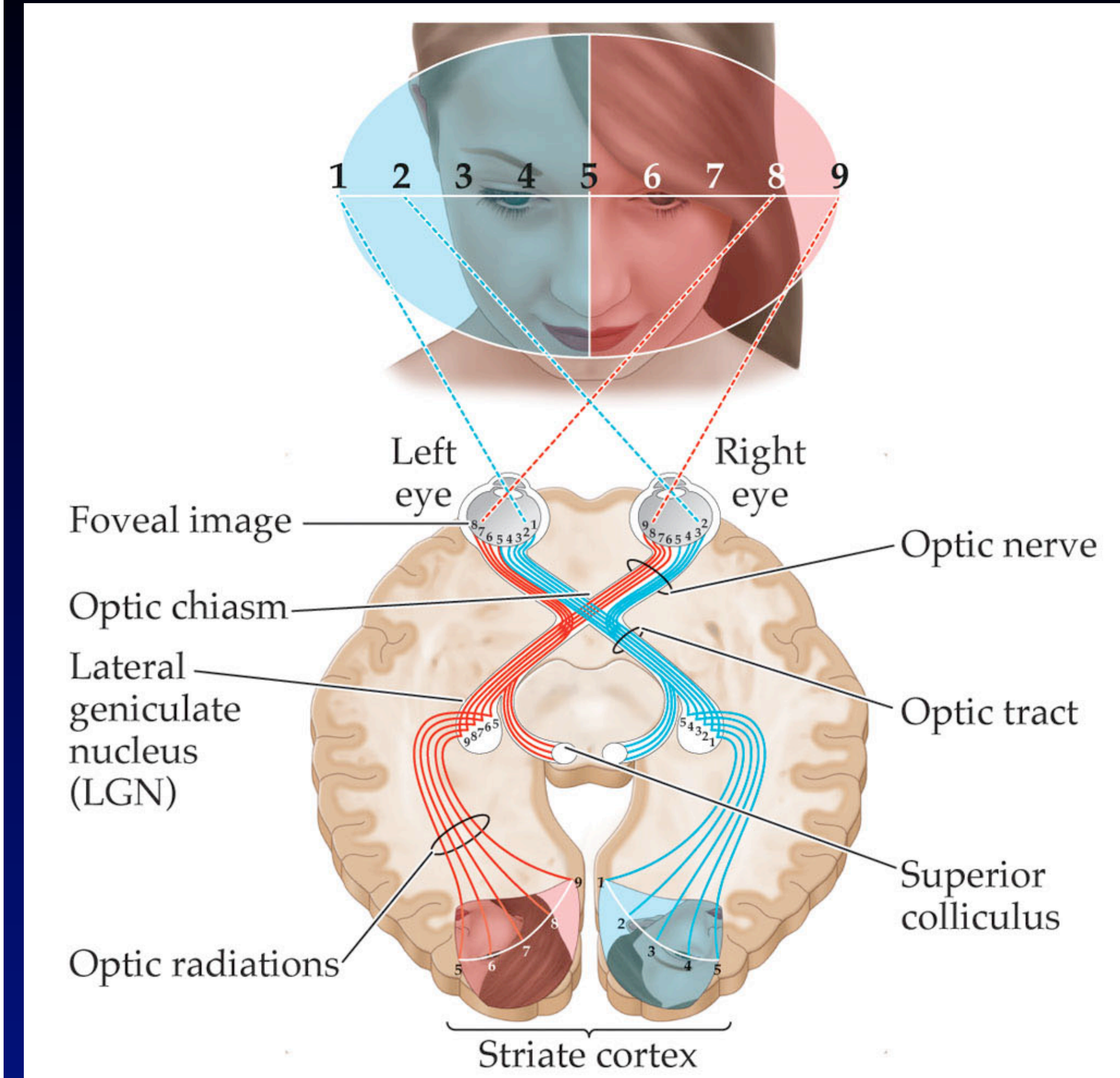


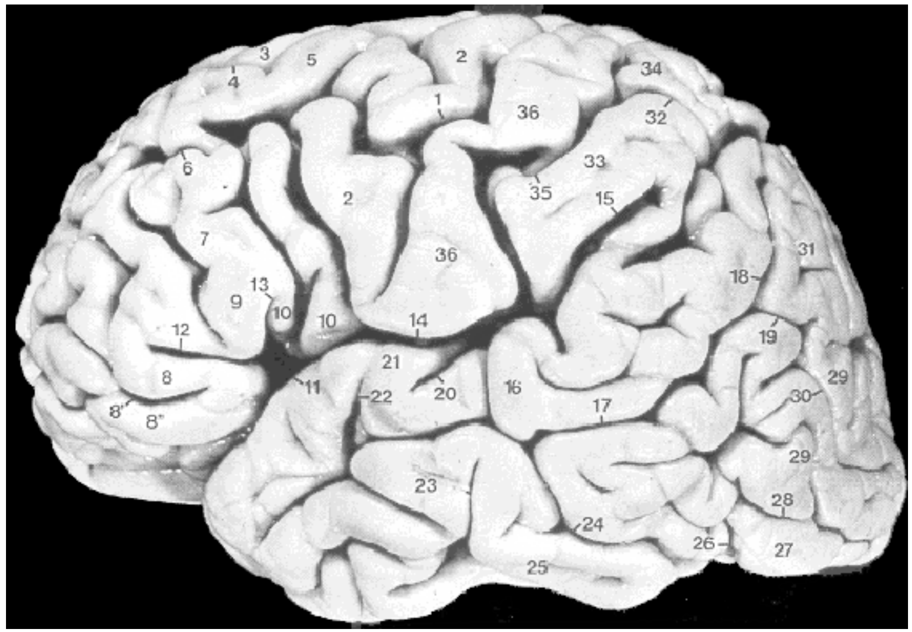
1 2 3 4 5 6 7 8 9
Left eye
Right eye
Foveal image
Optic nerve
Optic chiasm
Lateral geniculate nucleus (LGN)
Optic tract
Superior colliculus
Optic radiations
Striate cortex

