Reproductive Physiology

Lec.1

Spermatogenesis, prostate, and seminal vesicle function

By

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Objectives:

Spermatogenesis

Hormones affecting spermatogenesis

Sperm maturation

Sperm storage

Seminal vesicles function

Prostate gland function

Capacitation

Acrosome reaction

- The reproductive functions of the male can be divided into three major subdivisions:

(1) spermatogenesis, which means the formation of sperm;

(2) Performance of the male sexual act; and

(3) regulation of male reproductive functions by the various hormones.

Spermatogenesis

During formation of the embryo, the *primordial germ cells* migrate into the testes and become immature germ cells called *spermatogonia,*

The spermatogonia begin to undergo mitotic division, beginning at puberty, and continually proliferate and differentiate through definite stages of development to form sperm, as shown in Figure 80-2*B.*

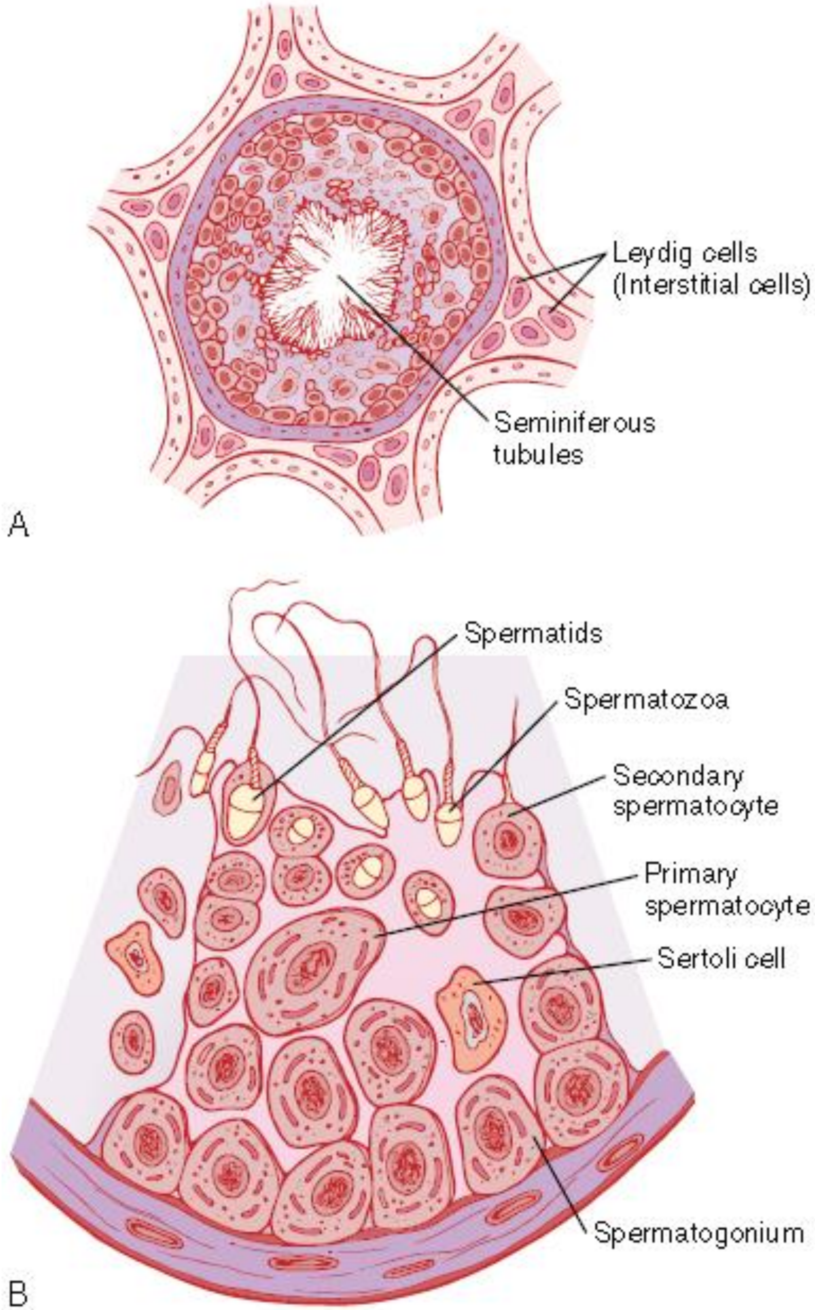


Figure 80-2 *A*, Cross section of a seminiferous tubule. *B*, Stages in the development of sperm from spermatogonia.

