FERTILIZATION

Biology in concert – how do sperm and egg find each other?

Fertilization as a process includes:

- membrane contact between sperm and egg
- entry of sperm cell into egg
- prevention of polyspermy
- metabolic activation of the egg
- meiotic completion by the egg
- formation and fusion of male and female pronuclei
- preparation for first mitosis (beginning of cleavage)

FERTILIZATION in the SEA URCHIN

Gamete release and transport

Sperm penetration of the egg (the acrosomal reaction)

1. sperm cell membrane changes upon contact with the egg jelly coat
   increased Ca++ permeability
   increased Na+ permeability
2. Ca++ flux into sperm causes fusion of acrosomal membrane with sperm cell membrane and release of acrosomal enzymes
3. Na+ influx, coupled with H+ efflux, leads to increased intracellular pH
4. G(lobular)-actin changes to F(ilamentous)-actin, forming the basis for the acrosomal process which is covered with glycoproteins called bindins

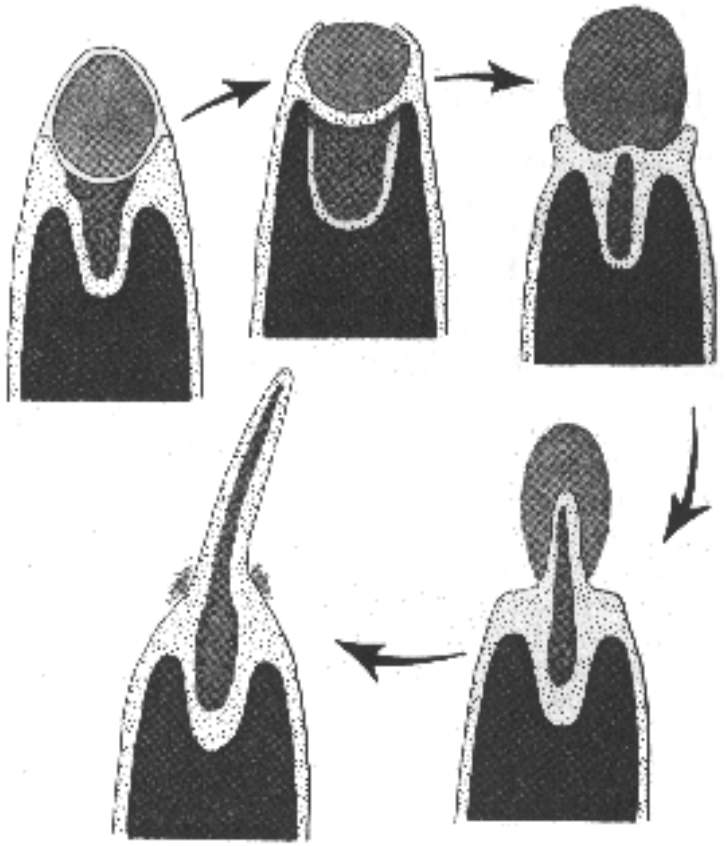


FIG. 4-1

FERTILIZATION in the SEA URCHIN

Sperm penetration of the egg (the acrosomal reaction)

5. The acrosomal process, aided by increased sperm motility and digestion by acrosomal enzymes (lysins), presses into the jelly coat
6. As acrosomal process contacts the vitelline envelope, bindins attach to ZP3 species-specific receptors
7. One sperm finally penetrates the vitelline envelope and makes the initial contact between sperm membrane and egg membrane
8. Increased swimming movements cause the sperm to press harder against the egg until the two membranes begin to fuse
9. This initiates the blocks to polyspermy

