3.10. FERTILIZATION (Fig. 3.21)

Fusion of a haploid male gamete (spermatozoon) and a haploid female gamete (ovum) to form a diploid cell, the zygote, is called fertilization.

Site of Fertilization. Fertilization in human female is internal as in other mammals. It takes place usually in the ampulla of the fallopian tube.

3.10.1. Arrival of Spermatozoa

Male discharges semen high up in the female's vagina close to the cervix during coitus (copulation). This is called **insemination**. From the vagina, the sperms reach the ampulla partly by their own effort and partly by the action of the uterus.

(a) Sperms' Effort. The sperms present in the semen travel a long way through the uterus into the fallopian tube by swimming in the fluid medium. The sperms may swim at the rate of 1.5 to 3 mm. per minute. A single ejaculate of semen into the vagina contains about 200 to 400 million sperms in some 3 ml of fluid secretions. Only 100 or so sperms reach the fallopian tube.

(b) Role of Uterus in Sperm Transport. Certain activities of the female reproductive tract help the sperms reach the site of fertilization. For example, extension of the cervix into the vagina aspirates the semen into the uterus from the vagina, and contractions of the uterus and fallopian tubes propel the sperms upward. Sperms may reach fallopian tube within five minutes. Although a sperm cell can survive in the female's reproductive tract for 1 to 3 days, it can fertilize the oocyte in the 12 to 24 hours following ovulation.

3.10.2. Arrival of Egg

The egg released from the mature Graafian follicle of an ovary (ovulation) is received by the nearby fallopian funnel and sent into the fallopian tube by movements of fimbriae and their cilia. It is in the secondary oocyte stage with the second meiotic division in progress. The oocyte can live for 72 hours but

binds to a complementary molecule on the surface of the sperm head. Binding of the sperm head to the receptor molecule ZP3 induces the acrosome of the sperm to release its hydrolytic enzymes by exocytosis. These are collectively termed **sperm lysins.** Main sperm lysins include —

(*i*) **Hyaluronidase** that hydrolyses hyaluronic acid of the follicular cells.

(*ii*) **Corona penetrating enzyme.** It dissolves corona radiata portion around the secondary oocyte by hydrolysing their ground substances.

(*iii*) **Zona lysine** or **acrosin.** It helps to digest zona pellucida. All these enzymes dissolve the corona radiata and the zona pellucida and enable the sperm to reach the plasma membrane of the egg. The above changes in the sperm head are called **acrosome reaction.**

Ca^{++} play important role in acrosomal reaction. Other essential parameters are optimum pH, appropriate Mg^{++} concentration, and temperature.

Acrosome reaction also exposes some proteins in the sperm membrane that bind to receptors on the egg plasma membrane. Now the plasma membrane of the sperm fuses with the egg plasma membrane making it possible for the sperm contents to enter the egg.

Binding of the sperm to the egg induces depolarization of the egg plasma membrane. Depolarization causes **fast block to polyspermy**, that checks additional sperms from joining the egg's plasma membrane.

(b) Cortical Reaction. Immediately after the fusion of sperm and egg plasma membranes, the egg shows a **cortical reaction** to further check the entry of more sperms. In this reaction, the cortical granules present beneath the egg's plasma membrane fuse with the plasma membrane and release their contents (enzymes) between the plasma membrane and the zona pellucida. These enzymes harden the zona pellucida which now functions as the **sure block to polyembryony.**

(c) Sperm Entry. The egg extends around the entering sperm finger-like processes, called **microvilli**, which constitute a **fertilization cone.** The latter take the entire sperm into the egg. The distal centriole of the sperm divides and forms two centrioles to generate the mitotic spindle for cell division. The mammalian egg lacks centrioles of its own.

