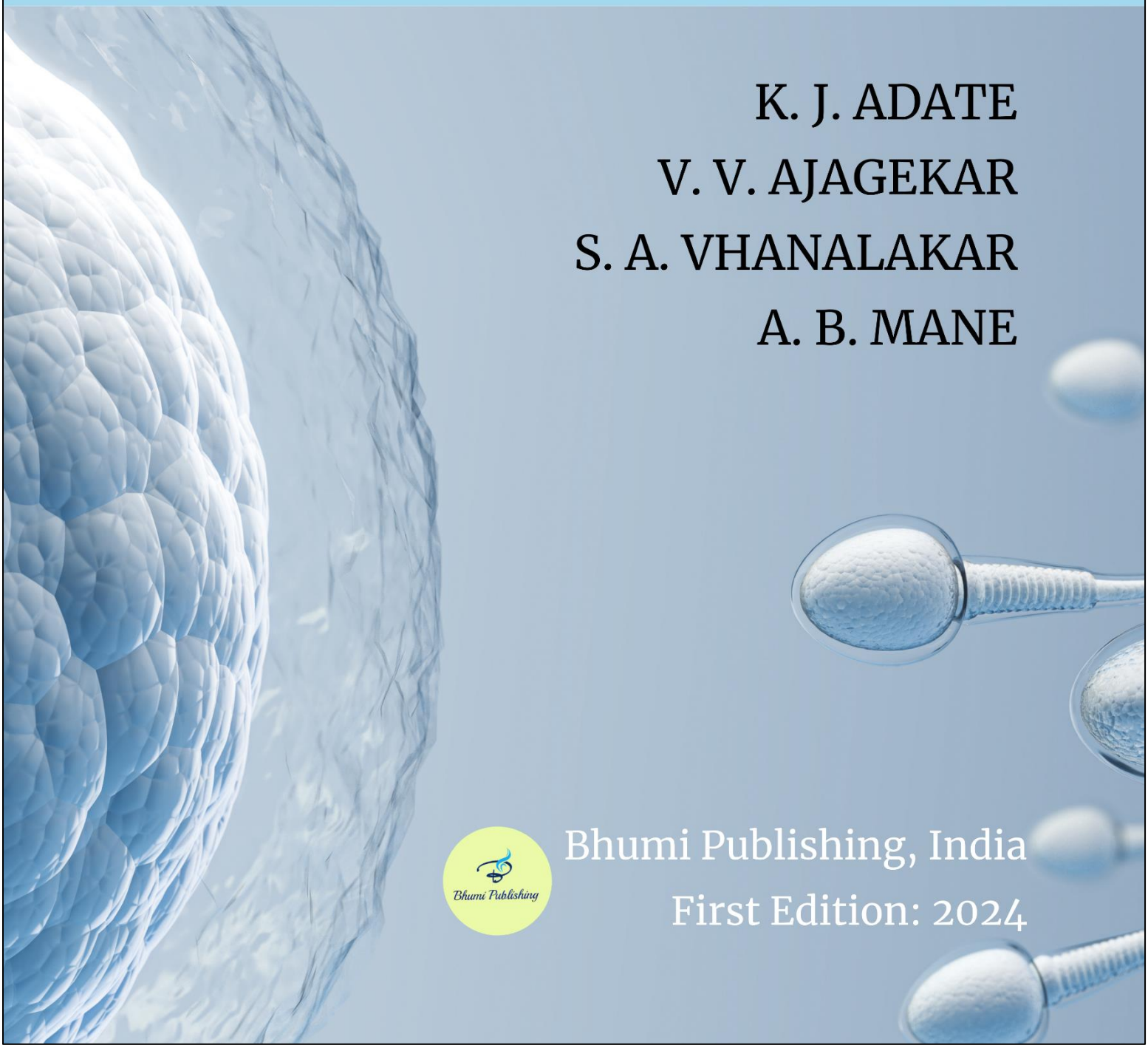
ISBN: 978-93-88901-86-4

REPRODUCTIVE BIOLOGY

From Gametes to Generations: A Comprehensive Exploration



K. J. ADATE
V. V. AJAGEKAR
S. A. VHANALAKAR
A. B. MANE

Bhumi Publishing, India
First Edition: 2024

Reproductive Biology

From Gametes to Generations: A Comprehensive Exploration

ISBN: 978-93-88901-86-4

Authors

Mr. Kishor J. Adate

Head,

Department of Zoology,

Shivraj College, Gadhinglaj,

Dist – Kolhapur, M.S., India

Dr. Vinayak V. Ajagekar

Head,

Department of Zoology,

Ajara College, Ajara,

Dist – Kolhapur, M.S., India

Dr. Sagar A. Vhanalakar

Head,

Department of Zoology,

Karmaveer Hire College, Gargoti

Dist – Kolhapur, M.S., India

Mr. Abhijit B. Mane

Head,

Department of Zoology,

Dr. Patangrao Kadam Mahavidyalaya,

Ramanandnagar (Burli), Sangli, M.S., India

Bhumi Publishing

2024

First Edition: January 2024

ISBN: 978-93-88901-86-4

Published by:

Bhumi Publishing,

Nigave Khalasa, Kolhapur 416207, Maharashtra, India

Website: www.bhumipublishing.com

E: mail: bhumipublishing@gmail.com

Book Available online at:

https: //www.bhumipublishing.com/book/

PREFACE

We are delighted to present this book of Reproductive Biology designed specifically for zoology students and teachers. This book is a result of the collaborative efforts of our esteemed team of authors, who possess extensive knowledge and experience in the field of Zoology.

This book aims to provide students with comprehensive knowledge of reproductive biology. The book is divided into several sections, covering topics such as Endocrinology, functional anatomy of female reproductive system, functional anatomy of male reproductive system and reproductive health. Each section has been carefully curated to align with the syllabus, ensuring that students receive a thorough understanding of the subject.

One of the key highlights of this book is its emphasis on understanding of structure and functions of different organs associated with reproductive system in human being. We firmly believe that this book will helps students to understand the concepts. Thus, this book includes a wide range of histological structures of different reproductive organs, information about reproductive health and contraceptives also.

The incorporation of relevant diagrams, illustrations and photographs further enhances the learning experience, making it visually appealing and relatable. We would also like to appreciate the efforts of the faculty at our institution, who have contributed their knowledge and expertise to curate the content of this book. Their dedication to providing quality education has played a crucial role in the development of this book.

Finally, we extend our best wishes to the students who will embark on the journey of exploration in Zoology. We hope that this book serves as a valuable resource, assisting you in understanding the intricate world of reproductive biology.

- Authors

CONTENT

Unit I: Structure and hormones of pituitary gland

Unit II: Functional anatomy of female reproductive system

A. **Anatomy of female reproductive system**

- **a.** Histology of Ovary
- **b.** Histology of Oviduct/Fallopian Tube
- **c.** Histology of Uterus
- **d.** Histology of Cervix and vagina
- **e.** Female sex hormones
- **f.** Folliculogenesis, process of Oogenesis and structure of ovum
- **g.** Menstrual cycle and hormonal regulation
- **h.** Transport of ovum and sperm in female genital tract
- **i.** Process of fertilization
- **j.** Hormonal control in Implantation
- **k.** Diagnostic features of pregnancy and hormonal regulation
- **l.** Mechanism and hormonal regulation of Parturition and Lactation

Unit III: Functional anatomy of male reproductive System

B. Anatomy of male reproductive System

- **a.** Histology of testis
- **b.** Histology of Epididymis
- **c.** Histology of Seminal vesicle
- **d.** Histology of prostate gland
- **e.** Histology of Cowper's gland
- **f.** Histology of penis
- **g.** Male sex hormones
- **h.** Process of spermatogenesis and structure of sperm

i. Epididymal functions and sperm maturation

j. Sperm transportation in male genital tract

k. Hormonal control of Testicular activities

Unit IV: Reproductive Health

a. **Infertility in Male:** causes, diagnosis and management

b. **Infertility in Female:** causes, diagnosis and management

c. **Assisted Reproductive Technology:** Sperm bank. Frozen embryos. Intrauterine Transfer (IUT), Zygote Intrafallopian Tube Transfer (ZIFT), Gamete Intrafallopian Transfer (GIFT), Intracytoplasmic Sperm Injection (ICSI)

d. **In vitro fertilization (IVF):** Ovarian stimulation, Egg retrieval, Sperm retrieval, Fertilization and Embryo transfer

Unit V: Contraceptive Methods

a. Temporary Methods

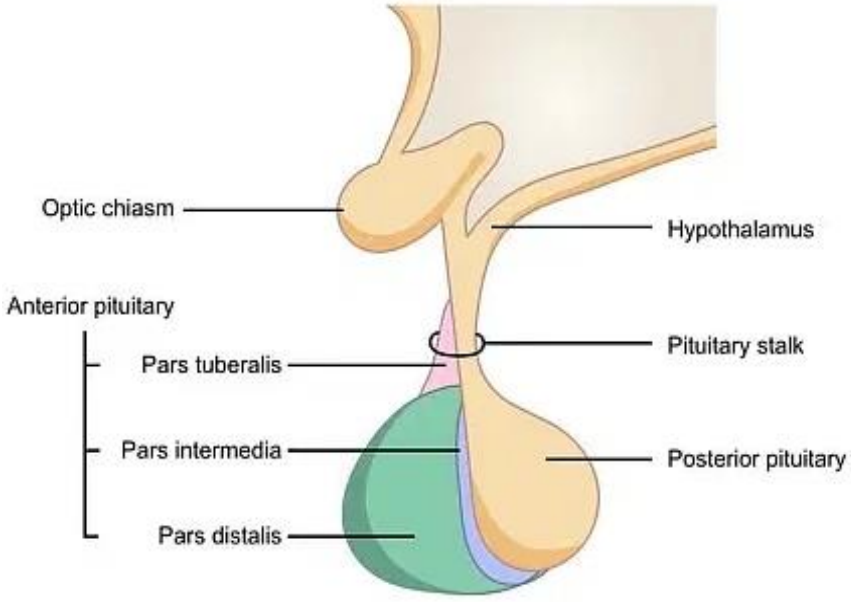
b. Permanent Methods

UNIT I: STRUCTURE AND HORMONES OF PITUITARY GLAND

STRUCTURE OF PITUITARY GLAND

The pituitary gland, often referred to as the **"Master Endocrine Gland"** is a small, pea-sized gland located at the base of the brain, just below the hypothalamus, within a bony structure called the sella turcica. It plays a crucial role in regulating various physiological processes by secreting hormones that control other endocrine glands in the body.

The pituitary gland is divided into two main parts: the anterior pituitary (adenohypophysis) and the posterior pituitary (neurohypophysis). Each part has a distinct structure and functions.



a. Anterior Pituitary (Adenohypophysis)

The anterior pituitary is composed of glandular tissue and is divided into three regions: the pars distalis, the pars intermedia, and the pars tuberalis.

1. **Pars Distalis**: This is the largest and main functional part of the anterior pituitary. It contains different types of cells that secrete various hormones. These cells include somatotrophs (produce growth hormone or GH), lactotrophs (produce prolactin or PRL), gonadotrophs (produce luteinizing hormone or LH and follicle-stimulating hormone or FSH), corticotrophs (produce adrenocorticotropic hormone or ACTH), and thyrotrophs (produce thyroid-stimulating hormone or TSH).
2. **Pars Intermedia**: This region is less distinct in humans but more prominent in other vertebrates. It produces melanocyte-stimulating hormone (MSH), which is involved in skin pigmentation.
3. **Pars Tuberalis**: This part surrounds the infundibulum (stalk of the pituitary) and is involved in the regulation of certain reproductive functions.

b. Posterior Pituitary (Neurohypophysis)

The posterior pituitary is an extension of the neural tissue of the hypothalamus and is composed of nerve fibers and nerve endings.

Hormones: Unlike the anterior pituitary, the posterior pituitary does not synthesize hormones. Instead, it stores and releases hormones produced by the hypothalamus. The two main hormones released are oxytocin and vasopressin (antidiuretic hormone or ADH).

HORMONES OF THE PITUITARY GLAND

The secretions of endocrine glands are called Hormones. Pituitary gland is the master gland of the endocrine system. The hormones diffuse into the blood and are carried by the blood stream to the distant part of the body. They act very specifically on certain organs and such organs are referred to as target organs. Pituitary gland secretes the following nine hormones.

1. Growth hormones (STH/GH)
2. Adrenocorticotropic hormone (ACTH)
3. Thyroid stimulating hormone (TSH)
4. Follicle stimulating hormone (FSH)
5. Luteinizing hormone (LH)
6. Luteotropic hormone (LTH)/Prolactin
7. Melanocyte stimulating hormone (MSH)
8. Vasopressin/Antidiuretic hormone
9. Oxytocin

[A] HORMONES SECRETED BY ADENOHYPOPHYSIS

It is the anterior glandular part of the pituitary and secretes the following six hormones.

1] GROWTH HORMONE (GH)/ SOMATOTROPIC HORMONES (STH)

It is secreted by the Acidophils of adenohypophysis. It regulates the normal growth of the body. It stimulates the growth of the bones and cartilage, also the amino acid uptake and protein synthesis. It increases the glycogen deposition in muscles and liver. It also increases the absorption of calcium for growth of bones. If the secretion of this hormone is decreased (Hypo secretion) during early life it leads to Dwarfism. But hypersecretion during early life results in Gigantism. Hyper secretion in adults produces protruding jaw bones. This abnormality is called Acromegaly.

Control of STH secretion

Hypothalamus secretes growth hormone releasing factor (secreting) GHRF, which stimulates adenohypophysis. It produced STH. Hypothalamus also secretes an inhibitory

hormone called Somatostatin. That inhibits the activity of adenohypophysis. It stops the secretion of STH/GH.

2) ADRENOCORTICOTROPIC HORMONE (ACTH)

It is secreted by the basophilic cells of the adenohypophysis. It is a protein hormone and is formed of a single polypeptide chain made up of 39 amino acids. It stimulates the activity of adrenal cortex inducing the secretion of Gluco-corticoids and mineralo-corticoids. These hormones are called cortical hormones. Gluco-corticoids stimulate carbohydrates metabolism. It is considered as a life saving hormone, e.g. Cortisol stimulates the conversion of protein to amino acids during fasting/hibernation. Mineralocorticoid or Aldosterone increases the reabsorption of Na+ from tubule and also increases excretion of K+ in urine. Deficiency causes rheumatic fever, Addison's disease etc.

Control of ACTH

Hypothalamus secretes a neurohormone- Corticotropin Releasing Factor (CRF), which stimulates pituitary secretion (ACTH). The secretion of ACTH is also controlled by a negative feedback mechanism.

3] THYROID STIMULATING HORMONE (TSH)

This hormone is secreted by the basophilic cells of the anterior lobe of the pituitary gland. It is a protein hormone. It controls the normal growth of the thyroid gland & secretion of this hormone thyroxine. It regulates the rate of iodine uptake by thyroid gland. Thyroxine increases the rate of metabolism of all cells of the body, hence TSH indirectly stimulates metabolism of the body by stimulating thyroid gland.

Control of TSH secretion

Hypothalamus secretes a hormone thyrotropic releasing factor (TRF).That stimulates the adenohypophysis. It secretes TSH.

4] FOLLICLE STIMULATING HORMONE (FSH)

It is secreted by the basophilic cells of the adenohypophysis. It is a protein hormone. In females it increases the number and size of Graafian follicle & in males; it stimulates the testis for spermatogenesis. It also stimulates the production of estrogen by the ovarian follicles.

5] LUTEINIZING HORMONE (LH)/INTERSTITIAL CELLS STIMULATING HORMONE (ICSH)

It is a gonadotropic hormone & is secreted by the basophilic cells of the adenohypophysis. It is a Glycoprotein. In females, it stimulates ovulation in the Graafian follicle to release the ovum outside, also called Gamete releasing hormone. It helps in converting empty follicle into corpus luteum, maintain it & stimulates to secrete

progesterone. In males this hormone stimulates interstitial cells of testis to secrete male sex hormone testosterone hence it is called as interstitial cells stimulating hormone (TCSH)

Control of GTH

GTH secretion is under the control of a feedback mechanism. Pineal gland and hypothalamus control the secretion of GTH. It is also regulated by stimuli like light, temperature, genital stimulation etc.

6] LACTOGENIC HORMONE / PROLACTIN/ LUTEOTROPIC HORMONE (LTH)

This hormone is secreted by the acidophilic cells called B-cells called mammotrophs. It is a protein with several disulphides. It regulates the development of mammary glands during puberty in females. It stimulates the mammary gland during pregnancy and after childbirth it controls secretion of milk in the mammary gland. It also maintains corpus luteum & secretion during pregnancy. It reduces the chances of pregnancy by preventing fertilization.

7] MELANOCYTE STIMULATING HORMONE (MSH)

It is secreted by pars intermedia & as in man pars intermedia is poorly developed. The importance of this in vertebrates like fishes, amphibians & some reptiles, it controls the synthesis & dispersal of melanin pigment in skin.

B] HORMONE OF THE NEUROHYPOPHYSIS

8] ANTIDIURETIC HORMONE/VASOPRESSIN

It is secreted by neurosecretory cells of the hypothalamus & released from pars nervosa. It increases the permeability of DCT & PCT of Nephrons in the kidney & absorbs much more water from renal fluid. It also increases blood pressure. ADH hormone contracts smooth muscles of arteries hence B.P. increases so called Vasopressin. In absence of ADH water reabsorption is reduced and person expel large amounts of dilute urine and causes diseases Diabetes insipidus (Polyurea) and polydispagia (Increased Thirst). Diabetes insipidus is also called as Drinker's Disease. ADH is secreted more in desert animals.ADH secretion suppressed in alcoholic condition.

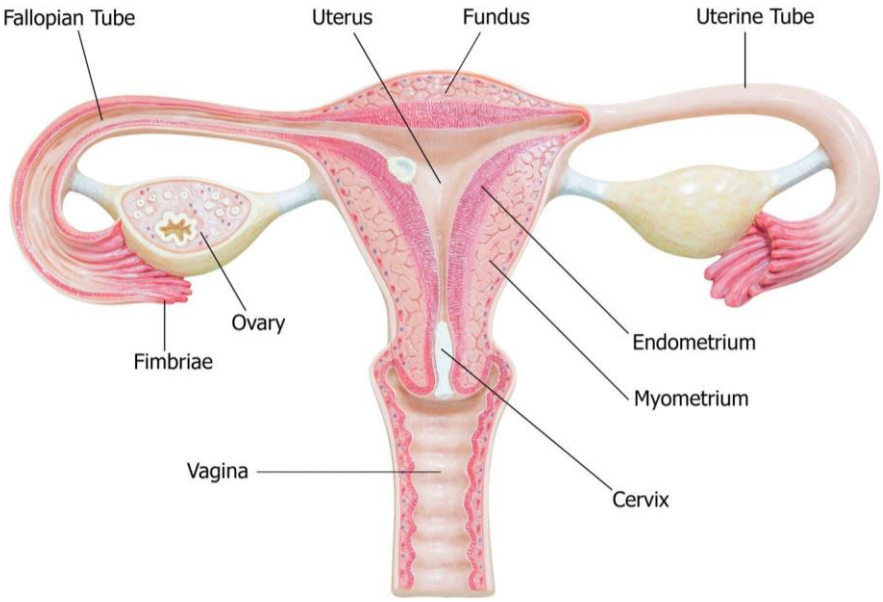
9] OXYTOCIN/PITOCIN

It is secreted by neurosecretory cells and released from pars nervosa. It stimulates contraction of smooth muscle of the uterus & brings easy parturition (delivery) of the baby from the uterus. As it secretes in large amounts at the end of pregnancy and helps in childbirth hence also called Birth Hormone. It is also helpful in ejection of milk from mammary glands so also called as milk ejecting hormone.

UNIT II: FUNCTIONAL ANATOMY OF FEMALE REPRODUCTIVE SYSTEM

A) ANATOMY OF FEMALE REPRODUCTIVE SYSTEM

The female reproductive system constitutes a pair of Ovaries, Fallopian Tubes, Uterus, Cervix, Vagina, Accessory Genital Glands and a pair of Mammary Glands.



a. Pair of Ovaries

Each ovary is of the shape of unshelled almond and the size is 3.5 cm long, 2 cm wide and 1 cm thick. It is placed in the abdominal cavity. Ovary is attached to the uterus by ovarian ligament. Ovary is suspended from the abdominal wall by a mesentery called mesovarium. Each ovary is lined by cuboidal germinal epithelium and is solid. Underneath the germinal epithelium lies a layer of connective tissue called tunica albuginea. Underlying this layer is stroma. Stroma is further divided into dense outer cortex and less dense inner medulla. Many Graafian follicles/ovarian follicles are present in the cortex and show different stages of development. Initial stage of development is the primary oocyte. As the primary oocyte develops it changes to secondary oocyte. Secondary oocyte is released from the ovary by the rupturing of the ovarian wall. This process is known as ovulation.

There are around four lakhs follicles in both the ovaries of an adult woman. Most of the follicles disappear by phagocytosis during reproductive years. This process is called follicular atresia. Due to this a female produces only around 450 ova in her entire reproductive life which ends between 40 and 50 years of age.

b. Fallopian Tube or Oviduct

Fallopian tube is around 10 cm long, muscular, tubular and ciliated structures. It lies in the pelvic region, just above the urinary bladder. Each fallopian tube is divided into Infundibulum, Ampulla, Isthmus and Uterine Part.

1. **Infundibulum**

This is a broad, funnel shaped proximal part. Finger-like projections arise from this proximal part and are called fimbriae. Infundibulum opens into the body cavity by an aperture called ostium. Ostium lies near the ovary and receives eggs from the ovary with the help of fimbriae.

2. **Ampulla**

It comprises the major portion of the fallopian tube. It is long, thin walled and wide.

3. **Isthmus**

It is a short, thick walled, ciliated and narrow straight path.

4. **Uterine Part**

It is a narrow inner part which opens in the upper part of the uterus.

c. Uterus

It is hollow, muscular, vascular and large (8 cm x 5 cm x 2 cm) pear shaped Structure which is present in the pelvic region above the bladder. It can be divided into three parts: fundus, body and cervix.

