VISION

John Gabrieli

Melissa Troyer

9.00

Objectives

- **Purposes of vision**
- **Problems that the visual system has to overcome**
- **Neural organization of vision**

Human Perceptual Abilities

- **Detect a candle, 30 miles away, on a dark, clear night**
- **Detect cochlear displacement equal to the width of a hydrogen atom**
- **Taste one teaspoon of sugar even when it is mixed into two gallons of water**
- **Smell a drop of perfume diffused into the space of a three bedroom apartment**

PURPOSES OF VISION

1. OBJECT RECOGNITION

2. NAVIGATION

PURPOSES OF VISION

1. OBJECT RECOGNITION (what)

link a unique image to what we know

objects have many possible versions

- **face - illumination, angle, distance, expression, shadows, occlusion**
- **letters - fonts, handwriting**
- **body - all the ways a person stands**

problems of equivalence **(same shape, different viewing conditions)**

- **size constancy**
- **shape constancy**
- **position constancy**

problems of generalization **(different shape, same object or type of object)**

- **addition or deletion of optional parts**
- **changes in the shapes of parts**
- **changes in spatial relations among parts**

problems of impoverished input **(partial information)**

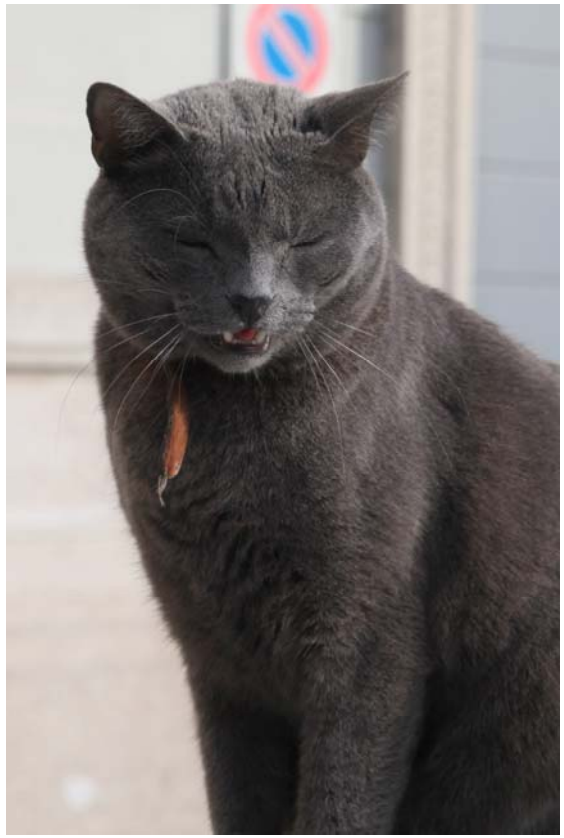
- **occlusion**
- **poor lighting**
- **multiple eye fixations**

2. NAVIGATION (where)

go through space, track

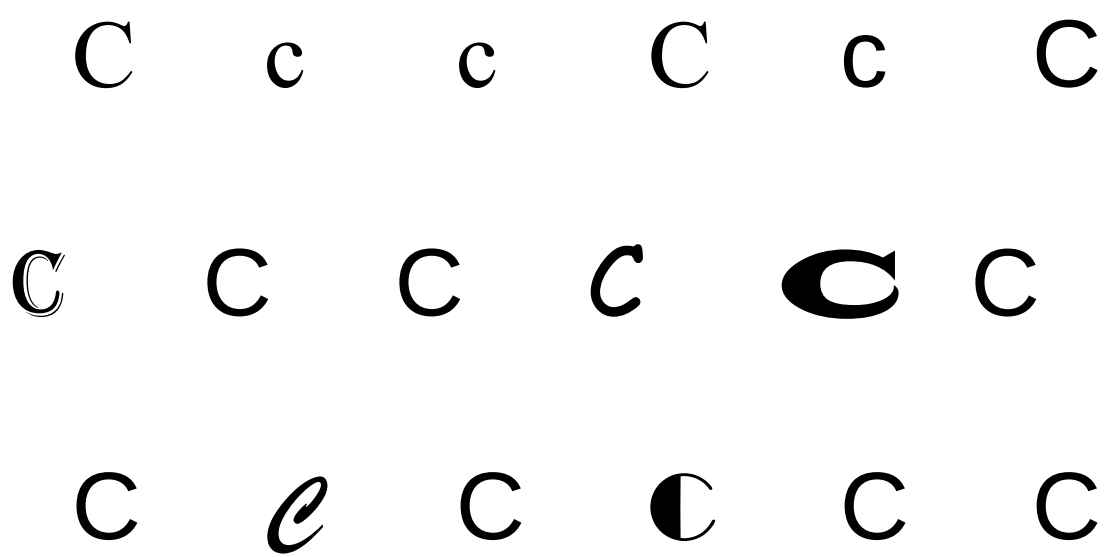
- **sources of movement - eyes, head, body, objects**

Shape constancy



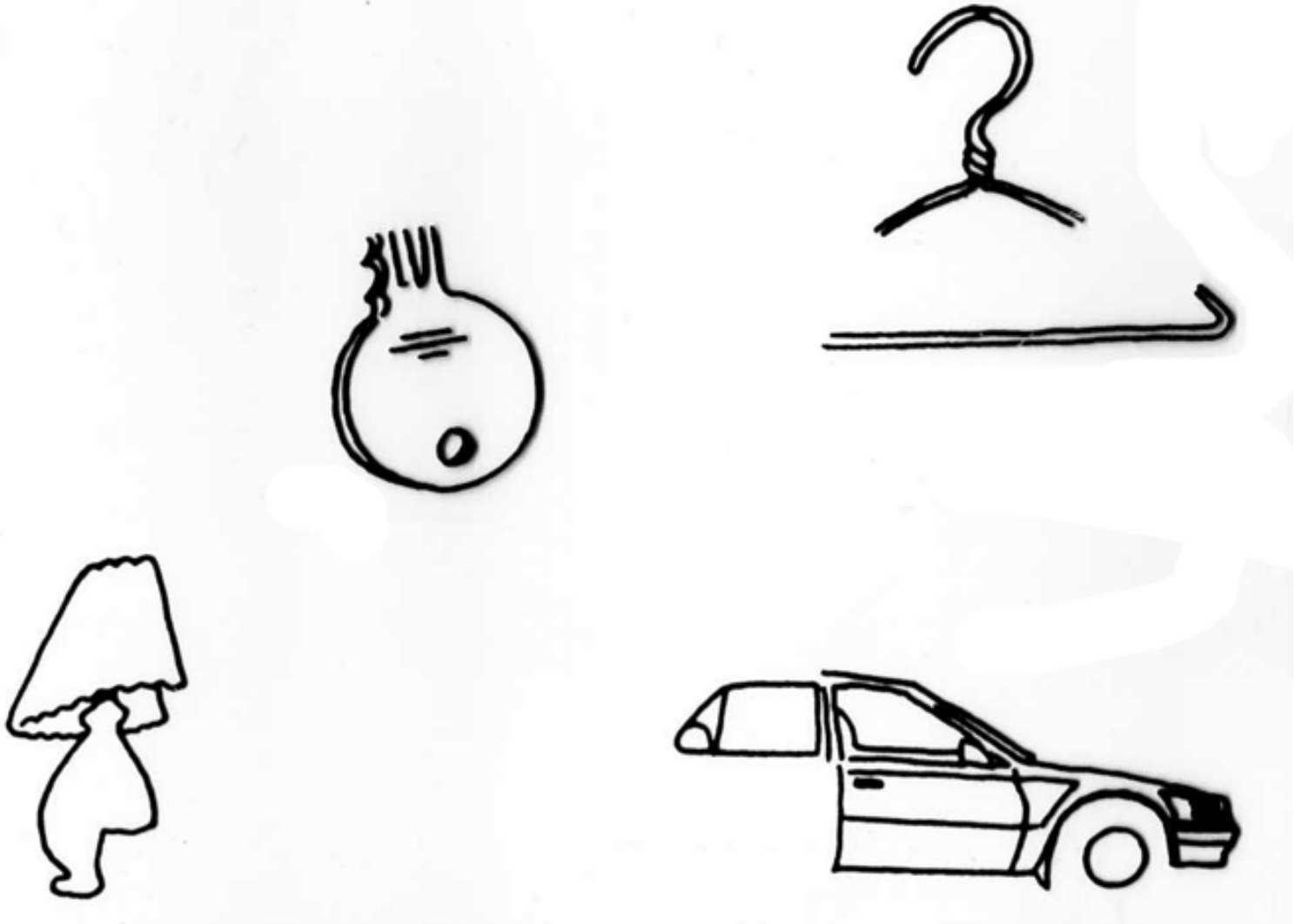
Position constancy

Problem of generalization



Various representations of C - yet in all cases, we recognize the symbols as C.

Problem of impoverished input



A variety of objects that are missing parts or are partially occluded.

Perceptual invariance

Image of atypical objects (i.e. a pink elephant, a lined image of Salvador Dali, a plaid apple, and a wooden artist's model) removed due to copyright restrictions.

Vision

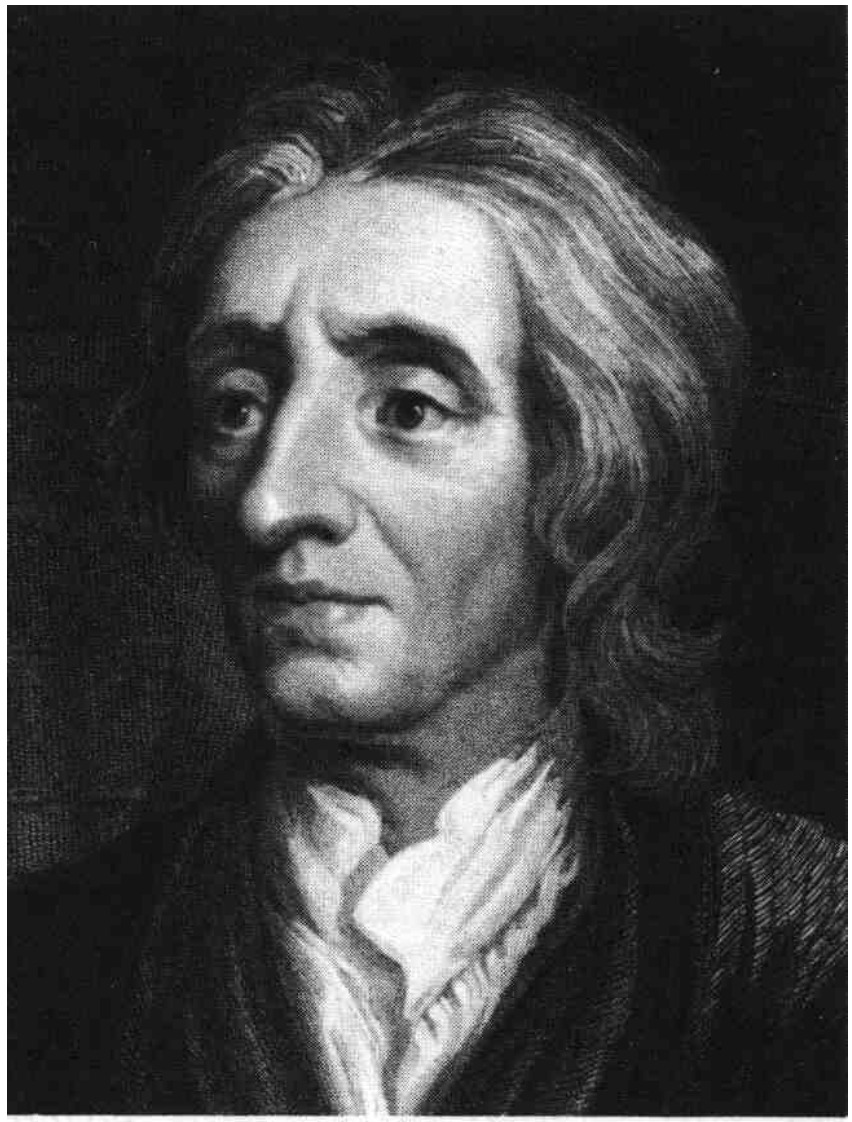
- **Seeing**
- **Retina**
- **Cortex**

John Locke and Perception
tabula rosa (blank slate)

Let us suppose the mind to be, as we say, a white paper void of all characters, without any ideas: - How comes it to be furnished? Whence comes it by that vast store which the busy and boundless fancy of man has painted on it with an almost endless variety?

Whence has it all the materials of reason and knowledge?

To this I answer, in one word. EXPERIENCE. In that all our knowledge is founded; and from that it ultimately derives itself (Locke, 1690).



Perception

- **Objectivist view (“blank slate” view)**
  - **Our senses precisely, and accurately, reflect the physical world. They provide us with a true, complete, and accurate representation.**
- **Subjectivist view (Gestalt)**
  - **There is no inherent organization to the world, but rather, our brain organizes our perceptions, and we therefore believe the world is, itself, organized.**

Gestalt Principles

- **In this view, our perceptions may be likened to the output of a piano: these perceptions are evoked by the world, much as the piano melody is evoked by the pianist.**
- **A piano can only emit its own notes – it can't sound like a clarinet. Similarly perceptions are evoked by the world, but they generate experiences limited by the neural structures of our brain.**
- **Our percepts are evoked by nature; but they are personal and not a copy of nature.**

Vision

- **vision is an *interpretation* of the world around us**
- **visual illusions demonstrate the gap between what is out there and how our minds and brains interpret what is out there**
- **illusions are rare because our minds and brains have evolved to have interpretations that almost always work brilliantly in our environment without us having to think about it**

Size Constancy (E.G. Boring)

Photos demonstrating size constancy removed due to copyright restrictions.
See: Perception Lecture: Depth, Size, and Shape.

