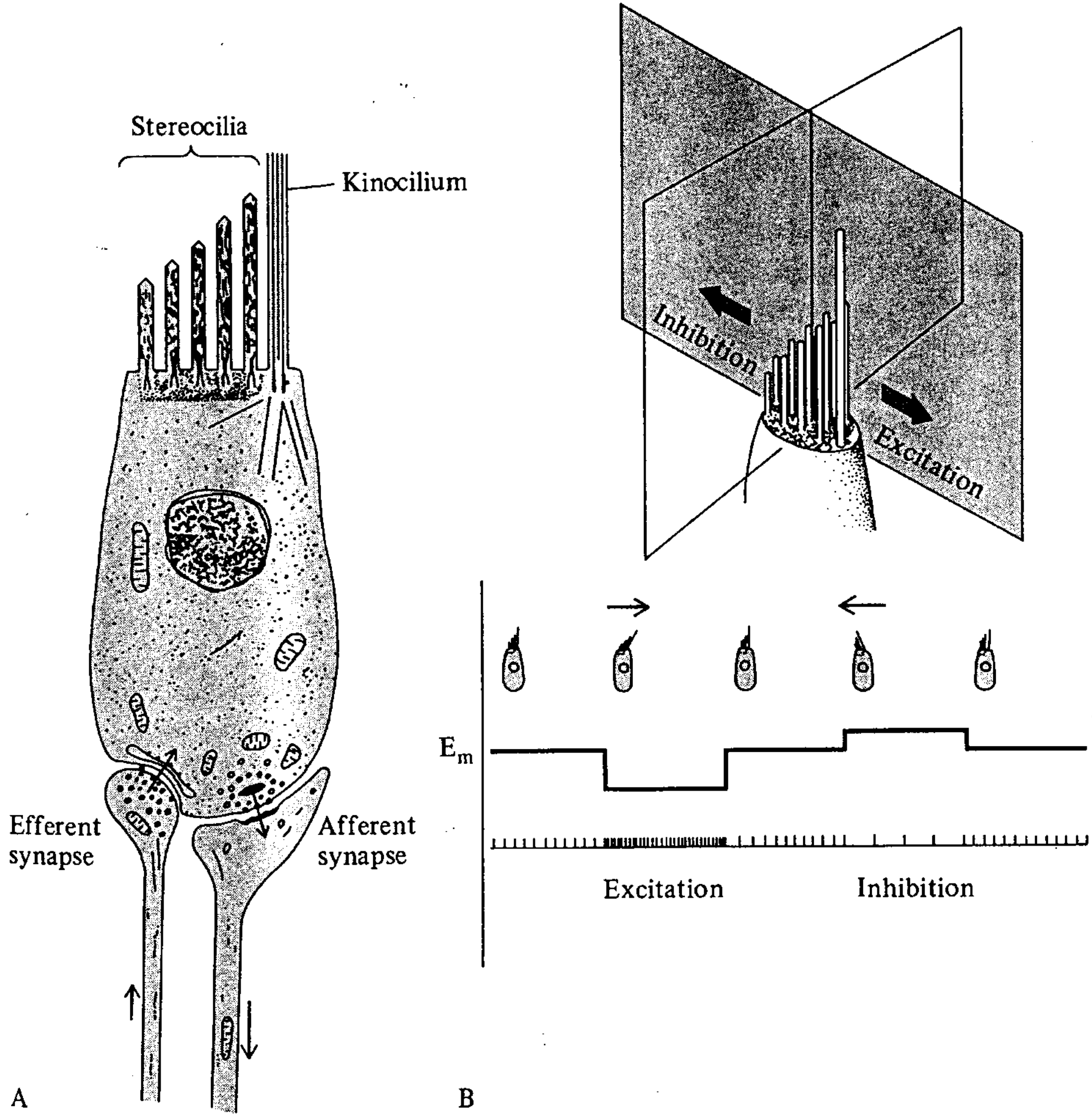
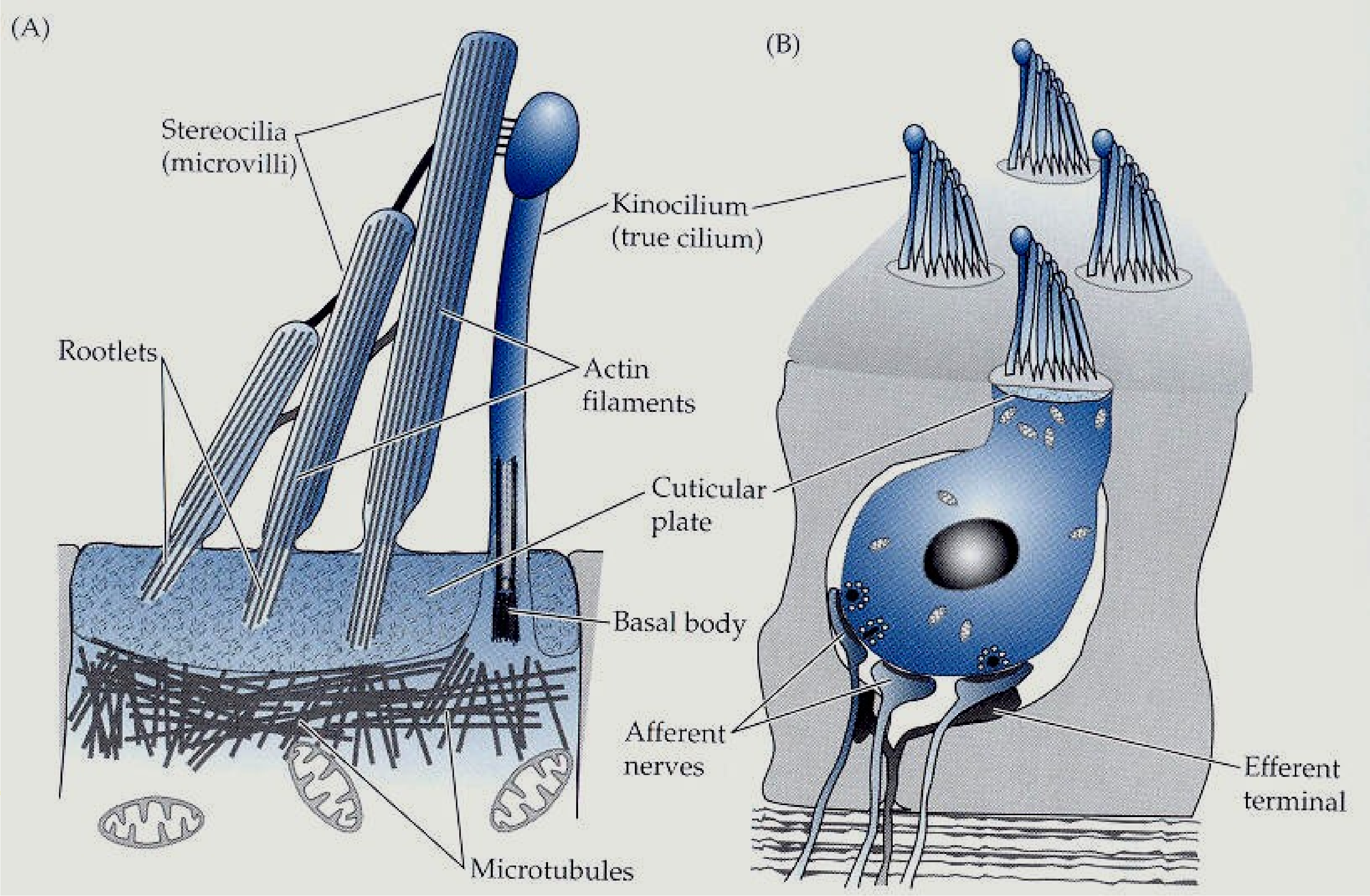
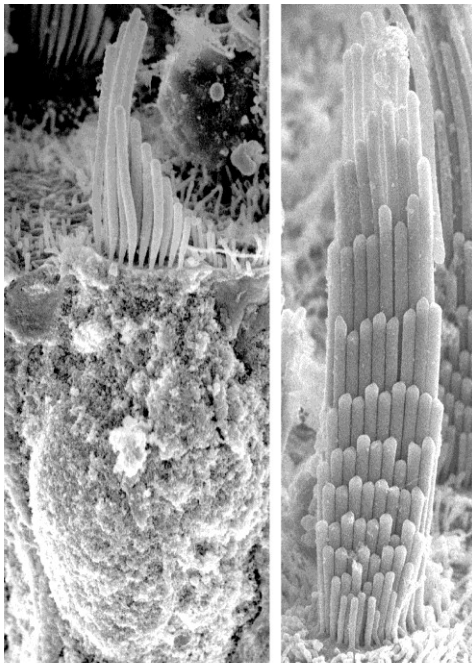
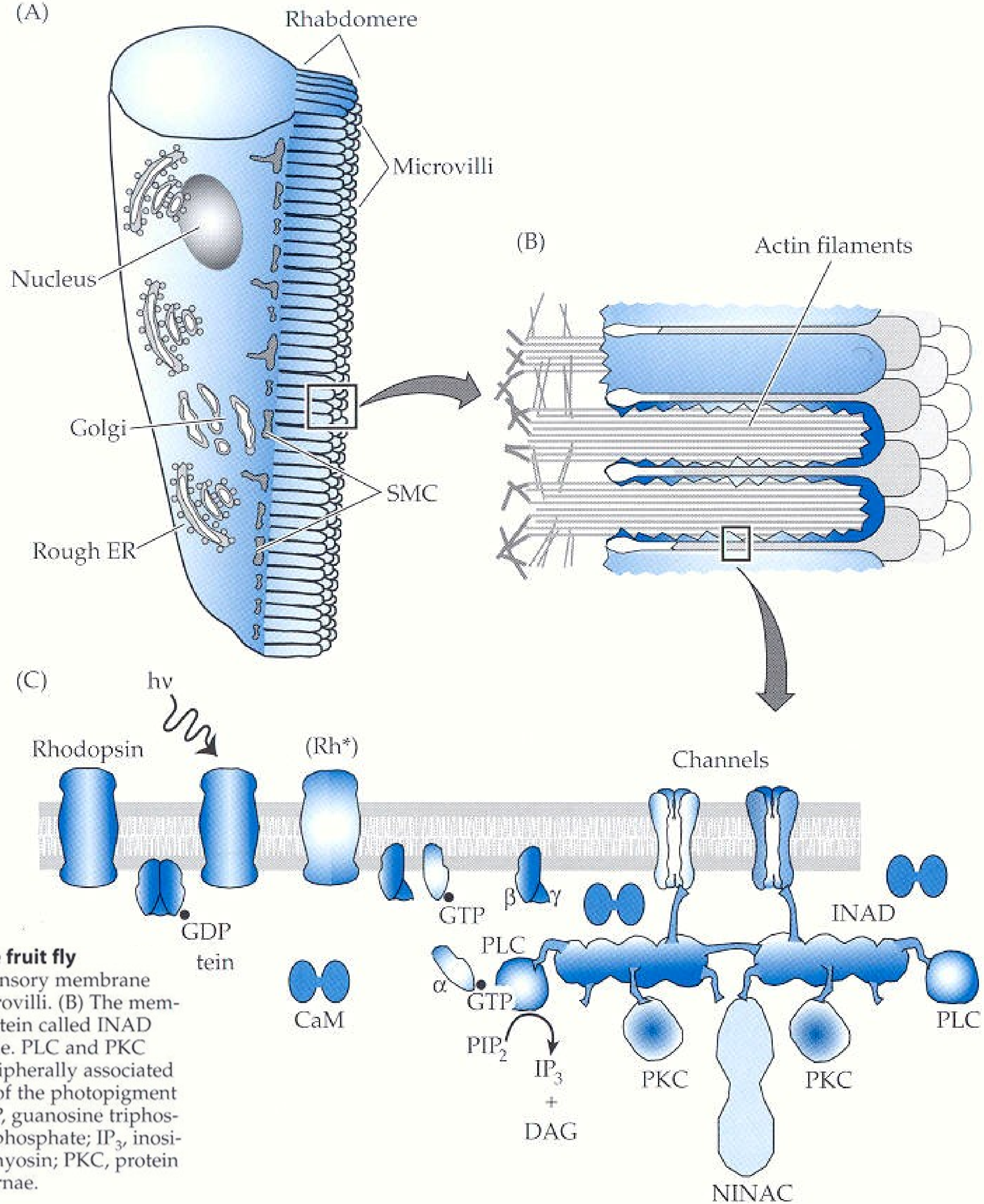

Stereocilia
Kinocilium
Efferent synapse
Afferent synapse
A
Inhibition
Excitation
E_m
Excitation
Inhibition
B


(A)
Stereocilia
(microvilli)
Kinocilium
(true cilium)
Rootlets
Actin
filaments
Cuticular
plate
Basal body
Microtubules
(B)
Afferent
nerves
Efferent
terminal





Organization of sensory membrane of a photoreceptor in the fruit fly *Drosophila* (A) Anatomy of a *Drosophila* photoreceptor. The sensory membrane forms a structure, called a rhabdomere, composed of 50,000 microvilli. (B) The membrane of the microvillus is highly organized by a scaffolding protein called INAD (C), which binds to proteins in the cytosol and plasma membrane. PLC and PKC proteins are shown as if cytosolic but are likely to be at least peripherally associated with the plasma membrane. Abbreviations: Rh^*, activated form of the photopigment rhodopsin; GDP, guanosine diphosphate; CaM, calmodulin; GTP, guanosine triphosphate; PLC, phospholipase C; PIP_2, phosphatidylinositol 4,5-bisphosphate; IP_3, inositol 1,4,5-triphosphate; DAG, diacylglycerol; NINAC, a form of myosin; PKC, protein kinase C; ER, endoplasmic reticulum; SMC, submicrovillar cisternae.

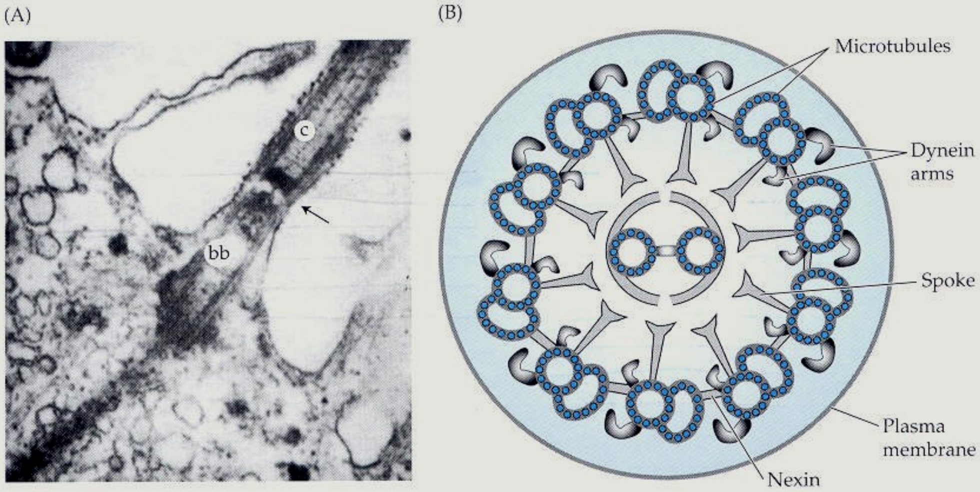


Figure 2.3
Cilium (A) Structure of a cilium from a sea urchin embryo. Note the basal body (bb) at the base of the cilium (c). Magnification 22,000×. (B) Schematic drawing of a cross section of cilium. (A from Chakrabarti et. al., 1998.)

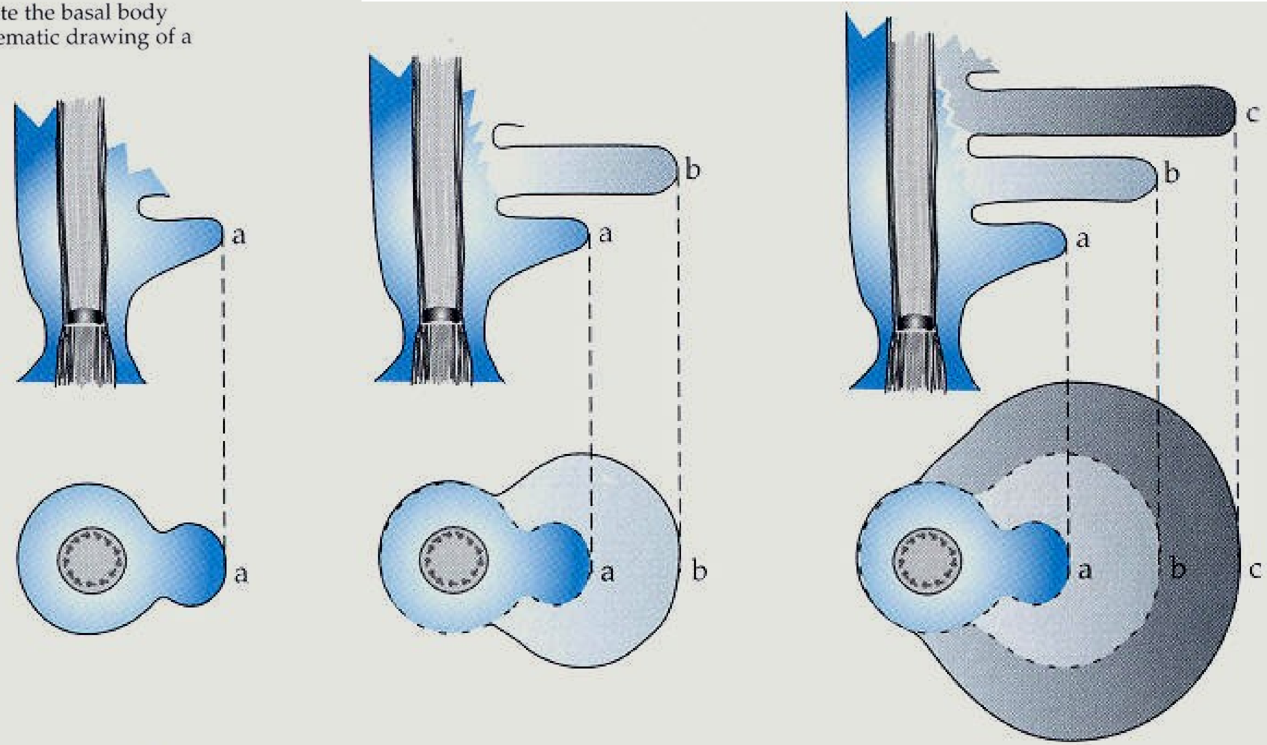
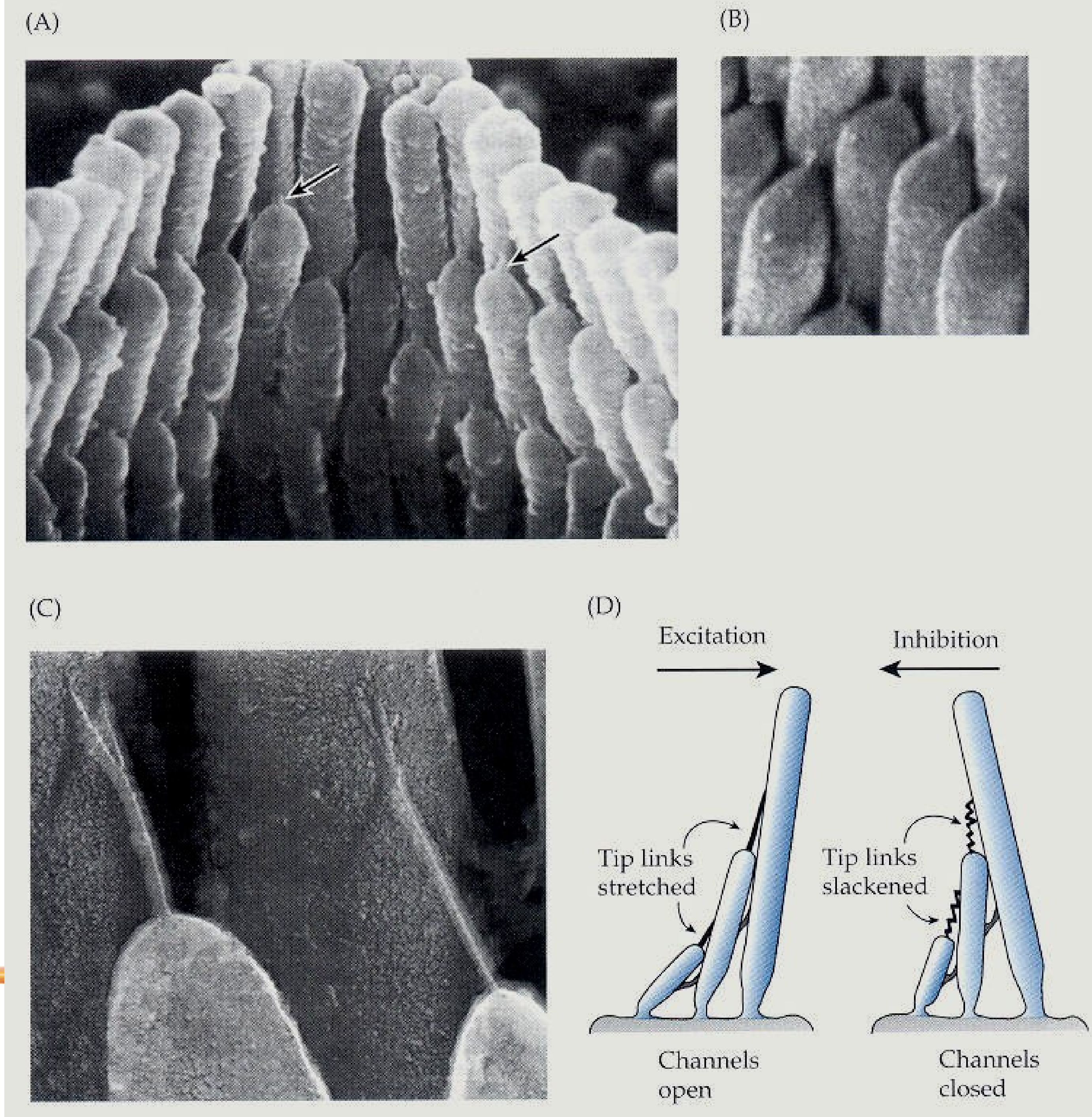
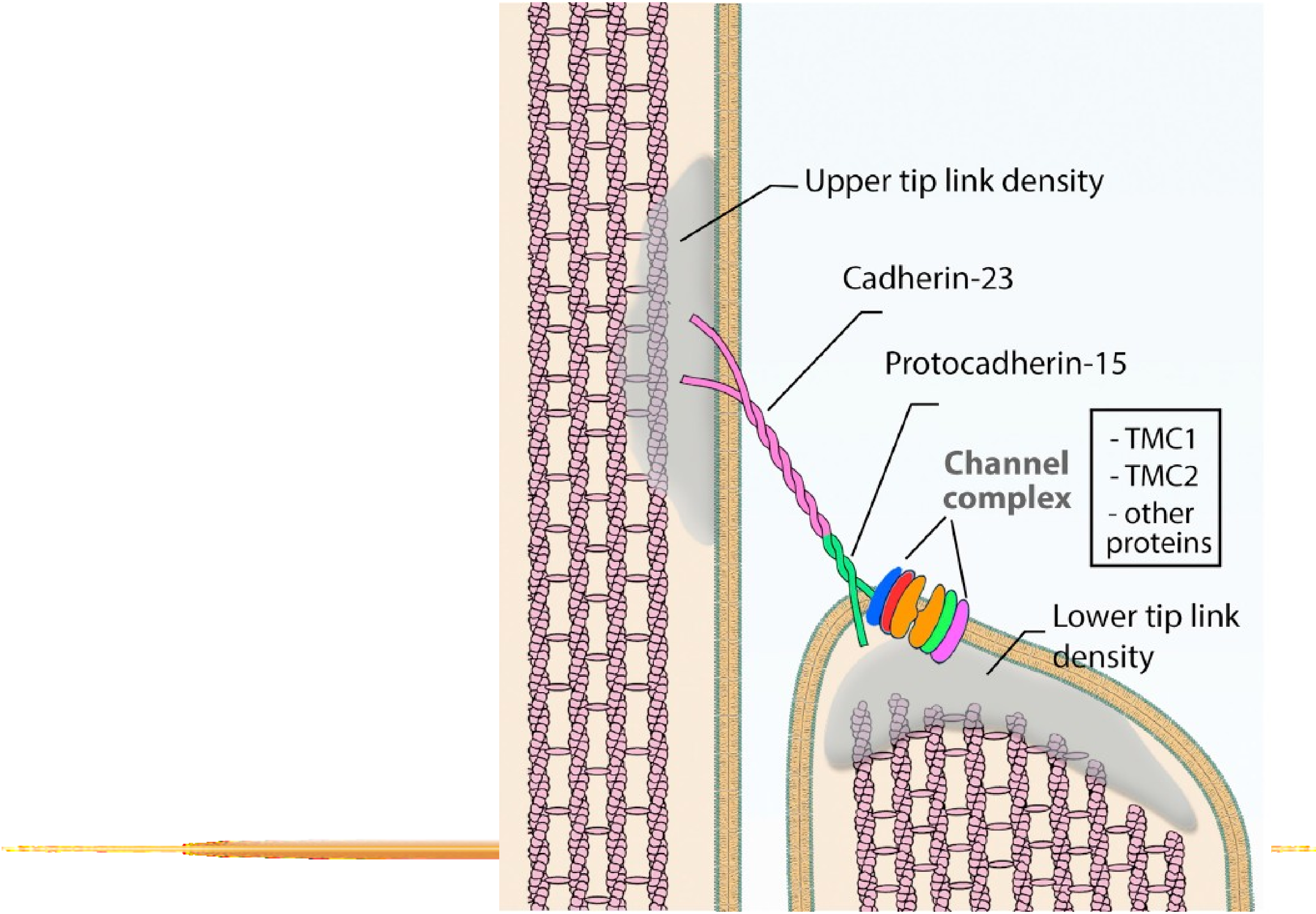
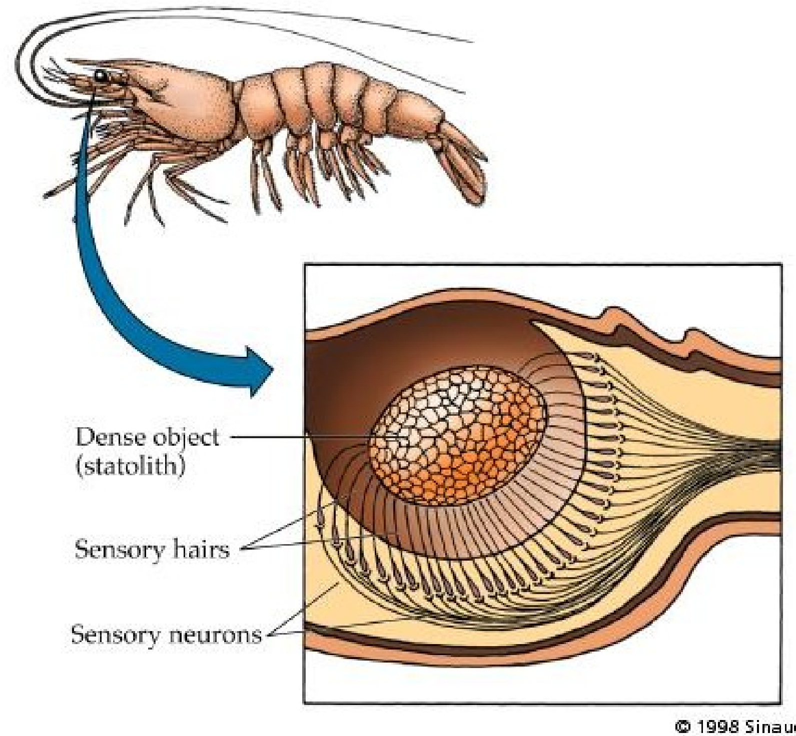


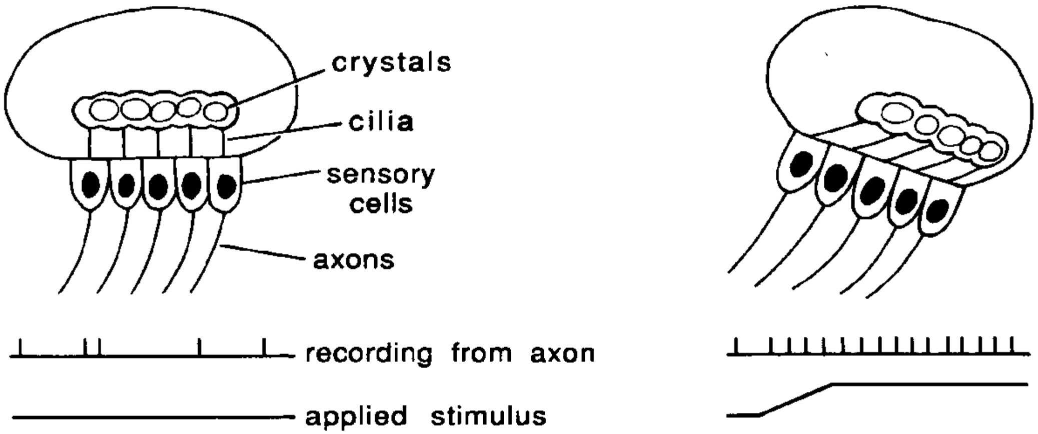
Figure 2.4
Formation of disks of a rod photoreceptor Disks are intiated at the base of the rod outer segment adjacent to a cilium. (After Steinberg, 1980.)


