

**Human Physiology**  
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**Lecture - 02**

## Spermatogenesis

Hello, and welcome to another new class of Human Physiology. Hopefully, you are enjoying the class. In the last class, we discussed the male reproductive organs. In this class, we will discuss the process of spermatogenesis, and we will see how the process of sperm formation happens. Let us stick with it. So, what different concepts will be covered in this class? We will discuss the process of spermatogenesis.

Then we will discuss the hormonal control of spermatogenesis. Then we will thoroughly discuss the sperm structure and its function. And then finally, we will discuss different factors that can affect the process of spermatogenesis. So, let us see them one by one.

Spermatogenesis is the complex process of sperm cell development within the seminiferous tubules of the testes. It involves mitotic and meiotic cell divisions as well as cellular differentiation. The main goal of spermatogenesis is to produce sperm. Continuous processes occur throughout a male's reproductive life. The seminiferous tubule inside the testis has mostly different types of cells; for example, germ cells.

These germ cells undergo spermatogenesis and also have Sertoli cells. What do Sertoli cells do? The Sertoli cells are support cells for crucial sperm development. And importantly, the lumen of the tubules where their mature sperm processes happen. So, basically, in the lumen of the tubule, what happens is that the mature sperm cells get developed and then they are released. Let us see what the different stages of spermatogenesis are.

So, spermatogenesis is broadly divided into three different phases. In the first part, what happens is like mitosis, where from the spermatogonium, it develops into the primary spermatocyte, and in this case, mostly as you know in the case of mitosis, the  $2N$  stays as  $2N$ . And after the primary spermatocyte preparation, we undergo the process of meiosis, which consists of two steps: one is meiosis I, and the second is meiosis II. So, in the case of meiosis, what happens is that the primary spermatocyte, which initially comes from the mitosis process, undergoes meiosis I and II to make haploid spermatids. So, eventually what is happening with the  $2N$  is that we are getting haploid spermatids by 2 steps of meiosis I and meiosis II.

And eventually, when the two steps of meiosis happen, the final maturation or differentiation occurs, resulting in mature sperm cells with haploid genetics. So, this whole process from spermatogonium to mature sperm is called spermatogenesis. And then what is spermiogenesis? This process of spermatids forming mature sperm is also called spermiogenesis. So, let us discuss each step a little more thoroughly. So, in the first step of mitosis, which is also called spermatocytogenesis, basically what happens is that spermatogonia, which are located in the basal compartment of the seminiferous tubules, are mostly diploid cells with  $2N$ .

They undergo mitotic divisions. Why? Mostly it has two roles to play. The first one is to replenish the spermatogonial population, and then it also produces the primary spermatocytes, which are committed to meiosis. It has different types of spermatogonia; for example, type A and type B, with varying proliferative potential. So, after the mitosis, it goes to the meiosis stage, right? So, what happens in meiosis 1 is basically a reduction division stage.

So, from the primary spermatocyte ( $2N$ ), it entered meiosis I, where homologous chromosomes separate, resulting in the two haploid secondary spermatocytes, and here crossing over occurs during the prophase I step, which also increases genetic diversity, and in meiosis II. Where sister chromatids get separated. In this case, secondary spermatocytes undergo meiosis II, where sister chromatids separate, resulting in 4 haploid  $N$  spermatids. So, eventually you can see that from the initial  $2N$ , what do we eventually get? We get one diploid, and eventually, we get four haploid spermatids, right? Each spermatid contains a unique combination of genetic material. So, in this process of meiosis, as you know, genetic diversity is increased, and it also ensures the correct genetic information is passed from parent cells to the daughter cells.

So, in the last step after meiosis one and two, spermiogenesis happens, which is basically a kind of differentiation or maturation process. In spermiogenesis, which is a complex process where round spermatids transform into elongated spermatozoa. So, initially in the spermatid, there are four haploid forms, but they are more of a round type of shape. However, they undergo a differentiation process and maturation process to become an elongated type of structure, which is our actual final sperm. It has some key events; for example, the formation of the that contains different enzymes that are very important.

We will discuss their function. Then, condensation and elongation of the nucleus also happen here. Development of the midpiece contains mitochondria. So, the midpiece also develops here in cases of sperm, and they are very rich in mitochondria that supply the energy. Then the formation of the tail happens here.

And this still helps in terms of the improvement of the motility of the sperm; finally, the shedding of the excess cytoplasm also happens. So, all these steps of differentiation and maturation occur in this step of spermiogenesis. It is very important to know the hormonal control of spermatogenesis. So, to start with, let us see how things happen. First, it gets secreted from our hypothalamus, like GnRH or gonadotropin-releasing hormone.

