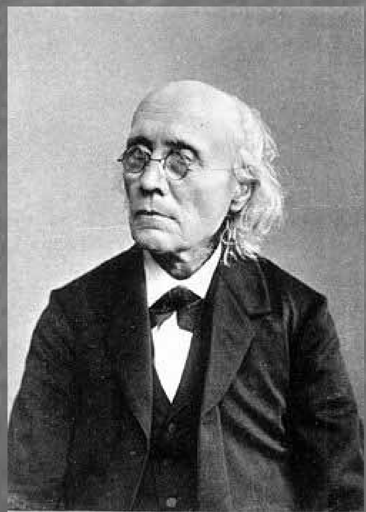
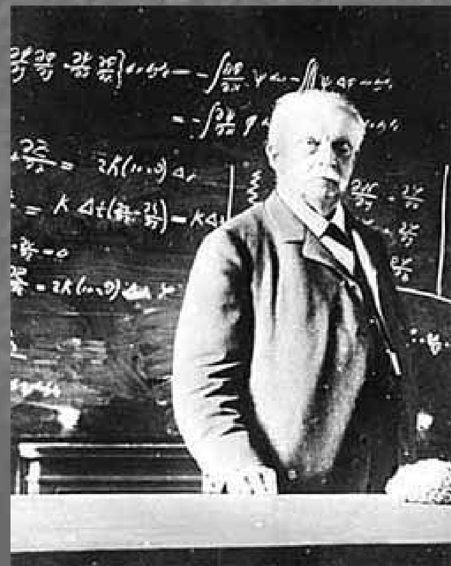
Obecná fyziologie smyslů

- Přes receptory vstupují informace do NS
- Smysly jsou branami do vědomí.
  - Jak vedou k subjektivní zkušenosti?
  - Jakými fyziologickými pochody?
  - Otcové experimentální psychologie

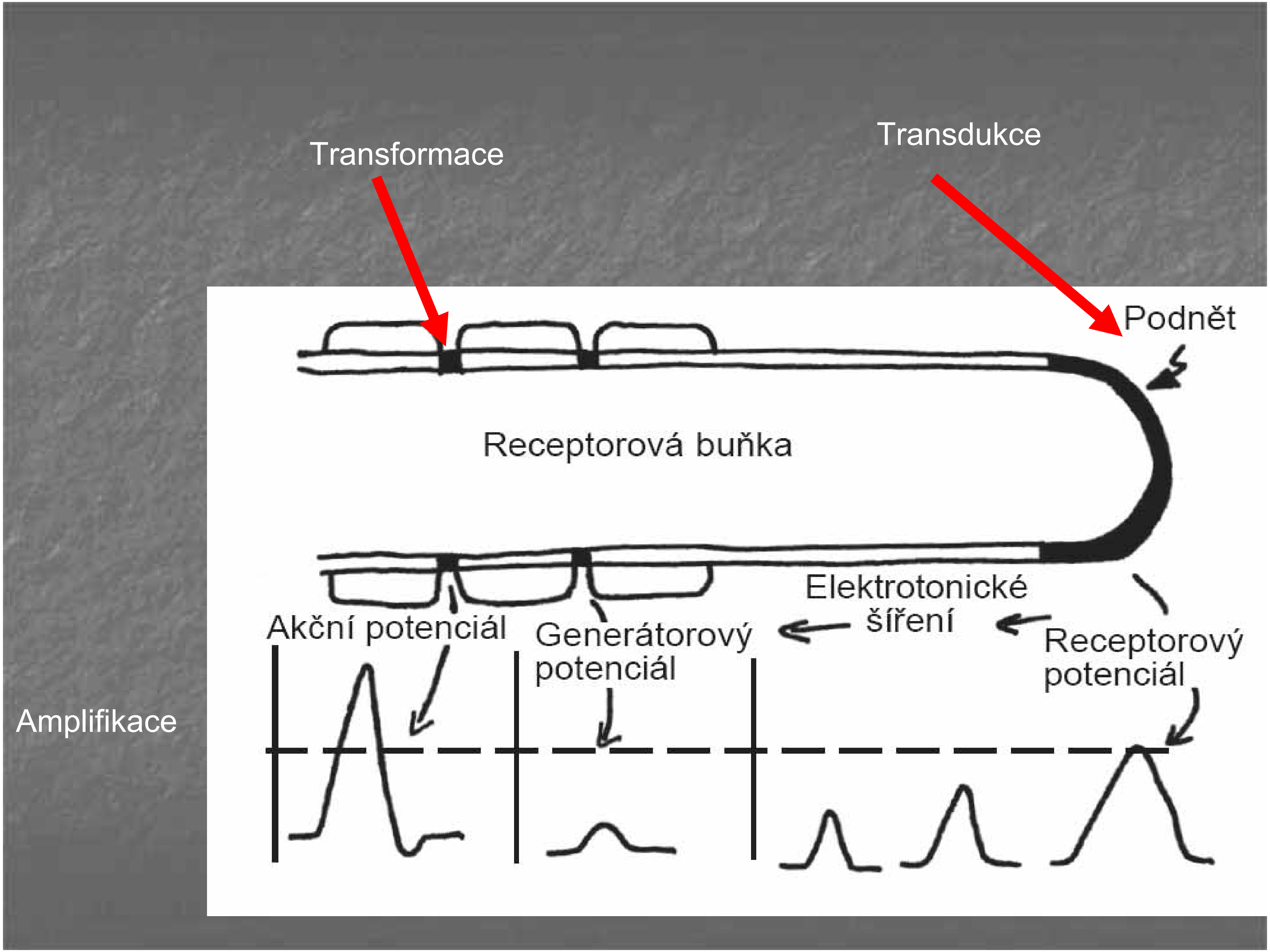
Ernst Weber
1795-1878



Gustav Fechner
1801-1887



Hermann Helmholtz
(1858 – 1871)


Transformace
Transdukce
Podnět
Receptorová buňka
Elektrotonické
šíření
Akční potenciál
Generátorový
potenciál
Receptorový
potenciál
Amplifikace

Obecné principy

- 4 základní vlastnosti podnětu:
  - Modalita
  - Lokace („adresa")
  - Intenzita
  - Trvání

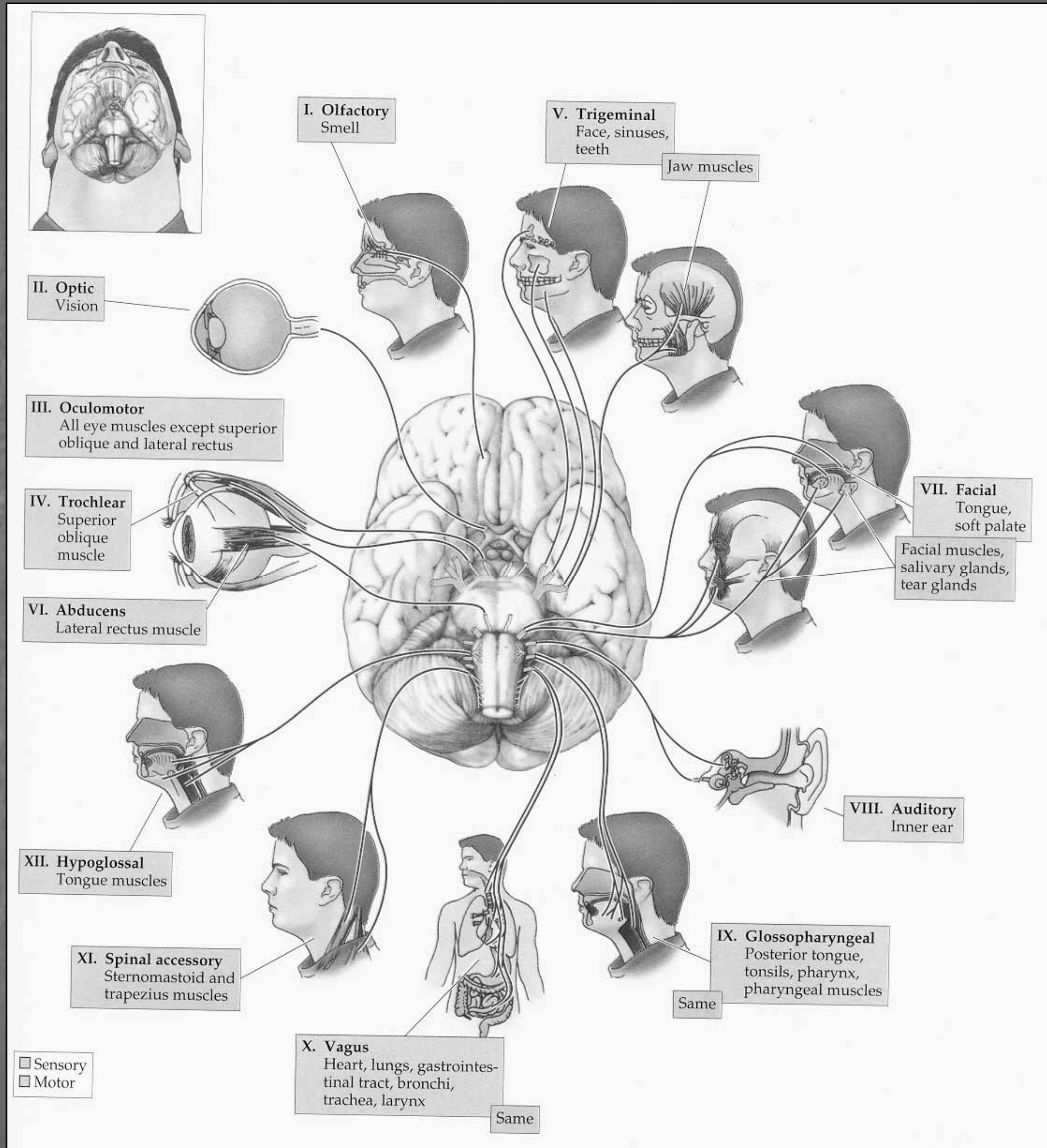
Modality – formy energie: chemická, teplotní, mechanická, světelná, elektrického a magnetického pole

Table 10.1 Main types of sensory modalities

Sensory modality	Form of energy	Receptor organ	Receptor cell
Chemical			
common chemical	molecules	various	free nerve endings
arterial oxygen	O_2 tension	carotid body	cells and nerve endings
toxins (vomiting)	molecules	medulla	chemoreceptor cells
osmotic pressure	osmotic pressure	hypothalamus	osmoreceptors
glucose	glucose	hypothalamus	glucoreceptors
pH (cerebrospinal fluid)	ions	medulla	ventricle cells
Taste	ions and molecules	tongue and pharynx	taste bud cells
Smell	molecules	nose	olfactory receptors
Somatosensory			
touch	mechanical	skin	nerve terminals
pressure	mechanical	skin and deep tissue	encapsulated nerve endings
heat and cold	temperature	skin, hypothalamus	nerve terminals and central neurons
pain	various	skin and various organs	nerve terminals
Muscle			
vascular pressure	mechanical	blood vessels	nerve terminals
muscle stretch	mechanical	muscle spindle	nerve terminals
muscle tension	mechanical	tendon organs	nerve terminals
joint position	mechanical	joint capsule and ligaments	nerve terminals
Balance			
linear acceleration (gravity)	mechanical	vestibular organ	hair cells
angular acceleration	mechanical	vestibular organ	hair cells
Hearing	mechanical	inner ear (cochlea)	hair cells
Vision	electromagnetic (photons)	eye (retina)	photoreceptors

Modified from Ganong (1985)

Vstup určuje Povahu (kvalitu) vjemu- Labeled lines



3 úrovně organizace sensorických systémů

A) Receptory
B) Sensorické obvody a dráhy
C) Sensorická percepce

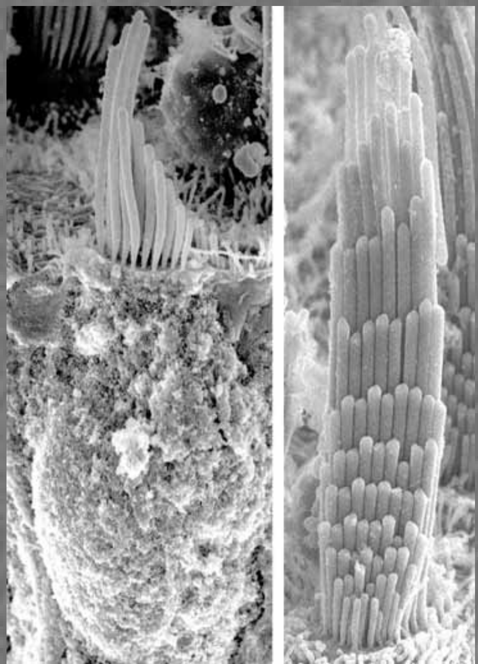
3 úrovně organizace sensorických systémů

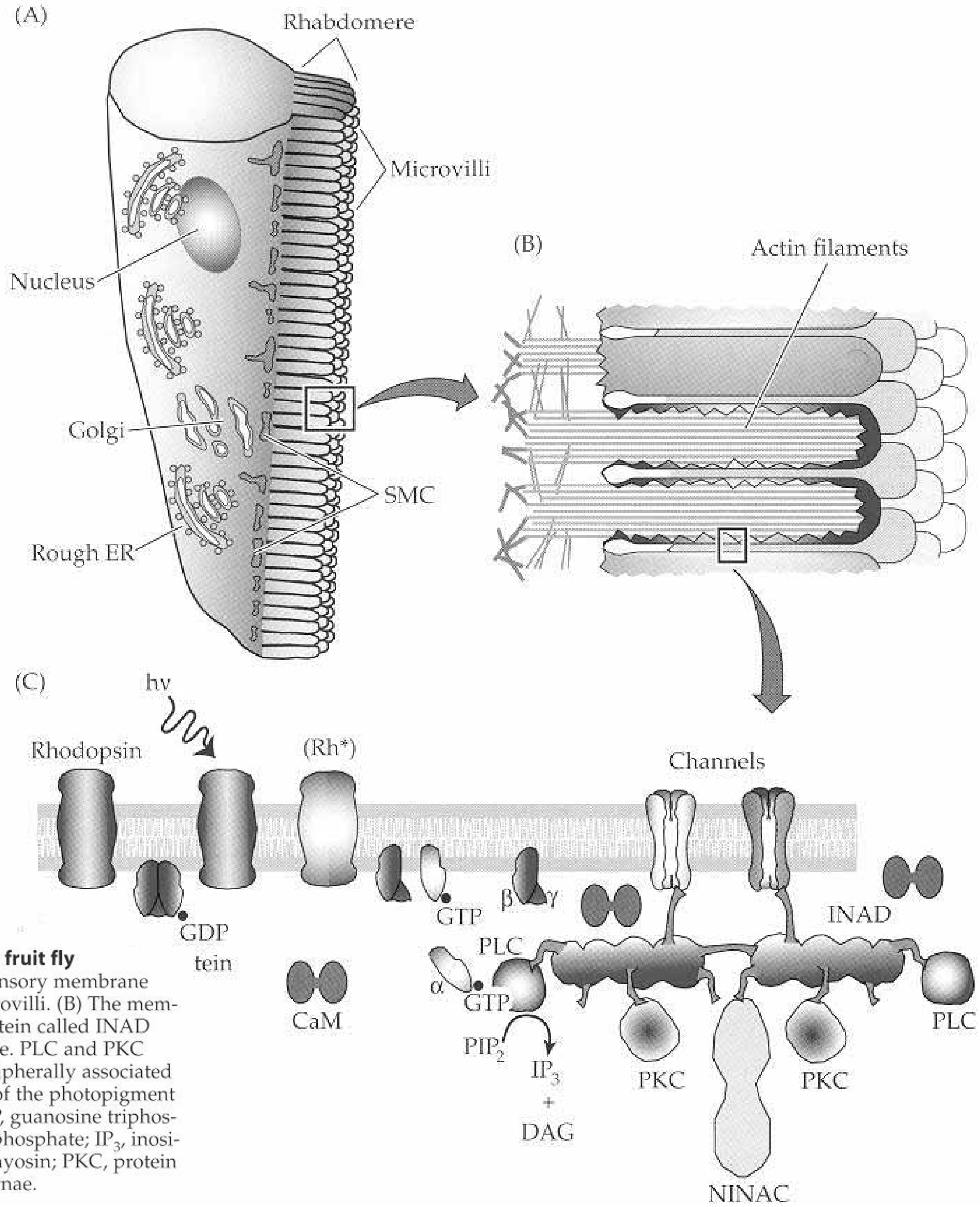
A) Receptory
Sensorická membrána

a) mikrovili- mikroklky (vláskové buňky, vomeronasální chemorecepce, fotorecepce členovců)

b) cilie – brvy, řasinky (čich v nosní sl., fotorecepce obratlovci)

Mikrovily, mikroklky
Mikrofilamenta
vláskové buňky,
čich, vom., foto. členov.





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.

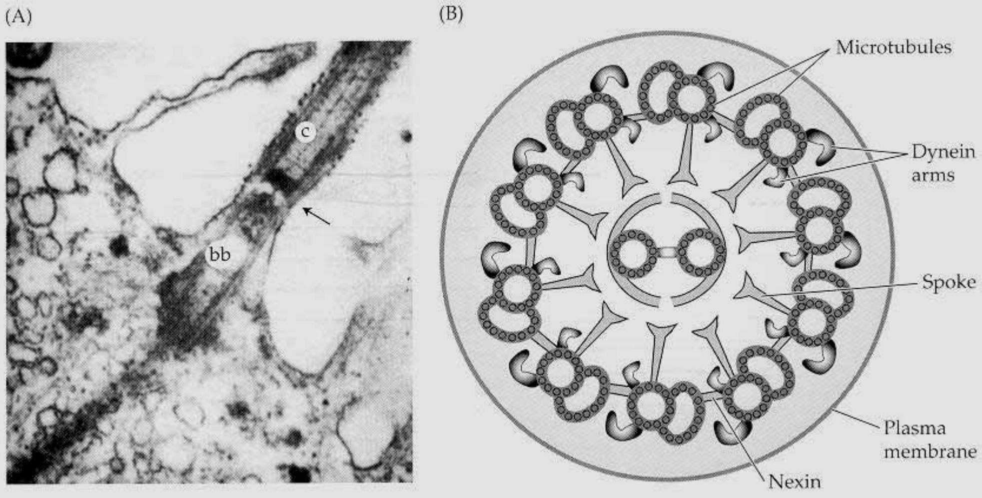


Figure 2.3
Cilium (A) Structure of a cilium from a sea urchin embryo. Note the basal body (bb) at the base of the cilium (c). Magnification 22,000×. (B) Schematic drawing of a cross section of cilium. (A from Chakrabarti et. al., 1998.)

Cilie (brvy, řasinky)
Mikrotubuly

cilie (čich v nosní sliznici, fotoreceptory obratlovců)

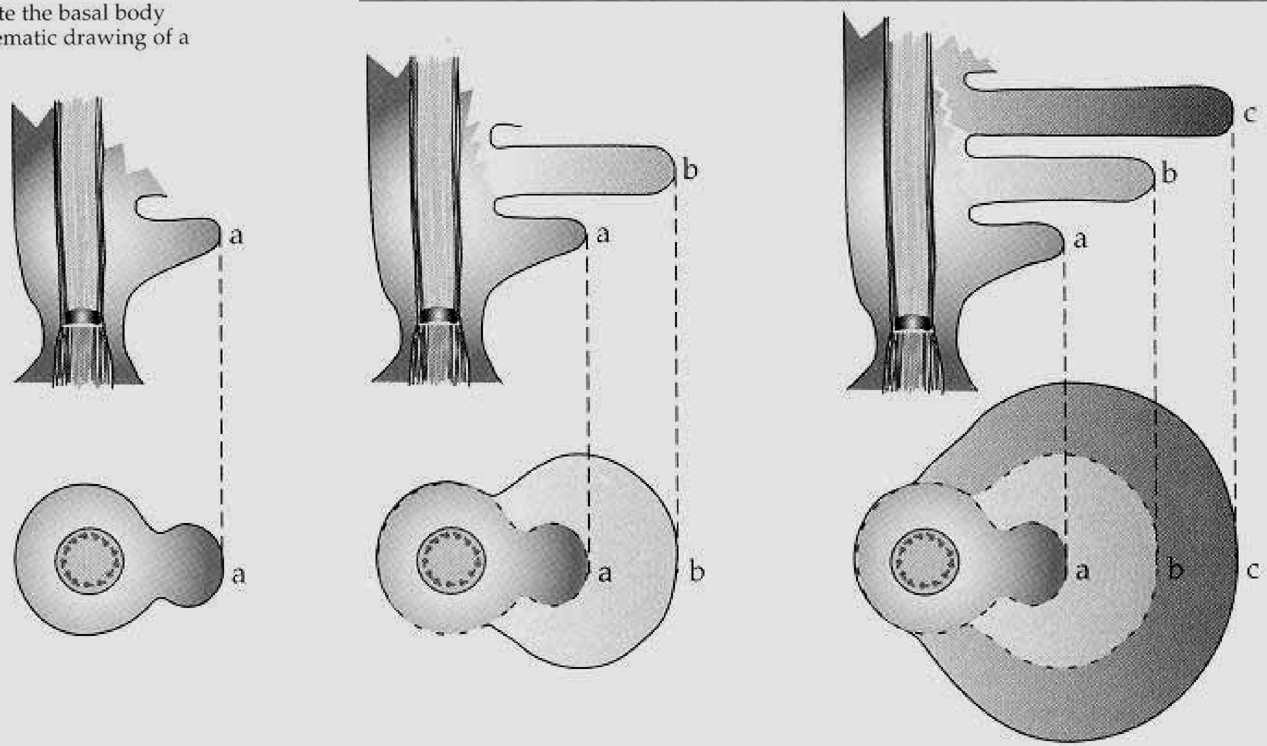
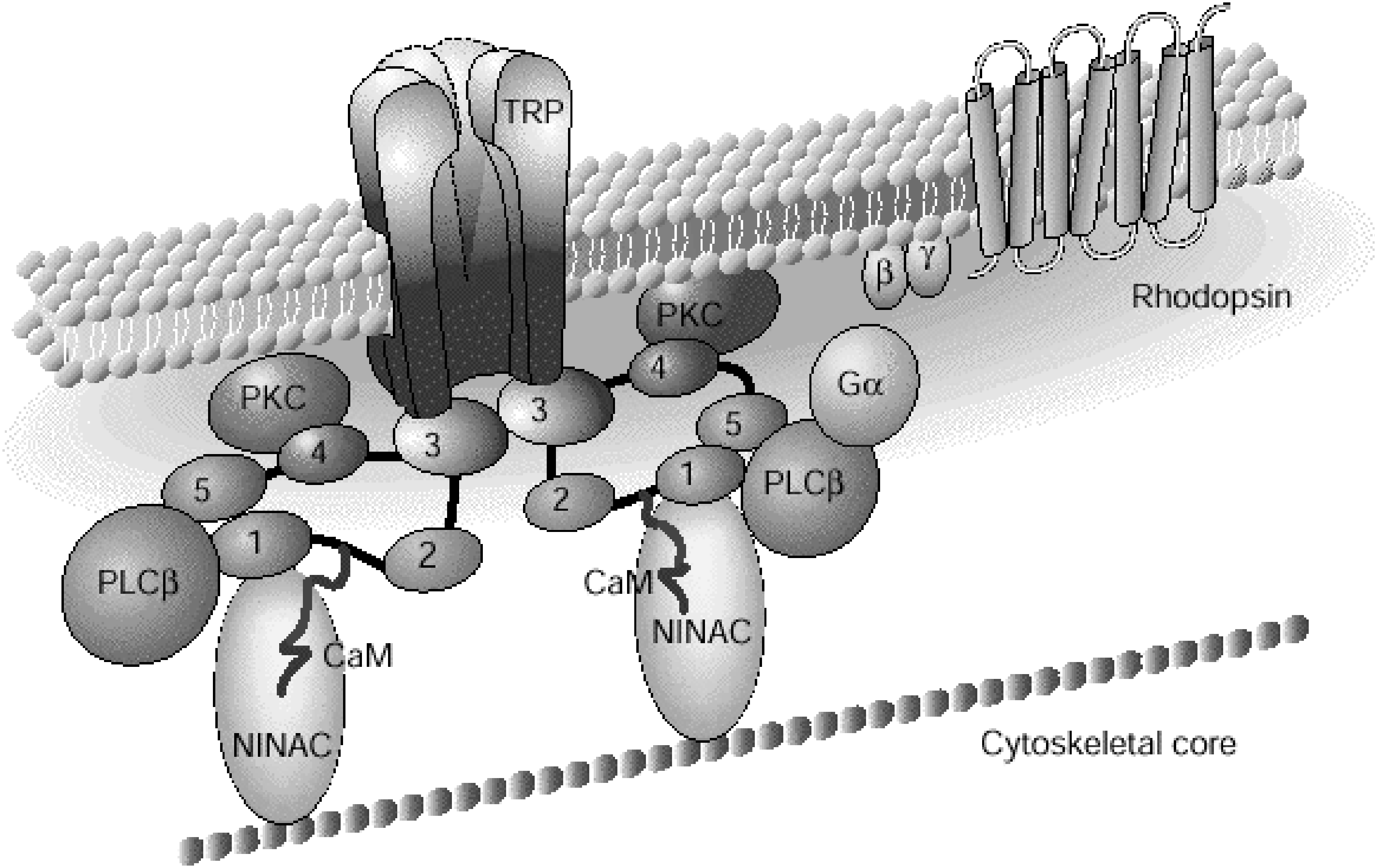


Figure 2.4
Formation of disks of a rod photoreceptor Disks are intiated at the base of the rod outer segment adjacent to a cilium. (After Steinberg, 1980.)

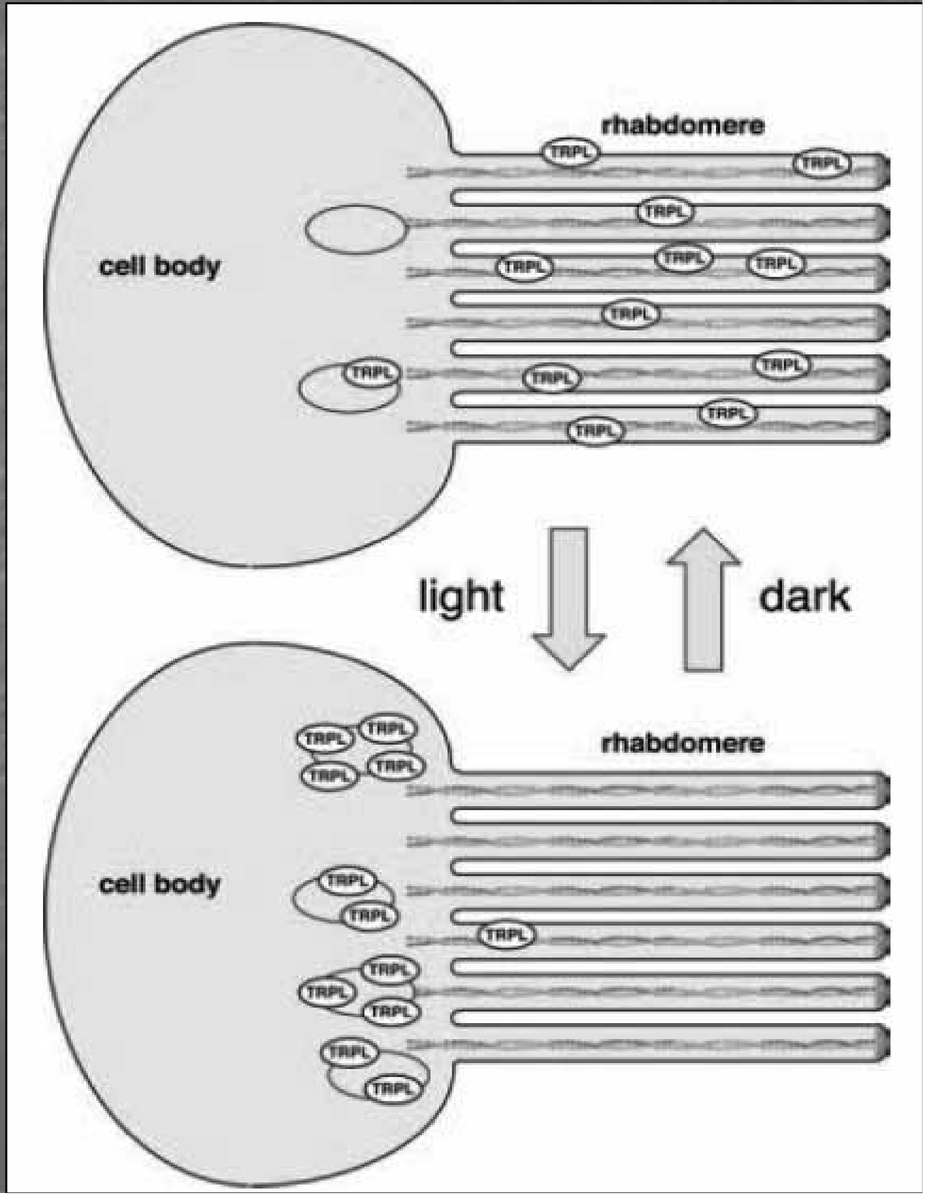
Úloha cytoskeletu v signálních drahách recepčních buněk

Difuzní model signálového přenosu x Signalplex (transducizóm), scaffolding proteins; Multimolekulární signalizační komplex



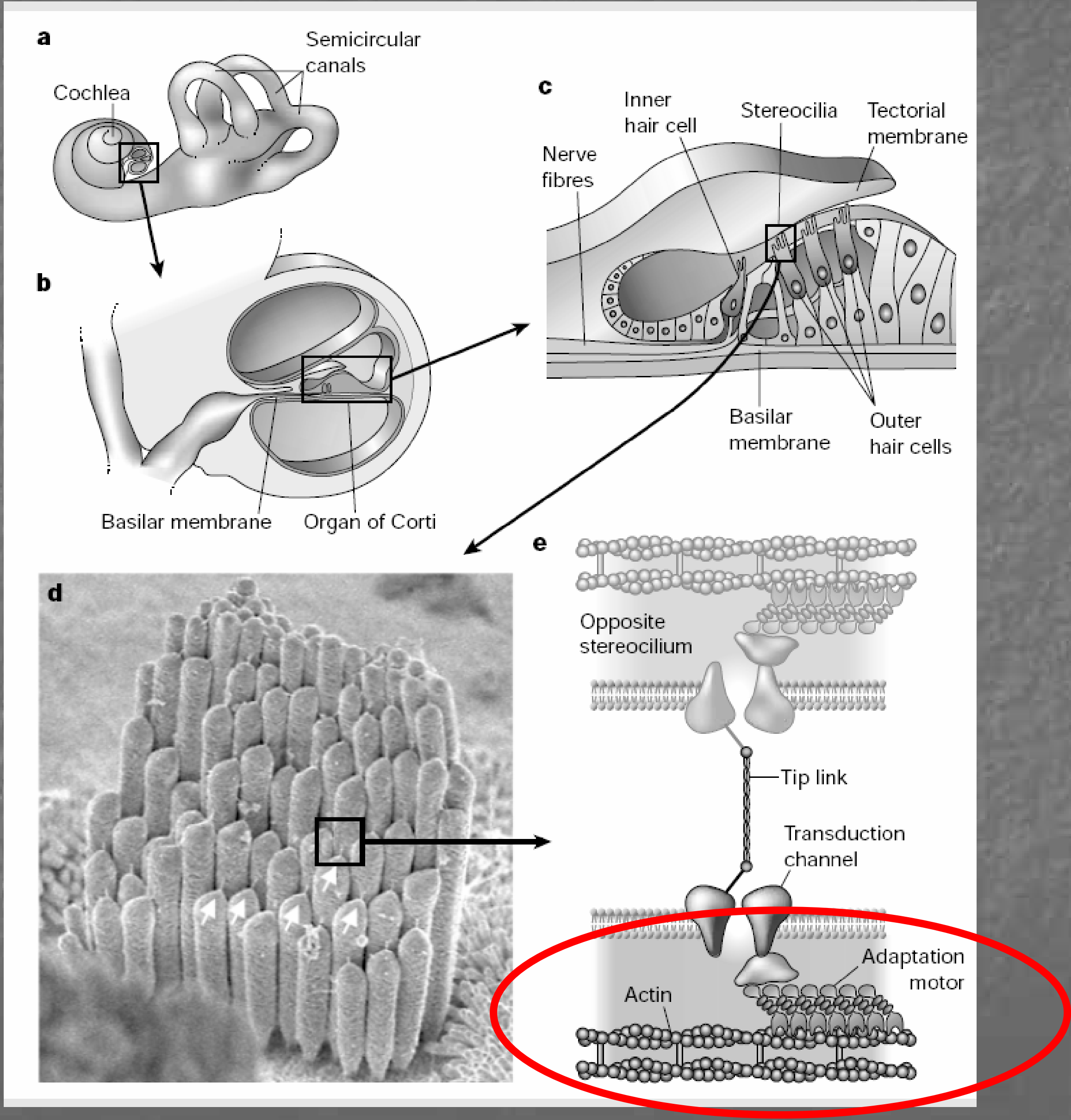
Úloha cytoskeletu v signálních drahách recepčních buněk

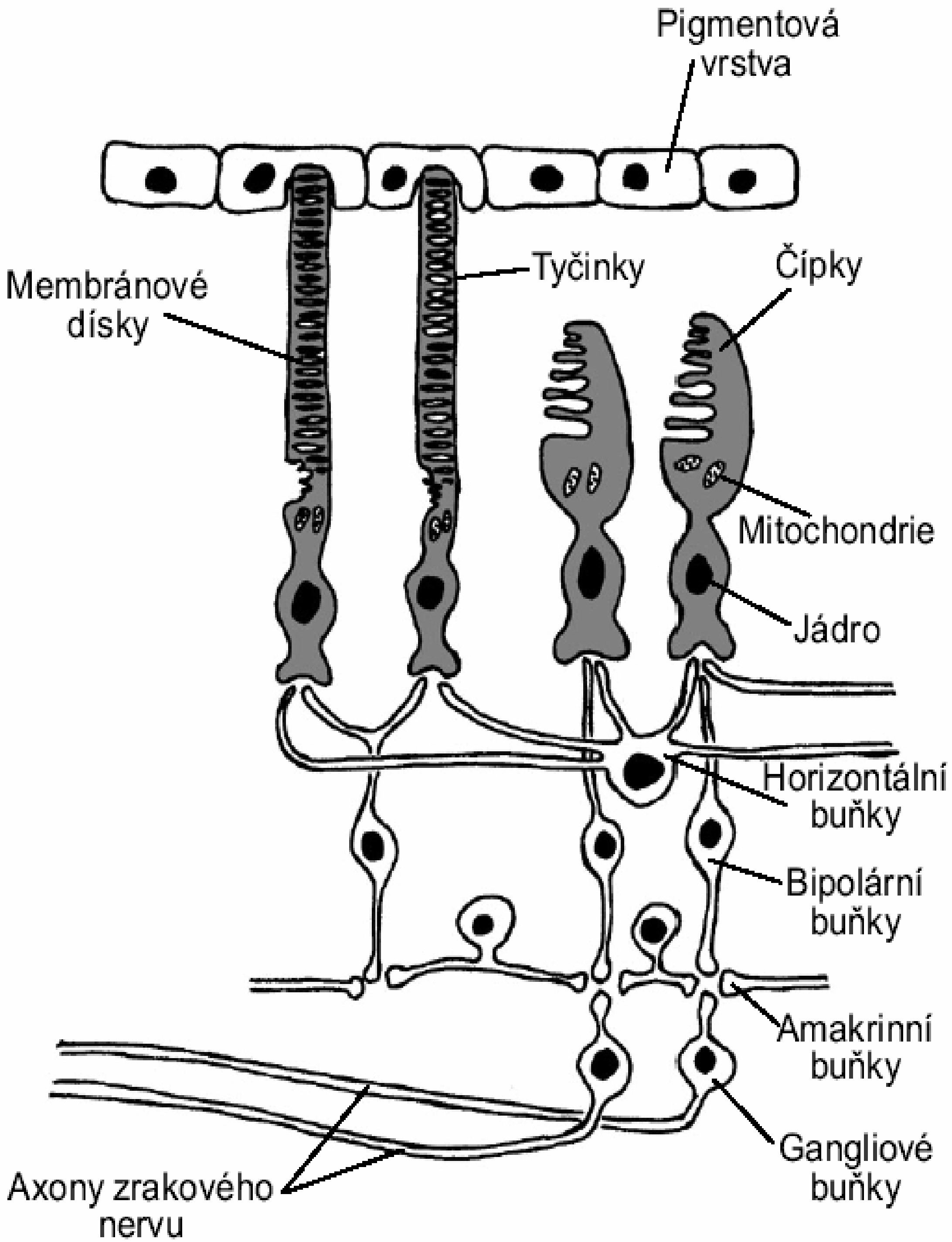
Velká adaptabilita zraku Drosophily
Translokace recepčního komplexu po aktinu
podle množství dopadajícího světla.



Úloha cytoskeletu v signálních drahách recepčních buněk

Adaptabilita sluchu na rozsah intenzit
Aktivní rezonanční aparát zesilující zvuky





Pigmentová vrstva
Membránové dísky
Tyčinky
Čípky
Mitochondrie
Jádro
Horizontální buňky
Bipolární buňky
Amakrinní buňky
Gangliové buňky
Axony zrakového nervu

Obnova membrány

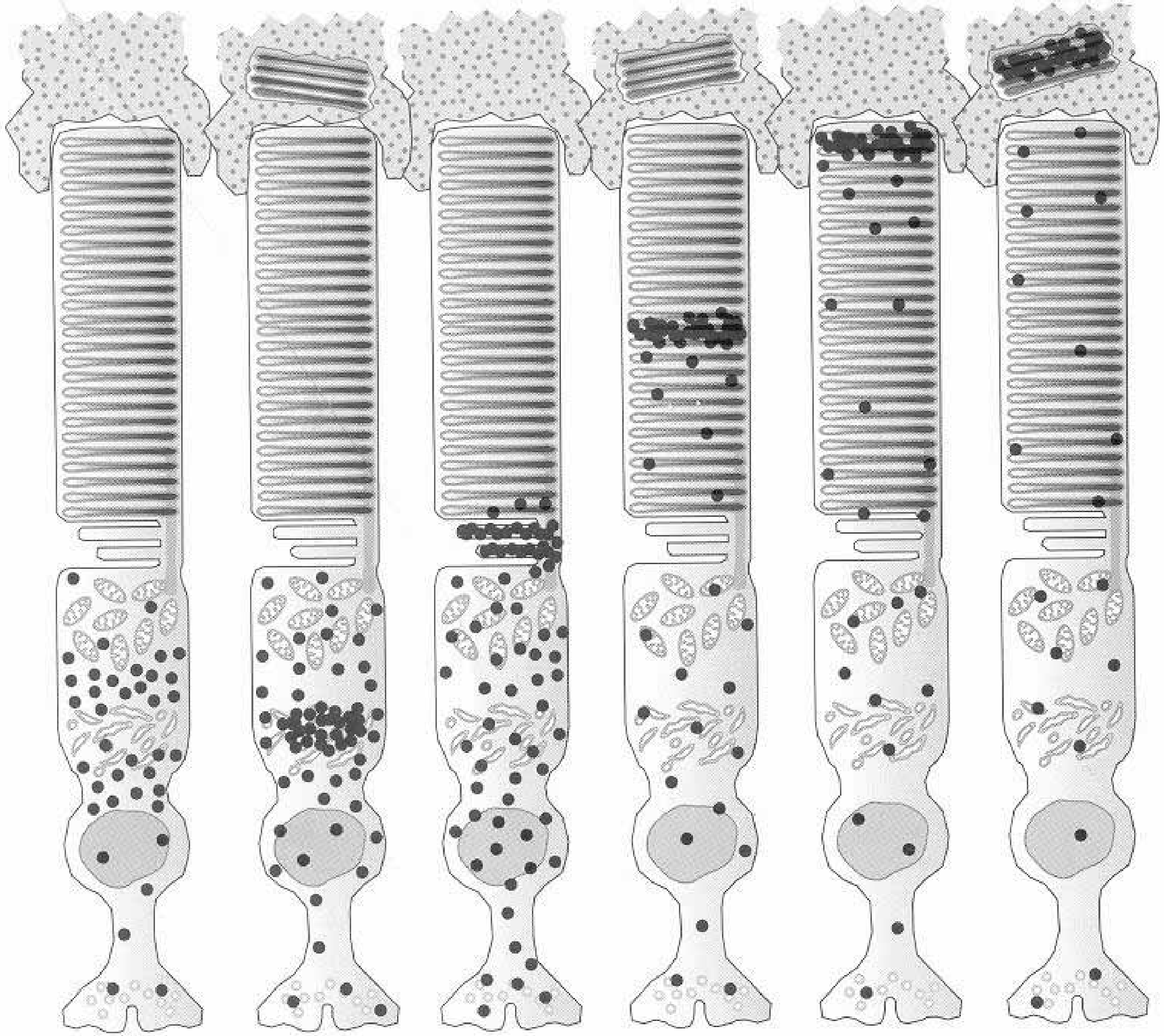
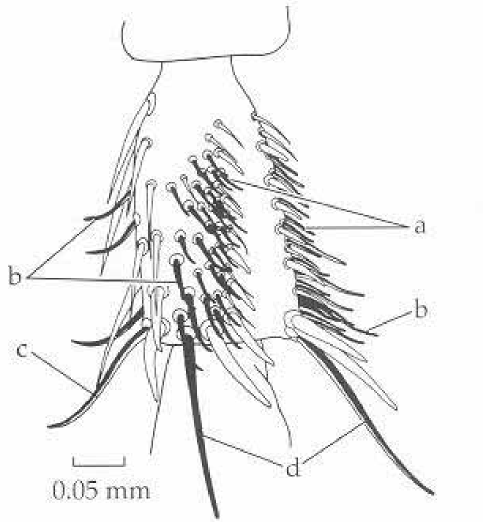


Figure 2.7
Renewal of sensory membrane in a vertebrate photoreceptor Renewal of membrane in the outer segment of rod photoreceptor. Black dots indicate labeled amino acid, first incorporated into protein in the inner segment, then transported to the outer segment as components of the disk (largely as rhodopsin). Synthesis of new disks pushes label upward until, after 10–14 days, it is shed by the outer segment and phagocytosed by the cells of an adjacent cell layer, called the retinal pigment epithelium. (After Young, 1976.)

