Biol 240

CHP 5: The organization of behavior: Neurons and hormones

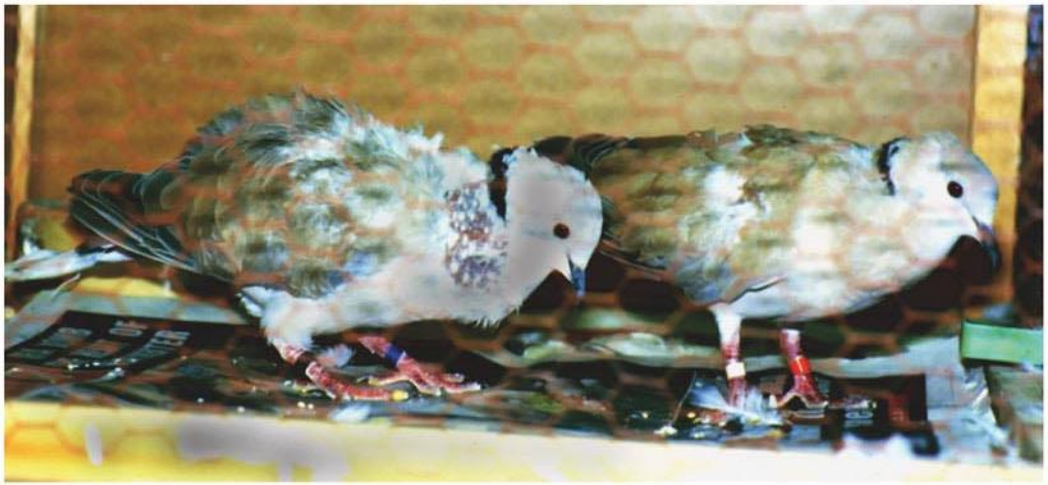
March 12, 2015

What if a flying male moth, exposed to ultrasound from a predatory bat, is simultaneously stimulated by the scent from a distant pheromone-releasing female?

- Pheromone – releasing female moth: mating behaviour in males
- Ultrasound waves from bats: escape behavior in males
- Female pheromones do not always stimulate mating behavior, in case of simultaneous presentation with the bat ultrasound
- Therefore: there must be a center that organizes different behaviors based on the importance of the stimulus

5.1 Different courtship displays of the male ring dove are under the control of different hormones

(A)



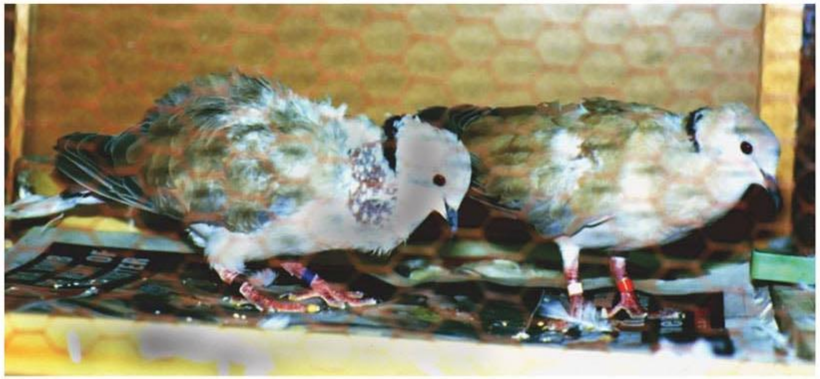
(B)

- Hormones often organize behavior in many animals
- Ex: male dove courting female: agressive strutting and bowing (a) followed by nest soliciting (b)

5.1 Different courtship displays of the male ring dove are under the control of different hormones

Strutting and bowing

(A)



Nest soliciting

(B)

Testosterone → Aromatase → Estrogen

How proximate mechanisms structure an individual's behavior, from moment to moment, over the course of the day, over a breeding season, or over a whole year?

How proximate mechanisms structure an individual's behavior, from moment to moment, over the course of the day, over a breeding season, or over a whole year?

- Neural command centers (communication)
- Biological clocks (schedule)
- Hormonal systems (priorities)

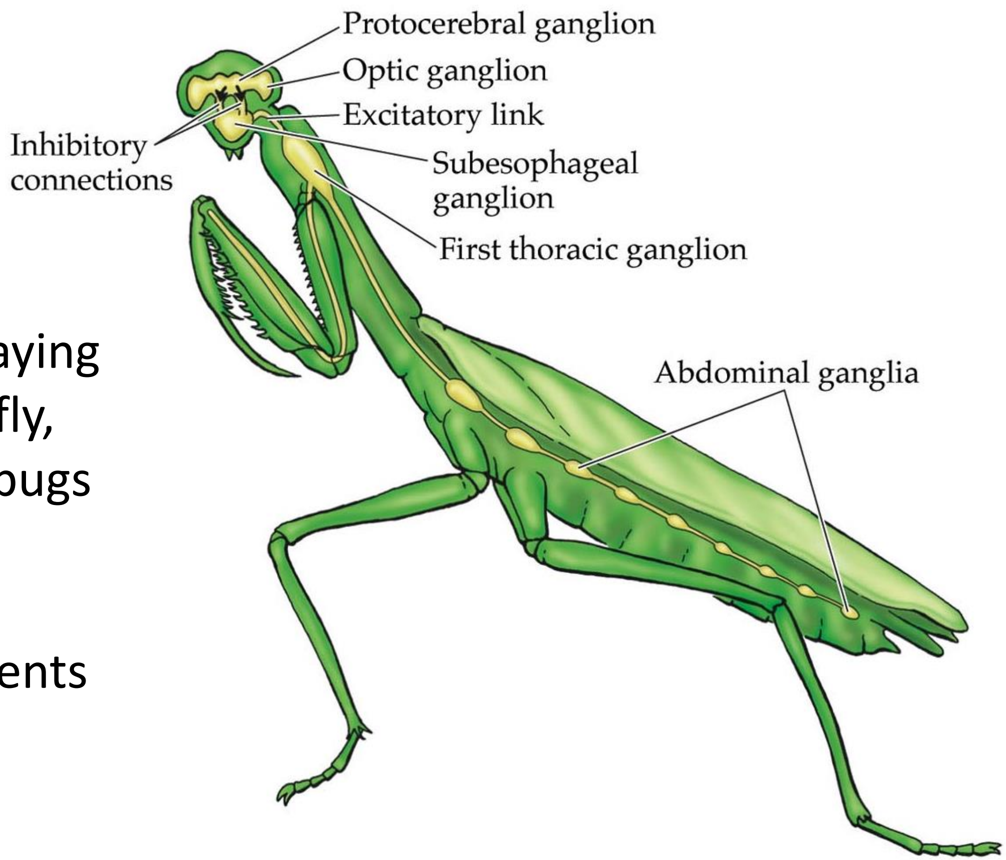
How neural command center organize bahaviour

- Nervous system is endowed with command centers, which include innate releasing mechanisms, central pattern generators, song control systems, etc.
- A command center consists of any number of interconnected batteries of neurons that are capable of unified decision making
- A single command center is responsible for activating a particular response
- Communication: suppression of competitive signals

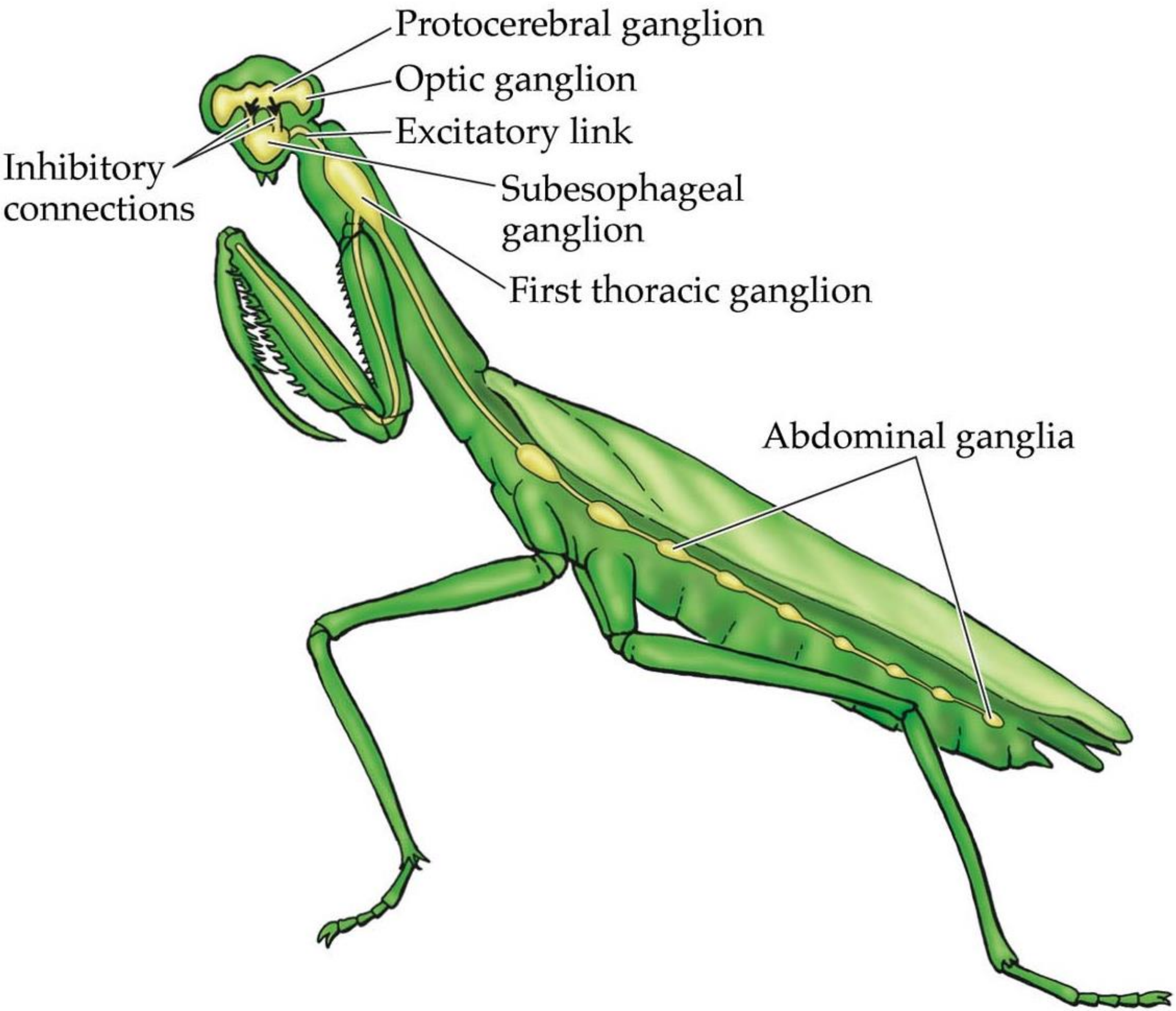
5.2 Nervous system of a praying mantis

- Example: the “groovy” looking praying mantis which can search for mates, fly, sunbath, escape from bats or catch bugs

- Presence of the prey: very rapid, accurate, powerful grasping movements with its front pair of legs

