Cognitive Construction of Space: Part II

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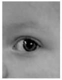
The Story of Epistemology So Far

- Kant claimed to had explained why arithmetic and geometry can be known *a priori* with certainty.
- He also claimed that he provided a refutation of Hume's skepticism about induction. Although the metaphysical skepticism is still there.
- Kant's idea is that the Euclidean space and time is the pure form of our intuition.
- But is that true? Can we learn about how we know where thing are using empirical methods?

The Construction of Space

How our senses and motor systems construct space?

Vision



Hearing

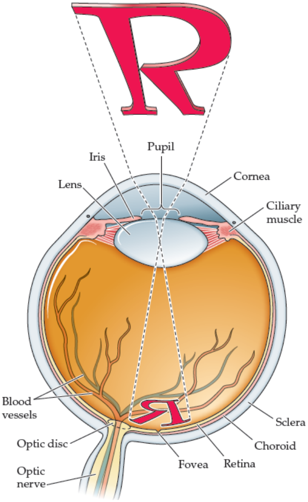
Touch

Body position

Movement

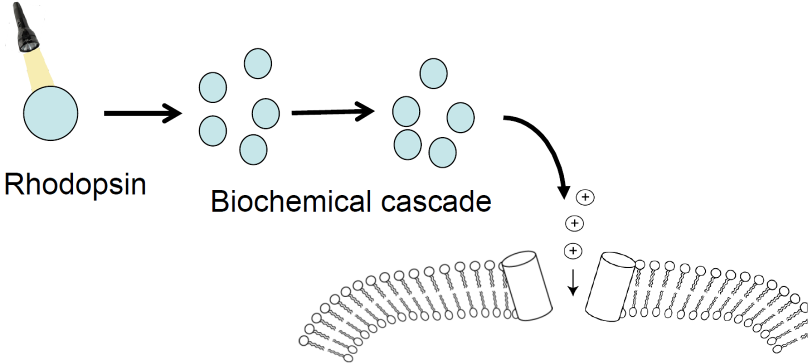
Balance

Visual System



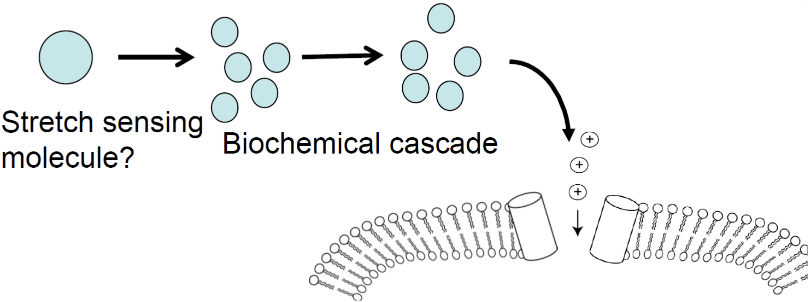
Behavioral Neuroscience, Figure 10.1

Visual Sensation

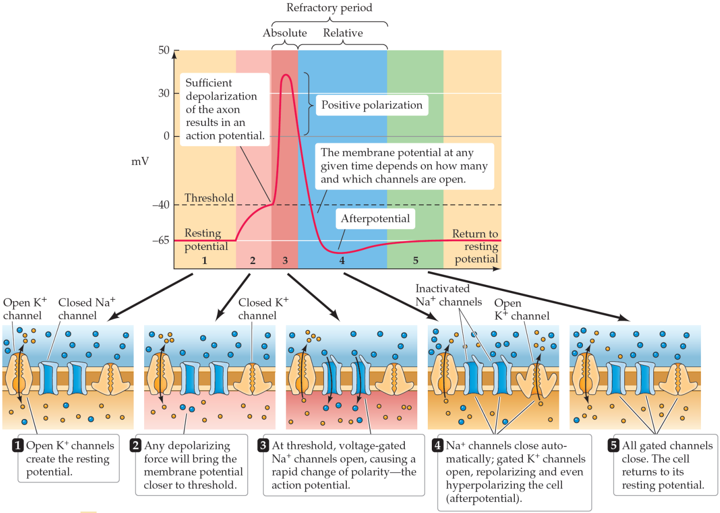


Possible mechanotransduction mechanism 2

Lackner, J. R. (1988)



The Action Potential



Biological Psychology, Figure 3.6

Outline

Figure-Ground Segregation

Rubin's Face-Vase Illusion

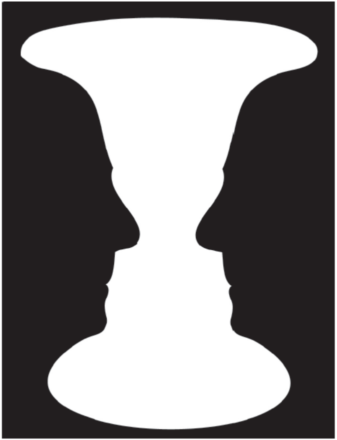
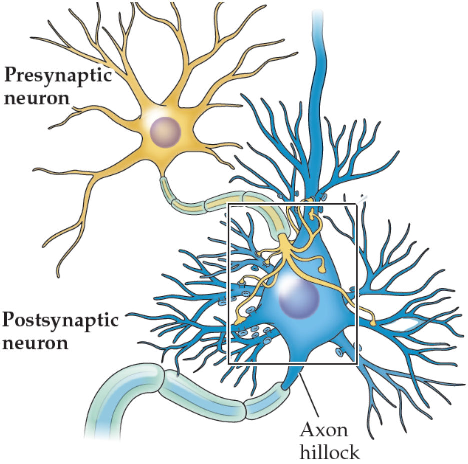