Externí specializace
Ochrana, podpora, účast na recepci



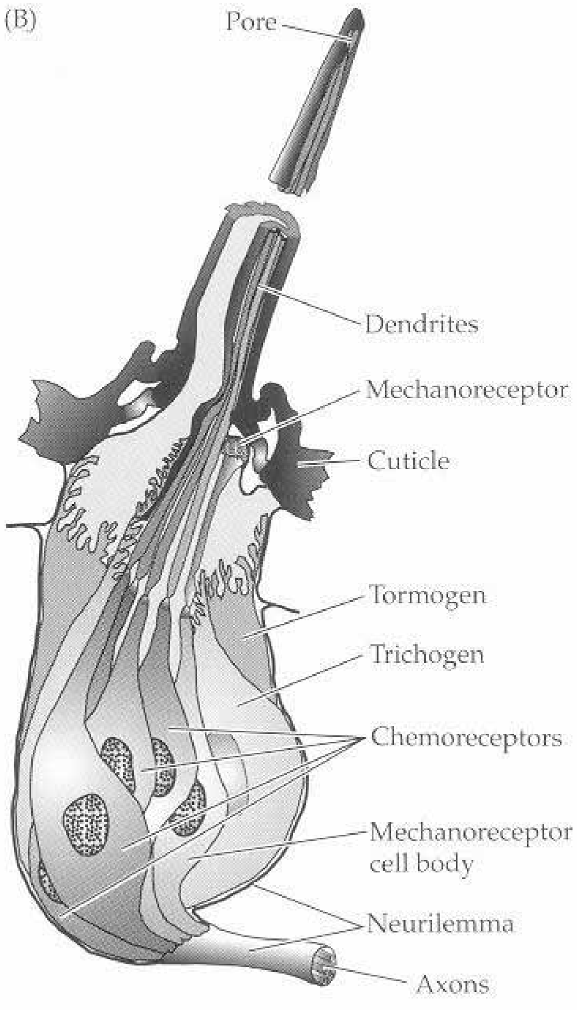
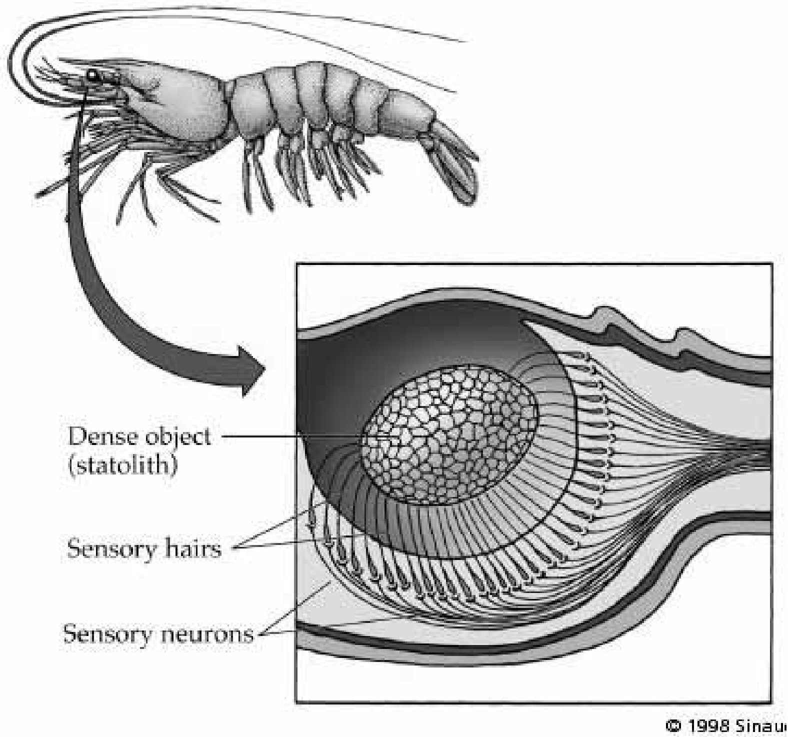
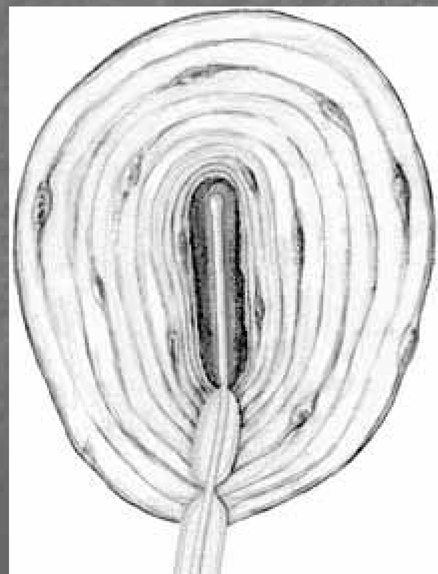
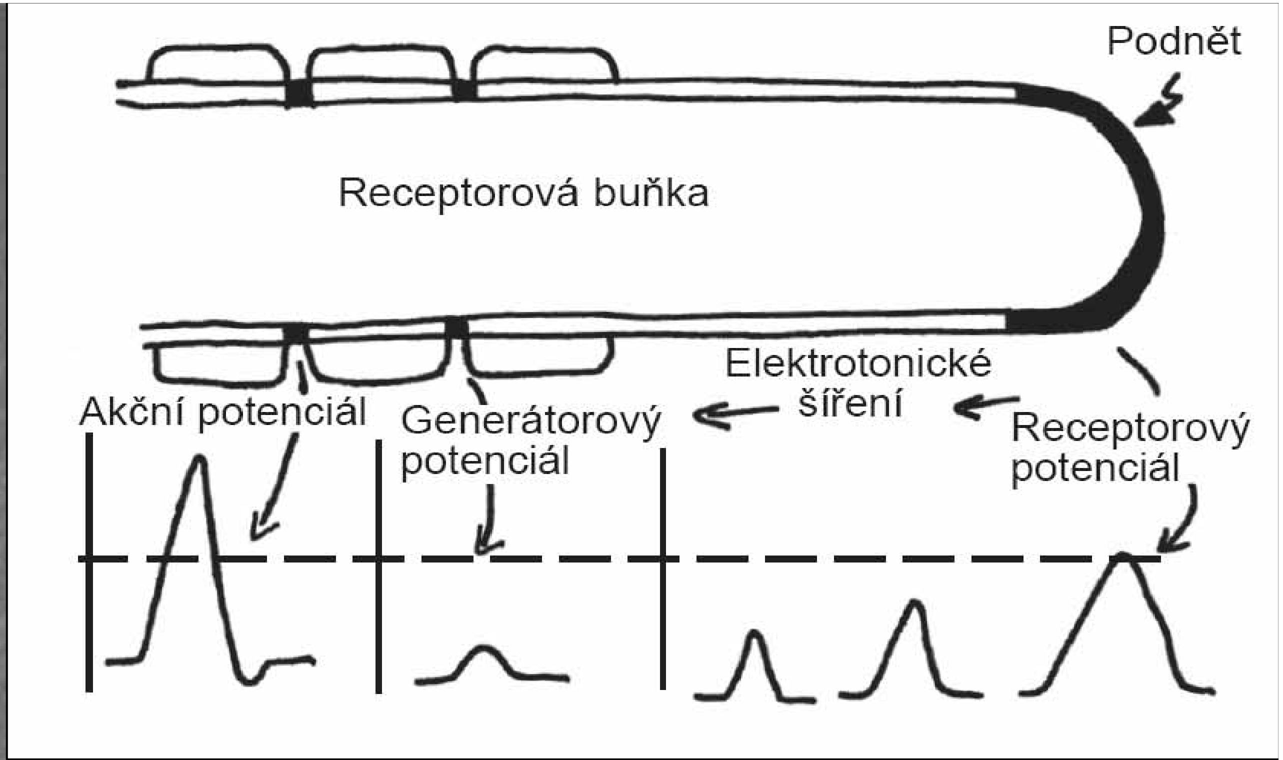


Figure 2.8
Taste receptors of the housefly
(A) Chemosensory bristles (hairs) on the tarsus of the housefly. Letters indicate different anatomical classes of hairs (type a, type b, etc; see discussion in Chapter 8). (B) Structure of a chemosensory bristle. In addition to two to four chemoreceptors, the bristle also contains a single mechanoreceptor. Trichogen and tormogen cells are accessory cells that secrete the hair and bristle socket.

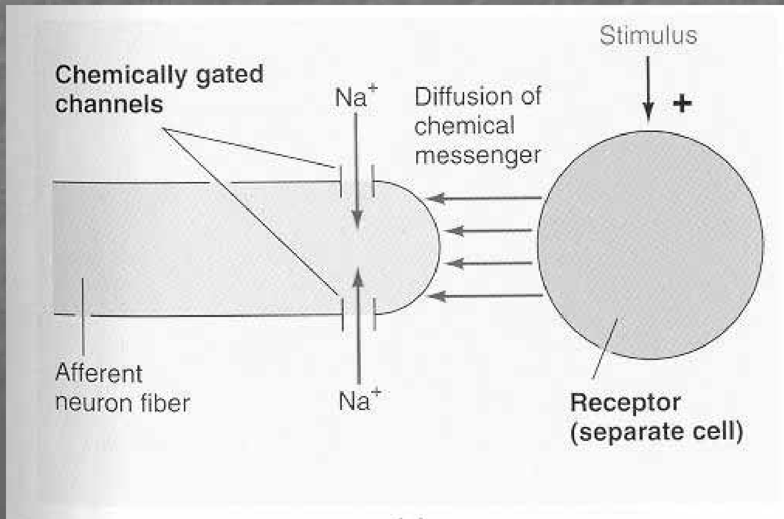




Kódování signálu



Sekundární receptor



Primární receptor

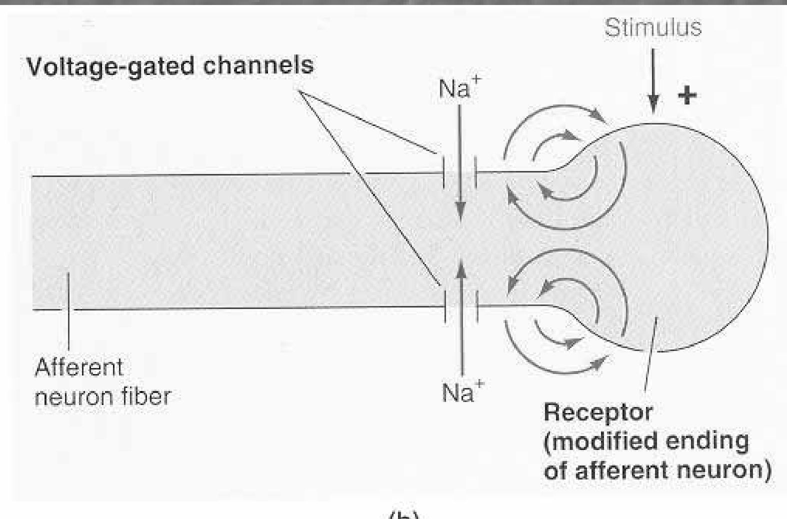


Table 10.1 Main types of sensory modalities

Sensory modality	Form of energy	Receptor organ	Receptor cell
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Taste	ions and molecules	tongue and pharynx	taste bud cells
Smell	molecules	nose	olfactory receptors
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Muscle			
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muscle stretch	mechanical	muscle spindle	nerve terminals
muscle tension	mechanical	tendon organs	nerve terminals
joint position	mechanical	joint capsule and ligaments	nerve terminals
Balance			
linear acceleration (gravity)	mechanical	vestibular organ	hair cells
angular acceleration	mechanical	vestibular organ	hair cells
Hearing	mechanical	inner ear (cochlea)	hair cells
Vision	electromagnetic (photons)	eye (retina)	photoreceptors

Modified from Ganong (1985)

Kódování signálu – překódování intenzity do frekvence AP

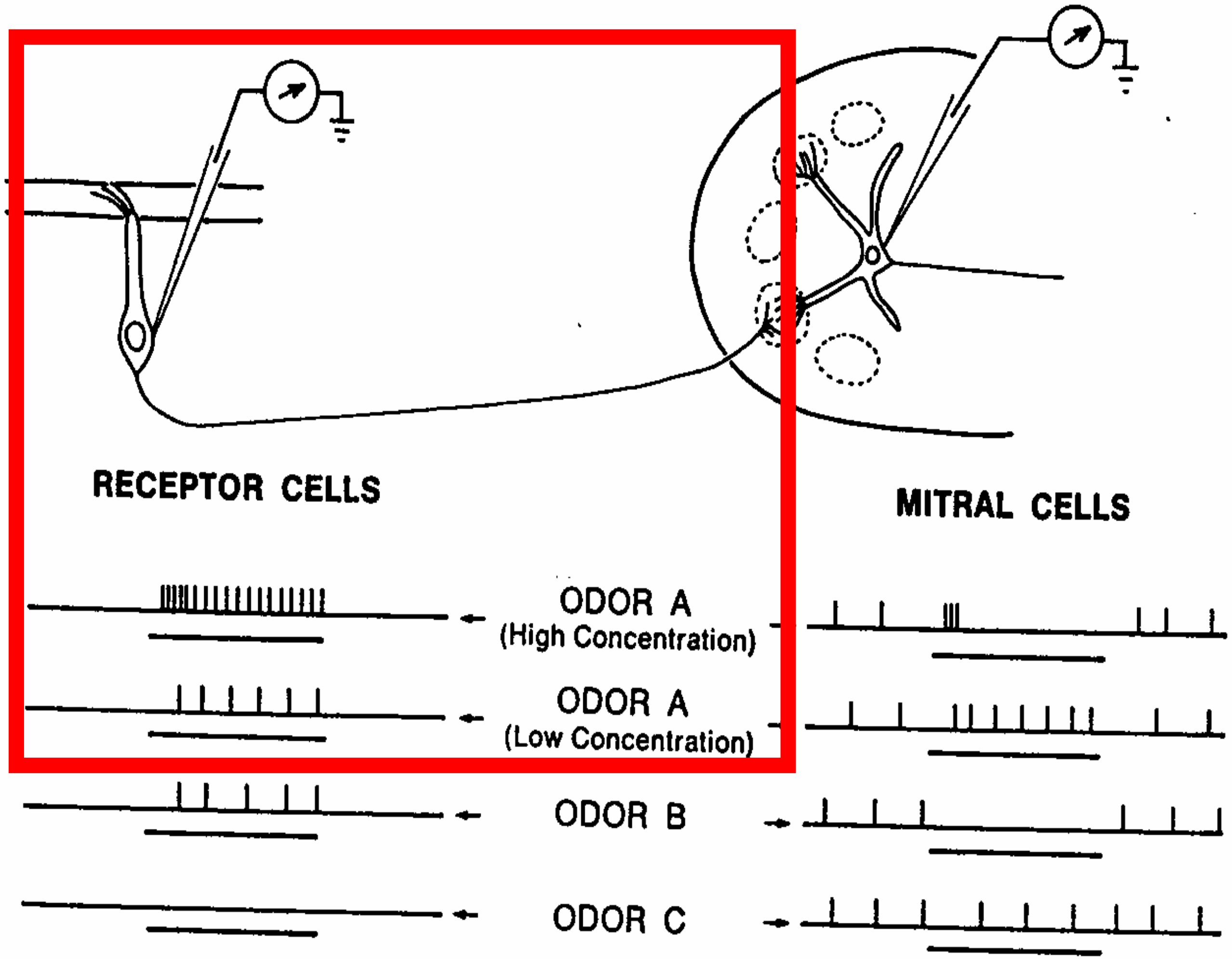


Fig. 11.11 Extracellular single-unit recordings of responses to odors of receptor cells *(left)* and mitral cells *(right)* in the salamander, showing different types of responses and different temporal patterns of activity. (After Kauer, 1974, and Getchell and Shepherd, 1978)

Spontánní aktivita a centrifugální řízení

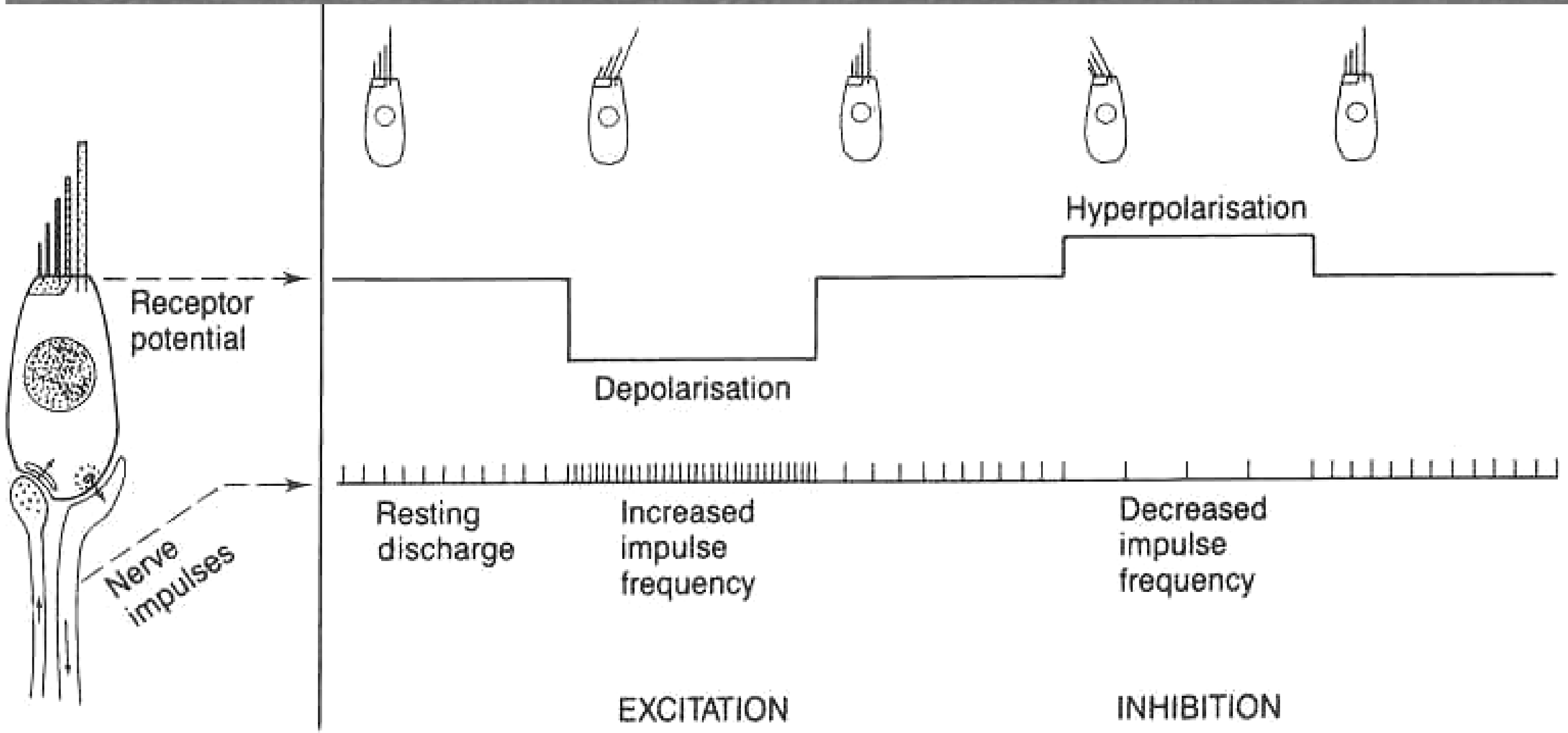


Table 10.3 Common operations in sensory transduction

Transduction operations	Operations in single sensory cells	Operations in cell populations
Detection ↓	Perireceptor mechanisms: filters: carriers: tuning; inactivation Sensitivity Rapidity	Perireceptor mechanisms: filters; carriers; tuning; inactivation Different thresholds
Amplification ↓	Positive feedback Active processes Signal/noise enhancement	Positive feedback Signal/noise enhancement
Encoding/ discrimination ↓	Intensity coding Quality coding Temporal differentiation	Different dynamic ranges Quality independent of intensity Center–surround antagonisms Opponent mechanisms Construction of maps
Adaptation and termination ↓	Desensitization Negative feedback Temporal discrimination Repetitive responses	Temporal discrimination
Sensory channel gating ↓	Open or close conductance gating	
Electrical response ↓	Depolarization or hyperpolarization	
Transmission to brain	Electrotonic spread Active properties Synaptic output or impulse discharges	Spatial patterns: maps and image formation Temporal patterns: directional selectivity, etc.

From Shepherd (1991b)

Jednoduchá receptorová buňka (primární receptor)
Inervovaná receptorová buňka (sekundární receptor)
Místa vzniku akčního potenciálu a speciální konstrukce synapsí (ribbon u sluchu)

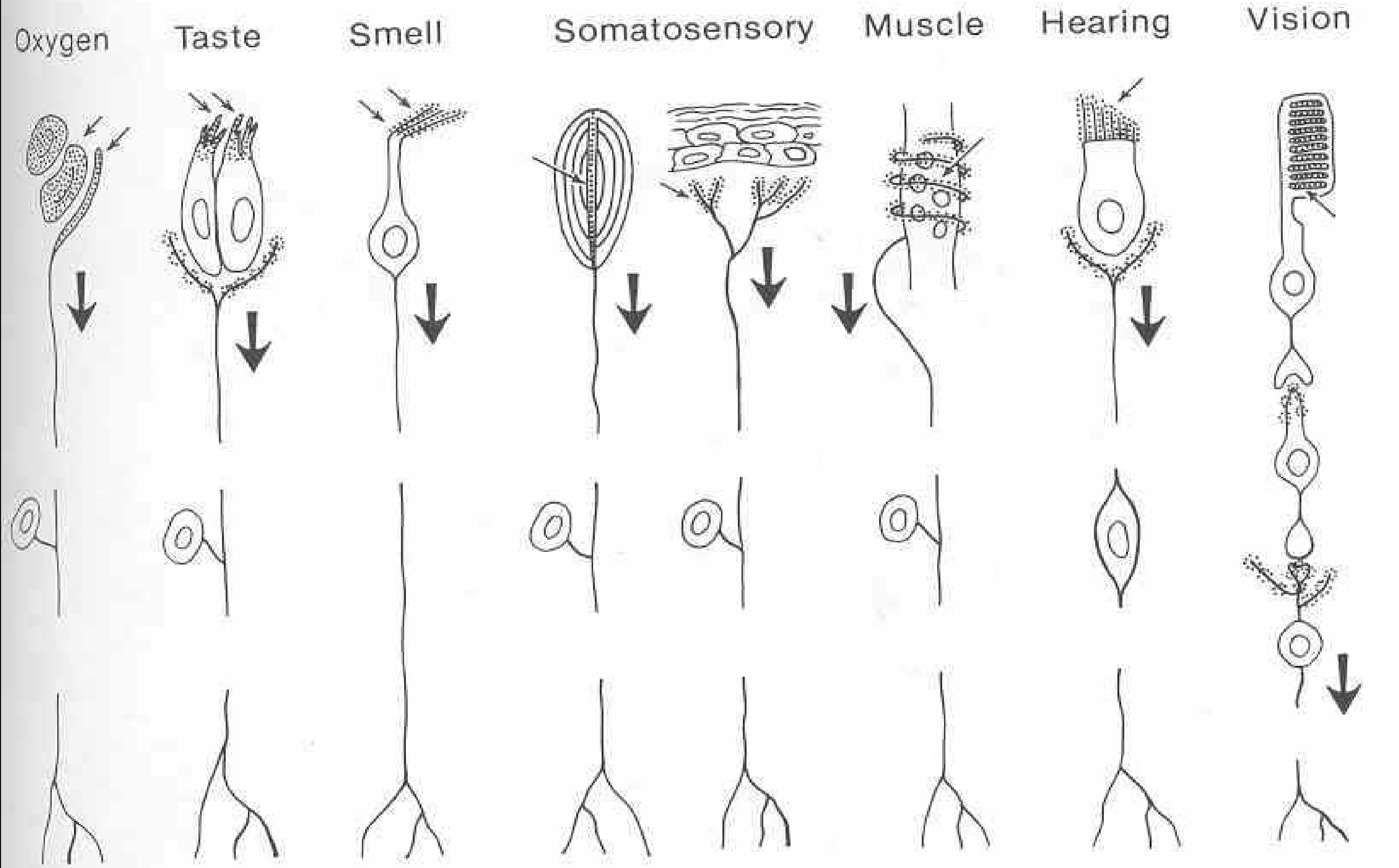


Fig. 10.1 Different types of sensory receptor cells in vertebrates. Small arrows indicate sites where sensory stimuli act. Stippling indicates sites for transduction of the sensory stimuli, and also for synaptic transmission; both of these sites mediate graded signal transmission. Heavy arrows indicate sites of impulse initiation. (Adapted from Bodian, 1967)

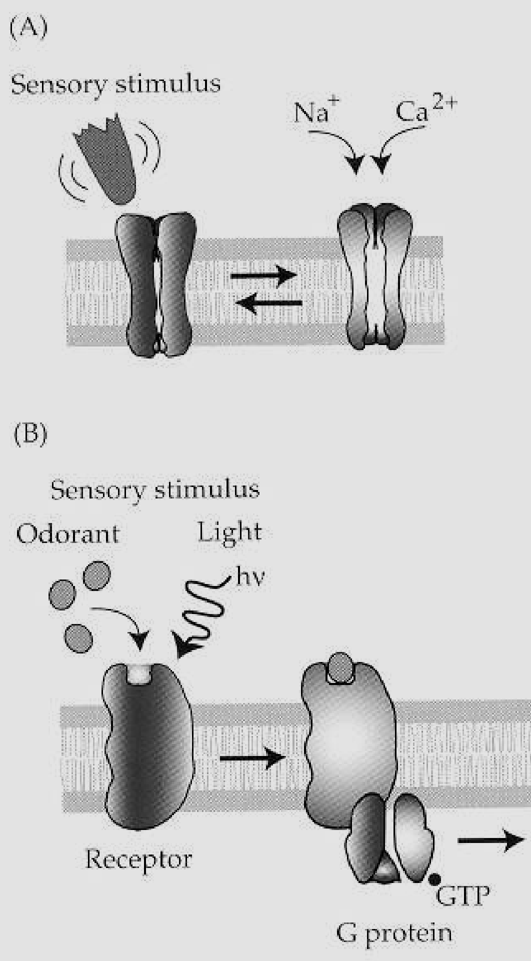


Figure 2.1
Mechanisms of sensory transduction
(A) Ionotropic transduction. The stimulus directly gates an ion channel that is part of the receptor molecule. (B) Metabotropic transduction. The receptor is not itself a channel but activates a heterotrimeric G protein that initiates a transduction cascade.

Ionotropní – přímá stimulace kanálu
Metabotropní – stejně jako hormony, transmitery...
Receptor ne vždy nutný – slano, MGP

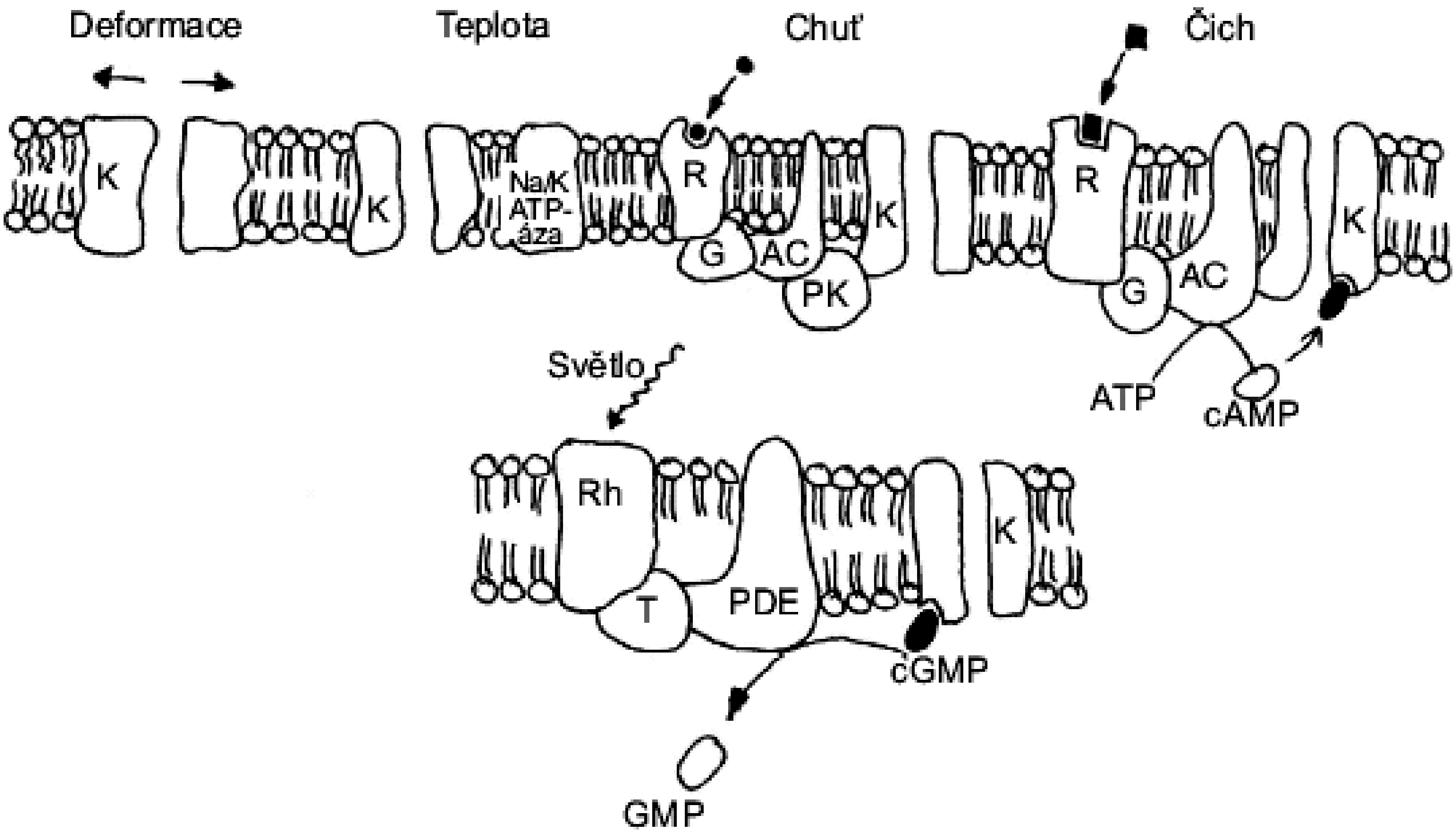

Deformace
Teplota
Chuť
Čich
K
K
Na/K
ATP-
áza
R
G
AC
PK
K
R
G
AC
K
ATP
cAMP
Světlo
Rh
T
PDE
K
cGMP
GMP

Table 10.2 Steps in sensory transduction

Transduction step	Vision	Olfaction	Taste: Sweet/bitter amino acids	Taste: Salt/sour	Mechanoreception (hair cells)
Energy	Photons	Molecules	Molecules	Na^+, H^+	Displacement
Membrane receptor	7TD family: rhodopsin	7TD family: olfactory	7TD family: gustatory	↓	↓
G protein	Transducin	G_{olf}	G_{gust}	↓	↓
G-protein target	Phosphodiesterase	Adenylate cyclase III; phospholipase C	AC; PLC	↓	↓
Second messenger	cGMP	cAMP; IP_3	cAMP; IP_3	↓	↓
Protein kinase	↓	↓	Protein kinase A?	↓	↓
Membrane channel	Cationic; inward	Cationic; inward Anionic; inward	K^+	Na^+; K^+	Cationic; inward
Sensory response	Close channel	Open channel	Close channel	Open; close	Open channel
Adaptation mechanism	Ca^{2+}; phosphorylation?; arrestin	Ca^{2+}; protein kinases ?	?	?	Myosin/actin motor; Ca^{2+}?
Cell body output	Synapses	Impulses	Synapses	Synapses	Synapses

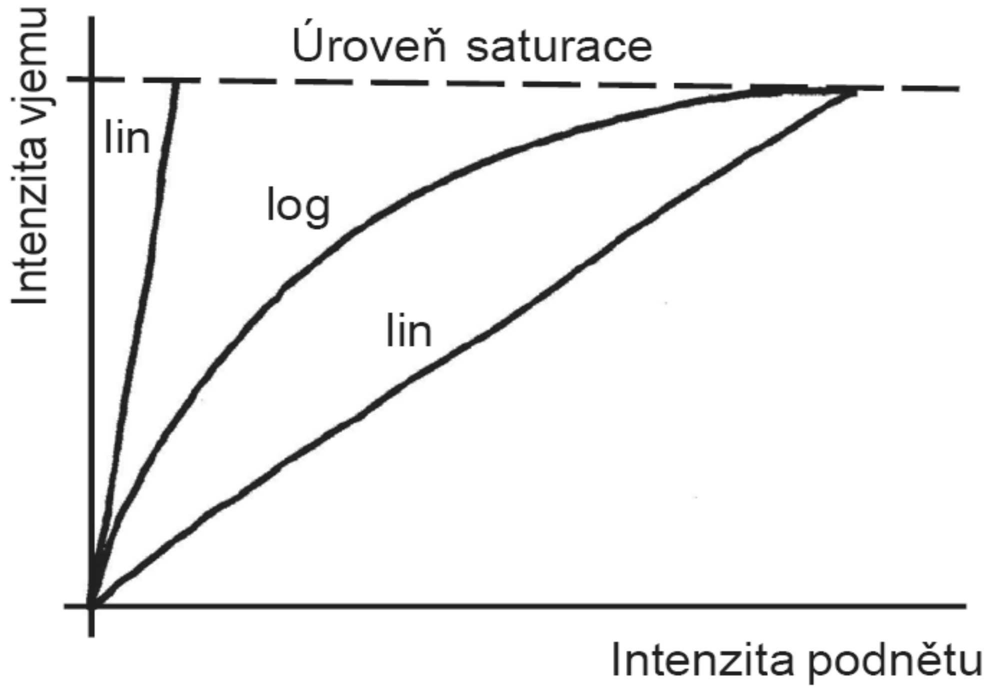
7TD family: 7 transmembrane domain receptor family.

From Shepherd (1991b)

Weber-Fechnerův psychofyzický zákon

$$S = a \log I/I_0 + b$$

Weber gradually increased the weight that a blindfolded man was holding and asked him to respond when he first felt the increase



Obr. 4.15. Intenzita vjemu roste s intenzitou podnětu logaritmicky – ne lineárně. Tento kompromis mezi rozlišovací schopností a saturačním prahem (nasycením) receptorů umožňuje zachovat odstupňovanou reakci na velmi široký rozsah intenzit současně s velkou citlivostí pro slabé podněty.

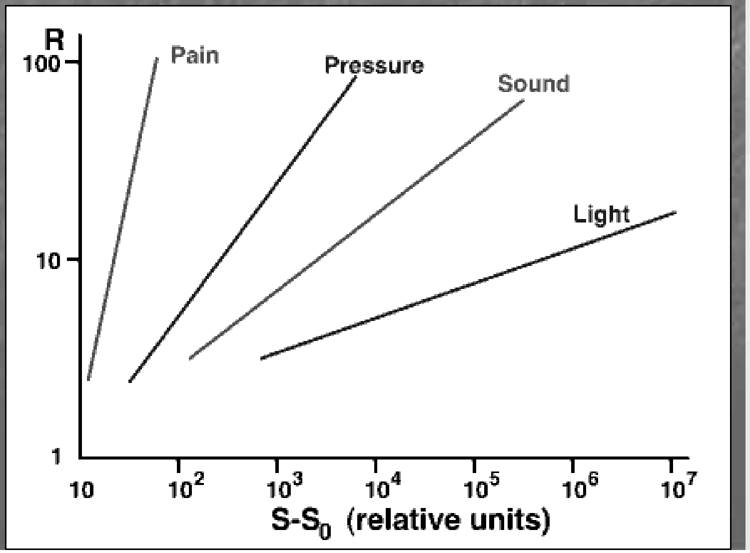
Neplatí ale pro všechny modality.

Sound perceived twice as loud as the standard should be given a number twice.

