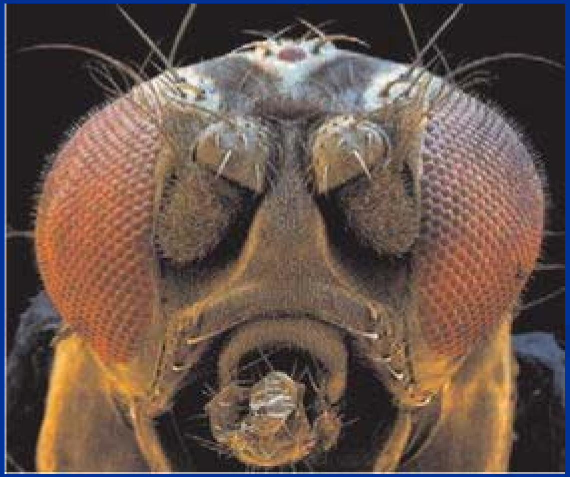
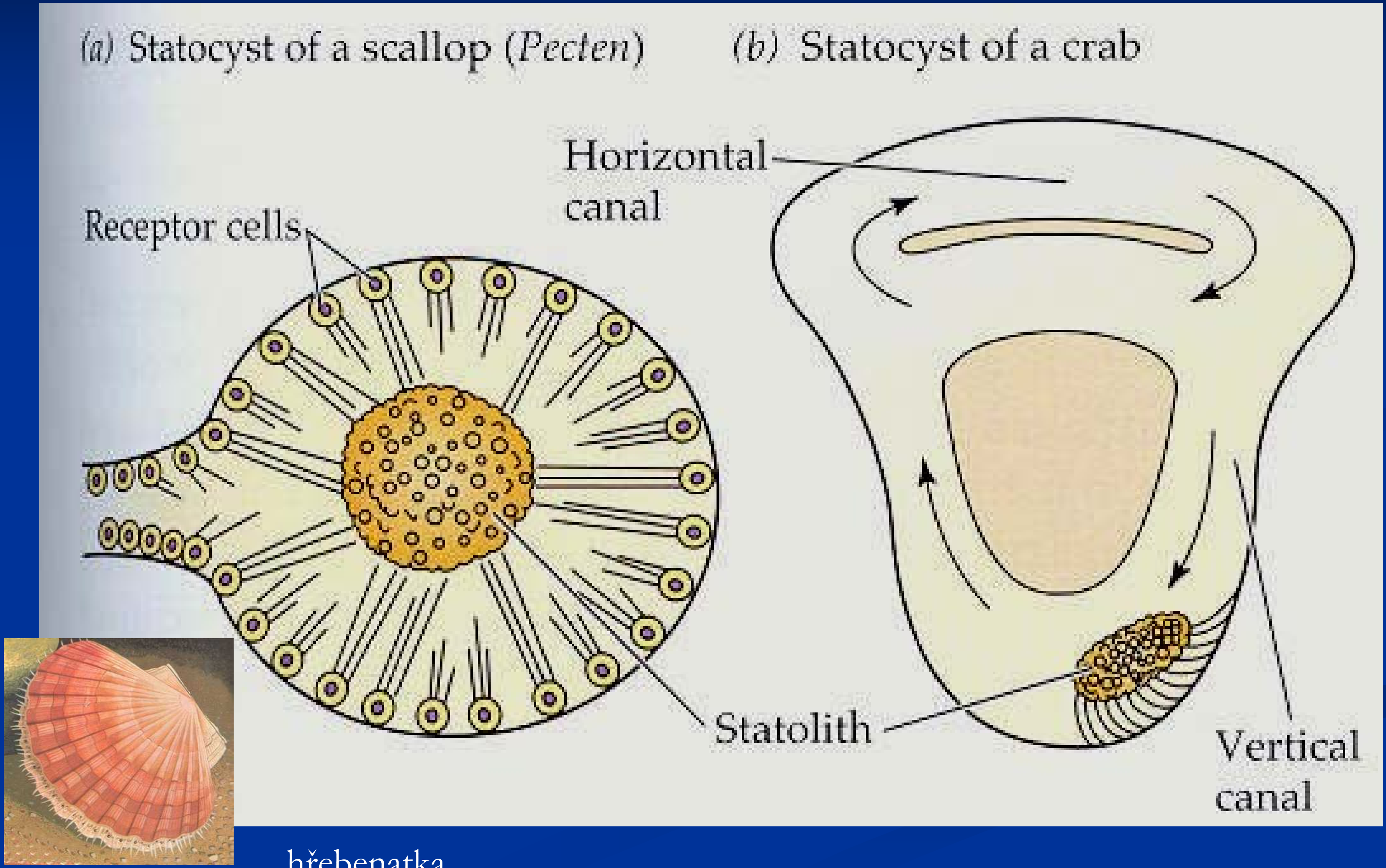
Smysly

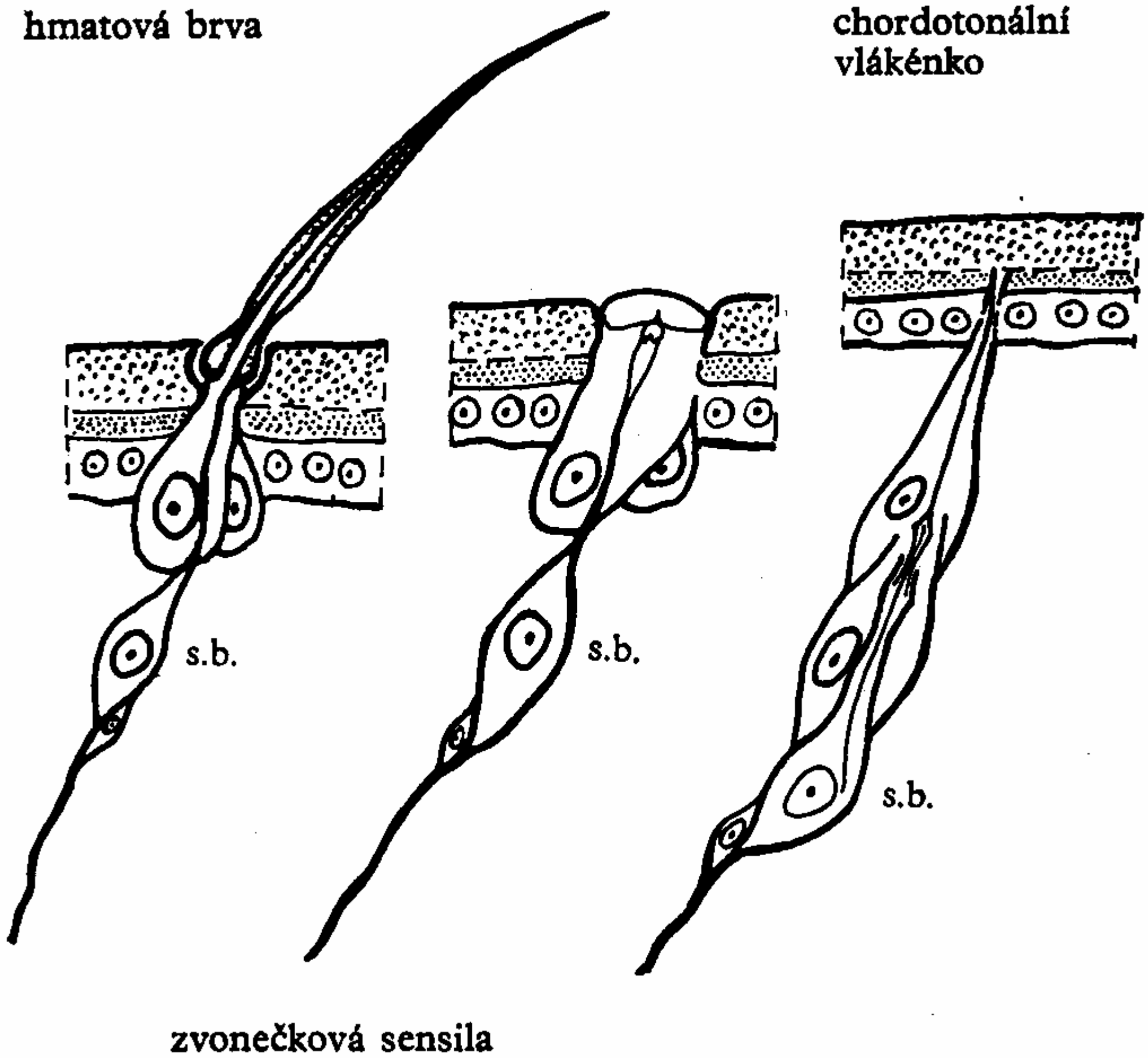


Mechanorecepce – Rheoreceptory ploštěnců
- Statocysta měkkýšů



hřebenatka

Mechanorecepce hmyzu



Tři typy mechanoreceptorů. Hmatová brva je kloubem spojena s povrchem kutikuly a její pohyb citlivě vnímá smyslová buňka (s. b.). Zvonečková sensila se napětím kutikuly deformuje, a to je rovněž vnímáno smyslovou buňkou. Součástí chordotonálního vlákénka je opět smyslová buňka citlivě reagující na napětí.

Sensila – smyslová buňka
Dendrit s tubulárním tělískem

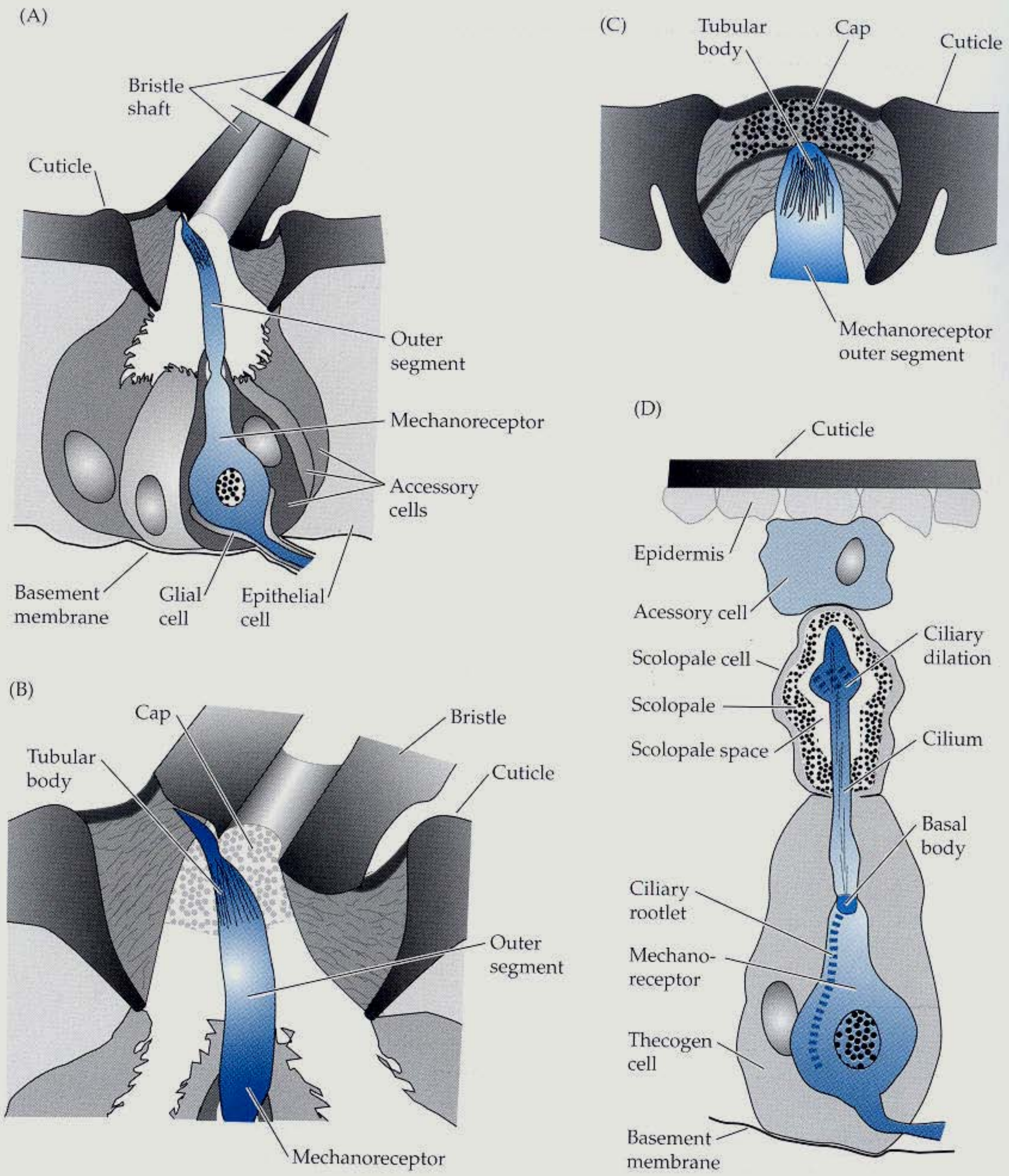
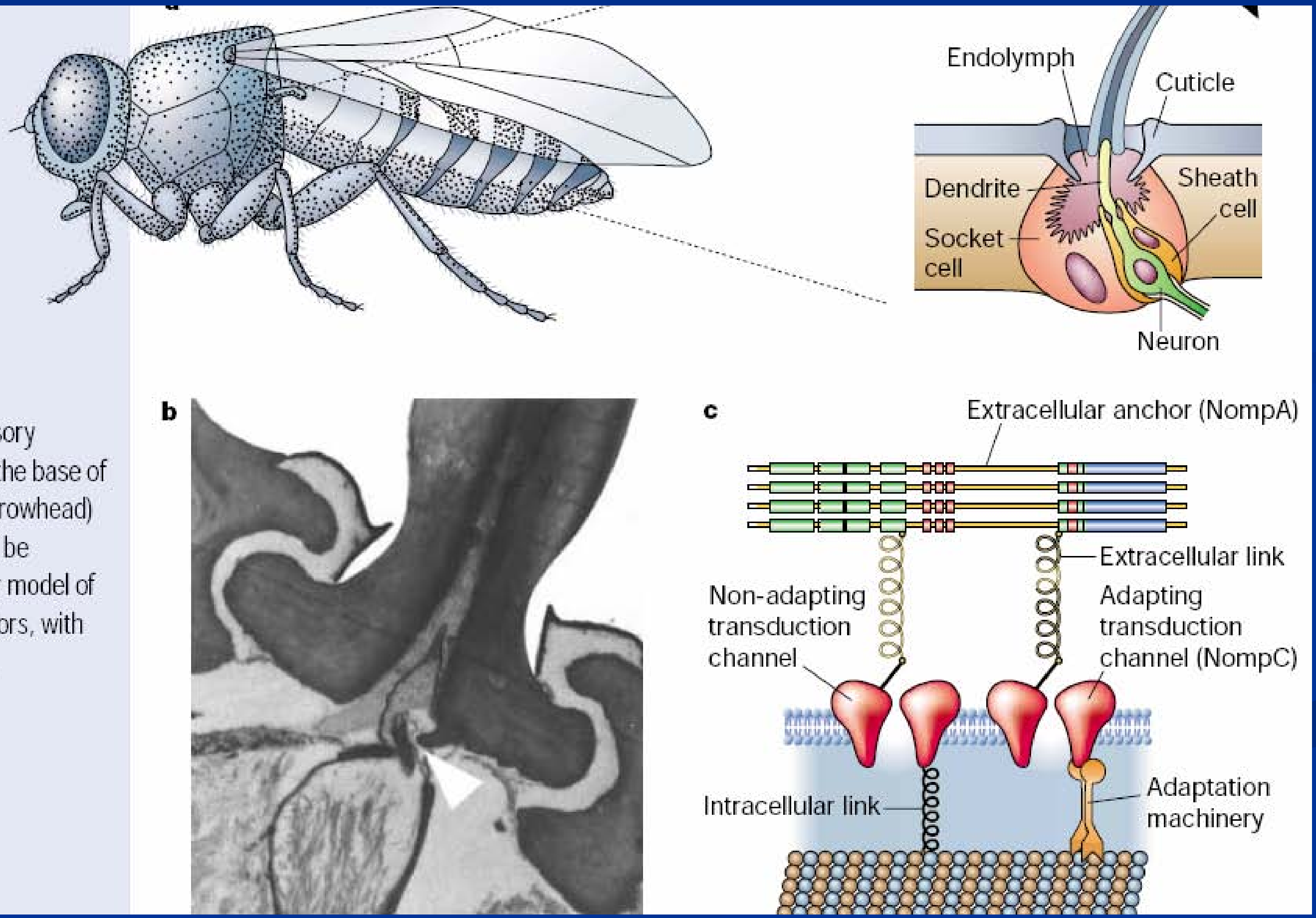


Figure 5.11
Anatomy of insect mechanoreceptive organs Schematic drawings of major morphological classes of touch sensilla. (A) Hair plate (bristle) sensillum. (B) Magnified view of hair plate sensillum. (C) Campaniform sensillum. (D) Scolopidial organ. The thecogen cell is a type of supporting cell. (After Thurm, 1964; Bullock and Horridge, 1965; Keil, 1997.)

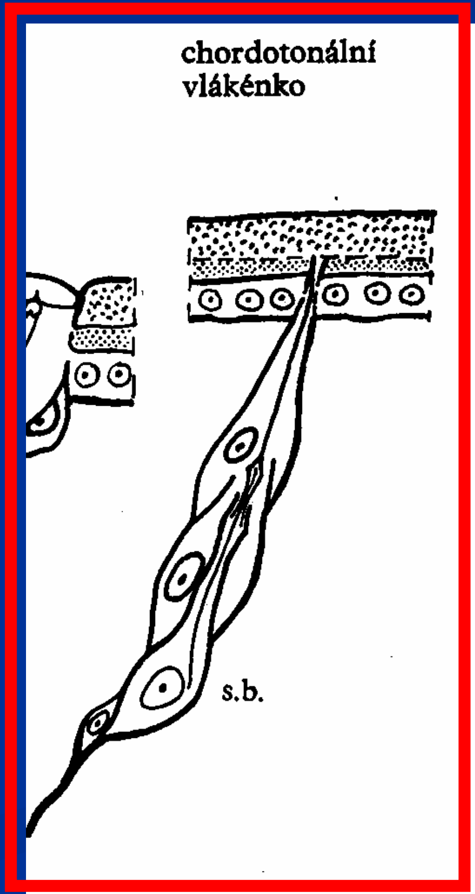
Drosophila – model pro molekulární podstatu mechanorecepce

Figure 3 *Drosophila* bristle-receptor model. **a**, Lateral view of *D. melanogaster* showing the hundreds of bristles that cover the fly's cuticle. The expanded view of a single bristle indicates the locations of the stereotypical set of cells and structures associated with each mechanosensory organ. Movement of the bristle towards the cuticle of the fly (arrow) displaces the dendrite and elicits an excitatory response in the mechanosensory neuron. **b**, Transmission electron micrograph of an insect mechanosensory bristle showing the insertion of the dendrite at the base of the bristle. The bristle contacts the dendrite (arrowhead) so that movement of the shaft of the bristle will be detected by the neuron. **c**, Proposed molecular model of transduction for ciliated insect mechanoreceptors, with the locations of NompC and NompA indicated.

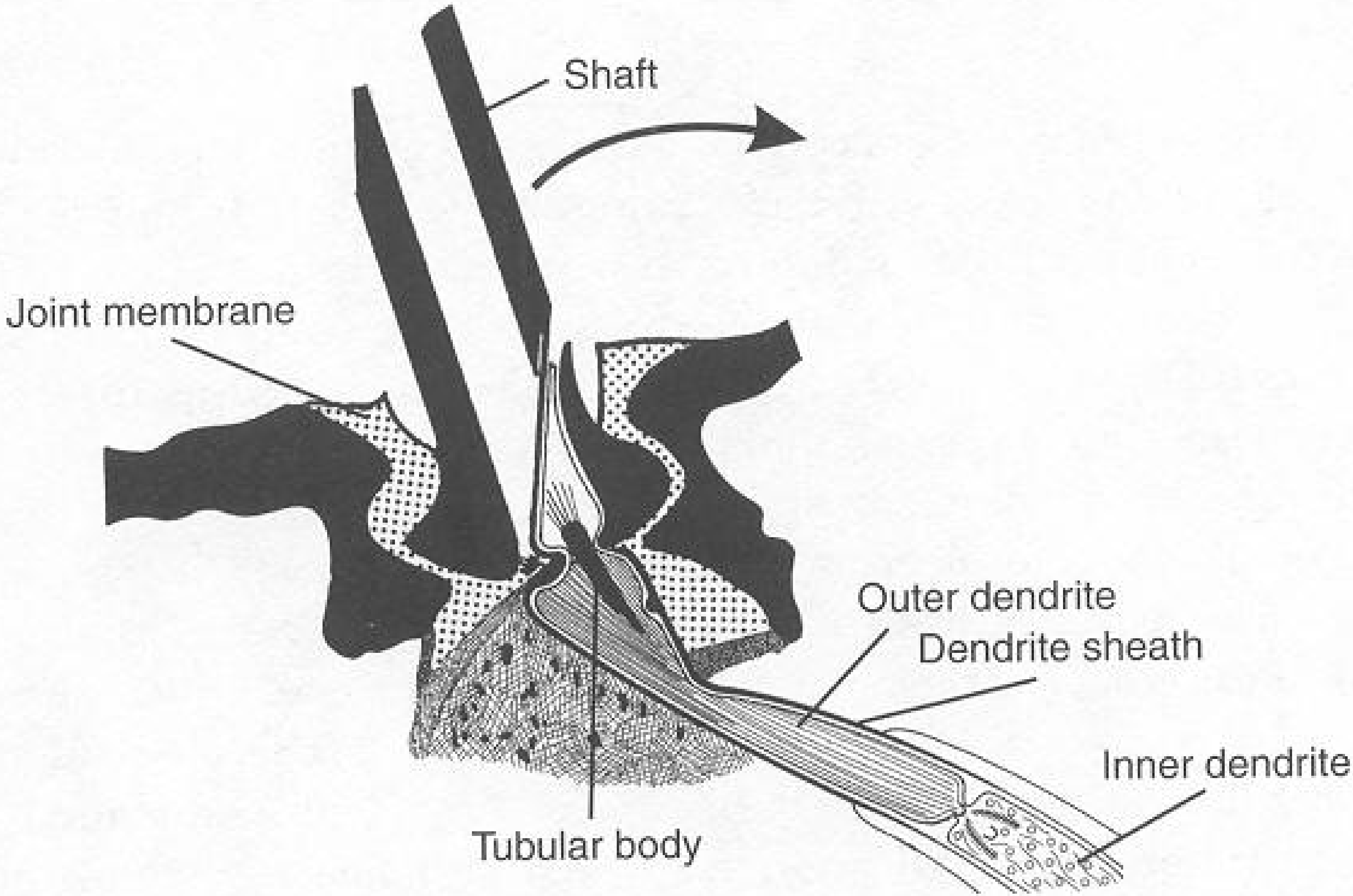


<u>Chordotonální sensily tvoří</u>:

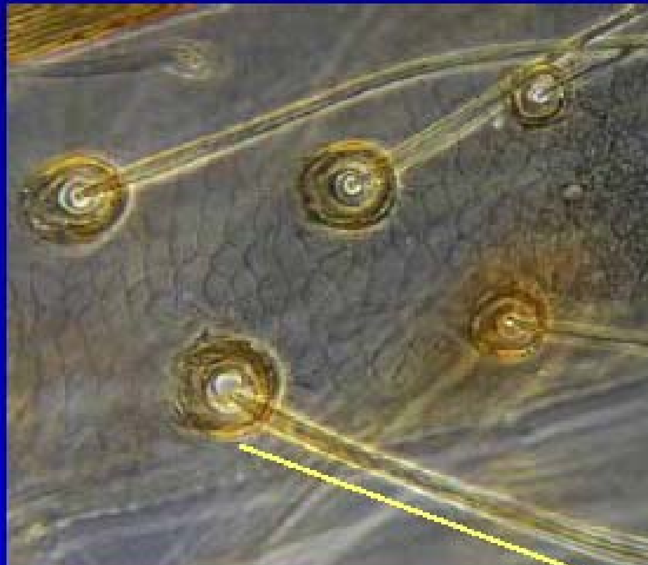
- A) subgenuální orgán
- B) Johnstonův orgán
- C) tympanální orgán

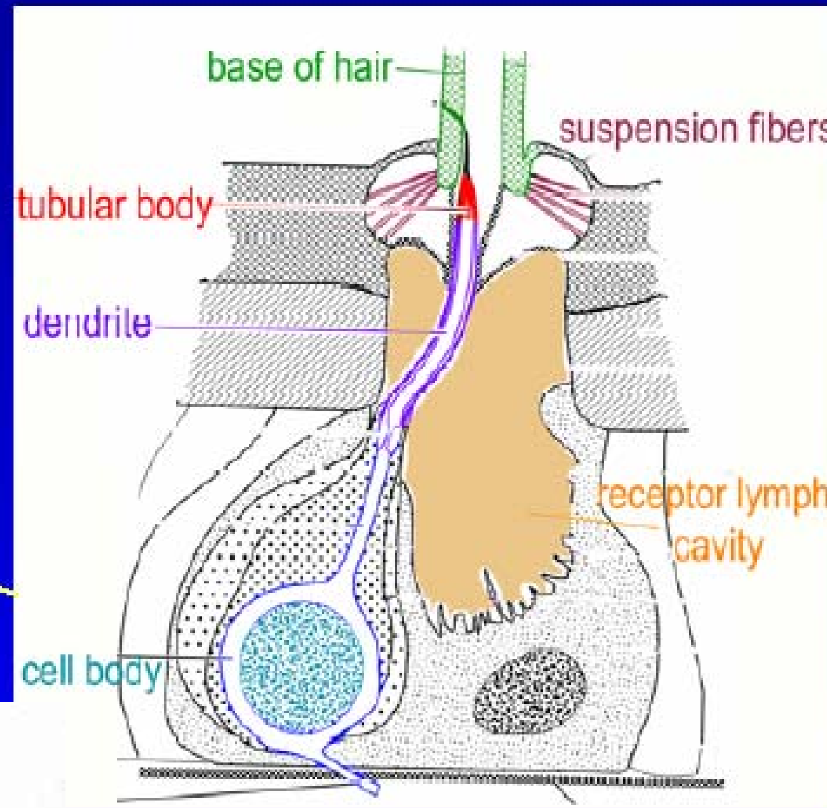


Tři typy mechanoreceptorů. Hmatová brva je kloubem spojena s povrchem kutikuly a její pohyb citlivě vnímá smyslová buňka (s. b.). Zvonečková sensila se napětím kutikuly deformuje, a to je rovněž vnímáno smyslovou buňkou. Součástí chordotonálního vlákénka je opět smyslová buňka citlivě reagující na napětí.


