EAZA RMG
EAZA Reproductive Management Group

# The Reproductive Physiology of Carnivores: Females

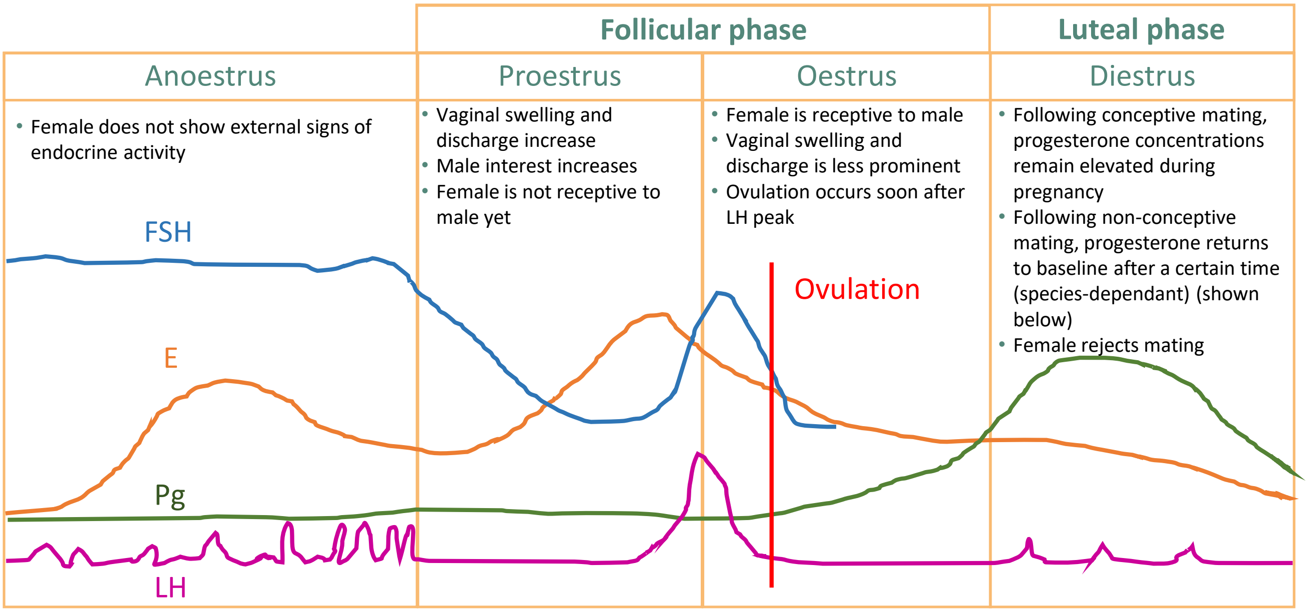


**Figure 1: General overview of the hormones involved in the female carnivore reproductive system.**

1a. In spontaneous ovulators gonadotropin releasing hormone (GnRH) from the hypothalamus stimulates the production of follicle stimulating hormone (FSH) and luteinizing hormone (LH) in the anterior pituitary gland.

1b. In induced ovulators, the LH surge occurs in response to an external stimulus e.g. vaginal stimulation by mating or pheromones.

2. FSH stimulates the growth of immature ovarian follicles and the secretion of oestrogen (E) from the granulosa cells.
3. Reproductive behaviour usually begins right after the E peak. This E peak further stimulates the secretion of LH, which promotes the final stage of maturation of dominant follicles and triggers ovulation.
4. The corpus luteum formed after the rupture of dominant follicles begins producing progesterone (Pg). During pregnancy, Pg concentrations remain elevated until shortly before parturition. If an oestrous cycle is non-conceptive, the corpus luteum slowly regresses, and Pg concentrations decrease.
5. In seasonal and monoestrous species, a combination of factors suppress the hypophysis-pituitary axis during anestrus. LH pulsatility becomes diminished or less effective until the spontaneous onset of a new pro-oestrus.

