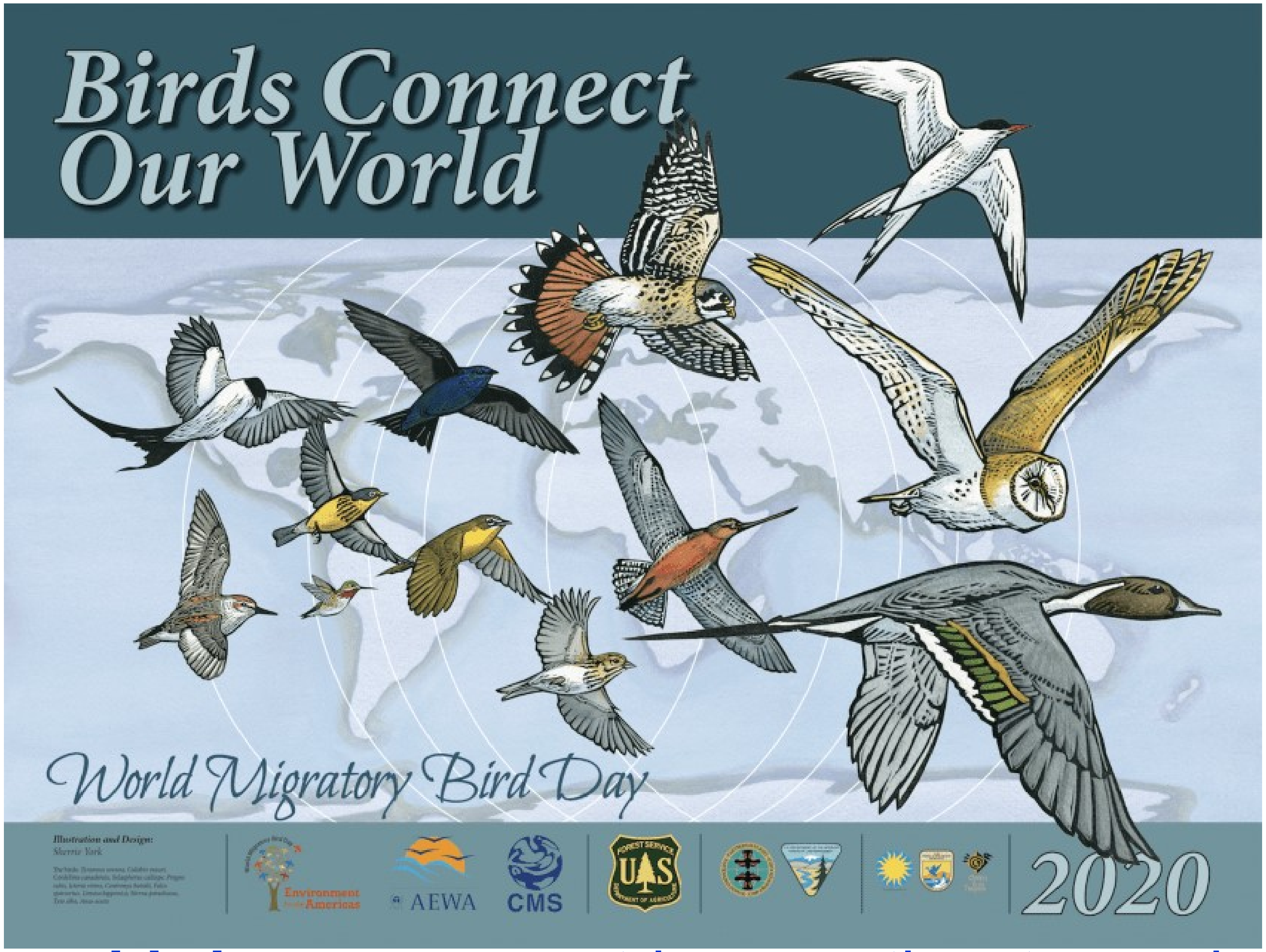
Regulation of seasonal migration: Bird as an example

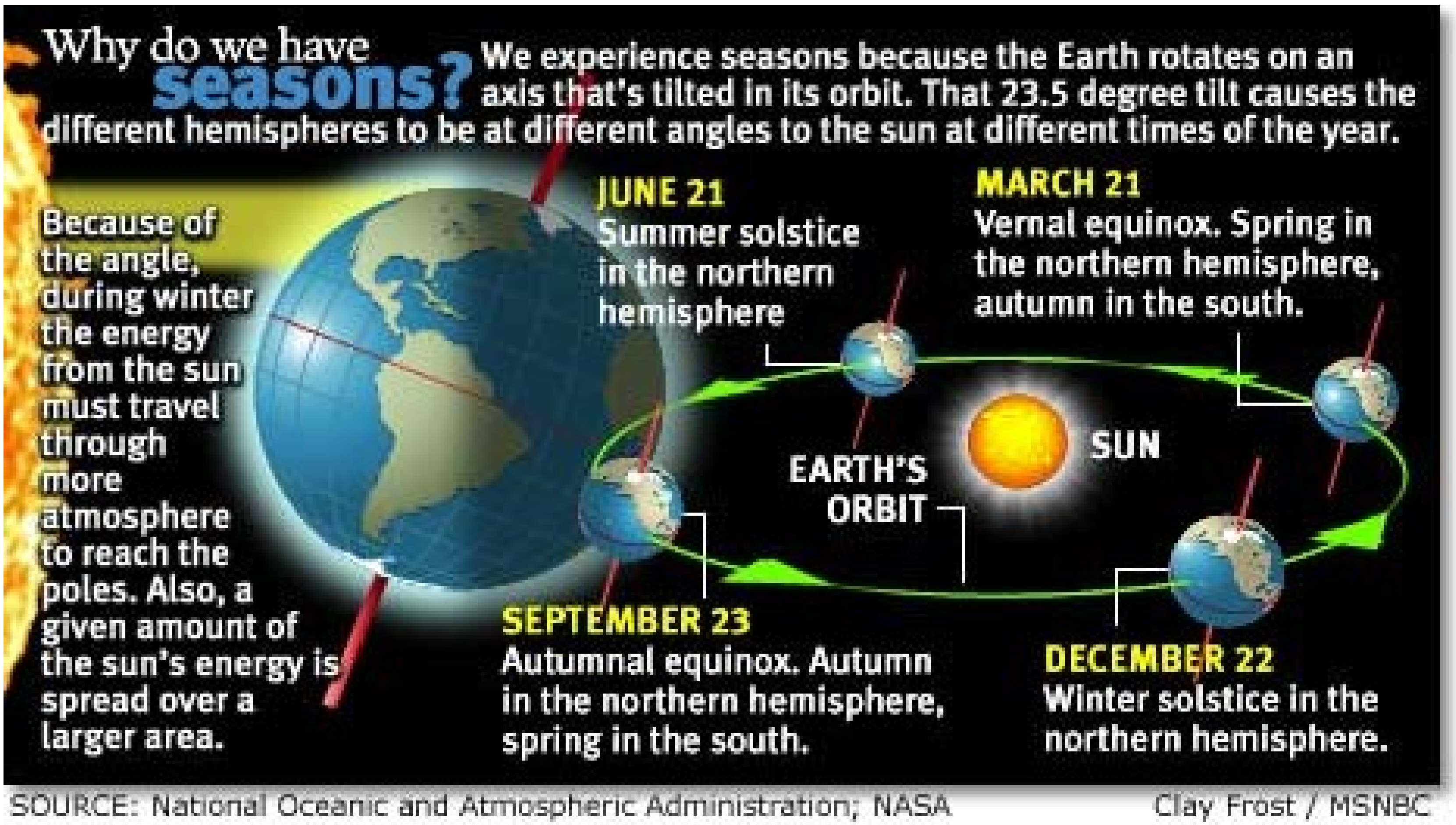
WMBD 2020 Poster



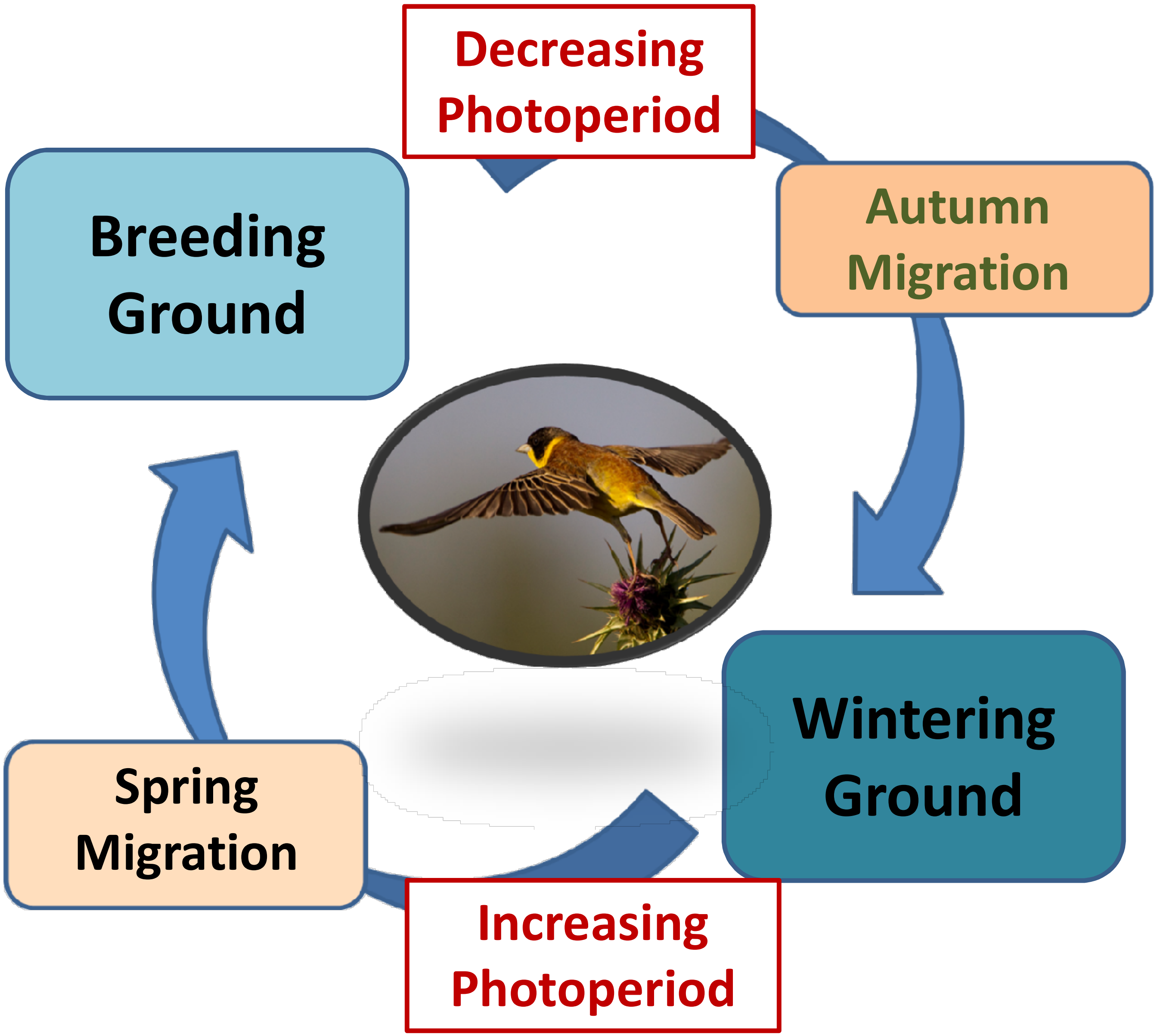
Migratory birds cross countries, continents, and oceans, connecting with people along the way. In **2020**, the **World Migratory Bird Day** conservation **theme** highlights the wonders of migrations and the many people who help to protect **birds**.

Migration is *"….. a regular, seasonal, large-scale, long distance movement of a population twice a year between a fixed breeding and non-breeding area"* (Lack 1968).

What instructs the organisms (birds) to migrate???



Life history stages of a migrant



Daily light changes in

- ✓Spectrum
- ✓Intensity
- ✓Duration

Organisms (birds) are able to detect these changes and respond accordingly

Why Migrate?

