Chapter - 31
Gametogenesis in Human

Formation of gametes by primordial sex cells in gonads is known as **Gametogenesis.** Sperms and ova are formed respectively in testes and ovary by primordial sex cells through spermatogenesis and oogenesis. In bisexual animals male and female gametes are produced by same individual, while in unisexual animals sperms are produced by male and ova are produced by female animal.

In gametogenesis, haploid gametes are formed from undifferentiated diploid germ cells for sexual reproduction. The process of gametogenesis is stimulated by follicle stimulating hormone.

Spermatogenesis

Formation of sperms in testes by primordial sex cells is known as spermatogenesis. One pair of testis is attached with dorsal body wall by mesorchium in vertebrates. Each testis is made of thousands of tube like seminiferous tubules. The tubules are covered around by tunica proporia membrane. Its inner layer, germinal epithelium is formed by two types of cells **Somatic** or **Sertoli cells** and **germ cells**. Somatic or sertoli cell provides support and nutrition to sperm. The head of sperm is embedded in it. Germ cells (spermatogonia) form sperms.

Seminiferous tubules remain separated by **interstitial cells** or **leyding cell** which secrete male hormone. Testis acts as exocrine and endocrine structure. Spermatogenesis is a continuous process in vertebrates. The different stages of its formation in testis are from periphery to central cavity, which is called hologonic type of sperm production. In insects and nematodes, it is telogonic type which takes place toward proximal to distal part. The process of spermatogenesis completes in 74 days in human.

This process completes in two steps -

1. **Formation** of **spermatid**
2. **Transformation into sperm or spermateleosis**

1. Formation of spermatid or spermatocytogenesis

This process begins after acquiring sexual maturation in animal. Formation of spermatid from primordial germ cells is performed in three steps-

(a) Multiplication phase - Undifferentiated primordial germ cells produce cells by successive mitotic division which are known as spermatogonia. Spermatogonia are diploid cells.

(b) Growth phase - After last division of multiplication phase some spermatogonia get nutrition from germ cells and become double in size, these are known as primary spermatocyte, which are diploid. Rest of spermatogonia remains in seminiferous tubules as additional stock. Growth phase is the longest phase.

© Maturation phase - Two haploid secondary spermatocytes are formed by first meiotic division (reductional division) in primary spermatocyte. These secondary spermatocytes are divided by meiosis II (equational division or second maturation division), as a result two spermatids are formed from each secondary spermatocyte means four haploid

spermatids are formed from a diploid primary spermatocyte.

Spermiogenesis: Differentiation of spermatid

Although the chromosome number in spermatids becomes haploid, but they don't have functional capacity of male gametes. Differentiation takes place in them to form sperms. This process is known as spermiogenesis or spermateleosis (Fig. 31.1 (a)).

The change by which spermatids are differentiated into spermatozoa, are much fundamental. In this differentiation nucleus of spermatid is contracted by removal of water from its nuclear sap and all chromosomes situated in it becoming together and arranged in comparatively small space. It is necessary to reduce the weight of motile sperm. Not only this, all unnecessary substances are removed from nucleus, i.e. RNA etc. Only DNA or genetic material remains in nucleus. The size of nucleus is also changed and to swim easily in water it becomes long and narrow from spherical shape. The shape of head depends on the shape of its nucleus, which are varying in different animals for example oval and laterally flat in human and bull, dagger shaped in rats and frogs and spiral shaped in birds.