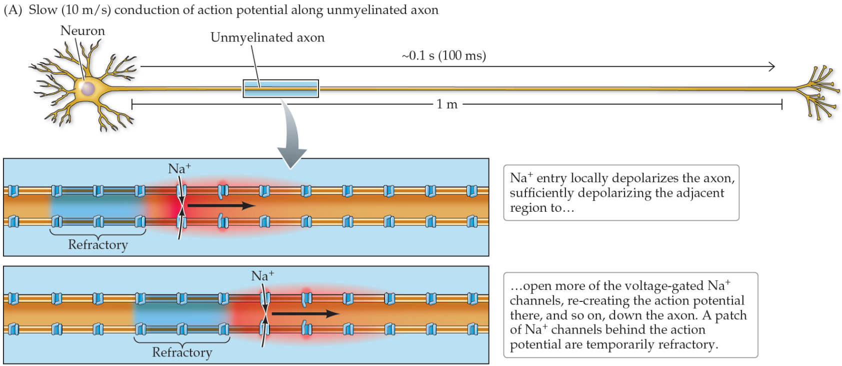
Figure-Ground Segregation

M. C. Escher "Mosaic II"

Neural Communication



Propagation of Action Potential

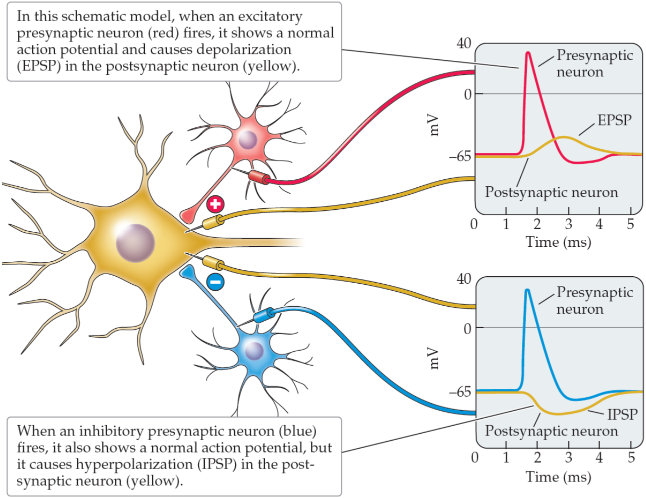


Biological Psychology, Figure 3.8

Postsynaptic Potentials

- Postsynaptic potentials are brief changes in the resting potential. 2 types:
- Excitatory postsynaptic potential: produces a small local depolarization, pushing the cell closer to threshold. This is caused by opening of Na+ channels on the post-synaptic membrane.
- Inhibitory postsynaptic potential: produces a small hyperpolarization, pushing the cell further away from the thredshod. Caused by the influx of Cl- into the cell. Not action potential, just the small fluctuation of input information for a neuron.

Postsynaptic Potentials

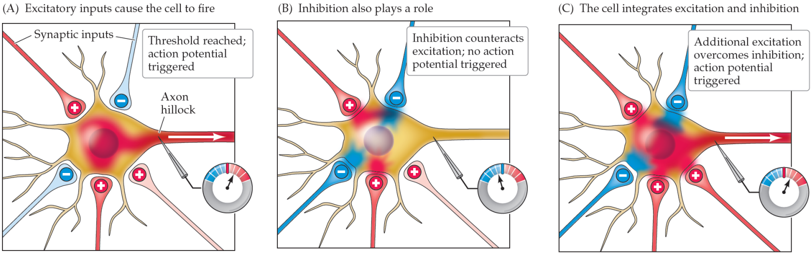


Biological Psychology, Figure 3.9

Postsynaptic Potentials

- Neurons perform information processing to integrate synaptic inputs.
- A postsynaptic neuron will fire an action potential if a depolarization that exceeds threshold reaches its axon hillock.
- Discovered by another Nobel Winner: Charles Sherrington (1932 Nobel Prize)

Postsynaptic Potentials



Biological Psychology, Figure 3.10

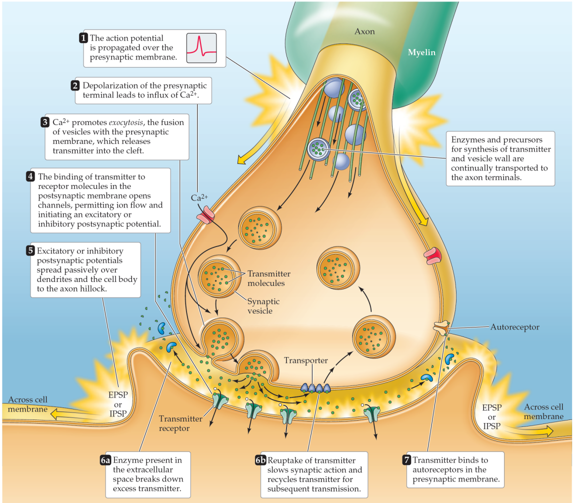
The Sequence of Transmission

1. Action potential travels down the axon to the axon terminal.
2. Voltage-gated calcium channels open and calcium ions (Ca 2+) enter.
3. Ca2+ entry causes synaptic vesicles fuse with membrane and release transmitter into the cleft.
4. Transmitter molecules cross the cleft to bind to special receptor molecules in the postsynaptic membrane, leading to the opening of ion channels in the postsynaptic membrane.

The Sequence of Transmission

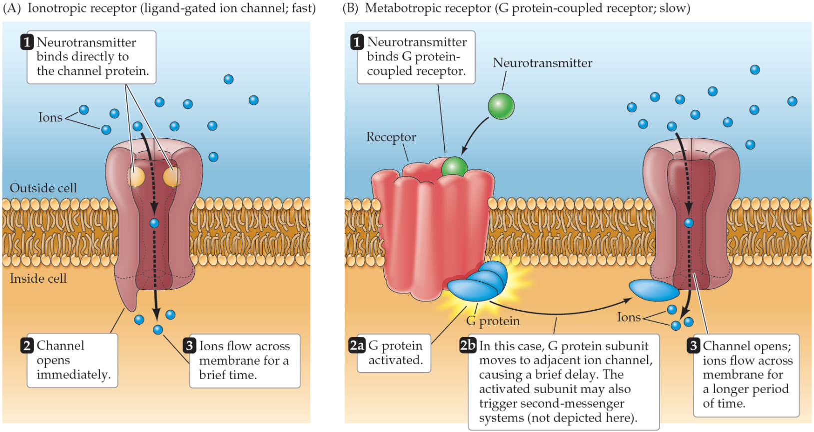
5. This ion flow creates a local EPSP or IPSP in the postsynaptic neuron.
6. Synaptic transmitter is either (a) inactivated (degraded) by enzymes or (b) removed from the synaptic cleft by transporters, so the transmission is brief and accurately reflects the activity of the presynaptic cell.
7. Synaptic transmitter may also activate presynaptic autoreceptors, regulating future transmitter release. membrane.

