Spermatogenesis

Lec.3

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- **Objective**
- Understand the Functions of the Testis
- Understand the steps involved in spermatogenesis.
- Describe the structure of sperm, acrosome reaction, and capacitation
- Identify the hormones involved in spermatogenesis and their action.
- Describe the hormonal control of male reproductive system.
- Understand the functions of testosterone.

- **Physiology of the Male Reproductive System**
  - The male reproductive system has two main functions

1. **Exocrine Function – Sperm Production**
   - The seminiferous tubules produce spermatozoa through the process of spermatogenesis.

2. **Endocrine Function – Hormone Production**

A. **Testosterone (Leydig cells)**Primary androgen which regulates male reproductive activity and secondary sexual characteristics

B. **Inhibin B (Sertoli cells)**

C. **Estrogens (from Sertoli & Leydig cells)**

- Unlike females, male gonadotropin secretion is continuous and noncyclical. Testicular function gradually declines with age, but the ability to produce viable sperm often persists throughout life.

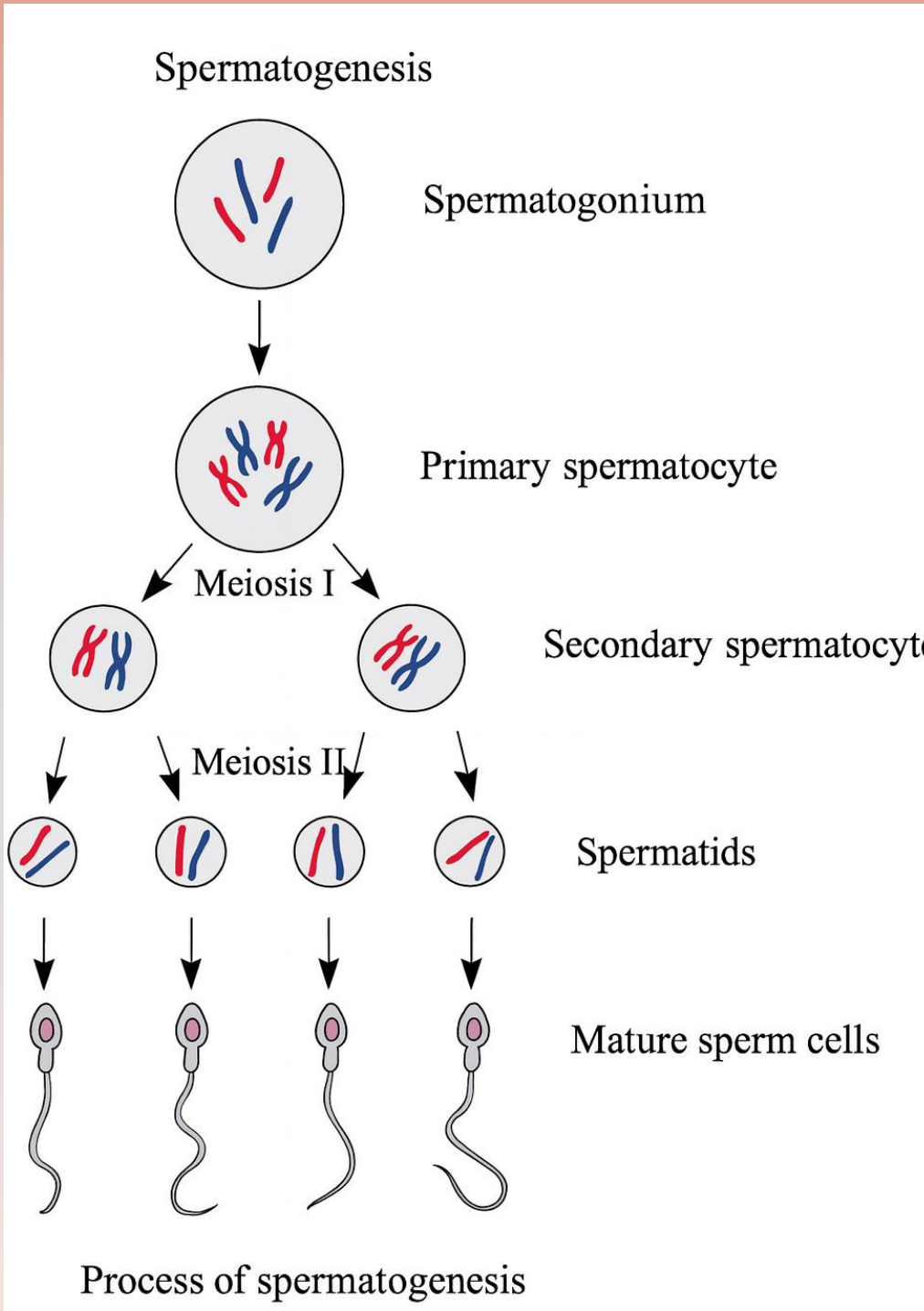
Spermatogenesis

- Spermatogenesis occurs in the seminiferous tubules during active sexual life as the result of stimulation by pulsatile release of gonadotropin-releasing hormone (GnRH) and release of anterior pituitary gonadotropic hormones., ((follicle-stimulating hormone (FSH) and luteinizing hormone (LH)))
