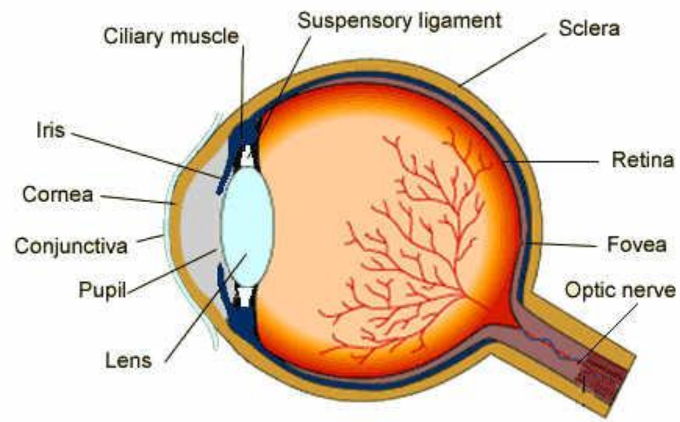
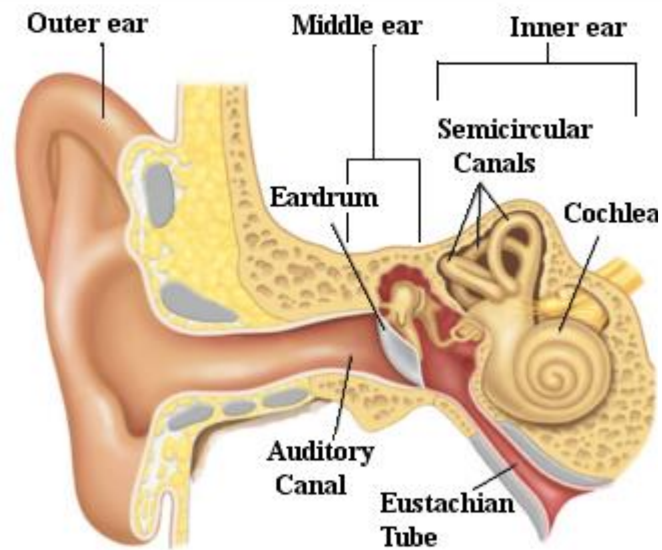
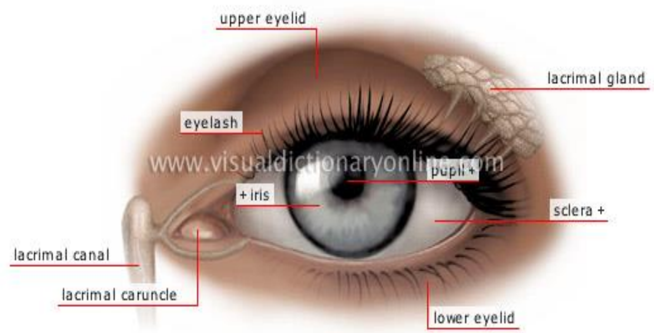
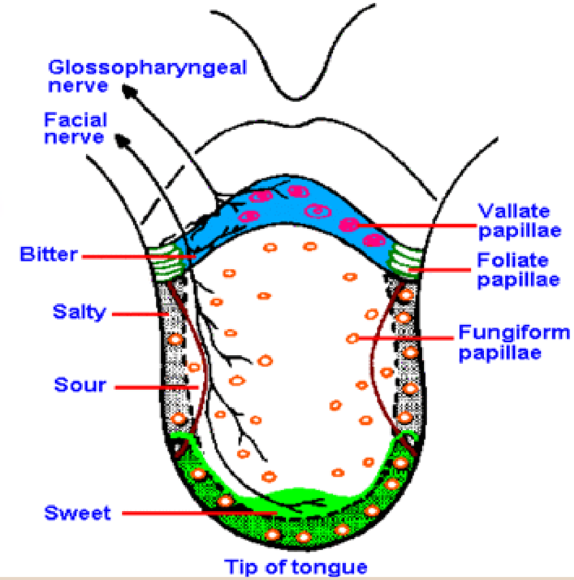
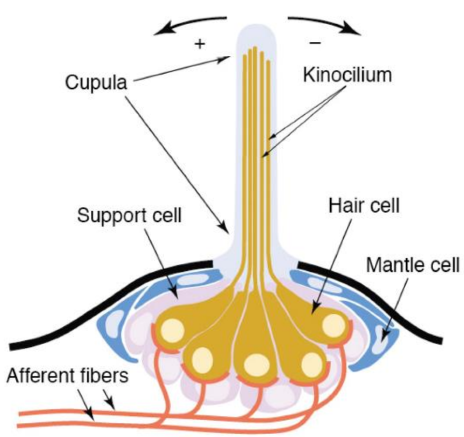
Smyslové vnímání

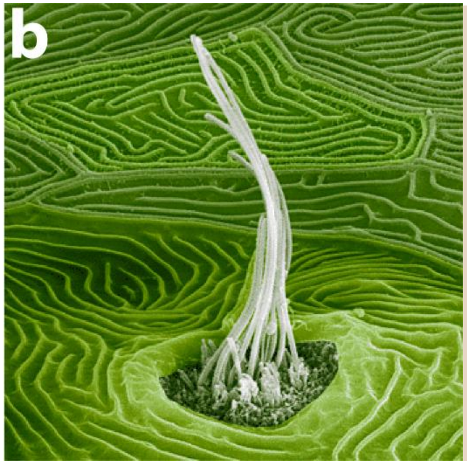


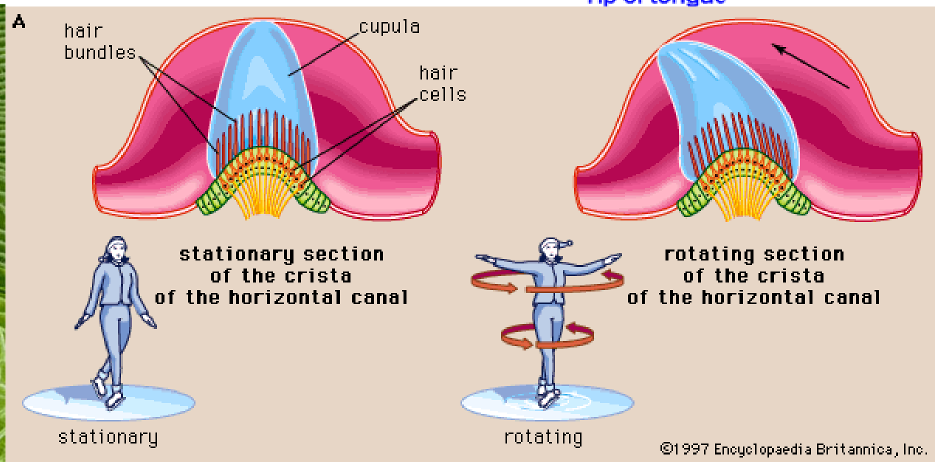












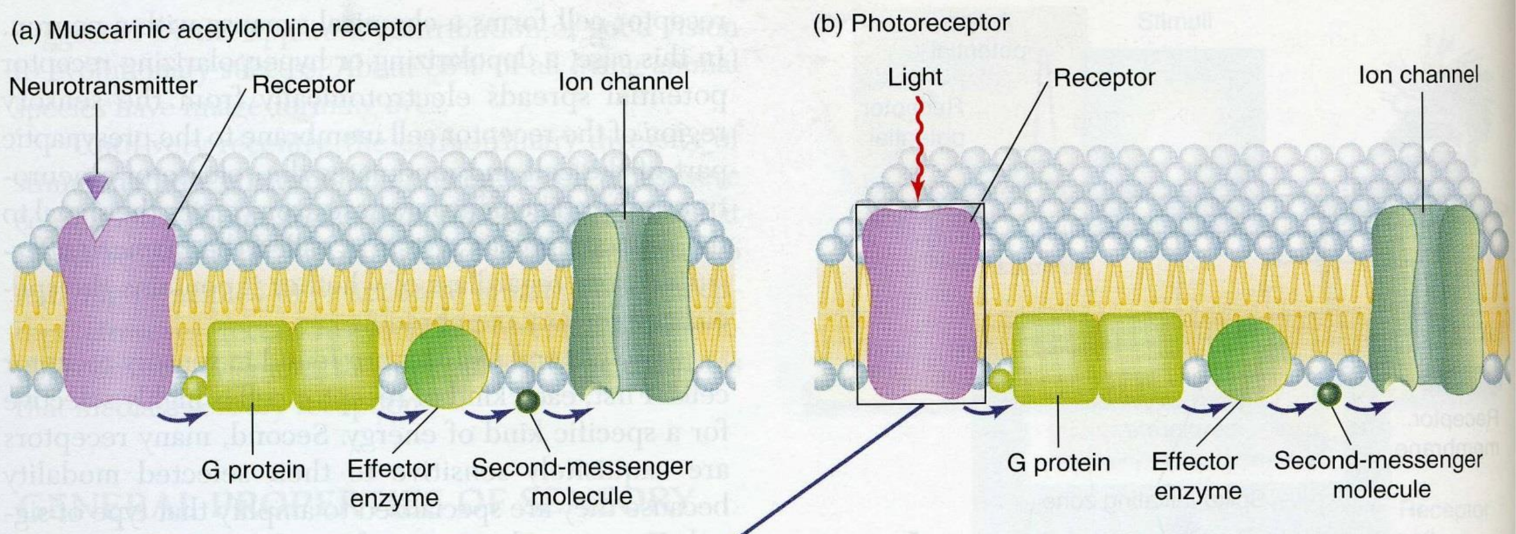
1

Table 7-1 General features and processes common to many types of sensory receptors

Transduction operations*	Found within single cells	Found in cell populations
Detection ↓	Mechanisms that select stimulus modality: filters, carriers, tuning, inactivation	Mechanisms that select stimulus modality: filters, carriers, tuning, inactivation
Amplification ↓	Positive feedback among chemical reactions or membrane channels Signal-to-noise enhancement Active processes in membranes	Positive feedback among cells Signal-to-noise enhancement
Encoding and discrimination ↓	Intensity coding Temporal differentiation Quality coding	Different dynamic ranges among cells Independent coding of quality and intensity Center-surround antagonisms Opponent mechanisms
Adaptation and termination ↓	Desensitization Negative feedback Temporal discrimination Repetitive responses	Temporal discrimination
Gating of ion channels ↓	Channels open or close	
Electrical response of membrane ↓	Depolarization or hyperpolarization	
Transmission to brain	Electrotonic spread Number and frequency of APs Synaptic transmission	Spatial patterns: maps and image formation Temporal patterns; directional selectivity, etc.

*Arrows indicate that these operations are a series of steps.

Srovnání mechanismu působení receptorů nervové a smyslové soustavy



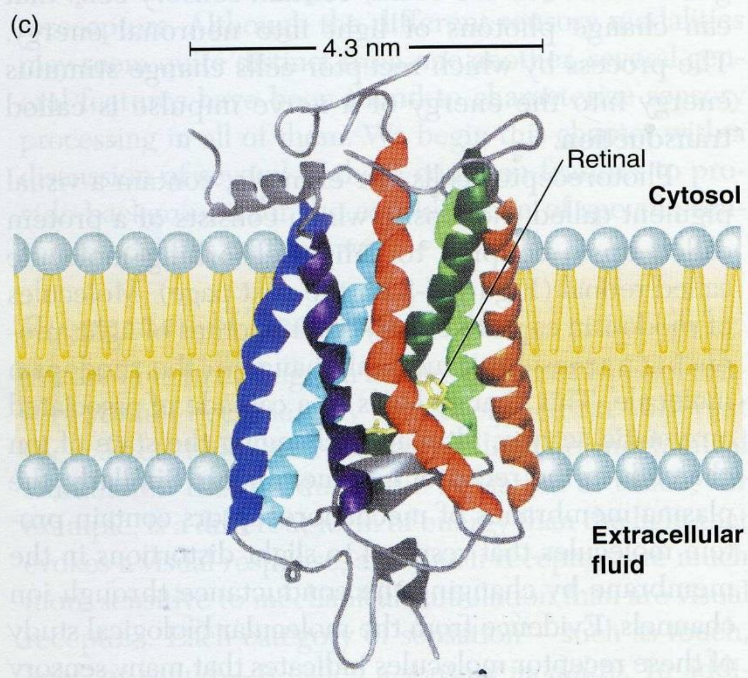
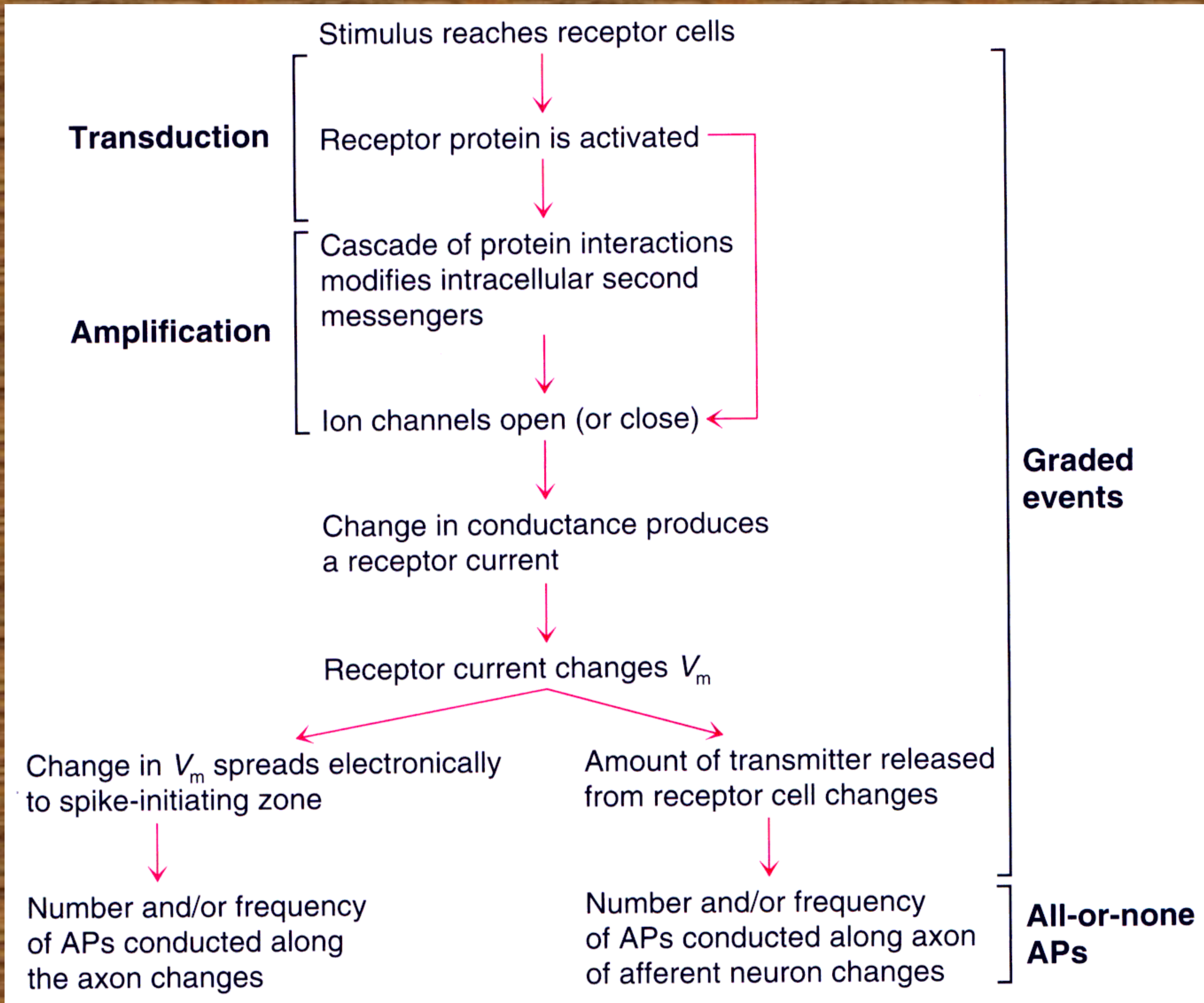
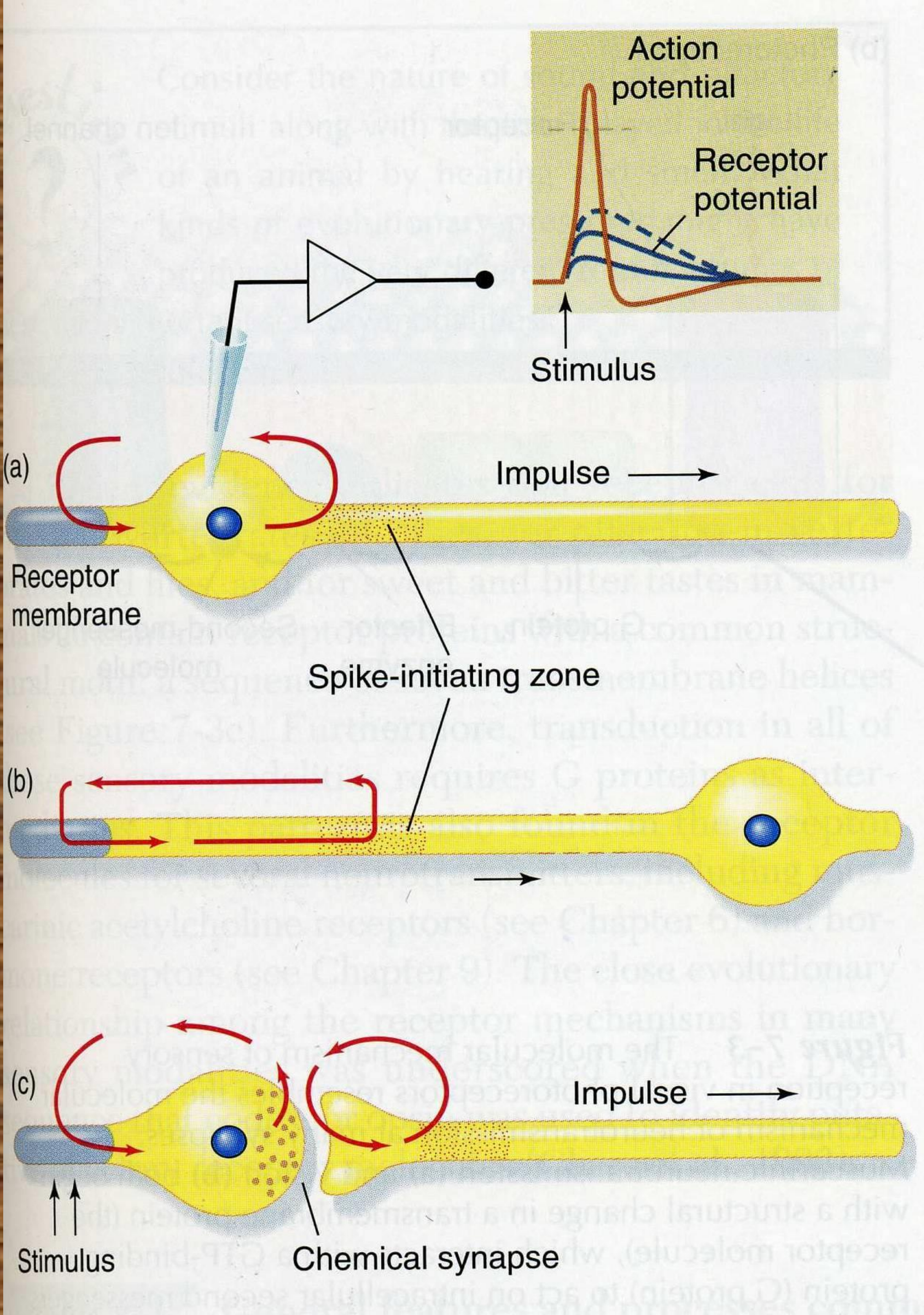


Figure 7–3 The molecular mechanism of sensory reception in visual photoreceptors resembles the molecular mechanism of neurotransmission at many synapses. Muscarinic neurotransmission **(a)** and vision **(b)** both begin with a structural change in a transmembrane protein (the receptor molecule), which interacts with a GTP-binding protein (G protein) to act on intracellular second messengers. The second messengers modify conductance through ion channels, either directly or indirectly, and can thus modify the pattern of APs in afferent neurons. **(c)** The detailed molecular structure of opsin and its relationship to retinal have recently been determined. A single opsin molecule contains seven helical domains that span the membrane. This motif of seven sequential transmembrane helices is common in sensory receptor proteins, as well as in many receptor molecules that respond to hormones or to neurotransmitters, including muscarinic receptors. [Parts a and b adapted from Bear et al., 1996; part c adapted from Bourne and Meng, 2000.]

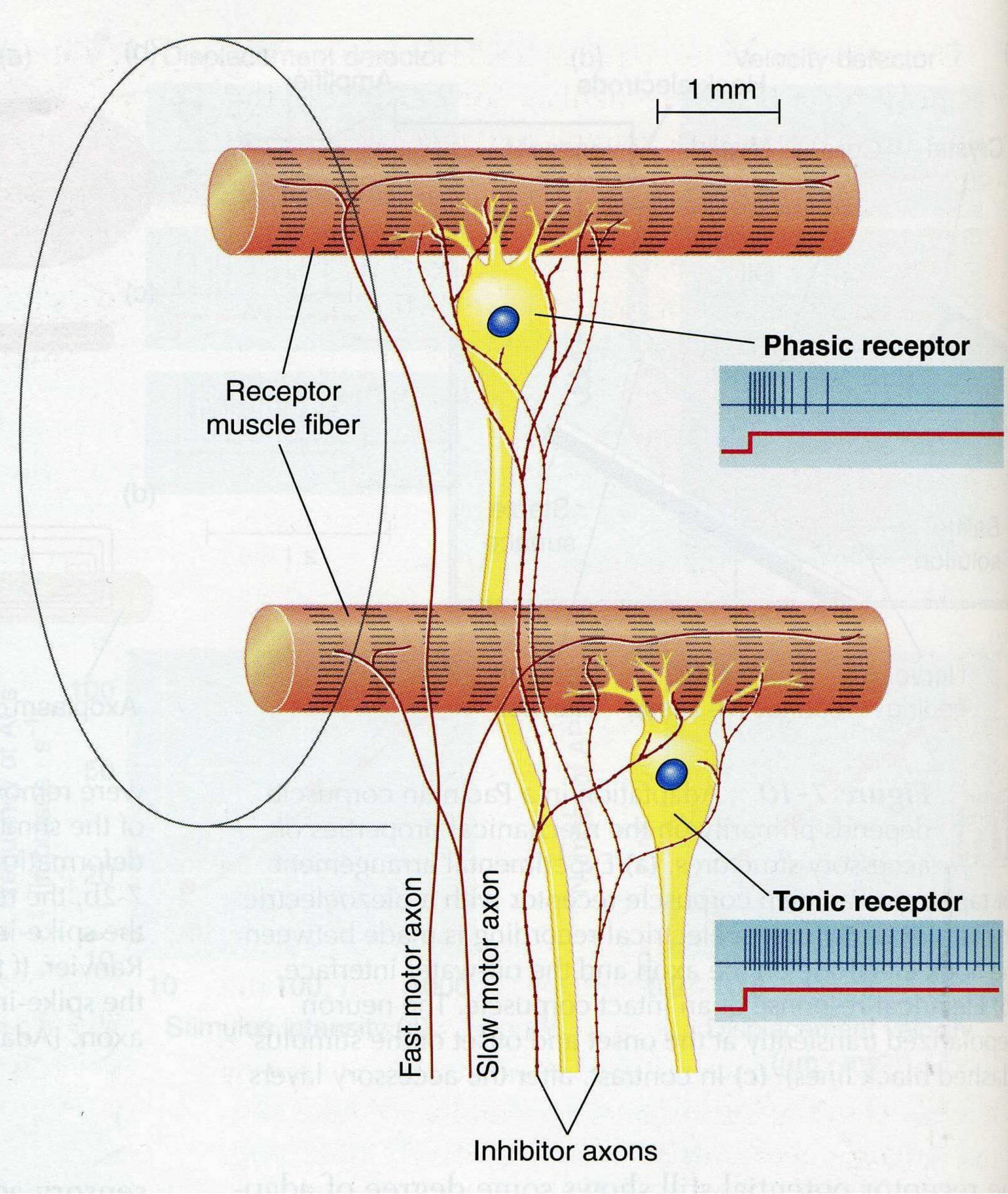
Kroky předcházející vzniku akčního potenciálu ve smyslových buňkách



