

Senses

Changes in the physical world

Natural, other individual, own

Unlimited possibilities, but there are physical and anatomical constraints.

Modality: channel (e.g. chemical, visual, magnetic)

Immense differences among species, between sexes, age groups

Perception:

1) what sensory organs can detect

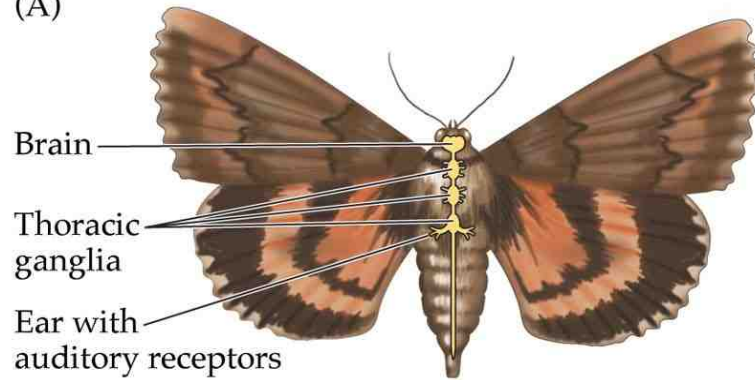
2) what CNS can abstract

Perception space – subjective universe – Umwelt

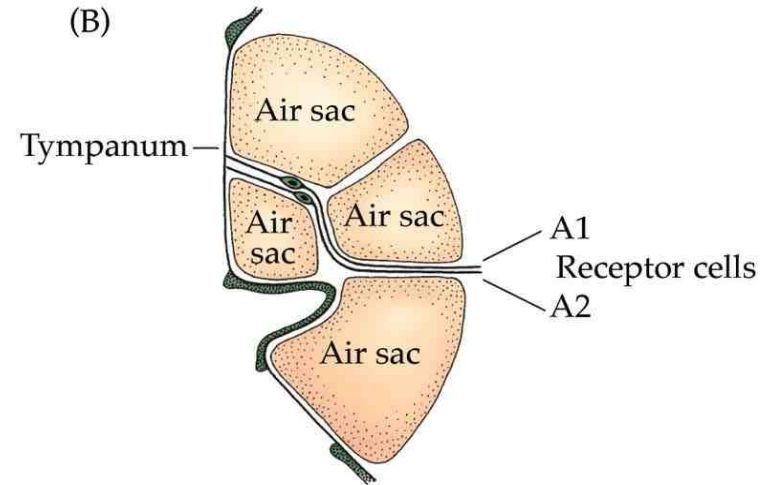
Cognitive space!

Auditory

(A)



(B)

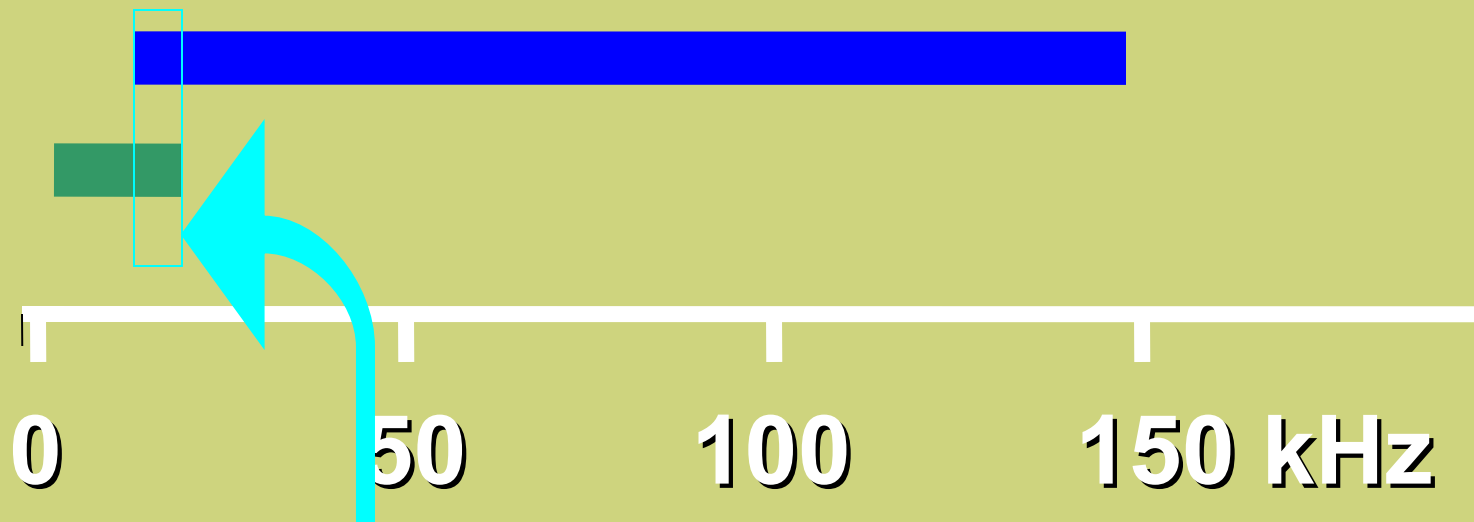


Ears: 2-2 neurons

Human vocalisation: cca. 2 kHz

Human hearing: 20 Hz – 20 kHz (actually from 4-5 Hz)

Bat vocalisation: 10 kHz – 150 kHz



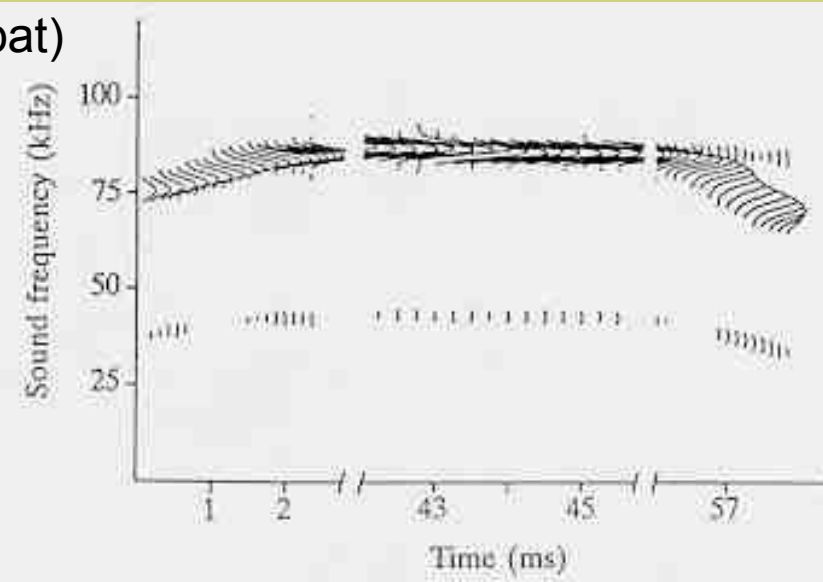
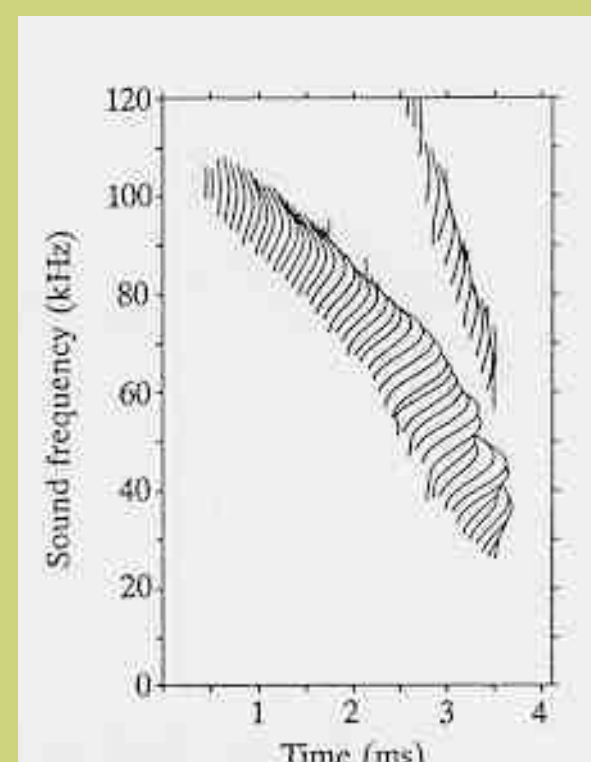
**High
intensity**

FM and CF sound production in bats

Echo locating bats use one or both (predominantly):

1. Frequency Modulated (FM) pulses 20-200 kHz
 - Broadband signals
 - < 5 ms in duration
 - Pulse starts high frequency, sweeps down
 - used to calculate target distance/detail
1. Constant Frequency (CF) pulses
 - Narrow frequency band
 - Fewer harmonics
 - Typically greater than 5 ms
 - Provides Doppler shift information (object movement relative to the bat)

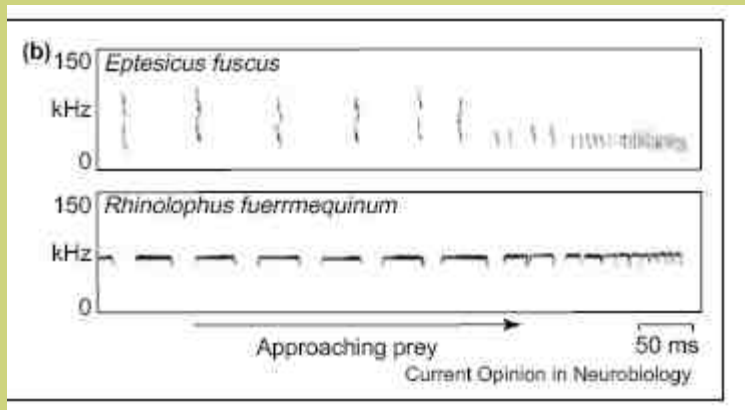
[www.as.wvu.edu/daly/439/
lecNotes/CH2/CH2L1.ppt](http://www.as.wvu.edu/daly/439/lecNotes/CH2/CH2L1.ppt)





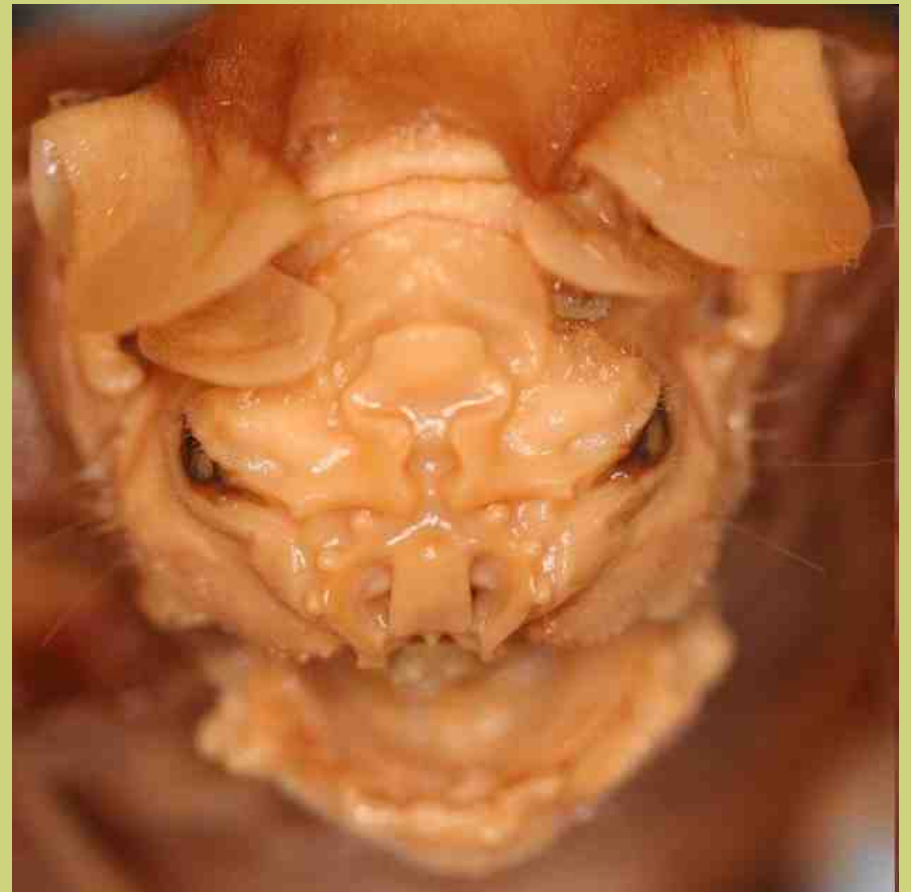
Bat

one call can contain both FM and CF



FM and CF-FM bat
frequency of clicks increase
when approaching prey

Bats



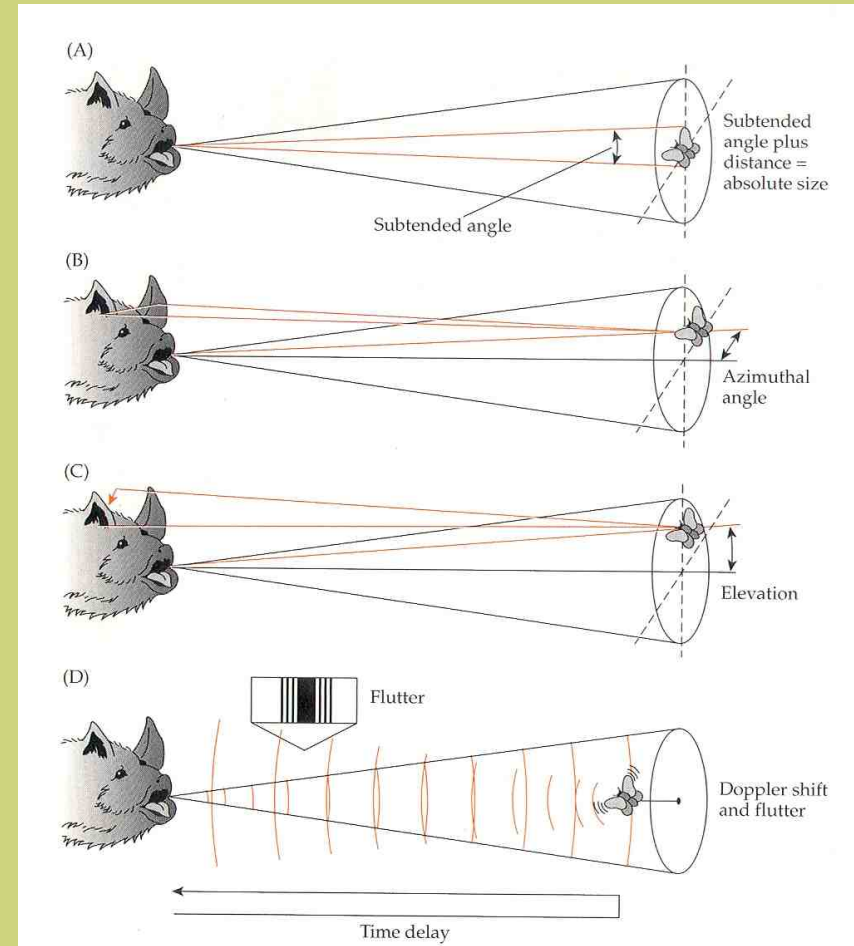
300 species emits clicks from nose

Zhuang and Müller (2006) PhysRevLett

3D PC simulation. Structure modifies sound

Specific parameters that bats extract from echoes about objects

- **Distance:** (FM). Based on echo delay
- **Subtended angle** or angular size. Based on echo loudness; (CF-FM)
- **Absolute object size**, based on Delay + loudness (CF-FM)
- **Azimuth:** the horizontal position (angle) of an object relative to the face. Based on aural delay (CF-FM)
- **Elevation** of object (vertical angle relative to face) differential loudness based on changing ear position
- **Texture** of object based on FM
- **Velocity/relative velocity** of object (change in distance relative to bat) Doppler shift



