ESSENTIALS OF HUMAN ANATOMY

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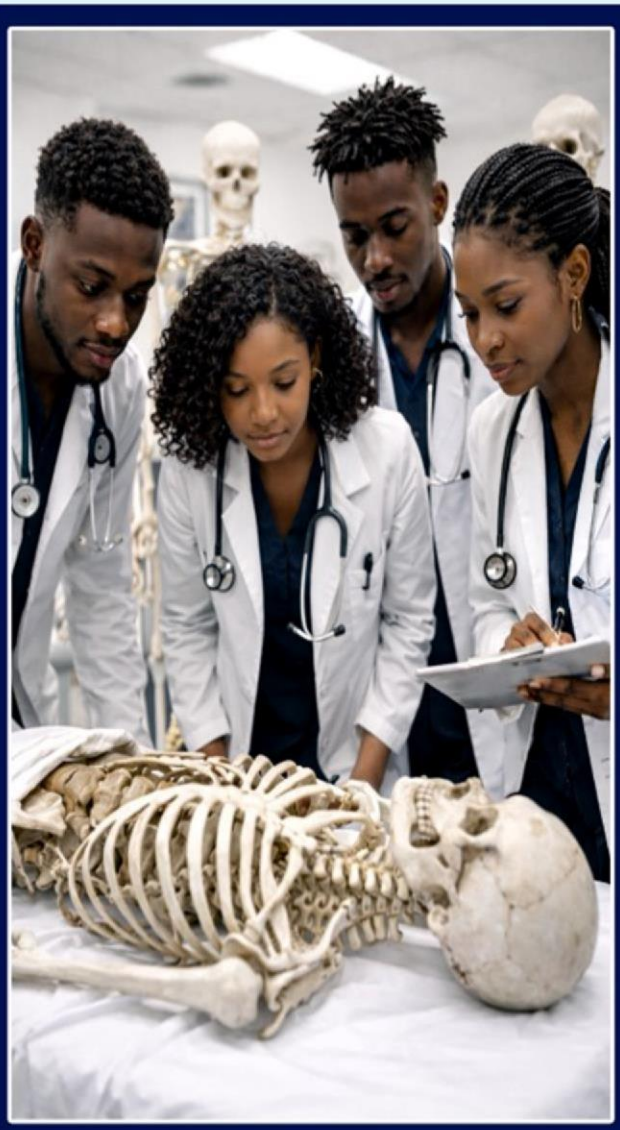
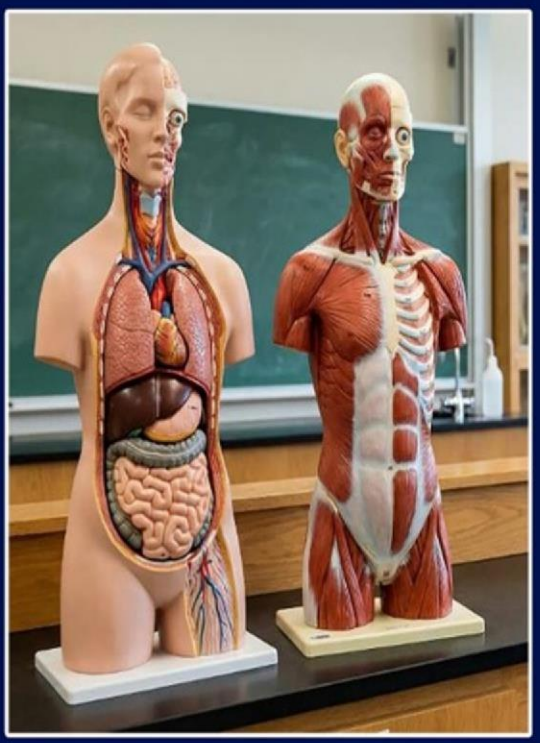
..... Lecture Notes for Beginners in Tropical Africa





Volume 2

DR. SAVIOUR ADJENTI

ESSENTIALS OF HUMAN ANATOMY

……. Lecture Notes for Beginners in

Tropical Africa

Vol. 2

Saviour Adjenti

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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 Service – Printing and Publication. 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 multidisciplinary 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.

Essentials of Human Anatomy Volume 2 is rich in everyday examples much like *Volume 1*, making the contents of this handbook easy to grasp, with its contents aligning most of the times with the syllabi of semester two scheme of work in most of the schools and colleges. 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 also 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

ANATOMY OF THE PELVIS AND PERINEUM

The bony pelvis

The bones forming the bony pelvis are loosely referred to as the pelvic girdle. The bony 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 appears 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. While 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** of the lumbar (fusion of L5 vertebra with sacrum) or **lumberisation** of the sacrum (fusion of S1 (first sacral vertebra) to the lumbar vertebrae).

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 bowl-shaped 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.

There is also the platypelloid type of bony pelvis which more often associated with the apes, but which also is occasionally found in humans.

Pelvic peritoneum

Visceral in the enclosed pelvic cavity is covered with a serous membrane called the pelvic peritoneum. This peritoneum reflects on organs in the pelvis to form pouches (hidden spaces). Two of such spaces in the female pelvis is the uterovesical and rectouterine pouches.

Pelvis - blood supply

The internal iliac artery is the main supply of blood to structures in the pelvis. The internal iliac artery divides into the anterior and posterior divisions in the pelvis with the former taking care of the blood supply of structures in the pelvis.

The branches from the anterior division are:

- obturator (parietal),
- umbilical (superior vesical – living part),
- uterine,
- Vaginal / inferior vesical for males,
- Middle rectal,

- Inferior gluteal (parietal) and
- Internal pudendal.

Pelvimetry

Pelvimetry is a hybrid word: Pelvis is basin (from Latin) and metron mean measure (from Greek). Therefore, pelvimetry means female pelvic measurements. It assesses the size of a pelvis of a woman aiming to predict whether she will be able to give birth vaginally or not. Pelvimetry is simply the assessment of the adequacy of the shape and size of the maternal pelvis (inlet, mid-pelvis and outlet) for vaginal birth through internal pelvic examination. Pelvimetry should not be confused with a standard pelvic examination which is required for the clinical assessment of cervical status. Pelvimetry can be done by radiography and magnetic resonance imaging (MRI). Low-dose CT scan can also be used for it.

Pelvimetry parameters

Three main diameters:

Pelvic inlet diameters: (transverse and conjugates: conjugate for the anteroposterior measurement). Three types of conjugates are often obtained for the inlet regarding the anteroposterior measurements (A-P) namely the:

- True conjugate,
- **Obstetric conjugate** and
- Diagonal conjugate diameters.

Mid-pelvis diameter and **pelvic outlet diameter.**

Pelvic inlet parameters: transverse diameter of the pelvic inlet

The end points are the illiopectineal lines as the widest transverse distance.

The standard measurements for this is 13 to 14.5cm.

Pelvic inlet parameters: obstetric conjugate

The end points are the line closest to the bony point of the sacral promontory and the pubic bone next to the symphysis pubis. The standard measurement for this is 10 to 12 cm.

Mid-pelvis parameters: inter-spinous distance

The end points are the line between the closest bone points of the two ischial spines.

The standard measurements are 9 to 11.5 cm.

Pelvic outlet parameters: sagittal pelvic outlet diameter

End points: These are the closest bony points of the sacrococcygeal joint and the pubic bone next to the symphysis pubis. This is also called the obstetric anteroposterior diameter of the pelvic outlet. Standard measurements are 9.5 to 11.5 cm.

Pelvic outlet parameters: inter-tuberous diameter

The end points are the closest bony points of the ischial tuberosities.

Standard measurements are 10 to 12 cm.

Anatomy of the perineum

The trunk is divided into main abdominal and pelvic cavities above and the **perineum** below by the levator ani muscles (pelvic diaphragm). With the thighs abducted and/or in the lithotomy position, the perineum is the diamond-shaped space bounded anteriorly by the symphysis pubis, posteriorly by the tip of the coccyx and laterally by the ischial tuberosities. In the lithotomy position, the perineum may be divided into two separate triangles by an imaginary line drawn between the two ischial tuberosities

(lateral extremes) into a urogenital triangle in front and the anal triangle behind. The anal triangle is bounded posteriorly by the tip of the coccyx and on each lateral side by the ischial tuberosities. The anus/anal canal lies in the middle of the anal triangle with the ischiorectal/anorectal fossa surrounding it (lateral to the anal canal). The most anterior limit of the urogenital triangle is pubis symphysis and laterally by the ischial tuberosities.

Fasciae in the perineum

The superficial fascia of the urogenital triangle is divided into fatty and membranous layers. The fatty layer (a.k.a Camper's fascia) is continuous with fat of the ishiorectal fossa and the superficial fascia of thigh. In the scrotum, this fatty layer is replaced by smooth muscles called **dartos muscle**. The membranous layer (a.k.a Colle's fascia) is attached behind to the posterior limit of the urogenital triangle and laterally to the margins of the pubic arch. Anteriorly, this membranous layer of fascia is continuous with that of the anterior abdominal wall (a.k.a Scarpa's fascia), and also continuous over the penis/clitoris as a tubular sheath, while also continuous into the scrotum / labia majora as a distinct layer.

Urogenital diaphragm

This is a musculofascial diaphragm in the anterior part of the perineum. It fills the gap sustained by the pubic arch. The urogenital diaphragm is formed by the sphincter urethrae and deep transverse perineal muscles together with the fasciae (superior and inferior layers) covering these muscles. The inferior layer of fascia covering the urogenital diaphragm is also known as the **perineal membrane**. The closed space contained between the superficial and deep layers of fascia over the urogenital diaphragm is known as the **deep perineal pouch**.

The **superficial perineal pouch** is the space enclosed by the membranous layer of superficial fascia below and the urogenital diaphragm above. The superficial perineal pouch is closed laterally and posteriorly, but communicates with the potential space between the superficial fascia of anterior abdominal wall and the anterior abdominal muscles.

Contents of the superficial perineal pouch (males)

Root of penis *plus* bulbospongiosus, and ischiocavernosus muscles; superficial transverse perineal muscles; perineal body (serving as central point of attachment for all perineal muscles) and perineal branch of pudendal nerve.

Contents of deep perineal pouch (males)

The following structures are found in the deep perineal pouch of the males: membranous part of urethrae muscles; sphincter urethrae muscles; bulbourethral glands; deep transverse perineal muscles; internal pudendal vessels and the deep dorsal nerve of penis.

Contents of the superficial perineal pouch (females).

The contents of the superficial pouch include: root of the clitoris together with the muscles covering it; superficial transverse perineal muscle; perineal body and perineal branch of the pudendal nerve.

Contents of the deep perineal pouch (females)

These include: part of the urethra; part of the vagina (lower half); sphincter urethrae muscles; internal pudendal vessels and dorsal nerve of clitoris.

Episiotomy and related structures

Structures to look out for in the perineum during an episiotomy procedure are: Fourechette; internal pudendal artery and vein; pudendal nerve; external anal sphincter; Bartholin glands and ducts; transverse perineal muscles; perineal body and anus.

UNIT TWO

THE REPRODUCTIVE SYSTEMS

Female genital system

Functions of the female genital system.

The Functions of the female genital system include:

(1) Production of female gametes (ova) by oogenesis,
(2) Reception of male gametes, the spermatozoa,
(3) Provision of suitable environment for fertilization of ovum by spermatozoa,
(4) Provision of an environment for the development of the foetus,
(5) Provision of a means of expulsion of the developed foetus and
(6) Provision of nutrition of the newborn,

Introduction

The female genital system consists of internal and external parts. The primary organ of the female genital system is the ovary, which produces the female germ cells (ova) and also secretes the hormones estrogen and progesterone. Estrogen is the principal female sex hormone and among other things is responsible for: the development of secondary sexual characteristics (for example, breast development, broadening of hips, growth of pubic hair), and the development of glands, ducts of reproductive tract during puberty.

Structures forming the female genital system

(1) The ovary; like the testis, arises from the posterior abdominal wall (adjacent to the kidneys) during early foetal development it then descends along that wall, like the testis but becomes interrupted early in its "journey" by a pair of ligaments to ovary and uterus and is retained in the pelvis (unlike the testis). (2) The uterus serves as a site for implantation and nourishment for the embryo and foetus. (3) The uterine tubes serve as a vehicle for the conduction of the freshly fertilized ovum to the uterus and as a passageway for the spermatozoa to the ovum. (4) The vagina, a fibromuscular sheath that receives the semen from the penis and transmits it to the uterus and acts also as birth canal from the uterus to the outside for the newborn child. The above listed structures constitute the internal reproductive organs (ovary, uterine / Fallopian tubes, uterus and vagina) of the females. Although the ovaries and testis share a common origin, the uterus, its tubes and the upper two-thirds of the vagina arise from a duct system quite different from that in the male.

The female external genitilia

The female external genital structures include mons pubis, labia majora, clitoris, labia minora, prepuce of clitoris and frenulum of clitoris. The other structures are fourchette, vestibule/pudendal cleft, orifice of urethra, paraurethral glands, hymen, vaginal orifice, vestibular glands and perineal body. The mons pubis and labia majora share a common structure: that is the adipose and fibrous tissues. The smaller, more pigmented labia minora contribute to the cloak of the clitoris anteriorly and merge with the labia majora posteriorly as the fourchette. The cleft between the labia minora is the vestibule or pudendal cleft. The vestibule receives the orifices of the short

urethra, the vagina and the small ducts of the four vestibular glands.

The orifices of the urethra and vagina are normally closed/collapsed when not aroused sexually. The hymen is a layer of mucosa/mucous membrane that completely covers the vaginal orifice in the sexually uninitiated. The remnants of hymen are often retained by the sides of the orifice in the sexually active. The perineal body, deep to the skin, anterior to the anus is a fibromuscular mass serving as a central support for the uterus and other perineal structures.

Summary of the female external genitilia

The left and right labia minora are hairless, highly pigmented (often reddish or shades of brightly pinkish to red). The point of union of the left and right labia minora anteriorly marks the position of clitoris – erectile tissue whereas the point of union of the two labia minora posteriorly is the fourchette. The left and right labia majora are lateral, anterior and posterior characterized with the presence of hairs and lots of subcutaneous adipose tissues.

The internal genitilia

Functions – internal structures of the female genital system

The functions of the female internal genitilia are:

Production of female gametes (ova) by oogenesis;

Reception of male gametes, the spermatozoa;

Provision of suitable environment for fertilization of ovum by spermatozoa;

Provision of an environment for the development of the foetus and

Provision of a means of expulsion of the developed foetus.

Ovary

This is an almond–shaped organ about 4 x 2 cm in its breadth and length dimensions. It is surrounded by a thin fibrous capsule called tunica albuginea which is overlain by a germinal epithelium (simple squamous to simple cuboid).

Structure of the ovary

The ovary is divided into an inner medullary region highly packed with blood vessels, nerves as well as lymphatics and an outer cortex. The cortex is mainly made up of reticular and collagenous fibres. Many ovarian follicles in various stages of development can be seen through the tunica albuginea.

Position of the ovaries

The ovaries lie on the posterolateral wall of the pelvis in a depression on the anterior portion of the innominate bone called the ovarian fossa.

Support of the ovary

The ovary is supported by the suspensory ligament of the ovary (which transmits the ovarian vessels); the ovarian ligament which is a fold of connective tissue connecting the ovary to the uterus and an extension of broad ligament (the double fold of peritoneum on the lateral side of the uterus).

Functions of the ovary

Function: Produces ova, eostrogen and progesterone.

Histology of the ovary

The ovary is made up of an outer cortex, composed of a stroma full of reticular and collagenous fibres and developing follicles at different stages. Medulla or the middle portion, composed of stroma, blood vessels and nerves and a hilum where the blood vessels and nerves enter its parenchyma. The tissues of the ovary is protected by a thin fibrous tissue surrounding it referred to as tunica albuginea. The tunica albuginea is overlain by the germinal epithelium (simple squamous to cuboidal cells) that delineate the outer surface of the ovary from the surrounding peritoneum.

Ovary – when things go wrong!

Ovarian cysts are not uncommon conditions with the ovary. Cancers of the ovary are also on the rise.

Uterine tubes/oviduct/fallopian tubes

These are lateral extensions of the uterus. The uterine tubes connect the peritoneal cavity in the region of the ovary with the cavity of the uterus. They are shaped like an elongated funnel and divided anatomically into four parts namely;

- intramural; portion embedded in the wall of the uterus.
- isthmus; section just outside the surface of the uterine wall that is narrowest.
- ampulla; a highly dilated portion which extends beyond the narrow portion (isthmus) and
- infundibular region (infundibulum), the expanded lateral extremities which bears the fingerlike projetions/extensions called the fimbriae.