Shaft
Joint membrane
Outer dendrite
Dendrite sheath
Inner dendrite
Tubular body

Propriorecepce





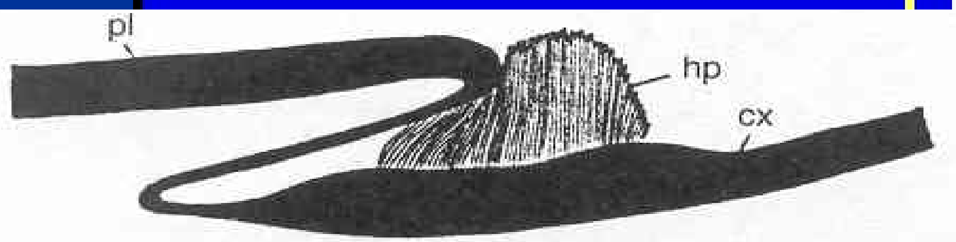
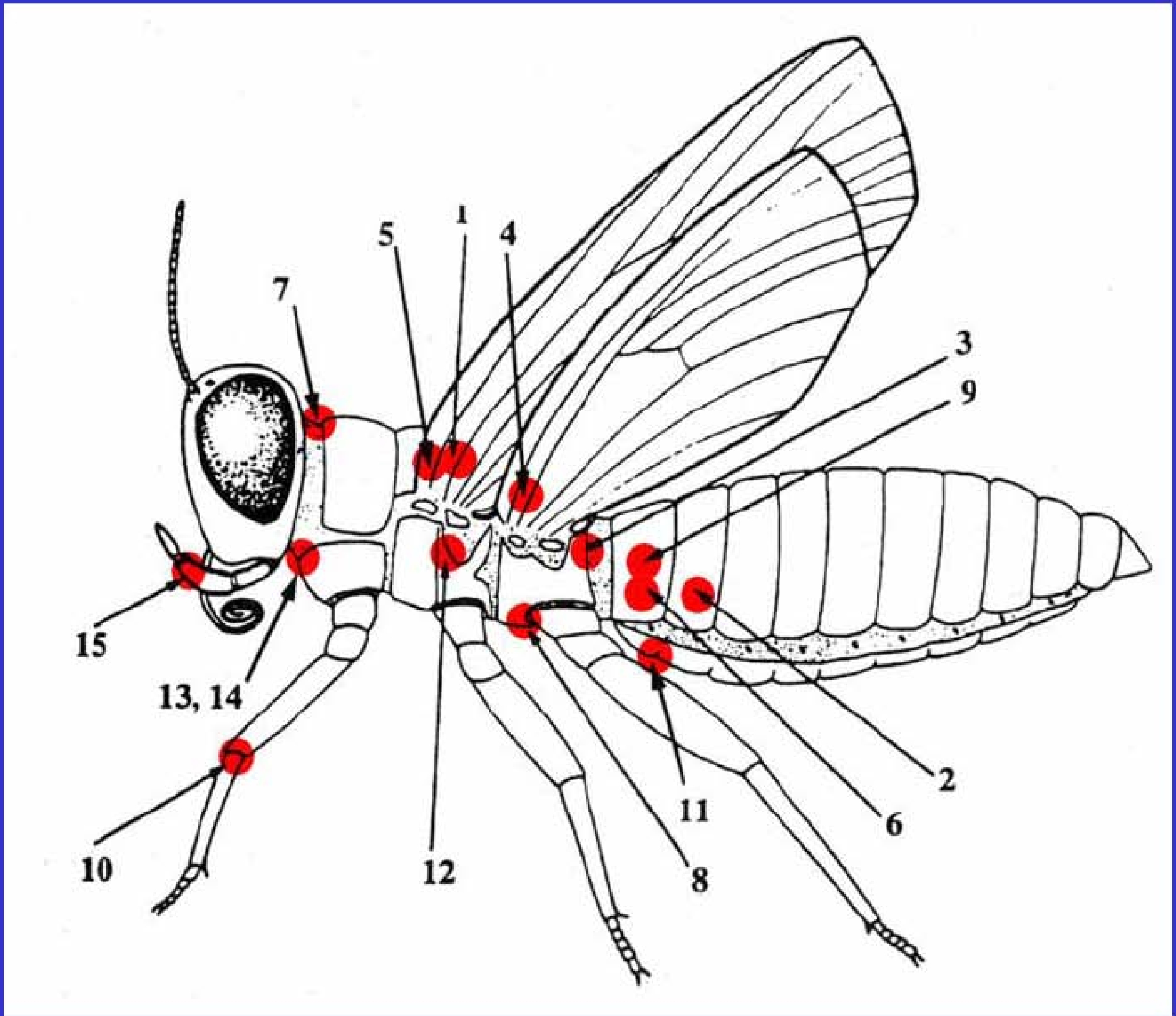


Figure 6.3 (a) The figure shows the brushwork of sensilla at the articulation of the second leg of the cockroach, *Periplaneta americana*. The thick cuticle of the pleuron (pl) thins to a delicate articular membrane and then thickens again to form the cuticle surrounding the coxa (cx), the first segment of the leg. The brush of sensilla forms a hairplate (hp). From Pringle, 1938

Where do insects have ears?



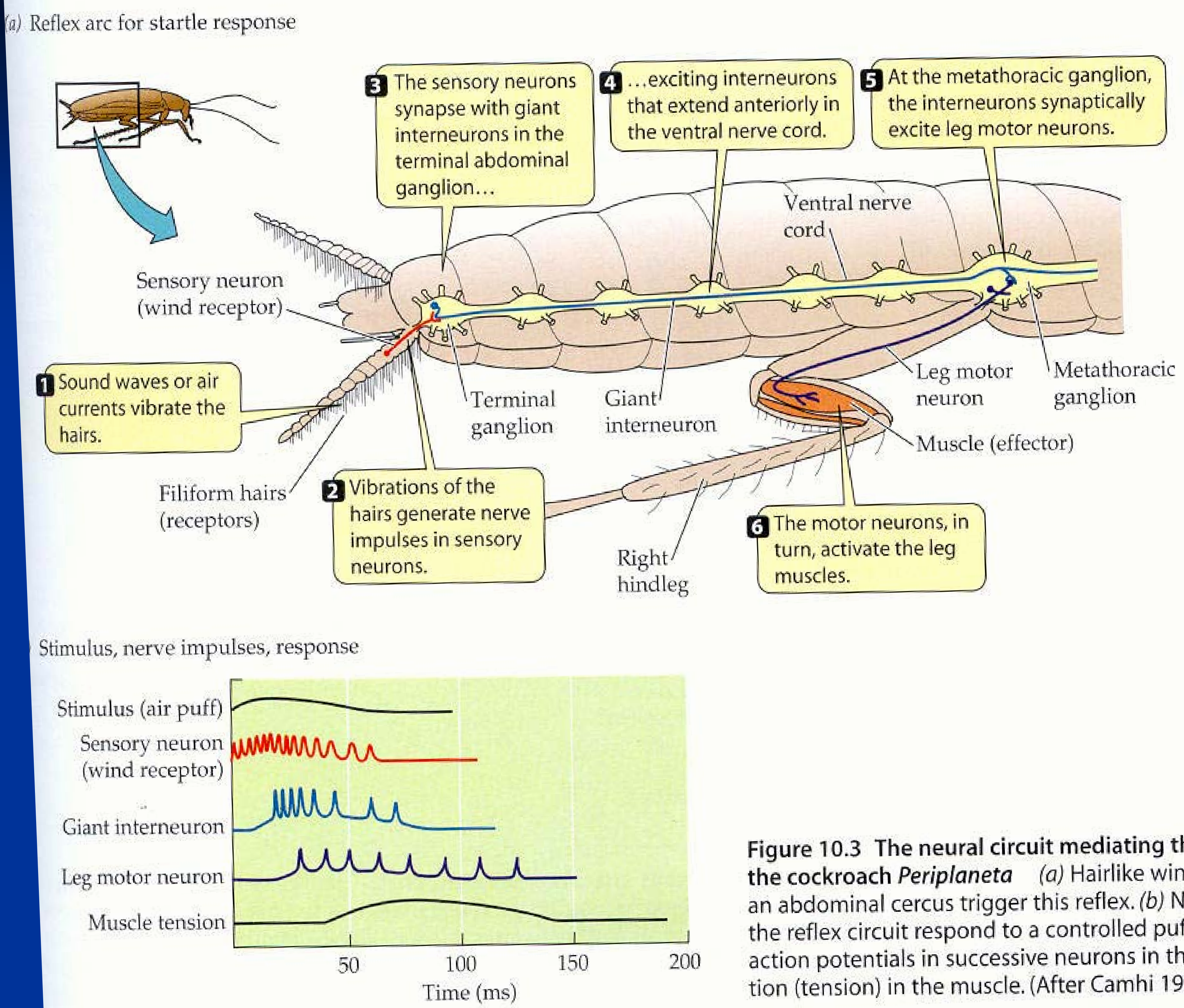
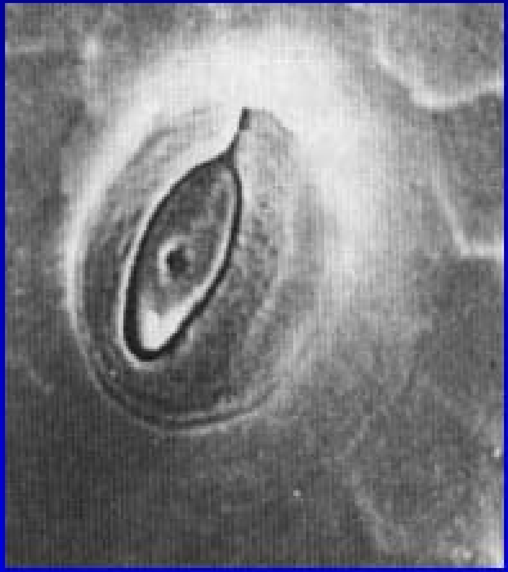
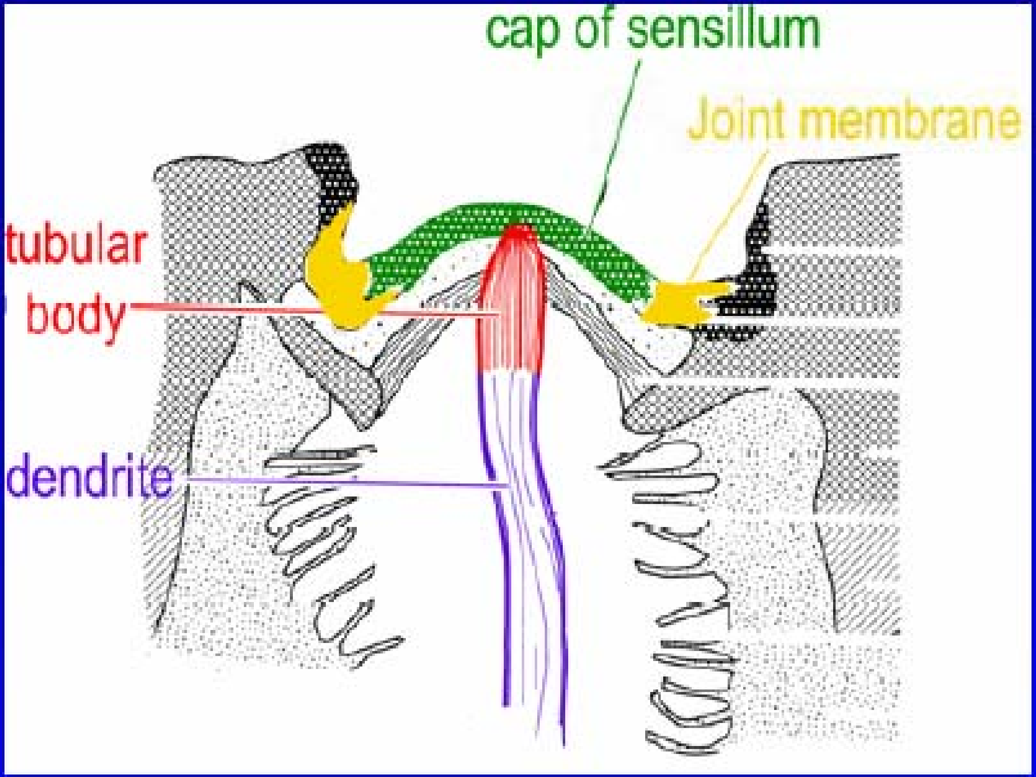
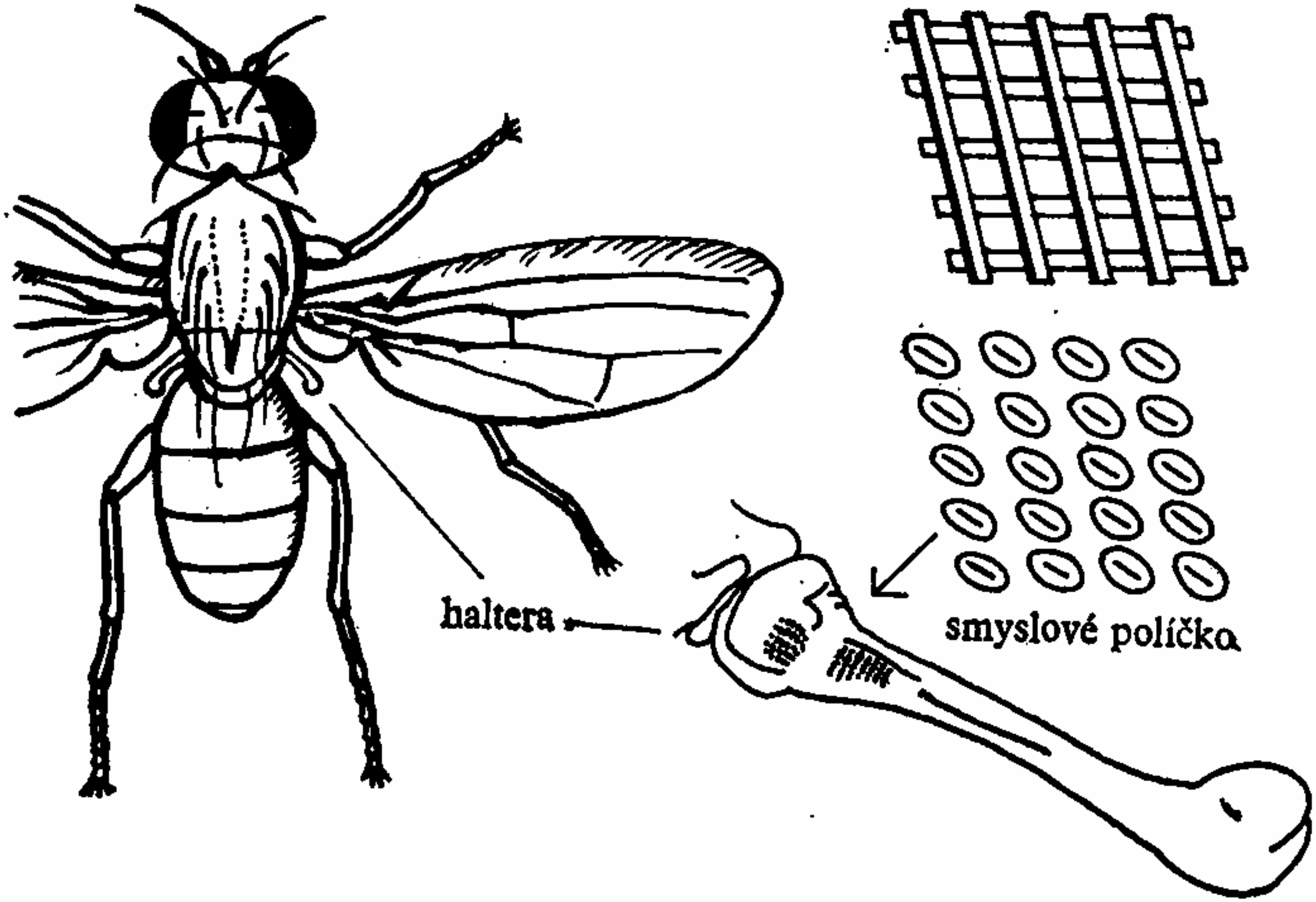


Figure 10.3 The neural circuit mediating the startle response in the cockroach *Periplaneta* *(a)* Hairlike wind receptors located on an abdominal cercus trigger this reflex. *(b)* Nerve and muscle cells in the reflex circuit respond to a controlled puff of air lasting 50 ms. The action potentials in successive neurons in the circuit lead to contraction (tension) in the muscle. (After Camhi 1984.)

Campaniform sensilla

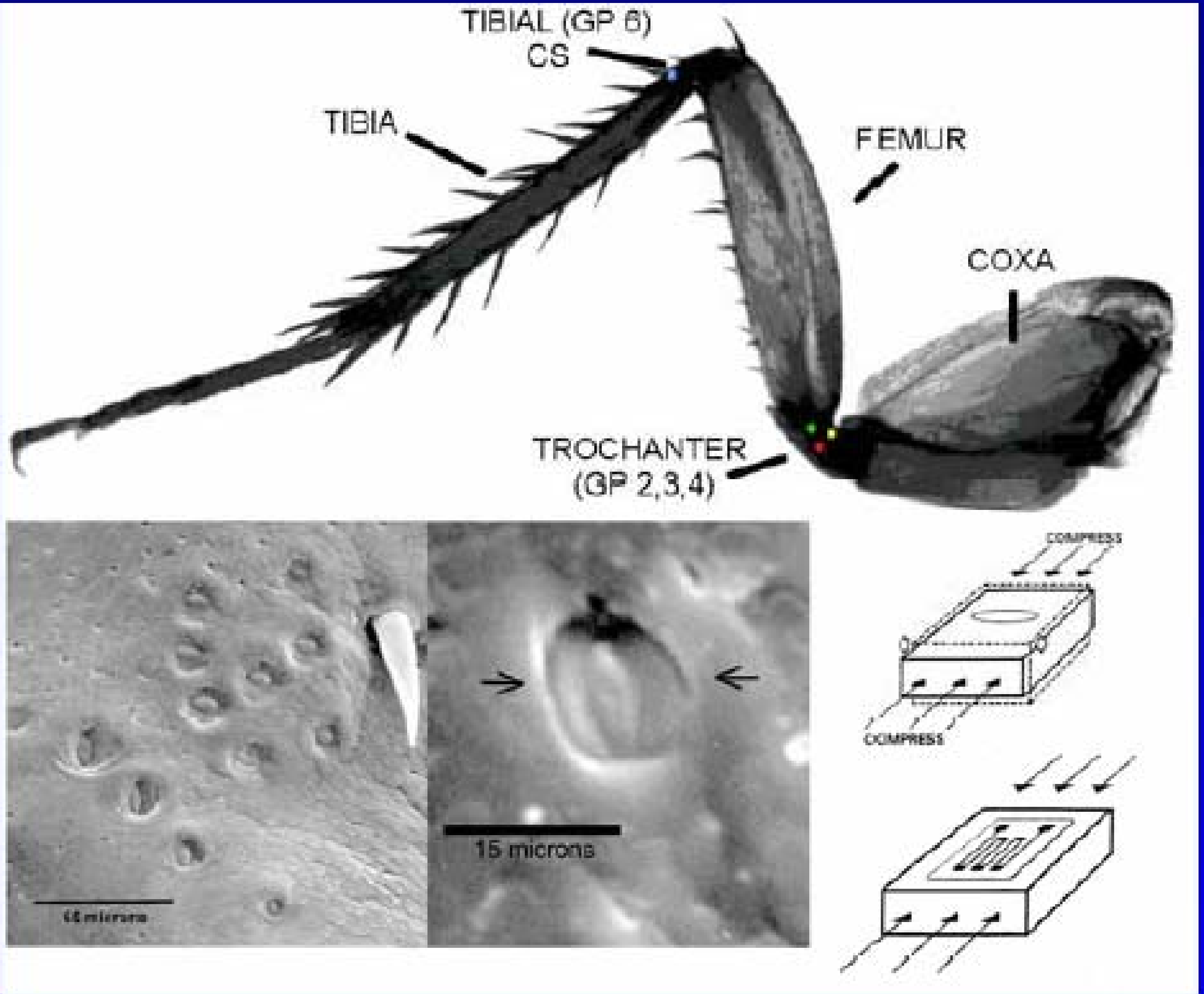




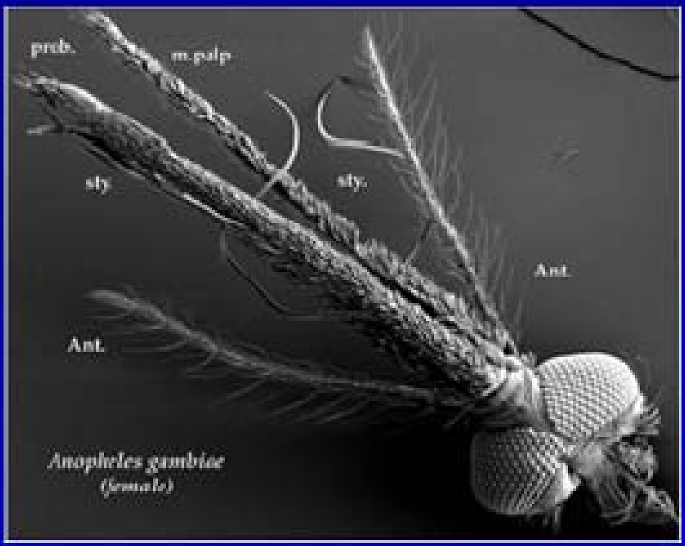


Haltery jsou zakrnělá a přeměněná zadní křídla much. Fungují jako letový gyroskop. Poblíž tělního kloubu jsou políčka pravidelně v řadách uspořádaných zvonečkových sensil, které se napětím deformují podobně jako laťová mřížka.

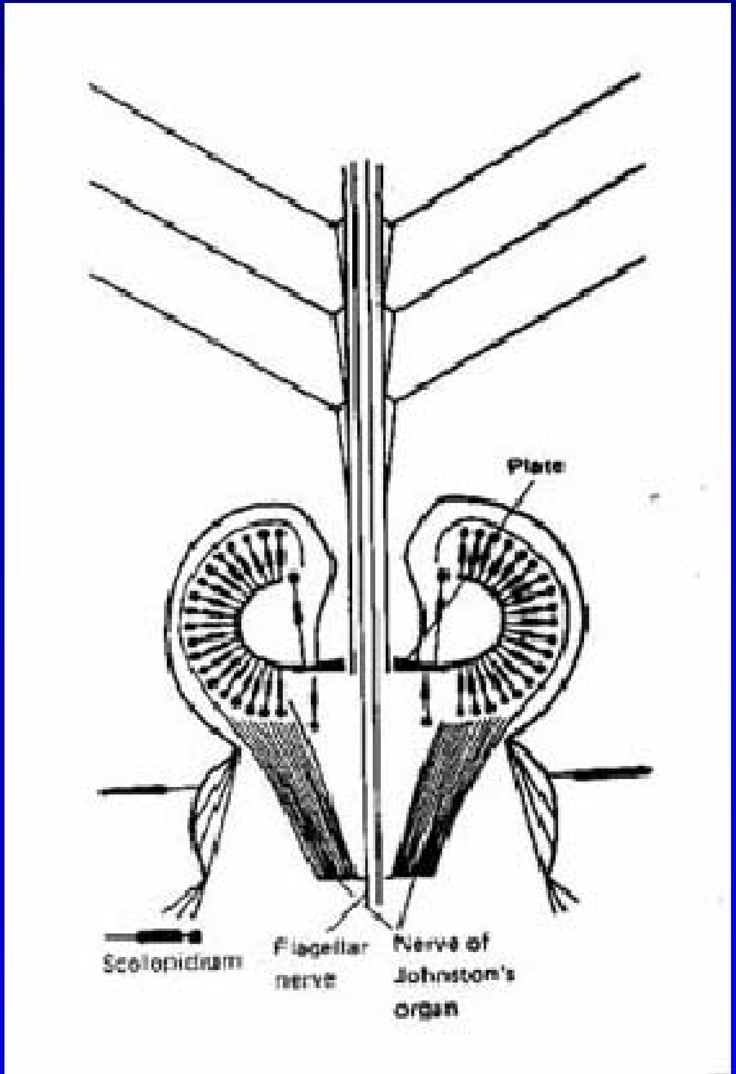
Campaniform sensilla act as proprioreceptors on an insect's leg

