Course Name :An Overview on Maternal Health Antenatal, Intranatal and Postnatal Care

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GAMETOGENESIS

Hello students. We meet here today for yet another session for the NPTEL certified online course on the topic An Overview on Maternal Health, the Antenatal, Intranatal and Postnatal Care. I am Dr. Barnali Ghosh, an Obstetrician and Gynecologist working at B.C.Roy Medical College and Medical Research Center, IIT Kharagpur. In the last classes, we have already discussed regarding the anatomy of female external and internal genitalia, an overview of the anatomy of the pelvic floor and perineal muscles. Today, we are going to discuss on gametogenesis.

Obstetrics as a whole, it deals with pregnancy and pregnant female. This pregnancy is the result of fertilization of two gametes that is the male and the female haploid gamete, which ultimately forms the diploid zygote or the embryo, which forms the fetus. So today the process of formation of these gametes, that is gametogenesis is our topic of discussion. Concepts covered in today's class Spermatogenesis, Oogenesis.

The keywords being Spermatogenesis, Oogenesis, Sperm, Ovum. So here this is a pictorial representation of fertilization, which is the union of two haploid gametes, the male gamete known as the sperm and the female gamete, which is called the ovum. And the process of formation of this sperm is called as Spermatogenesis and Oogenesis results in the formation of ovum. The union of these two will result in the formation of zygote, which is diploid. These two are haploid ultimately forming a diploid zygote.

To note gametogenesis starts from primordial germ cell. These primordial germ cell or primitive germ cell embryologically they develop from the epiblast. So they develop from the epiblast and they travel to the dorsal surface of the yolk sac at fourth week of intrauterine life. So at fourth week they travel to the dorsal surface of the yolk sac. These are primordial germ cells.

Then it will then reach the genital ridge at fifth week of intrauterine life. So these genital ridge we know they ultimately result in the development of ovary and testis that is the gonads

depending on the presence of Y chromosome. Absence of Y chromosome you know dictates the genital ridge to form into the testis and in absence of Y chromosome by default ovary is produced. So these primordial germ cells they get embedded or they are present within these developing gonads and they form spermatogonia in males, oogonia in females. Another talk on teratoma if from these primitive germ cells if they deviate from their usual path and if they reach sometimes they reach the neck region if they reach the neck region then these primitive germ cells will result in the formation of oropharyngeal teratoma.

These are actually formed from the primordial germ cell which instead of going to the genital ridge which is its usual position they get deviated and may reach the neck region leading to formation of teratoma. They are actually pluripotent cells what that means? It means that these are capable of formation of all the three layers that is the ectoderm, the endoderm and the mesoderm. So tumor originating from these primordial germ cells will result in formation of teratoma. Sometimes they may get you know they may deviate and reach the sacrococcygeal region and there ultimately they form sacrococcygeal teratoma right. So this is part of the embryology development and now we know that the primordial germ cells which actually form the ovum or the sperm they actually develop from the epiblast or the dorsal surface of the yolk sac.

Coming to the concept of haploid, diploid or triploid this is a haploid cell. So what that means that the chromosome, this is one chromatid right maybe this I will say this is the chromosome number say 9. This has one chromatid here this is the same chromosome containing the same genetic material but it has two chromatids. Here there are three chromatids. So depending upon the number of chromatids it is haploid containing only single one chromatid.

When two chromatids are present it is diploid cell and you know each chromosome has two chromatids. So or if it is three then it is triploid. So the gametes are actually haploid cells. Rest all the cells you know of all the body organs they are actually diploid cells. What is the chromosome number in case of humans? It is 46.

In females it is XX, in males it is XY right and in gametes it can be it is haploid so 23 X or 23 Y. We will go into the topic. So what are the types of cell division? Cell division number one is mitosis and two is meiosis. Mitosis is just replication of one cell to two cell, two daughter cell. There is no decrease or increase in the nuclear material.

