

Human Physiology
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Week - 10
Lecture – 02

Hello everyone, welcome to another new class in human physiology. In the last few classes, we have been discussing the ovarian cycle and also the menstrual cycle. We saw different hormonal regulation, and in this class, we will discuss fertilization and pregnancy. So, let us stick with it. So, what different content will be covered? Mostly, we will cover the process of fertilization; we will discuss the contact and fusion of gametes, examine the details of sex determination, and the processes of pregnancy during all three trimesters: first, second, and third. We will also explore how the physiological conditions change inside the mother, how the baby's development or maturation occurs inside the placenta, and different ways to detect pregnancy.

We will see how to determine the due date of the delivery, how labor happens, and what the different types of delivery processes are, such as normal delivery and c-section delivery. So, it will be a lot of information for this class. So, let us stick with it. So, what is basically the process of fertilization? Fertilization is like the process in which the fusion of the spermatozoon with the mature ovum occurs.

So, basically what we said around day 14 is that ovulation occurs, causing the mature egg or the secondary oocyte to come outside near the fallopian tube, where it waits for possible fertilization if sperm entry occurs. So, this process of the fusion of spermatozoa with the mature ovum is called the fertilization process. So, basically it starts with the collision of the sperm and the egg, and eventually it results in the production of the mononucleated single cell, which is also called a zygote. So, as you can see, if the ovum or the secondary oocyte comes out after ovulation, it enters the fallopian tube area. If it fuses with the sperm, then what it forms is a mononucleated cell, which is basically called the zygote.

Right, and in almost every case, like always or like every time, it has been seen that this fertilization happens in the ampullary portion of the fallopian tube. So, it is important that fertilization happens in the ampullary portion of the fallopian tube. And as you can see, the zygote converts into the embryo; eventually, the embryonic implantation happens inside the uterus, and then slowly the embryo is converted into the fetus, which, after delivery, becomes a delivered baby. So, what basically happens is that the ovum, which immediately comes out after ovulation, is picked up by the tubular fimbria and waits inside the fallopian tube for a possible fusion with the sperm. And as you can see, the ovum is rapidly transported in the ampullary part of the fallopian tube.

So, it is important to remember that the ovum is rapidly transported to the ampullary part of the fallopian tube, where it can wait for about 12 to 24 hours. So, basically, the lifespan of the oocyte ranges from 12 to 24 hours. whereas the lifespan of sperm during fertilization can be about two to three days. Out of hundreds of millions of sperm that can be deposited during intercourse or ejaculation, only thousands of such sperm or spermatozoa can eventually enter the uterine tube. So, it is basically important if I consider maybe hundreds of millions of sperm; if it is basically deposited during the process of ejaculation, only about less than 1 million,

maybe only 1,000, only thousands of sperm can eventually enter the uterine cavity or uterine tube.

And when, for example, if thousands of sperm enter the uterine cavity, what happens is that only 300 to 500 sperm can reach the ovum. So, basically only 300 to 500 sperm can reach the ovum. So, you can see it started with like hundreds of millions of sperm during the ejaculation from there only thousands got survived that could enter to the uterine cavity. Because, if you remember, we discussed that the uterine cavity is very acidic in nature. So, the majority of the sperm may get destroyed even before reaching the uterine cavity.

So, out of the 1000 sperm that reach the uterine cavity, only 300 to 500 sperm can eventually reach the ovum. So, now let us see the different sequences of events that happen during fertilization and how the sperm cell reaches and penetrates the egg cell to form a zygote. So, let us see this event one by one. So, initially, what happens is basically a step called chemoattraction. The eggs basically release a few chemical signals through which the sperm are attracted to the egg, and how many sperm are attracted or can eventually reach the egg or the ovum.

So, what we said is about 300 to 500 sperm, right? So, we said about 300 to 500 sperm; they basically get attracted due to chemoattraction. And once this sperm reaches near this egg, what it does is basically release acrosomal enzymes, like high aridinase. So, what happens is that this sperm, you remember, has this acrosome area, right? This sperm has the acrosome area, and from this acrosome area, it releases different types of acrosomal enzymes, such as high iron hydrates. This enzyme basically penetrates and destroys the zona pellucida and other membrane areas of the egg. So, what these acrosomal enzymes do is basically dissolve or dissociate the membranes present in the ovum, allowing at least one sperm to enter the egg.