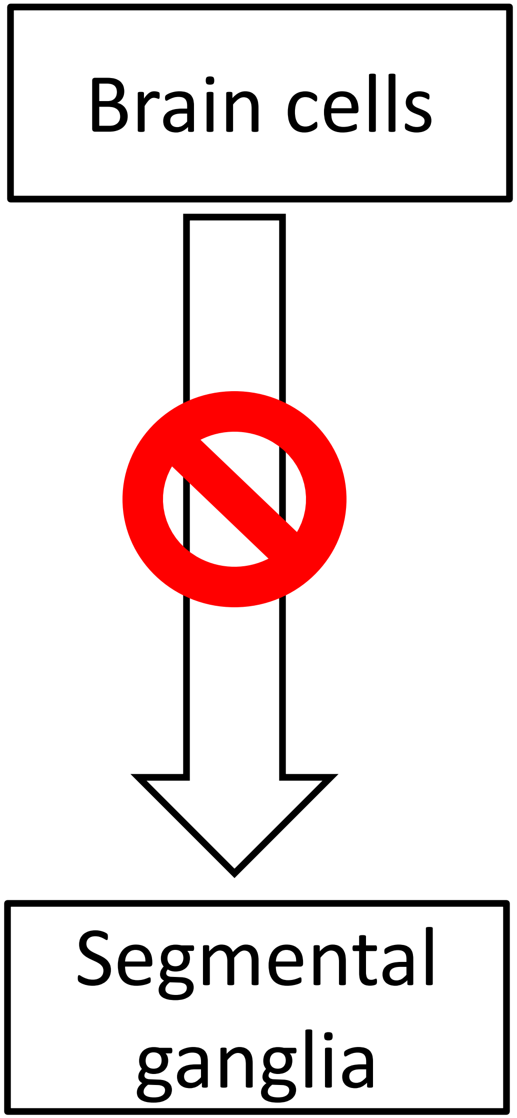


5.2 Nervous system of a praying mantis



- **The control of muscles in each of the insect's segments is the responsibility of that segment's ganglion**

5.2 Nervous system of a praying mantis



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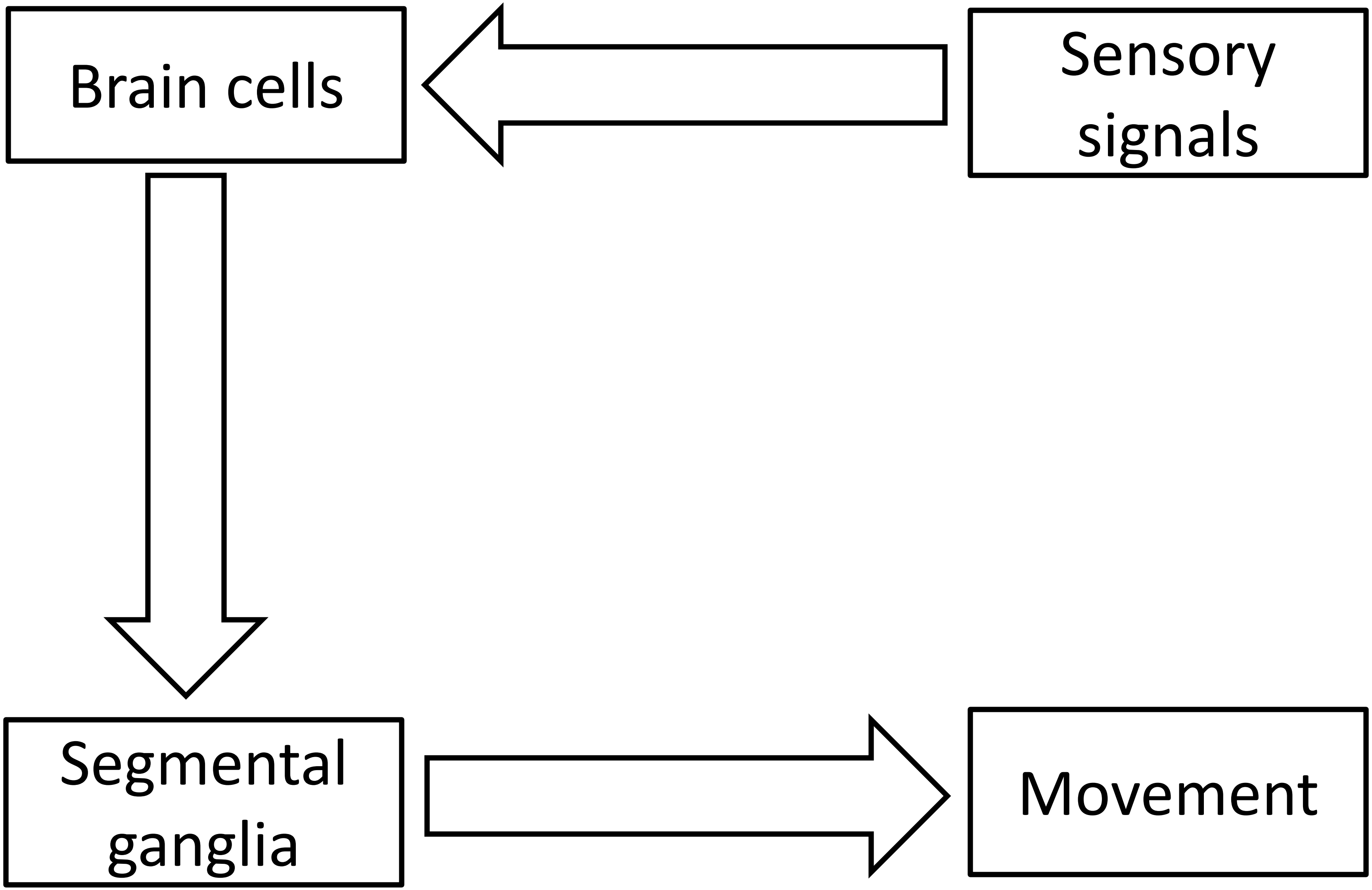
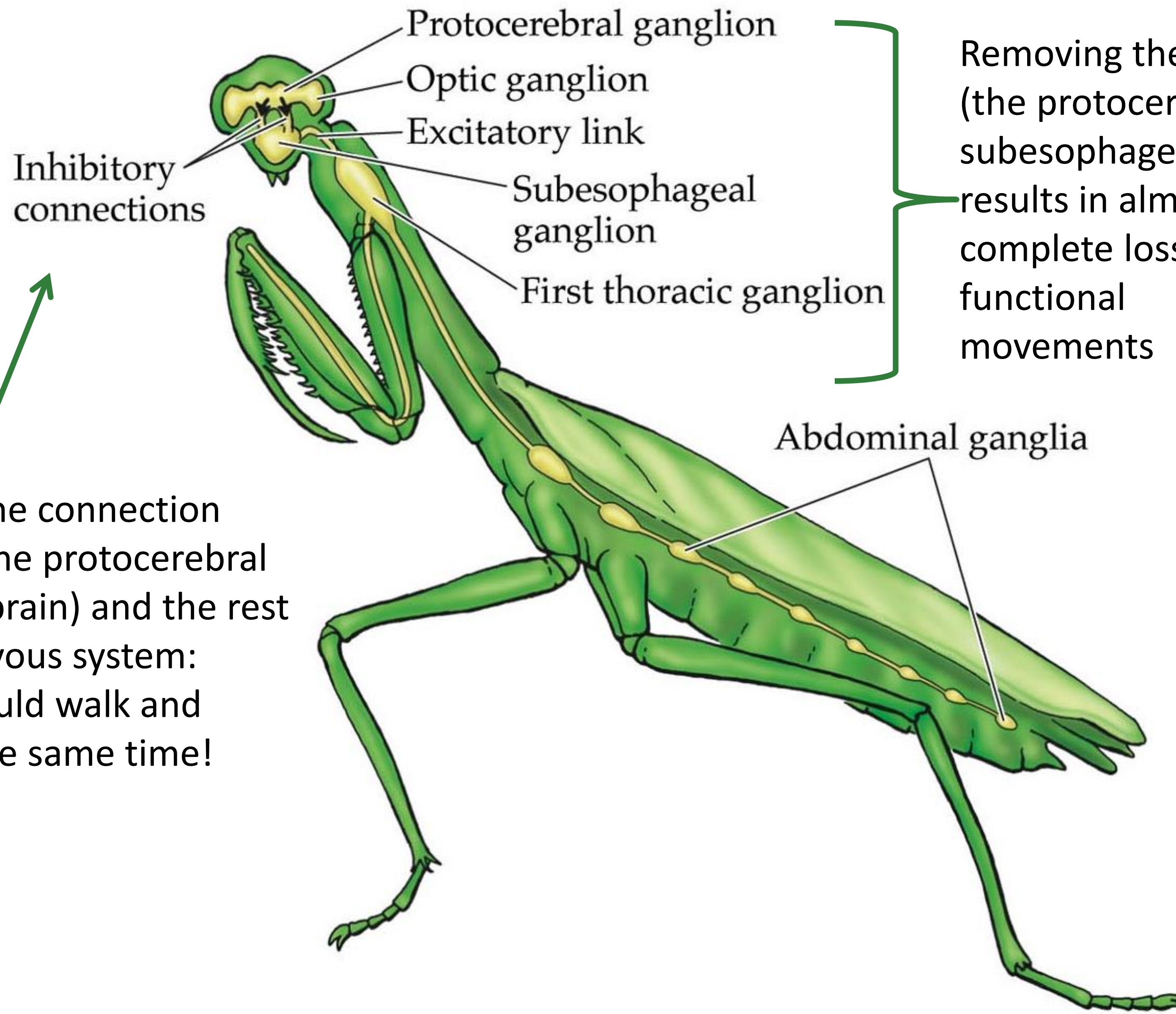
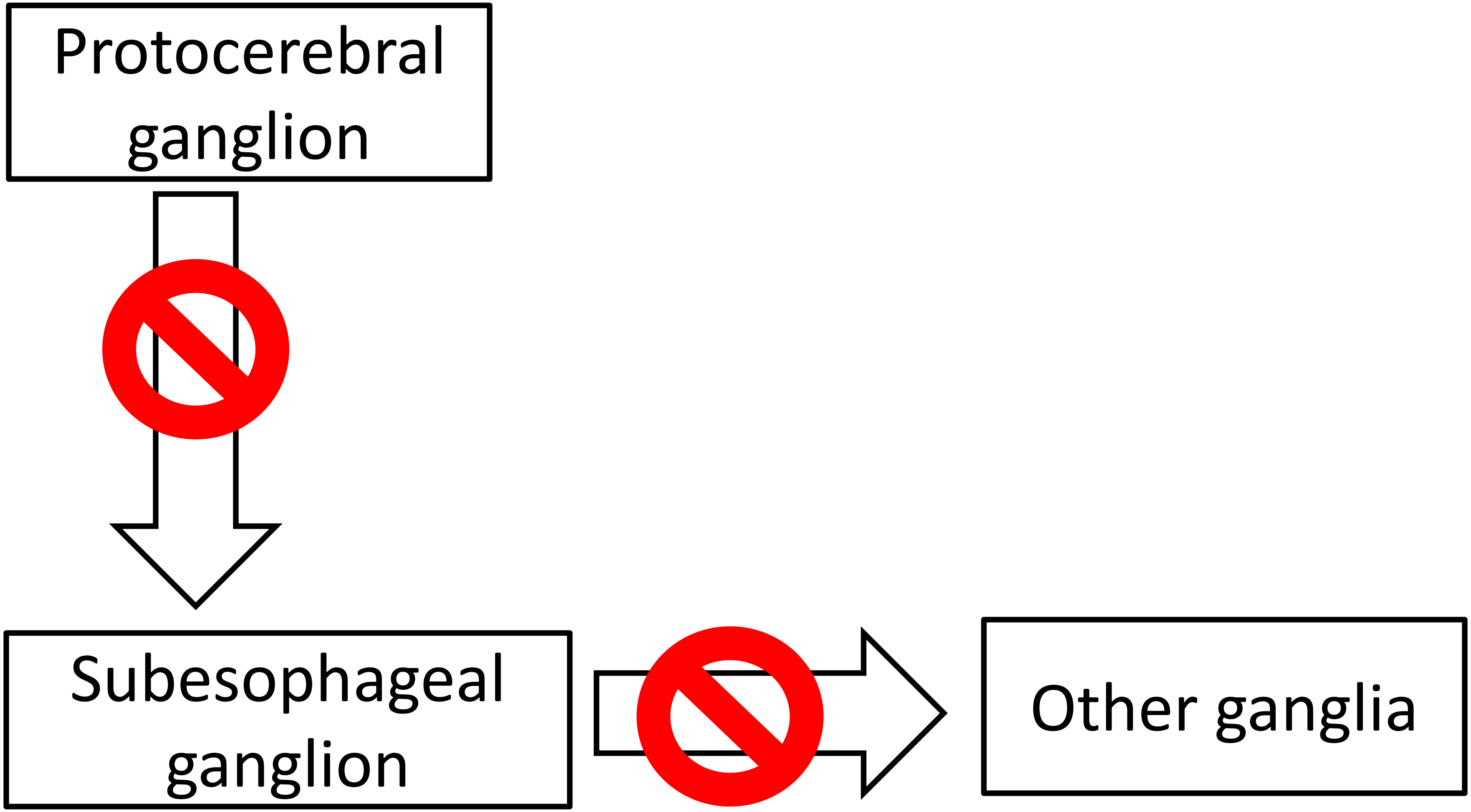


