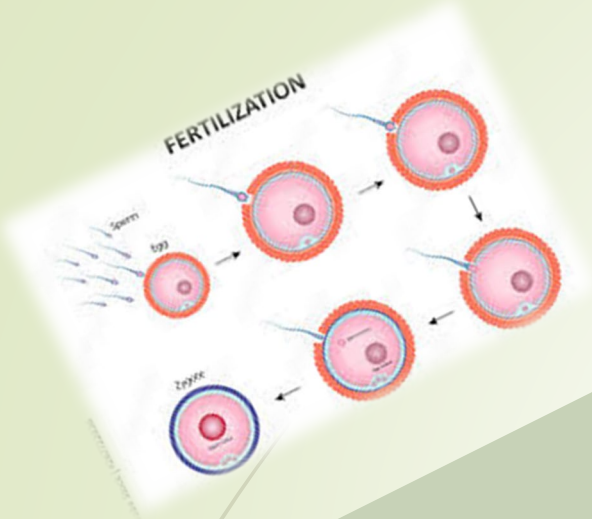
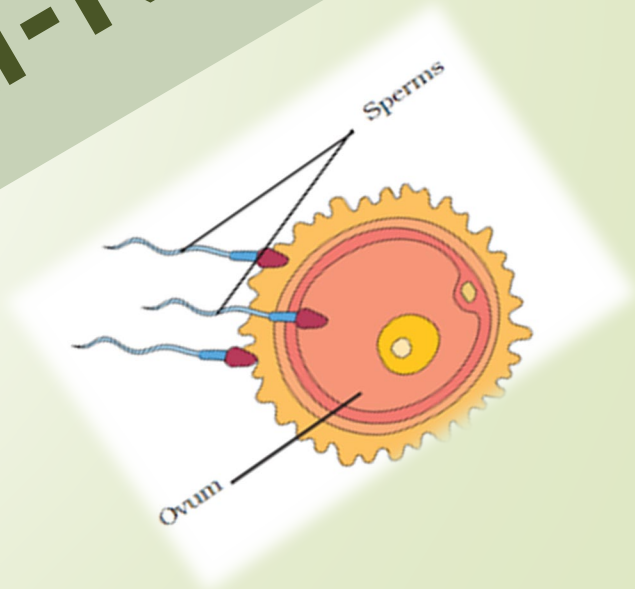


Fertilization

(2nd lecture)

Dr. Azal N. Al-Nusear



Fertilization: the process of a single sperm cell combining with single egg cell to form a zygote..

As a consequence of fertilization, the diploid number of chromosomes is restored, the sex of the individual is determined and biological variation results from the integration of paternal and maternal hereditary characteristics.

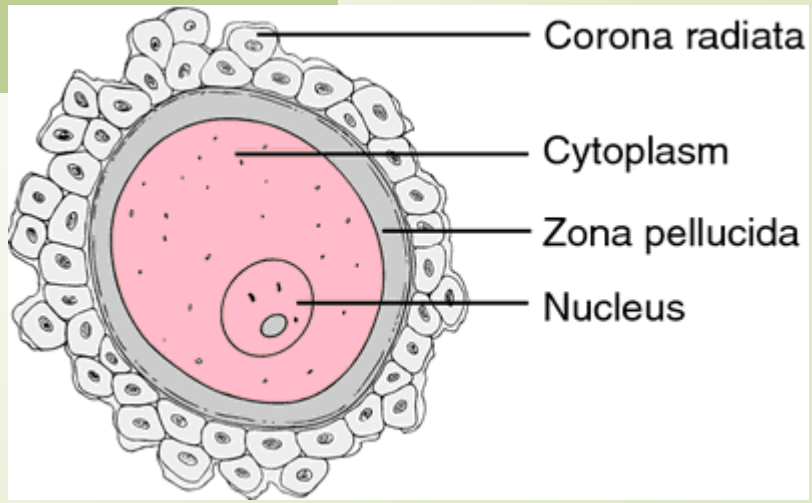
The egg is the largest cell produced in most animals species; a human egg cell is approximately 16 times larger than a human sperm cell. The eggs of different species have similar features in common, including:

1- Yolk: Eggs of different species contain varying amounts of yolk, the nutrients to support growth of the developing embryo.

2-Jelly layer or zona pellucida: Each egg is surrounded by a jelly layer, composed of glycoproteins (proteins that have sugars stuck to them), that releases species-specific chemo-attractants (chemical-attractors) that guide sperm to the egg. In mammals, this layer is called the zona pellucida. In placental mammals, a layer of follicular cells surrounds the zona pellucida.

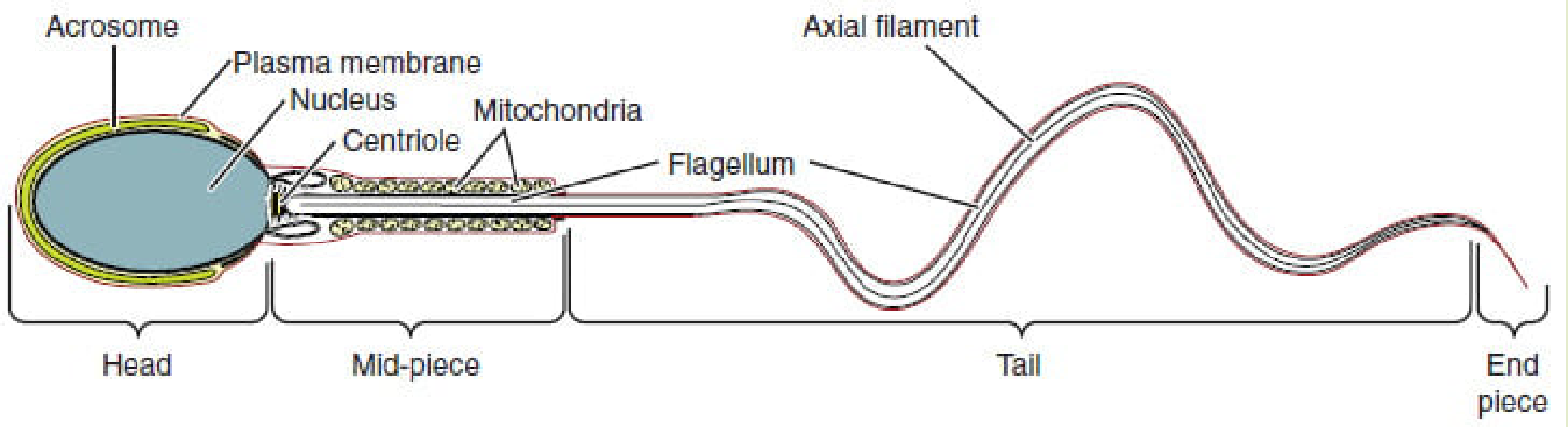
- **Vitelline envelope:** The zona pellucida/jelly layer is separated from the egg by a membrane called the **vitelline envelope**, which is a second membrane outside of the cell's plasma membrane.

