches is by dissection and viewing of microscopic slides.

Surface Anatomy: the study of internal organs as they relate to the overlying skin surface. Mainly studied by means of palpation – scientific and skillful way of touching the surface of the body in order to perceive the state of underlying structures.

Terminologies / anatomical nomenclature

To prevent misunderstanding among professionals of the medical fraternity, universally accepted terms are used to describe the body parts. An accurate use of anatomical terms is essential to avoid confusion and ambiguity. There is therefore, an international nomenclature, the basis of which is Latin. Anatomical terms can be divided into two general categories namely;

- names of parts of the body and
- descriptive terms that include adjectives and adverbs of body parts. For ease of naming body parts, the human body is conceptually divided into three main parts with each bearing its unique anatomical term or name.

These parts are:

- **Head and Neck**

Head describing any rounded end/extremity in the body. The anatomical term for head is *caput* while *capitis* is the adjective form of caput (*Latin = capit*). This is not to be confused with the English noun, *skull* which is the word that describes the bones of the head, protecting the brain. The anatomical term for skull, however is *cranium,* from which the adjective cranial is derived. In context, *cephalon* or *cephale* is the anatomical name

(Greek) for "the head" from which comes the adjective form, cephalic. Neck describes any constricted or narrowed part which is immediately following a rounded end. Two words are used to mean neck: **collum** and **cervix** *from these terms* are derived the possessive/adjectival forms **colli** and **cervical** respectively. The back of the *real* neck, referred to as **nucha**, but its derivative **nuchal,** is more commonly used for structures relating to the neck.

Trunk

This is sub-divided into chest; anatomical name is thorax or pectoral. Abdomen, pelvis and perineum are the other anatomical terms describing the remaining parts of the trunk. The abdomen lies immediately below the chest with the thoraco-abdominal diaphragm, which is a skeletal muscle separating the two. The back part of the abdomen is referred to anatomically as the *lumbar* region. Pelvis means basin in Latin: is the part of the trunk (appearing like a basin actually), that continuous below the abdomen. Perineum is the anatomical term for the most inferior part of the trunk. This is separated from the pelvis above by the pelvic diaphragm (muscles) and from the space below (external body environment) by the urogenital diaphragm. The external genitalia in both males and females are found in the perineum. The perineum is wrongly regarded colloquially as the *„private part"*.

Limbs: these are the attachments or appendages to the trunk. The anatomical name for limbs is **membra; membrum** = singular. The limbs are subdivided into four segments. For the upper limb, the segments are:

Shoulder (**acromion**); arm (**brachium**), forearm (**antebrachium**) and hand (**manus**). The two most conspicuous joints of the upper limb are the elbow (**cubital**) and wrist (**carpus,** *from this comes the word* ***carpal***).

Regarding the lower limbs, the segments are buttocks (**gluteus**); thigh (**femoral**); leg (**crus**; **crura =** plural) and foot (**pes/pedis**). The knee (**genu**) and ankle (**tarsus**; adjective = tarsal) are the most conspicuous joints of the lower limb.

Upper limb or lower limb is more appropriate anatomically than the words arm or leg. The arm **(brachium)** is the part of the upper limb between the shoulder and the elbow. Leg (**crus**) is the part of the lower limb between the knee joint and ankle joint.

Anatomical terms of positions, planes, direction and movement

Terms of positions, planes, directions and movement must be used in reference to the anatomic position and *are to be used systematically* to avoid confusion. Eponyms are not used in anatomy because *they* give no clue as to the type or location of a structure involved. *(Though clinicians do),* e.g **submandibular duct** instead of Wharton's duct or **inguinal ligament** instead of Poupart's ligament.

The anatomical position

The body is **erect**; **feet** together or *slightly apart**;*** the **upper limbs** *by the side* with the ***palm facing forward*** the **thumbs** *point away from the body.*

Source: https://www.spineuniverse.com/anatomy/anatomical-planes-body.

Terms of planes

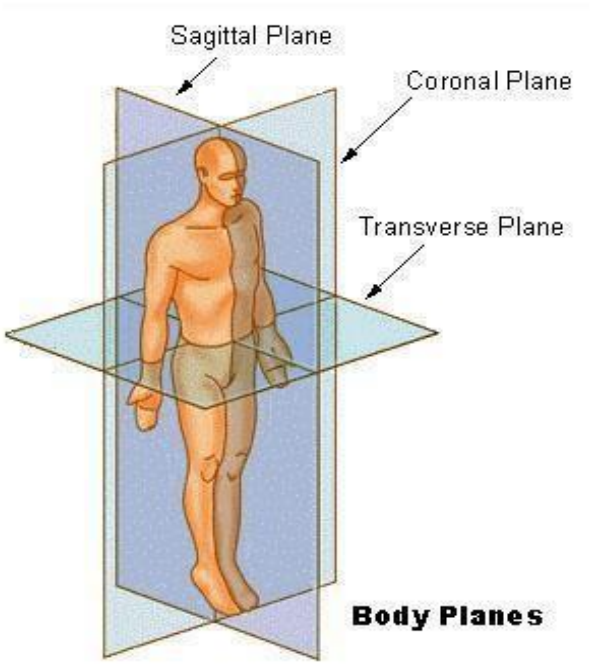
Planes are imaginary lines through parts of the body.

Median plane: this bisects the body into **equal** right and left halves. Any plane parallel to the median plane which is also dividing the body into a vertical left and right parts is known as the **sagittal plane.**

This implies that the **mid-sagittal plane** coincides with the median plane while the **para-sagittal plane** is skewed to the left or right of the median plane, giving left and right unequal parts.

A coronal plane is at right angles to the sagittal plane and bisects the body into front and back portions.

A transverse or horizontal plane is an imaginary plane passing through the body at right angles to both the median and coronal planes.



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Terms of positions

Terms of positions come in two contrasting pairs. **Medial** describes a position of a structure nearer to the median plane and **lateral** describes a position of a structure farther from the median plane.

Anterior describes a position of a structure nearer to the front of the body and **posterior** describes a position of a structure nearer to or towards the back. The terms **ventral** and **dorsal** may be used synonymously with anterior and posterior respectively, but are appropriately applicable in the description of structures in neuroanatomy and embryology.

Superior means structures lying above or towards the head and inferior means lying below or towards the foot.

Internal means towards or in the interior of an organ or cavity whereas external means a structure on the outer or towards the exterior part of an organ or cavity.

Superficial/superficialis means nearer to or on the surface of the body whereas **deep** or **profundus** means farther from the surface.

Proximal means nearest to the trunk or a point of origin/joint and with respect to the limbs *it* means closest to the *attached end* of the limb. **Distal** means farther from the trunk and in the limbs it means positions farther from the *attached end*.

In describing the limbs, all the above terms may be used, but in addition terms of positions of their paired bones are used.eg **in the upper limb,** the radius is the lateral bone of the forearm and ulna is the medial bone, therefore, **radial** refers to the thumb-side or lateral side while **ulnar** side refers to little finger or medial side. Thumb is **pollex** anatomically (*pollicis = adjective*).

With regard to the **lower limb,** the leg segment has tibia as the medial bone and fibula as the lateral bone. Therefore**, tibial side** refers to the big-toe side and **fibular side** refers to the little-toe side. Big toe is referred to anatomically as **hallux** (*hallucis = adjective*).

For the anterior surface of the hand, the term **palmar** is used, similarly **plantar** is used in describing structures towards or on the sole of the foot. The posterior surface of both hand and foot is referred to as **dorsum.** In the

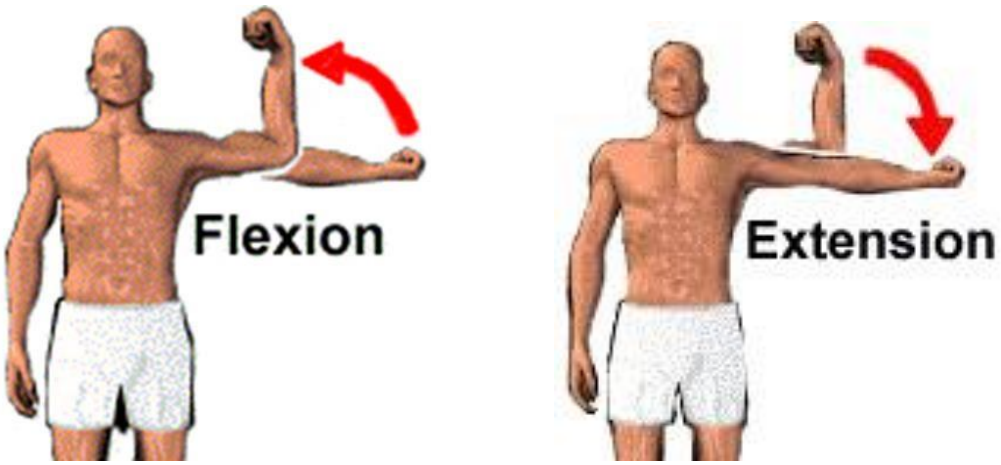
embryo, some additional terms are used. For example, structures close to the head are described as **cranial** or **rostral** while structures closer to the tail are described as **caudal.**

Anatomical terms of movement

Flexion: - Bending in a direction that **approximates** the ventral body surfaces of the body.

Extension: - Is the reverse of flexion and usually straightens a part by movement towards the original dorsal surface of the body. **Abduction:** - Means to draw away from the median plane.

Adduction: - The reverse of abduction, meaning to draw towards the median plane *except the digits* where the **middle** finger and toe serve as the reference line/plane.



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Spreading the digits apart is **abduction**, *drawing them together* is **adduction**. **Rotation** is a movement of a part around its long axis. **Circumduction** is a combination of all the above movements at a single point at the same time.

Supination and **pronation** refer only to movements of the forearm and hand. **In** the anatomical position, forearm and hand are supinated. When the

dorsum of the hand is turned forward without rotation of the arm, then the hand and forearm are pronated.

Inversion and **eversion** refer to movements of the foot only. **Inversion** is the movement that turns the sole of the foot **inward** or **medially** and eversion turns the sole **outward** or **laterally.**

UNIT TWO

THE CELL: STRUCTURE, FUNCTION AND CELL DIVISION

Cell structure

Introduction – why study about cells?

Most pathologic changes in the body are due to malfunctions of cells Infectious agents, for example viruses, bacteria and parasitic organisms act on or in human cells to cause *dis*-ease. Most clinical treatments involve surgical removal of cells or killing of unwanted cells while formulation of vaccines and new immunomodulatory drugs depend on cellular biology. Cancerous growth, formulation and new effective diagnostic and curative reagents depend on one's knowledge of cell biology.

The study of the cell provides a better understanding of the histology, pathology, physiology and the chemistry of the body. Anatomy is NOT only to describe structure but also to gain a true understanding of the biological processes which underlie that structural function. Human body is essentially a cellular structure; its existence as a single cell and subsequently develops by multiplication and differentiation of cells. Peak of growth is attained when cells and substance they generate mature. Generally, all cells can be separated into two categories: prokaryotic and eukaryotic cells; derived from the word ***karyon*** (Greek) meaning nucleus.

What is a cell?

Is the basic structural and functional unit of living organisms. It is the microscopic package that contains all the necessary components for survival of an organism.

Human body consists of **several trillions** of **cells** with varied **sizes**, **shapes** and **function**.

The study of cells is called ***cytology***. Robert Hooke was the first scientist to use the word cell. Robert Brown discovered the nucleus in 1833. Theodor Schwann discovered that animals were made of cells in 1838.

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The Cell Theory

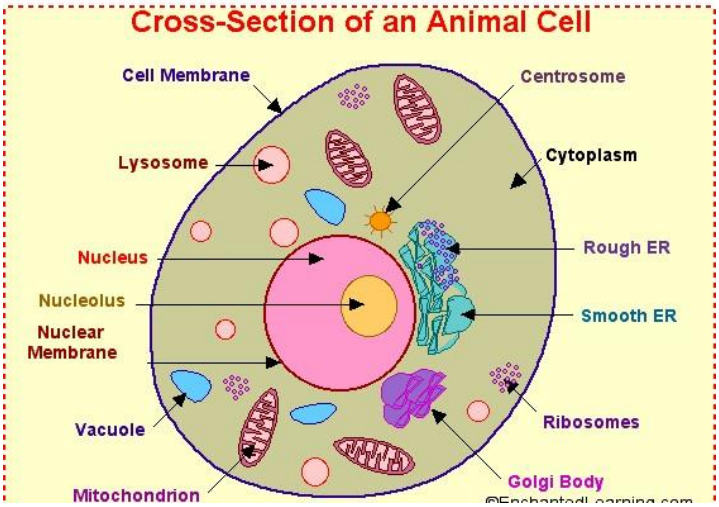
The Cell Theory states that:

1. All living things are composed of a cell or cells.
2. Cells are the basic unit of life.
3. All cells come from pre-existing cells.

Parts of the cell and cellular organelles

Human cells have three main parts: the plasma/cell membrane, cytoplasm and nucleus.

The cell membrane is a barrier and forms the outer boundary of the cell. Cytoplasm is the intracellular fluid with organelles which perform specific functions while the nucleus resides in the centre of the cytoplasm and *controls* the activities of the cell.



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Nucleus

It is located at the centre of the cell and controls all cellular activities. The genetic material resides in the nucleus. This genetic material, located in the nucleus contains **DNA** (?). A nucleus contains thin fibers of DNA and protein

called chromatin. The nucleus in turn contains a small round nucleolus which produces ribosomes. Nucleolus is the centre for rRNA and ribosome biosynthesis in the cell.

The nucleus is surrounded by a double membrane, which is frequently easy to see under light microscope. Usually there is one nucleus per cell, with only a few exceptions. The nuclear membrane is porous in nature.

Cytoplasm

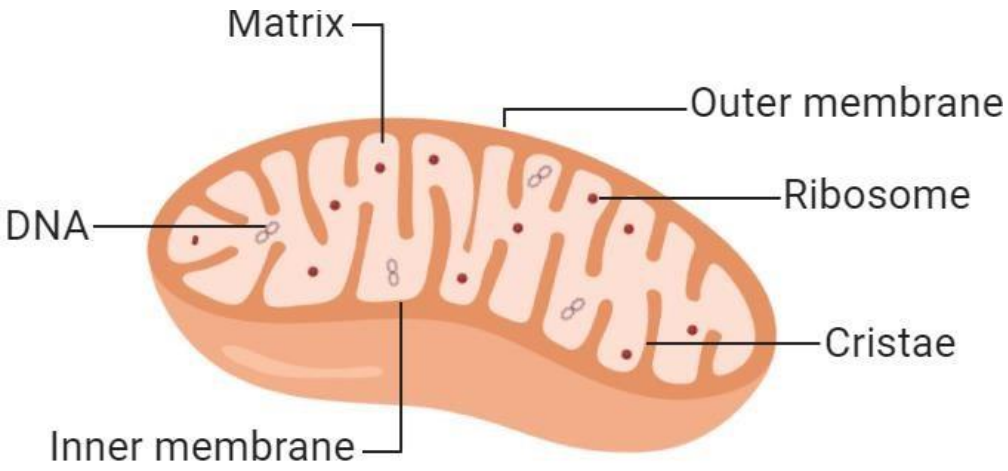
Cellular material between the plasma membrane and the nucleus. It is the site where most cellular activities occur. It consists of ***cytosol*** and **organelles.** The **cytosol** is the viscous, semi-transparent fluid in which other elements are suspended. **Organelles** are the components of the cell that carries out specific functions, for example synthesis of proteins. The cytoplasm provides shape and structure for the cell as well as helps in moving organelles around the cell. It consists mainly of water and dissolved substances like amino acids.

Organelles

These are membrane-bound structures, found in the cytoplasm and each has a specific function. Examples include:

Mitochondrion

It contains two membranes and has its own DNA. It functions in the production of high energy compound in the form ATP, which is made available for use by all other cellular activities. The number of mitochondria in a cell reflects its energy requirements levels.



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Ribosomes

These are small dark-stained granules, which serve as the center of protein synthesis. They are either free floating or attached to another type of organelle in the cell known as endoplasmic reticulum (ER). They are devoid of membranes characteristics of other organelles.

Endoplasmic reticulum

This is a complex network of transport channels. Two main types can be identified in the cell: smooth and rough ER. The smooth is ribosome-free, found away from the nucleus and functions in the synthesis of lipids (cholesterol). The rough ER contains ribosomes, are found near the nucleus and synthesizes protein.

Golgi apparatus

Tube-like cisterns found all over the cytoplasm. They are involved in modifying new proteins destined for lysosomes, secretion and plasma membrane. Golgi apparatus packages enzymes for lysosomes and proteins

for secretion. It sorts out all materials for lysosomes, secretion and incorporation into the plasma membrane.

Lysosomes

A membrane-bound organelle containing a variety of enzymes. They work best in acidic conditions. They help digest particles inside or outside the cell and are key in recycling cellular debris. Lysozymes are considered as the "demolition crew" of cells.

Peroxisomes

These are tiny, round-like organelles that are involved in oxidative activities of some specific biomolecules. They have an enzyme called catalase which is used to breakdown hydrogen peroxide into water in the cell.

Centrioles

They are paired tube-like structures found near the nuclear membrane. Play a role in the organizing of microtubules which serves as the cell"s skeletal system. Centrioles actively engage in the arrangement of mitotic spindles (thread-like proteins) during cell division.

Cytoplasmic inclusions

These are usually transitory components in the cell, composed mainly of accumulated metabolites or deposits. Examples of cytoplasmic inclusions are: accumulation of carbohydrates in the form of glycogen. Some occur in the form of organic pigments, for example lipofuscin, melanin, and others.

Cell death and renewal

Cell death and proliferation are balanced throughout the life of organisms. Animal development involves not only cell proliferation and differentiation

but also cell death. Most cell death occurs by a normal physiological process of programmed cell death. Peak of growth is attained when cells and substance they generate mature. ***Senescence*** however, sets in when cells begin to shrink, wither or decay, Death, therefore is the final cessation of ***all*** cellular activity. Cells are mostly renewed through cell division; i,e mitosis and meiosis.

Cell differentiation and specialisation

The general description of cells above is best suitable for undifferentiated *primitive cells* that exhibit several functional activities, each with little efficiency. But this primitiveness in cells has been transformed in eukaryotic cells into a variety of differentiated cells that become collectively able to perform some specific functions with much greater efficiency. The ***process*** by which a cell achieves specialisation is known as cell **differentiation.**

Examples of specialised cells

The cells identified as specialised in the body are: muscle cell/fibre; nervous cell; pancreatic cell/acinar; mucous gland cell; macrophages; sensory cells – they are involved in the ***transformation of physical and chemical stimuli into nervous impulses***. Others include: germ cells, some cells in the adrenal gland, testis and ovary which are involved in the ***synthesis and accumulation of steroids.*** The rest are: some cells in the intestine and kidney known as ***metabolite absorption cells*** and also some cells of the kidney tubules and salivary glands responsible for ***ion transport.***

Cells and aging

Aging is the general deterioration that gradually affects the structures and functions of our bodies/cells with the passage of time. There are five features associated with aging cell which are captured with the acronym, **CUPID:**

C = Cumulative; U = Universal; P = Progressive; I = Intrinsic and D = Deleterious.

Chromosomes and the cell cycle

Previous knowledge (recall): Cell is ***the smallest unit*** of the **living body *that can live on its own.*** Any part of the body is made up of lots of cells. Few cells in the human body are dead ones, examples of these are hair and the outer part nail.

Chromosome and chromatin

For a non-dividing cell the nuclear material is CHROMATIN. Chromatin has a homogenous appearance. During cell division, loss of this homogenous appearance of chromatin occurs.

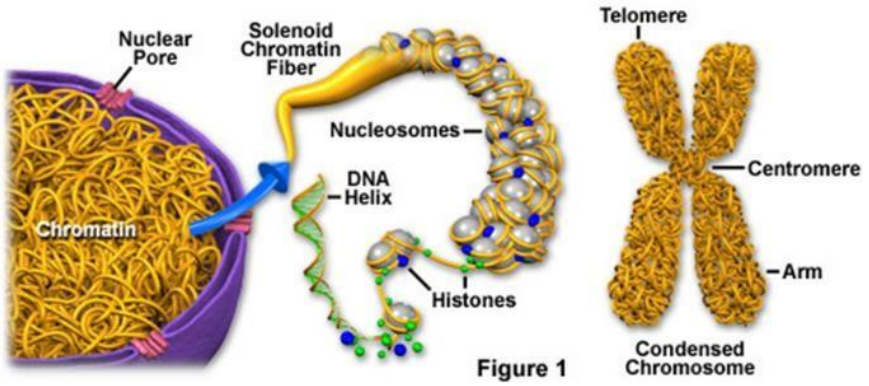

Figure 1

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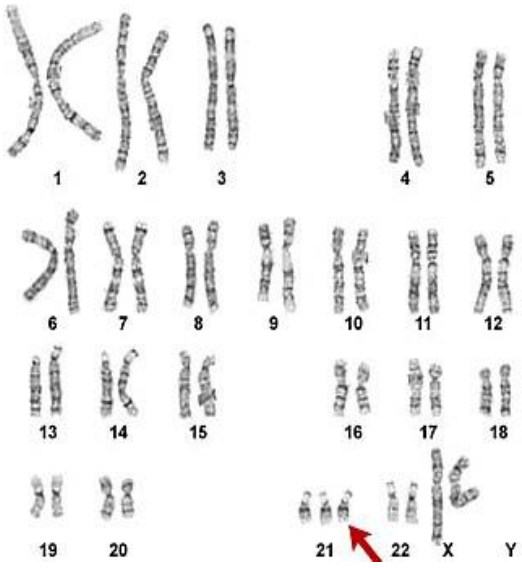
During cell division the genetic material condenses and transform into a number of rod-shaped "organelles" called chromosomes (stains deeply with dyes). Chromatin is composed of DNA and a complex class of proteins. The DNA molecule is double helix; this DNA repeatedly coiled around a central core of proteins. Chromatin, therefore can be considered as DNA combined

with multiples of central core protein. Several fibres of packed chromatin form the chromosome. Structurally, chromosomes contain DNA and are responsible for ***hereditary traits***.

Chromosomes, genes, gene map, alleles and inheritance

Genes are units or sequence of genetic information encoded on the chromosomal DNA. That is Anatomists regard genes as proteins in a linear order along chromosomes. Each gene occupies a precise position called **locus** on a chromosome. A gene map shows location of genes on chromosomes. A gene map is characteristic of each species and is same in all individuals within a particular species.

Human cells contain 46 chromosomes, constituting 23 pairs. Out of these 23 pairs, 22 pairs are alike in both males and females and are called autosomes. The remaining pair comprises the sex chromosomes are dissimilar, XX in females and XY in males. Members of a pair are called homologous chromosomes or homologs; that is they have the same gene loci.



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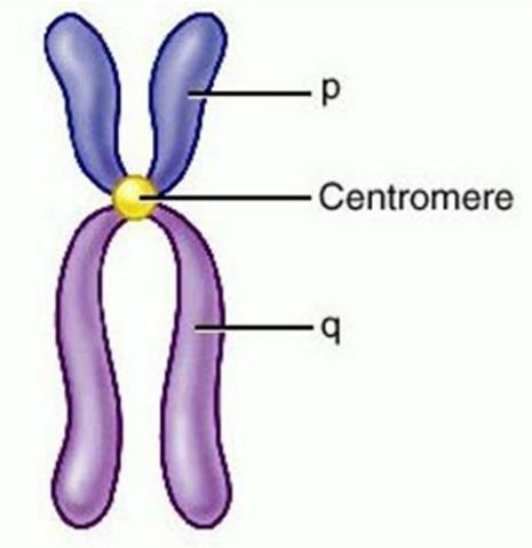
Chromosomes, genes, gene map, alleles and inheritance

Chromosomes, genes, gene map, alleles and inheritance genes at the same loci on homologs, coding for identical or slightly different forms of traits are known as alleles. Somatic cells have diploid (2n) chromosome complement, i.e 46 chromosomes. Gametes, sex cells have (n) chromosome complement, i.e 23 chromosomes.

Chromosomes, chromatin and chromatids

Chromosomes become more visible during cell division. At metaphase (during cell division), chromosomes appear to have a short arm and long arm, arising from a constricted region called the centromere.



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These arms (also called p and q arms) are sub units of chromosomes which are referred to as chromatids and are joined together at the centromere.

Based on location of a centromere, three types of chromosomes could be identified:

(1) Metacentric chromosome: the centromere is at the centre of the chromosome.

(2) Submetacentric chromosome, centromere closer to one end than the other and

(3) acrocentric chromosome has its centromere very near one end.

Anatomy of chromosomes and clinical application

Karyotype: This is the chromosome constitution of an individual (i.e number of chromosomes, sex chromosome constitution and morphology of chromosomes, size, shape and banding pattern).

Karyotyping: The process of photo-micrographing and arranging chromosomes according to standard classification. Any cell in the body except red blood cells can be a source of chromosomes for karyotyping in adults. It is best to use white blood samples separated from blood samples in adults. Chromosomes of fetuses are often obtained by either amniocentesis or chorionic villi sampling (CVS).

Amniocentesis: - is withdrawing a fluid from the uterus of a pregnant woman. (Not usually performed until about 14^{th} – 17^{th} week of pregnancy). This is an invasive method, requires about four weeks for results to be ready as cells need to be cultured to grow and increase in numbers. Risk of spontaneous abortions increases to about 0.3% after performing this procedure.

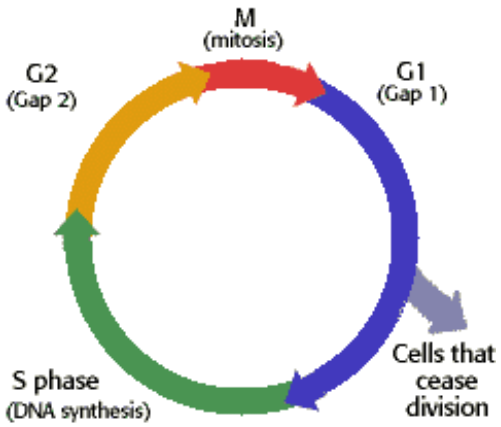
Chorionic villi sampling (CVS) may be done in the 5^{th} week of gestation. It is used to obtain foetal cells in the region where the placenta will develop. A thin suction tube is inserted through the vagina into uterus and cells withdrawn by suction. This is semi-invasive method, results are readily available in a shorter time but carries a higher risk of spontaneous abortion, about 0.8%

Cell cycle and cell division

Cells undergo two main types of division: mitosis and meiosis.

The cell cycle and mitosis

The life cycle of an individual cell is known as the cell cycle. Cell cycle is divided into two major phases: interphase and cell division. The cell cycle is the time interval between two mitotic divisions. This is subdivided into M, S, G1 and G2 phases/periods. M = mitotic; S = synthetic; G = Growth/ Gap. G1 is longer than G2 phase. The G1, S and G2 phases together are called **interphase** or **resting period.**



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Applied anatomy - the cell cycle and cancer cells

Cancer is a disease of the cell cycle and signal transduction pathways. A cell that is continually dividing is known as a cancer cell (no interphase). Normal cells become cancer cells through the process of transformation.

Mutant (changed or altered) genes that relax the controlling agents of the cell cycle are known as **oncogenes**. A tumour suppressor (gene) that regulates transcription is known p53. Cells that can enter the vascular system and invade other cells are known as metastatic cells. The suffix that identifies a

benign (friendly) cancerous growth is known as –"***oma"***. The suffix that identifies malignant cancerous growth of connective tissue or muscle is **sarcoma.**

Cell division

All cells come from pre-existing cells. The significance of cell division is that, it is vital for replacement of worn-out cells; required for growth and necessary for reproduction.

There are two types of cell division; mitosis and meiosis. Cells with diploid number of chromosomes replicate/divide by means of mitosis whereas those with haploid number of the genetic material undergo meiosis.

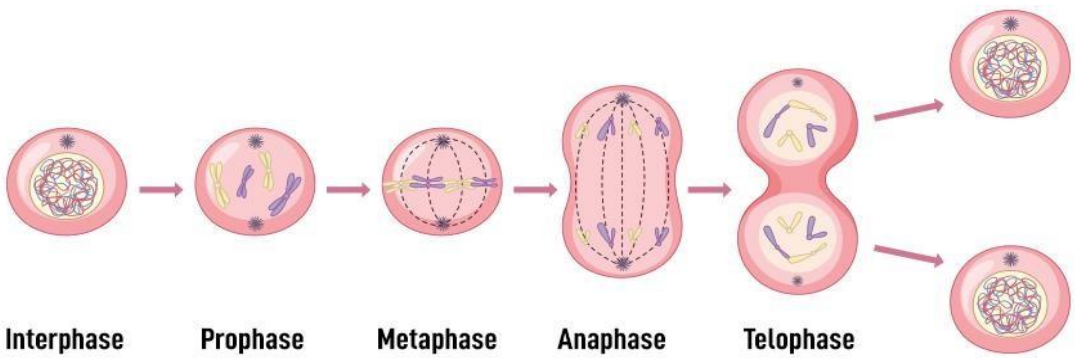
Mitosis – summary

The net result of mitosis is each chromosome in the nucleus splits to become two daughter chromosomes. The result is two identical daughter cells are eventually formed. Mitosis is divided into four overlapping stages namely;

Prophase

Key events include:

Shortening of chromosomes; chromosomes become condensed and more coiled; chromatids of chromosomes become more visible and the dissolution of nuclear membrane.



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Metaphase

Key evets include:

Nuclear spindle becomes more prominent; chromosomes move to the equatorial plane and nuclear spindles attached to chromosomes at centromeres.

Anaphase

Key events include:

Chromatids separate; each chromatid begins to move towards each pole of the cell.

Telophase

Key events include:

Nuclear membrane re-forms around each daughter nucleus; chromosomes uncoil.

Cytokinesis

Two daughter nuclei with chromosomal constitution identical to that of the original nucleus are formed.

Meiosis

This type of cell division is preceded by DNA synthesis and the process is split up into two cell divisions- meiosis I and meiosis II. Each is subdivided into prophase, metaphase, anaphase and telophase.

UNIT THREE

BASIC EMBRYOLOGY

Pre-zygotic processes (gametogenesis)

The pre-zygotic processes begin with the gametes: ovum or sperm cells. These processes are aptly termed gametogenesis, referring to the production of ova or spermatozoa. Therefore, gametogenesis is divided into two oogenesis - production of ova and spermatogenesis, the process of producing sperm cells/spermatozoa.

Spermatogenesis

Spermatogenesis: production of sperm

Each lobule in a testis is occupied by one to three coiled seminiferous tubules. Between the seminiferous tubules are groups of rounded interstitial cells called **Leydig cells** which produce the hormone, testosterone. The process starts at puberty and is marked by the hypothalamus secreting Releasing Hormones (RH). The RH stimulates anterior pituitary to start secreting follicle stimulating hormone (FSH). The FSH targets the testis to start sperm production. Prior to puberty, the testis has sex cords. At puberty, sex cords are transformed to seminiferous tubules with a lumen lined with epithelium. This epithelium is also called the germinal epithelial cells, which are supported by special cells called Sertoli cells. The germinal epithelial cells give rise to spermatogonia. The membranes of the Sertoli cells have receptors for the FSH. Sertoli cells after receiving the FSH stimulate spermatogonia to start the process of sperm production. The spermatogonia are situated below the cell membrane/occluding junctions of adjacent Sertoli cells.

Through the activity of FSH, spermatogonia begin to divide mitotically into two cell lines – spermatogonia type A and B.

Spermatogonia type A cells continue to divide by mitosis to form a pool of type A cells.

Spermatogonia type B cells ***differentiate*** to form **primary spermatocytes.** The primary spermatocytes then break down temporarily the occluding junction above it, and moves upwards between the adjoining supporting cells, and invaginate the plasmalemma of one supporting cell. Then the primary spermatocytes undergo **replication** to form **46 double stranded chromosomes** which then pair up to form **chiasmata**, exchange **chromatid material** and the primary spermatocytes then go on to produce **two secondary spermatocytes** each with **23 double-stranded chromosomes,** thereby marking **the end of the 1st (reduction) division** of meiosis. The secondary spermatocytes, this time *without* replication, goes through the second (equation) division of meiosis to produce 23 single- stranded chromosomes in cells called **spermatids.** The rounded spermatid now transforms itself into a small agile spermatozoon by a process called ***spermiogenesis*.** This involves;

(1) Shedding off most of its cytoplasm which is engulfed by the Sertoli cells.

(2) Formation of the acrosome from the Golgi apparatus.

(3) Formation of dispersing and dissolving enzymes by the endoplasmic reticulum to be stored in the acrosomal cap.

4) Formation of the flagellum (tail) by the centrioles.

(5) Aggregation of the mitochondria around the proximal end of the flagellum to form the middle piece.

(6) Condensation of the nucleus.

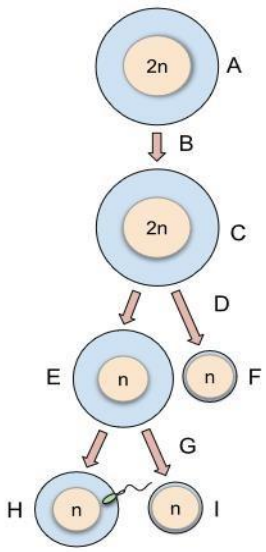
N.B: Spermiogenesis takes about two months.

Oogenesis/Ovogenesis

Oogenesis is the ***differentiation*** of egg cells (follicles) into a competent cell (ovum) capable of developing when fertilized. Oogenesis is ***initiated*** during the embryonic stage (intra-uterine life). The process ***developed*** from the primary oocyte stage by maturation. That is; oogenesis ***starts*** with the process of ***developing*** primary oocytes, which occurs by the ***transformation*** of oogonia to primary oocytes (completed before birth or shortly after birth). By the ***5th month*** of intra-uterine life about ***7 million*** primary oocytes are formed. As of the time of birth, the total numbers of primary oocytes remaining is approximately 1 – 2 million.

The entire process of oogenesis which is started during foetal life is halted at the dictyotene stage of prophase I. The process of oogenesis however, is only resumed at menarche under the influence of hormones.

