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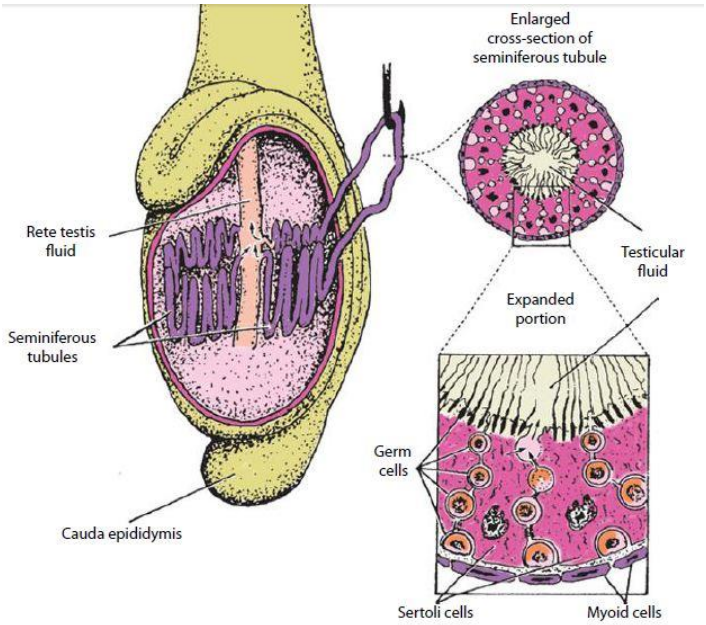
Male Reproduction in Mammals

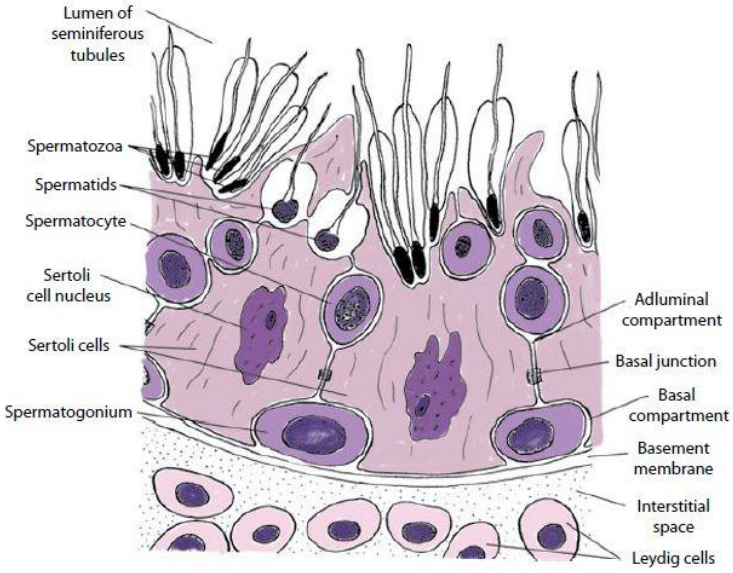
Detailed structure of the testicle:

- Only two of the many seminiferous tubule loops are shown.
- Testicular fluid is secreted by Sertoli cells into the lumen of the seminiferous tubules.
- Myoid cells are contractile cells contained within the basement membrane.



Schematic representation of the periphery of a seminiferous tubule:

- The Sertoli cells divide the seminiferous tubule into **ADLUMINAL** and **BASAL compartments** at their basal junction (tight junction).
- Leydig cells are in the interstitial space.
- The basal junction forms a blood–testis barrier whereby the tubule environment is controlled and spermatozoa are prevented from entering the interstitium.



Spermatogenesis:

The term spermatogenesis refers to the entire process involved in the transformation of germinal epithelial cells (stem cells) to spermatozoa and can be divided into two phases:

1. **Spermato-cytogenesis**
2. **Spermiogenesis**.

Spermatocytogenesis: is the proliferative phase whereby spermatogonial cells multiply by a series of mitotic divisions followed by the meiotic divisions which produce the haploid (n) number of chromosomes.

Spermatogenesis: The second phase of spermatogenesis, it involves maturation of the spermatids while they are still in the adluminal compartment. Spermiogenesis comprises a series of nuclear and cytoplasmic changes and transformation from a nonmotile cell (not able to move) to a potentially motile cell in which a flagellum (tail) has formed. The mature spermatids produced during the final phase of spermiogenesis are released into the lumen of the seminiferous tubules as spermatozoa.