So, most of the time, it has been seen that only one sperm can enter the egg by the process of this acrosomal enzyme. And once it enters the cell, it binds this sperm with the extracellular envelopes, and eventually, once it binds with the extracellular envelopes, it passes through the extracellular envelopes, right? It kind of basically breaks down different layers of the egg and eventually reaches the cell membrane. And after reaching the cell membrane, you can see that the fusion of the sperm and the egg happens. So, basically, once the fusion happens, it forms a diploid, right? So, eventually the sperm carries one egg, and then the egg also has one end. When they both fused, basically this diploid-like mononucleated cell eventually forms, which is called a zygote.

Very interestingly, whenever this fusion happens of one sperm to the egg, there is a mechanism called the Jonah reaction that claims and blocks this membrane because this Jonah membrane gets thicker and thicker. So, after one fertilization with one sperm, whenever this sperm is attached to the membrane and infused inside, due to the mechanism of the zona reaction and the cortical block, the thickness of this ovum becomes thicker and harder. So, basically, what we said is that once this is done, this membrane slowly becomes thicker and harder, causing no further penetration possibility from the other sperm. So, out of these 300 to 500 sperm, only one sperm can fertilize this egg, leaving all these other sperm outside. And now see again very slowly all these steps of fertilization and how the embryonic implantation happened in the uterus.

So, basically at day 14, you can see here on day 14. So, basically, at day 14, ovulation happens; ovulation causes this ovum to be released near the fallopian tube, where it basically waits for

the sperm to come. So, as the sperm comes, 300 to 500 sperm, only one sperm can eventually fuse and cause the fertilization and formation of these diploid mononucleated cells, which are called zygotes, right? So, basically, this process happened around day 0. So, after day 0, you can see that this zygote formation happens roughly on day 1. So, from the zygote formation, you can see that the zygote is basically a diploid cell, which is $2N$, and then it starts to undergo severe mitotic division or cell cleavage.

So, the first kind of cleavage happens. And basically, this cleavage continues as in day 2, forming from 2 to about 4 cell stages. So, you can see that from 2 it becomes like a 4-cell stage. In this case, this zygote is called blastomeres. So, what we just said is that initially the ovum came, it got fertilized with the sperm forming the zygote, and the zygote is generally diploid in nature, which is $2N$.

Then the mitotic division starts, or the cell cleavage starts, forming the 2-cell stage. From the 2-cell stage, it forms the 4-cell stage, and at this time these cells are called blastomeres. So, from the blastomere around day 3 to 4, it formed an 8-cell stage. So, further and further mitotic division happens. So, from the 4-cell stage, it forms like the morula, which is the 8-cell stage.

Then, as you can see, this morula further expands continuously, and eventually, it becomes like a mass of 16 to 32 cells. So, at this stage, morula can further have a total mass of 16 to 30 cells. And then on days 4 and 5, you can see that blastocyst formation happens. So, blastocyst, you can also see here that this started with a lot of differentiation of this cell, which is like the formation of the inner cell mass or the ICM, and then the formation of the trophoblast, like the trophoblast or the outer layer, right? So, this is the trophoblast formation, and inside it forms the ICM, or the inner cell mass. So, this cell is specifically like a differentiated cell called a blastocyte.

Now, this blastocyst slowly matures around day 5 to day 7. So, basically from this, the maturation of the blastocyst happens. So, the maturation of the blastocysts happens, and then the blastocell formation occurs, okay. So, after this maturation, what it forms is like the blastocyst, which is basically a fluid-filled cavity, and it is becoming more and more prominent now. Now, eventually this blastocyst around day 8 and 9 comes very close to the uterine membrane.

So, the endometrium you can see comes very close to the endometrium, and eventually, this is where implantation begins. So, initially, the diffusion happens to the blastocysts, which diffuse inside the endometrium of the uterus, and once it diffuses further, it goes inside the uterus and gets implanted; at this implanted state, the cell that is implanted is called an embryo. So, eventually, through all this process, embryonic implantation occurs. So, basically, through all this process, embryonic implantation occurs. So, we saw how, starting from this day, like 14, basically the ovulation happens, right? So, around day 14 of the ovarian cycle, ovulation happens.