General brain coordinates

Brain Directions

top, superior, dorsal

front
anterior
rostral

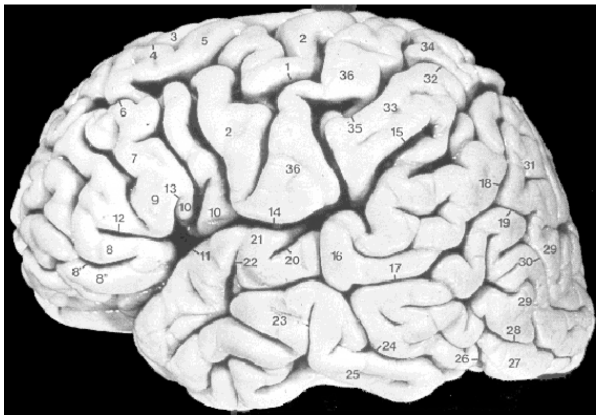


back
posterior
caudal

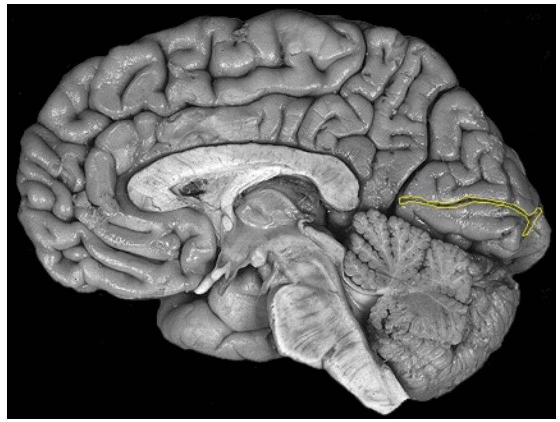
bottom, inferior, ventral

Brain Directions

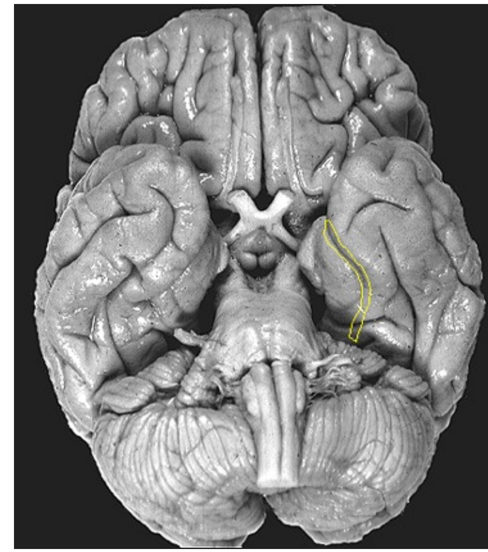
Lateral



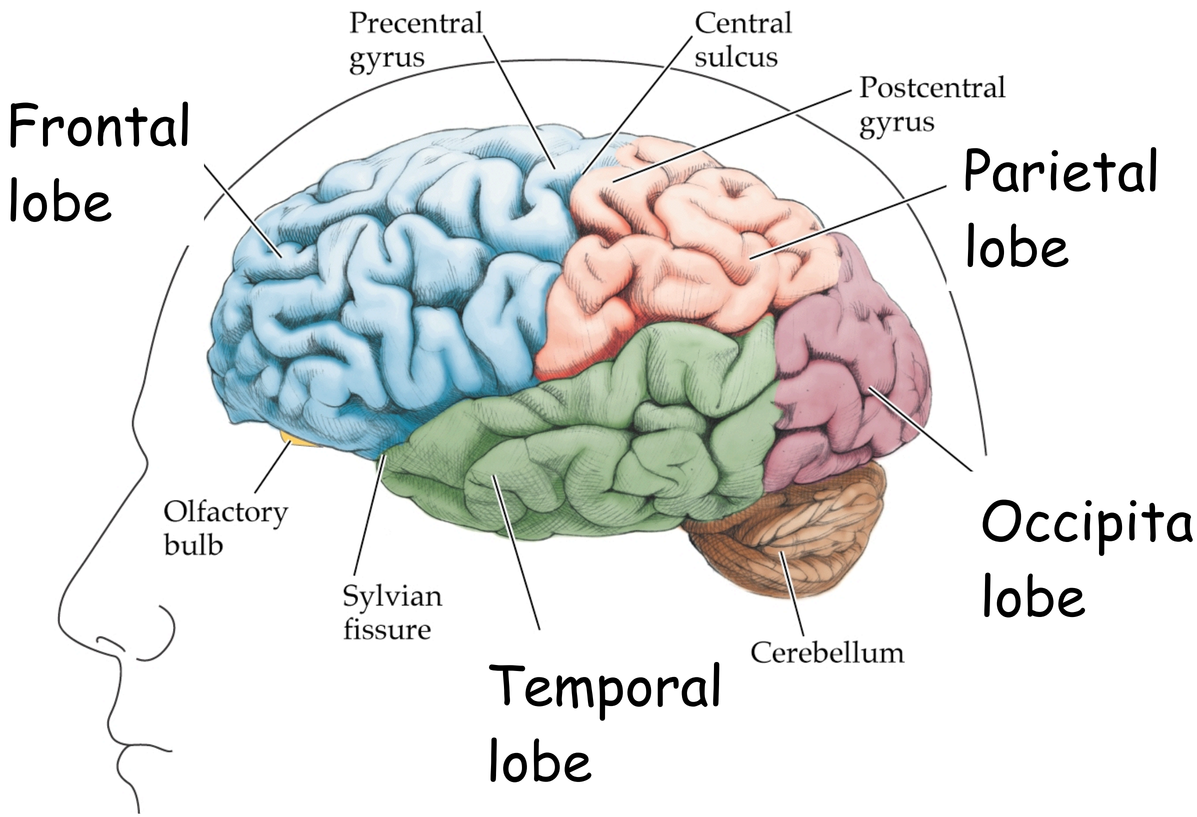
Medial

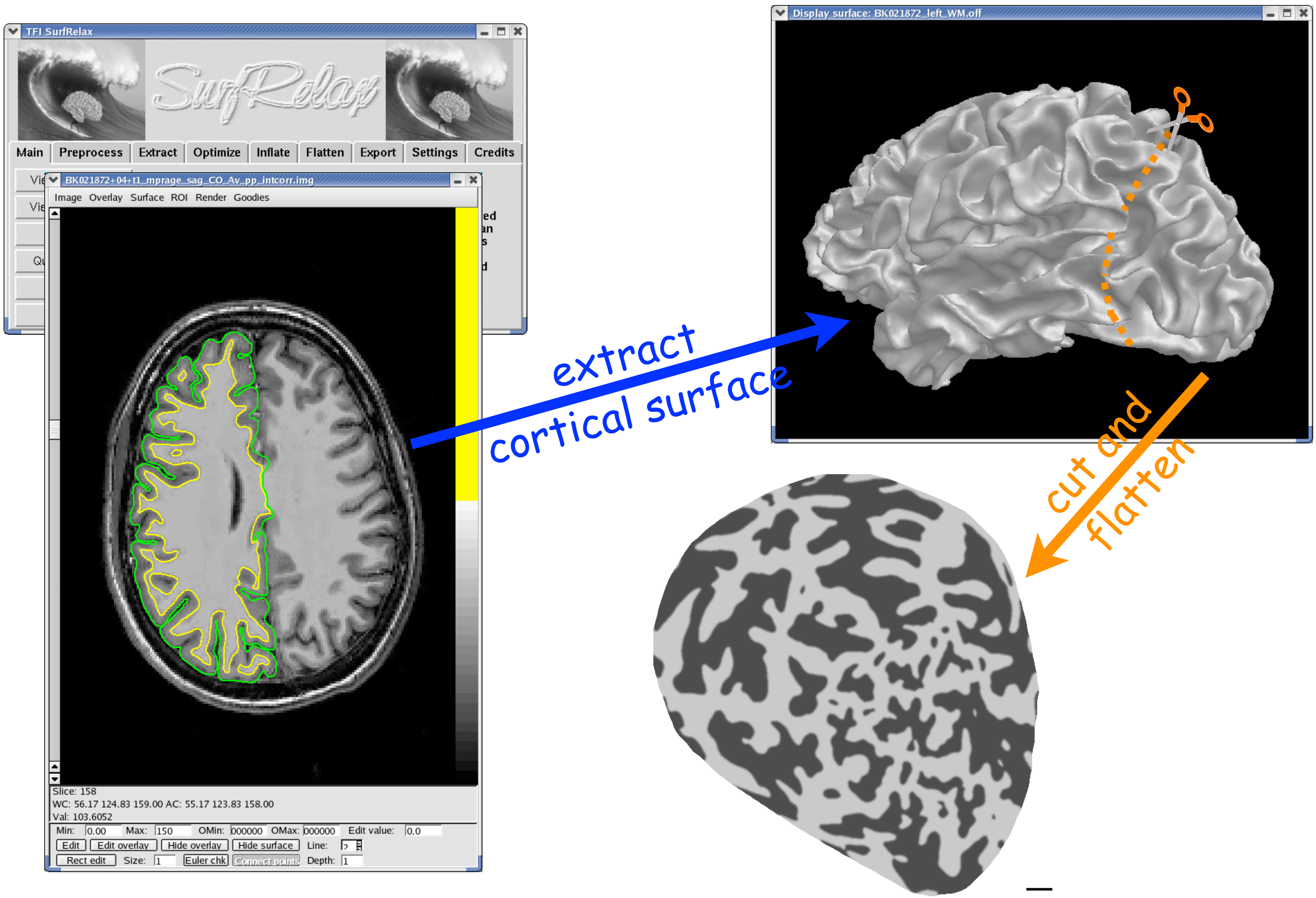


Ventral

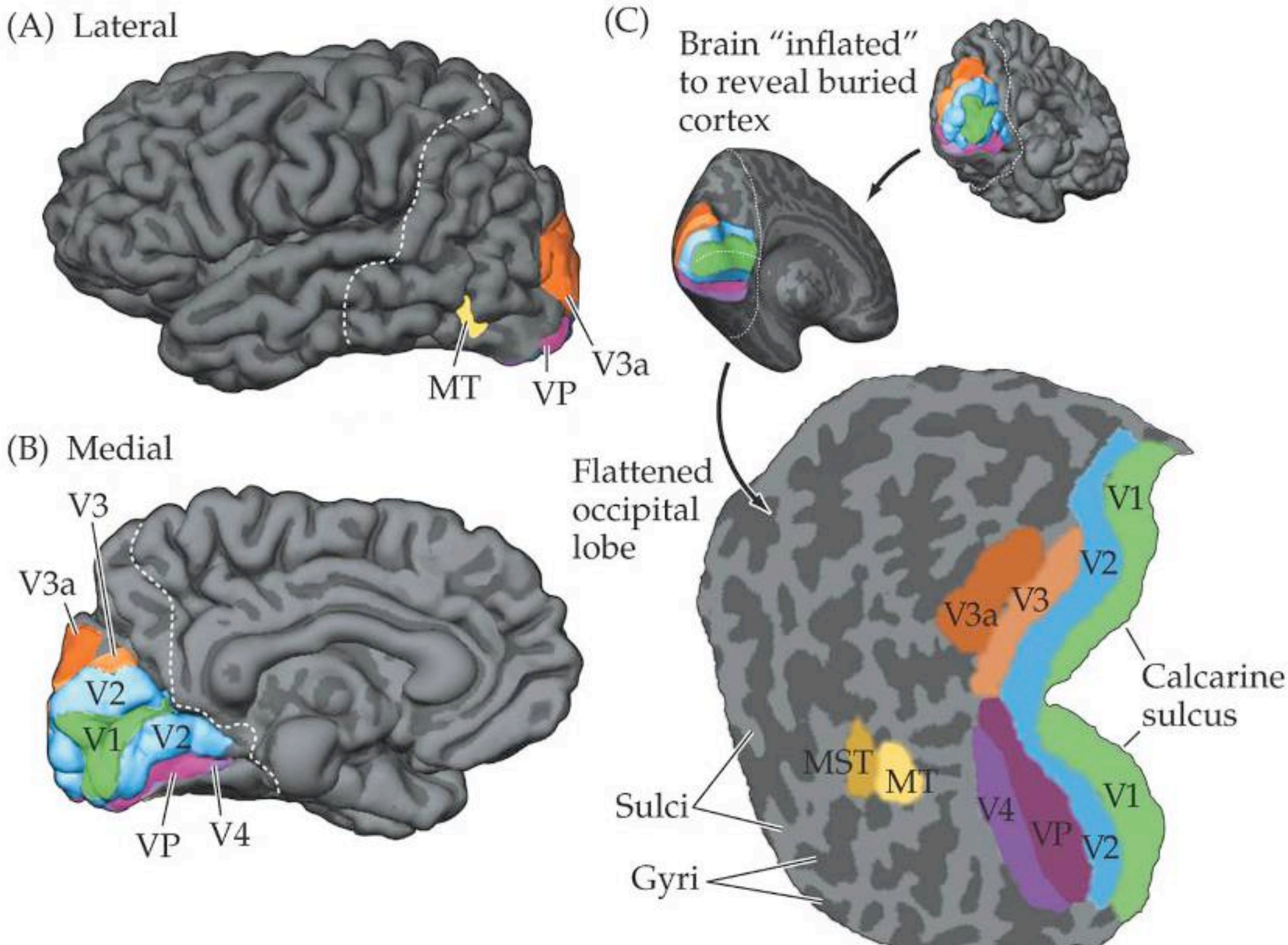


Lobes of the brain

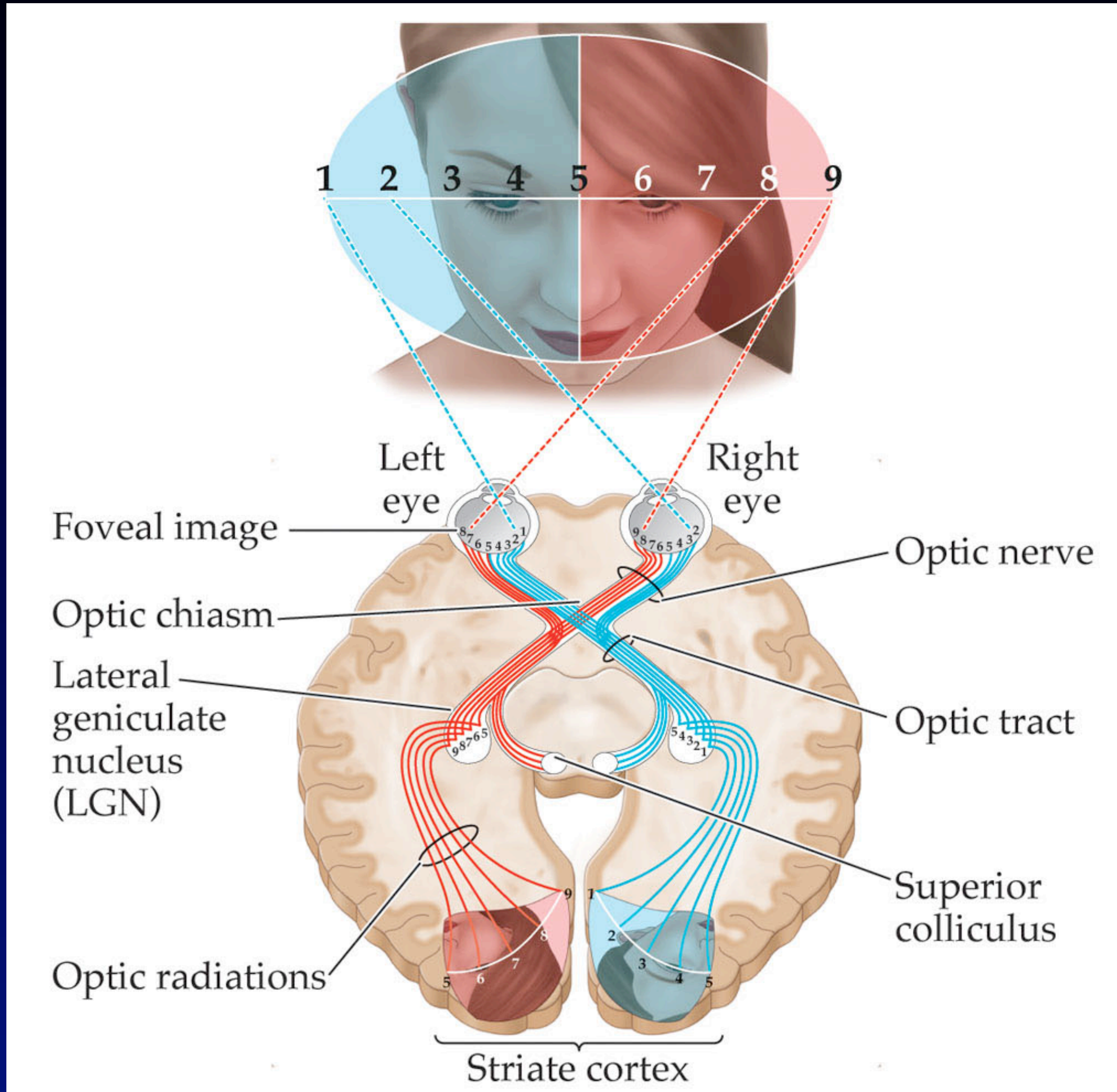


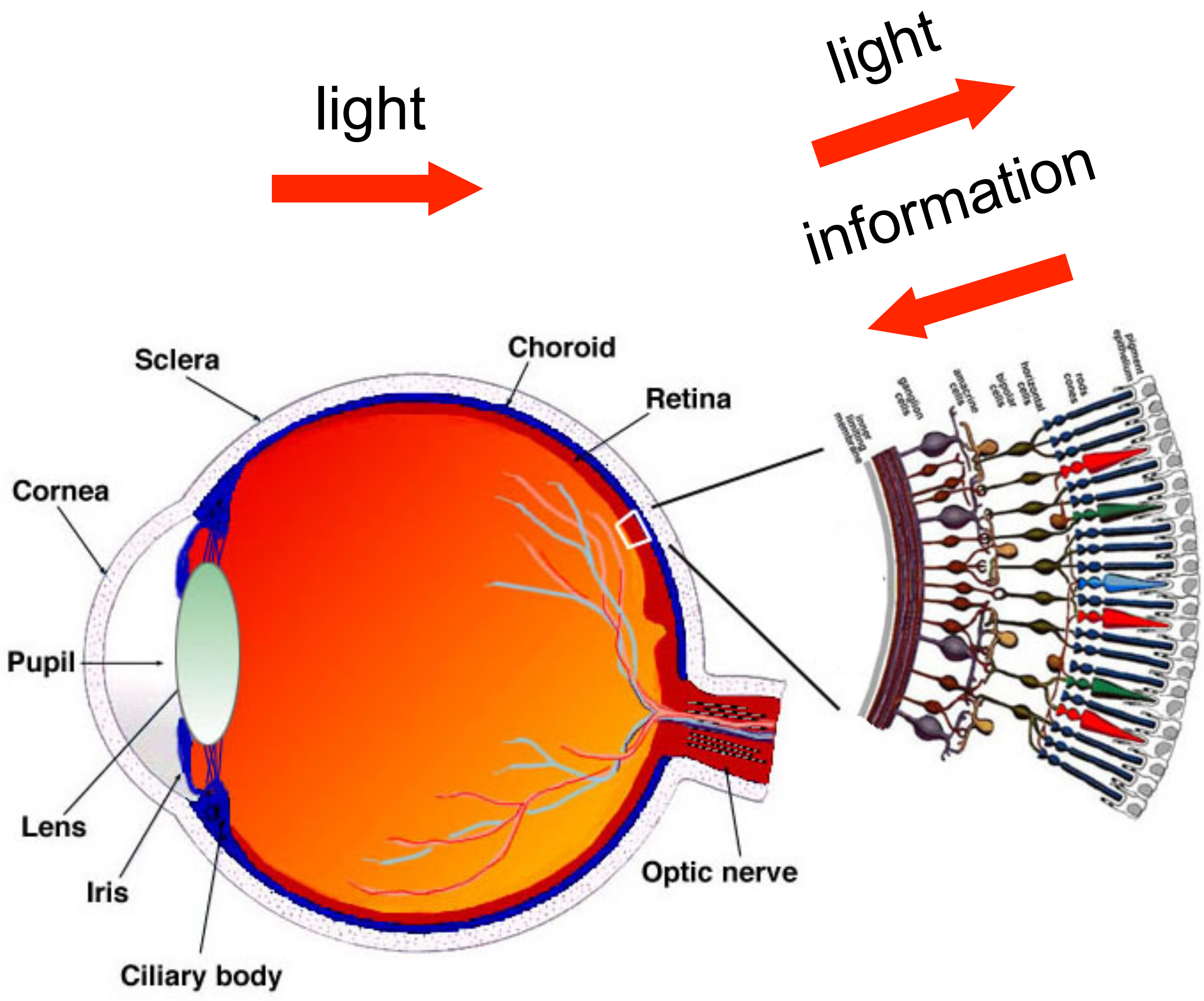


TFI SurfRelax
SurfRelax
Main
Preprocess
Extract
Optimize
Inflate
Flatten
Export
Settings
Credits
BK021872+04+t1_mprage_sag_CO_Av_pp_intcorr.img
Image
Overlay
Surface
ROI
Render
Goodies
Slice: 158
WC: 56.17 124.83 159.00 AC: 55.17 123.83 158.00
Val: 103.6052
Min:
Max:
OMin:
OMax:
Edit value:
Edit
Edit overlay
Hide overlay
Hide surface
Line:
Rect edit
Size:
Euler chk
Connect points
Depth:
Display surface: BK021872_left_WM.off
extract
cortical surface
cut and
flatten


(A) Lateral
MT
VP
V3a
(B) Medial
V3
V3a
V2
V1
V2
VP
V4
(C)
Brain "inflated" to reveal buried cortex
Flattened occipital lobe
V1
V2
V3a
V3
Calcarine sulcus
MST
MT
V4
VP
V2
V1
Sulci
Gyri

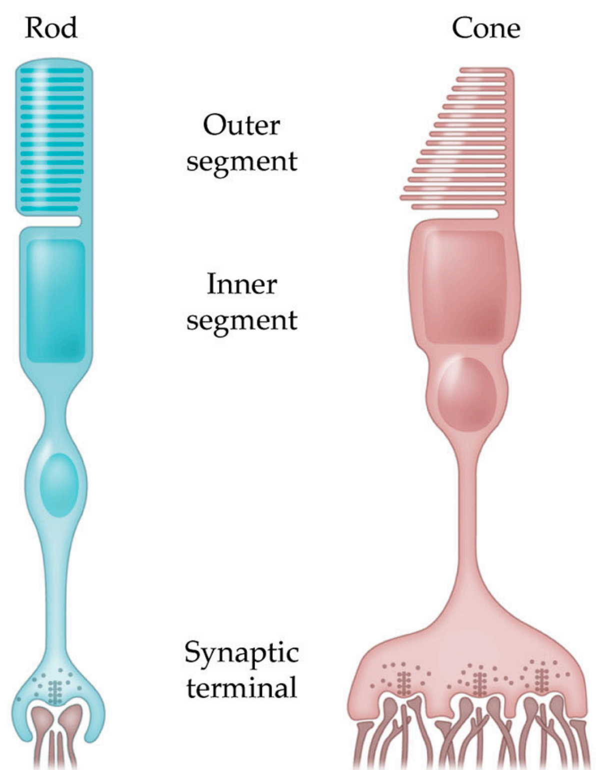
Visual Pathways: Retina


1
2
3
4
5
6
7
8
9
Left eye
Right eye
Foveal image
Optic nerve
Optic chiasm
Lateral geniculate nucleus (LGN)
Optic tract
Superior colliculus
Optic radiations
Striate cortex


light
light
information
Sclera
Choroid
Retina
Cornea
Pupil
Lens
Iris
Ciliary body
Optic nerve

Rods:
Scotopic
High sensitivity
Low spatial resolution
Achromatic

Cones:
Photopic
Lower sensitivity
High resolution
Chromatic

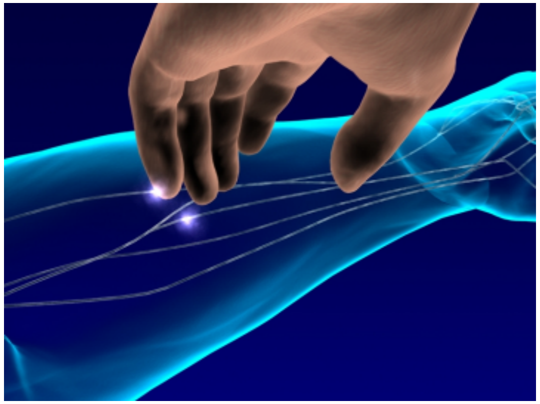


Receptive fields of visual neurons

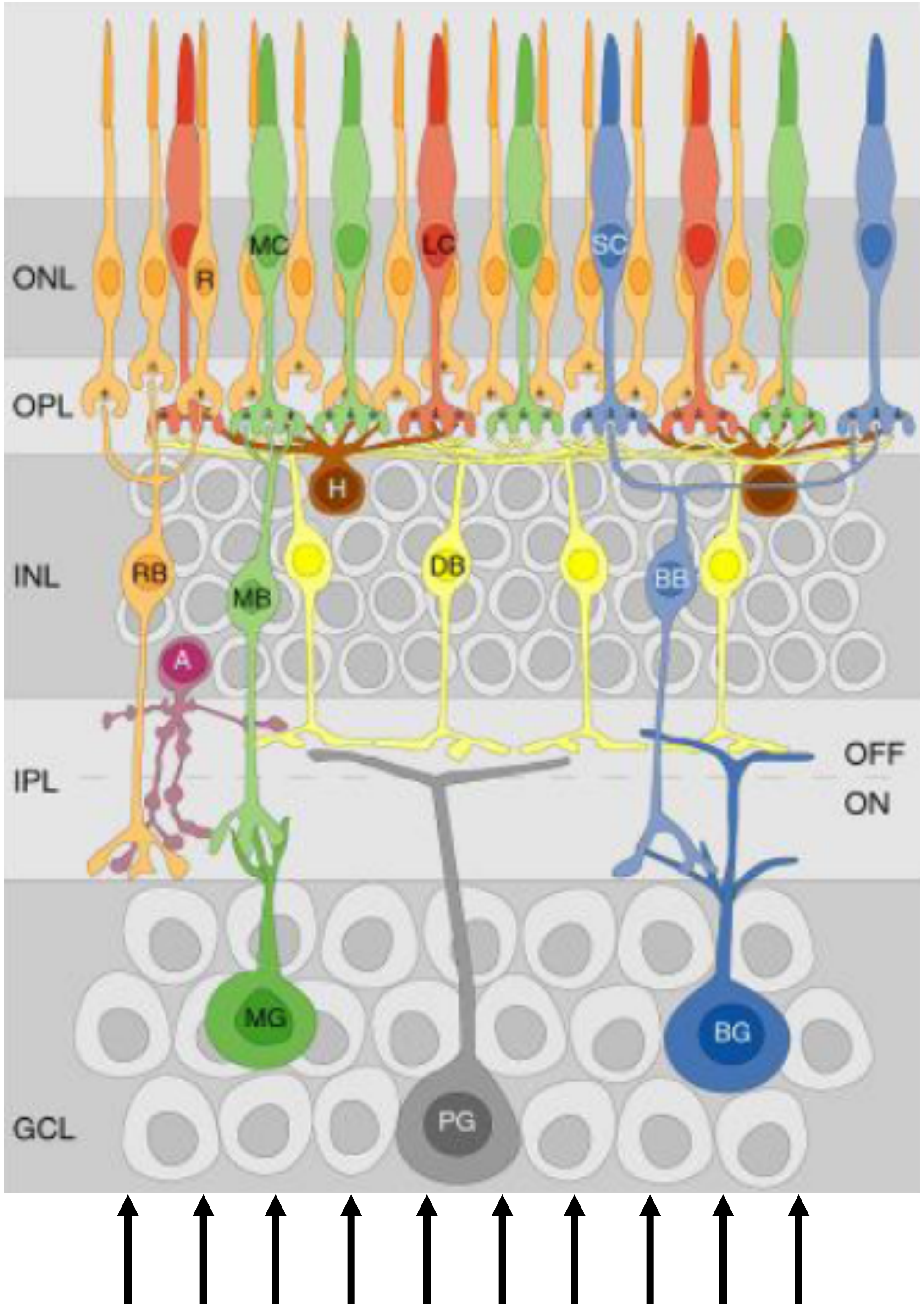
A receptive field for a given neuron is the area of the retina where the pattern of light affects the cell's firing pattern

Receptive fields:

- Correspond to location in space
- Can overlap
- Can be different sizes



Retinal Layers



Outer nuclear layer (photoreceptors)

Catch light

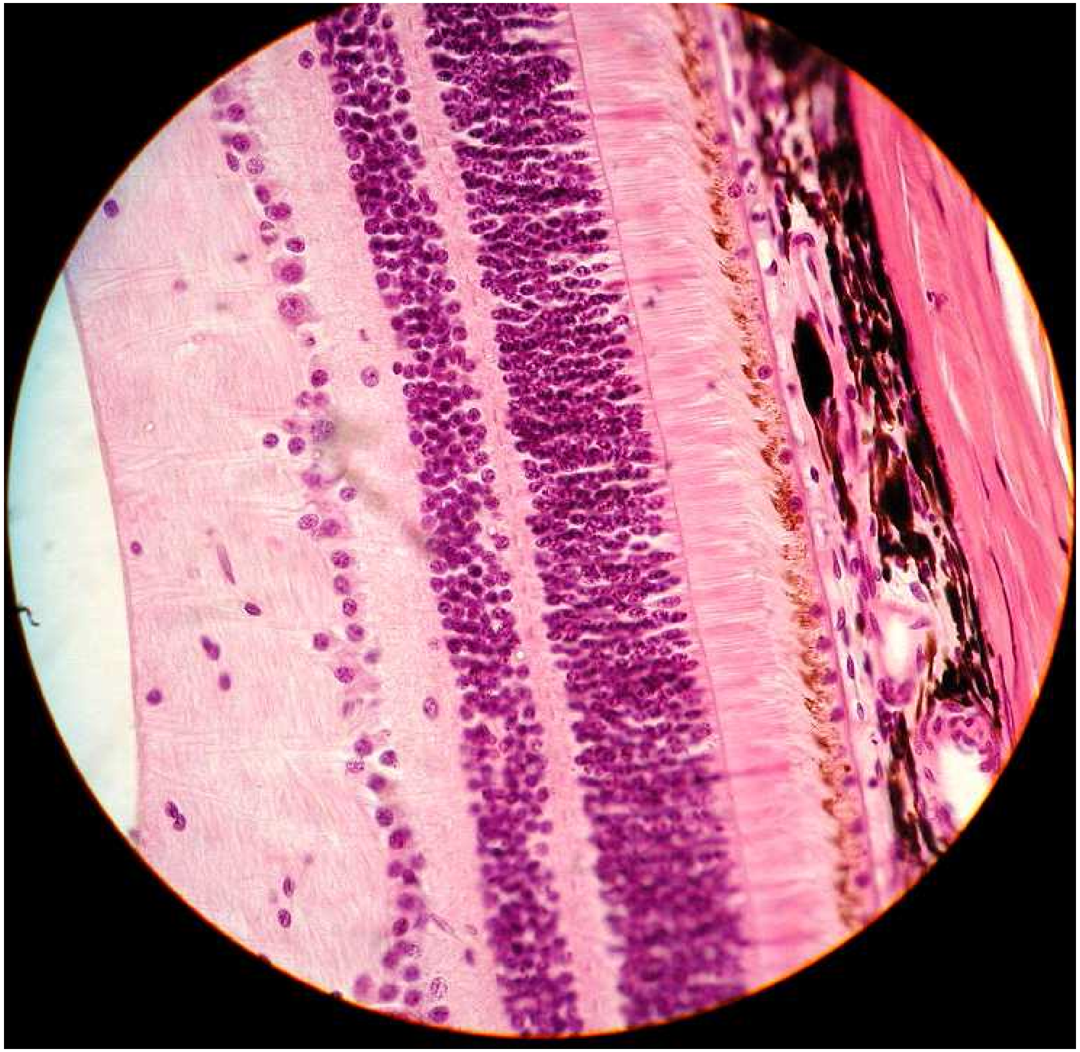
Inner nuclear layer (INL) (bipolar cells)