Grouping

Queen's Jubilee Gift

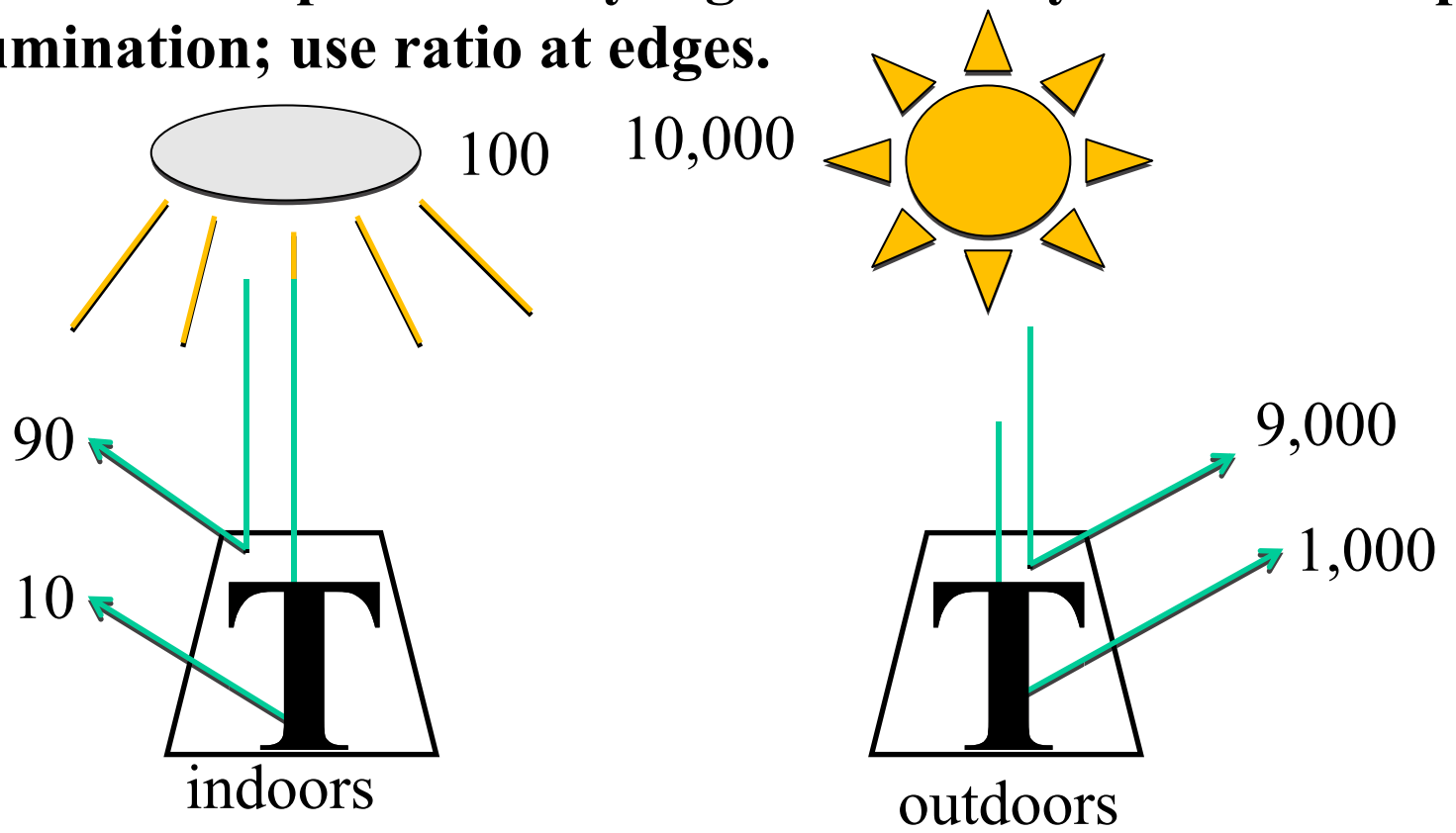
Goldstein's book, Perception

The Problem of Brightness Constancy

- ambient brightness varies greatly
  - outdoor sun, cloud
  - indoor, bright, less bright
  - shadows
  - - piece of coal in sunlight may reflect 10x as much light as snow in the shade
- but we recognize things by their brightness
- so we use unconscious inference to perceive an object's brightness

Hering, Wallach:

Observer simply computes luminance ratios across edges and does not need to perform any high-level analyses about shape or illumination; use ratio at edges.



Black "T" is 10x brighter outdoor than white paper indoor

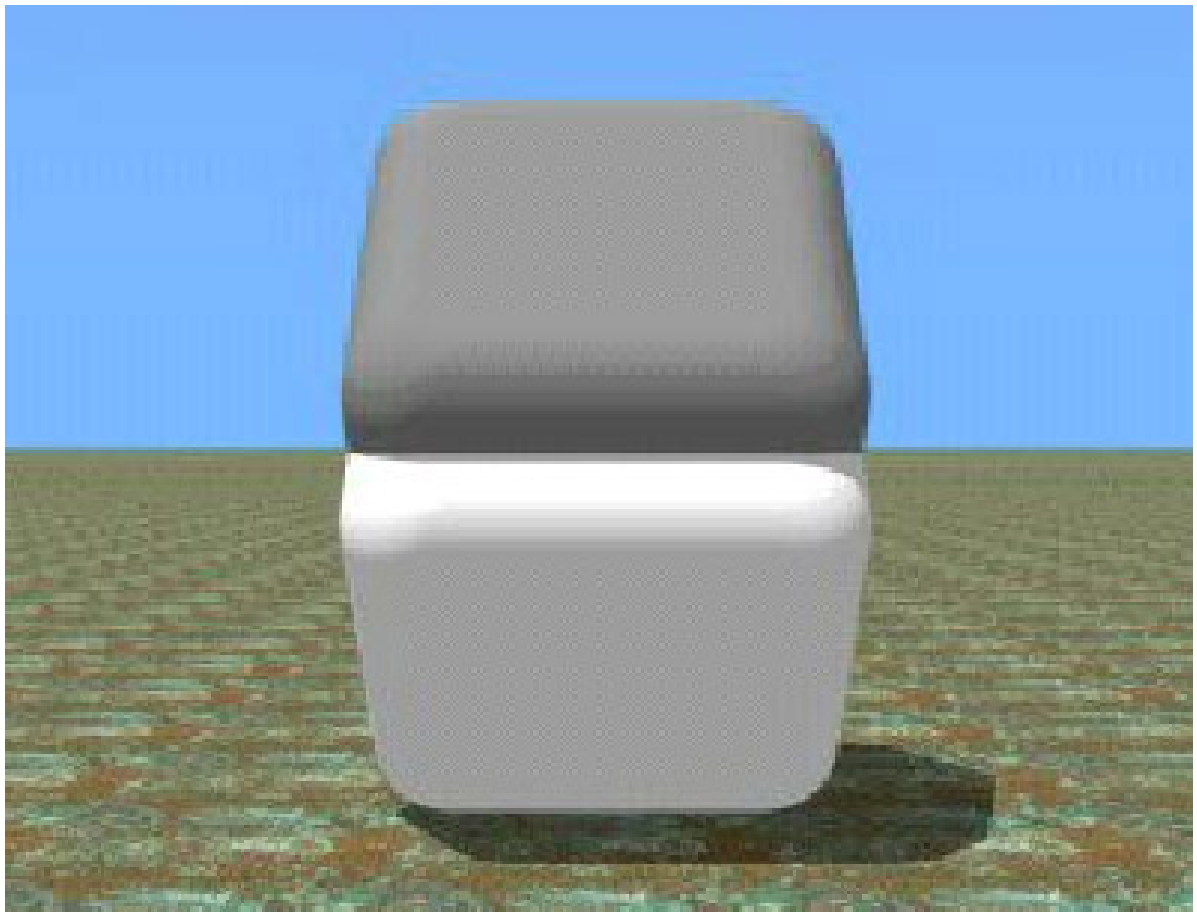
Lightness Perception

(Lotto and Purves)

Images removed due to copyright restrictions.
See: handprint.com

Interpretation
The essence of Perception

The perceptual importance of luminance ratios at edges:



Craik-O'Brien-Cornsweet Illusion

The perceptual importance of luminance ratios at edges:

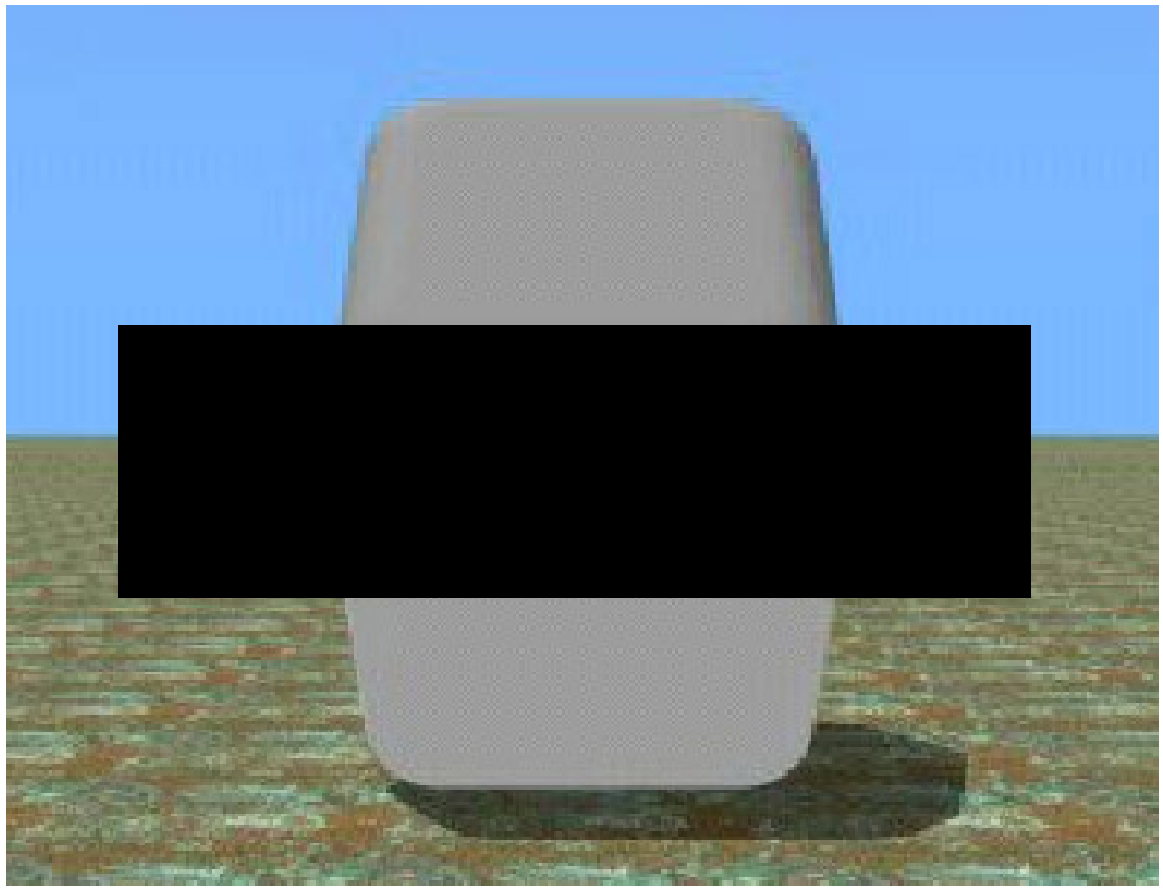


Image by R. Beau Lotto at www.lottolab.org. Used with permission.

