# GAMETOGENESIS

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# Introduction

- Gametogenesis is a biological process by which diploid or haploid precursor cells undergo cell division and differentiation to form mature haploid gametes. Depending on the biological life cycle of the organism, gametogenesis occurs by meiotic division of diploid gametocytes into various gametes, or by mitosis. For example, plants produce gametes through mitosis in gametophytes. The gametophytes grow from haploid spores after sporic meiosis. The existence of a multicellular, haploid phase in the life cycle between meiosis and gametogenesis is also referred to as alternation of generations

# Spermatogenesis

- **Spermatogenesis** is the process by which haploid spermatozoa develop from germ cells in the seminiferous tubules of the testis. This process starts with the mitotic division of the stem cells located close to the basement membrane of the tubules. These cells are called spermatogonial stem cells. The mitotic division of these produces two types of cells. Type A cells replenish the stem cells, and type B cells differentiate into spermatocytes. The primary spermatocyte divides meiotically (Meiosis I) into two secondary spermatocytes; each secondary spermatocyte divides into two equal haploid spermatids by Meiosis II. The spermatids are transformed into spermatozoa(sperm) by the process of spermiogenesis. These develop into mature spermatozoa, also known as sperm cells.[1] Thus, the primary spermatocyte gives rise to two cells, the secondary spermatocytes, and the two secondary spermatocytes by their subdivision produce four spermatozoa and four haploid cells.[2]
- Spermatozoa are the mature male gametes

# Spermatogenesis

- 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. In mammals it occurs in the seminiferous tubules of the male testes in a stepwise fashion. Spermatogenesis is highly dependent upon optimal conditions for the process to occur correctly, and is essential for sexual reproduction. DNA methylation and histone modification have been implicated in the regulation of this process.[3] It starts at puberty and usually continues uninterrupted until death, although a slight decrease can be discerned in the quantity of produced sperm with increase in age .

# Purpose of Spermatogenesis

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- Spermatogenesis produces mature male gametes, commonly called *sperm* but more specifically known as *spermatozoa*, which are able to fertilize the counterpart female gamete, the oocyte, during conception to produce a single-celled individual known as a zygote. This is the cornerstone 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 – which differs between species – one of 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 foetus .