The Key Figure



Biological Psychology, Figure 3.12

Receptors

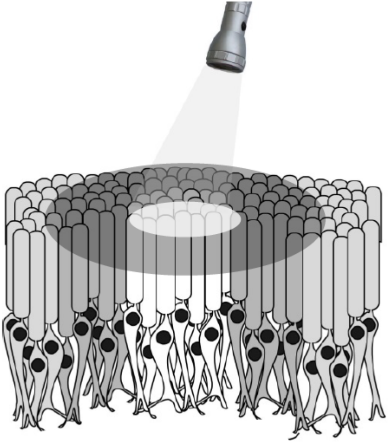


Biological Psychology, Figure 3.16

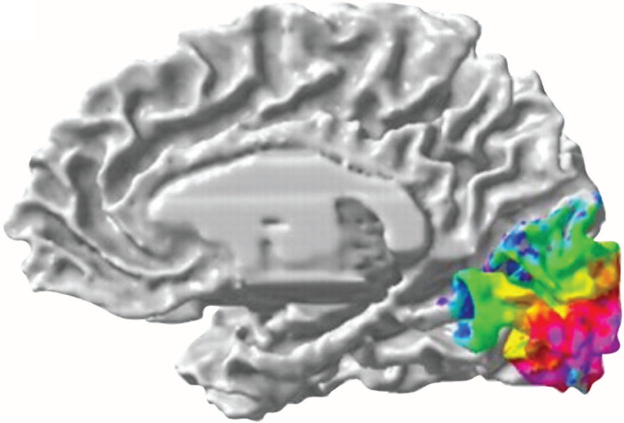
Center Surround Organization

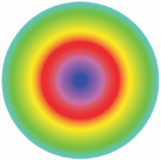
Hubel and Wiesel Video I

http://www.science.smith.edu/departments/neurosci/courses/bio330/h%26w.html



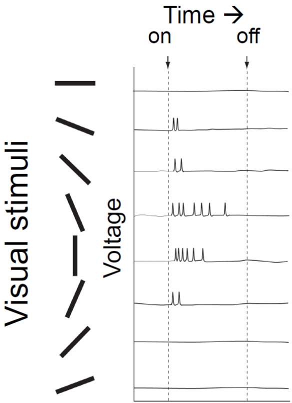
Retinotopic Maps



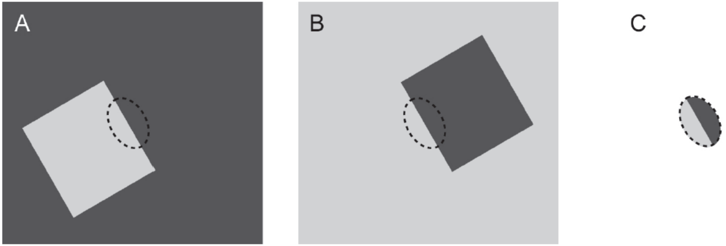


Orientation Selectivity

Hubel and Wiesel Video II

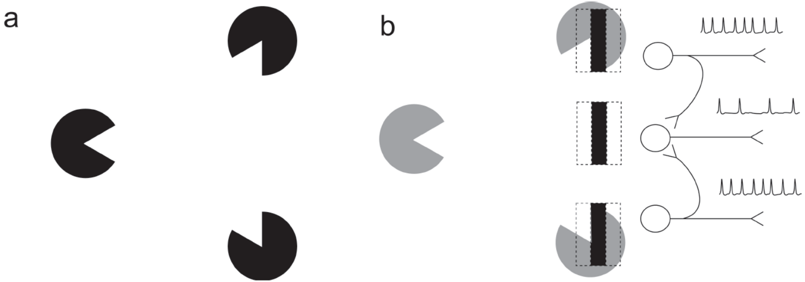


Border Ownership Selectivity



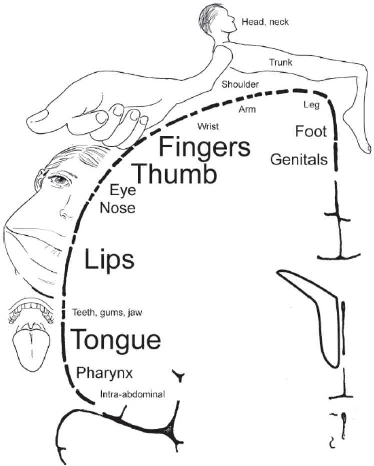
Zhou, H., H. S. Friedman and R. Von Der Heydt (2000). J. Neurosci. 20(17): 6594-6611.

