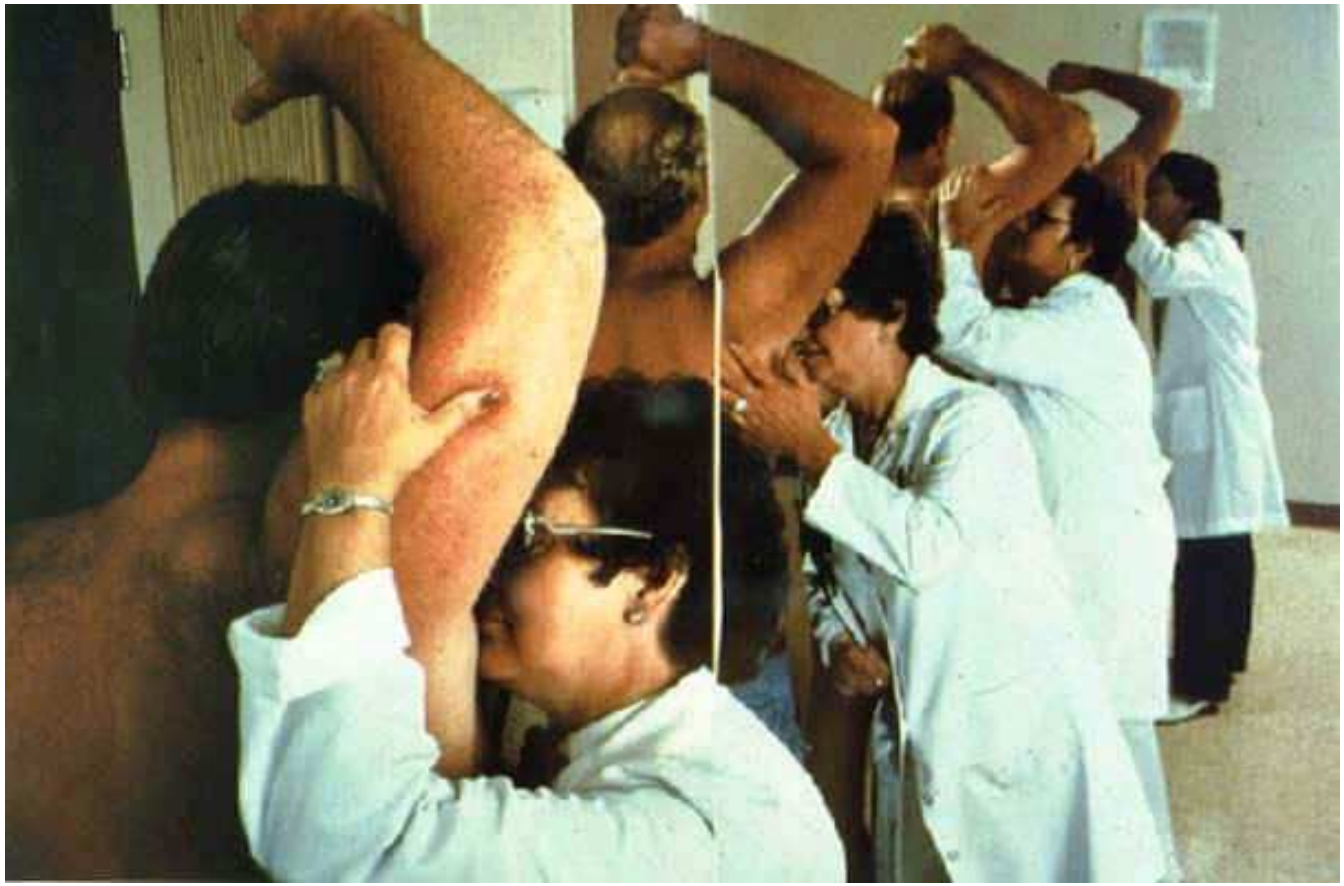
Chemorecepce



Čich

The Nobel Prize in Physiology or Medicine 2004

"for their discoveries of odorant receptors and the organization of the olfactory system"

Richard Axel

1/2 of the prize

USA

**Columbia University
New York, NY, USA; Howard Hughes Medical Institute**

b. 1946

Linda B. Buck

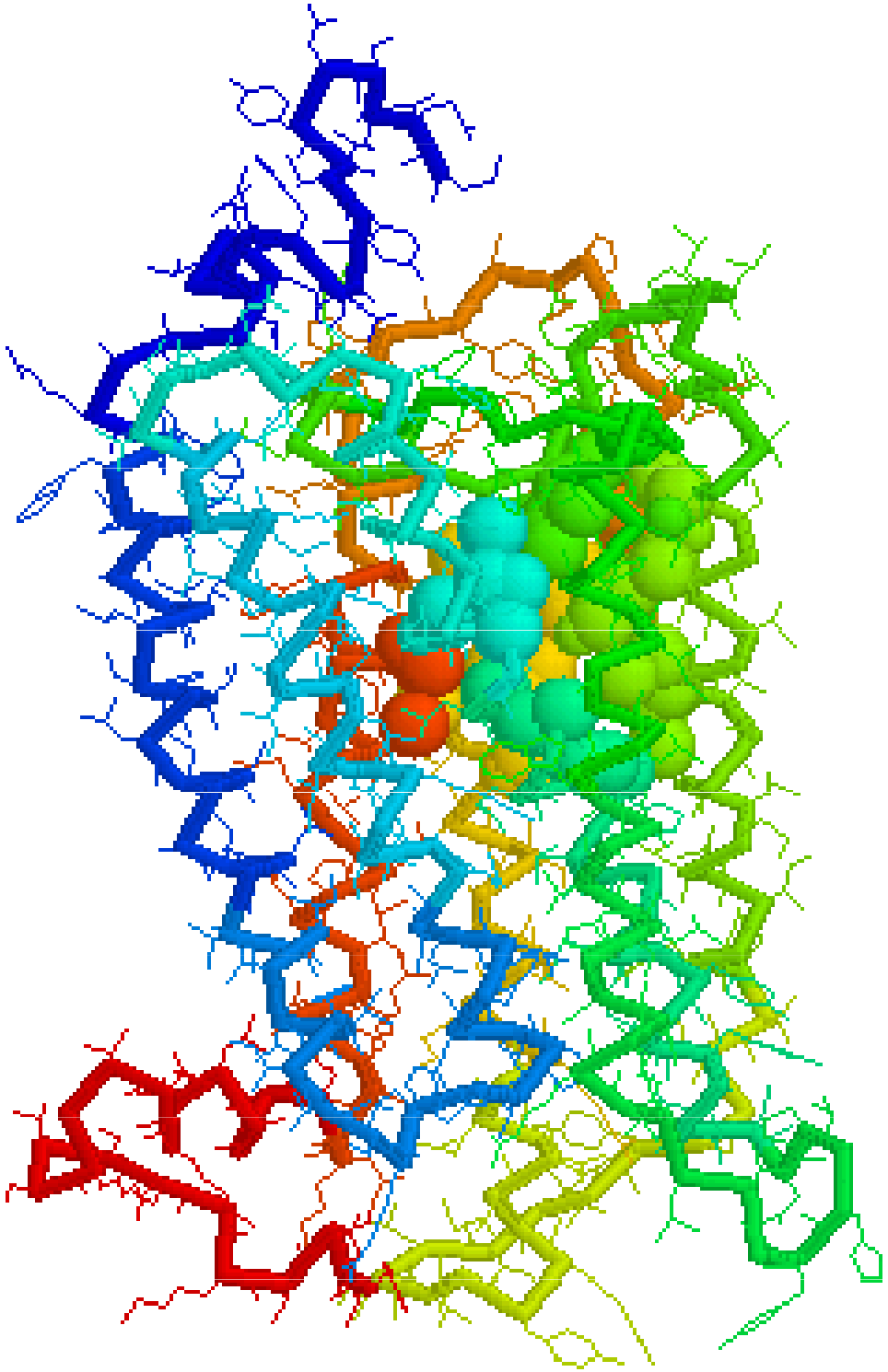
1/2 of the prize

USA

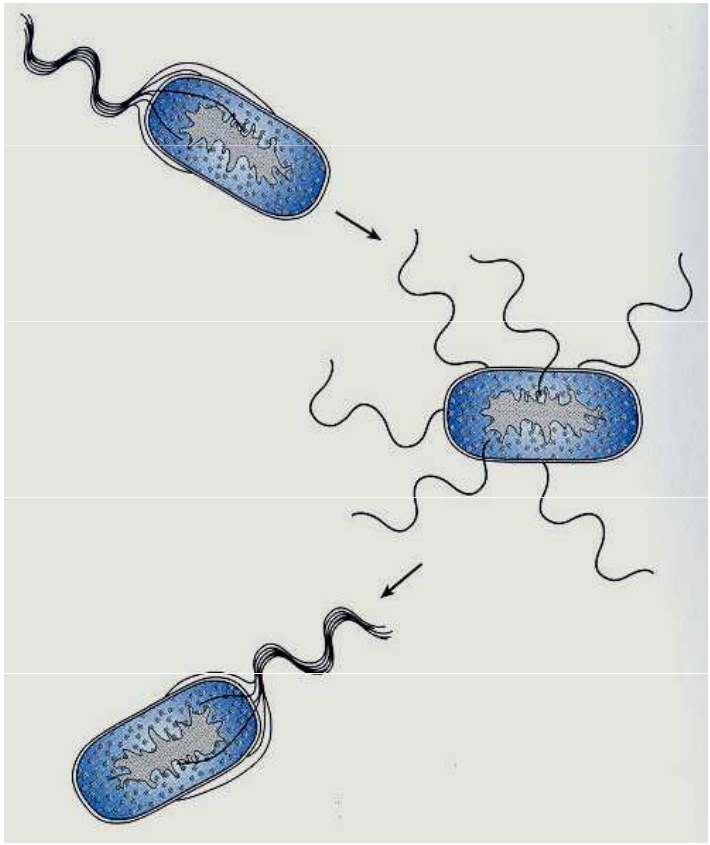
**Fred Hutchinson Cancer Research Center
Seattle, WA, USA; Howard Hughes Medical Institute**

b. 1947

7TM receptory
Metabotropní signalizace



E.coli



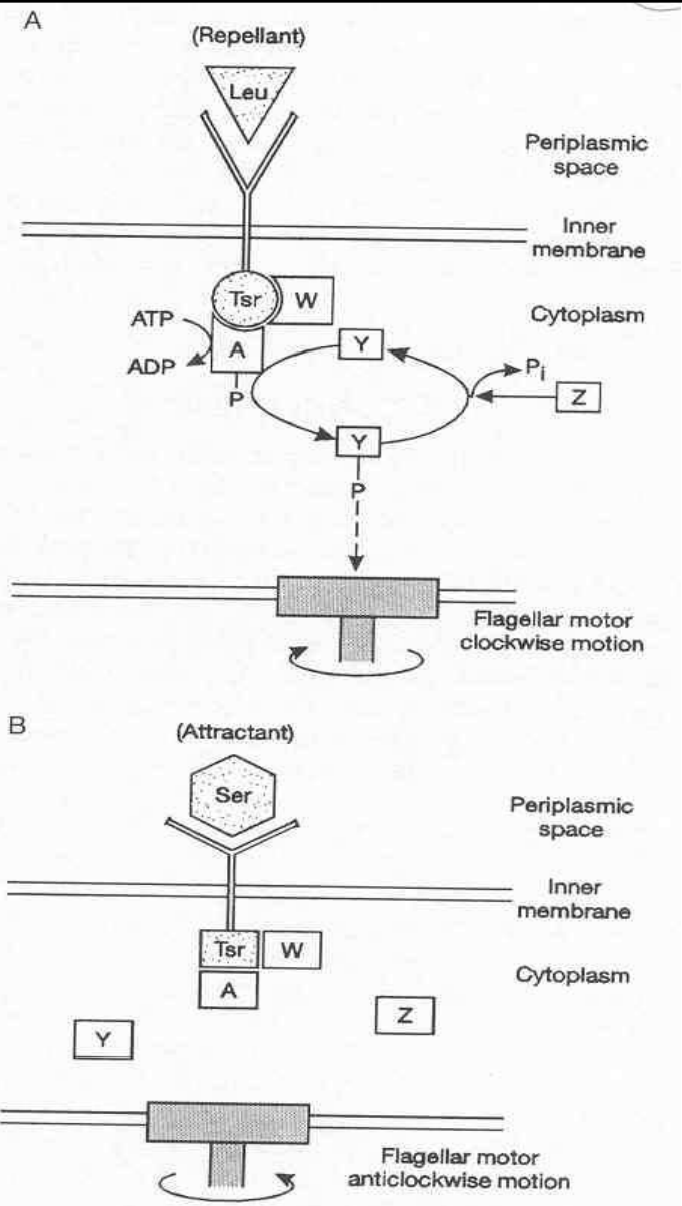
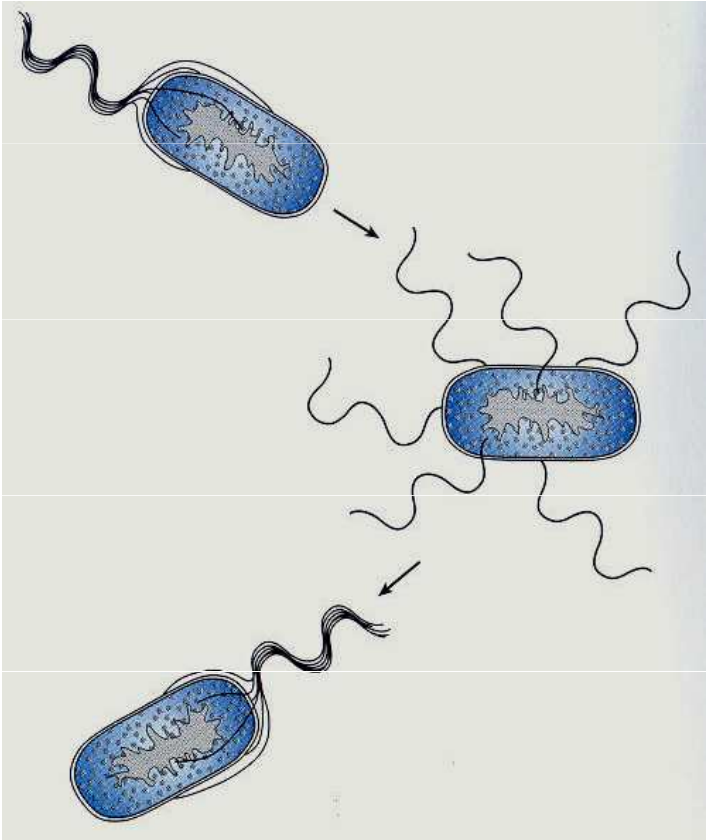
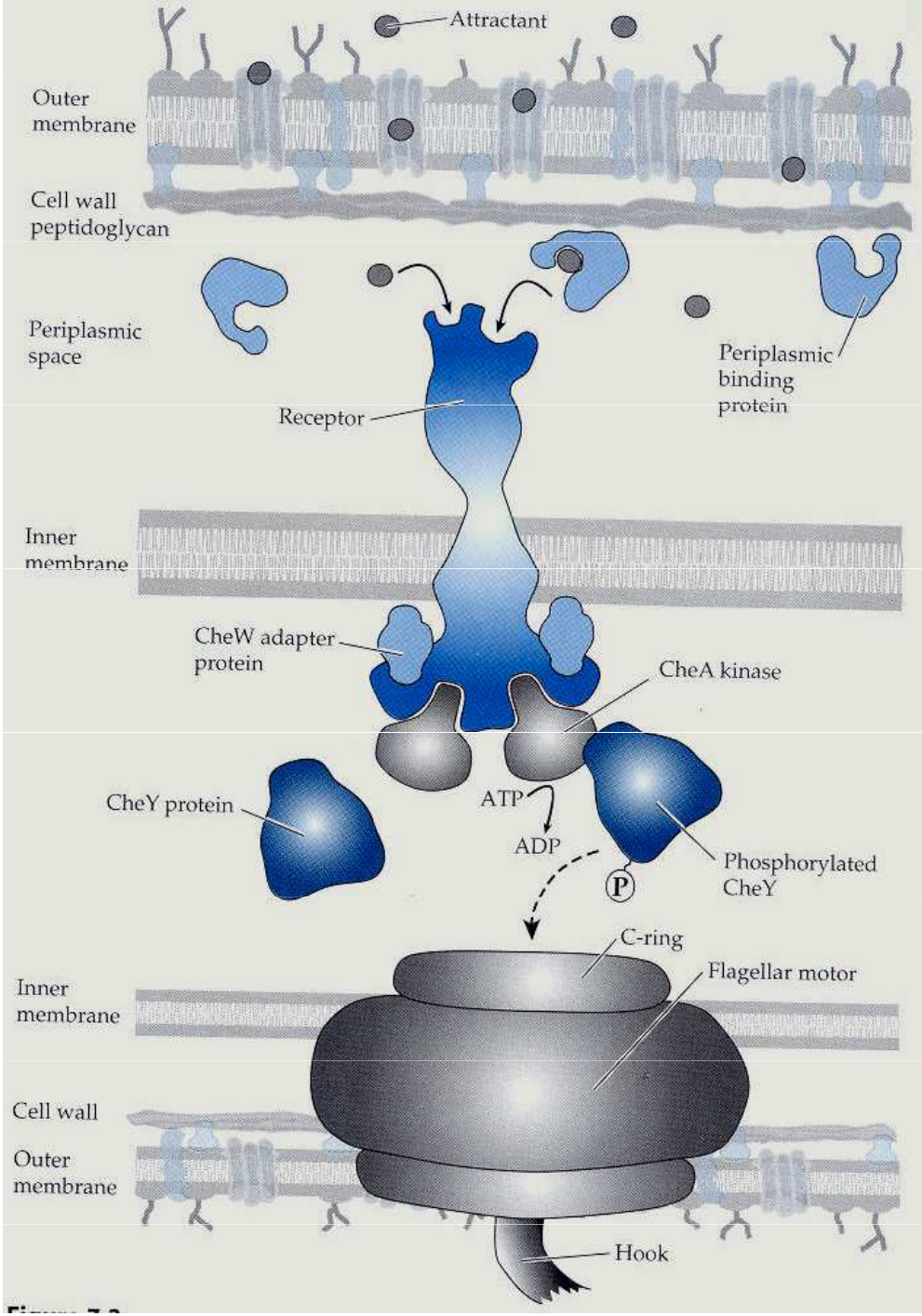


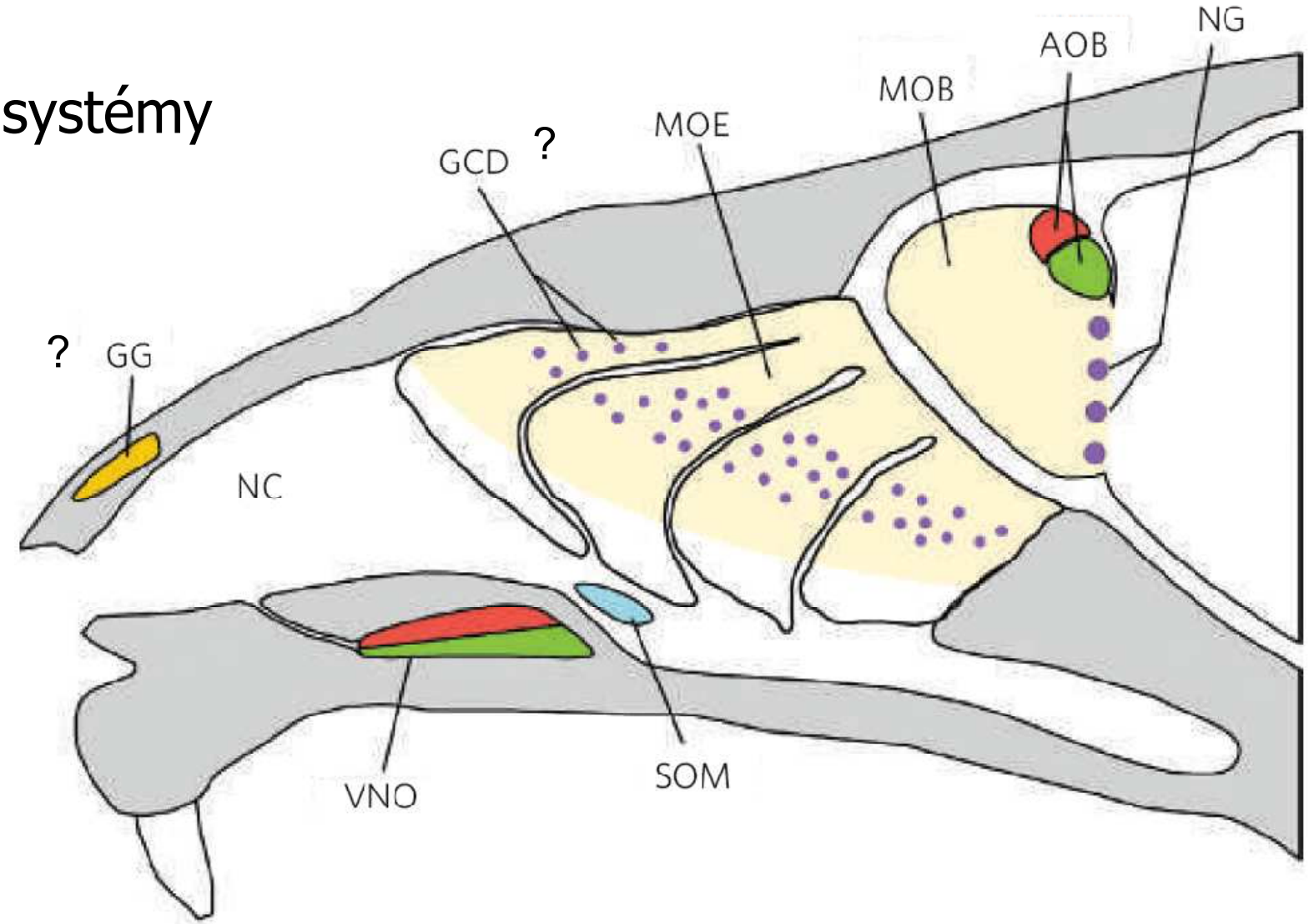
Figure 10.6 Molecular signalling in the *E. coli* chemosensory system. (a) The Tsr receptor-transducer protein accepts a repellant molecule (Leu). CheW and CheA are activated. CheA accepts phosphate from ATP and passes it on CheY. CheY diffuses to the flagellar motor and induces a clockwise rotation and hence tumbling. CheY is eventually dephosphorylated by CheZ. (b) The Tsr receptor-transducer accepts an attractant molecule (Ser). The consequent conformational change inactivates CheA and CheW so that CheY remains unphosphorylated and consequently inactive. The flagellum resumes its anticlockwise motion and the bacterium swims smoothly forward. A = CheA; W = CheW; Y = CheY; Z = CheZ. Data from Bourrett, Borkovich and Simon, 1991

E.coli

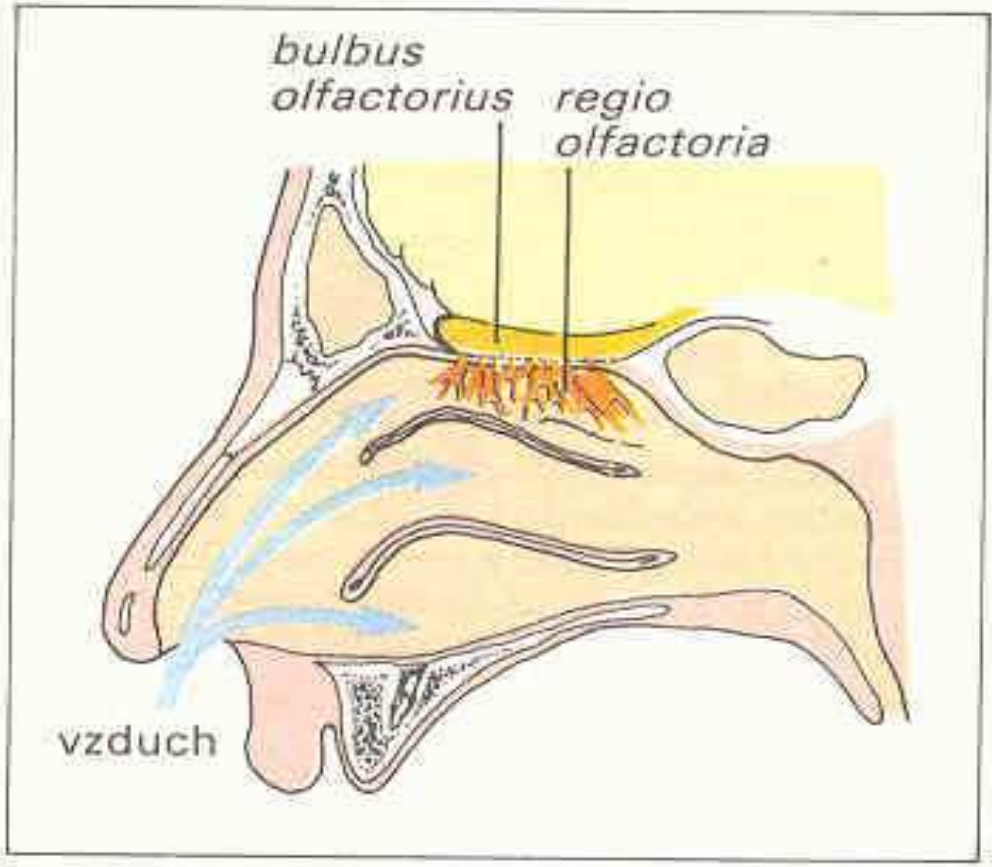



Attractant
Outer membrane
Cell wall peptidoglycan
Periplasmic space
Periplasmic binding protein
Receptor
Inner membrane
CheW adapter protein
CheA kinase
CheY protein
ATP
ADP
P
Phosphorylated CheY
C-ring
Flagellar motor
Inner membrane
Cell wall
Outer membrane
Hook

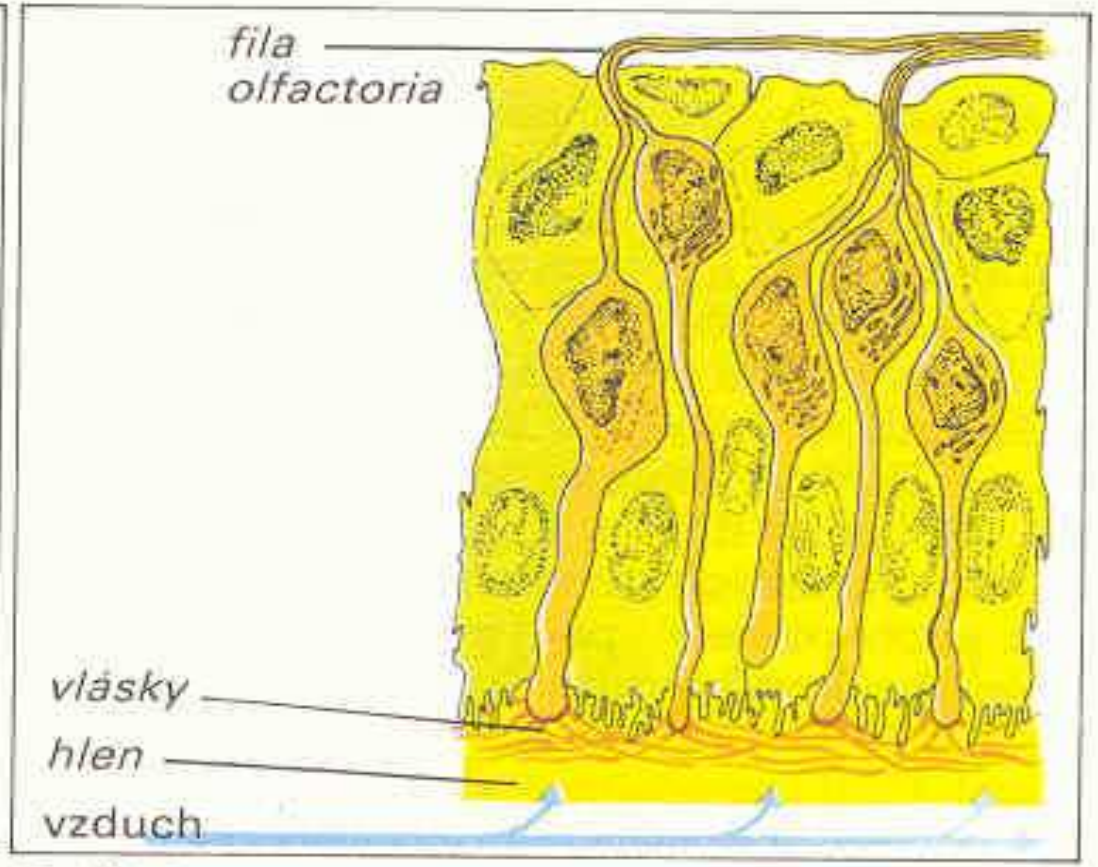
2 čichové systémy



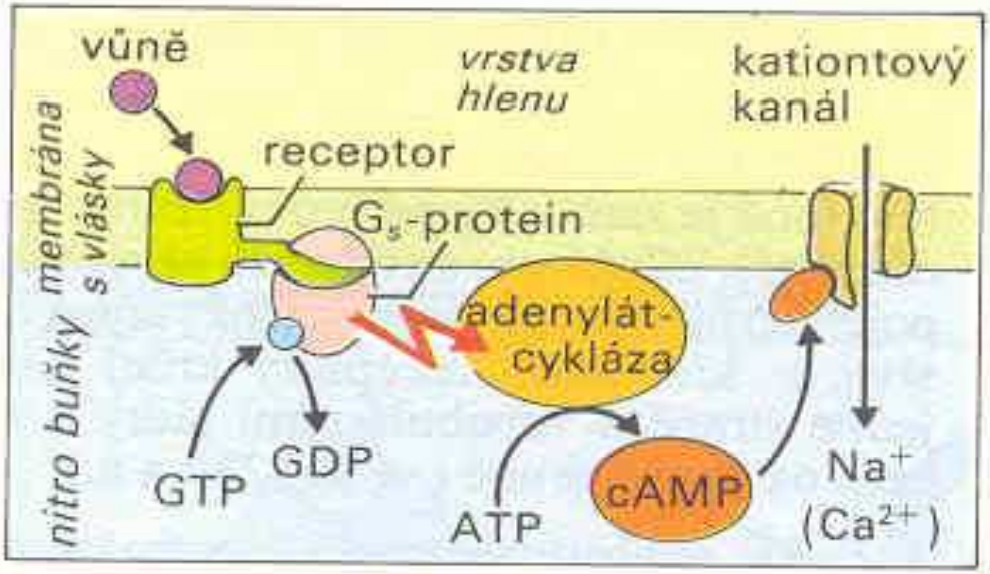
accessory olfactory bulb (AOB).
vomeronasal organ (VNO)
main olfactory epithelium (MOE) consists predominantly of ciliated olfactory sensory neurons (OSNs), which project to the main olfactory bulb (MOB)