Fimbriae enclose the anterior and superior surfaces of the ovary, "catches" the discharged ovum and then whisks it into its cavity – the cavity of the uterine tube.

The infundibular part with the fimbriae resembles the hand of the upper limb.

Histology of the uterine tubes

A cross section through the tubes shows an inner lining of epithelial of the simple columnar ciliated type; a middle smooth muscular layer and an outer adventitia layer blending with the surrounding peritoneum. The lumen/cavity appears star-shaped in cross-section.

Functions of the uterine cavity

- Reception of ovum from ovary,
- Site for fertilization (ampulla),
- Provision of nourishment for fertilized ovum,
- Conduit for spermatozoa to reach ovum and
- Conduit for fertilized ovum / zygote to uterine cavity.

Clinical application

Uterine tube ligation is the tying off of the uterine tubes. This prevents the sperm from ascending into the tube and thus preventing fertilization. This is a surgical procedure and bilateral is required for effective result.

The uterus

This is a hollow pear-shaped structure with thick muscular walls. It measures 8 x 5 x 2.5 cm in nulliparous adults. The uterus has a neck at its inferior part called the cervix which fits into the upper part of vagina and a

relatively upper expanded parts called the *body* and *fundus.* The part of the body stretching beyond and between the sites of emergence of the uterine tubes is the fundus. *The body* of the uterus is bent forward (anteflexed) over the long axis of the cervix and at the same time tilted anteriorly (anteverted) over the superior surface of the urinary bladder, such that its cervix (inferior narrow part) creates a perpendicular angulation with the long axis of the vagina.

Anteflexion *is the forward bending of the long axis of the body of the uterus on the long axis of the cervix forming an angle of 170 degrees.*

Anteversion *is the forward bending of the uterus on the vagina forming an angle of 90 degrees.*

Backward bending / tilting (retroflexion / retroversion) of the uterus is not uncommon, particularly in women with high parity (given birth repeatedly). The retroflexion and retroversion positions are significant and may induce a variety of complaints from pain during sex to infertility. The cervix which is inferior, has thickest wall with a cavity through it called cervical canal. Uterine cervix is a fibroelastic area of the uterus which expands considerably during intercourse.

Just lateral to the cervix is the ureter *en route* to the bladder which passes close to the uterine artery. The cervical canal communicates with the uterine cavity through the *internal os* and with the vagina below through the external os. The *external os* in a nulliparous individual is narrow, hardly capable of accommodating the tip of a finger, but dilates greatly at term in a pregnant woman.

Histology of uterus

The wall of uterus is made up largely of smooth muscle called myometrium. Outside this muscular wall is the adventitial layer. The uterine cavity is lined with glandular layer of epithelium which is basically simple columnar. The epithelium of the cavity is of variable thickness called endometrium which is extremely sensitive to hormones estrogen/progesterone. During the reproductive phase of a woman, the endometrium is divided into three distinct histological and functional layers known as the ***basal, spongy and compact layers***. The basal layer is closest to the myometrium, compact facing the uterine cavity directly with the spongy layer wedged between the two. The compact and spongy layers collectively formed what is known as the **functional layer –** usually shed during menstruation.

The myometrium expands greatly during pregnancy by means of *hyperplasia* and *hypertrophy*. The myometrium protects and provides a mechanism of expulsion of foetus during parturition. **Myometrium is capable of contraction and retraction/relaxation during term**.

The neck of the uterus (cervix) fits into the vagina with the cavity of the vagina forming a circular trough around the cervix, called *the fornix of the vagina*.

Blood supply to the uterus

Blood reaches the uterus mainly through the uterine arteries, with other collateral supply from nearby arteries. The uterine artery enters the myometrium (uterine muscular wall) in the region of the cervix between two leaflets (layers) of the broad ligament. Histologically, the blood vessels run in the long axis of the myometrium, ensuring adequate perfusion of the thick muscular wall. Contraction of uterus during term, occludes the blood vessels

thereby shutting blood supply.

Retraction/relaxation therefore restores blood supply to the uterine wall. Atonic uterus (unable to contract) after birth may lead to postpartum bleeding.

Supports of the uterus

The main supports of the uterus are:

- Levator ani muscle (pelvic diaphragm / floor),
- Perineal body.

Other supports are condensation of pelvic fascia to form the:

- Transverse cervical (cardinal) ligament,
- Pubocervical ligament.
- Sacrocervical ligament,
- Broad ligament of uterus and
- Round ligament of uterus (*keeps the uterus in the anteverted and anteflexed position*).

Uterus – when things go wrong!

Weakness in integrity of especially levator ani and perineal body results in prolapse of the uterus.

Causes of loss of integrity of the supports may be;

(i) prolific childbirth

(ii) Episiotomy

(iii) Damage to nerves supplying these structures (pudendal) nerve) *Sheehan's syndrome during postpartum haemorrhage???- READ FURTHER ON THIS!*

Uterine cervix - clinical importance

The area just surrounding the *external os* is a boundary zone of epithelium constantly swinging between simple squamous and stratified columnar epithelium. Sample of cells from this transitional zone are taken for examination in cervical or Pap smears

To detect any changes of the mucosal lining and/or for the presence or absence of the human papilloma virus as a routine method of screening for cervical cancer. The procedure is named after Dr. Papanicolaou – a Greek physician and researcher who first made this discovery.

The vagina

The vagina is a fibromuscular canal that extends upwards and backward from the vulva to uterus. It is about 8cm long, with anterior and posterior walls. The walls normally collapse in a relaxed state to obliterate the lumen. The upper end of the anterior wall is pierced by the cervix. The cavity of the vagina therefore surrounds the uterine cervix, creating a trough around it called *fornix.* There are four fornices; anterior; posterior, right lateral and left lateral fornices. The deepest and most important fornix is the posterior fornix. Owing to the closeness of the peritoneal cavity (pouch of Douglas) to the posterior fornix, amateur abortionist usually thrust non-sterile instruments into *it* (posterior fornix) instead of the external os of cervix.

Relations of the vagina

Anteriorly: - Urinary bladder above, urethra below.

Posteriorly: - Pouch of Douglas (peritoneal cavity), ampulla of rectum, anal canal and perineal body.

Laterally: - Ureter, levator ani muscle.

Vagina and Bartholin glands

Bartholin's glands (greater vestibular glands) are paired pea-sized exocrine gland (compound alveolar), located slightly posterior and to the left and right of the opening of the vagina. The gland is located in the superficial perineal pouch, (*unlike the bulbourethral glands in the males found in the deep perineal pouch*). The ducts of Bartholin's gland open on the surface of the vulva. The gland is basically for the production of mucoid secretion that aids in vaginal and vulvar lubrication. The gland and or its duct may be blocked and inflamed, with pain in Bartholinitis or a Bartholin's cyst. Bartholin's gland could also become hyperactive with excessive secretion of mucus.

The vagina – clinical importance

Pus in the peritoneal cavity may be drained through the posterior fornix with a needle without necessarily going thru surgery (culdocentesis). Sigmoid colon, rectum and canal may be palpated through the posterior fornix.

Female reproductive system - clinical application.

Anatomical knowledge on the structures of the internal structure of the female genital system may be used to interpret *hysterosalpingograms*. ***Paracentesis/Culdocentesis*** is the surgical means of drainage of accumulated fluid / blood or pus from the peritoneal cavity.

Applied anatomy/clinical correlations: vaginal and speculum examination

(1) Speculum Examination

Normally a speculum examination should precede digital examination so that the vaginal walls may be seen before they have been disturbed by the examiner's fingers.

The patient lies in the supine or left lateral position. In the supine position the patient's hips and knees are gently flexed, the feet placed together and the knees separated. The vulva, labia and perineum are first inspected. A lubricated bivalve speculum may be introduced in either the supine or left lateral position. The labia minora are parted with the fingers of the left hand while the right hand introduces the tip of the speculum through the introitus (vaginal orifice). This is introduced to its full length and when opened retracts both the anterior and posterior vaginal walls to expose the cervix. Gentle rotation of the speculum enables the 4 walls and fornices to be examined thoroughly.

2) Vaginal / Digital examination

It is normal practice to do a bimanual examination. The labia are parted by the thumb and middle finger of left hand while the index finger of the right hand is gently introduced into the vagina. If this is easily accommodated, the middle finger may also be introduced. The vaginal wall is palpated and then attention focuses on the cervix and its *external os*. The left hand is then placed on the lower abdomen. The fingers of the right hand are placed in the anterior fornix and the uterus is palpated between the left and right hands. The lateral fornices are examined next. A normal ovary may often be felt but the tubes are only palpable if thickened by diseases. The posterior fornix is next examined for abnormalities in the pouch of Douglas. Rectal examination may reveal additional information.

Facts to remember – female genital system

The posterior fornix is directly related to the pouch of Douglas - a careless instrumentation may therefore have serious consequences. The ureters lie adjacent to the lateral fornices. It would be theoretically possible to palpate

ureteric stone at these sites. The vagina slopes upwards and backwards. In the child or virgin, rectal examination may be more practical and rewarding than bimanual examination. When inserting the speculum, it should be passed along the posterior vaginal wall to avoid trauma to the urethral meatus and urethra.

The mammary gland - anatomy of the female breast

The breast is one of two prominences located on the upper ventral region of the torso. Anatomically and structurally, it can be considered as an appendage of the skin. In females, breast serves as the **mammary gland** which *produces* and *secretes* milk and *feeds* the new born. Breasts overlay the pectoralis major muscle. It is predominantly tear-shaped (roughly conical). Its base extends from the level of the 2^{nd} rib to the 6^{th} rib in front of the thoracic cage. The breast extends from the middle of the sternum to the axilla (armpit), forming the axillary tail of breast. The breast can reach as far as the latissimus dorsi muscle at the back. There exist a retromammary space which is a plane of loose connective tissue that separates the breast from underlying fascia of the pectoralis major muscles. Retromammary space allows movement of the breast on the thoracic wall. Histologically, breast is predominantly composed of **adipose tissue** and **glandular tissue**. Its superficial tissue layer (superficial fascia) is separated from skin by about 0.5 to 2.5 cm of subcutaneous fat (adipose tissue). There are fibrous tissue prolongations that radiate from the superficial fascia (called suspensory Cooper's ligament), to the dermis of skin. The breast may also be regarded as an **apocrine gland** (i.e a *modified sweat gland*) that produces milk used to feed infant.

Breast is composed of connective tissue (collagen & elastin). Each breast has

15 to 20 sections called lobes that are arranged like petals of a daisy. Each lobe has many smaller lobules, which end in dozens of tiny bulbs that can produce milk. The lobes, lobules, and bulbs are all linked by thin tubes called lactiferous ducts. These ducts lead to the nipple in the centre of a dark area of skin called the AREOLA. Deep to the areola, each duct has a small dilated portion called the lactiferous sinus. The areolar region contains modified sweat glands known as Montgomery's glands. These glands form bumps at the nipple called Montgomery's tubercles. Montgomery glands secrete oily fluid that lubricate and protect the nipple during breastfeeding, fat fills the spaces between lobules and ducts. The lobes, lobules and ducts form the **breast parenchyma**. The fibrous framework that separates the lobules and supports the lobes forms the **breast stroma**. There are no muscles in the breast, but muscles lie under (inferior to) each breast and cover the ribs. Each breast contains blood vessels and vessels that carry lymph. Lymph vessels lead to small bean-shaped organs called lymph nodes. Clusters of lymph nodes are found under the root of the arm, armpit (AXILLA), above the collar bone, and in the chest. About three-quarters of lymph from breast travels to the axillary lymph nodes while the remaining one-quarter travels to the parasternal lymph nodes. Sensation of the breast is from the peripheral nervous system by means of anterior and lateral cutaneous branches of the 4^{th} to 6^{th} intercostal nerves. These peripheral nerves relay all sensations from the breast to the central nervous system. The **T4 spinal nerve** supplies sensation to the nipple-areola complex of the breast.

Male genital system

The male genital system comprises the testes and epididymis which are

contained in the scrotum; the vas deferens/ ductus deferens which are contained in the spermatic cord in part of their course; the seminal vesicle; the ejaculatory duct; the prostate gland; the bulbourethral glands and the penis. All these are paired, except the scrotum and the penis. Scrotum and penis (phallic part) are collectively called the external genitilia.

The testis

It is the primary sex organ in the male. The testis is a firm, tough organ lying within the scrotum. The left testis lies at a lower level than the right. Each testis has superior and inferior ends (upper and lower poles), medial and lateral surfaces, anterior and posterior margins. Apart from production of spermatozoa, it is also endocrine in function – secrets a hormone that is responsible for male secondary sexual characters.

Histology of the testis

Each testis is surrounded by a tough, fibrous connective tissue capsule called the **tunica albuginea**. Extending from the inner surface of the capsule are series of fibrous septa that divide the interior of the organ into lobules. Lying within each lobule are one to three coiled tubules called **seminiferous tubules.** Each loop of the seminiferous tubules is drained via a **straight tubule** into a network of channels called the **rete testis**. Small **efferent ductules** connect the **rete testis** to the **upper end of the epididymis**.

Rete testis

This is an anastomosing network of seminiferous tubules. All the seminiferous tubules appear to start and end at the rete testis. The rete testis forms a kind of anatomical valve to prevent backflow of spermatozoa. It is found at the hilum of the testis (mediastinum testis). Found between the seminiferous tubules are blood vessels, lymphatics and groups of rounded interstitial cells called **Leydig cells** which produces the hormone **testosterone**. The epithelium of the seminiferous tubules has a basement membrane on which lie **germinal cells called spermatogonia** and sustentacular or **Sertoli cells**. Between adjacent Sertoli cells are found **tight and gap junctional complexes** which constitute a **blood-testis-barrier**. The sustentacular / Sertoli cells are involved in (i) maintenance of the bloodtestis-barrier and (ii) supporting mitosis and meiosis upon the activation/reception of follicular stimulating hormone (FSH) stimulation.

Passageway of spermatozoa in the testis

From seminiferous tubule to straight tubules. Then from the straight tubules to rete testis. From rete testis to efferent ductules and then from the efferent ductules to epididymis.

Testis: when things go wrong!

(Failure of testis to descend is known as cryptorchidism). When testis descended at an anomalous site, eg developed/stopped in the perineum or elsewhere apart from in the scrotum, then they are referred to as ectopia testis.

Hydrocoele testis is a collection of fluid in the serous cavity of the scrotum. This may be congenital due to the persistence of a communication between processus vaginalis and peritoneal cavity.

Clinical correlations (applied anatomy)

ASPIRATION OF A HYDROCOELE

The patient lies in the supine position and the extent of the hydrocoele is confirmed. The relative positions of the testis and hydrocoele are shown by palpation and trans-illumination. Trans-illumination may also reveal large superficial scrotal vessels which are best avoided by the trocar and cannula. The hydrocoele is usually anterolateral to the testis. The scrotum is held in the left hand and is compressed sufficiently to tense the hydrocoele. A fine trocar and cannula are then introduced, passing through the layers of the scrotum and into the hydrocoele.

Precautions/ facts to remember **(in aspiration of a hydrocoele testes)**.

Define the position of the testis before tapping. This will avoid injury to the testis and epididymis. After tapping the hydrocoele, the procedure is NOT complete until the testis has been re-examined.

The Epididymis

This is a firm C – shaped structure lying **posterior** to the testis with the **vas deferens** on its **medial side**. It has an upper expanded end, the **head**, a **body** and a pointed **tail** inferiorly. **Laterally,** there is a distinct groove between the

testis and the epididymis called the **sinus of the epididymis**. The epididymis is a much-coiled tube nearly **6m long**, embedded in connective tissue. The tube emerges from the **tail** of the epididymis as the **vas deferens**, which enters the ***spermatic cord***.

Epididymis – functions

It is for **storage** of spermatozoa and thus facilitates sperm **maturation**. Also involved in the **absorption of fluid** – maintains fluid composition of seminal fluid and **recycles damaged sperms**.

Vas / Ductus deferens

This is a thick–walled tube (45cm long), that conveys mature sperm from the epididymis to the ejaculatory duct and the urethra. It is made up of 3 layers namely; a mucous membrane, (which epithelium is pseudostratified columnar), a muscular coat – inner and outer longitudinal layers of smooth muscles together with a **middle circular layer** and an adventitia.

