FEMALE REPRODUCTION SYSTEM

Female reproductive system:

- The reproductive organ of female consists of two ovaries, two uterine tubes (oviducts), the uterus, vagina & vulva
- The ovum is released from the ovary & enters into the uterine tube
- Fertilization generally occurs in the uterine tube & the development of fertilized ovum or zygote takes place in uterus
- The fetus finally comes out through the vagina & vulva as a newborn (neonate)

Fertilized ovum- Zygote- Embryo- fetus Newborn (neonate)

Ovaries-

- These are paired glands found in the lumbar region of abdominal cavity
- They are primary reproductive organ of females like testes in male
- The ovaries are suspended from the body wall by serous membrane called mesovarium

- The medulla of the ovary is highly vascular while cortex consists of irregular connective tissue interspersed with follicles & having endocrine functions

Uterine tubes- Each uterine horn or infundibulum is attached to their respective ovaries & the uterus to serve the progression & fertilization of ova acts in this part. The wall includes a CT sub-mucosa & smooth muscle layer. They are supported by mesosalphynx

Uterus- It consists of a body, a neck (cervix) & two horns. The uterine wall consists of lining of mucous membrane & outer serous layer of peritoneum and are suspended & supported by the mesometrium

The mesometrium, mesosalphinx & mesovarium collectively constitute the broad ligament

Functions of the uterus-

- The endometrium & fluids acts as sperm transportation from the ejaculation site to fertilization site of oviduct
- It regulates the function of C.L.

- It also initiates the process of implantation, pregnancy & parturition by contraction of endometrium & stimulation and regression of C.L.
- The uterine glands are branched, coiled tubular glands throughout the endometrium of the uterus except in ruminants where they are in the form of mushroom like projection called carruncles for the attachment of the fetal membranes
- The cervix tends caudal to the vagina
- It is a heavy smooth muscle sphincter having rings in inner surface also called annular folds are tightly closed except during estrus for sperm mobilization & parturition for the expulsion of fetus
- The tunica muscularis (myometrium) of the uterine wall is separated by the outer longitudinal smooth muscle by a vascular layer increases the amount of muscle during pregnancy as in cell size (hypertrophy) & in cell number (hyperplasia)

Vagina-

- It lies within the pelvis between the cranially to the uterus & caudally to the vulva
- It consists of serosa on cranially & pelvic fascia (CT) caudally
- It generally acts as the birth canal for delivery of the fetus & the act of breeding or service (for the penis of male during copulation)

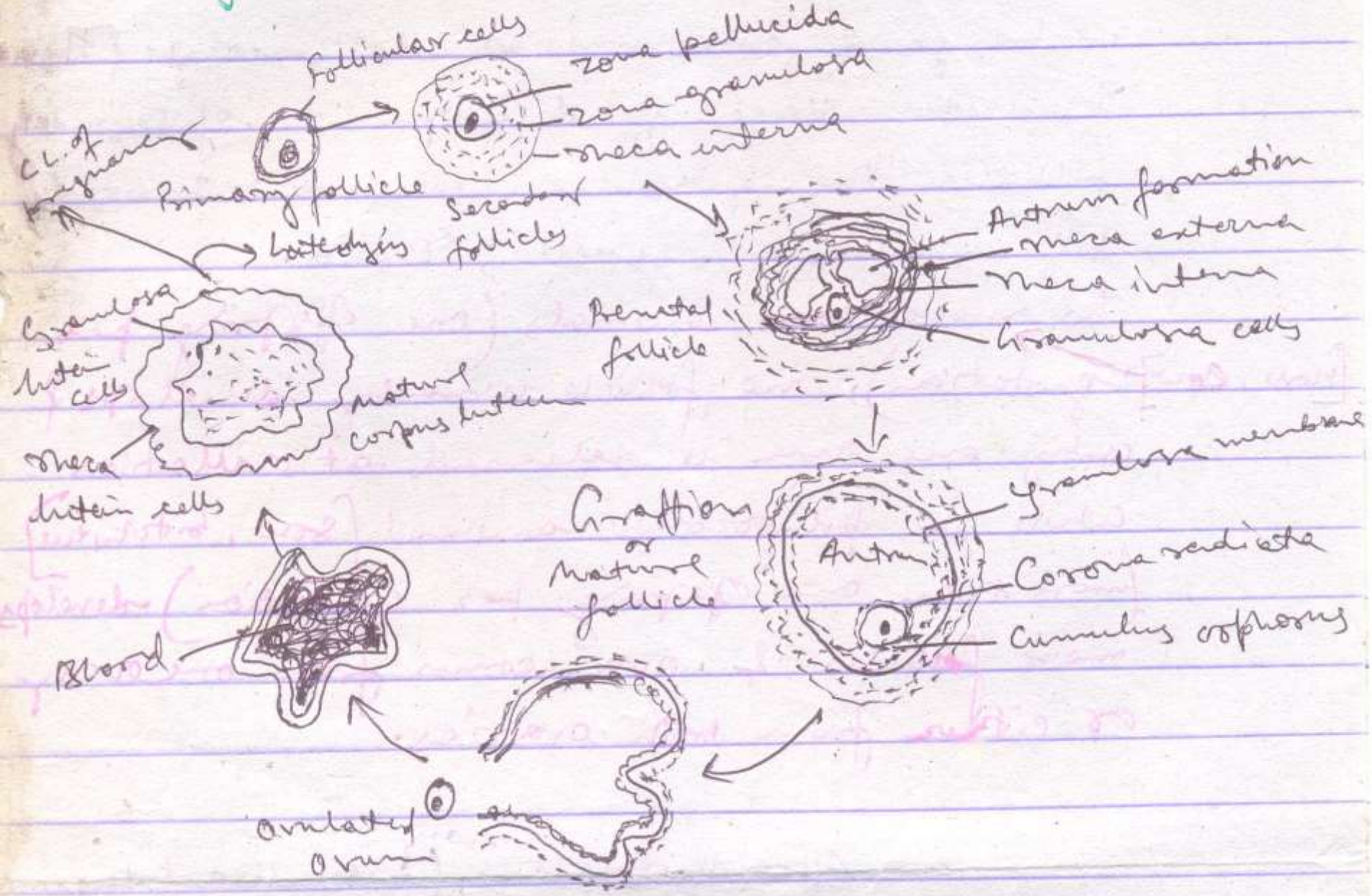
Vestibule & vulva-

- The vestibule lies between the vagina & vulva
- This part consists of external urethral orifice
- The vulva is the external genitalia comprises lt. & rt. labia which meet on the midline at the dorsal & ventral commissures
- The ventral commissure is usually pendulous or clitoris an erectile tissue which has sensory nerve endings
- The clitoris has specific similarities with the penis of the male having two crura or rods, a body & a glans (visible externally)
- It is concerned by stratified squamous epithelium