So, after ovulation, the ovum moves near the fallopian tube where fertilization occurs to form the zygote, and the zygote undergoes several rounds of mitotic divisions to form two cells, then four cells, eight cells, and then it basically forms the blastocyst after that, following the differentiation process. Then, after the differentiation of the blastocyst, it basically matures. So, following that, it becomes like the blastocyst, and this blastocyst basically diffuses inside the endometrium of the uterus, and eventually, the embryonic implantation happens. Then, as we know, basically, the mother is contributing one haploid cell, while the sperm from the father is

contributing another haploid cell, and when both of these merge, meiosis 2 occurs. Completed right, the fertilization happens, and then we see the new embryonic formation, which basically has a diploid gene or 46 chromosomes.

So, basically it gets 23 chromosomes from the mother and 23 from the father. And now, as you know, if the spermatozoon contains an X chromosome, a female embryo becomes XX; if it contains a Y chromosome, then it becomes a male embryo. So, basically, if the sperm is carrying an X. So, if the sperm is carrying X, then it mixes with the X from the mother and it becomes a female embryo.

So, it becomes a female embryo. Now, if the sperm carries the Y chromosome, it combines with the X chromosome of the mother. So, it becomes like XY, or it creates the male embryo. So, basically, the XX chromosome creates the female and the XY chromosome creates the male. Now, pregnancy is basically this whole process, not only just the fertilization or the embryonic development; it is also the next three trimesters or the next nine months, which is basically 7 days to carry that embryo inside the mother. And slowly, the placenta develops; slowly, the baby receives all the nutrition and oxygen from its mother, and eventually, the baby grows, all its body parts start to form, and eventually, after these 9 months and 7 days, the baby is delivered.

So, this whole process is called pregnancy. There are a lot of presumptive signs of pregnancy; basically, the first sign can be the absence of menstruation. Then there can be nausea or vomiting, which is also called morning sickness. Then the female can experience breast tenderness and swelling; there can also be increased frequency of urination, and fatigue and sleepiness may also occur. But these are all presumptive signs; to confirm, there are a lot of positive clinical experiments that can be done, and there can be a lot of supportive and confirmatory tests that can be conducted.

For example, ultrasonography can be done to visualize the embryo directly; the fetal heartbeat can be monitored using a Doppler, and fetal movement can also be examined. Apart from that, this human chorionic gonadotropin hormone, or HCG, which is basically secreted by the embryo, can also be monitored. So, these are different types of tests that can be done either at home; for example, this HCG can be tested with a pregnancy kit, right? So, basically, this HCG can be tested in a pregnancy kit where you will see that there is a positive line and a test sample, right? So, we will show you this here. So, in the pregnancy kit, especially in the early urine. So if you drop a few drops of urine here, this basically has a microfluidic channel, and there are HCG binding antibodies present where there is a positive control and a test sample.

So, if you draw a few drops of urine, this urine will basically migrate inside this microfluidics channel; the positive should always show up, right? So, the positive should always show up, but in cases of a test sample, it can either be blank. In cases of a test sample, if it is blank, that means there is no pregnancy, but if this test sample also shows a thicker kind of band, that means you can confirm the pregnancy. But you have to remember that there can still be inaccuracies sometimes; it can happen that the kits are not good enough, or maybe they are old, or maybe they are not stored at the proper temperature, and at that time it can happen that even with the presence of HCG, the lines may not show up; that can always happen. Further, at the early stages of the trimester, very early, like maybe in the first 7 to 10 days, the HCG concentration is not too high. So, at that time, even if you take the test, you may miss any line.

So, there are always both positive and negative aspects of this testing, but when there are about 3 to 4 weeks, more or less, all these 4 kinds of clinical tests will give you a positive signal in cases of pregnancy. Then there are a lot of physiological maternal changes that happen in the female body. For example, it increases the blood supply to the breasts and the uterus. It basically changes in terms of taste and smell. It increases like the need for glucose, oxygen, water, iron, and folic acid.

Heart rate can increase; it can also increase the breathing rate, affect kidney and bladder size, and high pigmentation of the skin can also be seen. So, there are a lot of physiological changes that are associated with the pregnancy that can be observed. Let's quickly see the different stages of pregnancy. Basically, in the first trimester, you can see, especially, the changes in the mother. So, you can see that during the first semester, hormonal changes affect almost every organ in the body.

The baby starts to develop rapidly. Menstruation will basically stop, and there will be a lot of signs, such as mood swings and morning sickness, etc. In the case of a baby, the baby's brain, heart, and spinal cord will start to develop. The baby's heart starts to beat within about 8 weeks. It is very important that within 8 weeks, the baby's heart starts to beat.