Stevensův vzorec:

$R = k (S-S_0)^{alfa}$

Exponent závisí na typu stimulu



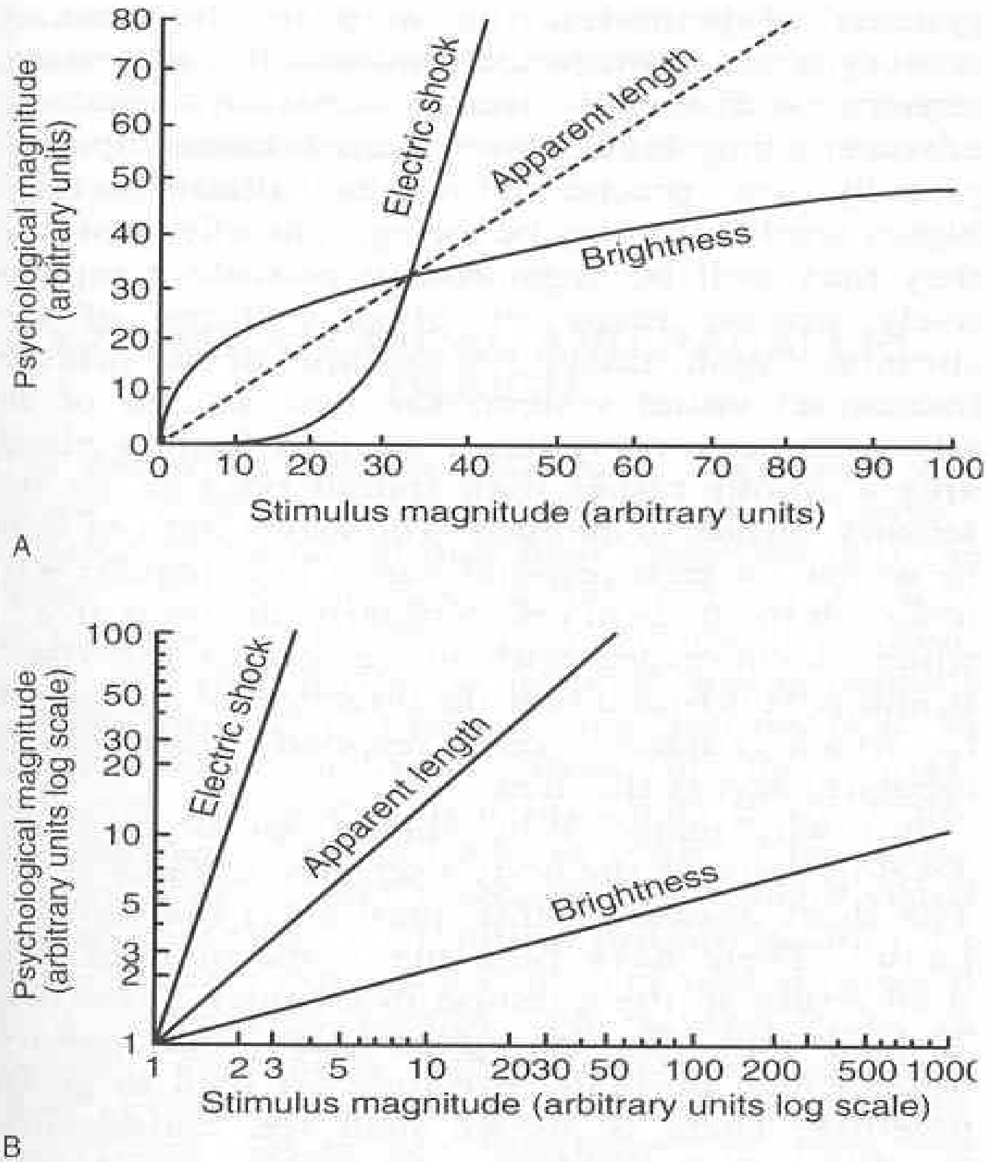
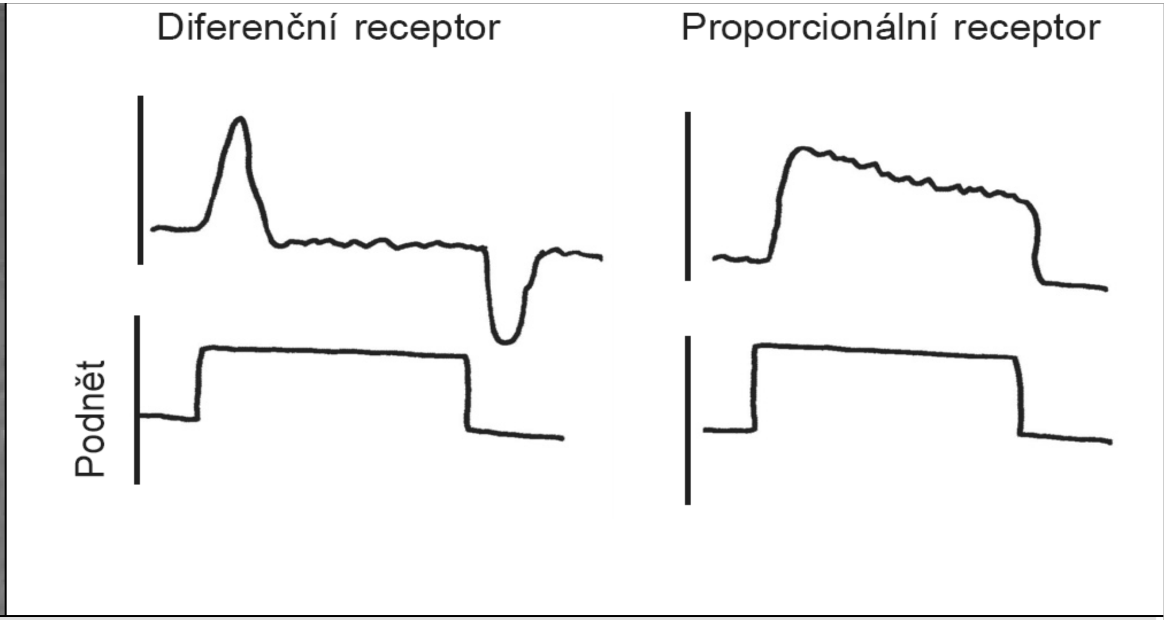
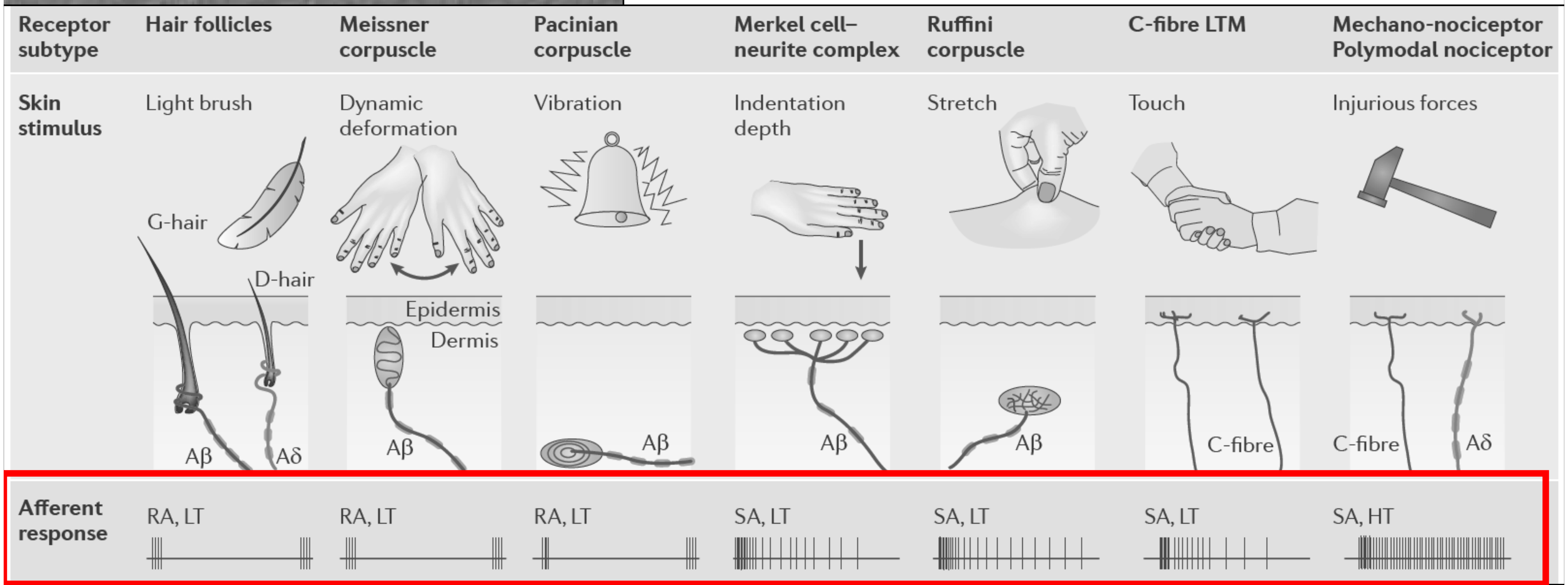


Figure 3.2 Psychophysical correlations. (a) When subjective magnitude is graphed against stimulus magnitude on linear coordinates the lines are frequently curved upwards or downwards. (b) When graphed against log–log coordinates straight lines are obtained whose gradients depend on the value of the exponent, 'n'. From Stevens, 1961

Sensorická adaptace





Adaptace: inaktivace kanálů, často pod vlivem Ca, odstředivé tlumení z CNS
Vliv přídatných struktur na adaptaci Paciniho tělíska

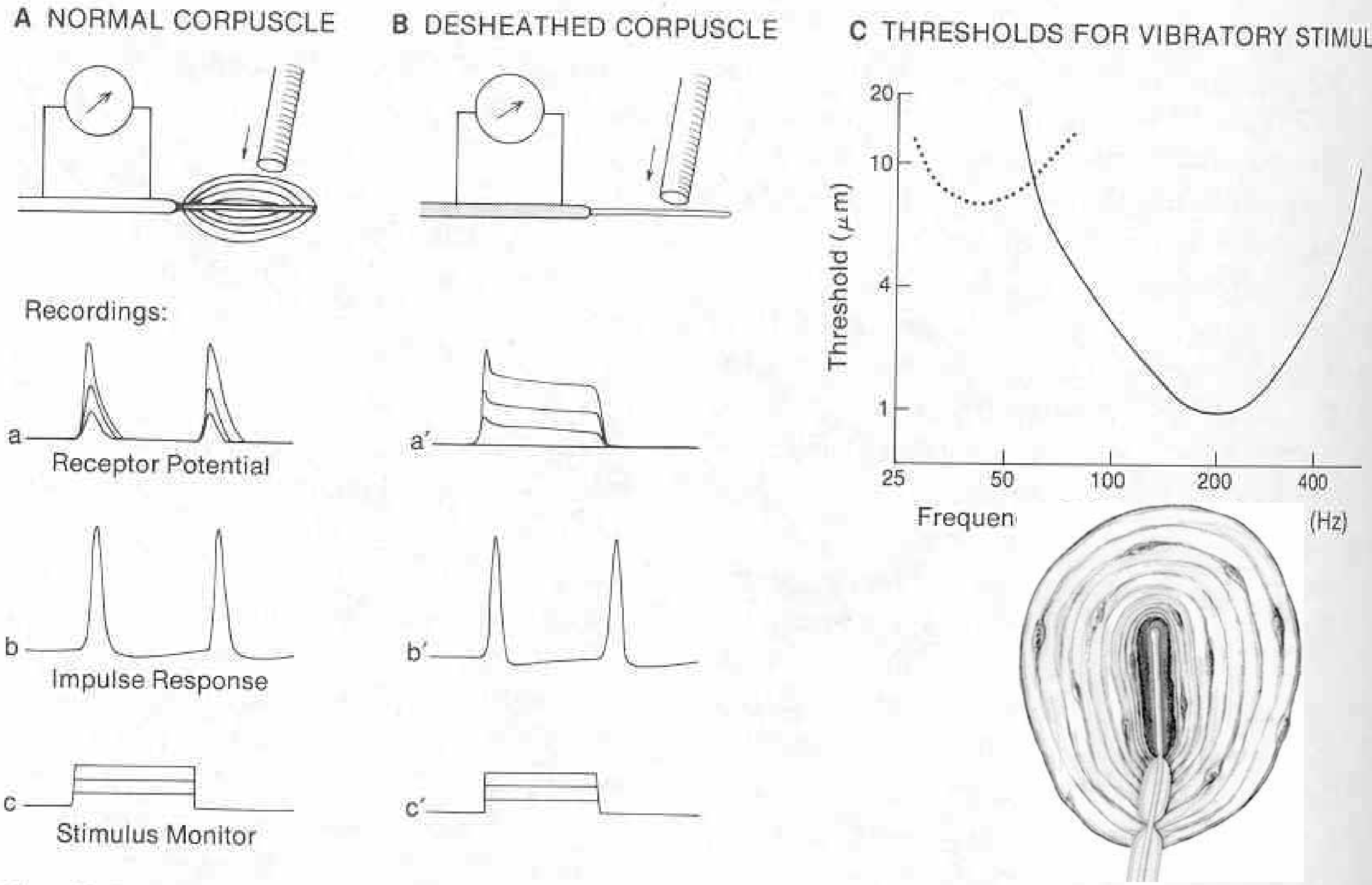


Fig. 12.5 Experimental analysis of transduction in the Pacinian corpuscle. **A.** Diagram showing probe for stimulating the intact corpuscle, and recording from the nerve. *(Below)* recordings of the receptor potential and impulse discharge. **B.** Repeat of experiment after removal of lamellae. **C.** Sensitivity of Pacinian corpuscle to vibratory stimulation at different frequencies. Sensitivity of Meissner's corpuscle is shown by dotted line. (A, B based on Loewenstein, 1971; C modified from Schmidt, 1978)

Smyslový práh
Zesílení, šum
Časová a prostorová sumace sníží práh, ale zhorší rozlišení.

Psychometrická křivka

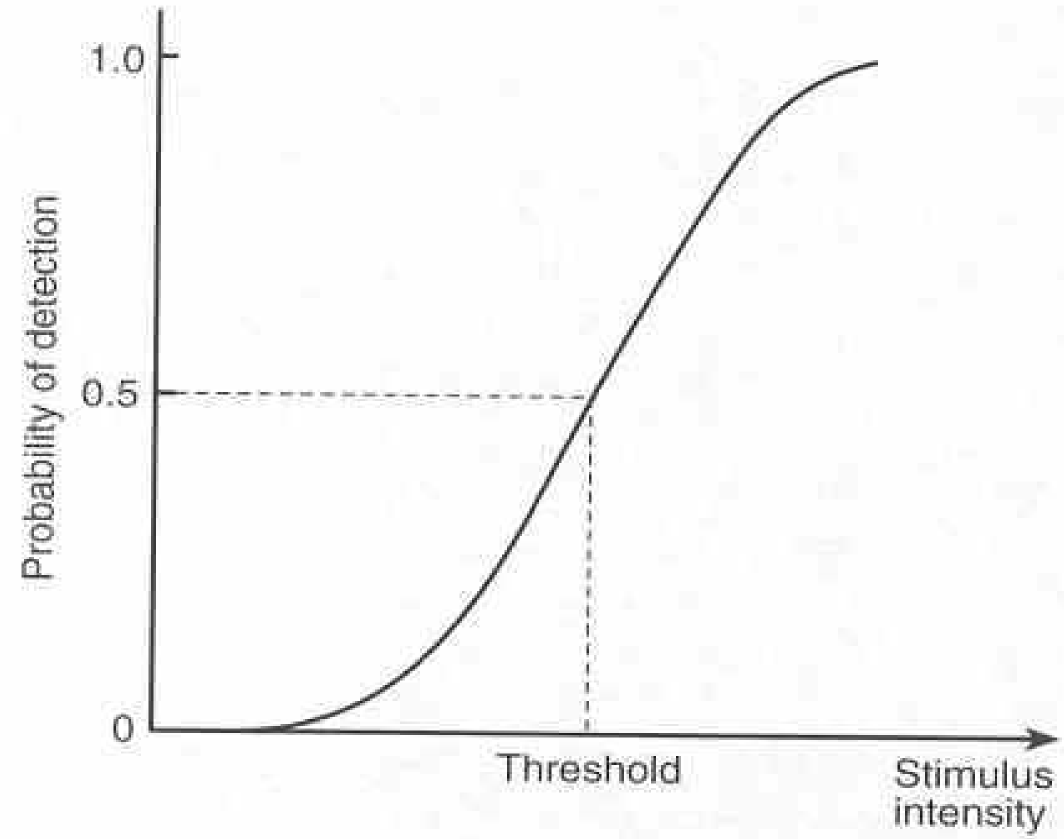
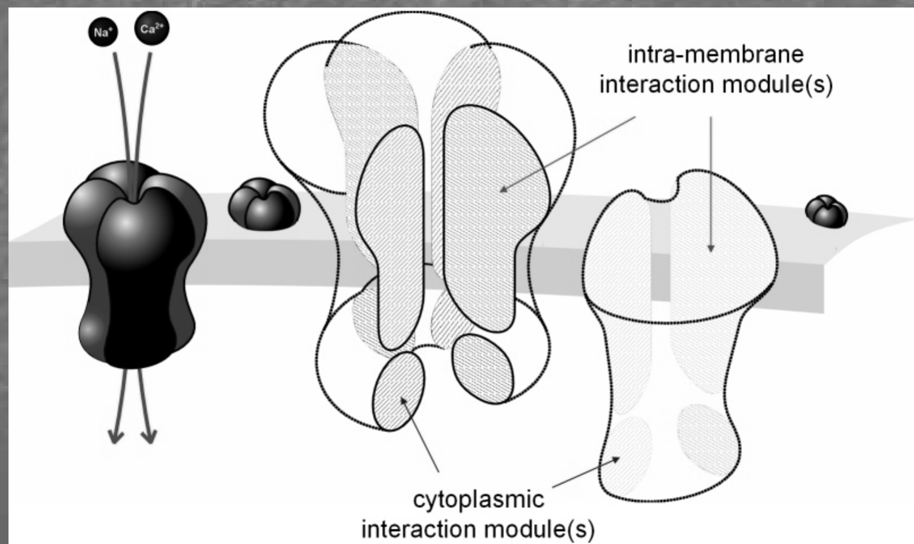
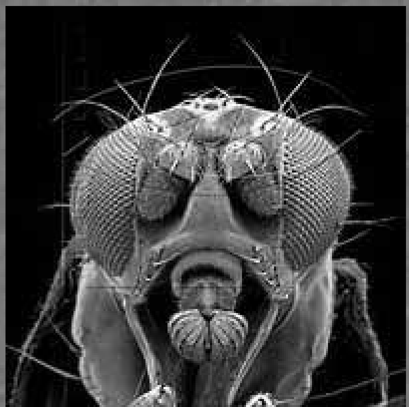


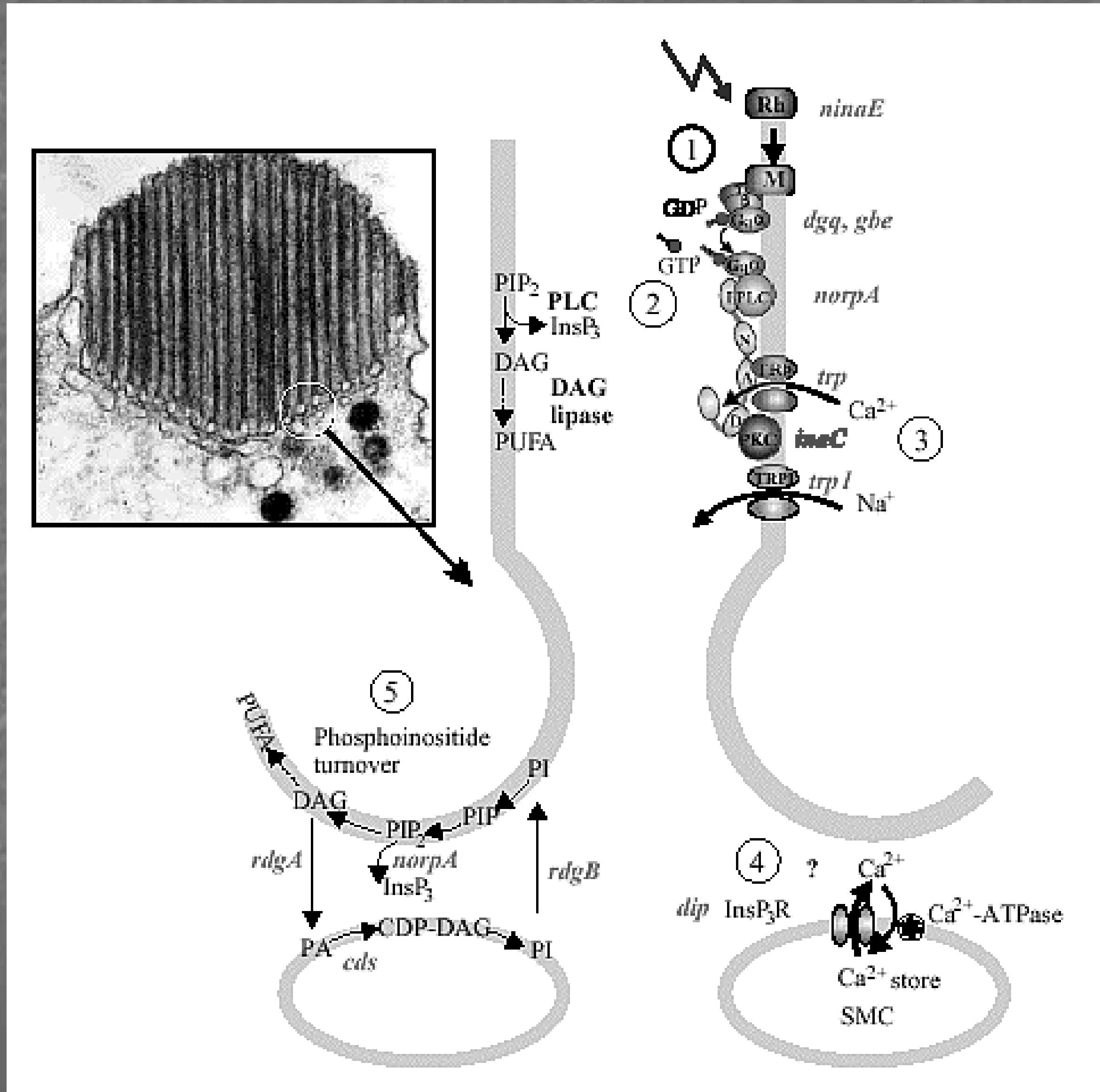
Figure 3.1 Psychometric curve. The threshold is defined as the intensity when half the responses are correct. The position of the curve on the ordinate is arbitrary. It will shift to the right or left according to circumstances

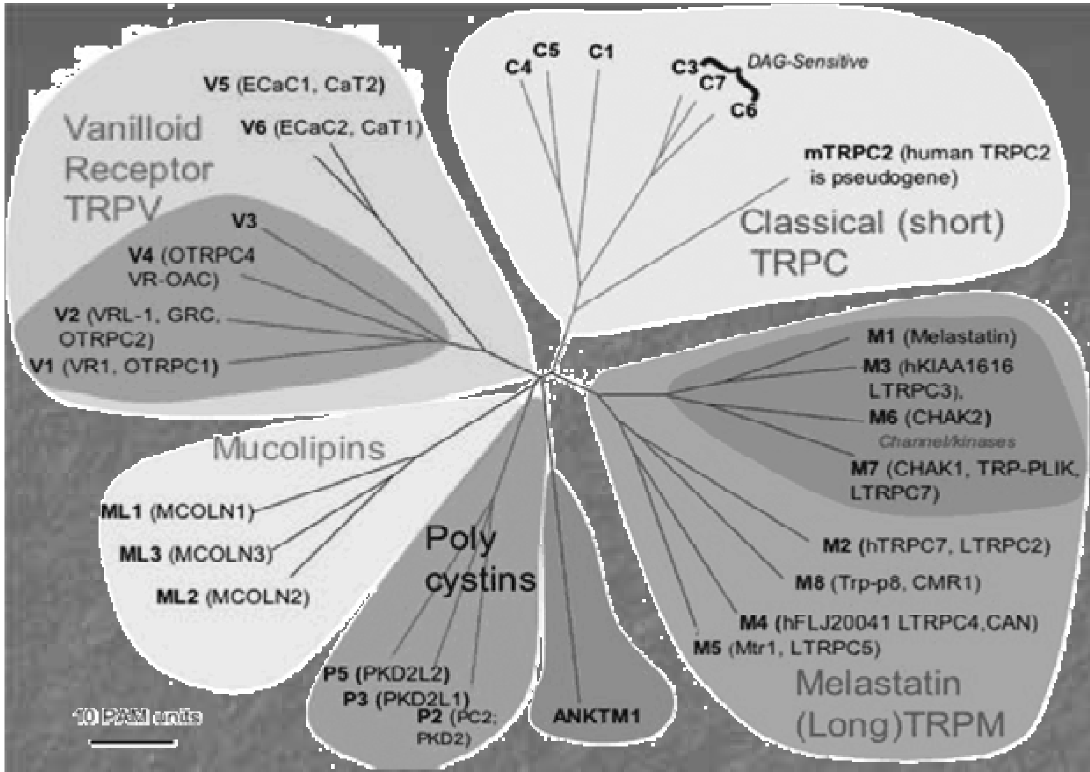
Cítění přes TRP kanály
TRP – transient receptor potential



TRP - 1969; Transient Receptor Potential – Přechodný receptorový potenciál, místo trvalé odpovědi na trvalé světlo







TRP kanály kromě **fotorecepce** *Dros*. řídí **mechanorecepci** háďátka, octomilky, myši, člověka.
Byly popsány v receptorech **bolesti** a **teploty**.
U myši TRP zprostředkují vnímání některých **chutí**.

UNIVERZÁLNÍ role ve smyslové transdukci

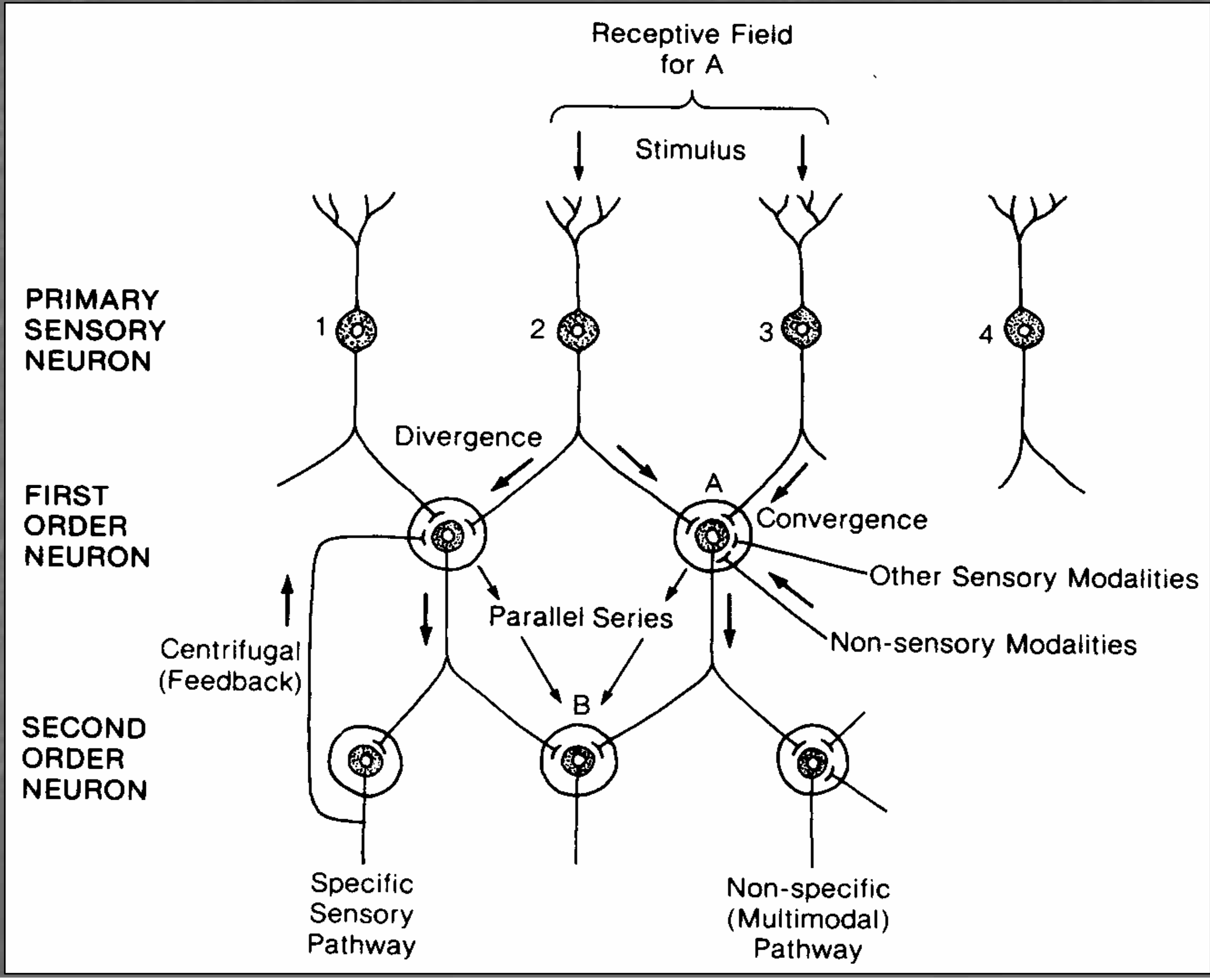
Více než 50 TRP kanálů u kvasinek, hlístů, hmyzu, ryb a savců.

3 úrovně organizace sensorických systémů

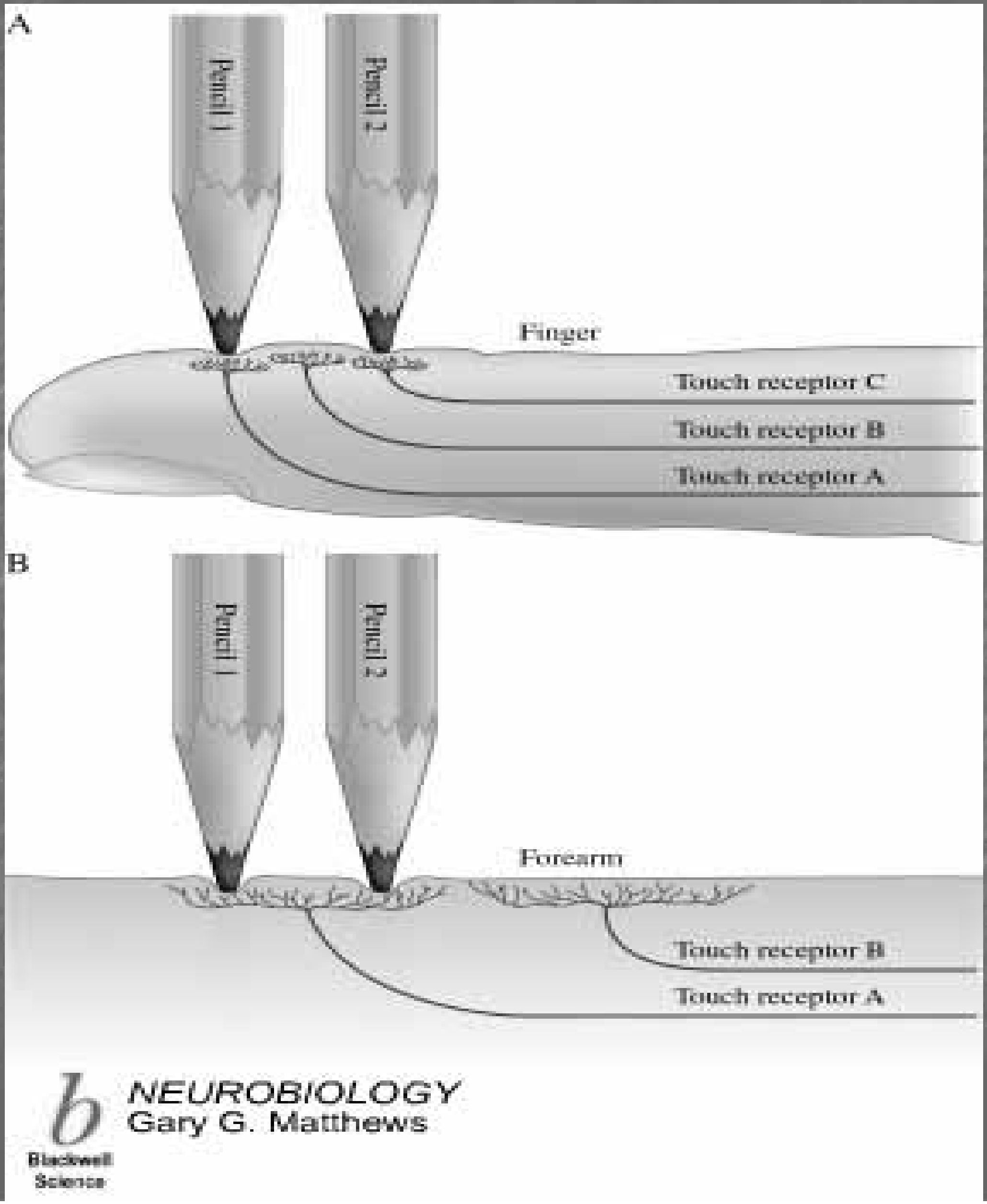
A) Receptory
B) Sensorické obvody a dráhy
C) Sensorická percepce

Ještě před vznikem digitálního zápisu se informace na periferii zpracovává.

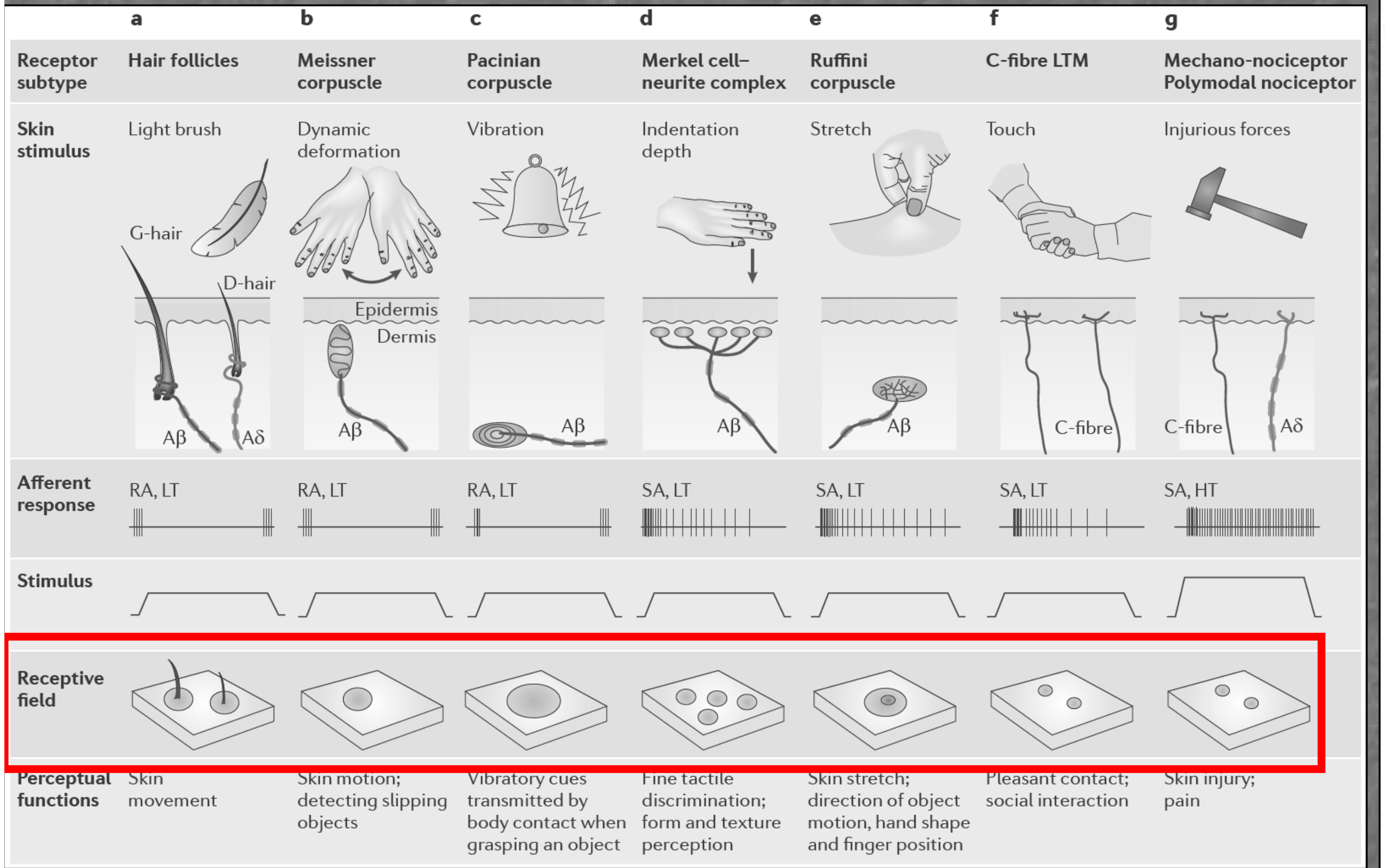
Konvergence, receptivní pole, zpětná vazba, syntéza, centrifugální vedení