- **Spermatogenesis** is the process by which **spermatogonia** (primitive germ cells near the basal lamina) develop into **mature spermatozoa**.

- Beginning at puberty and lasting about 74 days in humans.
- At puberty, spermatogonia begin to divide by mitosis, producing two diploid cells: **One** remains a **spermatogonium** to maintain the stem cell pool, The other becomes a **primary spermatocyte**.
- The primary spermatocyte enters Meiosis I, forming two secondary spermatocytes.
- Each secondary spermatocyte then completes Meiosis II, producing haploid spermatids (23 chromosomes).

- The spermatids undergo **spermiogenesis**, a maturation process that transforms them into spermatozoa .
- **Spermiogenesis** occurs within deep cytoplasmic folds of the Sertoli cells, which provide structural and nutritional support.
- Spermatids then differentiate into spermatozoa (sperm) through structural maturation while remaining connected by cytoplasmic bridges that ensure synchronized development.

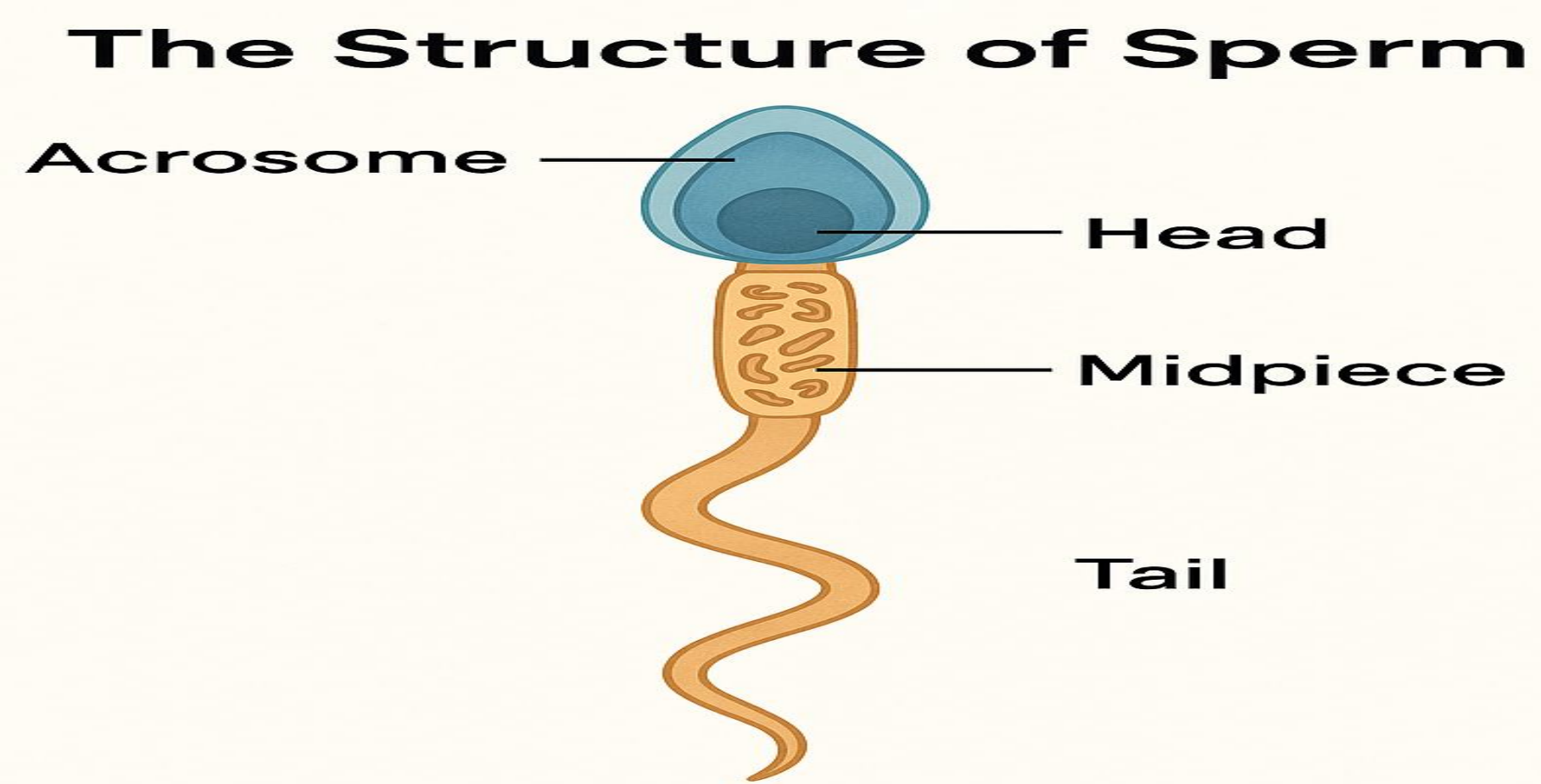
- Once spermiogenesis is complete, mature-looking spermatozoa are released into the lumen (**process called spermiation**) but they are still non-motile and not fully mature
- Each spermatogonium yields about **512 spermatids.** About **100 million sperm** are produced daily.



