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Endocrinology of the Estrous Cycle in Cows

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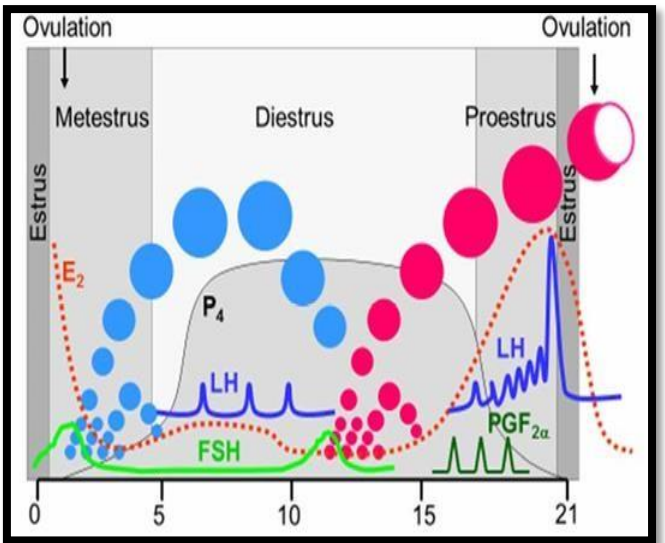
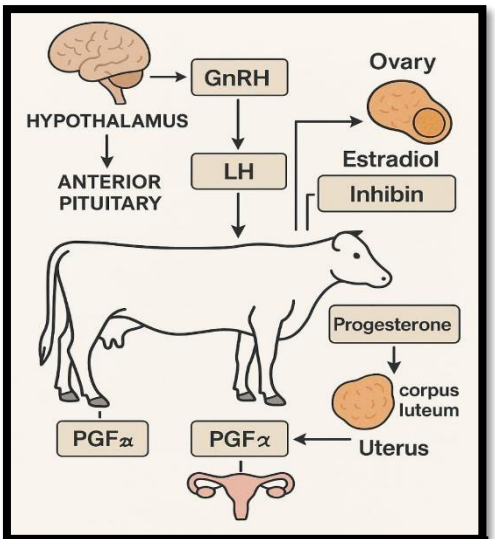
The estrous cycle in cows (*Bos taurus*) is a complex, hormonally regulated process that prepares the female for ovulation and potential pregnancy. Cows experience a non-seasonal, polyestrous reproductive cycle, typically lasting 18–24 days, with an average of 21 days. Estrous is the phase of peak fertility, marked by behavioural signs of heat and the release of a mature oocyte. The hormonal landscape during oestrus is finely tuned to ensure optimal conditions for ovulation and potential fertilization. Understanding the endocrinology around oestrus is essential for effective reproductive management in cattle, including artificial insemination (AI), synchronization protocols, and diagnosis of reproductive disorders.

I. Phases of the Estrous Cycle:

1. Proestrus (days -3 to 0 relative to estrus)
2. Estrus (Day 0)
3. Metestrus (Days 1–3)
4. Diestrus (Days 4–16)
5. Return to proestrus if pregnancy does not occur



Estrous cycle in Cow



Hormones during Estrous cycle

II. Hormonal Regulation of Estrous

1. Estradiol-17β (Estrogen)

Estradiol is the dominant hormone produced by the dominant ovarian follicle in response to follicle-stimulating hormone (FSH) and luteinizing hormone (LH) stimulation. Estradiol orchestrates the visible and internal manifestations of estrous, including: Behavioural estrous (mounting behaviour, standing heat, restlessness); Increased uterine tone and contractility; Hyperaemia and edema of the vulva; Secretion of clear cervical mucus; and Increased vascularization and receptivity of the reproductive tract.

Importantly, elevated estradiol levels exert a positive feedback effect on the hypothalamus and anterior pituitary, stimulating a surge in gonadotropin-releasing hormone (GnRH) and subsequently LH. This estrogen-induced LH surge is crucial for ovulation.

2. Luteinizing Hormone (LH)

Luteinizing Hormone plays a pivotal role in triggering ovulation. In response to rising estradiol, the hypothalamus releases a surge of GnRH, which stimulates the anterior pituitary to release a surge of LH. This LH surge initiates ovulation of the dominant follicle (occurring approximately 24-30 hours after the onset of estrous). It promotes luteinization of granulosa and theca cells, leading to corpus luteum (CL) formation. And also supports the early development and function of the CL.

