The Control of Behavior: Neural Mechanisms

Neural systems of reflexive behaviors

Konrad Lorenz: The **Fixed Action Pattern** (FAP)

- Graylag goose & egg rolling
- Herring gull & feeding

FAPs appear to be completely innate:

- Reproductive behaviors
  - Pheromone guided flight
  - Courtship dances/rituals
  - Copulation
- Escape responses
- Sensory and Motor Reflexes

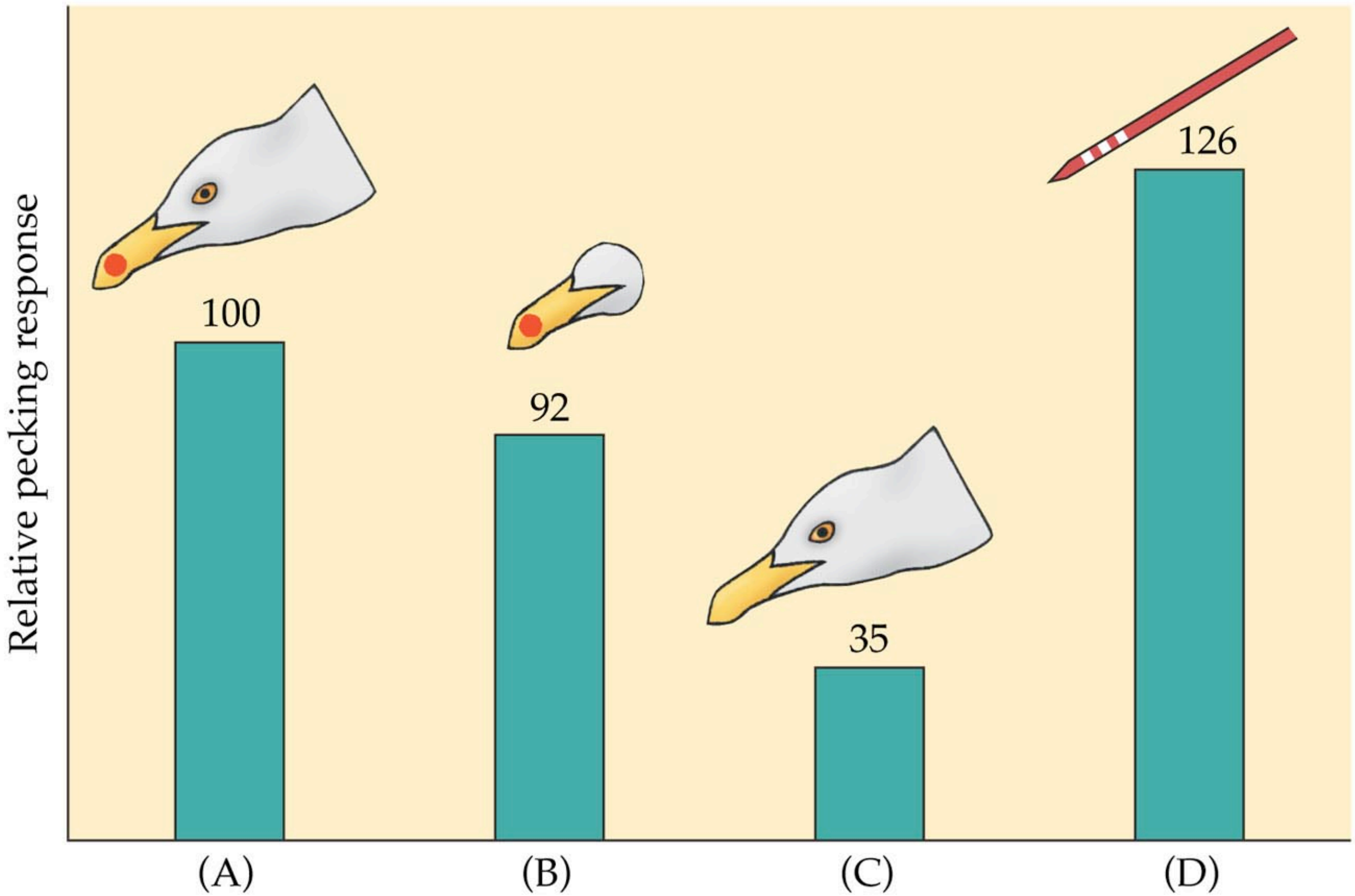
Advantage:

- Does not have to be learned.
- Does not change (works the first time every time)

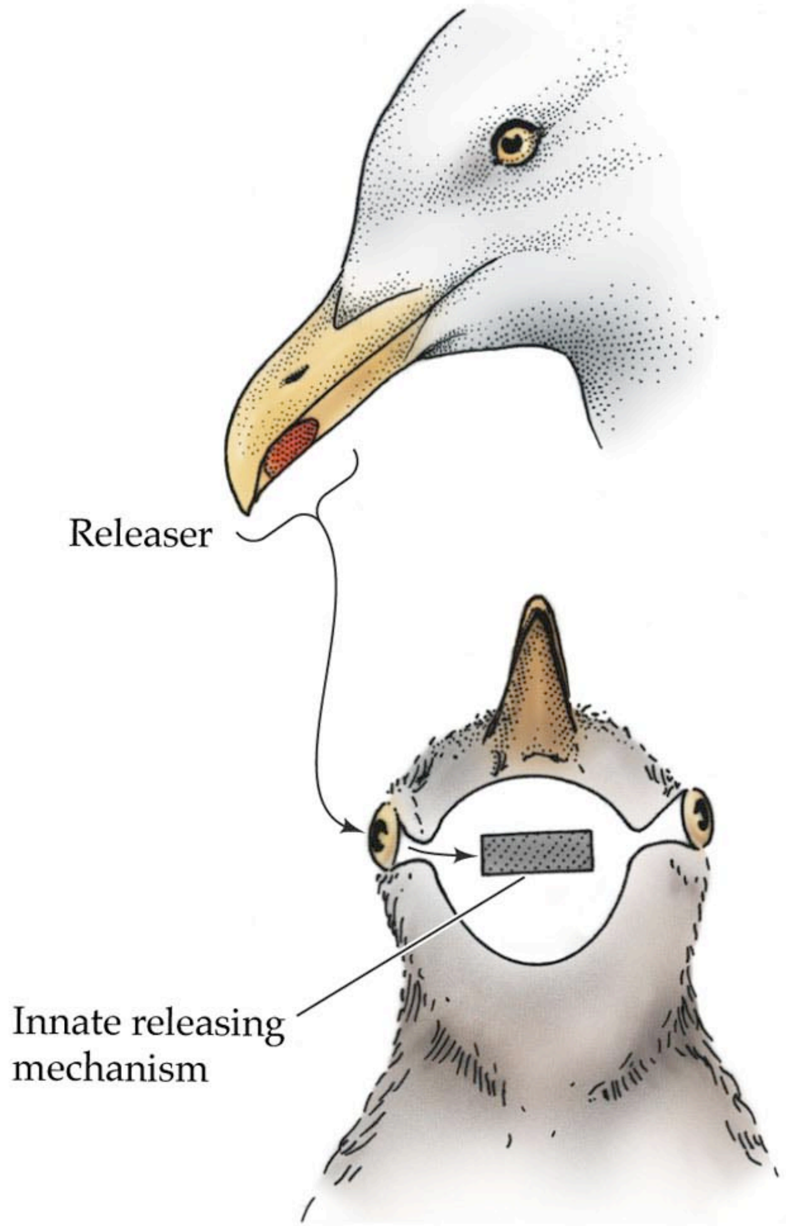
Disadvantage: Mimicry & Parasitism

- Cuckoo, a nest parasite
- Rover beetle nest parasite
- Orchid female insect “decoys” attract unsuspecting males
- Predatory firefly females “mimic” the call of other species females and lure males to “dinner”

4.5 Effectiveness of different visual stimuli in triggering the begging behavior of herring gull chicks



4.6 Instinct theory



Moths and Bats

- Classic example of neural control of behavior
  - Fact – Bats eat bugs in flight
- Selection should favor anti-bat behavior in a night flying insect.
- How do moths avoid bats?

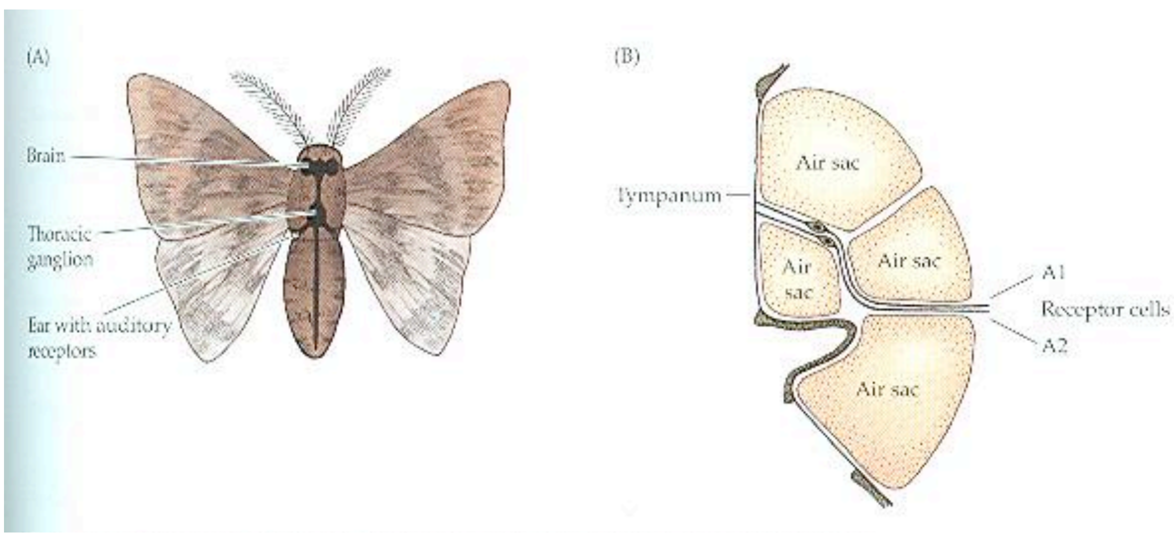
Bat Feeding

- Bats use sonar to detect prey
- High frequency ultrasonic pulses
- Bat feeding buzzes announce their presence to those that can detect high frequency sounds.

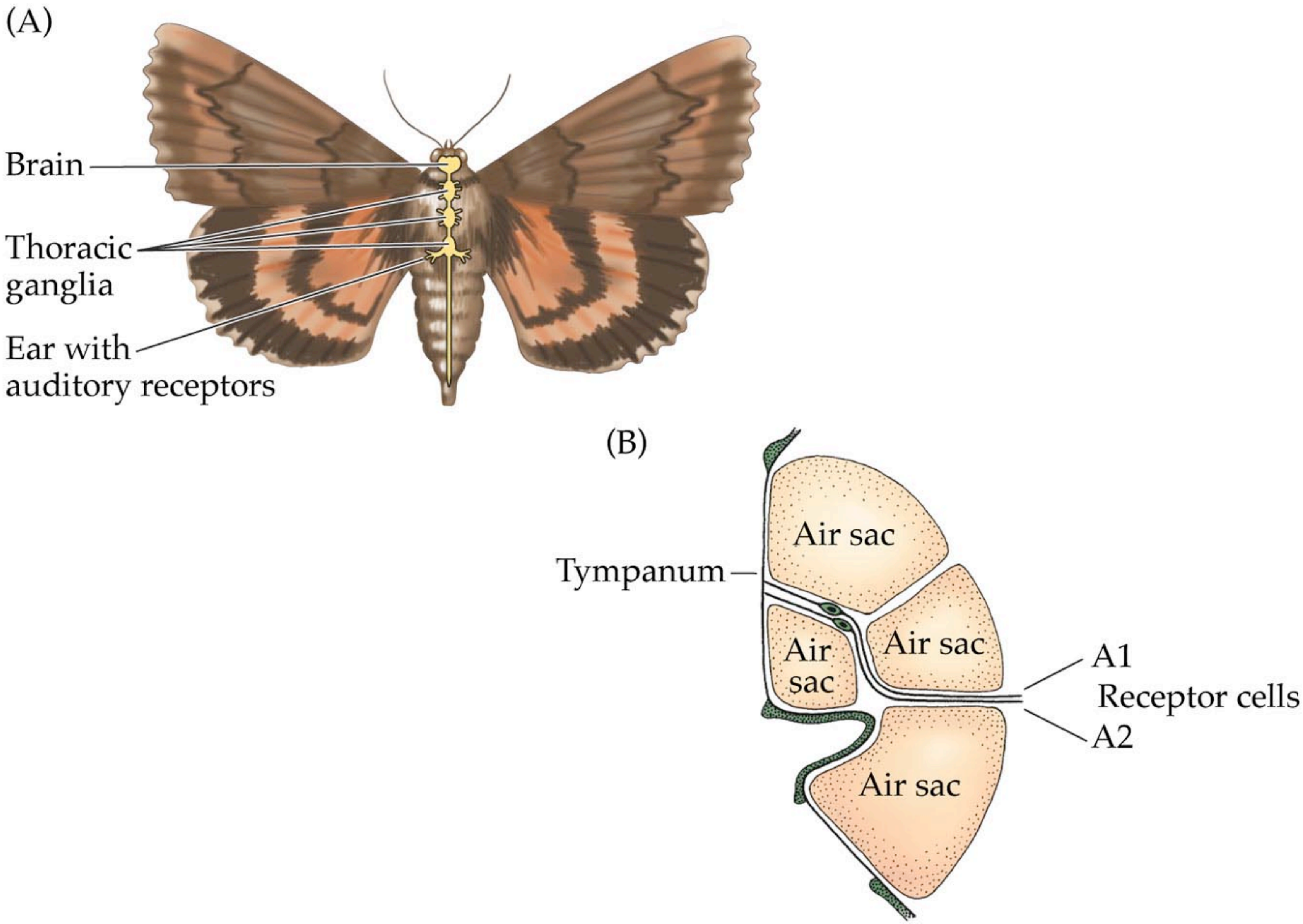
Moth Hearing

Moths have "ears" on the sides of the thorax

These structures are sensitive to high frequency sounds and deaf to others.



4.11 Noctuid moth ears



Basic Neurophysiology

- Neuron – nerve cell
- Sensory neuron – carry information from sensory organ to the central nervous system (CNS)
- CNS – brain and spinal cord
  - Most complex processing of information is done here
- Motor neuron – carry information from CNS to muscle groups

Action Potential

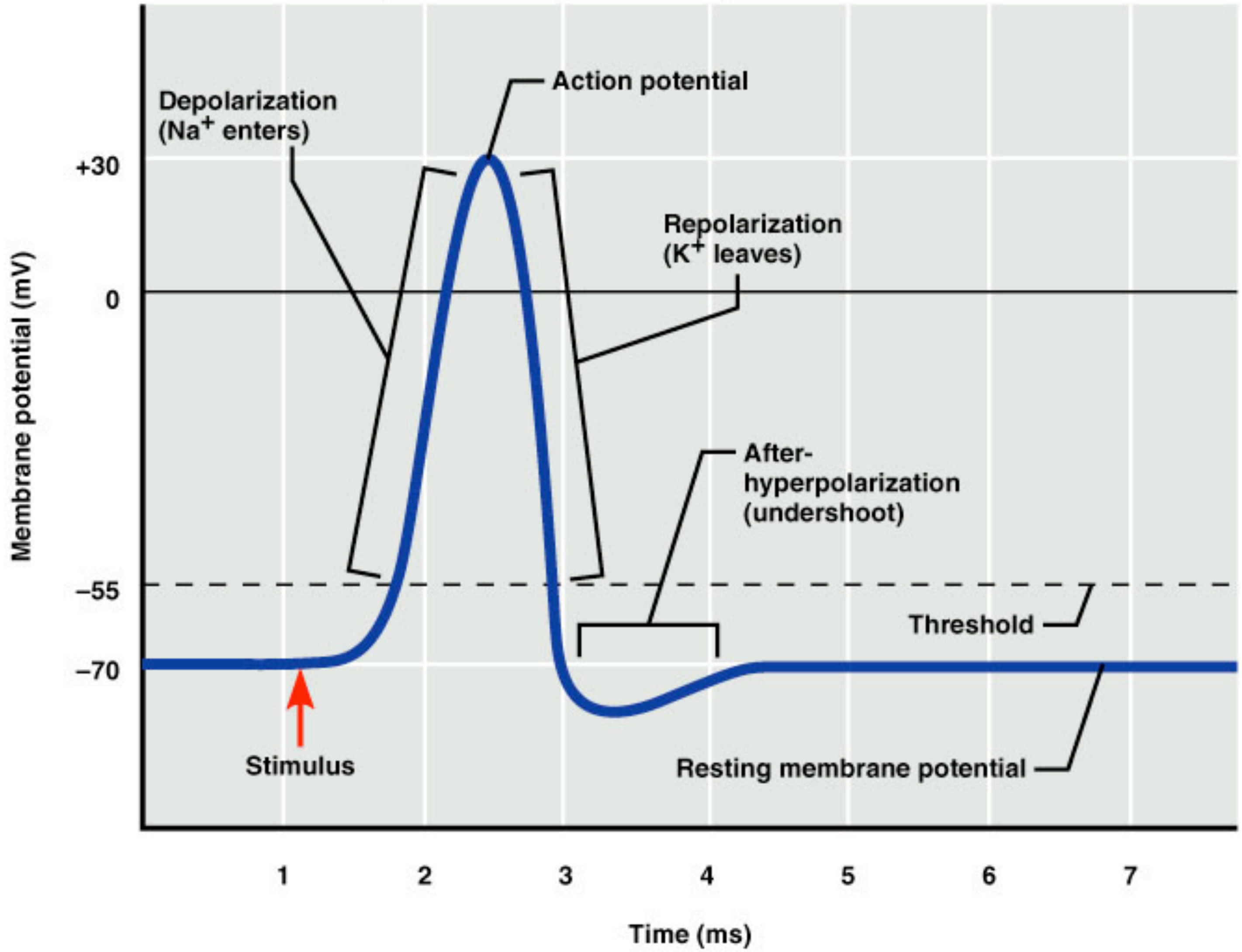
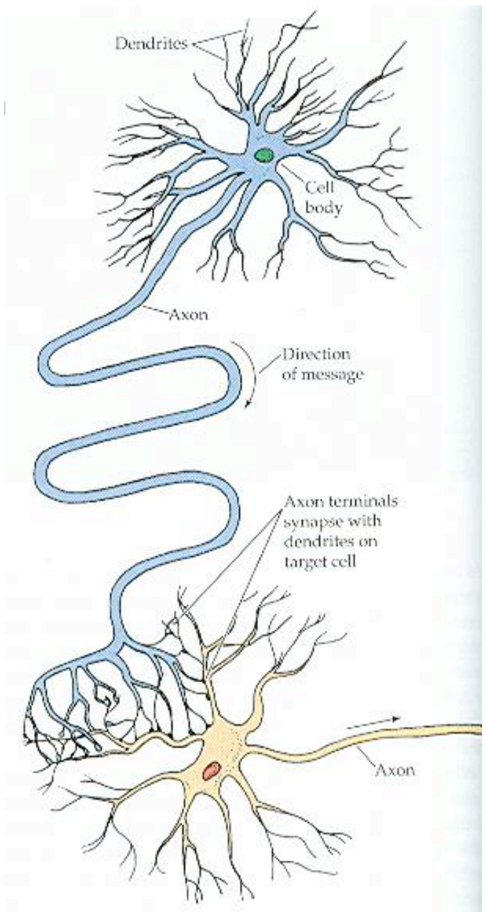
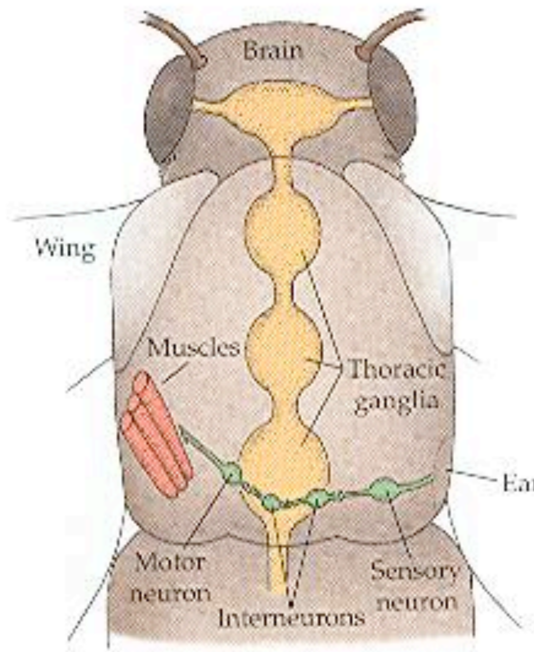