Process of spermatogenesis

- **The Structure of Sperm**
- A **sperm** consists of:
- A **head** containing condensed DNA and an **acrosome** rich in enzymes for ovum penetration.
- **Midpiece:** The region just before the tail. It contains a dense coil of mitochondria.
- A **tail** providing motility, powered by mitochondria in the **midpiece**.

- Once ejaculated into the female reproductive tract, spermatozoa travel through the uterus and reach the isthmus of the uterine tube, where they undergo **capacitation**



- **Capacitation** is an essential final maturation step that includes:
- **Enhancement of sperm motility**, allowing the sperm to move more vigorously.
- **Acquisition of full fertilizing capacity**, preparing the sperm to interact with the ovum.
- During capacitation, the sperm become capable of initiating the **acrosome reaction**.
  In this reaction, enzymes stored within the acrosome are released when the sperm contacts the ovum, enabling it to penetrate the oocyte's protective layers and achieve fertilization.

Hormonal Control of Spermatogenesis

I. Hypothalamic–Pituitary–Gonadal (HPG) Axis

- GnRH (Gonadotropin-Releasing Hormone):Secreted in pulses from the hypothalamus → stimulates the anterior pituitary:-
  - FSH (Follicle-Stimulating Hormone):Acts on Sertoli cells → promotes spermatogenesis by inducing androgen-binding protein (ABP), inhibin and growth factors.
  - LH (Luteinizing Hormone):Acts on Leydig cells → stimulates testosterone secretion.

II. Testicular Hormones

A. Testosterone

- Is the **primary male sex hormone**, produced mainly by **Leydig cells** in the testes under the influence of LH.
- Its effects begin during fetal life, continue at puberty, and persist throughout adulthood.
- Feedback : Inhibits GnRH & LH
- Testosterone acts either directly or after conversion to

1. **Dihydrotestosterone (DHT)**
2. **Estradiol** in some tissues.

Physiological Function of Testosterone:

