The Senses

Physics/Neuro 141

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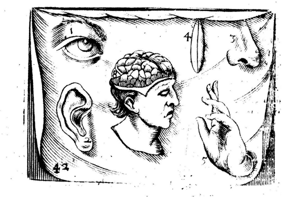
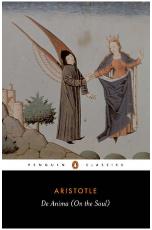


Week 1

Senses and cells



Aristotle's Senses

- Vision
- Hearing
- Taste
- Smell
- Touch

- Temperature
- Gravity
- Magnetic or electric fields
- Time
- Proprioception
- Oxygen or CO_2 detection
- Osmolarity detection
- Nociception
- Polarized light detection
- Pheromone detection
- pH-sensing

Others?

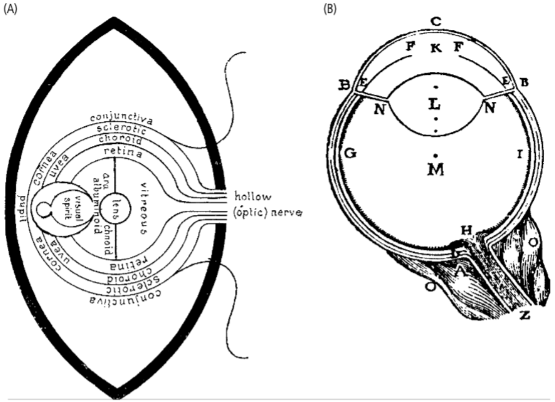


Figure 1.1 Structure of the eye. (A) Diagram of the eye from a ninth-century AD translation of Galen into Syriac by Humain Ibn Is-Hâq, in turn translated into English. (B) More anatomically correct diagram of cross-section of the eye made by René Descartes. ABCB, Cornea and sclera; EF, iris (in actual fact closer to the lens than shown in Descartes' diagram); K, aqueous humor; L, lens; EN, zonule fibers; M, vitreous humor; GHI, retina; H, optic nerve head; O, ocular muscles; and Z, optic nerve. (A from Meyerhoff, 1928; B from Descartes, 1637/1987.)

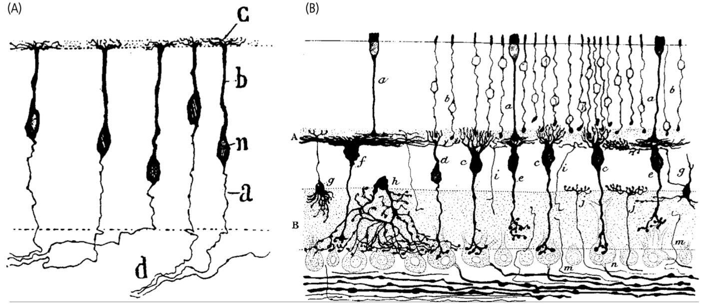


Figure 1.2 Sensory cells from the work of Ramón y Cajal. (A) Bipolar sensory neurons from mammalian olfactory mucosa. a, Axon; b, peripheral process; c, sensory dendrites; d, axon; n, nucleus. (B) Section of retina of an adult dog. A, Outer plexiform (synaptic) layer; B, inner plexiform (synaptic) layer; a, cone fiber; b, rod cell body and fiber; c, rod bipolar cell with vertical dendrites; d, cone bipolar cell with vertical dendrites; e, cone bipolar cell with flattened dendrites; f, giant bipolar cell with flattened dendrites; g, special cells stained very rarely (perhaps inter-plexiform cells); h, diffuse amacrine cell; i, ascendant nerve fibers (probably processes of cell not well stained); j, centrifugal fibers coming from central nervous system; m, nerve fiber (probably again of poorly stained cell); n, ganglion cell. (A and B from Cajal, 1893/1973.)

