46%

بسم الله الرحمن الرحيم

Male Reproductive Physiology (Pt.1)

Final | Lecture 4

﴿ قُلْ بِفَضْلِ ٱللَّهِ وَبِرَحْمَتِهِۦ فَبِذَٰلِكَ فَلْيَفْرَحُوا۟ هُوَ خَيْرٌ مِّمَّا يَجْمَعُونَ ﴾

Written by: Qusai Al-Shannag

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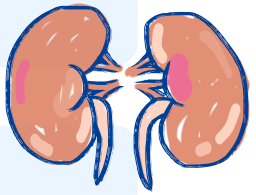

رسالة من الفريق العلمي

السلام عليكم ورحمة الله وبركاته

بعد أيام ستبدأ الأيام العشر من ذي الحجة، أعظم أيام الله، أيام عظمها الله فمن تعظيمنا لله نعظمها، لِنُدَلِّل لله تعالى على تعظيمه:
(ذلك ومن يعظم شعائر الله فإنها من تقوى القلوب)
كما وقد أقسم رب العزة بها: (والفجر (1) وليالٍ عشرٍ (2))...وهي ليالي العشر من ذي الحجة، فلا ينبغي أبداً أن تمر مثل أية أيام أخرى.

صح عن الحبيب المصطفى صلّى الله عليه وسلم أنه قال: (ما من أيامٍ العملُ الصالحُ فيهنّ أحبُّ إلى اللهِ من هذهِ الأيامِ العشرِ)، فقالوا: يا رسولَ اللهِ ، ولا الجهادُ في سبيلِ اللهِ؟ فقال: (ولا الجِهادُ في سبيلِ اللهِ، إلا رجلٌ خرجَ بنفسه ومالِهِ، فلم يرجعْ من ذلكَ بشيء).

فلو أنّ تاجراً حريصا على الربح تراكمت عليه الديون وجاء موسم تجارته فنام فيه، هل يكون عاقلا؟!
فلو لم يجتهد الإنسان في أحب أيام الله إليه فمتى؟ ولو نام الإنسان وضيّع على نفسه موسمًا نال فيه الآخرون عظيم الخيرات فأي خيرٍ بعد ذلك يغتنم؟
أخي المسلم، هذا موسمنا، وهذه تجارتنا، فيا باغي الخير أقبل، وأبشر بفضلٍ من الله وأجرٍ عظيم، وأبشر بمغفرةٍ تفوق ظنّك من الغفّار الرحيم.

فالهمّة الهمّة، أكثروا من الصلوات وقراءة القرآن والصيام والتفنن في بر الوالدين وصلة الأرحام وتفقُّد المساكين ودعوة الغافلين ونُصرة الدين.
أكثروا من التكبير والتهليل والتحميد في بيوتكم والطرقات وذهابكم وإيابكم.

اللهم بارك لنا في هذه الأيام الفضيلة، وأعنّا وافتح علينا إنّك أنت القويّ المعين.

بودكاست نافع للشيخ أمجد سمير عن فضل هذه الأيام العِظام: https://youtu.be/57p126d5w9k?si=DZt8T5IF8Yp-6y7S

MALE REPRODUCTIVE PHYSIOLOGY PART I

GUYTON & HALL, CHAPTER 81

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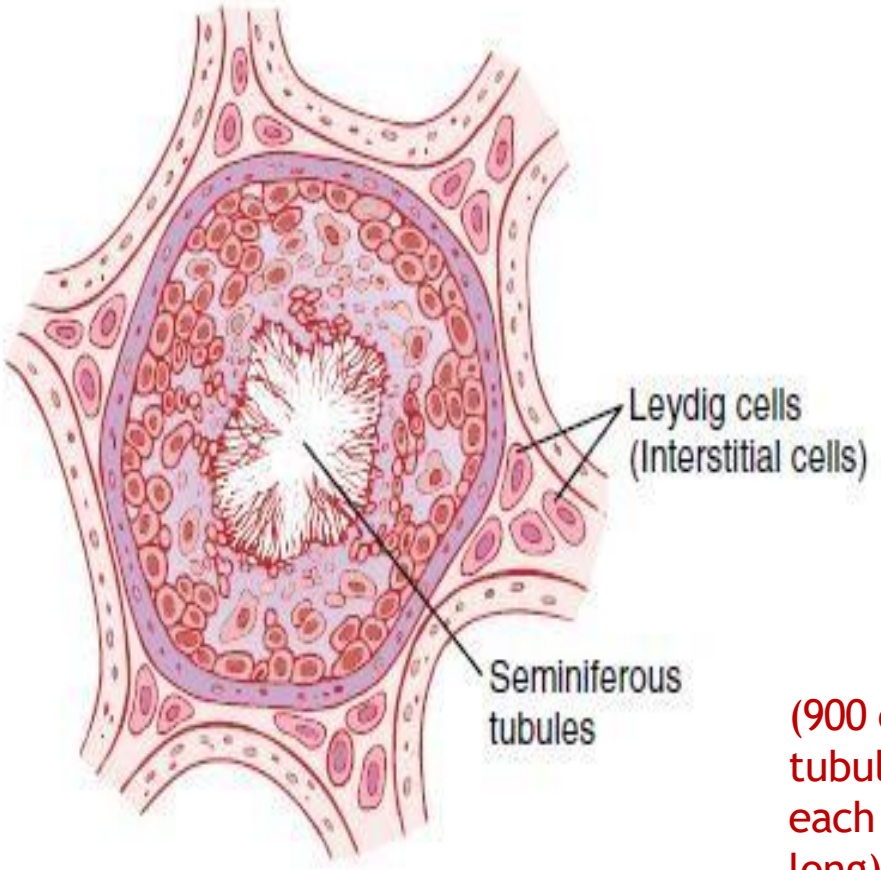
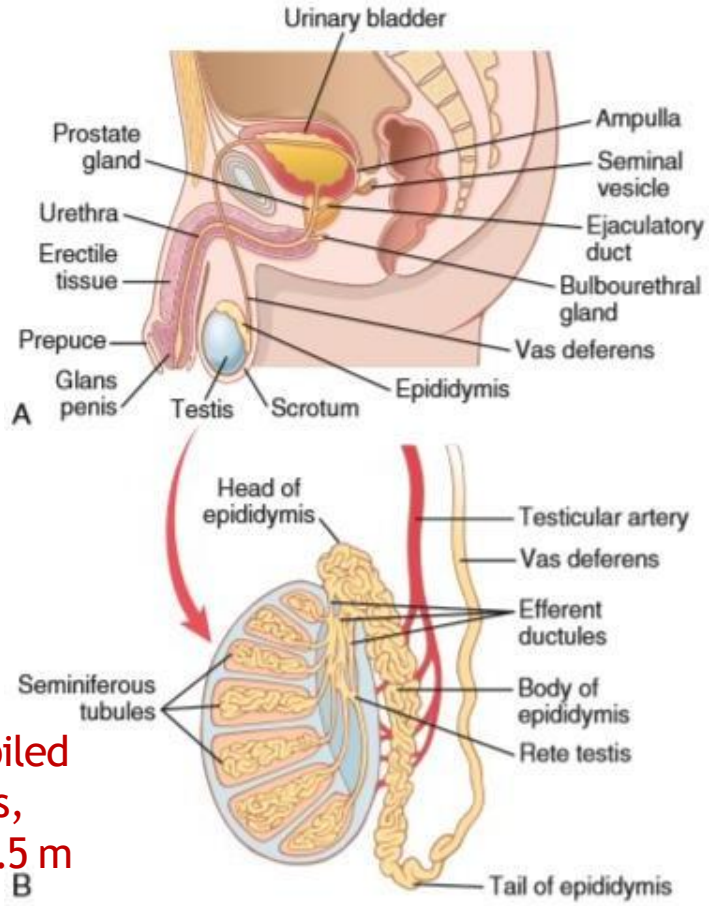
MALE REPRODUCTIVE SYSTEM I

