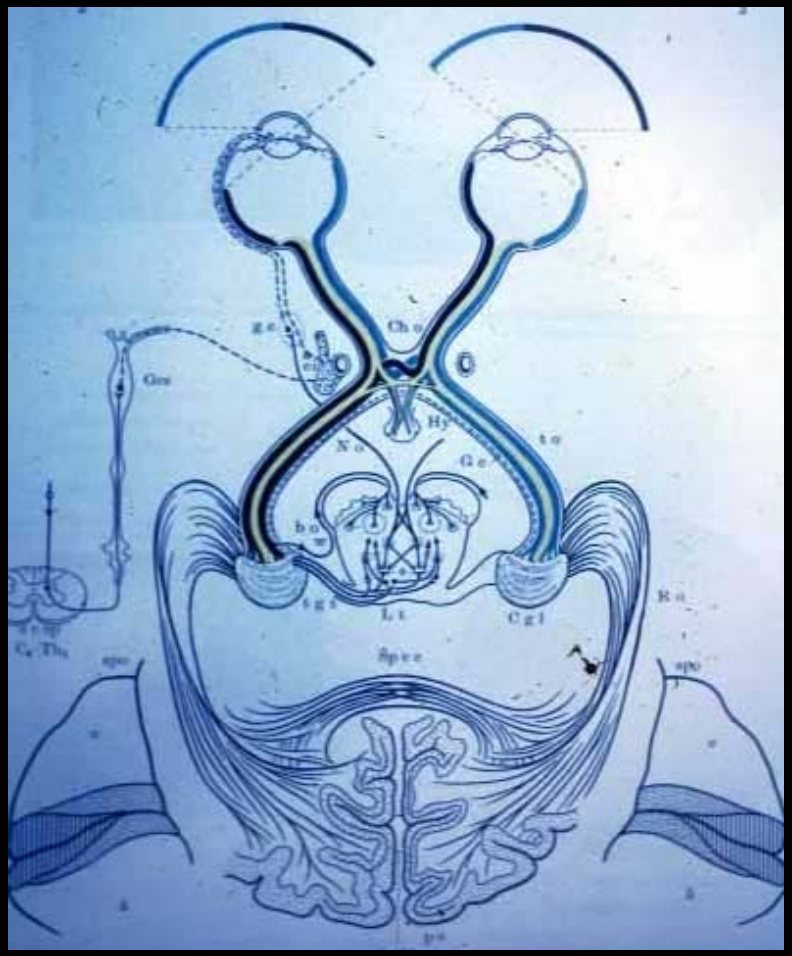
The Visual System



Behavioral and Cognitive Neuroanatomy

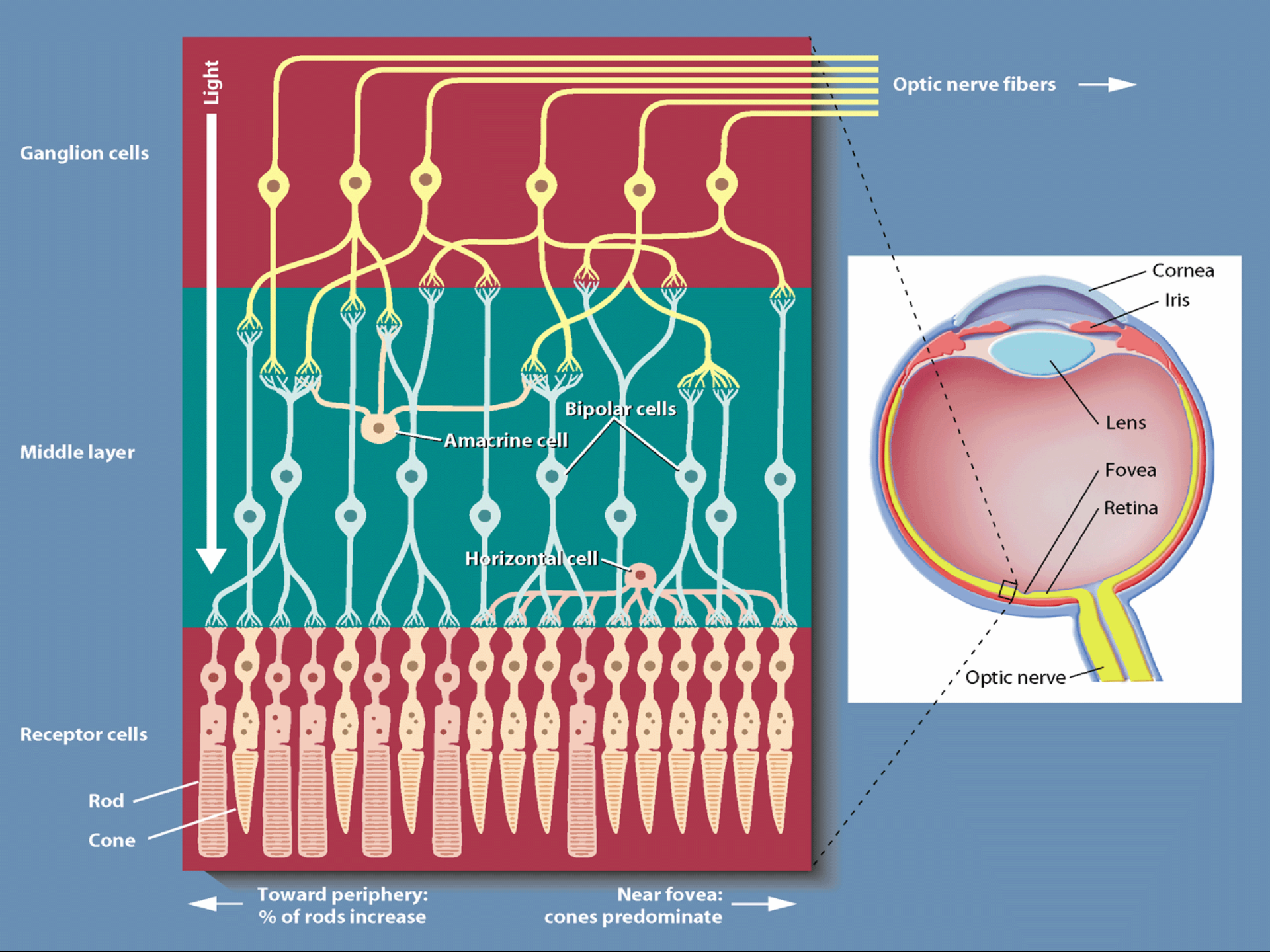
http://zlab.rutgers.edu/classes/BehaviorCogNeuro

Sean Montgomery - TA

smontgom@pegasus.rutgers.edu

Why the visual system?

- The brain is complex at multiple levels of analysis.
- The visual system is probably the best understood system from multiple levels of analysis.


Light
Ganglion cells
Optic nerve fibers
Middle layer
Bipolar cells
Amacrine cell
Horizontal cell
Receptor cells
Rod
Cone
Toward periphery:
% of rods increase
Near fovea:
cones predominate
Cornea
Iris
Lens
Fovea
Retina
Optic nerve

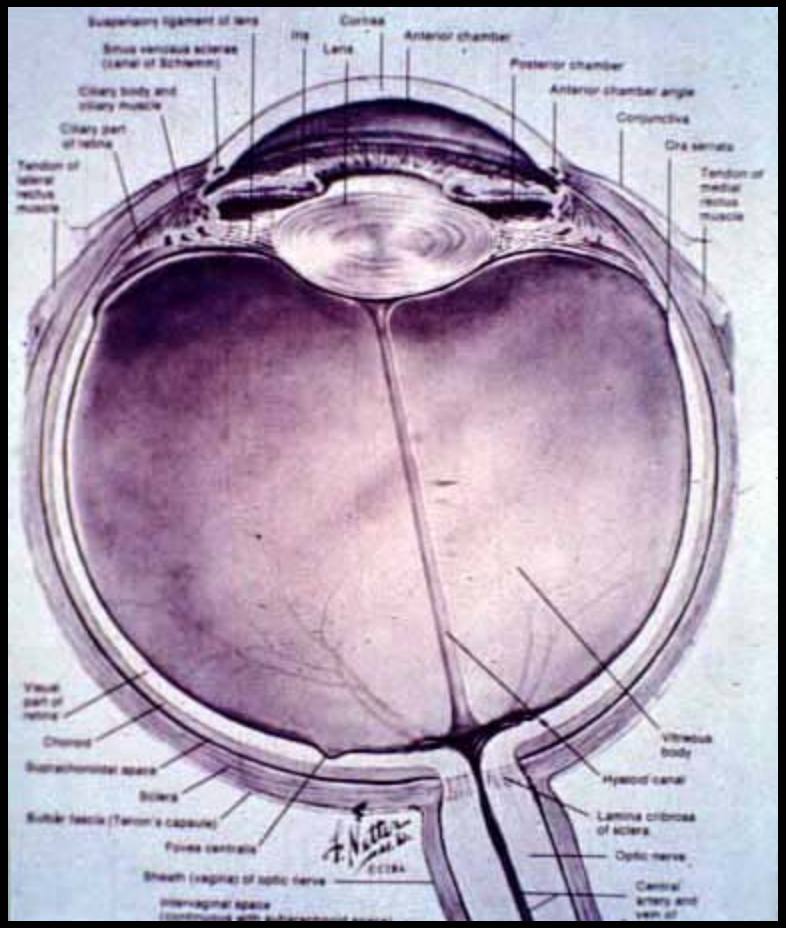
Photoreceptors

Rods:

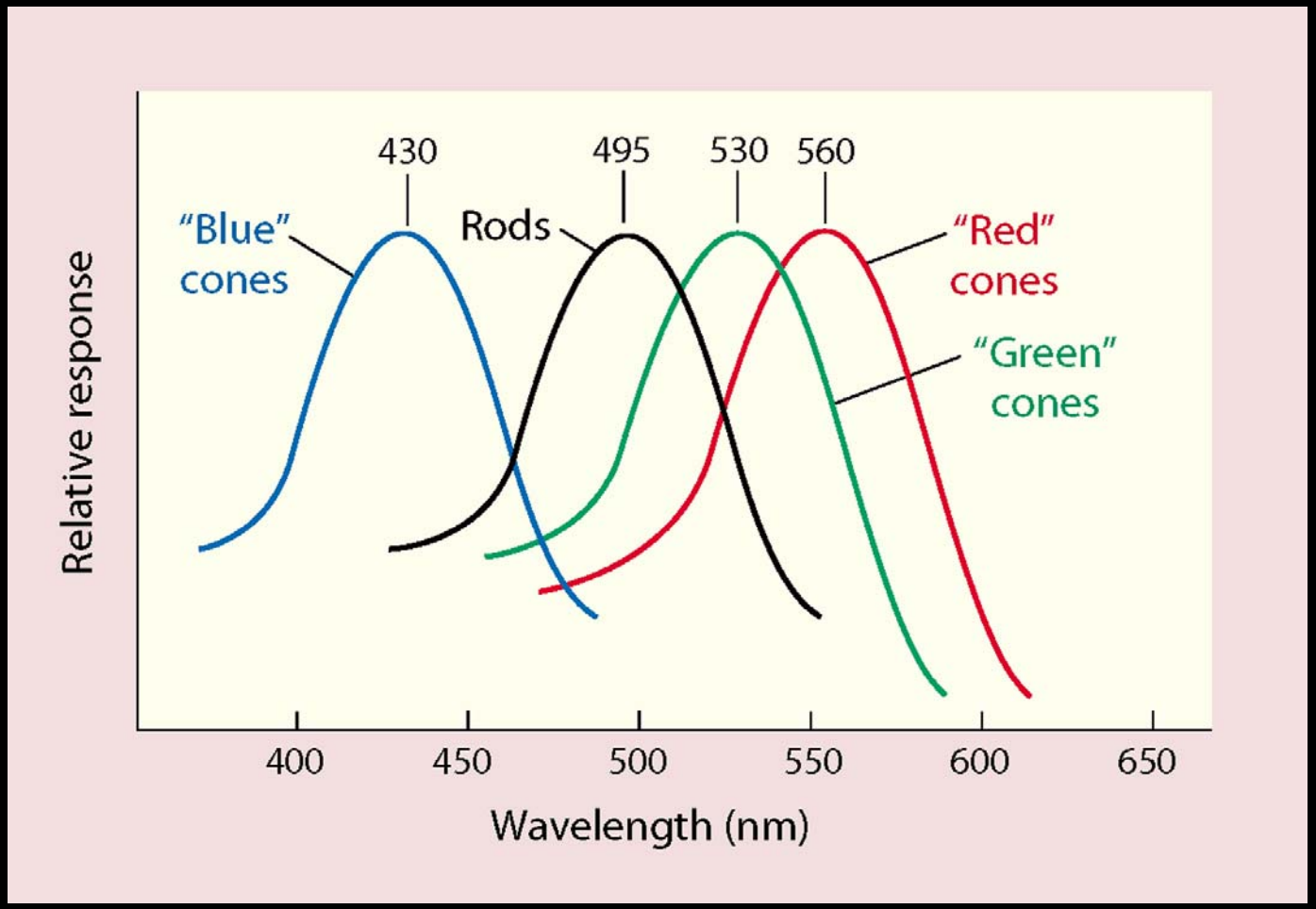
- Monochromatic
- Low spatial and temporal resolution
- Mostly in periphery of retina

Cones:

- 3 types respond to different wavelengths
- High spatial and temporal resolution
- Concentrated in fovea

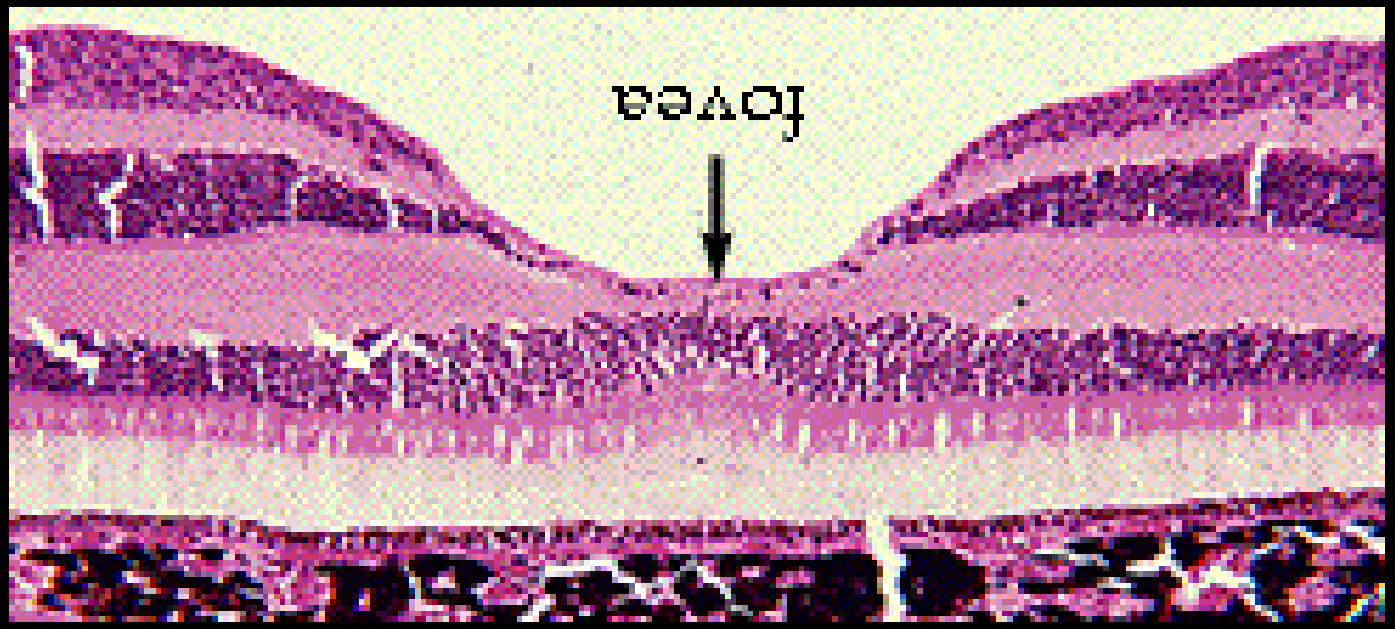


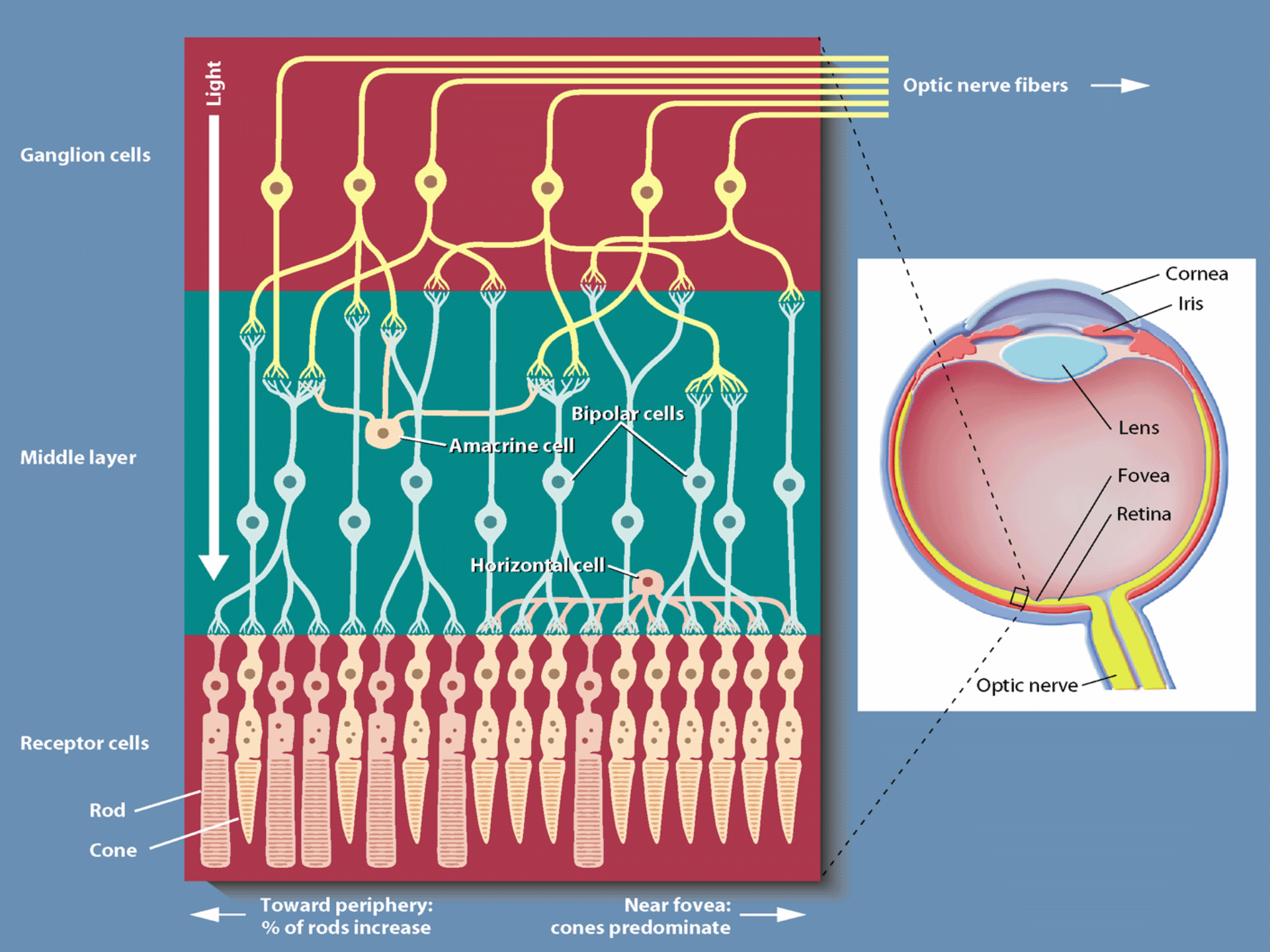
Cones are Tuned to Different Wavelengths of Light



The Fovea Has High Spatial Acuity

- Cones are concentrated in the fovea
- The outer layers of the retina get thinner at the fovea, allowing light to pass more easily and accurately to the photoreceptors