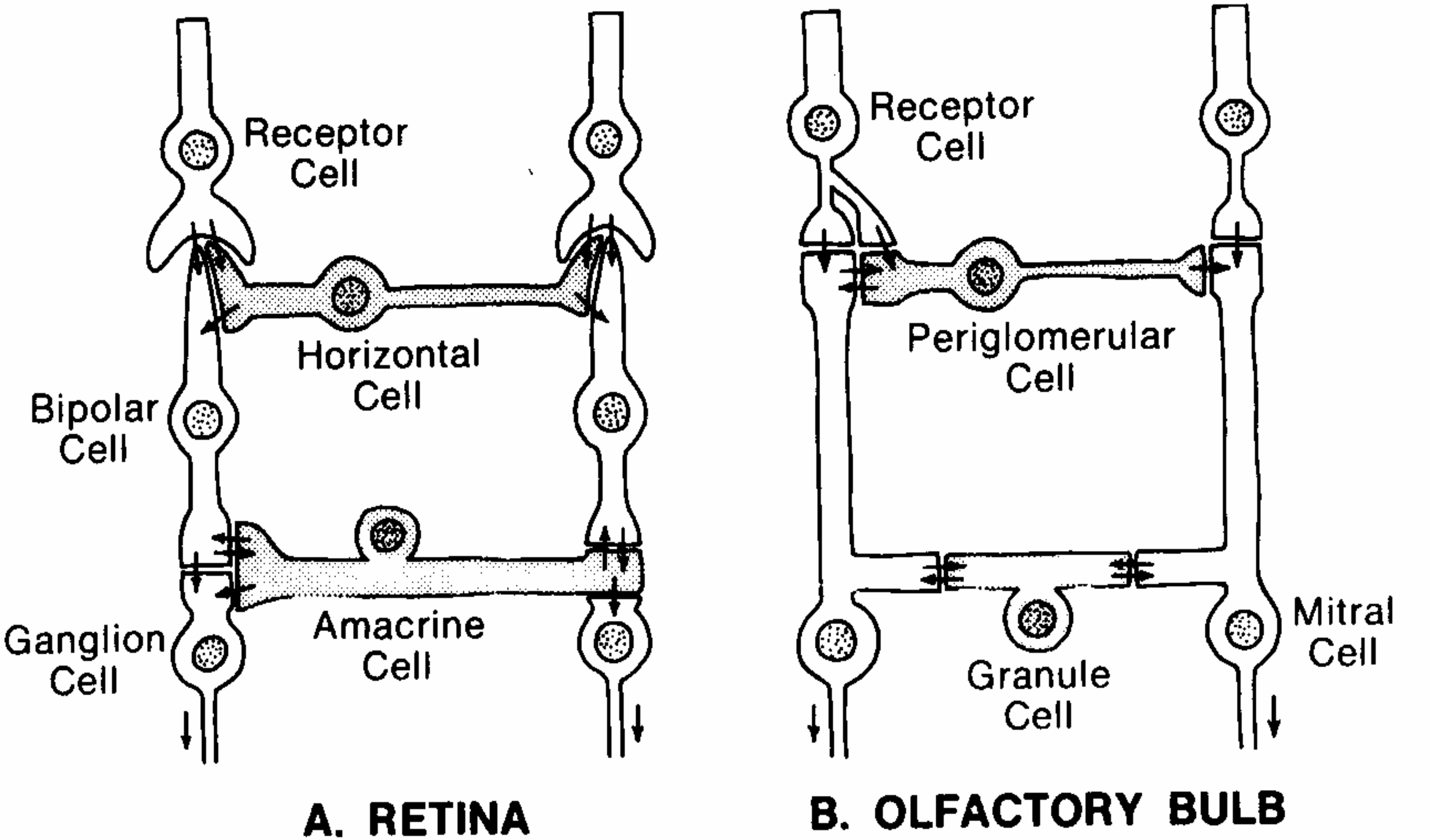
Receptivní pole – různé velikosti



Receptivní pole – různé velikosti
Velikost se může dynamicky měnit-sítnice

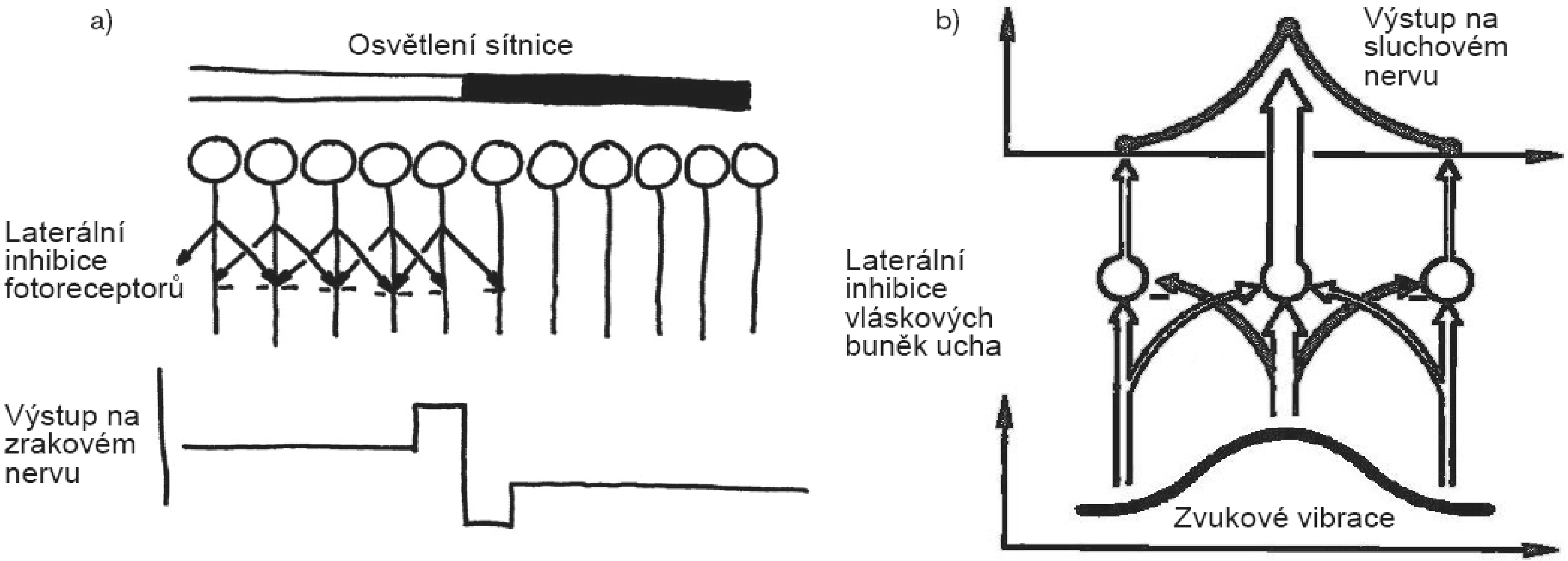


Shodná architektura sensorických drah – shodné požadavky



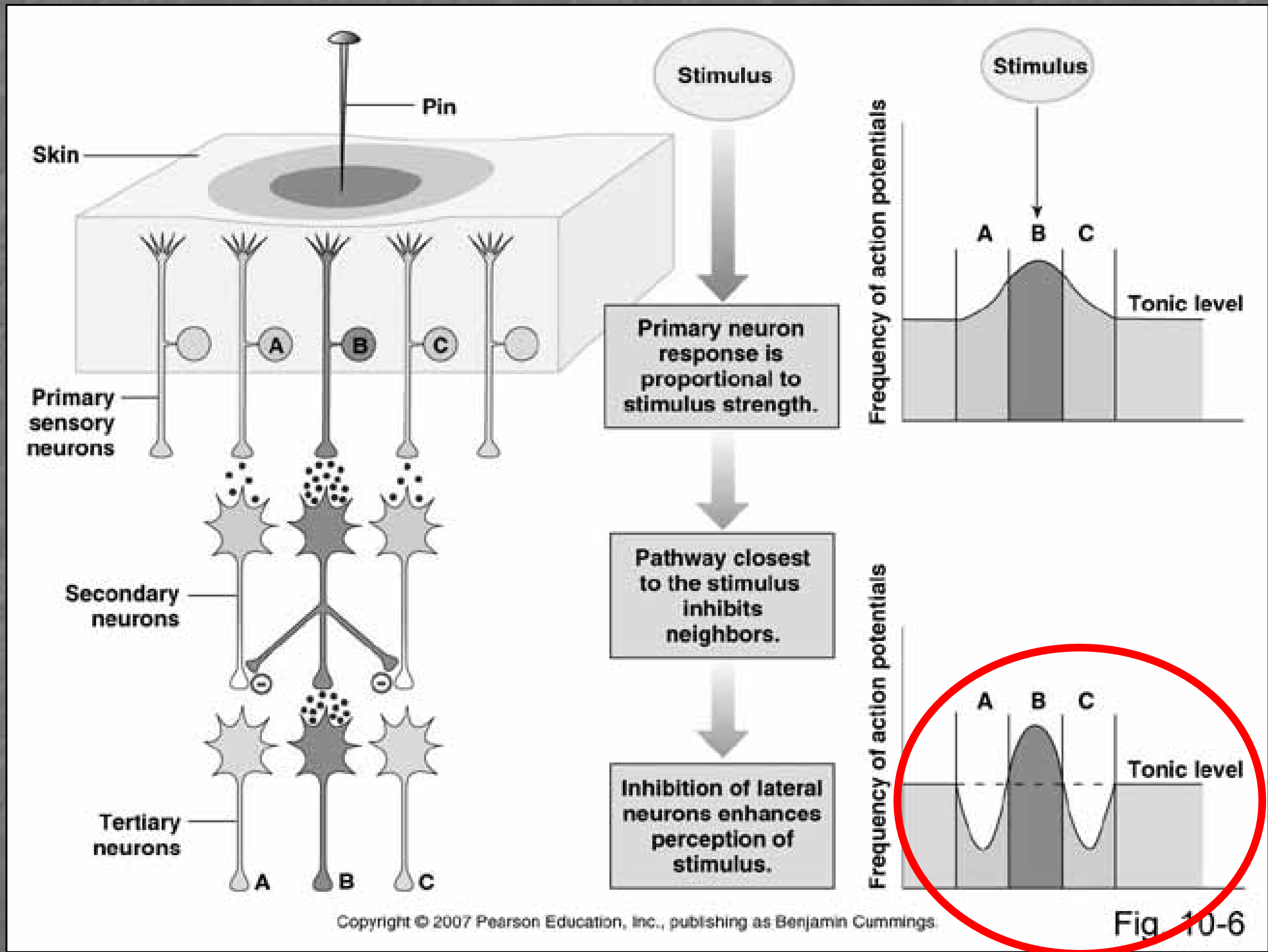
Comparison between simplified basic circuit diagrams of the vertebrate r
bulb. (After Shepherd, 1978)

Laterální inhibice

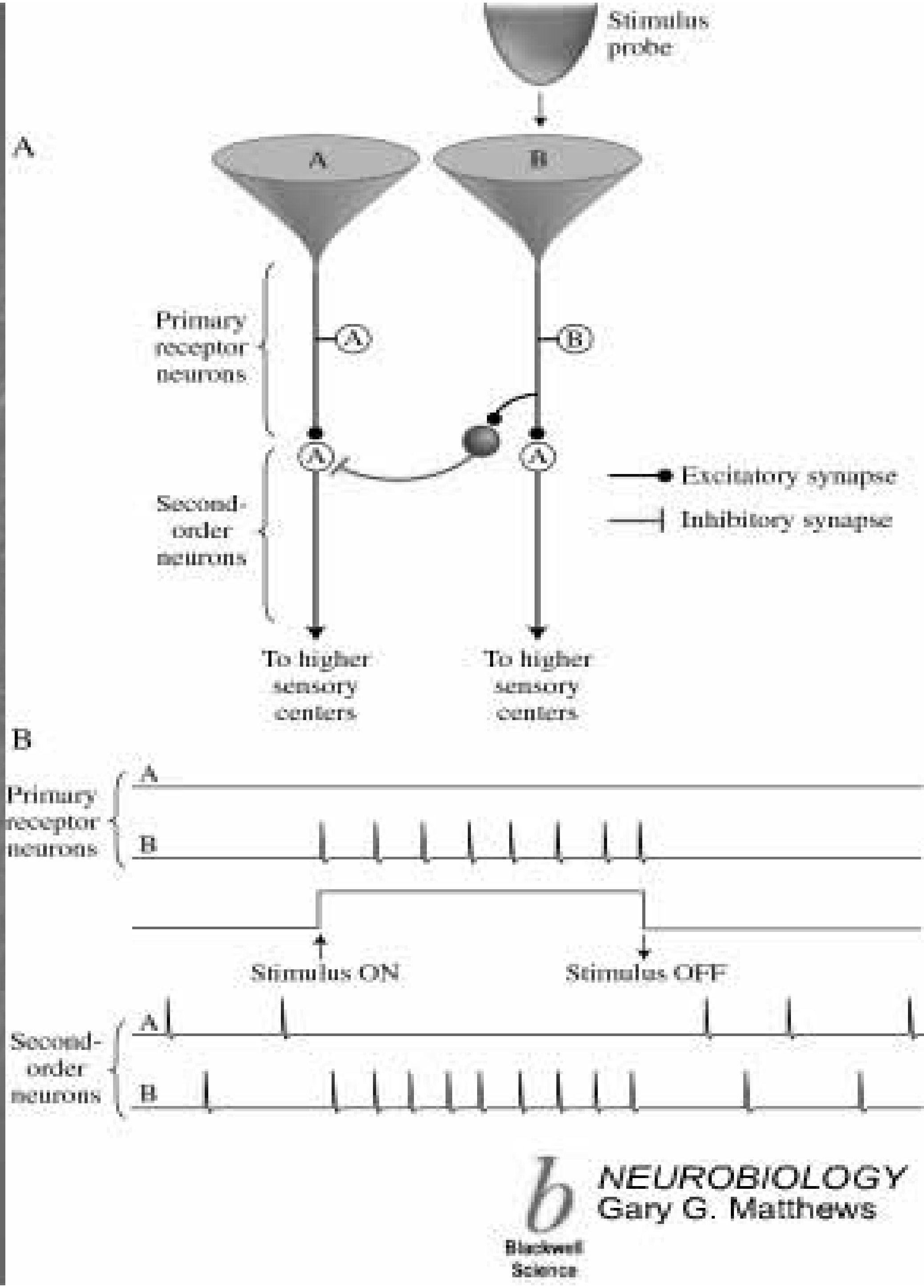


Obr. 4.17. Význam laterální inhibice při zpracování smyslových vstupů. a) Kontrastní přechod mezi osvětlenou a neosvětlenou sítnicí je ještě více zvýrazněn. b) Místo sluchového aparátu (hlemýždě), kde jsou zvukové vibrace maximální, je zvýrazněno proti méně vibrujícímu okolí – kontrast je ještě ostřejší.

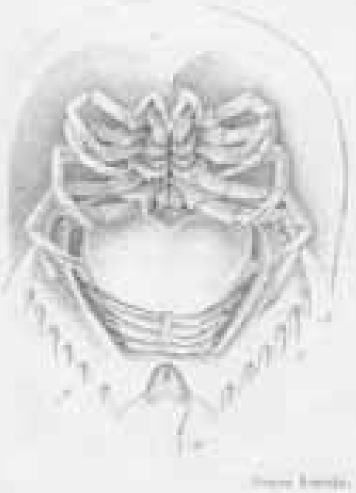
Laterální inhibice



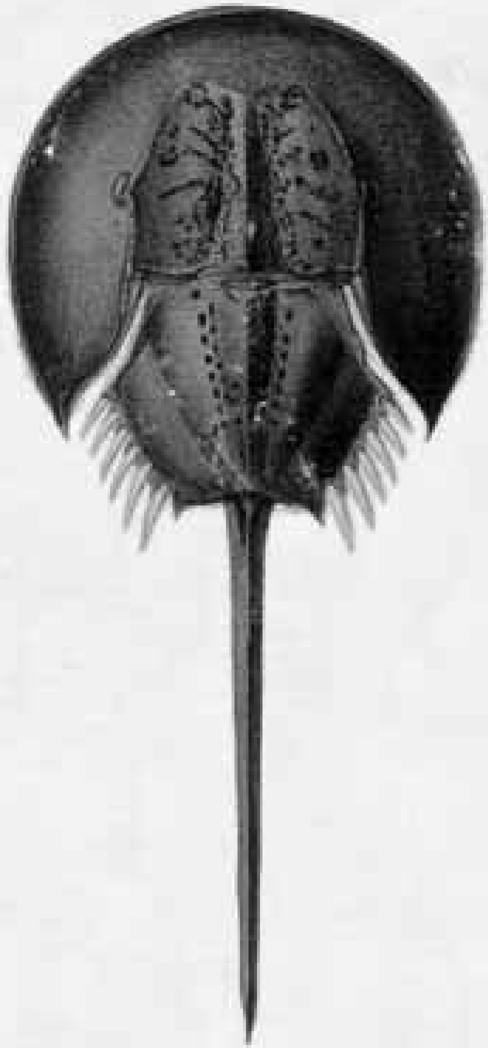
Laterální inhibice



The Horseshoe Crab
Limulus polyphemus

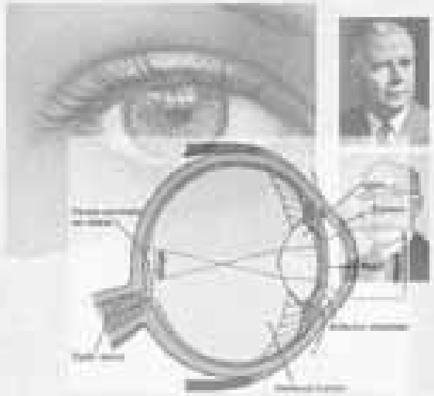


the animal

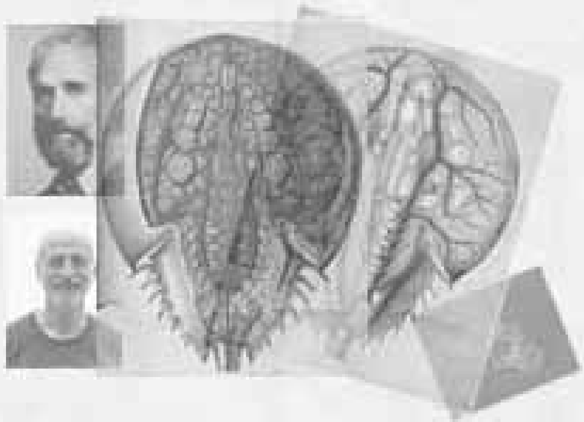


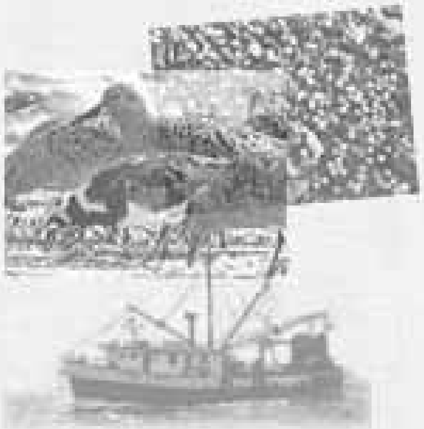
La Limule

MBL Home



the science





the issues

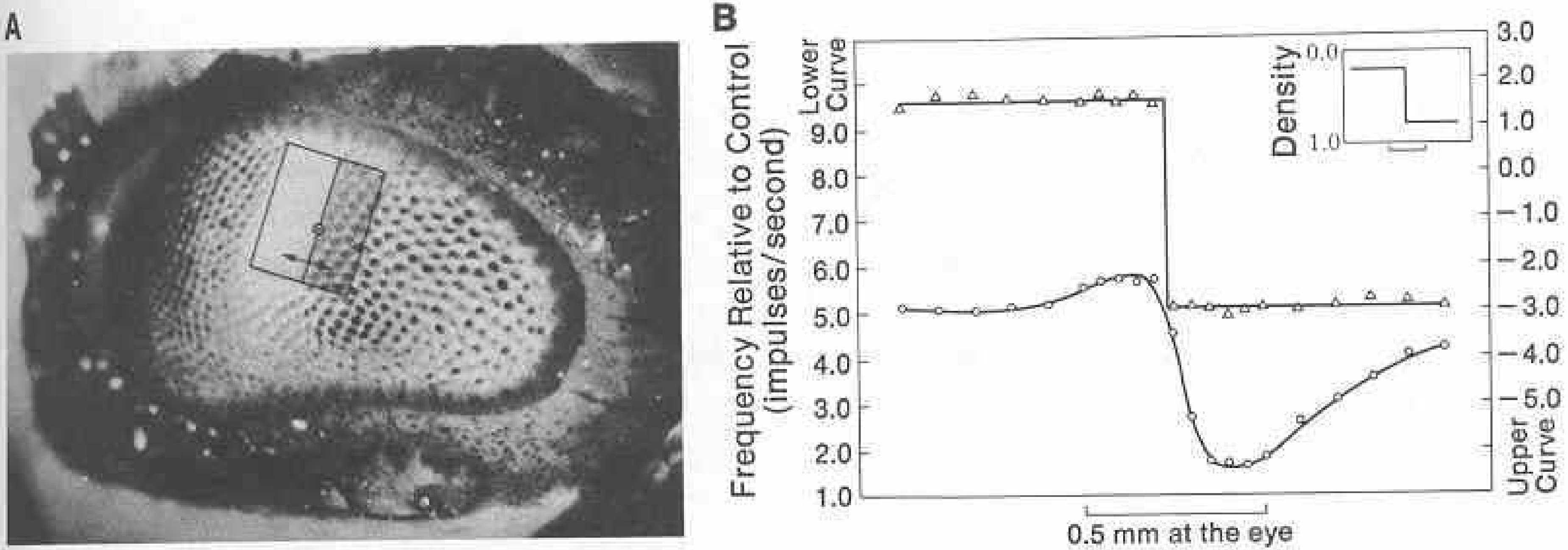
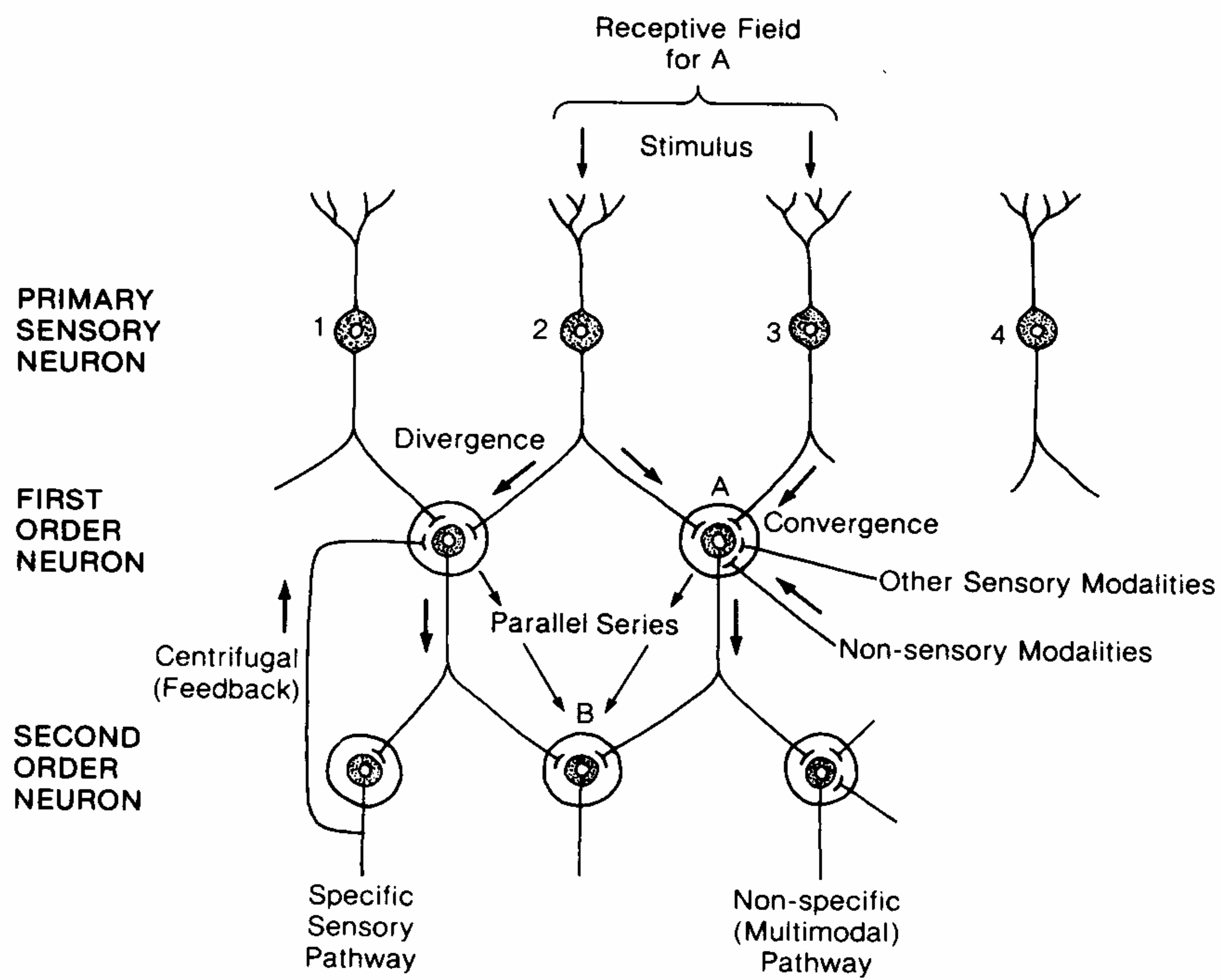
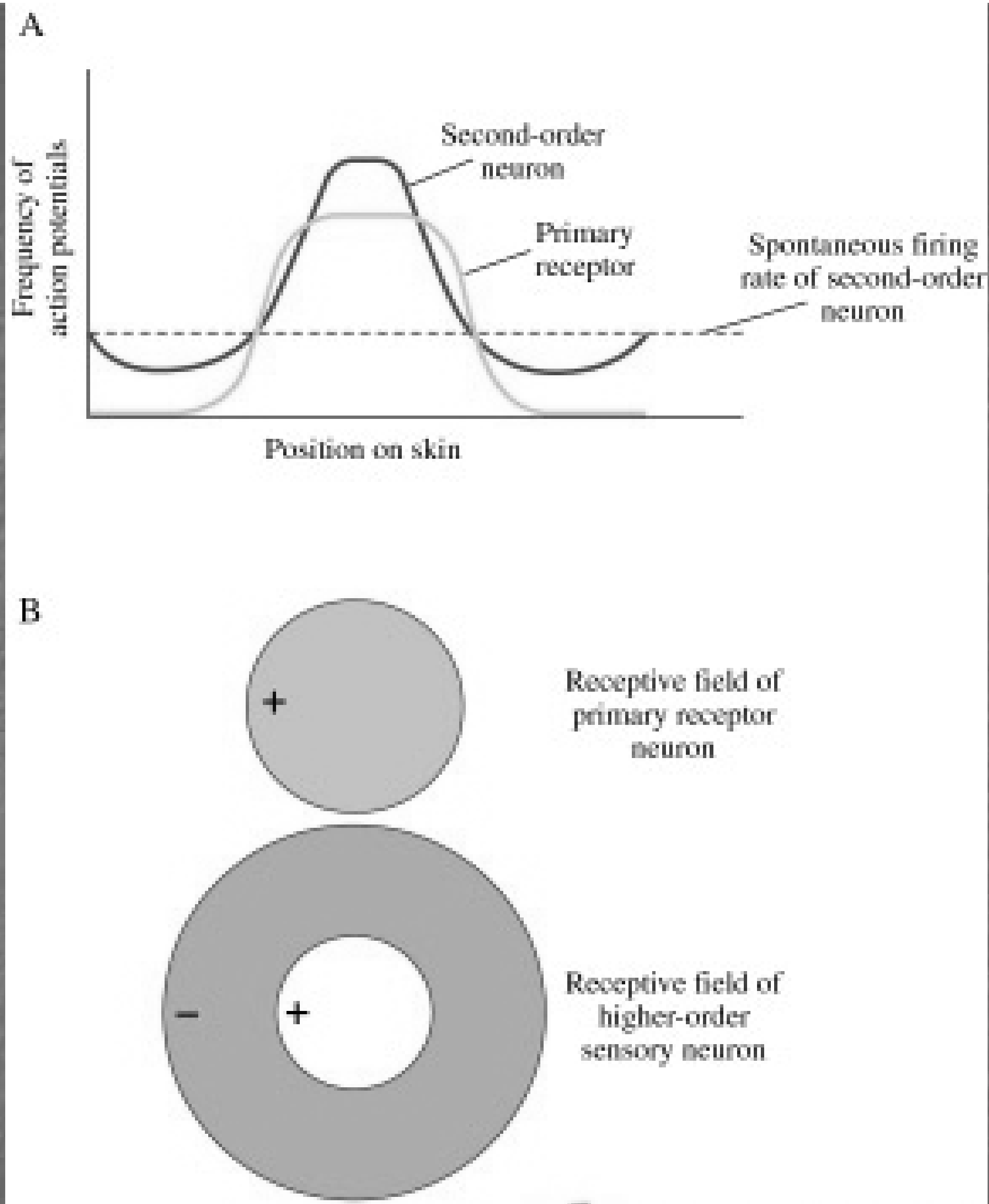


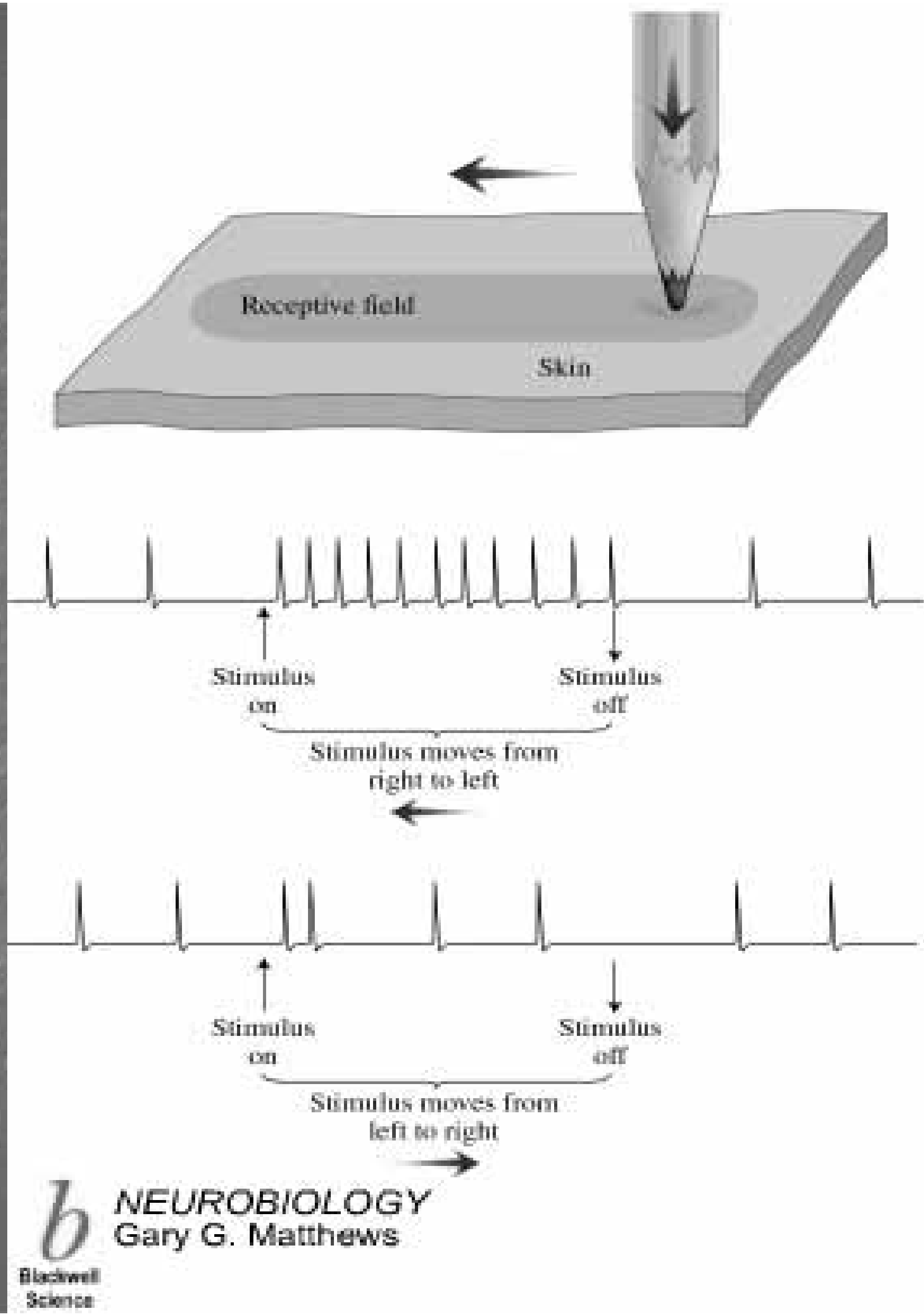
Fig. 10.6 Enhancement of spatial contrast in *Limulus* eye. **A.** Surface of *Limulus* eye, with superimposed rectangular stimulus pattern; pattern is divided into lighter (left) and darker (right) regions. Pattern is centered on test ommatidium (×). Arrows show directions in which the test pattern was displaced, to produce lower curve in graph in B. **B.** Recordings of spike frequency in axon from test ommatidium in A. *Lower curve:* responses to rectangular test pattern in A. *Upper curve:* responses to small spot of light, at high and low intensities corresponding to those of test pattern (see insert). The differences between the two curves illustrate that lateral inhibition enhances the response on the light side of an edge (because there is less inhibition from the more darkly lit neighbors to the right) and depresses the response on the dark side of an edge (because there is more inhibition from the brightly lit neighbors to the left). (From Ratliff, 1965)


Receptive Field
for A
Stimulus
PRIMARY
SENSORY
NEURON
1
2
3
4
Divergence
FIRST
ORDER
NEURON
A
Convergence
Other Sensory Modalities
Parallel Series
Non-sensory Modalities
Centrifugal
(Feedback)
B
SECOND
ORDER
NEURON
Specific
Sensory
Pathway
Non-specific
(Multimodal)
Pathway

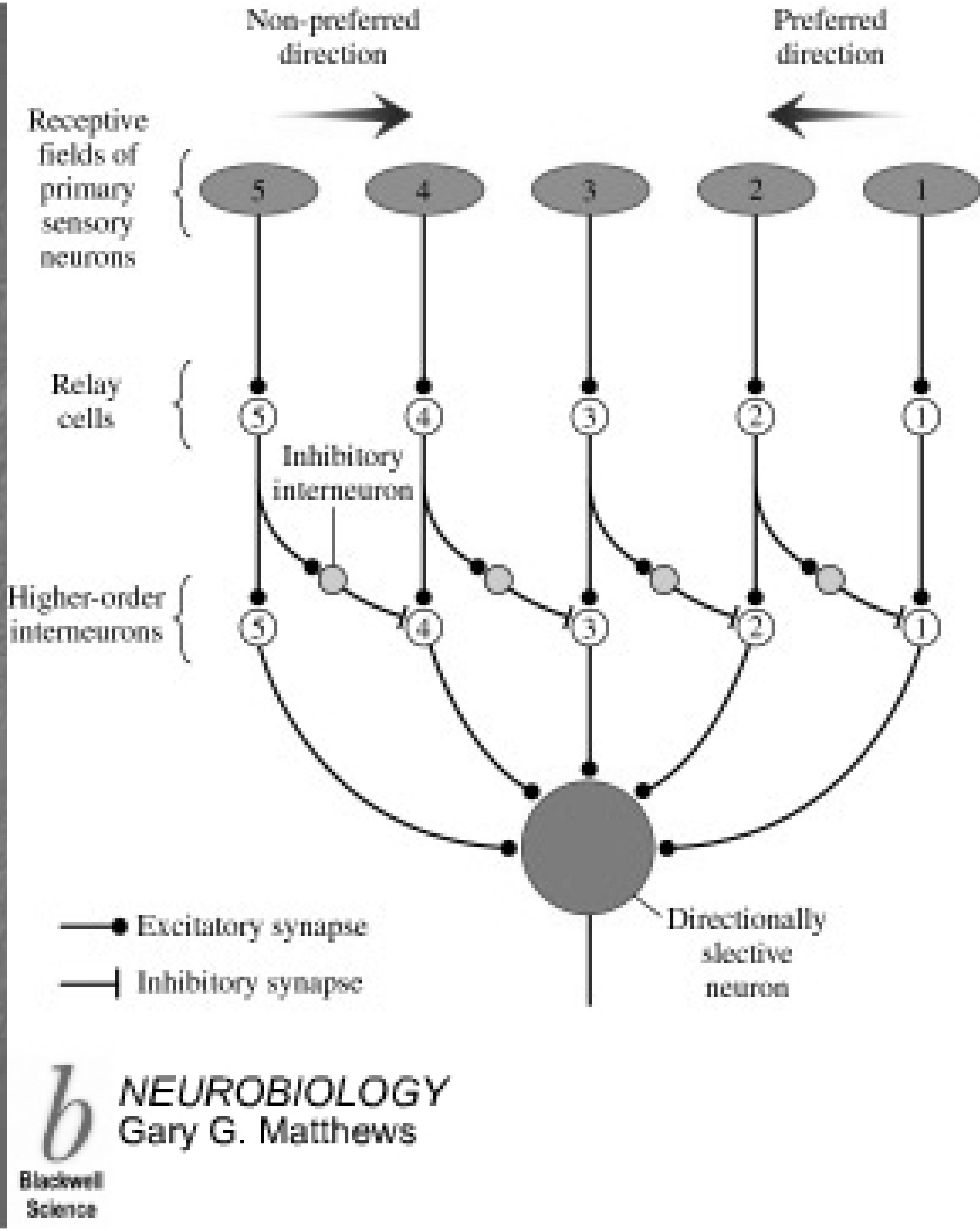


NEUROBIOLOGY
Gary G. Matthews
Blackwell Science

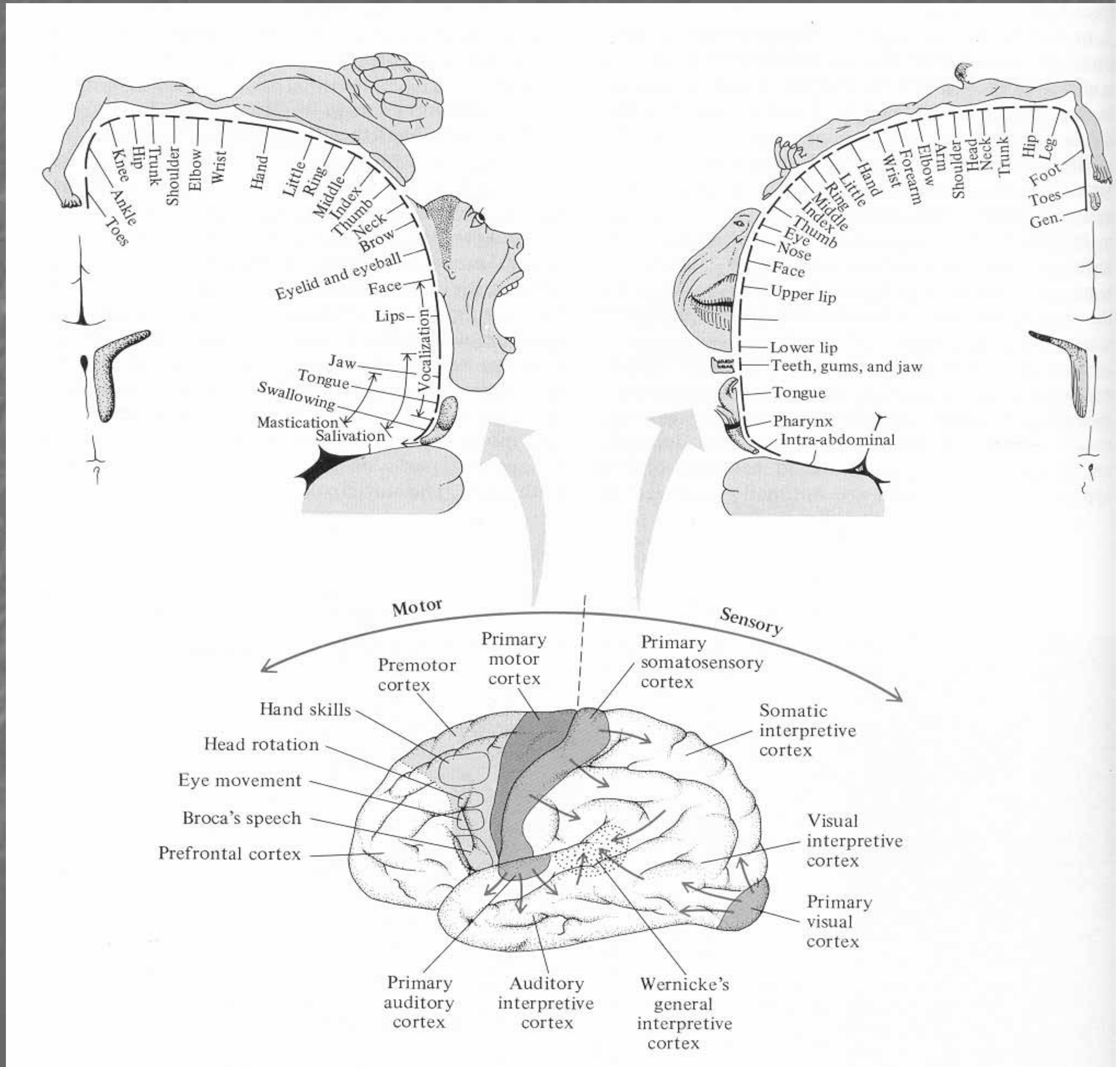
Detektor směru stimulu



Detektor směru stimulu



Topografie drah a polí - Sensorické mapy
- somatotopie
- retinotopie
- tonotopie
- chemotopie

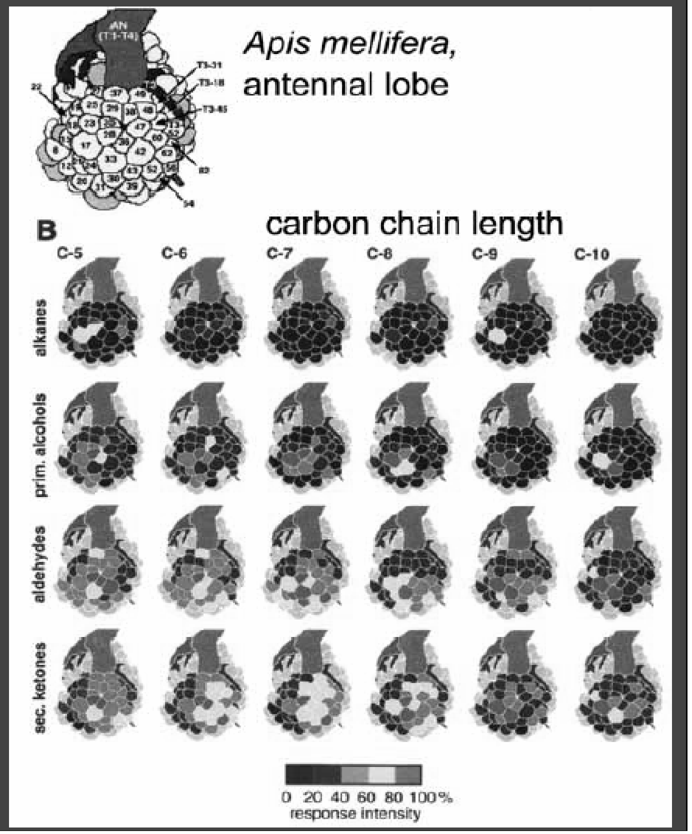


Sensorické mapy
- somatotopie
- retinotopie
- tonotopie
- chemotopie

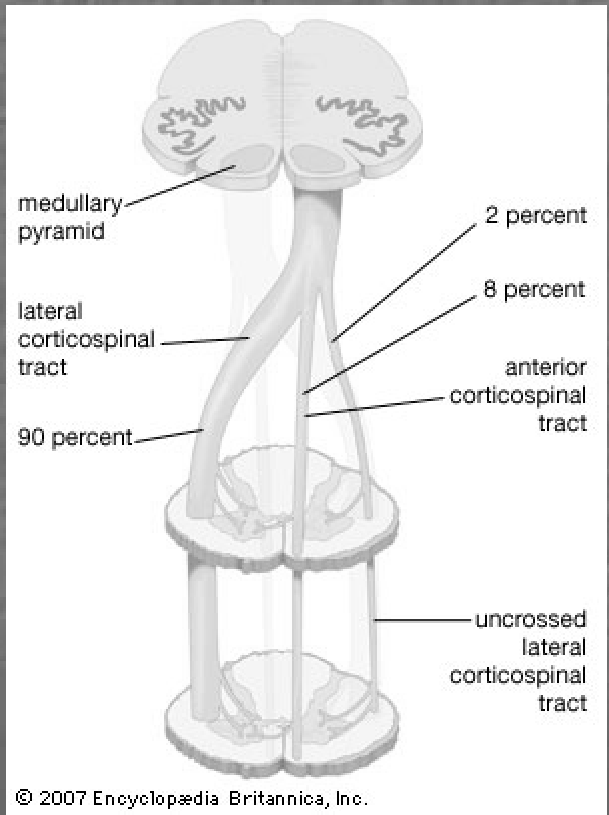
Reprezentace odpovídajících si plošných, ale i neprostorových vlastností.
Rychlost, směr, vůně
.