A haploid cell or you know here it is a diploid cell two ends. So a 2n cell when undergoes mitosis will form two 2n cells right. But in meiosis, meiosis is a reduction division. In meiosis reduction division. So what happens in meiosis one 2n or diploid cell this is the parent cell.

Here it will form four daughter cells but they are haploid right. So here each of the cells have

you know less chromatin or less nuclear material. The daughter cells are haploid. From diploid cells they are forming haploid cells. So this is a reduction division.

This meiosis occurs in the gametes or the gonads. Gametes are present in the gonads. So meiosis occurs only in the gonads, mitosis occurs everywhere in the brain, in the skin, in the liver, any other organ of the body. Mitosis occurs but in gonads meiosis occurs for the production of gametes. Coming to meiosis proper, meiosis now can be divided into meiosis one and meiosis two.

This is actually mitosis, 2n forming 2n cells so it is mitosis. Now this 2n will undergo meiosis division, meiosis one where there will be reduction in the nuclear material forming two haploid cells or containing n number of chromosomes. So coming to meiosis two, meiosis two is nothing but similar to mitosis. Here one cell containing n number of chromosomes will form two cells that will contain the similar amount of nuclear material that is n number of chromosomes. So from a diploid cell we are getting four haploid cells by the process of meiosis.

Mitosis one, meiosis two, each stage of meiosis next can be divided into four phases. They are the prophase, metaphase, anaphase, and telophase and this prophase phase can again be divided into five stages. What are they? Leptotin, zygotin, pectin, diplotin and diakinesis. So these are the stages of meiosis, meiosis one, meiosis two and the four phases of meiosis that is prophase, metaphase, anaphase and telophase. Coming to spermatogenesis proper, so cells of spermatogenesis where does the spermatogenesis occur? It occurs in testes.

The cells of the testes, they are two types, seminiferous tubular cells and the interstitial cells. Within the seminiferous tubule in a testes there are approximately 300 to 400 seminiferous tubules and within each of these seminiferous tubules there are again three types of cells. First is, no sorry two types of cells, first is the sertoli cell and this is also called as the sustentacular cell and other is the spermatogenic cells or the male germ cells in different stages of development. Within the interstitium there are three types of cells, leydig cells, fibroblast and neurovascular bundle. So this is the structure of the testes where these are the seminiferous tubules.

There are 300 to 400, so many seminiferous tubules are present. So these single, these are the seminiferous tubules and they drain or they are joined and they form the rete testes which ultimately will connect with the epidermis. So this is the tail of the epidermis, this is the tail of the epidermis and the head of the epidermis. This whole structure is the epidermis which will ultimately connect to the vast difference which goes ultimately forming the ejaculatory duct and ejaculatory duct which will help in ejaculation. So we will now study each of the seminiferous tubules, cross section this from this each of these seminiferous tubules we are studying a single seminiferous tubule, the cross section has been taken.

Now within the seminiferous tubules there is a lumen at the middle, this is the lumen at the middle and surrounding the lumen these are the sertoli cells, this violet colored structures are the sertoli cells. These will help in anchoring the male germ cells in different stages of development. This is Spermatogonia, this is the first male germ cell. Spermatogonia will undergo spermatogenesis in different stages, in different steps of the spermatogenesis and they are attached to the wall of the testicular cells or the sertoli cells. In the lumen then these Spermatozoa which are the end product of spermatogenesis they get dislodged and they will come into the lumen of the seminiferous tubule.

Outside this seminiferous tubule is the interstitium and in the interstitium there are three types of cells, these brown colored are the leydig cells, these are the vascular bundles and these are the fibroblasts right. So we will now study about the sertoli cells. See these sertoli cells, these sertoli cells, this is a sertoli cell right. So this sertoli cells and the adjacent sertoli cells they are connected by type junctions and this forms the blood testis barrier. There is a type junctions and any material like in the blood vessels there can be toxins, there can be chemicals.

