Module 2

(Reproductive Organs and the Sexual Cycle)

This module focuses on the reproductive organs of the mammals in particular the humans, which are involved in the transport of gametes to successfully fertilize the mature ovum. This part will also present the hormones for reproduction and the sexual cycle.

Learning Objectives : At the end of this lesson, the student should be able to:

1. Describe the mammalian (human) female and male reproductive organs and tracts.
2. Trace the pathway of the egg and sperm cells from their site of production to their final destinations.
3. Explain the ovarian cycle and menstrual cycle of humans by citing the events and hormones involved, as well as the roles of hormones in spermatogenesis.
4. Differentiate menstrual cycle from estrous cycle of other mammals.

Introduction

Before an animal embryo develops, there is of course reproduction first. Most animals reproduce **sexually**, which involves the production of two types of gametes – the sperms and the eggs. Typically, two separate parents (**dioecious**) are needed. A male parent contributes the sperm and the female parent contributes to the egg, or ovum (pl., *ova*). There are some animals, wherein a single individual (**monoecious)** produces the sperms and eggs, a case called **hermaphroditism.** If this is the case, sexual reproduction still exists in certain groups of animals with hermaphroditism, e.g., tapeworms.

In animals reproducing sexually, it might be energy - time consuming and demanding. But the benefit the offspring obtains from sexual reproduction outweighs the costs and demands entailed of it. One major benefit animals get from sexual reproduction is **genetic variability.** *Recall when in meiosis genetic variability occurs in the gametes.* Further genetic variability happens when the haploid male gamete fuses with the haploid female gamete during fertilization. This then increases the **fitness (reproductive success)** of the offspring. The combination of the of the inherited traits of two parents gives rise to offspring that may be better able to survive than either parent. *Do you think you are a better version of your parents? Are you more fit than your parents to adapt and survive in this "chaotic" time?*

Other advantages of sexual reproduction in animals are:

1. Since the offspring is **diploid,** there is a backup copy of their genes in case one copy gets damaged by mutation.

2. It permits beneficial mutations from each parent to come together in offspring that can reproduce and spread these mutations through the population.
3. It also removes harmful mutations from a population.

Discussion Link 2.1: What is mutation? Why are mutations not always a bad occurrence in genes and for the offspring? How can sexual reproduction spread these mutations? How can harmful mutations be removed from the population? Give your answers for the four questions in not more than five sentences (all in all).

The formation of gametes is called **gametogenesis** which takes place even as early in the embryonic stages of vertebrates. The formation of gametes occurs in the testes for males (**spermatogenesis**) and in the ovaries for females (**oogenesis**). Recall the significances of mitosis and meiosis in the formation of gametes.

We will now look briefly in the structures of both male and female reproductive organs which are involved in the transport of gametes in order for the ovum to be fertilized.

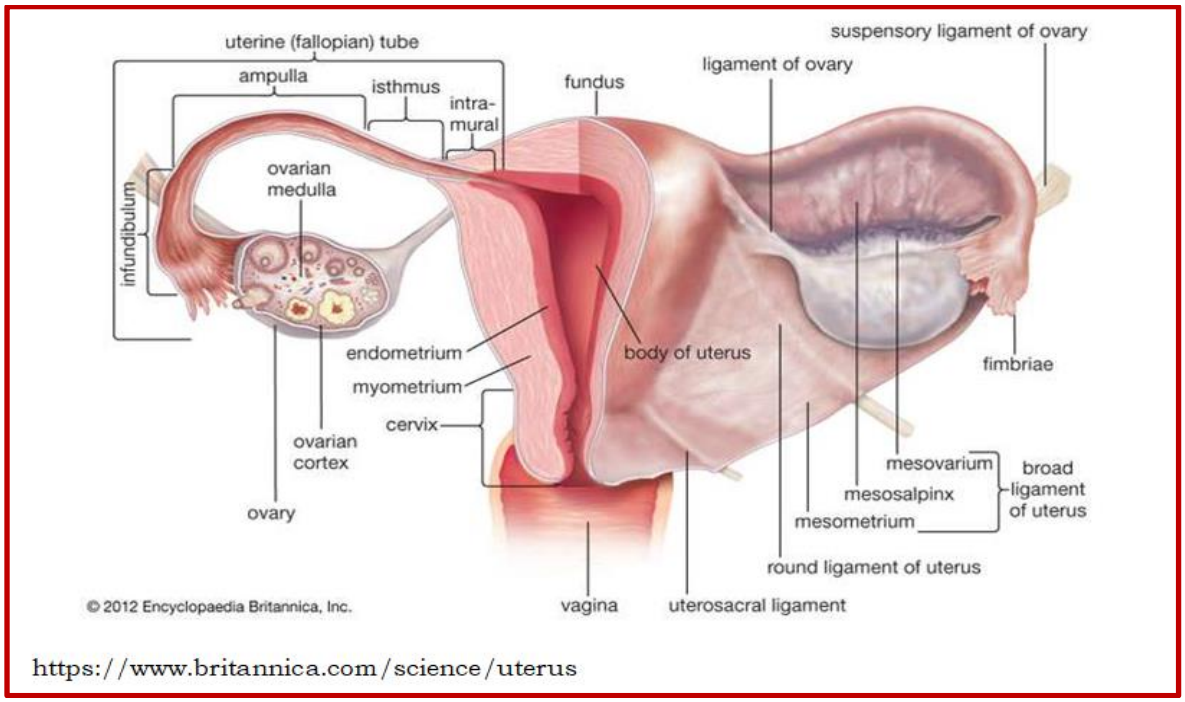
Also, whenever sexual reproduction in mammals is the topic, the roles of hormones are indispensable. A summary of these hormones and their roles in reproduction will be presented towards the end of this module.

A. Female and Male Reproductive Organs

1. Structure of the Female Reproductive Organs

The structure and function of the female reproductive tract are well adapted for the transport of gametes and maintenance of the embryo. The events in this tract are under hormonal control and are cyclical, which are of utmost importance in understanding gamete transport and embryonic development.

