

2021 Fall "Physiology"

Sensory Signaling and Perception

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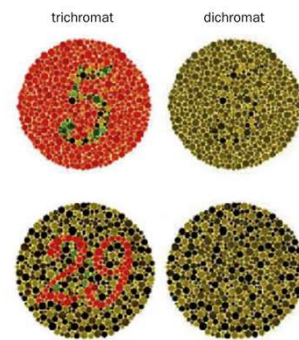


Figure 6.32 Principles of Neurobiology (© Garland Science 2016)

Androstenone: Human Pheromone?



- Offensive: sweaty
 - Pleasant: sweet, floral, vanilla
 - Odorless
- Or7D4: odorant receptor
single nucleotide polymorphism (SNP)

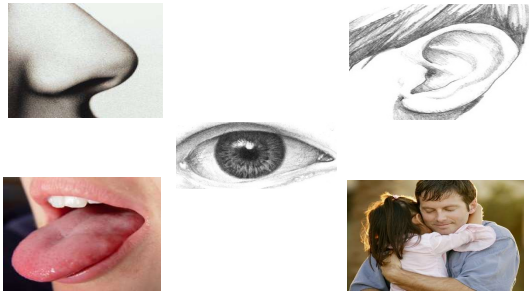
Keller et al. (2007)
Genetic variation in a human odorant receptor alters
odour perception.
Nature, 449: 468-472.



Priming image for Figure 25-3

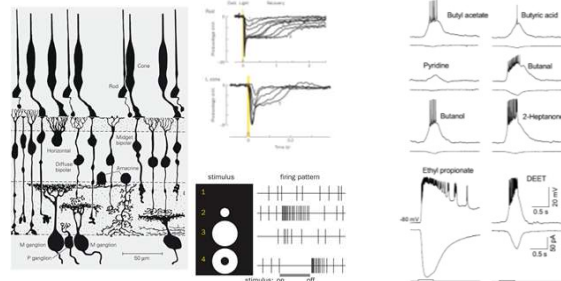


Sensory Modalities

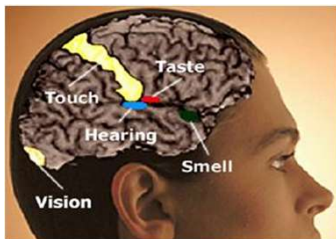


Sensory Coding

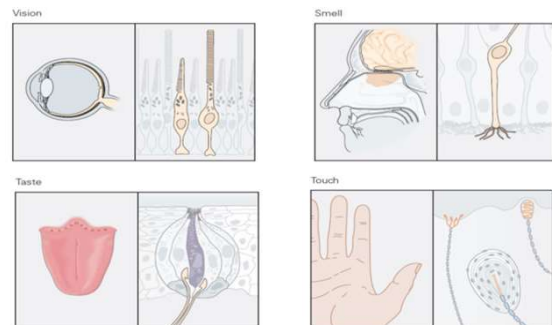
Codes: Spikes vs. Graded Potential
Features: Intensity, Duration, Quality