Craik-O'Brien-Cornsweet Effect

Additional images of the Craik-O'Brien-Cornsweet Effect removed due to copyright restriction.
See: Wikipedia

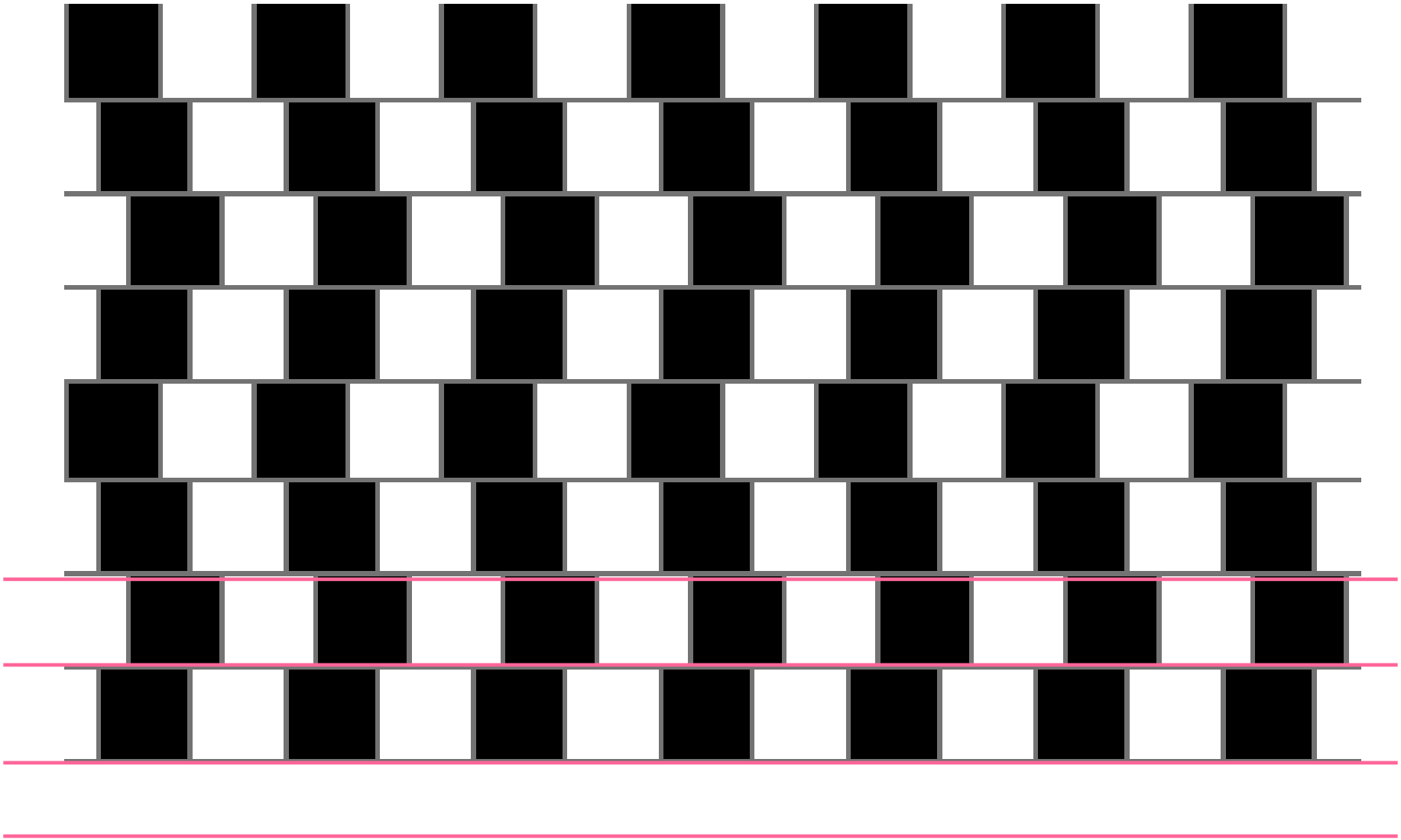
Visual System Interprets Images

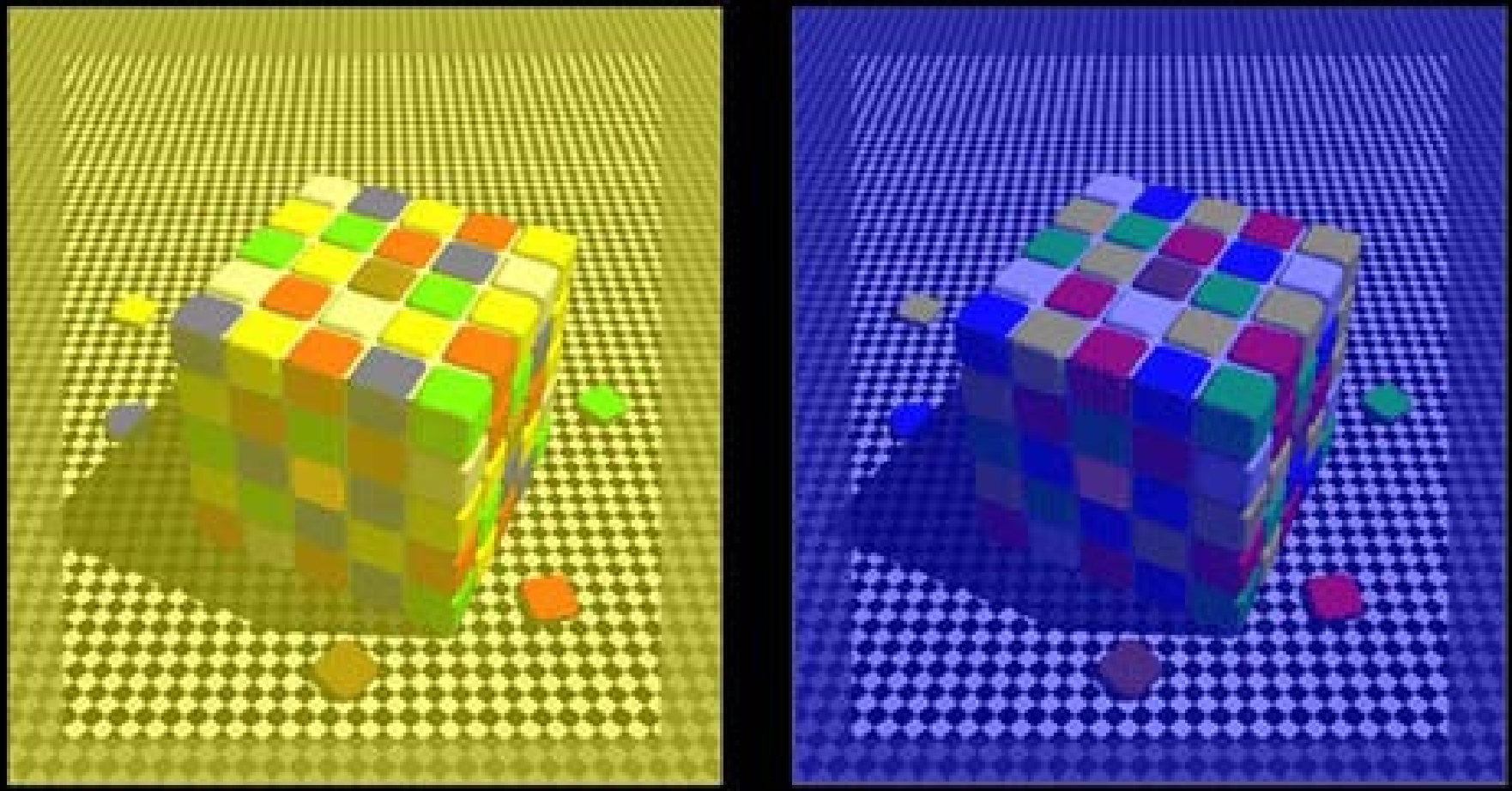
Image of Craik-O'Brien-Cornsweet effect from ""Natural image statistics mediate brightness "filling-in," Daxin and Bex, Proc. Roy Soc. (2003), removed due to copyright restrictions.

Some other perceptual illusions

Images of Fraser's Spiral removed due to copyright restrictions.
See: Fraser's Spiral at Michael Bach's "Visual Phenomena & Optical Illusions"

Café Wall Illusion





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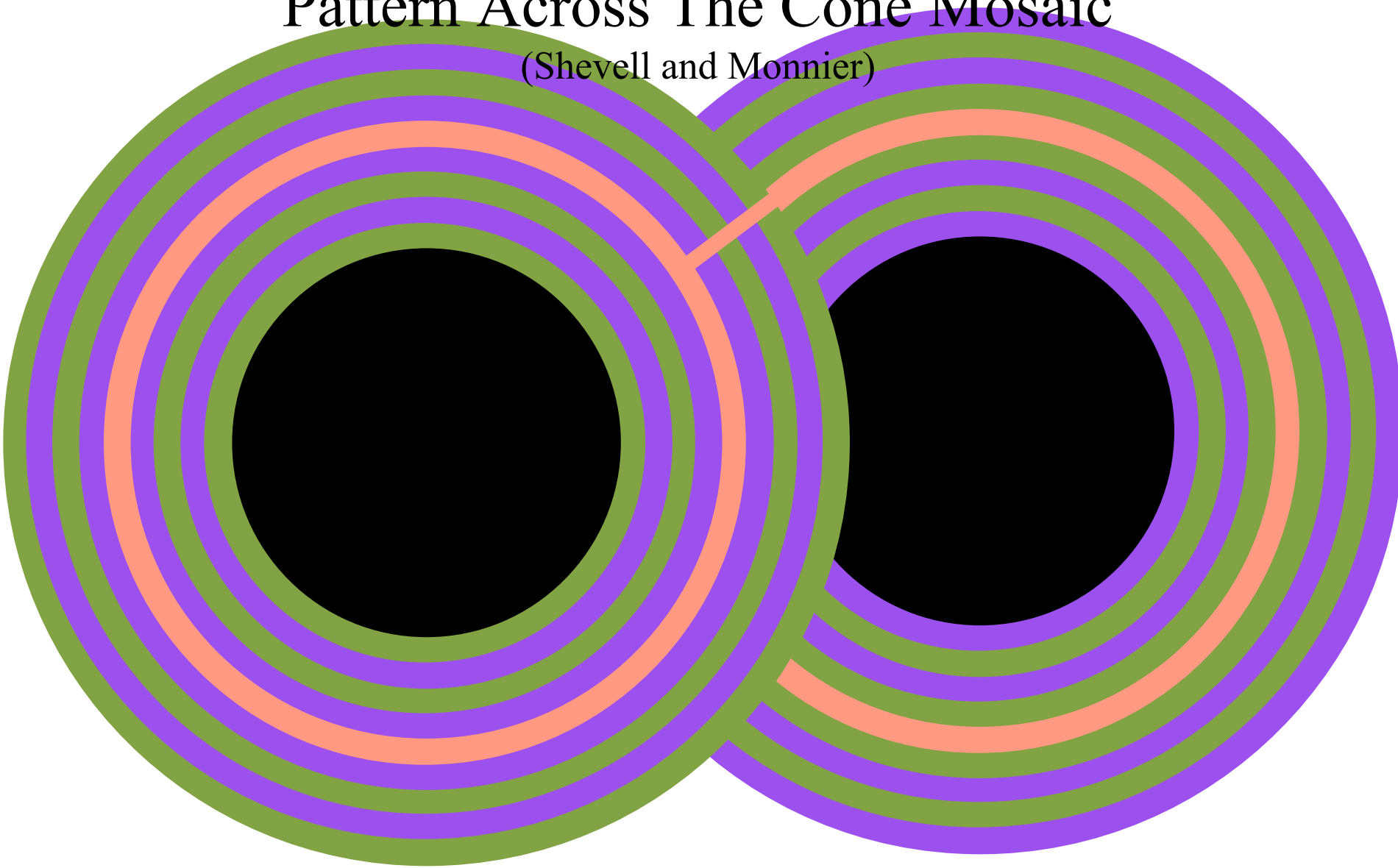
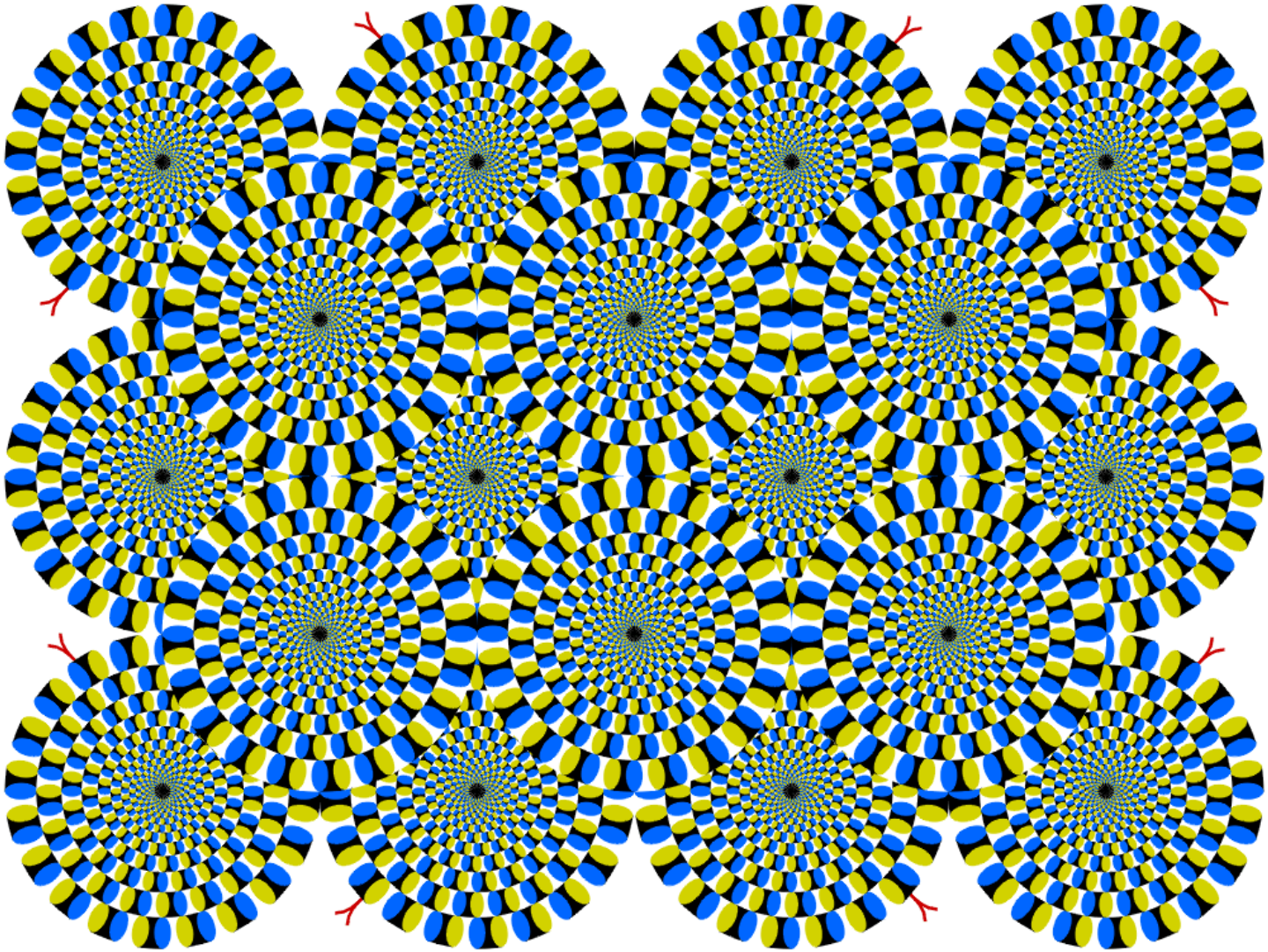
Color Appearance Depends On The Spatial Pattern Across The Cone Mosaic