- Migration as Opportunity
  - Nesting
  - Food
- Migration as Escape
  - From weather
  - From lack of food

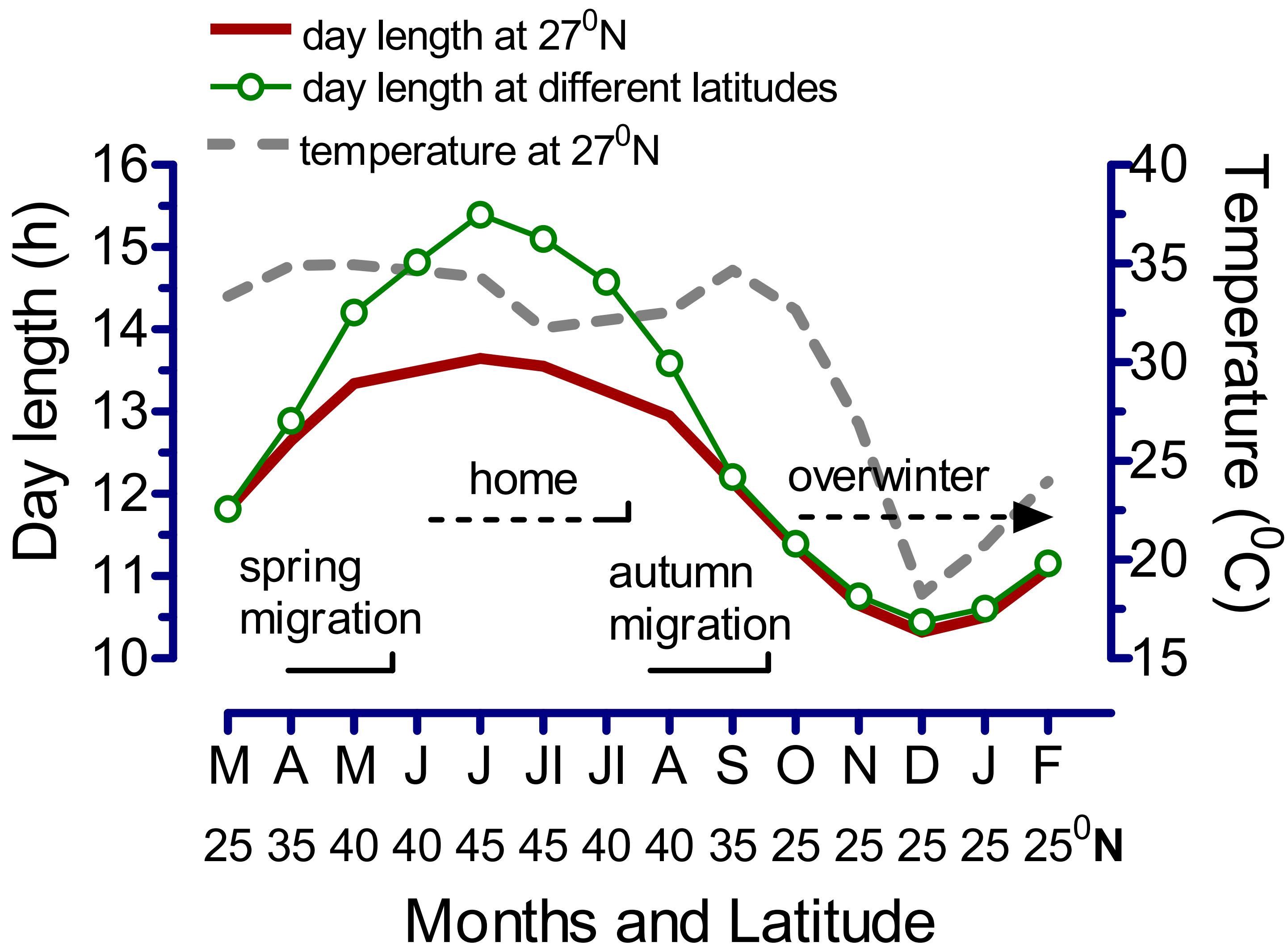
What are the Benefits of Migration?

- Avoid harsh and dangerous winter and summer climates
- Avoid lack of food during winter
- Avoid lack of cover during winter
- Migrate from area of sparse or no food to area of relatively abundant food

So migration enhances survivorship of many populations

Types of migration

- **Latitudinal migration**
- **Longitudinal migration**
- **Altitudinal migration**
- **Partial migration**
- **Vagrant migration**
- **Seasonal migration**


day length at 27⁰N
day length at different latitudes
temperature at 27⁰N
Day length (h)
16
15
14
13
12
11
10
Temperature (⁰C)
40
35
30
25
20
15
home
overwinter
spring
migration
autumn
migration
M A M J J Jl Jl A S O N D J F
25 35 40 40 45 45 40 40 35 25 25 25 25 25⁰N
Months and Latitude

The switches of seasonal migration

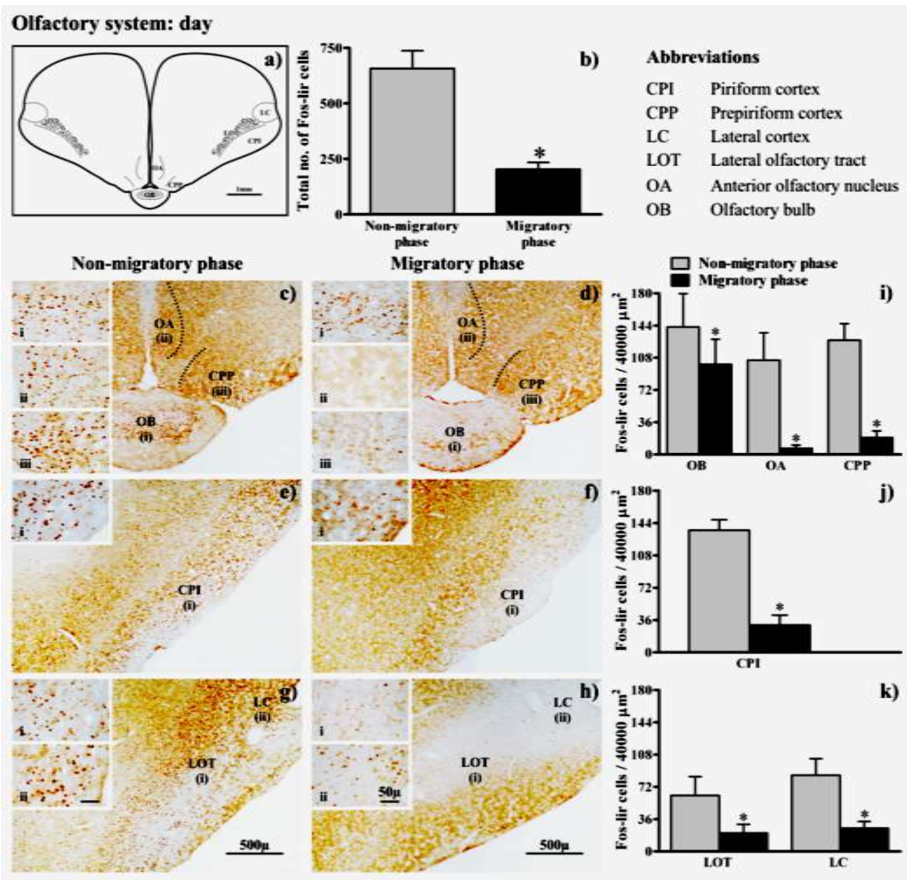
1- At neural level (e.g. olfactory and visual system).

2- At physiological level (e.g. molt, food intake, fat deposition, increase in body mass and gonad size; hormones).

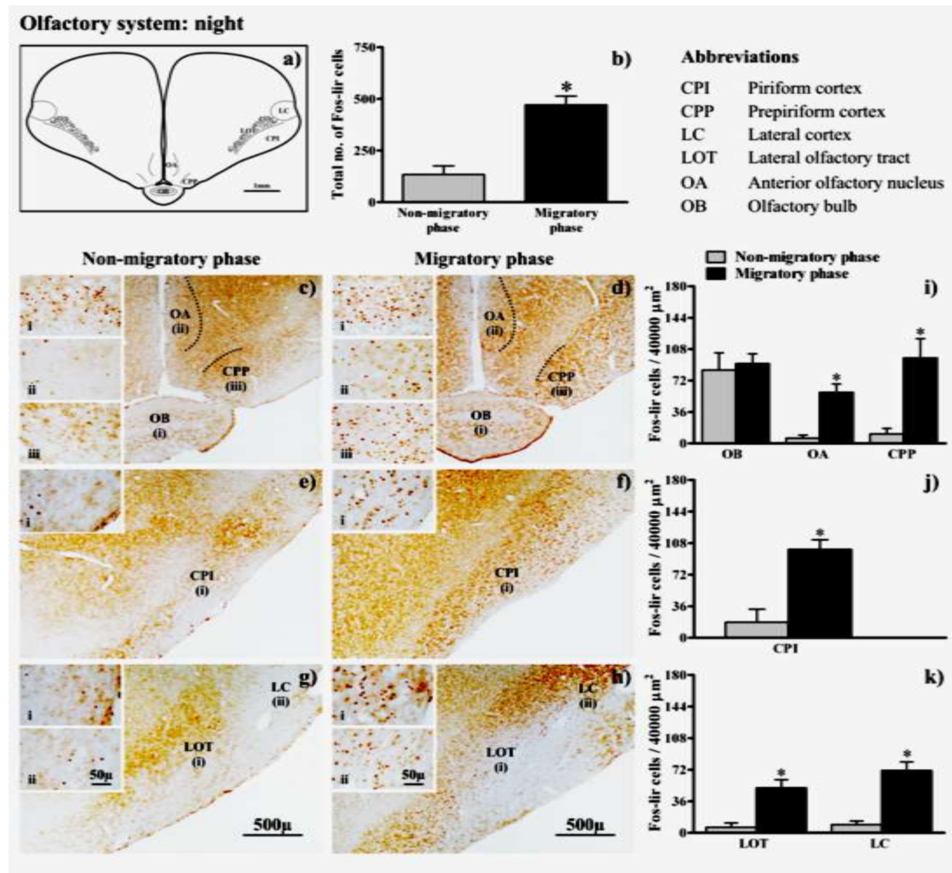
3- At behavioral level (migratory restlessness: *Zugunruhe; develops*).