So, when GnRH is secreted, it stimulates the anterior part of the pituitary. So, let us discuss one more time what is happening with the hypothalamus secreting the gonadotropic releasing hormone. Gonadotropic releasing hormone stimulates the anterior pituitary, and once it stimulates the anterior pituitary, it secretes two different hormones. One is follicle-stimulating hormone, or FSH, and the second is luteinizing hormone, or LH. So, what is the anterior pituitary doing? Once it is stimulated by the GnRH, it first secretes the follicle-stimulating hormone, or FSH, and next the luteinizing hormone, or LH.

Both FSH and LH are called gonadotropic hormones. They have a very important role to play. For example, FSH, or follicle-stimulating hormone, stimulates the Sertoli cells. Right, and certainly, cells, once stimulated by FSH secretion, trigger or stimulate the process of spermatogenesis. So, in the last few slides, as you saw, we discussed different stages of spermatogenesis, including mitosis, then meiosis I and II.

And finally, the differentiation and maturation. So, once this FSH gets secreted, it stimulates Sertoli cells, and it also further stimulates the spermatogenesis process. Now, let us see what the anterior pituitary does; it also stimulates the luteinizing cells or the luteinizing hormone, which is LH. This LH, once it gets secreted, stimulates the Leydig cells. And what these Leydig cells do is stimulate testosterone secretion.

So, what do these Leydig cells do? Once it is stimulated by the LH or luteinizing hormone, it influences the secretion of testosterone. And as you know, testosterone has several roles to play, including the development of our secondary male reproductive characteristics and sexual characteristics. It also helps to stimulate overall spermatogenesis or sperm growth. So, it is very important that the luteinizing cells stimulate the Leydig cells, as it helps to form a kind of testosterone secretion. The Sertoli cells have another role to play.

Once the FSH stimulates the Sertoli cell, it also stimulates the secretion of an even type of hormone. So, what FSH is doing, the primary role is to, of course, stimulate the sperm. But when there is a very significant amount of sperm formation, for example, let us consider we have like 10 million sperm, and then after a continuous spermatogenesis procedure, the number goes as high as 100 million. So, at a very high level, when there is enough production of sperm and the storage space is limited, these Sertoli cells kind of stimulate another hormone secretion, which is Inhibin. This inhibin only gets secreted when there is already a high number of sperm production, and it actually has an inhibition type of role or negative feedback loop role that affects the anterior pituitary to stop this initial secretion of FSH and LH.

So, what is happening is that whenever there is a high number of sperm production or a lack of storage capacity, the Sertoli cells stimulate the secretion of inhibin, and eventually this inhibin will create a negative feedback loop to stop the anterior pituitary from secreting more FSH and LH. In the same way, testosterone will also create a negative feedback loop on both the anterior pituitary and the hypothalamus so that further cycles of spermatogenesis are stopped. So, in this way it maintains an overall homeostasis of sperm production because there is not enough space to store a lot of sperm. Hopefully, it is clear. Let us finally see the different places of the sperm, their structure, and their function.

So, to start with, sperm is mostly divided into three parts. The first is the head, then we have the midpiece, and finally, the tail. This is a highly specialized type of cell that is highly motile. Its structure is highly streamlined and efficient, enabling it to reach and penetrate the egg. The main components, as we said, are the head, midpiece, and tail, and they have very specific roles and functions to play.

Let us start with the sperm heads. The head is the anterior part of the sperm cell, which is primarily composed of two different structures. One is the nucleus, which contains the genetic information, and the second is the acrosome. So, you can see the most important part is the nucleus; of course, it contains the genetic information, and then on top of that, you can see this part, which is called the acrosome. This is also like a cap-like structure.

It contains different types of enzymes, for example, acrosins, and what is the function of this enzyme? Basically, this enzyme helps to secrete in the female reproductive system before fertilization. So that various layers of the egg can be penetrated. What are the different layers? For example, the zona pellucida and corona radiata are very thick, and they generally do not allow any external interference to penetrate inside. So, this type of acrosine or hyaluronidase, a different type of this enzyme which is secreted from the acrosome, helps the penetration of

sperm to the egg. Also, it is important for the delivery of genetic information from the parent cells to the daughter cell.

The next important part is the sperm, midpiece, and the tail. So, in the midpiece part of the sperm, it contains a lot of tightly packed mitochondria. So, you can see that the midpiece part contains a lot of tightly packed mitochondria, and it is important because it can produce a lot of energy. In the tail part, or the flagellum part, which is shaped like a long tail with a similar structure, it originates from the mid part and has a really long tail. It is composed of different microtubules, and the function of this tail basically improves the motility or movement of the whole sperm.