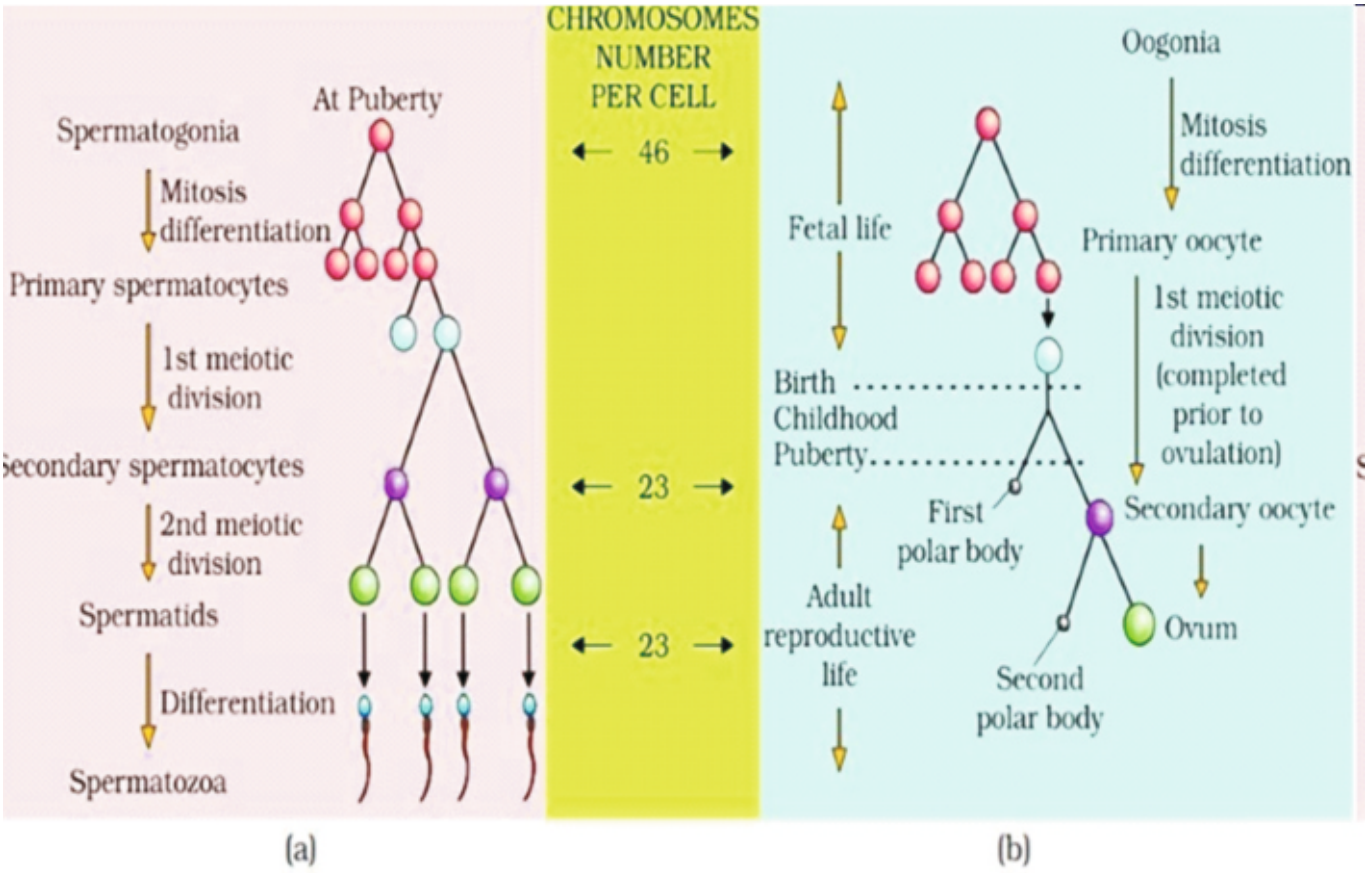

Fig. 31.1 Line diagram of (a) Spermatogenesis and (b) Oogenesis

Acrosome of sperm is developed from differentiation of golgi bodies. The golgi body of spermatid is made of membranes arranged in many cycles which surround many vacuoles in the centre. One or more vacuoles increases in size during differentiation and within the vacuole a micro dense - body is visible that is called pro acrosomal granule. If one or more than one vacuole and granules are formed, then at last all these are fused together and only one granulated vacuole remains. This granulated vacuole attaches with apical part of nucleus. The granules increases in size, now this is called acrosomal granule and it form the core of acrosome. The fluid from vacuole flows outside and

its membrane covers the anterior half of proacrosomal granule and nucleus just like bilobed cap. This double layered cover is called cap of sperm. Remaining part of golgi body discharged with excessive cytoplasm of spermatid. Acrosome granules have enzymes which are used in dissolving egg membrane during fertilization (Fig. 31.2).

