

# Summary: Reproduction and Embryonic Development

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# 1 The nature of asexual reproduction

**Reproduction**, or “the creation of new individuals from existing ones” is essential to the continuation of life over the lifespan of an organism. **Asexual reproduction** is one permutation of the two types of reproduction: sexual reproduction and asexual reproduction. In contrast to *sexual* reproduction, *asexual* reproduction poses no stipulations as to genetic diversity, nor the ability of a parent organism to find a mate: an organism may reproduce without sex via budding, fission, or the process of fragmentation and regeneration, for example.

Advantages	Disadvantages
Allows animals that live in isolation to produce offspring	Produces genetically uniform populations
Perpetuates a particular genotype precisely and rapidly	

Table 1: Advantages and disadvantages associated with asexual reproduction

# 2 The nature of sexual reproduction

**Sexual reproduction**, or “the creation of genetically unique offspring by the fusion of two haploid sex cells (gametes), forming a diploid zygote” is an alternative pathway to “reproduction” in organisms where the **fertilization of gamete** cells—sex cells with  $n$  chromosomes—is the desired mode of reproduction. In organisms where the mode of reproduction involves such fertilization, there exist two types of gametes:

- **Sperm**, the male gamete: travels by means of a flagellum and the
- **Egg**, the female gamete: is not self-propelled

The fusion of the two aforementioned cells leads to the formation of a **zygote**, which develops into a new individual.

In contrast with asexual reproduction, sexual reproduction increases genetic diversity in the resulting population through random fertilization and meiosis. The combination of these randomization factors results in the principal force of natural selection: genetic variability.

While the aspect of variability associated with sexual reproduction might be attractive for various mobile species, for isolated or immobile organisms, sexual reproduction is implausible, as it requires a mate with which to procreate. This inconvenience is addressed by the development of **hermaphroditism**, or the existence of both female and male reproductive systems in a single organism—“perfect” flowers with both stamens and carpels, are an example of such a development. The development of hermaphroditism can be seen as advantageous, as it allows for animals to reproduce with respect to environmental conditions.

Even with respect to sexual reproduction, there exist two separate development of reproductive mechanisms: **reproduction by external fertilization** wherein gametes are released into and fuse in the environment, and **reproduction by internal fertilization** wherein sperm are deposited in or near the female reproductive tract.

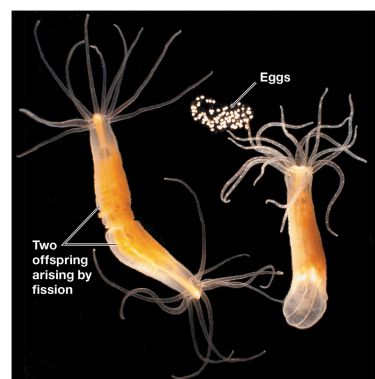


Figure 1: The utilization of both asexual and sexual reproduction in the hydra.

### 3 The human female reproductive system

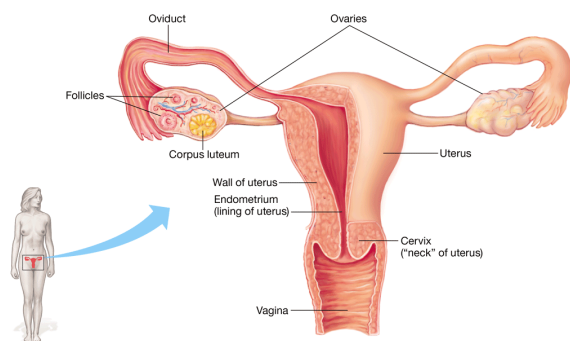


Figure 2: A diagram of the female human reproductive system.

The **ovaries** are the gamete-producing organs in the female reproductive system, and can be described as having a “bumpy” surface—caused by the **follicles** that both produce estrogen and enclose a developing egg cell.

In the process of **ovulation**, a female will release an immature egg via the cilia lining the **oviduct**, or *fallopian tube*—after starting puberty, of course—as a result of the maturation of a follicle, every 28 days. In addition, after having matured and formed the **corpus luteum**, a follicle will begin to release progesterone, alongside additional estrogen, complementing the maintenance of the uterine lining. This process usually ceases near the age of 50.