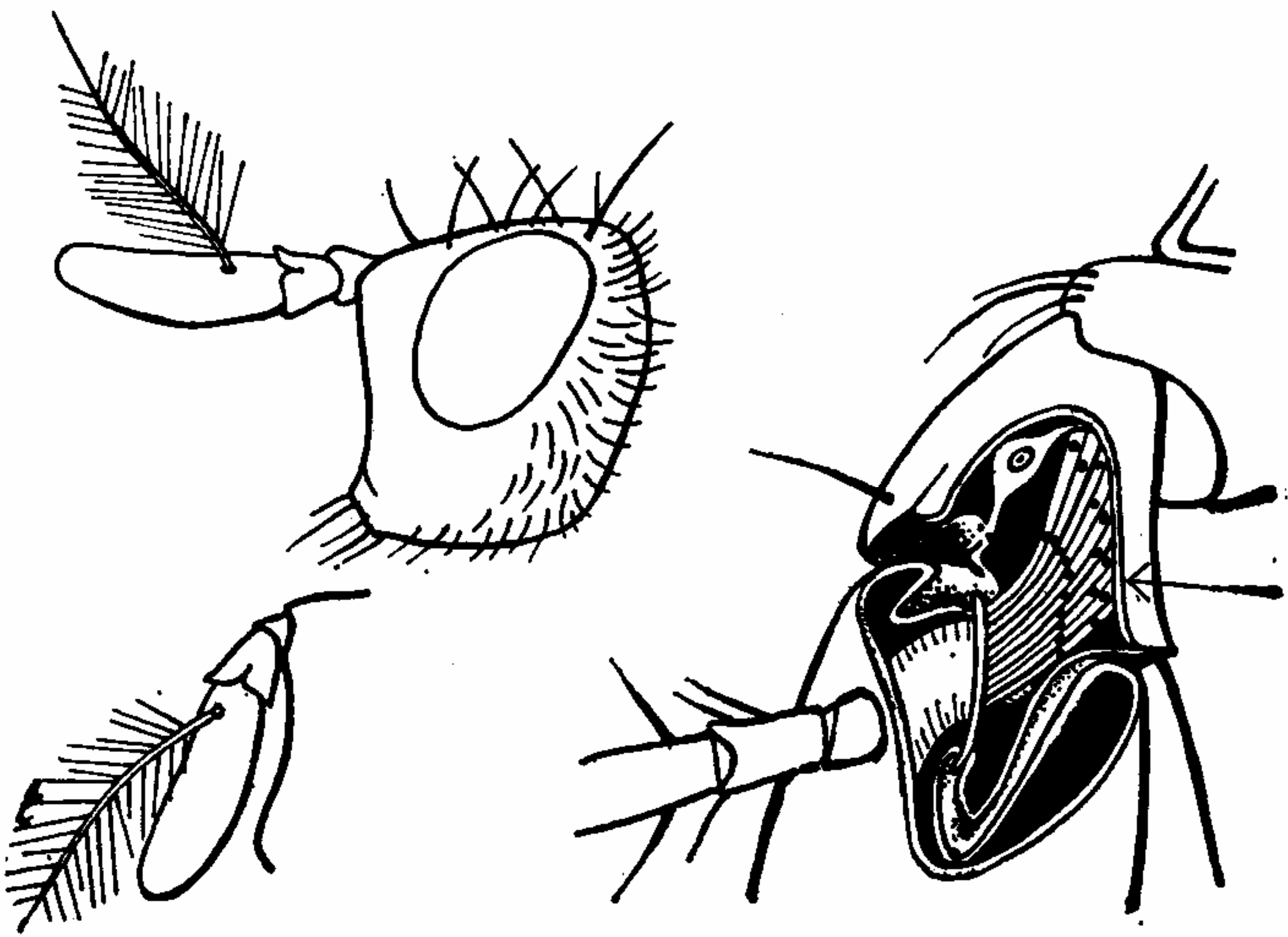


Johnston's organ - the antennal chordotonal organ: an auditory receptor

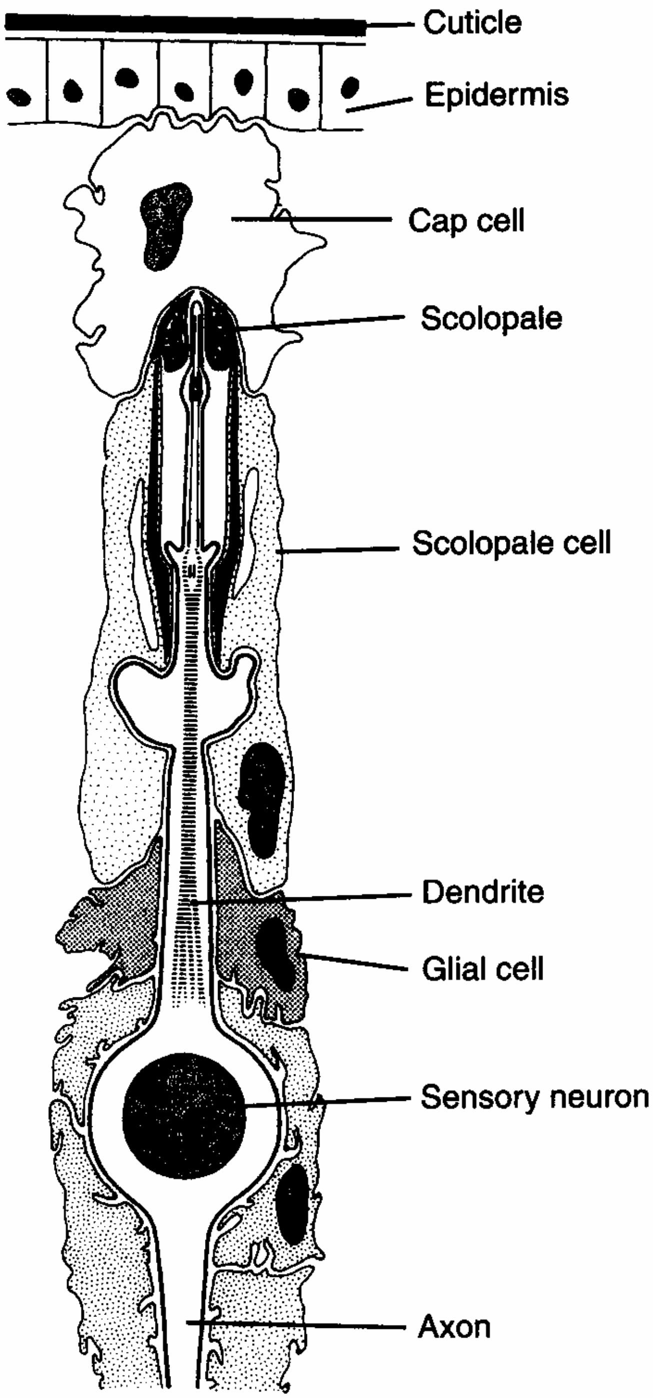


mosquito

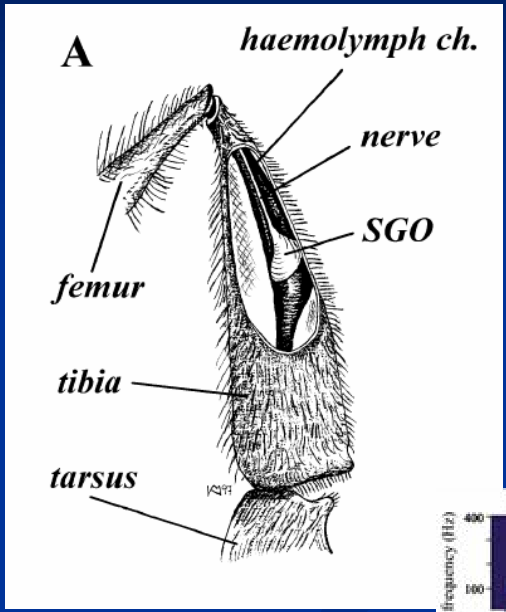




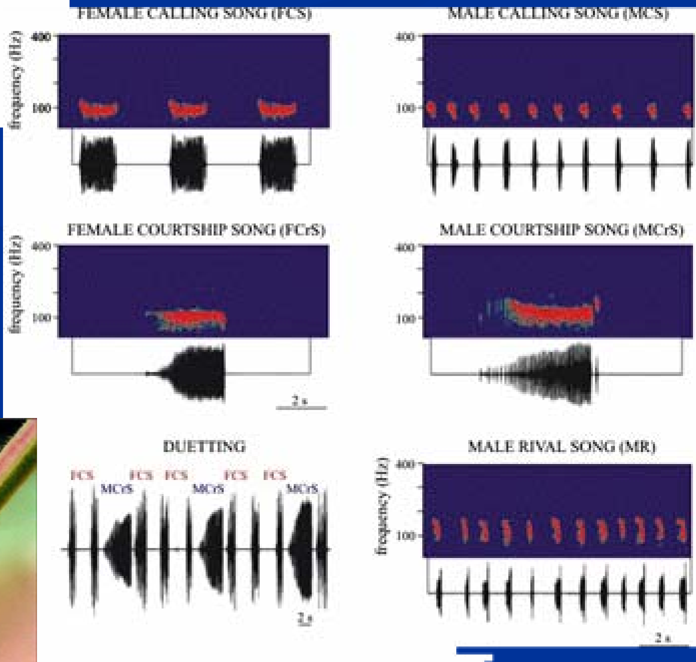
Muší tykadlo směřuje za letu kupředu a funguje jako rychloměr. Jeho ohyb způsobený proudem vzduchu vnímají smyslové buňky Johnstonova orgánu v základním článku tykadla.



Subgenuální orgán – propriorecepce, vibrace podkladu, ale i sluch, 10-9 cm



včela



re 2. Oscillograms (below) and sonagrams (above) of the vibrational songs of *N. viridula*.

Tympanální orgán
Cvrček – holeň
Saranče, motýl - zadeček

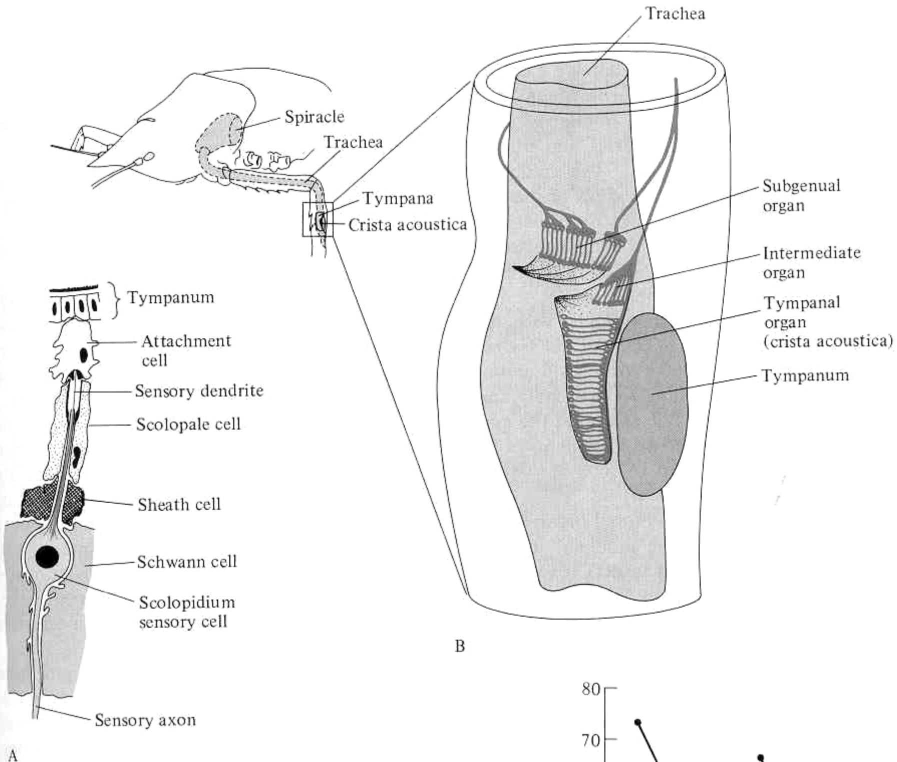
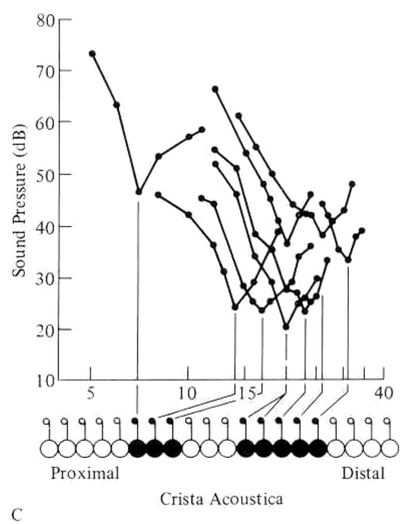
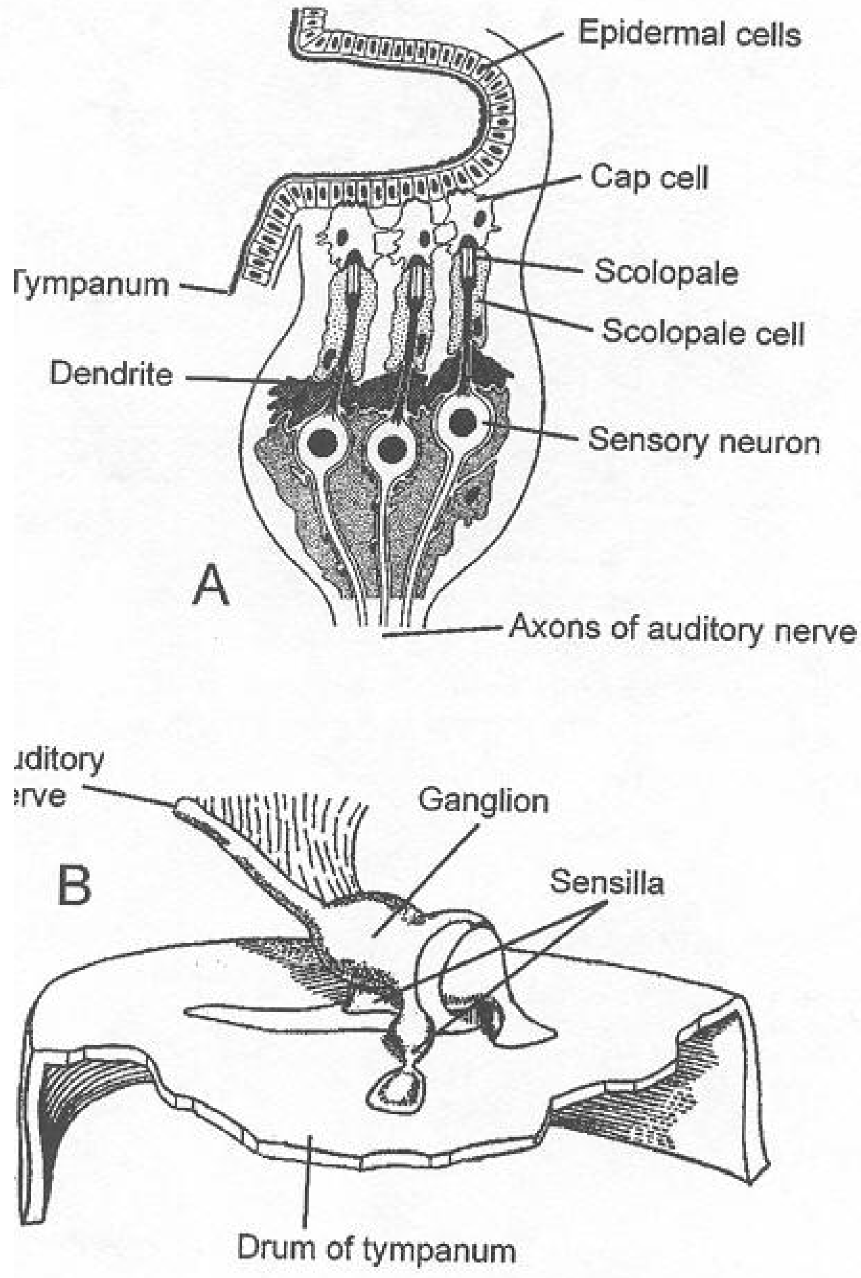
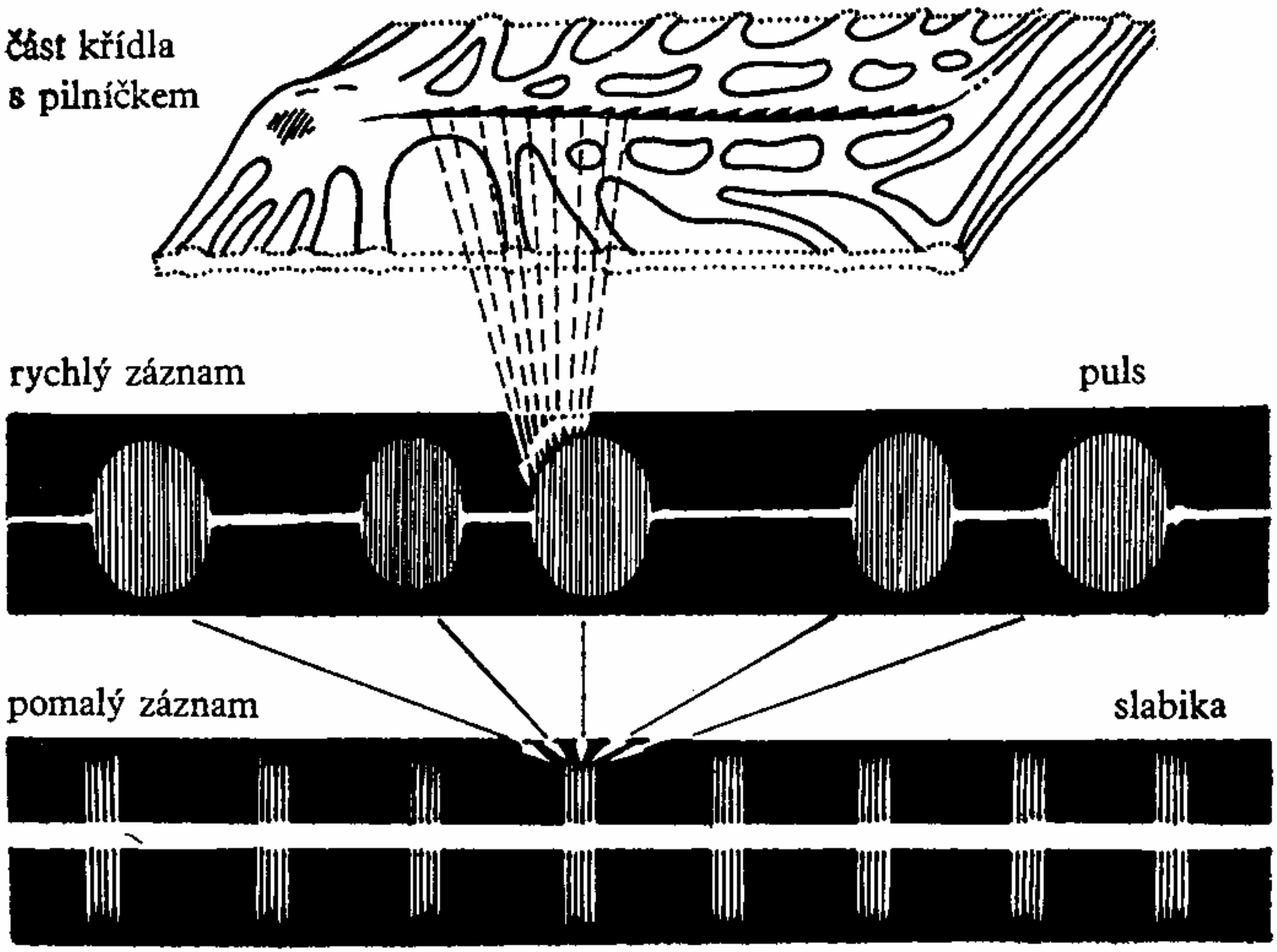


FIGURE 7–22 (A) A scolopidium of the locust auditory organ shows the complex structure of the sensory cells, their dendrite, and accessory scolopale and cap cells. (B) The tympanal organ of a bush cricket consists of a trachea and a complex group of sensory organs: the tympanal organ, the subgenual organ, and the intermediate organ. The crista acoustica of the tympanal organ contains numerous scolopidia. (C) The scolopidial receptors of the crista acoustica of the bush cricket respond preferentially to specific frequencies. (D) There is a tonotopic organization of the sensory receptive areas for audition in the nervous system (anterior ring tract) of the bush cricket. *(Modified from Oldfield 1985; Lakes and Schikorski 1990; Romer 1985.)*

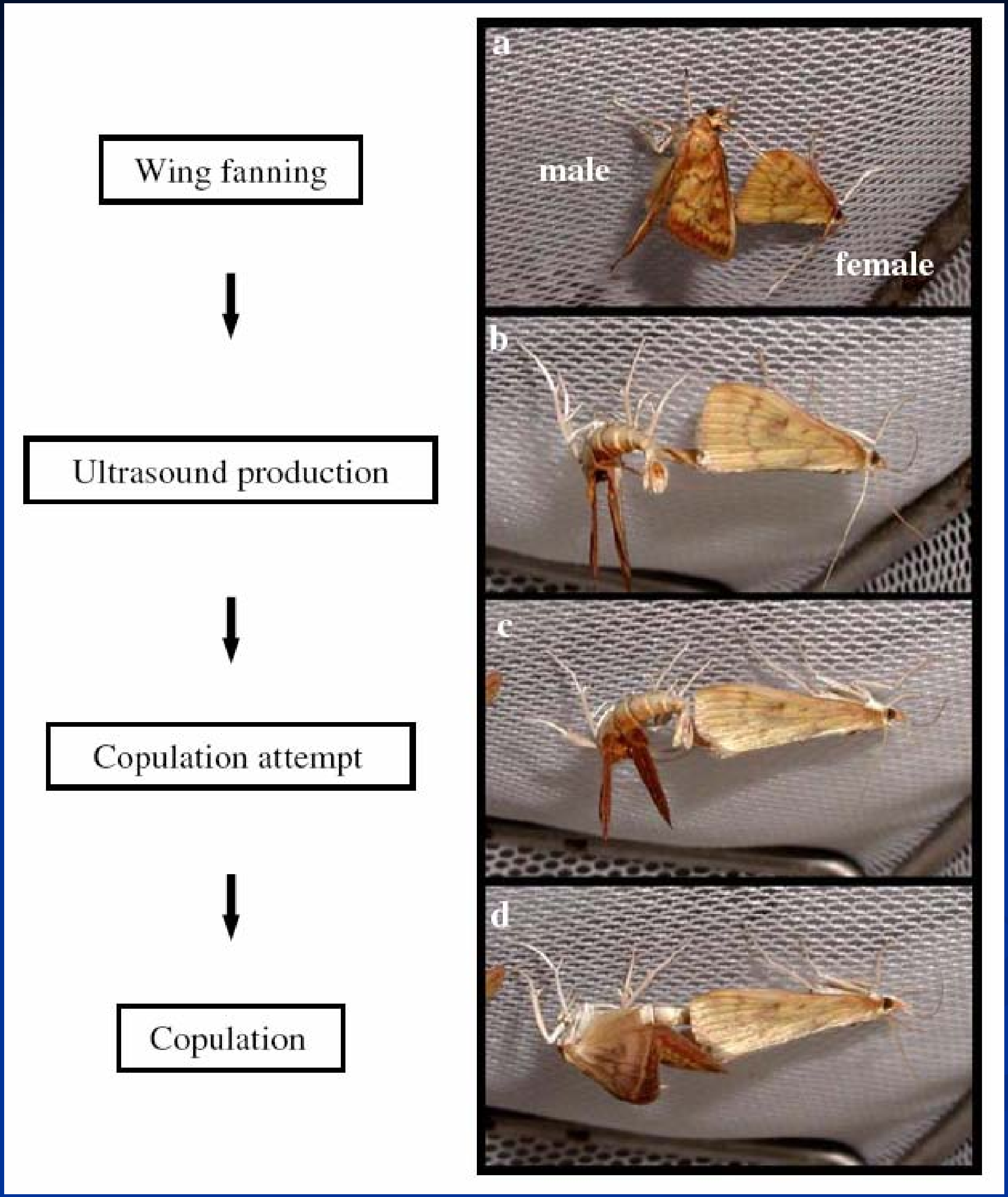




Zvuková komunikace
Důležitý je rytmus

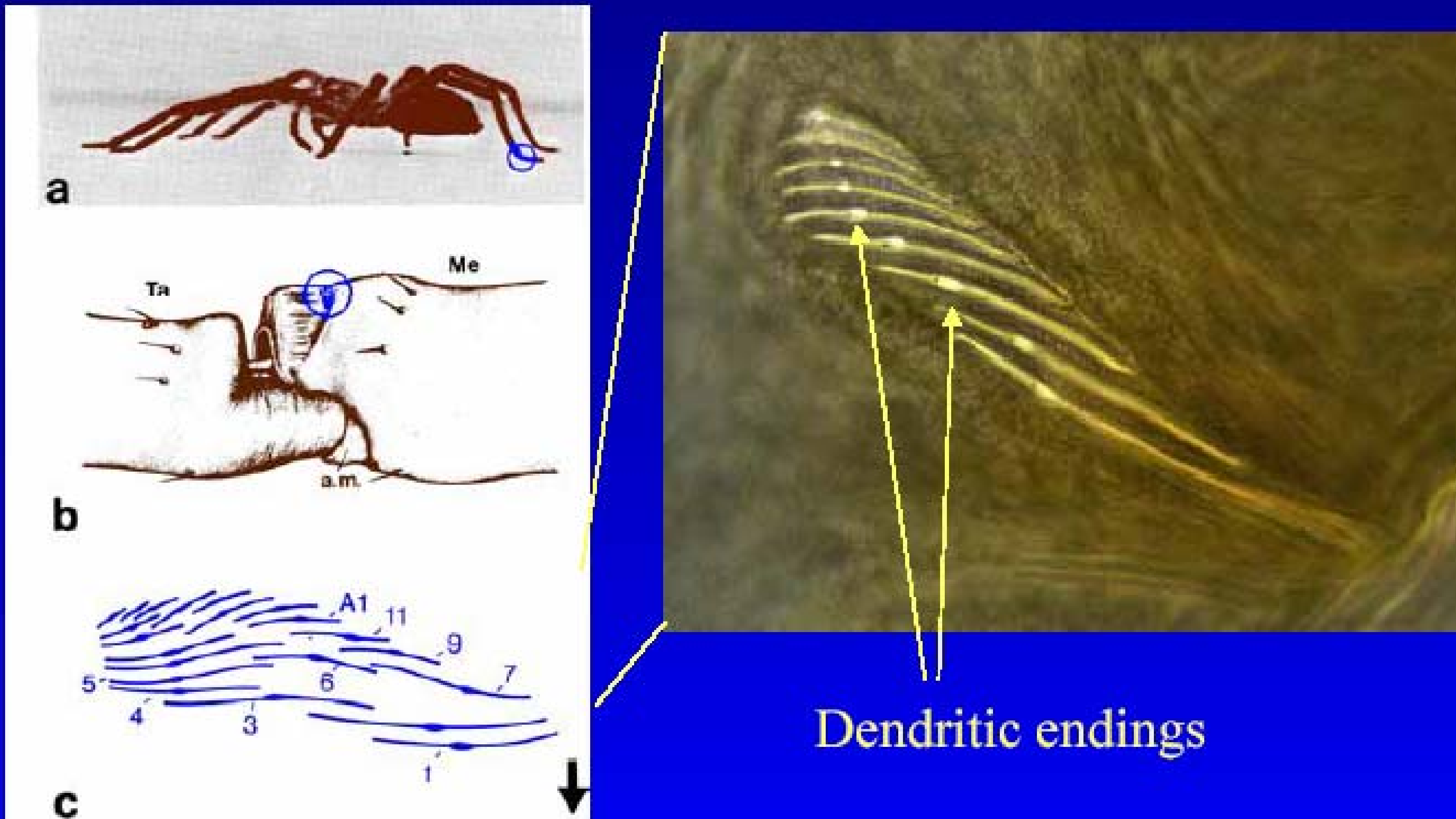


Osciloskopický záznam odhalil, jak vzniká nejlahodnější hmyzí zpěv, cvrkání cvrčka. Jednotlivé slabiky se skládají z několika pulsů čistého tónu, vzniklého zadrháváním řady zoubků pilníčku jednoho křídla o lištu druhého křídla.