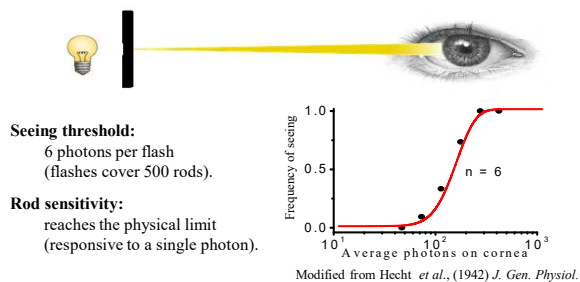
Sensory Cortex



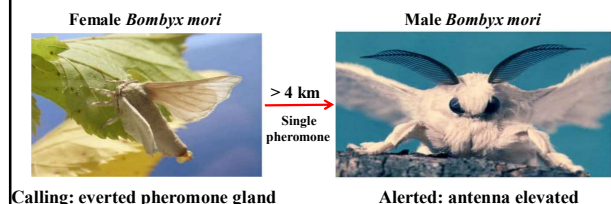
Sensory Receptor Cells



Single-photon Detection



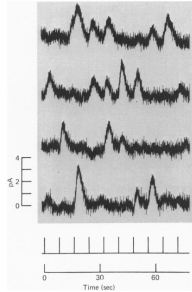
Chemoreception



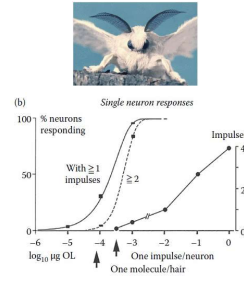
Rau and Rau (1929) *Trans. Acad. Sci. St. Louis*
Kaissling (2004) *Anir*

Ultra-sensitivity of the Senses

Single-photon Response Single-phermone Molecule Detection



Baylor D., et al. *J. Physiol.* (1979)



Minor AV et al. *Neurobiol. Chem. Commu.* (2003)

Sensory Perception:

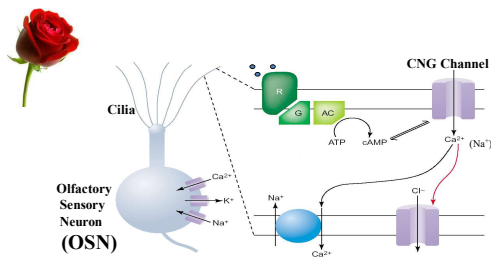
Approaching physical limits !!!

An optimal detector requires:

- Catching stimulus: count every bit of stimulus;
- Signal amplification: high gain and reproducibility;
- Synaptic transmission: high fidelity and low noise.

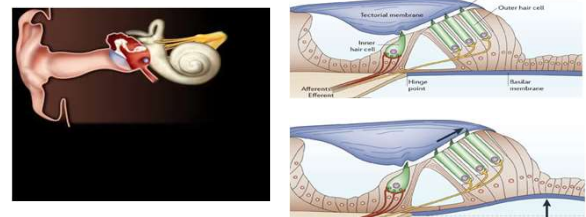
Bialek W (1987) Physical limits to sensation and perception. *Ann. Rev. Biophys. Biophys. Chem.*

Olfactory Transduction

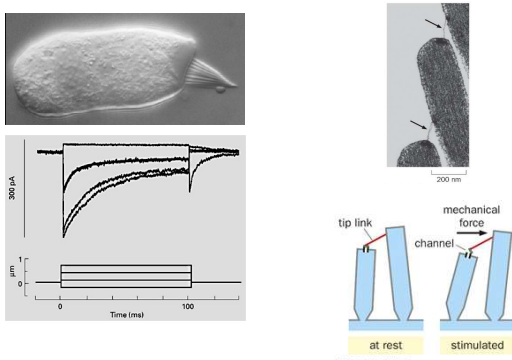


Matthews & Reisert, (2003) *Curr. Opin. Neurobiol.*

Cochlea and Hair Cells



Auditory Transduction



Sensory Transduction

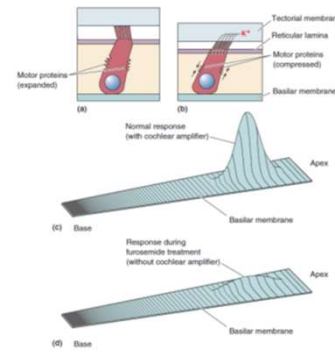
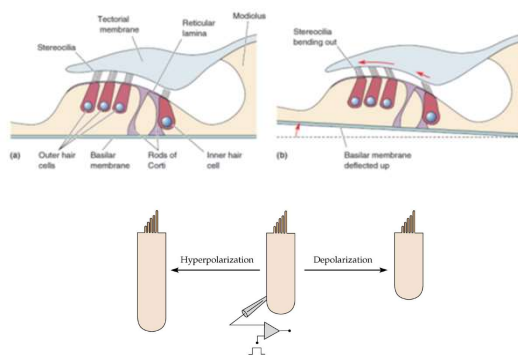
G-protein-mediated Signaling