Relay information

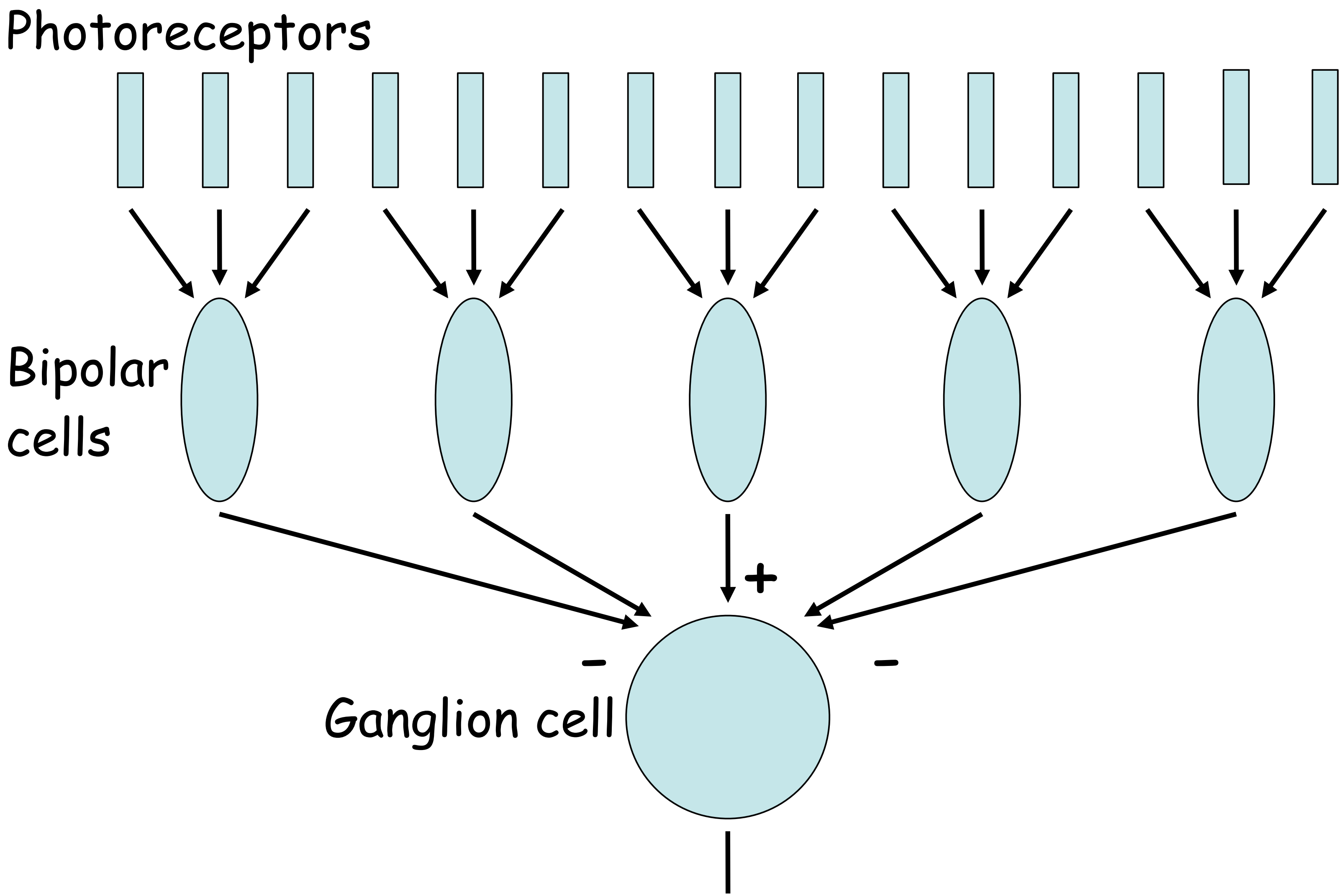
Ganglion cell layer (GCL) (ganglion cells)

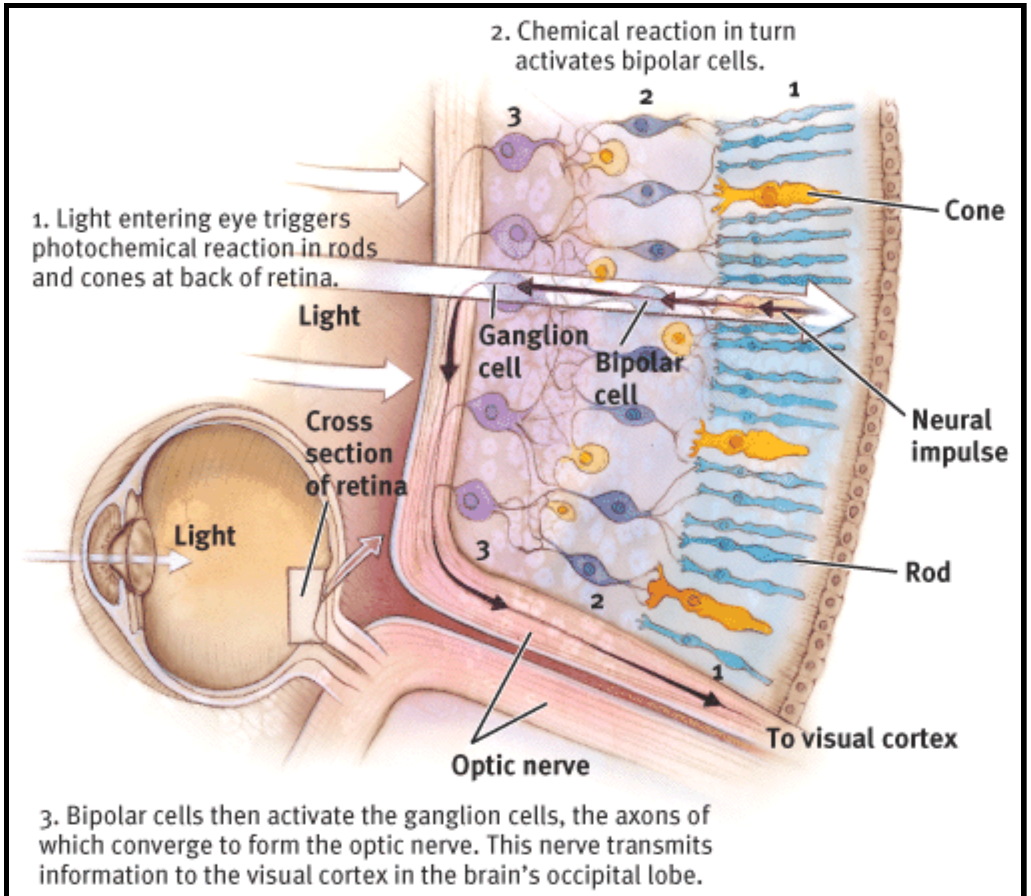
Send signals to brain

light



Linear Receptive Field Model





2. Chemical reaction in turn activates bipolar cells.
1. Light entering eye triggers photochemical reaction in rods and cones at back of retina.
3. Bipolar cells then activate the ganglion cells, the axons of which converge to form the optic nerve. This nerve transmits information to the visual cortex in the brain's occipital lobe.
Light
Light
Cross section of retina
Ganglion cell
Bipolar cell
Cone
Neural impulse
Rod
To visual cortex
Optic nerve
1
2
3
1
2
3

The Blind Spot

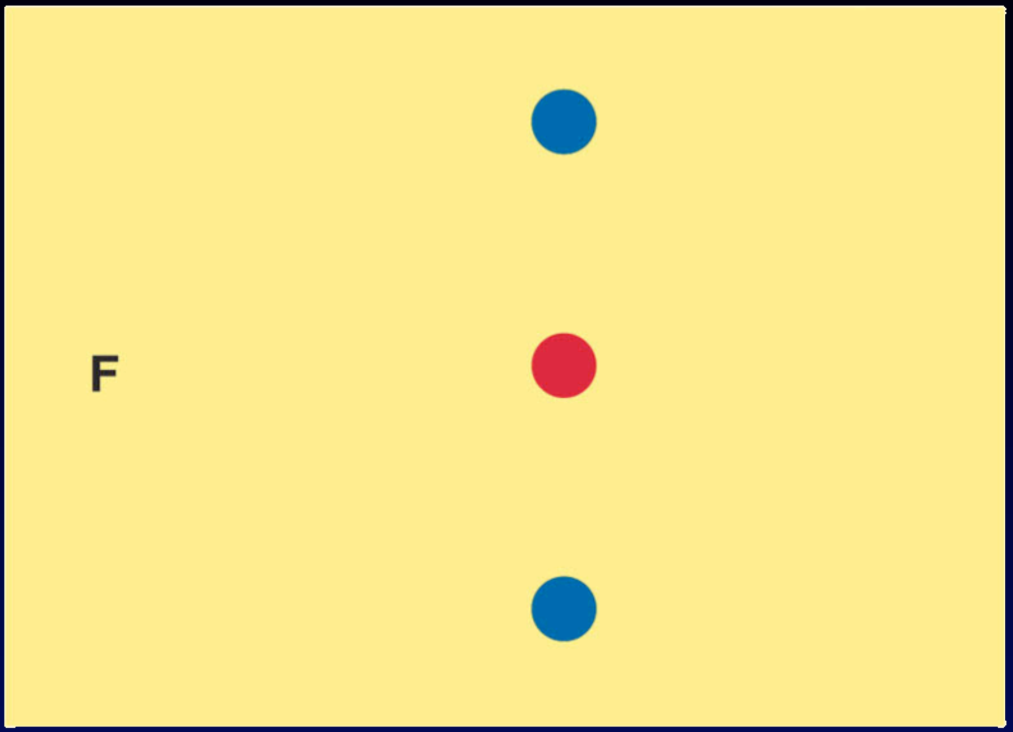
(a) Close your left eye

Fixate on the F

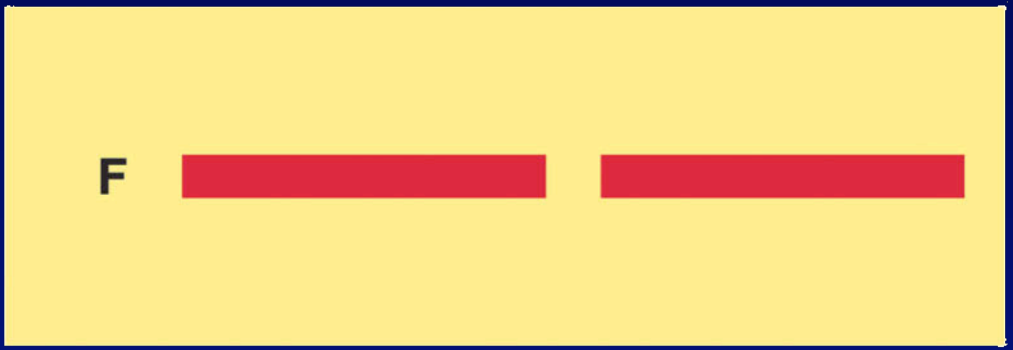
Adjust distance til the red circle disappears

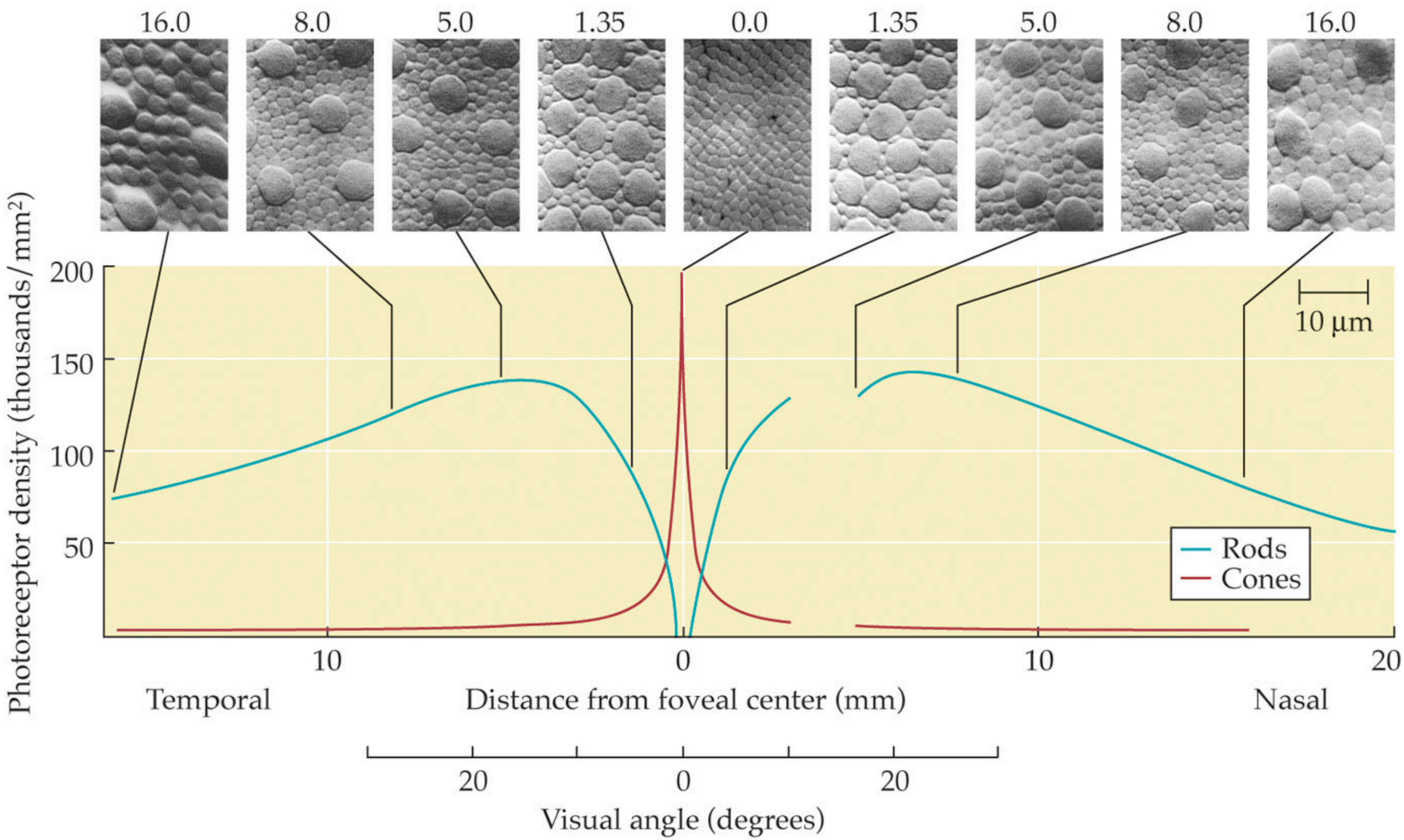
(b) Same thing, but you should see a continuous red line

(a)



(b)



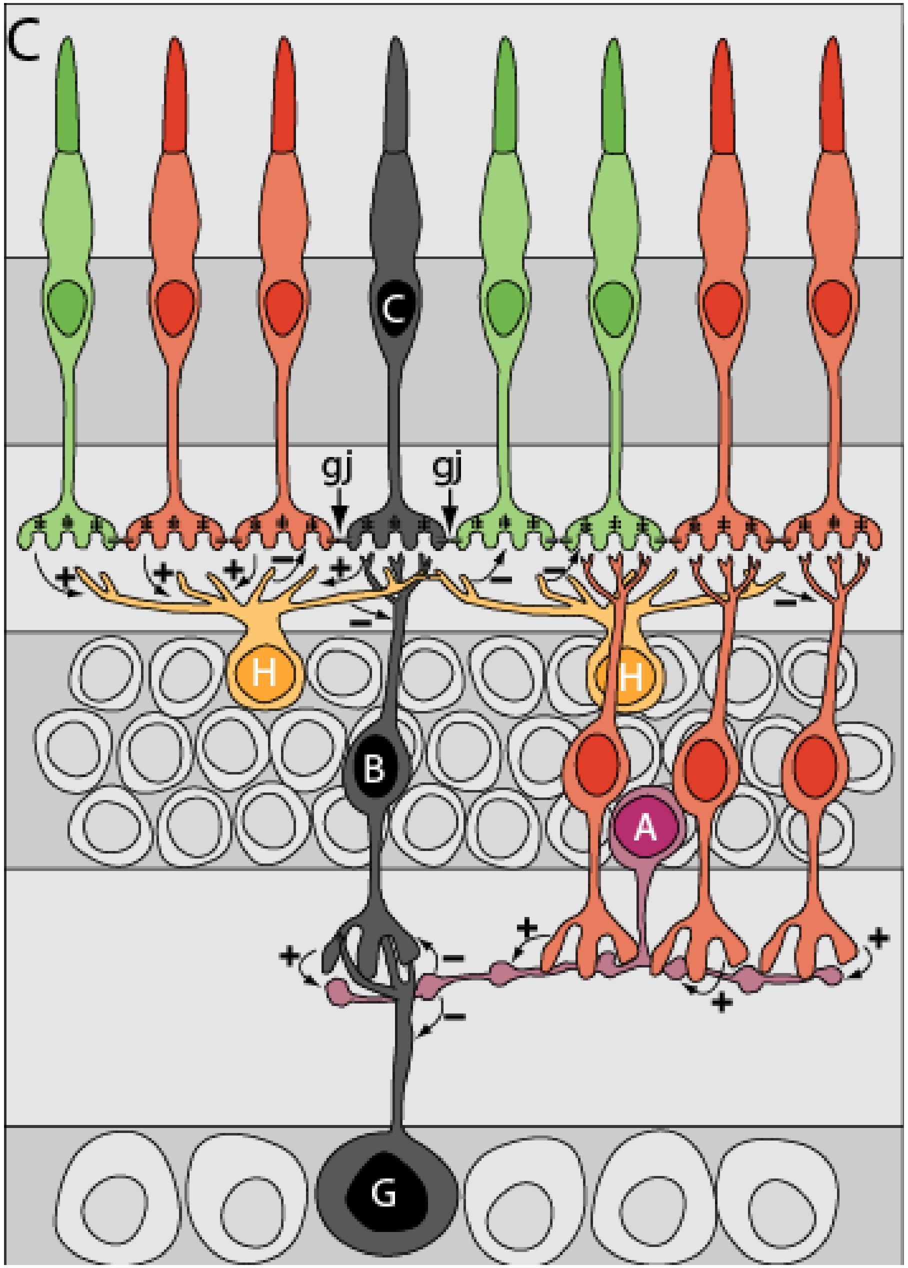


16.0
8.0
5.0
1.35
0.0
1.35
5.0
8.0
16.0
10 µm
Rods
Cones
Photoreceptor density (thousands/mm²)
200
150
100
50
10
0
10
20
Temporal
Distance from foveal center (mm)
Nasal
20
0
20
Visual angle (degrees)