(A)
(B)
(C)
(D)
Excitation
Inhibition
Tip links stretched
Tip links slackened
Channels open
Channels closed

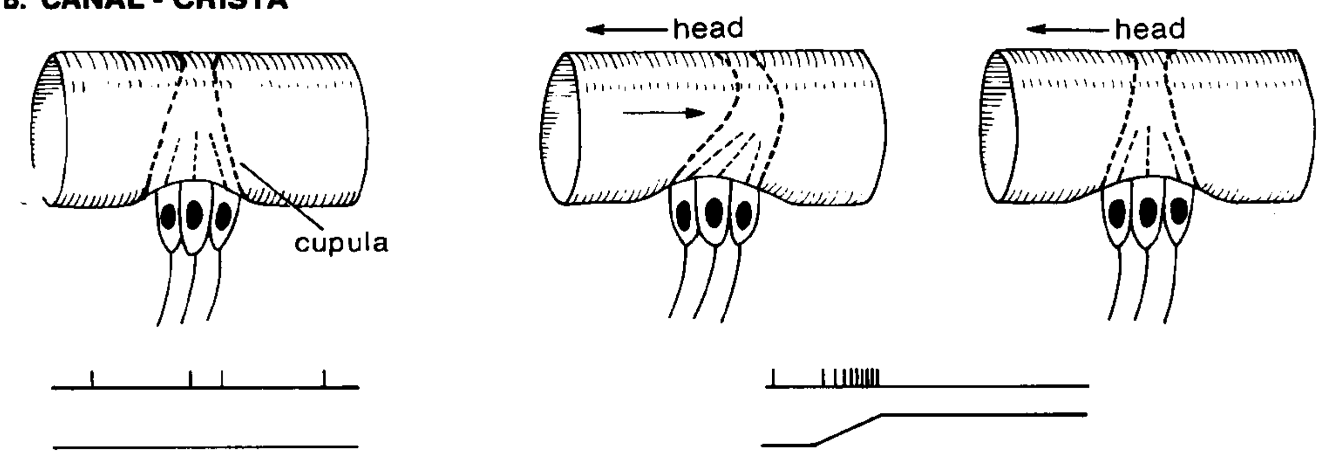

Upper tip link density
Cadherin-23
Protocadherin-15
Channel complex
- TMC1
- TMC2
- other proteins
Lower tip link density

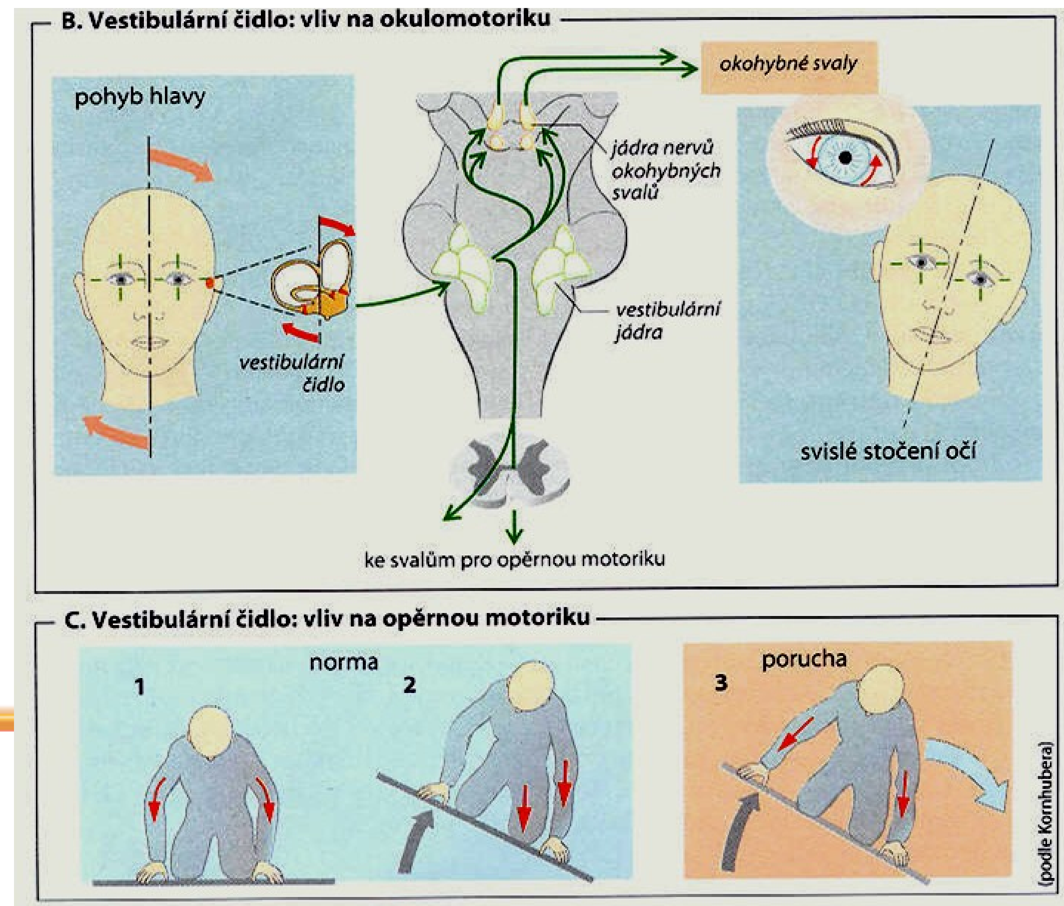


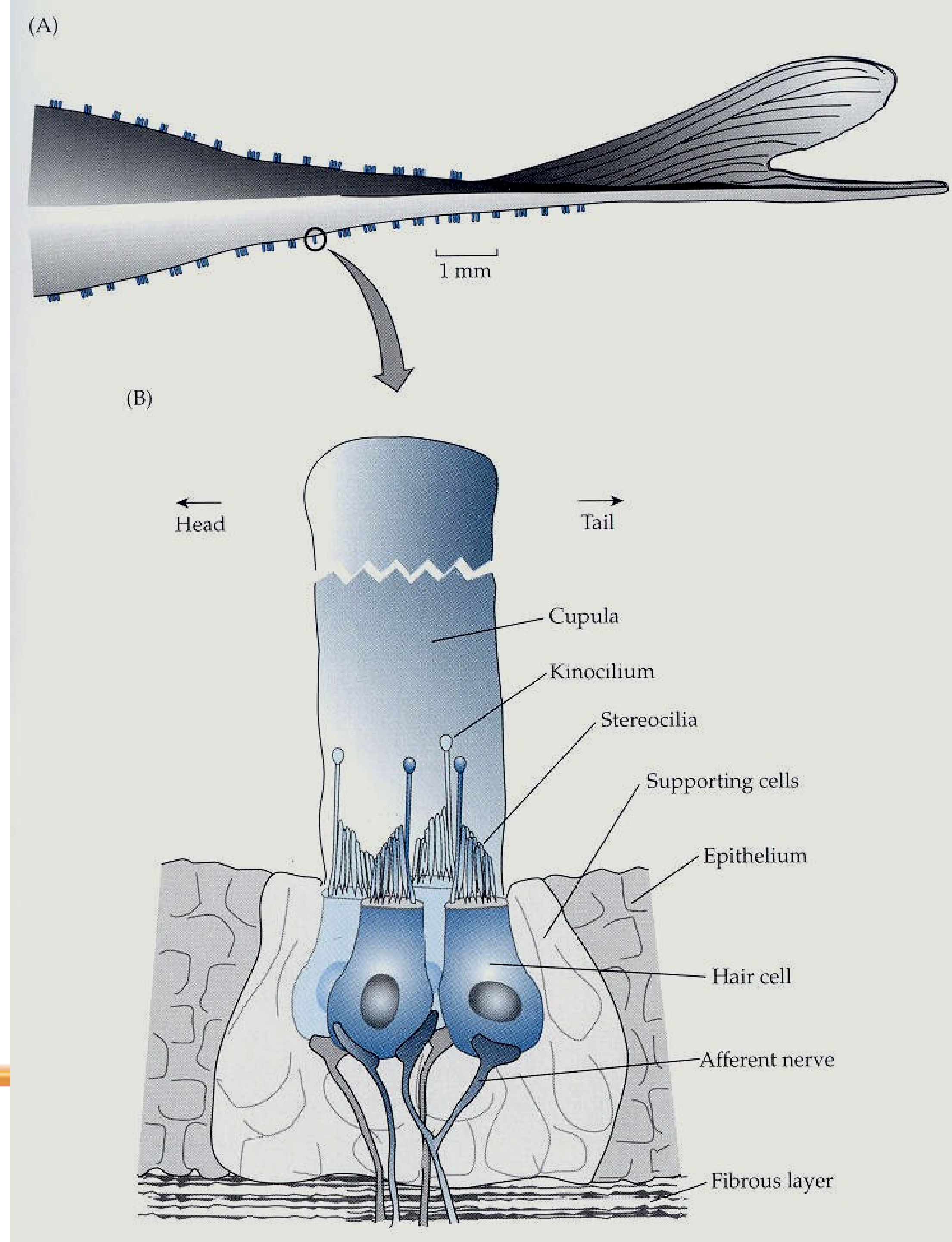
A. STATOCYST - MACULA



B. CANAL - CRISTA

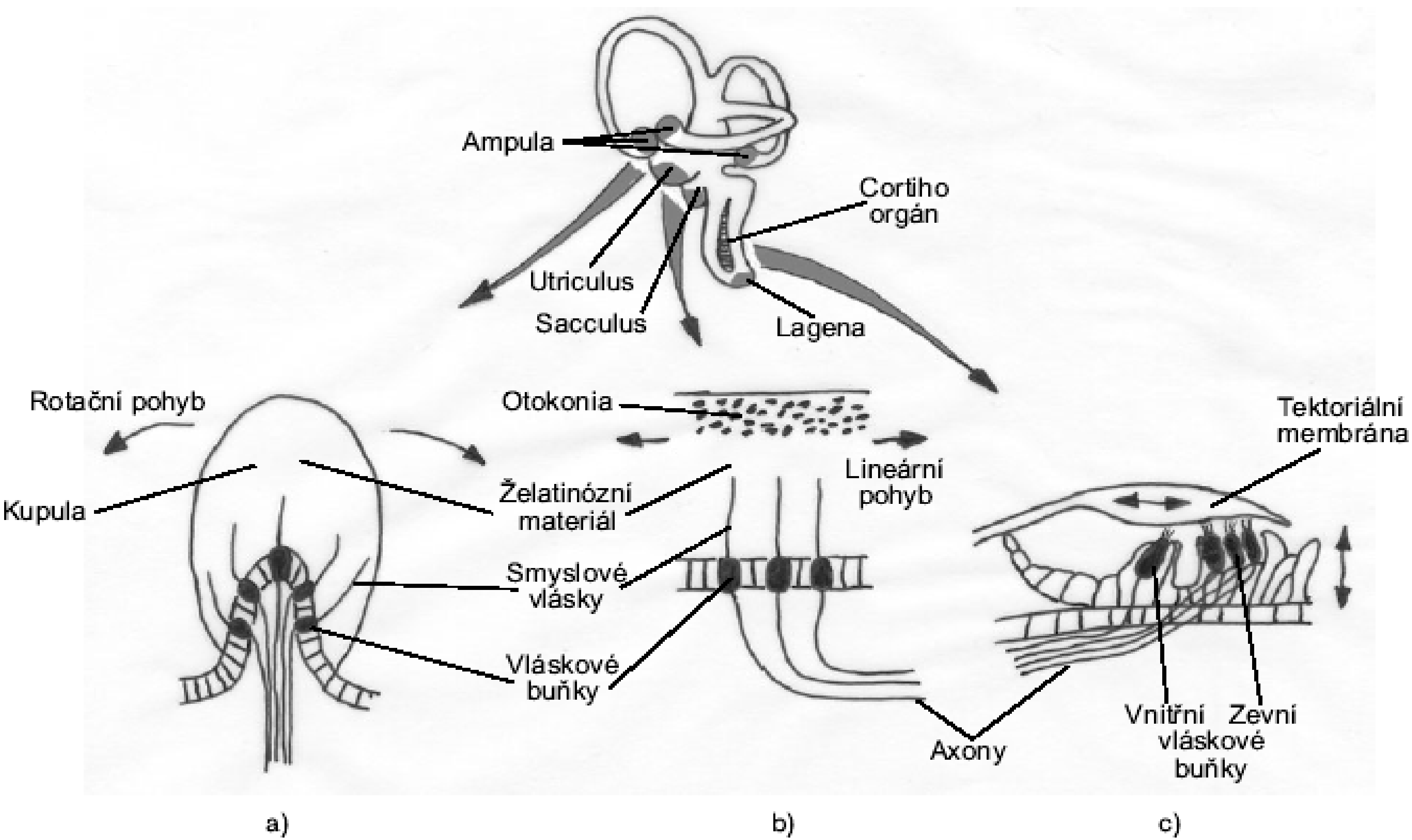



B. Vestibulární čidlo: vliv na okulomotoriku
pohyb hlavy
vestibulární čidlo
okohybné svaly
jádra nervů okohybných svalů
vestibulární jádra
svislé stočení očí
ke svalům pro opěrnou motoriku
C. Vestibulární čidlo: vliv na opěrnou motoriku
norma
1
2
porucha
3
(podle Kornhubera)



(A)
1 mm
(B)
Head
Tail
Cupula
Kinocilium
Stereocilia
Supporting cells
Epithelium
Hair cell
Afferent nerve
Fibrous layer

Video



Obr. 16.4. Vláskové buňky a stavba vnitřního ucha obratlovců (ptáka). Sluchové ústrojí je ve spojení se statokinetickým. Polokruhovité chodby s váčky (ampulami), v nichž se pohybuje želatinózní kupula, detekují rotační zrychlení (a). Lineární zrychlení a gravitaci detekují tři políčka vláskových buněk (utriculus, sacculus, lagena) s krystalky v želatinózní čepičce (b). Třetí orgán – Cortiho – slouží jako sluchový (c).

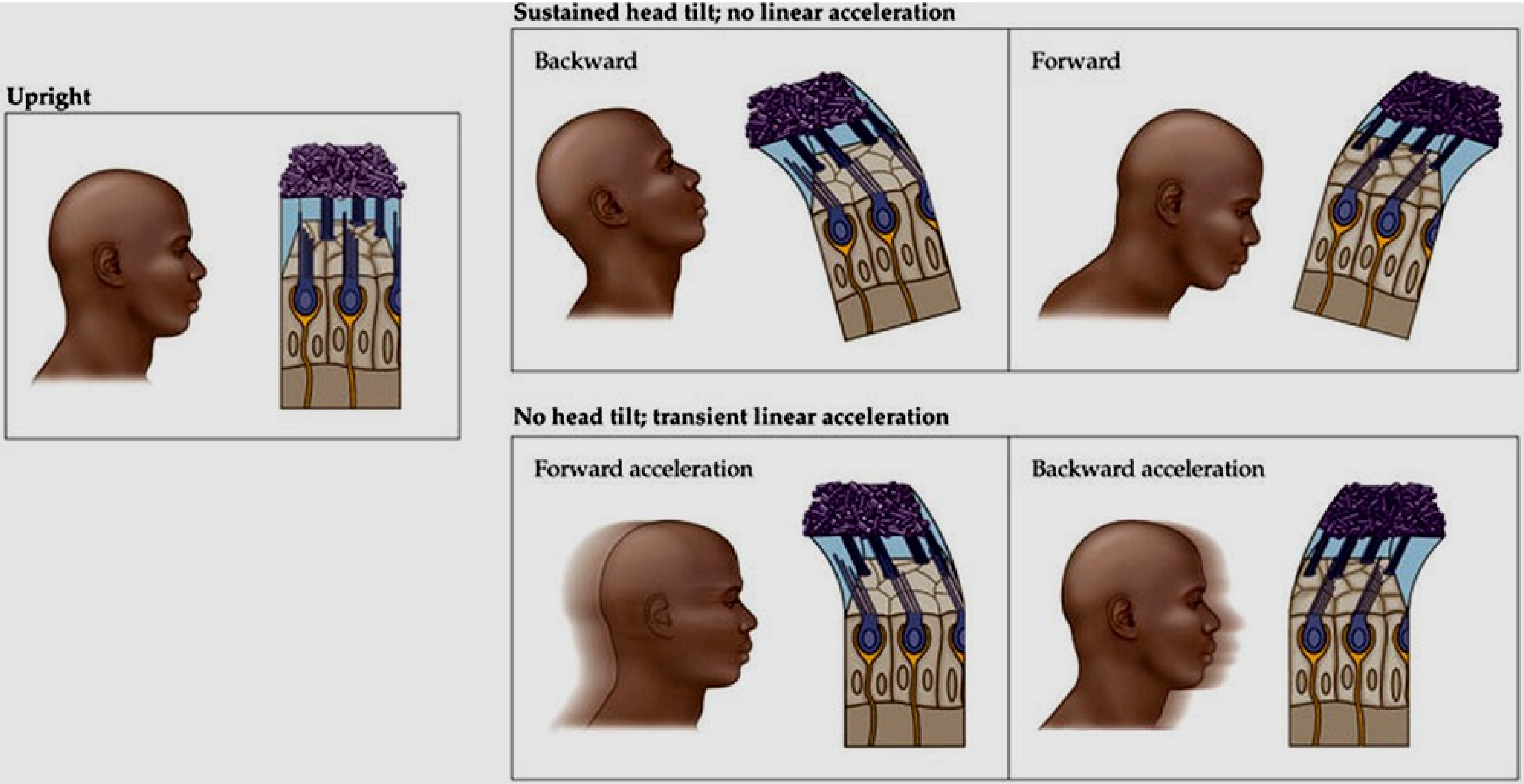
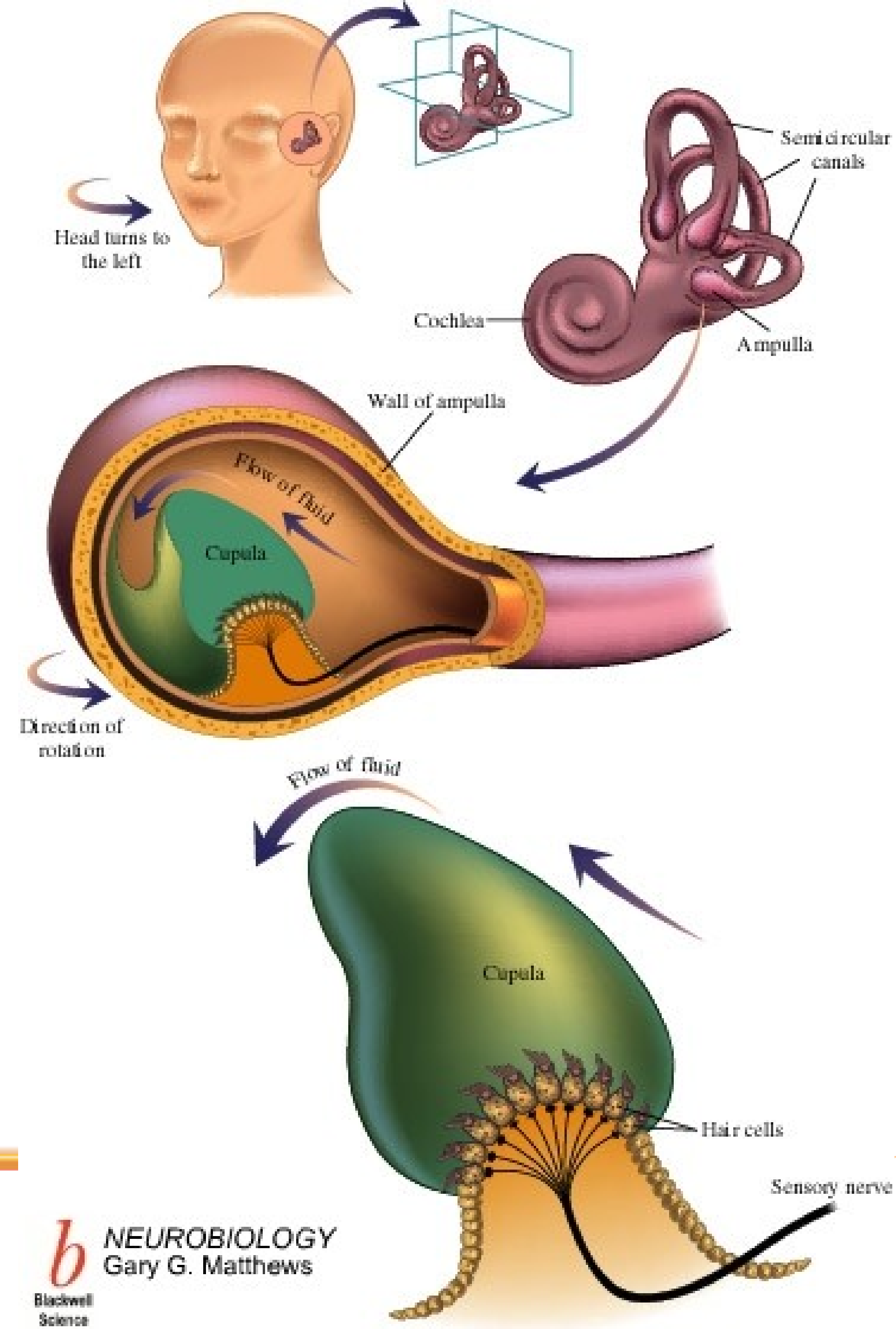
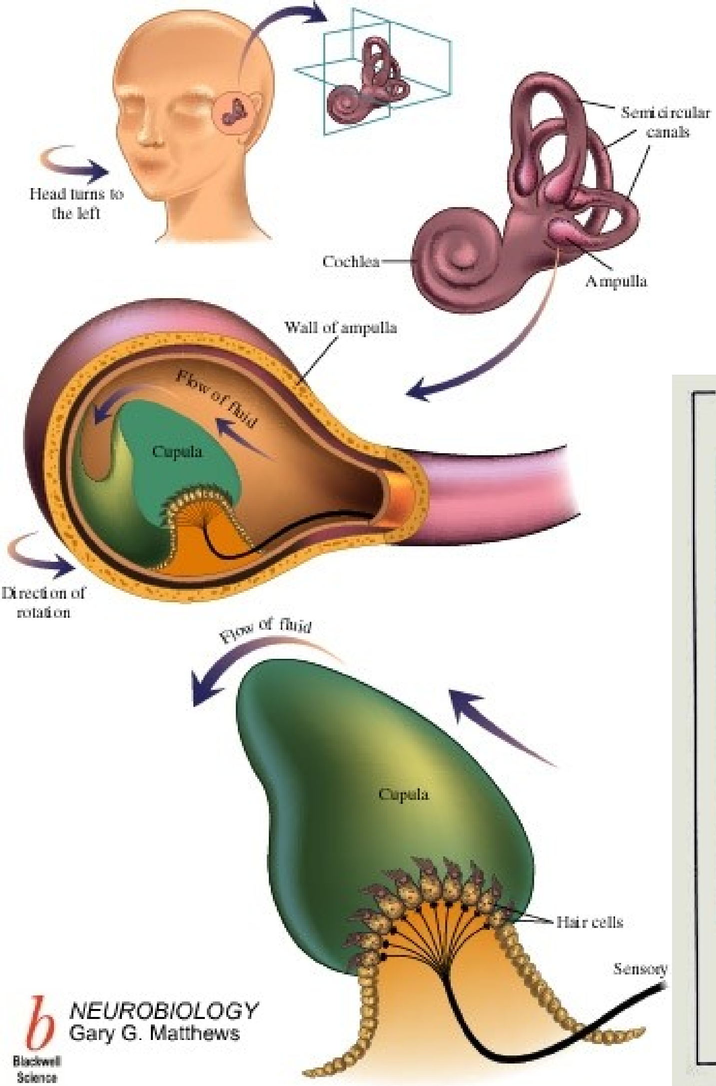


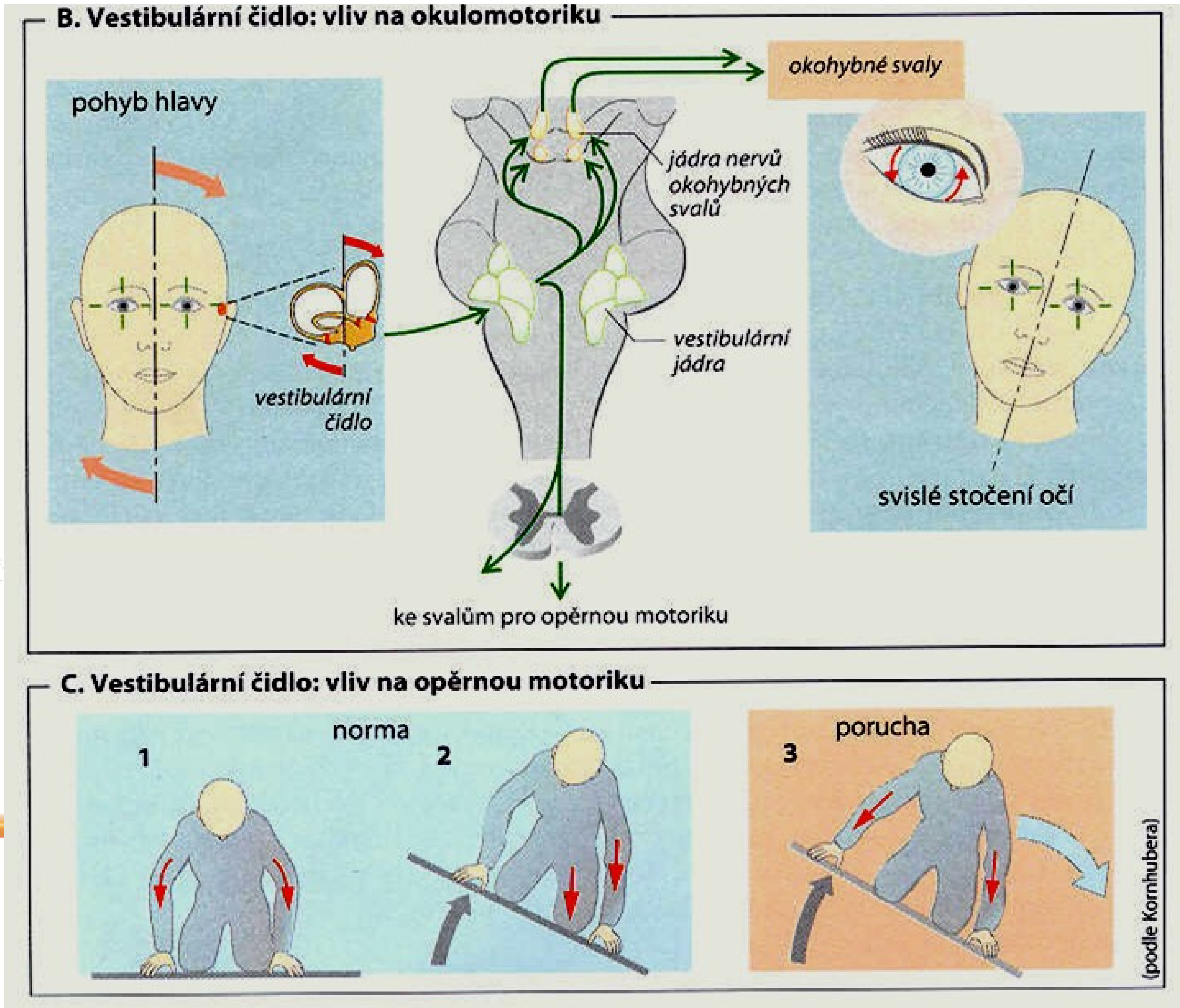
Figure 1 Forces acting on the head result in displacement of the otoconia. This example illustrates displacement of the utricular macula. For each of the head tilts and linear accelerations, some set of hair cells will be maximally excited, whereas another set will be maximally inhibited, according to the orientation of the hair cells. Note that head tilts and linear accelerations—when matched in direction and magnitude—produce similar otoconial movement, demonstrating that the otolith organs respond to both gravity and linear acceleration.



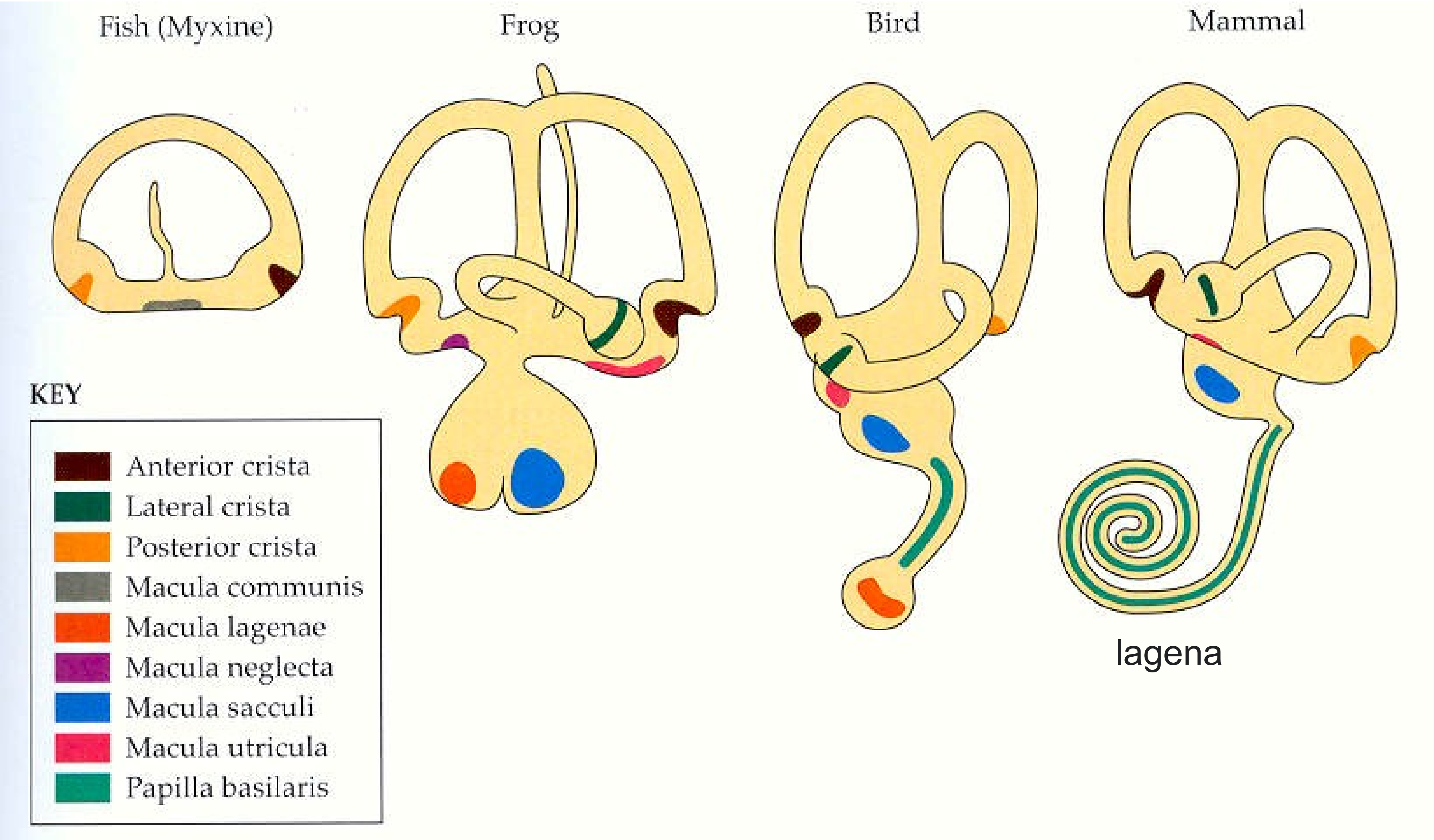
NEUROBIOLOGY
Gary G. Matthews
Blackwell Science



Head turns to the left
Semicircular canals
Cochlea
Ampulla
Wall of ampulla
Flow of fluid
Cupula
Direction of rotation
Flow of fluid
Cupula
Hair cells
Sensory
NEUROBIOLOGY
Gary G. Matthews
Blackwell Science



B. Vestibulární čidlo: vliv na okulomotoriku
pohyb hlavy
vestibulární čidlo
okohybné svaly
jádra nervů okohybných svalů
vestibulární jádra
svislé stočení očí
ke svalům pro opěrnou motoriku
C. Vestibulární čidlo: vliv na opěrnou motoriku
norma
1
2
porucha
3
(podle Kornhubera)


Fish (Myxine)
Frog
Bird
Mammal
KEY
Anterior crista
Lateral crista
Posterior crista
Macula communis
Macula lagenae
Macula neglecta
Macula sacculi
Macula utricula
Papilla basilaris
lagena