Figure 11.15

Route of Transmission

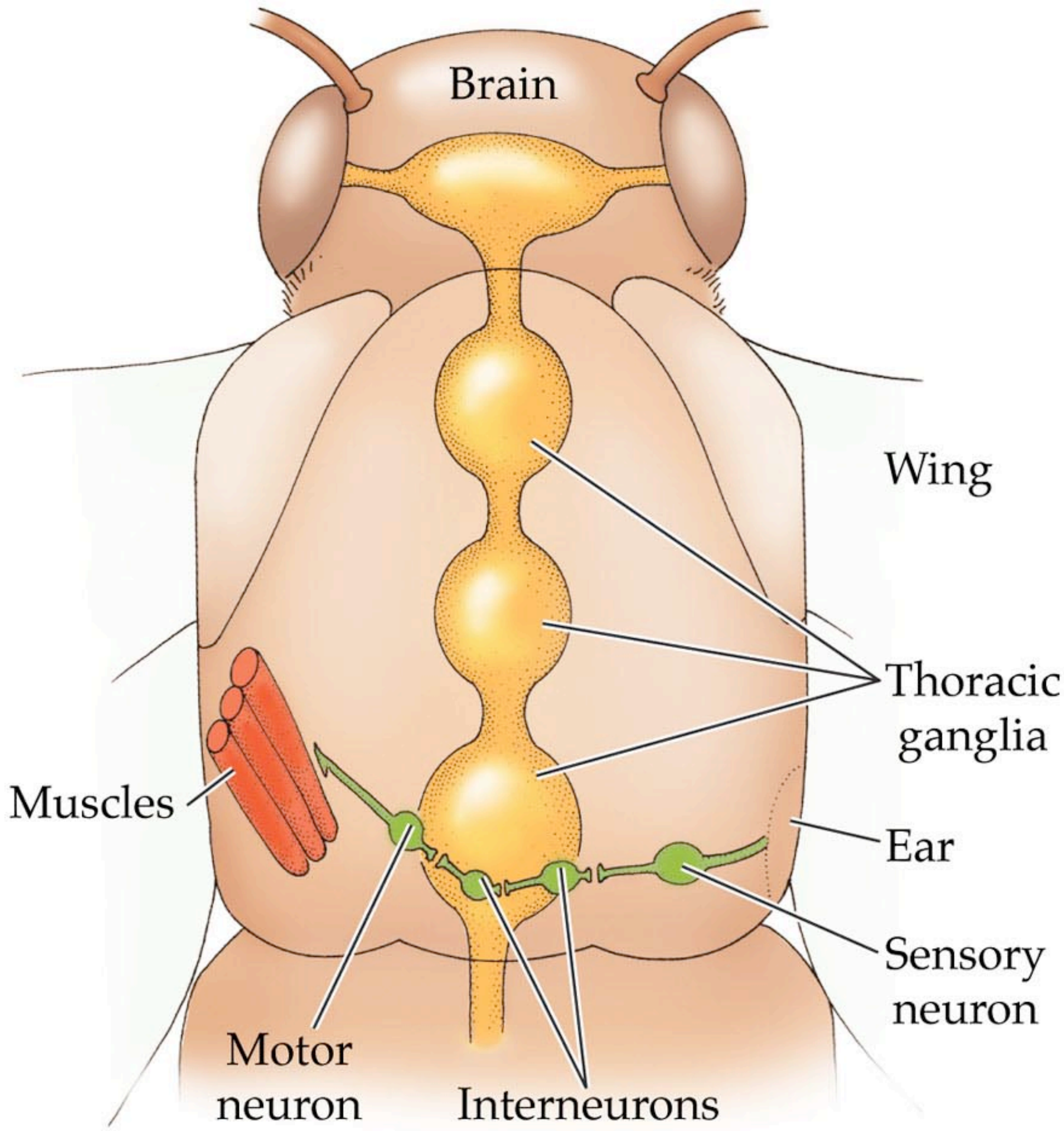
Ear ➞ Sensory neuron ➞ Interneuron ➞ Ganglion ➞ Motor neuron ➞ Muscles



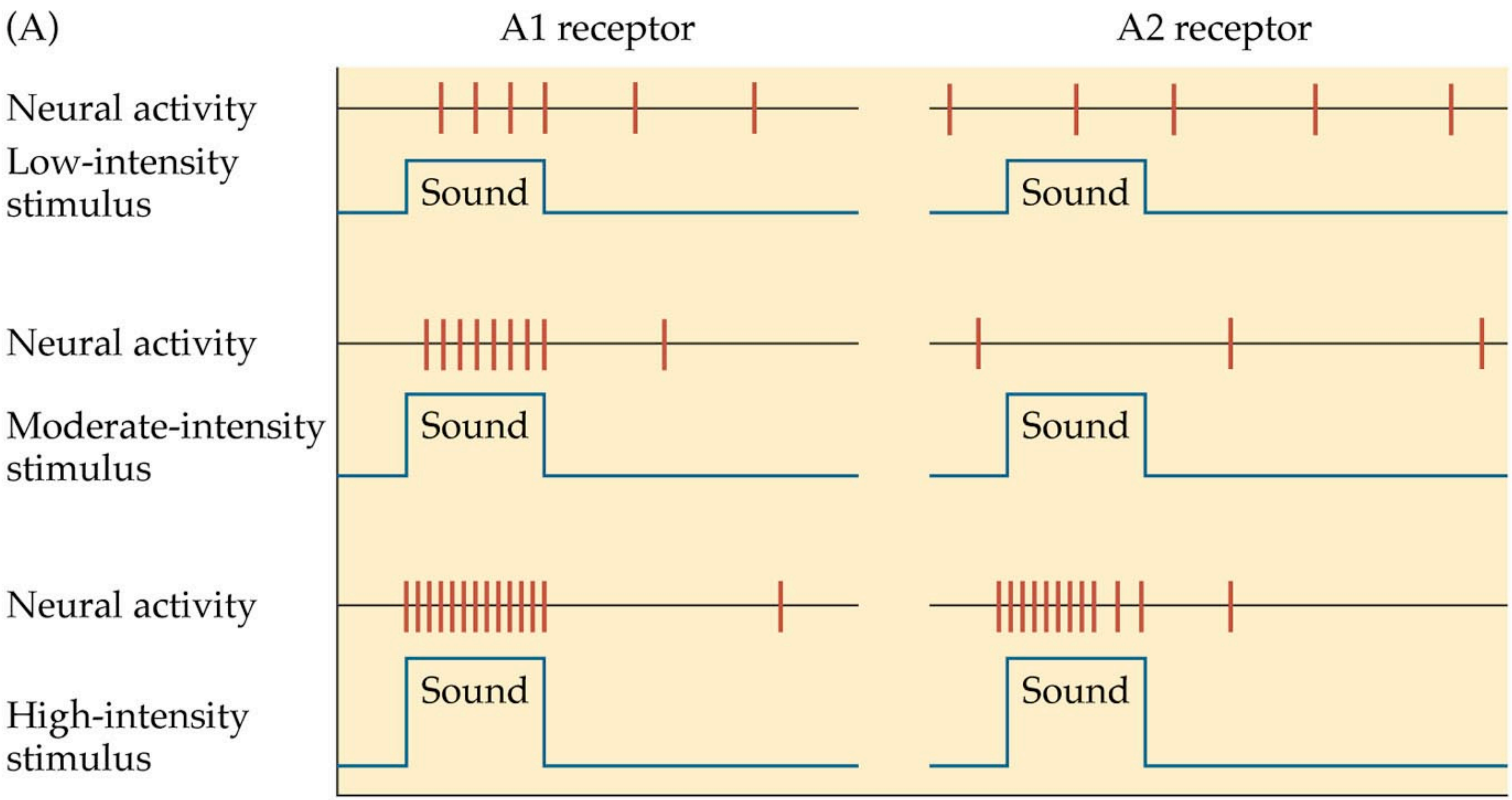


10 Neural network of a moth. Receptors in the ear relay information to interneurons in the thoracic ganglion, which communicate with motor neurons that control the wing muscles.

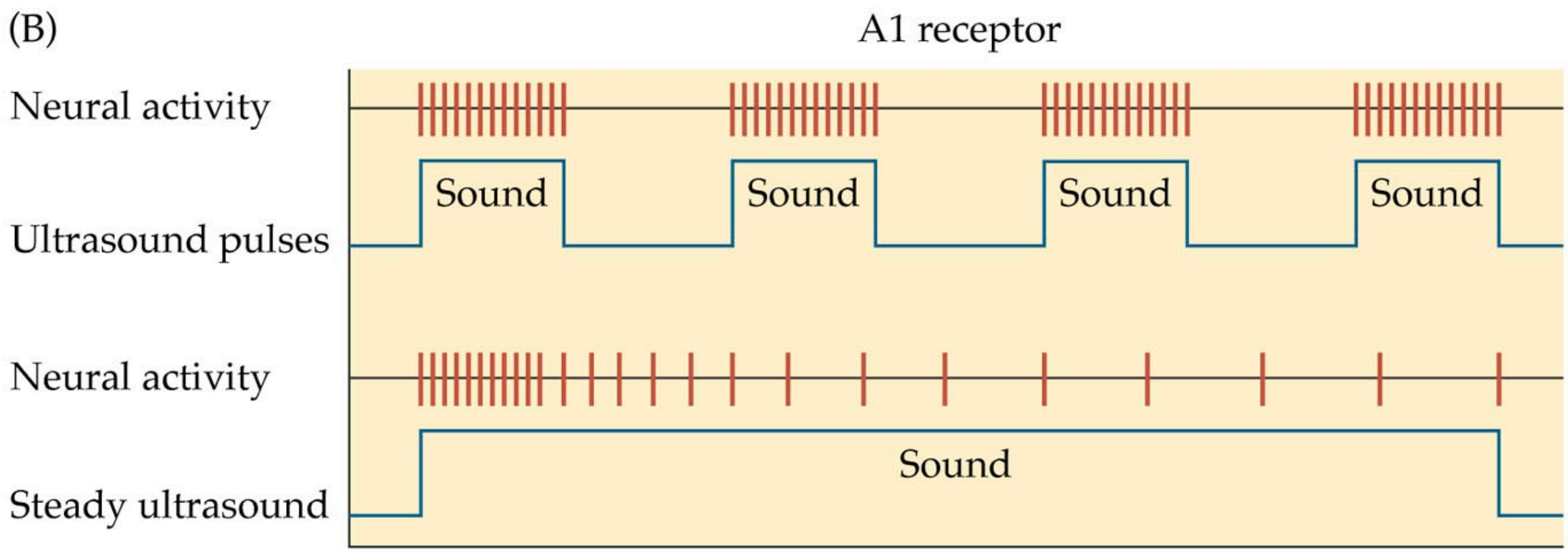
4.13 Neural network of a moth



4.14 Properties of the ultrasound-detecting auditory receptors of a noctuid moth (Part 1)



4.14 Properties of the ultrasound-detecting auditory receptors of a noctuid moth (Part 2)



What Does This Mean?

A1 receptor – fires rapidly but slows after a bit of a constant buzz (phasic)

A2 receptor – fires only on high intensity calls (bat near)

A1 sensitive to both low and high intensity bat feeding buzzes.

Rate of A1 “firing” ↑ as buzz intensity ↑

A1 responses to pulsed sound

Responds to 20-50 kHz sound

A2 responds only to high intensity sound

Summary

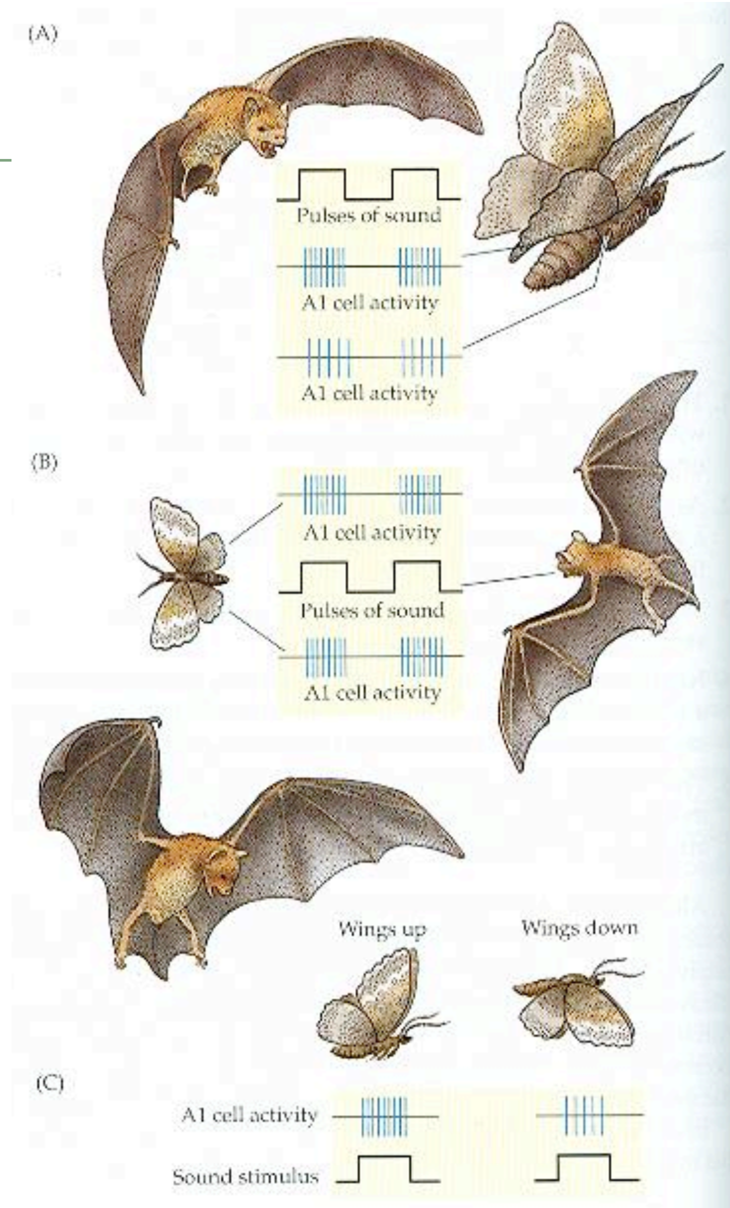
- A1 is main bat detector
  - Can detect a bat at 30 m.
  - As A1 rate of fire increases, moth should turn away from bat to reduce sonar echo.
- A2 is emergency system.
  - Initiates erratic flight and last ditch effort to evade capture

Orientation

Moth ears can tell location of bat by differences in signal received on left and right side of the body.