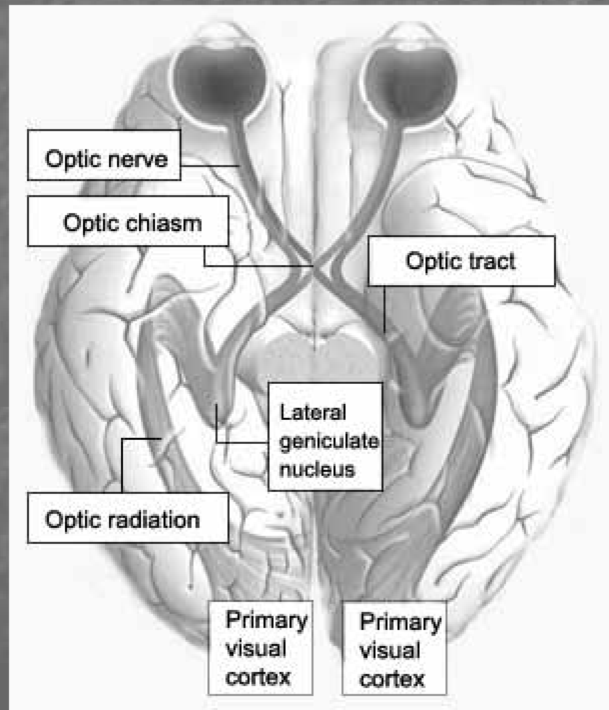
Glomeruli responses reflect odorants' structural properties (chain length, residues, polarity etc.):

odor map



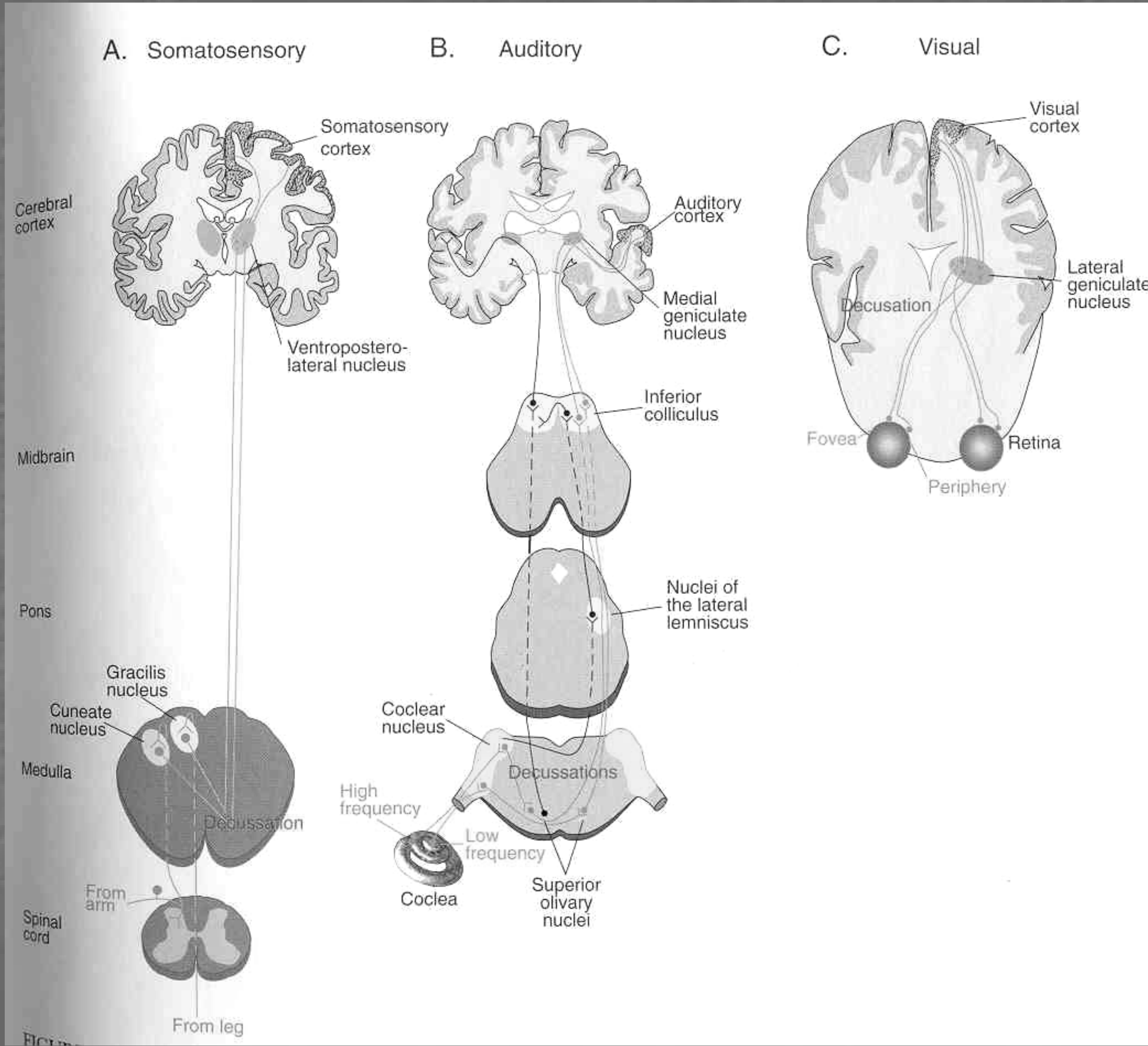
- Axony jednotlivých drah se kříží v centrální rovině před vstupem do thalamu.
- Zraková, sluchová i somatosenzorická dráha.
- Čichová a chuťová dráha ne.





- V rámci jedné modality vedou paralelní dráhy – možná kvůli větší rychlosti zpracování, možná různý původ.
- <u>Sluch</u>: pozice zdroje a parametry zvuku jsou zpracovávány odděleně
- <u>Zrak</u>: odděleně se vyhodnocuje barva, kontury, pohyb, pozice
- Úkol pro CNS zpětně je integrovat do jednoho celku.

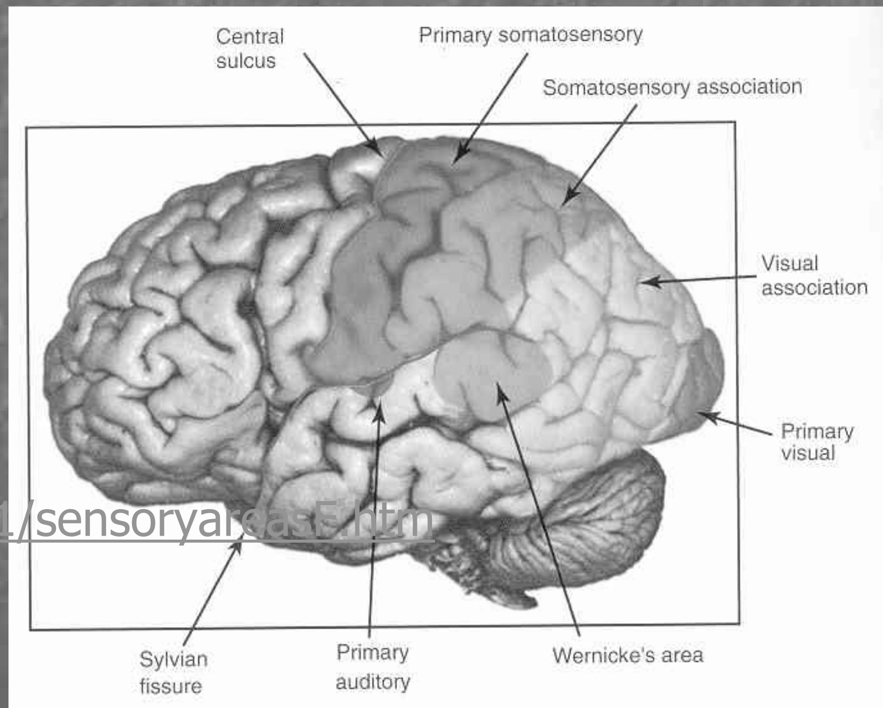
Každý sensorický systém (kromě čichu) má svá specifická jádra v thalamu.



3 úrovně organizace sensorických systémů

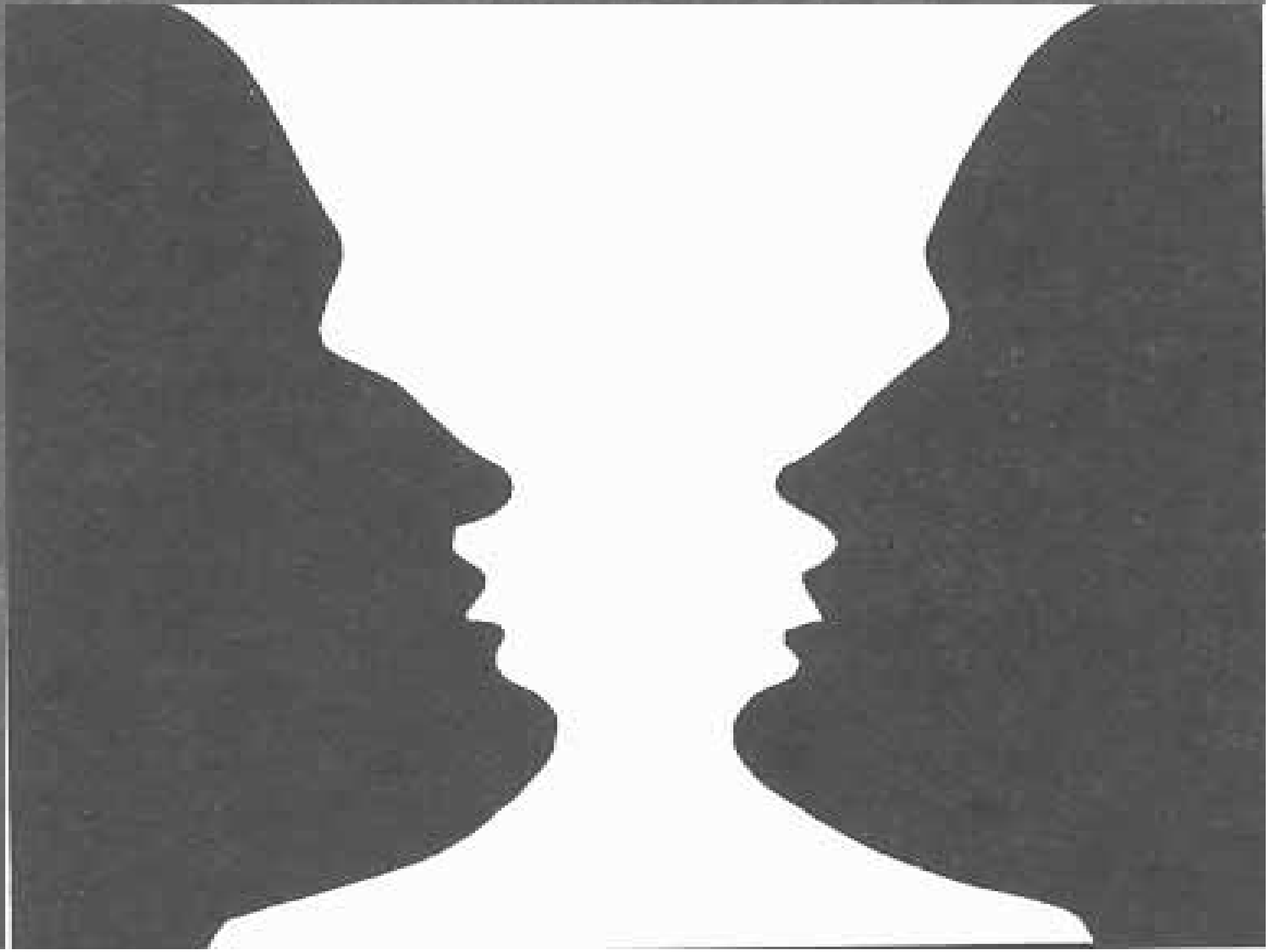
A) Receptory
B) Sensorické obvody a dráhy
C) Sensorická percepce

Sensorický kortex
Primární a sekundární (asociační, interpretační) oblasti kůry. Princip paralelních rysových analyzátorů – specialistů na linie, barvy, tóny, vzdálenosti, směry pohybu atd. Hierarchické skládání do celku

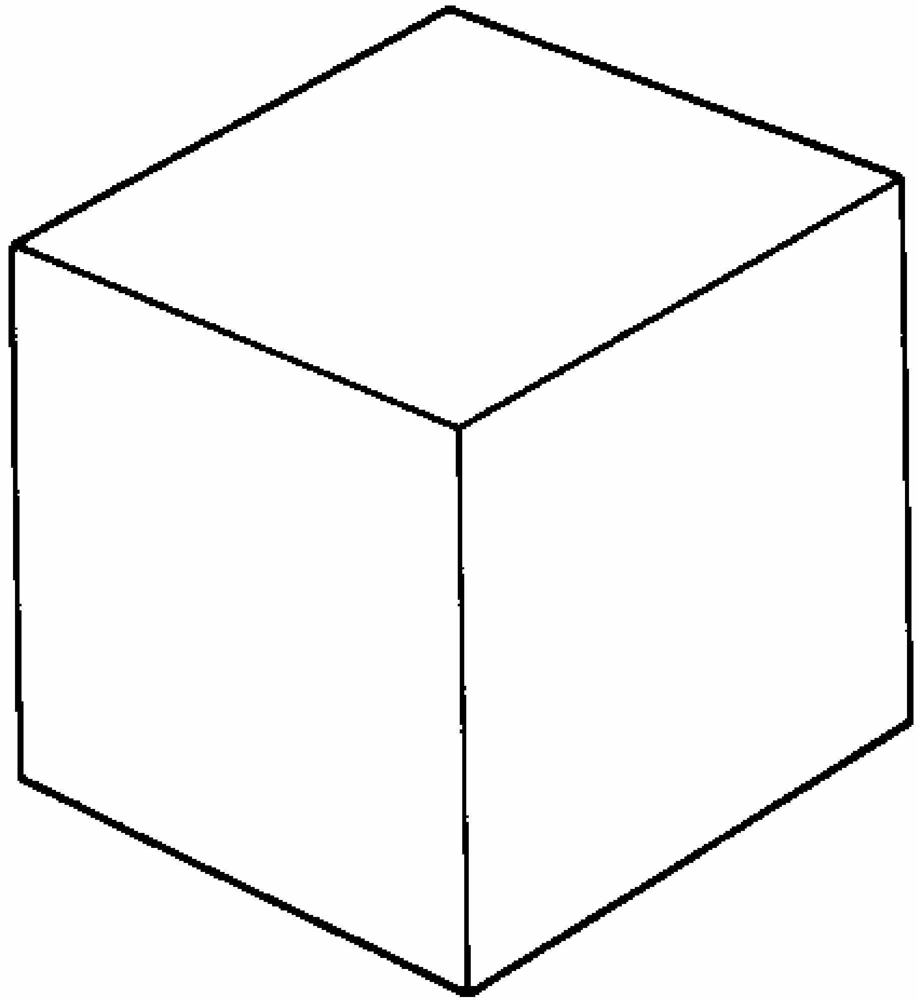


http://www.sinauer.com/wolfe/chap1/sensoryareasF.htm

Co vnímáme, když slyšíme a vidíme? Psychofyziologie.
Velká úloha zkušenosti a interpretace.
Vjemy jsou automaticky zařazovány, aktivně interpretovány.
Identifikace, emoce, paměť.



Co vidíme?



Kam se točí?

Mechanorecepce

- Vedle chemorecepce nejstarší smysl.
- Odhaluje podstatné vlastnosti prostředí. Sluch, hmat, rovnováha, zrychlení, propriorecepce, osmorecepce, hygrorecepce? magnetorecepce?
- Konzervativní molekulární mechanismus
- Typicky rychlé ionotropní řízení kanálů, ale:

- Mechanické podněty mohou zapínat a vypínat geny. V mnohobuněčné tkáni je každá buňka v kontaktu se svými sousedkami i s okolní extracelulární hmotou prostřednictvím mnoha typů přilnavých molekul, které přenášejí mezi buňkami nejen chemické signály, ale i síly mechanické a deformační. Většina buněk není schopna dlouhodobého života, pokud postrádá mechanické kontakty, ať už s okolními buňkami nebo s pevným povrchem.
- Mezenchymální kmenové buňky nasazené na podložky různé mechanické tuhosti diferencují na různé buněčné typy. Na měkkých podložkách se mění v neurony, na středně tuhých podložkách ve svalové buňky a na nejtvrdších v kostní buňky.

(Vesmír 3, 2010)

E. coli

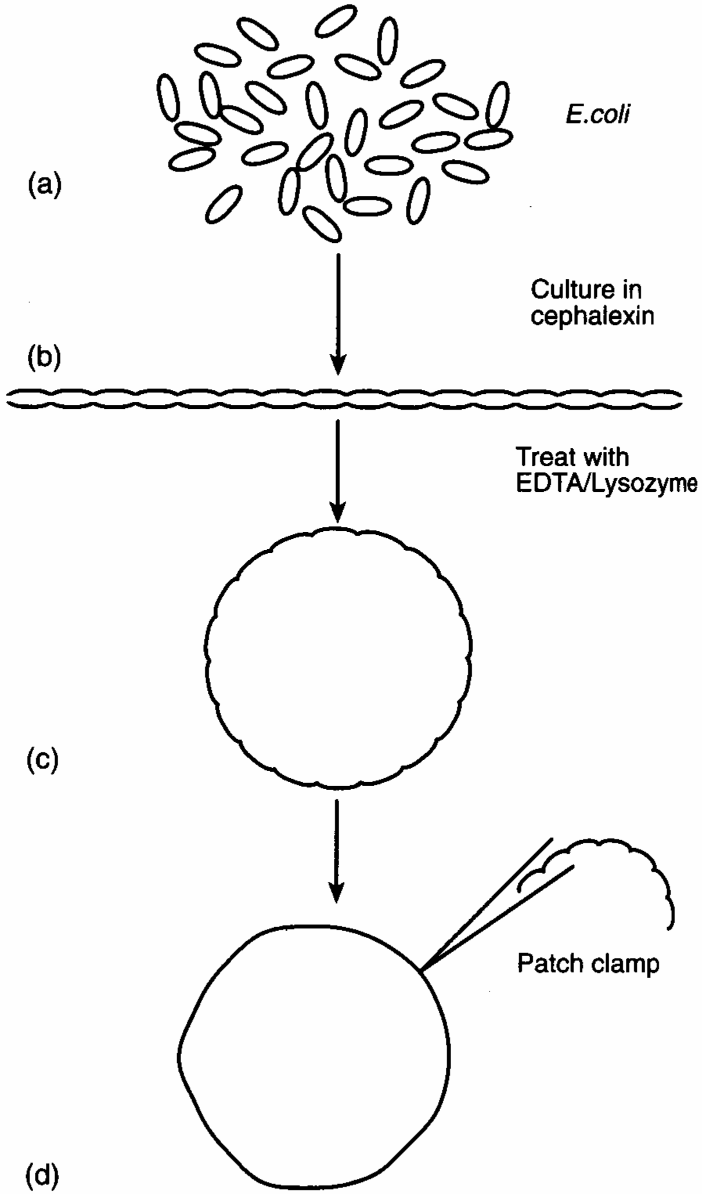
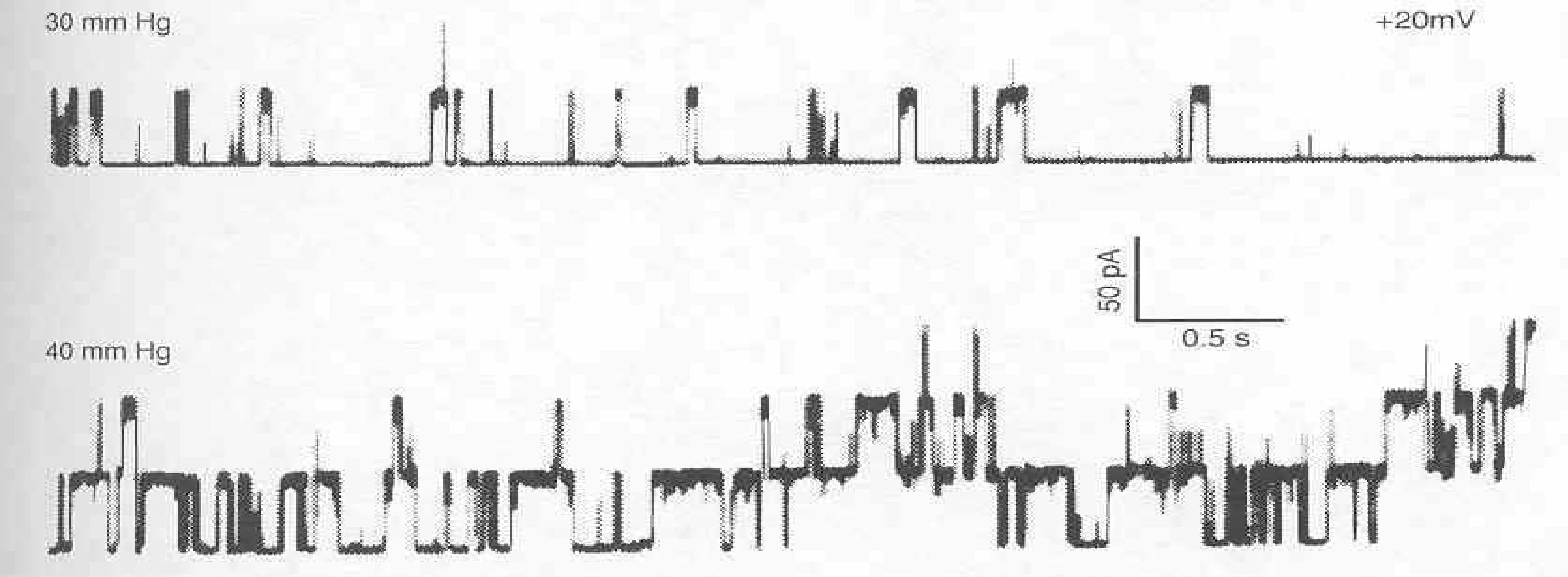
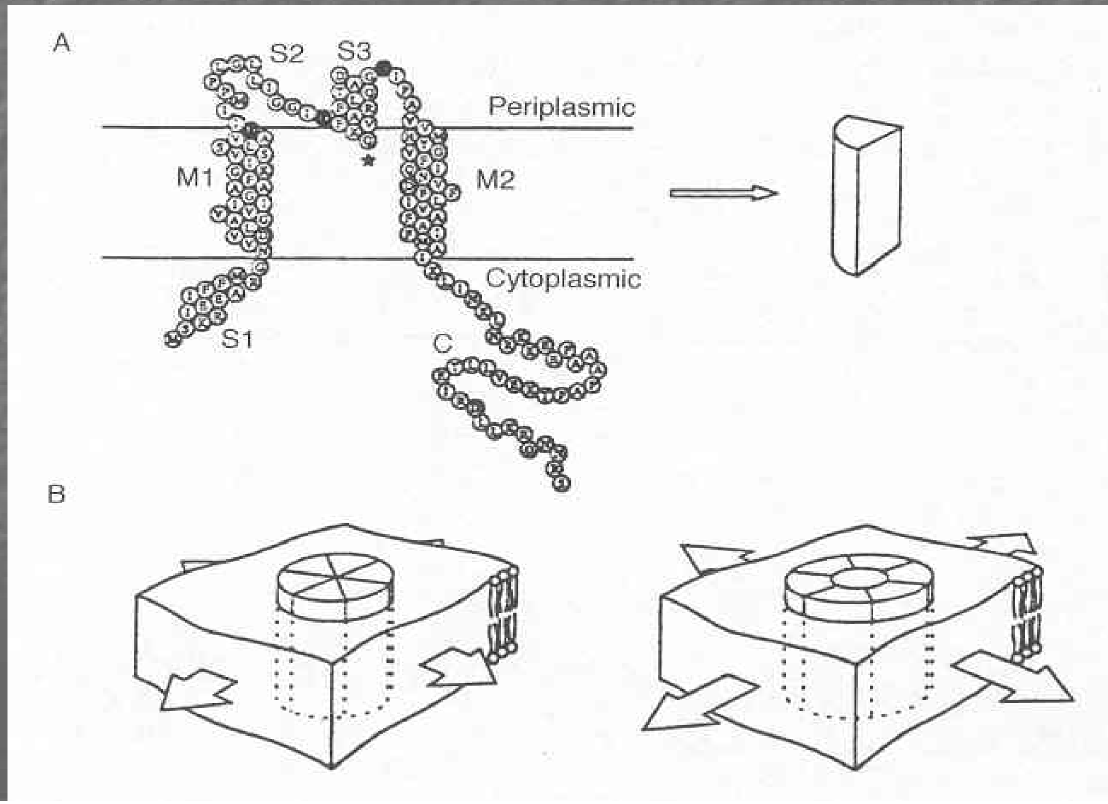


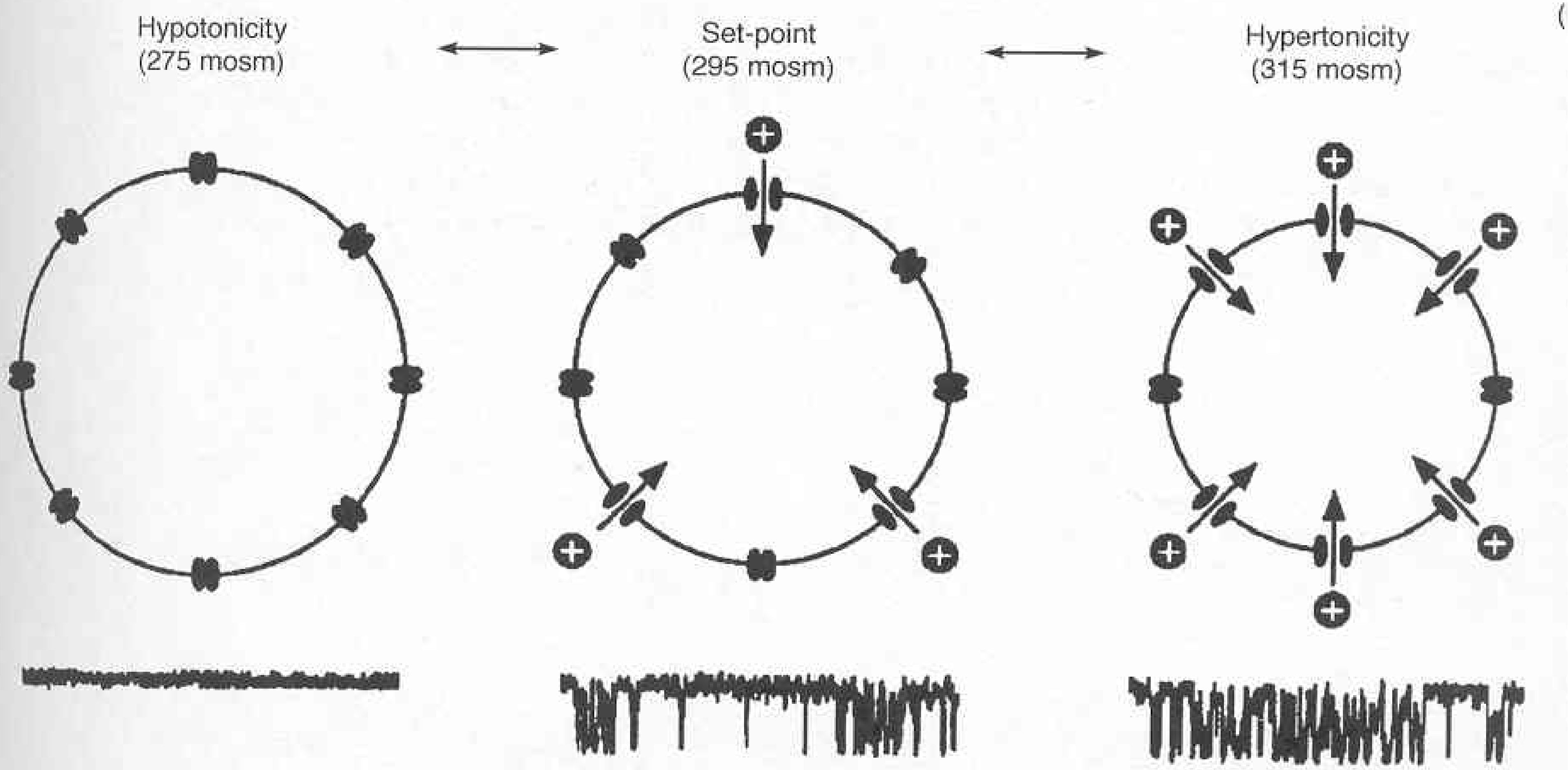
Figure 5.1 Patch-clamping *E coli*. (a) *E. coli* cell. (b) Cultured in medium containing cephalexin and forms lengthy filaments. (c) Filament treated with EDTA/lysozyme and rounds-up to form large spheroplast. (d) Microelectrode (tip diameter about 0.5 mm) inserted to form a patch-clamp. Further explanation in text

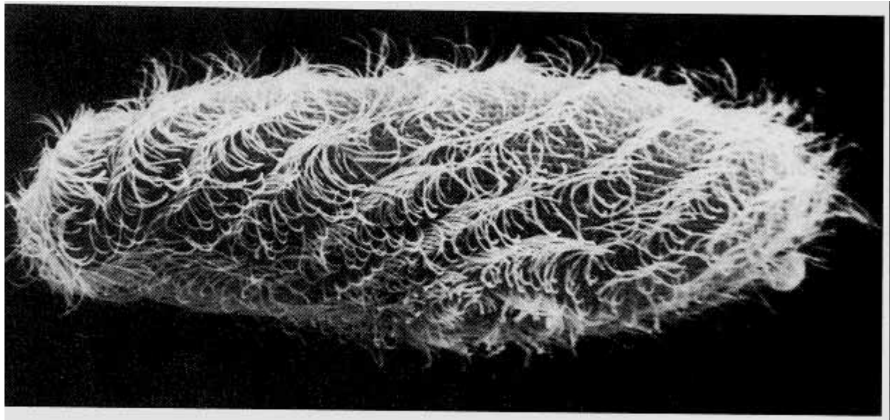


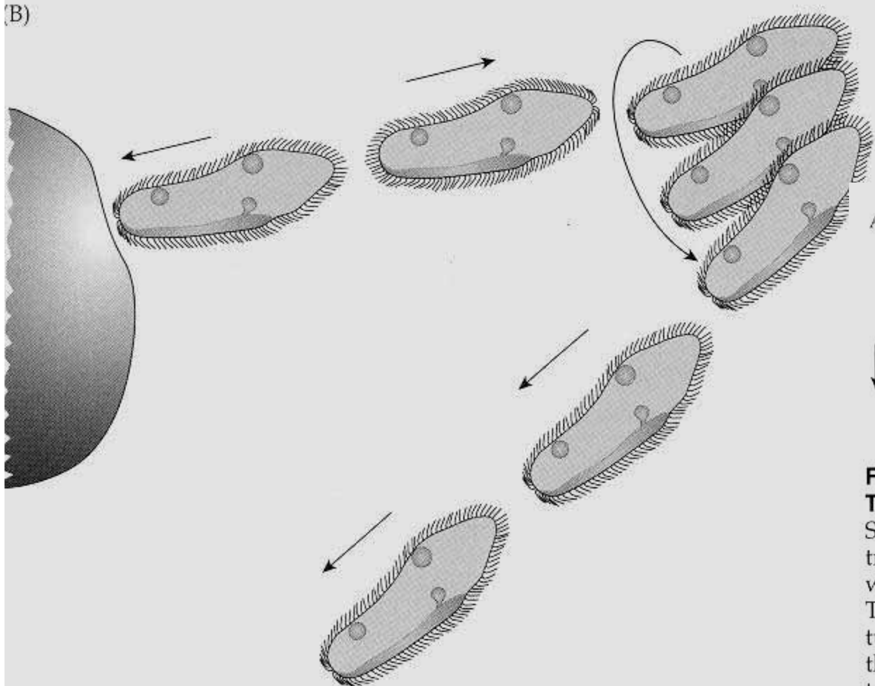
MscL kanál.
Největší známý
 kanál 2,5nm.
Chrání proti nárazům
osmolarity.



Savčí osmosensitivní buňka hypotalamu – spojení na hormonální osy vodního hospodaření.







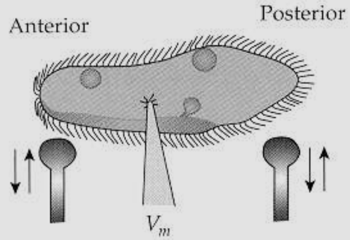
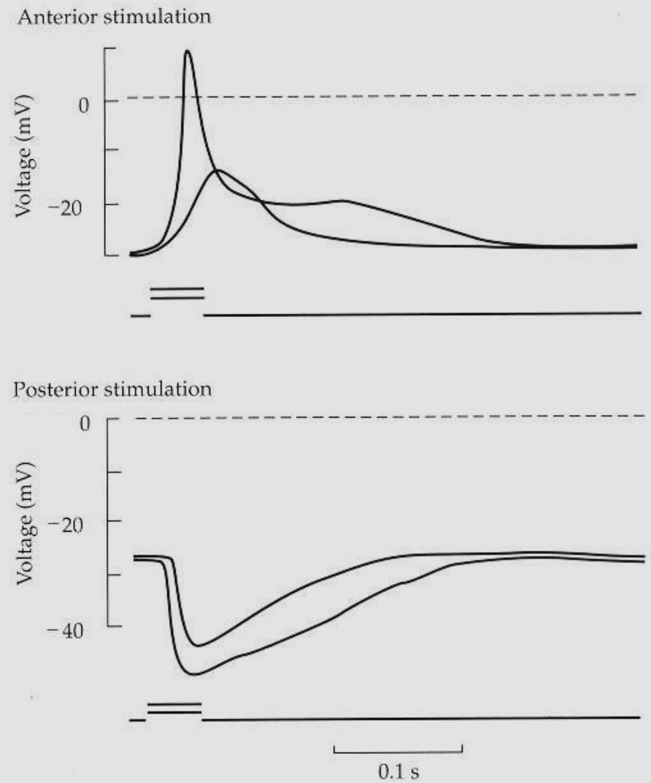
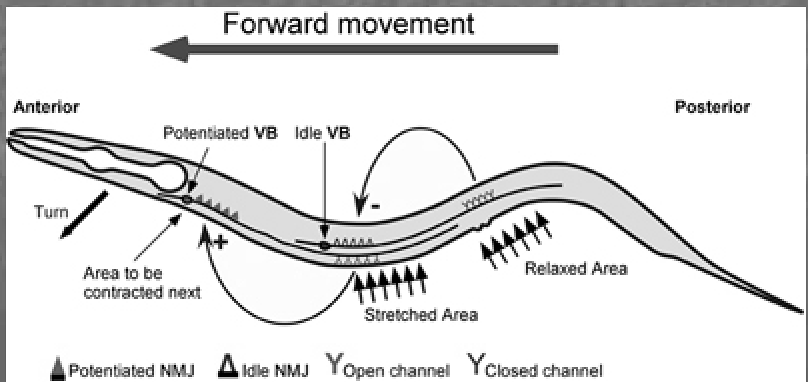


Figure 5.2
Touch responses of *Paramecium*
Stimuli were produced by an electrically driven microstylus that was pressed up against the cell. The timing and relative amplitude of the stimuli are shown in the traces below each of the electrical recordings. Two amplitudes of pressure were applied at each location. (From Eckert, 1972.)