The vas deferens arises from the lower end or tail of the epididymis and passes through the inguinal canal. It is surrounded by the pampiniform plexus of veins and forms part of the contents of the spermatic cord. The vas deferens continues upward from the superior end of the testis to the superficial inguinal ring, where it can be felt between thumb and index finger. It passes through the inguinal canal and emerges from the deep inguinal ring by passing around the lateral margin of the inferior epigastric artery. It then passes downward and backward on the lateral wall of the pelvis and crosses the ureter in the region of the ischial spine, where it runs on the posterior surface of the urinary bladder. The terminal part of the vas

deferens is dilated to form the ampulla of the vas deferens. The inferior end of the ampulla narrows down and joins the duct of the seminal vesicle to form the ejaculatory duct.

Vas / ductus deferens – clinical correlation

Vasectomy is usually performed by sectioning or ligating the ductus / vas deferens. Bilateral procedure is best. Although vasectomised male is sterile, he is able to engage in normal sexual activities and does not show signs of male hormone deficiency since the normal activity of the testis is not impaired in this procedure.

Seminal vesicle

These are two sacculated pouches that produce a large part of the semen. Each is much coiled tube with several diverticula (short branching). It is about 5cm long, lies on the posterior surface of the urinary bladder. Their broad ends of this organ are directed laterally, upwards and backwards. With their narrow end closely approaches that of the opposite vesicle. The seminal vesicles are embedded in a dense sheath, consisting of smooth muscle and fibrous tissue. Their lower ends are separated from the rectum by the rectovesical septum. The terminal parts of the ureters and ampullae of the ductus deferens are **medial** to the vesicles. The prostatic and vesical venous plexuses are **lateral to the vesicles**. **Inferiorly**, each seminal vesicle **narrows** and ***joins*** the vas deferens of the **same side** to form the **ejaculatory duct**. The seminal vesicle can be palpated per rectum when bladder is full.
The seminal vesicles are very sensitive to pressure when full.

Seminal vesicle – histology

Histologically, the seminal vesicle is nothing but simple tubular gland. It has mucosa, consisting of a lining interspersed columnar cells and laminar propria and a thick muscular wall. The lumen is highly irregular (giving an honeycomb-like appearance under low power view). Its epithelium is pseudostratified columnar.

Seminal vesicle – function

It contains fructose to feed sperm. Contains prostaglandins to stimulate smooth muscle contraction and also contains fibrinogen to clot semen.

Ejaculatory duct

This is formed by the union of the ductus deferens and the duct of the seminal vesicle. The two ejaculatory ducts pierce the posterior surfaces of the prostate gland to open into the prostatic part of the urethra.

Function

Its function is to drain the seminal fluid into the prostatic urethra.

Prostate gland

Prostate gland is a fibromusculo-glandular tissue. The prostate gland has no capsule but a fibromuscular band surrounding it. This gland is a walnut-sized structure, located between urinary bladder and penis. The gland is found just

anterior to (in front of) rectum. While urethra runs through its centre, letting urine from bladder to the penis out of the body. Its secretory epithelium is mainly pseudostratified columnar. The Stroma/parenchyma is of fibro-elastic fibres (connective tissue) and randomly oriented smooth muscle fibres.

The prostate gland is made up of three types of histological cells; namely: glandular, myoepithelial and subepithelial cells. The substance/parenchyma of the gland is divided into zones/lobes by the traversing urethra and the two ejaculatory ducts. These lobes are the anterior, posterior, right and left lateral and the median/middle lobe.

Prostate function

The prostate gland is involved in: (i) expulsion of semen from urethra (its stimulation also leads to orgasm), (ii) secretion contain simple sugars, alkaline in nature, and contains proteins for nourishment and enzymes, and (iii) vital for survival of sperm. The growth and function of the prostate gland is regulated by male hormones.

Prostate – clinical correlations

Benign prostate hyperplasia (BPH), is fairly common in men after the middle-ages. Other prostate conditions include: prostatitis and prostate cancer. The prostate gland is easily palpated and physically examined through the rectum.

Prostate – anatomical facts!

The prostate gland weighs about 11grams, ranging from (between 7g and 16g). The formula for its volume estimation is 0.52 x L x W x H; (*where L, W and H*) represent the length, weight and height of the organ). A volume greater than $30cm^3$ is regarded as prostatomegaly.

Bulbourethral gland

These are rounded structures, about 0.5 cm in diameter, situated on each side of the median plane. They are embedded in the substance of the sphincter urethrae, behind (posterior to) the membranous part of the urethra in the deep perineal pouch. These paired tiny glands secrete a mucus-like substance in the form of an alkaline lubricant into bulb of the penis. Their ducts end by opening into the lower aspect of the spongy part of the urethra.

The spermatic cord

This is a collection of structures that pass through the inguinal canal and pass to and from the testis. The spermatic cord begins at the deep inguinal ring lateral to inferior epigastric artery and terminate in the scrotum. It is covered with 3 concentric layers of fascia derived from the anterior abdominal wall namely; external spermatic fascia, cremasteric fascia and internal spermatic fascia.

The constituents of the spermatic cord include: (1) vas deferens, (2) testicular artery (3) testicular vein, and (4) testicular lymph nodes (5) autonomic nerves (6) remains of processus vaginalis. The rest are (7) cremasteric artery

(8) artery of vas deferens and (9) genital branch of genitofemeral nerve.

The penis

The penis consists of three bodies of erectile tissue, ensheathed in two layers of fasciae. These erectile tissues are the corpus cavernosum (corpora cavernosa): the two lateral bodies which arise from the underside of the pubic bone and a central corpus spongiosum that also originates from the urogenital diaphragm. It is through the bulb of the penis that the urethra passes from the prostate and urogenital diaphragm above. The three erectile bodies are bound together in a dense stocking of deep perineal fascia and hung as a unit suspended by the suspensory ligament.

The hidden part of the penis located deep in the perineum is the root. The root of penis comprises central bulb (corpus spongiosum part) and the left and right crura (crus – singular). The bulb arises from the urogenital diaphragm while the crura arise from the inferior pubic rami. Two skeletal muscles, bulbospongiosus and ischiocavernosus overlie the spongy tissues of the bulb and crura respectively. These skeletal muscles contract to stabilize an erected penis and with the bulbospongiosus particularly involved in emptying the last drop of semen or urine upon contraction.

Histologically, the erectile tissues consist of tiny lakes of veins called cavernous sinuses bound by fibroelastic tissue/capsule. These sinuses are fed by small branches of deep arteries to the penis. During sexual activity, these arteries dilate and the volume of blood entering the sinuses increases by expanding them (sinuses). As a result, the small veins, normally draining the cavernous sinuses, are pressed against the capsule of the erectile bodies and blood cannot be drained from them. The penis therefore enlarges, and

becomes rigid (erection). The glans penis however, does not incorporate a thick capsule, therefore as the arterial input increases, so does the venous drainage, and the glans remains non-rigid (flaccid). A rigid penis is generally required for vaginal penetration, therefore inability to achieve erection constitutes impotence.

Erection

This is enlargement of penis/clitoris which is under the influence of parasympathetics (nevi erigentes). Erection is brought about by spinal reflex, initiated primarily by touch receptors in the glans penis, which is richly supplied by tactile receptors. The immediate cause of erection is the abrupt vasodilation of the penile blood vessels. The physiological mechanism involves a relaxation of the smooth muscle in the walls of the arteries supplying the cavernous spaces. Following orgasm, the sympathetics take over, and the arteries become constricted, arterial flow is reduced and the penis/clitoris gradually returns to its flaccid condition.

Penis – when things go wrong!

The roots of the penis are the main structures occupying of the urogenital portion of the perineum in males. In the event of extravasation (leakage) of urine, the arrangement of fascial layers directs the accumulation of urine towards the anterior abdominal wall and around the penis but not into thigh or buttocks.

Summary of the reproductive system

MALE HOMOLOGY	FEMALE HOMOLOGY
Testis	Ovary
Penis	Clitoris
Scrotum	Labia majora
Ventral Penis	Labia minora
Spermatogonia	Oogonia
Seminiferous tubules	Ovarian follicles

UNIT THREE

RENAL / URINARY SYSTEM

Function

The renal system is involved in:

- Removal of waste products from the circulatory system,
- Regulation of blood pH,
- Regulation of ion balance (keeps the balance of minerals/ions in the blood),
- Regulation of water balance (cleans blood of excess water) – helps control blood pressure) and
- Helping to make red blood cells.

(*Thus, in a nutshell, they renal system is involved in homeostasis*).

Kidneys – summary of function

The kidneys basically filter, secrete and re(absorb). They are involved in homeostasis of blood and tissue fluid (cleaning/filtration); secretion of renin; secretion of erythropoietin; conversion of vitamin D to active forms and synthesis of glucose.

Kidneys

Kidneys are generally smooth-sided, reddish-brown organs (11cm in length). They are retroperitoneal and lie anterior to the quadratus lumborum on each side of the vertebral column (T12 – L3).

Relations of the kidneys

The right kidney lies anterior to 12th rib, slightly lower than the left. The right kidney lies posterior to: right suprarenal gland, liver, descending part of duodenum and right colic flexure.

Left kidney

The left kidney lies anterior to ribs 11 and 12 but is also situated posterior to the left suprarenal gland, spleen, tail of pancreas and left colic flexure.

Coverings of the kidney

Renal capsule: this is a tough fibrous layer surrounding the kidneys. This is followed by the perirenal fat (perinephric fat), which is an accumulation of fat overlying capsule. The renal fascia (Gerota fascia) which is a membranous condensation of extraperitoneal fascia lies outside or lateral to the perirenal fat. The renal fascia surrounds each kidney and its associated suprarenal gland, renal vessels, ureter and the capsule of perirenal fat. Pararenal fat accumulates posterior and posterolateral to each kidney, just next to parietal peritoneum.

Gross appearance of the kidneys

The lateral edge of each kidney is smooth and convex while its medial edge has a vertical hilum. The hilum pierced is by renal vein, renal artery and renal pelvis. The hilum expands inside the kidney as the renal sinus. At the hilar region, renal vein is most anterior, renal pelvis/ureter is most posterior

while renal artery is found in between the two structures. Each kidney has superior and inferior poles, anterior and posterior surfaces.

Kidney - fine structure

Histologically, the kidney is made up of an outer cortex and inner medulla and consists of about two million functional units called the **nephrons or renal tubules.** Its c**ortex** lies deep to the renal capsule and extends into the medullary region as the **renal columns.** The medulla is arranged in renal pyramids. A renal pyramid has a base facing outward and the apex fitting into a cup-shaped minor calyx. Up to 11 minor calyces merge to form **two or three major calyces**, which continue to form **the renal pelvis.**

Nephron – the functional unit of the kidney

One end of a nephron terminates blindly, the other empties into a collecting tubule, which is an excretory duct that conducts urine to a minor calyx. The blind end of each nephron is invaginated by **capillaries** to form a double–layered **glomerular capsule**. The convoluted tuft of capillaries is termed the **glomerulus**, whereas the **capsule and glomerulus** together are termed a **renal corpuscle.**

Glomerular filtration barrier

The glomerular filtration barrier is formed by: capillary endothelium, glomerular basement membrane and the visceral endothelium (podocytes).

Nephron – functions of various parts

Renal corpuscle – this is involved in selective filtration (formation of filtrates takes place here). **Proximal convoluted tubule** – rapid reabsorption of filtrates back to bloodstream (70%). **Loop of Henle** – concentration of filtrates and responsible for water conservation. **Distal convoluted tubule** – "fine tunes" the filtrate, reabsorbing solutes such as sodium and secreting solutes such as potassium. The proximal convoluted tubule (PCT) is the longest, most coiled, has simple cuboidal epithelium with brush border. The nephron loop is U shaped with descending and ascending limbs. This loop has a **thick segment, lined with** simple cuboidal epithelium and **thin segment** with simple squamous epithelium, and is very water permeable.
The distal convoluted tubule (DCT) is lined with cuboidal epithelium.

Blood supply

A single renal artery, a direct branch of the abdominal aorta at the level of L2 vertebra, normally supplies each kidney. The right renal artery is longer than the left artery and passes posterior to inferior vena. Renal artery divides near hilum to anterior and posterior segmental arteries.

Further subdivisions of the renal artery in the substance of the kidney are: segmental, lobar, interlobar, arcuate, cortical/interlobular, afferent glomerular arteriole and efferent glomerular arteriole.

Venous drainage of the kidneys

From glomerulus to **efferent arteriole** then to **interlobular vein** then to **arcuate vein** to **interlobar vein** to segmental vein (***often reported to be***

absent) and then to the **renal vein.** A single renal vein from each kidney drains into the inferior vena cava. Both renal veins receive a tributary from the ureteric veins. But only the left renal vein receives blood from the ***left suprarenal and left gonadal*** veins. On the right ***these veins*** drain directly to the inferior vena cava. The left renal vein is longer than the right one and it (left renal vein) passes anterior to the aorta immediately inferior to the origin of the superior mesenteric artery **(SMA).** Left renal vein is prone to renal entrapment (nutcracker syndrome). The longer length of the left renal vein makes the left kidney the preferred choice for organ donation.

Innervation of the kidney

The kidneys are innervated by the sympathetic nerves derived from T12 – L1 spinal nerves. Parasympathetic innervation is provided by the Vagus nerve (CN X).

Renal/kidney variations

The following types of kidneys also do exit: horse-shoe kidney, single kidney and situations with multiple renal veins.

Clinical application: kidney function- renal hypertension

In many kidney diseases, blood flow through the organ is compromised. The ischaemic kidney reacts by secreting the enzyme, renin, which *activates* a plasma protein fraction called angiotensin I. Angiotensin I is converted by another enzyme into angiotensin II, which is a powerful vasoconstrictor.

(Note: ***angiotensin is a peptide hormone***). The presence of angiotensin II in the body causes a narrowing of arterioles over the entire body. The resulting high blood pressure (renal hypertension) ensures a continuance of a sufficiently high blood pressure for producing an adequate volume of urine. In this way, the needs of the kidney are met, but at the price of chronic high blood pressure. ***NB: Angiotensin also stimulates the secretion of aldosterone from suprarenal cortex.***

Kidneys - clinical applications

Uraemia is defined as the accumulation of urea in the blood. Uraemia is an indirect or a direct measure of kidney function. Urea is an end-product of proteins (waste) which is being filtered and removed by the kidneys. Urea level is easily measured in the blood. A rise above normal is an indication of kidneys not functioning efficiently.

Causes of uraemia

Loss of blood: this will lead to drop of pressure in the arteries in the Bowman‟s capsule, and as such, there will be little or no urine at all produce, leading to an accumulation of urea in the blood. **Excessive loss of plasma and serum:** a severe loss of the fluid part of blood would mean, there would be little or no fluid in the blood to be filtered in the Bowman‟s capsule, and only very little urea will be filtered with the greater bit being accumulated in the blood. For example, as in severe burns, chronic diarrhea and vomiting. **Severe infections** which lead to blood poisoning may also lead to uraemia.

Kidney function and the creatinine test

Clinically, uraemia in most instances, uaemia investigation comes in the form of **creatinine test**. Creatinine test is basically a measure (direct or indirect) of kidney function. The creatinine test measures creatinine levels in blood and/or urine. Creatinine is a waste product made by muscle metabolism. Kidneys filter creatinine from blood and send it out through urine. If there is a problem with the kidneys, creatinine builds up in blood and less is released in the urine. High levels of creatinine in blood and low levels in urine indicate kidney disease or another condition that affects kidney function. Creatinine test is often ordered along with another kidney test called blood urea nitrogen (**BUN**) or as part of a comprehensive metabolic panel (**CMP**) test.

Clinical correlations

(1) Kidney stones (nephrolithiasis) – causes, signs and symptoms. Causes could be genetic predisposition or dietary (hypercalcemia). Most kidney stones are 80 – 90% are radiopaque (Ca oxalates); uric acid stones not visible on radiographs. Presentations are usually of sudden onset with pain along the flanks and back. Wave-like pain with pain frequently disappearing and resurfacing. Often with tenderness at the costophrenic angle. There may or may not be an associated haematuria. (2) Urinary tract cancer: This may be transitional cell tumours or renal cell tumours. (3) Other clinical considerations involving the kidneys include: Hydronephrosis; nephroptosis; nephrostomy; nephrectomy; nephrolithotomy and kidney transplant.

Anatomy, physiology and pathology of urine

Anatomically urine is considered as the main excretory product excreted by the kidney. It contains waste products which are largely large numbers of organic and inorganic substances.

Characteristics of normal urine include; **volume**: of about 1500 – 2000ml per day and **pH:** ranging between 4.5 and 8.2

Physiological (normal) urine

This is described as urine that contains a balance of organic (uric acid, urea, creatinine, ammonia) and inorganic (sodium, potassium, phosphates, and sulphates) substances.

Pathological urine (abnormal)

This is urine that contains substances essential to the body‟s cells and tissues (sugar, salts, proteins, albumin etc), in addition to normal organic and inorganic substances.

