Human Physiology
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Hello everyone, welcome to another new class in human physiology. In the last class, we just initiated the ovarian cycle; we discussed the process of oogenesis and how the formation of the egg happened. And we also kind of highlighted that the formation of eggs starts very early, around 4 weeks of embryonic development. We also thoroughly discussed the initial stages, like primordial germ cells, how they initially undergo mitosis, how oogonia are formed, and after that they get arrested, leading to the formation of primordial follicles or oocytes. And we also discussed that from the initially 14 million primordial germ cells, only a limited number, around 500,000 primary oocytes or primordial follicle cells, remain until puberty. So, we also kind of highlighted that this is very tricky, especially for the female body, because they have only a finite number of primordial follicle cells or oocytes.

In this class, we will thoroughly discuss how, once females attain puberty, they undergo the ovarian cycle each month, where the initial primordial follicle cells that were initially arrested in the meiosis I phase start the process of maturation and how ovulation happens. So, let us stay with it. So, what different content will be covered for this class is that we will basically see the primordial follicles and how they transform into the primary follicle. They will discuss how the primary follicle converts to the late primary follicle, followed by the secondary follicle.

Then we will see the steps of oocyte maturation followed by the formation of the graphene follicle. Finally, we will see where the ovulation or the ejection or removal of the matured eggs happens near the fallopian tube. Finally, we will also see how the corpus luteum formation happens and what the fate of the corpus luteum can be. So, this would be a very interesting class. So, let us stick with it.

So, do you remember where we ended in our last class? So, basically, we ended that at puberty; at puberty, what we had in the female body was around 500k oocytes, right? They have around 500,000 oocytes, which can also be called primordial follicular cells. So, how many do they have left with around 500k? Now, whenever a female attends puberty, each cycle, which is basically around a 28-day cycle, is also called the ovarian cycle. In this 28-day cycle, only a limited number of about 15 to 20 primordial follicle cells begin the maturation process in each ovary. So, you have to remember that each ovary has around 15 to 20 primordial follicles or oocytes that started to mature. But until this end, only one kind of mature egg is left.

So, basically, from the 15 to 20 primordial follicles that are initially in the arrested phase, only one egg eventually matures, and during ovulation, that mature egg is ejected. So, what happened to those other 14 to 19 primordial follicle cells? Basically, they form a kind of atresia or eventually they degenerate. So, by degeneration, they form like artesia, and then, basically, they kind of get degraded, okay. So, at this stage, you can see what types of changes can happen to the cell. So, we are at day 0, where each cycle is starting.

So, the ovarian cycle is now initiated at day 0. So, from day 0, only 15 to 20 primordial follicular cells come to this ovarian cycle, and then let us see what type of changes are happening. So, what basically happens initially is that the primordial follicle cells you can see

here on the left side convert to early primary follicle cells, and not all the cells convert to these primary follicle cells. So, if I consider this as the primary follicular cells of the primary follicle, out of 15 or 20, maybe only 2 or 3. So, maybe only 2 or 3 cells start to convert into the early primary follicle cells, and what changes you can see initially is that the follicular cells are mostly of a squamous type.

So, they are basically squamous type cells or flat type cells. Once they convert into the early primary follicle, you see the cells' nature is changing from squamous to cuboidal shape. So, from the squamous, they get into the cuboidal type of nature. So, this is initially like maybe around day 0 to day 2, out of these 15-20 primordial follicle cells or oocytes, only 2-3 cells get into this stage of maturation, where the first stage from the primordial follicle forms the early primary follicle, where the nature of the follicular cell is. The nature of the follicular cell changes from squamous to cuboidal, and what happens to the rest of those primordial follicular cells? We said that they formed artesia or basically they degenerate.

Let us see once it forms the primary follicular cells; only a few then convert into the late primary follicular cells. And here, some changes happen in cases of late primary follicular cells. So, you see in the late primary follicular cells initially we had a different layer of follicular cells that are cuboidal in nature. Now, you see that a rapid expansion of this cuboidal cell happens because previously, you remember we had the primary follicular cells, where outside there was only one cuboidal cell layer. But when it is slowly becoming the late primary follicle, you see rapid expansion and proliferation of these cuboidal cells, or the follicular cells, happening, and basically this layer kind of continuously grows, and around these cuboidal cells, you can also see there are different types of cells, which are stromal cells.

