SPERMATOGENESIS

Spermatogenesis is the process by which haploid spermatozoa develop from germ cells in the seminiferous tubules of the testis.

Purpose of spermatogenesis:

Spermatogenesis produces mature male gametes, commonly called sperm but more specifically known as spermatozoa, which are able to fertilize the counterpart female gamete (Oocyte) during conception to produce a single-celled individual known as a zygote. This is the basis of sexual reproduction and involves the two gametes both contributing half the normal set of chromosomes (haploid) to result in a chromosomally normal (diploid) zygote.

To preserve the number of chromosomes in the offspring that differs between species each gamete must have half the usual number of chromosomes present in other body cells. Otherwise, the offspring will have twice the normal number of chromosomes, and serious abnormalities may result. In humans, chromosomal abnormalities arising from incorrect spermatogenesis results in congenital defects and abnormal birth defects (Down syndrome, Klinefelter syndrome) and in most cases, spontaneous abortion of the developing fetus.

Location of spermatogenesis:

Spermatogenesis takes place within several structures of the male reproductive system. The initial stages occur within the testes and progress to the epididymis where the developing gametes mature and are stored until ejaculation.

<u>The seminiferous tubules of the testes are the starting point for the process</u>, where spermatogonial stem cells adjacent to the inner tubule wall divide in a

centripetal direction beginning at the walls and proceeding into the innermost part, or lumen to produce immature sperm.

Maturation occurs in the epididymis. The location [Testes/Scrotum] is exactly important as the process of spermatogenesis requires a lower temperature to produce viable sperm, specifically 2°-4 °C lower than normal body temperature.

Steps of spermatogenesis:

- This process starts with differentiation of the stem cells located close to the basement membrane of the tubules. These cells are called spermatogonial stem cells (**spermatogonium**) or sperm mother cell.
- The spermatogonium undergoes mitotic division to produce two types of cells. Type A cells replenish the stem cells, and type B cells developed into **primary spermatocytes.**
- The primary spermatocyte divides meiotically (Meiosis I) into **two secondary spermatocytes**; each secondary spermatocyte divides into **two equal haploid spermatids (spermoblast)** by Meiosis II.
- The spermatids are transformed (differentiated) into **spermatozoa (sperm**) by the process called spermiogenesis. These develop into mature spermatozoa, also known as sperm cells.
- Thus, the primary spermatocyte gives rise to two cells (secondary spermatocytes), and the two secondary spermatocytes by their subdivision produce four spermatozoa.
- Spermatozoa are the mature male gametes in many sexually reproducing organisms. Thus, spermatogenesis is the male version of **gametogenesis**, of which the female equivalent is oogenesis.

Duration of spermatogenesis:

The entire process of spermatogenesis duration defers from species to species, it is variously estimated as taking 74-120days including the transport on ductal system which it is takes 3 months. Testes produce 200 to 300 million spermatozoa daily. However, only about half or 100 million of these become viable sperm.

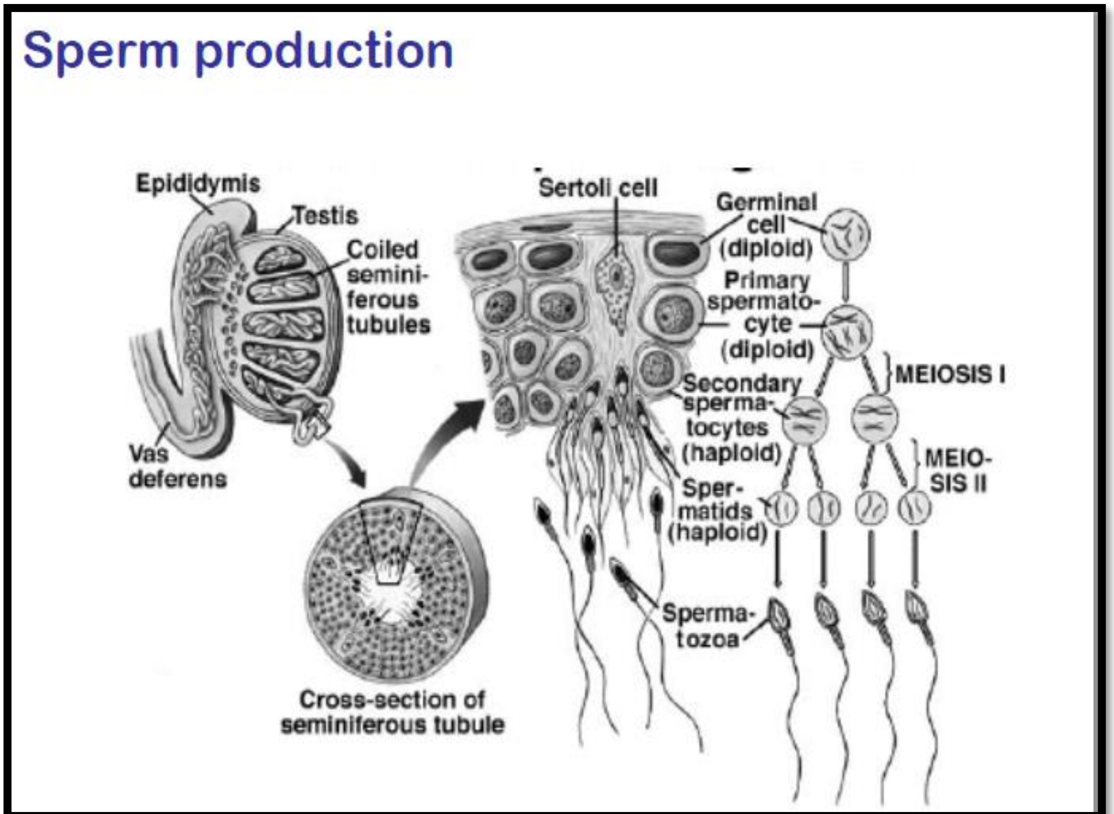
Stages of spermatogenesis:

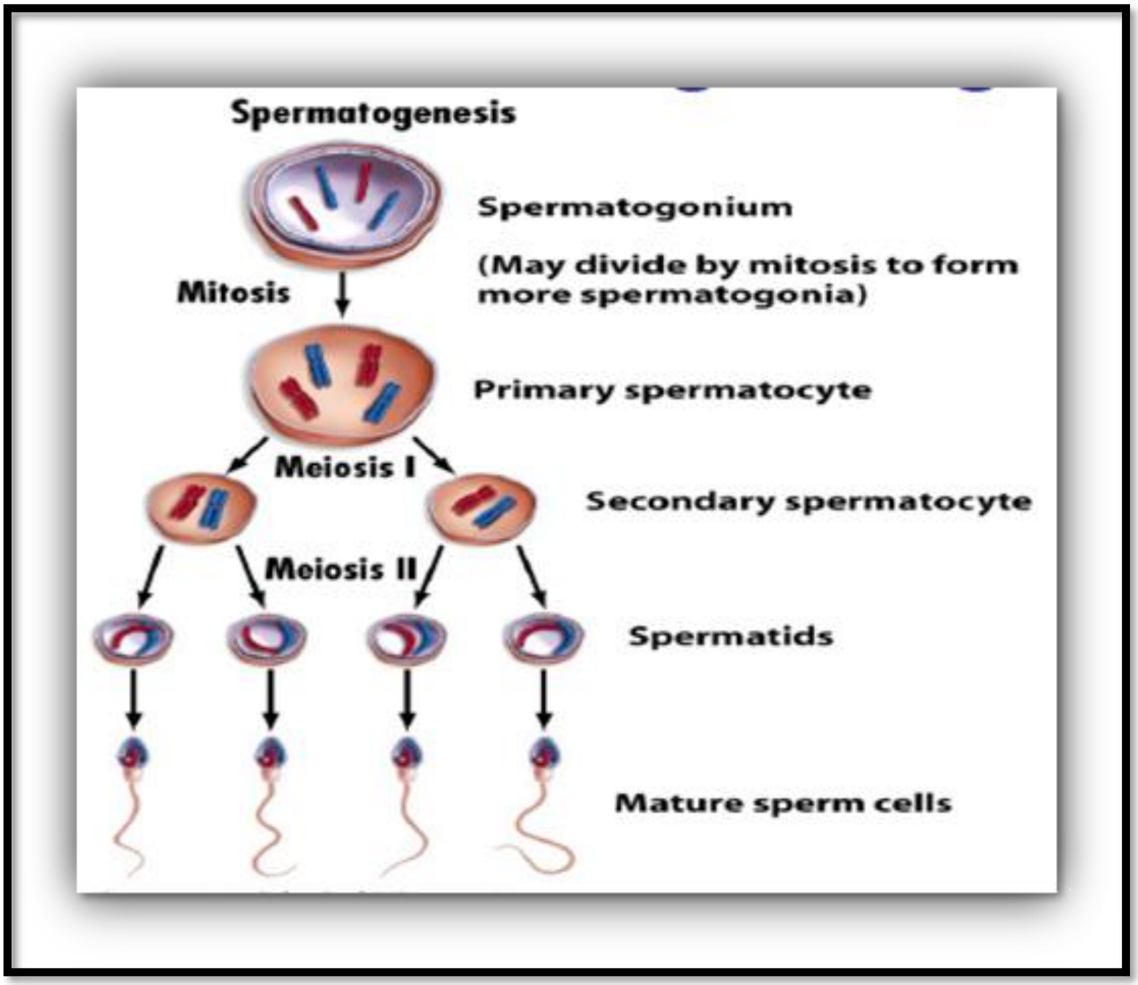
1. **Spermatocytogenesis:** Spermatocytogenesis is the male form of gametocytogenesis and results in the formation of spermatocytes possessing half the normal complement of genetic material. In spermatocytogenesis, a diploid spermatogonium, which resides in the basal compartment of the seminiferous tubules, divides mitotically, producing two diploid intermediate cells called primary spermatocytes. Each primary spermatocyte then moves into the ad luminal compartment of the seminiferous tubules, duplicates it is DNA, and subsequently undergoes meiosis I to produce two haploid secondary spermatocytes, which will later divide once more into haploid spermatids. Each cell division from a spermatogonium to a spermatid is incomplete; the cells remain connected to one another by bridges of cytoplasm to allow synchronous development. It should also be noted that not all spermatogonium divide to produce spermatocytes; otherwise, the supply of spermatogonium would run out. Instead, spermatogonial stem cells divide mitotically to produce copies of themselves, ensuring a constant supply of spermatogonium to fuel spermatogenesis.