Changes at neural level: Fos expression in olfactory system

Day



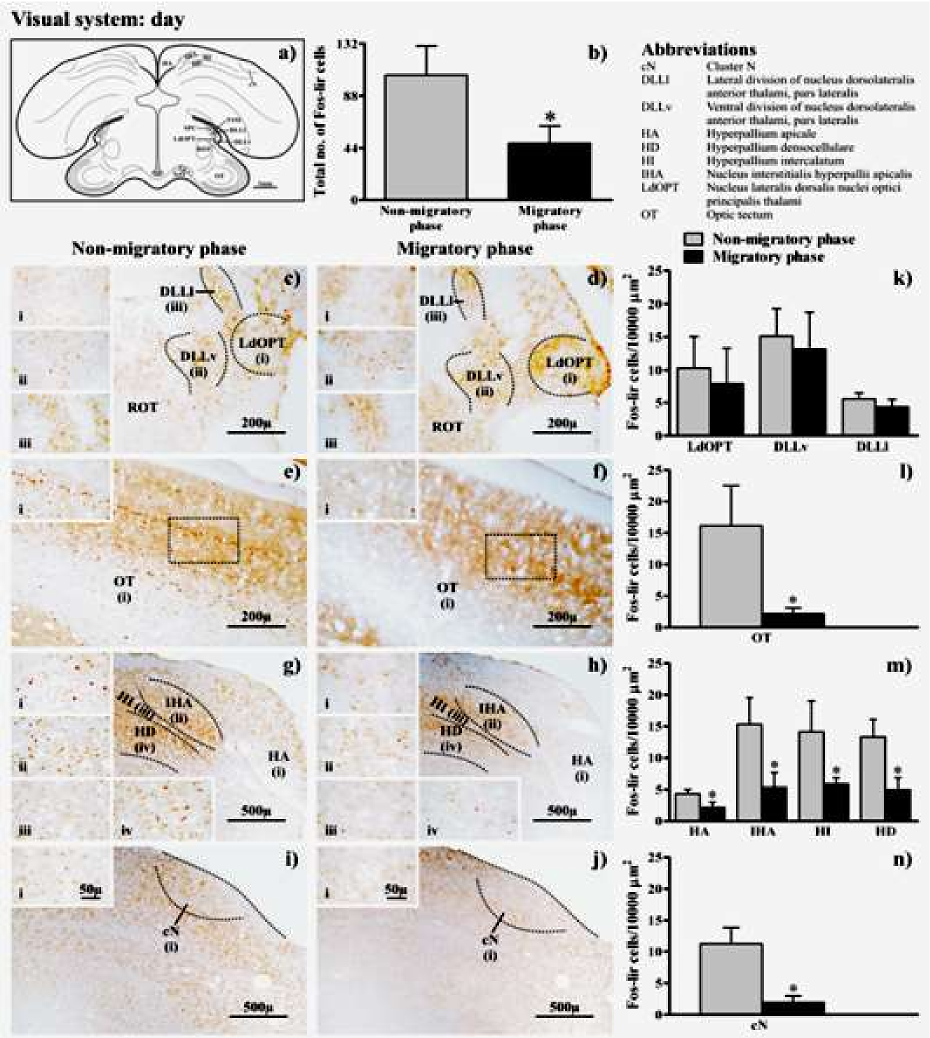
Night



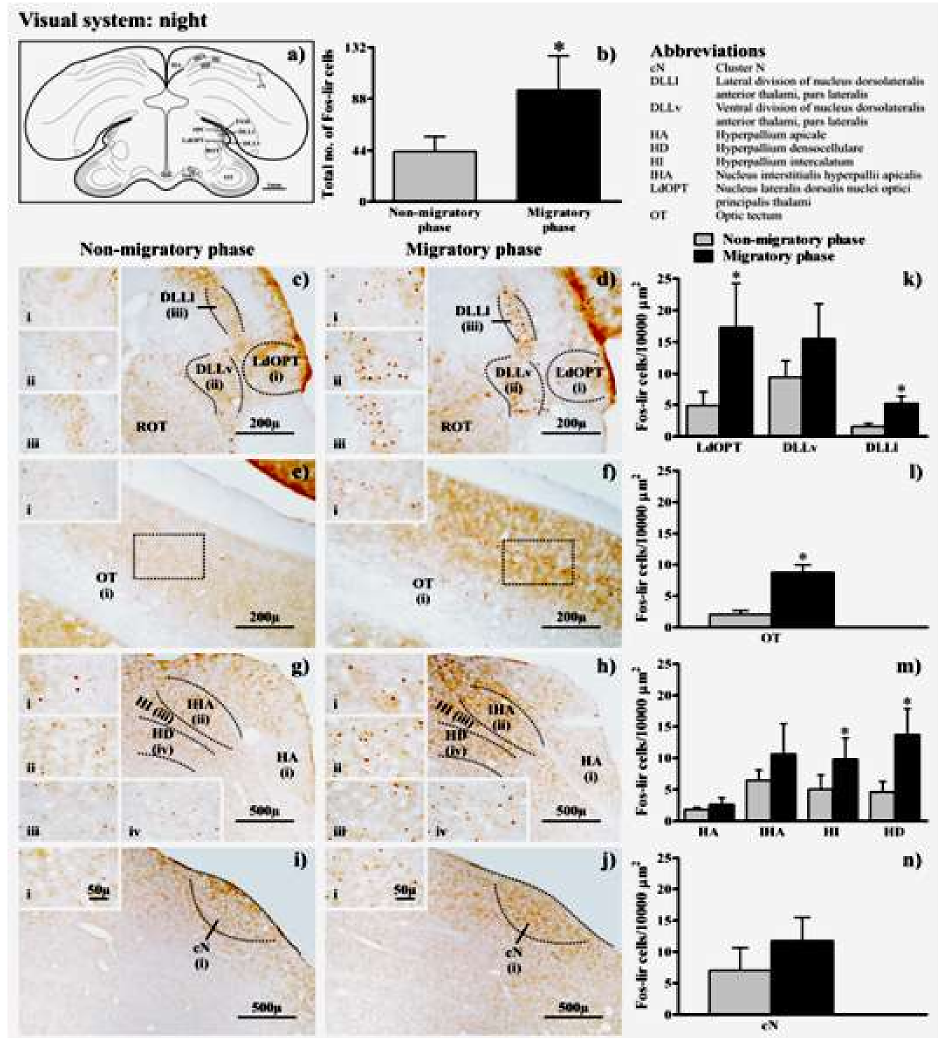
Rastogi et.al. EJN 2011

Changes on neural level: Fos expression in visual system

Day

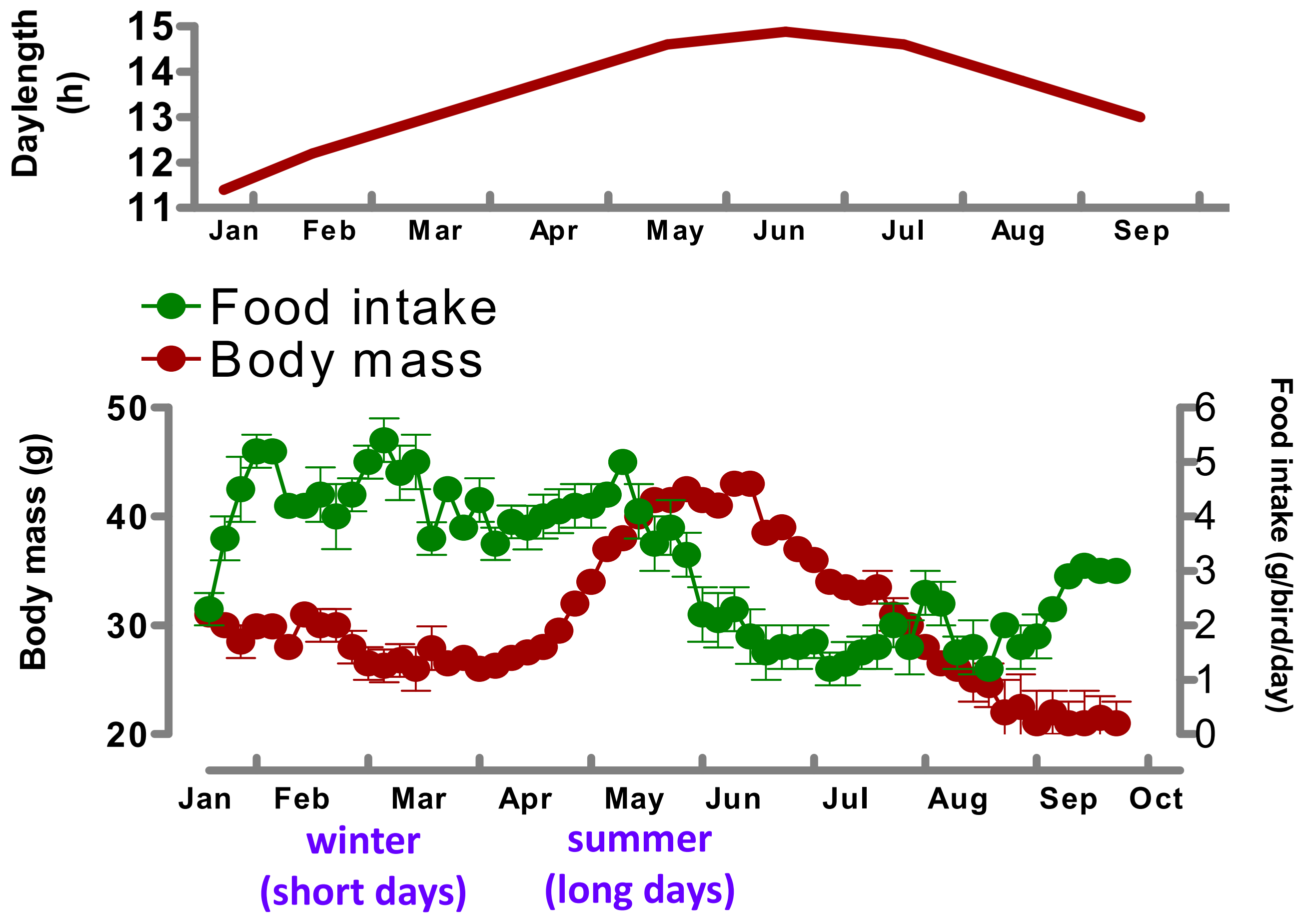


Night



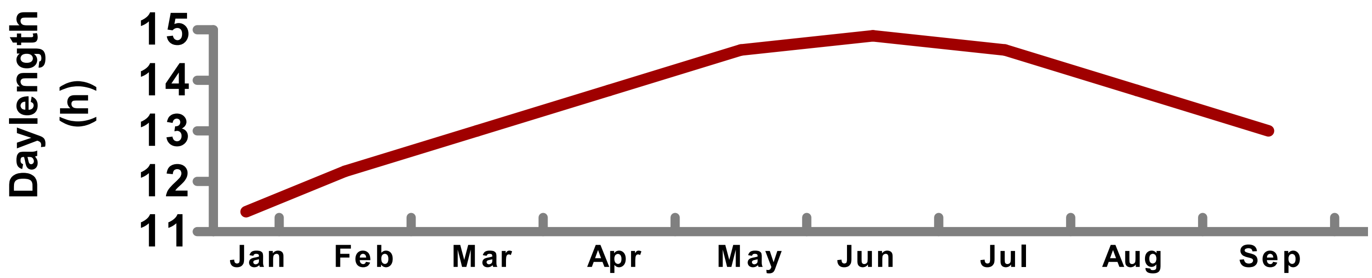
Rastogi et.al. EJN 2011

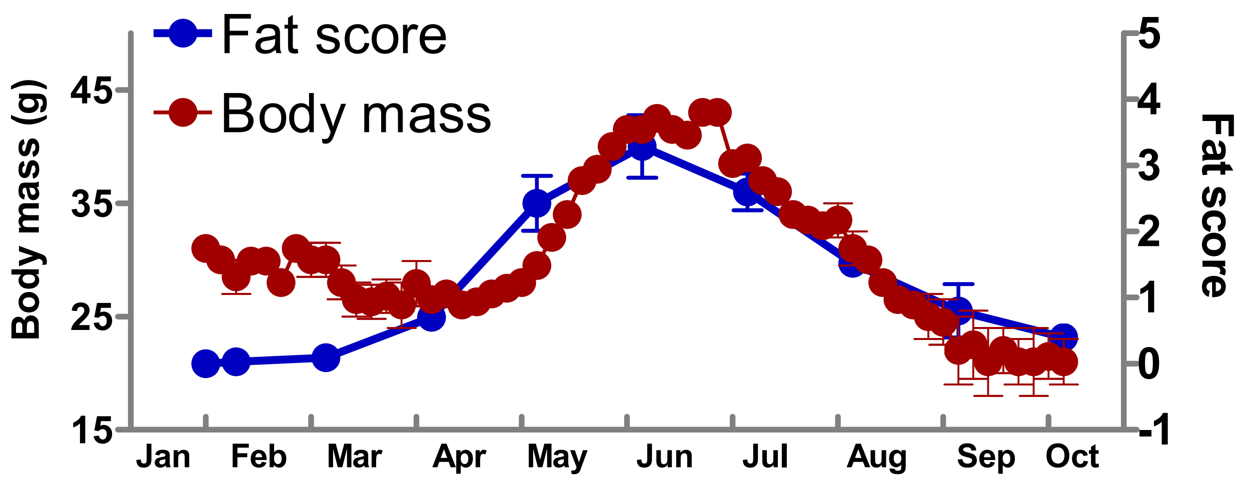
Changes at physiological level



Changes in food intake/ food preference

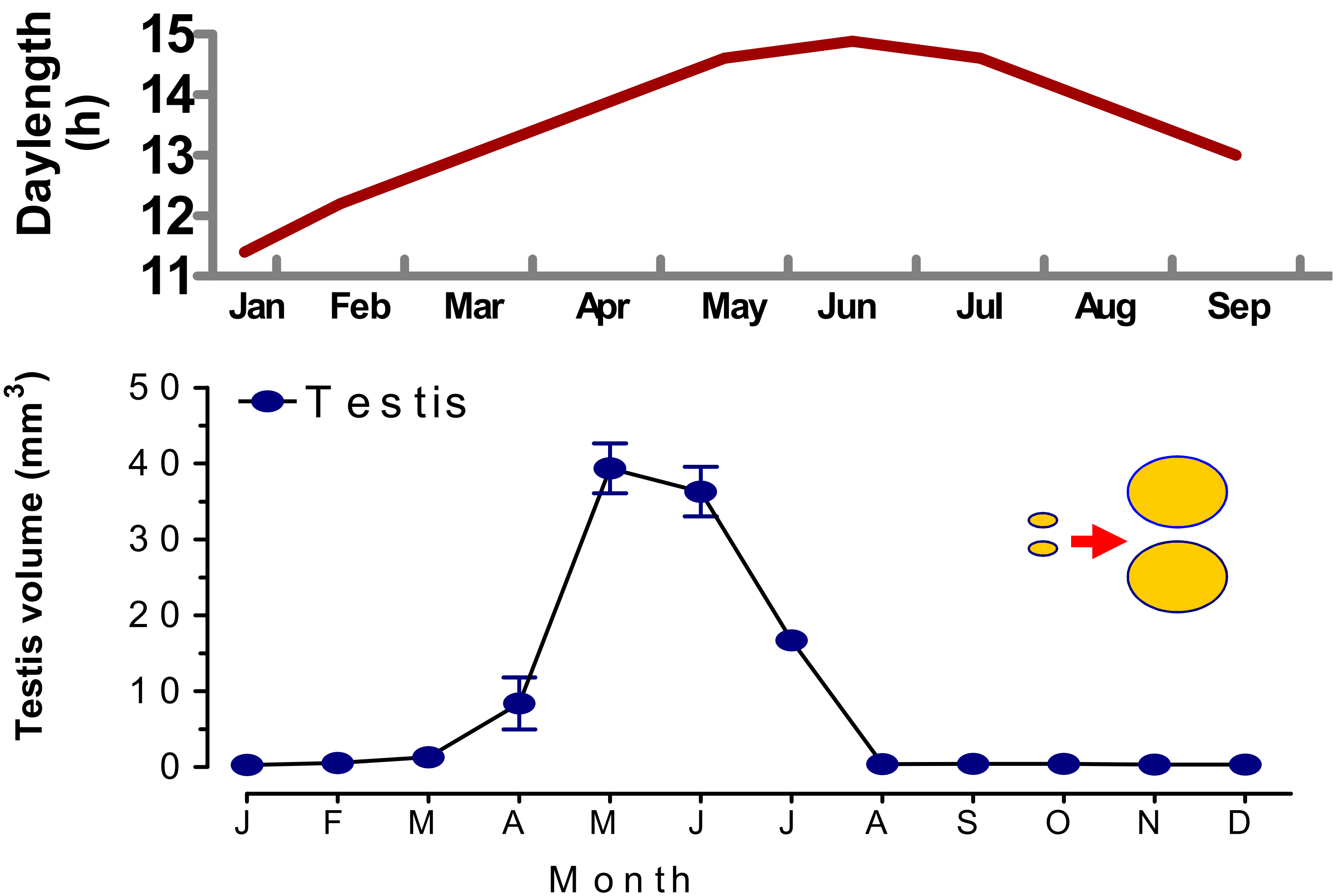
Jain and Kumar, J. Biosciences 1995





Fat Score….How to score….