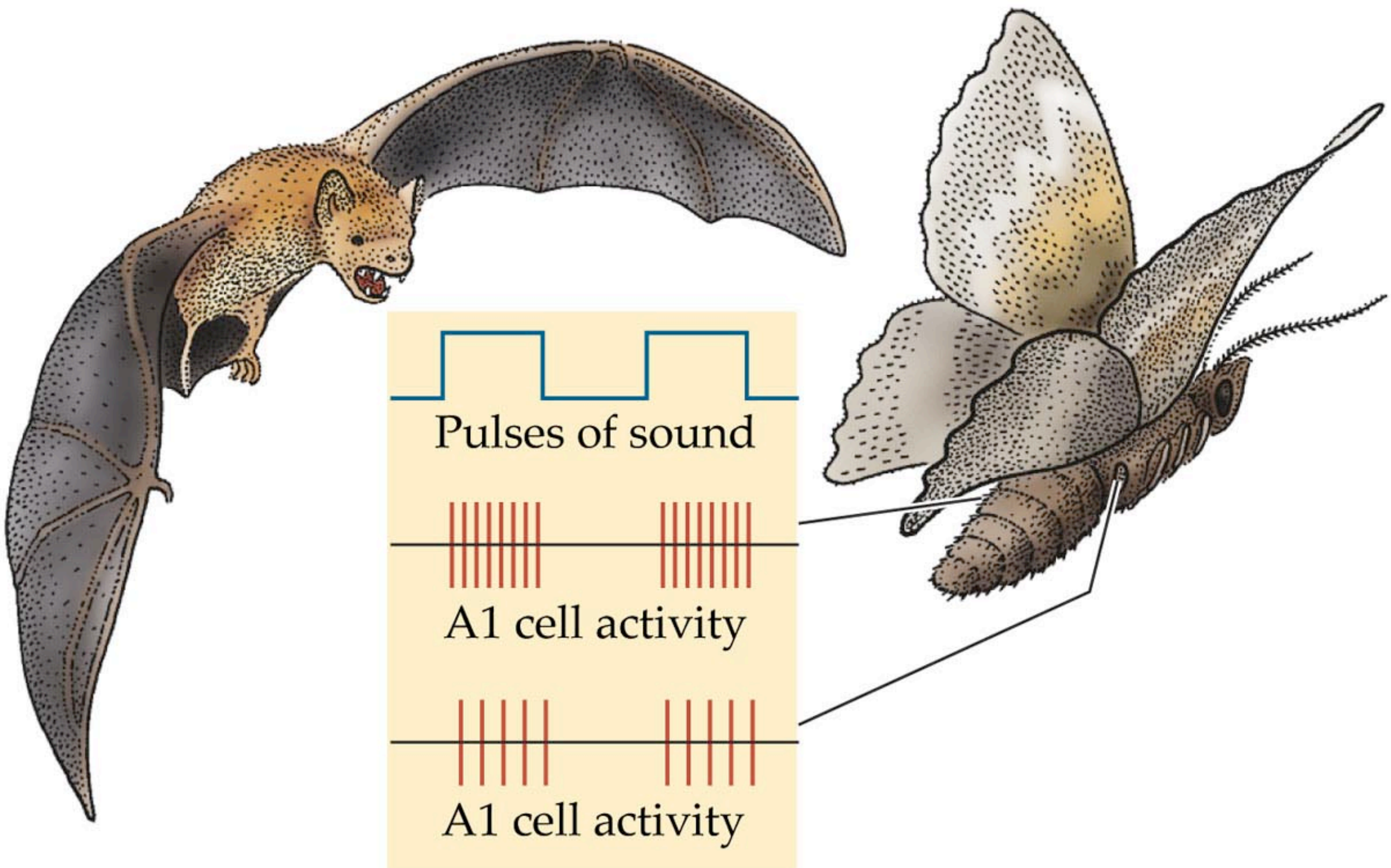
When the signal is even on both sides – bat is parallel.

If bat is above, detect during the up wing beats with a high firing rate.

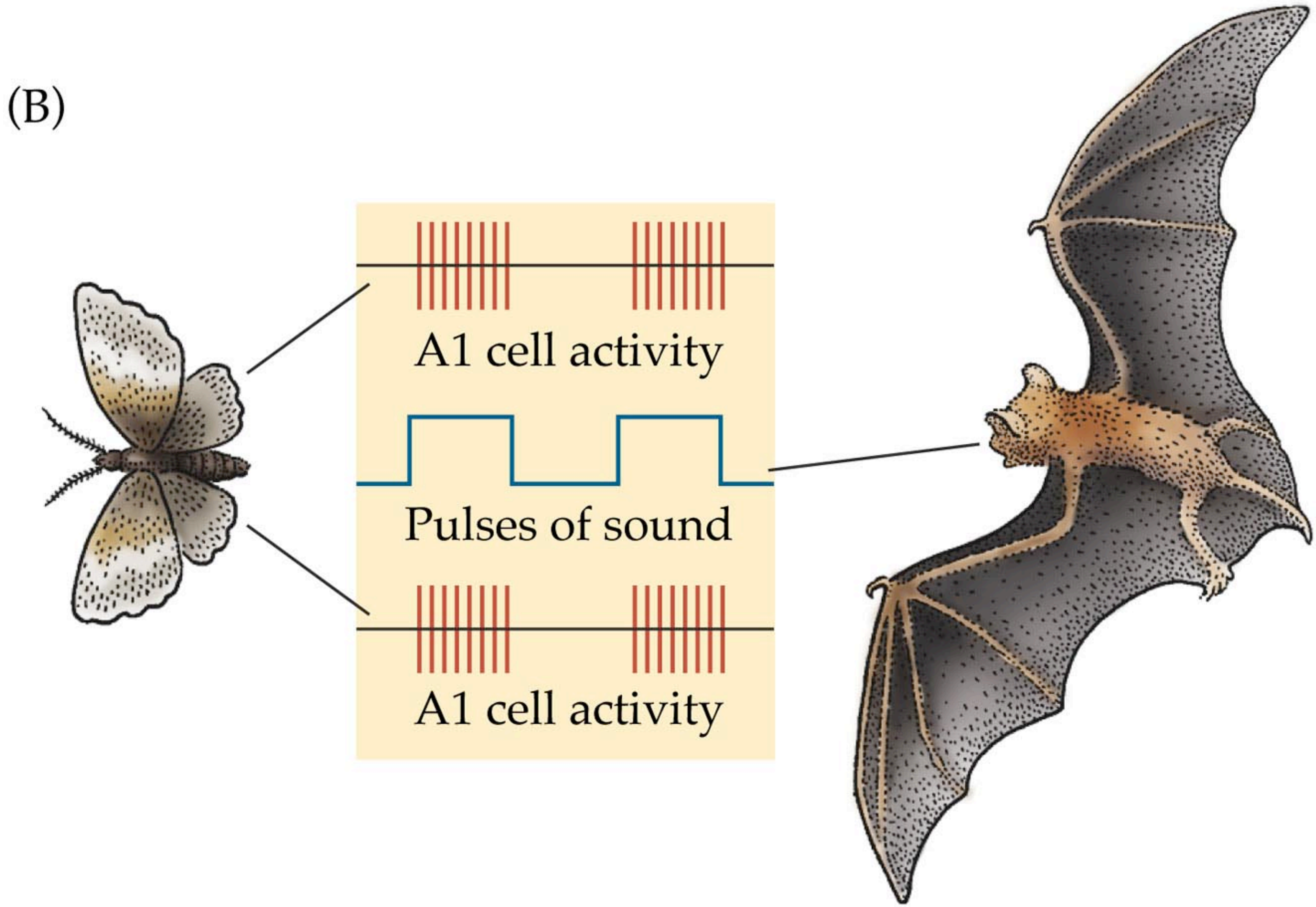


4.15 How moths might locate bats in space (Part 1)

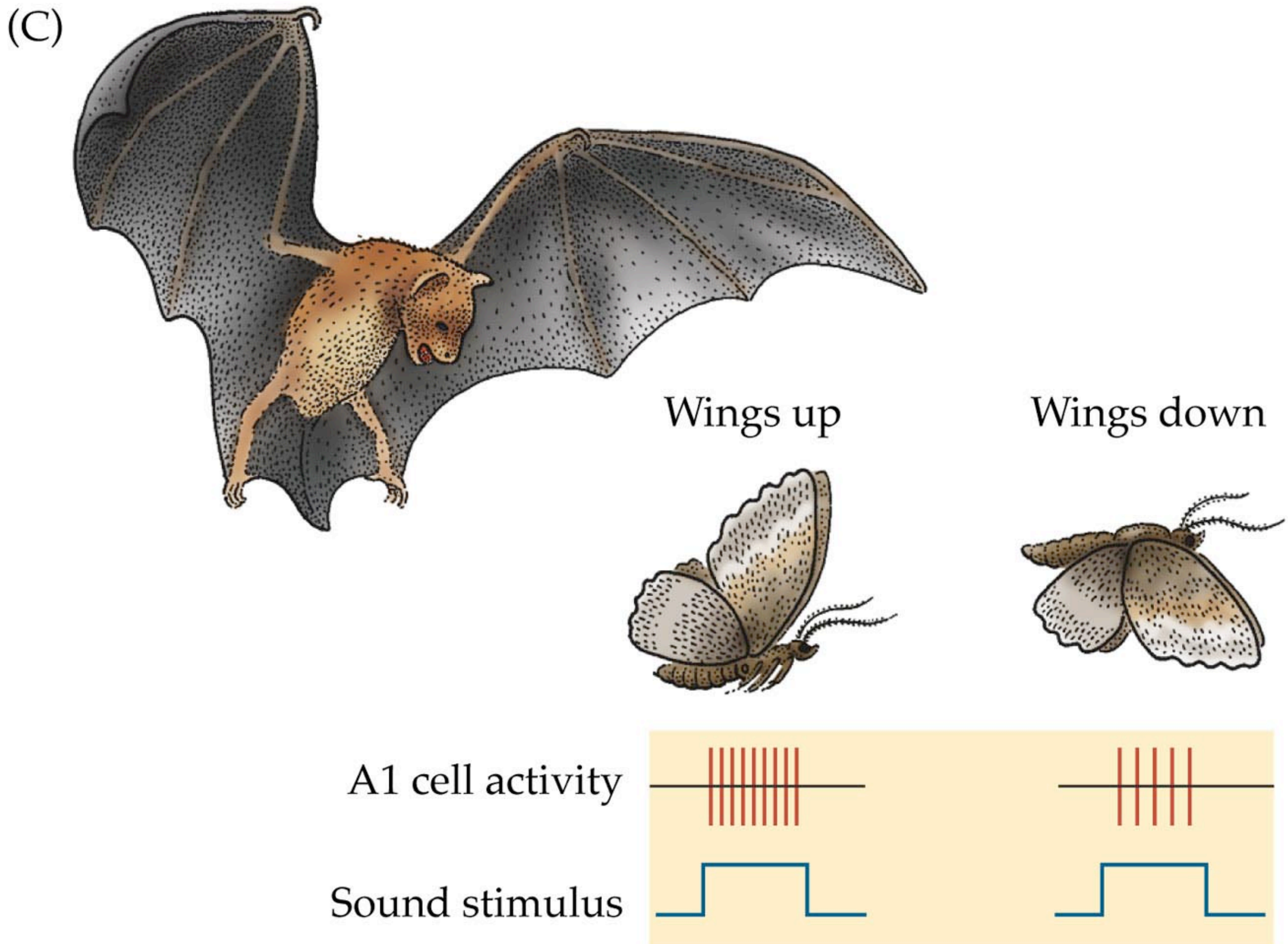
(A)



4.15 How moths might locate bats in space (Part 2)



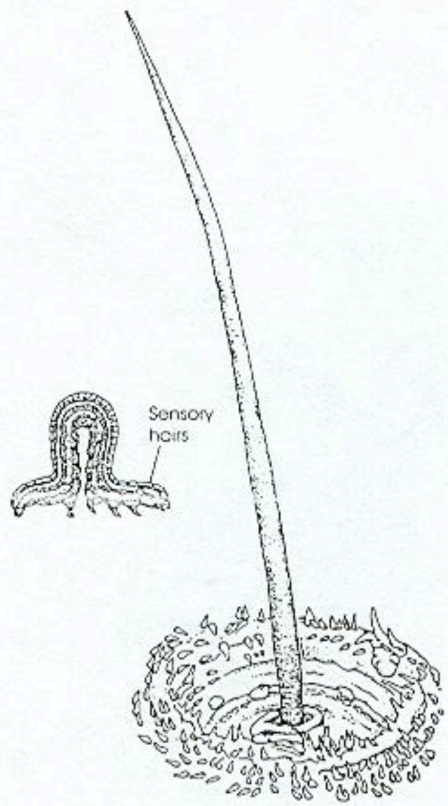
4.15 How moths might locate bats in space (Part 3)



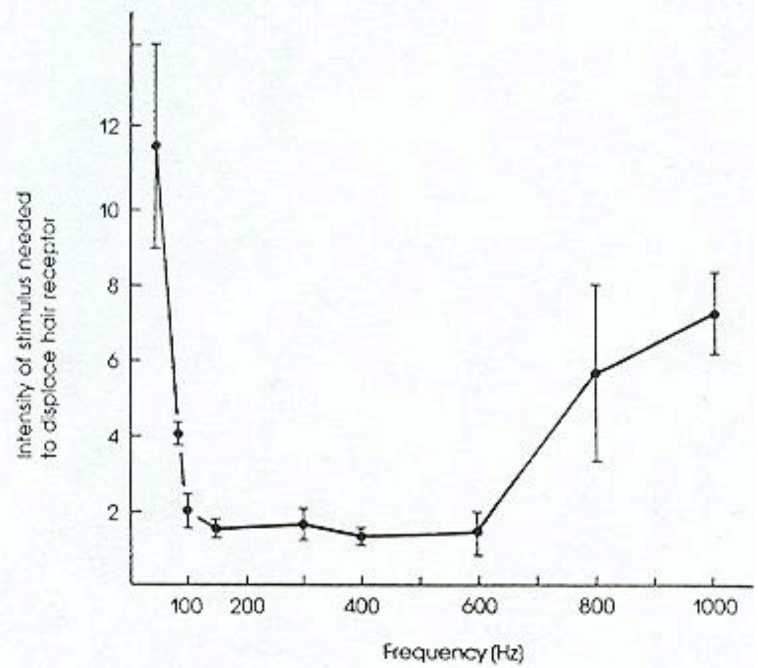
How Do They Hear?

Moth Larvae have sensory hairs that vibrate at a certain range of frequency. If it touches the side, will fire.

Most sensitive to 100-600 Hz (wing beat frequency of a parasitic wasp. If you hear this, JUMP!!!



Acoustical hair of a noctuid moth larva. The larva has eight hairs on each side of its body. Each hair is poised in a socket. Airborne vibrations can cause the hair to move, thereby triggering receptors associated with the hairs.



Tuning curve of the acoustical receptors of a noctuid larva, showing that this species is most sensitive to sound in the 100–600 hertz range. *Source:* Markl and Tautz [516].

Stimulus Filtering

- Respond selectively to important stimuli
  - Determined by natural selection
- Ex. From bat-moth interaction
  - Moth – A1 can habituate to a long pulse
  - A1 responds to 20-50 kHz and filters the rest.

Real World Examples of Stimulus Filtering

- Sleep
  - We filter out unnecessary sounds
- In the woods
  - Hear other voices easier than the background noise.
- We can only hear within a certain sound range
- Possess a fixed visual range as well.

Two Aspects of Stimulus Filtering

- Specialized detection system
  - Ex. Moth
- Post-detection filtering of stimuli by CNS.
  - Ex. Not hearing the train at night, but hearing the front door open.

Sound Perception in Bats

Specialized echolocation system

Discriminate your own echos from other echos.

Fact – echos return at a reduced intensity.

Echo detectors respond to low intensity ultrasound immediately AFTER a feeding buzzing, and at no other time

More Neurons

Tracking neurons

- Will keep firing as long as interval between buzz and echo decreases.