Light
Ganglion cells
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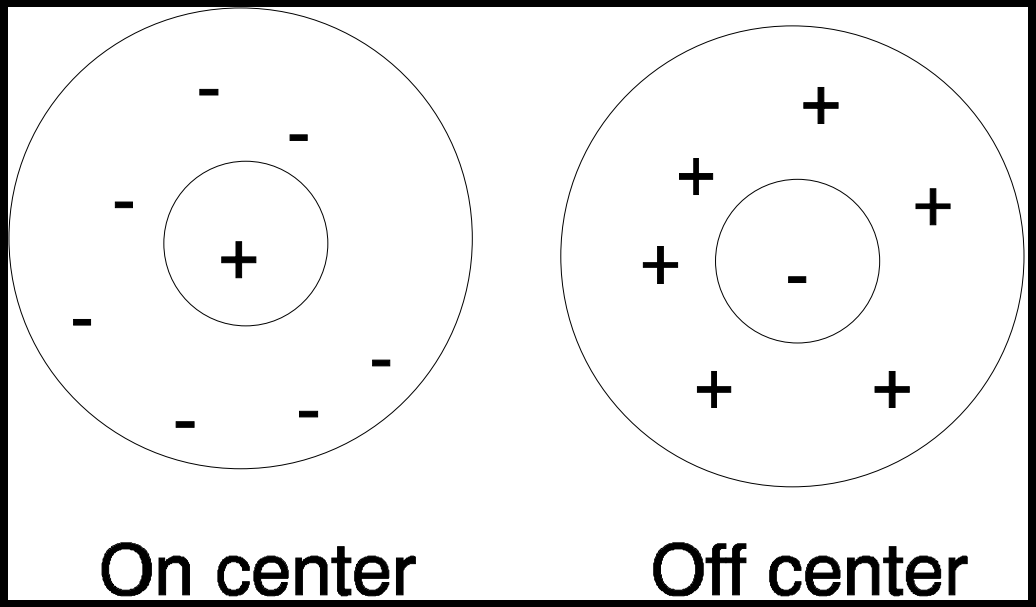
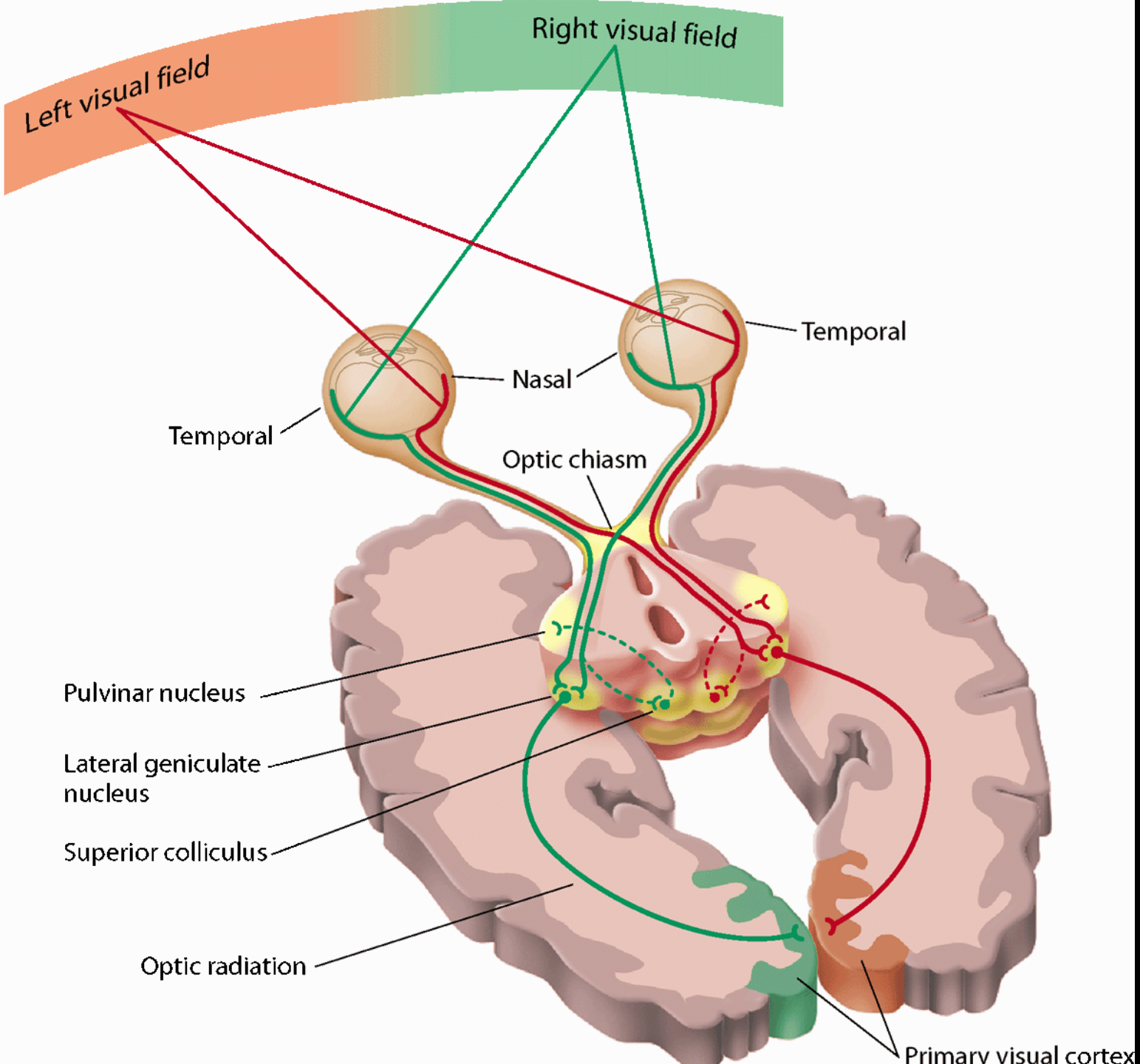
Receptor cells
Rod
Cone
Toward periphery:
% of rods increase
Near fovea:
cones predominate
Cornea
Iris
Lens
Fovea
Retina
Optic nerve

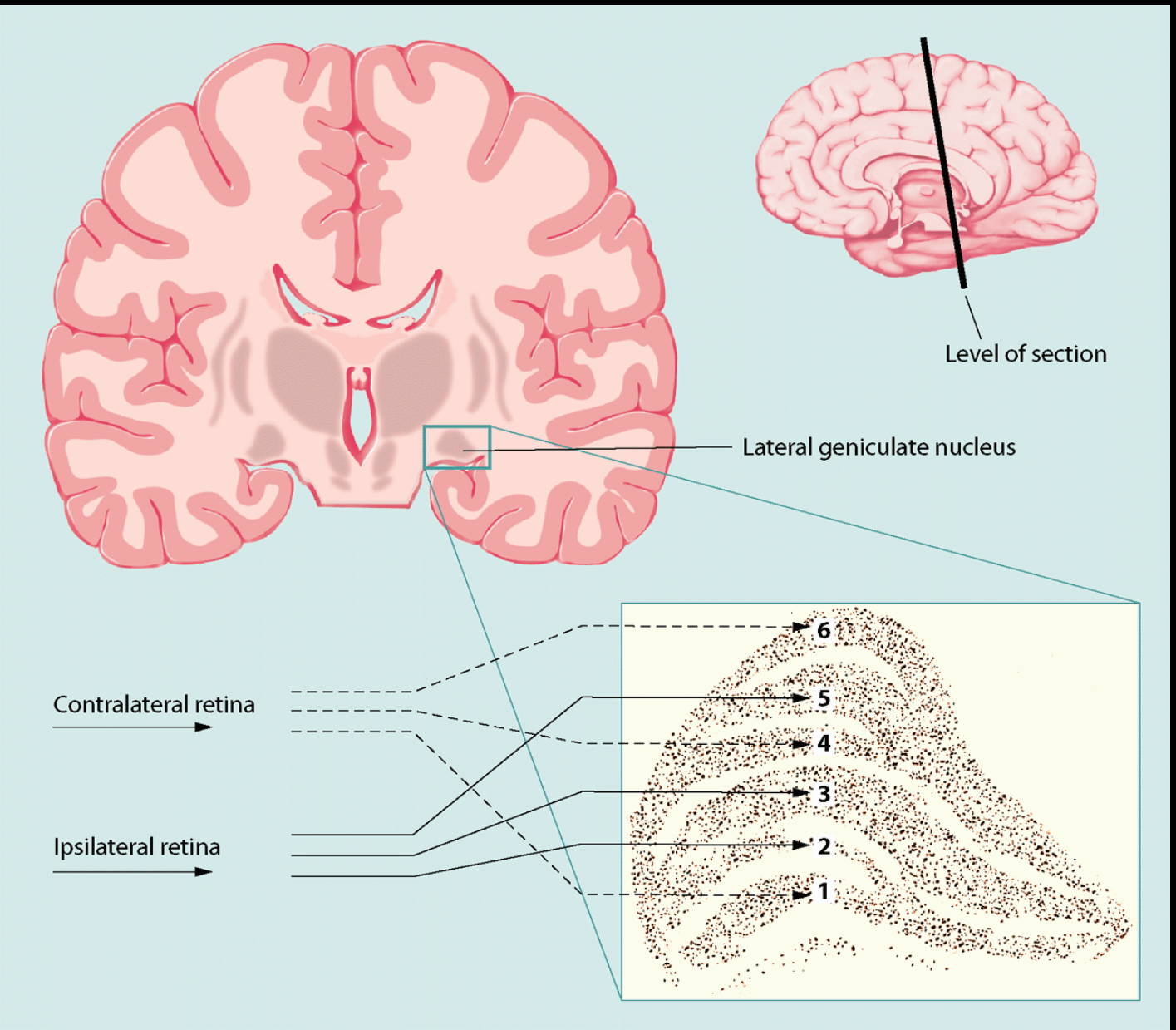
Lateral Inhibition in the Retina



- Lateral inhibition by horizontal cells leads to the On-Center and Off-Center receptive fields of bipolar cells

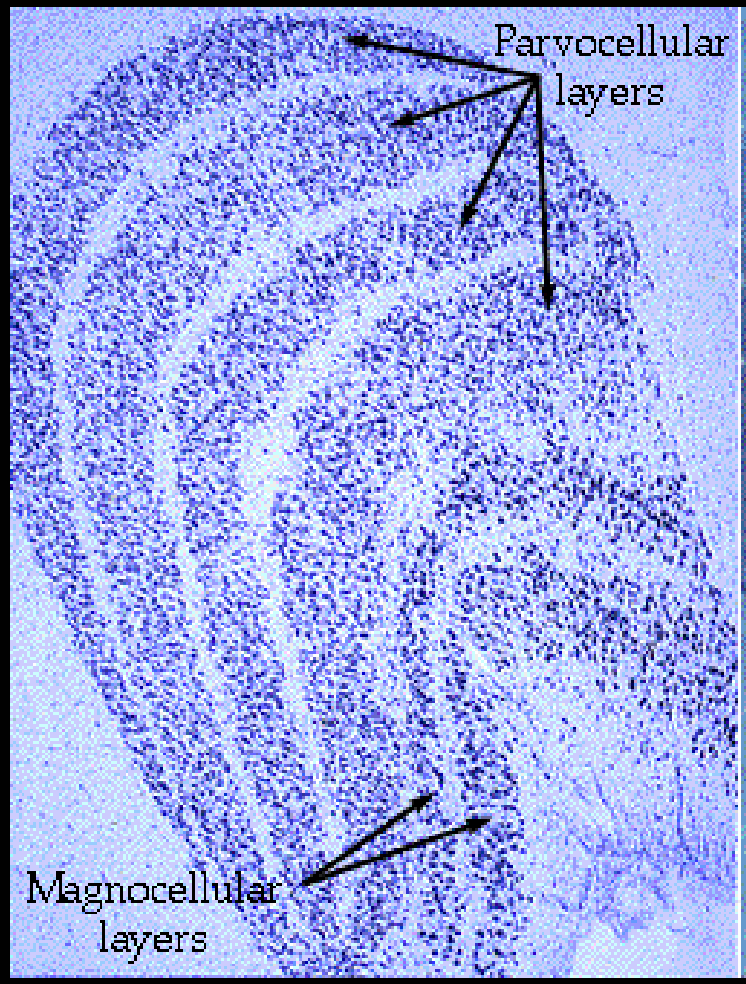

Left visual field
Right visual field
Temporal
Nasal
Temporal
Optic chiasm
Pulvinar nucleus
Lateral geniculate nucleus
Superior colliculus
Optic radiation
Primary visual cortex

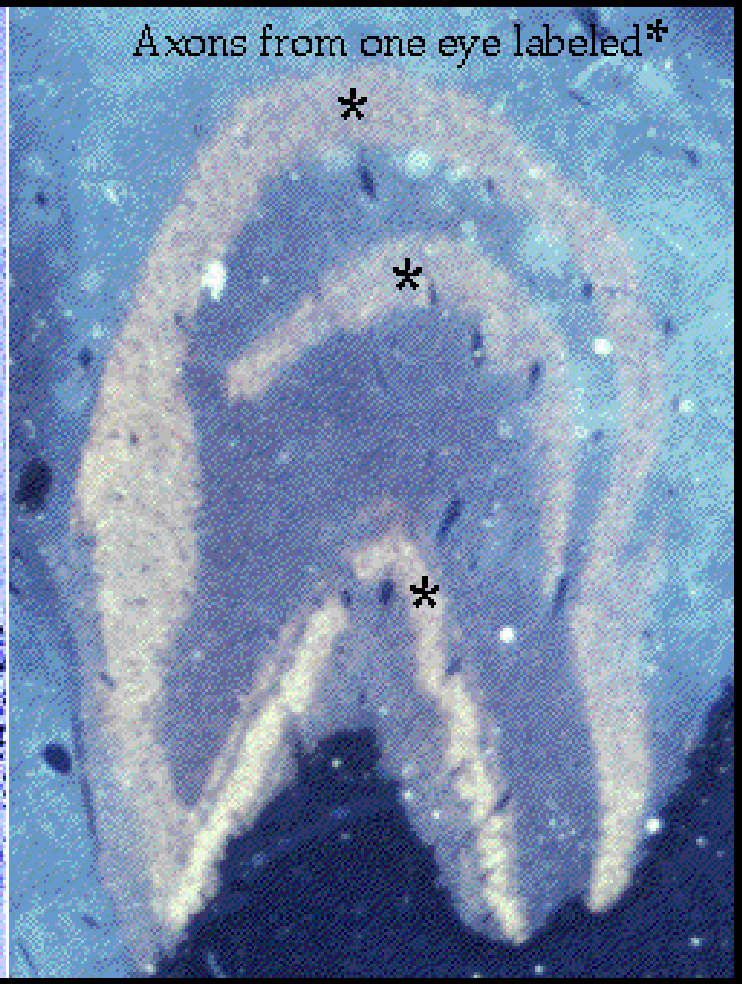
Organization of the Lateral Geniculate Nucleus



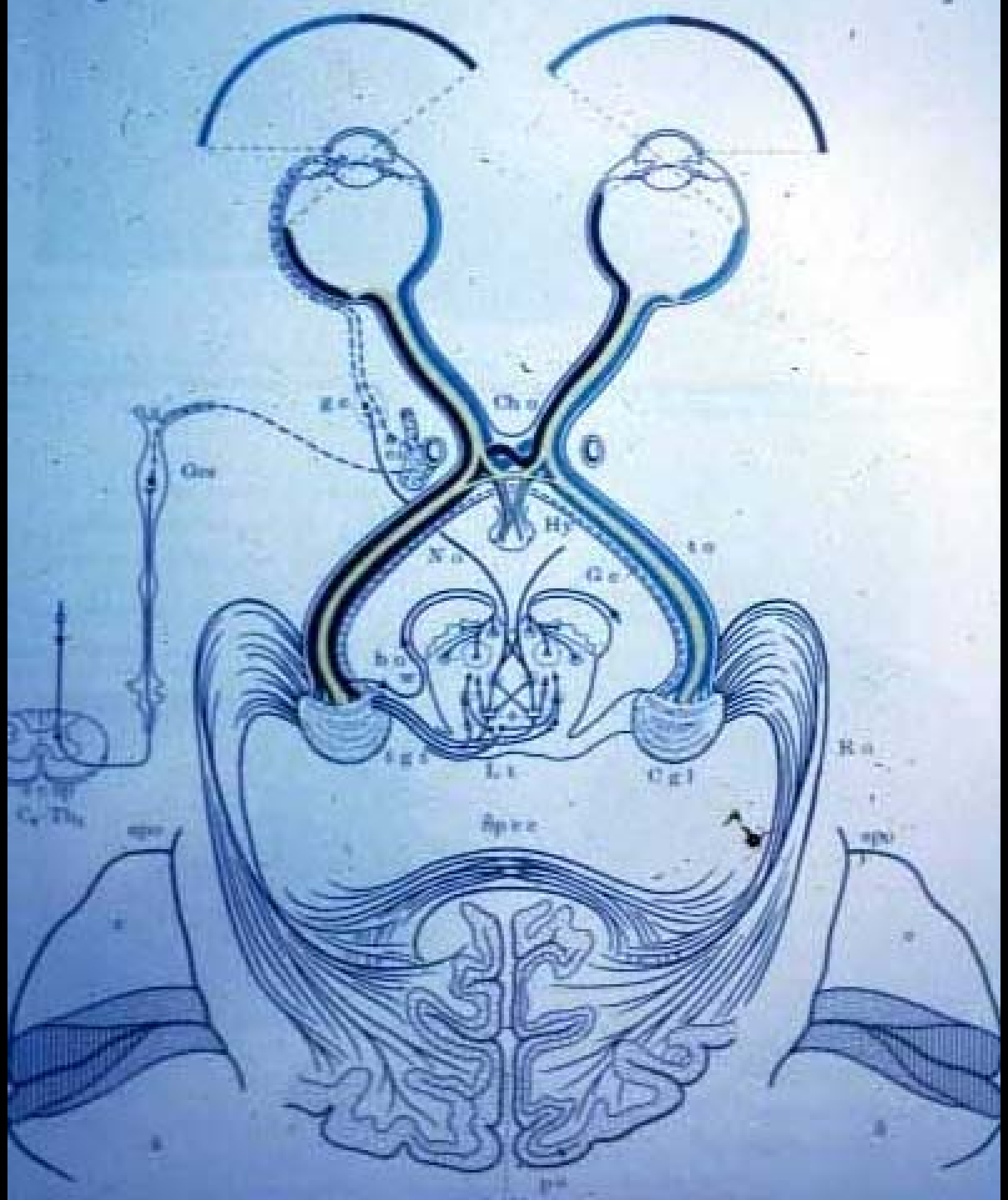
Each of the 6 LGN layers have a retinotopic representation

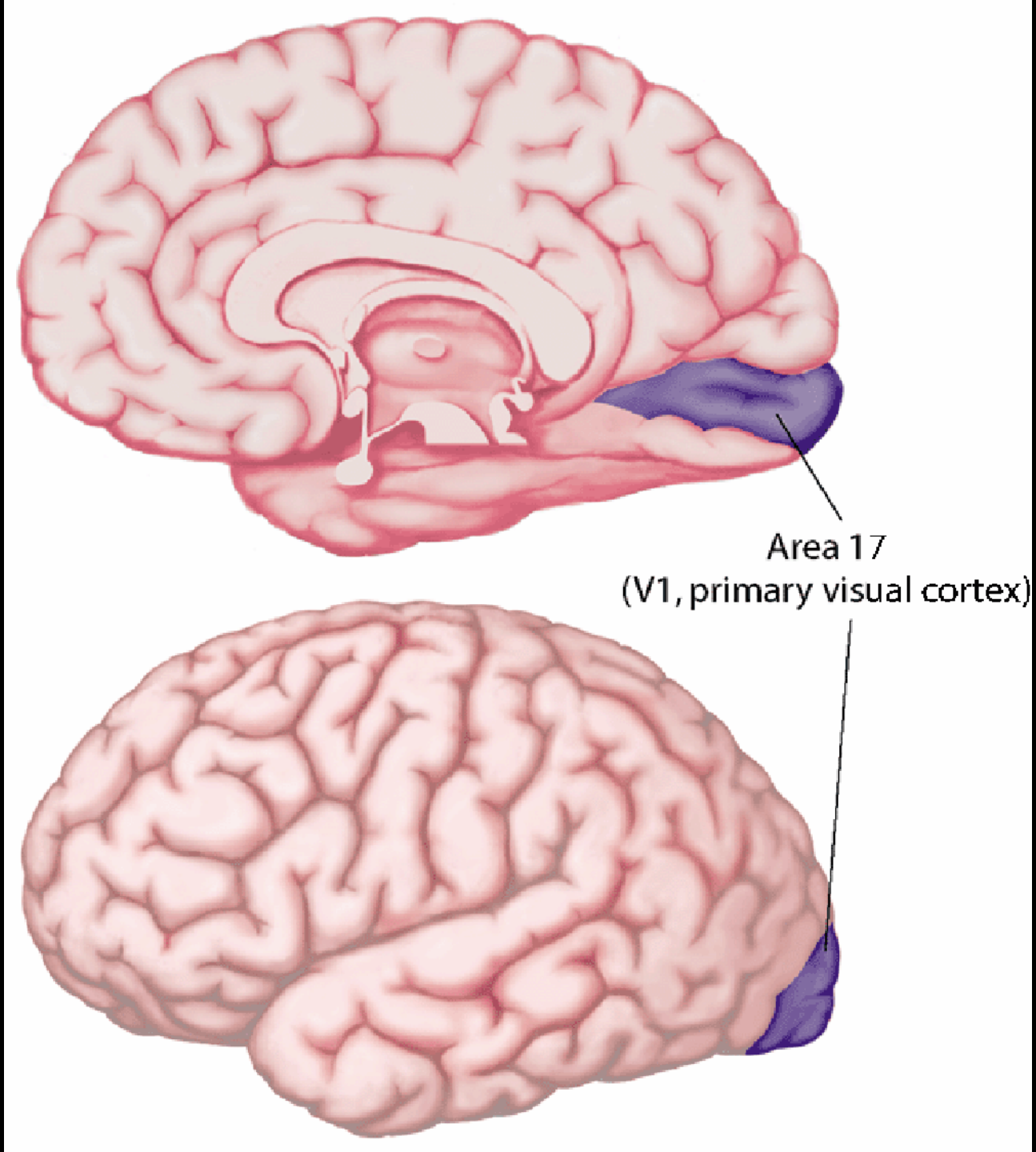
Parvocellular and Magnocellular Layers of the LGN