Detecting sensory detection

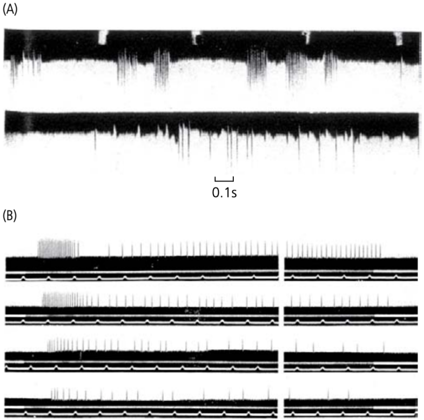


Figure 1.3 Early electrical recordings of sensory responses. (A) Action potentials recorded from single axons dissected from the cutaneous nerve of a frog. (B) Action potentials from the lateral eye of the horseshoe crab *Limulus*. Each trace gives the response to a different light intensity, which was systematically increased by an additional factor of ten from dimmest (bottom) to brightest (top). (A from Adrian, 1947; B from Hartline and Graham, 1932.)

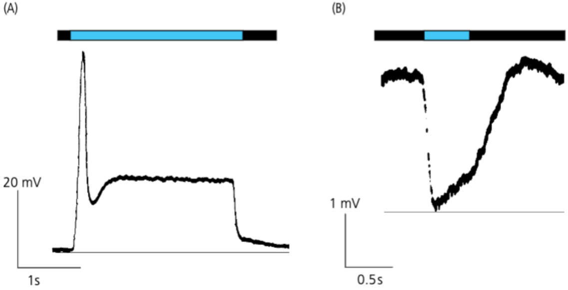


Figure 1.5 Intracellular recordings from sensory receptors. Bars above recordings show timing and duration of light flashes. (A) Depolarizing voltage response from photoreceptor of *Limulus* ventral eye. (B) Hyperpolarizing voltage response from photoreceptor (cone) of a fish. This is the first published recording of the response of a vertebrate photoreceptor. (A from Millecchia and Mauro, 1969b; B after Tomita, 1965.)

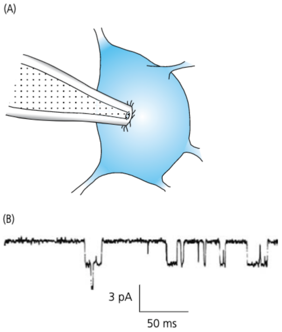


Figure 1.6 Patch-clamp recording from single channels. (A) The tip of a patch pipette is pushed against the cell body of a cell and slight suction is applied to form a seal. (B) Single-channel currents recorded from muscle acetylcholine receptors. The pipette contained 0.3 μM acetylcholine. Downward deflections indicate channel opening. At least two channels were present in this membrane patch. (B from Trautmann, 1982.)

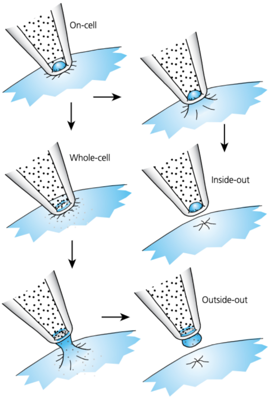


Figure 1.7 Different configurations of recording with patch-pipette technique. On-cell, whole-cell, inside-out, and outside-out recording techniques as described in the text.

Probing molecules

Genetic and structural analysis of receptors

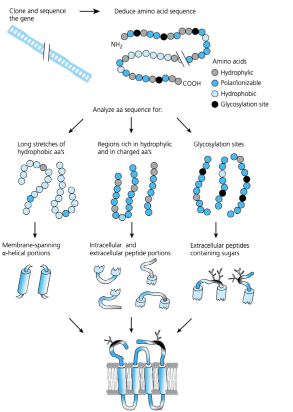


Figure 1.10 Analysis of hydropathy and the folding of membrane proteins. The amino acid sequence of a membrane protein can be used to make inferences about protein structure, as described in the text.