0- no subcutaneous fat
1- light deposits, underlying musculature and vasculature easily seen
2- Heavier deposits, underlying musculature and vasculature still visible
3- fat deposits overlie entire region
4- Area filled with bulging fat
5- Copious deposits overflowing onto outlying areas

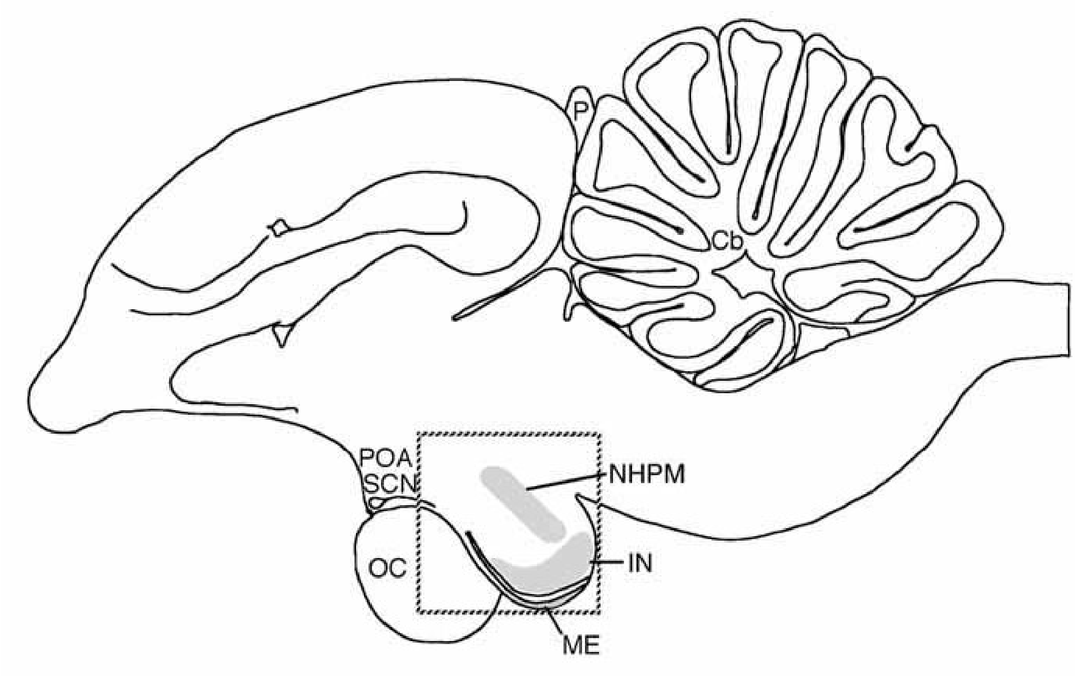


winter
(short days)

summer
(long days)

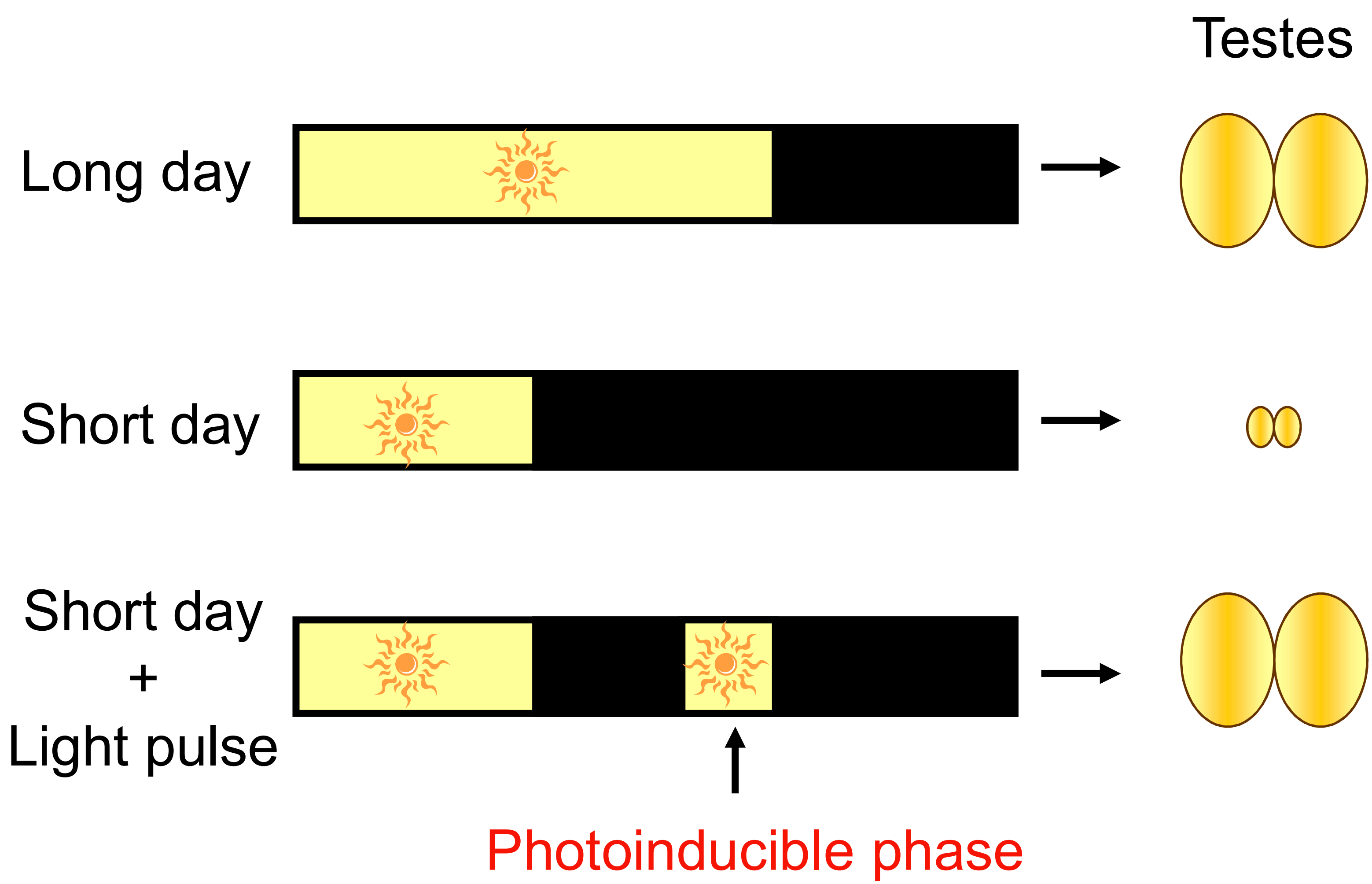
Jain and Kumar, J. Biosciences 1995

Mediobasal hypothalamus (MBH) is the center for photoperiodic time measurement

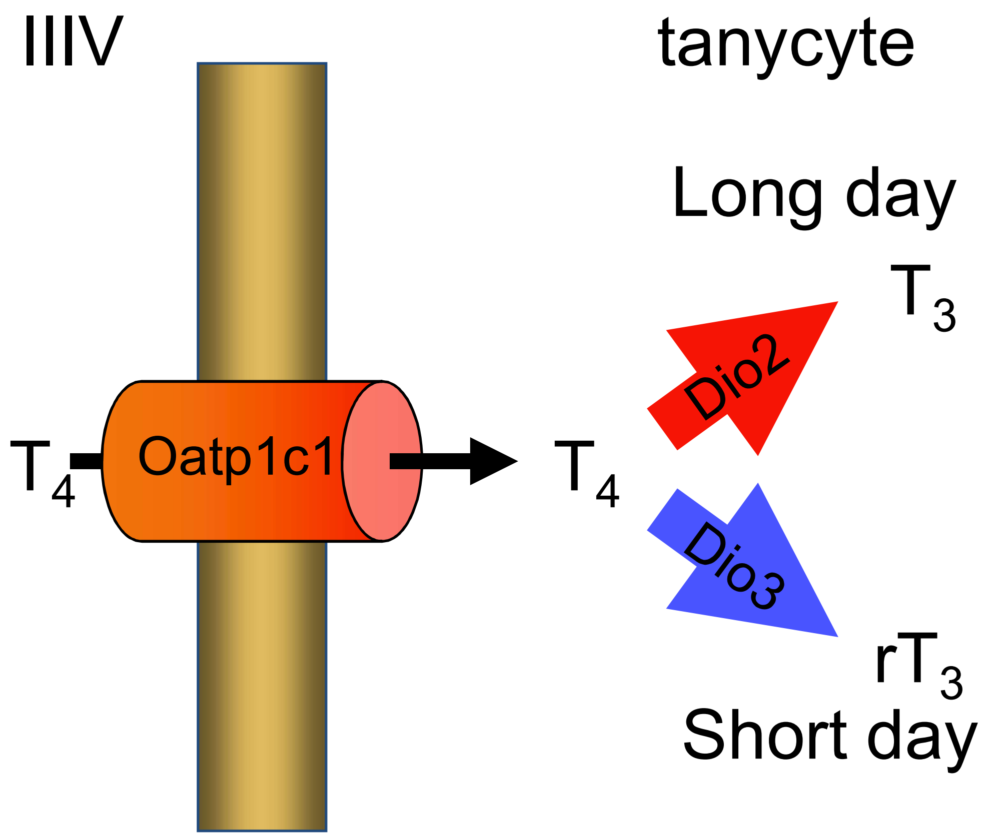


- Lesion blocks photoperiodic response of gonads.
- cFos is expressed by long day stimulus.
- Deep brain photoreceptors are thought to be localized.
- Electric stimulation causes LH secretion.
- Circadian clock genes are rhythmically expressed.