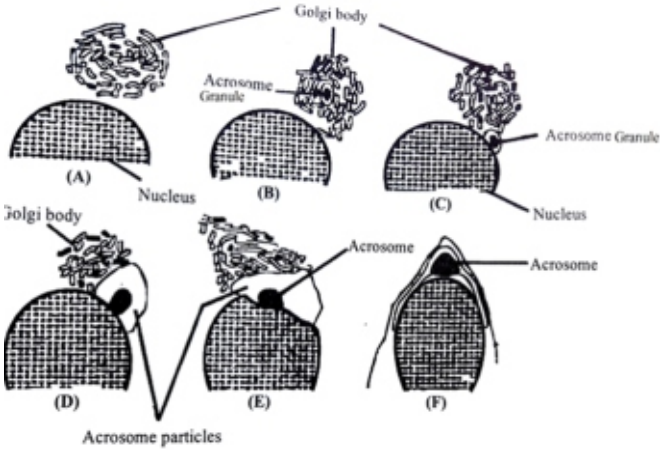

Fig. 31.2 Gradual development of acrosome and apical cap in sperm during spermeogenesis (A to F)

Centrosome of spermatid is made of two cylindrical centrioles, which are arranged at right angles to each other. A groove is formed at mid posterior region of nucleus in which one centriole is placed forming a right angle at longitudinal axis of sperm. This centriole is called proximal centriole. The other or distal centriole takes the position below proximal centriole placed in direction of longitudinal axis of sperm. Distal centriole which forms filament or it is basal granules of axial filament. Axial filament is the main part of tail of sperm. In simple condition the tail is formed from only axial filament lined by a thin layer of cytoplasm and plasmalema membrane. In complex condition tail includes other fibrils (as in mammals).

Maximum protoplasm of spermatid is useless for sperm and it is removed. At the time of formation of acrosome at apical part of nucleus the cytoplasm of spermatid begins to flow in opposite direction, due to which a thin layer of plasmalema membrane remains intact with acrosome and nucleus. When tail is being formed from middle part at that time remaining cytoplasm of spermatid is attached with middle part of sperm. After arranging the mitochondria around the basal part of axial filament remaining cytoplasm (with residue of golgi body) separates from sperm and at last, a thin layer of cytoplasm remains around the mitochondria in middle part. The separated cytoplasm is destroyed.

2. Spermateleosis

Morphologically, metabolically and functionally spermatid is differentiated into sperm by sperm metamorphosis. In this process spherical, non-motile, haploid spermatid developed from spermatocyte is converted into thread like, motile and haploid sperm. Nucleus of spermatid forms head and golgi body forms acrosome, mitochondria forms middle piece and distal centrosome forms tail. After spermatogenesis head of sperm is embeded into sertoli cells. At last sperms are released by the process of spearmiation from seminiferous tubules.

The formation of sperm in animals depends on temperature, hormones, mental status, and hormones secreted by anterior lobe of pituitary gland (luteinizing hormonesLH and follicle stimulating hormone FSH). Luteinizing hormone stimulates leydig cells by which androgens are secreted. Androgens stimulate spermatogenesis while follicle stimulating hormones stimulate sertoli cells which with some factors help in the process of spermiogenesis. At puberty, excess amount of Gonadotropin Releasing Hormone (Gn RH) starts spermatogenesis in significant amount. It is hypothalamic hormone, which stimulates anterior part of pituitary gland.

Sperms can remain alive for several years in tranquility, resting state and cold storage but their life span is up to 55-60 minutes in active condition, unavailability of food and high temperature.