A. Nosní dutina a čichový orgán



B. Čichový epitel (podle Andrese)

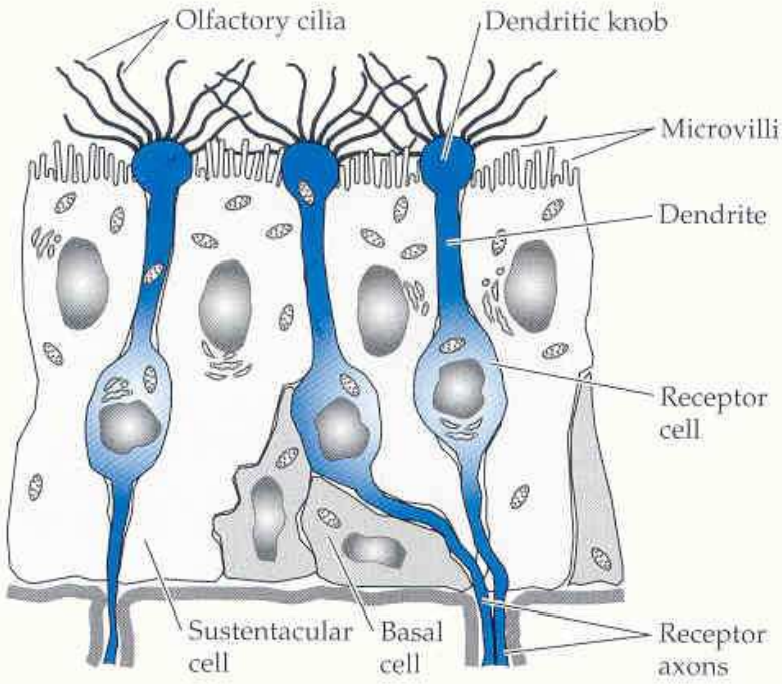


C. Transdukce čichového podnětu

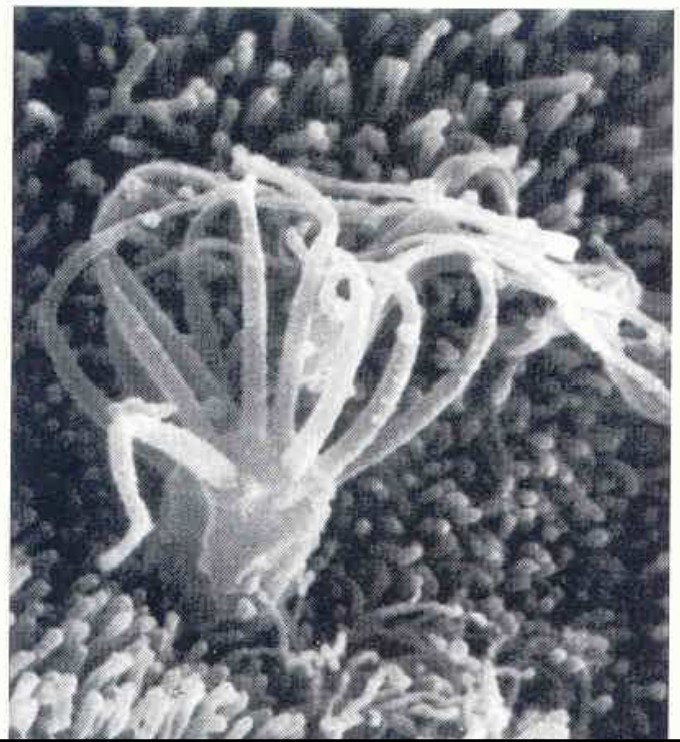
D. Adaptace čichu

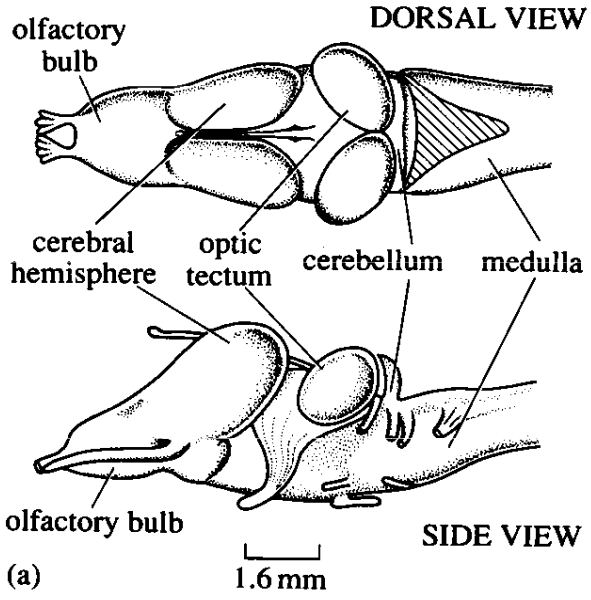
Figure 7.7
Olfactory epithelium (A) Schematic cross section of olfactory epithelium. (B) Scanning micrograph of a dendritic knob and dendrites of a human olfactory receptor neuron. Magnification: 18,500×. (From Morrison and Costanzo, 1990.)

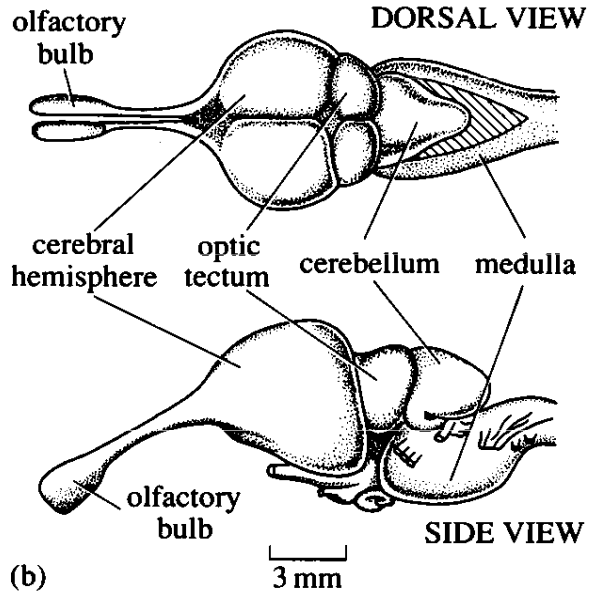
(A)

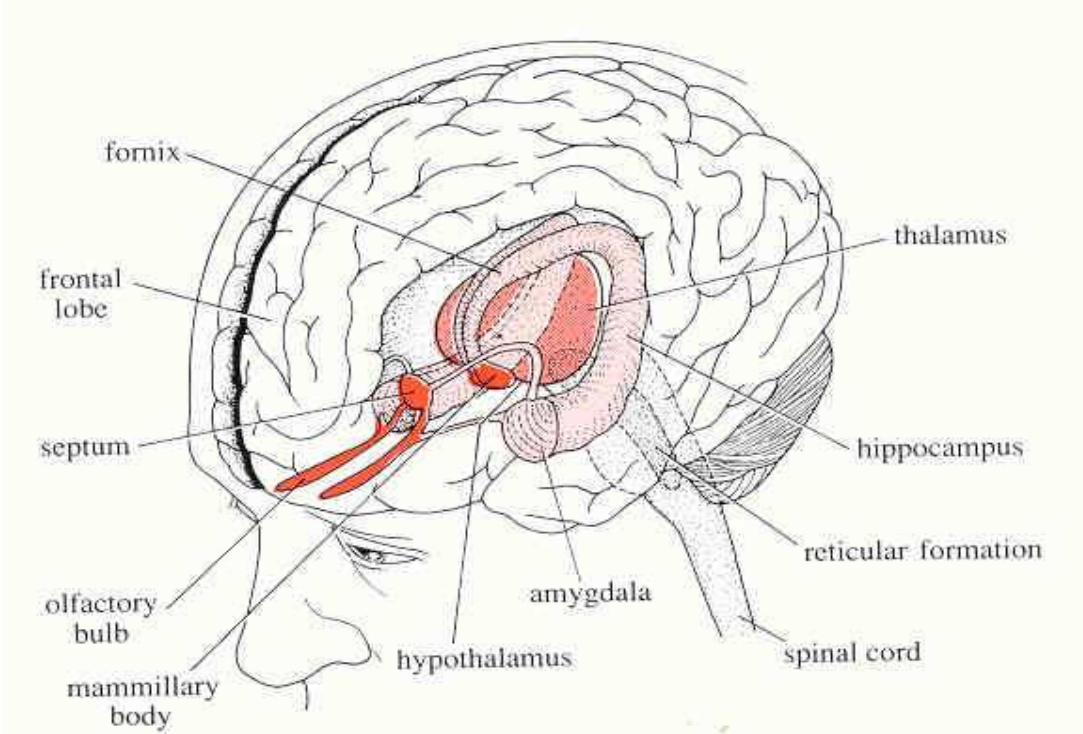


(B)





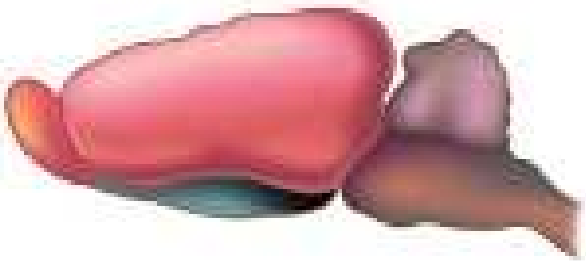




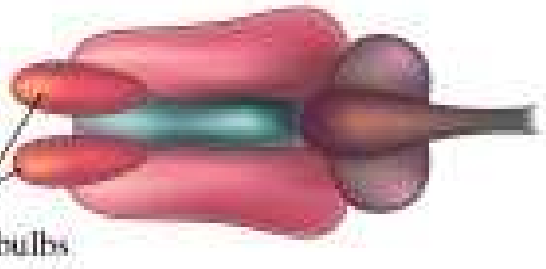
ıre 10.1 The limbic system (the main limbic system structures are shown i

Rat

Side view



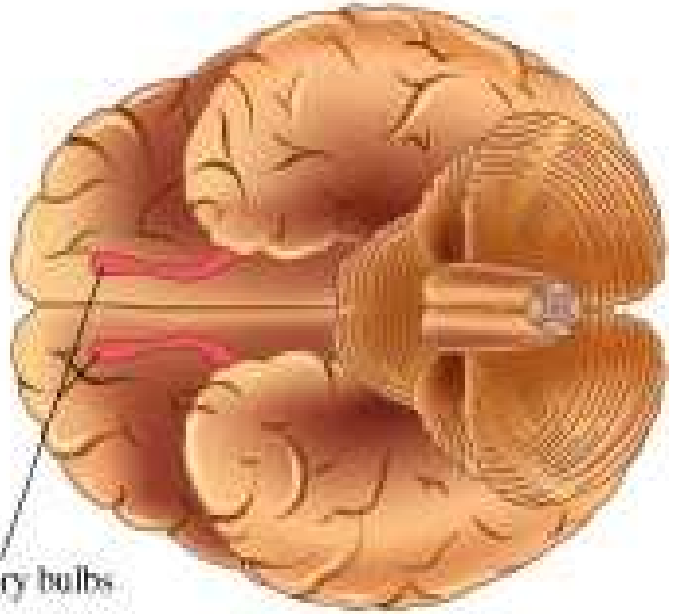
Bottom view



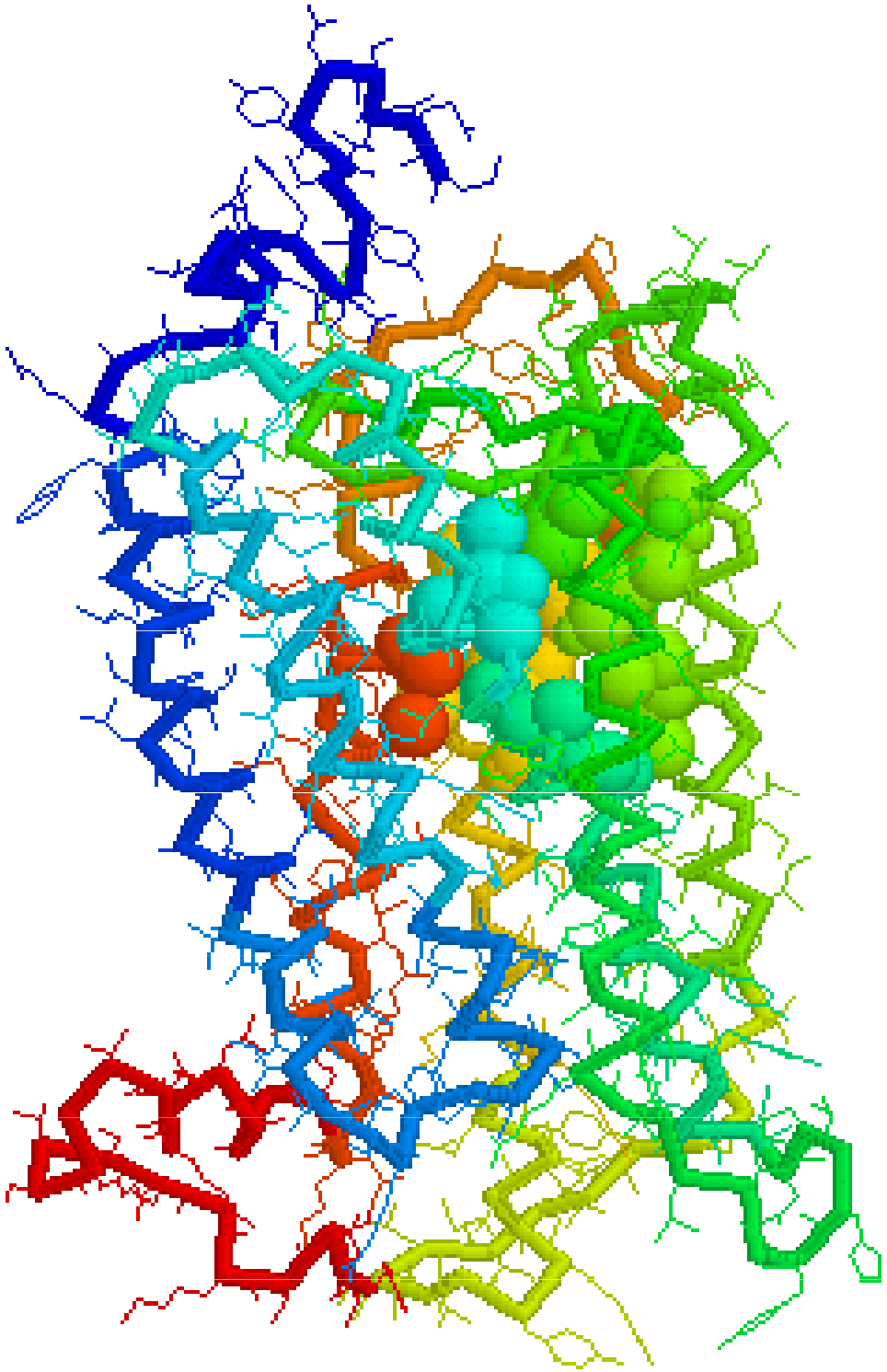
Human

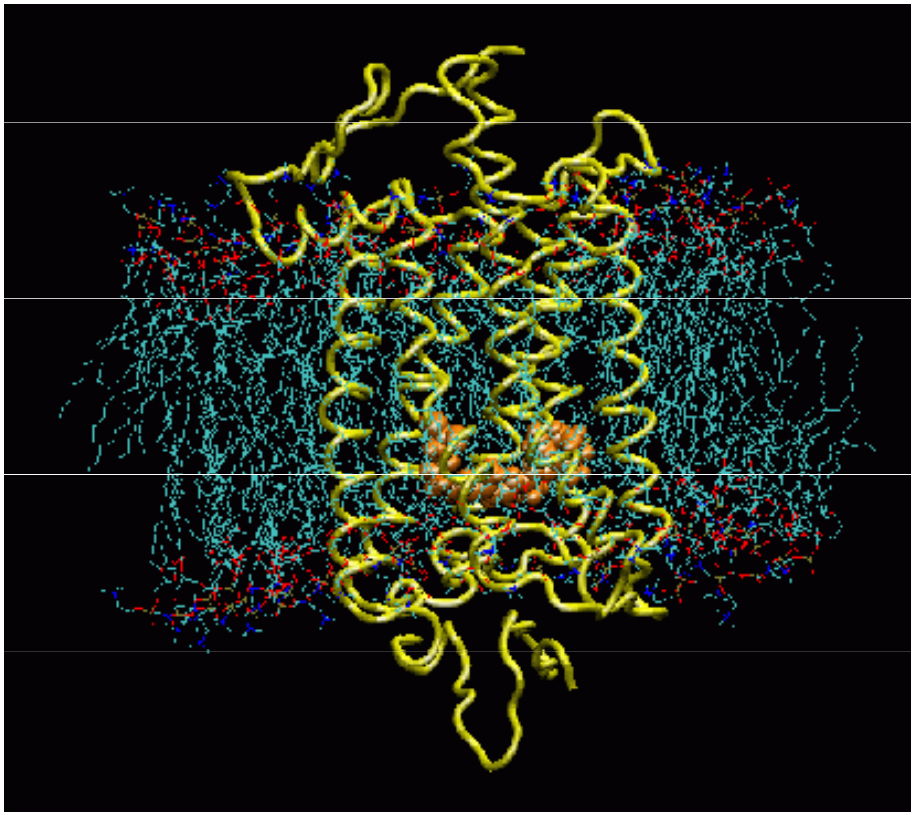
Side view

Bottom view



NEUROBIOLOGY
Gary G. Matthews
Blackwell Science





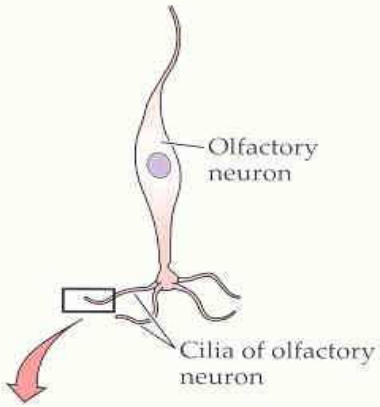
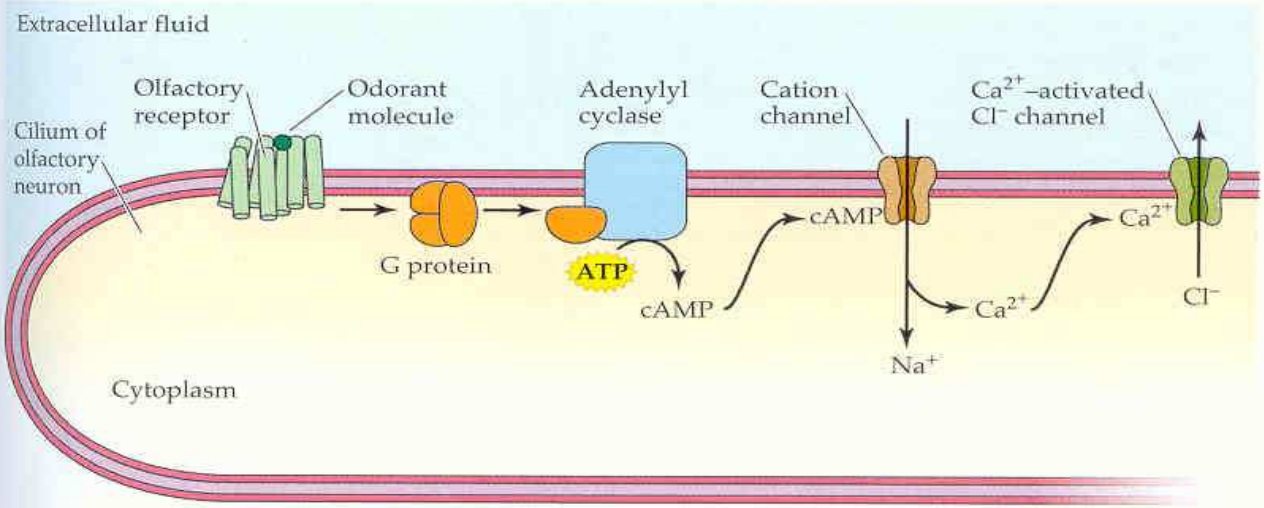
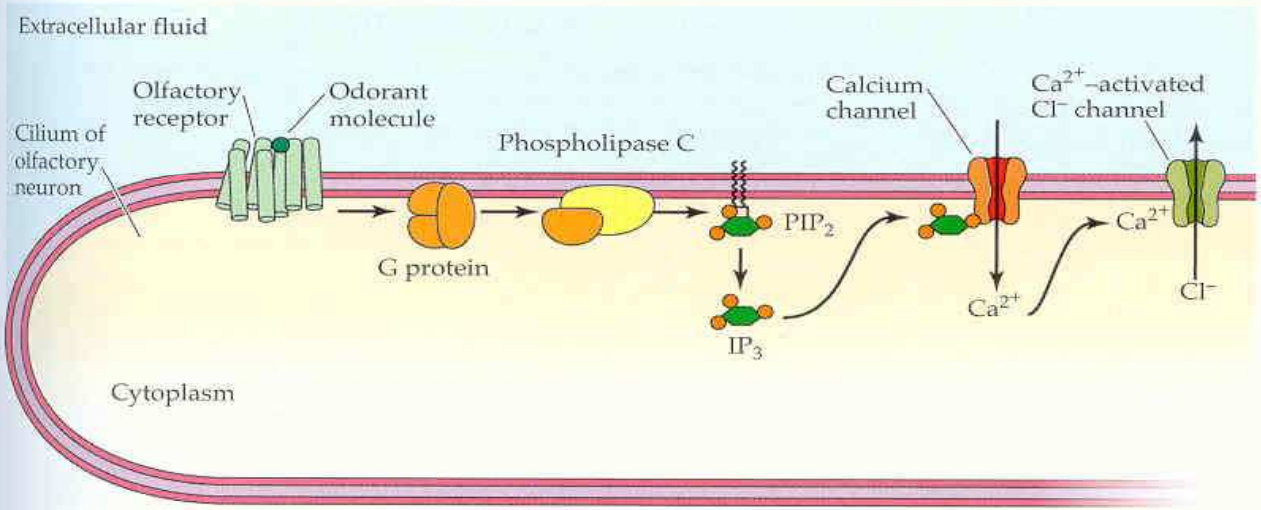


Figure 13.36 Olfactory transduction mechanisms in cilia membranes of olfactory neurons *(a)* Many odorants act to increase cyclic AMP. The odorant binds to an odorant receptor on the ciliary membrane; the receptor activates a G protein to activate adenylyl cyclase, producing cAMP. Cyclic AMP binds to and opens a cation channel, allowing entry of Na^+ and Ca^{2+} ions to depolarize the cell. Ca^{2+} binds to Ca^{2+}-activated Cl^- channels, augmenting the depolarization. *(b)* Some olfactory responses increase IP_3. This mechanism also starts with odorant binding to a G protein–coupled receptor, but in this case the G protein activates phospholipase C, forming IP_3 from PIP_2 (see Figure 12.21). IP_3 binds to and opens a calcium channel, letting Ca^{2+} enter to depolarize the cell. As in *(a)*, Ca^{2+}-activated Cl^- channels augment the depolarization.