"Unexpected threat
for a gleaning
insectivore"

Plecotus species
catches insects
from leaves



echolocation



A number of species:

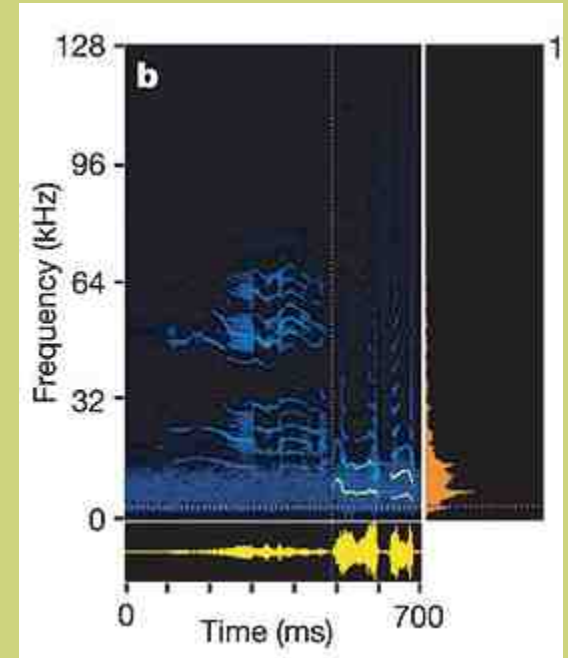
- Most cetaceans
- Some nocturnal birds (you can hear the clicks)
swiftlets, oil bird
- Some rodents
- Blind mole rat (*Spalax ehrenbergi*) generates seismic waves

(<http://jeb.biologists.org/cgi/reprint/208/4/647>)



Feng et al. (2006) Nature
Ultrasonic communication in
frogs

Amolops tormotus male frogs
respond to ultrasound calls



Plainfin Midshipman



Porichthys notatus male: loud call in spring and summer at night



Plainfin Midshipman

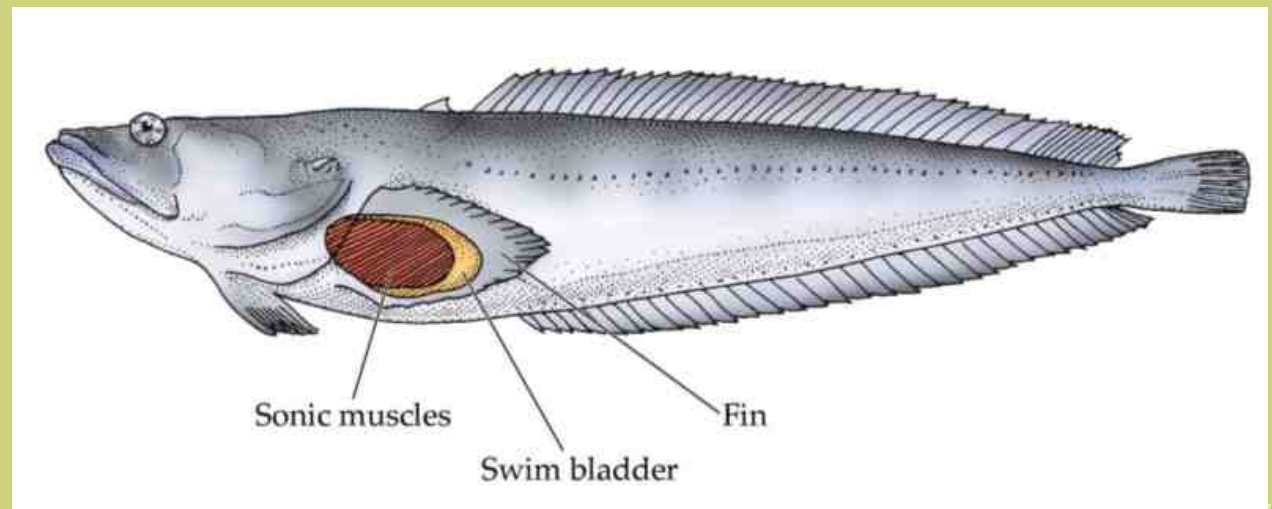


Attracts females

(estradiol injection increases their response).

How is sound generated?

Rhythmic movement of muscles around swim bladder



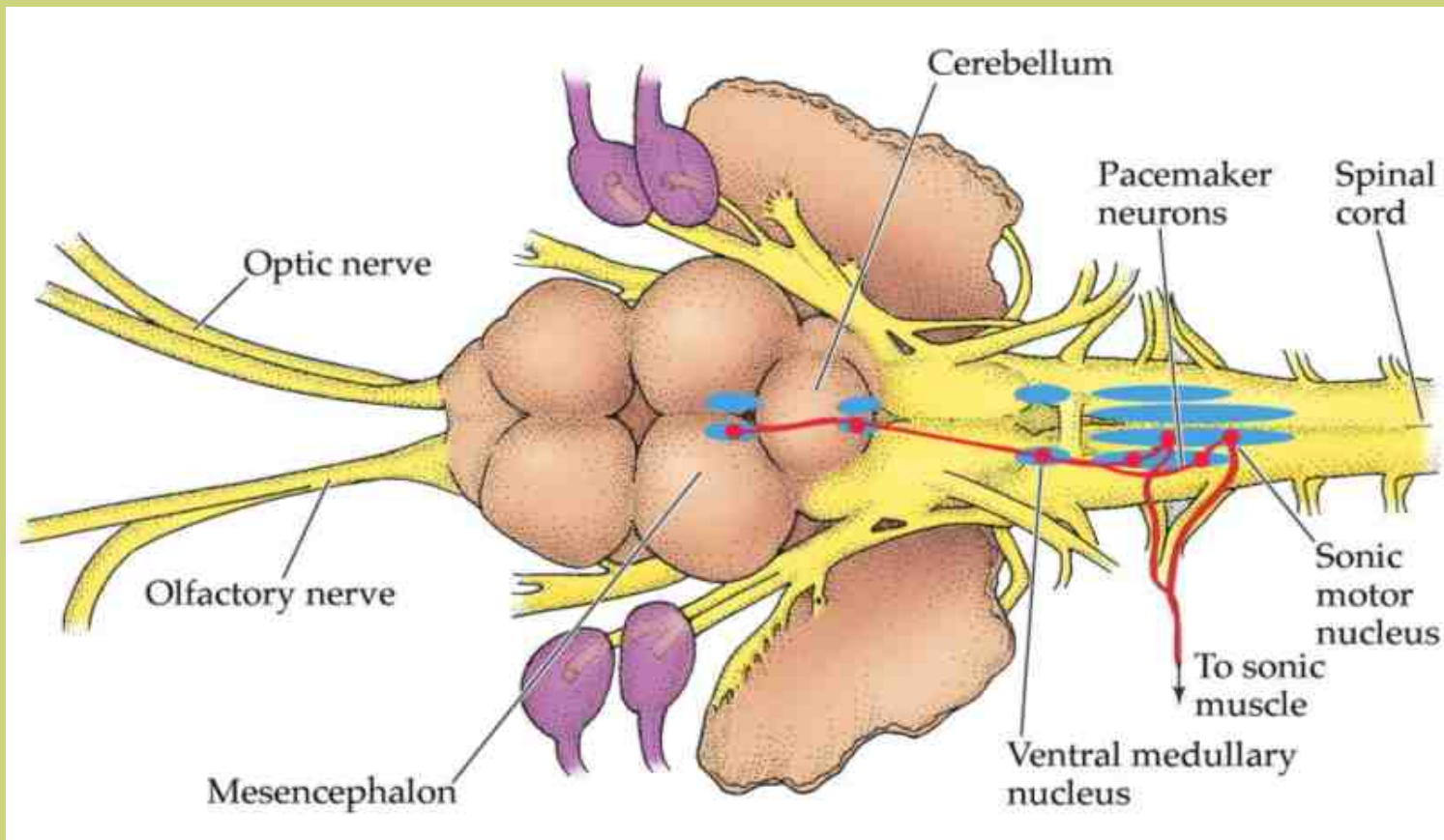
Plainfin Midshipman



CNS: path tracing by

Byocitin into motor neurons

Byoticin is taken and transferred through
synapses



Command from midbrain and cerebellum

Sonic motor nucleus (2 thousand neurons)

Pacemaker neurons (CPG)