Light pulses at the photoinducible phase induce photoperiodic response of gonads

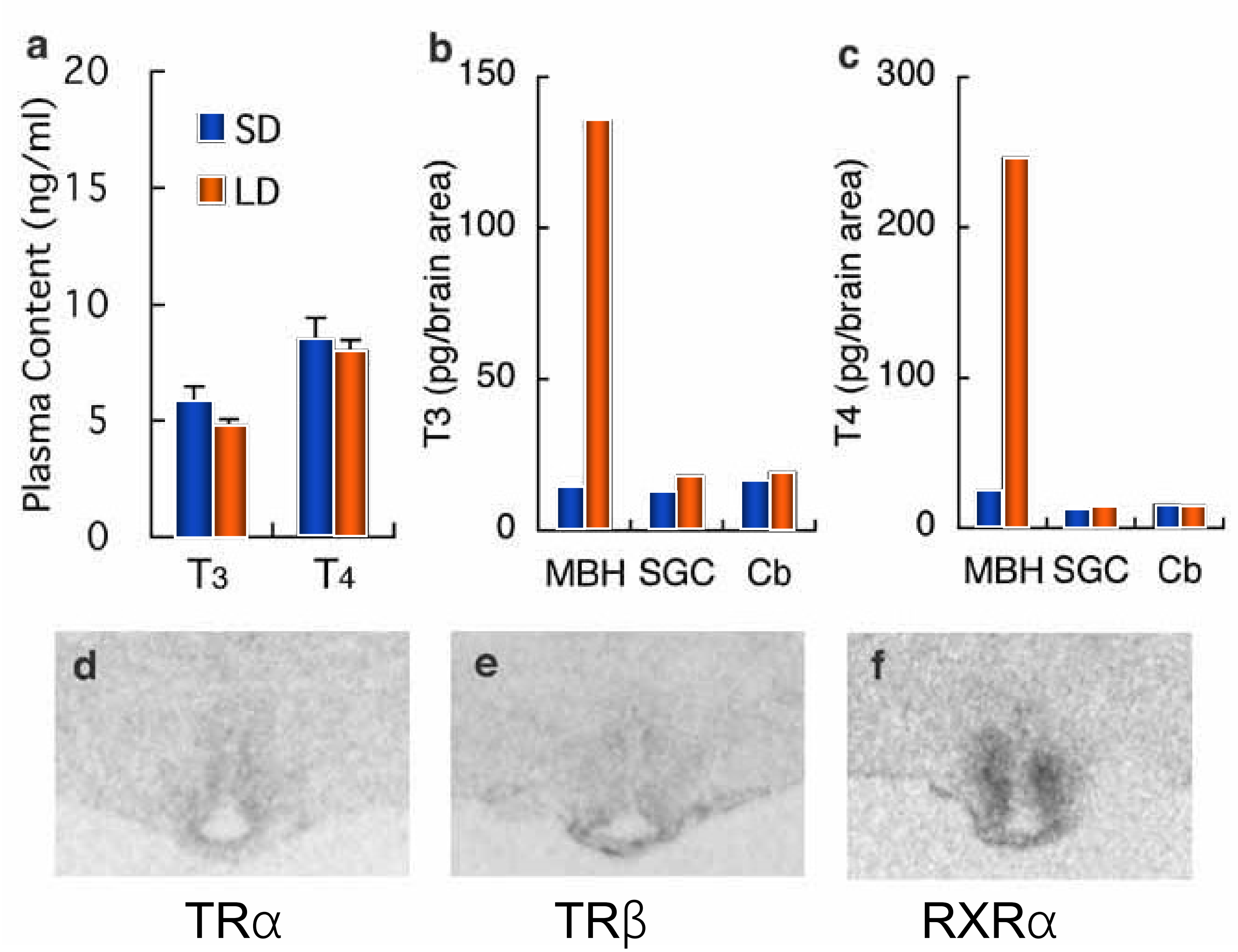


Fine-tuning of thyroid hormone concentration



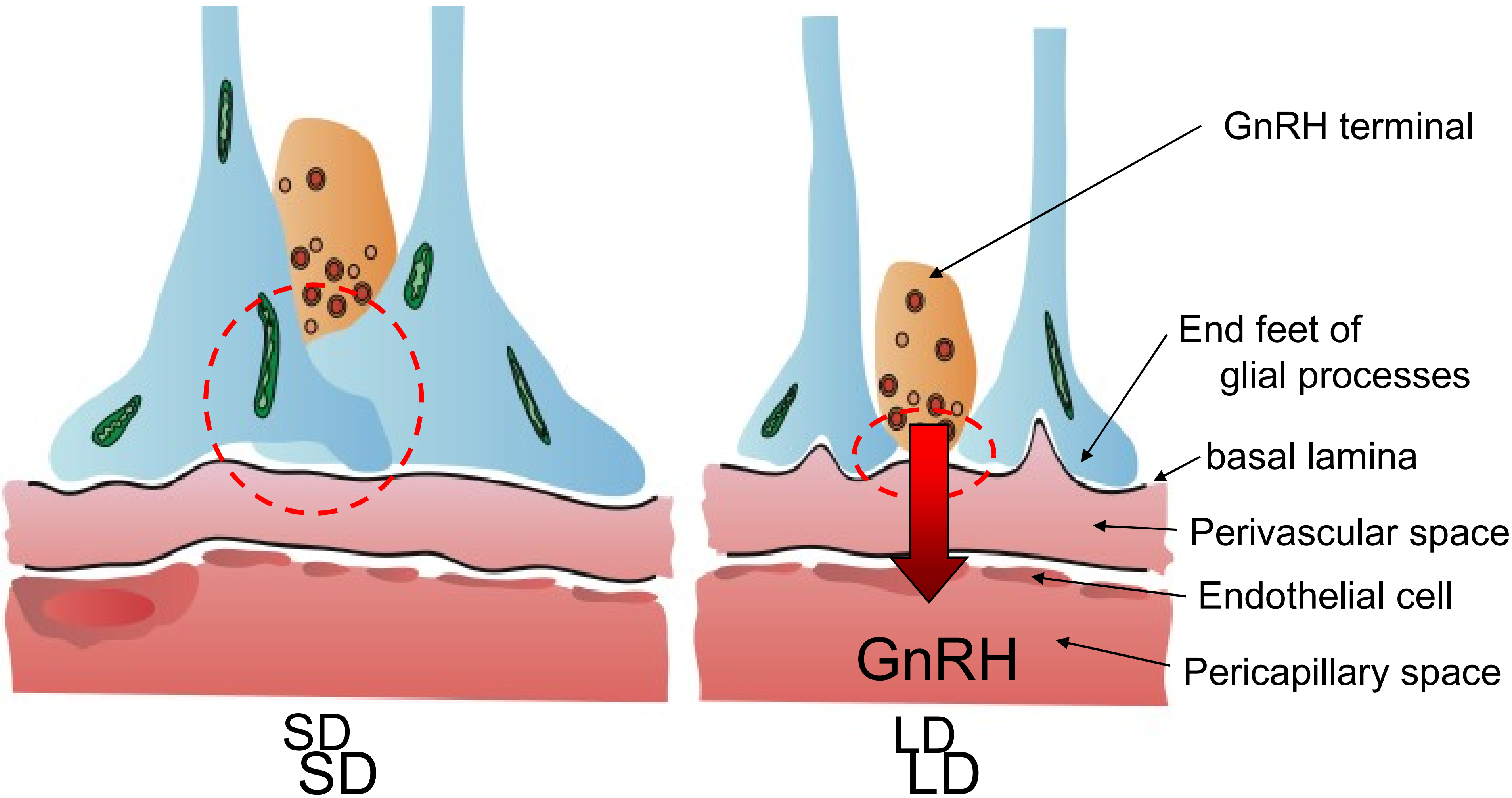
Nakao *et al.*, *Endocrinology* (2006)

Thyroid hormone receptors are expressed in the median eminence



Yoshimura *et al.*, *Nature* (2003)

Schematics of morphological changes of glial processes in the median eminence



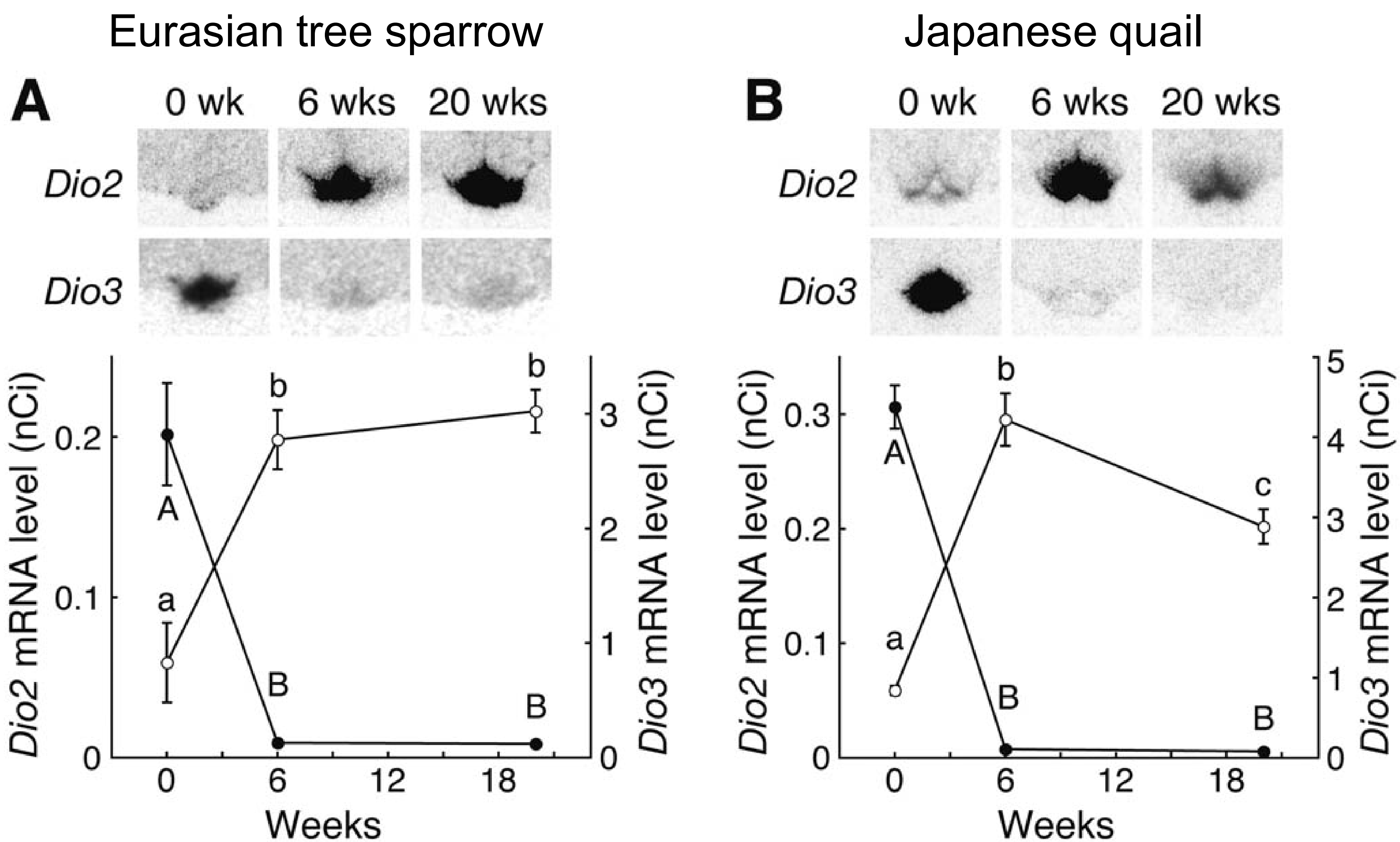
Conclusion 1

- Thyroid hormones were known to be involved in the photoinduction process.
- Long day-induced conversion of T_4 to T_3 appears to induce GnRH secretion.

Requirement of thyroid hormones to reduce the GnRH synthesis during photorefractoriness

- Photorefractoriness is the insensitivity of gonadal development to the stimulatory effects of long photoperiods.
- In absolute photorefractory birds, dramatic decline in hypothalamic GnRH content is observed, while no decline is observed in relative photorefractory quail (Dawson et al., 2001; Foster et al., 1988).
- Thyroidectomy prevents photorefractoriness in starling and sparrows, and hypothalamic GnRH levels increase in the thyroidectomized birds (Dawson et al., 2001).

Expression of *Dio2* and *Dio3* is photoperiod dependent



Conclusion 2

- Expression of *Dio2* and *Dio3* was directly related to photoperiod.
- High expression of *Dio2* and low expression of *Dio3* in the photorefractory tree sparrow seems to generate bioactive T_3 to decrease GnRH synthesis.
- In short day breeders such as sheep and goat, thyroid hormones are required for the transition from breeding to anestrus in the spring. The mechanism regulating short day breeders and long day breeders may not be radically different.

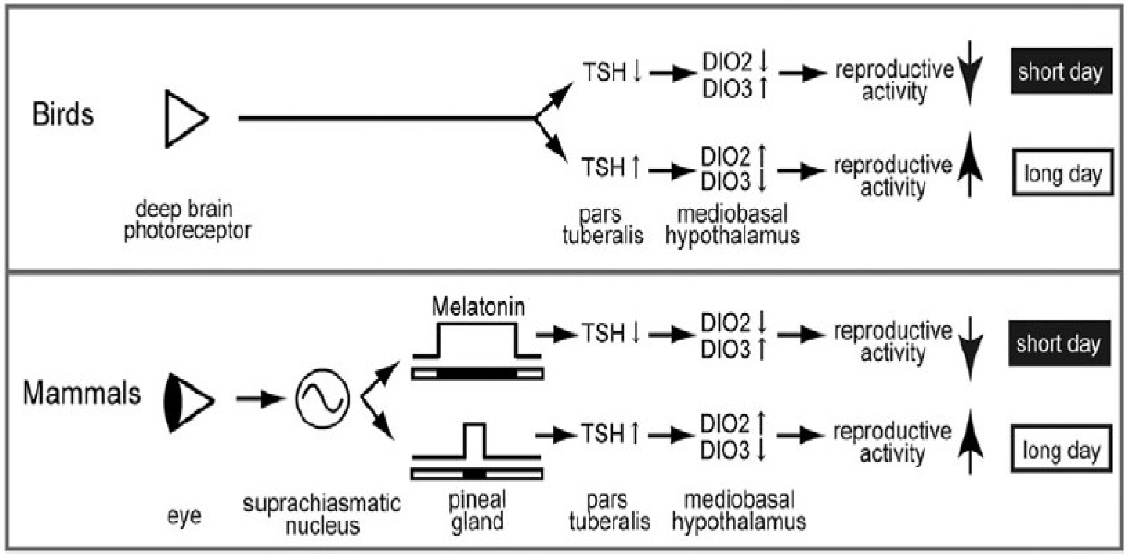


Figure 3 The neuroendocrine mechanisms involved in the control of seasonal reproduction in long-day breeding birds and mammals. In birds, long-day stimulus is perceived by deep brain photoreceptors and regulates the expression of thyroid-stimulating hormone (TSH) in the pars tuberalis. In mammals, light information is received by the eye and is transmitted to the pineal gland through the suprachiasmatic nucleus and controls the production and secretion of melatonin. The melatonin secretion pattern encodes the duration of night. TSH is a master factor regulating seasonal reproduction in both birds and mammals. (Modified from Ono *et al*. 2008).