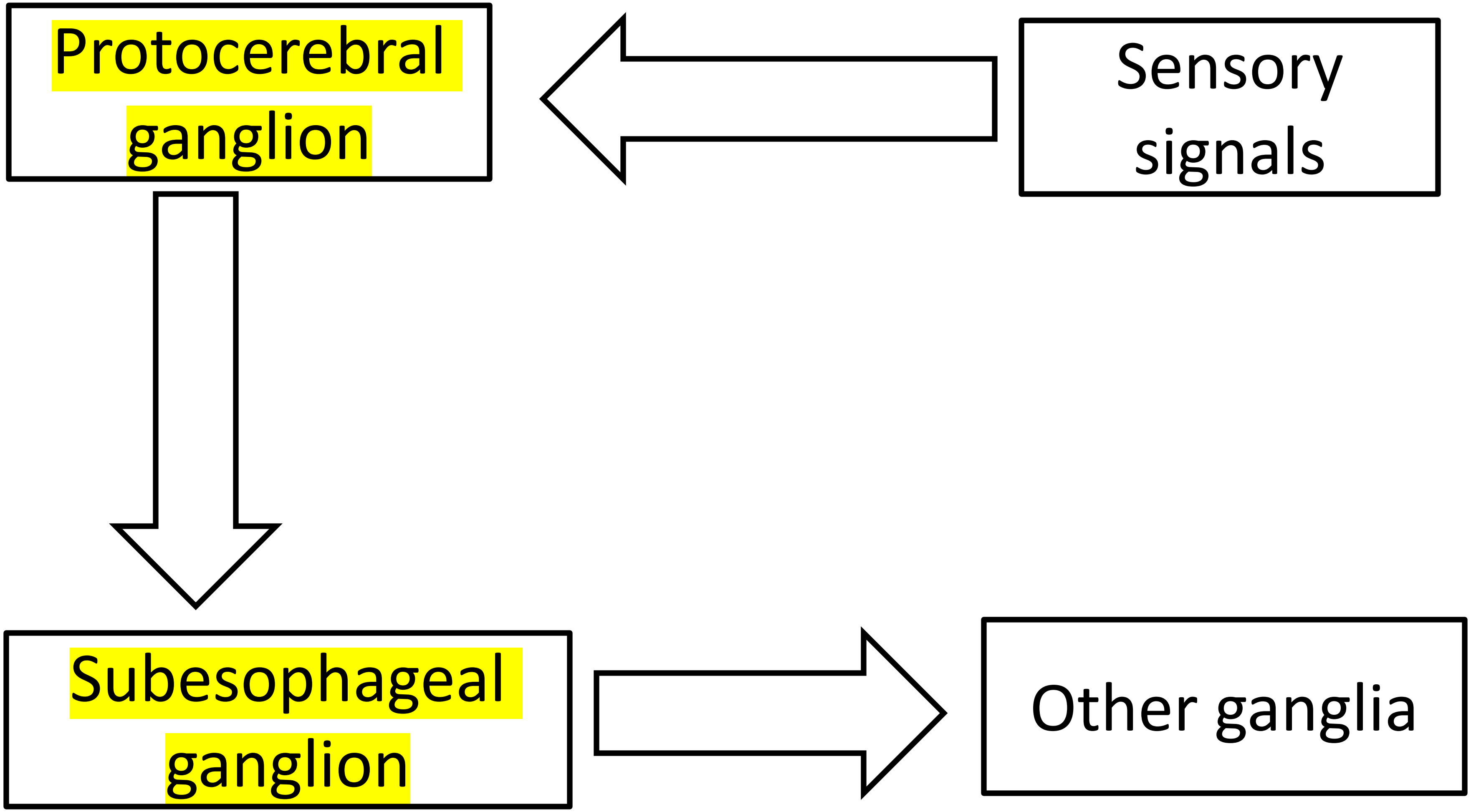


Removing the whole head (the protocerebral and subesophageal ganglia) results in almost complete loss of functional movements

Severing the connection between the protocerebral ganglion (brain) and the rest of the nervous system: mantis would walk and grasp at the same time!


Protocerebral ganglion
Subesophageal ganglion
Other ganglia

5.2 Nervous system of a praying mantis



- Sometimes a decapitated adult male mantis swings its body sideways in a circle while its abdomen is twisting around and down

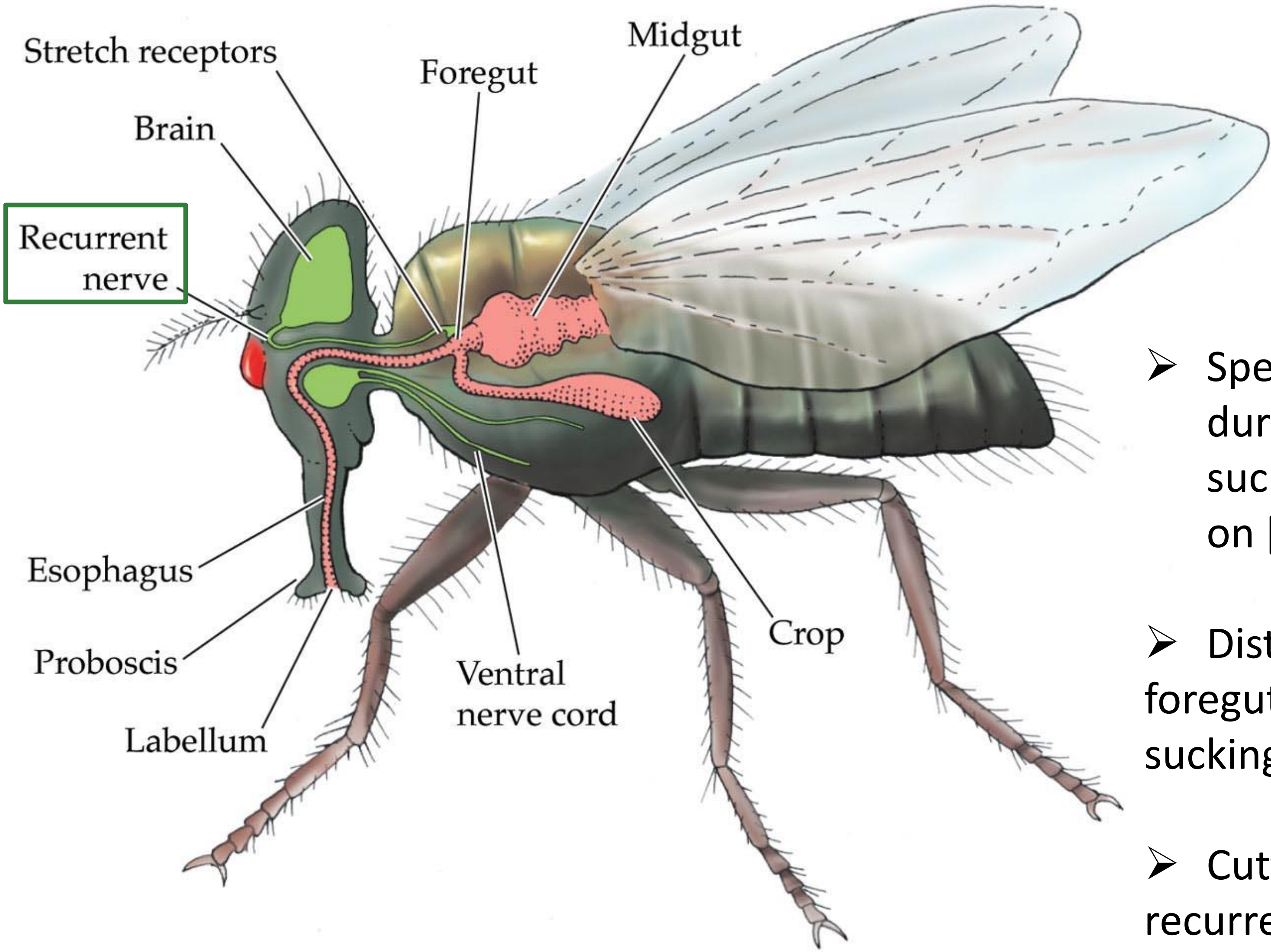
- These movements are normally blocked by signals coming from the protocerebral ganglion

- What would that behavior serve?

5.3 A no-brainer

- Sometimes the male loses his head over a female, when she grabs him and consumes him, head first

5.4 Nervous system and digestive system of a blowfly



- ➢ Speed and duration of sucking depend on [sugar] conc.
- ➢ Distension of the foregut stops sucking. How?
- ➢ Cutting the recurrent nerve results in which behaviour?

What if the hierarchical ordering of command centers has to change in order to meet the demands of the changing environment?