The figure below shows the female gonad, the **ovary** (ovaries, pl) and the reproductive tract called **oviduct** (divided generally into regions such as the **fallopian** or **uterine tube**, the **uterus,** the **cervix** and the **vagina.**



The ovaries are paired organs, almond-shaped, located on either side of the uterus and are positioned very near the open, funnel-shaped ends of the uterine tubes. Take note also that there are numerous, small, finger-like projections called **fimbriae** in the opening of the uterine tube located in the **infundibulum.** These fimbriae are involved in directing the ovulated egg into the tube. Other segments of the fallopian tube after the infundibulum are the *ampulla*, *isthmus* and the *intramural* segments. The lining epithelium of the uterine tubes contain a mixture of **ciliated** cells that assists in gamete transport and secretory cells that produce a fluid supporting early development of the embryo. Smooth muscle layers are also found throughout in the uterine tubes to provide the basis for peristaltic contractions allowing the egg (either fertilized or unfertilized) to be transported to the uterus.

The **uterus** is a pear-shaped organ whose main functions are to receive and maintain the embryo during pregnancy and to expel the fetus at the termination of the pregnancy. The function of the uterus in receiving, implanting and nourishing the embryo (if pregnancy is positive) is in the feature of its mucosal lining called the **endometrium.** The structure and appearance of this lining change daily throughout the **menstrual cycle.** As we will see in the next topics, several hormones are involved in these changes. The function of the uterus to expel the fetus at term is because of the layer of smooth muscles of the uterus called **myometrium.**

The lower outlet of the uterus is the **cervix.** The mucosal lining of the cervix is different from the lining of the endometrium and it has on its surface a variety of irregular crypts. The cervical epithelium produces a glycoprotein-rich cervical mucus, the composition of which varies considerably throughout the menstrual

cycle. The changing appearance and/or consistency of the cervical mucus throughout the menstrual cycle either makes it easier or more difficult for spermatozoa.

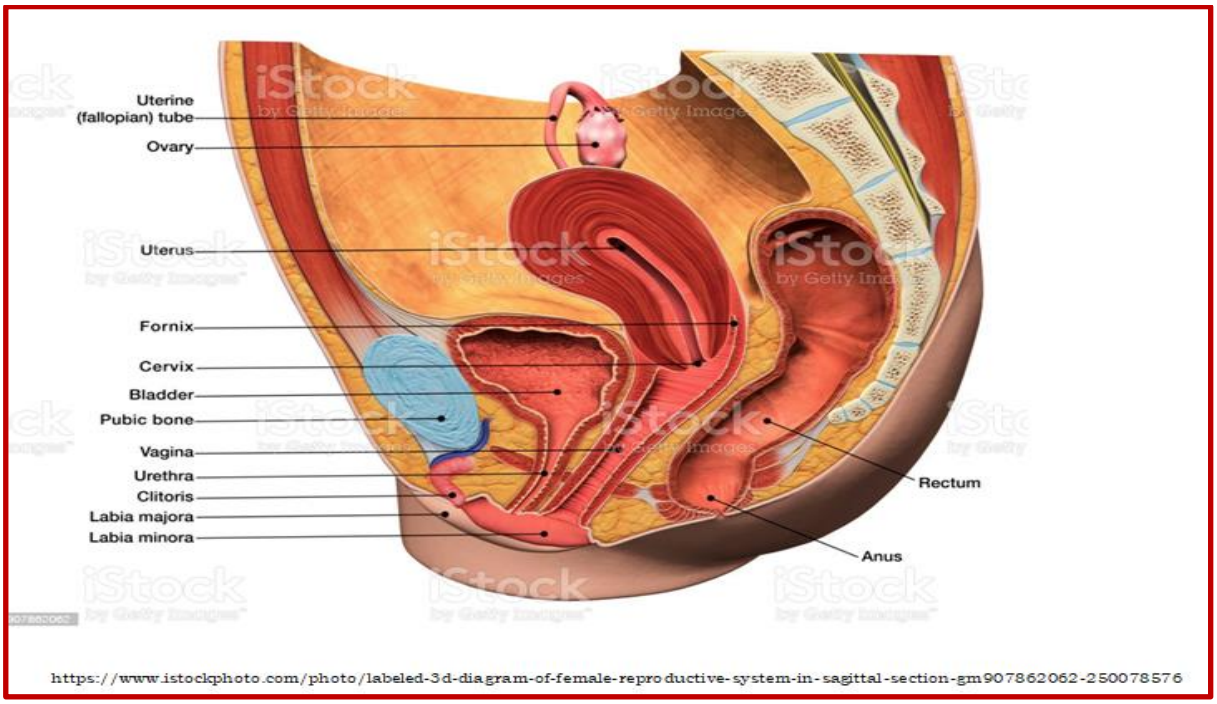
How about you girls, have you noticed changes in the consistency of this mucus secretion coming out from your body? Isn't it there are times when the secretion is sticky like a paste or sometimes it is too slimy like an egg white? When do you think you are most fertile, when the cervical mucus secretion is pasty or slimy? Girls, share your insights/experiences with the boys with no malice intended☺.

Discussion Link 2.2: What is the Billing's method? How is it used by women in checking their fertility for possible pregnancy or avoidance of pregnancy? Is this method a form of natural birth control? Why or why not? Answer all these questions in not more than five sentences.

Publish your answer in the discussion link .

The last segment of the oviduct in mammals is the **vagina**. In its capacity as a channel for sexual intercourse and the birth canal, the surface lining of this part of the tube is non-keratinized stratified squamous epithelium. Since the epithelial cells contain deposits of **glycogen,** which vary in amount throughout the menstrual cycle. The breakdown products of glycogen contribute to the low acidity (pH 4.3) of the vaginal fluids. The low pH of the upper vagina prevents infectious agents (bacteriostatic function) from entering the upper genital tract through the cervix that might spread to the peritoneal cavity through the open ends of the uterine tubes.