Annotated diagram of oogenesis



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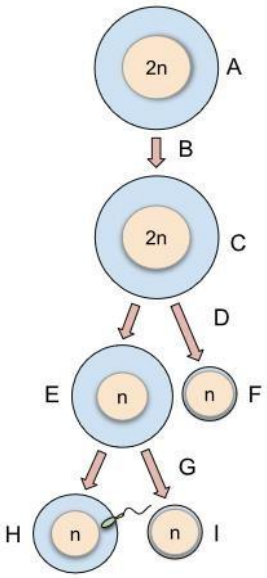
- **A** = oogonium
- **B** = differentiatiation & meiosis I begins.
- **C** = Primary oocyte
- **D** = meiosis I is completed & meiosis II begins.
- **E** = Secondary oocyte.
- **F** = First polar body.
- **G** = Ovulation must occur & sperm penetration induces meiosis II to completion.
- **H** = Ovum
- **I** = Second polar body.

OOGENESIS AND HORMONAL SECRETION



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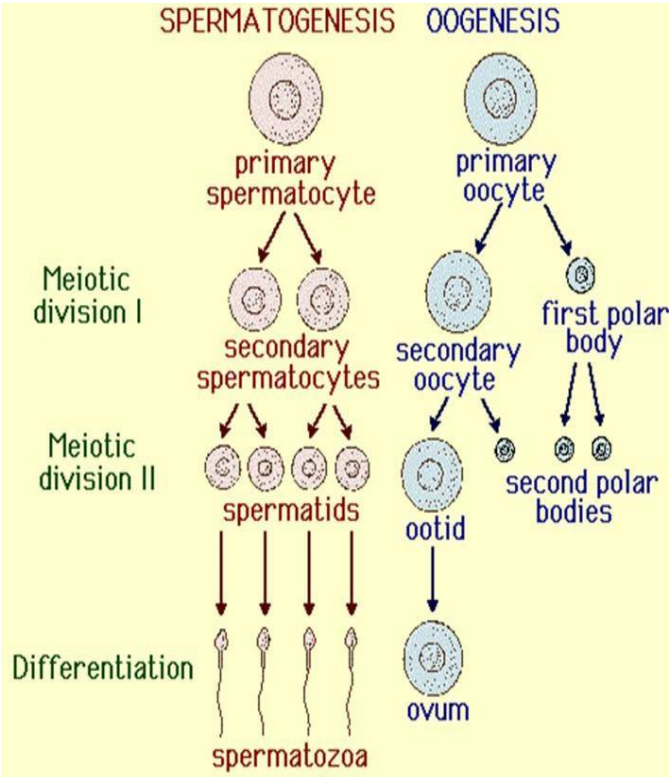
At puberty, **(D)** the hypothalamus secretes gonadotrophin-releasing hormones (GnRH). Its (GnRH) target organ is the anterior pituitary gland. Anterior pituitary in turn secretes follicle stimulating hormone (FSH) and luteinizing hormone (LH). The FSH targets ovaries (granulosa cells) and this FSH

causes about 15 - 20 oocytes to resume maturation per month per ovary (kick starts menstrual cycle). The LH also targets ovaries, but causes the ripening and release of an ovum (**G**).

Oögenesis: Implications

It results to unequal meiotic divisions produce only one gamete with a huge amount of cytoplasm.

Long suspension of division à probability of abnormal separation of chromosomes–„non-disjunction". Longer suspension may be the result of greater chances of chromosomal abnormalities.



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Oogenesis, female sexual cycles and hormone

Hormones that are responsible for menstruation.

Hormone **Target Organ**

Releasing hormone (RH)----------Anterior pituitary gland.

Follicle Stimulating Hormone (FSH) ----------Granulosa cells in ovary.

Oestrogen ----------Endometrium of uterus.

Luteinizing hormone (LH) ----------Thecal cells in ovary.

Progesterone ----------Endometrium of uterus.

Oogenesis, female sexual cycles and hormone

Hormones that are responsible for menstruation

Hormone **Source of secretion/Organ**

Releasing Hormone (RH) ---------- Hypothalamus.

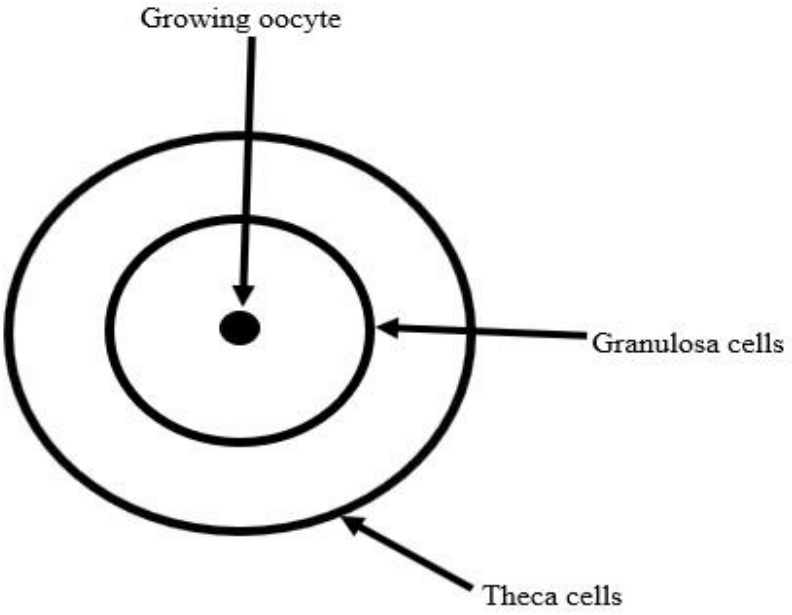
Follicle Stimulating Hormone (FSH)----------Anterior pituitary gland.

Oestrogen---------- Granulosa cells in ovary.

Luteinizing hormone (LH)----------Anterior pituitary gland.

Progesterone ----------Thecal cells in ovary.

NB: Growing oocyte - intimately surrounding it is the follicular granulosa cells outside these are found the follicular theca cells. This implies that corpus luteum has two layers of cells; the granulosa and theca layers. During ovulation corpus luteum in the ovary produces progesterone (in higher amount) and oestrogen (in smaller amount).



A diagram of the oocyte and its surrounding layers

Applied anatomy – *when things go wrong!*

non-disjunction (numerical chromosomal abnormality) can occur in any cell division. It can occur in somatic (non-gametogenic) cells with negligible consequences. Non-disjunction may also occur during spermatogenesis (paternal) or oögenesis (maternal). In either case, all embryonic cells will have a numerical chromosomal anomaly, for example Turner‟s syndrome: Karyptype = 45, XO; Klinefelter‟s syndrome: Karyotype = 47, XXY. The terms trisomy or monosomy refer to a specific chromosome that has suffered non-disjunction. Euploidy/aneuploidy refers to the total chromosomal complement of an individual.

Eupleudy = “good” (normal).

Structural chromosomal anomalies

Structural abnormalities do not affect the total chromosome number, but do have serious consequences. Translocation is an anomaly where a part of a chromosome breaks off and is attached to another. The two chromosomes may even „exchange" equal of unequal segments. In „deletion" a segment of a chromosome is lost. Inversion is an anomaly where a segment of a chromosome is detached and reattached in an inverted manner. Though this does not involve loss of genes, the disturbance of their sequence along the chromosome may be significant.

Embryology ii - pre-embryonic development (fertilisation to implantation)

The first 5 weeks of human development establish the human body plan and lay down the embryonic tissues that will become adult organs. There are three periods of development that contribute to the structure of the human body namely cleavage, gastrulation and morphogenesis.

Terminologies

Embryology = developing individual from conception to end of week eight.

Foetus = from end of week eight until birth.

Gestation period = time when mother is pregnant.

Gestation period

A). Embryologically: from **conception** or **implantation** until normal birth. Statistically this lasts roughly 38 weeks.

B) Clinically/Obstetrically: pregnancy is defined as starting from ***the first day of the last menstrual period.*** Statistically this lasts for about 40 weeks.

Ovum = the female gamete (haploid female sex cell). The "cell membrane" of the ovum is overlain by a shiny extracellular coat known as the zona pellucida, which is in turn surrounded by a layer of cells referred to as corona radiata.

Spermatozoon = the male gamete (haploid male sex cell). This happens to be the only human cell with a flagellum (has microtubules). The spermatozoon also structurally has the acrosomal cap, covering the head and a middle piece containing the mitochondria. The spermatozoon is surrounded by the spermatic fluid, fructose and fibrinogen (for clotting).

Fertilisation

A process of events which begins with spermatozoon making contact with zona pellucida of ovum. This involves fusion of male and female pro-nuclei. Prior to fertilization, an approximately seven hours of upstream journey towards the lateral end of uterine tube is needed for **capacitation.** Then the five to seven days downstream journey allows for maturation necessary **implantation.** The process of fertilization is most likely to occur during metaphase of first meiotic division of the ovum. Fertilisation thus results to the formation of a single cell with 46 chromosomes – the **zygote.**

Fertilisation takes place at the lateral end of uterine tube. There are "*rites of passage*"; which are necessary events for spermatozoa to undergo before fertilisation can occur are:

Capacitation; Acrosomal Reaction and Zonal and cortical reaction The net results/effects of fertilisation:

initiation of cleavage; restoration of the diploid chromosome number of the zygote; completion of 2^{nd} meiotic division of ovum; maintenance of corpus luteum for three months by human chorionic gonadotropin hormone (HCG). Others are: cessation of female sexual cycles and establishment of gender of the embryo

In less than 24 hours after fertilization, an immunosuppresive protein – early pregnancy factor (**EPF**) appears in the maternal serum. The EPF forms the basis of pregnancy test **prior to implantation.**

Post-fertilisation activities

The fertilised single cell/ovum is known as a zygote. After fertilization comes **development** which involves the processes that occur in the transformation of the zygote into a fully functional embryo. These developmental processes of the zygote are;

- (i) cleavage division,
- (ii) growth,
- (iii) morphogenesis and
- (iv) differentiation.

Stages of development of a zygote

These stages include all the events that occur from fertilization to birth/parturition. The time frame for these events is known as gestation period (GP) and is calculated as the last menstrual period (L.M.P) + 280 days. The GP lasts roughly between 36 – 40 weeks in humans (4 - 5% accurate).

The three main developmental periods after fertilization are:

Cleavage

This begins at fertilization and produces a blastocyst that is *implanted* into the uterine lining and thus begins embryonic development. During this phase two groups of cells develop: the trophoblast and inner cell mass.

Gastrulation

During this stage, the inner cell mass becomes the embryonic disc, which differentiates into three germ layers. The three germ layers from the inner cell mass are endoderm, mesoderm and ectoderm. These germ layers later develop into tissues and organs.

Morphogenesis

This period completes the body plan with organ rudiments appearing within the germ layers.

Ectodermal derivatives include brain, spinal cord, sensory neurons and epidermis.

Mesoderm derivatives include the dermis, most skeletal muscles, portions of the urinary and reproductive systems as well as the cardiovascular system.

Endodermal derivatives include most of the digestive tract.

Cleavage division - definition

Defined as series of rapid mitotic divisions to form a ball of cells. Increase in size does not accompany cleavage division. Each cell in cleavage receives full complement of chromosomes and genes. Each cell in cleavage is known as a **blastomere.** Compacted blastomeres divide to form a ball of 16-cell structure called **morula** (still enclosed in the zona pellucida). The solid ball of cells gradually **hollows out**, **zona pellucida disintegrates** and the structure now with **fluid-filled**, is known as a **blastocyst.** It is the blastocyst that implanted into the **endometrium**.

Within the blastocyst, cells in one region (embryonic pole) group to form the **inner cell mass** – eventually develops into the embryo proper. The cells that form the wall of the blastocyst are now called **trophoblast cells** – these will later develop into the extraembryonic membranes.

Implantation

The act/process of attaching and "**burrowing" the blastocyst into the endometrium** of the uterus. The endometrium undergoes changes configuration immediately and the process is termed as ***decidualization*** while the endometrium at the time of implantation is referred to as ***decidua***.

Clinical correlations: Cleavage and twinning (Identical twin formation)

Twins may also occur from a single fertilised ovum – monozygotic twins. This may happen when the two inner cell masses form within a blastocyst and each produces an embryo.

Cleavage: the anatomy of identical twin formation

If/when from the 1st cleavage division, the 2 cells formed **separate completely** from each other, then each can develop into an embryo.

Twins of this type share a single placenta, and they are **identical genetically.** They are always of the **same sex** and are very **similar in all aspects.**

Cleavage: when things go wrong! (developmental anomalies)

(1) Incomplete separation of a zygote at 1st cleavage stage may lead to conjoined twins when continue to develop into an embryo. Conjoined twins occur in 1 in 50,000 births and about 40% are stillborn. Siamese twin is synonymous for conjoined twins.

The word „Siamese"comes from Chang and Eng, born in Thailand (then called Siam) in 1811. They lived for 63 years; 2% of siamese twins are attached at the head – this is known as **craniopagus.**

2) Hydatidiform mole

This is abnormal pregnancy resulting from a pathologic zygote, - a mass of cysts. It may be as a result of failure of the developmental processes to occur (i.e cleavage division, growth, differentiation and growth).

(3) Hydramnios: Excess amniotic fluid in the pregnancy.

Terminologies associated with early embryology

Ingression; Egression; Invagination and Evagination. Others are: Involution; Evolution and Motility.

Embryonic Period (From 2nd week of fertilisation)

By the end of 1st week, embryo begins the process of implanting itself in the wall of the uterus.

Implantation

The process whereby the early blastocyst burrows into the endometrium with the primary purpose of ensuring nutrition for all its cells. Usually occurs on the posterior or anterior wall of uterus. The endometrium surrounding the embedded blastocyst becomes oedematous with its cells accumulating large quantities of glycogen and lipids.

Blastocyst and the process of implantation

This is called decidual reaction, soon spreads throughout the whole endometrium, which is now known as the ***decidua***. The trophoblast layer of cells differentiates into 2 layers:

- Outer (towards endometrium) = *Syncytiotrophoblast*
- Inner layer (towards blastocyst cavity) = *Cytotrophoblast*

Trophoblast layer of cells differentiates into 2 layers:

An outer (towards endometrium) is called the *syncytiotrophoblast* and the inner layer (towards blastocyst cavity) is the *cytotrophoblast*. The **syncytiotrophoblastic** cells differentiate to begin secreting a hormone called human chorionic gonadotropin (HCG) – which forms the basis for the urine pregnancy test. The HCG acts like Luteinizing Hormone (LH), in that it serves to maintain corpus luteus to keep producing its hormone (progesterone).

Cytotrophoblastic cells later differentiates to form the extraembryonic membranes. The inner mass of blastocyst later becomes the embryonic disc. By the end of the 2nd week, the embryonic disc (inner cell mass) differentiates into the primary germ layers in a process called gastrulation.

Implantation completed by end of 2nd week. By the beginning of the third week, 1st menstrual period missed by mother. The embryoblast (inner cell mass) changes to two layers.

Gastrulation and placentation

The bilaminar disc (hypoblast and epiblast). The epiblast faces towards the uterine wall while hypoblast – towards blastocyst cavity. The bilaminar germ disc later gives rise to the three germ layers: ectoderm, mesoderm and endoderm. During the 2nd week extra-embryonic structures such as amniotic cavity, amnion, yolk sac, connecting stalk and chorionic sac begins to form.

Gastrulation

The third week is marked by the conversion of the bilaminar embryonic disc into a trilaminar germ – gastrulation. Regarding gastrulation, first epiblast cells converge upon the midline, forming the primitive streak. The primitive streak folds-in and epiblast cells move laterally underneath the epiblast. The cells that remain in the epiblast become ectoderm, cells that displace the hypoblast become the endoderm, and cells that have migrated to lie between the endoderm and ectoderm become the mesoderm

Primitive streak

This is an opaque, thickened linear band of epiblast cells that appear caudally in the median plane of dorsal part of the trilaminar embryonic disc (TLED). The primitive streak elongates caudally. Cells at cranial end of primitive streak multiply to form the primitive node (knot) and a groove develops in the primitive streak, known as the primitive group. Primitive pit develops in the knot.

Mesenchyme forms from the deep surface of primitive streak. The primitive streak forms intraembryonic mesoderm up to the 4th week and thereafter the

primitive streak must degenerate and later disappear. A persistent or remnant primitive streak leads to an outgrowth (tumour) in the caudal part of the vertebral column known as sacrococygeal teratoma.

Primitive streak: summary

Establishes bilateral symmetry of the body; determines site of gastrulation; (thus it initiates germ layer formation); creates antero-posterior body axis. The primitive streak involves ingression of mesoderm and endoderm progenitor cells as well as the migration into position to form the three germ layers.

Notochord process and notochord formation

Some mesenchymal cells from primitive node form a median cellular cord – notochordal process.

A rod of cells formed thereafter is called the NOTOCHORD. Primitive pit extends into notochord to form a notochordal canal. The notochord thus becomes the structure around which the vertebral column forms

Notochord: summary

Notochord is composed of cells derived from mesoderm. It develops from epiblast that makes up floor of amniotic cavity. Notochord defines the primitive axis of embryo. It persist as nucleus pulposus of the intervertebral disc. Notochord is formed ventral to neural tube and it induces the formation of neural plate.

Neurulation

This refers to the formation of neural plate and neural folds and the closure of these to form neural tube. Neurulation is completed by the end of 4^{th} week. The process begins with ectodermal cells overlying the notochord thickening

to form the neural plate (NP). The neural plate appears cranial to the primitive node. Neural plate is also dorsal to the notochord and its adjacent mesoderm. After the formation of the neural plate, it then broadens and later invaginates along its central axis to form a median longitudinal depression called neural groove. The neural groove develops two folds on its either side called neural folds. By the end of third week, the neural folds fuse to form neural tube. The neural tube has openings at its cranial and caudal ends called neuropores. Some neuroectodermal cells along the crest of the neural fold lose touch with the surrounding epithelial cells. These are referred to as the **neural crest** cells on either side of the neural tube.

Placentation and formation of foetal membranes. Foetal portion results from cytotroblastic cells.

Embryology III – Placenta and Umbilical cord

Placenta

Etymology: From Latin meaning a type of cake; also, Greek which means flat or slab-like.

Placenta is a disc-shaped transitory organ which develops in the uterus during pregnancy.

It attaches to the endometrium of the uterus and the foetal umbilical cord arises from a portion of it.

Placenta – structure

Placenta is about 22cm in length; 2 – 2.5cm in thickness and it weighs roughly 500g (about 1/5 the weight of a baby). It has a dark reddish-blue or crimson colour. Placenta typically has two sides: foetal side also called chorion frodosum and maternal side known as the decidua basalis. The umbilical cord inserts into the chorionic plate of the foetal side. The vessels on the chorionic plate branch out to form a villous tree-like structure. The

maternal side is highly lobulated (15 – 20), called cotyledons. The villous tree from the chorionic plate penetrates into these lobes on the maternal side. Placenta grows throughout pregnancy. Development of the maternal blood supply to placenta is completed by the end of the first trimester of pregnancy.

Placental circulation

Placenta has two main sources of blood supply: from maternal placental circulation which begins at day 5 – 12 of pregnancy. During this period the spiral arteries in the decidua are remolded so that they become less convoluted and their diameter is increased. The increased diameter and straighter flow path, both act to increase maternal blood flow to the placenta as well as create a force enough to cause diffusion to occur. The relatively high pressure generated fills the inter-villous space with maternal blood, consequently this relatively high blood pressure in the inter-villous space thus allows exchange of gases to take place. Maternal blood flow is approximately 600ml per minute at term.

Foetal placental circulation

This begins between day 17 and 22 of pregnancy. Deoxygenated foetal blood passes through the umbilical arteries to the placenta. At the junction between umbilical cord and placenta, the umbilical arteries branch radially to form chorionic arteries. The chorionic arteries in turn branch into cotyledon arteries. In the villi, these arteries eventually branch to form an extensive arterio-capillary-venous system bringing The foetal blood extremely close to maternal blood but no intermingling (“placental barrier”).

Placenta – function

Placenta is involved in the following functions:

Nutrition and gaseous exchange; Excretion – removal of waste products from foetal blood; Immunity – IgG antibodies can pass through placenta, thereby providing protection to foetus in utero; Endocrine function in the secretion of HCG; Immunological barrier: able to recognize and afford immune tolerance and immune privilege to foetus and placenta without being regarded as a foreign body and serves as a reservoir of blood for the foetus.

Placenta and the process of "after birth"

Placental expulsion begins as a physiological/anatomical separation of placenta from the uterine wall. The period from just after the baby is born until shortly after the placenta is expelled from the body is called the "third stage of labour". Placenta is usually expelled within 15 – 30 mins of birth.

Placental expulsion may be facilitated by exogenous injection of oxytocin.

Placenta – when things go wrong.

Placenta accreta: implanting too deeply into the myometrium.

Placenta praevia: implantation too close to the uterine cervix.

Placenta abruptio: premature detachment of placenta (before week 28).

Umbilical cord

This is a tough, flexible cord that serves as a conduit between the developing foetus and the placenta. Umbilical cord is also called navel string, birth cord or funiculus umbilicus.

It is genetically and anatomically part of the foetus. Umbilical cord develops from and contains remnants of the yolk sac and allantois. It forms by the 5th week of development, replacing the yolk sac as the source of nutrients for the embryo. After birth the cord which has no nerve endings is clamped (to stop

bleeding) and cut close to the navel leaving a stub. The stub generally falls off in one to three weeks after birth. Umbilical cord normally contains two arteries and one vein. The umbilical cord vessels are buried in a protective membrane known as Wharton's jelly. In normal pregnancies the cord inserts into the middle of the placental mass and is completely encased by the amniotic sac, with the vessels well protected. The umbilical vein supplies the foetus with oxygenated, and nutrient-rich blood from the placenta. The foetal heart on the other hand pumps low-oxygen containing blood and nutrient depleted blood through the umbilical arteries back to the placenta.

Umbilicus/umbilical cord – structure

The length of the cord is roughly equal to the crown-rump length of the foetus throughout pregnancy. The cord at full term is about 50cm long (20inches) and about 2cm in diameter. The umbilical cord contains (is lined with) Wharton‟s jelly which is a gelatinous substance made largely from mucopolysaccharides which protects the blood vessels in it.

Umbilical cord – function

The umbilical cord enters the foetus via the abdomen, at the point which (after separation) will become the umbilicus (navel). Inside the foetus (that‟s away from the navel), the umbilical vein continues towards the porta hepatis (transverse fissure of liver) where it splits into two. One of the branches of the umbilical vein joins with the hepatic portal vein. The second branch (known as the ductus venosus) by-passes the liver and flows into the inferior vena cava. One of the branches of the umbilical vein joins with the hepatic portal vein. The second branch (known as the ductus venosus) is therefore, the one serving as a shunt, by-passing the liver and flows into the inferior vena cava. The two umbilical arteries branch from the internal iliac arteries

and pass on either side of the urinary bladder into the umbilical cord, completing the circuit back to the placenta.

Umbilical cord – changes after birth

Within the child, **the umbilical vein** and **ductus venosus** close up, and degenerate into fibrous remnants, known as the **round ligament of the liver** and the **ligamentum venosum** respectively.

Part of each umbilical artery closes up and degenerates into what is known as medial the umbilical ligament while the remaining section is retained as part of the circulatory system.

Umbilical cord – clinical correlations/applied anatomy

Umbilical catheterization – quite rewarding in neonates. Also serves as a storage of cord blood that is rich and readily available source of primitive, undifferentiated stem cells. These cord blood can be used for bone marrow transplant.

Umbilical cord – when things go wrong!

Umbilical cord compression – obstruction of blood flow through cord.

Nuchal cord – when umbilical cord becomes wrapped around neck of foetus.

Velamentous cord – a complication of pregnancy where the cord is inserted in the foetal membrane.

Vasa praevia – a condition in which the foetal vessels cross or run near the internal opening of the uterus.

UNIT FOUR

BASIC TISSUES

A tissue is defined as a collection of cells which are similar in structure and perform specific function(s) for the body. Four basic types could be identified namely; epithelial; connective; muscular and nervous. Though a fifth type could be identified in modern classification as wandering corpuscles of blood and lymph, they are largely, regarded as being part of connective tissues by anatomists.

Epithelial tissue (epithelium)

This type of tissue is characterized by the cells being arranged in the form of a sheet and their main function is to cover the surfaces of structures and hollow organs, to protect them.

This tissue types are avascular, sit on a sheet-like structure called basal lamina. A basal lamina, fibres together with the matrix constitute what is known as the basement membrane.

Epithelial tissues could be made up of one or several layers of cells and the shape of cells vary from between being flat to being very tall. Examples of places in the body where epithelial tissues are found are; epidermis of skin; coverings in the mouth, ear and nose; coverings of hollow organs such as found in the inside of organs constituting the digestive, respiratory, genital and urinary systems.

Classification of epithelial tissue

They are classified base on shape of cells and number of layers of cells.

TYPE A: - Based on shape of cells:

(i) squamous, (ii) cuboidal, (iii) columnar and (iv) ciliated

TYPE B: - Based on number of layers: (i)
simple and (ii) stratified

Common epithelial tissues and their locations in the body

Simple squamous: - lining of the blood vessels; linings of the peritoneal cavity.

Simple cuboidal: - lining surfaces of small ducts and tubules with excretory, secretory and absorptive functions.

Simple columnar: - linings of highly absorptive surfaces e.g small intestines and stomach.

Simple columnar ciliated: - has surface specializations callead cilia. Found in the oviduct.

Pseudostratified columnar ciliated: lining of the respiratory tract.

Stratified squamous: - lines places which are subjected to mechanical abrasion e.g linings of the oral cavity, pharynx, oesophagus, anal canal, uterine cervix and vagina.

Could be keratinized as in epidermis of skin and thick skin.

Stratified cuboidal: - Found in larger glands of the exocrine glands.

Transitional epithelium: - Found lining the urinary bladder.

Glands

Some epithelial tissues are further modified to produce secretions for lubrication. These group of secretory cells are called glands, but are still basically epithelial tissues.

Glands are of two main types; those with ducts, called exocrine and those without ducts endocrine glands.

Membrane specialisation of epithelial tissues

(1) At the Intercellular surfaces

Cell junctions: - These are of three types namely;

(a) Occluding junctions, also known as tight junctions. They are found beneath simple columnar epithelium, where they seal the intercellular spaces so that luminal contents cannot penetrate between cells. E.g intestinal linings.

(b) Adherent junctions: Tightly bind the individual cells of the epithelium together and act as anchorage sites for cytoskeleton.

Bind whole epithelial mass into a structurally coherent unit. Different types exist namely, zonula adherens; desmosomes / macula adherens (small circular patches).

(c) Communicating junctions / nexus / gap junctions: - Membranes of 2 adjoining cells are closely apposed but separated by a space or gap (2nm wide), which still comprise of an array of hollow tube-like structiures formed by proteins. (Not exclusive to epithelial tissue, but also present in cardiac and visceral muscles).

(2) At the Luminal surfaces:

There are three main types of specialization at the sites namely; (a)

Cilia, (b) microvilli and (c) stereocilia.

Cilia are long and motile structures; microvilli are short, numerous projections while stereocilia are extremely long microvilli and not motile (found only in male reproductive tract).

(3) At the Basal surfaces:

(a) Basement membrane: - This is the interface between epithelial tissues and underlying supporting tissues. It is made up of basal lamina, together with reticular fibres plus matrix (ground substance).

(b) Hemidesmosomes: - This is a type of desmosome on the inner aspect of the basal plasma membrane to give an additional anchorage to the basement membrane and underlying supporting tissues.

Connective tissue

This tissue is modified mainly for the function of connecting one structure to the other. Connective tissue consists basically of three components namely; cells; strands or fibres; and intercellular matrix – a jelly-like material in which lies the cells and fibres.

Connective tissue performs other functions such as storage of fat, support and protection. Examples of connective tissue include: fat under the skin, cartilage, bone, blood etc.

Cells modified mainly for the function of connecting one structure to the other. Connective tissue comprises much of the body. They are the most abundant type of tissue by weight and are characterised with the presence of abundance of intercellular material or matrix between them.

Connective secretes extracellular matrix, usually proteoglycan and glycoproteins that bind everything together. The matrix consists of fibres and ground substance. Consistency of this ground substance/matrix varies from fluid to semisolid to solid. The ground substance binds, supports and provides a medium through which substances may be transferred among tissue.

The three fundamental types of connective tissue are: connective tissue proper (*also subdivided into dense regular, dense irregular; loose/areolar*); specialised connective tissue and mesenchyme.

Types of cells in connective tissue

Connective tissue contains a variety of cell types, examples of which include: Fixed cells: these are usually present in stable numbers, for example fibroblasts and mast cells and wandering cells, for example. Macrophages; temporarily appear in tissues, usually in response to an injury or infection.

Fibre types in connective tissue

(a) Collagenous fibres: - These are thick threads of the protein called collagen. They have great tensile strength. Are abundant in body parts that hold structures that hold relatively firmer structures together, for example tendons and ligaments.

(b) Elastic fibres: These are composed of bundles of microfibrils in a protein called elastin. The fibres branch, forming complex networks in various tissues. They are weaker than collagenous fibres but very elastic.

(c) Reticular fibres: These are very thin collagenous fibres. They are highly branched and form delicate supporting networks in a variety of tissues. Generally, adipose tissues form about 15% to 18% of the total body weight in men and 20 – 22% of the total body weight in women. Cartilage is avascular connective tissue that heals very slowly.

Muscular tissue

Cells of this tissue are modified so that they can contract. There are three main types namely:

- Skeletal / Striated / Voluntary muscular tissue. -
  Smooth / Non-Striated / Involuntary muscular tissue and
- Cardiac muscular tissue.

Nervous tissue

This consists of cells that have been made in such a way that they initiate and conduct impulses or stimuli / instructions to all parts of the body, in order to regulate their activities. Each cell in a nervous tissue consists of a **cell body,** which contains a nucleus, and a long extension of the cytoplasm called **axon.**

Anatomy of blood

Blood – What is it?

Blood is body **fluid –** a substance that is easily compressible (***mixture of solid, liquid and gas***).

Blood is a **colloid**: substance of gelatinous consistency; of large molecules.

Blood is specialized connective tissue.

Clinical application

Intravenous (IV) fluids are of two types: colloids and crystalloids. Crystalloids are aqueous solutions of mineral salts or water-soluble molecules. An average adult has about 5 to 6 liters of blood circulating daily. About 600ml per minute is pumped to the uterus during pregnancy.

BLOOD – Why connective tissue?

Blood is a connective tissue because, as a tissue it has been modified mainly for the function of connecting one structure to the other. It is characterised by the presence of three components; cells; strands or fibres; and intercellular matrix – a fluid-like material in which lies the cells and fibres. The cells are modified mainly for the function of connecting one structure to the other with lots of intercellular material or matrix between them. BLOOD – General functions

- Transportation of gases, nutrients, hormones and waste products,
- Fighting against infections
- Production of immune reactions and

- Coagulation/formation of clotting reactions.
- **Hydraulic function – (erection; penis/clitoris)??*

Blood histology

The cells in blood are suspended in a liquid portion called plasma (ground substance/matrix).

Plasma = 55% of blood and is mostly water 92% by volume. Plasma is the straw-coloured liquid portion of blood. A film/sample of blood is usually made up of about 45% cells by volume. This % is called the packed cell volume (PCV) or haematocrit. Blood plasma is the liquid portion that holds the blood cells (45%) in suspension. Blood plasma is a yellowish liquid. Serum is the fluid and solute part of blood which does NOT play a role in clotting. Serum may be defined as blood plasma without fibrinogen. The amber-coloured protein rich liquid which separate when blood coagulates is known as serum.

This implies that, histologically blood is made up of ***formed elements*** and plasma. Plasma is mainly 92% water and plasma proteins [7%] (***main plasma protein is albumin, others are globulin and fibrinogen – principal clotting protein***) and salts, gases, nutrients (lipids, glucose, amino acids, nitrogenous wastes (urea/uric acid), hormones, vitamins, etc. The formed elements of blood include: red blood cells (erythrocytes); white blood cells (leucocytes) and platelets (thrombocytes – responsible for blood clotting).

Plasma proteins

Albumin: plays an important role in keeping the fluid in the blood from leaking into the tissues. (*Think of what will happen in the case of hypoalbuminea*).

Globulin: the major functions of the alpha and beta globulin proteins in plasma are: develop colloidal osmotic pressure; help in immune response; act as carrier proteins and act as antigens. **Fibrinogen –** Is the principal clotting protein.

The leucocytes (white blood cells) are of two main types: granular leucocytes (granulocytes *also known as* polymorphonuclear leucocytes); examples are the basophil, eosinophil and neutrophil as well as the agranular leucocytes (agranulocytes), example lymphocytes – *produces antibodies* and monocytes. Erythrocytes or red blood cells contain haemoglobin – an iron-containing protein which facilitates oxygen transport by reversibly binding to oxygen. Blood is circulated in the body by blood vessels (arteries and veins), and pumped by the heart. Blood is formed pre-natally by the liver and during post-natal life by the lone bone marrows, and the sternum in adults.

Blood – terms and terminologies

Blood clotting is clinically referred to as haemostasis/coagulation.

Haemo-/haemato- or hemo/hemato (Greek)"

Haematocrit = packed cell volume = **Haematocrit = proportion of cells to plasma in the blood. Normal haematocrit values** Males (45+/-7) ie (38 – 52%) Female (42+/-5) ie 37 – 47%).

Blood pH = 7.35 – 7.45.

Plasma profile: Is the analysis of components of plasma.

Differential cell count is an analysis of the different cells that make up the blood.

Source: *https://images.app.goo.gl/XqLw7uarg3HmTibe8*

Blood – Cell types

Erythrocytes (red blood cells – RBC)

These are small, flexible biconcave disc shaped cells containing **haemoglobin** in their cytoplasm. Haemoglobin gives blood its typical red (maroon) colour. Mature RBCs lack nuclei.

Erythrocytes – structure and function

The plasma membrane of RBCs may contain a number of **antigens.** These antigens are the basis of the ABO blood groups that are commonly known as blood types. Antigens are complex sugar molecules (polysaccharides) ***sometimes*** combined with proteins.

Clinical application

Red blood cells and erythrocyte sedimentation rate (ESR)

The Erythrocyte Sedimentation (ESR) tests for inflammation or infections on the RBC. When things go wrong, thus in the event of inflammation or infections, abnormal proteins get formed, clumped on the surface of the RBC and the affected RBCs fall faster when allowed to settle through a film of blood, thus making the ESR high in the case of infections or inflammation. The ESR test in itself may not be a diagnostic one but may be requested alongside other test such as the C- reactive protein (CRP) test to establish a case. The CRP values are low in normal cases but the liver turns to secrete more in the event of an inflammation. Consequently, a high ESR plus high CRP values may be building up a valid point for suspected inflammatory cases.