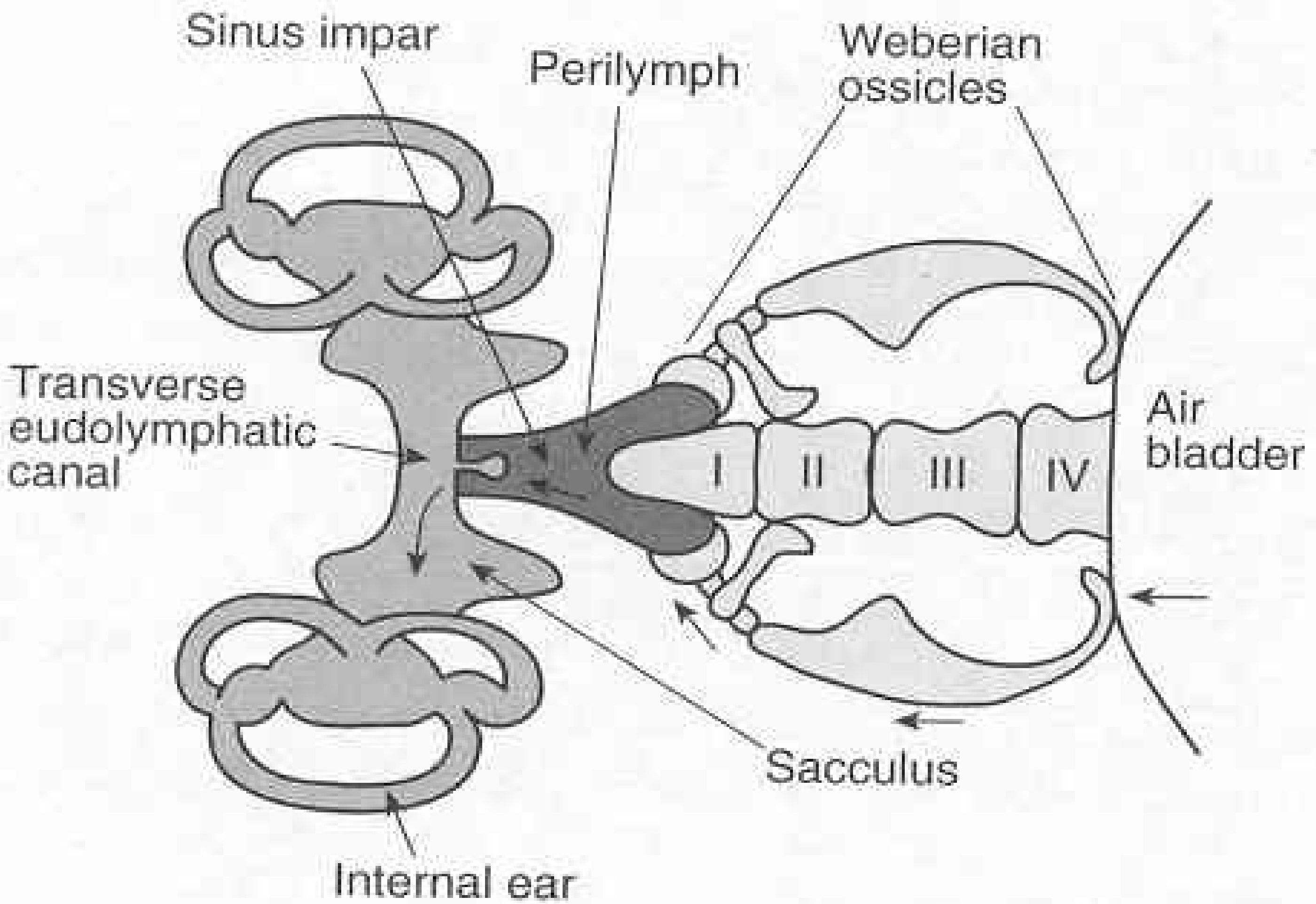
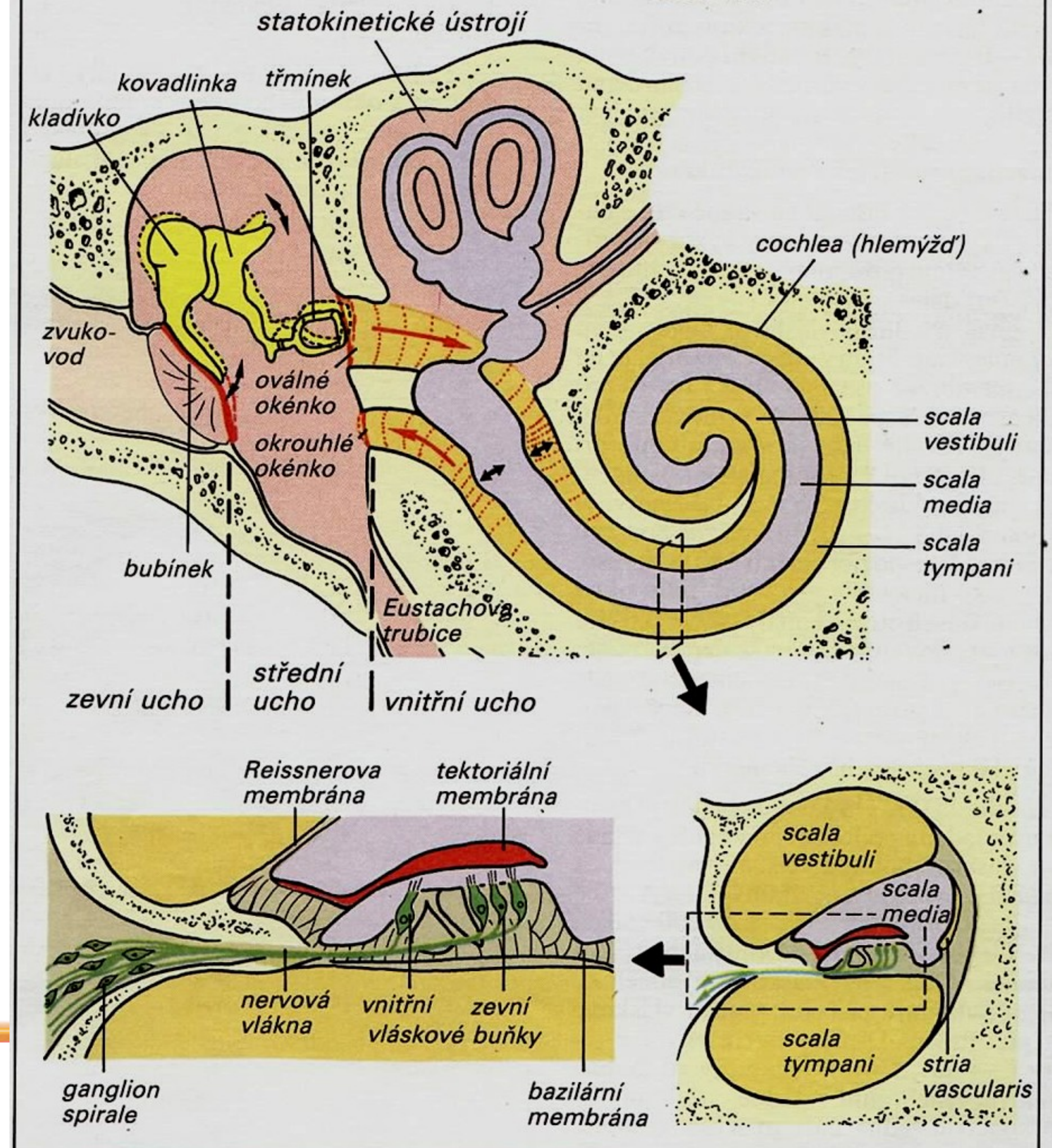
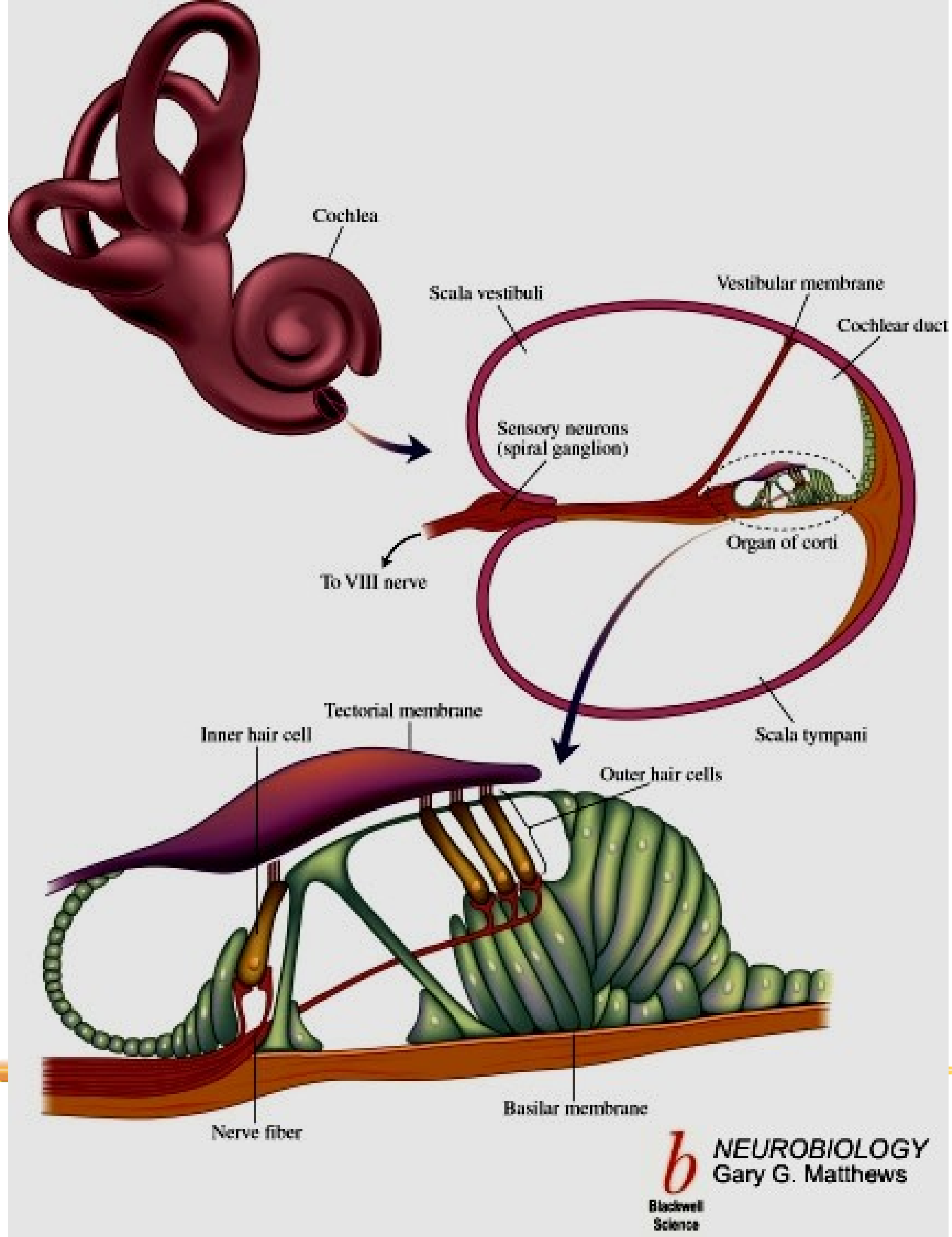


Figure 8.10 Weberian ossicles. The figure shows a horizontal section through the anterior region of the body of a carp (*Cyprinus carpio*). The arrows indicate the direction of vibrations from the swim bladder to the sacculus. I, II, III, and IV indicate the four vertebrae from which the ossicles are derived. Modified from Romer, 1970



statokinetické ústrojí
kovadlinka
třmínek
kladívko
cochlea (hlemýžď)
zvukovod
oválné okénko
okrouhlé okénko
scala vestibuli
scala media
scala tympani
bubínek
Eustachova trubice
střední ucho
zevní ucho
vnitřní ucho
Reissnerova membrána
tektoriální membrána
scala vestibuli
scala media
nervová vlákna
vnitřní
zevní
vláskové buňky
scala tympani
stria vascularis
ganglion spirale
bazilární membrána


Cochlea
Scala vestibuli
Vestibular membrane
Cochlear duct
Sensory neurons
(spiral ganglion)
To VIII nerve
Organ of corti
Scala tympani
Tectorial membrane
Inner hair cell
Outer hair cells
Basilar membrane
Nerve fiber
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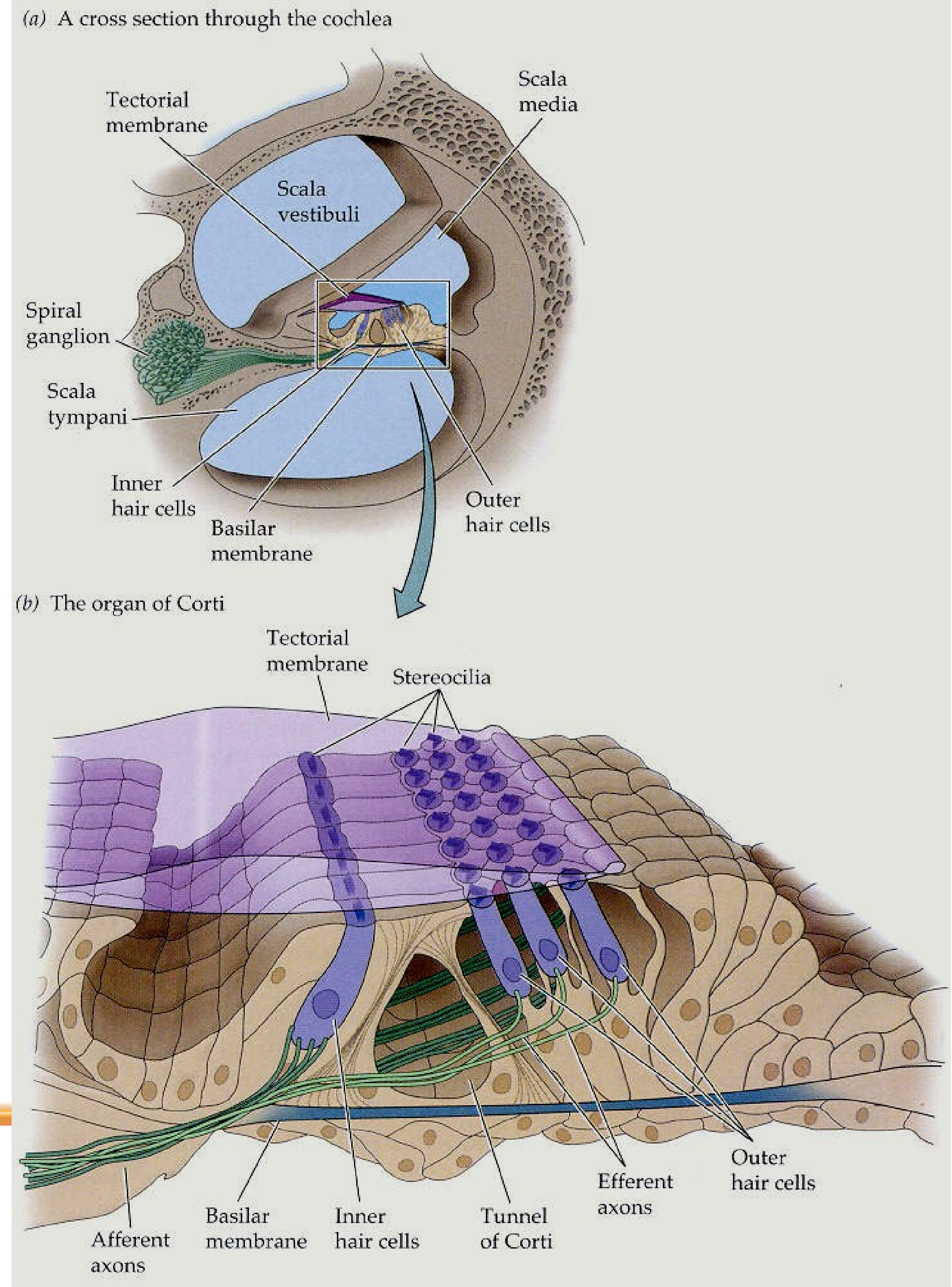
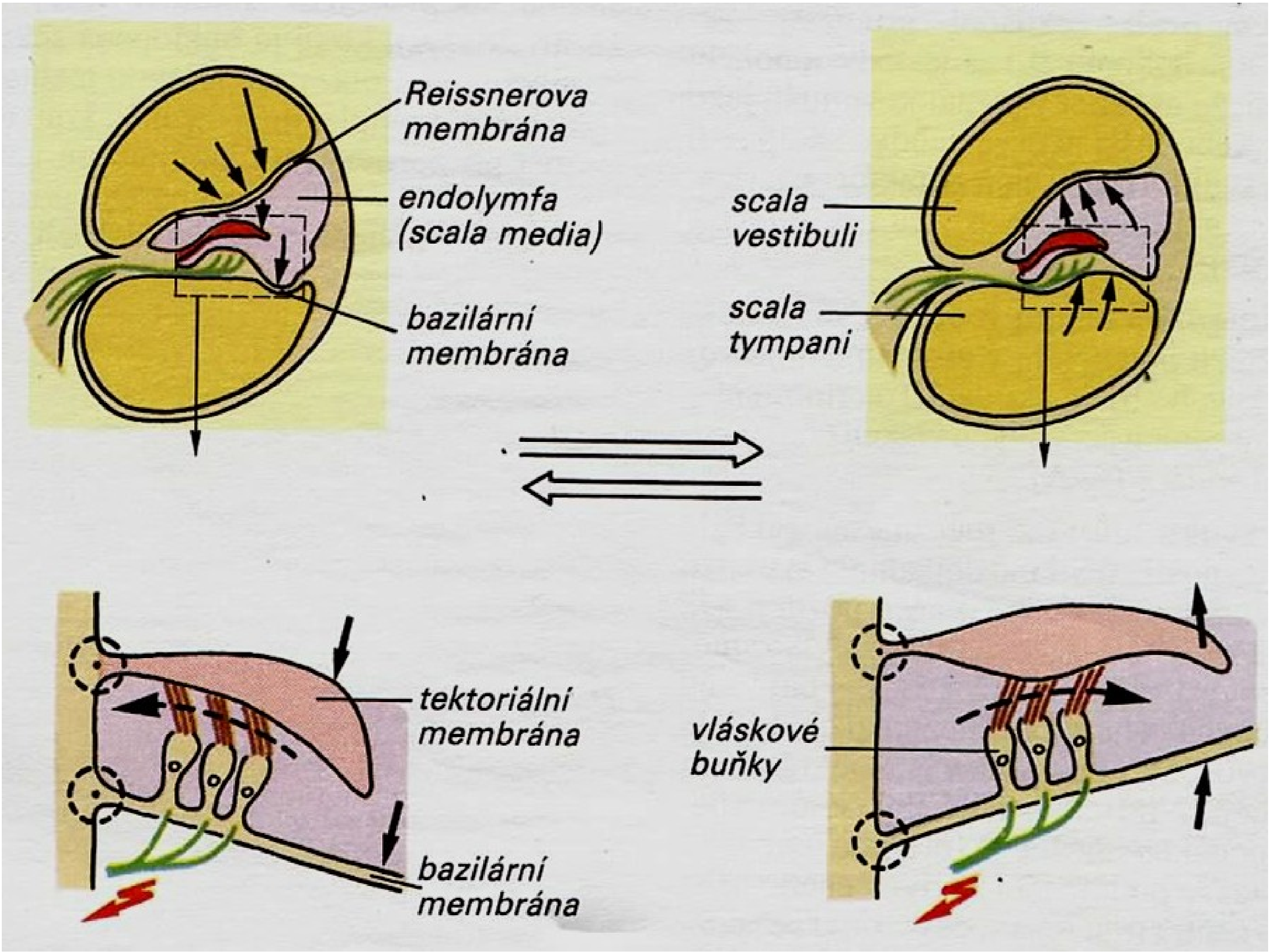
Science

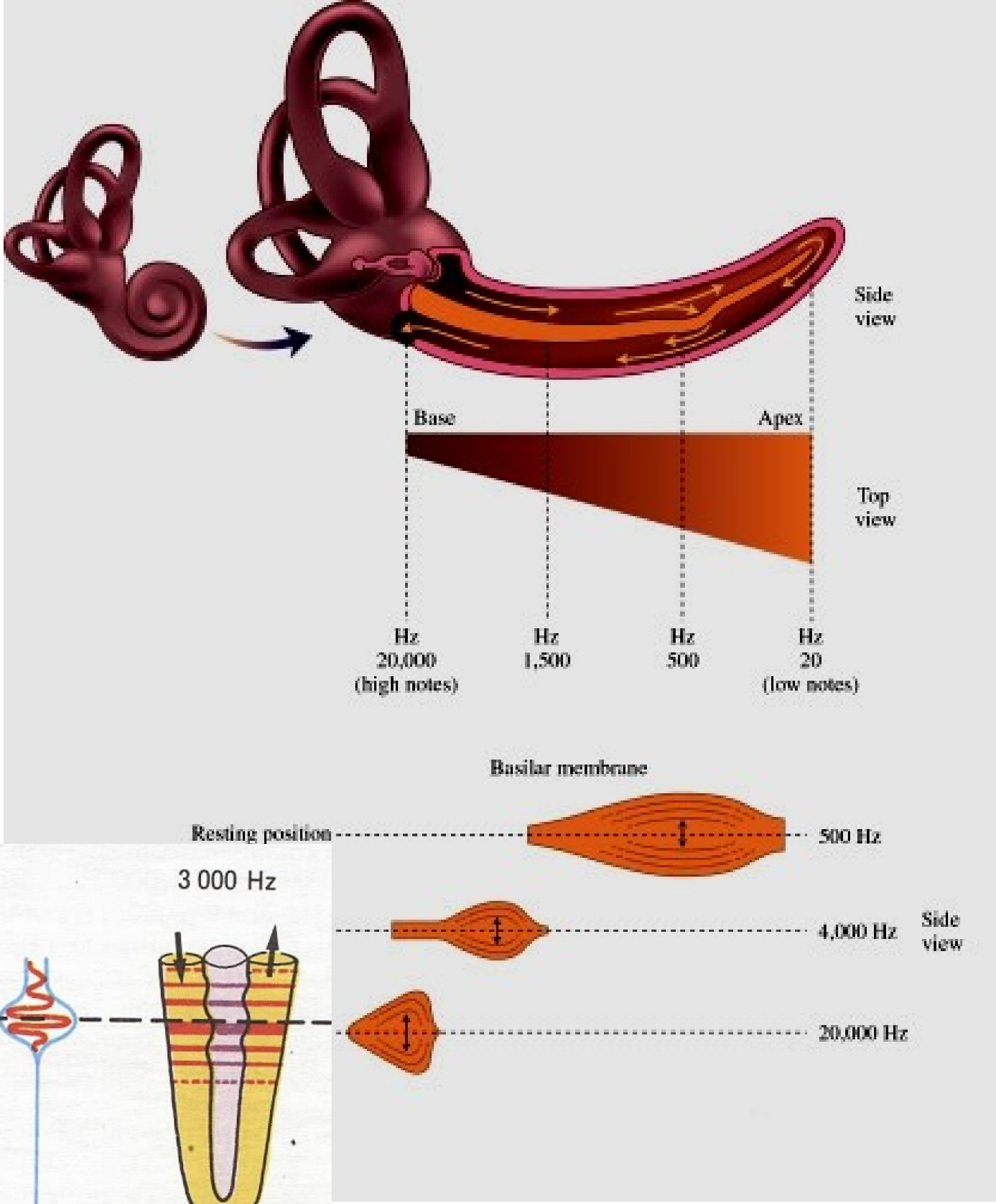


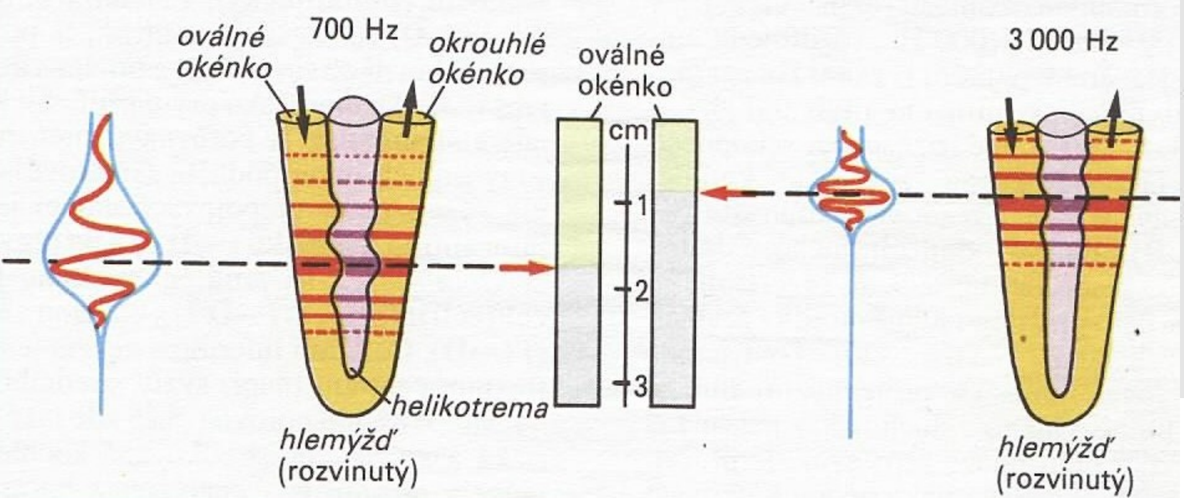
[Animace ear](#)

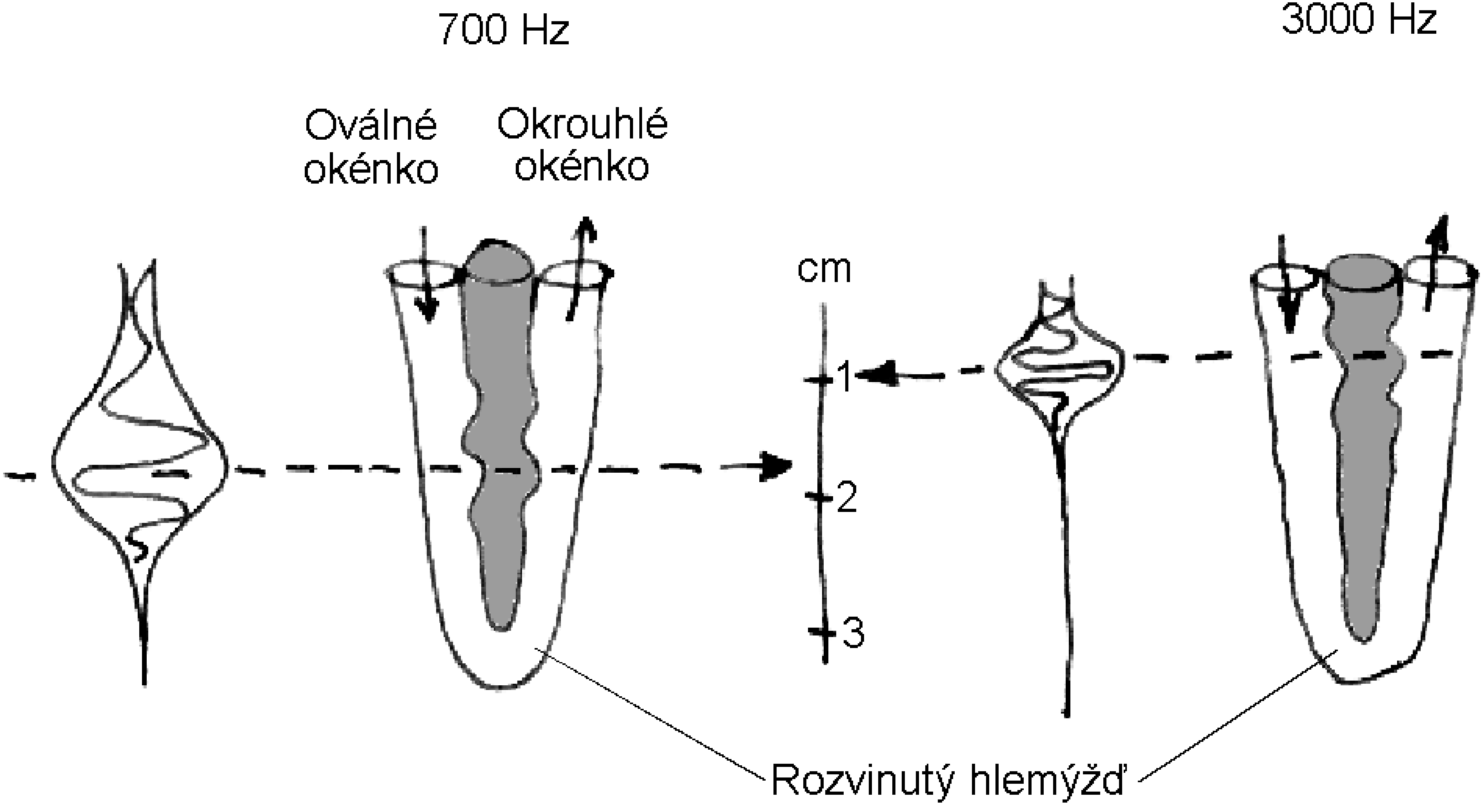
http://highered.mcgraw-hill.com/olc/dl/120108/bio_e.swf

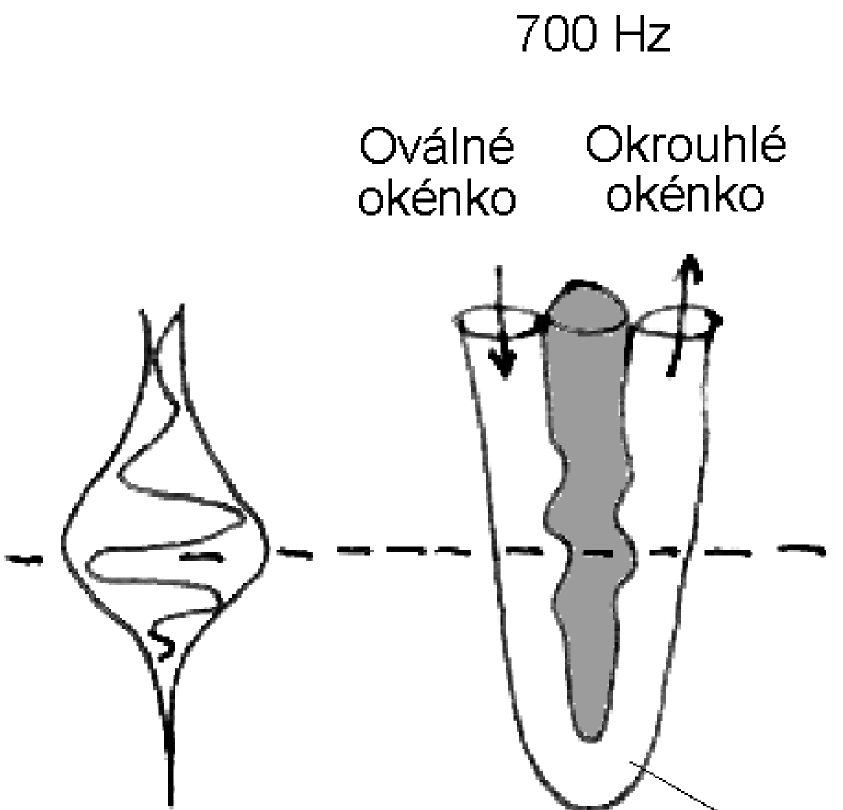


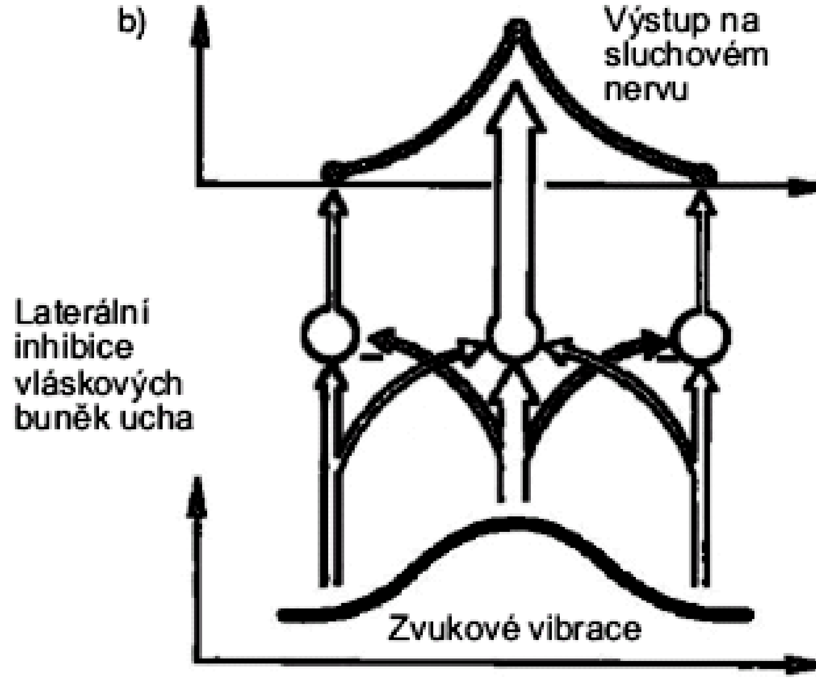
http://www.the-scientist.com//?articles.view/articleNo/43884/title/Hearing-Explained/

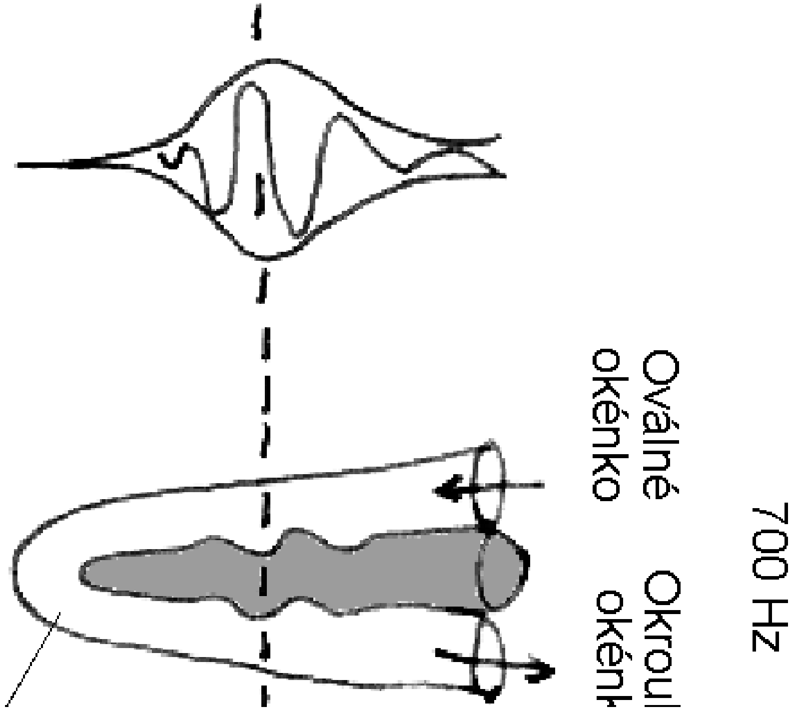

Side view
Base
Apex
Top view
Hz 20,000 (high notes)
Hz 1,500
Hz 500
Hz 20 (low notes)
Basilar membrane
Resting position
500 Hz
4,000 Hz
Side view
20,000 Hz

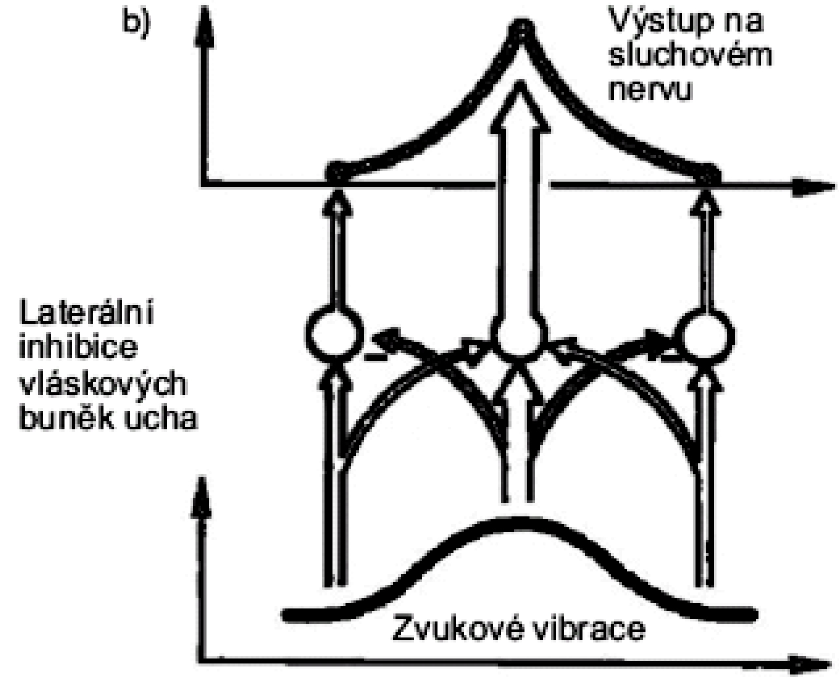

oválné okénko
700 Hz
okrouhlé okénko
oválné okénko
cm
1
2
3
helikotrema
hlemýžď (rozvinutý)
3 000 Hz
hlemýžď (rozvinutý)