(Shevell and Monnier)

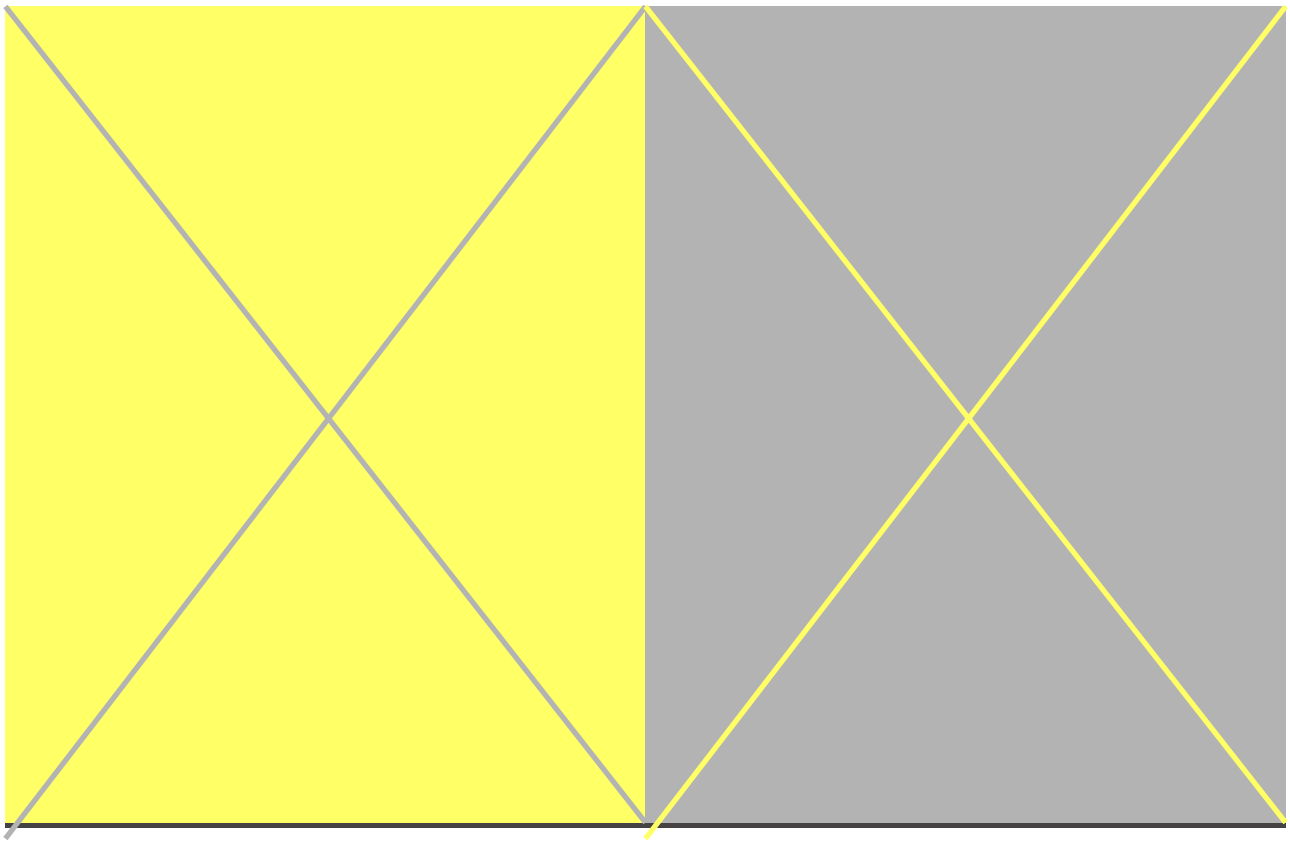


Illusory Motion

http://www.ritsumei.ac.jp/~akitaoka/saishin-e.html

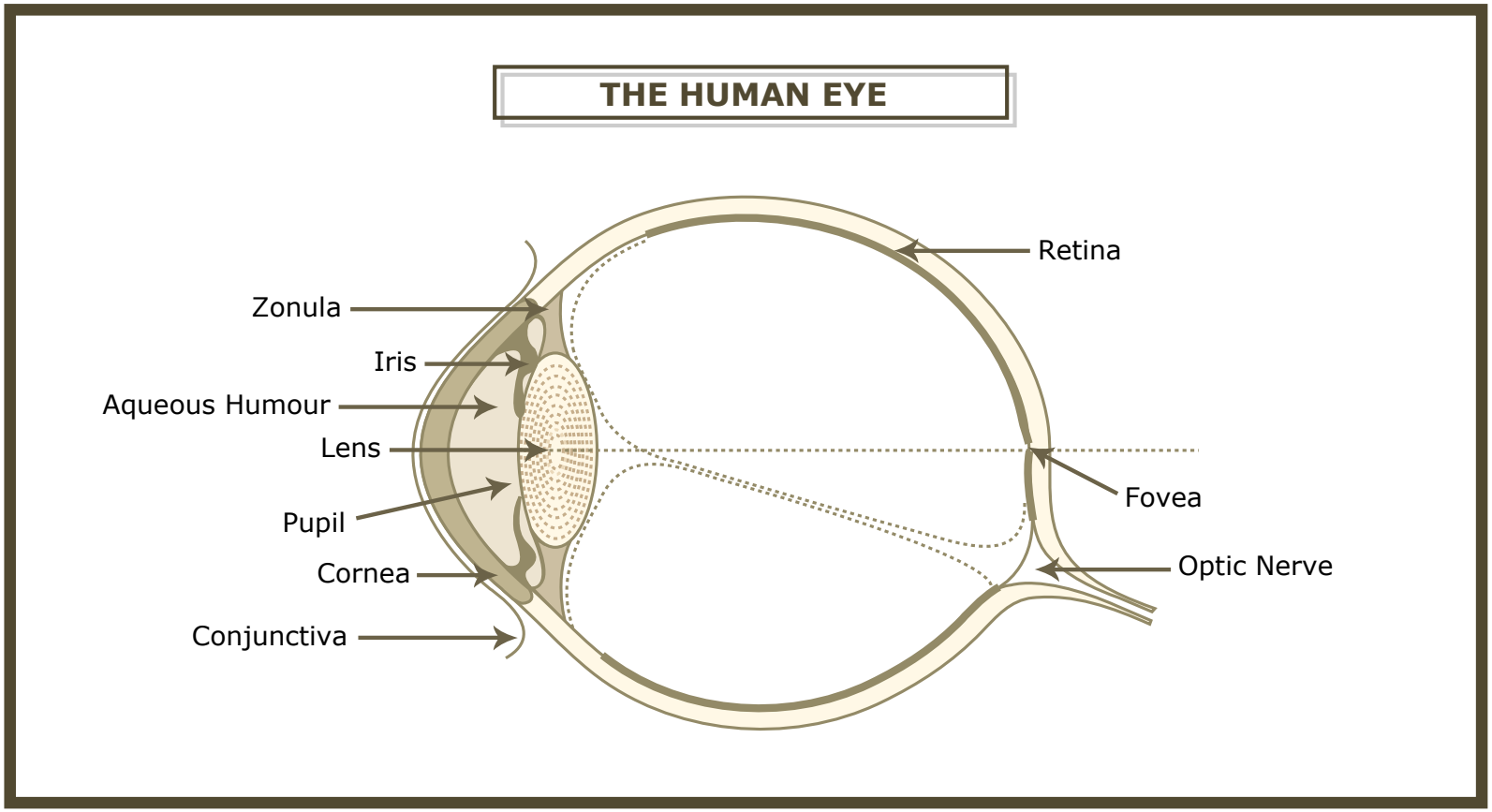


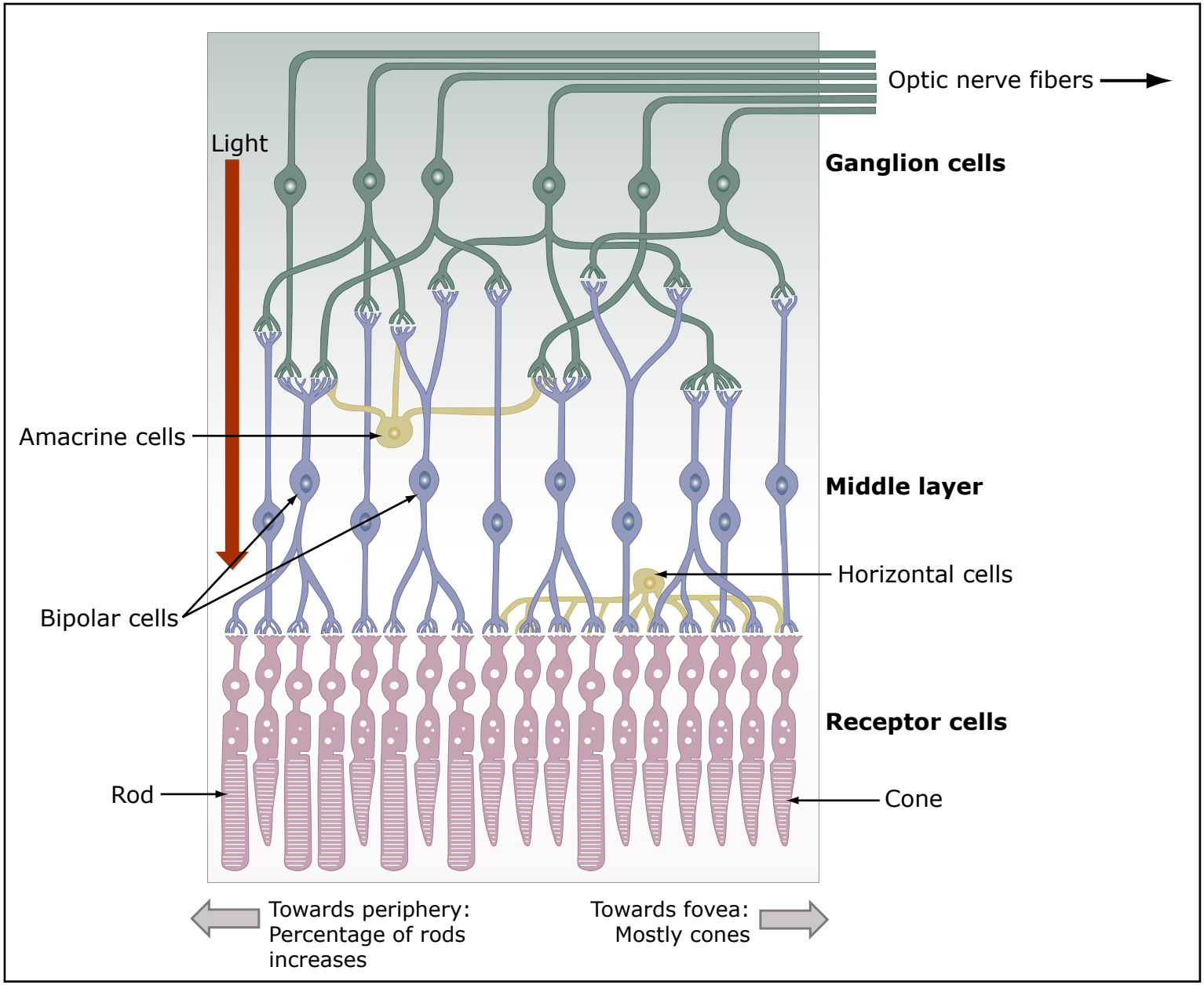
Albers



Perception: Our Approach

- **Objectivist view (“blank slate” view)**
  - **Our senses precisely, and accurately, reflect the physical world. They provide us with a true, complete, and accurate representation.**
- **Subjectivist view (Gestalt)**
  - **There is no inherent organization to the world, but rather, our brain organizes our perceptions, and we therefore believe the world is, itself, organized.**
- ***Synthetic view***
  - **The world appears to us the way it does because:**
    (1) We perceive only within the limits of our nervous system
    (2) Our nervous system has evolved to reflect portions of the world very accurately.