- The hierarchical organization between the different command centers are dynamic so that animals can change their behavior according to different environmental circumstances
- Example: *Teleogryllus* crickets usually hide during the day and search for mates during the night
- Therefore, the inhibitory influence on the command centers changes cyclically every 24hrs

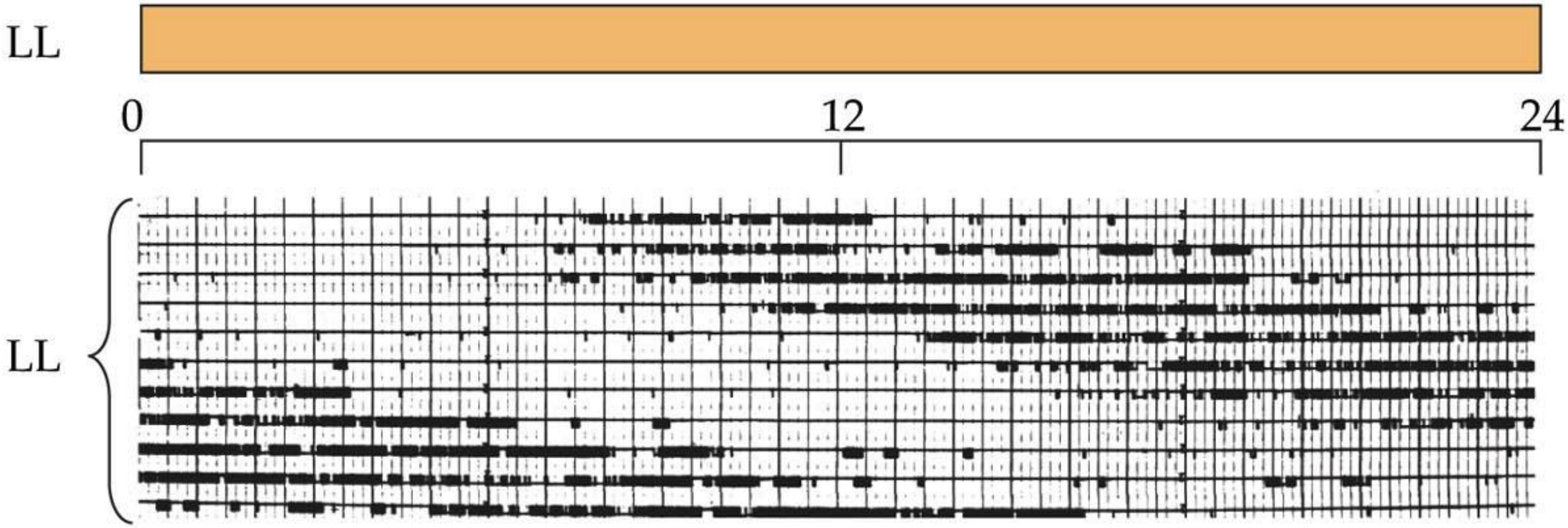
Behavioural schedules-What regulate these changes?

- Two major competing theories:

1. Built-in timing mechanisms **independently of any environmental cues**
2. Timing mechanisms that strictly **depend on environmental cues**

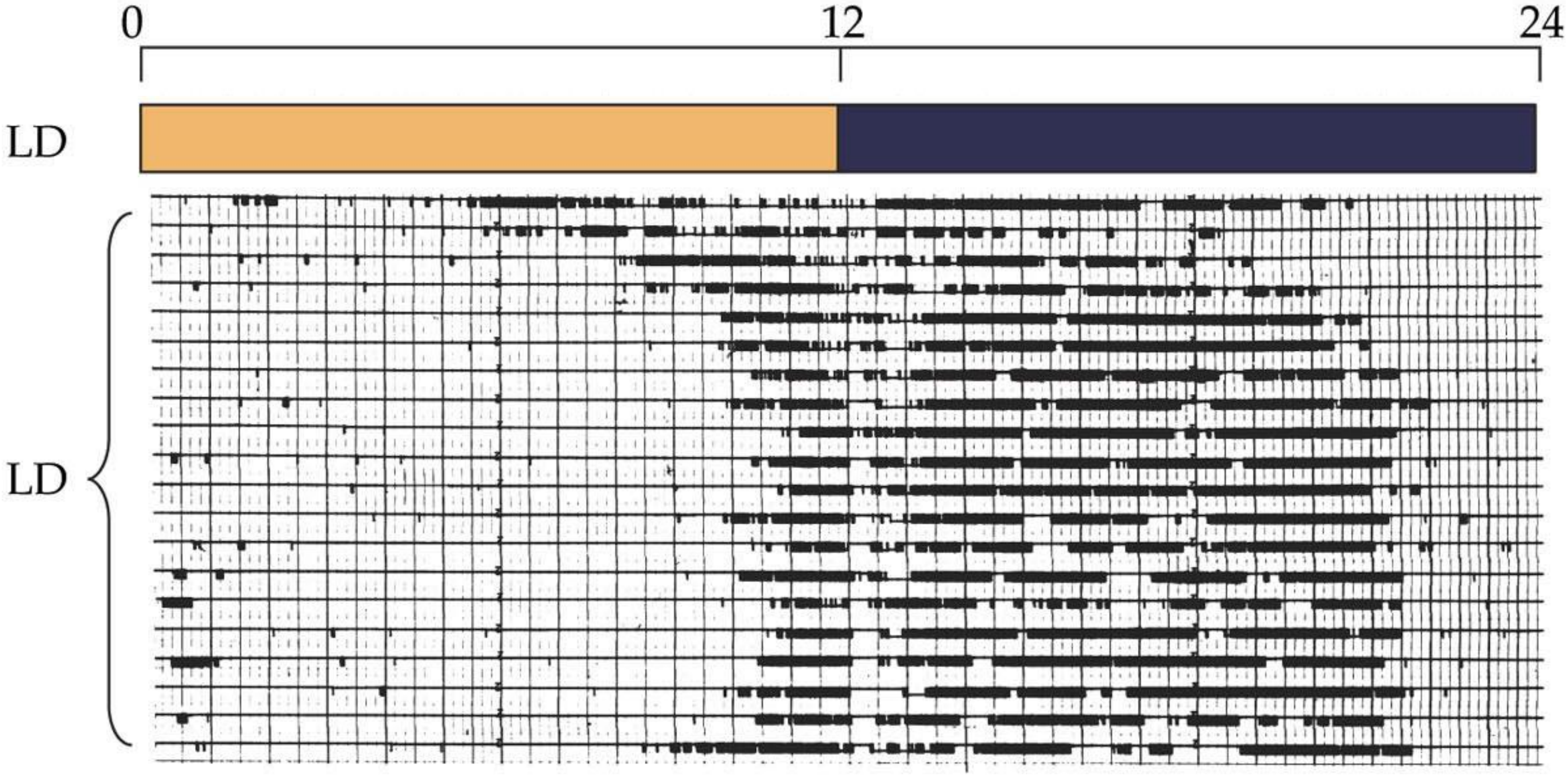
- What experiments can you suggest to test the above mentioned timing mechanisms?
- Alternating animals between constant and changing environmental conditions

5.6 Circadian rhythms in cricket calling behavior



- Calling starts later every day
- Activity that does not match to environmental cues: **free-running cycle**
- Cyclical pattern of cricket calling caused in part by environment-independent **internal circadian rhythm**

5.6 Circadian rhythms in cricket calling behavior



- Calling 2h before the lights go off, thus anticipating "nightfall"
- Cycle that match the natural one (synchronised with dusk)
- **Entrained (reset)** in reference to certain stimuli

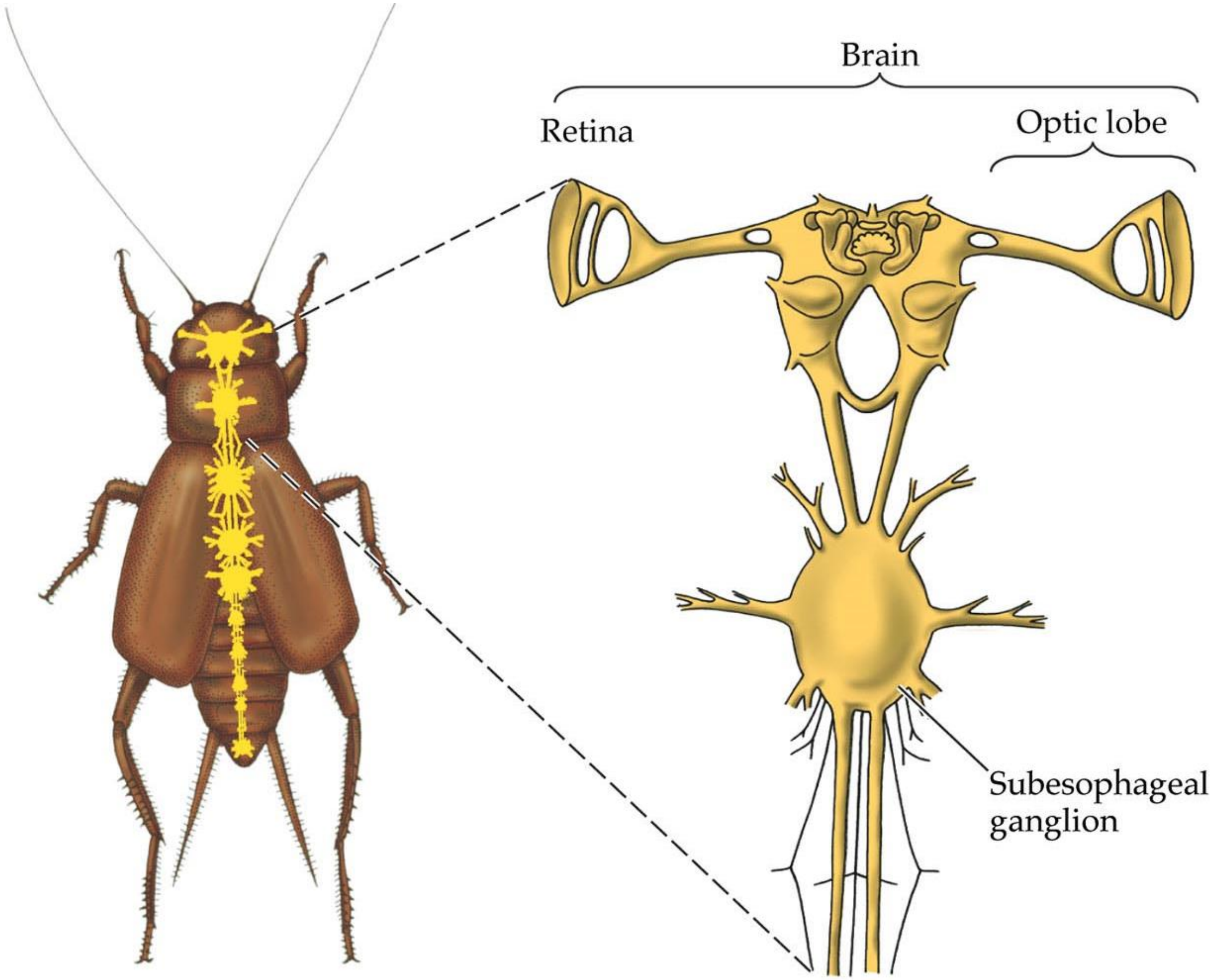
Complete control system for cricket calling has **both environment-dependent and environment-independent timer (<u>biological clock</u>), set on a cycle that is not exactly 24h long, and an environment-activated device that synchronized the clock with local light conditions**

Any suggestions?