Looking at the sagittal view of the female pelvis below, the anatomical position of the uterus is between the urinary bladder (ventral) and the rectum (dorsal). The **external genitalia** of the female are complex structures grouped about the vaginal orifice (opening) which constitute collectively the **vulva**. Shown in the figure below is a sagittal section of the lower part of the human female trunk (called **pelvis).** The outermost structures are a pair of fat-containing folds of skin known as **labia majora.** Within the cleft between the labia majora is a second, smaller pair of skin folds that are highly vascular and devoid of the fat, the **labia minora**. Partially enwrapped by the labia minora where they meet anteriorly is the **clitoris**, a small erectile organ which is the homologue of the penis of the male. (text lifted from Carlson, 1996).



Discussion Link 2.3: In the book of Carlson (1996) where the text above was lifted from, the last sentence of the paragraph states that "In virgins the entrance into the vagina is narrowed by a thin fold of tissue known as the ***hymen".*** *I want to hear your opinion if you agree or disagree with the last sentence of Carlson? Type in your comments in not more than five sentences.*

2. Structure of the Male Reproductive Organs

The schematic plan of the male reproductive organs spread out in frontal aspect and the tubes of the testis are shown below. Let us trace the pathway of sperm cells from the testes (plural) to the outside of the male body.

In humans and other vertebrates, spermatogenesis occurs in the paired male gonads called the **testes** (testis, sing.) which are enclosed by a part of the skin in the groin region, the **scrotum.** Spermatogenesis takes place in highly convoluted tubules, the **seminiferous tubules (15).** *Guess how long can these tubes be in humans? 360 meters in human testes account for the daily production of 95 million spermatozoa. DAILY!!! WHOA!!!!*

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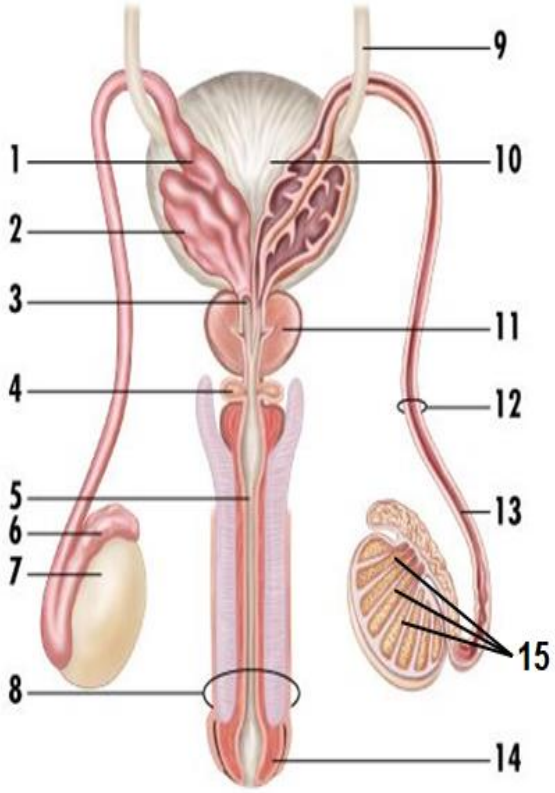

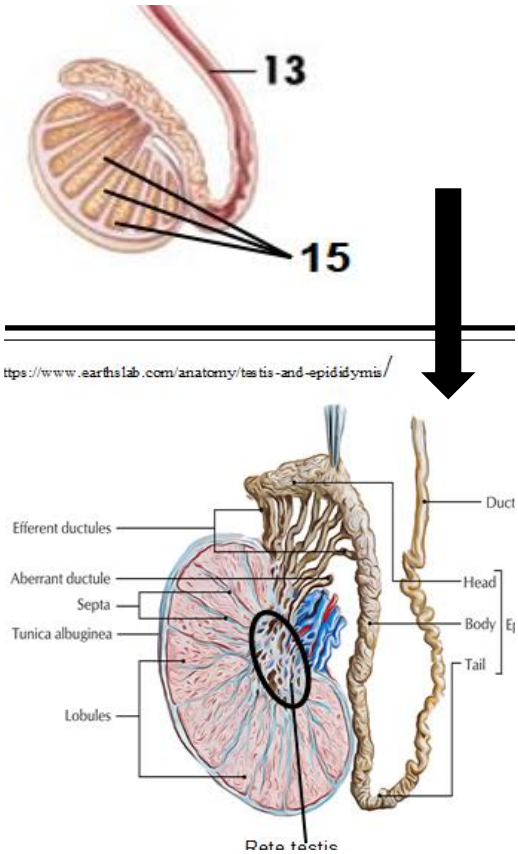

If we trace the pathway of these sperm cells to their outside world, look at the image below the solid black arrow. From the smeiniferous tubules, they find their way into an irregular network of slender anastomosing ducts, the **rete testis.** From here, the spermatozoa are collected by the **efferent ductules/ductuli efferentes**, which in turn leads them to the highly convoluted and compact **head of the epididymis**, then to a lesser compact **body of the epididymis**, then to a single less convoluted segment, the **tail of epididymis.** This then leads to a straighter tube, the **ductus deferens/vas deferens (13).** *Disregard the label no. 12.* The vas deferens **(1)** (re) enter the pelvic cavity through the narrow **inguinal canal** on both sides of the body (not shown in the images). The cases of **inguinal hernia** or locally called "**luslos"**, occur here in these canals. Since the inguinal canal is a weak opening, straining the abdominal muscles by lifting heavy objects, for example, tears the tissues in this site and cause some intestinal loops to bulge into the scrotum.

Discussion Link 2.4: What is the role of the scrotum in sperm development? What is cryptorchidism and how can this condition lead to male sterility? Can cryptorchidism be corrected? If yes, in what ways (just give answers in phrases or bullet form). What is the pampiniform plexus? What is its role in protecting the developing sperm cells? Answer in not more than five sentences.

