Prof. Kay Tye
9.17
3-11-2013

Rat Barrel Cortex

Principles of Sensory Processing

Last week: Information theory, mutual info between stimulus and neural activity, rate coding.

"What does this cell's activity tell us about the world?"

The somatosensory and visual systems.

Somatotopic/retinotopic organization, cortical magnification, and the homunculus.

Adaptation and lateral inhibition.

Rat barrel cortex.

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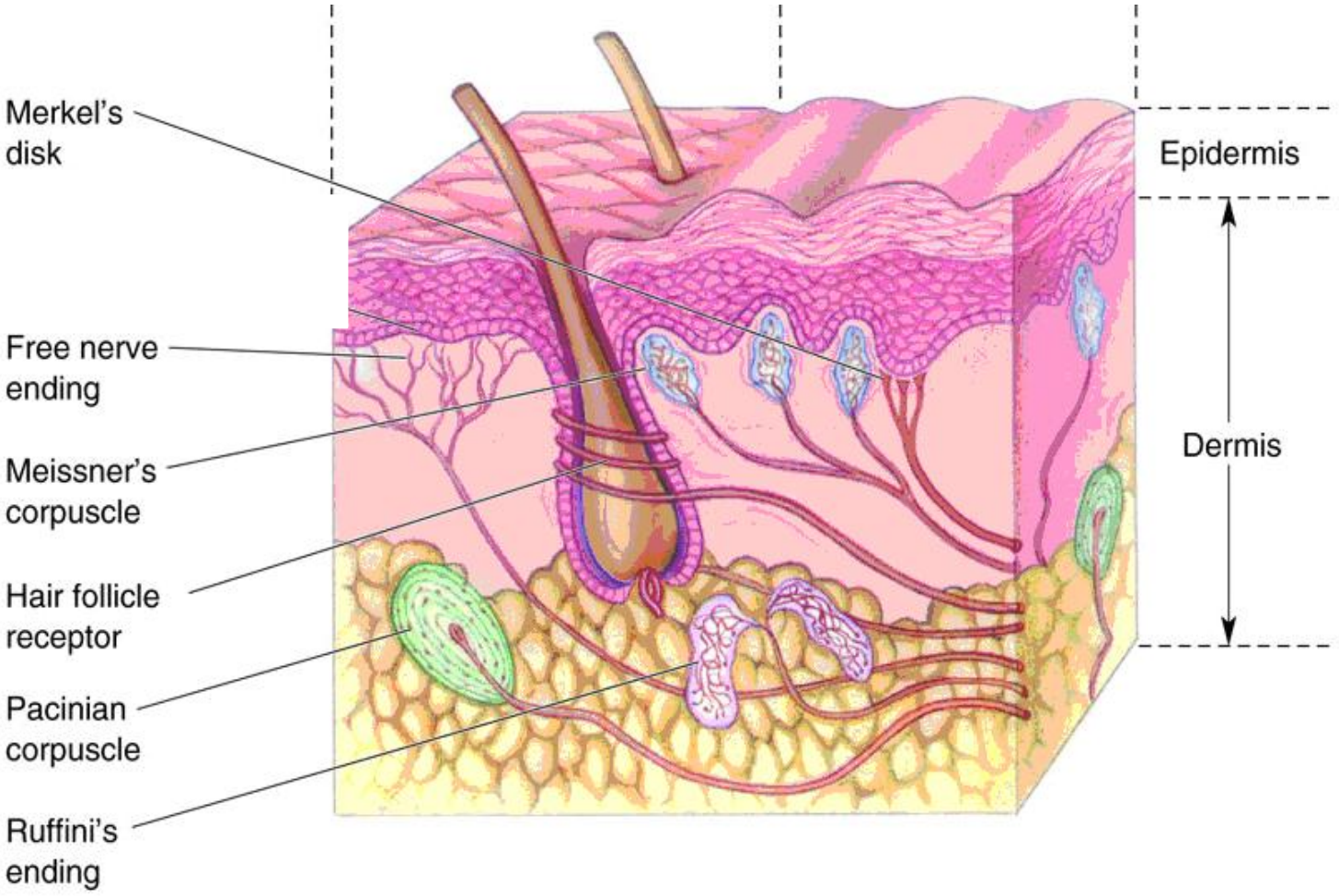
Introducing the somatosensory system