During calls increases threshold of hearing → disturbs anglers but not himself

Searching for a host

Ormia fly female injects eggs into
male crickets Video



Searching for a host

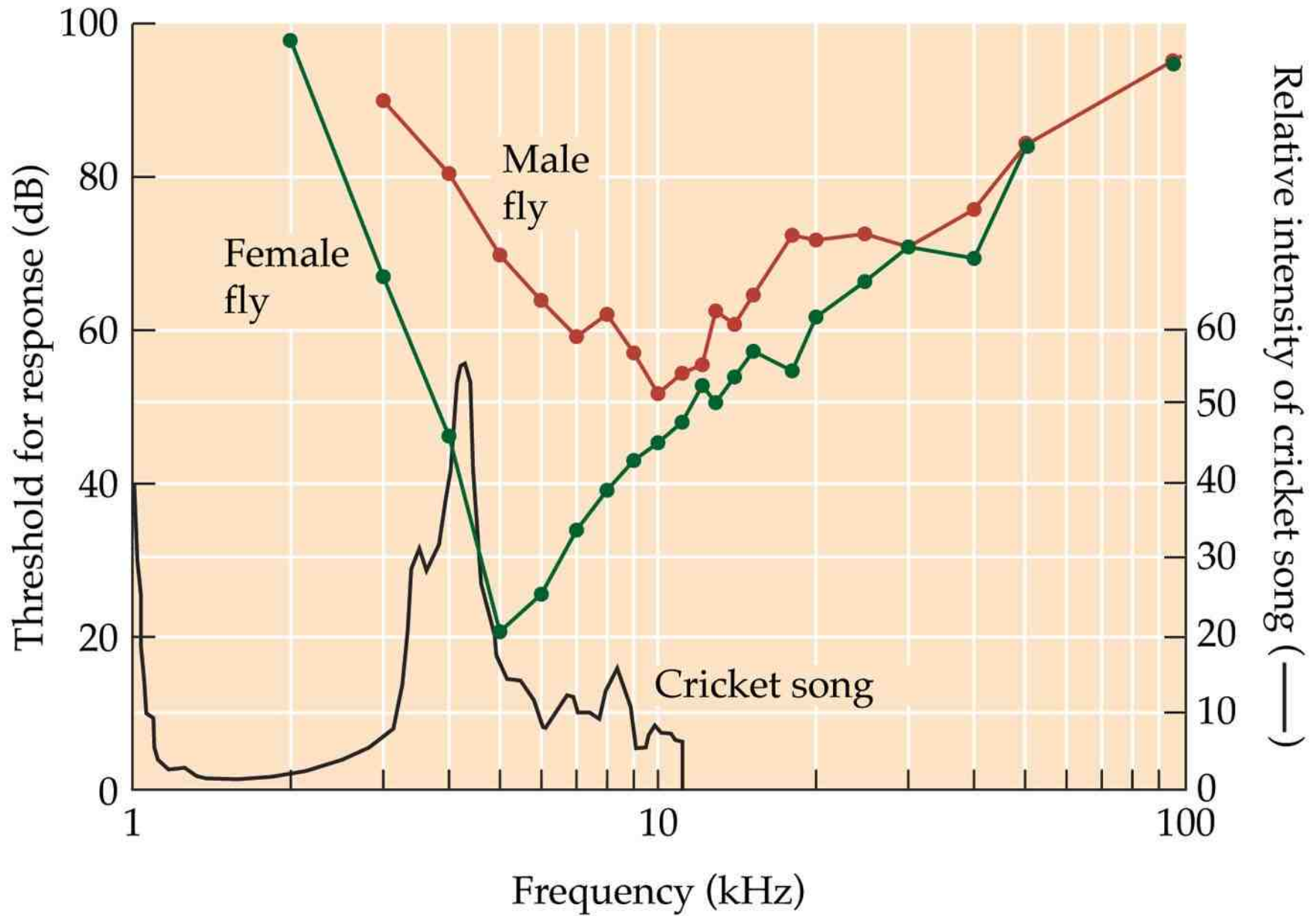


Ears on two sides of thorax

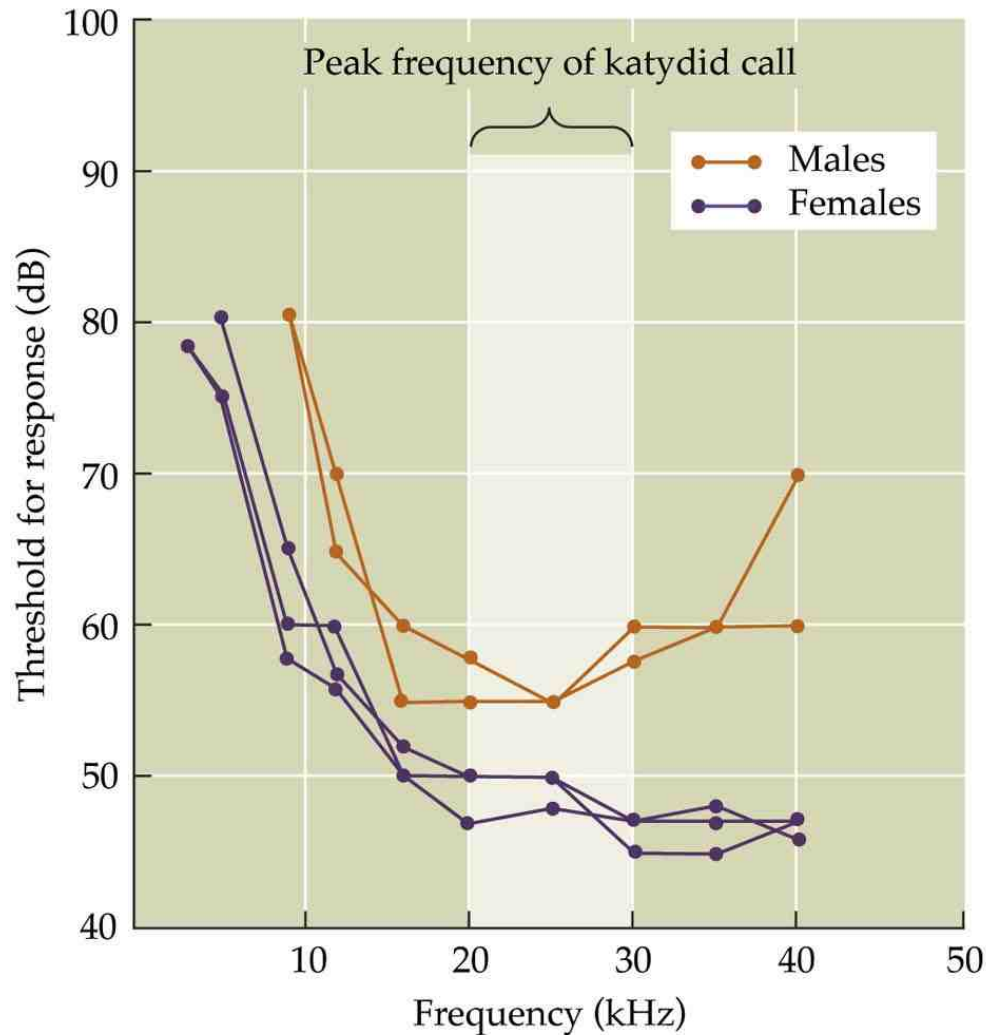
Sexual dimorphism

Female senses cricket calls at a distance of several hundred meters

4.25 Tuning curves of a parasitoid fly

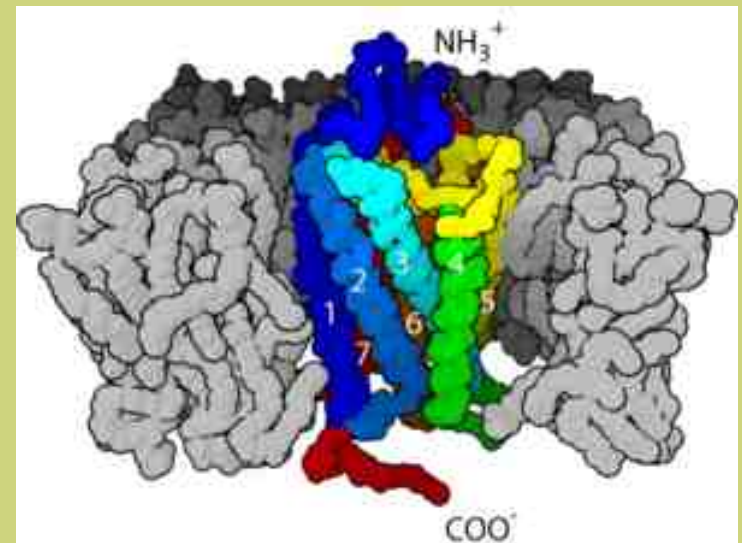
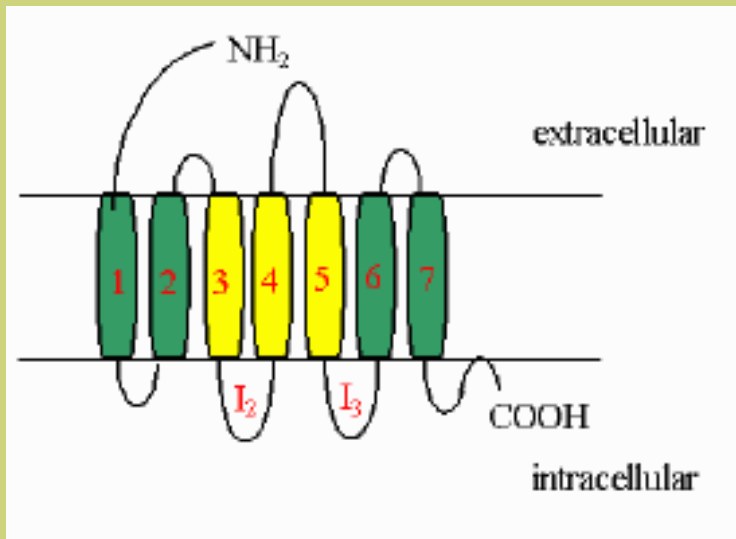


Tuning curves of a katydid killer (*Therobia leonidei*)



Olfaction

Olfactory receptors: one type can bind several similar molecules
Odour is perceived as an activation pattern of neurons with different receptors



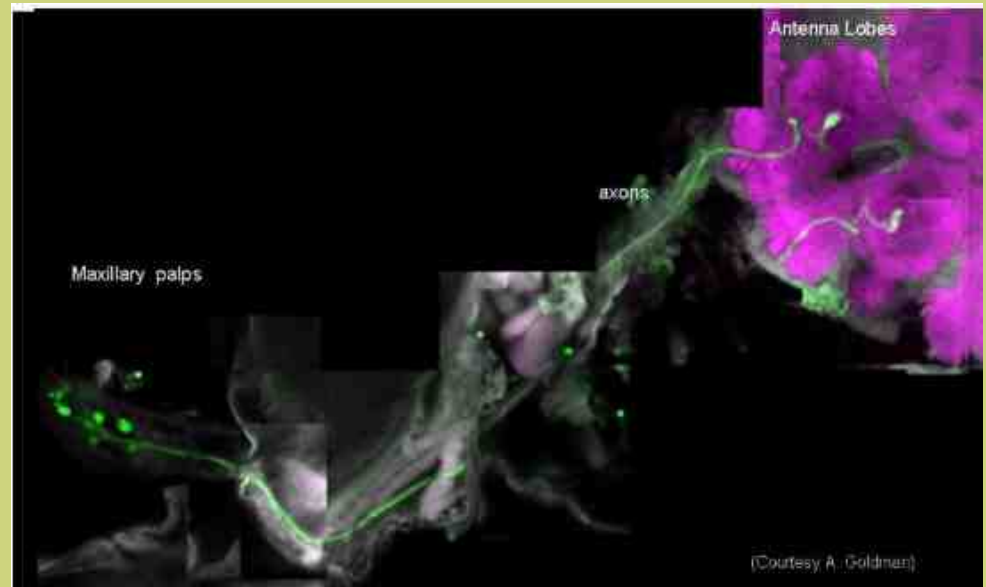
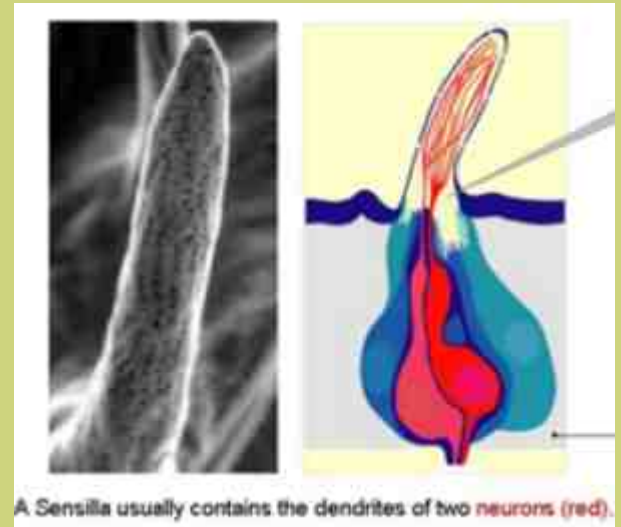
Olfaction

Drosophila: sensilla

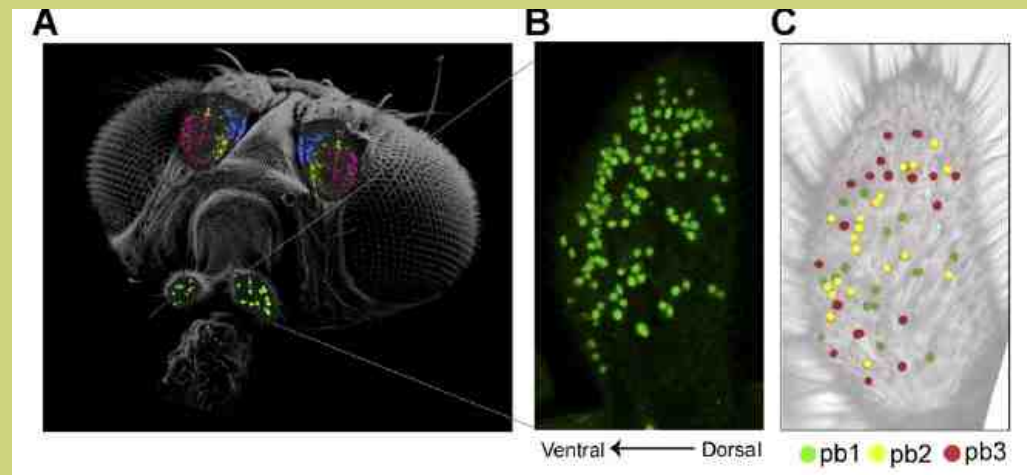
Each sensillum contains
two types of neurons
(A and B)

A single type of olfactory
receptor(OR) is
expressed in a single
neuron

Identical neurons
innervate the same area



Olfaction



Drosophila: 60 OR genes

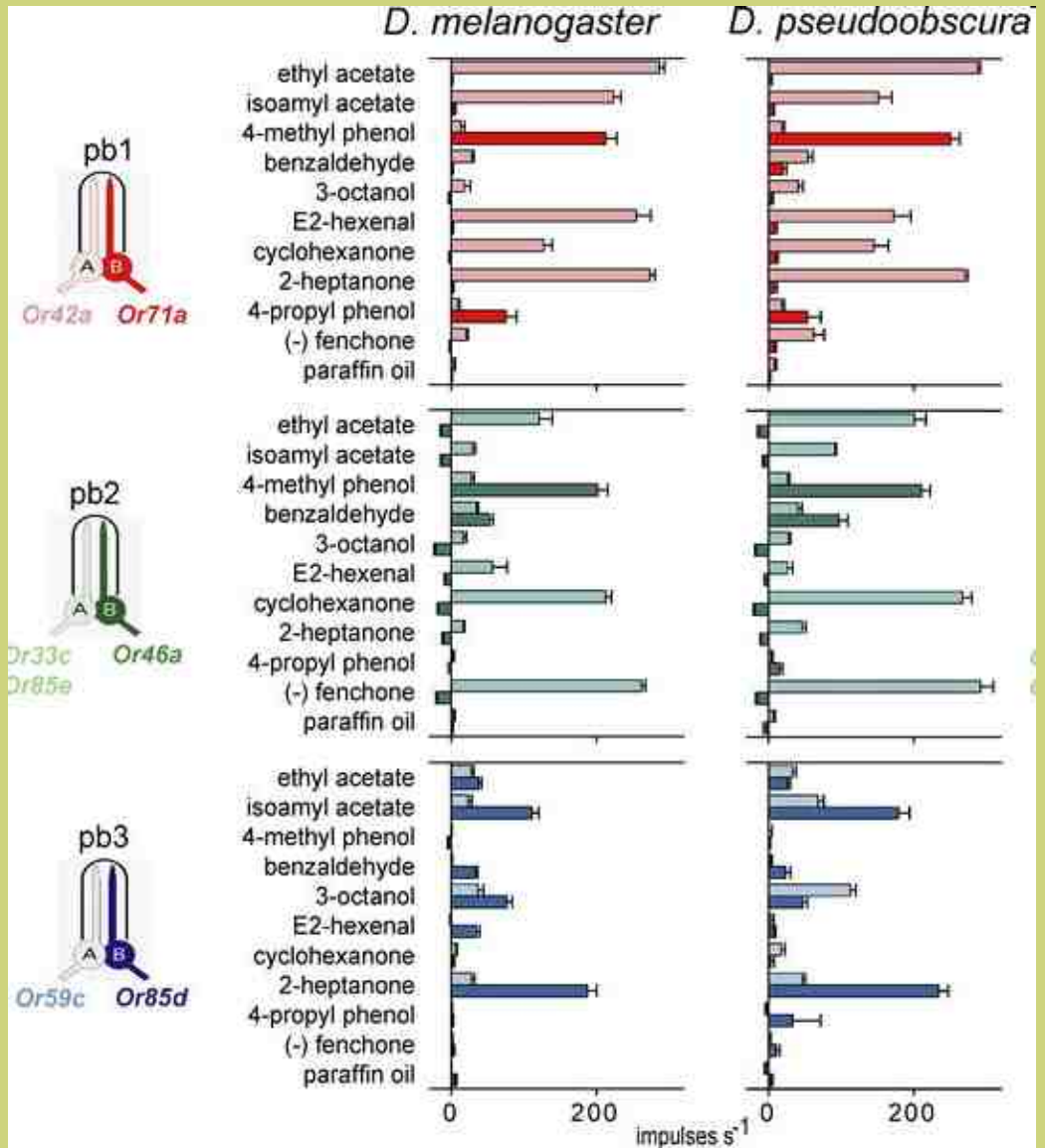
Ray et al. (2008) PLOS Biol.