- Explain how the hypothalamus and anterior pituitary gland regulate the male reproductive function
- Explain the *spermatogenesis* and the functions of the male reproductive organs and glands

MALE REPRODUCTIVE ORGANS



(900 coiled tubules, each 0.5 m long)



(6 m long)

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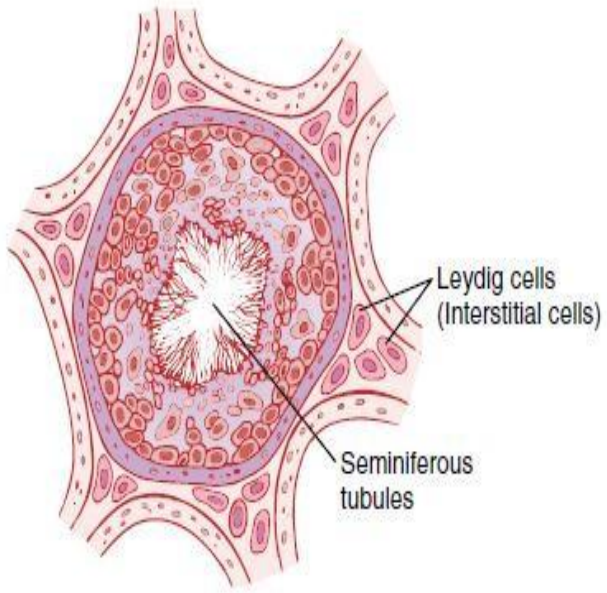
Male Reproductive System

- The main organs of the male reproductive system are the **testes**, which represent the male gonads. They are responsible for **spermatogenesis (sperm production)**.
- The testes are highly coiled organs composed of approximately **900 seminiferous tubules**, with each tubule measuring about **half a meter in length**.
- The contents of the seminiferous tubules pass into another highly coiled tubular structure called the **epididymis**, which is approximately **6 meters long**. The epididymis functions in sperm maturation and transport.
- From the epididymis, sperm move into the **vas deferens**, which connects the testes and epididymis to the rest of the male reproductive tract.
- The vas deferens enlarges to form the **ampulla of the vas deferens**, which then joins the **ejaculatory duct**.
- The **seminal vesicles** also drain their secretions into the ejaculatory ducts.
- The ejaculatory ducts open into the **prostatic urethra** within the **prostate gland**, where prostatic secretions are added.
- All these secretions then pass through the **urethra** to the exterior.
- Additional glands, such as the **bulbourethral glands**, also contribute secretions into the urethra.

Cont...:

- This is a cross-section of the seminiferous tubules where sperm cells are formed, and the structures and cell types of the seminiferous tubules, as well as the process of sperm formation, will be discussed in more detail later.



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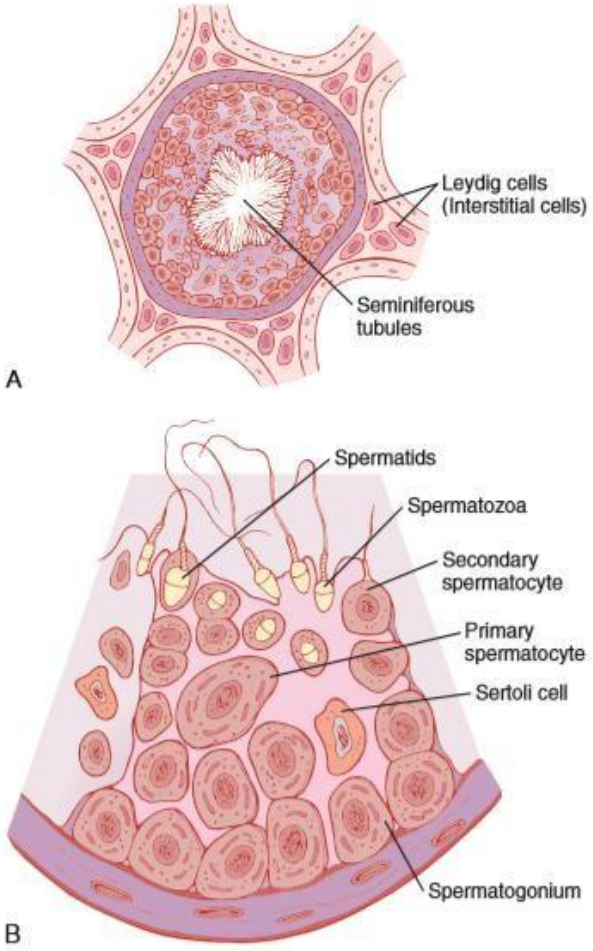
SPERMATOGENESIS