Cutting the connections between various components and predict their possible roles

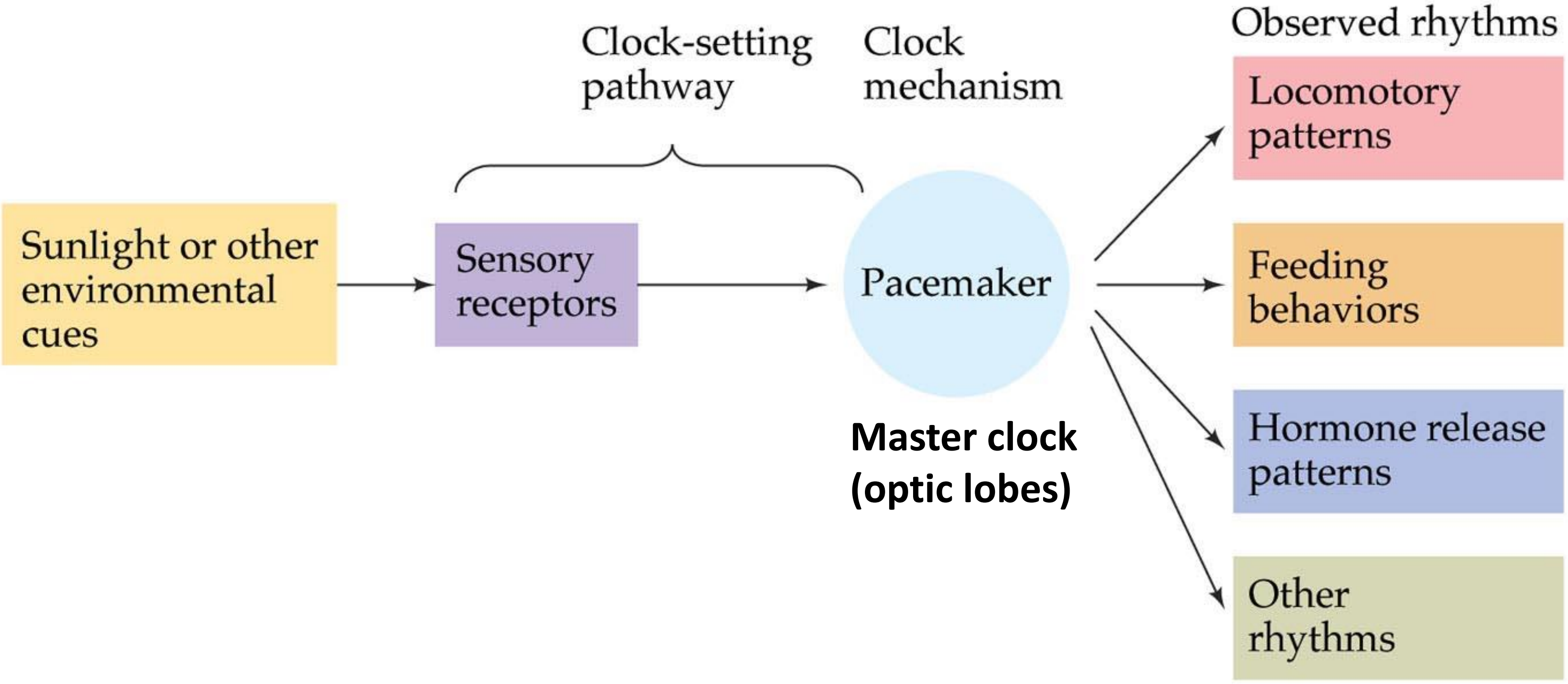
5.7 The cricket nervous system

- Visual information from the eye is relayed to the optical lobes



- Cutting of optic nerve (from eyes to optic lobes): free-running cycle
- Disconnection of both optic lobes: loses of the ability to maintain a circadian rhythm

5.8 A master clock may regulate mechanisms controlling circadian rhythms within individuals



Master clock (optic lobes)

- In mammals and some invertebrates, the hypothalamus (more specifically the suprachiasmatic nucleus: SCN) plays a major role in setting the biological clock.
- This pacemaker/clock setting activity by the SCN can be shown by surgically removing these nuclei: arrhythmicity in hormone secretion, feeding and locomotion.
- Transplanting fetal SCN in these arrhythmic animals returns the circadian rhythm

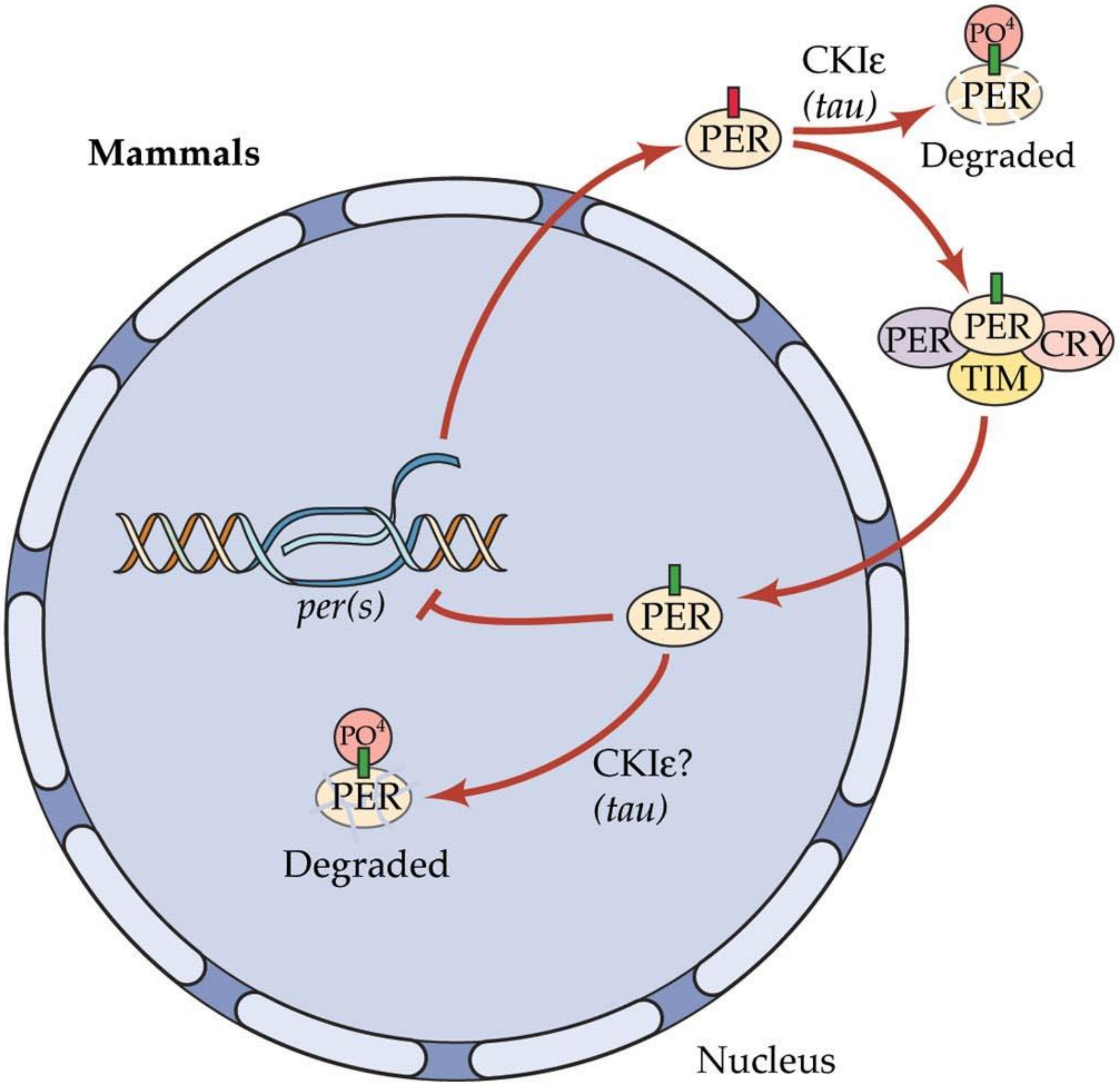
- A gene named *per* codes for PER (period) protein is usually up and down regulated in a cyclic manner every 24 hrs
- Mutation in *per* gene causes arrhythmia in the circadian cycle
- The expression of this gene depends on the age and kind of the animal
- Young nursing bees that stay in the hive taking care of the eggs and larvae as opposed to foraging bees that have to leave the hive to collect pollen and nectar during daylight

1. *per* coding for PER: Gradually builds-up inside and outside nucleus

2. *tau* (vs *dbt* in flies) coding for CKIε (Casein Kinase I epsilon): Breaking down of PER

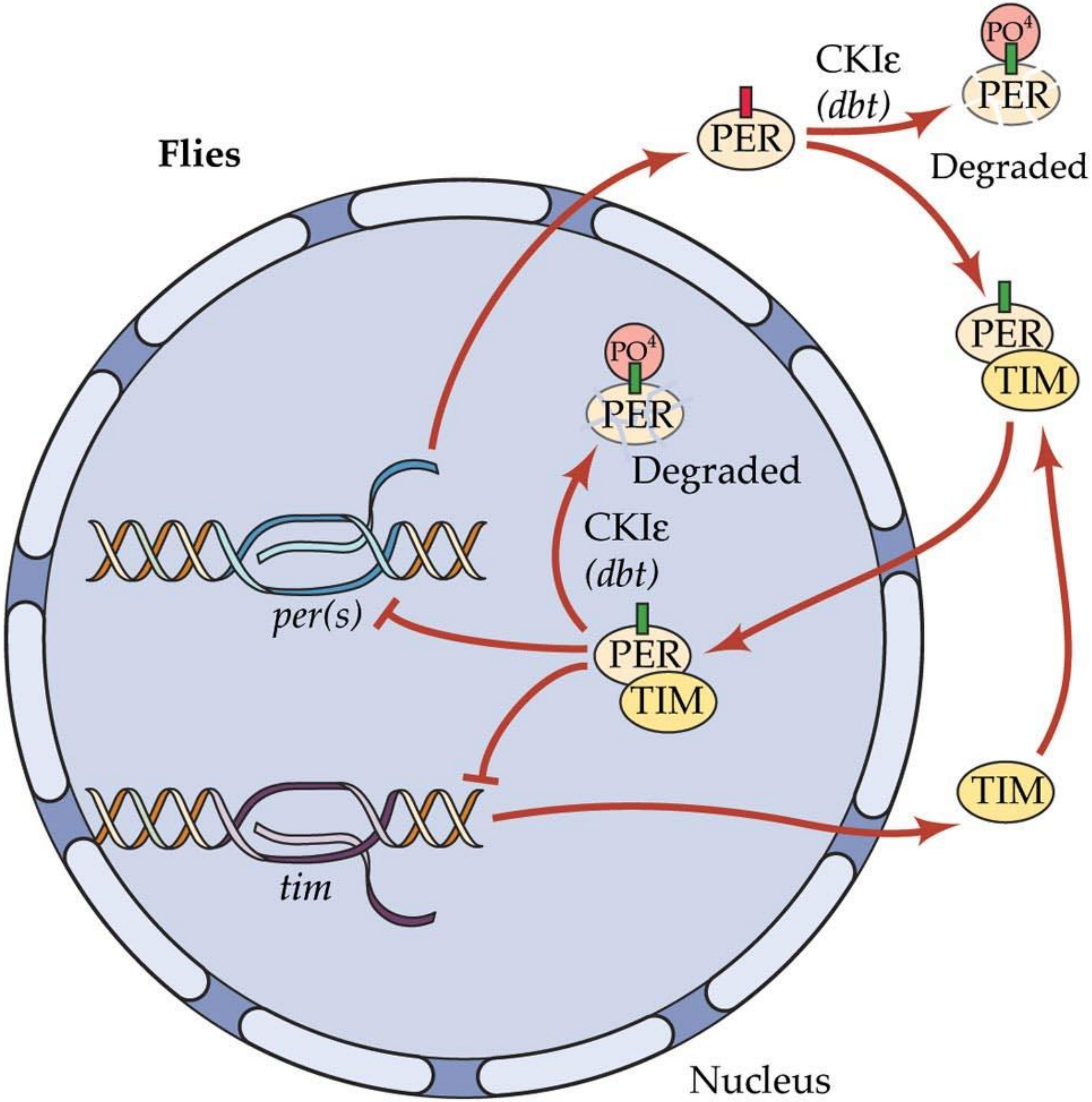
3. *tim* (timeless) coding for TIM: binding to PER to prevent breaking down by CKIε