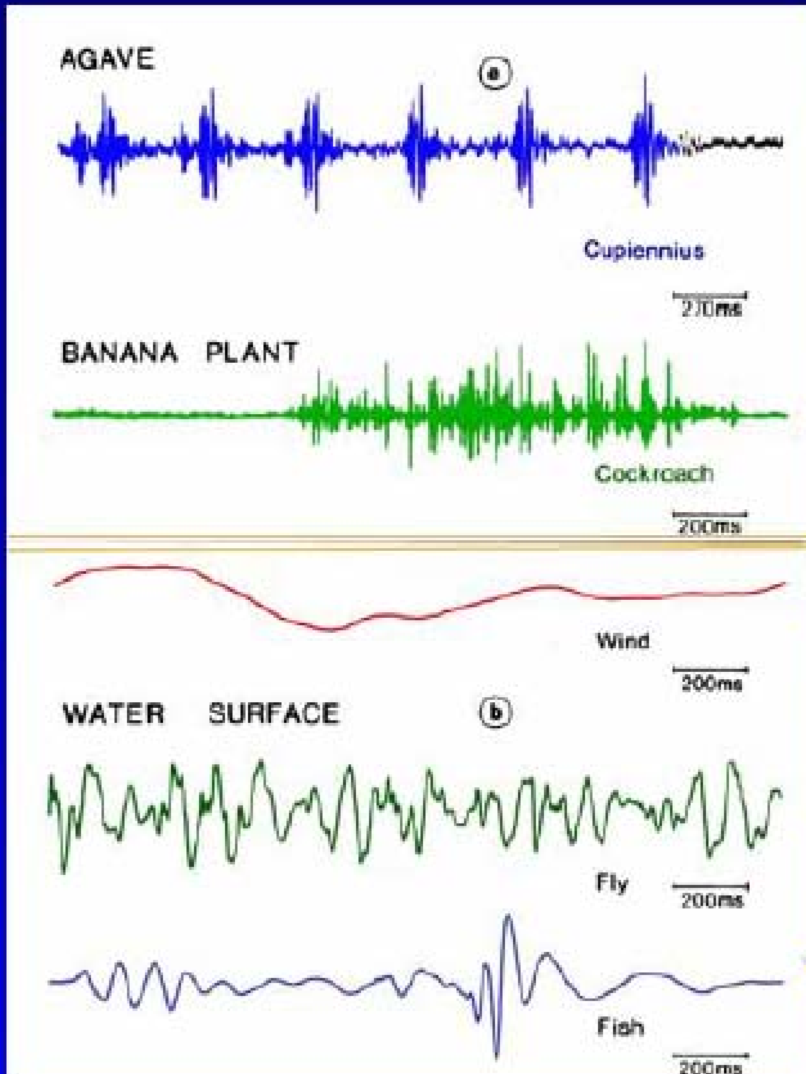
Wing fanning
Ultrasound production
Copulation attempt
Copulation
a
male
female
b
c
d

Slit sensilla in spiders: positional and vibrational sensors



Female spiders must distinguish many different vibrational signals to respond appropriately

Plants



← Male courtship signal

← Prey signal

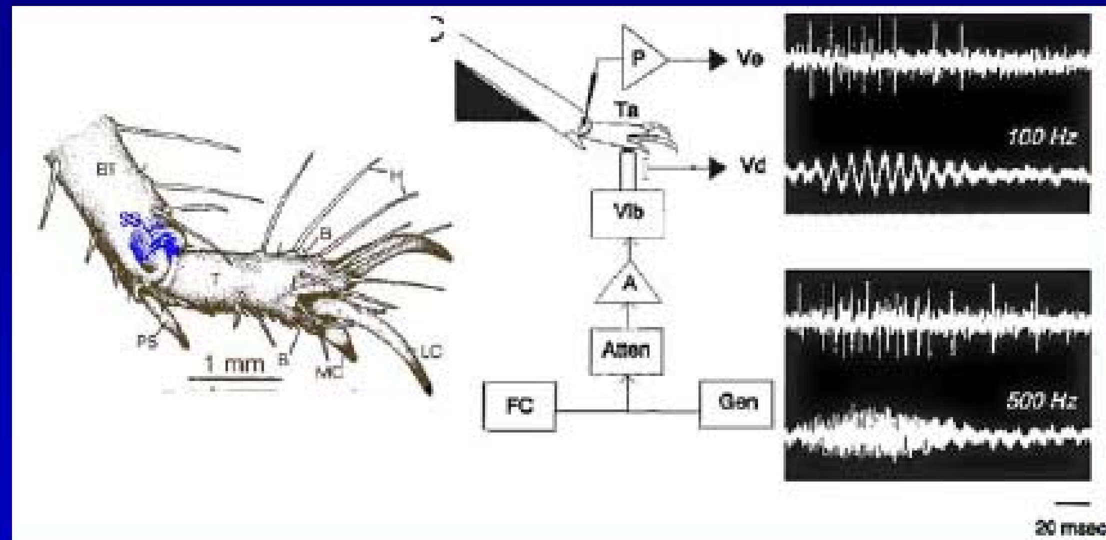
Water

← Wind (background)

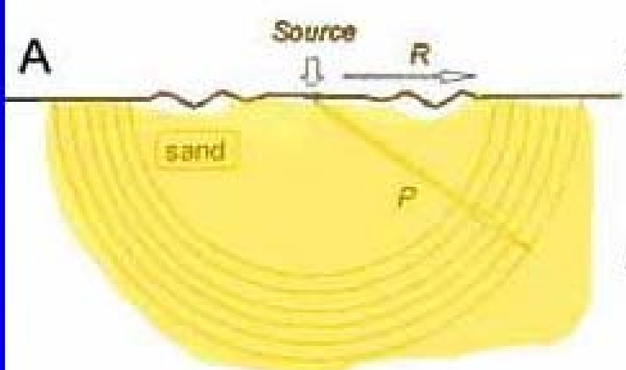
← Prey signal (fly)

← Predator signal (fish)

Scorpion prey detection using waves in sand

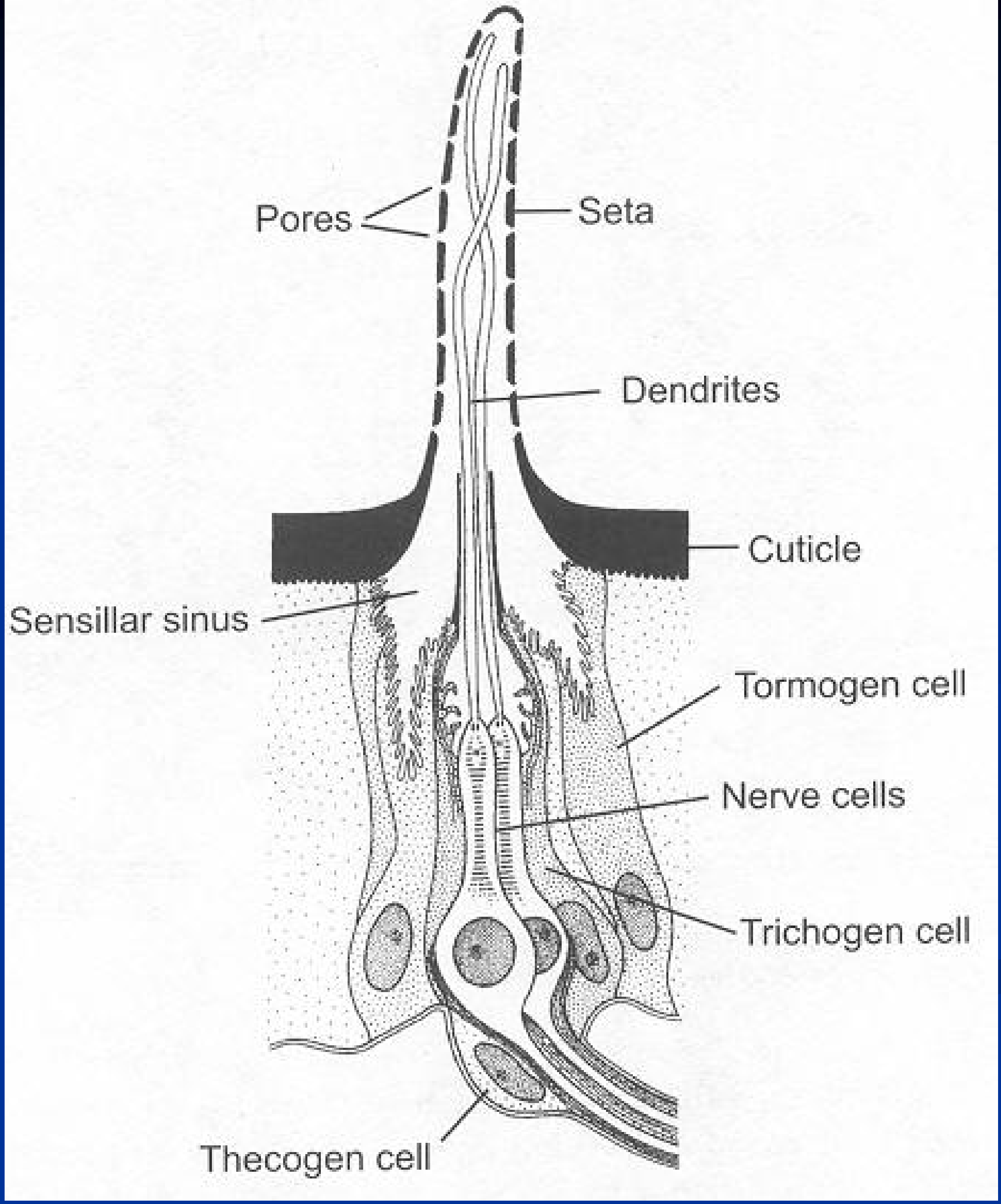


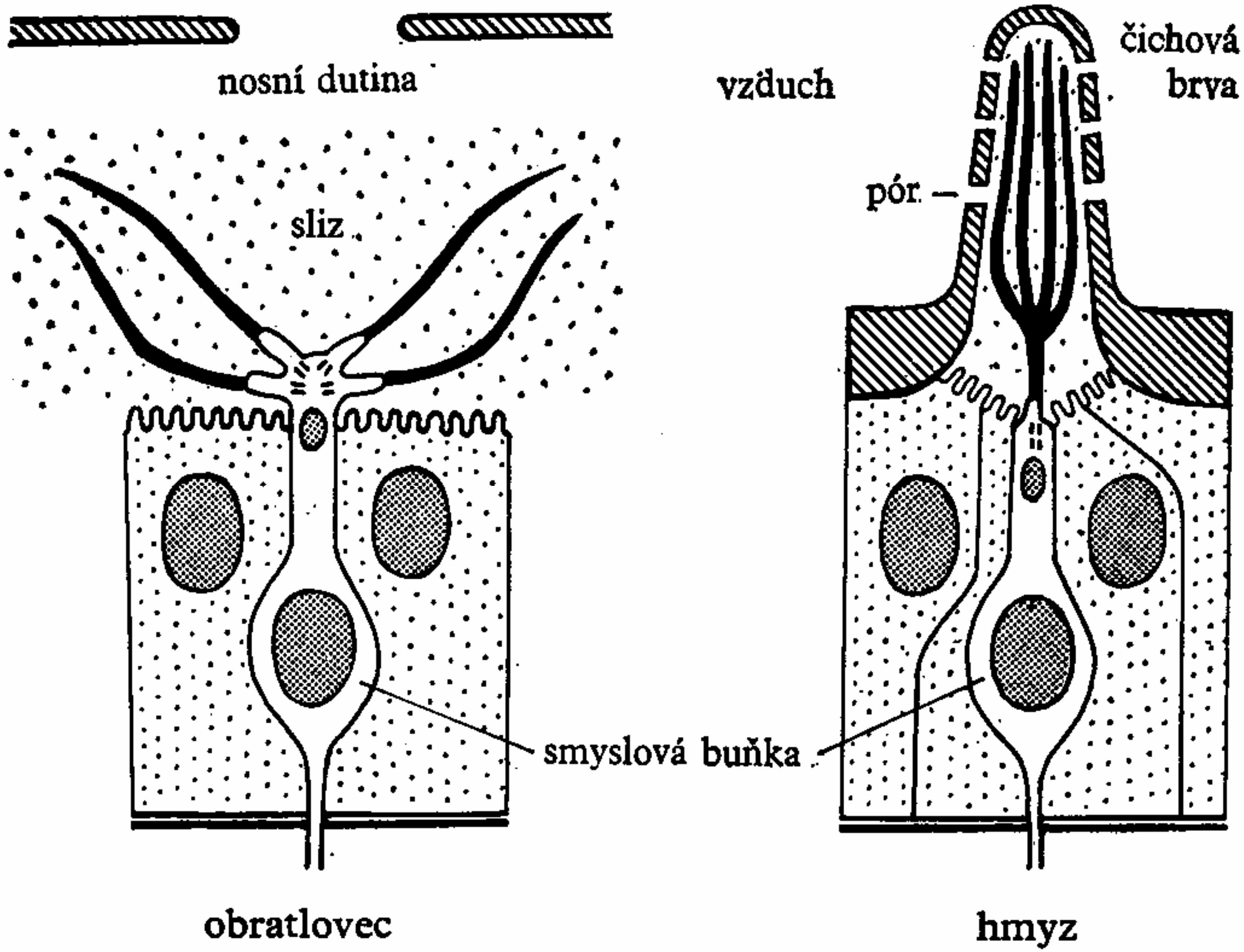
Vibrational wave transmission in sand



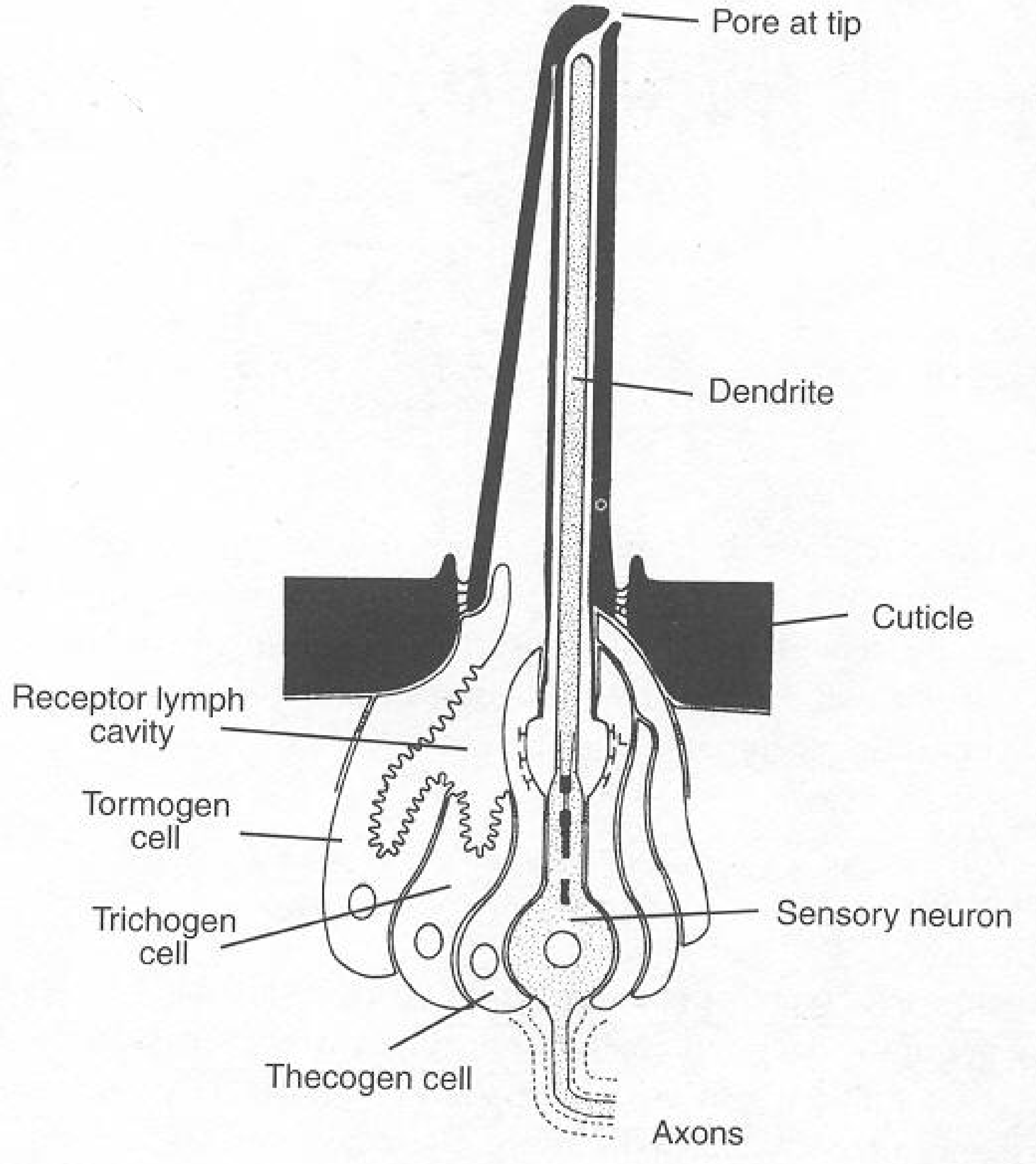
	V (m/s)	Freq (Hz)	λ (cm)	G(r)	α_{10} (db/cm)
Surface waves (>70%)					
Rayleigh (R)	45-50	300-400	~ 10-15 cm	~ 1/r	0.20-0.40
Love (L)	< 40>	---		~ 1/r	---
Body waves (<30%)					
Compressional (P)	140-150	< 2000	~ 7-15 cm	~ $1/r^2$	< 1
Shear (S)	< 120>	---		~ $1/r^2$	---

Chemorecepce



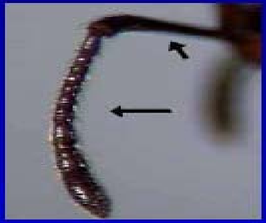


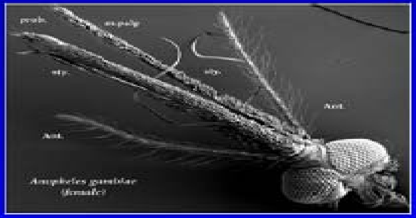
Diagramatické znázornění čichové sensily obratlovce a hmyzu představuje analogické struktury obou smyslových orgánů



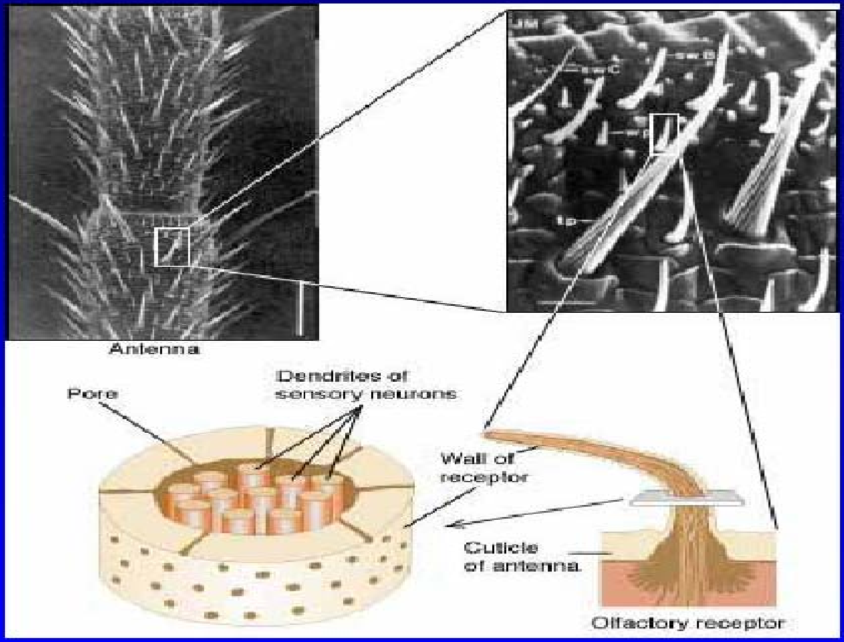
Pore at tip
Dendrite
Cuticle
Receptor lymph cavity
Tormogen cell
Trichogen cell
Sensory neuron
Thecogen cell
Axons