With consideration to the above structural definitions, the following statements regarding the development of a zygote, and the eventual birth of a human fetus can be made:

1. When ovulation occurs, if sperm are present in the upper part of the oviduct, fertilization may occur.
2. After fertilization occurs, the zygote should continuously divide as it traverses the oviduct, eventually becoming an embryo.
3. In the **uterus**—the site of pregnancy<sup>1</sup>—, an **embryo** will be deposited in the inner lining of the uterus **endometrium**.
4. After implantation, the embryo will complete development until the 8th week of pregnancy, when the developing human will, henceforth, be referred to as a **fetus**.
5. After continued development of the fetus, the **vagina** will serve as the canal through which the baby is born. The vagina is separated from the uterus by the **cervix**—the “neck” of the uterus.

In addition to each of the aforementioned structures utilized in embryonic and fetal development, various external structures collectively referred to as the **vulva** provide functionality in copulation<sup>2</sup>:

- In sexual intercourse, the **vagina** serves as a repository for sperm, and is guarded by the **labia minora** and **labia majora**.
- Though it does not provide additional *necessary* functionality in reproduction, the **clitoris**—an erectile organ consisting of a short shaft, followed by the **prepuce**, a small hood of highly sensitive skin—does serve a purpose in reproduction in that it evokes a highly presurable sensation when stimulated. As do the vagina and the labia minor, this organ enlarges during sexual activity as a result of increased concentration of blood in the area.

### 4 The human male reproductive system

As is the case with many other mammals, the natural temperature of the human body presents a challenge for the proper development of sperm cells within the **testes**—the male gonads. That is, in humans, the most desirable temperature for sperm development is approximately 2°C less than the normal human body

<sup>1</sup>In rare cases, an **ectopic pregnancy** may commence, where an embryo implants itself in the oviduct, potentially rupturing surrounding tissues.

<sup>2</sup>The **hymen** could be categorized as one such structure, but provides little functionality in reproduction, and is ruptured in vigorous physical activity or intercourse.

temperature of 36.5–37.5°C. In humans, the **scrotum** solves this dilemma by keeping sperm-forming cells within the acceptable temperature range.

After a sufficient volume of sperm cells have been produced in the testes, sperm leave the gonads through the **epididymis**, where sperm cells will continue to develop until **ejaculation**. Once the muscular contractions necessary for ejaculation to occur take place, the sperm will leave the epididymis via the **vas deferens**, and travel upward around the bladder, where the vas deferens joins with the **seminal vesicle**. Finally, sperm will be conveyed via the urethra. Thus, it follows that, in contrast with the female reproductive system, the male reproductive system is directly related and physically connected to the urinary system. This entire process is controlled by FSH and LH hormones, and, by extension, the hypothalamus. The former of the aforementioned hormones, FSH stimulates sperm production, while LH promotes androgen secretion.

However, the important distinction between sperm and nourishing fluid contained in semen must be made: **glandular secretions** are produced by the **prostate gland**, and are initially separate from sperm. Alongside **alkaline mucus** produced by the **bulbourethral glands** and sperm, these fluids comprise **semen**, the fluid ejaculated from the penis during orgasm.

As does the female reproductive system, the male reproductive system consists of various external structures:

- The **scrotum**: stores sperm at a suitable temperature
- The **penis**: similarly to the clitoris, this organ is composed of erectile tissue forming a shaft, supporting a sensitive glans, and is engorged during sexual arousal<sup>3</sup>