Ranging neurons

- Respond to specific echo delays

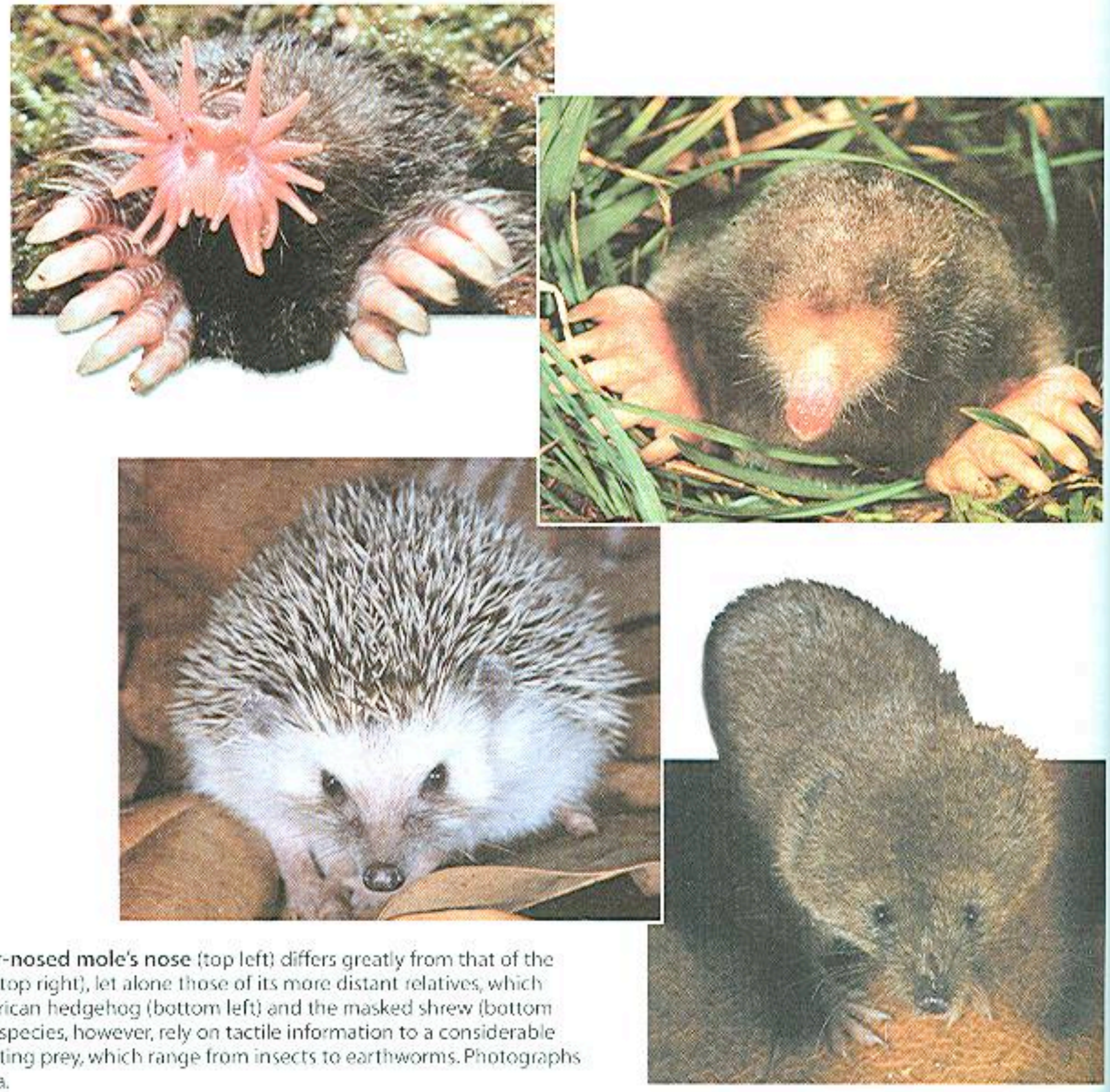
Short delay neurons and long delay neurons

↓ close to object

↓ far from object

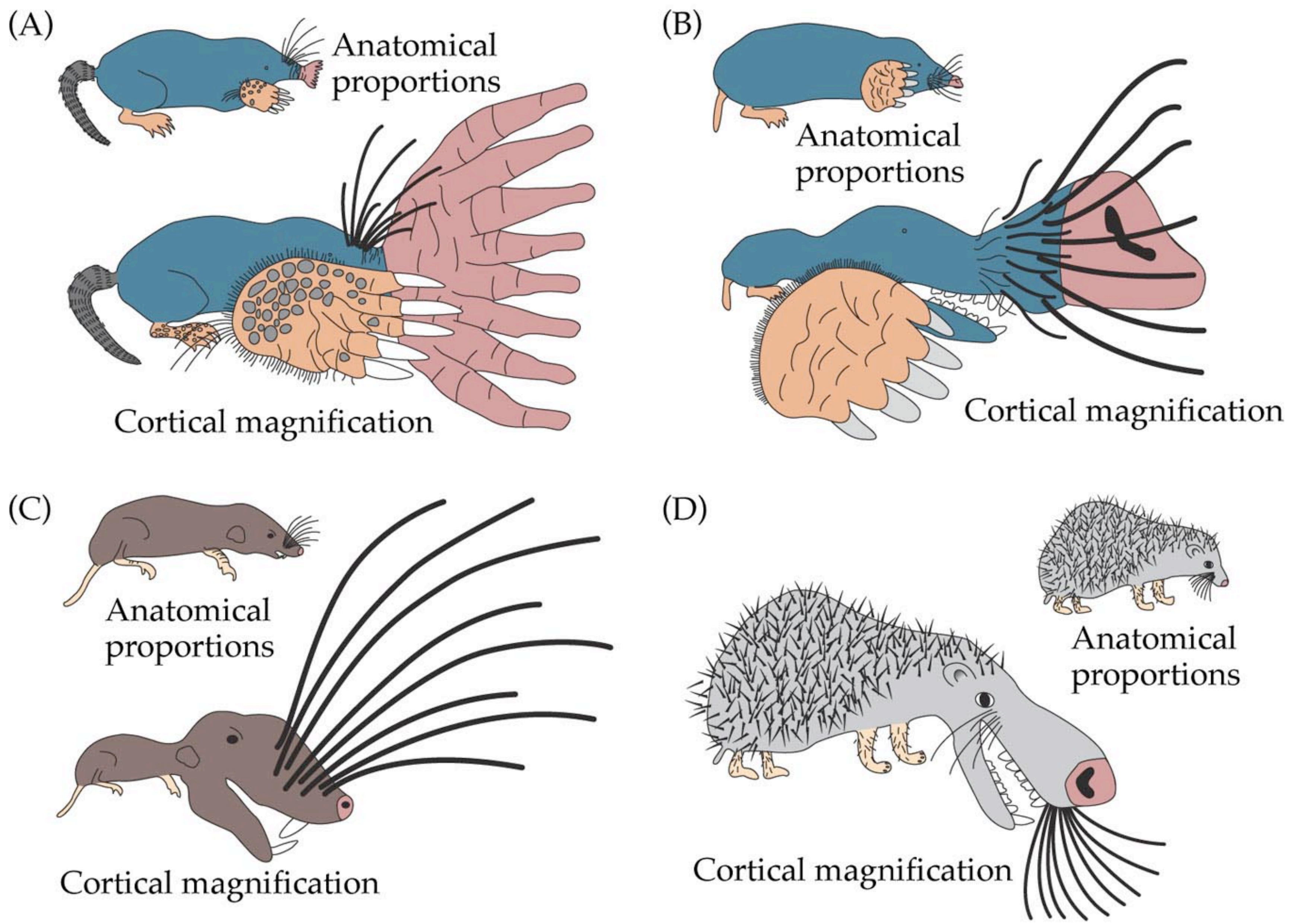
Selective Tactile Detection

Insectivores tend to dedicate different amounts of brain function to particular senses.

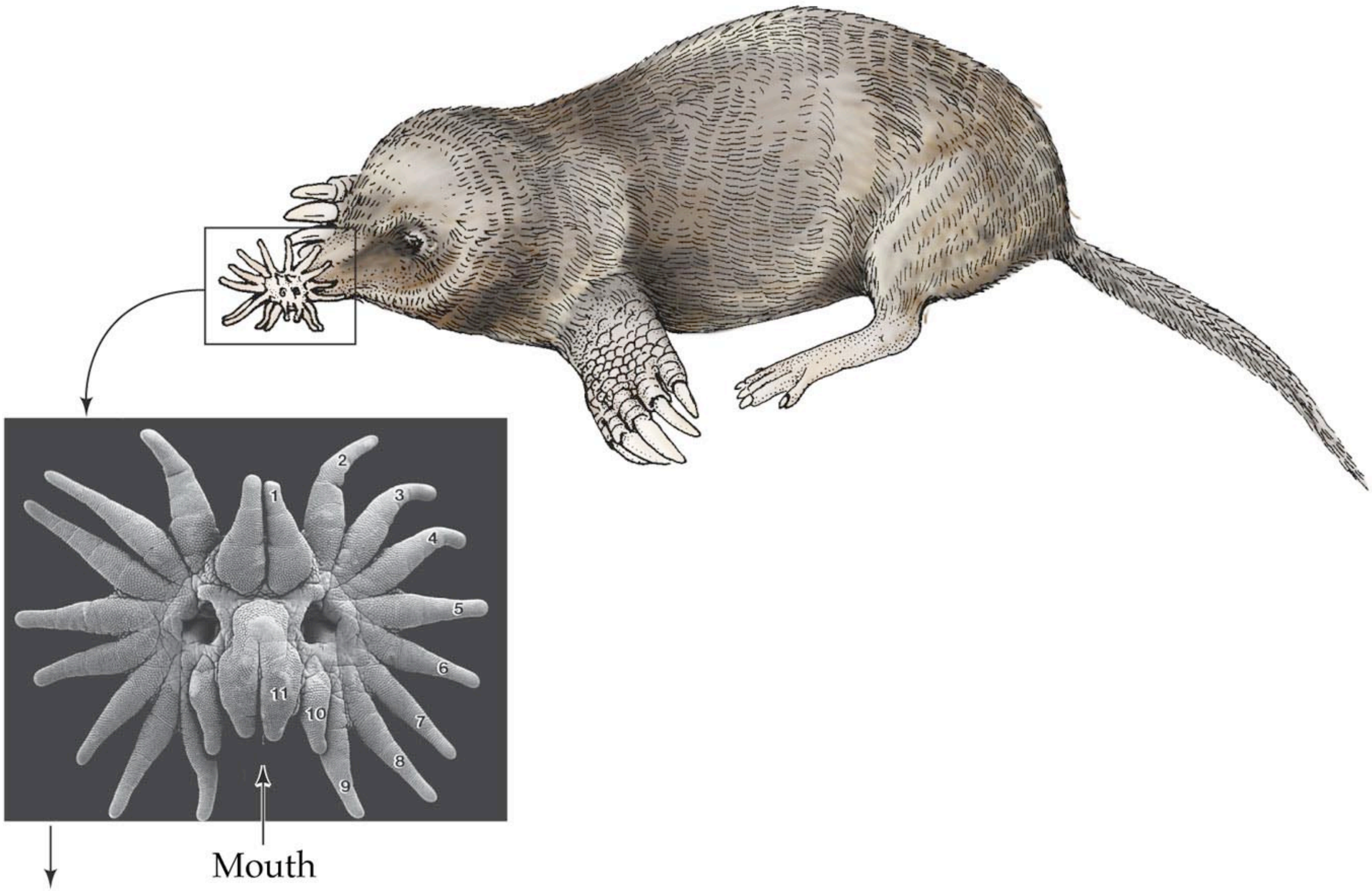


23 The star-nosed mole's nose (top left) differs greatly from that of the eastern mole (top right), let alone those of its more distant relatives, which include the African hedgehog (bottom left) and the masked shrew (bottom right). All four species, however, rely on tactile information to a considerable degree in locating prey, which range from insects to earthworms. Photographs by Ken Catania.

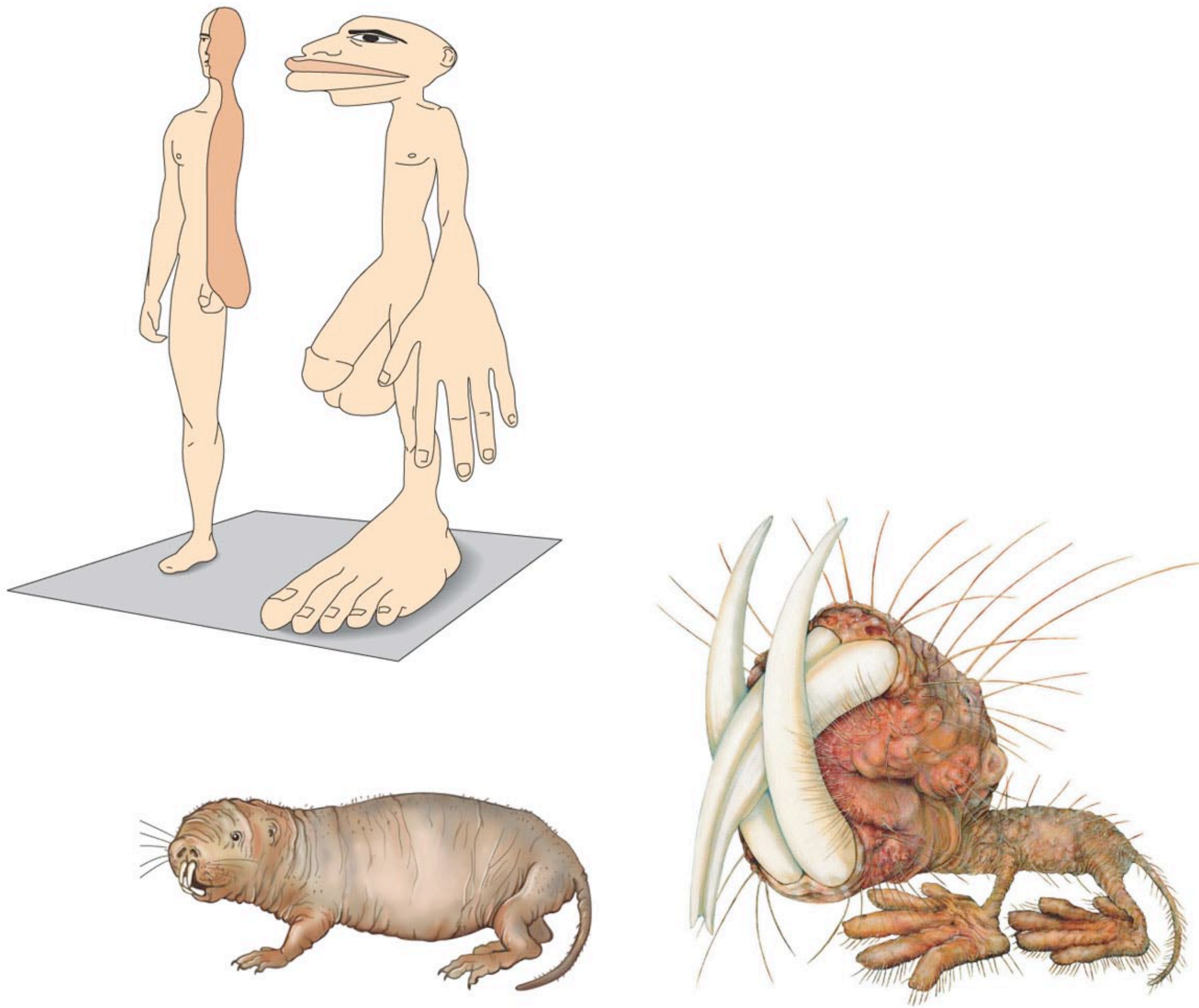
4.30 Sensory analysis in four insectivores



4.28 A special tactile apparatus (Part 1)

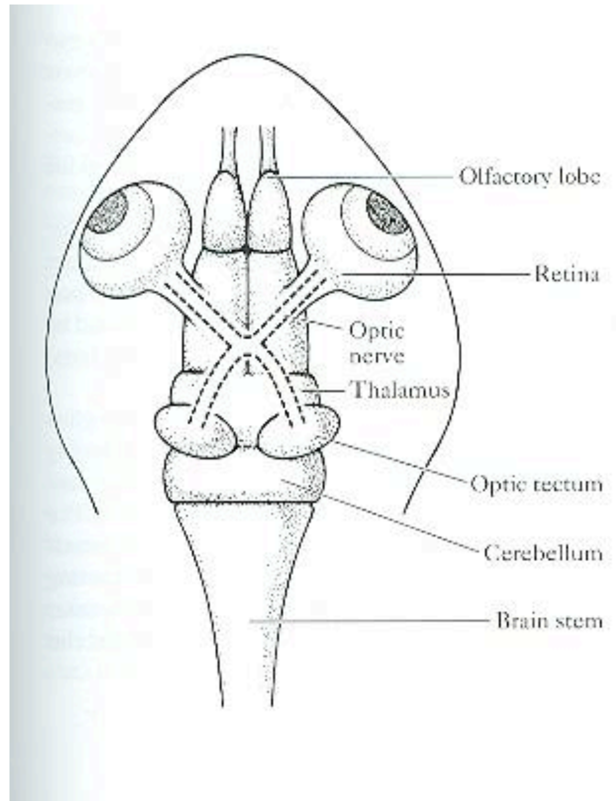


4.31 Sensory analysis in humans and naked mole-rats



Selective Visual Perception

- Example of toads
- Has two eyes, but may not be seeing anything?!?!?!?
- Light sensory neurons in retina get struck with photons, the neurons pass down the optic nerve, cross brain hemispheres to the optic tectum and thalamus.
- Why aren't they seeing?



I'm BLIND…too the obvious

- Eyes do not respond (neurons fire) without movement.
  - The eye gets habituated to image.
- So, when toads are sitting still and nothings happening, they don't "see" a thing!
  - An example of stimulus filtering by ganglion cells.

Ganglion Cells

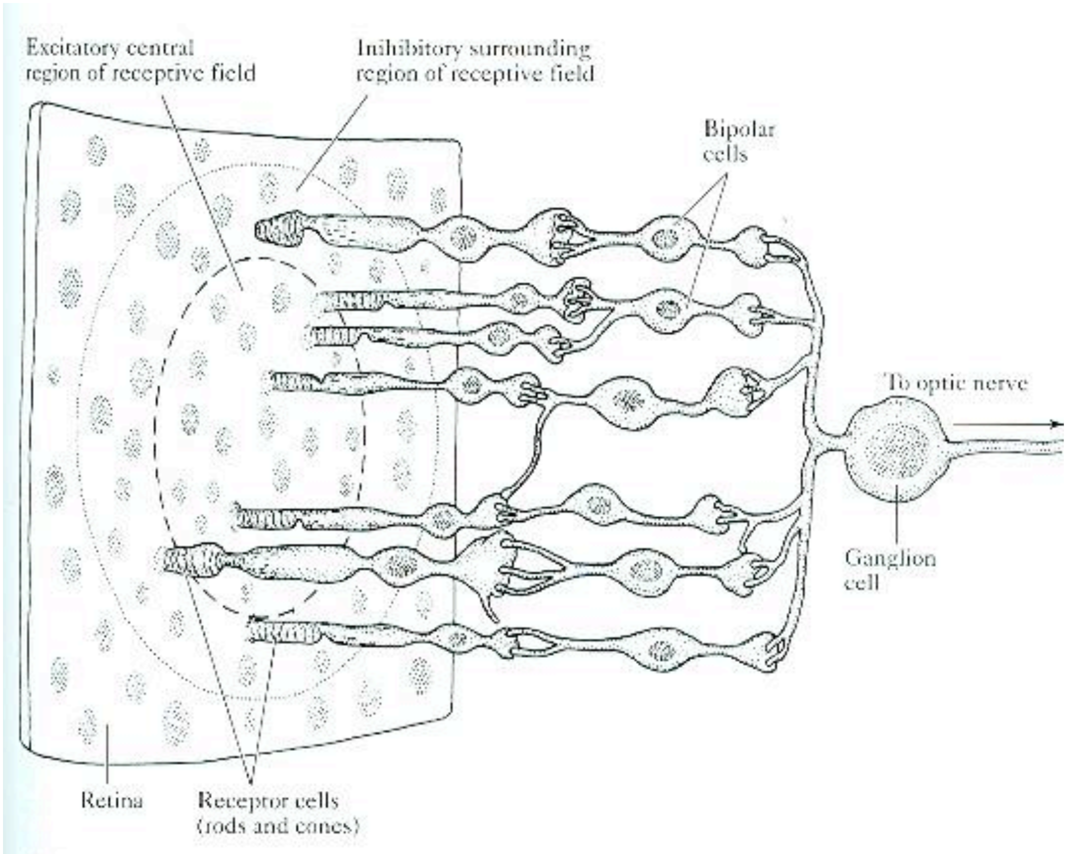
Receive input from several receptors/ sensory neurons.