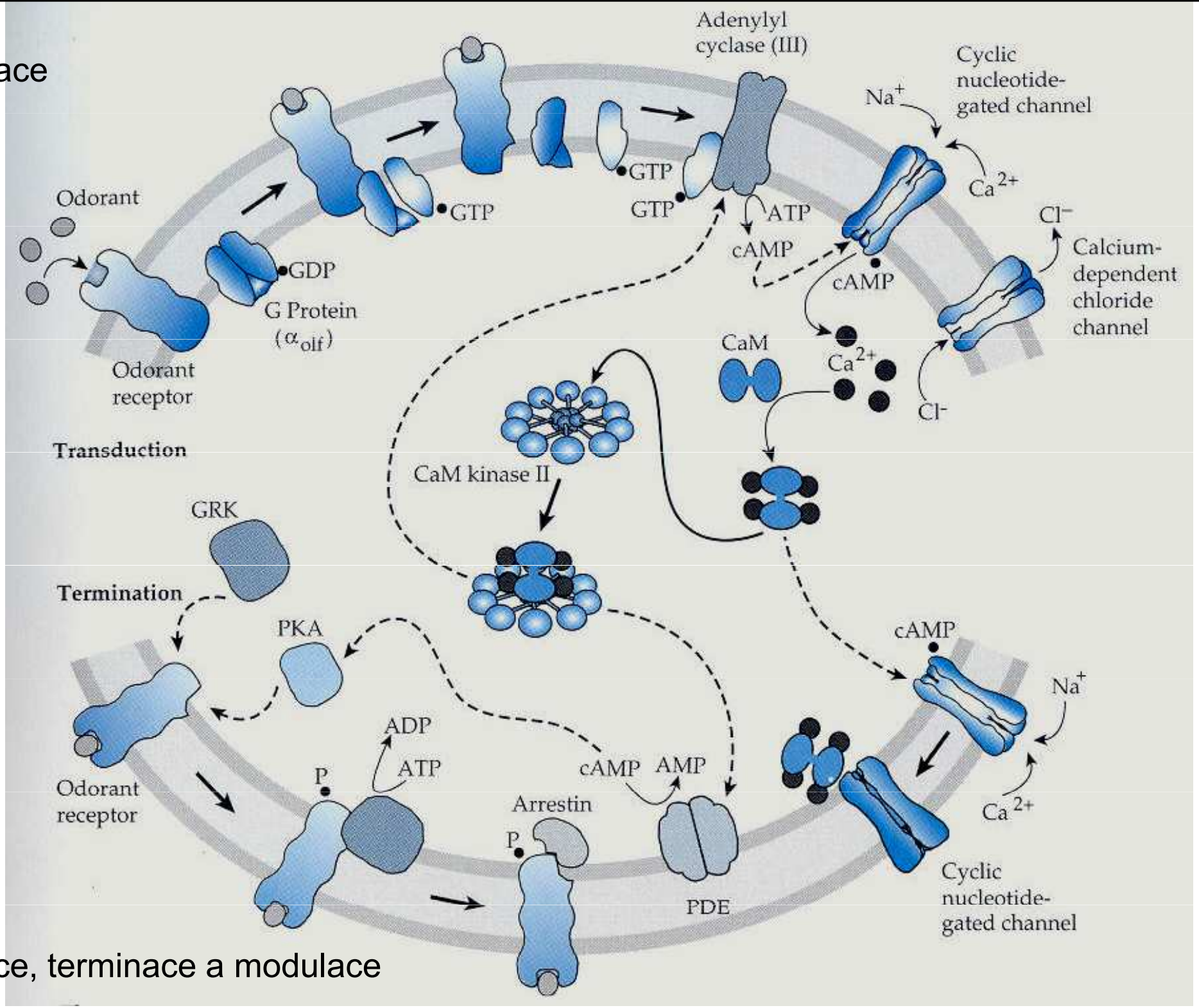
(a) Increase in cAMP



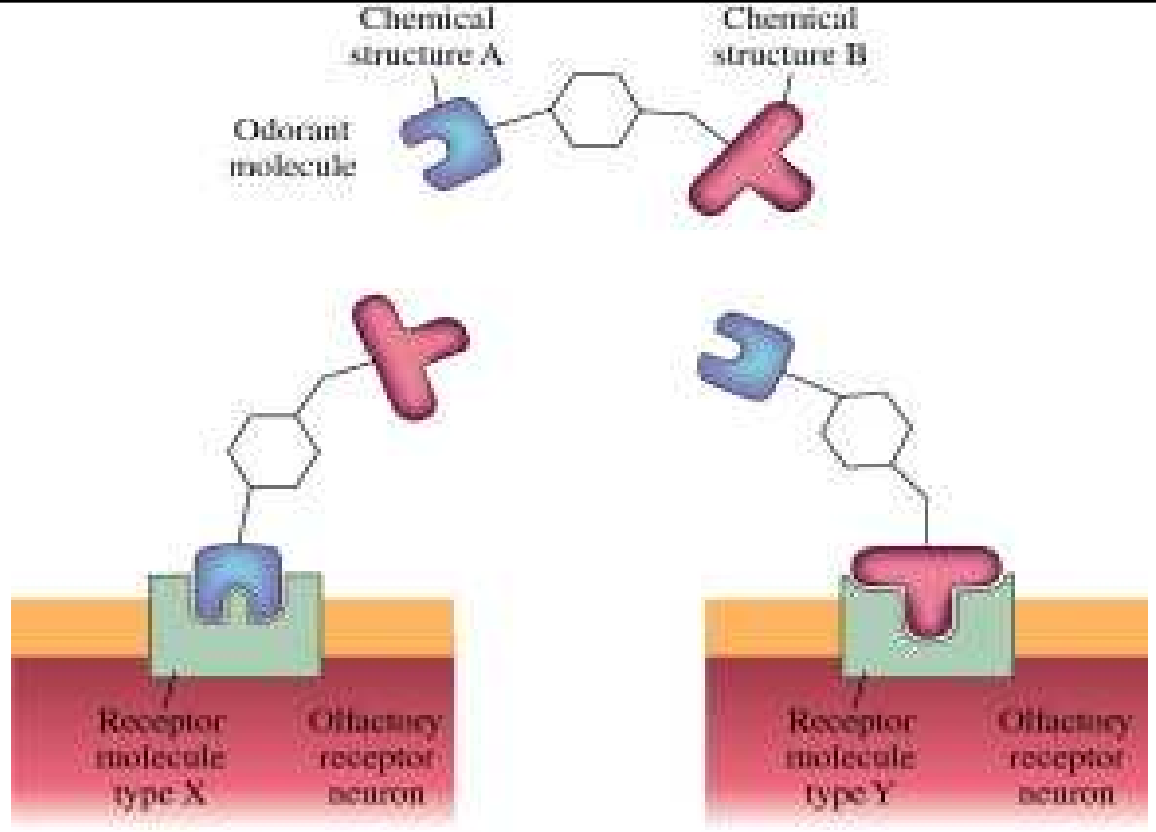
(b) Increase in IP_3

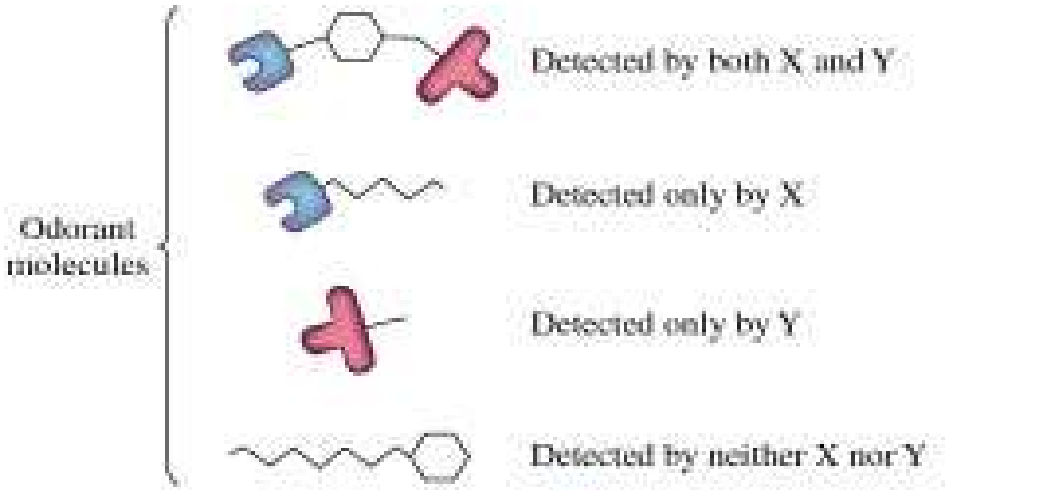


Aktivace

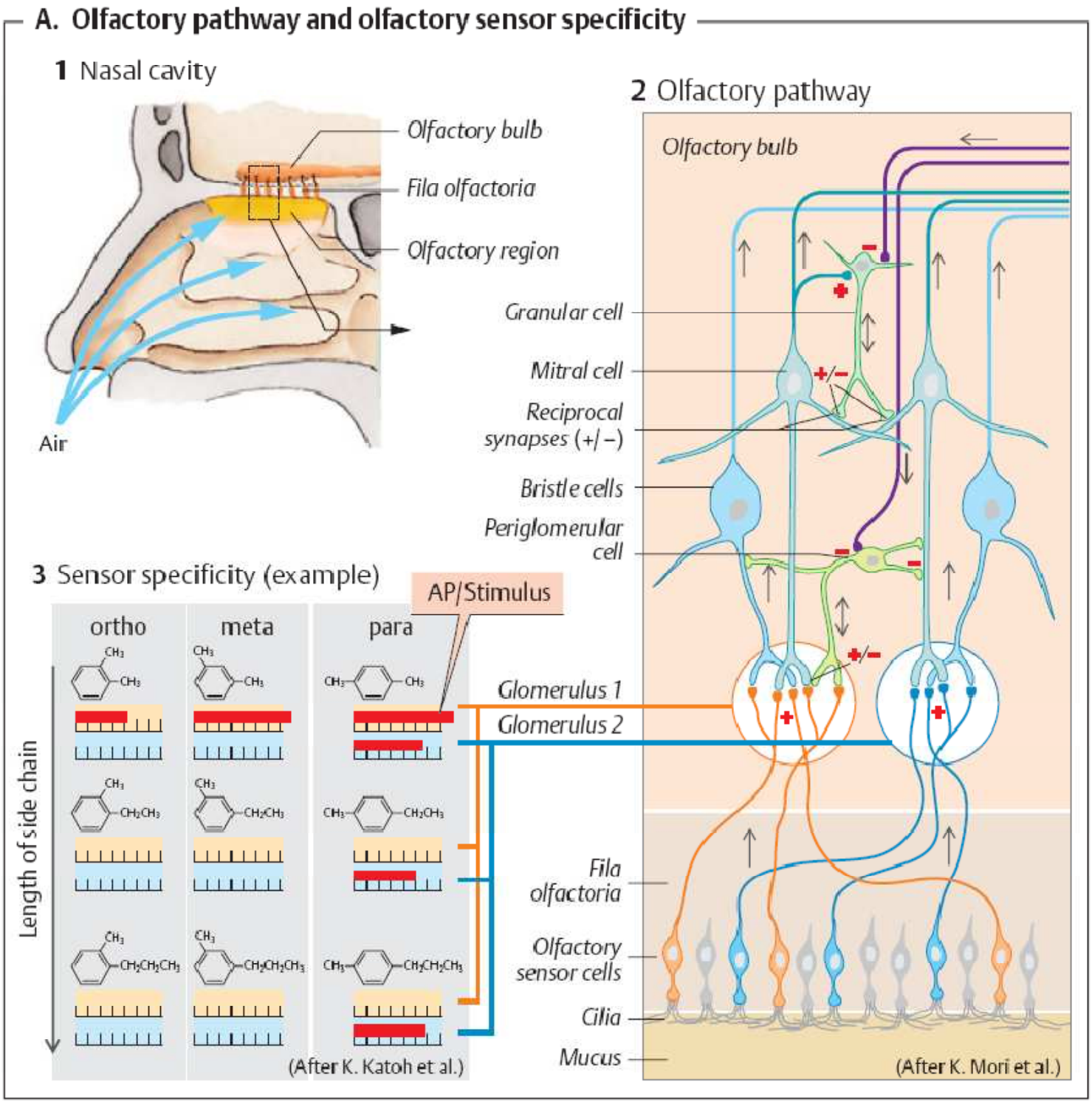


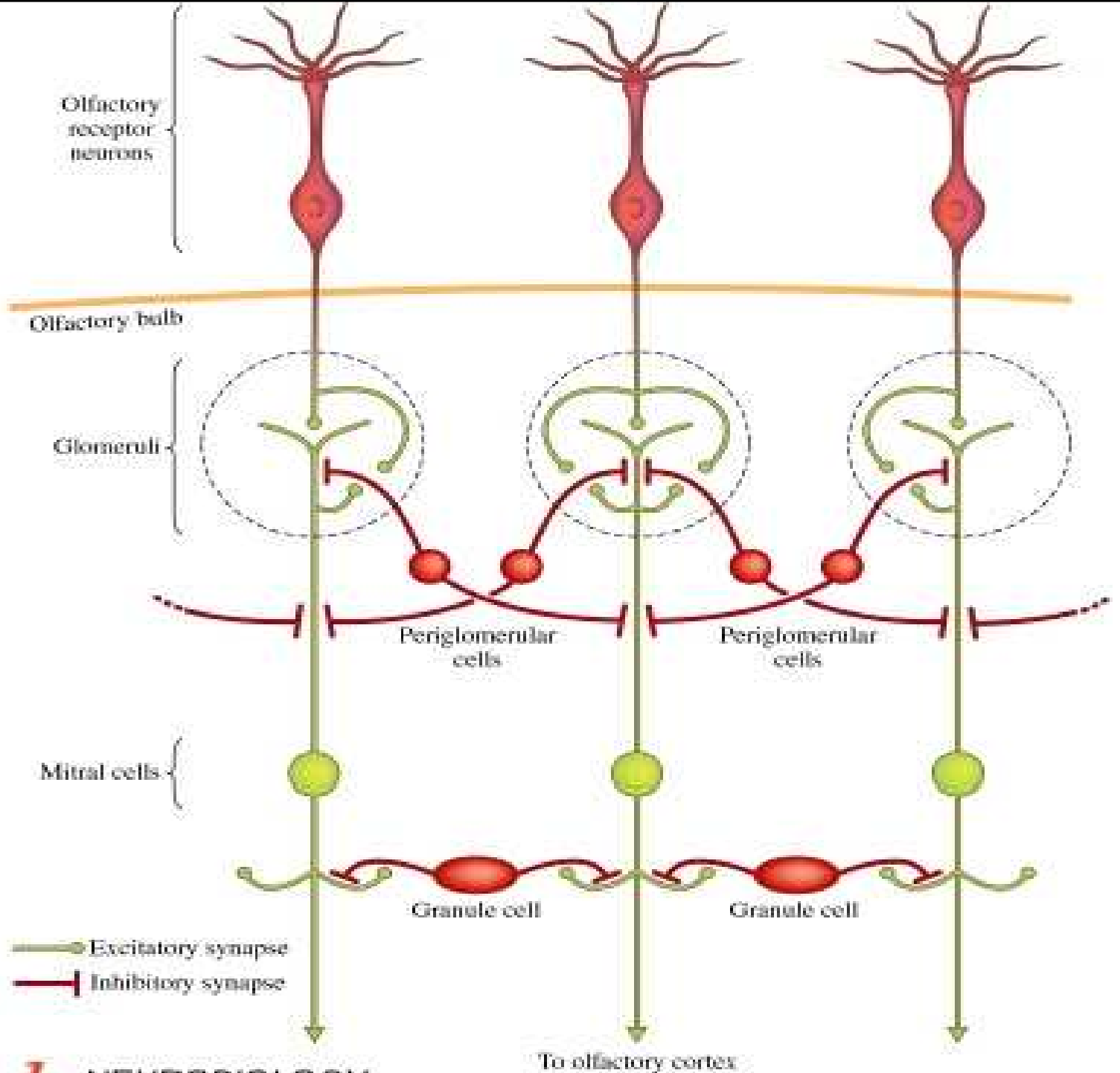
Adaptace, terminace a modulace





NEUROBIOLOGY
Gary G. Matthews
Blackwell Science

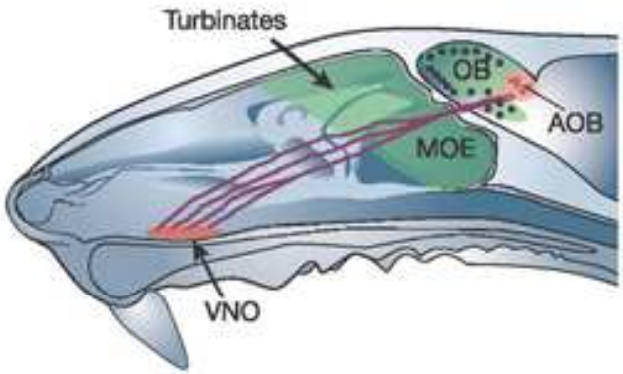

A. Olfactory pathway and olfactory sensor specificity
1 Nasal cavity
Olfactory bulb
Fila olfactoria
Olfactory region
Air
2 Olfactory pathway
Olfactory bulb
Granular cell
Mitral cell
Reciprocal synapses (+/–)
Bristle cells
Periglomerular cell
3 Sensor specificity (example)
AP/Stimulus
ortho
meta
para
Length of side chain
Glomerulus 1
Glomerulus 2
Fila olfactoria
Olfactory sensor cells
Cilia
Mucus
(After K. Katoh et al.)
(After K. Mori et al.)



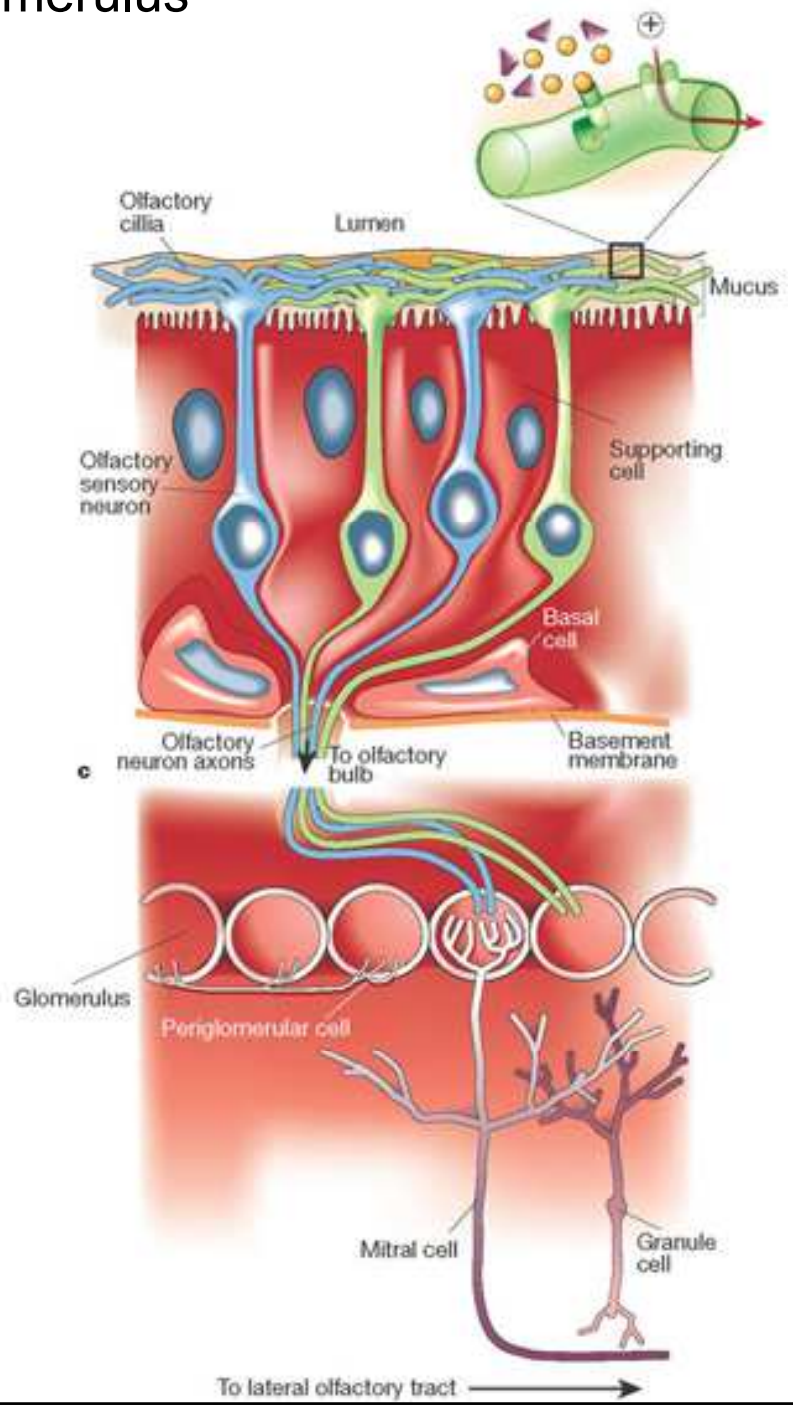
NEUROBIOLOGY
Gary G. Matthews

Blackwell Science

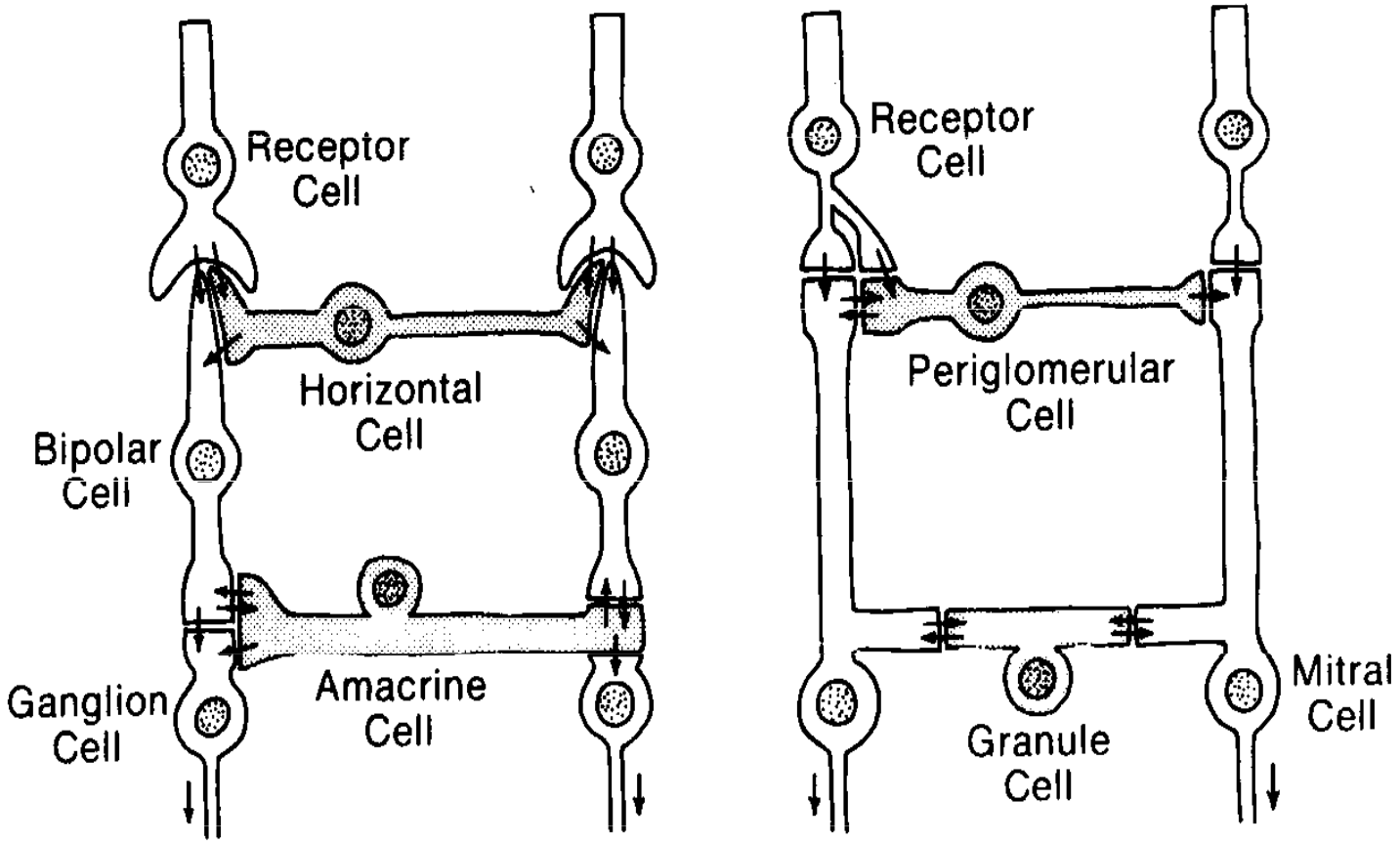
Konvergence na příslušný glomerulus



MOE = main olfactory epithelium.
OB = olfactory bulb.
AOB = accessory olfactory bulb.
VNO = vomeronasal organ.



Podobnost architektury sensorických obvodů a drah



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

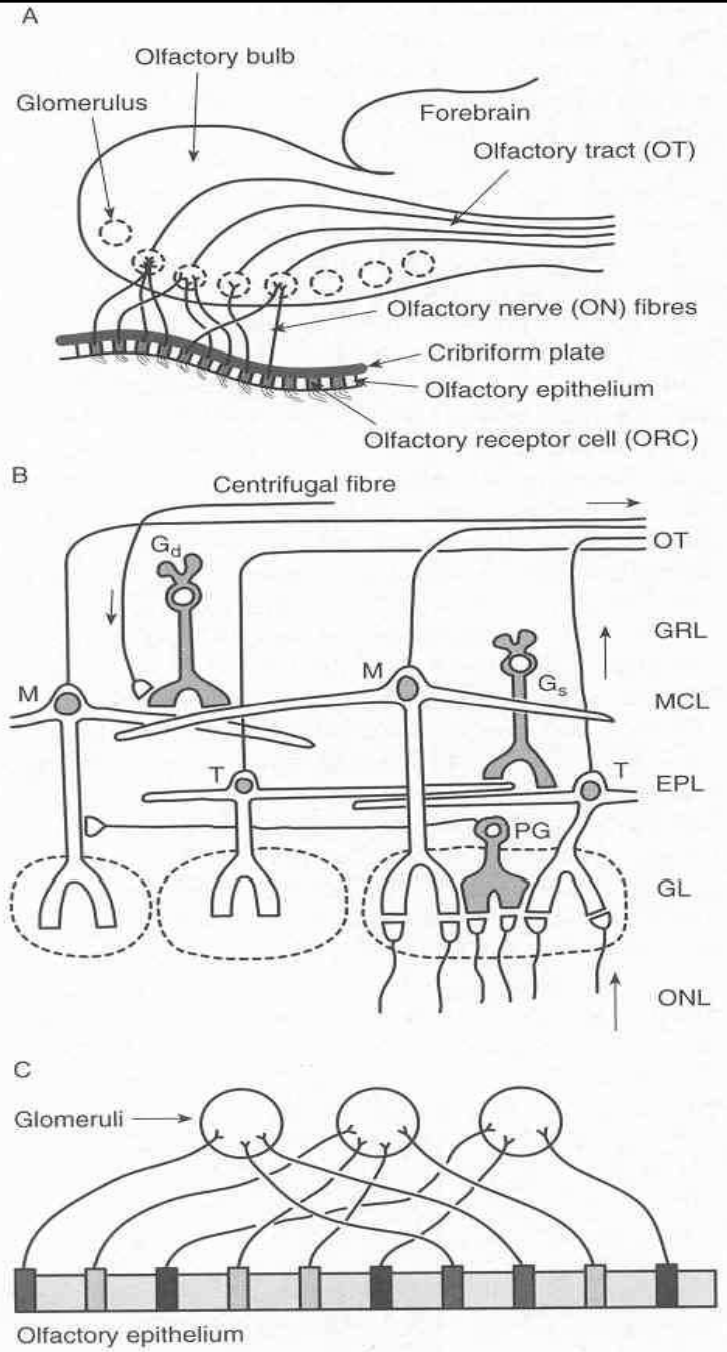
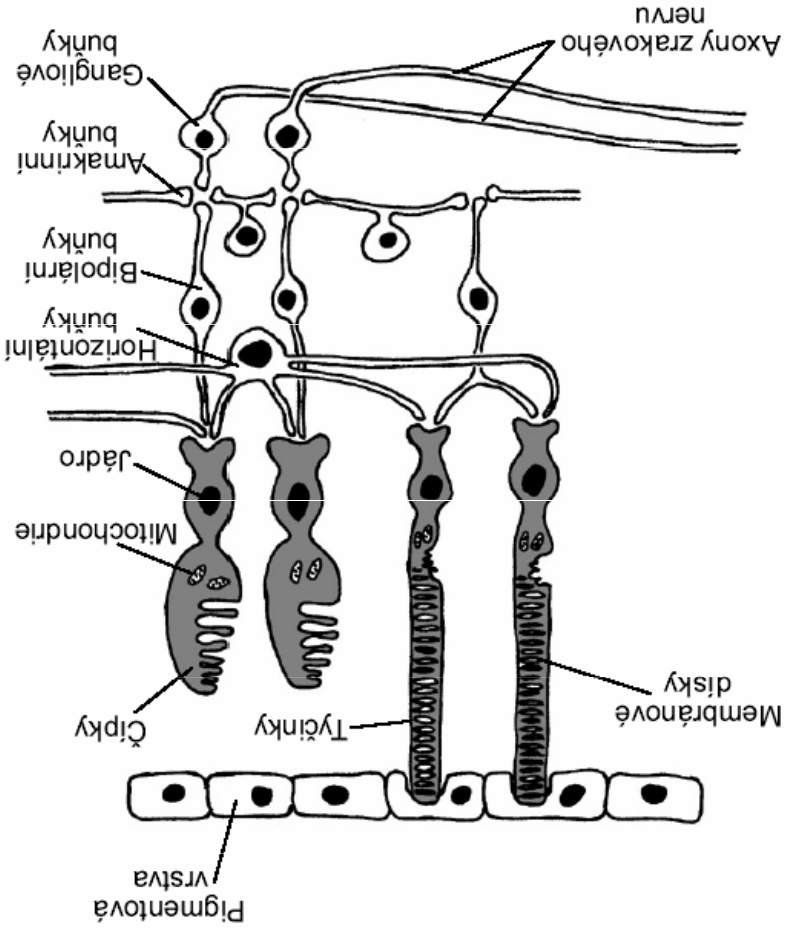
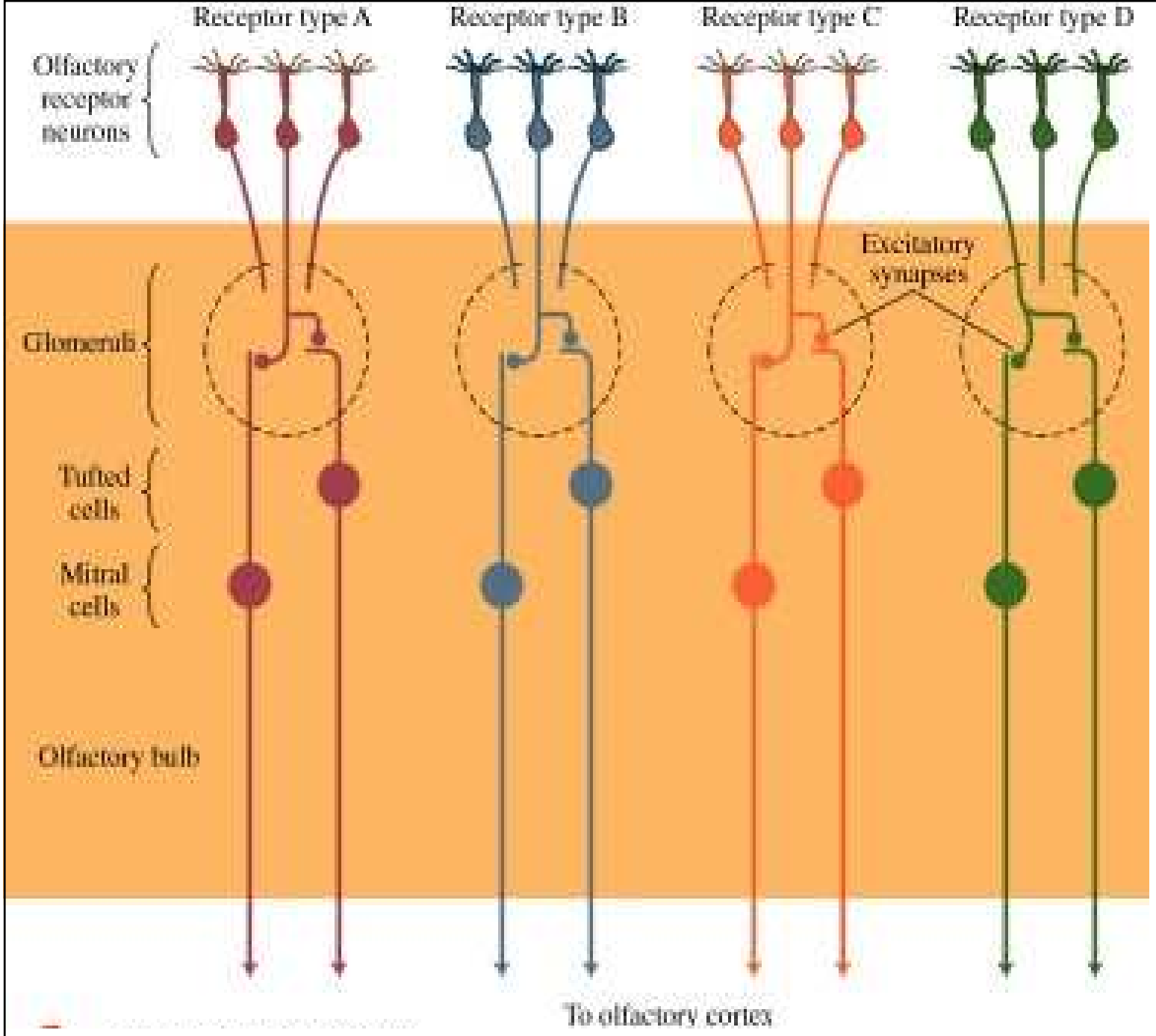
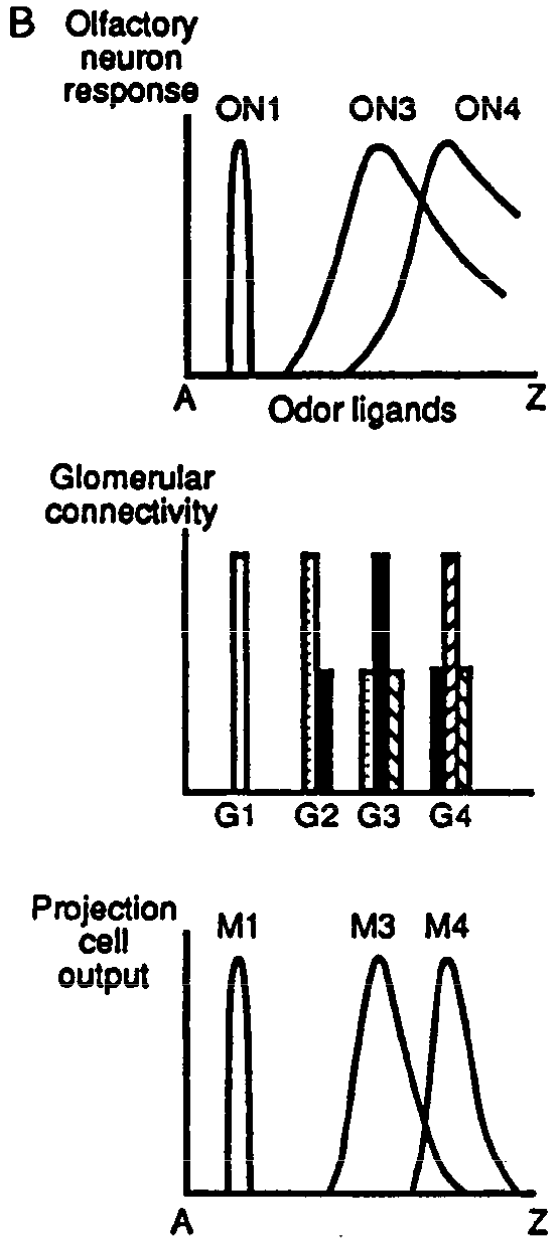