Blood & nerve supply of the female reproductive tract-

- The ovaries are supplied by the ovarian artery
- The uterine tube & uterine horn are supplied by the uterine artery & branch of ovarian artery
- The uterine artery is derived from the umbilical artery except in horse from internal iliac artery
- Vaginal artery, the branch of the internal pudendal supplies the blood to caudal part of the uterus, its cervix & vagina
- The distal branches of internal pudendal artery supplies blood to the caudal vagina, vulva & anus & all these vessels are mainly bilateral
- The venous drainage runs close to the arteries & drain to the caudal vena cava
- Sympathetic innervations arrives from the caudal mesentric ganglia via hypogastric nerves
- Parasympathetic fibres emerges from the sacral spinal cord segments & travel to the reproductive organs in the pelvic nerves
- The pudendal & perineal nerves provide motor & sensory innervations to the external genitalia respectively

Functions & Structure of graffian follicles cycles:-



Functions & structure of graffian follicle cycle-

- The oocytes are surrounded by the granulosa (epithelial) cells called primordial follicle
- Ovarium stroma separates the various primary follicles lies in the periphery (cortex) of ovary
- Development of primordial follicles involves transformation of follicular epithelial cells into a single layer of cuboidal cells surrounding the oocyte & this composite structure is k/a primary follicles
- After getting puberty, few primary follicles develop into secondary follicles involving ↑ in size of the oocytes & no. of granulosa cell layers
- During the development of secondary follicles, the granulosa cells secrete glycoprotein as a protective shell Zona pellucida around the oocyte
- Cytoplasmic process of granulosa cells penetrate the zona for exchange & communication between oocyte & them

- In later stage, development of secondary follicles and granulosa cells are surrounded by a layers of cells; Theca
- In monotocus animals horse & cow (one offspring per gestation), one follicle usually develops & only one ovum is released at ovulation
- While in polytocus animal sow, bitch & ewe (more than one offspring per gestation) develops more follicles & ova comes from one ovary or either from both ovaries. Up to this point the development is independent of hormones
- After this stage, ovary (granulosa & theca of secondary follicles) develop cellular receptors for FSH & LH & it is also useful for the normal follicular development
- On influence, androgens (androstemedione & testosterone) that diffuses into granulosa
- FSH acts as proliferation of granulosa cells which connects androgens to estrogens (estradiol) by developing cellular enzymes
- These cellular enzymes accumulates among the granulosa cells and looks like a fluid filled cavity also called as Antrum

- Then these follicles are identified as Tertiary or graffian follicles
- The theca has now two layers theca externa and interna
- The internal layer is highly vascularised and consists of steroid producing cells while theca externa consists of connective tissue
- The granulosa cells produced estrogen acts on the granulosa cells to ↑ FSH & LH receptors
- By a local +ve feedback effect the estrogen promote the development of the follicle from which they are being produced
- The developing follicles ultimately produce the ovum & ovulate is the +ve feedback while it has also a –ve feedback with FSH secretion from the adenohypophysis
- During this period FSH ↓^{es} causing atresia of slowly developing follicles
- Within the ovary, estrogens promote an ↑ in LH receptors in theca cells for production of androgens for responding LH at the time of ovulation

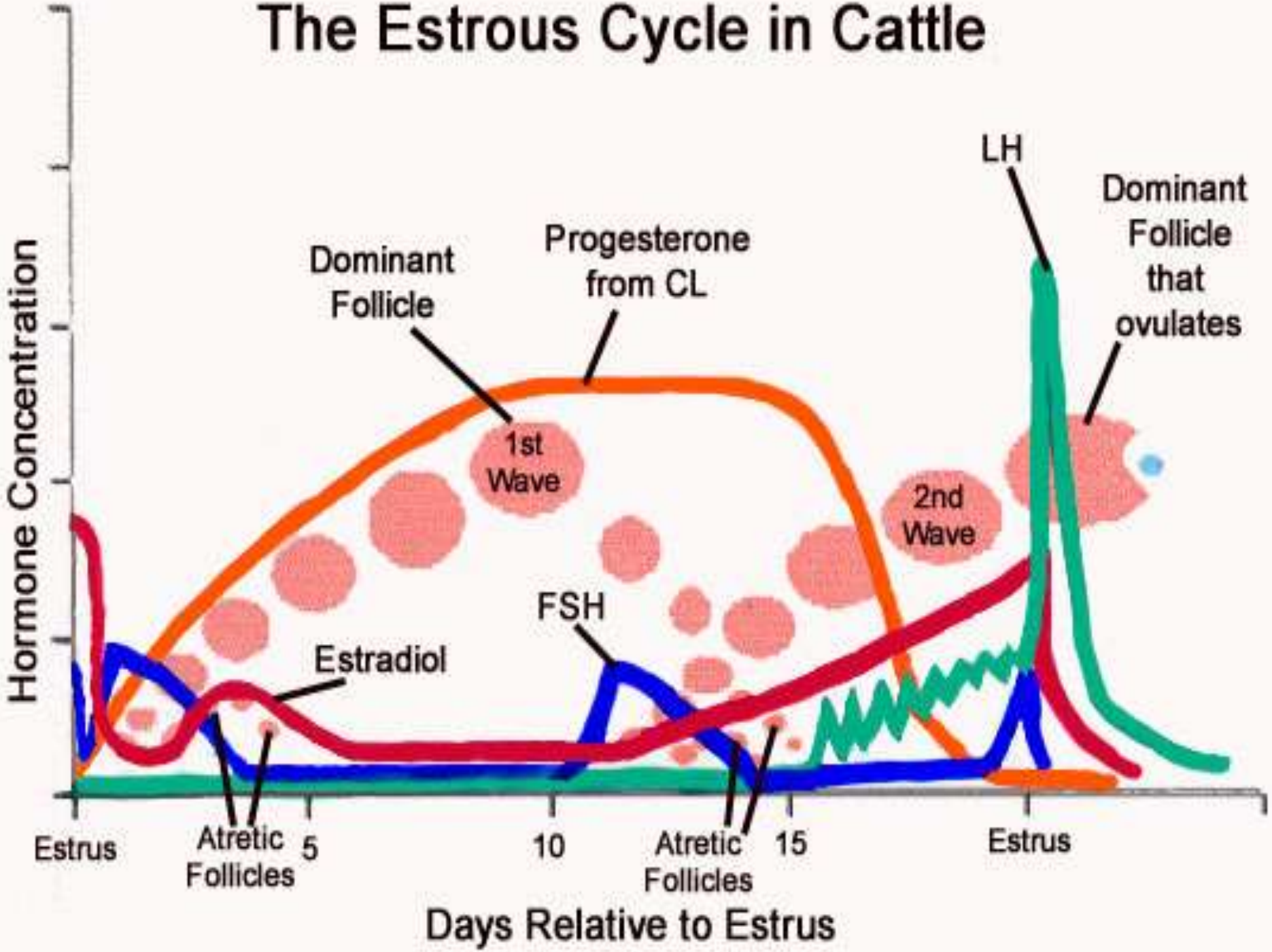
- The ovum is provided by the dominant follicle & is possess after the corpus luteum from the previous estrous cycle has regressed (luteolysis)
- The estrous phase during which there is no corpus luteum & the dominant follicles is developing in **follicular phase** of estrous cycle
- The **luteal phase** is the part of cycle when C.L. intacts with dominant follicles & secreting progesterone
- Mature follicles does not ovulate rather undergo atresia, if C.L. remains intact
- At that point, another dominant follicular begins to develop rapidly, so that ovulation can occur soon after luteolysis
- Because dominant follicles may develop while a C.L. remains intact, so large domestic animals have always the overlapping of follicular & luteal phases
- **Inhibins;** peptide hormones secreted by granulosa cell of developing follicles ↑ with follicular development & have a –ve feedback effect on FSH release

- In litter bearing animals, inhibins suppress other follicles to control the litter size but do not suppress LH secretion which is necessary for ovulation

Luteinizing hormone surge- Generally, LH releases from adenohypophysis ↑^{es} during 24 to 36 hrs prior to ovulation is the LH surge.