Spermiation: The release of matured spermatids into the lumen of the seminiferous tubules**.**

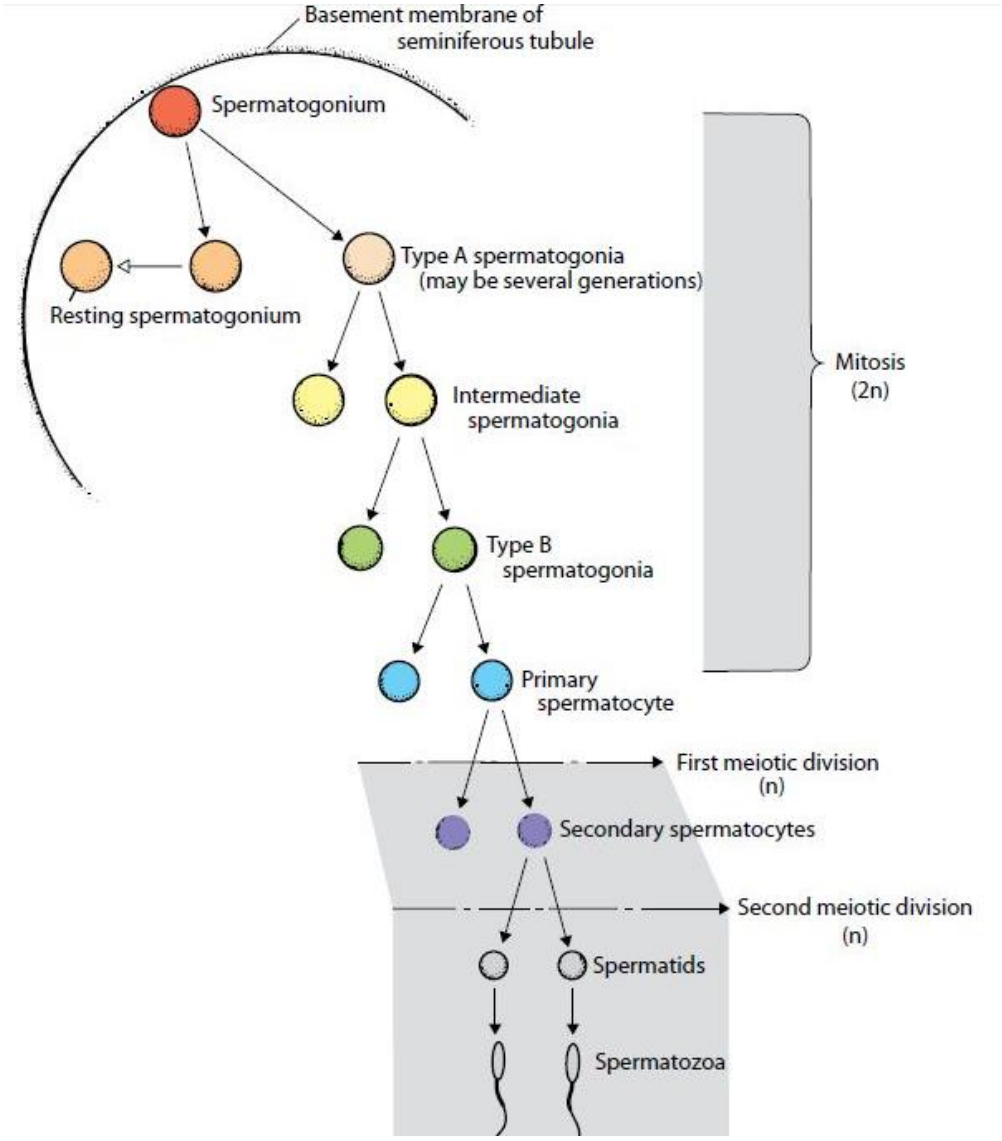


Fig: Diagrammatic representation of the stages of spermatogenesis in mammals; The chromosome number (2n, diploid; n, haploid) is also shown for each stage.

Epididymal Transport of Spermatozoa

The newly formed spermatozoa are essentially immotile. They are transported to the epididymis by fluid secretions into the seminiferous tubules and rete testis and by activity of contractile elements in the testis that direct fluid flow to the head of the epididymis.