Paramecium

Caenorhabditis elegans (háďátko)
960 buněk
302 neuronů
1998 genom



Caenorhabditis elegans – háďátko

15 genů *mec*

Mutace *mec* – ztráta reakce

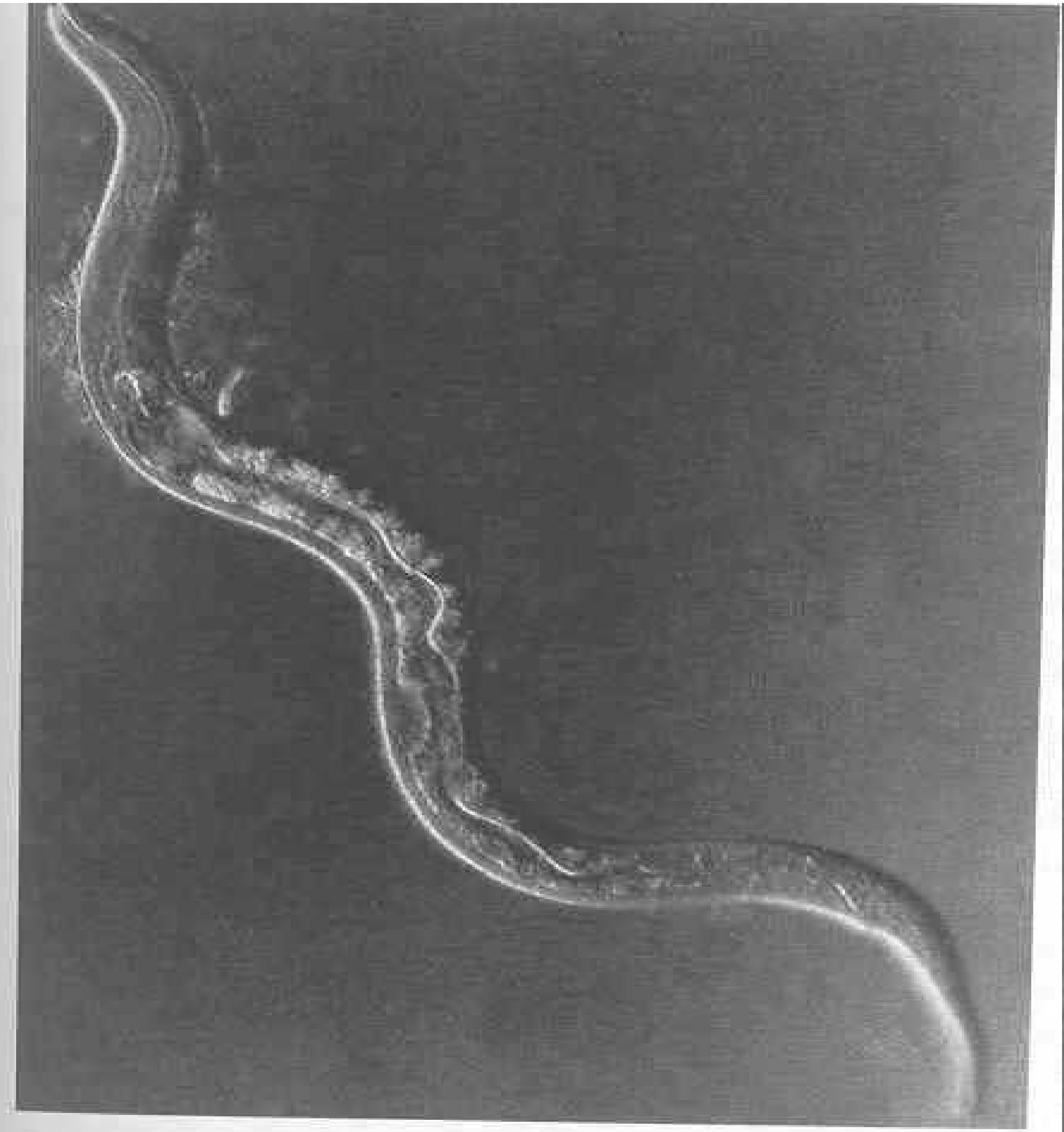
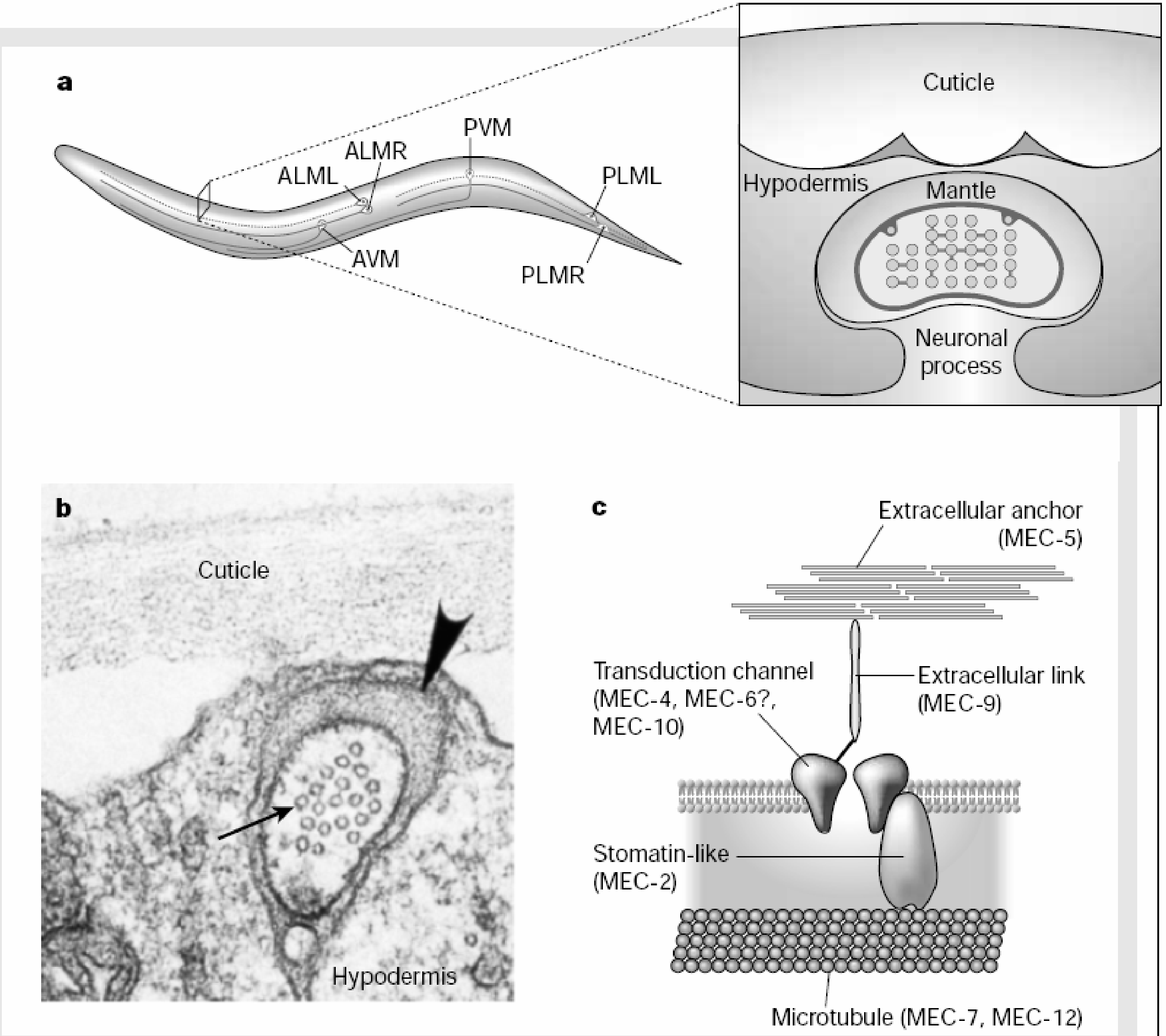


Figure 7.1 *Caenorhabditis elegans.* This worm is about 200 mm in length. *C. elegans* consists of 959 somatic cells of which 302 constitute the nervous system. The body is translucent and many of its cells can be distinguished in the living animal. Reprinted from J. G. White, 1985, 'Neuronal connectivity in Caenorhabditis elegans', *Trends in Neurosciences* 8, 277 with permission from Elsevier Science

6 hmatových neuronů se svazky mikrotubulů

Figure 2 *C. elegans* touch-receptor structure and transduction model. **a**, View of *C. elegans* showing positions of mechanoreceptors. AVM, anterior ventral microtubule cell; ALML/R, anterior lateral microtubule cell left/right; PVM, posterior ventral microtubule cell; PLML/R, posterior lateral microtubule cell left/right. **b**, Electron micrograph of a touch-receptor neuron process. Mechanotransduction may ensue with a net deflection of the microtubule array relative to the mantle, a deflection detected by the transduction channel. Arrow, 15-protofilament microtubules; arrowhead, mantle. Modified from ref. 3. **c**, Proposed molecular model for touch receptor. Hypothetical locations of *mec* proteins are indicated.



Bohaté na mikrotubuly

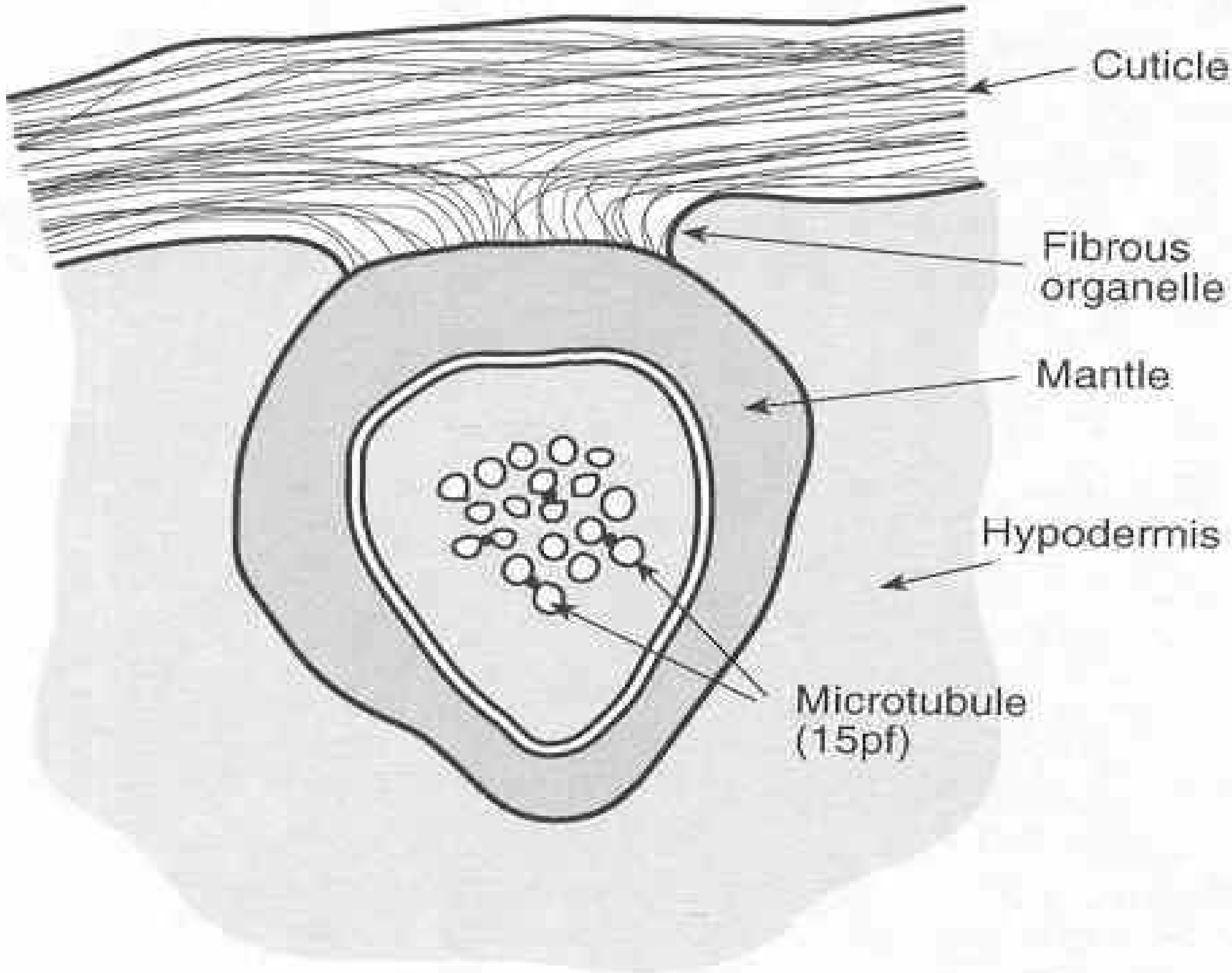


Figure 7.3 Ultrastructure of *C. elegans* touch receptor neuron in transverse section. The neuron is surrounded by a connective tissue mantle and is attached to the cuticle by a 'fibrous organelle'. It contains a bundle of microtubles (each composed of 15 protofilaments (pf)). After Tavernarakis and Driscoll, 1997

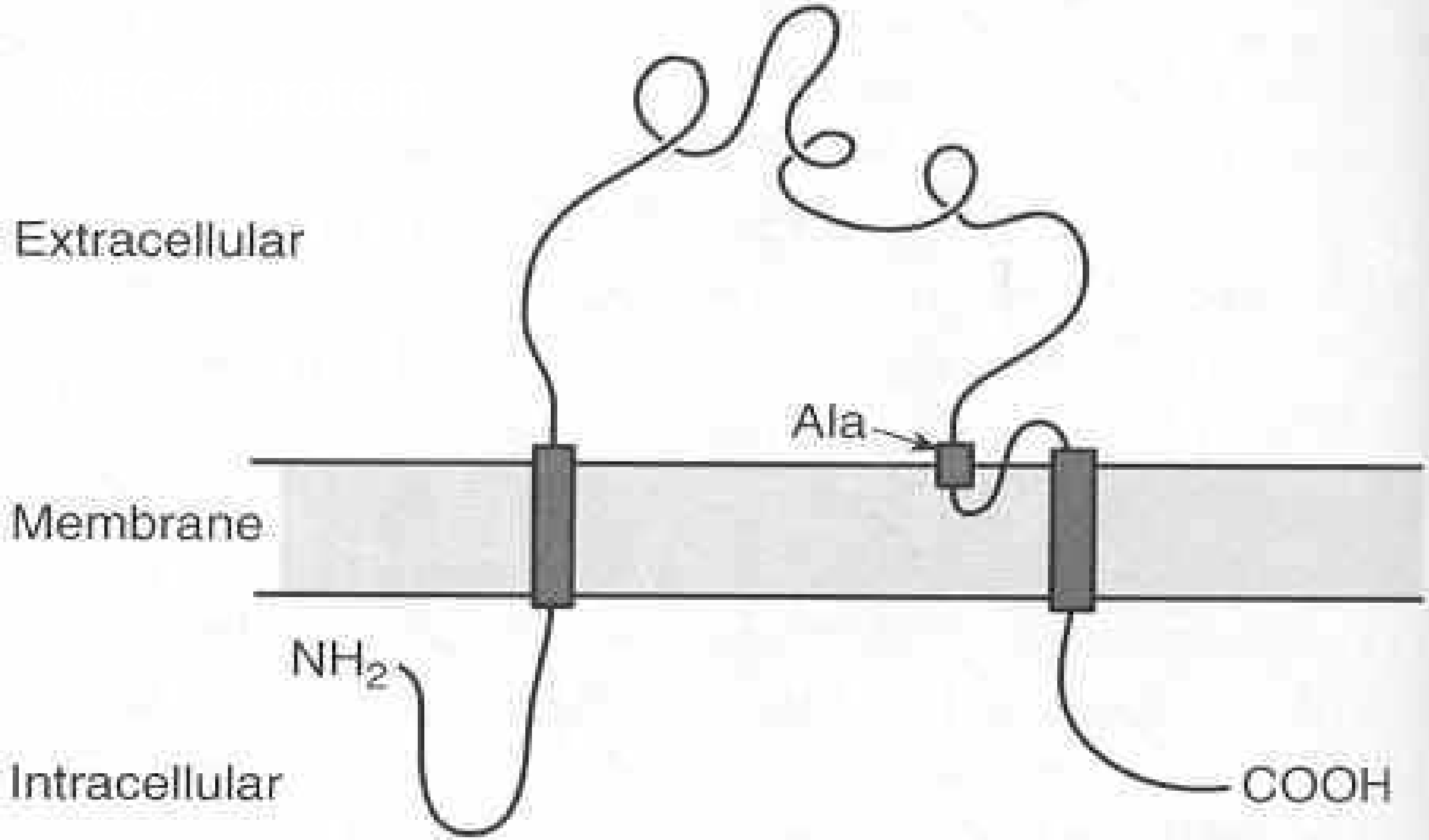


Figure 7.4 Transmembrane topology of the MEC-4 protein. There are two transmembrane domains and a small membrane insertion just before the second transmembrane helix. The bulk of the 768 residue protein is, as indicated, in the extracellular space. When Alanine_{713} (Ala) is replaced by a bulkier amino acid cell death ensues. After Tavernarakis and Driscoll, 1997

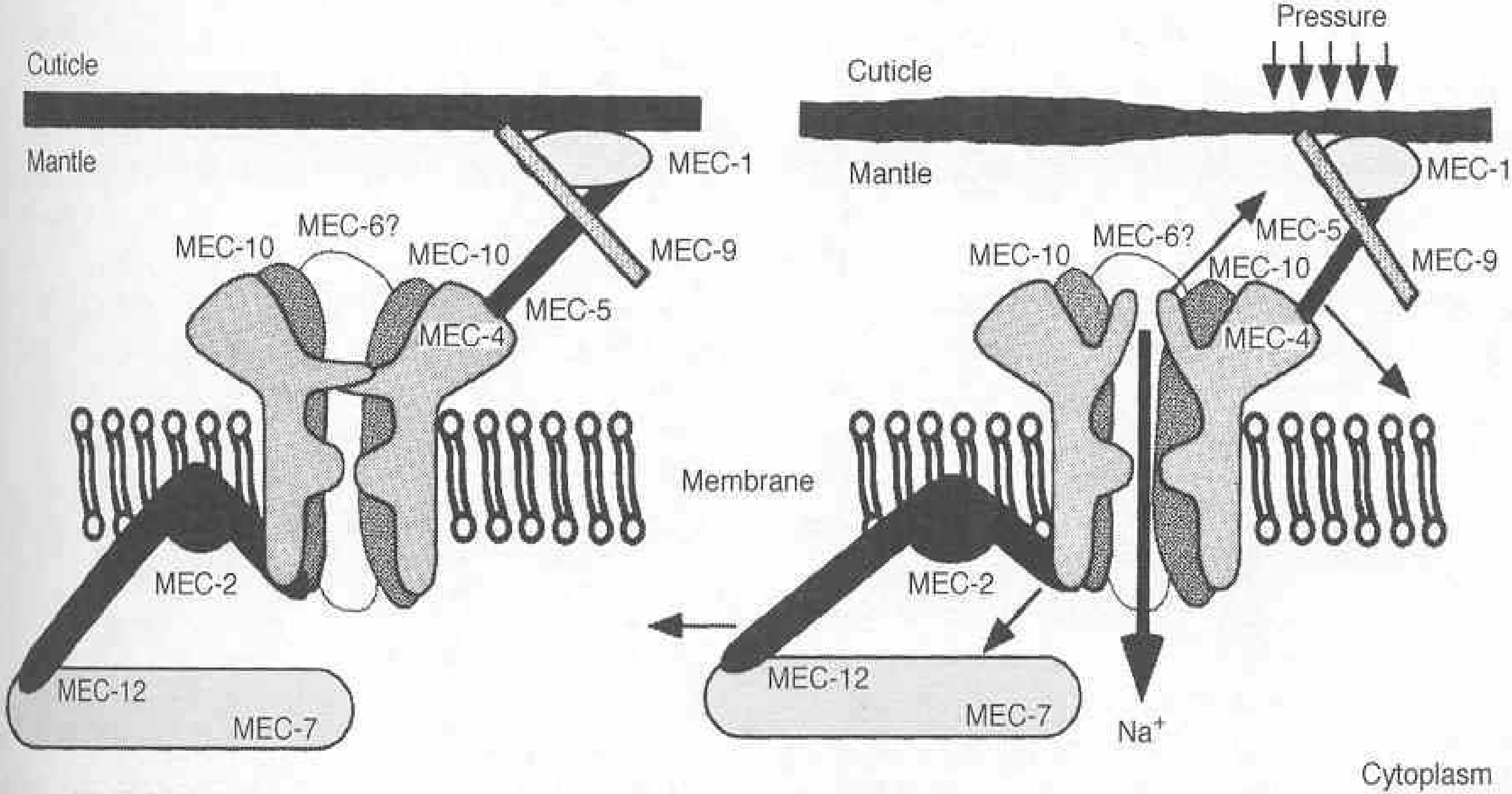
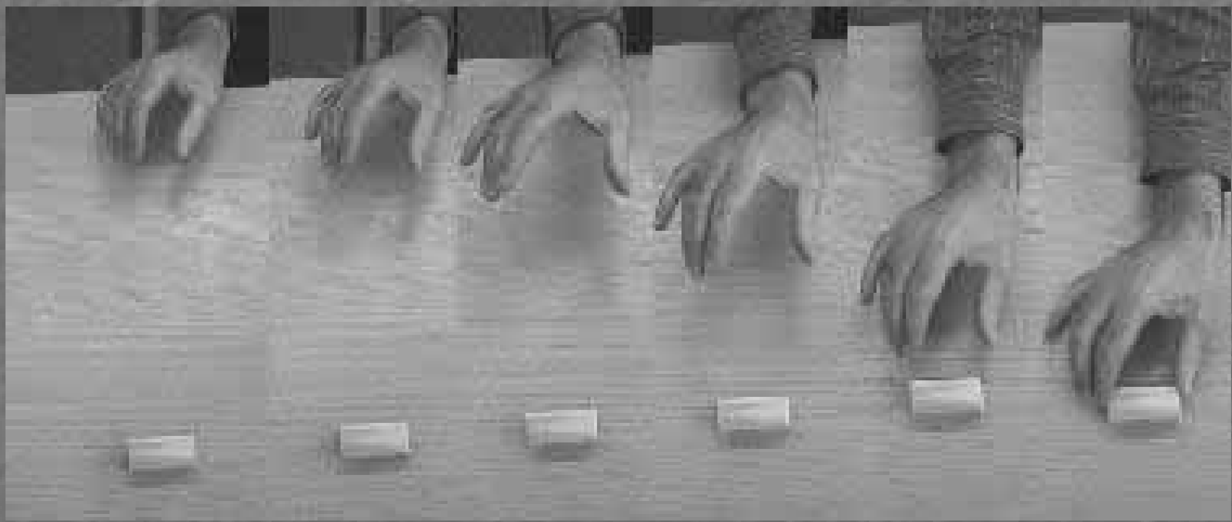


Figure 7.6 Conceptual model of *C. elegans* touch receptor. Explanation and nomenclature in text. From N. Tavernarakis and M. Driscoll, 1997, 'Molecular modelling of mechanotransduction in the nematode *Caenorhabditis elegans*', *Annual Review of Physiology*, **59**, 679. With permission, from the *Annual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

Propriorecepce- somatický smysl



Aktivní zvířata potřebují informace o poloze těla a končetin
S exoskeletem odlišně od endoskeletu

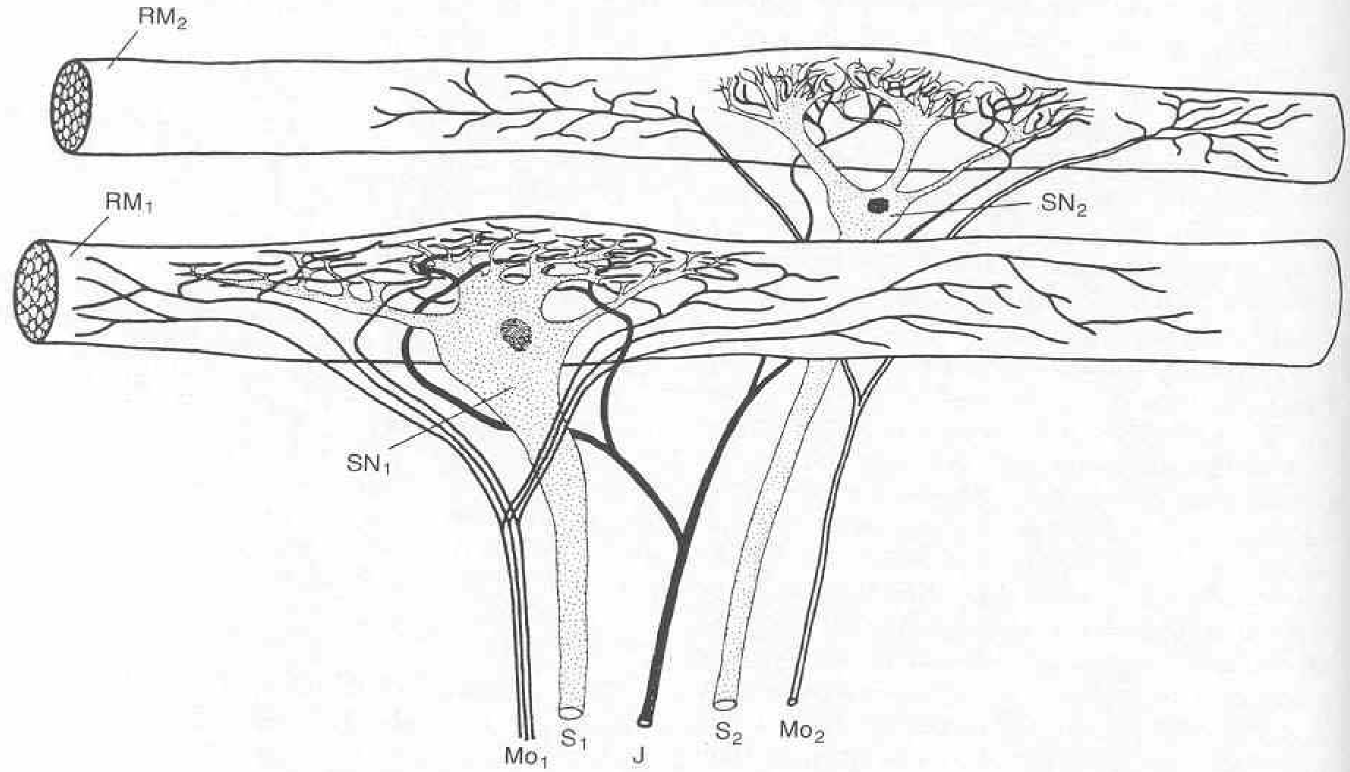
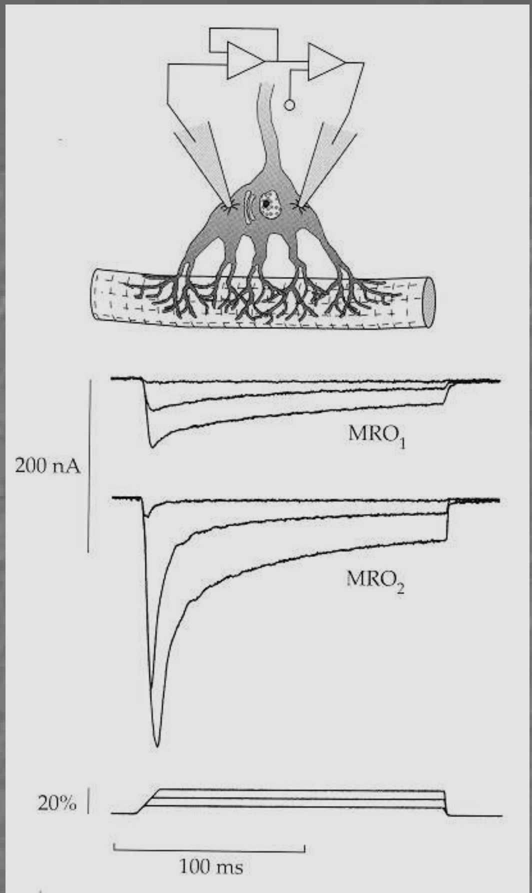


Figure 6.1 Schematic drawing of the stretch receptors in the abdominal segments of the crayfish, *Astacus fluviatilis*. RM1, RM2 = receptor muscles 1 and 2. SN1 = slow adapting sensory neuron; SN = fast adapting sensory neuron; S1, S2 = sensory fibres; Mo1 = three thin motor fibres to RM1; Mo2 = thick motor fibre to RM2; J = inhibitory fibre. From *Handbook of Physiology*, Section 1, Volume 1, *Neurophysiology* (1959), p. 378. Reproduced by permission of The American Physiological Society

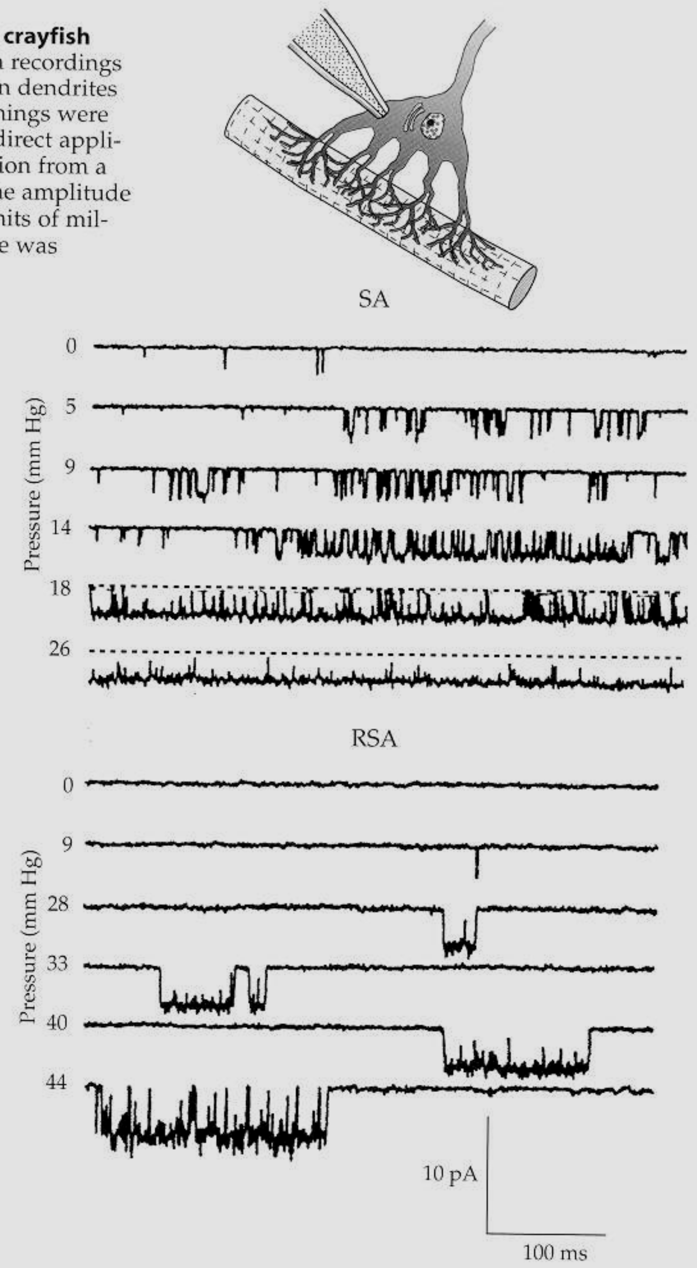
Svalová propriorecepce raka



V- clamp

Svalová propriorecepce raka

Figure 5.10
Single-channel recordings from crayfish stretch receptors On-cell patch recordings made from the cell body and main dendrites of stretch receptors. Channel openings were produced as in Figure 3.4 by the direct application to the patch pipette of suction from a calibrated pressure transducer. The amplitude of suction is given to the left in units of millimeters of mercury (Hg). Pressure was applied continuously for the duration of each record. Patches were voltage-clamped at the resting membrane potential (for SA) and 50 mV negative to the resting membrane potential (for RSA). (From Erxleben, 1989.)



Patch clamp

S exoskeletem – Hmyz

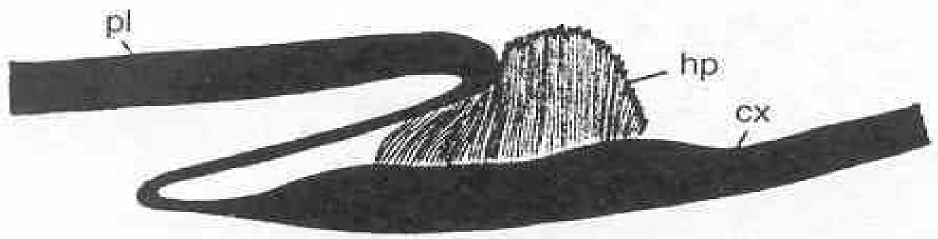
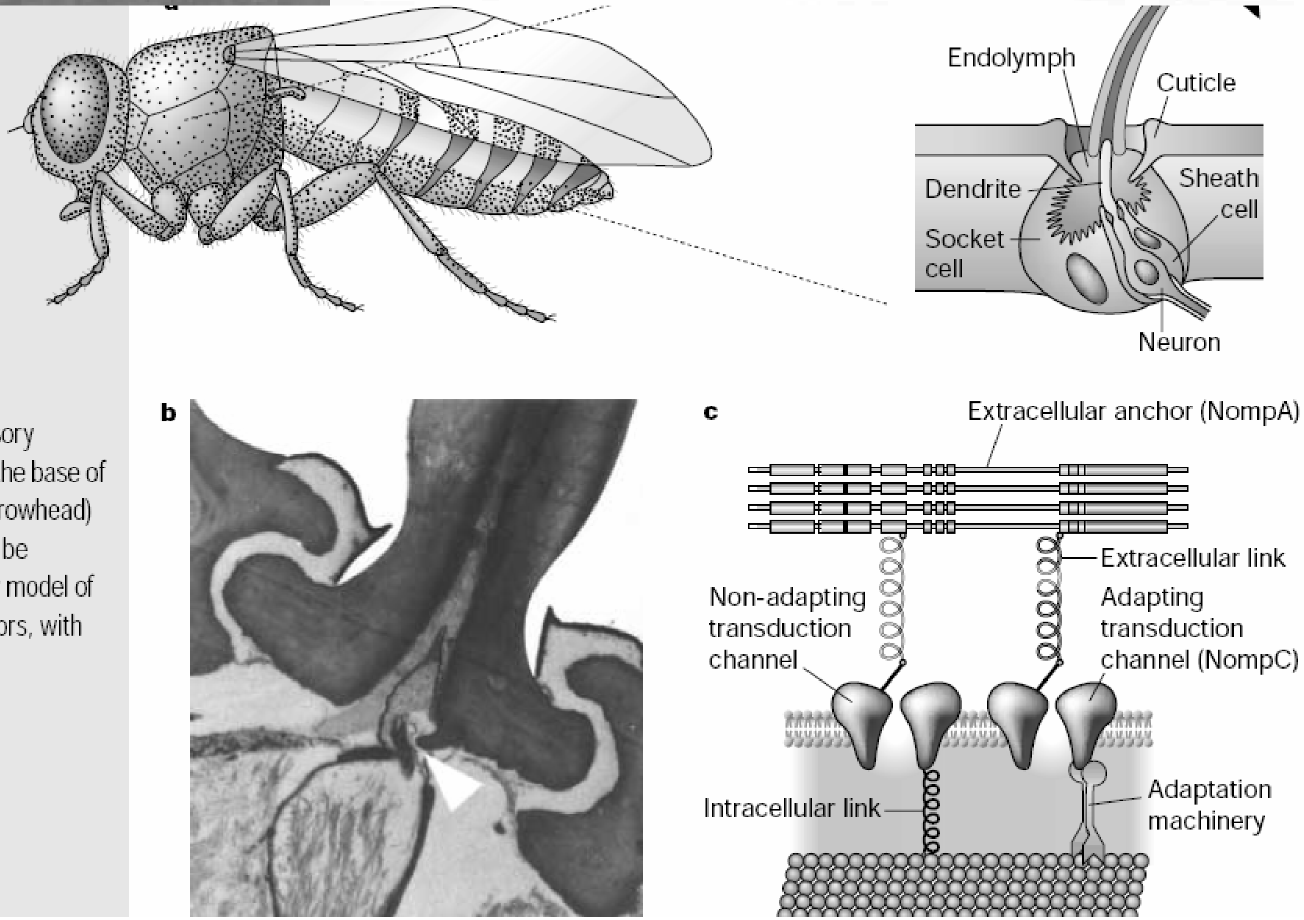
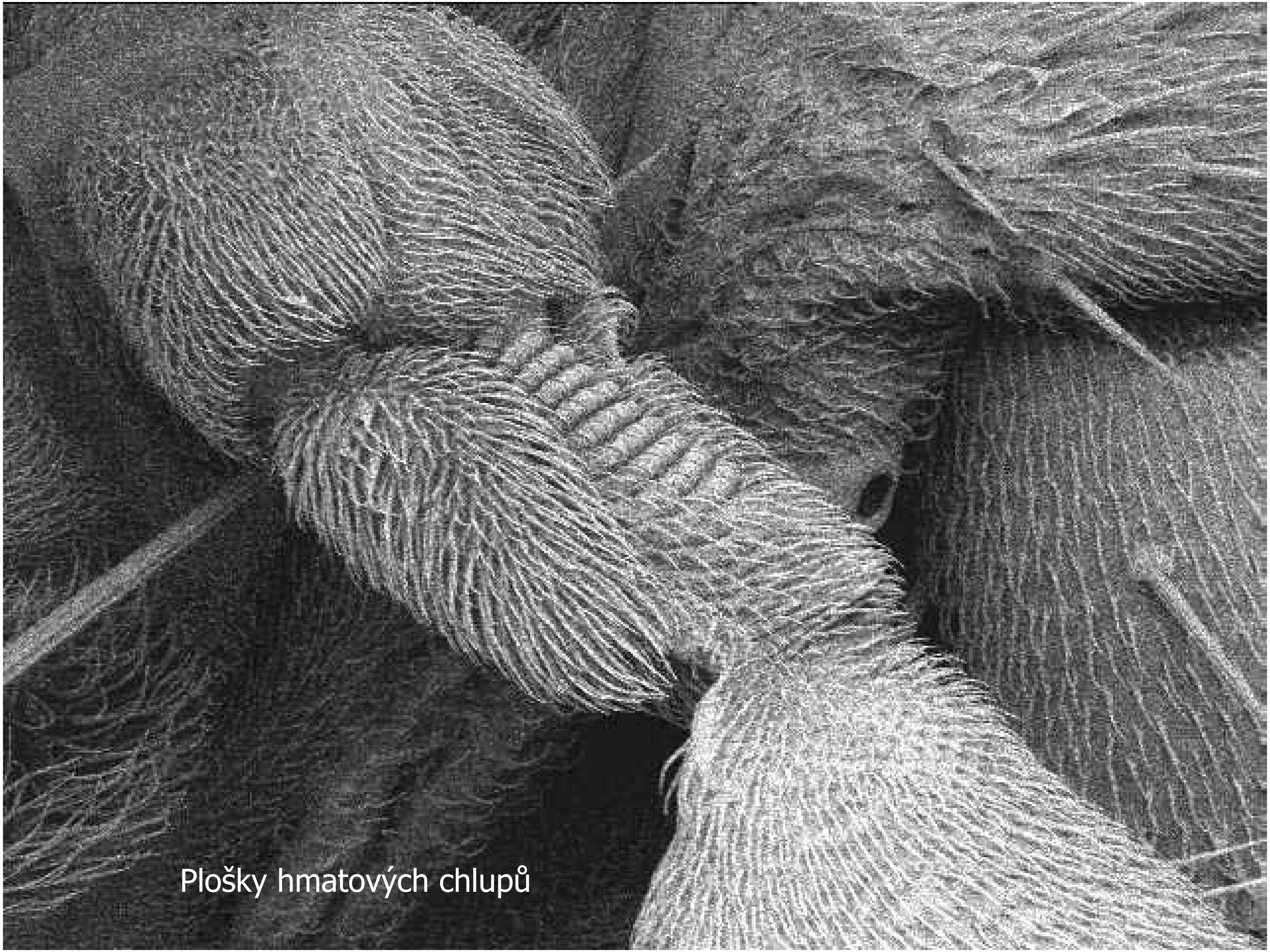


Figure 6.3 (a) The figure shows the brushwork of sensilla at the articulation of the second leg of the cockroach, *Periplaneta americana*. The thick cuticle of the pleuron (pl) thins to a delicate articular membrane and then thickens again to form the cuticle surrounding the coxa (cx), the first segment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

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.