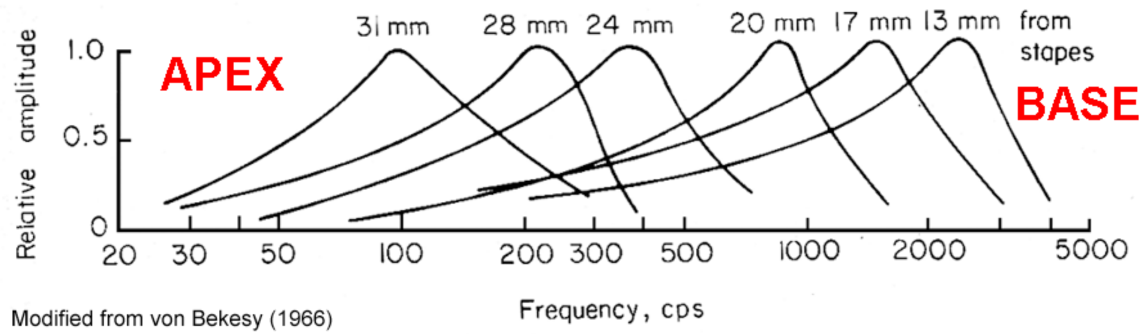

700 Hz
3000 Hz
Oválné okénko
Okrouhlé okénko
cm
1
2
3
Rozvinutý hlemýžď


700 Hz
Oválné okénko
Okrouhlé okénko

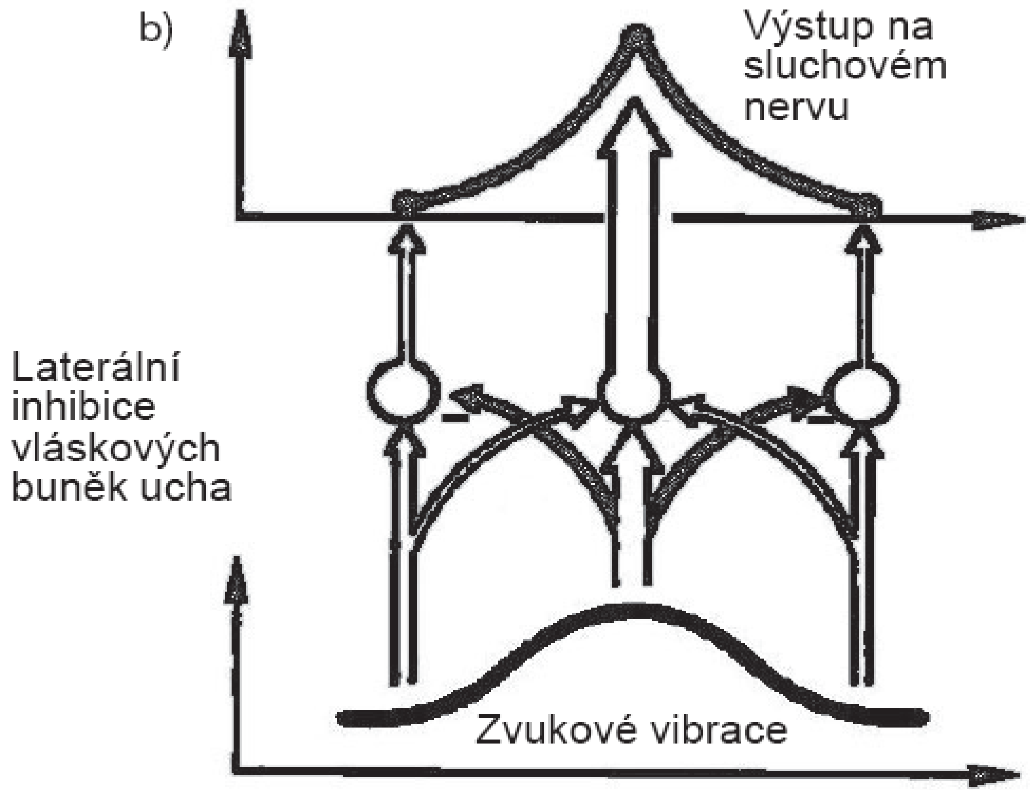

b)
Výstup na sluchovém nervu
Laterální inhibice vláskových buněk ucha
Zvukové vibrace

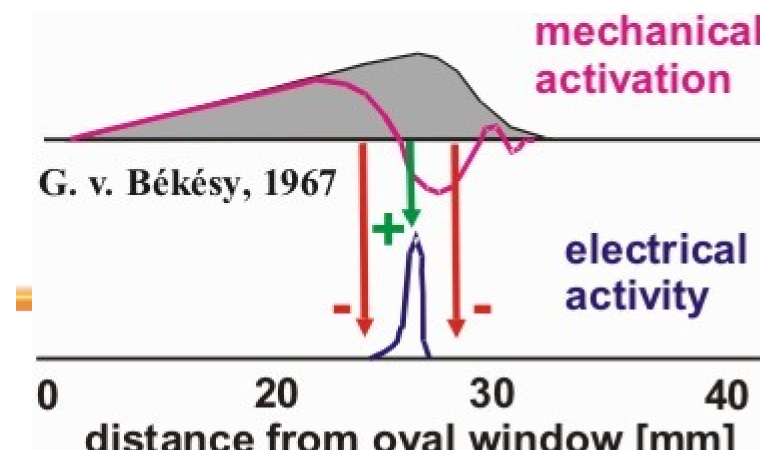

Oválné
okénko
700 Hz

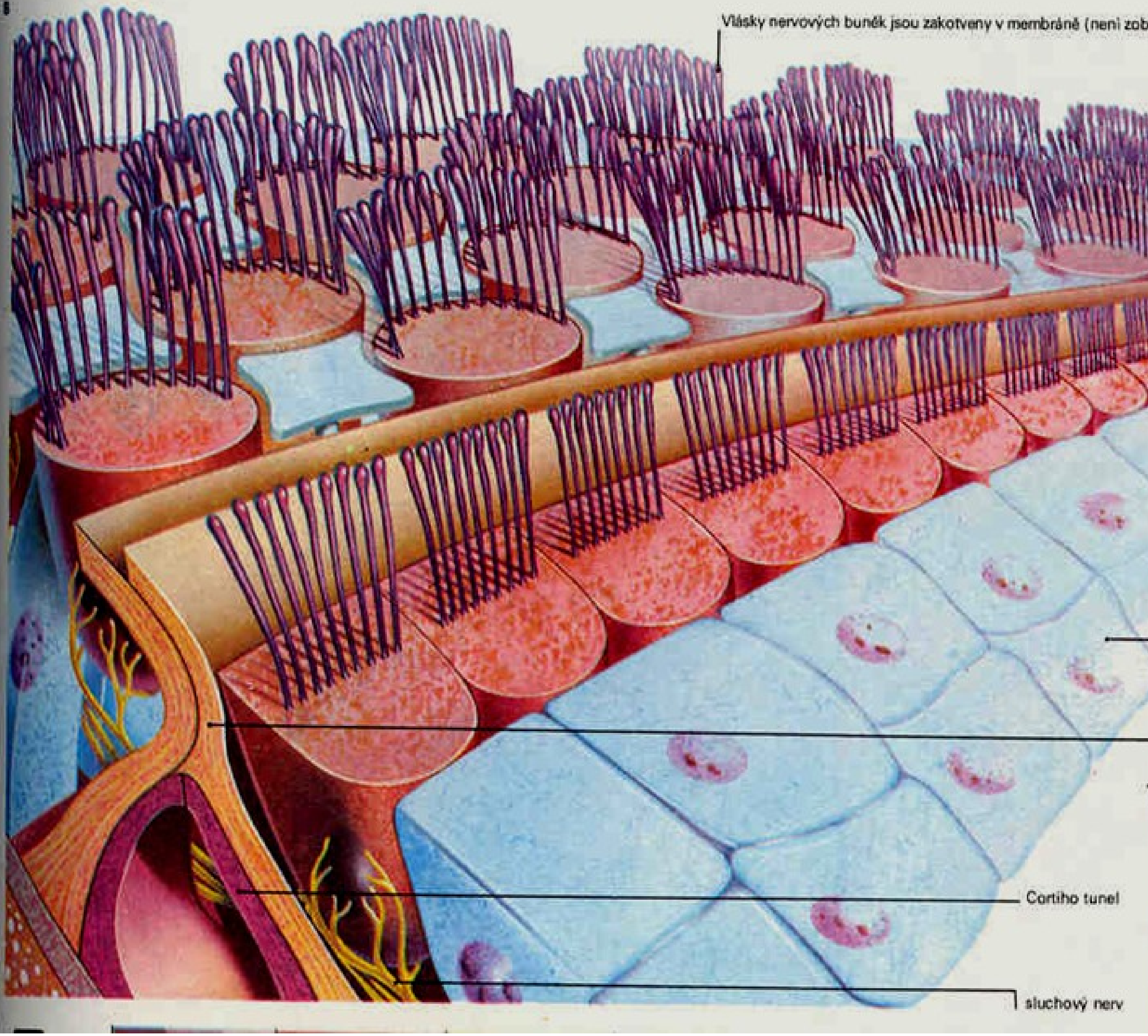

b)
Výstup na
sluchovém
nervu
Laterální
inhibice
vláskových
buněk ucha
Zvukové vibrace



Modified from von Bekesy (1966)

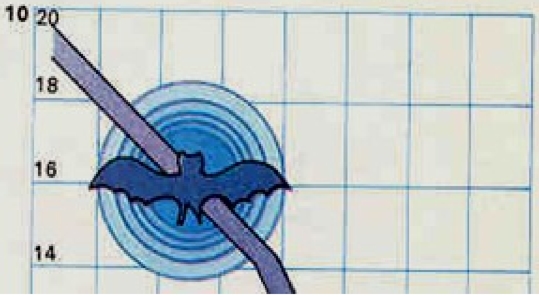


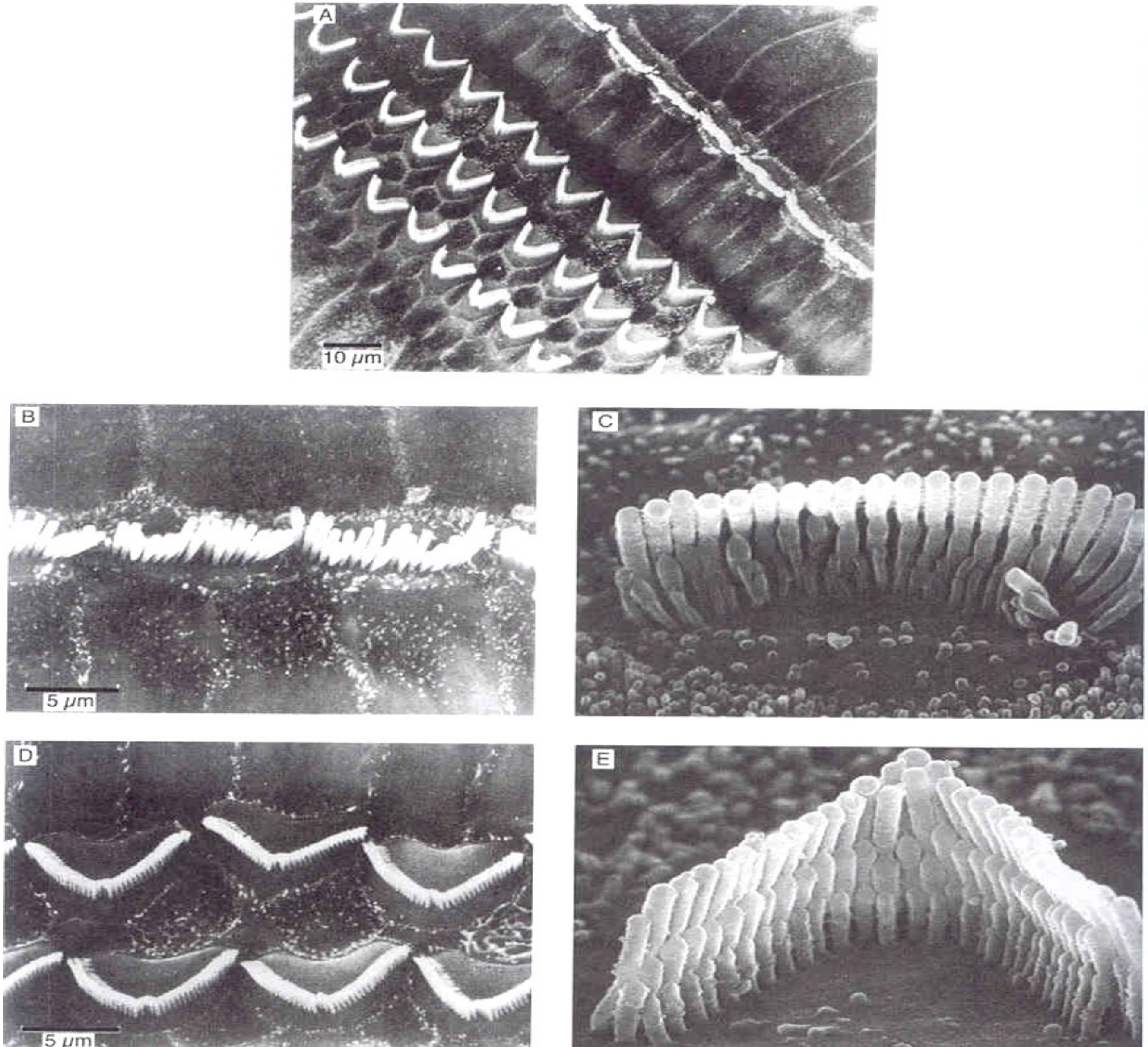


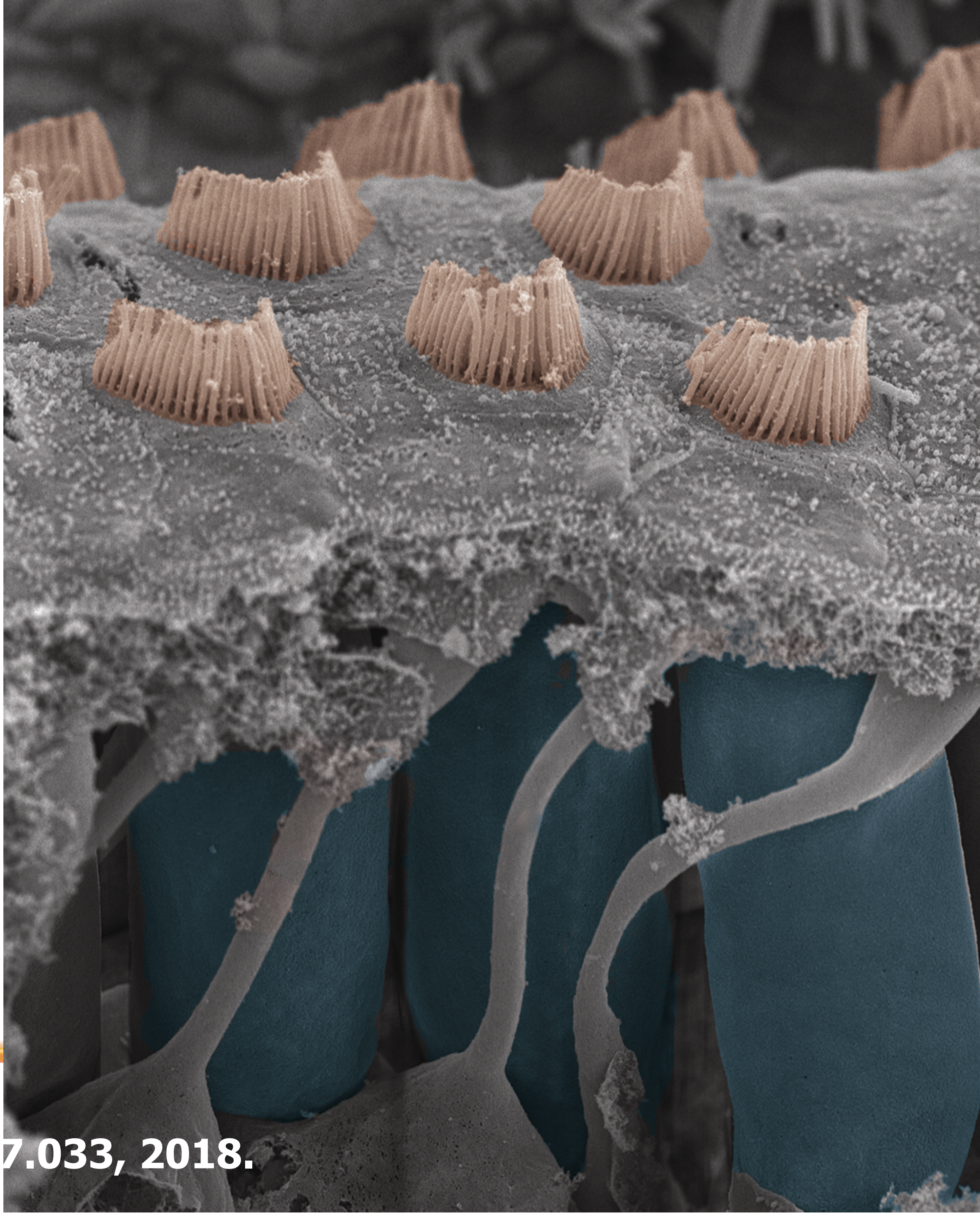


8 Cortiho orgán je při natažení hlemýždě dlouhý 2,5 cm, ale obsahuje asi 25 000 smyslových buněk. Jsou drážděny vlnami šířícími se v tekutině; podráždění převádějí na elektrické vzruchy vedené do CNS. Konce vlásků receptorových buněk Cortiho orgánu kotví v želatinovité membráně.

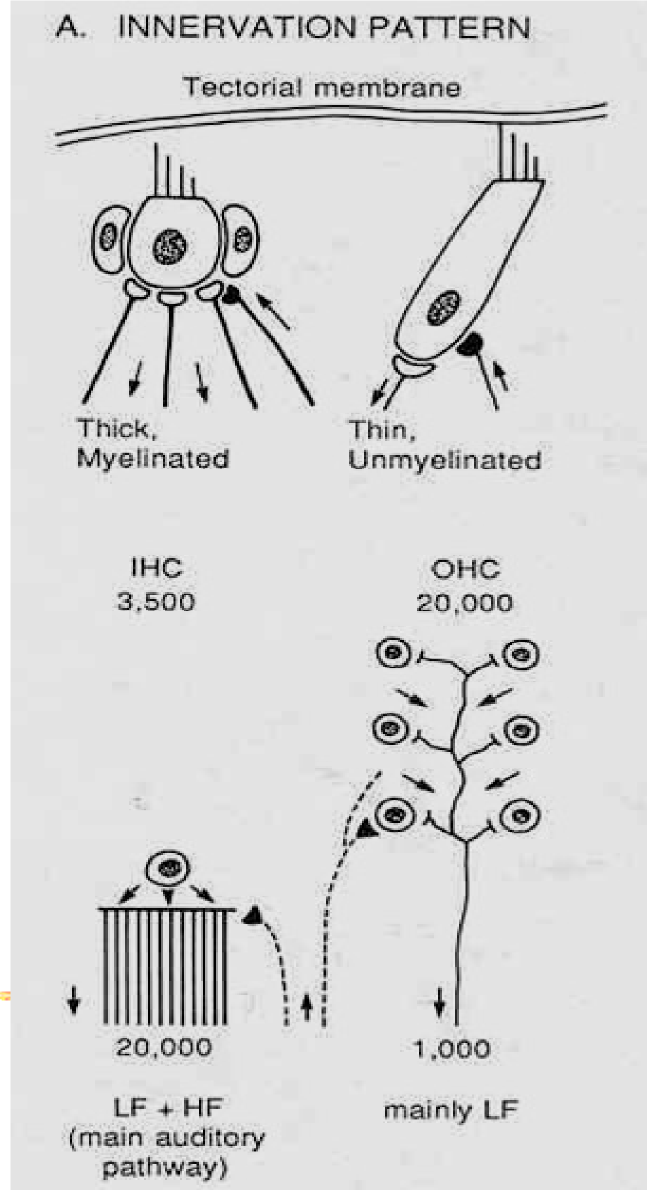
10




A
10 μm
B
5 μm
C
D
5 μm
E



7.033, 2018.



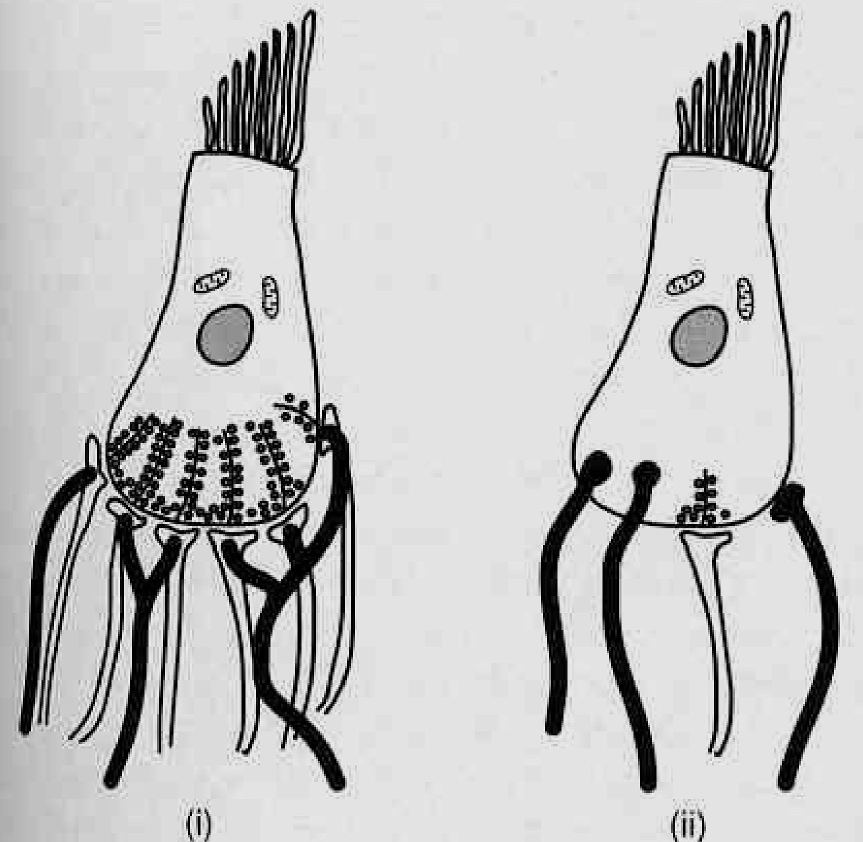
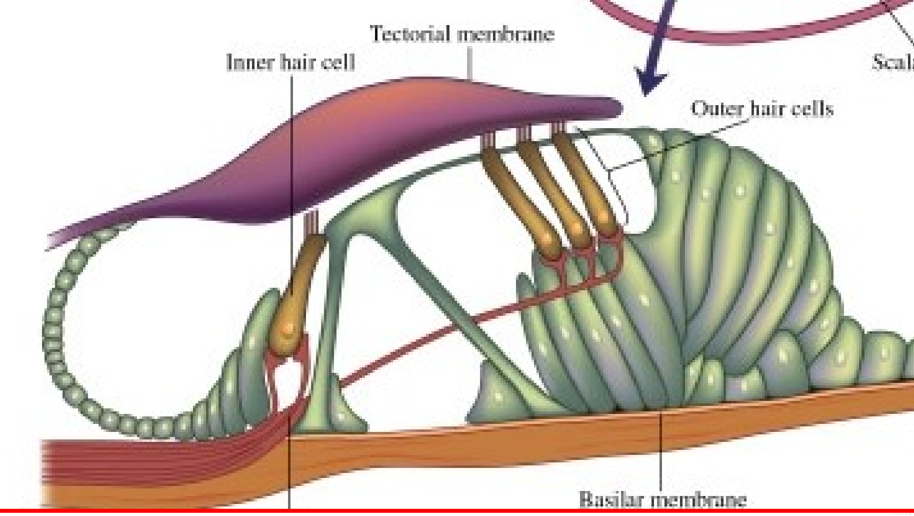
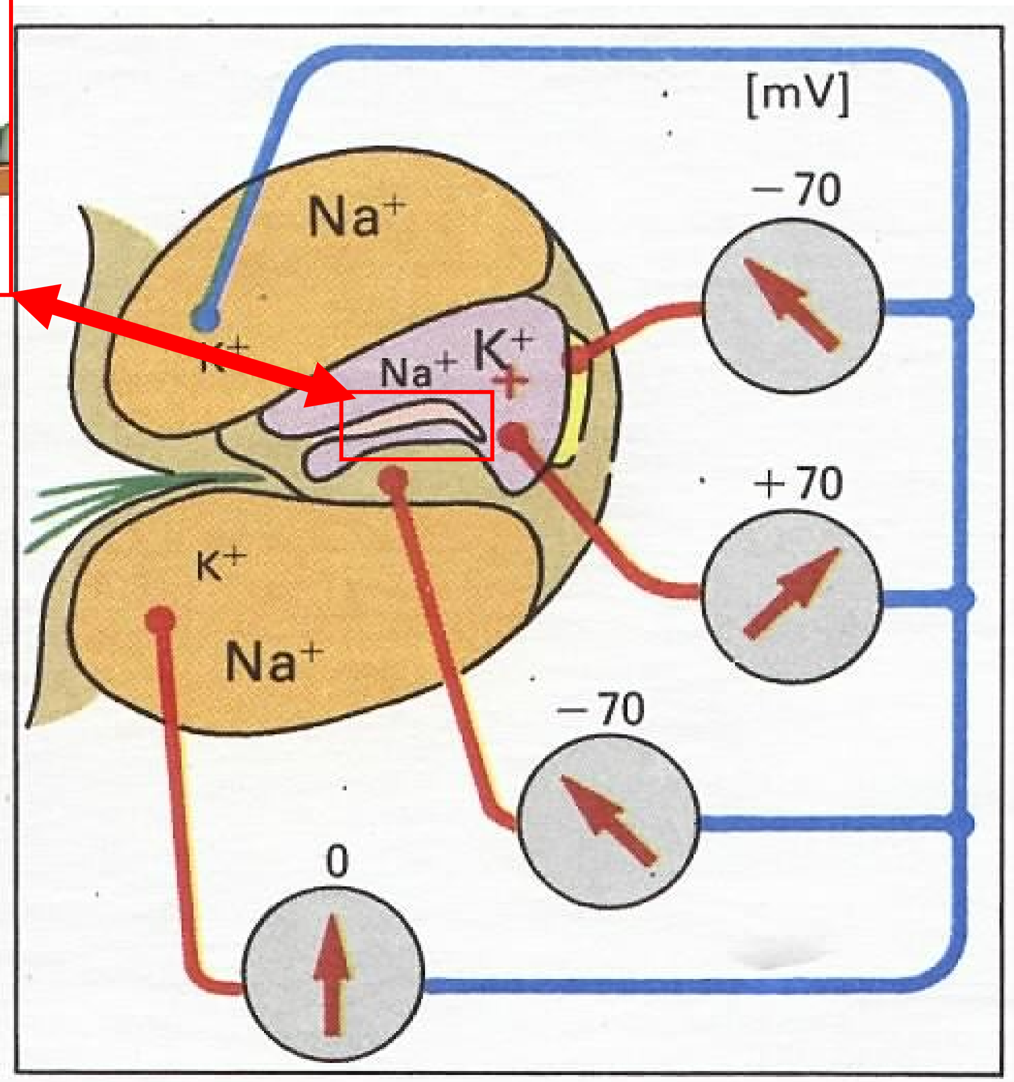


Figure 8.16 Innervation of inner and outer hair cells in the organ of Corti. The schematic figure shows afferent fibres (white) and efferent fibres (black). (i) Inner hair cell. The efferent fibres make synaptic contact with the dendritic endings of the afferent fibres. (ii) Outer hair cell. The efferent fibres synapse directly on the hair cell which makes rather few synapses (only one shown) with sensory (afferent) fibres





C. Kochleární potenciály a rozložení elektrolytů v oddílech hlemýždě

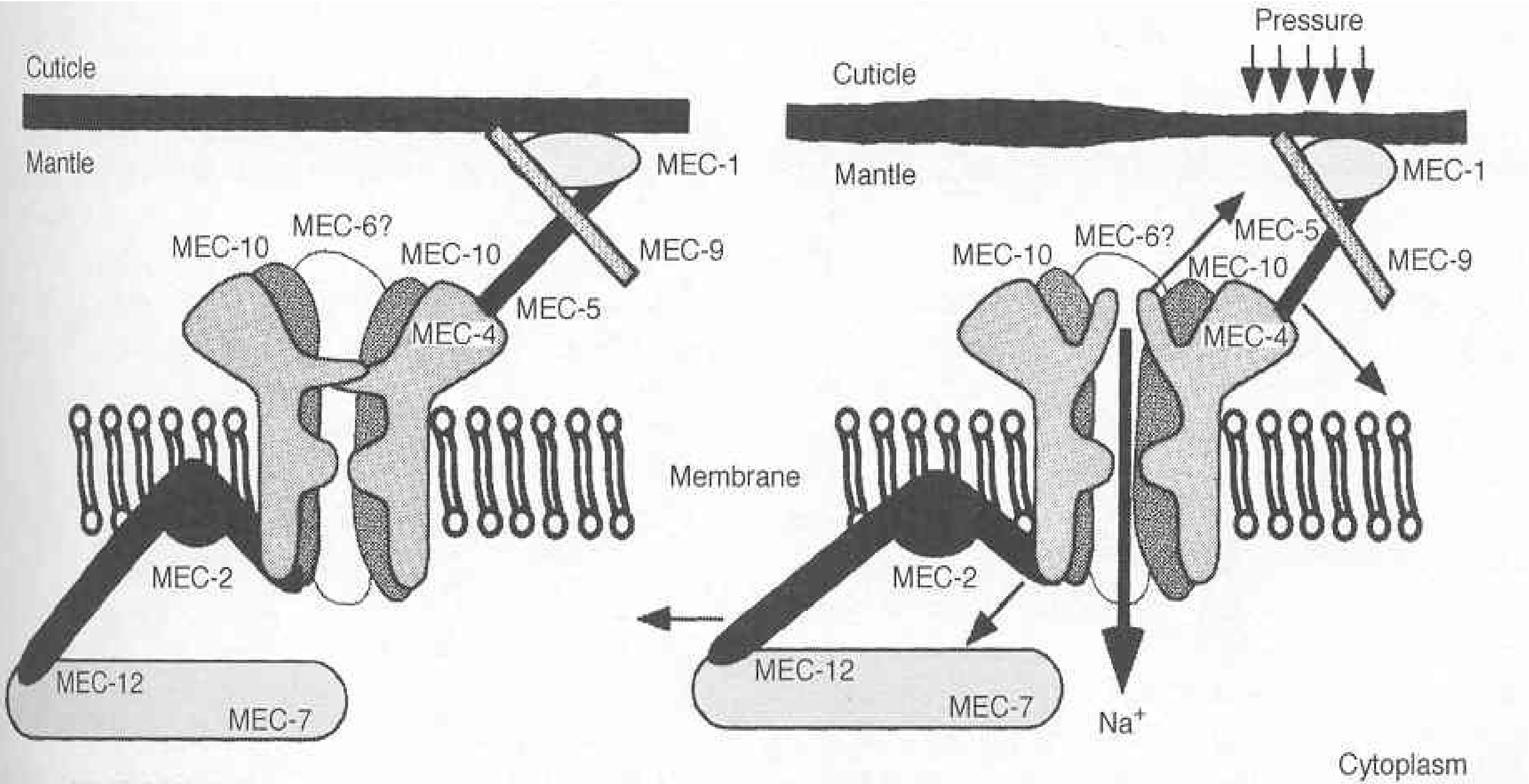
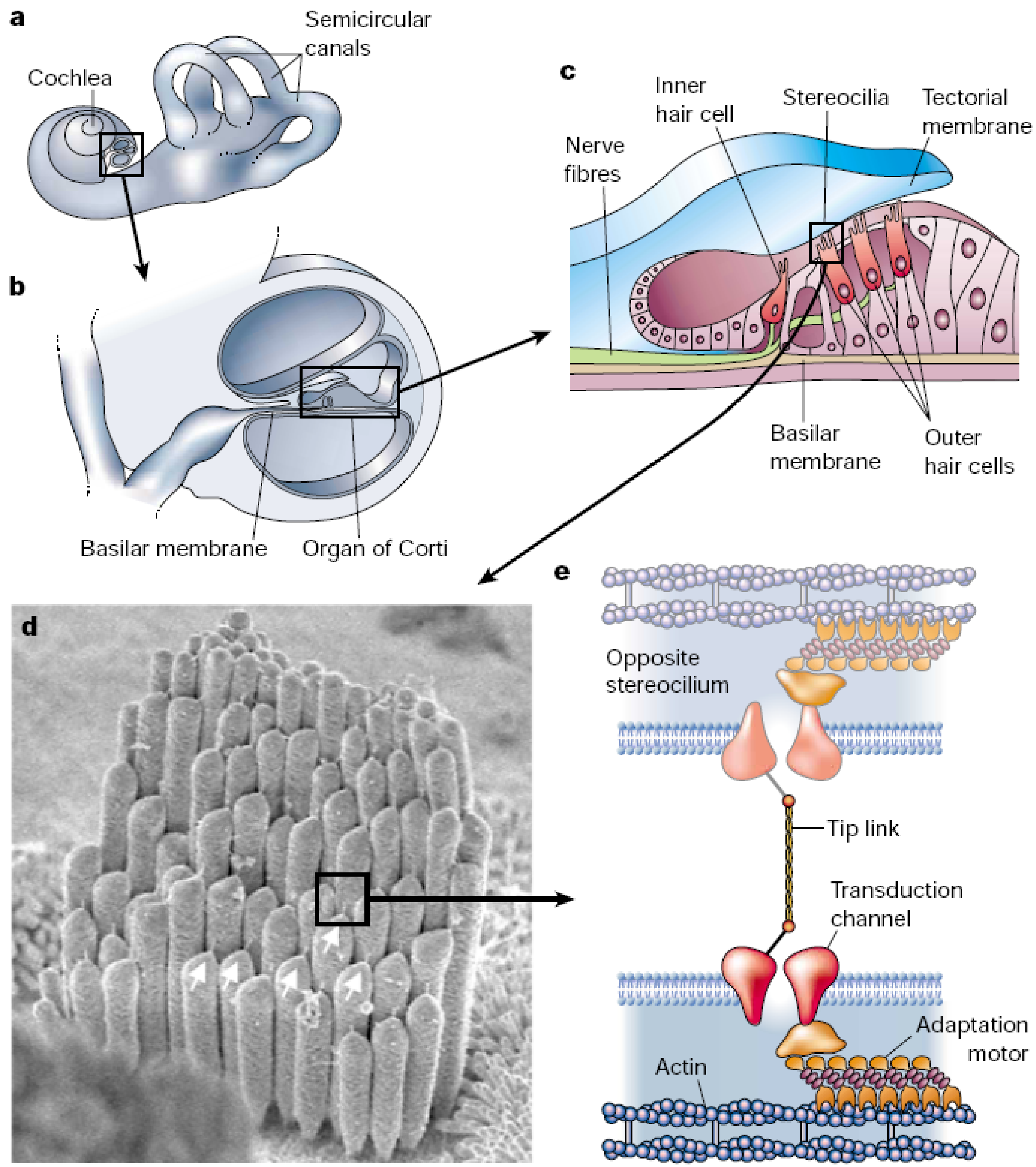
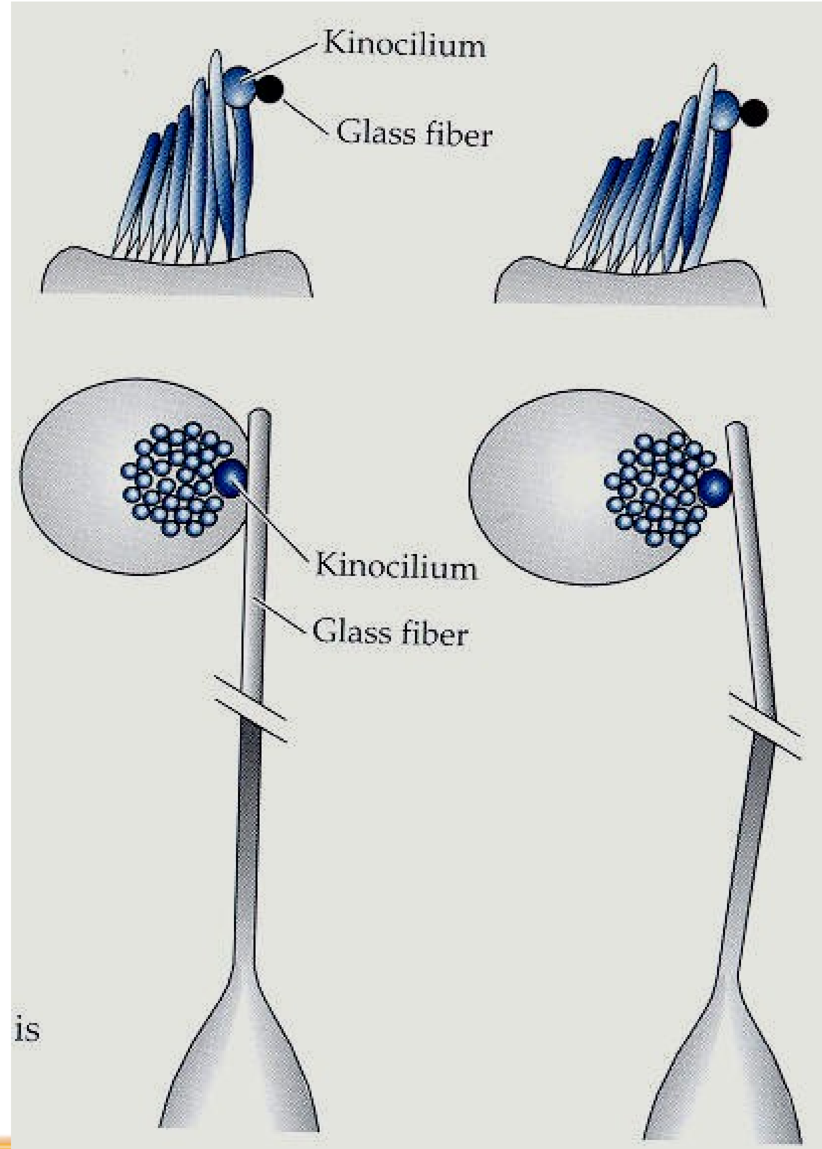