Abnormal constituents of urine

(1) Sugar (glucose): This type of urine is said to be associated ailment such as glycosuria and or diabetes mellitus.

(2) Ketone bodies: These tend to be associated with ailments which include: ketouria/diabetes mellitus, hepatomegaly, carbohydraturia and starvation.

(3) Albumin This is thought to be associated with such conditions as

proteinuria, and in some rare cases liver disease as well as cases of severe exercise, high protein meal,and nephritis.

(4) Bile pigments: This is linked to ailments such as jaundice and hepatitis.

(5) Blood: Known clinically as haematuria; causes may be traced to acute inflammation of urinary organs, tuberculosis, haemolytic jaundice and others.

(6) Pus: Commonly associated with conditions such as pyuria; inflammation of the urinary bladder, urethra, and kidney.

Investigation of the urinary tract

Intravenous urogram (pyelogram), ultrasound, computed tomography and nuclear medicine.

Assignment

Which part of the kidney and how do the following hormones fit into the functions of the kidneys? **Aldosterone; angiotensin II** and **renin.**

Ureters

These are long (25 – 30cm), retroperitoneal, paired muscular tubes. Ureters transports urine from the renal pelvis of kidney to urinary bladder. They are found descending from the posterior abdominal wall (on the psoas major) and become pelvic structures after crossing the bifurcation of the common iliac arteries (CIA). In the abdomen, the ureters are crossed anteriorly by the

gonadal vessels. Anterior to the internal iliac arteries in the pelvis in **males**, the ureters lie posterior to the ductus deferens which crosses it superiorly near the urinary bladder whereas in the **females**, they lie medial and inferior to the uterine arteries which cross it anteriorly and superiorly in the **base of the broad ligament.**

Ureteric constrictions

Ureter has three constrictions or narrowing along its length. These are located at:

(1) ureteropelvic junction, (2) pelvic inlet and (3) ureterovesical junction.

Ureters – innervation and blood supply

Innervation is by autonomic nerve plexuses along their path to the bladder: these are the renal; aortic; superior and inferior hypogastric plexuses. There are vascular anastomosis of several blood vessels along its length: in the abdomen arteries include branches from aorta, renal, gonadal and common iliac. Branches from the superior vesical, inferior vesical and uterine arteries supply the pelvic part. Venous drainage accompanies the arteries and empties towards the iliac veins. Lymphatic drainage is to the common iliac, external iliac, internal iliac and lumbar lymph nodes.

Ureters – histology

As a muscular tube, its wall is in coats or layers. The muscular coat is made up of two layers: an inner longitudinal and outer circular muscle fibres. While its mucosal or inner layer in contact with the lumen is lined by

urothelium (transitional epithelium). Epithelium sits on lamina propria. The third and outermost coat/layer is the adventitia. In cross-section, the lumen has a somewhat distorted star-shaped appearance.

Urinary bladder

This is a m**uscular** hollow organ, lined with **epithelium** for storage of urine. Its shape, size and position vary with age and the amount of urine it contains.

Position and shape

The empty urinary bladder lies entirely or almost entirely within the pelvis, and rests on the pubis and the adjacent part of the pelvic floor. As the bladder is being filled with urine, it gradually rises into the abdomen, reflecting the peritoneum upwards and it may reach the level of the umbilicus at times.

Parts of the urinary bladder

The empty bladder has four surfaces; a superior, two infero-lateral and a posterior. The posterior surface is also called the fundus or base of the bladder. The superior and two inferolateral surfaces meet anteriorly at the **apex**. The two inferolateral surfaces meet inferiorly at the **neck**. Portion of the urinary bladder between apex anteriorly and base posteriorly is called the **body**.

Urinary bladder and peritoneal covering

The superior surface and upper part of the base are covered by peritoneum. As the bladder fills and rises into the abdominal cavity, peritoneum is lifted away from its superior surface and then reflected unto the lower part of the anterior abdominal wall. Posteriorly, the peritoneum is reflected onto the uterus in the female (to form the vesico-uterine pouch) and on to the rectum in the male to form the rectovesical pouch.

Urinary bladder – relations

The superior surface of the bladder is related through the peritoneum to the coils of the small intestine or to the sigmoid colon. In the female, the body of the uterus is above the bladder ***when it (bladder) is empty***. The inferolateral surfaces and the rounded margin between them lie adjacent to the **retropubic space** which contains retropubic **pad of fat, and plexus of veins**. The base of the urinary bladder (in males) is downward and related to the **seminal vesicles** in the **lateral part** and also to **ampullae of vas deferens** and **rectum** on the **lower medial sides.** In the female, the base is connected by loose fibrous tissue with the anterior wall of the vagina below and with the supravaginal part of the cervix.

Urinary bladder and its attachments

The neck of the urinary bladder is the least mobile part. It is firmly anchored to the pelvic diaphragm. In the male, it (the **neck**) is continuous with prostate gland. In the female, the neck is lower than that of the male and it rests on the pubococcygeal parts of the levator ani. Three ligaments help fix the

bladder; (1) medial pubovesical, (2) lateral pubovesical and (3) lateral ligament of bladder. (**All are local thickenings of the superior fascia of the pelvic diaphragm**).

The interior of the urinary bladder

The mucous membrane of the greater part of the empty bladder is thrown into folds, but the mucosa covering the internal surfaces of the base of the bladder between the openings of the urethra and two ureters is always smooth and flat and is referred to as the trigone. The smooth muscle fibres which form the wall of the bladder is known as the **detrusor** muscles. The fibres of the muscular wall are arranged in outer longitudinal, middle circular and inner longitudinal. The epithelium lining the inner aspect of the bladder is known as urothelium or transitional epithelium.

Urethra

The urethra is a **tubular passageway**, **arising from the neck** of the urinary bladder inferiorly and traverses the **pelvic floor** as well as passing through the **perineum,** before voiding urine out of the body through the external urethral meatus. It is lined with specialized type of **epithelium called urothelium or transitional epithelium**. The male urethra is roughly 20 cm long and divided into three parts; (1) prostatic urethra passing the prostate gland, (2) membranous urethra – in the urogenital diaphragm and (3) spongy or penile urethra in the penis. The penile urethra runs through the corpus spongiosum portion of the penis. It is the longest and most curved part of urethra and opens to exterior through the external urethral meatus/orifice.

The part of the penile urethra in the glans is dilated to form the **navicular fossa** before opening to the exterior through the **external urethral meatus**.

The entire male urethra is sigmoid in shape.

Female urethra

The female urethra is about 3.8 cm long. It extends from the neck of the urinary bladder to the external urethral meatus where it opens into the vestibule below the clitoris (2.5 cm below). It passes through the sphincter urethrae and lies immediately anterior and superior to the vaginal orifice. At the sides of the external urethral meatus are openings of the ducts of the paraurethral glands. The female urethra is wider and more dilatable than that of the males.

Clinical correlations - urethral catheterisation

During this procedure, the patient lies supine. A right-handed operator stands on the patient‟s right side and holding the penis in his/her left hand, carefully retracts the prepuce (if present). The penis is held erect at right angles to the anterior abdominal wall and the lubricated catheter is passed through the narrow external orifice. Easy passage in the spongy part, but resistance at the membranous portion. Deep respiration to relax the patient and the sphincter is required or light, general anaesthesia is required. The catheter then passes through the membranous and prostatic urethra and into the urinary bladder. Catheterisation in females is much easier because urethra is shorter, wider and more dilatable.

(2) **Cystoscopy** – (*Done almost in the same way as catheterisation*) **(3)**

Suprapubic puncture

This technique not only enables uncontaminated urine to be obtained for analysis but also can provide an alternative site of catheterisation. Bladder must be full first of all; this must be confirmed by palpation and percussion. This ensures that the needle does not pass inadvertently through the peritoneal cavity. In the adults, site of puncture is the midline through linea alba (**must avoid pyramidalis and rectus abdominis if truly midline**). The needle is introduced 4–5cm above the pubic symphysis and directed slightly caudally. Needle may be felt to enter the bladder with a distinct "give" sound and urine sample obtained or a catheter introduced.

Precautions / things to remember

With these procedures/techniques, replace prepuce after procedure (1) above, otherwise paraphimosis may result thereafter. Do not attempt to force a reluctant catheter/ cystoscope as false urethral passage may be made. Suprapubic puncture of pregnant women near term is complicated by the compression of urinary bladder by gravid uterus (this must be avoided in pregnant women).

Urethra - when things go wrong! extravasation of urine

This is the leakage of urine into surrounding tissue outside the urethra. This occurs most frequently following rupture of the membranous portion of the urethra. Such damages may also affect the bulb of the penis and urine escapes through the superficial perineal pouch into the subcutaneous perineal cleft. Urine then passes anteriorly to reach the anterior abdominal wall, into

the scrotum/labia majora, around penis / clitoris. Urine does not pass down the thigh because of attachment of deep fascia to inguinal ligament and ischiopubic rami. It does not also pass posteriorly because of fusion of superficial fascia to posterior border of the urogenital diaphragm.

UNIT FOUR

NERVOUS SYSTEM

Human beings depend upon the integrity of the **nervous system.** As long as the brain, spinal cord and nerves are intact and functioning normally, people are able to perceive, think, talk and move. Their limbs never seem to strive for independence.

The nervous system is divided structurally into two parts;

(i) The central nervous system, (CNS) comprising brain and spinal cord and

(ii) Peripheral nervous system (PNS) which comprises spinal nerves (31 pairs) and cranial and (12 pairs) as well as associated ganglia. The nervous system again could be divided functionally into two parts i.e

(i) Somatic nervous system (SNS) which controls voluntary activities for example, innervation of skeletal muscles for voluntary movement and

(ii) Autonomic nervous system (ANS) which controls involuntary activities such as innervation of smooth muscles and glands for involuntary activities. These are sub-divided into the sympathetic and parasympathetic nervous system.

Structural organization of the nervous system

The central nervous system (CNS) – Composed of millions of nerve fibres and glial cells. A nerve cell/fibre or neuron consists of a cell body and processes that extend beyond the cell body called dendrites. A single long, unbranched dendrite is called an axon. A covering found around axons that

helps to increase the speed of transmission is known as myelin sheath. Glial cells are non-excitable and supporting cells of the nervous system. The glial or neuroglial cells are the nervous systems own connective tissue. Four general types of glial cells could be identified namely:

Astrocytes – these types of cells act as a conduit for metabolites, sometimes acting phagocytotic and generally serve as electrical insulators. Oligodendrocytes - they form myelin sheet around neurons in the central nervous system similar to Schwann cells in the peripheral nervous system. Microglia - Mainly protect the nervous system against foreign invasion and cleans it of dead cells. Analogous to blood monocytes, increase in numbers in case infections. Ependyma – These can be regarded as the nervous system's own version of epithelial cells. That is they line cavities of the brain and central canal of the spinal cord.

Overview of the central nervous system

The enlarged head-end (rostral part) of the central nervous system is the brain or cerebrum. This is enclosed by the cranium. (NB: encephalitis = inflammation of the brain). The brain presents three division; the forebrain (prosencephalon); the midbrain (mesencephalon) and the hindbrain (rhombencephalon).

The forebrain (prosencephalon) has two subdivisions namely; (a) telencephalon (end-brain) i.e cerebral hemisphere, (b) diencephalons (interbrain). The hindbrain also has two subdivisions namely; metencephalon (afterbrain) and myelencephalon (narrow-brain).

The bulk of the brain is formed by the two convoluted cerebral hemispheres which belong to the telencephalon. The cerebral hemisphere is distinguished

by the convolutions or gyri on their surfaces which are separated by the sulci.

The diencephalons comprising the thalamus and hypothalamus lie between the two cerebral hemispheres. The term brainstem is used to describe the midbrain, pons and medulla oblongata. The cerebellum is a fissured mass of gray matter that occupies the posterior cranial fossa. The convolutions of the cerebellum are called folia / folium. The cerebellum is attached to the brainstem by three pairs of limbs referred to as peduncles. The superior cerebellar peduncles connect it to the midbrain. The middle cerebellar peduncle connects it to the pons. The inferior cerebellar peduncle connects it to the medulla. Apart from these divisions the cerebral hemisphere is divided into functional lobes according to their location with respect to the various cranial bones; e.g, frontal lobe, parietal lobe, temporal lobe and occipital lobe. The frontal lobe is responsible for highest mental activity such as intelligence, memory, motor speech and motor movements. The parietal lobe is for interpretation of cutaneous body sensation. Temporal lobe notably is responsible for the sense of hearing and for housing the sensory speech area. The occipital lobe is for the sense of vision. The motor speech area (of Broca) located on the frontal lobe is responsible for the ability to talk or make sounds while the sensory speech area (of Wernicke) located on the temporal lobe, sometimes stretching into the lower part of the parietal lobe, is responsible for the ability to read, understand, hear and speak. There is also the insular lobe which bears no relation with any cranial bone but lies buried deep between the frontal and temporal lobes. This is responsible for gustatory activities (salivating and taste).

Brain lateralisation

Brain lateralisation is a phenomenon of cerebral activity in which the left hemisphere controls right side of body and vice versa. This however, is not absolute; for example, in about 90% of the population, the left brain is dominant for movement of the hand; but about 95% of the population show dominance of language on right side of the brain.

Internal features of the brain

The outer part of both cerebral and cerebellar cortex is composed of gray matter which is of only a few millimeters thick. The interior is composed of white matter. The gray matter consists of nerve cell bodies and glial cells whereas the white matter consists largely of processes / axons of nerve fibres and glial cells. The interior of the cerebral hemisphere and diencephalons contain not only white matter but also well demarcated masses of gray matter collectively called basal nuclei / ganglia in the cerebral hemisphere, and thalamus and hypothalamus in the diencephalons. The most prominent nuclei group of the basal ganglia are known as caudate and lentiform nuclei. The interior of the cerebellum also has collections of gray matter in the form of discrete nuclei, the largest of which is known as the dentate nucleus. A prominent feature of the interior of the brainstem is a diffuse mixture of white and gray matter known as reticular formation.

In feedback mechanism, the cerebellum is involved in motor coordination. It fine tunes or edits of voluntary movement to correspond with initial plan by the motor cortex. The cerebellum also sets to maintain muscle tone; record memories of previous actions to ensure repetition. Damaged to cerebellum leads to intention tremors; lack of perfection upon repetition. Basal nuclei:

provide feedback to cortex and smoothing out movement like the cerebellum. Damage leads to Huntington's chorea and to some extent Parkinson's disease. Language: Wernicke's area and Broca's area are all part of the association cortex. Wernicke's area is involved in language comprehension ie ability to understand language. Broca's area involved in language expression i.e ability to speak or write words. Damage to Wernicke or Broca's area leads to aphasia Eg: how are you? Fine (slurred for Broca's aphasia) and meaningless (i am eating) for Wernicke's aphasia.

Sleep: cyclically occurring state of decreased (but not absent) motor activity and perception. e.g. Movement during sleep, perception of sound and touch which can wake one. It is an active process. Usefulness of sleep includes: provides rest, helps conserve energy, facilitates the storage of long-term memory and helps maintain adequate immune system, dreaming.

Central nervous system and memory

Memory occurs at two levels: short term and long term. Short term memory is the first destination for incoming information. It has temporary storage property lasting for few seconds up to few hours. Information stored here is easily lost if not transferred to long term. This type of memory involves the cerebellum, basal nuclei and pons. Long term: consolidate information stored in short term for years and even life time. Repetition appears to help in consolidation. It involves the hippocampus.

Central nervous system and cavities

The interior of the brain also contains cavities called ventricles. The cavities of the cerebral hemispheres are known as the lateral ventricles. The cavity of the diencephalons is known as the third ventricle. While the cavity of the midbrain is referred to as the cerebral aqueduct and the cavity of the hindbrain is known as the fourth ventricle.

Limbic system of the brain

This is a collection of closely associated cortical regions, subcortical nuclei and tracts in the forebrain that function in learning and emotion. The limbic system includes: the amygdala, hippocampus, fornix and cingulate gyrus of the cortex as well as portions of the thalamus and hypothalamus. The amygdala is involved in memory and emotions especially fear. The hippocampus is involved in learning and emotions.

Blood supply to the central nervous system

The central nervous system accounts for about 2% of the body weight but receives about 15% blood pumped by heart to meet high metabolic demands. The CNS consumes about 20% of body oxygen and about 50% of body glucose consumption. Blood to the brain is by paired vertebral arteries and paired internal carotid arteries, all forming a network at the base of the brain called the Circle of Willis. Disruption of blood supply (block or rupture of vessels) to CNS for about two to five minutes can cause irreversible damage to brain; for example, stroke.