Once the **ampulla of the vas deferens (1)** has looped over the ureter (9) inside the pelvic cavity, the distal end of it is the **seminal vesicle (2**). It was

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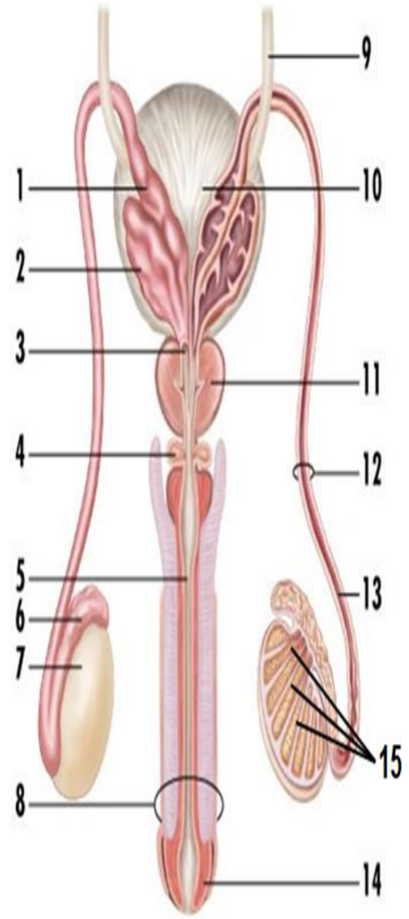
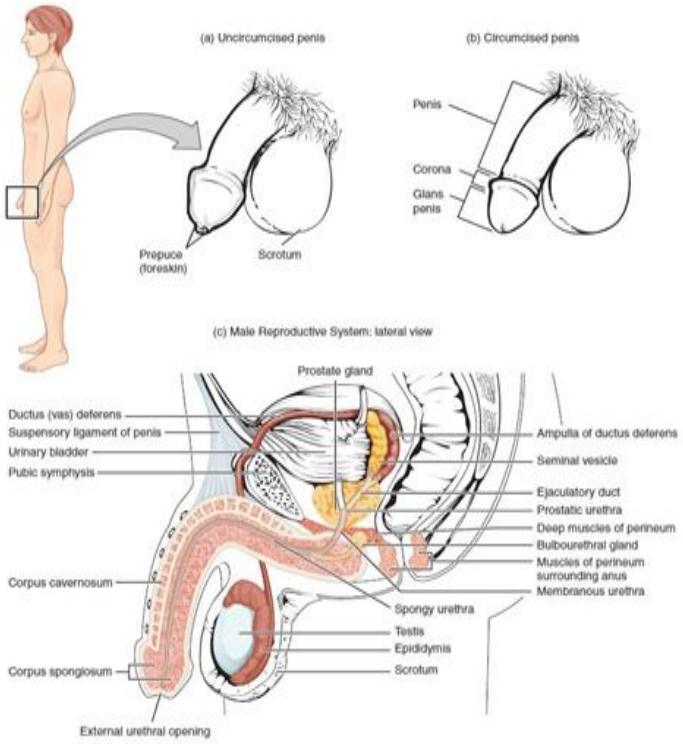


Differentiate seminal fluid from semen.

The figure below shows a side view of the human penis and its uncircumcised and circumcised appearances.

Discussion Link 2.5: What makes an uncircumcised penis look different from a circumcised penis? What is "revealed" after circumcision? As future medical doctors, do you think circumcision is necessary? Why or why not? What do you think is the ideal time or age for the male child to be circumcised? Answer these questions in not more than five sentences.



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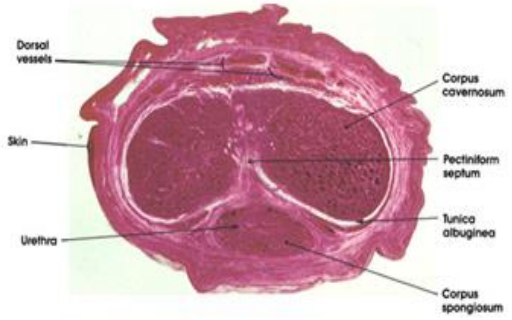
The image on the upper left (kindly zoom it) also shows to you the ducts or tubes of the glands mentioned earlier. The ampulla of the vas deferens and the seminal vesicle has a common tube, the **ejaculatory duct (ED).** The ED joins with the urethral part in the prostate gland called the **prostatic urethra** (PU) and form a common tube, the **membranous urethra (MU)** that continues into the **spongy urethra** of the penis.

Note the proximity of the rectum with the male reproductive tract. *Can you imagine now how a digital/manual rectal exam for possible prostate cancer is done?*