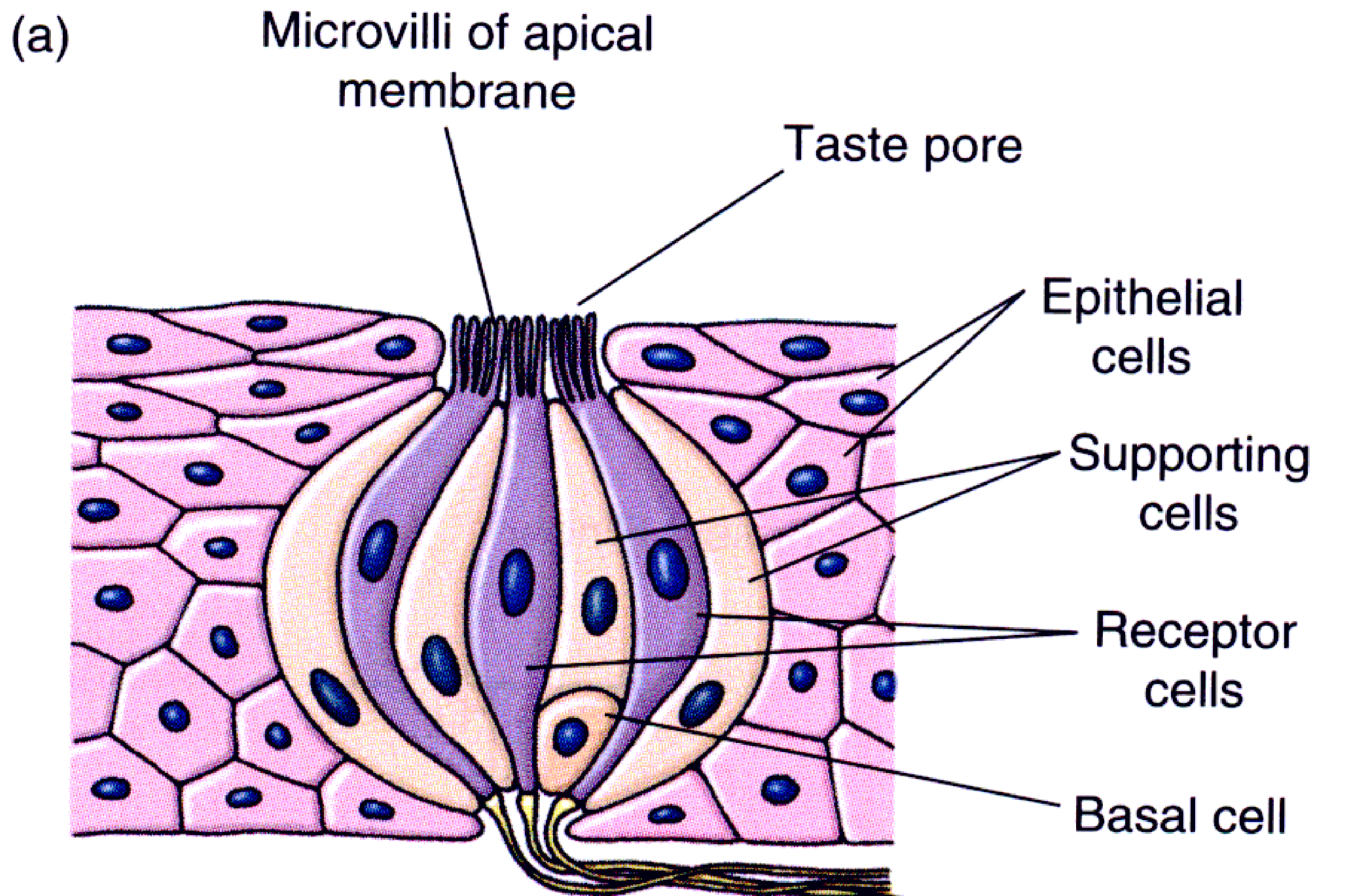


Primární (a, b) a sekundární (c) receptory

Fázické a tonické receptory

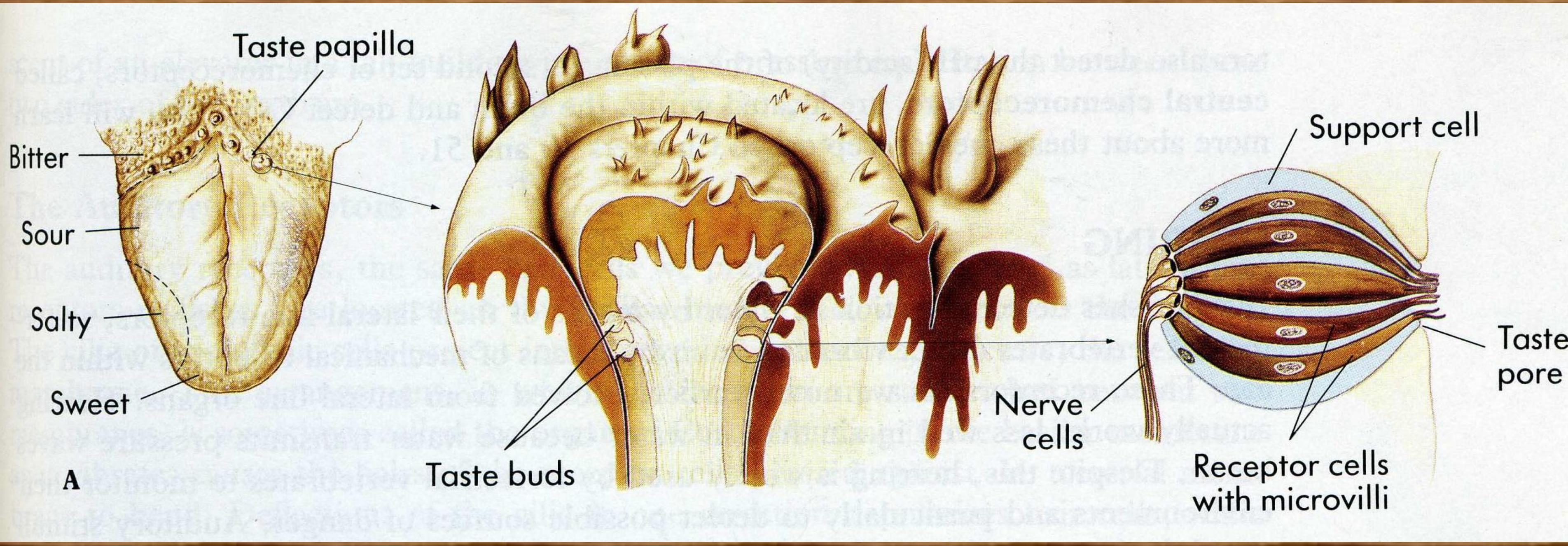


Chemoreceptory – chuťové orgány



Vertebrate taste bud

Chuťové receptory a jejich rozmístění na jazyku



8

Každý druh chuti spouští jiný mechanismus smyslové recepce

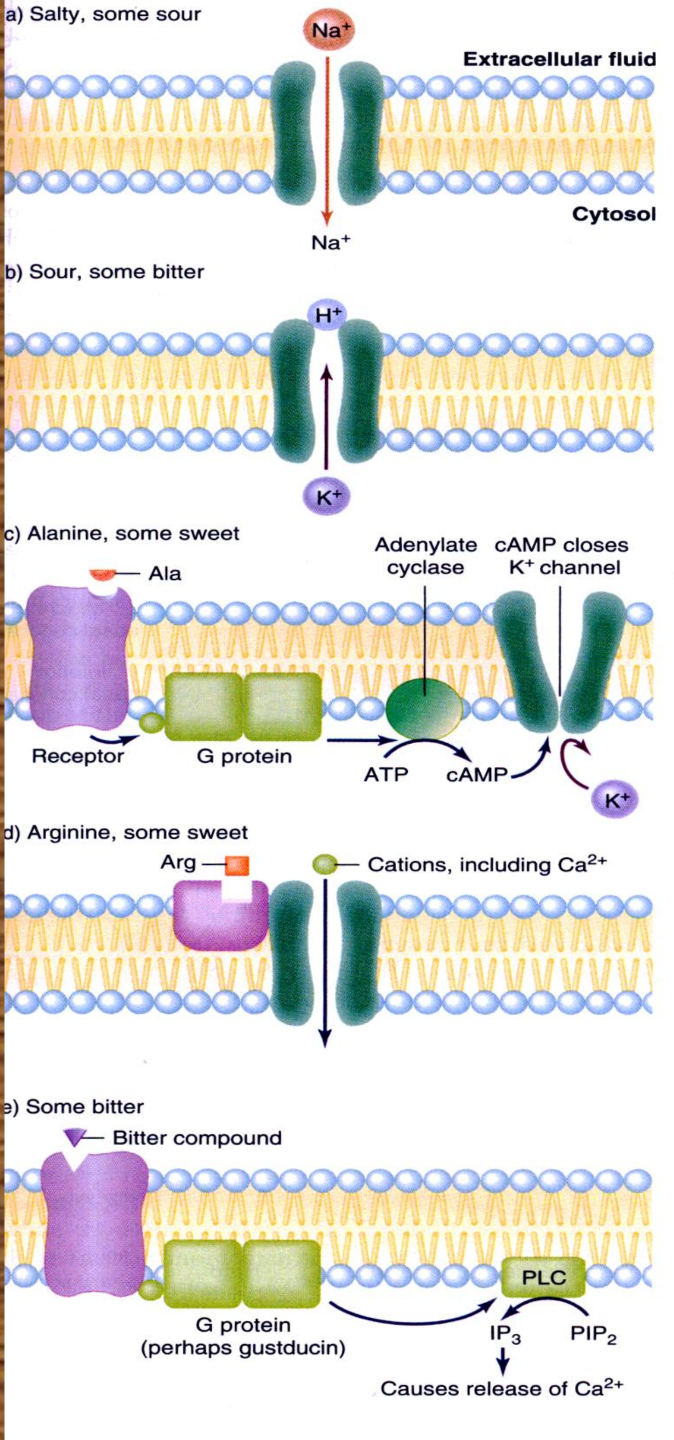
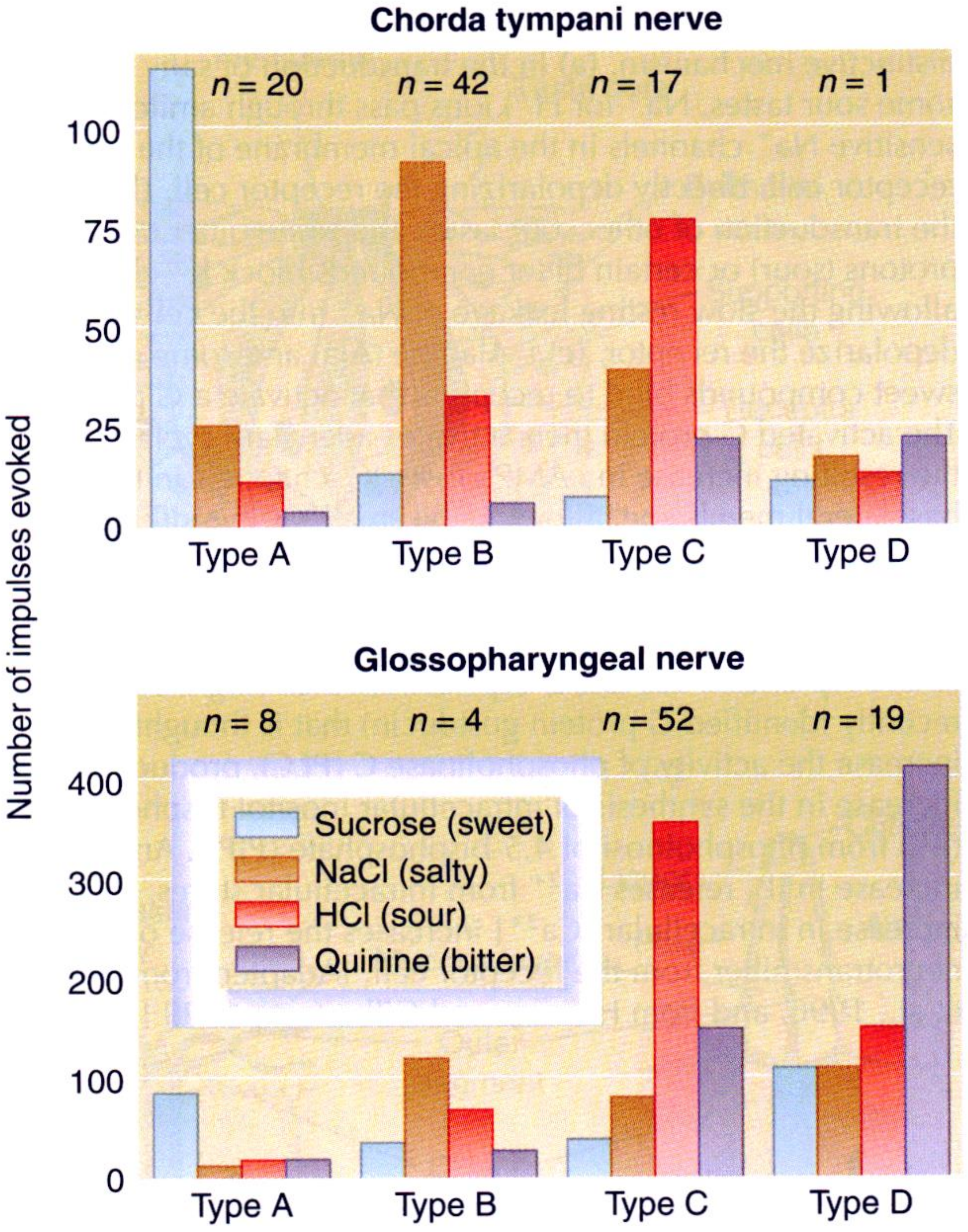
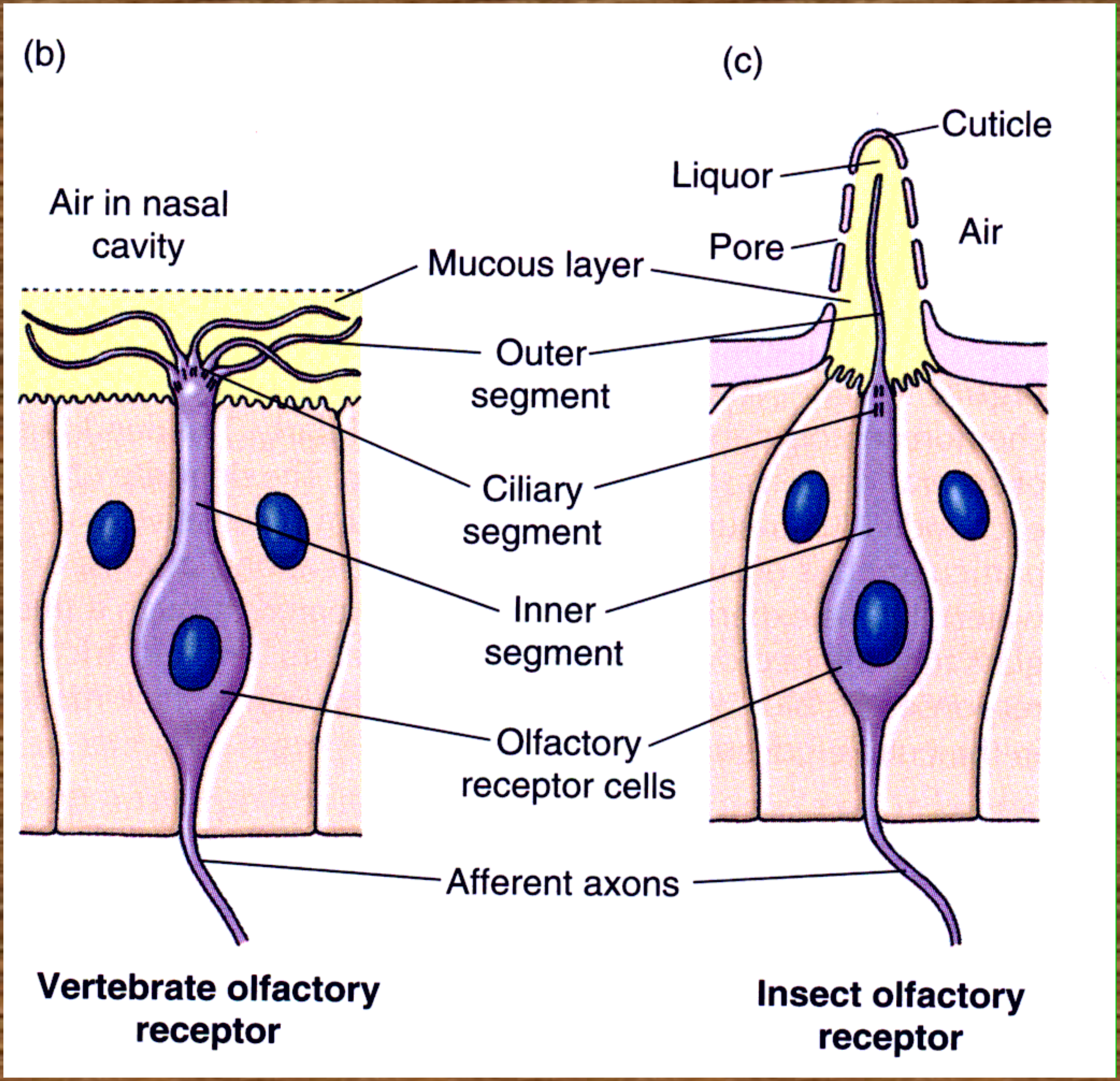


Figure 7-17 Each quality of taste is transduced by a distinctive mechanism. **(a)** In the transduction of salty and some sour tastes, Na^+ (or H^+) ions pass through amiloride-sensitive Na^+ channels in the apical membrane of the taste receptor cell, directly depolarizing the receptor cell. **(b)** In the transduction of other sour tastes and some bitter tastes, protons (sour) or certain bitter compounds block K^+ channels, allowing the slow resting leakage of Na^+ into the cell to depolarize the receptor. **(c)** L-Alanine (Ala) and some other sweet compounds bind to receptors that activate a G protein. The activated G protein then activates adenylate cyclase, and the resulting increase in cAMP closes K^+ channels in the basolateral membrane, allowing the small resting influx of Na^+ to depolarize the cell. **(d)** L-Arginine (Arg) and some sweet compounds bind to and open a ligand-gated, nonselective cation channel. **(e)** Some bitter compounds bind to a receptor and activate a G protein (which might be the recently identified G protein gustducin) that is thought to increase the activity of phospholipase C (PLC), producing an increase in the synthesis of intracellular inositol trisphosphate (IP_3) from phosphoinositol 4,5-bisphosphate (PIP_2). An increase in IP_3 releases Ca^{2+} from intracellular stores, and the increase in intracellular [Ca^{2+}] increases the release of neurotransmitter from the receptor cell. [Adapted from Bear et al., 1996, and from Herness and Gilbertson, 1999.]

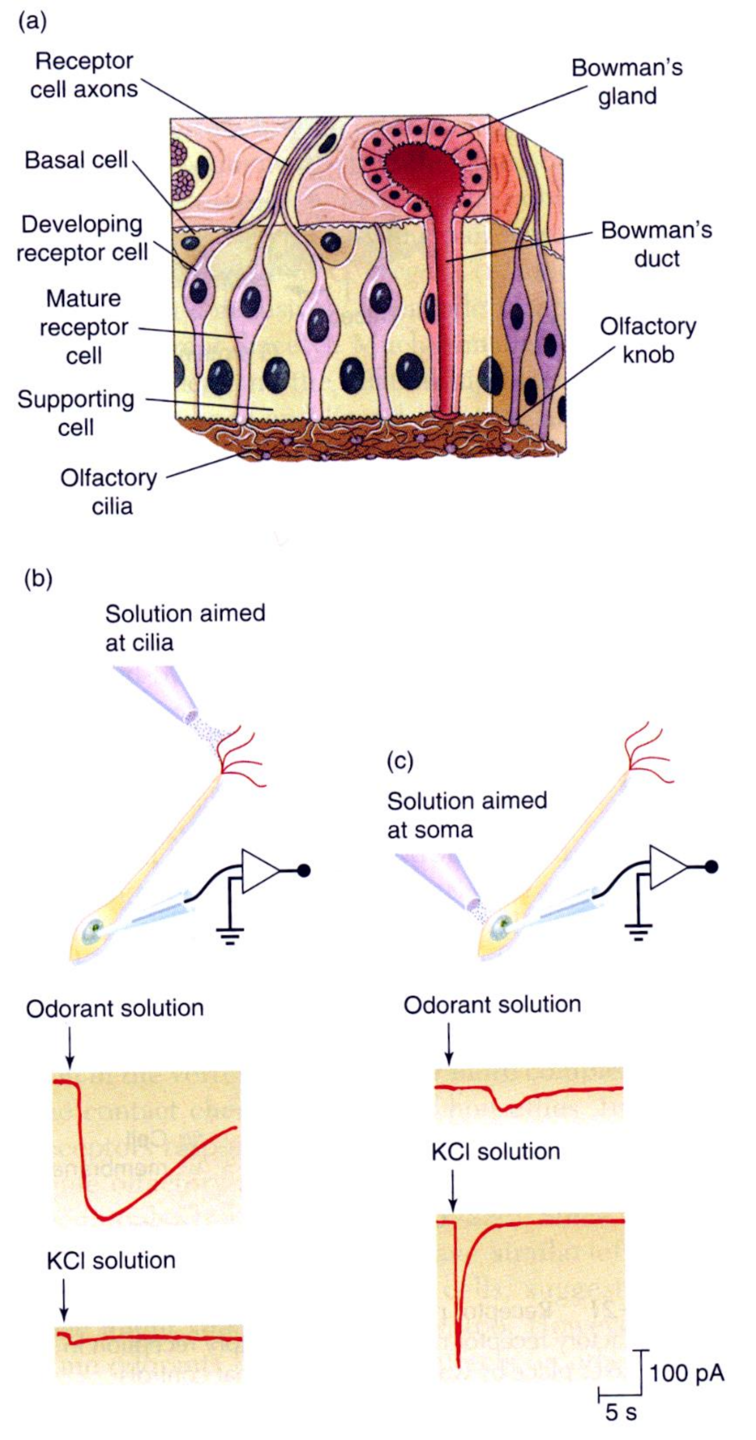


Každý chuťový pohárek je specializován na určitý druh chuti

Chemoreceptory – čichové orgány



11



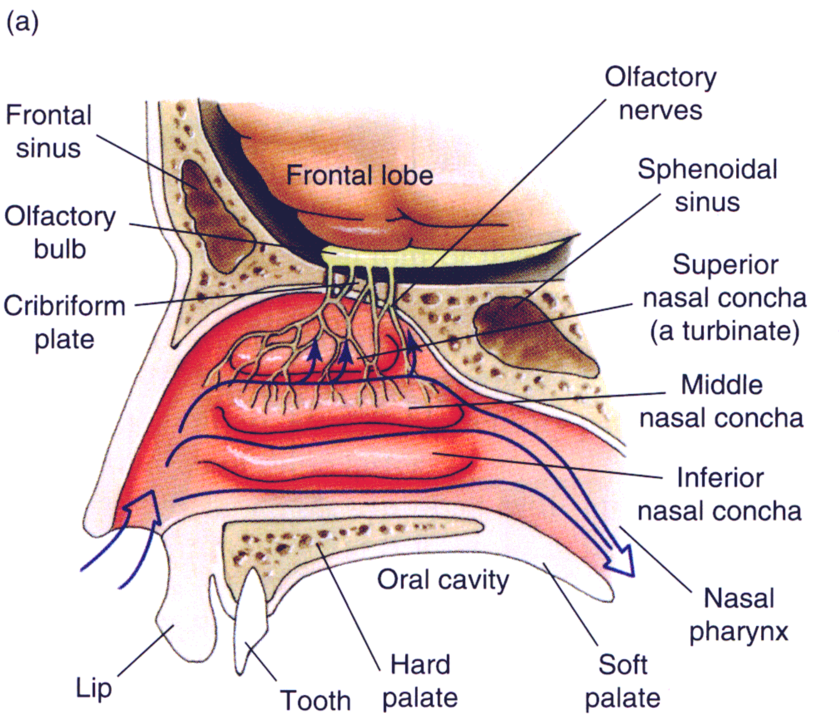
a) Sliznice savčího čichového orgánu

b) Aplikace pachu nebo KCl na mikrovilly čichové buňky

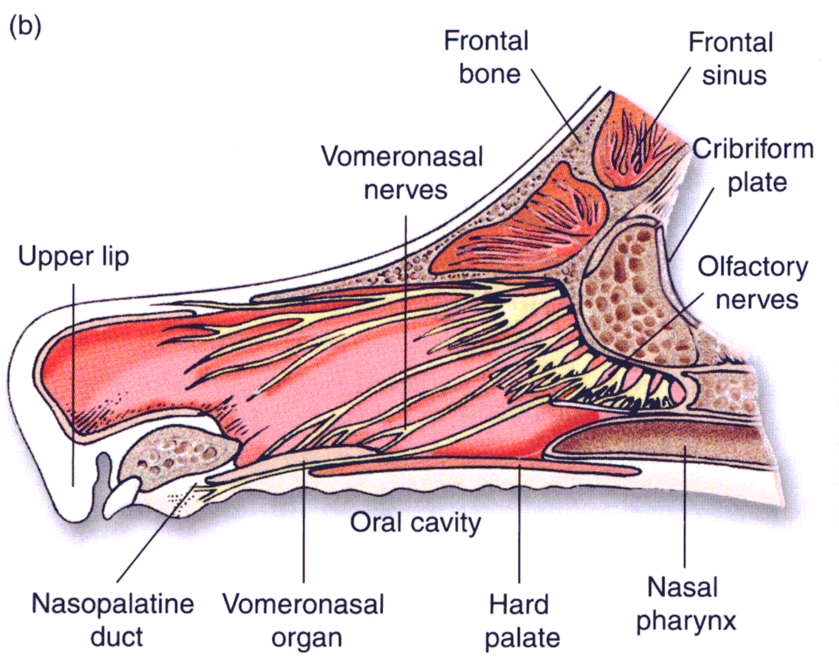
c) Aplikace pachu nebo KCl na tělo čichové buňky

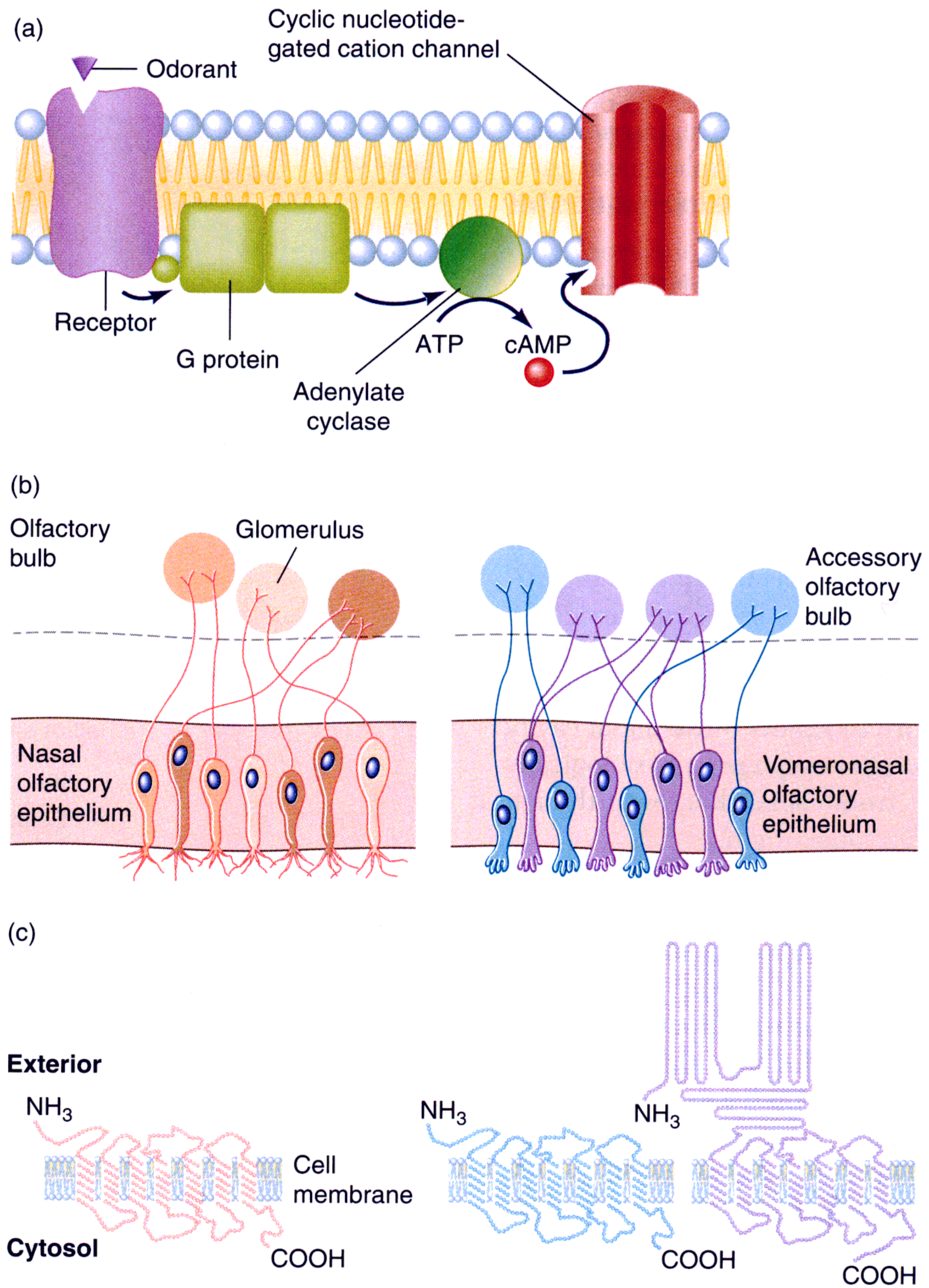
Čichový orgán:

(a) člověka



(b) Psa



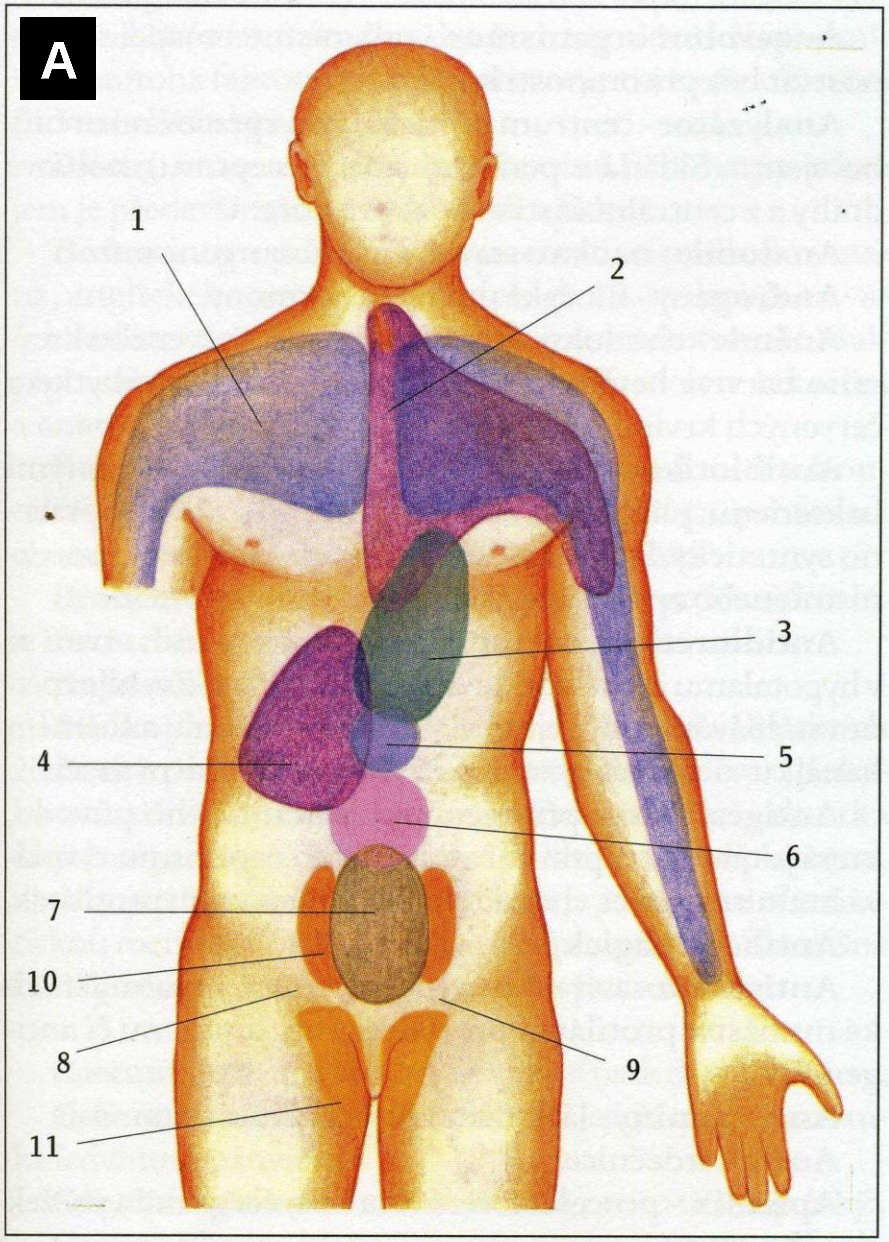


a) **Mechanismus vzniku AP u čichového receptoru: receptor – G-protein – adenylát cykláza – cAMP – aktivace kationového kanálu – depolarizace – AP**

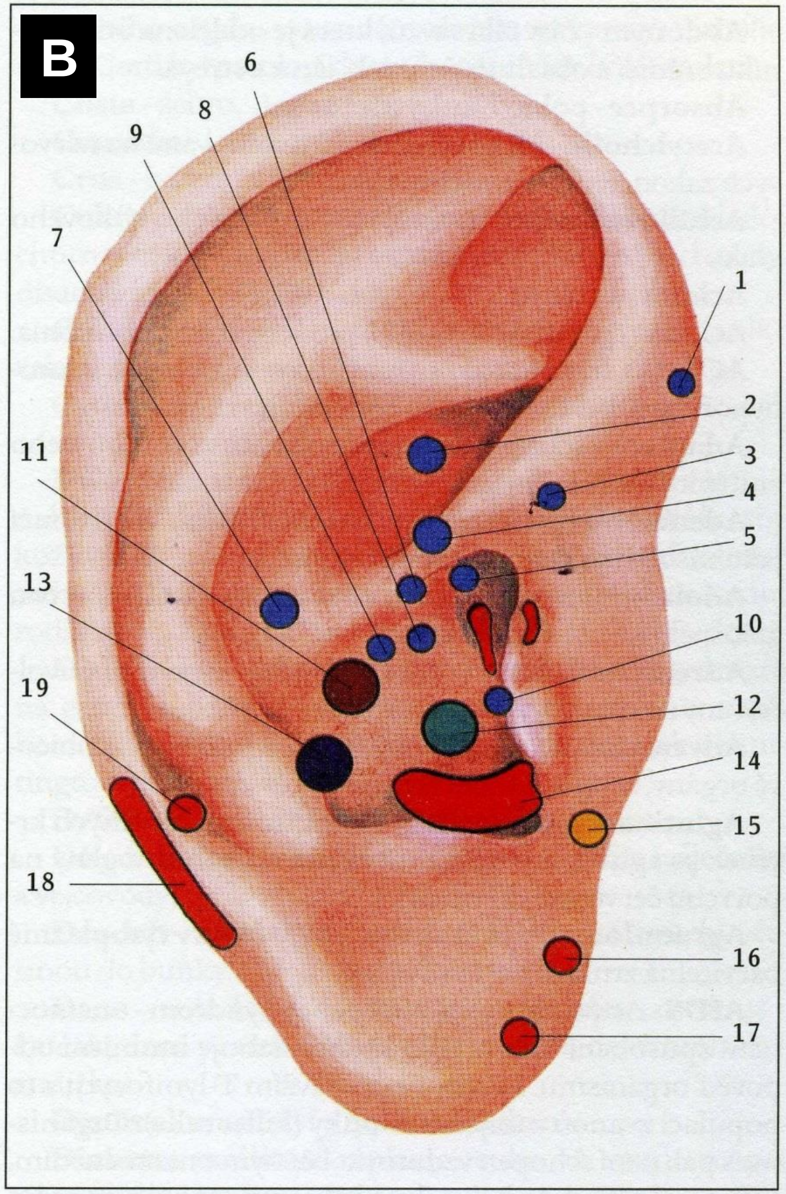
b) **Organizace čichové a vomeronasální sliznice – existence glomerulu**

c) **Struktura receptoru G-proteinu**

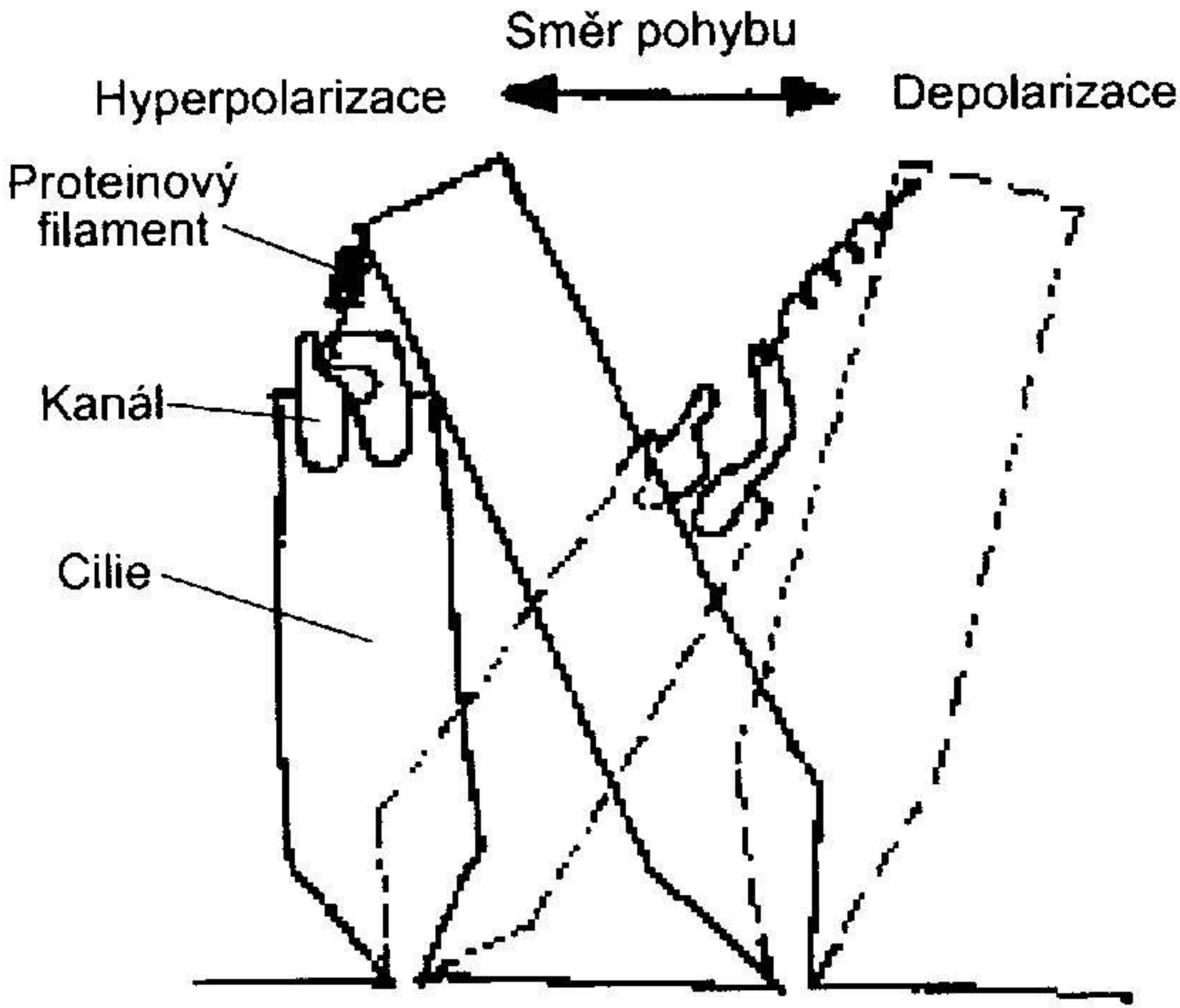
14



Obr. 16-26: Hedovy zóny: Na obrázku je znázorněn princip přenesené bolesti (referred pain) z vnitřních orgánů na kůži. 1 - srdce; 2 - jícen; 3 - žaludek; 4 - játra a žaludek; 5 - pankreas; 6 - pupek; 7 - apendix a tenké střevo; 8 - pravá ledvina; 9 - levá ledvina; 10 - tlusté střevo; 11 - močový měchýř.

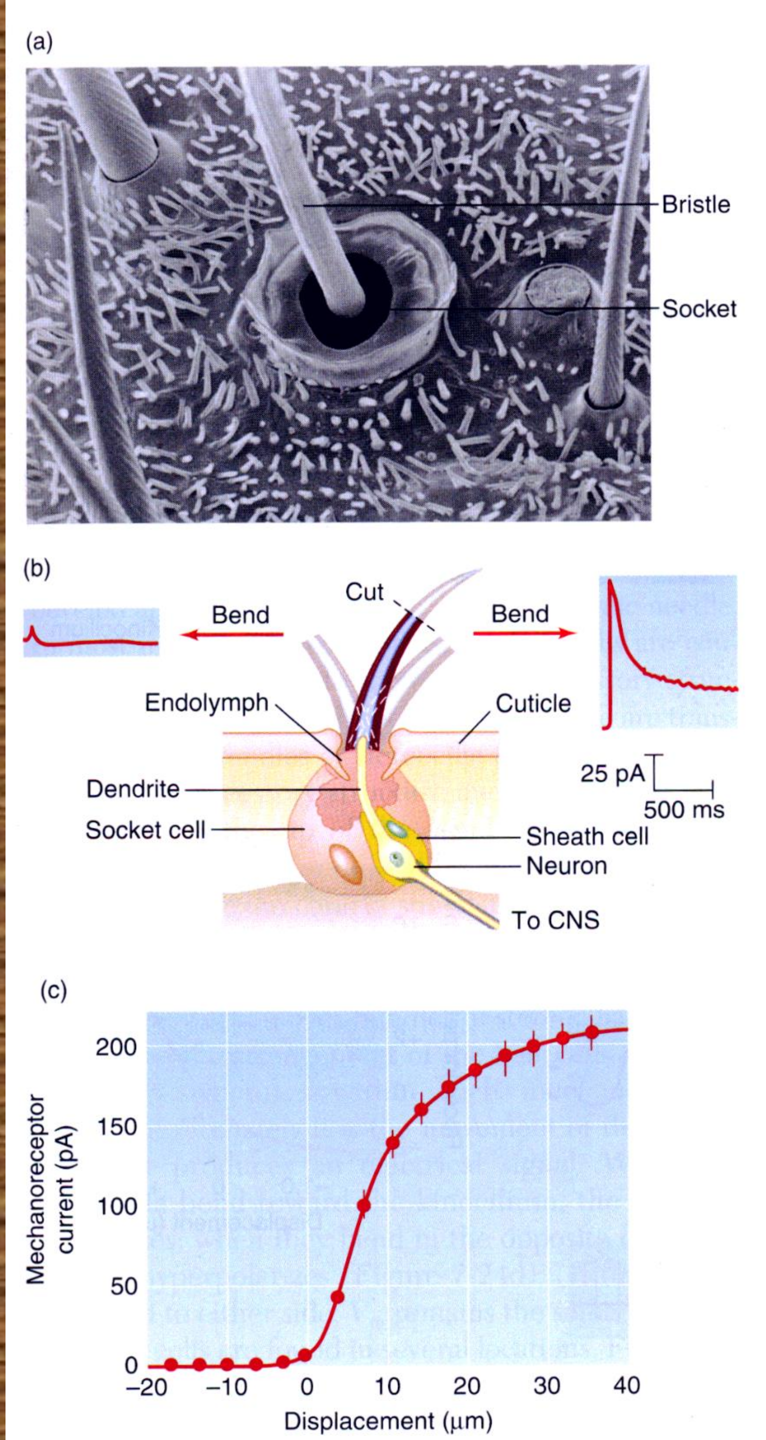


Obr. 16-27: Aurikuloakupunktura. Projekce různých orgánů a systémů na ušní boltec. 1 - zevní pohlavní orgány; 2 - močovod; 3 - močová trubice; 4 - konečník; 5 - žaludek; 6 - česlo žaludku; 7 - slezina; 8 - plíce a srdce; 9 - průdušky; 10 - mozkový kmen; 11 - průdušinky; 12 - ušní žláza; 13 - bod pro bolest zubů; 14 - vrchol lebky; 15 - bod vysokého tlaku; 16 - analgezie během extrakce zubu; 17 - neurorastenie; 18 - adenoidní vegetace; 19 - appendix.

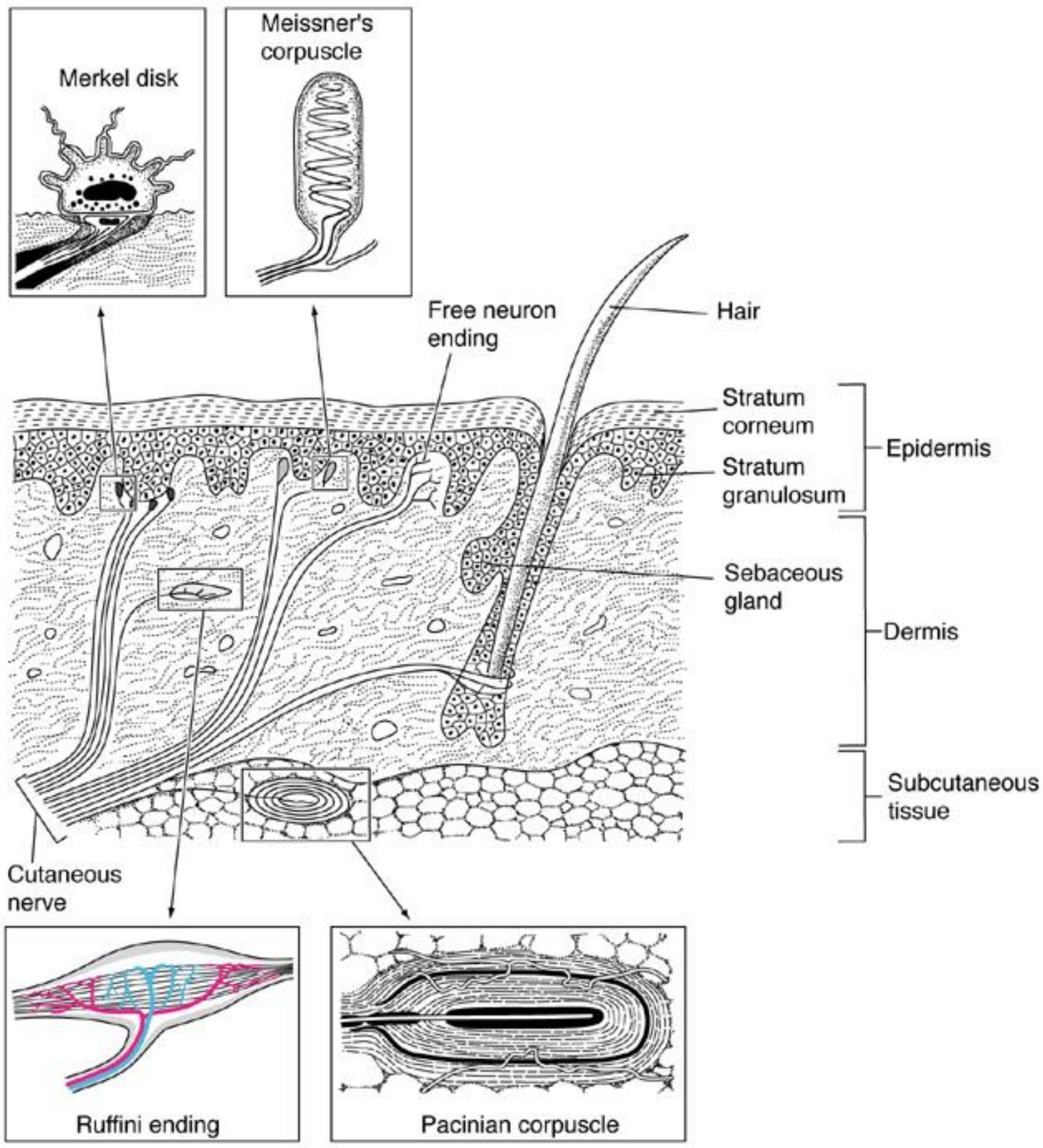


Obr. 17.2. Transdukce mechanického podnětu na vláskových buňkách. Pohyblivá doména kationtového kanálu jednoho vlásku (cilie) je spojena se sousedním vláskem. Vzájemný pohyb cilií vede k otevírání a zavírání kanálu a vzniku receptorového potenciálu. Pohyb doprava depolarizuje, doleva hyperpolarizuje.

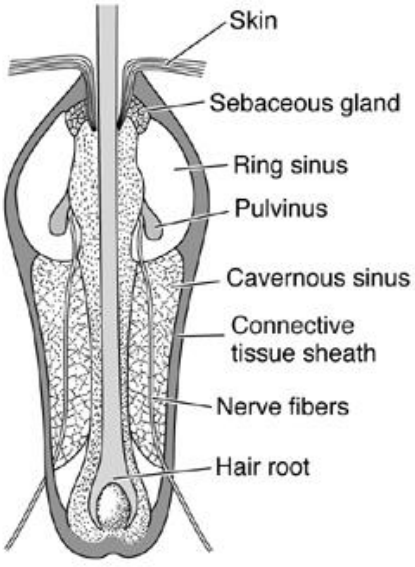
Hmyzí mechanoreceptor – trichoidní senzila – kutikulární chlup



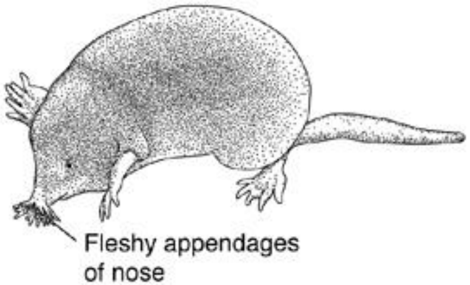
Přehled jednoduchých kožních mechanoreceptorů



A. General sensory receptors of mammalian skin



B. Sinus hair (whiskers)



C. Star-nose mole, Condylura

Termoreceptory u hadů

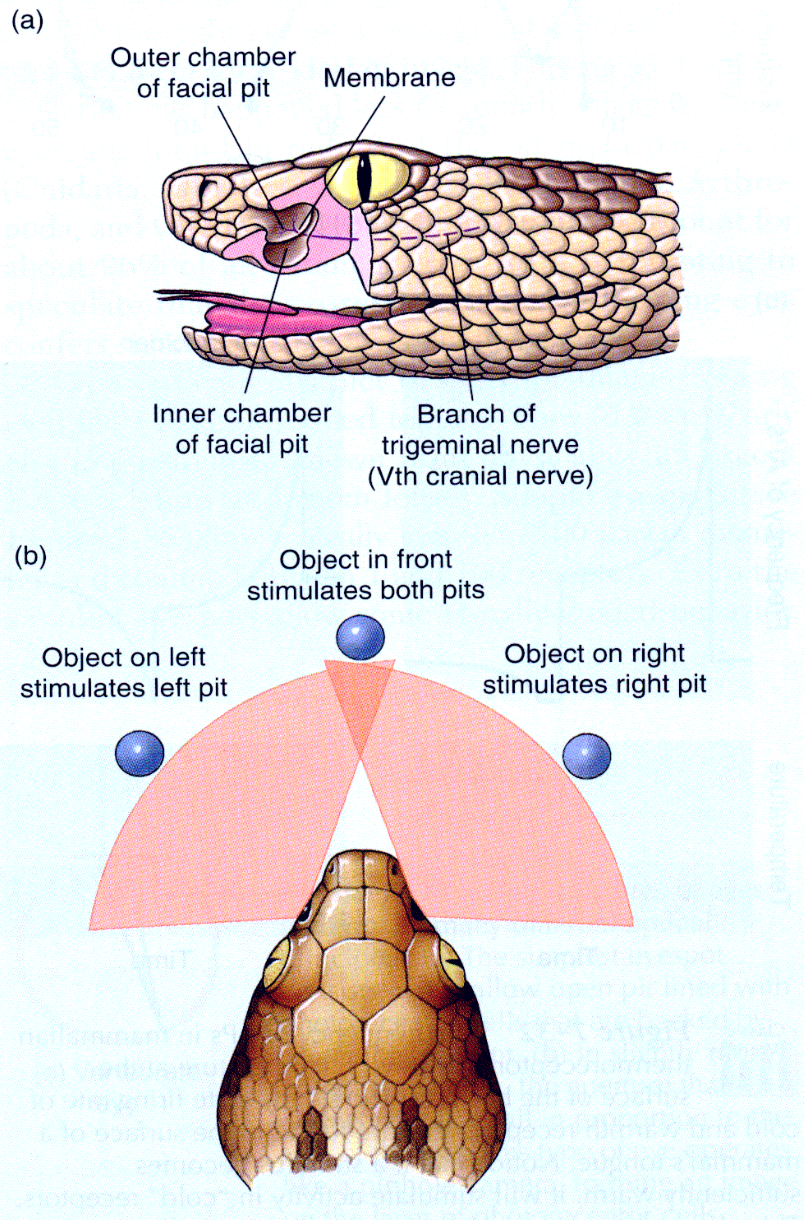
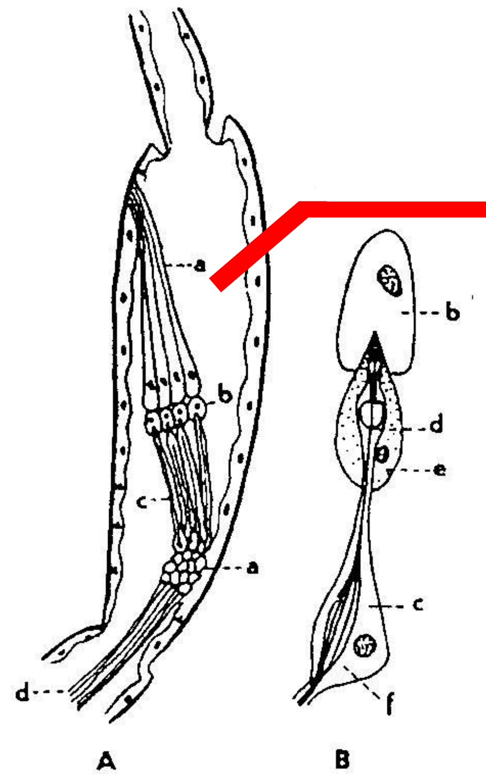


Figure 2 *The facial pits of rattlesnakes contain extraordinarily sensitive thermoreceptors.* ***(a)*** *Structure of a facial pit in the rattlesnake* Crotalus viridis. ***(b)*** *The position of the facial pits makes thermoreception directionally sensitive. [Adapted from Bullock and Diecke, 1956.]*

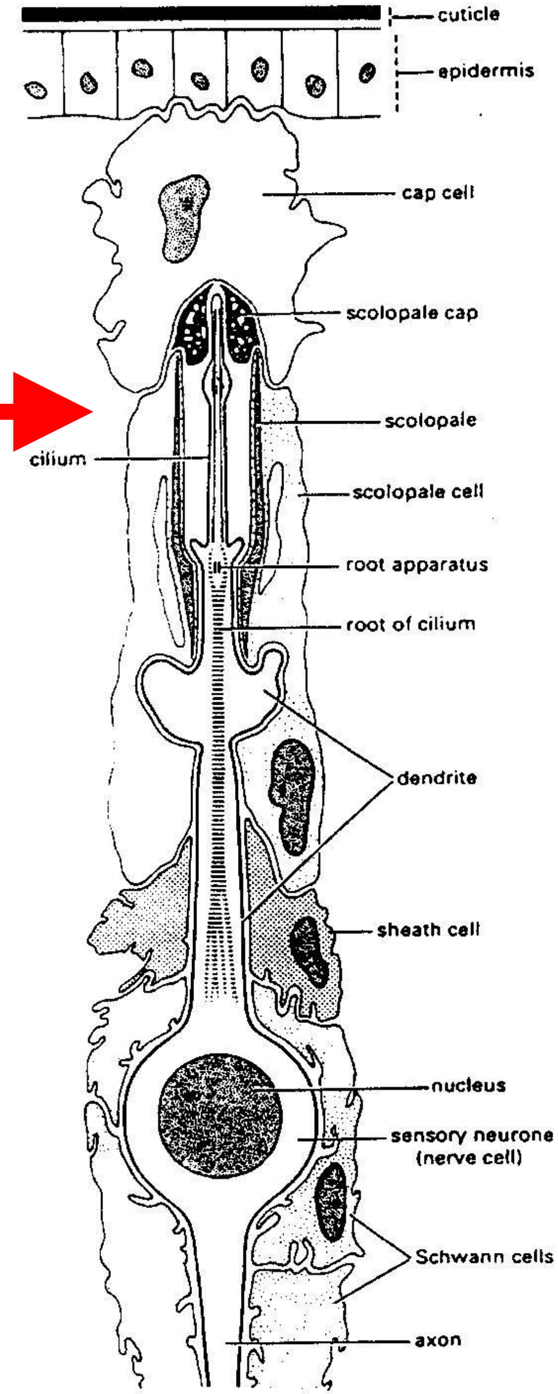
Schéma hmyzího chordotonálního orgánu (vlevo) a jeho detail (vpravo)



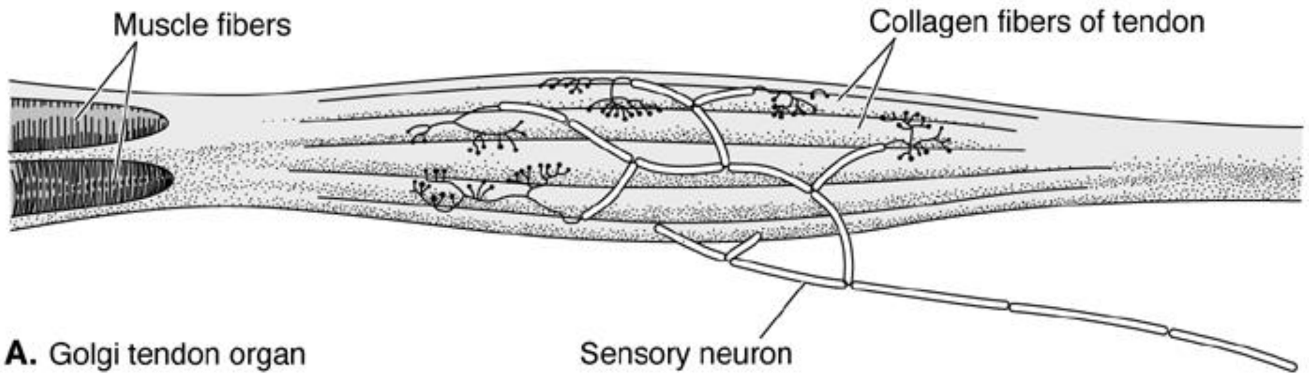
Chordotonální ústrojí hmyzu

A – chordotonální orgán zavěšený v dutině holeně hmyzu,
B – scolopophor z tympanálního orgánu sarančete