Generally, the brain is supplied by a pair of **internal carotid arteries (ICA)**

which after forming the carotid syphon at the base of the brain, contribute to the formation of the arterial circle of Willis, together with the paired terminal branches (posterior cerebral arteries) from the vertebral arteries. The circle of Willis is notorious for aneurysms. Venous blood of the brain is drained into the dural sinuses which are in turn drained by the paired internal jugular vein. Histologically, there exist a blood-brain barrier: special structural (tight junction in endothelial cells). And functional (lack of some transport proteins in endothelial cells) of brain capillaries that limit access of material into the brain. This is to protect brain tissue from damage. Some substances that can easily cross the blood-brain-barrier are glucose, amino acids, choline, and aspirin. The blood-brain-barrier accounts for the difference in composition between plasma and the cerebrospinal fluid (CSF).

Gray and white matter of the nervous system

Gray matter of the brain constitutes about 40% of the brain mass. This is made up of cell bodies, dendrites and axon terminal of presynaptic cells. Synaptic transmission and neural integration occur at the site of presynaptic cells. White matter forms about 60% of the entire mass of the nervous system. This is made up of axons most of which are myelinated. Myelin (made of fat) accounts for the white appearance. In the BRAIN, gray matter is outside while white matter is inside. This however, is reversed in the spinal cord.

White matter of the nervous system

The white matter of the central nervous system is usually classified into one of the following: (i) projection fibers or tracts: These connect the cerebral cortex with lower levels of the brain or spinal cord. Eg: corticospinal tract. (ii) Association fibers: these types of fibres connect one area of the cerebral cortex to another area of the cortex on the same side of the brain. Eg: arcuate fasciculus connects Broca's area to Wernicke's area. (iii) Commisural fibres: connect cortical regions on one side of the brain with corresponding cortical regions on the other side. Eg: corpus callosum connects the two cerebral hemispheres.

The ventricles and cerebrospinal fluid

Found in the ventricles is choroid plexus (pia matter + ependyma + capillaries) which secretes the cerebrospinal fluid (CSF). About two-thirds of the (CSF) is secreted by the choroid plexus of lateral ventricles. It passes through the ventricular system and into the subarachnoid cisterns over the brain and around the spinal cord. From the ventricles, the first subarachnoid space for the CSF to come into contact is the cerebello-medullary cistern or cisterna magna. The CSF in the subarachnoid space flows over the brain surface and is then drained/absorbed back into the blood largely through the arachnoid villi (several villi grouped together form the arachnoid granulation).

Composition of CSF

It is a clear, colourless liquid, containing very small number of proteins and differs from blood in its electrolyte contents (usually moresalty). Total intracranial volume is estimated at 123ml: 25ml in the ventricles and 98ml in the subarachnoid space.

Normal pressure of CSF in the recumbent position is 60 – 150 mmH_2O.

Function

Protection /Mechanical support, buoyancy, serving as a reservoir and assisting in the regulation of contents of skull and for the nourishment of nervous tissues.

Clinical investigation of ventricles

This is normally done through computed tomography (CT) and magnetic resonance imaging (MRI) scans and also through intracranial pneumography (replacing CSF with air).

Ventricles, CSF and clinical correlation

Papilodema: This is congestion of the retinal vein as a result of raised/ increased CSF pressure, leading to a bulging forward of the optic disc. **Rhinorrhea**: Leakage of CSF through the nose as a result fracture of the cribriform plate and damage to the meninges. **Hydrocephalus:** An abnormal increase in volume of CSF within the skull. Causes may be due to: **abnormal increase in formation** e.g tumors **or blockage of circulation:** one sided or double sided; congenital or accidental. Congenital double sided in infants

leads to sunset eyes syndrome (amorphous and outrageously enlarged skull) and/or **diminished absorption.**

Functions of the parts of the CNS

Cerebral hemisphere (telencephalon) – controls highest mental and behavioural activities. Controls learning, speech activities, memory, intelligence function. Controls muscular movement and controlling of most sensory activities.

Thalamus (diencephalons) – Serves as a relay centre for all sensory impulses (except olfactory).

Hypothalamus (diencephalon) – Regulation of most visceral activities; for example, the regulation of renal water flow; Regulation of body temperature; Regulation of hunger; Regulation of heartbeat; Regulation sexual function; Regulation of secretory activities of endocrine and exocrine glands; Regulation of emotional behaviour; Regulation of sleep; Regulation of metabolism of food and carbohydrate.

Midbrain (mesencephalon) – Notable among them are co-ordination of visual and auditory reflexes.

Cerebellum (rhombencephalon) – Regulation of balance (automated movement and posture); Motor co-ordination (unconscious activities).

Pons – Serves as a relay centre (contain many pontine nuclei).

Medulla Oblongata (myelencephalon) – Serves as a relay centre, contains many nuclei; Controls breathing activities - respiration; heartbeat; vasoconstriction; swallowing etc (autonomic visceral centre).

Spinal cord

Is a long, almost cylindrical mass of nervous tissues, oval or rounded in transverse section. It occupies about the upper two-thirds of the vertebral canal (spinal cavity).

Begins from below the foramen magnum and ends at the lower border of L1 vertebra in adults and at the level of L3 vertebra in infants. It can loosely be regarded as that portion of the central nervous system outside the cranial cavity. Grossly, the spinal cord appears to have two enlargements, along its entire length – the cervical and lumbar. Ventrally, it possesses a deep midline groove – the anterior median fissure, and dorsally, a shallow sulcus – dorsal median sulcus. The spinal cord is also invested with the three meninges as seen in the brain. The spinal dura extends downward to the level of S2 vertebra. The spinal pia matter condenses below the apex of the spinal cord (conus medullaris) as the filum terminale and then pierces through the dura at S2 vertebral level to attach to the back of the first coccygeal bone. All spinal nerve roots below L1 descend vertically on each side of the filum terminale to form a leash of nerves referred to as cauda equina.

Function

(i) Provides means of neural communication to and from the brain through tracts of white matter. (ii) It serves as a centre for spinal reflex: the quickest means of neuronal communication.

Coverings/meninges of spinal cord and the internal features of the spinal cord.

The three meninges namely dura mater, arachnoid mater and pia mater surround and protect the spinal cord. It is further protected by CSF that surrounds it in the subarachnoid space.

Internal features

In a transverse section, the gray matter of the spinal cord is found in its interior and surrounding this gray matter externally is the white matter. This gray matter presents with an "H"- shaped pillar with anterior and posterior gray columns or horns. The gray columns / horns are united in the midline by a thin gray commissure which contains the central canal. The white matter is divided into ventral / anterior, lateral and dorsal / posterior columns or funiculi. Attached to the spinal cord on each side is a series of nerves called spinal nerve roots aptly referred to as dorsal and ventral roots of the spinal nerve. The neurons (nerve cells) of the spinal cord include; motor neurons – the axons of which leave the spinal cord by way of the ventral roots to supply skeletal muscles; transmission neurons and interneurons concerned with sensory and reflex mechanisms.

A spinal segment is a portion of the spinal cord from which **a pair of spinal nerves arises.** The white matter contains ascending and descending fibres called tracts. The one most clinically important descending tract is the lateral corticospinal tract; involved in motor movements. Neurons of this tract eventually synapse on muscle spindles located in the muscle fibres acting as the effector organs. Ascending tracts have their receptors often located in the dermis of skin. The single most important ascending tract in the spinal cord is the lateral spinothalamic tract, which conveys pain and temperature sensations to the brain for interpretation. Another equally important ascending tract found in the spinal cord is the gracile and cuneate fasciculi/tracts, which are responsible for conveying sensations from joints and muscle spindles for processing by the brain (parietal lobe). The area of skin supplied by a single spinal nerve is known as dermatome.

The peripheral nervous system (PNS)

The peripheral nervous system (PNS) includes afferent neurons which transmit information from organs to CNS - somatic sensory neurons (associated with skin, muscles and joints) and efferent neurons which transmit information from CNS to organ in the periphery called effector organs (eg muscles and glands). The PNS also largely involves or includes the special senses (vision, hearing, touch, smell and taste) as well as the visceral senses (blood pressure, pH, fullness of stomach, etc). The cranial and spinal nerves and the associated ganglia, largely fall under the PNS.

Spinal cord, PNS, spinal nerves and nerve plexuses

Shortly after the spinal nerve is formed, it divides into two branches – a dorsal ramus and ventral ramus. The posterior area of the trunk is supplied by the dorsal rami and the anterior area and the extremities (limbs) by the ventral rami. A nerve plexus is formed from several nerve branches (fibres) which divide and coalesce (re-unite) to form a network of nerves which eventually re-group into discrete nerves to supply / innervate structures. A nerve plexus, thus is defined as a network of peripheral nerve fibres that distribute axons toward their destination. Innervation of the upper and lower limbs is derived from ventral rami of spinal nerves which form nerve plexuses. Common nerve plexuses in the body are: **cervical plexus:** theses are derived from the ventral rami of the 1st through 4th cervical nerves (C1 – C4) and supplies the skin and **muscles of the neck**, and the thoracic diaphragm. The ***phrenic nerve arises from this plexus.*** **Brachial plexus:** derived from the ventral rami of the 5th through 8th cervical nerves as well as the 1st thoracic nerves (C5 – T1). This plexus supplies the skin and muscles

of the upper limb, together with the muscles that originate from the chest wall and neck (except trapezius muscles).

Organization of the brachial plexus

The brachial plexus is conceptually arranged, from origin to termination into: **r**oots, **t**runks, **d**ivisions and **c**ords. (This mnemonic may do in remembering this general organization: *"**R**eally **T**ired? **D**rink **C**offee!").* Regarding the terminal branches of the brachial plexus this mnenomics may apply: *"**A** **r**are **m**an **m**asticates **u**nnoticed".* The nerves that arise as terminal branches from this plexus are: **a**xillary; **r**adial; **m**edian; **m**usculocutaneous and **u**lnar.

Lumbar plexus: - Derived from the ventral rami of L1 – L4 nerves and s**acral plexus** is formed from the ventral rami of L4 – S3 nerves. Together these plexuses innervate the muscles and skin of the posterior abdominal wall, pelvis and the lower limbs. The **coccygeal plexus** is formed by the ventral rami of S4, S5 and Co1. From the lumbar plexus arises the following nerves: femoral nerve; lateral femoral cutaneous nerve; obturator nerve and saphenous nerve. Some significant nerves arising from the sacral plexus arises are: common peroneal; superficial peroneal; deep peroneal; medial plantar nerve; lateral plantar nerve; pudendal nerve; sciatic nerve and tibial nerve.

Spinal cord, reflex arc and peripheral spinal/tendon reflexes

The reflex arc

It is the quickest means of communication between the central nervous system and the peripheral structures. It involves the spinal cord as its

terminal point in initiating a response. A typical reflex arc comprises; (1) a sensory receptor e.g skin / hair (2) a sensory neuron (3) a central synapsing somite (CNS) / interneurons (4) motor neuron and (5) An effector organ e.g muscle fibre or gland.

Deep tendon reflexes

The common deep tendon reflexes and their respective spinal cord segments are:

- Archilles tendon (ankle) reflex – S1 and S2 spinal segment.
- Patella/knee jerk reflex – L3 and L4 spinal segment.
- Biceps reflex – C5 and C6 spinal segment.
- Triceps reflex – C7 and C8 spinal segment.

Testing of tendon reflexes

Reflexes are routinely tested and the response shown is graded from 0 to 4+ (2+ is normal). For each tendon reflex, the right and left side should be compared. Particular attention should be paid to asymmetries; that is reflexes that are brisker on one side than the other. In that case one should look out for hyperflexia. The examiner should use several senses in this case.

1) Abdominal reflex

With the patient lying supine with relaxed abdominal muscles, stroke the skin of each quadrant of the abdominal wall briskly with a pin from the periphery towards the umbilicus. Normally, the local muscles contract, causing the umbilicus to move toward the quadrant stimulated.

2) Cremasteric reflex

In men, stroking the inner side of the proximal third of the thigh causes retraction of the ipsilateral testicle.

3) Plantar response (Babinski reflex)

Stroke the outer surface of the foot lightly with a large pin or wooden applicator from the heel towards the base of the little toe and then across the ball of the foot. The normal plantar response consists of plantar flexion of all toes, with slight inversion and flexion of the distal portion of the foot. In **abnormal** responses, there may be extension of the great toe, with fanning and flexion of the other toes (+ve Babinski sign/response) – suggesting a dysfunction of the corticospinal system.

Cranial nerves

Most of the twelve pairs of cranial nerves arise directly from the brain stem. They traverse the foramina in the floor of the cranial cavity as they course to their area of distribution. They transmit fibres whose cells are located in discrete clumps known as nuclei within the brain. Cranial nerves may differ from spinal nerves in that some transmit only sensory fibres while others transmit only motor fibres. Others are similar to spinal nerves in that they transmit both motor and sensory fibres. All cranial nerves transmitting general sensory fibres have ganglia interposed on the nerve, similar to dorsal root ganglia of spinal nerves. Except for the vagus (CN X) and spinal accessory (CN XI) nerves, cranial nerves are limited in distribution to structures to only head and neck regions. All cranial nerves transmitting general sensory fibres have ganglia interposed on the nerve, similar to dorsal

root ganglia of spinal nerves.

Cranial nerves – summary

Cranial nerves I, II and VIII are for special sensory.

Cranial nerves III, IV and VI control eye movements and pupillary constriction.

Cranial verves XI and XII are pure motor.

Cranial nerves V, VII, IX and X are mixed

Cranial nerves III, VII, IX and X carry parasympathetic fibres.

Apart from cranial nerves I and II the nuclei of all the others are located in the brainstem.

Cranial nerves and location of nuclei

Piriform cortex (between frontal and temporal lobes = CN I. Thalamus (diencephalon) = CN II. Midbrain = CN III and CN IV; Pons = CN V, CN VI and CN VII. Medulla oblongata = CN VIII, CN IX, CN X, CN XI and CN XII.

Functional components of the cranial nerves

The functional components are conveyed from or to the brainstem by **six types** of nerves:

(1) Somatic efferent fibres, also called **g**eneral **s**omatic **e**fferents fibres, innervate striated muscles that are derived from somites and are involved in eye (III, IV and VI) and tongue (XII) movements (**GSE**).

2) Branchial efferent fibres, also known as **s**pecial **v**isceral **e**fferent fibres. They innervate muscles that are derived from branchial arches (**SVE**). These are involved in chewing (V2), making facial expression (VII),

swallowing (IX and X), producing vocal sounds (X) and turning the head (XI).

3) Visceral efferent fibres are also called **g**eneral **v**isceral **e**fferent fibres. (They form the preganglionic parasympathetic component of the cranial division (**GVE**). They travel within nerves III (smooth muscles of the inner eye), VII (salivatory and lacrimal glands), IX (parotod gland), and X (smooth muscles of heart, lung, bowel that are involved in movement and secretion.

4) Visceral afferent fibres, also called **g**eneral **v**isceral **a**fferent fibres (**GVA**). They convey sensation from alimentary tract, heart, blood vessels, and lung by way of IX and X. A specialized visceral afferent component is involved with the sense of taste carrying gustatory impulses which are present in cranial nerves VII, IX and X (**SVA**).

5) Somatic afferent fibres, often called **g**eneral **s**omatic **a**fferent fibres. (**GSA**). They convey sensation from the skin and the mucous membrane of the head. They are found mainly in the trigeminal nerve (V). A small number of afferent fibres travel with the facial (VII), glossopharyngeal (IX) and vagus (X) nerves. These fibres terminate on trigeminal nuclei on brainstem.

6) **S**pecial **s**ensory fibres **(SSA).** These are found in nerves I (involved in smell), II (vision), and VIII (hearing and equilibrium).

Pain

Pain is abnormal sensation as a result of pathophysiological activity from a cell / tissue / organ which is accompanied by discomfort. Pain is associated with the ascending tracts, lateral spinothalamic tract; thalamus; parietal lobe (postcentral gyrus) of cerebrum and the sensory neuron or its receptors in the

skin.

Types

(a) Nociceptive pain

Pain that originates from tissues other than the CNS or PNS. They are generally musculoskeletal pain.This type of pain usually arise from the 4Is: **I**nflammation; **I**nfection; Irritation and **I**njury

(b) Neuropathic pain

This type of pain develops secondary to direct nerve injury. It is characterized with complains of burning, lancinating (piercing), and/or dysesthetic (unpleasant) pain.