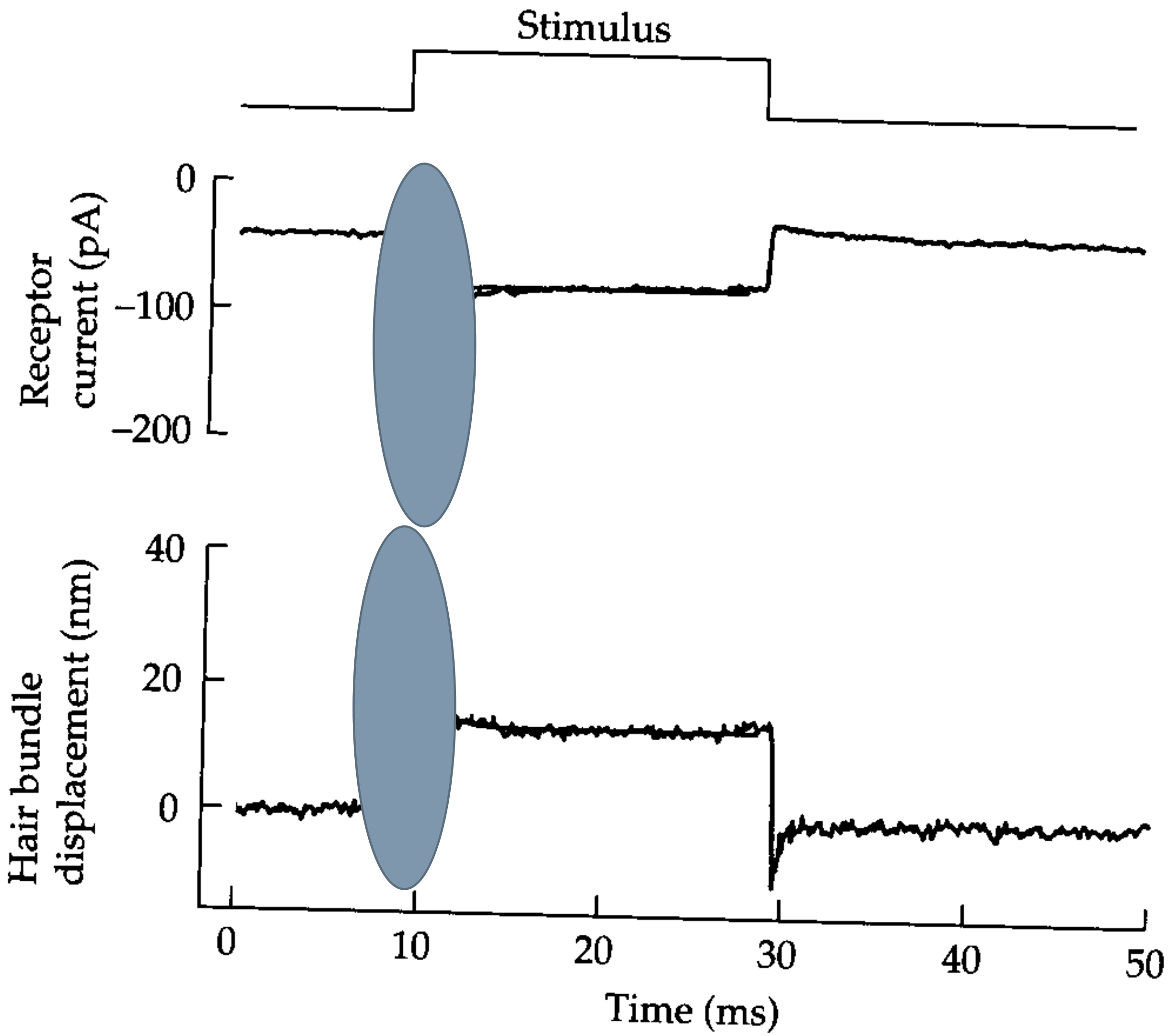
Figure 7.6 Conceptual model of *C. elegans* touch receptor. Explanation and nomenclature in text. From N. Tavernarakis and M. Driscoll, 1997, 'Molecular modelling of mechanotransduction in the nematode *Caenorhabditis elegans*', *Annual Review of Physiology*, **59**, 679. With permission, from the *Annual Review of Physiology*, Volume 59, ©1997, by Annual Reviews www.annualreviews.org

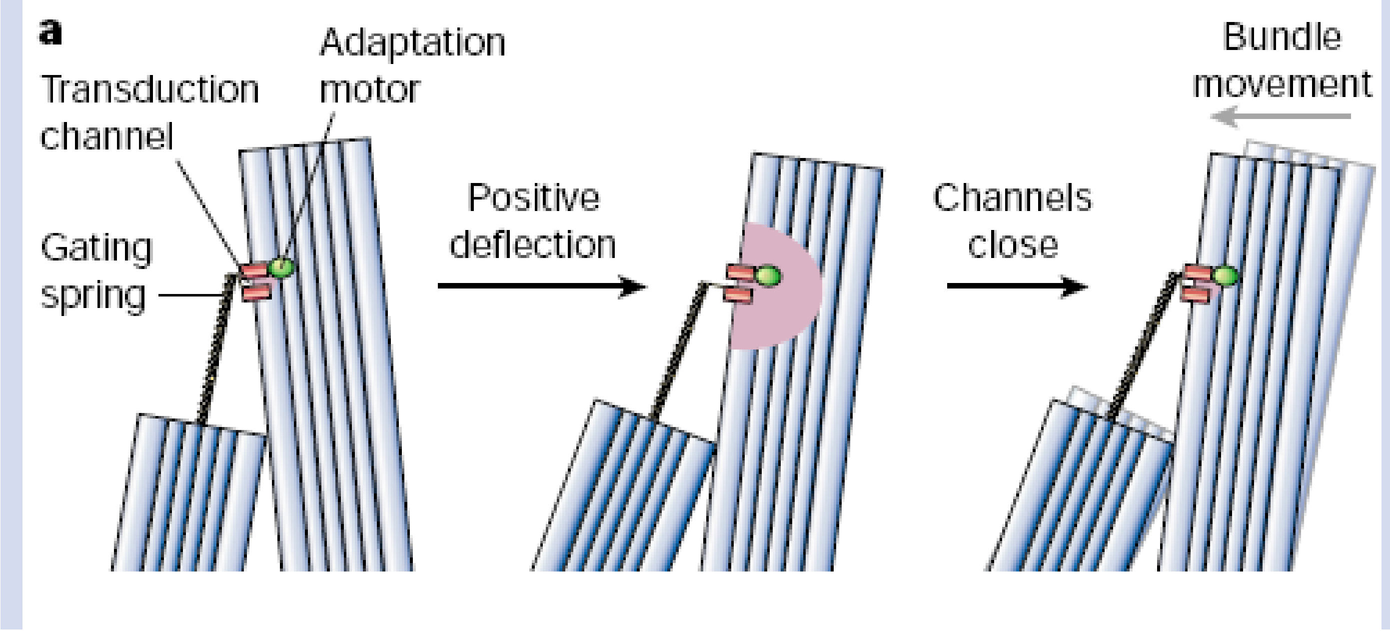
Figure 4 Inner-ear structure and hair-cell transduction model. **a**, Gross view of part of the inner ear. Sound is transmitted through the external ear to the tympanic membrane; the stimulus is transmitted through the middle ear to the fluid-filled inner ear. Sound is transduced by the coiled cochlea. **b**, Cross-section through the cochlear duct. Hair cells are located in the organ of Corti, resting on the basilar membrane. **c**, Sound causes vibrations of the basilar membrane of the organ of Corti; because flexible hair-cell stereocilia are coupled to the overlying tectorial membrane, oscillations of the basilar membrane cause back-and-forth deflection of the hair bundles. **d**, Scanning electron micrograph of hair bundle (from chicken cochlea). Note tip links (arrows). **e**, Proposed molecular model for hair-cell transduction apparatus.



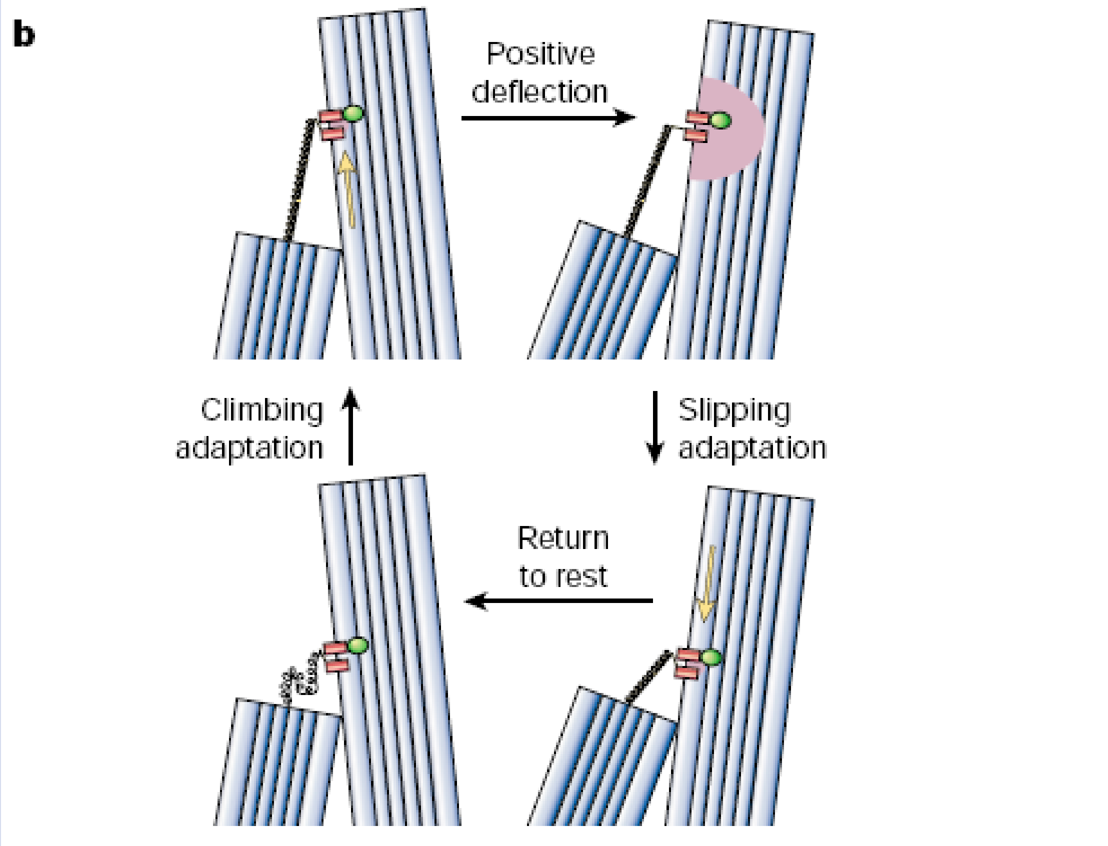
Obecný molekulární
Princip mechanorecepce


Kinocilium
Glass fiber
Kinocilium
Glass fiber
is

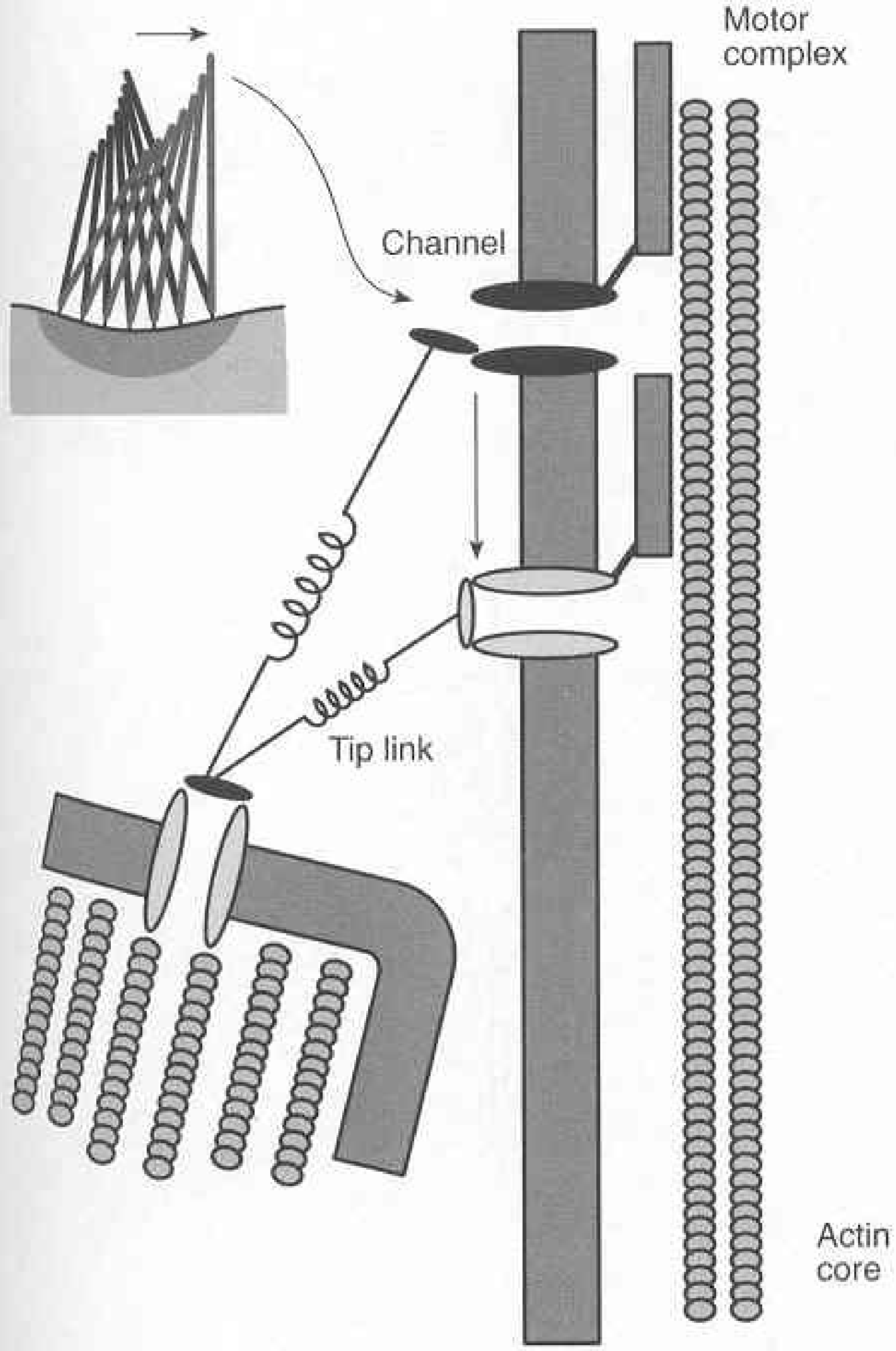

Stimulus
Receptor current (pA)
0
−100
−200
Hair bundle displacement (nm)
40
20
0
0
10
20
30
40
50
Time (ms)



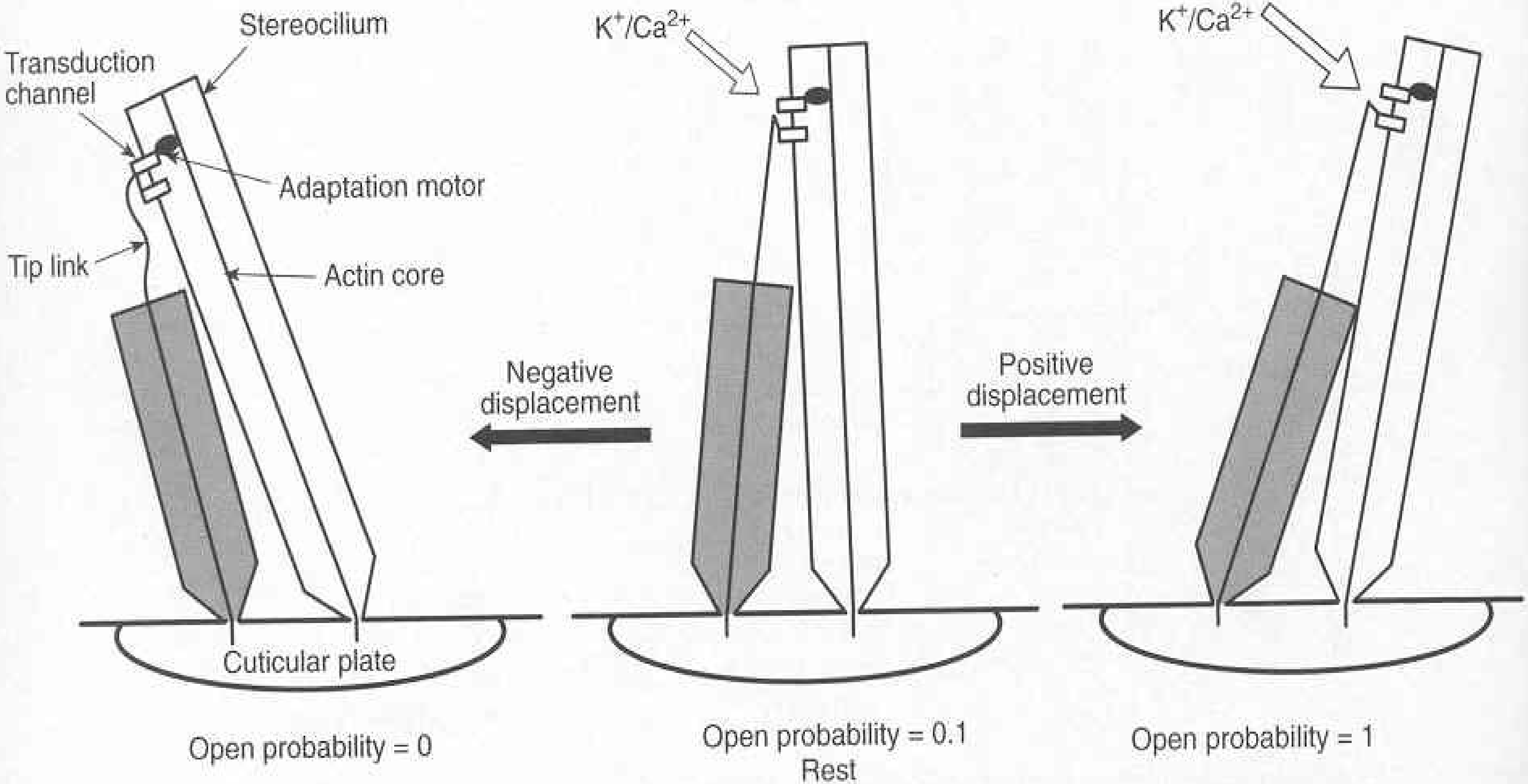
a
Adaptation motor
Transduction channel
Gating spring
Positive deflection
Channels close
Bundle movement

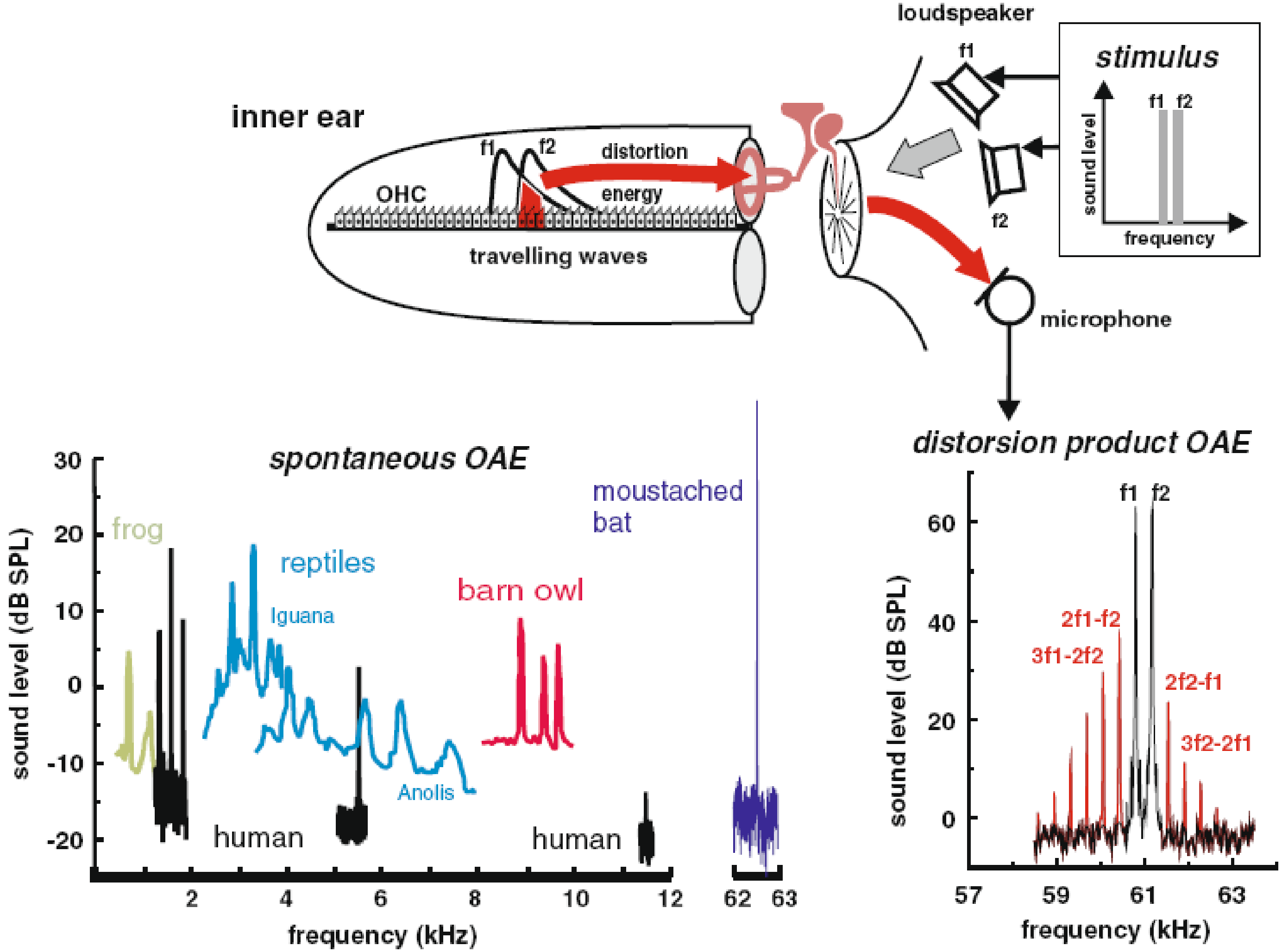


Box 2 Figure Hair-cell transduction and adaptation. **a**, Transduction and fast adaptation. At rest (left panel), transduction channels spend ~5% of the time open, allowing a modest Ca^{2+} entry (pink shading). A positive deflection (middle) stretches the gating spring (drawn here as the tip link); the increased tension propagates to the gate of the transduction channel, and channels open fully. The resulting Ca^{2+} flowing in through the channels shifts the channels' open probability to favour channel closure (right). As the gates close, they increase force in the gating spring, which moves the bundle back in the direction of the original stimulus. **b**, Transduction and slow adaptation. Slow adaptation ensues when the motor (green oval) slides down the stereocilium (lower right), allowing channels to close. After the bundle is returned to rest (lower left), gating-spring tension is very low; adaptation re-establishes tension and returns the channel to the resting state.

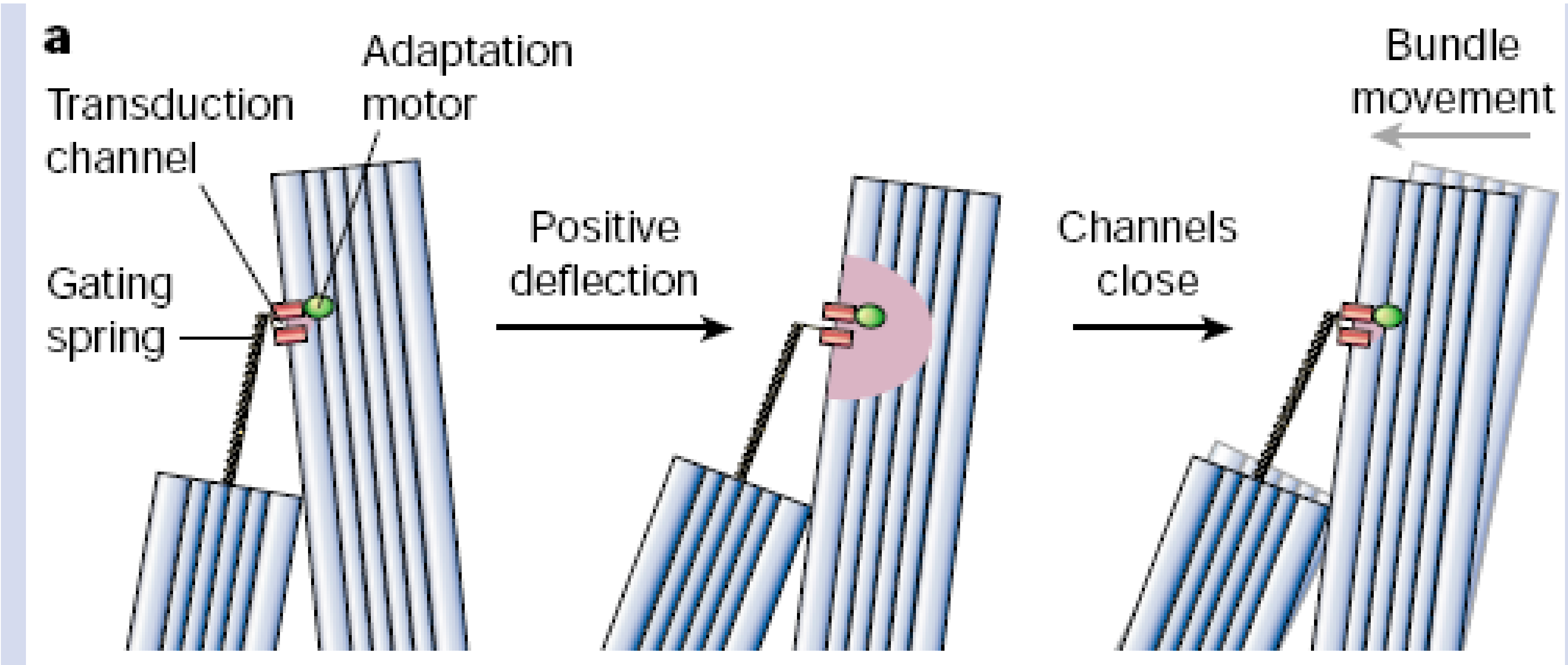


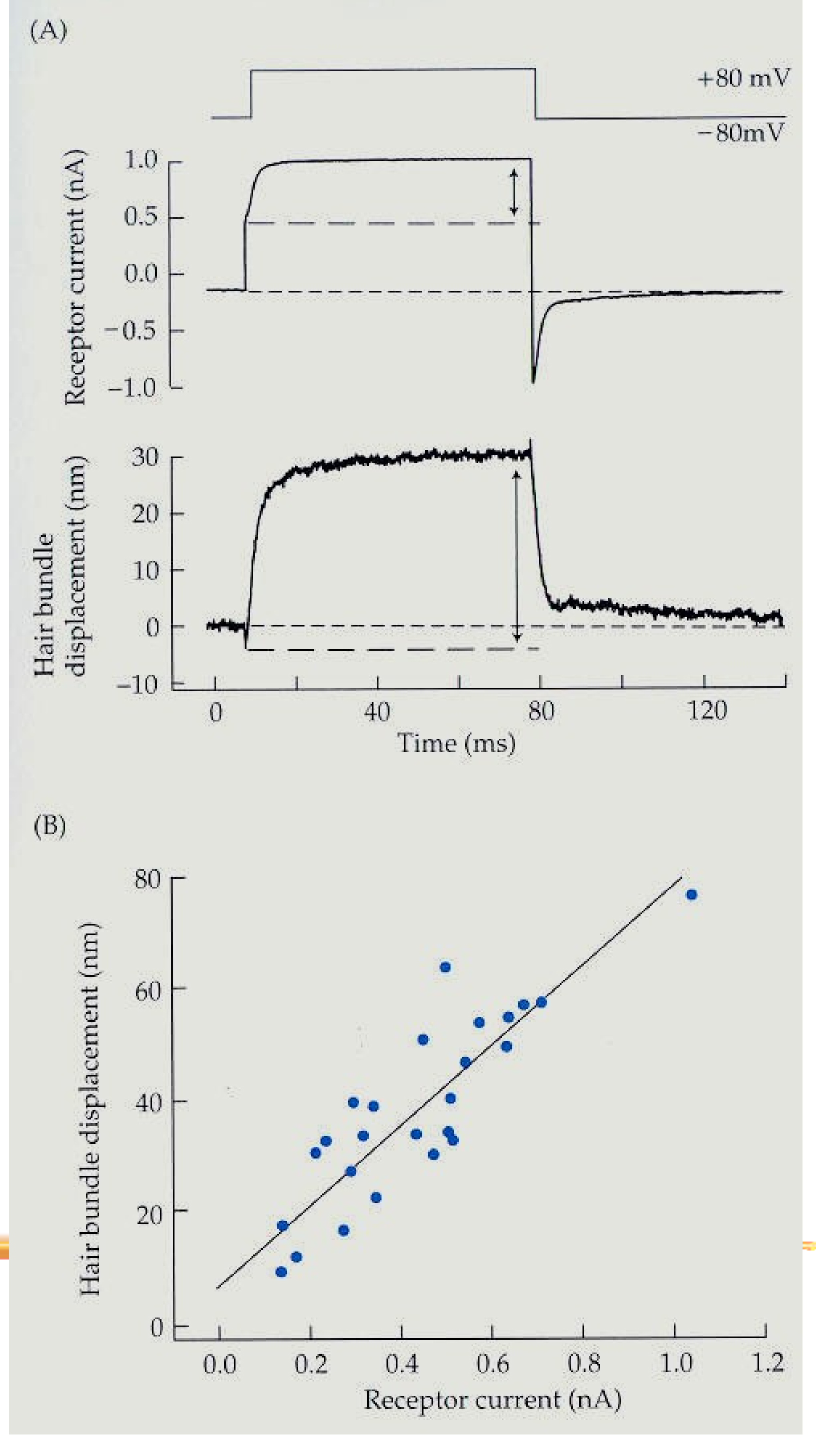
Motor complex
Channel
Tip link
Actin core