5.9 The genetics of biological clocks in mammals and fruit flies (Part 1)

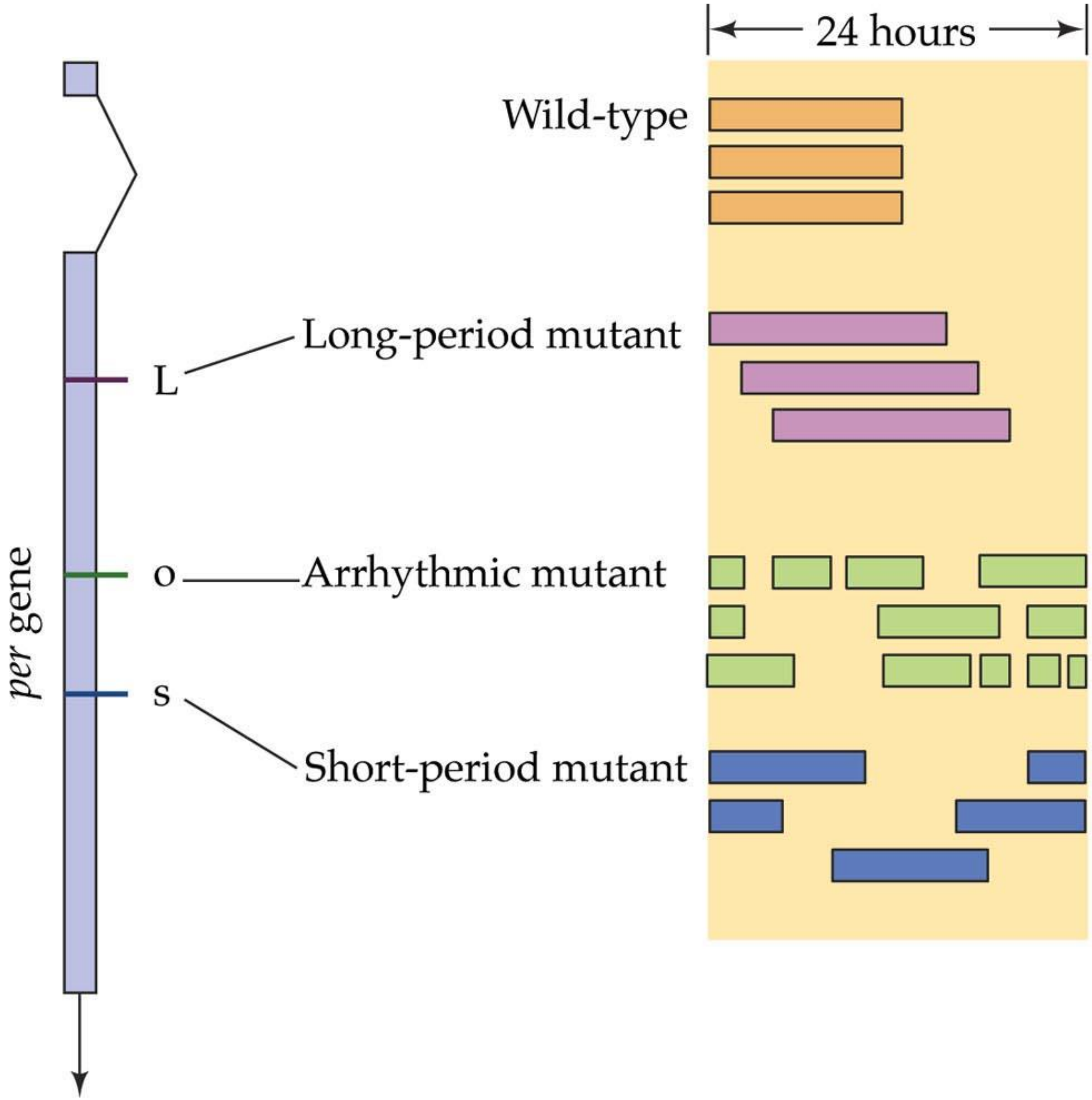


ANIMAL BEHAVIOR, Eighth Edition, Figure 5.9 (Part 1)

5.9 The genetics of biological clocks in mammals and fruit flies (Part 2)



5.10 Mutations of the *per* gene affect the circadian rhythms of fruit flies



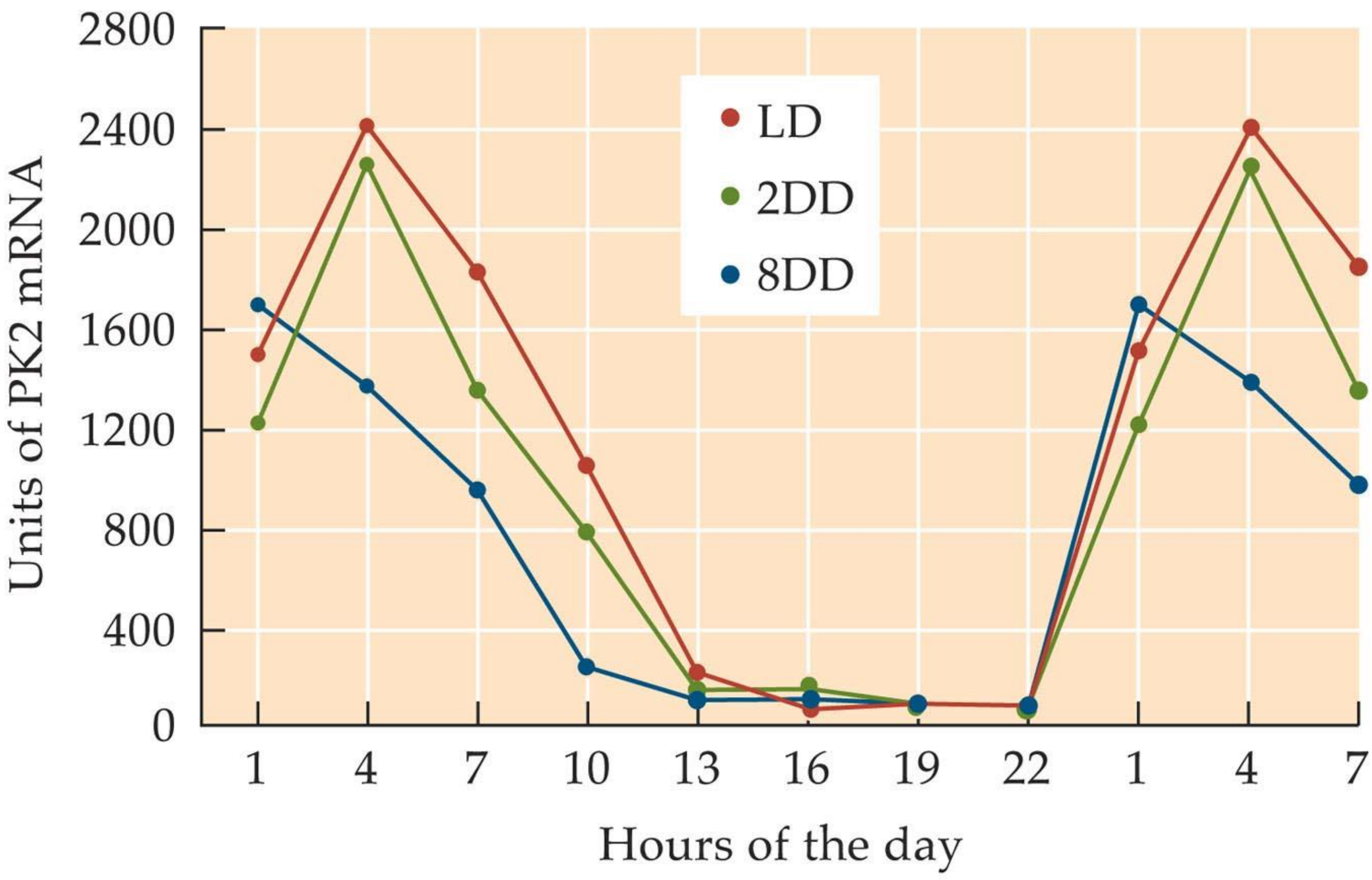
- *Per* gene is expressed in SCN neurons (master clock) with a host of other brain components, thus regulating many different behaviors on a daily schedule. **How?**

- A chemical messenger should be regulated in SCN and released as a signaling molecule on their targets