(d) Karyogamy (Amphimixis). The sperm entry stimulates the egg (secondary oocyte) to resume and complete the suspended meiosis- II. This produces a haploid mature ovum and a second polar body. At this time, the head of the spermatozoon, which consists of the nucleus, separates from the middle piece and the tail, and becomes the **male pronucleus.** The second polar body immediately degenerates, and so does the sperm tail. The chromosomes of the ovum are not organized into a nucleus. They represent the **female pronucleus.** The chromosomes of the sperm are set free by breakdown of nuclear envelope. The two sets of chromosomes go over a spindle formed between the centrioles. Mixing up of the chromosomes of a spermatozoon and an ovum is called **karyogamy**, or **amphimixis**. This completes the act of fertilization. It combines the genetic information from two parents. The ovum is now a diploid cell having 23 pairs of chromosomes, and is termed **zygote** (Gr. *zygon* = yolked together). The first cell of the new individual, thus, comes into existence. However, it has 46 chromosomes rather than an organized nucleus with the nuclear envelope. The mother is now said to be **pregnant.** No nuclear envelope is formed around the chromosomes as they are already double, each consisting of two chromatids, and the zogote is ready for the first cleavage.

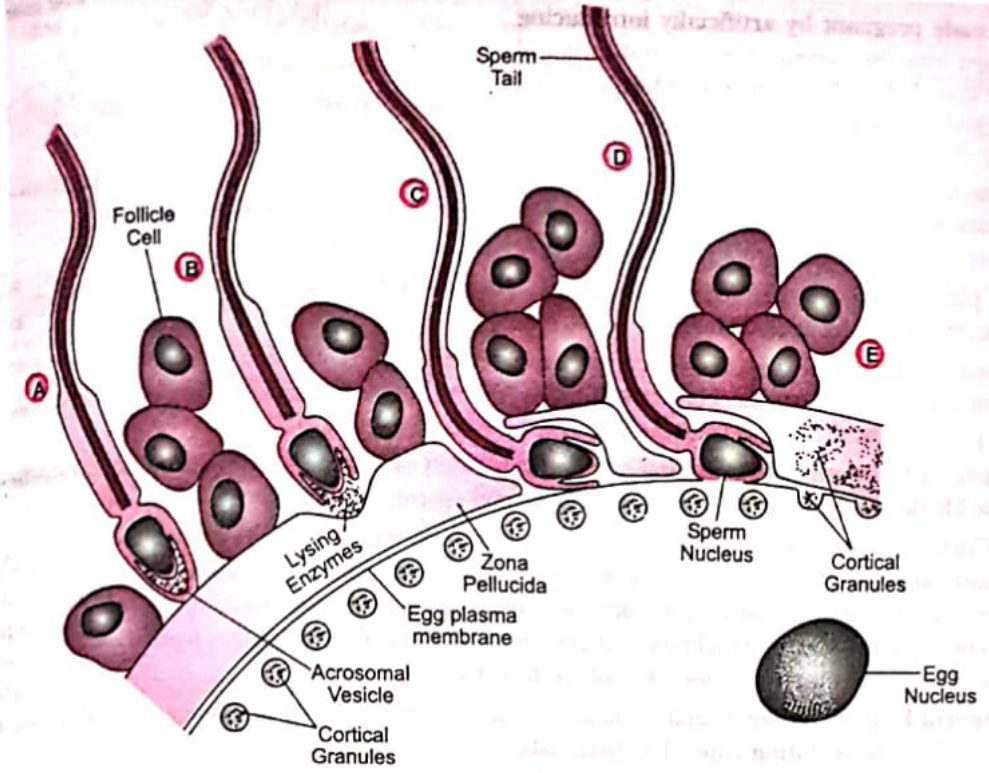
(e) Activation of Egg. Sperm entry stimulates metabolism in the zygote. Within minutes, the rates of cellular respiration and protein synthesis increase greatly.

Fertilization is irreversible and usually species specific. Sperm fertilizes an agg (if one is present) within 30 minutes of ejaculation. If egg is not fertilized, it disintegrates and is absorbed probably by leucocytes.