Different receptor types <=> different stimulus characteristics

Cutaneous receptors

Modality
temperature
pain

Structure
hair deflection

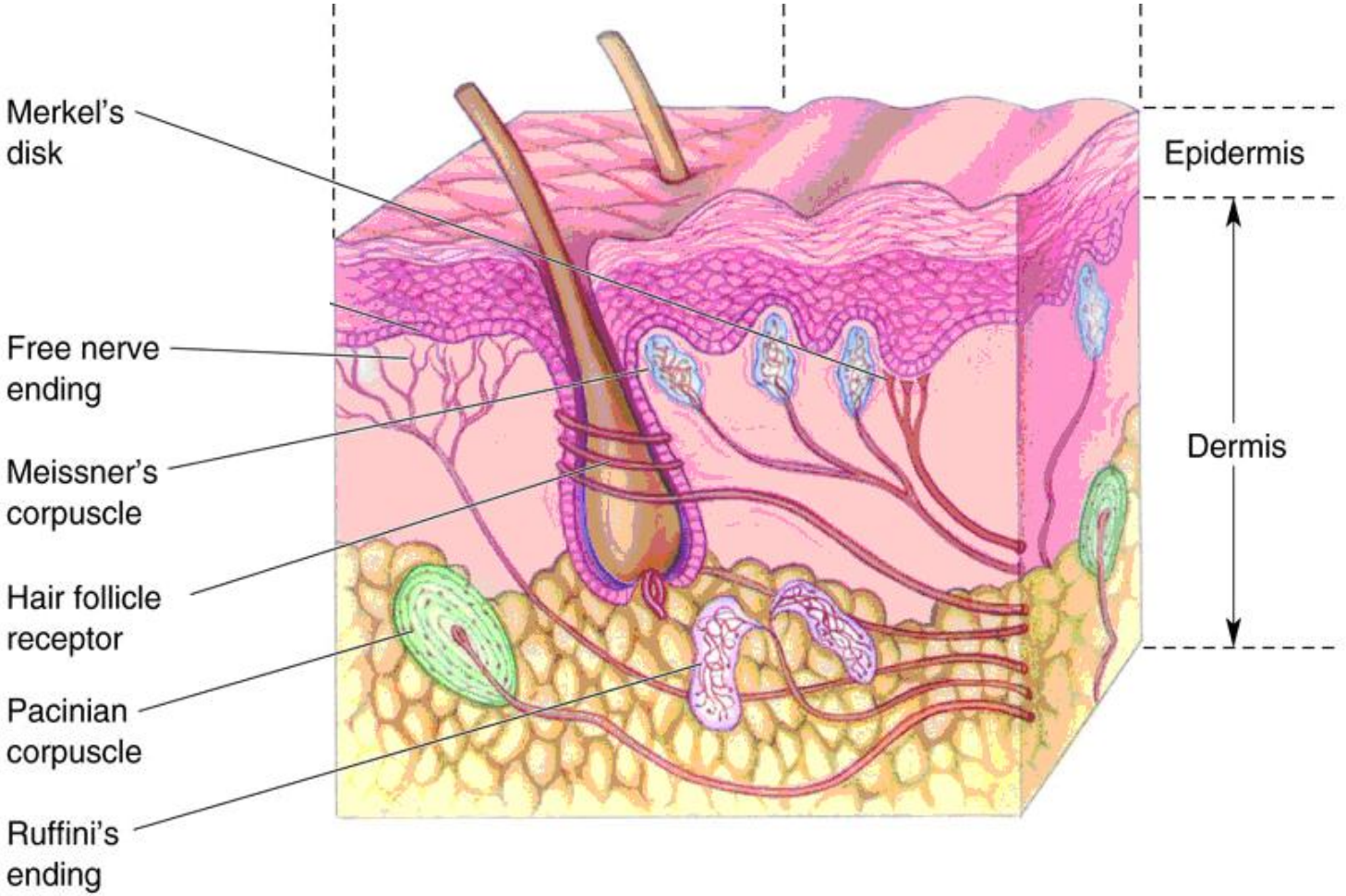


Introducing the somatosensory system

Different receptor types <=> different stimulus characteristics

Cutaneous receptors

Skin pressure
receptive field size
adaptation



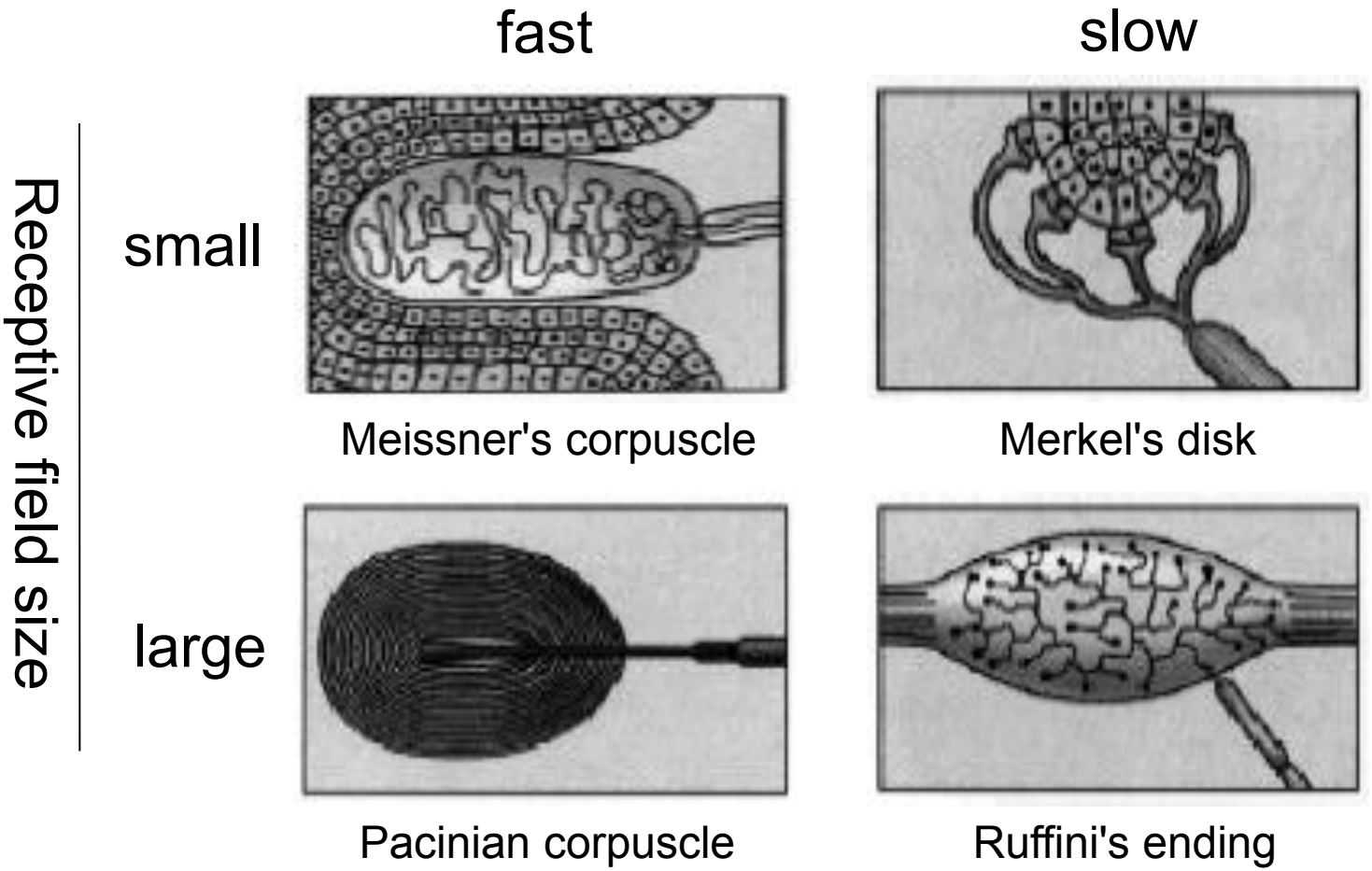
Receptive field sizes

"Figure 22-3 Mechanoreceptors in glabrous skin vary in the size and structure of their receptive fields" removed due to copyright restrictions. See Garner, Esther P., John H. Martin, and Thomas M. Jessel. "The Bodily Senses." Chapter 22 in *Principles of Neural Science*. Edited by Eric R. Kandel, James H. Schwartz, and Thomas M. Jessell. 4th ed, MGraw-Hill Companies, 2000. pp. 434.