Neurons of 4 types of OR were stained
in 3 types of sensillum (pb1, pb2, pb3)

Food makes male flies frisky

Removing the gene for an olfactory protein called IR84a makes male flies less apt to perform their song and dance

Phenylacetic acid and phenylacetaldehyde are released by food of larvae



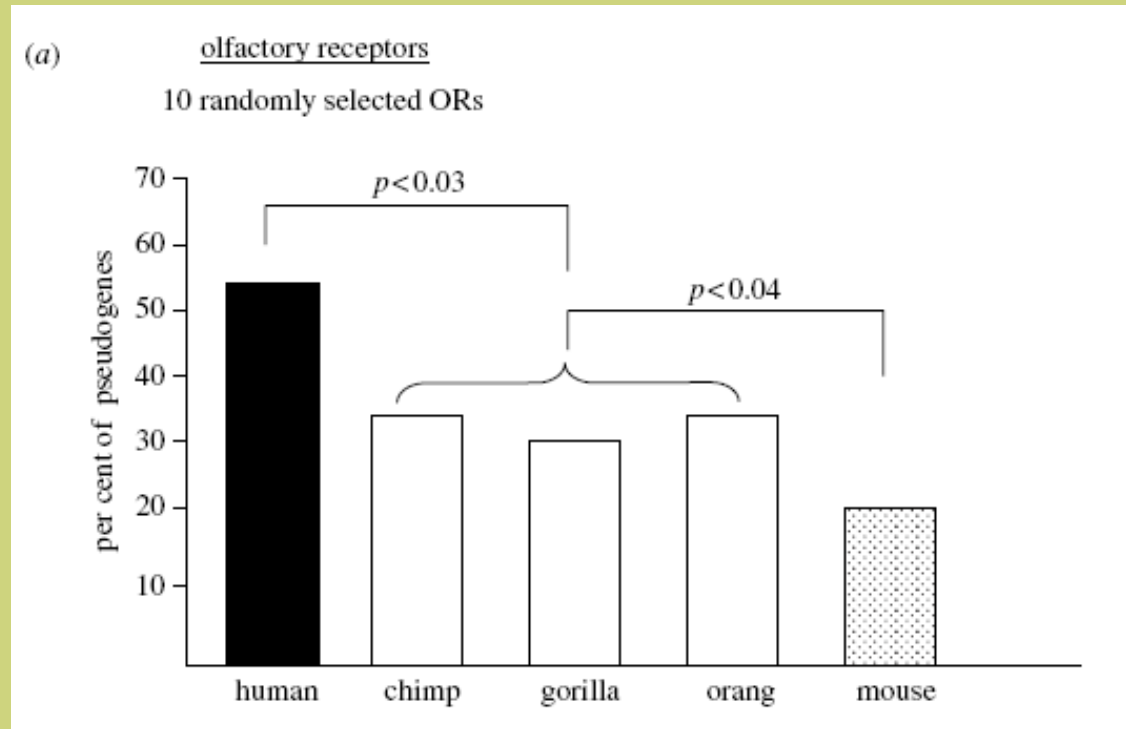
Odour combinations, new odours differentiated by the differential pattern

Ray et al. (2008) PLOS Biol.

Vertebrates: cca. 1000 OR genes

Apes: most genes went wrong – pseudogenes

(humans have about 400 functional OR genes)

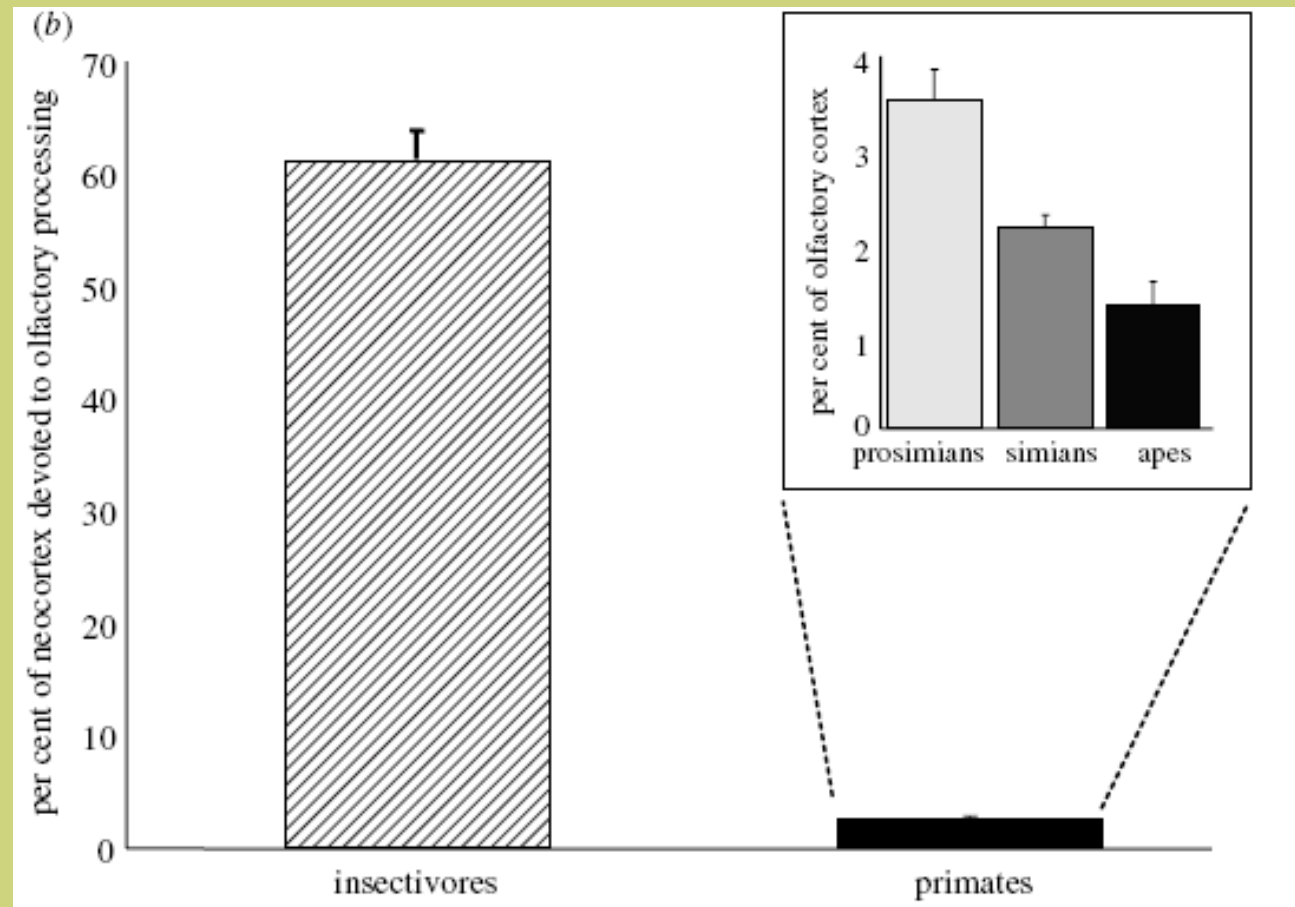


Wouldn't it be nice to sniff as a rat?

Processing:

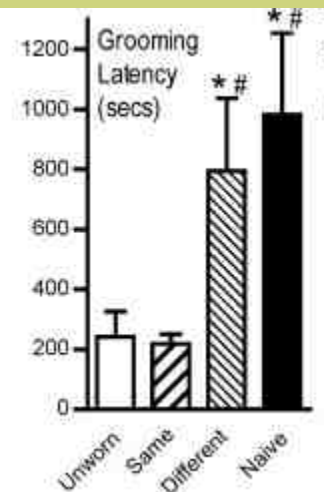
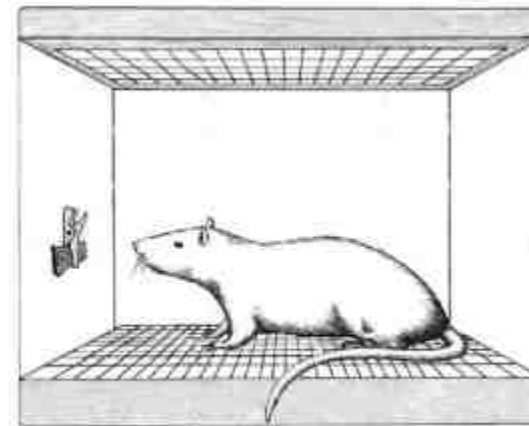
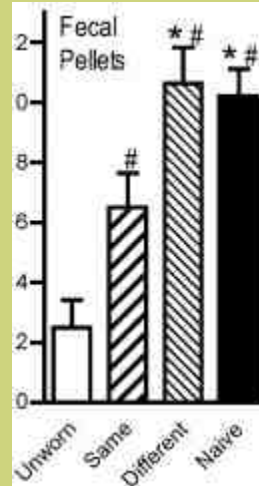
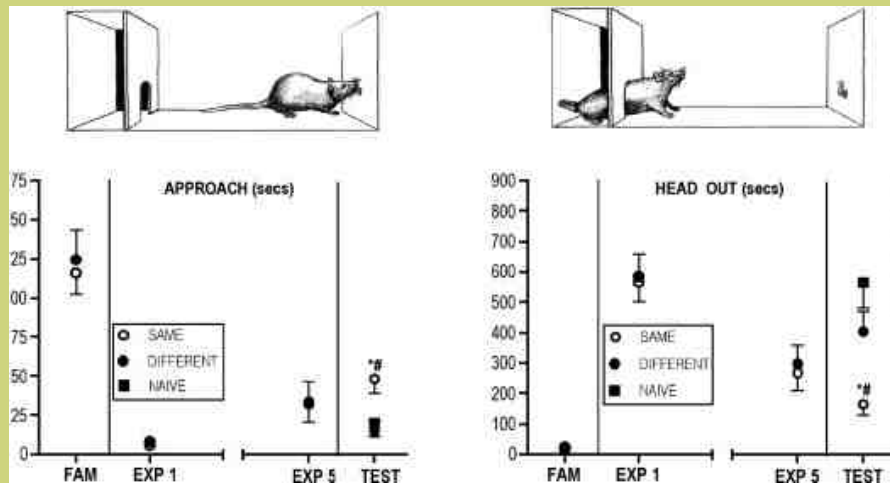
insectivores: 60% of neocortex

apes: 1-2%



Rats can identify individual cats by smell (habituation to collar)

McGregor (2008) Neuroscience Biobehav Rev.



Olfaction

Mammals:

primary: nose

secondary: vomeronasal organ
(VNO):

Flehmen



Figure 4.26 The star-nosed mole's nose differs greatly from that of the eastern mole and even more from those of its distant relatives



Figure 4.27 A special tactile apparatus (Part 1)