Referred pain

This is a localization of a visceral pain on the body surface, often far away from the organ involved. Nerves to the painful surface area arise from the same spinal cord segment as the nerve fibres supplying the viscus in question. That is pain fibres from the body wall and those from the viscera share a common neuronal pool (spinal cord segment) in the spinal cord. Visceral pain impulses to this common segment/area excites the somatic pain fibres whose response is misinterpreted by the brain as cutaneous pain in the peripheral dermatome supplied by this particular nerve or nerves. For example, a gall bladder disease may show severe pain in the upper right abdominal region and over the right infrascapular region.

(2) Lumbar puncture/cisternal puncture/subdural tap (*in infants performed only by paediatrician*)

Lumbar puncture

May be performed in the recumbent position or more usually in the left lateral position. The foetal attitude is adopted with the full spinal flexion, the

knees being drawn up to the flexed neck. This opens up the spaces between the vertebral spines.

The patient's back is positioned at right angles to the bed to avoid rotation of the spine. The position of entry is at the level of L4 or better still between L4 and L5 intervertebral space. It may also be performed one intervertebral space cranially, at or between L3 and L4.

(3) Plegias

Plegia is a kind of paralysis with no movement. A hemiplegia is defined as paralysis of one side of the body. It generally results from stroke or other injury to the brain or spinal cord, especially one that interrupts the nerve fibres that carry the main voluntary „commands" to the muscles. These fibres cross from one side of the body to the other in the medulla and upper spinal cord, so that one side of the brain „commands" the opposite side of the body. Damage to this pathway in the brain therefore results in paralysis of the opposite side of the body. Damage in the spinal cord may paralysis on the same side, depending on its location with crossing of the pathway. If the damage is not extensive, sometimes the brain can evoke movements through other connections especially to the proximal limb muscles. The capability for these movements increases with time after the original injury and can be strengthened by training (physiotherapy) so that hemiplegics can hope for some restoration. Paraplegia is defined as paralysis of the lower half of the body. It results when the spinal cord is completely severed by such injuries as broken back. The portion of the spinal cord caudal to this break no longer has connections with the brain. This lack of control is total and permanent and frequently, the urinary bladder and rectum spontaneously empty when full, since these reflexes are intact, but their control from the brain has been abolished.

Dermatomes and shingles

Shingles or herpes zoster, is a viral infection of the dorsal root ganglion. Small vesicles (blisters) and discoloration of the skin occur over the dermatomal pattern of the skin, supplied by nerves from involved ganglion. These lesions develop as circular bands of blisters around the neck and trunk and somewhat vertical bands along the limbs.

UNIT FIVE

SPECIAL SENSE ORGANS – EYE AND EAR

Anatomy of the human eye.

The bony orbit, eyeball and extra-ocular muscles.

The eyeball occupies the anterior part of the orbit. The eyeball is a spherical organ, about 2.5cm in diameter located in bony orbit of the skull. It is accompanied by the six extraocular muscles; ophthalmic vessels and the five cranial nerves. Periorbital fat supports and surrounds these structures. The extrinsic muscles of the eye consist of four straight muscles – the superior, inferior, medial and lateral recti, two oblique muscles: the superior and inferior; and the levator palpebrae superioris (**two parts: smooth and skeletal**). The smooth muscle portion is innervated by sympathetic nerves while the skeletal part by oculomotor nerve). The recti muscles originate from the margin of a fibrous cuff, which is fixed posteriorly to the periosteum and dural sheath of the optic nerve at the optic margin of the superior orbital fissure. The lateral rectus is split into upper and lower heads at its origin with vessels and nerves entering the orbital cavity between the two heads. The recti muscles spread out to insert into a band-like aponeurosis encircling the sclera just behind the corneoscleral junction.

The levator palpebrae superioris is separated superiorly from the superior rectus and inserts into the tarsal plate of the upper eyelid and the superior fornix of the conjuctivum. The tendon of the superior oblique passes through a fascial pulley; the trochlea, attached to the medial wall of the orbit and reverses direction before inserting into the sclera. The inferior oblique muscle, located in the anterior part of the orbital cavity has an origin from the floor of the orbital cavity, different from the other extrinsic ocular

muscles. The equator of the eyeball divides this spherical organ into anterior and posterior halves. All of the recti muscles attach anteriorly and the obliques posteriorly.

Levator palpebrae superioris

Origin: orbital roof anterior to optic canal. Insertion: upper lateral plate (eyelid) and superior fornix of conjunctivum. Action: elevates upper eyelid. Nerve supply: oculomotor.

Superior oblique muscle

Origin: Roof of orbital cavity between superior and medial recti and anterior to optic canal. Insertion: slender tendon passes through fibrous ring (trochlea); reverses direction to insert deep to superior rectus. Nerve supply: Trochlear (CN IV).

Inferior oblique muscle

Origin: Floor of orbital cavity lateral to lacrimal canal. Insertion: sclera between superior and lateral recti. Nerve supply: Oculomotor (CN III)

Action of extra ocular muscles

Adduction: by **medial**, superior, and inferior recti.

Abduction: by inferior and superior oblique; **lateral rectus.**

Elevation: by inferior oblique; **superior rectus.**

Depression: by superior oblique; **inferior rectus.**

Medial rotation: by superior rectus; superior oblique

Lateral rotation: by inferior oblique; inferior rectus

Arterial supply to the orbital cavity

Ophthalmic, origin/source is a branch from the internal carotid artery (ICA).

Supraorbital; origin/source: a branch of the ophthalmic artery.

Supratrochlear; origin/source: a branch of ophthalmic artery.

Lacrimal; origin/source: a branch of ophthalmic artery.

Dorsal nasal: origin/source: a branch of ophthalmic artery.

Long posterior ciliaries (2): origin/source: a branch of ophthalmic artery.

Posterior ethmoidal: origin/source: a branch of ophthalmic artery.

Anterior ethmoidal: origin/source - a branch of ophthalmic artery.

Infraorbital: origin/source is internal maxillary artery.

Central artery to retina: origin/source is ophthalmic artery.

Anterior ciliary arteries: origin/source: muscular branches of ophthalmic.

The central artery of retina is an end artery therefore if blocked, there are no anastomoses with other arteries to sustain circulation to the retina. The result is sudden, total blindness of the affected eye. An occlusion may result from several causes, such as a tumor, a thrombus or massive oedema.

Venous drainage of the orbital cavity

Venous drainage of the orbit is by the superior and inferior ophthalmic veins. Superior ophthalmic vein is formed by the union of the supraorbital and supratrochlear veins. Superior ophthalmic vein drains into the cavernous sinus. The inferior ophthalmic vein originates from floor of the orbit, communicates through the infraorbital fissure with pterygoid plexus of veins OR through the superior orbital fissure with the cavernous sinus.

Structure of the eye

The anterior part of the eyeball is protected anteriorly by eyelids which are lined internally by the conjunctival membrane (conjunctivum). Anatomically, the conjunctiva is thin delicate transparent membrane covering cornea and the inner aspect of eyelid. The conjunctival membrane of the eyelid is reflected on to the outer coat of the eyeball (posteriorly and anteriorly) to form the conjunctival fornix.

Eye and lacrimal apparatus

The lacrimal gland is an exocrine in nature located in the supero-lateral part of orbit with its ducts opening into superior fornix of the eye. Lacrimal gland produces tears which are wiped medially across ***cornea*** when the eye blinks. Tears are collected by two lacrimal canaliculi which open at the lacrimal punctae, situated on the eyelid margin about 2 – 3cm lateral to the medial angle of the eyelid. The tears are then drain from here (lacrimal puncta) into the lacrimal sac and then down the nasolacrimal duct to the inferior meatus of the nasal cavity.

Eyeball – the tunics / coats / layers

Cornea represents about one-sixth of the orbital globe and is more convex than the **sclera** which forms the remaining fifth-sixths of the outer coat of the eyeball. The cornea is **transparent, non-vascular layer** of the eyeball. It is the **major refracting medium** of the eye ***unlike*** the **sclera which is dense and opaque**. ***Clinical footnote:*** Corneal transplants have a high success rate because the cornea is avascular and therefore is not "seen" by the body"s immune system. Near the cornea-scleral junction is the endothelial-lined canal which drains aqueous humour from the anterior chamber of the eye to the blood stream (the canal of Schlemm).

The **middle layer** of the eyeball is a **continuous structure** consisting of **the choroid**, **ciliary body** and **iris**. The ciliary body has a dual function: (i) produces the aqueous humour and (ii) provides origin for the suspensory ligaments (holding the lens in position). The iris is a pigmented adjustable diaphragm (partition) which lies anterior to the lens and forms the pupil (window of/to the lens). Iris divides that portion of the eyeball, anterior to the lens and behind the cornea, into the anterior and posterior chambers. Iris consists of a **circular smooth** muscle layer known as the **sphincter pupillae,** responsible for **constriction of the pupil** and another layer of smooth muscles made up of **radial fibres** called **dilator pupillae** which allows **pupillary dilation**. The sphincter pupillae is innervated by parasympathetic fibres (from CN III – oculomotor) while the dilator pupillae muscle has sympathetic innervation.

The retina

This is the innermost coat of the eyeball, which is in turn made up of ten

separate cellular layers: the most inner one of these sublayers being the ganglionic cell layer of which processes (extensions) become the optic nerve posteriorly; and the outermost of these layers (retinal) is the retinal pigment epithelium. The optic nerve appears as a pale disc situated in the nasal half of the retina. Optic nerve is enclosed in three sheaths which are direct extensions of the meninges of the brain. Visual resolution is greatest at the macula lutea (yellow spot). This appears as a pale area, two discs lateral to the optic disc. A central depression of the macula lutea is known as the fovea centralis. A rise in intracranial pressure is transmitted through the subarachnoid space which can be seen through the opthalmoscope as a swelling of the optic disc (papillodema). The central artery of the retina emerges from the disc and divides into equal branches, superior and inferior. Each branch then divides in turn into a nasal and temporal branch which thus supply the retina in a quadratic fashion.

The lens

Immediately deep to the iris and pupil is the transparent lens which bends light rays to enable them (light rays) converge on the retina (film of the eye– sensitive neuronal layer).

Fluid media of the eyeball

Aqueous humour is transparent, watery fluid which fills the anterior and posterior chambers of the eyeball (found between the lens and cornea). This fluid similar to plasma but low in proteins. Aqueous humour functions to maintain an intraocular pressure (that is keeps the shape of the eyeball

intact). It provides nutrition for avascular eye tissues and also involve in immune responses. **Vitreous humour** is a transparent gelatinous tissue filling the eyeball, located posterior to the lens and in front of the retina. It is produced by cells in the non-pigmented portion of the ciliary body. Vitreous humour protects and maintains spherical shape of eyeball. It has collagenous fibres that attaches firmly to retina. The fluid contains phagocytes that fight foreign materials. Vitreous humour resists putrefaction upon death (more than any other body fluid). *Potassium ion concentration in the fluid is said to rise significantly in corpses after death (hours, days and weeks) and this could be used to estimate time of death in forensic investigations. Glucose level analysis is preferred from vitreous humour in forensic investigations to that from systemic circulation.*

Eye – when things go wrong

Stye – this is an infection of one of the glands along the edges of the eyelids, behaving like a boil.

Conjunctivitis – infection or inflammation of the conjunctiva eg. **Apollo 11**. This causes eyes to become **red**, may feel **itchy** and the **eyelids become swollen**. May discharge **pus** and **shining light on eyeball makes it all the more painful**.

Pterygium – an outgrowth of the conjunctiva which slowly goes to cover the cornea. The overgrowth becomes opaque and if it covers a large part of the cornea, it interferes with vision.

Cataracts – this condition develops as **one grows older**. It is an **opacity of the lens**.

Squint (**Strabismus**) – usually due to abnormal development of the eye. This then causes one eye to look in one direction while the other looks in a different direction. May also be caused by one or more of the extra-ocular muscles (**Gen. 29:17 – Leah???**).

Glaucoma – a condition in which fluid in the eyeball is not able to drain away into the bloodstream as it is being continuously produced. This causes a rise in pressure inside the eye. If occurrence is of sudden onset, then it is referred to as acute glaucoma.

Myopia (Short-sightedness): It is a condition in which the eyeball is too long and the focus of objects lies anterior to the retina, rather than on it. The individual is unable to produce images of objects from a distance with such a condition.

Hyperopia (Long-sightedness) is the opposite: the focus lies posterior to the retina. Affects the ability to see nearby objects (no problem seeing distant objects). Obviously either condition causes faulty vision, which is correctible by lenses that will focus the image on the retina.

Colour blindness

This is the inability to distinguish colours correctly. To have normal colour vision, there must be three types of cones in the retina. Each type responds only to a particular colour: red, green or violet. ***When all three cones are equally stimulated, sensation of white results.*** Very few people are truly colour blind, but many are colour weak because they have difficulty in distinguishing hues (shades). Colour blindness is controlled by sex-linked recessive genes and manifests itself much more frequently in the male than the female. *Read on the following:* ***miosis; mydriasis****;* ***anisocoria*** *and* ***ptosis.***

Assignment

- What is cornea?
- What/which structure in the eye or orbit protects the cornea from damage?
- What happens when the cornea becomes permanently dried?
- What is the anatomical basis of weeping with tears having to flow through the nostril?
- Which **specific nerve** (named nerve) "commands" the lacrimal gland to begin secretion?
- What type (functional composition) nerve is this (described above)?
- Which named **cranial nerve** oversees the secretion/functioning of the lacrimal gland?

Anatomy of the human ear

The human ear consists of three parts: external/outer, middle ear and internal/inner ears.

The external ear

The external ear consists of the auricle/pinna, external auditory meatus/canal; auricle is composed of elastic fibrocartilage, covered by skin; cartilage which is a continuation of the outer part of the auricle, and forming about the lateral third of the canal (3 – 5cm). In the external meatus are special glands (ceruminous) which secrete a brown waxy substance that traps a lot of dust and small pieces of foreign bodies entering the tube and prevent them from going to hit the eardrum. The skin is also characterized with the presence of hair follicles and sebaceous glands. The eardrum is the third component of the outer ear and separates the external ear from the middle ear. At birth the

external auditory meatus is entirely cartilaginous except in its roof. In the adult, the medial two-third is part of the temporal bone. The external auditory meatus is S-shaped but can be straightened in the adult by traction on the auricle in an upward and backward direction. In the infant, traction downward and backwards is more rewarding.

Middle ear

The middle ear is separated from the external auditory meatus by the paperthin eardrum (tympanic membrane). This space is connected to the nasopharynx by the Eustachian tube (pharyngotympanic tube). The main structures in the middle ear are the three small bones (ossicles) arranged in a chain such that when one moves, the others also move. One of the bones (malleus) is attached to the inner surface of the eardrum and the third one (stapes) fits into the hole that leads into the third chamber (inner ear). There are two small muscles in the middle ear, one attached to the first ossicle (malleus) and the other to the third ossicle (stapes). When these muscles contract, they prevent the ossicles from over-vibrating. The tympanic membrane is a rounded structure facing downwards and forward, but the effect of parallax makes it appear oval when seen through the auriscope. The membrane is glistening and semi-opaque and the handle of the malleus can normally be seen attached to it.

Inner ear

Cochlea is a structure shaped like the shell of a snail that occupies part of the inner ear. Inside the cochlea are very sensitive hair-like structures supplied by nerves. The rest of the space in the cochlea is full of fluid. Movement of

the fluid in the cochlea moves the tiny hair-like structure which send impulses to the brain. Also found in the inner ear are three semicircular canals arranged at right angles to each other. Similar to the cochlea they contain fluid and sensitive hair-like structures. When the head is moved in one direction, the fluid in one or the other semicircular canals move, causing the hair-like structures also to move, thereby sending impulses to the brain to determine in which position exactly the head is and thus help us to maintain balance.

Ear – when things go wrong!

The glands in the external auditory meatus sometimes produce excessive secretion. This dries up and partially or completely blocks the meatus at the membrane and causes ear ache and partial deafness in that ear. Children also have the habit of pushing foreign objects into the ear, causing infections and production of discharge or fluid with offensive smell.

Otitis media

This is especially common in children: It is an inflammation of the middle ear. Appear to be widely common in children than in adults because anatomically, children the Eustachian tube is wider and shorter than in adults. Ear ache and air travels also has to do with middle ear and its anatomy. With the inner ear, usually dizziness (semicircular canals) and partial or complete deafness (cochlea) are associated with it.

UNIT SIX

ENDOCRINE SYSTEM

Introduction.

The endocrine system consists of highly integrated and widely distributed group of organs.

Function

The endocrine system orchestrates a state of metabolic equilibrium among the various organs of the body (homeostasis). The organs of this system secrete substances that serve as signals to other (target organs) in the body. Signaling by extracellular secreted molecules can be classified into three types based on the **distance** over which the signal acts, referred to as autocrine, paracrine or endocrine glands.