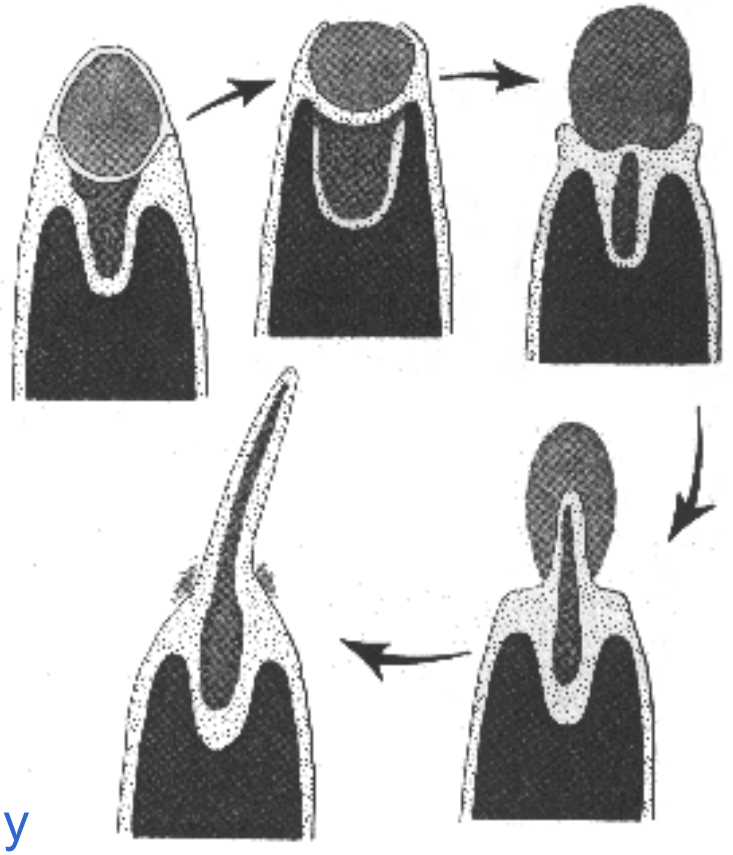


FIG. 4-1

FERTILIZATION in the SEA URCHIN

Blocks to polyspermy

Fast block to polyspermy

1. Initial contact between cell membrane of acrosomal process and egg cell membrane causes rapid influx of Na+ into egg (2 – 3 seconds to get in place)
2. Na+ influx causes a positive membrane potential to sweep across egg cell membrane, persisting for ~60 seconds

1. Accomplishes two things:

   -- sperm cannot bind to the negatively-charged egg

   -- Na+ influx initiates the slow block to polyspermy by mobilizing stored Ca++ in the egg

FERTILIZATION in the SEA URCHIN

Blocks to polyspermy

Slow block to polyspermy

What are cortical granules?

What is the cortical reaction?

1. Na+ causes release of stored Ca++ within the egg
2. Increased free Ca++ causes cortical granules to attach to egg cell membrane, fuse with it, and burst into the perivitelline space. Granular contents then:

-- Proteolytic enzymes from granules breaks bonds between vitelline membrane and egg cell membrane

-- GAGs hydrate, resulting in the "raising of the fertilization membrane"