Fundus is the upper, dome-shaped part above the opening of the fallopian tube. The middle and major part of the uterus is the body. The lower narrow part which opens in the body of the uterus by internal Os and in vagina by external Os is called cervix. Uterus is the site of fetal placentation, its growth and parturition.

d. Vagina

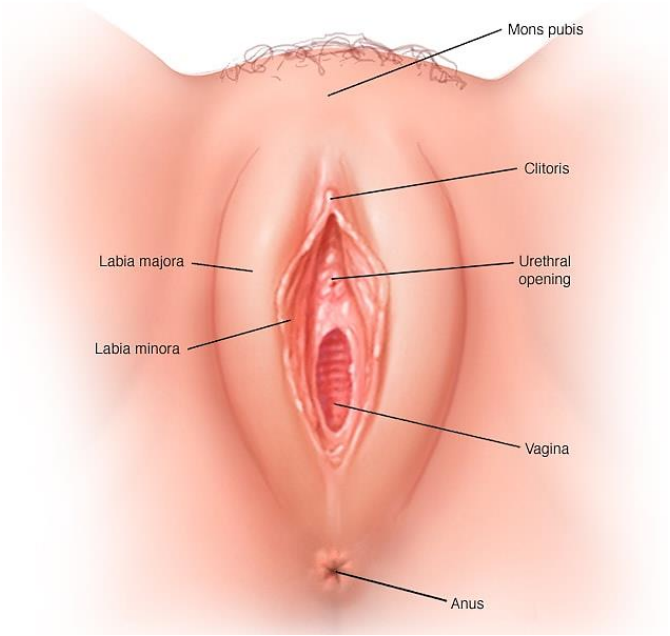
This is a tubular structure, 10-12 cm long and extends from the cervix to the outside of the body. It receives the sperms during copulation, is passage for menstrual flow and forms the birth canal during labor. Hymen is the membranous structure which covers the opening of vagina, the vaginal orifice. Vagina is lined by non-keratinized stratified squamous epithelium. Glands are absent in the vaginal wall.

e. Vulva

This is the external genitalia of females. It consists of the vestibule or urino-genital sinus which is in the form of depression and is in the front of anus. It has two apertures, upper external urethral orifice and lower vaginal orifice.

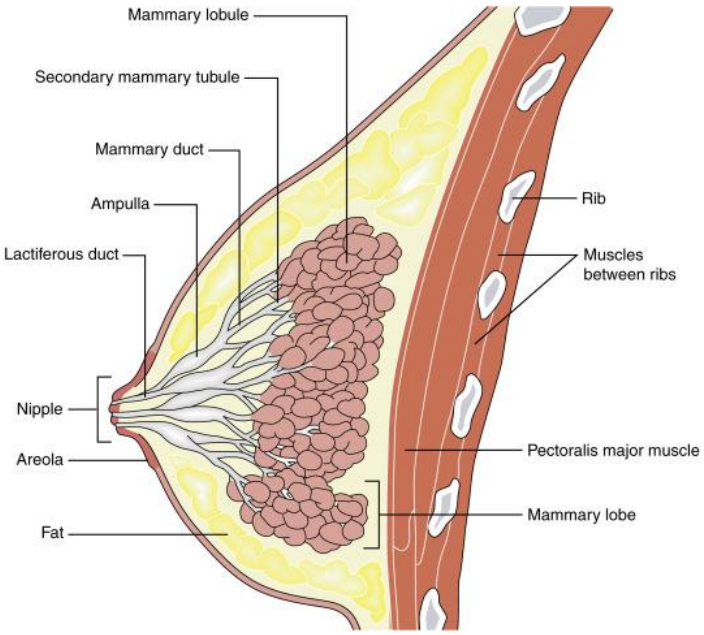
The anterior part is fatty and covered with pubic hair. This portion is called Mons pubis. Corresponding to the male penis, clitoris is present in the females which are made of erectile tissue. Two large, thick- walled folds of skin form the boundary of the vulva. These are labia majora and contain sebaceous glands. Between labia majora two small folds are present and are called labia minora. Labia minora fused posteriorly to form fourchette.

On either side of the vaginal orifice there is a pair of Bartholin's glands. This gland secretes a clear, viscous fluid which works as a lubricating agent during copulation. The area below the fourchette and anus is perineum.



f. Mammary Gland or Breast

In human being mammary glands are one pair and present on ventral thoracic walls. They are modified sweat glands. In males it is rudimentary whereas in females it is well developed. Hormone estrogen and progesterone are responsible for their development. After child birth, the anterior lobe of pituitary secretes oxytocin. The former is responsible for production of milk and later stimulates its release.



The breast is externally covered with skin and in the center, there is a nipple made of erectile tissue. Nipple is surrounded by a pigmented area called areola. Areola has numerous sebaceous glands called areolar glands. Human milk is made of organic, inorganic compounds and water. Milk is poor in iron. It mainly consists of fat droplets, lactase, casein, vitamins and minerals like sodium, potassium, calcium, phosphate etc. Glandular, fibrous and adipose tissues constitute the mammary glands.

1. Glandular Tissue

This tissue consists of around 20 lobes and each lobe has 15-20 lobules. Each lobule is made of a group of glandular alveoli and unit to form a lactiferous duct. These ducts expand to form lactiferous sinuses which store milk during lactation. Each sinus opens to the outside by narrow ducts which are 0.5 mm in diameter.

2. Adipose Tissue

The surface of the glands is covered by adipose tissue. It is also found between the lobes. The size of the breast is determined by adipose tissue.

3. Fibrous Tissue

Glandular tissues and ducts get support from this tissue.

PUBERTY IN FEMALES

Puberty age in females is between 10 and 14 years and is characterized by menstrual cycle and ovulation. Estrogen secretion maintains growth and maturation of the reproductive tract and development of accessory sexual characters. The physical and psychological changes that take place in females during this phase are

b. Enlargement of breasts.

c. Growth of pubic and axiliary hair.

d. Increase in subcutaneous fat in buttocks, thighs and face.

e. Beginning of menstrual cycle and ovulation.

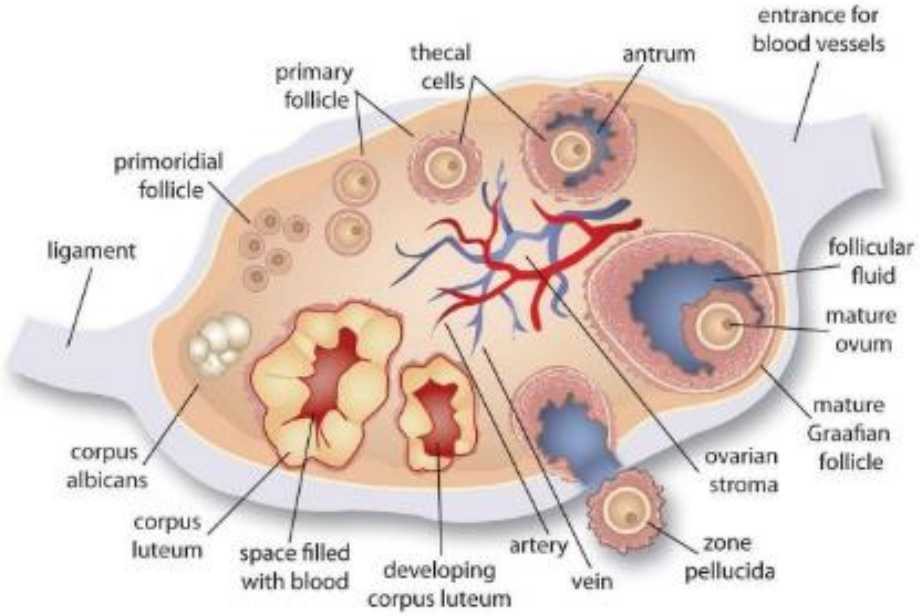
f. Broadening of hip region due to widening of pelvis.

g. Stoppage of growth of long bones.

A. HISTOLOGY OF OVARY

Pair of ovaries is situated in the pelvic region, one on either side of the uterus. They are attached to the uterus by ovarian ligament and are suspended from the dorsal abdominal wall by a fold of peritoneum called mesovarium. Histologically the ovary shows the following different parts. Ovary is externally lined by a single layer of germinal epithelium. Inner to the germinal epithelium there is a fibrous covering of connective tissue called Tunica albuginea. Inside the tunica albuginea connective tissue stroma is present,

which is differentiated into the outer cortex and inner medulla. The medulla is the central region of the ovary and is made up of loose connective tissue containing blood vessels, nerve fibers etc. The germinal epithelium undergoes the process of Oogenesis to form follicles in different stages of development in cortex as primordial follicle, primary follicle, and secondary follicle and finally, mature follicle called Graafian follicle.



A] PRIMORDIAL FOLLICLE

This oocyte is surrounded by a single layer of follicular cells resting on the basement membrane. The single layer of follicular cells divides into many layers called stratum Granulosa.

B] PRIMARY FOLLICLE

The oocyte enlarges and gets separated from the follicular layer by a zone called zona pellucida.

C] SECONDARY FOLLICLE

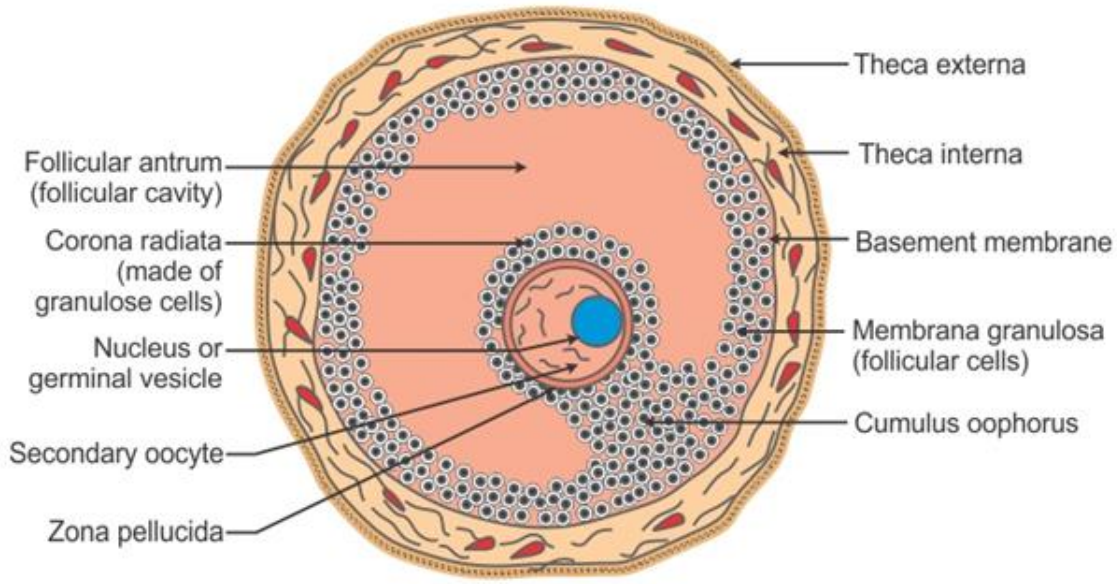
A cavity appears in the follicle called the antrum that gets filled with Liquor folliculi. Outside the follicle the stroma cells form a layer called Theca folliculi.

D] GRAAFIAN FOLLICLE/MATURE FOLLICLE

It was discovered by Dutch scientist Reginior Degraaf. It is spherical in outline and measures about 2mm in diameter externally it is covered by stroma cells layers, outer Theca Extena and inner Theca Interna. Below the Theca interna many follicular layers are present called stratum granulosa. It is divided into membrane granulosa and cumulus oophorus/discus proligerus due to presence of an antrum, which is filled with a viscous fluid called liquor folliculi. In the cavity of the follicle, the ovum is suspended eccentrically

by a stalk of cumulus oophorus cells to membrane granulosa cells forming a germ hill. The ovum is externally surrounded by three layers such As

1) Vitelline Membrane: It is the transparent, glasslike limiting membrane of the ovum itself.
2) Zona pellucida: A non cellular zone which separates the ovum from follicular cells.
3) Corona Radiata: Cumulus oophorus cells immediately surrounding the zona pellucida are called Corona Radiata.



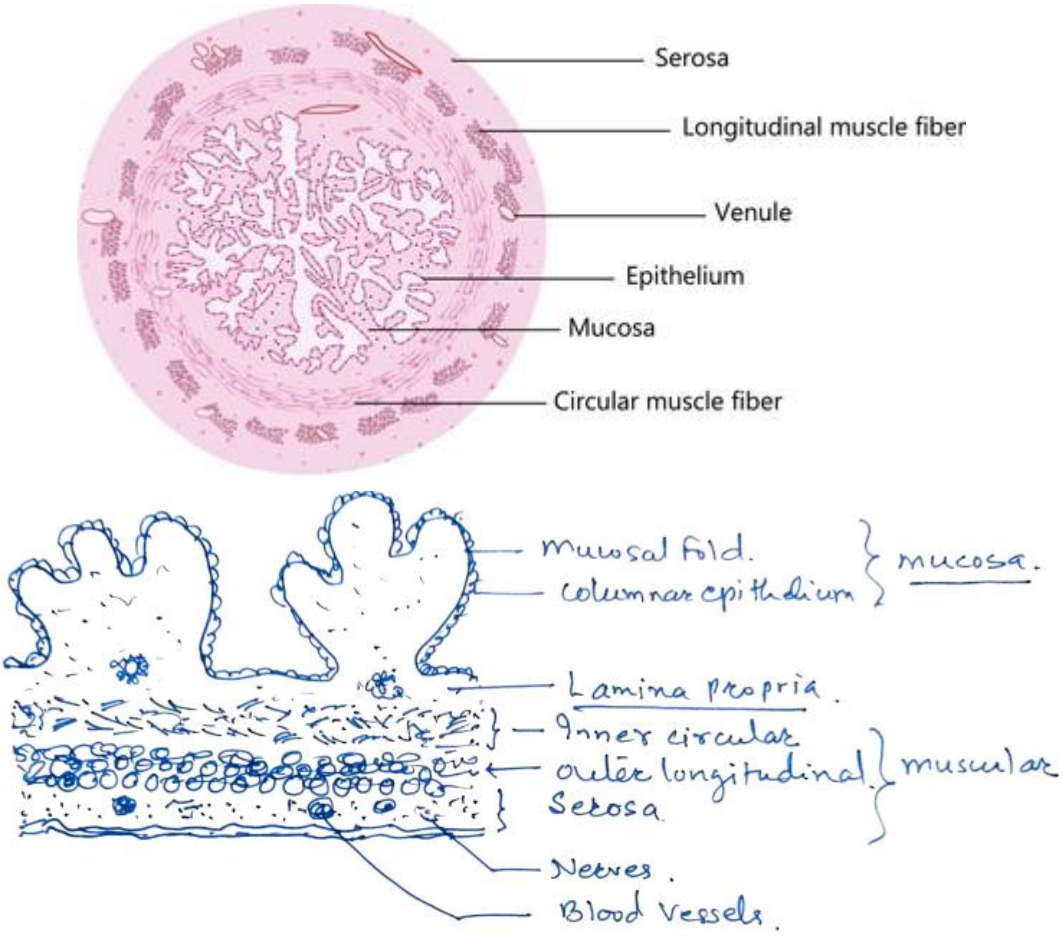
In the ovary out of many developmental follicles only one attends the maturity to form Graafian follicle in every month. During mid-day of menstrual cycle, the Graafian follicle rupture and ovum is released from ovarian walls at spot stigma. It is called Ovulation. After ovulation, empty Graafian follicle is covered into a yellow glandular mass made up of lutein cells called Corpus Luteum. It secretes another female sex hormone Progesterone. If the egg is not fertilized the corpus luteum forms corpus Albicans. The Graafian follicle secretes female sex hormone Estrogen. It regulates secondary sexual characteristics in females.

E] ATRETIC FOLLICLES

The number of primordial follicles does not reach maturity, but they get degenerated. Such a degenerating follicle is called an atretic follicle and the process is called Atresia. In the stroma of cortex such follicles are also observed under microscope.

B. HISTOLOGY OF FALLOPIAN TUBE

The fallopian tubes, also known as uterine tubes or oviducts, are a pair of slender, tubular structures in the female reproductive system. They extend from the upper lateral corners of the uterus and are essential for the transport of eggs (oocytes) from the ovaries to the uterus. Additionally, they are the site of fertilization, where sperm and egg meet. Let's explore the histology of the fallopian tube:



Mucosa (or Mucous Membrane)

The innermost layer of the fallopian tube is the mucosa, which is composed of simple columnar epithelium. The epithelium is lined with cilia, hair-like structures that beat in a coordinated manner towards the uterus. The cilia create currents in the fluid within the fallopian tube, helping to move the egg and captured sperm toward the uterus. The mucosa also contains secretory cells that produce nourishing fluids to support the oocyte and early embryo.

Lamina Propria

The mucosa is supported by a thin layer of connective tissue called the lamina propria, which contains blood vessels, lymphatics and nerves.

Muscularis

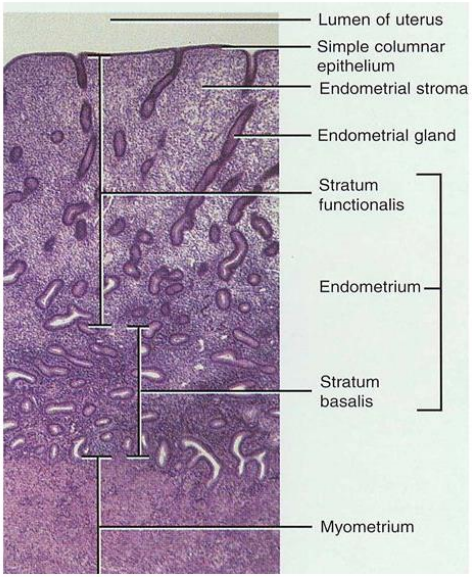
Surrounding the lamina propria is the muscularis layer, consisting of smooth muscle fibers. The muscularis layer exhibits peristaltic contractions, which aid in the movement of the egg and embryo through the fallopian tube.

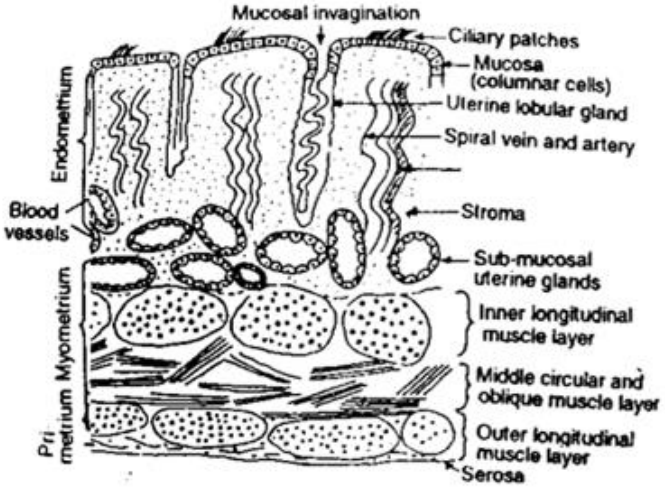
Serosa (or Adventitia)

The outermost layer of the fallopian tube is either a Serosa (if covered by peritoneum) or an adventitia (if covered by connective tissue). The Serosa/adventitia provides structural support and allows the fallopian tube to be anchored within the pelvic cavity.

The fallopian tubes' histological features, particularly the ciliated epithelium and smooth muscle layer, play a crucial role in the transport of the oocyte and sperm, as well as the early stages of embryonic development. Fertilization typically occurs within the ampulla of the fallopian tube, where the sperm encounter the mature egg. After fertilization, the resulting zygote undergoes rapid cell divisions (cleavage) as it travels through the fallopian tube toward the uterus, where it eventually implants and develops into an embryo.

C. HISTOLOGY OF UTERUS





Human uterus is hollow, pear shaped, highly distensible muscular sac situated in between vagina and fallopian tube. It is specialized for the development of embryos. Uterus is differentiated into three parts.

a) FUNDUS: It is an upper dome shaped part. At its upper corner oviducts open on both sides called cornua.

b) BODY/CORPUS: It is the middle part of the uterus. Its wall is made up of three layers-

outer covering is primetrium, middle muscular myometrium and inner highly vascular and glandular endometrium.

c) CERVIX: It is the lower part of the uterus that opens into vagina. The cervix communicates with the body of the uterus by an aperture called internal Os. Two are called the cervical canal.

Histologically the wall of uterus shows three layers

1) Primetrium – outermost coat
2) Myometrium – middle muscular coat
3) Endometrium – Innermost coat

1) PRIMETRIUM / SEROSA

Is the outermost protective serous coat of peritoneum. It extends from the sides of the uterus forming the broad ligaments, through which blood vessels, lymphatics and nerves reach the uterus on each side.

2) MYOMETRIUM / MUSCULARIS

It is the middle muscular coat of the uterus. It is a very thick layer of smooth muscle fibers with connective tissue. Muscle fibers are arranged in three distrinct layers. The middle layer is circular, and outer & inner layers are longitudinal or oblique. The middle region contains many large blood vessels. The hormone oxytocin controls the movement of these muscles.

3) ENDOMETRIUM OR MUCOSA

It is the innermost layer of the uterus. This is the layer which undergoes cyclic changes in structure and secretory activity in response to the female sex cycle (menstrual); such a changing layer of mucosa is called endometrium functionalis. The region of endometrium that remains unchanged even during the destructive period of sex cycle is called endometrium basalis.

A) ENDOMETRIUM FUNCTIONALS

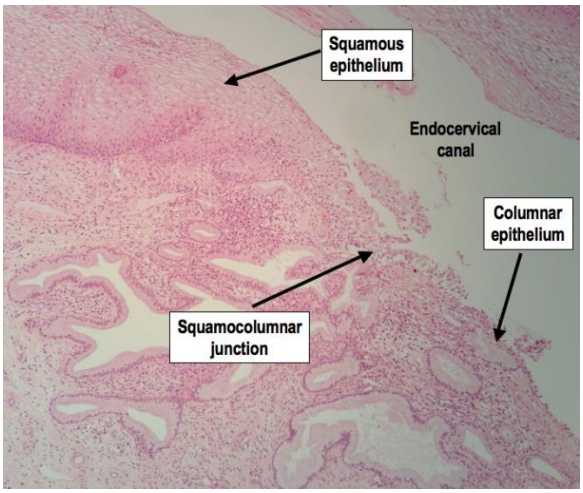
Histologically it is characterized to contain mucosal epithelium and underlying submucosa. Mucosal epithelium consists of a simple columnar epithelium which is ciliated at some regions. The uterine glands are developed by the imagination of this epithelium into the stroma. It has large spiral arteries, veins and sub mucosal uterine glands.

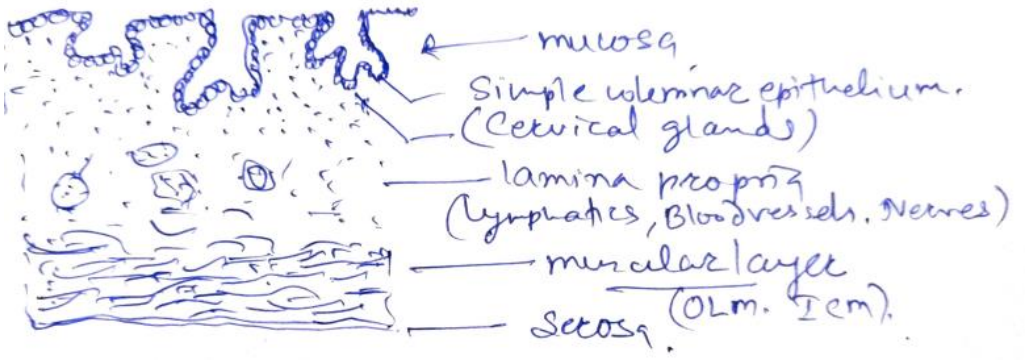
B) ENDOMETRIUM BASALIS

It mainly consists of sub mucosal uterine glands and loose connective tissue.