Eccentricity Magnification Illustration

Image

Representation



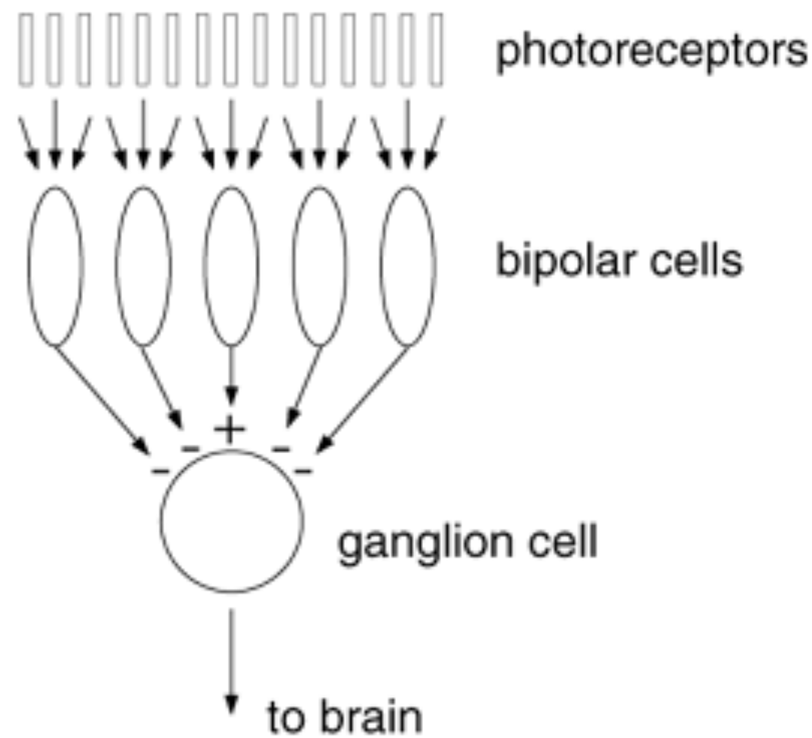
Horizontal processing in the Retina

Horizontal cells:
Integrate across many (100s) photoreceptors

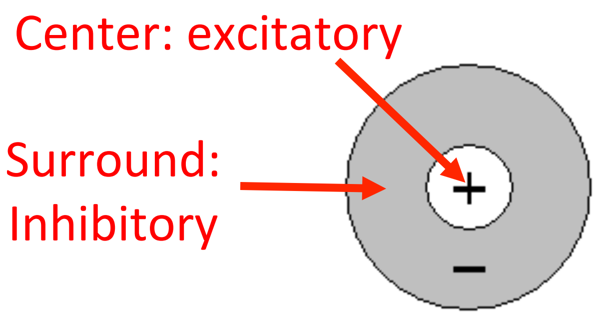
→ *Calculate mean Luminance*
GABA

Amacrine cells:
integrate across many bipolar cells

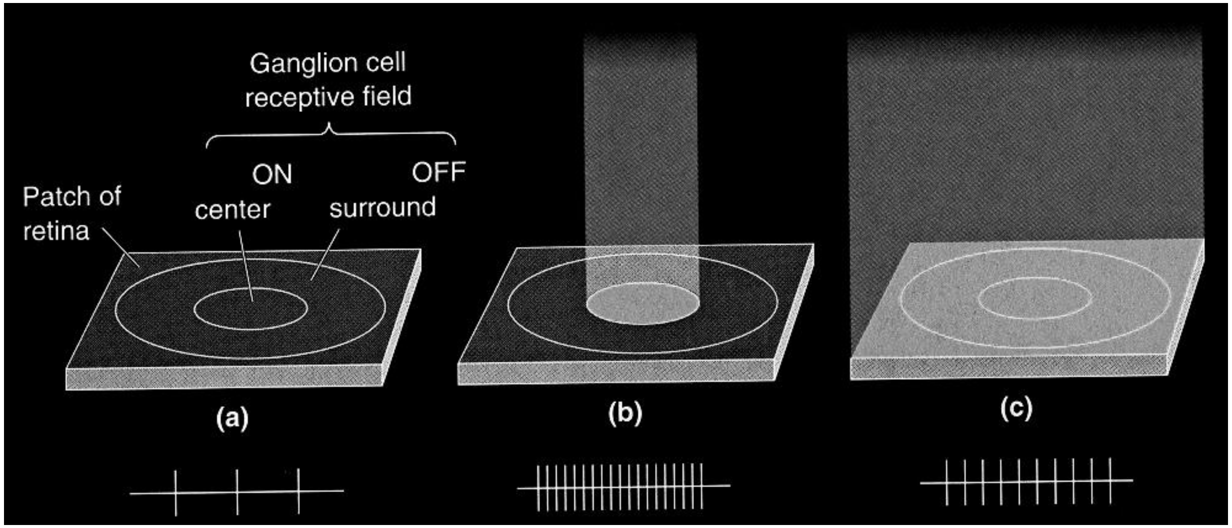
→ *Feedback to bipolar & ganglion cells*
GABA


photoreceptors
bipolar cells
+
-
-
-
-
ganglion cell
to brain

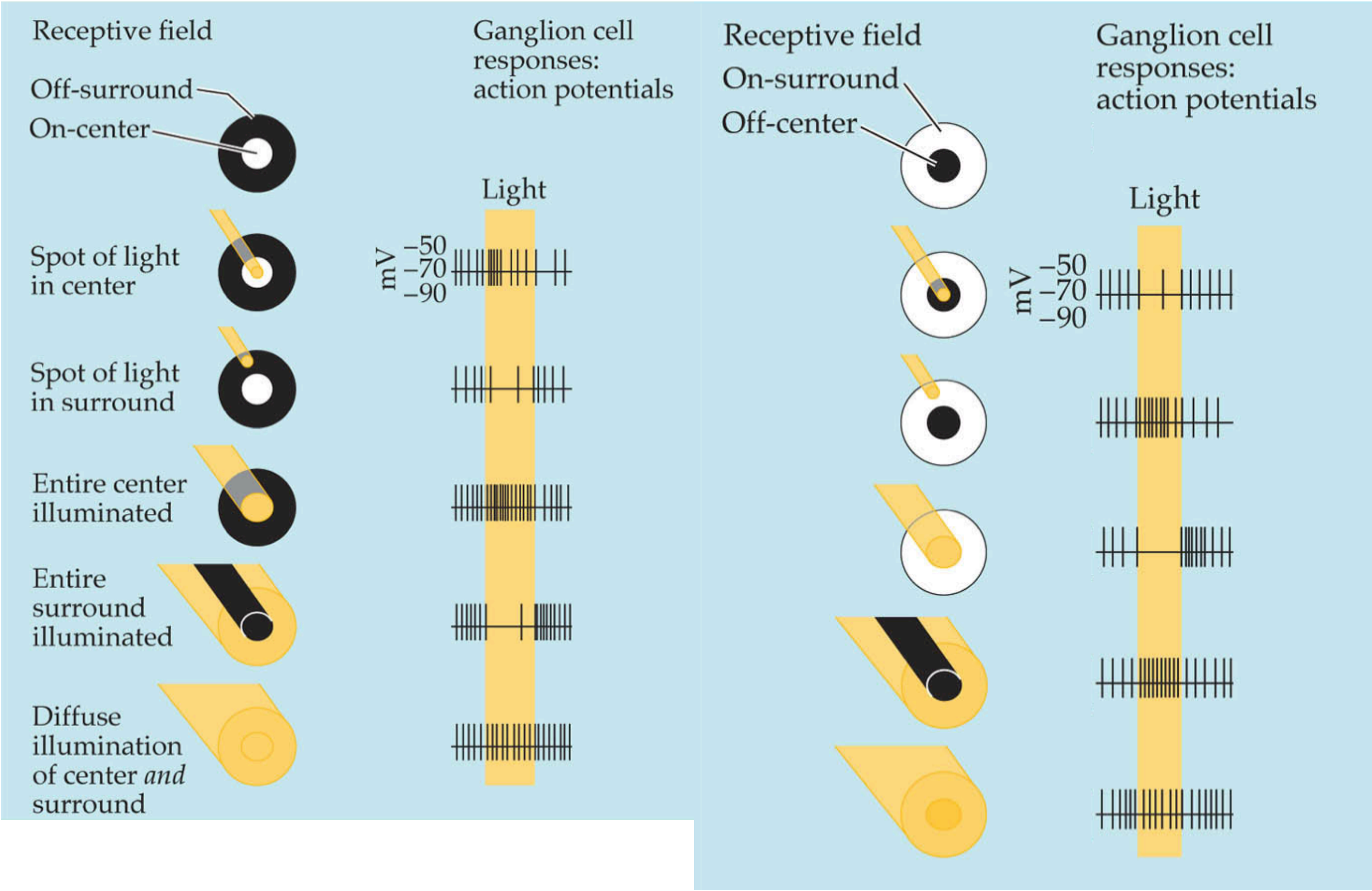
Center-Surround Organization: Function



ON-center cell



RGC Spikes



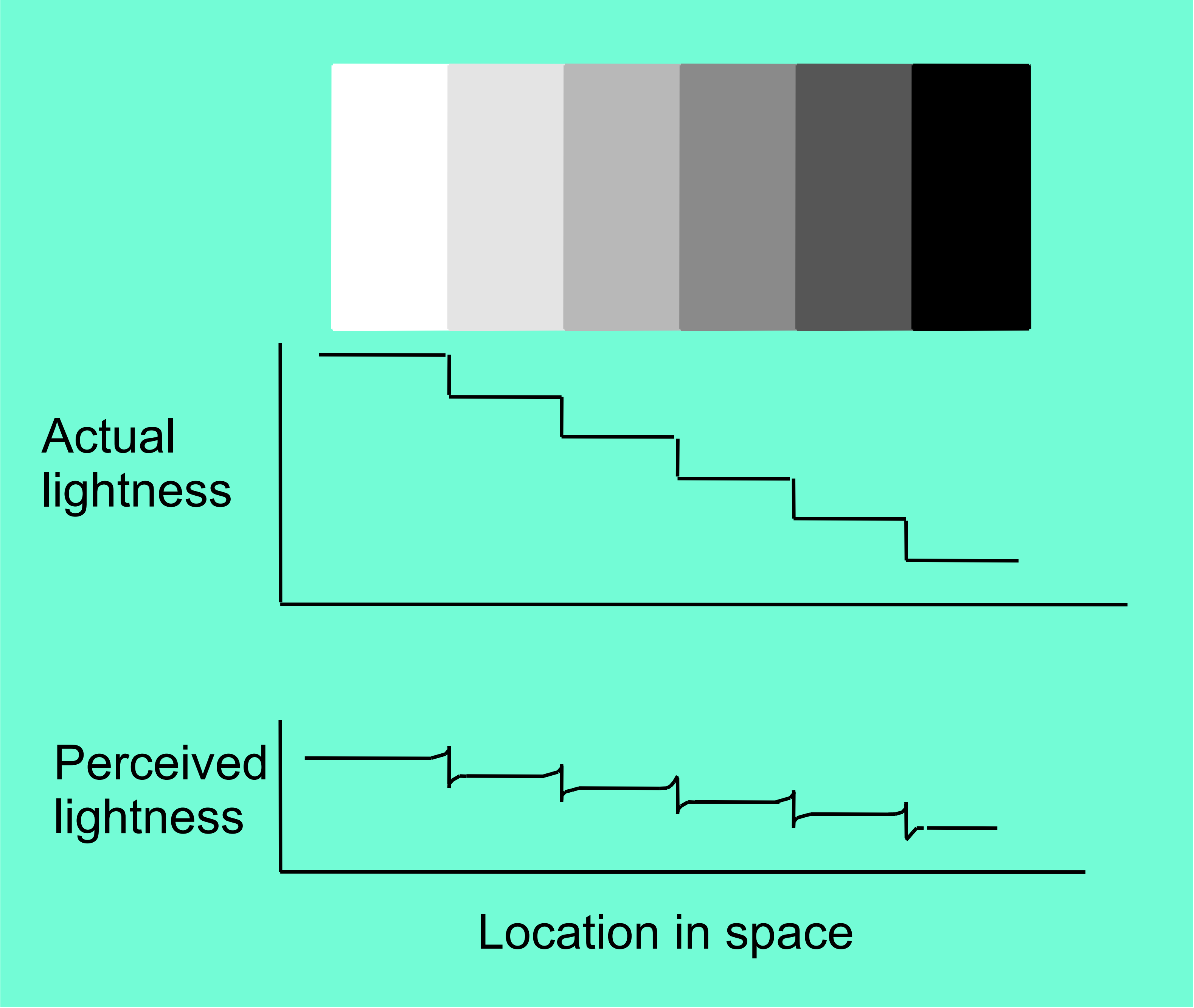
Receptive field
Off-surround
On-center
Ganglion cell responses: action potentials
Light
mV
−50
−70
−90
Spot of light in center
Spot of light in surround
Entire center illuminated
Entire surround illuminated
Diffuse illumination of center *and* surround
Receptive field
On-surround
Off-center
Ganglion cell responses: action potentials
Light
mV
−50
−70
−90

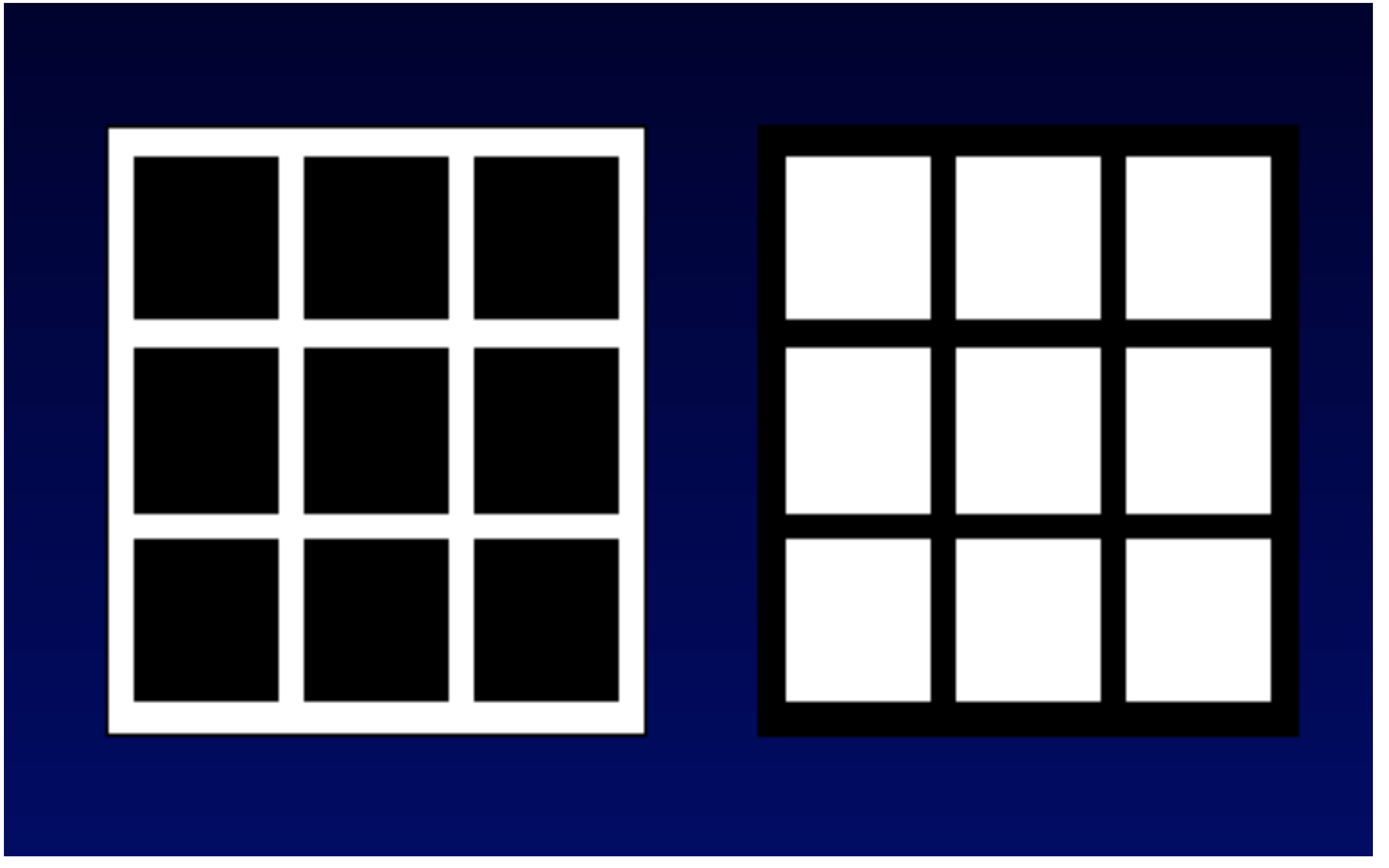
Neural image

Input image
(cornea)

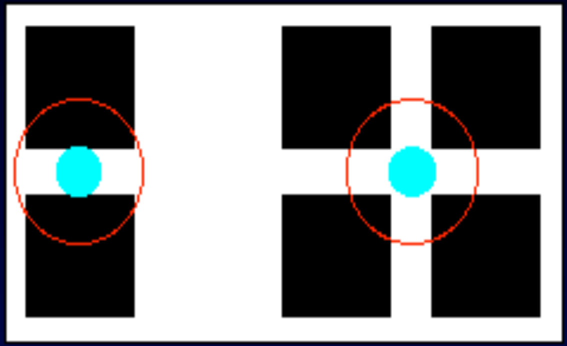
"Neural image"
(retinal ganglion cells)

Center-surround receptive fields: emphasize edges.

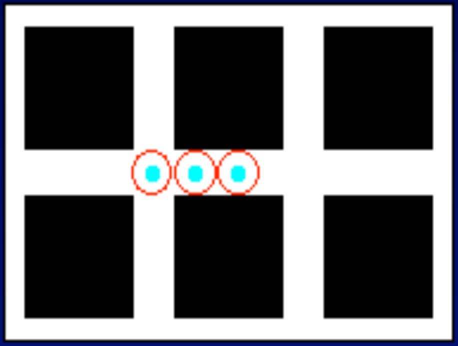

Actual lightness
Perceived lightness
Location in space



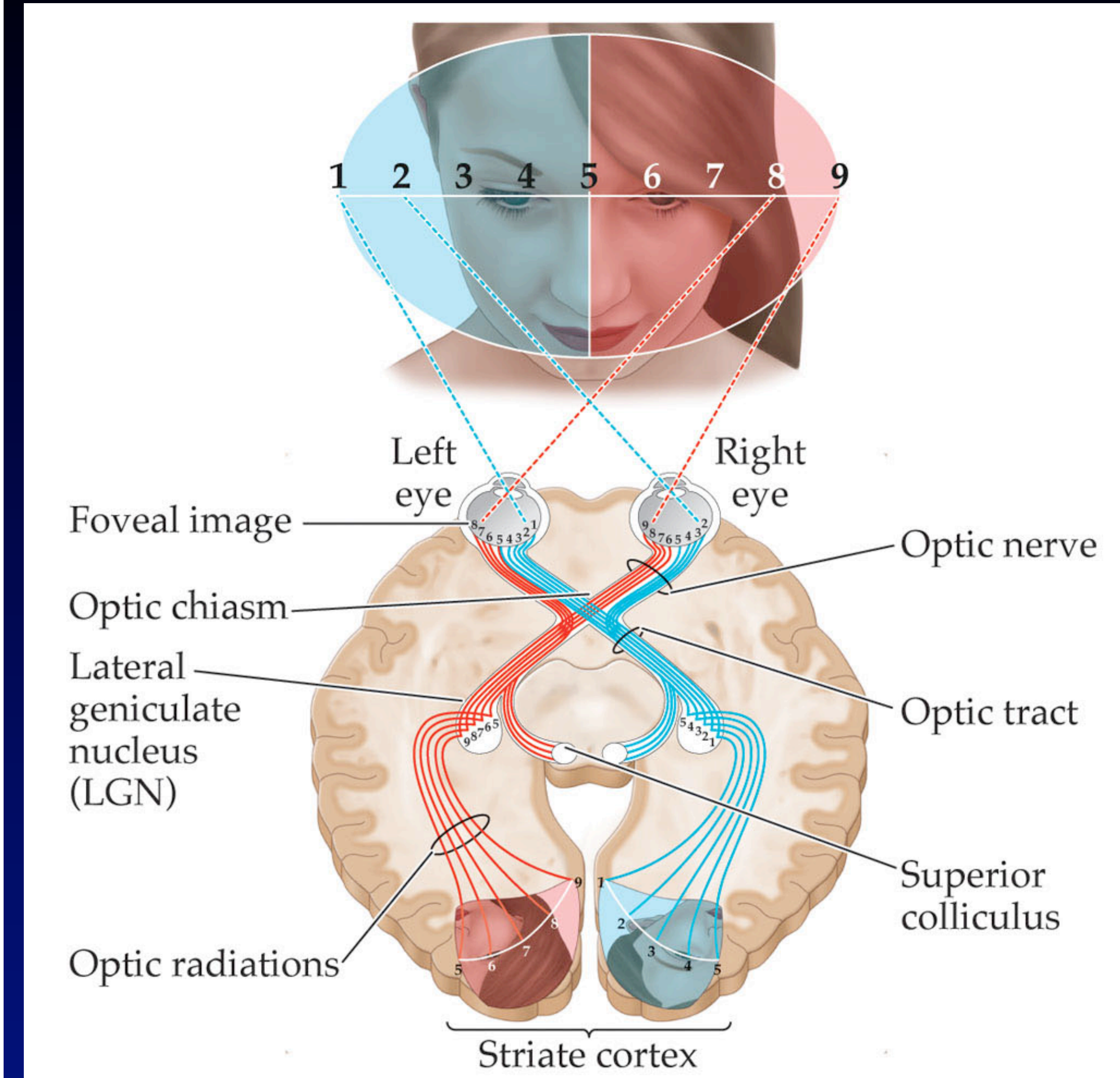
What is going on?



Why don't you see a spot where you are fixating?