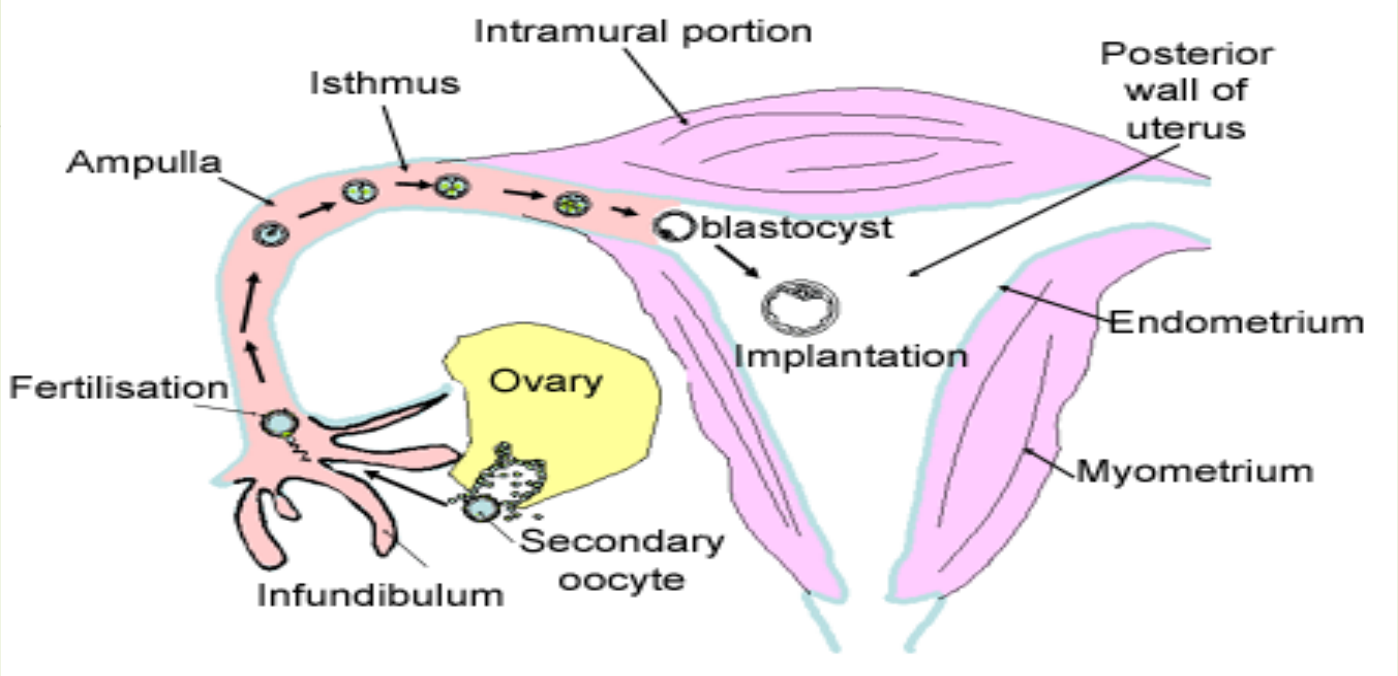
- **Cortical granules:** Just underneath the egg's plasma membrane are **cortical granules**, vesicles containing enzymes that will degrade the proteins that hold the vitelline envelope around the plasma membrane when fertilization occurs (more on this below).



The sperm is one of the smallest cells produced in most animal species. The sperm of different species have similar features in common, including:

- **Sperm structure:** The sperm consists of **head** containing tightly packed DNA, a **flagellar tail** for swimming, and many **mitochondria** to provide power for sperm movement.
- **Binding proteins:** The plasma membrane of the sperm contains proteins called **binding**, which are species-specific proteins that recognize and bind to receptors on the egg plasma membrane.
- **Acrosome:** In addition to the nucleus, the sperm head also contains an organelle called the **acrosome**, which contains digestive enzymes that will degrade the jelly layer/zona pellucida to allow the sperm to reach the egg plasma membrane.


Acrosome
Plasma membrane
Nucleus
Centriole
Mitochondria
Flagellum
Axial filament
Head
Mid-piece
Tail
End piece



Fertilization occurs in the ampullary region of the uterine tube. This is the widest part of the tube and is close to the ovary. Sperm may remain viable in the female reproductive tract for several days.

Internal Fertilization

Internal fertilization occurs most often in land-based animals, although some aquatic animals also use this method. Internal fertilization has the advantage of protecting the fertilized egg from dehydration on land. The embryo is isolated within the female, which limits predation on the young. Internal fertilization enhances the fertilization of eggs by a specific male. Fewer offspring are produced through this method, but their survival rate is higher than that for external fertilization.