D. HISTOLOGY OF CERVIX

The cervix is the lower part of the uterus that connects to the upper part of the vagina. It plays a crucial role in the female reproductive system by facilitating the passage of menstrual blood and sperm, and it also serves as a protective barrier during pregnancy. Let's explore the histology of the cervix.





Cervical Canal Epithelium

The cervical canal is the passageway that extends through the center of the cervix. The lining of the cervical canal is characterized by two types of epithelium:

a. **Simple Columnar Epithelium:** This type of epithelium lines the cervical canal's inner portion, also known as the endocervix.
b. **Stratified Squamous Epithelium:** This epithelium lines the portion of the cervix that protrudes into the vagina, known as the ectocervix or exocervix.

The boundary between the two types of epithelium is called the transformation zone. This zone can shift during a woman's life, and its position is significant in cervical cancer screening.

Cervical Glands

The cervix contains numerous glands that secrete mucus. These glands are mainly located in the endocervix and extend into the underlying cervical stroma. The mucus

produced by these glands varies in consistency during the menstrual cycle, influenced by hormonal changes. This mucus plays a vital role in fertility and acts as a barrier against infections.

Cervical Stroma

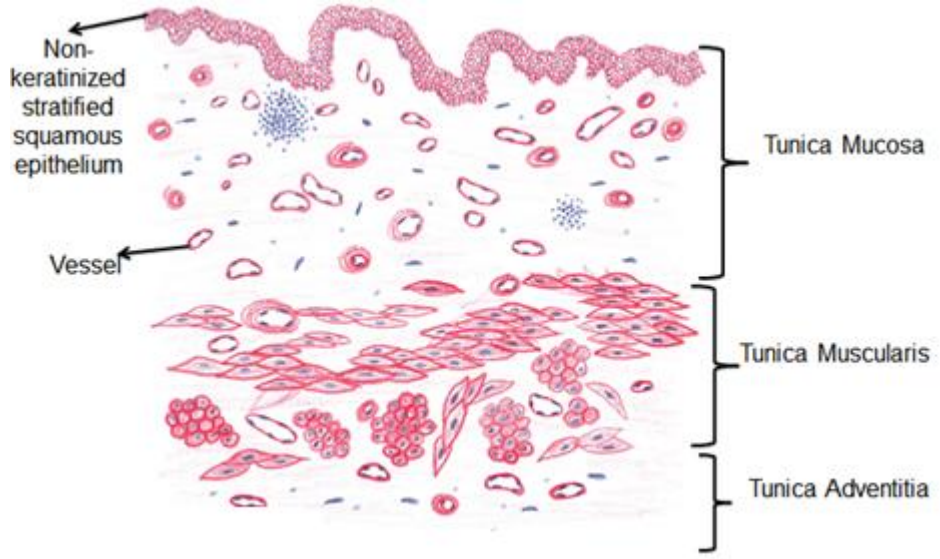
The stroma refers to the connective tissue matrix that supports the epithelial layers and glands of the cervix. It contains fibroblasts, collagen fibers and blood vessels, providing structural support to the cervix.

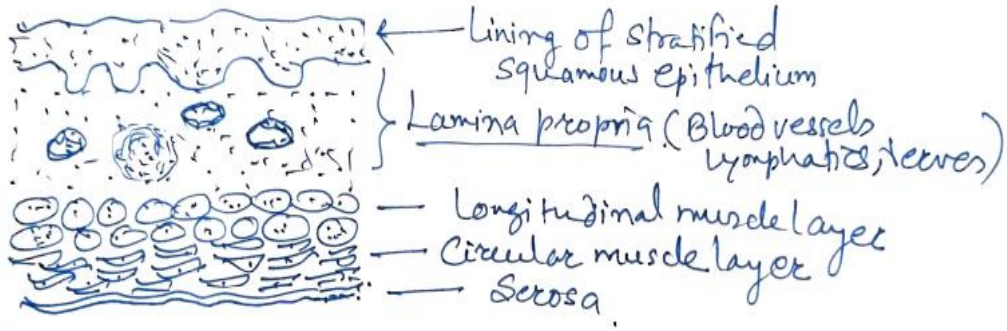
Ligaments and Supportive Structures

The cervix is supported by several ligaments and connective tissues that anchor it to the surrounding pelvic structures**.**

E. HISTOLOGY OF VAGINA

The vaginal wall is composed of several layers, each with specific characteristics:





a. Mucosa (or Mucous Membrane)

The innermost layer of the vaginal wall is the mucosa, which is lined with non-keratinized stratified squamous epithelium. This epithelium is designed to withstand friction and acidic environments and serves as a protective barrier against infection. The

surface cells are constantly being shed and replaced, maintaining the integrity of the mucosal layer.

b. Lamina Propria

Beneath the epithelial layer is the lamina propria, which consists of connective tissue containing blood vessels, nerves, and lymphatics. It also contains elastic fibers that allow the vaginal wall to stretch during intercourse and childbirth.

c. Muscularis

The muscularis layer is composed of smooth muscle fibers arranged in inner circular and outer longitudinal layers. These muscles contribute to the contractility and elasticity of the vagina.

d. Adventitia (or Serosa)

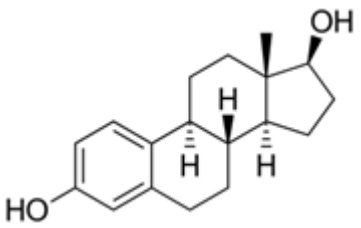
The outermost layer of the vaginal wall is the adventitia, which consists of connective tissue and collagen fibers. It provides support and connects the vagina to the surrounding structures, such as the pelvic floor.

F. FEMALE SEX HORMONES

The major hormones secreted by the ovaries are oestrogen and progesterone, both important hormones in the menstrual cycle. Oestrogen production dominates in the first half of the menstrual cycle before ovulation, and progesterone production dominates during the second half of the menstrual cycle when the corpus luteum has formed. Both hormones are important in preparing the lining of the womb for pregnancy and the implantation of a fertilized egg, or embryo. If conception occurs during any one menstrual cycle, the corpus luteum does not lose its ability to function and continues to secrete oestrogen and progesterone, allowing the embryo to implant in the lining of the womb and form a placenta. At this point, development of the foetus begins.

1. ESTROGENS

The estrogens are C-18 steroids and differ from androgens in lacking the methyl group C_{10}. The ring A is aromatic. The androgens, testosterone, and androstenedione are precursors for the synthesis of the estrogens in testis, ovaries, adrenals and placenta.



Function

- **a.** Estrogens are responsible for the growth of the uterus, vagina, pelvis, breasts, pubic and auxiliary hair.
- **b.** They influence the menstrual cycle and are essential for breast development.

c. On administration, they promote mitotic activity in the uterine muscle and endometrium.

d. The vaginal epithelium is sensitive to the action of estrogen.

e. They influence the secretion of the gonadotrophs hormones in the anterior pituitary.

f. They increase the plasma levels of thyroxine and Cortisol binding globulins.

g. They cause rapid increase in RNA synthesis in uterine tissue.

h. They prevent lipid accumulation in liver when administered to animals having diets deficient in lipotropic factors i.e. methionine and choline.

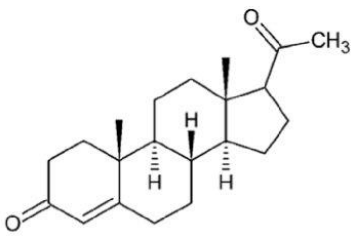
i. They cause decrease in cholesterol level and other lipids in plasma. This is why the incidence of atherosclerosis is low in women as compared to men.

j. They regulate normal bone metabolism. Women after menopause develop osteoporosis.

k. Normally the females excrete estrogens 5-100 mg/24 hours in urine.

2. PROGESTERONE

This hormone is formed in the corpus luteum of the ovary. It is also formed in the placenta during the latter part of pregnancy. It is secreted 1 or 2 days before ovulation takes place. It is synthesized from cholesterol. It is also formed in the adrenal cortex as a precursor of both C-19 and C-21 corticosteroids.



Functions

a. Progesterone causes the development of the endometrium preparing it for the implantation of fertilized ovum for conception.

b. It suppresses estrus, ovulation and the production of luteinizing hormone. When pregnancy occurs, the ovulation and menstruation are suspended by the action of this hormone.

c. It stimulates the mammary glands.

d. It increases BMR during the luteal phase of normal menstrual cycle.

e. In the normal menstrual cycle, the anti-ovulatory effect of progesterone is the basis for the use of certain synthetic progestins as oral contraceptive agents.

f. The normal level of progesterone in serum is 0.2-1.5 mg/ml

G. FOLLICULOGENESIS, PROCESS OF OOGENESIS AND STRUCTURE OF OVUM

FOLLICULOGENESIS

Folliculogenesis is the process by which ovarian follicles develop and mature within the ovaries. These follicles play a crucial role in the female reproductive system, as they are responsible for the production of eggs (oocytes) and the synthesis of sex hormones. The process is complex and occurs in various stages. Let's break down the key steps in folliculogenesis:

1. Primordial Follicle Formation

Primordial follicles are the earliest stage of follicular development. They consist of an immature egg cell (oocyte) surrounded by a single layer of flattened granulosa cells. Primordial follicles are present in the ovaries at birth and remain dormant until later stages of development.

2. Primary Follicle Formation

Activation of primordial follicles leads to the formation of primary follicles. Granulosa cells surrounding the oocyte proliferate and become more cuboidal in shape. The oocyte begins to grow and undergoes structural changes.

3. Secondary Follicle Development

Primary follicles further develop into secondary follicles. Antrum, a fluid-filled cavity, begins to form between the granulosa cells, creating a distinction between the granulosa cell layers. The oocyte is now surrounded by multiple layers of granulosa cells.

4. Graafian Follicle Formation

Among the secondary follicles, one dominant follicle becomes the Graafian follicle. The Graafian follicle is characterized by a large, fluid-filled antrum and a well-developed corona radiata, a layer of granulosa cells surrounding the oocyte. The oocyte completes its maturation process.

5. Ovulation

Ovulation is the release of the mature egg (oocyte) from the Graafian follicle. It typically occurs around the middle of the menstrual cycle in response to a surge in luteinizing hormone (LH).

6. Corpus Luteum Formation

After ovulation, the remaining structure of the Graafian follicle transforms into the corpus luteum. The corpus luteum is a temporary endocrine structure that produces hormones like progesterone to prepare the uterus for a potential pregnancy.

7. Corpus Luteum Regression

If pregnancy does not occur, the corpus luteum regresses, and the menstrual cycle proceeds to the next follicular phase.

8. Atresia

Atresia is the process of degeneration and reabsorption of non-selected follicles during each menstrual cycle. Many follicles initiated during each cycle do not reach full maturity and are eliminated through atresia.

Folliculogenesis is tightly regulated by various hormones, including follicle-stimulating hormone (FSH), luteinizing hormone (LH) and sex steroids like estrogen and progesterone. This dynamic process ensures the cyclical development and release of eggs, contributing to the female reproductive cycle.

OOGENESIS

The process of oogenesis occurs in the cells of the germinal epithelium of the ovary, such cells are known as **primordial germinal cells**. The oogenesis is completed in the following three successive stages

1. Multiplication phase
2. Growth phase
3. Maturation phase.

1. Multiplication Phase

The primordial germinal cells divide repeatedly to form the **oogonia** (Gr., *oon*=egg). The oogonia multiply by the mitotic divisions and form the **primary oocytes** which pass through the growth phase.

2. Growth Phase

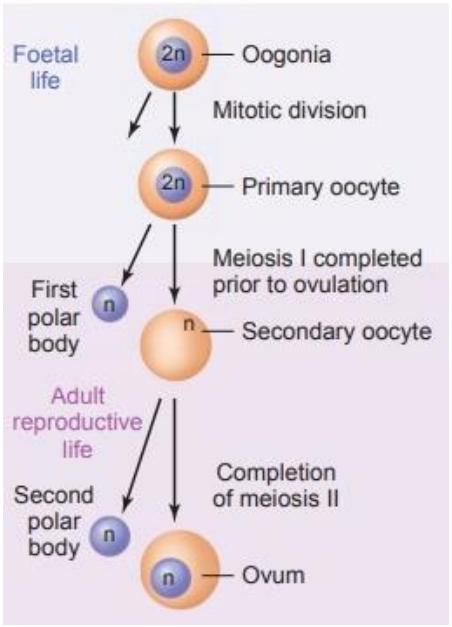
The growth phase of the oogenesis is comparatively longer than the growth phase of the spermatogenesis. In the growth phase, the size of the primary oocyte increases enormously. For Eg., the primary oocyte of the frog in the beginning has the diameter about 50 mm but after the growth phase the diameter of the mature egg reaches about 1000mm to 2000mm. In the primary oocyte, large amount of fats and proteins becomes accumulated in the form of **yolk** and due to its heavy weight (or gravity) it is usually concentrated towards the lower portion of the egg forming the **vegetal pole**. The portion of the cytoplasm containing the egg pronucleus remains often separated from the yolk and occurs towards the upper side of egg forming the **animal pole**.

The cytoplasm of the oocyte becomes rich in RNA, DNA, ATP and enzymes. Moreover, the mitochondria, Golgi apparatus, ribosomes, etc., become concentrated in the cytoplasm of the oocyte. In certain oocytes (Amphibia and birds) the mitochondria become accumulated at some place in the oocyte cytoplasm and forming the **mitochondrial clouds**. During the growth phase, tremendous changes also occur in the nucleus of the primary oocyte. The nucleus becomes large due to the increased amount of the nucleoplasm and is called **germinal vesicle**. The nucleolus becomes large or its number is

multiplied due to excessive synthesis of ribosomal RNA by rDNA of nucleolar organizer region of chromosomes. The chromosomes change their shape and become giant **lampbrush chromosomes** which are directly related with increased transcription of mRNA molecules and active protein synthesis in the cytoplasm. When the growth of the cytoplasm and nucleus of the primary oocyte is completed, it becomes ready for the maturation phase.

3. Maturation Phase

The maturation phase is accompanied by the maturation or meiotic division. The maturation division of the primary oocyte differs greatly from the maturation division of the spermatocyte. Here after the meiotic division of the nucleus, the cytoplasm of the oocyte divides unequally to form a single large sized haploid egg and three small haploid **polar bodies** or **polocytes** at the end. This type of unequal division has the great significance for the egg. If the equal divisions of the primary oocyte might have been resulted, the stored food amount would have been distributed equally to the four daughter cells and which might prove insufficient for the developing embryo. Therefore, these unequal divisions allow one cell out of the four daughter cells to contain most of the cytoplasm and reserve food material which is sufficient for the developing embryo.



a. First maturation division

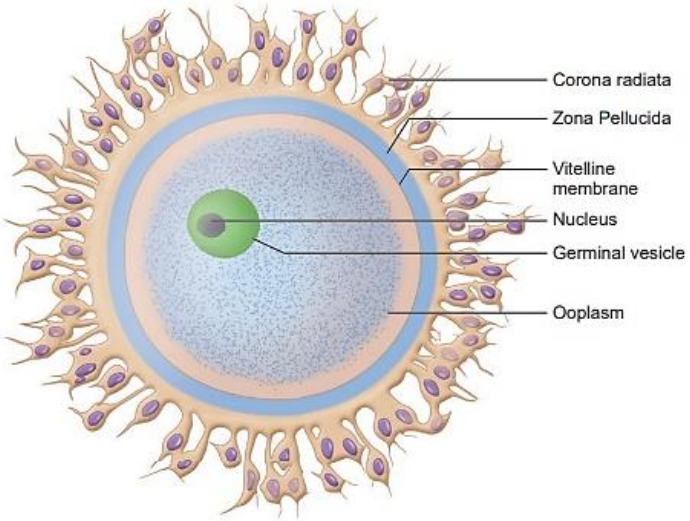
During the first maturation division or first meiosis, the homologous chromosomes of the primary oocyte nucleus pass through the pairing or synapsis, duplication, chiasma formation and crossing over. Soon after the nuclear membrane breaks and the bivalent chromosomes move towards the opposite poles due to contraction of chromosomal fibres. A new nuclear envelope is developed around the daughter chromosomes by the

endoplasmic reticulum. After the karyokinesis the unequal cytokinesis occurs and a small haploid polar body or polocyte and a large haploid secondary oocyte or ootids are formed.

b. Second meiotic division

The haploid secondary oocyte and first polocyte pass through the second meiotic division. Due to the second meiotic division the secondary oocyte forms a mature egg and a second polocyte. By the second meiotic division the first polocyte also divides into two secondary polocytes. These polocytes ooze out from the egg and degenerate while the haploid egg cell becomes ready for the fertilization.

STRUCTURE OF OVUM



The ovum, or egg cell, is the female gamete involved in sexual reproduction. In humans, the structure of the ovum is characterized by its specialization for fertilization and the initiation of embryonic development. Here's an overview of the structure of the human ovum:

a. Cell Membrane (Plasma Membrane)

The outermost layer of the ovum is the cell membrane, also known as the plasma membrane. It acts as a selectively permeable barrier, regulating the movement of substances in and out of the cell.

b. Zona Pellucida

Surrounding the cell membrane is the zona pellucida, a glycoprotein layer. The zona pellucida is essential for species-specific recognition during fertilization and serves as a protective barrier.

c. Vitelline Membrane (Zona Radiata)

Beneath the zona pellucida, there is the vitelline membrane or zona radiata. It is a transparent layer that provides additional protection to the ovum.

d. Cytoplasm

The cytoplasm of the ovum is rich in nutrients and organelles essential for the early stages of embryonic development. It contains mitochondria, which provide energy for cellular activities.

e. Nucleus

The nucleus houses the genetic material of the ovum. It contains a haploid set of chromosomes (23 chromosomes in humans), which combines with the sperm's haploid set during fertilization to form a diploid zygote.

f. Pronucleus

After fertilization, when the sperm penetrates the ovum, the male and female pronuclei form. The pronuclei represent the nuclei of the sperm and ovum before they merge into a single nucleus in the zygote.

g. Centrioles

The centrioles are small organelles that play a crucial role in cell division and the organization of the microtubules of the cytoskeleton.

h. Mitochondria

Mitochondria in the ovum provide the energy necessary for various cellular processes, including fertilization and early embryonic development.

i. Endoplasmic Reticulum (ER)

The endoplasmic reticulum is involved in the synthesis and processing of proteins.

j. Golgi Apparatus

The Golgi apparatus is responsible for modifying, packaging, and transporting proteins within the cell.

k. Ribosomes

Ribosomes are involved in protein synthesis.

l. Lysosomes

Lysosomes contain enzymes that play a role in cellular digestion and recycling.

m. Microvilli

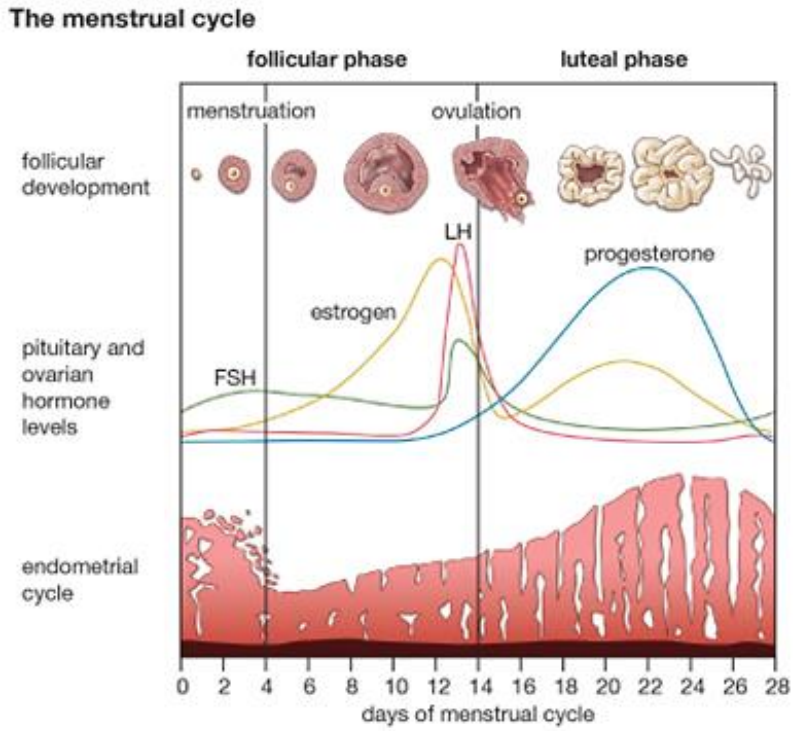
Microvilli are small projections on the surface of the ovum that increase the surface area for interactions with sperm during fertilization.

n. Cortical Granules

Cortical granules are small vesicles found in the cytoplasm of the ovum. After fertilization, they release enzymes that modify the zona pellucida to prevent polyspermy (fertilization by multiple sperm). The structure of the human ovum is adapted to its roles in fertilization and early embryonic development. It undergoes changes during fertilization

and early embryogenesis, ultimately contributing to the formation of a multicellular organism.

H. MENSTRUAL CYCLES AND HORMONAL REGULATION



Menstruation, also known as a period or monthly, is the regular discharge of blood and mucosal tissue (known as menses) from the inner lining of the uterus through the vagina. The first period usually begins between twelve and fifteen years of age, a point in time known as menarche. However, periods may occasionally start as young as eight years old and still be considered normal. . The typical length of time between the first day of one period and the first day of the next is 21 to 45 days in young women and 21 to 31 days in adults (an average of 28 days). Bleeding usually lasts around 2 to 7 days. Menstruation stops occurring after menopause, which usually occurs between 45 and 55 years of age. Periods also stop during pregnancy and typically do not resume during the initial months of breastfeeding. Up to 80% of women report having some symptoms prior to menstruation. Common signs and symptoms include acne, tender breasts, bloating, feeling tired, irritability and mood changes. These may interfere with normal life, therefore qualifying as premenstrual syndrome, in 20 to 30% of women. In 3 to 8%, symptoms are severe.