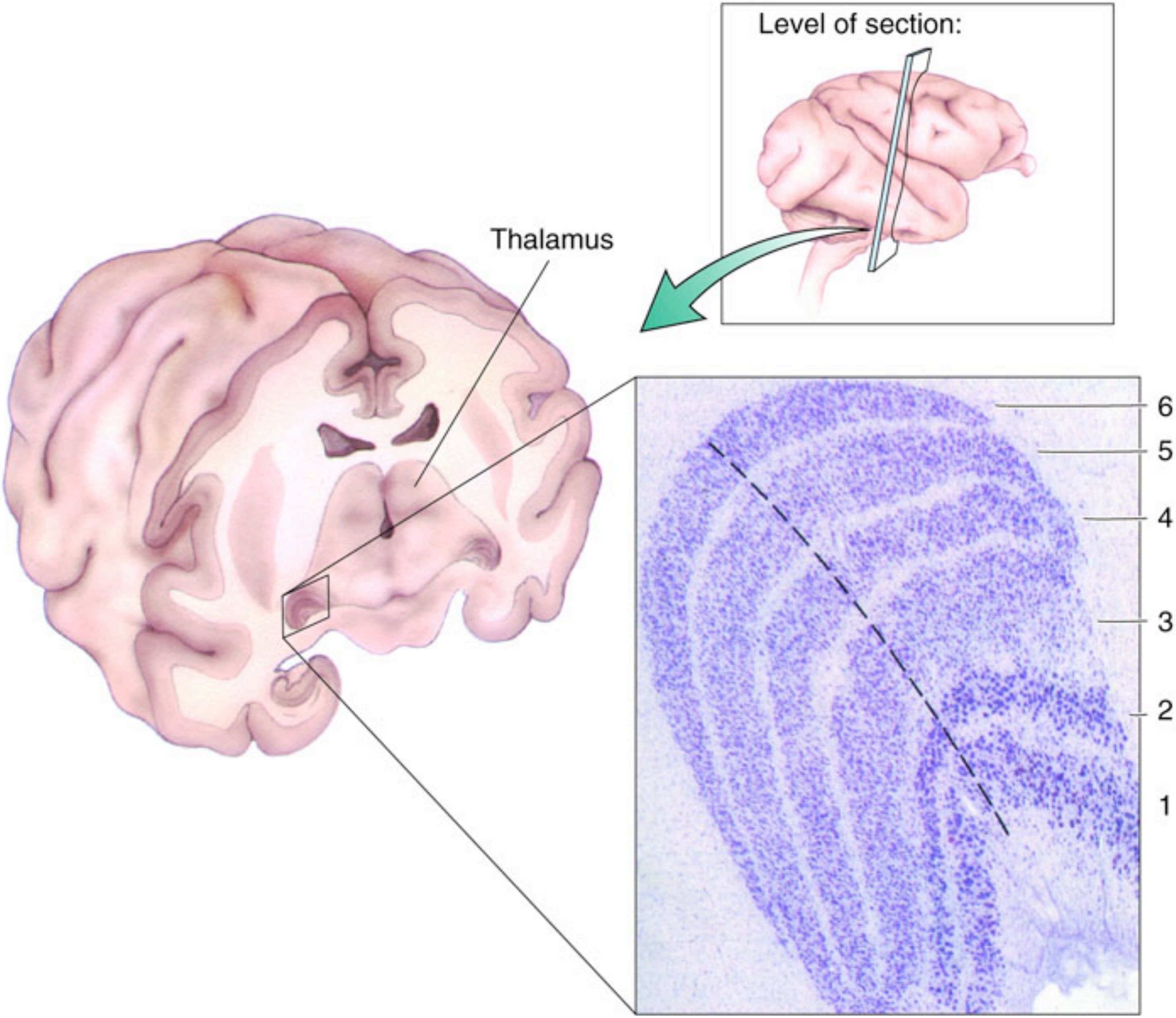


Visual Pathways: LGN

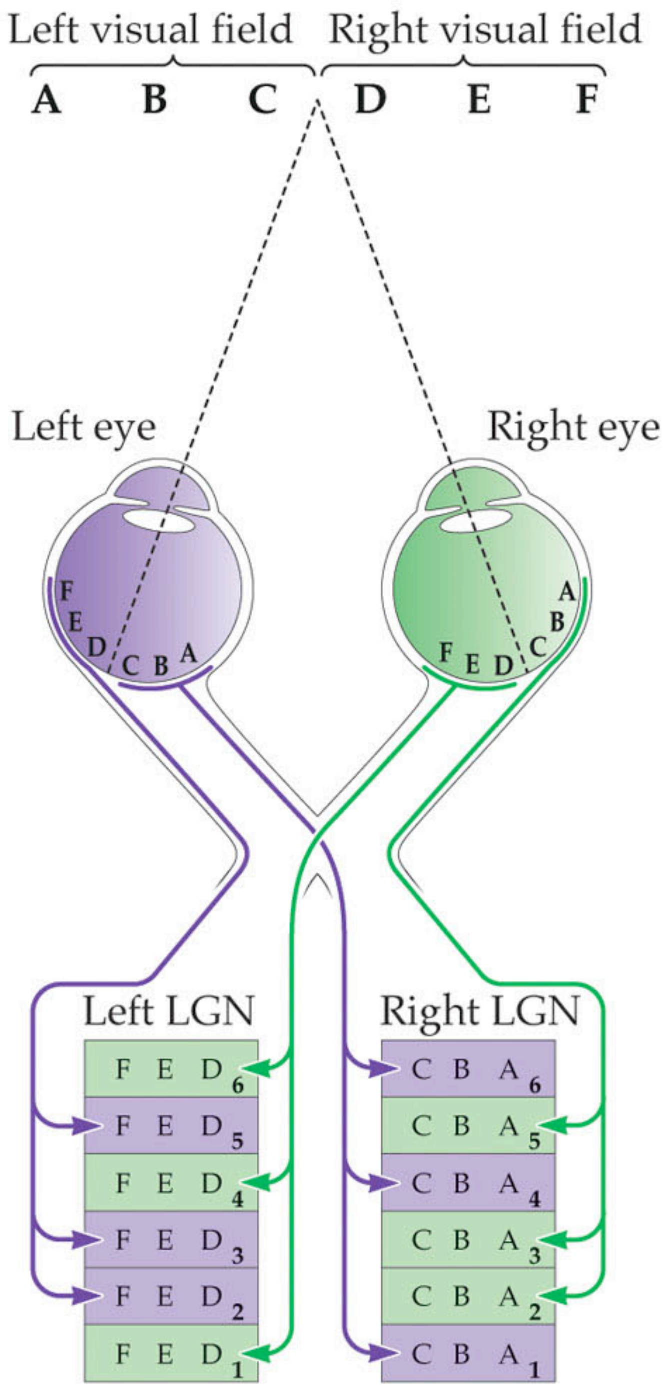


1 2 3 4 5 6 7 8 9
Left eye
Right eye
Foveal image
Optic nerve
Optic chiasm
Lateral geniculate nucleus (LGN)
Optic tract
Superior colliculus
Optic radiations
Striate cortex

Retina to LGN to Primary Visual Cortex



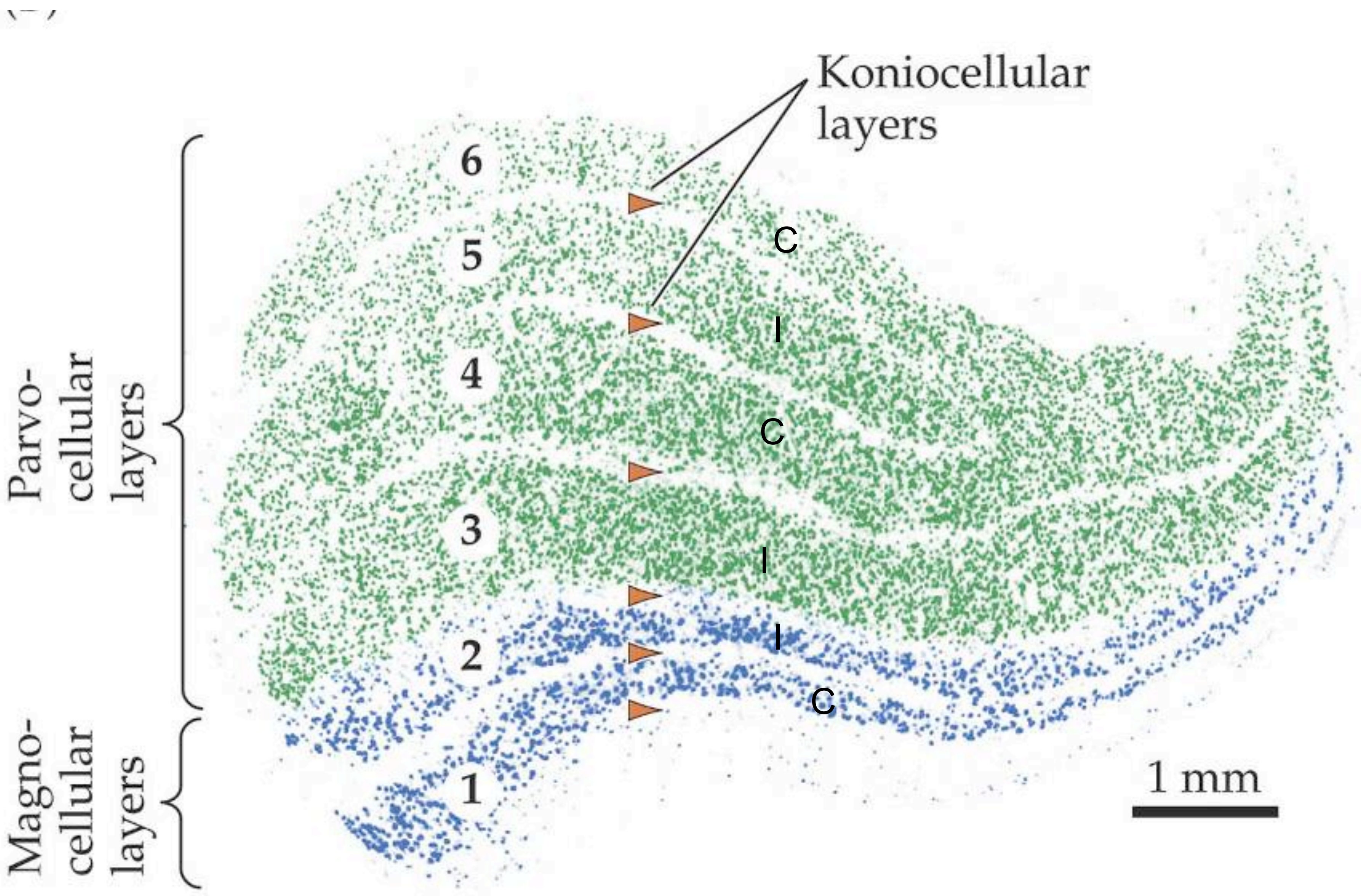
Level of section:
Thalamus
6
5
4
3
2
1



80% of the projections are to LGN

20% to superior colliculus

- Visual orienting
- Eye movements
- Multisensory – auditory input
- “where pathway”



Koniocellular
layers
6
5
4
3
2
1
C
I
C
I
I
C
Parvo-
cellular
layers
Magno-
cellular
layers
1 mm

Parallel visual processing streams:

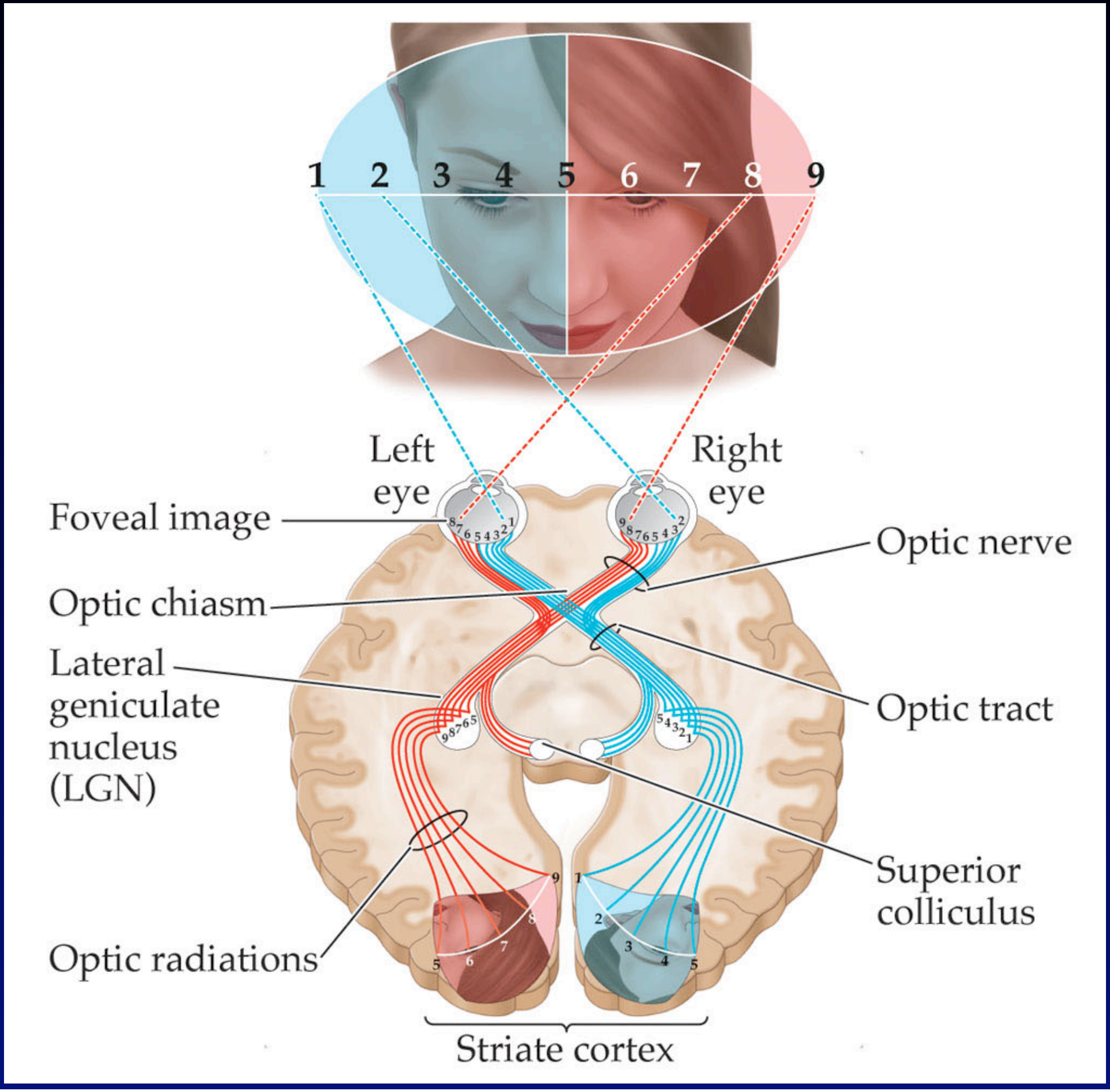
Parvocellular

- Midget ganglion cells
- Small – pools over fewer receptors
- Have a sustained response
- Involved in color, fine details, textures, and depth processing
- High resolution

Magnocellular

- Parasol ganglion cells
- Large cells – pools over many receptors
- Fire in bursts
- Involved detection of motion
- Low resolution

Visual Pathways: V1


1 2 3 4 5 6 7 8 9
Left eye
Right eye
Foveal image
Optic nerve
Optic chiasm
Lateral geniculate nucleus (LGN)
Optic tract
Superior colliculus
Optic radiations
Striate cortex

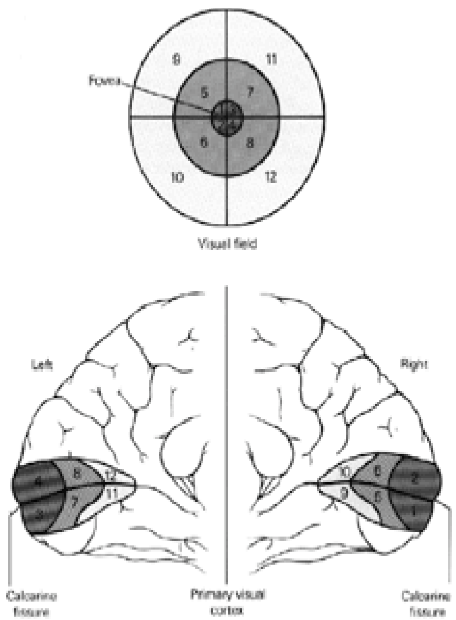
Projections from LGN to V1

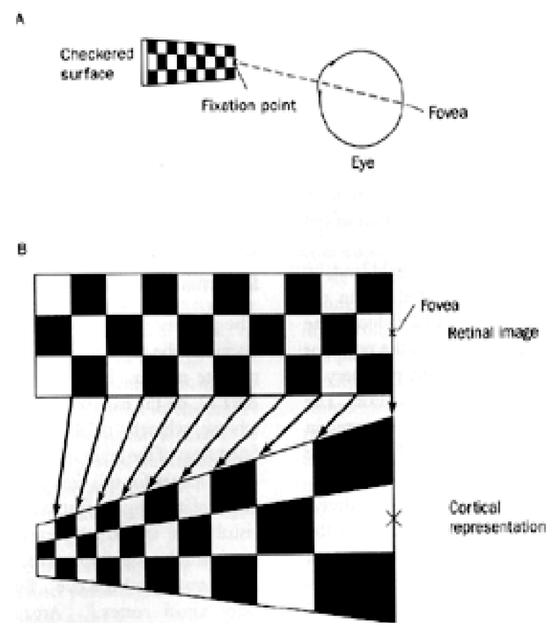
Topographic mapping

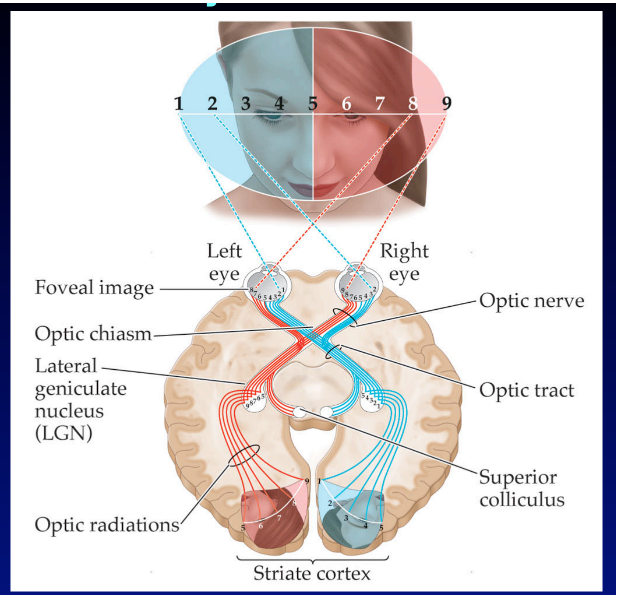
- There is an ordered representation throughout the visual system

Cortical magnification

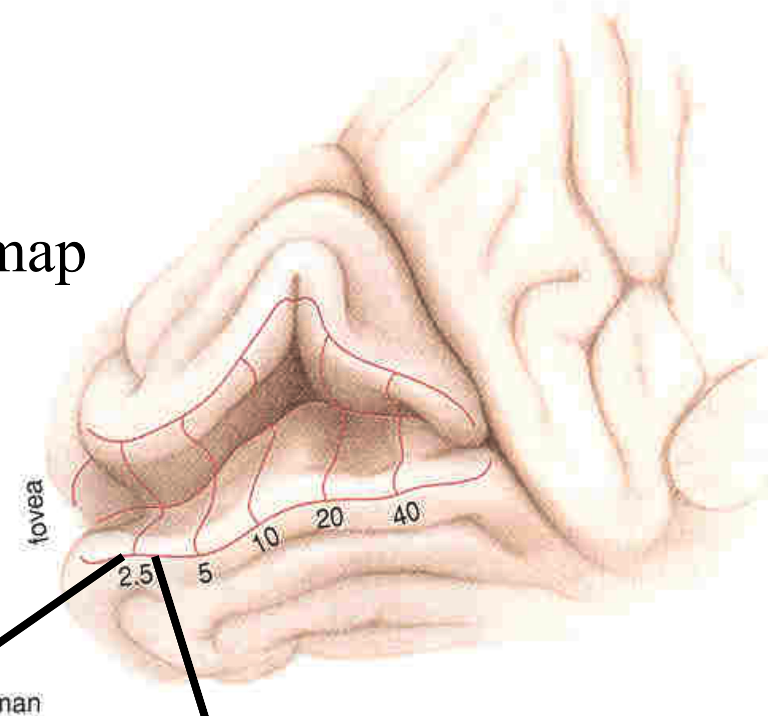
- Large portion of the cortex is devoted to a small portion of the retina