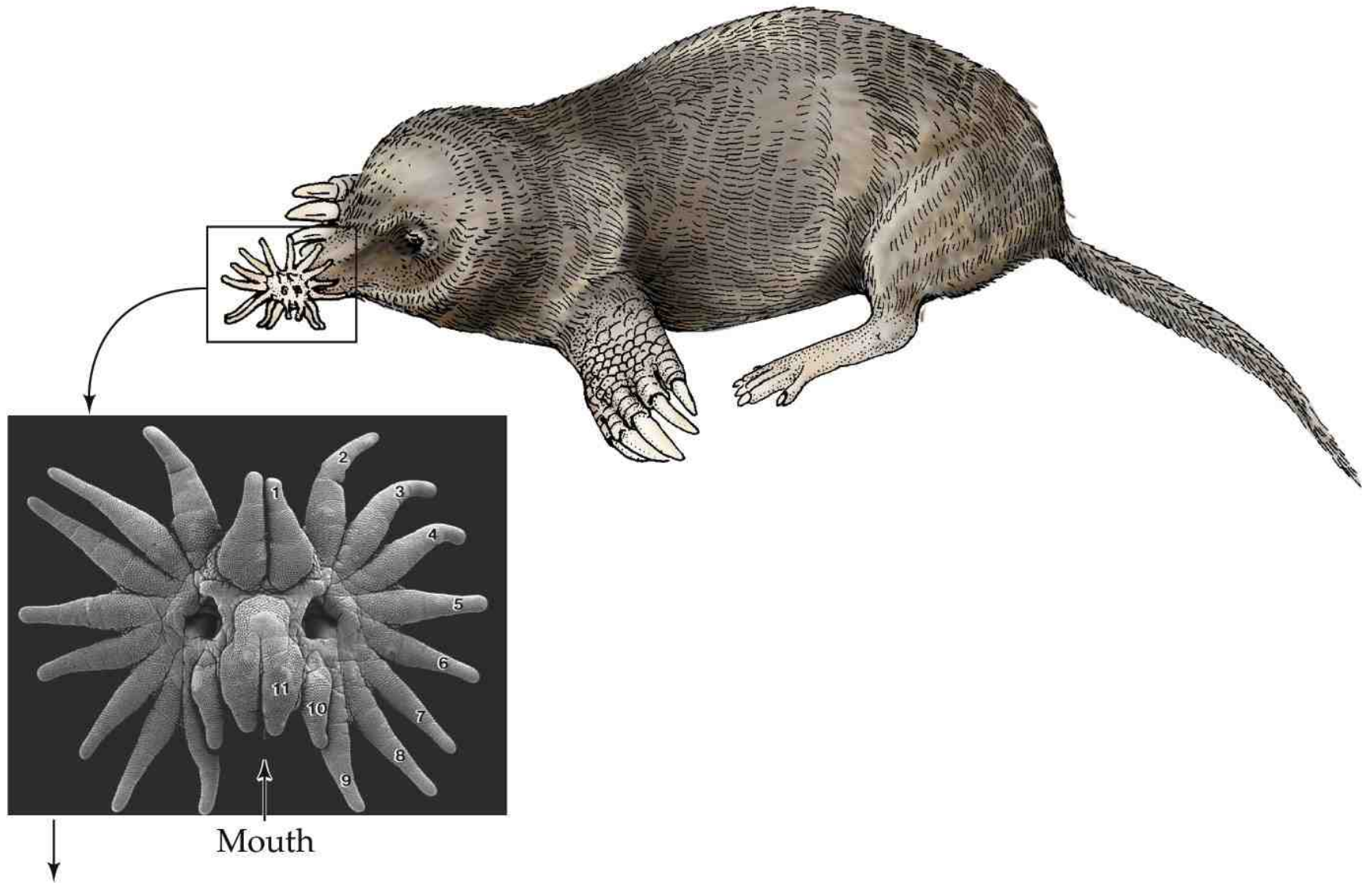
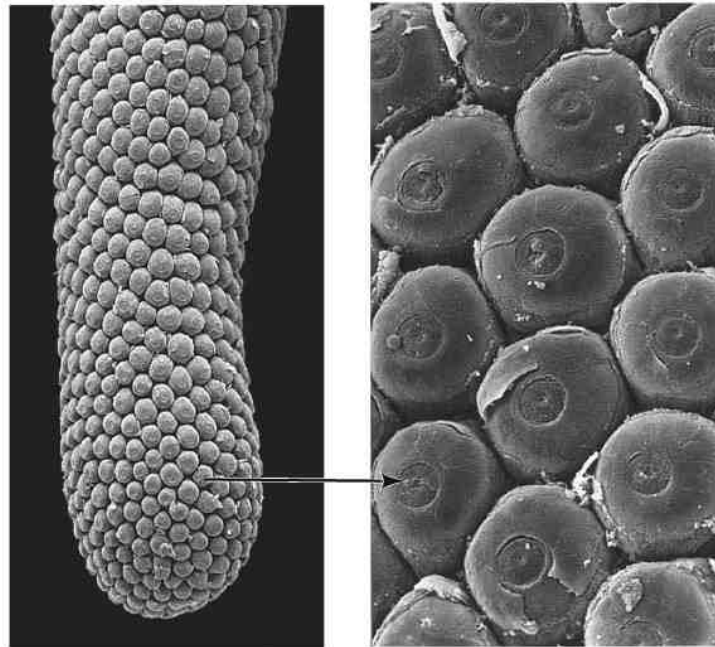
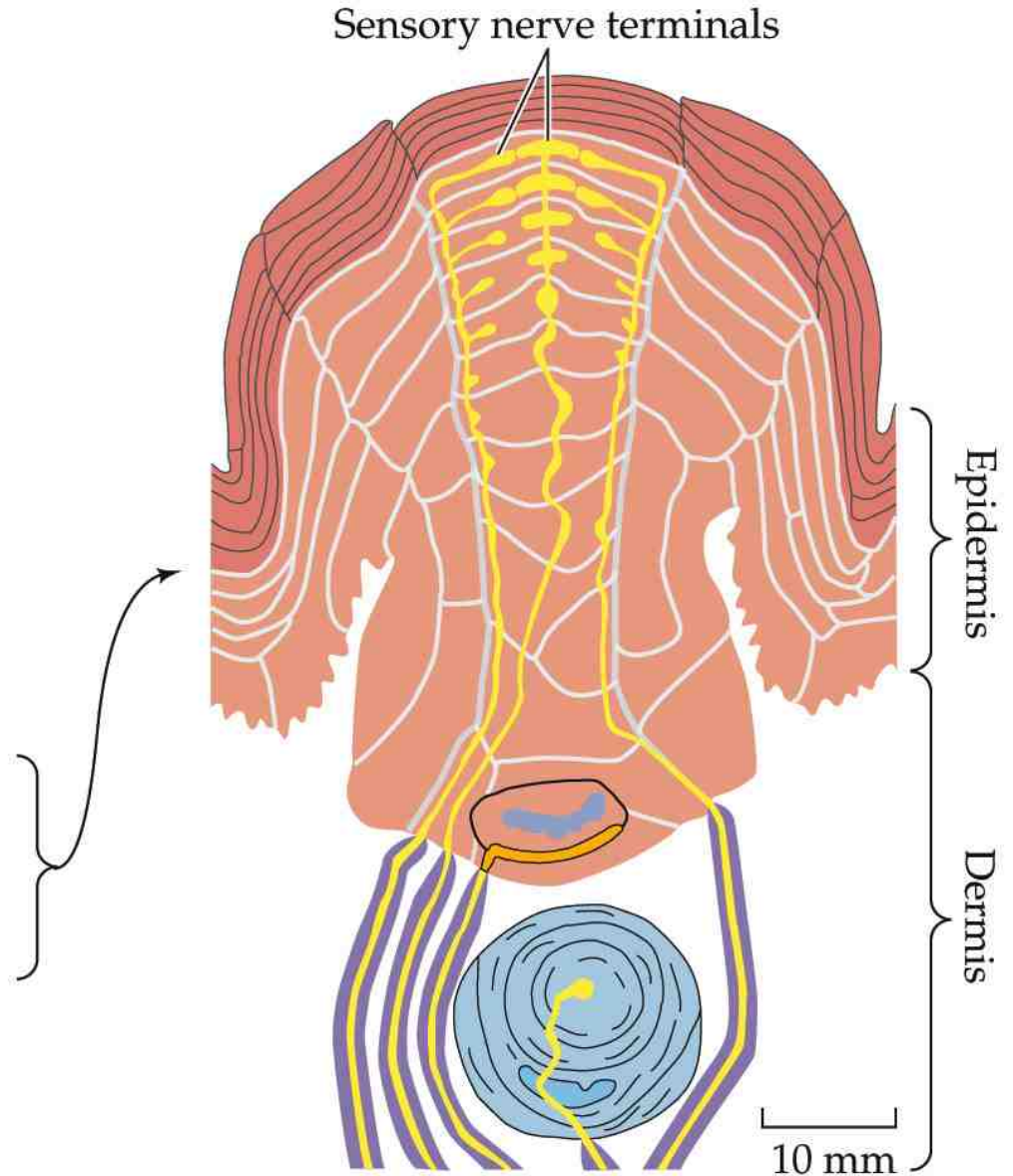


Figure 4.27 A special tactile apparatus (Part 2)



Eimer's organs

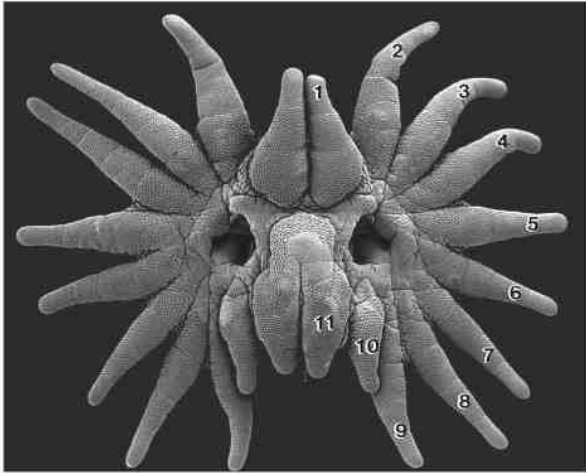


A single Eimer's organ

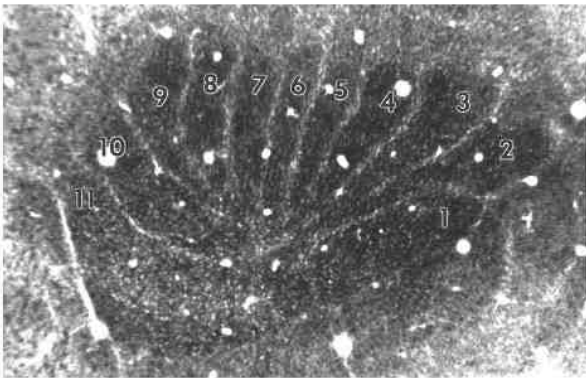


Figure 4.28 The cortical sensory map of the star-nosed mole's tactile appendages is disproportionately weighted toward appendage 11

(A)



(B)



(C)

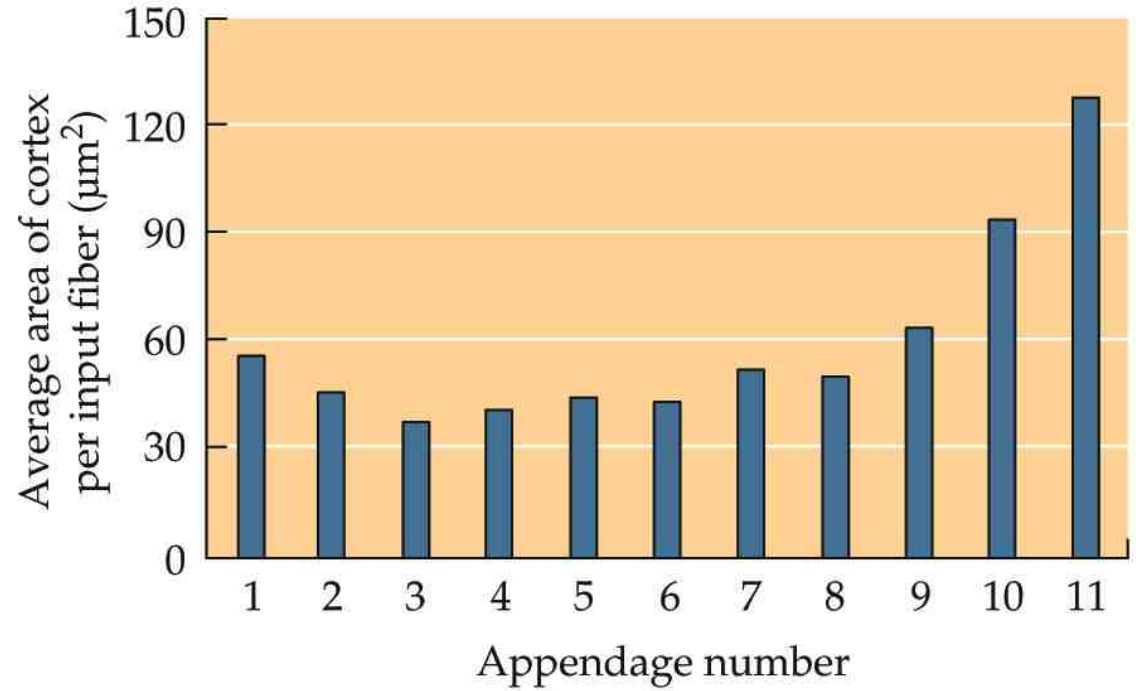
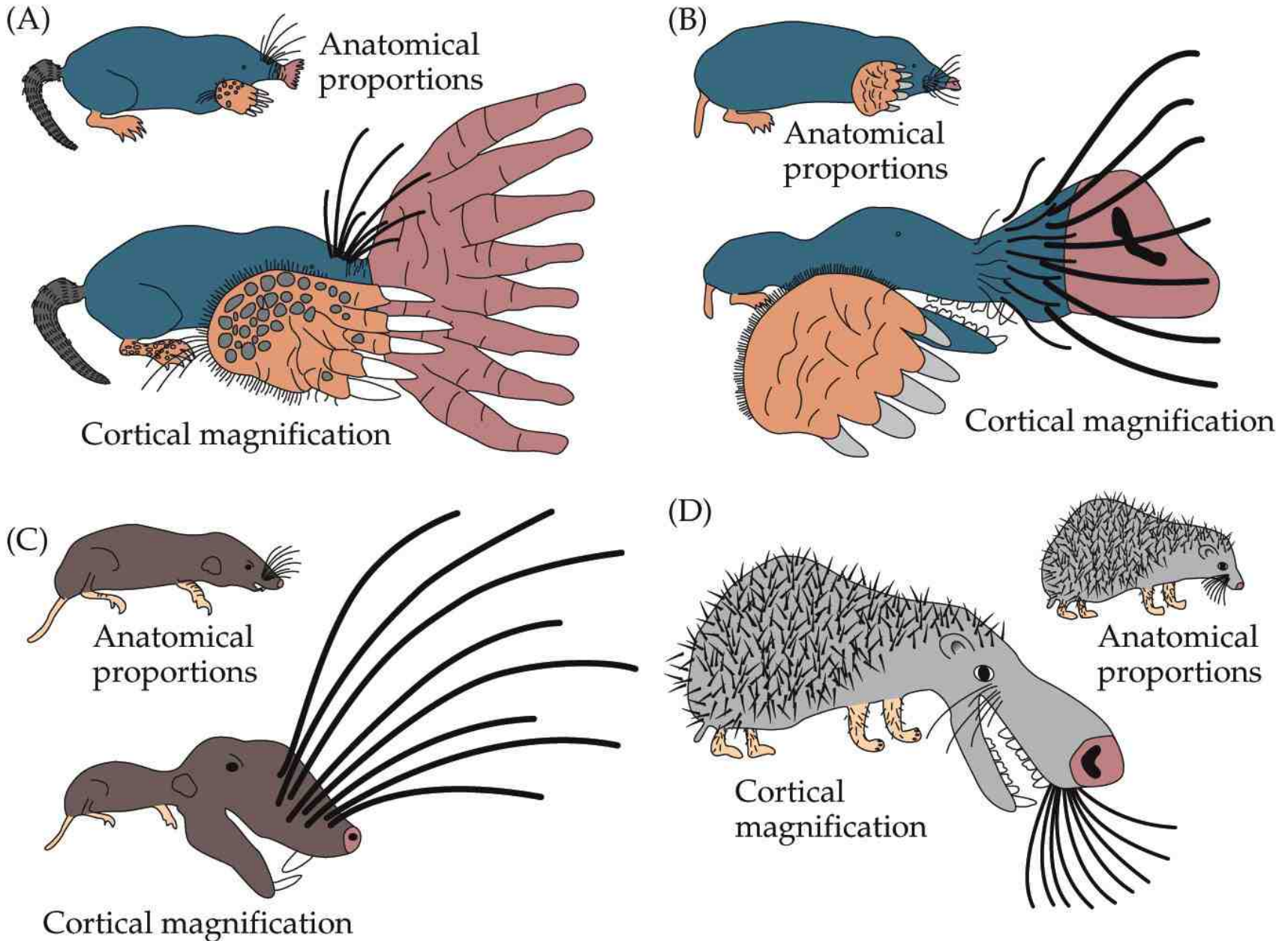