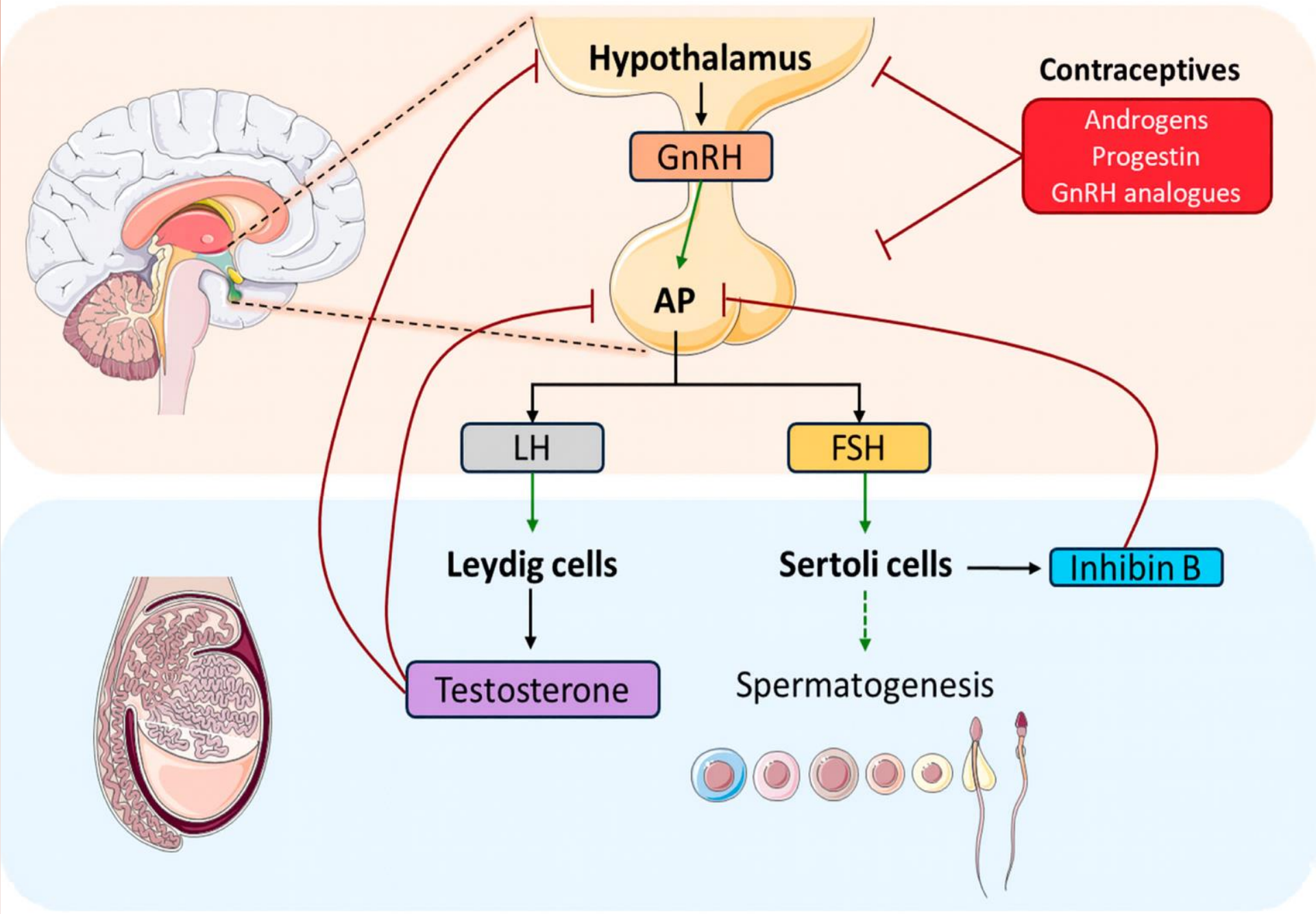
System	Function of testosterone
1. Reproductive	Spermatogenesis, libido, growth of genital organs
2. Growth	Muscle hypertrophy, bone growth, enhance RBC production
3. Secondary sexual characteristics	Hair growth, voice deepening, skin thickening
4. Metabolic effect	↑ BMR, ↑ protein synthesis, ↓ fat mass
5. Fetal development	Male genitalia differentiation, testicular descent

B. **Inhibin-B (from Sertoli cells):**

- Provides negative feedback on FSH secretion
- Helps regulate the rate of spermatogenesis.

C. **Estrogens (small amount)**

- Formed by aromatization of testosterone inside Sertoli cells.
- Support maturation of sperm and fluid absorption.
- **Growth hormone, prolactin, thyroid hormones, and glucocorticoids** could also have an impact on spermatogenesis and male reproductive hormones.