Plošky hmatových chlupů

3 typy mechanoreceptorů Hmyzu

Plošky hmatových chlupů
Zvonečkové sensily
Chordotonální vlákna

Bipolární neuron, ciliární výběžek s tubulárním kotvením, extracelulární struktura

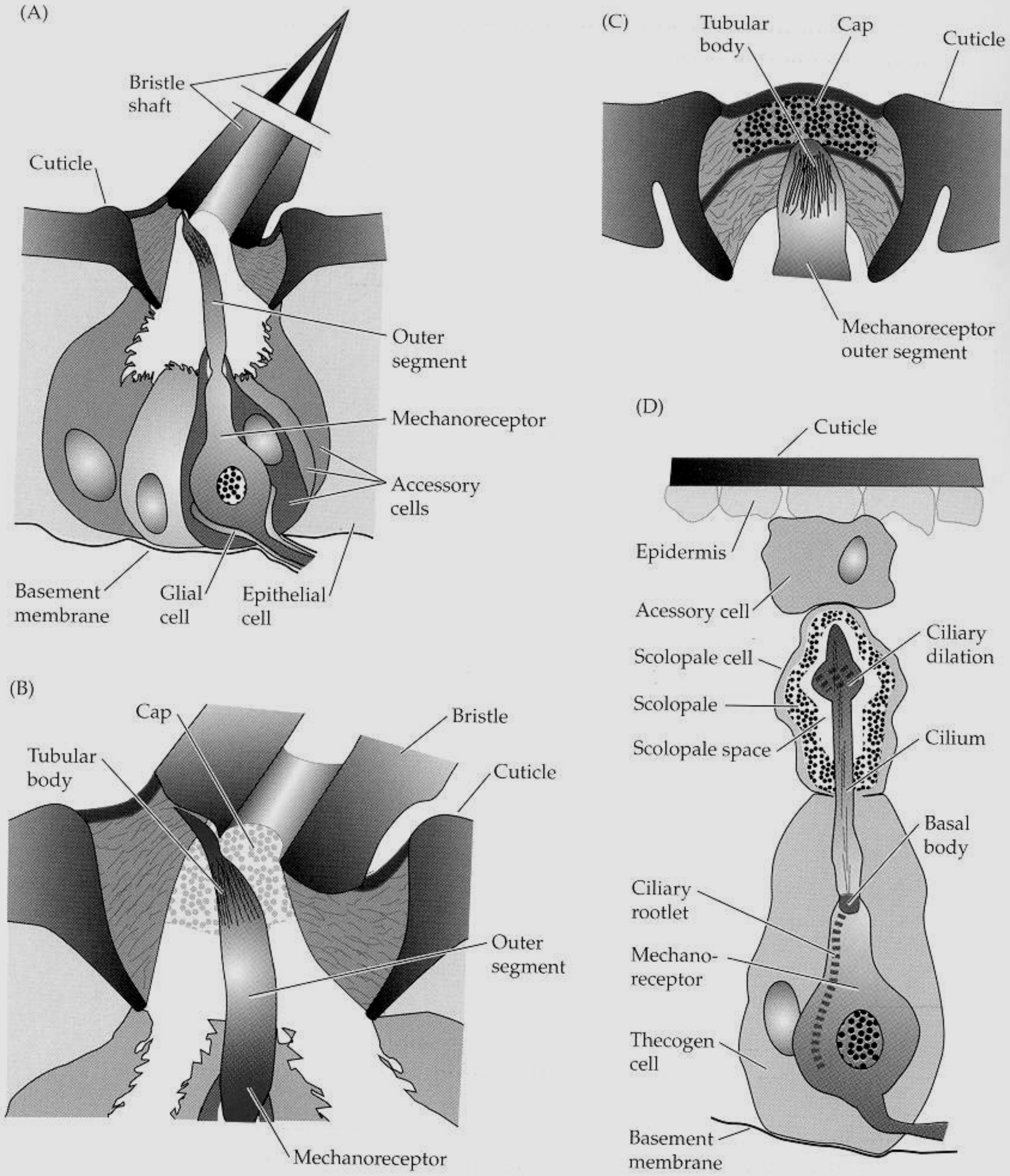


Figure 5.11
Anatomy of insect mechanoreceptive organs Schematic drawings of major morphological classes of touch sensilla. (A) Hair plate (bristle) sensillum. (B) Magnified view of hair plate sensillum. (C) Campaniform sensillum. (D) Scolopidial organ. The thecogen cell is a type of supporting cell.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

Behaviorální skríning
a elektrický záznam z brvy

Mutanti NompA a C
Necitliví na dotek, ale i
nekoordinovaní a hluší
Pozn. NompC je TRP kanál

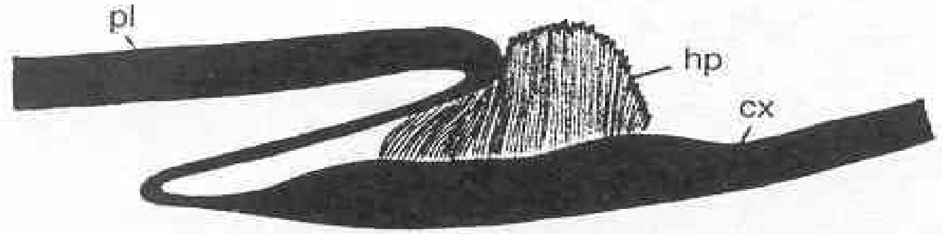
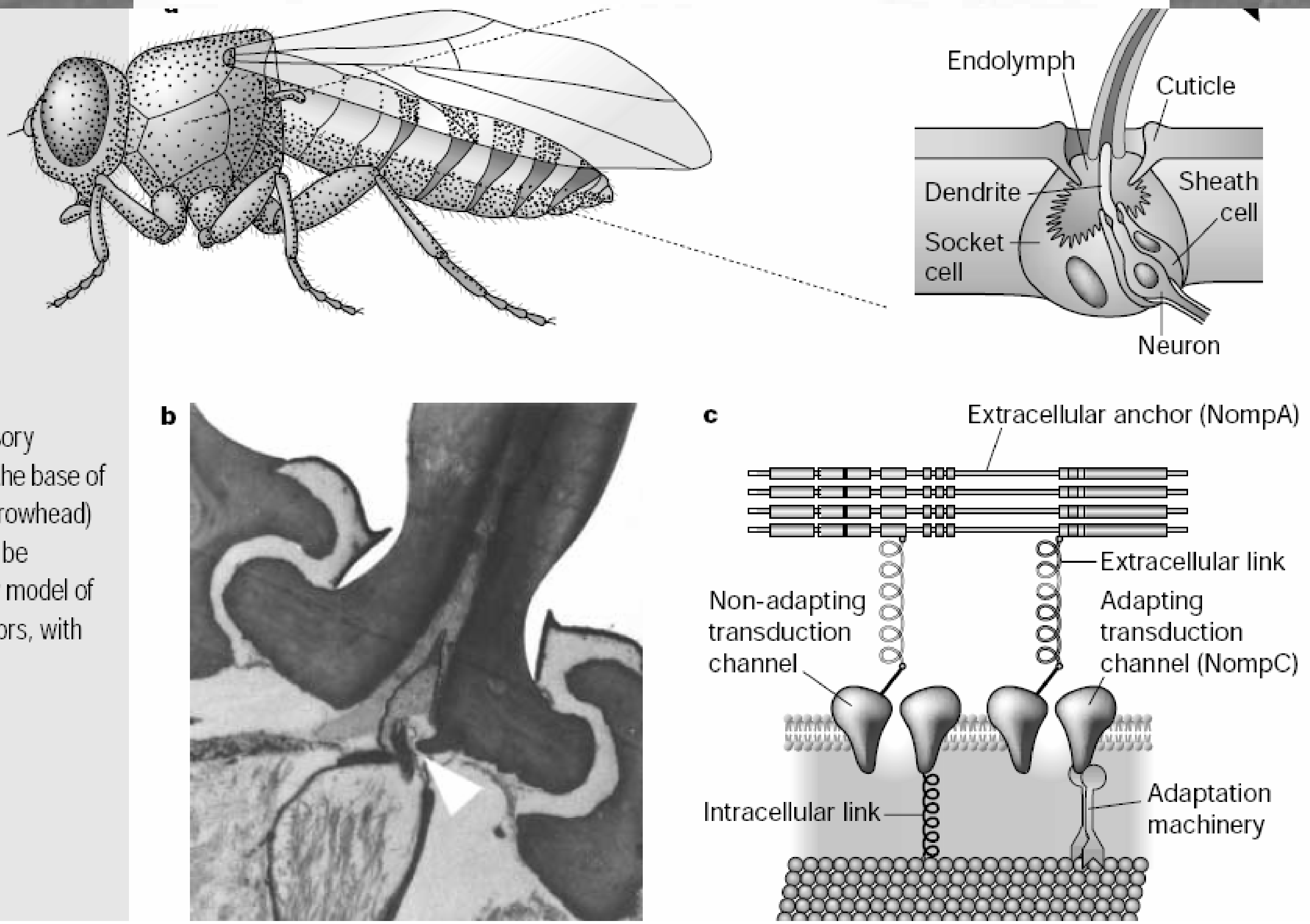


Figure 6.3 (a) The figure shows the brushwork of sensilla at the articulation of the second leg of the cockroach, *Periplaneta americana*. The thick cuticle of the pleuron (pl) thins to a delicate articular membrane and then thickens again to form the cuticle surrounding the coxa (cx), the first segment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

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.



Drosophila:
TRP kanál
Shodný předek s vláskovými buňkami obratlovců
Obecné schéma mechanorecepce:
Ionotropní, ukotvený, adaptabilní

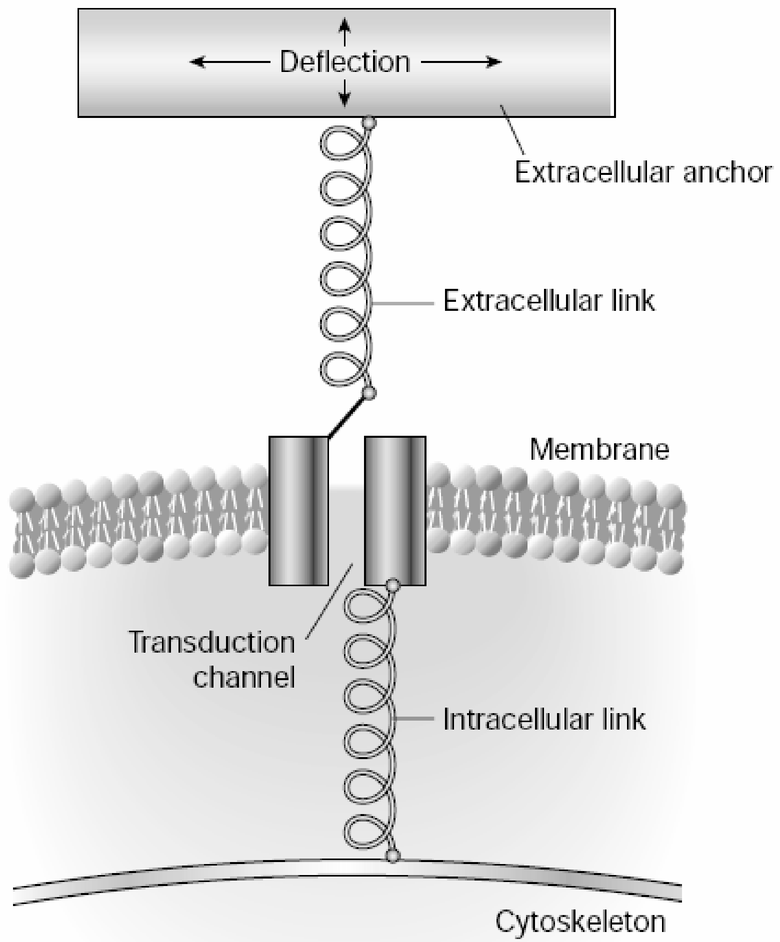
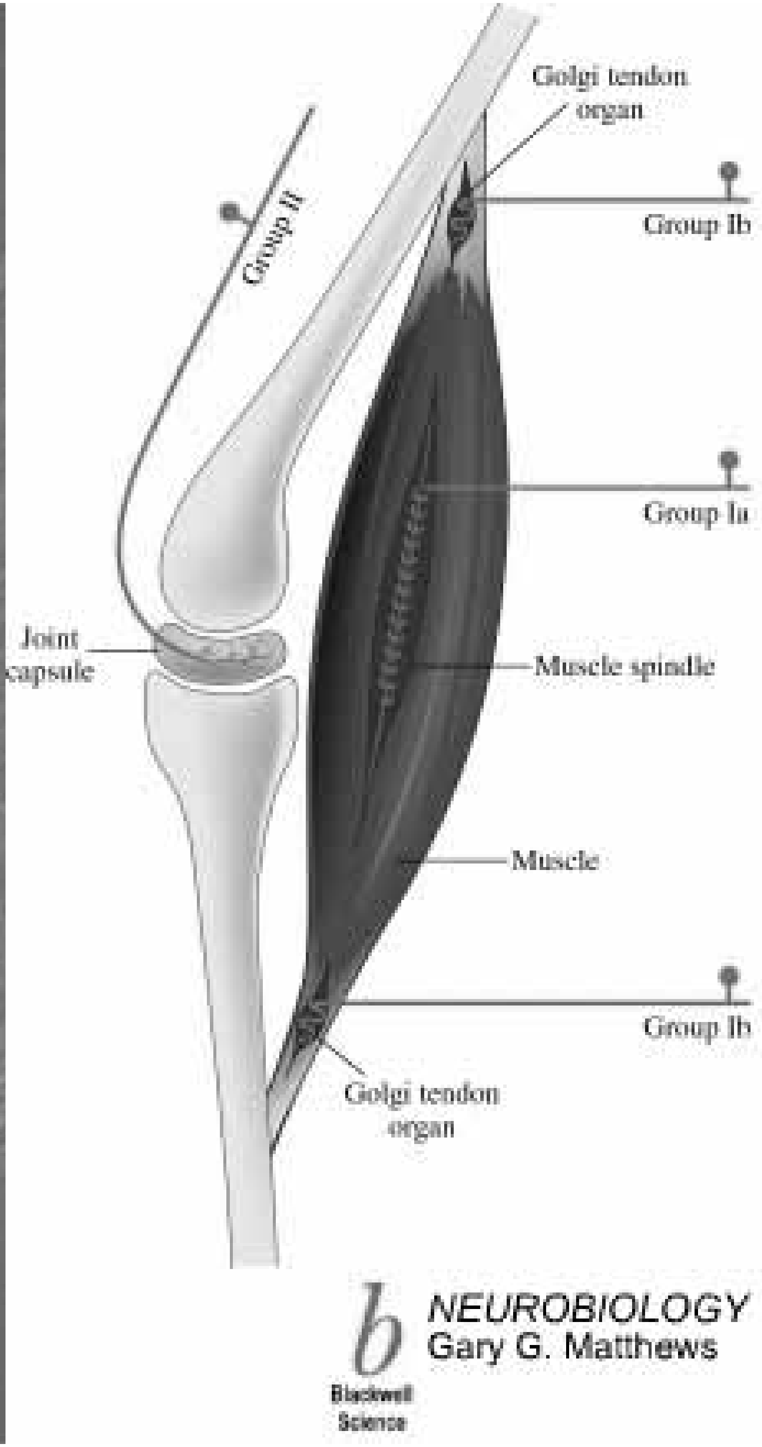


Figure 1 General features of mechanosensory transduction. A transduction channel is anchored by intracellular and extracellular anchors to the cytoskeleton and to an extracellular structure to which forces are applied. The transduction channel responds to tension in the system, which is increased by net displacements between intracellular and extracellular structures.

Propriorecepce u endoskeletu
Svalová vřeténka
Šlachová tělíska
Spolu se zrakem a kožním čitím a vestibulárním aparátem dodávají obraz o poloze těla



Život bez „obrazu o vlastním těle"

12.1 Living Without Kinesthesis

Close your eyes. Now cross your legs. Tap your foot. Raise your left hand. Touch your nose with your right index finger. These tasks shouldn't be too difficult (unless you're just back from a night on the town).

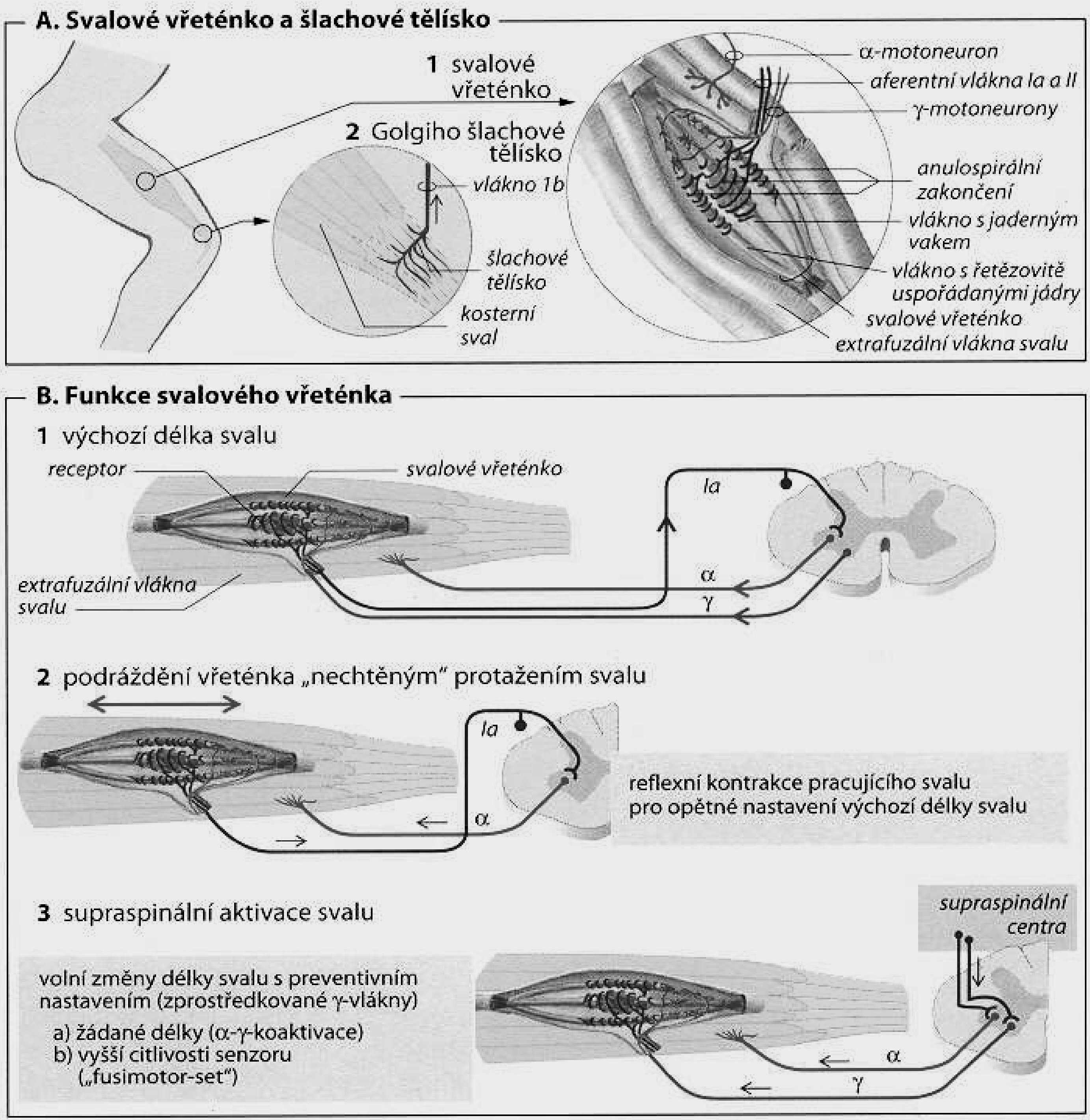
But at the age of 19, Englishman Ian Waterman suffered a viral infection and lost the ability to do these things. Not because he was paralyzed: his muscular control was unaffected by the infection. What was affected was his sense of **proprioception**, a word that literally means "sense of self," but is used by psychologists to describe our perception of where our body parts are. Proprioception, like its sister sense **kinesthesis**, is driven by somatosensory receptors in our muscles and joints, and the nerves connecting Waterman's proprioceptive receptors to his brain had been cut off.

Waterman was initially confined to a wheelchair because of his condition, but over a number of years he eventually learned to use his eyes to tell him what his proprioceptive receptors no longer could. He is able to walk now because he watches his legs move and puts one foot down when it moves in front of the other.

Waterman's case is described in a book called **Pride and a Daily Marathon**, by his physician, neurologist Jonathan Cole. A summary of the case is available in an archived article in the *APA Monitor*, linked below.

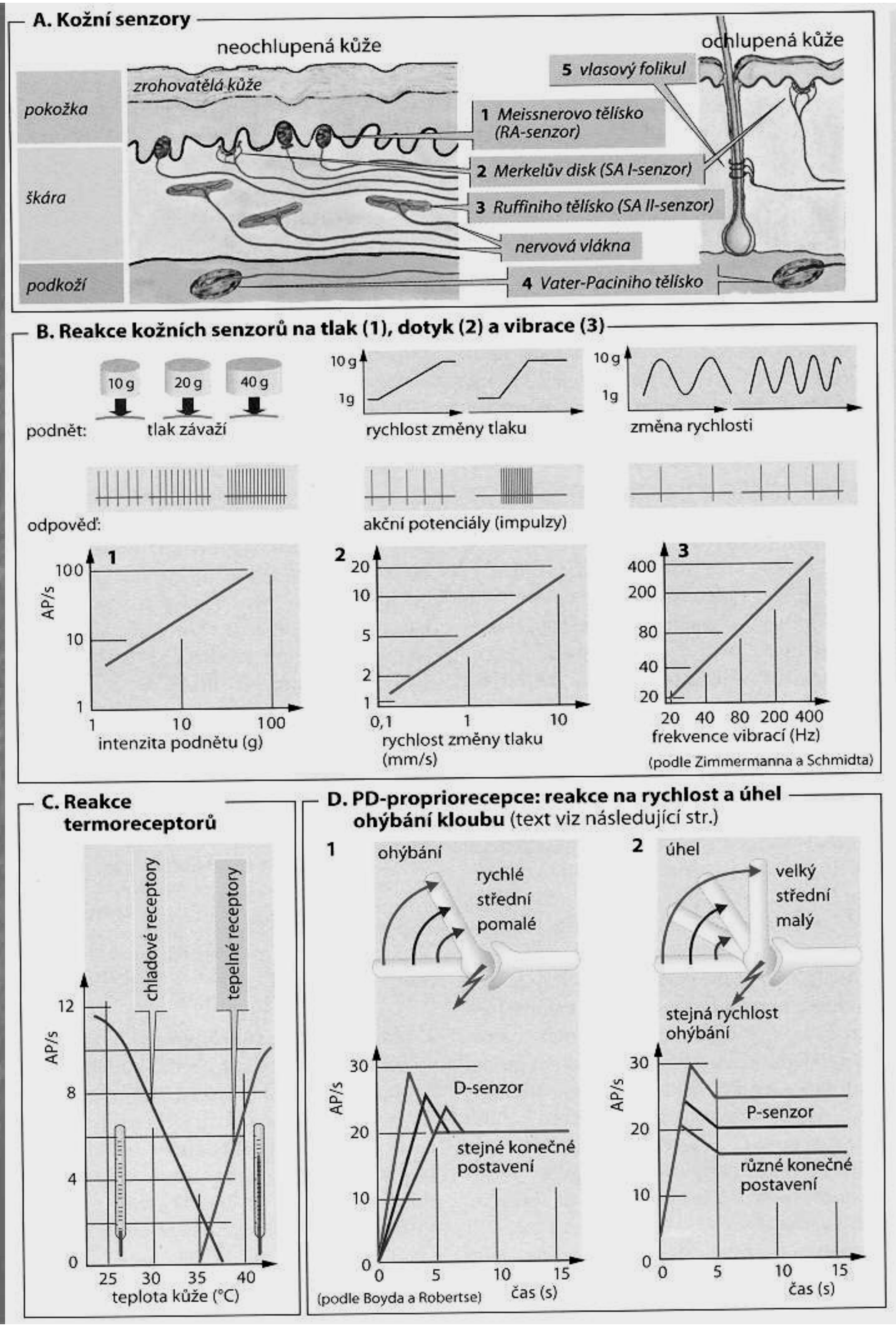
S.v.- regulace délky
Svalu
Eferentní inervace

Š.ť. – ochrana před
přepětím



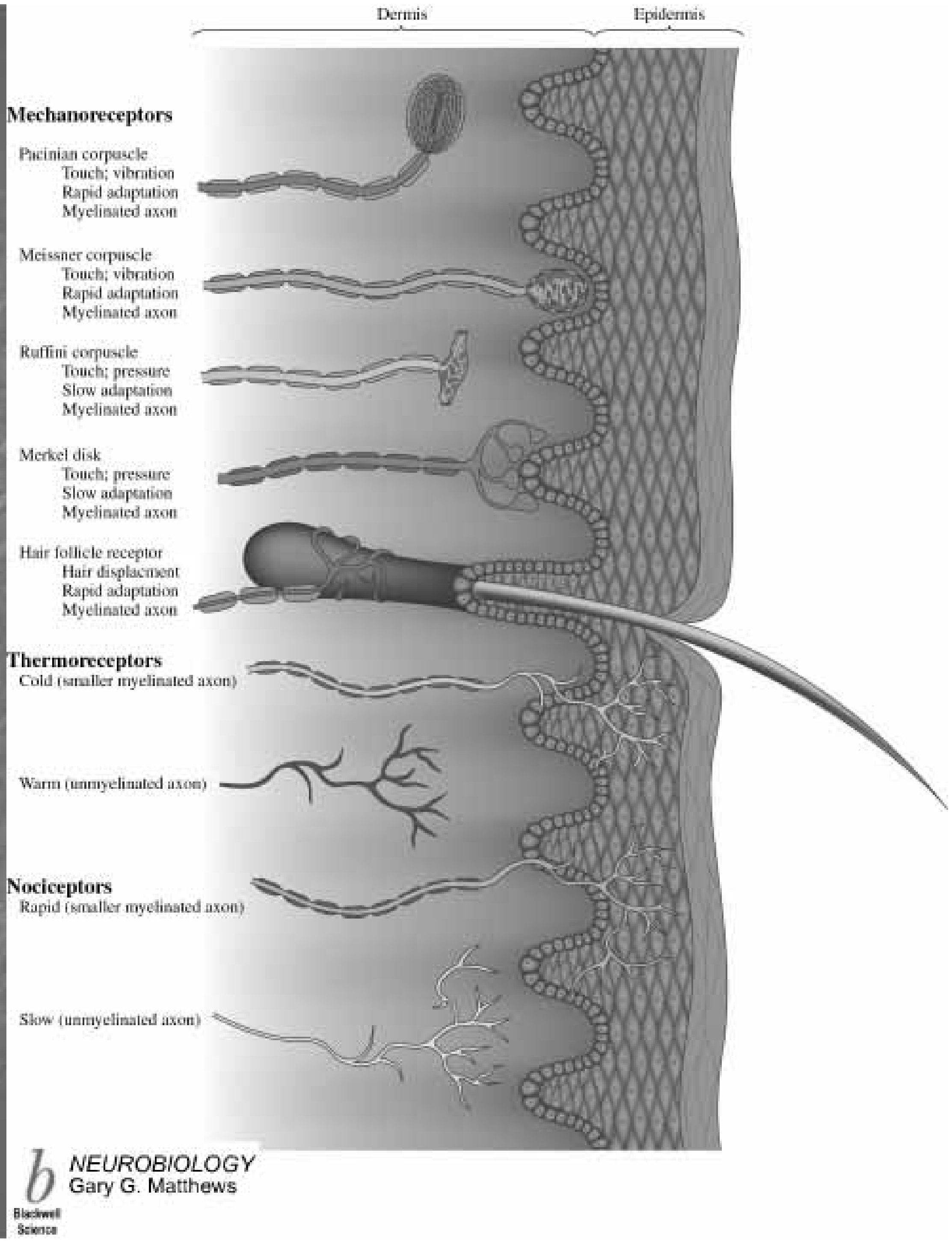
Taktilní kožní receptory – smysl pro dotek a hmat, teplotu a bolest

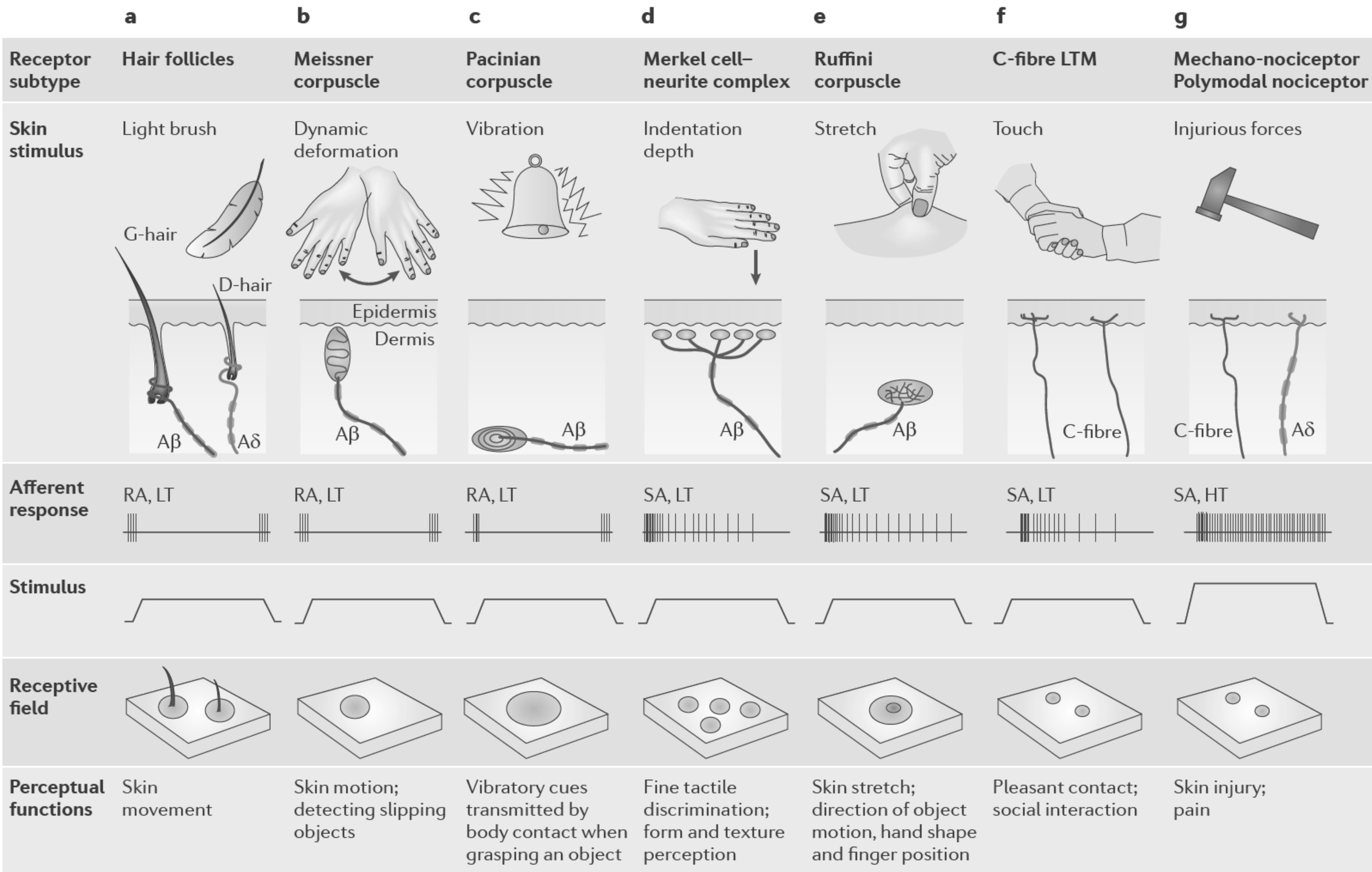
Tlak, dotyk, vibrace.
Různá adaptace receptorů



Receptory on-line

http://www.sinauer.com/wolfe/chap12/ssreceptorsF.htm





Velikost receptivních polí

Adaptace Rapidly Adapting, Low Treshold

Paciniho tělísko a vliv kapsule na adaptaci

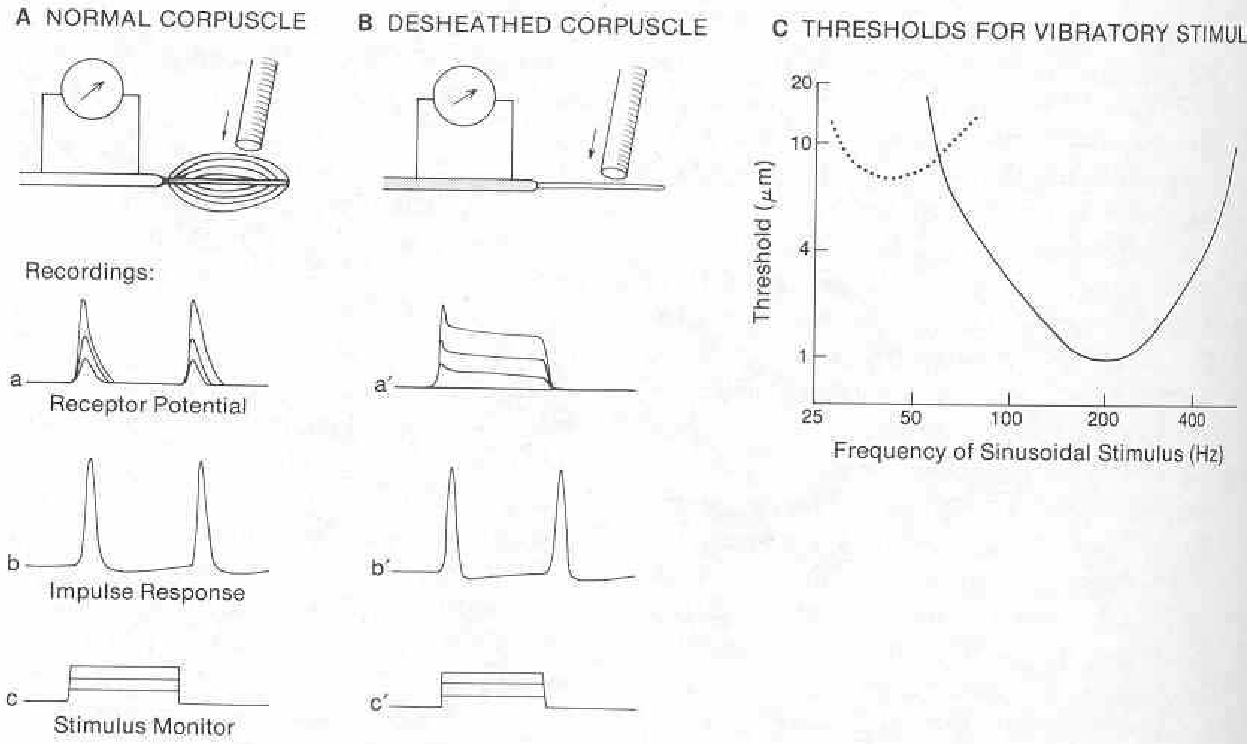
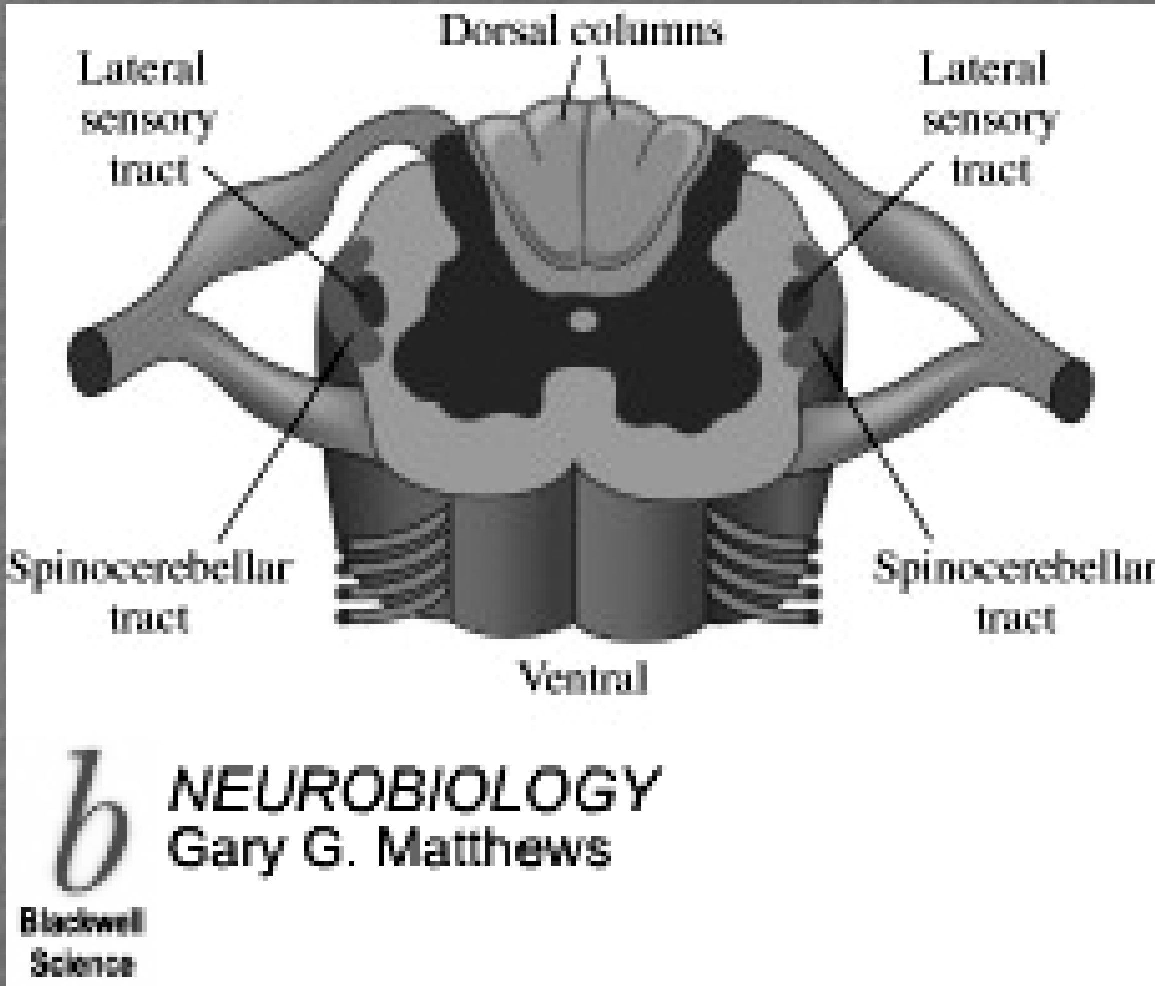