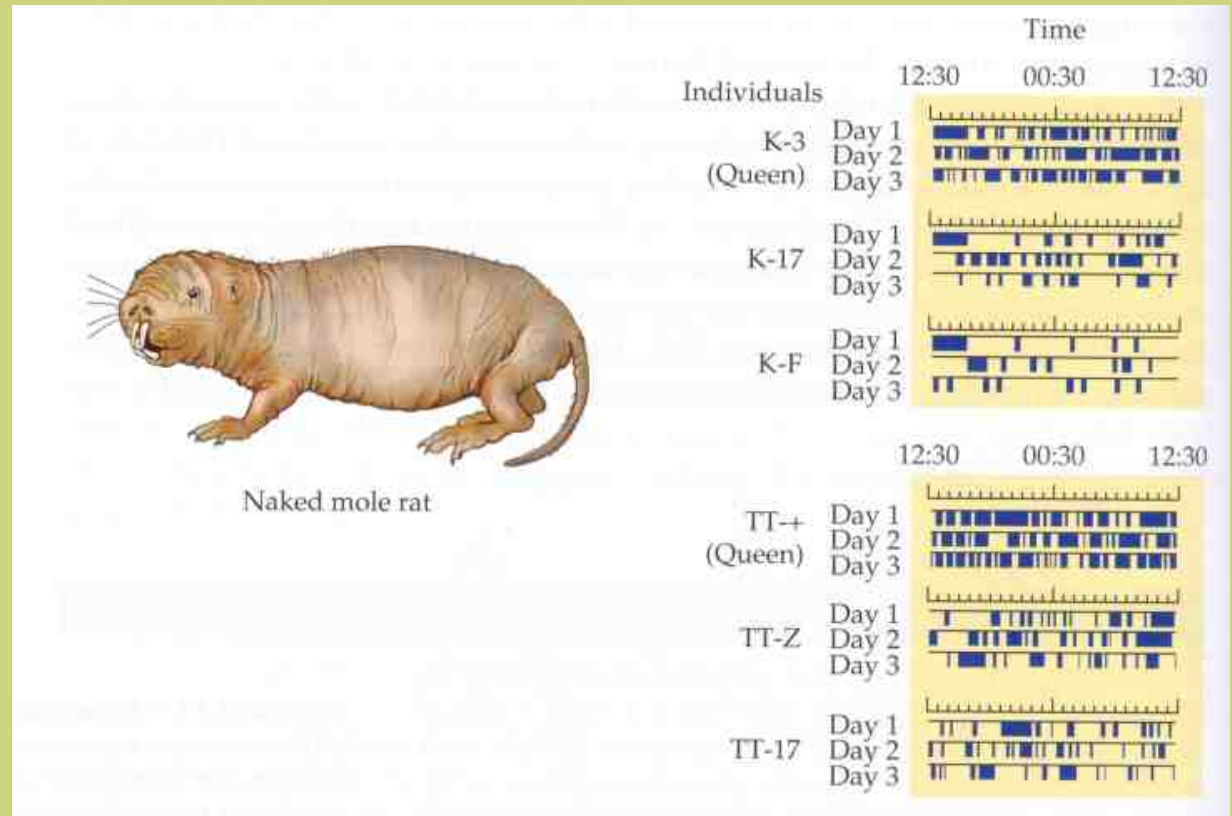
Figure 4.29 Sensory analysis in four insectivores



tactile

Naked mole rat (*Heterocephalus glaber*)
under ground, eusocial

Memo:
no circadian
rhythm



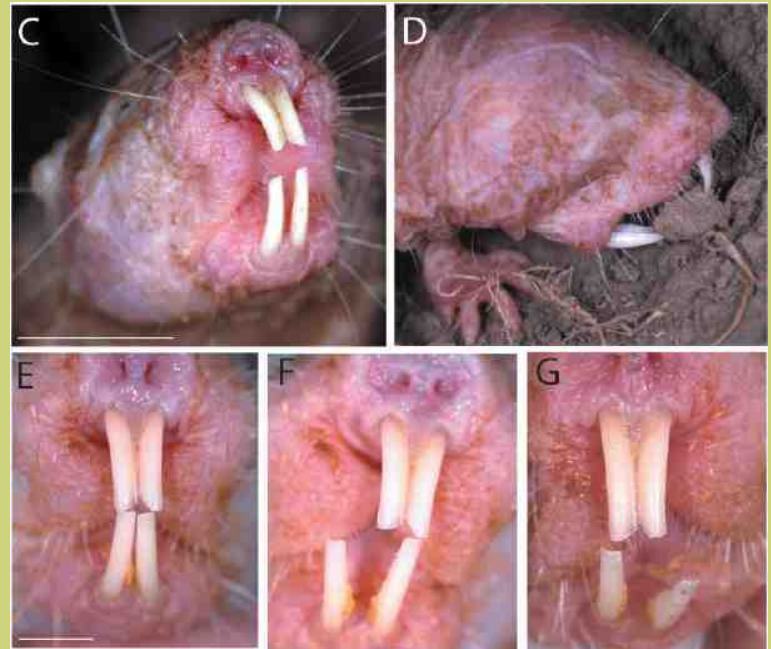
Tactile

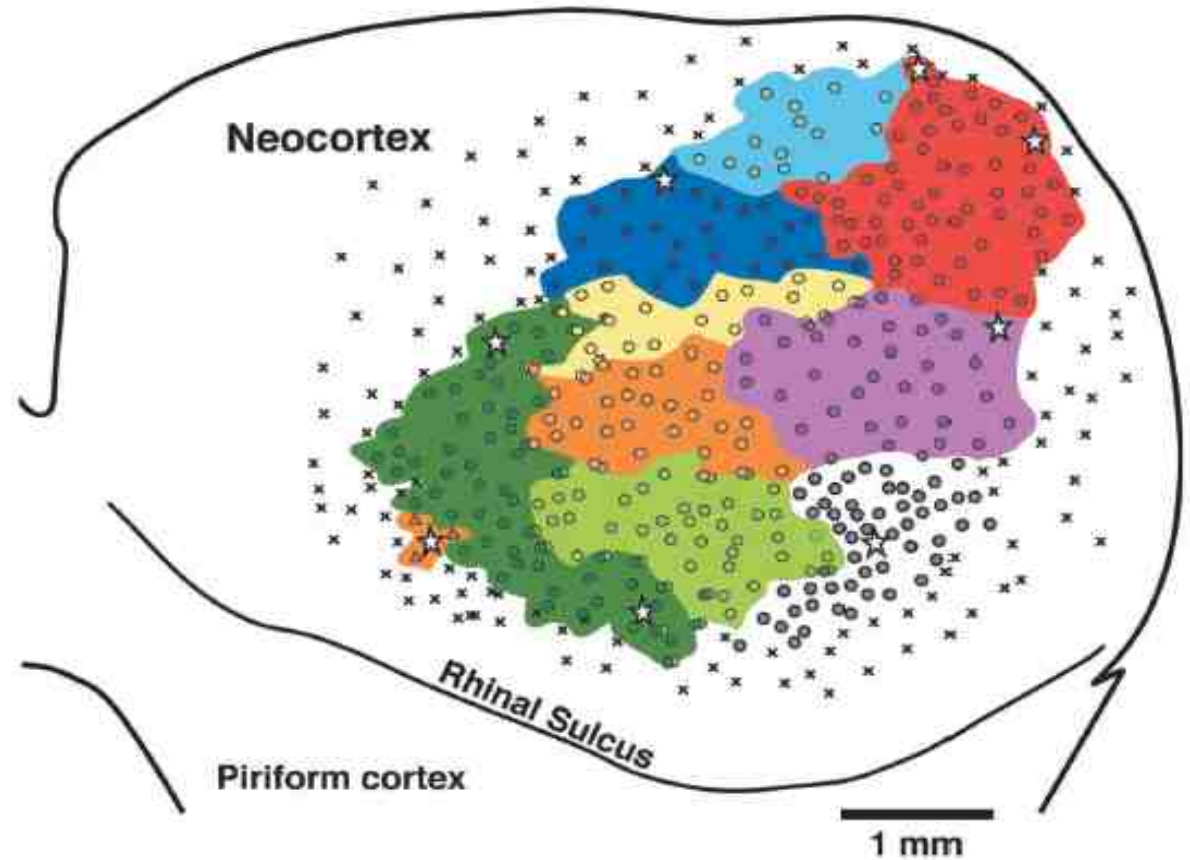
Naked, reduced eye, ear

How does it sense the environment?



Can move lower incisors independently
Catania and Remple (2002)
mapped cortical representation

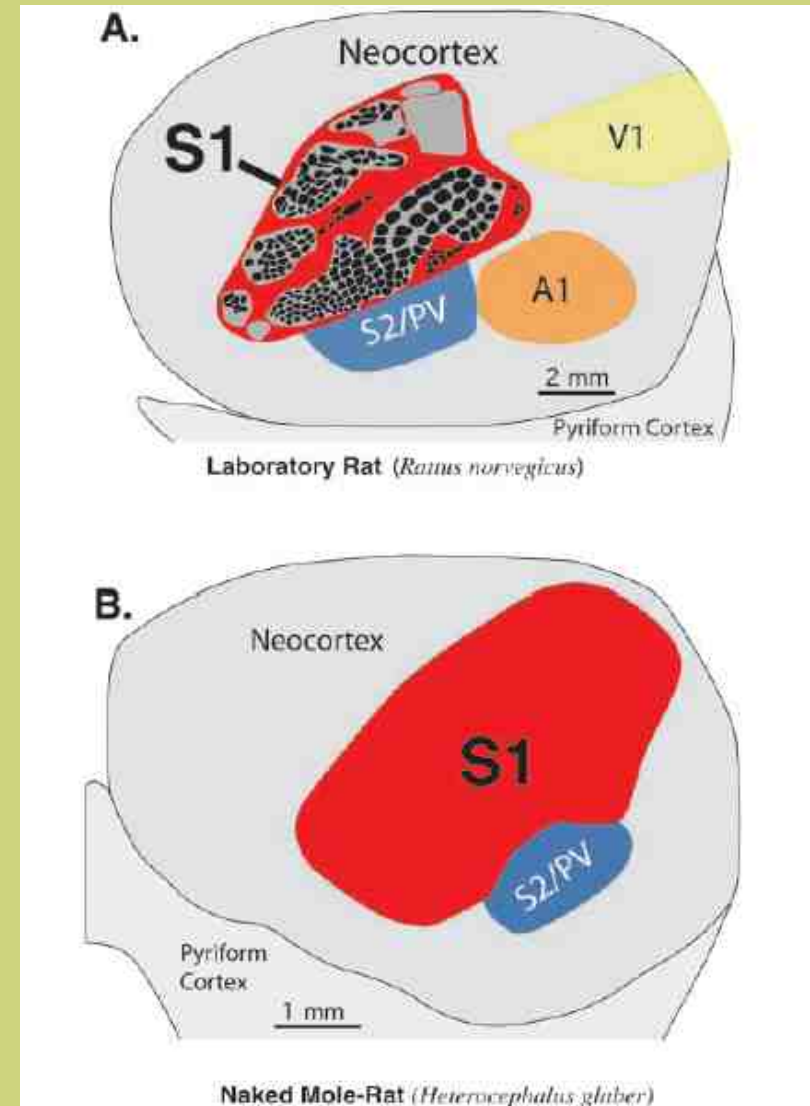




<http://www.pnas.org/content/99/8/5692.full.pdf+html>

Rat and mole rat

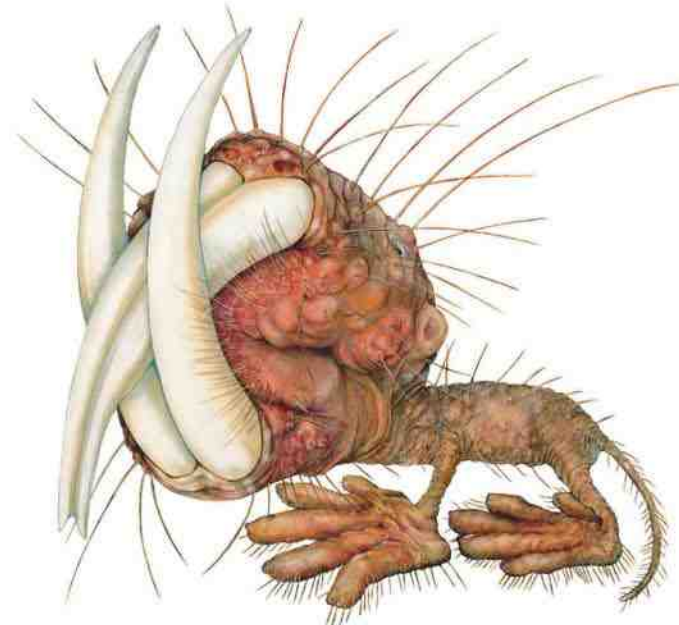
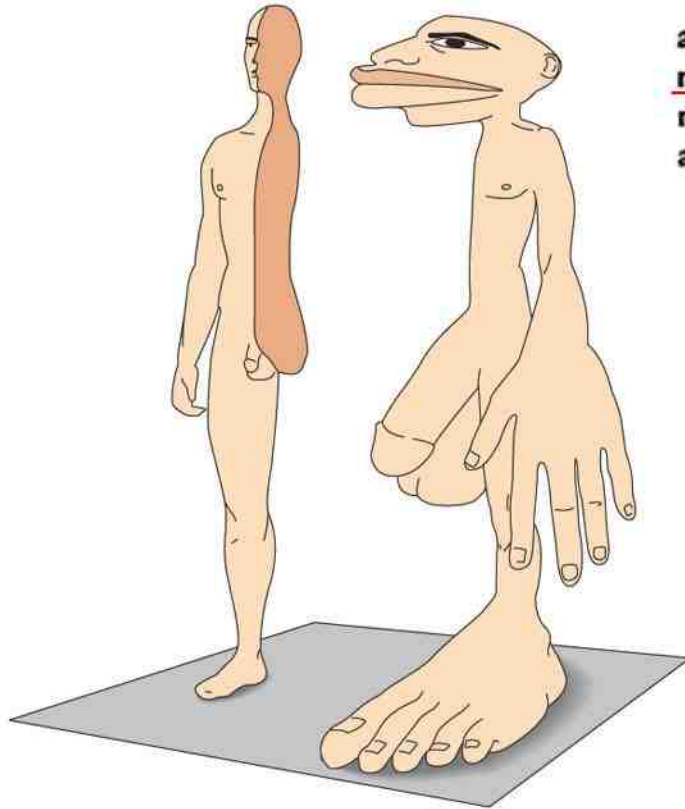
Somatosensory cortex
(S1) in
rat 21%
mole rat 31%
at the expense of visual
(V1) and auditory
sensory cortex (A1)



<http://www.pnas.org/content/99/8/5692.full.pdf+html>

and motor factors).⁶ Moreover, it is particularly significant that no mention is made of the female homunculus or the ways in which it differs from the male. In much of the relevant literature, the homunculus is *explicitly* described as male, and there is no mention of what this means for women.