- After reaching peak, LH ↓^{es} so that the plasma levels return to preovulatory levels
- LH surge depends on changes in the hypophyseal-adenohypophysis axis & an ↑ in adenohypophysis content of LH induced by the rapid rise in estrogen production by large mature follicles
- The high level of LH promote the final development of the primary oocyte & prepares the oocyte for ovulation
- Granulosa cells respond to LH surge by transforming from estrogen producing cells to progesterone producing cells
- Also transformation of granulosa cells to luteal cells prior to ovulation, this process occurs & ↓ the estrogen level by ↑^{ing} the progesterone level

The Estrous Cycle in Cattle



- Under the influence of LH surge, granulosa cells synthesize leukotreienes
- These agents combindely weakens the follicle wall & promote its rupture

Spontaneous ovulators- The preovulatory ↑ in estrogen from developing follicles is the primary event for ovulation takes place. It occurs in almost all domestic animals.

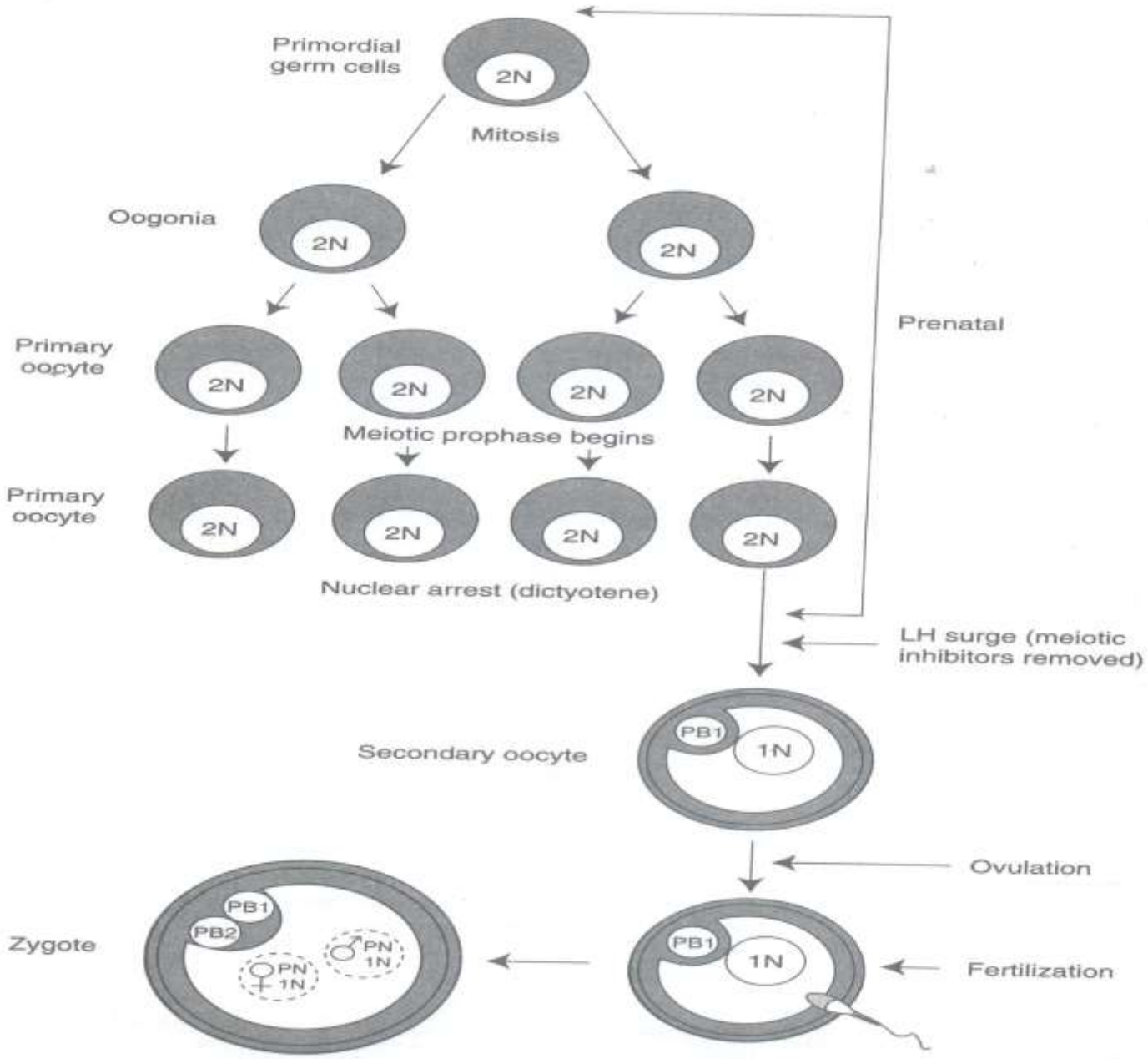
Induced ovulators- They have a characteristic estrous cycle & follicular development, mature follicles regress if copulation does not occur. The final preovulatory surge of GnRH & LH surge is depend on neural reflex elicited by vaginal stimulation during copulation.

Corpus luteum- It is the endocrine gland which primary secretes progesterone.

- It forms or develops after the collapse of the follicle at ovulation
- Under the influence of LH, the granulosa cells lining the empty follicular cavity begins to multiply and form corpus luteum

- So corpus luteum cells derived from the granulosa cells & some cells from theca interna
- The size of the CL is almost same as of graffian follicle, the difference is only that CL feels solid while mature follicle filled with fluid feels as blister
- After ovulation as CL grow the plasma progesterone level ↑es
- If the fertilization of the ova doesn`t occur (pregnancy not established), the CL regresses
- The CL regression consists of death of luteal cells removal & replacement of CL occurs forming corpus albicans
- Regression of CL prevents, if pregnancy occurs or develops
- The progesterone acts as preparation of pregnancy
- The progesterone level ↑es uterine gland secretion and inhibits uterine mortality to promotes implantation & maintain pregnancy
- The progesterone acts on hypothalamic adeno-hypophyseal axis to inhibit LH secretion
- It also promotes mammary gland development

Schematic of the major steps of oogenesis:



- Luteolysis stimulation occurs in non pregnant uterus by secretion of $PGF_2\alpha$ i.e., the humoral sign
- $PGF_2\alpha$ secretion ↑^{es} after ovulation & luteolysis shortly occurs