Adaptation in cutaneous receptors

"Figure 21-1 The sensory systems encode four elementary attributes of stimuli—modality, location, intensity, and timing—which are manifested in sensation." removed due to copyright restrictions. See Garner, Esther P., and John H. Martin. "Coding of Sensory Information." Chapter 21 in *Principles of Neural Science*. Edited by Eric R. Kandel, James H. Schwartz, and Thomas M. Jessell. 4th ed, MGraw-Hill Companies, 2000, pp. 412.

Adaptation



Hair follicle receptors: Usually fast adaptation (see recitation papers)

Free nerve endings: Slow adaptation

Proprioception

tendon tension

muscle stretch

joint angle

Images removed due to copyright restrictions. See http://neurobiography.info/teaching.php?mode=view&lectureid=67&slide=1

Generally slowly adapting (like the roach?)

Figure 9.1 General organization of the somatic sensory system removed due to copyright restrictions. See "Cutaneous and Subcutaneous Somatic Sensory Receptors." Chapter 9 in *Neuroscience*. Edited by D. Purves, GJ Augustine, D Fitzpatrick et al. 2nd ed, Sinauer Associates, 2001.

Receptor: Cell body in dorsal root ganglion or trigeminal ganglion.

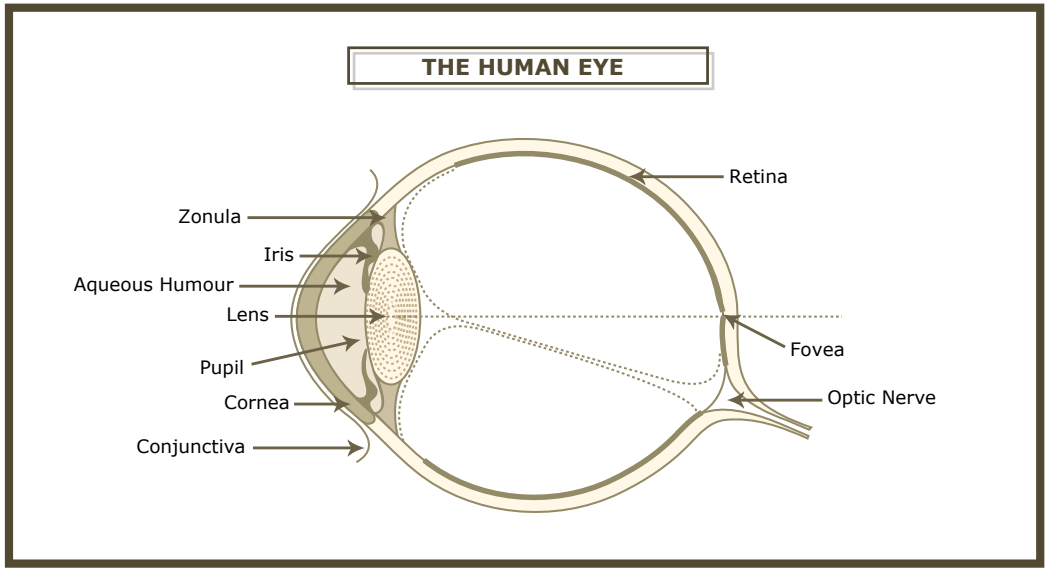
Brainstem: Dorsal column nuclei or trigeminal nucleus.

Thalamus: Ventral posterior nucleus.
ventral posterolateral (VPL): body
ventral posteromedial (VPM): face

Cortex: Primary somatosensory (S1)

Note **contralateral** body surface represented in thalamus and cortex.

Introducing the visual system



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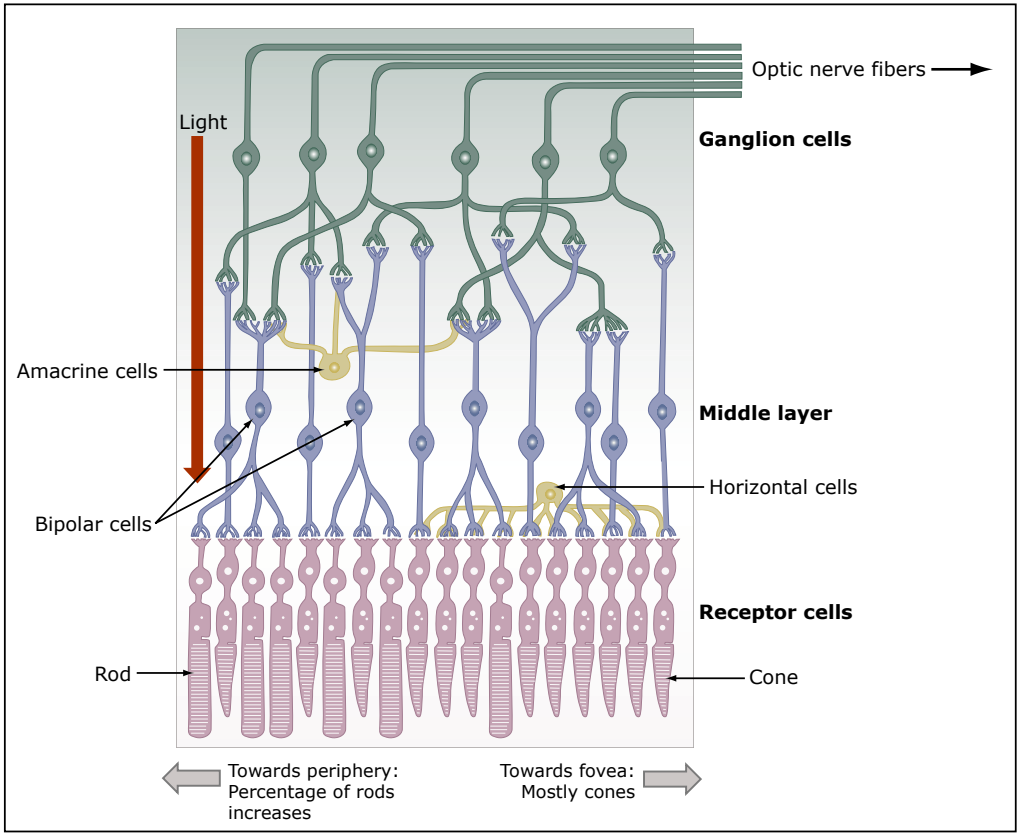