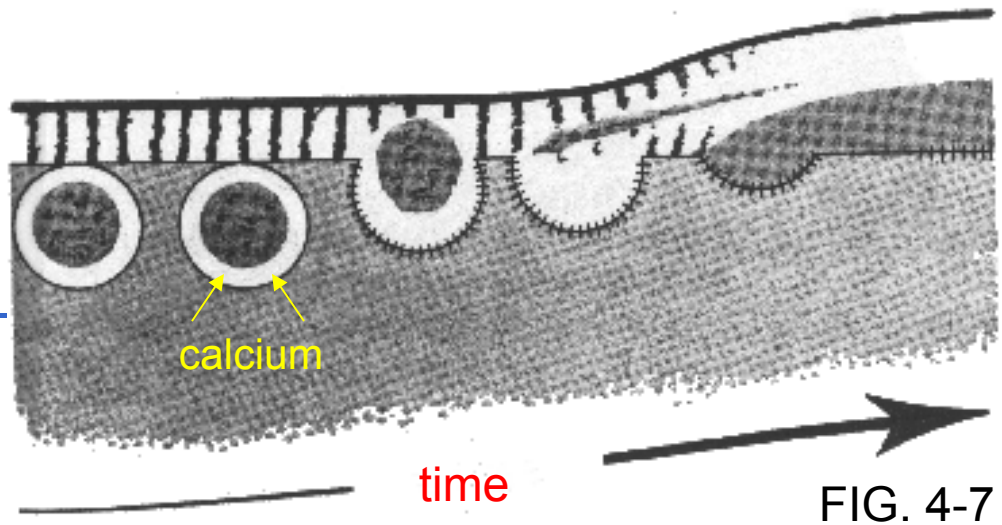


FIG. 4-7

FERTILIZATION in the SEA URCHIN

Blocks to polyspermy

Slow block to polyspermy

-- Granular enzymes alter sperm receptors, causing any attached sperm to fall off

-- Ovoperoxidase causes cross-linking of tyrosine residues in released structural proteins, leading to hardening of the fertilization membrane

-- Hydrogen peroxide kills any sperm that have penetrated the vitelline envelope

Accomplishments of the blocks:

1. No polyspermy
2. Extra cell membrane for cleavage
3. Metabolic activation of the egg

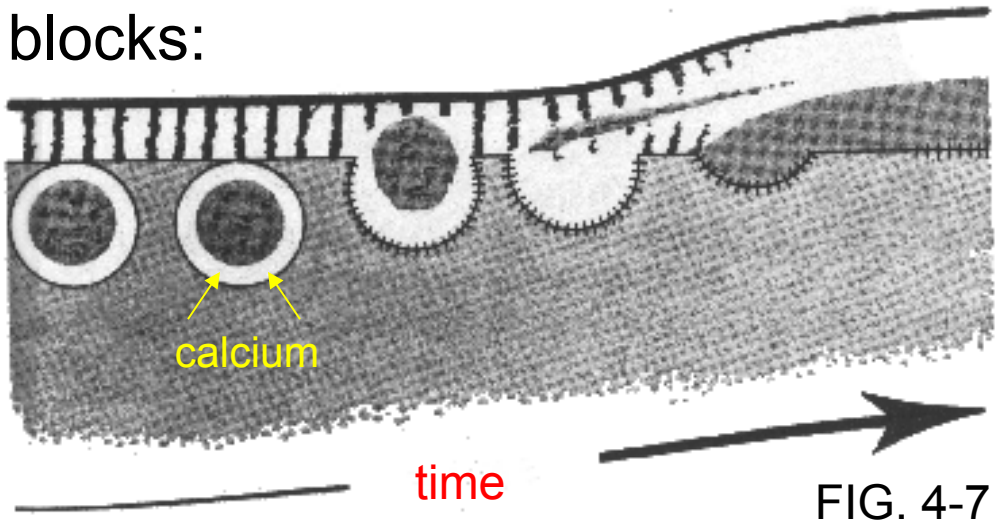


FIG. 4-7

FERTILIZATION in the SEA URCHIN

Metabolic activation of the egg

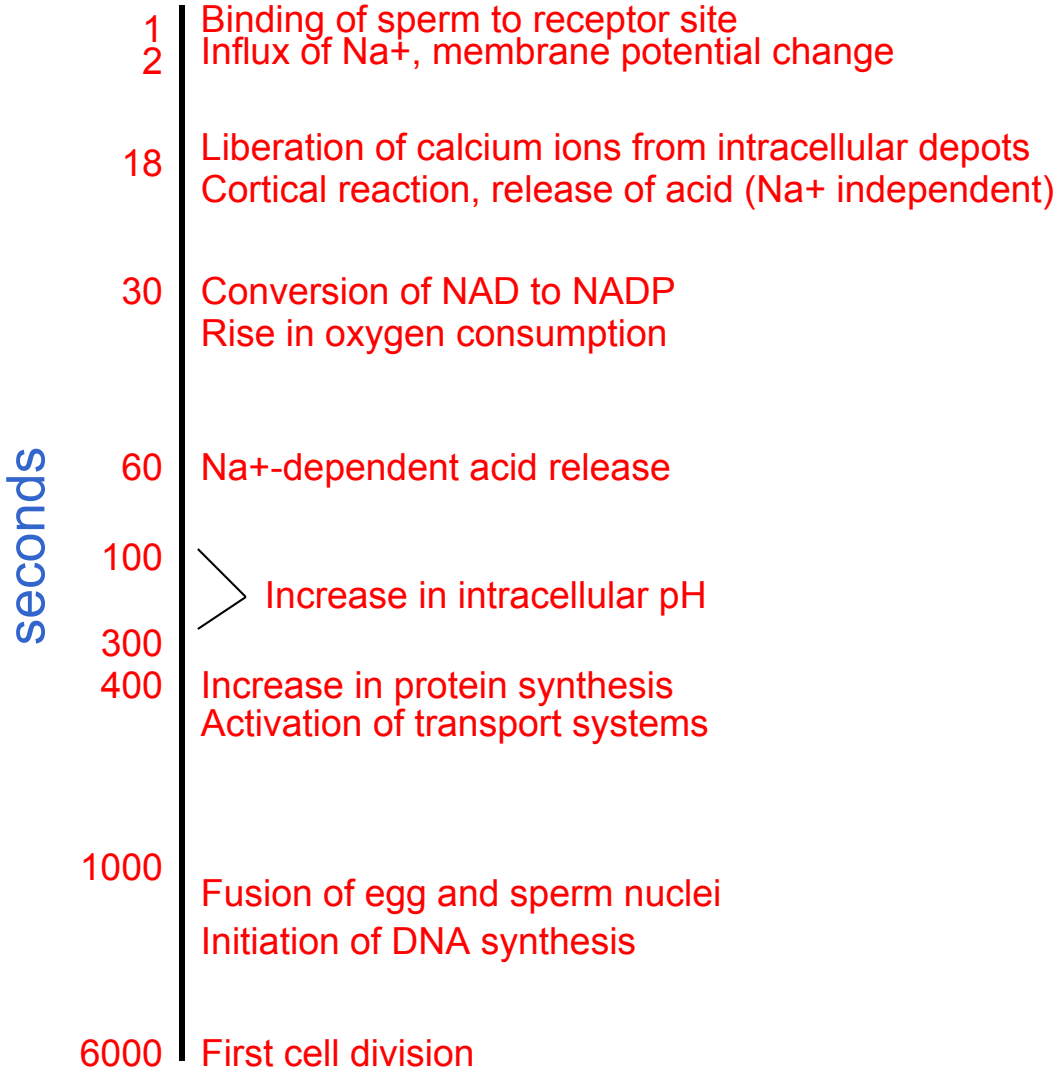


FIG. 4-8

FERTILIZATION in the SEA URCHIN

- Penetration of spermatozoon into egg
  - What happens to the sperm cell membrane?
  - What happens to the sperm chromatin?
  - What happens to the other sperm components?
- Fusion of the male and female genetic material
  - What is the sperm aster?
  - What is pronuclear fusion?
- Fertilization is over when…

MAMMALIAN FERTILIZATION

Union of gametes

- What is capacitation?
- Sperm must meet the egg in the upper 1/3 of the oviduct for a successful pregnancy. How do they get there?
- Penetration of the corona radiata uses hyaluronidase released from the acrosome during acrosome reaction and lashing of flagellum.
- Sperm bind to ZP3 receptors on zona pellucida.
- Narrow path is digested through zona pellucida, using acrosin.
- Sperm membrane contacts egg membrane.
- Blocks to polyspermy are initiated and metabolic activation of the egg begins.