Figure 13.7 Olfactory bulb. (a) The figure shows olfactory axons passing through the cribriform plate to end in glomeruli in the olfactory bulb. (b) Basic circuit of the mammalian olfactory bulb. Layers: EPL = external plexiform layer; GL = glomerular layer; GRL = granule cell layer; OT = olfactory tract; MCL = mitral cell layer. Cells: G_d = deep granule cell; G_s = superficial granule cell; M = mitral cell; PG = periglomerular cell; T = tufted cell. Inhibitory cells stippled. Simplified from





Překryv



„Zostření“ naladění ve vyšších patrech dráhy

Také adaptace může být na úrovni vyšších pater smyslové dráhy

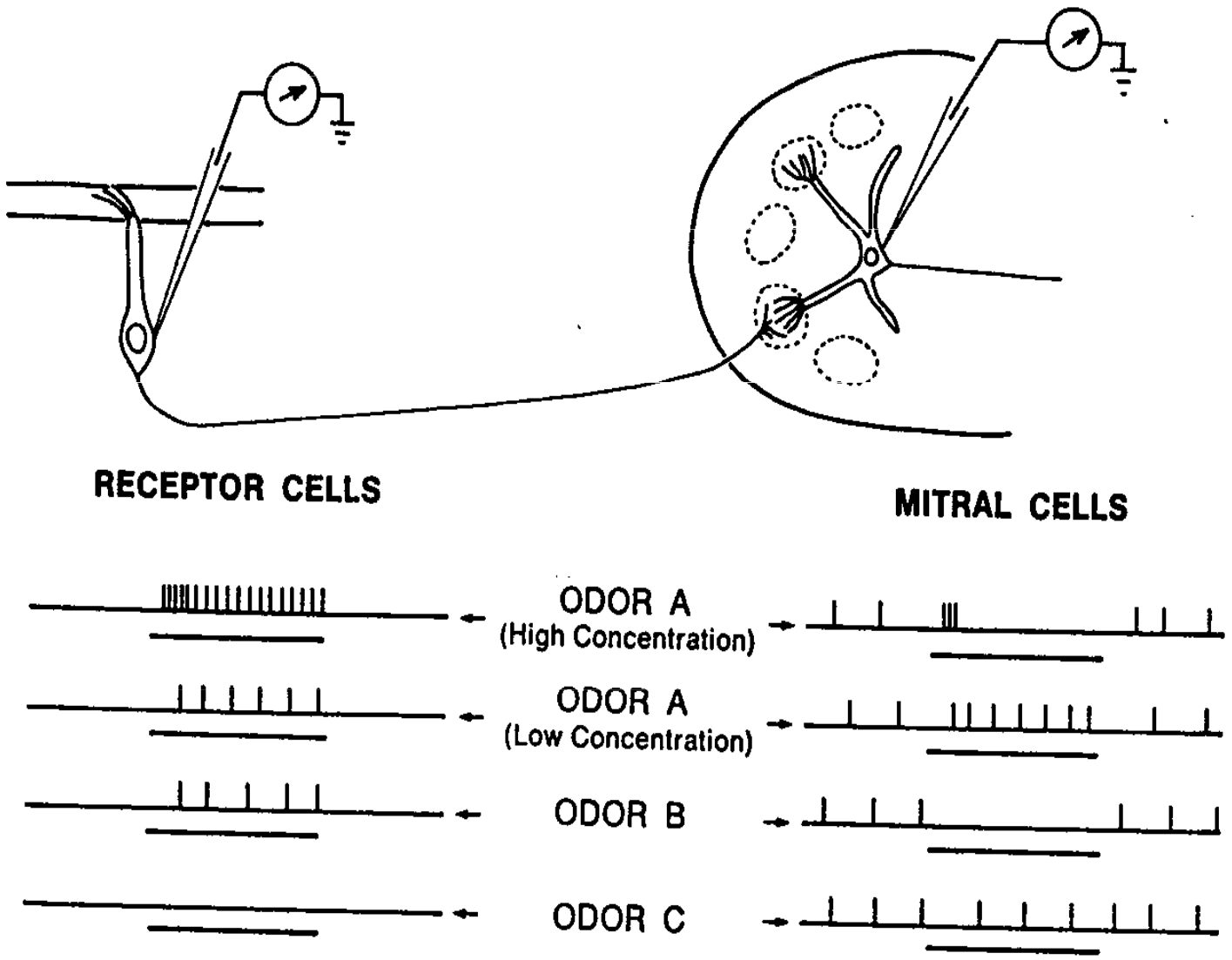
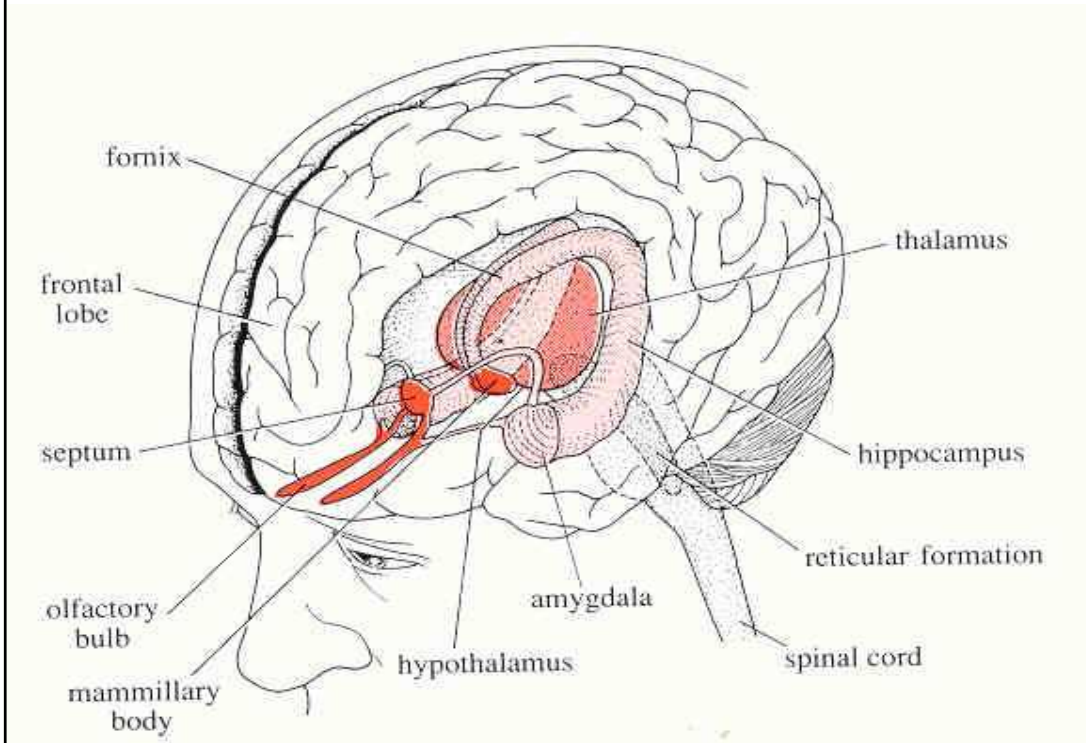
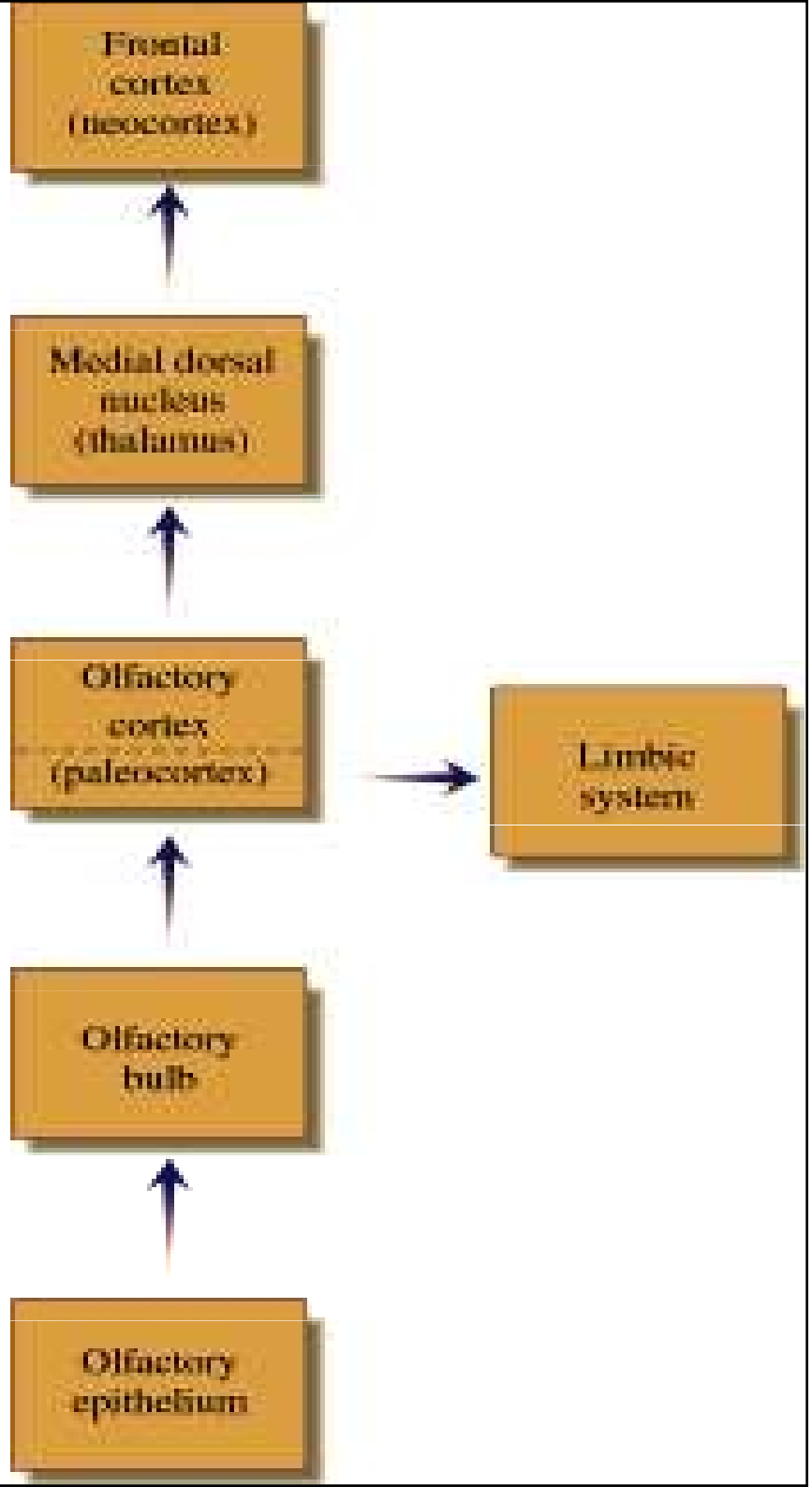


Fig. 11.11 Extracellular single-unit recordings of responses to odors of receptor cells *(left)* and mitral cells *(right)* in the salamander, showing different types of responses and different temporal patterns of activity. (After Kauer, 1974, and Getchell and Shepherd, 1978)



ure 10.1 The limbic system (the main limbic system structures are shown i

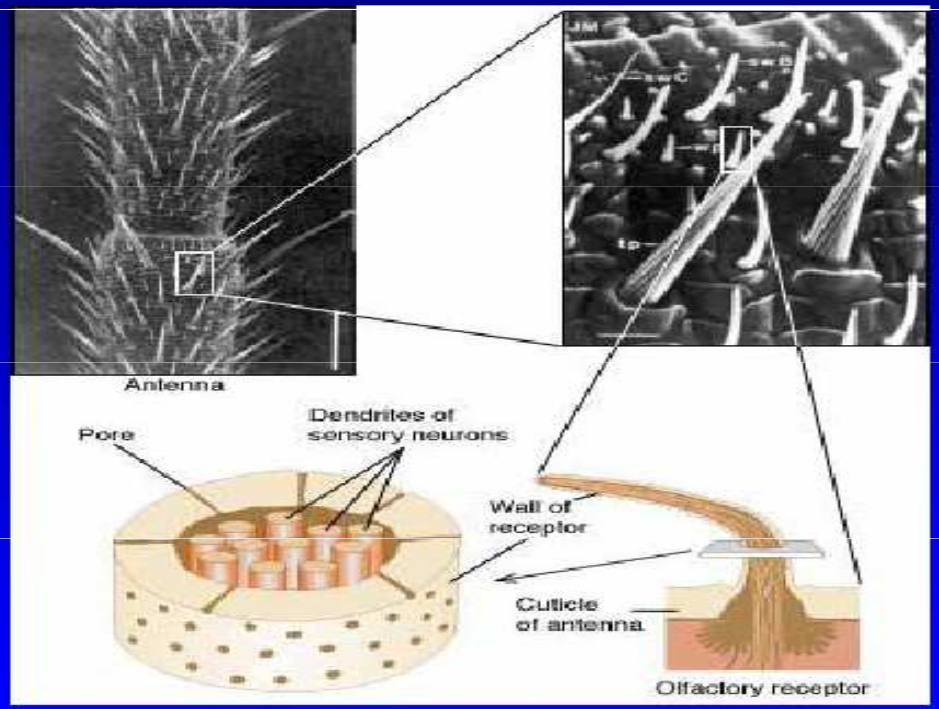


Antennal morphology diversity

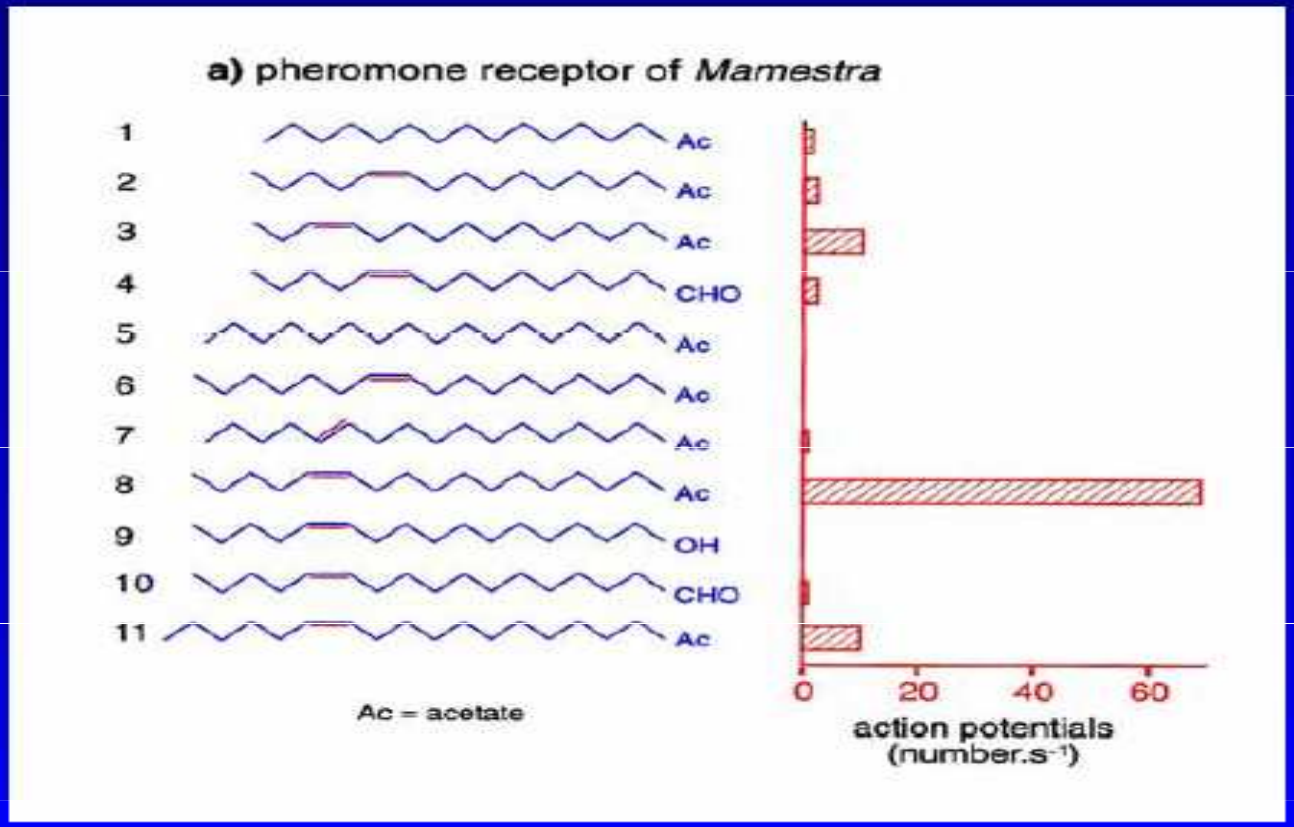




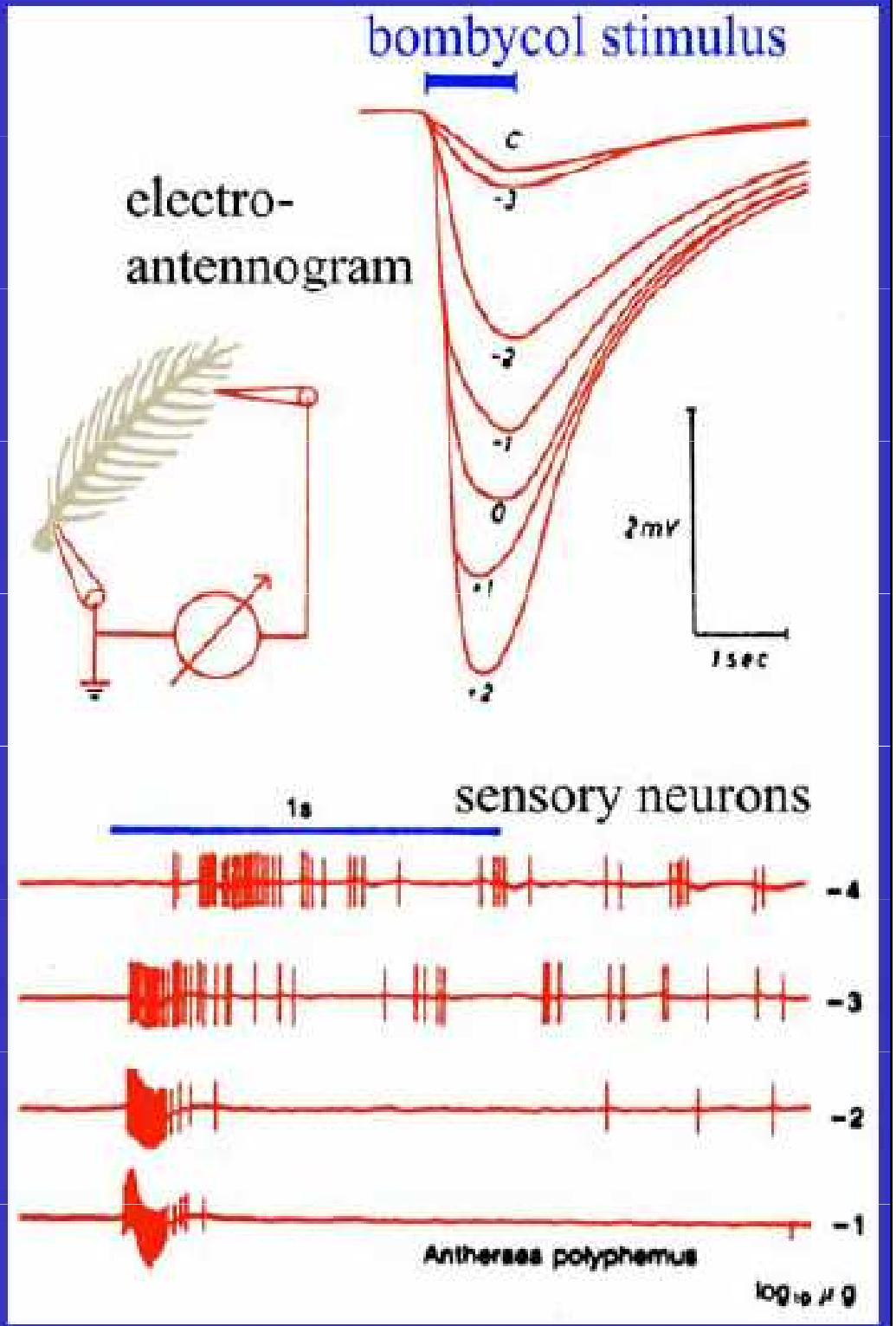

Anatomy of an antennal sensilla



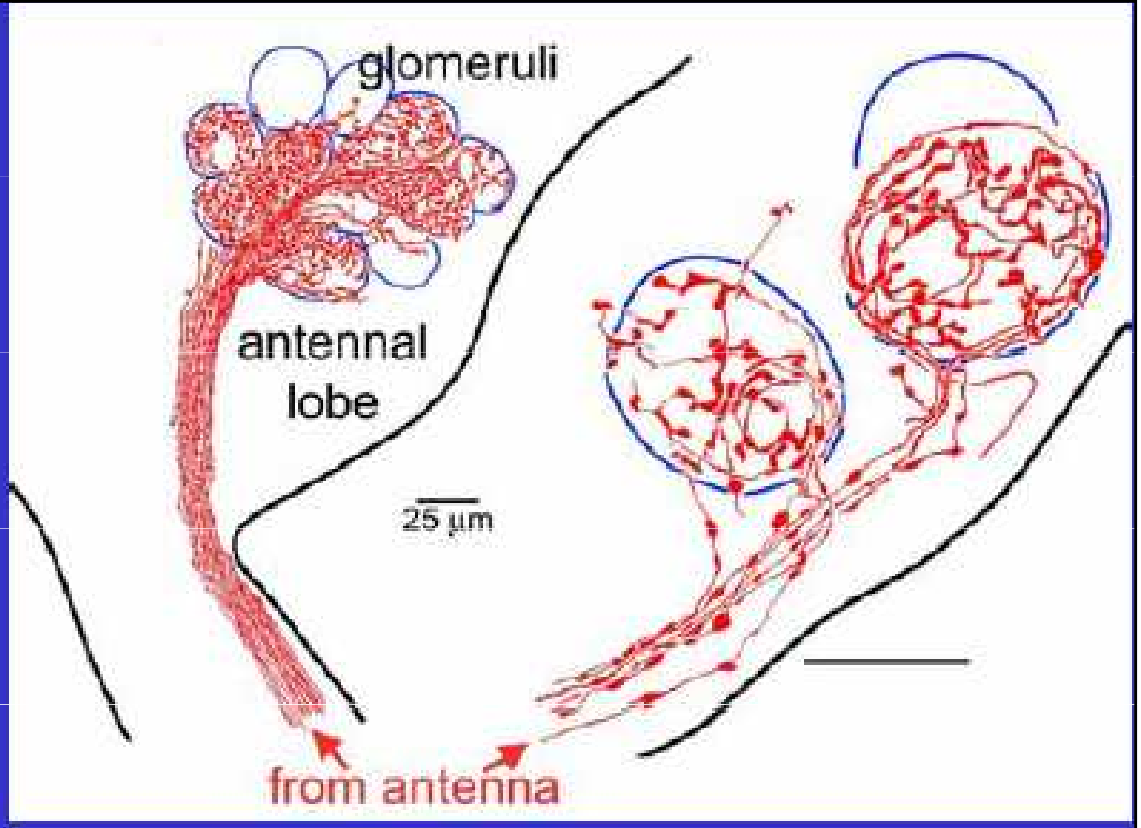
Response specificity to size and composition of odorant molecule

