# Fertilization and Early Growth

When an egg cell is released from the ovary it is arrested in metaphase of meiosis II and is termed a secondary oocyte. **Fertilization** occurs when a sperm penetrates an egg cell at this stage and the sperm and egg nuclei unite to form the zygote. Fertilization is always regarded as time 0 in a period of gestation (pregnancy) and has five distinct stages (below). After fertilization, the zygote begins its **development** i.e. its growth and differentiation into a multicellular organism (see next page).

## Fertilization (Time 0)

The stages in fertilization are represented below in a numbered sequence (1-5)

### 1. Capacitation

The surface of the sperm cell undergoes changes that are essential to enabling the acrosome reaction and sperm entry.

### 2. The Acrosome Reaction

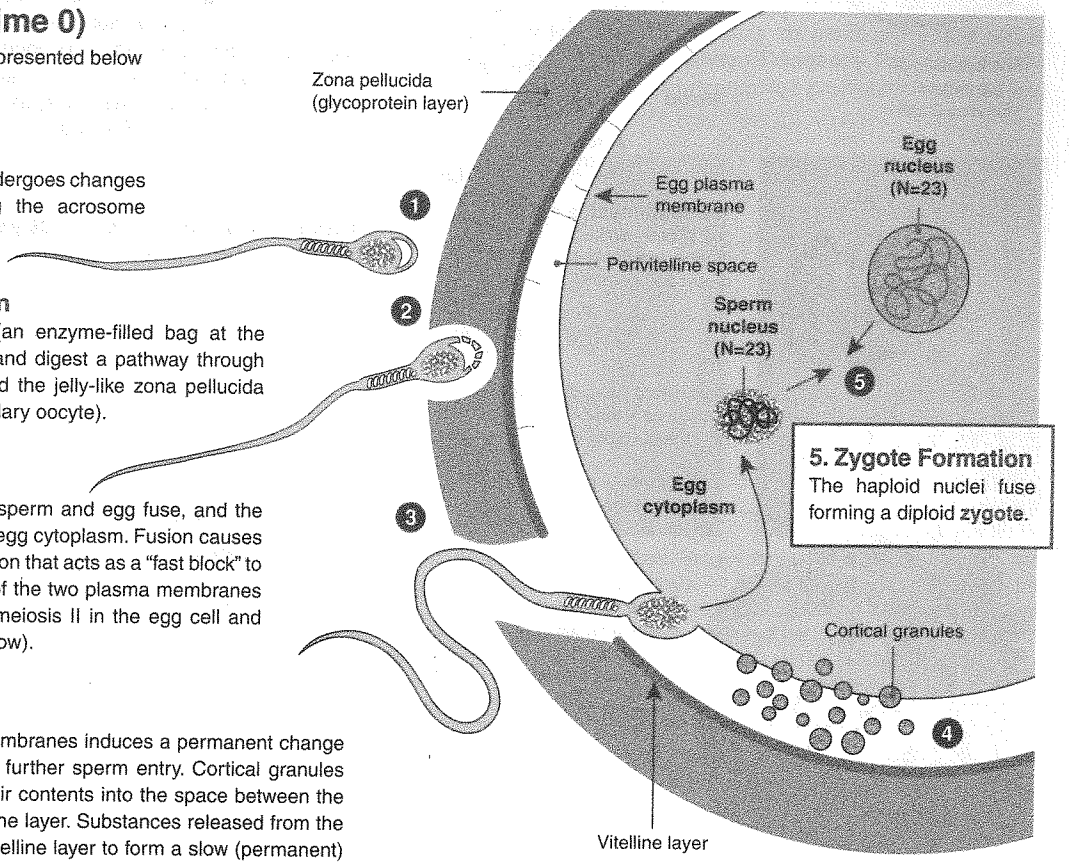
Enzymes from the acrosome (an enzyme-filled bag at the tip of the sperm) are released and digest a pathway through the follicle cells (not shown) and the jelly-like zona pellucida surrounding the egg cell (secondary oocyte).

### 3. Fusion of Sperm Head

The plasma membranes of the sperm and egg fuse, and the nucleus of the sperm enters the egg cytoplasm. Fusion causes a sudden membrane depolarization that acts as a "fast block" to further sperm entry. The fusion of the two plasma membranes also triggers the completion of meiosis II in the egg cell and induces the cortical reaction (below).

### 4. The Cortical Reaction

The fusion of the two plasma membranes induces a permanent change in the egg surface that prevents further sperm entry. Cortical granules in the egg cytoplasm release their contents into the space between the plasma membrane and the vitelline layer. Substances released from the granules raise and harden the vitelline layer to form a slow (permanent) block to further sperm entry.