There are three ways that offspring are produced following internal fertilization.

1-oviparity:

fertilized eggs are laid outside the female's body and develop there, receiving nourishment from the yolk that is a part of the egg. This occurs in most bony fish, many reptiles, some cartilaginous fish, most amphibians, two mammals, and all birds. Reptiles and insects produce leathery eggs, while birds and turtles produce eggs with high concentrations of calcium carbonate in the shell, making them hard. Chicken eggs are an example of this second type.

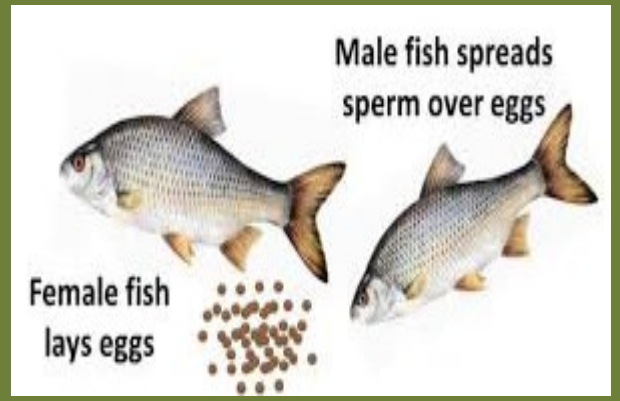
2-**ovoviparity**: fertilized eggs are retained in the female, but the embryo obtains its nourishment from the egg's yolk and the young are fully developed when they are hatched. This occurs in some bony fish (like the guppy), some sharks, some lizards, some snakes (such as the garter snake), some vipers, and some invertebrate animals (like the Madagascar hissing cockroach).

3-**viviparity**: the young develop within the female, receiving nourishment from the mother's blood through a placenta. The offspring develops in the female and is born alive. This occurs in most mammals, some cartilaginous fish, and a few reptiles.

External Fertilization

External fertilization usually occurs in aquatic environments where both eggs and sperm are released into the water. After the sperm reaches the egg, fertilization takes place. Most external fertilization happens during the process of spawning where one or several females release their eggs and the male(s) release sperm in the same area, at the same time. The release of the reproductive material may be triggered by water temperature or the length of daylight. Nearly all fish spawn, as do crustaceans (such as crabs and shrimp), mollusks (such as oysters).

Many aquatic animals release ova and sperm into the water and fertilization takes place in this aqueous environment. that gametes are released at approximately the same time and in close proximity to each other, Relative to mammalian species, aquatic animals and amphibians produce large quantities of zygotes; however, In contrast, birds and mammals produce relatively fewer zygotes.



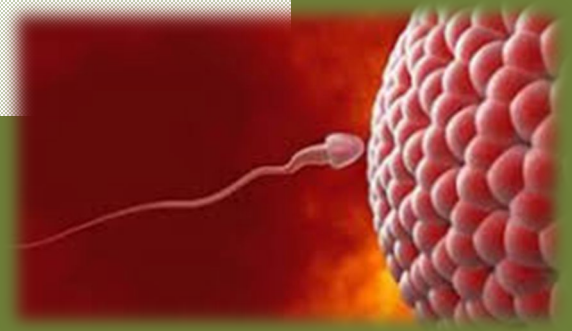
Before fertilization, the sperm must gain the ability to disintegrate the various oocyte barriers.

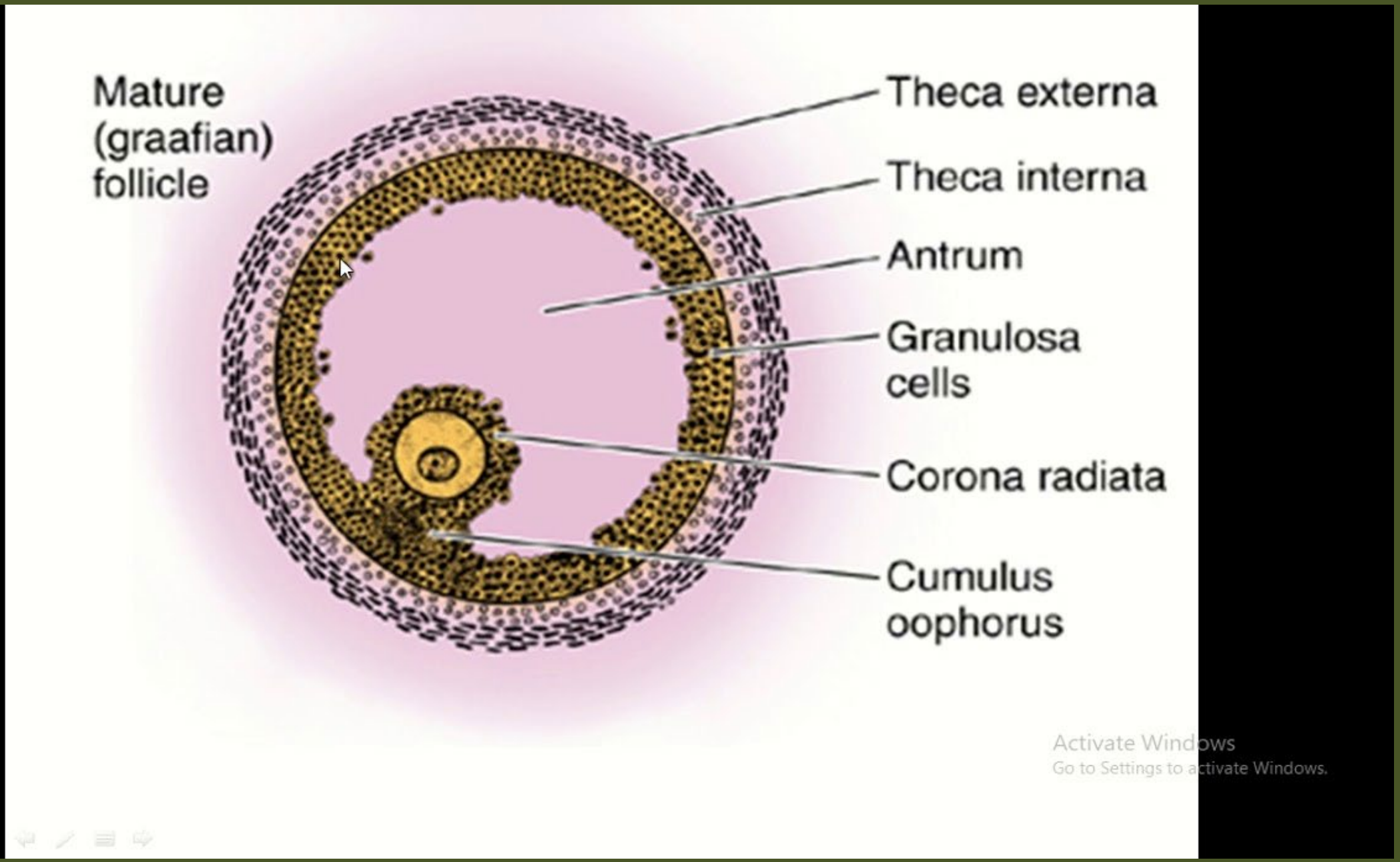
1. **First barrier** is formed by **cells of corona radiata**.
2. **Second barrier** is formed by **zona pellucida** made of glycoproteins, ZP1, ZP2, and ZP3.
3. **Third barrier** is formed by **vitelline membrane** of oocyte itself.