Structure of Human Sperm

Male gamete or sperm is very much specific cell for providing haploid set of chromosomes and to activate egg during sexual reproduction. A typical mammalian sperm is divided into three parts (a) Head (b) Middle piece and © Tail.

(a) Head - It is formed by nucleus and acrosome. Haploid set of chromosomes is found with protamine protein in nucleus for heredity function. Acrosome is situated on the anterior end of

sperm between nucleus and plasma membrane. Acidic protein antifertilizin is found on the head of sperm and inside sperm lysine enzyme as hyaluronidase and cathapsins are found (Fig. 31.3).

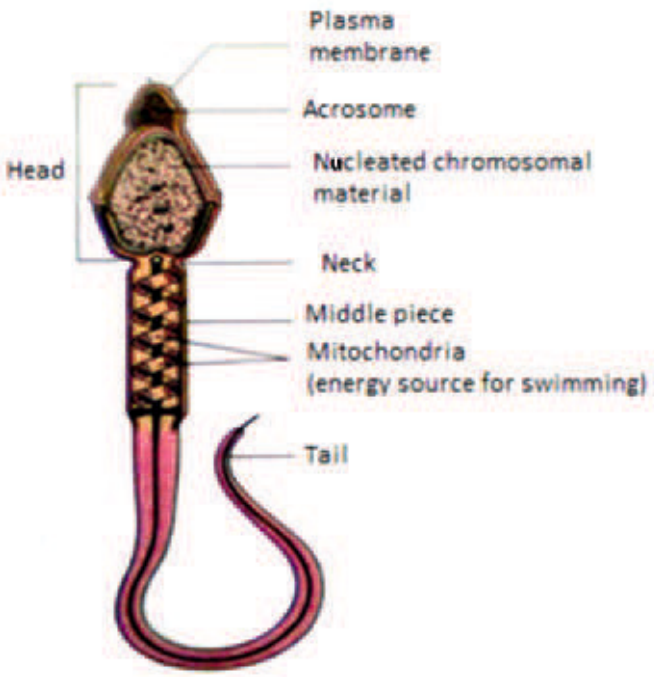

Fig. 31.3 Structure of sperm

(b) Middle piece - Middle piece joins head by the neck. Neck has two similar centrioles but different of function. Proximal centriole is helpful in mitotic spindle formation after fertilization. This is situated perpendicular in main axis. Distal centriole forms the axis of sperm. Structure of axial filament is similar to flagellum i.e. 9+2 type. Distal centriole also works as basal body.

Filaments are surrounded by mitochondria in middle piece, which are active for oxidizing phosphorylation by respiratory enzymes. In mammals mitochondria joining together to form ribbon like nebenkern while a thin layer of cytoplasm forms manchette toward periphery in middle piece. At the end of middle piece a fibrous ring is present which is called **Ring centriole** or **Annulus** or **Jenson's ring.** Its function is to prevent entry of mitochondria in tail region.

(C) Tail - Tail is the longest part of sperm. The end part forms pointed region of tail while main part forms the major part of tail in which in addition to 9+2 structure, cytoplasm and a thick filament are also present (Fig 31.3).

Stored food, ribosomes, endoplasmic reticulum, nucleolus and RNA are absent in sperm.

Sperms are released by seminiferous tubules of testes of male, which are transported with secretion of epididymis, vas deferens, seminal vesicle and prostate by accessory ducts, which are essential for maturation and mobility of sperm. Semen is formed by seminal plasma with sperm. Male human releases about 200 to 300 million sperms at a time, out of these 60% must be of normal shape, size and 40% of fast mobility. This activity is performed by testicular hormone (androgen).

By the process of gametogenesis in male and female reproductive cells all formed four gametes or sperms are active in male, while in female only one gamete or ovum is develops.