- Formation of sperm from spermatogonia.
- Occurs in seminiferous tubules influenced by GnRH & gonadotropins of ant. pituitary hormones.
- Starts 10-13 years old > ↓ older people, climacteric

- Sertoli cells: large with overflowing
- cytoplasmic envelopes that surround the
- developing spermatogonia around the central
- lumen of the seminiferous tubules. (nourish and support) (FSH)
- Leydig cells: lie with interstitium between the seminiferous tubules. (LH testosterone)
- numerous in the newborn male infants ONLY for the first few months of life
- active at puberty & throughout adult life & secrete testosterone.

Further explaination:

- The main function of the male reproductive system is the production of sperm cells, which are the male gametes responsible for fertilizing the female gamete (ovum) to produce the fertilized ovum that gives rise to the offspring. This process is called spermatogenesis, which refers to the formation of sperm cells from immature cells known as spermatogonia.
- When examining a cross-section of the seminiferous tubules, spermatogonia can be observed along the inner lining of the tubules. These cells originate from primordial germ cells that migrate to the seminiferous tubules during the fifth week of gestation.
- **Sperm production begins only at puberty, although spermatogonia are present since birth.** Sperm formation may decrease in older individuals and may eventually cease at the age referred to as the climacteric period, a concept that also applies to females.

Cells Involved in Spermatogenesis

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- Several types of cells support the process of spermatogenesis, the most important being **Sertoli cells** and **Leydig cells**.

- **Sertoli Cells**
- Sertoli cells are large supporting cells located within the **seminiferous tubules**. They have extensive cytoplasmic processes that surround and support the developing spermatogonia and other germ cells during spermatogenesis.
- Their main functions include:
- ✓ Nourishing developing germ cells
- ✓ Providing structural and functional support during sperm development
- ✓ Sertoli cells function under the influence of **follicle-stimulating hormone (FSH)** secreted by the anterior pituitary gland.

- **Leydig Cells**
- Leydig cells are located in the **interstitial tissue between the seminiferous tubules**.
- They are stimulated by **luteinizing hormone (LH)** secreted by the anterior pituitary gland.
- Their primary function is the production and secretion of **testosterone**, the principal male sex hormone.
- Leydig cells may be present during the first few months after birth, then disappear until puberty. At puberty, stimulation by gonadotropic hormones and increased LH secretion cause the reappearance of Leydig cells, which continue producing testosterone throughout adult life.

HORMONAL FACTORS THAT STIMULATE SPERMATOGENESIS

1 -Testosterone,

by the Leydig cells for growth and division of the testicular germinal cells.

2 -Luteinizing hormone,

stimulates the Leydig cells to secrete testosterone.

3 -Follicle-stimulating hormone,

stimulates the Sertoli cells; without this, no spermatogenesis

4 -Estrogens

formed from testosterone by the Sertoli cells when they are stimulated by FSH hormone, are probably also essential.

5 -Growth hormone,

metabolic function in testes and promotes early division of the spermatogonia themselves; in pituitary dwarfs ? spermatogenesis?

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Hormonal Control of Spermatogenesis

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Several hormones are essential for normal spermatogenesis:

1. Testosterone

Testosterone is secreted by the **Leydig cells** located in the interstitial tissue between the seminiferous tubules.

It is essential for:

- Growth and division of germ cells
- Normal progression of spermatogenesis

Testosterone also has additional functions in the male reproductive system that are discussed later.

2. Luteinizing Hormone (LH)

LH is secreted by the **anterior pituitary gland**.

It stimulates Leydig cells through specific receptors, leading to:

- Testosterone production
- Testosterone secretion

Therefore, LH indirectly supports spermatogenesis through its stimulation of testosterone synthesis.

3. Follicle-Stimulating Hormone (FSH)

FSH secretion is stimulated by **gonadotropin-releasing hormone (GnRH)** from the hypothalamus.

FSH acts mainly on **Sertoli cells**, stimulating and supporting their function.

Since Sertoli cells are essential for supporting developing germ cells, spermatogenesis cannot occur without

Cont...:

4. Estrogen

Evidence suggests that estrogen in the testes is formed by conversion of testosterone into estrogen within the **Sertoli cells**.
This conversion is also stimulated by FSH.
Estrogen is believed to play an important role in normal spermatogenesis.

5. Growth Hormone (GH)

Growth hormone is important for the metabolic functions of the testes and provides the background support necessary for multiple stages of spermatogenesis, especially the early cell divisions.
Its importance is demonstrated in **pituitary dwarfism associated with GH deficiency**, where spermatogenesis is impaired.