This ability is achieved by two processes

(a) **capacitation.**

(b) **acrosome reaction**.



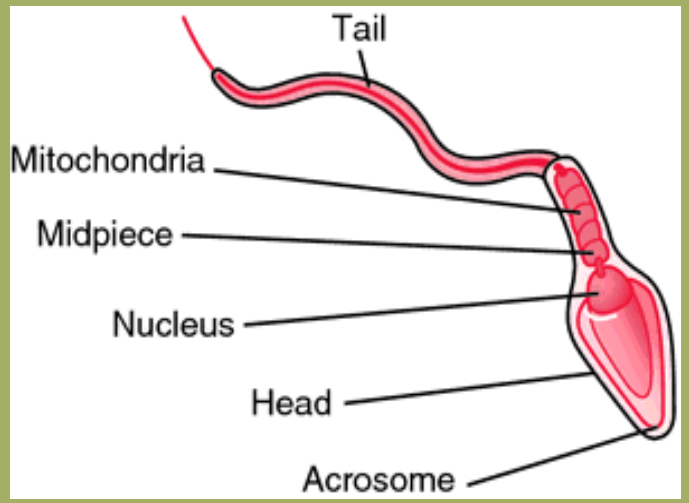


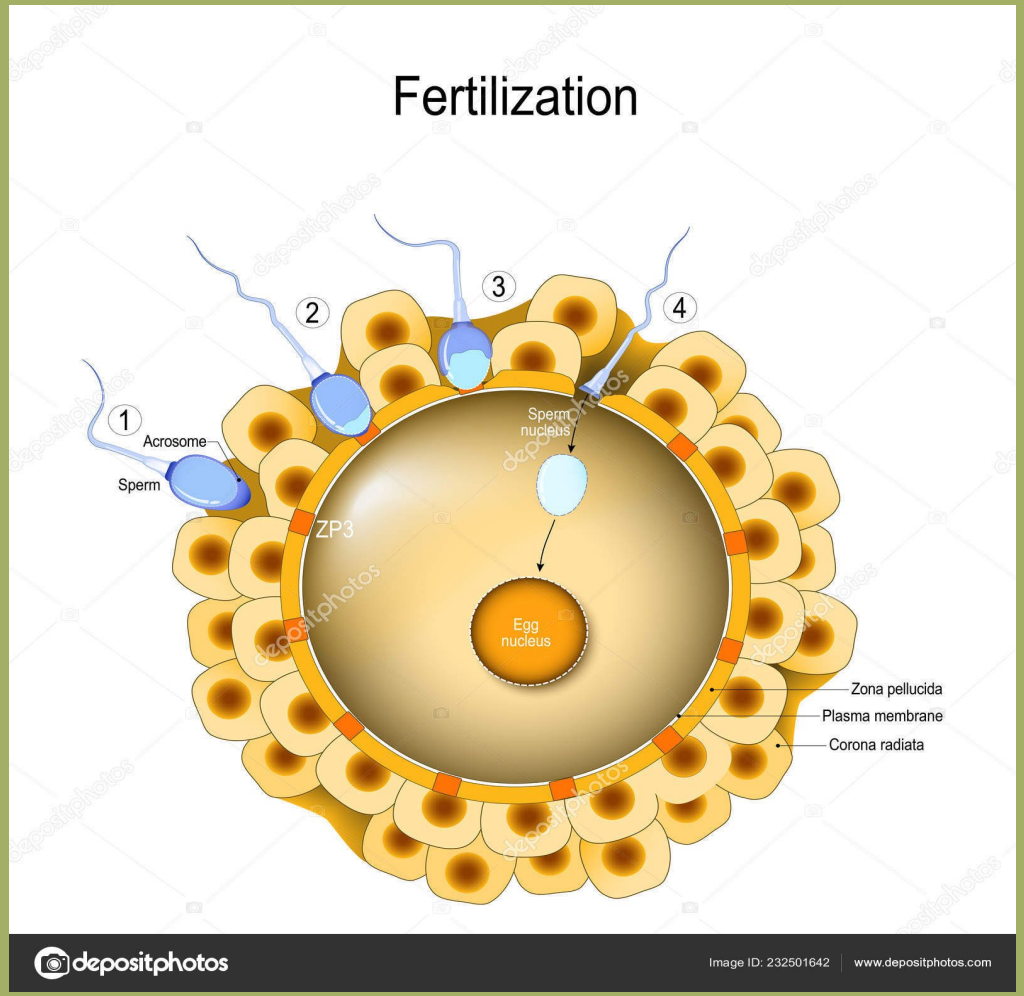
Capacitation

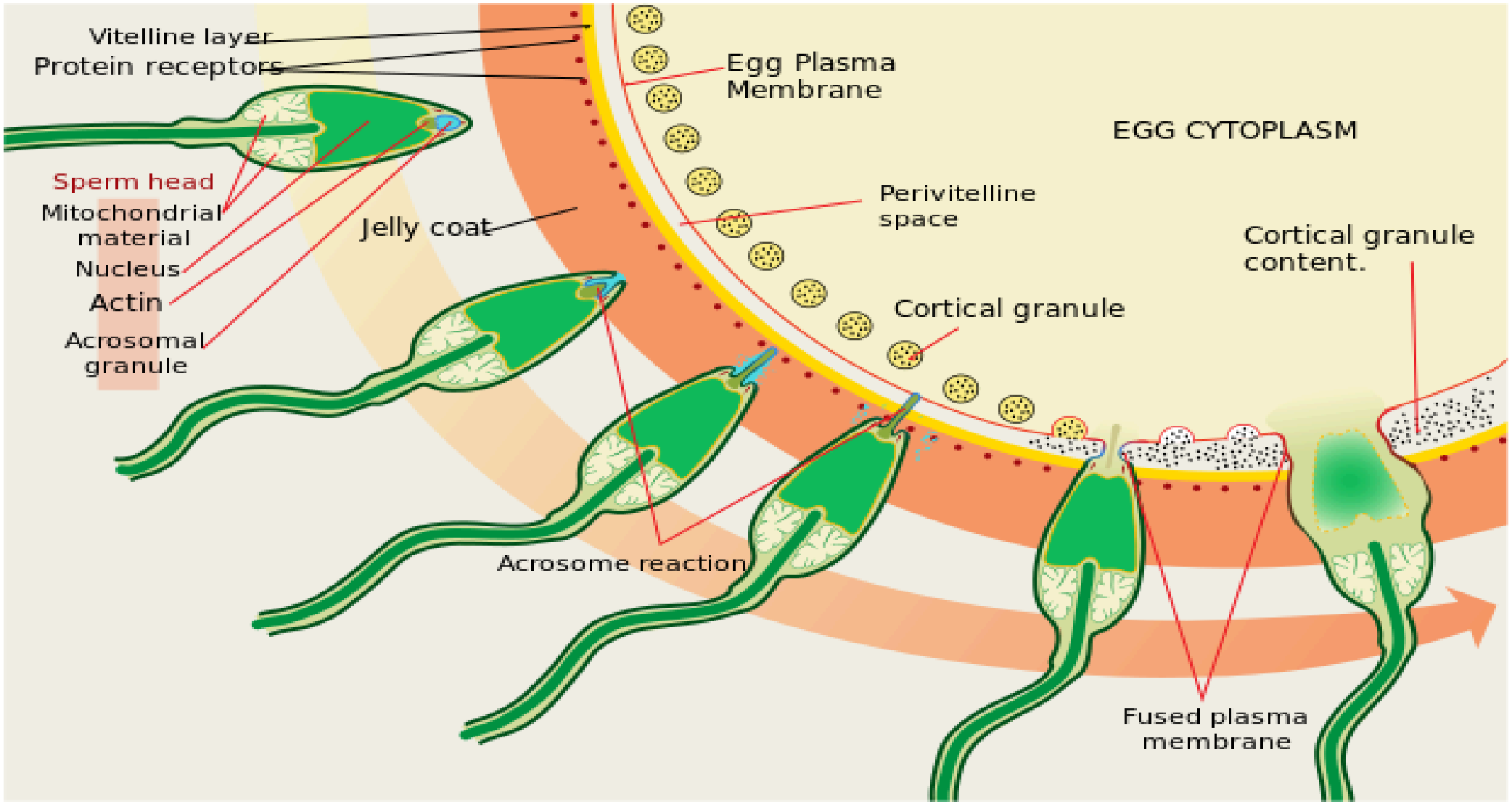
is a period of conditioning in the female reproductive tract. Much of this conditioning, which occurs in the uterine tube, entails epithelial interactions between the sperm and mucosal surface of the tube.

During this time a glycoprotein coat and seminal plasma proteins are removed from the plasma membrane that overlies the acrosomal region of the spermatozoa. Only capacitated sperm can pass through the corona cells and undergo the acrosome reaction.

The **acrosome reaction,** which occurs after binding to the zona pellucida, is induced by zona proteins. This reaction culminates in the release of enzymes needed to penetrate the zona pellucida, including acrosin and trypsin-like substances