- Vision and olfaction
- High amplification
- Slow response

Direct Channel-Gating Signaling

- Audition, and some taste senses
- Low amplification
- Fast response

Sound Amplification



Key Features of Sensory Detection

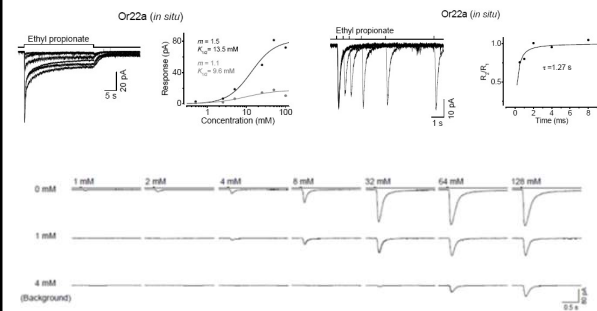
➤ Ultrasensitivity

- Vision: single-photon detection
- Hearing: detection of Brownian motion by hair cells
- Olfaction: single pheromone molecule detection

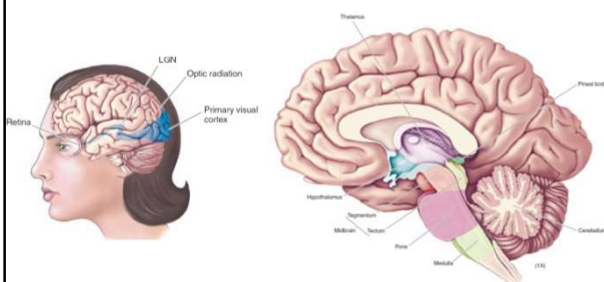
➤ Huge dynamic range

- Vision: moonless night to sunshine at noon, with illumination spanning 10^{12} -folds
- Hearing: ticks of watch to thunder, with sound intensity spanning 10^{10} -folds