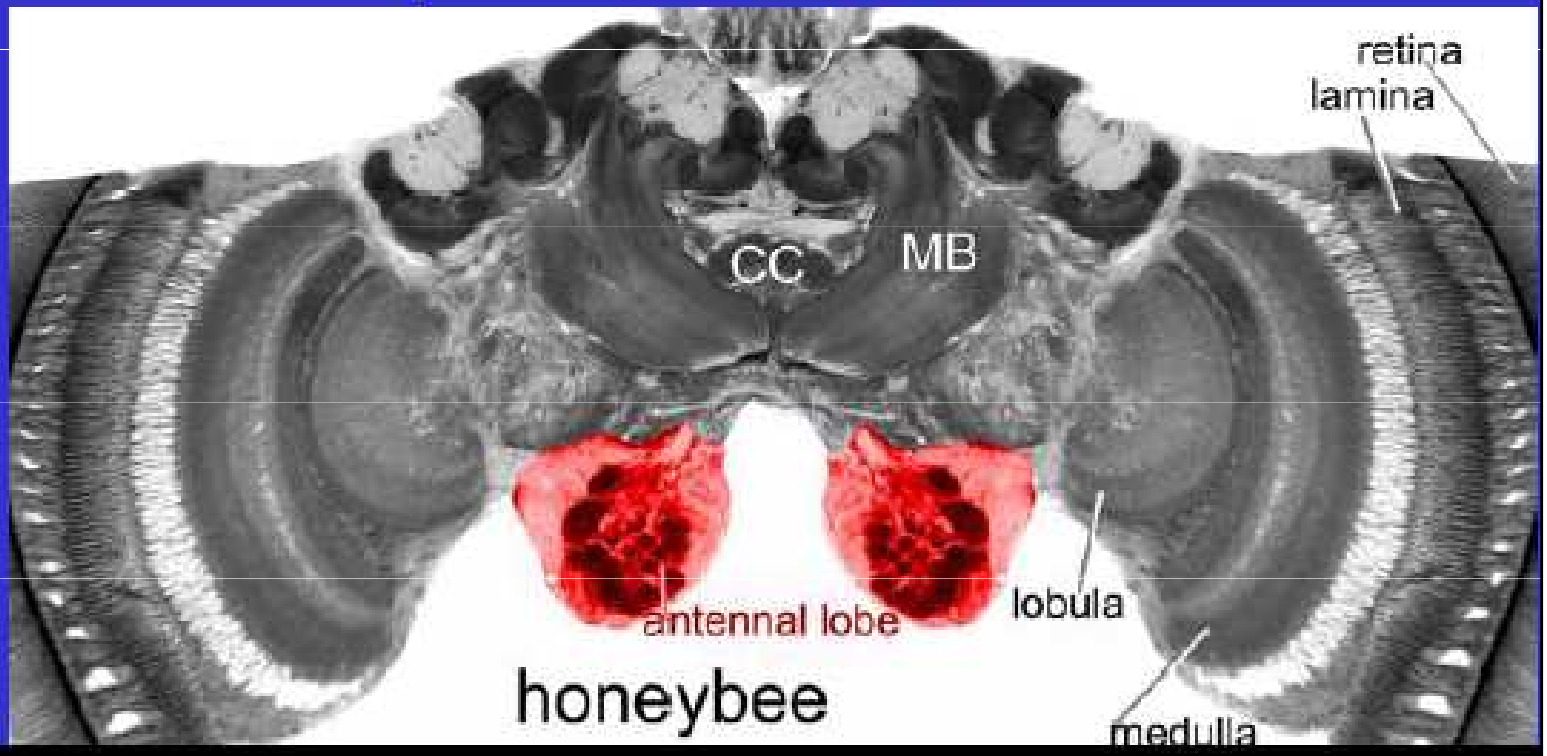


Olfactory receptor neurons respond to odorants

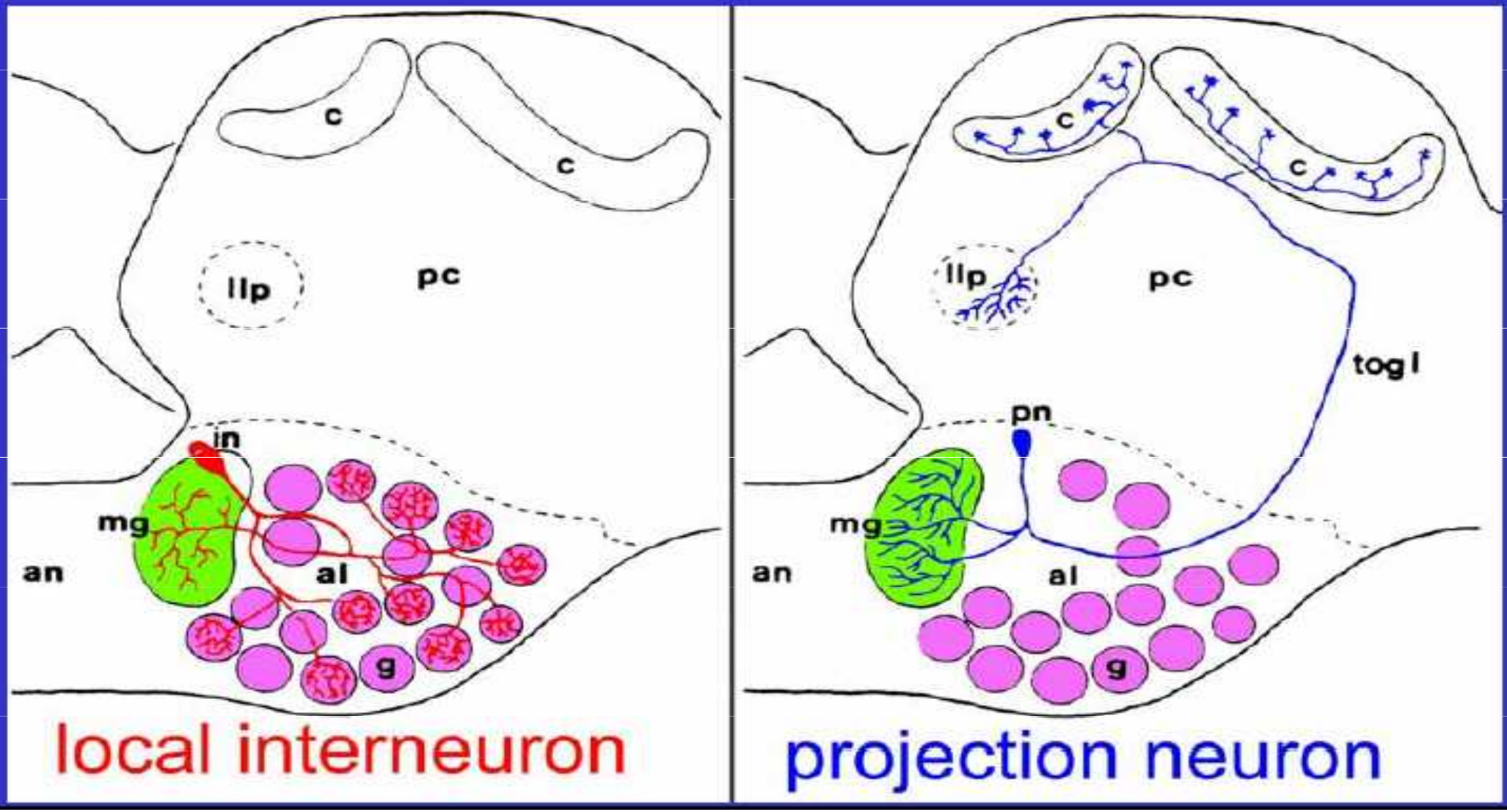


Antennal olfactory receptor neurons terminate in antennal lobe **glomeruli**

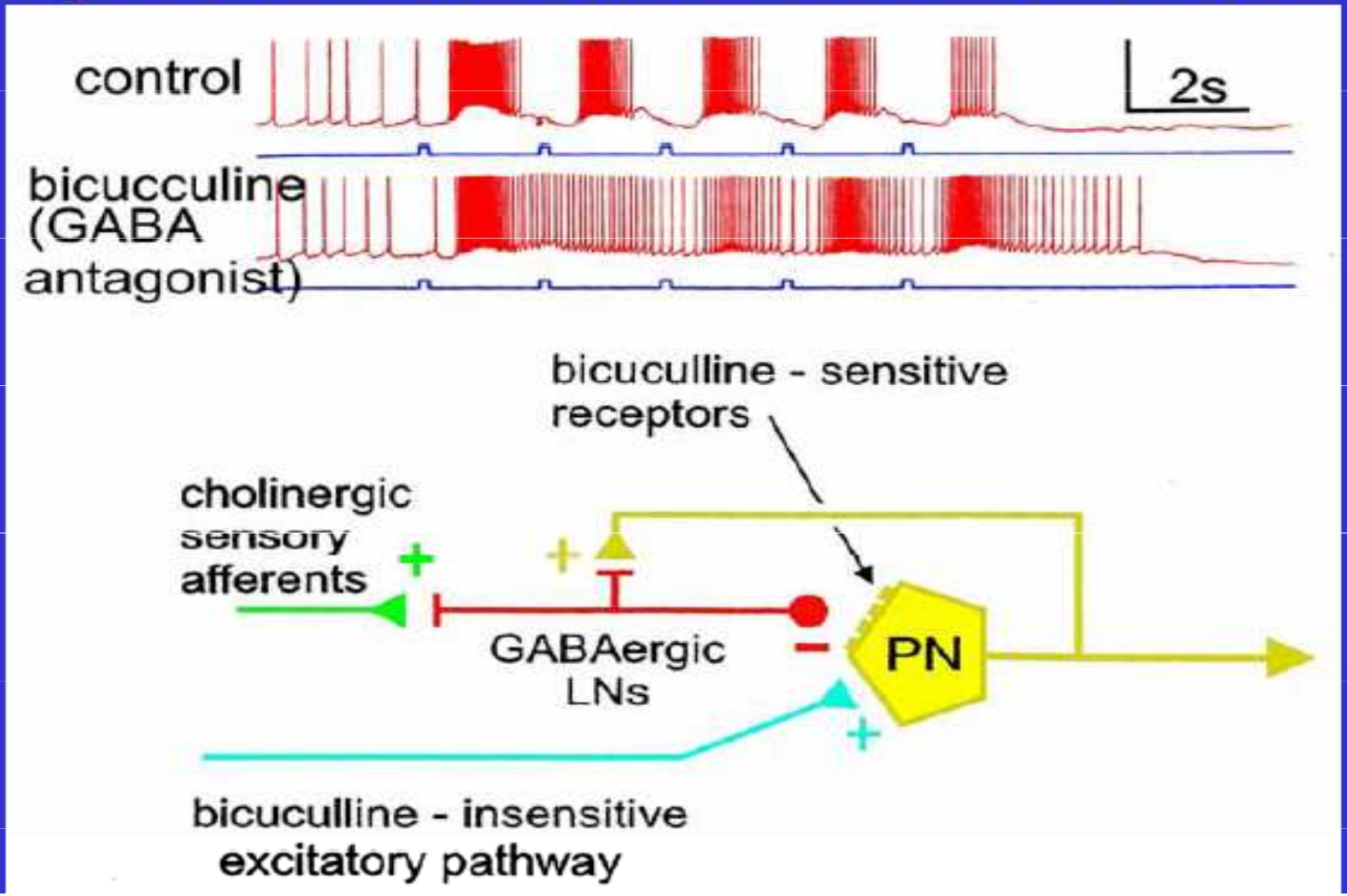




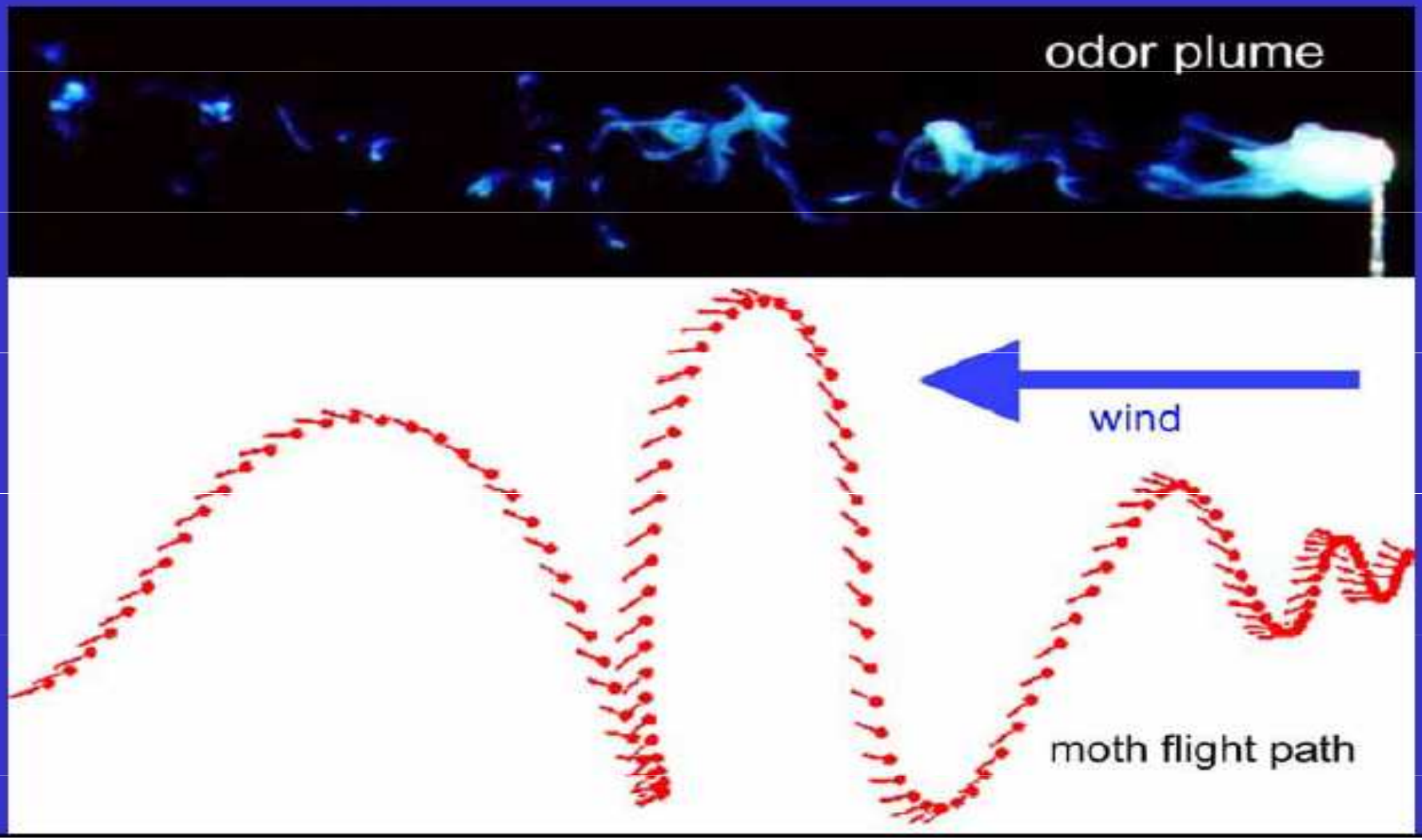
Antennal lobe: two major classes of neurons



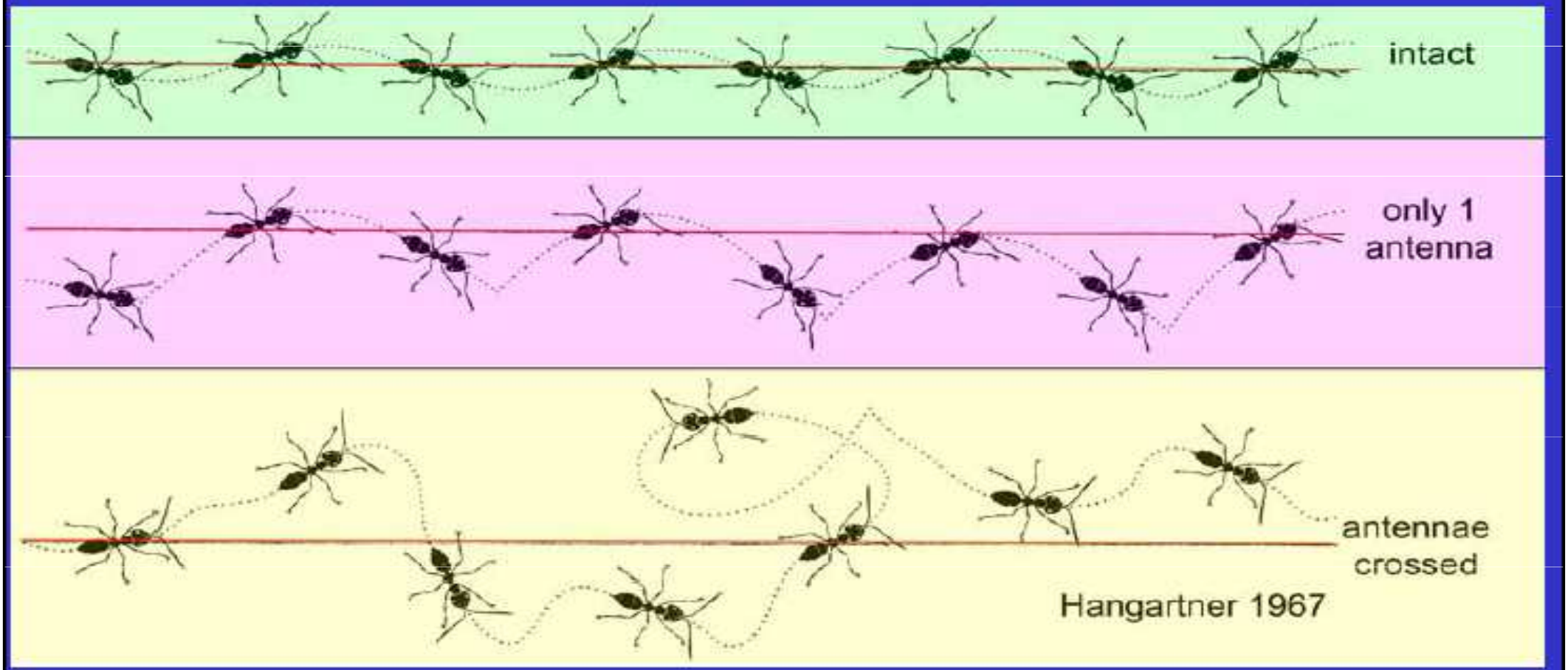
Inhibition 'sharpens' the PN response (temporal and odor discrimination)



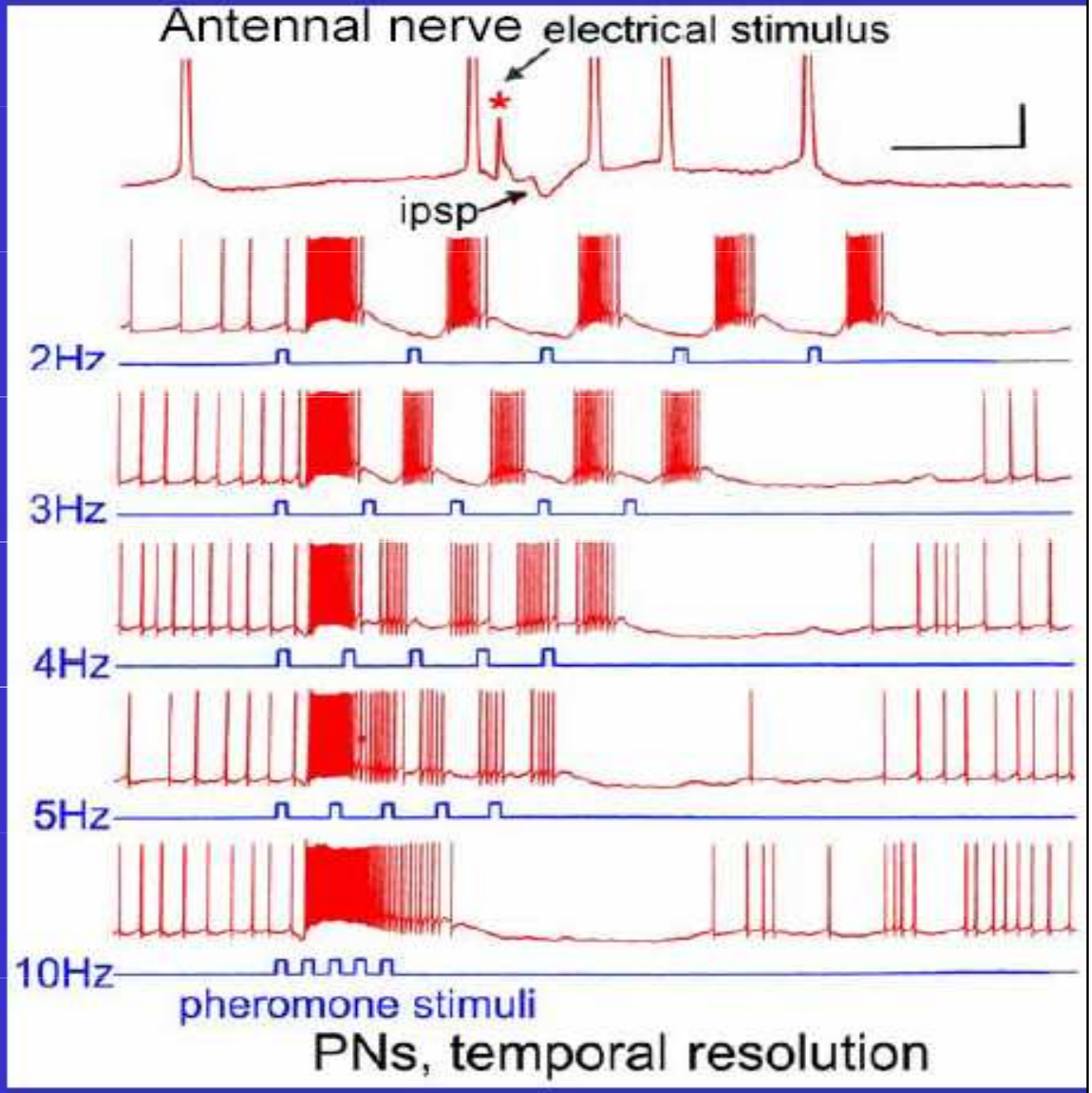
Odor is discontinuously distributed in air



Even when following an odor trace, perception is discontinuous

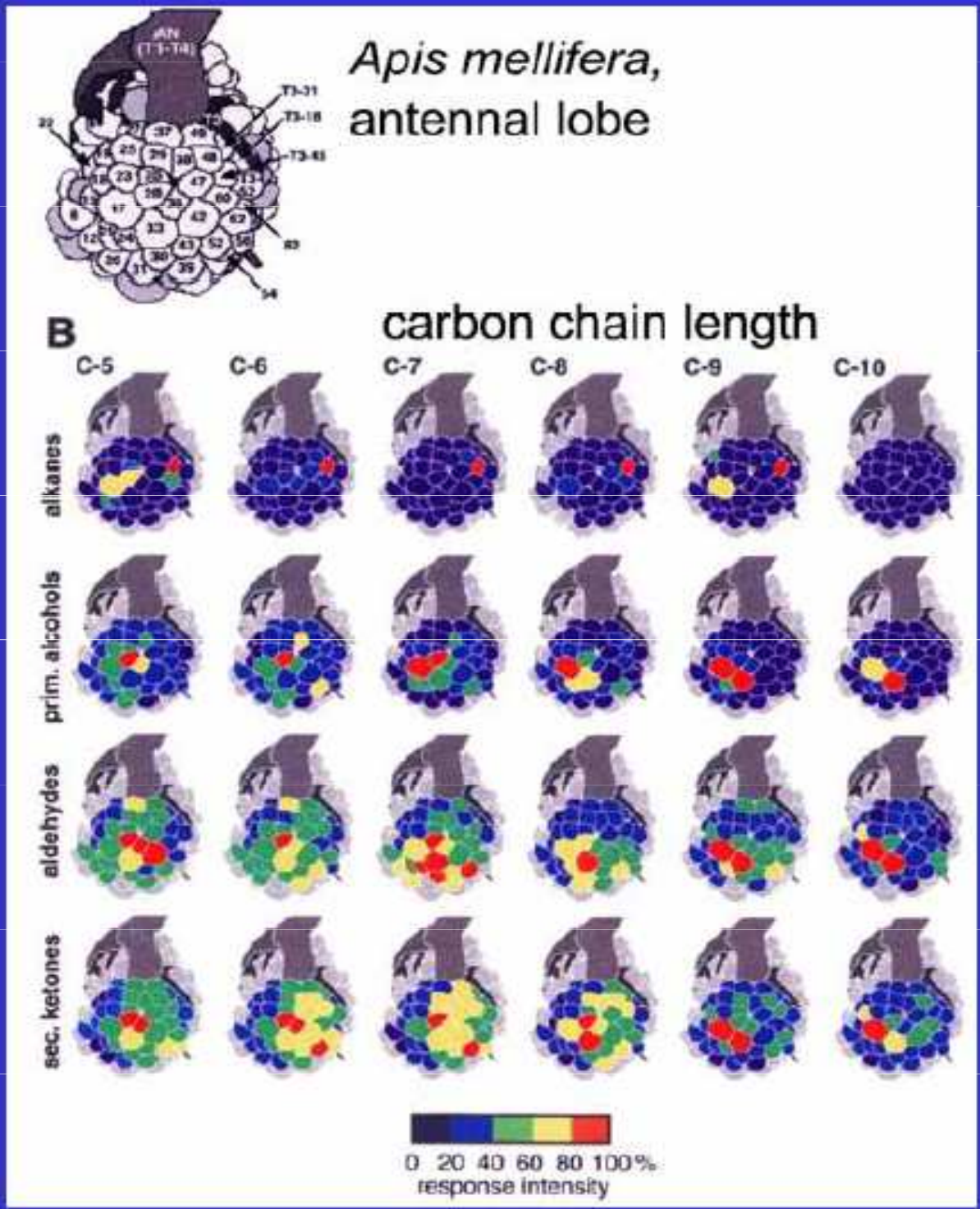


Temporal resolution is limited

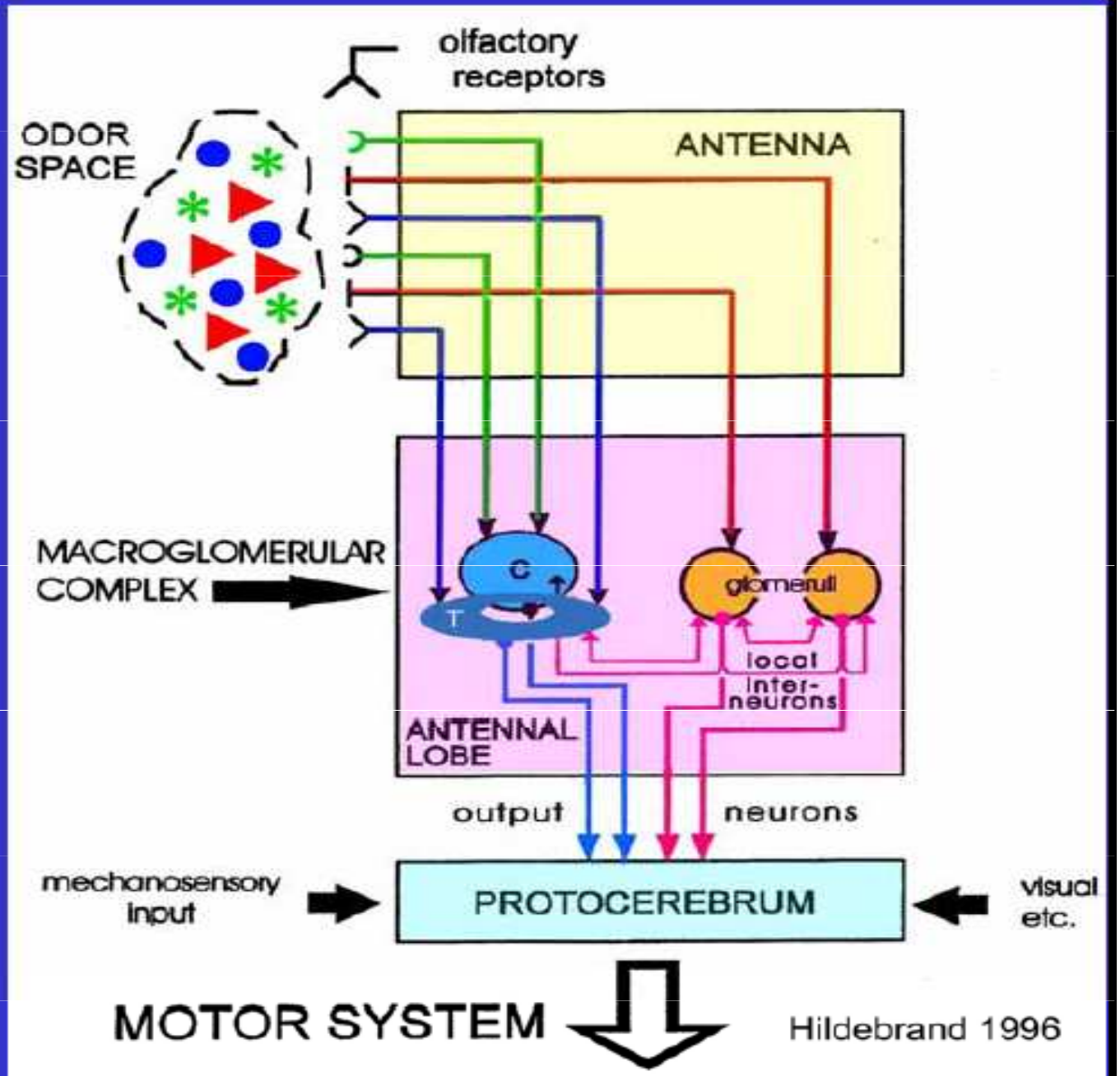


Glomeruli responses reflect odorants' structural properties (chain length, residues, polarity etc.):

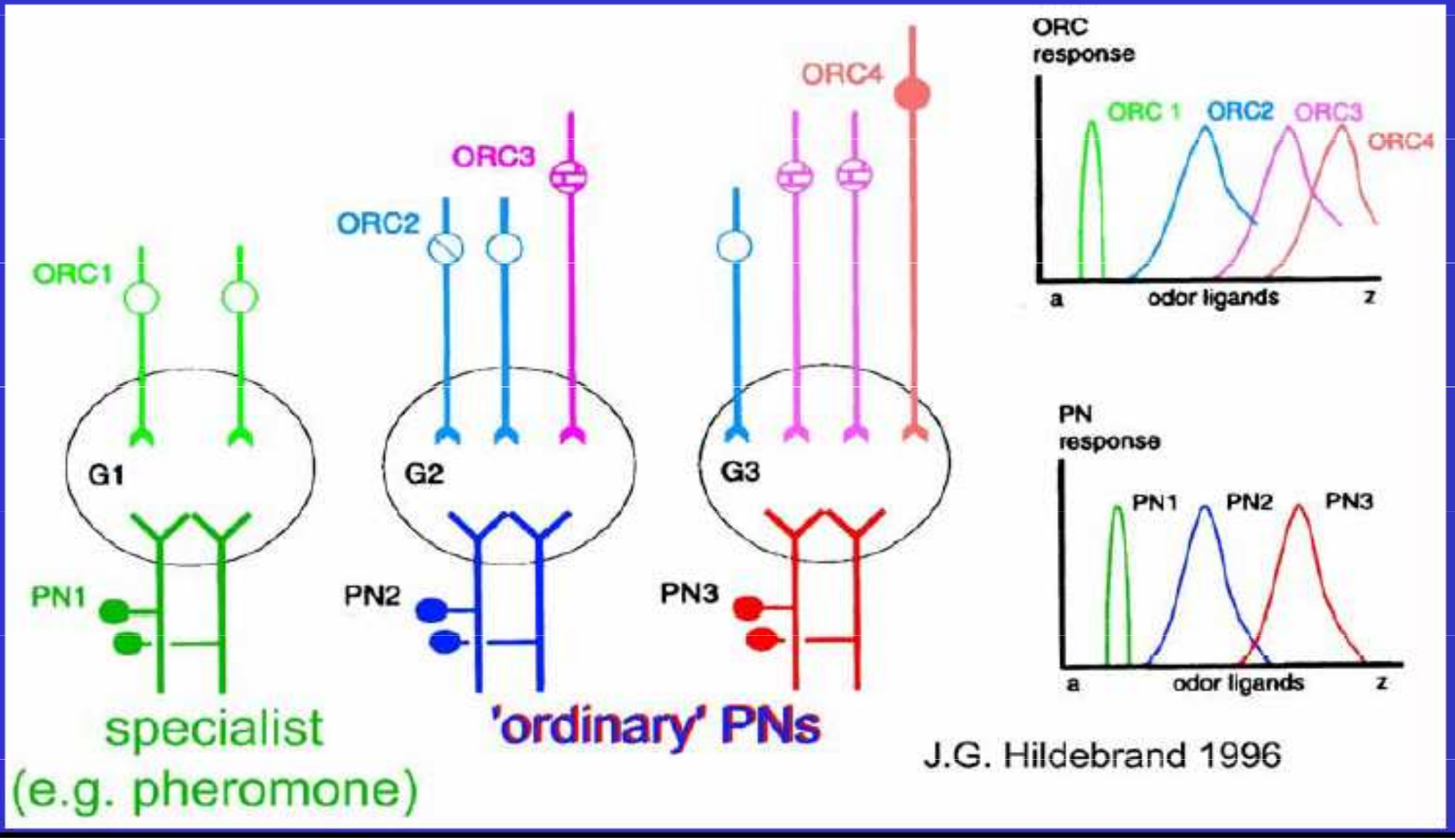
odor map



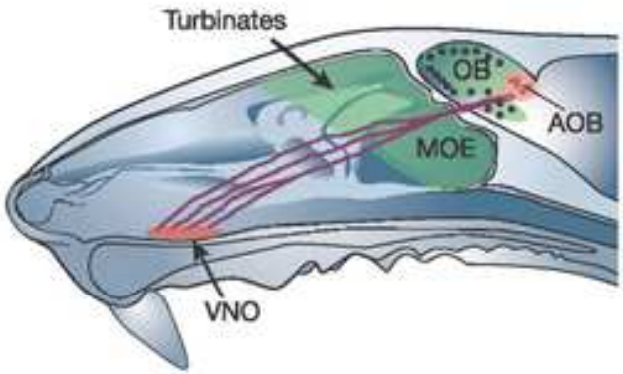
(sex) pheromones and 'ordinary' odors are processed by two different pathways