So, what are the different functions in terms of the meat piece? It helps in energy production, and this energy is required for sperm to swim the long distance to the female reproductive tract to reach the egg. And the tail part helps in terms of improved motility by doing whip-like movements to propel the sperm forward. The speed and pattern of sperm motility are highly crucial for successful fertilization. Lastly, let us discuss the different factors that can affect spermatogenesis. Of course, we discussed the hormonal factor where we saw that whenever there is excess sperm production, how these different hormones like inhibin and even testosterone can create a negative feedback loop to our anterior pituitary and the hypothalamus to stop the function.

So, this is called an endocrine disruptor. It is important to maintain the proper homeostasis of the sperm. Apart from that, there are other controllers; for example, anabolic steroids. So, those who use excess anabolic steroids, for example, take testosterone for muscle building and for overall exercise; this exogenous testosterone can suppress the body's natural production of follicle-stimulating hormone and luteinizing hormone. So, they can interfere; this type of anabolic steroid can significantly cause interference with this hormonal secretion, leading to reduced testicular function and impaired sperm production.

Apart from that, there can be different thyroid disorders; for example, both hyperthyroidism and hypothyroidism can actually negatively affect sperm quality and quantity. There can also be pituitary disorders. For example, if there is a pituitary disorder, it would significantly affect the direct release of the gonadotropic releasing hormone, which can also significantly impact the release of FSH and LH. So, they directly will inhibit the proper testosterone function. So, all these different kinds of things can cause the spermatogenesis process and negatively impact it.

Apart from that, there can also be genetic abnormalities. For example, just as Y chromosome microdeletions can occur, cystic fibrosis or genetic mutations can occur, and all these cases can cause significant genetic mutations or deletions, leading to certain genetic disorders. Apart from that, there can also be environmental toxins that have a significant effect on our sperm quality and spermatogenesis. For example, heavy metals like lead, mercury, cadmium, or arsenic can damage the testes, different types of testicular cells, and sperm cells. Exposure to high radiation can have a detrimental effect on spermatogenesis and on the overall sperm number and quality.

Apart from air pollution, pesticides, and herbicides, this can also negatively impact the process of spermatogenesis and sperm production. So, all these genetic abnormalities, environmental toxins, or natural metabolic activities can negatively impact our body, including the spermatogenesis process. Finally, as you remember, in the last class, I told you that for optimum

sperm production and health, the proper heat balance needs to be maintained. So, in case of high heat exposure or lack of heat control in the scrotum, sperm health can be significantly damaged. Additionally, there can be various infections, such as sexually transmitted diseases, for example, STIs.

Like gonorrhea, they can cause inflammation, which can also lead to fibrosis or scar tissue formation in our reproductive tract. They can also potentially damage or negatively impact the spermatogenesis process, including sperm quality and health. Along with that, if significant fibrosis or scar tissue formation occurs, it can also cause blockages of sperm movement. So that the sperm cannot come out of the area, and during the fertilization process, it will not be able to reach the female reproductive organ. There can be different lifestyle factors that can negatively impact, for example, smoking, excessive alcohol consumption, obesity, stress, or poor diet; all of these can cause negative production of sperm along with their health and quality.

And finally, while men can produce sperm throughout their lives, with advancing age, the quality and quantity of it can decrease. So, finally, hopefully you like the spermatogenesis class; you saw how the process of spermatogenesis happens initially from mitosis and then meiosis I and II. And finally, the differentiation and maturation of the sperm, how a developed sperm can occur, and what are the different functions of the sperm structure. We also saw different factors that can negatively impact sperm production. And lastly, the very important one is the hormonal control of spermatogenesis.

Finally, do you know it takes about 74 days for a single sperm cell to develop from a spermatogonium to a mature spermatozoon? So, it takes almost 74 days to go from a single sperm cell to becoming like a mature sperm cell. Activity question: What would be the likely effect on spermatogenesis and testosterone levels if the Sertoli cells were damaged? So, can you tell if the Sertoli cells are damaged what their effect would be on the spermatogenesis process and on the testosterone level? Will they be able to produce evenly, or would there be damage in the regulation of even production? Explain this with proper reasoning, okay? Thank you for attending today's class on spermatogenesis. Hopefully, we are enjoying the human physiology classes. If you have any questions, please interact with us. And ask us during the live sessions; you can also drop your question to my email.

Thank you again for attending this class on spermatogenesis; I hope to meet you in another new class very soon. Thank you.