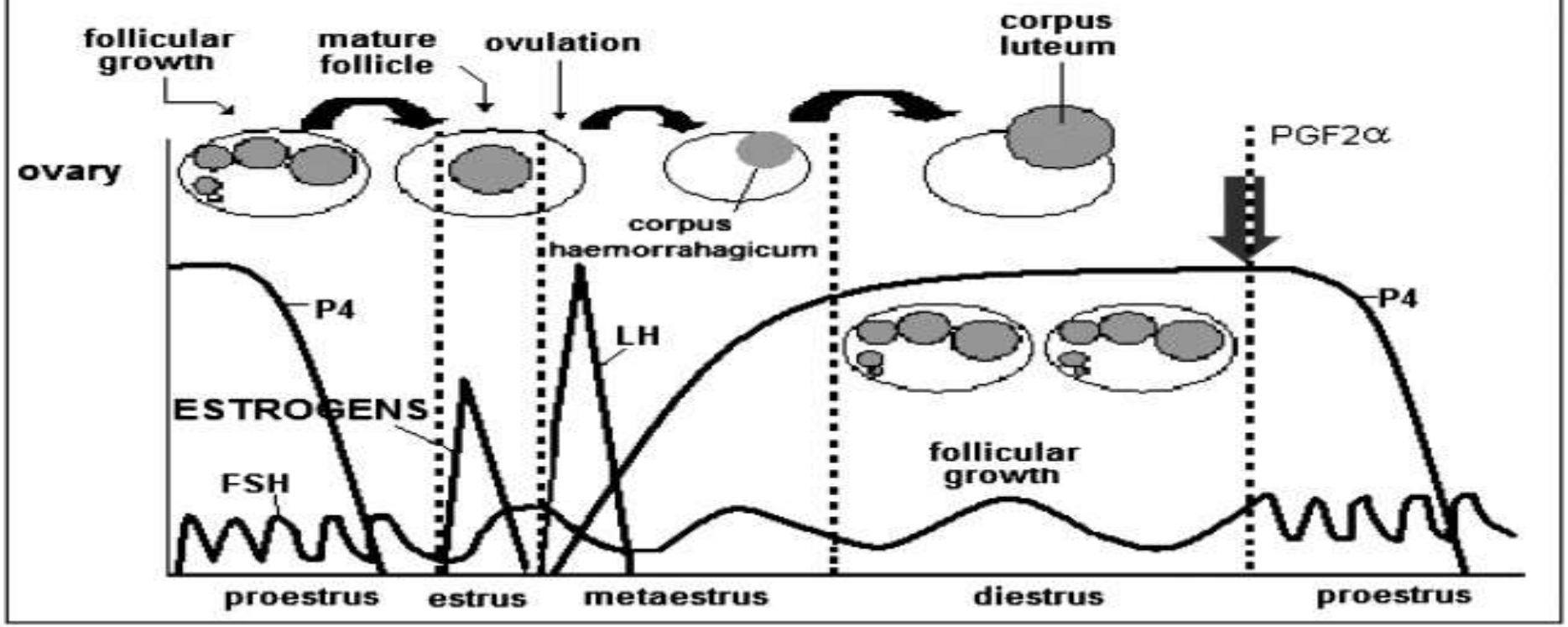
Phases of the estrus cycle: The estrus cycle is divided into several phases based on structural & behavioral changes in external & internal genitalia

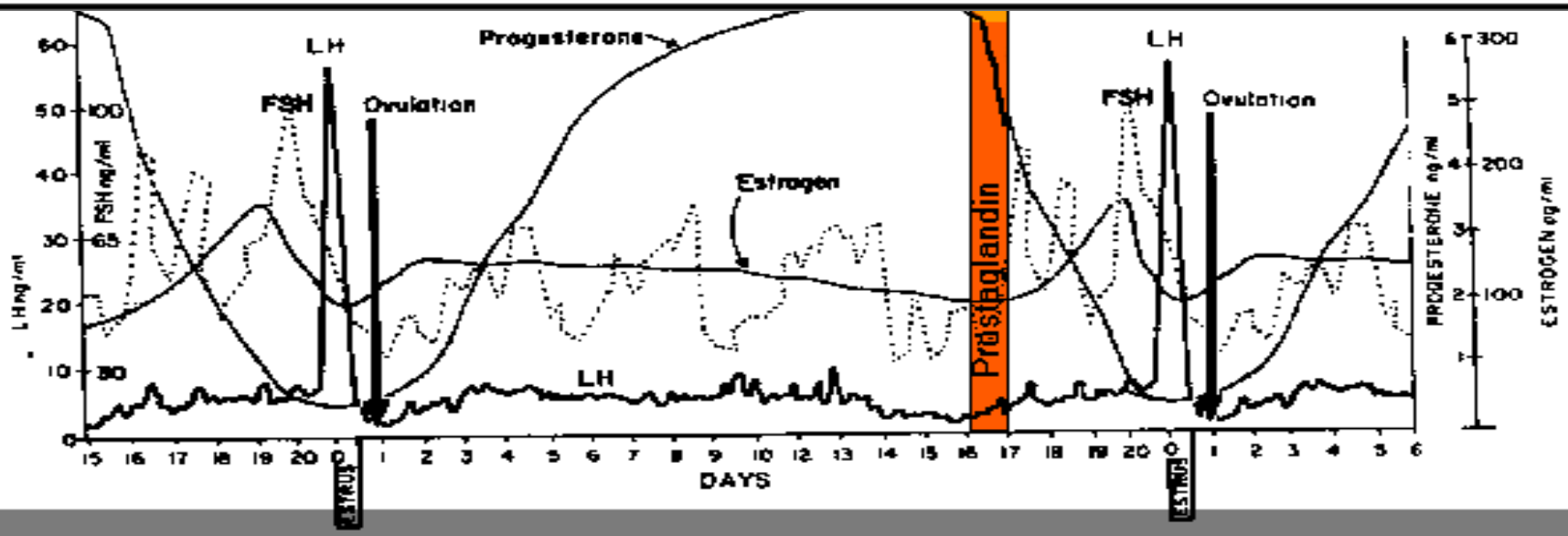
➢ **Proestrus-**

- It is the 1st phase of estrus cycle consists of building up phase
- It usually begins after the regression of C.L. from the previous cycle
- This phase includes enlargement of ovarian follicle (under the influence of FSH & LH) & estrogen secretion
- Estrogen comes into the blood stream from follicles to ↑ vascularity & cell growth of genitalia for preparation of estrus & pregnancy
- In later stage of this phase vaginal wall thickens & vascularized (redness & swelling) prepare for copulation

- **Estrus-**
  - Just before ovulation, mature follicles secrete estrogen in high amount preparing for sexual receptivity
  - In almost all domestic animals, ovulation occurs within a day or two after the onset of behavioral estrus (swollen vulva, mucus discharge, mounting, micturition, bellowing etc.)
- **Metestrus-**
  - This is post ovulatory phase begins with end of the sexual receptivity & dominated by the function of corpus luteum
  - During this phase estrogen level $\downarrow^{ed}$ with the $\uparrow^{es}$ in progesterone level
  - The endometrium get thickens, uterine gland enlarges & have developed uterine muscles
- **Diestrus & anestrus-**
  - This is the short inactive phase prior to proestrus
  - The animals (seasonal breeders) have long period of inactivity termed anestrus