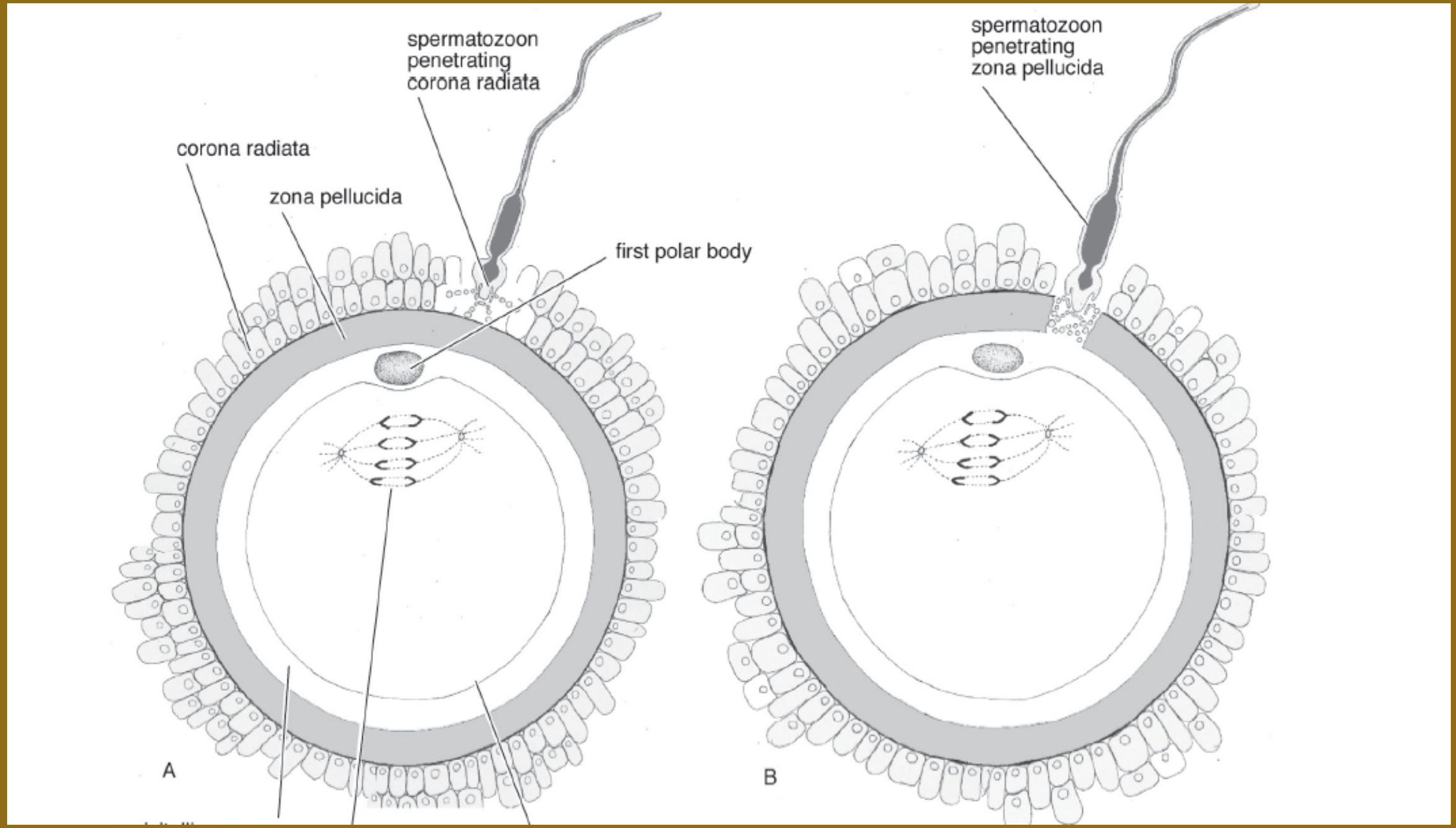


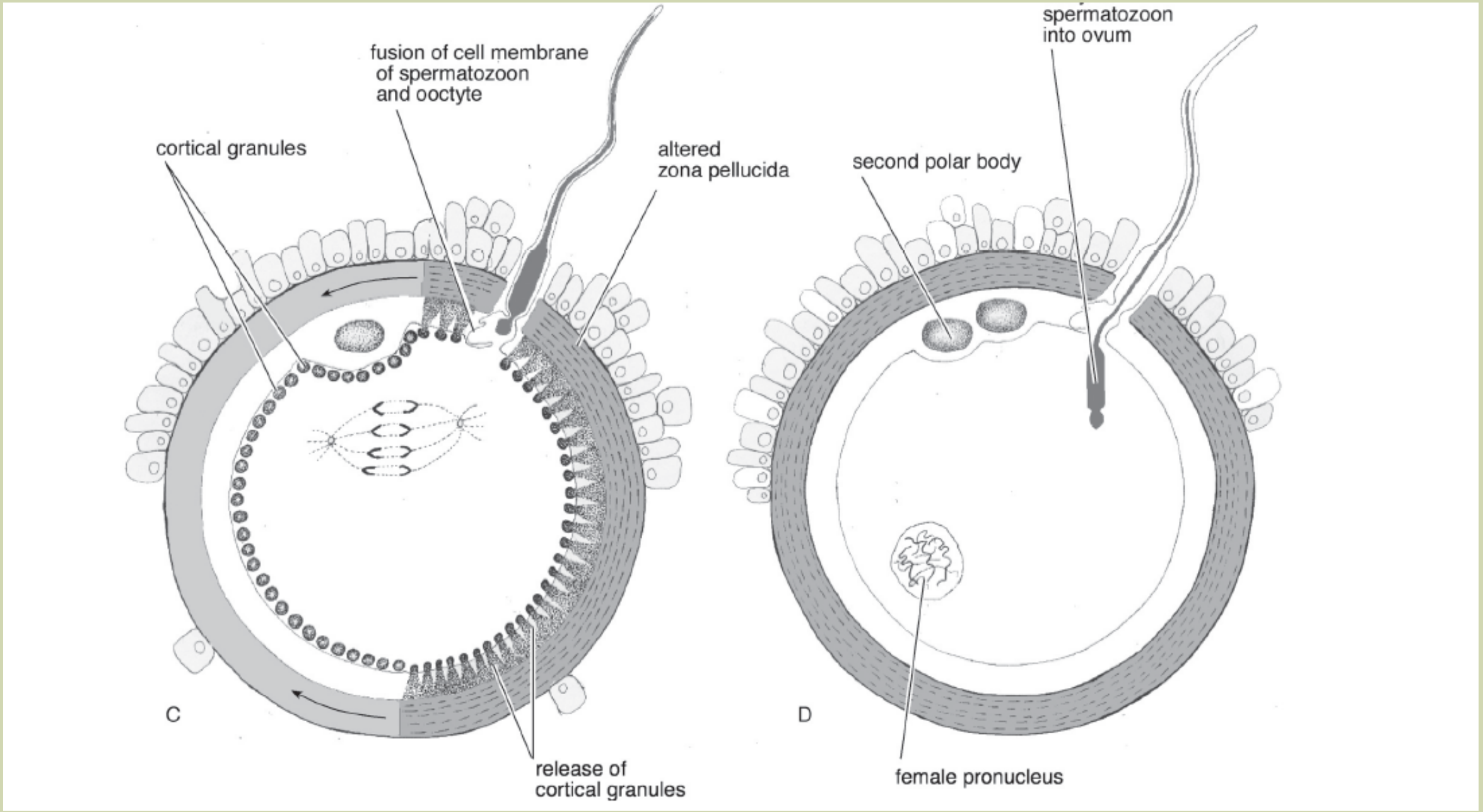


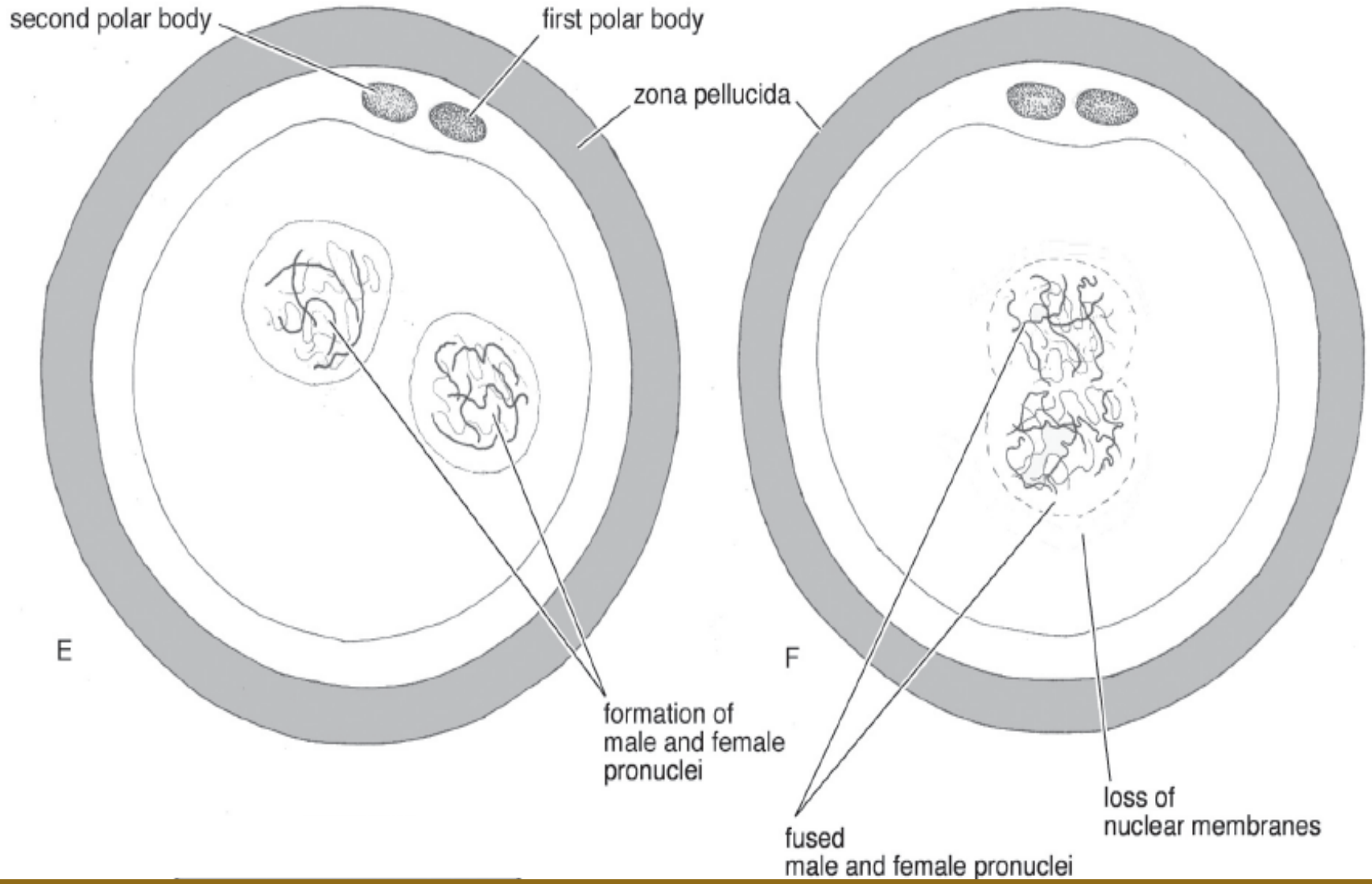

Vitelline layer
Protein receptors
Egg Plasma Membrane
EGG CYTOPLASM
Sperm head
Mitochondrial material
Nucleus
Actin
Acrosomal granule
Jelly coat
Perivitelline space
Cortical granule content.
Cortical granule
Acrosome reaction
Fused plasma membrane