Stereocilium
Transduction channel
Adaptation motor
Tip link
Actin core
Cuticular plate
K+/Ca2+
K+/Ca2+
Negative displacement
Positive displacement
Open probability = 0
Open probability = 0.1
Rest
Open probability = 1

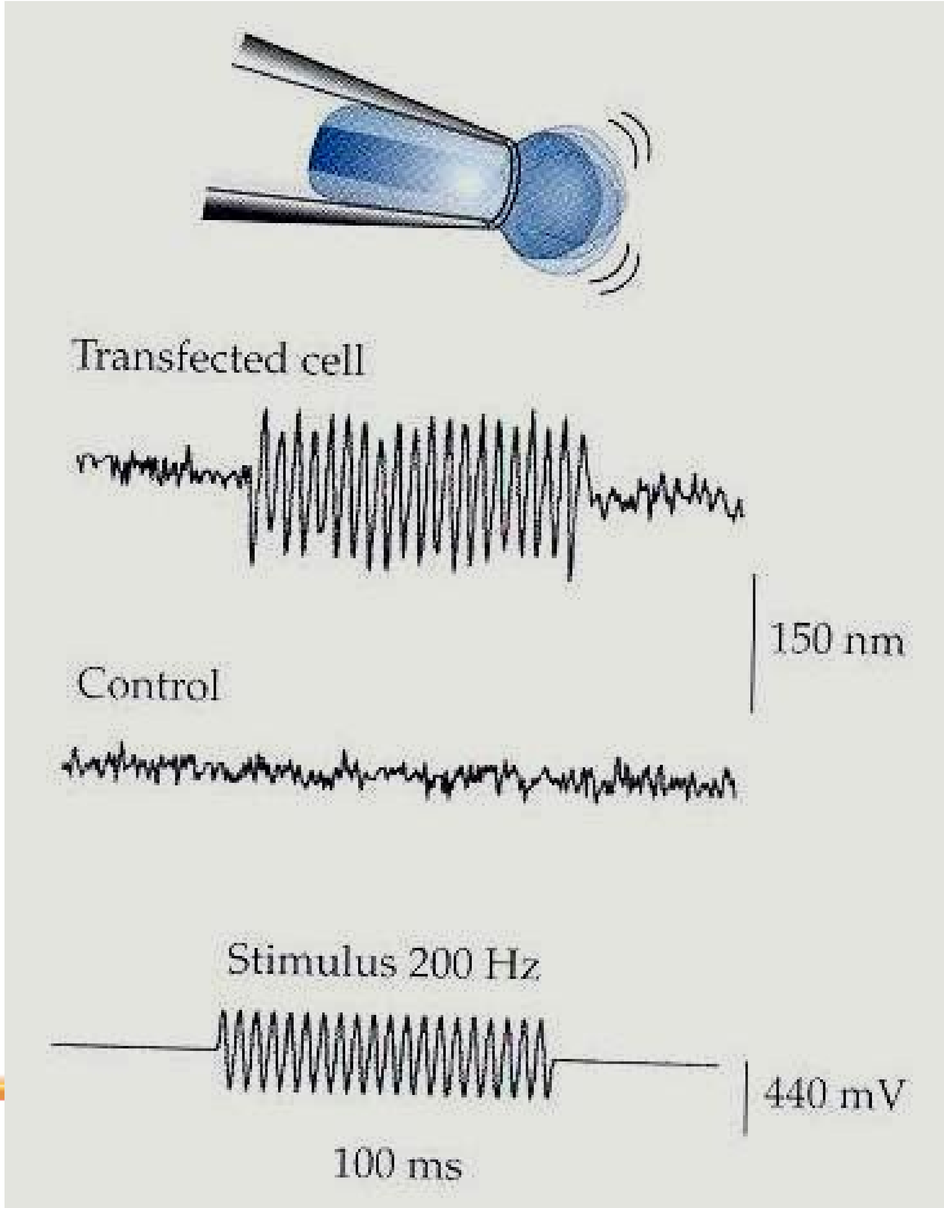


loudspeaker
f1
stimulus
f1 f2
sound level
frequency
f2
inner ear
f1 f2
distortion
energy
OHC
travelling waves
microphone
spontaneous OAE
30
20
10
0
-10
-20
sound level (dB SPL)
frog
reptiles
Iguana
barn owl
moustached bat
Anolis
human
human
2
4
6
8
10
12
62
63
frequency (kHz)
distorsion product OAE
f1 f2
60
40
20
0
2f1-f2
3f1-2f2
2f2-f1
3f2-2f1
sound level (dB SPL)
57
59
61
63
frequency (kHz)


a
Adaptation motor
Transduction channel
Gating spring
Positive deflection
Channels close
Bundle movement



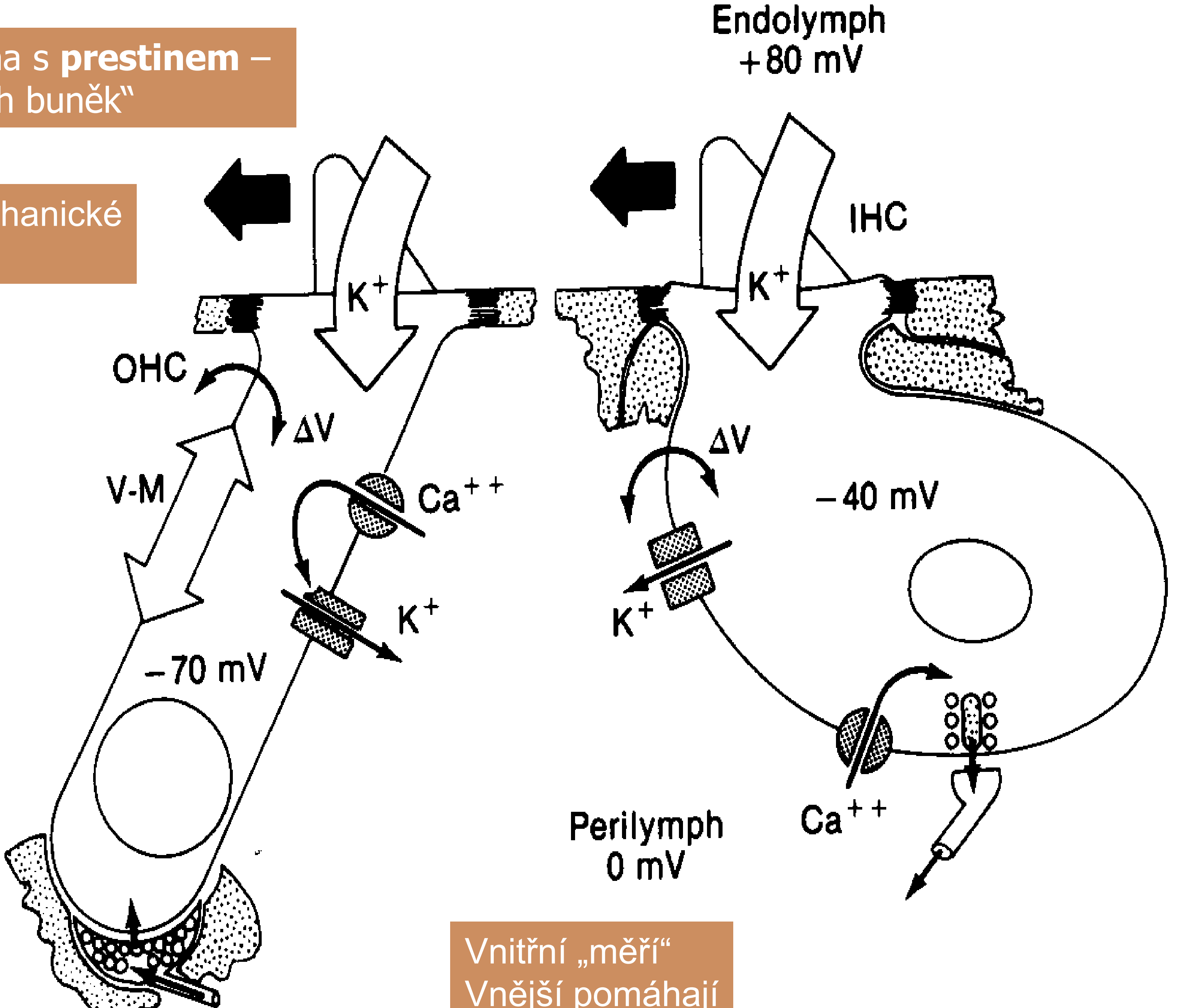
(A)
+80 mV
−80mV
Receptor current (nA)
1.0
0.5
0.0
−0.5
−1.0
Hair bundle displacement (nm)
30
20
10
0
−10
0
40
80
120
Time (ms)
(B)
Hair bundle displacement (nm)
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Receptor current (nA)



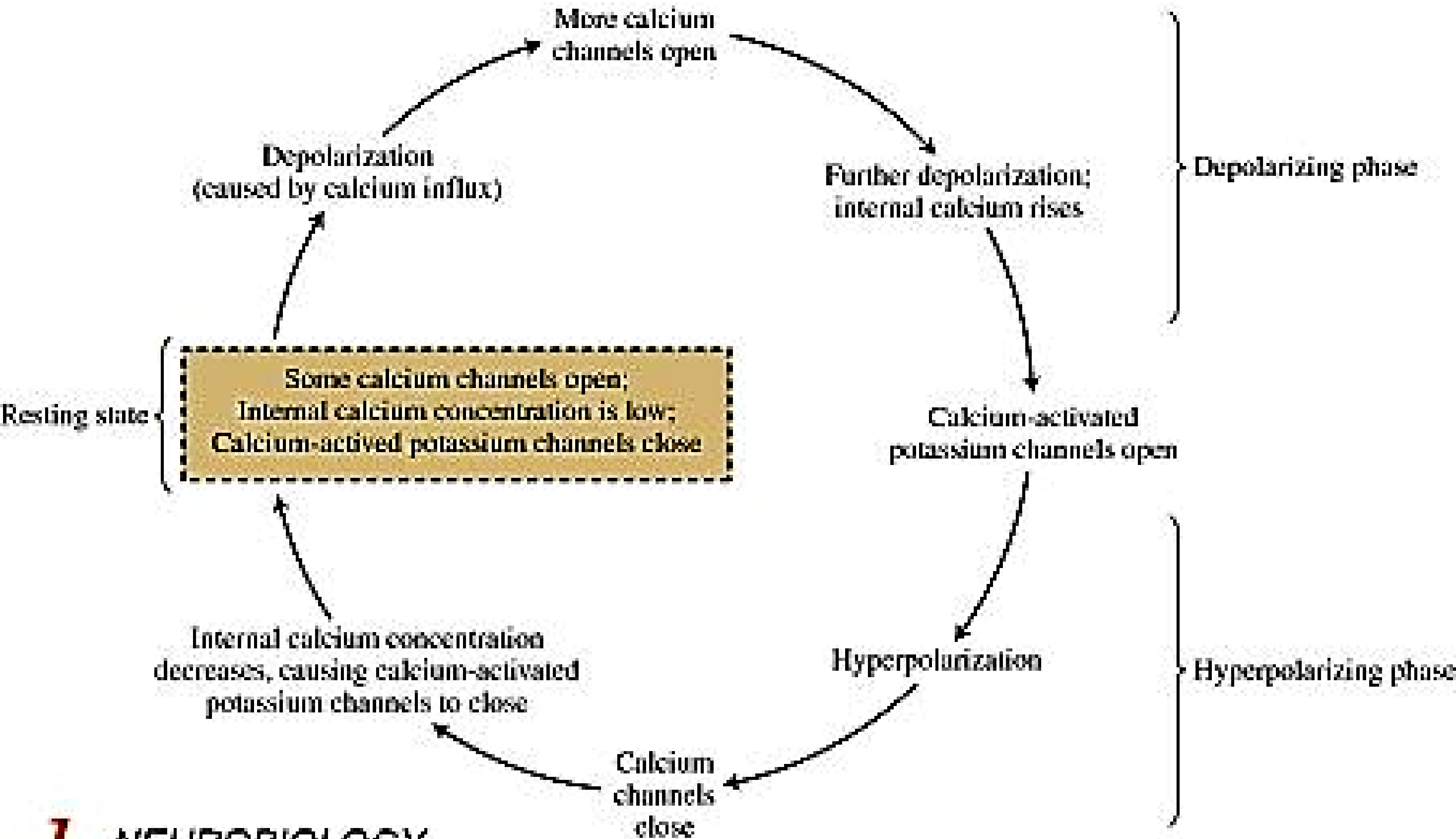
„Tancující" membrána

B) Membrána s **prestinem** – pohyb celých buněk"

Elektro-mechanické spřažení

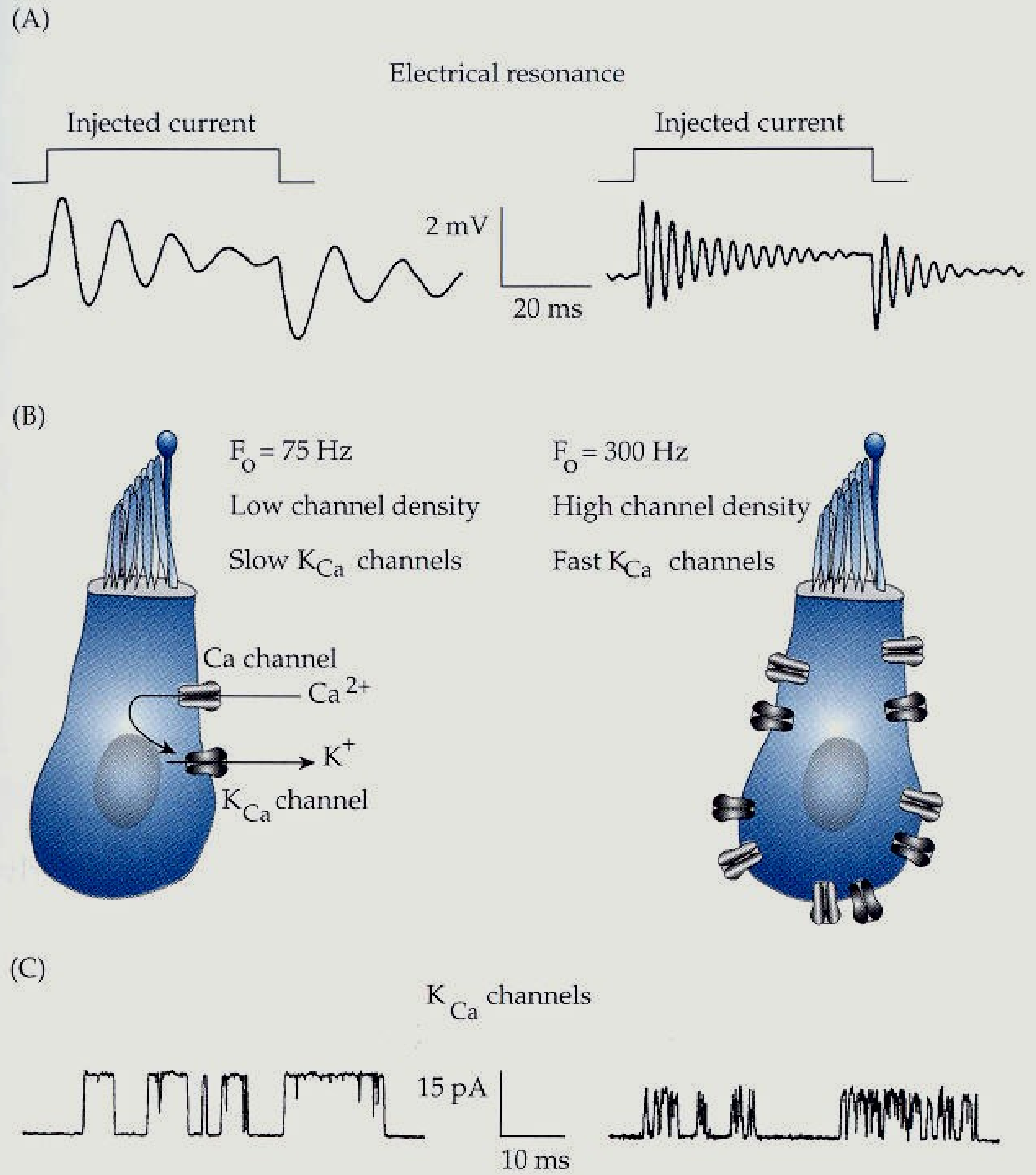


Vnitřní „měří"
Vnější pomáhají

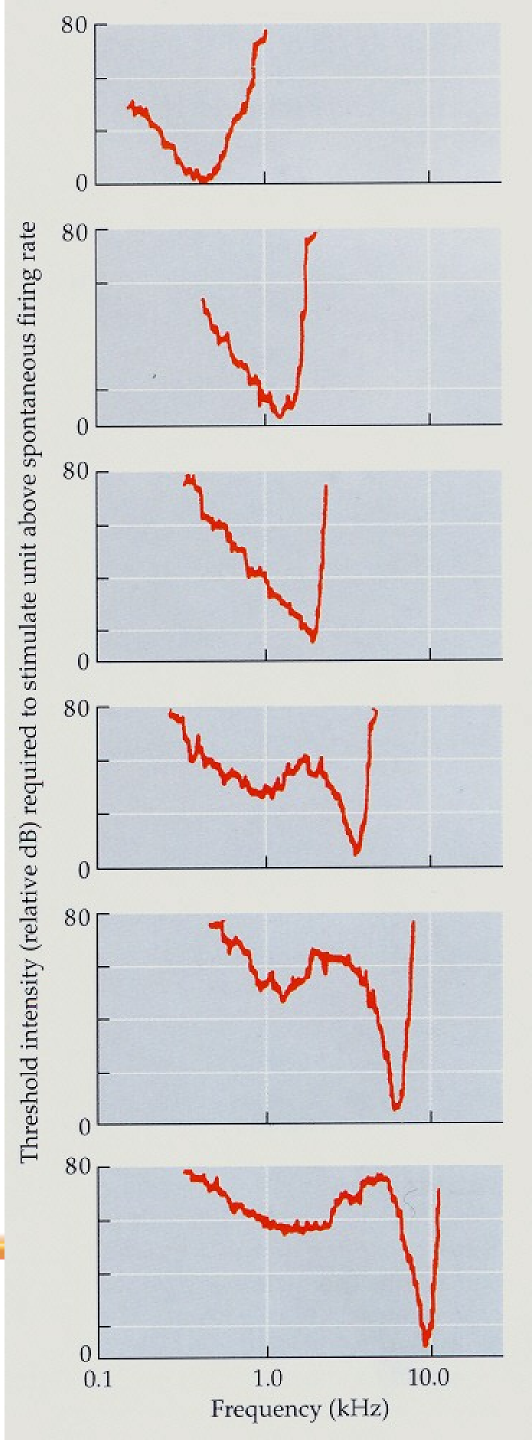


NEUROBIOLOGY
Gary G. Matthews

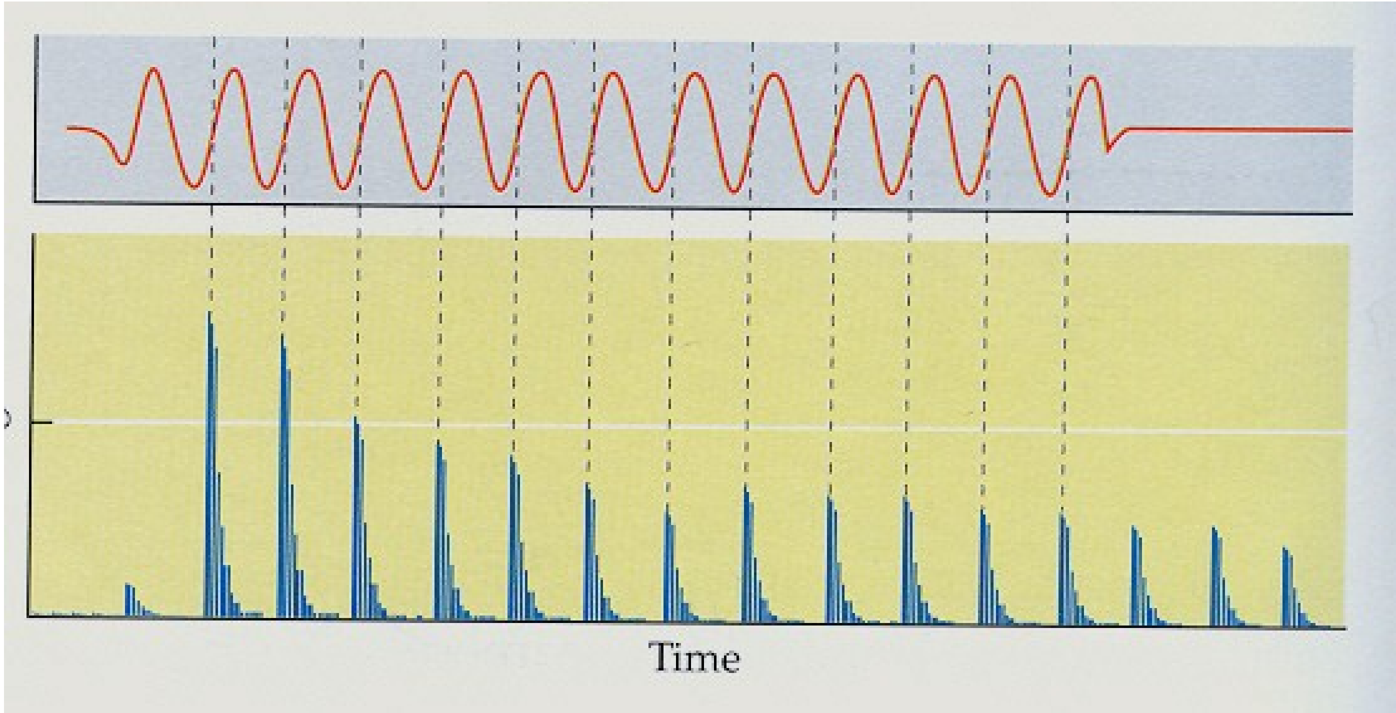
Blackwell Science



(A)
Electrical resonance
Injected current
Injected current
2 mV
20 ms
(B)
F_o = 75 Hz
Low channel density
Slow K_{Ca} channels
F_o = 300 Hz
High channel density
Fast K_{Ca} channels
Ca channel
Ca^{2+}
K^+
K_{Ca} channel
(C)
K_{Ca} channels
15 pA
10 ms

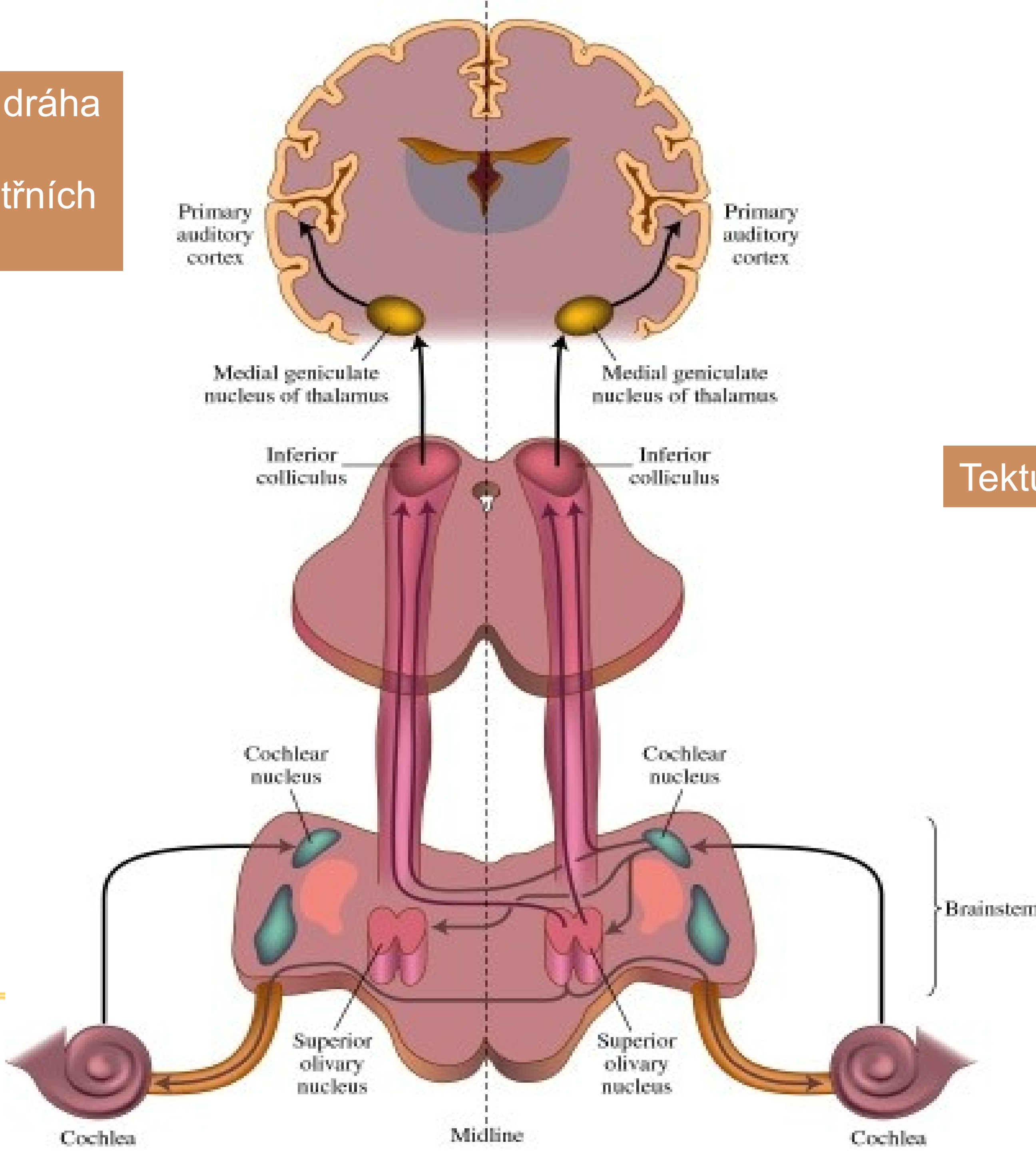


Threshold intensity (relative dB) required to stimulate unit above spontaneous firing rate
80
0
0.1
1.0
10.0
Frequency (kHz)

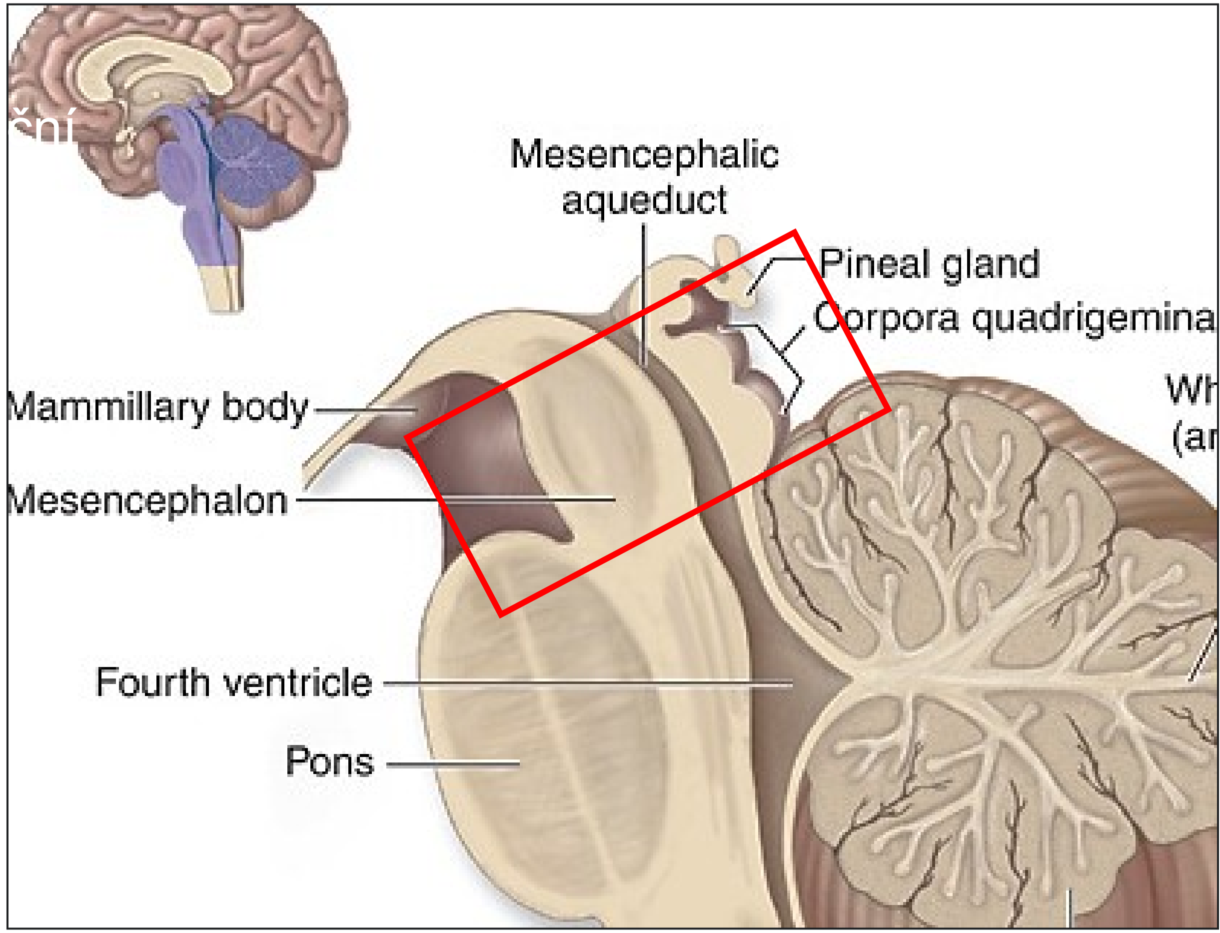

Time

Sluchová dráha

90% z vnitřních v.b.