The sex organs slowly start to take form. Around 12 weeks, we can see if it is a baby boy or girl. In the second stage of pregnancy, you can see in cases of mothers that most of the symptoms of early pregnancy basically disappear. Apart from that, backache, leg swelling, and heartburn can happen. Apart from that, the uterus starts to grow rapidly in size. The fetus basically starts to move about from 18 to 22 weeks.

And of course, you can experience an increase in heart rate and blood flow to accommodate the needs of the fetus. In the second semester, in cases of pregnancy, the muscle tissue and bone continue to form; skin begins to form around 16 weeks, the baby can hear and swallow around the 20th week, and real hair starts to form around the 24th week. By the end of this second trimester, the baby is now about 30 centimeters in size, so you can see almost proper formation of the baby at around 30 centimeters. In the third trimester, you can see that the mother already has an almost fully developed baby. So, in the body of the mother, you can see that it starts to further expand inside the area.

So, the fetus grows larger, and the body organs also mature; you can say that a fetus usually settles into a head-down posture in the uterus. So, basically, it has been seen that slowly, even though in the early stages, the head is in an upper posture. But as it goes, the head weight also decreases, and for this reason, a head-down posture can be seen very close to that of pregnancy. Then, in cases of the third trimester, the baby's bones are fully formed around the 34th week. The eyes are now open, and they can also kind of close their eyes.

So, they have a sense of light. By the end of 37 weeks, a baby is considered full term. So, this is highly important; at the end of 37 weeks, the baby is considered full term and ready to be delivered. So, near the due date, the baby may turn its head down for birth. So, near this due date, you may see that the baby is in a head-down position, which, of course, makes delivery easier in cases of the head-down position. Sometimes it can also be seen that this head can be turned to the backward side or the head can also stay in the upward position.

So, in this position where the head is towards the spinal cord of the mother's spine or in an upward position, sometimes there is an observance of difficulties or challenges during the

normal delivery. So, what we just said in cases of a baby's position is that the head is down near the cervix. If the head is near this belly area of the mother, generally the pregnancy, the normal pregnancy, is smooth. But it has been seen that if the baby rotates his head towards the mother's spinal cord side or if the baby's head is in an upward position, sometimes there is a complication during the normal delivery, and the doctor, depending on the distress and stress of the baby, can decide to take the mother for a C-section or cesarean delivery. So, the due delivery is calculated based on Nagel's rule, which uses the last menstruation period.

So, if you consider that the last menstruation period is about 8th May 2009, basically you add 1 year, then you subtract 3 months, and lastly you add another 7 days. So, basically, it is 9 months and 7 days. You add this time to the last menstruation period, and you basically decide on a date of delivery. But you have to remember that these dates are not accurate. Sometimes babies can be like little premature ones, or sometimes, depending on the contractions, the baby can stay longer inside the mother's womb.

So, basically, labor is the start of the contraction, and it is the time or situation when the female body starts to contract from the uterus and the cervix, and eventually there is a cervical gap which initiates the dilation. This dilation is initiated by uterine contractions, and the effacement of the cervix happens. So, you can see how the effacement of the cervix happens: initially, the cervix is thicker, but with time, the cervix gets thinner and thinner; further, the dilation of the cervix occurs. So, you can see from 1 centimeter to basically 5 centimeters to 10 centimeters. So, here the cervix is very thin, and there is enough dilation for the baby to come out.

There are a lot of hormones that are also responsible; oxytocin is one of the very important and crucial hormones, as mentioned in the endocrine gland classes, and it is also called the love hormone. Oxytocin is very important for uterine contraction. So, corticotropin-releasing hormone, or CRH, which is also produced by the placenta, is thought to have a role in initiating labor. So, basically, the CRH hormone is important for initiating labor, the oxytocin hormone is important for uterine contractions, and the relaxin hormone is important for relaxing the pelvic ligaments. Then the prostaglandins, for example, prostaglandin E2 and prostaglandin 2 alpha, have an important role in terms of uterine contraction and cervical ripening.

And finally, the estrogen hormones have an increasing sensitivity of the uterine muscle to oxytocin. So, basically, estrogen increases the sensitivity of oxytocin towards the cervical and uterine muscles. The primary hormone for uterine contraction is oxytocin, right? Okay, so you remember this one then. As we said, if everything is perfect—the baby's head position is nice, the cervical dilation is sufficient, maybe more than 10 to 15 centimeters—then the doctor can easily bring the baby out, and once they bring the baby out, they have to remove the placenta as well. So, basically, they will clamp here inside the placenta, which is connected to the umbilical cord.