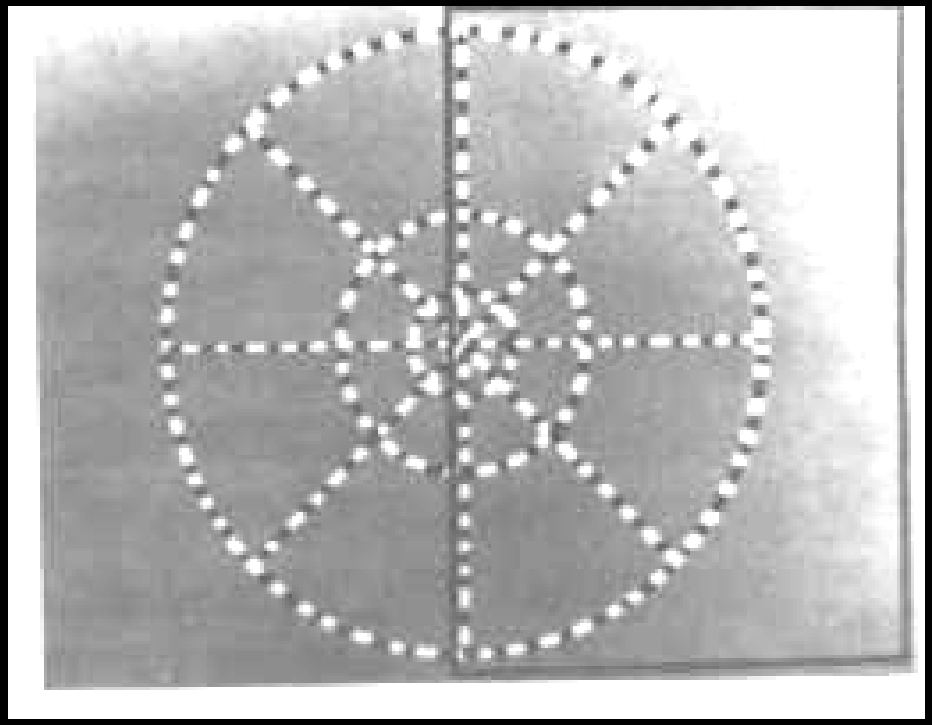
Parvocellular layers process information about details, while the Magnocellular layers process information about motion

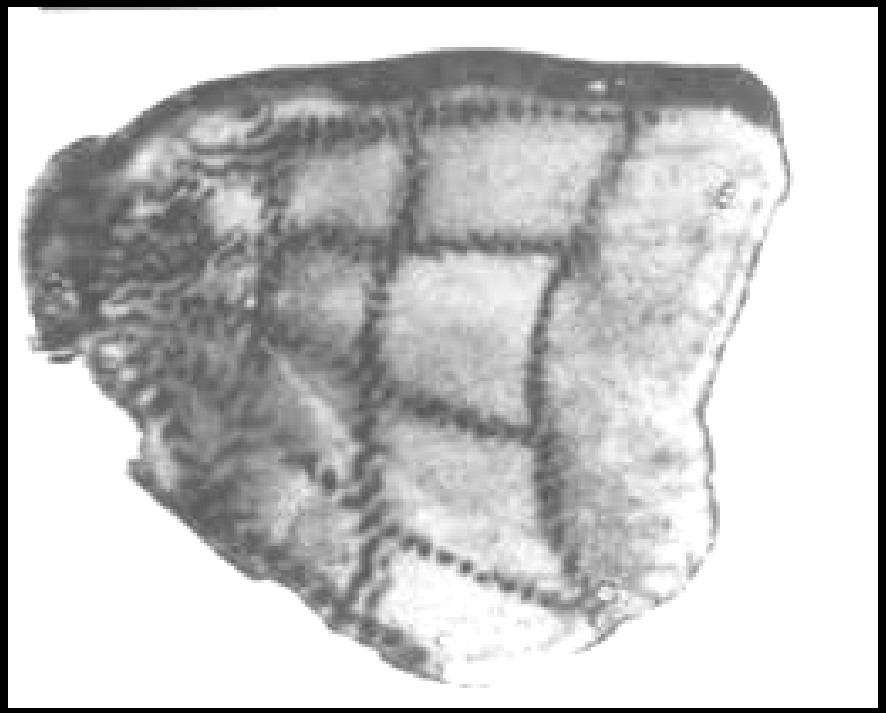

Ch
Ge
Ca
Ra
Spre
Pa


Area 17
(V1, primary visual cortex)

6(b).

Retinotopic Mapping onto V1

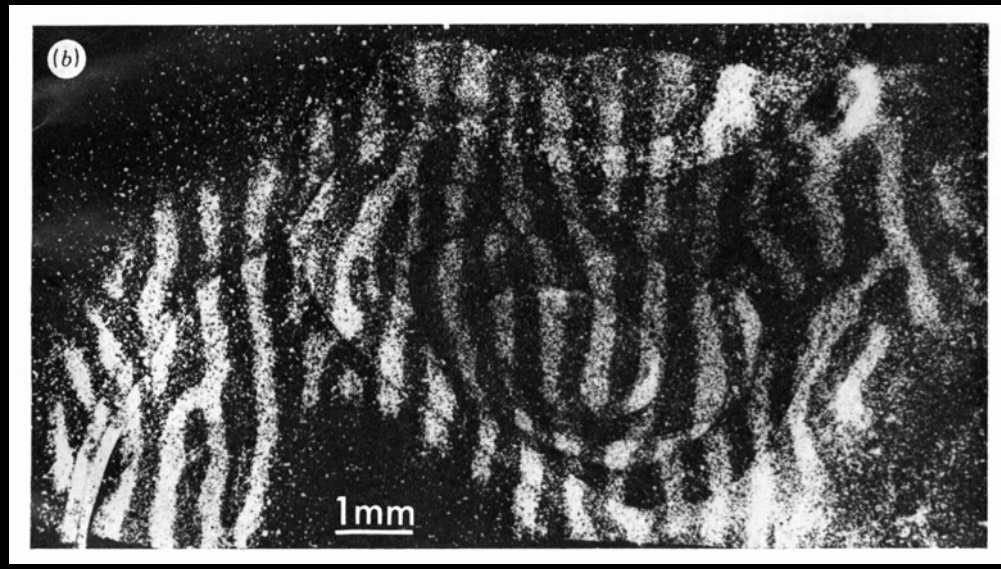




Divide & Conquer

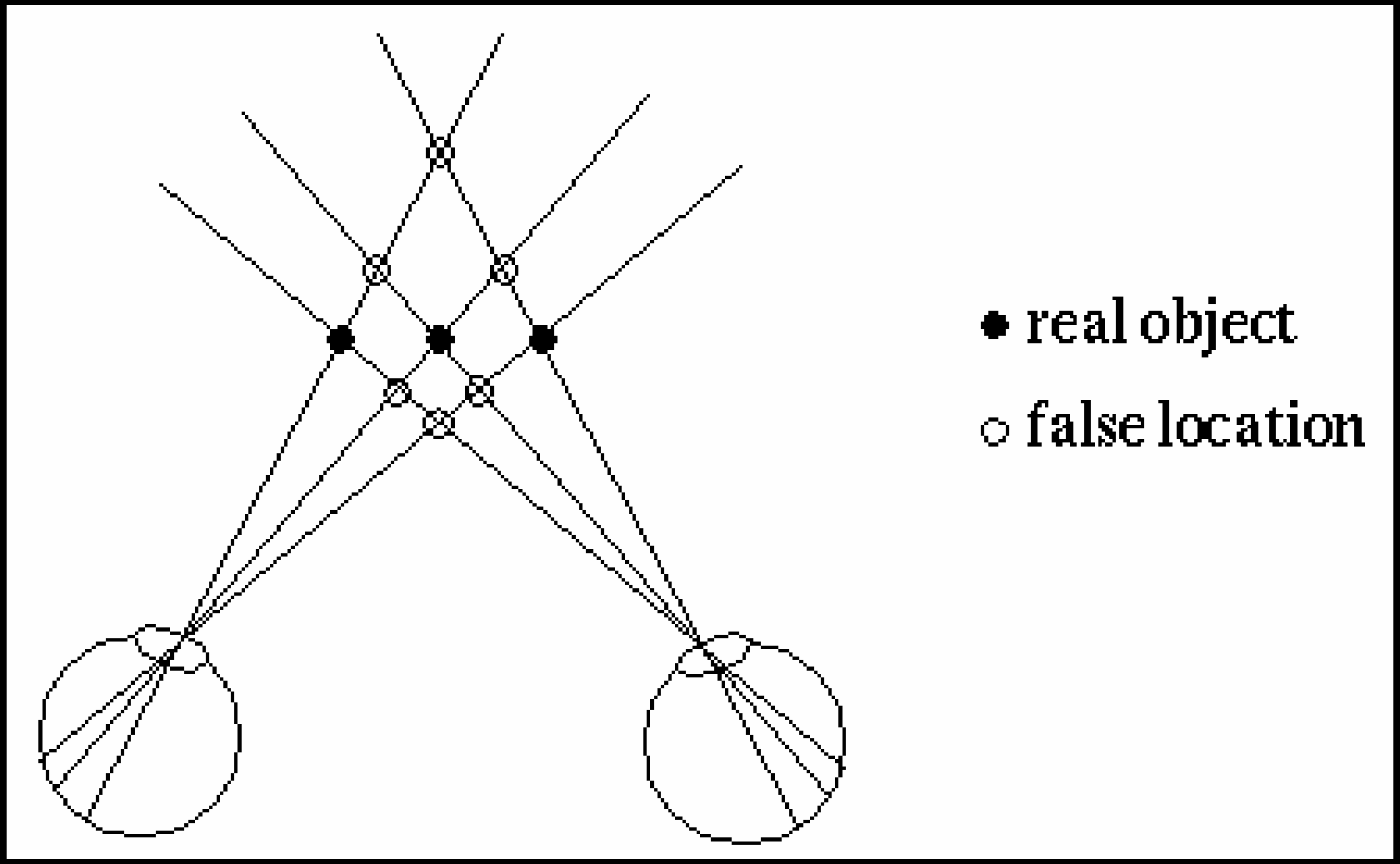
- There are many levels of organization in the visual cortex
- Visual cortices are highly specialized to represent particular features of the visual world

Ocular Dominance Columns

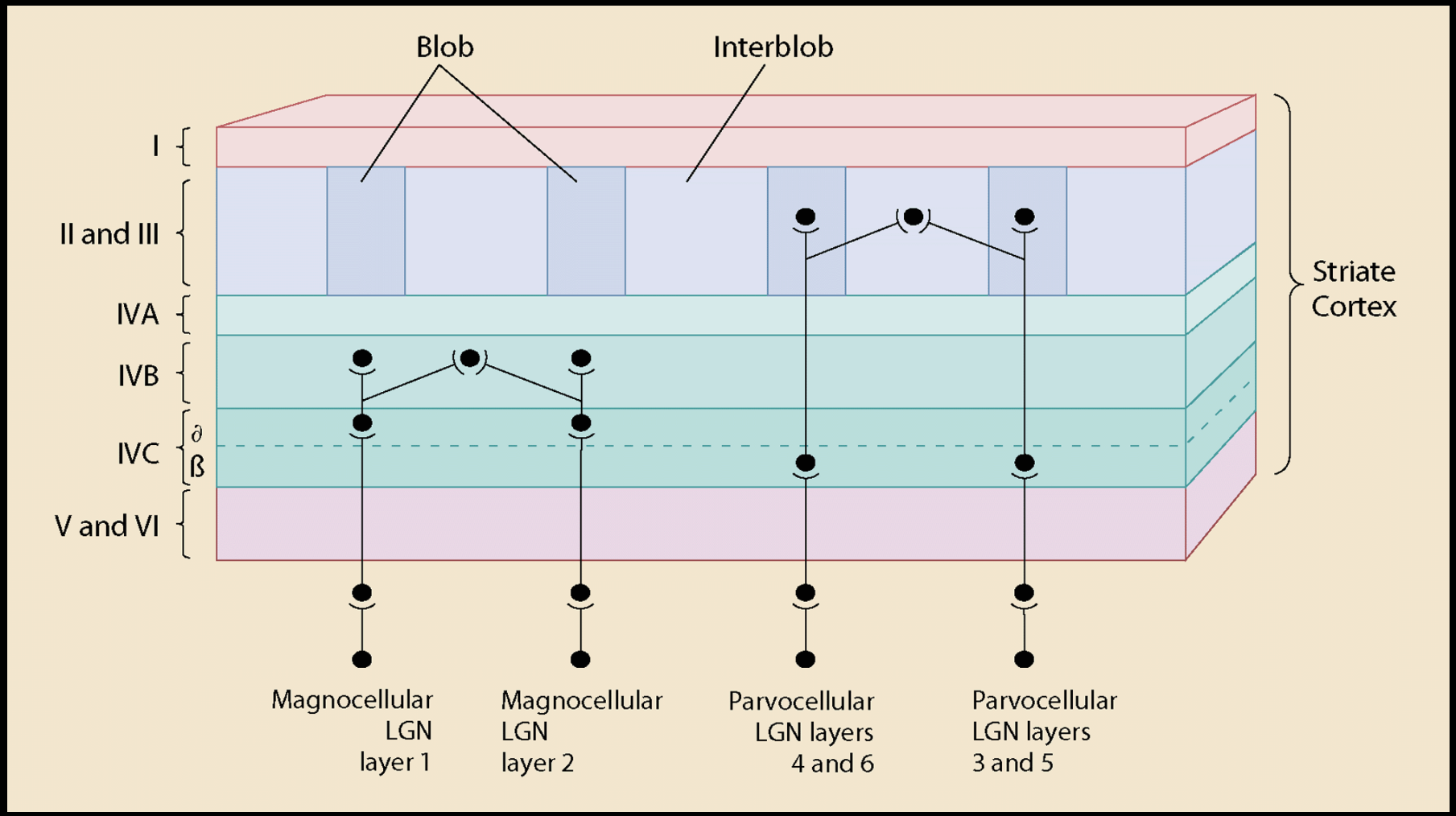


Primary Visual Cortex Segregates Information from the Right and Left Eye

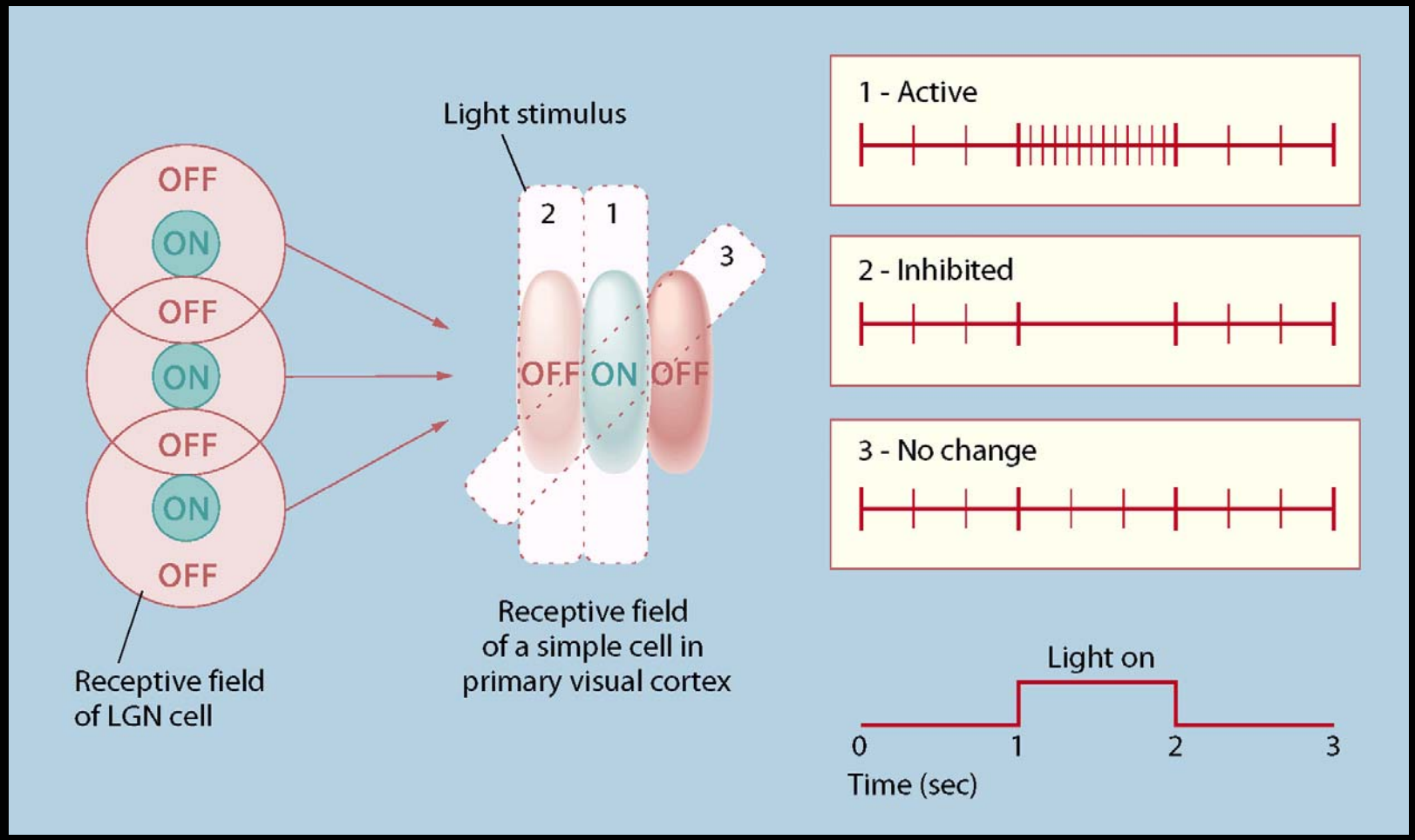
Binocular Visual Representations Identifies Distance from Perceived Object



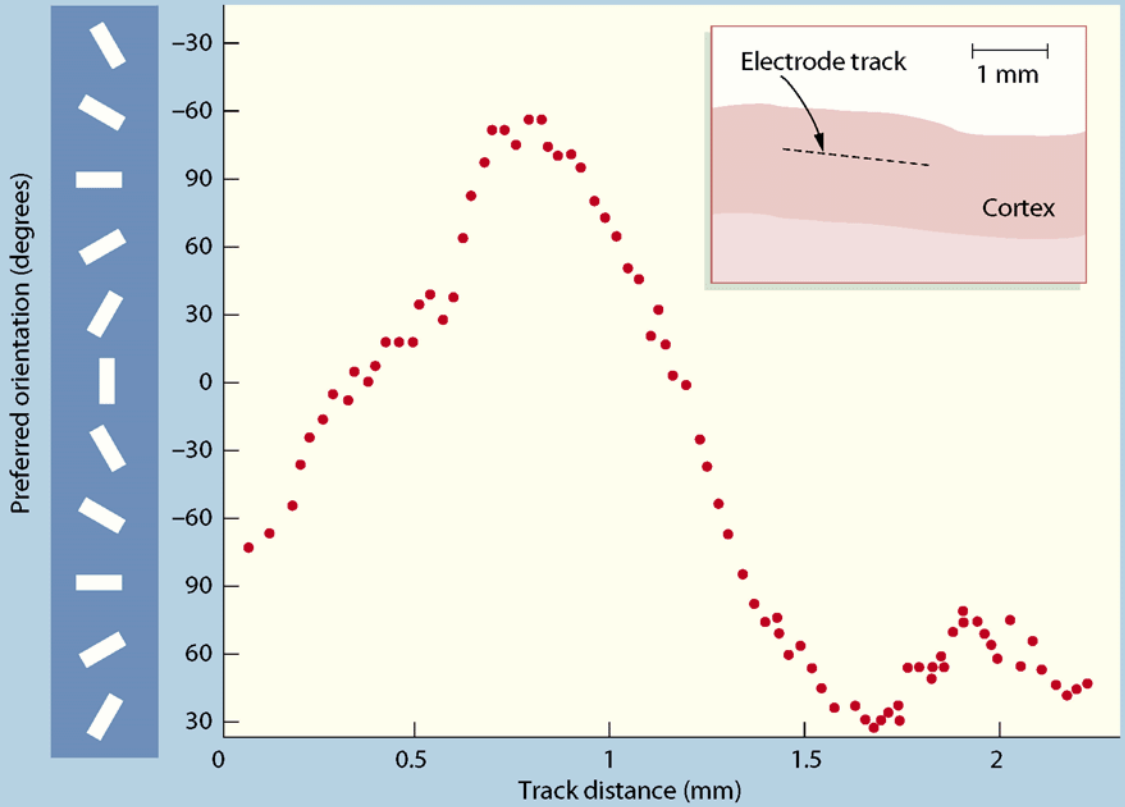
Parvocellular and Magnocellular Projections to the Visual Cortex