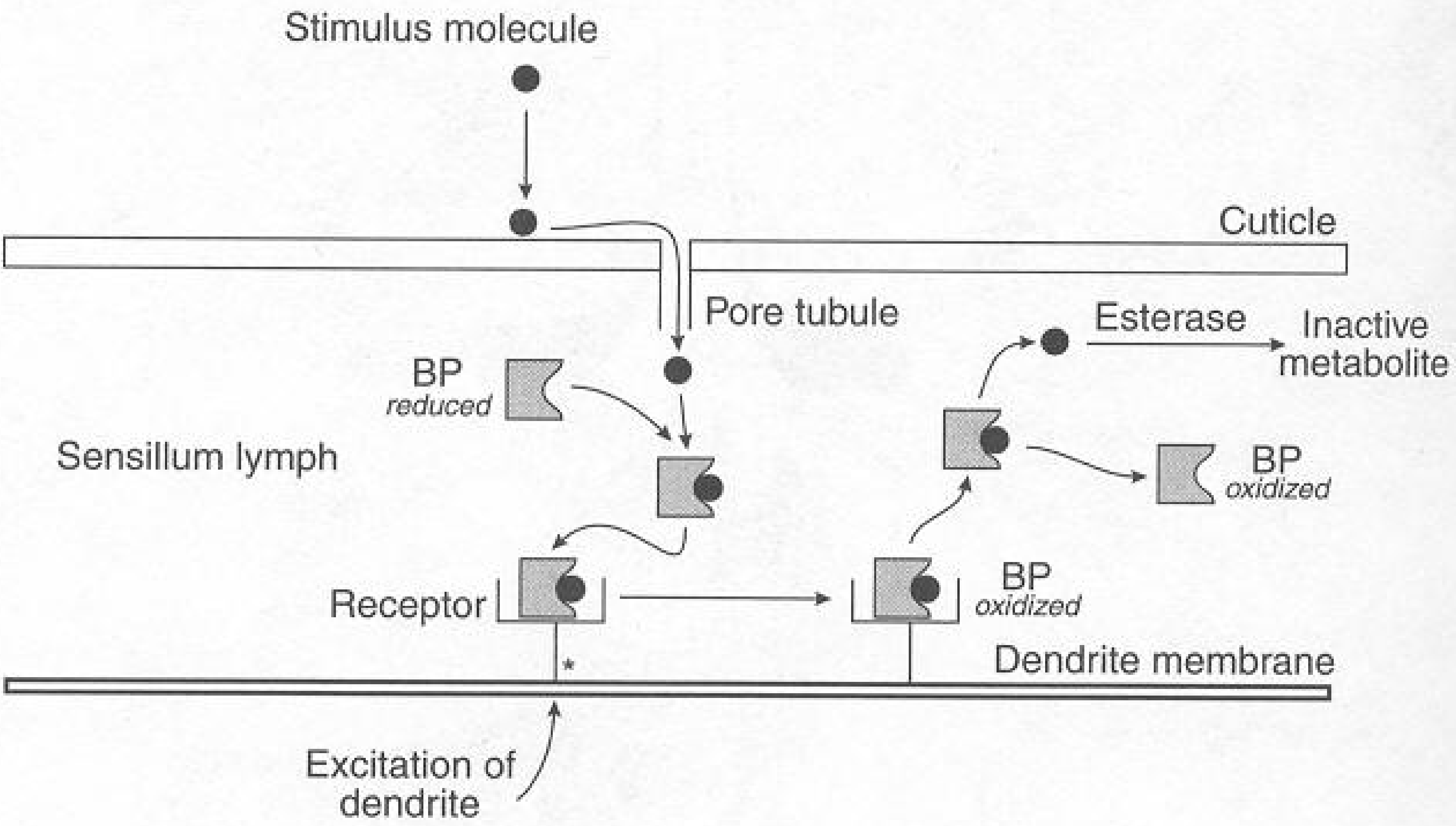
Antennal morphology diversity



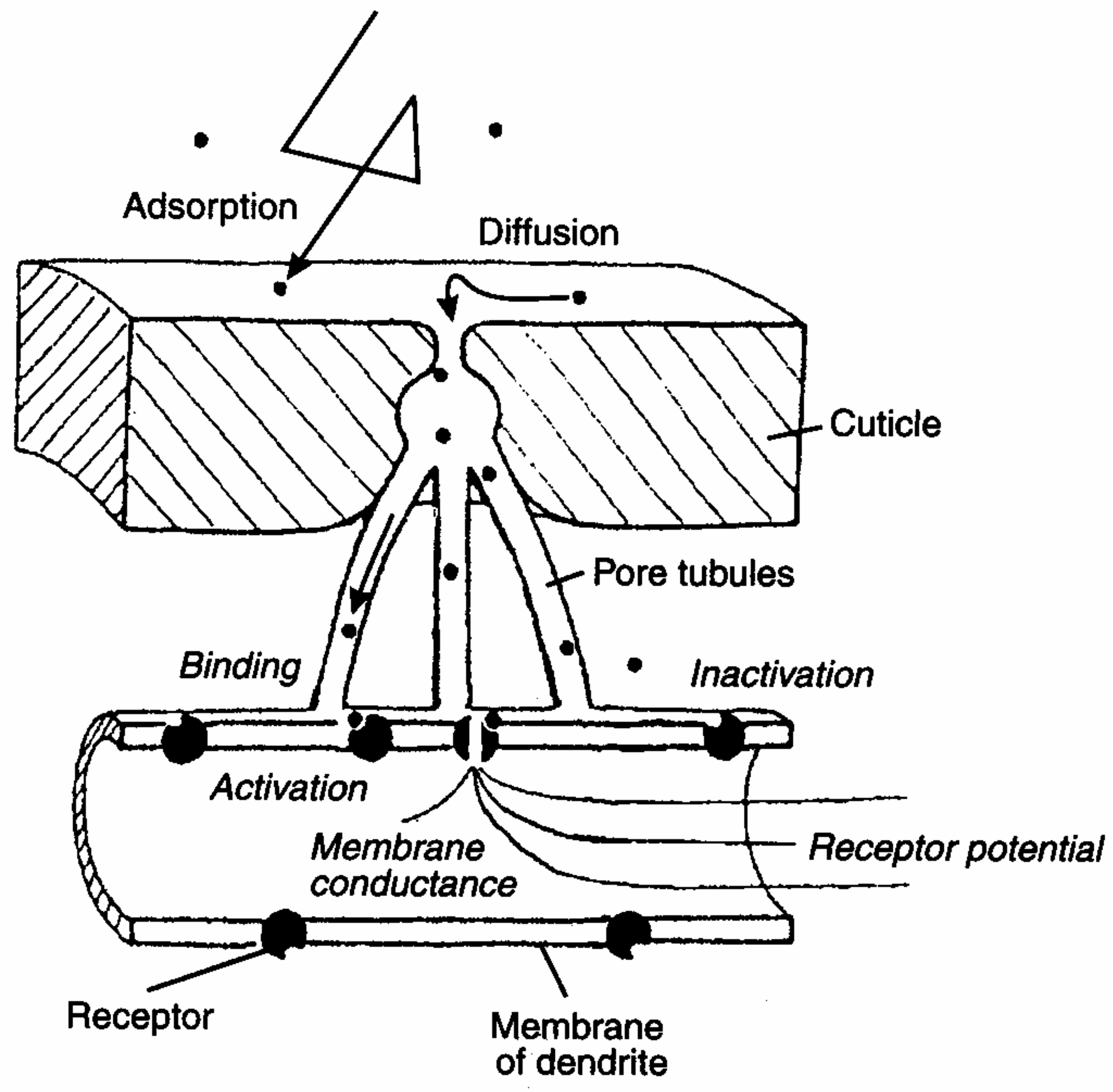


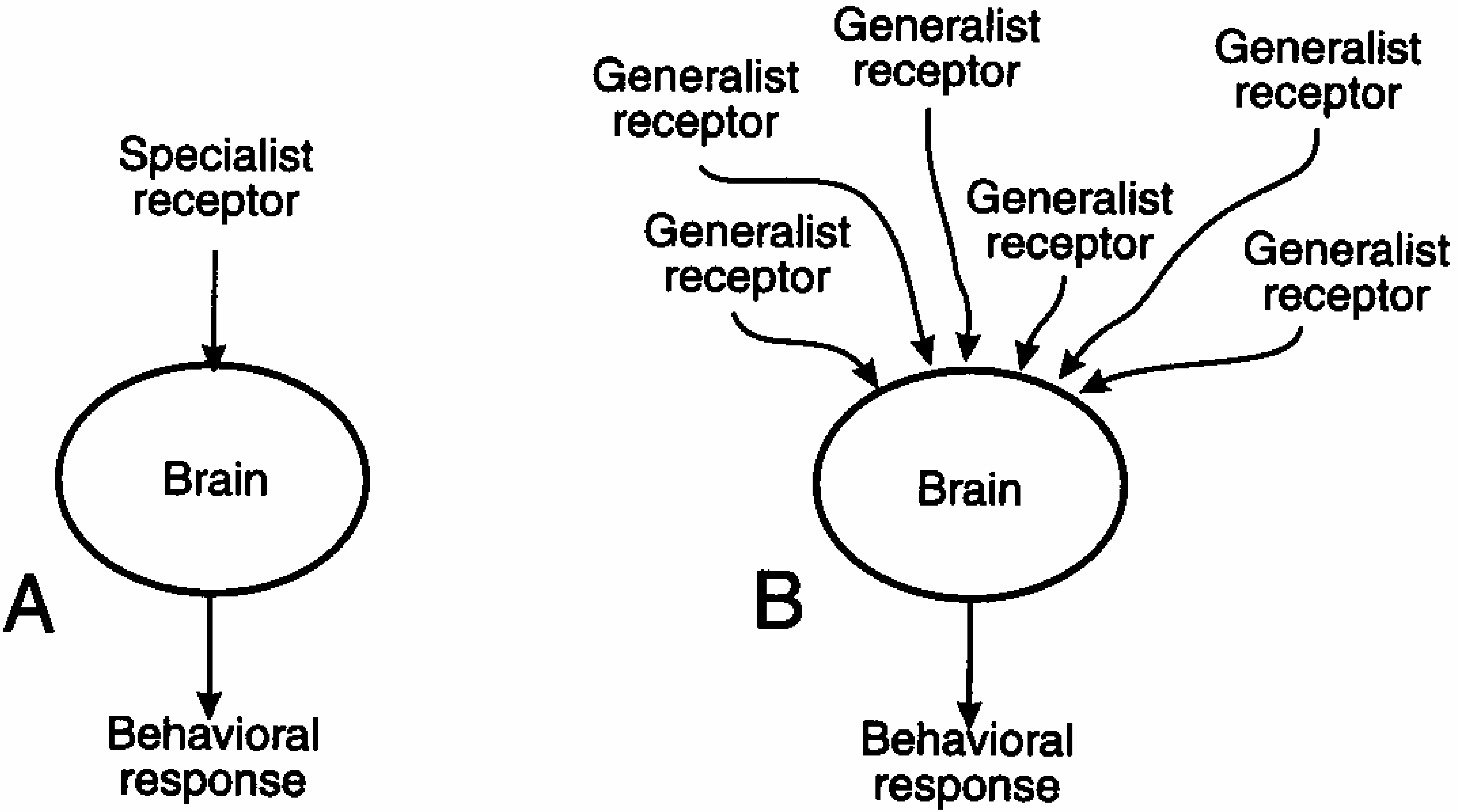
Anatomy of an antennal sensilla



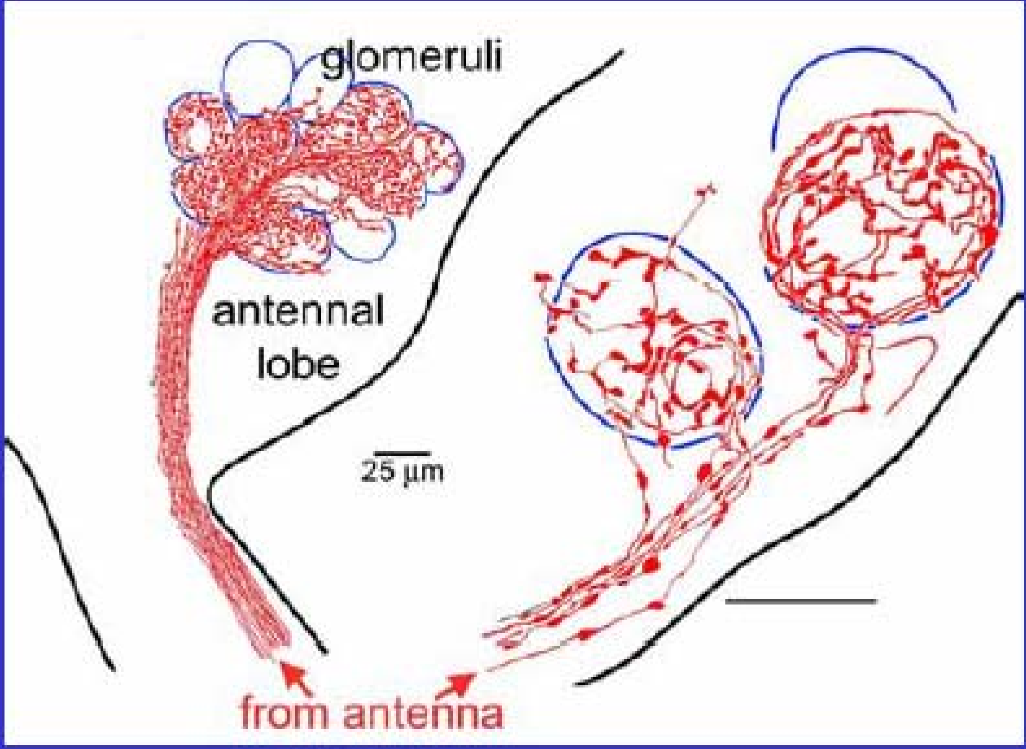


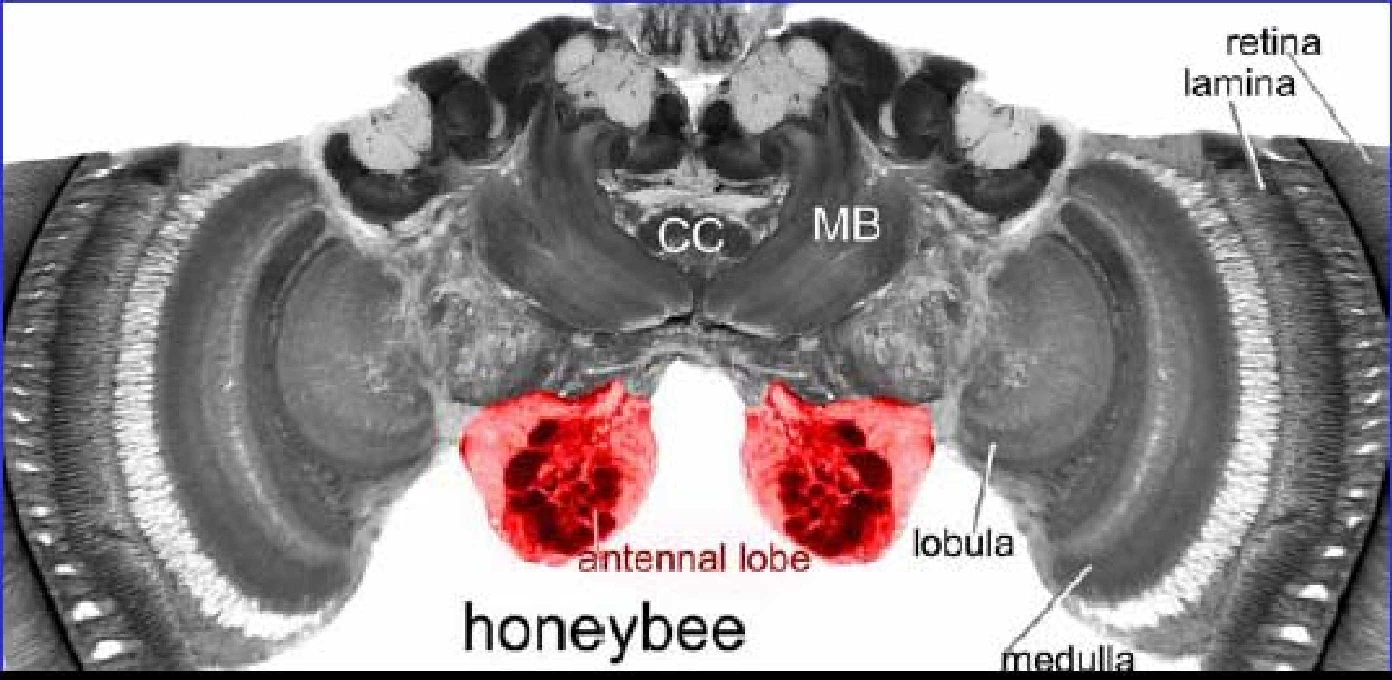
Stimulus molecule
Cuticle
Pore tubule
Esterase
Inactive metabolite
BP
reduced
Sensillum lymph
BP
oxidized
Receptor
BP
oxidized
*
Dendrite membrane
Excitation of dendrite


Adsorption
Diffusion
Cuticle
Pore tubules
Binding
Inactivation
Activation
Membrane
conductance
Receptor potential
Receptor
Membrane
of dendrite


Specialist receptor
Brain
Behavioral response
A
Generalist receptor
Generalist receptor
Generalist receptor
Generalist receptor
Generalist receptor
Generalist receptor
Brain
Behavioral response
B

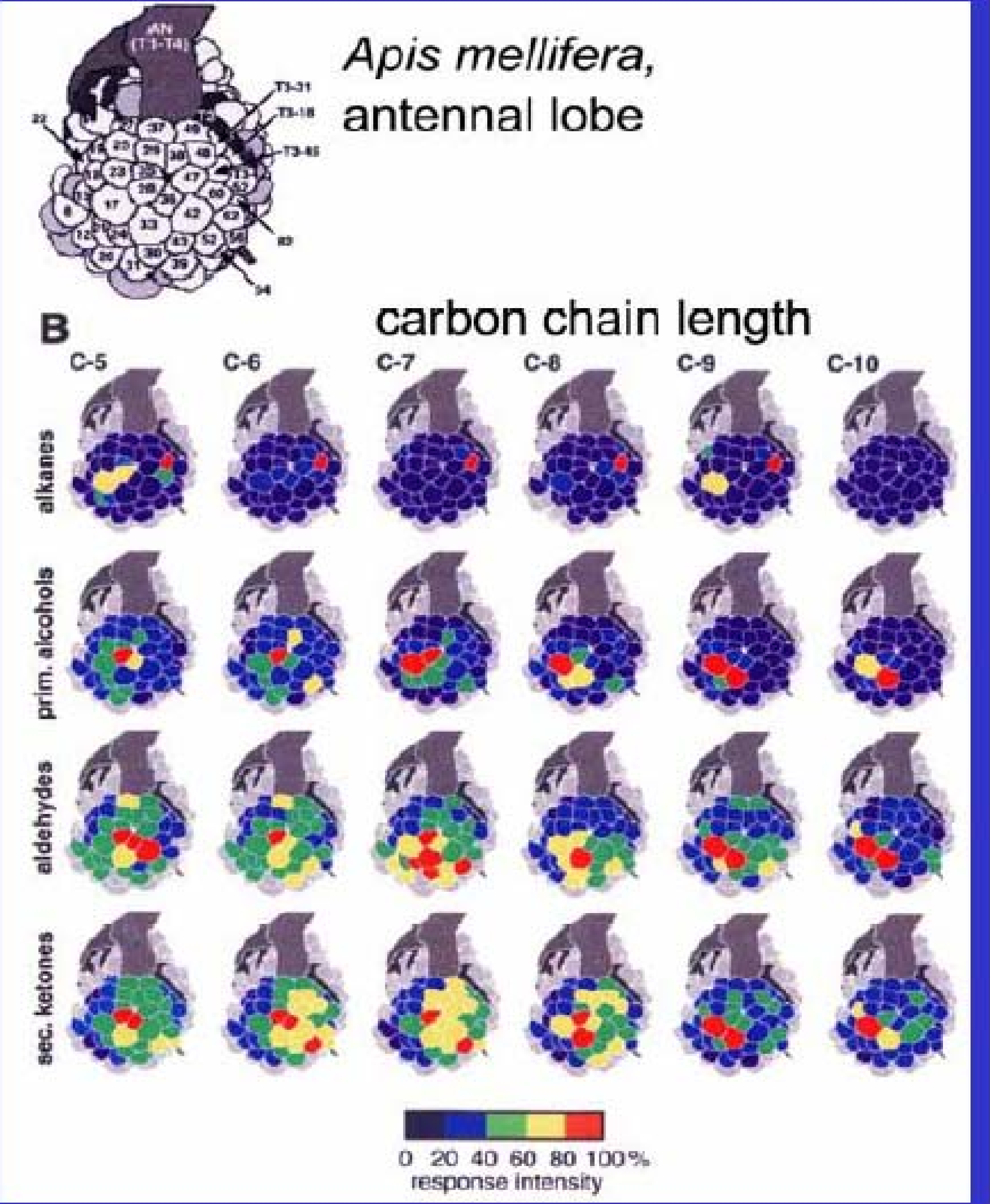
Antennal olfactory receptor neurons terminate in antennal lobe **glomeruli**

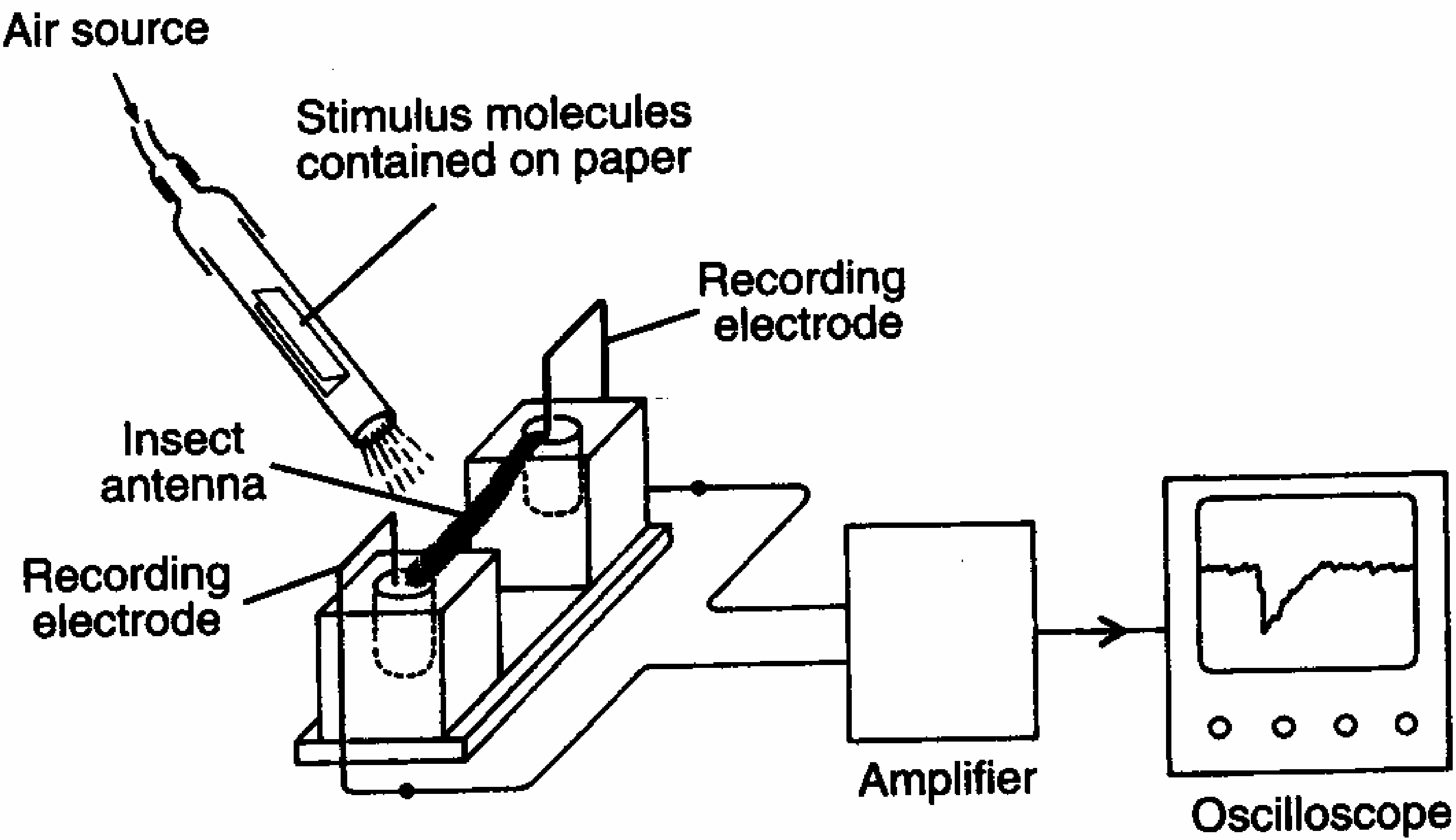




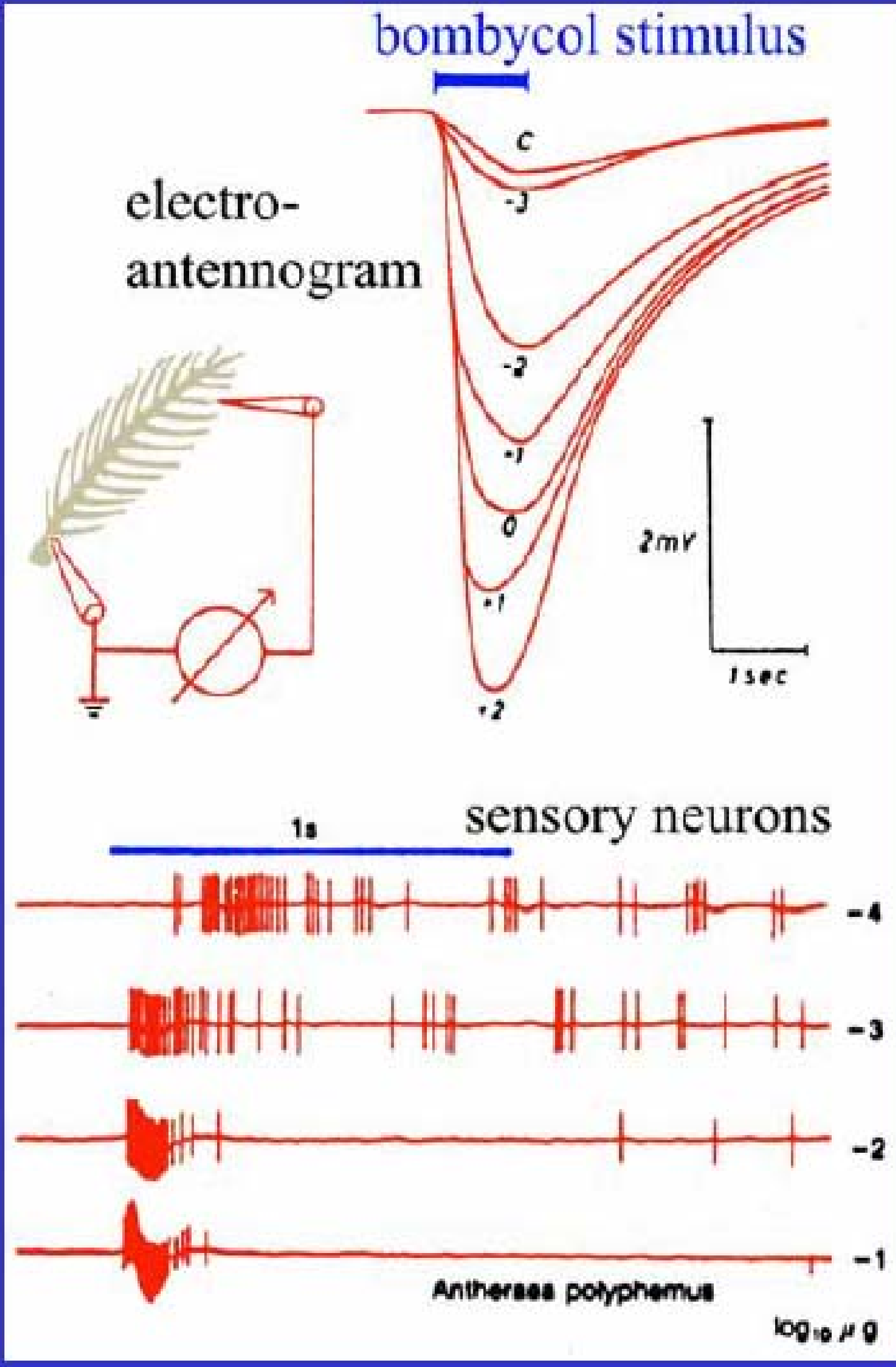
Glomeruli responses reflect odorants' structural properties (chain length, residues, polarity etc.):

odor map

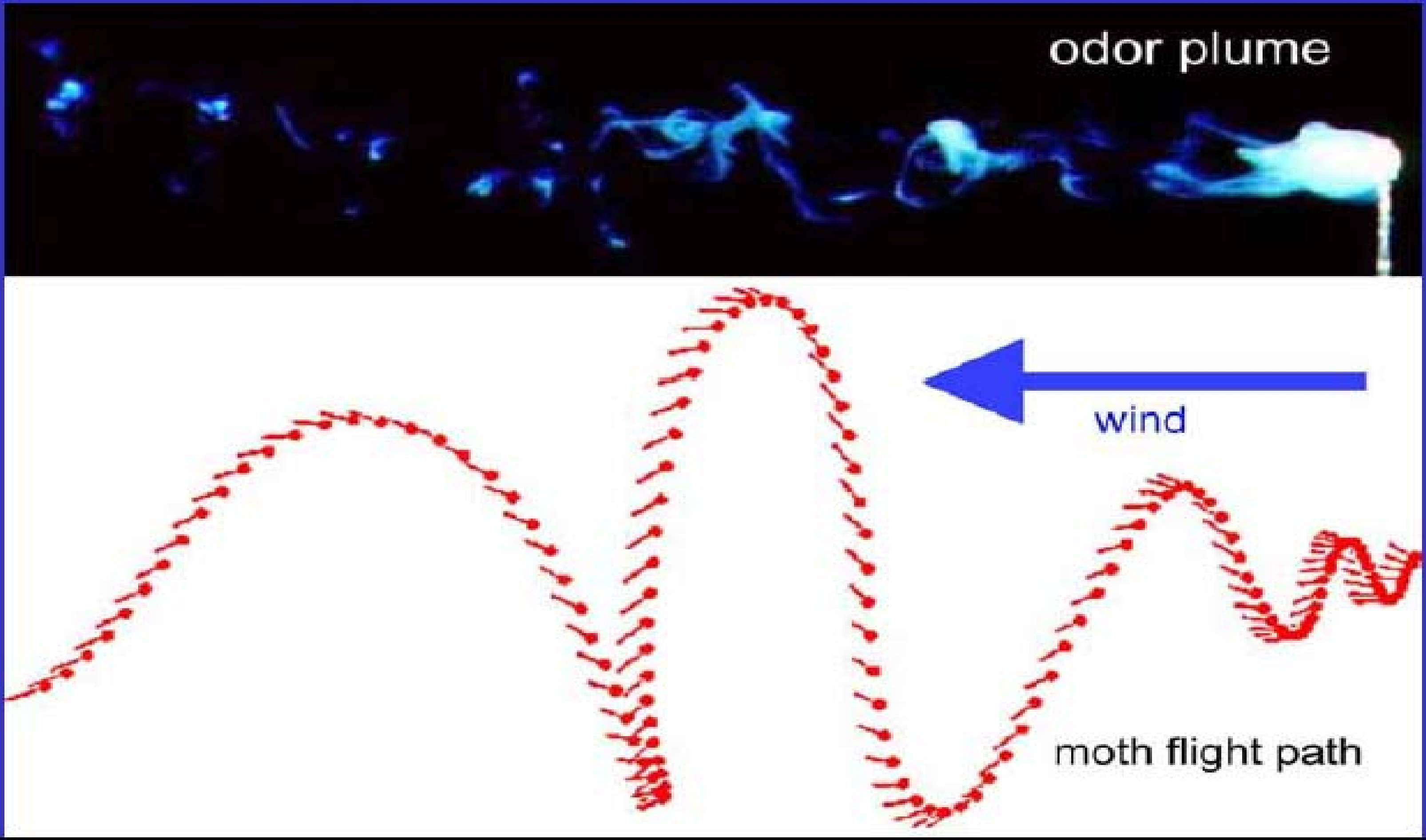


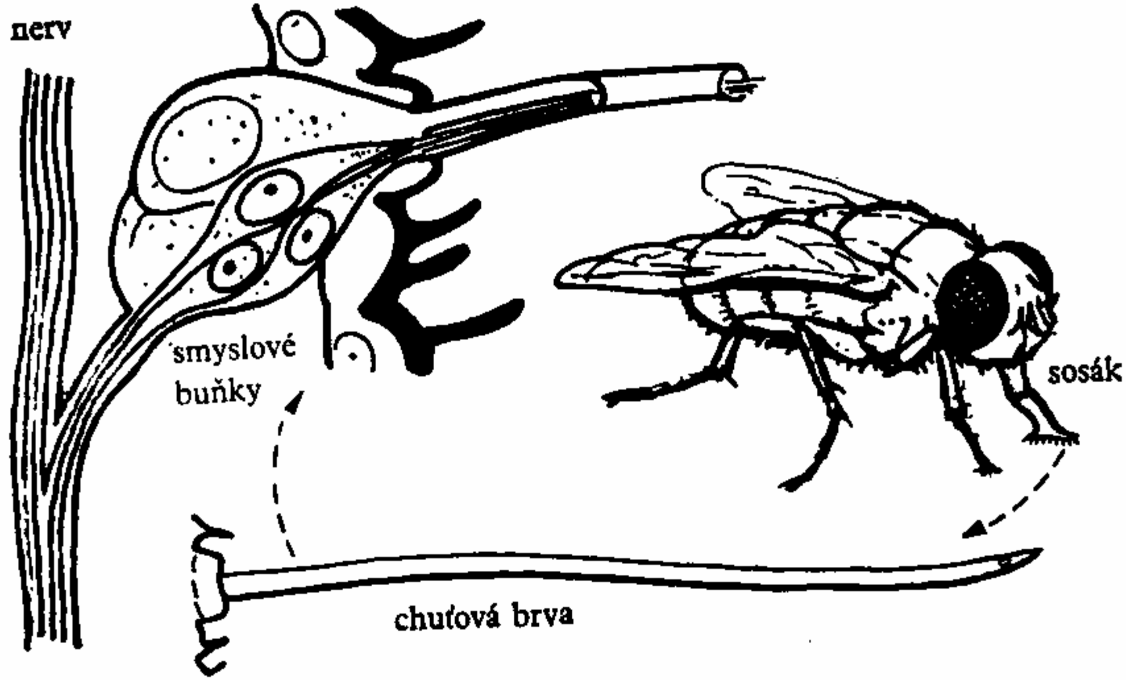

Air source
Stimulus molecules contained on paper
Recording electrode
Insect antenna
Recording electrode
Amplifier
Oscilloscope

Olfactory receptor neurons respond to odorants



Odor is discontinuously distributed in air

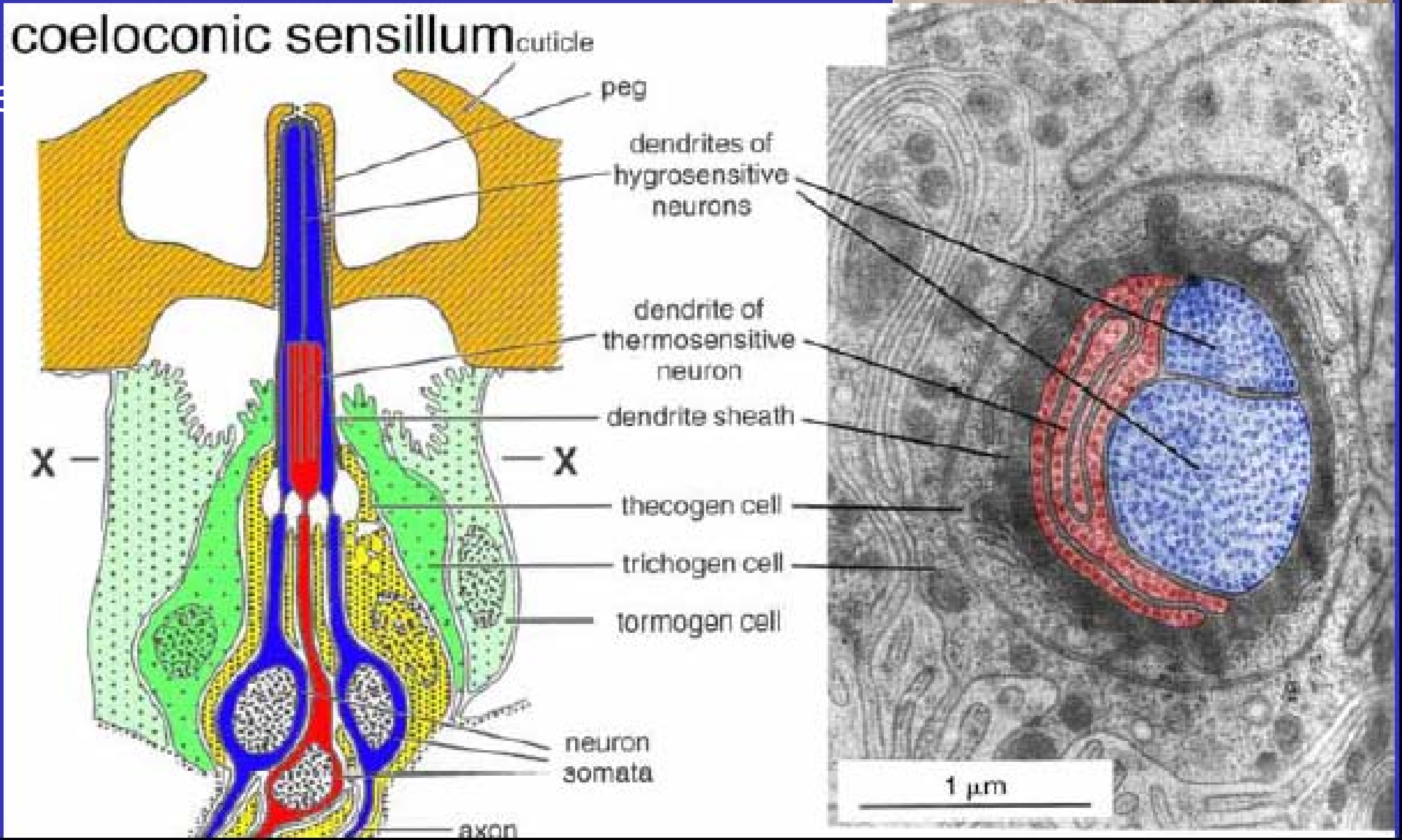




Chuťové sensily z konce mušího sosáku jsou dlouhé brvy s otvůrkem na konci. Teprve mikroskopický řez odhalí tři smyslové buňky v základu brvy, jejichž citlivé výběžky zasahují až ke špičce.