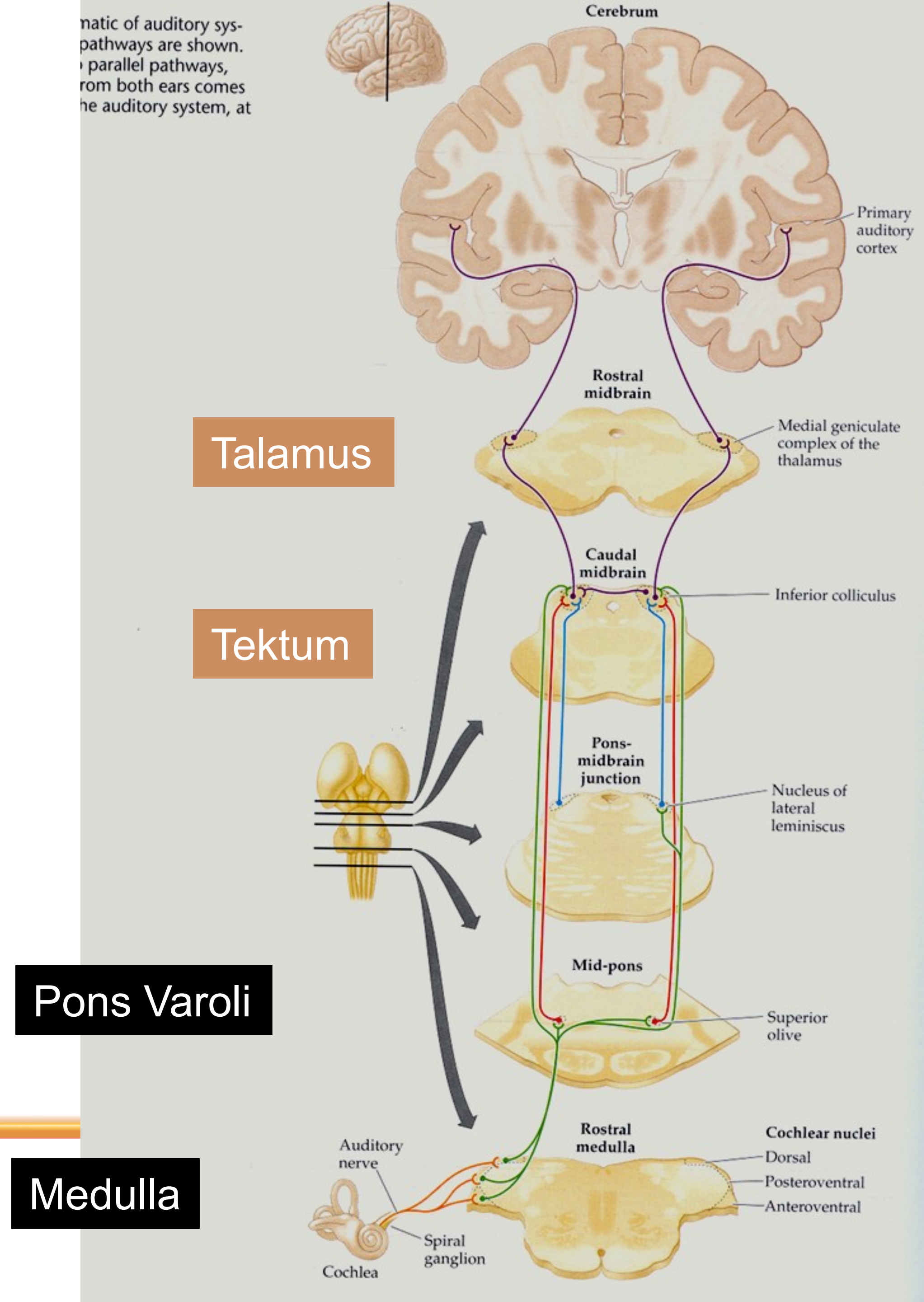


Tektum



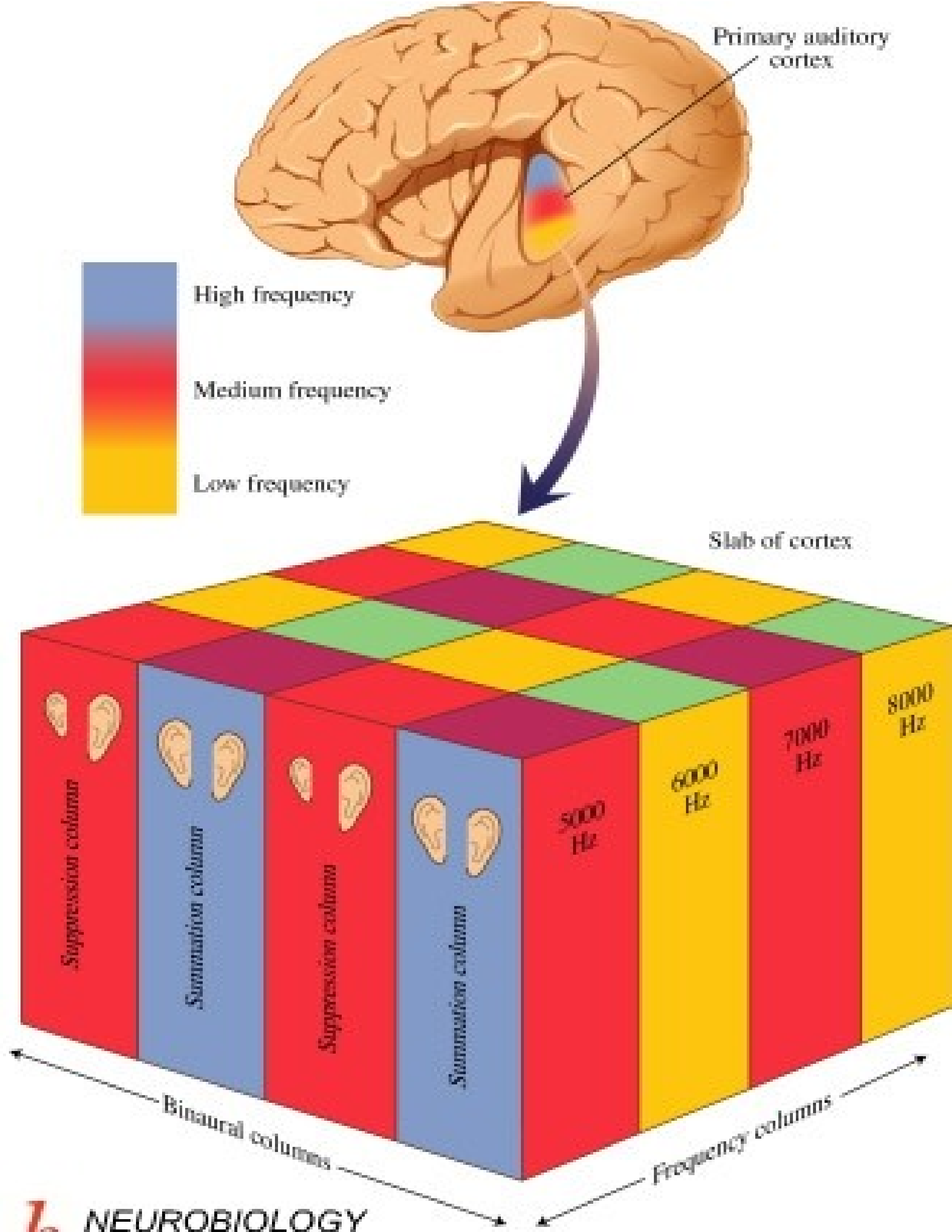
Mesencephalic aqueduct
Pineal gland
Corpora quadrigemina
Mammillary body
Mesencephalon
Fourth ventricle
Pons

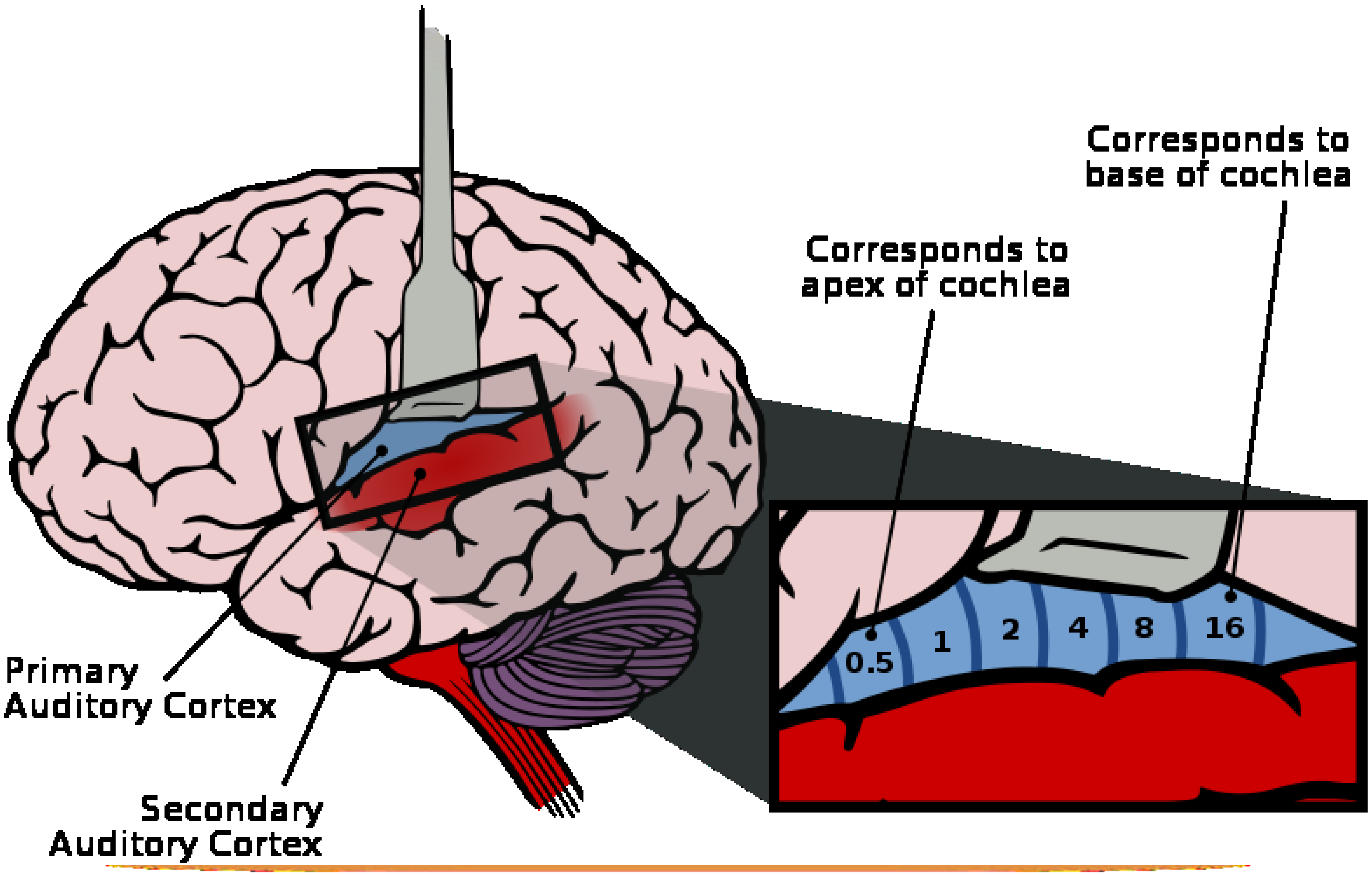
matic of auditory sys-
pathways are shown.
parallel pathways,
rom both ears comes
he auditory system, at



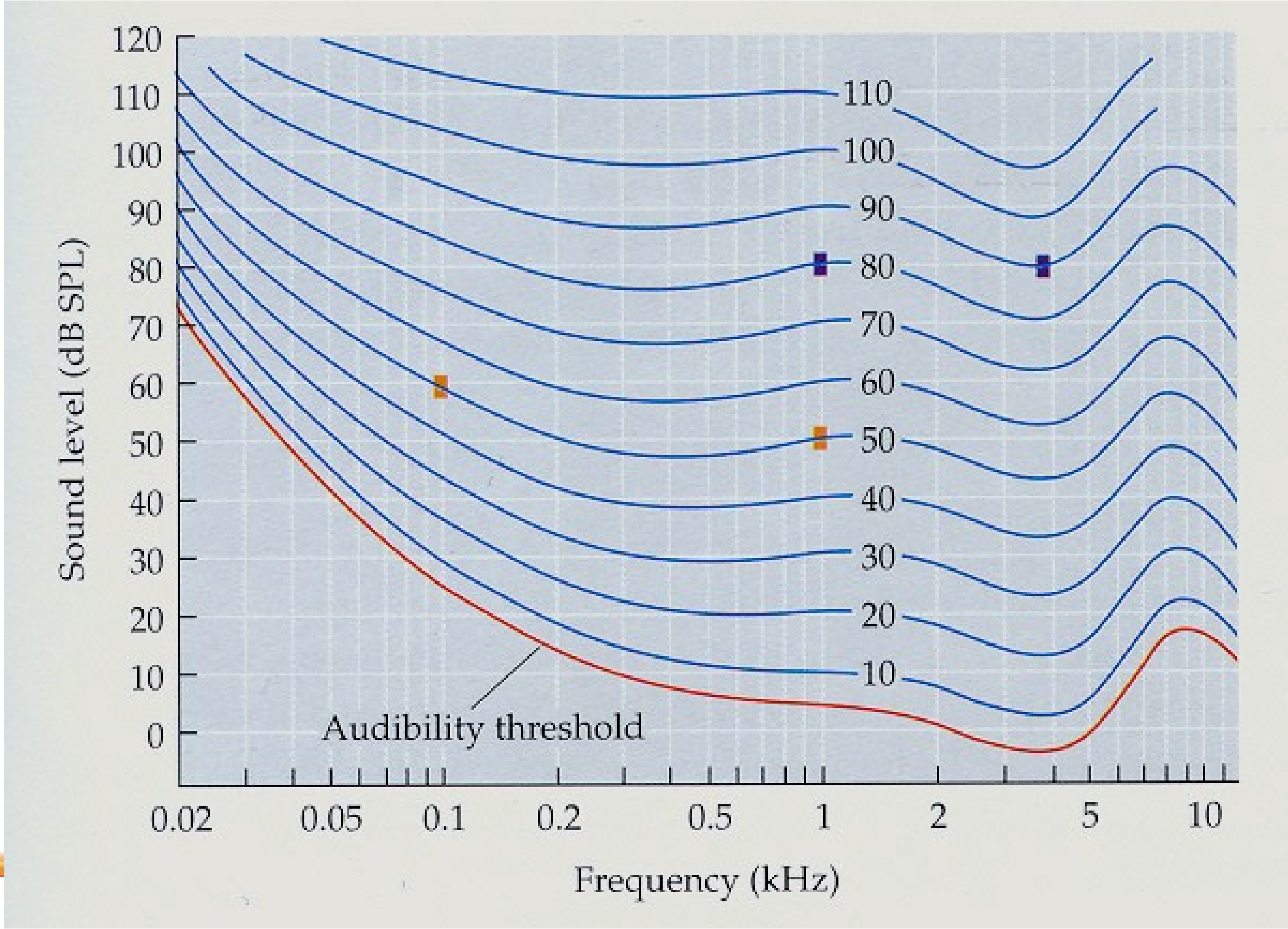
Tonotopická a bilaterální organizace primární sluchové kůry
Neurony citlivé na modulované frekvence nebo volání

Některé sloupce sumují aktivitu z obou uší, jiné reagují na vstup jen z jednoho ucha a umlkají, přicházejí-li vstupy z obou. Jsou zde bb, které nereagují jen na určité čisté tóny ale jsou naladěny na specificky modulované frekvence stoupavé nebo klesavé. Podobně jako to uvidíme u zrakové kůry, jsou tu buňky aktivované zcela specifickými druhy volání – v primární kůře makaků. Dokonce voláními individuálních jedinců.




Corresponds to
base of cochlea
Corresponds to
apex of cochlea
0.5
1
2
4
8
16
Primary
Auditory Cortex
Secondary
Auditory Cortex

http://newt.phys.unsw.edu.au/jw/hearing.html



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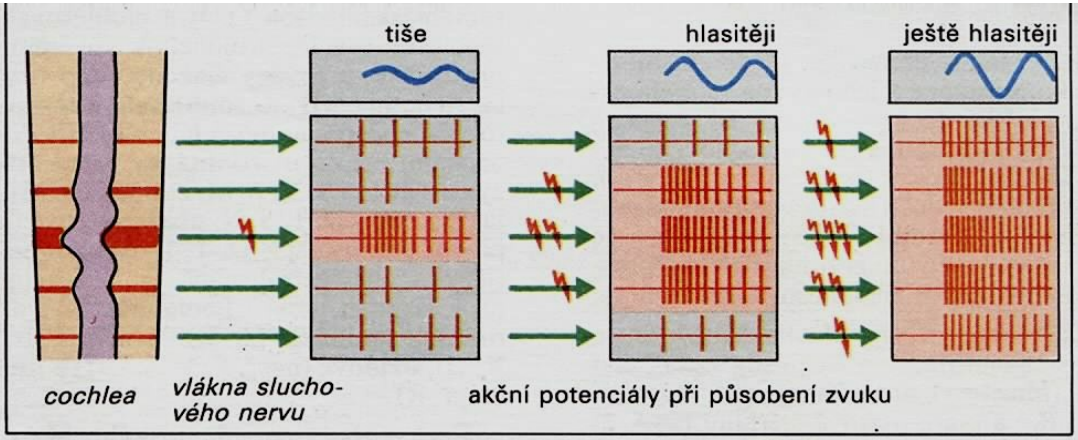
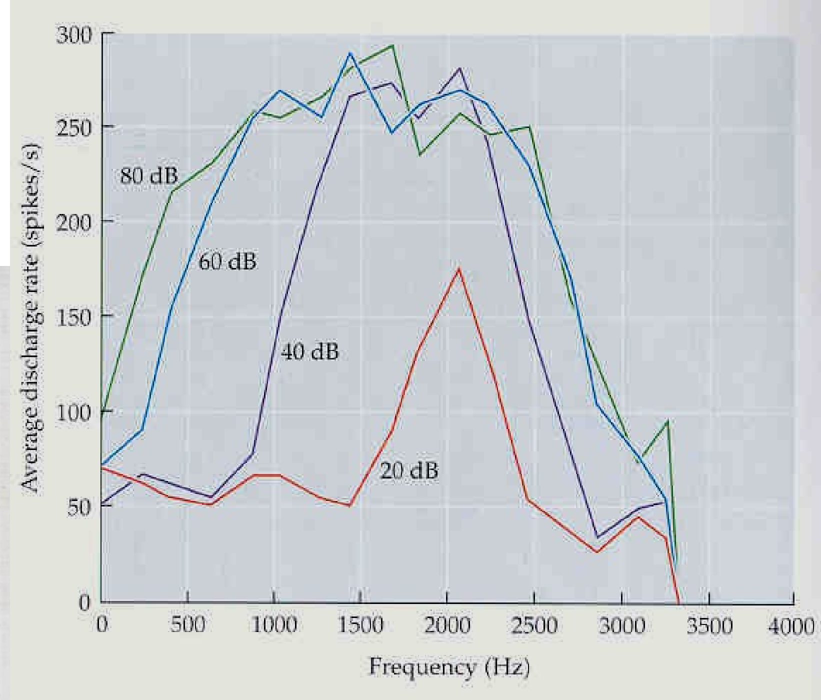
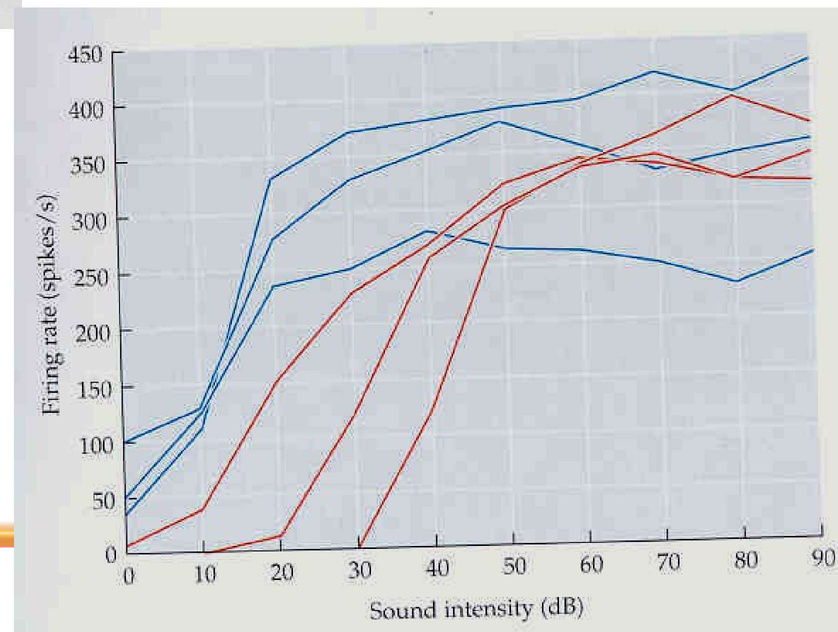
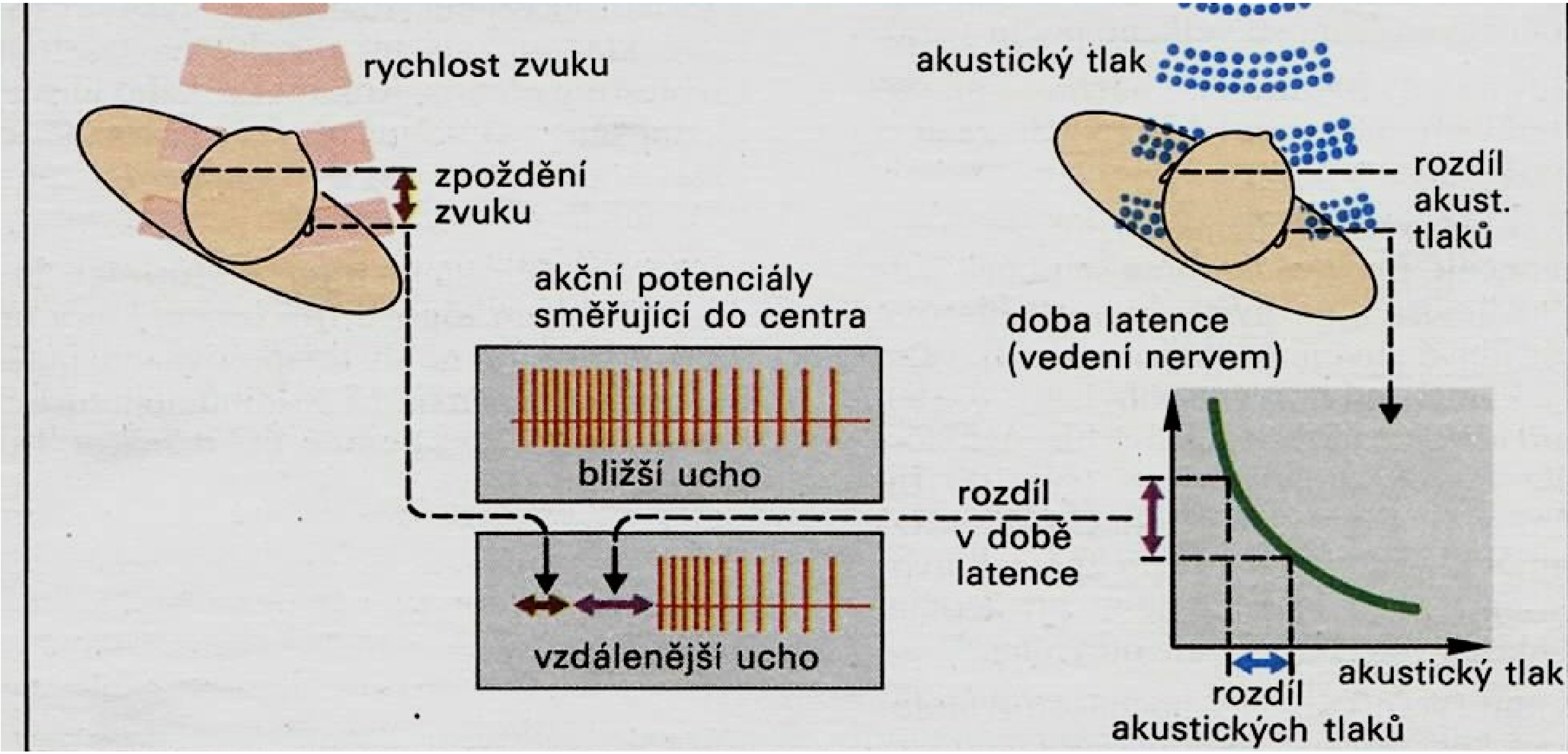
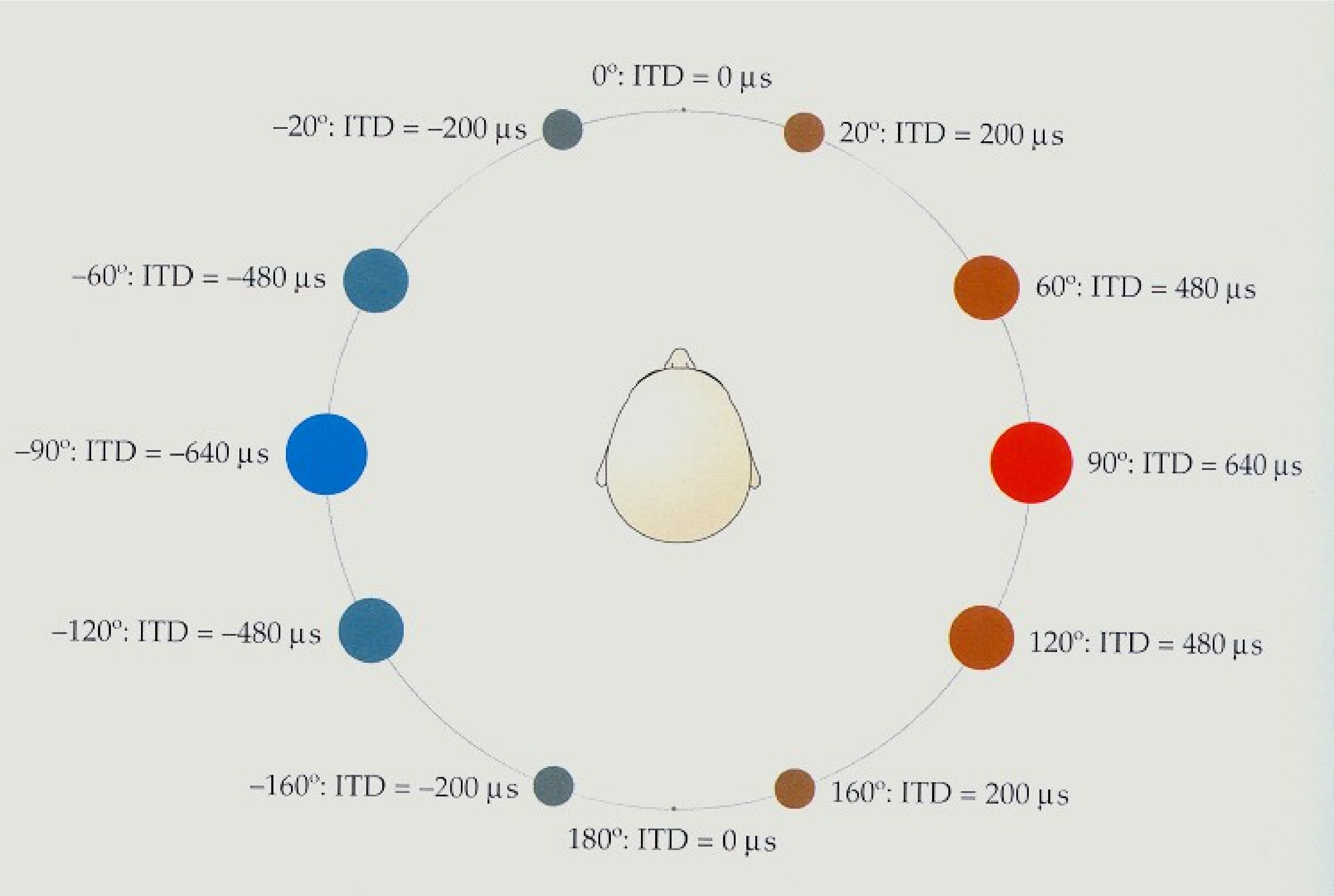


A. „Hlasitá a tichá" informace ve sluchovém nervu (zvuková frekvence nezměněna)






rychlost zvuku
zpoždění
zvuku
akustický tlak
rozdíl
akust.
tlaků
akční potenciály
směřující do centra
doba latence
(vedení nervem)
bližší ucho
rozdíl
v době
latence
vzdálenější ucho
akustický tlak
rozdíl
akustických tlaků


0º: ITD = 0 µs
–20º: ITD = –200 µs
20º: ITD = 200 µs
–60º: ITD = –480 µs
60º: ITD = 480 µs
–90º: ITD = –640 µs
90º: ITD = 640 µs
–120º: ITD = –480 µs
120º: ITD = 480 µs
–160º: ITD = –200 µs
160º: ITD = 200 µs
180º: ITD = 0 µs

Simultánně
Offset

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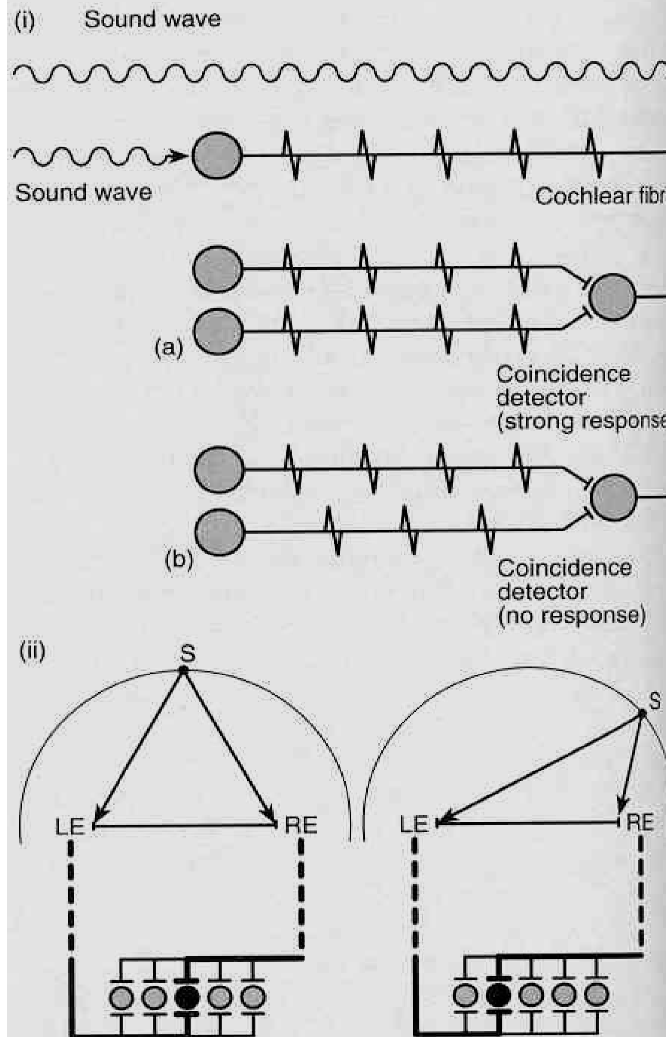
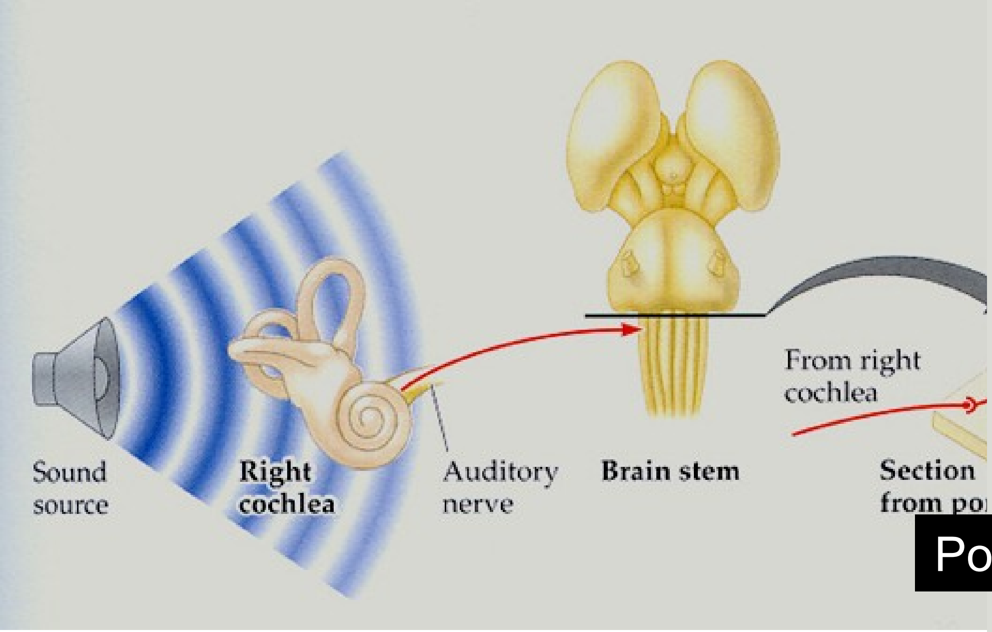
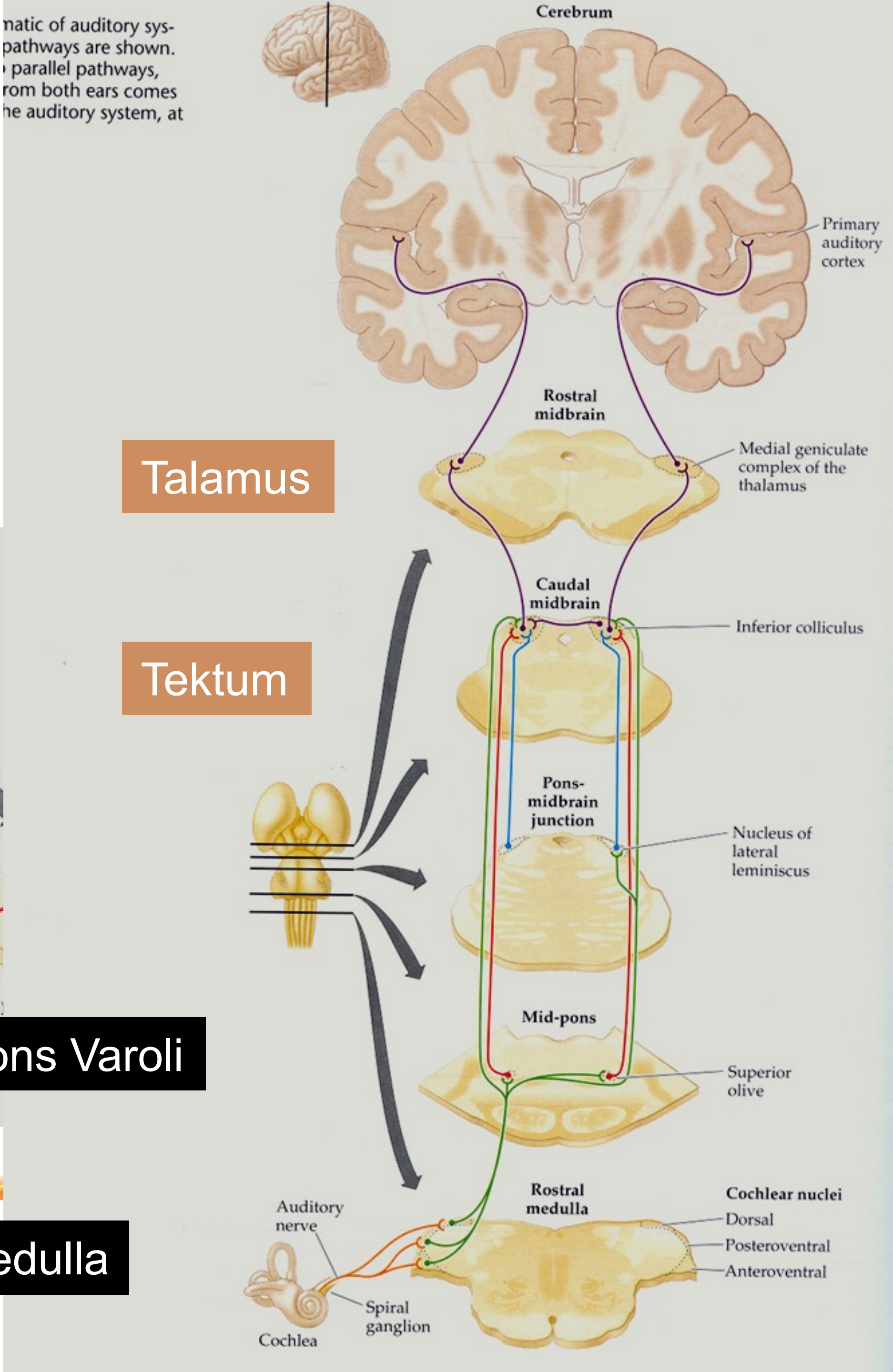