Erythrocytes and blood conditions/diseases

The reduction of the effective numbers of RBCs or diminishing levels of the normal amount of haemoglobin in each RBC in the body is known as

anaemia. Several factors may cause/lead to anaemia, for example: **loss of blood** (bleeding); **lack of essential chemicals** for the manufacture of haemoglobin; **destruction of RBCs** (either at site of production or during circulation).

A **hereditary** form of anaemia that interferes with the **synthesis of haemoglobin** such that erythrocytes have insufficient quantities of or abnormal combinations of haemoglobin subunits is known as ***Thalassemias.***

When the **bone marrow fails** to produce enough RBCs in adults then **aplastic anaemia** is said to occur. When the erythrocytes die pre-maturely then **haemolytic anaemia** is said to occur.

Sickle cell disease is a condition inherited from parents in which the structure of the RBC is become like quarter moon-shaped (sickle), with the haemoglobin also being abnormal and thus reducing the amount of oxygen to be carried by such individuals. Leucocytes (white blood cells – WBC)

Generally, there are three main granulocytes and two main agranulocytes. The names of the **granulocytes** (**NEB**) are derived from the type of stain they most readily take up:

- Neutropthils take up neutral dyes • Eosinophils take an eosin dye and
- Basophils take up a basic dye.

Leucocytes – types

Basophils

Basophils have granular cytoplasm; stain dark blue with H&E. They have a bi-lobed nucleus and are the least numerous and largest of all WBCs. They function in inflammatory reactions during immune responses eg formation of allergies. Basophils produce substances such as histamine and serotonin that

induce inflammation reactions and heparin that prevent blood clotting. Mast cells are basophils in connective tissue.

Eosinophils

These are granular, stains brightly red with haematoxylin and eosin (H&E). They have a bi-lobed nucleus and they have strong affinity for acidic dyes. Eosinophils functions mainly in viral and parasitic diseases in a similar fashion as basophils. They are involved in fibrin removal during inflammatory reactions and also noted for the production of growth factors and enzymes during inflammatory reactions.

Neutrophils

Neutrophils are the most abundant type of granulocytes. They form about about 40 – 70% of all WBCs. They stain neutral pink with (H & E) during routine histological/cytological preparations. Neutrophils contain a nucleus with 2 – 5 lobes. Neutrophils are short-lived and highly mobile. Neutrophils help in damaged tissues and resolve infections. Neutrophils, (much like monocytes) have their numbers/levels increase naturally in response to infections, injuries and cellular stress conditions.

Functionally, they are seen as a type of phagocyte (fight infections by eating up/engulfing foreign cells). Neutrophils are normally found in the blood stream. Neutrophils are recruited to a site of injury within minutes following trauma and are typically characteristic cells associated with acute inflammation.

Monocytes

Cell (monocyte) is a relatively large white blood cell. Monocytes form about 2 - 10% of the entire, nucleated-blood cell population. The entire numbers of monocytes tend to shoot up considerably in a *total blood count* during high

infectious and stress situations. Monocytes are the precursors of macrophages.

Macrophages are WBCs that have left the vessels and are found in tissues. The largest WBC and source of a family of phagocytic cells is monocytes. Monocytes have agranular cytoplasm with a unilobed nucleus - typically resembling a bean/kidney.

Lymphocytes

Lymphocytes have agranular cytoplasm with a spherical nucleus. Generally, two types have been described based on origin or location:

- B-lymphocytes produce antibodies: from bone marrow or associated with bone marrow. These are used in attacking foreign cells and toxins.
- T-lymphocytes become immunocompetent in the thymus gland.

Lymphoblasts are unipotent cells that develop into lymphocytes. Lymphokines are chemical signals that cause T-cells to destroy foreign cells. In terms of function, lymphocytes are classified as natural killer cells – function in cell mediated, cytotoxic innate immunity, called T-lymphocytes, and B-lymphocytes for humoral, antibody-driven adaptive immune activitities/reactions. Lymphocytes are found in lymph. Clinically, **CD4** or **CD8** cells often describe types of T-lymphocytes. The **CD4 cells or T-Helper cells** play important role in the immune system. That is T-Lymphocytes **directly (CD8)** or **indirectly (CD4)** clear infections. **CD4 (T-Helper cells**) and **CD8 (T-Killer cells)** got their names from a surface receptor and functions. Whereas the B-lymphocytes produce antibodies. CD4 cells count typically is used as a litmus test for the immune system especially in people with HIV. HIV attack destroys CD4 cells. A CD4 test of greater than **500** cells per mm^3 of blood passes the immune system as healthy; **between 250 – 500** cells per mm^3 of blood is indicative of a compromise

immune system whereas a test showing less than **200** cells per mm^3 of blood is a **diagnosis of AIDS.**

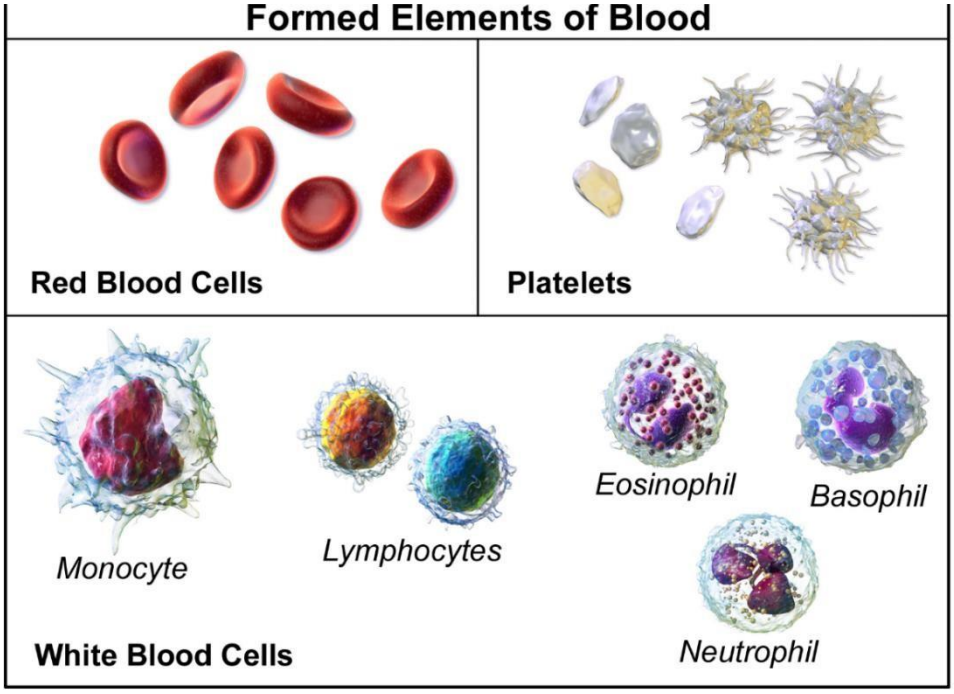
Platelets (thrombocytes)

These are relatively small in size and numbers in comparison with other formed elements. They come mainly in the form of cytoplasmic fragments in blood, also known as thrombocytes.

The main function of platelets is to prevent bleeding; they maintain haemostasis – ensure normal circulation of blood. Fibrinogen is the protein in platelet responsible for the production of fibrin. Fibrin is the insoluble molecule that form a mesh of fibres (clot) during coagulation.

Low platelet numbers or lack of chemicals for clotting may pose a danger of bleeding to death even from small cut, eg – haemophilia disease.

High platelet count (thrombocytosis) is a strong indicator/predictor of an underlying condition such as cancer.



Source: ***https://images.app.goo.gl/gsXnxcG446iZvoj28***

Blood and cholesterol

Cholesterol is an organic molecule; a sterol or a kind of lipid. It is basically a small bio-sythesized molecule forming part of the plasma membrane. Lipoproteins are molecules made up of proteins and fat that carry cholesterol throughout the bloodstream. There are two basic types of lipoproteins in the body:

Types of lipolipids

- High density lipoprotein (HDL): this is "good" lipoprotein: It tends to remove cholesterol from the blood.
- -Low density lipoprotein (LDL): - this is "bad" lipoprotein: It raises the level of cholesterol in the blood.
- High levels of cholesterol circulating in the blood increase the risk of atherosclerosis – a disease of the arteries characterized by the deposition of fatty material on the inner wall.

Blood clinical correlations/Applied Anatomy

Reason out the relevant anatomical basis for the following clinical procedures/practices:

If Hb is as low as 3, why put a patient on intravenous fluid (IV)?

In a severe post-partum haemorrhage situation what does a patient need most/urgently? Fluids or cells?

Before the blood arrives in a severe post-partum haemorrhage situation, what do you do as a matter of urgency? – ***keep circulation running*: IV at full rate/flow.**

What is the anatomical basis for the following variables in a blood test request prior to blood transfusions?

- Cross matching; Clotting factor; Hb level; Platelet count; BUN; Emergency room blood - O negative must always be present (why?) Snake venoms and bleeding – platelets and coagulation problem.

Some medications and bleeding problems: for example, what role do the NSAIDS drugs eg asprin, morphines have on the composition of blood?

Case study

Carboxyhaemoglobin (HbCo) is formed when carbon monoxide binds to haemoglobin. This reaction is not reversed easily and death occurs from tissue hypoxia. One common source of carbon monoxide is cigarette smoke, which bind 20% of all available haemoglobin in a smoker. What symptoms are produced from this reaction? What does the body do to compensate?

Solution to Case study

The major symptoms associated with the formation of carboxyhaemoglobin caused by cigarette smoking include any symptom associated with hypoxia: **increases respiratory rate** and **hypoxia of tissues with high metabolic rate** such as the heart, brain and kidneys. To compensate for this oxygen lack, the **kidneys release erythropoietin**, thus producing an **increased haematocrit** (polycythemia).

Blood – when things go wrong!

Leukemia: This is a type of cancer involving blood and blood-forming tissues, usually bone marrow. Often associated with leucocytes (***why?***).

UNIT FIVE

RESPIRATORY SYSTEM

Introduction

Anatomically, the respiratory system is made up of five major regions/structures namely: **nasal cavities; pharynx; larynx; trachea and lungs.** Functions

Mainly involved in (i) the exchange of two important gases with the blood and tissues, (ii) Supply of Oxygen, (iii) Removal of CO_2 and water vapour from blood (purification of blood); (iv) Protective function - coughing, sneezing and (v) Talking.

Anatomy of the nose/cavity and the respiratory system

Nose is a medially located organ in the face, made up of partly of bone cartilage (elastic). Its parts are the nostrils/nares – the anterior nasal aperture or entrance to the nasal cavity. The (*borders of nostrils are soft and pliable – wholly elastic cartilage*); the nasal cavity (chamber with walls – lateral, medial, superior and inferior) and the choana or posterior nasal aperture which leads to the nasopharynx.

Nose/nasal cavity – functions

(i) Serves as a receptacle for air as well as a conduit for the airway; (ii) Moistens and warms air; (iii) Filters air; (iv) Resonating chamber for speech and (v) Centre for olfactory receptors.

Nasal cavity and paranasal air sinuses (*Refer to skull bones*)

Respiratory system – structure and function

Air enters the respiratory system through the nasal cavity. The entire respiratory system is divided into upper and lower respiratory tracts. The

trachea marks the beginning of the tracheobronchial tree lower respiratory tract (LRT).

The nasal cavity, pharynx and larynx form the upper respiratory tract (URT). Pharynx connects the nasal cavity with the larynx and trachea. Pharynx is a common food and air passage ways – the posterior most limit of oral and nasal cavities plus most superior limit of the "food passage tube").

Larynx is box-like organ for phonation/production of sound. Lower limit of larynx is used to mark the beginning of trachea.

The respiratory tract is tube-like with progressively decreasing lumen and can be regarded as tree, generally distributing air throughout the lungs.

Anatomy of the tracheobronchial tree

The tracheobronchial tree is characterized with mucous glands–located in the mucosa and submucosa, supply mucus to the bronchi. The mucosa lines all passages, becoming progressively thinner as branching proceeds. The submucosal layer contains both **collagen** and **elastic** fibres which confers tensile strength as well as resilience/elastic properties to the tract. The muscularis layer of this tree is made up of smooth muscle fibres.

Trachea

Conducts air between the larynx and the lungs. It begins at the level of the sixth cervical vertebra (C6), i.e the lower border of the cricoid cartilage. The trachea bifurcates at the junction between the fourth and fifth thoracic vertebra (T4 and T5), (mainly T4). It is made up of roughly twenty Cshaped cartilage rings (15 – 20). The C-shaped cartilage rings are located in the adventitia. The cavity of the trachea is lined with pseudostratified columnar epithelium. The epithelium is dotted with goblet cells which produces mucus. The epithelium and lamina propria form its **mucosal layer.** The submucosal

layer is external to the mucosa and houses the vessels of the trachea. Goblet cell is regarded as the smallest exocrine gland.

Bronchi

The primary bronchi branch from the trachea into the lungs. The terminal cartilage of the trachea bulges into the luminal surface as the carina. The primary/principal/main bronchi branch from the trachea and enter the lungs at the mediastinal surface. Secondary bronchi lead to each lobe of lung, while tertiary bronchi lead to a bronchopulmonary segment. A bronchopulmonary segment is an independent branch of the tracheobronchial tree, with its own air passageway, artery, vein lymphatics and nerve supply.

Bronchioles

Bronchioles are regions of the tracheobronchial tree with luminal diameter less than 1mm. They also lack cartilage and mucous glands in their walls. Histologically, three main types of bronchioles have been identified; bronchiole proper which the first part, followed by the terminal bronchiole and finally the respiratory bronchiole. That is respiratory bronchioles connect terminal bronchioles to alveolar ducts. The wall of a respiratory bronchiole consists of smooth muscles, and the lumen is lined with non-ciliated, simple cuboidal epithelium. Characterised with the presence of Clara cells to replace goblet cells found in the bronchioles. Asthma narrows the lumen of the bronchioles making breathing difficult. In the respiratory zone of the bronchopulmonary tract (primary lobule) is found the following: respiratory bronchioles which lead into: alveolar ducts - tiny ducts connecting respiratory bronchioles to alveolar sacs.

Pulmonary lobules / lung

Each alveolar sac making up a collection of **alveoli**. Distal termination of the alveolar ducts are **atria**. Two or three alveolar sacs may arise from an atrium of an alveolar duct. Deoxygenated blood enters the primary lobule through the pulmonary arteries. One half of a primary lobule is known as acinus. The pulmonary capillary bed covers each alveolus.

Pulmonary exchange surfaces/lung histology

Gases are exchange in the alveolar septa of the lungs. The alveolar septum consists of elastic fibres which provide lungs with **resilience** and collagen fibres providing lung with tensile **strength**. The epithelium lining the alveoli is simple squamous. Distributed among the epithelial cells of the alveoli are the pneumocyte cells. There are two types of pneumacyte cells: pneumocytes type I is the **primary gas exchange cells** of the alveoli and pneumocyte type II are the **surfactant secreting cells** of the alveoli. Surfactant is a phospholipid detergent that reduces surface tension in the lungs

Respiratory system and ventilation: the anatomy of the thoracic cage

The thoracic cage function on the principles **pressure** = force / area. The thoracic cage has three main diameters: anteroposterior (AP); vertical and transverse. All of these diameters increased during the inspiration phase of respiration.

The thoracic cage is a region between neck and abdomen. Its main functions include: protection; housing and conduit for other organs/structures.

Composition of the thoracic cage (*refer to notes on skeletal system*)

Gross anatomy of the lungs

Lungs are paired conical spongy organs contained in the thoracic cavity. They are soft and spongy in the healthy individual and easily crepitates when squeezed. Lungs represent the "business end" of the respiratory system. Each lung has lobes, created by fissures. They have a base, apex, mediastinal surface, costal surface, anterior and posterior borders.

Lobes and fissures

With surface anatomy of the trunk, the oblique fissure is considered to correspond to outline origin of the spine of opposite scapula posterior, and descends to the level 6^{th} costochondrial junction anteriorly. The horizontal fissure corresponds to the 4^{th} costal cartilage anteriorly up to the mid-axillary line on the right.

Lungs and pleurae

Lungs are contained within a pleural cavity formed by two membranes, the parietal and visceral pleurae in the thoracic cavity.

Development of the respiratory system

Pulmonary epithelium is derived from endoderm and mesoderm produces the parenchyma of the lung tissues. Lung development goes through five stages and this resembles that of a compound gland.

Developmental stages of the respiratory tree

The embryonic stage (4 – 7 weeks); pseudoglandular stage (8 – 16 weeks); canalicular stage (17 – 26 weeks) and terminal stages [TS], (26 – 38 weeks).

The terminal stage is subdivided into two: (a) – saccular stage (26 – 36 weeks) and (b) – alveolar stage (36 – 38 weeks).

Trachea and primary bronchi develop from lung buds early in development, then lung buds developing into trachea and primary bronchi. During the pseudo-glandular stage, the lungs resemble exocrine glands. The bronchi, bronchioles and mucous glands of the conducting zone formed during the pseudo-glandular stage.

The **canalicular stage forms the passages of the respiratory zone**. The **lung acini are completed during the terminal stage**. **Alveoli and alveoli septum mature during the postnatal development stage (alveolar stage}.**

Respiratory system: when things go wrong/clinical application

Infant respiratory distress syndrome may be as a result of inability to secrete surfactant, therefore difficulty in inflating the alveoli. Treatment may consist of application of continuous positive airway pressure and spraying of surfactant into the respiratory passages.

Smoking destroys cilia and decrease function generally. Cough is used by smokers to move the clogged mucus (smoker‟s cough). Cilia located in the nose may be paralysed by cold air; which results in a “runny nose”.

Clinical application: respiratory system and auscultation

The choice of stethoscope for chest examination (pulmonary purposes) is not so critical as the choice for cardiac auscultation. A stethoscope should be used with both the diaphragm and bell functions. These may have two separate heads, one head that can be rotated or one head that changes from bell to diaphragm functions with pressure. When the bell is lightly placed against the skin, low-pitched sounds are heard better. The diaphragm placed firmly against the skin is used for high-pitched sounds. Most of the sounds that reach the chest wall from the bronchi and lungs are of low frequency;

thus the bell should be used in preference to the diaphragm. However, most clinicians use the diaphragm for the chest examination because it is easier to use. Normal sounds of breathing depend on where the stethoscope is placed during auscultation. Tracheal breath sounds are loud, harsh and high-pitched. They may be heard better while listening over the trachea in the neck than in the chest. These do not provide significant diagnostic information.

Bronchial breath sounds

These are loud and high pitched, with air swishing past. They are normally heard while auscultating over the mid-sternum. They may be heard over the periphery of the lungs, but sound as if the examiner were listening over the trachea or main bronchi.

Bronchovesicular sounds

These are a mixture of peripheral lung vesicular breath sounds and bronchial breath sounds and are heard near where the mainstream bronchi begin to branch. On the chest wall, they are heard by listening anteriorly over the 1st and 2nd intercostal spaces lateral to the sternum and posteriorly medial to the scapulae.

Vesicular breath sounds

These are soft, low pitched, airy and swishing as air rushes into the alveoli in most of the lung.

The abnormal absence of breath sounds may be caused by several disorders: mucus plugging of a bronchus, pneumothorax, pleural effusion, or pulmonary emphysema may each prevent breath sounds from being heard in a particular portion of the chest.

Clinical application: respiration rate

- Adults: 12 – 16 times per minute.
- Children: 12 – 20 times per minute.

Bradypnea is the clinical name for slow breathing rate; **tachypnea** is the clinical term used to describe rapid, shallow breathing while **hyperpnea** describes rapid, deep breathing with increased minute ventilation disproportionate to metabolic needs.

Clinical symptoms of respiratory disease

The list of symptoms of respiratory disease include; Cough; Sputum; Haemoptysis; Chest pain; Dyspnea; Wheezing and stridor; Hiccup (singultus) and Cyanosis.

Sputum or phlegm is a secretion from trachea, bronchi or lung coughed up through the glottis.

Hemoptysis is the expectoration (spitting-up) of blood-streaked sputum of gross blood. **Chest pain:** may originate from intrathoracic or extra-thoracic structures intensified by breathing is typical of pleural involvement (pleuritic chest pain).

Dypsnea is the clinical term used to describe difficult or labored breathing. This requires effort in breathing, commonly called shortness of breath. Dypsnea that occurs when the patient is lying flat may be **orthopnea and** is characteristic of heart failure but is also found with obstructive airways and bilateral paralysis of diaphragms. Orthopnea is relieved at once by sitting up or by elevating the head and thorax on two or three pillows. There is also **paroxysmal nocturnal dyspnea** (PND), which does not begin at once after lying down, nor is relieved at once by sitting up. With PND the patient is dramatically awakened from sleep, gasping for air, sensing impending suffocation. Paroxysmal nocturnal dyspnea may be indicative of pulmonary congestion (acute pulmonary oedema caused by heart failure).

Wheezing and stridor: This is the high-pitched musical breath sound caused by air rushing past secretions, oedema, tumour or an aspirated foreign body. Stridor occurs with inspiration; indicates severe airway obstruction.

Hiccups (Singultus): not necessarily a disease of chest. However, mediastinal, pleural or bronchial problems may result in hiccups. Many disorders have been associated with it. The aetiology however remains undetermined.

Cyanosis: the bluish colour of the skin or mucous membrane caused by an excess of reduced haemoglobin in underlying capillaries. Cyanosis becomes apparent when amount of reduced haemoglobin falls below 5g/dl.

Central cyanosis is prominent on lips, tongue and face. It occurs because of inadequate oxygenation in the lungs or because of diseases that allow blood to bypass the lungs.

Peripheral cyanosis involves the hands, cheeks, lips and ears and may result from cold-induced vasoconstriction with resulting circulatory stasis. Excessive oxygen extraction by the tissues is the cause of peripheral cyanosis. Shock syndrome (cardiogenic or septic) may also result in peripheral cyanosis

Clinical application: the anatomy / pathophysiology of cough

The cough reflex can be divided into four distinct components: air is inspired into the lungs, and the glottis is closed. Compression of the lungs results from contraction of thoracic, diaphragmatic and abdominal muscles. As the glottis is opened suddenly, intrapulmonary pressure expels particles from the trachea or bronchi. A cough with sputum is called productive cough.

When things go wrong – pleura and pleural cavity.

Hydropneumotharax is the clinical/pathological condition that results when air and serous fluid accumulate in the pleural cavity. Pyopneumothorax

describes the accumulation of air and pus in the pleural cavity. Haemopneumothorax = Air + blood; Pus only (without air) in pleural cavity = empyma while accumulation of serous fluid only is referred to as pleural effusion.

UNIT SIX

ANATOMY OF THE LARYNX AND PHARYNX

Anatomy of larynx

The larynx is located at the anterior part of neck at the level of the third to sixth cervical vertebrae (C3 – C6) in adults. In infants and children, it is more anterior and almost at the levels of C2 – C3 vertebrae. It is commonly called voice box. Anatomically, the larynx is an organ in the upper part of the neck that is involved in breathing, voice production and protecting trachea against food aspiration. The larynx houses the vocal cords and manipulates pitch and volume during phonation.

It is situated just below where the tract called **pharynx** splits into the trachea and oesophagus.

Larynx – functions (summary)

The larynx produces vocalizations (phonation); provides an open airway (breathing); has a switching mechanism to route air and food into proper channels; that is, it is able to close during swallowing and open during breathing (sphincteric action).

Larynx – structure

It is a triangular-shape; consists largely of **cartilages** that are attached to one another and to surrounding structures by **muscles**/fibrous and **elastic tissues**. It is lined by **ciliated mucous membrane**. The cavity of the larynx extends from its triangle-shaped inlet (epiglottis) to the circular outlet at the lower border of the cricoid cartilage below, which is continuous with the lumen of the trachea. The mucous membrane lining the larynx forms two pairs of lateral folds that jut inward into the cavity. The upper folds are called the vestibular folds (false vocal folds). The lower pair are the vocal folds – their movements produce the sounds needed for speech and phonation. The slit-

like space between the left and right vocal folds is called the **rima glottidis** (narrowest part of the larynx). The vocal folds and the space between them is known as **glottis**. The laryngeal cavity above the vestibular folds is called the **vestibule**. The rima glottides varies in size during phonation similar in action to *pupil of eye during accommodation*

Larynx - cartilages

The larynx is composed of **six different types of cartilages** in all: three are **single** while the other three are **paired**. The e**piglottis**, **thyroid** and **cricoid** cartilages are ***single*** while the **arytenoid**, **corniculate** and **cuneiform** are ***paired***. The **hyoid bone,** although in proximity to the larynx, and the larynx is suspended from this hyoid bone, it (hyoid bone) is anatomically **NOT** considered as being part of the laryngeal cartilages.

The thyroid cartilage (hyaline) – forms the **Adam's apple – laryngeal prominence**.

The thyroid membrane is a ligament associated with the thyroid cartilage and connects the cartilage to the hyoid bone.

Cricoid cartilage is a ring of hyaline cartilage that forms the inferior wall of the larynx. It is attached to the top of the trachea.

Epiglottis is a large, spoon-shaped piece of **elastic cartilage**, which also resembles a leaf. It is situated at the posterior part of the larynx with **two surfaces**: a portion facing the cavity of the larynx and the other side facing the oral cavity.

Laryngeal cartilages - epiglottis

The lower end of the epiglottis (stalk) originates from the back (posterior part) of the thyroid cartilage and its upper part is free, projects into the oropharynx, just behind the root of the tongue. Functionally, the epiglottis

prevents food from entering the vestibule of the larynx (**digestive function**) and also directs ***conditioned air*** into the larynx (**respiratory function**).

During swallowing the pharynx and larynx rise. The elevation of the pharynx widens the epiglottis to receive food/drink. Similarly, elevation of the larynx causes the epiglottis to move down and form a lid over the glottis, closing it off.

Larynx – paired cartilages

The **arytenoid** (most important of the paired cartilages), because they influence the position and tension of the vocal folds. They abduct and adduct the vocal cords. The arytenoid cartilages are triangular pieces of mostly **hyaline cartilage** located at the **postero-superior** border of the cricoid cartilage.

Corniculate cartilages: these are horn-shape pieces of **elastic cartilage** located at the **apex** of each arytenoid cartilage.

The **Cuneiform cartilages** are club-shaped pieces of elastic cartilages located anterior to the corniculate cartilage.

Larynx – muscles

The muscles of the larynx is divided into intrinsic and extrinsic muscles. The intrinsic laryngeal muscles are divided into respiratory and phonatory muscles (i.e; controlling of laryngeal inlet and controlling movement of vocal folds). The respiratory muscles move the vocal cords apart and serve breathing.

The phonatory muscles move the vocal cords together and serve the production of voice.

The **main respiratory muscles of the larynx** are the posterior cricoarytenoid muscles.

The phonatory muscles are divided into adductors of vocal cord (lateral cricoarytenoid, arytenoid muscles) and tensors of the vocal cord (cricothyroid muscles, thyroarytenoid muscles). These intrinsic laryngeal muscles are responsible for controlling sound production. Cricothyroid muscles lengthen and tense the vocal fold while posterior cricoarytenoid muscles abduct the vocal folds. The lateral cricoarytenoid adducts and internally rotates the arytenoid cartilages - it increases medial compression. Transverse arytenoid muscles adduct the arytenoid cartilage, resulting in adducted vocal folds. The oblique arytenoid muscles narrow the laryngeal inlet by constricting the distance between the arytenoid cartilages. The only muscles involve in controlling of laryngeal inlet is oblique arytenoids. Thyroarytenoid muscles narrow the laryngeal inlet, shortening the vocal folds and lowering voice pitch. The internal thyroarytenoid is the portion that vibrates to produce sound. The only muscle capable of separating the vocal cords for normal breathing is the **posterior cricoarytenoid.** If this muscle is incapacitated on both sides, the inability to pull the vocal cords apart (abduct) will cause difficulty in breathing. Bilateral injury to the recurrent laryngeal nerve would cause this condition. All intrinsic muscles of the larynx are innervated by the recurrent laryngeal branch of the vagus EXCEPT the cricothyroid muscle which is innervated by the superior laryngeal nerve (a branch of vagus).

Larynx – extrinsic muscles

The extrinsic laryngeal muscles **support and position** larynx in the midcervical region. They are divided into **depressors** and **elevators** of the larynx.

Depressors of larynx:

These are: sternothyroid; omohyoid; sternohyoid and inferior constrictor.

Elevators of larynx

The elevators of the larynx are: thyrohyoid; digastric; stylohyoid; mylohyoid; geniohyoid; hyoglossus and genioglossus.

Larynx - innervation

Sensory innervation of the mucous membrane above vocal fold is by the internal laryngeal nerve – a branch of superior laryngeal branch of the vagus while sensory innervation from mucuos membrane below the vocal folds is by the recurrent laryngeal nerve. The **motor innervation of the intrinsic laryngeal muscles** is by the **recurrent laryngeal nerve EXCEPT** the ***cricothyroid muscle*** which is by the **superior laryngeal** branch of the vagus.

Larynx – innervation (when things go wrong!)

Injury to the external laryngeal nerve causes weakened phonation because the vocal cords cannot be tightened. Injury to one of the recurrent laryngeal nerves produces hoarseness of voice.

If both recurrent laryngeal nerves are damaged, The voice may not be preserved; breathing becomes difficult.

Larynx – blood supply

Above vocal folds is supplied by the superior laryngeal branch of the superior thyroid artery. Below the vocal fold is supplied by the inferior laryngeal branch of the inferior thyroid artery.

Clinical application: larynx, coughing and the gag reflex

Coughing is produced by forcing air suddenly out of the larynx. It is a reflex action caused by any particle or phlegm that might be going into the larynx and by so doing, possibly cause obstruction to the passage of air. By forcing

the blast of air out in coughing, it brings up these little particles or phlegm into the throat, to be got rid of as spit. The reflex coughing may not succeed in bringing anything up. This is what is called „dry cough" as opposed to a „productive cough" when phlegm is produced every time we cough. The mucous membrane and nerves of the larynx are all sensitive to this stimulus.

Larynx and piriform fossa

On either side of the laryngeal opening is the piriform fossa bounded medially by aryepiglottic fold, laterally by the thyroid cartilage & thyrohyoid membrane. Deep to the mucuous membrane here is the recurrent laryngeal nerve (motor) and the internal laryngeal nerve (sensory). This area is notorious for accidental lodging of foreign particles eg fins, bones etc.

When things go wrong!

Viral croup

This is an infection and inflammation of the glottis and laryngeal regions. Usually caused by the parainfluenza virus and affects children between six months and five years of age. The typical clinical course involves upper respiratory tract symptoms.

Typical symptoms and diagnosis

These come in the form of upper respiratory tract (URT) symptoms (eg runny nose, nasal congestion, mild fever) with rapid progression to a „barking" cough, which is usually worse at night (*why?*).

In most cases, there may be inspiratory and expiratory stridor (*a wheezing sound caused by air rushing across a narrowed laryngeal inlet*). Evaluation and a diagnosis should be based on history and clinical examination. Croup usually resolves after a few days.

Epiglottitis

This is an inflammation of the epiglottis usually by *Haemophilus bacteria type B bacteria*. It often attacks children between the ages of one and five years (usually at risk) but can also occur in adults. Symptoms may begin as an URT infection and progress to a high fever accompanied by severe throat pain.

Epiglottitis – *classical symptoms*

Respiratory distress can occur as infection progresses. Classically patients lean forward, drooling from the mouth and trying to breathe through the mouth, with severe respiratory stridor. Leaning forward is an instinctive response that causes the epiglottis to tilt forward, opening the airway to facilitate breathing.

Epiglottitis – *investigations, diagnosis and management*

Lateral neck radiographs show the classic „thumbprint“ sign – the epiglottis, which is usually a thin structure, swells and looks like a thumb. Treatment of epiglottis is aimed at maintaining a stable open airway because progressive epiglottic swelling will cause the airway to close and result in asphyxiation – deficient supply of oxygen to the body arising from abnormal breathing.

With prompt treatment, epiglottitis usually resolves in several days.

Expect the following conditions in/with the larynx:

Acute laryngitis; ulcers; polyps and nodules; cancer of the larynx and vocal cord paresis.

Anatomy of the pharynx

The pharynx is a funnel-shaped chamber is situated behind nasal and oral cavities, and anterior and superior to the larynx, connecting them to the oesophagus. Anatomically, it can also be described as a membrane-lined part of the alimentary canal immediately behind (posterior to) the mouth. It is commonly referred to as **throat.**

Pharynx is the **first** clearly **tubular portion** of the digestive system. It is considered as forming part of both the respiratory and digestive systems. For the digestive system its muscular walls function in the process of swallowing

Regions of the pharynx

The pharynx is divided into three regions namely **nasopharynx, oropharynx** and the **laryngophaynx.**

Nasopharynx

This is the upper part of the pharynx, lies posterior to nasal cavity and above the soft palate. Anteriorly, the nasopharynx communicates with the nasal cavity thru the **choanae.**

Structures associated with the nasopharynx

The **orifices of the pharyngotympanic tube** are located on the lateral wall of the nasopharynx.

Above these orifices are the **torus tubarius** – cartilaginous part of the pharyngotympanic tube bulging into the wall.

The **Salpingopharyngeal fold** – this is formed by the ***salpingophayrngeus muscle*** deep to the mucosa, extending inferiorly from the torus tubarius.

Pharyngeal tonsils (adenoids) – located in the roof of the nasopharynx.

Oropharynx

The oropharynx lies posterior to the oral cavity, extends superiorly to soft palate and inferiorly to top of the larynx. The posterior tongue forms its anterior boundary.

Structures associated with the oropharynx

In the oropharynx are found the two arches: **anterior palatoglossal arch** (fold) and **posterior palatoglossal arch** (fold), formed by the **palatoglossus** and **palatopharyngeus** muscles respectively.

They separate the **oropharynx** from the **oral cavity**. Both **palatoglossus** and **palatopharyngeus** muscles are innervated by the vagus nerve (CN X). The palatoglossus is a muscle that elevates and retracts the tongue towards the back of the oral cavity and by so doing raises the tongue and depresses the soft palate.