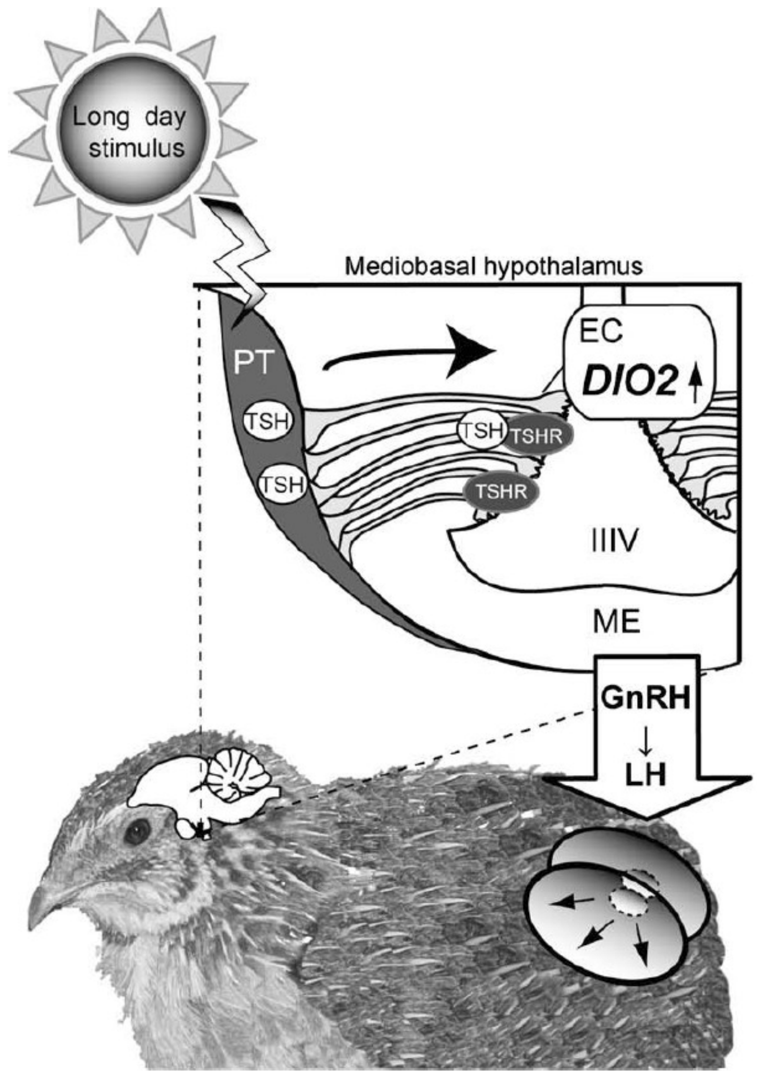
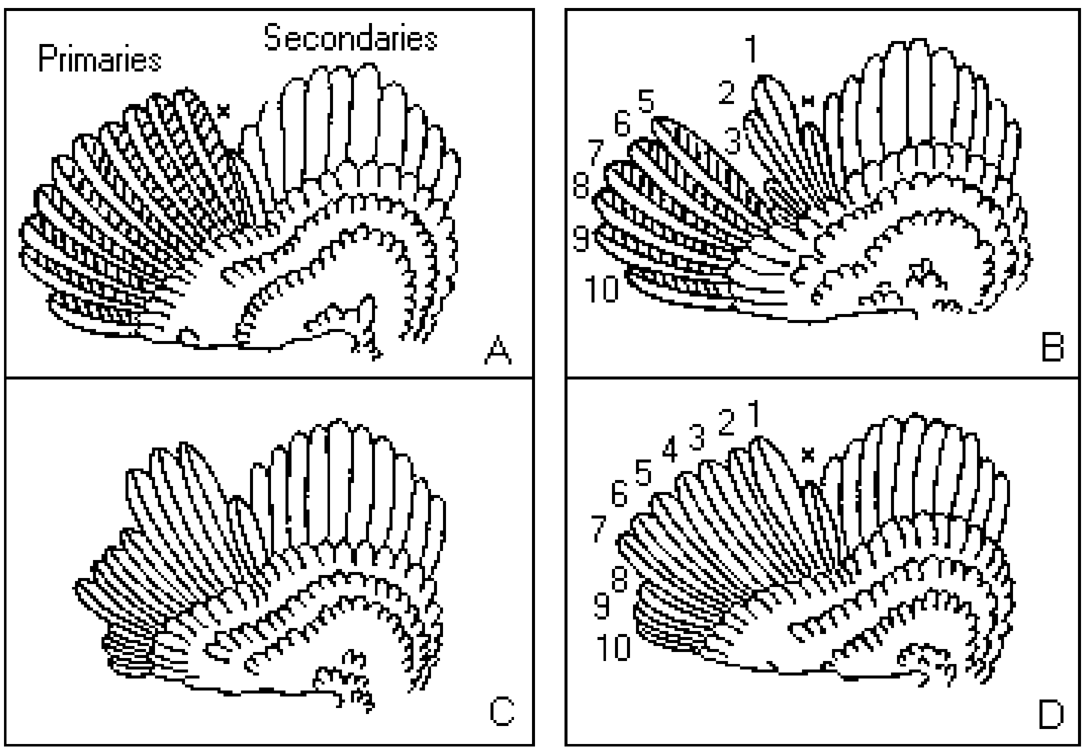
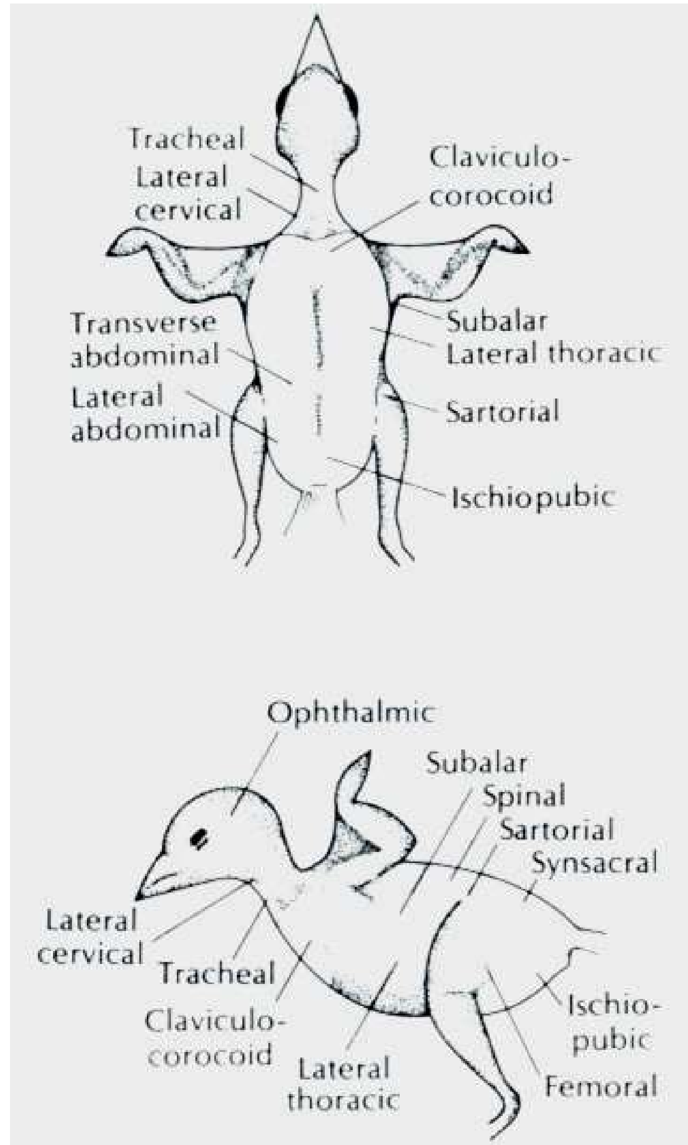


Fig. 3. The photoperiodic signal transduction pathway. A long-day stimulus induces TSH expression in the pars tuberalis (PT) of the pituitary gland. Pars tuberalis TSH acts on through TSH receptor (TSHR) in the ependymal cells (ECs) to induce the expression of *DIO2*, which triggers the neuroendocrine pathway stimulating gonadotropin secretion and gonadal growth.

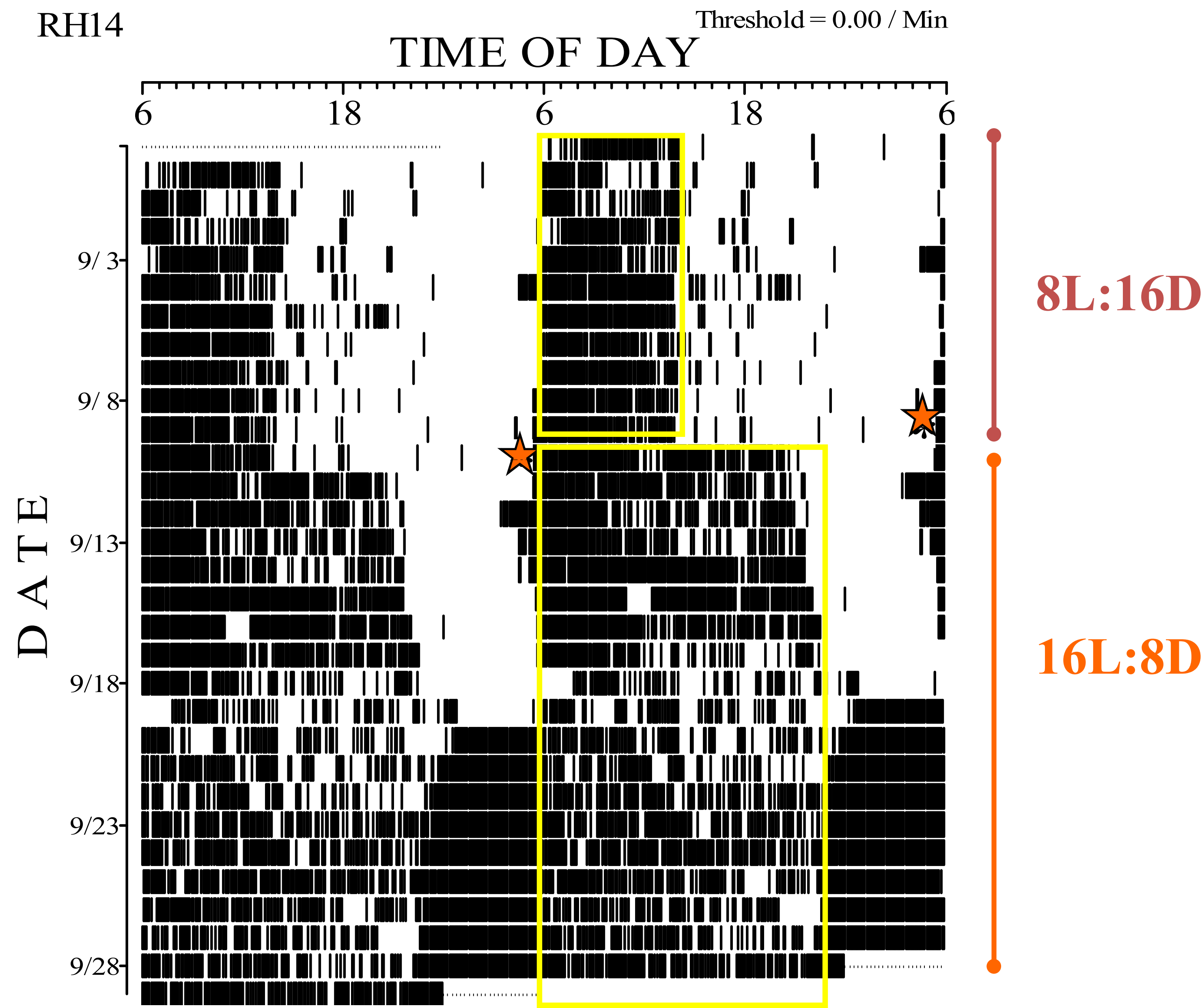
Molting

Postnuptial molt
New feather growth needed for long migratory flights





Bird showing *Zugunruhe*



Resident species

Migratory species

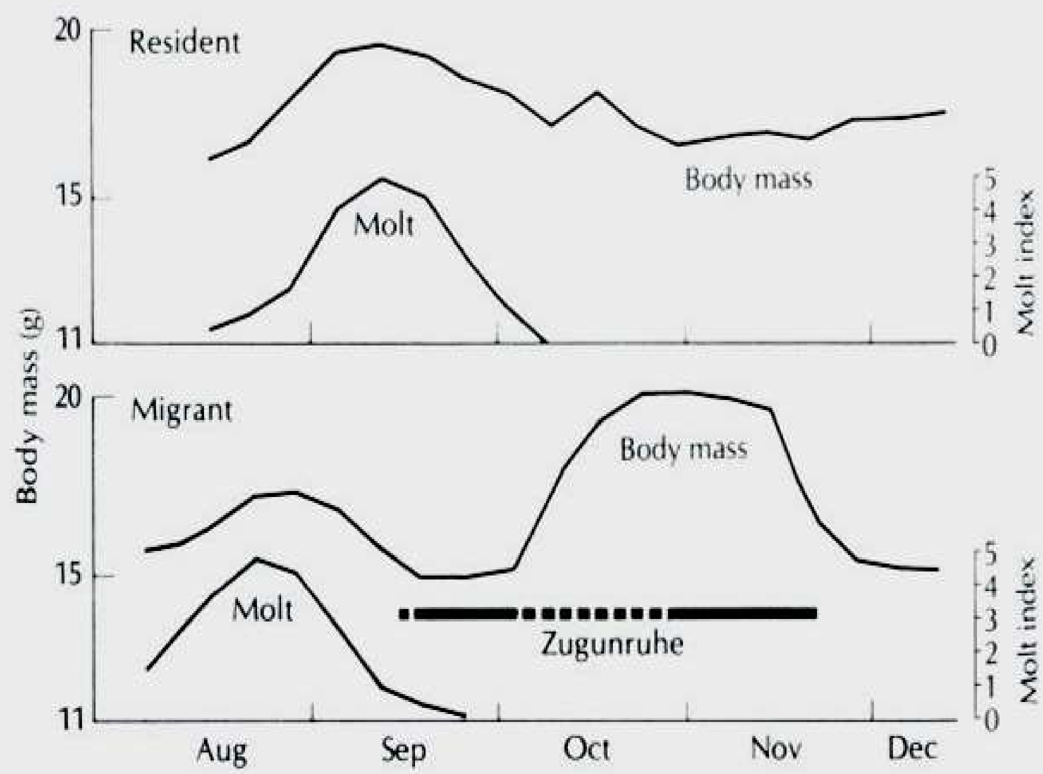


Figure 12–4 Body mass (in grams), molt, and *zugunruhe* behavior (migratory restlessness) of (top) a young resident and (bottom) a young migratory European Robin in the laboratory. Breeding experiments revealed a genetically based polymorphism for migratory behavior, including early molt, premigratory fattening, and migratory restlessness in the two forms of this species. A molt index of 1 indicates the beginning or the end of the molt. A molt index of 5 indicates a heav[y] molt that includes most of the feather coat. (After Biebach 1983)

Orientation & Navigation

It has been demonstrated that birds rely on different cues: visual landmarks, geomagnetic field, solar compass, skylight polarization pattern/stars, and olfaction- for their orientation and navigation across vast stretches of land

Orientation & Navigation

- While traveling, birds cross several ecological zones, and in many cases several time zones. The migratory birds must appropriately orient their flights, both in time and space.