Image by MIT OpenCourseWare.

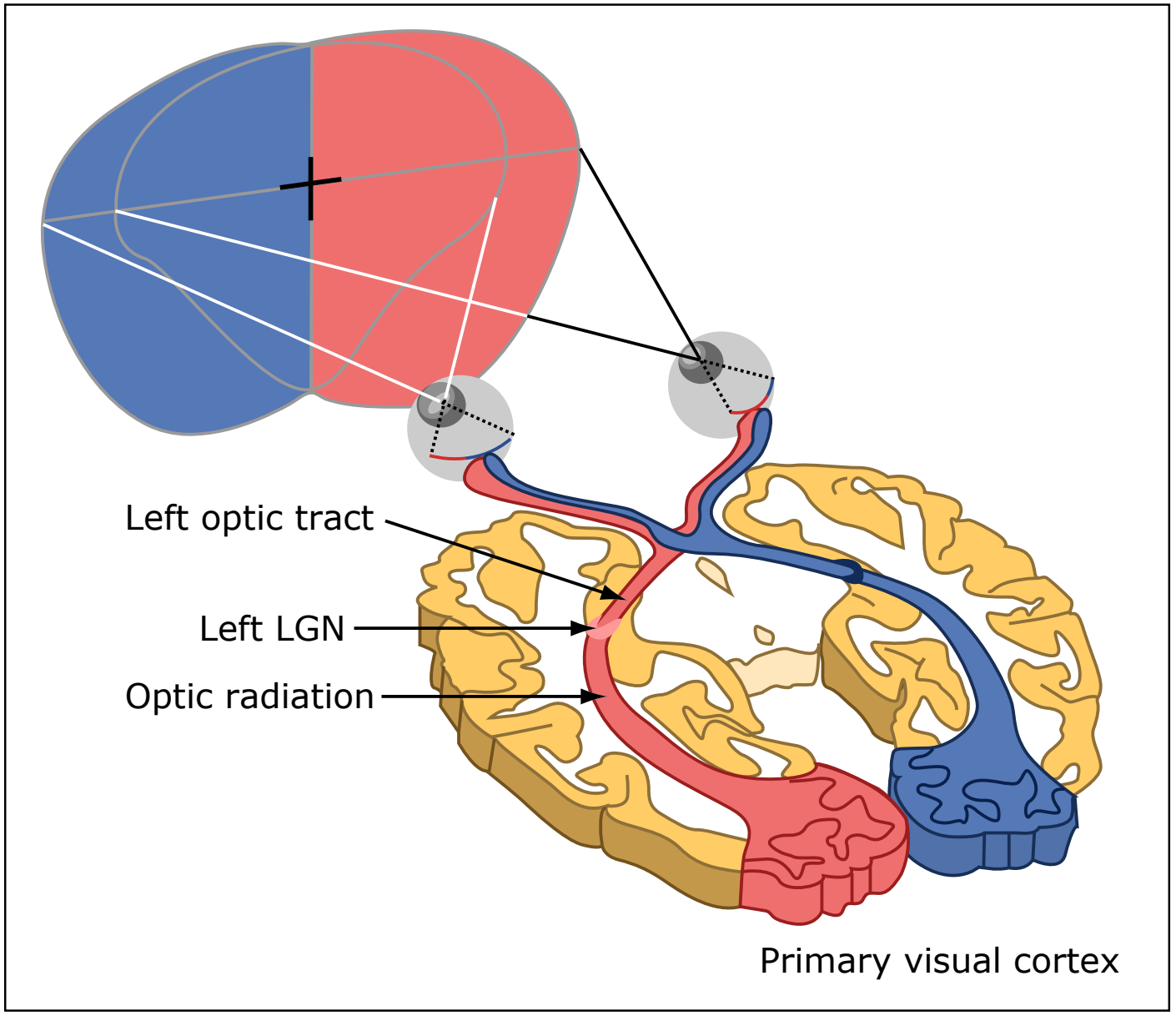

Image by MIT OpenCourseWare. After Figure 10-4b in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. MD: Lippincott Williams & Wilkins, 2007. ISBN: 9780781760034.

Note **contralateral** visual hemisphere represented in thalamus and cortex.

Last week: Information theory, mutual info between stimulus and neural activity, rate coding.

The somatosensory and visual systems.

Somatotopic/retinotopic organization, cortical magnification, and the homunculus.