Thermoreceptors are often associated with hygro-receptors in sensilla embedded within the cuticle

Termorecepce



Hygrorecepce

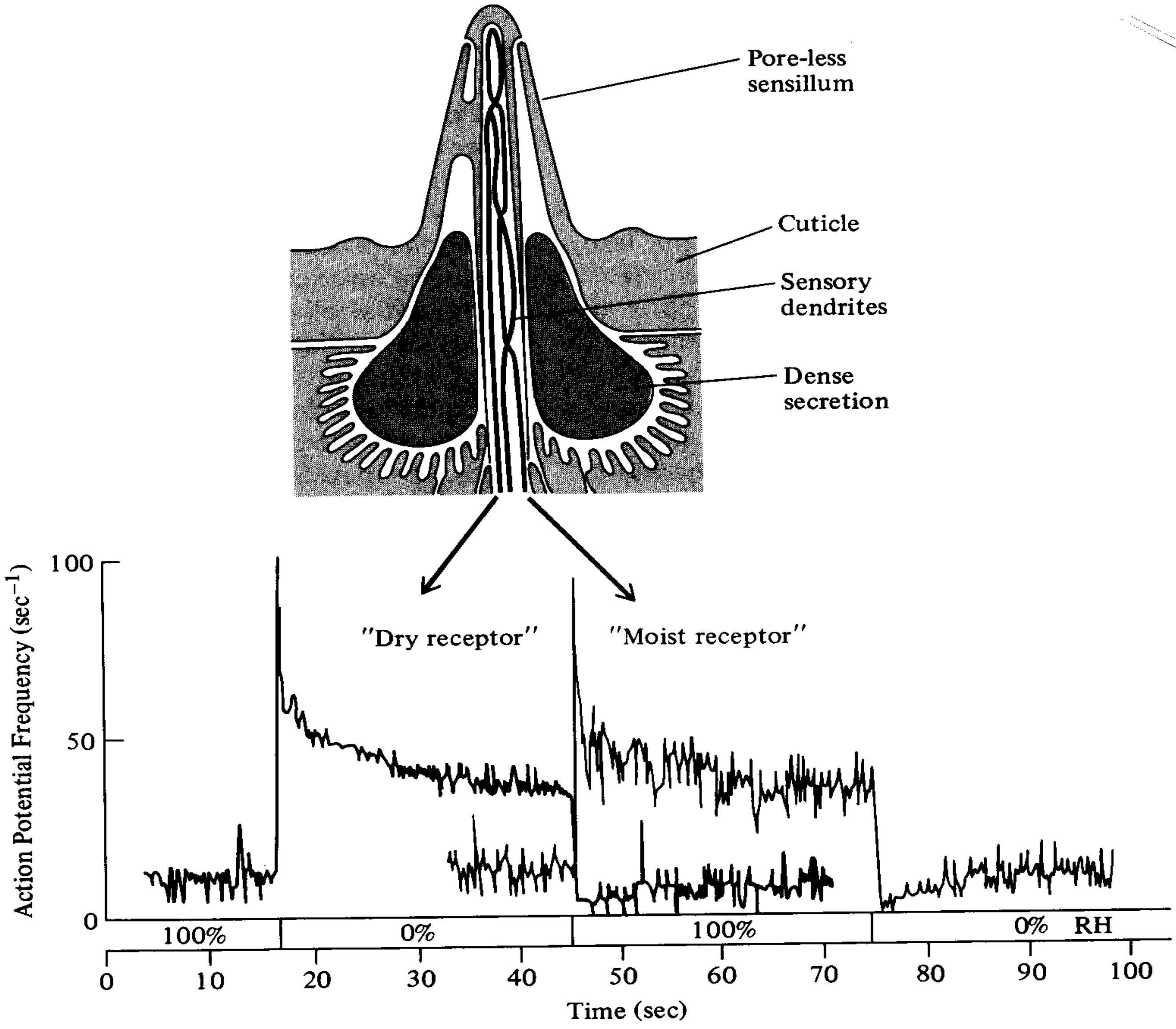


FIGURE 7–18 The "cold-moist-dry" triad sensory sensillum of the cockroach contains three bipolar sensory neurons; one neuron of the hygroreceptor responds to high humidity ("moist" receptor) and one to low humidity ("dry" receptor). The receptor cavity of the poreless sensillum is filled with a dense secretion. *(Modified from Yokohari and Tateda 1976; Schaller 1978.)*

Some beetles can detect forest fires

IR recepce

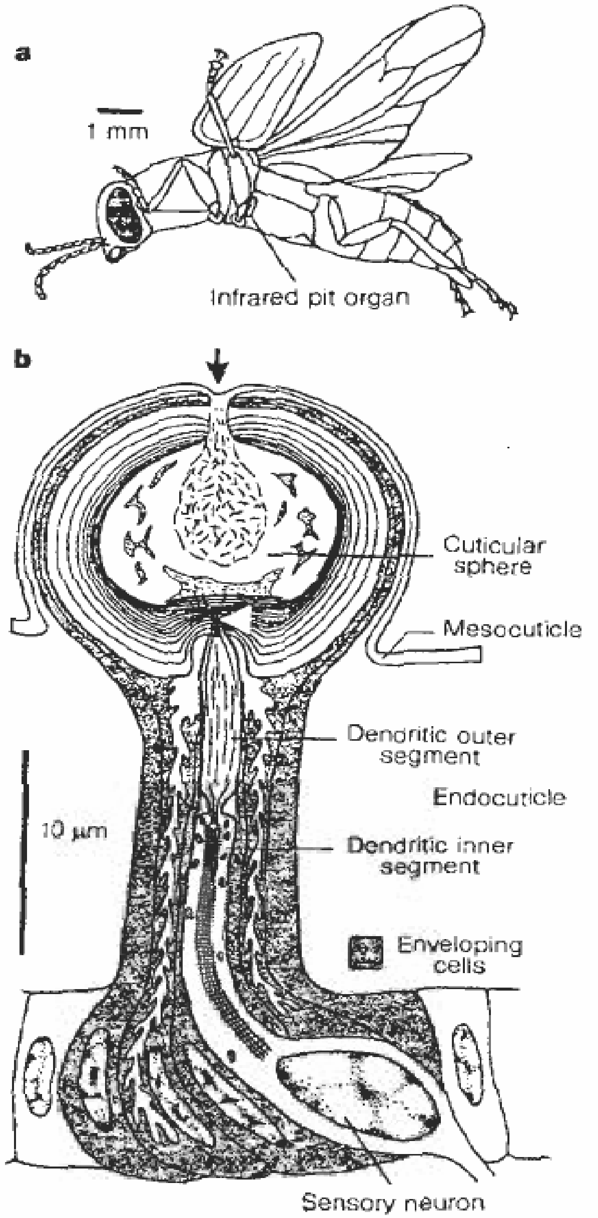


Figure 1 a, Diagram of *Melanophila* (body length 10 mm). The infrared pit organs, situated next to the coxae of the middle legs, are completely exposed during flight. b, An infrared sensillum, redrawn from ref. 3.

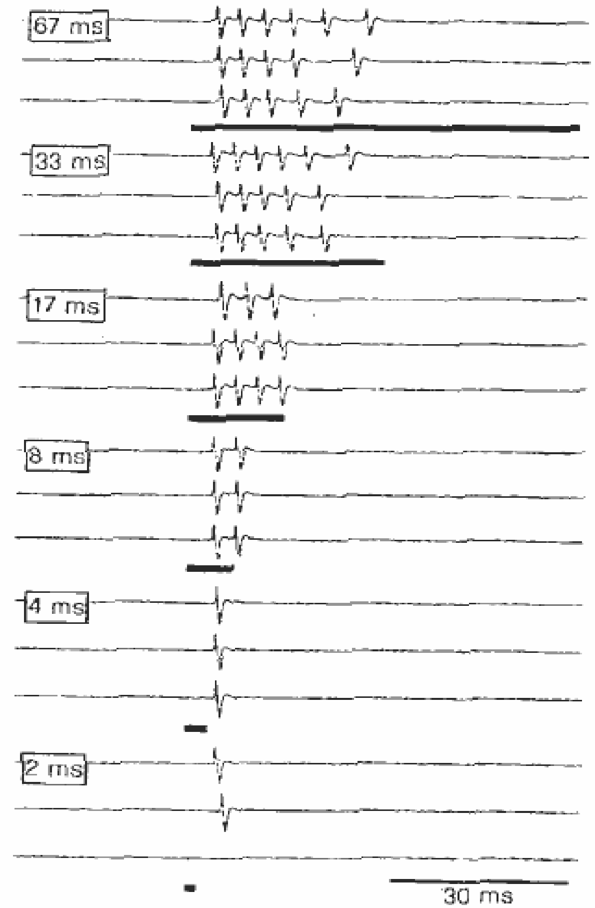
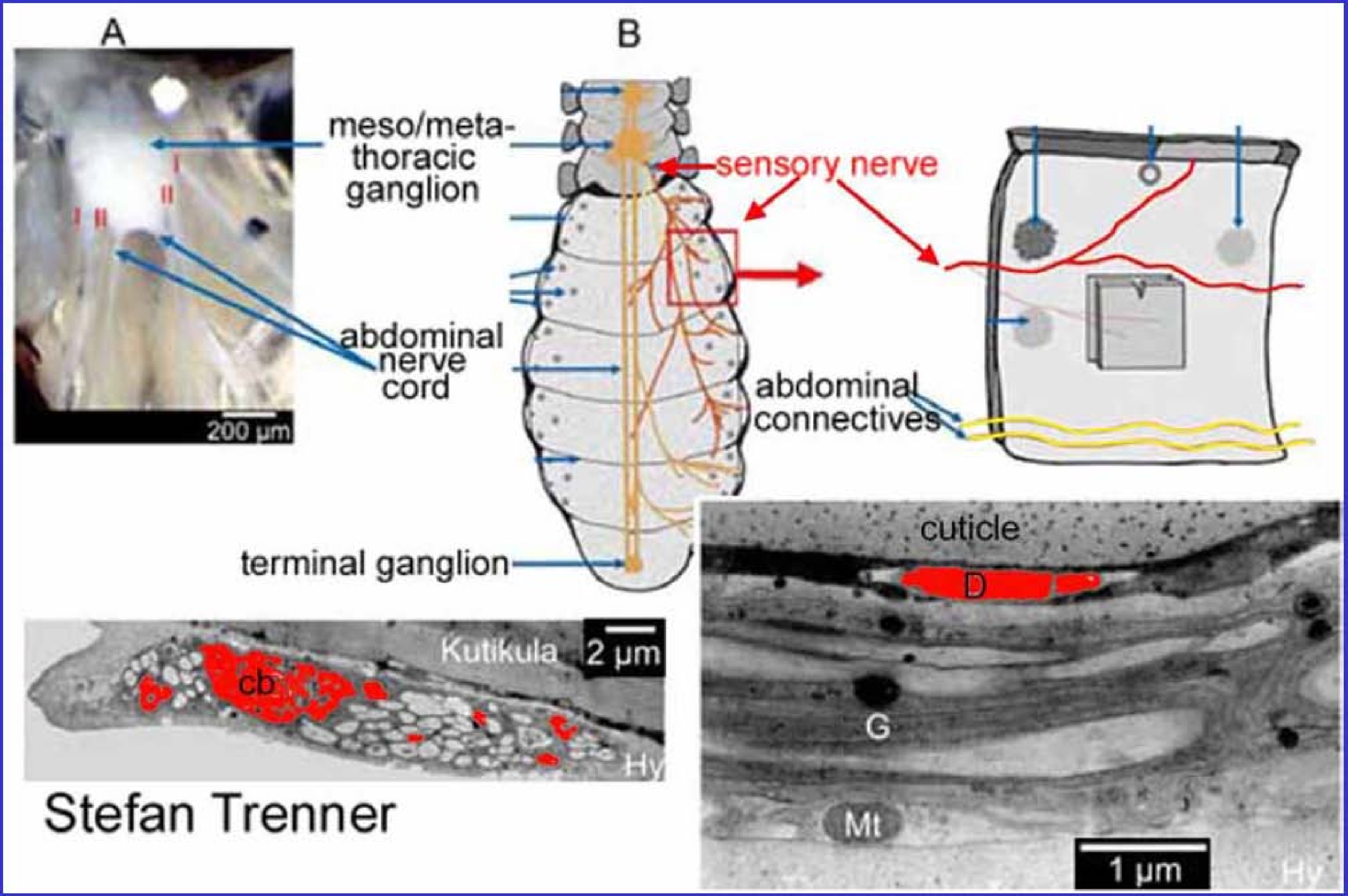


Figure 2 The responses of a neuron, recorded from the pit organ, to various infrared stimuli. Each trace shows the original response to one stimulus. Horizontal bars indicate exposure times. Each trial was repeated three times. The number of action potentials decreases with decreasing stimulus duration; 2 ms was sufficient to generate a response. If the mirror was covered, no response was recorded at any of the infrared intensities and shutter speeds tested.

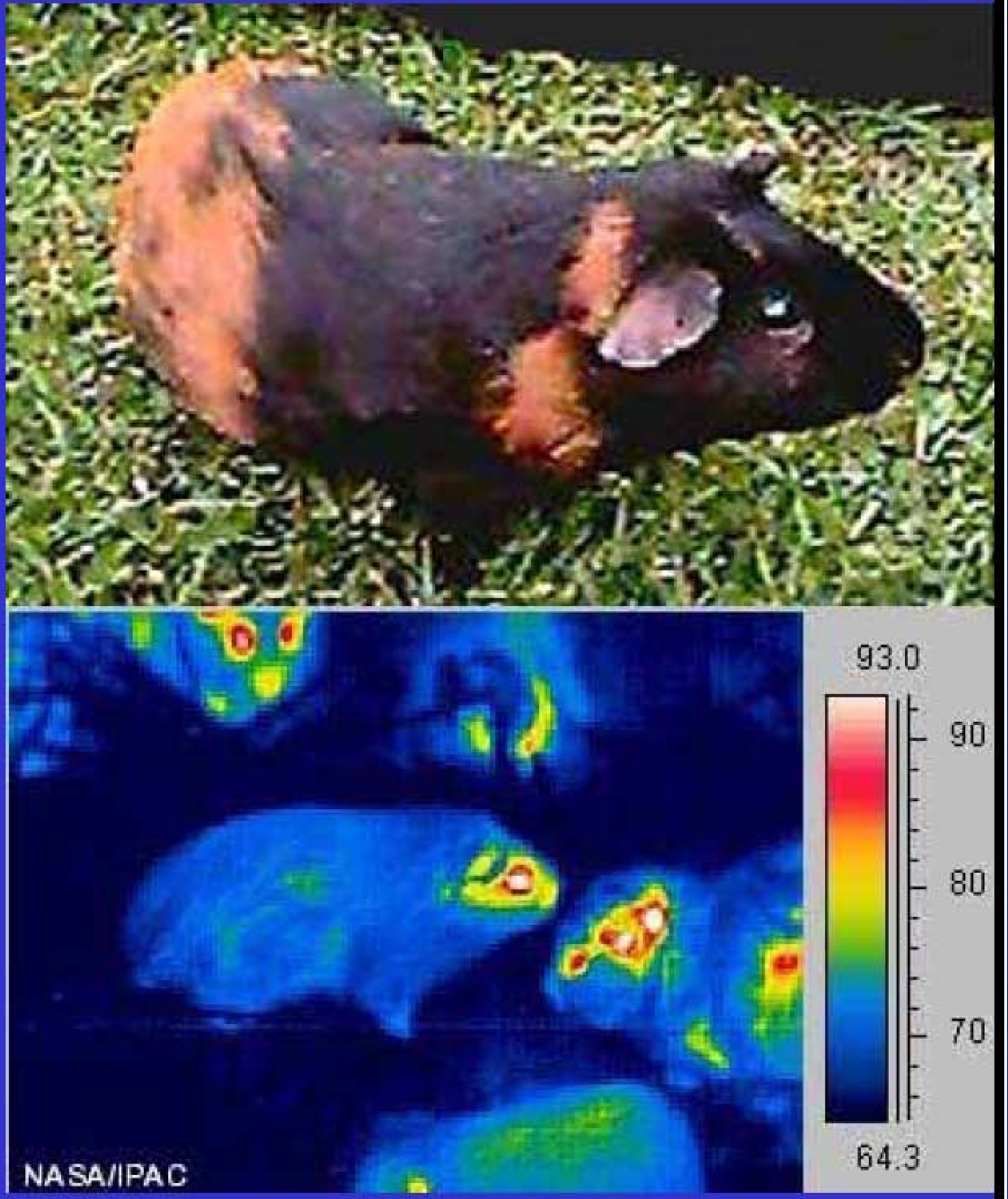
pass infrared filter (50% cut-on at 1.8 µm) and neutral-density filters. At a radiation intensity of 24 mW cm^{-2} single neurons

Warm stimuli are probably perceived by non-specialized dendrites in the body-wall of *Rhodnius*



Warm-blooded animals emit infrared radiation

('heat')



Infrared photograph:

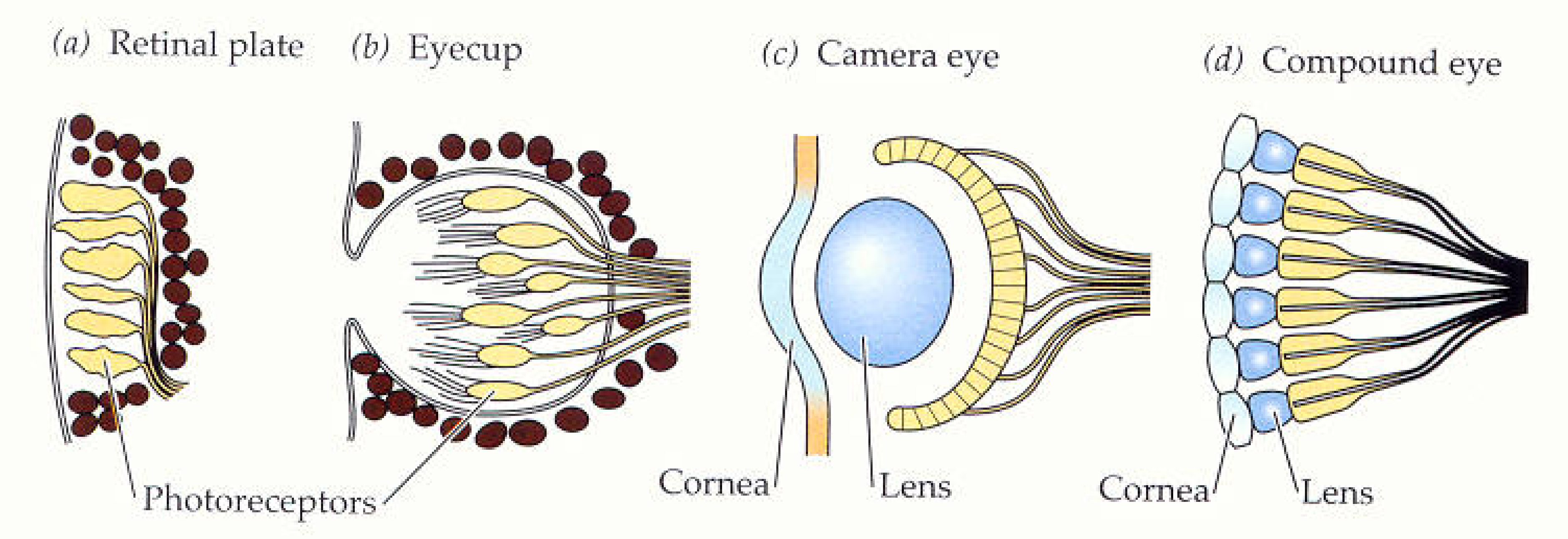
reflected 'light' (ca. 800-1200 nm)

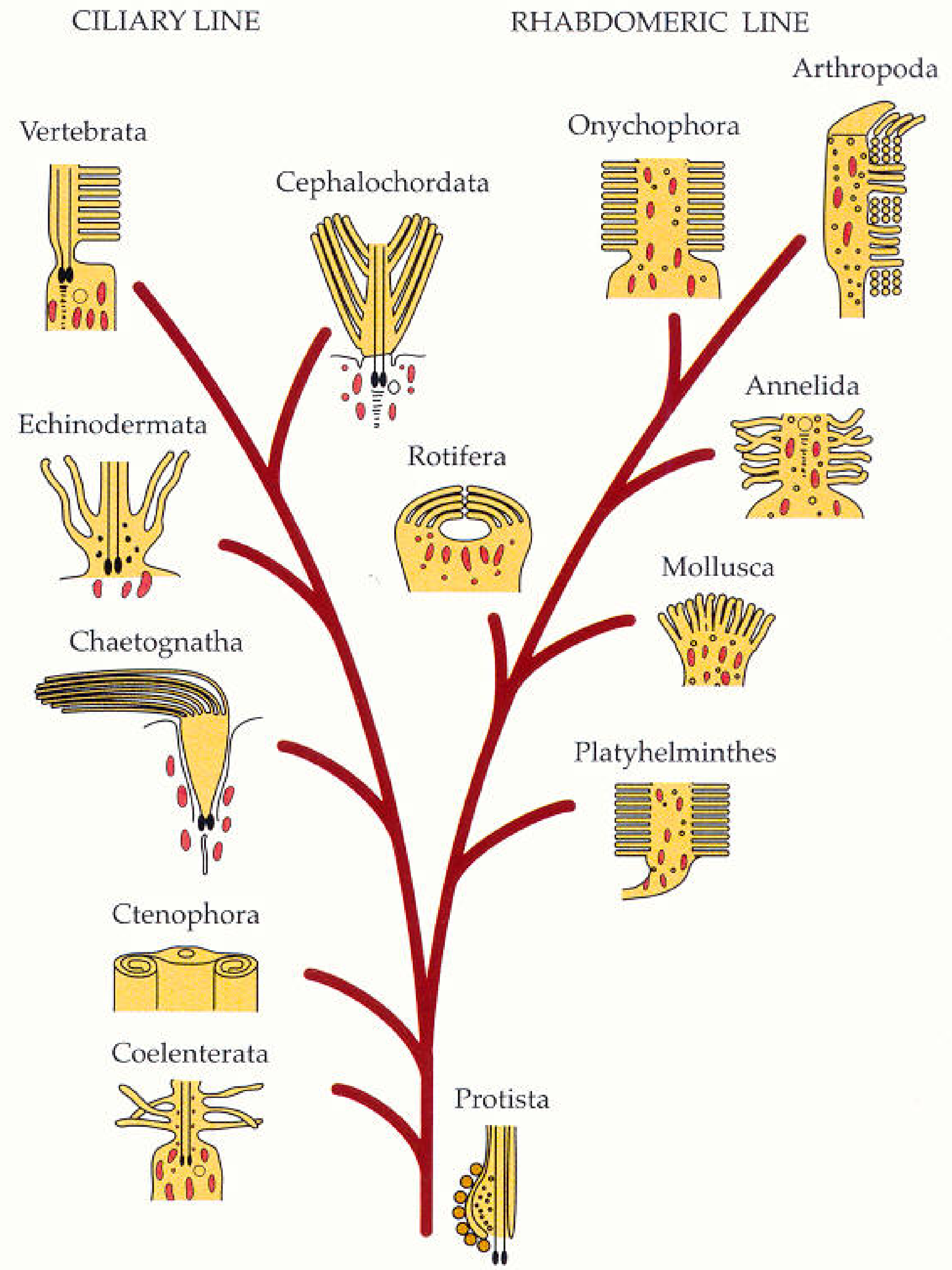
Thermograph:

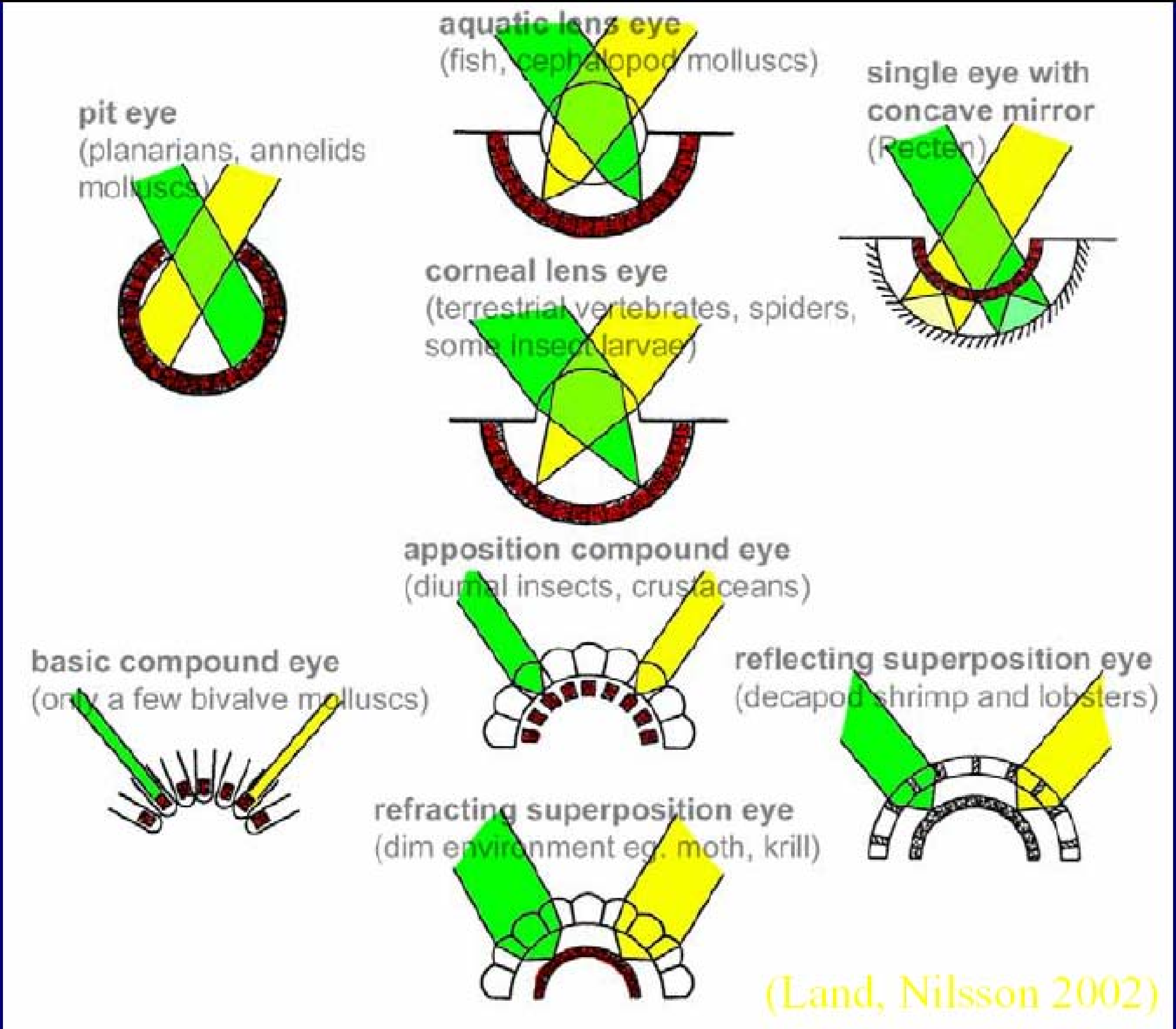
'heat'

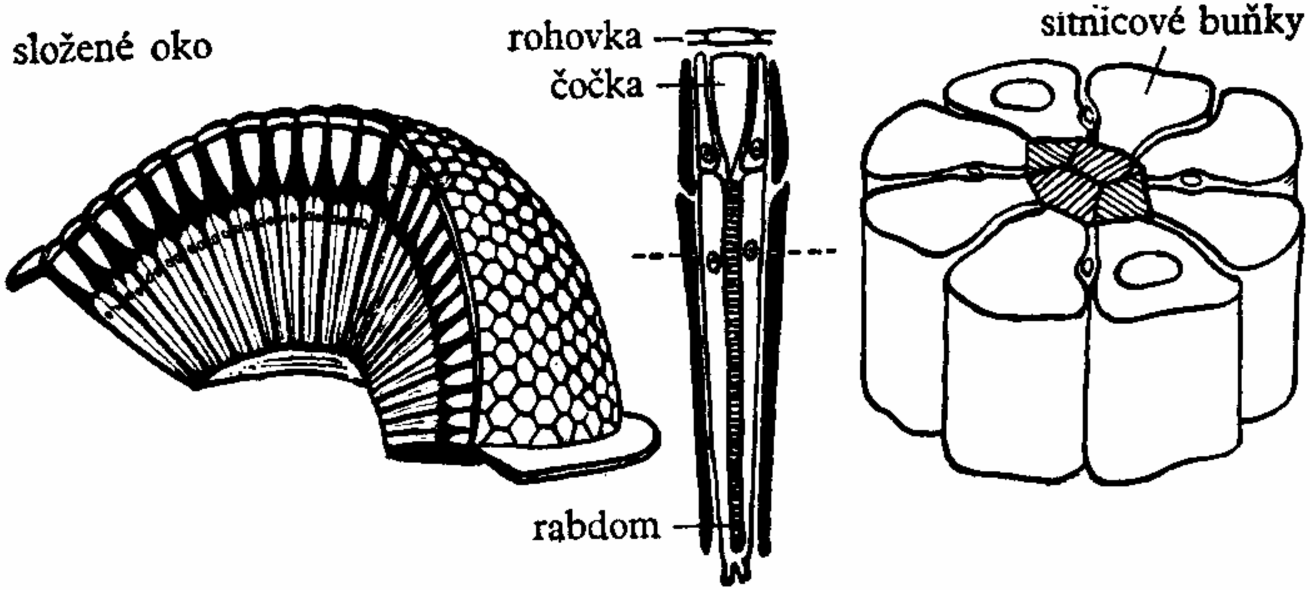
(ca. 3000 - 14000 nm)

Fotorecepce




CILIARY LINE
RHABDOMERIC LINE
Arthropoda
Vertebrata
Onychophora
Cephalochordata
Annelida
Echinodermata
Rotifera
Mollusca
Chaetognatha
Platyhelminthes
Ctenophora
Coelenterata
Protista


aquatic lens eye
(fish, cephalopod molluscs)
single eye with
concave mirror
(Pecten)
pit eye
(planarians, annelids
molluscs)
corneal lens eye
(terrestrial vertebrates, spiders,
some insect larvae)
apposition compound eye
(diurnal insects, crustaceans)
basic compound eye
(only a few bivalve molluscs)
reflecting superposition eye
(decapod shrimp and lobsters)
refracting superposition eye
(dim environment eg. moth, krill)
(Land, Nilsson 2002)



Složené oko hmyzu se skládá z mnoha omatidií, oddělených od sebe pigmentem. Každé omatidium má vlastní rohovku, čočku a sítnicovou tyčinku (rabdom) tvořenou osmi sítnicovými buňkami, jež přecházejí v nerv.