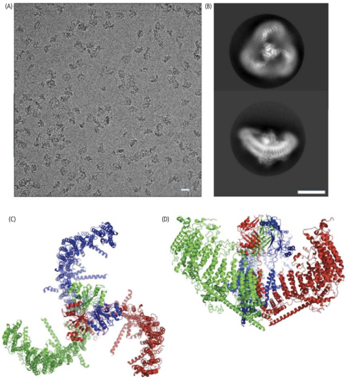
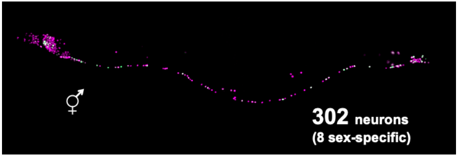


Figure 1.13 Cryo-EM structure of Piezo1. The gene for the Piezo1 protein was expressed in a cell line and purified. The protein was suspended on an electron-microscope grid and rapidly frozen by plunging the grid first into liquid ethane and then into liquid nitrogen. (A) Representative raw micrograph of the protein on the grid; scale bar is 200 Å (20 nM). (B) Protein images like those in (A) were separated into groups according to their orientation, first manually to produce templates and then automatically under computer control. Images in each class were averaged, and representative averaged classes are shown viewed from the top (upper image) and side (lower image); scale bar is 100 Å (10 nM). (C, D) Atomic model of the trimeric channel at an overall resolution of 3.7 Å shown as a ribbon diagram, viewed from the top (C) and side (D). The three subunits have been given different colors. (From Guo and MacKinnon, 2017.)

Psychophysics

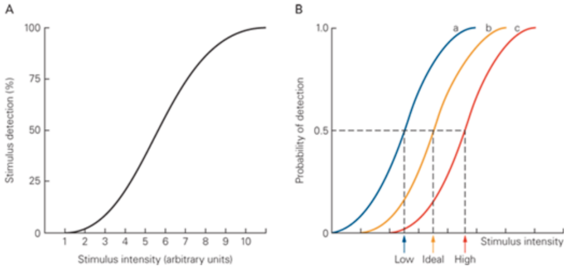
- **Psychophysics** describes the relationship between the physical characteristics of a stimulus and the attributes of the sensory experience.
- **Sensory physiology** examines the neural consequences of a stimulus — how the stimulus is transduced by sensory receptors and processed in the brain.
- *Is it possible to connect psychophysics and whole-brain physiology during animal behavior?* **Yes.**



Weber's Law

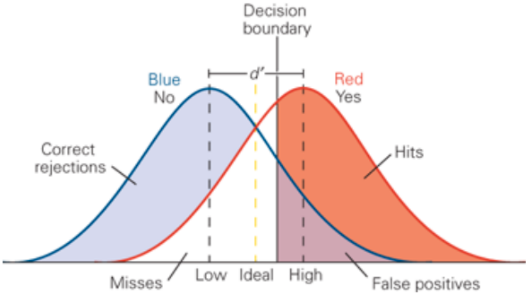
- It is easy to tell 1 kg from 2 kg
- It is hard to tell 50 kg from 51 kg
- The "just noticeable" stimulus depends on stimulus intensity: $\Delta S = KS$

The psychometric curve



Detection and discrimination thresholds depend on the criteria used. An ideal observer correctly detects the presence and absence of stimuli with equal probability (curve b). An observer who is told to respond to the slightest indication of a stimulus reports many false positives and has low sensory thresholds (curve a). An observer who is told to respond only when very certain has many false negatives and has high sensory thresholds (curve c).

Decision Theory



The stimuli tested in a discrimination task are represented by Gaussian curves that represent the fluctuation in sensations from trial to trial. The discriminability of a pair of stimuli is correlated with the distance between the peaks of the two curves and the overlap between them. When two stimuli are similar in magnitude, no criterion allows error-free responses. The frequency of hits and false positives (and their complements, misses and correct rejections) is determined by the criteria used in the decision task.