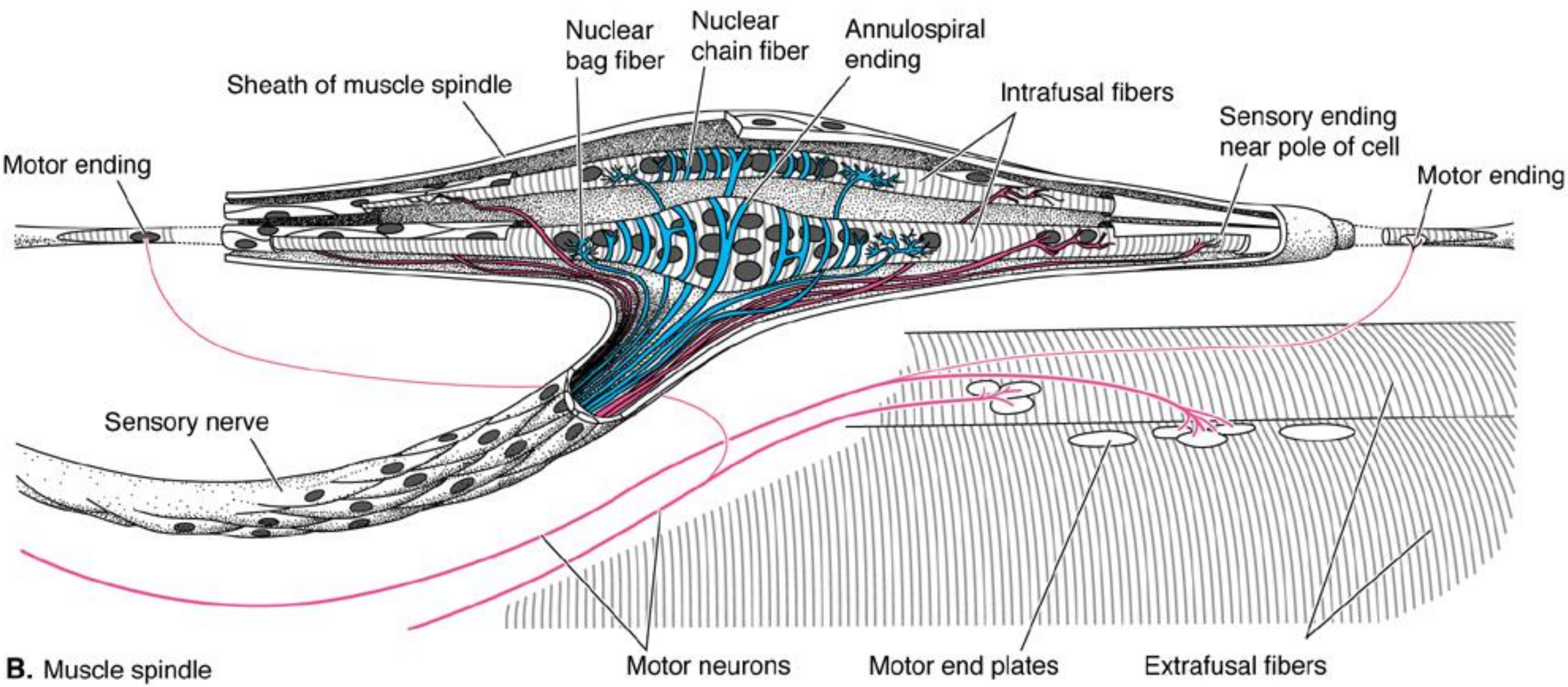
a = upevňovací buňky, b = krycí buňky, c = smyslové buňky s cípky, d = cípek smyslové buňky, e = obalová buňka, f = neurofibrily



Přehled vnitřních mechanoreceptorů



A. Golgi tendon organ



B. Muscle spindle

Proudový smysl ryb a obojživelníků

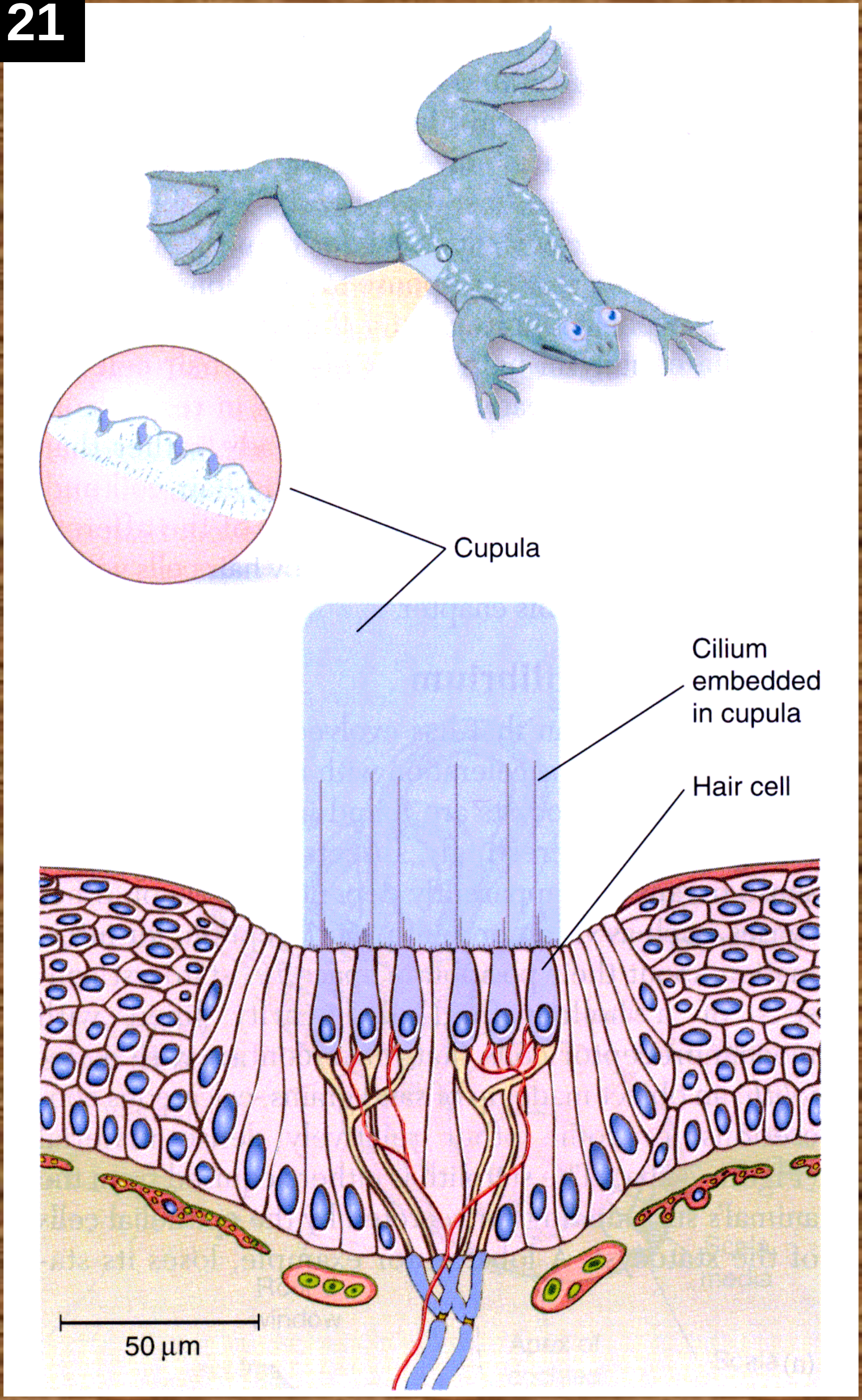
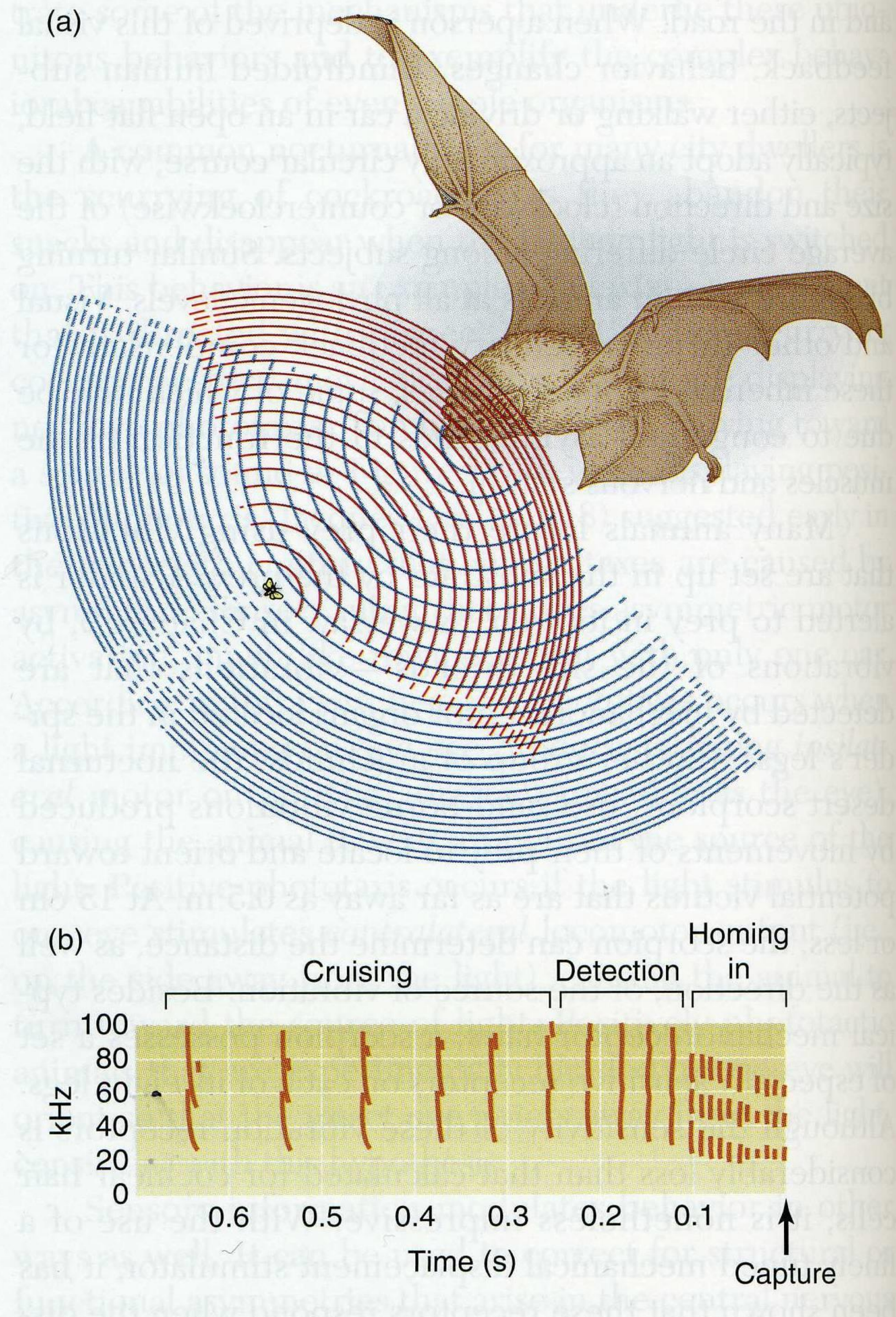
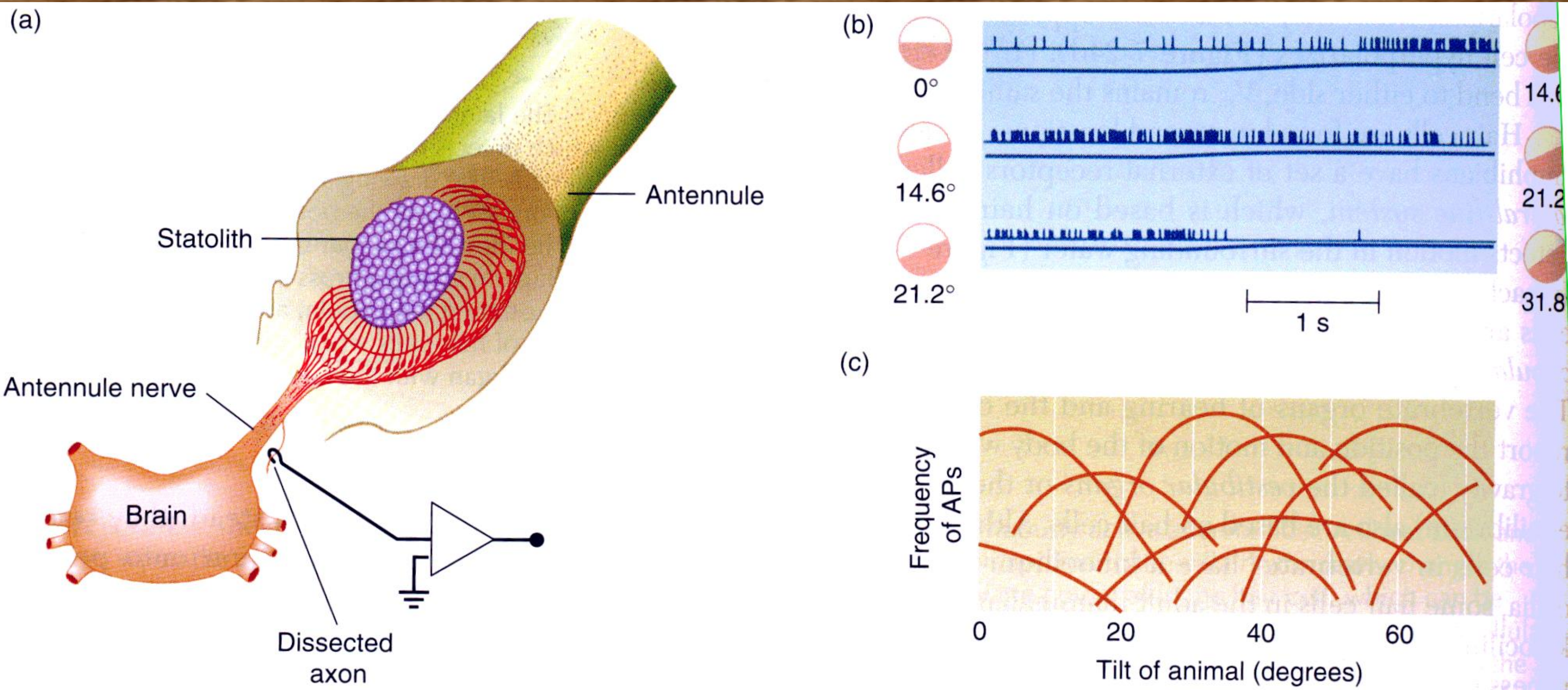


Figure 7-25 The lateral-line sensory system of fishes and amphibians, which detects motions in the surrounding water, is based on hair cells. The drawing shows the location of these mechanosensory organs along the body of an African clawed frog *(Xenopus)*. The inset shows four units along the lateral line. The lower diagram shows a cross-section through part of the lateral line, illustrating the cupula, an accessory structure that bends the cilia of hair cells when it is displaced. Compare the structure of this organ with the hair cells shown in Figure 7-24.

Echolokace u netopýra



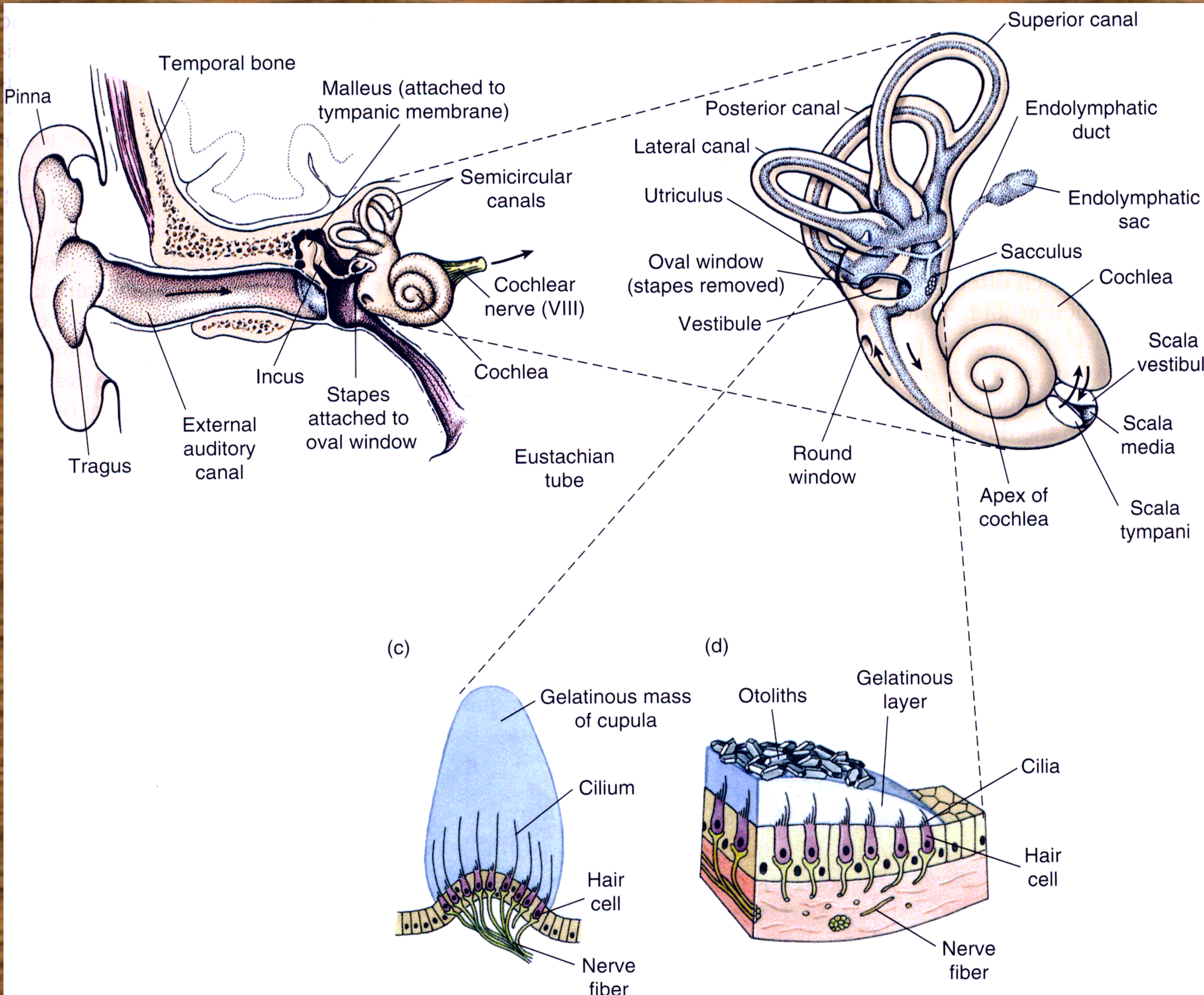
Statocysty korýšů

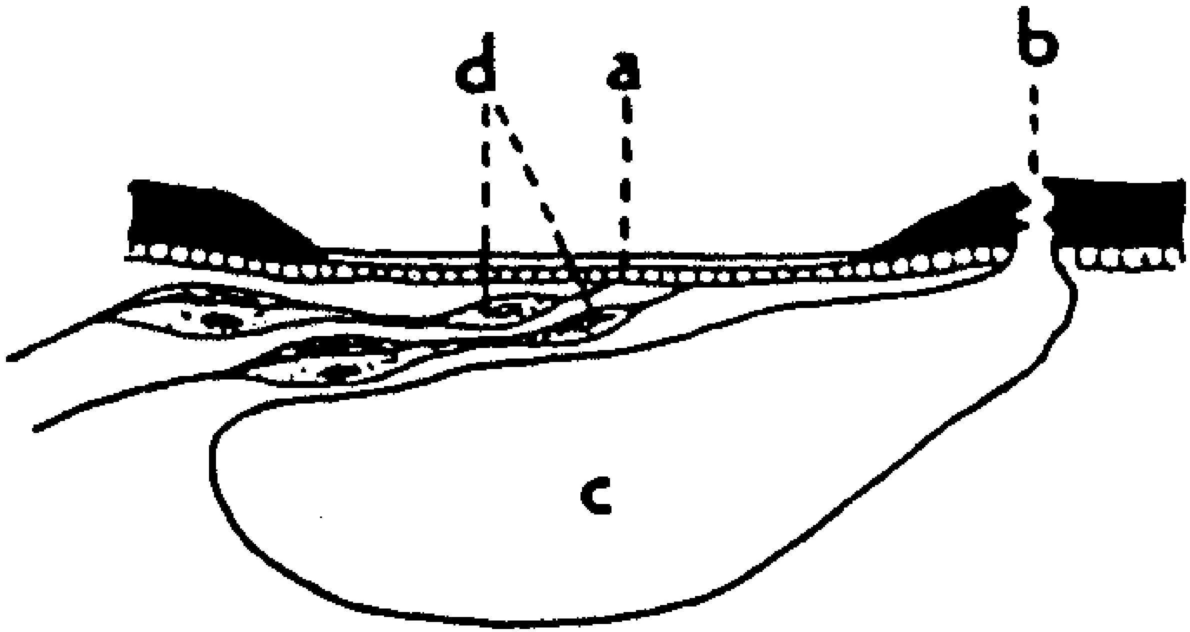


Classic Work

Figure 7-26 Statocysts sense position and acceleration with respect to gravity. **(a)** Structure of a statocyst in a lobster. A statolith rests on an array of ciliated cells that, unlike vertebrate hair cells, themselves send axons to the brain. **(b)** Action potentials recorded from individually dissected nerve fibers while a lobster was being tilted. All three recordings show the response of a single receptor, and the trace below the recording indicates the initial and final angle and the time course of the tilt. Notice that this receptor is tonically active any time the animal is tilted between 10 and 25 degrees. **(c)** Frequencies of APs recorded from different fibers plotted as a function of the position of the animal. Each cell responded with a maximum rate of discharge when the animal's body was held at a particular position, and the orientation that produced a maximal response varied among fibers. [Adapted from Horridge, 1968.]

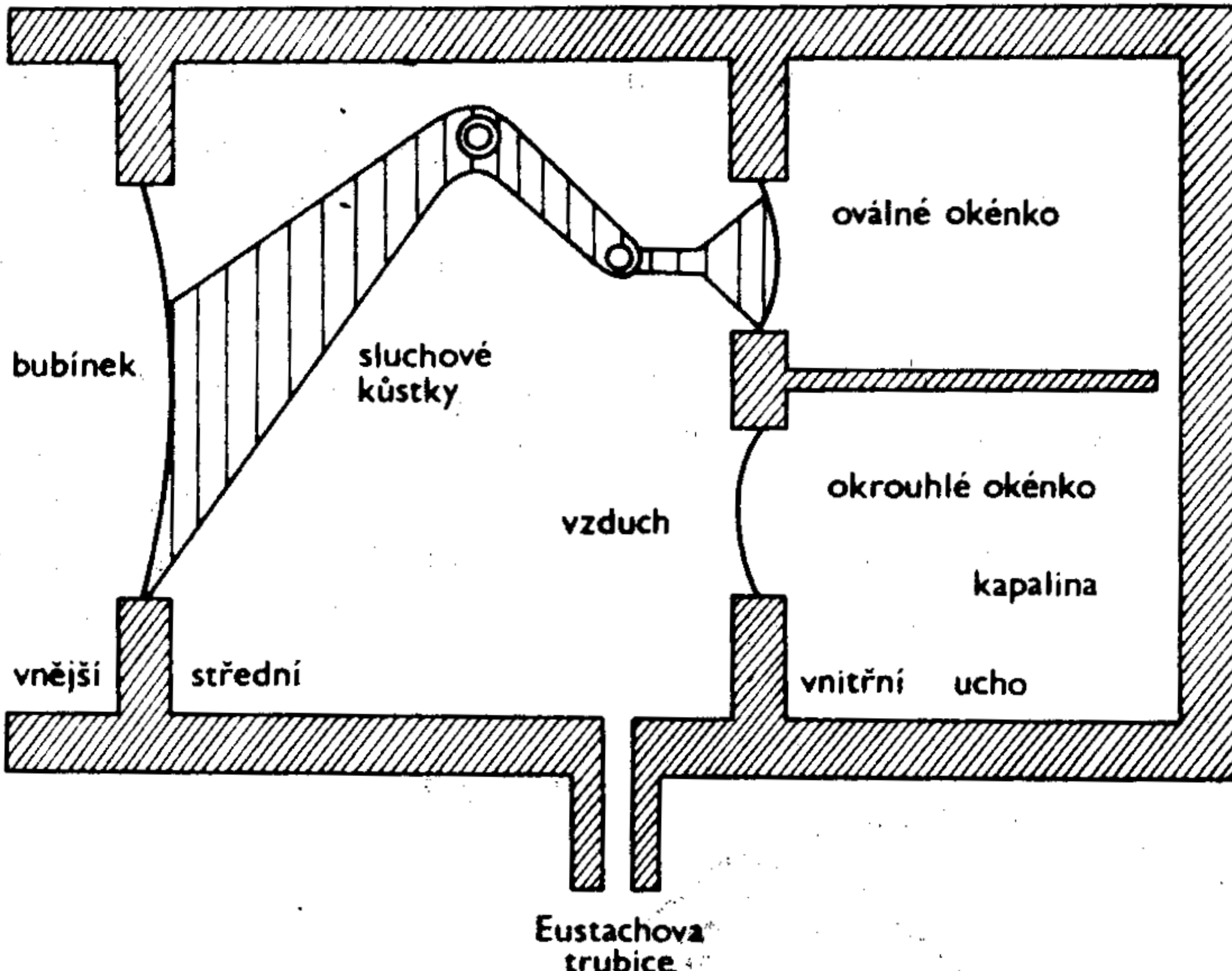
Sluchový a rovnovážný orgán člověka





Tympanální ústrojí hmyzu (saranče)

a = bubínek, b = stigma vzdušnice, c = rezonátor (váček nadmuté vzdušnice), d = smyslové buňky (crista acustica)



Obr. 208. Schematické znázornění převodu vibrací z vnějšího do vnitřního ucha.