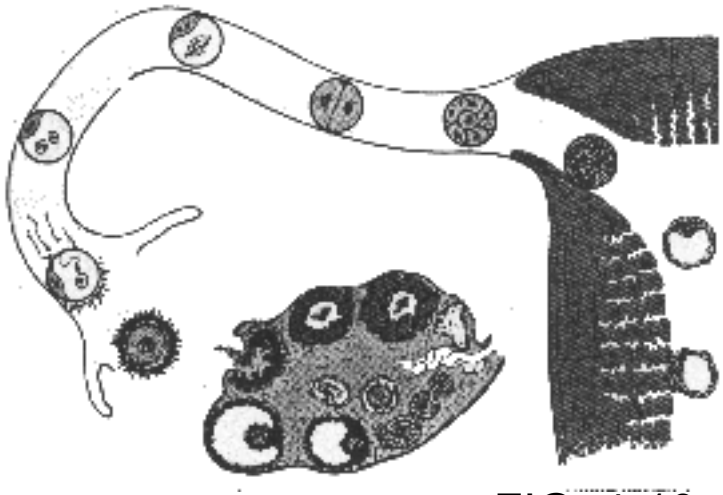


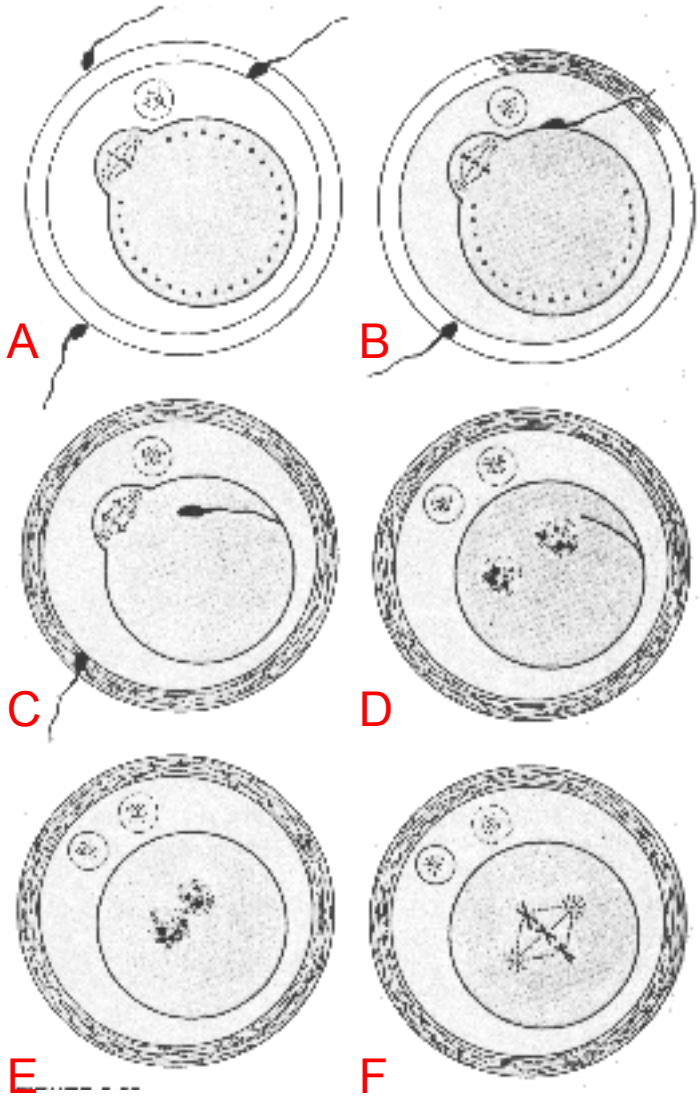
FIG. 4-10

MAMMALIAN FERTILIZATION

Development and fusion of pronuclei

- Second meiotic block lifted
- Sperm nuclear membrane breaks down
- Nuclear contents of sperm and egg interact
- Decondensation of nuclear DNA
- Both sets of DNA replicate
- Chromosomes align in metaphase for first mitotic division of cleavage

FIG. 4-13



ESTABLISHMENT OF POLARITY

What are the polar axes of the vertebrate body?