Obr. 77

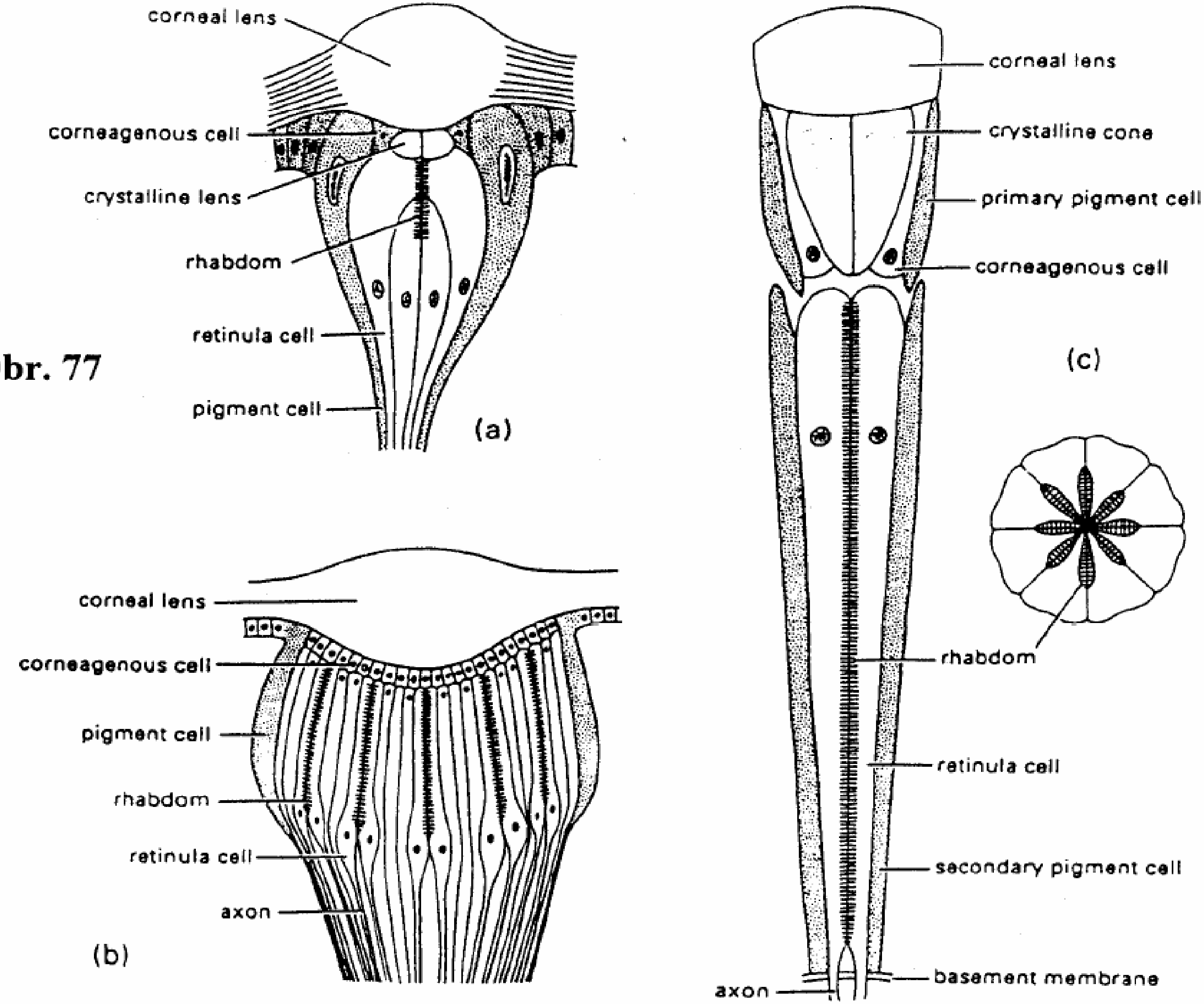
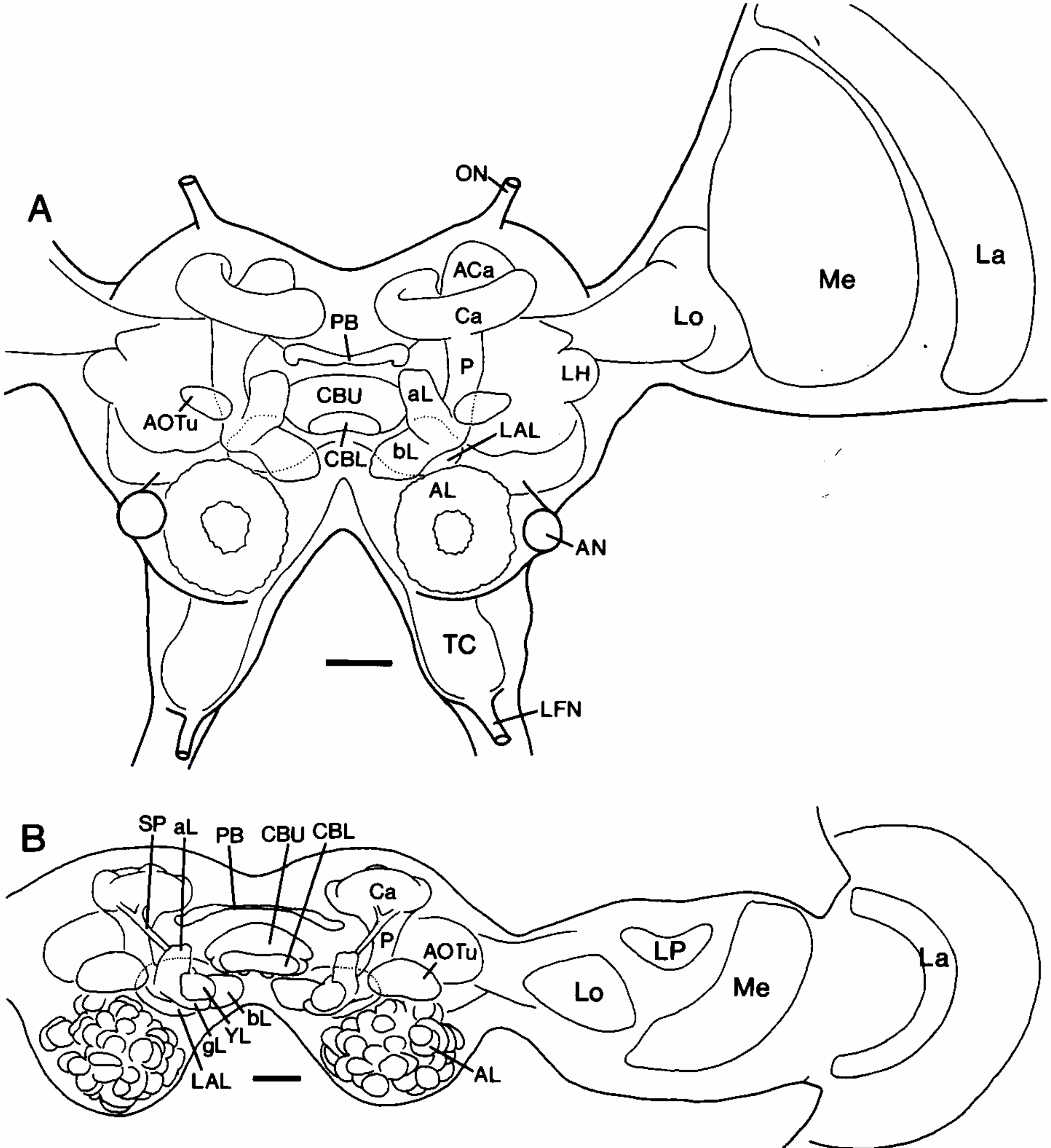
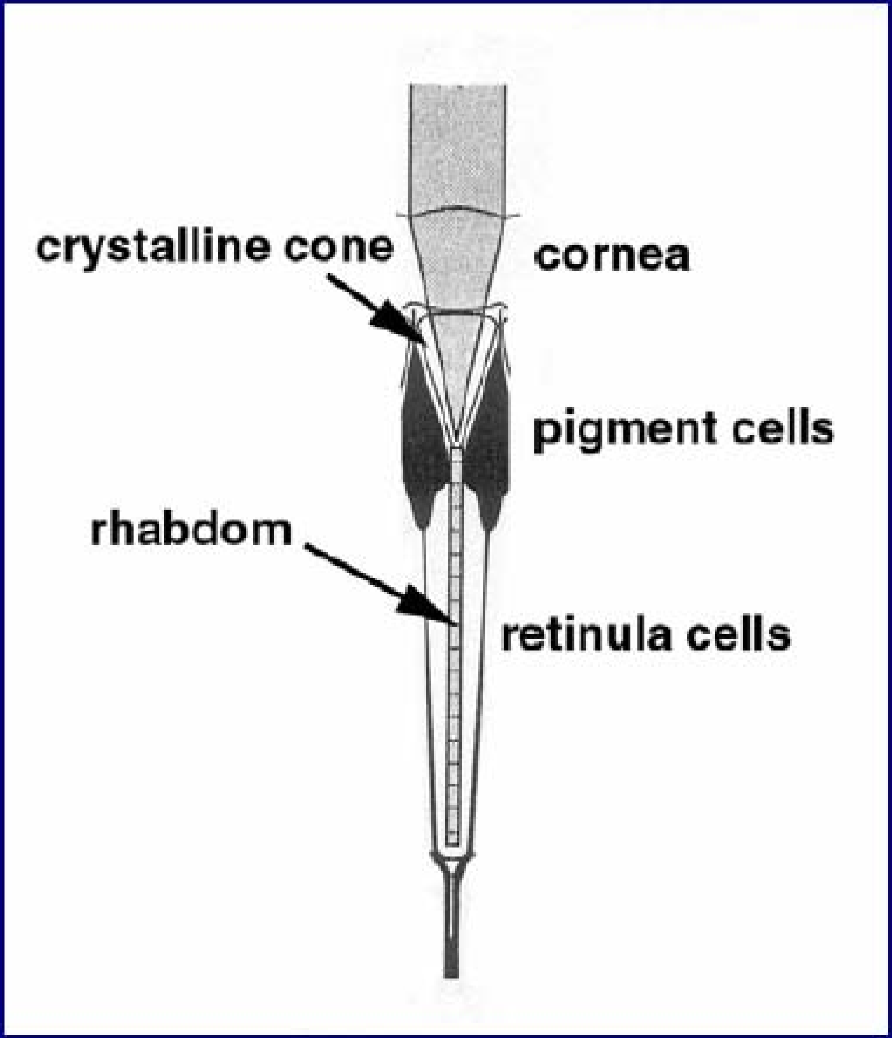


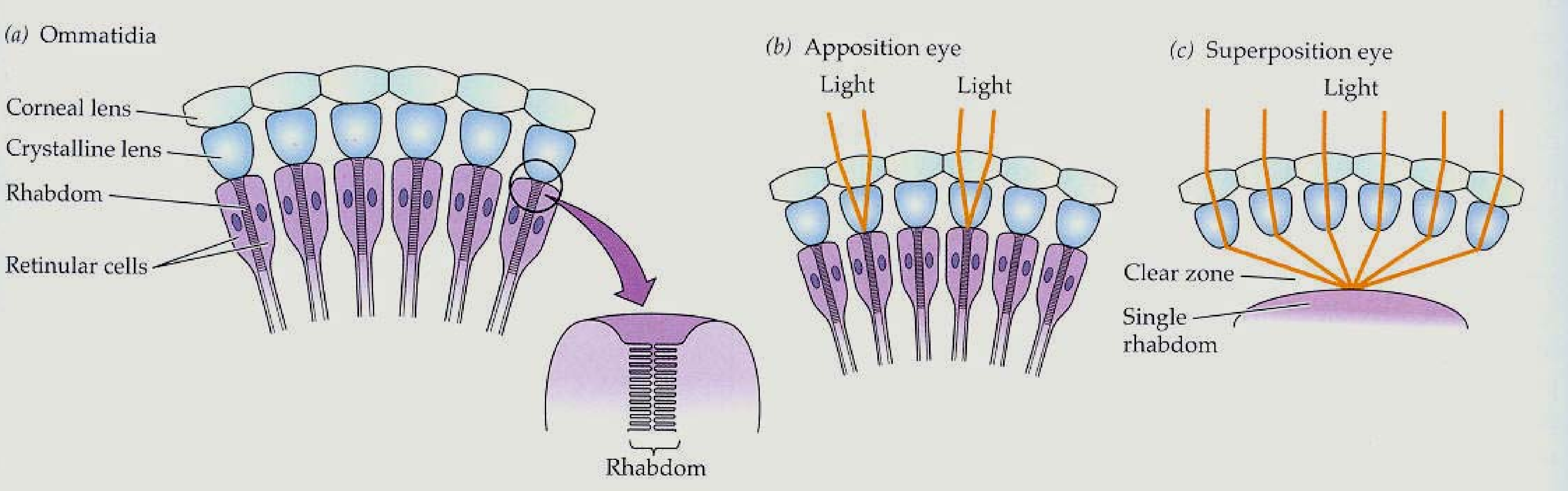
Fig. 4.10 Longitudinal sections through the rhabdoms in simple and compound eyes: (a) a simple stemma of a lepidopteran larva; (b) dorsal ocellus of a adult bug; (c) an ommatidium from a compound eye, with enlargement showing a transverse section. ((a) After Snodgrass, 1935; (b) after Link, 1909; (c) after CSIRO, 1970.)

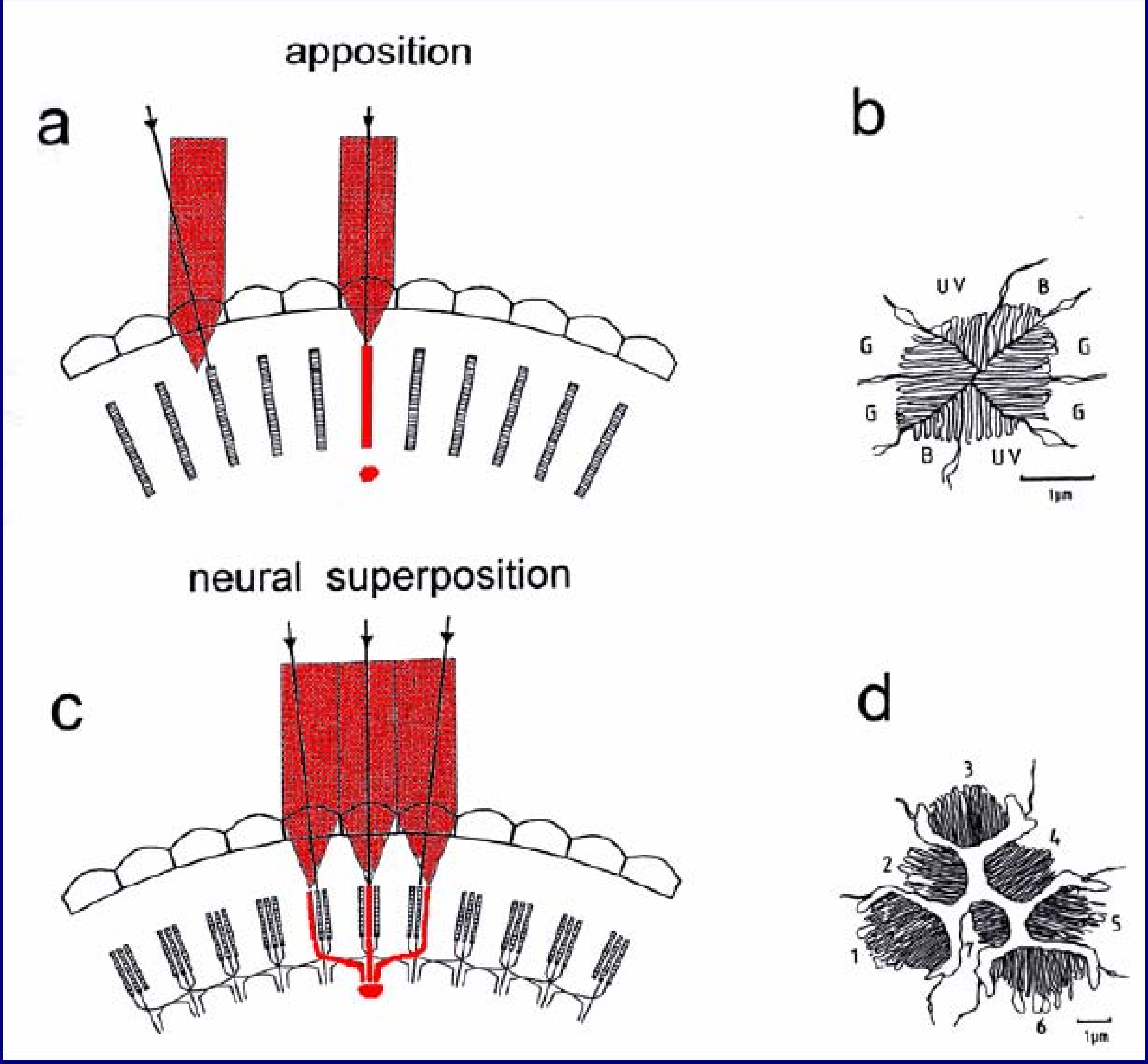

A
ON
ACa
Ca
PB
P
LH
Lo
Me
La
CBU
aL
AOTu
LAL
CBL
bL
AL
AN
TC
LFN
B
SP
aL
PB
CBU
CBL
Ca
P
AOTu
LP
La
Lo
Me
bL
YL
gL
LAL
AL



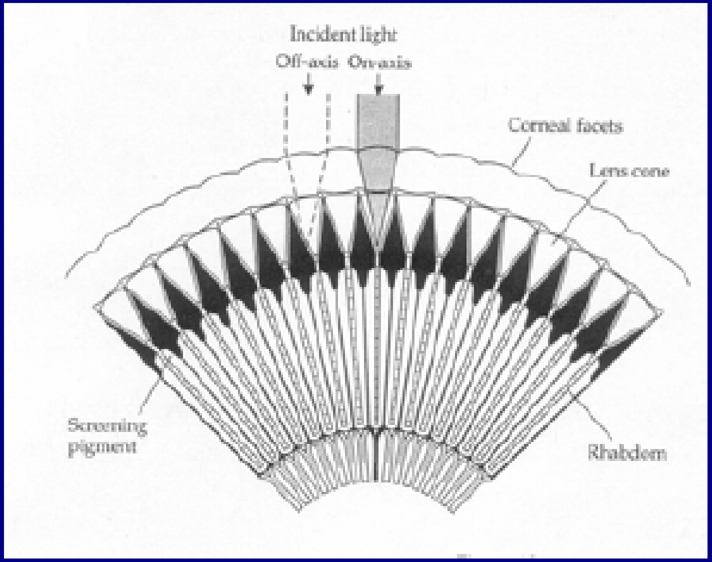
In all types of compound eyes facets are constructed from the same components which are organized into long and narrow channels each with 8-10 photoreceptors.

Apoziční vs. superpoziční

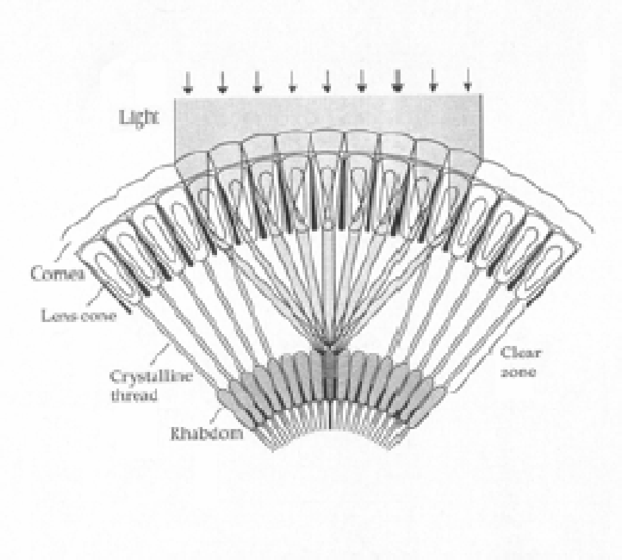



apposition
a
b
UV
B
G
G
G
G
B
UV
1µm
neural superposition
c
d
3
4
2
5
1
7
6
1µm

Insect eye diversity



Focal Apposition Eye
(Honeybee)

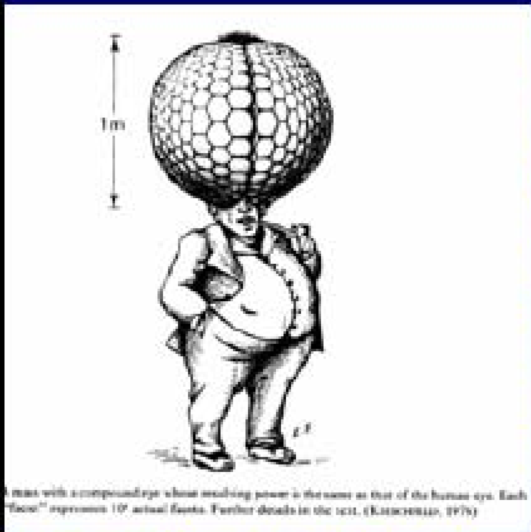


Refracting Superposition Eye
(Firefly)

Adult insects have many eye types (e.g. apposition, superposition, neural superposition etc). These are all types of compound eyes and their image resolution is never higher than the number of facets.

After D.-E. Nilsson (1989), Facets of Vision

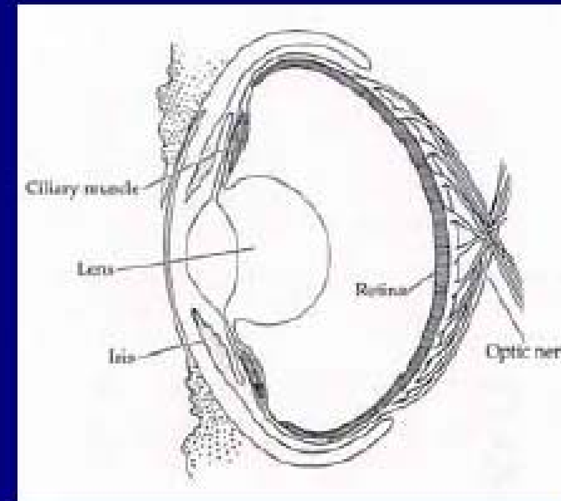

BEE BRAINS RECOGNISE
HUMAN FACES



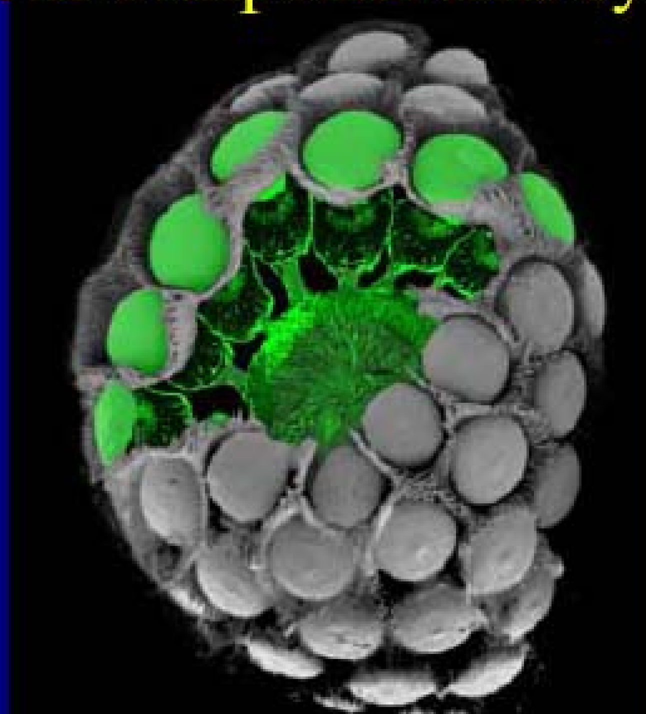
(after Kirschfeld 1976)

Due to the diffraction limit the lens diameter in compound eyes can not be decreased below a certain value.

