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# Circannual rhythm in bird migration

The annual life cycle of many birds includes breeding, moult and migration. All these processes are time and energy consuming and the extent of investment in any one may compromise the others. The output from breeding is of course the ultimate goal for all birds, while the investment in moult and migration should be selected so that lifetime fitness is maximized. In particular, long-distance migrants breeding at high latitudes face severe time pressures, which are a probable reason why natural selection has evolved efficient behaviours, **physiological** and morphological adaptations allowing the maximum possible migration speed. Optimal migration theory commonly assumes time minimization as an overall strategy, but the minimization of energy cost and predation risk may also be involved.

**Circannual rhythms** are internal, biological cycles that occur annually, regulating migration, breeding, and molting in birds.

The text describes how birds allocate time and energy across different life stages, which are controlled by hormonal and behavioral changes linked to circannual rhythms.

Hormones like melatonin, corticosterone, and gonadotropins play a key role in regulating these phases, ensuring timely migration and reproduction.

Environmental cues like photoperiod (day length) act as triggers, aligning migration with seasonal changes.

How to Strengthen the Write-Up for Circannual Rhythms?

To explicitly connect it with circannual rhythms, consider adding:

✅ The role of internal biological clocks (endogenous rhythms) in timing migration.

✅ The impact of photoperiod (day length) on hormonal regulation.

✅ Specific hormones involved in regulating breeding, migration, and molting cycles.

✅ How birds adjust behavior and physiology in anticipation of seasonal changes.

Circannual rhythms are **biological cycles that occur approximately every year**, regulating seasonal behaviors in animals, including **migration, reproduction, and molting**. In birds, these rhythms are **endogenously controlled** (internally generated) but are also influenced by **external environmental cues** such as **photoperiod (day length), temperature, and food availability**.

**Role of Circannual Rhythms in Bird Migration**

Bird migration is a highly energy-demanding and time-sensitive process. The **internal biological clock** ensures that migration occurs at the most favorable time for survival and reproductive success. **Key factors influenced by circannual rhythms include:**

1. **Timing of Migration** → Birds initiate migration in response to changes in **day length (photoperiod)**, which stimulates hormonal changes, preparing them for long journeys.
2. **Physiological Changes** → Hormones such as **melatonin, corticosterone, and gonadotropins** regulate fat deposition, metabolism, and muscle strength, ensuring birds have enough energy reserves.
3. **Behavioral Adaptations** → Birds exhibit **zugunruhe** (migratory restlessness) before migration, a clear behavioral indicator of circannual rhythm.
4. **Navigation and Orientation** → Internal biological clocks help birds **synchronize their journey** with seasonal wind patterns and food availability.

**Hormonal Regulation of Migration**

Hormonal changes play a crucial role in regulating the migratory cycle:

- **Melatonin:** Influences circadian (daily) and circannual rhythms.
- **Corticosterone:** Increases energy mobilization for long flights.
- **Thyroid Hormones (T3 & T4):** Regulate metabolism, aiding in endurance and muscle function.
- **Gonadotropins (FSH, LH):** Influence breeding readiness before migration.

**Significance of Circannual Rhythms in Long-Distance Migrants**

Long-distance migratory birds, such as **Arctic Terns and Bar-tailed Godwits**, rely heavily on their internal circannual rhythms to synchronize their migration with changing seasons. They must balance **breeding, molting, and migration** within tight timeframes to ensure survival.

Based on these assumptions, it is possible to derive adaptive behaviours such as when and at which fuel load a stopover site should be abandoned. The time constraints on migrants increase with increasing body size.

**(a) Flight behaviour**

i)In time-selected migration, the optimal flight speed should be greater than the maximum range speed associated with energy-selected migration.

ii)Cross-country soaring is limited to the daytime hours when thermal activity provides raising air, which is used by soaring birds. Thermals are typically available for about 8 hours in temperate regions (Konrad 1970; Rowland 1973) and not much longer in the tropics.

iii)Observations of nocturnal migratory flight in otherwise typical soaring migrants therefore provide support for a time-selected strategy (Stark & Liechti 1993).