The **palatine tonsil** lies between these **two arches** in the tonsillar fossa. The median fold of mucosa (**median glossoepiglotic**) divides the space between the base of the tongue & the epiglottis. The spaces on either side of the fold are called **valleculae.**

Examination of oropharynx and tongue

To fully examine the tongue and oropharynx, a tongue blade is used to depress the tongue in its horizontal portion; this enables the vertical portion, epiglottis, and posterior wall of the oropharynx to be seen.

Laryngopharynx

This portion of the pharynx lies posterior to the larynx extends from the epiglottis to the inferior border of the cricoid cartilage, where it narrows and is continuous with the esophagus.

Structures associated with the laryngopharynx

The laryngopharynx communicates with the larynx through the **laryngeal inlet**. The a**ryepiglottic folds** separate the laryngeal inlet from **mucus-lined fossae** on the lateral wall of the pharynx called the **piriform recesses/fossae**.

Pharynx

The pharynx generally serves as a pathway for the movement of food from mouth to esophagus. For the respiratory system, it conducts air from nasal cavities to the larynx and into the middle ear through the Eustachian (pharyngotympanic) tube.

Pharynx and the digestive tract

The wall of the pharynx has three layers which are the mucous, fibrous and muscular layers.

The mucous membrane is continuous with that of nasal cavity, mouth and larynx. The nasal part of mucous membrane is lined with ciliated columnar epithelium; the lower part of mucous membrane is lined with **stratified squamous epithelium.** The fibrous layer lies between the mucous membrane and muscle layers. This fibrous layer is thicker above, where it is strongly connected to base of skull below the fibrous layer becomes continuous with the submucosa of the oesophagus. The muscular layer consists of the superior, middle and inferior **constrictor muscles.**

The muscle fibres run in a basically circular direction ***unlike*** the **stylopharyngeus** and **salpingopharyngeus** muscles which fibres run basically longitudinally. The **pharyngeal tonsils** (adenoids) are located in the roof of the nasopharynx.

Musculature of the pharynx

The **intrinsic or circular muscles:**

Superior constrictor

Action: constricts pharynx. Nerve supply: Pharyngeal plexus (CN X).

Middle constrictor

Action: constricts pharynx. Nerve supply: Pharyngeal plexus (CN X).

Inferior constrictor

Action: constricts pharynx. Nerve supply: Pharyngeal plexus (CN X); superior laryngeal (external branch) and recurrent laryngeal nerve (CN X).

Extrinsic / Longitudinal muscles

Salpingopharyngeus

Action: elevates pharynx. Nerve supply: pharyngeal plexus (CN X)

Salpingopharyngeus, swallowing and eustachian tube.

During swallowing, the **salpingopharyngeus muscle tenses** the mucosa of the *Eustachian tube*, **opens** the tube and hence equalizes the pressure of the middle air with the level of the outside atmospheric pressure.

Extrinsic/Longitudinal muscles

Palatopharyngeus

Action: elevates pharynx and larynx. Nerve supply: Pharyngeal plexus (CN X).

Stylopharyngeus

Action: elevates pharynx. Nerve supply: **Glossopharyngeal nerve (CN IX).**

Musculature of pharynx – summary of function

The **constrictor muscles** (superior; middle and inferior) – [**intrinsic]** function by ***relaxing*** **below** the **descending bolus** and ***constrict*** **above** the

bolus. The **longitudinal muscles** (palatopharyngeus; salpingopharyngeus and stylopharyngeus)–[**extrinsic**] ***suspend*** the pharynx from the skull and ***raise/elevates*** pharynx during swallowing.

Pharynx and the other tonsils

Tonsils are masses of lymphoid tissue found in the mucosal lining of the pharynx.

These tonsils form an incomplete circular ring called Waldeyer's ring around the superior part of the pharynx. The tubal tonsils are paired and located near the orifice of the pharyngotympanic tube. The palatine tonsils (paired), are located in the fossae between the palatoglossal and palatopharyngeal arches. The lingual tonsils are also paired, located on the posterior one-third part of the dorsum of tongue.

Pharynx and other tonsils

Lymphatic drainage of the tonsils

The tonsillar lymphatic vessels drain *first* to the jugulodigastric nodes near the angle of the mandible before eventually draining to the deep cervical lymph nodes.

Neurovasculature of the pharynx

Direct and indirect branches of the external carotid artery supply the pharynx. These include the facial; lingual; ascending palatine; descending palatine and ascending pharyngeal arteries.

Venous drainage

Venous drainage passes through the pharyngeal venous plexus to the internal jugular vein.

Neurovasculature of the pharynx

Sensory innervation of the pharynx varies by region: the maxillary nerve (CN V2) innervates the nasopharynx. The glossopharyngeal nerve (CN IX) innervates the oropharynx while the vagus nerve (CN X) *via* its internal laryngeal branch innervates the laryngopharynx.

Pharynx and second phase of swallowing

In deglutition, the tensor veli palatini muscle initially *tautens (makes tight)* the soft palate, then the levator veli palatini *elevates* the soft palate to *seal off* the nasopharynx. The pharynx is actively involved in the second phase of swallowing. During this phase, *the larynx* rises and constrictor muscles propel the bolus downwards. Food is thus prohibited from entering the trachea by this action (pharyngeal phase). The second phase occurs almost simultaneously. This involves elevation of the soft palate and the contraction of superior constrictor muscles, closing off the nasopharynx. The elevation of hyoid bone and thyroid cartilage also help in closing off the entrance of the nasopharynx as well as closure of the lateral folds of the upper larynx occurs. During the second phase of swallowing, the **pharynx** and **larynx** also rise. **Elevation of the pharynx widens the epiglottis** to receive food/drink while the e**levation of larynx causes the epiglottis to move down** and form a lid over the glottis, **closing off the entrance to the windpipe**.

Pharynx – when things go wrong!

Tonsillectomy

During a tonsillectomy, the palatine tonsils are removed from the tonsillar bed along with their accompanying fascia. The glossopharyngeal nerve which lies on the lateral wall of the pharynx, is vulnerable to injury during

the procedure and may result in loss of sensation and taste of the posterior one-third of tongue.

Tonsillectomy and bleeding in the pharynx

Bleeding may occur from the large external palatine vein or from the tonsillar branches of the facial, ascending pharyngeal, maxillary and lingual arteries. The internal carotid artery may also be vulnerable because it turns just lateral to the tonsil.

Pharynx and the gag reflex

The gag reflex is a *reflexive contraction* of the pharyngeal muscles that *protect the airway* by ***preventing accidental ingestion and aspiration***. It is elicited by touching the soft palate or back of tongue. The Glossopharyngeal nerve (CN X) is the **a**fferent limb **and** the Vagus nerve (CN X) serve as **efferent limb** of the reflex.

Tonsilitis – inflammation of the tonsils.

Adenoids is actually a *pathologic condition* of the pharyngeal tonsil *characterized* by infection and hypertrophy of its lymphoid tissue. The marked enlargement of the gland *blocks* the choanae which necessitates the person to breathe through the mouth. If the condition persists, the child develops a characteristic facial expression called *adenoid facies,* defined as a „dull expression with open mouth". Infection is likely to spread to the surrounding Waldeyer's ring and Eustachian tube, causing swelling and closure of the tube.

Pharyngotympanic tube infection

This is very common in children and may result from *recurrent adenoids* with infections easily likely to cause mastoiditis, meningitis and otitis media (middle ear infection).

Pharyngitis (Sore throat)

This is mostly caused by viruses and **cannot** easily be treated with antibiotics, although some are caused by bacteria. Depending on the severity of the infection. The pharyngotympanic tube may be occluded, thereby predisposing the patient to otitis media.

Typical symptoms include: throat pain, which is worsen on swallowing; occasionally pain radiates to the ears because they have several nerves in common and painful sore throats and fever.

Examination of a sore throat reveals an erythematous posterior oropharynx and usually, tender cervical adenopathy (palpable lymph nodes). Diagnosis is based on culture obtained from ***swabbing the posterior oropharynx and tonsil***.

Pharynx and suffocation

A falling back of the tongue into the pharynx could lead to suffocating. The genioglossus muscles *prevent* the tongue from *falling* backward into the throat therefore *preventing suffocation*. Damage to the nerve (hypoglossal nerve, CN XII) supply to this muscle on both sides may lead suffocation.

UNIT SEVEN

CARDIOVASCULAR SYSTEM

Cardiovascular system – early scientist's viewpoint: *"the heart, with the veins and arteries and the blood they contain, is to be recognized as the beginning and author, the fountain and origin of all things in the body, the primary course of life"- **Wlliam Harvey, 1628.***

Heart and mediastinum

Mediastinum

Mediastinum is a space superimposed between the two lungs in the thoracic cavity. It houses the heart and its coverings as well as the great/big vessels. In theory, the mediastinum is divided into a superior and inferior mediastini by an imaginary horizontal line, passing through the sternal angle and corresponding to the level of the fourth and fifth thoracic vertebrae posteriorly. The inferior mediastinum is further sub-divided into an anterior, middle and posterior mediastini, with the heart and its coverings together with the big vessels, mainly found in the middle mediastinum.

The equilibrium of the entire thoracic cavity is disturbed when this space is shifted. For example, as in air gushing out of lung as a result of damage to pleura and/or air accumulating in pleural cavity. Or when lung parenchyma becomes glandular/solid, rather than being air-filled.

Mediastinal shift

Mediastinal shift may result from damage to pleura leading to a reduction in surface tension between the visceral and parietal pleura. This generally creates a negative pressure in the thoracic cavity, hence the displacement of the mediastinum to one side. A collapsed lung resulting in an inability to fill lung to capacity during inspiration on affected side may also cause mediastinal shift. This is evident radiographically with a displacement of the

trachea towards the site of injury – mediastinal shift and the dome of the diaphragm also being higher than usual on affected side.

Heart

The heart is a hollow muscular, pumping organ located in the mediastinum.

External features of the heart

The heart is roughly conical in shape, with its base, anchored by the great vessels on its superior and posterior surfaces. The apex of the heart is located approximately at the fifth left intercostal space along the mid-clavicular line. The heart has two small appendages, called the right and left auricles. They are basically, anterior extensions of the atria on either side of the pulmonary trunk and aorta.

Surfaces of the heart

Sternocostal - on anterior side of heart. This is **formed largely by the right ventricle** with portions of the right atrium and left ventricle also contributing to this surface. The base of the heart also forms part of the sternocostal surface. The base of the heart is largely formed by the left atrium and portions of the right atrium.

Diaphragmatic – This is on the inferior side of the heart. It is formed by **the left and right ventricles.**

Borders of the heart

The borders of the heart define the shadows seen in radiographic images of the heart. These are:

Right cardiac border - defined by ***right atrium, superior vena cava and inferior vena cava.*** **Apex – this is defined by the tip of the left ventricle.**

Left cardiac border - defined by the ***aortic arch (aortic knob/knuckle), pulmonary trunk and left ventricle.***

Inferior cardiac border: This is *defined by the left and right ventricles.* An enlarged heart (hypertrophy) is marked by a disproportionate appearance of any one of these borders in radiographs.

Surface markings of the borders of the heart

Upper border is marked by a straight line from the lower border of the second left costal cartilage to the third right costal cartilage. This line starts and ends 1.5cm from edge of the sternum.

The lower border is a straight line from the lower border of the sixth costal cartilage on the right, about 1.5cm from the sternum to the apex of the heart. The **right border** is marked by a line, **slightly convex to the right**, joining the right ends of the upper and lower borders while the **left border** is marked by a line, **slightly convex to the left**, joining the left ends of the upper and lower borders.

Coverings of the heart

The heart is enclosed in a connective tissue sheath in the mediastinum. Collectively, this is a three-layered coat referred to as the pericardium. The outermost part of this pericardium is made up of a tough fibrous tissue. Lined on the inner aspect of this fibrous sac/layer, is a serous membrane. This serous layer is in turn made up of two separate layers; the parietal part which is tightly knitted to the inner aspect of the fibrous pericardium and an inner smooth, thin layer that is intimately investing the outer surface of the heart tissue – the visceral pericardium. A potential space exists between the parietal and visceral pericardium, the pericardial cavity. The visceral pericardium secretes a slimy, viscous capillary fluid, the pericardial fluid

which lubricates the surface of the heart in the living. The pericardial fluid is found in the pericardial cavity.

Walls of the heart

The heart, being a hollow muscular organ is seen to have a wall bordering its internal chambers/cavities. This can be well demonstrated in both the coronal and transverse sections of the heart. This wall comprises from withoutinward the:

Epicardium – thin and loose connective tissue layer through which all the neuro-vasculature to the heart runs. Often times this layer is also infiltrated with variable amount of adipose tissue.

Myocardium – this is the largest layer, made up of the specialised cardiac muscle fibres. These cardiac muscles fibres are responsible for the contraction of the heart. Each of these muscle fibres are joined to one another by a unique, connective tissue plate-like substance called the intercalated disc.

Endocardium – this is the epithelial lining the chambers of the heart and is continuous with the endothelium of the great vessels. This is simple squamous epithelium (mesothelium), protecting the inner chambers of the heart and in contact with blood flowing through the chambers.

Grooves on the external surface of the heart

The coronary sulcus (atrioventricular) appears as a shallow depression on the external surface of the heart, demarcating the atria from the ventricles. It runs in a somewhat circumferential manner around the heart.

Similarly, on the anterior and posterior surfaces of the ventricles are found the anterior and posterior interventricular sulci respectively. In these sulci run the coronary vessels that perfuse and drain the heart with blood.

Internal features of the heart – the chambers

The heart has four chambers. The **left and right atria (atrium - singular)** form the in-flow chambers of the heart. They serve as receptacles for blood. The atria are separated by an interatrial septum in the adult heart. The **left and right ventricles** are the outflow chambers of the heart. The two ventricles are separated by a powerful interventricular septum.

Atrium

Atria are thin-walled inflow chambers of the heart. The right atrium receives from the superior vena cava and inferior vena cava. The left atrium receives from the four pulmonary veins. Developmentally, the left atrium is regarded as a coalescing point between the left and right paired pulmonary veins

Each atrium is associated with an auricle (an ear-shaped appendage/extension) of the atria anteriorly on either side of the pulmonary trunk and aorta. The right side of interatrial septum is marked with a shallow depression called the fossa ovalis. This fossa ovalis is the remnant of the foramen ovale - a shunt in atria during pre-natal circulation.

The anterior wall of right atrium is roughened but the posterior wall is smooth. Crista terminalis is a ridge that demarcates the two inner walls if this atrium. Externally, the position of the crista terminalis is evident by a shallow groove called the sulcus terminalis.

The left atrium is smaller with thicker wall than the right atrium. Its walls are completely smooth and receives blood from the four pulmonary veins (lungs).

Ventricles

These are thick-walled chambers. The ventricular walls are marked with a meshwork of muscular ridges known as **trabeculae carneae.** The ventricles connect to the outflow channels of the heart. The right ventricle connecting

to pulmonary trunk while left ventricle connects to the aorta. The two ventricles are separated by an intermuscular septum (IMS) or interventricular septum. This IMS is mainly muscular except for superior end which is membranous.

The right ventricular wall is thinner and smaller than the left ventricle. Anterior and posterior papillary muscles arise from the floor of right ventricle. A third one, the septal papillary muscle arises from the interventricular septum. Another structure in this ventricle is a muscular septo-marginal trabecula or moderator band which extends from the septum to the base of anterior papillary muscle. Conus arteriosus (infundibulum) is the smooth outflow channel of the right ventricle leading to the pulmonary trunk.

The left ventricle on the other hand, includes the apex of the heart. It has thicker wall than the right ventricle. Has two papillary muscles: one large anterior and a small posterior papillary muscle, all arising from its floor. The aortic vestibule is a smooth-walled, curved outflow channel of the left ventricle that flows into the aorta.

Conducting system of the heart

The conducting system of the heart comprises of:

(i) The sino-atrial node (SAN), largely regarded as the pacemaker cells of the heart. It is a special tissue (cluster of cells) located at the inner wall of the right atrium, near the junction between the superior vena cava and right atrium.

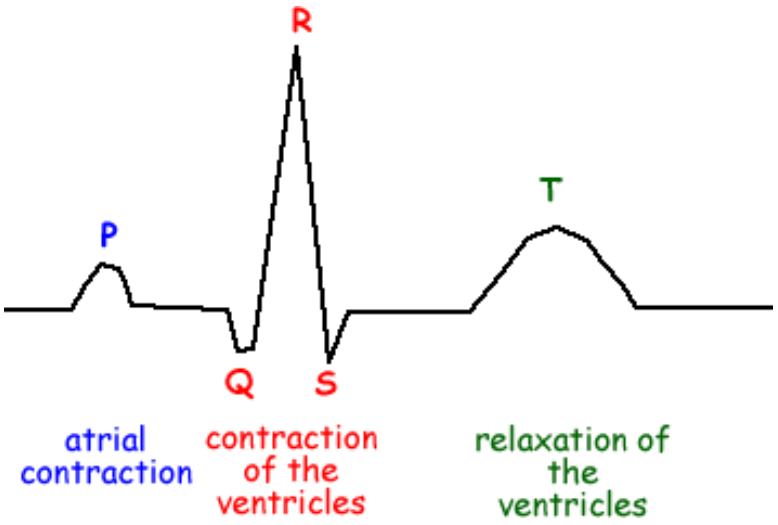
(ii) The atrioventricular node (AVN) – a small cardiac muscle tissue, located in the right atrium. Somewhat near the orifice of the coronary sinus. It is regarded as an electrical „gatekeeper“ between the atria and ventricles, and introduces a delay between atrial and ventricular excitation.

(iii) AV Bundle (Bundle of His), named after a Swiss cardiologist – special muscle fibres running along the interventricular septum. This special tissue is innervated by the thin Purkinje fibres. The Bundle of His help communicate a single rhythm of contraction to all parts of the heart. The Bundle of His by description is a heart tissue that take part in electrical conduction of the heart. By location, the Bundle of His runs through the interventricular septum and branched into both the left and right bundles. By function the Bundle of His receives electrical impulses from the SA-node and transmits them to the fascicular bundles. That is the Bundle of His helps in transmitting electrical impulse from the SA-node to the ventricles.

(iv) Moderator band/septo-marginal trabecula. Bundle branch present only in the right ventricle, spreading to the base of anterior papillary muscle. It ensures equal conduction time in the left and right ventricles.

(v) Purkinje fibres (named after a Czech Anatomist): These are branched fibres that carry electrical impulse to the ventricle. The found in the ventricular walls of the heart and receives electrical impulse from the fascicular bundles and transmit them to the ventricles. The Purkinje fibres cause contraction of the heart muscles that ejects blood out into the circulation and also acts as an alternative pacemaker when the SA-node fails to generate impulse.

The electrical activities in the conducting system of the forms the basis of the PQRST-wave complex generated in an electrocardiogram.



Source: https://images.app.goo.gl/LySWmRarHPAZAMmE7

Valves of the heart

The heart has two different sets of structural and functional valves. These are the atrioventricular (A-V) or in-flow and semilunar or outflow valves. The A-V valves separate atria from ventricles and prevent regurgitation of blood into atria during contraction of the ventricles.

Atrioventricular valves

Morphologically, the A-V valves are made up of cusps, thin leaflets with free inner margin with their outer margins that are attached to the fibrous rings of the cardiac skeleton and slender fibrous cords known as the chordae tendinae, which attach the free edges of the leaflet to the papillary muscles. Each cusp attaches to chordae tendinae from more than one papillary muscle. The tricuspid valve separates right atrium from the right ventricle while bicuspid (mitral) valve separates the left atrium from the left ventricle. Chordae tendinae maintain closure of the valves and prevent regurgitation of blood during ventricular contraction.

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Semilunar valves

The semilunar valves prevent outflow of blood from the ventricles as they fill and also prevent backflow of blood into ventricles after expulsion. Each valve is composed of three half-moon shaped cusps with free inner margins and outer, attached margins fitted into tunica intima of the origins of aorta and pulmonary trunk. The two most, well-developed semilunar valves are the pulmonary valve, found between the pulmonary trunk and the right ventricle and the aortic valve, between the origin of the ascending aorta and the left ventricle.

The pulmonary valve has cusps affixed in the anterior, right and left positions while those for the aortic fixed in the posterior, right and left positions. (***Read on: mitral valve prolapse and aortic valve stenosis).***

Heart sounds and auscultation sites

Closure of the heart valves produces characteristic sounds described as "lub-dub". The closure of the tricuspid and mitral valves (atrioventricular) during ventricular contraction produces the heart sound ("lub"). The closure of the pulmonary and aortic valves during ventricular relaxation produces the second heart sound ("dub"). Sounds created by blood as it flows or negotiates against a resistance in a vessel or chamber of the heart is best heard at what is known auscultation sites on the surface of the body.

Apex beat of the heart – applied anatomy

The classical methods of physical examination employed on the heart are; (i) inspection, (ii) palpation, (iii) percussion and (iv) auscultation. The apex beat may be determined in some people by inspection. (2) Palpation – The heart rate is commonly 70 beats per minute, but considerable variation (50 – 90) occurs. The neonatal rate is twice as fast. Hands should be warm and palpation should be gentle. (3) Percussion – Listening to vibrations set up in

tissues by means of a sharp tap. In the case of the heart, the middle finger of the left hand (pleximeter) is placed in firm contact with the chest wall (heart) and the other fingers of their hand are raised.

A sharp tap is then made on the middle phalanx of this finger (left) with either the index or middle finger of the right hand (plexor or percussor). Normal heart produced a dullness sound. Extreme resonance means abnormal heart (containing for much fluid ie. air or liquid – termed tympani sound). Finally, auscultation or listening to the heart sounds with the aid of a medical instrument – the stethoscope.

Positions and auscultation sites of cardiac valves

Aortic valve

Anatomical position = Left sternal border at the level of third costal cartilage (***just below and medial to pulmonary valve***). **Auscultation site** is site of maximum audibility is at the right second intercostal space near the sternal margin.

Pulmonary valve

Anatomical position = Left sternal border at the level of third costal cartilage. **Auscultation site** is located at the second intercostal space at the sternal margin.

Bicuspid valve

Anatomical position = Left fourth and fifth costal cartilage. **Auscultation site** is located at the fifth left intercostal space in the mid-clavicular line, FLICS $^{(MCL)}$ - (apex beat).

Tricuspid valve

Anatomical position: Sternum at the level of the third costal cartilage.

Auscultation site is at the fifth right intercostal space at the sternal margin.

Blood supply to the heart

At base (origin) of aorta are the aortic valves. Between the aortic valves and inner wall of aorta are aortic sinuses. From these aortic sinuses arise the aortic ostia (openings) that lead into the left and right coronary arteries. Originating from the **anterior aortic sinus** is an ostium that forces blood into the **right coronary artery** during diastole. The right coronary artery passes between the auricle and the infundibulum of right ventricle. It then courses vertically downward in the atrioventricular groove. At the inferior border of the right atrium, gives off the marginal branch, turns backward and posteriorly to lie in the posterior interventricular groove as the posterior interventricular artery.

From the **left (posterior) aortic sinus** is an ostium which serves as a receptacle for oxygenated blood during ventricular relaxation. Oxygenated blood from this ostium is forced into the **left coronary artery** during diastole. Left connects with the posterior aortic ostium which in turn opens into the posterior/left aortic sinus at the origin of the aorta.

The left coronary artery runs between the left auricle and the pulmonary trunk, gives off circumflex branch and continuous downward to lie in the anterior interventricular groove as the left anterior descending (LAD) of the heart.

The LAD forms several anatomosis with the apex, and with other branches in the atrial and ventricular walls.

Foetal circulation and congenital anomalies

Foetal circulation

This basically involves the umbilical veins bringing oxygen and nutrients from the placenta to the liver and then to the heart of the fetus. Foetal circulation is typically associated with three right to left shunts (shortcuts) because oxygenated blood is derived from the placenta. All the foetal shunts become obliterated to form ligaments in adult life. These foetal shunts are: ductus arteriosus, becomes ligametum arteriosum; foramen ovale becomes fossa ovalis while the ductus venosus becomes ligamentum venosum during adult life. Note that the foetal interventricular wall has no shunt.

Patent ductus arteriosus (what is it?)

Patent ductus arteriosus (**PDA**) is a congenital disorder in the heart wherein a neonate's ductus arteriosus fails to close after birth. Early symptoms are uncommon, but in the first year of life include increased work of breathing and poor weight gain. With age, the PDA may lead to congestive heart failure if left uncorrected. In the developing foetus, the ductus arteriosus (DA) is the vascular connection between the pulmonary artery and the aortic arch that allows most of the blood from the right ventricle to bypass the fetus' fluid-filled compressed lungs.

During fetal development, this shunt protects the right ventricle from pumping against the high resistance in the lungs, which can lead to right ventricular failure if the DA closes in-utero. When the newborn takes its first breath, the lungs open and pulmonary vascular resistance decreases. After birth, the lungs release bradykinin to constrict the smooth muscle wall of the ductus arteriosus and reduce blood flow through the DA as it narrows and completely closes, usually within the first few weeks of life.

In most newborns with a patent ductus arteriosus the blood flow is reversed from that of in utero flow that is the blood flow is from the higher-pressure

aorta to the now lower pressure pulmonary arteries. In normal newborns, the DA is substantially closed within 12–24 hours after birth, and is completely sealed after three weeks. The primary stimulus for the closure of the ductus is the increase in neonatal blood oxygen content. Withdrawal from maternal circulating prostaglandins also contributes to ductal closure.

The residual scar tissue from the fibrotic remnants of DA, called the ligamentum arteriosum, remains in the normal adult heart.

Pathophysiology of patent ductus arteriosus

The ductus arteriosus is a normal fetal blood vessel that closes soon after birth. In a patent ductus arteriosus (PDA) the vessel does not close but remains "patent" resulting in irregular transmission of blood between two of the most important arteries close to the heart the aorta and the pulmonary artery. Patent ductus arteriosus (PDA) is common in neonates with persistent respiratory problems such as hypoxia, and has a high occurrence in premature children. In hypoxic newborns, too little oxygen reaches the lungs to produce sufficient levels of bradykinin and subsequent closing of the ductus arteriosus.

Premature children are more likely to be hypoxic and thus have PDA because of their underdeveloped heart and lungs. A patent ductus arteriosus allows a portion of the oxygenated blood from the left heart to flow back to the lungs by flowing from the aorta (which has higher pressure) to the pulmonary artery. If this shunt is substantial, the neonate becomes short of breath: the additional fluid returning to the lungs increases lung pressure to the point that the neonate has greater difficulty inflating the lungs. This uses more calories than normal and often interferes with feeding in infancy. This condition, as a constellation of findings, is called congestive heart failure. In some cases, such as in **transposition of the great vessels** (the pulmonary artery and the aorta), a PDA may need to remain open. In this cardiovascular condition, the

PDA is the only way that oxygenated blood can mix with deoxygenated blood. In these cases, prostaglandins are used to keep the patent ductus arteriosus open.

Signs and symptoms of PDA

While some cases of PDA are asymptomatic, common symptoms include: tachycardia; respiratory problems; shortness of breath; continuous machinelike murmur; enlarged heart; left sub-clavicular thrill; bounding pulse; widened pulse pressure. Patients with PDA typically present in good health, with normal respirations and heart rate.

If the ductus is moderate or large, widened pulse pressure and bounding peripheral pulses are frequently present, reflecting increased left ventricular stroke volume and diastolic runoff of blood into the initially lower-resistant pulmonary vascular bed. Prominent suprasternal and carotid pulsations may be noted secondary to increased left ventricular stroke volume. Poor growth and differential cyanosis, i.e. cyanosis of the lower extremities but not of the upper body.

Etiology of PDA

A patent ductus arteriosus can be idiopathic (i.e. without an identifiable cause), or secondary to another condition. Some common contributing factors in humans include: preterm birth; congenital rubella syndrome and chromosomal abnormalities such as Down syndrome.

Tetralogy of Fallot (TOF) – what is it?

This is a combination of four congenital heart defects namely: pulmonary stenosis; a narrowing of the exit of the right ventricle; a ventricular septal defect; a hole between the two ventricles; a right ventricular hypertrophy; a

thickening of the right ventricular muscle; an overriding aorta; which allows blood from both ventricles to enter the aorta.

Tetralogy of Fallot – symptoms

Cyanosis; difficulty in breathing; heart murmurs and finger clubbing.

The blood vascular system

The blood vascular system includes the closed network of vessels through which the heart circulates blood throughout the body. These comprises the arteries, veins and capillaries.

Arteries

Arteries carry blood away from the ventricles of the heart and to the beds of capillary vessels.

The pulsating of the heart can be felt in most arteries in the body especially when compressed against a hard tissue.

At each bifurcation, the units of this distributing system decrease in size. Arteries are classified as elastic or large arteries, muscular or medium-sized arteries and arterioles.

Arterioles are regulatory portion of the arterial tree that connect arteries to the capillaries.

The walls of arteries are much thicker than the walls of veins of corresponding diameter.

Thus, arteries are less predisposed to collapse as blood pressure falls during diastole.

As branching arteries decrease in diameter, the elastic tissue component of the walls diminishes and is replaced by smooth muscle.

At the arteriolar level, all elastic tissue has been essentially replaced.

Some named arteries in the body

The biggest artery in the body is the aorta, arising directly from the left ventricle. It has three distinct parts namely:

Ascending, arch and descending aorta.

The arch of the aorta gives off three important branches: brachiocephalic trunk, left common carotid artery and left subclavian artery (*from left to right respectively*).

Brachiocephalic trunk shortly divides into right common carotid artery which is responsible for blood supply to both the head and neck and intracranial regions on the right side.

The left common carotid also takes care of the blood supply of the left side of the head and neck region as well as the left intracranial structures including brain tissues.

The most lateral direct branch of the arch of the aorta, the left subclavian artery is responsible for blood supply to the entire left upper limb. Perhaps this is the rationale behind why the left arm almost always is preferred to the right in the estimation of blood pressure from a patient.

The subclavian runs inferior to the clavicle, and soon distally to cross the first rib to become the axillary artery. The axillary artery traverses the axilla (armpit) and upon crossing the lower margin of the teres major muscle, becomes the brachial artery in the arm. The brachial artery then runs distally in the arm and in the cubital fossa (depression in front of the elbow), divides into a medial ulnar artery and lateral radial artery.

The descending aorta runs through the posterior mediastinum of the thorax, crosses the diaphragm (T12 vertebral level) to become the abdominal aorta. After giving off series of paired lateral branches and three unpaired branches anteriorly, the abdominal aorta finally bifurcates into left and right common iliac arteries at the level of the fourth lumbar vertebra.

The common iliac artery divides into internal and external iliac arteries at the brim of the pelvis. The internal iliac enters the pelvic cavity to supply structures in and around the pelvis.

The external iliac artery on the other hand, runs forward, crosses the inguinal ligament to become the femoral artery in the thigh region. The femoral artery will later find itself posteriorly in the depression behind the knee to be known as the popliteal artery which in turn divides to form the anterior and posterior tibial arteries supplying blood to the remaining part of the lower limb.

Before reaching the foot, the anterior tibial (tibialis anterior) artery lies in the depression in front of the ankle joint as the dorsalis pedis artery – another useful site for peripheral arterial pulse investigation.

Clinical correlation

Aneurysm

An aneurysm is a thin, weakened section of an artery or vein that bulges outward forming a ballon-like sac or causing a permanent dilation of the blood vessel.

An aneurysm may burst and cause massive haemorrhage with shock, severe pain, stroke, or death, depending on which vessel is involved.

Capillaries

These are too small to be visualized, but play an important role in the exchange of blood and tissue fluid across the one-cell-thick walls.

Capillaries are one-cell-thick vessels that form anastomotic network between arterioles and venules.

More metabolically active tissues (eg. glands and muscles) have more extensive capillary beds than do less active tissues (eg. tendons and ligaments).

Avascular structures (eg cartilage, cornea and epidermis) have no capillary beds.

Modifications in the vascular communication between arterioles and venules, in the form of sinusoids occur in some organs (eg spleen, liver, bone marrow and pituitary gland).

Sinusoids are wide, irregular channels, which are often, partially lined by phagocytic cells.

Veins

Venous channels originate opposite the arteriolar side of capillary networks as small – caliber venules.

The venules coalesce to form veins of increasing diameter that ultimately empty into the atria of the heart. Meaning all veins drain towards the right; a fact that underpins the orientation of the needle during injection, especially if it has to do with intravenous drug administration.

Veins have tributaries not branches, as smaller veins turn to drain into larger veins.

Veins are usually more superficial, have thinner walls, are more numerous, and are of larger caliber than their companion arteries.

Blood flow through veins is slower and under much less pressure than through arteries of a comparable size.

Veins of the pulmonary circulation drain into the left atrium, whiles venous drainage for the systemic circulation draining the body wall, abdominal viscera and vertebral column empty into the right atrium.

Venous drainage from the gastrointestinal tract forms the hepatic portal system, which drains through the portal vein into the liver.

Venous drainage of the thoracic cavity (especially the posterior thoracic wall and posterior abdominal wall) forms the azygous venous system of veins which eventually empty into the inferior vena cava.

Veins drain capillary beds. Many veins have valves to ensure unidirectional flow of blood.

Veins that accompany major deep arteries in the upper and lower limbs usually occur in pairs called and usually regarded as deep veins. This type of vein may be more than one running alongside an artery.

Other veins in the limbs are the superficial veins, running immediately beneath the surface of the skin, and venae comitantes (or accompanying veins), which turn to link superficial veins to deep veins or link two or more deep veins together.

Veins on the dorsum of both hand and foot unite (coalesce) to form two major superficial veins in the limbs. The cephalic (lateral side) and basilic (medial) in the upper limb.

The basilic vein drains into the brachial vein whereas the cephalic vein drains into the axillary vein. Usually, these two superficial veins are linked by another obliquely running superficial vein, the median cubital vein in the cubital fossa. The latter becoming an easy target during phlebotomy. Both the superficial and deep veins of the upper limb will drain their contents in the axillary vein which continues upward beneath the clavicle as the subclavian vein which in turn unites with the vein from the head and neck region before emptying into the heart.

It is therefore, possible to inflame the inner lining of the heart (endocardium) with infections from the peripheral veins of the limbs.

The superficial veins from dorsal arch of the foot form the long/great and short/small saphenous veins in the lower limb. The long saphenous vein runs on the medial and anterior side of the lower limb to empty into the femoral vein while the short saphenous vein lies on the posterior surface of the leg to drain into the popliteal vein.

Superficial vein in the limbs provide easy access to the circulatory system for intravenous infusions.