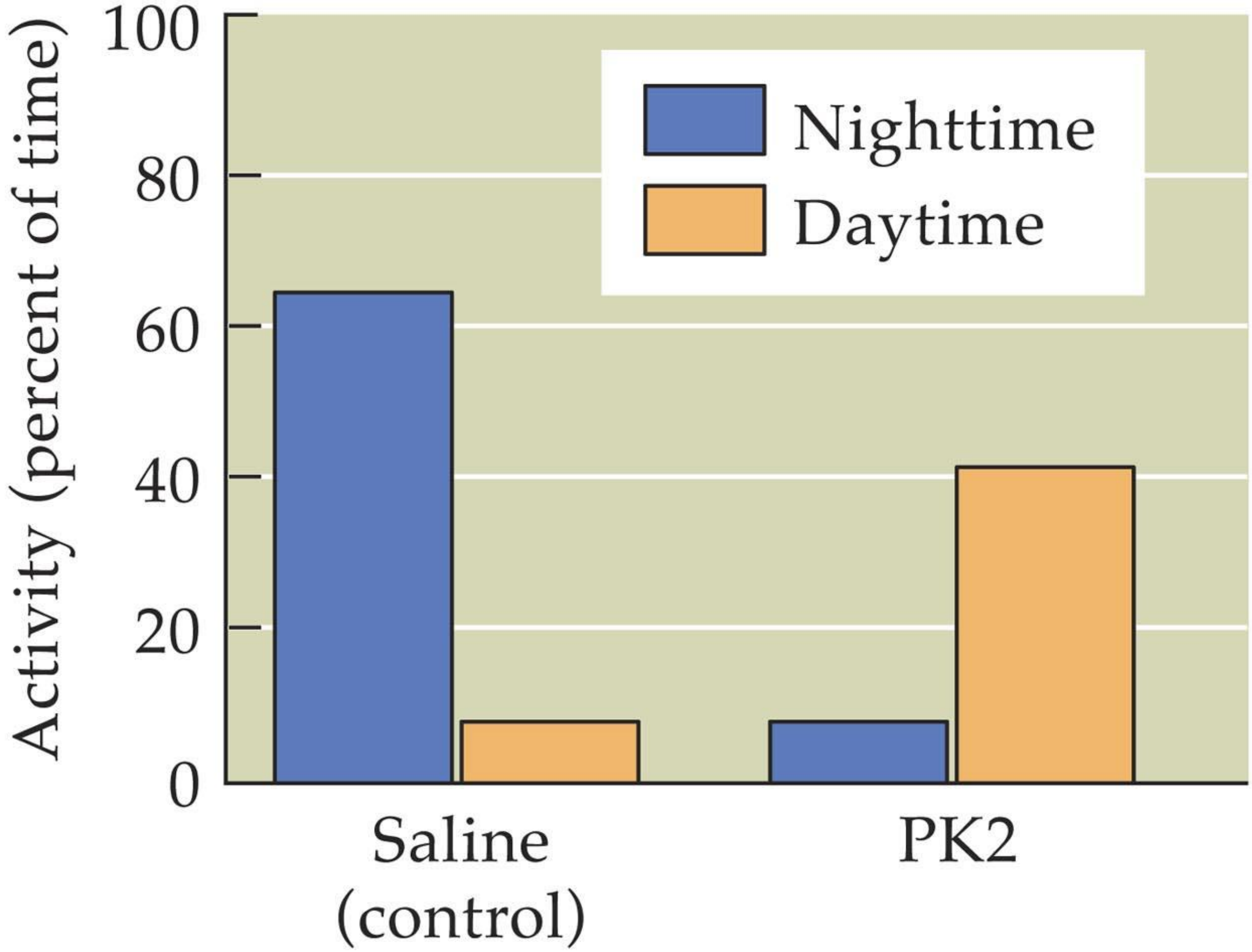
- Target cells express receptors for this protein

- Administration of this chemical experimentally disrupts the regular rhythms

5.11 Expression of the gene that codes for prokineticin 2 in the SCN



5.12 Circadian control of wheel-running by white rats changes when the rats are injected with PK2



- PK2 is the chemical messenger that mammalian SCN uses to communicate with target centers in the brain

- The SCN, in turn, receives information from the retina about the dark-light cycle of the animals’s environment, so it can fine-tune its autoregulated pattern of gene expression

Adaptive value of the clock system

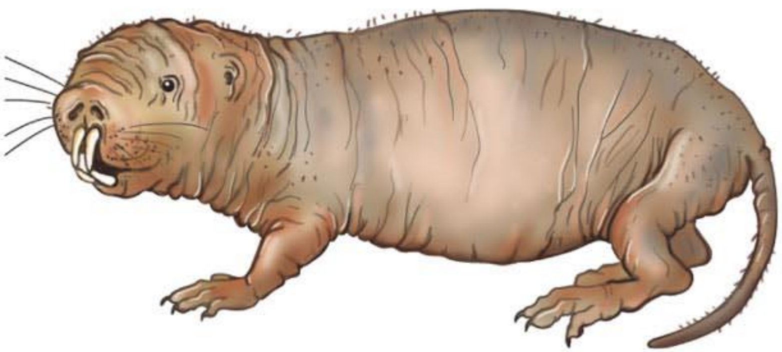
- Environment-independent element:

Alter timing of behavioral and physiological cycles without having to constantly check the environment to see what time it is

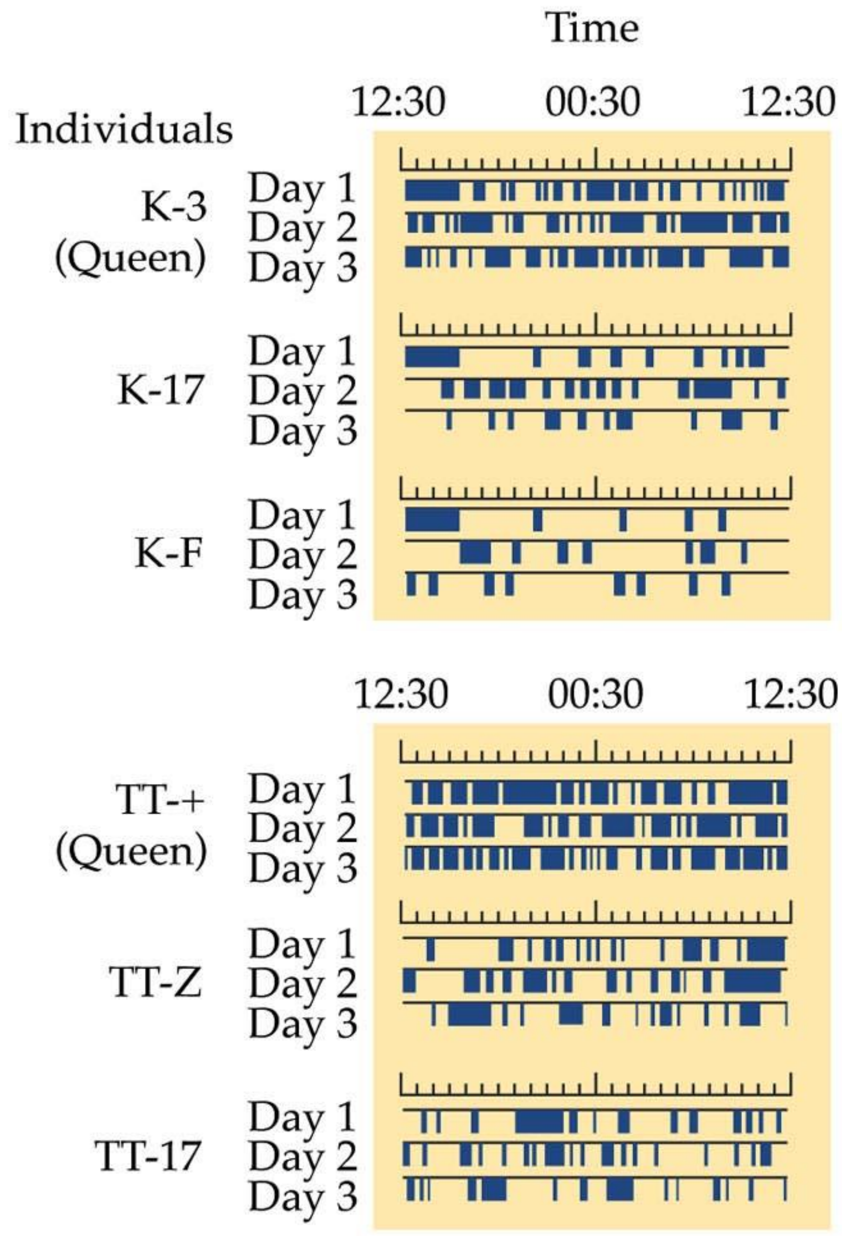
- Environement-dependent element:

Adjust cycles in keeping with local conditions (day length, time zone, etc.)

5.13 Naked mole-rats lack a circadian rhythm



Naked mole-rat



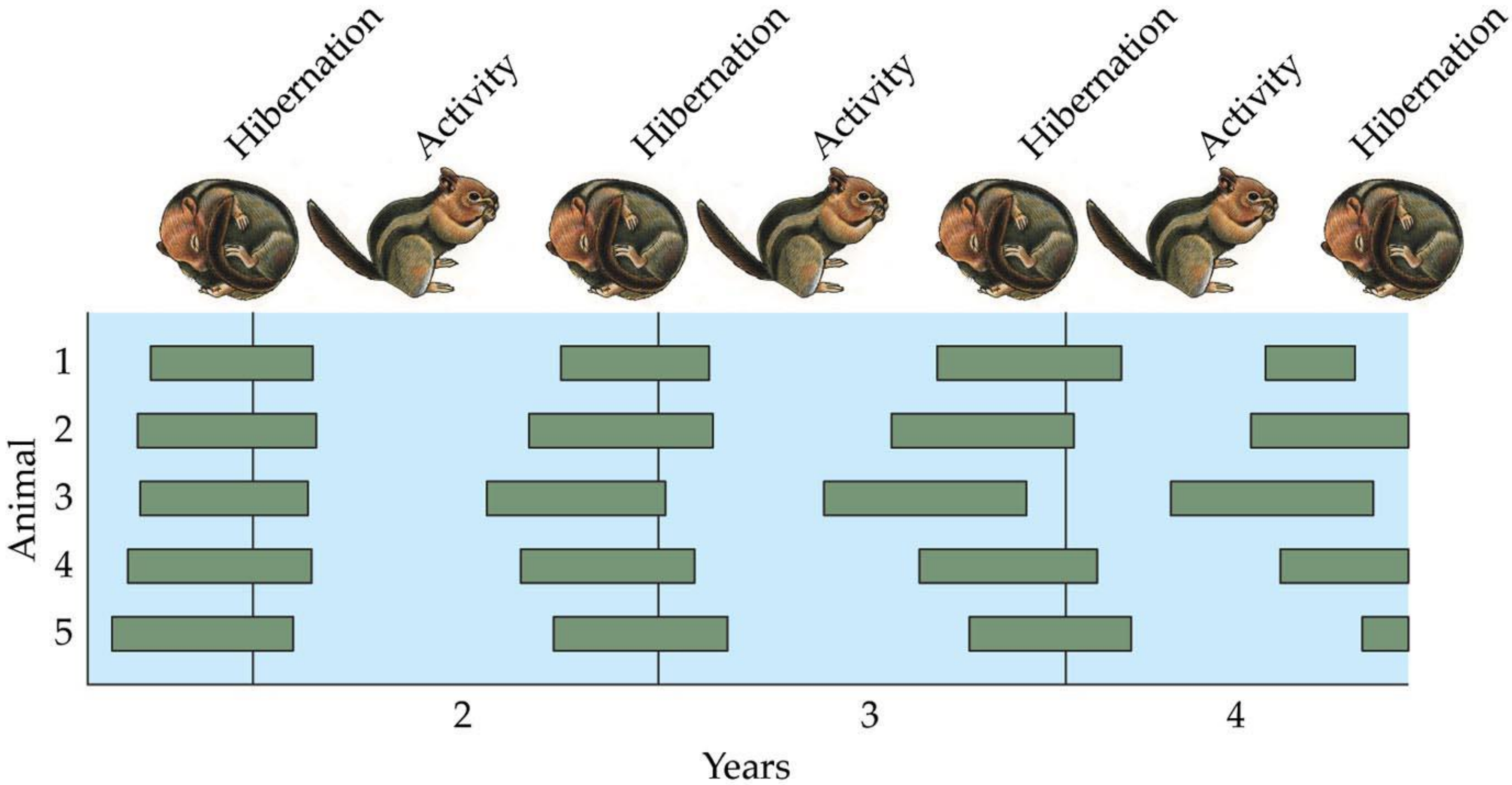
Individuals under constant low light scatter generally brief episodes of activity among longer periods of inactivity, with the pattern changing irregularly from day to day