Hypothalamus
GnRH
AP
Contraceptives
Androgens
Progestin
GnRH analogues
LH
FSH
Leydig cells
Sertoli cells
Inhibin B
Testosterone
Spermatogenesis

Physiological Factors Modifying Spermatogenesis

1. **Temperature:** Optimum ≈ 34 °C. High temperature (fever, varicocele, tight clothing) impairs spermatogenesis.
2. **Nutrition**: Adequate protein, zinc, vitamins A & E & C, folate.
3. **Age:** Gradual decline in sperm count and quality.
4. **Sleep / circadian rhythm:** Affects GnRH and testosterone secretion (GnRH secretion exhibits a circadian pattern, with its highest pulsatile peak occurring during the REM phase of sleep.

- **Physiology of Erection**
- Penile erection is a **physiological** process in which the erectile tissues become filled with blood due to increased arterial inflow and reduced venous outflow. Arteriolar dilatation is produced by :

1. **Neural Control**

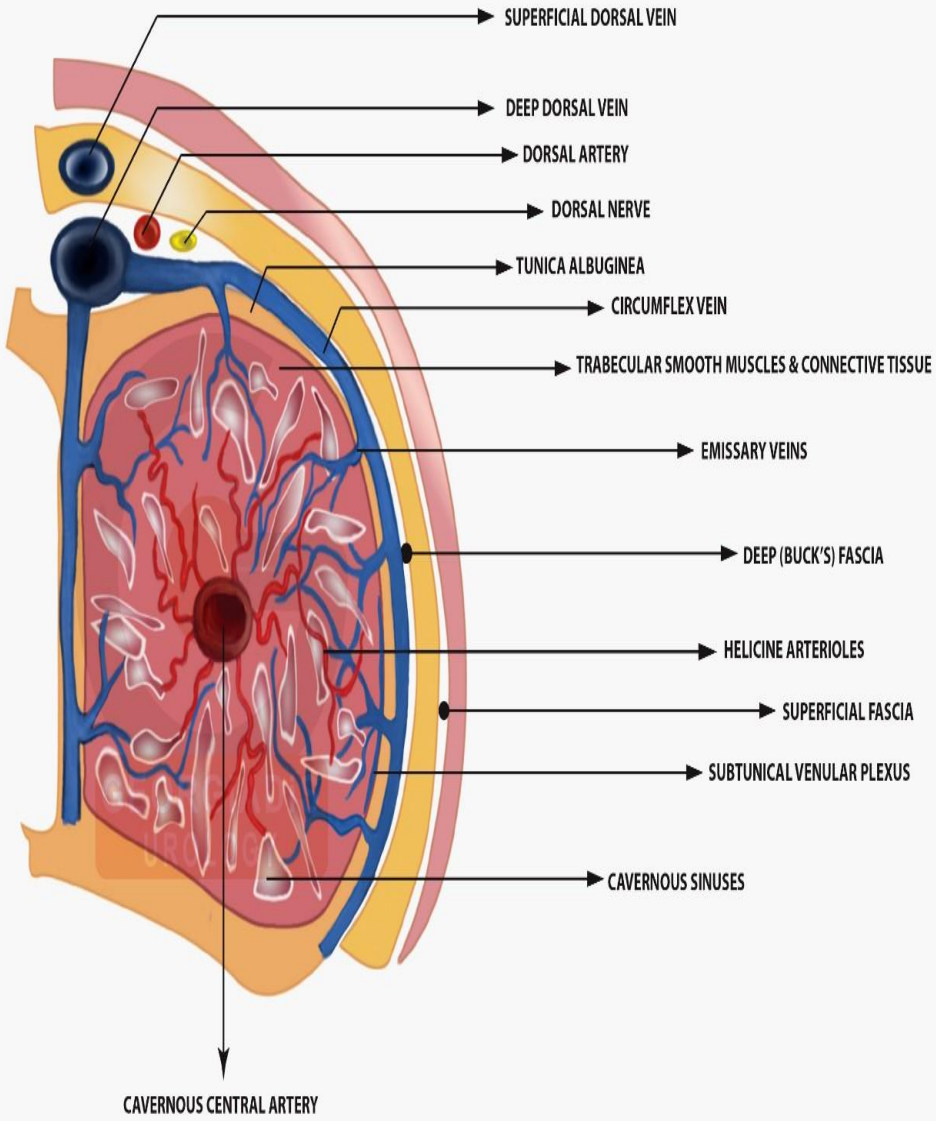
- **Parasympathetic Nervous System (S2–S4) – *Main controller***:

- Sexual stimulation activates the parasympathetic nerves fibers that release nitric oxide (NO) in the corpora cavernosa.
- NO causes relaxation of the cavernosal smooth muscle