MENSTRUATION

Cyclic discharge of blood, mucus, cellular debris and unfertilized ovum from the uterus through vagina at an interval of every 28 days is called Menstruation. Menstruation

gets suppressed for temporary period during pregnancy, lactation and permanently stops at menopause. Menstrual cycle is divided into 4 different phases

1. Menstrual
2. Follicular or Proliferative
3. Ovulatory
4. Post ovulatory or secretary phase.

1] MENSTRUAL PHASE – (1st to 5th day)

It occurs in absence of pregnancy. If ovum is not fertilized, the corpus luteum begins to degenerate which results in sudden fail in progesterone and oestrogen level. As a result the highly vascular and glandular endometrium breaks off. As the endometrium is broken, the blood vessels ruptured and blood, mucus, cellular debris and unfertilized ovum together known as menses discharged through vagina i.e. bleeding takes places. Physiologists describe this phase as Weeping of uterus due to loss of ovum. Low level of oestrogen and progesterone stimulates hypothalamus and pituitary gland to secrete FSH-RF and FSH respectively by feedback mechanism.FSH stimulates the development of follicles.

2] FOLLICULAR OR PROLIFERATIVE PHASE (6th to 13th day)

FSH stimulates the development of follicles. In each cycle only one follicle attends maturity to form Graafian follicle**.** Follicular cells, membrane granulose secretes oestrogen which repairs the wall of uterus which is damaged at previous phase. The endometrium becomes 2.3mm thick vascular and glandular. The uterine gland elongates and becomes prominent and show profuse branching. The epithelium of fallopian tube becomes thick and densely ciliated to conduct the ovum or zygote. At the end of these phase oestrogen level increases, it inhibits the secretion of FSH by negative feedback mechanism results in atresia i.e. degeneration of other development follicles.

3] OVULATORY PHASE (14th day)

At the 14th day of cycle there is sudden rise in LH secretion from pituitary gland called LH-surge. LH surge is due to peak in oestrogen and fall in FSH. Under the influence of LH liquor follicle and antrum increases and exerts pressure on follicular wall. As a result, Graafian follicle rapture and ovum released outside, the process is called Ovulation

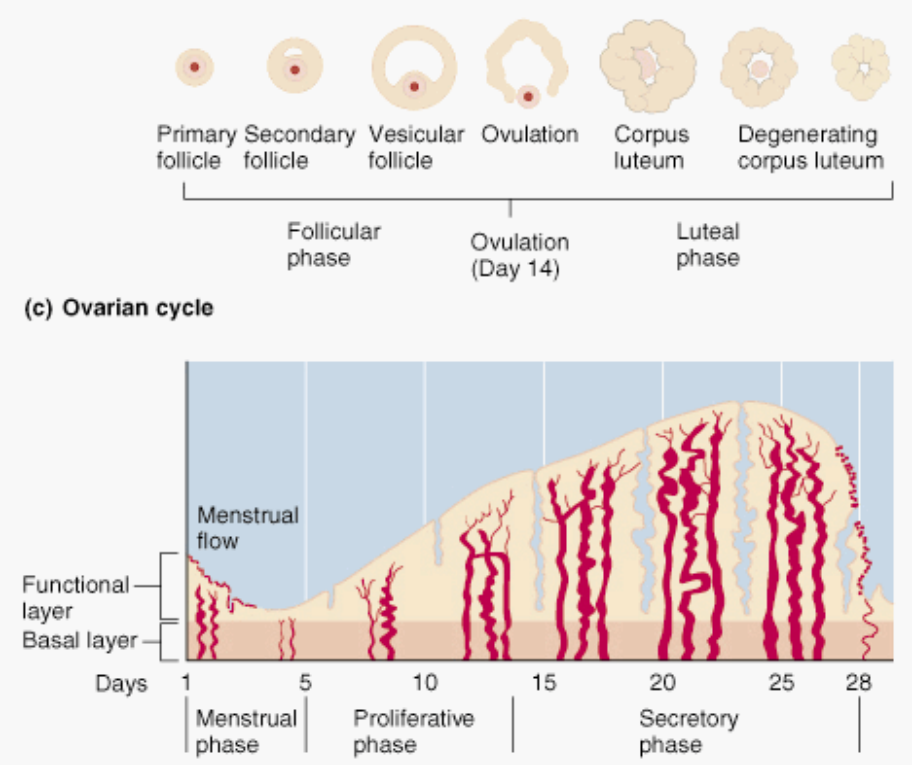
4] POST OVULATORY OT SECRETORY PHASE (15th to 28th day)

After ovulation, LH with LTH converts empty Graafian follicle into corpus luteum which contains yellow glandular leutin cells and secretes large amount of progesterone and small amount of oestrogen. The progesterone and oestrogen stimulate the prolongation of

endometrium and makes it highly vascular and glandular to secrete uterine milk and nourish the developing embryo. It becomes comfortable cushion for implantation and further growth of fertilized egg. If pregnancy occurs i.e. egg get fertilized. HCG (Human chorionic gonadotrophin) from embryonic membrane retains corpus luteum as a result, secretion of progesterone and oestrogen increased, which maintain the endometrium of pregnancy. If fertilization does not take place, the corpus luteum degenerate causing dramatic fall in progesterone and oestrogen levels results in menstruation. Thus, the cycle repeated once again.

HORMONAL CONTROL OF MENSTRUAL CYCLE

FSH secrete by pituitary gland stimulates growth, development and maturation of Graafian follicle. LH secreted by pituitary helps ovulation and formation of corpus luteum. Oestrogen secreted by follicular cells stimulates repairing of endometrium. Progesterone secreted by corpus luteum maintains endometrium, prepare endometrium for pregnancy.



TRANSPORT OF OVUM AND SPERM IN FEMALE GENITAL TRACT

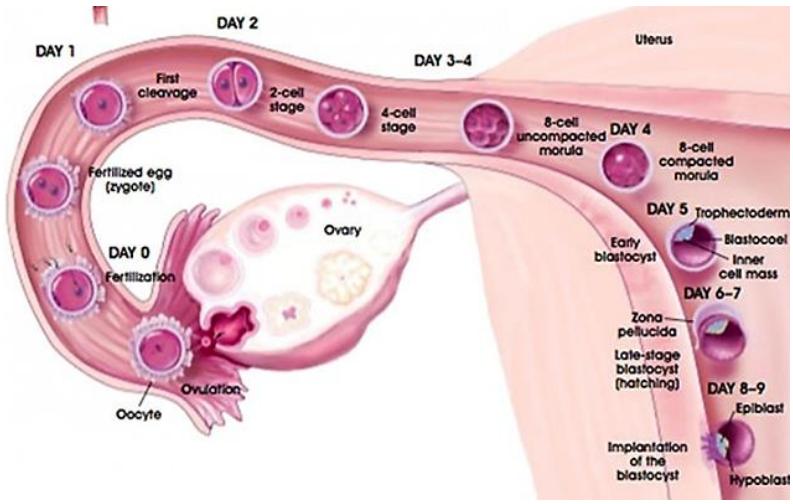
1. OVUM TRANSPORT IN THE FEMALE GENITAL TRACT

Egg transport refers to the movement of the oocyte from its expulsion from the ovarian follicle to its entry into the distal segment of the fallopian tube, preceding fertilization. Following fertilization in the ampullary segment of the fallopian tube, the developing embryo takes approximately 5 days to traverse the remaining oviductal

segments before reaching the uterine cavity at the blastocyst stage. For clarity, "egg transport" here pertains specifically to the post-ovulation and pre-fertilization phases, covering the haploid life span of the ovulated oocyte. Subsequent sections will address the transport of the fertilized diploid oocyte (zygote) and pre-implantation embryo.

The anatomy and physiology of the fallopian tube significantly influence egg transport and fertilization. Comprising four regions, the fallopian tube is a muscular tube around 11–12 cm long. The infundibulum, the most distal part, includes finger-like fimbriae with densely ciliated and convoluted epithelial lining, crucial for capturing the cumulus-oocyte complex. The ampulla, averaging 5–8 cm, is where fertilization and early embryo development primarily occur. The isthmus, approximately 2–3 cm in length, regulates sperm and embryo transport, while the intramural segment links the isthmus to the uterine cavity.

Cyclic changes, mirroring the menstrual cycle, occur in both ciliated and non-ciliated cells of the fallopian tube. Each segment is preferentially regulated by hormones, leading to the distinct regional activities depending on the menstrual cycle day. For instance, during the early follicular phase (day 4), propulsive forces act throughout the tube towards the uterus. By day 8 (mid-follicular phase), alternating forces operate in the ampulla. Ovulation (around day 14) sees increased ipsilateral transport to the ovary, with observed higher pregnancy rates in women exhibiting this transport pattern. The fallopian tubes function is critical for early fertilization stages.

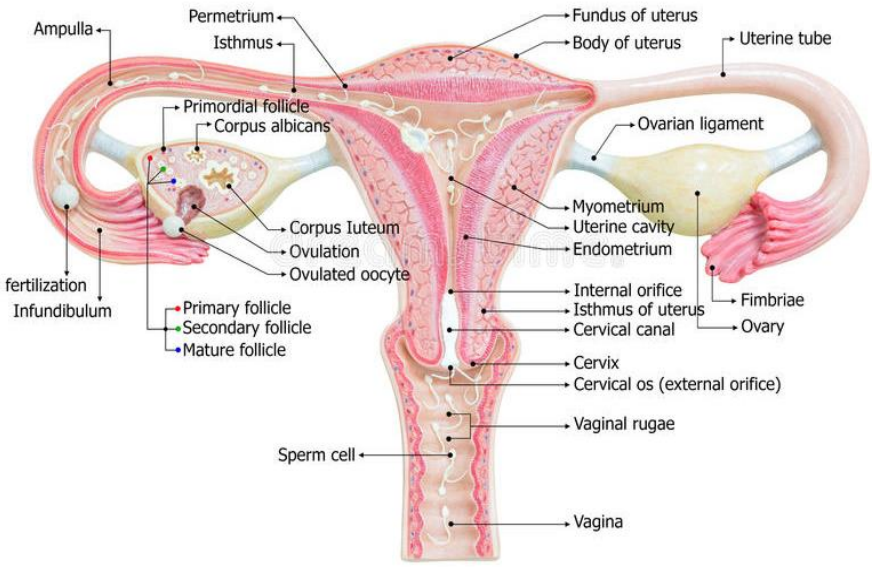


At ovulation, the oocyte is enveloped by specialized granulosa cells, forming the cumulus-oocyte complex (COC). The cumulus maturation results in the corona radiata, facilitating metabolic exchange via transzonal projections. The mature COC, sticky in nature, aids adherence to the fimbriae after expulsion from the follicle during ovulation.

The mechanism of COC pickup into the fallopian tube lumen remains uncertain. Possibilities include the fimbriated end of the fallopian tube sweeping over the ovary, drawing the COC into the tubular lumen through muscular control. However, cases of pregnancy in women without the fallopian tube on the side of ovulation challenge this theory. Ciliary beating, muscular contractions creating negative pressure and peristaltic pumping of the female tract are proposed mechanisms. Recent research suggests mucus strand connections between fimbriae and ovary may act as a tether facilitating COC capture. Overall, COC pickup involves multiple mechanisms, including ciliary beating, fimbriae sweeping and peristaltic pumping, occurring within 2 to 3 minutes after ovulation.

1. SPERM TRANSPORT IN THE FEMALE GENITAL TRACT

Sperm transport within the female reproductive tract is a collaborative process involving the functional interplay between sperm, seminal fluid and cyclic adaptations of the female reproductive system. The journey of sperm involves overcoming various barriers as they move towards the ovulated egg.



During human coitus, semen is deposited in the upper vagina near the cervix. However, the normal acidic pH of the vagina (below 5.0) is inhospitable to sperm survival. This acidity is a protective mechanism against sexually transmitted pathogens. Vaginal epithelial cells, containing glycogen, are broken down by lactobacilli, producing lactic acid and raising the pH to a favorable level for sperm motility within 8 seconds of semen introduction.

Shortly after coitus, semen coagulates due to semogelin, possibly aiding in keeping sperm near the cervical opening. Within 30 to 60 minutes, prostate-specific antigen (PSA)

degrades the coagulated semen, allowing active sperm movement. Sperm motility is facilitated by fructose from seminal vesicles.

The cervix, with a small entrance (Os) blocked by cervical mucus, poses another barrier. Cervical mucus is typically sticky but becomes more penetrable (E mucus) around ovulation due to estrogen. The passage of sperm through the cervix remains uncertain, with some reaching the upper reaches of uterine tubes shortly after coitus, possibly aided by muscular contractions.

Most sperm traverse the cervical mucus over hours or days, with uncertain storage in the cervix. Uterine contractions likely assist sperm transport through the uterus towards the uterine tube, where the majorities are cleared from the reproductive tract by white blood cells.

The uterotubal junction presents a further hurdle, as only a small fraction of sperm successfully enters the correct tube. Sperm that attach to the uterine tube epithelium undergo capacitation, involving the removal of cholesterol and glycoproteins. Capacitation allows sperm to fertilize an egg by removing molecular shields. Concurrently, hyperactivation enhances sperm swimming vigor, aiding their release from tubal epithelial binding.

Once capacitated, hyperactivated sperm navigate the upper uterine tube with their own movements, peristaltic contractions, and ciliary activity, reaching the ovulated egg in the upper third of the tube. Out of the millions of sperm initially introduced, only one will successfully fertilize the egg, marking the culmination of their intricate journey.

EMBRYO TRANSPORT

As mentioned previously, fertilization occurs in the ampullary segment of the fallopian tube. Transit time of the zygote from the ampulla to the ampulla-isthmic junction is approximately 30 hours, after which the zygote remains in the isthmus another 30 hours before resuming transit through the isthmus. It is not until the 5th or 6th day after fertilization that the pre-implantation embryo arrives into the uterine cavity. During the time frame from fertilization to deposition of the embryo in the uterus, the propulsive forces in the fallopian tube are towards the uterus.

The fallopian tube and its microenvironment are ideal for early embryo development. Indeed, when human embryos are co-cultured on human fallopian tube epithelial cells, higher implantation and lower spontaneous abortion rates are achieved. Therefore, it would appear that complex interactions take place between the oviductal epithelium and the embryo. Human oviductal cells are known to secrete growth

factors, cytokines, and other embryo tropic factors (ETFs) that enhance and support the development of the pre-implantation embryos. Oviductal cells may also affect gene expression of the pre-implantation embryo. Much more knowledge is necessary before we can understand the contributions of the tubal environment to embryo development. However, synchrony between uterine endometrium and embryo development must be in place for successful implantation to be achieved.

I. PROCESS OF FERTILIZATION

The fusion of a haploid male gamete (sperm) and a haploid female gamete (ovum) to form a diploid zygote is called fertilization. The idea of fertilization was known to Leeuwenhoek in 1683. Fertilization in the human beings is internal and takes place at the ampullary-isthmic junction of fallopian tube of the female.

Fertilization in Human: Process, Events and Significance

Definition

The process of union of a haploid male gamete or sperm with a haploid female gamete or ovum to form a diploid cell, the zygote, is called fertilization.

Site of Fertilization

In man fertilization is internal (external in case of frog) as in other mammals. It takes place usually in the ampulla of the fallopian tube.

Process of Fertilization

Male discharges the semen into the vagina of the female during copulation (coitus). From the vagina, the sperms reach the ampulla partly by the movement of their tails and partly by the action of uterus. The sperms present in the semen travel a long way from vagina through the uterus into the fallopian tube.

Sperms may reach fallopian tube within five minutes. The sperm can survive in the female's reproductive tract for 1 to 3 days and it can fertilize the ovum in 12 to 24 hours following ovulation. During sexual intercourse, nearly 300 million sperms are introduced into the vagina, but only few hundreds of them reach near the ovum.

Events of Fertilization

1. Activation of sperm and ovum

The sperms can fertilize an ovum only they are able to secrete the chemical hyaluronidase and possess a surface protein called antifertilizin (composed of acidic amino acid). The ovum secretes a chemical named fertilizin (composed of glycoprotein = mono saccharides + amino acids). It mixes with the water to form egg water which attracts the sperms of its own species.

2. Penetration of sperm

The fertilizin of an egg interacts with the anti fertilizin of sperm of the same species. This attraction between fertilizin and antifertilizin makes the sperms stick to the egg surface. The process of acquiring the capacity to fertilize the egg by the sperm is called capacitation. In this process, the membrane surrounding the acrosome of the sperm breaks and releases its contents, the sperm lysin. It is the chemical substance present in the sperm's acrosome.

The ovum is surrounded by three membranes such as corona radiata, zona pellucida and the vitelline membranes. At first the sperm passes through corona radiata to reach zona pellucida. There it releases the enzyme hyaluronidase or sperm lysin from its acrosome. This enzyme dissolves zona pellucida as a result of which the sperm reaches the plasma membrane of the egg. The above changes on the sperm head are called acrosome reaction.

At the point of contact with the sperm, the egg forms a projection, termed the cone of reception or fertilization cone which receives the sperm. Once one sperm has entered the egg (ovum) the vitelline membrane thickens and is converted into fertilization membrane. This membrane is rigid and never allows other sperms to pass through this membrane. Penetration of the sperm initiates a second maturation division of the ovum and a second polar body is given off.

3. Amphimixis

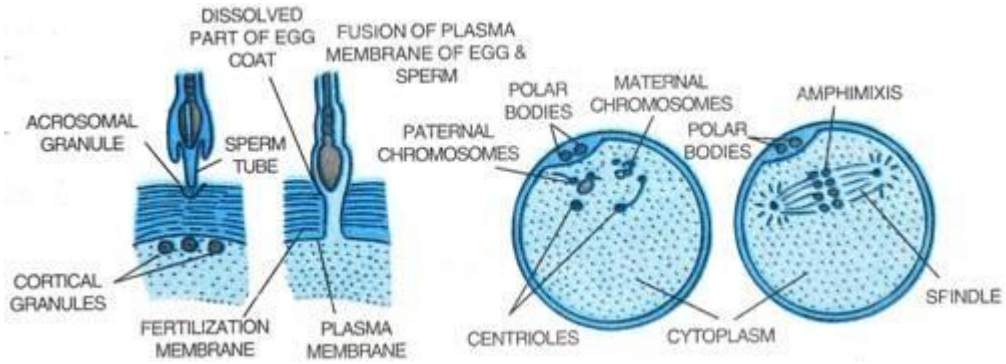
A sperm consists of three parts: head, middle piece and tail. Shortly before or after entering the egg, the sperm loses its tail. After the sperm entering the egg, the membrane of head and middle piece dissolves, and is liberating nucleus, centrosome and mitochondria. Now the sperm nucleus enlarges to form the male pronuclear and the nucleus of the ovum becomes female pronuclear.

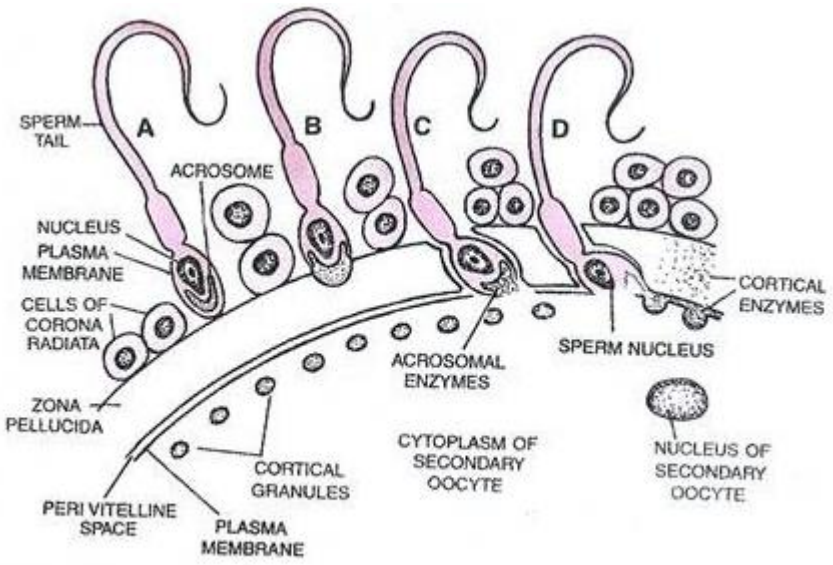
The male pronuclear moves inwards and then changes its direction to meet the egg nucleus. The initial path is known as penetration path and the second path is known as copulation path. The chromosomes (haploid set) of (he sperm and the chromosomes (haploid set) of the egg or ovum are set free by the breakdown of their nuclear envelops.

Mixing up of the chromosomes of a sperm and an ovum resulting in a diploid zygote nucleus is known as amphimixis or karyogamy. The mother is now said to be pregnant. The centrosome form asters and spindle fibers. The paternal and maternal chromosomes move to lie in the equator of the spindle and the zygote is ready for division by cleavage.

Fertilization has the following significance

1) Fertilization restores the diploid number of chromosomes, i.e. 46 in human being.
2) It provides stimulus for the ovum to complete its maturation.
3) Fertilization combines the characters of two parents. This brings about recombination of genes and introduces variations.
4) It determines the sex of the embryo in humans.
5) Fertilization introduces the centrioles which are absent in ovum.
6) Fertilization membrane formed after the entry of the sperm prevents the entry of additional sperms.





Stages of sperm entry into the ovum during fertilization.

J. HORMONAL CONTROL OF IMPLANTATION

The process of attachment of the blastocyst (mammalian blastula) on the endometrium of the uterus is called implantation. Though the implantation may occur at

any period between 6th and 10th day after the fertilization but generally it occurs on seventh day after fertilization.

MECHANISM

First of all, the blastocyst is held closely against the uterine endometrial epithelium. The uterine capillaries and uterine wall in the immediate vicinity of the embryo become more permeable and a local stromal oedema is developed. Soon the endometrium around the embryo shows the first sign of a decidual cell reaction (DCR) which involves:

a) The epithelium becomes disrupted and the loosely packed fibroblast-like cells of the stroma are transformed into large rounded glycogen-filled cells.

b) The area of contact becomes more vascular.

c) The decidual cells form an "implantation chamber" around the embryo and probably help in nutrition to embryo before the formation of a functional placenta.

d) The trophoblast is developed from the superficial layer of the morula stage. Later, the trophoblast is lined by mesoderm to form the chorion which contributes to the placenta formation.

HORMONAL CONTROL IN IMPLANTATION

(a) Role of estrogens

These are a group of steroid hormones mainly secreted by follicular epithelial cells of Graafian follicle though these are also produced by adrenal cortex and placenta. These include β-estradiol, esterone, estriol etc. Out of which most important estrogen is P-estradiol. Secretion of estrogens is stimulated by FSH of anterior lobe of pituitary gland. These stimulate the uterine endometrial epithelium to enlarge, become more vascular and more glandular. The uterine glands become tortuous and cork-screw shaped. So the endometrium prepares itself for implantation. This stimulation by the estrogens on the uterus generally occurs on the 4th day of pregnancy.

Some of these proteins act as enzymes which activate the blastocyst for implantation which, in turn, stimulates the uterine endometrium to undergo decidual cell reaction which is essential for implantation.