3.10.5. Sex of the Offspring

In human beings, each diploid cell has 46 chromosomes. Of these, 44 (22 pairs) are autosomes and 2 (1 pair) are sex chromosomes. Human female has XX (homomorphic) sex chromosomes while the human male has XY (heteromorphic) sex chromosomes. The female, therefore, produces same type of gametes

FIGURE 3.21



A-Sperm passes through corona radiata. B-Acrosome reaction, releasing lysing enzyme. C-Sperm passes through pellucida and reaches oolemma. D-Sperm and egg plasma membranes fuse, enabling the sperm contents to enter egg. E-Cortical reaction, releasing enzymes to harden zona pellucida

can be fertilized only during the first 24 hours of this period. Recent research suggests that this period is just 6 hours. If copulation occurs at the appropriate time, the egg is surrounded by numerous sperms. Most of the sperms contribute enzymes which disrupt the follicular cells still investing the egg. Only one sperm succeeds in fertilising the egg, others degenerate and engulfed by leucocytes.

3.10.3. Capacitation of Sperms

The sperms in the female's genital tract are made capable of fertilizing the egg by secretions of the female genital tract. These secretions alter or remove certain molecules deposited on the surface of the spermatozoa from the semen. This process is called **capacitation** of sperms. It takes about 6 hours.

The secretions of seminal vesicles, prostate gland and Cowper's glands present in the semen contain nutrients which activate the sperms and substances that neutralise the acidity in the vagina. Sperms need an alkaline medium in order to be motile.

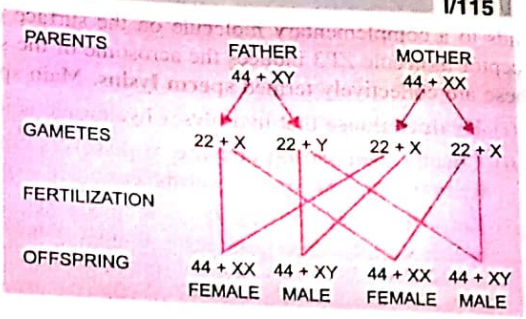
3.10.4. Chemical and Physical Events of Fertilization[1]

These events comprise 5 processes : acrosome reaction, cortical reaction, sperm entry, karyogamy and activation of egg.

(a) Acrosome Reaction. The secondary oocyte reaching the fallopain tube is surrounded by zona pellucida and corona radiata. A capacitated sperm passes through the corona radiata to reach the zona pellucida. One of the three glycoproteins of zona pellucida, named ZP3, functions as a sperm receptor and

1. Many events of fertilization in mammals have been found to differ from those in sea urchin egg from which most of the information about the act of fertilization was originally derived.

(ova), each having X chromosome. The male, on the other hand, produces two types of gametes, *i.e.*, 50% gametes having X chromosome and 50% having Y chromosome. The sex of the child is determined at the time of fertilization when male and female gametes fuse to form zygote. If a sperm (male gamete) carrying X chromosome fertilizes an egg (female gamete) carrying X chromosome, then the offspring will be a female. If the sperm carrying Y chromosome fertilizes an egg, then the offspring will be a male.



3.10.6. Significance of Fertilization

Fertilization has a manifold significance :

1. It provides stimulus for the egg to complete its maturation.
2. It activates the ovum to develop into a new individual by repeated mitotic divisions.
3. Fertilization restores the diploid number of chromosomes (46 in man) in the zygote by adding male's haploid set of chromosomes.
4. It makes the egg more active metabolically.
5. It combines characters of two parents. This introduces variations, which make the offspring better equipped for the struggle for existence and contribute to evolution of the race.
6. It determines the sex of the young one to be developed from the zygote in humans.
7. Oolemma's depolarization and hardening of zona pellucida resulting after sperm entry check the entry of additional sperms.
8. Fertilization introduces centrioles which are missing in the ovum.