Steps of Spermatogenesis

Spermatogenesis occurs in the seminiferous tubules during active sexual life as the result of stimulation by anterior pituitary gonadotropic hormones, beginning at an average age of 13 years and continuing throughout most of the remainder of life but decreasing markedly in old age.

In the first stage of spermatogenesis, the spermatogonia migrate among *Sertoli cells* toward the central lumen of the seminiferous tubule.

The Sertoli cells are large, with overflowing cytoplasmic envelopes that surround the developing spermatogonia all the way to the central lumen of the tubule. Sertoli cells serve as nourishment cells for spermatogonia

Meiosis:

Spermatogonia that cross the barrier into the Sertoli cell layer become progressively modified and enlarged to form large *primary spermatocytes* (Figure 80-3).

Each of these, in turn, undergoes meiotic division to form two *secondary spermatocytes.* After another few days, these too divide to form *spermatids* that are eventually modified to become *spermatozoa* (sperm).

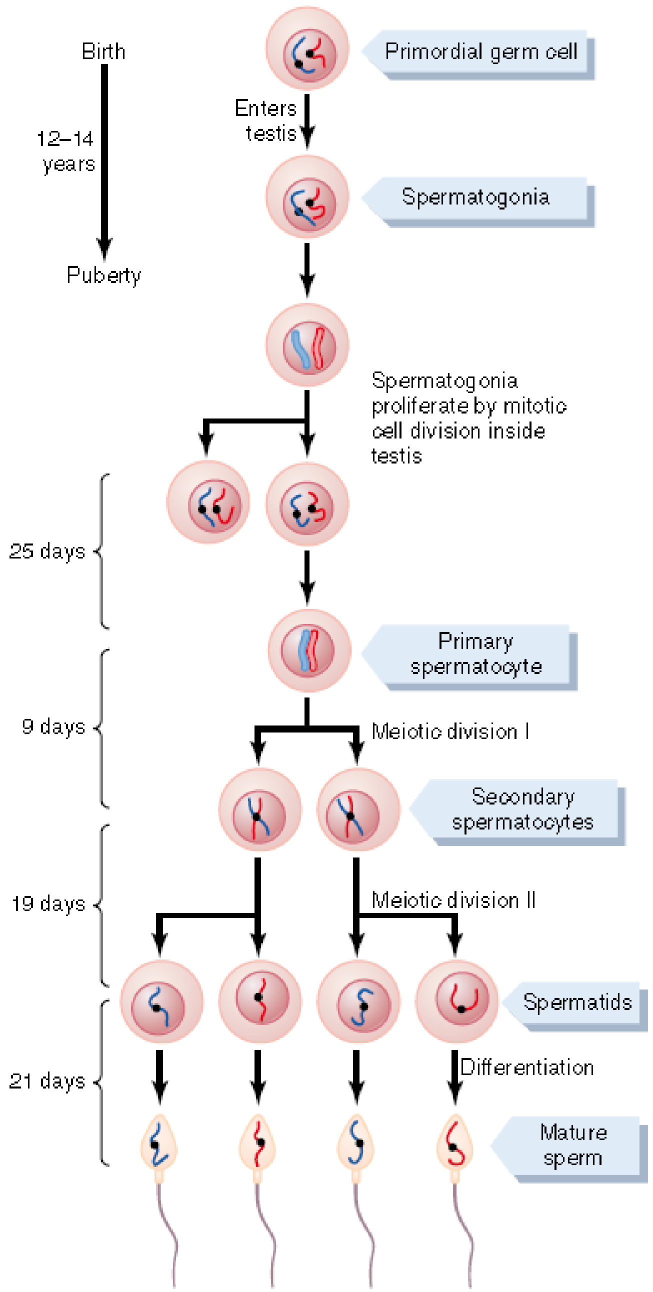


Figure 80-3 Cell divisions during spermatogenesis. During embryonic development the primordial germ cells migrate to the testis, where they become spermatogonia. At puberty (usually 12 to 14 years after birth), the spermatogonia proliferate rapidly by mitosis.