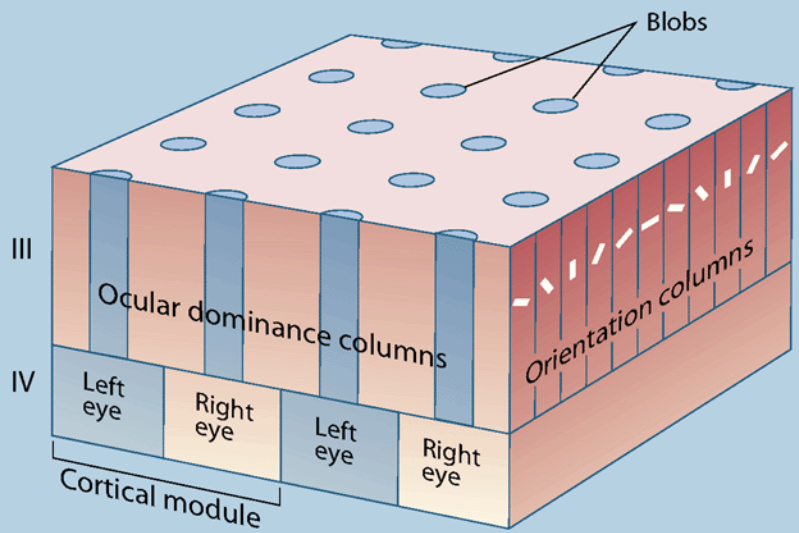


Parvocellular Pathway – Interblob Regions Respond to Orientation



Orientation tuning gradually shifts across adjacent areas of V1



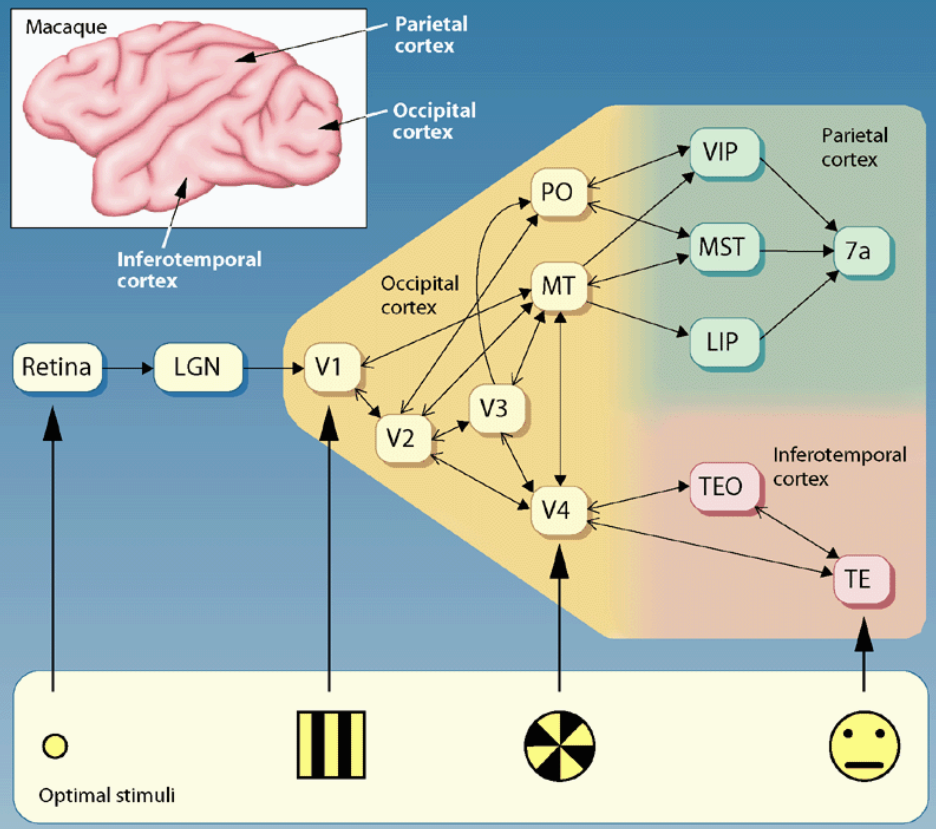


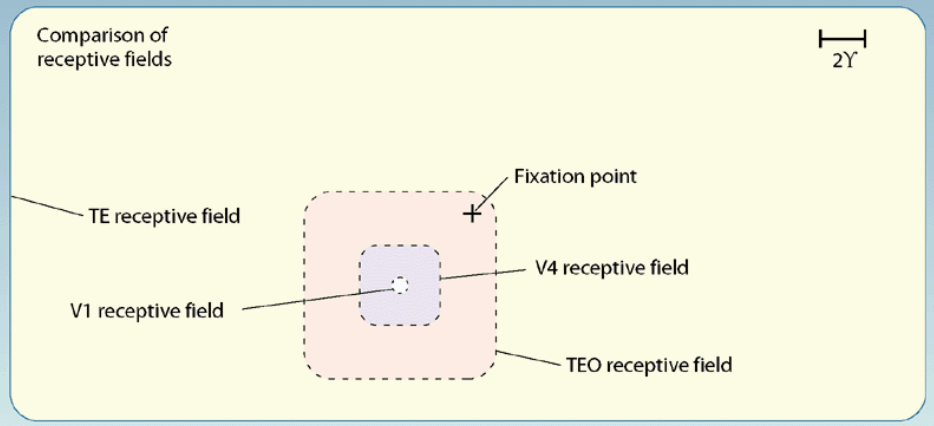
Specialization in V1

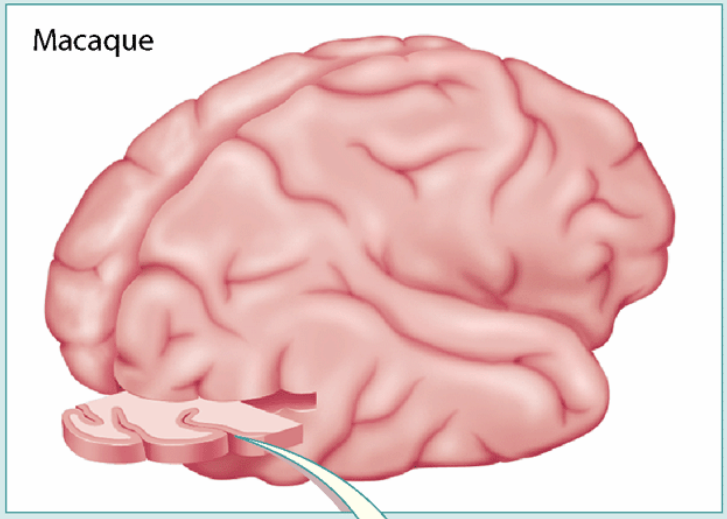
Parallel Pathways in Visual Perception

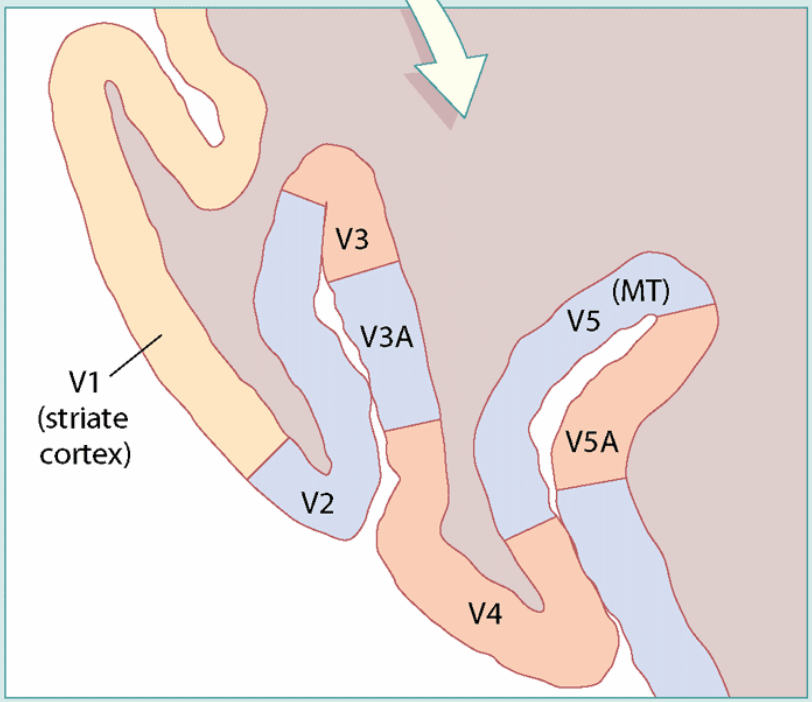
Neural Structure	Cell Types		
Thalamus (LGN)	**Magnocellular**	**Parvocellular**	
Area 17 (VI)	Layer 4b	Blobs	Interblobs
Area 18 (V2)	Thick stripes	Thin stripes	Interstripes

Cellular Correlates			
Contrast (brightness)	high	high	low
Location	low	low	high
Motion	high	low	middle
Color	low	high	middle
Orientation	middle	low	high

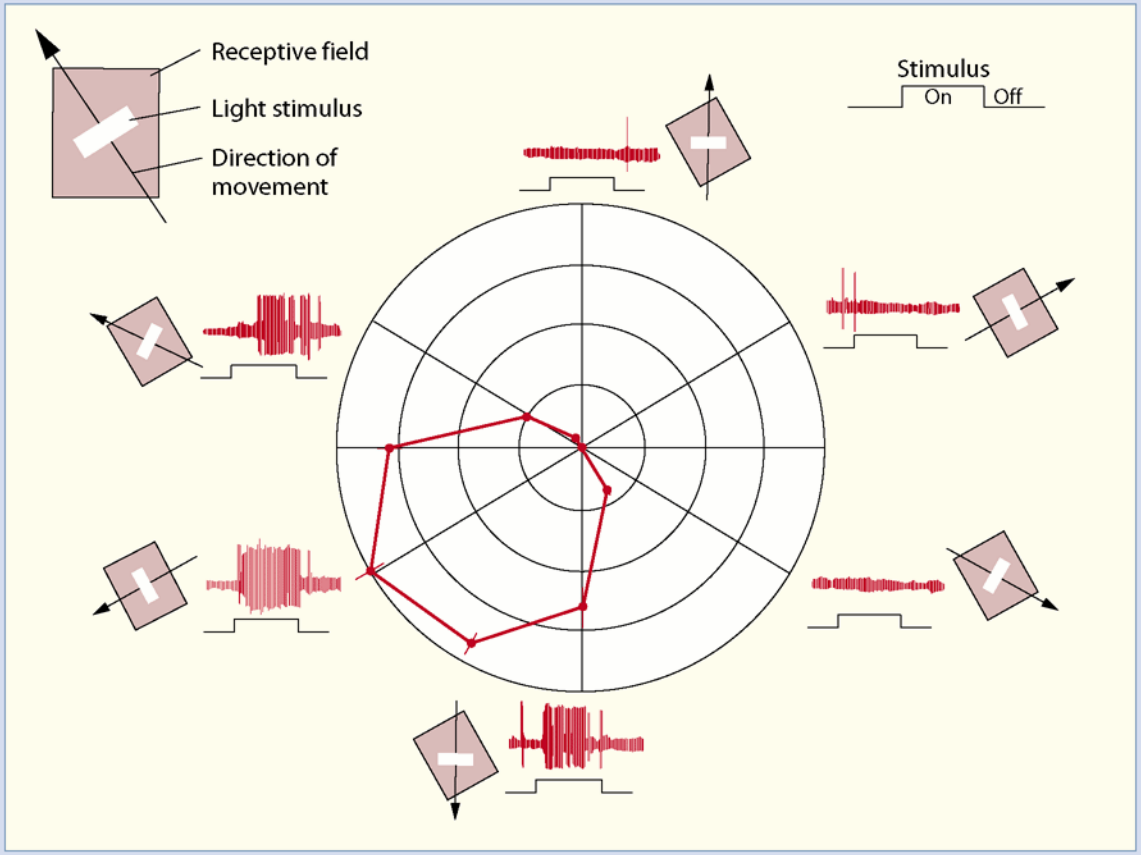

Macaque
Parietal cortex
Occipital cortex
Inferotemporal cortex
Retina
LGN
V1
V2
V3
V4
PO
MT
VIP
MST
LIP
7a
TEO
TE
Parietal cortex
Occipital cortex
Inferotemporal cortex
Optimal stimuli

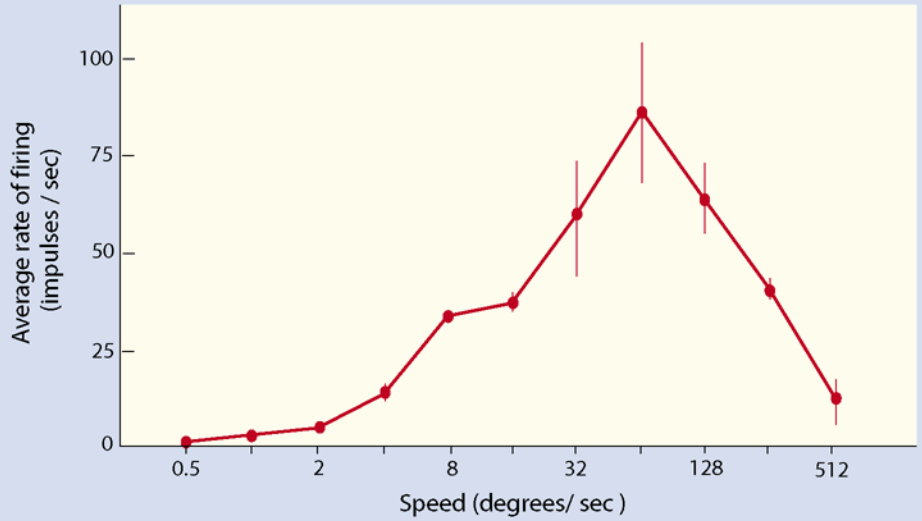

Comparison of receptive fields
2Y
Fixation point
TE receptive field
V4 receptive field
V1 receptive field
TEO receptive field


Macaque

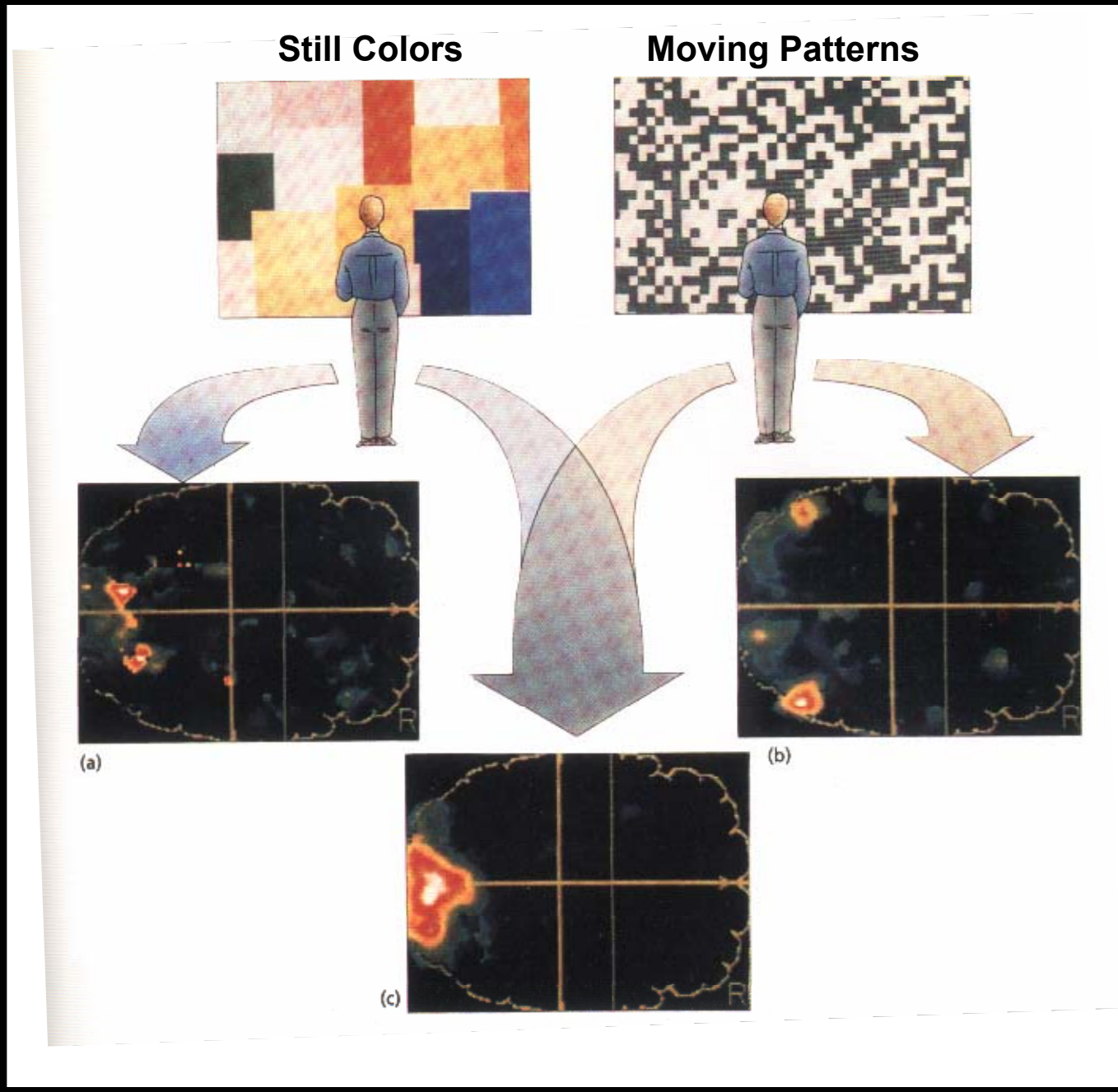

V1
(striate
cortex)
V2
V3
V3A
V4
V5
(MT)
V5A

Area MT processes movement information from the magnocellular pathway

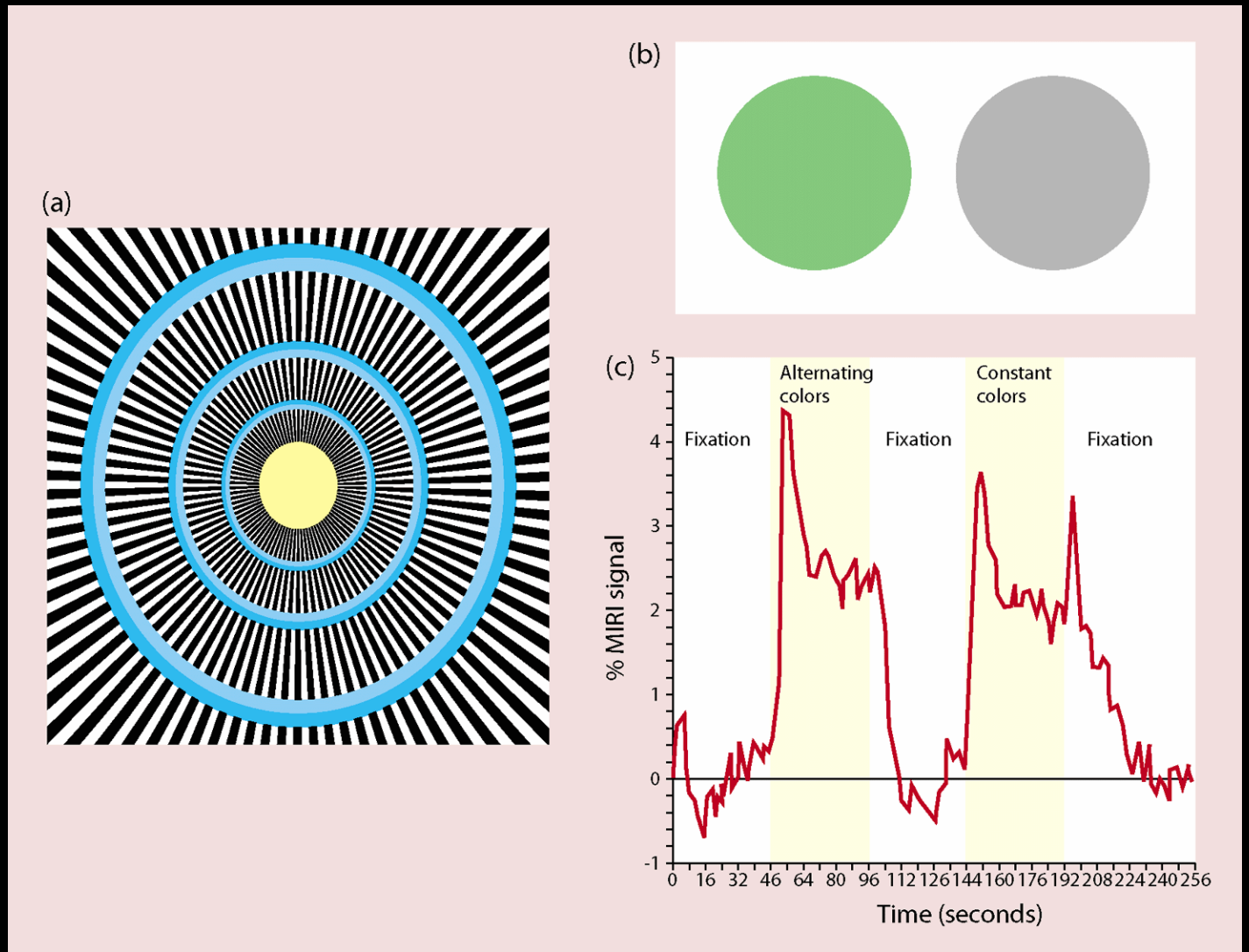




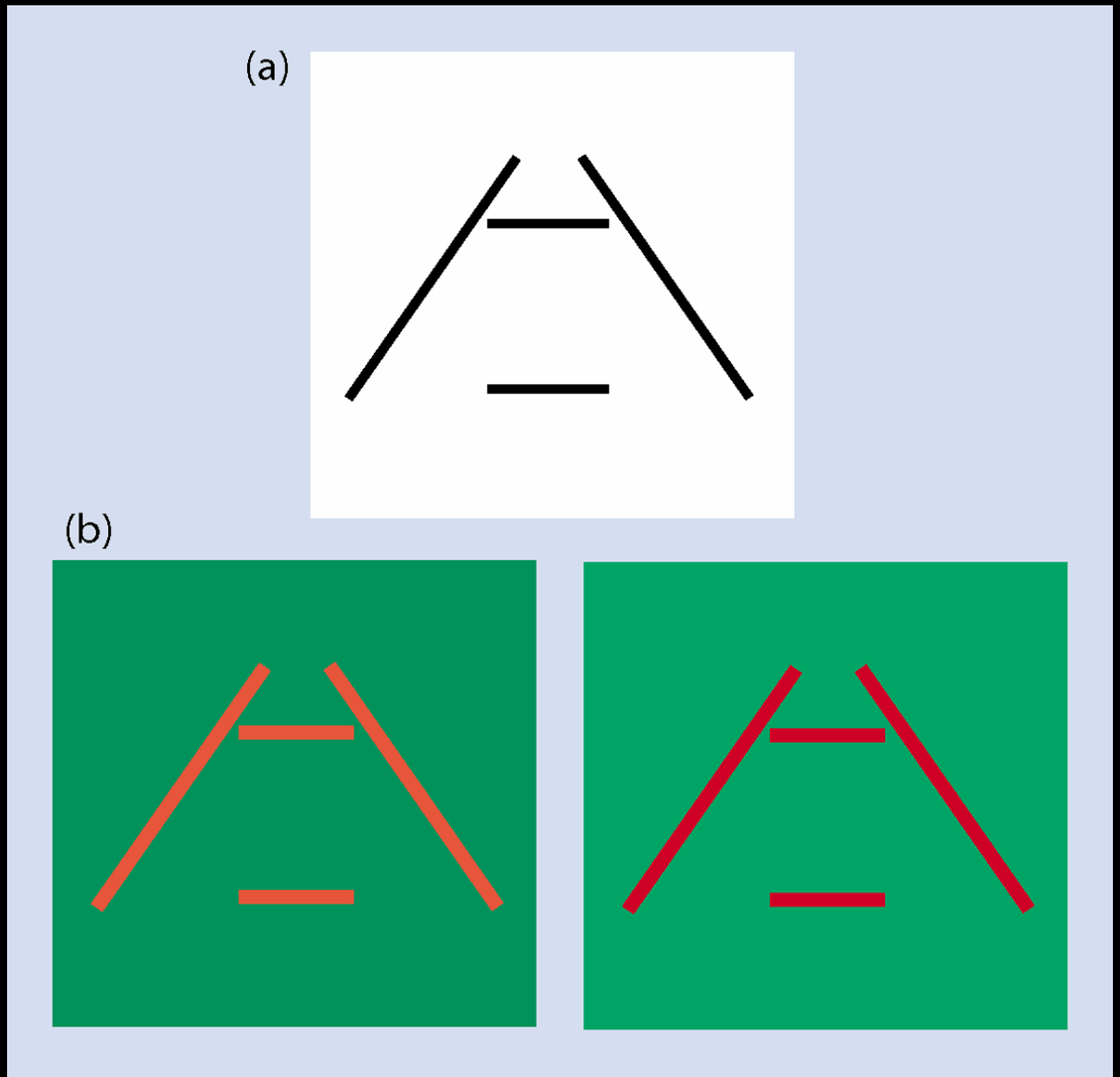
PET studies demonstrate that color activates V4, while motion activates MT