Kanizsa Triangle: Illusory Contours

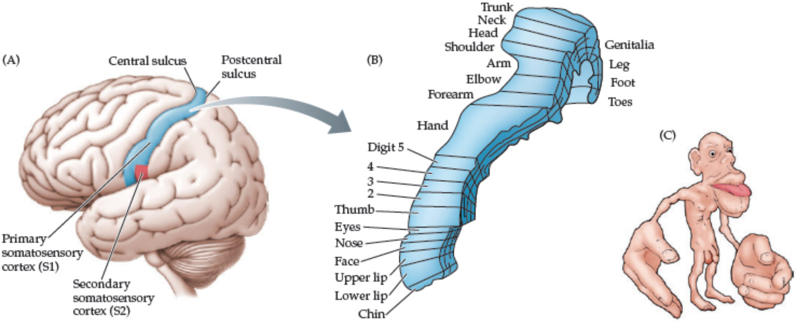


Phantom Limb and Body Map

Amputees feel like missing limb is still present

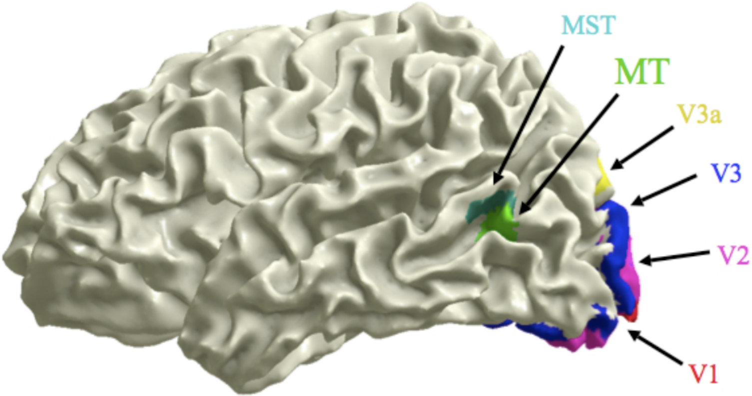


The Body Map



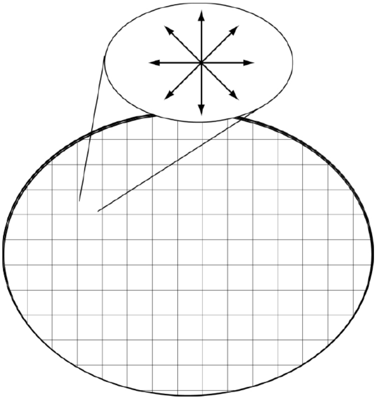
8.10 REPRESENTATION OF THE BODY SURFACE IN SOMATOSENSORY CORTEX (A) The locations of primary (S1) somatosensory cortex on the lateral surface of the parietal cortex. Secondary somatosensory cortex (S2) is much smaller than S1. (B) The order and size of cortical representations of different regions of skin. Note that information from the various parts of the hand and fingers takes up much more room than does information from the shoulder. (C) The *homunculus* (literally, "little man") depicts the body surface with each area drawn in proportion to the size of its representation in the primary somatosensory cortex.