The major site of sperm storage within the male reproductive tract is the tail (last portion) of the epididymis. About 70% of the total number of spermatozoa in the ducts outside the rete testis (excurrent duct system) are found in the tail of the epididymis. Many of the spermatozoa formed in the testes are either phagocytized in the excurrent duct system or lost into the urine. About 85% of the daily sperm production in sexually inactive rams are voided in the urine.

Spermatogenic Wave

- If all segments of the seminiferous tubules were involved in the same activity at the same time, a continuous supply of spermatozoa would not be produced because for spermatocytogenesis (development from spermatogonia to spermatozoa) to proceed requires about 64 days (in the bull) in the adluminal compartment.

- While this development is continuing, a new type A spermatogonium migrates through the Sertoli cell barrier into the adluminal compartment to begin its development behind the developing type A spermatogonium that preceded it.
- In the bull, this occurs every 14 days. Since 64 days are required for development to spermatozoa, there will be 4.6 cycles (64/14) of development before the first cycle from a given area of seminiferous epithelium begins to arrive at the rete testis.
- **[A cycle is defined as a series of changes in a given area of seminiferous epithelium between two appearances of developmental stages.** A portion of tubule at one stage is usually adjacent to portions of tubule in stages just preceding it or following it in time. **This sequential change in stage of cycle along the length of the tubule is known as the spermatogenic wave.]**

Hormonal Control

[N.B. Follow the info from **source** of hormone & **regulation** of hormone]

Erection

An increase in the turgidity of the penis is known as erection. It is caused by an increase in blood pressure within the cavernous sinuses of the penis as a result of greater blood inflow than out-flow.

Mounting and Intromission

Mounting: is the stance assumed by the male by which the penis is brought into apposition with the vulva of the female. Successful mounting must be preceded by a receptive stance on the part of the female. Failures in mounting are encountered when there are injuries, weakness, or soreness in the hindlimbs of the male.

Intromission: Introduction of the penis into the vagina and its maintenance within the vagina during coitus**.** Pelvic thrusts assisted by the abdominal muscles assist penetration of the penis into the vagina. The duration of intromission varies among species: it is shortest for the bull and ram and longest for the boar.

Emission and Ejaculation

Ejaculation is the discharge of semen (normally containing sperm) from the male reproductive tract, usually accompanied by orgasm. It is the final stage and natural objective of male sexual stimulation, and an essential component of natural conception.

Mechanism of emission & ejaculation:

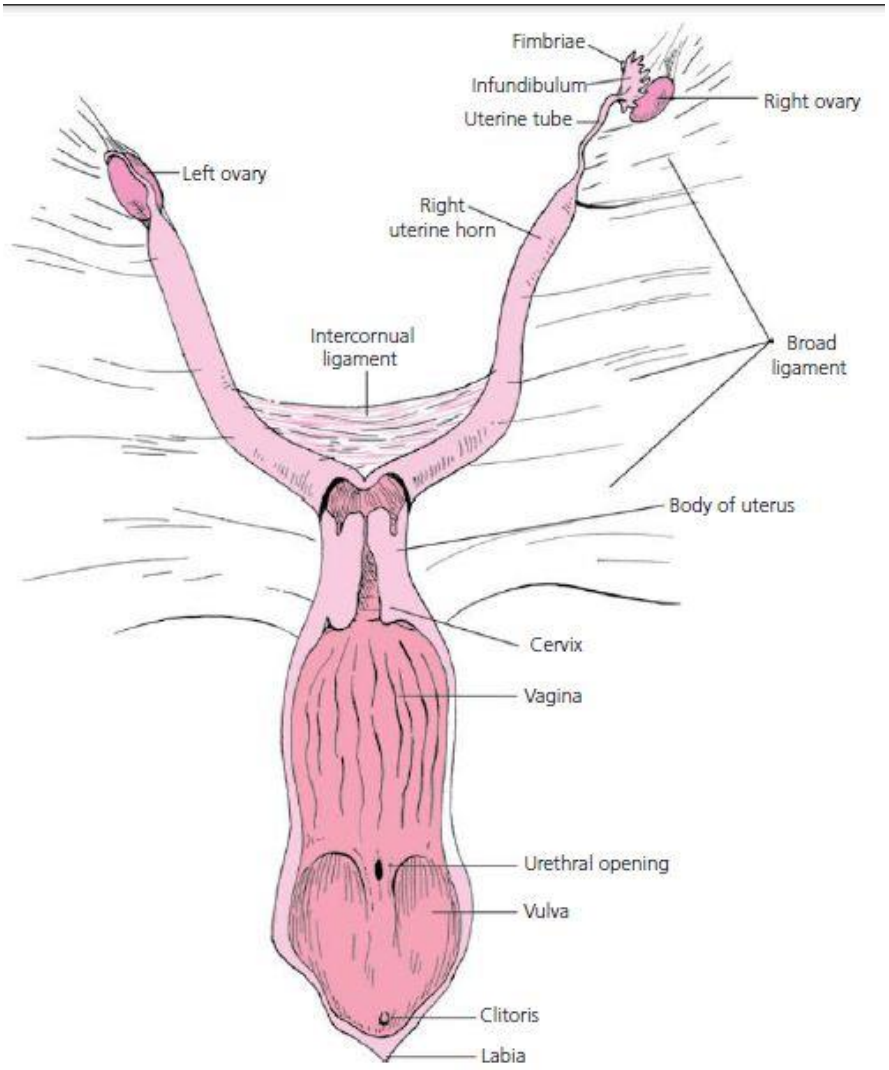
- As sexual stimulation increases, a point is reached at which reflex centers in the spinal cord bring about emission and ejaculation.
- Emission precedes ejaculation.
- It results from sympathetic innervations whereby sperm and fluids in the vasa deferentia and ampullae are emptied into the urethra along with fluids from the other accessory glands (seminal plasma).
- The sympathetic innervations provides peristaltic movement for transport to the urethra and constricts the neck of the bladder to minimize reflux (backward flow) of sperm and fluids into the urinary bladder.
- Once emission has been accomplished, reflex peristalsis of the urethral muscles propels the urethral contents toward the external urethral orifice.
- The latter phase, peristalsis of the urethra, is assisted by contraction of the bulbospongiosus muscle, which in turn compresses the urethra.
- The combination of pressure and peristalsis forces the semen (mixture of seminal plasma and sperm and fluid from the epididymides) from the urethra to the exterior, the process of ejaculation.
- Stimulation for emission and ejaculation is derived from sensory nerves located in the glans penis.
- Sperm and fluids are **ejaculated** near the **opening** of the **cervix in cattle and sheep**, **directly into the uterus in swine**, and **partially into the uterus in the horse**.

Factors Affecting Testicular Function

- Testicular function becomes manifest at the **onset of puberty**.

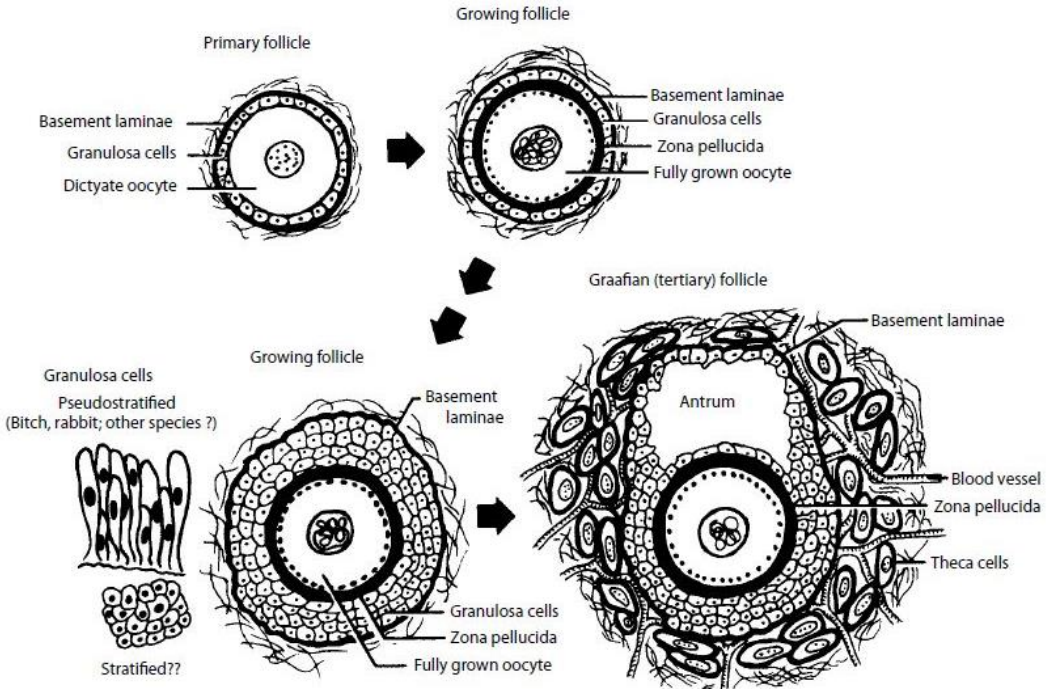
- It is believed that puberty is correlated with decreased sensitivity of the hypothalamus to testosterone, so that LH is secreted in greater amounts.
- An increased LH concentration stimulates the Leydig cells to secrete testosterone in greater quantities, and all aspects of testosterone function begin to appear.
- FSH is essential for the initiation of spermatogenesis at puberty.
- In some species, changes in **photoperiod (length of daylight)** have a marked influence on testicular function.
- Photoperiod is also related to ovarian activity in the female of these same species.
- The purpose of this sensitivity to photoperiod is the coordination of birth with favorable weather conditions.
- Sheep and goats have major periods of testicular regression during increasing photoperiod, which is restored by decreasing photoperiod.
- In the stallion, decreasing photoperiod reduces testicular function.
- The pineal gland (also known as the pineal body) is an endocrine gland attached by a stalk to the dorsal wall of the third ventricle of the cerebrum.
- The pineal gland is inhibitory to the gonads and is the principal mechanism involved in the effect of photoperiod on testicular and ovarian function.
- The pineal gland mediates the photoperiod response in the ram and ewe and is probably involved in the response of the other species.
- Testicular function and photoperiod in cattle and swine are related only to a minor degree.
- When spermatogenesis is stopped during photoperiod inhibition, FSH is again required for its initiation.