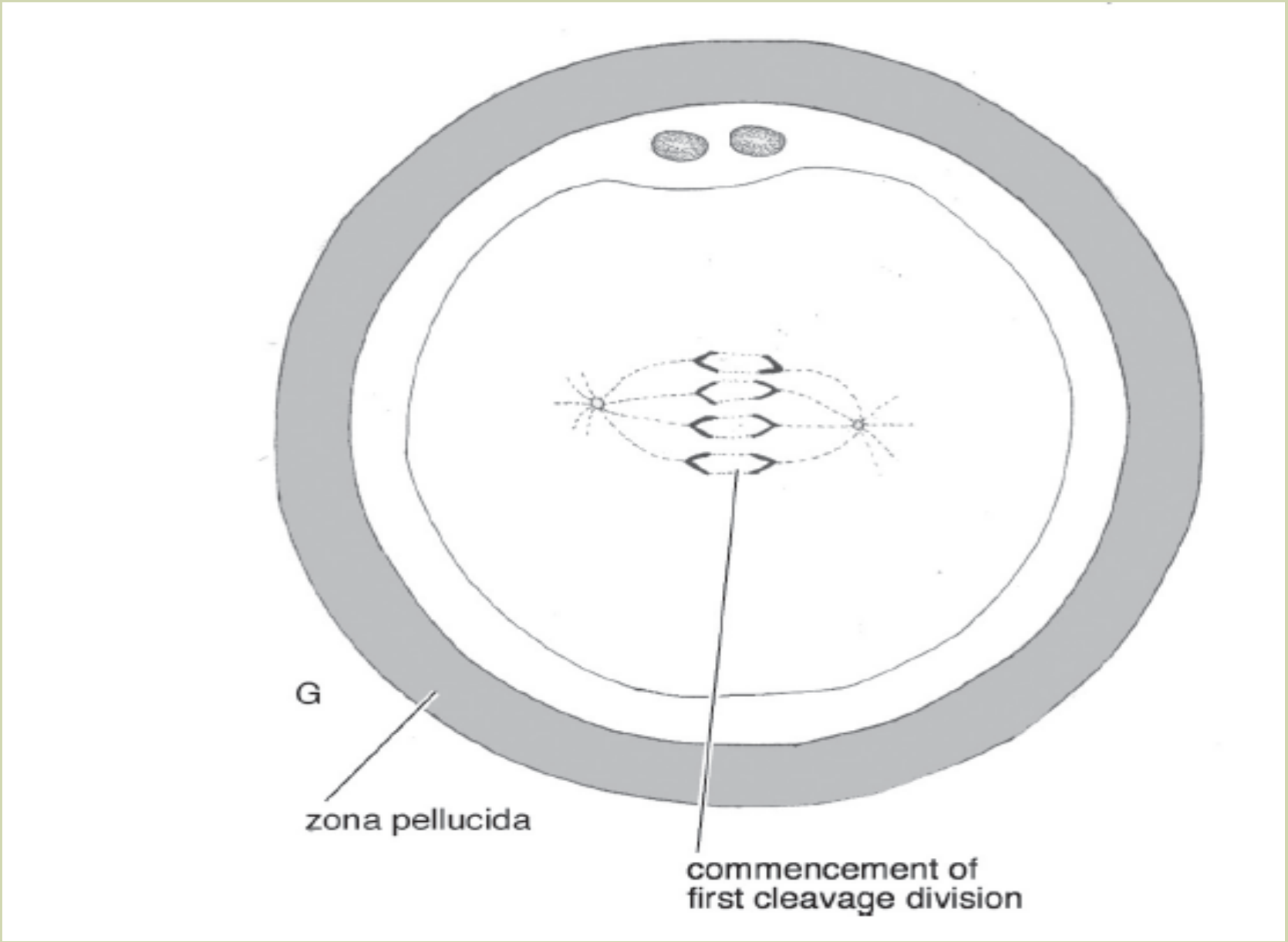
Steps/Phases of Fertilization

1. **Penetration of corona radiata:**
2. **Penetration of zona pellucida:**
3. **Fusion of sperm and oocyte cell membranes**
4. **Completion of second meiotic division of oocyte and formation of female pronucleus**
5. **Formation of male pronucleus**
6. **Formation of zygote**


spermatozoon
penetrating
corona radiata
corona radiata
zona pellucida
first polar body
A
spermatozoon
penetrating
zona pellucida
B


fusion of cell membrane
of spermatozoon
and ooctyte
cortical granules
altered
zona pellucida
C
release of
cortical granules
spermatozoon
into ovum
second polar body
D
female pronucleus


second polar body
first polar body
zona pellucida
E
formation of
male and female
pronuclei
F
fused
male and female pronuclei
loss of
nuclear membranes


G
zona pellucida
commencement of
first cleavage division

Results of Fertilization:

When the oocyte is fertilized by the sperm a life of new individual begins. The main results of fertilization are as follows.

1. **Completion of second meiotic division of the female gamete (i.e., secondary oocyte)**: As soon as the sperm enters into the secondary oocyte the latter completes its second meiotic division and extrudes the second polar body into the perivitelline space.

2. **Restoration of diploid number of chromosomes:** The male and female pronuclei (both haploid) fuse with each other to restore normal diploid number of chromosomes.

3. **Determination of chromosomal sex of the new individual**: The oocytes are only of one type, i.e., they contain only ‘X’ chromosomes whereas the sperms are of two types: (a) ‘Y’-bearing sperms (androsperms) and (b) ‘X’-bearing sperms (gynosperms).

If an oocyte (X) is fertilized by ‘Y’- bearing sperm the result will be a male baby and if an oocyte is fertilized by an ‘X’-bearing sperm the result will be a female baby. Therefore, it is the father who is responsible for determination of the sex of the baby and not the mother

.4. **Initiation of cleavage**: After fertilization, the zygote undergoes a series of rapid mitotic divisions. This is called cleavage.

5. Variation of species: It occurs due to mingling of maternal and paternal chromosomal complements of two new species. If the ovum of one species, viz., Tiger is fertilized by the sperm of other species, viz., Lion, the baby born will be called Liger. Similarly, if the ovum of female donkey is fertilized by the sperm of horse the baby born will be called mule.