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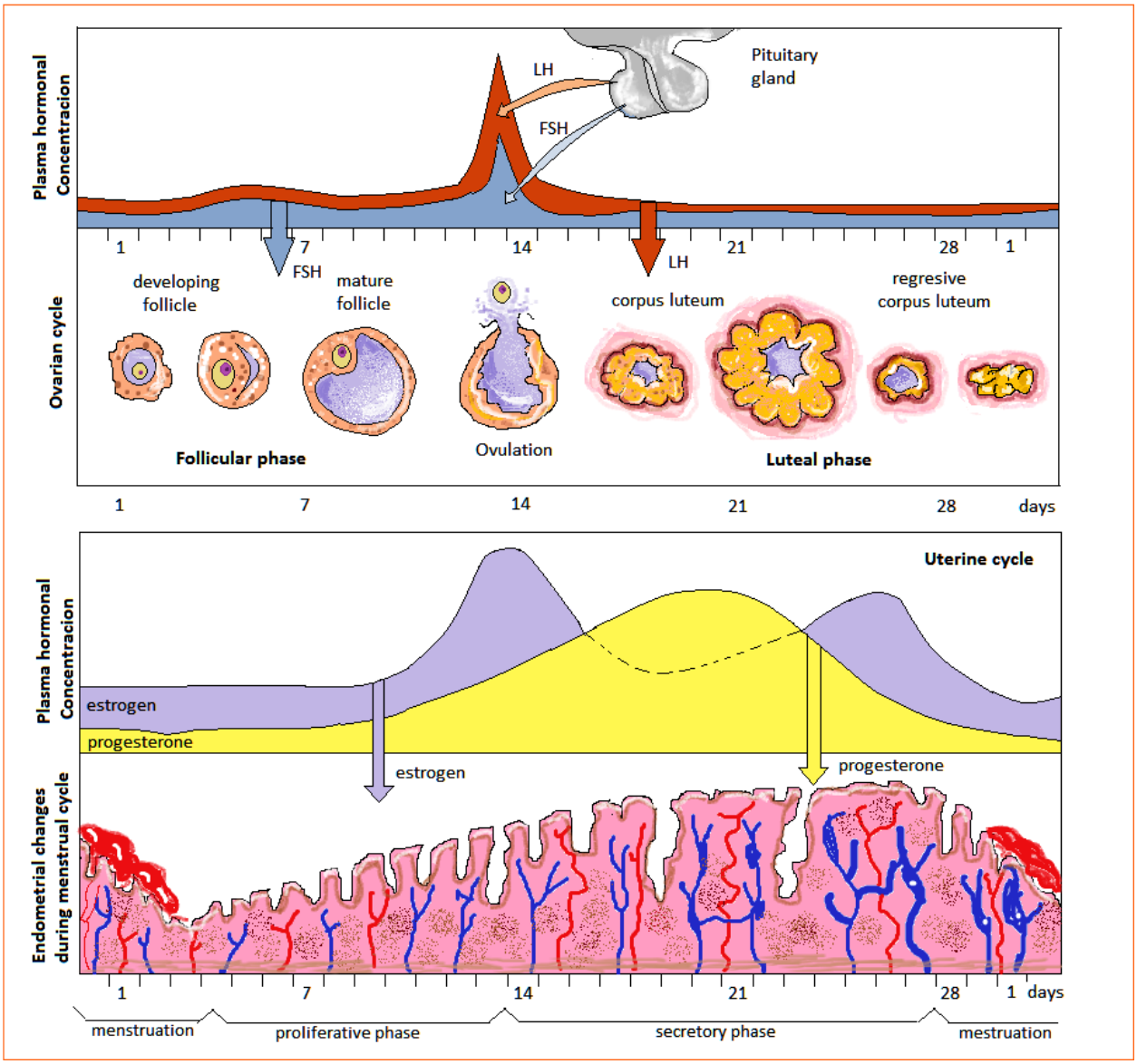
The image at the bottom is a cross-section shaft of the HUMAN penis. The penis is the male external genitalia with three rodlike masses of erectile tissue held by dense connective tissue and covered by freely movable skin. The paired dorsal tissues are the ***corpora cavernosa (cavernosum, sing.).*** The single erectile tissue is the ***corpora spongiosum***is located in the ***glans penis***. The terminal end of the urethra is the **external urethral opening** through which the urine and the semen pass out of the male human body.

*Differentiate a **flaccid** penis from an **erect penis.***

B. SEXUAL CYCLES and HORMONAL ACTIONS IN MAMMALS

1. Female cycles

Shown below is a graphic summary of the female sexual cycles, consisting of the ovarian and menstrual cycle in primates (particularly humans) and the interplay of hormones in these two cycles. We will "dissect" each part of the graph to fully understand the sexual cycles in female mammals.



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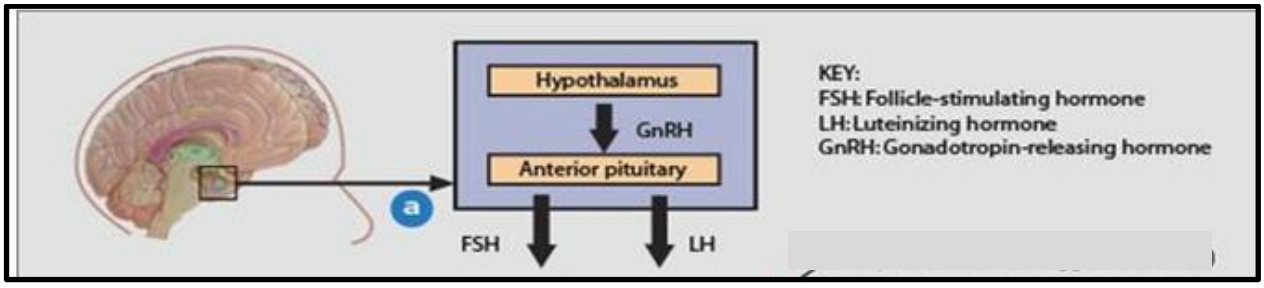
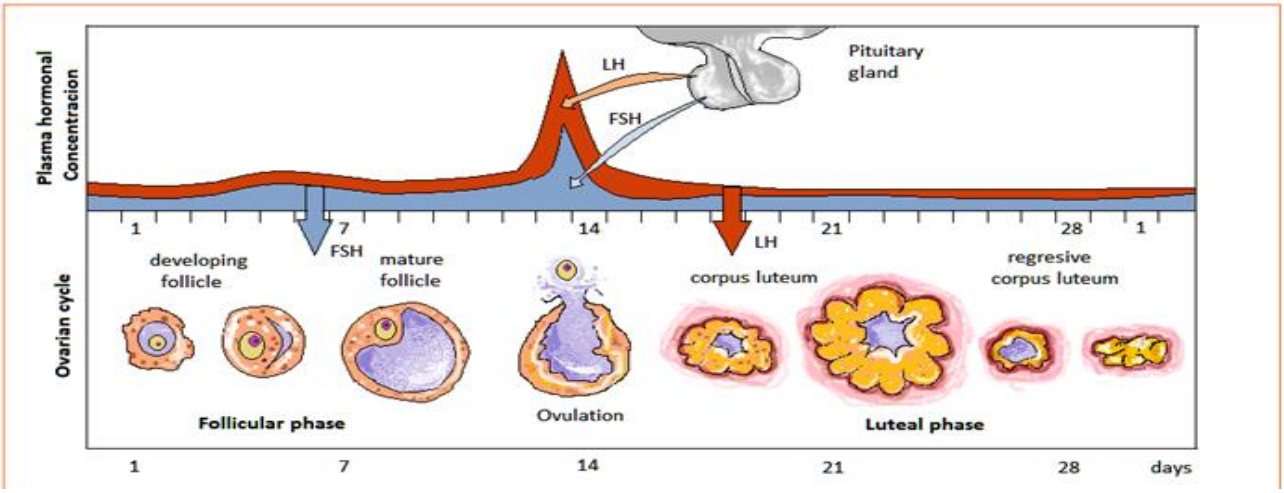
(a) When a female begins to undergo regular monthly cycles at the time of puberty, she begins to undergo regular monthly cycles. These cycles known as **sexual cycles**, which are controlled by the brain part, **hypothalamus.** The hypothalamus as shown on the diagram below releases **GnRH (gonadotropin releasing hormone/factor)**. The release of this hormone is known to be stimulated by internal and environmental stimuli (e.g., internal stimuli = levels of sex hormones in the blood; environmental stimuli = olfactory or smell signals). Once the GnRH is