(b) Progesterone

It is also a steroid hormone secreted by yellow-coloured endocrine gland, called corpus luteum, formed from empty Graafian follicle during the pregnancy. Small amount of progesterone is also secreted by adrenal cortex and placenta, Secretion of progesterone is stimulated by LH of anterior lobe of pituitary gland. Progesterone acts on only those uterine cells which have been earlier stimulated by estrogens. Progesterone further

stimulates the proliferation of endometrium of uterus and prepares it for implantation. It also helps in implantation, placenta formation and normal development of the foetus in the uterus.

DIAGNOSTIC FEATURES OF PREGNANCY AND HORMONAL REGULATION

PREGNANCY DIAGNOSIS

A. Menstrual Cessation

Pregnancy is often first suspected when a woman experiences a cessation of her menstrual cycle.

B. Abdominal Swelling

The development of abdominal swelling becomes noticeable as pregnancy progresses.

C. Nausea and Vomiting

Nausea and vomiting typically manifest between the 6th and 12th weeks of pregnancy.

D. Fetal Heartbeat Audibility

The audible detection of fetal heartbeats becomes possible at a certain stage of pregnancy.

E. Maternal Sensation of Fetal Movements

By the 18^{th} to the 20^{th} week, the mother can perceive the kicking movements of the developing fetus.

F. X-ray Pregnancy Detection

Pregnancy can be identified through X-ray methods as early as the 16th week.

G. Sperm Shielding Test

A unique diagnostic approach involves injecting 5ml of urine into male frogs. Presence of sperm in the frogs' urine within 4 hours is considered a positive indication of pregnancy.

Pregnancy can be studied for convenience into two phases

A] Luteal Phase B] The Placental Phase

A] THE LUTEAL PHASE OF PREGNANCY

Due to fertilization the secretory phase or luteal phase of menstrual cycle does not terminate as usual but continues directly as a luteal phase of pregnancy. During this phase following events takes place.

1. The fertilized egg undergoes cleavages to form blastocyst.
2. The blastocyst migrates to the uterus and establish and implantation.

3. A number of fingers like processes arise from the outer coverings of the embryo and are embedded in the tissue of uterus.
4. In the ovary, the corpus luteum grows and starts secreting more amount of progesterone (which increases as pregnancy advances.)
5. The placentation is stimulated by progesterone hormone of corpus luteum.

B] THE PLACENTAL PHASE OF PREGNANCY

1. After implantation of blastocyst into uterine wall, pools of blood gather around the finger like process of blastocyst.
2. A firm vascular connection between foetus and maternal tissue is established called Plancentation.
3. The placenta also serves to eliminate the secretory products of foetal metabolism.
4. The fetus derives its nourishment and oxygen from the mother through placenta.
5. Human placenta functions as an endocrine organ secreting hormones like oestrogen, progesterone human chorionic gonadotrophin (HCGn), Human placental lactogen (HPL) and Relaxin.
6. Though the fetal and maternal tissues are in close contact in placenta, there is no mixing of maternal and fetal circulation. It is separated by thin membranous partition. Which allow the exchange of various substances by the diffusion or by the active transport.
7. The main blood vessel from the placenta enters the fetus through a thick cord called Umbilical cord.
8. After birth this cord is cut and after which the baby will not receive any nourishment through the placenta.
9. The growing foetus is also attached by the amniotic fluid with the maternal tissue which can be freely exchanged with the maternal fluids.
10. The placental phase continues up to nine months during which all systems are properly developed.

OTHER PHYSIOLOGICAL CHANGES DURING PREGNANCY

1. Birth canal is enlarged and relaxation of pelvic ligaments takes place.
2. Breasts are properly developed to start lactation after parturition. In this period the pigmentation of Areola and Nipple occurs due to ACTH & MSH.
3. The volume of the blood increases by 1-2 liters of extra blood. Blood count and blood cholesterol are increased.

4. Endocrine glands like adrenal cortex, anterior pituitary and thyroid shows enlargement.
5. FSH and LH secreted by pituitary stimulate ovary to produce Graafian follicle which then start secretion of oestrogen.

Oestrogen stimulates pituitary to secrete LH & LTH which brings about ovulation & corpus luteum formation. Corpus luteum secretes progesterone which brings about plancentation on one hand & prevents further ovulation on the other hand, thus maintains pregnancy.

Pregnancy test detects human pregnancy hormone (human chorionic gonadotrophin (HCG)) to determine whether an individual is pregnant. HCG testing can be performed on a blood sample (typically done in a medical office or hospital) or on urine (which can be performed in an office, hospital or at home.)

The most common tests use markers found in blood and urine, specifically one called human chorionic gonadotrophin (HCG). Identified in the early 20th century, HCG rises quickly in the first few weeks of pregnancy, peaking at 10 weeks. It is produced by the syncytiotrophoblast cells of the fertilized ova (eggs) as the cells invade the uterus' lining and start forming what will become placenta.

Urine tests will typically show positive around four weeks after the last menstrual period (LMP) and are best did in the morning as HCG levels are then highest. Because of their cut-off HCG level, a positive result is less likely to be incorrect than a negative one, and how much water/fluids have been consumed *can* affect the results as well. Blood HCG tests for a more specific part of the HCG molecule and can detect pregnancy earlier than urine, even before a period has been missed. Obstetric ultrasonography may also be used to detect pregnancy. The order of detection from earliest to latest is that HCG can be detected earliest in the blood, then a urine test, then ultrasound.

HORMONAL REGULATION OF PREGNANCY

Pregnancy is a rollercoaster of shifting hormone levels which can have numerous effects. This graphic looks at six key hormones during pregnancy, their roles in the development of the baby, and other effects are as follows.

1) Human chorionic gonadotropin (HCG)

HCG is an important hormone in early pregnancy is produced by the placenta after implantation, and supports the function of the corpus luteum. The corpus luteum is a temporary structure in the ovaries which produces other key hormones during early pregnancy. hCG is also the hormone detected by pregnancy tests. Its concentration

increases from conception and peaks 8–11 weeks after. For the first few days after conception its levels are too low to detect with pregnancy tests, but after implantation its levels double every 48 hours.

2) Progesterone

During the early weeks of pregnancy, the corpus luteum produces progesterone. After 8-12 weeks, the placenta takes over. Progesterone stimulates growth of the blood vessels that supply the womb lining. It also stimulates the lining to release nutrients, providing nourishment for the early embryo. Additionally, progesterone inhibits contraction of the smooth muscle of the uterus so that it grows as the baby does. Progesterone levels continue to rise as the pregnancy progresses. Along with oestrogen, it promotes the growth of breast tissue and milk duct development. Progesterone prevents lactations during pregnancy, which only starts when levels drop after birth. This hormone also plays an important role in preparation for birth: it strengthens the pelvic wall muscles required for labour. Noticing increased hair growth during pregnancy? That's also due to progesterone!

3) Oestrogen

As with progesterone, the corpus luteum produces oestrogen in the early stages of pregnancy before the placenta takes over. Oestrogen is actually a collective group of similar compounds: oestrone, oestradiol, and oestriol. Oestrogen helps the uterus grow and maintains its lining. It supports fetal development, including the development of organs and bodily systems. It also activates and regulates the production of other important pregnancy hormones.

4) Prolactin

Prolactin is the main hormone needed to trigger the production of breast milk. It enlarges the mammary glands to prepare for this (though as previously noted progesterone levels prevent lactation until the baby is born). Prolactin has other roles unrelated to milk production. It contributes to the development of the foetal lungs and brain, and also to the mother's immune system tolerating the foetus.

5) Relaxin

Relaxin levels are highest during the first trimester of pregnancy, but it is present throughout. It has several roles, including prohibiting contraction of the uterine muscles to prevent premature birth. Relaxin's name gives a clue to its more important roles. It relaxes blood vessels, increasing blood flow to the placenta and kidneys. This helps the mother's body cope with the increased demand for oxygen and nutrients from the developing baby.

Relaxin also helps the mother's body prepare for birth. It relaxes joints in the pelvis and softens and widens the cervix to make delivery of the baby easier.

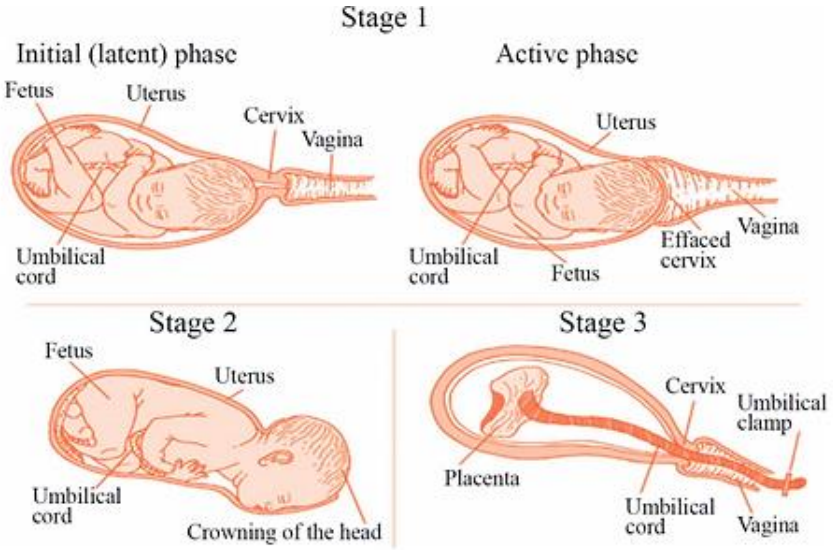
6) Oxytocin

Oxytocin only appears in significant amounts towards the end of pregnancy, though it is present in lower amounts before this. Its levels rise when labour starts, triggering contractions. If labour doesn't start naturally, oxytocin (or synthetic equivalents) can be used to induce it.

MECHANISM AND HORMONAL REGULATION OF PARTURITION AND LACTATION

PARTURITION

It is the expelling of the fully formed young from the mother's uterus after the gestation period (about 280 days or 40 weeks in human female) i.e., of about 9.5 months.



MECHANISM

Parturition is induced by a complex neuroendocrine mechanism which is triggered by fully formed foetus and the placenta called fetal ejection complex. A developing foetus secretes hormones from its adrenal glands. These hormones diffuse into the maternal blood and accumulate to stimulate the release of oxytocin (birth hormone) from the mother's posterior pituitary.

Oxytocin causes the forceful contraction of smooth muscles of myometrium, called labour pains, which pushes the young gradually out through the dilated cervix (caused by relaxin) and vagina, with the head foremost. Uterine contraction, in turn, stimulates further secretion of oxytocin.

The stimulatory reflex between the uterine contraction and oxytocin secretion continues resulting in stronger and stronger contractions. It is aided by a reflex (whose centre lies in the lumbar region of spinal cord) and voluntary contraction of abdominal muscles. In the beginning, the labour pains occurs once every half or quarter of an hour, called mild ejection reflex, but soon become more frequent.

The fetal membranes burst and amniotic fluid is released but foetal membranes remain behind. This expulsion stage lasts about 20 minutes to one hour. It is followed by placental stage of 10-45 minutes during which the umbilical cord, placenta and foetal membranes are expelled as decidua or after birth.

It is because after the child birth, the uterus reduces in size causing detachment of placenta. Umbilical cord is tied and then cut which finally shrinks into a depressed scar called umbilicus or navel. Sometimes, the foetus fails to come out then the baby is delivered by a surgical procedure. Such a baby is called cesarean.

Parturition is controlled by hormones

a) **Oxytocin:** Causes powerful contractions of myometrium during parturition.
b) **Relaxin:** Causes widening of pelvis by relaxing the pubic symphysis of the pelvic girdles.

LACTATION AND ITS HORMONAL REGULATION

Lactation is the physiological process wherein milk is secreted from the mammary glands to nourish offspring, and it is a common feature among post-pregnancy female mammals. In humans, this feeding process is referred to as breastfeeding or nursing. Newborn infants may even produce a small amount of milk from their own breast tissue, colloquially known as "witch's milk."

While most mammals release milk through nipples, monotremes (egg-laying mammals) lack nipples and excrete milk through abdominal ducts. Notably, in the Dayak fruit bat from Southeast Asia, milk production is a normal male function.

Galactopoiesis, the maintenance of milk production, is reliant on prolactin, while oxytocin is crucial for the milk let-down reflex in response to suckling. Galactorrhea, the production of milk unrelated to nursing, can occur in both males and females due to hormonal imbalances like hyper prolactinemia.

The primary purpose of lactation is to provide nutrition and immune protection to the offspring after birth, ensuring the survival of the mother-young pair even in challenging environmental conditions. The substantial investment of energy and resources into milk production is justified by the benefits to offspring survival. In most mammals, lactation

induces a period of infertility (lactational amenorrhea in humans), optimizing birth spacing for offspring survival.

HORMONAL INFLUENCES DURING LACTATION INCLUDE

1) **Progesterone:** Stimulates the growth of alveoli and lobes. High levels inhibit lactation before birth, but a drop in progesterone post-birth triggers abundant milk production.
2) **Estrogen:** Stimulates the growth and differentiation of the milk duct system. High levels also inhibit lactation, dropping at delivery and remaining low during initial breastfeeding months.
3) **Prolactin:** Enhances alveolar growth, influences ductal structure differentiation, and maintains tight junctions in the ductal epithelium. High levels during pregnancy and breastfeeding increase insulin resistance, elevate growth factor levels, and modify lipid metabolism.
4) **Human Placental Lactogen (HPL):** Released from the second month of pregnancy, it contributes to breast, nipple and areola growth in conjunction with prolactin.
5) **FSH, LH, and HCG**: Essential for controlling estrogen, progesterone, prolactin, and growth hormone production.
6) **Growth Hormone (GH):** Structurally similar to prolactin, independently contributes to galactopoiesis.
7) **ACTH and Glucocorticoids:** Induce lactation in various species, playing a regulatory role in tight junction maintenance.
8) **TSH and TRH:** Important galactopoietic hormones with naturally increased levels during pregnancy.
9) **Oxytocin:** Contracts uterine smooth muscle during and after birth, facilitating the milk ejection reflex in response to suckling.

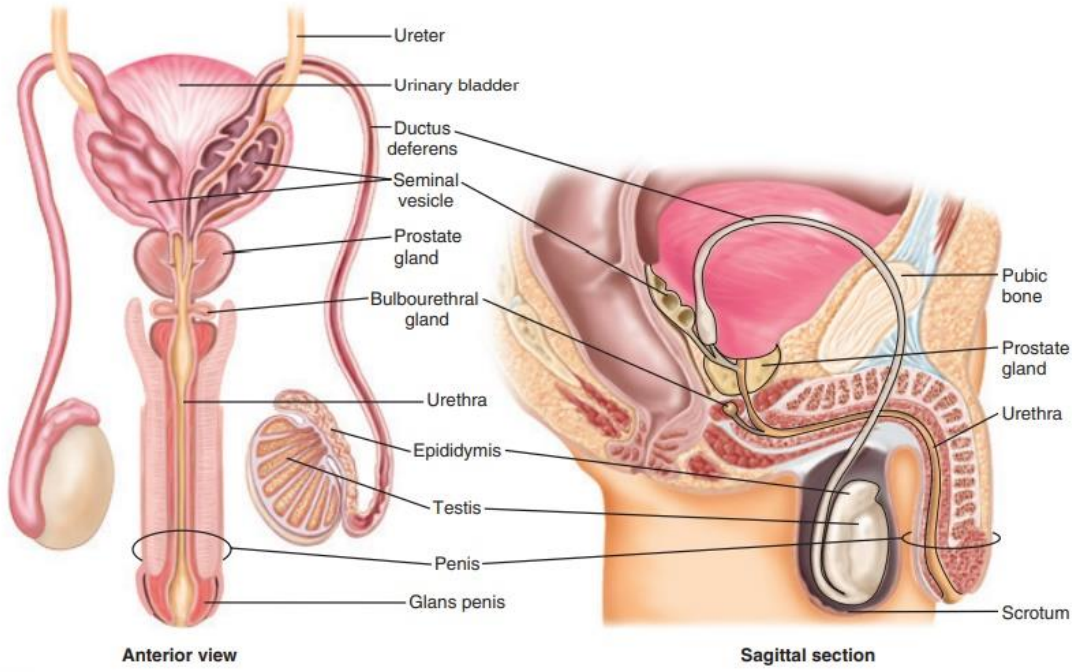
Thus lactation involves a sophisticated interplay of hormones, ensuring the survival and well-being of offspring through the provision of essential nutrients and immune protection.

UNIT III: FUNCTIONAL ANATOMY OF MALE REPRODUCTIVE SYSTEM

Anatomy of male reproductive System

- **a.** Histology of testis
- **b.** Histology of Epididymis
- **c.** Histology of Seminal vesicle
- **d.** Histology of prostate gland
- **e.** Histology of Cowper's gland
- **f.** Histology of penis
- **g.** Male sex hormones
- **h.** Process of spermatogenesis and structure of sperm
- **i.** Epididymal functions and sperm maturation
- **j.** Sperm transportation in male genital tract

ANATOMY OF MALE REPRODUCTIVE SYSTEM



Male Reproductive System of Humans

a. Testes

There is a pair of testes whose size is 4.5 cm x 2.5 cm x 3 cm. It is oval in shape and pink in colour. It is the primary sex organ in males. Testes are lodged in a thin walled skin pouch called scrotum or scrotal sac. Testes are extra abdominal. The reason behind this is that testicular temperature should be 2°C lower than the body temperature for normal spermatogenesis to occur. Rise in temperature kills sperms. In case testes do not descend in the scrotum it causes infertility as the formation of sperms does not occur because of

rise in temperature. When it is cold, testes shrink to bring it close to the body to keep it warm and in summers it is relaxed and thin. Scrotal sac is tilled with a tissue fluid called as hydrocoel. Testes are held in the scrotal sac by thick fibrous tissue called spermatic cord or gubernaculum. There is a cavity between abdominal cavity and scrotal sac called as inguinal canal. When the testes descend in the sac they pull their nerves, blood vessels and conducting tubes after them. The connecting tissue along with the cremaster muscles form spermatic cord. Any damage to inguinal tissue may cause budging out of intestine into scrotum. Such a condition is called inguinal hernia. Septum scorti divides the scrotum internally into two parts. Externally this division is marked by a scar, raphe.

b. Vasa Efferentia:

Rete testes gives rise to 10-20 ductules called as vasa efferentia or ductuli efferentes. Vasa efferentia enters the head of epididymis. They are lined by pseudo stratified epithelium which helps in sperm movement.

c. Epididymis

It is a 6 meter long coiled tube found in the poster lateral side of each testes. It is divided into three parts

- **i.** Upper head or caput epididymis or Globus major — this part is wide and receives vasa efferentia.
- **ii.** Corpus epididymis or Globus minor or body – It stores sperms for a short duration, which undergoes maturation. It lies in the lateral side of testes.
- **iii.** Cauda epididymis or Globus minor or tail – Before entering the vas deferens the spermatozoa is stored here. This part lies on the caudal side of the testes and is wide.

d. Vas Deferens

This is also called as seminal duct. It is around 30 cm long, narrow, muscular and tubular structure which starts from the tail of epididymis, passes through the inguinal canal, then over the urinary bladder and then joins the duct of seminal vesicle to form a 2 cm long ejaculatory duct. After passing through the prostate gland it joins the urethra. Before the sperms are transferred to urethra they are stored in spindle like ampulla of vasa deferens.

e. Penis

It is the male genetalia. It is erectable, copulatory, cylindrical organ. It is made up of three erectable tissues. Two of the three are posterior and made of yellow fibrous ligament

and is called as Corpora cavernosa. One is anterior, spongy and highly vascular Corpus spongiosum.

It surrounds the urethra. The tip of penis is highly sensitive and is called glans penis. There is a retractile fold of skin on glans penis and is known as far skin or prepuce. The erection of penis is due to rush of arterial blood into sinuses of corpus spongiosum.

ACCESSORY SEX GLANDS OF MALES

These are a pair of seminal vesicles, prostate gland and a pair of Cowper or bulbourethral glands.

a. Seminal Vesicle

They are convoluted, glandular sacs of 4 cm length. They are lined by pseudo stratified epithelium and lie near the ampulae of the vasa deferentia. It provides seminal fluid, which is alkaline and viscous. It contains fructose and prostaglandins. Fructose provides energy to the sperms for swimming and prostaglandins stimulate vaginal contraction which helps in the fusion of gametes.

b. Pair of Cowper's gland / bulbourethral gland

These are pea seed sized, white in colour and located at the base of penis. Its secretion helps in lubrication of vagina for smooth movement of penis during copulation.

c. Prostate Gland

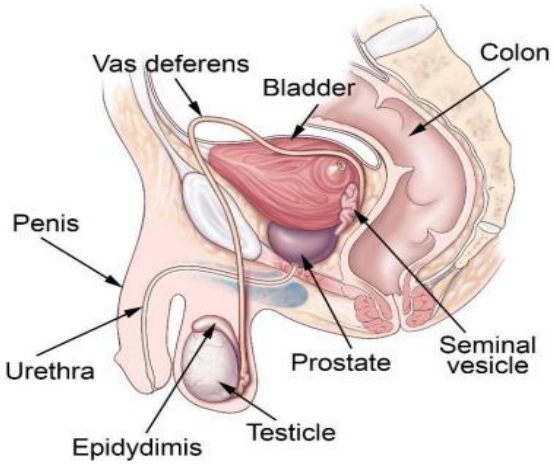
It surrounds the proximal part of urethra. It is large and lobulated. It pours alkaline secretion through 20-30 openings. This secretion contains lipids, bicarbonate ions, enzyme and small amount of citric acid. The secretion of accessory sex glands, i.e. prostate gland and mucus from seminal vesicles combine with sperm to form seminal fluid or semen. The pH is alkaline, i.e. 7.3 – 7.5.