Some begin meiosis to become primary spermatocytes and continue through meiotic division I to become secondary spermatocytes.

After completion of meiotic division II, the secondary spermatocytes produce spermatids, which differentiate to form spermatozoa.

During the change from the spermatocyte stage to the spermatid stage, the 46 chromosomes (23 pairs of chromosomes) of the spermatocyte are divided, so 23 chromosomes go to one spermatid and the other 23 to the second spermatid.

This also divides the chromosomal genes so that only one half of the genetic characteristics of the eventual fetus are provided by the father, whereas the other half are derived from the oocyte provided by the mother.

The entire period of spermatogenesis, from spermatogonia to spermatozoa, takes about 74 days.

Sex Chromosomes:

In each spermatogonium, one of the 23 pairs of chromosomes carries the genetic information that determines the sex of each eventual offspring.

This pair is composed of one X chromosome, which is called the female chromosome, and one Y chromosome, the male chromosome.

During meiotic division, the male Y chromosome goes to one spermatid that then becomes a male sperm, and the female X chromosome goes to another spermatid that becomes a female sperm.

The sex of the eventual offspring is determined by which of these two types of sperm fertilizes the ovum.

Formation of Sperm:

When the spermatids are first formed, they still have the usual characteristics of epithelioid cells, but soon they begin to differentiate and elongate into spermatozoa.

As shown in Figure 80-4, each spermatozoon is composed of a head and a tail. The head comprises the condensed nucleus of the cell with only a thin cytoplasmic and cell membrane layer around its surface.

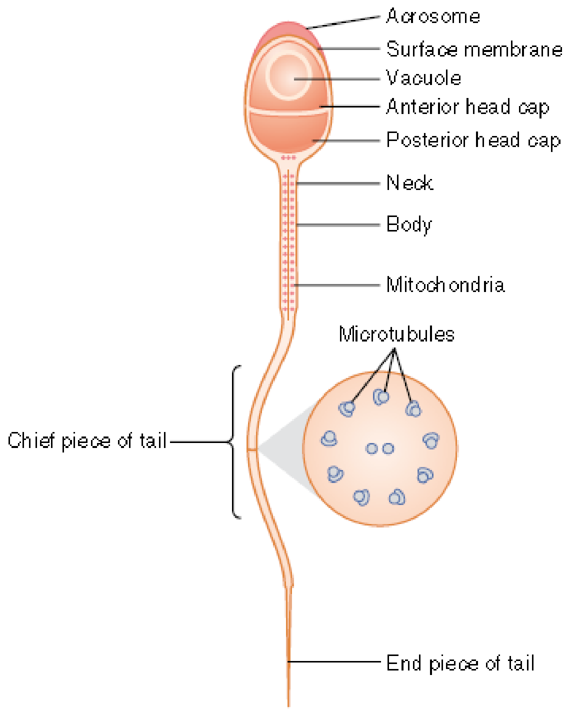


Figure 80-4 Structure of the human spermatozoon.

On the outside of the anterior two thirds of the head is a thick cap called the acrosome that is formed mainly from the Golgi apparatus.

This contains a number of enzymes similar to those found in lysosomes of the typical cell, including hyaluronidase (which can digest proteoglycan filaments of tissues) and powerful proteolytic enzymes (which can digest proteins).

These enzymes play important roles in allowing the sperm to enter the ovum and fertilize it.

The tail of the sperm, called the flagellum, has three major components: (1) a central skeleton constructed of 11 microtubules, collectively called the axoneme (2) a thin cell membrane covering the axoneme; and (3) a collection of mitochondria surrounding the axoneme in the proximal portion of the tail (called the body of the tail).