Vnitřní ucho - detail

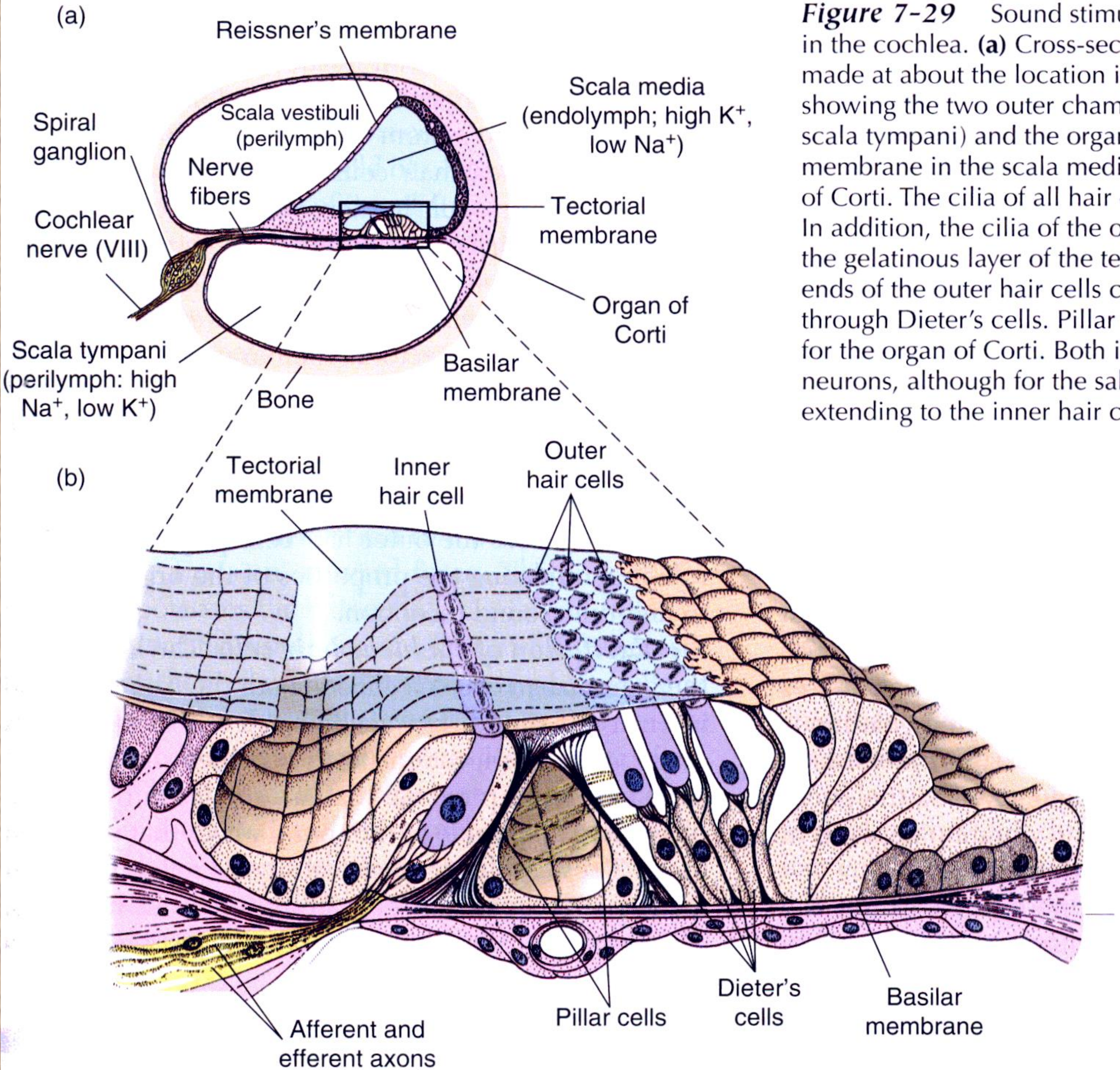
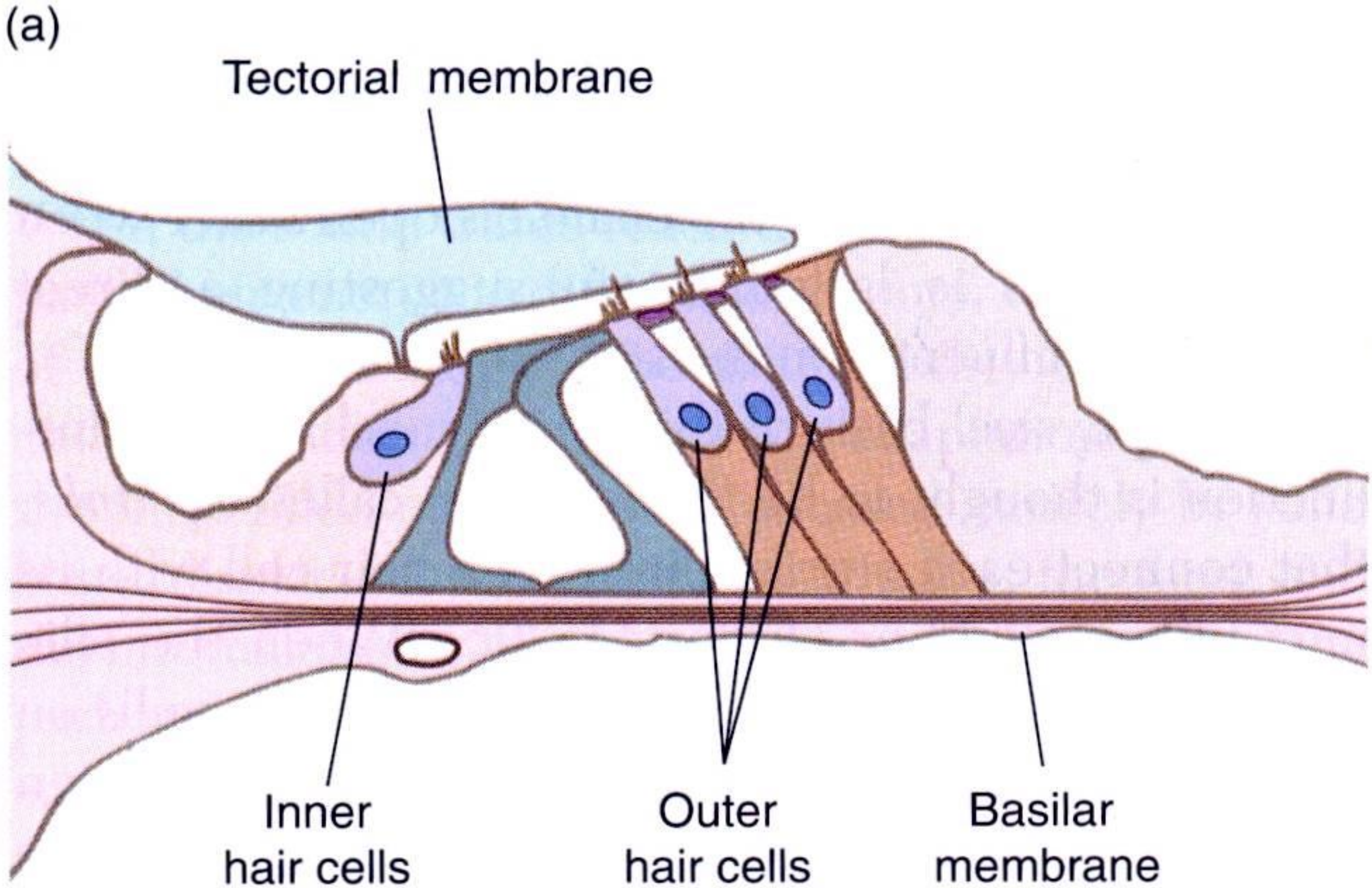


Figure 7-29 Sound stimuli are transduced by hair cells in the cochlea. **(a)** Cross-section through cochlear canal, made at about the location illustrated in Figure 7-27b, showing the two outer chambers (the scala vestibuli and the scala tympani) and the organ of Corti attached to the basilar membrane in the scala media. **(b)** Enlargement of the organ of Corti. The cilia of all hair cells are bathed in endolymph. In addition, the cilia of the outer hair cells are embedded in the gelatinous layer of the tectorial membrane. The basal ends of the outer hair cells connect to the basilar membrane through Dieter's cells. Pillar cells provide structural support for the organ of Corti. Both inner and outer hair cells contact neurons, although for the sake of clarity only the fibers extending to the inner hair cells are shown in this diagram.

Vnitřní ucho, tektoriální membrána - detail



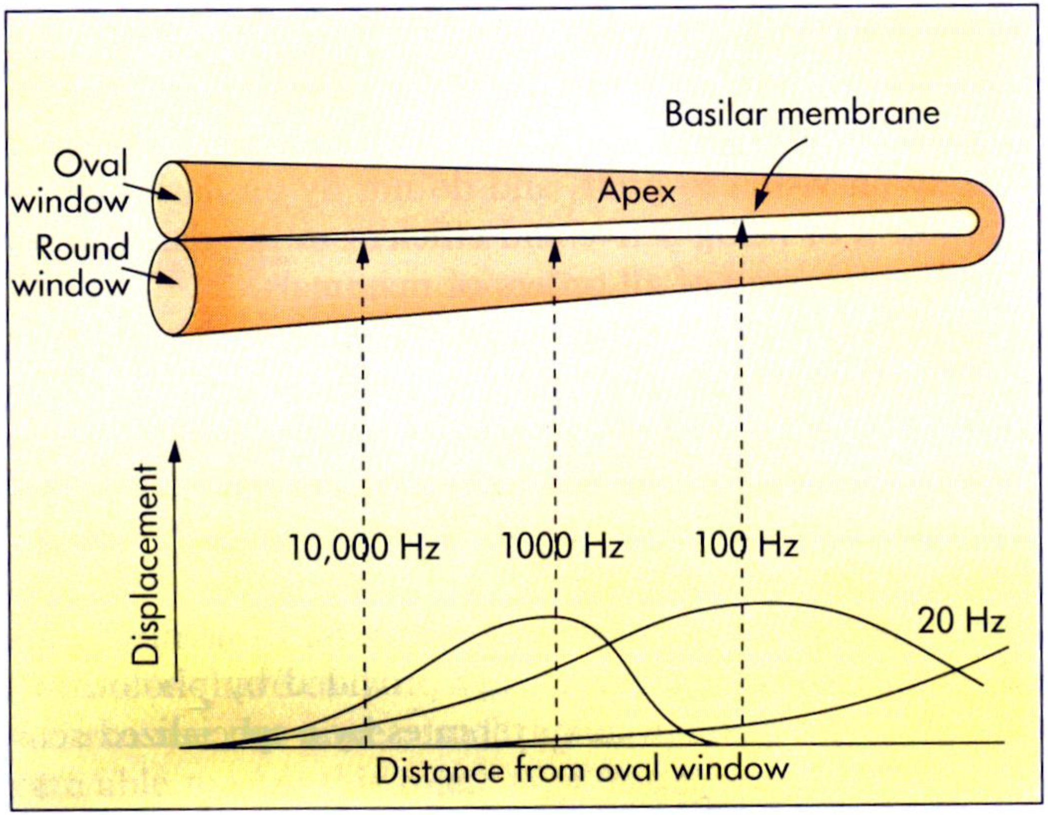
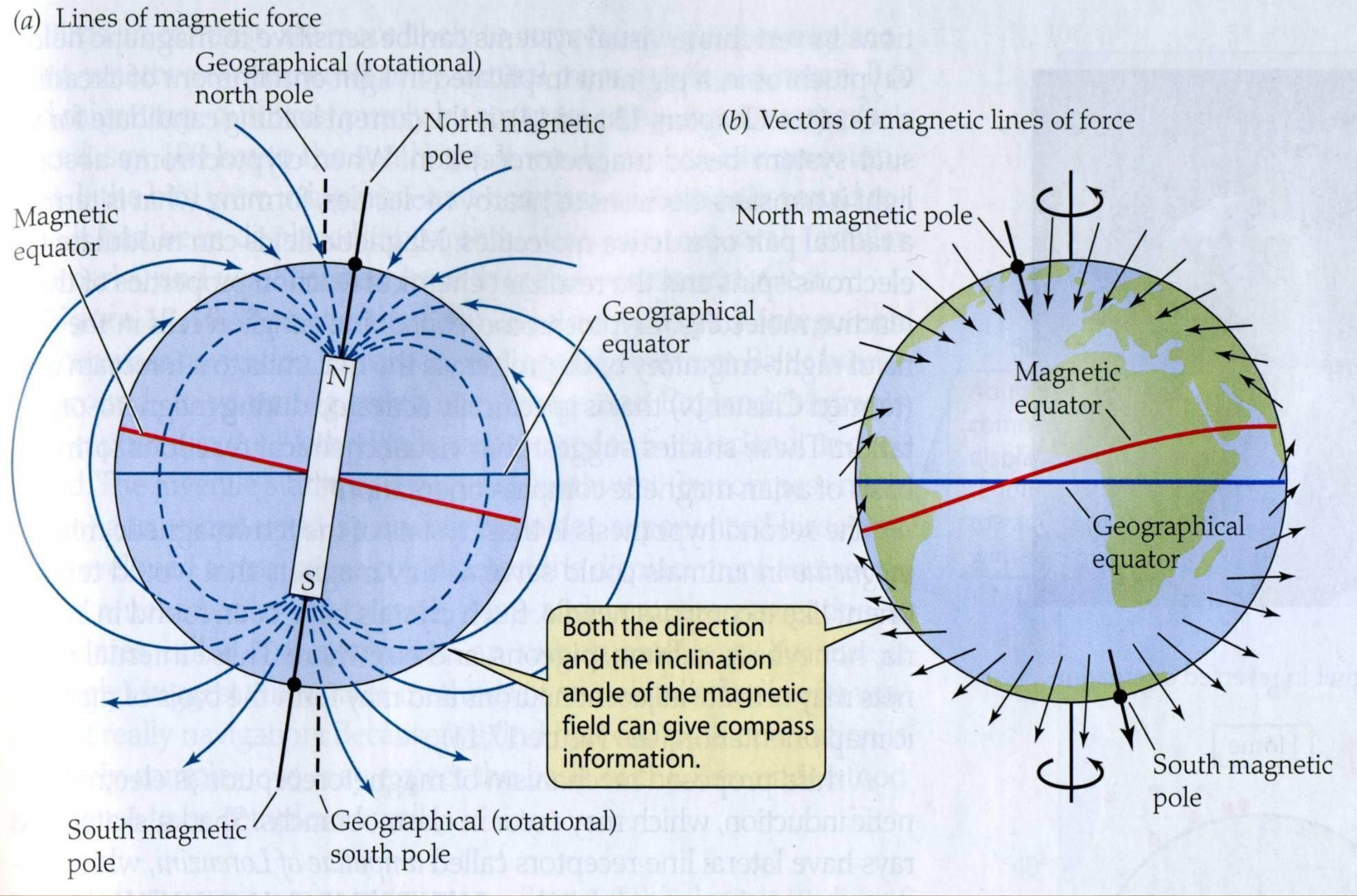


FIGURE 46-15

Frequency localization in the cochlea. The cochlea is shown unwound at the top, while the resonance of the basilar membrane in response to different sound frequencies (tones) is illustrated below. The parts of the basilar membrane nearest the oval window resonate preferentially to sounds of high frequency; at increasing distances from the oval widow progressively lower resonant frequencies are encountered.

https://www.youtube.com/watch?v=MXt_gX2Srgo

Magnetické pole Země



31

Důkaz orientace holuba podle magnetického pole Země

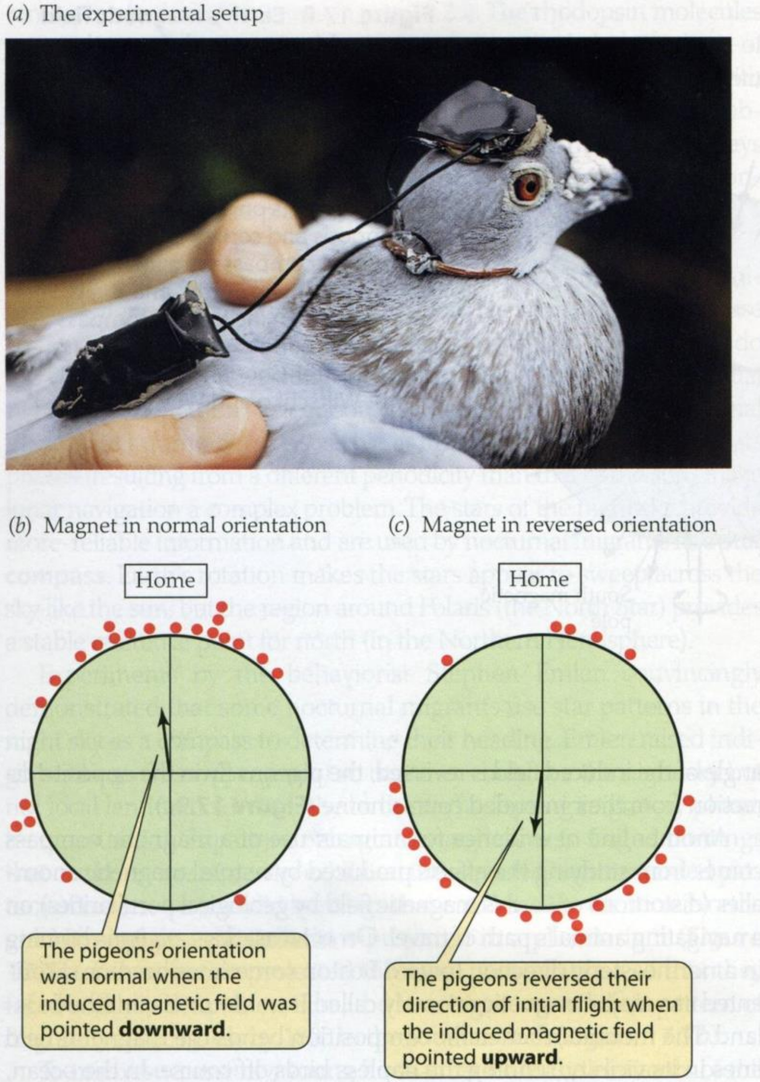
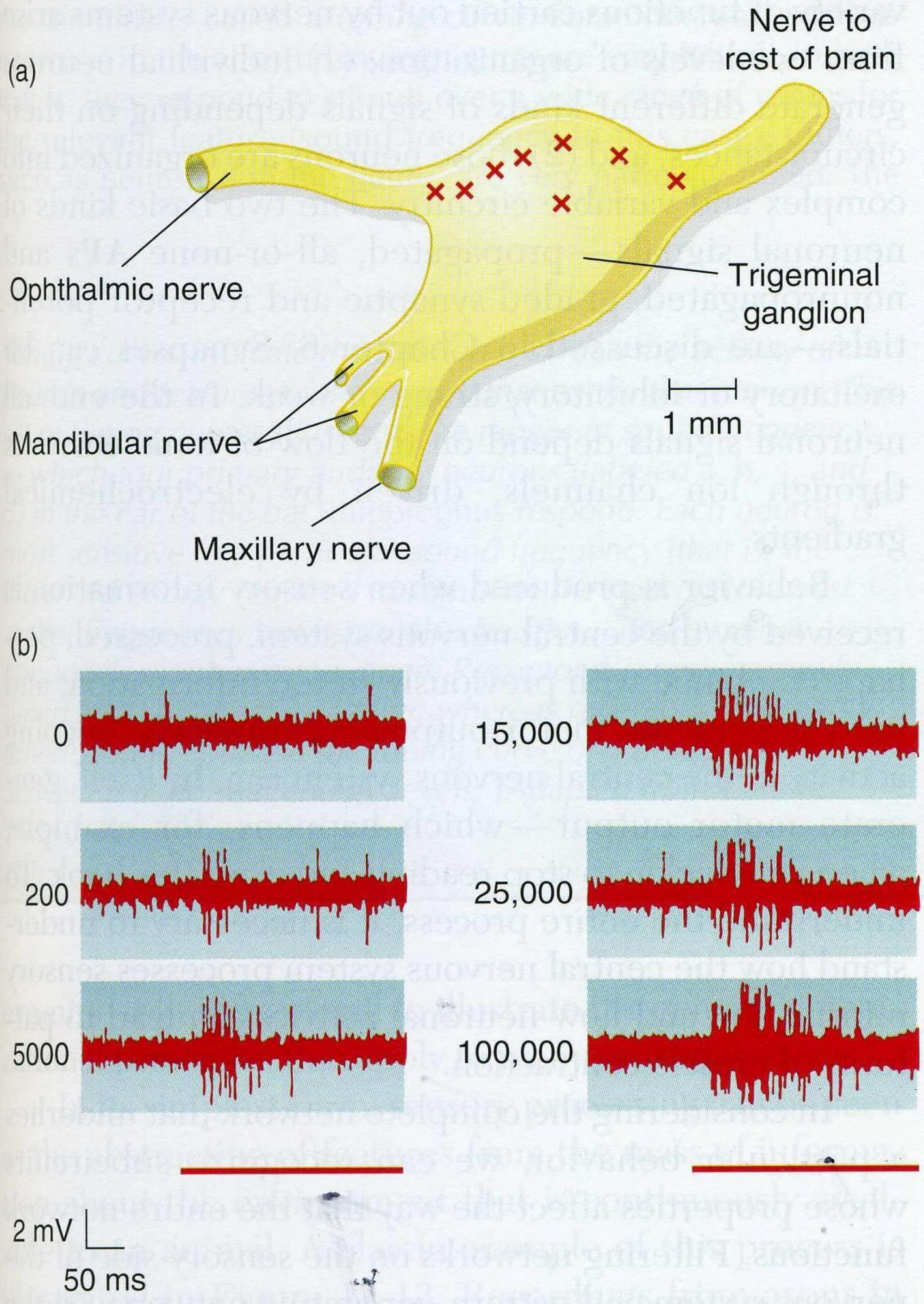


Figure 17.9 Changing the magnetic field changes the orientation of released pigeons (*a*) A small Helmholtz coil is shown attached to a pigeon's head, with a power pack on the pigeon's back. Reversing the direction of electrical current flow through the coil reverses the direction of the magnetic field. (*b, c*) Pigeons with Helmholtz coils were released south of home on overcast days. They interpreted the direction in which magnetic lines dip into Earth as north. Each dot outside the circle represents the direction in which a released pigeon vanished over the horizon. The arrow at the center of each circle is the mean vanishing bearing for the group. (After Walcott and Green 1974.)

Umístění magnetických částic v nervové soustavě stěhovavých ptáků



Elektrický orgán ryb

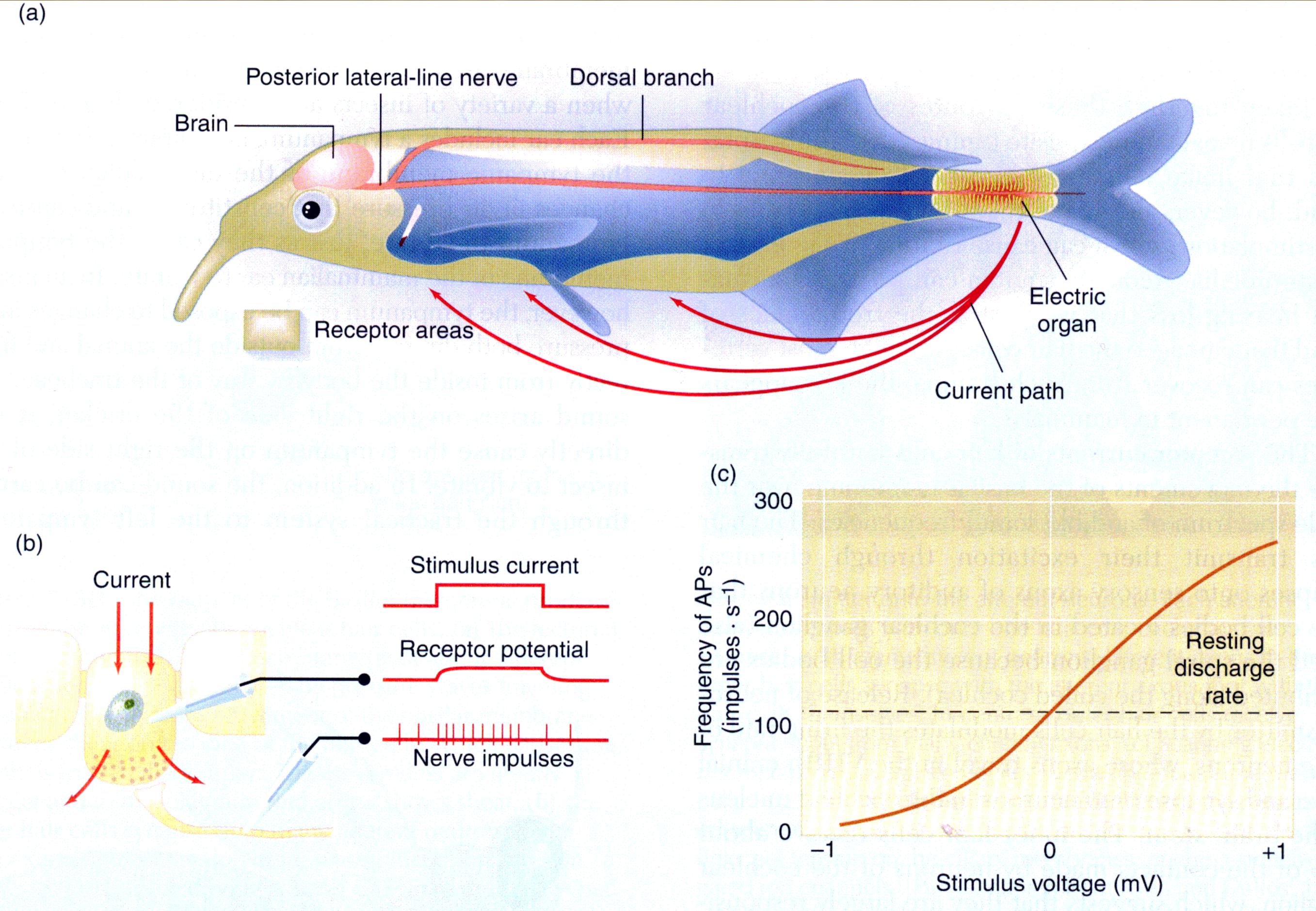
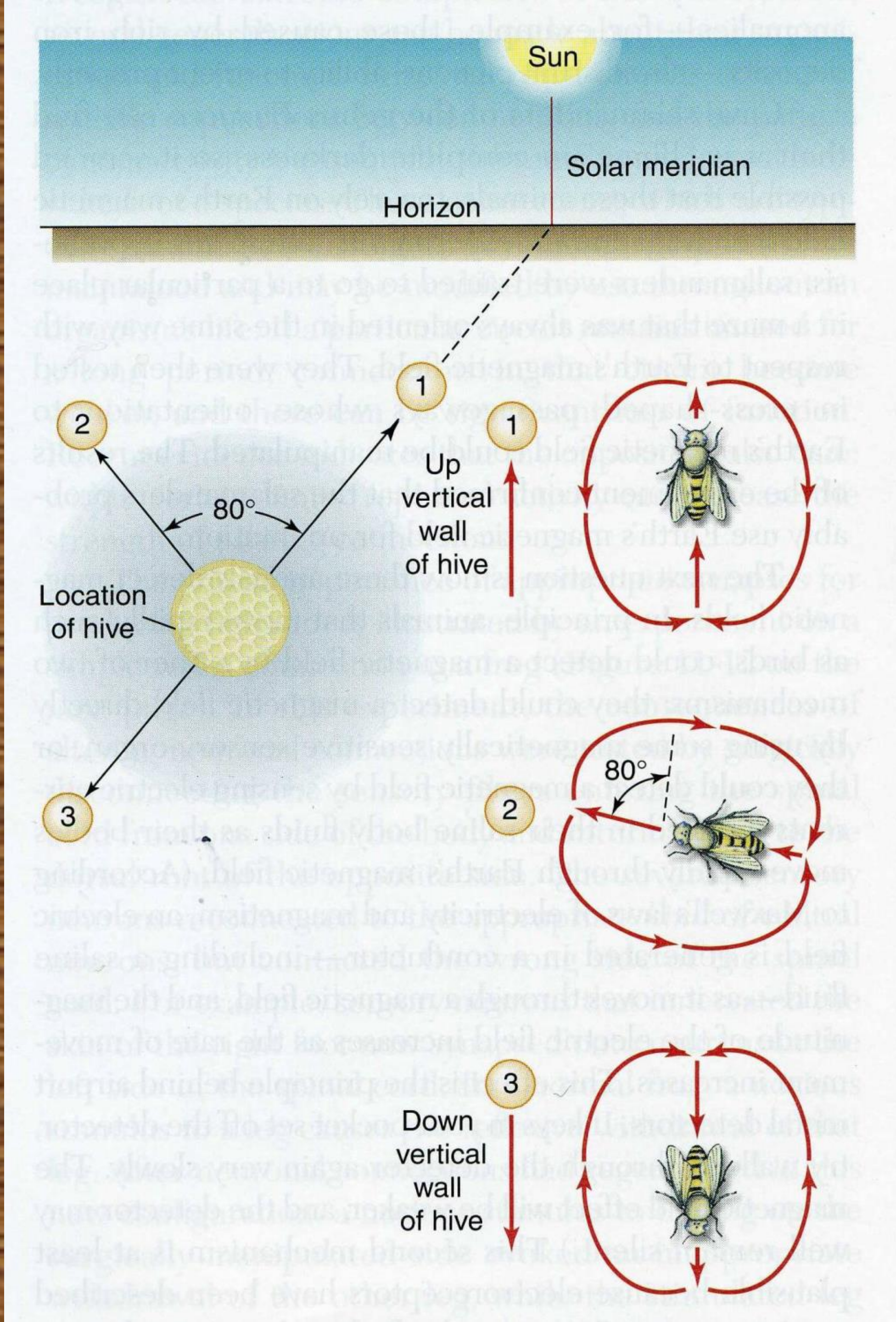


Figure 1 *Specialized receptors allow animals to respond to tiny changes in their environment.* ***(a)*** *Weakly electric fishes have an electric organ, located near the posterior of the body, that produces an electric field. This electric field can be detected by electroreceptors distributed on the body surface.* ***(b)*** *At the base of each electroreceptor pore lies an electroreceptor cell whose apical membrane has a low electrical resistance compared with that of its basal membrane. These receptor cells release transmitter molecules spontaneously. Current entering the cell depolarizes it, increasing the rate of transmitter release and hence the frequency of APs in the primary afferent neuron that contacts the cell. Current leaving the cell decreases the rate of transmitter release. The amount of transmitter released by the receptor cell changes when* V_m *is altered by only a few microvolts.*

Classic Work

(c) *Relation between stimulating voltage of an electroreceptor cell and the frequency of APs in the primary afferent axon of a neuron that receives input from an electroreceptor. [Parts b and c adapted from Bennett, 1968.]*

Včelí „tance“ – sdělení navigačních informací



Orientace holuba podle slunečního kompasu a vnitřních hodin

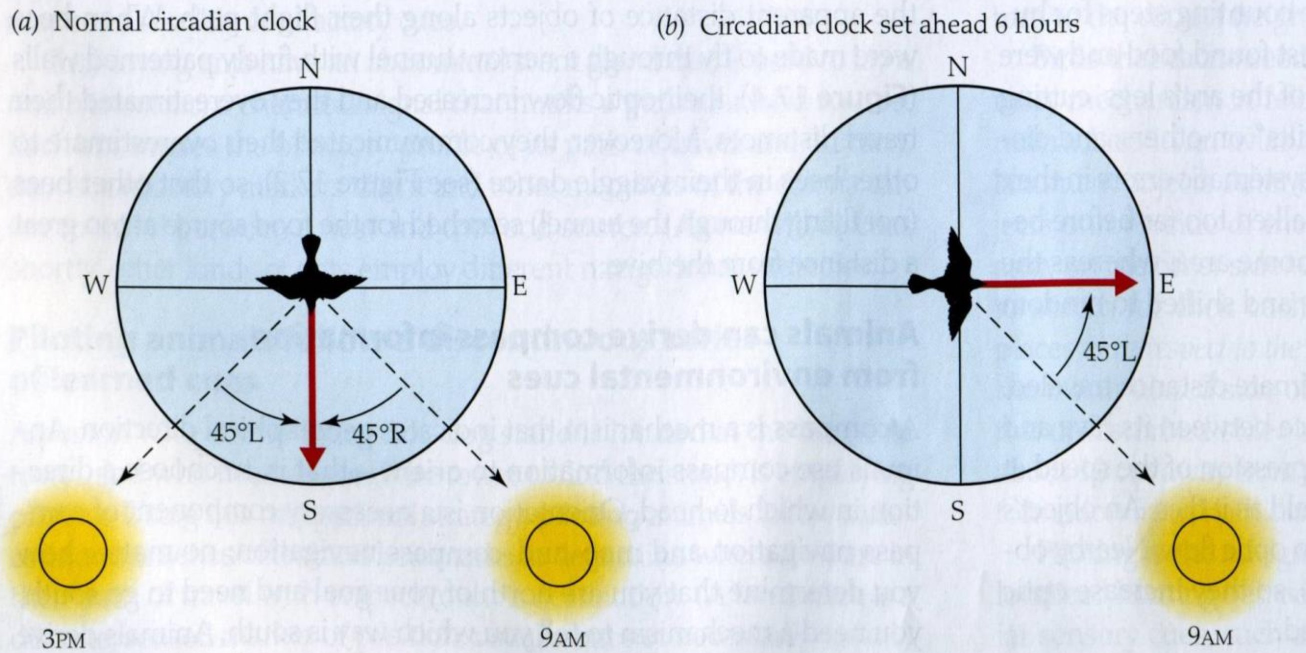


Figure 17.5 Homing pigeons use a sun compass on sunny days The direction in which individual pigeons vanished over the horizon from a release point north of home. (*a*) Control pigeons oriented in the homeward direction (south) when released at any time of day. They used the sun's position and their internal circadian clocks to determine which direction was south. (*b*) Pigeons whose circadian clocks had been shifted 6 hours ahead misinterpreted the sun's position and departed approximately 90° to the left of the homeward direction. If released at 9:00 AM, they thought it was 3:00 PM and departed 45° to the left of the sun's position (appropriate for 3:00 PM).