Female Reproduction in Mammals



Reproductive tract of the cow (dorsal aspect)

Development of an ovarian follicle:

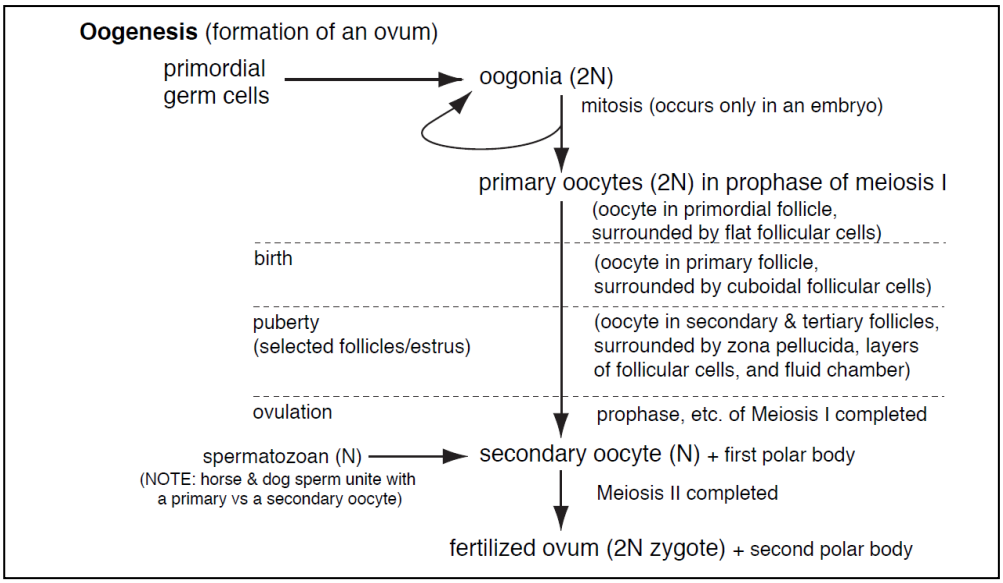


Follicle Regression

- Considerable atresia (regression) of the many primordial follicles occurs by birth and throughout the reproductive life of the female.
- At the end of the female's reproductive life, only a few primordial follicles remain, and even these undergo atresia soon thereafter.
- Growth of some number of primordial follicles does occur after birth and before puberty, but these never reach the Graafian follicle stage and regress.
- The growth that occurs before puberty is not hormone related and is probably controlled by an unknown intraovarian factor.
- The formation of Graafian follicles is hormone dependent and begins at puberty when tonic levels of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) begin to rise and fall with each estrous cycle.
- Many of the follicles that undergo growth and maturation with each cycle never ovulate.
- Therefore, the number of primordial follicles that reach the Graafian follicle stage and proceed to ovulation is a very small fraction of the birth number.