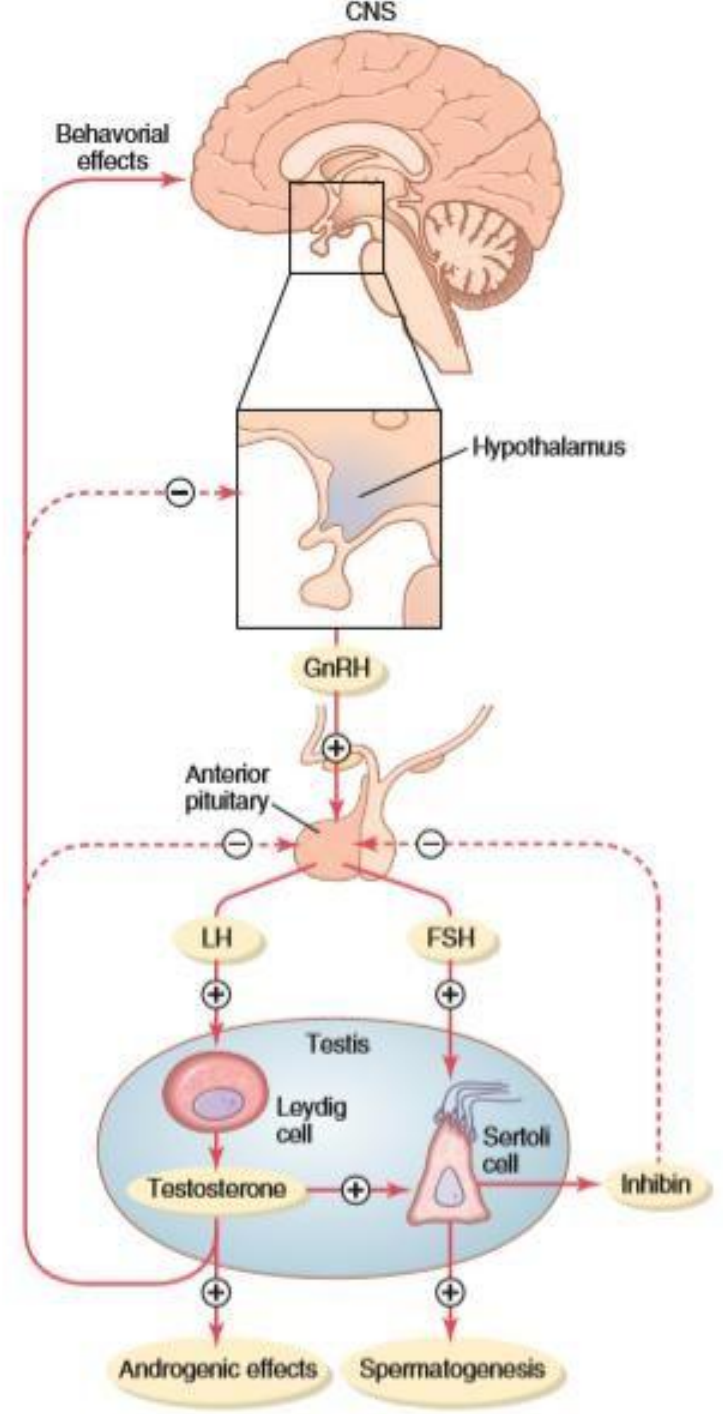
Main Hormonal Pathway

- **Hypothalamus**
  → releases **GnRH**
- **Anterior pituitary gland**
  → releases **LH** and **FSH**
- **LH**
  → stimulates **Leydig cells**
  → Leydig cells secrete **testosterone**
- **FSH**
  → stimulates **Sertoli cells**
- **Sertoli cells**

  → provides support for the spermatocytes to facilitate their development (Spermatogenesis)
  → convert testosterone into **estrogen**
- **Testosterone**
  → supports Sertoli cells to facilitate spermatogenesis

  → Aids in the development of secondary androgenic effects
- **Growth hormone**
  → supports testicular metabolism and early germ cell divisions

HYPOTHALAMIC-ANTERIOR PITUITARY-GONAD'S AXIS



Stages of Spermatogenesis

1. Origin Before Puberty
- **Primordial germ cells** migrate from the **yolk sac** to the **gonads/testes** during embryonic development.
- They differentiate into **spermatogonia**.
- Before puberty, these cells are present but sperm production has not fully begun.

2. Start of Spermatogenesis
At puberty, under the influence of **gonadotropin-releasing hormone, GnRH**, spermatogonia begin **mitotic proliferation** inside the testes.

Main Stages
Stage 1: Spermatogonia
- Spermatogonia undergo **mitosis**.
- They enlarge and develop into **primary spermatocytes**.
- This takes about **25 days**.

Stage 2: Primary Spermatocytes
- Primary spermatocytes are **diploid cells**.
- They contain **46 chromosomes**.
- They undergo the **first meiotic division**.
- This takes about **9 days**.
- The result is **secondary spermatocytes**.

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Stage 3: Secondary Spermatocytes

- Secondary spermatocytes are **haploid cells**.
- They contain **23 chromosomes**.
- They undergo the **second meiotic division**.
- This takes about **19 days**.
- The result is **spermatids**.

Stage 4: Spermatids

- Spermatids are also **haploid cells**.
- They contain **23 chromosomes**.
- They undergo further differentiation.
- They develop into **mature sperm cells**.

Overall Duration

The entire process of spermatogenesis takes approximately:

74 days

➢ Simple Flow:

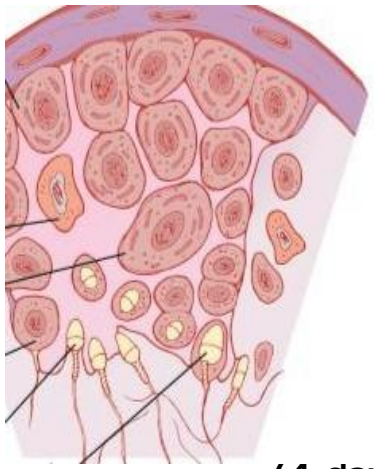
Primordial germ cells
→ spermatogonia
→ primary spermatocytes, 46 chromosomes
→ secondary spermatocytes, 23 chromosomes
→ spermatids, 23 chromosomes
→ mature sperm cells

➢ Movement in the Seminiferous Tubules:

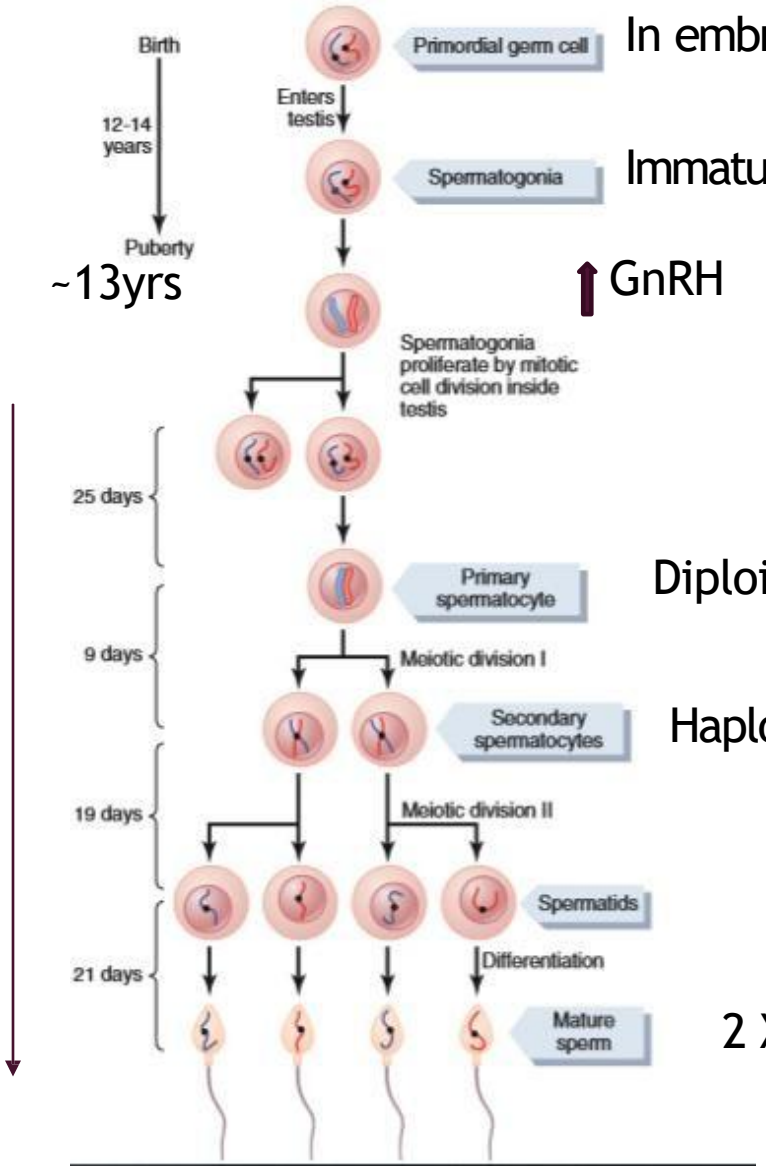
- As the developing gamete passes through its stages, it moves:

From the periphery of the seminiferous tubule towards the **central lumen.**

- By the time it reaches the central lumen, it has become a **sperm cell**.
- Throughout this movement, the developing cells remain surrounded by **Sertoli cells**, which support their maintenance and development.



74 days



In embryo, migrate

Immature, sem.

↑ GnRH

Diploid 46 ch

Haploid 23 ch

2 X, 2 Y

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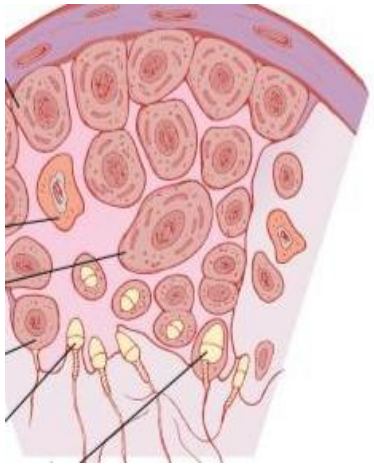

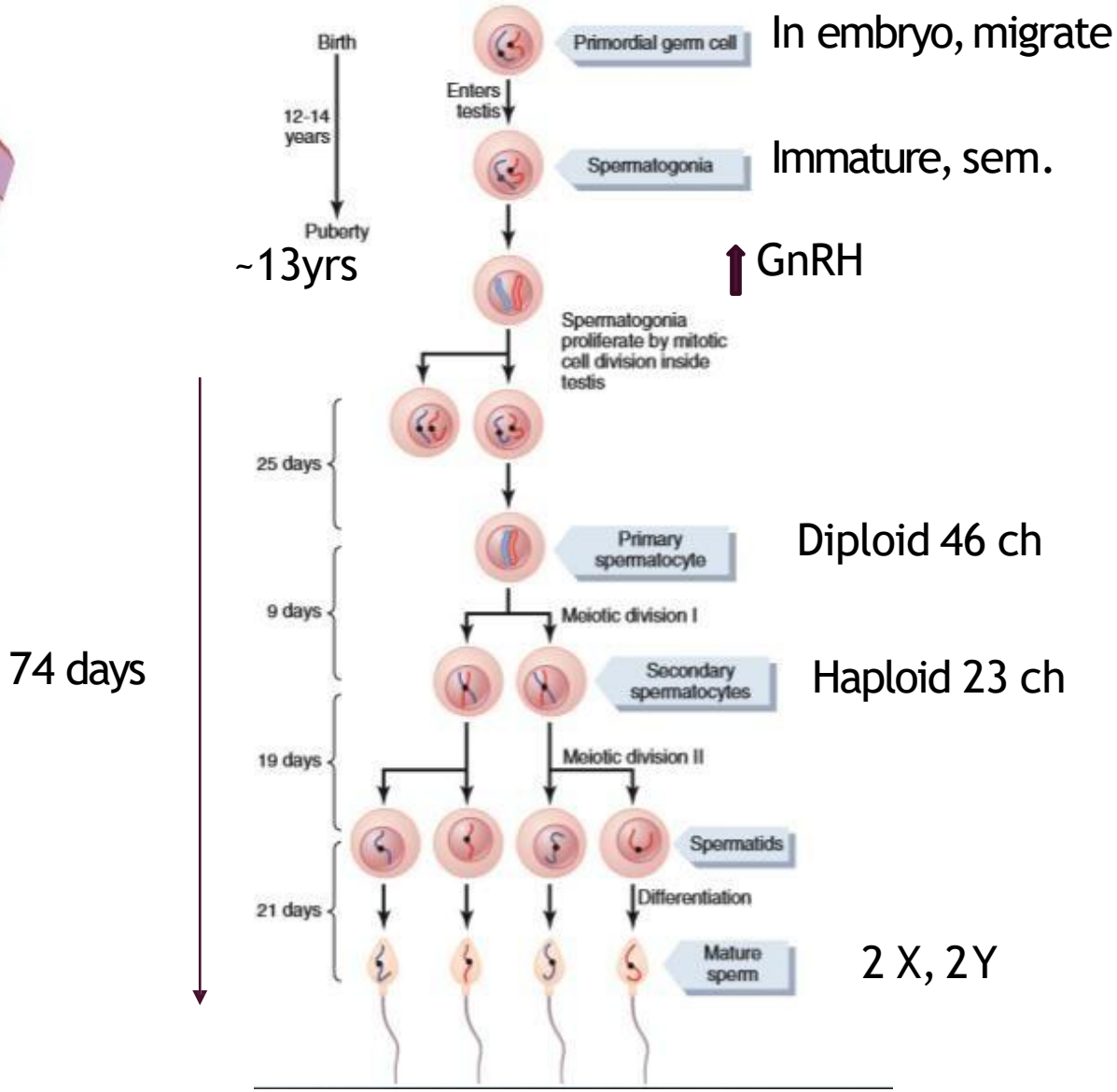

As shown in the figure, during spermatogenesis, developing germ cells (spermatogonia and their descendants) migrate gradually toward the central lumen of the seminiferous tubules.