Oogenesis

The process of oogenesis in female's ovary is more complicated than spermatogenesis. In addition of four haploid cells, yolk is stored in it. During oogenesis the cell separates from germinal epithelium and enters into cortex of ovary. This diploid cell is with totipotiency that is called primordial germ cell. The process of oogenesis is also completed in three steps (Fig 31.1 (b)).

1. Multiplication phase 2. Growth phase 3. Maturation phase

1. **Multiplication phase -** The primordial germ cells is transformed into egg mother cell.By successive mitotic division in it oogonia are formed. One oogonium takes part in oogenesis and rest oogonia changes into nurse cells or follicle cells. The oogonia are neither formed nor add after birth.

2. **Growth phase -** The essential nutritive materials are synthesized and deposited in this important phase. The oogonia increase unexpectedly in size that is called **primary oocyte.** The growth of oocyte is by follicle cells in mammals. In egg laying animals, yolk is synthesized in liver which is transfered in oocyte through mother's blood. Growth phase can be divided into two phases, pre vitellogenesis and vitellogenesis. The volume of nucleus and cytoplasm increases in pre vitellogenesis. Lamp brush chromosome is formed and cytoplasm

increases qualitatively and quantitatively in it. Ooplasm is organized with glycogen, carbohydrate, fat and protein or Yolk is synthesized and deposited in vitellogenesis period. The chemical composition of Yolk is in the form of 48.7% water, 16.7% protein, 32.6% phospholipid and neutralized fat and 1% carbohydrate.

3. Maturation phase - Maturation phase starts after completion of growth phase in primary oocyte or it under goes by meiotic division which includes two successive divisions. In meiosis first primary oocyte divides into two unequal cells. First is very large having Yolk and second is very small. Large cell is called secondary oocyte and second small is called first polar body.

After this meiosis second takes place in both cells, it is also unequal resulting larger yolked daughter cell is called ootid or actual ovum and small cell called second polar body. Only ovum takes part in reproduction rest polar bodies do not take part in reproduction and at last destroyed.

In most of animals, only first meiotic division is performed in maturation phase of oogenesis and usually there in no any division in secondary oocyte till fertilization. Meiosis second occurs along with fertilization in egg cell.

Each primary oocyte is surrounded by granulosa cells that is called primary follicle. A large number of theses follicles are destroyed during the period from birth to become adult, by which only 60000 to 80000 primary follicles are remained in each ovary.

This primary follicle is surrounded by several new granulosa layers **theca**, these are called secondary follicle. These are soon converted into tertiary follicle in which fluid cavity, antrum is found. Theca remains in the form of two layers theca interna and theca externa. In these tertiary follicles primary oocyte increases for meiosis first. After meiotic divisions tertiary follicle transforms into mature follicle means Graafian follicle. Secondary oocyte is formed as a result of meiotic division a new membrane zona pellucida is formed around it. Secondary oocyte is released by the graafian follicle from ovary. This process is known as ovulation, which are repeated after28 days in human.

Egg of Mammal

The eggs of mammals are alecithal and isolecithal type. Their diameter is up to 100 to 150 µm. The ovum released from ovary is not completely mature, it is secondary oocyte. Nucleus is situated towards large sized animal pole. The quantity of Yolk is much less or negligible. Outside the cell membrane a transparent, non-cellular **zonapellucida** named covering is present. Outside of zone pellucida a covering of follicle cells **corona radiata** is found (Fig. 31.4).