Visual Illusions Activate Higher Visual Cortical Areas



Segregation of Color and Depth Information



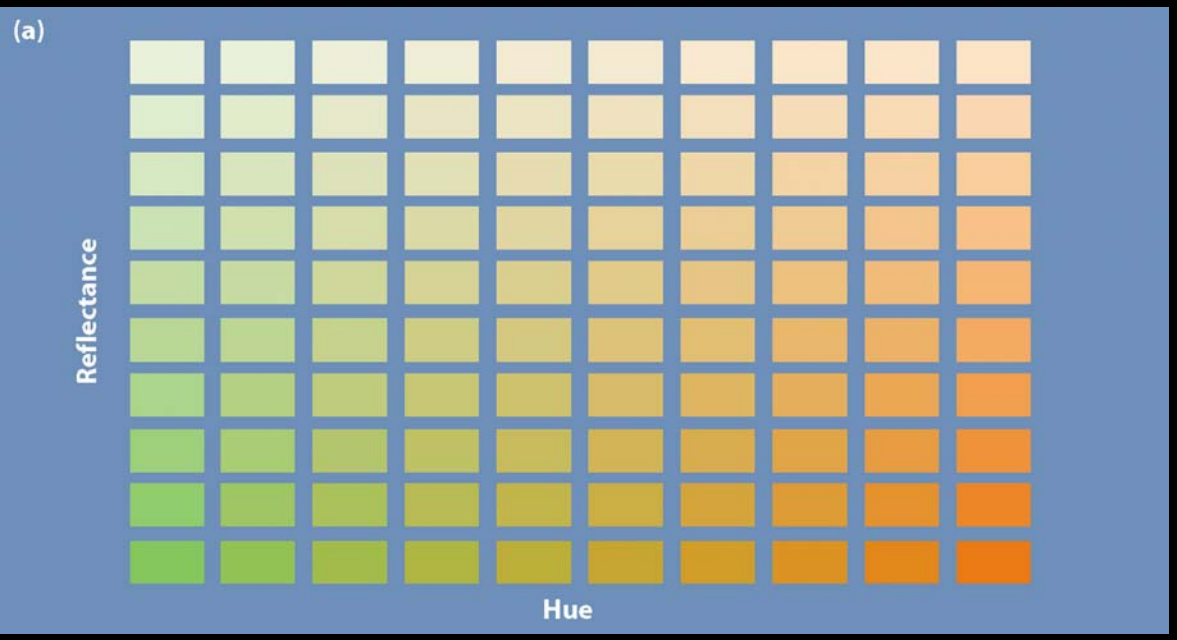
People fail to perceive the illusion when iso-illuminant lines are used because the P-blob pathway is depth insensitive

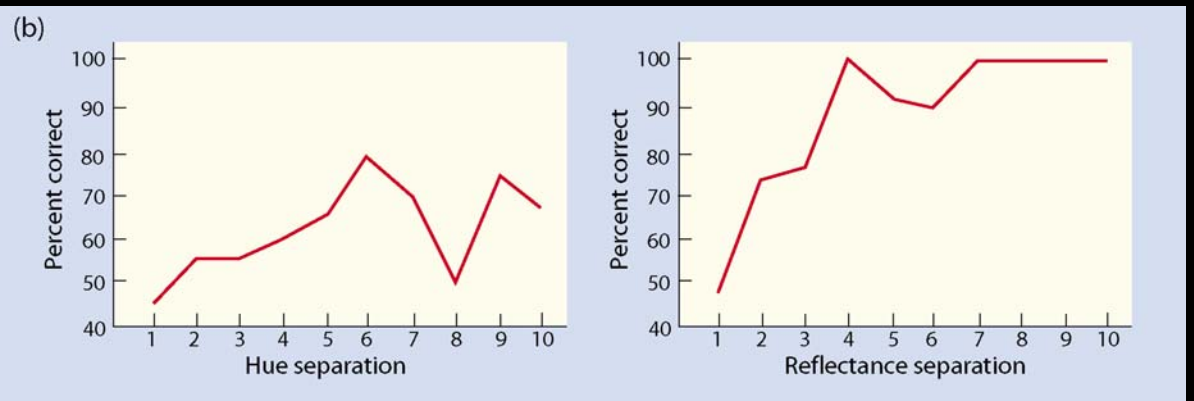
Disorders of Feature Perception

Disorders of feature perception offer another tool to investigate underlying brain mechanisms.

Converging evidence from different methodologies can provide support for models of visual perception

A stroke lesioning V4 can lead to Achromatopsia

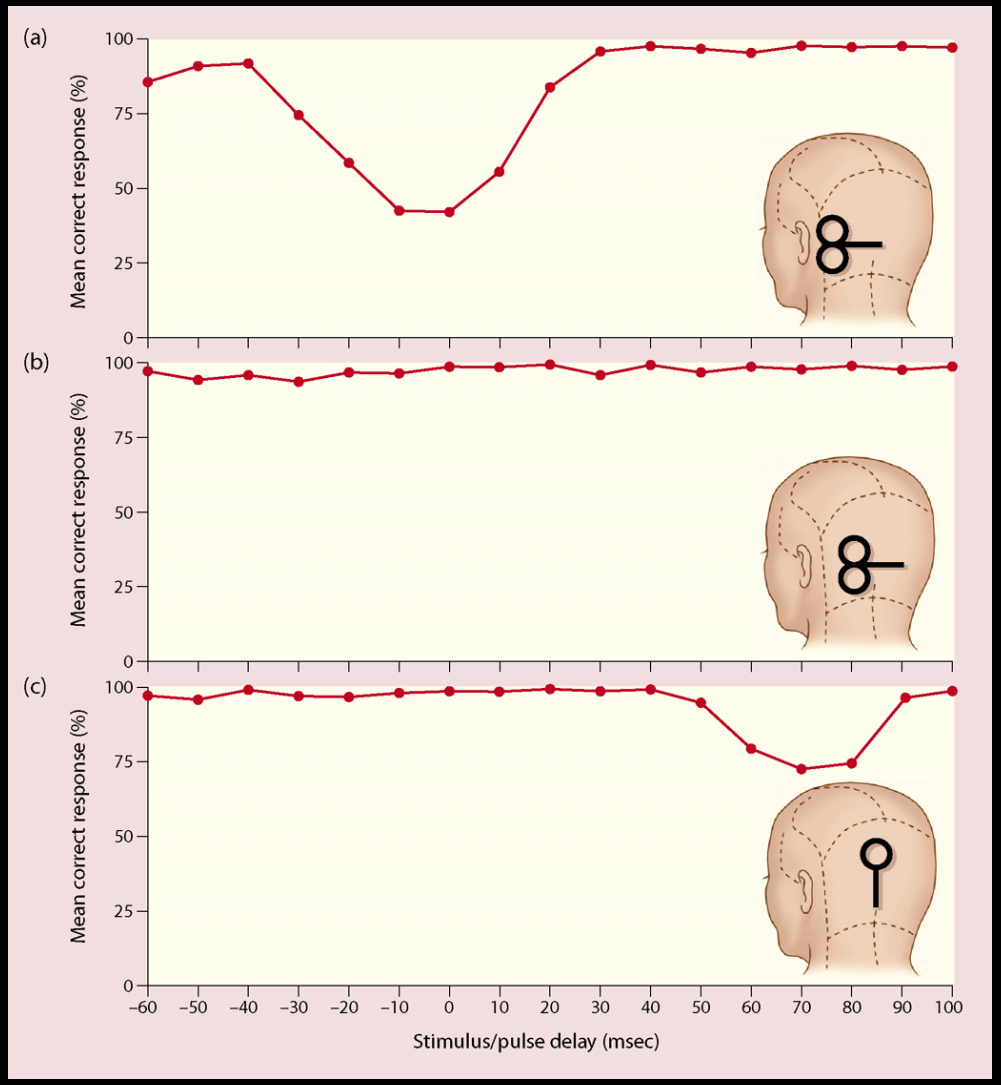




But, hue deficits are often accompanied by other perceptual deficits

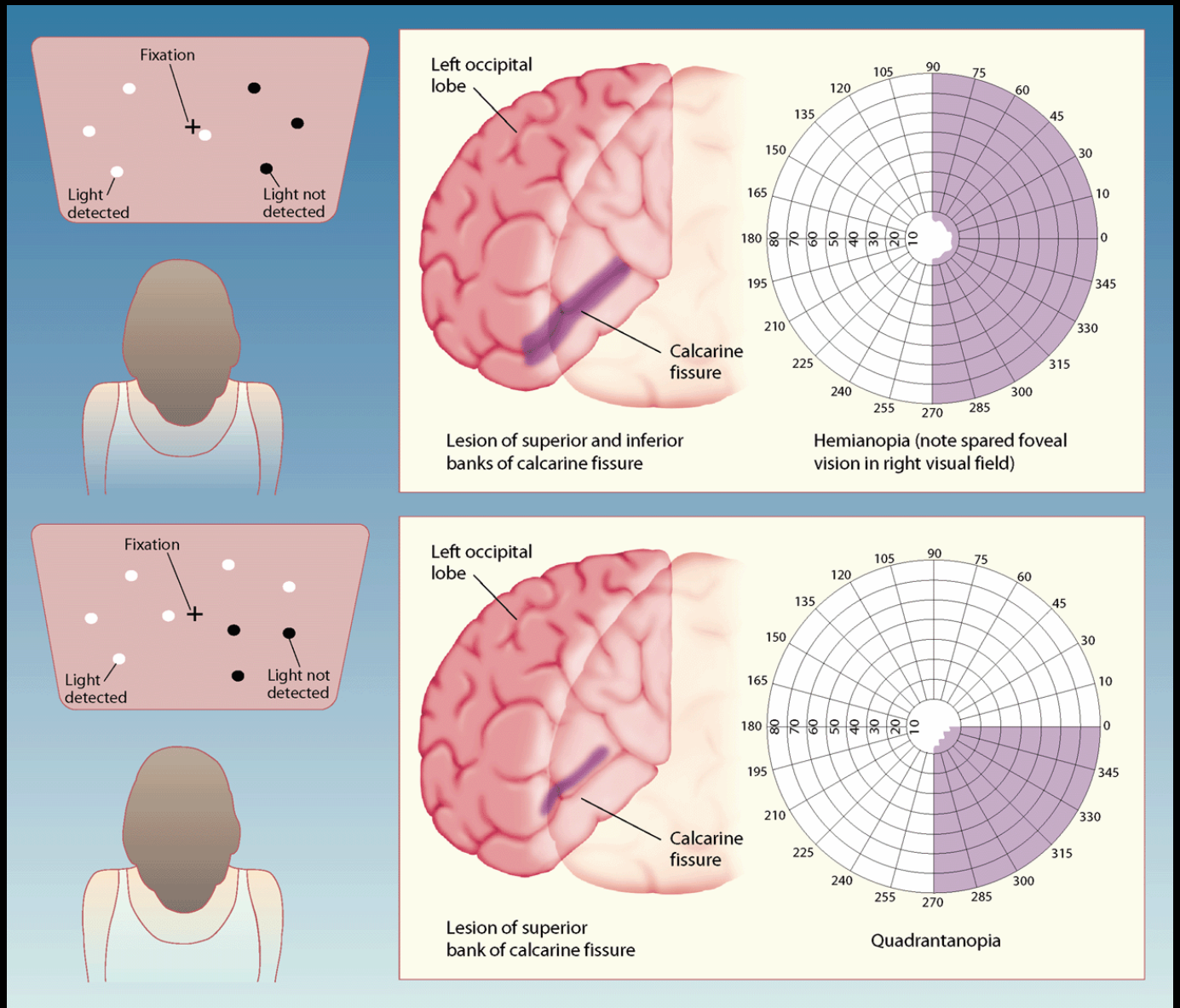
And monkeys with lesions in V4 can still descriminate hue, but have trouble distinguishing changes in reflectance (e.g. from shadows) from changes in hue

Lesions in the M System lead to Akinetopsia

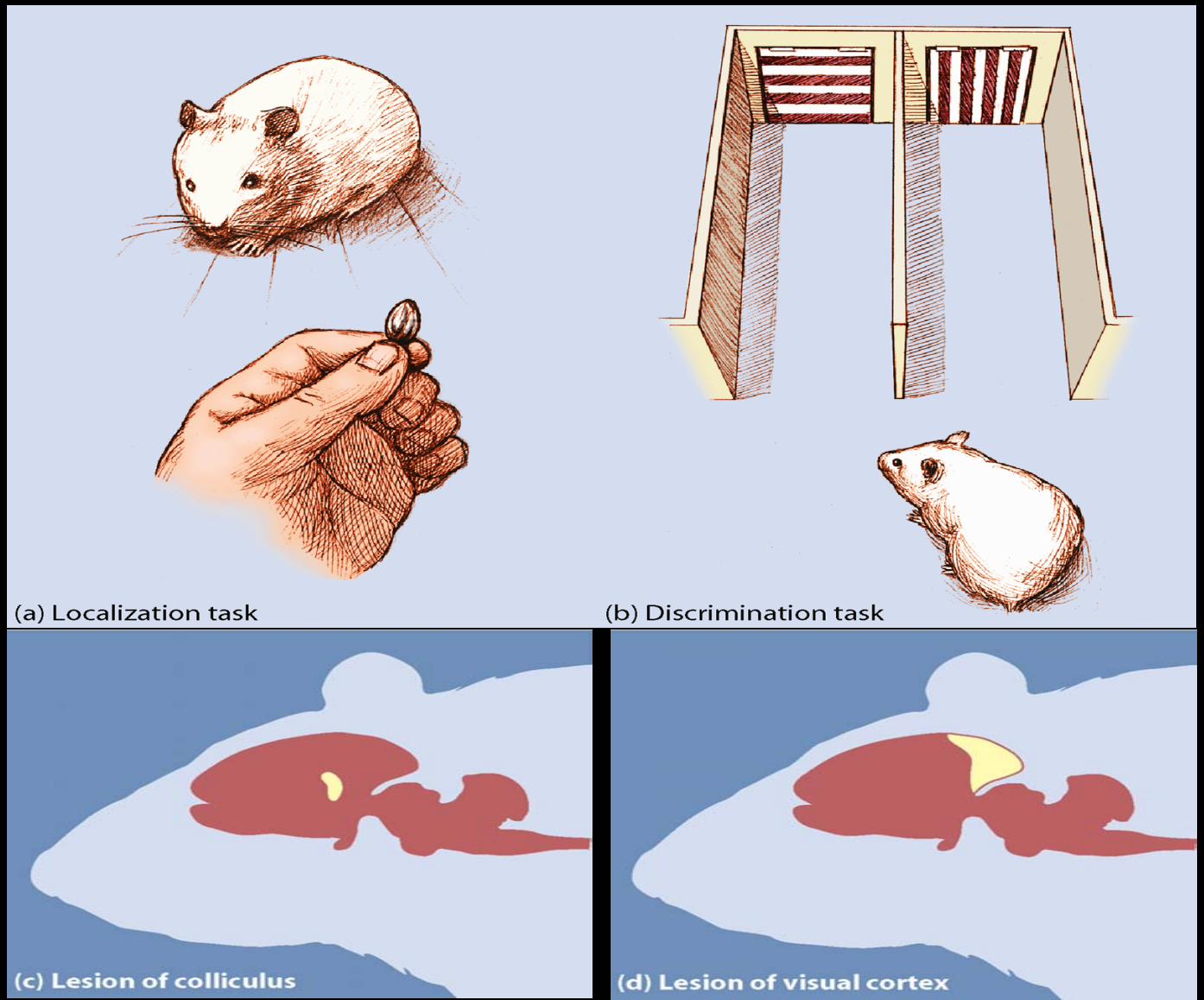


Temporary brain inactivations using transcranial magnetic stimulation (TMS) over area MT can produce deficits in motion perception