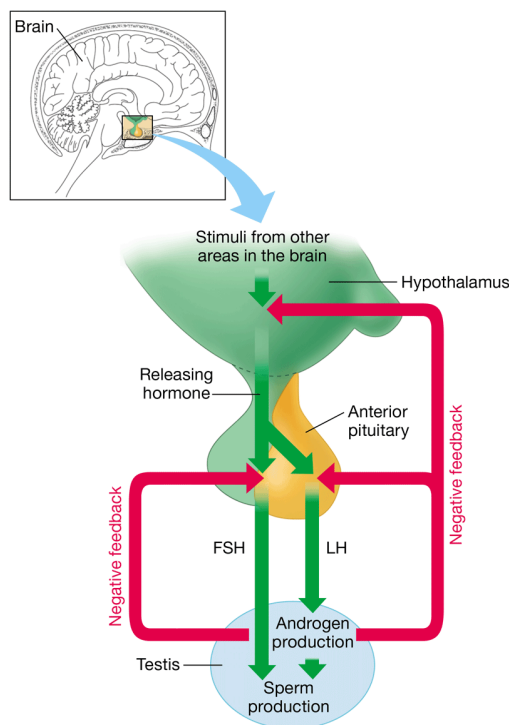


Figure 3: Hormonal control of the testis by the hypothalamus

## 5 The production of gametes via meiosis

<sup>3</sup>In individuals with **erectile dysfunction (ED)**, or a tendency to **impotence**, engorgement of the penis is made improbable. This condition can result from drug use, alcohol, or psychological problems.

Both egg and sperm cells must be produced through the procedure of meiosis, or **gametogenesis**.

## 5.1 Spermatogenesis

**Spermatogenesis**, or the formation and development of sperm cells, necessitates the conversion of initially diploid cells ( $2n$ ) in the outer walls of the coiled seminiferous tubules of the testis to secondary haploid spermatocytes ( $n = 23$ ). In human males, this process takes approximately 10 weeks to complete, and is usually continuous through the entirety of a male's adult life.

## 5.2 Oogenesis

As is the case in spermatogenesis, in oogenesis, the majority of gamete production and development takes place in the respective gonad—the ovary. However, in contrast to that which was demonstrated by the male reproductive system, the female reproductive system does not produce gametes “on-demand”—that is, the gametes are produced on a regular basis, each 28 days, on the basis of the release of a follicle-stimulating hormone (FSH). This process is, in part, reminiscent of sperm production, as it is ultimately rigged by the hypothalamus. However, these two mechanisms do, of course, differ in the fact that:

1. Oogenesis occurs in a cyclic fashion, while spermatogenesis will be triggered by sexual stimulation
2. Oogenesis is only carried out between puberty and menopause, while spermatogenesis usually lasts the entirety of a male's adult life
3. Naturally, oogenesis produces far less gamete cells than spermatogenesis, simply due to the mechanical stipulations of human sexual reproduction

The end result of each of these processes is, of course, a haploid gamete cell.

# 6 The female mammalian reproductive cycle is coordinated by hormone secretion

## 6.1 Important distinctions between mammalian reproductive cycle subprocesses.

The female mammalian reproductive cycle can be divided into two distinct subprocesses: the *ovarian* cycle and the *menstrual* cycle.

The former of these processes deals exclusively with the production of gamete cells, while the latter deals with the preparation of the female reproductive system for the potential implantation of an embryo. Messaging via the exchange of hormones between these processes allows for the production of gamete cells with respect to a uterine lining conducive to the growth of an embryo. More specifically, LH and FSH hormones act to mediate this synchronization effect.

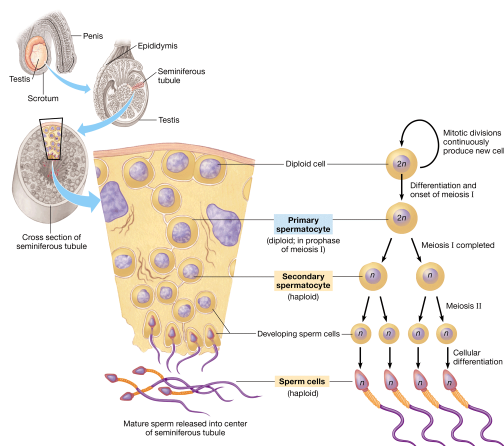


Figure 4: The production of gametes in a human male (spermatogenesis).

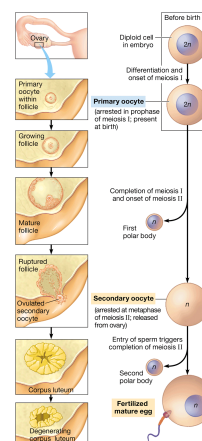


Figure 5: The production of gametes in a human female (oogenesis).