Figure 9.8 (i) Phase locking and coincidence detection. The cochlear fibre fires in response to every second peak in the sound wave. (a) If cochlear fibres from opposite ears converge on a coincidence detector the latter will fire if the two signals are delivered within a few tens of microseconds of each other; (b) if the time differential is greater the detector will respond only weakly or not at all. (ii) The principle of source location by way of interaural time differences (ITDs). A sound source (S) equidistant from the two ears will stimulate a certain coincidence detector (dark circle); a sound source further from one ear than the other will stimulate a different coincidence detector. LE = left ear; RE = right ear. Further explanation in text. After Konishi, 1993





Talamus

Tektum

Pons Varoli

Medulla

Akustika sálů,

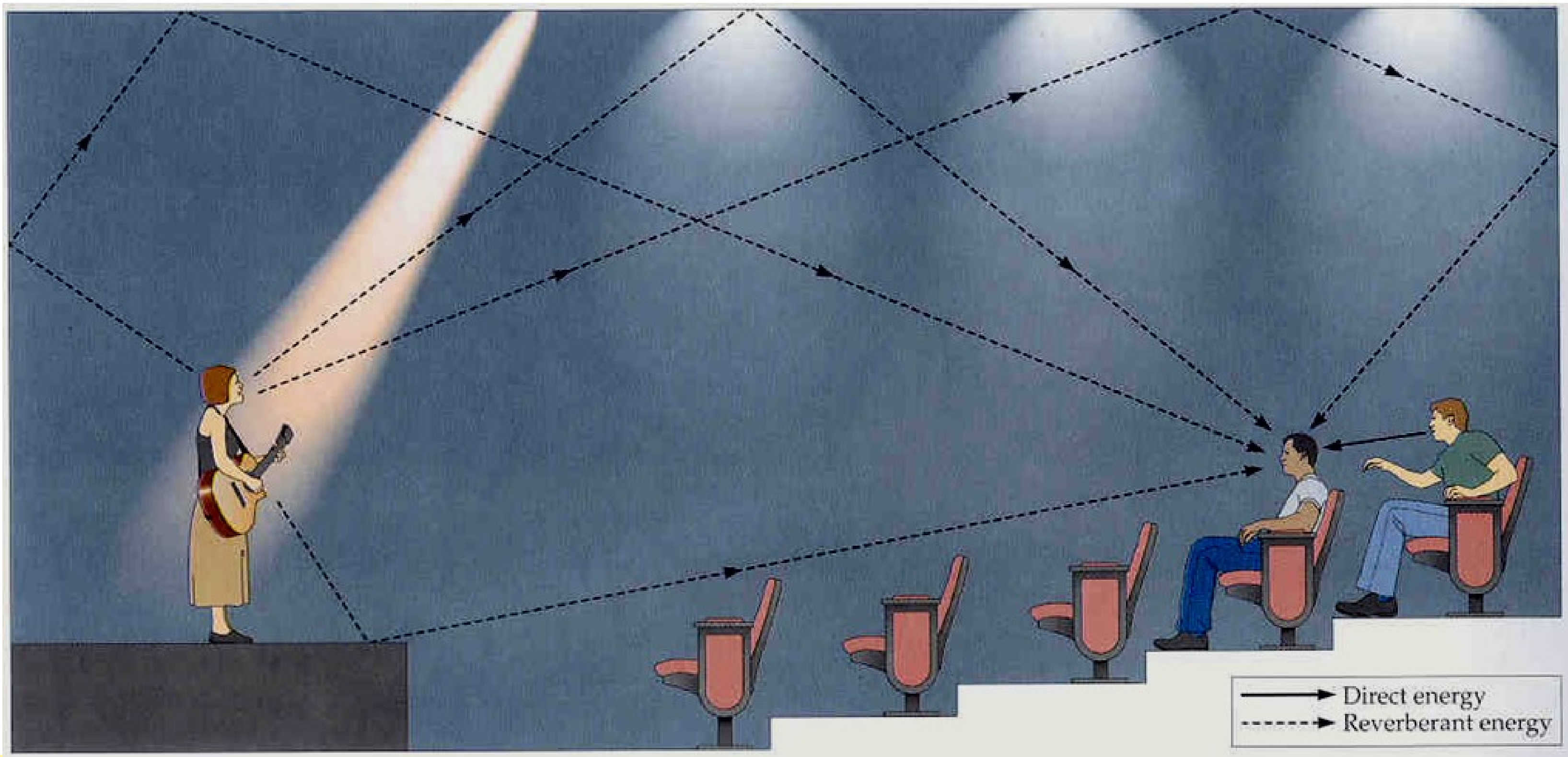
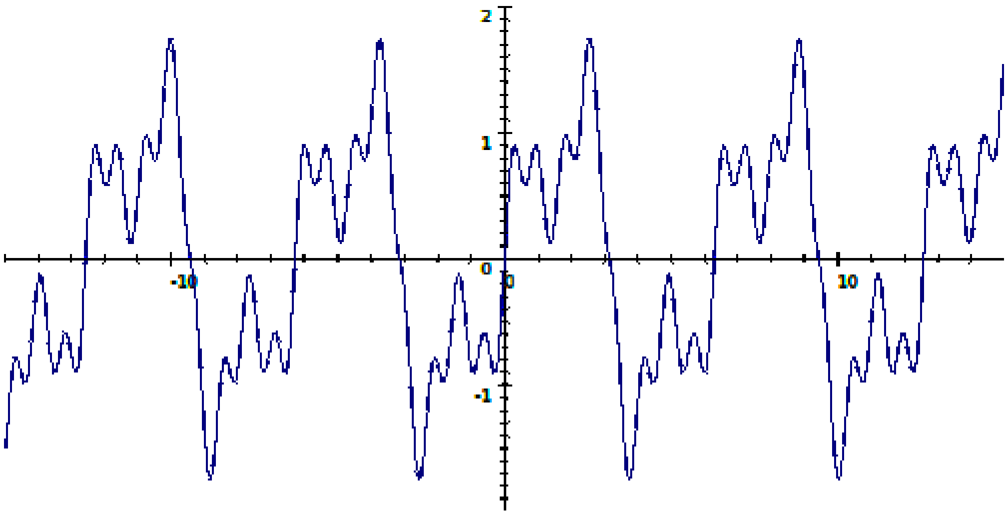
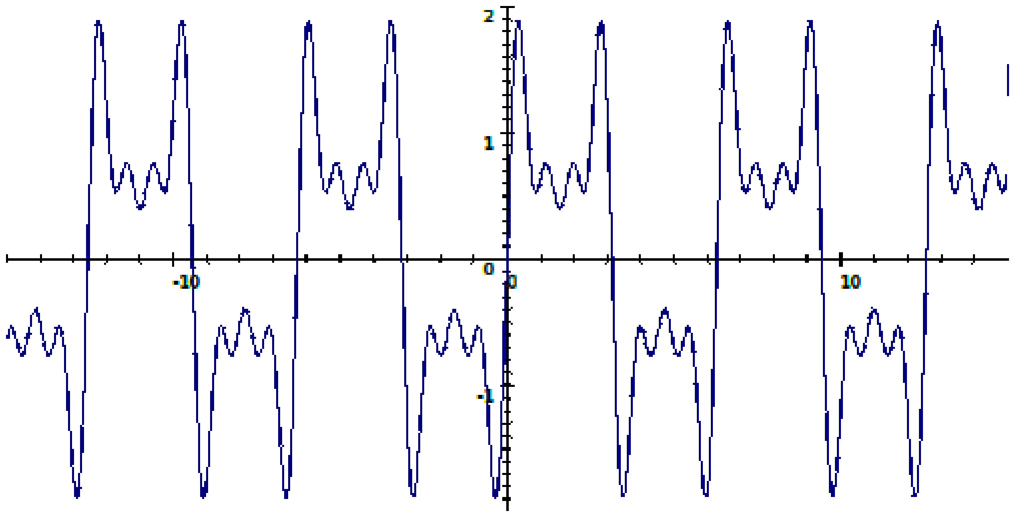


FIGURE 10.11 The relative amounts of direct and reverberant energy coming from the listener's neighbor and the singer will inform him of the relative distances of the two sound sources.

more like a "boom." Note that this auditory cue is analogous to the visual depth cue of atmospheric perspective (more distant objects look more blurry).

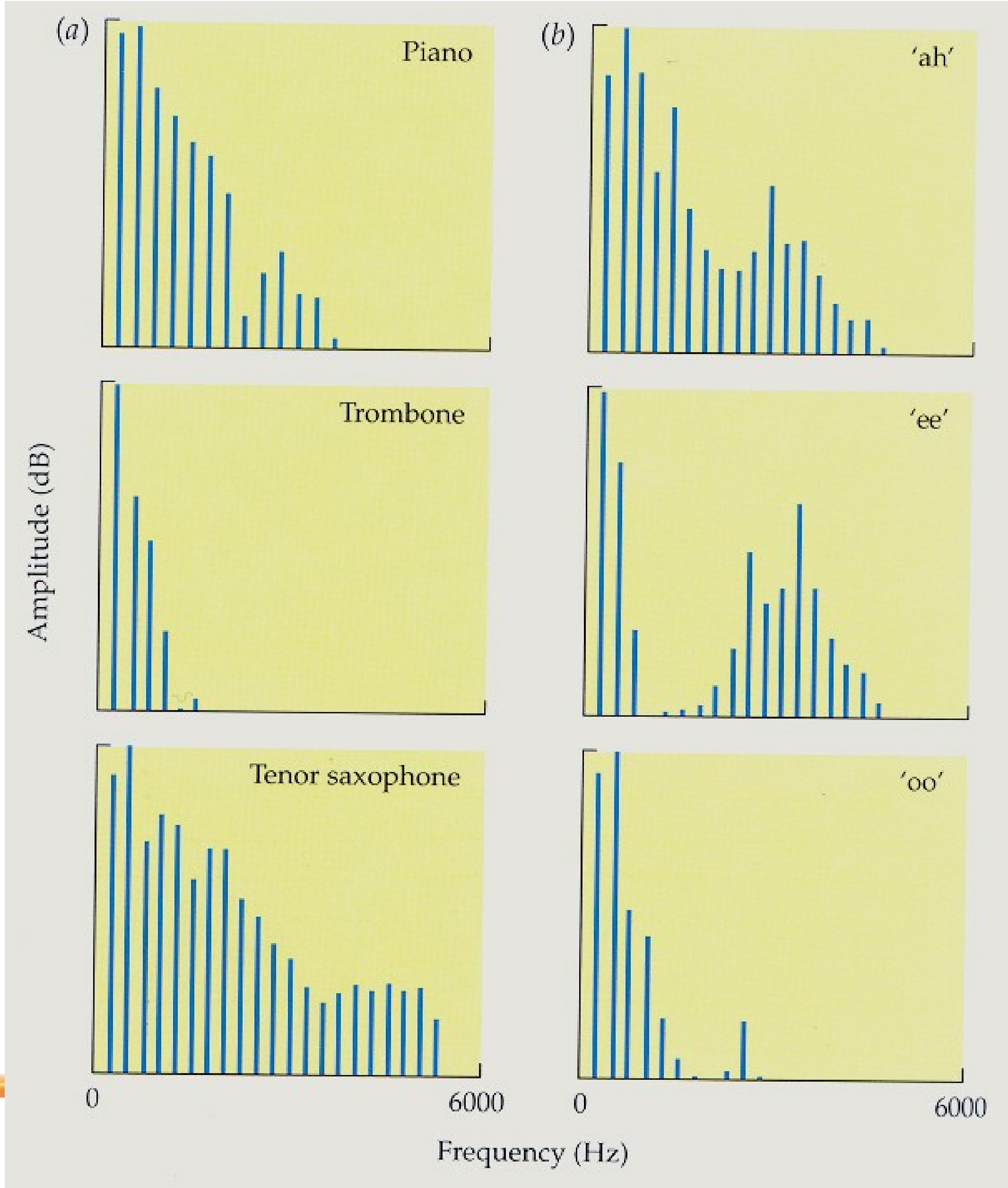
A final distance cue stems from the fact that, in most environments, the


2
1
0
-1
-10
10

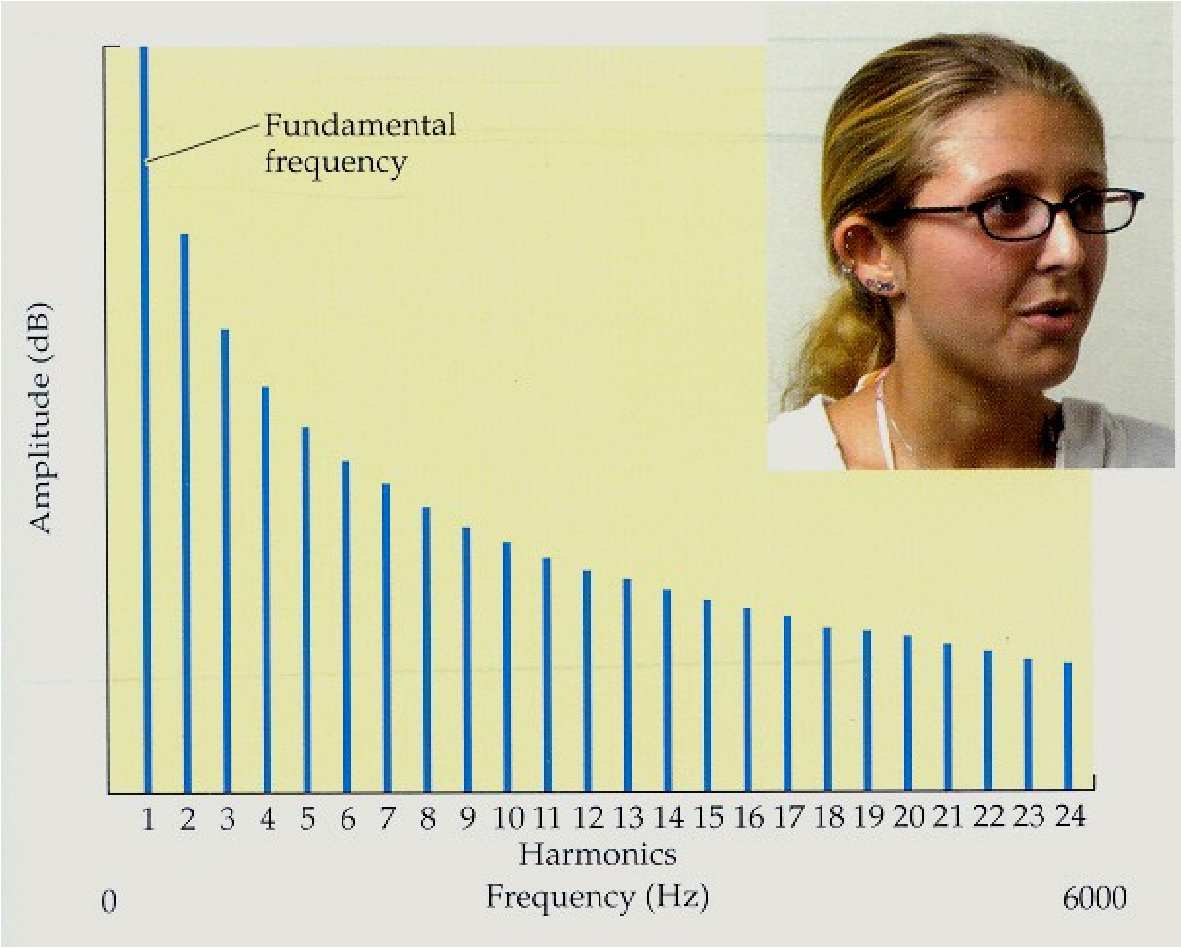


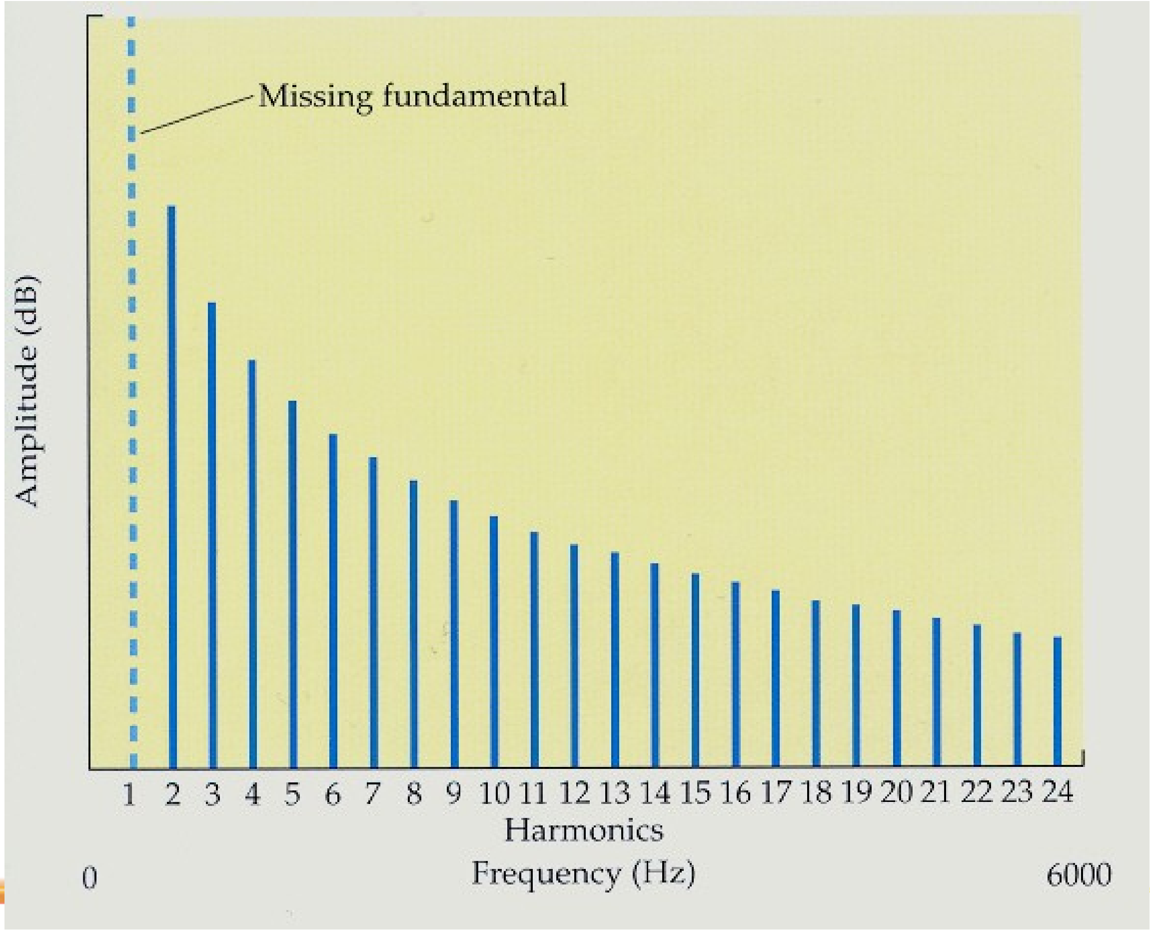
2
1
0
-1
-10
10

Barvu tónů určuje spektrum



Harmonické frekvence





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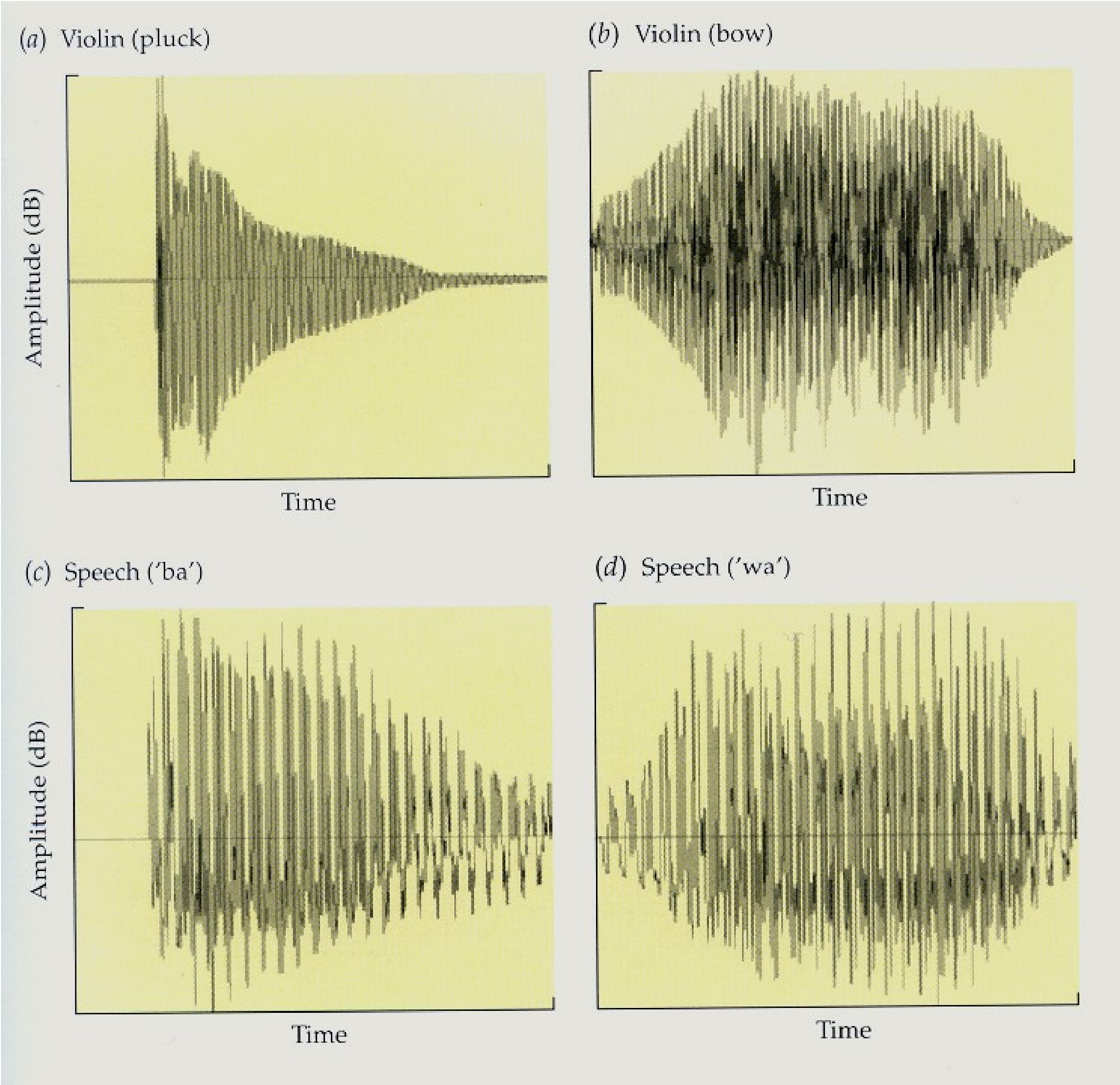

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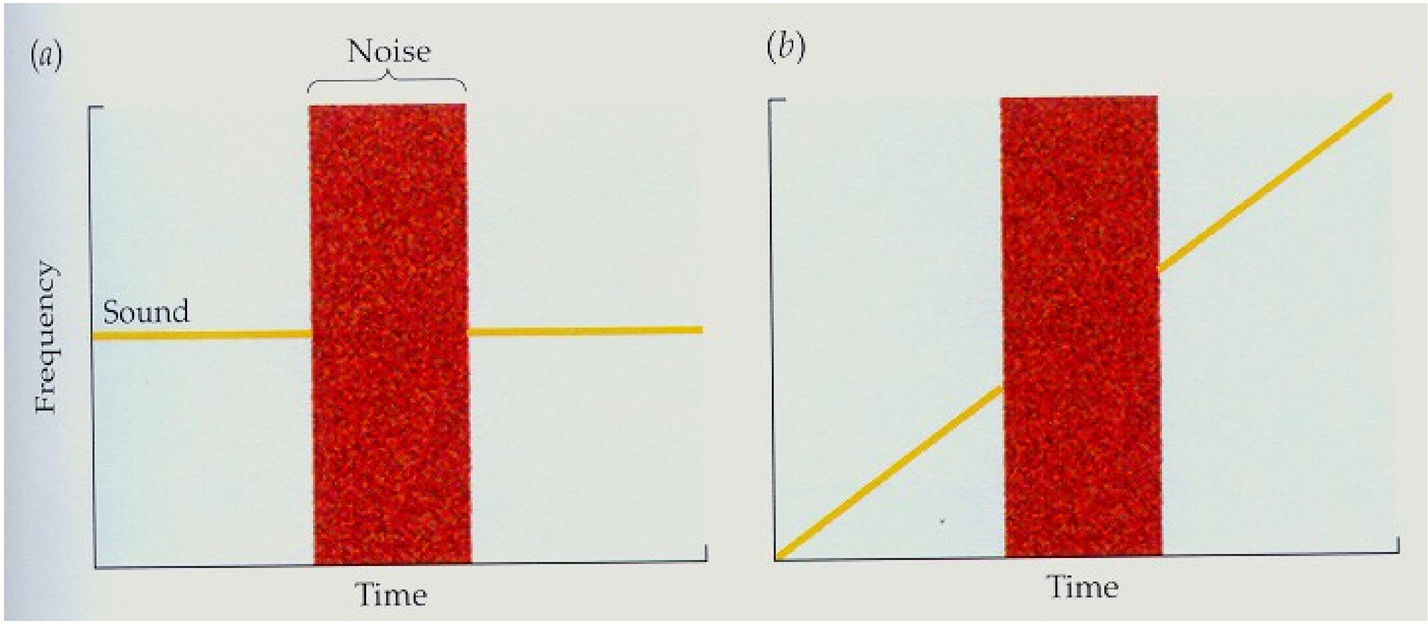
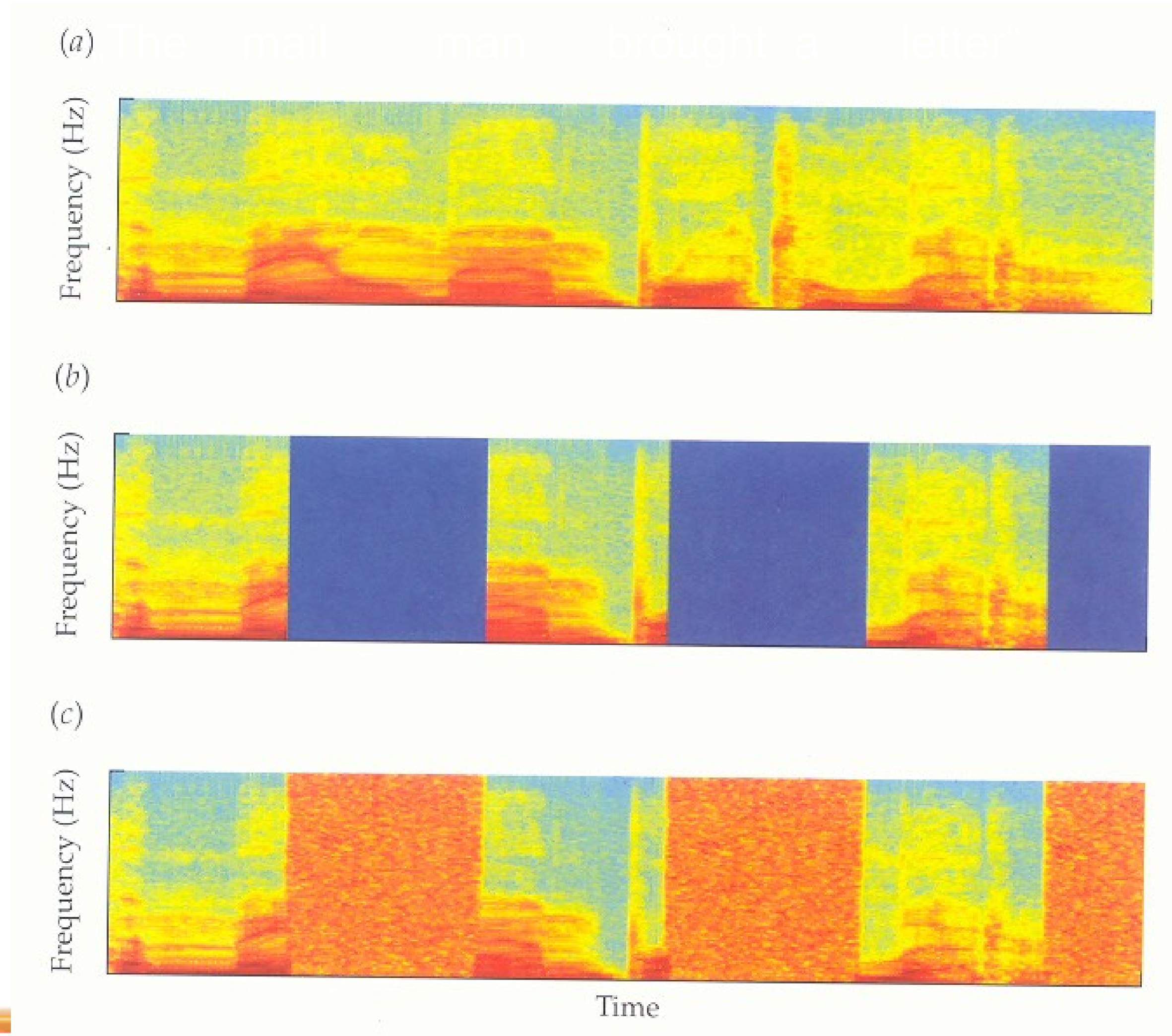

(a)
Noise
Frequency
Sound
Time
(b)
Time



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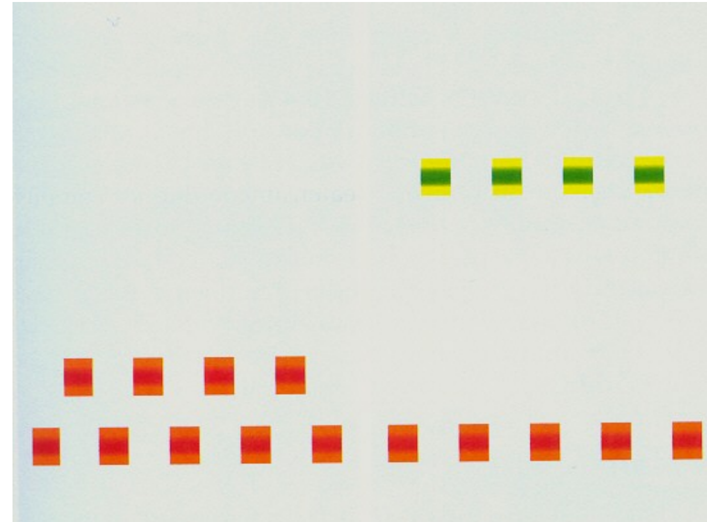

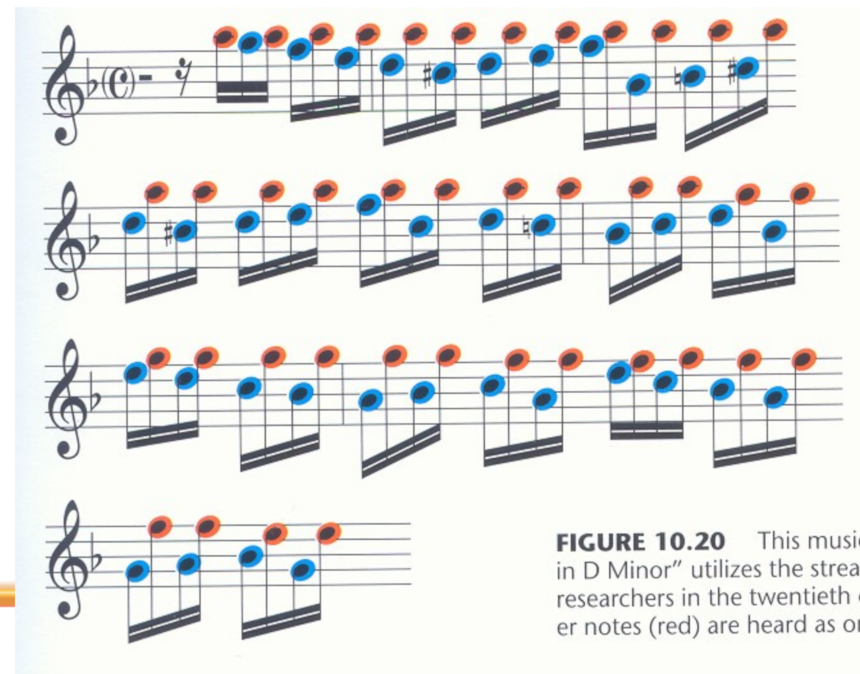

FIGURE 10.20 This musica
in D Minor" utilizes the strean
researchers in the twentieth ce
er notes (red) are heard as one

https://oup-arc.com/access/content/sensation-and-perception-5e-student-resources/sensation-and-perception-5e-activity-10-4?previousFilter=tag_chapter-10