Follicular phase

Luteal phase

### *Induced ovulators*

Females will ovulate in response to copulation (i.e. intromission and vaginal stimulation) and additional chemical, visual and/or olfactory external stimuli (e.g. pheromones secreted by a male or by sperm). The timing within the oestrus (in association with oestrogen exposure), the duration of the mating period, and the number of intromissions may relate to the strength of the LH surge required for ovulation. Induced ovulation is most common in solitary species with a multiple male mating system and in species without a fixed breeding season[1]. Females will show regular follicular cycles (increases in FSH, LH, and E) without males.

*Species:* most felids[2], red panda[3], wolverines[4], maned wolves[5], island fox[6], many bears including black bears[7], black bears[8], polar bears[9].

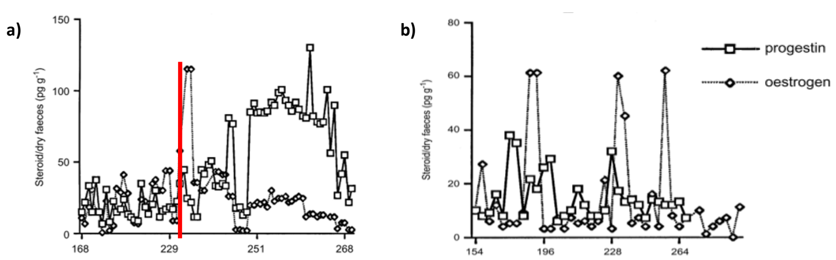


**Figure 5: Progesterone and oestrogen profiles of two female red pandas *(Ailurus fulgens)*.** The red line indicates observed mating. The sustained progesterone concentrations following mating (a), and the lack thereof without (b) suggests that red pandas are induced ovulators. The observed mating was non-conceptive as progesterone concentrations returned to baseline after 18 days (a). Periodic oestrogen peaks in the female that was not mated (b) likely correspond with oestrus periods. Figure adapted from Spanner et al. (1997)[3].

### *Spontaneous ovulators*

Females will ovulate without copulation, and even without the presence of a male or any additional external stimuli.

*Species:* most canids[10] , hyaena[11], giant panda[12].

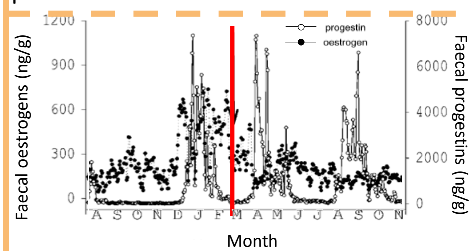


**Figure 2: Progesterone and oestrogen profiles of a female bush dog *(Speothos venaticus)*.** The red line indicates the date of male-female introduction. Sustained elevations in progesterone concentrations following peaks in oestrogen without the presence of a male indicate that females can spontaneously ovulate. Male presence does however, increase the duration of the progestin elevation, and reduces the duration of the inter-oestrous intervals. Figure adapted from DeMatteo et al. (2006)[13].

### *Facultative induced ovulators: the best of both worlds?*

Ovulation can be both spontaneous or induced in some carnivores. Differences between individuals may also occur.

*Species:* Occasionally in lions, leopards, Pallas and fishing cats[2]. Regularly occurs in clouded leopards and margay.[2]

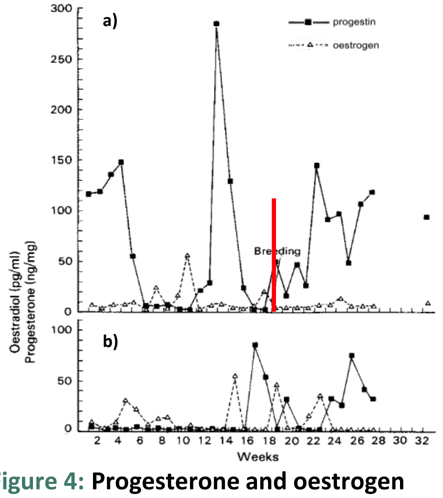


**Figure 4:** **Progesterone and oestrogen profiles of two lionesses *(Panthera leo)*.** The red line indicates observed mating. The increased progesterone concentrations following mating (a) as well as without mating (b) suggest lionesses are both spontaneous and induced ovulators. The increase in progesterone in the mated female (a) is indicative of pregnancy. Figure adapted from Schmidt et al. (1979)[21].