1. Briefly describe the significant events (and their importance) occurring at each of the following stages of fertilization:

   (a) Capacitation: _____

   _____

   (b) The acrosome reaction: _____

   _____

   (c) Fusion of egg and sperm plasma membranes: _____

   _____

   (d) The cortical reaction: _____

   _____

   (e) Fusion of egg and sperm nuclei: _____

   _____

2. Explain the significance of the blocks that prevent entry of more than one sperm into the egg (polyspermy):

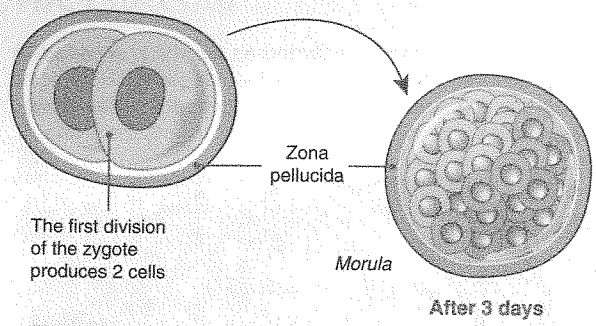
   _____

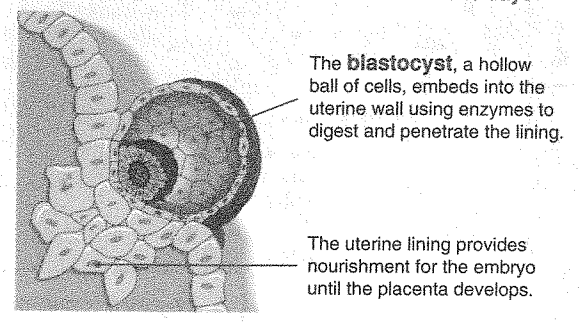
   _____

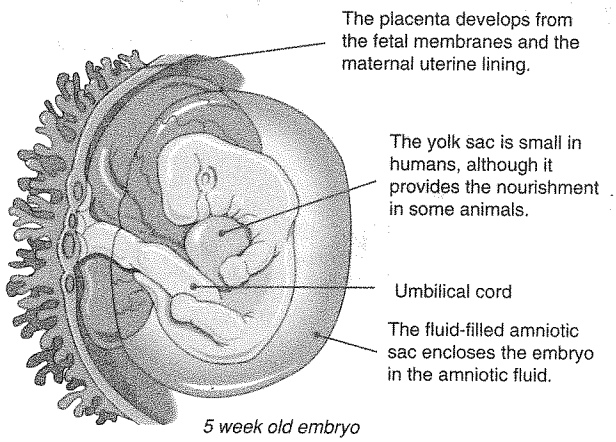
3. (a) Explain why the egg cell, when released from the ovary, is termed a secondary oocyte: _____

   _____

   (b) At which stage is its meiotic division completed? _____




*5 week old embryo*

# Early Growth and Development

## Cleavage and Development of the Morula

Immediately after fertilization, rapid cell division takes place. These early cell divisions are called **cleavage** and they increase the number of cells, but not the size of the zygote. The first cleavage is completed after 36 hours, and each succeeding division takes less time. After three days, successive cleavages have produced a solid mass of cells called the **morula**, (left) which is still about the same size as the original zygote.

## Implantation of the Blastocyst (after 6-8 days)

After several days in the uterus, the morula develops into the blastocyst. It makes contact with the uterine lining and pushes deeply into it, ensuring a close maternal-fetal contact. Blood vessels provide early nourishment as they are opened up by enzymes secreted by the blastocyst. The embryo produces **HCG** (human chorionic gonadotropin), which prevents degeneration of the corpus luteum and signals that the woman is pregnant.

## Embryo at 5-8 Weeks

Five weeks after fertilization, the embryo is only 4-5 mm long, but already the central nervous system has developed and the heart is beating. The embryonic membranes have formed; the amnion encloses the embryo in a fluid-filled space, and the allanto-chorion forms the fetal portion of the placenta. From two months the embryo is called a fetus. It is still small (30-40 mm long), but the limbs are well formed and the bones are beginning to harden. The face has a flat, rather featureless appearance with the eyes far apart. Fetal movements have begun and brain development proceeds rapidly. The placenta is well developed, although not fully functional until 12 weeks. The umbilical cord, containing the fetal umbilical arteries and vein, connects fetus and mother.

4. State what contribution the sperm and egg cell make to each of the following:

   (a) The nucleus of the zygote: Sperm contribution: _____ Egg contribution: _____

   (b) The cytoplasm of the zygote: Sperm contribution: _____ Egg contribution: _____

5. Explain what is meant by cleavage and comment on its significance to the early development of the embryo:

   _____

   _____

6. (a) Explain the importance of implantation to the early nourishment of the embryo: _____

   _____

   (b) Identify the fetal tissues that contribute to the formation of the placenta: _____

   (c) Suggest a purpose of the amniotic sac and comment on its importance to the developing embryo: _____

   _____

   (d) Suggest why the heart is one of the very first structures to develop in the embryo: _____