Endocrine regulation of the bovine estrous cycle





Average length of various parts of reproductive cycle:

Species	Length of estrous cycle (days)	Length of estrus	Time of ovulation	Time fertilized ova enter uterus (after conception) (days)	Time of implantation (after conception) (days)	Type of placenta	Length of pregnancy (days)
Cow	21	18 h	12 h after end of estrus	3–4	30–35	Epitheliochorial	280
Ewe*	17	36 h	30 h after beginning of estrus	3–4	15–18	Syndesmochorial	147
Sow	21	45 h	36–40 h after beginning of estrus	3–4	14–20	Epitheliochorial	113
Mare*	21	5–6 days	Last day of estrus	3–4	30–35	Epitheliochorial	345
Doe* (goat)	20	40 h	30–36 h after beginning of estrus	4	20–25	Syndesmochorial	147
Bitch	In estrus at 7- to 8-mo intervals depending on breed	Proestrus, 9 days; estrus, 7–9 days	Days 3–6 of estrus	5–6	15	Endotheliochorial	64
Queen*	16 (nonbred) (pseudopregnancy lasts 36 days)	5–6 days	Induced 24–32 h after coitus	4	13	Endotheliochorial	65

- During this phase; the vulva, vagina, uterus & uterine tubes shrink & small until the next breeding season
- It is the time for initiating follicular development in polyestrus animals

Puberty- It may be defined as the very first estrus accompanied by ovulation. It is affected by inter & intra species depending upon climate, nutrition and hereditary.

Pregnancy-

- It is the physiological condition of a female animal after fertilization & implantation in which their young ones are developing within her uterus.
- The pregnancy interval or gestation period includes of fertilization (ovums to the birth of offspring), early embryonic development (in uterus), implantation (in the uterine wall), placentation (development of fetal membranes) and growth of the fetus

Fertilization-

- After the meiotic division of ovum (1st meiotic division completed of full term or ovulation in fox, horse & dog to become zygote whereas commonly it takes 2nd meiotic division to become folliculogenesis & ovulation for zygote) to become zygote on maturation is essential for fertilization
- Same as the condition with sperm
- Sperm capacitation is needed which is just capability of attaching to and penetrate the ovum
- The hydrolytic enzymes (hyaluronidase & aerosin) of acrosome plays a vital role in penetration of ovum
- There is interaction of sperm & ovum in the ampulla
- The sperm head is attached to the zona pellucida regulated by zona receptors
- Proteolytic enzyme (trypsin) blocks sperm attachment
- The sperm penetration occurs within 5 to 15 minutes after its attachment

- Acrosin enzyme acts as zona lysin & helps in penetration
- The acrosome reaction is a pre-requisite for fusion between ova & spermatozoa in the vitelline membrane covered by dense micro villi at the equatorial segment
- Immediately after fertilization the ovum surface changes to prevent fusion of additional spermatozoa
- Fertilization failure between different species is due to genetically determined difference in the physiologic constitution of the genital tract not due to genetic constitution of sperm or egg

Cleavage- Embryos goes under several mitotic divisions but to attain a similar somatic cells, cell divisions occur without an ↑ in cell mass referred as cleavage

The site of fertilization is the lower region of ampullae

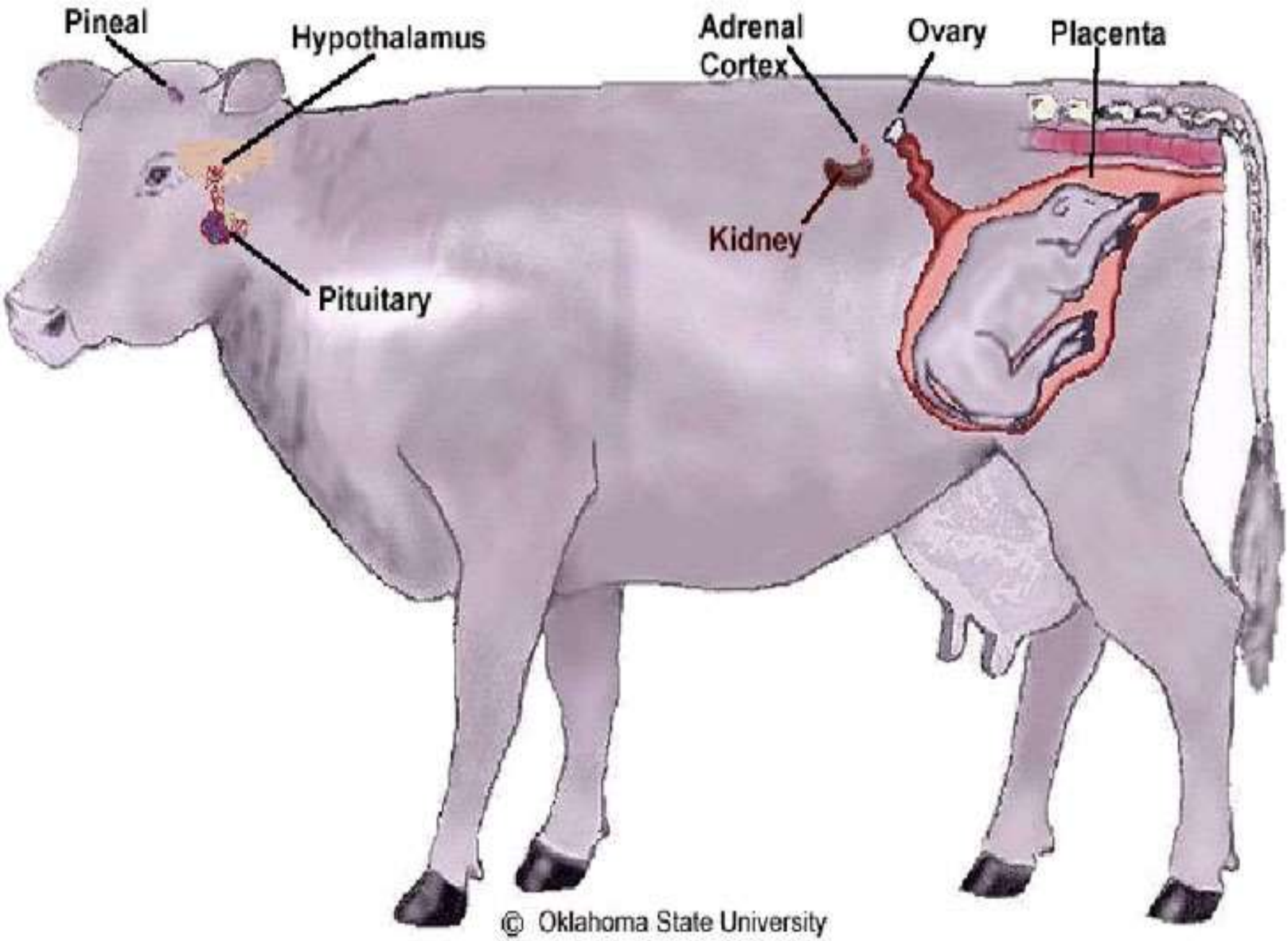
Implantation- It is the attachment of a blastula to the uterine epithelium