- Craniocaudal (anteroposterior) axis
- Dorsoventral axis
- Mediolateral axis

Amphibian polarity

- Primary polarity determined by distribution of yolk in egg
  - -- animal pole vs. vegetal pole (craniocaudal)
- Secondary polarity established at fertilization
  - --reorganization of cytoplasm to form the gray crescent (dorsoventral)

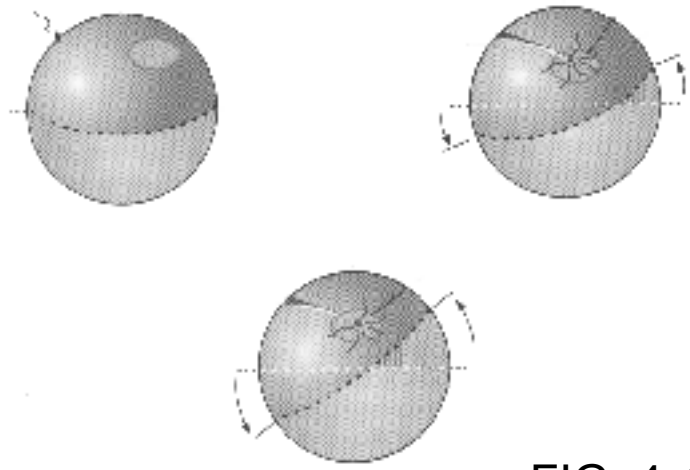


FIG. 4-16

ESTABLISHMENT OF POLARITY

- Polarity in birds
  - Craniocaudal axis seems to be determined by gravity
  - Dorsoventral axis related to cells facing yolk
  - Mediolateral axis (?)
- Polarity in mammals (?)

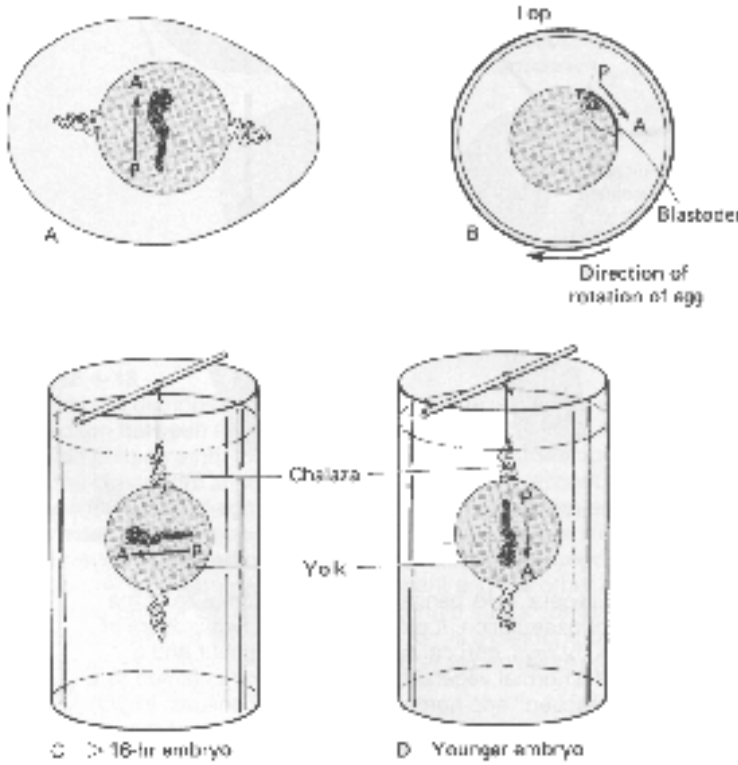


FIG. 4-20