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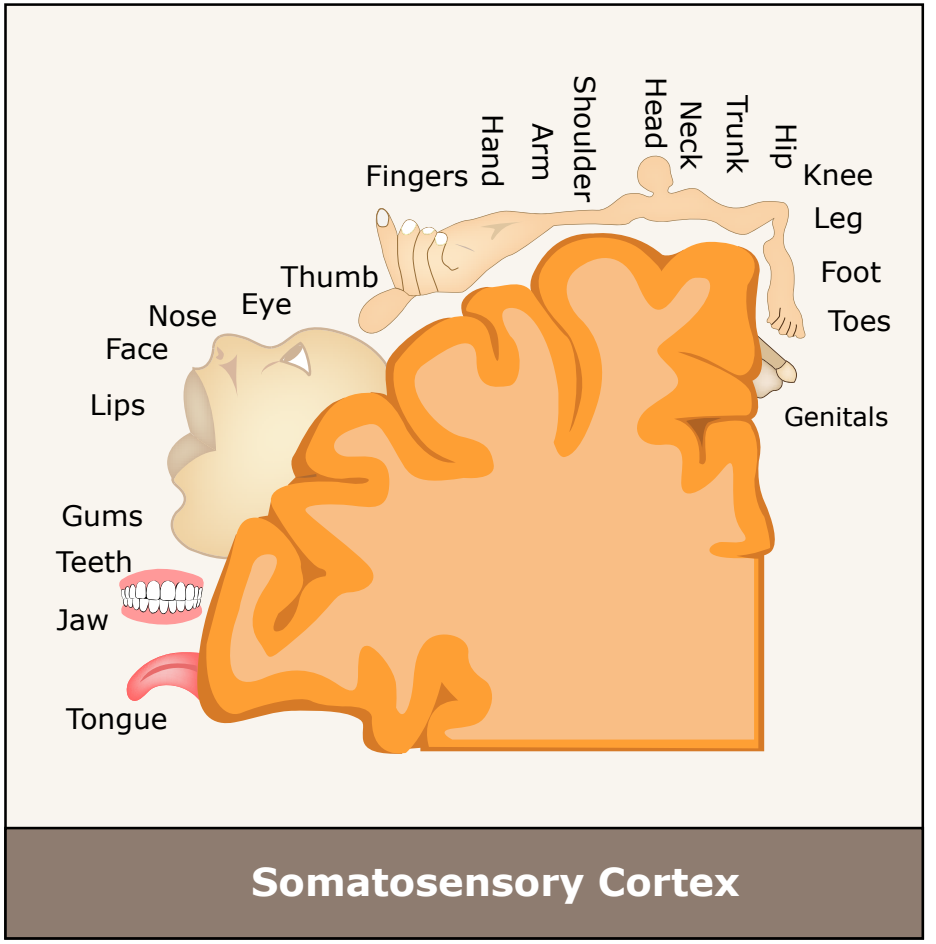
Rat barrel cortex.

Principle of sensory coding:
Somatotopic (somatosensory)/ Retinotopic (visual) organization

Adjacent points on the sensory surface are represented at adjacent locations in the brain.



Principle of sensory coding:
Cortical magnification of high-acuity areas

High acuity parts of the sensory surface are represented by larger areas of cortex than low acuity parts.

Fovea:
5% of visual field
40% of V1

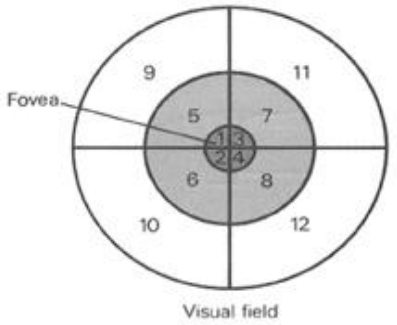
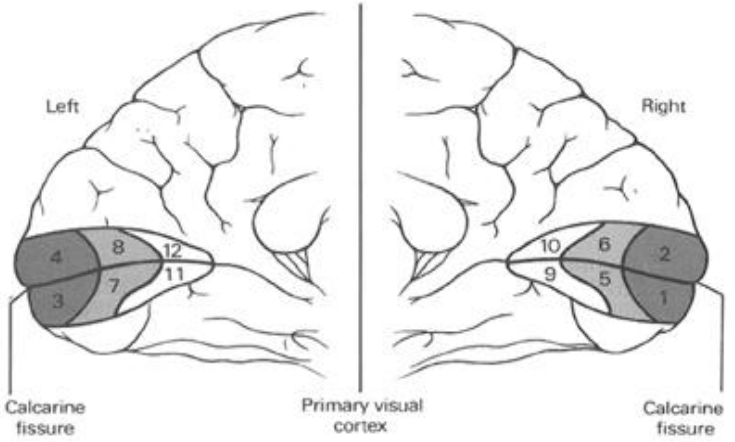


Fig. 7-10. Visual acuity as a function of position on the retina removed due to copyright restrictions. See http://michaeldmann.net/mann7.html.



Courtesy of Askenasy and Lehmann. Used with permission. CC BY. Source: Askenasy, Jean and Joseph Lehmann. "Consciousness, brain, neuroplasticity." *Frontiers in Psychology* 4 (2013): 412. doi: 10.3389/fpsyg.2013.00412.

What is “acuity”?

Ability to discriminate between close, but different, stimuli.

Two-point discrimination

Image of two-point discrimination test removed due to copyright restrictions.