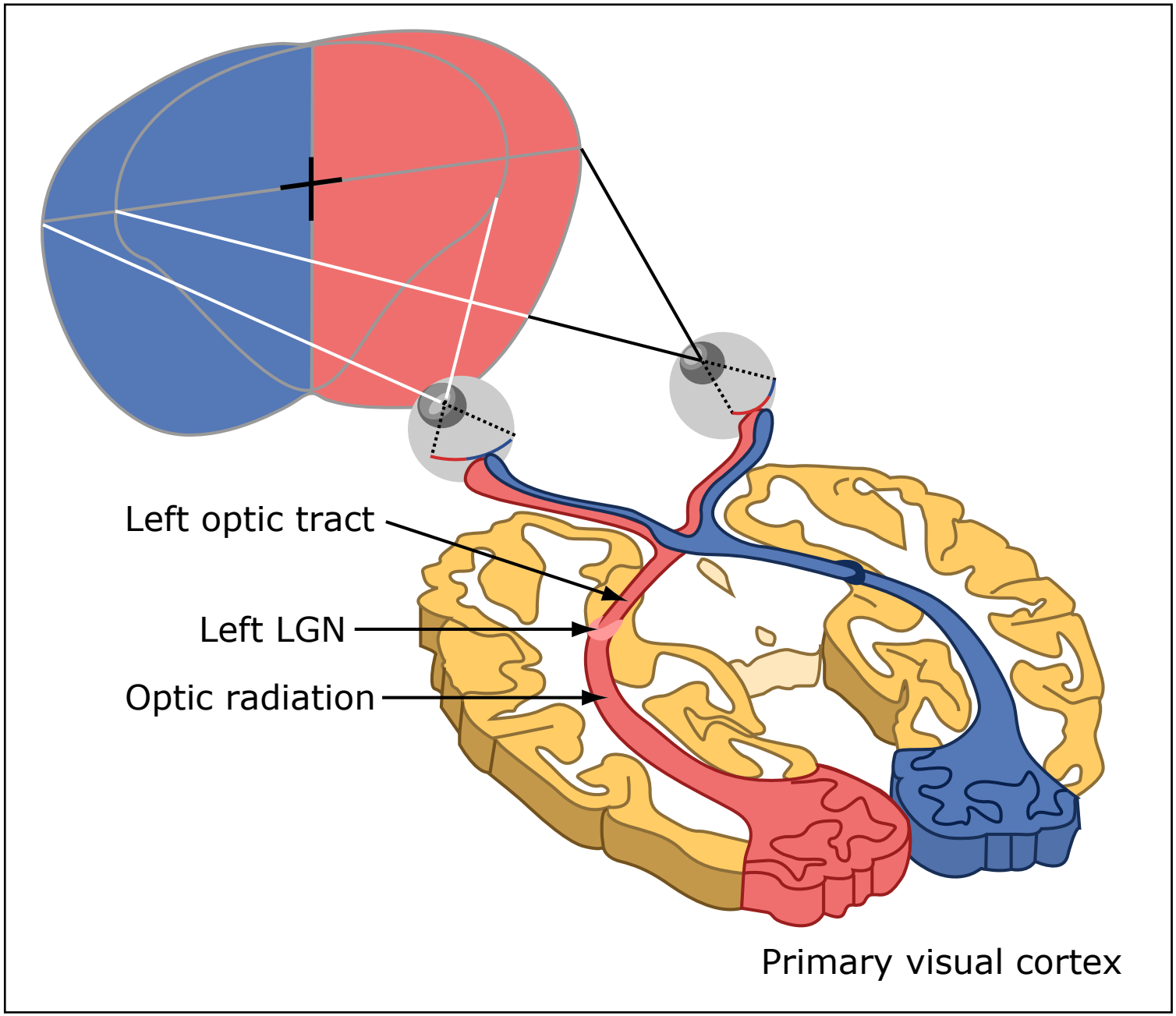


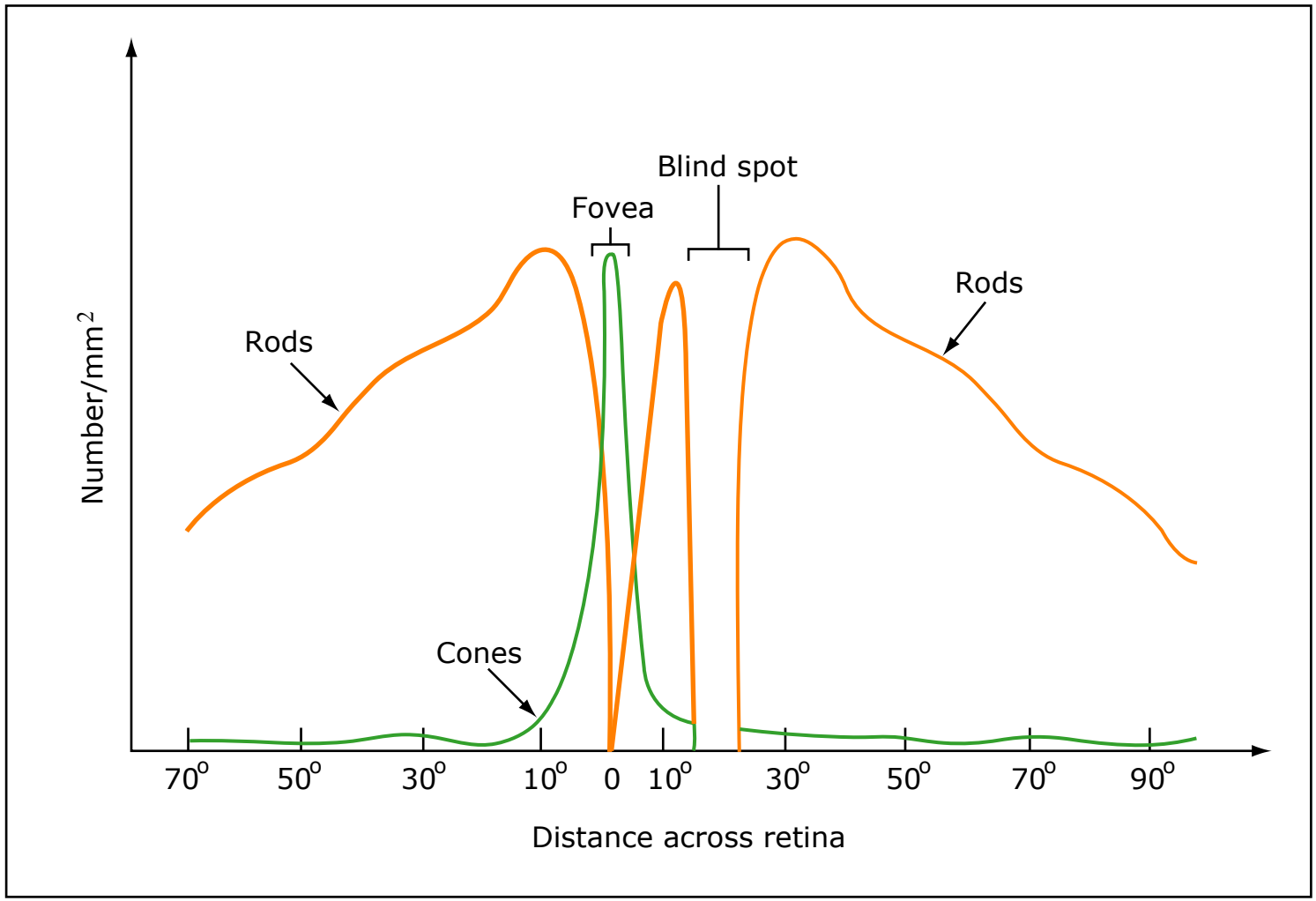
Image by MIT OpenCourseWare.
After Figure 10-4b in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007. ISBN: 9780781760034.

Rods and Cones

http://webvision.med.utah.edu/photo1.html

Rods and cones seen through a scanning electron microscope. Each rod is about one micron across.

Spatial Distribution of Receptors



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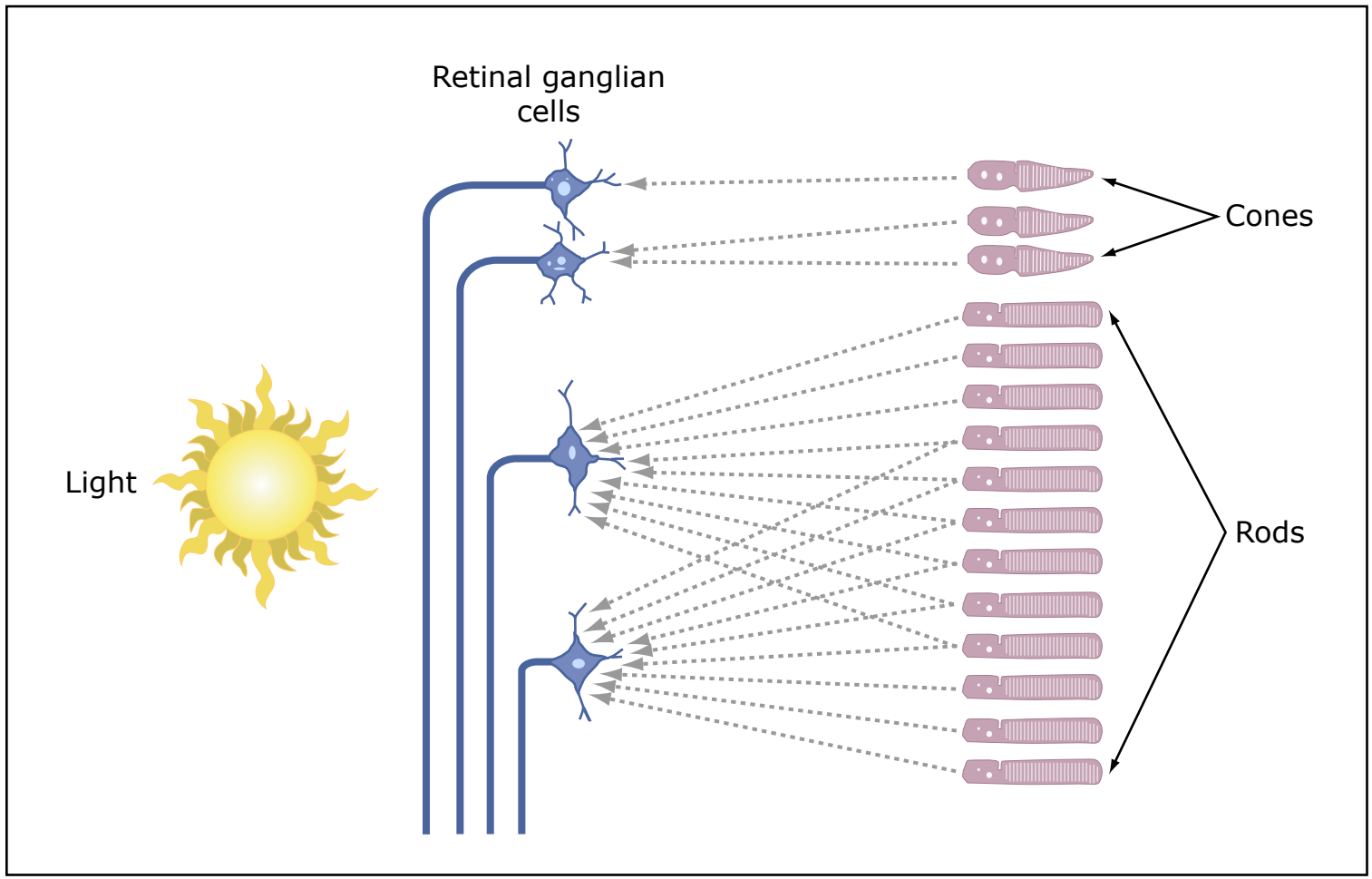


Image by MIT OpenCourseWare.

FIGURE 7.6. A schematic representation of the convergence of rods and cones on retina ganglion cells. There is a high degree of convergence in the rod system and a low degree of convergence in the cone system.

Receptive fields **- area of external space in which a stimulus activates a neuron**

Retinotopy **- topographic map of visual space across a restricted region of the brain - maintenance of orderly spatial relations**

Certain Retinal Ganglion Cells Project to the Lateral Geniculate Nucleus; Signals Are Then Sent To Primary Visual Cortex

Myer's loop

Optic nerve

Optic chiasm

Optic tract

Lateral geniculate nucleus

Optic radiation

Primary visual cortex

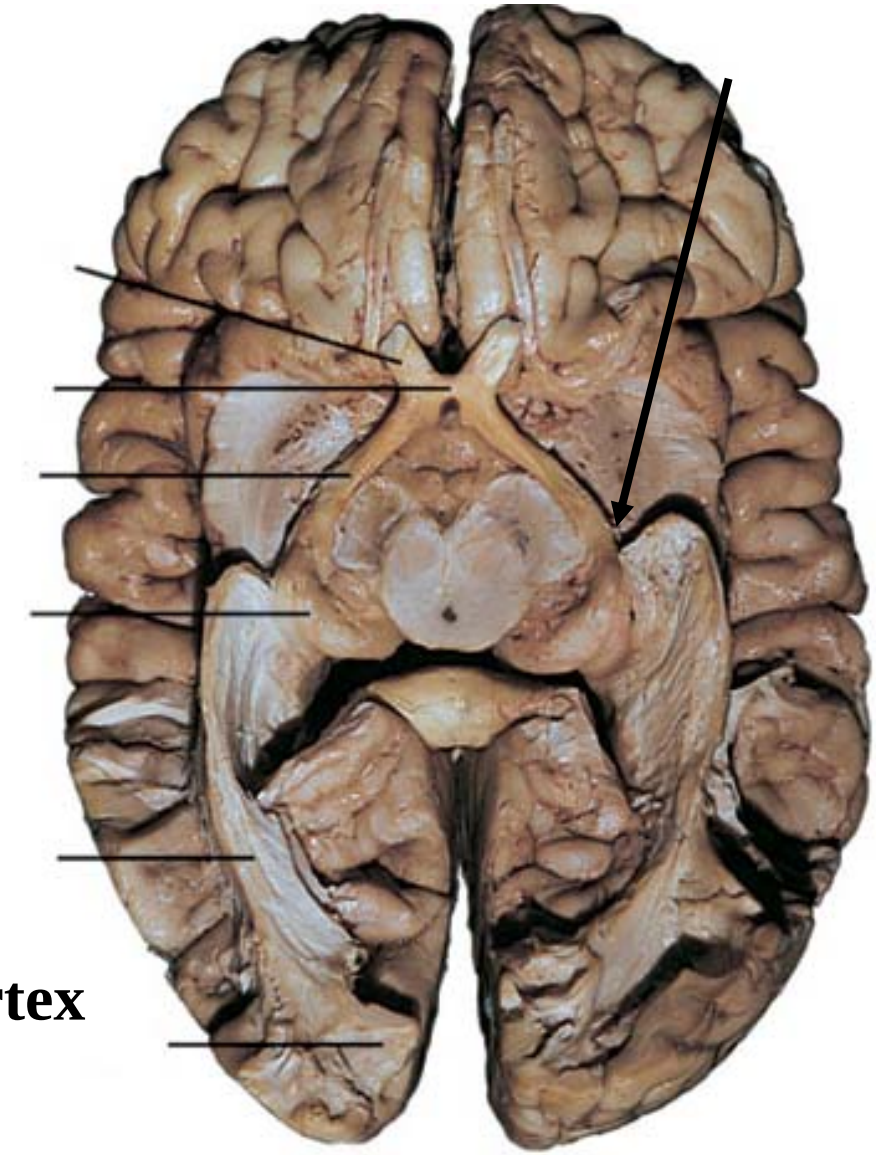


Image of lgn in a macaque monkey removed due to copyright restrictions.
See: Oxford Journals