Semen performs the following functions

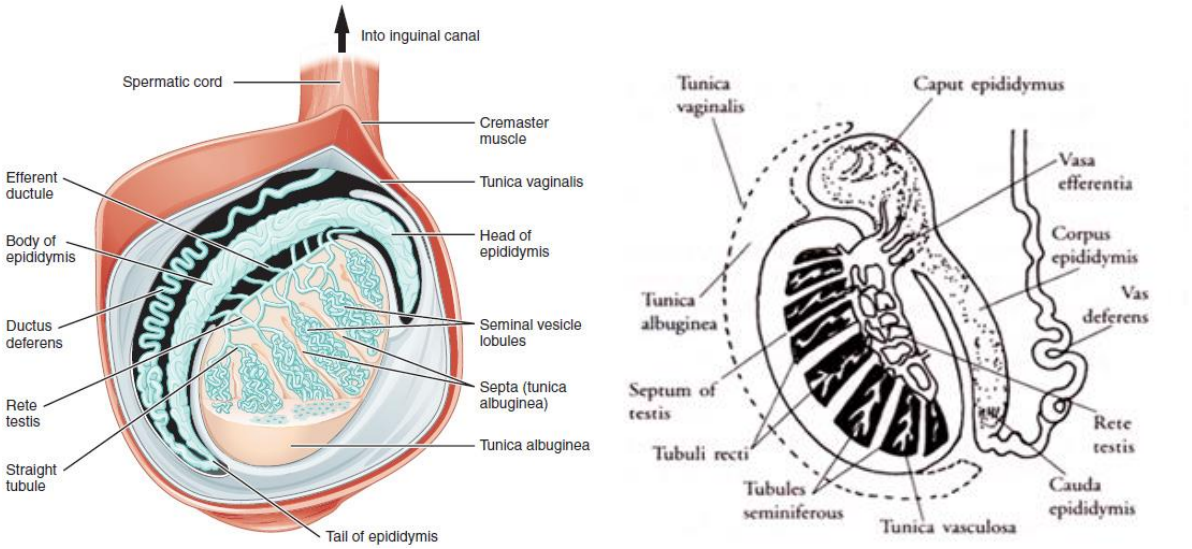
i. It provides nourishment to the sperms which keeps them viable and motile.
ii. Since it is alkaline it neutralizes the acidity of urine in urethra of male and vagina of female to save the sperm.
iii. It helps in transfer of sperm into the vagina of female.

Hormonal Control:

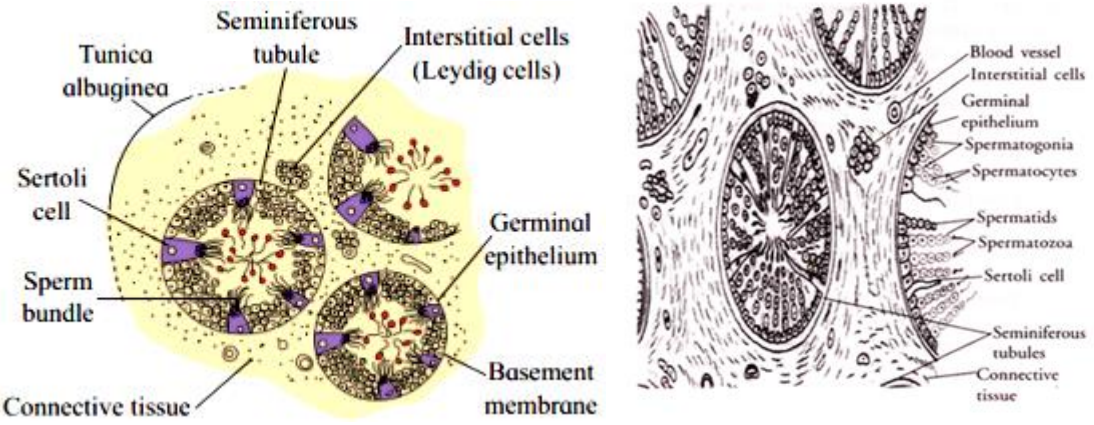
The hormones responsible for the normal growth and functioning of seminiferous tubule and Leydig cells are, Follicle Stimulating Hormone (FSH) and Lutenizing Hormone (LH). These are secreted from anterior lobe of pituitary.



A) HISTOLOGY OF TESTIS



V. S. of Testis



T. S. of Testis

Outer most cover of testes is called as tunica vaginalis which is the visceral layer of peritonium. Under this there is a dense fibrous cover called as tunica albuginea. Under this

coat there is a loose connective tissue and blood vessels which together form the tunica vasculosa. Internally tunica albuginea divides each testis into 200-300 lobules.

Spermatogenetic tissues

Each of these lobes consists of 1-3 convoluted seminiferous tubules. Seminiferous tubules are a tubular structure which has both the ends terminating into short tubules called tubular recti. Tubular recti connect seminiferous tubules to rete testis. Rete testis is convoluted labyrinth of cuboidal epithelium.

Each testis consists of 1000 seminiferous tubules. There are two kinds of cells found in seminiferous tubules. They are spermatogenic cells (germ cells) and Sertoli or supporting cells (nurse cells). Sertoli cells were discovered by Enrichno Sertoli, an Italian histologist. As the name signifies, germ cells from the spermatozoa by spermatogenesis and nurse cells provide nourishment to the developing sperm.

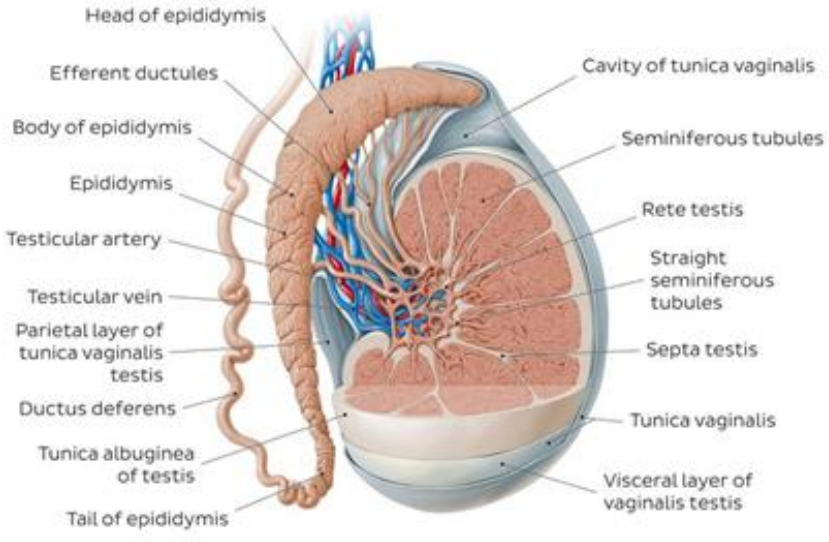
Between the seminiferous tubules, Leydig cells are found. These are polygonal in shape and secrete a male steroid hormone called testosterone. Testosterone controls the development of secondary sexual characters in males. Leydig cells were discovered by Franz von Leydig, a German anatomist.

B) HISTOLOGY OF EPIDIDYMIS

EPIDIDYMIS

It is a comma-shaped structure lying on the postero lateral aspect of testis medial to vas deferens. It has head, body and a tail. Head is formed by efferent ductules derived from the rete testis. These efferent ductules form the canal of epididymis, which passes through the body and tail. Tail continues as vas deferens

Structure of epididymis

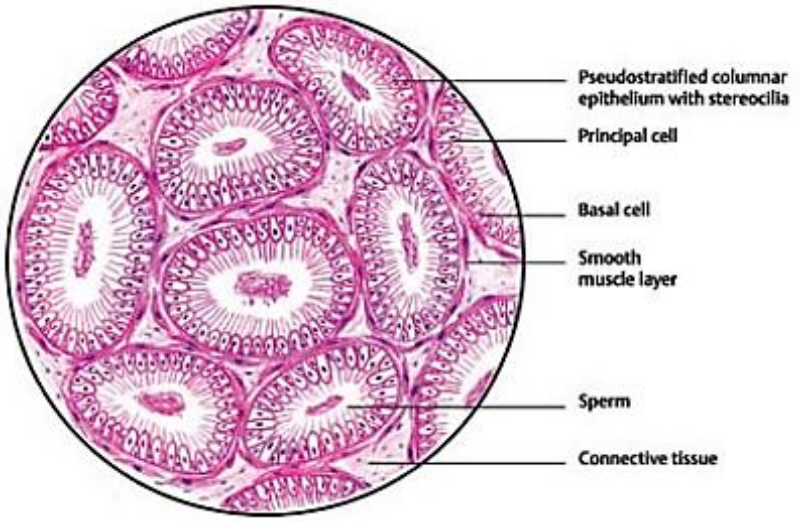


a) Caput (Head): The caput, or head, of the epididymis functions as the initial recipient of spermatozoa from the efferent ducts of the mediastinum of the testis. Histologically, it is distinguished by a robust epithelium featuring long stereocilia (as described below) and a minimal presence of smooth muscle. Its primary role involves the absorption of fluid, contributing to the concentration of sperm. Notably, the sperm concentration in this region is initially dilute.

b) Corpus (Body): The corpus, or body, of the epididymis possesses an intermediate epithelium and a moderate thickness of smooth muscle. This region plays a crucial role in further maturation and storage of sperm.

c) Cauda (Tail): The cauda, or tail, represents the distal portion of the epididymis and is characterized by the thinnest epithelium among the three regions. Additionally, it contains the highest quantity of smooth muscle. The primary function of the tail is to facilitate the propulsion of matured sperm during ejaculation.

HISTOLOGY OF EPIDIDYMIS



Histology of Epididymis

a) Section of epididymis shows the tubules lined by pseudo stratified columnar epithelium with stereocilia.

b) The epithelium consists of two types of cells

Principal cells: Principal cells are tall columnar cells with basal elongated nuclei."Apical portion of cells contain microvilli known as stereocilia. These cells secrete glycoprotein, which helps in the maturation of sperms.

Basal cells: Basal cells do not reach the lumen." Basal cells act as stem cells.

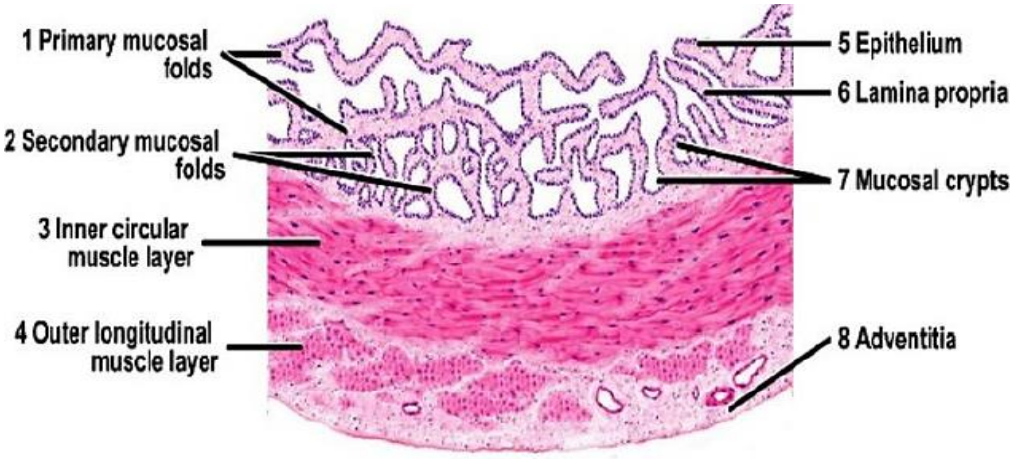
c) Surrounding the tubules there is a layer of circularly arranged smooth muscles. Rhythmic contraction of these smooth muscles helps in the expulsion of sperms during ejaculation.

Functions of Epididymis

a) Storage and maturation of sperms.
b) Epithelial cells phagocytose the degenerated sperms and residual bodies.
c) Secretion of epididymis adds to the bulk of semen.

C) HISTOLOGY OF SEMINAL VESICLE

They are convoluted, glandular sacs of 4 cm length. They are lined by pseudo stratified epithelium and lie near the ampulae of the vasa deferentia. It provides seminal fluid, which is alkaline and viscous. It contains fructose and prostaglandins. Fructose provides energy to the sperms for swimming and prostaglandins stimulate vaginal contraction which helps in the fusion of gametes.



1. **Compound Tubulo-Alveolar Gland**

The seminal vesicle is classified as a compound tubulo-alveolar gland, indicating its complex structure composed of both tubular and alveolar components.

2. **Glandular Epithelium**

The glandular epithelium of the seminal vesicle is pseudo stratified columnar and includes a few spherical basal cells. This arrangement contributes to the structural complexity and specialized functions of the gland.

3. **Intralobular and Main Excretory Duct**

In bulls, both the intralobular and main excretory ducts are lined by a simple cuboidal epithelium. In contrast, equines exhibit a lining of stratified columnar epithelium. This divergence in epithelial composition reflects species-specific variations in the histological characteristics of the seminal vesicle.

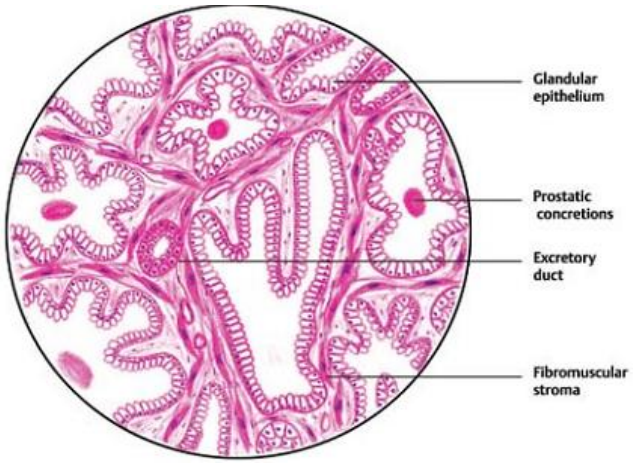
4. **Lamina Propria**

The lamina propria underlying the epithelium is a highly vascularized loose connective tissue. It forms trabeculae that intricately divide the gland into numerous lobules. This vascular network likely plays a role in supporting glandular functions and providing the necessary nutrients for secretory activities.

5. **Tunica Muscularis and Adventitia**

The seminal vesicle is further characterized by the presence of tunica muscularis, contributing to its muscular layer. Additionally, an adventitia layer is present, adding structural support to the gland. These layers collectively contribute to the coordinated contraction and expulsion of seminal fluid during ejaculation.

HISTOLOGY OF PROSTATE GLAND



PROSTATE GLAND

The prostate gland is the male accessory gland which is a chestnut-shaped gland located between the bladder and penis. Its secretion provides nourishment and protection to the sperms. The muscles of the prostate gland also help in propelling the seminal fluid into the urethra during ejaculation.

Histology of Prostate gland

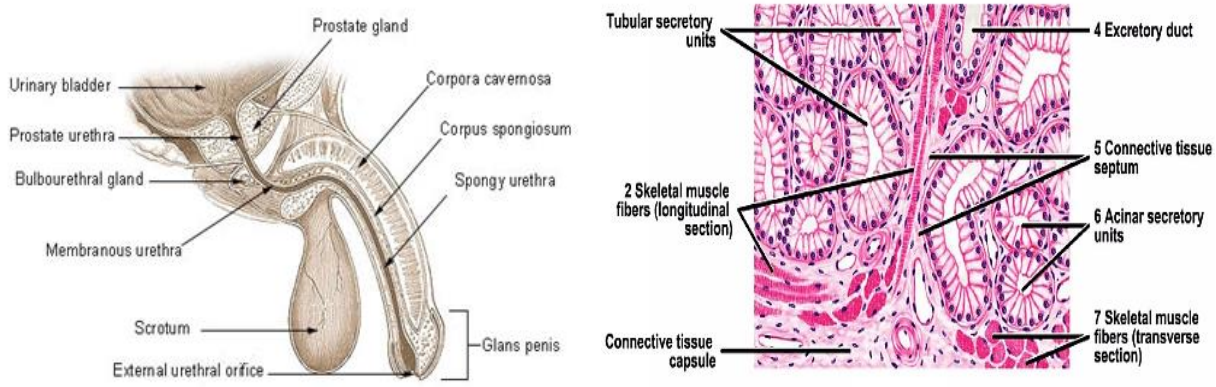
a) Prostate is a fibro muscular gland surrounding the neck of urinary bladder
b) It is surrounded by a thick capsule, which is adherent to the gland.
c) It sends numerous fibro muscular septa surrounding the glandular tissue.
d) It is made up of 30 to 50 compound tubuloalveolar glands embedded in the fibro muscular stroma.
e) These glands are arranged in the form of numerous follicles.
f) Each follicle is lined by simple or pseudo stratified columnar epithelium which is thrown into numerous folds. Secretions from these glands drain into excretory ducts

g) Ducts are lined by bilayered epithelium— cells toward the lumen are columnar and basal cells are cuboidal.

h) The fibro muscular stroma is made up of collagen fibers and smooth muscles, running in various directions

COWPER'S GLANDS / BULBOURETHRAL GLAND

The bulbourethral glands or Cowper's glands (named for English anatomist William Cowper) are two small exocrine glands in the reproductive system of many male mammals. They are homologous to Bartholin's glands in females. The bulbourethral glands are responsible for producing a pre-ejaculate fluid called Cowper's fluid (known colloquially as *pre-cum*), which is secreted during sexual arousal, neutralizing the acidity of the urethra in preparation for the passage of sperm cells. The paired glands are found adjacent to the urethra just below the prostate. Prostate cancer is the second-most common cause of cancer-related mortality in males in the USA.



HISTOLOGY OF COWPER'S GLAND

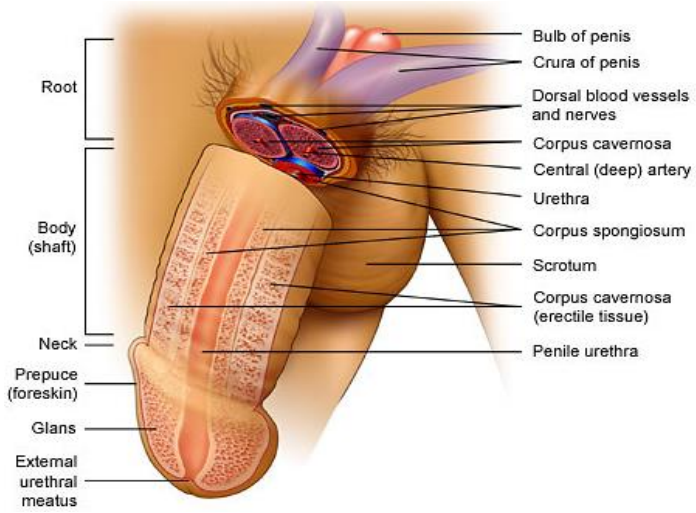
The bulbourethral glands are compound tubulo-alveolar glands, each approximately the size of a pea in humans. They are composed of several lobules held together by a fibrous covering. Each lobule consists of a number of acini, lined by columnar epithelial cells, opening into a duct that joins with the ducts of other lobules to form a single excretory duct. This duct is approximately 2.5 cm long and opens into the bulbar urethra at the base of the penis. The glands gradually diminish in size with advancing age.

FUNCTION

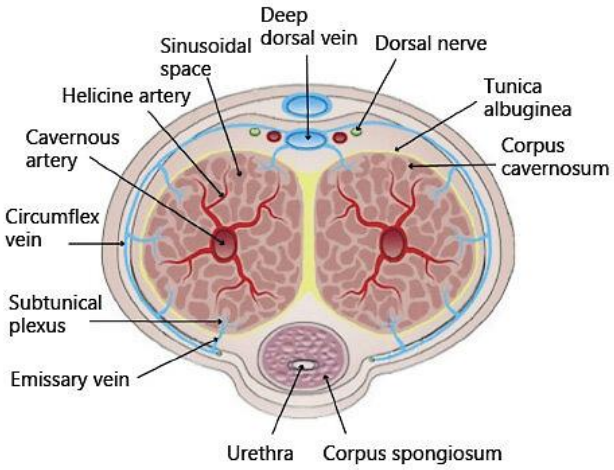
The bulbourethral gland contributes up to 4 ml of fluid during sexual arousal. The secretion is a clear fluid rich in mucoproteins that help to lubricate the distal urethra and neutralize any acidic urine residue that remains in the urethra.

HISTOLOGY OF PENIS

In humans the **penis** is an external male sex organ (intromittent organ) that additionally serves as the urinary duct. The main parts are the root (radix); the body (corpus); and the epithelium of the penis including the shaft skin and the foreskin (prepuce) covering the glans penis.



1. The human penis is made up of three columns of tissue: two corpora cavernosa lie next to each other on the dorsal side and one corpus spongiosum lies between them on the ventral side.
2. The corpus cavernosum forms most of the penis and contains blood vessels that fill with blood to help make an erection. The crusts of the penis are the proximal parts of the corpora cavernosum.
3. The corpus spongiosum is an erectile tissue surrounding the urethra. The proximal parts of the corpus spongiosum form the bulb of penis and the distal ends form the glans penis.
4. The enlarged and bulbous-shaped end of the corpus spongiosum forms the glans penis with two specific types of sinusoids, which supports the foreskin, or prepuce, a loose fold of skin that in adults can retract to expose the glans.
5. The area on the underside of the penis, where the foreskin is attached, is called the frenum, or frenulum. The rounded base of the glans is called the corona.
6. The penile raphe is the noticeable line along the underside of the penis.
7. The urethra, which is the last part of the urinary tract, traverses the corpus spongiosum, and its opening, known as the meatus, lies on the tip of the glans penis. It is a passage both for urine and for the ejaculation of semen.



T. S. of Penis

D) MALE SEX HORMONES

Androgens are male hormones of C19 steroid family. Naturally occurring androgens are testosterone, 5α–dihydrotestosterone (5α–DHT), 5α–androstenediol, androstenedione, dehydroepiandrosterone (DHEA) and androsterone. Testosterone is the principal masculinizing hormone secreted from the Leydig cells present in the interstices of seminiferous tubules. Leydig cells constitute about 20% of the mass of testes. Testes secrete several male sex hormones like androstenedione, dihydrotestosterone but testosterone secretion is abundant.

FUNCTIONS OF TESTOSTERONE

It is known for masculinizing character of male. Even in the fetal life testosterone secreted from the placenta under the influence of chorionic gonadotropin and it continues until the birth.

Development of primary and secondary sexual characteristics

Testosterone secretion causes development of the penis, scrotum and testes and to enlarge about eight-fold before the age of 20 years. The secondary sexual characteristics develop with the attainment of puberty and ending at the maturity under the influence of testosterone. The secondary sexual characteristics are

1. **Distribution of body hair:** It causes growth of hair over the pubis, on the face, usually on the chest.
2. **Baldness:** Testosterone decreases the growth of hair on the head and it assists the process of baldness which depends upon the genetic background of baldness.
3. **Masculine voice:** Testosterone works on laryngeal mucosa and enlargement of the larynx which leads to first a relatively discordant, “cracking” voice and gradually changes into the typical adult masculine voice.

4. **Skin Pigmentation and thickening:** Skin pigmentation and tanning effect of ultraviolet light on skin is intensified by androgen. Secretion from sebaceous glands of skin and axillary gland enhances with androgen stimulation leading to an increased sebum production.

E) PROCESS OF SPERMATOGENESIS AND STRUCTURE OF SPERM

SPERMATOGENESIS

Mammalian spermatogenesis is a highly synchronized, regular, long and extremely complex process of cellular differentiation by which a spermatogonial "stem-cell" is gradually transformed into a highly differentiated haploid cell 'Spermatozoon." This differentiation involves three distinct classes of germinal cells - the spermatogonia, the spermatocytes, and the spermatids. In the adult mammals spermatogenesis is a continuous process, which can be divided into two distinct phases and each is characterized by specific morphological and biochemical changes of nuclear and cytoplasmic components.