**(b) Stopover behaviour**

i)A central prediction for time-selected migration is that **departure fuel load** ($f_{dep}$) depends on the rate of fuel deposition (k).

ii)In one study of spring migrating wheatears *Oenanthe oenanthe*, it was only the males that showed a significantly positive relationship while females departed with the same $f_{dep}$ irrespective of k (Dierschke et al. 2005), suggesting a time-selected strategy in males and an energy minimization strategy in females.

iii)In the robin (*Erithacus rubecula*) study, the experimentally fed birds departed with larger fuel reserves than non-fed birds, suggesting a time-minimization strategy.

iv)The slope of the relationship between $f_{dep}$ and k is invariably lower than that predicted under local variation.

v)If birds update their expected migration speed according to their current experience (global variation), then the slopes observed are close to the prediction.

vi)**In energy selected migration**, there is no predicted relationship between $f_{dep}$ and k.

vii) If birds are minimizing the total energy cost of migration, the expected slope between $f_{dep}$ and k is lower than under time-selected migration and global variation.

## Hormonal Changes related to Bird migration

Organisms synchronize the events of the annual cycle with environmental signals. Environmental information is perceived and transduced by the neuroendocrine system, which affects the timing of breeding (Figure 8.1). The vernal increase in daylength stimulates neuroendocrine pathways, leading to production and secretion of gonadotropin-releasing hormone (GnRH) and gonadotropininhibiting hormone (GnIH), both of which influence secretion of the gonadotropins (GTHs) luteinizing hormone (LH) and follicle-stimulating hormone (FSH). In males, LH induces production of testosterone (T) by the Leydig Cells in the interstitium of the testis. Follicle-stimulating hormone induces growth and development of the seminiferous tubules of the testis as well as stimulating steroidogenesis and the production of androgen-binding protein, all of which promote and sustain spermatogenesis. In the ovary, LH and FSH enhance folliculogenesis as well as steroidogenesis of estradiol and progesterone and production of protein hormones and growth factors. As the follicle matures, the release of progesterone promotes development of the oviduct and estradiol enhances breeding behavior. Rapidly rising progesterone has positive feedback on GnRH release and induces the LH surge that culminates in ovulation of the ova and oviposition of the egg. In both males and females, steroids secreted into the peripheral circulation feed back on the pituitary and hypothalamus to regulate secretion of GTHs

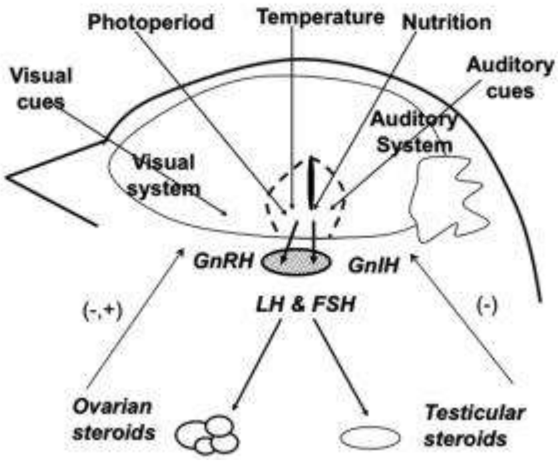


**FIGURE:** Sagittal schematic of the passerine brain, anterior pituitary, and gonads. External stimuli are perceived by the sensory systems and reach brain regions to evoke a neuroendocrine response. Hatched lines depict the hypothalamus, containing the third ventricle (filled structure). Neuroendocrine pathways of gonadotropin-releasing hormone (GnRH) and gonadotropin-inhibiting hormone (GnIH) reach the anterior pituitary (stippled oval structure), each influencing the secretion of gonadotropins (luteinizing hormone (LH) and follicle-stimulating hormone (FSH)), which in turn affect the development and endocrine secretion of the gonads (ovaries and testes). Gonadal steroids exert both positive and negative feedback on the hypothalamus and the pituitary, regulating gonadotropin (GTH) secretion.