### *Types of oestrus*

*Monoestrous:* species in which females have one oestrous cycle per year or season.

***Species:*** wolves[14], bears (excluding sun bears)[15,16], lynx[17].

*Polyoestrous:* species in which females have several oestrous cycles throughout the year.

*Species:* bush dogs[13], sun bears[15,18], lions[19], cheetah[19].

*Seasonally polyoestrous:* species in which females have multiple oestrous cycles during certain times of year.

*Species:* Siberian tigers[20].

### *Pseudopregnancy*

A prolonged luteal phase (i.e. ovulation and increased progesterone) following a non-conceptive oestrus period may occur in both induced and spontaneous ovulators[22,23].

*Note:* Non-conceptive mating and pseudopregnancies may lead to an increase in the risk of developing reproductive pathologies such as endometrial hyperplasia and pyometra in some species e.g. felids[24], African painted dogs[25].

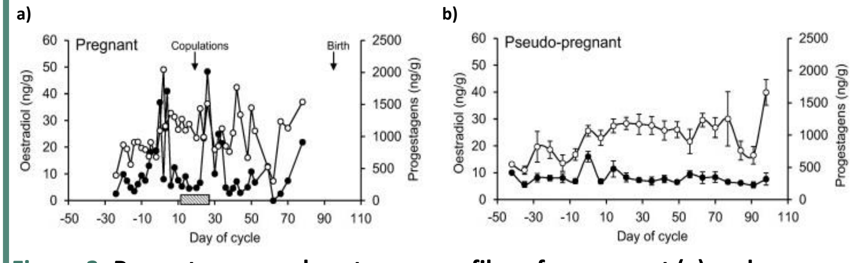


**Figure 3:** **Progesterone and oestrogen profiles of a pregnant (a) and pseudopregnant (b) African wild dog *(Lycaon pictus)*.** Figure adapted from Van der Weyde et al. (2015)[22].

### *Delayed implantation*

Development of the newly fertilised egg is suspended (diapause) instead of being directly implanted in the uterus. The duration of diapause can range between a few days to 10 months.

*Species:* pinnipeds[26], bears (excluding sun bears)[15] and many mustelids[27,28]

## The Reproductive Physiology of Carnivores: Males

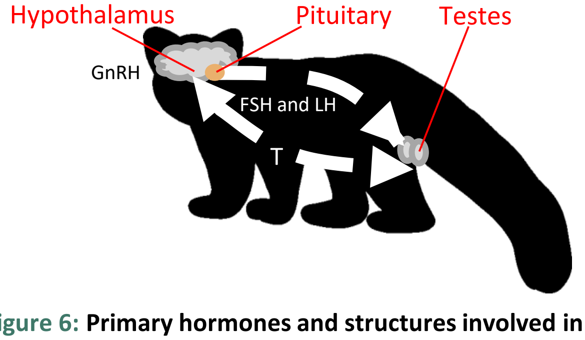


**Figure 6:** **Primary hormones and structures involved in the male red panda reproductive system.**

1. Gonadotropin releasing hormone (GnRH) from the hypothalamus stimulates the production of follicle stimulating hormone (FSH) and luteinizing hormone (LH) in the anterior pituitary gland.
2. FSH aids in sperm production.
3. LH stimulates the production and secretion of testosterone from the testes, which is required to continue spermatogenesis.

### *Reproductive seasonality*

Like females, males tend to have seasonal increases in testosterone concentrations, coinciding with the breeding season. During this time, testosterone mediated behaviour e.g. aggression and libido increase, spermatogenesis and sperm quality increase, and testes will also usually increase in size.