In spite of his manifest sexism, Gorman makes it clear that the homunculus



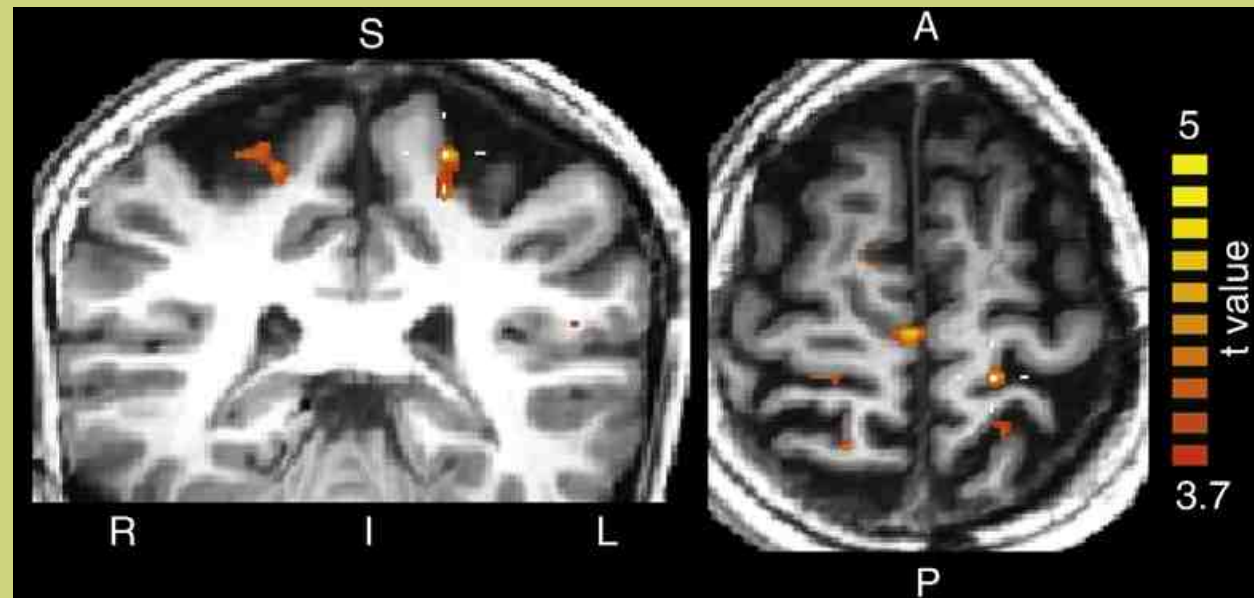
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L. Michels et al. The somatosensory representation of the human clitoris: An fMRI study

NeuroImage (2009) activity changes in primary somatosensory cortex during clitoral stimulation

Relative area?

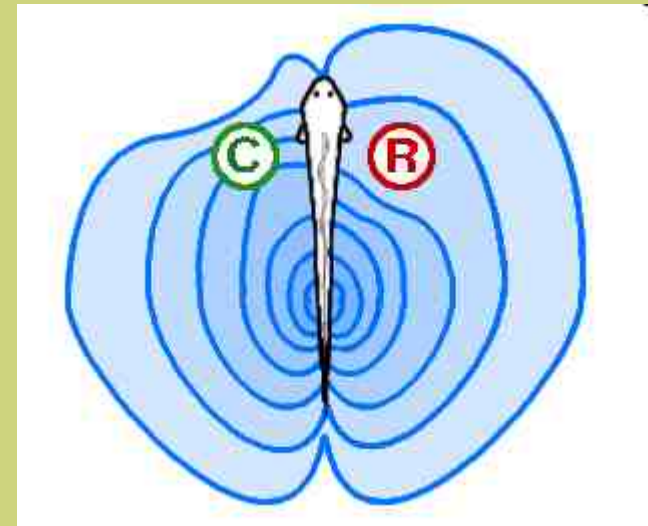


Electric field

- Many fishes, platypus
- Electric eel generates potential between head and tail.
- Senses changes in electric field

Good conductor (green),

Poor conductor (red)



Geomagnetic field

Experiment:

Lohmann et al. captured sea turtles

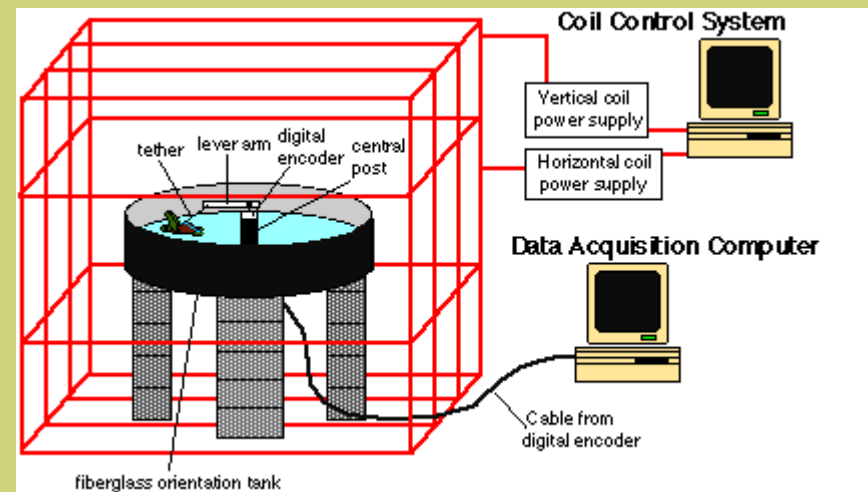
<http://www.unc.edu/depts/oceanweb/turtles/>

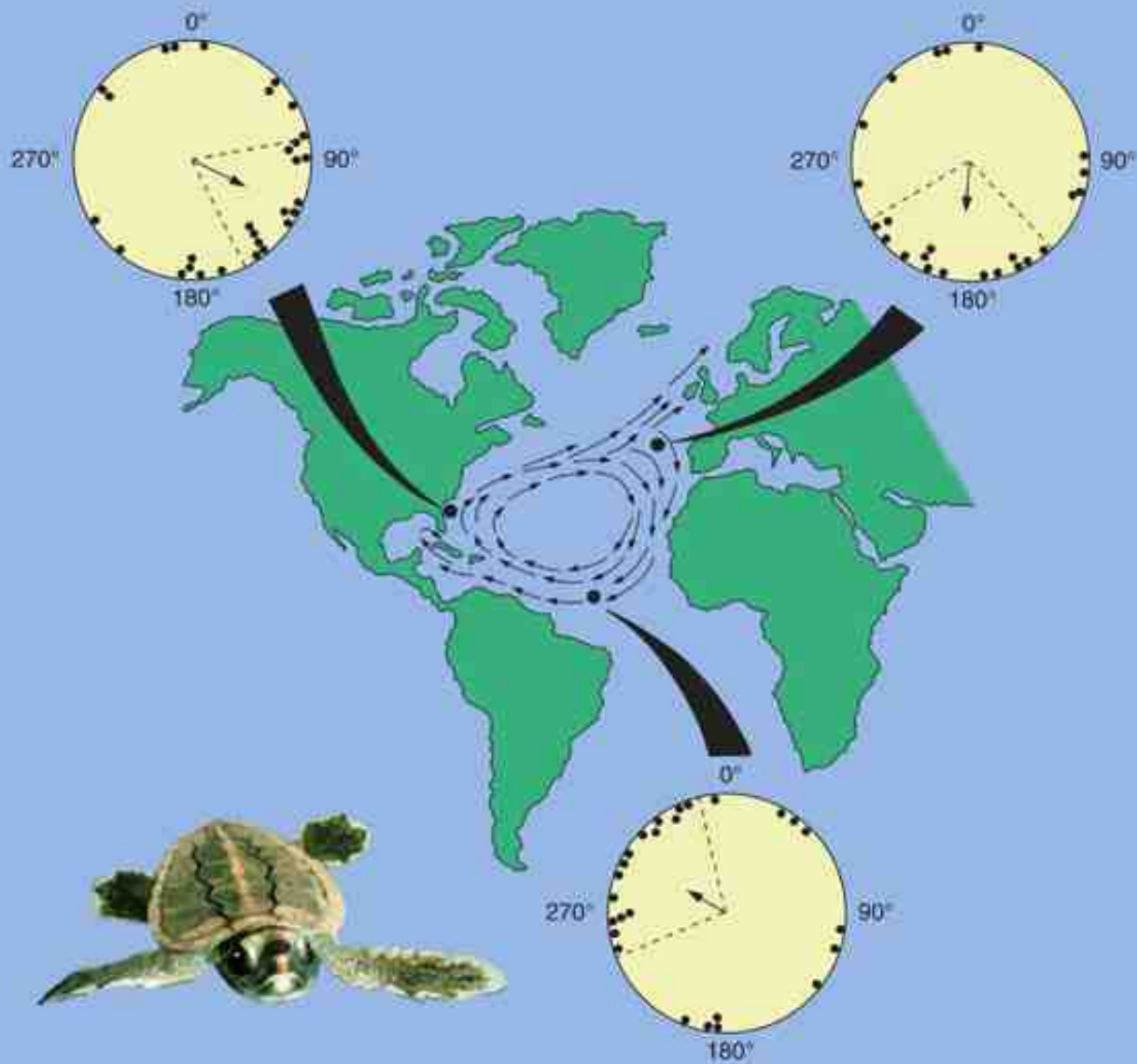


Geomagnetic field

Fitted collar on them

Put in pool and recorded direction of swimming while manipulating magnetic field around pool





Hynek Burda et al. (2008 PNAS) recorded orientation of 8500 cattle in 300 pastures by GoogleEarth

Most individuals oriented North – South

Reaction to Northern winds?

Their heads oriented toward geomagnetic North and not to geographical North

In Oregon State the difference is 17.5 degrees



Light dependent **magnetoreception** in birds

- The **magnetoreceptor** is located in the right eye
 - Birds cannot remain oriented to a magnetic field in darkness
- Light must of specific wavelengths
 - Blue light is needed to remain oriented to a magnetic field
 - Birds may orient to red light if they are given time to adjust
- **Cryptochrome**: a **photopigment** involved in magnetoreception
 - Stimulates photoreceptors differently depending on the orientation of the magnetic field
 - Migratory birds sense the **magnetic field** as a **visual pattern**

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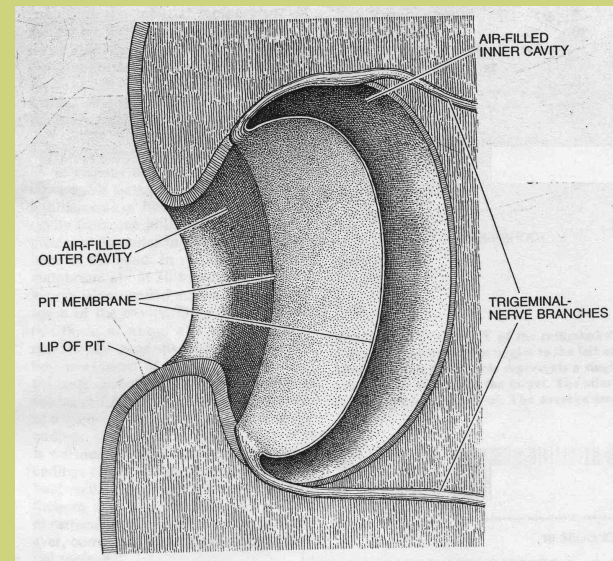
Alternate mechanism: magnetites