Motion Perception



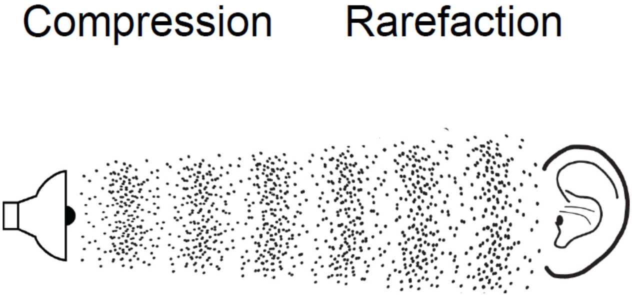
Retinotopic Map and Velocity Submap

Hubel and Wiesel Video III

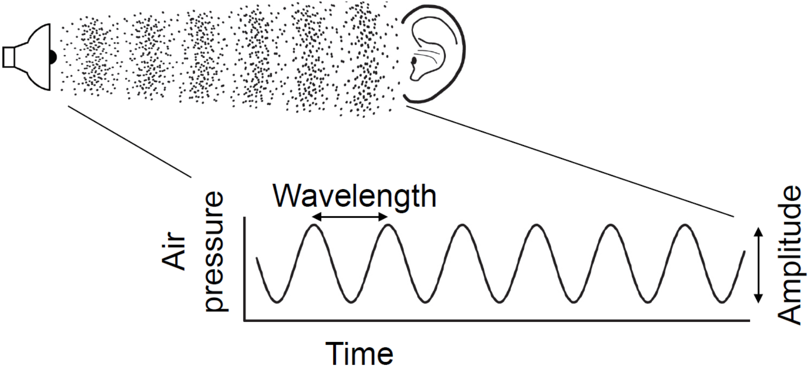


Outline

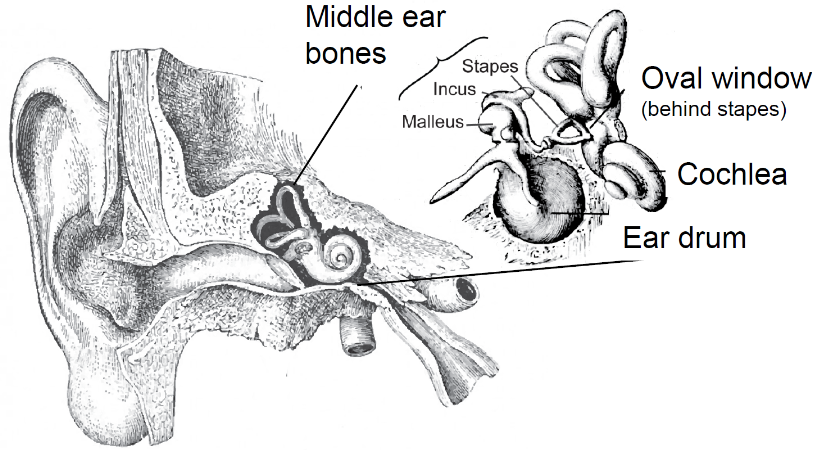
Sound is a Pressure Wave



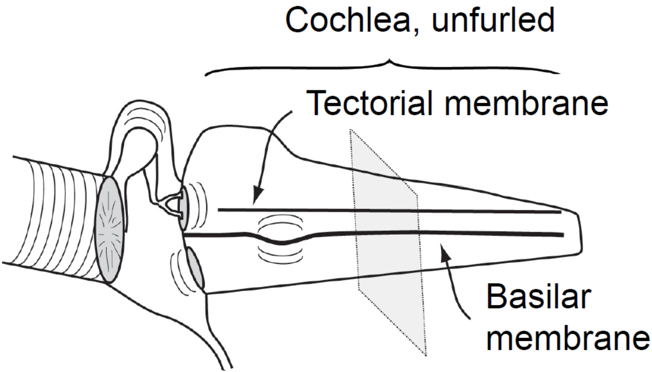
Sound is a Pressure Wave



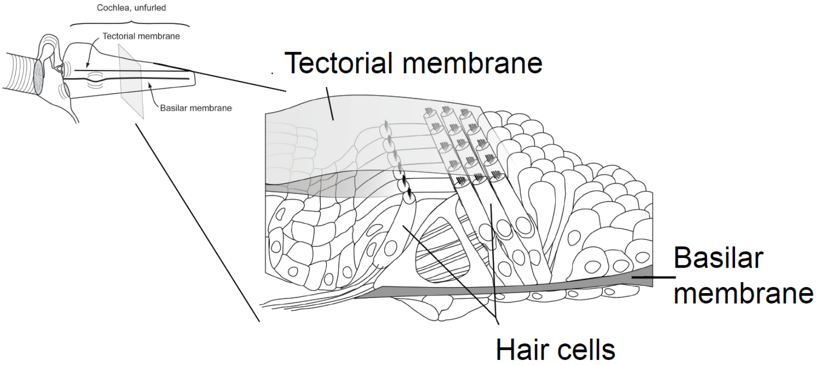
The Structure of the Inner Ear



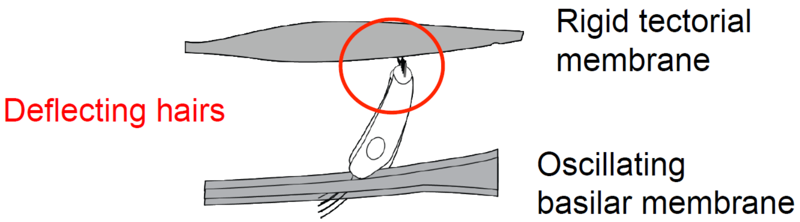
The Structure of the Cochlea



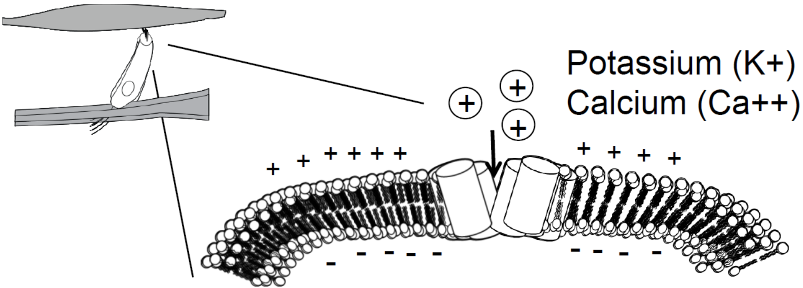
The Structure of the Cochlea



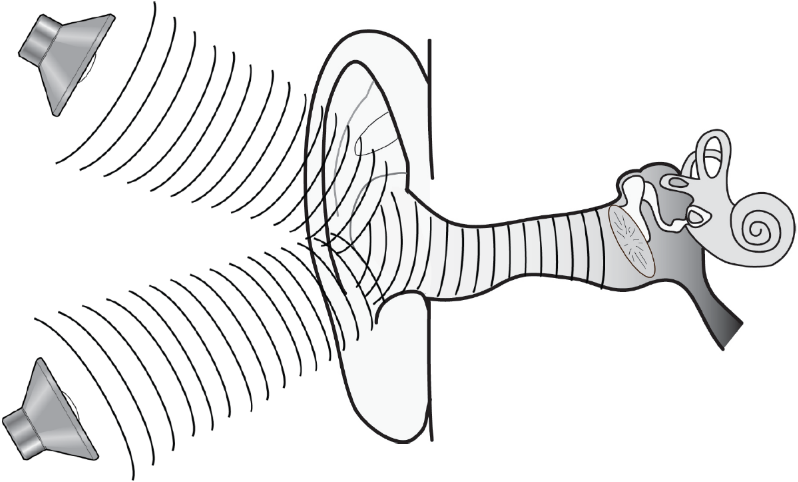
Auditory Transduction



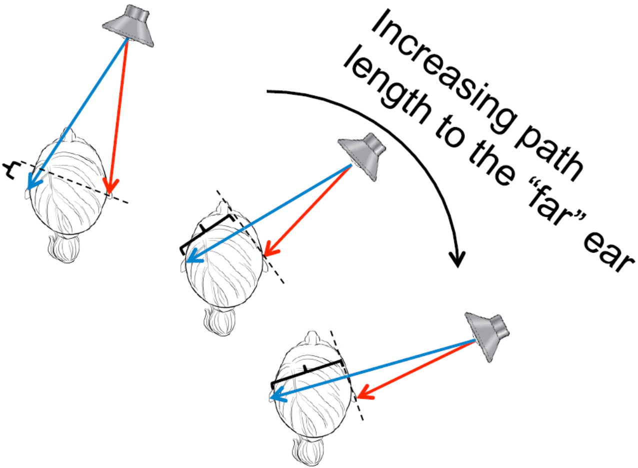
Auditory Transduction



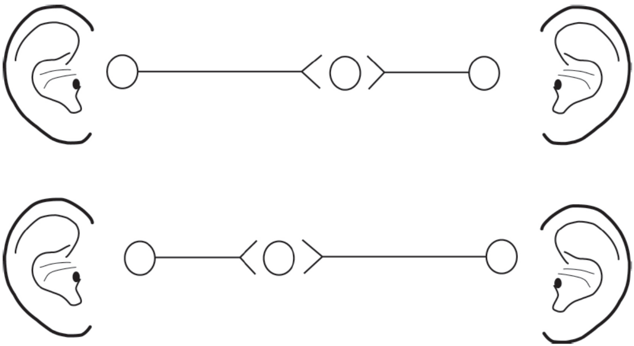
No image formation



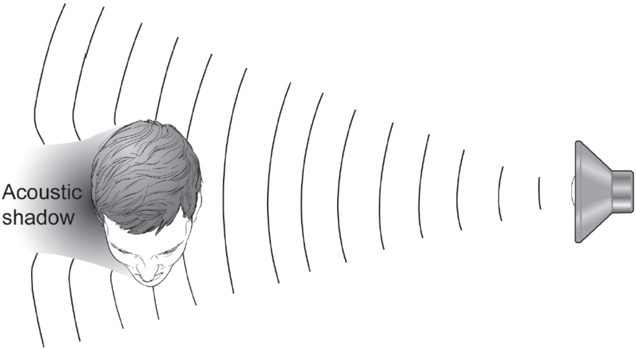
Computing Sound Location



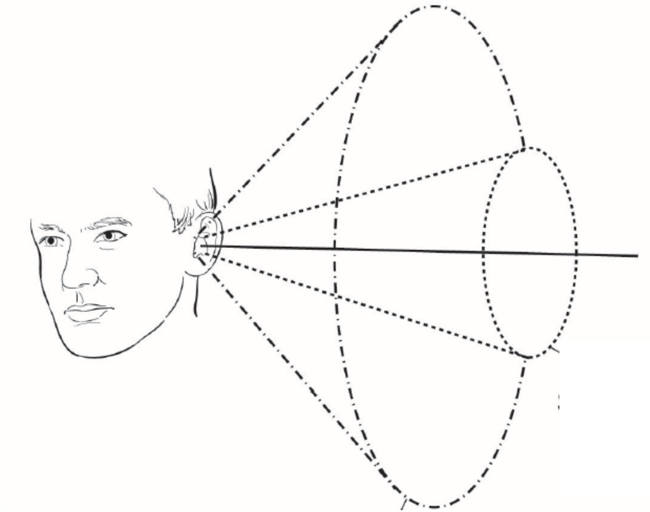
Detecting Interaural Timing Differences: Delay Lines