The two phases include

A. Formation of spermatids (mitosis and meiosis) and usually are arranged in concentric layers in the seminiferous tubules.
B. Spermiogenesis

Formation of spermatids

This phase of spermatogenesis is further subdivided into three phases.

1. Multiplication phase

This phase is also known as proliferation and renewal of spermatogonia. During this phase the diploid spermatogonia which are situated at the periphery of the seminiferous tubule, multiply mitotically to form spermatocytes and also to give rise to new spermatogonial stem cells and enter the phase of growth.

2. Growth phase

During this phase, a limited growth of spermatogonia takes place; their volume becomes double and they are now called primary spermatocytes which are still diploid in number. Now these primary spermatocytes enter into the next phase namely, maturation phase.

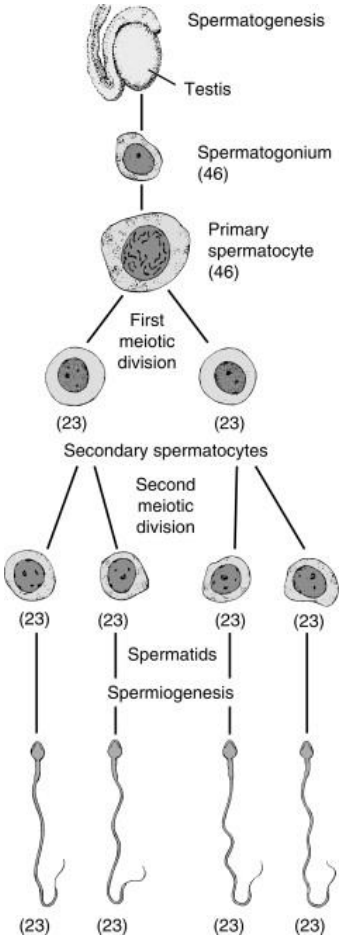
3. Maturation phase

The primary spermatocyte enters into the prophase of meiotic or maturation division. Meiotic prophase is a very complex process characterized by an ordered series of chromosomal rearrangements which are accompanied by molecular changes. During meiosis, first nuclear DNA duplicates, each homologous chromosome starts pairing

(synapsis) and longitudinally splits up into two chromatids, both of which remain joined by a common centromere. By chiasma formation mutual exchange of some chromosome material between two non-sister chromatids of each homologous pair (tetrad) occurs (crossing over) to provide an almost indefinite variety of combinations of paternal and maternal genes in any gamete.

Lastly, two chromosomes of each homologous pair (tetrad) migrate towards opposite poles of the primary spermatocyte. Now each pole of primary spermatocyte has haploid set of chromosomes. Each set of chromosomes is surrounded by the nuclear membrane developed from the endoplasmic reticulum. The first meiotic division, as a rule, is followed by the division of cytoplasm (cytokinesis) which divides each primary spermatocyte into two haploid, secondary spermatocyte.

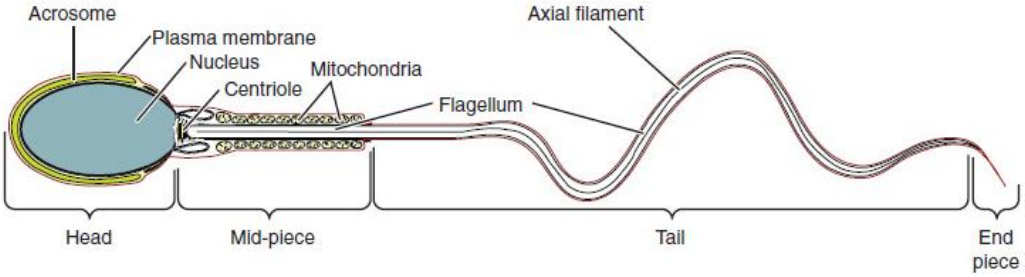
Each secondary spermatocyte undergoes second meiotic or maturation division which is a simple mitosis and produces four haploid spermatids. These are non-functional male gametes. To become functional spermatozoa, they have to undergo a complex process of cytological and chemical transformations; a process usually referred to as spermiogenesis.



Spermiogenesis

The changes in the spermatids leading to the formation of spermatozoa constitute the process of spermiogenesis. Because a spermatozoon is a very active and mobile cell, in order to provide real mobility to it, all the superfluous materials of the developing spermatozoa are to be discarded and a high degree of specialization takes place in the sperm cell through a number of steps.

STRUCTURE OF SPERM



Sperms are smaller than most cells in the body; in fact, the volume of a sperm cell is 85,000 times less than that of the female gamete. Approximately 100 to 300 million sperm are produced each day, whereas women typically ovulates only one oocyte per month. As is true for most cells in the body, the structure of sperm cells speaks to their function. Sperm have a distinctive head, mid-piece, and tail region.

The head of the sperm contains the extremely compact haploid nucleus with very little cytoplasm. These qualities contribute to the overall small size of the sperm (the head is only 5 μm long). A structure called the acrosome covers most of the head of the sperm cell as a “cap” that is filled with lysosomal enzymes (Hyaluronidase and Acrosin) important for preparing sperm to participate in fertilization. Tightly packed mitochondria fill the mid-piece of the sperm. ATP produced by these mitochondria will power the flagellum, which extends from the neck and the mid-piece through the tail of the sperm, enabling it to move the entire sperm cell. The central strand of the flagellum, the axial filament, is formed from one centriole inside the maturing sperm cell during the final stages of spermatogenesis.

F) EPIDIDYMAL FUNCTIONS AND SPERM MATURATION

The epididymis is a coiled tube located on the posterior surface of each testicle in the male reproductive system. Its main function is to store and transport sperm produced in the testes and to facilitate their maturation. Sperm are not fully mature and motile when they leave the testes, and they require sometime within the epididymis to undergo specific changes that enhance their ability to fertilize an egg.

Here's a breakdown of the epididymal function and sperm maturation:

a) Sperm Production in the Testes

Spermatozoa (sperm cells) are produced in the testes through a process called spermatogenesis. Immature sperm, also known as spermatozoa, are released into the seminiferous tubules of the testes.

b) Transport to the Epididymis

From the testes, the immature sperm are transported to the epididymis through a network of ducts. The epididymis is a long, convoluted tube divided into three regions: the head, body, and tail.

c) Storage and Maturation in the Epididymis

Once in the epididymis, sperm are stored and undergo a maturation process. This process takes about 2-3 weeks. During this time, the sperm gain the ability to move (motility) and acquire the capacity to fertilize an egg. The epididymis provides a suitable microenvironment for sperm maturation, allowing them to develop the ability to swim and undergo changes in their structure.

d) Functional Changes in Sperm

Acquisition of Motility: In the epididymis, sperm undergo changes that enable them to become motile. Initially, sperm in the testes are immotile and lack the ability to swim. Maturation in the epididymis involves the development of a functional tail (flagellum) that allows sperm to move actively.

e) Capacitation

Capacitation is another crucial aspect of sperm maturation. This process occurs when sperm are exposed to the female reproductive tract. Capacitation involves changes in the sperm cell membrane, allowing it to fuse with the egg during fertilization.

f) Transport to the Vas Deferens

Mature and motile sperm leave the epididymis through the vas deferens, a muscular tube that carries sperm from the epididymis to the ejaculatory duct. During ejaculation, sperm are propelled through the vas deferens and mix with seminal fluid from the seminal vesicles and prostate gland to form semen.

Thus the epididymis plays a vital role in sperm maturation, providing the necessary environment for sperm to become motile and functionally competent for fertilization.

G) SPERM TRANSPORTATION IN MALE GENITAL TRACT

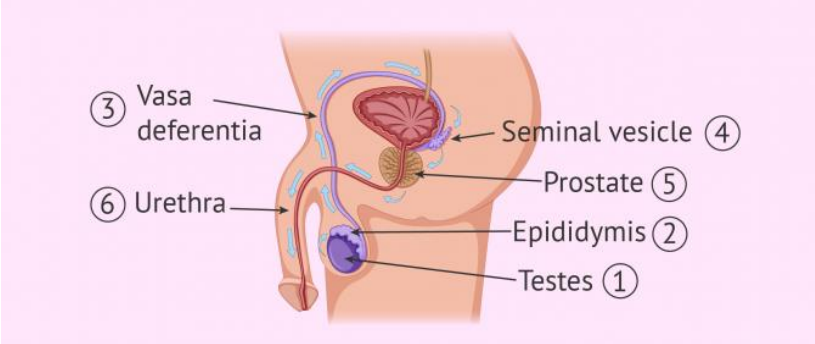
Sperm Transport

Sperm transport is a vital process occurring in both the male and female reproductive tracts. In males, it is intricately linked to the structural and functional

maturation of spermatozoa, while in females, it is crucial for the sperm to reach the upper uterine tube, where fertilization with the ovulated egg takes place.

Following spermiogenesis in the seminiferous tubules, spermatozoa are morphologically mature but lack motility and the ability to fertilize an egg. They undergo passive transportation via testicular fluid, moving from the seminiferous tubules to the caput (head) of the epididymis through the rete testis and efferent ductules. Fluid pressure from the seminiferous tubules, along with smooth muscle contractions and ciliary currents in the efferent ductules, propels the spermatozoa. Spending approximately 12 days in the convoluted epididymal duct, measuring 6 m in humans, spermatozoa undergo biochemical maturation, including changes in the glycoproteins on the sperm head membrane. By the time they reach the cauda (tail) of the epididymis, they become capable of fertilizing an egg.

Upon ejaculation, spermatozoa swiftly traverse the ductus deferens, mixing with fluid secretions from the seminal vesicles and prostate gland. Prostatic fluid is rich in citric acid, acid phosphatase, zinc, and magnesium ions, while seminal vesicle fluid is abundant in fructose (the main energy source for spermatozoa) and prostaglandins. The ejaculate, typically 2 to 6 mL, comprises 40 to 250 million spermatozoa mixed with alkaline fluid from the seminal vesicles (60% of the total) and acidic secretion (pH 6.5) from the prostate (30% of the total). The pH of normal semen ranges from 7.2 to 7.8. Despite an abundant number of spermatozoa (often xceeding 100 million) in an ejaculate, fertility can still be maintained with as few as 25 million spermatozoa per ejaculation.



Hormonal control of Testicular Activities:

Gonadotropin-Releasing Hormone (GnRH):

GnRH is produced by the hypothalamus, a region in the brain. It acts as the primary regulator of reproductive function by stimulating the release of gonadotropins from the pituitary gland.

Gonadotropins (Luteinizing Hormone - LH and Follicle-Stimulating Hormone - FSH):

In response to GnRH, the anterior pituitary gland releases LH and FSH. LH primarily targets the Leydig cells in the testes.

Leydig Cells and Testosterone Production:

LH stimulates the Leydig cells to produce testosterone. Testosterone is crucial for the development and maintenance of male reproductive organs and secondary sexual characteristics. FSH primarily targets the Sertoli cells in the testes.

Sertoli Cells and Spermatogenesis:

FSH stimulates Sertoli cells to support spermatogenesis, the process by which sperm cells develop.

Testosterone:

1. Testosterone, produced by Leydig cells, has several effects throughout the body.
2. It promotes the development and maintenance of male reproductive organs, including the testes and accessory structures.
3. It stimulates the development of secondary sexual characteristics such as facial hair, deepening of the voice, and increased muscle mass.
4. It plays a crucial role in libido and overall male reproductive health.
5. It provides negative feedback to the hypothalamus and pituitary gland, inhibiting the release of GnRH and LH when testosterone levels are sufficient.

Inhibin:

1. Inhibin is produced by Sertoli cells in response to FSH.
2. It inhibits the secretion of FSH from the pituitary gland.
3. This negative feedback mechanism helps regulate the rate of spermatogenesis by adjusting FSH levels.

Regulatory Loop:

The hypothalamus releases GnRH, stimulating the pituitary gland to release LH and FSH. LH stimulates Leydig cells to produce testosterone. Testosterone, in turn, provides negative feedback to the hypothalamus and pituitary gland, inhibiting the release of GnRH and LH. FSH stimulates Sertoli cells, which produce inhibin. Inhibin inhibits the release of FSH, completing the negative feedback loop.

This regulatory system maintains a delicate balance, ensuring that testosterone and sperm production are appropriately controlled. It also allows the body to respond to changes in reproductive needs, such as during puberty, adulthood, and aging. The coordination of these hormones is essential for maintaining male reproductive health and fertility.

Unit IV: REPRODUCTIVE HEALTH

a) **Infertility in Male:** causes, diagnosis and management
b) **Infertility in Female:** causes, diagnosis and management
c) **Assisted Reproductive Technology:** Sperm bank. Frozen embryos. Intrauterine Transfer (IUT), Zygote Intrafallopian Tube Transfer (ZIFT), Gamete Intrafallopian Transfer (GIFT), Intracytoplasmic Sperm Injection (ICSI)
d) **In vitro fertilization (IVF):** Ovarian stimulation, Egg retrieval, Sperm retrieval, Fertilization and Embryo transfer

Unit V: Contraceptive Methods

a) Temporary methods
b) Permanent Methods

INFERTILITY IN MALE AND FEMALE: CAUSES, DIAGNOSIS AND MANAGEMENT:

INFERTILITY

Infertility is the inability to produce children for a couple in spite of unprotected sexual co-habitation within one year or more. A large number of couples all over the world including India are infertile. The causes of infertility may be physical, congenital, disease, drug, immunological or even psychological.

In India, when a couple is childless, the female is usually blamed. But more often, the males are detected to be responsible. However, now, specialized health care units known as infertility clinics are available. They could identify the cause of infertility and take up treatment to remove the disorder

1. FEMALE INFERTILITY

A woman may be infertile due to several causes. Some important reasons are as follows.

a. Failure to Ovulate

Failure to ovulate is one common cause of infertility in females. This is because the pituitary or hypothalamus fails to produce the FSH which is required for follicle development or LH required for release of the egg from the ovary. It may also be because the ovaries fail to produce oestrogen or progesterone. Hormonal imbalances may be corrected by administering synthetic hormones to the affected individual.

The most commonly used drug is Clomiphene, a synthetic oestrogen like drug which stimulates ovulation. Tamoxifen is another drug used. These pills are taken orally for five days soon after the menstrual cycle starts. Injection of HCG, which is chemically similar to

LH is given at the middle of the cycle to stimulate ovulation. 'Fertility drugs' which contains FSH and LH or only FSH is also used.

But these have the danger of multiple egg release and consequently multiple pregnancies. Advance techniques include small implants in the upper arm which releases small amounts of GnRH mimicking the activity of the hypothalamus.

b. Damage to Oviducts

The fallopian tubes may be blocked or narrowed in some women. This interferes with the movement of the eggs and fertilization. This can be treated by laser surgery.

c. Damage to Uterus

In about 5-10% cases, infertility problems are due to a damaged uterus. The uterus is unable to maintain pregnancy, i.e., the fertilized zygote does not get implanted. Sometimes large non-malignant tumours called fibroids or smaller growths known as polyps which grow in the walls of the uterus can cause infertility.

These can be surgically removed. IUCD or PID also causes inflammation in the uterus and cause problems. This can be treated by using antibiotics. Adhesion in the uterus, i.e. sticking of parts of the uterus which occurs as a result of an abortion is another reason for infertility.

d. Damage to the Cervix

The cervix is the neck of the uterus. The cervix may become damaged because of the abortion or difficult birth. A narrow cervix may interfere with sperm movement.

e. Antibodies to Sperm

In some rare cases, women may produce antibodies against sperms. These are found in the cervix, uterus and oviducts. These may be treated using immunosuppressant drugs, but IVF is a better method of treatment.

2. MALE INFERTILITY

Infertility in males may be due to the following causes.

a. Azoospermia

Absence of sperms in the semen is known as azoospermia. This may occur because of lack of sperm production or because of blocked tubes which does not permit the sperms to appear in the semen. Blockage can occur due to an infection or injury.

Failure of the ejaculation mechanism is another possible reason of azoospermia. Failure to produce sperms may result because of injury to the testes or as a result of infection such as mumps virus or due to hormonal reasons.

b. Oligospermia

Low sperm count is known as Oligospermia. More than 90% males suffer from infertility due to low sperm count.

c. Abnormal Sperms

Abnormal sperms may possess two heads or no tail or may have abnormal shapes. The reasons are not known and may be because of hormonal malfunctions.

d. Autoimmunity

In some males, the immune system may attack the sperms and reduce the sperm numbers. Treatment is not usually possible.

e. Impotence and Premature Ejaculation

The inability to achieve an erection of the penis is known as impotence. Psychological counseling may help in some cases. Premature ejaculation is a condition where the man releases the semen even before penetration into the vagina. This condition is treatable with psychological treatment.

f. Cryptorchidism

It is a condition in which the testes are unable to descend into scrotal sacs, so that; sperms are not produced (azoospermia).

g. Oligospermia

It is a defect with testes due to which very less number of sperms is produced. Due to infections like mumps, infection of seminal vesicle and prostate there is less concentration of spermatozoa in semen, the ovum is not fertilized.

h. Alcoholism

Regular intake of alcohol reduces spermatogenesis.

i. Impotency

In this condition the male is unable to erect and penetrate the penis into vagina of female.

j. Hormone deficiency

Deficiency of gonadotropin (LH, FSH) thyroid dysfunction may be the cause of male infertility.

k. Infertility may be due to prolonged use of antihypertensive and antipsychotic drugs.

l. Immotile cilia

Absence of tail in sperm makes it immotile. Hence, sperms cannot move from vagina to upper portions of genital tract of female.

m. Absence of Y-chromosome

Sometimes, deletion of Y-chromosomes in primordial germ cells leads to sperm production without Y-chromosome. Such sperms cannot form viable zygote.

TREATMENT FOR INFERTILITY

The treatment for infertility depends on the underlying cause and may vary from lifestyle changes and medications to surgical procedures. It's essential for individuals or couples facing fertility issues to consult with a healthcare professional, typically a reproductive endocrinologist or a fertility specialist. Here are some common treatments for infertility

a) Lifestyle Modifications

Weight Management: Both overweight and underweight conditions can affect fertility. Achieving a healthy weight through diet and exercise is crucial.

Smoking and Alcohol Cessation: Smoking and excessive alcohol consumption can reduce fertility. Quitting these habits can improve reproductive health.

b) Medications

1. Ovulation Induction: Some women may have irregular ovulation or no ovulation. Medications like Clomiphene citrate or letrozole can stimulate the ovaries to release eggs.
2. Hormone Therapy: Hormonal imbalances, such as problems with the thyroid or polycystic ovary syndrome (PCOS), can be addressed with hormone therapy.

c. Assisted Reproductive Technologies (ART):

Intrauterine Insemination (IUI): IUI involves placing sperm directly into the uterus during the woman's fertile period to increase the chances of fertilization.

d. In Vitro Fertilization (IVF)

IVF is a multi-step process where eggs and sperm are combined in a laboratory dish, and the resulting embryos are transferred into the uterus.

e. Surgery

1. **Laparoscopic Surgery:** This minimally invasive surgery is used to treat conditions such as endometriosis, uterine fibroids, or ovarian cysts.
2. **Varicocele Repair:** Surgery to correct enlarged veins in the scrotum, which may improve sperm production and quality.

f. Donor Eggs or Sperm

1. Egg Donation: Women with diminished ovarian reserve or poor egg quality may use eggs from a younger, healthier donor.

2. Sperm Donation: Used when male infertility is a concern. Donor sperm may be used for insemination or IVF.

g. Gestational Carrier (Surrogacy)

In cases where a woman cannot carry a pregnancy, a gestational carrier (surrogate) may be used. The embryo is created using the intended mother's eggs or a donor's eggs and the intended father's sperm.

h. Genetic Testing

Pre implantation Genetic Testing (PGT): Before implantation during IVF, embryos can be screened for genetic abnormalities to increase the likelihood of a healthy pregnancy.

i. Psychological Support

Infertility can be emotionally challenging. Counseling, support groups, or therapy can help individuals and couples navigate the emotional aspects of fertility treatments.

It's essential to emphasize that the choice of treatment is highly individualized. A thorough evaluation by a fertility specialist is crucial to identify the specific causes of infertility and tailor the treatment plan accordingly. Additionally, the emotional well-being of individuals and couples should be considered, and seeking psychological support can be an important aspect of the overall fertility treatment process.

j. Assisted Reproductive Technology:

Sperm bank. Frozen embryos. Intrauterine Transfer (IUT), Zygote Intrafallopian Tube Transfer (ZIFT), Gamete Intrafallopian Transfer (GIFT), Intracytoplasmic Sperm Injection (ICSI)

SPERM BANK

A sperm bank, semen bank or cryobank is a facility or enterprise which purchases, stores and sells human semen. The semen is produced and sold by men who are known as sperm donors. The sperm is purchased by or for women for the purpose of achieving a pregnancy or pregnancies other than by a sexual partner. Sperm sold by a sperm donor is known as donor sperm. Sperm is introduced into the recipient woman by means of artificial insemination or by IVF and the process may also involve donated eggs or the use of a surrogate.

From a medical perspective, a pregnancy achieved using donor sperm is no different from a pregnancy achieved using partner sperm, and it is also no different from a pregnancy achieved by sexual intercourse. By using sperm from a donor rather than from the woman's partner, the process is a form of third party reproduction.

COLLECTION

A sperm donor must generally meet specific requirements regarding age and medical history. In the United States, sperm banks are regulated as Human Cell and Tissue or Cell and Tissue Bank Product (HCT/Ps) establishments by the Food and Drug Administration. Many states also have regulations in addition to those imposed by the FDA. In the European Union a sperm bank must have a license according to the EU Tissue Directive. In the United Kingdom, sperm banks are regulated by the Human Fertilization and Embryology Authority.

A sperm donor will usually be required to enter into a contract with a sperm bank to supply his semen, typically for a period of six to twenty-four months depending on the number of pregnancies which the sperm bank intends to produce from the donor. Where local regulations or the sperm bank's own rules limit the number of pregnancies which a single donor can achieve, his donations will be limited for this reason. In the United Kingdom, for example, where a donor is not permitted to father more than ten families, a sperm bank will generally need a maximum of 100 straws prepared for IUI insemination, so that a man will generally not donate for more than twelve months, unless the sperm bank exports or exchanges sperm with sperm banks outside the UK.

However, not all donors complete the intended program of donations. If a sperm bank has access to world markets e.g. by direct sales, or sales to clinics outside their own jurisdiction, a man may donate for a longer period than two years, as the risk of consanguinity is reduced (although local laws vary widely). Some sperm banks with access to world markets impose their own rules on the number of pregnancies which can be achieved in a given regional area or a state or country, and these sperm banks may permit donors to donate for four or five years, or even longer. Faced with a growing demand for donor sperm, sperm banks may try to maximize the use of a donor whilst still reducing the risk of consanguinity.