Under certain conditions, ganglion cells will pass information onto the CNS.

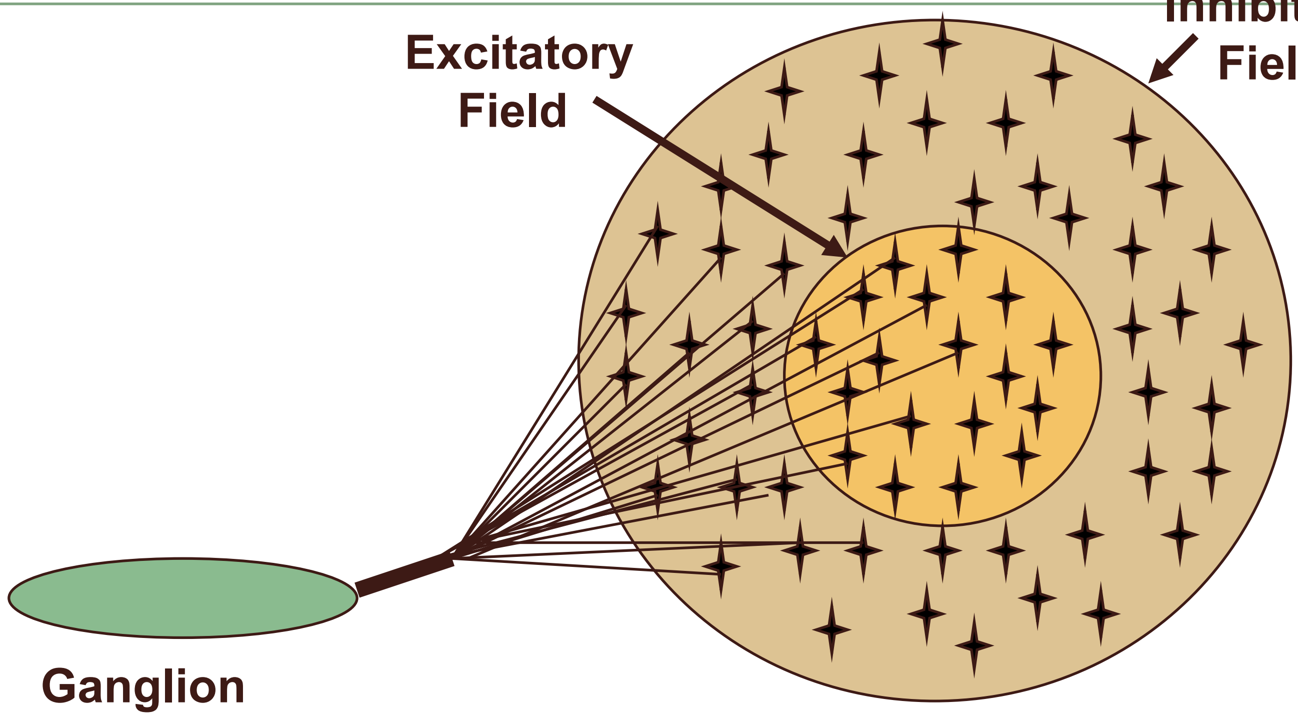
A ganglion cell is attached to photoreceptors in the retina that define a receptive field.

Receptive Fields – 2 Types

- Excitatory field
  - Increases chances of ganglion firing.
- Inhibitive field
  - Reduces ganglion chances of firing.



Receptive Field

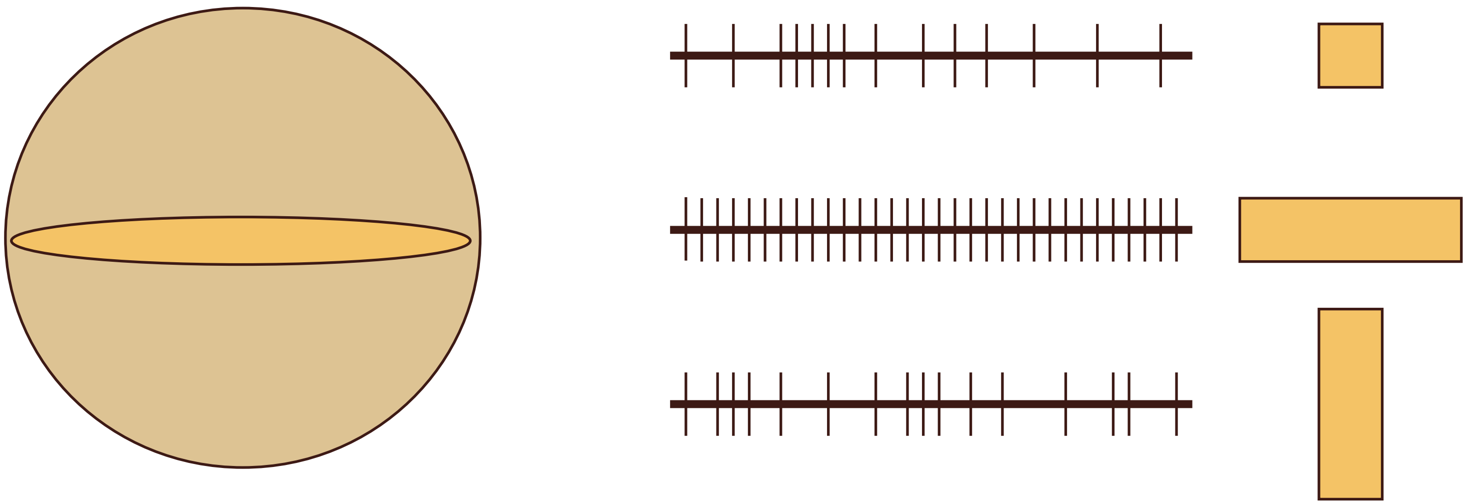


This is a design for a small object detector.

Large objects will not make this ganglion fire, too inhibitory.

Worm Detectors in Toads

Need a long, thin detector

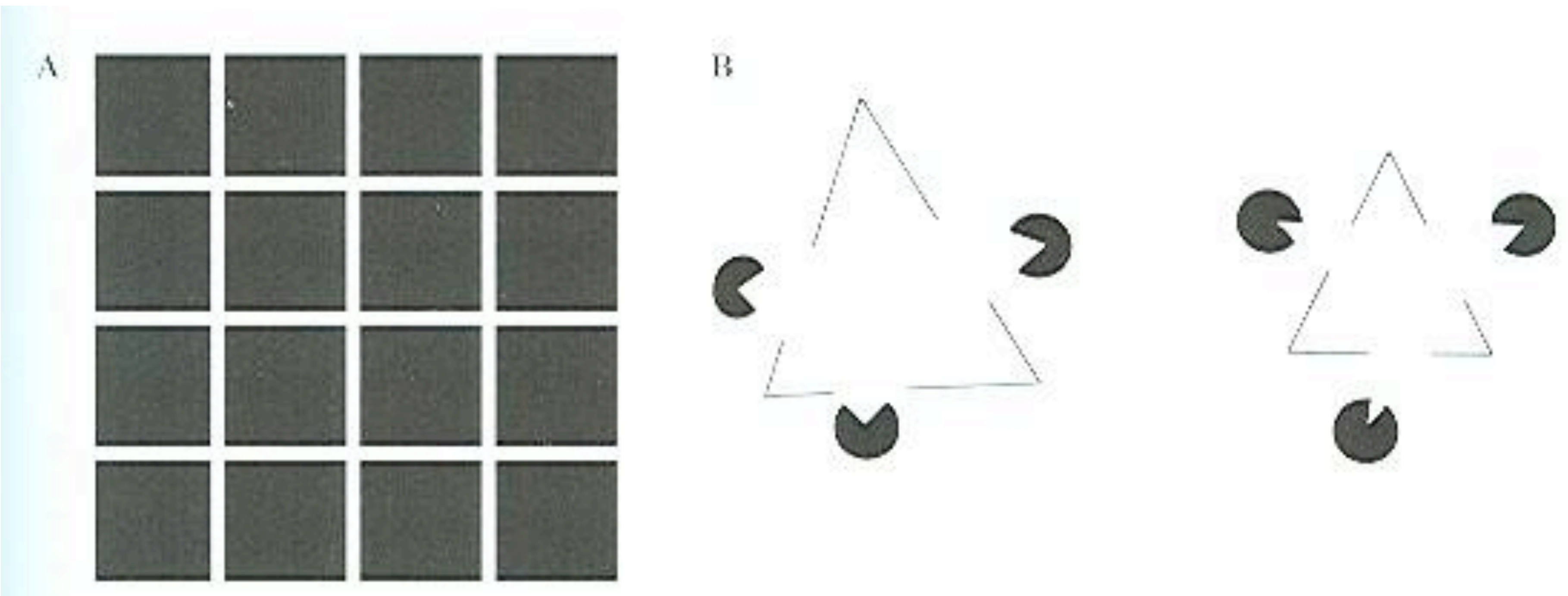


Also have a vertical worm detector

All fields are processed together into a single image. Still don't know how this exactly works.

Optic Illusions

Brain fills in gaps it thinks is missing



Another Brain Trick

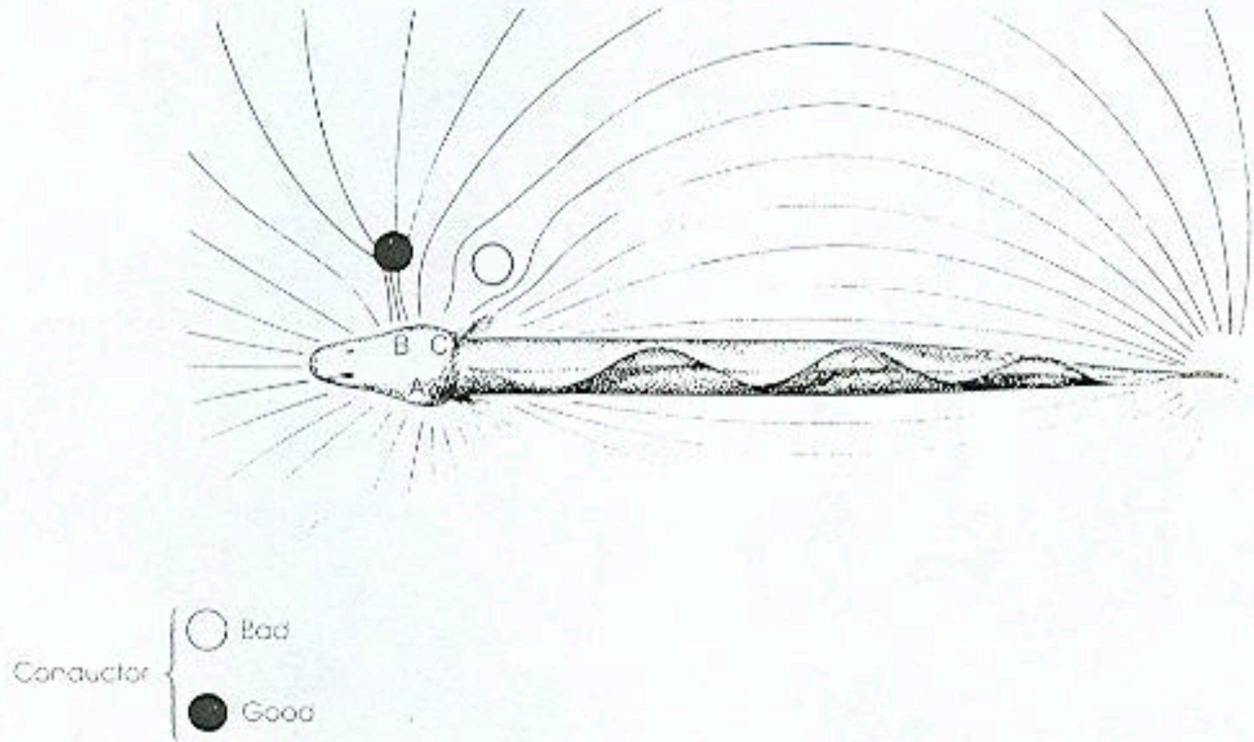
Can you read this?

I cdnuolt blveiee taht I cluod aulaclty uesdnatnrd waht I was rdanieg The phaonmneal pweor of the hmuan mnid Aoccdrnig to a rscheearch at Cmabrigde Uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoatnt tihng is taht the frist and lsat ltteer be in the rghit pclae. The rset can be a taotl mses and you can sitll raed it wouthit a porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe. Amzanig huh? yaeh and I awlyas thought slpeling was ipmorantt.

Electric Field Perception

- Many fish are capable of this
- Possess a lateral line
- Electric eel can create charge between head and tail.
- Uses charge to sense within its field
  - If non-living or poor conductor gets in field, it spreads the lines of magnetism.
  - If living or good conductor enters, lines narrow.

Charged up eels



The self-generated electric field surrounding an electric fish with an electric organ in its tail. Objects near the animal distort the field, and these changes are detected by electroreceptors in the fish's skin. Receptor activity is normal at A, elevated at B, and depressed at C.

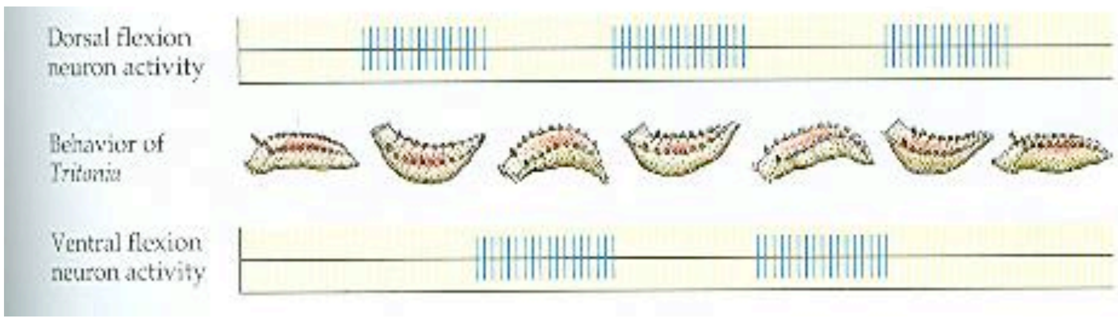
Central Pattern Generators

- Functional clusters of cells in the CNS
  - Generate a pattern of neural signals needed to produce a specific sequence of responses.
- No sensory feedback is required for operation
  - Sensory feedback can **modify** the central pattern generator

Examples

Sea Slug

- Will fire dorsal then ventral over and over again with no other input than the need to swim.



Grasshopper flight

- Can trick it into thinking its flying by blowing on its face
- Pattern in elevator/depressor firing pattern

Midshipman fish

- “Drumming” of swim bladder by sonic muscles creates mating song. Read Bass 1996 for more.

