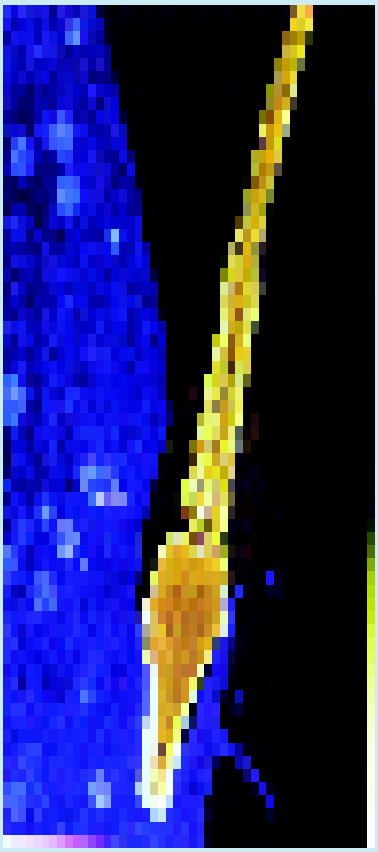
CHAPTER

21

Fertilization



One sperm penetrates the membrane surrounding mammalian egg.

The union of the cytoplasm and pronuclei of the male and female gametes is known as the **fertilization** (L., *fertilis* = to bear). The fertilization is the most commonly used method for the production of the diploid zygotes in the sexually reproducing organisms of Metazoa and Metaphyta.

In the process of the fertilization the haploid male gamete (spermatazoa or pollen), which carries the paternal genetic information, unites with the haploid female gamete (ovum or egg), which carries genetic informations of female parent, to form a diploid zygote. The zygote ultimately, produces a diploid multicellular organism by the several repeated and organised mitotic divisions and cellular differentiation.

EXTERNAL AND INTERNAL FERTILIZATION

The fertilization always occurs in the aquatic media such as sea water, fresh water or intra-somatic (body) fluid of the maternal individual. If the fertilization occurs outside the body of the organism, it is known as **external fertilization** and if it occurs inside the body of the organism then it is termed as **internal fertilization**. The external fertilization is common in various invertebrates and chordates, while the internal fertilization occurs only in those animals which possess specialized sex organs for receiving and transmitting the sperms, *e.g.*, reptiles, birds, mammals and angiosperms, etc.

External fertilization is seen in fish.

FERTILIZIN AND ANTIFERTILIZIN

The process of fertilization is very specific. The sperms of one particular species fertilize the ova of the same species. This type of specificity of male and female gametes is of utmost biological importance and is achieved by the help of certain chemical compounds. It is found that the egg contains a chemical substance known as **fertilizin** (**Lillie**, 1919). The fertilizin is a glycoprotein which is composed of different types of amino acids and monosaccharides (glucose, fucose, fructose and galactose) according to the species. The molecular weight of the fertilizin is 300,000 and it contains large molecules.

The surface layer of sperm contains another proteinous substance known as **antifertilizin**. The antifertilizin is a protein which is composed of acidic amino acids. It has small molecules and the molecular weight is about 10,000.

The fertilizins of the eggs are supposed to attract the sperms which contain a particular type of antifertilizin. It has been found that egg fertilizin of any species reacts efficiently with the sperm antifertilizin of the same species. It has also been reported that the fertilizin in egg-water attracts the sperms of the same species and many sperms adhere together. This type of mutual adhesion of the sperms is known as the **agglutination**.

Internal fertilization is essential for reproduction on land.

PROCESS OF FERTILIZATION

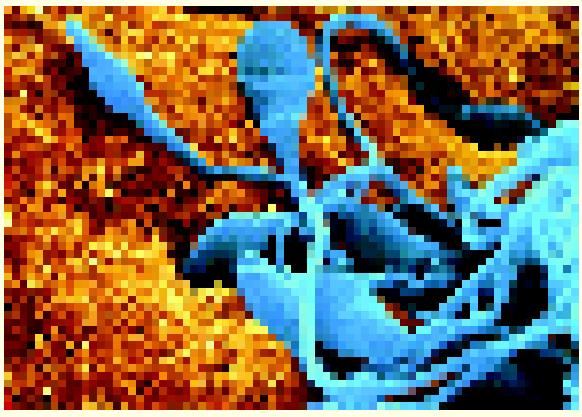
The process of fertilization includes two successive steps which are as follows :

1. The activation of the egg; 2. The amphimixis.

1. Activation of the Egg

1. The process of activation of eggs is completed in following stages :

(i) Movement of the sperm towards the egg. The sperms which occur in the external or internal fluid media around the egg, swim towards the egg randomly. They collide with the egg by chance. The chance of colliding of the sperms with the egg occurs regularly in the nature and remains fruitful only due to the large number of the sperms and enoromously large size of the ovum. The fertilizins and antifertilizins become active after the chance collision of the sperms with the ova. The egg fertilizin usually occurs in the jelly surrounding the egg. It gradually dissolves in the surrounding water of the egg and forms the so called egg water.



Sperms surround the oocyte, attacking its defensive barriers.