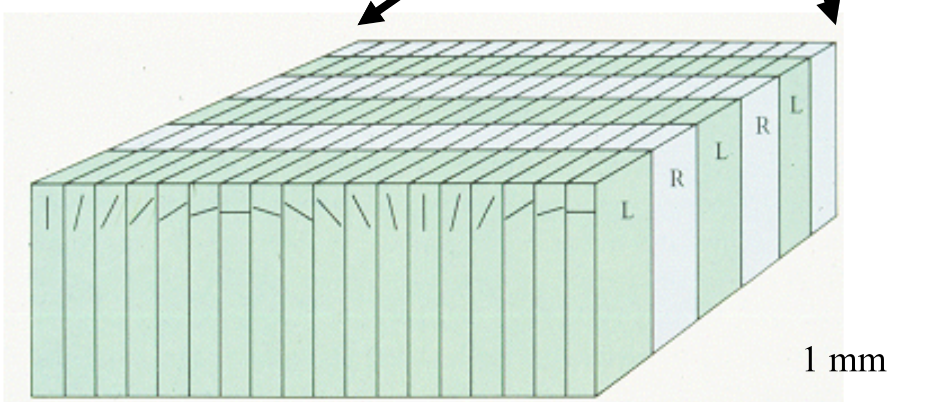




Retinotopic map

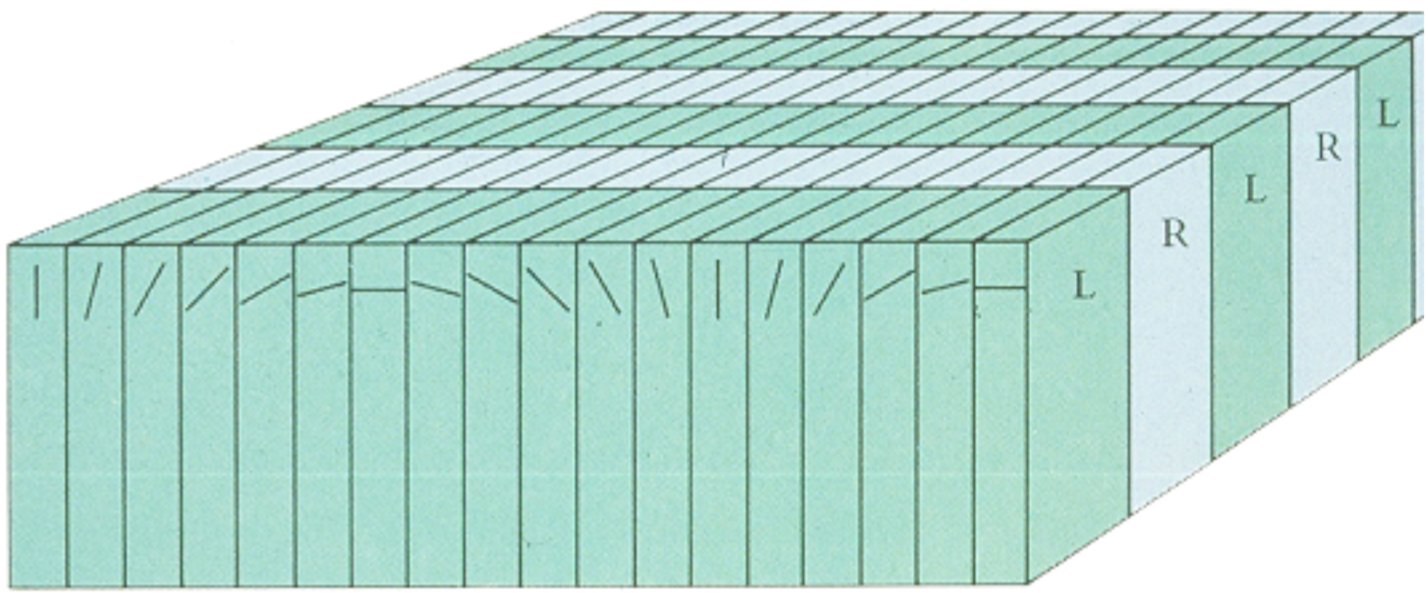


Columnar architecture

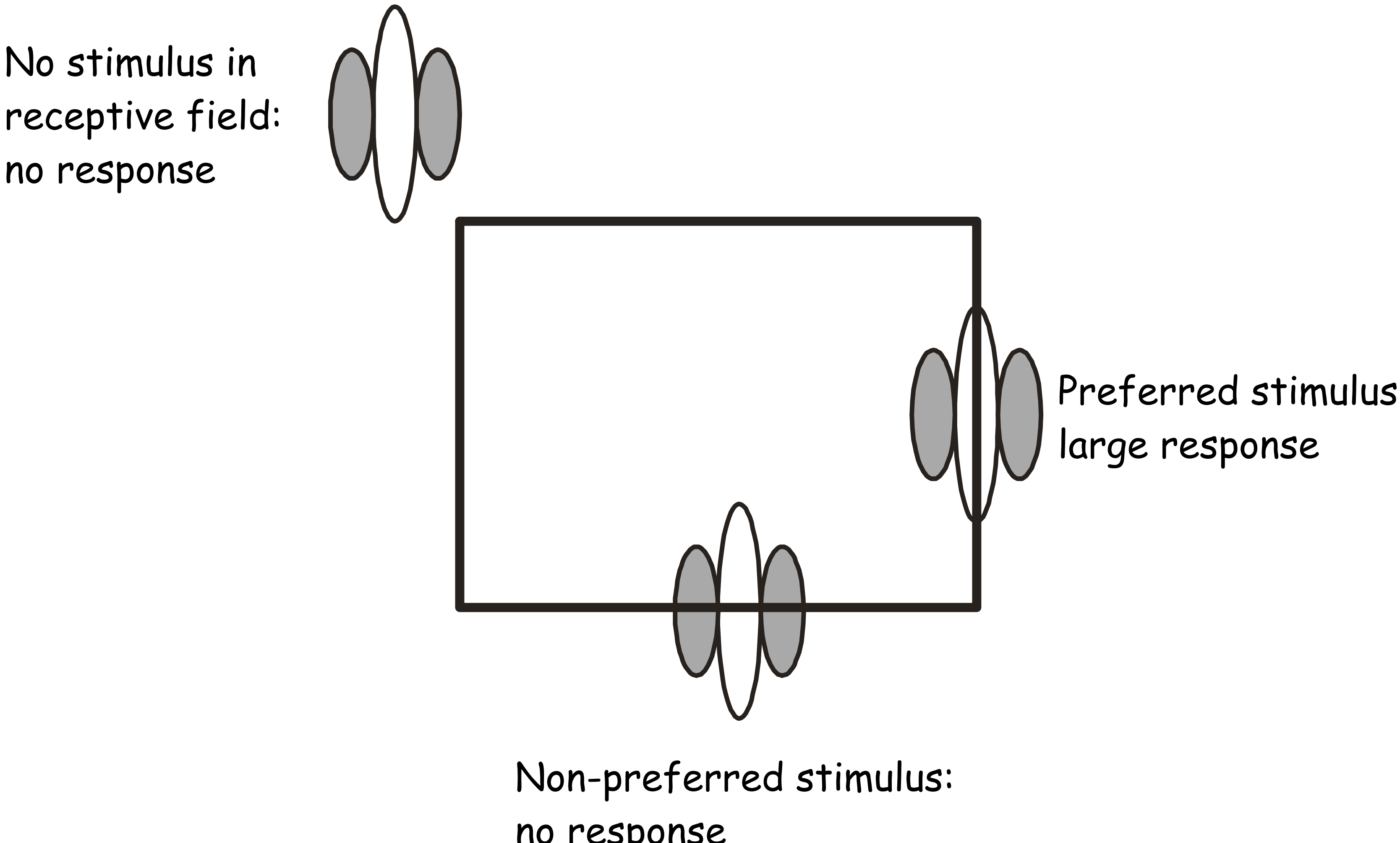


V1 Ocular dominance and orientation columns
(Hubel & Wiesel; Ice cube model)

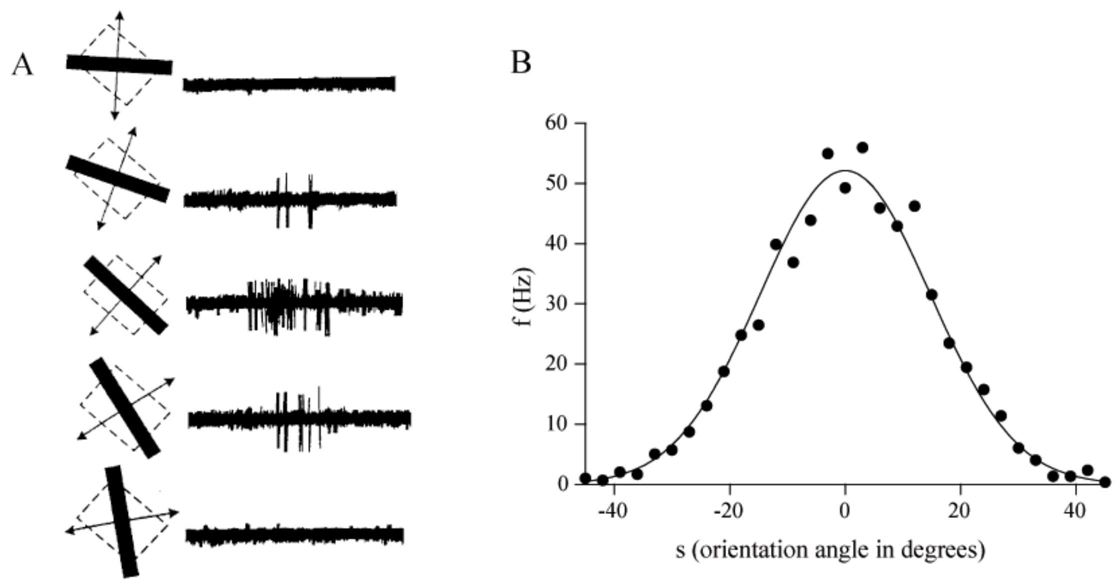
Vertical column: same orientation, ocular dominance
Next column: nearby orientation, ocular dominance
Systematic changes across cortical surface
Hypercolumn = functional unit



Function of V1: Bring together information for the two eyes and reorganize the inputs so that cells respond best to oriented lines.


No stimulus in
receptive field:
no response
Preferred stimulus:
large response
Non-preferred stimulus:
no response

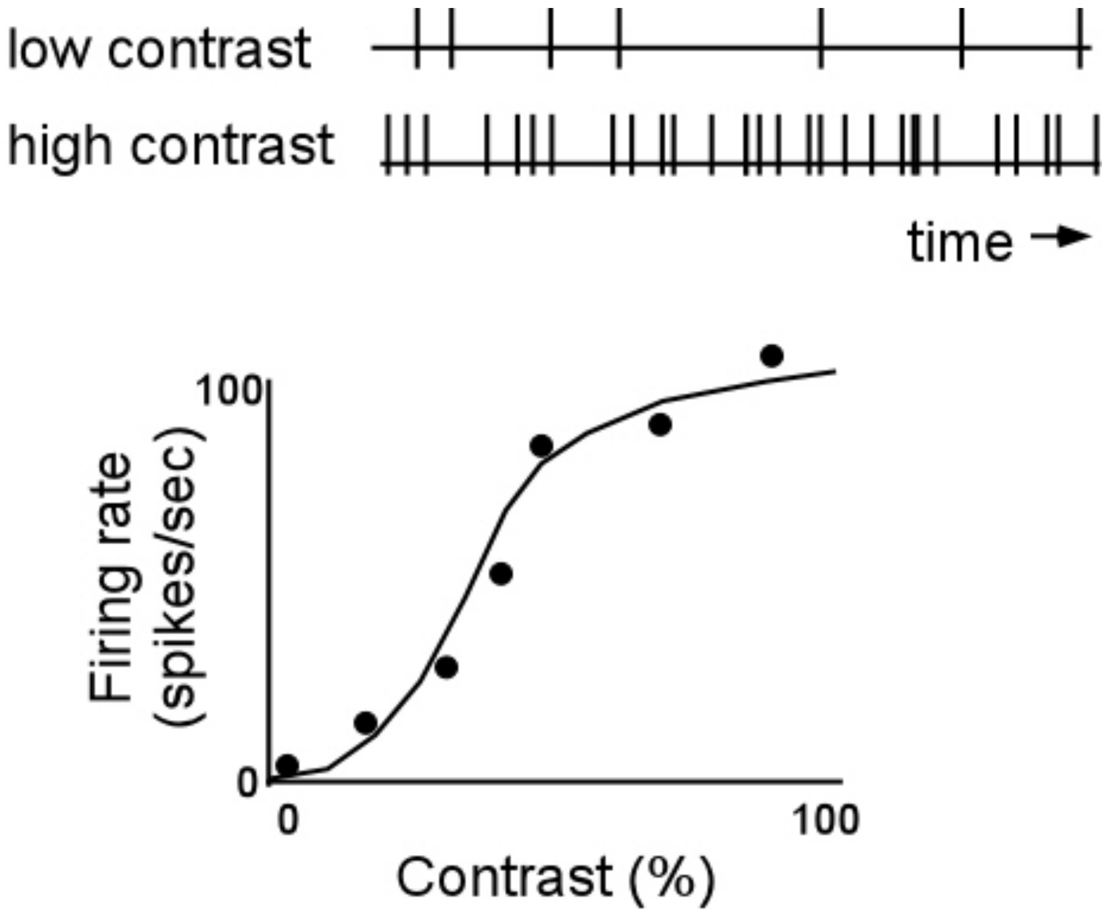
Single unit recordings in V1: Orientation selectivity

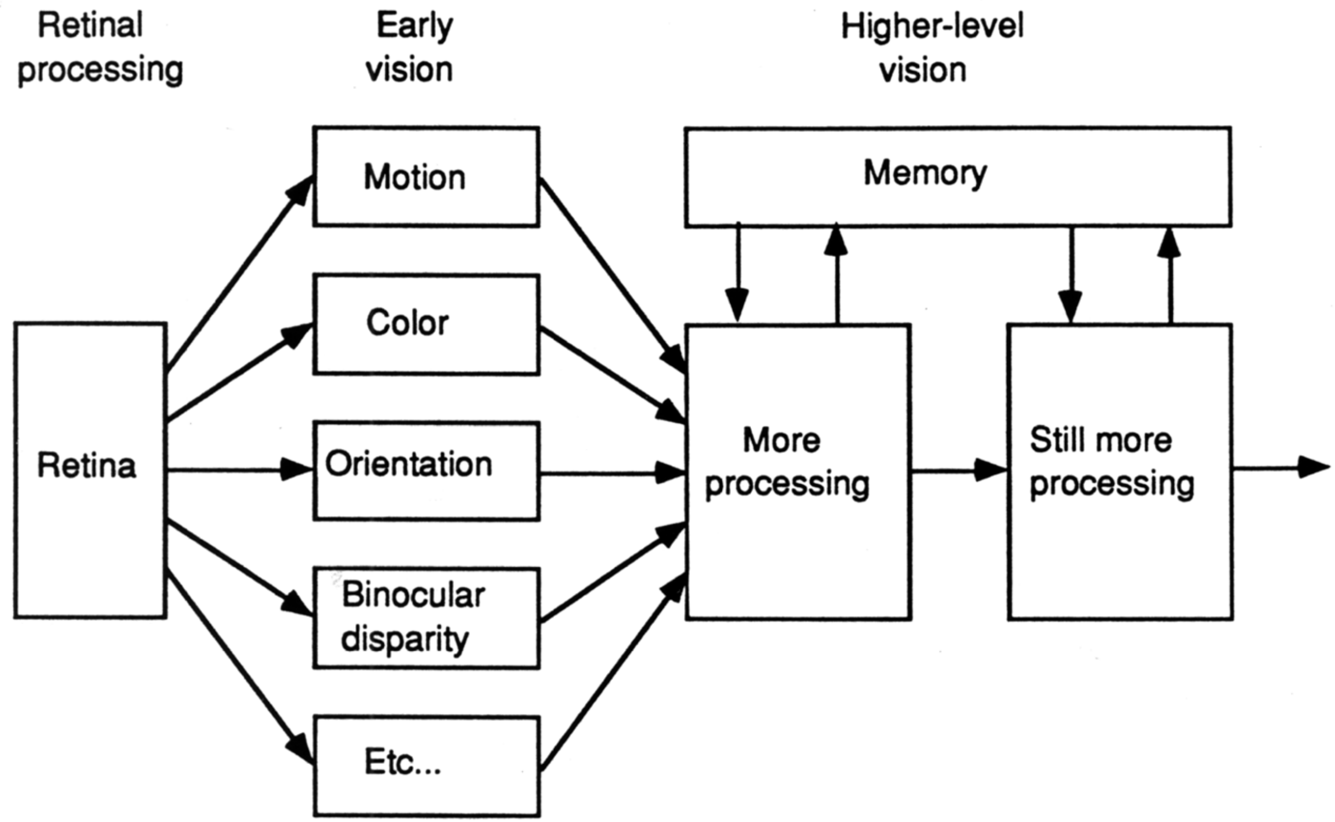


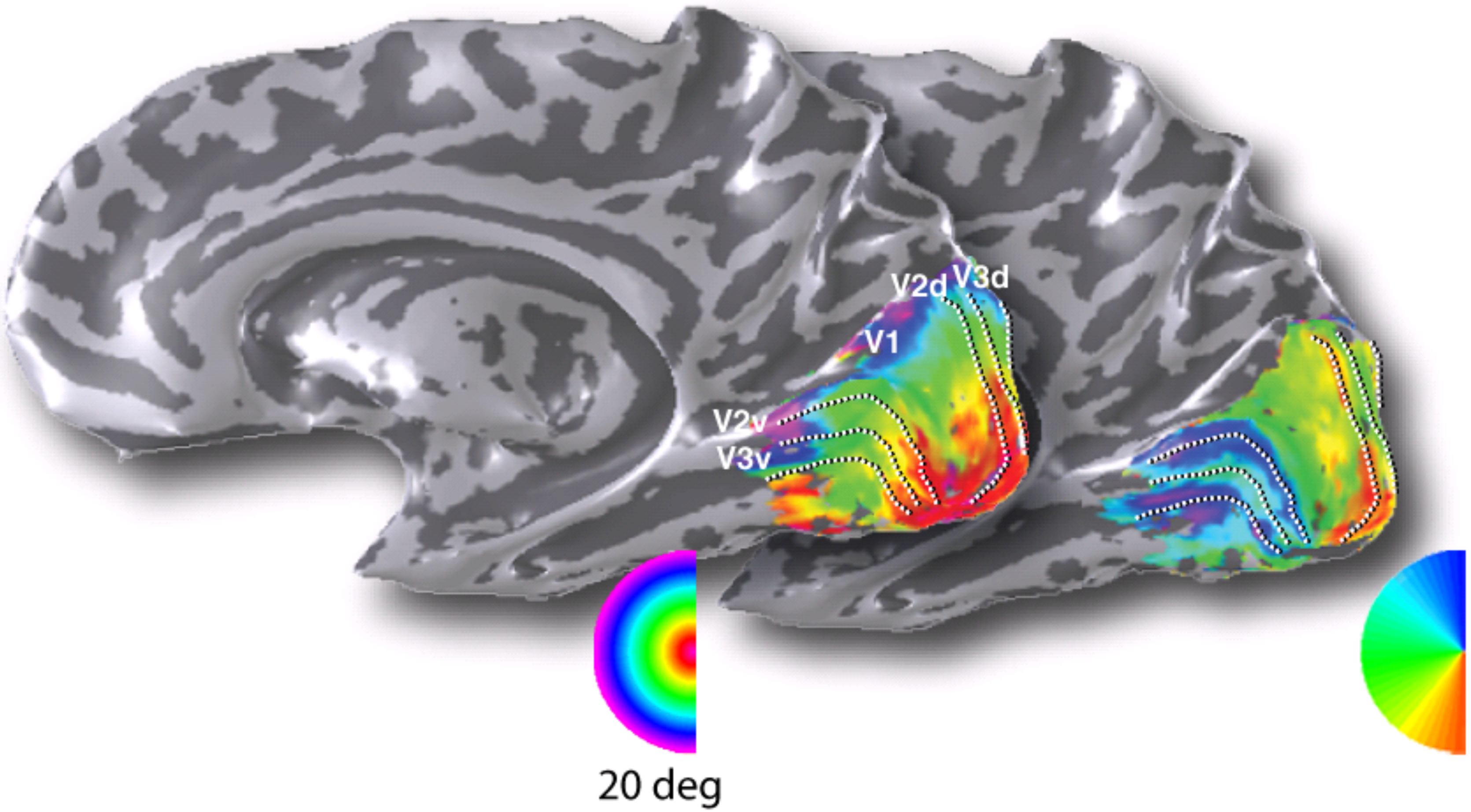
V1 data

Stimulus orientation (deg)