In endocrine signaling, the secreted molecules (**hormones**) act on target cells that are distant from their site of synthesis. Endocrine hormones are carried by the blood stream. The **target** tissue often secretes factors that downregulate the activity of the gland producing the stimulating hormone in a process known as feedback inhibition.

Glands of the endocrine system are generally derived from covering epithelia by means of proliferation and invasion of adjacent connective tissue followed by differentiation into secretory units. The glands from the endocrine system are ductless because they sever their connection with the surface epithelial cells

Characteristic features of endocrine glands

Many of the hormones (eg peptide hormones) are unable to diffuse across the plasmalemma of target cells because they are not lipid-soluble. They need special receptors to trigger chains of events leading to a particular cellular reaction. Endocrine glands are exclusively dependent on the circulatory system for the distribution of their products to target organs, hence they tend to be highly vascularized with fenestrated capillaries. The major (primary) glands of the endocrine system are the pituitary, thyroid, parathyroid, suprarenal islets of pancreas, pineal body, thymus and liver.

Pituitary gland (hypophysis)

This is an appendage of the brain is a small ovoid structure, attached to the under surface of the hypothalamus by the pituitary stalk. It is lodged in the sella turcica (pituitary fossa) of the sphenoid bone. The gland is divided into an anterior lobe (adenohypophysis) and a posterior lobe (neurohypophysis).

Pituitary gland produces two kinds of functional hormones: **(a) hormones which act on non-endocrine tissues** examples include: growth hormone, prolactin, antidiuretic hormone (ADH), oxytocin, melanocyte stimulating hormome (MSH) and **(b) hormones which modulate the secretory activities of other endocrine glands** (tropic hormones).

Anterior pituitary

About 80% of the gland is considered as anterior pituitary. Production of most pituitary hormone is controlled predominantly by a positive-active releasing factors from the hypothalamus to the anterior pituitary by the

hypophyseal portal system.

Histology of the anterior pituitary gland

In routine histological sections of the anterior pituitary, a colourful array of cells is present that contain either eosinophilic cytoplasm (acidophil), basophilic cytoplasm (basophil), or poorly staining cytoplasm (chromophobic cells). Six cell types are identifiable with the anterior pituitary. These cells are: somatotrophs (produce growth hormones, acidophilic in nature and constitute more than half of the anterior pituitary cells), lactotrophs (produce prolactin, are acidophilic). corticotrophs (produce adrenocorticotropic hormone, (ACTH) and are basophilic. Melanocyte-stimulating hormone, MSH, endorphins and lipotropin producing cells; are also basophilic. thyrotrophs (produce thyroid-stimulating hormone, TSH, are pale basophilic cells and gonadotrophs (produce both follicle-stimulating hormone, FSH and luteinizing hormone, LH, are basophilic.

Posterior pituitary (neurohypophysis)

The posterior pituitary consists of modified glial cells – pituicytes and axonal processes extending from the hypothalamus. Two types of peptide hormones are secreted from the posterior pituitary: **oxytocin – produces contraction of the smooth muscles of the uterus and smooth muscles in breast to stimulate ejection of milk during lactation and antidiuretic hormone (ADH)/vasopressin – controls amount of water excreted by kidney and also produces constriction of arterioles, and therefore a rise in blood pressure.** The ADH typically promotes re-absorption of water by kidney

tubules with the result that less water is lost in urine (conserves water in the body). Posterior pituitary hormones are actually synthesized by hypothalamus and stored within axon terminals residing in the posterior pituitary and released in response to appropriate signals.

Pituitary gland – relations

The location of the pituitary gland in the cranial cavity is clinically significant. Its immediate relations include: superiorly, the diaphragma sella (dura) with an aperture for the passage of pituitary stalk. Inferiorly is found the body of sphenoid bone with the sphenoidal air sinuses in it, laterally is the cavernous sinus. The posterior side of the gland is found the dorsum sella, basilar artery and pons while anteriorly is the optic chiasma.

Pituitary gland – blood supply

Arterial supply: superior and inferior hypophyseal arteries (branches of the internal carotid artery). Venous drainage: superior and inferior hypophyseal veins which in turn empty into cavernous sinus.

Pituitary gland – summary

The gland is responsible for the secretion of **seven hormones**: five of these hormones are from anterior pituitary, two from the posterior pituitary – ADH (vasopressin and oxytocin). Sheehan's syndrome may set in with a woman suffering from excessive postpartum haemorrhage, as blood supply to pituitary gland could be drastically reduced. The first sign is lack of lactation

(prolactin effect), *others follow.*

Clinical correlation - pituitary gland: (when things go wrong!)

Pituitary tumors; tunnel vision; insufficient secretion of ADH causes **excessive water loss** in the urine (***diabetes insipidus***).

Thyroid gland – anatomical description

The thyroid gland is largest endocrine gland in the body. It is one of two endocrine organs in the anterior part of cervical region. Thyroid gland is lobulated, lies in the neck, in front of and lateral to the trachea. It has two main lobes. The gland is very vascular, surrounded by a sheath of fascia from the pretracheal layer. Thyroid gland lies deep to the sternohyoid and sternothyroid muscles. The gland is found anterolateral to larynx and trachea and extends between C5 and T1 vertebral levels. Its left and right (lateral) lobes connected to each other by a narrow isthmus anteriorly. The isthmus is anterior to second and third tracheal rings. There is a pyramidal lobe present in about 50% of the population. This represents a remnant of the embryonic thyroglossal duct that extends from the isthmus to the hyoid bone. A fibrous capsule encloses the entire thyroid gland. The pretracheal fascia of the neck lies outside the thyroid capsule.

Function

Thyroid gland produces two types of hormones; (i) An iodine–containing hormone called thyroxine which has an important role in growth and maturation of tissues and (ii) Calcitonin which regulates blood calcium levels i.e (lowers blood calcium levels).

Thyroid gland and the iodine-containing hormones

The iodine-related hormones are of two main kinds: thyroxine (T4 hormone) and tri-iodothyroxine (T3) hormone. When the thyroid-stimulating hormone (TSH) arrives from the pituitary gland, the thyroid gland secretes thyroxine (T4) in response. The T4 hormone must be converted to T3 hormone (active form) in order for the body to use it. Tri-iodothyroxine (T3) is the more active form of the hormone but it is the T4 version that is secreted in large quantities by the gland. The greater the amount of T3 and T4 circulating in the blood, the faster the metabolism. The conversion of T4 to T3 takes place outside the thyroid gland; mostly in the liver and gut. If the conversion of T4 to T3 is poor, one may experience some common hypothyroid symptoms like fatigue, depression sensitivity to cold temperatures, difficulty in concentrating etc; stress and impaired liver function can affect the conversion of T4 to T3. Traditionally, practitioners screen thyroid function by looking at one main lab value called thyroid stimulating hormone (TSH). This may be a good test in the case of Graves‟ disease, in which case the TSH levels will remain low as the overactive thyroid gland signals the pituitary gland not to secrete TSH.

Histology of the thyroid gland

Three primarily histological features can be identified associated with this gland. These are the presence of follicles, follicular cells and parafollicular cells. Follicles are small spherical groupings, rich in blood supply, nerves and lymphatics. The follicles surround a colloid that consists mainly of thyroid hormone precursor proteins. Follicular cells form single layer of cells surrounding the core of the spherical follicles. They secrete the thyroid

hormone when stimulated by TSH. The parafollicular cells are scattered among the follicular cells and in spaces between the spherical follicles. They secrete calcitonin and are also called the C cells.

Blood supply:

Arteries

Superior thyroid – from external carotid.

Inferior thyroid – from the thyrocervical trunk.

Thyroidea ima (if present) – from brachiocephalic trunk or arch of aorta.

Veins:

Superior thyroid – drains into internal jugular vein.

Middle thyroid vein – drains into internal jugular vein.

Inferior thyroid vein – drains into left brachiocephalic vein.

Thyroid gland – when things go wrong!

Excessive secretion of thyroxine is evident in the enlargement of the gland (goiter). Under secretion of thyroxine in children results in dwarfism and mental retardation (**cretinism**). Calcitonin injections are sometimes given to patients with postmenopausal osteoporosis. ***Graves' disease*** is an autoimmune disorder characterized by hyperthyroidism. Symptoms of **hyperthyroidism** include ***but not limited to:*** excessive agitation, unexplained weight loss, rapid heartbeat, increased in bowel movements, irregular menstrual periods, irritability, anxiety, mood swings, protruding eyeballs, muscular weakness, insomnia and brittle hair.

Symptoms of **hypothyroidism** include ***but not limited to:*** physical and

mental sluggishness, unexplained weight gain, hair loss; constipation; exaggerated sensitivity to cold; irregular menstrual periods; depression; voice change (hoarseness or low pitch); memory loss and tiredness.

Parathyroid gland

These are very small, ovoid endocrine glands that lie on the posterior surface of thyroid gland. The parathyroid glands are yellowish brown bodies, found on the posterior border of the thyroid gland within its (thyroid) fascial capsule. They are normally four glands (two superiorly and 2 inferiorly). The location of the superior gland in the substance of the thyroid gland is fairly constant: always near the lower border of cricoid cartilage, the inferior on is inconstant.

Function

It secretes parathyroid hormone (parathormone) which raises serum/blood calcium levels; (that is the presence of this hormone promotes breakdown of bone).

Histology of the parathyroid gland

The parathyroid gland has densely packed cells (in comparison to thyroid). Two unique types of cells can be identified; chief cells – small, dark when loaded with the hormone and oxyphil cells – lighter in appearance and increase in numbers with age.

Parathyroid gland – when things go wrong!

Insufficiency causes stiffness, cramps, spasm and convulsion due to muscle inactivity. That is hypoparathyroidism leads to increased nerve excitability. The low blood calcium level triggers spontaneous and continuous nerve impulses which then stimulates muscle contraction. Over-activity results in deposition of calcium, formation of stones (bile and kidney) and bone diseases (demineralization).

Adrenal glands / (supra renal glands)

These are flattened paired glands found closely applied to the upper pole of each kidney. The gland is divided into suprarenal cortex and medulla. The adrenal cortex is essential to life but the medulla may be removed without any life-threatening effects. The two glands are dissimilar morphologically: The left is crescentic (leaf-like) and the right is almost like an irregular tetrahedron. The **suprarenal medulla** produces two hormones called ***epinephrine adrenaline*** (previously) and ***norepinephrine***. Epinephrine acts just like the sympathetic nervous system (that is it prepares the body for fight, flight or freight). These two hormones (from the suprarenal medulla) are secreted in response to stimulation of sympathetic nerves, particularly during stressful situations. Intramuscular and intravenous adrenaline may be used in the treatment of anaphylaxis. Adrenaline may also be applied directly to wounds on gauze or lent to produce **painless** and **bloodless** operations.

Histology of the suprarenal gland

Suprarenal cortex secretes a variety of steroid hormones/cortisones which are concerned with **electrolyte**, **fluid control**, and **sex control** in the body. **The mineralocorticoid** – are secreted from the outermost part of cortex. The principal mineralocorticoid hormone is ***aldosterone***, which acts to conserve sodium ions and water in the body. **Glucocorticoid** – From the middle part of cortex. The principal glucocorticoid is ***cortisol***, which increases blood glucose levels. **Gonadocorticoid** – This is secreted from the innermost part of cortex (close to medulla). In females, the musculinisation effect of androgen secretion may become evident after menopause when oestrogen levels from the ovaries decrease.

Supra renal gland - blood supply

Arterial supply

Superior suprarenal artery – from the inferior phrenic artery.

Middle suprarenal arteries – from aorta

Inferior suprarenal artery – from the renal artery.

Venous drainage

Left suprarenal vein drains into the left renal vein.

Right suprarenal vein drains into inferior vena cava.

Suprarenal gland – when things go wrong!

Adrenal cortex is necessary for life. Insufficiency of adrenocortical function results in **Addison's disease** which is characterised by: inability to withstand stress, no appetite, weakness, low blood pressure, cutaneous pigmentation and many other symptoms.

Excessive secretion of glucocorticoids causes ***Cushing's syndrome*** which

is characterised by: poor wound healing, increased deposition of fat, moon face appearance and serious metabolic deficiencies. **The most common cause of Cushing's disease is the administration of prednisone, a steroid hormone used to treat inflammatory arthritis and asthma.**

Over secretion of gonadocorticoids leads to; virilism, musculinization of females and precocious development of secondary sexual characters. Lack of secretion from the **suprarenal medulla** has no significant effects. Hypersecretion, usually from a tumour, however causes prolonged or continual sympathetic responses.

Pancreas

This is a long, soft organ, lying transversely along posterior abdominal wall in the abdominal cavity. It is located posterior to the stomach and extends from duodenum to spleen. The pancreas has a head, uncinate process, body and tail. Histologically, the pancreas is regarded as a glandular tissue with most part of it being exocrine in nature. The exocrine part secretes digestive enzymes that are poured into duodenum.

Endocrine part of the pancreas consists of **pancreatic islets** located near the tail portion of it. The cells of the endocrine part of the pancreas secretes **glucagon** and **insulin**.

Histology of pancreas

The **alpha cells** of pancreatic islet secrete glucagon in response to low concentration of blood glucose levels. Whereas the **beta cells** secrete insulin in response to high blood glucose concentration.

Pancreas – when things go wrong!

Failure of beta cells of the endocrine pancreas to function/secrete leads to a disease condition known as **diabetes mellitus**. (***Does insufficiency of insulin lead to hypoglycaemia?*** Is ***glucagon involved in hypoglycaemia?)***

Endocrine pancreas and clinical correlations

Pancreas and diabetes mellitus

Diabetes mellitus: ***what is it?***

This is a disorder in which the body **does not** produce enough or respond normally to insulin, causing blood sugar (***glucose***) levels to be **abnormally high**.

Etymology

Diabetes = Greek; meaning siphon or to pass through (passing through). Mellitus = Latin; meaning sweet.

WHY WOULD SOMETHING SWEET (*SUGAR)* BE ***PASSING THROUGH*** BLOOD?

From the anatomical point of view, that means things have wrong! Sugar is normally needed in cytoplasm of the cell for metabolic activities. Glucose however, is unable to diffuse directly into most cells. (*Read on the glycolytic pathway & role of liver in glucose metabolism*). The beta cells of pancreas secrete insulin in response to high blood sugar levels. Cells in the body must have receptors for the hormone (insulin) in order to mop up the excess sugar in blood. Lack of secretion of insulin from the ***beta cells of pancreas and/or lack of receptors*** for it (insulin) may result to sugar ***passing through*** blood instead of into the cell for metabolism. (***Insipidus = Latin for tasteless.)***

Types of diabetes

The most common types of diabetes are said to be type 1, type 2 and gestational.

Type 1 is thought to be due to an autoimmune reaction that stops the body from making insulin (the body attacks itself by mistake). In this case the body‟s own immune system attacks and destroys the insulin-producing beta cells. This type is also known as juvenile-onset or insulin-dependent diabetes; the body stops making insulin completely.

Type 2 diabetes

This type is described as a chronic condition that affects the way the body processes blood sugar (glucose). With type 2 diabetes, either the body does not produce enough insulin or resists insulin. *Metformin for its management.*

The main difference between the two types of diabetes is that type 1 diabetes is a genetic disorder that shows up early in life and type 2 is largely dietrelated which develops over time.

Gestational diabetes – surfaces during pregnancy and may recede after parturition.

Pancreas and blood sugar levels

A blood sugar (glucose) level of **less than 140mg/dL (7.8mmol/L)** is generally accepted as **normal. Between 140mg/dL and 199mg/dL (7.8mmol/L and 11.0mmol/L)** is termed as **prediabetes**. Blood glucose level consistently ***greater than the prediabetic values*** is diagnosed as **diabetes mellitus (DM).**

How is diabetes mellitus (DM) diagnosed?

(1) A1C Test – A1C test measures the average blood sugar levels over the past two or three months. (2) Fasting blood sugar test. (3) Glucose tolerance test. (4) Random blood sugar test. (5) Glucose screening test.

Early signs and symptoms of diabetes

Diabetes mellitus (DM) is associated with absolute or relative deficiency of insulin which leads to hyperglycaemia and glucosuria. The hyperglycaemia causes intermittent visual disturbances and the glucosuria results in polyuria; nocturia; polydipsia (increased thirst); polyphagia (excessive eating) and marked gluconeogenesis and lipolysis. Others symptoms include increased hunger; polyphagia (excessive eating), unexplained weight loss; slow and poor healing cuts and wounds and a tingling sensation or numbness in the hands or feet.