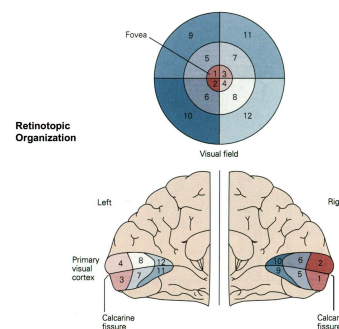
Odor Adaptation in *Drosophila* OSNs



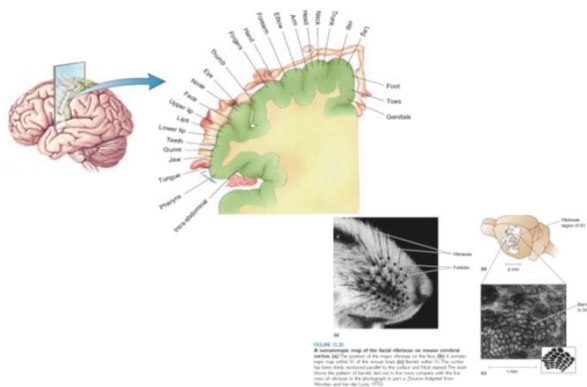
Sensory Circuits in the Brain



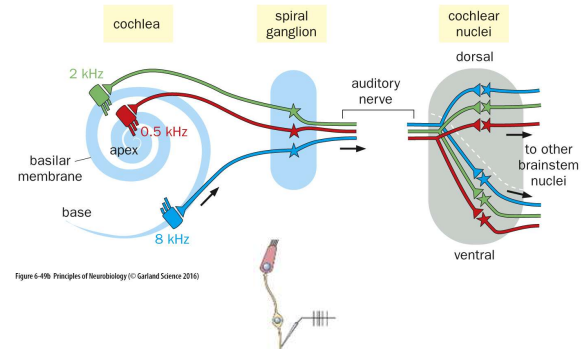
Retinotopic Map



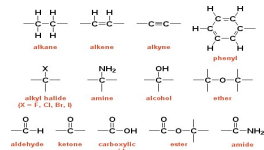
Somatotopic Map in the Brain



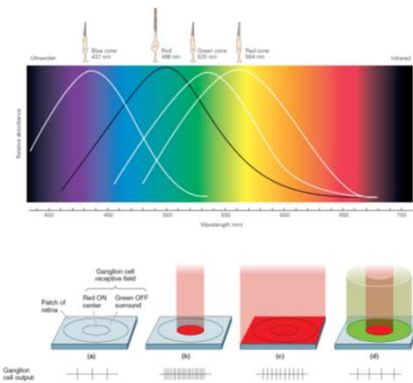
Tonotopic Maps



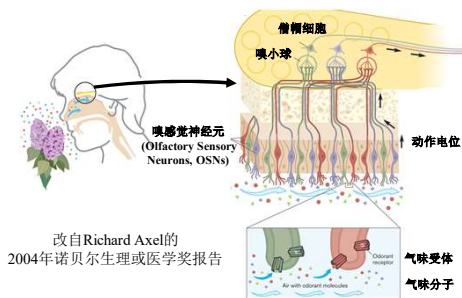
Sensory Discrimination



Color Opponency



Olfaction: the sense of smell



2004 Nobel Prize in Physiology or Medicine

Linda Buck

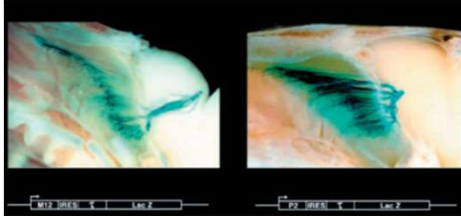


Richard Axel



Cloned ~1,000 Or genes in rodents;
4-5% genes in the whole genome. (1991, Cell)

Olfactory Glomerulus



Axel R. 2005

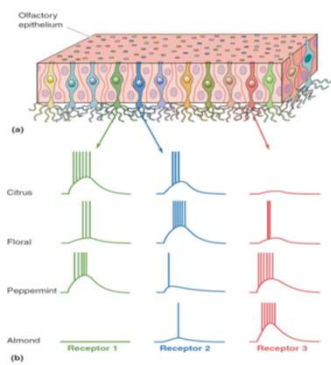
Combinatorial Coding in Olfaction

	OR genes	Intact OR genes
Rat	1576	1284
Mouse	1375	1194
Dog	971	713
Chimp	899	353
Human	851	384

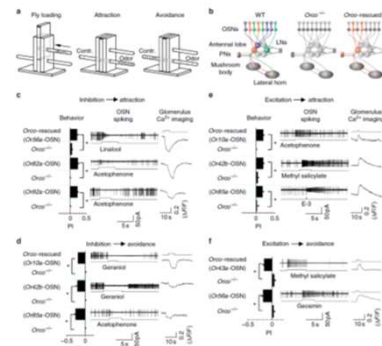
Zhang and Firestein (2009)

Odorant receptors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Description
A															citrus, rose, grape like
B															citrus, rose, grape like
C															citrus, rose, grape like
D															citrus, rose, grape like
E															citrus, rose, grape like
F															citrus, rose, grape like
G															citrus, rose, grape like
H															citrus, rose, grape like

Modified from Malnic *et al.*, (1999) *Cell*

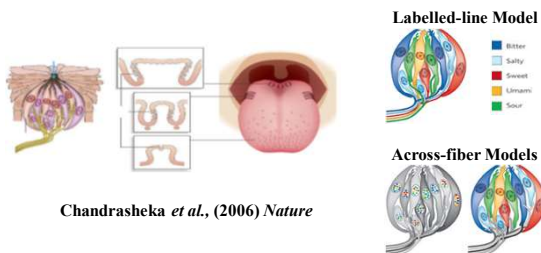


Bidirectional Odor Coding



Cao LH, et al., *Nat. Commun.*, 2017

Taste Coding



Chandrasekha *et al.*, (2006) *Nature*