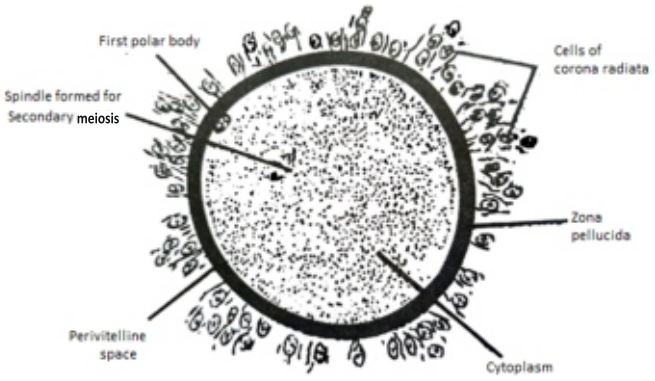

Fig. 31.4 Structure of human ovum at a ovulation

Practice Questions

Multiple choice Questions-

1. Releasing the mature ovum from ovary is called -
   (a) Implantation (b) Fertilization
   (c) Ovulation (d) Parturition
2. How long spermatozoa entered in vagina is survive?
   (a) 1-2 days (b) 3-4 days
   (c) 5-10 days (d) 1 week
3. Breaking the membrane covering of acrosome of mammalian sperm is called.
   (a) Activation (b) Capacitation
   (c) Agglutination (d) Cavitation
4. Which of the following is immortal?
   (a) Glomerular cell (b) Germ cell
   (c) Pituitary's cell (d) Somatic cell

5. Which phase of sperm development does not participate in ovum development?
   (a) Formation of polar body
   (b) Growth phase
   (c) Multiplication phase
   (d) Spermiogenesis
6. Oogenesis has
   (a) Multiplication phase
   (b) Growth phase
   (c) Maturation phase
   (d) All of above
7. The process of ova formation is called-
   (a) Ovipary (b) Oogenesis
   (c) Oviposition (d) Ovulation
8. Arrangement of fibrils in the tail of sperm is-
   (a) 9 (singlet)+2(Doublet)
   (b) 9 (singlet)+9 (Doublet)
   (c) 9 (Singlet)+2 (Doublet)
   (d) 9 (Singlet) + 9(Doublet)+ 2 (Singlet)
9. In which process polar body is formed?
   (a) Regeneration (b) Spermiogenesis
   (c) Oogenesis (d) Fertilization
10. How many ova are produced from one primary oocytein oogenesis?
   (a) One (b) Two
   (c) Eight (d) Four

Very Short Answer Questions-

1. Which type of eggs is of placental mammal?
2. Which apical part of sperm comes in contact to ovum at the time of fertilization?
3. Which accessory cell organelles are involved in the formation of middle part of sperm?
4. What are the cells called formed during second maturition division?
5. In which baar body is present?
6. Why are the sperms produced in much quantity in comparison of eggs?
7. Write the name of hormone found on the surface of egg.

Short Answer Questions-

1. Describe the structure of human sperm.
2. Describe the formation of acrosome.
3. Write in brief about three phases of gametogenesis.

Essay Type Questions-

1. Describe growth phase of oogenesis.
2. Describe the process of spermatogenesis with diagram.
3. Draw line diagram of spermatogenesis and oogenesis.
4. Mention differences between spermatogenesis and oogenesis.

Answer Key-

1. (c) 2. (a) 3. (b) 4. (b) 5. (d)
6. (d) 7. (b) 8. (d) 9. (c) 10. (a)

Chapter - 32
Fertilization in Human

The union of haploid male (sperm) gametes and female (ovum) gametes and fusion of pronuclei of both gametes is called fertilization. Fertilization results in the formation of diploid zygote.

The fusion of pronuclei of gametes is called Karyogamy, while mixing of two sets of chromosomes of two gametes is known as amphimixis. As in other mammals fertilization is internal in female human. Generally it occurs in ampulla of fallopian tube.

Types of Fertilization

The process of fertilization is of two types

1. External fertilization-

In external fertilization male and female gametes are fused outside the body. This fertilization process is carried out in aquatic medium. Mostly, it is found in fishes (*Labeo*), amphibians (Frog) and all Echinoderms (Starfish).

2. Internal fertilization-

In internal fertilization, the fusion of gametes takes place in some part of female genital duct and generally near the ostium. It is found in oviparous (all birds, prototherians), ovoviviparous and viviparous (all marsupials and eutherians) animals.

Artificial insemination

The process of liberation of sperms by male in the body of female for fertilization is called insemination. When sperms are collected artificially, preserved and stored and fertilization is being done by liberating them in female uterus, as needed, this process is known as artificial insemination. This process is used to improve breed in Livestock.

