

FERTILIZATION

Fertilization is a process whereby two gametes fuse together to form a zygote. It generally consists of four major events.

1. Contact and recognition between sperm and egg.
2. Regulation of sperm entry into the egg.
3. Fusion of the genetic material of sperm and egg.
4. Activation of egg metabolism to start development.

The male gamete, the sperm cell, is a small cell with a greatly reduced cytoplasm and a haploid nucleus. Sperm usually consists of two morphologically and functionally distinct regions enclosed by a single plasma membrane the tail and the head. A midpiece is present between head and tail which mainly contains mitochondria.

The female gamete (egg) of most animals is giant single cell. It contains all the materials needed for initial development of the embryo. There are three main ways to provide nutrition to the developing embryo.

1. Supply the embryo with yolk.
2. Form a larval feeding stage between the embryo and the adult
3. Create a placenta between the mother and the embryo.

Events of Fertilization

Sperm-egg association:

The acrosome reaction of spermatozoa is a prerequisite for the association between a spermatozoon and an egg, which occurs through fusion of their plasma membranes. After a spermatozoon comes in contact with an egg, the acrosome, which is a prominence at the anterior tip of the spermatozoa, undergoes a series of well-defined structural changes. A structure within the acrosome, called the acrosomal vesicle, bursts, and the plasma membrane surrounding the spermatozoon fuses at the acrosomal tip with the membrane surrounding the acrosomal vesicle to form an opening. As the opening is formed, the acrosomal granule, which is enclosed within the acrosomal vesicle, disappears. The dissolution of the granule releases a substance called a lysin, which breaks down the egg's vitelline coat, allowing passage of the spermatozoon to the egg. The acrosomal membrane region opposite the opening adheres to the nuclear envelope of the spermatozoon and forms a shallow outpocketing, which rapidly elongates into a thin tube, the acrosomal tubule that extends to the egg surface and fuses with the egg plasma membrane. The tubule thus formed establishes continuity between the egg and the spermatozoon and provides a way for the spermatozoal nucleus to reach the interior of the egg. Other spermatozoal structures that may be carried within the egg include the midpiece and part of the tail; the spermatozoal plasma membrane and the acrosomal membrane, however, do not reach the interior of the egg. In fact, whole spermatozoa injected into unfertilized eggs cannot elicit the activation

reaction or merge with the egg nucleus. As the spermatozoal nucleus is drawn within the egg, the spermatozoal plasma membrane breaks down; at the end of the process, the continuity of the egg plasma membrane is re-established.