Meet the Homunculus

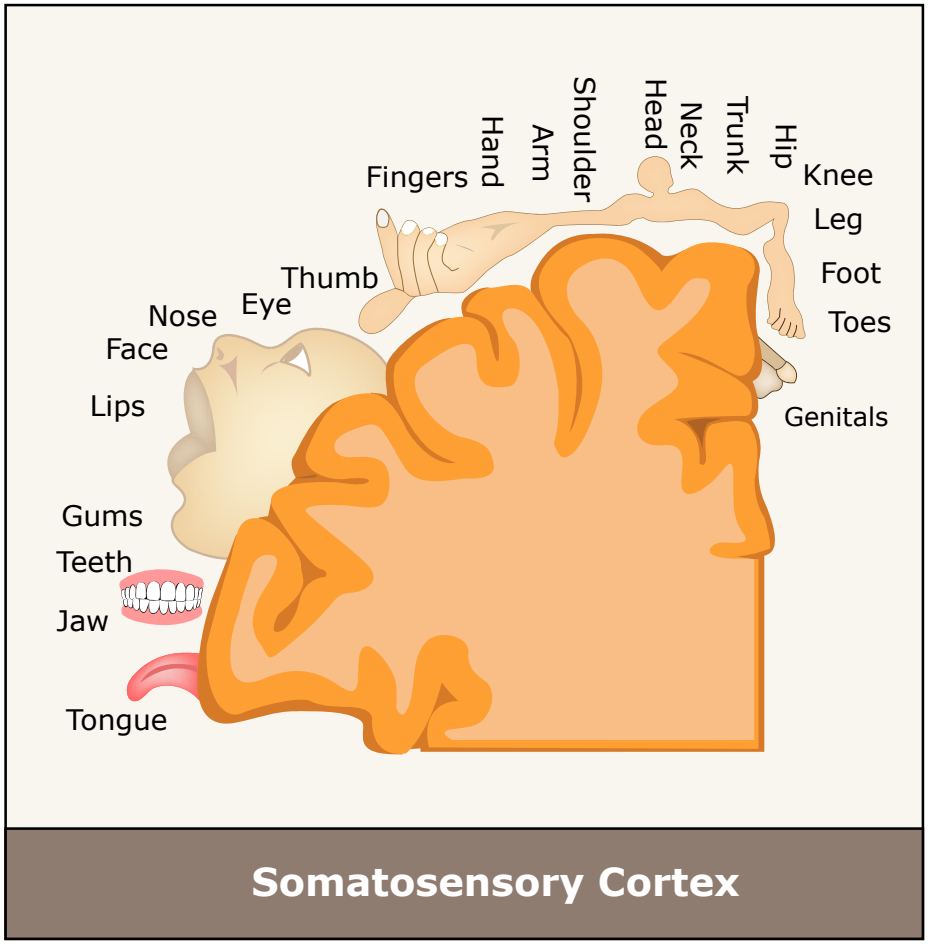
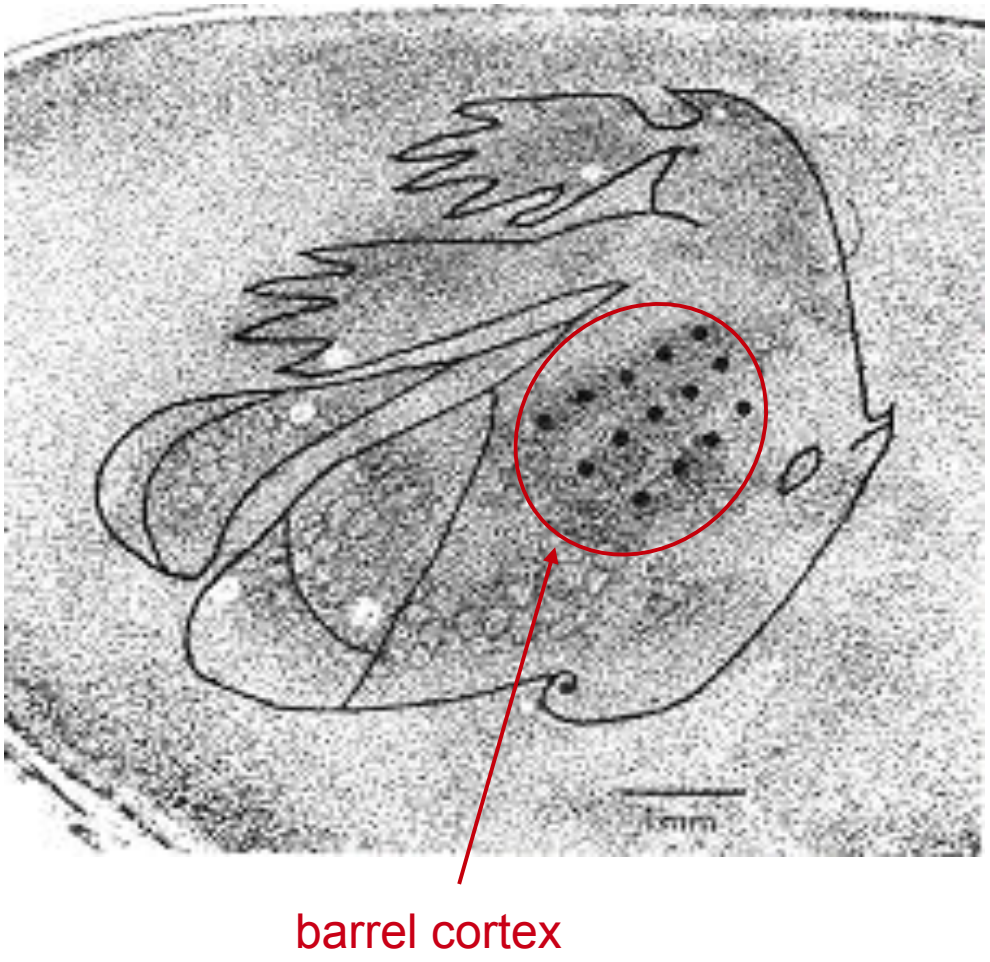


Image by MIT OpenCourseWare.

"Figure 20-5 Different species rely on different parts of the body for adaptive somatosensory information" removed due to copyright restrictions. See Kandel, Eric R. "From Nerve Cells to Cognition: The Internal Cellular Representation Required for Perception and Action." Chapter 20 in *Principles of Neural Science*. Edited by Eric R. Kandel, James H. Schwartz, and Thomas M. Jessell. 4th ed, MGraw-Hill Companies, 2000, pp. 387.



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Adaptation and lateral inhibition.

Rat barrel cortex.

Adaptation, more generally: Detect **novelty.**

visual cortex

current injection

Fig. 3. Two distinct firing patterns are evident in CP neurons A and B removed due to copyright restrictions. See Locke, Rachel E., and Jeanne M. Nerbonne. "Role of Voltage-Gated K+ Currents in Mediating the Regular-Spiking Phenotype of Callosal-Projecting Rat Visual Cortical Neurons." *Journal of Neurophysiology* 78, no. 5 (1997): 2321-35.