Single lens eyes are problematic if you are small



The compound lens eye



Pro:
high resolution despite of small space

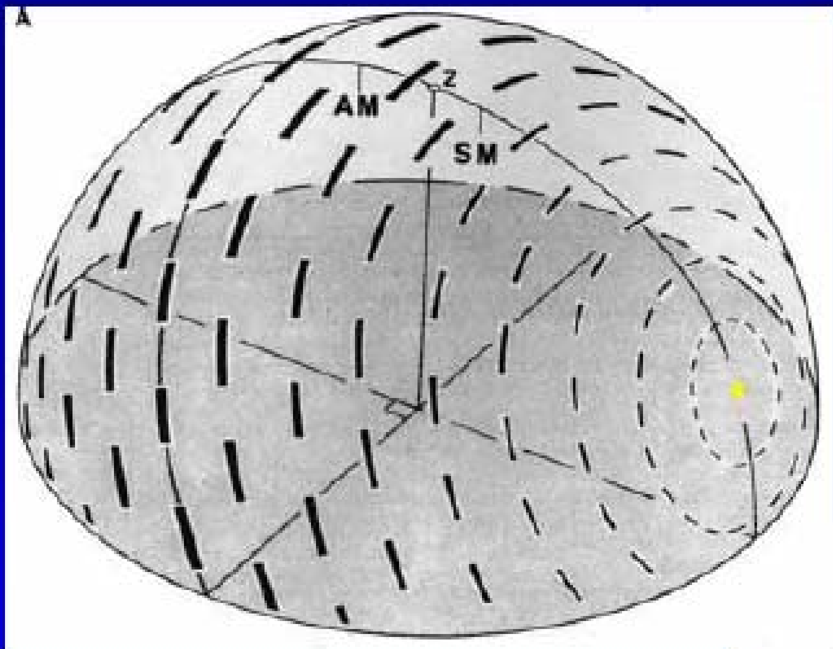
Contra:
irregular sampling between lenses

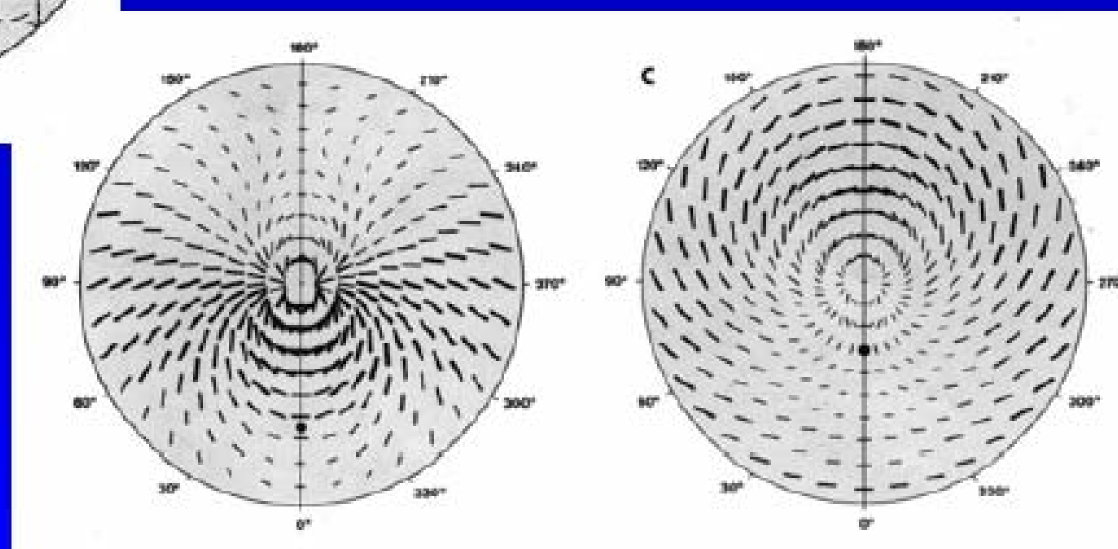
The ability to detect ultraviolet light

Human's view.

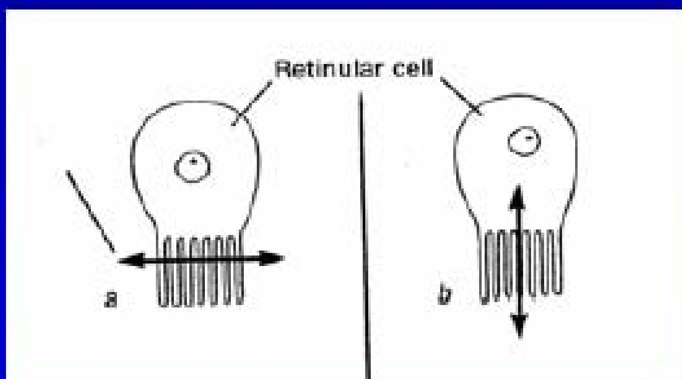
Insect's view (simulated through UV film.

Polarized light patterns in the sky

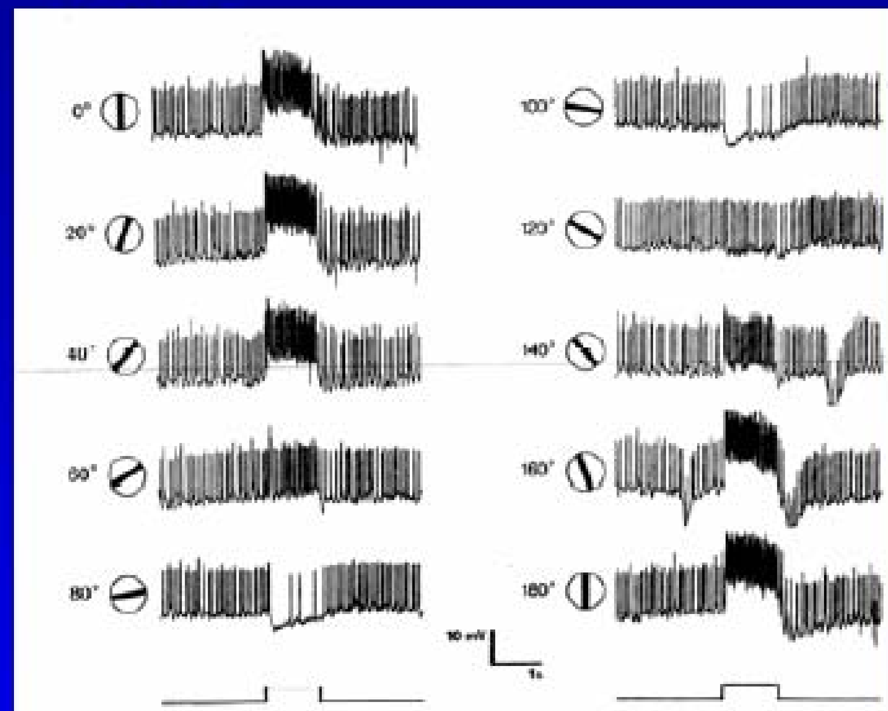




Arthropod visual neurons can be sensitive to specific planes of polarized light

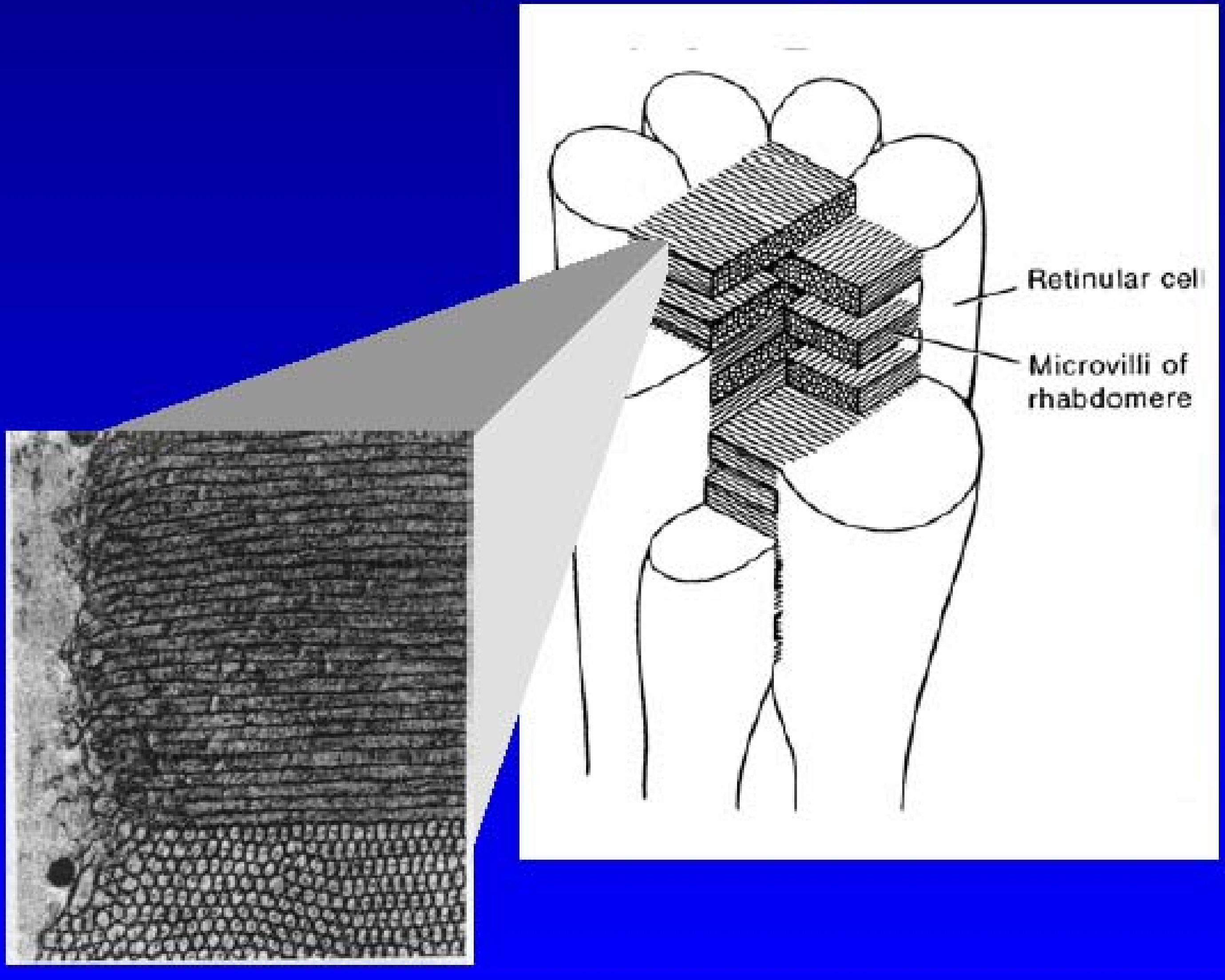


Cricket



(Wehner 1989)

Organization of retinular cells allows for detection of polarized light



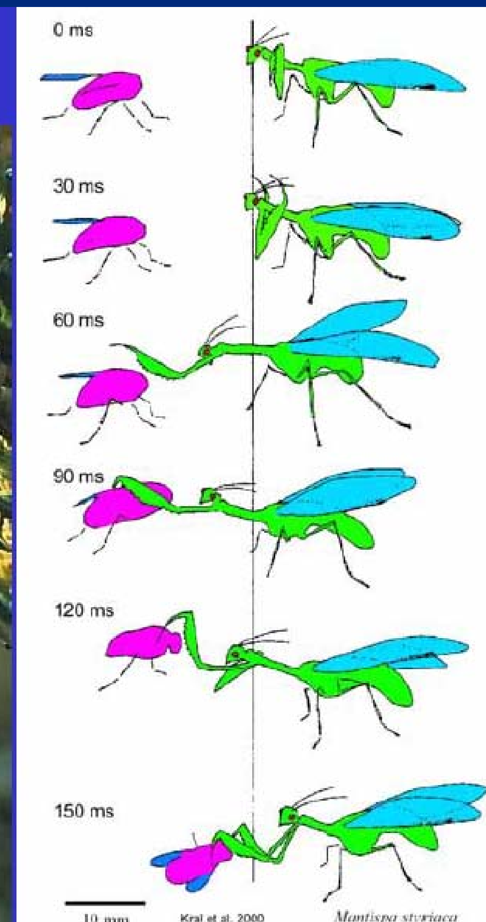
Chování - limity

Mantis:

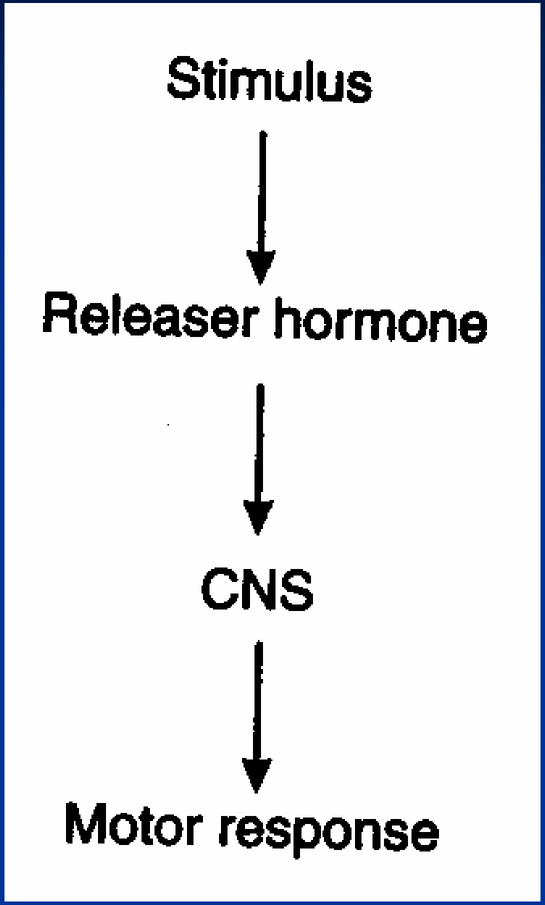
exquisite visual resolution; responds to movement as slow as 0.25°/min.

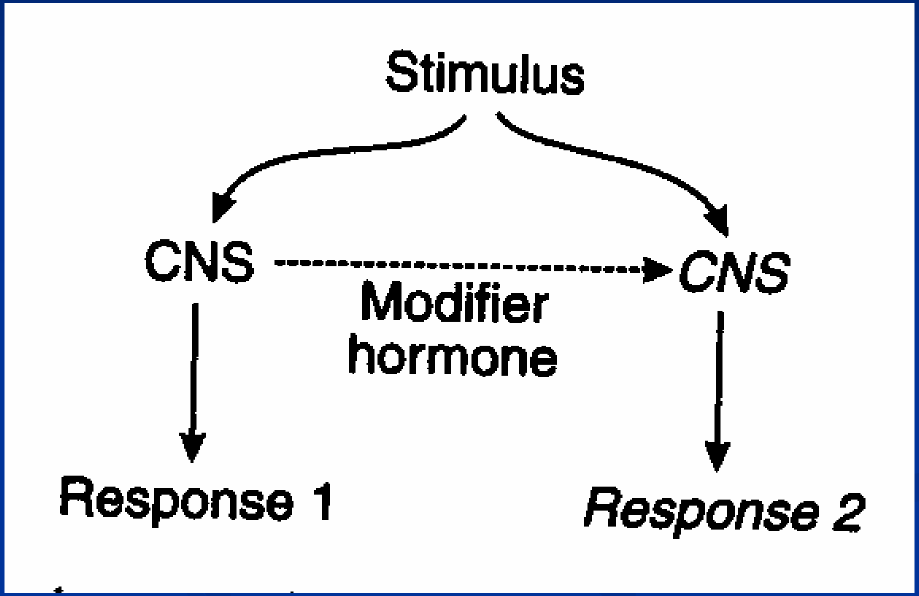
The final strike is very fast (ca. 30 ms) and open loop.

The same is true for the (smaller) mantisflies



Hormonální regulace chování



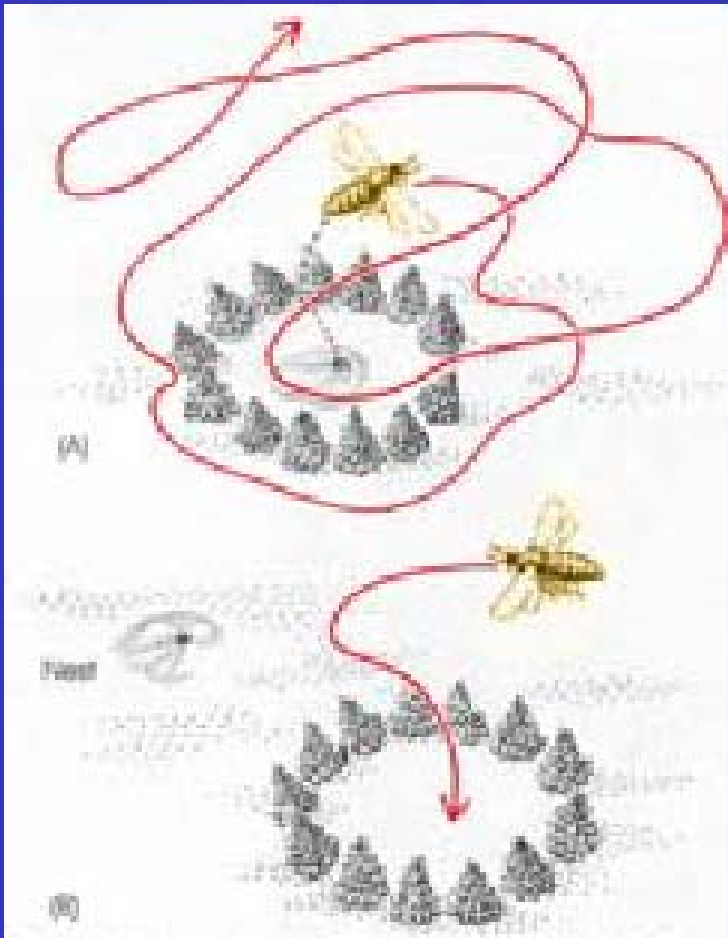


Feromony

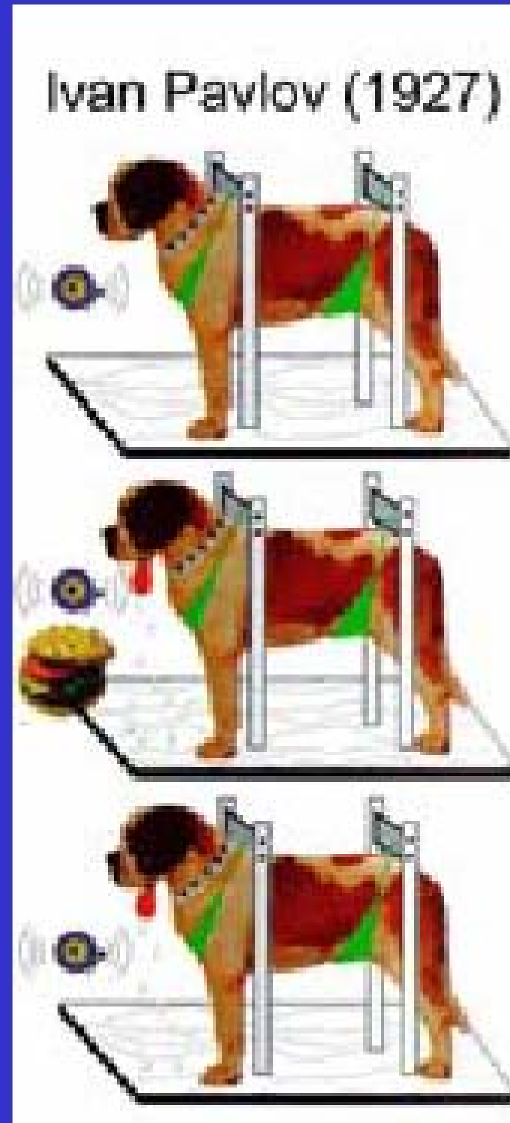
vábení opačného pohlaví a spuštění sexuálního chování	- sexuální feromony
vábení obou pohlaví dohromady	- agregační feromony
poplach	- poplachové feromony
rozptýlení po okolí	- disperzní feromony
tah	- migrační feromony

synchronizace vývoje (akcelerace nebo inhibice)	- maturační feromony
inhibice ovárií	- substance královny
určení kast (u larev termitů) nebo změny v chování včelích dělnic z úlových včel - kojiček-3, stavitelek-4, čističek-1, krmičky-2, stražkyně5 na létavky-6.	- modifikátory kast

Learning and memory

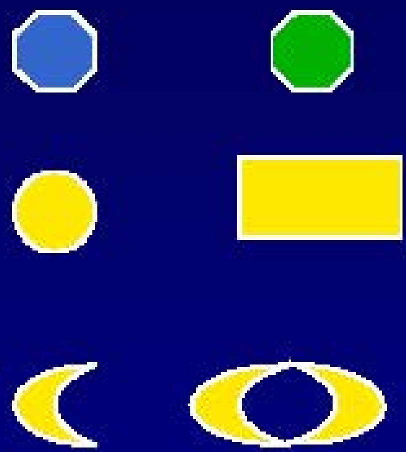


A digger wasps learns landmarks surrounding her nest (A) and returns to a wrong location after displacement of the pine cones (B). Tinbergen 1960

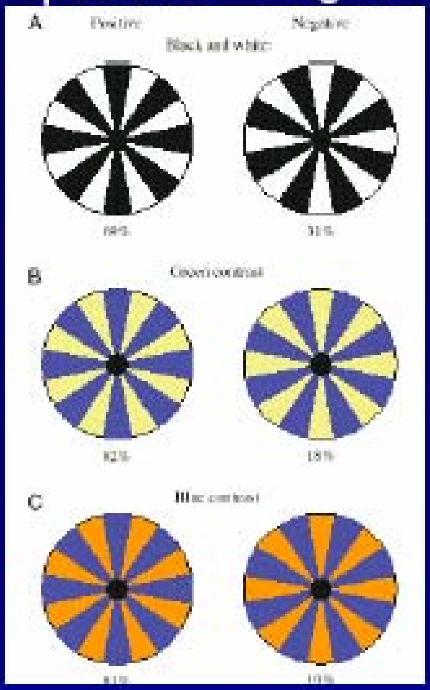


Honey bees can learn visual cues associated with nectar rewards

- Colors
- Shapes
- Symmetry
- Complex patterns

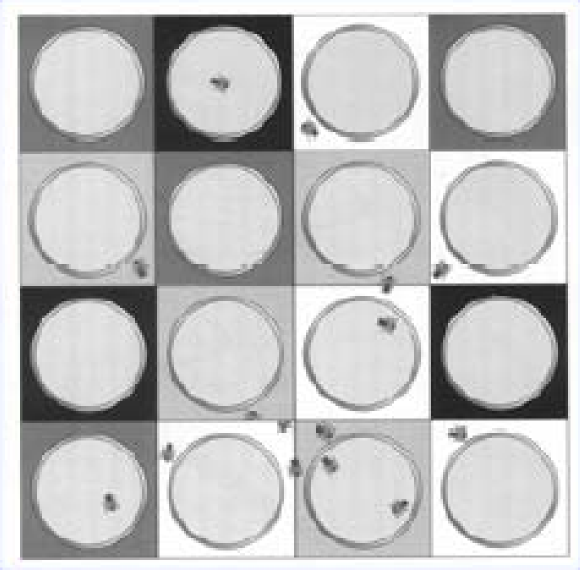


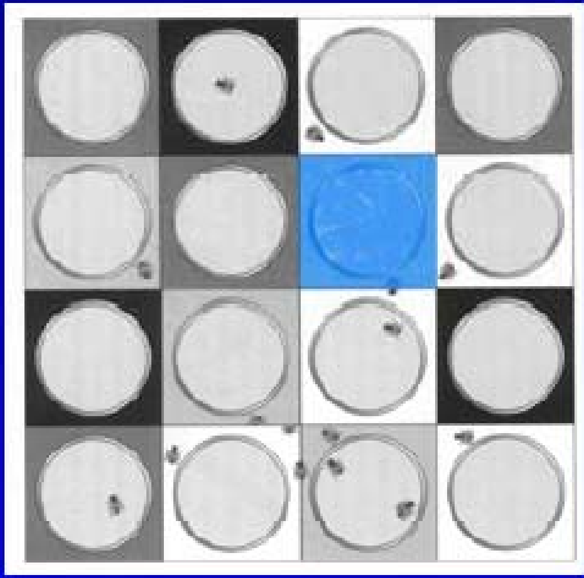
positive negative



1. Train bees with sugar water on colored background

2. Test bees with variety of shades, one color





What the bee sees
(no color vision)

What the bee sees
(color vision)

Classical Conditioning: Honey bee Proboscis Extension Reflex (PER)

<u>Conditioned stimulus (CS)</u>
Odor

<u>Unconditioned stimulus (US)</u>
Sugar water

<u>Unconditioned stimulus</u>
Proboscis extension (PER)

<u>Conditioned Response (CR)</u>
PER with CS

Orientace

Hmyz běhající po zemi zřejmě monitoruje pohyby končetin k odhadu jak daleko a kam došel, zatímco létající hmyz monitoruje „optický tok“.

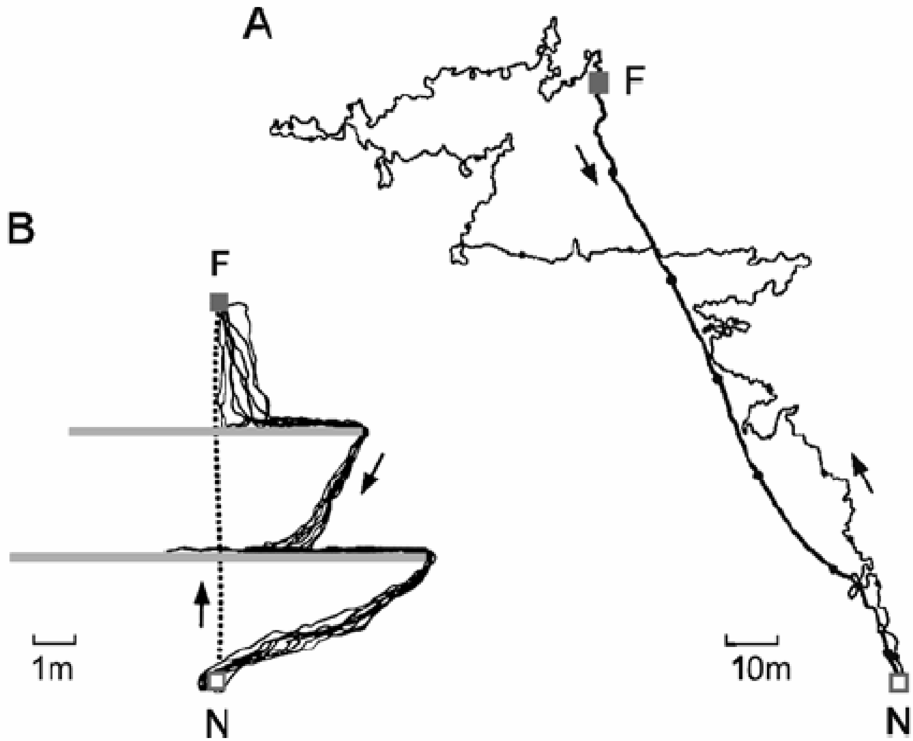


Fig. 2A, B Path integration (vector navigation) in *Cataglyphis fortis*. **A** An ant's tortuous outward (foraging) and straight homeward path recorded in a featureless salt pan. **B** Straight outward paths indicated by the *dotted line*and multi-leg homeward paths caused by experimental barriers *(grey bars)*, which the ant could pass on its way out (from *N* to *F*) but not on its way in. Nine successive runs of one ant. *F* feeding site, *N* nest. **A** from Wehner and Wehner (1990), **B** from D. Andel and R. Wehner (unpublished observations)