Placentation-

- It is development of placenta or extra-embryonic membranes
- This is exchange site between fetal and maternal circulations for nutrition from the dam & waste products from the fetus

Decidua- The maternal placenta

- The fetal placenta consists of chorion, allantois, amnion & vestigial yolk sac
- The **chorion**, outermost membrane always contact with maternal uterus outermost to inner
- **Allantois** is a continuous layer consist of a sac, allantoic cavity
- The **amnion** inner most membrane nearest to fetus is a fluid filled cavity contains fetus
- The allantoic cavity consists water bag is called 1st water bag while the amniotic cavity or sac terms 2nd water bag which expelled 1st & then 2nd during parturition
- The umbilical arteries & veins run through the CT between the allantois & chorion


Pineal
Hypothalamus
Adrenal Cortex
Ovary
Placenta
Kidney
Pituitary
© Oklahoma State University

- Umbilical arteries carry un-oxygenated blood from the fetus to the placenta while umbilical veins carry oxygenated blood from the placenta to the fetus
- Ruminants have a cotyledonary type of placental attachment also k/a placentomes
- These cotyledons are mushroom like projection, **caruncles**
- The size of caruncles ↑ with progress of pregnancy & are larger in the gravid horn than in the non-gravid horn

Hormones of pregnancy:

➢ Progesterone- To maintain normal pregnancy it serves as

- It provides –ve feedback to the hypothalamus to inhibit any further estrus cycle
- By inhibiting uterus smooth muscle to permit the attachment & development of fetus
- It maintains the cervix contraction to protect the uterine environment

Progesterone plasma level maintains initially by corpus luteum & secondary sources are placenta

Equine chorionic gonadotropin (eCG) or PMSG-

- Equine placenta secretes the protein hormone eCG after 1st month of gestation until about 4 months of gestation which is similar to the L.H
- During this period follicular development occurs on the ovary & eCG promotes its luteolization & accessory corpora lutea secretes progesterone for maintain pregnancy
- eCG are produced by the trophoblastic cells of fetal origin in endometrial cups

Structural organization of mammary gland:

- These glands are modified sweat glands produce milk for their offspring's
- Each gland consists of ducts connect with mass of secretory epithelium surrounded by CT & fat and supported in a fibroelastic capsules

- The secretory parenchyma to CT is proportionally hormonal regulated
- During lactation, the secretory tissue ↑es in volume due to the proportion of estrogen & progesterone presence
- When the animal becomes dry the progesterone level cause the regression of secretroy tissues & CT constitutes a greater percentage of the gland
- These glands (mammary) develop from bilateral thickening of ventro-lateral ectoderm of embryo also called milk lines or mammary ridges
- Mostly in domestic animals these glands are situated inguinal usually two or four quarters but in case of carnivores & sows they develop throughout axillary to inguinal extent of the ridges
- In case of monkey & elephant, these glands develop in pectoral region
- Each glands referred as quarters and they are independent from each other in so far as blood supply, nerve supply & suspensory apparatus concerned

- The secretory units, alveoli are lined by a simple epithelium
- The various small ducts cover to form large ducts & terminate into a single large sinus (basin, cavity) **lactiferous sinus**
- The lactiferous sinus is divided into two cavity gland cistern (pars glandularis) & teat cistern (pars papillary)
- The teat cistern continues through a narrow opening in the end of the teat, papillary duct (streak canal) which opens at the ostium papillae
- Sphincter of smooth muscle fibres surrounds the streak canal at the distal end of the teat
- The udder is supported by a dense system of fibroelastic ligaments called suspensory approach consists of medial laminae & lateral laminae
- The blood supply to the udder is primarily through external pudendal artery continues to ventral perineal artery for supplying each teats
- Where external pudendal vein receives blood from the quarters continuing with perineal vein & caudal superficial epigastric vein drains blood to cranial vena cava

Relaxin-

- This protein hormone secretes from the corpus luteum & in some species from the placenta also
- It acts in opening of the cervix & relaxation of the muscle & ligaments associated with birth canal during parturition
- It's secretion also ↑^{es} during last gestation to facilitate mammary gland development to prepare for lactation

Parturition- It is the termination of pregnancy. It is the act of giving birth to young. It may be divided into three stages-

- The 1st stage consists of uterine contraction to force the fetus & fetal membrane to the cervix
- The 2nd stage consists of the delivery of fetus to vagina with rupture of one or both water bags
- It consists the contractions of uterine & abdomen to fetus through the birth canal while the 3rd stage consists of the delivery of the fetus or placenta
- Attaining parturition, there is several changes occur physically & chemically in the body

- The vulva swells & discharge mucus, mammary gland enlarges & redness, animals may become restlessness, micturition etc.
- While there is hormonally change also occurs
- When fetus enters into the birth canal reflex acts on neurohypophysis & oxytocin releases to enhance uterine smooth muscle contraction & promote delivery
- Prior to parturition, level of glucocorticoids ↑^{es} through fetal adrenal cortex
- The rising fetal glucocorticoids affect the placenta & maternal uterus
- Placenta secretes estrogen which ↑ relative to progesterone
- Glucocorticoids & estrogens act synergistically for uterine synthesis & secretes $PGF_2\alpha$
- $PGF_2\alpha$ releases & initiating parturition by acting as luteolytic factor which remains the progesterone source