Steps of Fertilization

1. Approach of Sperm to Ovum

During copulation, male ejaculates semen (3-5ml) in vagina near uterine duct in female is called insemination. About 400 million sperms are found in this ejaculation but out of these 100 sperms can reach up to fallopian tube, because many sperms die due to acidity of female genital duct. Several sperms are ingested by phagocytic cells of vaginal epithelium. The sperms swim at the rate of 1-4 mm per minute in seminal fluid. This movement of sperms is due to the uterine contraction process and peristaltic movement of fallopian tube. After some time of entering in female uterus, the sperm became capable for fertilization. The capability of fertilizing an ovum of its own species is known as sperm's capacitation(Fig. 32.1).

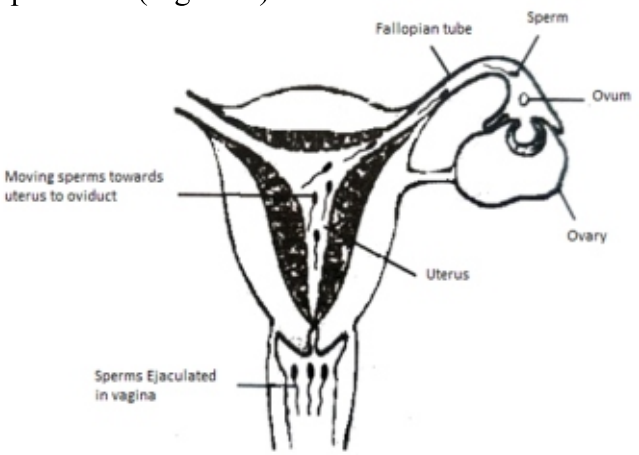

Fig. 32.1 The path of sperms in female reproductive system for fertilization

In this process the physiological maturation of sperm occurs in which due to activity of lysigenous enzyme sperm enters into ovum by penetrating egg membrane. This process takes about 5-6 hours. After this the sperm, fertilizes the ovum.

2. Entry of sperm

The ovum secretes a chemical substance which is called fertilizin. Its surface has sperms affinate sites where specific sperms are attached by its antifertilizin site.By the interaction of fertilizin antifertilizin ovum and sperm are agglutinize together.

Penetration by sperm is a chemical mechanism. In this, acrosome takes part and releases some sperm lysins which make the path for entrance of sperm by dissolving egg membrane. The sperm lysin is an acidic protein having lysigenic enzyme hyaluronidase which dissolves hyaluronic acid polymer present in intercellular spaces. This acid keeps together the granulosa cells of corona radiata. The corona piercing enzyme dissolves corona radiata and acrosin dissolves zona pellucida .

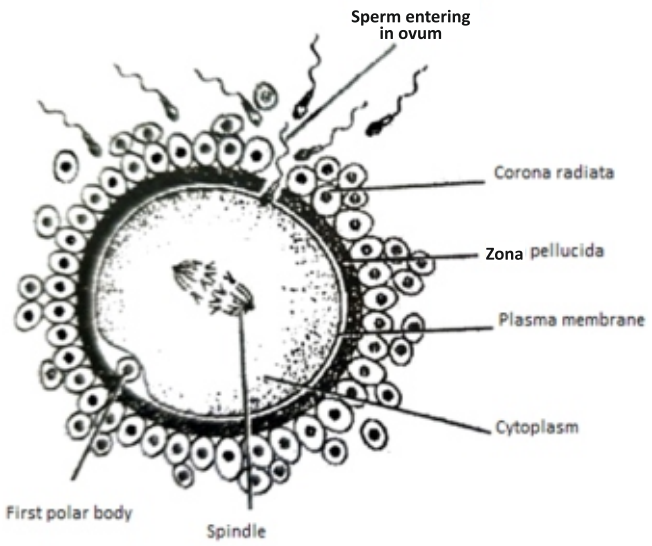

Fig. 32.2 Entery of sperm in an ovum

3. Cortical reaction

Just after entry of sperm cortical reactions takes place to prevent entry of other sperms into ovum. In this reaction the cortical granules present below the plasma lemma of ovum chemical substances are present in between cytoplasm of ovum and vitelline membrane. After entry of sperm into ovum following metabolic activities are induced :-