Long-term cycles of behaviour: circannual rhythm

- Instead of the rhythm running of a 24hrs basis, this rhythm runs approximately for 365 days cycles **(circannual rhythm)**
- Needless to say, this is more difficult to study than circadian cycles
- Animals would have to kept in constant environmental conditions (light, food, temperature, etc…) for at least two years after being removed from their natural environment

5.14 Circannual rhythm of the golden-mantled ground squirrel

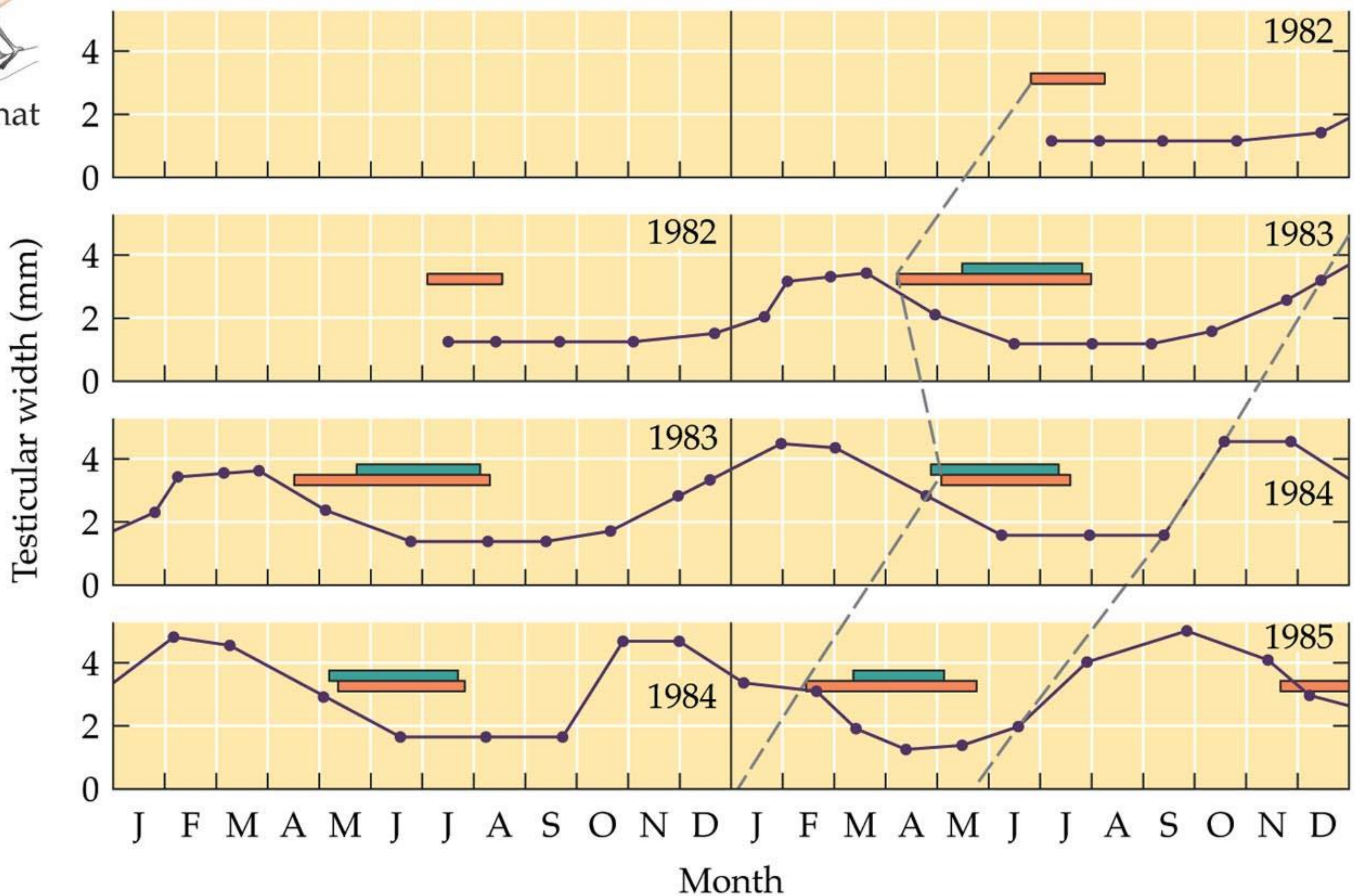
- Constant darkness, constant temperature, abundance of food



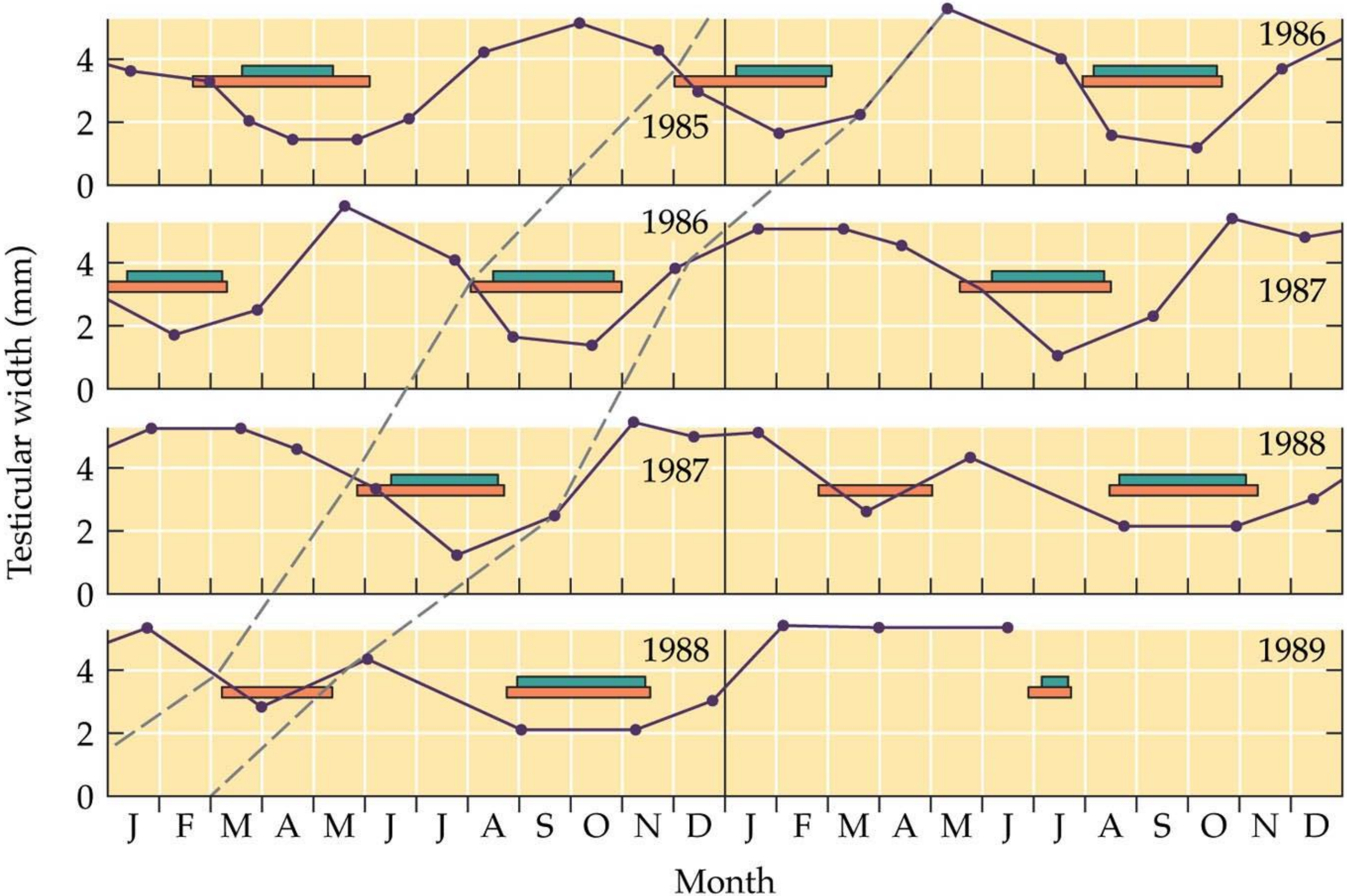
ANIMAL BEHAVIOR, Eighth Edition, Figure 5.14

5.15 Circannual rhythm in a stonechat (Part 1)

- Constant temperature and photoperiod

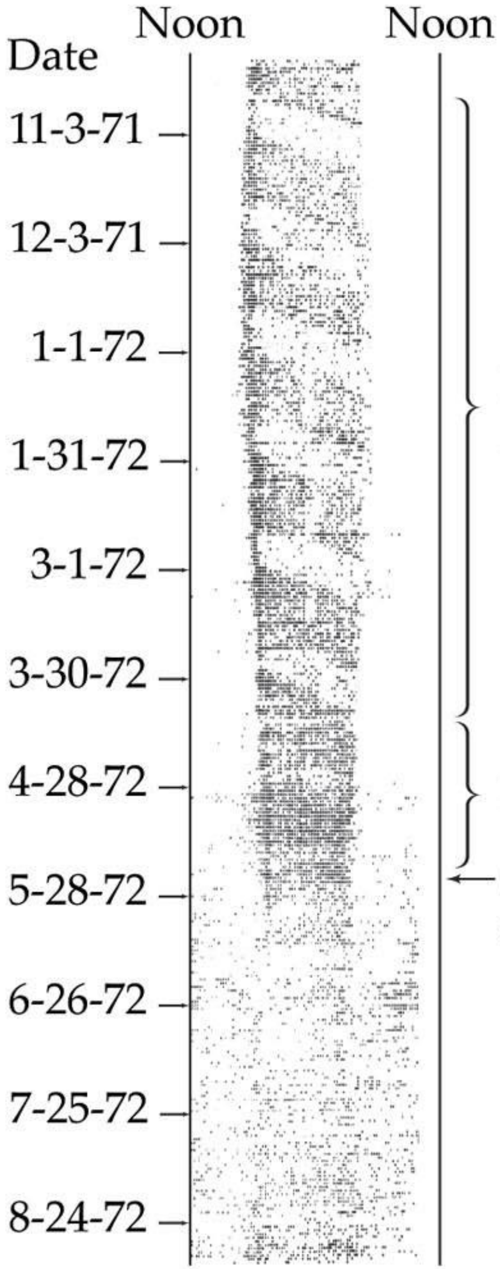


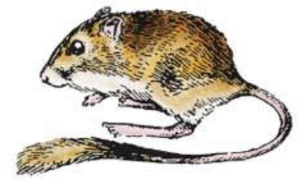
5.15 Circannual rhythm in a stonechat (Part 2)



- Long-term cycle of testicular growth and decline, as well as regular feather molts
- The cycle was not exactly 12M long, so the timing shifted over the years

5.16 Lunar cycle of banner-tailed kangaroo rats





Banner-tailed kangaroo rat

Animals active at night only when the moon was not shining