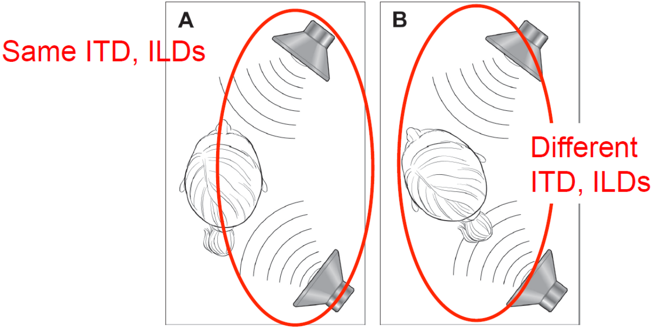
Interaural Level Differences



The Cone of Confusion



Solution: Head Movement



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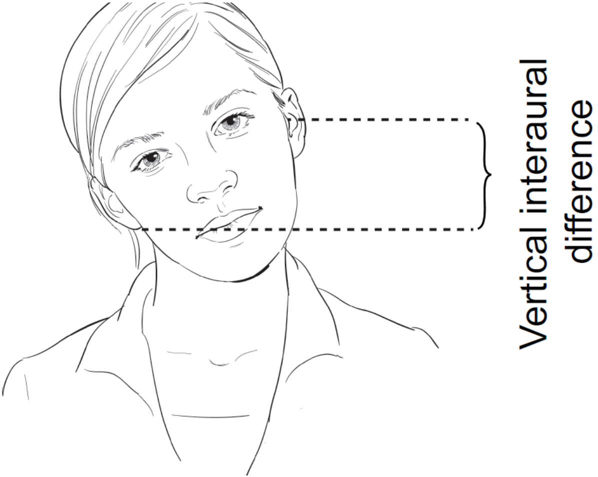


Symbol Representations

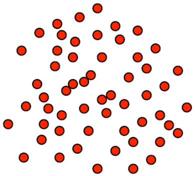
- Symbol

0	0	1	1	1	0	0	0

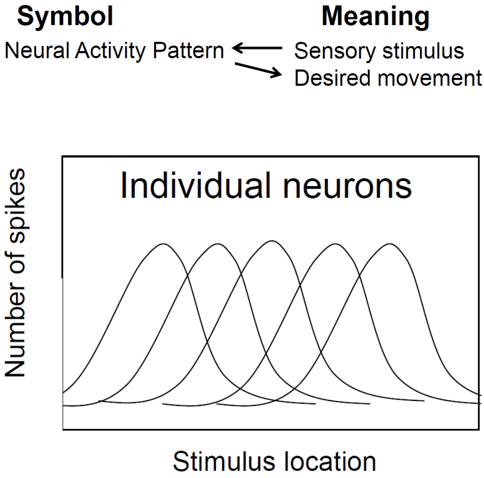
$$2^5 + 2^4 + 2^3$$

$$32+16+8 = 56$$

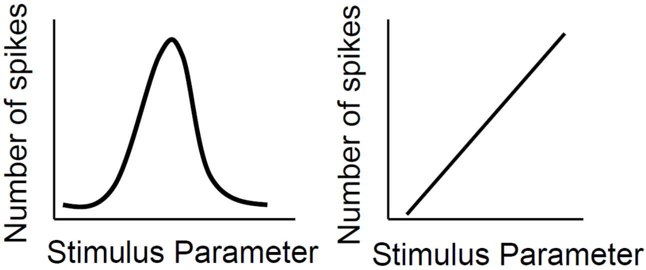
- Meaning



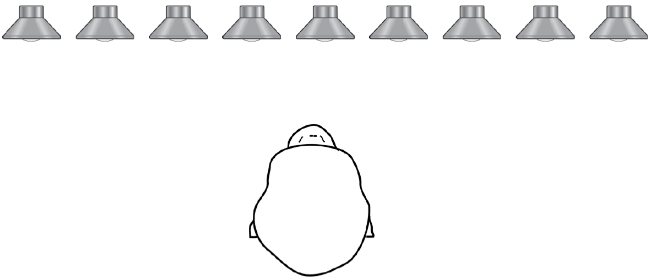
Neural Representations



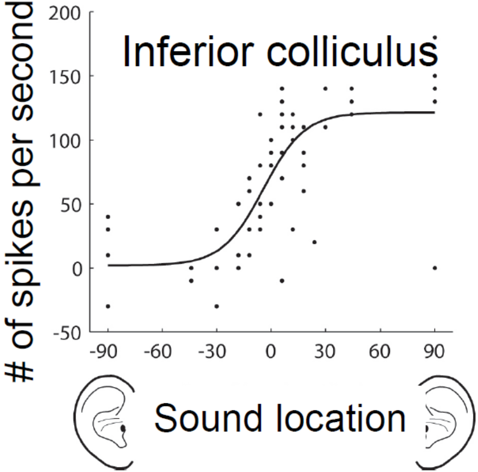
Maps/Tuning vs. Meters/Proportional Coding