released by the hypothalamus, it is transported to the **anterior lobe of the pituitary gland (adenohypophysis)** by way of blood vessels known as the **hypothalamohypophyseal portal system** and stimulates it to secrete its hormones. *And what are these hormones?* These two hormones released by the adenohypophysis are the **gonadotropins**: **follicle-stimulating hormone (FSH)** and **luteinizing hormone (LH).** *What are the targets or the effects of these two hormones?* Another gonadotropin that is released by the adenohypophysis is the hormone **prolactin** (not shown in the diagram) whose role is important during and after pregnancy.

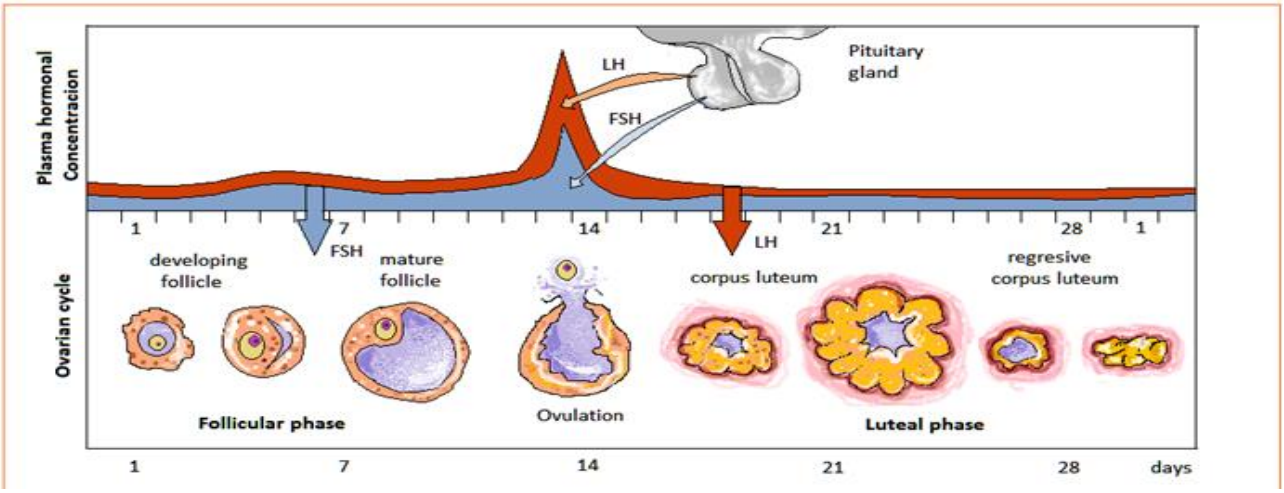


(b) The diagram below shows the concentrations of FSH and LH in the blood before and after **ovulation**, which is the time a mature ovum is released from the ovary for possible fertilization by the spermatozoa. It can be seen in the graph that although there is a higher level of FSH in the follicular phase (leftmost of the ovulation period) than LH, both increases their peak just prior to ovulation (usually on the middle of the cycle, which is 14 days for a 28 day human menstrual cycle). Then, just after ovulation, the blood levels of the two hormones decline to levels like in the start of the cycle.



(c) What then are the effects of FSH and LH in the growth and development of the ova? The role of FSH, as its name implies, is to stimulate the development of follicle cells around the ova (primary oocyte stage) of about 5 to 12 in numbers at the start of the ovarian cycle. The role of LH in females is to stimulate the follicle cells for further growth and maturation and allows the release of the ripe egg during the ovulation period. After ovulation, LH role is to maintain the **corpus luteum** because

it releases important hormones for maintaining pregnancy. If there is no pregnancy the corpus luteum undergoes **atresia** or degeneration or regression.