Oogenesis

- The process by which oocytes are formed is known as oogenesis.
- The oocyte of the primordial follicle is a primary oocyte that is in a quiescent (arrested) stage of meiosis.



- Meiosis resumes at the time of ovulation.
- Whereas four spermatozoa arise from one primary spermatocyte, only one oocyte develops from the reduction division of a primary oocyte.
- A polar body, which lacks sufficient cytoplasmic material for viability, develops when a primary oocyte divides to form a secondary oocyte.
- Another polar body is formed by the division of the secondary oocyte at the time of ovulation.
- The surviving oocyte has a haploid (n) number of chromosomes (similar to a spermatozoon) so that the union of a spermatozoon with an oocyte produces a cell with the diploid (2n) number of chromosomes.

Hormones of Female Reproduction

[N.B. Follow the info from **source** of hormone & **regulation** of hormone]

Ovulation

When the oocyte is released into the abdomen from its protruding follicle, it is covered by those granulosa cells that immediately surrounded it just before ovulation; these are known as the corona radiata. The oocyte and granulosa cells are evacuated with an enveloping viscous (gelatinous) follicular fluid. At ovulation, the oocyte, together with its surrounding cells and gelatinous mass, is swept into the uterine tubes by motility of the fimbriae.

Ovulation is spontaneous (no stimulation needed) in all the domestic species except the cat. The cat and other nonspontaneous ovulators (e.g., mink, rabbit, and ferret) are reflex ovulators, in that coitus is required for ovulation to occur. Coital contact apparently brings forth an LH surge.

Corpus Luteum Formation and Regression

- Formation of the CL involves luteinization of the granulosa, by which the granulosa is converted from estrogen secretion to progesterone secretion (LH receptors on the granulosa cells were previously induced by FSH).
- The process is initiated by the preovulatory LH surge.
- The cavity of the ruptured follicle and the fibrin clot within serve as the framework on which the granulosa cells develop.
- Blood vessels from the theca externa invade the developing CL, and it becomes vascularized. Maintenance of the CL is provided by LH derived from the LH surge and by the basal circulating levels of LH. In the sheep, prolactin, a gonado-tropic hormone for some species, is required to maintain the CL, in addition to LH.
- The uterus (endometrium) plays a major role in controlling the lifespan of the CL in nonpregnant mares, cows, sows, ewes, and does (goats), but is not active in CL regression in the bitch (dog) and queen (cat).
- **PGF2α** is released by the nonpregnant uterus about 14 days after ovulation and is considered to be the natural **luteolytic substance (causes regression of the CL)**.
- The venous return of uterine blood to the right heart and from there to the lung before transport of arterial blood to the ovary results in inactivation by the vascular endothelium of about 90% of PGF2α.
- To ensure that enough PGF2α is delivered directly to the ovary for luteolysis, the anatomic arrangement of the uterine vein and ovarian artery is such that PGF2α can diffuse from the vein to the artery and ovarian perfusion of PGF2α can occur before circulation through the lungs.
- For PGF2α to be effective when it enters the general circulation, it must either be secreted by the uterus in larger amounts, or be more resistant to degradation in the lungs, or both.
- Survival of PGF2α in the general circulation is more important in the sow and mare.

Persistent Corpus Luteum

- Prolongation of the luteal phase beyond 14 days to perhaps 1–5 months is known as persistent corpus luteum.
- The presence of a persistent CL prevents a return to the follicular phase and its next ovulation.
- The immediate reason for persistent CL is the failure of the endometrium to synthesize PGF2α. Often the failure is caused by an acute or chronic endometrial inflammation.

Estrus cycle

- Estrus cycle may be defined as rhythmic behavioral, structural and functional changes that occur in female at regular interval.
- **Estrus:** The period of sexual receptivity of female is called estrus or period during which the female will allow her to be mated.
- **Length of Estrous Cycle:** The estrous cycle averages 21 days in cows, mare and sow.
- **Phases of the Estrous Cycle:**
    - Estrous Cycle can be divided into 4 phases based **on behavioral changes or structural** changes in internal and external genitalia of female reproductive tract. These phases are: **Proestrus, Estrus, Metestrus, and Diestrus.**
    - On the basis of **hormonal or endocrine changes** during estrous cycle can be divided into 2 phases: **Follicular phase** (Estrogen dominant) and **luteal phase** (progesterone dominant)

Changes in the Endometrium During Estrus Cycle/ Stages of Estrus Cycle

1. Proestrus

- Endometrial changes occur eg. Thickening of the mucosa, congestion and edematous proliferation.
- Blood progesterone level falls.
- Rising of estrogen level.