So, a stromal cell layer also forms. And what is the stromal cell layer? Basically, they are connective cells of the ovary that form in the outer layer. And inside, in the very interior, you can see there is this blue layer formation, which is basically a glycoprotein layer formation also called the zona pellucida. So, what is basically happening is that a zona pellucida formation layer is occurring, which is essentially a glycoprotein layer, and this is very important during fertilization because this glycoprotein layer has certain receptors; these are like glycoprotein receptors, and they ensure that only species-specific fertilization occurs. So, basically, this glycoprotein receptor will only accept a sperm if it is of human origin.

So, this glycoprotein receptor is highly species-specific; it will not allow the entry of any sperm from other species. So, this zona pellucida layer is very important. And now you can see that inside this layer, we know we have the egg inside, which is still in the arrest stage phase. So, you have to remember that at this stage the egg is still in the arrested phase, and at which stage it was arrested? It was arrested in the meiosis I stage. Hopefully, you remember that.

Now, you can see that a lot of multiple layers of these cuboidal follicular cells form stromal cells. So, eventually from outside the blood circulation or outside the availability of nutrients, the eggs are growing further and further. So, the egg may basically get deprived of the nutrients and the essential ions; that is why you can see this from the zona pellucida layer, where these finger-like processes have been initiated. So, this blue color, small finger-like structure, you can see a lot of these finger-like processes that got initiated from the zona pellucida layers, and these finger-like processes also help in delivering nutrients and other essential ions to the arrested egg. So, eventually at these late primary follicles, you can see that this type of development happens.

So, initially, this cuboidal layer-like formation occurs in layers due to proliferation. So, this thick layer formation happens, which is also called the granulosa cell thick layer, and then once this granulosa cell formation happens, eventually it gets covered by the stromal cell layer, and then the zona pellucida layer also forms. The zona pellucida layer eventually creates small finger-like processes to deliver nutrients to the arrested egg, which is deep inside. Right, and then you see another last layer, which is the theca folliculi, this red layer of stromal cells, which was initially the stromal cells; they kind of combine together to form a layer called theca folliculi. So, this is basically a vascularized layer.

So, at this stage, we now have the late primary follicle. So, what we have is a late primary follicle, which basically may occur around day 2 to day 3, or maybe from day 2 to day 4 of the ovarian cycle. Then, from the late primary follicles, it forms the secondary follicle. So, you see, initially from day 0, now we are here, right? Late, initially it was primarily like a follicle or the early primary follicle; from there we got the late primary follicle, maybe around day 3 to day 4. Now, around maybe day 5 to day 7, we got the development of the secondary follicle.

So, now see what changes are happening to the follicle. We see a lot of further proliferation of the granulosa cells, and overall, the eggs or oocytes are getting bigger and larger. So, basically, the overall oocytes are becoming larger and larger, having a lot further proliferation of the follicular granulosa cells. Right, and these granulosa cells also secrete a lot of fluid, and you see there is this one fluid-filled cavity or fluid-filled sac eventually formed, which is called the antrum. So, eventually, a fluid-filled cavity, which is also called an antrum, formed, and then you can see that there are these stromal cell layers, which were initially called theca folliculi.

This is getting thicker and thicker. So, initially in the early stages of the follicle, which had this thicker follicular layer, you now see it is becoming thicker; now you see it is becoming much thicker, and once it is becoming thicker, it creates two distinct layers. So, what it creates is this theca folliculi; it differentiates and creates two distinct layers: one is the internal layer, which is theca interna. And this theca interna is highly vascularized, which means it has a lot of blood vessels, and these blood vessels can supply. So, these blood vessels can supply oxygen, these blood vessels can supply nutrients, and sometimes they can supply different essential ions as well.

So, this internal layer of the stromal cell layer, which was initially called theca folliculi, is now called theca interna, which is a highly vascularized layer. Its main role is to supply oxygen, nutrients, and essential ions to the egg, and it also has a very important role in hormone secretion. We will discuss what type of hormone it secretes in our next class, where we will thoroughly discuss the hormonal regulation of the menstrual cycle, which combines both the ovarian and uterine cycles. But just remember that theca interna is highly important, and the outer layer, the outer layer of the theca, is called theca externa. So, the outer layer is called theca externa, and the theca externa has a very crucial role to play in helping to contract during the ovulation process.