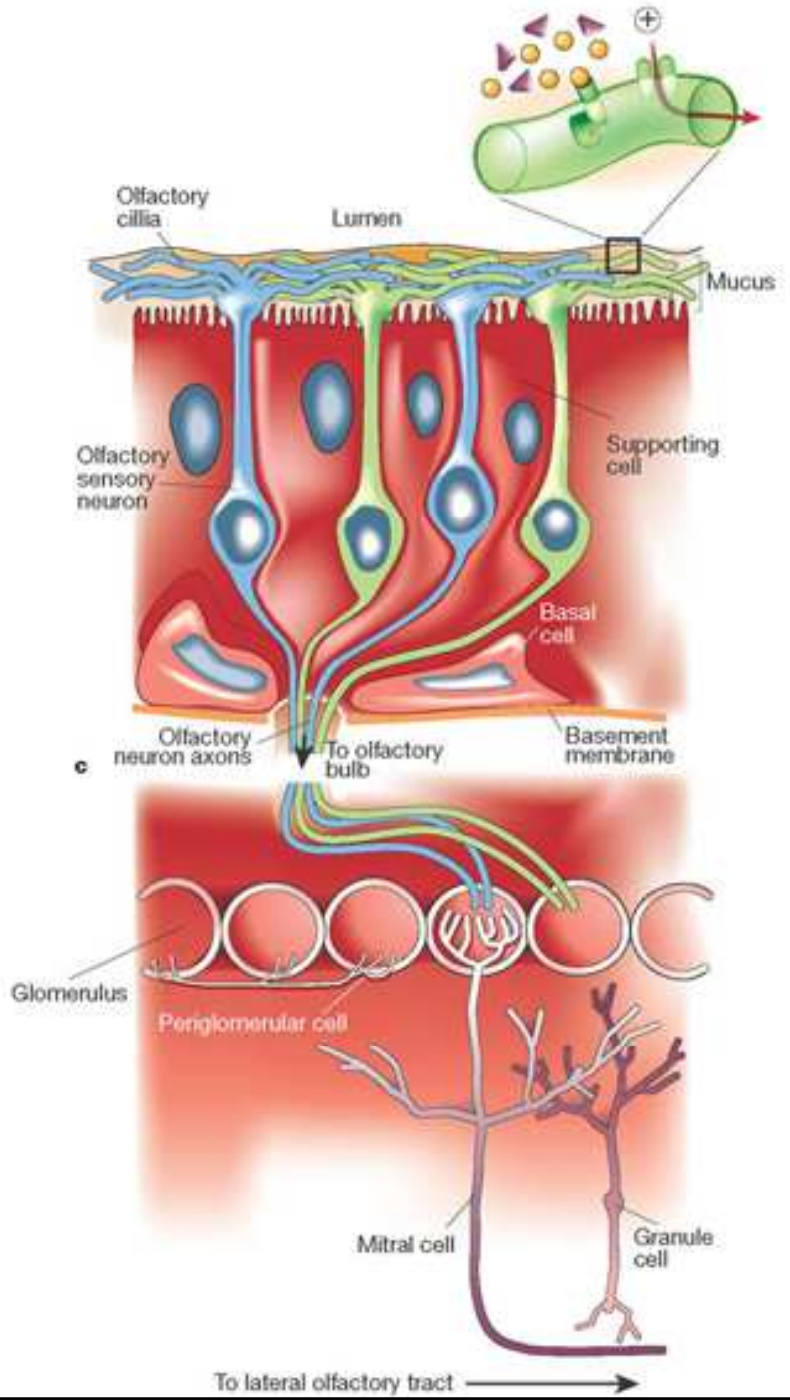
PNs may have narrower response spectra than receptor neurons

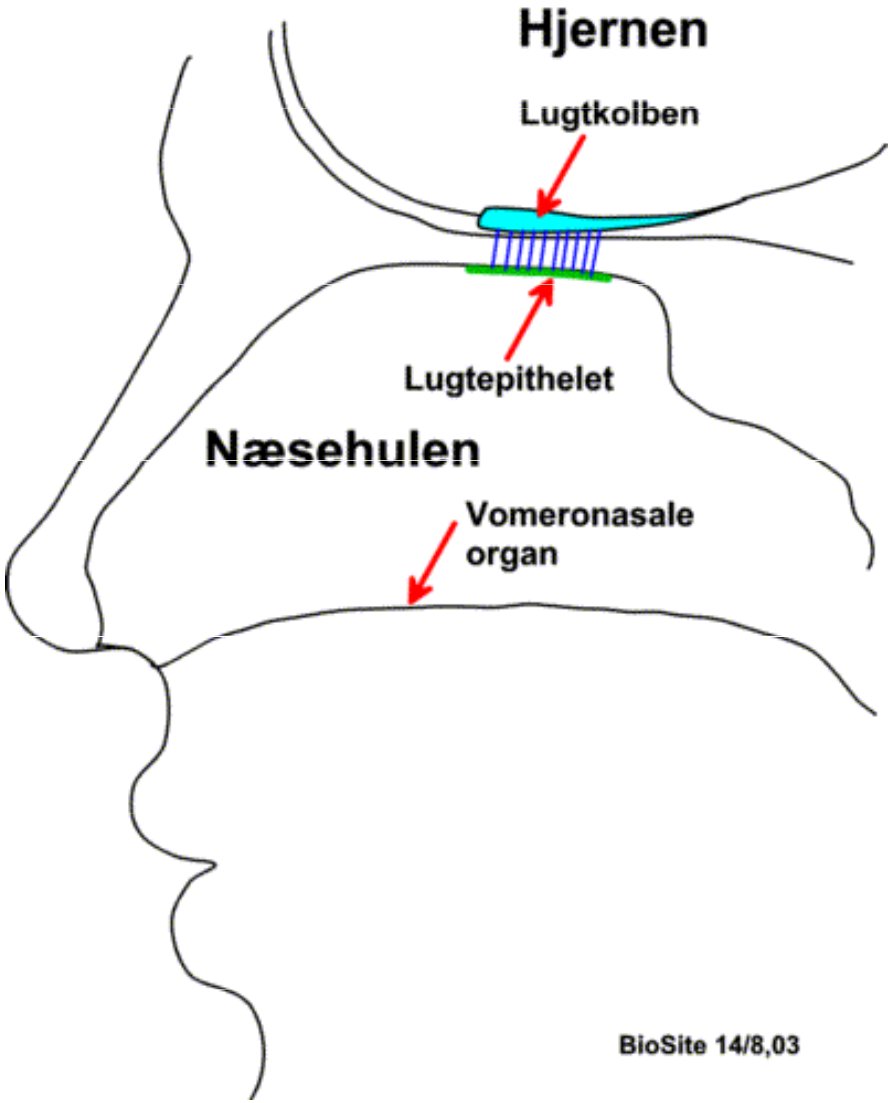


Vomeronasální, Jacobsonův orgán

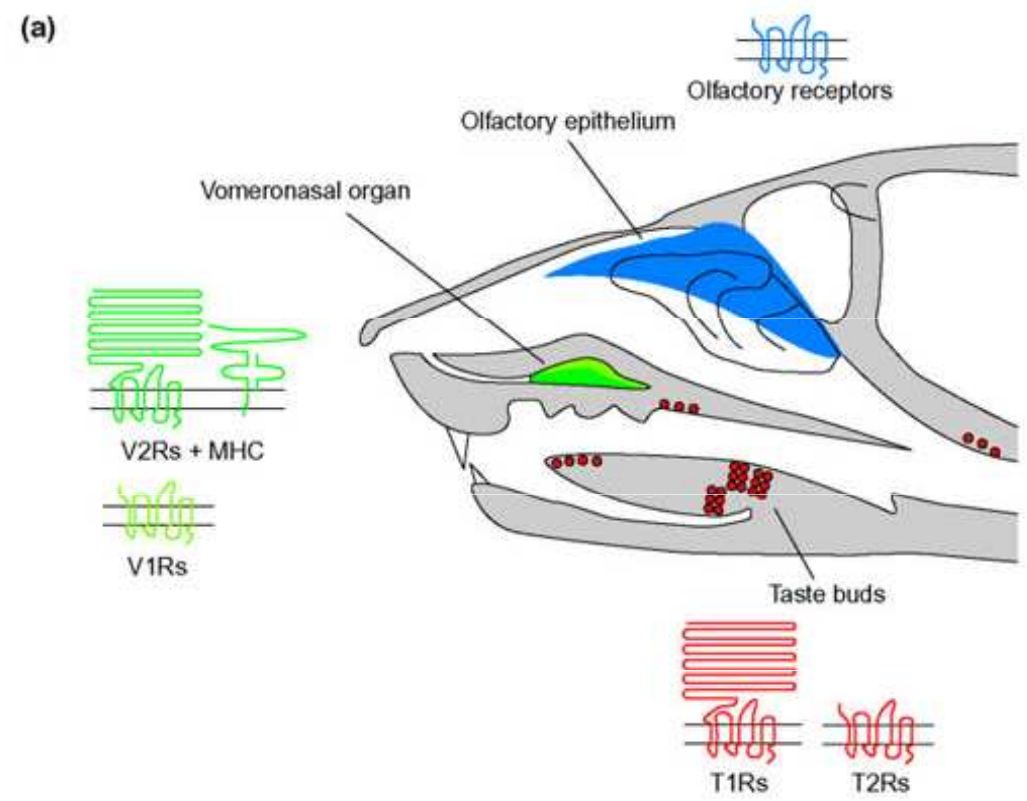


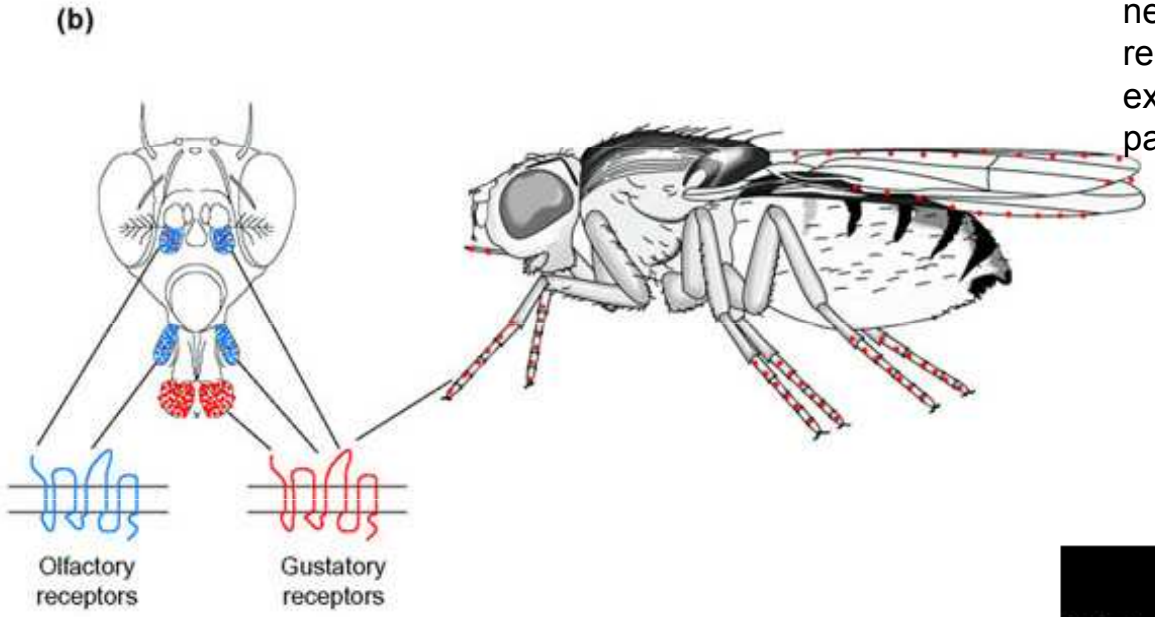
MOE = main olfactory epithelium.
OB = olfactory bulb.
AOB = accessory olfactory bulb.
VNO = vomeronasal organ.





BioSite 14/8,03



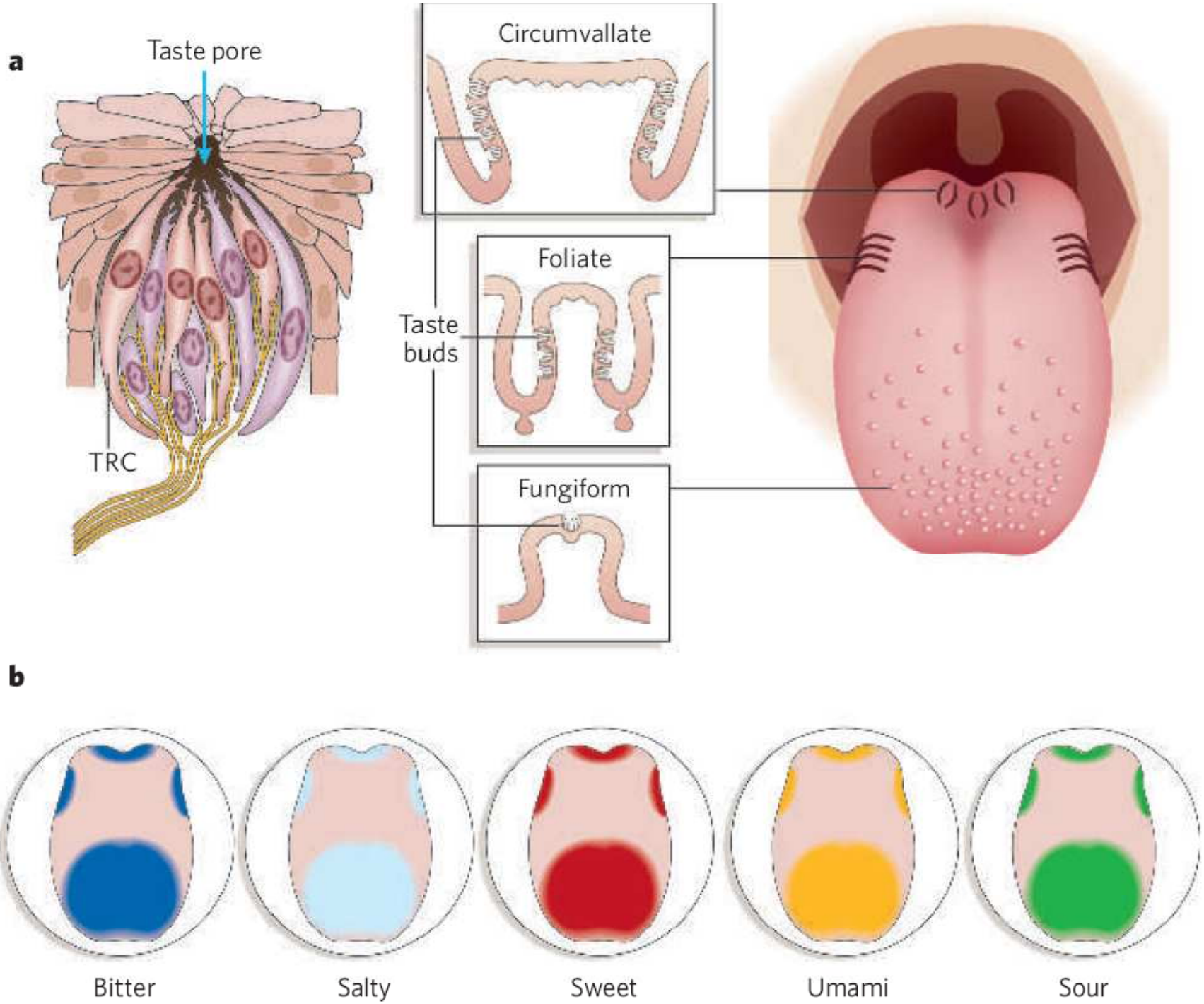


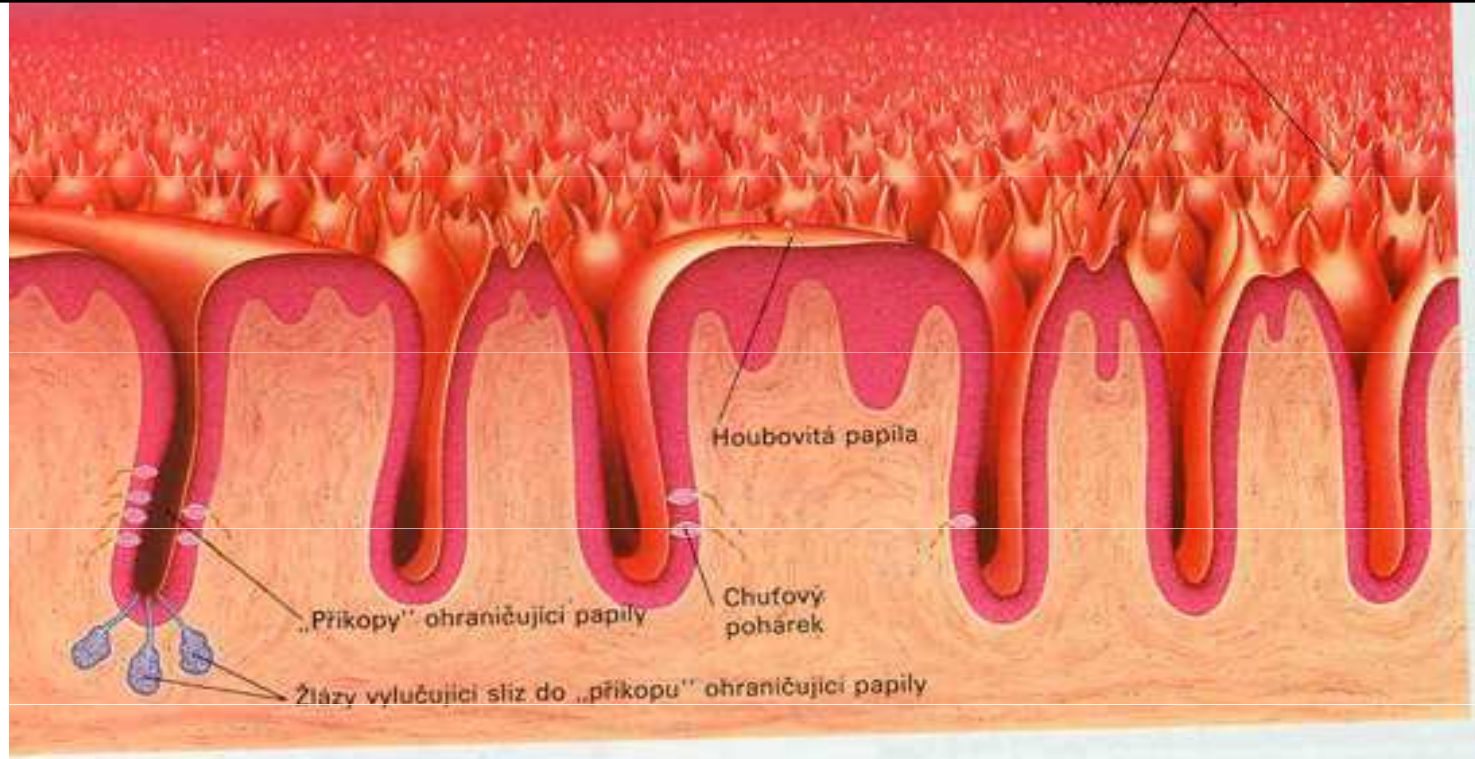
The location of chemosensory organs in the mouse and *Drosophila*. **(a)** A sensory neuron in the olfactory epithelium of mice expresses one of about 1,000 olfactory receptors. Neurons in the apical and basal layers of the vomeronasal organ express distinct, unrelated classes of G-protein-coupled pheromone receptors (V1Rs in the apical and V2Rs in the basal layer). In addition, a small family of MHC class I-like molecules is coexpressed with V2Rs in neurons of the basal layer. The taste cells in the tongue, palate and pharynx express other classes of GPCRs, one encoding sweet-taste receptors (T1Rs) and one encoding receptors for bitter compounds (T2Rs). Note that V1Rs and T2Rs are related to each other, as are V2Rs and T1Rs, respectively. **(b)** The olfactory neurons of *Drosophila* are located in two pairs of appendages in the head, the third antennal segment and the maxillary palps, and each neuron expresses very few, possibly just one, of the 61 olfactory receptor genes identified so far. The gustatory or taste sensory neurons are located in numerous organs, including the two labial palps on the head, internal sensory clusters in the pharynx (not shown), all the legs and the anterior wing margin. Each neuron expresses a few, possibly just one, gustatory receptor gene. A few gustatory receptor genes are also expressed in olfactory neurons of the antenna and maxillary palps.

Čich a chuť

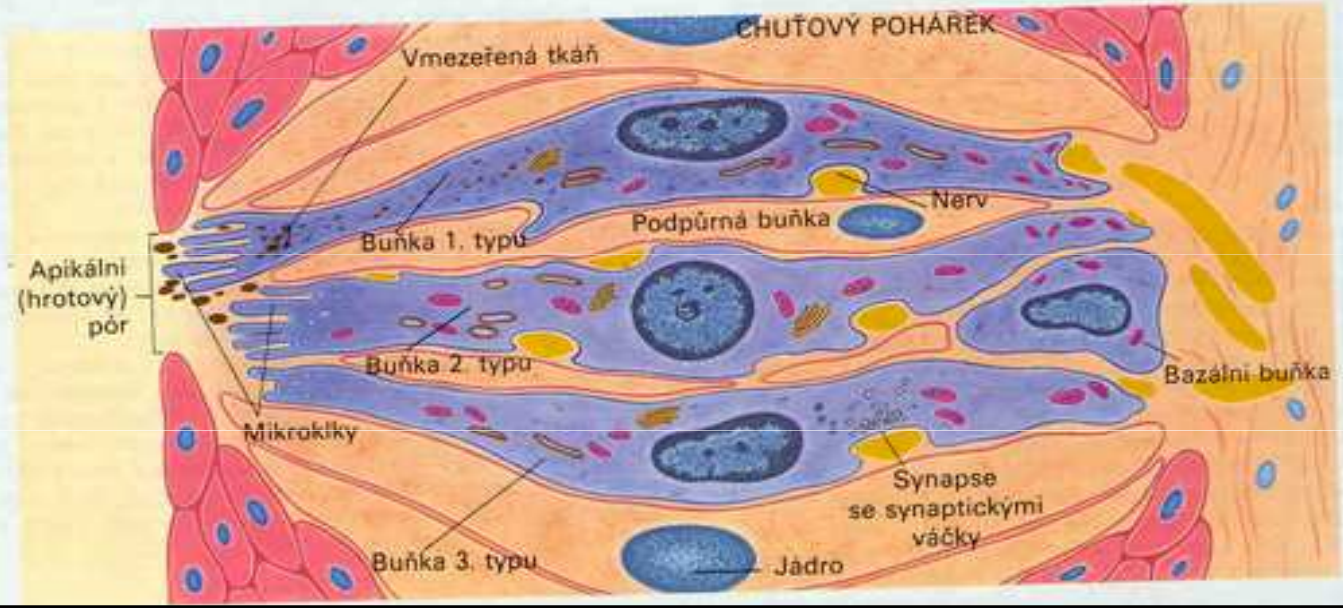
GB.c

Chuť

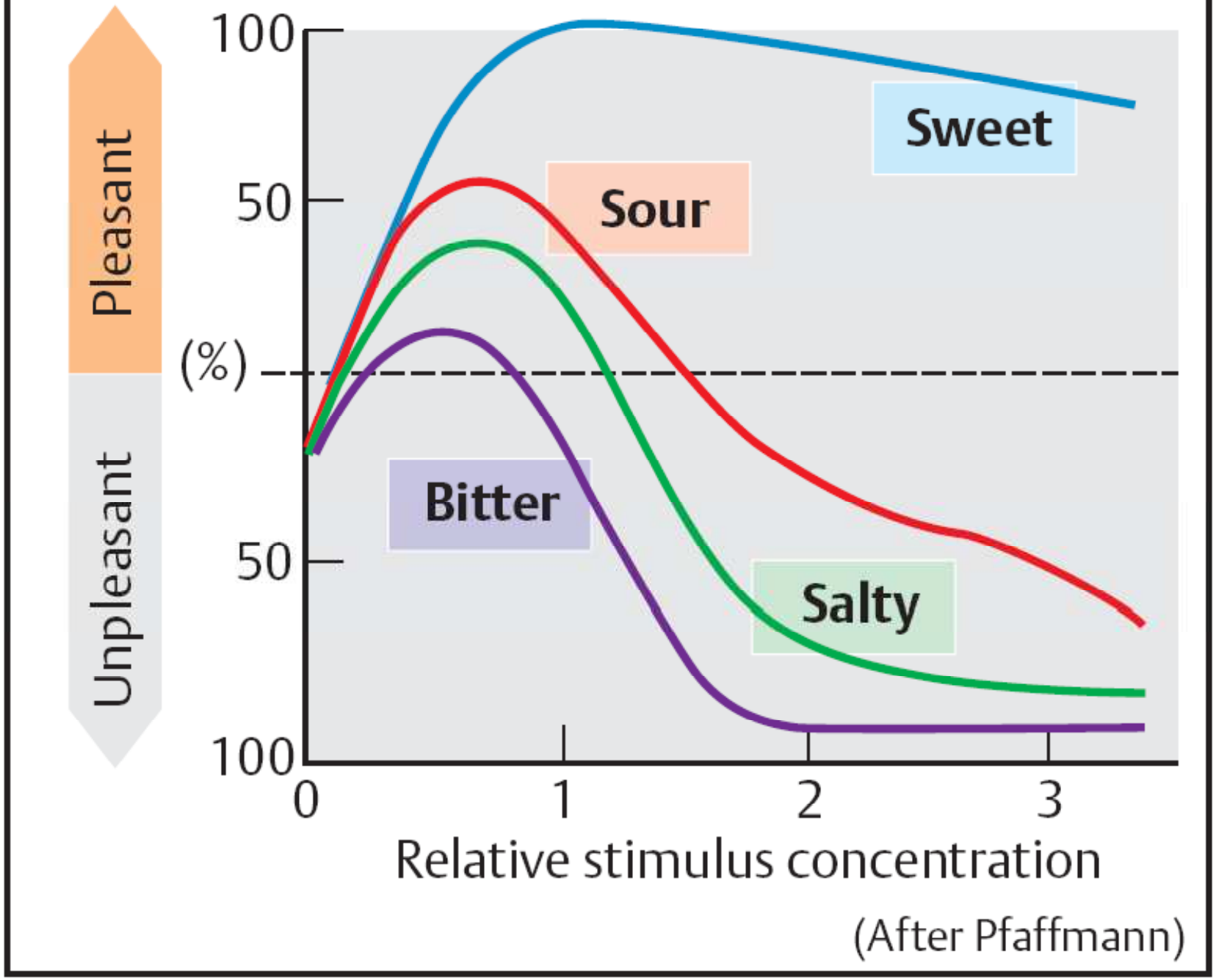

a
Taste pore
TRC
Circumvallate
Foliate
Taste buds
Fungiform
b
Bitter
Salty
Sweet
Umami
Sour

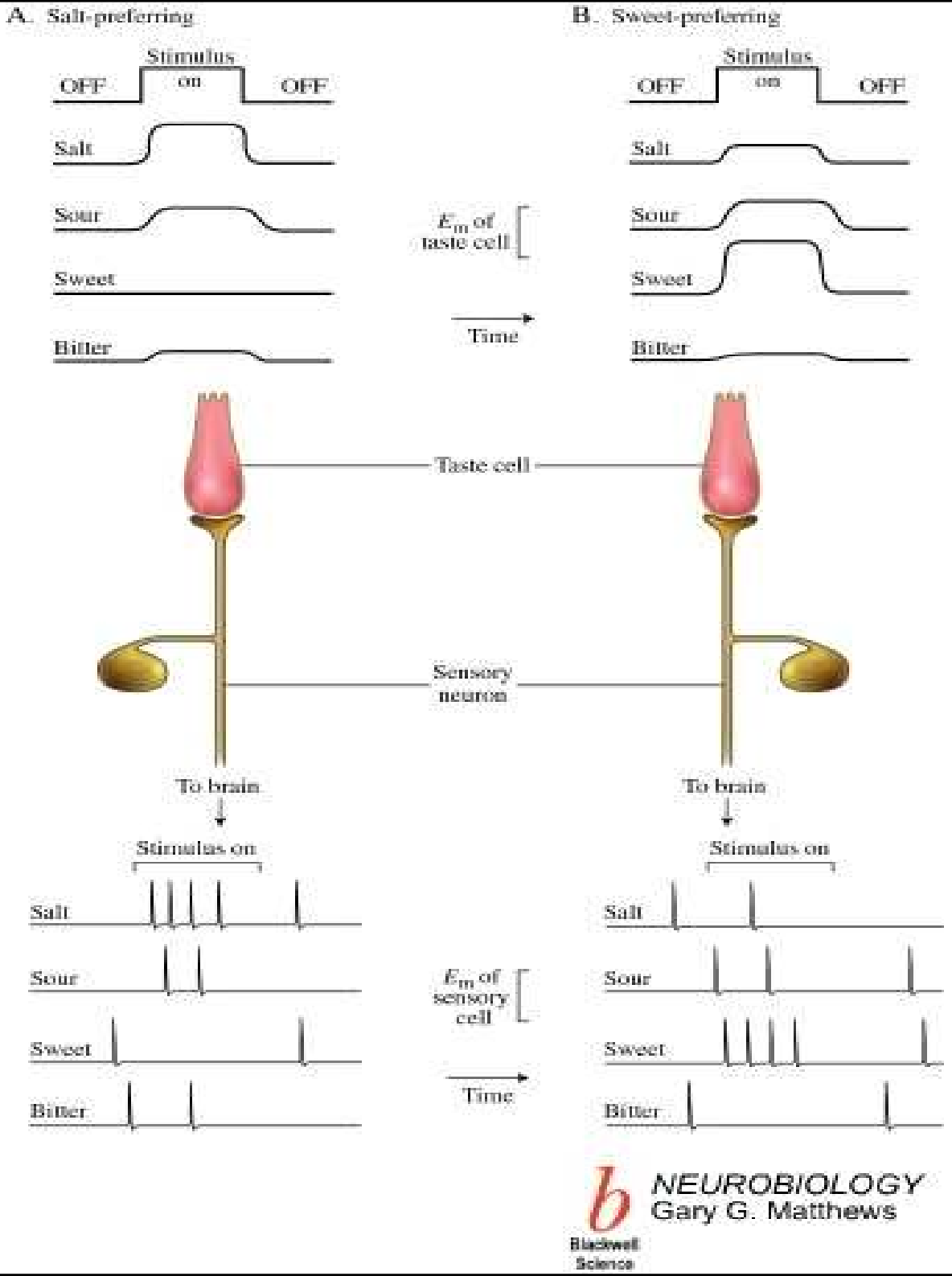


v „příkopech" obklopujících jejich centrální val, reagují na chutě hořké. Mezery mezi papilami zvlhčuje sliz, vylučovaný žlázami umístěnými na bázi těchto mezer. Chuťové molekuly se musí v tomto vlhkém prostředí nejprve rozptýlit, a teprve poté je mohou chuťové pohárky detekovat.