Heat

Pit Vipers



Pit Organ

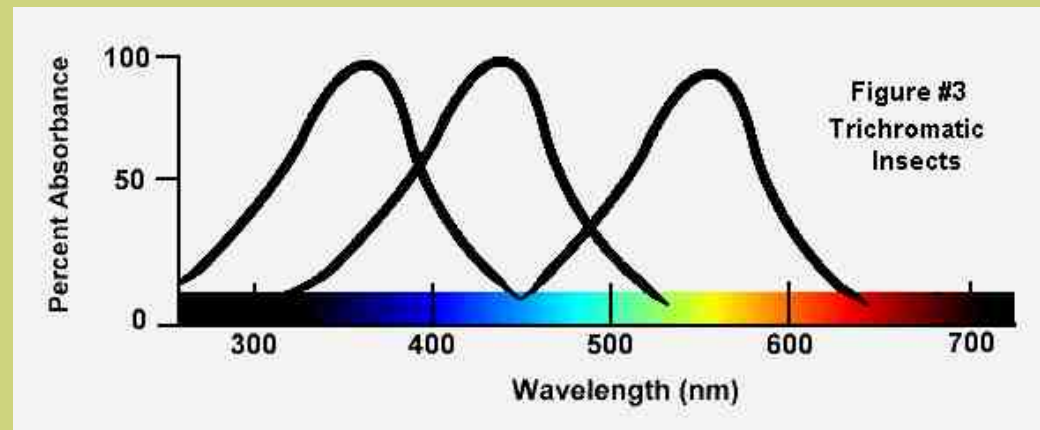
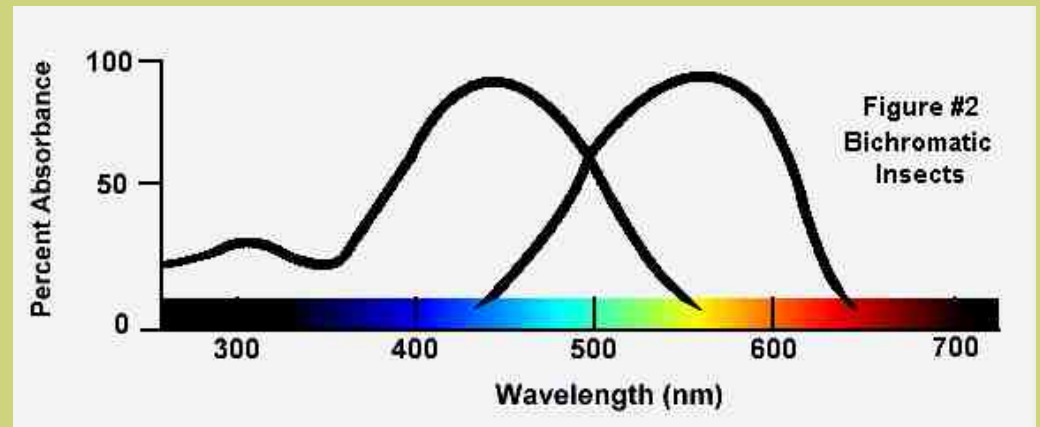
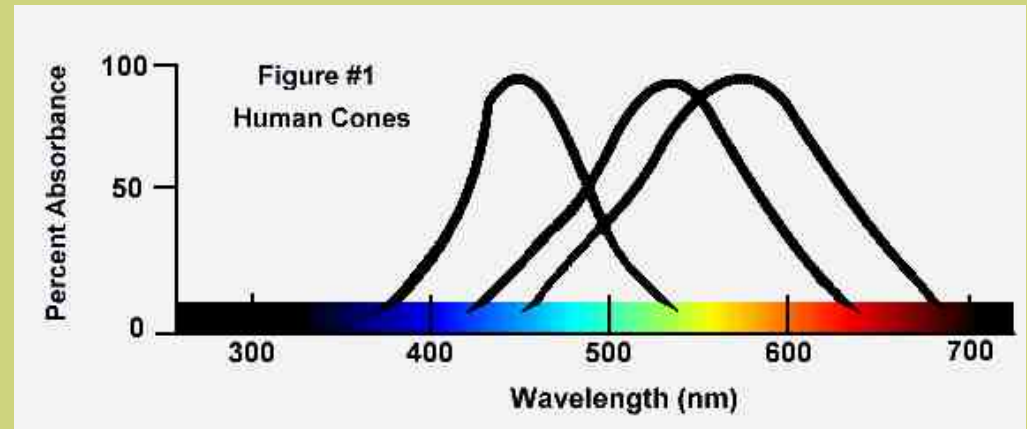


Vision

Apes
trichromatic

Most mammals
dichromatic

bees and wasps
di- + UV



Landing marks in UV

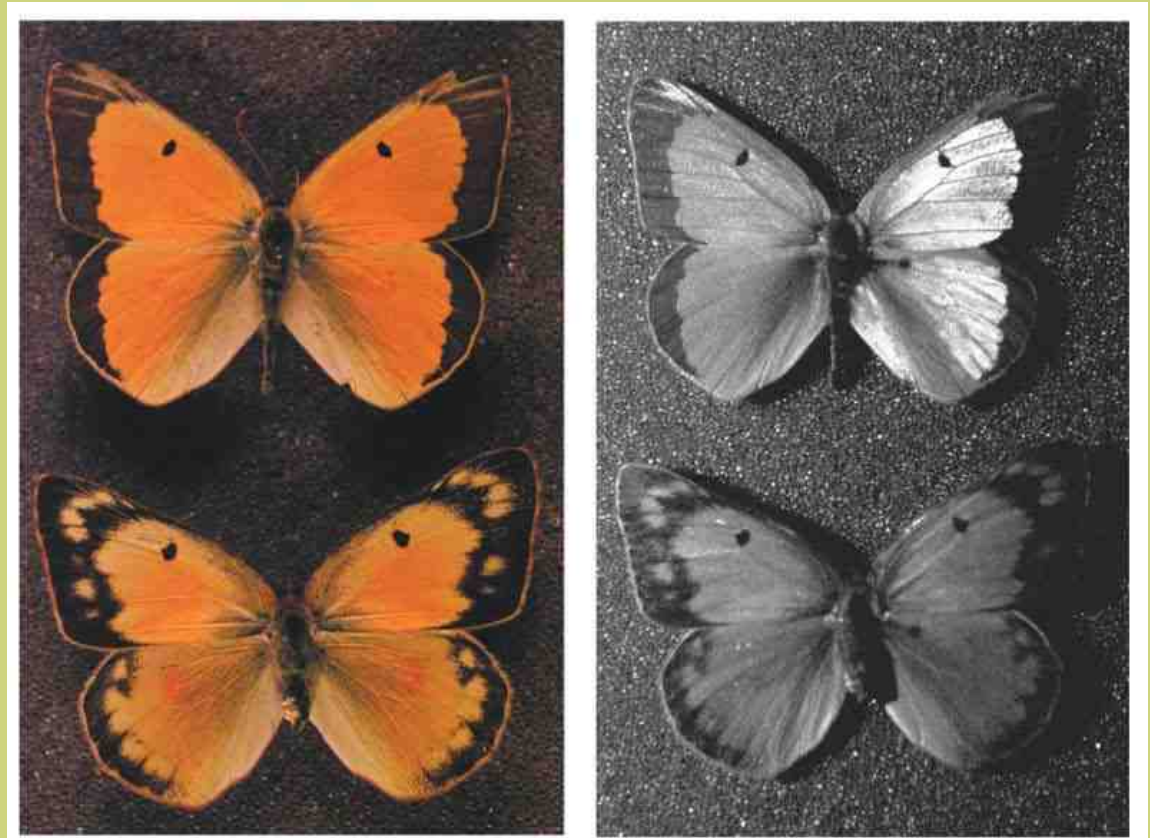


Upper row: as we see, Lower row: in UV

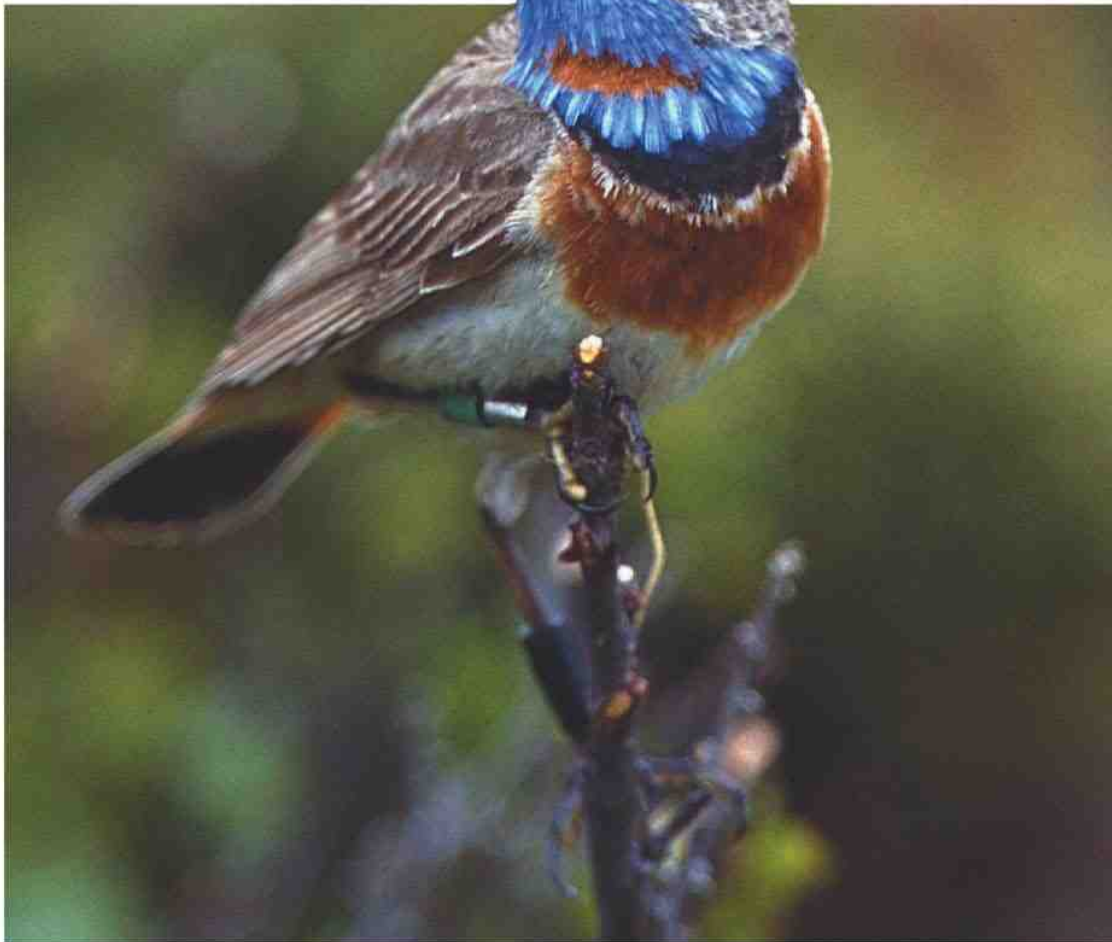
http://www.naturfotograf.com/UV_flowers_list.html

UV

Madarak



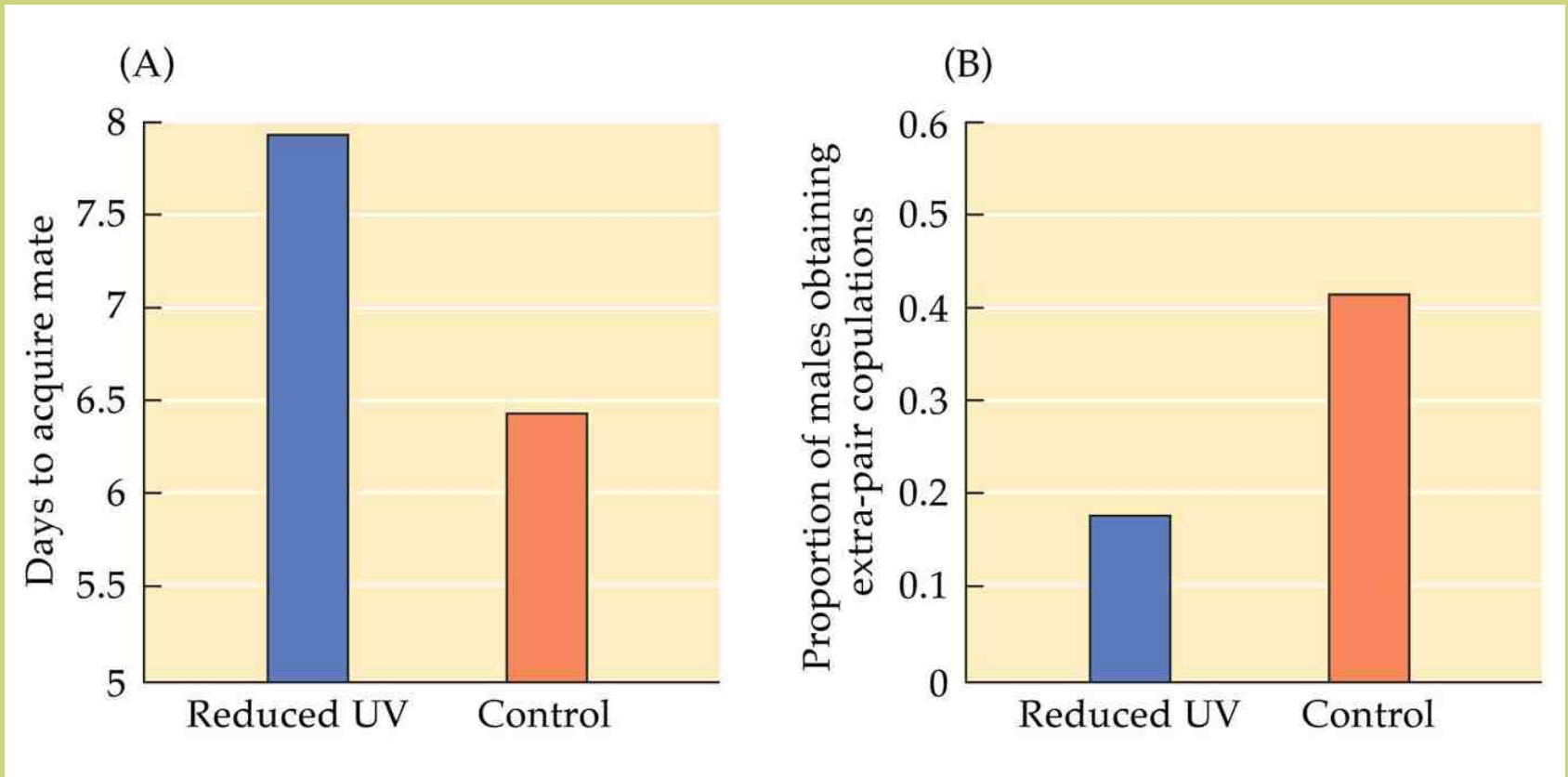
Birds (*Luscinia svecica*)



UV reflectance and mate choice

a group of males were treated by tanning oil + uropygial gland (preening gland) oil

controls recieved only uropygial gland oil



Take home messages:

Organisation of behaviour: parallel and hierarchy

Neural mediation similarly:

- simple repetitive movements – CPG

- simple calculations: simple neural network

Biological rhythms are the major organisers

Know the Umwelt of the species you study.

- They live in a different world