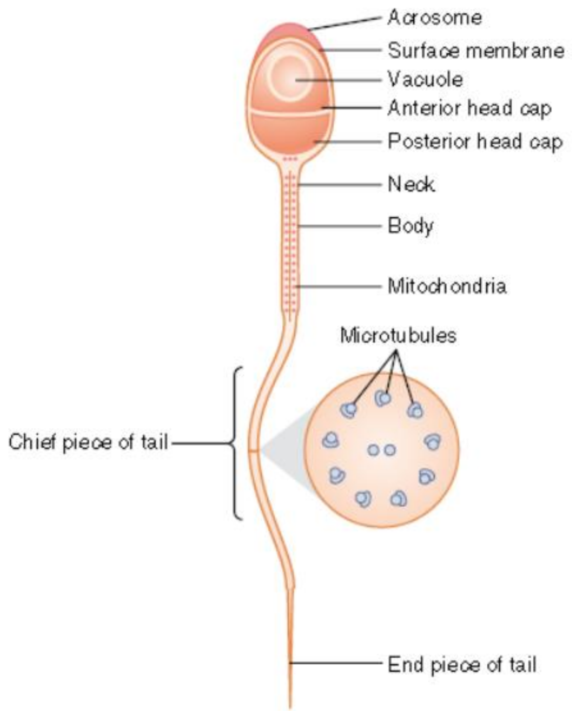


Figure 80-4 Structure of the human spermatozoon.

Back-and-forth movement of the tail (flagellar movement) provides motility for the sperm.

This movement results from a rhythmical longitudinal sliding motion between the anterior and posterior tubules that make up the axoneme. The energy for this process is supplied in the form of adenosine triphosphate, which is synthesized by the mitochondria in the body of the tail.

Normal sperm move in a fluid medium at a velocity of 1 to 4 mm/min. This allows them to move through the female genital tract in quest of the ovum.

Hormonal Factors That Stimulate Spermatogenesis:

1. Testosterone, secreted by the Leydig cells located in the interstitium of the testis (see Figure 80-2), is essential for growth and division of the testicular germinal cells, which is the first stage in forming sperm.

2. Luteinizing hormone, secreted by the anterior pituitary gland, stimulates the Leydig cells to secrete testosterone.

3. Follicle-stimulating hormone, also secreted by the anterior pituitary gland, stimulates the Sertoli cells; without this stimulation, the conversion of the spermatids to sperm (the process of spermiogenesis) will not occur.

4. Estrogens, formed from testosterone by the Sertoli cells when they are stimulated by follicle-stimulating hormone, are probably also essential for spermiogenesis.

5. Growth hormone (as well as most of the other body hormones) is necessary for controlling background metabolic functions of the testes.

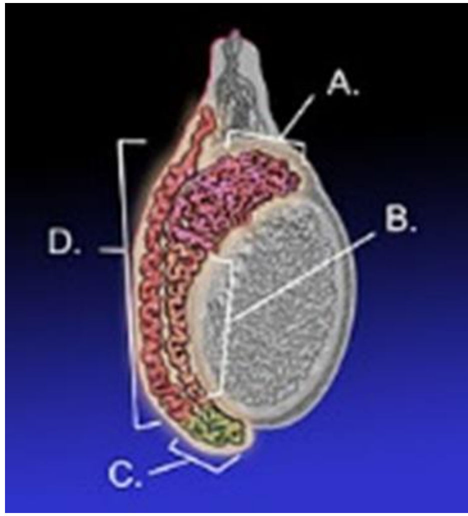
Growth hormone specifically promotes early division of the spermatogonia themselves; in its absence, as in pituitary dwarfs, spermatogenesis is severely deficient or absent, thus causing **infertility**.

Maturation of Sperm in the Epididymis:

After formation in the seminiferous tubules, the sperm require several days to pass through the 6-meter-long tubule of the epididymis.

Sperm removed from the seminiferous tubules and from the early portions of the epididymis are non-motile, and they cannot fertilize an ovum.

However, after the sperm have been in the epididymis for 18 to 24 hours, they develop the capability of motility, even though several inhibitory proteins in the epididymal fluid still prevent final motility until after ejaculation.



Storage of Sperm in the Testes:

The two testes of the human adult form up to 120 million sperm each day.

A small quantity of these can be stored in the epididymis, but most are stored in the vas deferens. They can remain stored, maintaining their fertility, for at least a month.

During this time, they are kept in a deeply suppressed, inactive state by multiple inhibitory substances in the secretions of the ducts. Conversely, with a high level of sexual activity and ejaculations, storage may be no longer than a few days.

After ejaculation, the sperm become motile, and they also become capable of fertilizing the ovum, a process called maturation.

The Sertoli cells and the epithelium of the epididymis secrete a special nutrient fluid that is ejaculated along with the sperm.

This fluid contains hormones (including both testosterone and estrogens), enzymes, and special nutrients that are essential for sperm maturation.