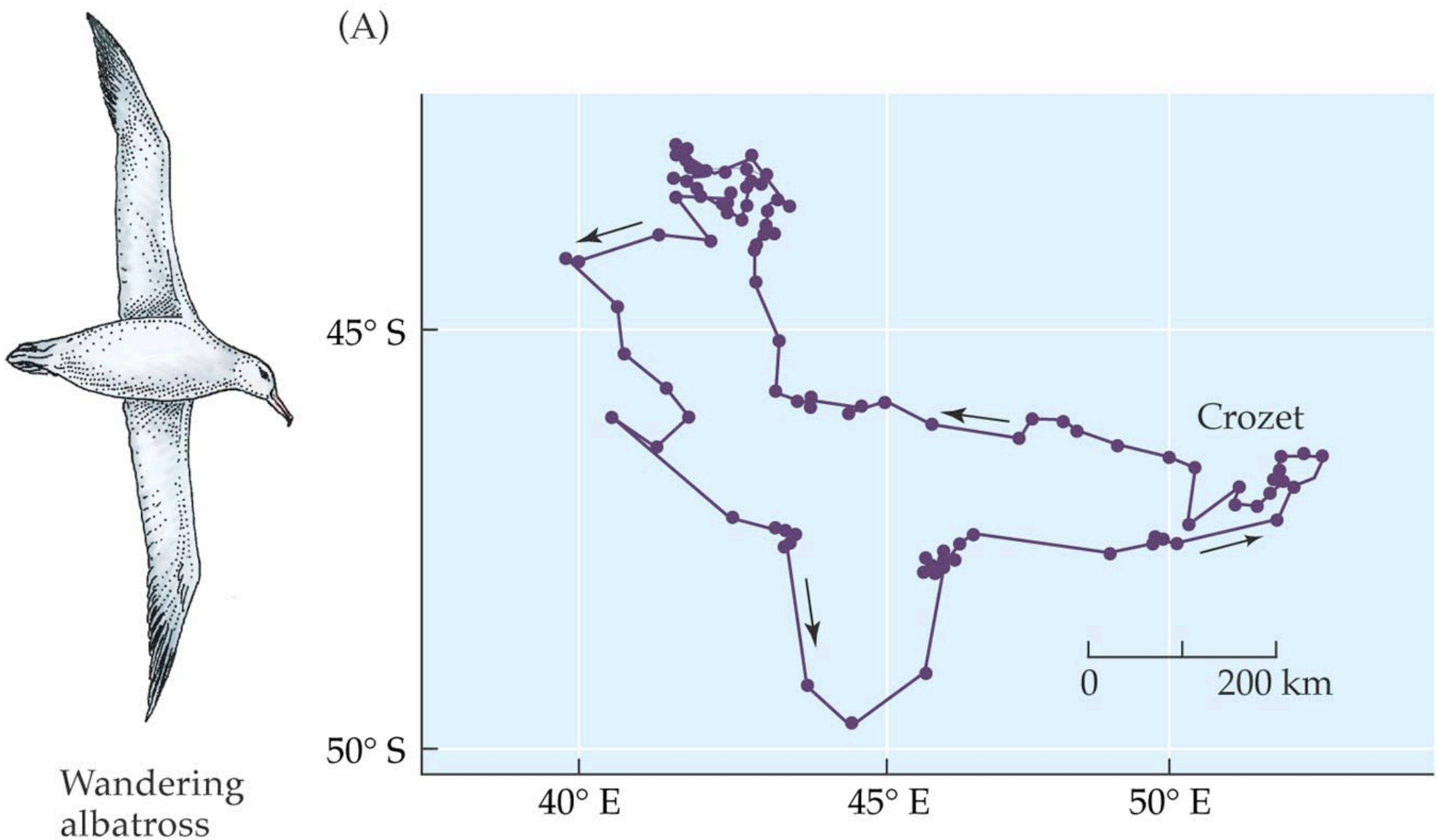
Vertebrate Examples

- Birds
  - Flight can be run on a CPG
  - Can cut spinal cord and a bird can continue in a straight line.
- Humans
  - Breathing is a CPG

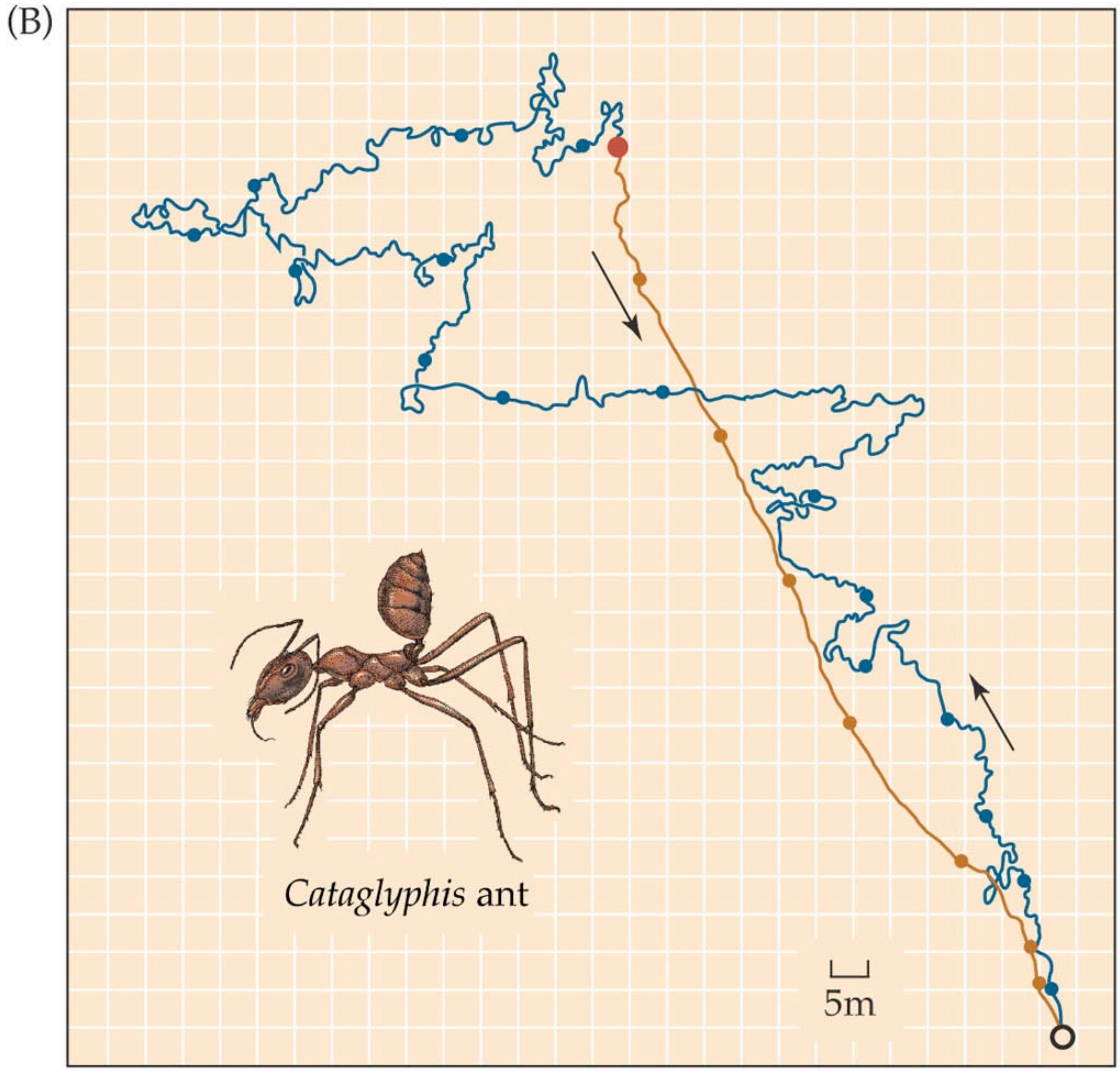
4.32 Ultraviolet-reflecting patterns have great biological significance for some species

4.33 A bird that can sense ultraviolet light

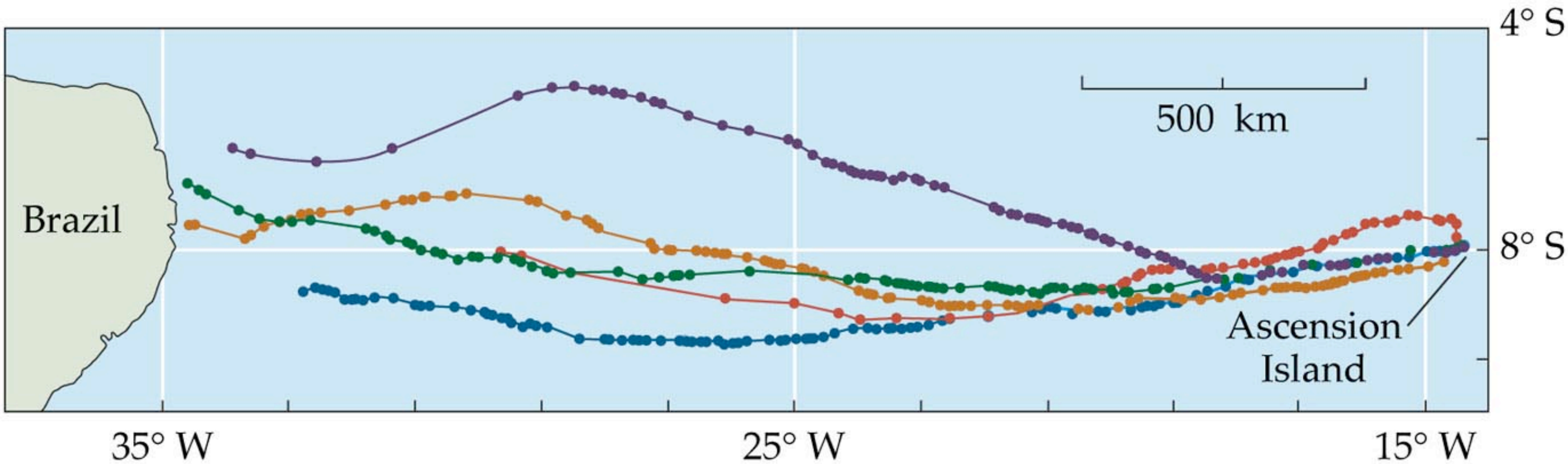
4.40 The ability to navigate unfamiliar terrain requires a compass sense and map sense (Part 1)



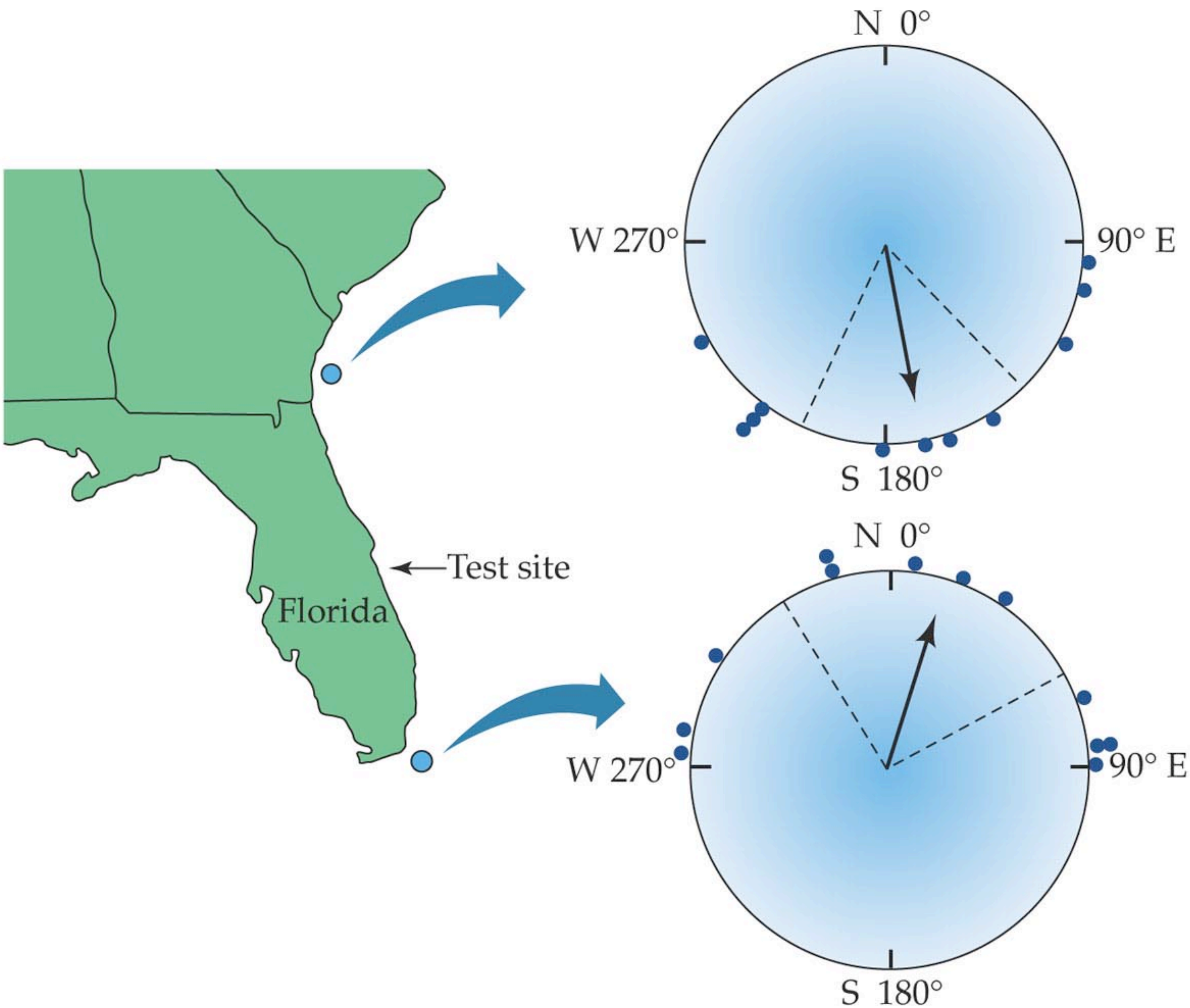
4.40 The ability to navigate unfamiliar terrain requires a compass sense and map sense (Part 2)



4.45 Migratory routes taken by five green sea turtles that nested on Ascension Island

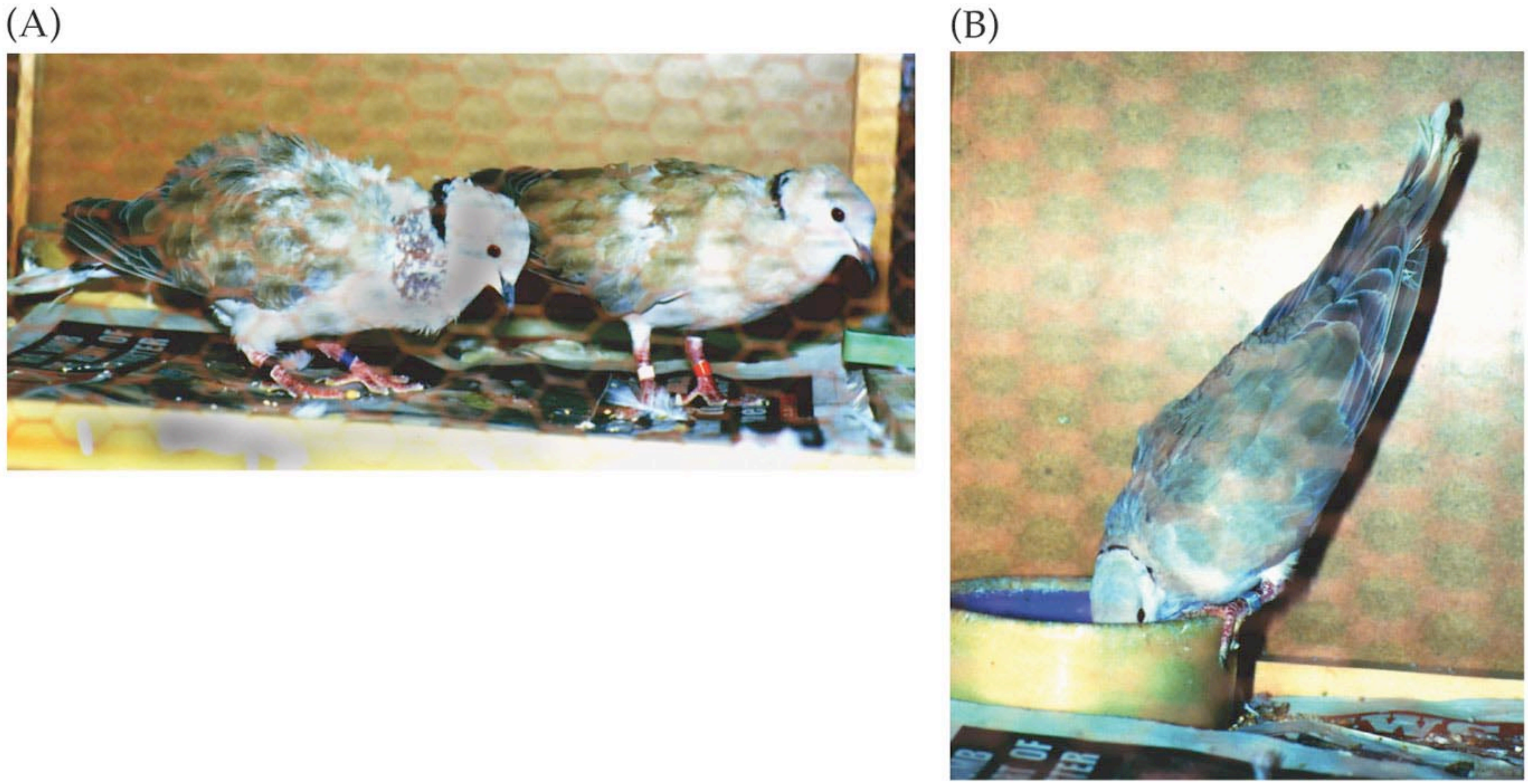


4.46 Experimental manipulation of the magnetic field affects the orientation of green sea turtles



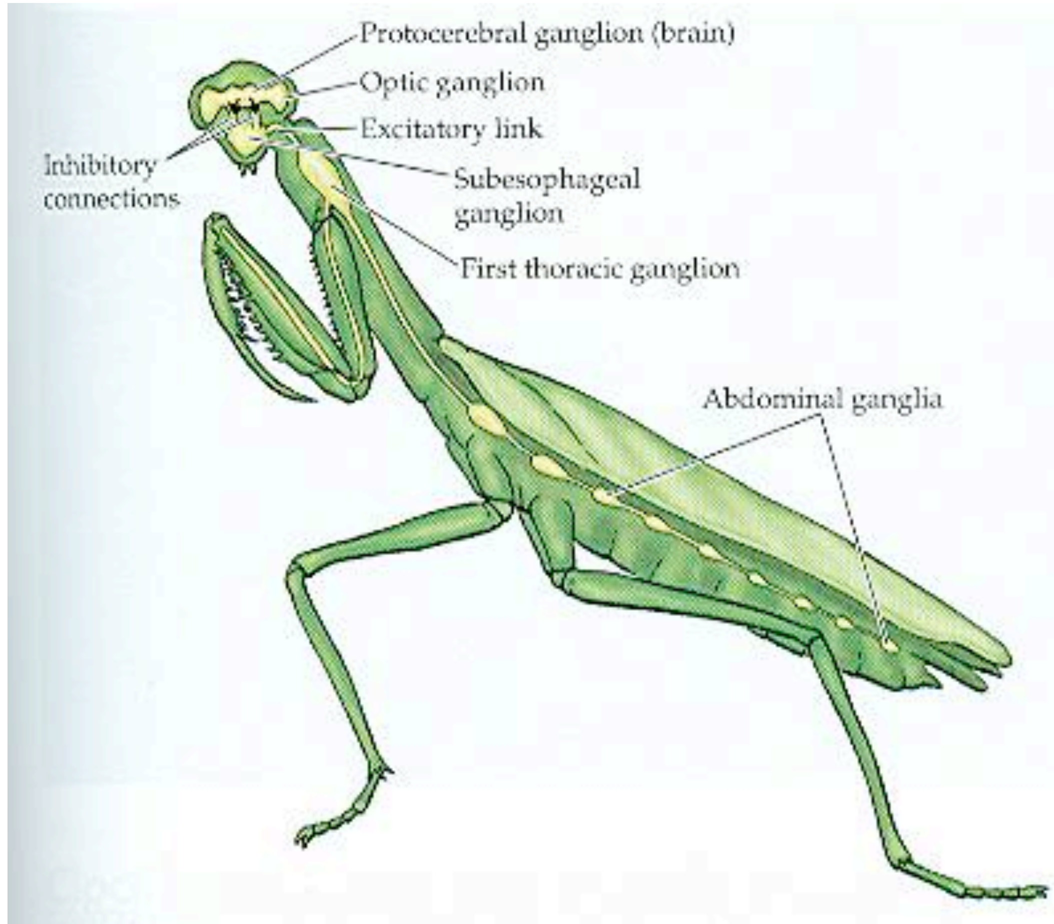
- Fact – All animals have many behaviors that they could perform at a given time.
- Question: How do you avoid **maladaptive** behavioral conflicts in which two or more things are done at once?