Magnocellular	*Parvocellular*
large cells	**small cells**
rods	**cones**
large RFs (3X)	**small RFs**
rapid, transient,	**slow, sustained,**
color-blind	**wavelength-sensitive**
low contrast sensitivity	**high contrast sensitivity**
	unique to primates
	10 X more than M cells

Visual Field Maps in Human Visual Cortex

Left visual field images are communicated to right (contralateral) visual cortex.

Right visual field images are communicated to left visual cortex.

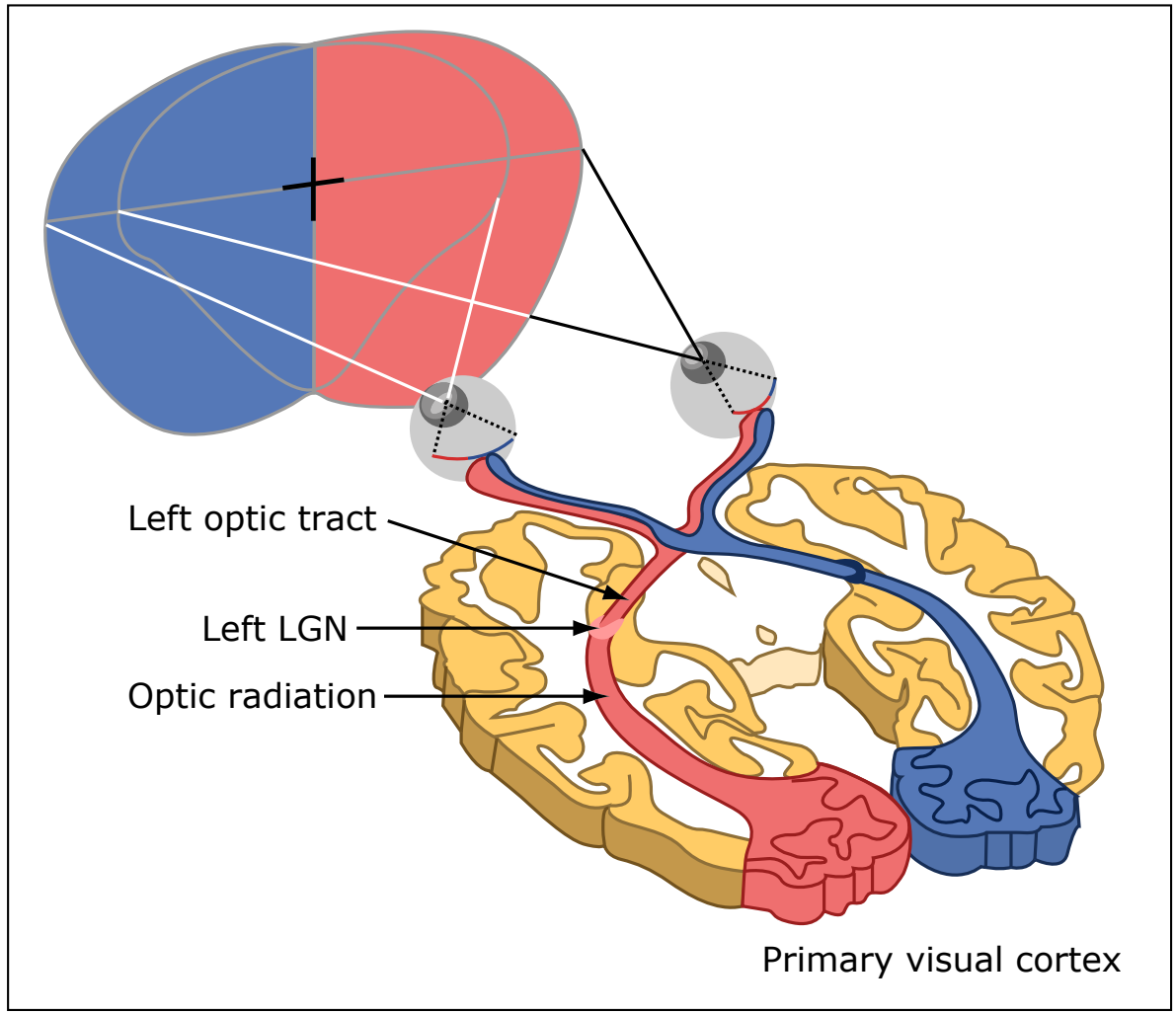


Image by MIT OpenCourseWare.
After Figure 10-4b in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. Neuroscience: Exploring the Brain. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007. ISBN: 9780781760034.

Cortical Vision

- **55% of primate cortex is visual**

  11% touch, 3% auditory

- **32 distinct visual areas in monkey**
- **proliferation**

  one LGN = 1 million neurons

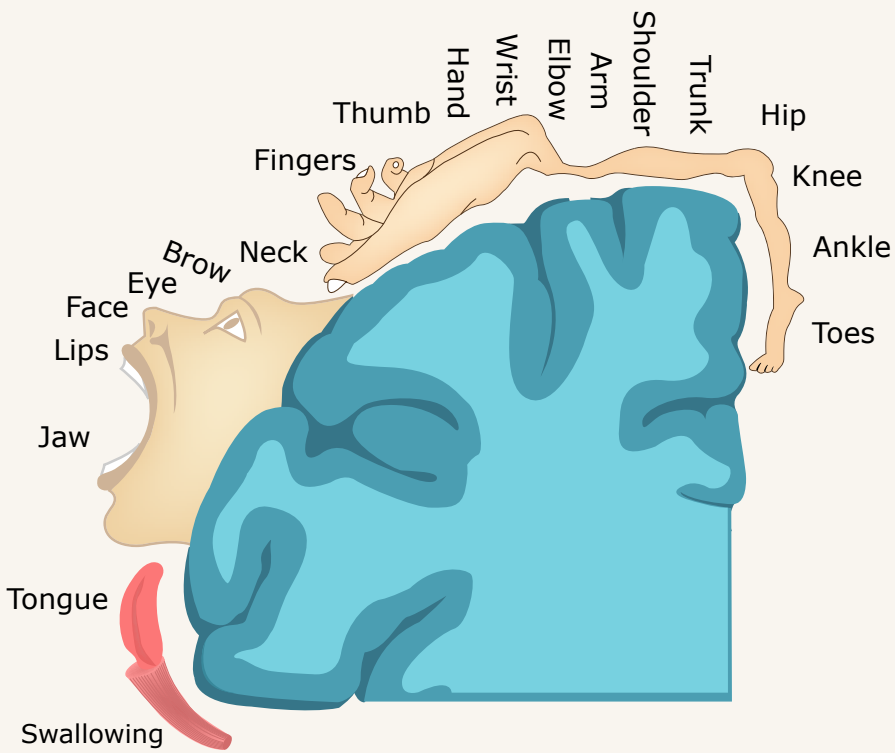
  V1 (striate)= 250 million neurons

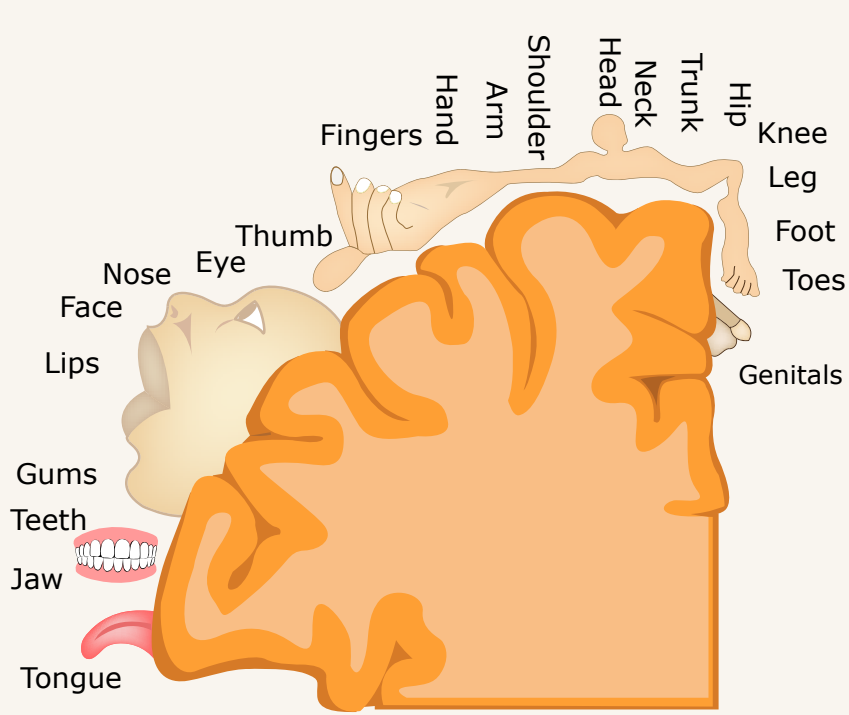
  extrastriate = 400 million neurons

  1.3 billion visual cortical neurons

  600 cortical/1 LGN neuron

Image highlighting the primary visual cortex removed due to copyright restrictions.
See: Wikipedia





Motor Cortex **Somatosensory Cortex**

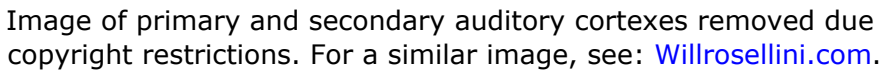
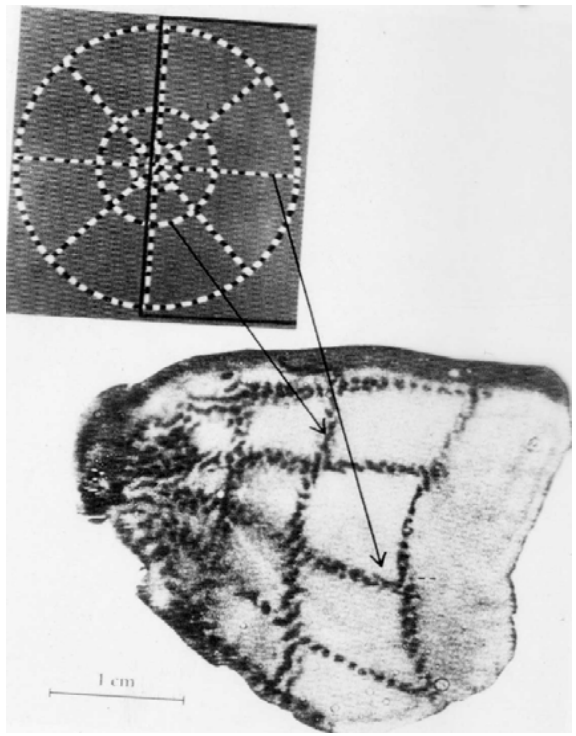
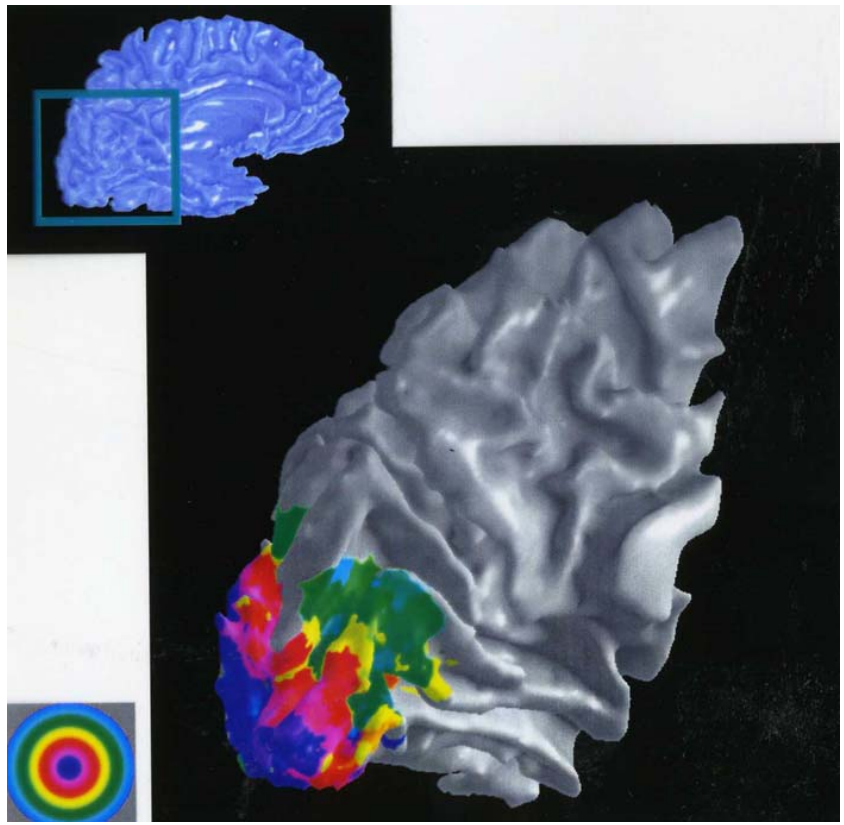


Image of primary and secondary auditory cortexes removed due to
copyright restrictions. For a similar image, see: Willrosellini.com.