Accurate timing of the LH surge is critical for successful artificial insemination, which should occur close to the time of ovulation.

3. Follicle-Stimulating Hormone (FSH)

FSH is responsible for the recruitment and growth of ovarian follicles. During the estrous cycle, multiple waves of follicular development occur, with one dominant follicle eventually selected for ovulation. Around estrus, FSH levels are suppressed due to negative feedback from inhibin and estradiol produced by the dominant follicle. Though FSH is not at its peak during estrus, its earlier activity is essential for establishing follicular dominance.

4. Gonadotropin-Releasing Hormone (GnRH)

GnRH is released in a pulsatile manner and serves as the master regulator of pituitary gonadotropins (LH and FSH). As estradiol levels rise during proestrus and early estrus, GnRH pulse frequency increases, leading to the LH surge. The GnRH-LH cascade is essential for timely ovulation. Exogenous GnRH administration is often used in reproductive protocols to induce ovulation or synchronize estrous.

5. *Progesterone*

At estrous, progesterone levels are at their lowest, following luteolysis of the previous cycle's CL. The absence of progesterone is critical because it removes the inhibitory effect on GnRH and LH secretion, allowing the estradiol-induced LH surge to occur. After ovulation, the newly formed CL begins secreting progesterone, preparing the uterus for potential pregnancy by Suppressing further estrous behaviour; supporting endometrial secretions for embryo survival and inhibiting myometrial contractions.

If conception does not occur, progesterone remains high until luteolysis is triggered by prostaglandin $F_2\alpha$ ($PGF_2\alpha$).

6. Prostaglandin $F_2\alpha$ ($PGF_2\alpha$)

While not secreted at the time of estrus, PGF2α plays a crucial role in terminating the previous cycle by inducing luteolysis. This leads to the decline of progesterone, resetting the hormonal environment for the next estrous cycle. Exogenous PGF2α is widely used to synchronize estrous in reproductive management.

7. *Inhibin*

Inhibin selectively inhibits FSH release from the anterior pituitary, preventing the development of additional follicles once a dominant follicle is selected. This feedback mechanism ensures that only one follicle reaches ovulatory maturity during a natural cycle.

III. Timeline of Hormonal Events Leading to Estrous

Day (Relative to Estrous)	Hormonal Event	Hormone(s) Involved	Physiological Outcome
Day -5 to -3	Luteolysis of Corpus Luteum (CL)	$PGF_2\alpha$ ↓ P4	Decline in progesterone
Day -3 to 0	Follicular wave resumes; dominant follicle grows	↑ Estradiol (E2)	Follicle matures Estradiol rises
Day 0 (Estrous)	Estradiol peaks → GnRH → LH surge	↑ E2 → GnRH → LH surge	Behavioural estrous Prepares for ovulation
Day 0 to +1	Ovulation ~24–30 hrs after onset of estrous	LH surge	Ovulation occurs; corpus luteum begins to form
Day +1 to +5	Corpus luteum forms and secretes progesterone	↑ Progesterone (P4)	End of estrous; Prepares uterus for possible pregnancy

IV. Behavioural and Physiological Signs of Estrous:

1. Standing to be mounted (most reliable indicator)
2. Mounting other cows
3. Clear mucous vaginal discharge
4. Vulvar swelling and reddening
5. Increased activity and restlessness
6. Bellowing and reduced appetite

These signs coincide with peak estradiol levels and are essential for determining optimal AI timing.

V. Clinical Applications and Reproductive Management

Understanding the endocrine dynamics of estrous is fundamental for:

1. ***Heat detection***: Accurate estrus detection improves conception rates.
2. ***Timed AI protocols***: Hormonal synchronization with GnRH and PGF2α.
3. ***Treatment of reproductive disorders***: Anovulation, cystic ovarian disease.
4. ***Superovulation:*** Use of exogenous FSH to recruit multiple follicles.
5. ***Embryo transfer:*** Synchronization of donor and recipient cows.

VI. Summary:

The estrous phase in the cow is governed by a finely tuned hormonal interplay that ensures successful ovulation and reproductive readiness. Estradiol-induced behavioural and physiological changes signal peak fertility, while the LH surge initiates ovulation. Low progesterone levels at this stage permit these events to proceed unimpeded. The precise timing and coordination of these hormonal events form the cornerstone of effective reproductive management in cattle. A thorough understanding of estrous endocrinology enables veterinarians and producers to enhance fertility outcomes, implement synchronized breeding programs, and address reproductive inefficiencies.