Lesion of V1 Causes a Scotoma

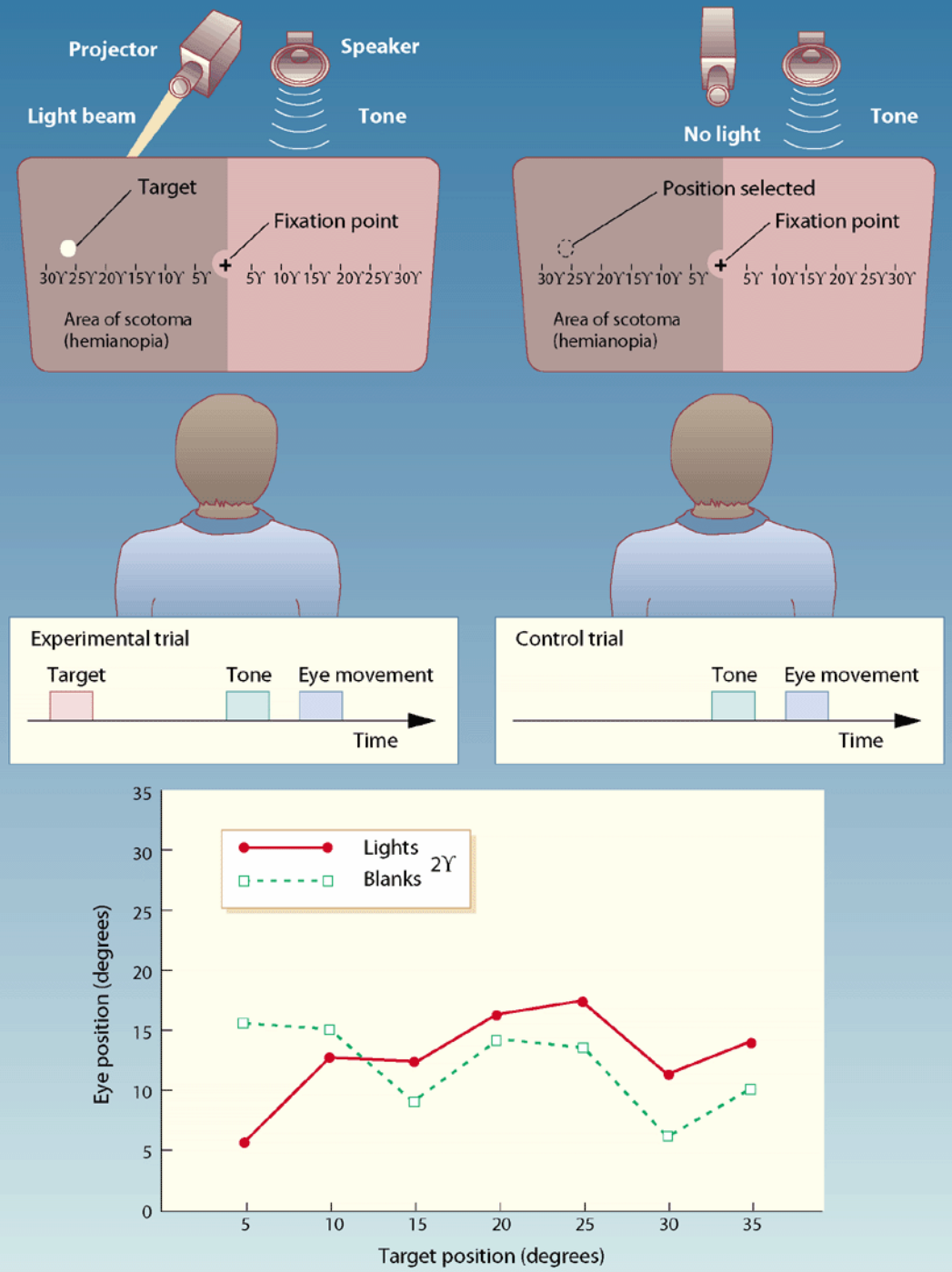


Subcortical Visual Pathways



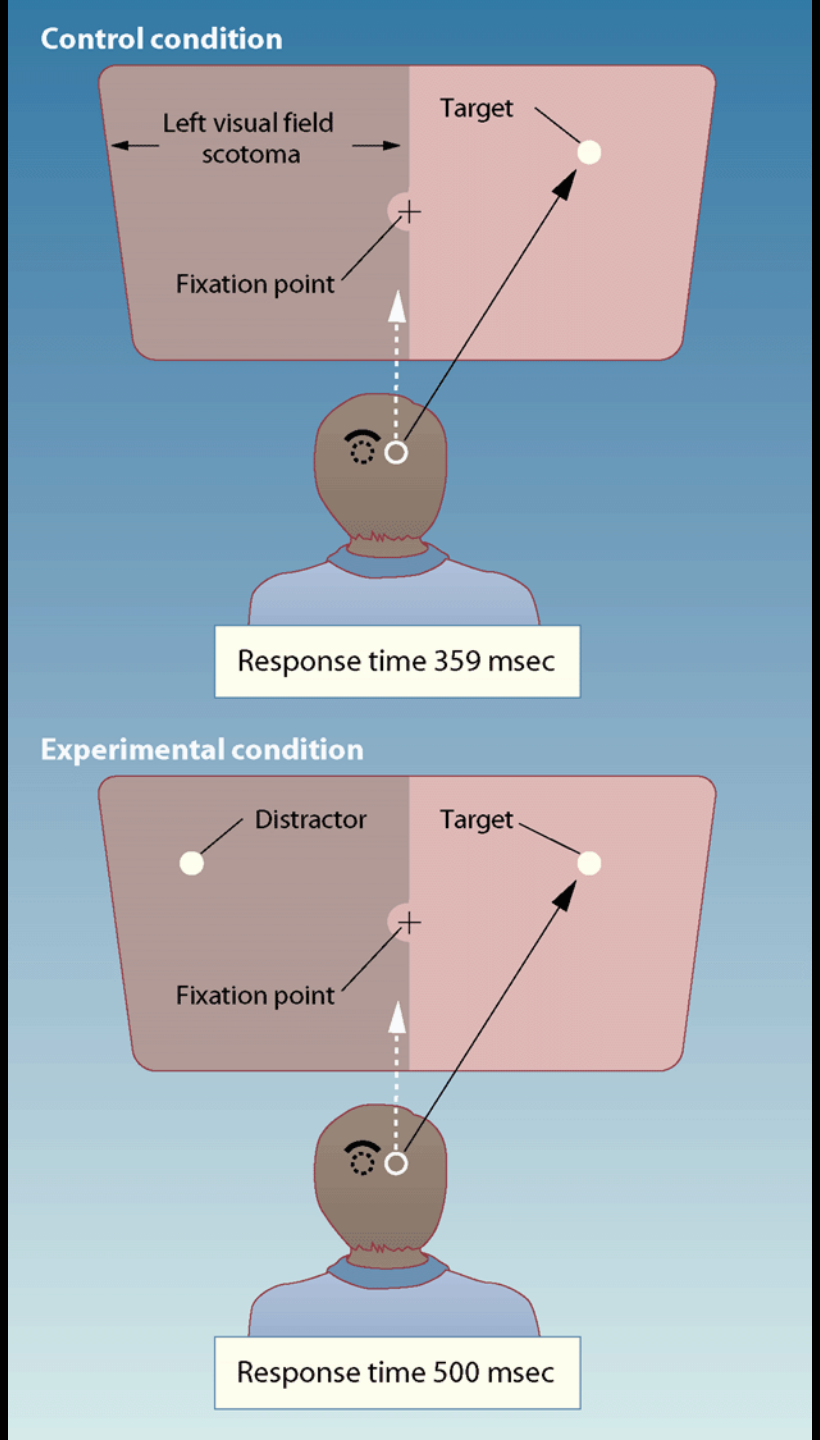
Blindsight

An ability to react to the presence of an object in the area of a scotoma without conscious perception of the object.

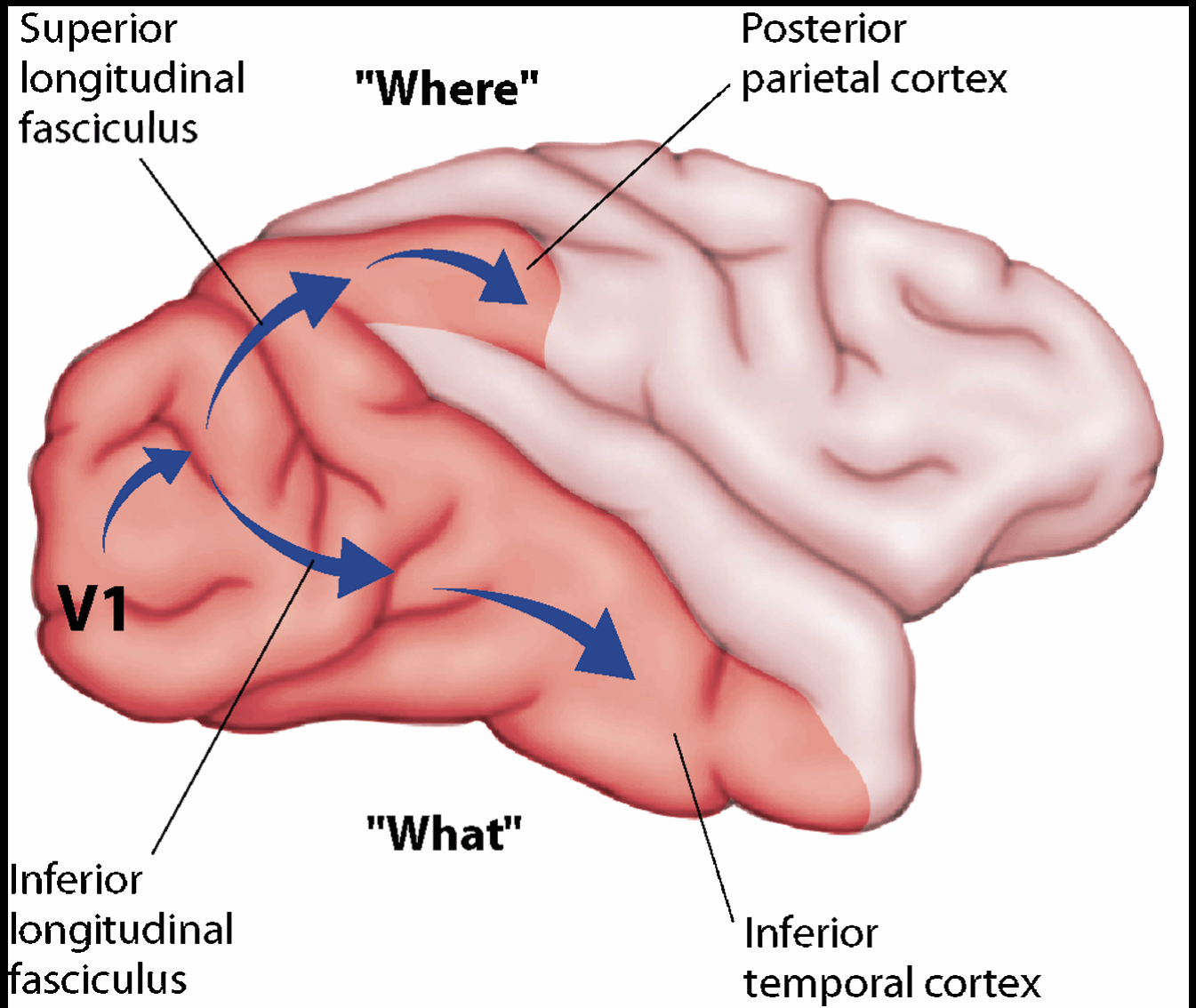


Blindsight

Blindsight may utilize subcortical areas and higher visual cortical areas in the absence of V1 processing

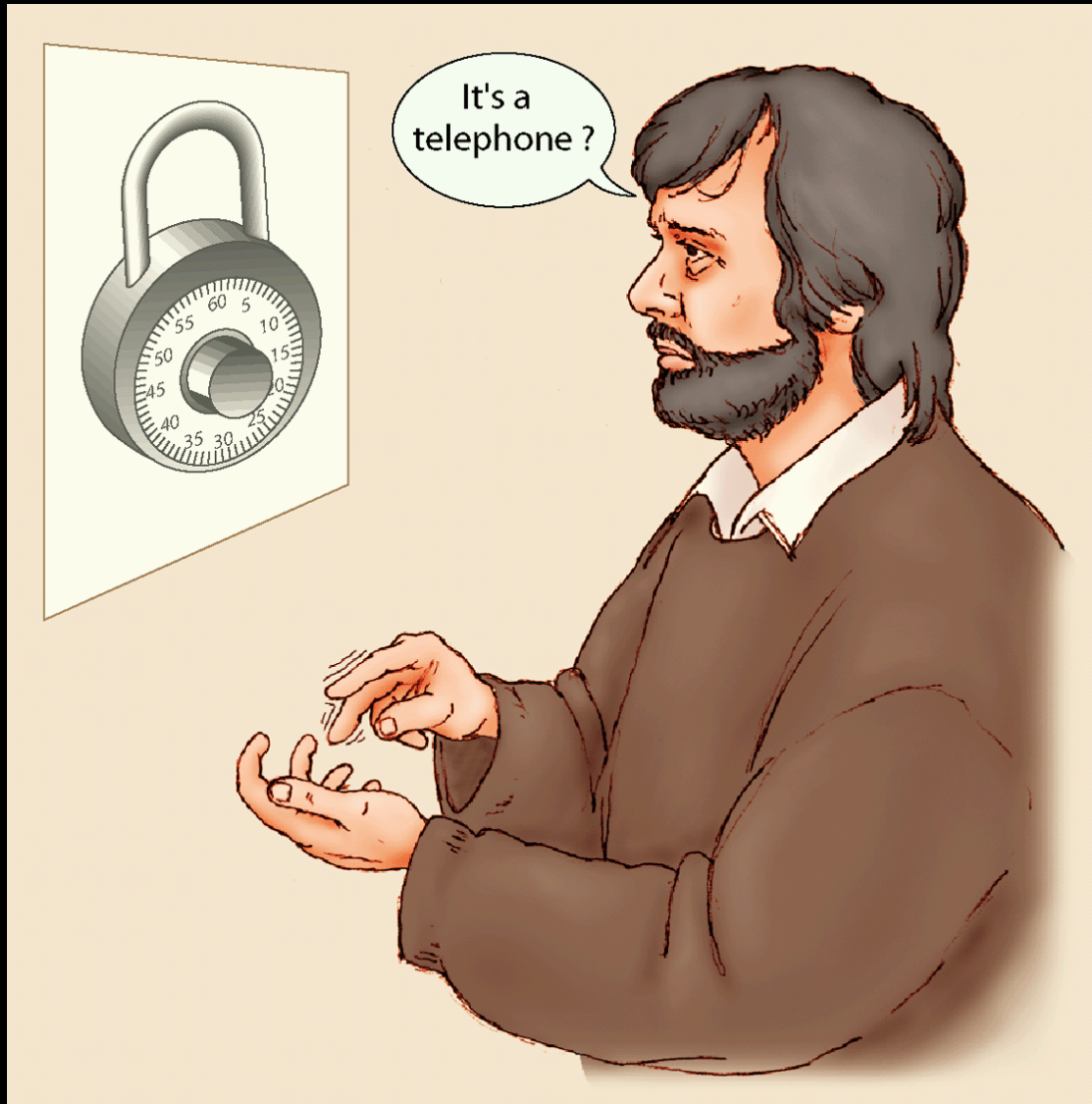


Dorsal Vs. Ventral Streams

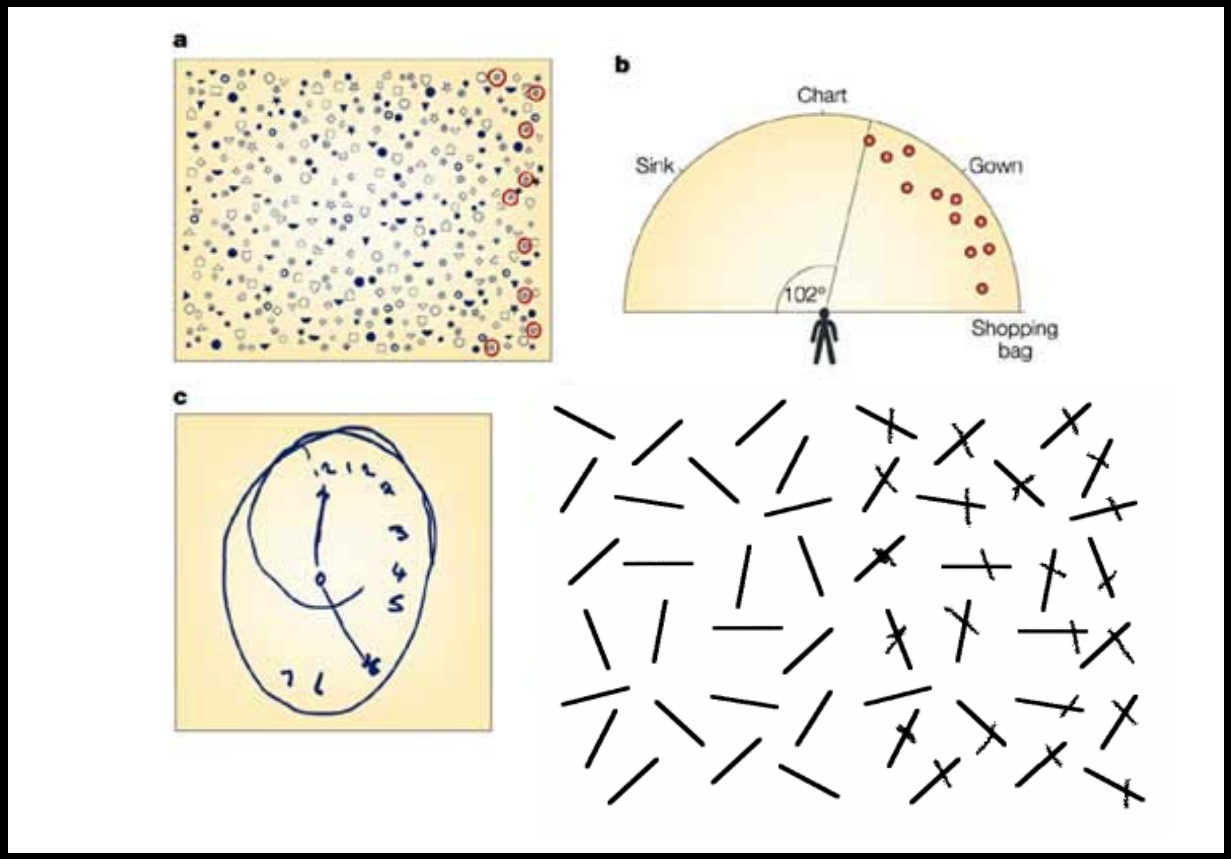


Damage to Temporal Cortex Leads to Visual Agnosia

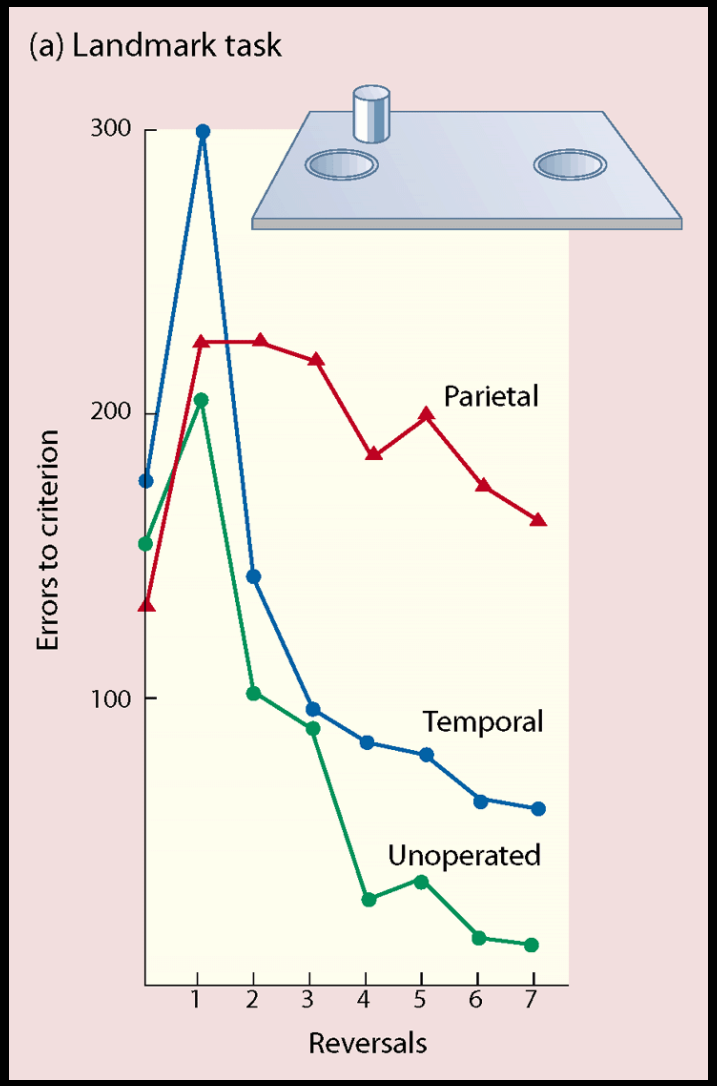
- Patients can describe the visual features of an object, but cannot name the object
- Patients can easily name objects presented through other modalities (auditory description, smell, etc.)
- A particular type of visual agnosia, call prosopagnosia involves impaired recognition of faces