Topography:
Retinotopy in visual cortex





Monkey V1 (2-deoxyglucose)

Human visual cortex (fMRI)

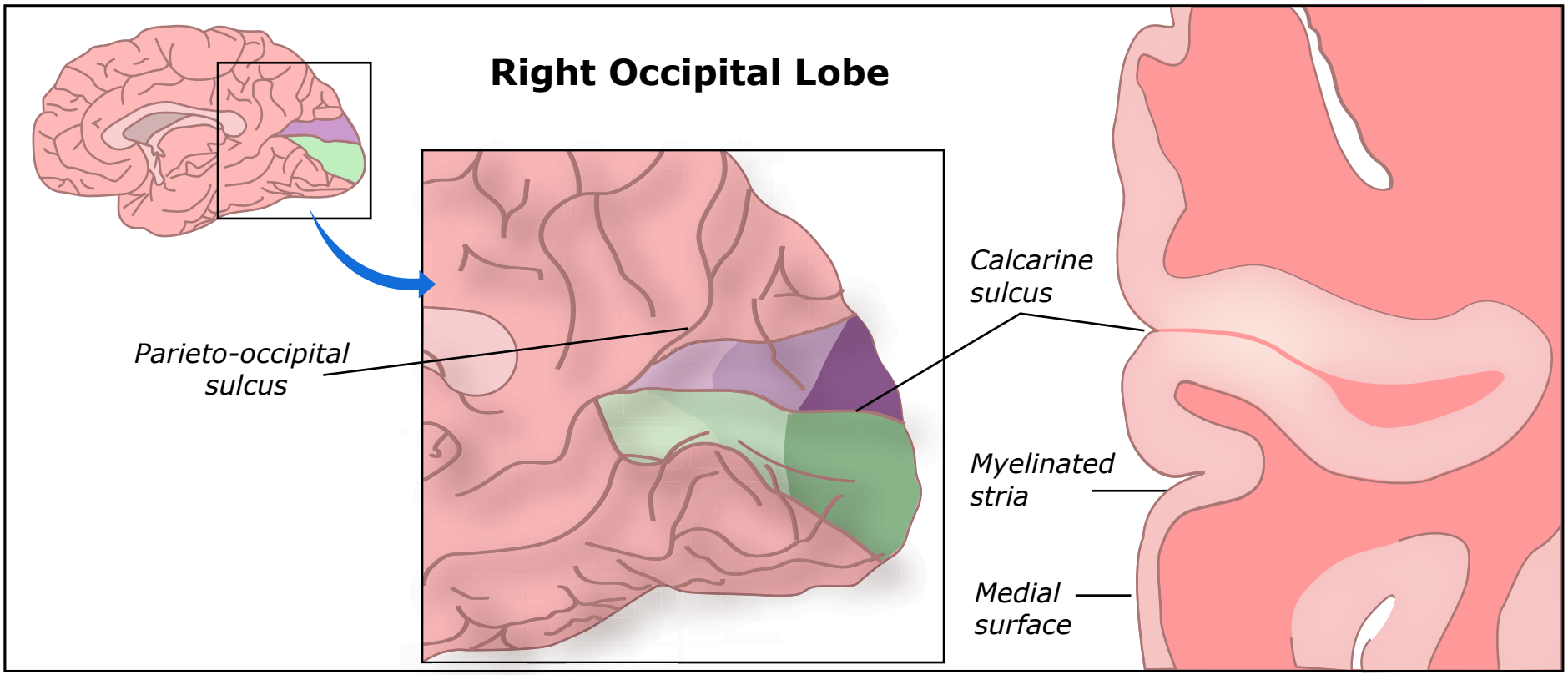
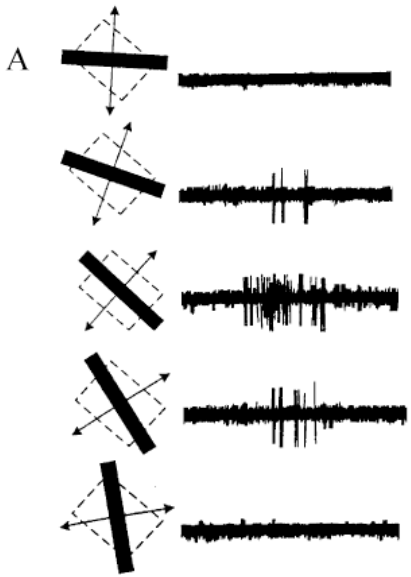


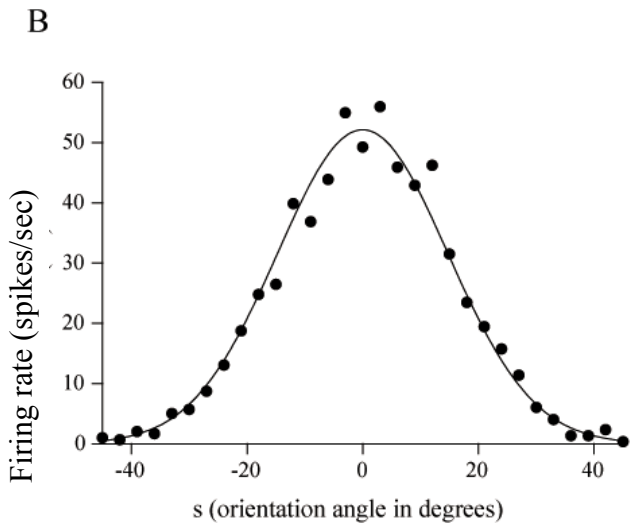
Image by MIT OpenCourseWare.

Visuotopic organization of the striate cortex in the right occipital lobe (mid-sagittal view):
Foveal Magnification

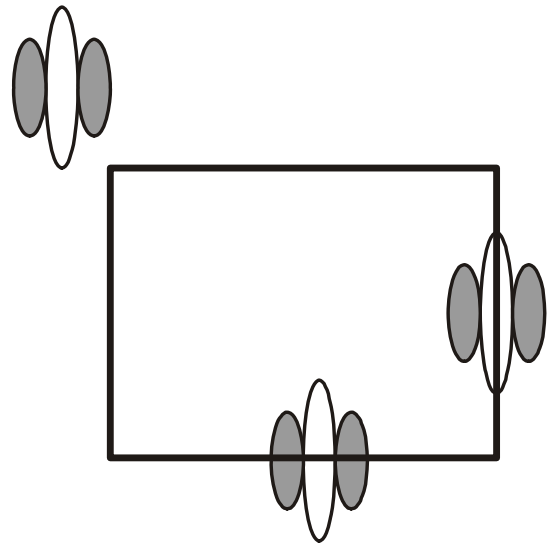
Single unit recordings in V1: Orientation selectivity



V1 data



Stimulus orientation (deg)



Model

Diagram of the “wiring map” of projections removed due to copyright restrictions.

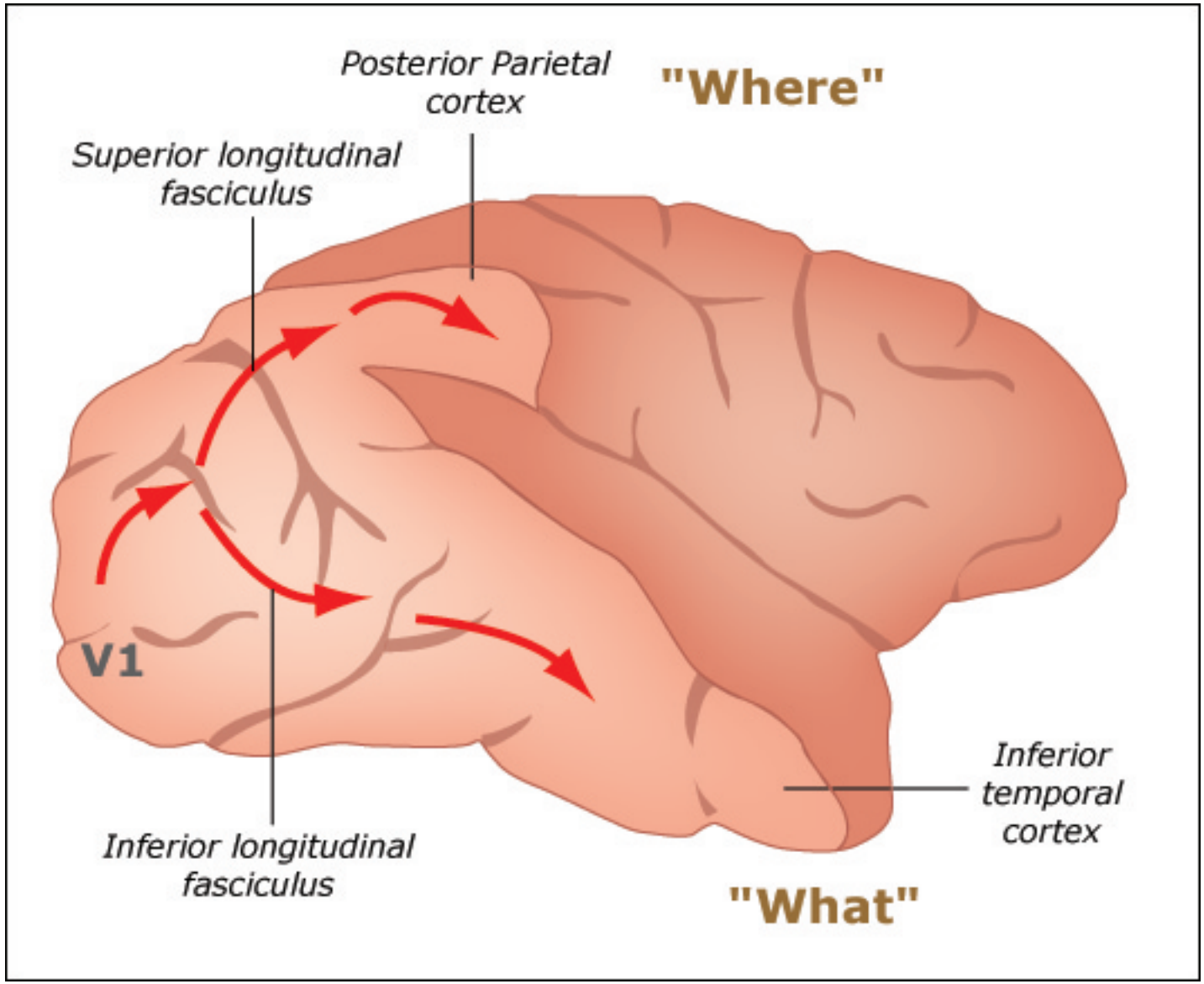
For a similar image, see MIT.edu.