Rachel E. Locke and

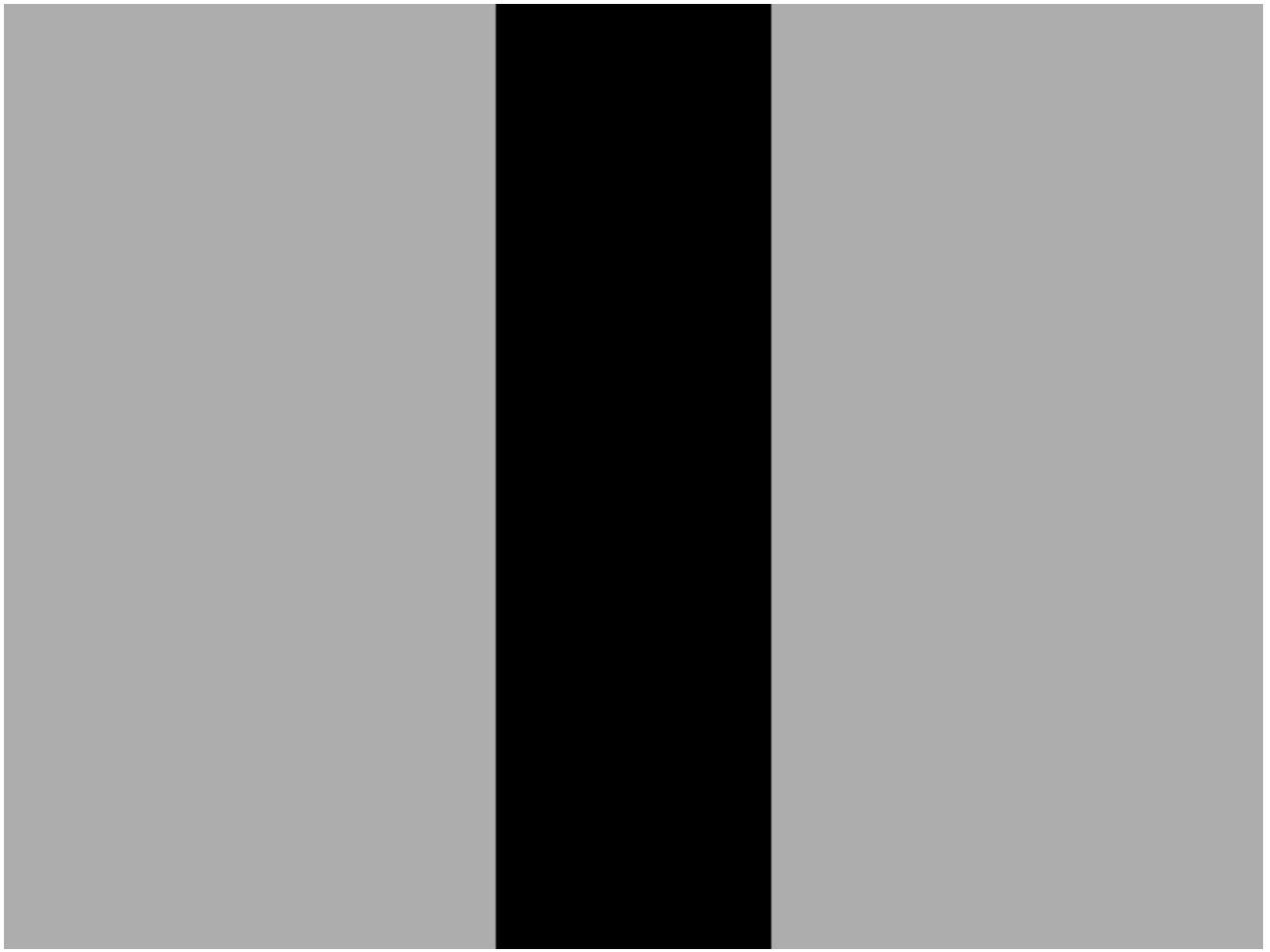
Jeanne M. Nerbonne, 1997

Principle of sensory coding: Reduce redundancy

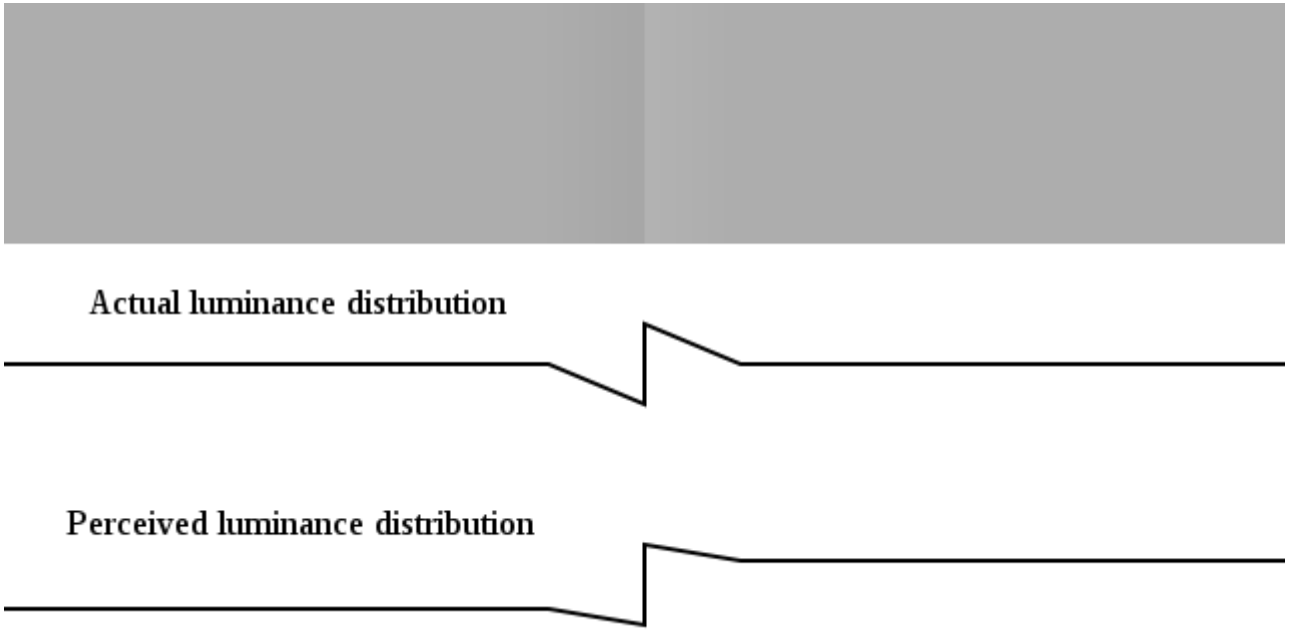
Principle of sensory coding:
Encode **contrast** (the “surprising bits”)