(ii) Activation of the sperm. When a sperm with a specific antifertilizin comes in contact with the egg water of its own species then certain significant changes occur in the acrosome of the sperm.

The peripheral portion of the acrosome of sperm collapses and its enzymes the **lysins** are extruded and dissolve in the water. The central portion of the acrosome elongates and forms a 1 to 75µm long, thin tube known as the **acrosomal filament**. The acrosomal filament is the rigid tube which protrudes out from the sperm head. When the sperm possesses such an acrosomal filament it is said to be activated for the penetration in the unfertilized egg. When the activated sperms reach the egg the acrosomal filaments penetrate into the egg jelly and vitelline membrane by the help of dissolving action of the sperm lysins. As soon as the tip of the acrosomal filament touches egg membrane (plasma membrane), various important morphological and physiolgical changes are started in the egg.

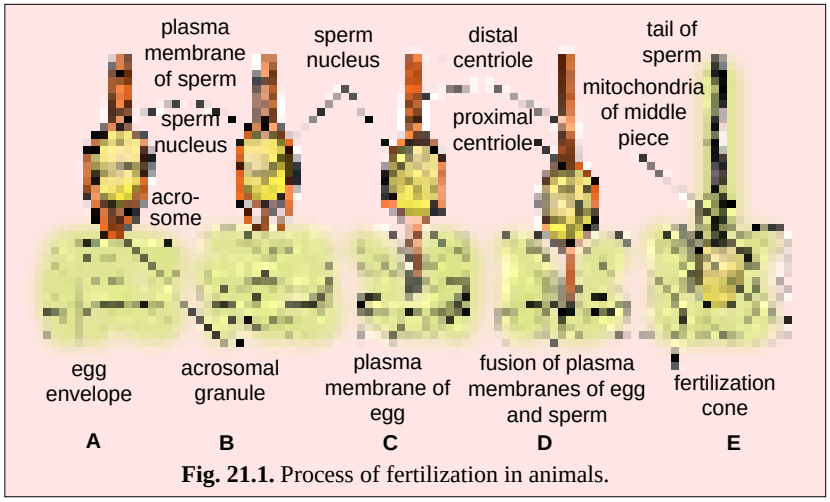
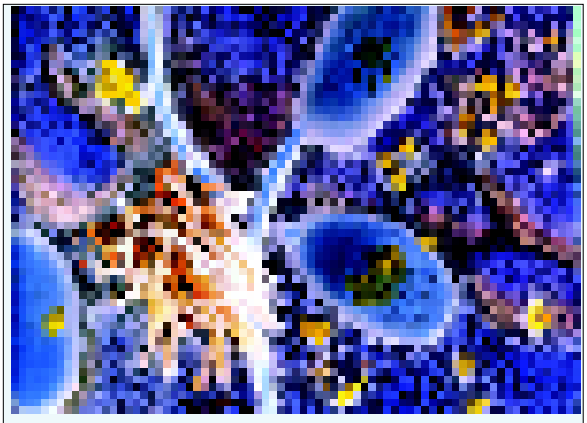


Fig. 21.1. Process of fertilization in animals.



SEM of human sperm cells migrating inside the uterus travelling across a background of uterine mucosa cell.

(iii) The activation of egg insemination. As soon as the acrosomal filament touches the egg surface the ooplasm protrudes out at the point of contact into a cone-like process known as the **fertilization cone** (Fig. 21.2). The fertilization cone may be conical, cylindrical or irregular. When the fertilization cone is irregular in shape it contains many pseudopodia-like processes of the ooplasm. The fertilization cone is composed of the plasma membrane and hyaline cytoplasm. The fertilization cone engulfs the sperm and the sperm which is surrounded by the hyaline cytoplasm move inwards. The penetration of the sperm in the egg is known as the **insemination**. Immediately after the insemination a thin membrane known as the **fertilization membrane** is formed around the plasma membrane of the egg. The fertilization membrane prevents the entrance of further sperms in the egg.

2. Amphimixis

During the insemination the entire sperm may enter in the egg such as in the mammals or the tail of the sperm remains outside the egg such as in the echinoderms. In certain cases as in *Nereis*, the tail and middle piece of the sperm remain outside the egg and only the head and centrosome enter in the egg.

The nucleus of the sperm is known as the **male pronucleus.** The male pronucleus swells up by absorbing the water from the surrounding ooplasm and it becomes vesicular. The compactly arranged chromatin material of the male pronucleus becomes finely granular. The centriole of the sperm is

surrounded by the centrosome and microtubules which form aster rays. The male pronucleus and the centriole move towards the egg pronucleus.

In the case of sea urchins and vertebrates, the two pronuclei (male and female) come close to each other and the close contact takes place between the two. The nuclear envelope is broken at the point of contact and the nuclear contents of both pronuclei are intermingled. The endoplasmic reticulum forms a new common nuclear envelope around the both pronuclei and, thus, forms a **zygote nucleus**. In case of *Ascaris*, annelids and molluscs this type of fusion of two pronuclei does not occur. In these animals the centrioles form the achromatic spindle from the microtubules of the ooplasm and both male and female pronuclei come close to each other, their nuclear envelopes are dissolved. The paternal and maternal homologous chromosomes get arranged on the equator of the achromatic figure and the first cleavage (mitotic) division of the egg occurs. After this division, the nuclear envelope is formed around the chromosomes of the daughter nuclei.