Gonads: testes and ovaries

Testis produces male sex hormone broadly known as androgens. The principal androgen is called **testosterone**. Testosterone is responsible for the development of male secondary sexual characters.

Histology of the testis

Situated among the **seminiferous tubules** are groups of **rounded interstitial cells** called **Leydig cells** which produce the hormone **testosterone**.

Ovaries – endocrine function

There are two groups of female sex hormones from the ovaries: these are **oestrogen** and **progesterone**. They both contribute to the development and

function of the female reproductive organs and secondary sexual characters. Oestrogen sets in at puberty and promotes development of breasts; distribution of fat in hips and breasts; maturation of the uterus and vagina. Progesterone causes the uterine lining to thicken in preparation for pregnancy and prepares the breast for lactation.

Pineal gland

This is also called pineal body or epiphysis cerebri. It is a small reddish-gray organ which extends posteriorly from 3rd ventricle of brain between the two superior colliculi. The pineal gland secretes melatonin which affects reproductive organ development and the daily circadian rhythms.

Function of the pineal gland

Melatonin secretion is stimulated by darkness and inhibited by light. Melatonin modulates sleep patterns. The secretion from the pineal gland also inhibits the secretory activities of other endocrine glands as well as hypothalamic activities. Melatonin reaches target organs via cerebrospinal fluid and or bloodstream. The gland is active during darkness.

Histology of the pineal gland

The gland consists of lobular parenchyma of pinealocytes in humans. The gland parenchyma in turn surrounds connective tissue spaces. The entire gland is covered by a pial capsule.

Pineal gland: when things go wrong!

Pineal gland is associated with the disease condition known as **brain sand (pineal calcification).**

Pineal calcifications are fairly common in young adults. Damage of gland in

children results in accelerated development of sexual characters.

Thymus

Thymus is located in the anterior-superior mediastinum, just above and in front of the heart. **It** is part of the lymphatic system where it plays a critical role in the seeding of lymphatic organs. Thymus consists of two lobes, with a dense outer cortex and an inner less dense medulla. It is surrounded by a capsule that extends into the interior of the gland, together with blood vessels.

Histology of the thymus

The gland is made up of an outer cortex and inner medulla. Cortex is mainly made up of thymocytes and supported by finely-branched epithelial reticular cells. Its medulla has a network of reticular cells, coarser than in cortex. There are also fewer lymphocytes in medulla than in thymic cortex. Lymphocytes in the medulla are in concentric nest-like bodies called the **Hassall's corpuscles**. These are **whorls of epithelial cells** that increase in numbers throughout life. A hormone manufactured by the epithelial reticular cells of the thymus that stimulates the lymphoid stem cells to proliferate is known as ***thymopoietin*.**

Endocrine function of thymus

Thymus is also believed to produce a hormone, called **thymosin** that enhances the development of T-lymphocytes. **Thymosin** makes the new T-lymphocytes active by stimulating the cell to express specific receptors on its cell surface. Thymus–body ratio is greatest during infancy (*gland regresses with age*). The organ increases in size up to about puberty, beyond which it decreases; *said to have undergone involution in adult.*

Thymus – Blood supply

Arterial supply

Thymus receives its arterial blood from branches of the internal thoracic and inferior thoracic arteries.

Venous drainage

The gland is drained by small thymic veins that end up in the: left brachiocephalic vein, internal thoracic vein and inferior thyroid vein.

Hormones – flip side!

There are four human hormones which turn to determine ***happiness***.

These are:

endorphins: *exercising* (*playing*) turn to release this. (ii) **Dopamine**: accomplishing big or little tasks release this (i.e *receiving appreciation or acknowledgement* cause its release), (iii) **serotonin**: released in a way through acts that benefits others (*sharing*) and (iv) **oxytocin**: released when we become close to others (i.e *hugs; hand-shakes; arms around someone's shoulder).*

UNIT SEVEN

INTEGUMENTARY SYSTEM

Introduction.

What is it?

The skin, sometimes called cutaneous membrane or the integument, forms the continuous, movable external surface (envelope) that covers the entire body. It also blends with the sensitive mucous membranes of the mouth, nose, eye and anal and urogenital openings. Skin as the largest component of the integumentary system consists of two distinct layers, epidermis, an outer epithelial investment of closely packed and the dermis, a deeper layer of dense irregular collagenous fibres interlaced with blood vessels, nerves and lymphatics. **Skin is the largest organ of the body, is of *clinical concern due to many conditions associated with it; eg* burns and carcinomas.**

Anatomical classification of skin

Thin skin: this is very hairy and cover over most parts of the abdomen, thigh and arm. Thick skin: Hairless type of skin characterised with the presence of several sweat glands. For example, the palms of the hand and soles of the feet.

Functions of skin

The skin is involved in protection; sensation; thermoregulation and metabolic function.

Protection: The skin offers protection against: injury, dehydration and

infection acting as physical barrier to invasion by micro-organisms. (b) Sensation: It serves as site of communication between internal and external environments using sensory receptors. The skin is the largest sensory organ. It contains variety of receptors for touch, pressure, pain and temperature. (c) Thermoregulation: the skin is involved in the regulation of heat loss. The human body is basically insulated against heat loss by the presence of hairs and subcutaneous adipose tissue. Heat loss facilitated also by evaporation of sweat from the surface of the skin and increased blood flow through the **rich vascular network of the dermis**. (d) Metabolic functions: The skin is involved in the synthesis and secretion of a variety of products. For example, vitamin D is synthesized in the epidermis to supplement that derived from dietary sources.

Structure of skin

Skin varies in thickness, colour and the presence of hairs, glands and nails in different regions of the body. All types of skin have the same basic structure. The external surface of skin consists of a keratinized, flattened epithelium called the epidermis. The epidermis is supported and nourished by a thick layer of dense, fibro-elastic tissue called dermis, which is highly vascular and contains many sensory receptors. The dermis is attached to underlying tissues by a layer of loose tissue called hypodermis or subcutaneous layer which contains variable amounts of adipose tissue. Hair follicles, sweat glands and nails are appendages of the epidermis but they take their origin from the hypodermis during early development.

The epidermis of the skin

The epidermis provides tough, outer barrier for the body. It is keratinized and become very thick in areas that receive use or wear. It is avascular; in thick skin usually, five distinct layers can be identified. These are from superficial to deep: stratum corneum, stratum lucidum; (**found only thick skin**), stratum granulosum, stratum spinosum and stratum basale (germinativum).

The stratum corneum is the surface layer of the skin. It consists of several layers of dead cells. Stratum germinativum (basale) is the germinal layer of the epidermis which cells divide to produce the cells in the superficial layers. This layer contains the basal cells (keratinocytes) and the melanocytes that produce the pigment melanin.

Cell types in the epidermis of skin

There are 4 cell types in the epidermis namely: (1) Keratinocytes; (2) Melanocytes; (3) Langerhans' cells and (4) Merkel's cells.

(1) Keratinocytes (basal cells): these are the predominant cells. They occur in the stratum germinativum. They undergo differentiation from stratum germinativum to stratum corneum in a process known as keratinisation. (2) Melanocytes: These are rounded cells, scattered among the keratinocytes of the stratum germinativum. They produce the pigment melanin which contributes to skin, eye and hair colour. (3) Langerhans' cells: These are starshaped cells, occur mainly in the stratum spinosum. They are antigen-presenting cells, which initiate cutaneous contact hypersensitivity reactions (contact allergic dermatitis). (4) Merkel's cells: These are regarded as modified keratinocytes, found in the stratum germinativum. They are

associated with mechanoreceptor mechanisms; are strikingly more numerous in thick skin than thin skin.

The dermis of skin

It is derived from dermatome and lateral plate mesoderm. It forms the inner/deeper connective tissue layer of the skin. Dermis is made up of two non-distinctive layers: upper papillary layer and the lower reticular layer which binds the entire dermis to the hypodermis below. The papillary layer is the region immediately beneath the epidermis. It consists of **loose connective tissue.** This layer contains blood vessels that serve but do **NOT** enter the epidermis. The papillary layer is characterized by the presence of millions of **dermal papillae**. Dermal papillae are folds of the dermis found at the border of the dermis and epidermis and also at the base of the hair bulb. They (dermal papillae) turn to increase the surface area of the dermis. Extensions of the dermis into the epidermis forms what is known as **dermal ridges.** These **dermal ridges** form unique patterns in individuals better known as **fingerprints (dermatoglyphics),** serving as unique body marker in humans with a strong genetic correlation. D**ermal ridges** resemble epidermal appendages that remain in the papillary layer of the dermis. The reticular layer is deeply situated and is made up mainly **dense irregular connective tissue**. Most collagen fibres that give elasticity to the skin are found in this layer. The reticular layer has many **elastin and collagen fibres** embedded in its matrix. The reticular layer also contains many arteriovenous shunts that control the amount of blood reaching the surface of the skin and therefore help in regulating heat loss and blood pressure. The reticular layer also contains a rich supply of sensory receptors e.g Paccinian and Meissner‟s

corpuscles.

When things go wrong!

Epidermis

Epidermolysis bulbos simples (EBS) – affects keratinization of cells, producing cells that cannot withstand physical contact. This affects all epidermal layers except germinativum. The keratinocytes in the spinosum layer cannot assemble a network of intermediate filaments, and all subsequent layers are affected. **Psoarisis** – this is caused by rapid cell proliferation, resulting in improper keratinization of cells. The cells in the germinativum layer divide so rapidly that they begin to push non-cornified cells to the surface. **First degree burns** – this involves just the peeling off of the epithelial layer.

Dermis

A hereditary disease of the elastic fibres in which the skin does not snap back into place when stretched is known as **cutis elaxa**. A **blister** occurs when the dermis has been separated from the epidermis; plasma then leaks out of the capillaries and this separation becomes a fluid-filled pocket. **Tattoos** are difficult to remove because the dyes are injected into the dermis. **Scars** and **stretch marks** are also permanent because they involve the dermis.

Dermis – clinical application

Lines of cleavage (Langer's lines): These are faint linear clefts in the skin, indicative of the direction of the underlying collagen fibres. They are fairly

consistent in most individuals – being longitudinal in the limbs and circular in the neck and trunk. Especially evident in the palmer surface of the fingers.

The anatomy of skin comes in handy during the techniques involved in drug/injection administration.

Appendages of the skin – hair

Hair is a **thin keratinized** structure that protrudes from follicles. It can also be regarded as a filamentous projection of fused keratinized cells from the surface of the epidermis of skin. Hair grows in an **oblique invagination of epidermis** into the **dermis** called **hair follicle**. The base of the hair follicle is dilated to form a bulbous structure known as **hair bulb**. The hair bulb is invaginated by a highly vascularized connective tissue known as **dermal papilla.** Melanocytes occur in the hair bulb and transfer the pigment to the hair shaft. ***Mitotically active epidermal cells surround the dermal papilla*** to form the **hair root**. The hair root divides mitotically and is continuous with the hair shaft, which typically protrudes beyond the epidermis of skin as the dead, fused keratinized cells. The bulb, root and shaft are all contained in the hair follicle.

Colour, size and disposition of hair vary according to race, colour, age, sex and region of the body. Arrector pilli muscle (smooth muscle) is associated with the hair bulb (in the dermis), hair follicle and the surface of skin. Arrector pilli muscle is involved in goose pimples formation and thermoregulation. Hair follicle, dermis and surface of skin, defines a triangle with the sebaceous gland at the centre of this triangle.

Nail

What is it? Nail is a **flattened, horny plates of epithelial cells** (a keratinous envelope - tough protective layer of proteins) on the dorsal part of the distal phalanges. Nail has different parts, namely: **nail plate** - this is the hard part of nail, made of translucent keratin protein. The nail plate consists of a compact layer of highly adherent and keratinized epithelial cells. Several layers of dead compacted cells cause the nail plate to be strong but flexible. In common usage, the word nail often refers to the nail plate. **The fine margin**, or **distal edge** is the anterior margin of the nail plate. The fine margin corresponds to the **abrasive** or **cutting-edge part of the nail**. The **hyponychium** is the epithelium located beneath the nail plate at the junction between the free edges and skin of the fingertip. The hyponychium forms a seal that protects the nail bed. **Nail bed**: this is the skin beneath the nail plate. This skin comprises of dermis and epidermis, with the epidermis here being made up of stratum germinativum only. **Nail matrix**: this is the tissue which nail plate protects. Nail matrix is part of the nail bed that is beneath the nail. The nail matrix contains nerves, lymph and blood vessels. Nail matrix produces cells that later becomes the nail plate in a process known as **keratinization**. Nail matrix is also known as keratogenous membrane. The nail matrix continues to produce cells as long as it receives nutrition and remains in healthy conditions. As new nail plate cells are made, they push older nail plate forward in this way older cells become compressed, flat and translucent (**keratinization**). Nails grow in a distal direction, sliding over the skin of the nail bed which is called **hyponychium**. **Lunula** is the visible part of the nail matrix. It is a whitish crescent-shaped base of the visible nail. Lunula is white because the dermal papillae in this region are less vascular and also because the stratum germinativum is thick and opaque. **Nail sinus** is

where the root of nail is (the proximal part of the nail plate is the **nail root**).

That is the base of the nail plate underneath the skin. Nail sinus originates from the actively growing tissues below the matrix. Nail root emerges from a groove in the skin to form the nail plate/body. Nail root if covered by a fold of skin called **proximal nail fold. Eponychium**, together with cuticle forms a protective seal. The **cuticle** is the semicircular layer of almost invisible dead skin cells that "ride out on" and cover the back of the visible nail plate while the **eponychium** is the fold of cells that produces the cuticle. Both (cuticle and eponychium) are continuous. It is **the cuticle** (nonliving part) that is removed during a manicure but the eponychium (living part) should not be touched, due to risk of infection. The eponychium is a small band of living cells (epithelium) that extends from the posterior nail wall onto the base of the nail. The eponychium is therefore, regarded as the stratum corneum of skin of the nail fold that extends over the body of the nail for a short distance. The eponychium is the end of the proximal fold that folds back upon itself to shed an epidermal layer of skin onto the newly formed nail plate.

Nail growth

Growing part of the nail is under the skin at the nail's proximal end beneath the epidermis. Nail grows continuously from proximal to distal fashion. Fingernails grow averagely at about **3.5mm per month** while toenails half this rate slower.

Nail permeability

Ironically, nails are much more permeable than skin. Nail permeability is clinically significant.

Functions of nail

Protection of the distal phalanx and surrounding soft tissues from injuries. Nails in humans are for e**nhancing of precise** delicate movements (maneuvers) of distal digits and also serve **as an enabling tool**, for instance enabling "extended precision grip" (cutting/scraping/pulling actions) all facilitated by the possession of nails.

Clinical significance of nails

Serves as an indicator of certain shock states such as **hypovolemia**. **Nail growth** can serve as a **diagnostic tool**. **Beau's lines** (horizontal and never along nail plate) may serve as a **natural consequence of aging**. **Discolouration, thinning, thickening, brittleness, splitting, grooves, white spots, receded lunula, clubbing (convex), flatness and spooning (concave)**; these may all be **indicative of illness in other areas of the body or nutrient deficiencies or drug reactions or poisoning or merely a local injury.**

Bluish or purple fingernail beds may be a **symptom of peripheral cyanosis, which indicates oxygen deprivation.** Nail diseases can be very subtle and **should be evaluated and diagnosed by a dermatologist**.

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Nails – when things go wrong!

Overly thickened nails (**onychogryphosis**); loosened nails (**onycholysis**); nails infected with fungus (**onychomycosis**); nail degeneration (**onychodystrophy**); in-growing toenail – a common nail disorder (**onychocryptosis**).

Sweat gland

Sweat glands are single, tubular glands present over the entire body, except lips and glans penis. Sweat glands are either eccrine or apocrine glands. Eccrine sweat glands cool the skin and are independent of hair follicles. The secretion of eccrine glands is known as perspiration, is a clear, hypotonic solution containing various electrolyte. Apocrine sweat glands are associated with hair follicle. They secrete a watery substance containing proteins, carbohydrates, ammonia, lipids and fatty acids.

Sebaceous glands

Sebaceous glands secrete an oily substance that lubricates and protects the skin. Their oily secretion known as sebum, makes the skin essentially waterproof. Sebaceous glands develop as down growths from hair follicles into the dermis.

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ABOUT THE BOOK

Essentials of Human Anatomy Vol. 2 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: Anatomy of the pelvis and perineum; The Reproductive systems; Renal/Urinary system and Nervous system. Other topics covered in this volume include the: Anatomy of the special sense organs – eye and ear; Endocrine system and Integumentary system. Some of the interesting sideline throughout the book are: when things go wrong and the applied or clinical anatomy bits 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.

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