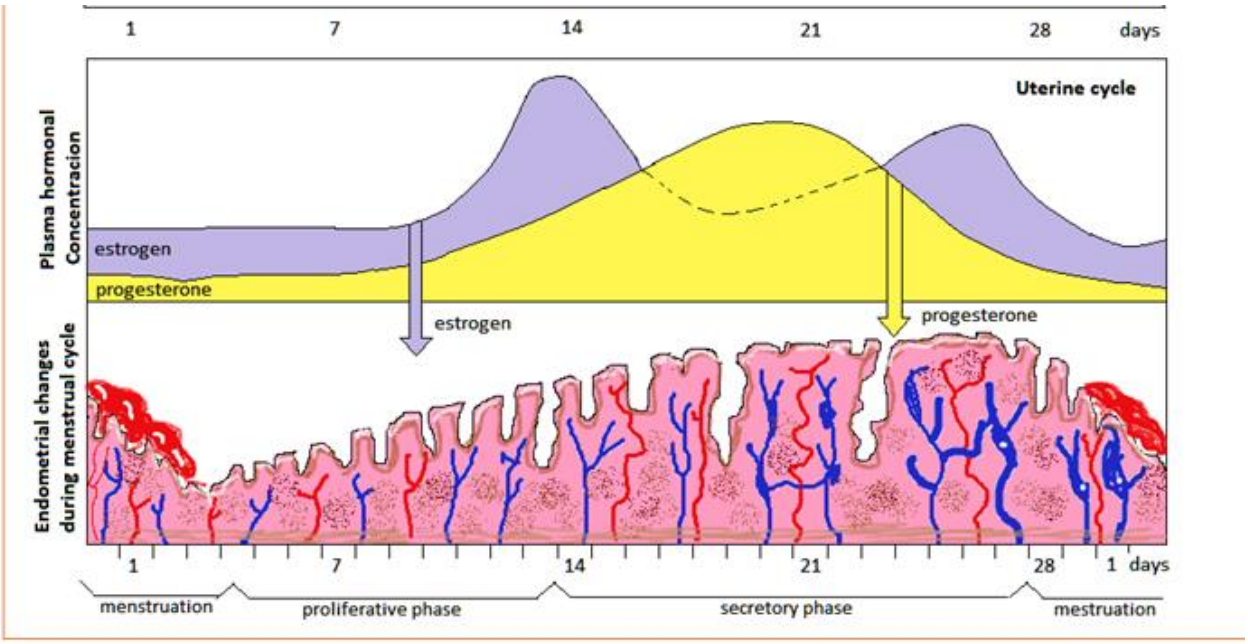


The first half of the ovarian cycle is the **follicular phase.** *Why do you think it is called that phase*? The other half of the cycle is the **luteal phase** which occurs once the mature egg is ovulated or liberated from the ovary. *Why is this phase called such?* In the graph above, we can see the transformation of the ovum from the developing form → mature follicle→ ovulation→ corpus luteum → atresia.

This is just an overview of the changes in the egg cell that is to be ovulated and possibly be fertilized in a 28 day menstrual cycle of a human. There are still details you should be familiar with in events of the ovarian cycle. The details of oogenesis and spermatogenesis as well, will be taken up in the next module.

Why are these stages of follicular cell development important? Two important steroid hormones are produced by these follicle cells and are secreted into the blood plasma. These hormones are **17β-estradiol/estrogen** and **progesterone.**

These hormones are key players in the *third level* of hormonal control. *Which one is the first level and which one is the second level? (Go back to the start of the female sexual cycle☺).* This 3rd level occurs in the ovaries and during pregnancy in the placental tissues. Looking now at the lower half of the graph,



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a constant level of estrogen is seen from day 0 to about 10 days of the cycle, after which there is an upward surge to the 14th day , the day of ovulation. Then it slowly declines to a level not lower than in the first half of the cycle then peaks again then declines again prior to menstruation if there is no pregnancy. These rise and fall of the estrogen levels are correlated with the growth and decline of the follicular cells. By the way, only one "lucky" preovulatory follicle will be targeted by FSH and LH, the rest will degenerate. After ovulation, the estrogen will be secreted by the corpus luteum.

How about for progesterone? *Interpret the levels of progesterone from day zero to 28 days? Relate it to the ovarian cycle in particular to the growth and decline of the follicle cells? At what phase of the ovarian cycle is there a high level of progesterone in the blood plasma? What secretes the progesterone?*

Now that estrogen and progesterone are circulating in the blood at higher levels from day 10 to 28 of the menstrual cycle, what are the effects of these two hormones to the lining of uterus? In the lower part of the graph, there are three distinct phases of the menstrual cycle: menstruation (bleeding phase), the proliferative phase, and the secretory phase.

Menstruation is the time when bleeding occurs in females which takes about 5 days (in average). Bleeding happens when the ovulated egg is not fertilized by a sperm cell (Why do you think the egg was not fertilized?).

After bleeding stops, the dominant hormone is estrogen and it stimulates mitosis of the endometrial cells of the uterus and also promotes the start of the growth of the uterine glands. Progesterone, though at lesser levels than estrogen also helps

in building back the lining of the uterus and making it more vascularized (more blood vessels) prior to ovulation. Why? This is to prepare the endometrial lining for possible implantation of an embryo should there be successful fertilization of the ovulated egg. These events occur during the **proliferative phase** and looking back at the diagram in the previous page, you can see the difference in the thickness of the endometrium after bleeding to pre-ovulation.

By the time the egg is ovulated, the endometrial lining is already thick enough, with more blood vessels and uterine glands, all set to receive an embryo for implantation. This phase of the menstrual cycle is the **secretory phase.** Going back to the graph, after ovulation, the levels of estrogen is now lower than progesterone. Why? Once an ovum (Graafian follicle) is ovulated, all the follicle cells around the ovum is damaged already and estrogen is not released anymore. However, the resulting body of follicle cells after ovulation called corpus luteum will be the one to secrete the estrogen and progesterone which will then maintain the strength and integrity of the endometrial lining of the uterus.

If there is no fertilization of the ovulated ovum, the corpus luteum regresses into corpus albicans until it just leaves a scar on the ovarian issues. Once atresia of the follicles happen, there is lower levels of estrogen and progesterone, the integrity of the endometrium is weakened until it is "destroyed" again during the **menstruation phase.** And the cycle begins again. Now if there fertilization and successful implantation of the embryo, another set of hormone comes around and this is the (**human) chorionic gonadotropin**, produced by the placental tissue to maintain corpus luteum for it to secrete more estrogen and progesterone.