## 6.2 Overview: The female mammalian reproductive cycle

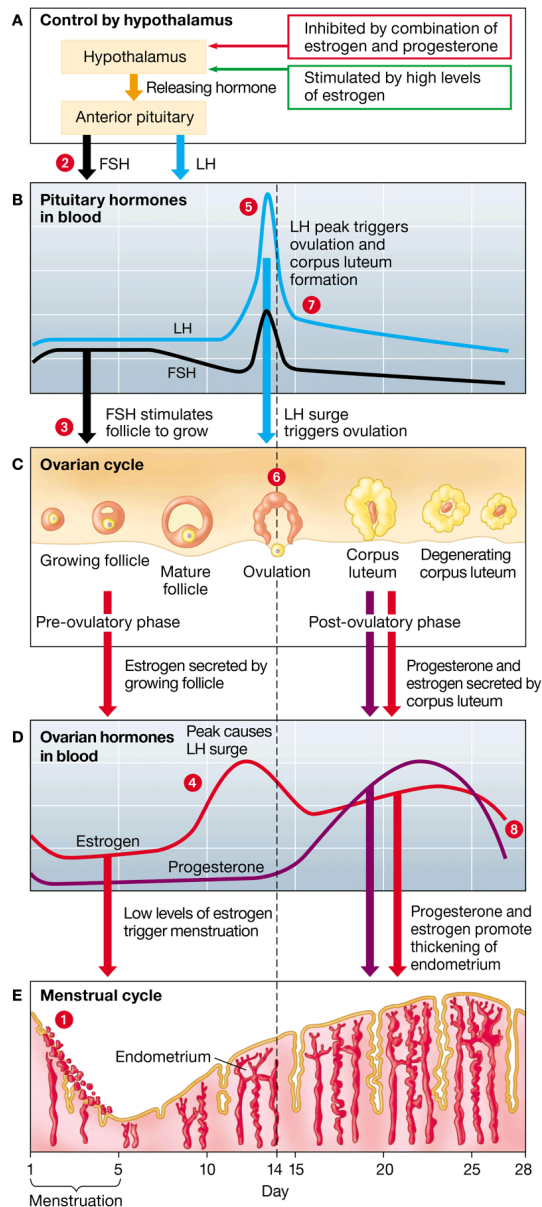


Figure 7: The reproductive cycle of the human female.

With respect to the discharge of ovules from the ovaries, the ovarian and menstrual cycles can be separated into two distinct parts:

- The pre-ovulatory phase: the period in which a follicle begins growth
- The post-ovulatory phase: the period in which the follicle has become a corpus luteum

Typically, when accounting for each of these “parts” of the reproductive cycle, the following sequence of structural events takes place:

1. **Menstruation:** for 3–5 days, the endometrium is in a breakdown process, resulting in uterine bleeding. This even occurs at the same time as the pre-ovulatory phase of the ovarian cycle.
2. The endometrium begins to regrow.
3. After 20–25 days, if the embryo has not implanted itself in the uterine lining, the ovarian and menstrual cycles restart.

FSH, LH, progesterone and estrogen are the primary hormones responsible for synchronizing the ovarian and menstrual cycles. The functions of each of the aforementioned hormones in coordinating the reproductive cycle are as follows:

- **FSH**, or follicle-stimulating hormone: prompts the growth of a follicle in the ovaries. In other words, this hormone kicks off the ovarian cycle
  - Follicles produced as a result of the secretion of FSH themselves secrete estrogen, preventing bloodstream concentration of FSH and LH low during the pre-ovulatory phase
- **Estrogen:** As the period of ovulation approaches and the size of the follicle continues to increase, estrogen levels increase dramatically. This results in the secretion of FSH and LH en masse.
- **LH:** stimulates the completion of meiosis I, marking the production of the secondary oocyte, when the follicle is ruptured.
  - Encourages estrogen secretion by the corpus luteum.
- **Estrogen and progesterone:** signals to the hypothalamus that FSH and LH level ought to drop, preventing a secondary follicle from developing. This effect experiences gradual decay, until the end of the post-ovulatory phase, at which point an embryo should have been implanted into the uterus. In other words, the decay of this effect marks the beginning of the next reproductive cycle.