So any material cannot pass through this blood brain barrier, it cannot pass this is called as the blood testis barrier which is formed by the sertoli cells and this helps to safeguard the gametes of the testis like the male gametes. It will safeguard the gametes from any external circulating carcinogen or chemicals right. So one function is formation of the blood testis barrier. Next is these sertoli cells as they help or anchor the male gametes they will provide nourishment to these gametes right and also it has a hormonal activity, it secretes androgen binding protein, androgen binding protein, it secretes inhibin B and it secretes the transferring. These are the hormones secreted from the sertoli cells and these cells are under the action of FSH.

The leydig cells are outside the blood testis barrier in the interstitium and they secrete testosterone right. The secret testosterone and they are under the action of LH. So we have discussed these are the leydig cells which will secrete the testosterone and these are the single these single are the sertoli cells they are present within the seminiferous tubules right and these are blue coloured these are the male germ cells in different stages of development and this is the lumen which will contain the spermatozoa right. So first the tail gets dislodged then the head of the spermatozoa into the lumen. Sertoli cells yes what are the functions of sertoli cells or such testicular cells they provide nourishment to the male germ cells.

They form the blood testis barrier by the tight junctions and thereby safeguarding the germ cells from the external any insult and there is also secretion of hormones from these cells releasing of androgen binding protein that transferrin and inhibin B. Another point here is this androgen binding protein these will know help to concentrate the testosterone. Testosterone is released from the LH I mean leydig cells and this testosterone will gain entry into the

seminiferous tubules and this androgen binding protein which are released from the seminiferous tubule they will help to concentrate they will help to concentrate that testosterone within the seminiferous tubules. The testosterone concentration is as high as 50 to 60 times inside the seminiferous tubules in comparison to seminiferous tubules in comparison to the plasma concentration. So this increased concentration of testosterone within the seminiferous tubule is required for the process of spermatogenesis.

So sertoli cells we have discussed now the spermatogenic cells or the male germ cells they actually start from spermatogonia. Spermatogonia will develop from the primordial germ cells we have talked about it. It arises from the arises in the yolk sac from the epiblast and they come to the genital ridge and they enter the testes by fifth week of intrauterine life. Leydig cells they are outside the seminiferous tubules in the interstitium they secrete testosterone they are under the influence of LH and they are present outside the blood brain barrier right and because it secrete testosterone it helps in the formation of secondary sexual characters in male. Now this is the HPO axis what happens the HPO axis is activated at puberty.

Spermatogenesis starts from puberty and it continues till death even we can collect you know spermatogonia or spermatozoa or the sperm can be collected from the testes of a dead man right even 48 hours after his death. So, this spermatogenesis starts from the puberty and it continues throughout his life until death what happens there is activation of HPO axis at puberty. This is the hypothalamus, pituitary and ovarian axis. Pituitary HPO axis is hypothalamus pituitary and ovarian axis or in females and testes in case of males. So, hypothalamus pituitary gonadal axis right.

So, the hypothalamus will be secreting GnRH this is getting activated at puberty and GnRH is being released from the hypothalamus it will activate the anterior pituitary which will secrete FSH and LH. This FSH and LH will activate the testes and there will be production of testosterone which have negative feedback on the hypothalamus thereby decreasing the secretion of GnRH and also thereby there is decreased secretion of FSH and LH. So, this cycle goes on in female similarly from the ovaries there is production of estrogen which will then again have feedback inhibition on the hypothalamus. So, the HPO axis activate at puberty, spermatogenesis start from puberty and continue till death. Whereas, in females this is a point of differentiation the oogenesis start in the intra uterine life before birth of the female fetus, but it is arrested in the prophase of meiosis I and this meiosis I resumes at puberty after the activation of the HPO axis in females.