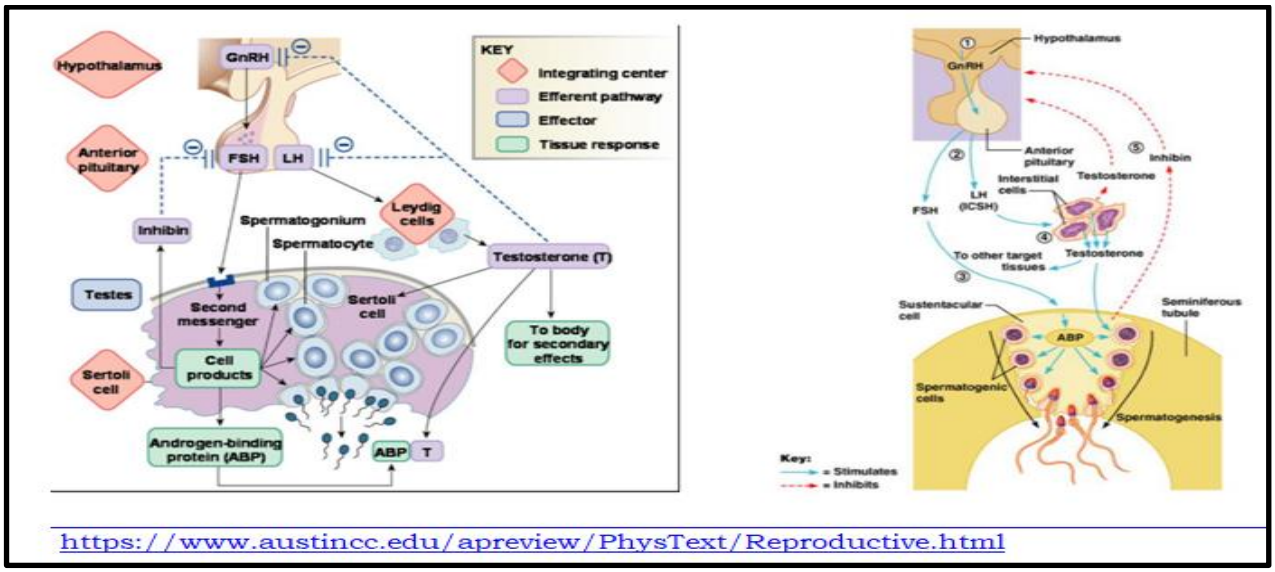
What will stop or slow down further growth of follicle cells before ovulation? It is by an inhibitory substance **inhibin** that is released by the ovary. This substance, plus estrogen are brought to the hypothalamus to stop releasing the GnRH, thus stopping the adenohypophysis to release FSH and LH? Is this a negative feedback mechanism or a positive feedback mechanism?

In summary, the **ovarian cycle** in mammals (and for other vertebrates) is simply the changes in the ovary and the ova that happen in a regular cycle once reproductive capacity and/or ability is reached by the organism. **Menstrual cycle,** on the other hand, occurs only in primate mammals. The females are characterized by **menstruation**, which is the bloody discharge of the uterine lining, mucus and cellular debris at periodic intervals (4 weeks approximately in humans). The first appearance of menstruation in humans is called **menarche** (around 12 to 14 years old, or maybe earlier or later) and continues non-stop until the time of **menopause** (during late forties, or maybe earlier or later). Although, the term menstrual cycle is used to refer to the changes in the uterus, it will include both ovarian and menstrual cycles.

Discussion Link 2.6: What is Mittelschmerz? Are the girls of this class aware of this sensation at one day of the month? Why is this used as a sign of ovulation in a woman? What are the other signs girls should be aware of when they are ovulating? Give at least two more signs. Answer in not more than five sentences.

2. Male cycle and its hormones

The first and second levels of hormonal actions in males are very much similar with the females. When a boy reaches the age of 10 years old, at the first level of hormonal action, the hypothalamus releases GnRH to stimulate the adenohypophysis (second level) to release FSH and LH. The target organs now of these two hormones are the paired testes. FSH stimulates the **Sertoli cells** or **Sustentacular cells** to secrete **androgen-binding protein (ABP)** [see diagram below on the right] and other signalling molecules that are necessary for spermatogenesis. LH, on the other hand, stimulates the **interstitial** or **Leydig cells** to secrete **testosterone.** The Leydig cells are located in small clusters among the seminiferous tubules in the testes. The human pituitary secretes LH in humans in pulses roughly at 90-minute intervals especially at night. The local effect of the testosterone is to maintain spermatogenesis. But since it is transported by blood, it reaches other tissues and organs, including the brain of the male body.



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The levels of testosterone in the seminiferous tubules are maintained by the ABP. The regulation of the release of FSH and LH is mediated also by **inhibin** by reducing the activity of the hypothalamo-hypophyseal axis.

Discussion Link 2.7: What can happen in males if the level of testosterone is lower than the normal level? If castration is done before the onset of puberty, how does the male child appear and behave in adulthood? How about if the testes are removed after puberty, can the male still be masculine in appearance and behaviour? Answer in not more than five sentences.

C. ESTROUS CYCLE

Menstrual cycles are only seen in humans and some other primates. Most other mammals have **estrous cycles**, wherein females are ruled by sexual periodicity. Meaning, females have a period of strong mating impulse and is therefore, sexually

receptive. This period is what animal breeders call the "**period of heat**" and biologists speak of it as **estrus**. Among male mammals, breeders call this brief period of pronounced sexual activity as the "rutting" season.

The same reproductive organs and hormones are involved in the estrous cycle of these mammals. One difference though is that no bleeding occurs in these female mammals. The uterus reabsorbs the thickened lining of the endometrium if conception or fertilization of the ova does not occur. Recall that in mammals with the menstrual cycle, the endometrium is released during menstruation if there is no fertilization of the ovulated ovum.

There are still a lot of things to know about the estrous cycle, but for this course, this would be enough for now.

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