1. A fertilization cone is formed on the surface of ovum.
2. Vitelline membrane changes into fertilization membrane.
3. Movement is found in cytoplasm.
4. Permeability of plasma membrane increases.
5. The rate of protein synthesis increases.
6. Mitotic division starts.

4. Fusion of pronuclei

Entry of sperm in ovum acts as a stimulation. As a result second maturation division takes place. After entry of sperm in ovum the head and middle piece of sperm rotates by angle, due to which mitochondria and proximal centriole related to middle piece reach forward to head. Centriole carried by sperm is divided into two parts and forms chromosomal spindle in the centre of active cytoplasm. With the formation of second polar body, egg nucleus or female pronuclei becomes prepared to fuse with pronuclei of sperm's head.

After following the sperm penetration path, male pronucleus moves directly to female pronucleus. In several circumstances less change take place in this path of sperm. In such conditions, the part of path of sperm is known as copulation path.

Significance of Fertilization

1. It stimulates the egg for complete maturation.
2. It activates ovum for continuous mitotic division to develop a new organism.
3. It makes the number of chromosomes diploid (in human 46) in zygote by fusion of haploid set of male chromosomes.
4. It makes the egg metabolically more active.
5. It joins the characters of two parents and develops variations. Thus, it also helps in evolution.
6. Sex chromosomes of sperm are X or Y by which it also helps in sex determination.

7. Formation of fertilization membrane takes place after entry of sperm, by which poly spermy is checked.
8. Copulation path determines the axis of division.

Pracice Questions

Multiple choice Questions-

1. Importance of fertilizin antifertilizin process in fertilization is-
   (a) To attract gametes to each other
   (b) Protection of sperms
   (c) Fusion of gametes of same species
   (d) All of above
2. Fertilization is -
   (a) Fusion of male and female pronuclei
   (b) Fusion of two gametes
   (c) Fusion of two gametes of same species
   (d) All of above
3. At the time of fertilization, the part of sperm that comes in contact with ovum is
   (a) Acromion (b) Acromegaly
   (c) Acronia (d) Acrosome
4. The enzyme secreted by acrosome of sperm is
   (a) Hyaluronidase (b) Pepsin
   (c) Carboxylase (d) Dehydrogenase
5. When sperms of human come in contact with vaginal discharge then these acquire capability of fertilization. This process is called.
   (a) Cortical reaction (b) Capacitation
   (c) Acrosome reaction (d) Mating
6. The substance which conserves energy during sperm mobility is-
   (a) Androgamone I (b) Androgamone II
   (c) Gynogamone I (d) Gynogamone II
7. Site of fertilization in female human is
   (a) Vagina (b) Spermatheca
   (c) Uterus (d) Fallopian tubes
8. Gyanogamone is secreted by
   (a) Ovum
   (b) Spermatid
   (c) Graafian follicle cells
   (d) Ovary
9. Sperm moves by
   (a) Tail (b) Head
   (c) Acrosome (d) Middle piece
10. Development of unfertilized egg is called
    (a) Transformation (b) Metamorphosis
    (c) Morphogenesis (d) Parthenogenesis.

Important Questions-

1. Who postulatefertilizin theory in fertilization process?
2. Where is fertilizin present?
3. Which scientist studied acrosome reaction?
4. Define fertilization.
5. What is parthenogenesis?
6. What is amphimixis?
7. What is activation of ovum?
8. What is capacitation process?

Answer Key-

1. (c) 2. (c) 3. (d) 4. (a) 5. (b)
6. (a) 7. (d) 8. (a) 9. (a) 10. (d)