E. Evaluation of taste stimuli





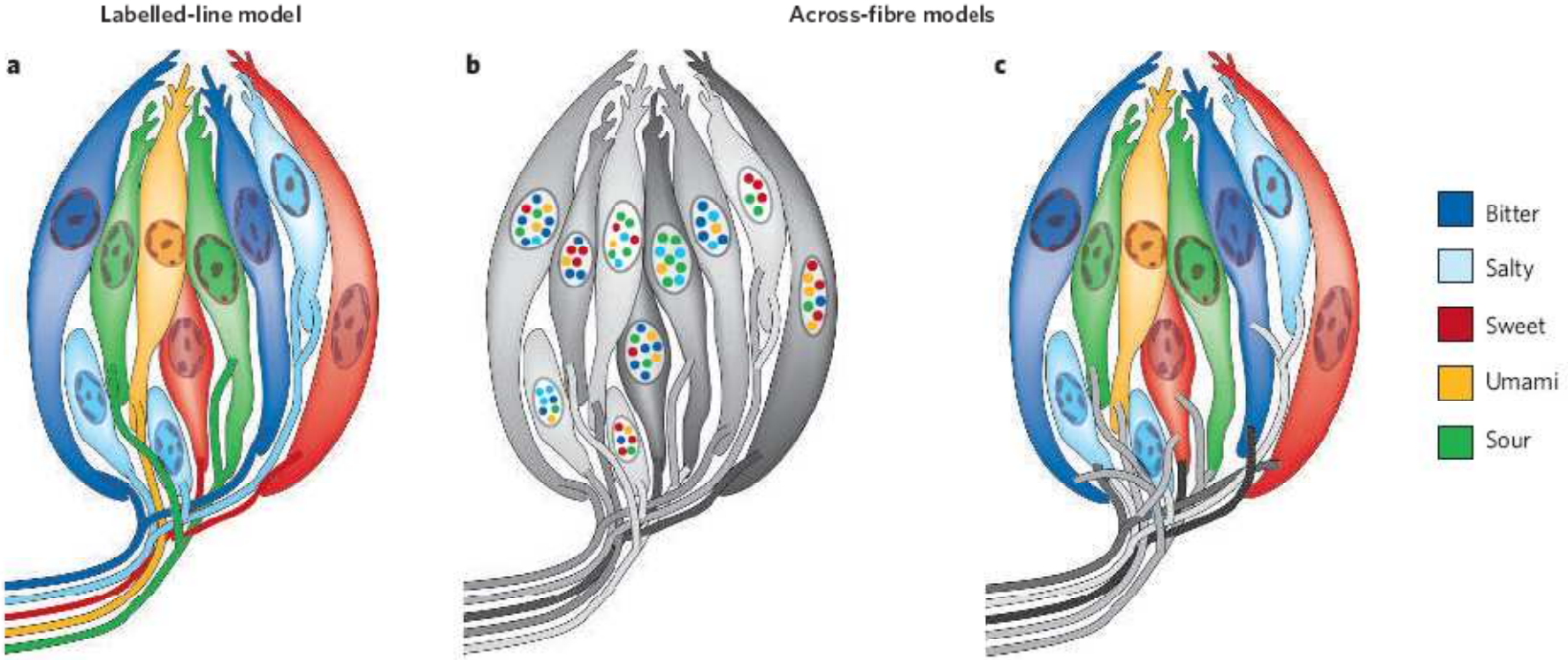
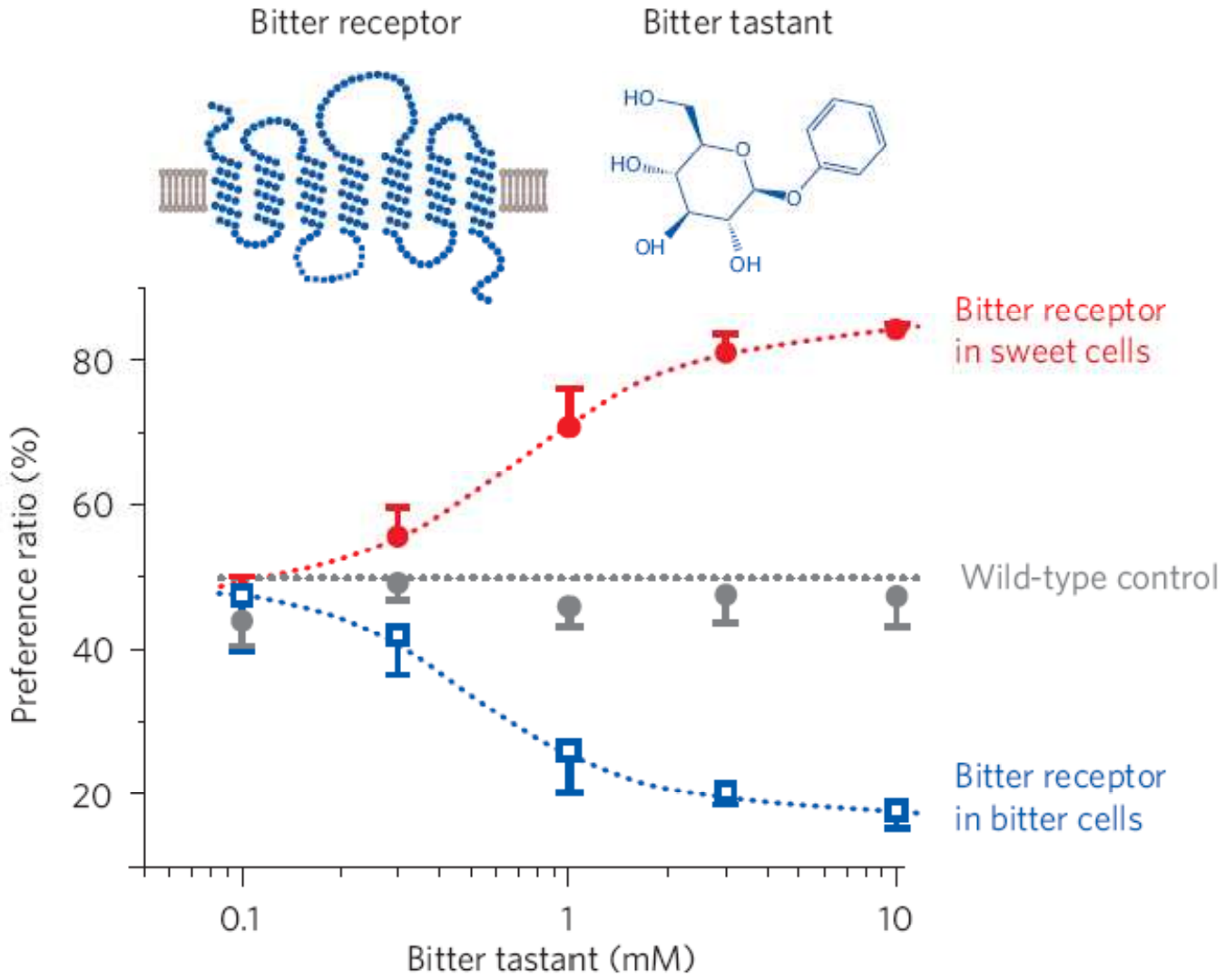


Figure 2 | Encoding of taste qualities at the periphery. There are two opposing views of how taste qualities are encoded in the periphery. **a**, In the labelled-line model, receptor cells are tuned to respond to single taste modalities — sweet, bitter, sour, salty or umami — and are innervated by individually tuned nerve fibres. In this case, each taste quality is specified by the activity of non-overlapping cells and fibres. **b**, **c**, Two contrasting models of what is known as the 'across-fibre pattern'. This states that either individual TRCs are tuned to multiple taste qualities (indicated by various tones of grey and multicoloured stippled nuclei), and consequently the same afferent fibre carries information for more than one taste modality (**b**), or that TRCs are still tuned to single taste qualities but the same afferent fibre carries information for more than one taste modality (**c**). In these two models, the specification of any one taste quality is embedded in a complex pattern of activity across various lines. Recent molecular and functional studies in mice have demonstrated that different TRCs define the different taste modalities, and that activation of a single type of TRC is sufficient to encode taste quality, strongly supporting the labelled-line model.

Transgenní myši



the perception of sweet or bitter)
is a reflection of the selective activation of T1R- versus T2R-expressing cells, rather than a property of the receptors or even of the tastant molecules.

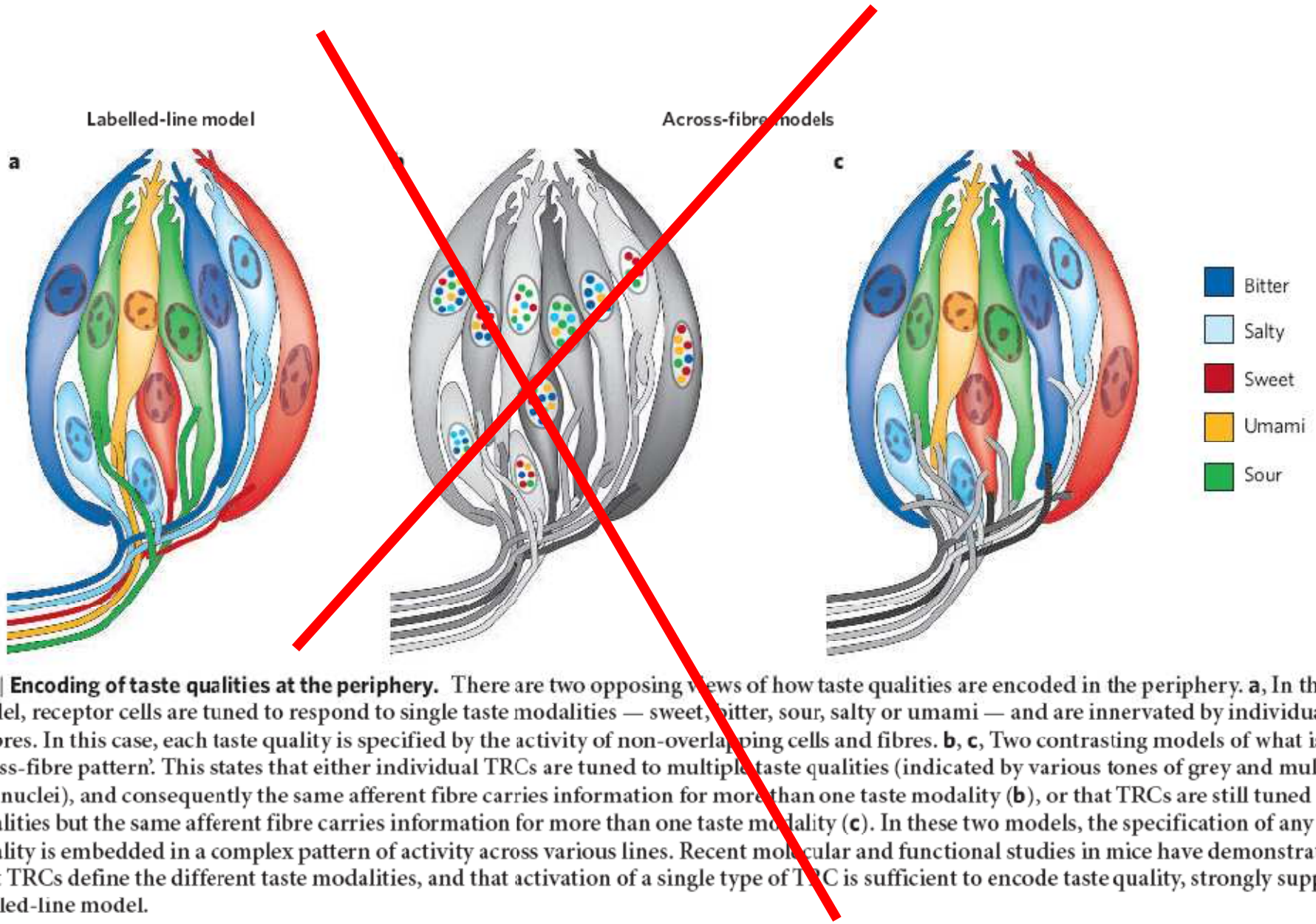
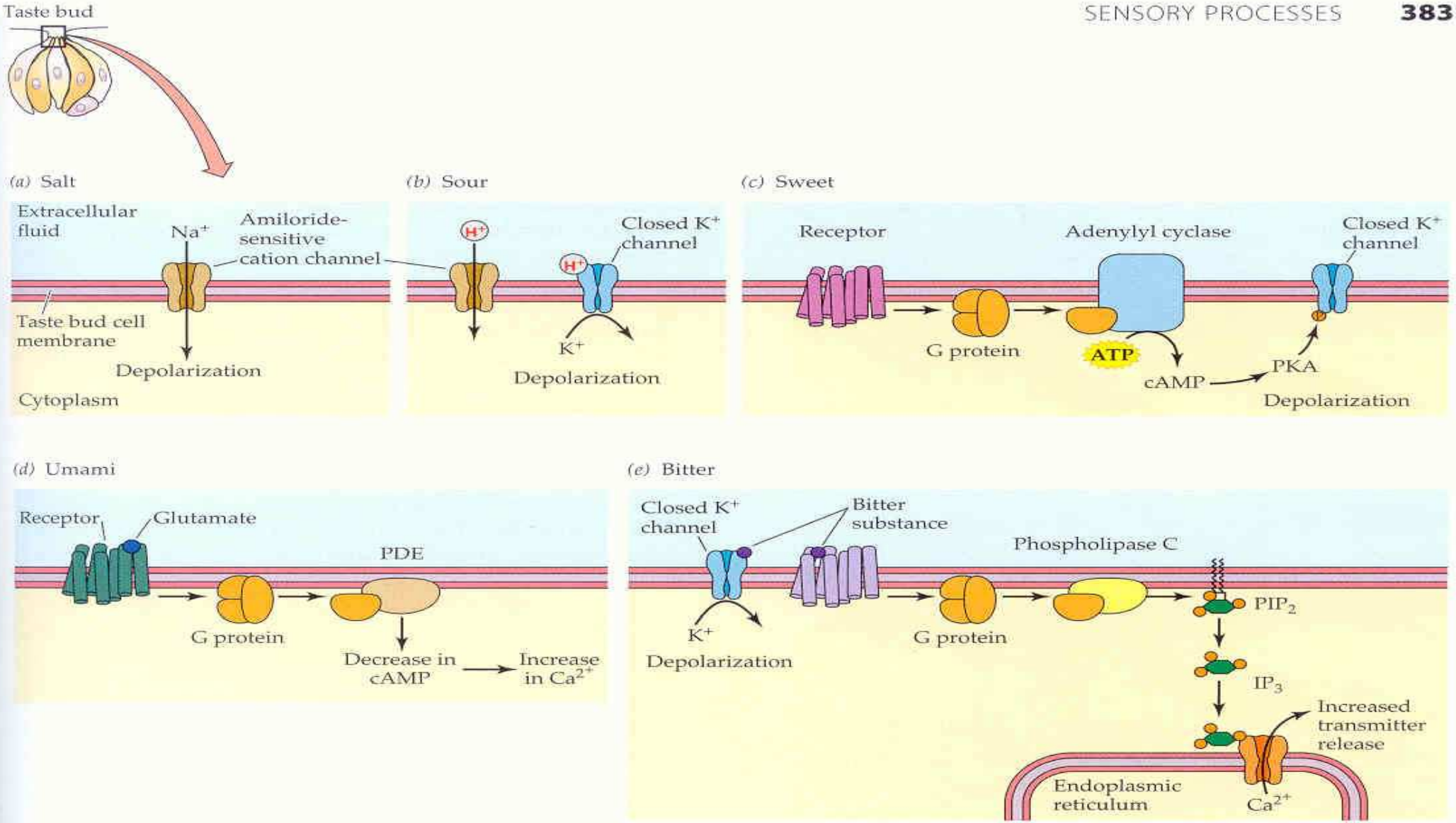
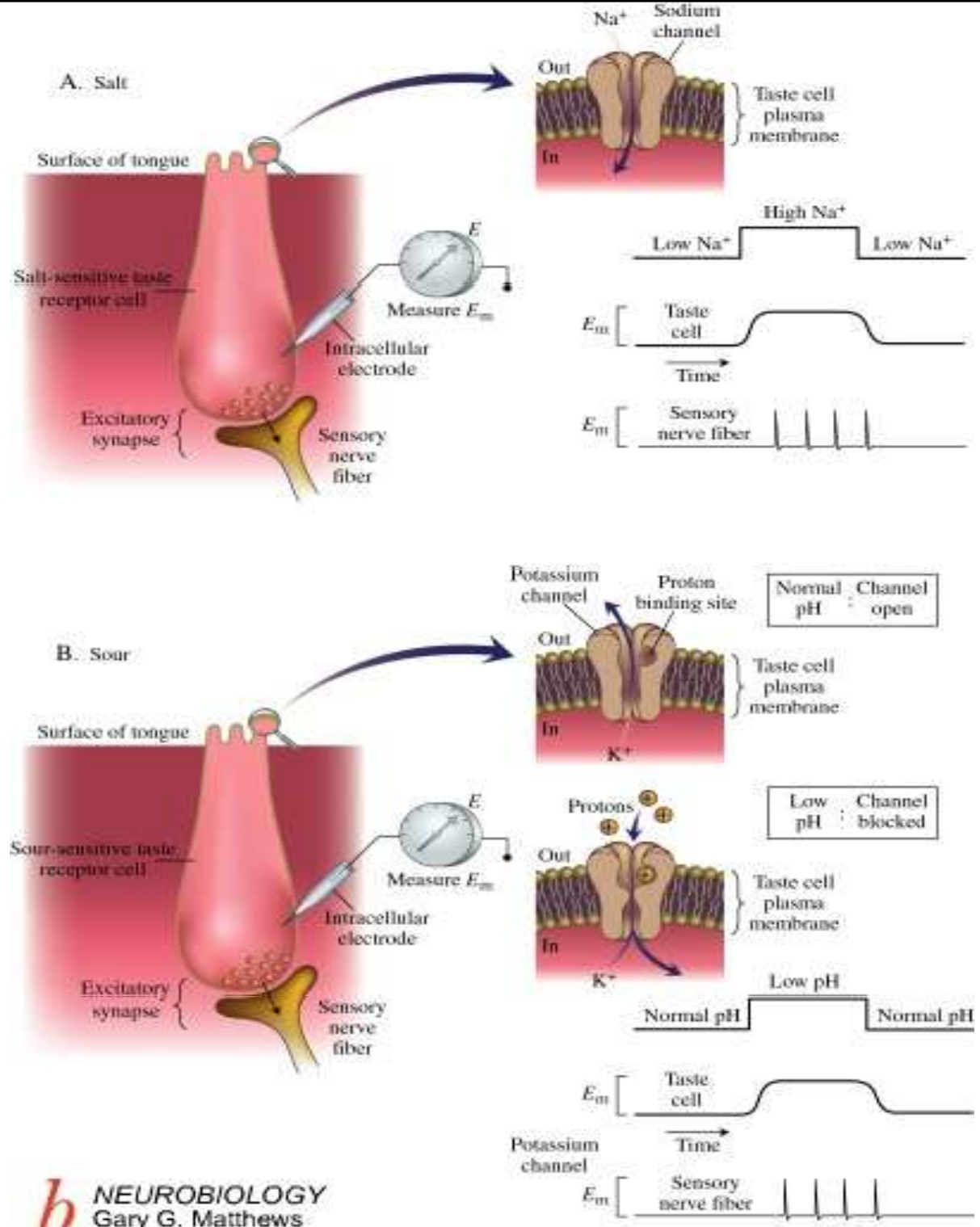


Figure 2 | Encoding of taste qualities at the periphery. There are two opposing views of how taste qualities are encoded in the periphery. **a**, In the labelled-line model, receptor cells are tuned to respond to single taste modalities — sweet, bitter, sour, salty or umami — and are innervated by individually tuned nerve fibres. In this case, each taste quality is specified by the activity of non-overlapping cells and fibres. **b**, **c**, Two contrasting models of what is known as the 'across-fibre pattern'. This states that either individual TRCs are tuned to multiple taste qualities (indicated by various tones of grey and multicoloured stippled nuclei), and consequently the same afferent fibre carries information for more than one taste modality (**b**), or that TRCs are still tuned to single taste qualities but the same afferent fibre carries information for more than one taste modality (**c**). In these two models, the specification of any one taste quality is embedded in a complex pattern of activity across various lines. Recent molecular and functional studies in mice have demonstrated that different TRCs define the different taste modalities, and that activation of a single type of TRC is sufficient to encode taste quality, strongly supporting the labelled-line model.

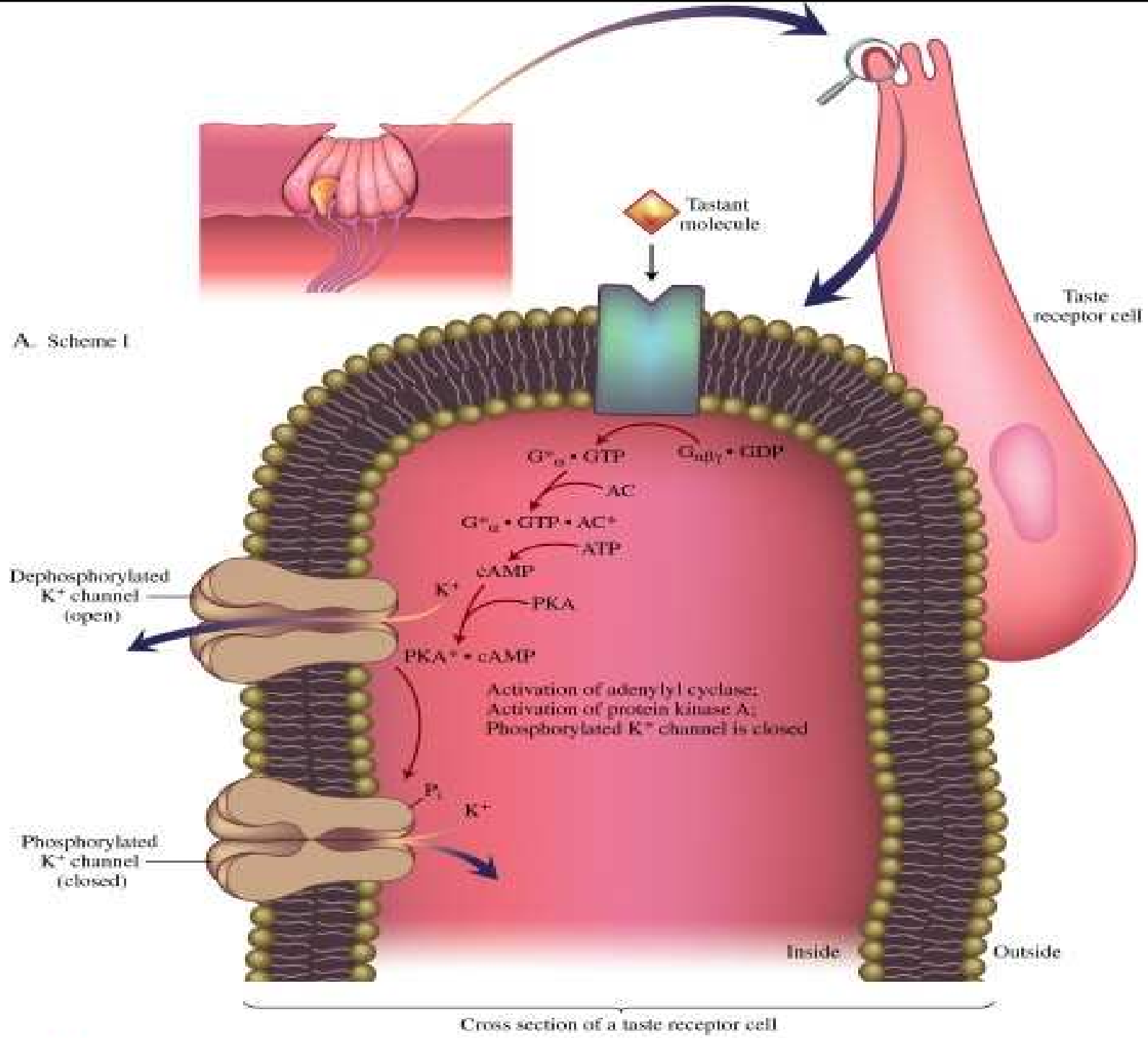


igure 13.34 Taste-transduction mechanisms differ for different aste qualities All transduction mechanisms except the IP_3 action in) lead to *depolarization*, which spreads to the basal end of the cell nd opens voltage-gated Ca^{2+} channels to allow Ca^{2+} entry and trans-itter release. *(a)* For salt taste, sodium ions enter a taste bud cell hrough amiloride-sensitive cation channels, directly depolarizing the ell. *(b)* In sour taste, either H^+ ions enter the cell through amiloride-ensitive cation channels, or they close K^+ channels to produce depo-rization. *(c)* Sweet taste is most commonly mediated by the binding f sugars to a G protein–coupled receptor, which acts via a G protein to ctivate adenylyl cyclase and produce cyclic AMP. Cyclic AMP then acti-ates protein kinase A (PKA) to close a K^+ channel (by phosphorylating it), producing depolarization. *(d)* The amino acid glutamate (monosodium glutamate, MSG) stimulates the taste quality umami (a savory or meaty quality). Glutamate binds to a G protein–coupled receptor (related to synaptic metabotropic glutamate receptors) to activate a phosphodiesterase (PDE) and decrease the concentration of cAMP. The decrease in cAMP leads to an increase in intracellular Ca^{2+} concentration. *(e)* Bitter taste mechanisms can involve a G protein–coupled receptor for bitter substances that acts via a G protein and phospholipase C to produce IP_3. IP_3 liberates Ca^{2+} ions from intracellular stores, eliciting transmitter release without requiring depolarization. Other bitter substances bind to K^+ channels and close them to depolarize the cell.