Coming to the steps of spermatogenesis there are 5 steps number 1 is from spermatogonia to primary spermatocyte to secondary spermatocyte then to spermatids and ultimately spermatozoa or the sperm right. So, we will come to one by one this is a 2N cell this is called as spermatogonia this is a diploid cell they are present in the testes they are formed from the

primordial germ cell and are present from birth up to the puberty at puberty the spermatogonia and the primary spermatocyte this is primary spermatocyte this is formed from spermatogonia by the prophase of mitosis. Then what happens now this is the onset of puberty in males then the prophase of meiosis starts right. So, meiosis I is a division of reduction in nuclear material the 2N diploid cell will become haploid cell and these are called as the secondary spermatocyte right. Ultimately each of the spermatocyte will undergo the each of the secondary spermatocyte will undergo meiosis II and they will form 4 spermatid.

This spermatid will undergo transformation you know in its structure in its content of cytoplasm you know in its tail formation and they will form ultimately spermatozoa or the sperm. Point to note is from spermatogonia to the production of spermatozoa this full process is called as spermatogenesis. And the process by which spermatid is develops into the spermatozoa this is only you know a development or a transformation in the cell and this process is called as spermiogenesis right. So, spermiogenesis is not mitosis or meiosis no change in the nuclear material occurs between the spermatid and spermatozoa. The nuclear material in spermatozoa and spermatid are same, but there is change in the structure of the cell right the spermatozoa has tail and this spermatozoa when they get dislodged into the lumen of the cell this is called as spermatization.

This process of dislodgement of the spermatozoa from the wall of the sustentacular cell into the lumen of the seminiferous tubule that process is called as spermiation. The duration of spermatogenesis is 60 to 74 days of which the duration of this spermiogenesis this duration is 10 to 14 days. This cell this is a pictorial representation where we can see the sertoli cells this is the blood testis barrier within the this is the you know seminiferous tubule and a part of that seminiferous tubule showing the sertoli cells and the different male germ cells in different stages of development. And this is the lumen where the spermatozoa will get dislodged from the you know wall of that sustentacular cells they will go into the lumen and from the lumen it will be transported through the ducts. Duration yes 60 to 74 days location of spermatogenesis is in seminiferous tubules it is in seminiferous tubules from the seminiferous tubule from the lumen the spermatozoa will go into the epidermis right.

And in the epidermis there will be maturation as well as attainment or attain maturation and motility of the sperm this occurs in the epidermis. What is the purpose of spermatogenesis? It is to form sperm or male gametes. Now coming to structure of sperm it is a single cell it has a nucleus which forms the head of the sperm the Golgi apparatus they form the acrosomal cap mitochondria forms the middle piece the centrioles they form the neck of the sperm and axial filaments in arrangement of 9 plus 2 it forms the tail of the sperm. There is a specialized protein called the dynein protein in the tail which helps to assimilate these microtubules. So, this is the sperm and this is the acrosomal cap this is the acrosomal cap and this contains Golgi apparatus.

This is the head of the sperm which will contain the nucleus haploid nucleus right. So, this part is the neck containing the centrioles this is the middle piece which contains the mitochondria which gives energy to the sperm for its motility and this is the tail of the sperm right. Coming to the length yes it is you know from this approximately length comes out to be 60 micrometer length of a single spermatozoa. So, this is the spermatogenesis coming to oogenesis. Oogenesis in females it starts in the ovary right the female gonads and it starts in intrauterine life before birth at 20 weeks of intrauterine life there is 7 million oogonia which comes down to 2 million at birth right.

So and then at puberty the number of primary oocytes is 4 lakh. Now in both the ovaries then during the reproductive years during the reproductive age group which is approximately 15 to 45 years of age the ovulation there is ovulation of approximately 400 to 500 secondary oocytes and at menopause there is less than 1000 oocytes in the ovaries. So, there is gradual decrease in the number of oogonia or primary oocytes in the ovaries with age as the age increases the number of oocytes decreases and thus decrease the ovarian reserve. So, oogenesis proper same as spermatogenesis it starts from oogonium which is a diploid cell it forms primary oocyte and this is also diploid this primary oocyte will undergo meiosis one to form here is the difference it will form one secondary oocyte and one primary polar body right. So, secondary oocyte in case of males secondary spermatocyte was two from a single spermatogonia, but in females one secondary oocyte is being produced from one single oogonium.