In the popliteal fossa behind the knee join lies the popliteal vein, a typical example of the deep vein of the lower limb which is often prone to clots due to poor and prolong sitting habits coupled with defective clotting factors, leading to the incidence of deep vein thrombosis (DVT).

Popliteal vein ascends deep in the thigh muscles, turning antero-medially before itself disappearing beneath the inguinal ligament to continue into the trunk of the body as the external iliac vein. The external iliac vein unites with its counterpart from the opposite side anterior to the body of the fifth lumbar vertebra to form the inferior vena. Substances introduce into any vein (superficial or deep) in the lower limb, thus eventually arrives in the heart through the inferior vena cava.

Veins from the head and neck region mainly drain into one of two major veins in the neck: superficial structures around the head and neck region drain into the external jugular vein which run obliquely superficial across the sternocleidomastoid muscle and the internal jugular, serving as the main drainage channel for the intracranial dural sinuses. The external jugular vein also empty its contents into the internal jugular vein.

Internal jugular vein on one half of the neck unites with the subclavian vein of same side to form the brachiocephalic vein of the same side. (*NB: do not to confuse the brachiocephalic vein with the brachiocephalic trunk which is the first branch from the arch of aorta and as such, an artery*). The left and right brachiocephalic veins unite deep in the base of the neck to form the superior vena cava draining into the right atrium of the heart.

A portal vein is one that is interposed between two capillary beds. i.e has capillary beds at its origin and destination, for example, the hepatic portal vein.

Clinical correlations

Most common disorder of the vascular system is the dilation, elongation and tortuosity of the superficial veins of the lower limb, called varicose veins.

Principal cause of this affliction is an increased venous pressure with dilation of veins, largely due to valvular incompetence and gravity from upright position.

Portosystemic venous anastomosis

Tributaries of the portal vein communicate with systemic veins in several location particularly; (i) in the lower end of the esophagus (ii) in the lower end of the rectum and (iii) around the umbilicus.

Ordinarily, these channels are collapsed with little blood flow, because blood drains from the abdominal viscera through the portal vein to the liver. If venous flow through the liver is impeded by a blood clot or scarring in the liver (cirrhosis), the portal vein pressure rises markedly.

This is known as portal hypertension and the result is that veins of the portal system, including some or all of the anastomotic channels become distended. This cause varicosities of the umbilicus (caput medusae).

Collateral circulation

Collateral circulation is the mechanism whereby blood may flow to an organ or region after its normal course has been blocked. This is necessary when occlusion of a vessel from a blood clot, foreign body, tumors or ligation occurs. If the segment distal to the occlusion is to remain viable, it must receive a new blood supply. When a collateral circulation develops the blood by-passes, the obstruction by an anastomosis, and may even flow in both directions in anastomotic artery to supply all tissue distal to the occlusion.

Importance: Collateral circulation prevents necrosis (i.e death of tissue distal to the occlusion is avoided).

UNIT EIGHT

LYMPHATIC/RETICULO-ENDOTHELIAL SYSTEM

The lymphatic system is the body's second circulatory system. It slowly delivers lymph, a plasma-like substance from the tissues to the blood through a series of vessels that resemble veins. Also sometimes referred to as the immune system that protects the body against effects of a great variety of foreign cells and substances. Lymph is interstitial fluid that accumulates in the lymphatic vessels. Lymphatic capillaries collect lymph from tissues. The collecting vessels contain valves and may pass through lymph nodes on the way to larger vessels known as trunks.

Lymphatic system: lymph and lymphatic vessels

Lymph vessels begin as blind-ended capillaries within the tissue space. Lymphatic capillaries consist of a single layer of endothelium. They have no fenestration in their endothelial cells; no zonula occludens between neighbouring cells and also have no basal lamina. Their lumens are held open by numerous microfibrils. A mesh of microfibrils also bind the walls of the lymph vessels, firmly to the surrounding connective tissue (hence the origin of the name reticuloendothelial system).

The lymphatic trunks drain into the right lymphatic duct; the right lymphatic duct drains lymph from the right arm and right upper side of the body whereas the thoracic duct/trunk drains lymph from the rest of the body. These ducts drain lymph into the brachiocephalic veins. Lymphatic vessels contain one-way valves similar to veins.

Some named lymphatic vessels

The jugular trunks–lie beside the internal jugular vein, receive lymph from each side of the head and neck. Subclavian trunks – drain the upper limbs and chest. The broncho-mediastinal trunks- drain the organs of the thorax. In

the abdominal cavity is the cisterna chyli draining into thoracic duct (lower half and left upper extremes). The thoracic duct drains into the junction between the left subclavian vein and left internal jugular vein. The right jugular trunk (right lymphatic duct) empties into the venous system at junction between the right internal jugular vein and right subclavian veins.

Lymph vessels – summary

The four major lymphatics in the body from smallest to largest are: capillaries, collecting vessels, trunks and ducts.

Lymphatic system: tissues and organs

The tissues and organs of the lymphatic system filter out antigens and act as site for B-lymphocyte and T-lymphocyte production. From simple to most complex, these structures are: the lymphatic nodules, lymph nodes, tonsils, thymus and spleen.

Lymphatic vessels – when things go wrong

Penetration injury to lymph trunks is fatal unless the injury is corrected surgically. Lymph cannot clot, therefore loss of a large amount of lymph results to loss of substantial quantities of fat and proteins, followed by emaciation and death.

Lymphatic system – lymph node

Lymph node (lymph gland) is a kidney-shaped organ of the lymphatic system.

About 450 lymph nodes in a healthy adult. They are small in size ranging from 0.1cm – 2.5cm. A number of lymph nodes are linked throughout the body by lymphatic vessels. Lymph nodes are major sites of lymphocytes that include B- and T-cells. A lymph node is enclosed in a fibrous capsule and is

made up of outer cortex and inner medulla. The capsule extends into the substance to form trabeculae. Lymph node has a hilum on its concave side. Lymph enters the convex side of a lymph node through multiple afferent lymphatic vessels and flows into a series of sinus. After entering the lymph node from the afferent lymphatic vessels, lymph flows into a space underneath the capsule called the sub-capsular sinus, then to the cortical sinuses. After passing through the cortex, lymph collects in the medullary sinuses. All these sinuses drain into the efferent lymph vessels to exit at the hilum on the concave side via the efferent lymphatic vessel.

A lymph node is divided into compartments called nodules (lobules), each consisting of a region of cortex with combined follicular B-cells, a paracortex of T-cells and a deeper part of the nodule called medulla. Cortex alone has subcapsular part and a deeper part, the paracortex. The outer part of the cortex consists of groups of mainly inactivated B-cells, when activated they develop into what is called the germinal centre. The deeper paracortex mainly consists of T-cells.

The medulla contains large blood vessels, sinuses and medullary cords that contain antibody-secreting plasma cells. There are fewer cells in the medulla than cortex.

Lymph nodes – when things go wrong!

Lymphadenopathy – swellings/enlargements of the lymph nodes.

Tonsils

They form a ring of lymphoid tissues around the entrance of the throat (pharynx). Tonsils are basically a collection of lymphoid/immunocompetent tissues. They are found facing the aerodigestive tract. Function

Tonsils form the immune system‟s first line of defense against ingested or inhaled foreign pathogens. Collectively they form the Waldeyer‟s ring;

which is formed by the paired palatine tonsils; lingual tonsils; tubal tonsils and a single pharyngeal tonsil (adenoids). Anatomically, tonsils consist of an elevation of mucous membrane of the mouth and pharynx. They play an important role in the protective mechanism of the body against infections.

Tonsils – histology

The main substance of tonsils is composed of loose connective tissue, containing lymph corpuscles, packed in a dense nodules or follicles. The epithelium of tonsils

(stratified squamous and pseudostratified columnar), is highly folded to form the tonsillar crypts.

Pharyngeal tonsils - histology

This is located at the roof of the pharynx (sphenoid bone). It is just a single mass of lymphoid tissue buried in the mucosa of the sphenoid bone.

Its characteristic features include:

Lined with pseudostratified columnar ciliated (respiratory); being incompletely encapsulated; lack crypts, but has small folds; easily recognised because they are covered by a stratified squamous epithelium at places where the epithelium dips into the tonsil in the form of crypts.

Palatine tonsils - histology

Deep to the epithelium in the oropharynx is diffuse lymphoid tissue in which typical lymphatic nodules are present. They are the largest of all the tonsils. They are paired, characterised with crypts and happen to be the most infected.

Lingual tonsils - histology

Lingual tonsils are characterised by non-keratinised squamous epithelium. They exhibit incomplete encapsulation, long branched crypts. Lingual tonsils are located behind the zenith (apex) of the terminal sulcus of tongue; that is near the junction between the anterior two-thirds and posterior one-third of the tongue. They usually occur in large numbers.

Tonsils – when things go wrong!

Inflammation of tonsils is not uncommon; this is known as tonsillitis.

Lymphatic/immune system: spleen and its functions

Spleen plays multiple supporting roles in the body. It acts as a filter for blood as part of the immune system. Old (aged) red blood cells are recycled in the spleen and platelets and white blood cells are also stored in it. Spleen also helps fight certain kinds of bacteria that cause diseases.

Immune system: spleen and its functions

Spleen holds a reserve of blood – comes in handy in the event of haemorrhage shock. It recycles iron; it metabolises haemoglobin removed from senescent red blood cell. The globin portion of the haemoglobin is degraded to its constitutive amino acids. The haem portion is metabolized to bilirubin, which is removed in the liver. The spleen traps and destroys debilitated erythrocytes and platelets and serves as a site for lymphocyte production and immune surveillance.

Histology of spleen

Histologically, it is characterized by the presence of splenic cords, white and red pulps. The splenic cords are structures that trap platelets, macrophages

and old erythrocytes. While its white pulp contains lymph nodules, T-Lymphocytes activated and B-lymphocytes stimulated to produce antibodies. And the red pulp filters erythrocytes through filtration passages.

Spleen histology – blood circulation

From splenic arteries to trabecular arteries, to central arteries in white pulp, to marginal zone where lymph is sent to white pulp and blood to red pulp. Lymph in the white pulp flows to efferent lymphatics then to trabeculae, and finally to the hilum. As soon as blood gets to the red pulp, it flows to the venous sinuses, then to pulp veins, to trabeculae veins and the then to the splenic vein. The red pulp is considered not to have an open circulation system.

Gross anatomy of the spleen

Found in the left upper quadrant of the abdomen, underneath the diaphragm. Has a smooth, convex surface that faces the diaphragm. Lies underneath the ninth to eleventh rib on the left. Its medial or visceral surface is divided by a ridge into two regions:

An anterior gastric portion and a posterior renal portion. The gastric surface is directed forward, upward and toward the middle is broad, concave and in contact with the posterior wall of the stomach. Below this, the gastric surface is in contact with the tail of the pancreas. The renal surface of the visceral portion is directed medially and downward. This surface (renal) is somewhat flattened and narrower and is in relation with the upper part of the anterior surface of the left kidney and suprarenal gland.

Gross anatomy of the spleen - measurements

Healthy adult spleen measures roughly 7cm – 14 cm in length.

The easiest way to remember the gross anatomy of the dimensions of the spleen is the: **1x3x5** x7x **9x10x11** rule.

1x3x5 inches in length (3x8x13cm); **weighs 7ounces** (200g) and **lies between ribs 9 and 11** on the left.

Spleen – blood supply

Splenic artery from abdominal aorta and the short gastric arteries supply blood to the spleen. Splenic veins, drains it with deoxygenated blood. Like the thymus, the spleen has only efferent lymphatic vessels. Its germinal centres are supplied by arterioles.

Lymphatic system – thymus

- *(Thymus to be discussed in details under the endocrine system*)

The thymus secretes hormones called **thymosin** that activate T-lymphocytes. The epithelial reticular cells of the thymus also manufacture another hormone called **thymopoietin** that stimulates the lymphoid stem cells to proliferate**.** Afferent arterioles do not enter the thymus; therefore, lymph vessels do not drain into this structure.

Lymphatic system – when things go wrong!

Abnormal accumulation of tissue fluid in extracellular space is known as oedema. Lymphangitis is the clinical term for infection of lymph vessels and lymphadenitis are infections of the lymph nodes. Thymic hypoplasia (DiGeorge syndrome) is characterized by lack of thymic function. T-lymphocytes are most affected with this syndrome. This disease is usually fatal in infancy, and viral and fungal infections often occur.

UNIT NINE

DIGESTIVE SYSTEM

Introduction

The digestive system is a highly specialized tube which basic function is involved in mechanical and chemical breakdown of food; absorption of digested materials (nutrients) into the bloodstream as well as elimination of unabsorbed food materials from the body**.** This digestive tube (tract) is associated with accessory organs which are specialized structures that project into the tube. The area from the esophagus to the rectum is known as the **gastrointestinal tract.** The entire tube from the mouth to the anus is known as **alimentary canal.**

Anatomy of the alimentary canal - general plan

The digestive tract is a hollow tube composed of a lumen of variable diameter, surrounded by a wall made up of four principal layers: the muscosa, the submucosa, the muscularis externa and the serosa.

Digestive system – developmental origin and mechanism of action

Developmentally, the gastrointestinal tract is derived from endoderm and is divided into foregut, midgut and hindgut. The process of digestion begins with the oral cavity (mouth) where ingested food is **pulverized** by the **molar teeth** and ripped/**torn** by the **canines** and **incisors**.

Regions of the digestive tract

Oral cavity

The oral cavity is the entrance to the digestive system. The mouth is the opening into the oral cavity. The space between the teeth and lips and cheeks is the vestibule. The lips (upper and lower) form the boundaries or borders of the mouth. The anatomical name for lips is RIMA ORIS. The mouth is

further protected by the upper and lower jaws (***maxillae & mandibles respectively***). The tongue forms its floor, while the hard and soft palates form its roof. The posterior part of this roof is formed by the soft palate, which projects posteriorly in a leaf-like fashion into the oropharynx as the uvula (elastic cartilage). The arched opening of the oral cavity into the oropharynx is the **fauces**.

The tongue mixes food and helps us to speak and its nerve endings enhance the pleasure of eating by sensing texture and taste of food. The underside (inferior surface) of the tongue is connected to the floor musculature by a fibrous tendon known as the **frenulum**.

Digestive system - teeth

A tooth is a hollow core of sensitive material found in the oral cavity. Teeth grip, slice and crush food during a lifetime of chewing that prepares chunks of food for digestion. Teeth also enhance the aesthetic beauty of the face and preserve the anatomy of the skull.

Each tooth is composed of a portion that projects above the gingival/gum called the crown and one or more roots below the gingival that hold the teeth in bony sockets called alveoli/lus.

The crown is covered by the extremely hard enamel (hardest material in the body) while the roots are covered by cementum. These two (enamel and cementum) coverings meet at the neck (or cervix) of the tooth. The interior of a tooth contains another calcified material called dentin that surrounds a tissue filled space known as the pulp cavity. The pulp cavity extends to the apex of the root/canal where an orifice called apical foremen allows for the passage of blood vessels, lymphatics and nerves into the pulp cavity. The tooth is fixed into the alveolus/bony socket by the periodontal ligaments/membrane that inserts into the cementum. Two sets of teeth (dentition) develop in a lifetime of humans. The first is called deciduous/milk

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teeth, which erupt between the sixth and thirty-sixth month after birth. These number up to ten in the lower jaw and ten in the upper jaw. Each tooth type develops on both sides, thus in the milk set, there are five different types of teeth: two incisors, one canine, and two molars. Adult humans have thirty-two permanent teeth and are dispersed in two bilaterally symmetric arches in the maxillary and mandibular bones (upper and lower jaws). These teeth comprise eight in each quadrant; two incisors, one canine, two premolars and three molars. There are no deciduous precursors of the twelve permanent molar teeth. As the permanent teeth push toward the surface, they cause resorption of the roots of the milk teeth ahead of them. Following the resorption of the dentin the crowns of these milk teeth dislodge and fall out, usually painlessly and without bleeding. Permanent teeth appear between ages six and twenty-one years.

Digestive system – salivary glands

Salivary glands are exocrine glands that produce saliva through a system of ducts into the alimentary tract. Three major pairs exist in humans: parotid, submandibular and sublingual.

Histologically, secretions from these salivary glands can be classified as: serous, mucous or seromucous (mixed). Serous secretion contains ptyalin (alpha-amylase) that breaks down starch into maltose and glucose and mucous secretion contains mucin which acts as a lubricant. Mucous secretion also contains lysozymes that break down bacteria.

About 0.5 – 1.5L of saliva is produced daily. The secretion of saliva is mediated by parasympathetic nerve stimulation. Structurally, the secretory portions of salivary glands may be rounded (acini), pear-shaped (alveoli), tubular or a mixture.

Salivary glands – functions of saliva

Functions of saliva include: digestion of food, lubrication of food, solvent action of food and cleansing of the mouth, excretion – organic, inorganic materials. Drugs and organisms can be excreted in saliva.

Some named salivary glands:

(1) Parotid gland

These are paired, major salivary gland around the ramus of mandible. It is the largest of salivary glands. It secretes saliva to facilitate chewing and swallowing and amylase to start digestion of starches. The gland is enclosed in a tough capsule. This capsule extends into parenchyma of gland in the form of fibrous septa. Large depots of adipose tissue cells line most of the septa. The secretory portion of this gland is composed of tubulo-alveolar acini. Cuboidal epithelial cells line the secretory portion. Its duct opens the **serous secretion** into the oral cavity opposite the second upper molar tooth. Parotid gland is significantly related to the terminal branches of facial nerve which becomes exposed to iatrogenic lesions in the substance of gland.

Parotid gland – histology

Parotid gland is highly lobulated. About 20% of all salivary content in mouth is from this gland.

Mump is a viral infection that usually affects the parotid gland. Adenoma of the gland is also fairly common.

(2) Submandibular salivary glands

Secretion of the submandibular gland opens into oral cavity (beneath tongue) through the submandibular duct/Wharton's duct on either side of frenulum just behind lower incisors.

More than two-thirds of saliva in the mouth is from the submandibular gland. This gland can be palpated in the superior, superficial cervical region. It can be felt as a rounded ball underneath mandible. It is located about two finger breadths above Adam's apple (laryngeal prominence). Submandibular salivary gland is surrounded by a tough capsule and has a fibrous septa dividing it into lobes and lobules. There is almost no adipose tissue within gland. The secretory portion is composed of tubulo-alveolar acini. Its secretion is mixed – seromucous. Most of the acini secretion is serous.

(3) Sublingual salivary gland

The sublingual salivary gland is situated below the floor of mouth. Lies anterior to submandibular gland. Its secretions enter the mouth through about eight to ten short ducts. The gland lacks a fibrous capsule but a loose connective tissue septa divide it into lobes and lobules.

(3) SUBLINGUAL SALIVARY GLAND - HISTOLOGY

The secretory portion of this gland is composed of tubulo-alveolar acini. Its secretion is mixed – seromucous, with most of the secretion of the acini portion being mucous.

Digestive tract – pharynx

(*Refer to notes on anatomy of the pharynx*)

Muscles of mastication

These are powerful skeletal muscles which actions collectively or individually, help move the mandible in different planes and thus facilitate the chewing actions of the teeth. The muscles of mastication are: temporalis, masseter, lateral pterygoid and medial pterygoid.

Temporalis

Origin: Temporal fossa and temporal fascia.

Insertion: Coronoid process and anterior border of ramus of mandible.

Action: - Raises and retracts mandible (ensures closure of mouth).

Nerve Supply: From Mandibular (V3) division of trigeminal.

Masseter

Origin: Lower border and deep surface of zygomatic arch.

Insertion: Lateral surface of ramus and coronoid process of mandible.

Action: Raises and help protract mandible.

Nerve Supply: From Mandibular (V_3) division of trigeminal.

Lateral Pterygoid

Origin: Greater wing of sphenoid and lateral pterygoid plate.

Insertion: Neck of mandible and capsule of temperomandibular joints.

Action: Produces and depresses mandible; draws mandible towards opposite side.

Nerve Supply: Form mandibular (V_3) division of trigeminal.

Medial pterygoid

Origin: Maxillary tuberosity and medial surface of lateral pterygoid plate.

Insertion: Mandible between mandibular foramen and angle of mandible.

Action: Raises/elevates mandible and protrudes mandible, draws mandible to opposite side.

Nerve Supply: Mandibular division (V3) of the trigeminal nerve.

Pathway of food through esophagus

Swallowing (*clinical term is deglutition*) can be divided into **three rapidly successive phases**:

moving food from oral cavity into oropharynx (**buccal phase**), movement of food from oropharynx past larynx (**pharyngeal phase**) and movement of food into the esophagus (**esophageal phase**).

Anatomy of swallowing

During the first phase, tongue is raised against palate, palatoglossal arches close together and food is forced back into oropharynx (buccal phase) and in the second phase, the larynx rises and constrictor muscles propel the bolus downward. Food is prohibited from entering the trachea during the pharyngeal phase. This phase also involves the tensor veli palatine initially tautens (makes tight) the soft palate, then the levator veli palatini elevates the soft palate to seal off the nasopharynx. During the second phase of swallowing, there is elevation of hyoid bone and thyroid cartilage also, which all help in closing off the entrance of the nasopharynx. There is also a closure of the lateral folds of the upper larynx occurring during this phase. The third phase of swallowing simply involves the food being forced down behind and alongside the larynx. It involves shortening of the pharynx and contraction of the inferior constrictor muscles commits the food to the esophagus. Peristalsis action moves the bolus to the stomach.

Esophagus

The esophagus is a muscular tube (25cm long) connecting pharynx to stomach. The musculature of the esophagus is divided into three. The upper one-third is marked by purely skeletal muscle, while the middle one-third is composed of a mixture of skeletal and smooth muscle fibres and the wall of the lower one-third is wholly smooth muscle fibres. The esophagus has 3 anatomical constrictions along its entire length. The **first or upper constriction** is seen at where the **pharynx joins the upper end** of esophagus. The **second or middle one** is located at where the **aortic arch**

and the **left bronchus cross** the **anterior surface** of the esophagus and the **third or lower constriction** is located at where the esophagus **passes** through **the diaphragm** into the stomach. These constriction sites are places where swallowed foreign bodies can lodge or sites where it may be difficult to pass an esophaguscope.

Nerve supply to the esophagus and stomach is from the parasympathetic and sympathetic afferent and efferent fibres which reach these organs through the vagus and sympathetic trunks.

Esophagus – histology

Characterised with four layers: mucous membrane, submucosa, muscular coat and adventitia.

Esophagas – when things go wrong!

Heartburn occurs when the esophageal sphincter does not close completely, thus allowing the high acidic gastric contents to reflux into lower esophagus.

Digestive system and the anterior abdominal wall.

The anterior abdominal wall is composed of skin, fascia and muscles, supported by ribs, lumbar vertebrae and bony pelvis.

Function of the anterior abdominal wall

The anterior abdominal moves and stabilises the trunk; supports abdominal viscera; creates intra-abdominal pressure (good for digestion and respiration), muscular wall offers little protection for viscera and bony pelvis protects viscera of lower part of the wall.

Regions and planes of the abdominal wall

The anterior abdominal wall has four quadrants and nine regions are defined using standard vertical reference lines and standard transverse planes.

Coordinates for the quadrants of the abdominal wall

Two perpendicular lines that intersect at the umbilicus: mid-sagittal line and the trans-umbilical lines demarcates the anterior abdominal wall into four quadrants namely: right upper quadrant (RUQ), right lower quadrant (RLQ), left upper quadrant (LUQ) and left lower quadrant (LLQ).

McBurney's point which is a surface landmark for identifying the position of the vermiform appendix in majority of individuals falls in right lower quadrant. The McBurney's point is actually a spot on the anterior abdominal wall, situated midway between the lateral one-third and middle third of an imaginary line from the anterior superior iliac spine (ASIS) and the umbilicus on the right side.

Coordinates for the nine planes or regions of the abdominal wall

Two imaginary vertical and two horizontal lines demarcates the anterior abdominal wall into nine regions. The vertical imaginary lines are the left and right midclavicular lines while the two horizontal ones are passing through (a) the lowest point of tenth costal cartilage/rib (subcostal line)upper line and (b) the lower one through the tip of the left and right iliac crests (inter-cristal line). The three median regions demarcated by the intersection of these lines are from superior to inferior: epigastric, paraumbilical and hypogastric respectively. The regions to the left and right of these median ones are hypochondriac, lumbar and iliac, top-down

respectively. This suffice that the McBurney's point described above falls to the right iliac region if the regions are used instead of quadrants for description.

Regions and planes of the abdominal wall

A transpyloric plane also could be obtained if the above lines describing the nine regions are played around with. An imaginary horizontal line passing somewhere half-way between the jugular notch and pubic crest, roughly with cut through the body of the first lumbar vertebra or very close to pylorus of stomach, hence the transpyloric plane is a useful landmark on the anterior abdominal wall.

Structure of the abdominal wall

The layers of the anterior abdominal wall comprise of skin; superficial fascial layer which is deep to the skin but superficial to muscular layer. This superficial fascial layer has two parts the **superficial fatty layer** (Camper's fascia) and **deep membranous layer** (Scarpa's fascia), known as Colles‟ fascia in the perineum.

The muscular layer of the anterior abdominal wall comprises of four separate flat sheets of muscles on the flanks. The flat muscles of the anterolateral wall of the abdomen are the external oblique, internal oblique and transverse abdominis, referred to anatomically as obliquus externus abdominis, obliquus internus abdominis and transversus abdominis respectively. These muscles have a fleshy belly laterally and thin flat sheet of tendon (aponeusosis) medially as the all approach the fourth straight muscle (rectus abdominis) in the median plane. They also have aponeurosis in the inferior most fibres.

Rectus abdominis is a straight striped muscles in the median plane of the anterior abdominal wall. The muscle is strengthened on its anterior and posterior sides along a greater part of its length by the aponeuroses of the three anterolateral muscles. This is the rectus sheath which is made up of anterior and posterior layers to wrap round the muscle completely in some areas. The rectus sheath around the left rectus muscle interdigitates with its

counterpart from the right in the midline to form the linea alba. A landmark that runs along the midline of the anterior abdominal wall. The rectus abdominis is also associated with tendinous intersections which are bands of transversely running connective tissues that intercept the length of the muscle at three separate locations on the anterior abdominal wall. The bands may occur below, at and above the level of the umbilicus, on each side, giving the torso the six-pack appearance seen in individuals with well-developed abdominal musculature.

Inguinal region

The lower portion of the anterior abdominal wall which represents the transition zone between the front of the trunk and lower limb, is referred to as the inguinal region. This region is clinically important because of the presence of the following structures: the superficial inguinal ring, the deep inguinal ring, inguinal canal, inguinal ligament and the spermatic cord/round ligament of the uterus.

Superficial inguinal ring

This is a triangular–shaped defect in the external oblique aponeurosis, lies immediately superior and medial to the pubic tubercle.

Deep inguinal ring

An oval opening in the fascia transversalis, lies above the inguinal ligament and is found midway between anterior superior iliac spine and the symphysis pubis.

Inguinal canal

This an oblique passage through the lower part of the anterior abdominal wall. It is 4cm long and stretches from the deep inguinal ring to superficial

inguinal ring. It is parallel to and just above the inguinal ligament. The inguinal canal has four walls namely:

Anterior wall: made up of the external oblique aponeurosis, reinforce laterally by the origin of internal oblique muscle.

Posterior wall: made up of conjoint tendon medially and transversalis fascia laterally.

Roof/superior wall: made up of the arching fibres of internal oblique and transversus abdominis muscles.

Floor/inferior wall: Made up of inguinal ligament and lacunar ligament.

Inguinal ligament

It is the folding–over of the inferior margin of the aponeurosis of the external oblique muscle running between the pubic tubercle and anterior superior iliac spine (ASIS).

The inguinal region is notorious for the protrusion of viscus to the exterior, a condition termed clinically as hernia. Two main types are clinically diagnosed from this part of the anterior abdominal wall: direct and indirect inguinal hernias.

Indirect inguinal hernia - characteristics

Hernia sac is the remains of the processus vaginalis. Hernia sac enters inguinal canal through deep inguinal ring and lateral to inferior epigastric vessels. Neck of the hernia sac is narrow.

The hernia sac may leave inguinal canal through superficial inguinal ring above and medial to pubic tubercle. Hernia sac may extend down into scrotum labium majus (complete inguinal hernia).

Direct inguinal hernia - characteristics

More common in children and young adults than adults; more common in elderly men with weak anterior abdominal muscle; very rare in women; hernia sac bulges forward through the posterior wall of inguinal canal, medial to the inferior epigastric vessels and the neck of the hernia sac is wide.

Digestive system – abdominal cavity, peritoneal cavity and related structures.

Peritoneum

Many structures in the abdominal cavity are covered with a serous membrane called the peritoneum. This sereous membrane forms lining of abdominal cavity or coelom. It covers most of the intra-abdominal (coelomic) organs. Two parts are often described– parietal and visceral peritoneum.

Peritoneum – description and function

Composed of a layer of mesothelium which is supported by a thin layer of connective tissue. It serves as conduit for blood vessels, lymphatics and nerves.

Peritoneum and the abdominal cavity

The abdominal cavity is a space bounded by the vertebrae, abdominal muscles, diaphragm and pelvic floor. The intraperitoneal space is located within the abdominal cavity, but wrapped in peritoneum. The disposition/orientation of stomach divides the peritoneal cavity into: greater sac and lesser sac. The two sacs communicate with each other through **the epiploic foramen.**

Peritoneum – structure and types

The peritoneum, although a continuous sheet, is made up of 2 laminae (sheets); a parietal peritoneum which is attached to the abdominal wall and pelvic floor and visceral peritoneum; wrapped around visceral organs. Visceral peritoneum is located inside the abdominal and pelvic cavities. The visceral peritoneum is for protection *although* it is thinner than parietal peritoneum.

Peritoneum and testis

Peritoneum covering testis is known as **tunica vaginalis**; tunica vaginalis is derived from the **processus vaginalis,** which is an outpouching of peritoneum in the inguinal canal.

Peritoneum - subdivisions

In the abdominal cavity, peritoneal folds come in the form of: omentum, mesentery and ligaments.

Omentum

This is a long fold of peritoneum, loaded with fat which is attached to the stomach Greater omentum attaches to the greater curvature of the stomach and hangs down as far as to the pelvis. Lesser omentum is between the lesser curvature of stomach to inferior surface of liver.

Mesentery

Mesentery is a double layer of peritoneum which attaches the small intestine unto the posterior abdominal wall. It is fan-shaped with its shorter edge attached to the posterior abdominal wall

The term mesocolon, mesorectum, meso-appendix, refers to a similar fold of peritoneum that attaches to parts of the colon, rectum and appendix.

Ligaments and folds of peritoneum

A fold of peritoneum between two organs or structures in the abdominal cavity are known as ligaments. The falciform ligament attaches the liver to anterior abdominal wall; round ligament attaches liver to umbilicus and coronary ligament attaches the liver to thoracic diaphragm. All these developed from ventral mesentery.

Classification of abdominal organs in relation to peritoneum.

Abdominal organs are classified as intraperitoneal, retroperitoneal and infra-peritoneal depending on whether covered with visceral peritoneum **or** attached by mesentery.

Intraperitoneal structures

Examples of intraperitoneal structures include: stomach, first part of duodenum, jejunum, ileum, caecum, appendix, transverse colon, sigmoid colon, upper one-third of rectum, liver, spleen, pancreas (tail) and ovaries.

Retroperitoneal structures

These include: second to fourth parts of duodenum, ascending colon, descending colon, rectum (mid one-third), pancreas (minus tail), kidneys, adrenal glands, proximal ureter, renal vessels, inferior vena cava and aorta.

Infraperitoneal/subperitoneal

Rectum (lower one-third); urinary bladder, distal ureters, gonadal vessels, uterus and fallopian tubes.

Peritoneal structures – characteristics

Intraperitoneal are generally mobile while retroperitoneal are relatively fixed.

A typical example of primary retroperitoneal organ is kidney a typical example of secondary retroperitoneal is large part of duodenum. Secondary retroperitoneal structures develop intraperitoneally but lost mesentery and becomes retroperitoneal.

Peritoneum - clinical application/applied anatomy

Peritoneal dialysis

Glucose solution is sent through a tube into peritoneal cavity. The fluid is left for a prescribed amount of time to absorb waste products and then removed through the tube. Due to high number of arteries and veins in peritoneal cavity then through the mechanism of diffusion, waste products are removed from the blood.

Peritoneum – when things go wrong!

Peritonitis

Inflammation of the peritoneum, more commonly associated with infection from punctured organs

Ascites: Accumulation of fluid in the peritoneal cavity; a pathological accumulation of fluid in the peritoneal cavity. It is often due to: congestive heart failure and/or obstruction of inferior vena cava. Primary peritoneal cancer: This is cancer of the cells lining the peritoneum.

Digestive system - stomach

The stomach is the first abdominal subdivision of the alimentary canal. It is a dilated segment of the digestive tract.

Functions

Adds acidic fluid/juice to the ingested food; transforms ingested food by its muscular activity into a viscous mass called chyme; secretion of an enzyme,

pepsin that facilitates digestion of protein materials and serves as a temporary storage site for ingested food.

The size, position and configuration of stomach are determined by its physiologic state, impingement of other abdominal viscera and general body build. Classically, it is described as pear-shaped or J-shaped with its upper ends related to the left dome of the diaphragm. The upper and lower ends of the stomach are relatively fixed. Its mid portion moves as the position of other viscera or its contents may require. By gross inspection, the stomach could be divided into four regions namely; cardiac portion, (ii) fundus, (iii) body and (iv) pylorus.

Histologically, there are only three regions because, the fundus and body are identical.

Histology of the stomach

Stomach mucosa is basically mucus-secreting and is lined with simple columnar epithelium.

Lamina propria of mucosa is composed of loose connective tissue that lies in spaces between glands. Glands of stomach are simple tubular or branched tubular types. The Cardiac glands are compound tubular and secrete mucus. Fundus and body glands are simple branched tubular. Regarding the fundus and body part of the stomach, four types of secretory cells can be identified: chief/peptic cells are lipase and amylase secreting cells; parietal/oxyntic cells (HCl-producing cells) – these are fewer and scattered; mucous neck cells, secrete mucus and argentaffin cells or endocrine cells.

Pylorus glands are simple branched tubular and are highly coiled. The pyloric glands secrete mucus and a hormone called gastrin.