V noci migrující ptáci se orientují podle hvězd

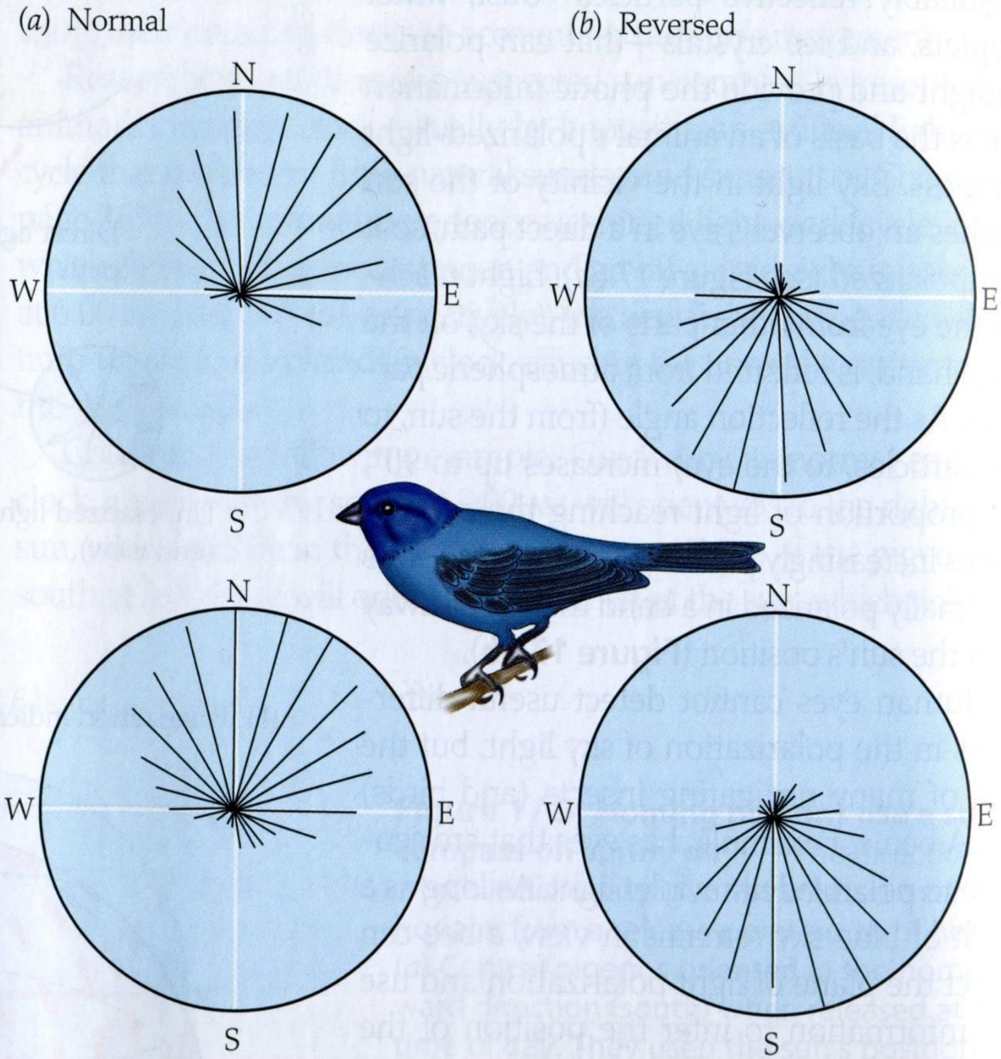


Figure 17.7 Planetarium experiments demonstrate that nocturnally migrating birds use star patterns for orientation Indigo buntings were raised so that they could see the night sky but not local landmarks. The orientation preferences of their migratory restlessness (indicated by the radiating black lines) were then tested in a planetarium with either normal star patterns (*a*) or star patterns reversed in direction (*b*). The results for two buntings shown here reveal that the star pattern is the dominant determinant of orientation direction.

Orientace živočichů podle polarizovaného světla

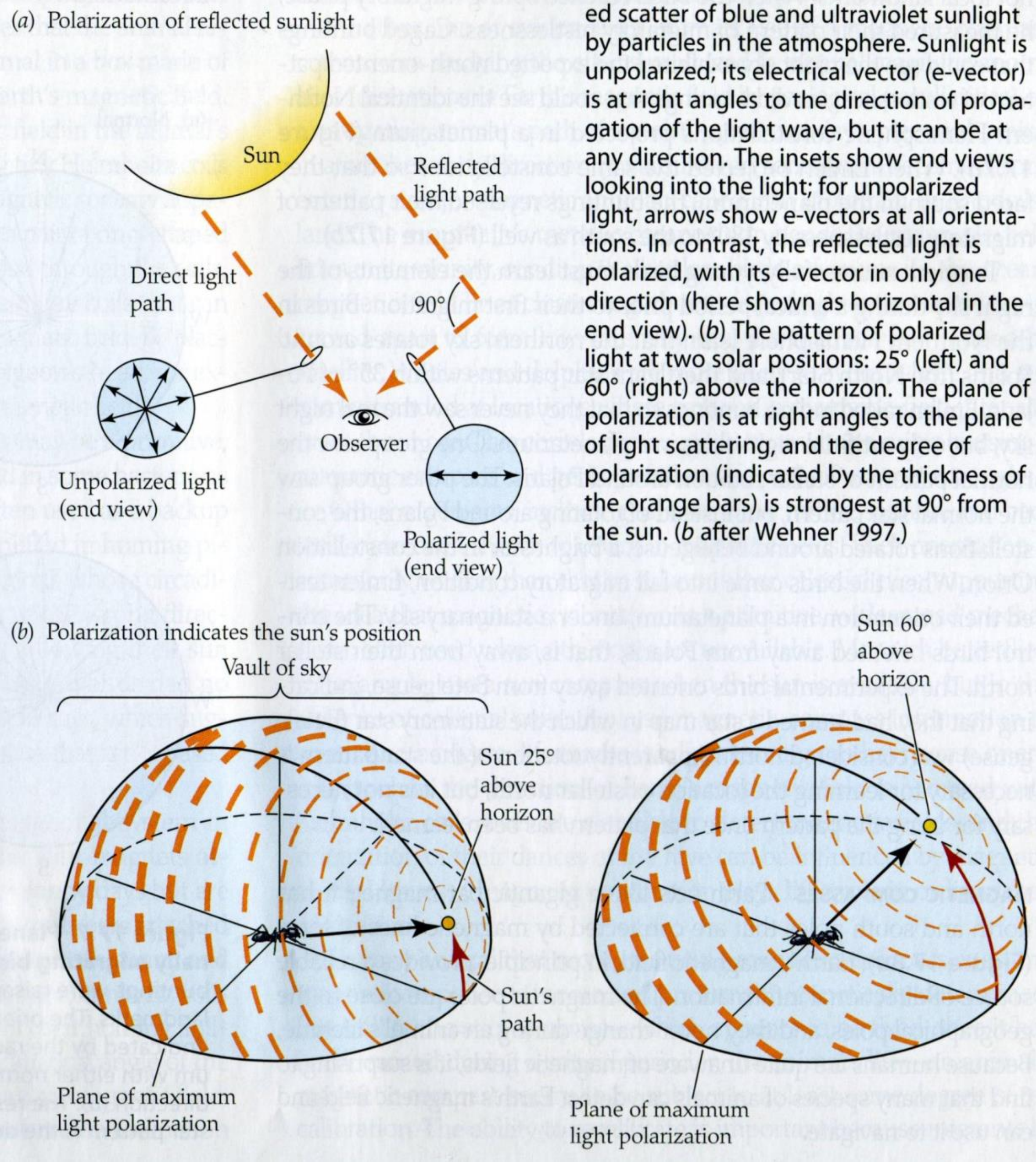


Figure 17.6 Polarization of sky light can aid in determining the sun's position (*a*) The blue sky results from reflected scatter of blue and ultraviolet sunlight by particles in the atmosphere. Sunlight is unpolarized; its electrical vector (e-vector) is at right angles to the direction of propagation of the light wave, but it can be at any direction. The insets show end views looking into the light; for unpolarized light, arrows show e-vectors at all orientations. In contrast, the reflected light is polarized, with its e-vector in only one direction (here shown as horizontal in the end view). (*b*) The pattern of polarized light at two solar positions: 25° (left) and 60° (right) above the horizon. The plane of polarization is at right angles to the plane of light scattering, and the degree of polarization (indicated by the thickness of the orange bars) is strongest at 90° from the sun. (*b* after Wehner 1997.)

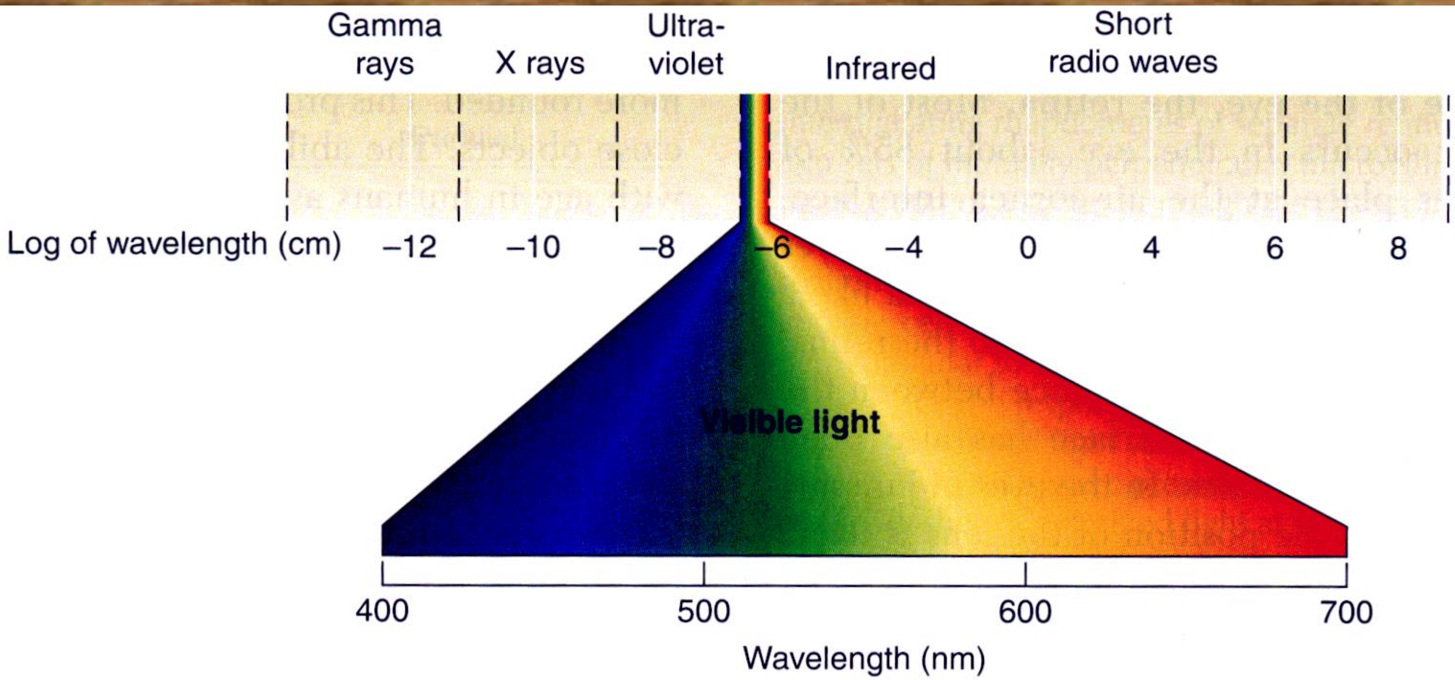
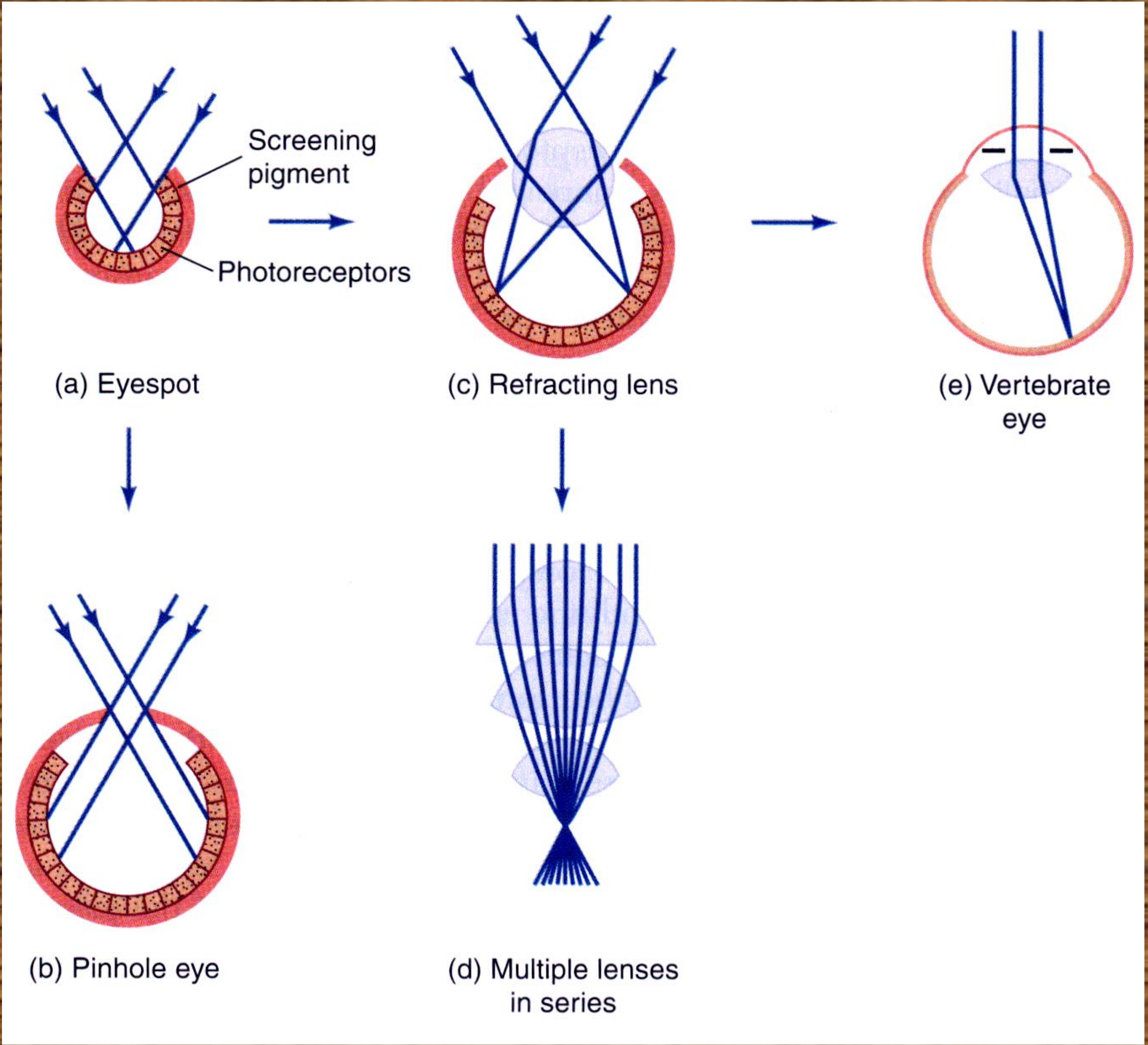


Figure 7-38 The spectrum of electromagnetic radiation encompasses a broad range of energy that is detected by various sensory modalities. Most photoreceptors detect energy in the "visible" range, shown in this diagram, but some can detect light in the ultraviolet range as well. The pit organs of some snakes can detect infrared radiation, although they appear to measure the increased temperature of surrounding tissue that has absorbed the infrared energy, rather than responding directly to the infrared radiation (see Spotlight 7-2).

Různé typy očí – aplikace několika optických principů



Kvalita vidění složeným okem hmyzu a komorovým okem obratlovců

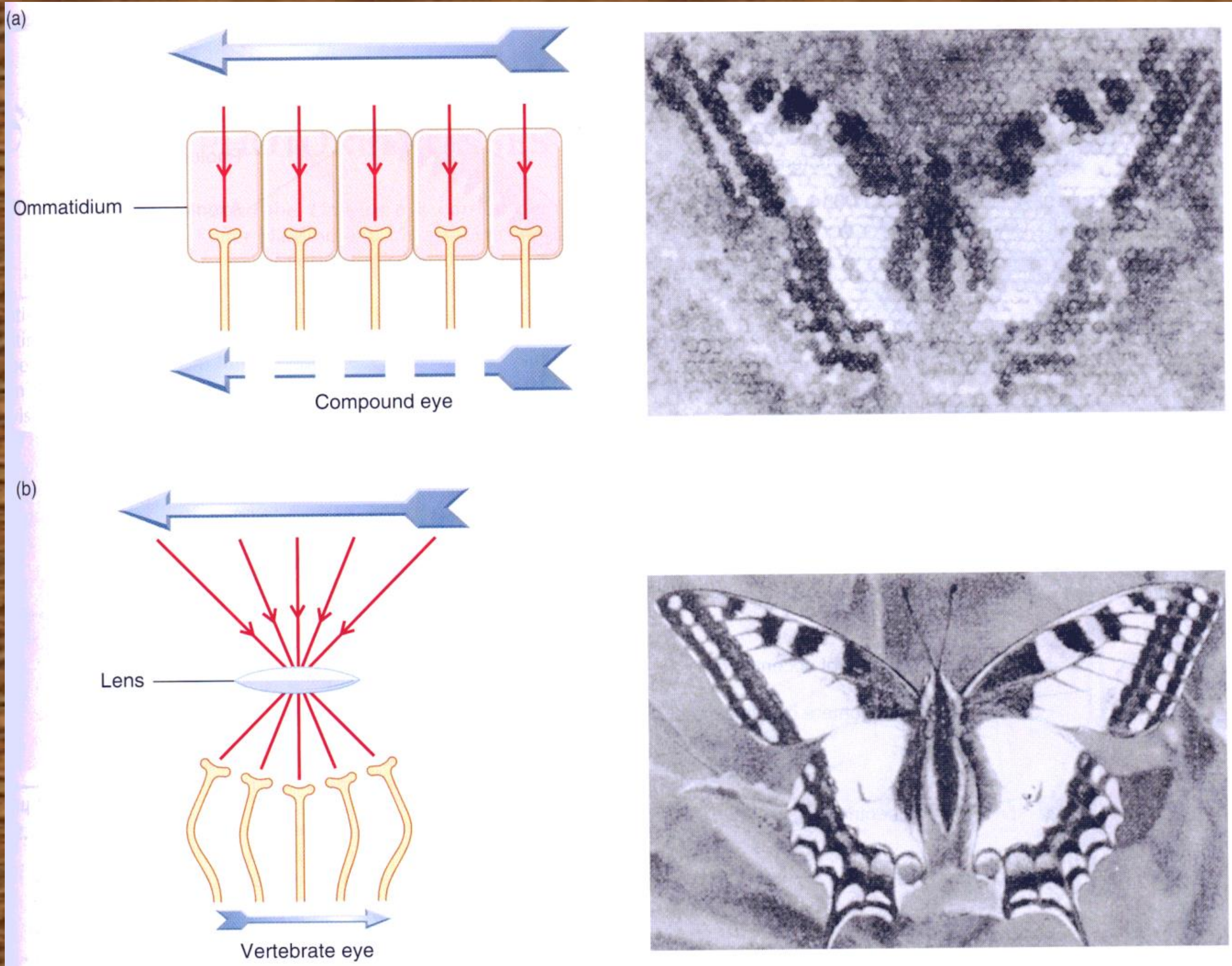
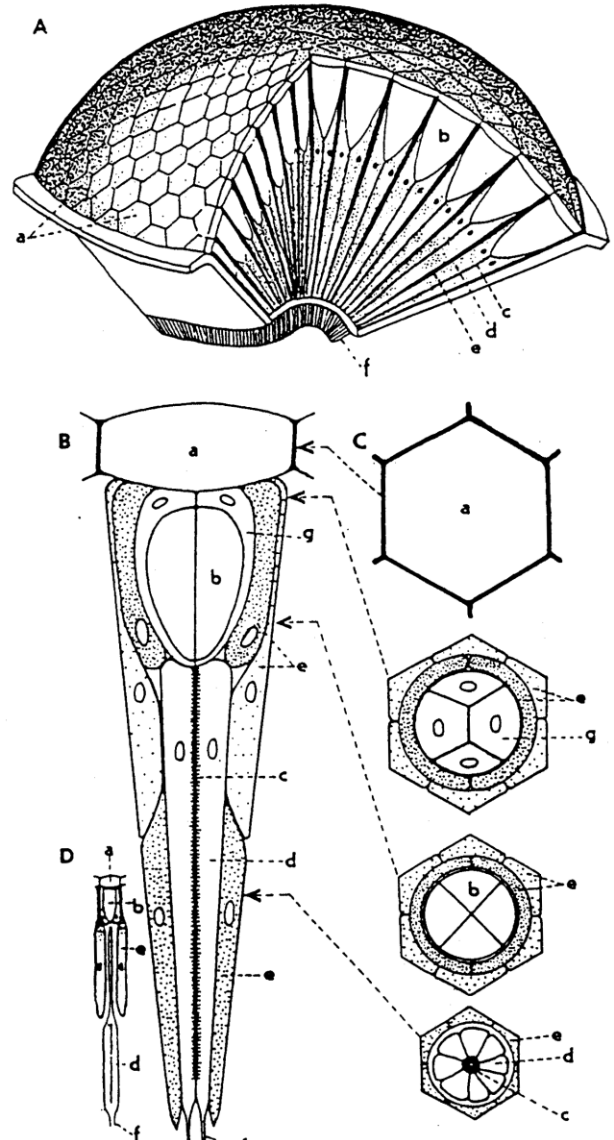


Figure 7-34 Compound eyes produce mosaic images, whereas the optics of simple vertebrate eyes produce higher spatial resolution. **(a)** (Left) In a compound eye, each ommatidium samples a different part of the visual field through its own separate lens. (Right) The image of a butterfly as it might be perceived by a dragonfly through its compound eyes at a distance of 10 cm. **(b)** (Left) In a vertebrate eye, each receptor cell samples a small part of the visual field through a lens that is shared by all receptor cells. (Right) The same butterfly as it might be perceived by the vertebrate eye. Arrows show that the optics of a vertebrate eye invert the image on the retina, whereas the optics of a compound eye do not. [Adapted from Kirschfeld, 1971, and Mazokhin-Porshnyakov, 1969.]