What and Where Systems

- **landmarks test in monkey**

  where - parietal impaired, temporal ok

  what - temporal impaired, parietal ok



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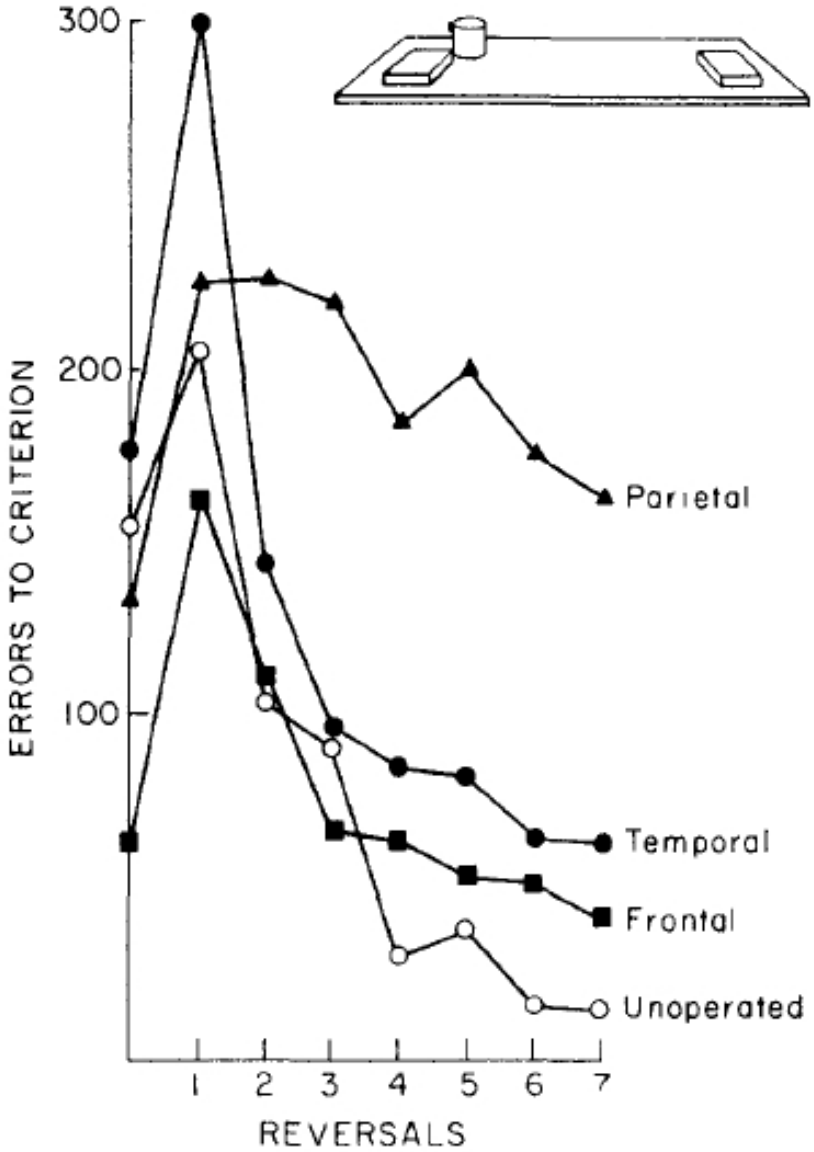


FIG. 6. Performance of unoperated control and three lesion groups on the landmark reversal task. (Upper diagram represents test situation.)

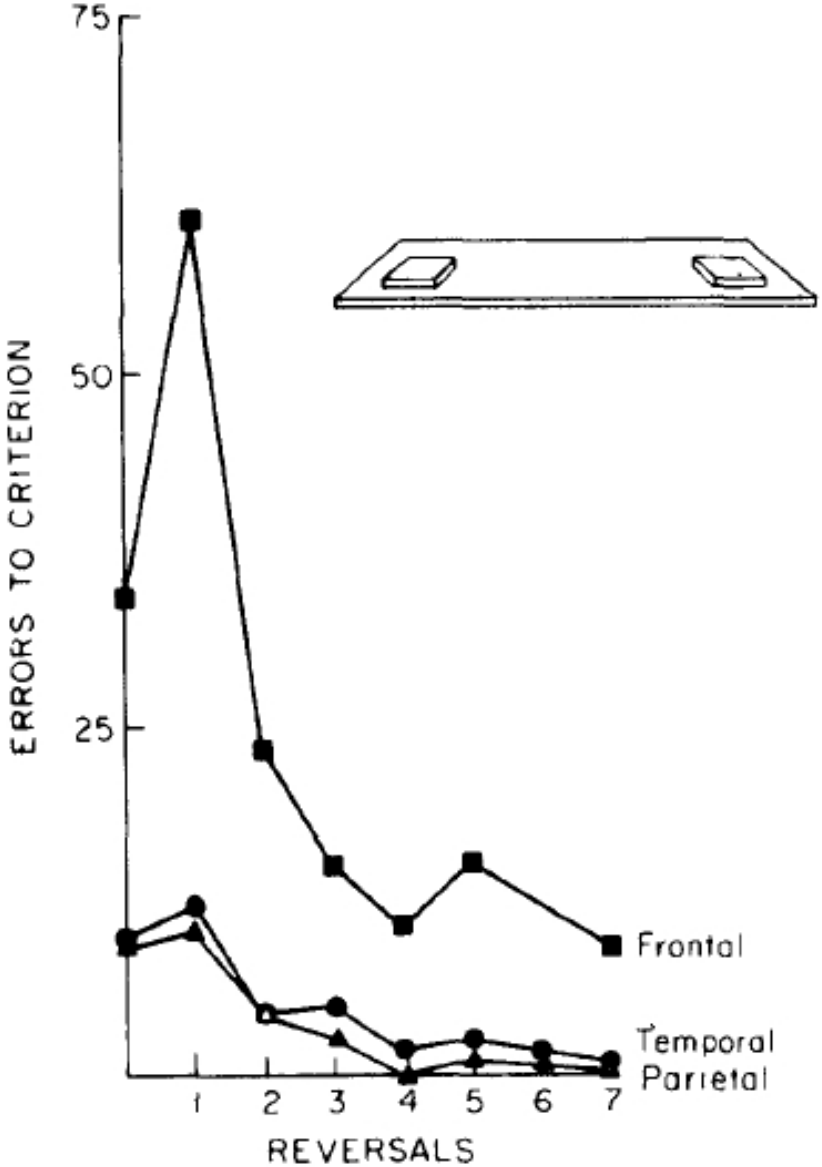


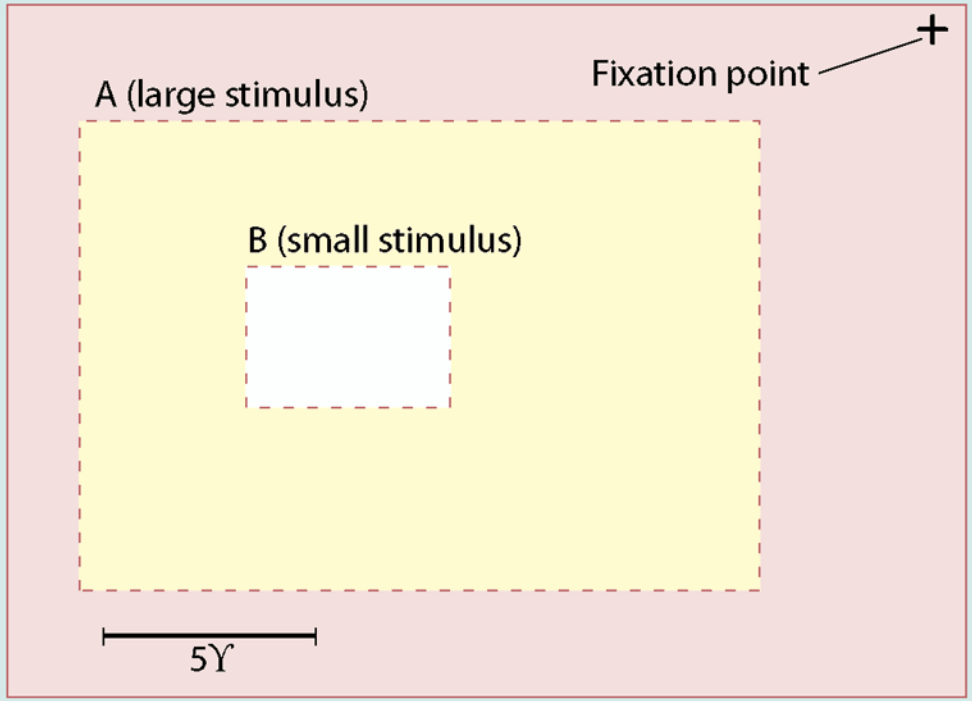
FIG. 7. Performance of three lesion groups on the place reversal task. (Upper diagram represents test situation.)

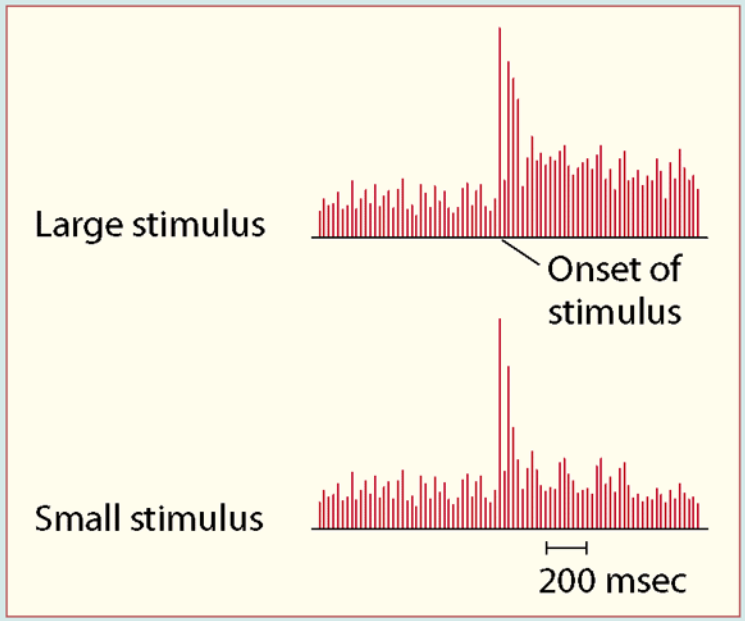
Where:

40% of parietal neurons have foveal receptive fields, 60% have non-foveal receptive fields;

What:

100% of temporal neurons have foveal receptive fields





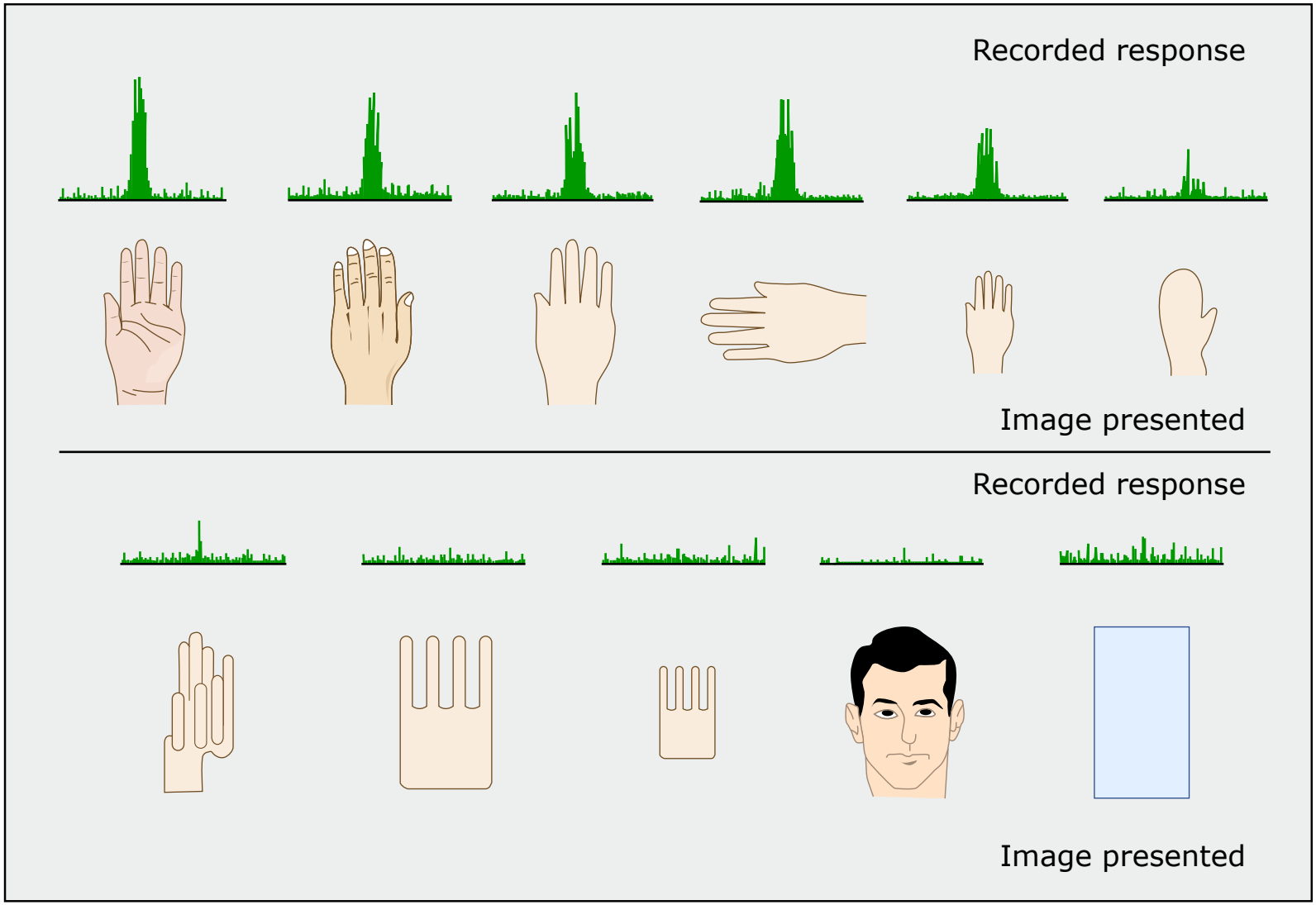


Image by MIT OpenCourseWare.

Graphs related to response spikes of facial recognition removed due to copyright restrictions. For the graphs from which the image was adapted, see Perrett, D. I., E. T. Rolls, and W. Caan. "Visual Neurones Responsive to Faces in the Monkey Temporal Cortex." *Exp Brain Res* 47 (1982): pp. 329-42.

What and Where Systems

- **Balint's syndrome**

  bilateral parietal-occipital lesions

  identification (what) intact

  problems in localizing, reaching, redirecting gaze, estimating distance, navigation

What and Where Systems

- **Where system = vision for action?**

Patient DF

Extensive ventral bilateral damage

Poor perception of shape and orientation (what)

Reaching for slot at different orientations

Good hand orientation and grasping

Dissociation of object perception and use of that information to guide action

9.00SC Introduction to Psychology
Fall 2011