This movement occurs between the **Sertoli cells**, which are large supporting cells with extensive cytoplasmic processes that surround and support the developing germ cells throughout their maturation process.

LEYDIG CELLS

- Testosterone is formed by the *interstitial cells of Leydig*
- They constitute about 20 % of the mass of the adult testes
- Leydig cells are almost nonexistent in the testes during childhood when the testes secrete almost no testosterone
- But they *are* numerous in the newborn male infant for the first few months of life (then they disappear until puberty). and in the adult male after puberty; at which they secrete large quantities of testosterone.

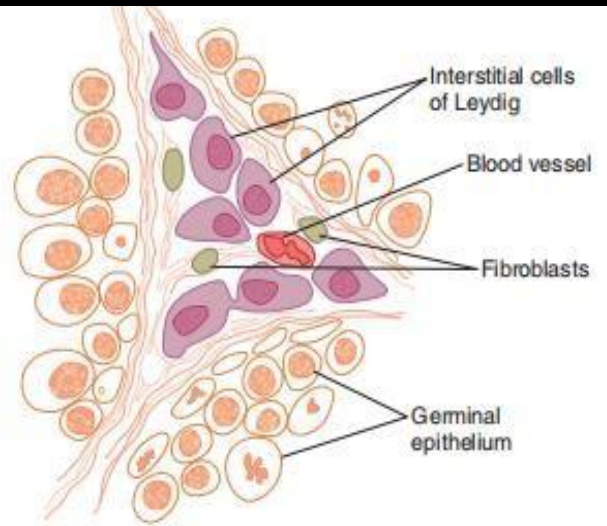

Figure 81-7. Interstitial cells of Leydig, the cells that secrete testosterone, located in the interstices between the seminiferous tubules.

- injection of purified LH into a child at any age or secretion of LH at puberty causes testicular interstitial cells that look like fibroblasts to evolve into functioning Leydig cells.

Interestingly, injection of LH into a prepubertal child can stimulate interstitial cells resembling fibroblasts to differentiate into functional Leydig cells.

PHYSIOLOGY OF MATURE SPERM

- Mature sperm are motile (1-4mm/min) & capable of fertilizing the ovum & their activity is enhanced in a neutral & slightly alkaline medium & depressed in mildly acidic medium.
- ejaculated sperm live in the female genital tract for not more than **only 1 to 2 days**
- **The acrosome** (Golgi) stores large quantities of **hyaluronidase** (to digest proteoglycans) **and proteolytic enzymes, these enzymes help in** digesting the cells and structures surrounding the ovum, ie: facilitates the pathway for the sperm so that it can reach the ovum).

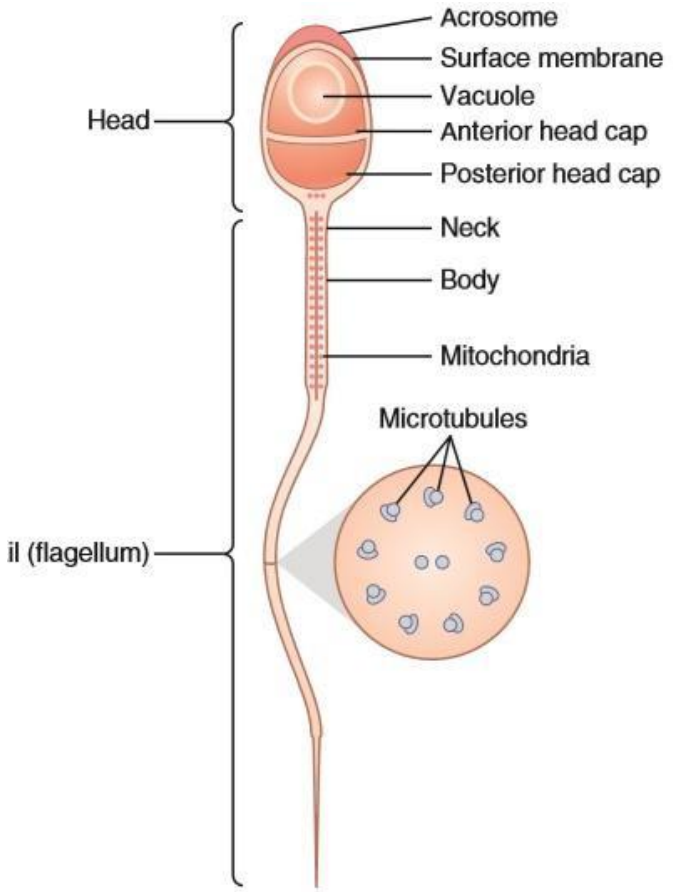

Figure 81-4. Structure of the human spermatozoon.

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Structure of the Mature Sperm Cell

- A mature sperm cell consists of: A **head** and a **tail (flagellum)** and is and **capable of movement.**
- Sperm cells require a **neutral or slightly alkaline environment** for survival, while acidic conditions decrease their lifespan and may kill them.