2. Estrus: The period of **sexual receptivity** is called estrus. It is primarily initiated by the elevation in estrogens from mature follicles just prior to ovulation.

- Period of sexual receptiveness.
- Ovulation occurs.
- Estrogen level declines at end of this stage.
- Endometrial edema and hyperemia are maximum.

3. Metestrus

- It is a period of corpus luteum development and initial progesterone secretion.
- Edema of the endometrium lessens and breakdown of blood vessels.

4. Diestrus

- Phase of active corpus luteum formation.
- Under the influence of progesterone the endometrium change from proliferative to secretory type; glandular coiling, epithelial growth and secretion.

Sexual receptivity

If copulation is to occur near ovulation, the female must be receptive to the male. Initiation of sexual receptivity in all animals requires estrogen derived from the antral follicles. Also, in some species (e.g., bitch, ewe, sow, cow), progesterone acts synergistically with estrogen for manifestation of receptivity. Neurons associated with a “sex center” are located diffusely in the hypothalamus and are critical in initiating the mechanisms of sexual behavior as a response to hormones. It seems that progesterone (tonic levels) acts as a primer for the hypothalamic sexual centers so that estrogen becomes effective.

Estrous cycle and related factors

The term **estrous cycle** refers to the rhythmic phenomenon observed in all mammals involving regular but limited periods of sexual receptivity (estrus) that occur at intervals characteristic of a species. One cycle interval is defined as the time from the onset of one period of sexual receptivity to the next (**the ovulatory interval**).

Animals are usually classified as **monestrous or polyestrous**.

- **Monestrous** animals are characterized by experiencing estrus once each year. Most wild carnivorous mammals are mones-trous and, with some variation, the bitch is usually considered to be monestrous.
- **Polyestrous** animals, including most domestic species, have more than one period of estrus in a year.
- A **seasonally polyestrous** animal is one that has repeated estrous cycles within a physiologic breeding season (some part of a year), followed by a period of anestrus until the next breeding season.