Craik-O'Brien-Cornsweet illusion

Craik-O'Brien-Cornsweet illusion



Craik-O'Brien-Cornsweet illusion



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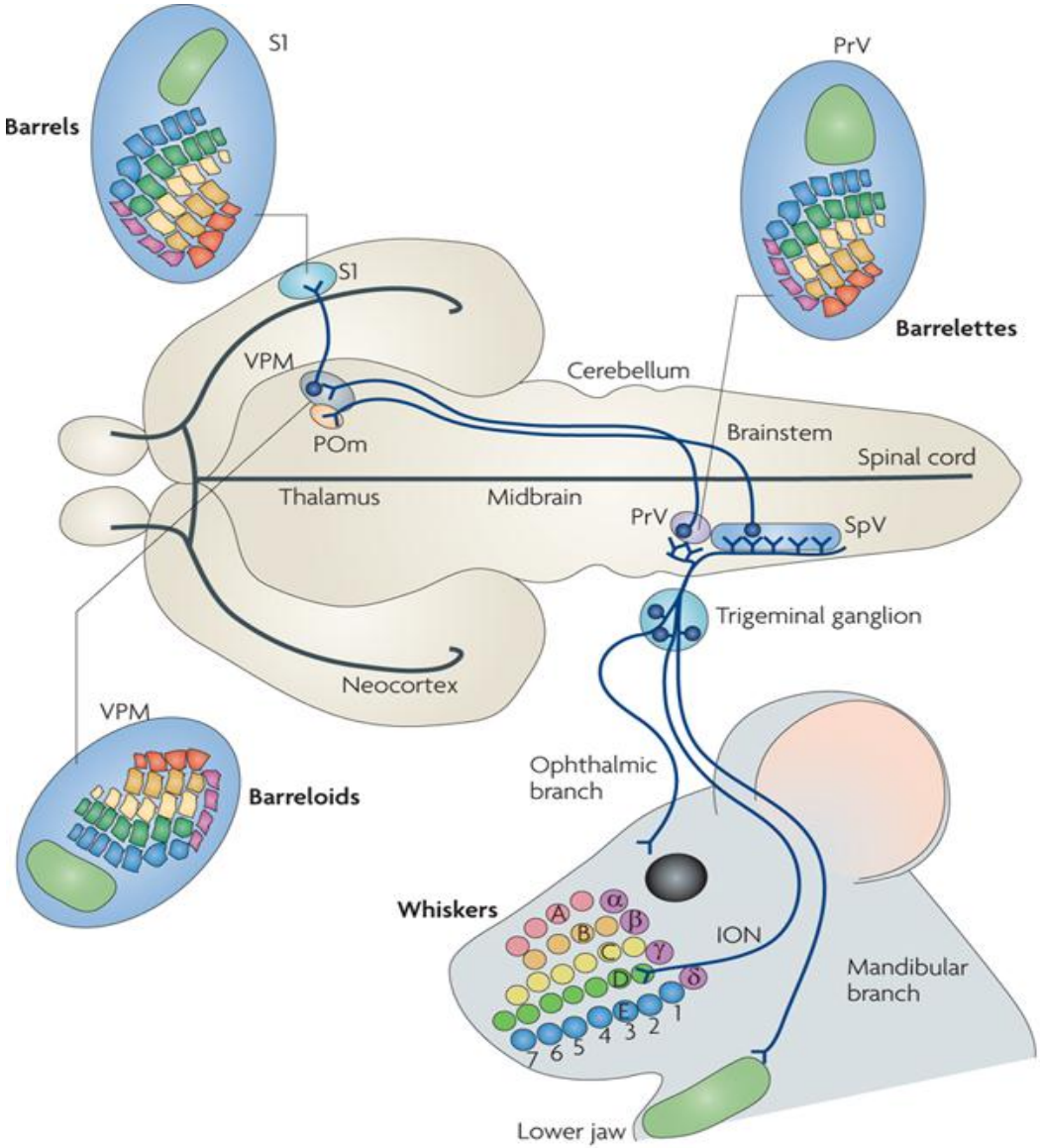
Somatotopy is preserved from face to cortex



Trigeminal ("three twins") ganglion

Brainstem

Thalamus (contraleral)

Primary somatosensory cortex (S1) (contralateral)

Rats “whisk” to actively sense their environment

5 – 10 Hz
Tracked by high-speed video

Movie screenshot removed due to copyright restrictions. See Supplemental Movie. "Tracking Whisker and Head Movements in Unrestrained Behaving Rodents." *Journal of Neurophysiology* 93, no. 4 (2005): 2294-301.

The barrel cortex of the rat

Know this!

Rows A through E (dorsal to ventral)
Whiskers numbered posterior to anterior
Posterior inter-row whiskers with special names, or Greek characters

"Figure 23-9 The representation of whiskers in the somatosensory cortex of the rat" removed due to copyright restrictions. See Gardner, Esther P., amd Eric R. Kandel. "Touch." Chapter 23 in *Principles of Neural Science*. Edited by Kandel, Eric R., James H. Schwartz, and Thomas M. Jessell. 4th ed, MGraw-Hill Companies, 2000. pp. 462.

Things to investigate:

Whisker displacement vs. velocity? (adaptation)

For the most part, tap whisker lightly – Armstrong-James and Fox

Size of receptive field – one whisker or multiple?

Somatotopy?

Direction selectivity?

9.17 Systems Neuroscience Lab

Spring 2013