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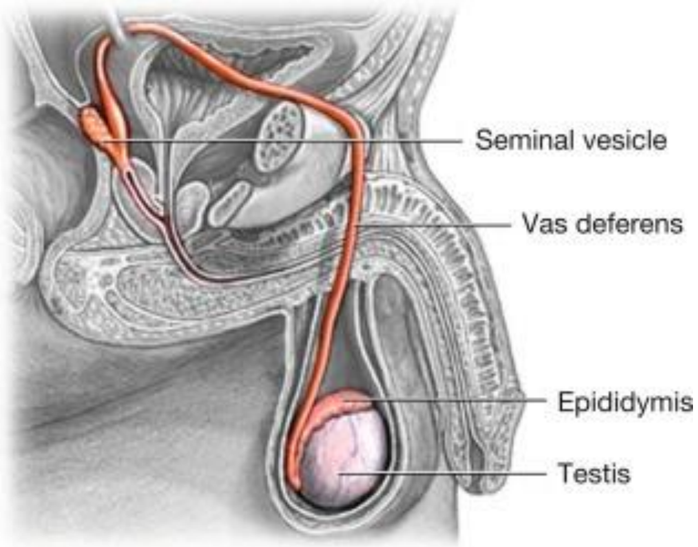


Physiology of the Mature Sperm:

The normal motile, fertile sperm are capable of flagellated movement through the fluid medium at velocities of 1 to 4 mm/min.

The activity of sperm is greatly enhanced in a neutral and slightly alkaline medium, as exists in the ejaculated semen, but it is greatly depressed in a mildly acidic medium.

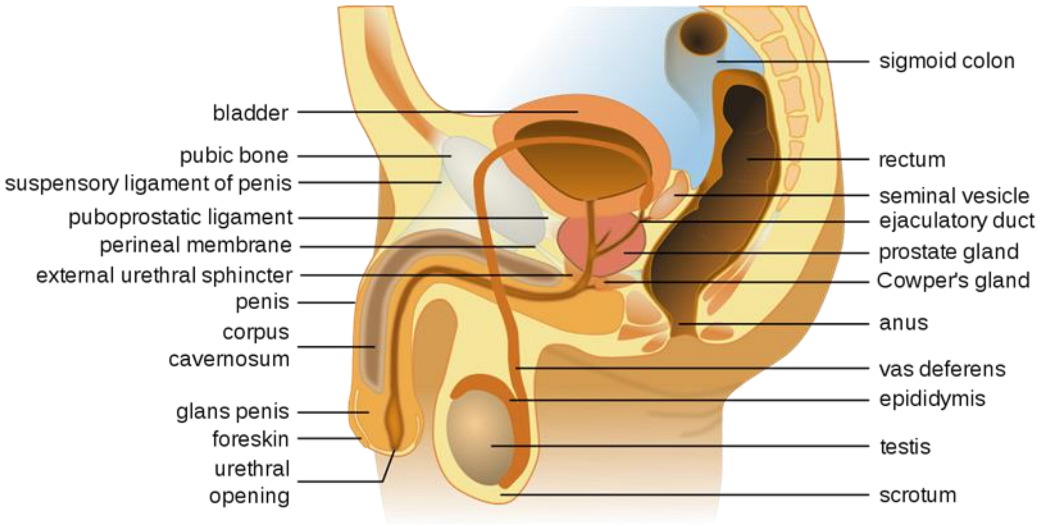
A strong acidic medium can cause rapid death of sperm.

The activity of sperm increases markedly with increasing temperature, but so does the rate of metabolism, causing the life of the sperm to be considerably shortened.

Although sperm can live for many weeks in the suppressed state in the genital ducts of the testes, life expectancy of ejaculated sperm in the female genital tract is only 1 to 2 days.

Function of the Seminal Vesicles:

Each seminal vesicle is a tortuous, loculated tube lined with a secretory epithelium that secretes a mucoid material containing an abundance of fructose, citric acid, and other nutrient substances, as well as large quantities of prostaglandins and fibrinogen.