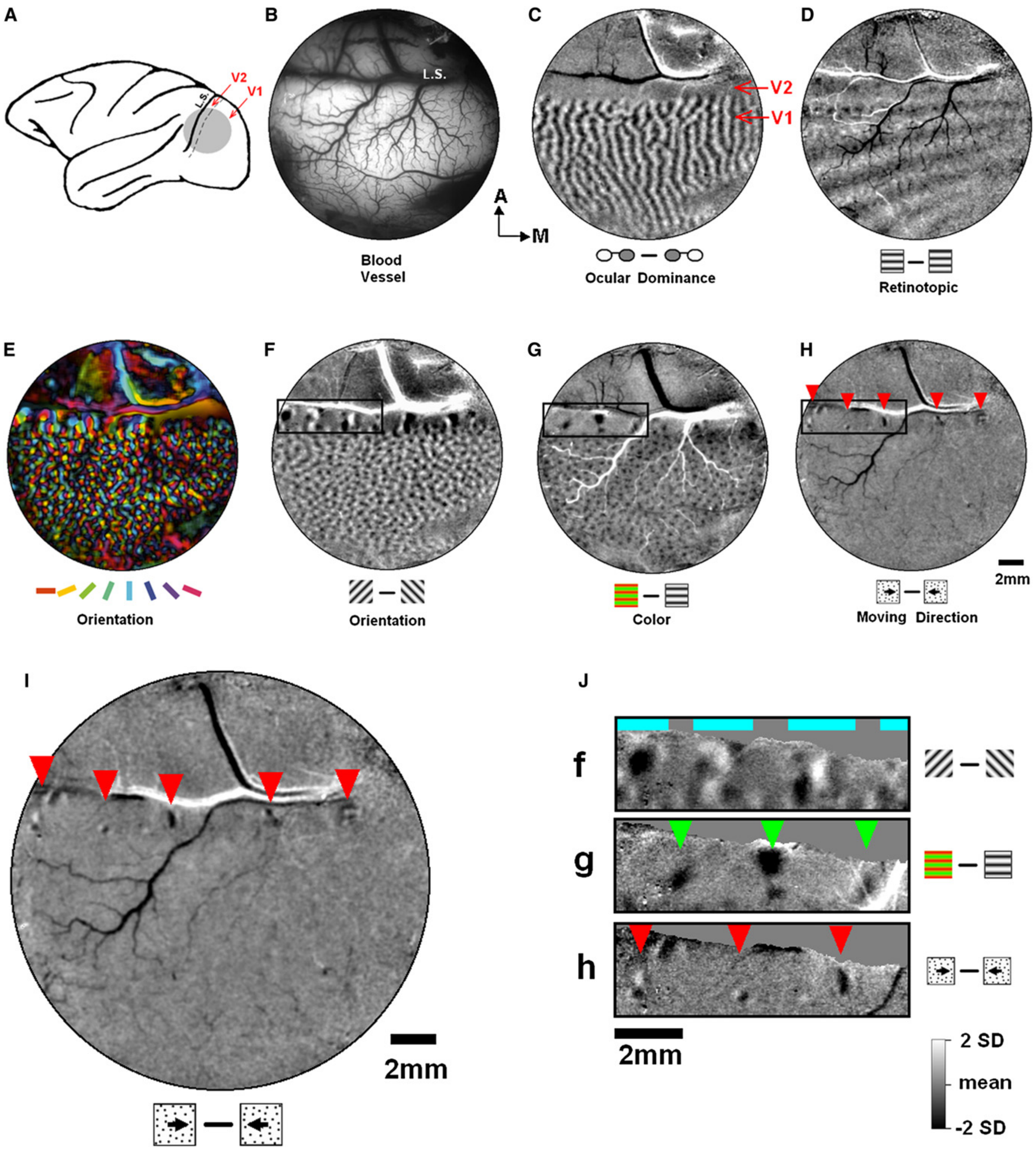
http://www.youtube.com/watch?
v=X8AukcNn_Zk


low contrast
high contrast
time
100
0
Firing rate
(spikes/sec)
0
100
Contrast (%)


Retinal processing
Early vision
Higher-level vision
Memory
Motion
Color
Retina
Orientation
More processing
Still more processing
Binocular disparity
Etc...

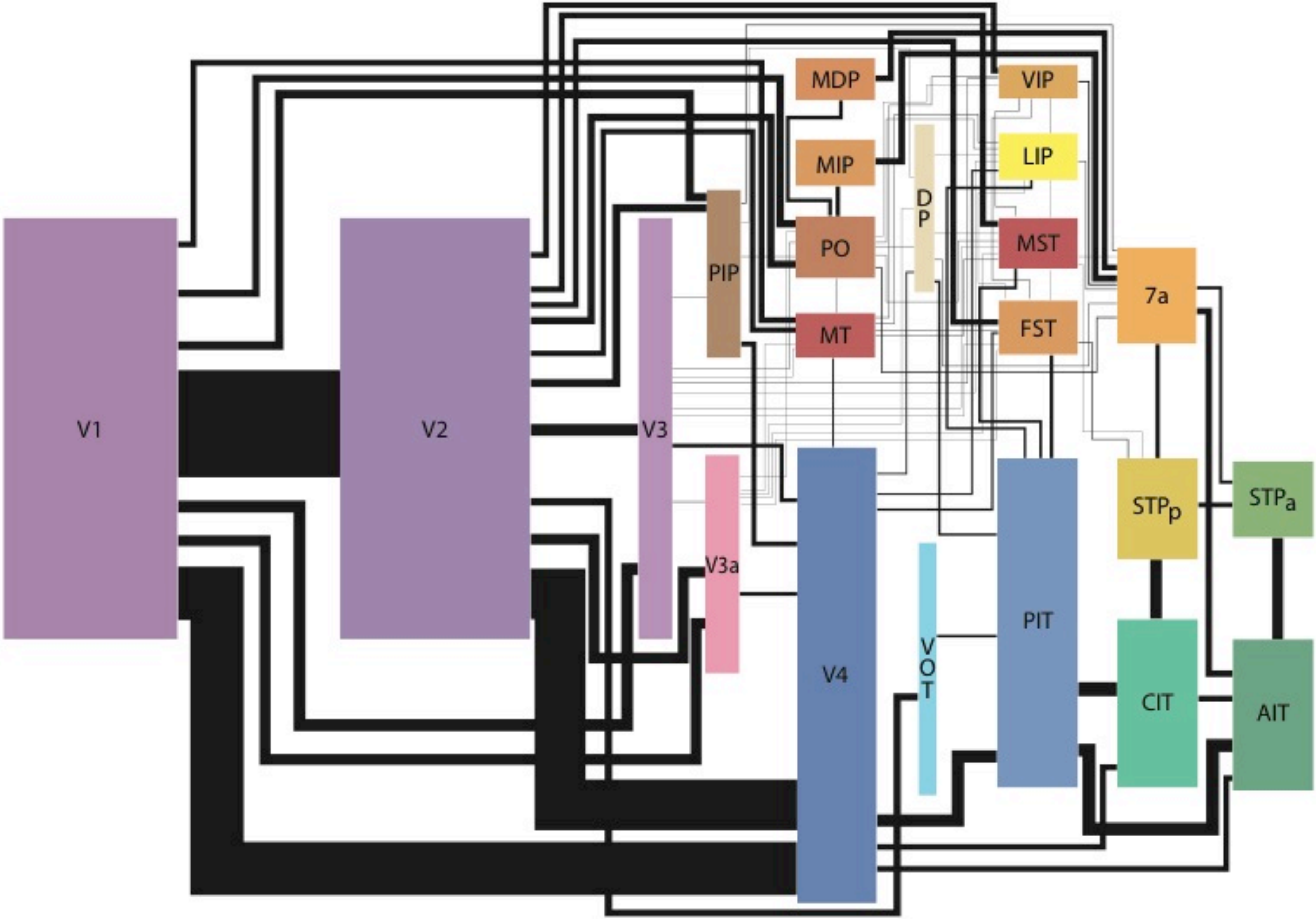

V2d
V3d
V1
V2v
V3v
20 deg

Functional compartments in V2 (Lu et al 2010)



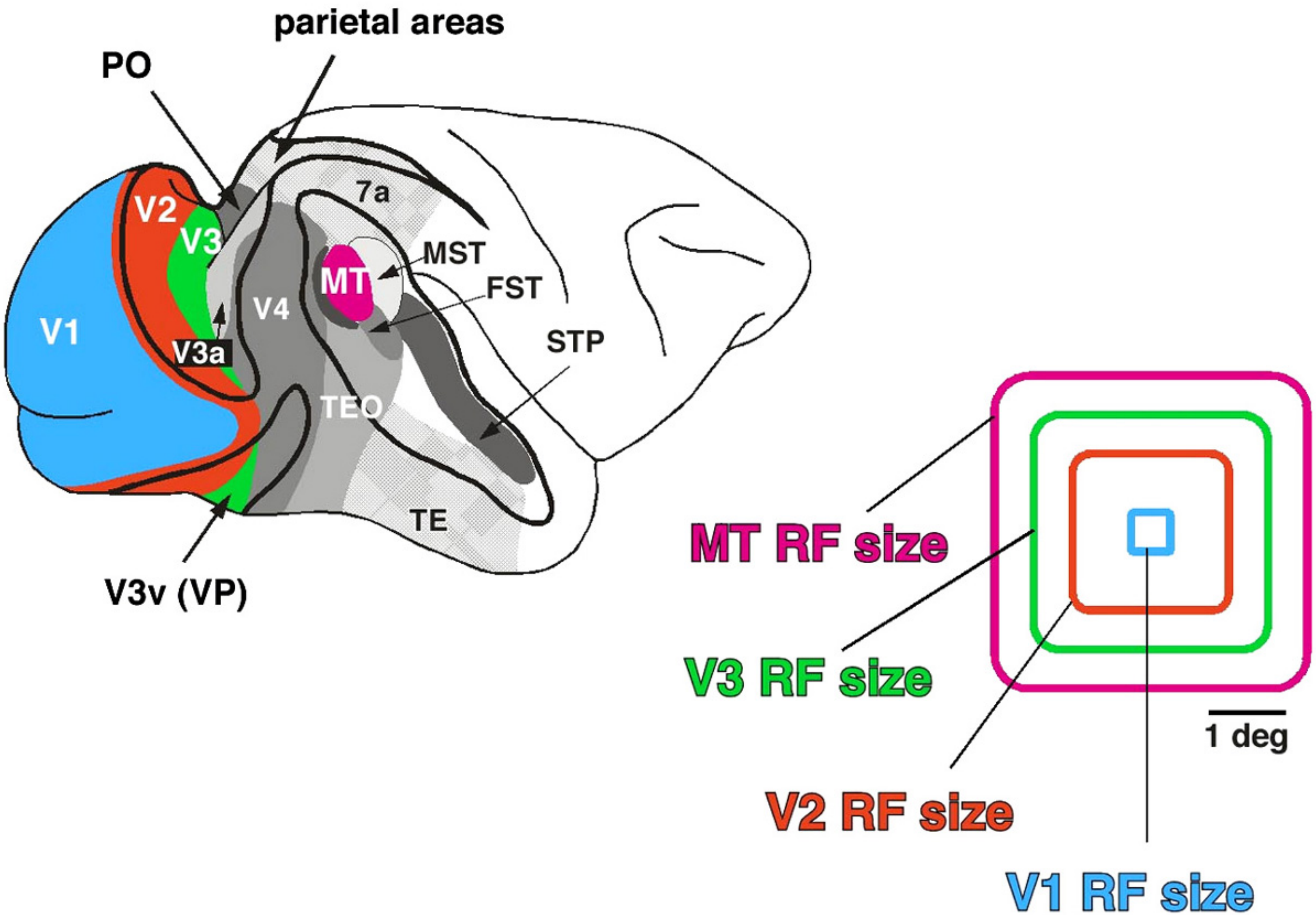
(A) Illustration of a macaque brain and the approximate location of imaging area. L.S., location of lunate sulcus.
\(B) Surface blood vessel pattern of the imaging area.
(C) Ocular dominance map (left-eye minus right-eye stimulation) reveals ocular dominance columns in V1 and lack thereof in V2. The imageable area of V2 is located between the V1/V2 border and the lunate sulcus.
(D) Retinotopic mapping (subtraction of two stationary phase-shifted vertical squarewave gratings) reveals cortical representation of vertical lines in the visual field. Left side of the image is closer to the fovea and has higher cortical magnification.
(E) Orientation vector map. Different colors represent different orientation preferences
(F) Orientation map (45-135 deg gratings) reveals locations of orientation-selective domains corresponding to thick/pale stripe locations in V2 (indicated by cyan bars in top panel of J).
(G) Color map (isoluminant red/green minus luminance gratings) reveals blobs in V1 and color preference domains corresponding to thin stripe locations in V2 (indicated by green arrowheads in middle panel of J).
(H) Motion direction map (rightward minus leftward drifting random dots). Red arrowheads: areas in V2 with directional response preference. No directional preference domains are seen in V1 and other parts of V2. (I) Enlarged view of (H).
(J) f, g, and h: Enlarged view of boxed regions of V2 shown in (F), (G), and (H), respectively.
Strong blood vessel noise overlying large vessel in lunate sulcus is replaced with even gray (top portion of each panel). Thick/pale stripes (indicated by cyan bars) contain orientation preference domains (f). Thin stripes (indicated by green arrowheads) contain color preference domains (g). Note that color preference regions (green arrowheads in g) occur in regions with poor orientation selectivity (even gray zones aligned with spaces between cyan bars in f) and interdigitate with orientation-selective regions. Directional domains (h, red arrow- heads) fall within thick/pale stripe zones and avoid thin stripe zones. Maps (C)–(J) are displayed using the gray scale shown on the lower-right corner (SD: standard deviation of pixel distributions for each individual maps).