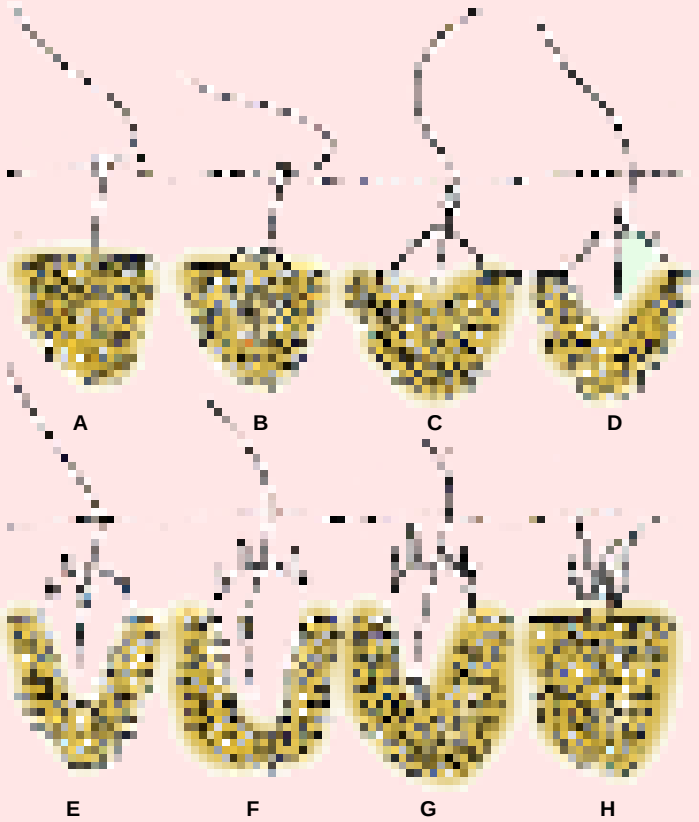


Fig. 21.2. Fertilization cone formation during fertilization of *Holothuria* (after Balinsky, 1976).

Post-Fertilization Changes in the Egg

After the fertilization following changes occur in the egg:

1. The zygote becomes ready for the cleavage and for the formation of the embryo.

2. The oxygen consumption of the zygote increases enormously.

3. The metabolic rate of the zygote increases greatly. For instance, the amount of amino acids and the permeability of the plasma membrane of the egg increases the volume of the egg, decreases the exchange of phosphate and sodium ions between the zygote and the surrounding media. Further, diffusion of the calcium ions from the egg starts and the hydrolysing activities of the proteolytic enzymes increase.

4. The protein synthesis is started.

KINDS OF FERTILIZATION

In the organisms following types of fertilization occur :

1. Monospermic fertilization. In most animals usually only one sperm enters in the egg, this

type of fertilization is known as **monospermic fertilization**. The monospermic fertilization is common in the coelenterates, annelids, echinoderms, bony fishes, frogs and mammals.

2. Polyspermic fertilization. When many sperms enter in the egg, the fertilization is known as the **polyspermic fertilization**. It may be of two types :

(i) Pathological polyspermy. Under certain abnormal conditions when in a monospermic type of egg many sperms enter in the egg, the condition is known as the **pathological polyspermy**. This type of egg does not develop further and dies soon.

(ii) Physiological polyspermy. In the animals with large yolky eggs such as molluscs, selachians, urodels, reptiles and birds, the polyspermic fertilization usually occurs. Such polyspermic fertilization is known as **physiological polyspermy**. In these cases, many sperms enter in the egg but the pronucleus of only one sperm unites with the pronucleus of the egg and rest are degenerated soon. Such eggs are viable and develop further.

3. Polyandry. When two male pronuclei unite with a female pronucleus, the union is known as polyandry, *e.g.*, man and rat.

4. Polygamy. When two egg pronuclei unite with single male pronucleus, the phenomenon is known as polygamy, *e.g.*, sea urchins, polychaete worms, urodels and rabbits.

5. Gynogenesis. When only sperm activates the egg but its pronucleus does not unite with the egg pronucleus, *e.g.*, planarians and nematodes.

SIGNIFICANCE OF FERTILIZATION

1. The fertilization ensures the usual specific diploidy of the organisms by the fusion of the male and female pronuclei.
2. The fertilization establishes definite polarity in the eggs.
3. The fertilization provides new genetic constitution to the zygote.
4. The fertilization activates the egg for the cleavage.
5. The fertilization increases the metabolic activities and rate of the protein synthesis of the egg.
6. The fertilization initiates the egg to start cleavage and embryogenesis.

REVISION QUESTIONS

1. Define the term fertilization. What is the significance of fertilization ?
2. Describe the process and mechanism of fertilization in animals.
3. Write short notes on the following:
   (1) External and internal fertilization; (2) Post-fertilization changes in the egg; (3) Amphimixis; (4) Polyspermy; and (5) Fertilizin and antifertilizin reaction.