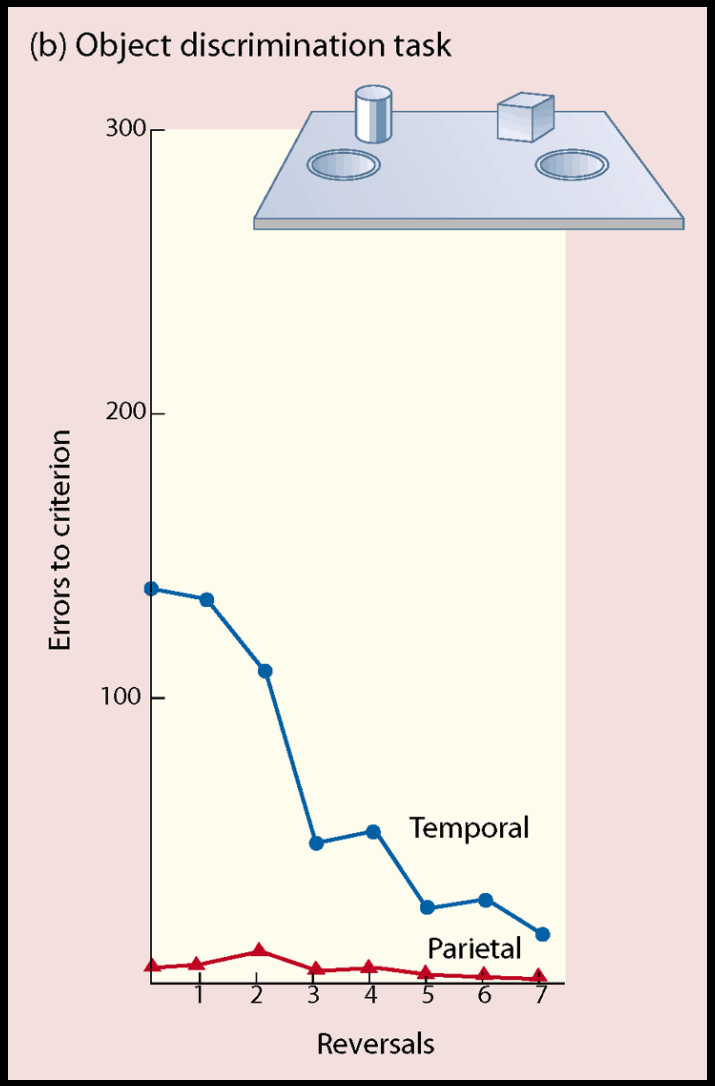


Unilateral Damage to Parietal Cortex Leads to Hemispatial Neglect

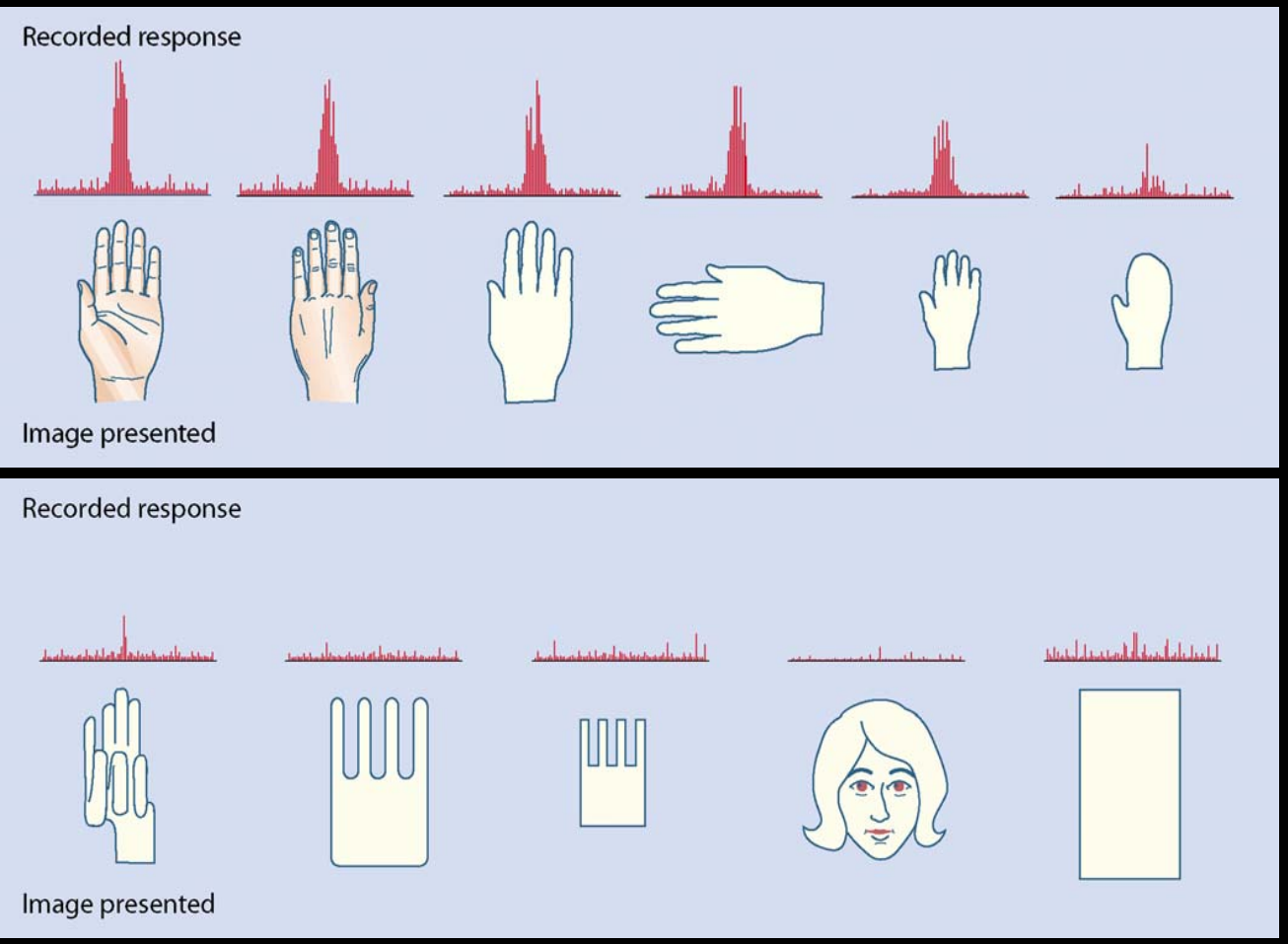


Temporal Vs. Parietal Lesion Experiments Show a Double Dissociation in Deficits

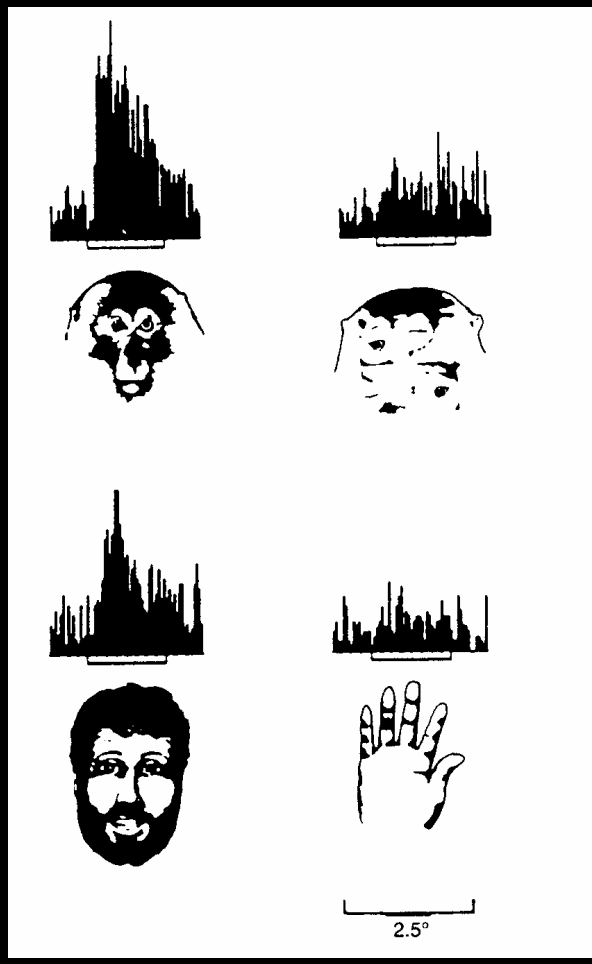




Responses of Neurons in the Temporal Cortex

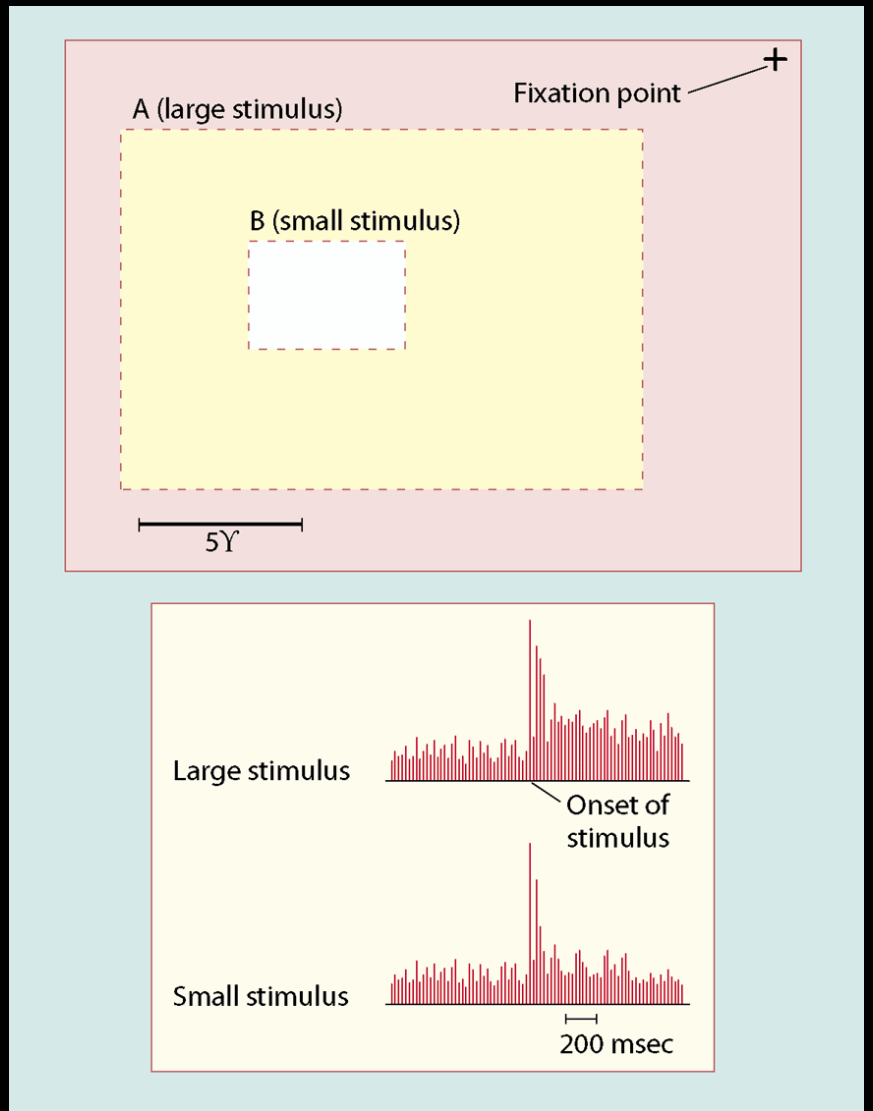


"Hand Neuron"

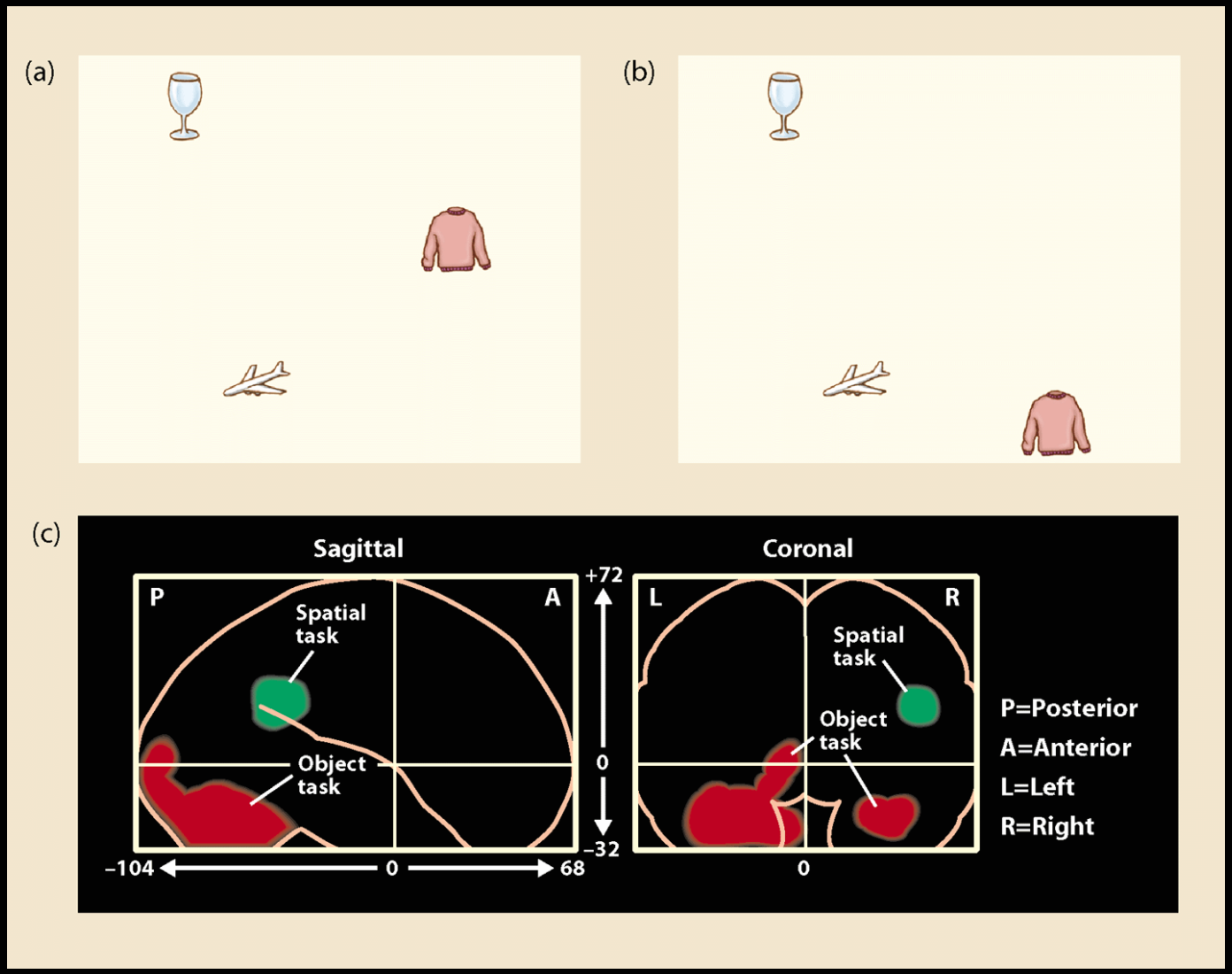


"Face Neuron"

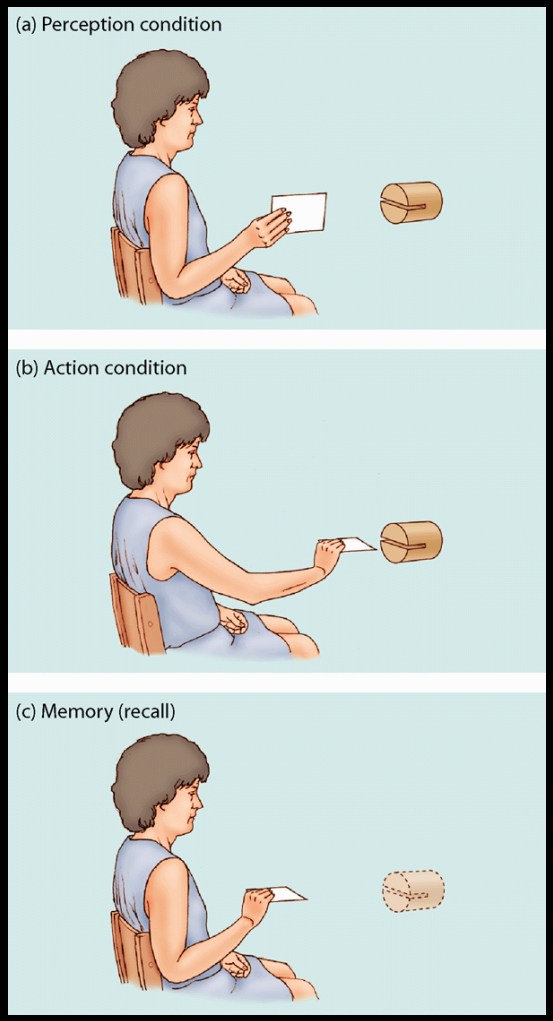
Responses of Neurons in the Parietal Cortex



PET Imaging Supports “What” and “Where” Roles for the Ventral and Dorsal Streams



Some Deficits Argue for “What” Vs. “How” Distinction

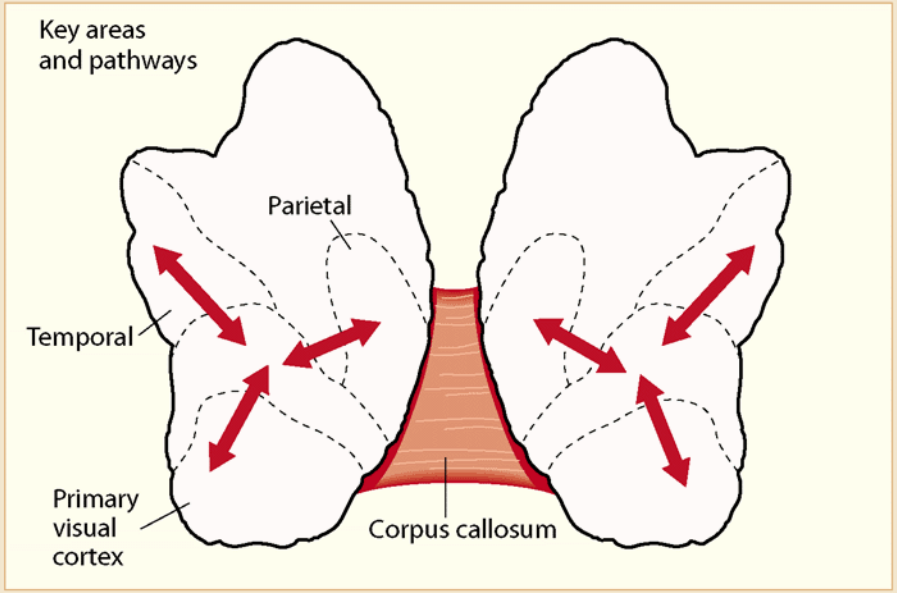


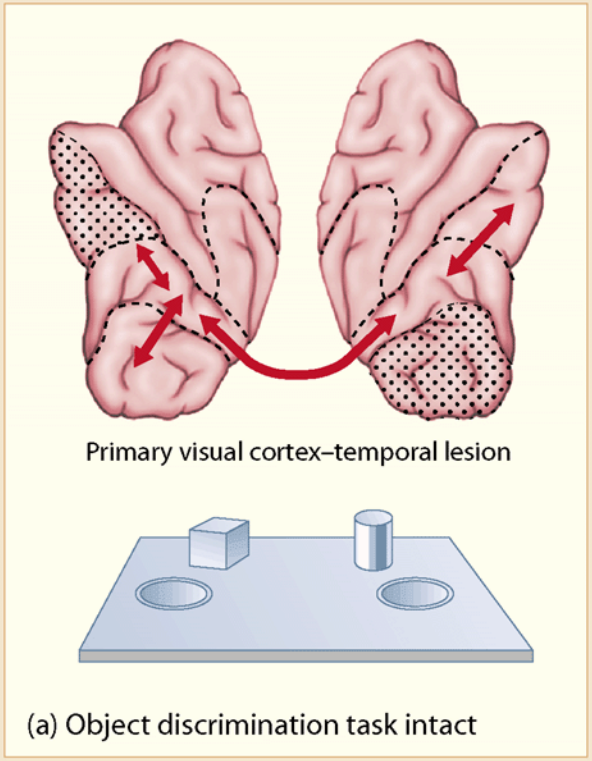
(“What” deficit)

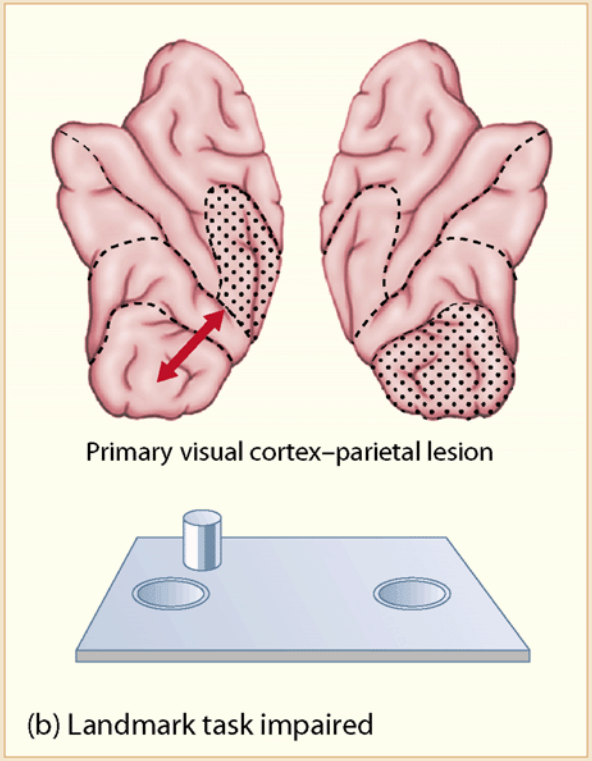
Vs.