Stomach – general description

The stomach has anterior and posterior surfaces as well as greater and lesser curvatures.

The muscosa and submucosa of the non-distended stomach are thrown into longitudinal folds known as rugae.

Stomach – relations

The anterior surface of the stomach is closely related to the diaphragm, left lobe of liver, and the left rectus abdominis muscle.

Posterior surface is related to many structures which collectively make up the "bed of the stomach"

Posterior relations of stomach

These structures include; the body of pancreas, splenic artery, medial border of left kidney, left suprarenal gland, spleen, diaphragm, transverse colon, and transverse mesocolon.

Stomach – blood supply

Blood supply to the stomach as well as all foregut structures is from the celiac artery/trunk which is the first anterior branch of the abdominal aorta.

Anatomy of the stomach and prevention of autodigestion

Autodigestion of the stomach is achieved by increased mucous secretion; secretion of zymogenic enzymes and increased mitosis of the epithelium. Stomach uses all these three mechanisms to prevent autodigestion. The **small intestine** increases mucous secretion and bicarbonate secretions and releases zymogenic enzymes from the intestinal glands.

Upper gastrointestinal tract (UGIT)

Upper gastrointestinal tract (UGIT) is between oral cavity and duodenum. The suspensory muscle of duodenum separates UGIT from LGIT. This muscle also delineates the embryonic borders between foregut and midgut. Suspensory muscle of duodenum is also used clinically to describe GIT bleeding as either UGIT bleeding or LGIT bleeding. It attaches to the superior border of the last part of duodenum (ascending) and on to the diaphragm. It is used to distinguish between duodenum and jejunum.

Anatomy of the digestive tract and prevention of infections

Prevention of infection is achieved by embedding unencapsulated lymph nodules in the submucosa i.e by the possession of mucosa associated lymphoid tissues (MALT).

The lymph nodules are present in the small intestines and gradually increase in numbers down the gastrointestinal (GI) tract. The stomach also prevents infection by maintaining a highly acidic environment that is not hospitable to pathogens.

Accessory glands of GIT

Liver

This is the organ where nutrients absorbed in the digestive tract are **processed for use by other parts** of the body. It is the **interface** between the **digestive** system and the **blood vascular system**. Liver is the largest gland in the body. The main structural component of the liver is the liver cell or hepatocyte (functional unit). Gross-wise the liver has four surfaces: superior (convex) surface; anterior surfaces; posterior surfaces and inferior (visceral) surface. The porta hepatis, is a relatively deep and wide area of 5cm long, through which the portal vein, hepatic bile ducts, nerves and lymphatics pass

into the substance of the liver. The porta hepatis separates the quadrate lobe inferiorly from the caudate lobe superiorly.

Liver and its blood supply

The liver receives blood from two sources: **the hepatic portal vein** – carries **oxygen poor** but ***nutrient rich blood*** from the abdominal viscera and h**epatic artery,** and supplies **oxygen–rich** blood. The hepatic portal vein originates behind/posterior to the head of the pancreas by the union of the splenic and superior mesenteric veins.

The hepatic veins draining the liver begin as central veins of the liver lobules. These small veins drain into sublobular veins as tributaries of the **hepatic veins**, which empty into the inferior vena cava.

Gall bladder

Gall bladder is a small piriform sac that serves as a reservoir for bile. It can store 30 – 50ml (60ml – 150ml) of bile. Gall bladder releases bile as a result of high levels of cholecystokinin (CCK) secreted by duodenal cells due to the arrival of fat-rich chyme.

It is attached to or lies in a small fossa on the visceral surface of the liver. It has three identifiable parts, the fundus, body and neck. Surface anatomy of fundus is: point of intersection of **L1 (*transpyloric/subcostal plane*) *and right midclavicular line.***

Gall bladder communicates with the hepatic duct through the short 2-3cm long cystic duct.

Cystic duct and hepatic duct unite to form the common bile duct. The common bile duct unites with main pancreatic duct before opening into the second part of the duodenum. The mucosa of the gall bladder is characterised by the presence of large, numerous folds.

Pancreas

It is an elongated endocrine and exocrine gland that lies obliquely on the upper part of the posterior abdominal wall. It extends from the concavity of the duodenum to the spleen. It is soft and pliable, contains a minimum of connective tissue. Pancreas is further divided into a head with uncinate process, body and tail. Its endocrine portion is composed of the islets of Langerhans located at the tail portion. The exocrine portion is a compound acinar gland (similar in structure to the parotid gland).

Spleen

Found in the left hypochondriac region of abdomen, posterior to stomach and inferior to left dome of diaphragm but not associated with digestion. It is the largest lymphoid organ in the circulatory system in man (*refer to notes on the gross anatomy of the spleen in the section under the lymphatic system*).

Histology of the digestive tract

1. Mucosa: This is the innermost layer; in contact with the chyme. It is made up of:

epithelium (innermost) – responsible for digestive, absorptive and secretory processes; ***lamina propria*** - a layer of connective tissue (usually cellular); ***muscularis mucosa*** – this is a thin layer of smooth muscle that aids in the passing of materials and enhance the interaction between epithelial layer and the contents of the lumen by agitation and peristalsis.

2) Submucosa: Consists of a dense irregular layer of connective tissue with large blood vessels, lymphatics and nerves. It contains submucosal plexus (enteric nervous plexus).

3) **Muscularis externa (muscular layer)**

Consists of an inner circular and outer longitudinal layer. Inner circular prevents food from travelling back; the outer longitudinal shortens the tract.

(***A 3rd oblique layer is present in between the two layers in the stomach***). Found between the circular and longitudinal layers is the myenteric plexus (controls peristalsis).

4) **Adventitia and serosa**. This is the outermost layer of GIT. It consists of several layers of connective tissue. The intra peritoneal part of the GIT is covered with serosa while the retro peritoneal part is covered with adventitia.

Timing of GIT activities

It takes less than an hour after a meal for 50% of stomach contents to empty into duodenum.

Total emptying takes about 2 hours. Subsequent emptying of duodenum and small intestines takes between one and two hours. Transit of chyme through the colon takes twelve to fifty hours.

GIT and immune system

The GIT forms an important part of the immune system. The GIT prevents pathogens from entering blood and lymphatic circulations. Intestinal mucosal barrier is composed of physical, biochemical and immune elements elaborated by intestinal mucosa. Micro-organisms are kept at bay by an extensive GALT (gut-associated lymphoid tissue).

Clinical correlations (GIT – when things go wrong!

Infections, inflammations (eg appendicitis, colitis, etc); cancers. Developmental disorders include: diverticulitis; intussuception;

Hirschsprung‟s disease and polyps.

Symptoms of GIT conditions:

Vomiting; diarrhea; constipation; and blood in stool are some of the symptoms associated with GIT disorders. There are two **types of blood-in-stool; maroon-coloured blood** (fresh blood in stool) = **hematochezia** (commonly associated with **LGIT** condition) and **tarry-coloured blood** or **melena** (commonly associated with **UGIT** condition).

Common investigations of GIT conditions

Radio opaque dyes may be swallowed to produce a barium swallow.

Endoscopy – eg colonoscopy, sigmoidoscopy etc; Plain abdominal X-ray.

Some uncommon abdominal/GIT conditions

Ascites = pathological accumulation of peritoneal fluid (also associated with heart failure); Liver cirrhosis (also associated with heart failure; inferior vena cava obstruction); Caput medusa = dilated superficial veins of the anterior abdominal wall; Jaundice/bilirubin; Splenomegaly and Ulcers.

Digestive system – intestines

Small intestine extends from pyloric sphincter of stomach to anus. It consists of two segments; small intestines and large intestines. The small intestines comprise duodenum, jejunum and ileum. Small intestine begins from distal thickening of the stomach (pylorus) as the duodenum.

The small intestine part of the lower gastrointestinal tract is roughly 6 – 7m long. The main function is to absorb products of digestion into blood stream; serving as a site of greatest amount of digestion and absorption. Cells of mucosa of the small intestine are absorptive, granular, and endocrine in nature.

Small intestine secretions

The mucosa of the small intestine secretes: mucus which protects against digestive enzymes and stomach acids and also digestive enzymes such as disaccharidases: break down disaccharides to monosaccharides; peptidases: hydrolyze peptide bonds and nucleases which break down nucleic acids.

Small intestine functions

The mucosa of the small intestine absorbs: 80% ingested water; electrolytes; vitamins; minerals; carbonates; proteins; lipids; monoglycerides; fatty acids and others. The mucosa also secretes digestive enzymes: peptidase; sucrases; maltase; lactase; saccharidases; lipase and nucleases.

Small intestines – duodenum

This part of the small intestine is about 20 -25cm long. It is C-shaped and sub-divided into four parts. The pancreatic secretions and bile open into its second part. The endocrine cells in first part releases a hormone, cholescystokinin (CCK) with the arrival of chyme rich in proteins and fat. This hormone (CCK) targets the gall bladder and pancreas to release of bile and pancreatic juice respectively into the second part of duodenum. Cholecystokinin is also thought to act as a hunger suppressor. Duodenum generally receives chyme from the stomach plus pancreatic juice containing digestive enzymes and bile from the gall bladder. Its digestive enzymes break down proteins, the bile emulsifies fat into micelles. The mucosa of duodenum contains lots of Brunner's glands which produce mucus-rich alkaline secretion containing bicarbonates. All secretions and bicarbonates also from pancreas neutralize stomach acids in the chyme.

Small intestines – jejunum

Mid-section of small intestines and connects duodenum to ileum. It is about 2.5m long, contains circular folds/plicae circulares and villi to increase surface area. Plica circulares is more conspicuous in the jejunum than in any other portion. Product of digestion (sugars, amino acids, fatty acids) are absorbed into the bloodstream via jejunum.

Small intestine – ileum

Ileum is the last section of the small intestine; about 3m long. It contains villi similar to jejunum

This segment of the small intestine absorbs mainly vitamin B12, and bile acids and any remaining nutrients.

Anatomy of the small intestine and prevention of auto-digestion

The **small intestine** increases mucous secretion and bicarbonate secretions and releases zymogenic enzymes from the intestinal glands.

Digestive system – large intestine

Extends from ileocecal valve to anus. The different regions of the large intestine are:

Cecum – Appendix; Colon (ascending; transverse; descending; sigmoid); Rectum and Anal canal.

Large intestine – histology

No villi; no permanent circular folds; has taeniae coli (smooth muscle); haustra (sacculation); Has epiploic appendages. Otherwise, large intestine is just like the rest of GI tract.

Large intestine – composition

Cecum- This is a blind sac, with the vermiform appendix attached to it.
Colon – Comprising ascending, transverse, descending and sigmoid.

Rectum – A straight muscular tube and

Anal canal which houses an internal anal sphincter (smooth muscle), external anal sphincter (skeletal muscle) and plexus of veins.

Secretions of large intestine

Mucus in the large intestine provides protection and the following actions:

- Parasympathetic stimulation increases rate of goblet cell secretion.
- Pumps.
- Exchange of bicarbonate ions for chloride ions.
- Exchange of sodium ions for hydrogen ions.
- Bacterial actions produce gases called flatus.

Large intestines – functions

Involve in mechanical digestion; chemical digestion – bacterial digestion ferments carbohydrates and protein/amino acid breakdown. This is the part of the GIT that absorbs more water; Vitamins B, K and concentrate/eliminate wastes.

Caecum

Large blind pouch (5 -8cm) long at beginning of large intestine. Ileum opens into it medially through a longitudinal slit – ileocaecal orifice, guarded by a valve. Below the orifice, the vermiform appendix opens into the caecum, which usually lies in the right iliac fossa, immediately above the left half of the inguinal ligament.

Vermiform appendix

A blind tube, about 5mm thick and 10cm long. It is suspended by a mesentery – the mesoappendix. Appendix has no fix position, but commonly moves with the caecum and usually lateral or anterior to it. Medial and retrocecal positions are also not uncommon.

Rectum

It is continuous with sigmoid colon superiorly & anal canal inferiorly rectosigmoid junction which is located anterior to the third sacral (S3) vertebra and terminates at anorectal junction by passing through the **pelvic diaphragm** anterior to tip of coccyx. The rectum lies anterior to lower sacrum and coccyx. It rests on anococcygeal ligament.

Rectum - relations

Anteriorly: bladder, seminal vesicle and prostate gland (males) and vagina (females). Rectovesical or rectovaginal septum separates it from anterior structures.

Rectum has no mesentery, its superior two-thirds is retroperitoneal, distal one-third is sub-peritoneal. Rectum lacks taeniae coli, haustra and epiploic appendices.

Rectum – structure and function

Internal wall has three transverse folds: one on the right and two on the left. It creates lateral flexures which are visible externally. The ampulla is the most distal portion of it. Rectum stores faecal material prior to defaecation. It is important in faecal incontinence. The ampulla narrows to join anal canal.

Rectum – blood supply

Rectum has dual blood supply: superior rectal artery; right and left middle rectal arteries.

Venous drainage: Rectal veins drain a submucosal rectal venous plexus (**RVP**). The RVP has two components – external and internal. The external communicates with visceral plexuses in the pelvis while the internal communicates with rectal arteries to form the haemorrhoidal plexus at the anorectal junction.

Rectum – venous drainage

Venous blood from rectum drains into the portal and caval (systemic) venous system. The superior rectal vein drains upper rectum (portal vein); middle and inferior rectal veins drain the lower rectum and anal canal. Communication between the superior, middle and inferior rectal veins form the portocaval anastomosis. This enlarges in portal hypertension.

Rectum – lymph drainage

Upper rectum drains into inferior mesenteric nodes eventually to lumbar lymph nodes. Lower rectum drains into the sacral lymph nodes or directly to internal iliac nodes

Rectum – nerve supply

Sympathetic nerves carried by lumbar splanchnic verves to the hypogastric and inferior mesenteric plexuses. Parasympathetic also carried by the splanchnic nerves

Anal canal – description and topography

Terminal part of digestive system. This is located between rectum and anus and below level of pelvic diaphragm. The aperture at its terminal portion is

known as the anus which situated in anal triangle of **perineum.** The anal canal is found between the left and right **ischioanal fossa – *(inferior rectal nerve runs here to external anal sphincter)***.

Anal canal – function

It regulates release of faecal matter to the exterior by means of two muscular sphincters – external and internal.

Anal canal - structure

Anal canal is about 2.5cm – 4cm long. It starts from anorectal junction to anus. It is directed downwards and backwards and surrounded by inner involuntary sphincter and outer voluntary sphincter. The inner anal sphincter is from the inner circular layer of the gut muscles (smooth muscle) and forms the upper two-thirds of the canal. The external anal sphincter is from the anoccygeal raphe (skeletal muscle). The sphincters keep the lumen closed. Internally, the canal is differentiated from rectum by a transition of endodermal tissue to ectodermal tissue. Its inner aspect is divided into upper and lower halves by the pectinate line (aka dentate line). The epithelium of the upper half is simple columnar, while the lower half is stratified squamous epithelium. Anal glands are present at the lower half, which secrete lymphoid discharges.

Anal canal – blood supply, venous and lymphatic drainage

Blood supply, venous drainage and innervation is similar (same as) for rectum.

Lymph drainage

Lymph from the lower half drains to the superficial inguinal lymph node while those from the upper half into the internal iliac lymph nodes.

Anal canal – clinical considerations

Excessive contraction of anal sphincters leads to painful defeacation. Tightened anal sphincter could be relaxed via sphincterectomy (often targeting the external anal sphincter. The inferior rectal nerve is in danger of damage in the ischioanal fossa during a sphincterectomy maneuver. Damage to inferior rectal nerve and/or external anal sphincter may lead to faecal incontinence.

External haemorrhoids are thrombosis of the external venous plexus which are associated with pregnancy and or chronic constipation. These lie below dentate line; covered by skin and are more painful. **Internal haemorrhoids** however, are considered to originate from dilated veins of internal rectal plexus, lie above the dentate line and are associated with portal hypertension. These are painless and their bleeding is bright red due to anastomosis between vein and the rectal arteries.

Megacolon (Hirschsprung's disease): This is a congenital disease, usually associated with infants. It results from failure of ganglia to develop

(Meissner and Auchbach's plexuses). It is characterised with distended bowel due to lack of muscle tone.

UNIT TEN

SKELETAL SYSTEM

Introduction

Clinicians define the skeletal system as comprises of bones, joints and cartilages. We will focus mainly on the clinical anatomy of these three, while occasionally expanding on the relevant functional histology of each of these. For a clear understanding of the contents on the skeletal system and, as is the case with the study of human anatomy, the reader is advised to consult any atlas on both the gross and microscopic anatomy of the human.

Functions

The skeletal system is involved in the following functions for the human body:

- Protection for vital organs;
- Support for the body;
- Mechanical basis for movement
- Storage for vital salts (for example calcium salts) and
- Serving as a continuous source of supply of new blood cells (hematopoeisis).

In the field of forensic science, anthropology and pathology (medico-legal issues), skeletal parts may be used to determine age and sex of individuals. Bone constitutes more than 70% of the skeletal system. Bone has two different meanings. Bone may be an organ, such as the humerus or upper arm bone, with a distinct shape and function. While bone may also be a tissue or material with a particular capacity for growth. As a tissue, it also has a distinctive chemical composition, and unique properties as a substance, all of which are reflected in its radio-opacity in the field of radiology. Histologically, bone can be regarded as a connective tissue, consists of matrix and cells. The matrix is formed by osteoid and hydroxyapatite

crystals. The cell types that make up bone are osteocytes, osteoblasts, osteoclasts and osteoprogenitor cells.

Bone formation and growth are associated with two main processes: ossification and calcification. Ossification is defined as the formation of new bones by the replacement of pre-existing tissues while calcification is regarded as the deposition of hydroxyapatite (inorganic bone salts) into osteoid to form new bone tissue. Hydroxyapatite are the calcium phosphate crystals that harden the osteoid. Removal of the hydroxyapatite from bone is known as decalcification. Osteoid is a protein mixture secreted by osteoblasts that form the organic matrix of bone. Ossification occurs when osteoprogenitor cells and blood vessels encounter appropriate conditions. Ossification is mainly by the activities of osteoblasts and osteoclasts. These generally are in response to hormonal secretion from the thyroid and parathyroid glands. Parathormone (PTH) secretion stimulates osteoclasts and raises blood calcium levels. Secretion of calcitonin from the thyroid gland lowers blood calcium levels by stimulating osteocytes to deposit calcium in the bone matrix. Bone resorption and ossification repeat continuously throughout lifetime. Primary centres of ossification produce the shaft of long bones. A disease of older people in which deposition of bone fails to keep up with bone reabsorption is known as osteoporosis.

The matrix of bone is characterized with the presence of narrow tubules called canaliculi that connect adjacent lamellae of bone tissue into which processes of osteocytes appear to exchange nutrients and waste materials. There are also series of microscopic tubules found at the outside (cortex) of long bones known as the Haversian (central) canals. They allow blood vessels and nerves to pass through them to supply the osteocytes. The Haversian canal occupies the centre of each osteon – the unit of a long bone.

An osteon comprises of a barrel-like arrangement of bone calls (osteocytes) with the Haversian canal occupying the centre of these barrels (concentric arrangement of osteocytes and their processes in spaces – lacunae).

Volkmann's canal appears to run horizontally from the periosteum to link with the Haversian canals. The Volkmann's canal thus serves as conduit for blood vessels and nerves to reach the osteons (Haversian canals).

In a human skeleton, normally there are 206 individual bones. Most of these are paired as in left and right humerus, while others occur as units. In terms of regional anatomy, the entire skeletal system can be grouped under two: axial and appendicular skeleton.

Bony composition of the skeletal system

The axial skeleton refers to all the skeletal parts found in the trunk (torso) and skull regions of the body and generally serve to protect vital organs in the body.

The major bones of the skull add up to 22. These are individual flat bones united at immobile joints called *sutures*. The mandible (lower jaw) is the only skull bone united by a mobile joint, the temporomandibular joint.

Bones of the skull can be divided into:

- Those of the cranium (covering or protecting the brain) and those of the face.
- The cranium consists of the following bones, two of which are paired;
- Frontal = 1; Parietal = 2; Occipital = 1; Temporal = 2; Sphenoid = 1; Ethmoid = 1.
- The facial bones consist of the following; two of which are single;
- Zygomatic = 2, Maxillae = 2, Nasal = 2, Lacrimal = 2, Vomer = 1, Palatine = 2, Inferior conchae = 2, Mandible = 1.

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Located in the middle ear of the skull are 6 small ear bones (3 pairs) called ossicles. Also attached to the front of the neck, almost at the junction between the skull and neck is the single, U-shaped hyoid bone.

Anatomy of the skull and scalp.

Skull is defined as the bones covering the head while scalp is the tissues covering the skull. The word *scalp* is often regarded loosely by anatomists as an *acronym,* with each word representing one layer of the tissues forming the scalp from *without-inwards.*

- (**s**kin, **c**onnective tissue, **a**poneurosis, **l**oose connective tissue, **p**eriosteum).

Skull and calvarium

Calvarium is the cap of the skull. This is made up of four bones: frontal, occipital, and the paired parietal bones. Bones of the calvarium is composed of 3 layers:

- - a dense outer table,
- - thin inner table and a
- - middle spongy layer known as *diploe.*

Anatomy of the lateral surface of the skull.

On the lateral surface of the skull is an "H"-shaped, thin point of articulation of four bones of the skull, called the **pterion**. The bones constituting the pterion are:

Frontal, parietal, temporal and the greater wing of sphenoid. Clinically, the location of the pterion defines the pathway of anterior branches of the middle meningeal vessels on the internal aspect of the skull. Any traumatic impact to the pterion may rapture these vessels, resulting in an internal bleeding onto

the outer covering of the brain, in a clinical/pathological condition known as extradural haematoma/haemorrhage.

Skull bones and bony cavities

The base of the cranium joins the cranial bones to the facial bones. Located in the skull are four cavities namely:

- orbital, nasal, oral and paranasal sinuses.

There are also, three fossae found in the skull, in which are found the three main divisions of the brain (fore-; mid- and hind-). These fossae are formed by the cranial bones and are described as:

- **anterior cranial fossa**; **middle cranial fossa and posterior cranial fossa.**

The **anterior cranial fossa** is formed by: **frontal**, **ethmoid** and **sphenoid bones**; **middle cranial fossa** is formed by: **sphenoid** and **temporal bones** while the **posterior cranial fossa** is formed by the **temporal** and **occipital bones**.

Skull bones and the bony orbit

The anterior part of the skull is occupied by the paired orbits that lie on either side of the superior part of the nasal cavity. These orbits are superior to maxillary sinuses and inferior to the anterior cranial fossae.

Each orbit is shaped like a four-sided pyramid with seven separate bones forming its walls. The bony orbit could also be viewed as being conical, with the base of this conical figure being quadrangular (four-sided), directed anteriorly with its apex pointing posteriorly – that is towards the cranial cavity. The orbit has a roof (superior), lateral wall, medial wall and floor. The roof is formed by frontal bone and the lesser wing of sphenoid; lateral wall by the zygomatic and greater wing of sphenoid bones. The orbital plate of the **ethmoid bone** *together with* lacrimal, nasal and sphenoid bones make up the

very thin medial wall of the orbit. The floor of the orbit is thin formed by the maxillary bones.

Found between the roof and lateral wall is the superior orbital fissure (SOF) and the inferior orbital fissure (IOF) is located between the lateral wall and the floor of the orbit. The optic canal is situated posteromedial between the lesser wing of sphenoid and body of sphenoid bone.

The numerous openings found in the orbit allow nerves and vessels to pass between the orbit and the: middle cranial fossa, nasal cavity, pterygopalatine fossa (around the pterion region of the skull) and face. These openings facilitate the spread of infections from the lateral sides of the skull, scalp and face to middle cranial fossae. (These possible routes/channels are discussed in details under the cardiovascular section).

Skull bones and the nasal cavity

This mnemonic may be useful in remembering the thirteen different skull bones forming the nasal cavity:

- "**E**ating **L**egumes **M**ay **P**roduce **V**ery **N**asty **S**mells" (*all paired except "v"- the vomer*).

These bones are ethmoid, lacrimal, maxillae, palatine, vomer (nasal septum), nasal and sphenoid bones respectively.

The nasal cavity is a clinically important opening of the skull which communicates with the outside through the nares or nostril (external/anterior nasal aperture) and with the pharynx through the choana or posterior/internal nasal aperture. Along the lateral wall of the nasal cavity is found three turbinates (bulging of bones) called conchae. Below each of these conchae are winding recesses (hidden spaces known as nasal meatuses. The inferior nasal meatus, communicates with the nasolacrimal duct which opens into it.

The later drains the eyeball with lacrimal fluid (tears). A sphenoethmoidal recess is also located posterosuperior to the superior nasal meatus of the

lateral wall of the nasal cavity. Through this channel (sphenoethmoidal recess), the nasal cavity communicates with the sphenoidal air sinuses. These channels/recesses form routes of spread of infection from the nasal cavity.

Anatomy of the sphenoid bone

The most complicated and difficult to visualize bone of the body. Owing to its shape, the sphenoid bone is also known as the "wasp bone". It makes up most of the middle part of the base of the skull and contributes to the floor of the middle cranial fossa. No matter from which perspective the skull is viewed, it is difficult to see completely the sphenoid bone as it is deeply hidden inside the cranial base and gives stability to the inner skull.

The sphenoid bone has four different main parts (body, lesser wing, greater wing; pterygoid process – *Isaiah. 6: 2; angel with 6 wings*). It is definitely an important bone of the skull as it is involved in the architecture of the nasal cavity, the hypophyseal fossa, the optic canal, the lateral wall of the orbit, the opening of the foramen rotundum and foramen ovale and many others.

Paranasal air sinuses

The frontal, maxillae, sphenoid and ethmoid bones of the skull have hollow spaces in them called *air sinuses, sometimes called paranasal air sinuses*. These air sinuses are lined with mucous membrane and are easily infected with germs.

Functions of the nasal air sinuses

- Reduce weight of skull bone grossly, by making it relatively lighter,
- Act as resonance structures and therefore
- Assist in the production of melodious speech. Compare the sound of one speech with severe nasal congestions with normal nasal cavity.
- Help in humidifying and heating up inspired air.

Neonatal skull and cranial sutures

At birth large fibrous areas of skull remain and allow for continued growth of brain after birth, such that not all the flat cranial bones are fully united in forming the sutures as at the time of birth. Those areas of the cranial bones that are united with large areas of fibrous connective tissue is called *fontanelle.* The largest of these is the anterior fontanelle found at the areas of union between frontal and paired parietal bones. It normally closes by 18 months (18 -24) after birth. There also exist a much smaller posterior fontanelle between the two parietal bones and the occipital bones, which closes much earlier, usually before the first birthday.

Axial skeleton: vertebral column

The vertebral column, also called the spinal column is the central bony pillar posteriorly in bipedal creatures as well as all vertebrates. It is made up of spiral chain of bones in the various regions of the trunk posteriorly and forms a major component of the axial skeleton. It is commonly referred to as the backbone in everyday usage.

The vertebral column consists 33/26 separate bones referred to as the vertebrae. The respective bones in each region of the trunk are as follows:

- Cervical region: seven vertebrae,
- Thoracic region: twelve vertebrae,
- Lumbar region: five vertebrae,
- Sacral region: five separate vertebrae (which are fused to form **one** big sacrum in adults) and
- Coccygeal region: four separate vertebrae *in utero* (which are fused to form **one** coccyx).

Successive bones in the vertebral column (vertebrae) are separated from each other by a piece of fibrocartilage called the intervertebral disc.

Cervical vertebrae are distinguished by the presence of bifid spinous process and the foramen transversarium in their transverse process for the transmission of vertebral vessels. C1 and C7, however generally lack some of these distinctive features.

Thoracic vertebrae are identified easily with the presence of facets on their body and transverse process for articulation with ribs. They also are marked with the possession of long backwardly pointing spines.

The lumbar vertebrae are characterized with the presence of thick heavy bodies and short quadrangular shaped spinous processes.

With regards to the three main parts of the vertebra, the centrum/body is located anteriorly, with the pedicle and lamina completing the vertebral arch posteriorly. The vertebral foramen is central, surrounded by the body and arch.

Some vertebrae have unique or special names, for instance the C1 vertebra (first cervical vertebra) is also called **atlas.** The second cervical vertebra (C2) is referred to as **axis** while the seventh or last cervical vertebra is known as **vertebra prominens.**

Curvatures of the vertebral column

When viewed from the side, (lateral view) the adult vertebral column has four normal curvatures.

The cervical and lumbar regions have curvatures that are convex anteriorly (bulging forward) while the thoracic and sacral curvatures are concave anteriorly (curving in).

Foetal vertebral column has only one curvature: concave anteriorly.

Vertebral column and curvatures – when things go wrong!

Lordosis: this is described as an exaggerated lumbar curvature.

A pronounced thoracic curvature (highly protruding posterior curvature) is known as kyphosis (hunchback).

An abnormal lateral curvature (side-to-side) is referred to as scoliosis.

The intervertebral disc is also predisposed to protrusion especially with advancing age and/or increasing load on the vertebral column in a clinical condition known as disc herniation).

Common complications associated with the vertebral column

Occasionally the last lumbar vertebra (L5 vertebra) partly or completely fused with the sacrum in a clinical/pathological condition referred to as *sacralisation* of L5.

Similarly, there could also be the fusion of the first sacral vertebra (S1) to the last lumbar vertebra in a condition known as lumbarization. This leaves a sacrum with only three pairs of sacral foramina, instead of the normal four pairs.

Also, with advancing age comes outgrowths of bony twigs along the vertebral bones (osteophytes), which stand a great deal of impeaching on spinal nerves, thereby causing pain and discomfort in the respective dermatomes.

Axial skeleton: the anterior part.

The anterior portion of the trunk consists of the twenty-four ribs and one sternum. In summary the individual pieces of bones making up the axial skeleton are:

Twenty-five anteriorly,

Twenty-six located posteriorly (vertebrae) and

The cumulative twenty-nine bone in the skull region, amount to eighty. The sternum or breast bone is made up of three parts, which during intrauterine life form separate components that fuse before birth and continue to ossify

during adult life. The component parts are the manubrium superiorly, the body in the middle with the xiphoid process that remains largely cartilage throughout life before being *ossified* to bone.

The point of articulation (junction) between manubrium and body is marked externally by a slight ridge called the sternal angle or (angle of Louis). This angle corresponds to the level of the intervertebral disc between the fourth and fifth thoracic T4/T5 vertebrae. The clinical importance of this sternal angle as a landmark for clinical practice will be discuss later under the respiratory and cardiovascular sections.

The clinician performing cardiopulmonary resuscitation (CPR) need to remember that although the xiphoid process is cartilage (hyaline), it is one of the last parts of the skeleton to ossify. It may completely ossify until at about age forty-five years and above. When CPR is forcefully and inaccurately done in the elderly, the xiphoid process is likely to be driven into the liver by an inexperienced practitioner.

Cardiopulmonary resuscitation (CPR) and the anatomy of the ribs

In performing CPR, the clinician must be conversant with the anatomy of the ribs in relation to the skeletal framework protecting the viscera in the chest cavity, referred to as the thoracic cage.

There are twelve pairs of ribs which by extension, complete the arches on the lateral and anterolateral segments of the thoracic cage by articulating with the vertebral column posteriorly and sternum anteriorly directly or indirectly through pieces cartilages (*costal*). The thoracic cage can be conceptualised as having two *central* bony pillars in its framework: vertebral column posteriorly and the sternum anteriorly.

A rib thus, is classified as true, false or floating depending on whether it articulates with the sternum directly through its own *numerical* cartilage, or joins the sternum by hiking on a costal cartilage other than that of the

corresponding rib, or as to when a rib, makes no contact with the sternum respectively.

Ribs are numbered from above downwards, such that the rib one is superior and mostly obscure from view as a greater part of its curved surface remained buried beneath the clavicle (collar bone). The last or twelfth rib is inferior, delimiting the thoracic part of the trunk from the abdominal or lumbar part. Each rib is positioned with some space between it and the other. Successive space between two ribs is known as the *intercostal space* that in the living are filled with three thin layers of skeletal muscles, actively involved in the *ventilation* process. This space stretches both anteriorly towards the sternum as the anterior intercostal space and posteriorly near the vertebral column as the posterior intercostal space.

Ribs are also classified as typical or *atypical* by way of their morphology.

Typical ribs have a *head* mostly with two facets (shallow depressions), distinctive constriction immediately distal to the head called the *neck*, a bump (raised/roughened area on the neck) known as *tubercle* and a flattened portion, the *shaft* or *body*. The region beyond the tubercle where the rib begins to curve to form the shaft is known as the angle. Angle of a rib is susceptible to fracture during anteroposterior compression of the thoracic cage, for example, in the performance of a CPR procedure.

Atypical ribs may lack one or two of these features described. For instance, the last two ribs (eleventh and twelfth) have no neck, tubercle nor angulation.

Articulation of ribs with vertebral column

The understanding of ribs and their articulation with the central bony pillars, especially with the vertebral column is useful in pulmonary physiology. Taking for example, a typical rib like the fifth rib, it forms synovial joints with two separate thoracic vertebrae, one numerically above it, thoracic vertebra four (T4) and one corresponding to it (thoracic vertebra five – T5).

The head of each rib faces posteriorly by forming unions/joints with the vertebral column. The facet on the tubercle of the fifth rib forms a synovial joint with the facet on the transverse process of the fifth thoracic vertebra.

The two facets on the head of the rib are known as superior and inferior facets respectively. The **superior articular facet on the head of the fifth rib** forms a synovial joint with the **inferior** articular facet on the body of the **fourth thoracic vertebra**. Note that a thoracic vertebral bone also has a shallow depression on its body and the transverse process to *partner* with those found on the ribs.

The **inferior articular facet on the head of the fifth rib** forms a synovial joint with the **superior** articular facet on the body of **thoracic vertebra five** (corresponding vertebra).

Generally, ribs form costovertebral, of which one is the costotransverse joints with the thoracic cage. The other joints with the skeletal parts of the thoracic cage in which ribs are involved are the sternocostal (between sternum and cartilages), costochondral (between a rib and cartilage) and interchondral (between costal cartilages).

The appendicular skeleton

The components of the skeletal parts found in the limbs collectively form the appendicular skeleton. The bones of the appendicular skeleton are basically for movement. The upper limb bones are shaped to suit prehensile and manipulative movements while the lower limb bones are built for supportive and locomotor movements.