   _____

7. State why the fetus is particularly prone to damage from drugs towards the end of the first trimester (2-3 months):

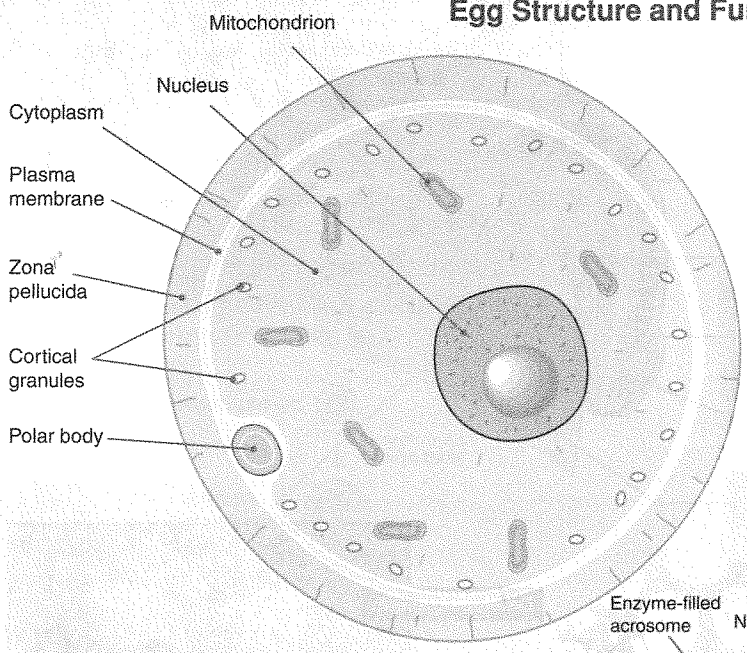
   _____

   _____

# Gametes

**Gametes** (eggs and sperm) are **haploid** sex cells formed by reduction division in the gonads of females and males. Eggs and sperm differ greatly in their size, shape, and number. These differences reflect their different roles in fertilization and reproduction. Human sperm (or spermatozoa) are highly motile and produced in large numbers. Eggs (or ova) are large, few in number, and immobile in themselves. They move as a result of the wave-like motion produced by the ciliated cells lining the Fallopian tube. Egg cells contain some food sources to nourish the developing embryo. In humans, this food source is very limited because once implantation into the uterus takes place, the fetus derives its nutrient supply from the mother's blood supply.

## Egg Structure and Function




The ovum has no propulsion mechanism of its own and is a simpler structure than the sperm cell. It is required to survive for a much longer time than a sperm, so it contains many more nutrients and metabolites and, as a result, it is much larger than a sperm cell (up to 100 µm).

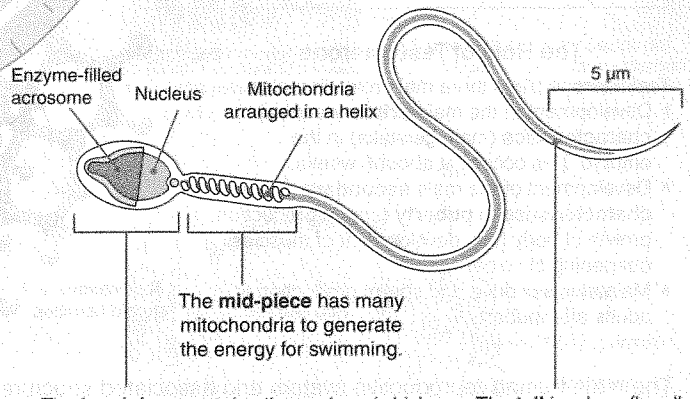
The contents of the ovum are similar to that of a typical mammalian cell, although it is externally surrounded by a jelly-like glycoprotein called the **zona pellucida**. A small polar body (the remnants of a sister cell) lies between the plasma membrane and zona pellucida. Cortical granules around the inner edge of the plasma membrane contain enzymes that are released once a sperm has penetrated the egg.

## Sperm Structure and Function

Mature sperm are produced by **spermatogenesis** in the testes. Meiotic division of spermatocytes produces spermatids, which then differentiate into mature sperm.

A sperm's structure reflects its role, which is to swim through the female reproductive tract to the egg, penetrate the egg's protective barrier, and donate its genetic material, fusing with the egg cell nucleus to produce a zygote. A sperm cell comprises three regions: a headpiece, containing the haploid nucleus and penetrative enzymes, an energy-producing mid-piece, and a tail for propulsion.

Human sperm live only about 48 hours, but they swim quickly and there are so many of them (millions per ejaculation) that usually some are able to reach the egg to fertilize it.




The **mid-piece** has many mitochondria to generate the energy for swimming.

The **headpiece** contains the nucleus (which fuses with the egg nucleus to form the zygote) and the acrosome, which contains the enzymes that help penetrate the egg.

The **tail** is a long flagellum that propels the sperm in its swim to the egg.

1. Explain why sperm need to be motile: _____

2. (a) Explain how the egg cell moves along the Fallopian tube: _____

   (b) Explain why a mature ovum needs to be so many times larger than a sperm: _____

3. Describe the role of each of the following components of the sperm cell in relation to its role in reproduction:

   (a) Acrosome: _____

   (b) Nucleus: _____

   (c) Mitochondria: _____

   (d) Flagellum: _____