## 7 The mechanics of fertilization

Fertilization is, of course, the first step in the development of an embryo—that is to say, the fusion of two haploid cells from two different individuals is required in order for the normal pathway of embryo development to ensue.

It is needless to say that the action of fertilization is not inherently probabilistic: each actor—the sperm cell and the egg cell—participating in the conjunction of genetics possess certain properties that make fertilization possible. The sperm cell, for example, is composed of a plasma-membrane enclosed haploid nucleus, an **acrosome** containing enzymes that help penetrate the surface of the egg cell, a flagellum tail, and mitochondria.

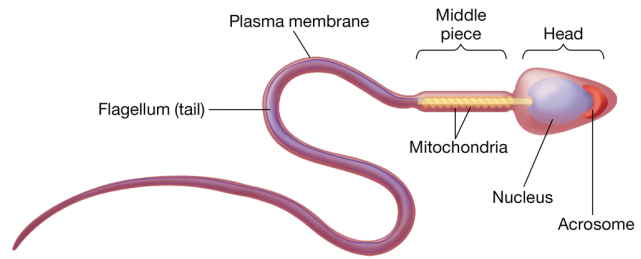


Figure 8: The structure of a human sperm cell.

With consideration to the biological theme of correlation between structure and function, it follows that the components found in a typical sperm cell serve some purpose in fertilization. Thus, one must turn to the natural process of fertilization itself:

1. The sperm cell traverses the uterus, and, eventually, the fallopian tubes, utilizing its mitochondria and flagellum tail
2. A sperm cell binds to an egg cell
3. The plasma membrane of the cell that will be fertilized becomes impenetrable
4. The vitelline layer of the egg becomes impenetrable
5. The fusion of the egg and the sperm nuclei is complete
6. DNA synthesis begins
7. The zygote divides

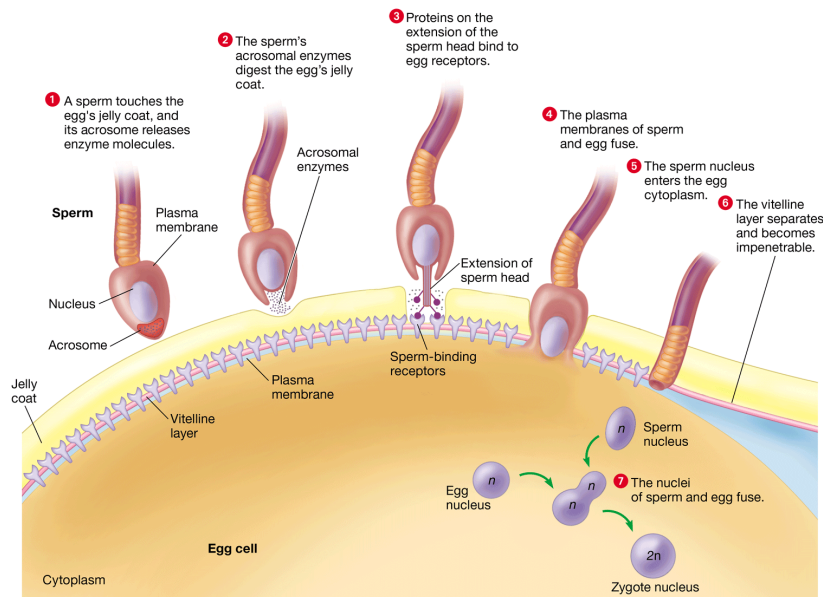


Figure 9: The process of fertilization in a sea urchin

## 8 The mechanics of cleavage

**Cleavage** is defined as the first stage in a series of carefully controlled cell divisions and specialization ultimately leading to the maturation of an organism. More specifically, cleavage is the stage during which rapid successive divisions of a zygote lead to the production of a “multicellular ball.” Or, in other words, the completion of this process results in the transformation of the zygote into an embryo.