In the upper limb is found the shoulder girdles which comprise the clavicle or collar bone (paired) and scapula or shoulder blade (also paired). The remaining upper limb bones include the humerus; radius; ulna, all of which are paired; sixteen carpal or wrist bones (eight in each limb); ten short hand bones or carpals (five in each hand) and twenty-eight finger bones or

phalanges (fourteen in hand). The four medial finger bones or phalanges are made up of three segments also termed proximal, middle and distal phalanx. The thumb or pollex has only two of these segments – proximal and distal phalanx.

Scapula

Functionally, this shallow flat bone could be regarded as suspending the upper limb on to the trunk (thoracic cage). Its actions by way of the muscles attached to it are all geared towards making the upper limb efficient in its function. The scapula is located on the upper part of the posterior chest wall.

Structure

Scapula is triangular in shape with uniformly flat anterior surface, the subscapular fossa that is directly in contact with the posterior part of the ribs. Prominent on the posterior surface of the scapula is a ridge-like process called spine of scapula which divides the posterior surface into two shallow fossae – the supraspinous and infraspinous fossae. The spine of the scapula is subcutaneous and palpable especially in the chronically ill and emaciated patients. The position of the spine on the superomedial side of the scapula, corresponds to the fourth thoracic vertebra, while laterally this spine greatly expands to form the acromial process or acromion: a bony prominence on the summit of the shoulder. Note that the spine runs somewhat obliquely, from a point on the upper one-third of the medial border towards the superolateral angle, such that the infraspinous fossa below is larger than the supraspinous fossa. This disposition of the spine of the scapula makes the acromion to be positioned more superolaterally than on the lateral side. The scapula has superior and inferior angles that corresponds to the second and seventh thoracic vertebrae respectively. Scapula has a medial border which is vertical (straight) and a lateral border that is oblique or slanted. Laterally at

the point of convergence (union) of the lateral and medial borders below the angle of the acromion is a shallow depression known as the glenoid fossa, serving as a point of articulation for the head of the humerus. Superior to the glenoid fossa is the coracoid process – a prominent bony elevation on the superolateral border of the scapula, bothering the supraclavicular notch. There exists a narrow interval between the medial border of the bodies of the upper seven thoracic vertebrae (paravertebral space) which can be a useful area in auscultating some lobes of the lungs posteriorly.

Forearm bones

The ulna is the medial of the two forearm bones. The other bone is called the radius, which is lateral. The two bones run parallel and the radius crosses obliquely anterior to the ulna only during pronation. The proximal part of the ulnar looks like a widely opened jaw, with the olecranon process the facing posteriorly (representing upper jaw), coronoid process anteriorly (lower jaw) and the wide trochlear notch (opened mouth) between the two processes. The bony prominence at the posterior surface of the elbow joint is the olecranon process which fits into the olecranon fossa on the posterior part of the distal end of the humerus, during extension or supination of the forearm. Immediately below (distal to) the coronoid process is a roughened area known as the ulnar tuberosity. The extreme distal end of this medial forearm bone, is marked by the styloid process of the ulna. The ulnar styloid process is the palpable bony prominence at the dorsum of the wrist joint in line with the little finger. The shaft/body of the ulnar bone is marked with two sharp borders; interosseous more laterally and an anterior border on the medial side. Found between these two sharp edges is a relatively shallow area referred to as the anterior surface.

The radius is more slender than the ulna and appears to have a head proximally and broad distal end with less defined styloid process on the

lateral side. The proximal part of the radius also has a rough surface that is skewed to the anteromedial side - the radial tuberosity. Beyond this point (radial tuberosity) to the distal end are found the sharp edges, called the anterior border on the lateral side and the interosseous border on the medial side. The anterior surface is located between these two borders just as described for the ulna.

The wrist or carpal bones, although relatively small and irregular, their names and positions are worth memorizing as they are frequently involved in fractures and dislocation in especially children and the elderly. They are arranged in two separate rows of four bones each, from proximal (*in contact with the distal part of radius and ulna*) to distal (*near the bases of the metacarpals/hand bones*). It is easier to start naming or identifying the bones in each row, in a lateral to medial direction. This mnemonic may be useful, although funny: (***S**ome **L**overs **T**ry **P**ositions **T**hat **T**hey **C**an"t **H**andle!).* Scaphoid (most lateral), lunate, triquetrum and pisiform (most medial). This is the proximal row.

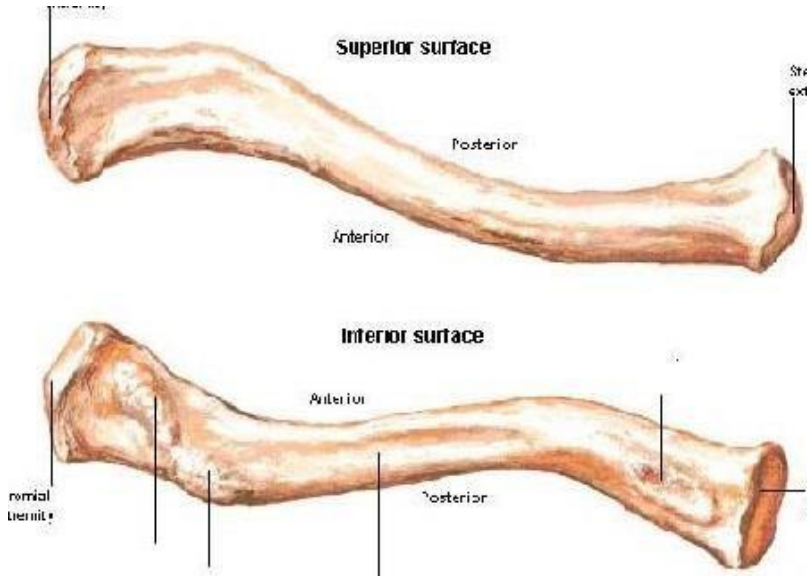
The distal row comprises of trapezium (most lateral), trapezoid (*remember letter "i" comes before letter "o" in the alphabets list*), capitate and hamate (most medial).

Anatomy of the clavicle

Due to its fragility to fractures and dislocations, the anatomy of the collar bone is worth mastering. The clavicle is a long bone in the body that lies horizontal, It serves as a strut between the shoulder blade and sternum. It is S-shaped with 2 ends: medial (proximal) which is somewhat rounded and a lateral (distal) with slightly flat ends. The curved shaft/body between the two ends, comprises of two surfaces: superior (smooth) and inferior (rough).

The medial two-third portion of the shaft is convex forward (anteriorly) while the lateral one-third is concave forward. The bone is palpable

throughout its length (very subcutaneous). The clavicle is one of the most frequently fractured bones in the body. It is usually fractured when a person falls from a height and outstretches an arm to try and break the fall. The clavicle is specially designed to break at the junctions of its curves to prevent severing major arteries and nerves in the region.



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Appendicular skeleton – lower limb bones

In the exception of a few, the lower limb has bones that look similar in numbers and configuration to those of the upper limb. Lower limb bones are, however, larger and stronger. The lower limb also has the following bones;

- Femur – 2,
- patella – 2,
- fibula – 2,
- tibia – 2,
- tarsals – 14, • metatarsals – 10 and
- phalanges – 28.

Axial skeletal and the bony pelvis

The bones forming the bony pelvis are loosely referred to as the pelvic girdle. The bony pelvis is made up of the left and right hip bones, anatomically known as the coxa or innominate bones laterally and the sacrum and coccyx bones posteriorly.

The two coxa bones unite in the median plane anteriorly to form a secondary cartilaginous joint, while each coxa bone forms a synovial joint posteriorly with the sacrum.

These synovial joints (sacroiliac joints), reinforced by the presence of strong ligaments together with the articulation of the coxa bones anteriorly and the underlying skeletal muscles in these regions are what defines a basin-like space called the bony pelvis.

Bony pelvis has a protective and supportive function, with the female bony pelvis appearing to be shaped for additional obstetric roles.

Anatomy of the pelvic bones

The coxa/innominate bone

During intrauterine life the coxa bone appear to be three separate bones; ilium, ischium and pubis which gradually fused as development progresses. The point of fusion of all three bones in the adult is marked by the presence of a cup-shaped depression known as the acetabulum.

The acetabulum is found laterally on the posteroinferior part of the hip bone. This accommodates the head of the femur.

Morphologically, the hip/coxa bone appear to be shaped somewhat like an invented letter “Y”;

With the vertical stroke of this invented letter “Y” facing superiorly (representing the ilium) and the two branched strokes each facing inferiorly in the anterior (the pubis) and posterior (the ischium) directions.

Each of these three separate parts of the hip bone has one or two landmarks of clinical significance.

Notable bony landmarks associated with the Ilium are **iliac crest** and **anterior superior iliac spine (ASIS).**

The iliac crest is a ridge that forms the most superior limit of the hip bone, stretching from anterior to superior and separates the lower limb from the trunk.

In the akimbo position with the hands resting on the trunk, the space between the outstretched index and pollex fingers are thus touching/palpating the iliac crest.

In the akimbo position with the hands resting on the trunk, the tip of the index finger is touching or palpating the **ASIS.**

The **ASIS** serves as a point of attachment for many muscles including the lateral point of insertion for the **inguinal ligament**, a structure that separates the front part of the trunk from the lower limb.

The ischium is associated with the **ischial tuberosity**, the most roughened part of the entire hip bone and the ischial spine.

The ischial tuberosity serves as a point of attachment for the hamstring muscles and also bears the weight of the body in the seated position. The pubic tubercle and crest are also useful palpable bony landmarks on the pubic part of the hip bone. The sacrum also usually has four pairs of anterior and posterior sacral foramina, an increase or decrease of which could be said to have arisen from either sacralisation or lumbarization of this bone.

Orientation of the bony pelvis

In the anatomical position it appears as though the anterior superior iliac spine (ASIS) and pubic tubercle lie in the same vertical plane with the acetabulum facing laterally on the posterio-inferior half. This arrangement allows the bony pelvis to create a small angulation with the trunk.

Pelvic cavity

The region enclosed by bony pelvis, muscles and ligaments define a space called the pelvic cavity, which looks basin-like. Pelvic cavity has brim also known as pelvic inlet.

Pelvic brim or pelvic inlet is the boundaries/outlines of the entrance to the true pelvis/lesser pelvis.

The pelvic brim/inlet is defined by:

- sacral promontory posteriorly. Sacral promontory is the inner bulging margins of the first sacral vertebra.
- pecten pubis (pectineal line) and arcuate line laterally. These are raised linear elevations on the pubic bone and
- pubic symphysis (upper margin) anteriorly. This is a piece of fibrocartilage at the point of union of the two hip bones anteriorly.

The female pelvic cavity

This is a short, curved canal divided into two parts by the pelvic brim. Above the brim is the false pelvis or greater pelvis which leads directly to the abdominal cavity above.

Below the brim is the true pelvis or lesser pelvis. The true pelvis is a bowlshaped structure which contains and protects the lower parts of the gastrointestinal tract, the urinary tracts and the internal organs of reproduction.

The true pelvis has an inlet, an outlet and a cavity. The cavity is short and curved, comprising of walls:

- - lateral (two)
- - posterior
- - anterior
- - inferior (floor) – made up wholly of skeletal muscles.

Types of bony pelvis

Gynecoid – inlet more rounded, greatest transverse diameter (TD) is skewed more anteriorly.

Anthropoid – oval shaped inlet, relatively longer anteroposterior (AP) diameter;

Android – heart-shaped inlet due to more prominent sacral promontory (broad posteriorly and narrow anteriorly); greatest transverse diameter (TD) lies more posteriorly.

Lower limb bones

Generally, the bones of the lower limb sustain the body weight when one stands and walks. The femur is the longest and strongest bone in the body. Its rounded head proximally is clearly set at a wide angle away from the shaft or body by the neck – a constricted part connecting the head to the shaft. The neck of the femur is frequently fractured in the elderly, often misnamed as "broken hip". The head articulates with the acetabulum (acetabular fossa) of the hip bone. The summit of the head is found a pit called fovea. In the living, the ligament of the head of femur attaches to this part of the bone and firmly secures the head in the shallow acetabular fossa. Nutrient vessels of the femur also penetrate the marrow of the femur through the fovea at the head. The greater and lesser trochanters are the most conspicuous structures marking the beginning of the proximal shaft. These two surface markings are more pronounced on the posterior side of the proximal shaft than the anterior. Anteriorly, the shaft of the femur is relatively smooth whereas the posterior surface of the shaft is marked by a roughened linear ridge, the linea aspera nearly on its midline. Proximally, the linea aspera appears to separate out into two sharp borders referred to as the medial and lateral lips. The medial and lateral condyles mark the distal end of the shaft of the femur. Anteriorly, between the medial and lateral condyles is a smooth, relatively shallow

notched area called the patellar surface for accommodating the biggest sesamoid bone in the body (patellar). The patellar bone forms the movable cap in the anterior part of the knee joint. On the posterior surface of the distal femur, between the lateral and medial condyles is, a deep rough depression known as the intercondylar fossa.

The distal end of the femur articulates with the two bones of the leg region of the lower limb – the tibia and fibula. The tibia is robust, thick and on the medial side of the leg while the fibula is slender and run parallel lateral to the tibia. The fibula is easily fractured in trauma cases of the leg, with its distal lateral malleolus often dislocated in „twist-and-turn" forceful movements occurring at the ankle joint. The proximal part of the fibula has a relatively pointed summit called the apex, immediately below which if found the somewhat rounded head. Distal to the head is the narrow neck which continues with the shaft. On the medial side of the apex of the fibula is found a facet for articulation with the inferior surface of the flared part of the lateral condyle of the tibia. The shaft of the fibula has smooth lateral and medial surfaces which are separated by the prominent linear ridge called the interosseous border, as well as a relatively smoother posterior surface. The distal end of the fibula is nicely fisted to form the lateral malleolus which is the prominent bony feature on the outer part of the ankle joint. Apart from its proximal ends that can be palpated in the living, the entire shaft of the fibula is under covered by the lateral muscles of the leg.

The proximal part of the tibia is flared (broad) to form the wide and shallow lateral and medial condyles for articulation with those of the distal end of the femur. At the peak of the condyles of the tibia are two small, horn-like bony projections called the intercondylar eminences (separately they are the lateral and medial intercondylar tubercles). The shallow articular surfaces of the condyles of the tibia are deepened in the living, with a C-shaped fibrocartilage, called the medial and lateral menisci. The lateral meniscus is

smaller and nearly circular in shape. The medial meniscus of the tibia is more injured than the lateral meniscus because it is broad and firmly attached to the medial (tibial) collateral ligament and the joint capsule.

Immediately below the condyles anteriorly and posteriorly, are rough surfaces for attachment of skeletal muscles. The tibial tuberosity is the most prominent on the anterior, proximal shaft, almost below the condyles in the midline. On the posterior surface of the proximal shaft however, is the soleal line which represents an easily identified longitudinal ridge. Anteriorly, the shaft of the tibia is marked with three linear elevations: the interosseous border on the lateral side, anterior border in its median plane and the medial border medially. The sharp anterior border is separated from the interosseous border by the smooth lateral surface while the medial surface separates the anterior border and medial borders. This border is highly subcutaneous is the main reason for the shin-guard worn by many a contact sports athletes as a protective gear for the leg. A smooth posterior surface is found between the interosseous and medial borders. The distal end has a broad styloid-like process on its medial side, called the medial malleolus whereas the lateral side of the distal extremity terminates blindly with a highly notched area for articulation with the terminal part of the shaft of the fibula. The medial malleolus marks the prominent bony structure that is easily palpated on the inner part of the ankle joint. In the living, a huge gap is formed between the lateral and medial malleoli that looks like a mortise, into which fits one of the bones of the ankle joint, the talus. The talus bone in the ankle joint is, therefore highly stable by this bony arrangement between the medial and lateral malleoli created by the distal ends of the tibia and fibula respectively. Among the seven bones forming the ankle joint, the talus appears to be positioned in a much higher plane than the remaining. The navicular which is almost in direct articulation with the talus anteriorly, is at a slightly lower plane than the latter, thereby giving the foot a sloping and arch-like

appearance from proximal to distal and medio-lateral view. The head of the talus articulates with the navicular anteriorly (distally) while the trochlear portion of the talus fits into the mortise of the malleoli, proximally (posterior and superior aspect of the foot). The talus is in a more superior, anterior and medial position than the calcaneus (heel bone), which is posterior and inferior and tend to bear the entire weight of the body in the erect position. The distal end of the calcaneus is contact with the cuboid bone. The cuboid is lateral to the navicular; together the navicular on the medial side and cuboid on the lateral side, form the intermediate pair of the foot bones. The bases of the fourth and fifth metatarsals, thus the last two lateral foot bones articulate with the cuboid bone. The three cuneiforms (medial, intermediate and lateral) are placed at the distal ends of navicular and cuboid bones. The bases of the first three metatarsals also articulate with the three cuneiform bones (medial to lateral respectively).

The heads of the metatarsals are distal and form joints with the bases of the phalanges. In the tip-toe position, the entire weight of the body is transmitted to the heads of the metatarsals. The numbering of the metatarsals begin with the most medial (in line with the big toe, hallux first) to the most lateral.

Classification of bones

According to structure (histological classification)

(i). **Compact bone** comprises of solid mass of bone material; very dense and hard in nature. Generally, this forms the outer layer of bone structure or its functional unit, the ***Haversian system.***

(ii). **Cancellous or spongy** bone: This type contains spaces filled with bone marrow; regarded as being made up of an incomplete ***Haversian system.***

Bone classification according to shape

(a). Long bones: These are bones with length greater than breadth. They consist of shaft (diaphysis) and two extremities (epiphysis). The **diaphysis** is filled with yellow marrow; a cylindrical, large space or canal at the centre.

The **epiphysis** is made up of cancellous tissue

e.g.: femur, humerus, tibia, fibula, radius, ulna, phalanges

Two types of membranes (connective tissues) associated with long bones ar*e:* **periosteum** and **endosteum.**

(b). Short bones: These are mostly cuboidal shape spongy bone, with a thin coat of compact bone. Examples include the carpals (wrist), tarsal (ankle) bones and ***sesamoid bones*** -- short bone embedded in long tendon e.g.: patella.

(c). Flat bones: These are broad or elongated flat plates of bone tissue used for protection and muscle attachments. By composition they have two thin layers of compact tissue enclosing a thin layer of spongy bone. Examples are the bones of the skull, sternum, ribs and scapula.

(d). Irregular bones: These are bones with no specific shape and include all other bones not assigned to the categories described above. For instance, the vertebrae, pelvic bones and bones forming the base of the skull – sphenoid, mandible etc.

Surface markings of bones

Bone as an organ comes with various surface markings which form definitive features on each bone. These markings are of different shapes, variations, kinds and configurations. The frequently encountered surface markings are in the form of:

Linear elevation: - The types of linear elevations may be one of the following:

- Line, for instance the superior nuchal line of the occipital bone.

- Ridge: Linear but denser than a line. Examples are the medial and lateral supracondylar ridges along the distal end of the humerus.
- Crest: This also appear linear on bones but more conspicuous and thicker the ridge. An example is found on the iliac portion of the hip bone as the iliac crest.

Rounded elevation: This type of surface marking also occurs in the following forms and listed according to order of increasing intensity:

- i. Tubercle: eg. Pubic tubercle on the pubic portion of the hip bone being the least in configuration among the rounded elevations. This is followed in intensity by a:
- ii. Protuberance - eg. External occipital protuberance, which can be palpated through the scalp of the occipital bone, as the roughened area of the occiput.
- iii. Tuberosity: This type of rounded surface marking is also more pronounced than the earlier two described. - eg. Deltoid tuberosity on the shaft of the humerus.
- iv. Malleolus: A well-developed and rounded type of rounded elevation. This are unique and confined only to the distal ends of the two long bones in the leg as the medial malleolus of tibia and the lateral malleolus of the fibula. The medial and lateral malleoli form the bony prominences at the junction between the leg and foot, on the medial and lateral sides respectively.
- v. Trochanter: Appear like a ball on the proximal part of the femur as the greater and lesser trochanters of the femur. By description, they are the largest of the rounded surface elevations.
- **3. Sharp elevation:** - This may also occur in the form of;
- (i) Spine or spinous process eg. Ischial spine, spine of vertebra.
- (ii) Styloid process - eg. Styloid process of temporal bone. The base of the skull is characterized with the presence of styloid processes.

They are prone to fractures in traumas involving the skull.

- **4. Expanded ends for articulation:** These occur in the form of:
- - (i) Head: A rounded end/tip of especially long bones. - eg. head of humerus, head of femur etc.
- - (ii) Condyle - eg. Medial and lateral condyle of femur.
- - (iii) Epicondyle - eg. Medial and lateral condyles of femur (prominence situated just above a condyle).
- **5. Small flat area for articulation:** - This occurs as;
- Facet - eg. Facet on head of rib for articulation with vertebral body.
- (ii) Depressions - These are in the form of:
- (iii) Notch - eg. Greater sciatic notch hip bone.
- (iv) Groove or sulcus - eg. Bicipital groove of humerus,
- (v) Fossa: Has more depth and width than all in this category. Eg the acetabular fossa of hip bone.
- **6. Openings** - These usually appear in the form of;
- Fissure: This appears in the form of natural cracks in a bone. - eg. Superior orbital fissure.
- Foramen: This type of surface marking appears in the form of a tiny opening that leads from the exterior into interior of a bone - eg. Infra orbital foramen of the maxilla
- Canal: This type comes in the form of a passageway of tunnel through a bone - eg. carotid canal of temporal bone.
- Meatus: This is like a winding or meandering canal in a bone - eg. External acoustic meatus of temporal bone.

Joints

A joint is the contact or union between two or more bones or cartilages. It is also called an articulation. The scientific study of joints is called **arthrology**

whereas the study of the motion of the human body is called **kinesiology.** Both are inter-related.

Classifications:

Functional classification: This focuses on the amount of movement. There three main types based on this category:

- ***Synarthroses*** (immovable joints),
- ***Amphiarthroses*** (slightly movable joints) and
- ***Diarthroses*** (freely movable joints).

Classification according to types of tissues lying between the bones (structural classification). Under this classification, we have:

Fibrous joints (united by a minimal amount of fibrous tissue); cartilaginous joints and synovial joint – articulating bones are surrounded by an outer sleeve of connective tissue called the joint capsule).

Fibrous joints are characterized by bones that are united by a minimal amount of fibrous tissue.

Little or no amount of movement may be possible with fibrous joints. Fibrous joints are subdivided into different categories, depending upon the nature of the joint.

Syndesmosis type of fibrous joint - two bones entering into the union are typically separated from each other by a considerable space but united by fibrous connective tissue that bridges this space. Little movement is possible with this type of joint. Example is the inferior tibiofibular joint.

Sutures: - A type of fibrous joint usually formed between flat bones. The bones are closely apposed and often firmly inter-locking along a wavy line and united by a small amount of dense connective tissue. Example is found in the sutures of the skull. Very little or no movement is possible with sutures.

Gomphosis type of fibrous joint

This type of fibrous joint comes with practically no possible movement between the two bones unless in pathological conditions. It takes the form of a peg fitting into a hole and being held firmly in position by connective tissues. This is the type of joint found forming the attachment of the roots of the teeth to the sockets of jaw bones (maxillae and mandible).

Synovial joints

Anatomy of synovial joints

The articular surfaces of the bones forming synovial joints are covered by a thin layer of hyaline cartilage separated by a joint cavity. The cavity of the joint is lined by synovial membrane. The synovial membrane is protected on the outside by a tough fibrous membrane called the joint capsule. The articular surfaces of the bones involved are lubricated by a viscous fluid called synovial fluid. Highly movable.

Types of synovial joints

They are all diarthroses (freely moving).

Synovial joints are called either simple or composite, according to whether the bones forming the joint are two or more.

Apart from this classification, synovial joints may also be classified based on shapes of the articulating surfaces.

Recent classification combines shape of the articulating bones and type of possible movements possible. Eg.

- Plane synovial joint eg. Sternoclavicular and acromioclavicular.
- Hinge Synovial joint eg. Elbow, knee and ankle joints.
- Pivot Synovial joint eg. Superior radioulnar joint; atlanto–occipital joint.
- Condyloid synovial joint eg. Metacarpophalengeal joint
- Ellipsoid synovial joint eg. Wrist joint
- Saddle synovial joint eg. Carpometacarpal joint of the thumb.
- Ball–and–socket synovial joints eg. Shoulder joint, hip joint.

The stability of synovial joints depends on:

Shape, size and arrangement of the articular surfaces of bones; the surrounding ligaments and the tone of muscles around the joint.

Cartilaginous joints:

With this type of joint, the articulating surface of bones are united or separated by means of cartilage. Two sub-varieties are often described; A primary cartilaginous joint (synchondroses) – The articulating surfaces of bones are united by a plate or bar of hyaline cartilage (epiphyseal plate). This can be found between the epiphysis and diaphysis of growing long bones and also between the first rib and manubrium of sternum. In the case of long bones, the bone in question is capable of growth as long as the plate of hyaline cartilage still exists and intervenes between the epiphysis and diaphysis. Fusion of the epiphysis and diaphysis is said to occur in long bones when this hyaline cartilage is used up, and thus marks the end of growing long bones (*synostosis of long bones*).

No movement is possible with primary cartilaginous joints.

A secondary cartilaginous joint (symphysis).

The articulating bones taking part in secondary cartilaginous joint formation are united by fibrocartilage. This type of joint allows only a limited degree of movement to occur.

Secondary cartilaginous joints appear to unite structures in the midline. Examples of places in the body where this type of joint can be found include; between the bodies of adjacent vertebrae where fibrocartilage, in the form of intervertebral disc unites them; at the pubic symphysis, uniting the left and right hip bones anteriorly in the midline and the symphysis menti, transforming the mandible into one complete bone with this articulation.

Cartilage

This is the third component of skeletal system.

It is a supportive connective tissue with a flexible rubbery matrix. Cartilage gives shape to structures such as the external ear, the tip of the nose, and the larynx in the body.

The cells secreting the matrix in cartilage are called chondroblasts. Chondroblasts latter differentiate into chondrocytes. Cartilage is free of blood vessels except when transforming into bone. That means nutrition and waste removal depend on solute diffusion through the stiff matrix. Since this is a slow process, chondrocytes tend to have:

- low rates of metabolism; - low rate of cell division and
- slow healing rate during injury.

The matrix in cartilage is rich in chondroitin sulphate and contains collagen fibers that range in thickness from invisibly fine to conspicuously coarse. Differences in the fibers provide a basis for classifying cartilage into three types namely as hyaline, elastic cartilage and fibrocartilage. The whitish, semi-rigid structures forming the articular surfaces of joints is an example of hyaline cartilage. Hyaline cartilage also forms the C-shaped rings of the trachea and the framework of long bones. The epiglottis of larynx, borders of the nares and the lowermost pliable part of the ear lobe are some examples of structures with elastic cartilage while the intervertebral disc and the piece of cartilage at the pubic symphysis are examples of some of the places in the body where fibrocartilage is found.

Quick recall/revision

Bony prominence of face is the **zygomatic bone**.

Bony prominence at the back of head is the **external occipital protuberance.**

Bony prominence at the back of earlobe (pinna) is the **mastoid process of the temporal bone (skull).**

Prominence in front of neck (Adam‟s apple) is the **thyroid cartilage.** Bony prominence on the edges of shoulder is the **acromion or acromial process of scapula.**

UNIT ELEVEN

MUSCULAR SYSTEM

Conventionally the muscular system generally describes muscle tissues found attached to skeletal components. They only contracts when a nerve impulse reaches them, hence are also known as voluntary muscles. Microscopically skeletal muscles have cross-striped appearances therefore also called striated / striped muscles.

Major functions include: body movement; maintenance of body posture and production of body heat.

Properties of the tissues of the muscular system

Tissues of the muscular system are characterised by unique qualities, therefore the aim of any therapy, palliative or rehabilitative is to improve on these qualities or properties for optimum function. These properties are:

- Excitability or irritability – ability to respond to chemical stimuli by producing electrical signals (action potential).
- Conductivity – ability to propagate the action potential along the plasma membrane.
- *Contractility – ability to shorten in response to stimulus and become able to generate force to do work.
- Extensibility – ability to stretch.
- Elasticity – ability to regain shape.
- Extensibility and elasticity properties confers mechanical qualities on muscles and allow muscles to become adaptable to forces that act on them.

The administration of rehabilitative programmes and/or chemotherapy directly or indirectly improves the contractile, extensible and elastic properties of muscles.

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Anatomy of the skeletal muscle.

A skeletal muscle, usually referred to simply as a muscle is primarily a collection of striated muscles fibres, which are bound together in a connective tissue sheath or are surrounded by an envelope of connective tissue. This collection also involves the tendons that bind the muscle to bone as well as the branches of blood vessels and nerves within this unit.

Parts of a muscle

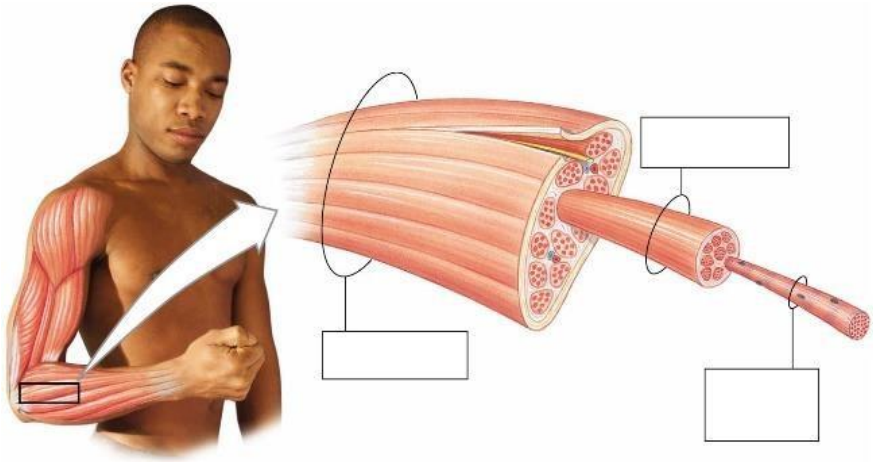
Belly: This is the fleshy part of a skeletal muscle; tendons – are the knot-like connective tissue components with which the muscle fibres are joined to bone. An aponeurosis is another form of tendons associated with flat thin muscles, and appears in the form of a sheet of connective tissue, with which these flat muscles use to join to skeletal parts. A raphe is an inter-digitation or point of union of two juxtaposing sheets of aponeuroses.

Commonly, most skeletal muscles have two points of attachments: *origin* and *insertion*. The point that moves the least when the muscle contracts (shortens) is the *origin* and one that is highly mobile during contraction is the *insertion.* Movement of the body is attained as a result of a muscle moving an attached bone.

Internal structure of skeletal muscles

Each muscle fibre is surrounded by a delicate connective tissue sheath called endomysium.

Several muscle fibres are grouped together to form a fasciculus. Each fasciculus is surrounded by a connective tissue sheath called perimysium. A muscle as a whole is made up of many fasciculi which are surrounded by a connective tissue called epimysium.



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Internal structure of skeletal muscles - pennation

Skeletal muscles shorten by one-third the resting length when they contract. Skeletal muscles may have fibres which run parallel to the line of pull or have fibres which run obliquely. Examples of muscles with parallel arranged fibres are sternocleidomastoid, rectus abdominis, sartorius. Muscles whose fibres run obliquely to the line of pull are referred to as pennate muscles (they resemble a feather). A unipennate muscle is one in which the tendon is directed along one side of the muscle and the muscle fibres pass obliquely to it. A bipennate is one in which the tendon lies in the centre of the muscle and the fibres pass to it from two sides, for example. Rectus femoris.

A multipennate muscle may be arranged as a series of bipennate muscles lying alongside one another or may have the tendon lying within its centre and the muscle fibres passing to it from all sides converging as they go, for example, tibialis anterior, deltoid.

Microanatomy of a muscle fibre (cell)

Skeletal muscles are organized in a hierarchical manner from the functional point of view.

From smallest to largest unit in the hierarchy is sarcomere; myofilament; myofibril; muscle fibre; muscle fascicle and a named muscle. Each of these tissues has a connective tissue layer surrounding it, such that connective tissue mass plays a substantial role in skeletal muscle mass.

One myofibril is made up of a chain of sarcomeres. Sarcomeres are composed of thick and thin myofilaments. These myofilaments slide across each other during contraction.

Factors influencing a skeletal muscle bulk (diameter)

Variation in the mass (+diameter) of skeletal muscle fibres depends on such factors as; the specific muscle; the age; the sex; nutritional status and physical training of the individual.

Skeletal muscles and physical exercise

Physical exercise enlarges the musculature and decreases fat depots. The increase in a muscle (through exercise) is caused by the formation of new myofibrils (unit of a muscle) and a pronounced growth in the diameter of individual muscle fibres. This process characterized by augmentation of cell volume, is called hypertrophy. The overall effects of physical exercise on skeletal muscles are: increase in muscle size; increase in muscle strength; increase in muscle efficiency and a muscle becoming more fatigue resistant.

Some skeletal muscle terminology

The term associated with muscle *disuse is* **atrophy** whereas **hypertrophy** is the increase in size of cells or tissues in response to various stimuli e.g exercise, drug etc. Tissue growth by increase in the number of cells is termed as **hyperplasia**. Hyperplasia does not occur ordinarily in either skeletal or cardiac muscle, but takes place in smooth muscles, which cells/fibres still have the capacity to divide by mitosis.

Skeletal muscles and body movements

For muscles to create a movement, they can *only* ***pull***, not push. Muscles in the body rarely work alone, and are usually arranged in groups surrounding a joint. A muscle that contracts to create the desired action is known as an ***agonist*** or ***prime mover.*** A muscle that helps the agonist is a ***synergist*** whereas a muscle that opposes the action of the agonist, therefore undoing the desired action is an ***antagonist.***

A skeletal muscle may work in four different ways; (i) as a prime mover, (ii) as an antagonist (iii) as a fixator and (iv) synergist. The state of partial contraction of a skeletal muscle while resting is known as a muscle tone.

Skeletal muscle nomenclature

Skeletal muscles are named according to the following criteria:

(i) Direction of muscle fibers. Example: rectus (straight).

(ii) Relative size of the muscle. Example: maximus (largest).

(iii) Location of the muscle. Example: many muscles are named for bones (e.g., temporalis).