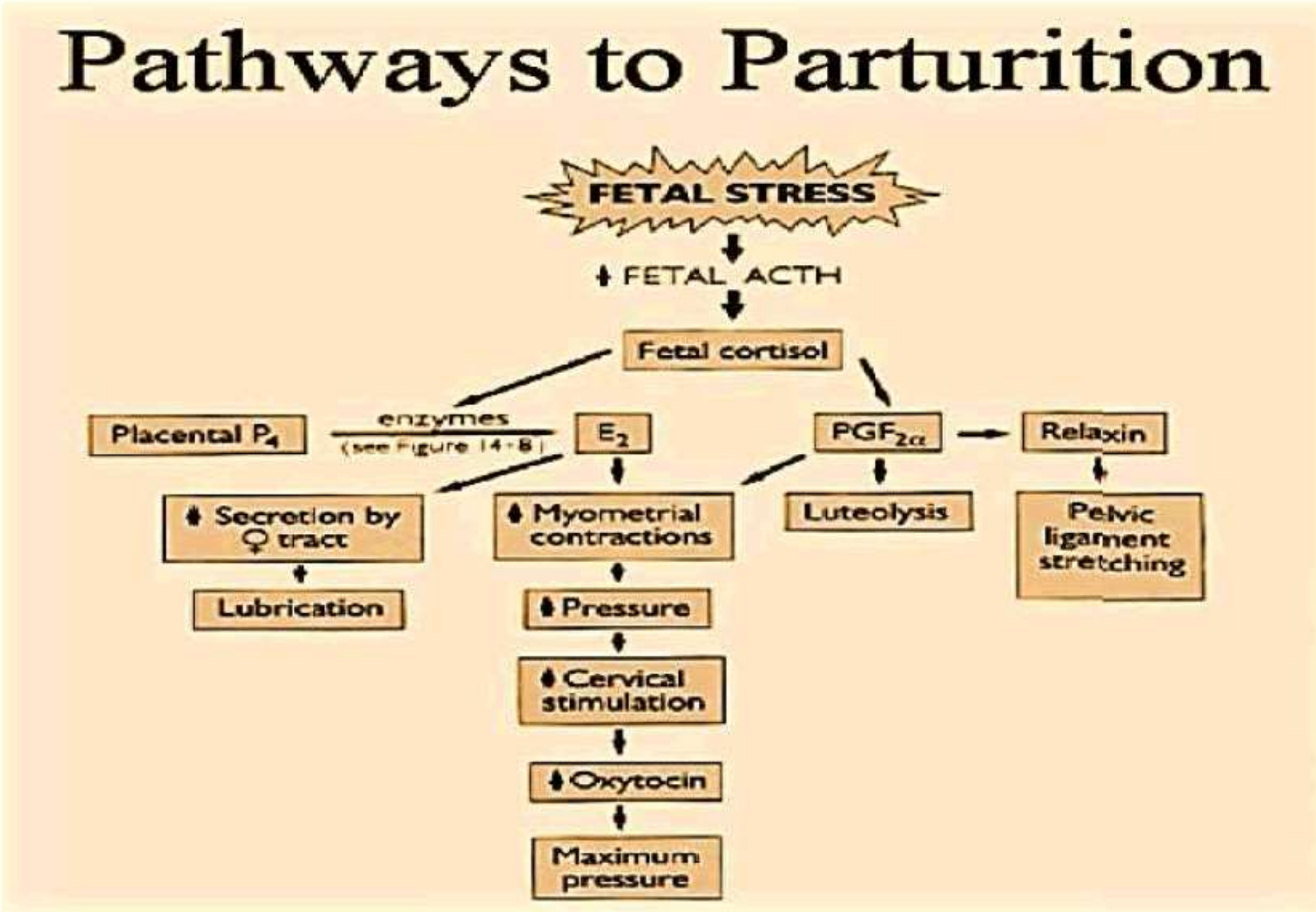


Fig 2. Pathway to parturition

- Since, progesterone acts as tone of cervix now reduce & level of $PGF_2\alpha$ ↑^{es} which acts as contraction of uterine smooth muscle to move the fetus into the birth canal & promotes the dilation of cervix to act of parturition

Lactogenesis-

- It is the establishment of milk secretion
- It includes the growth & development of the secretory epithelium & the ductile network of the mammary gland
- Since, Estrogen promotes the growth of the ductile system at each estrus while progesterone promotes the anatomic development of secretory alveoli not the functional development
- Normal secretion of growth hormone & glucocorticoids also required for complete development (anatomically & functionally) of mammary gland
- During pregnancy, prolonged exposure of progesterone promotes the anatomic development of mammary gland secretory alveoli but inhibits functional growth & production of intracellular enzymes necessary for normal milk secretion

- During late gestation, prolactin receptors ↑ in mammary gland releases from the adenohypophysis & regulated by humoral inhibitor factor from the hypothalamus
- Prolactin promotes the anatomic & functional development of the secretory epithelium of mammary glands
- It`s ↑^{ed} level helps alveoli to produce intracellular enzymes necessary for milk production & secretion
- The ↑^{ed} level of glucocorticoids also helps in functional development of the alveolar secretory cells
- The placenta of ruminants produce a protein hormone, placental lactogen or chorionic somatomammotrophin similar in structure & function to prolactin is believed to be more responsible for mammary gland development in these species
- The level of placental lactogen ↑ in late gestation

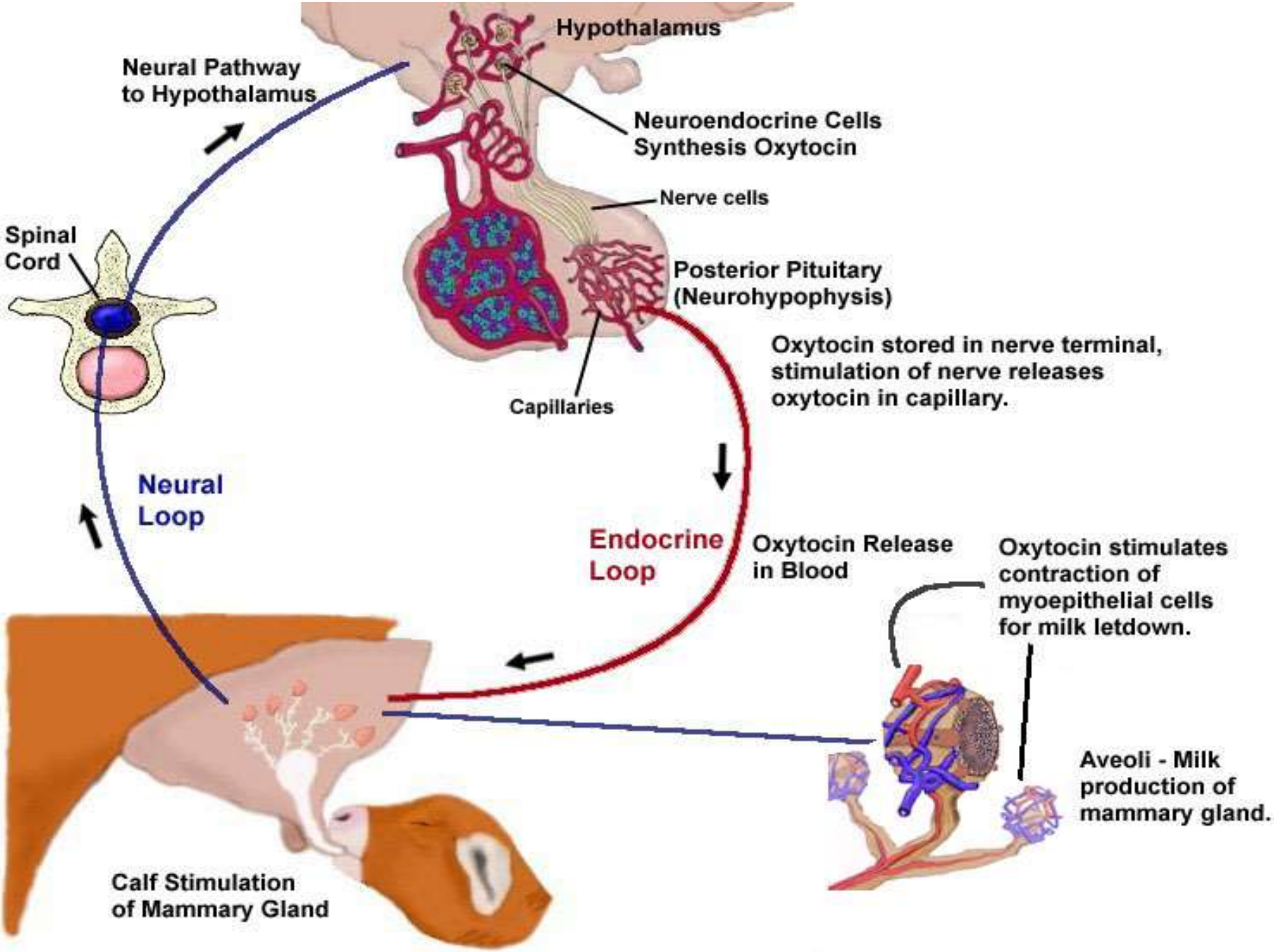
Galactogenesis- It is the continued production of milk by the mammary glands.