Secondary oocyte will undergo meiosis two to form one ovum and this is a polar body right and these two are also polar bodies three polar bodies are formed from oogenesis only one ovum is being produced from spermatogenesis four sperms are being produced from a single cell of spermatogonia right. Now, we have known yes in the fetal ovary in the fetus before birth in the intrauterine life these female germ cells they are present as oogonium which is diploid 44xx they form primary oocyte in the fetal life in the fetal ovary and these primary oocytes they get arrested this meiosis one will get arrested at the prophase diplotene stage of prophase of meiosis one here the meiosis one gets arrested and this arrest remains till puberty after puberty with the onset of puberty with the activation of the HPO axis this arrest goes off and meiosis one is completed thereby producing the secondary oocyte and one polar body. So, this is at you know puberty right. So, first phase of meiotic division is completed at puberty just prior to ovulation and it enters into the second meiotic division that is meiosis two secondary oocyte now entering the meiosis two and again it gets arrested in the metaphase stage this metaphase stage arrest will go away only if the ovum or this secondary oocyte is fertilized by a sperm if there is no fertilization then the secondary oocyte will not complete the second meiotic division and it will get destroyed. According to the ovarian follicles these female germ cells are you know they get they are contained within the different ovarian follicles which are present in the ovarian cortex.

So, till puberty the female germ cells remains as primary oocyte. So, this is the primary oocyte

right this is the primary oocyte and primary oocyte gets covered by granulosa cells this forms the primordial follicle. Very slowly along the stage of development they will form primary follicle then the secondary follicle and this is the mature tertiary follicle right. So, this is also called as the enteral follicle which will ultimately form the graafian follicle at the time of ovulation. This is the mature graafian follicle which will undergo ovulation and thereby release of secondary oocyte.

Up till this is the primary oocyte, but just prior to ovulation the primary oocyte gets converted to secondary oocyte which is released into the peritoneum during the process of ovulation. And the rest part of the ovarian follicle will get converted to corpus luteum and if there is no pregnancy this slowly gets atrophic, atretic to form corpus albicans. So, oogonia form primary oocyte just a revision primary oocyte remains as primary follicle in the intrauterine life. They are arrested in the prophase that is the depleting stage of prophase of meiosis 1 at puberty after the establishment of HPO axis there is release of FSH and LH right. So, this is a primary oocyte this is 2N we cannot say 2N, but it is arrested right.

It has not been complete if the first meiotic division has not been complete. So, it is a primary oocyte and these are the cuboidal flattened cuboidal cells all around this structure is called as the primordial follicle which is present in the fetal ovary. Now this primary follicle primordial follicle will form the primary follicle where the flattened cells will become cuboidal right, but inside is the same primary oocyte with puberty with the action of FSH you know there will be growth of these are the cuboidal cells they are nothing, but the granulosa cells of the ovary. There will be growth of the granulosa cells and it will form the secondary follicle right. Now and these are the theca cells this is the secondary follicle and this also contains the primary oocyte right.

Now slowly there will be you know fluid cavity inside the granulosa cell this is the fluid cavity this is called as the antrum with the appearance of antrum the secondary follicle is called as the tertiary follicle or the antral follicle. So granulosa cells around the primary oocyte leads to secondary follicle and this secondary follicle within the secondary follicle there is a formation of cavity or antrum which leads to the formation of tertiary follicle. This tertiary follicle there are many tertiary follicle and from there only one dominant follicle is selected and that dominant follicle will form the graafian follicle which is approximate size is 18 to 20 millimeter. So that this graafian follicle with LH surge with LH surge till then there this is the primary oocyte after the LH surge this primary oocyte there will be resumption of meiosis 1 the arrest will go away and it will form the secondary oocyte and the first polar body. This secondary oocyte is this is the secondary oocyte which is getting you know dislodged or it will be it will get rupture into the peritoneal cavity during the process of ovulation.