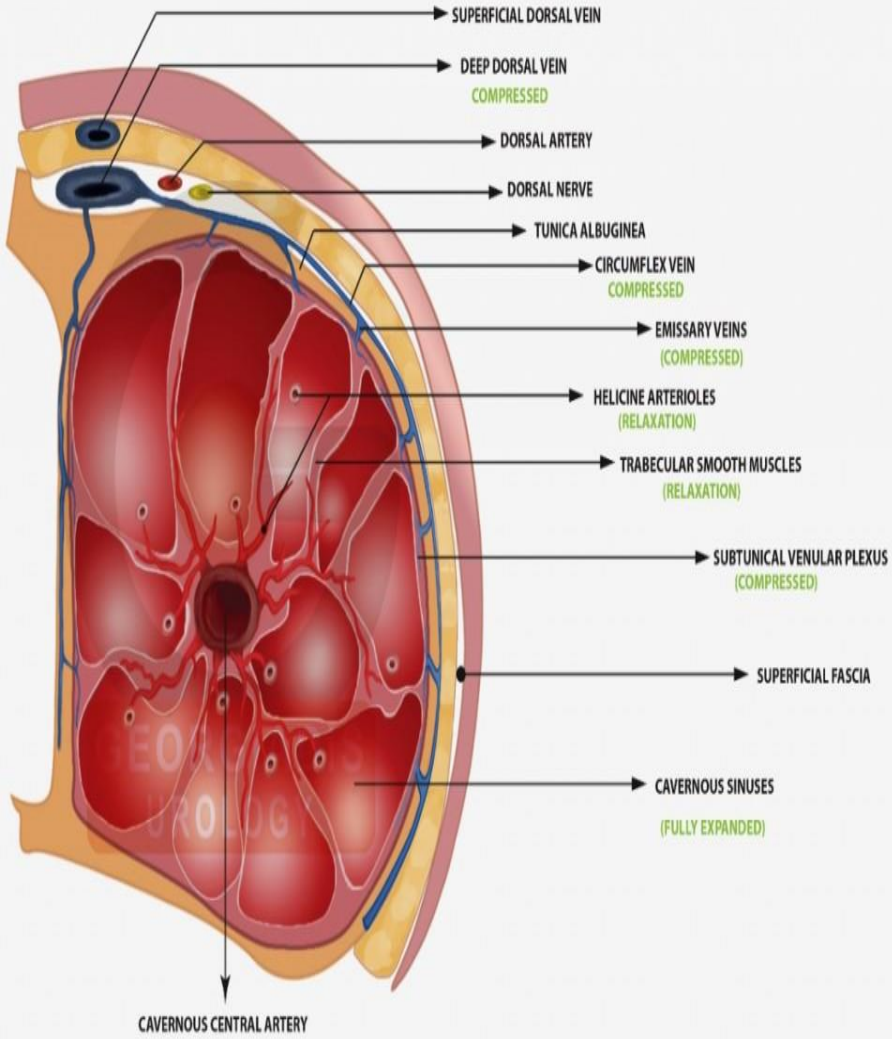
2. Vascular Mechanism

- Smooth muscle relaxation allows the cavernosal arteries to dilate, increasing arterial inflow.
- The sinusoids inside the erectile tissue fill and expand with blood .
- Expansion compresses the subtunical veins against the tunica albuginea , greatly reducing venous outflow . Blood enters but cannot leave → erection becomes firm.
- After ejaculation., erection is ended (detumescence) when sympathetic activity increases, leading to vasoconstriction, smooth muscle contraction, and restoration of venous drainage.

FLACCID STATE



ERECT STATE



- **Physiology of Ejaculation**
- Ejaculation is the process of expelling semen out of the urethra, and it requires coordinated action of nerves, glands, and muscles. Because this process involves many organs, the body organizes it into two main stages

1. **Emission Phase (Sympathetic – T12–L2):**

- This is the preparation phase, where all components of semen are collected in the posterior urethra , initiated by sympathetic stimulation.
- Causes peristaltic contractions of the vas deferens, seminal vesicles, and prostate. This reflex is integrated in the lumbar spinal cord.
- Semen is delivered into the posterior urethra , Internal urethral sphincter contracts to prevent retrograde ejaculation.