Optic Ataxia

(“How” deficit)







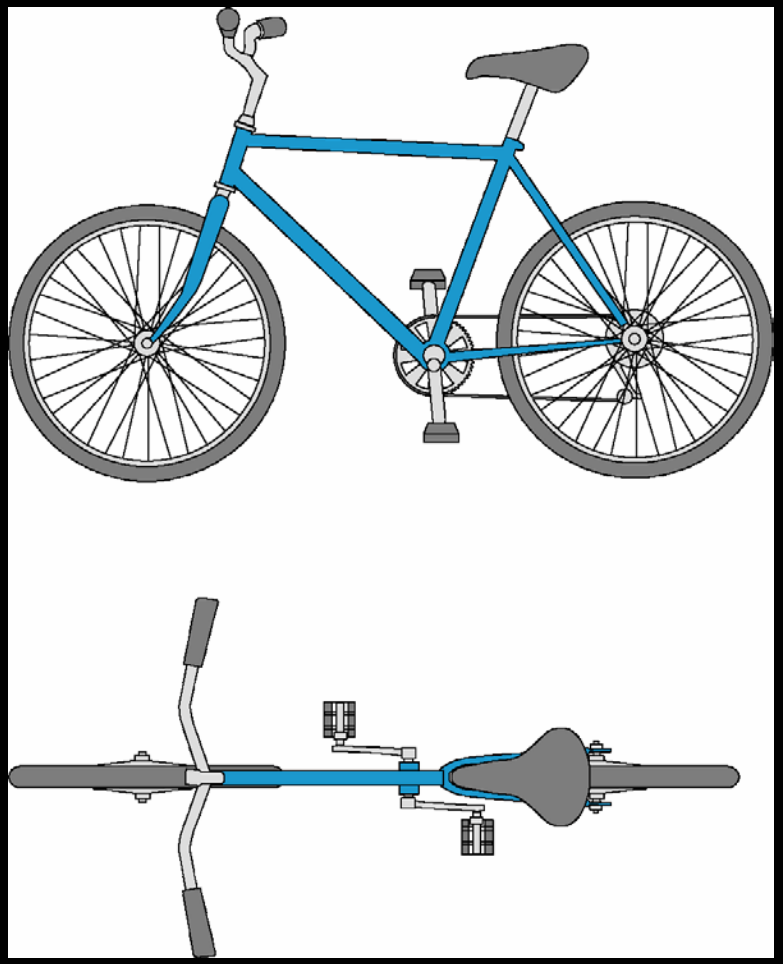
The corpus callosum provides interhemispheric for ventral stream, but the dorsal stream appears to be more hemispherically segregated

Object Constancy

Despite continual changes in:

- viewing position
- illumination
- obstruction

View-Dependent Vs View-Invariant Recognition



View-Dependent Theories

- Storage of many visual representations of the same object from different vantage points

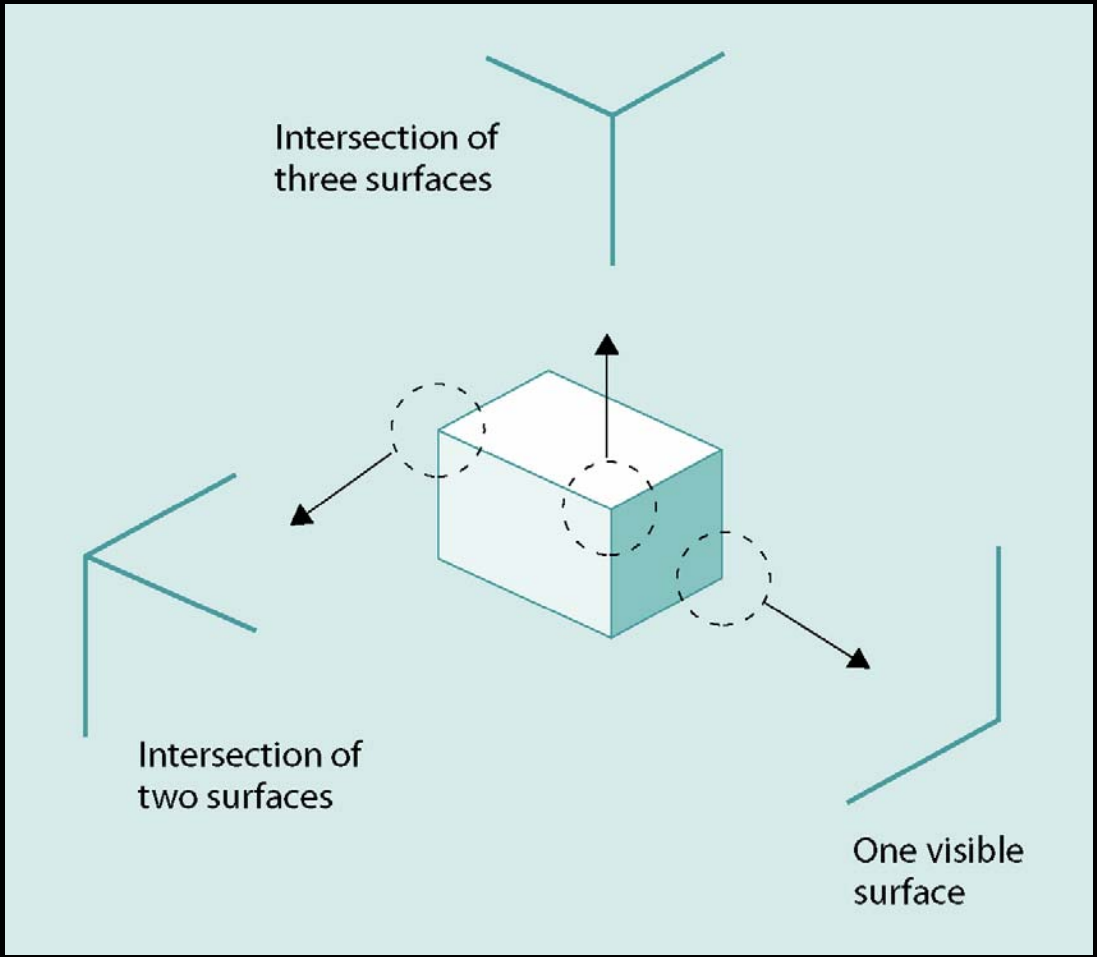
- When a novel viewpoint is encountered, we interpolate between stored representations a choose the best match

View-Invariant Frame of Reference

- Determine features that define the major and minor axis of the object

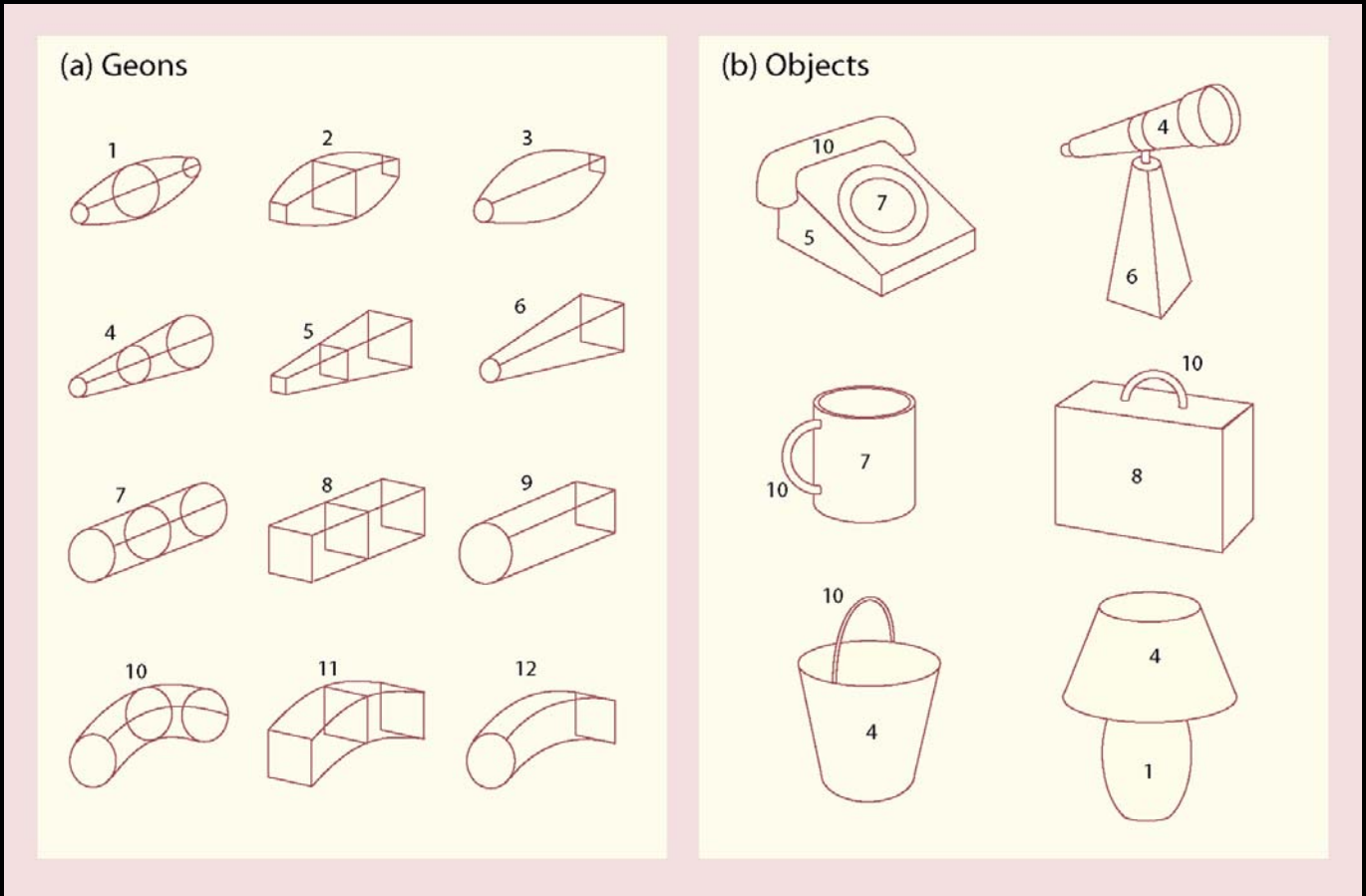
- These axes define the object through nearly all view points

Shape Encoding



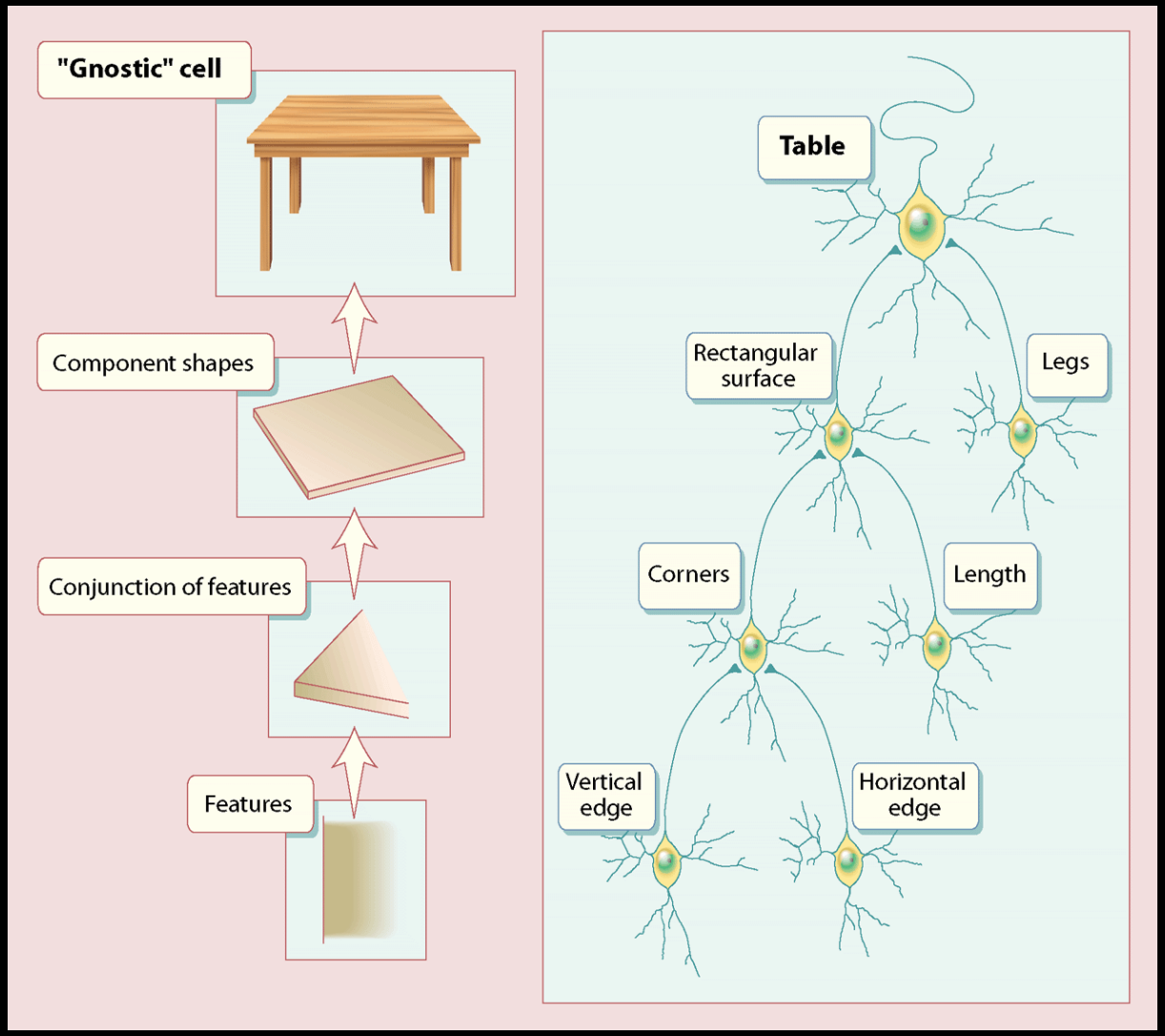
Salient features of the object give invariant cues to surface perception

“Geons” as the Fundemental Building Blocks of Object Recognition



But what about objects that are easily identified as different that have similar geons, like dogs & cats?

Hierarchical Representations of Objects



Problems with a Gnostic cell theory

1) What if our “table cell” dies?

2) How do we perceive new objects?

Ensemble Coding of Objects

Cells coding for different features of an object or face work together to permit perception

Specialization of Face Processing

- Diagnosis of Prosopagnosia argues for a specialized system for face processing
- This conclusion must be approached cautiously because it is hard to use object that match the complexity of faces
- Most tests for prosopagnosia involve discriminating different faces versus discriminating tables and chairs

Face Perception is Altered by Orientation

Face Perception is Altered by Orientation

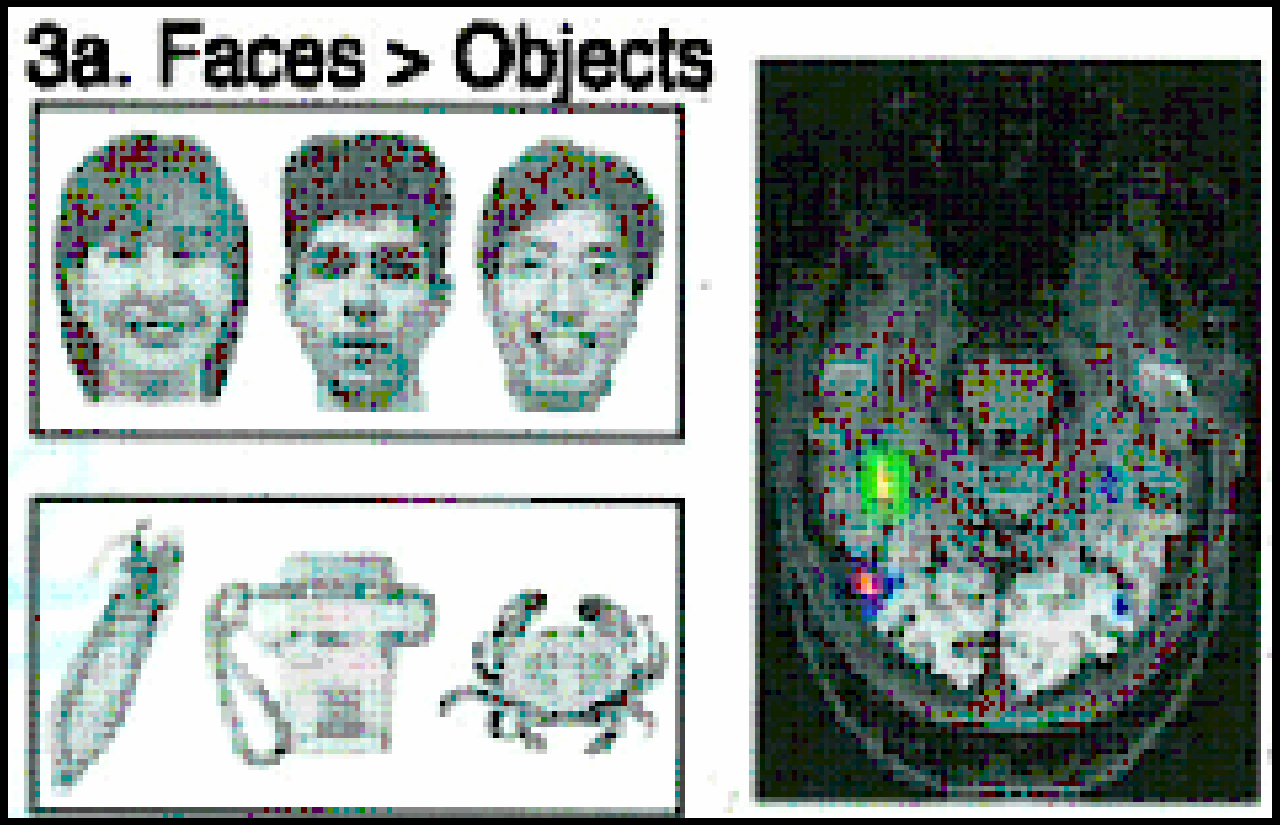
Prosopagnosia Can Depend on Upright Orientation

In contrast to normal subjects, prosopagnostic patient L.H. better identified faces if they were presented upside down

Specialization of Face Processing

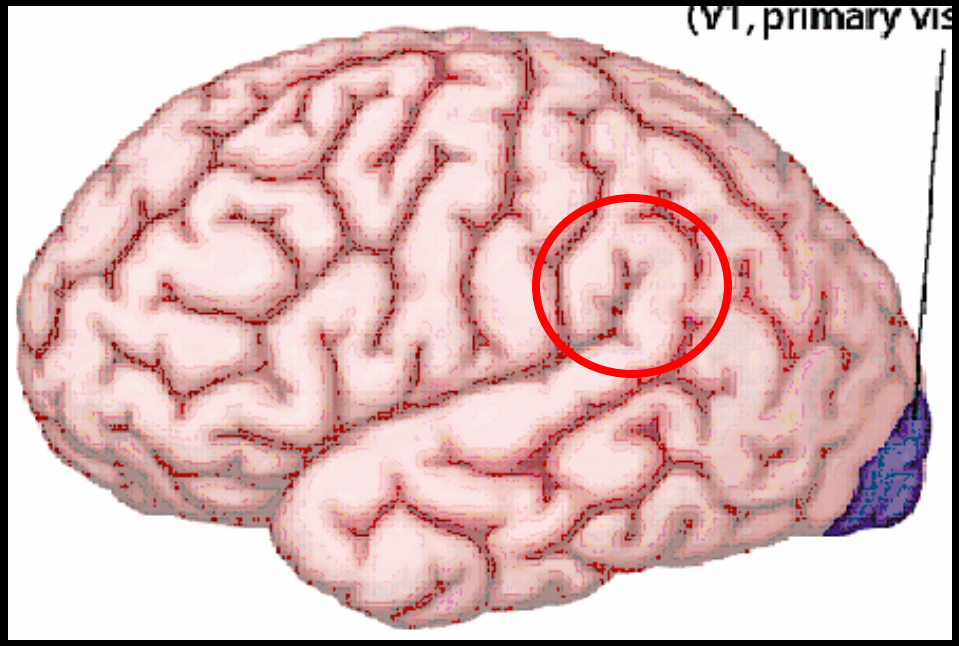
Patient C.K. had severe object recognition deficits, but could perceive faces with relatively little trouble

Fusiform Face Area is Activated During Face Processing



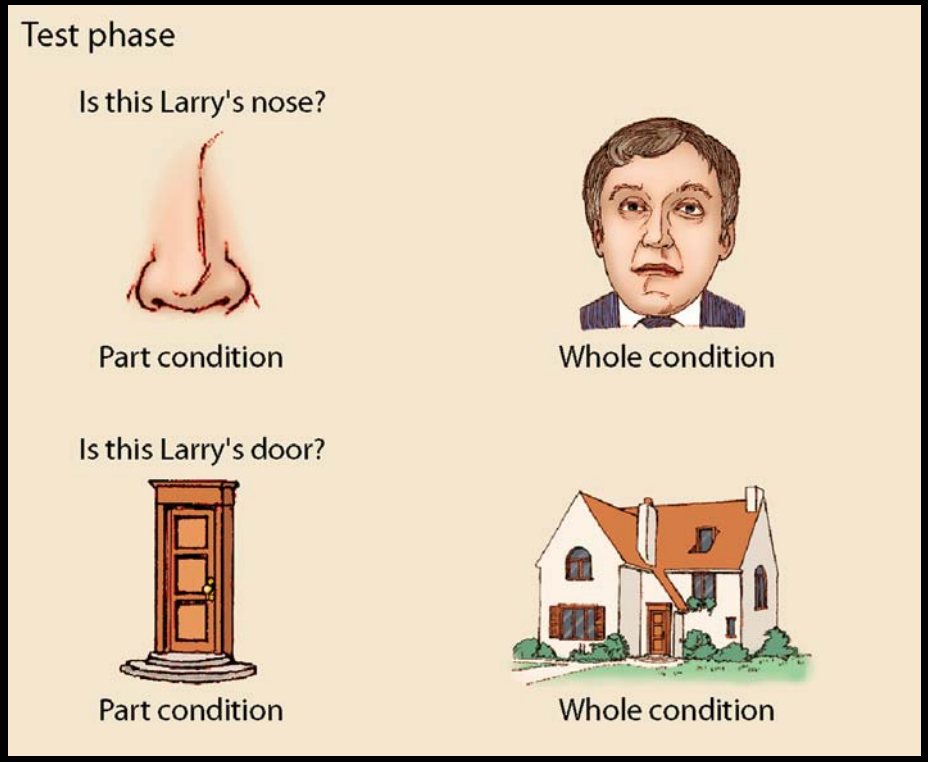
Alexia is Caused by Damage to the Left Angular Gyrus

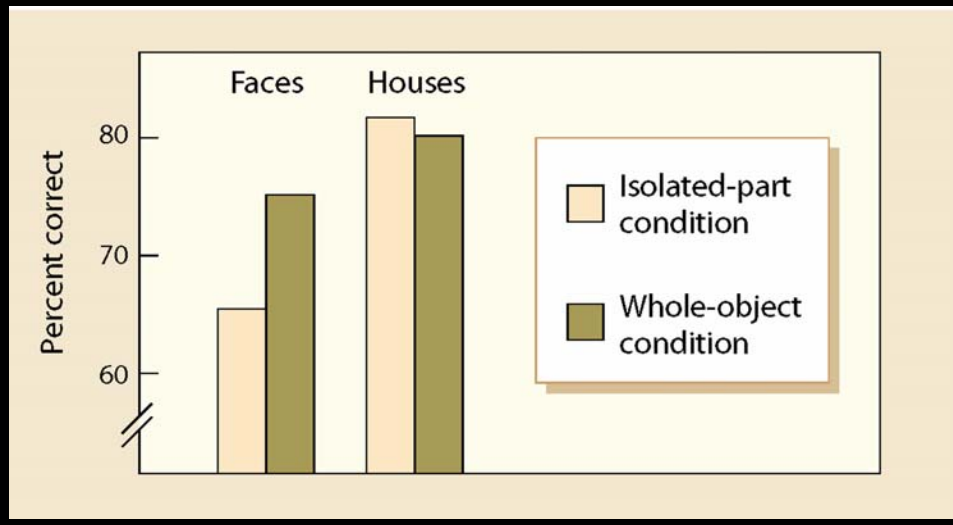
- Alexia is a deficit in the perception of words
- Ball may be misread as doll or snake as stale



Alexia and Prosopagnosia do not occur together, but agnosia for objects is always accompanied by a deficit in either word or face perception

Analytic Vs. Holistic Processing





Face processing is impaired if only part of the face can be viewed, while object processing remains intact

Analytic Vs. Holistic Processing