But how do young birds migrating for the first time know to reach their population-specific wintering area which is completely unknown to them??????

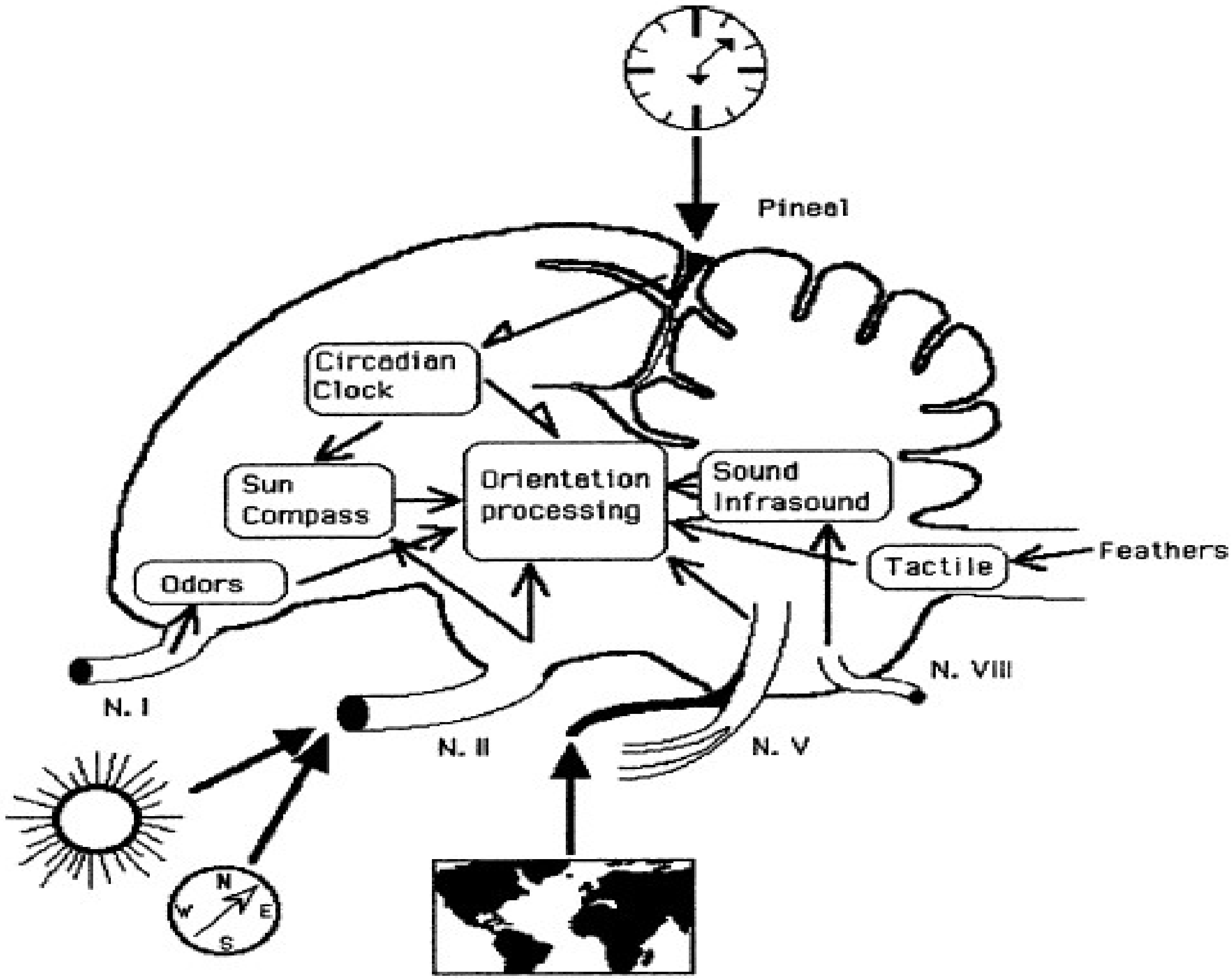
- Major orientation cues used by birds include ***landmarks, sun compass, polarized light, stars, magnetic field and wind***.
- It appears that ***neurophysiological mechanisms*** are involved in the orientation process. Not much is known however at this time, but experiments carried out by Bingman in late 1980s on pigeons indicate that the ***hippocampus was involved in spatial orientation***.
- ***Magnetically sensitive materials*** have been found in the head regions of birds. The detection of the magnetic field may occur within the visual system (trigeminal nerve).

Orientation and navigation (contd..)

Neurologists have discovered a specialized night vision area in night migratory song birds.

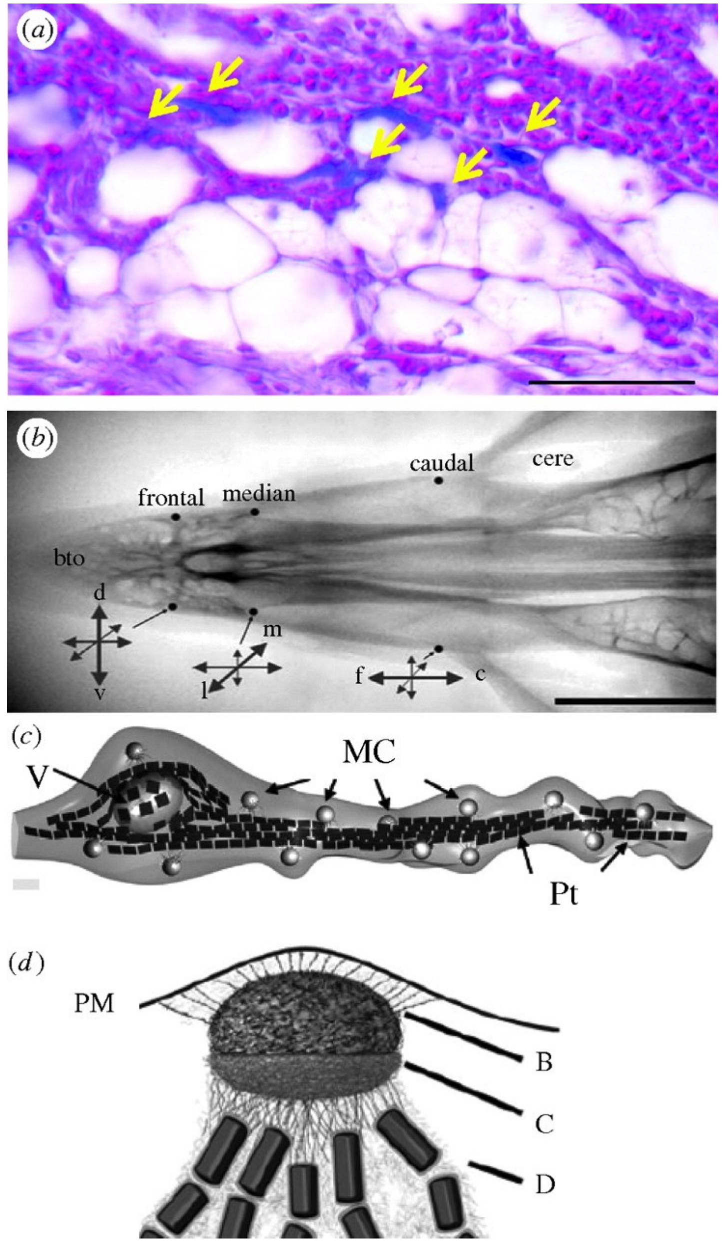
They believe this area might enable the birds to navigate by star, and can visually detect the Earth's magnetic field through photoreceptor molecule whose light sensitivity is modulated by fields.

The retinal receptor is sensitive to one or more photopigments, perhaps cryptochromes.



Sources of sensory information used for navigation and potential neural interconnections

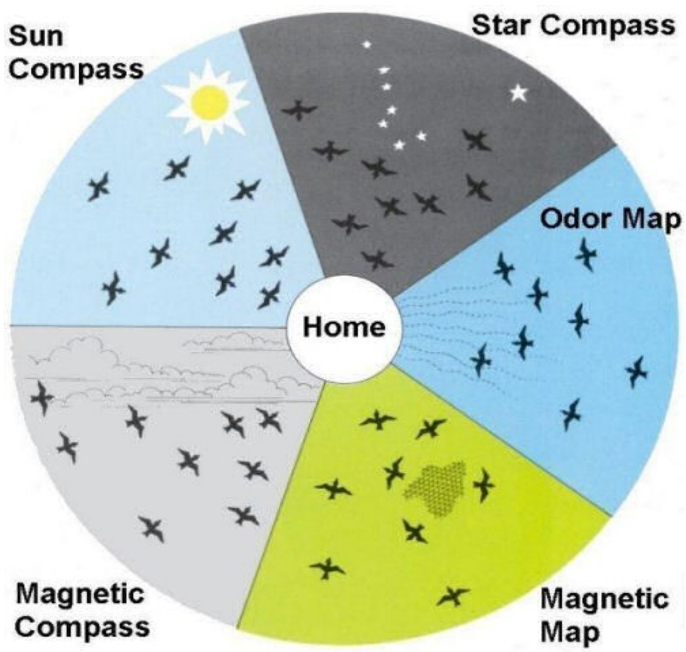
Presence of SPM magnetite in the upper skin of the beak of the homing pigeon (*Columbia livia*)



Cadiou H , and McNaughton P A J. R. Soc. Interface 2010;7:S193-S205

Bird Navigational Techniques

- **Sun Compass** -- Some birds can find the proper direction only if they have a clear view of the sun. Even night migrants appear to use the sun as a cue, as most take off during twilight.
- **Star Compass** -- Night migrants orient themselves in the proper direction under clear, starry skies but become disoriented when it is cloudy. These birds learn and orient by the spatial relationships among the constellations, rather than by using information supplied by any single star.
- **Odor Map** -- Some short-distance migrants use an "odor map" to return to nesting and wintering sites. Studies show that young pigeons learn the odors carried by the wind which reach their home sites.
- **Magnetic Map** -- Migratory birds may rely on an instinctual map to find their way back to nesting or wintering sites. Magnetic disturbances may interrupt these abilities.
- **Magnetic Compass** -- Several birds appear to possess a built-in magnetic compass to use on cloudy days. Birds tested in a controlled environment showed that they were aware of the direction to migrate even without the sun or stars.



Med. & biol. Engng. Vol. 4, pp. 457–466. Pergamon Press, 1966. Printed in Great Britain

A MULTI-CHANNEL TRANSMITTER FOR THE PHYSIOLOGICAL STUDY OF BIRDS IN FLIGHT*

O. Z. ROY† and J. S. HART‡

Abstract—This paper describes a light-weight, rugged, multi-channel transmitter designed for telemetering biological data such as tidal volume, electrocardiograms, and body temperature, from birds in flight. The transmitter operates at 230 Mc/s, and uses FM–FM modulation. It measures 3 in. in length, 1 in. dia. and weighs 30 g with two 100-mA hr Silvercel batteries.

1. INTRODUCTION

A LIMITED amount of information is available on the physiology of birds during flight; much of the effort thus far has been spent on tracking birds with radar during migration, or in tracking animals in their natural habitat using cw techniques. Radio telemetric studies on flying ducks have been done by ELIASSEN (1960, 1963) who studied cardiac performance, and by LORD, BELROSE and COCHRAN (1962) who studied respiration rates in ducks. Studies of pigeons have also been carried out by our group, ROY and HART (1963) and by TOMLINSON (1957). The system to be described is now being used to monitor both deep body and subcutaneous temperature, tidal volumes, respiration rates, electromyograms, and heart rates.

The design criteria set down by the physiologist for a telemetry system were listed by HAAHN (1965) as follows: size—zero: weight—zero: range—infinite: power supply life—infinite: sensor and transducer pathological effects—none: number of parameters monitored—infinite: degree of automation—complete, i.e. no electronics background required for using the equipment. We have not met these specifications; however, with the use of integrated circuitry and with the battery manufacturers chasing the watt-hour per pound ratio, these specifications will be approached.