- **Head of the Sperm**
- The head contains the **acrosome**, which forms a cap-like structure over the anterior part of the sperm head.
- The acrosome contains enzymes and substances necessary for:

✓ **Digesting the cells surrounding the ovum**
✓ **Facilitating penetration and fertilization**

- **Tail of the Sperm**

The tail includes:

✓ **Neck region**
✓ **Body (midpiece)**
✓ **Flagellum**

These regions contain:

✓ **Mitochondria** → provide energy
✓ **Microtubules** → responsible for movement

MATURATION OF SPERM IN THE EPIDIDYMIS

- After their formation in the seminiferous tubules, sperms require several days to pass through the epididymis (non-motile).

- After 18 to 24 hrs→ they develop the capability of motility in epididymis

- (some inhibitory proteins in the epididymal fluid prevent final motility until after ejaculation).

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Sperm cells acquire the ability for motility after spending approximately **18–24 hours in the epididymis**.

However, despite gaining this capacity, their movement remains inhibited by **inhibitory proteins present in the epididymal fluid**.

This inhibition persists until ejaculation occurs, after which sperm become actively motile.

STORAGE OF SPERMS

The 2 testes of adult human form up to 120 million sperms each day.

– Most are stored in the epididymis

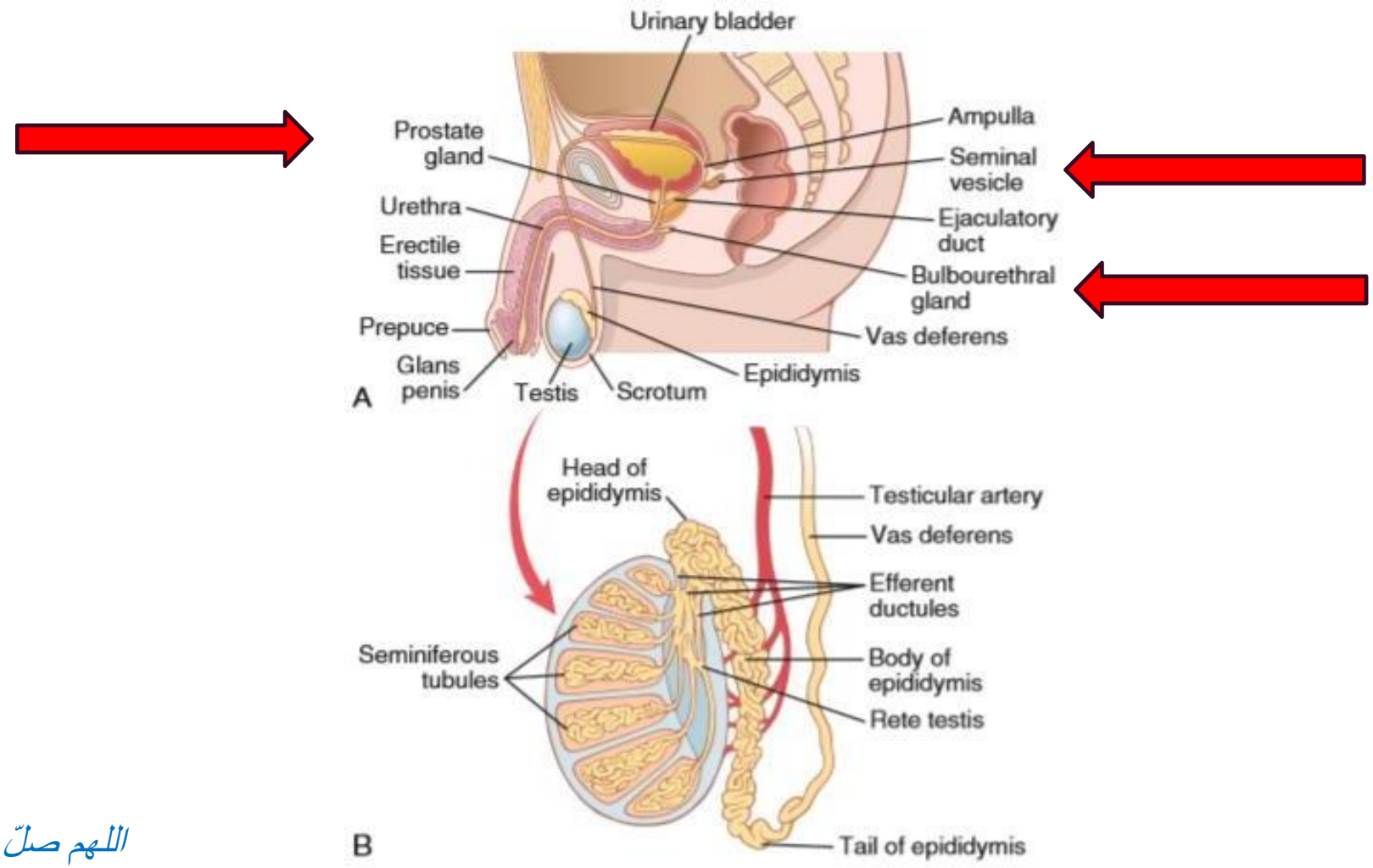
– Small amounts are stored in the vas deferens.

- Suppressed when stored but still maintain fertility for a month at least

After ejaculation, the sperm becomes motile & capable of fertilizing the ovum "maturation"

– The sertoli cells and epithelium of the epididymis secrete nutrient fluid which contains (testosterone & estrogens), enzymes & nutrients essential for sperm maturation.

SECRETION OF MALE GLANDS



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SEMINAL VESICLES FUNCTION

•– During emission and ejaculation: mucoid material containing fructose, citric acid & nutrient **(substances Important for nourishing the sperm)** & large quantities of prostaglandins and fibrinogen. Emptied after vas difference empties the sperms **(After the contraction of the vas deferens).**

- The prostaglandins help in fertilization in two ways:

1 - by reacting with the female cervical mucus making it more receptive to sperm movement.

2 - by causing backward reverse peristaltic contractions of the uterus & fallopian tubes to move the ejaculated sperm toward the ovaries(upper end of FT).