Složené oko mouchy

Obr. 78

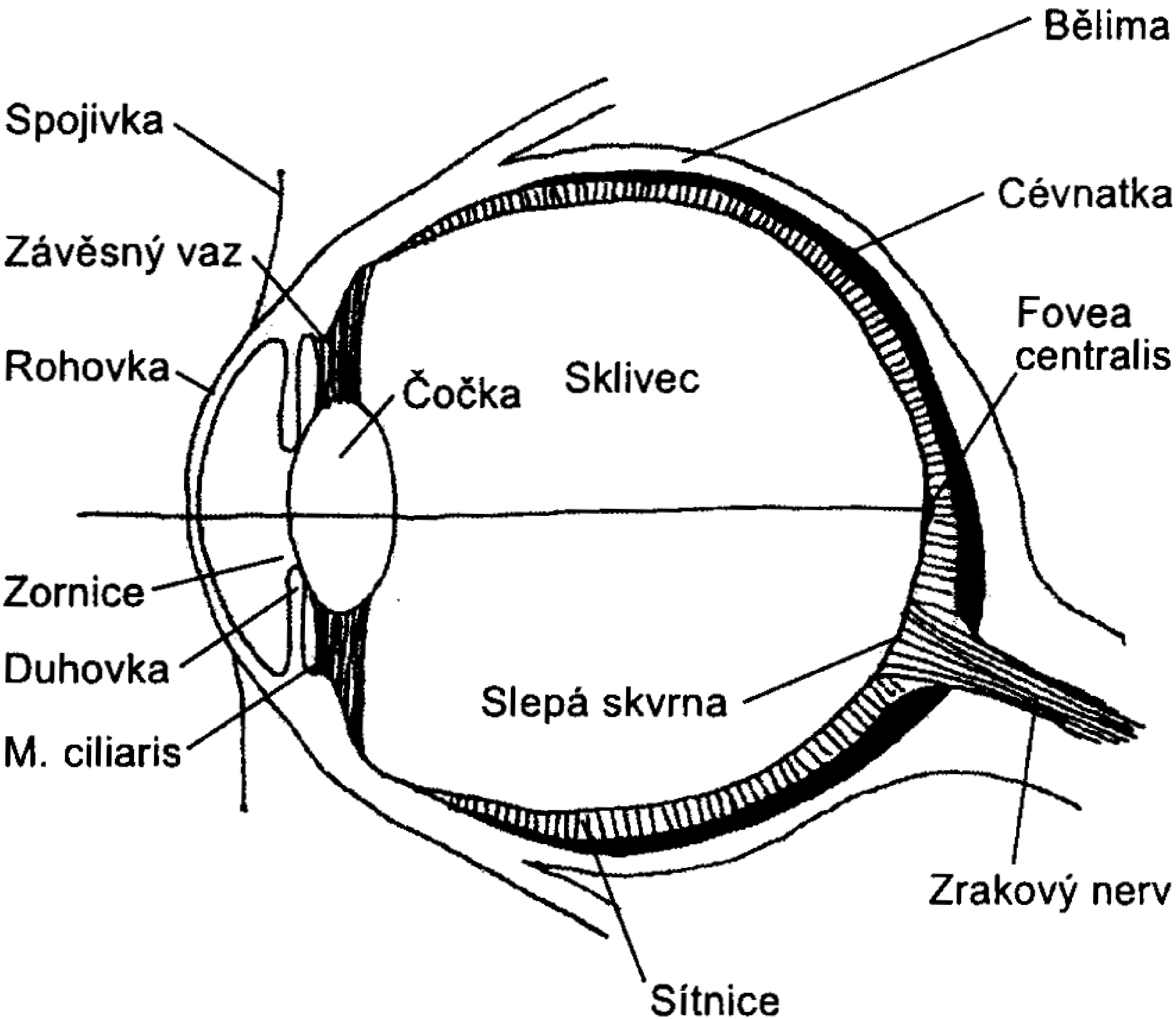


Složené oči členovců

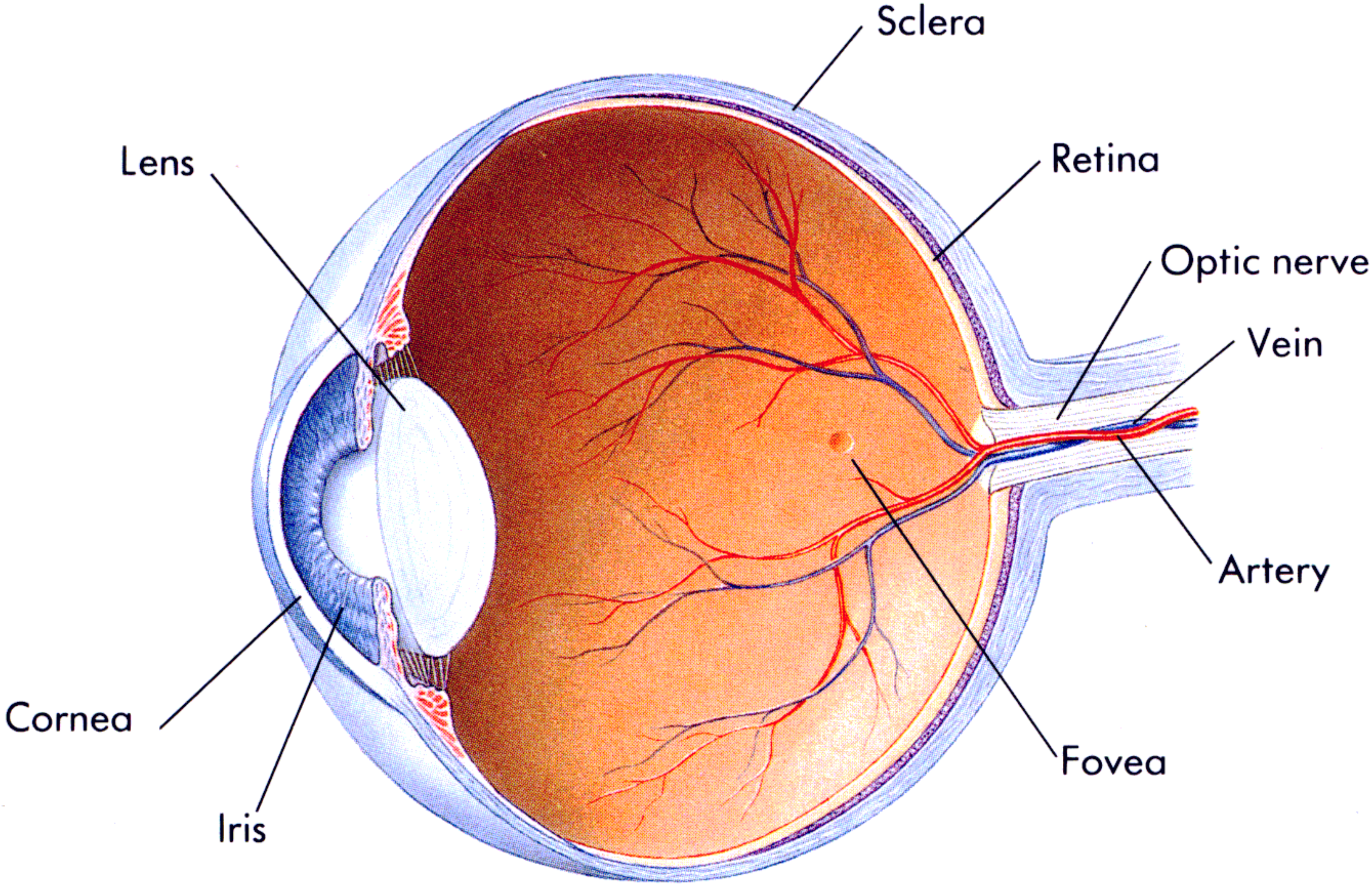
A - celkový pohled na složené oko,
B - detailní stavba apozičního omatidia na podélném řezu,
C - na příčných řezech v úrovních označených šipkami,
D - superpoziční omatidium při malém zvětšení

a = faceta, b = křišťálový kužel, c = rhabdom, d = zraková buňka (primární buňka smyslová), e = pigmentová buňka, f = nervové výběžky zrakových buněk, g = křišťálotvorná buňka

Komorové oko obratlovců



Obr. 17.9. Schéma savčího oka a jeho součástí.



Human Eye Structure
Figure 46–17

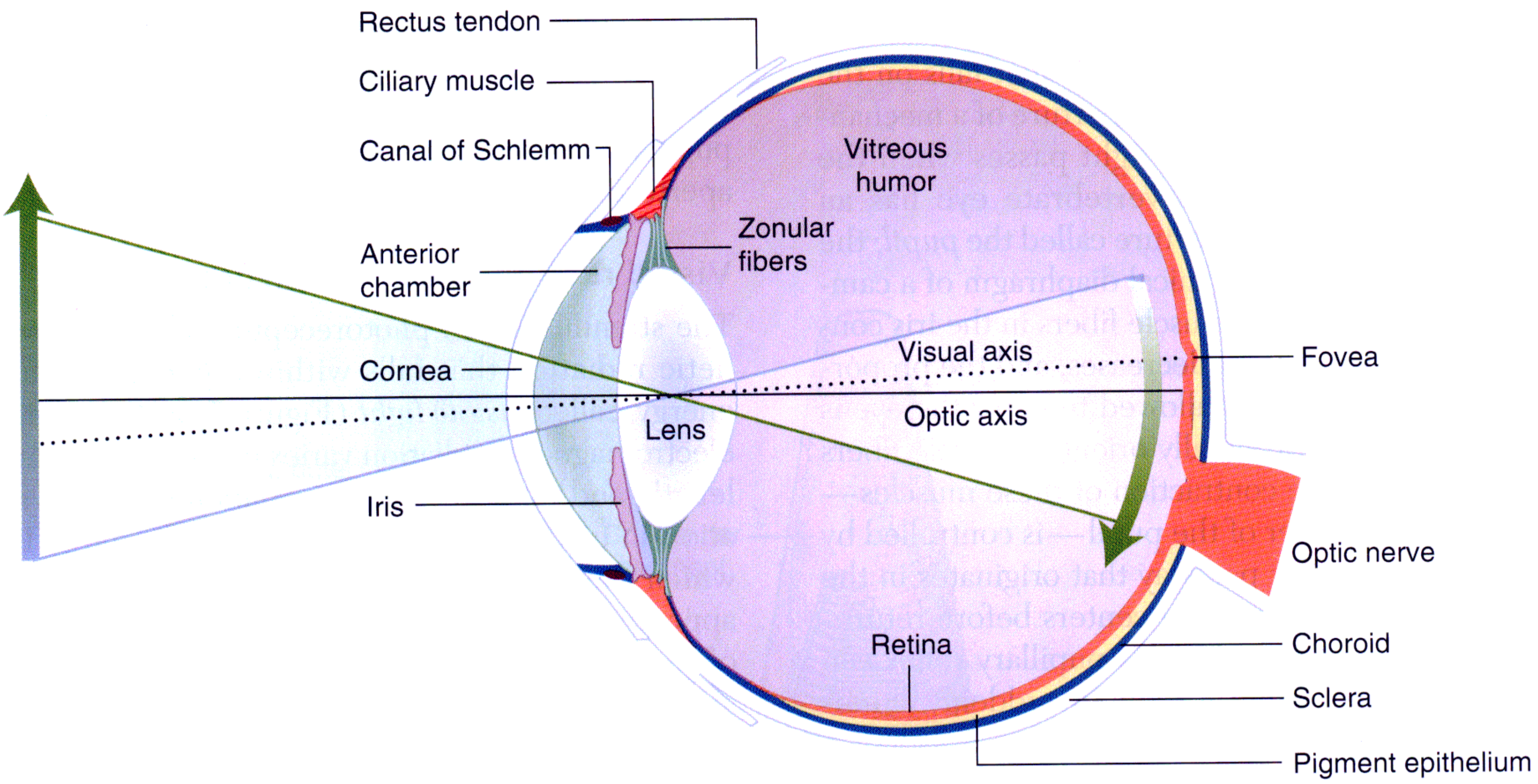
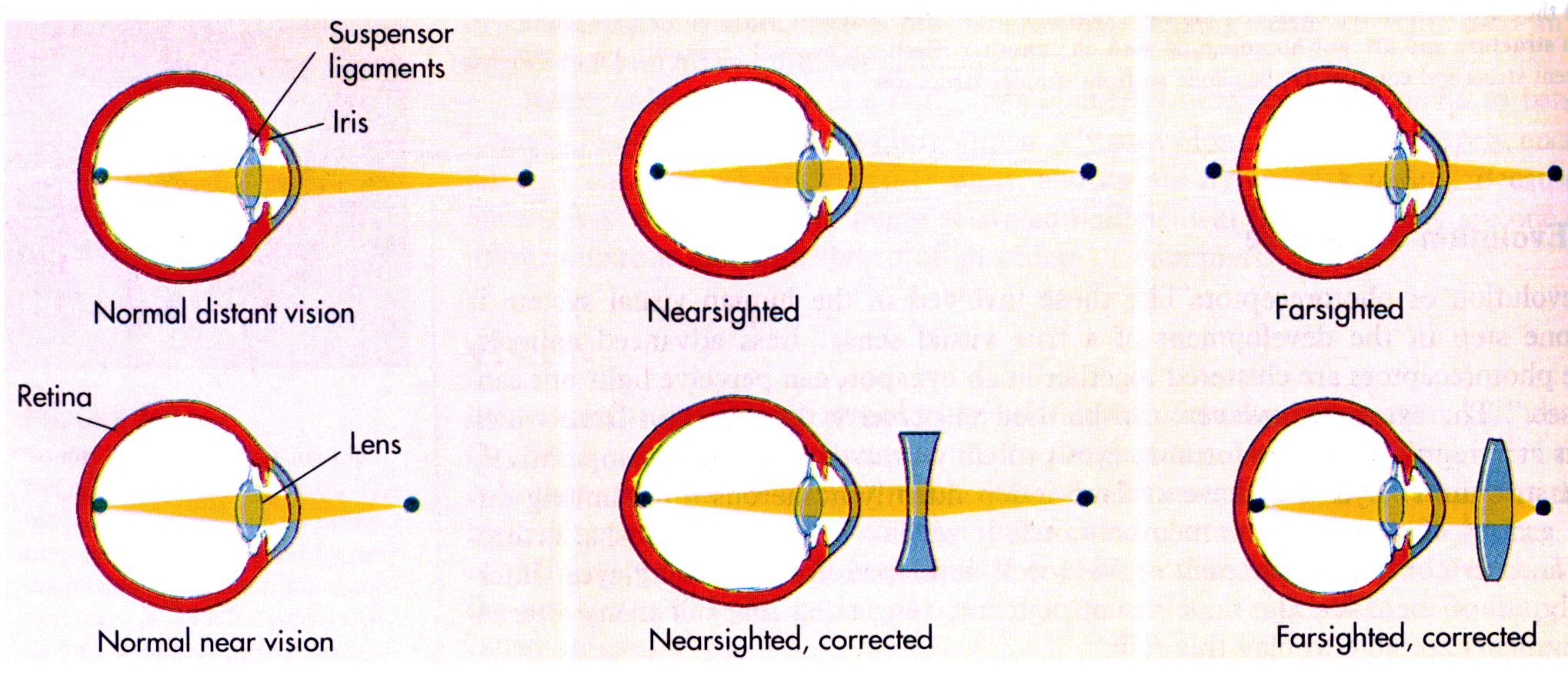
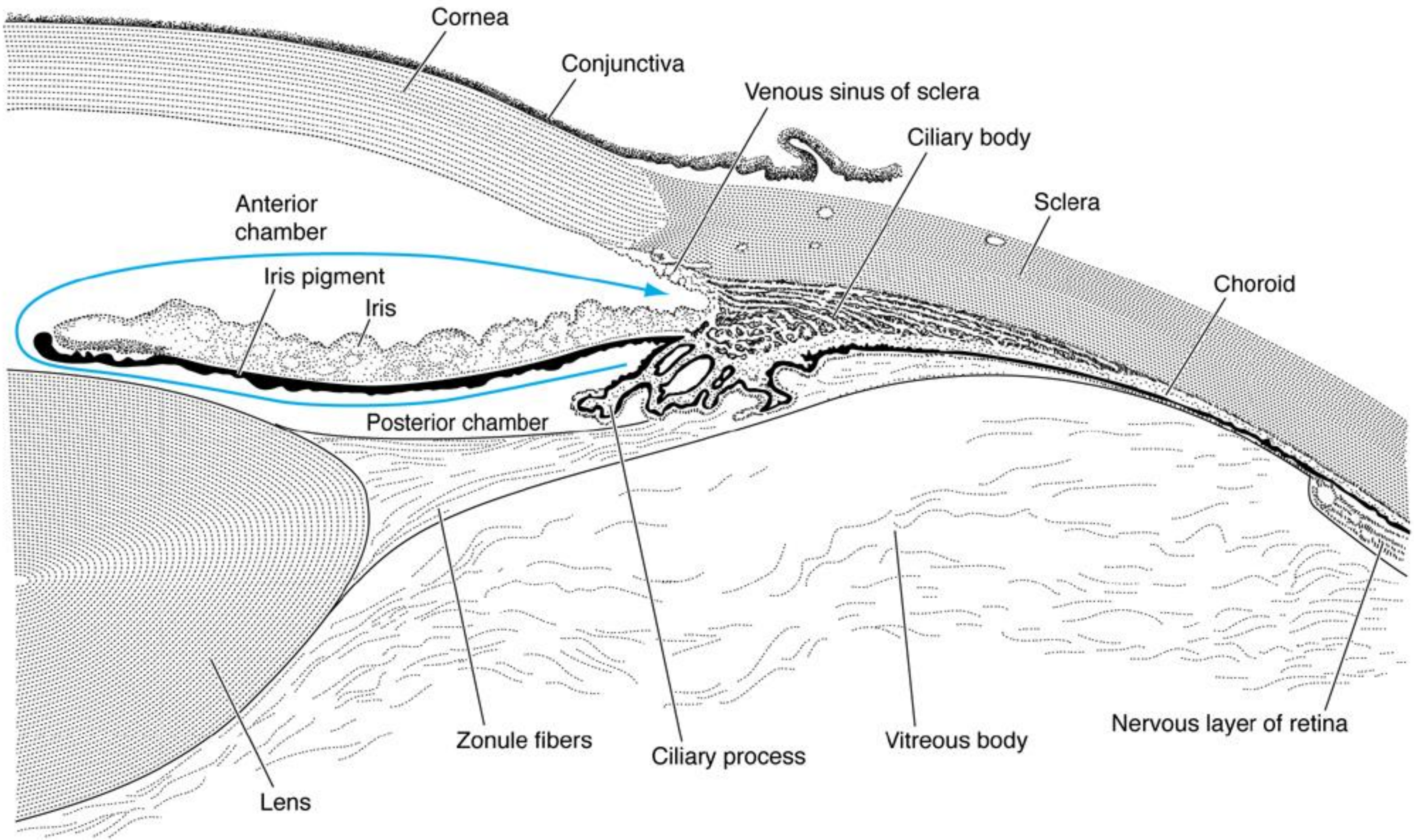


Figure 7-37 In the mammalian eye, incident light is refracted by the cornea and the lens and is focused on the photosensitive retina. In this diagram, the refraction of light has been simplified: refraction at the air-cornea interface is omitted, even though this boundary in reality provides most of the refraction. The image focused on the retina is inverted by the lens. The lens is held in place by the zonular fibers. When ciliary muscle fibers contract, tension on the zonular fibers is reduced, and the elastic properties of the lens cause it to become more rounded, shortening the focal length.