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



Chapter 5 Opener: Male red-sided garter snakes emerging from hibernation are ready to mate

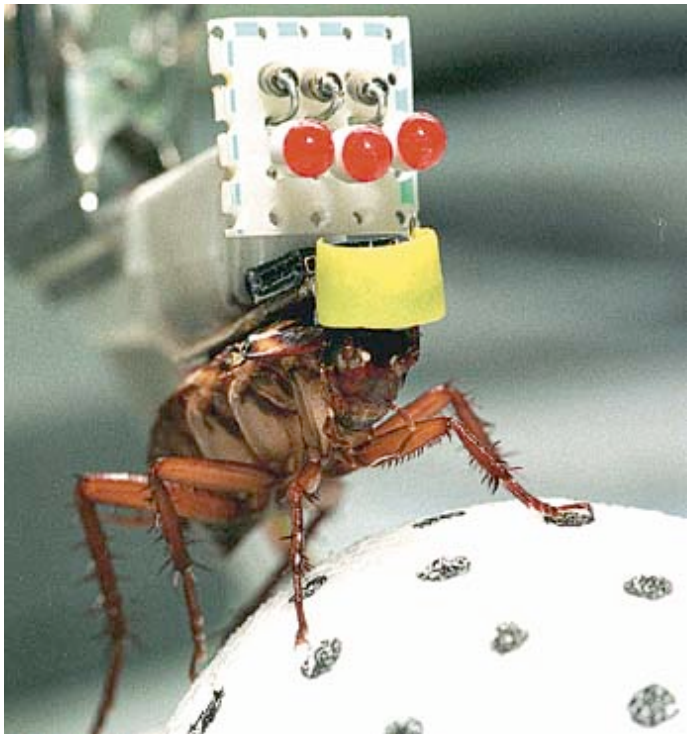
- Nervous system organized in a hierarchy of command centers.
- These command centers are in neural contact.
  - One command center can inhibit another
  - Ex. Praying mantis

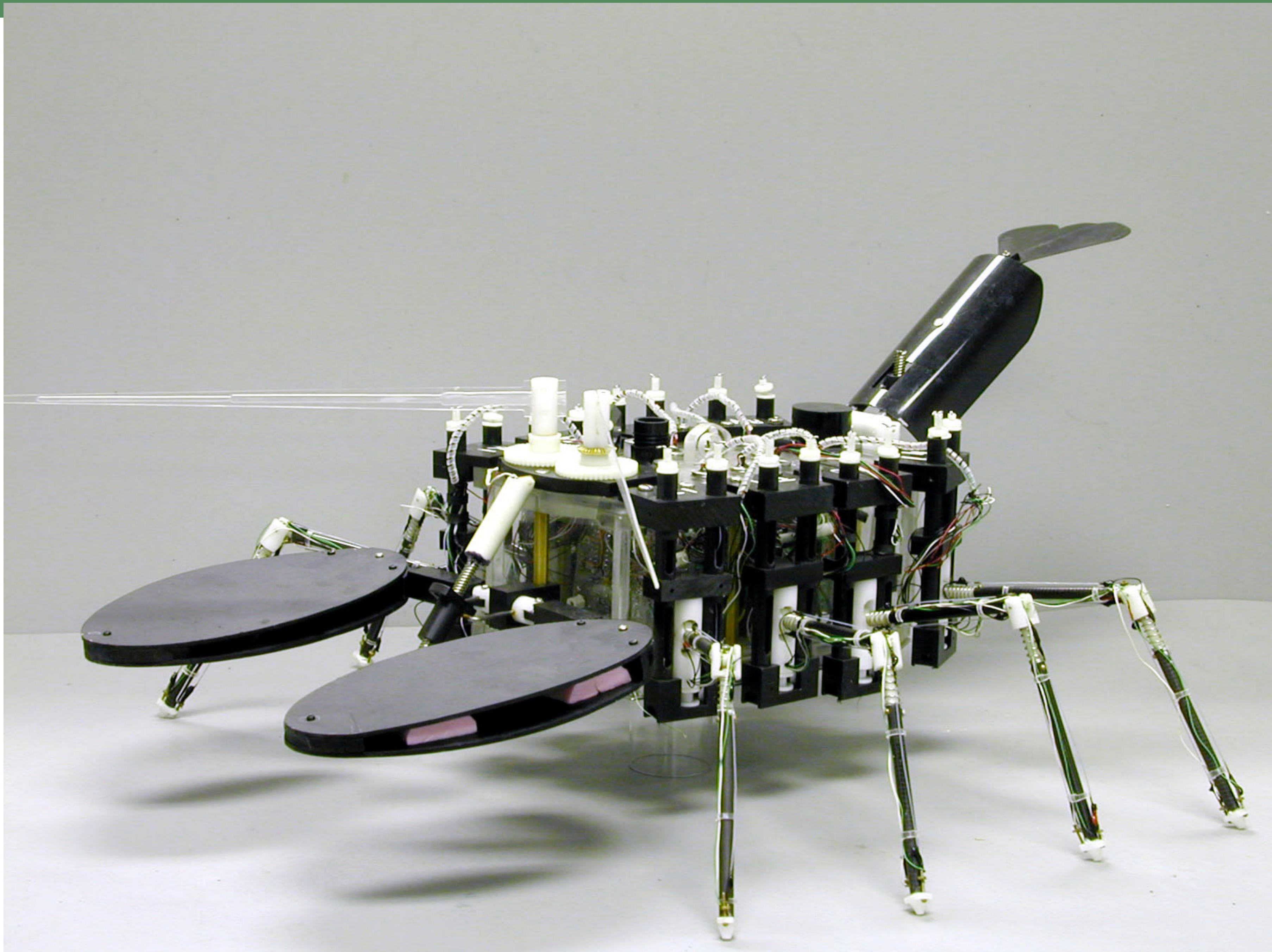


- Can surgically isolate ganglia from CNS.
  - Behaviors soon become out of sync
  - Suggests that ganglia are command centers and that they are controlled by other parts of the CNS.
- What happens if you sever the protocerebral ganglion (PCG) or brain?
  - Mantis attempts to do many things at once
  - Suggests that PCG inhibits many command centers.

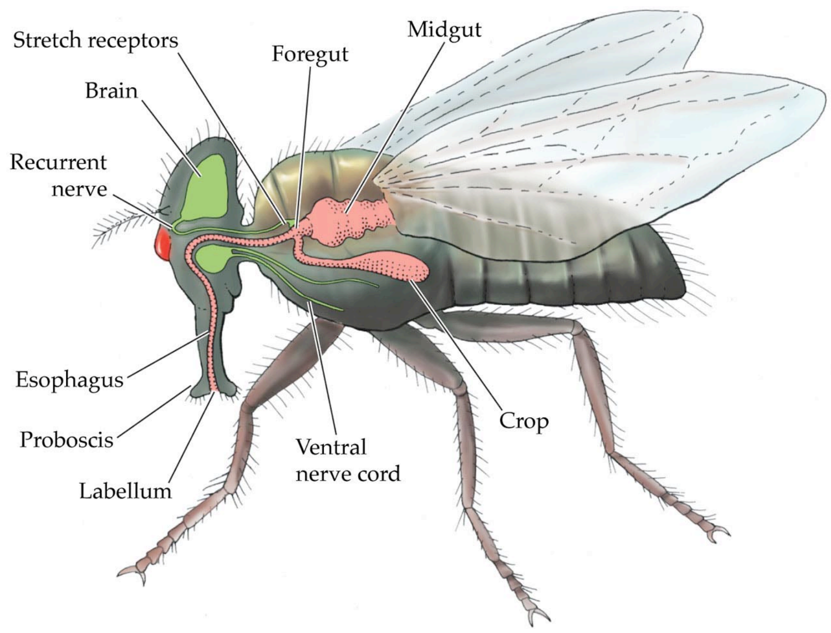
- What happens if you cut its head off (remove the subesophageal ganglion or SEG)?
  - Mantis become mobile
  - SEG controls other motor command centers
  - In absence of SEG, other command centers are not stimulated
- Thus, even beheaded, ♂ praying mantis can continue mating.

- It is possible to replace the PCG and SEG with microcircuitry.
- Can make them walk left, right, turn, forward, etc.





- Feeding command center is inhibited by stretch receptors in the foregut.
- If the recurrent nerve is cut, feeding continues in 90 second intervals until gut ruptures.



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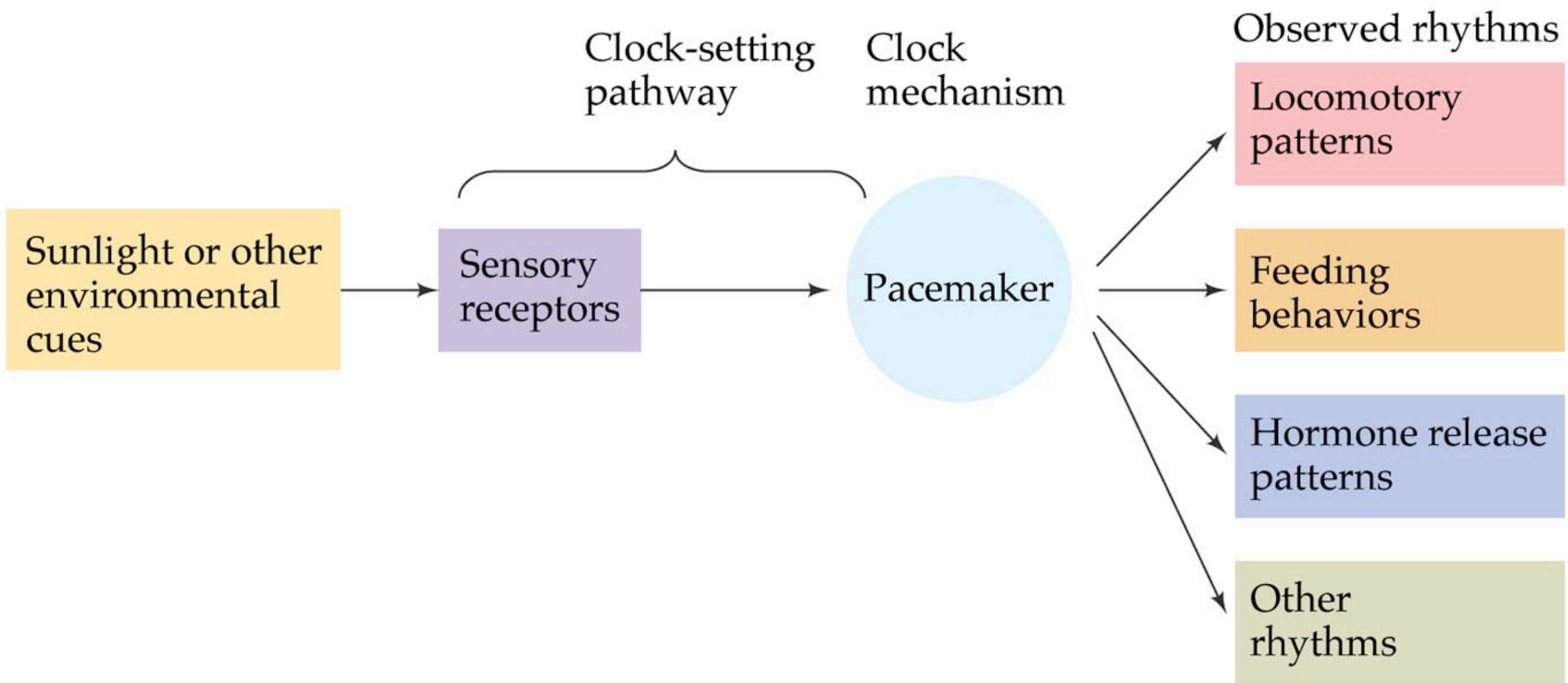
- 24 hour cycles of behavior change
  - Period of activity and inactivity (often sleep).
- Two hypotheses for controlling circadian rhythms
- Run by an internal clock
- Response to external environmental changes
  - Ex. Crickets calling/moving after dark.

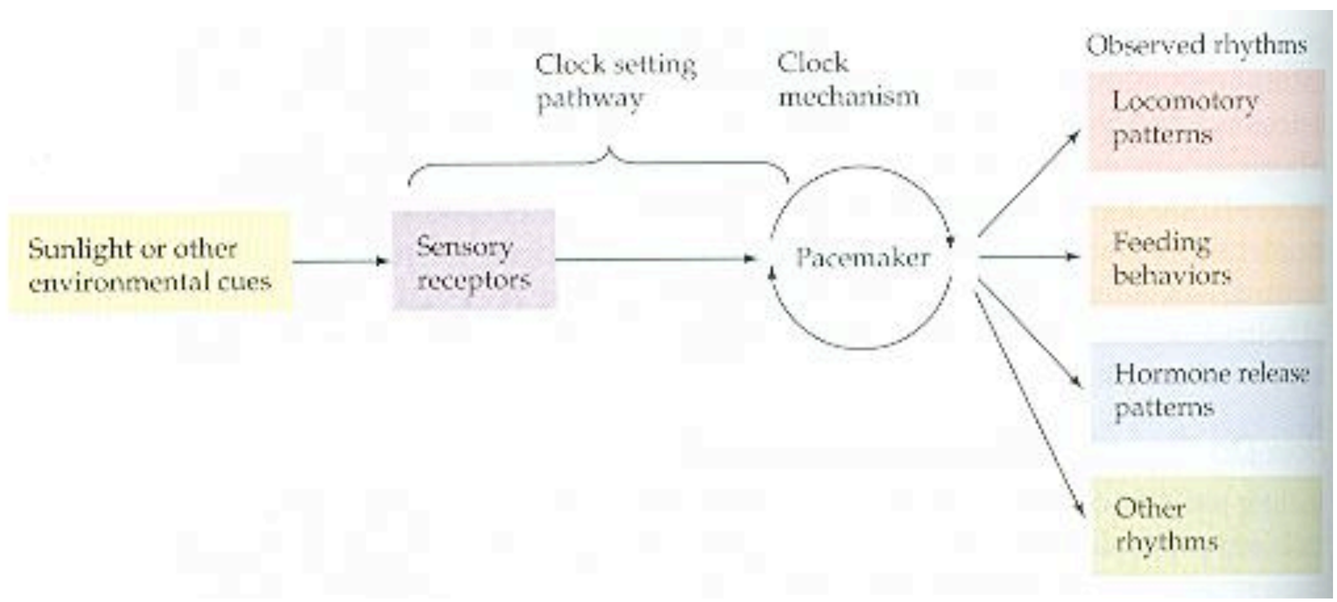
5.8 A master clock may regulate mechanisms controlling circadian rhythms within individuals



House Sparrow Example

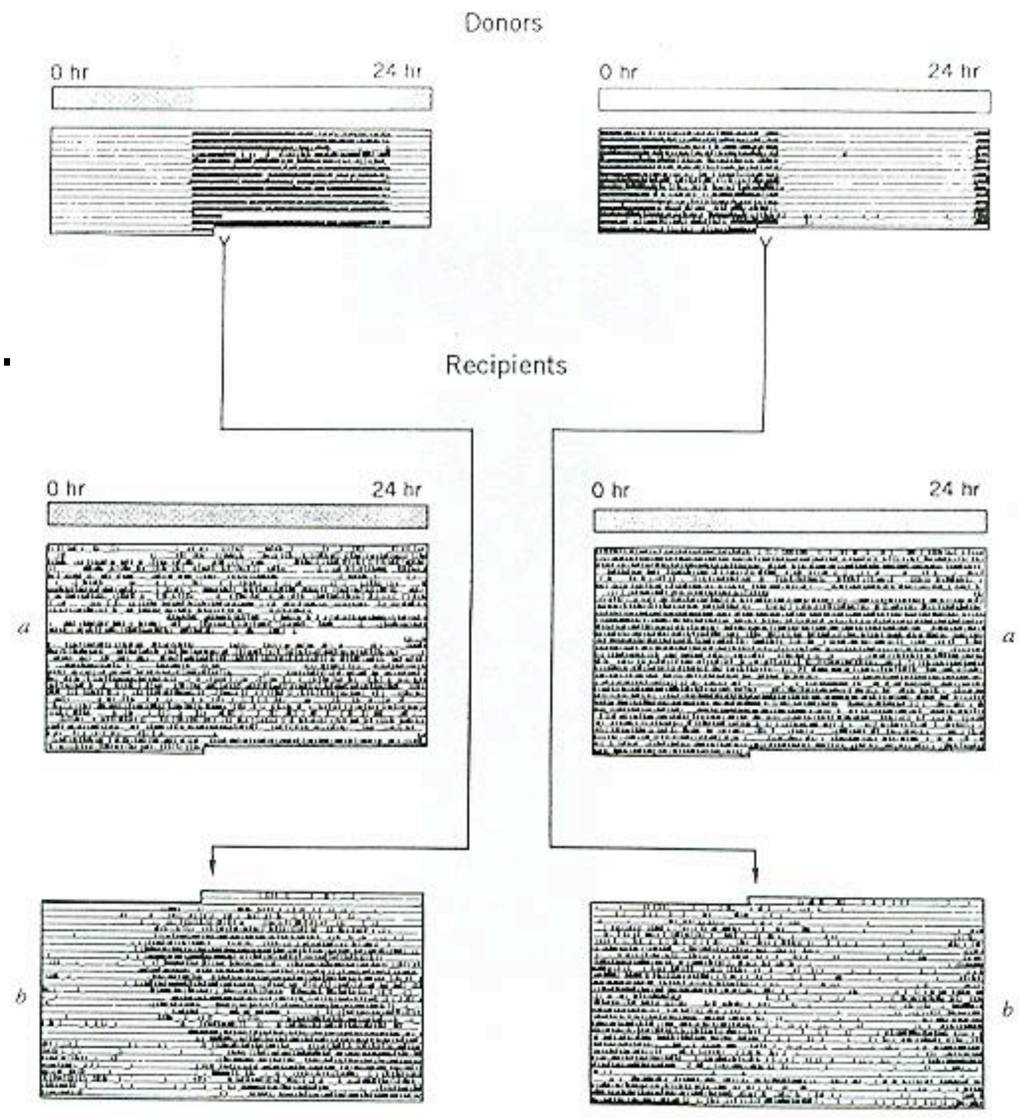
- Have 25 hour cycle
  - Period of activity changes over time
- If you pluck the feathers from the head of a blind bird– activity period is entrained with light cycle
- If scalp is inked, 25 hour cycle fails
- If you remove the ink, 25 hour cycle is set by light cycle.