(iv) Number of origins. Example: triceps (three heads); biceps – two head or origins.

(v) Location of the muscle's origin and insertion. Example: sterno (on the sternum).

(vi) Shape of the muscle. Example: deltoid (triangular), gracilis (thin),

(vii) Action of the muscle. Example: flexor and extensor (flexes or extends a bone)

(viii) Action is also reflected in names such as Ievator scapulae.

(ix) Action and shape are also often combined as in for example pronator quadratus.

(x) Action and location are combined. For example, flexor digitorum profundus.

Disorders of muscular system

Fatigue: Lack of response by a muscle to continuous stimulation due to lack of oxygen or build-up of lactic acid and carbon dioxide. Cramps: Is an involuntary and complete tetanic contraction in a muscle. Shivering: Increase tone as the muscle become colder. Shivering is due to these "prepared" muscles contracting spasmodically. This produces heat and helps to raise the body temperature. Contracture describes a painful, hard, shortened muscle associated with vigorous exercise or muscle tendons. Strain is the overstretching near a joint (may or may not lead to tendinitis). * *Sprain** is stretching or tearing of a ligament. This is clearly a skeletal system disorder; must not be confused with a strain. Myalgia is the general term for an inflammation of muscle tissue. Compartment syndrome describes a collective clinical condition including swelling, pain and tenderness associated with a group of muscles.

Some selected muscles or muscle groups in the body

Arm muscles

The arm muscles are divided into fascial compartments as the anterior compartment and posterior compartments.

Anterior fascial compartment

The group name of muscles in the anterior compartment of the arm is *flexor.* Together the muscles in this compartment are three in number.

Most anterior part of the anterior compartment is occupied by the **biceps brachii.**

Origin: Long head = supra-glenoid tubercle of scapula. Short head from the tip of coracoid process. Insertion: Tuberosity of radius. Action: Flexes forearm and arm. It is also a powerful supinator of hand. Nerve supply: Musculocutoneous nerve. Biceps brachii is also weak flexor of forearm upon extension of elbow joint and a powerful supinator of forearm when partially flexed. Tendon of long head stabilises humeral head in glenohumeral joint. Its action is seen in such actions as corkscrewing and pulling of cork.

Medial to biceps brachii, in the proximal part of arm is the **coracobrachialis and** inferior or deep to biceps brachii (i.e underneath it) on the distal two-thirds part of arm is the **brachialis.**

Coracobrachialis

Origin: Tip of coracoid process. Insertion: Middle one-third of the medial surface of humerus.

Action: Flexes and adducts arm. (Adductor +Weak flexor at the shoulder joint). Nerve supply: Musculocutoneous nerve.

Brachialis

Origin: Distal two-thirds of the anterior surface of humerus. Insertion: Coronoid process and tuberosity of ulna. Action: Main flexor of arm. It resists/controls hyperextension of arm under gravity. Nerve supply:

Musculocutaneous nerve

Posterior fascial compartment

The group name of the muscles in this compartment is *extensors.* This compartment of the arm is occupied by only one muscle – triceps brachii.

Triceps brachii

Origin: Long head – Infra-glenoid tubercle; lateral head from the posterior surface and lateral border of humerus; medial head posterior surface of distal half of humerus. Insertion: Posterior aspect of olecranon process of ulnar. Action: Extends forearm, long head aids in extension and adduction of arm. Nerve supply: Radial nerve. Action: Extends arm; executing blows; use of the arms to get in and out of chair involves this muscle. Actively involved in wheel-chairing. Long head adducts partially flexed arm.

In describing the muscles of the upper limb also comes the need to describe one important anatomical region of the body called the axilla or armpit. The muscles of the axilla also form a significant functional part of the arm.

Axilla

This is a **four-sided pyramidal shaped region** found between the upper part of the arm and the lateral thoracic wall.

Boundaries of axilla

It has an **apex** which is bounded by **three bones**: **scapula** postero-laterally; **first rib** medially and the **clavicle** anteriorly. From each of these bony boundaries arises **a muscle** extending downwards to form part of the c**orresponding walls of the axilla.** Thus, the muscular walls of the axilla are formed by: **subscapularis** (posterior wall); **serratus anterior** (medial wall) and **pectoralis major** (anterior wall). Part of the **humerus** forms the narrow **lateral wall**, with the **humerus** being covered by the **biceps brachii** and **coracobrachialis** muscles. The **posterior axillary fold** is formed by both the **teres major (primarily)** and **latissimus dorsi** muscles. The lower edge of teres major marks the junction between the arm and axilla. Each of the **four walls** of the axilla is formed partly by bone and partly muscle. The

base/floor of the axilla is formed by **axillary fascia** and **skin** between the upper arm and lateral thoracic wall.

Contents of the axilla

Axillary artery and its branches; axillary vein and its tributaries; axillary lymph nodes and vessels; ***cords*** and ***terminal branches of the brachial plexus; the*** axillary sheath – an extension of fascia from neck ensleeving the axillary vessels; axillary tail of breast (post-pubertal females) - embedded in the axillary fat.

Axilla and intermuscular clefts/spaces

Latissimus dorsi muscle turns around the lower end of the teres major muscle near the chest wall to reach humerus. Near the humerus, the latissimus dorsi muscle leaves lower part of its anterior surface uncovered. The latissimus and teres major tendons fuse as they approach the humerus, but separable from the lower edge of the subscapularis. The triangular gap produced by these muscles together with the humerus is crossed vertically by the long head of the triceps and is thus dividing the space into a lateral triangular space and a medial triangular space. Through the quadrangular space passes the axillary nerve and the posterior circumflex humeral vessels.

Axilla and clinical significance

It serves as a: conduit for spread of infection; house (lodging site) *and* conduit for nerves sub-serving upper limb; metastasis of breast malignancies – critical area for management of breast cancer; forms a useful surface landmark of demarcating the torso: anterior axillary, mid-axillary and posterior axillary lines. Axilla serves as a useful landmark of the trunk - imaginary longitudinal lines through its anterior -, middle- and posterior-most limits.

Rotator cuff muscles (posterior shoulder region) - muscles that stabilize the shoulder joint

Supraspinatus

Origin: Supraspinous fossa (medial two-thirds). Insertion: - Superior portion of greater tubercle of humerus. Action: Initiates abduction of arm and augments deltoid function of abduction. Nerve Supply: Suprascapular nerve.

Intraspinatus

Origin: Infraspinous fossa (medial three-quarters). Insertion: Mid-portion of greater tubercle of humerus. Action: Main lateral rotator of arm. Nerve Supply: Suprascapular nerve.

Subscapularis

Origin: Subscapular fossa (medial two-thirds). Insertion: Lesser tubercle of humerus. Action: Principal medial rotator of arm; also assits in flexion, extension and adduction of arm. Nerve Supply: Upper and lower subscapular nerves.

Teres minor

Origin: Upper portion of lateral border of scapula. Insertion: Inferior portions of greater tubercle of humerus. Action: Rotates arm laterally and acts as main adductor of the arm. Nerve Supply: Axillary nerve.

Prime movers of abduction and adduction of the arm at the shoulder joint.

1**. Deltoid**

A triangular multipennate muscle, forming the rounded contours of the shoulder.

Origin: Lateral one-third of anterior border of clavicle, acromion, and posterior border of lower part of spine of scapula. Insertion: - Deltoid tuberosity of humerus. Action: Main abductor of arm; also aids in flexion, extension, adduction and medial and lateral rotation of arm. Nerve supply: Axillary nerve.

Deltoid muscle and intramuscular injection

With the deltoid chosen for intramuscular injection, the following anatomical relations must be considered ***in order to avoid:*** damage to cephalic vein medially; puncturing acromion (bone) superiorly; puncturing and damaging tendon to the muscle inferiorly; and the cutaneous branches of musculocutaneous nerve inferiorly as well as damage to axillary nerve posteriorly. The ideal site therefore, for deltoid intramuscular injection is midway in the belly of the muscle fibres situated in the three apices of the muscle.

2**. Teres major**

Origin: Posterior surface of inferior angle and lower portion of lateral border of scapula. Insertion: Medial lip of intertubercular groove of humerus. Action: Adducts and medially rotates arm. Nerve supply: Lower subscapular nerve.

Prime movers of abduction and adduction of arm at the shoulder joint.

3. **Pectoralis major**

Origin: Clavicular head from medial half of clavicle; sternal head- from sternum and costal cartilages; abdominal head from external abdominal oblique aponeurosis. Insertion: Lateral lip of intertubercular groove of humerus. Action: Flexes, adducts and medially rotates arm. Nerve supply: Lateral and medial pectoral nerves

Muscles that pull on the pectoral girdle from the anterior chest wall.

1. **Pectoralis minor**

Origin: - Anterior aspect of ribs three to five. Insertion: Coracoid process of scapula. Action: Draws scapula inferiorly and elevates ribs. Nerve supply: - Medial pectoral nerve.

2. **Subclavius**

Origin: Junction of first rib and costal cartilage. Insertion: Inferior surface of clavicle. Action: Draws clavicle inferiorly and anteriorly. Nerve supply: Nerve to subclavius.

3. **Serratus anterior**

Origin: Digitation from lateral, (under) surface of upper eight ribs. Insertion: Anterior lip of medial border of scapula. Action: Protracts the pectoral girdle (draws scapula anteriorly and rotates inferior angle of scapula laterally.

Nerve supply: Long thoracic nerve.

Muscles of the superficial back

Shoulder muscles that suspend the pectoral girdle from the vertebral column.

Trapezius

Origin: External occipital protuberance, superior nuchal line, ligamentum nuchae, spinous process of C7 vertebra to all thoracic vertebrae. Insertion: Anterior border of spine of scapula, acromion and lateral one-third of posterior border of clavicle. Action: Adducts and rotates scapula; upper part elevates scapula; lower part depresses scapula. Nerve Supply: Spinal accessory nerve.

Shoulder muscles that suspend the pectoral girdle from the vertebral column.

1. Levator scapula:

Origin: Transverse processes of first to fourth cervical vertebral. Insertion: Posterior lip of medial border of scapula. Acton: Elevates scapula and inclines head. Nerve supply: Dorsal scapular nerve.

2. Rhomboid major

Origin: - Spinous processes of second to fifth thoracic vertebra. Insertion: Posterior lip of lower half of medial border of scapula. Action: Adducts and laterally rotates scapula. Nerve supply: Dorsal scapular nerve.

3. Rhomboid minor

Origin: Spinous processes of seventh cervical and first thoracic vertebrae. Insertion: Root of spine of scapula. Action: Adducts and laterally rotates scapula. Nerve Supply: Dorsal scapular nerve.

Muscles of the superficial back that attach the upper limb to the trunk

Latissimus dorsi

Origin: Spinous processes of all vertebrae below 6th thoracic, lumbosacral fascia, iliac crest, lower three or four ribs (9 – 12 ribs). Insertion: Floor of intertubercular groove of humerus. Action: Adducts, rotates medially & draws arm posteriorly (as in rowing and climbing of a rope).

Principal muscles of ventilation

1. The diaphragm (thoracoabdominal diaphragm)

This is a sheet of internal skeletal muscle. It is the principal muscle of breathing/ventilation.

It separates thoracic cavity from abdominal cavity. **NB: (Coronary ligament is a connective tissue that links the superior surface of the liver to thoracic diaphragm. Remember the b*are area of liver and lymphatic drainage*).**

The contraction of the diaphragm increases high oxygen consumption power than any skeletal muscle. Its contraction also increases volume of thoracic cavity, thereby creating negative pressure, which therefore draws air into the lungs.

Histologically, the muscle fibres of the diaphragm are highly vascularized and rich in mitochondria. Gross-wise, the diaphragm has an upward curve (C-shape) structure, made up of fleshy muscle tissue peripherally and fibrous tissue centrally (tendon). The central tendon is more aponeurotic and is closer to the front than the back. Muscle fibres emerge from surrounding structures to hold the diaphragm in position internally: at the front, fibres arise/insert into xiphoid process and costal margins; laterally, muscle fibres insert into ribs six to twelve.

Posteriorly, the muscle fibres insert into T12 vertebra, and with two extensions – the right and left crura, which descend to insert in front of to the lumbar vertebra. The right crus inserts to L1 – L3 vertebra while the left crus inserts on L1 and L2 vertebrae. The crura tend to blend with the anterior longitudinal ligament. The diaphragm is associated with three arc-shaped (arcuate) ligaments: the medial, lateral and median arcuate ligaments.

Openings in/through the diaphragm ***(VOA: 8-10-12)***

The diaphragm is associated with three main openings for the passage of structures to and fro:

1) Caval opening: *just remember* vena cava (8 letters). This opening is located at the level of thoracic vertebra eight (T8). Vena cava passes (through aponeurosis of the muscle at T8).
2) Oesophageal opening: *just remember* oesophagus (10 letters). Oesophagus passes through the fleshy belly of the diaphragm at the level of thoracic vertebra 10 (T10) to reach the stomach in the abdominal cavity.
3) Aortic hiatus: (12 letters). The aorta passes through the diaphragm to reach the abdominal cavity at the level of thoracic vertebra 12 (T12). This occurs in front of the vertebra in between the left and right crura.

Nerve supply to the diaphragm

Motor innervation to the diaphragm is mainly by phrenic nerve (C3-C5). Sensory supply: the central tendon has its sensory innervation from phrenic while the muscular domes (periphery) are innervated from intercostal nerves (T5 –T11) and subcostal nerves (T12).

Blood supply

Branches of internal thoracic arteries; namely the pericardiophrenic and musculophrenic supply blood to the diaphragm, also the superior phrenic artery from thoracic aorta and lower lumber arteries supply this muscle with oxygenated blood.

Venous drainage

Venous blood from the diaphragm drains into the: brachiocephalic veins; azygous vein as well as small veins that drain into the inferior vena cava and left supra renal vein.

Diaphragm and when things go wrong!

Spasmodic contraction of the diaphragm leads to hiccup (singultus). One-sided paralysis results in difficulty in breathing on the affected side. Double-sided lesion/paralysis of the diaphragm results to death (from asphyxia).

(ii) Intercostal muscles

Typically, most intercostal space is occupied by the three intercostal muscles – external intercostal; internal intercostal and innermost which in turn has three parts namely: sternocostalis (transversus thoracis); innermost intercostalis and subcostalis.

The intercostal muscles are all located at the same position (between ribs), with the orientation of the muscle fibres set at right angles to one another. The fibres of the external intercostal muscles running downward and forward in an intercostal space (that is medially and downward), while the internal run downward and outward (that is outward and backward) with most fibres of the innermost running transversely across.

The concentric contraction of these muscles turns to increase all diameters of the thoracic cage, thereby drawing air into the lungs, hence their

consideration as respiratory muscles. They are innervated by the intercostal nerves.

Muscles of the forearm and their relationship

Muscles divided into fascial compartments. The "anterior" fascial compartment located anteromedially and comprises muscles around the medial epicondyle and supracondylar ridges of humerus. This muscle group forms the flexor-pronator compartment by way of action.

The "posterior" fascial compartment lies postero-laterally. This comprises of muscles around the lateral epicondyle and supracondylar ridges of humerus. This group forms the extensor-supinator compartment by way of action. Generally, the flexors are found in the anterior compartment and extensors in the posterior compartment and separated by ulna and radius proximally and by the interosseus membrane distally.

Architecture of the muscles of forearm

1. Generally, the forearm muscles are designed with bulky fleshy bellies proximally. The fleshy bulky bellies are either located anteromedially or postero-laterally in the proximal part of forearm.
2. Long tendons in the anterior or posterior forearm located distally. All the tendons are held in place firmly by retinacula.

Action of muscles of the forearm

Execute flexion and extension at: (1) Wrist joint and (2) phalengeal joints or pronation and supination upon contraction.

Innervation of muscles of forearm

Anterior compartment: Median and/or ulnar nerves. Posterior compartment: Radial nerve.

Arrangement of forearm muscles

Anterior compartment

Three different planes/layers; superficial, intermediate and deep. Superficial plane has four muscles: pronator teres; flexor carpi radialis; palmaris longus and flexor carpi ulnaris – all with a common origin.

The intermediate plane has a single muscle called flexor digitorum superficialis and the deep layer with three muscles namely flexor digitorum profundus; flexor pollicis longus and pronator quadratus. The superficial layer of muscles of the anterior forearm cross the elbow joint but the three deep do not.

Posterior compartment

Anatomically organised into two planes/layers of muscles: superficial and deep. In the superficial group of the posterior compartment, four of the muscles arise from a common extensor origin; these are: extensor carpi radialis brevis; extensor digitorum; extensor digiti minimi and extensor carpi ulnaris. The other two, however (brachioradialis and extensor carpi radialis longus) originate from this superficial group/layer also arise from different locations. The deep group/layer of muscle in the posterior compartment of the forearm all act on the thumb (pollex) and/or index finger. These muscles are the abductor pollicis longus; extensor pollicis brevis and extensor indicis. The seemingly odd muscles in the posterior compartment in terms of fascial group layout are the supinator: lies deep in cubital fossa (floor). It is involved in slow unopposed supination (extended forearm) and anconeus – distal part of arm and proximal forearm posteriorly.

Another odd muscle in the posterior compartment with respect to location, action and nerve supply is ***brachioradialis*** which is located superficial and on the posterolateral aspect of the forearm. This muscle almost serves as a

border between the flexors and extensors on the lateral side in the anatomic position. The brachioradialis flexes a partially flexed forearm and is innervated by radial nerve. Functionally the muscles in the posterior compartment could be categorized in three groups: (i) extend and abduct or adduct hand at wrist joint. These muscles include: extensor carpi radialis longus, extensor carpi radialis brevis and extensor carpi ulnaris. - (ii) Extend the medial four fingers and the muscles involve in this action are: the extensor digitorum, extensor indicis and extensor digiti minimi and (iii) muscles which extend or abduct thumb namely: (abductor pollicis longus, extensor pollicis longus and extensor pollicis brevis.

The forearm muscles are a total of **twenty in all.**

Muscles of the hand

Hand muscles are divided into thenar muscles/eminence and the hypothenar muscles/eminence; small intrinsic muscles and the palmaris brevis.

Thenar eminence

(i) Abductor pollicis brevis. This abducts the thumb, assists in flexion of proximal phalanx

Nerve supply is median nerve, (ii) Flexor pollicis brevis: Flexes thumb and assists in opposition. It is innervated by median nerve, (iii) Opponens pollicis. This draws the first metacarpal towards the centre of the palm in an action known as opposition. Nerve supply is median nerve and (iv) Adductor pollicis; Adducts thumb; assists in opposition. Nerve supply is ulnar nerve.

Hypothenar eminence

Abductor digiti minimi. Abducts fifth digit, nerve supply is the Ulnar nerve, (ii) Flexor digiti minimi brevis. This flexes the proximal phalanx of fifth digit

and is innervated by the ulnar nerve, (iii) Opponens digiti minimi. Draws fifth metacarpal forward in cupping of hand. Nerve supply: ulnar nerve and (iv) Palmaris brevis

Origin: Medial aspect of flexor retinaculum. Insertion: Skin of palm. Action: Wrinkles skin of palm. Nerve supply: Ulnar nerve.

Intrinsic muscles of hand (small muscles of hand)

(1) Lumbricals (4)

Originate from the ends of the long flexor digitorum profundus tendons. Flex the metacarpophalangeal (M-P) joints and extend interphalangeal (I-P) joints. This type of action is exemplified in the action of "holding a pen/pencil in a bid to write or draw" or waving "good-bye" with a motion of the medial four fingers. Nerve supply: The first and second lumbricals is supplied by median nerve while the third and fourth lumbricals is by the ulnar nerve.

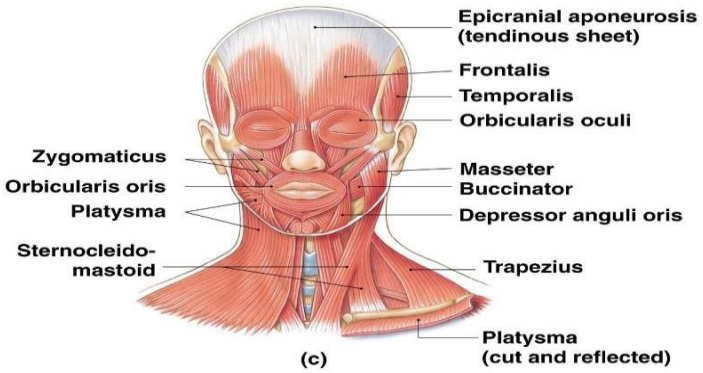
(2) interossei muscles

Dorsal interossei (four in all). Action: Abduct fingers ie. second, third and fourth. Nerve supply: Ulnar nerve.

Palmar interossei (three in all). Action: Adducts fingers ie. second, third and fourth fingers. Nerve supply: Ulnar nerve.

Some selected muscle groups in the body

1. Facial muscles



Source: https://images.app.goo.gl/a49vwUu5J6s46oLfA

Facial muscles insert into the skin of the face.

2. Neck muscles – Sternocleidomastoid muscle

Sternocleidomastoid (SCM) visibly divides neck into anterior and posterior triangles (anterior and lateral cervical regions). Origin: has two heads; sternal head from manubrium of sternum and clavicular head from medial one-third of clavicle. Insertion: Mastoid process of temporal bone. Action: (a). Together (both): flex the cervical part of vertebral column (neck), thus extend head at the atlanto-occipital junction. (b) One contracts: tilts head towards ipsilateral shoulder, simultaneously rotating head so as to turn face towards opposite side. For example, as in sideways glance and side to side rotation of head (c). Accessory inspirational muscle. Nerve supply: motor innervation by accessory spinal nerve (CN XI). Sensory innervation (sensation and proprioception) by the cervical plexus (C2 and C3 ventral rami). Most of the rest of muscles of the neck are either elevators or depressors of the hyoid bone/larynx. (*Refer to notes on anatomy of larynx and pharynx*).

Muscles of the lower limb

a) Gluteal muscles (muscles of the buttocks)

(i) Gluteus maximus

Origin: Upper portion of ilium; posterior aspect of sacrum and coccyx as well as sacrotuberous ligament. Insertion: Gluteal tuberosity and iliotibial tract. Action: Chief/principal extensor of thigh and powerful lateral rotator of the thigh. Nerve supply: Inferior gluteal nerve.

gluteus maximus and intramuscular injections

Prior to injection, the muscle is divided into four quadrants. Safest site for intramuscular injection is the upper outer/lateral quadrant. The aim is to

avoid damage to iliac crest superiorly and sciatic nerve coursing superomedially and infero-medially.

(ii) Gluteus medius

Origin: llium between middle gluteal line and iliac crest. Insertion: Greater trochanter and oblique ridge of femur. Action: Abducts and rotates thigh medially. Nerve supply: superior gluteal nerve.

(iii) Gluteus minimus

Origin: llium between middle and inferior gluteal lines. Insertion: Greater trochanter and capsule of hip joint. Action: Abducts and rotates thigh medially. Nerve supply: Superior gluteal nerve.

Small muscles of the buttocks (gluteal region)

(i) Piriformis

Origin: Internal aspect of sacrum; greater sciatic notch and sacrotuberous ligament Insertion: Upper part of greater trochanter. Action: Rotates thigh laterally. Nerve supply: S1 and S2 spinal nerves.

(ii) Superior Gemillus

Origin: Upper margin of lesser sciatic notch / spine of ischium. Insertion: Upper border of greater trochanter. Action: Lateral rotator of thigh and hip joint. Nerve supply: Sacral plexus (branches)

(iii) Inferior Gemillus

Origin: Ischial tuberosity. Insertion: Upper border of greater trochanter. Action: Lateral rotator of thigh and hip joint.

(iv) Quadratus Femoris

Origin: Lateral border of ischial tuberosity. Insertion: Posterior aspect of greater trochanter and adjoining of shaft of femur. Action: Rotates thigh laterally. Nerve supply: L4, L5 and S1 nerve.

Posterior compartment of the thigh (hamstrings)

Biceps femoris

Origin: Long head – common tendon with semitendinosus from ischial tuberosity; short head – linea aspera and upper half of supracondylar ridge of femur. Insertion: Common tendon on to head of fibula. Action: Flexes knee; rotates leg laterally; long head extends hip. Nerve supply: Long head by tibial portion; short head by peroneal portion of SCIATIC nerve.

Semitendinosus

Origin: Ischial tuberosity (in common with long head). Insertion: Upper part of medial surface of tibia. Action: Flexes knee; rotates leg medially; extends hip joint. Nerve supply: Tibial portion of SCIATIC nerve.

Semimembranosus

Origin: Ischial tuberosity. Insertion: Medial condyle of tibia. Action: Extends hip joint; flexes knee; rotates leg laterally. Nerve supply: Tibial portion of SCIATIC nerve.

Muscles of the lateral thigh

Tensor fasciae latae

Origin: iliac crest and anterior border of ilium. Insertion: lliotibial tract. Action: Tenses fascia lata, assists in flexion, abduction and medial rotation of thigh. Nerve supply: Superior gluteal nerve.

Muscles of anterior compartment of the thigh

Iliopsoas: Compound muscle: formed by the union of iliacus and psoas major muscles.

Iliacus: Origin: iliac fossa and lateral portion of sacrum. Insertion: Lesser trochanter of femur by way of iliopsoas tendon. Action: Flexes thigh. Nerve supply: Femoral nerve.

Psoas major:

Origin: Lumbar vertebrae. Insertion: Lesser trochanter of femur by way of iliopsoas tendon. Action: Flexes and rotates thigh medially. Nerve supply: second and third lumbar nerves.

Sartorious

Origin: Anterior superior iliac spine. Insertion: Upper part of medial surface of tibia. Action: Flexes leg; acts on both hip and knee joints. Nerve supply: Femoral nerve.

Pes anserinus

This is the conjoined tendons of the three muscles that insert onto the anteromedial surface of proximal tibia. Also described as the area on the inside of the knee where tendons for the, satorious, gracilis and semitendinosus (SGS) attach.

Anterior thigh muscles - quadriceps femoris

Quadriceps femoris: Consists of rectus femoris and the three vasti muscles. The four muscles combine into a common aponeurotic and tendinous insertion on to the tibial tuberosity, with the patella interposed as a sesamoid bone.

Rectus femoris

Origin: Straight head: anterior inferior iliac spine; reflected head – posterior superior aspect of rim of acetabulum. Insertion: Tibial tuberosity. Action:

Extends leg and flexes thigh. Nerve supply: Femoral nerve.

Vastus lateralis

Origin: Intertrochanteric line, greater trochanter, line aspera and lateral Intermuscular septum.

Insertion: - Tibial tuberosity. Action: Extends leg. Nerve supply: Femoral nerve.

Vastus medialis

Origin: Intertrochanteric line, spiral line and medial intermuscular septum. Insertion: Tibial tuberosity. Action: Extends leg. Nerve supply: Femoral nerve.

Vastus intermedialis

Origin: Upper two-thirds of shaft and distal half of lateral intermuscular septum. Insertion: Tibial tuberosity. Action: Extends leg. Nerve supply: Femoral nerve.

Articularis genus

Variable slip of muscle on deep aspect of vastus intermedius that, in extension of knee pulls synovial membrane out of the articular surface.

Medial thigh muscles – (adductors of the thigh).

Adductor longus

Origin: Body of pubis immediately below pubic crest. Insertion: Linea aspera of femur. Action: Adducts, flexes and rotates thigh medially. Nerve supply: Obturator nerve.

Adductor brevis

Origin: Body of pubis below origin a longus. Insertion: Between lesser trochanter and linea aspera together with upper part of linea aspera. Action: Adducts, flexes and rotates thigh medially. Nerve supply: Obturator nerve.

Adductor magnus

Origin: Side of pubic arch and ischial tuberosity. Insertion: Linea aspera, medial supracondylar ridge, and adductor tubercle. Action: Adducts, flexes and rotates thigh medially; distal fibres assist in extension and lateral rotation of thigh. Nerve supply: Obturator nerve and distal portion by sciatic nerve.

Pectineus

Origin: Pectineal line and pectineal surface of pubis. Insertion: Posterior aspect of femur, between lesser trochanter and linea aspera. Action: Adducts and assists in flexion of thigh.

Nerve supply: Obturator and femoral nerves.

Gracilis

Origin: Lower half of body of pubis. Insertion: Upper part of medial surface of tibia. Action: Adducts thigh; flexes knee joint and rotates leg medially.

Nerve supply: Obturator nerve.

Obturator externus

Origin: Margins of obturator foramen and obturator membrane. Insertion: Posterior aspect of intertrochanteric fossa of femur. Action: Flexes and rotates thigh laterally. Nerve supply: Obturator nerve.

Posterior leg muscles

Gastrocnemius

Origin: Lateral head – lateral condyle of femur; medial head popliteal surface and medial condyle of femur. Insertion: With soleus through calcaneal tendon into posterior surface of calcaneus. Action: Plantar flexes foot and flexes knee. Nerve supply: Tibial nerves.

Soleus

Origin: Upper one-third of fibula, soleal line on tibia. Insertion: With gastrocnemius through calcaneal tendon into posterior surface of calcaneus. Action: Plantar flexes foot. Nerve supply: Tibial nerve.

Plantaris

Origin: Popliteal surface of femur above lateral head of gastronecmius. Insertion: Into medial side of calcaneal tendon. Action: Plantar flexes foot. Nerve supply: Tibial nerve.

Popliteus

Origin: Popliteal groove, lateral condyle of femur. Insertion: Tibia above soleal line. Action: With knee fully extended, rotates femur laterally. Nerve supply: Tibial nerve.

Flexor digitorum longus

Origin: Middle half of tibia below soleal line. Insertion: Distal phalanges of four lateral toes.

Action: Flexes phalanges of four lateral toes; continual action plantar flexes and inverts foot.

Nerve supply: Tibial nerve.

Flexor hallucis longus

Origin: Lower two-thirds of fibula and intermuscular septa. Insertion: Base of distal phalanx of great toes. Action: Flexes great toe, continued action plantar flexes and inverts foot. Nerve supply: Tibial nerve.

Tibialis posterior

Origin: Interosseous membrane and adjoining tibia and fibula. Insertion: Into tuberosity of navicular with slips into cuneiform, cuboid and base of second to fourth metatarsals. Action: Principal invertor of foot, plantar flexes foot. Nerve supply: Tibial nerve.

Muscles of anterior compartment of the leg

Tibialis anterior

Origin: Lateral condyle of upper two-thirds of tibia and interosseus membrane. Insertion: First cuneiform and first metatarsal. Action: Dorsiflexes and inverts foot. Nerve supply: Deep peroneal nerve.

Extensor digitorum longus

Origin: Lateral condyle of tibia, upper three-quarters of fibula and interosseous membrane. Insertion: Second to fifth toes - ie. metatarsophalangeal joints. Action: Extends toes; continued action dorsiflexes and everts foot. Nerve supply: Deep peroneal nerve.

Peroneus tertius

Origin: Distal one quarter of fibula and interosseus membrane. Insertion: Fifth metatarsal or deep fascia of foot. Action: Dorsiflexes and everts foot. Nerve supply: Deep peroneal nerve.

Extensor hallucis longus

Origin: Middle half of fibula and interosseus membrane. Insertion: Base of distal phalanx of great toe. Action: Extends great toe, and aids in dorsiflexion and inversion of foot.

Muscles of lateral compartment of leg

Peroneus longus

Origin: Lateral condyle of tibia, head and upper two-thirds of fibula. Insertion: First metatarsal and first cuneiform. Action: Everts and aids in plantar flexion of foot. Nerve supply: Superficial peroneal.

Peroneus brevis

Origin: Lower two-thirds of fibula. Insertion: Base of fifth metatarsal. Action: Everts and aids in plantar flexion of foot. Nerve supply: Superficial peroneal nerve.

Muscles of dorsum of foot: extensor digitorum brevis

Origin: calcaneous, interosseous talocalcaneal ligament and the inferior extensor retinaculum.

Insertion: into the long extensor tendons of the lateral digits. Function: extension of last four toes at the metatarsophalangeal (M-P) and interphalangeal (I-P) joints (assists extensor digitorum longus). Nerve supply: deep fibular nerve.

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ABOUT THE BOOK

Essentials of Human Anatomy Vol. 1 is a spotlight on the understanding of the structure and functions of the human body. It chronicles and integrates the contents in the light of academic requirements of many universities and colleges of health science institutions across Tropical Africa. The book gives the reader a feel of what to expect during advanced levels of the training as a potential healthcare professional, with a firm grasp of the basic knowledge of human anatomy. Some of the topics covered in this volume include: Anatomical nomenclature; Cell Structure; Basic Embryology and Basic Tissues. Other topics covered in this volume include the anatomy of the: Respiratory system; Larynx and Pharynx; Cardiovascular system; Reticulo-endothelial system; Digestive system; Skeletal system and Muscular system. Some of the interesting sideline throughout the book are: when things go wrong and the applied or clinical anatomy bit that follow every topic.

ABOUT THE AUTHOR

Dr. Saviour Adjenti is an academic and researcher with over 20 years of teaching and research experiences in higher education. He is a Neurodevelopmental Anatomist by training and Fellow of the West African College of Morphologists (Anatomy option). For his Doctorate degree, the author studied Anatomy & Cell Biology from the Faculty of Health Sciences, University of Cape Town, South Africa and an M.Phil degree in Anatomy from the University of Ghana Medical School, Korle-bu, Accra. Prior to these special training, Dr. Saviour Adjenti had matriculated into the University of Lagos, Akoka, Nigeria for his undergraduate education, later transferred to Kwame Nkrumah University of Science & Technology (KNUST), Kumasi, Ghana, where he graduated with an Honours degree. He is a dynamic, passionate and gifted teacher who is devoted to the teaching of all aspects of Human Anatomy with clarity to all cadre of health science students and professionals especially in deprived and underprivileged institutions. He started his professional career as a Lecturer in Anatomy with the University of Ghana Medical School, Korle-bu, Accra and later joined the Department of Physician Assistantship Studies, Central University, Miotso, near Tema in 2018, after over a decade of teaching experience in Ghana"s premier medical school. He rose through the ranks and later served as the Head of Department. Dr. Saviour Adjenti currently serves as a Senior Lecturer in Clinical Anatomy and the Dean of Central University"s School of Medical Sciences. The author also holds Adjunct teaching positions from several medical and health sciences institutions both locally and abroad.

Design & Printed by:
DanGrace Services
(Opeemu, +233 240871397)

ISBN: 978-9988-41-098-8

EBOOK