The contract may also specify the place and hours for donation, a requirement to notify the sperm bank in the case of acquiring a sexual infection, and the requirement not to have intercourse or to masturbate for a period of usually 2–3 days before making a donation.

A sperm donor generally produces and collects sperm at a sperm bank or clinic by masturbation in a private room or cabin, known as a 'men's production room' (UK), 'donor cabin' (DK) or a masturbatorium (USA). Many of these facilities contain pornography such as videos/DVD, magazines, and/or photographs which may assist the donor in becoming

aroused in order to facilitate production of the ejaculate, also known as the "semen sample". In some circumstances, it may also be possible for semen from donors to be collected during sexual intercourse with the use of a collection condom.

STORAGE

The sperm is stored in small vials or straws holding between 0.4 and 1.0 ml of sperm and cryogenically preserved in liquid nitrogen tanks. It has been proposed that there should be an upper limit on how long frozen sperm can be stored; however, a baby has been conceived in the United Kingdom using sperm frozen for 21 years and andrology experts believe sperm can be frozen indefinitely. The UK government places an upper limit for storage of 55 years.

Before freezing, sperm may be prepared (washed or left unwashed) so that it can be used for intracervical insemination (ICI), intrauterine insemination (IUI) or for in-vitro fertilization (IVF) or assisted reproduction technologies (ART).

Following the necessary quarantine period, which is usually 6 months, a sample will be thawed and used to artificially inseminate a woman or used for another assisted reproduction technologies (ART) treatment.

FROZEN EMBRYOS

The process of freezing one or more embryos to save them for future use is called frozen embryos. Embryo freezing involves in vitro fertilization, a procedure in which eggs are removed from a woman's ovary and combined with sperm in the laboratory to form embryos. The embryos are frozen and can later be thawed and placed in a woman's uterus.

ASSISTED REPRODUCTION

Assisted reproductive technology (ART) has enabled millions of infertile couples worldwide to have children. ART refers to manipulation of eggs, sperm and embryos outside the body in order to achieve a pregnancy. Intrauterine insemination (IUI), which involves only the manipulation of sperm, is considered by some but not all as type of ART.

In Vitro Fertilization and Embryo Transfer (IVF and ET)

In vitro fertilization broadly deals with the removal of eggs from a woman, fertilizing them in the laboratory, and then transferring the fertilized eggs (zygotes) into the uterus a few days later.

Embryo Transfer (ET)

Embryo at a stage between pronuclei and blastocyst stage are transferred. Conventionally, 4- 8 cell stage embryos are transferred between 48-60 hours following insemination. The transfer procedure is carried out by use of a catheter.

Not more than three embryos are transferred (per cycle) to minimize multiple pregnancies. However, in the women above the age of 40 years, higher number of embryo may be transferred. (Note: Excess oocytes and embryos are cryopreserved for further use. This will reduce the cost, besides the risk of ovarian hyper stimulation).

Luteal phase support is given by administration of progesterone for about two weeks. By this time, the diagnosis of pregnancy can be assessed by estimating human chorionic gonadotrophin (HCG)

Gamete Intra-Fallopian Transfer (GIFT)

Gamete intra-fallopian transfer involves the transfer of both sperm and unfertilized oocyte into the fallopian tube. This allows the fertilization to naturally occur in vivo. The prerequisite for GIFT procedure is that the woman should have at least one normal fallopian tube.

The induction of ovulation and the monitoring procedures for GIFT are almost the same as described for IVF. A couple of hours prior to oocyte retrieval, semen specimens are collected. Two oocytes along with 2-5 lakhs motile sperms for each fallopian tube are placed in a plastic tube container. It is then inserted (by laparoscopy) 4 cm into the distal end of the fallopian tube, and the oocyte sperm combination is injected.

The overall pregnancy rate is as high as 30- 40%. The take home baby rate is about 25%. This is much higher when compared to IVF. But the major limitation is the requirement of laparoscopy (a major surgical procedure) to transfer oocytes and sperms into the fallopian tubes.

Zygote Intra-Fallopian Transfer (ZIFT)

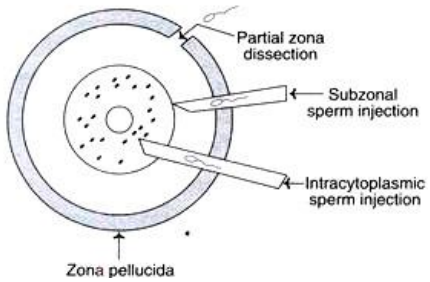
ZIFT is suitable when the infertility lies in men, or in case of failure of GIFT. The wife's oocytes are exposed to her husband's sperms in the laboratory. The fertilized eggs (zygotes) within 24 hours are transferred to the fallopian tube by using laparoscopy. ZIFT has an advantage over GIFT with male factor infertility. Further, it can be known whether the wife's oocytes have been fertilized by her husbands' sperms.

Intra-Cytoplasmic Sperm Injection (ICSI)

Intra-cytoplasmic sperm injection is a new and novel infertility treatment utilizing the micromanipulation technology. Many of the previous treatment processes for male infertility have been abandoned in favor of ICSI. The male factor infertility could be due to low sperm counts, poor sperm motility, and poor quality of sperm to penetrate oocyte. By partial zona dissection (PZD), the zona pellucida is opened using either chemical dissolution or a sharp instrument. A single spermatozoon can be directly injected into the

cytoplasm of the oocyte through the micro-puncture of zona pellucida. A micropipette is used to hold the oocyte while the spermatozoon is deposited inside the ooplasm of the oocyte. Besides using normal sperms, round-headed sperms, sperms collected directly from the epididymis and previously cryopreserved sperms can be used in ICSI.

Among the micromanipulation techniques ICSI is the most successful one with a fertilization rate of about 65%. Attempts are on to improve this further. In fact, ICSI has revolutionized assistant reproductive technology by utilizing the sperms of husbands who were once considered to be unsuitable for fertilization process.



Pronuclear stage tubal transfer (PROST):

It is similar to ZIFT, uses in vitro fertilization. But it transfers the fertilized egg to the fallopian tube before cell division occurs. These procedures have higher costs and risks related to laparoscopy. And they do not provide as much useful information about embryo development as IVF does. For these reasons, these procedures are rarely used.

In vitro fertilization (IVF) process:

Ovarian Stimulation:

During this phase, the woman receives hormonal medications, often in the form of injections, to stimulate the ovaries to produce multiple eggs.

Regular monitoring through blood tests and ultrasounds ensures the optimal timing for egg retrieval.

Egg Retrieval:

Once the eggs reach a mature stage, a minor surgical procedure called egg retrieval or aspiration is performed. A thin, hollow needle is inserted through the vaginal wall and into the ovaries, guided by ultrasound. The follicular fluid containing the eggs is aspirated, and the eggs are isolated from this fluid.

Sperm Retrieval:

A sperm sample is collected, either through ejaculation (in the case of the male partner) or through other methods such as testicular sperm extraction (TESE) or epididymal sperm aspiration (TESA). The collected sperm is then processed to obtain a concentrated and motile sample for fertilization.

Fertilization:

In the laboratory, the eggs and sperm are combined in a culture dish, and fertilization is monitored. In some cases, intracytoplasmic sperm injection (ICSI) may be used, where a single sperm is directly injected into an egg to facilitate fertilization.

Embryo Transfer:

After fertilization, the embryos are cultured and monitored for development. A few days after egg retrieval, one or more viable embryos are selected for transfer to the woman's uterus. The embryo transfer is a relatively simple procedure where the selected embryos are introduced into the uterine cavity using a thin catheter.

Throughout the entire process, careful monitoring and coordination are crucial. Hormone levels, ultrasound imaging, and other assessments help ensure that the conditions are optimal for each step. The number of embryos transferred is often carefully considered to balance the chances of success while minimizing the risk of multiple pregnancies. After the embryo transfer, a waiting period begins to determine if the procedure has resulted in a successful pregnancy.

UNIT V: CONTRACEPTIVE METHODS

The prevention of pregnancy or conception is called contraception. The devices used for contraception are called contraceptives. Contraceptive methods can be broadly categorized into temporary and permanent options, each serving different purposes and preferences. It's important to note that the choice of a contraceptive method depends on individual health, lifestyle and family planning goals. Here's an overview of both temporary and permanent contraceptive methods

1. Temporary methods
2. Permanent Methods

TEMPORARY METHODS

1. **Natural method**
   - **a.** Total abstinence of coitus.
   - **b.** Interrupted coitus.
   - **c.** Rhythm.

2. Mechanical method: Diaphragm, cervical cap, condom/sheath (Nirodh)
3. Chemical method: Foam tablets, Jellies and creams
4. Intrauterine devices (IUD): Copper-T and Loop
5. Oral contraceptives Pills/Tablets.

1] NATURAL METHOD

A] TOTAL ABSTINENCE OR COITUS

Conception is prevented when the couple obtains from intercourse. One can apply this method with full understanding of the partner. This is the real, sure way of preventing conception.

B] INTERRUPTED COITUS

This is the earliest form of birth control. It needs knowledge of the reproductive process. Conception requires not only sexual union but also ejaculation of semen into the female tract. During sexual intercourse one has to withdraw the penis from the vagina before ejaculation. Failure in this method is either due to pre-ejaculatory escape of fluid containing sperm or failure to withdraw before ejaculation

C] RHYTHM/CALENDAR METHOD

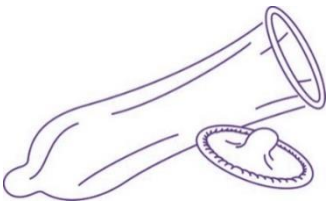
In this method one must have the knowledge of reproductive physiology that ovum can be fertilized only during a period of 3-5 days in each menstrual cycle. Those days are 3 days before ovulation (11, 12, and 13). The day of ovulation (14^{th} day) and three days after ovulation i.e. (15, 16, & 17). During these mentioned days couples must retain from intercourse effectiveness of such a rhythm method for birth control is poor because all

ladies will not have a regular cycle. Couples are instructed to know and understand the rhythm of their sexual cycle.

2] MECHANICAL METHOD

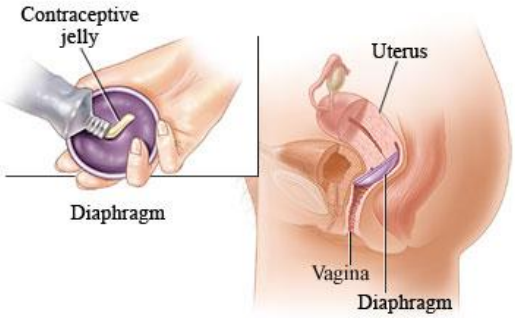
In this method a barrier is created between the male organ and the interior of the female passage. The barrier is purely mechanical like condom diaphragm, cervical cap etc.

A] CONDOM



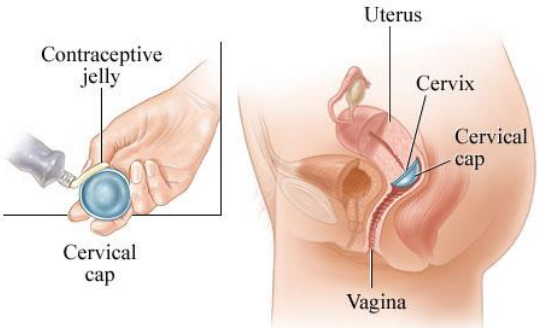
Condoms are of two types like Male condoms and Female condoms. In male it is placed over penis and hence it prevents the deposition of sperms in the vagina. Male condom is a elastic pouch rolled and placed in a safe packet. Before intercourse it is taken out of the packet to place on the erect penis, leaving space at the tip. Unrolling is then done gradually covering the whole penis. This method also prevents various STD infections (sexual transmitting diseases) and it is the only contraceptive to prevent AIDS infection too. A female condom is inserted to fit over the cervix. It is essential to do the proper use of condoms during each sexual intercourse.

B] DIAPHRAGM



It is a dome shaped rubber structure that fits over the cervix. Diaphragm prevents the sperms from passing into the cervix. It is generally used with spermicidal agent that kill the sperms. Diaphragm should be fitted by a physician.

C] CERVICAL CAPS

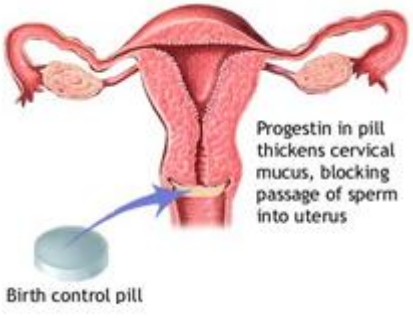


It is a plastic cap of 4cm diameter. It fits snugly over the cervix and it is held in position by suction. It is also fitted by a physician.

3] CHEMICAL METHOD

Use of foam tablets, jellies and creams are the chemical method of contraception.

A] FOAM TABLETS



These are the tablets which produce foam when they are moistened. They are used one at a time. A tablet is moistened and placed deep in vagina before the intercourse. The foam produced destroys the sperm during intercourse.

B] JELLY

This is available in the market in a tube along with its applicator and its operation is to be done carefully. One has to fix the applicator to jelly tube. If a jelly tube is pressed the applicator naturally gets filled with felly. Such an applicator full of jelly is then inserted into the vagina. If the plunger is pressed slowly while taking out the applicator the jelly will be released into the vagina. Jelly destroys the sperms during intercourse.

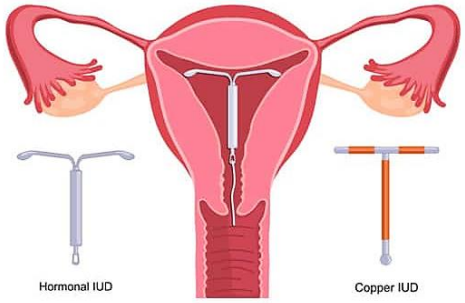
C] CREAMS

Various creams are also used as contraceptives. They are applied to vagina before the intercourse. These creams are spermicidal in their actions to kill the sperms in vagina.

4] INTRAUTERINE DEVICES (IUD)

The commonly used IUDs are copper-T and Lippies loop. They are small objects made of copper, stainless steel and plastic. Plastic Loop is not commonly used but copper-T is in best use. Plastic Loop is a device made of polyethylene. It is a relatively permanent method.

COPPER-T



It is a permanent method of contraception for a relatively long period. Once it is introduced into the uterus it does not allow the egg to implant and thus pregnancy is prevented. Copper-T is to be introduced into the uterus by doctors. One has to change or replace old by new one after 3 years. Loops also prevent a fertilized egg from being implanted into the uterus. Following are the some advantage and disadvantage of copper-T

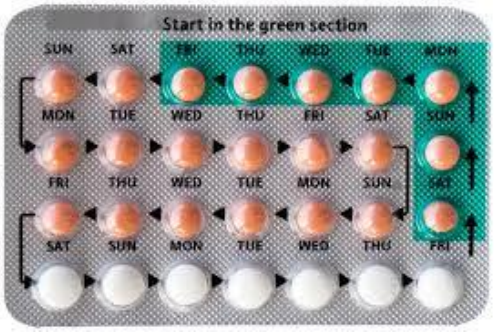
ADVANTAGES OF COPPER-T

1. It is effective (100%)
2. It is aesthetic and reversible.
3. It is non-interfering and reversible.
4. Its association is painless.
5. No problems of storage and disposal.
6. It provides opportunity for gynecological examination

DISADVANTAGES OF COPPERT

1. Sometimes they can cause cramps like pain. Back ache, menstrual bleeding, spotting etc.
2. These side effects are not serious and usually disappear after a few months.

5] ORAL CONTRACEPTIVES (O.C./Pills)



Pregnancy can be prevented by suppressing ovulation. This is done by some oral contraceptive agents, which are available in the form of tablets or capsules/pills. The oral contraceptives pills/tablets contain high concentration of progesterone and low concentration of estrogen. The tablets should be taken for 21 days continuously starting on the 5th day of the menstrual cycle and finishing on the 25th day. Bleeding usually occurs on the 28th day. The next course of tablets should begin again on the 5th day of the next cycle.

PERMANENT METHODS

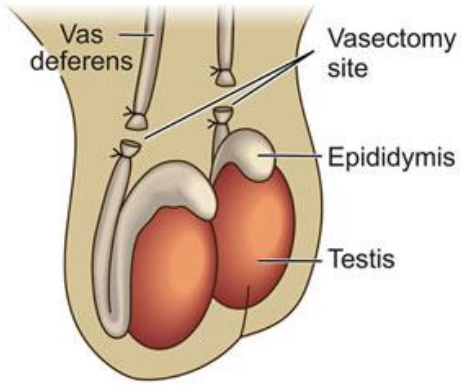
1. Sterilization operations: a] Male sterilization- Vasectomy
   b] Female sterilization or Tubectomy/ Tubal ligation.
2. Abortion Medical pregnancy termination- MTP.

1] STERILIZATION OPERATIONS

It is a popular method of birth control. By this method relatively permanent infertility is achieved. In the case of male, it is called Vasectomy and in females it is called Tubectomy.

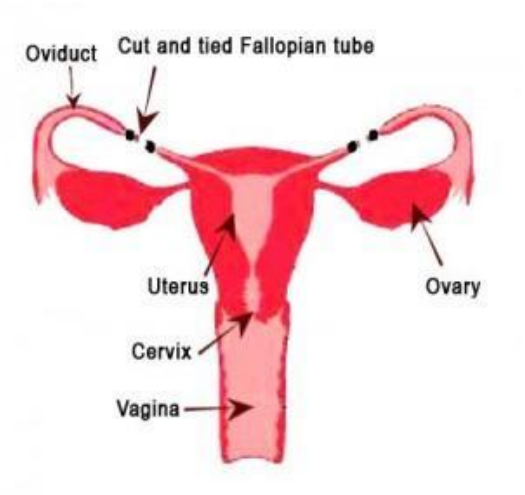
A] VASECTOMY

It is a surgical operation done is male. In male vasectomy, the vas deferens is cut on the sides of the testis. The cut ends are made into knots. This operation is simple and is completed within 20 minutes.



B] TUBECTOMY

It is also called Tubal ligation. In Tubectomy the fallopian tubes are cut and cut ends are made into knots. So that the passage of sperms into the tubes is blocked therefore there will not be any fertilization as such after separation she should not carry weights or do not heavy manual work for at least one month.



2] ABORTION

Abortion is the expulsion of conception products from the uterus. It is done by a physician. It is a birth control method and should be done before the 20th week of gestation. In the medical field, abortion is called MTP (Medical termination of pregnancy), D & C(Dilation and surgical curettage).In MTP the cervix is dilated with an instrument and the embryo is sucked out.

It's crucial for individuals or couples to consult with healthcare professionals to discuss their options understand the benefits and potential risks of each method and choose the one that aligns with their needs and preferences. The effectiveness of contraceptive methods can vary, and proper use is essential for optimal results.

REFERENCES:

Abbott, J. K., Norde, A. K., & Hansson, B. (2017). Sex chromosome evolution: historical insights and future perspectives. *Proceedings of the Royal Society of London. Series B, Biological Sciences, 284*, 20162806.

Alberts, B., Johnson, A., Lewis, J., et al. (2015). *Molecular Biology of the Cell, 6th edn.* New York, NY: Garland Science.

Alcock, J. (2013). *Animal Behavior: an Evolutionary Approach, 10th edn.* Sunderland, MA: Sinauer Associates.

Avise, J. C. (2008). *Clonality: The Genetics, Ecology and Evolution of Sexual Abstinence in Vertebrate Animals.* New York, NY: Oxford University Press.

Birkhead, T. R., Hosken, D. J., & Pitnick, S. S. (Eds.). (2008). *Sperm Biology: An Evolutionary Perspective.* London: Academic Press.

Bourlière, F. (1964). *The Natural History of Mammals, 3rd edn.* New York, NY: Knopf.

Cavicchioli, R. (Ed.). (2007). *Archaea: Molecular and Cellular Biology.* Washington, DC: ASM Press.

Finch, C. E. (1990). *Longevity, Senescence, and the Genome.* Chicago, IL: University of Chicago Press.

Flatt, T., & Heyland, A. (Eds.). (2011). *Mechanisms of Life History Evolution.* Oxford: Oxford University Press.

Fusco, G., & Minelli, A. (2019). References. In *The Biology of Reproduction* (pp. 415-436). Cambridge: Cambridge University Press. doi:10.1017/9781108758970.012

Futuyma, D. J., & Kirkpatrick, M. (2018). *Evolution, international 4th edn.* New York, NY: Oxford University Press, Sinauer Associates.

Godfrey-Smith, P. (2009). *Darwinian Populations and Natural Selection.* New York, NY: Oxford University Press.

Pradeu, T. (2012). *The Limits of the Self: Immunology and Biological Identity.* Oxford: Oxford University Press.

Wolpert, L. (2007). *Principles of Development, 3rd edn.* New York, NY: Oxford University Press.

Reproductive Biology

From Gametes to Generations: A Comprehensive Exploration

ISBN: 978-93-88901-86-4

About Authors

Prof. K. J. Adate is working as a Head, Department of Zoology, Shivraj College Gadhinglaj, Dist-Kolhapur since last twenty two years. He has published many research papers in reputed journals. He ahs completed one minor research project of UGC. Till today Published nine books for B. Sc. I and B. Sc. II Zoology on Theory and practical syllabus of Shivaji University, Kolhapur.

Mob. 9271692747

Dr. V. V. Ajagekar is working as a Head, Department of Zoology, Ajara Mahavidyalaya, Ajara, Dist-Kolhapur since last twenty six years. He is Research guide for M.Phil. and Ph.D. of Shivaji University, Kolhapur. He has completed one Minor Research Project and published sixteen research papers in reputed Journals. Till today Published nine books for B. Sc. I and B. Sc. II on syllabus of Shivaji University Kolhapur.

Mob. 9890087915

Dr. S. A. Vhanalakar is presently working as a Vice Principal and Head, Department of Zoology, Karmaveer Hire College, Gargoti, Dist – Kolhapur. He has 13 years of teaching experience and 14 years of research experience. There are 50 research papers, 12 book chapters 14 edited book, 50 popular newspaper articles and 2 books on the name of Dr. Vhanalakar. He worked as an organizing secretary for two international, three national and ten university level conferences and seminars.

Mob. 9511266950

Mr. Abhijit Bhagwan Mane is working as Assistant Professor & Head, Department of Zoology, Dr.Patangrao Kadam Mahavidyalaya, Ramanandnagar (Burli). He has 24 years of teaching experience in Mumbai & Shivaji University, Kolhapur affiliated colleges. He has authored 4 books. He has published 15 International Research Papers in high impact factor journals. He has completed one Minor research project funded by UGC. Also has several invited talks as resource person.

Mob. 9860028234

Bhumi Publishing

ISBN 978-93-88901-86-4

9 789388 901864