Hormonal changes & regulation of estrous cycle

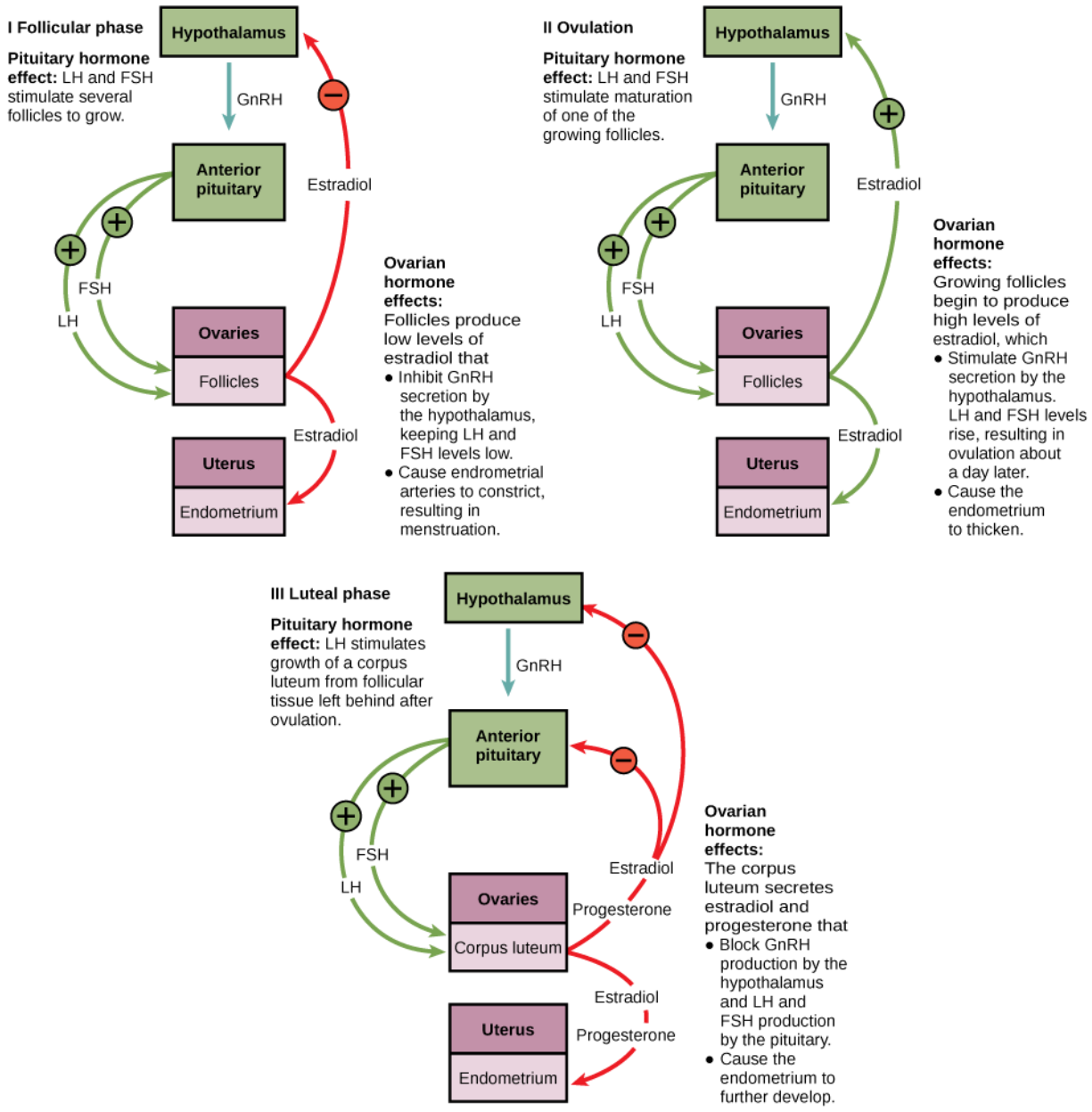


Fig: Hormonal changes & regulation of estrous cycle

Pregnancy

Pregnancy is the condition of the female in which unborn young are contained within the body. Pregnancy is also called gestation, and its length is frequently known as the gestation period, extending from fertilization through birth. Pregnancy begins with fertilization, ends with parturition,

and includes the essential aspects of implantation and placentation. Before fertilization, the oocyte and sperm are transported to appropriate sites in the uterine tubes.

Parturition

Parturition, sometimes called labor, is the physiologic process by which the pregnant uterus delivers the fetus and fetal mem-branes from the mother.

Signs of approaching parturition

- Throughout pregnancy the abdomen continues to enlarge, and its maximum size is reached just before parturition.
- The mammary glands also continue to enlarge and, within a few days of parturition, begin to secrete a milky material.
- Other signs include swelling of the vulva and a discharge of mucus from the vulva.
- The abdominal muscles relax, which causes the belly to drop and the rump to sink on both sides of the tailhead.
- It is believed that the hormone relaxin, in association with the increasing level of estrogen in late pregnancy, causes the relaxation of ligaments to enable the birth canal to enlarge.
- Also, it is thought that PGF2α helps to relax the cervix.
- In addition to these physical signs, certain behavioral signs are characteristic, such as restlessness, frequent lying down and getting up, and frequent urination.
- The bitch and sow often attempt to build elaborate nests.

Stages of parturition

The three stages of parturition are as follows:

1. **Uterine contractions** (contribute to dilatation of cervix and presentation of fetus)
2. **Contractions associated with expulsion of fetus** (involve abdominal muscle contraction)
3. **Expulsion of fetal membranes.**

Table 27-1. Average Ages or Times of Reproductive Parameters for Selected Species

Animal	*Onset of Puberty*	*Age of First Service*	*Estrous Cycle*	*Estrus*	*Gestation*
Mare	18 mo	2–3 yr	21 d	6 d	336 d
Cow	1–2 yr	1–2 yr	21 d	18 hr	282 d
Ewe	8 mo	1–1.5 yr	17 d	1–2 d	150 d
Sow	7 mo	8–10 mo	21 d	2 d	114 d

Menstrual cycle	Estrus cycle
This cycle is full filled within 28 days.	This cycle is full filled within 21 days.
This cycle occurs in human(woman)	This cycle occurs in animal.
There is no definite heat period in this cycle.	There is definite heat period in this cycle.
In this cycle the inner layer of the uterus broken down and the menstrual fluid comes out.	In this cycle the inner layer of the uterus broken down but no fluid comes out.