- Free-running circadian cycle is timed internally
  - 25 hour cycle in house sparrow
- Cycle can be **entrained** to the day/light cycle by light itself.
- Entrainment pathway → clock mechanism → observed rhythms



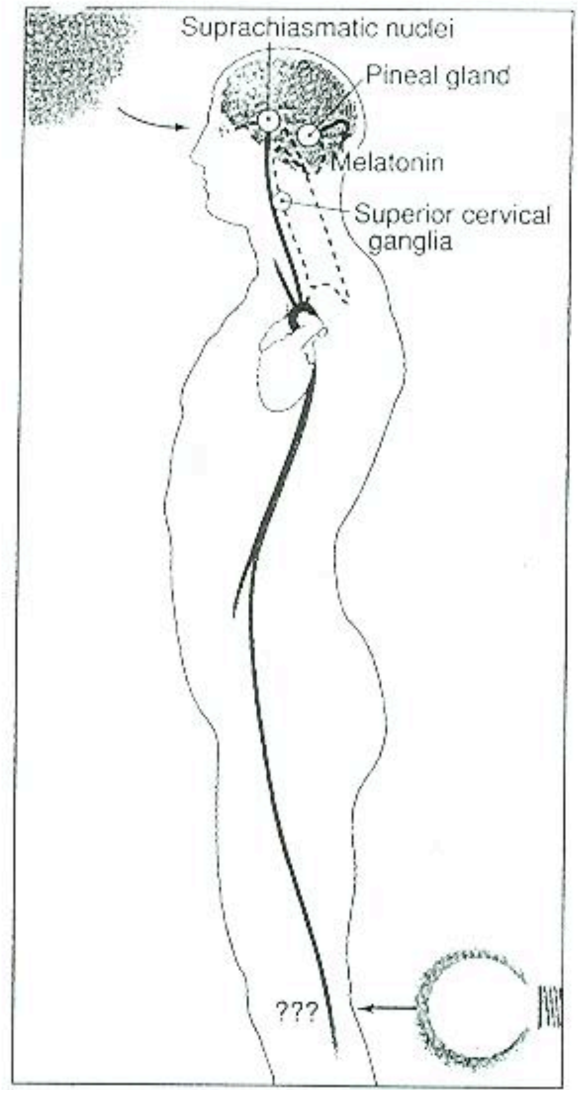
- SCN – suprachiasmatic nucleus
  - This contains the timing mechanism
- If you oblate this region (electrically fry it), the brain loses its rhythm.
- Entrainment pathways differ across animals.
- **Mammals** – phototransduction (light to brain) thru vision. Eyes – SCN
  - A neural pathway
- **Birds and Reptiles** – pineal gland detects light directly
  - A photo sensitive part of the brain that releases a hormonal signal to the SCN.

- Set 2 birds to have pineal glands to inverted light cycles.
  - A. L/D   B. D/L
- Put the glands in other birds with removed pineal glands
  - Now have cycle of A or B donor, respectively.

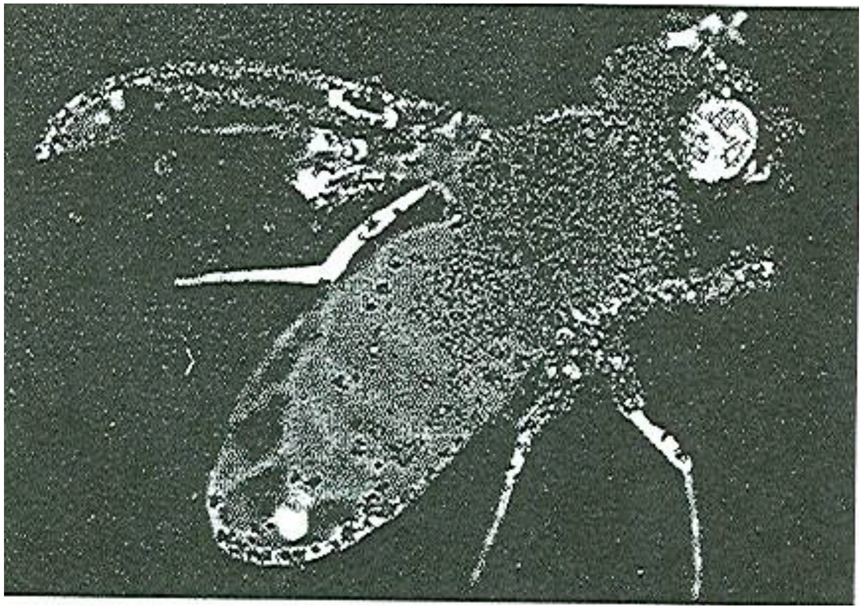


- SCN is the pacemaker of the clock.
  - A structure in hypothalamus
- Eyes → neurons → SCN (entrainment pathway)
- SCN is linked via neurons to the pineal gland.
- Pineal gland secretes rhythmic pulses of melatonin.
  - This is the messenger to the rest of the body.

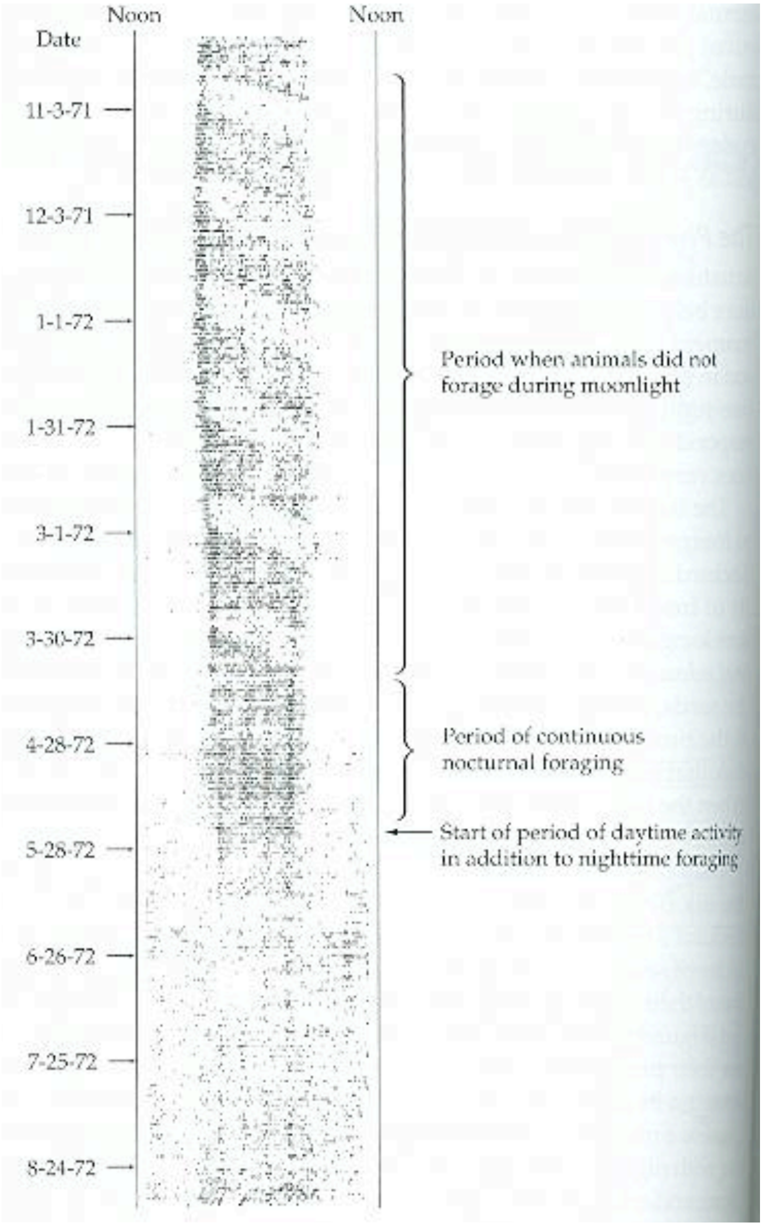
- Humans – Extraoccular phototransduction of circadian rhythms
- Evidence – can entrain a photoperiod with a light against the back of the knee????



- Independent clocks throughout the body. These clocks can be set on different cycles.
- In humans: overall activity entrains to photoperiod
  - Can entrain clock of stomach on a non 24 hour cycle
  - Another study on fruit flies
  - showed multiple biological
  - clocks as well.

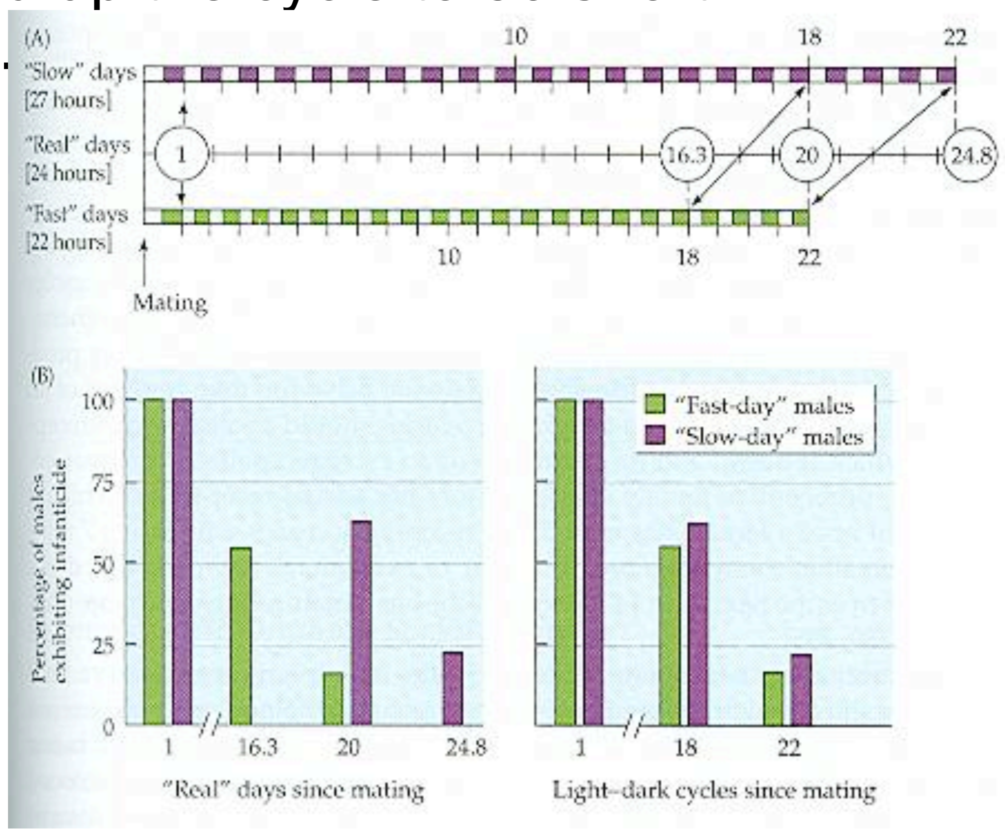


- Lunar cycle – 28 to 29 day cycle
- Many nocturnal rodents follow this
- Clear avoidance of moonlight
- Activity period reflects this fact
- Is this run by a clock?
- Lets look at *Dipodomys spectabilis* – banner–tailed K-rat
- Seem to anticipate moonrise
- Can't locate or identify this clock yet.



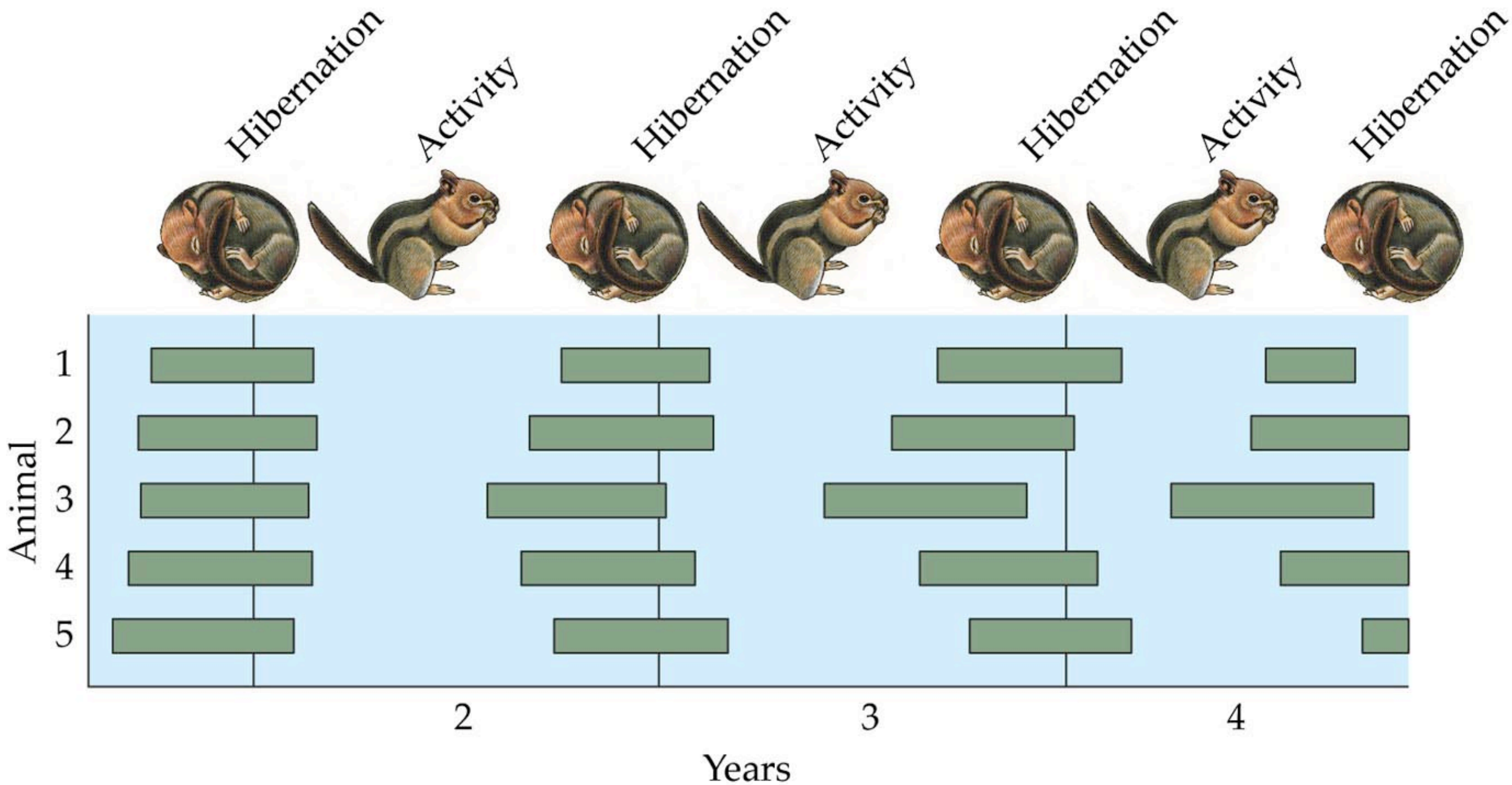
- The Reproductive Cycle of *Mus musculus*
- Copulation
- Followed by male aggression and infanticide
- Kill all young mice in home range (2-3 weeks)
- Gradual shift to parental mode when own offspring born
- Weening of young promotes copulation again.

- We know it's a clock because we can mess with it.
- A timer (somewhere) counts 50 photoperiods after copulation in ♂.
- If you speed up day (24 to 19 hour light cycle)
- You can speed up the cycle to 50 short photoperiods.



- Yearly cycles of behavior
- Ultimate selection pressure is winter
  - Summer is transition
- Tropics : annual precipitation cycle. Dry → Wet.
- Circannual rhythms are timed by a biological clock of some sort.
  - Pineal? SCN? Not well understood.

5.14 Circannual rhythm of the golden-mantled ground squirrel



- Food
- Little food – some animals will not breed
  - Ex. Pinyon jays – only breed if they see green pine cones in spring
- Circannual cycle of WCSP
- Spring → Summer → Fall → Winter
- Gonadal Breeding Migration Non-reproductive
- growth behavior

Social Influences on Circannual Timing

- Breeding activities re-enforces start of breeding activity
- Ex. Elk (red deer)
- Early spring – play roaring calls of males on tape.
- Females will start ovulating
- Suggests a variable reproductive environment