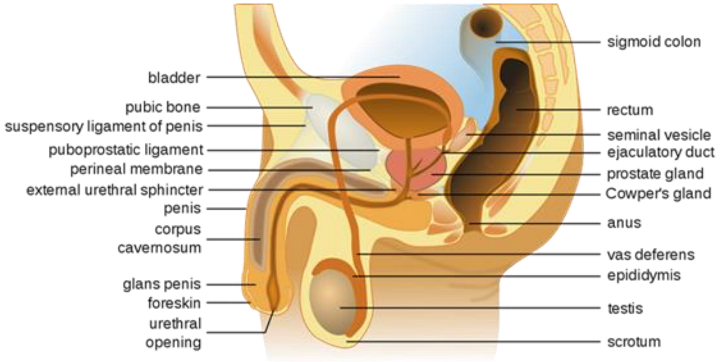


During the process of emission and ejaculation, each seminal vesicle empties its contents into the ejaculatory duct shortly after the vas deferens empties the sperm.

This adds greatly to the bulk of the ejaculated semen, and the fructose and other substances in the seminal fluid are of considerable nutrient value for the ejaculated sperm until one of the sperm fertilizes the ovum.

Function of the Prostate Gland:

The prostate gland secretes a thin, milky fluid that contains calcium, citrate ion, phosphate ion, a clotting enzyme, and a profibrinolysin. During emission, the capsule of the prostate gland contracts simultaneously with the contractions of the vas deferens so that the thin, milky fluid of the prostate gland adds further to the bulk of the semen.



A slightly alkaline characteristic of the prostatic fluid may be quite important for successful fertilization of the ovum because the fluid of the vas deferens is relatively acidic owing to the presence of citric acid and metabolic end products of the sperm and, consequently, helps to inhibit sperm fertility. Also, the vaginal secretions of the female are acidic (pH of 3.5 to 4.0).

Sperm do not become optimally motile until the pH of the surrounding fluids rises to about 6.0 to 6.5.

Consequently, it is probable that the slightly alkaline prostatic fluid helps to neutralize the acidity of the other seminal fluids during ejaculation and thus enhances the motility and fertility of the sperm.

Semen:

Semen, which is ejaculated during the male sexual act, is composed of

the fluid and sperm from the vas deferens (about 10 percent of the total),

fluid from the seminal vesicles (almost 60 percent),

fluid from the prostate gland (about 30 percent),

and small amounts from the mucous glands, especially the bulbourethral glands.

Thus, the bulk of the semen is seminal vesicle fluid, which is the last to be ejaculated and serves to wash the sperm through the ejaculatory duct and urethra.

Capacitation:

Although spermatozoa are said to be “mature” when they leave the epididymis, their activity is held in check by multiple inhibitory factors secreted by the genital duct epithelia.

Therefore, when they are first expelled in the semen, they are unable to fertilize the ovum.

However, on coming in contact with the fluids of the female genital tract, multiple changes occur that activate the sperm for the final processes of fertilization. These collective changes are called capacitation of the spermatozoa. This normally requires from 1 to 10 hours.

Acrosome Reaction:

Stored in the acrosome of the sperm are large quantitie of hyaluronidase and proteolytic enzymes. Hyaluronidase depolymerizes the hyaluronic acid polymers in the intercellular cement that holds the ovarian granulosa cells together.

The proteolytic enzymes digest proteins in the structural elements of tissue cells that still adhere to the ovum.

When the ovum is expelled from the ovarian follicle into the fallopian tube, it still carries with it multiple layers of granulosa cells.

Before a sperm can fertilize the ovum, it must dissolute these granulosa cell layers, and then it must penetrate though the thick covering of the ovum itself, the zona pellucida.

To achieve this, the stored enzymes in the acrosome begin to be released. It is believed that the hyaluronidase among these enzymes is especially important in opening pathways between the granulosa cells so that the sperm can reach the ovum.

Why Does Only One Sperm Enter the Oocyte?

within a few minutes after the first sperm penetrates the zona pellucida of the ovum, calcium ions diffuse inward through the oocyte membrane and cause multiple cortical granules to be released by exocytosis from the oocyte into the perivitelline space.

These granules contain substances that permeate all portions of the zona pellucida and prevent binding of additional sperm, and they even cause any sperm that have already begun to bind to fall off.

Thus, almost never does more than one sperm enter the oocyte during fertilization.

The perivitelline space is the space between the zona pellucida and the cell membrane of an oocyte or fertilized ovum.

Thank You