2. **Spermatidogenesis:** Spermatidogenesis is the creation of spermatids from secondary spermatocytes. Secondary spermatocytes produced earlier rapidly enter meiosis II and divide to produce haploid spermatids. The brevity of this stage means that secondary spermatocytes are rarely seen in histological studies.

3. **Spermiogenesis:** During spermiogenesis, the spermatids begin to form a tail by growing microtubules on one of the centrioles, which turns into basal body. These microtubules form an axoneme. Later the centriole is modified in the process of centrosome reduction. The anterior part of the tail (called midpiece) thickens because mitochondria are arranged around the axoneme to ensure energy supply. Spermatid DNA also undergoes packaging, becoming highly condensed. The DNA is packaged firstly with specific nuclear basic proteins, which are subsequently replaced with protamine during spermatid elongation. The resultant tightly packed chromatin is transcriptionally inactive. The Golgi apparatus surrounds the now condensed nucleus, becoming the acrosome. Maturation then takes place under the influence of testosterone, which removes the remaining unnecessary cytoplasm and organelles. The excess cytoplasm, known as residual bodies, is phagocytized by surrounding Sertoli cells in the testes. The resulting spermatozoa are now mature but lack motility, rendering them sterile. The mature spermatozoa are released from the protective Sertoli cells into the lumen of the seminiferous tubule in a process called **spermiation.** The non-motile spermatozoa are transported to the epididymis in testicular fluid secreted by the Sertoli cells with the aid of peristaltic contraction. While in the epididymis, the spermatozoa gain motility and become capable of fertilization. However, transport of the mature spermatozoa through the remainder of the

male reproductive system is achieved via muscle contraction rather than the spermatozoon's recently acquired motility.





Role (functions) of sertoli cells

Sertoli cells serve a number of functions during spermatogenesis; they support the developing gametes in the following ways:

1. Maintain the environment necessary for development and maturation, via the blood-testis barrier. The blood-testis barrier was protecting spermatids from the immune system.
2. Secrete androgen-binding protein (ABP), which concentrates testosterone in close proximity to the developing gametes. Testosterone is needed in very high

quantities for maintenance of the reproductive tract, and ABP allows a much higher level of fertility.

3. Secrete hormones affecting pituitary gland control of spermatogenesis, mainly the polypeptide hormone (inhibin).
4. Secretion of anti-Mullerian hormone causes decline of the Mullerian duct.
5. The intercellular adhesion molecules (ICAM) which regulate spermatid adhesion on the apical side of the barrier (towards the lumen).

Factors effect on the spermatogenesis:

The process of spermatogenesis is highly sensitive to fluctuations in the environment, particularly hormones and temperature.

1. Testosterone is required in large local concentrations to maintain the process, which is achieved via the binding of testosterone by androgen binding protein present in the seminiferous tubules.
2. Seminiferous epithelium is sensitive to elevated temperature in humans and some other species, and will be harmfully affected by temperatures as high as normal body temperature. So, the testes are located outside the body in a sack of skin called the scrotum. The optimal temperature is maintained at 2 -4 °C below body temperature. This is achieved by regulation of blood flow and positioning towards and away from the heat of the body by the cremaster muscle and the dartos smooth muscle in the scrotum.
3. Dietary deficiencies (such as vitamins B, E and A).
4. Exposure to pesticides, x-ray, metals (cadmium and lead) poisoning, alcohol, and infectious diseases also affects spermatogenesis.