So, basically, with the placenta, the baby's umbilical cord is connected. So, the baby's umbilical cord is connected. So, basically, the doctor will create a clamp in order to prevent any blood loss, and after the clamping, the doctor has to first remove the baby. So, the doctor needs to first remove the baby, and once the bleeding is stopped, the doctor also needs to remove the whole placenta because if the placenta stays inside the uterus, it can cause a lot of issues, and fragments of the placenta in the long run can also form a uterine tumor. It is important that after either natural delivery or, as we already said, in cases of problems in natural delivery, a surgical delivery can be obtained.

So, in cases of surgical delivery, the first doctor needs to create an incision in the mother's abdomen, followed by the removal of the baby from the abdomen, and once the baby is delivered, they have to clamp the cord, remove the baby from this connection, and finally, deliver the placenta. So, the delivery of the placenta is equally important as the delivery of the baby. So, basically, you can remember it as a two-step process: one is the delivery of the newly born baby, and the second is the delivery of the placenta. So, basically, both normal delivery and the c-section depend on the delivery of the baby and the delivery of the placenta; it is basically like a two-step process. And in the case of a C-section, once both deliveries are done, the doctor will basically suture or stitch this incision area of the abdomen.

And you have to remember that once the delivery happens, sometimes what has been seen is that the baby's head, because the baby is experiencing huge pressure, specifically at the cervix, is shown in the last slide; the cervix is so narrow that the baby's head is experiencing huge pressure. So, whenever after this delivery, you can see the baby's head in a more narrow or elongated shape. But do not worry because once the baby is delivered, after about half an hour, the baby's head will take on a proper shape. So, due to high pressure and high friction after the delivery, the baby's head is a little bit elongated. But do not worry; after some time, maybe like 30 to 40 minutes, the baby will get a proper round shape or proper shape of their head.

So, there are different reasons for a C-section, as we already said that the doctor will basically monitor for fetal distress; they may also monitor for placenta previa and consider the mother's history, such as if she has a previous C-section history, in which case the doctor may again opt for another C-section. In cases of multiple pregnancies, the doctor may also decide on a C-section, but primarily the doctor tries to monitor factors such as the baby's distress and whether the baby is getting enough oxygen. If there is a risk to either the baby or the mother, the doctor may decide to operate quickly instead of waiting for overall contractions. So, one thing you have to remember is that the contraction process involves the uterine contractions. So, basically, the uterine contraction along with the cervix dilation can take up to 24 to 48 hours.

So, it is important that proper uterine contraction, along with the dilation of the cervix, can take about 24 to 48 hours, and this is a prolonged time. So, in case the baby is stressed and not getting proper oxygen, it can cause brain damage or a hypoxic condition. Along with that, if the mother has diabetes or any type of high or low blood pressure, there can be a situation where the doctor will take the patient to a C-section. So, generally within about 30 minutes to 1 hour, the delivery is done by the process of C-section.

But you have to remember everything has an advantage and a disadvantage. Generally, natural delivery is recommended because the recovery from natural delivery is fast enough for the mother, and within a few days, like 2 to 3 days, mothers are fully recovered. But in cases of C-section, as you know, there is a cut inside the abdomen. So, there can be a risk of infection, and it is associated with a lot of pain as well. So, it mostly takes about 10 to 14 days for a mother who underwent the C-section procedure to recover. But sometimes the complication can further arise with a long-term infection or sometimes the formation of any type of disease or other internal injury, but generally both processes are equally safe if it has been done under watchful guidance and watchful procedures by the doctor.

So, think about it: where does fertilization usually take place in the human body, what is implantation, what is the term for the development of the baby in the womb, what are the final stages of pregnancy called, and what is colostrum? So, try to answer this question; if you have further questions, you can discuss them with us during the live session, or you can also drop

your questions by email. Hopefully, you are enjoying the class. We have discussed different topics such as the female reproductive organ and male reproductive organs.

We discussed the ovarian cycle. We discussed menstrual cycles. In this class, we thoroughly discussed fertilization and pregnancy. Hopefully, you are enjoying the human physiology classes. We will meet with you very soon for another new class. Thank you again.