Testing Auditory Coding

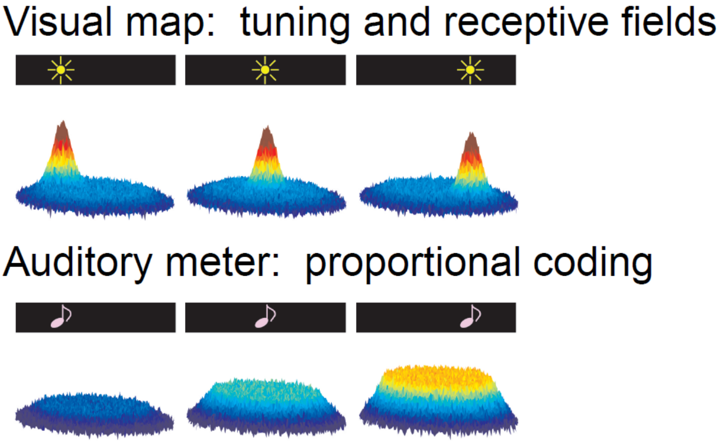


Coding of Sound Location



Werner-Reiss and Groh, J. Neurosci, 2008

Integration of Image and Sound Location Coding: Superior Colliculus



Werner-Reiss and Groh, J. Neurosci, 2008

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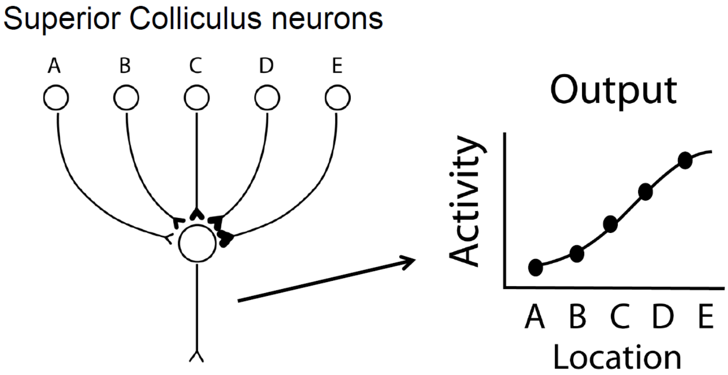
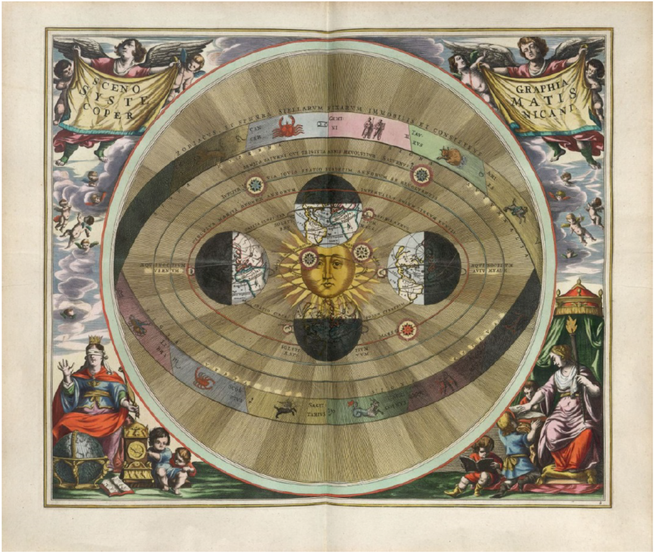