- Stimulation of the nipples or suckling elicits an abrupt ↑ in prolactin

- The ↑ in prolactin results a neural reflex to prolactin release from adenohypophysis
- The surge of prolactin is essential to maintain normal lactation in host species
- But for maintenance & level of milk production in cows, growth hormones appears to be more important
- Growth hormone supplementation in cattle is associated with a variety of physiologic changes that promote milk production
- It include ↑^{ed} mobilization of stored energy (body) to milk production, ↑^{ed} food intake, ↑^{ed} nutrient absorption & conversion of nutrients to milk by the mammary gland
- When milking is stopped, abruptly a no. of changes occurs in the udder like
  - At the end of 24 hrs, the alveoli become distended & capillaries are full of blood
  - Between 36 to 48 hrs, there is ↓ in patent (open) capillaries & alveoli don't respond to I/V oxytocin
- The protein that inhibits milk production, (inhibitor of lactation) is apparently produced in the mammary gland

Milk ejection or Letdown-

- This is the emptying of cisterns & largest ducts of the udder
- The myoepithelial cells surrounds the alveoli when stimulated by oxytocin cause contraction of the cells release from neurohypophysis of the pituitary
- The nipples or teats must have sensory nerves which when stimulate & signals reach to hypothalamus regulates & release of the oxytocin from the neurohypophysis suckling the teats by the young is the usual stimulus for the milk ejection reflex
- Oxytocin is given I/M in the animals for letdown of milk in emotionally disturbed animals such as dog barking, unusual noisy pain, demise of their young unconditionally etc


Hypothalamus
Neural Pathway
to Hypothalamus
Neuroendocrine Cells
Synthesis Oxytocin
Nerve cells
Spinal
Cord
Posterior Pituitary
(Neurohypophysis)
Oxytocin stored in nerve terminal,
stimulation of nerve releases
oxytocin in capillary.
Capillaries
Neural
Loop
Endocrine
Loop
Oxytocin Release
in Blood
Oxytocin stimulates
contraction of
myoepithelial cells
for milk letdown.
Aveoli - Milk
production of
mammary gland.
Calf Stimulation
of Mammary Gland

Colostrum-

- The first milk produced upon delivery of the newborn
- It is important for the survival & vitality of newborns
- Mainly it consists of milk proteins & lipids having high concentration of immunoglobulin's needed by the neonate to provide temporary immune protection against infectious agents
- It is the high source of energy for the newborn

Composition of milk-

- Milk contains all the nutrients necessary for survival & initial growth of neonates
- The nutrients include source of energy (lipids & CH_2O), proteins to provide amino acid, vitamins, minerals (ash), water & electrolytes
- The relative amount of these nutrients in milk vary among species

Typical values of constituents of milk in grams/litre

Species	Lipids	Lactose	Protein	Total Minerals (Ash)	Calcium
Cow	38	48	37	7.0	1.3
Mare	16	50	24	4.5	1.0
Ewe	70	40	60	8.0	1.9
Sow	80	46	58	8.5	2.0
Doe	40	45	35	7.8	1.2

- ❖The principal carbohydrate in milk is Lactose
- ❖The major milk proteins are the Caseins

Milk composition of different species:

Species		Percentage by weight							Energy (kcal/100 g)
				Protein					
		Water	Fat	Casein	Whey	Total	Lactose	Ash	
Aardvark	*Orycteropus afer*	68.5	12.1	9.5	4.8	14.3	4.6	1.4	184
Bat, fringed	*Myotis thysanodes*	59.5	17.9	ND	ND	12.1	3.4	1.6	223
Bear, black	*Ursus americanus*	55.5	24.5	8.8	5.7	14.5	0.4	1.8	280
Buffalo, water	*Bubalus bubalis*	82.8	7.4	3.2	0.6	3.8	4.8	0.8	101
Camel	*Camelus dromedarius*	86.5	4.0	2.7	0.9	3.6	5.0	0.8	70
Cow	*Bos taurus*	87.3	3.9	2.6	0.6	3.2	4.6	0.7	66
Dog	*Canis familiaris*	76.4	10.7	5.1	2.3	7.4	3.3	1.2	139
Dolphin	*Tursiops truncatus*	58.3	33.0	3.9	2.9	6.8	1.1	0.7	329
Donkey	*Equus asinus*	88.3	1.4	1.0	1.0	2.0	7.4	0.5	44
Echidna	*Tachyglossus aculeatus*	63.2	19.6	8.4	2.9	11.3	2.8	0.8	233
Elephant, Indian	*Elephas maximus*	78.1	11.6	1.9	3.0	4.9	4.7	0.7	143
Goat	*Capra hircus*	86.7	4.5	2.6	0.6	3.2	4.3	0.8	70
Guinea pig	*Cavia porcellus*	83.6	3.9	6.6	1.5	8.1	3.0	0.8	80
Hedgehog	*Erinaceus europaeus*	79.4	10.1	ND	ND	7.2	2.0	2.3	100
Horse	*Equus caballus*	88.8	1.9	1.3	1.2	2.5	6.2	0.5	52
Human	*Homo sapiens*	87.1	4.5	0.4	0.5	0.9	7.1	0.2	72
Kangaroo, red	*Macropus rufus*	80.0	3.4	2.3	2.3	4.6	6.7	1.4	76
Manatee	*Trichechus manatus*	87.0	6.9	ND	ND	6.3	0.3	1.0	88
Opossum	*Didelphis virginiana*	76.8	11.3	ND	ND	8.4	1.6	1.7	142
Pig	*Sus scrofa*	81.2	6.8	2.8	2.0	4.8	5.5	1.0	102
Rabbit	*Oryctolagus cuniculus*	67.2	15.3	9.3	4.6	13.9	2.1	1.8	202
Rat	*Rattus norvegicus*	79.0	10.3	6.4	2.0	8.4	2.6	1.3	137
Reindeer	*Rangifer tarandus*	66.7	18.0	8.6	1.5	10.1	2.8	1.5	214
Seal, fur	*Callorhinus ursinus*	34.6	53.3	4.6	4.3	8.9	0.1	0.5	516
Sheep	*Ovis aries*	82.0	7.2	3.9	0.7	4.6	4.8	0.9	102
Shrew, tree	*Tupaia belangeri*	59.6	25.6	ND	ND	10.4	1.5	ND	278
Sloth	*Bradypus variegatus*	83.1	2.7	ND	ND	6.5	2.8	0.9	62
Squirrel, gray	*Sciurus carolinensis*	60.4	24.7	5.0	2.4	7.4	3.7	1.0	267
Yak	*Bos grunniens*	82.7	6.5	ND	ND	5.8	4.6	0.9	100
Zebu	*Bos indicus*	86.5	4.7	2.6	0.6	3.2	4.7	0.7	74