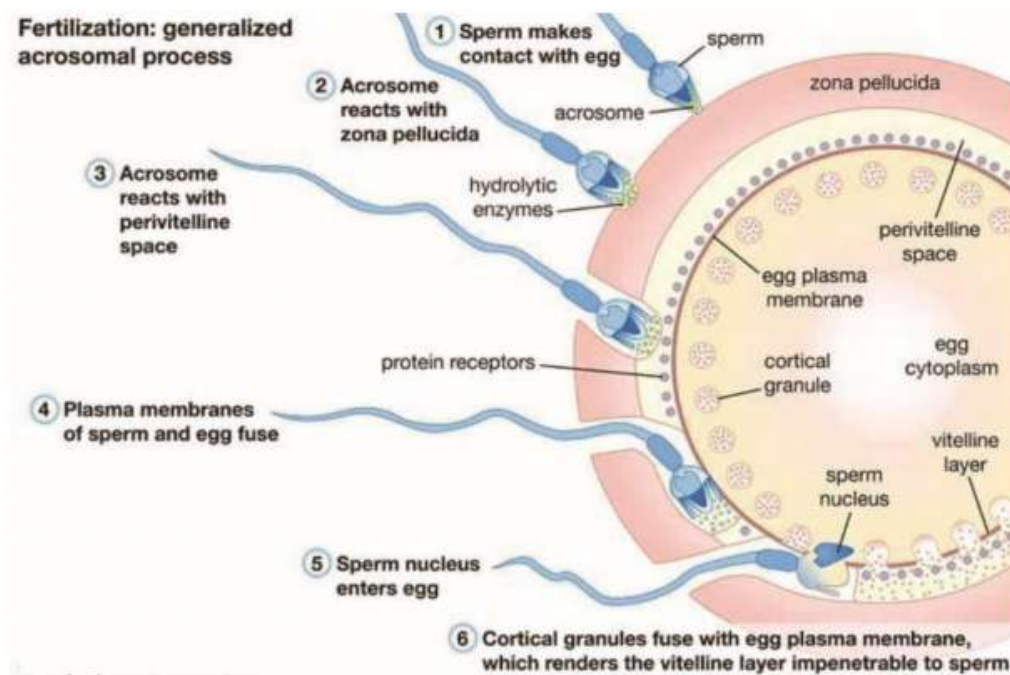


Fig. Fertilization generalized acrosomal process

Fertilization:

After a sperm cell comes in contact with the outer layers of an egg cell, the acrosome, which is a prominence at the anterior tip of the spermatozoa, undergoes a series of well-defined structural changes that opens a path for the sperm nucleus.

During their passage through the female genital tract of mammals, spermatozoa undergo physiological change, called capacitation, which is a prerequisite for their participation in fertilization; they are able to undergo the acrosome reaction, traverse the egg envelopes, and reach the interior of the egg. Dispersal of

cells in the outer egg envelope (corona radiata) is caused by the action of an enzyme (hyaluronidase) that breaks down a substance (hyaluronic acid) binding corona radiata cells together. The enzyme may be contained in the acrosome and released as a result of the acrosome reaction, during passage of the spermatozoon through the corona radiata. The reaction is well advanced by the time a spermatozoon contacts the thick coat surrounding the egg itself (zona pellucida).

Specificity of sperm-egg interaction:

Fertilization is strictly species-specific, and the egg's coating, the zona pellucida, plays an important role in the binding process between sperm and egg. In general, the biochemistry of the zona pellucida of one species differs from that of another, and thus it only matches up and binds with sperm of the appropriate species.

Prevention of polyspermy:

Most animal eggs are monospermic; i.e., only one spermatozoon is admitted into an egg. In mammalian eggs defense against polyspermy depends on properties of the zona pellucida; i.e., when a spermatozoon has started to move through the zona, it does not allow the penetration of additional spermatozoa (zona reaction).

Formation of the fertilization membrane:

The most spectacular changes that follow fertilization occur at the egg surface. An immediate response to fertilization is the raising of a membrane,

called a vitelline membrane from the egg surface. In the beginning the membrane is very thin; soon, however, it thickens, develops a well-organized molecular structure, and is called the fertilization membrane. At the same time an extensive rearrangement of the molecular structure of the egg surface occurs. The events leading to formation of the fertilization membrane require about one minute.

At the point on the outer surface of the egg at which a spermatozoan attaches, the thin vitelline membrane becomes detached. As a result the membranes of the cortical granules come into contact with the inner aspect of the egg's plasma membrane and fuse with it, the granules open, and their contents are extruded into the perivitelline space; i.e., the space between the egg surface and the raised vitelline membrane. Part of the contents of the granules merge with the vitelline membrane to form the fertilization membrane; if fusion of the contents of the cortical granules with the vitelline membrane is prevented, the membrane remains thin and soft. Another material that also derives from the cortical granules covers the surface of the egg to form a transparent layer, called the hyaline layer which plays an important role in holding together the cells (blastomeres) formed during division, or cleavage of the egg.

Formation of the zygote nucleus

After its entry into the egg cytoplasm, the spermatozoal nucleus, now called the male pronucleus, begins to swell, and its chromosomal material disperses and becomes similar in appearance to that of the female pronucleus. Although the membranous envelope surrounding the male pronucleus rapidly disintegrates in the egg, a new envelope promptly forms around it. The male pronucleus, which rotates 180° and moves towards the egg nucleus, initially is accompanied by two

structures (centrioles) that function in cell division. After the male and female pronuclei have come into contact, the spermatozoal centrioles give rise to the first cleavage spindle, which precedes division of the fertilized egg.