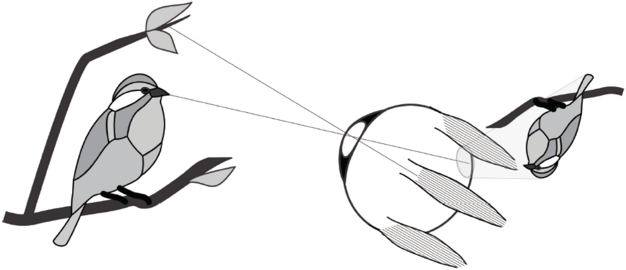
Outline

Ptolemy: Earth at center

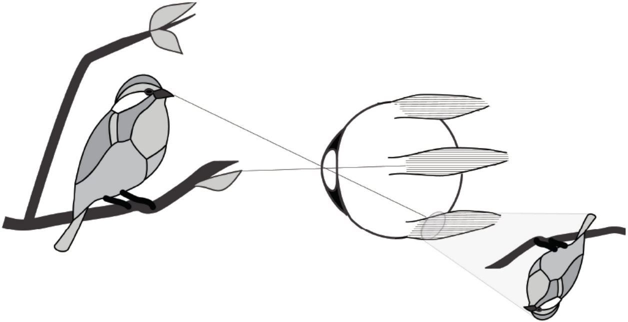
Ptolemy: Earth at center



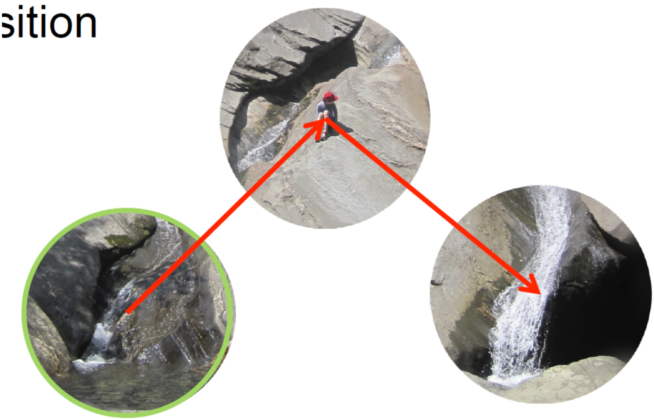
Location Constancy



Location Constancy

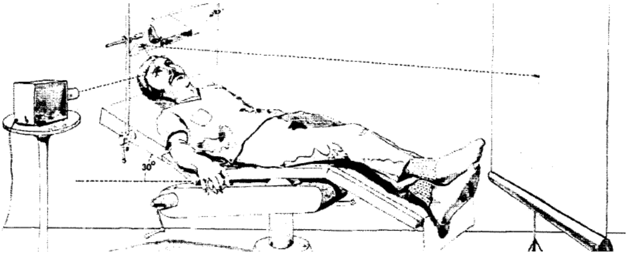


Synthesizing a Mental Visual Image



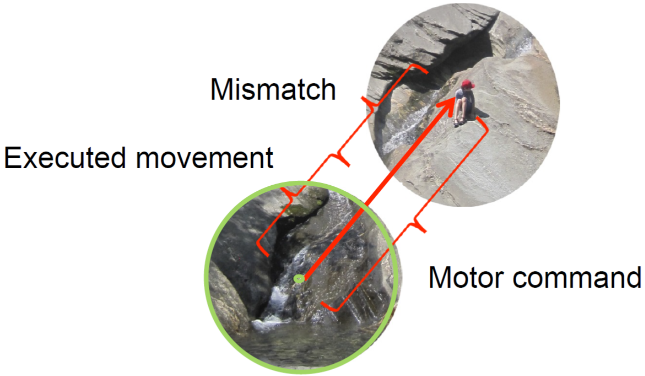
Synthesizing a Mental Visual Image

Stevens' Experiment

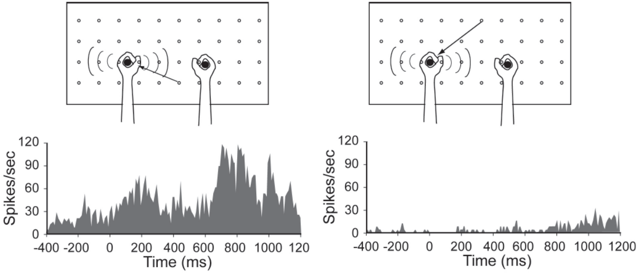


Stevens, J. K., R. C. Emerson, G. L. Gerstein, T. Kallos, G. R. Neufeld, C. W. Nichols and A. C. Rosenquist (1976).Vision Research 16(1): 93-99.

Stevens' Experiment

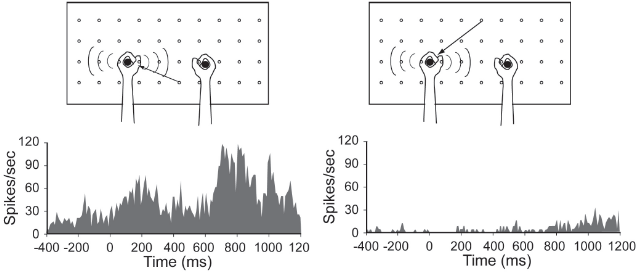


Coordinating Between Vision and Touch



Groh and Sparks, J. Neurophys. 1996

Coordinating Between Vision and Touch

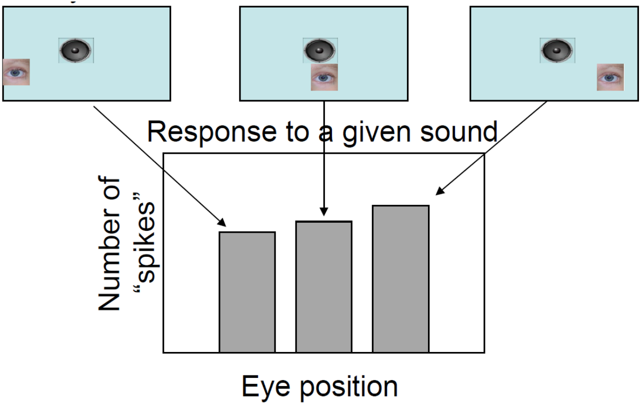


Groh and Sparks, J. Neurophys. 1996

The McGurk Effect

Video

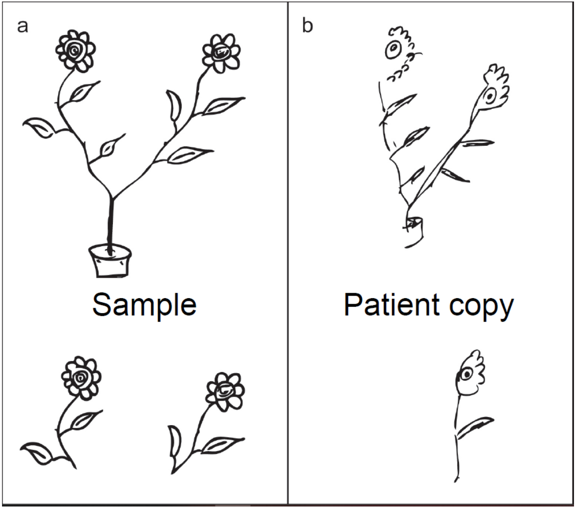
Coordinating Between Vision and Sound



Groh JM, Trause AS, Underhill AM, Clark KR, Inati S (2001) Eye position influences auditory responses in primate inferior colliculus. Neuron 29:509-518.

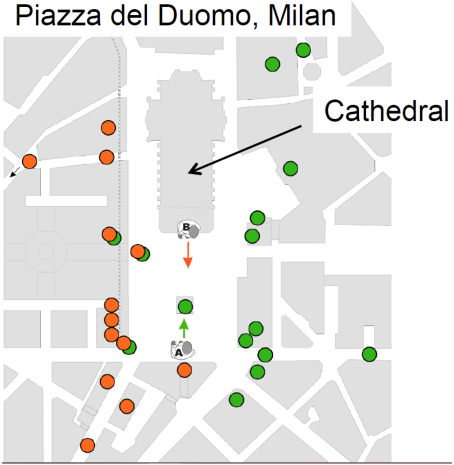
Outline

Lesions of Parietal Cortex



Marshall and Halligan J. Neurology 240:37-40(1993)

Parietal Cortex and Reference Frames



Bisiach and Luzatti "Unilateral neglect of representational space." Cortex 14 (1978):129-133.

Morris Water Maze Task

Hippocampal "place cell" Neurons are Sensitive to Location

Space and Memory are Linked

- Memory needed for navigation
- "Episodes" occur in spatial locations
- Location serves as an index to retrieve those memories

What is Right about Kant

- We do construct the space.
- The construction is not subject to our free will.
- Spatial experience is part of our intuition.

What is Wrong about Kant

- We do need experimental methods to investigate our cognitive faculties.
- Our spatial experience can be changed and learned.
- The spatial experience is not just inside of our mental world. It is out there in the real world.
- Perception can be a source of knowledge about the object world, although not necessarily reliable.
- Condition of possibility of spatial experience is not unique.
- We simply cannot stop at Kant. General level descriptions of knowledge are abstract, and we need details even for a comprehensive understanding.

Reference

- Jennifer M. Groh. (2014) *Making Space: How the Brain Knows Where Things Are*, Harvard University Press.
- S. Marc Breedlove, Neil V. Watson. (2016) *Behavioral Neuroscience*, 8th edition. Sinauer Associates, Inc. Publishers.
- Wikimedia Commons https://commons.wikimedia.org/
- Jennifer M. Groh's Slides on "Brain and Space"