PROSTATE GLAND FUNCTION

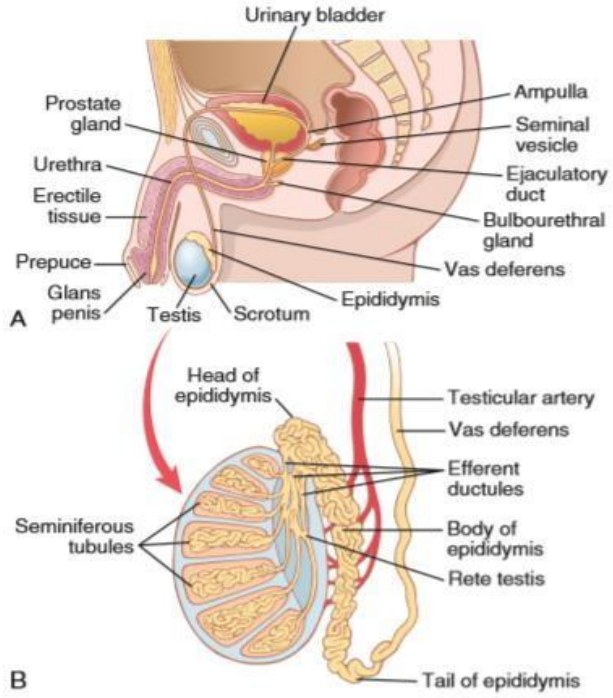
During emission, The prostate gland contracts and secretes ***thin milky fluid*** containing; Ca2+, citrate ion, phosphate ion, a clotting enzyme & profibrinolysin. The alkaline prostatic fluid is important for sperm motility and successful fertilization of the ovum .

Alkaline prostate fluid function:

1 helps to neutralize the slightly acidic fluid of the vas deferens (due to the presence of citric acid and metabolic product of the sperm which inhibits its fertility).

2 helps to neutralize the acidic vaginal secretions (pH 3.5-4.0) to optimize it for better sperm motility (pH 6.0-6.5)

SEMEN



Ejaculated semen (pH 7.5)

is composed of :

– the fluid & sperm from the from the testes and epididymis throughout **vas deferens** (~10%) milky
– fluid from the **seminal vesicles** (~60%) mucoid
– fluid from the **prostate gland** (~30%) clotting enzyme
– small amounts from the mucous glands the **bulbourethral glands**.

Clotting enzymes in the prostate:
Acts on **fibrinogen from the seminal vesicles** to induce **coagulation of semen after ejaculation**, which is important for **maintaining these fluids within the female genital tract.**

SPERM VIABILITY

- After ejaculation, their max life span is 24-48 hrs at body temperature, however, a small number of sperm cells may survive for up to 4–5 days.
- At lower temperature, for weeks
- When frozen, for years

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Capacitation of the Spermatozoa

- Freshly ejaculated semen undergoes "**capacitation**" within 1-10 hours.

1. inhibitory factors are washed out by uterine and fallopian fluids
2. the sperm swims away from cholesterol vesicles(acrosome gets thinner)
3. the membrane of the sperms becomes more permeable to Ca^{++}, Which is necessary for fertilizing the ovum.

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ACROSOME ENZYMES, THE "ACROSOME REACTION," AND PENETRATION OF THE OVUM

- large quantities of *hyaluronidase* and *proteolytic enzymes* in the acrosome of the sperm.
  - Hyaluronidase depolymerizes the hyaluronic acid polymers in the inter cellular cement that holds the ovarian granulosa cells together.
  - The proteolytic enzymes digest proteins in the structural elements of tissue cells that still adhere to the ovum.
- Sperm should penetrate zona pellucida, ant sperm binds receptors in ZP, in minutes the acrosome dissolves, pathways open, within 30 min (cell membranes fuse)
- **Why only one sperm enter**? Within a few minutes after sperm penetration Ca++ diffuses to oocyte releasing cortical granules that permeate in ZP and prevent other sperms

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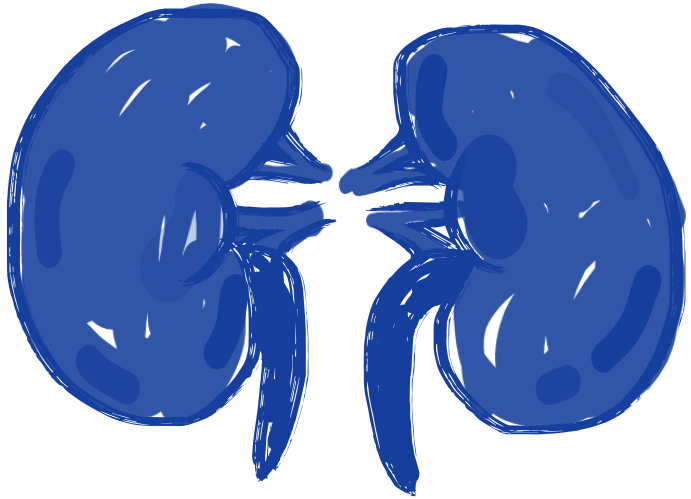
Feature	Maturation of Spermatozoa	Capacitation of Spermatozoa
Definition	Process by which sperm acquire structural and functional maturity	Functional activation process that enables sperm to fertilize the ovum
Site	Epididymis	Female reproductive tract (mainly uterus and fallopian tubes)
Time	Occurs after sperm spend about 18–24 hours in the epididymis	Occurs after ejaculation inside the female tract
Main Purpose	Acquisition of motility and maturation	Preparation for acrosome reaction and fertilization
Motility	Sperm gain the capacity for motility	Sperm become fully active and hypermotile
Acrosome Reaction	Does not occur	Becomes possible after capacitation
Key Mechanism	Epididymal maturation and protein modifications	Removal of inhibitory factors/coating from sperm membrane
Role of Epididymal Fluid	Contains inhibitory proteins that suppress motility until ejaculation	Inhibitory factors are removed during capacitation
Outcome	Mature sperm capable of movement	Fertilization-competent sperm



PHYSIOLOGY QUIZ LECTURE 4

اللهم صلّ وسلّم على سيدنا محمّد

External Resources

رسالة من الفريق العلمي

اللهم إن عمر عطية في ذمتك وحبل جوارك، فقِه من فتنة القبر وعذاب النار،
أنت أهل الوفاء والحق، فاغفر له وارحمه إنك أنت الغفور الرحيم.

Scan the QR code or click it for FEEDBACK

Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1			
V1 → V2			