So this is as a whole primordial follicles converting to primary follicles secondary follicle

tertiary follicle all containing primary oocyte at arrested at prophase of meiosis 1 then the graafian follicle or the mature follicle just prior to ovulation and the from the graafian follicle during the process of ovulation there is release of the secondary oocyte. Now to sum up from the follicles in the ovary from the follicular pool in the ovary some follicles are you know they are selected or they are recruited from that follicular pool and they go into the process of oogenesis right. So this recruitment of follicles from the pool this is not FSH dependent up till the formation of you know preantral up till the formation of secondary follicle from the pre antral it is FSH before preantral it is you know gonadotropin independent. Then from pre antral they are become they become FSH dependent and gradually FSH causes a proliferation of the granulosa cell and there will be formation of pre antral antral follicle ultimately graafian follicle or the dominant follicle which under the action of LH will rupture causing ovulation right and the rest of the follicle there will be luteinization to form the corpus luteum. This is the same we are you know slowly towards the right side we are going into the more advanced stages of ovarian follicle.

Another thing to note is when the ovulation what is released number 1 is the secondary oocyte. This is the secondary oocyte and around the oocyte is the zona pellucida a membrane this is the zona pellucida this white red portion is the zona pellucida and a part of the granulosa cells surrounding the oocyte these are you know arranged in a form of rays this is known as corona radiata they are nothing, but the granulosa cells surrounding the oocytes. So, this is released during the process of ovulation right. So, this is oogenesis to you know summarize oogenesis from oogenesis primary oocyte will ultimately form a single ovum single ovum right and 3 polar bodies this is the first polar body and these are the 2 polar bodies. So, single ovum is produced from one primary oocyte, but in spermatogenesis one primary spermatocyte will form 4 sperms and the fertilization between this ovum and the sperm will result in the formation of zygote.

Now coming to some of the MCQs right. Now, coming to some of the MCQs in this chapter oogenesis starts in the early fetal life. The basic difference between spermatogenesis and oogenesis is mature ovum is diploid and sperm is haploid no one mature ovum is produced in oogenesis and 4 mature sperm is produced in spermatogenesis yes one mature ovum from one oogenesis right. So, this is the correct statement rest are all incorrect you can read through them. Acrosome of sperm is formed from acrosome it contains the Golgi apparatus. The process of spermatogenesis is induced by process of spermatogenesis it is induced by FSH.

Actual genetics section of sperm know is its that means, where is the actual gene that is the nucleus of the sperm it is in the head of the sperm. Polar bodies are formed during yes in oogenesis. The surge in LH that occurs during the middle of ovarian cycle triggers LH surge will trigger in ovulation right LH surge occurs just prior to ovulation which will result in ovulation. Which type of cell is actually ovulated from the ovary? From the ovary the cell is secondary oocyte primary oocyte is arrested from the intra uterine life and it remains in that

arrested position just prior to ovulation this primary oocyte the arrest goes away in it forms secondary oocyte.

So, during ovulation secondary oocyte is released. Second polar body is released from the oocyte second polar body that means, in meiosis II the secondary oocyte will undergo meiosis II to form the ovum and the second polar body and this meiosis II arrest goes away only after fertilization. So, answer D few hours after the sperm enters the oocyte that is after fertilization. Ovulation coincides with LH surge LH surge occurs you know 12 to 14 hours before ovulation right. So, this is the end of this session reference taken are from D.C.Dutta textbook of obstetrics the Grey's anatomy and the Williams obstetrics. Thank you.