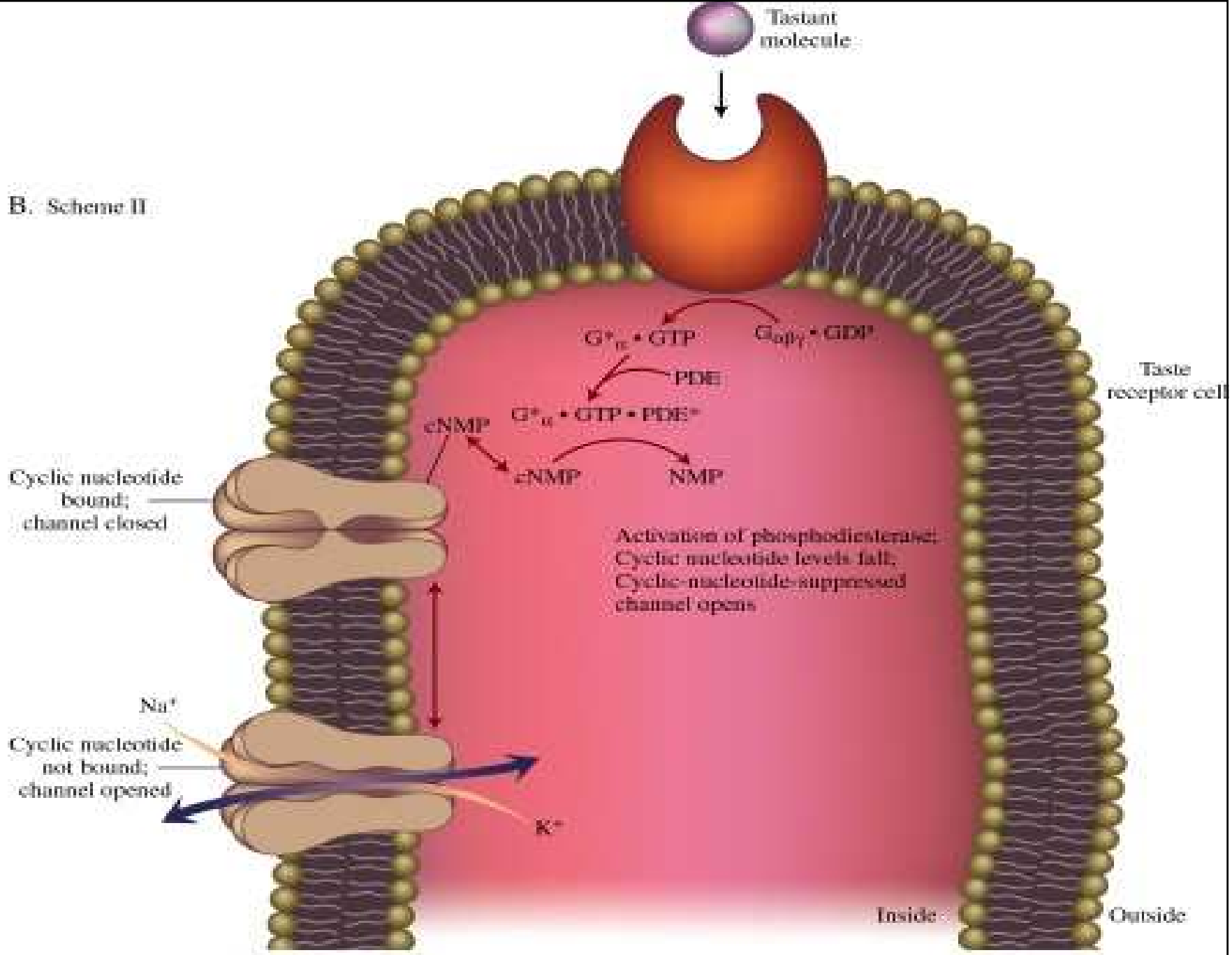


NEUROBIOLOGY
Gary G. Matthews
Blackwell Science

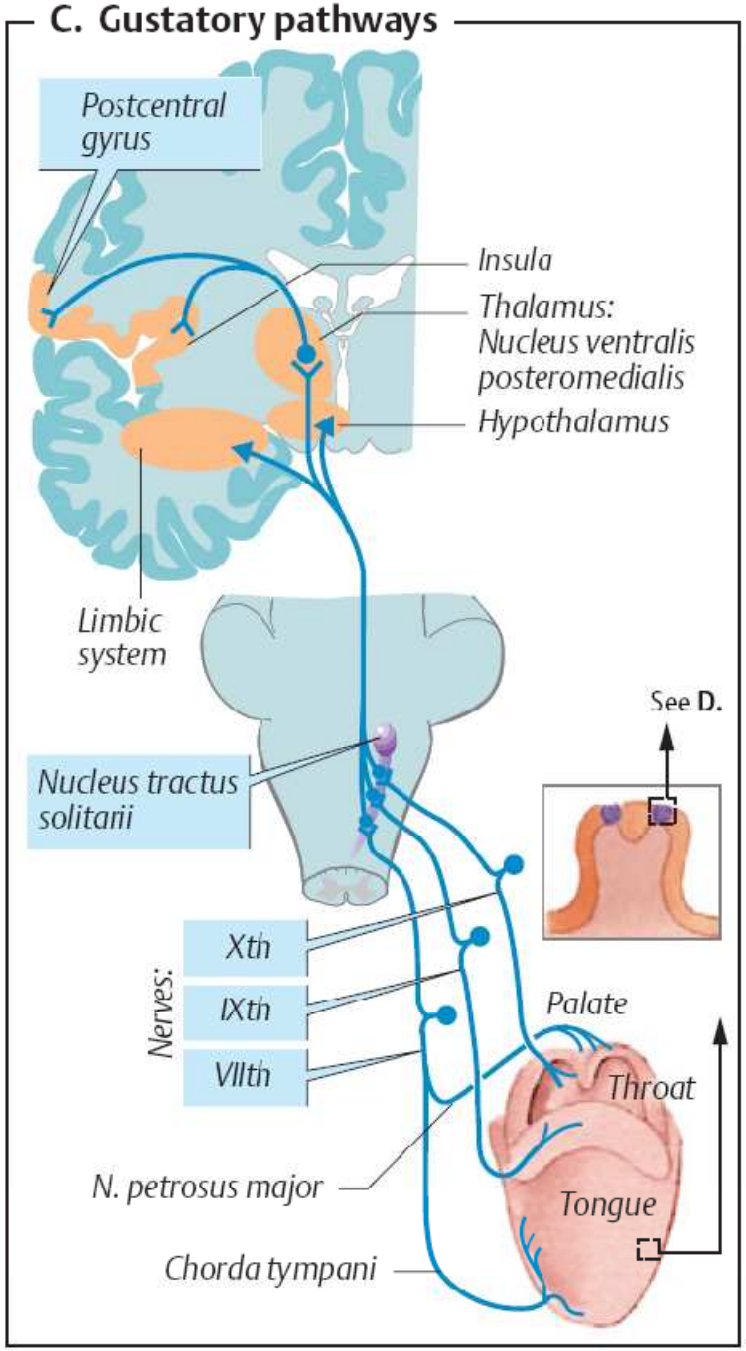
Sweet

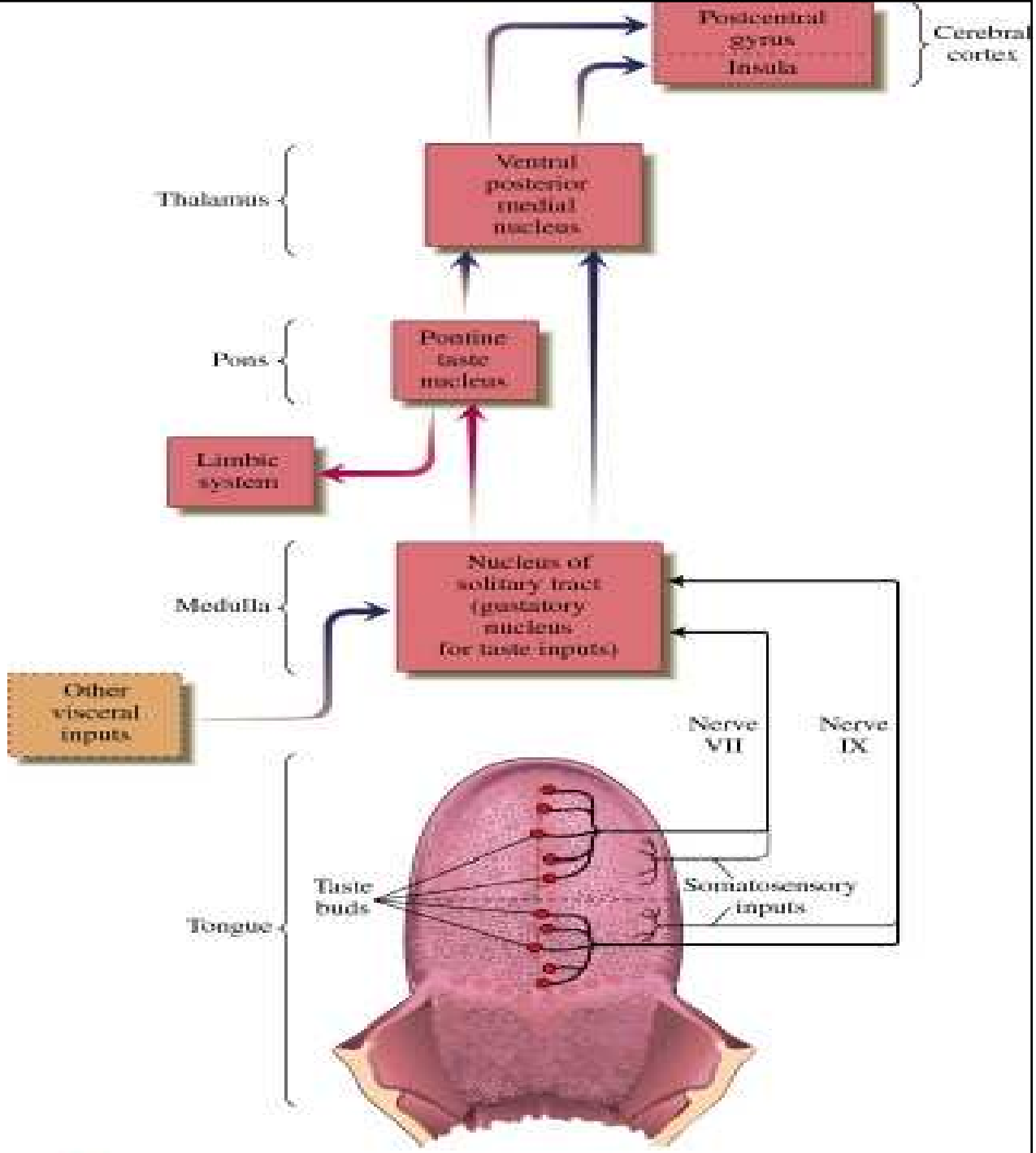


NEUROBIOLOGY
Gary G. Matthews
Blackwell Science

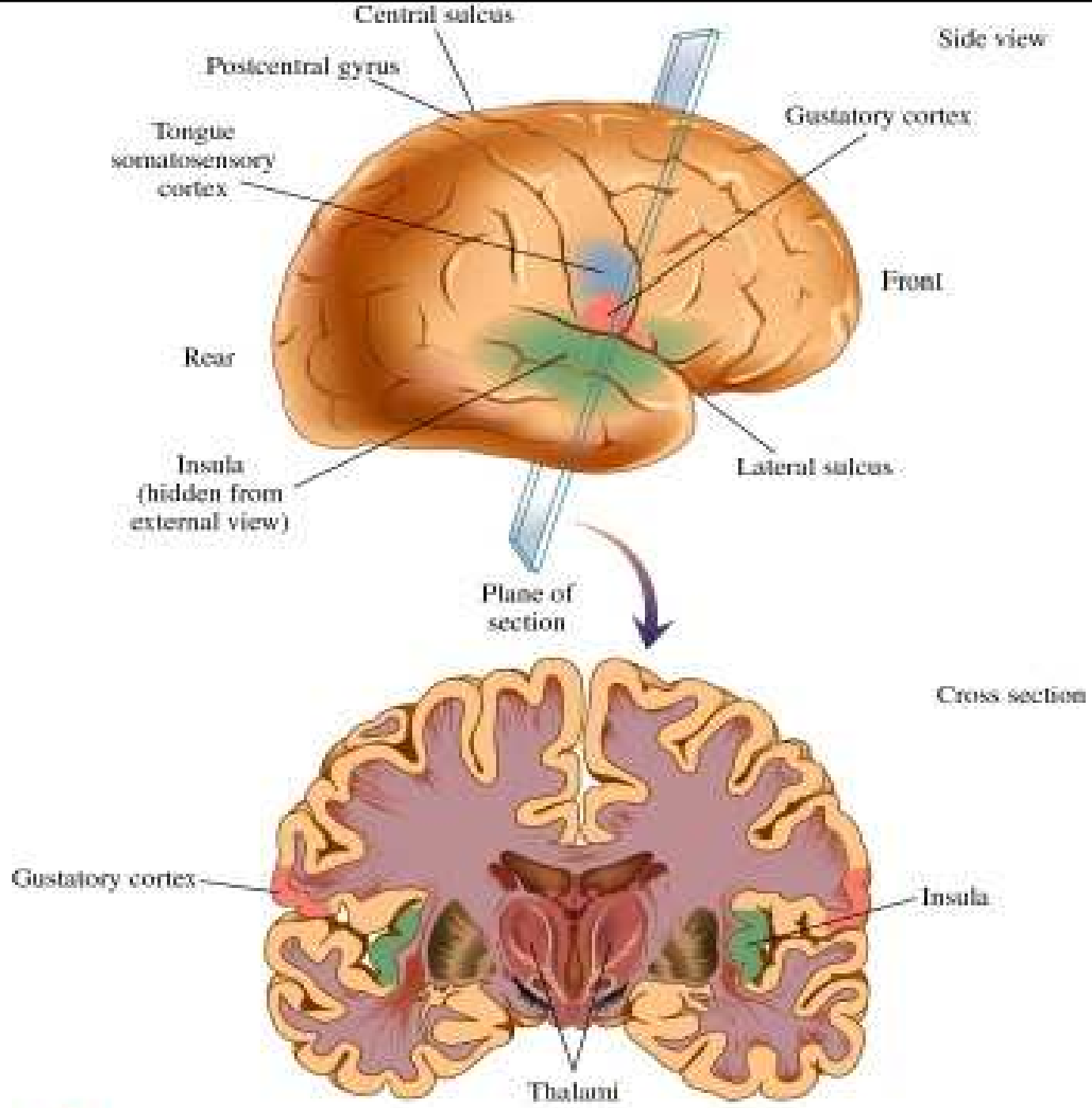


NEUROBIOLOGY
Gary G. Matthews
Blackwell Science





NEUROBIOLOGY
Gary G. Matthews
Blackwell Science



NEUROBIOLOGY
Gary G. Matthews
Blackwell Science

Hygrorecepce

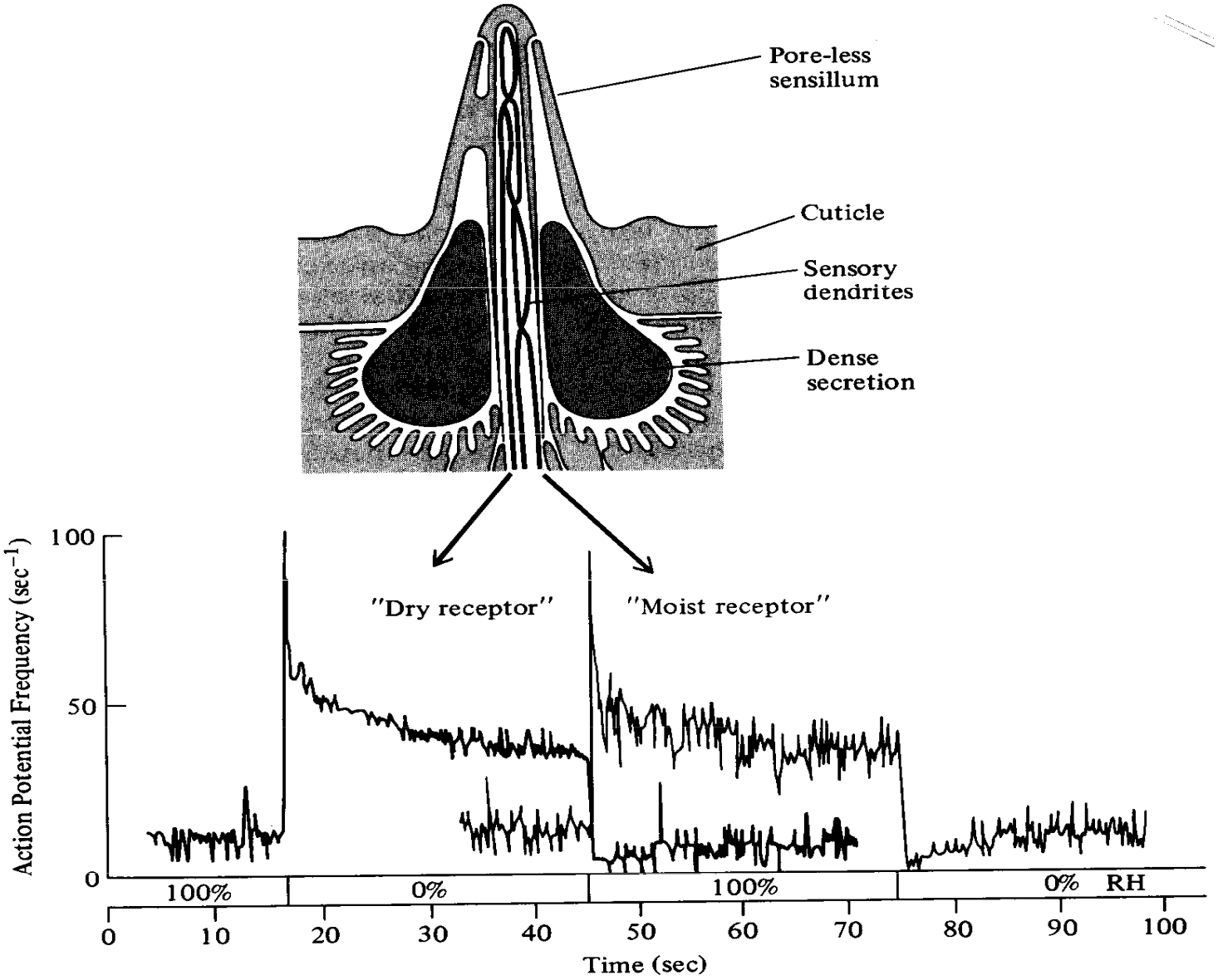


FIGURE 7–18 The "cold-moist-dry" triad sensory sensillum of the cockroach contains three bipolar sensory neurons; one neuron of the hygroreceptor responds to high humidity ("moist" receptor) and one to low humidity ("dry" receptor). The receptor cavity of the poreless sensillum is filled with a dense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

Termorecepce

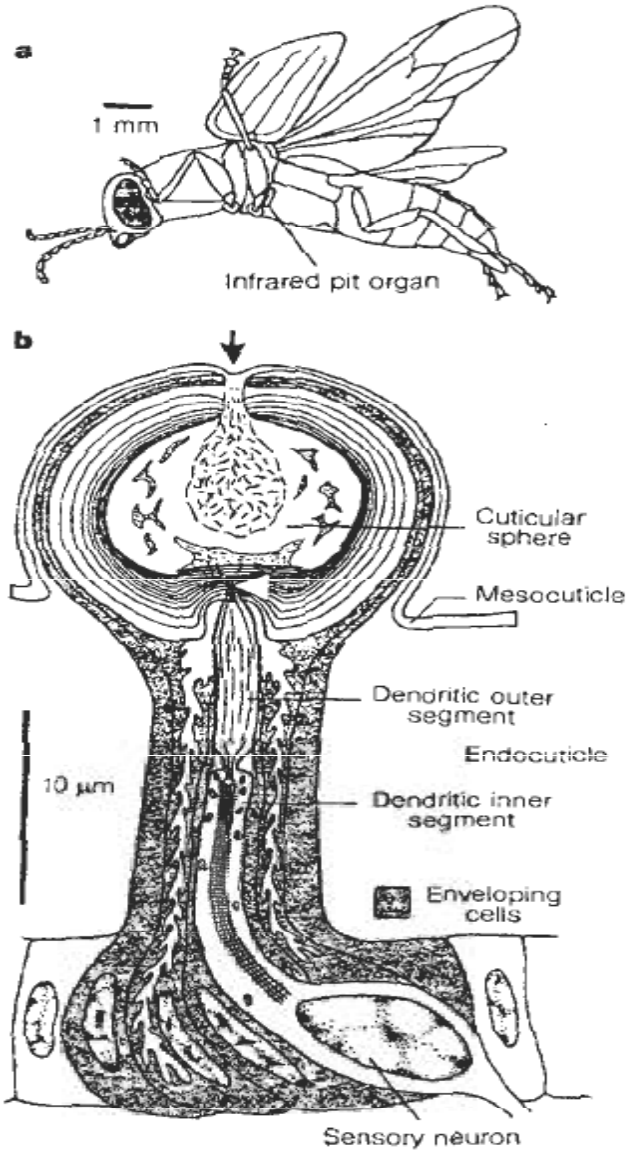


Figure 1 a, **Diagram of *Melanophila* (body length 10 mm). The infrared pit organs, situated next to the coxae of the middle legs, are completely exposed during flight.** b, **An infrared sensillum, redrawn from ref. 3.**

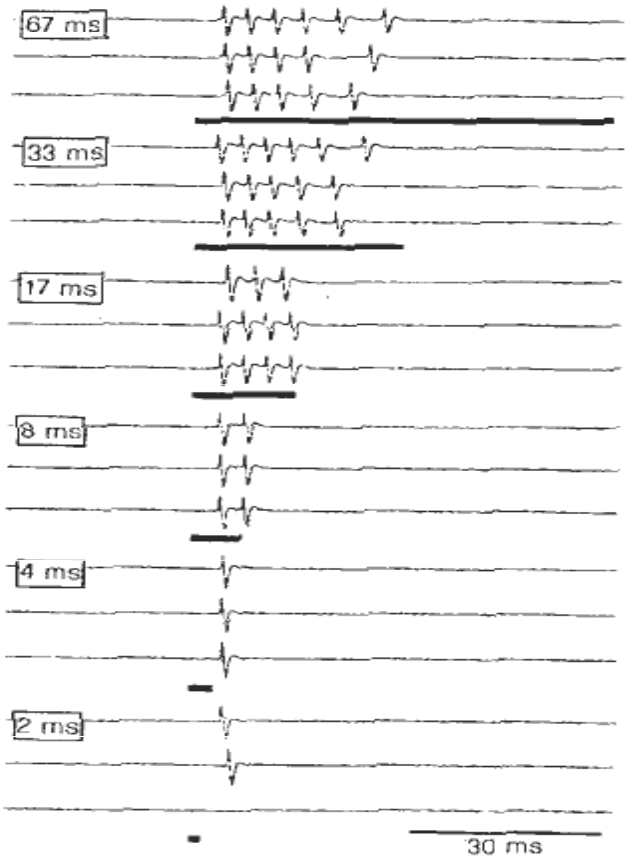


Figure 2 **The responses of a neuron, recorded from the pit organ, to various infrared stimuli. Each trace shows the original response to one stimulus. Horizontal bars indicate exposure times. Each trial was repeated three times. The number of action potentials decreases with decreasing stimulus duration;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

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

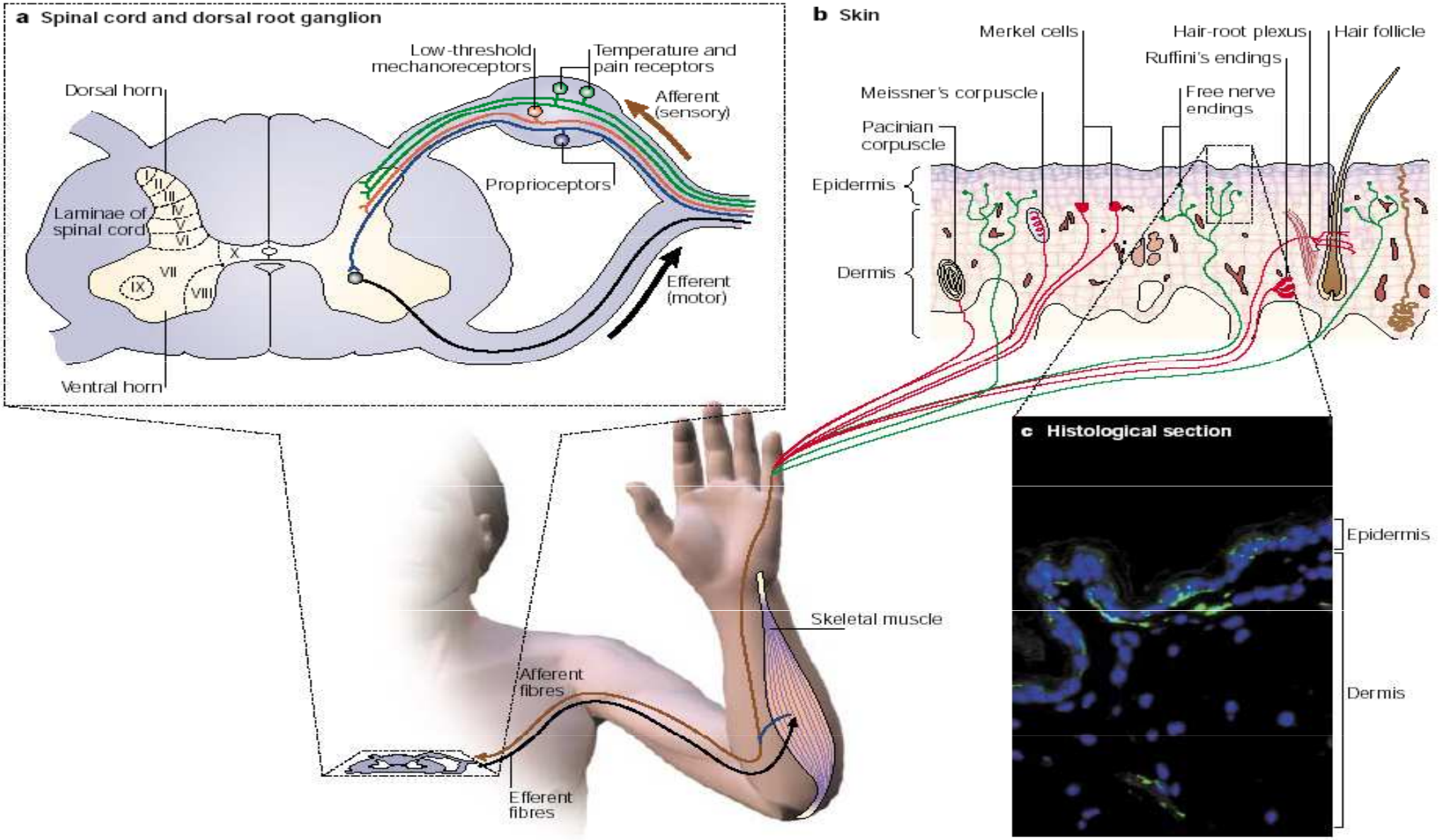


Figure 1 | **Anatomic and functional organization of touch. a** | Spinal nerves formed by the joining of afferent (sensory) and efferent (motor) roots provide peripheral innervation to skin, skeletal muscle, viscera and glands. Arrows denote the direction of incoming sensory and outgoing motor impulses. The cell bodies of motor neurons are located within the ventral horn (laminae VII–IX) of the spinal cord. Cell bodies of sensory neurons are located in the dorsal root ganglia (DRG). Within the DRG there are subclasses of sensory neurons known as proprioceptive (blue), low-threshold mechanosensitive (red) and temperature- and pain-sensing neurons (green). These neurons project centrally to dorsal horn interneurons (laminae I–VI of the spinal cord) and peripherally to target tissues. Proprioceptive neurons (blue fibre) project to specialized structures within target tissues such as muscle, and sense muscle stretch. **b** | Low-threshold mechanosensitive neurons (red fibres) project to end organs that transmit mechanical stimuli. Five types of mechanosensitive assemblies have been described and are illustrated in the figure. Temperature and pain sensing neurons (green) do not project to specialized end organs; instead they terminate as free nerve endings in all layers of the skin, and near blood vessels and hair follicles. **c** | Section of skin showing free nerve endings (green fibres) stained with the pan-neuronal marker PGP9.5. The nuclei of skin cells are stained (blue) with 4,6-diamidino-2-phenylindole (DAPI). Free nerve endings are found in both the epidermal and dermal layers.

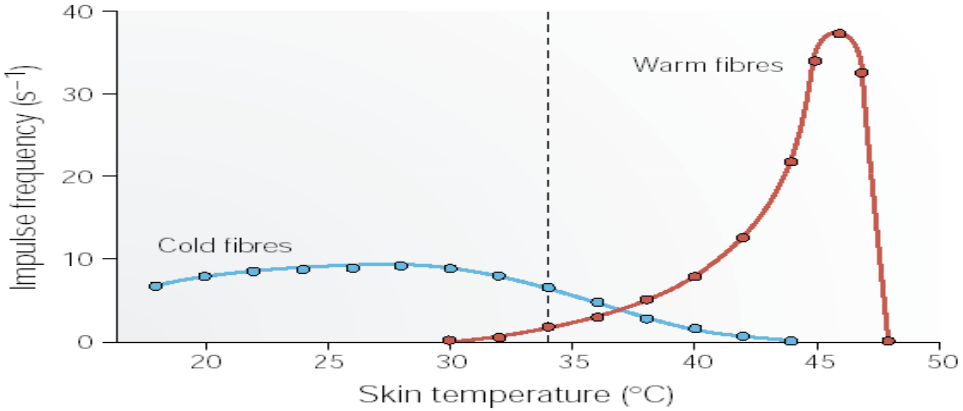


Figure 2 | **Average discharge frequency of individual cold- and warm-sensitive fibres in response to changes in skin temperature.** The dotted line indicates the normal skin temperature (33°C). Cold-sensitive fibres respond only to cooling, whereas warm-sensitive fibres respond to warming. Neither type of fibre responds to mechanical stimulation. Adapted, with permission, from REF. 13 © (1969) The Physiological Society.

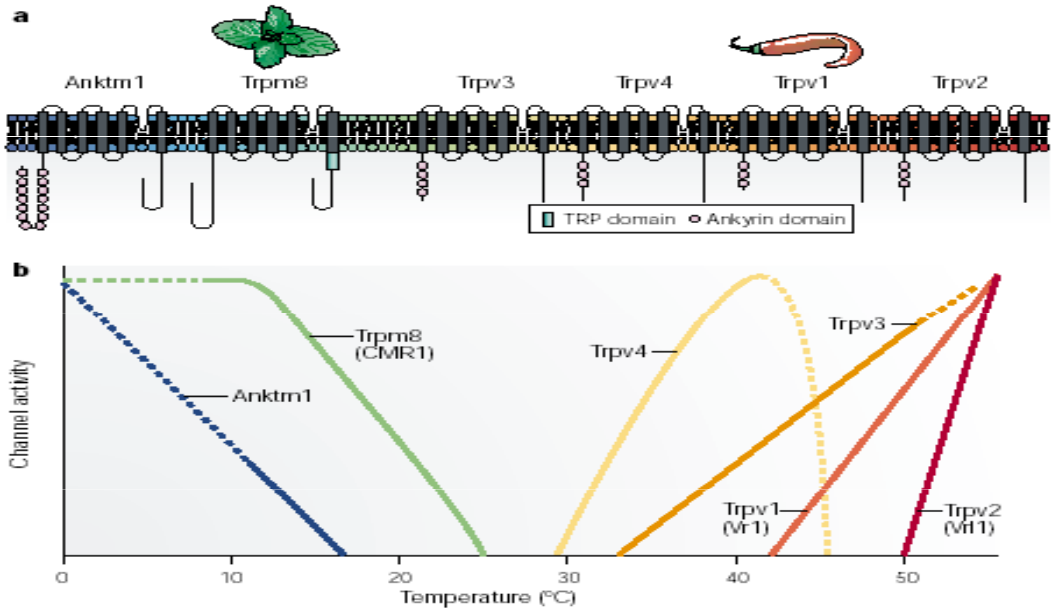


Figure 3 | **Domain organization and temperature thresholds of temperature-activated transient receptor potential ion channels (thermoTRPs).** a | TRP channels are composed of six putative membrane-spanning units and cytoplasmic amino and carboxyl termini. Some TRPs also have variable numbers of ankyrin repeats at the amino terminus, or a conserved TRP domain of 25 amino acids after the transmembrane regions. b | Temperatures ranging from noxious heat to noxious cold activate several members of the TRP family. The cooling compound menthol and capsaicin (the hot ingredient of chilli pepper) act as non-thermal activators of Trpm8 and Trpv1, respectively. The thresholds of activation and maximal activation are based on activity of these channels in heterologous systems; some of these thresholds are averaged values from different studies. Dashed lines indicate an uncertainty in the exact slope of the lines.