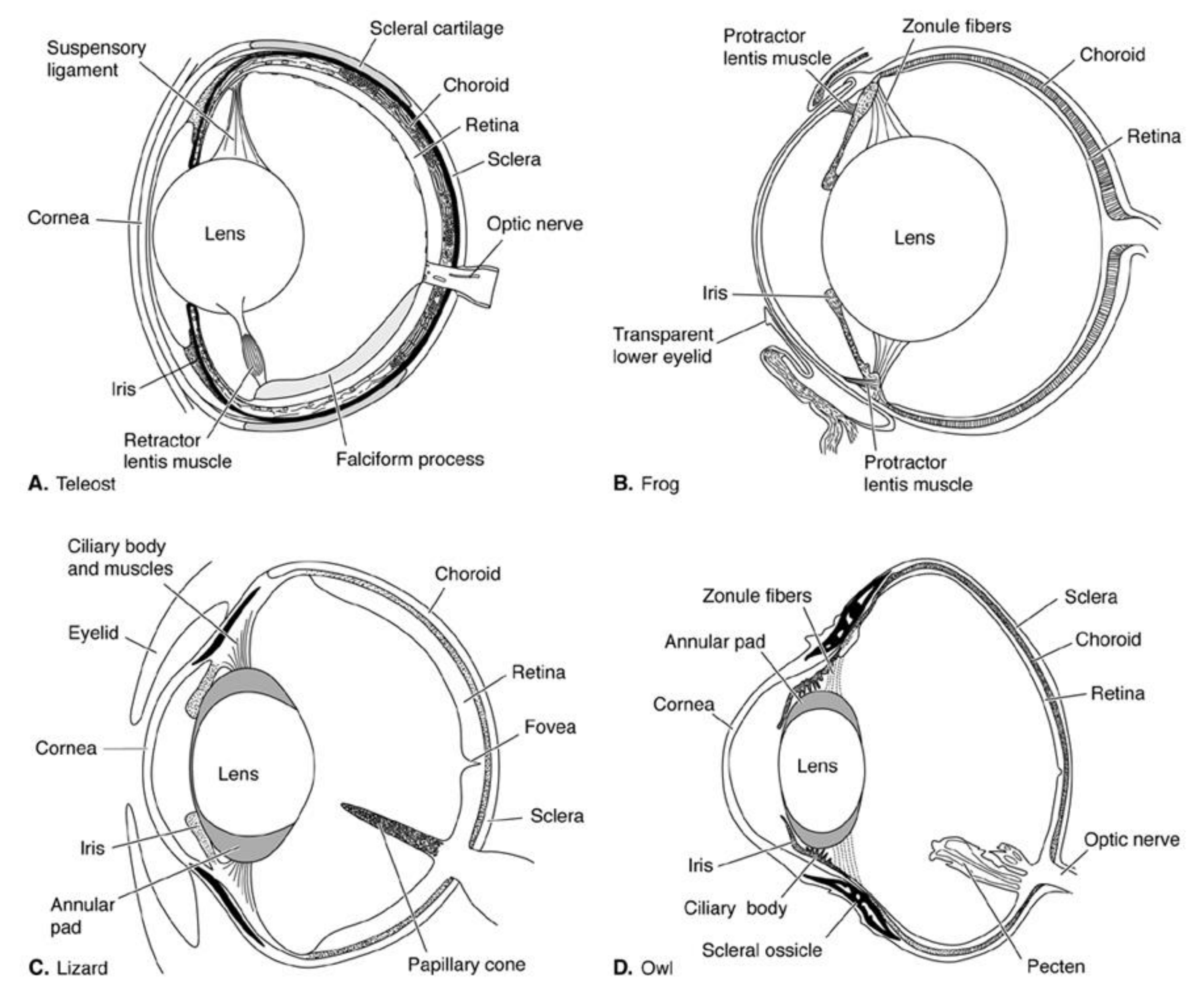
Vady lidského oka a jejich korekce



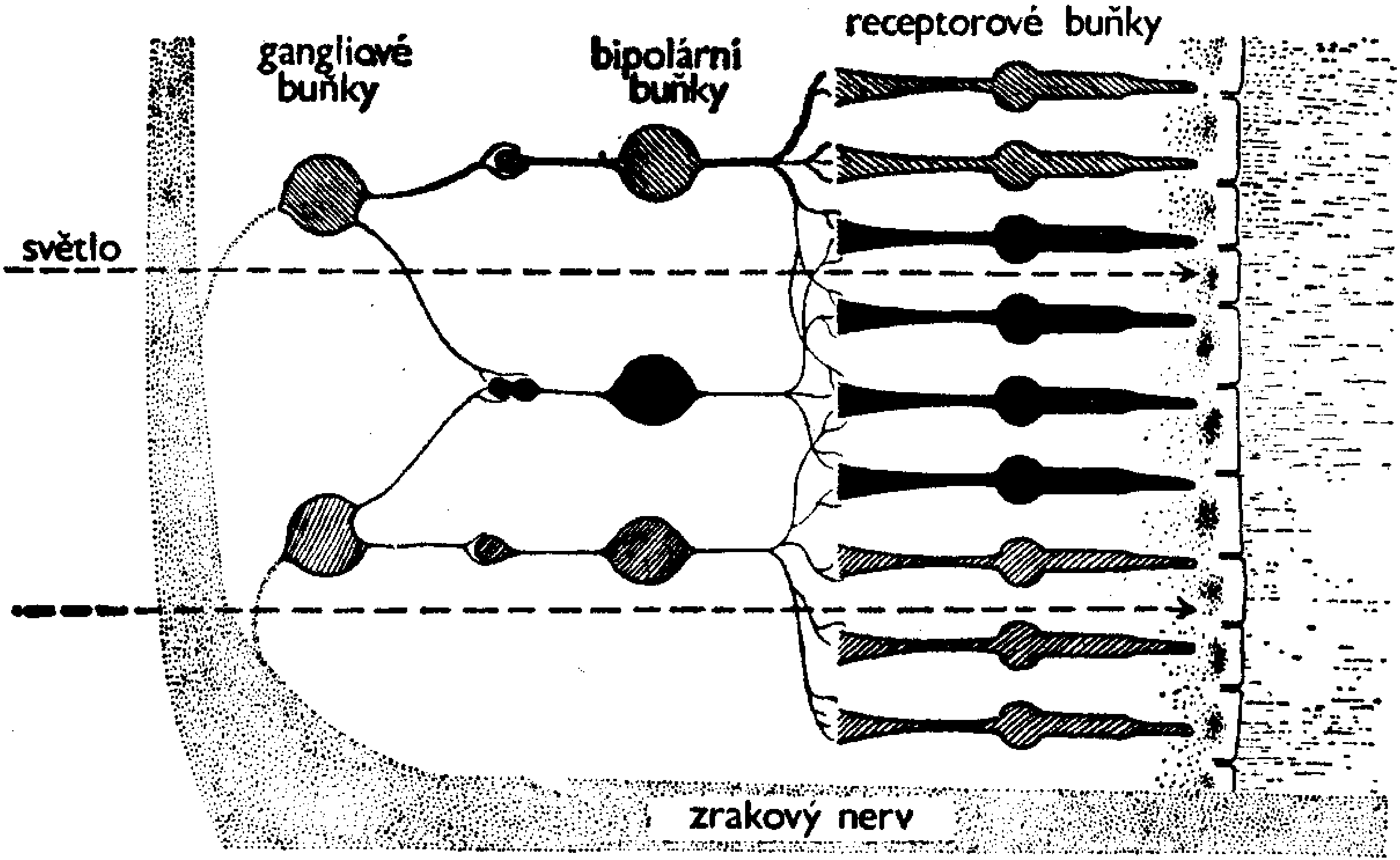
Přední a zadní oční komora



Srovnání struktury oka u různých obratlovců

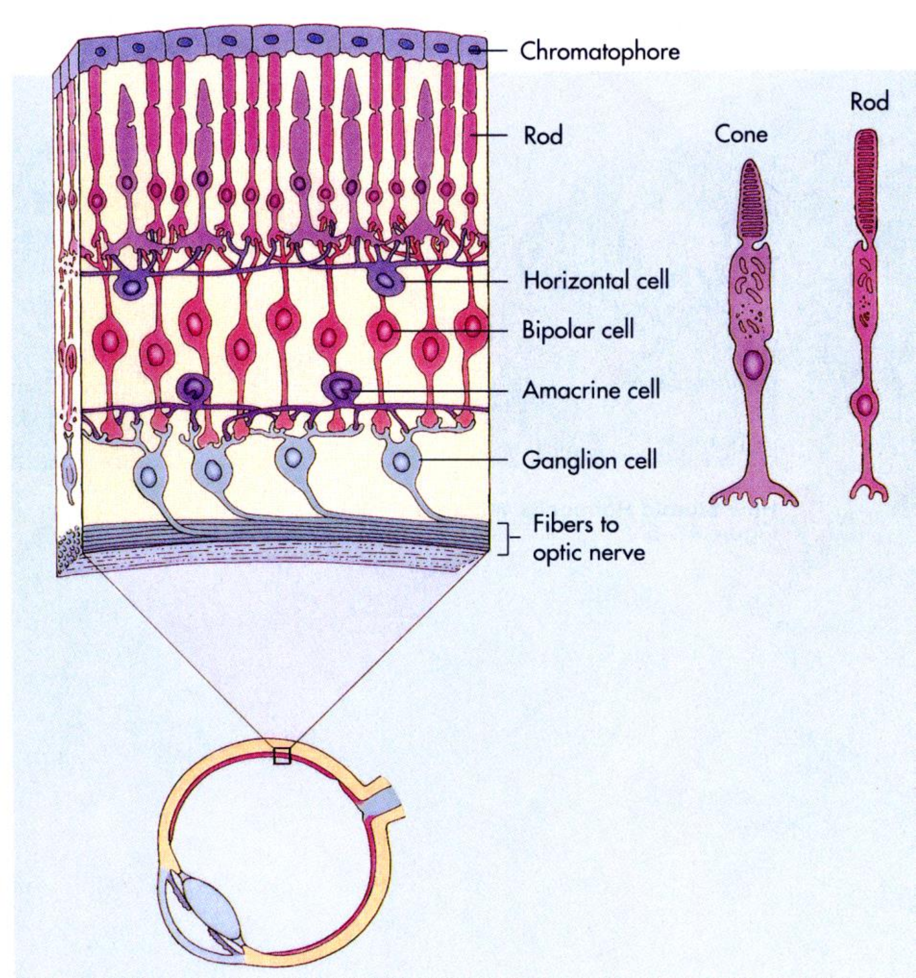


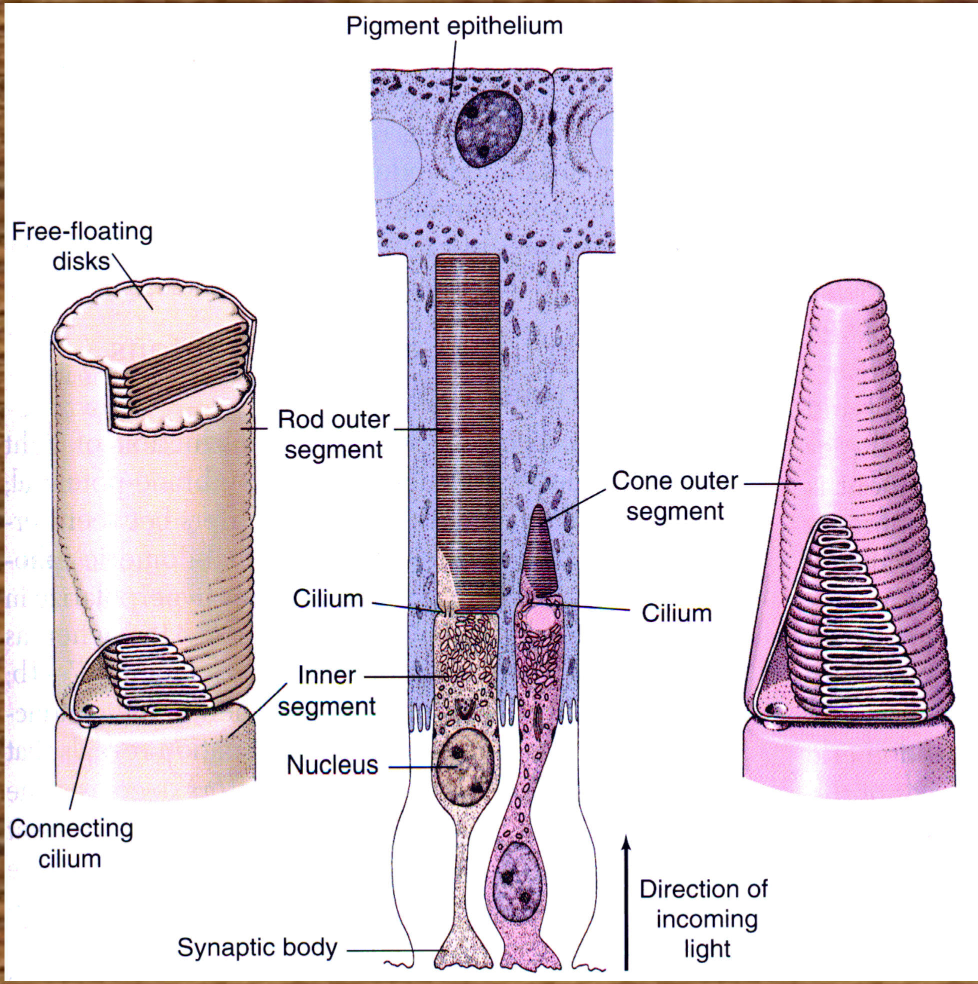
Inverzní oko obratlovců

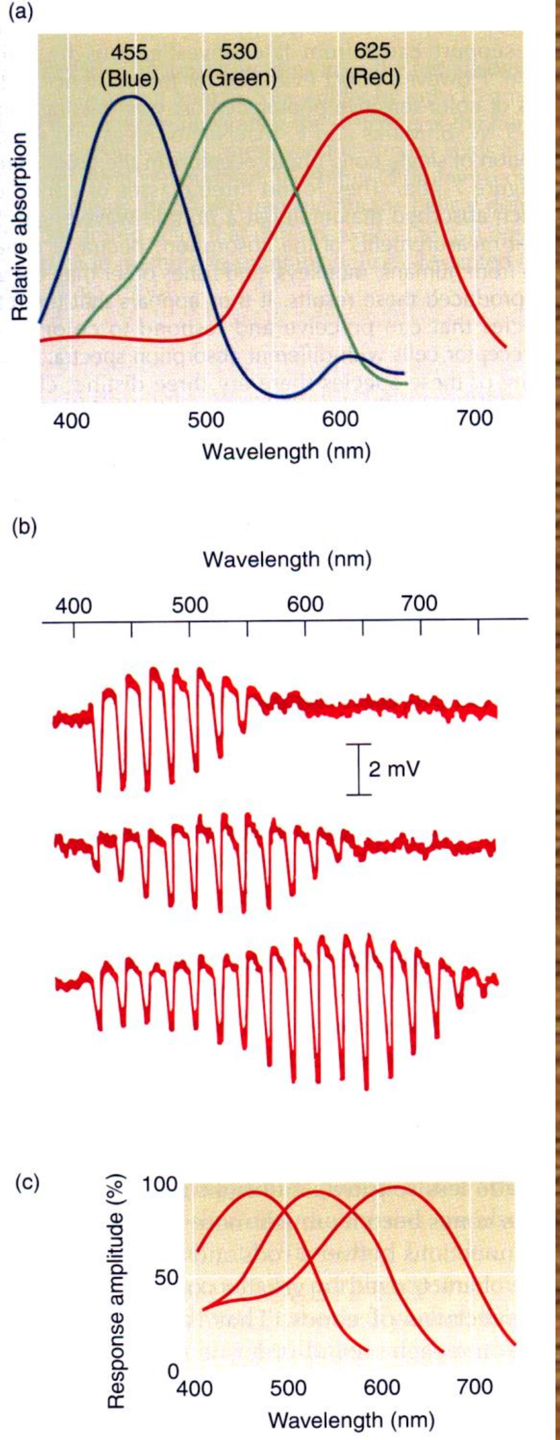


Obr. 221. **Struktura sítnice obratlovců.**

Sítnice je složena ze světločivných buněk tyčinek a čípků

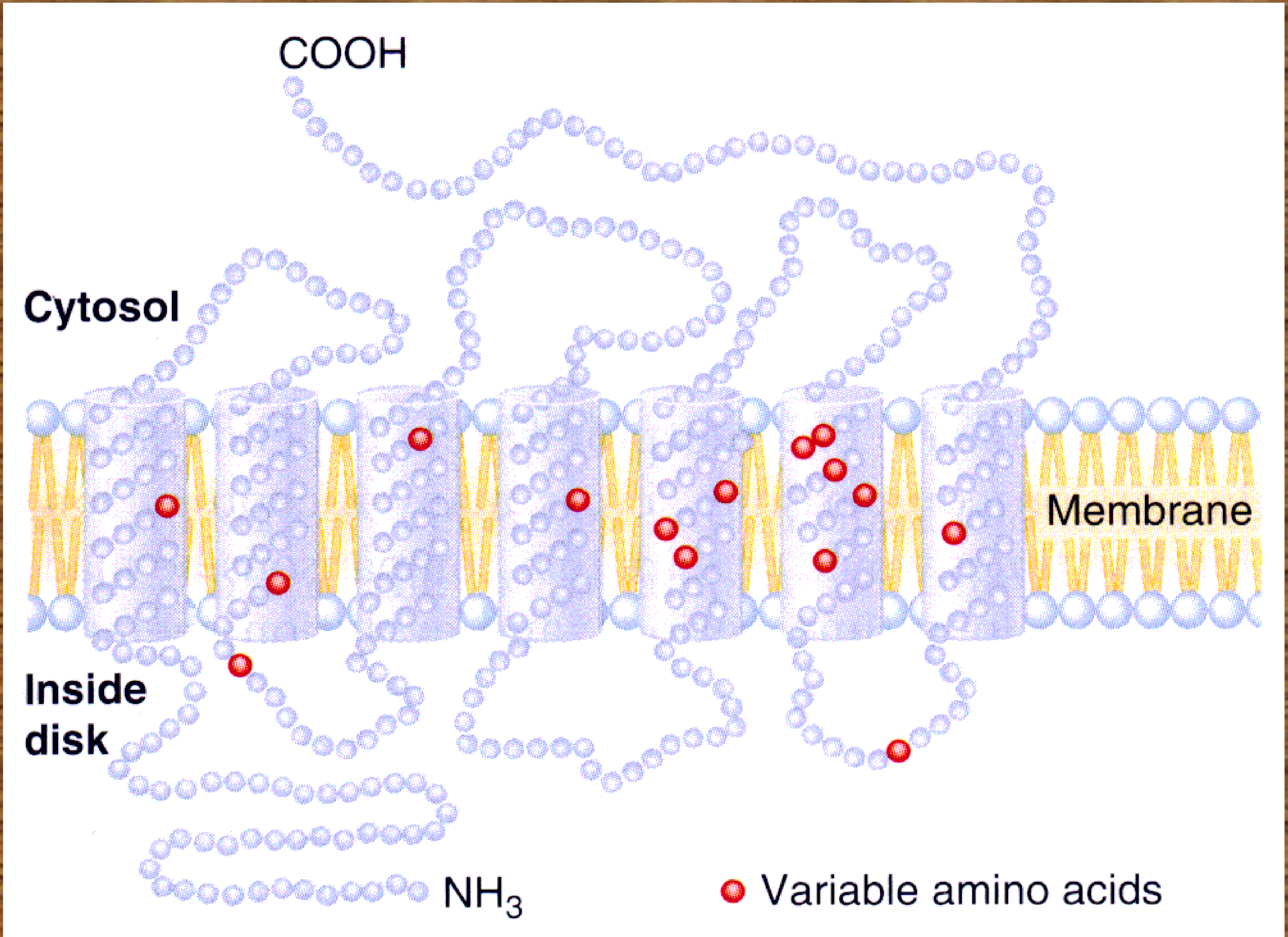




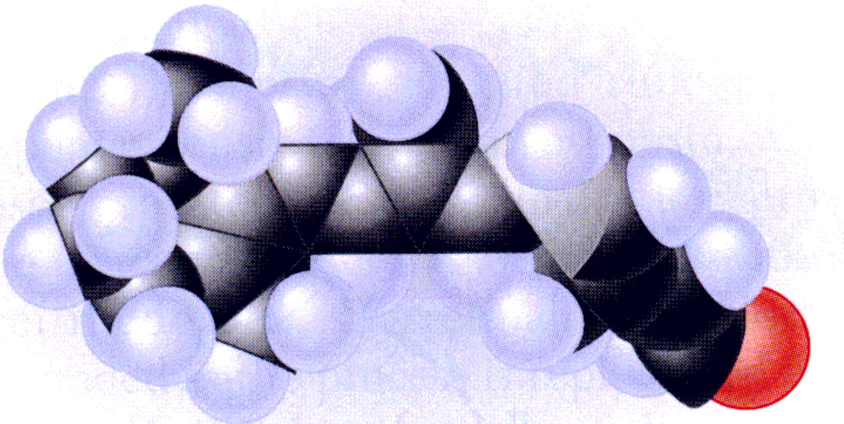


Sítnice oka obsahuje tři typy čípků pro vnímání modrého, zeleného a červeného světla

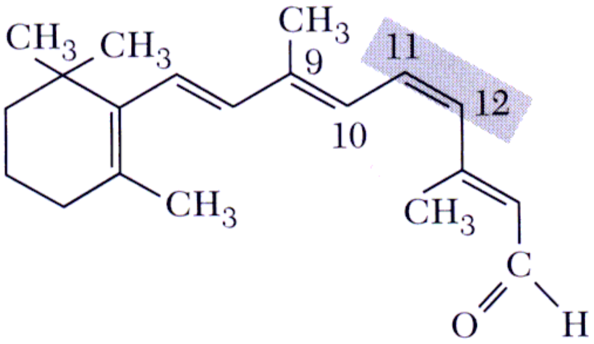
Opsin – transmembránový protein obsažený ve fotosenzitivních buňkách



Struktura retinalu

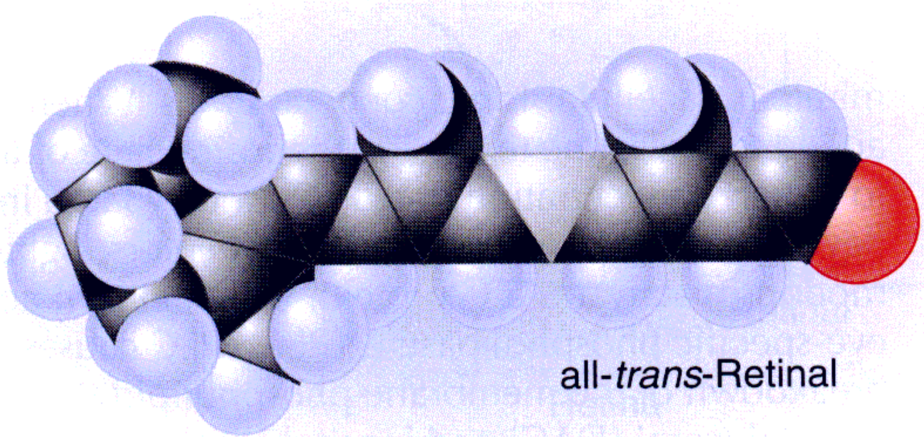


11-*cis*-Retinal

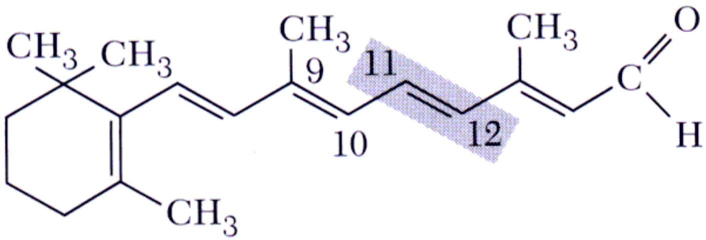


11-*cis*-Retinal

Light ↓

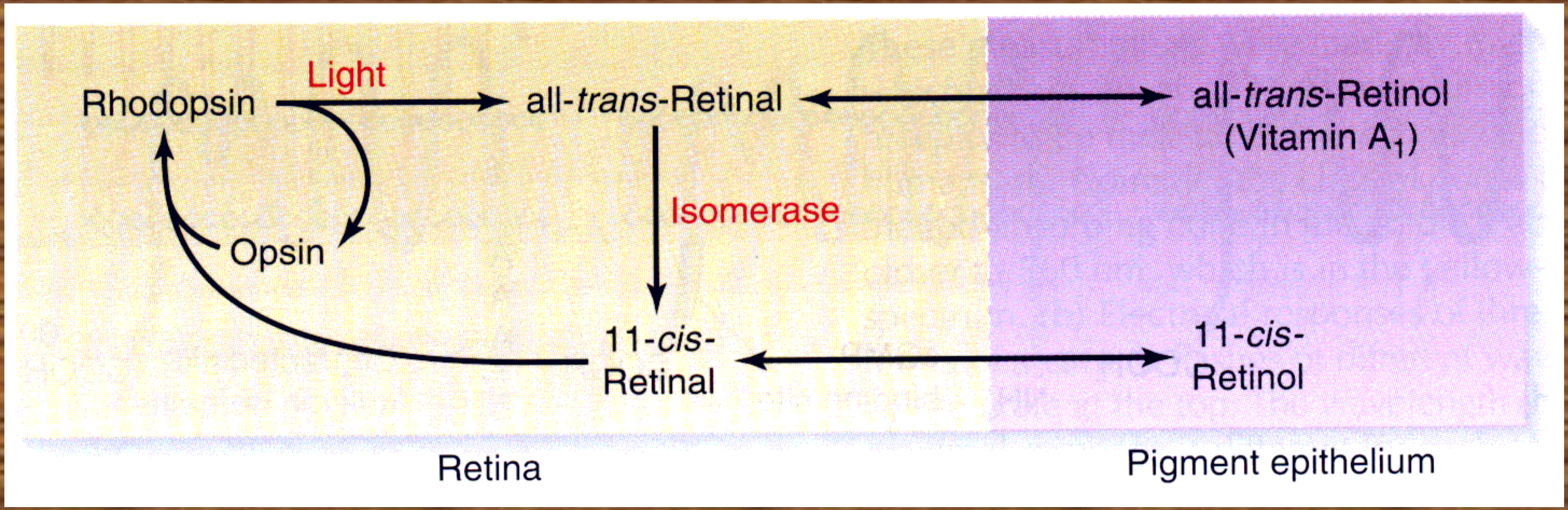


all-*trans*-Retinal

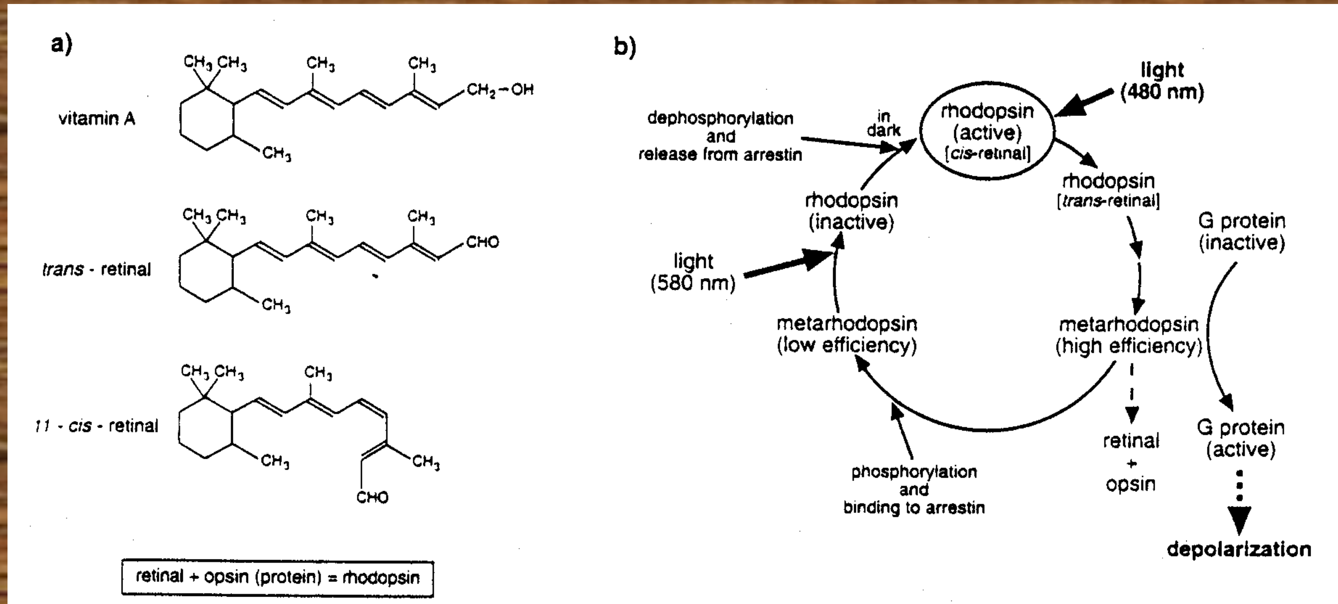


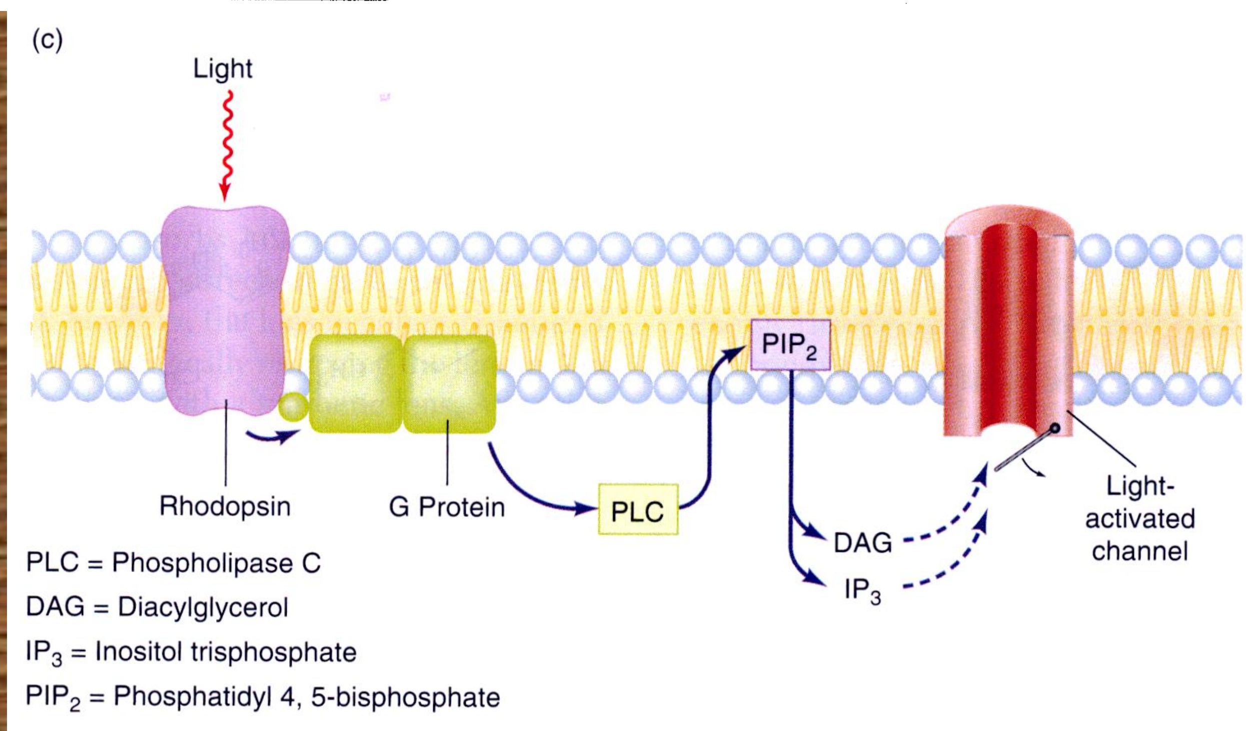
all-*trans*-Retinal

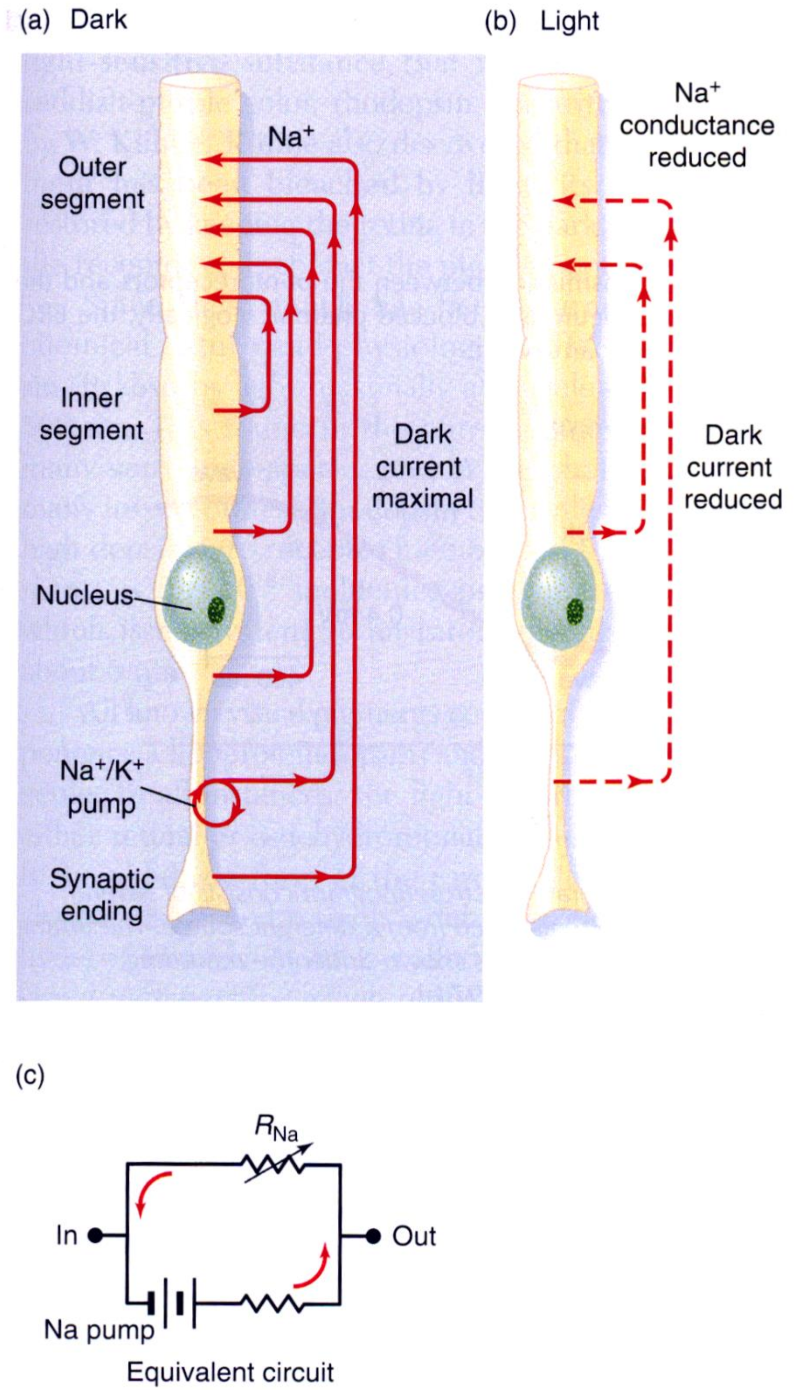
Membránové děje probíhající při fotorecepci



Fotochemie vidění u bezobratlých



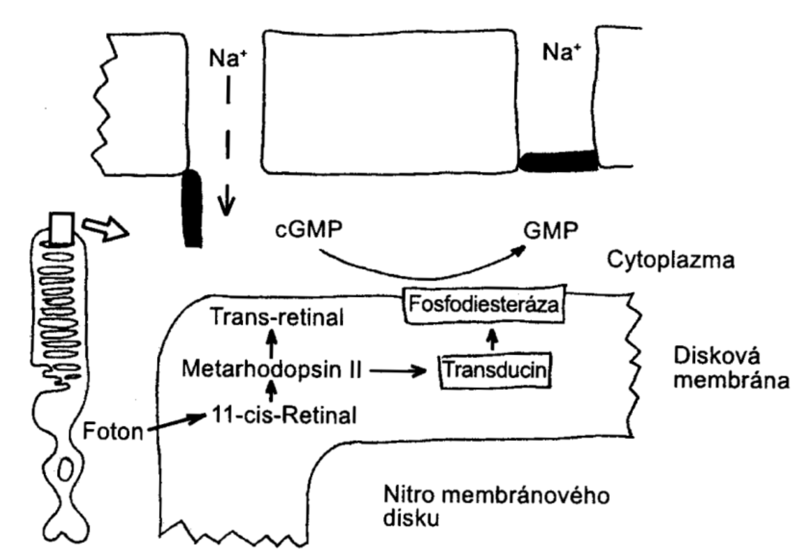




Temnostní proudy v tyčinkách komorového oka

Figure 7-42 Illumination reduces the dark current in vertebrate rods and cones. This diagram illustrates the current in rods. The g_{Na} across the membrane of a rod outer segment is high in the dark **(a)** and lower in the light **(b)**. For this reason, the dark current, which is carried by Na^+ ions entering the outer segment, drops during illumination. By analogy with an equivalent circuit **(c)**, the "battery" providing the driving force for the dark current is the asymmetry of ionic concentrations maintained across the plasma membrane by the Na^+/K^+ pump. The light-inactivated variable resistor (R_{Na}) represents the g_{Na} of the outer segment. [Adapted from Hagins, 1972.]

Membránové děje probíhající při fotorecepci u obratlovců



Obr. 17.10. Membránové děje při fotorecepci na tyčince. Na vnitřních membránových discích je vázán pigment rhodopsin. Dopad světla vyvolá jeho rozpad. Meziprodukt metarhodopsin II spouští aktivační kaskádu završenou hydrolýzou cytoplazmatického cGMP na GMP. Pokles koncentrace cGMP zavírá u obratlovců Na^+ kanály za vzniku hyperpolarizačního receptorového potenciálu.