So, basically, at day 14. So, basically around day 14, what happens is that whenever the egg matures. Right whenever the eggs mature, this thicker external layer helps in fusing the egg to the membrane of the ovary, and basically, once this matured egg is fused through contraction, it helps to remove this matured egg near the fallopian tube. So, the role of the theca externa is to help in terms of ovulation through the process of contraction. Then in the next stage, you can see that it is very important that at this stage, where the secondary follicle eventually forms, the oocyte maturation or the late secondary follicular stage eventually initiates. And at this

stage, you remember that in the last discussion we said that the cells or the eggs were still in the arrest stage of meiosis I.

So, you remember we said that the cells were still arrested in meiosis I. But now, at this stage where the late secondary follicle happens, or the formation of the late secondary follicle initiates, the arrested phase cells automatically enter the meiosis I phase. So, basically here meiosis I gets completed, and once meiosis I gets completed, it will form two cells: one primary follicle, which is also called the late secondary follicle, and another small polar body. So, here the steps of meiosis I are completed, and eventually, it will create one major cell that is called the secondary oocyte. Along with that major cell, there is another formation of a small cell called the polar body, which eventually gets degenerated.

What happened? This polar body gets degenerated and destroyed, and this secondary oocyte eventually participates in the next stages of the ovarian cycle. And you see some further changes happen to the cell; the layers become more prominent, and you can see the formation of the antrum, which basically becomes larger and larger, right? You see the antrum is becoming larger and larger; theca interna and theca externa are already there, the secondary oocyte has eventually formed, and you have to remember that this has already completed the meiosis one step, but there is one more interesting twist. Whenever it completes meiosis I, it enters meiosis II, but again it gets arrested, so again it gets arrested here. So, basically at this secondary oocyte, it gets arrested again in the meiosis II phase, it gets arrested again in the meiosis II stage. So, step by step, initially, what we had—do you remember in the last class we discussed? We had about 14 million primordial germ cells, right? And through mitosis, it formed a lot of oogonia.

So, initially it has 2N; now, after the mitosis, we have oogonium, which is 2N. Now, it enters meiosis one step, but eventually it was initially arrested. And whenever it reaches that secondary follicular stage formation, it enters meiosis and creates one primary or secondary oocyte; it creates one secondary oocyte. It creates one secondary oocyte, and this secondary oocyte eventually participates in the ovarian cycle; it continues to participate in the ovarian cycle, and then it also forms a small cell called the first polar body, which eventually degenerates or degrades. You remember that, right? One more important thing is that in this arrested phase, where it gets arrested in meiosis II, it gets arrested in metaphase.

So, in cases of meiosis I arrest, it is arrested in the prophase stage, but in cases of entry into meiosis II where the secondary oocyte gets arrested, it happens in the metaphase state. Now, what do we have? We have the secondary oocyte, right? What do we have now? We have a secondary oocyte, right, which is arrested. We have a secondary oocyte that is arrested. So, from the secondary oocyte, which is arrested, it now starts its maturation step to form the graphene follicle, and this is also called the dominant follicle. So, the graphene follicle is also called the dominant follicle.

So, eventually it forms a graphene, a graphene follicle or dominant follicle, and at this stage, typically only one single graphene follicle survives. So, you can see there are certain kinds of antrum that are getting bigger and bigger; the cell size is now further larger, right? The cell size is further larger, right? And eventually, on the outside of this egg, you see there is the formation of a layer which is called the corona radiata. Right, which is basically granulosa cells that form a crown-like structure around the oocyte. So, those are like a crown-like structure that is called the corona radiata. So, this crown-like structure is also called the corona radiata.

So, this is almost like the now dominant follicle from there on; further expansion, of course, happens. You can see that all the granulosa cells have slowly covered the whole follicle; eventually, the follicle is getting larger, and you can see this egg, which was in the array state phase, just in early meiosis 2. Now, this eggs is getting deattached. So, basically, this egg, which was under arrest condition in meiosis 2, basically gets detached from the follicular cells or the granulosa cells. So, unless it is detached, it will not be able to come out.

So, at this stage, the dominant follicle or the Graafian follicle forms where the eggs, which are in the arrested phase of meiosis II, get detached from the overall granulosa follicle. And now you see around Day 14. So what we said around day 14, basically, the external theca layer helps in terms of the contraction. So basically that matured egg comes close to the ovarian membrane through the process of contraction. So through the process of contraction, then the process of fusion is followed by ejection.

So, multiple steps happen initially: contraction, followed by the fusion of the egg membrane and the ovarian membrane, followed by the ejection. So, eventually the egg that was initially there and was arrested, of course, comes out. Where does it come out? It comes out near the fallopian tube. It comes out near the fallopian tube. It happens on day 14, which is also called ovulation.