2) Expulsion Phase (Somatic – Pudendal nerve S2–S4)

- Semen is pushed out by muscle contractions (somatic)
- Controlled mainly by somatic motor fibers of the pudendal nerve.
- Bulbocavernosus muscle contracts, forcefully ejecting semen out of the urethra.
- Coordinated in the sacral spinal cord.
- Ejaculation is influenced by both genital sensory signals sent to the spinal cord and psychogenic inputs from the brain, which can **initiate**, **enhance**, or **inhibit** the spinal ejaculation reflex.

- 1.5-5 ml of seminal fluid containing several hundred million spermatozoa are deposited in the female vagina during a normal of complete penis erection and ejaculation process.

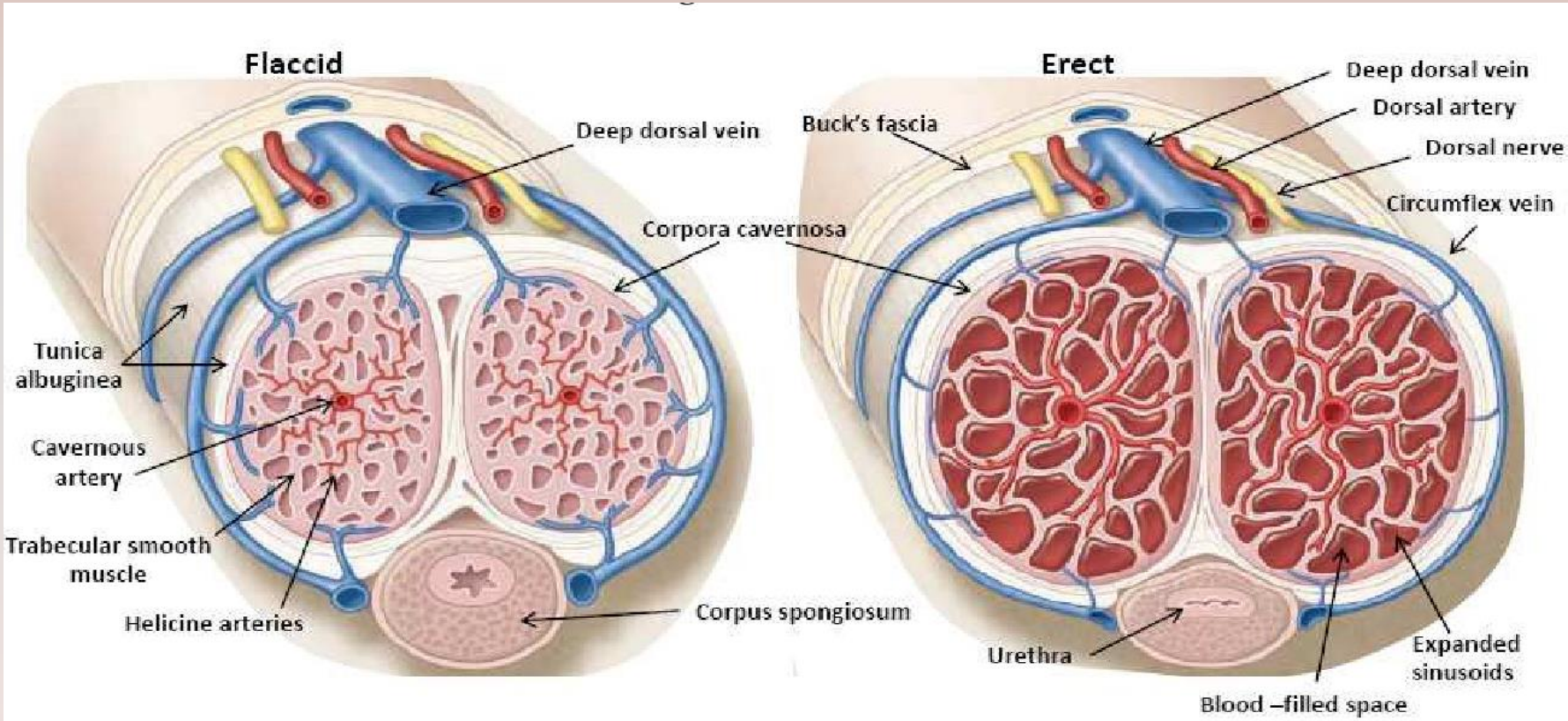


Fig. 1. Penile anatomy. Adapted from Fazio and Brock , 2004.[15]