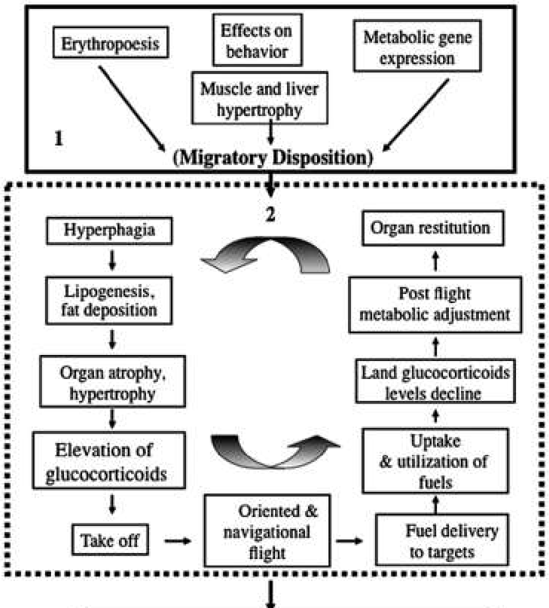


**FIGURE:** Diagram of the three phases of vernal and autumn migration life-history stages in birds. Phases of migration are outlined in the three larger boxes: (1) the developmental phase (enclosed by a solid line), (2) the mature capability phase (enclosed by a dotted line), and (3) the termination phase (enclosed by a double line). Substages are defined in smaller boxes outlined with a single line: substages enclosed in the developmental phase are changes in gene expression, morphology, and physiology; during the mature capability phase, birds initiate processes of fueling and flight cycles, which may repeat multiple times until the destination is reached (revolving arrows); the termination phase begins with arrival biology as the destination is approached, but final completion is not attained until conditions are optimal for either breeding or overwintering.

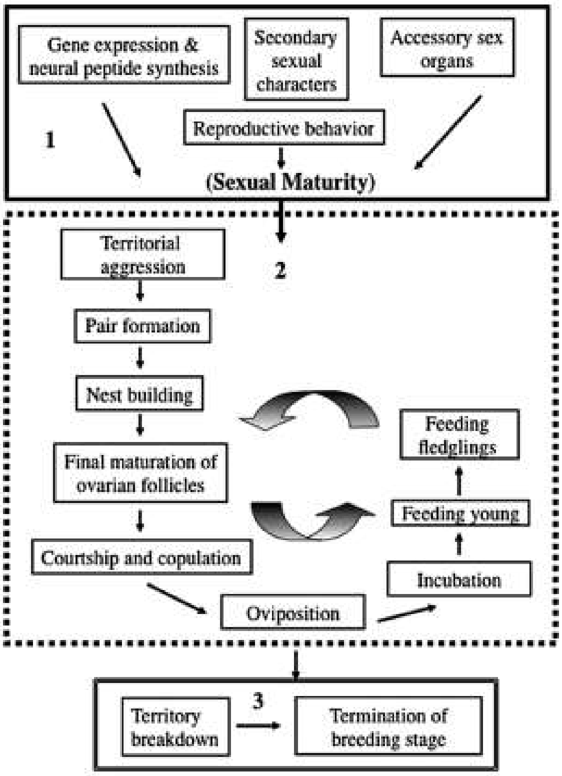


**FIGURE:** Diagram of the three phases of the breeding life-history stage. Phases of breeding are outlined in the three larger boxes: (1) the developmental phase (enclosed by a solid line), (2) the mature capability phase (enclosed by a dotted line), and (3) the termination phase (enclosed by a double line). Substages are defined in smaller boxes outlined with a single line: increase in daylength induces changes in gene expression of neural peptides, gonadal development, and behavior, which culminate in sexual maturity; expression of diverse physiological and behavioral substages of the mature capability phase proceeds sequentially and may have repeating cycles (revolving arrows) for multiple-brooded species; the termination of breeding begins with onset of photorefractoriness, molt, and finally territory breakdown.