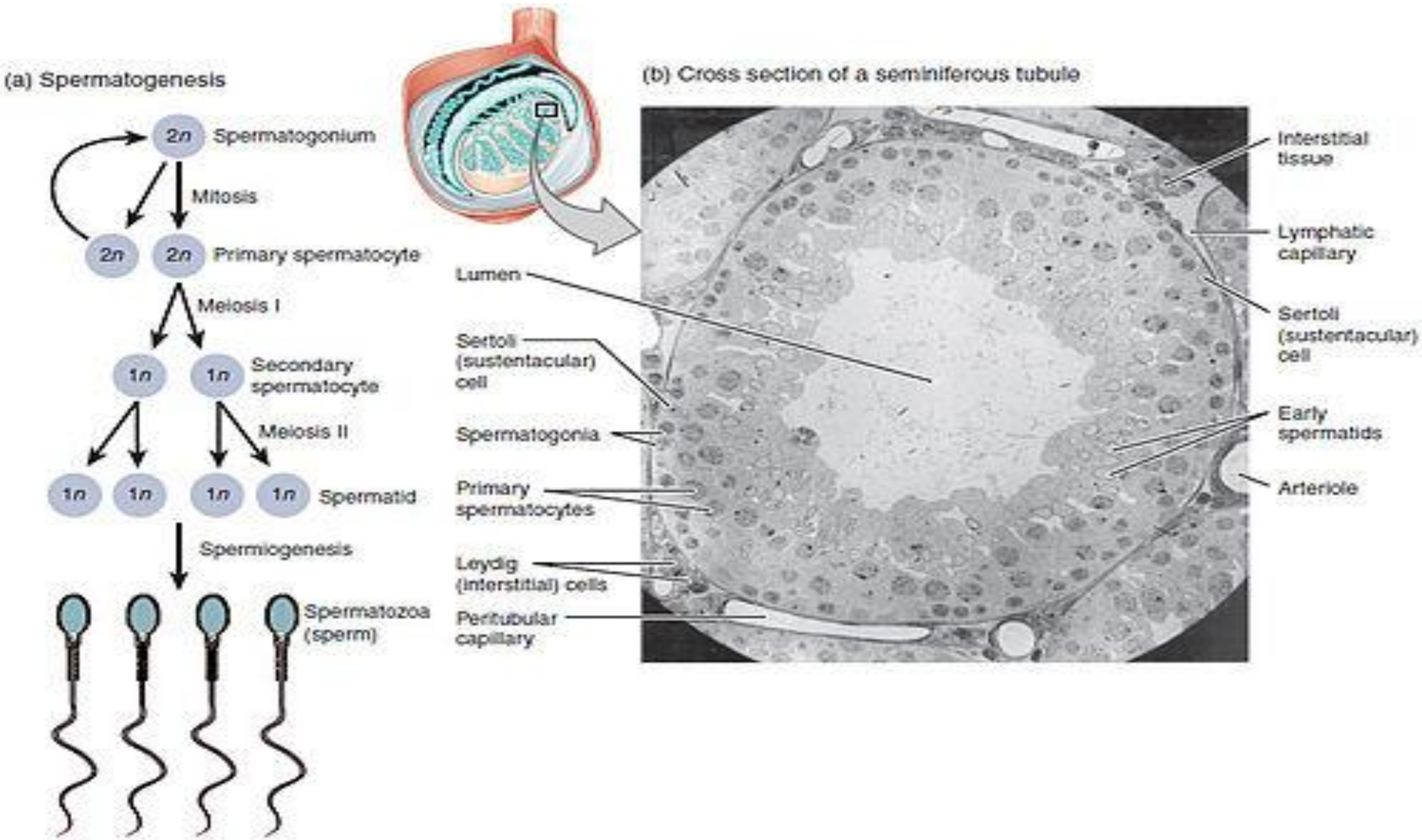
# Location in Human

- 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. The seminiferous tubules of the testes are the starting point for the process, 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 specifically important as the process of spermatogenesis requires a lower temperature to produce viable sperm, specifically 1°-3 °C lower than normal body temperature of 37 °C (98.6 °F). Clinically, small fluctuations in temperature such as from an athletic support strap, causes no impairment in sperm viability or count.

# Duration and Stages

- Duration
- For humans, the entire process of spermatogenesis is variously estimated as taking 74 days (according to tritium-labelled biopsies) and approximately 120 days(according to DNA clock measurements). Including the transport on ductal system, it takes 3 months. Testes produce 200 to 300 million spermatozoa daily.However, only about half or 100 million of these become viable sperm.
- Stages
- The entire process of spermatogenesis can be broken up into several distinct stages, each corresponding to a particular type of cell in humans. In the following table, ploidy, copy number and chromosome/chromatid counts are for one cell, generally prior to DNA synthesis and division (in G1 if applicable). The primary spermatocyte is arrested after DNA synthesis and prior to division.

# Stages of Spermatogenesis



# Spermiogenesis

- **Spermatidogenesis**
- Spermatidogenesis is the creation of spermatids from secondary spermatocytes. Secondary spermatocytes produced earlier rapidly enter meiosis II and divide to produce haploid spermatids.
- **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 non-motile spermatozoa However, transport of the mature spermatozoa through 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. the remainder of the male reproductive system is achieved via muscle contraction rather than the spermatozoon's recently acquired motility.
- 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 protamines 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 phagocytosed 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*.

# Function of Sertoli Cell

- Sertoli cells serve a number of functions during spermatogenesis, they support the developing gametes in the following ways:
- Maintain the environment necessary for development and maturation, via the blood-testis barrier
- Secrete substances initiating meiosis
- Secrete supporting testicular fluid
- 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
- Secrete hormones affecting pituitary gland control of spermatogenesis, particularly the polypeptide hormone, inhibin
- Phagocytose residual cytoplasm left over from spermiogenesis
- Secretion of anti-Müllerian hormone causes deterioration of the Müllerian duct[14]
- Protect spermatids from the immune system of the male, via the blood-testis barrier
- Contribute to the spermatogonial stem cell niche

# Hormonal control

- Hormonal control of spermatogenesis varies among species. In humans the mechanism is not completely understood; however it is known that initiation of spermatogenesis occurs at puberty due to the interaction of the hypothalamus, pituitary gland and Leydig cells. If the pituitary gland is removed, spermatogenesis can still be initiated by follicle stimulating hormone (FSH) and testosterone. In contrast to FSH, luteinizing hormone (LH) appears to have little role in spermatogenesis outside of inducing gonadal testosterone production.
- FSH stimulates both the production of androgen binding protein (ABP) by Sertoli cells, and the formation of the blood-testis barrier. ABP is essential to concentrating testosterone in levels high enough to initiate and maintain spermatogenesis. Intratesticular testosterone levels are 20–100 or 50–200 times higher than the concentration found in blood, although there is variation over a 5- to 10-fold range amongst healthy men. FSH may initiate the sequestering of testosterone in the testes, but once developed only testosterone is required to maintain spermatogenesis . However, increasing the levels of FSH will increase the production of spermatozoa by preventing the apoptosis of *type A spermatogonia*. The hormone inhibin acts to decrease the levels of FSH. Studies from rodent models suggest that gonadotropins (both LH and FSH) support the process of spermatogenesis by suppressing the proapoptotic signals and therefore promote spermatogenic cell survival.

# Hormonal Control

- The Sertoli cells themselves mediate parts of spermatogenesis through hormone production. They are capable of producing the hormones estradiol and inhibin. The Leydig cells are also capable of producing estradiol in addition to their main product testosterone. Estrogen has been found to be essential for spermatogenesis in animals.However, a man with estrogen insensitivity syndrome (a defective ERα) was found produce sperm with a normal sperm count, albeit abnormally low sperm viability; whether he was sterile or not is unclear. Levels of estrogen that are too high can be detrimental to spermatogenesis due to suppression of gonadotropin secretion and by extension intratesticular testosterone production.Prolactin also appears to be important for spermatogenesis.