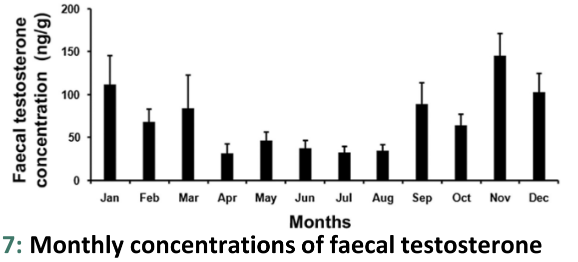


**Figure 7:** **Monthly concentrations of faecal testosterone metabolites in a male red panda housed in India.** Faecal testosterone concentrations are higher during the breeding season (November – March) than outside of the breeding season. Elevated concentrations of testosterone correlate to increases in breeding behaviours towards females[29]. Figure from Budithi et al. (2016)[29].

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# Contraception in carnivores

The use of progestin-based contraceptives like Depo-Provera, Implanon, Nexplanon, Jadelle, or oral contraceptive pills are not recommended for long term use (>2 years) in female carnivores due to the increased risk of developing reproductive pathologies[30,31,32].

### *GnRH Agonists*

These products mimic endogenous GnRH by stimulating GnRH receptors, promoting the secretion of LH and FSH and an initial stimulation phase in both males and females. Due to the sustained stimulation of the receptors, pituitary sensitivity to GnRH decreases, resulting in a 'reproductive shut down' that will inhibit the production of testosterone in males and the secretion of oestrogens and progesterone in females until the GnRH agonist is removed or has expired.

### *Recommended contraceptive protocol in carnivores:*

**Deslorelin acetate (Suprelorin) subcutaneous implant:** 4.7 mg implants will last for a **minimum** of 6 months, and 9.4 mg implants will last for a **minimum** of 1 year. However, the duration of efficacy shows individual variation, and, in certain carnivores, like felids, effects can last twice as long. When individuals are first implanted, a 3–4-week stimulation of the reproductive system will occur resulting in a surge of testosterone in males, and induced oestrus in females. This stimulation phase should be suppressed in females by giving them oral megestrol acetate pills (Megace/Ovarid) for 7 days before and 7 days after implant insertion. The stimulation phase cannot be suppressed in males. In males, fertile sperm may be present for 2 months or longer so additional contraception in the females will be needed or the sexes should be separated during this period. Implants should be removed to facilitate reversal; to ease the process of locating and removing the implant, we would advice to place the implants in a location with thinner skin such as the base of the ear, inner thigh, or umbilical region. One frequent side effect of deslorelin is feminisation of males; it is therefore important to think about the implications that can occur within the exhibit when the secondary sexual characteristics of the treated male are removed. Other possible effects in males are decrease in testicular size and body size.

Doses and duration of efficacy will vary depending on species and sex; contact the EAZA RMG (contraception@chesterzoo.org) for comprehensive guidelines.

### *Key reproductive hormones*

***Gonadotropin releasing hormone (GnRH):*** produced by the hypothalamus. Triggers the secretion of LH and FSH.
***Follicle stimulating hormone (FSH):*** produced in the pituitary gland. Stimulates the development of immature ovarian follicles in females and the development of spermatocytes in males.
***Luteinising hormone (LH):*** produced in the pituitary gland. Triggers ovulation in females and the production of testosterone in males.
***Oestrogens (E):*** produced by the ovarian follicles. Involved in the development of female secondary sexual characteristics and sexual behaviour. E concentrations during oestrus have influence on the secretion of luteinising hormone (LH) and subsequent ovulation.
***Progesterone (Pg):*** primarily produced by the corpus luteum. Involved in regulating the oestrous cycle and in maintaining pregnancy.
***Testosterone (T):*** the primary male sex hormone. Involved in the maturation of sex organs and the development of male secondary sexual characteristics and behaviour. Testosterone also has a role in the development of spermatogenic tissue in the testes and in normal sperm development.


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