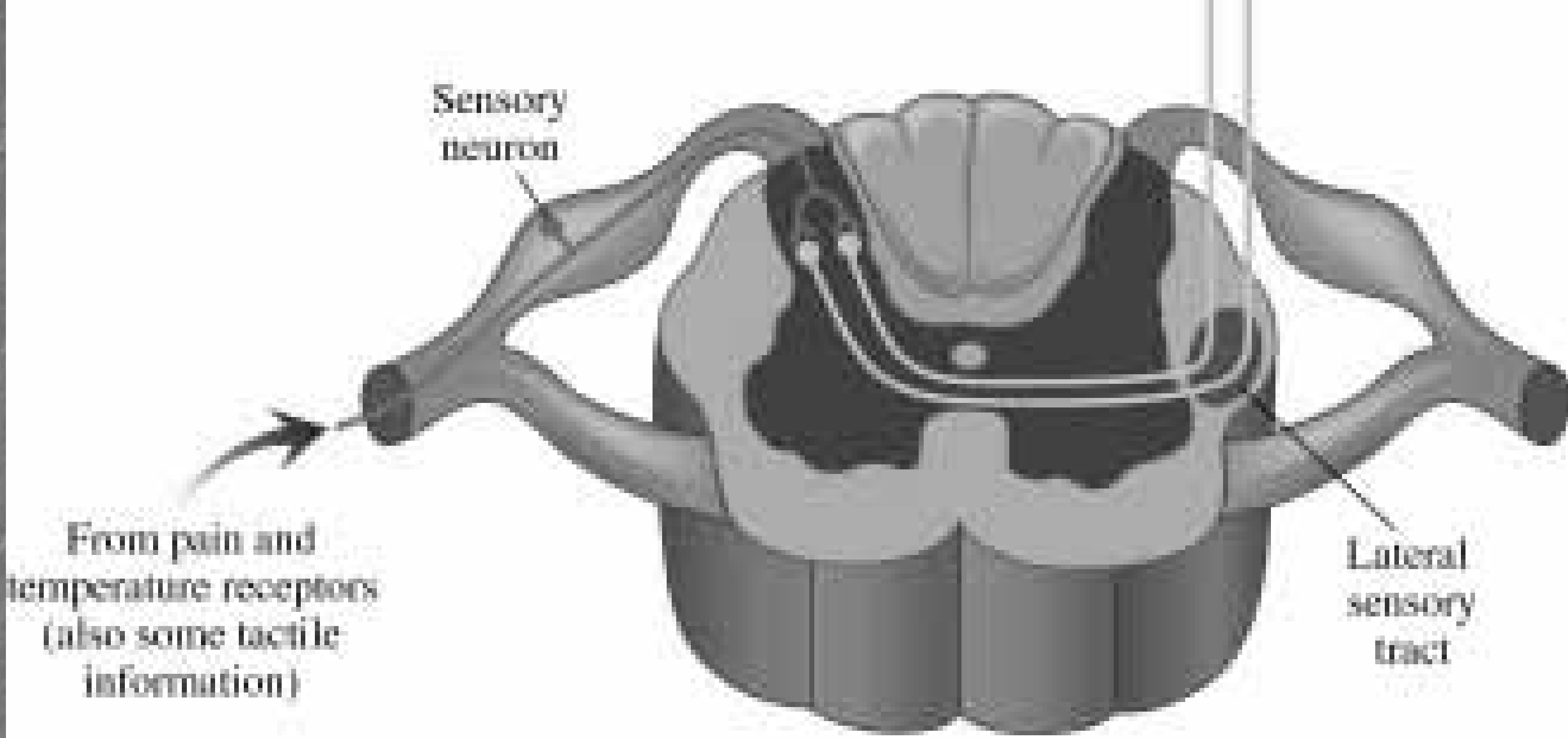
Fig. 12.5 Experimental analysis of transduction in the Pacinian corpuscle. **A.** Diagram showing probe for stimulating the intact corpuscle, and recording from the nerve. *(Below)* recordings of the receptor potential and impulse discharge. **B.** Repeat of experiment after removal of lamellae. C. Sensitivity of Pacinian corpuscle to vibratory stimulation at different frequencies. Sensitivity of Meissner's corpuscle is shown by dotted line. (A, B based on Loewenstein, 1971; C modified from Schmidt, 1978)

různé dráhy
do somatosensorické
kůry



Bolest a teplota

Vstup dorzálními kořeny a laterálním sensorickým traktem do mozku



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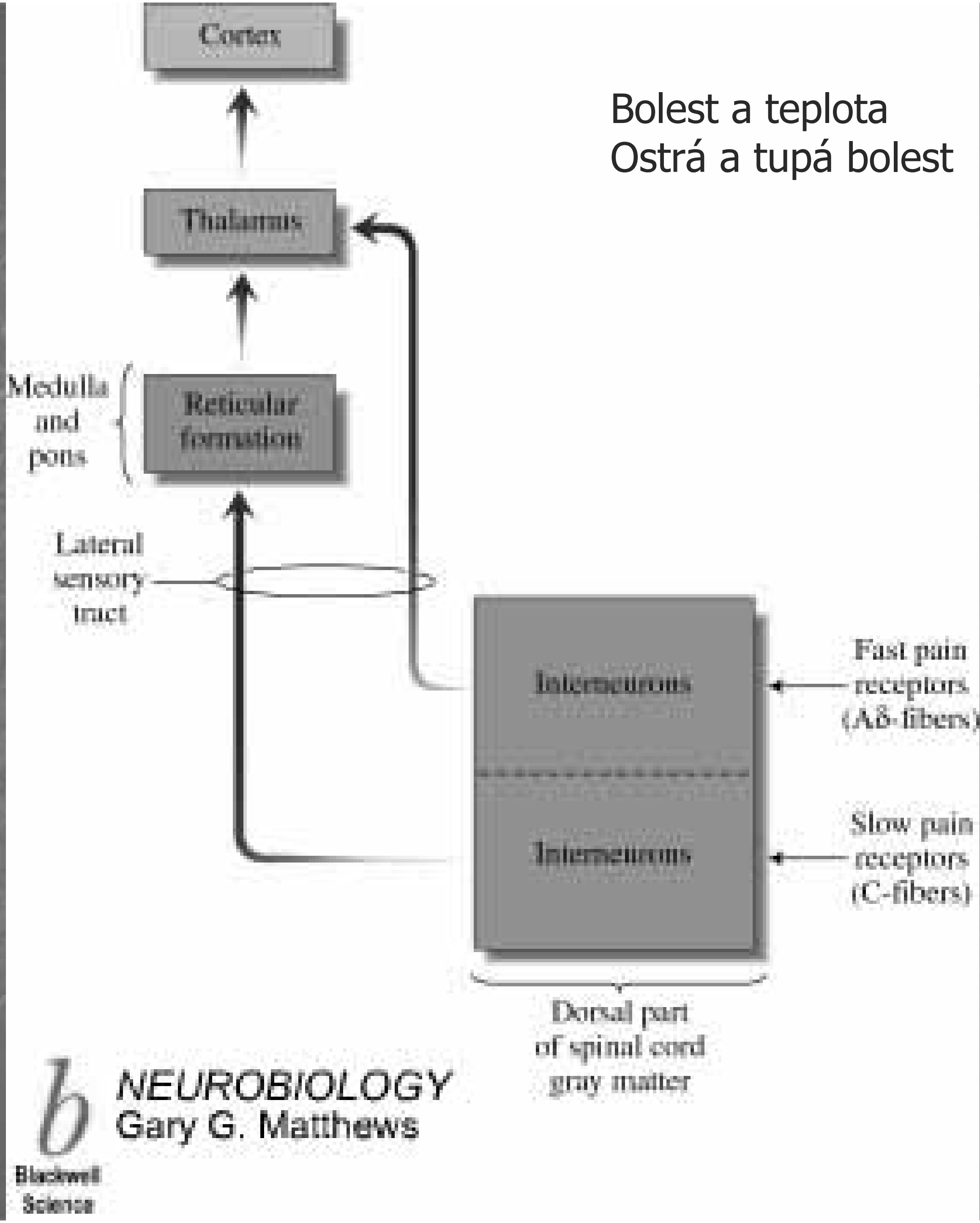
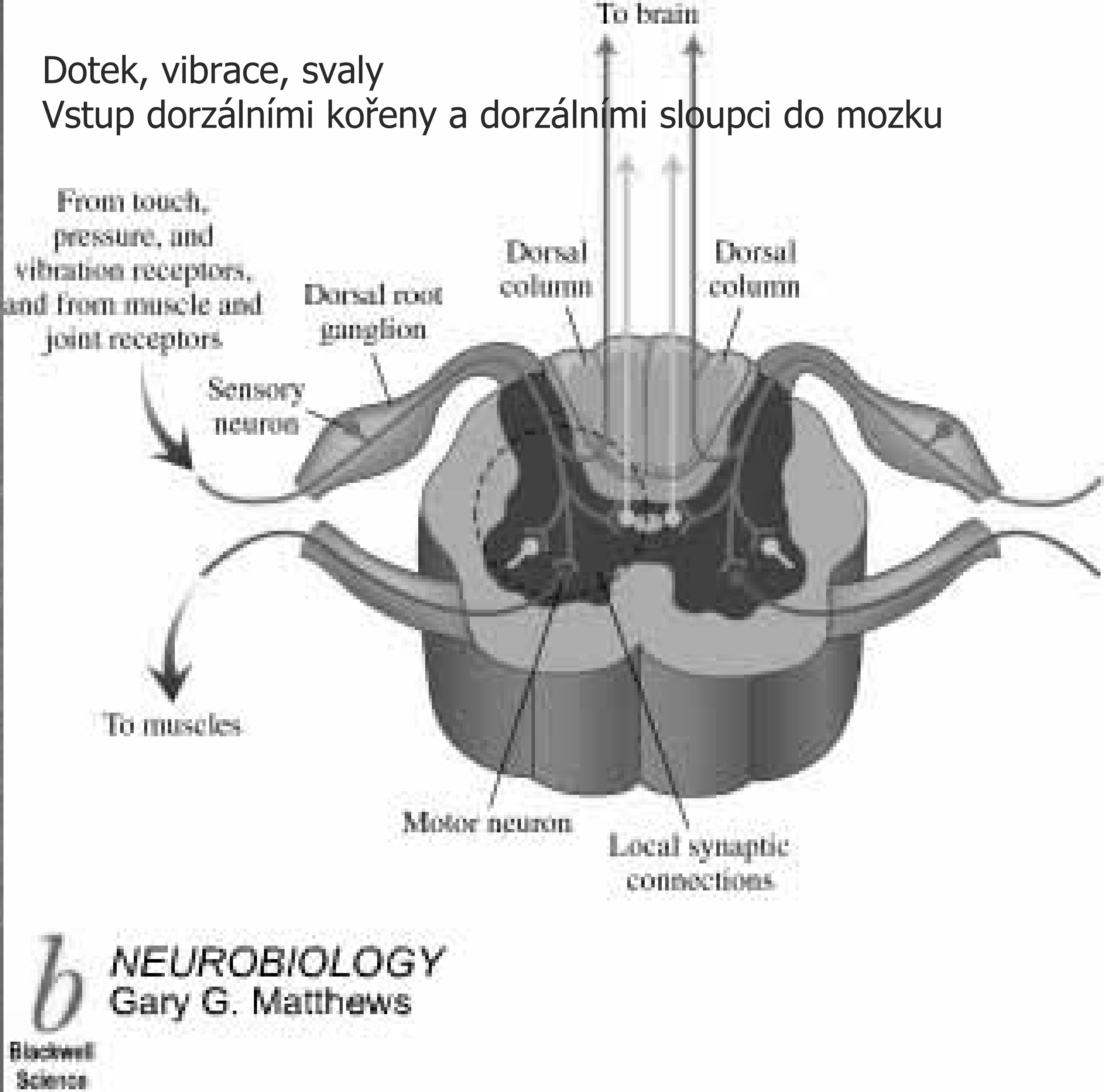
Bolest a teplota
Ostrá a tupá bolest

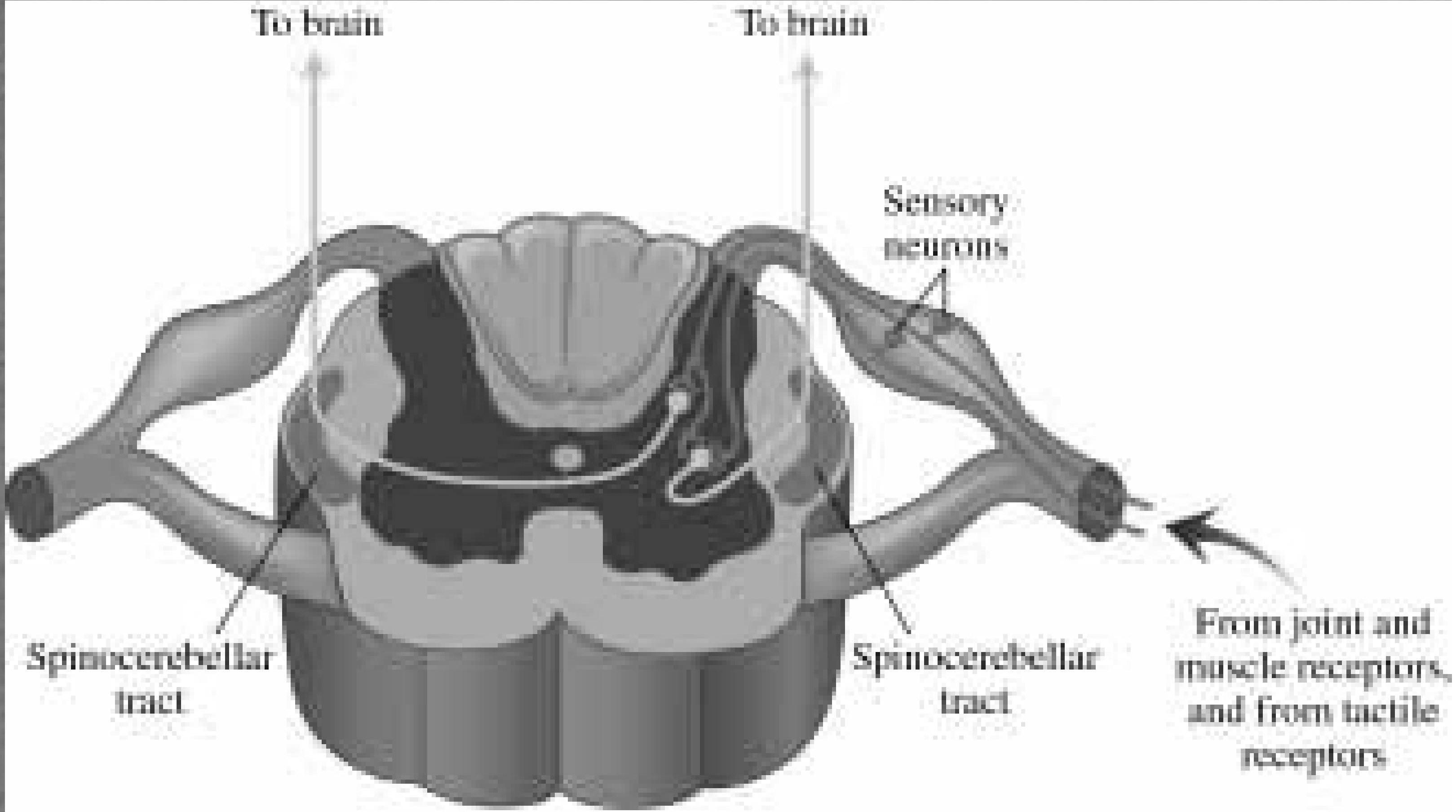


Dotek, vibrace, svaly
Vstup dorzálními kořeny a dorzálními sloupci do mozku



Proprioreceptory

Vstup dorzálními kořeny a spinocerebrálním traktem do mozku



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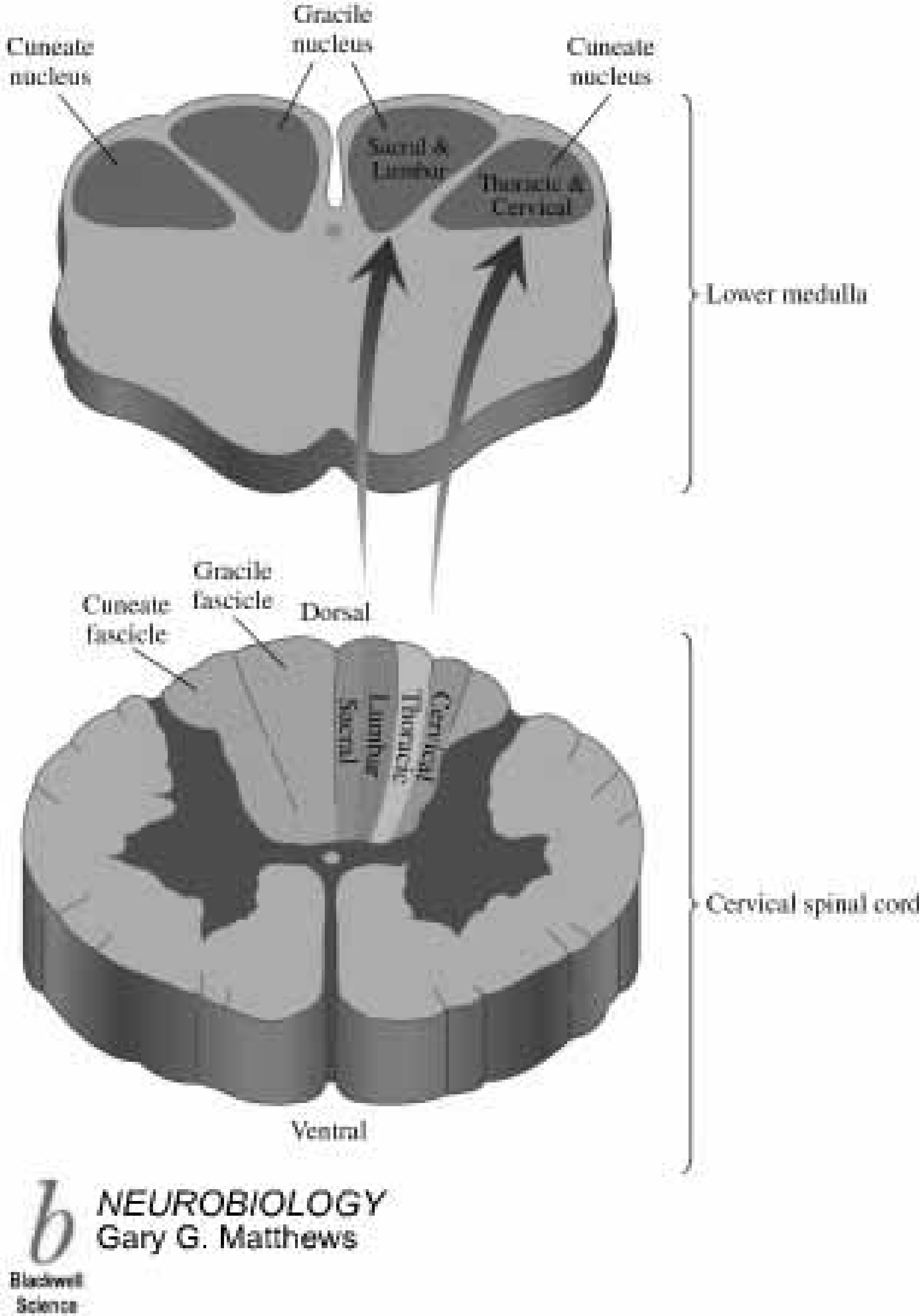
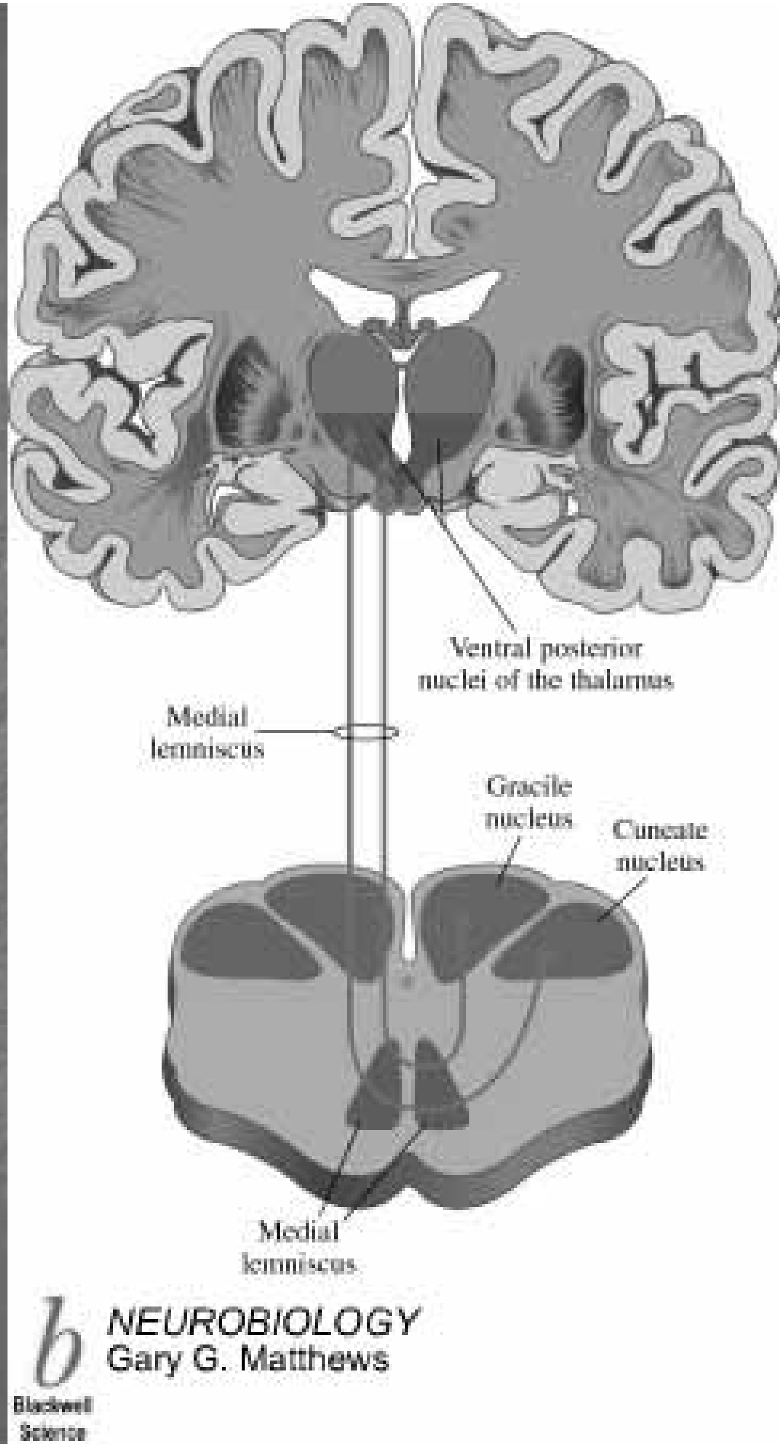
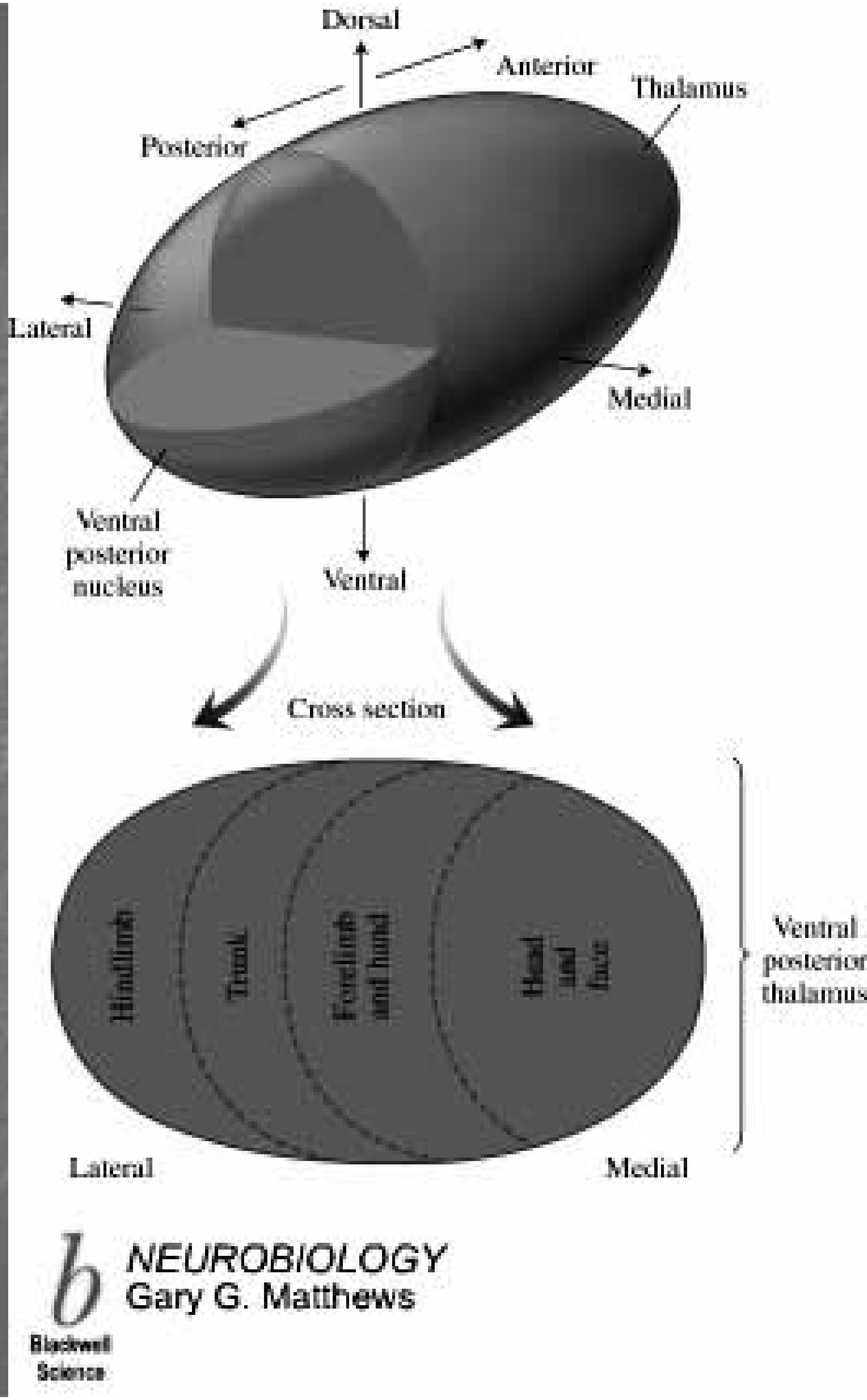
Somatotopie
Sensorické dráhy



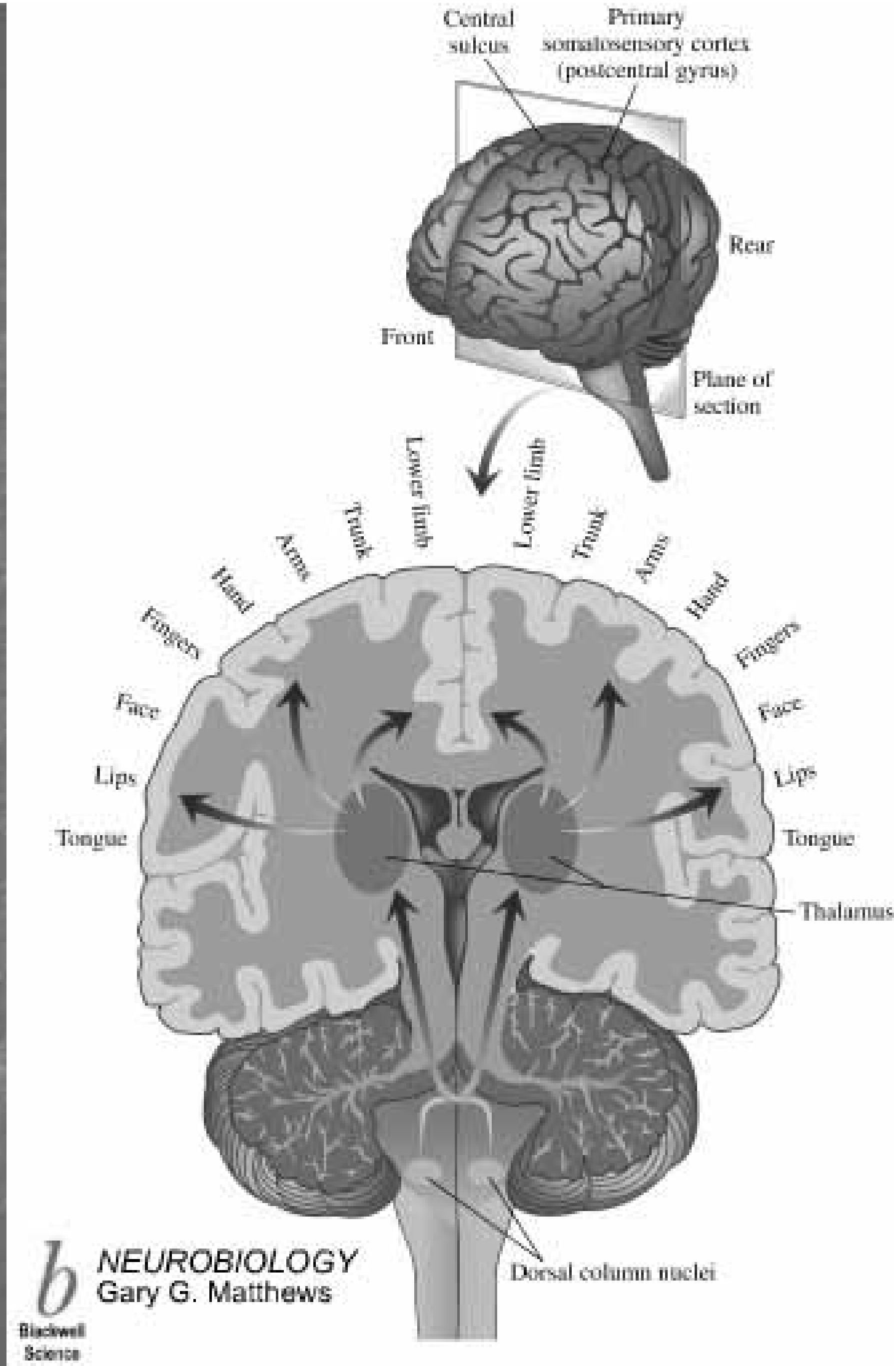
Somatotopie
Vstup do talamu



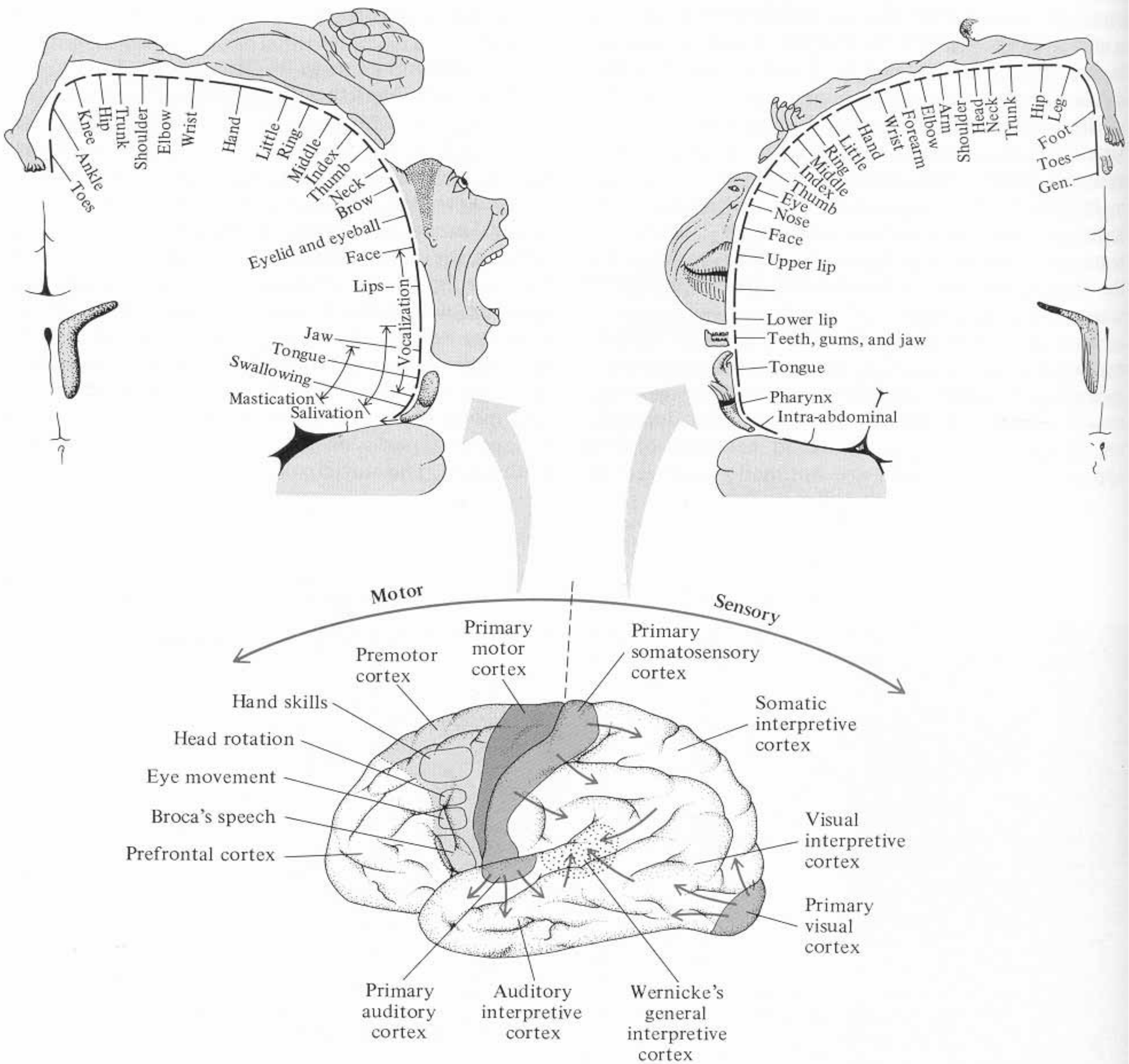
Somatotopie talamu



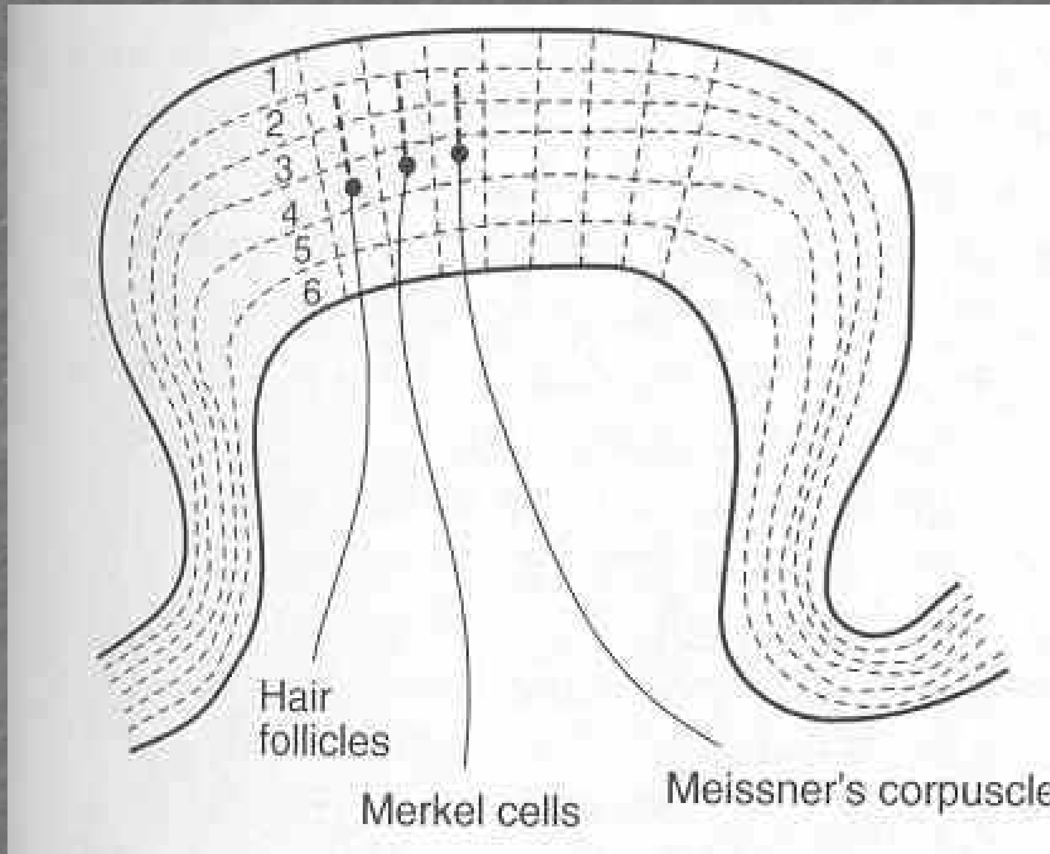
Somatotopie somatosenzorické kůry



Somatotopie somatosenzorické kůry



Vertikální členění kortexu



Plasticita somatosenzorické kůry

Reprezentace se mění
Podle používání

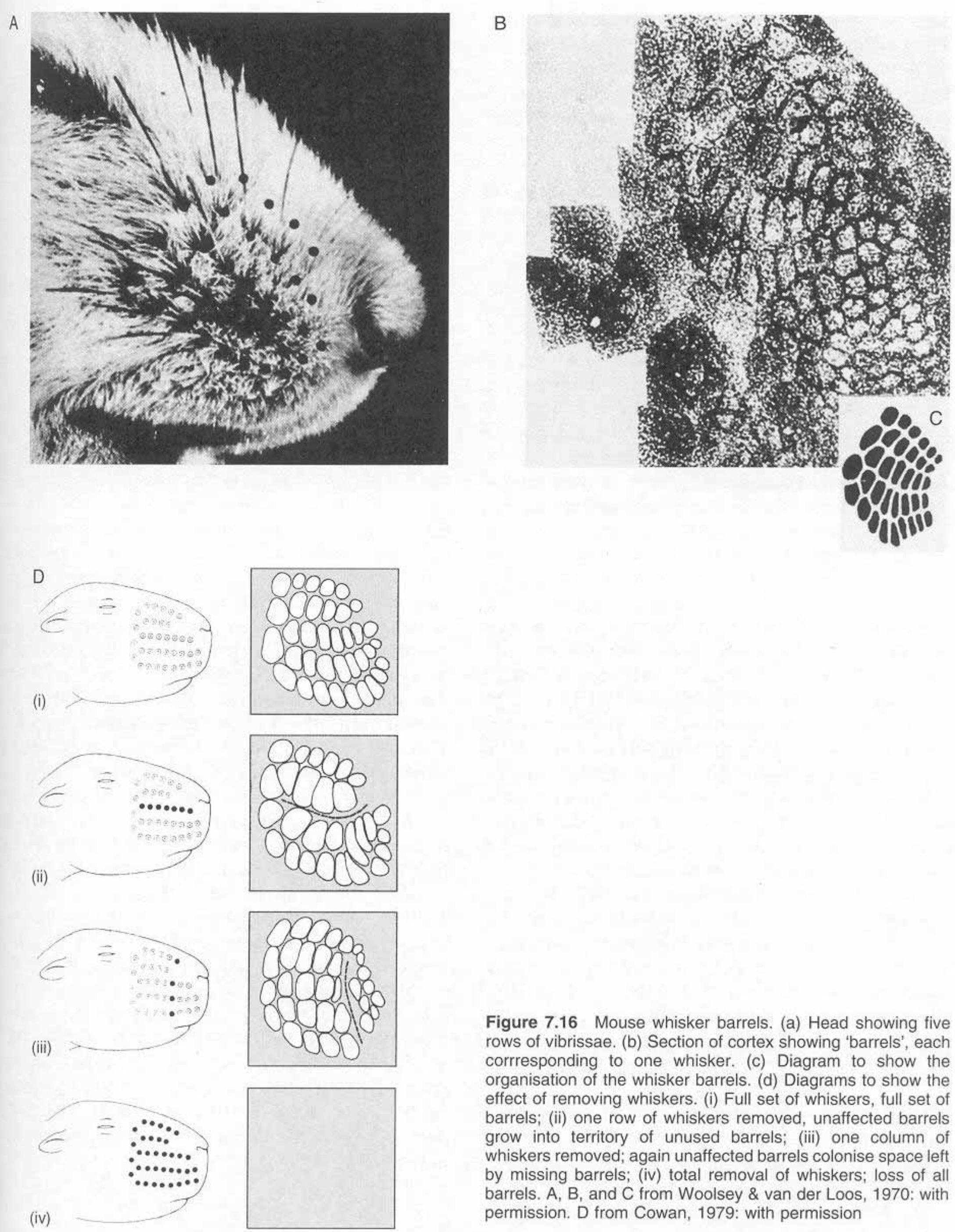


Figure 7.16 Mouse whisker barrels. (a) Head showing five rows of vibrissae. (b) Section of cortex showing 'barrels', each corrresponding to one whisker. (c) Diagram to show the organisation of the whisker barrels. (d) Diagrams to show the effect of removing whiskers. (i) Full set of whiskers, full set of barrels; (ii) one row of whiskers removed, unaffected barrels grow into territory of unused barrels; (iii) one column of whiskers removed; again unaffected barrels colonise space left by missing barrels; (iv) total removal of whiskers; loss of all barrels. A, B, and C from Woolsey & van der Loos, 1970: with permission. D from Cowan, 1979: with permission