The transmitter used in our studies uses standard FM–FM techniques and discrete components throughout. It is cylindrical in shape, measures 1 in. dia. and 3 in. in length and weighs a total of 30 g with a 3-V 100-mA hr battery.

The high-frequency section of the transmitter is shown in Fig. 1. It consists of a tuned-collector, tuned-emitter oscillator with capacity feedback, a common-base output stage and a common-emitter modulation stage. The oscillator is tuned to operate in the general telemetry band 230 Mc/s and is frequency modulated by shifting its operating point and thus varying the transistor capacitance across the tuned circuit: the oscillator is deviated ± 75 kc/s for an input swing of 200 mV. The oscillator feeds an output stage which has a 10 dB power gain but is primarily used as an isolation circuit to decouple the antenna from the oscillator and thus minimize the detuning effect of the rather violent movement which occurs during flight. The efficiency of this high frequency section is about 12 per cent; it can put out 2·5 mW into 50 Ω with a battery voltage of 3 and a current

* *Received* 26 *November*, 1965.
† Radio and Electrical Engineering Division, National Research Council, Ottawa, Ontario, Canada.
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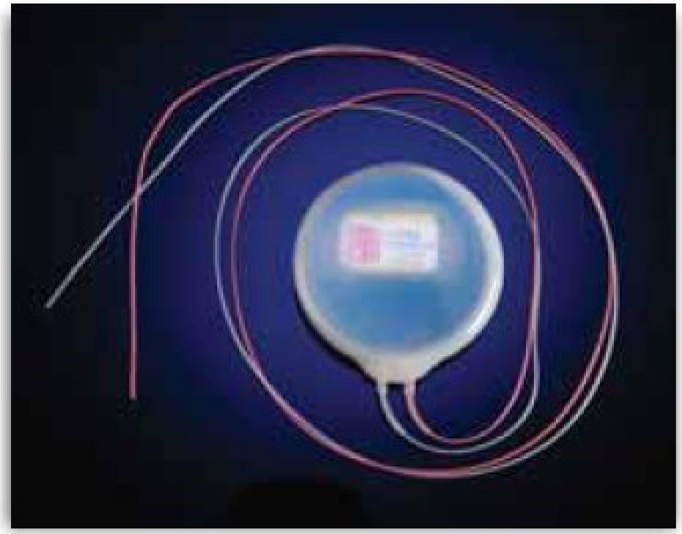
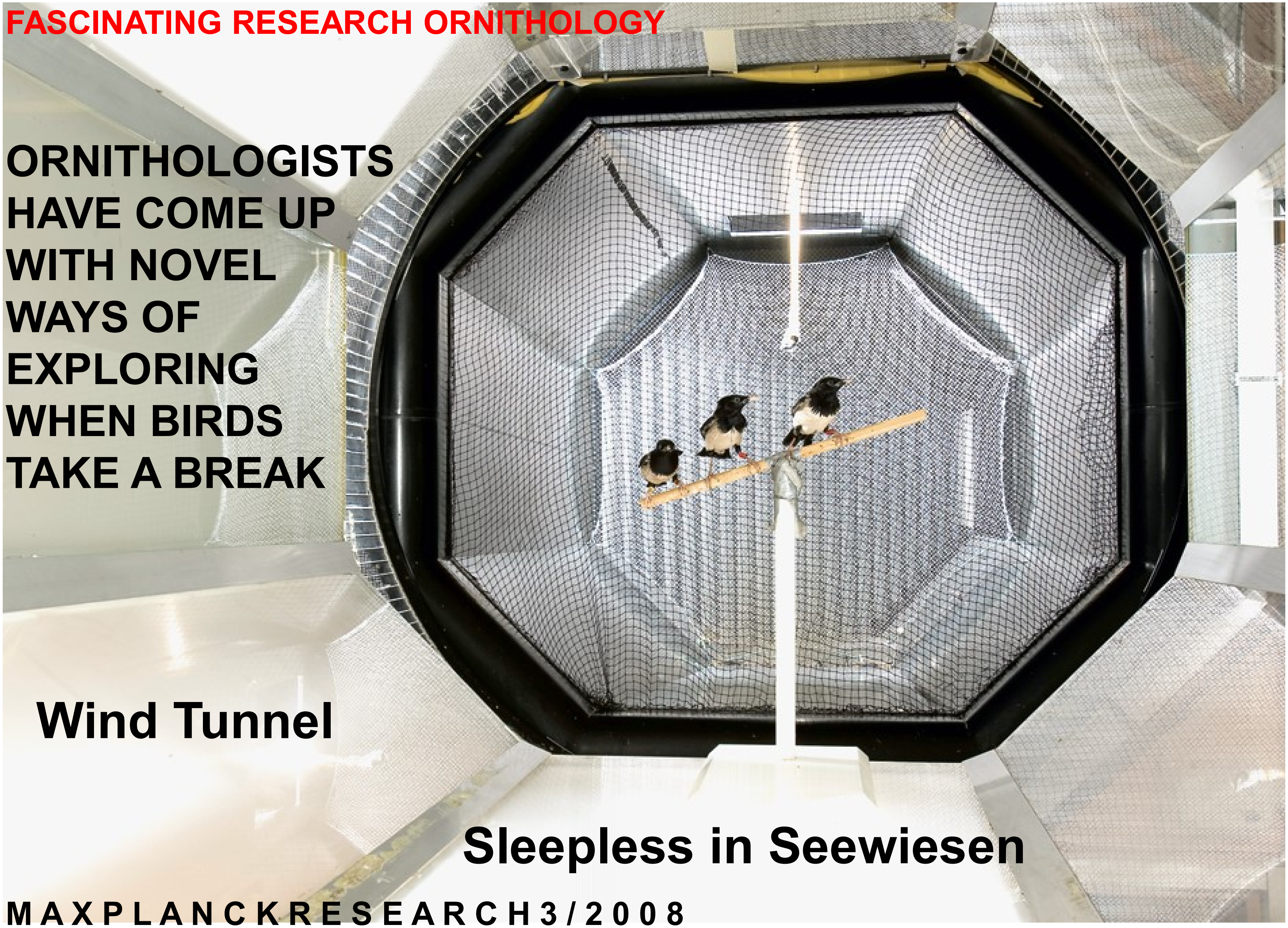


Physiologic data collection using telemetry has many advantages over older, traditional methods of data collection such as restraints, cuffs and tethers.
In some cases, anesthesia is still used in obtaining physiologic data. However, the anesthesia itself may affect the data being collected. Telemetry eliminates the need for such data collection methods and provides researchers with data that are free from stress-induced artifact and the effects of anesthesia.

FASCINATING RESEARCH ORNITHOLOGY

ORNITHOLOGISTS HAVE COME UP WITH NOVEL WAYS OF EXPLORING WHEN BIRDS TAKE A BREAK



Wind Tunnel

Sleepless in Seewiesen

Summary and perspective

- The migratory birds have two distinct phases of migration (vernal and autumnal) in their annual life cycle.
- Both are different in physiological and other survival strategies.
- Birds are equipped with excellent navigational procedures which are endogenous but also make the use of visible landmarks and other factors, like wind, sun compass, star compass, etc.
- Endogenous mechanisms control migratory course, migratory restlessness, hyperphagia (increased food intake), food utilization, fat deposition and dissimilation, and so they constitute an integral part of the system that is involved in the adjustment of different adaptations.

Summary and Perspective (contd..)

- The neural, cellular and molecular components that control migration are needed to be identified and the mechanisms of their interaction be understood.
- We in India are in unique position to study the vernal phase of migration in birds which has not been adequately studied even in other relatively well studied migratory system.

Besides *birds* migration is seen in other organisms too…

1. Butterflies, moths, aphids, dragon flies, locusts, etc.
2. Fish: salmon, sea lamprey, tuna, sea trout, three-spined stickleback, eels, etc.
3. Mammals: Wildebeest, bearded pig, zebra, bats, Asian elephants, antelope, lemming, whales, etc.

Migratory Insects

Monarch Butterflies

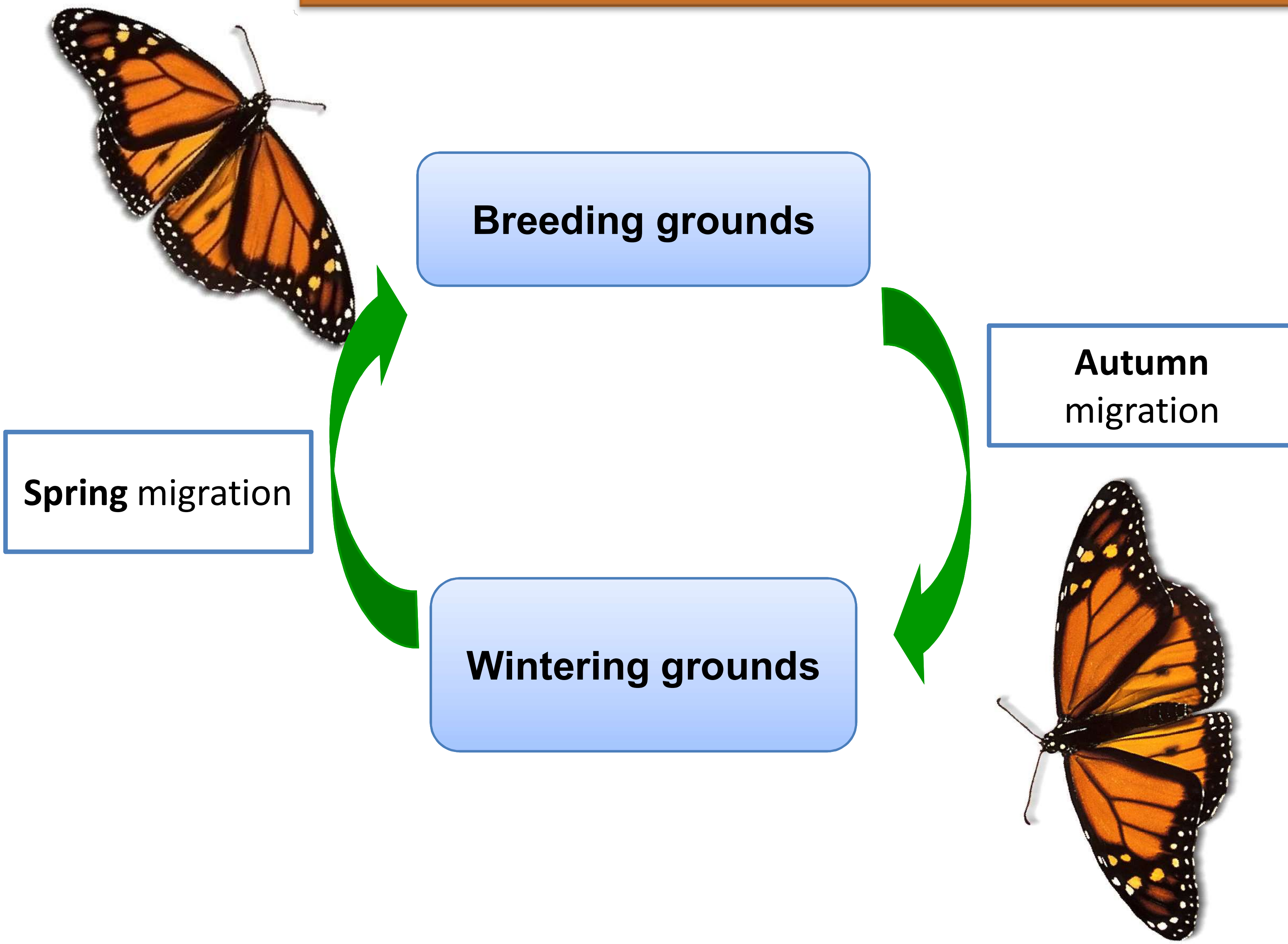
Dragonflies

Moths

Locusts

Aphids

Life history stages



- Adult female monarchs lay their eggs on the underside of milkweed leaves (Mexico).
- Egg, Larva, Pupa occurs at milkweed plant in Mexico.
- Adult stage butterflies return to the north (Canada) in spring season.

Signals inducing migration

- Change in day length (photoperiod), changes in season due to the position of the sun
- Endogenous Clock mechanism
- Polarized Light as well as polarization of the sky when the sun is occluded by clouds.
- The Earth's magnetic field on the basis of the presence of magnetite particles.

Types of migration (Fish)

- Alimental migration:- this is in search of food and water.
- Gametic migration:- for reproduction.
- Climatic migration:- to secure more suitable climatic conditions.
- Osmoregulatory migration:- maintains Osmoregulation.

Patterns of migration

- POTAMODROMOUS MIGRATION
- OCEANODROMOUS MIGRATION
- DIADROMOUS MIGRATION

(a) Anadromous migration

(b) Catadromous migration

(c) Amphidromous migration

Endocrine glands/ hormones

- Pituitary glands (Prolactin, corticotropin, growth hormone etc.)
- Urophysis and corpuscles of stannius
- Pineal gland
- Thyroid gland (calcitonin)


Read related papers too