So, on day 14, ovulation happens, and the matured egg basically comes out. So, when the eggs come out, they leave with the leftover granulosa cells, right? Because you see only the matured egg, only the matured egg that comes out near the fallopian tube, right? Near the fallopian tube, but it still leaves with these granulosa cells, it still leaves with these granulosa cells, and these granulosa cells see some changes and become the lutein cells; they become the lutein cells and eventually form a yellow body. Eventually, it forms a yellow body which is called the corpus luteum. So, what is called is the yellow body or corpus luteum, and it has a different role in releasing a specific hormone. The type of hormone released and its specific role will be discussed in our hormonal regulation class in the next session.

But in general, the corpus luteum secretes important hormones to support the embryo and the uterine lining. It is highly crucial for early pregnancy. And then, basically, let us see how ovulation happens in this chart. So, basically, if the ovarian cycle is 28 days, ovulation happens on day 14. So, this is a general cycle; this is a general menstruation or ovarian cycle that is observed in the case of females, with a standard cycle of 28 days.

So, in a 28-day cycle, ovulation happens on day 14, but let us see what will happen in the case of a short cycle. So, in cases of a 21-day cycle, ovulation happens on day 7. So, in cases of short cycle ovulation, it happens on day 7 because we have to remember that once the cycle begins, ovulation occurs and it takes about 14 days to prepare the uterus for possible embryonic formation and implantation. So, basically, if the cycle is short, ovulation happens at day 7; if the cycle is long, for example, if the cycle is about 35 days. Then you can see where the ovulation happens; it will occur around day 21.

So, basically, on day 21, ovulation happens in cases where the cycle is long. So, you have to remember that it takes at least 14 days for the female body to prepare the uterus. So, fertilization happens, and eventually, embryonic implantation can occur in the uterus. So, it needs at least 14 days. So, for a regular cycle, ovulation happens at 14 days; in a short cycle of 21 days, ovulation will happen on day 7, and for a 35-day cycle, ovulation will happen on day 21.

By monitoring this chart, a natural kind of prevention of pregnancy can also be practicable. But you have to remember that the female body is highly complicated, and even though monitoring of the terms and monitoring of the cycles can be done precisely, there is always a high risk because sperm can live for at least 3 to 4 days inside the female body, and any miscalculation can cause a risk of pregnancy. So, lastly, what would be the fate of this corpus luteum or yellow body? So basically, if fertilization occurs, if sperm enters and fertilization occurs, this corpus body or corpus luteum will eventually grow stronger; they'll produce a lot of hormones for the uterus to grow. However, if there is no fertilization, even after sperm is emptied or without sperm, this corpus luteum or yellow body eventually converts to corpus albicans or white body. Eventually, it will convert to the white body or corpus albicans, and finally, this will be degenerated.

Finally, body will not require anymore. So, this white body will get degenerated. Finally, this body will degenerate. So, this is the whole ovarian cycle; in the last class, we ended here with the primary follicles, where the cells were arrested in the meiosis one step. From there, we get some of the steps of maturation. So, basically, all these stages are steps of maturation that eventually undergo from day 0 to day 28.

So, in this stage, whenever these secondary follicles occur, meiosis 1 is completed, and the cells enter meiosis 2. Again it gets arrested; eventually, a dominant follicle forms, and once the dominant follicle forms, the egg gets detached. Lastly, with the help of the theca externa, on day 14, ovulation happens. On day 40, ovulation happens again; the matured egg gets ejected near the fallopian tube, and the remaining granulosa cells become the lutein cells, forming the corpus luteum. If fertilization happens, the corpus luteum will keep secreting hormones that will support uterine development and embryonic development.

If there is no fertilization, the corpus luteum will convert to the corpus albicans or white body, and eventually it will degenerate, and the body will again prepare for the next cycle. So, let us think about it like this: what is the zona pellucida, what happens to the corpus luteum if fertilization takes place, and what are the fimbriae? So, let us try to think about this; you may also refer to Guyton's textbook and Tortora's textbook. If you have any further questions, please discuss them during the live session, or you can also leave your questions by email. Hope you enjoyed both classes on the ovarian cycle.

In the next class, we will mostly discuss the uterine cycle. Along with that, we will discuss various roles of female hormones to see how all these cycles are directly correlated and interconnected with various hormonal activities. So, thank you again for attending today's class. Very soon we will meet with you with another new lecture on human physiology. Thank you.