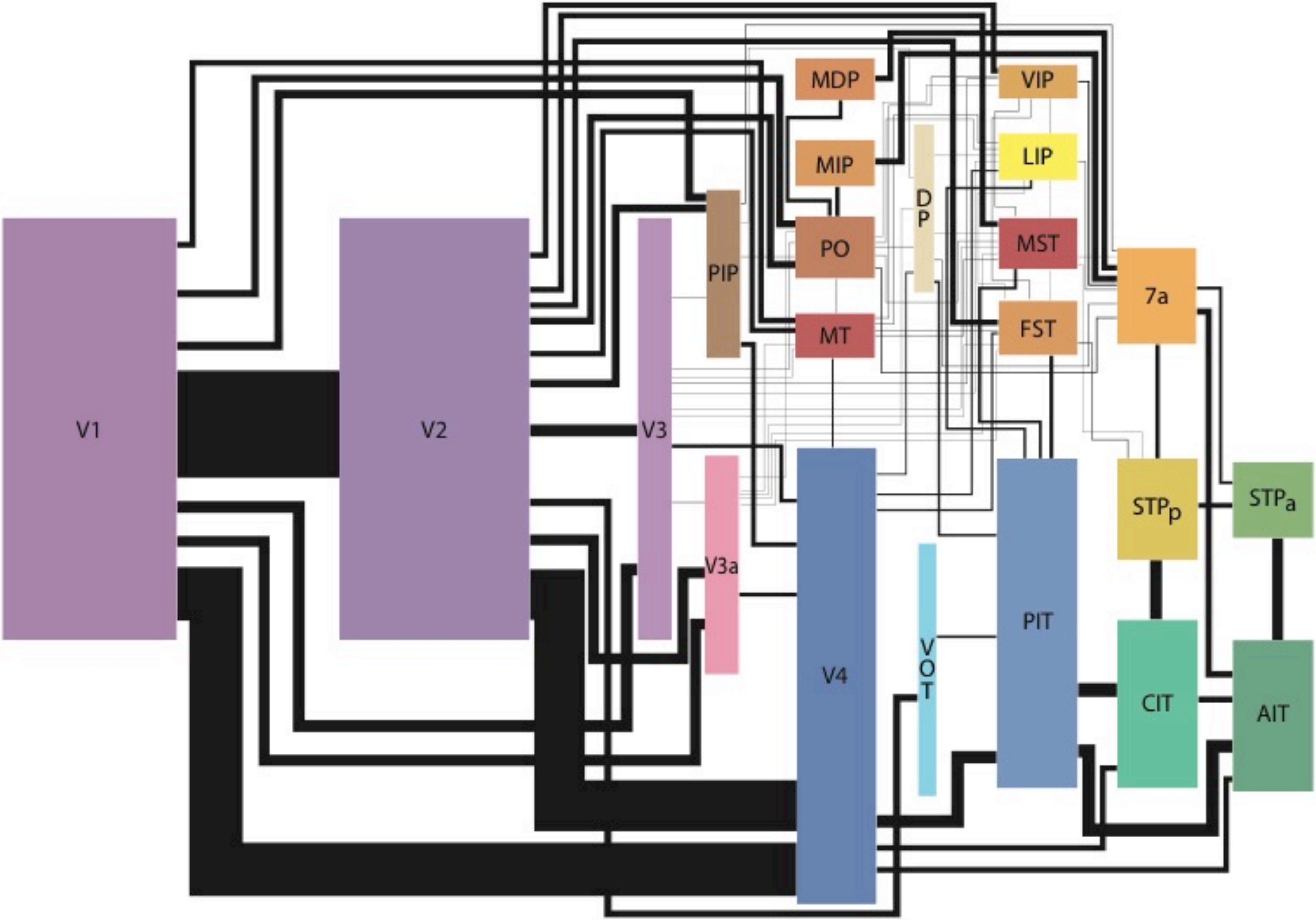
Visual Pathways: beyond V1



Wallisch & Movshon, 2008

after Felleman & Van Essen, 1991

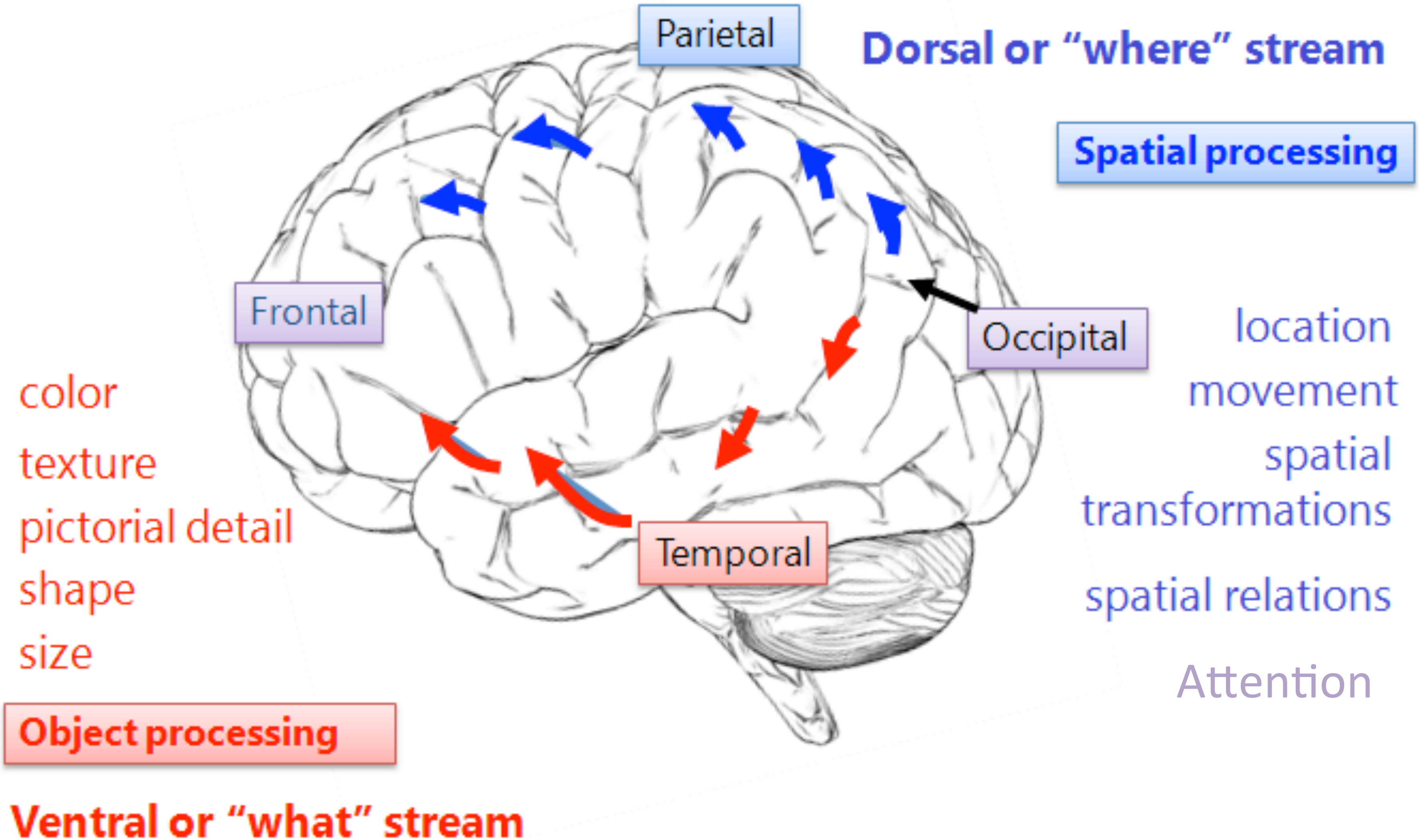

parietal areas
PO
V2
V3
7a
MST
MT
FST
V1
V4
V3a
STP
TEO
TE
V3v (VP)
MT RF size
V3 RF size
1 deg
V2 RF size
V1 RF size



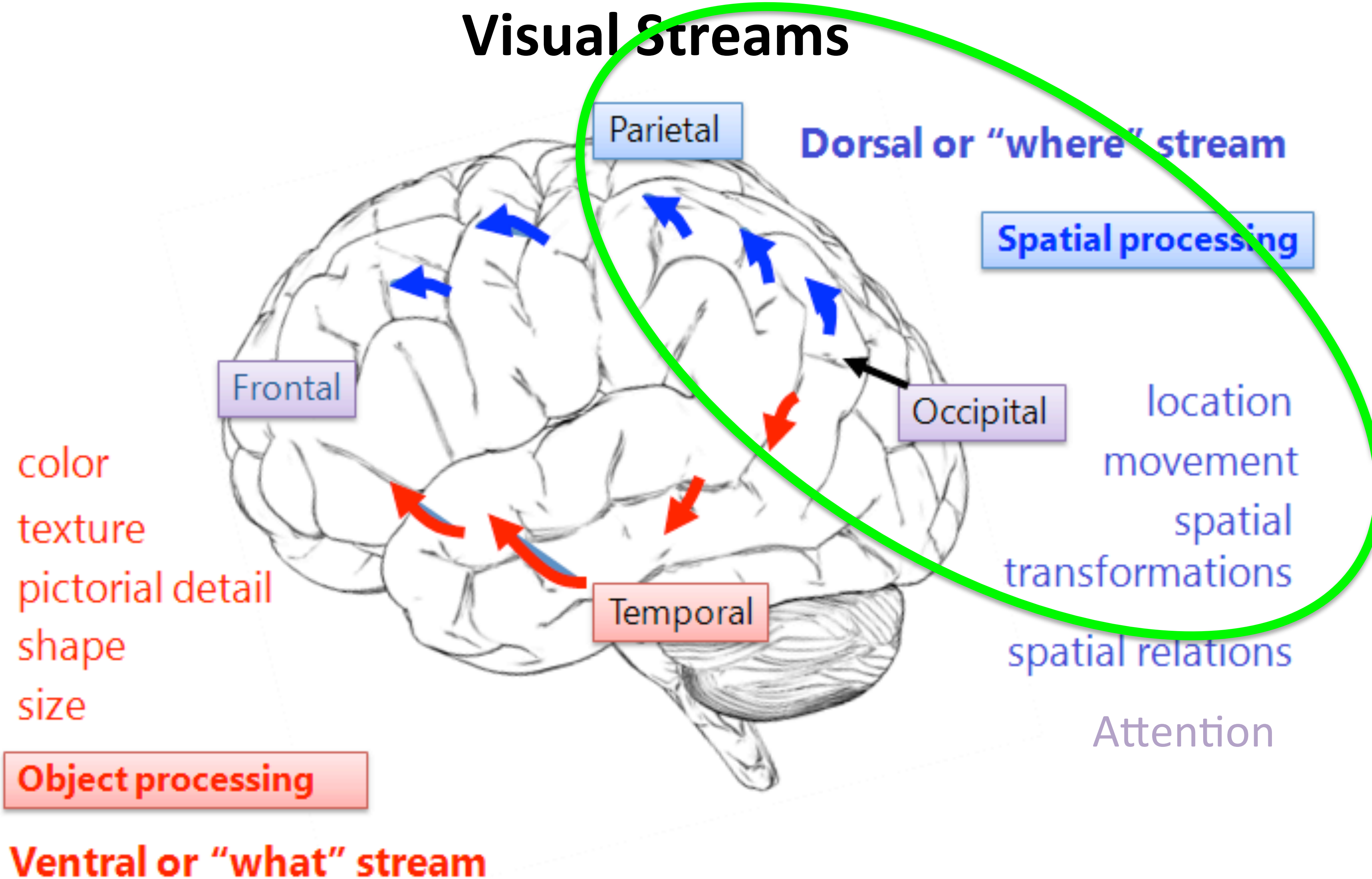
Wallisch & Movshon, 2008

after Felleman & Van Essen, 1991

Visual Streams

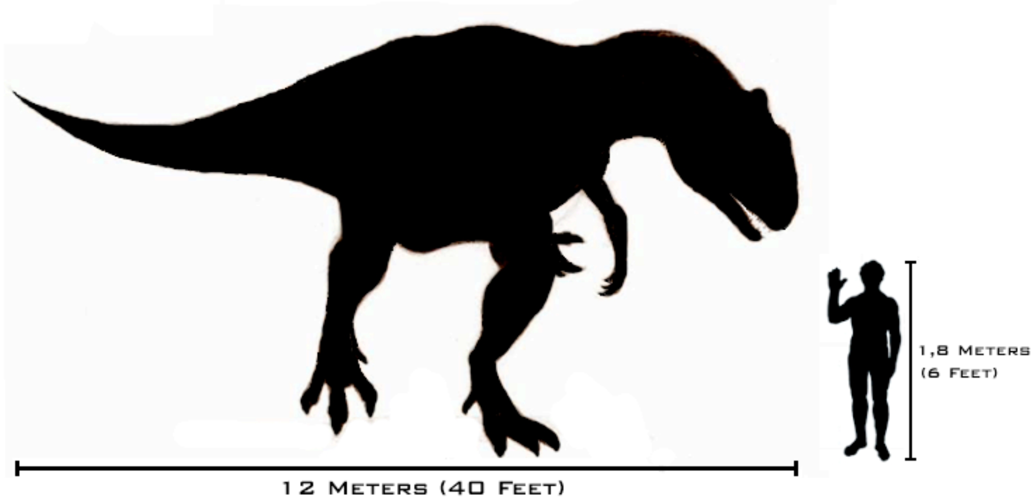


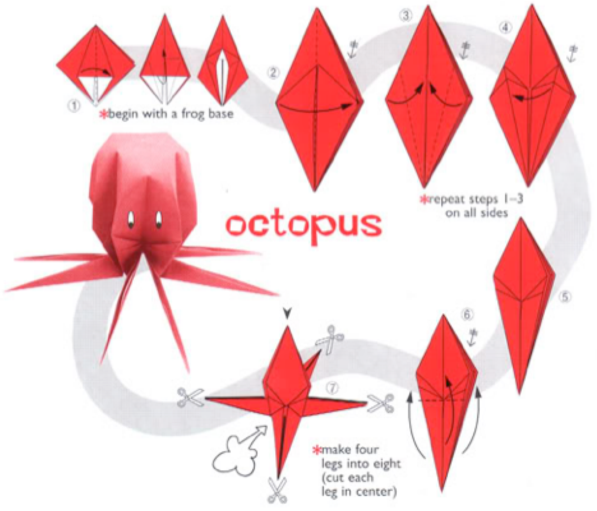
Visual Streams

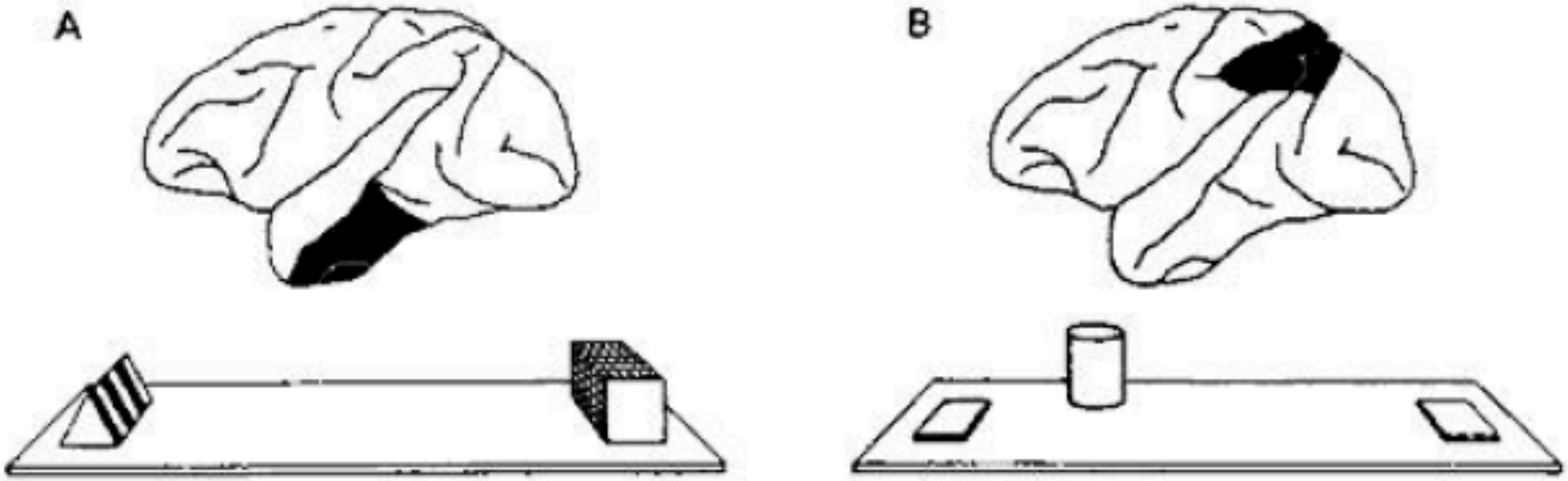


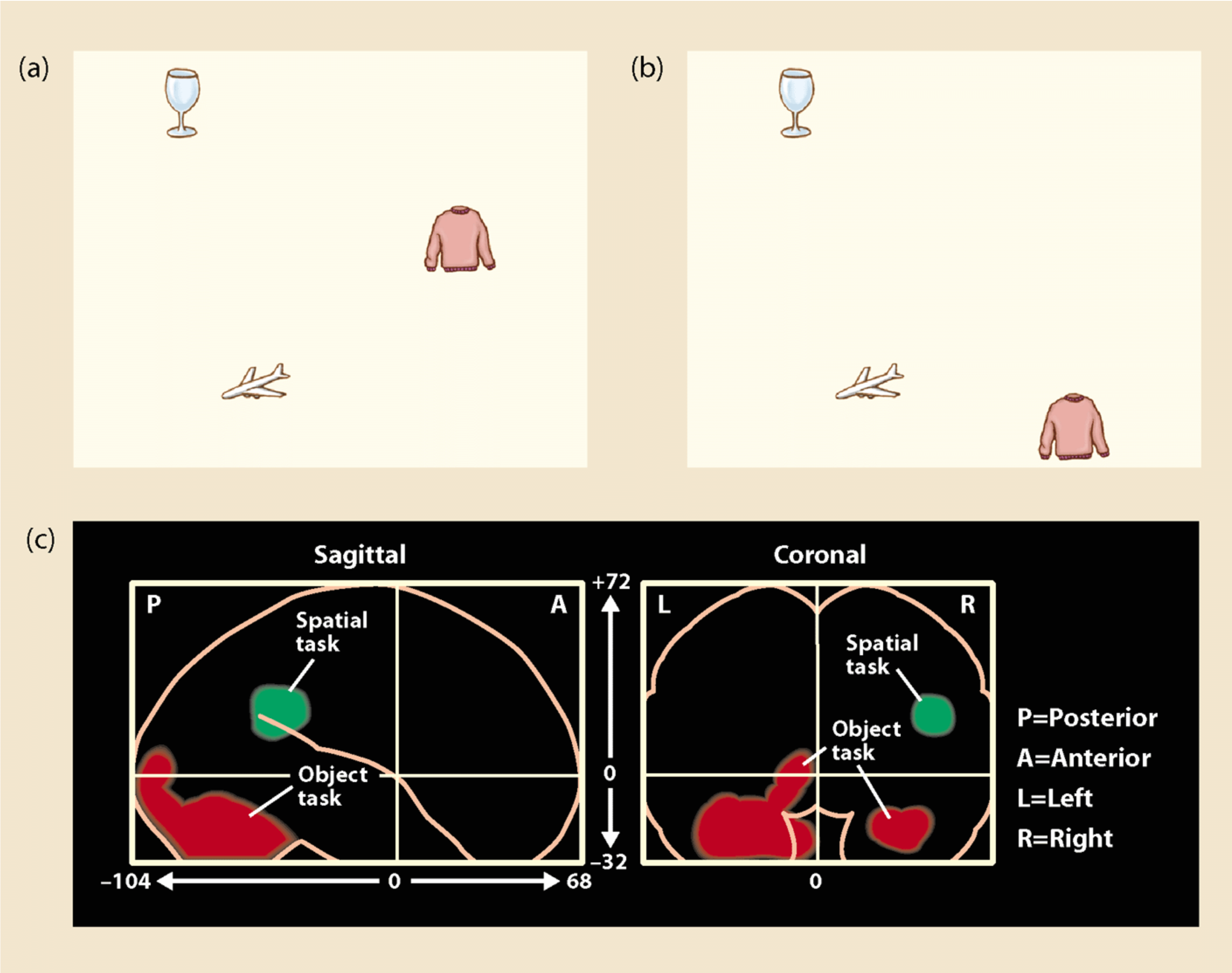

PIRATES
55

Vision beyond identification

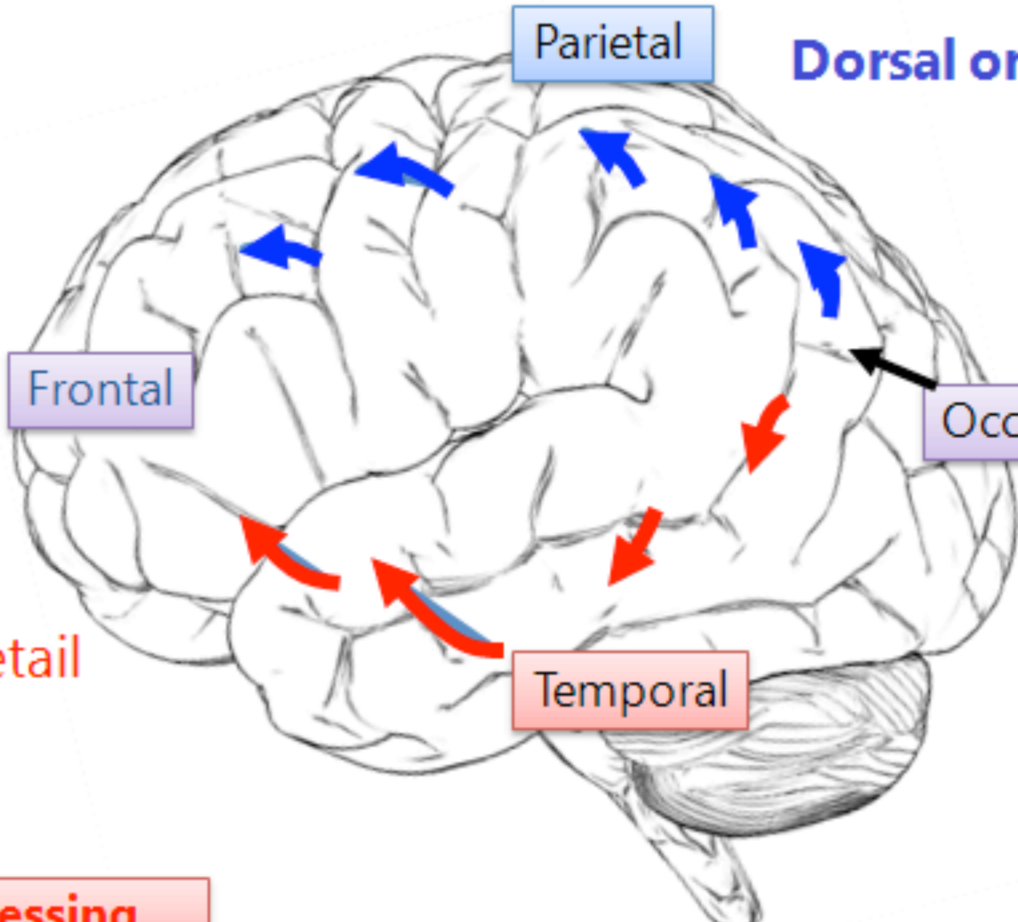





A
B


(a)
(b)
(c)
Sagittal
Coronal
P
A
L
R
Spatial task
Object task
Spatial task
Object task
+72
0
–32
–104
0
68
0
P=Posterior
A=Anterior
L=Left
R=Right

Visual Streams



Dorsal or "where" stream

Spatial processing

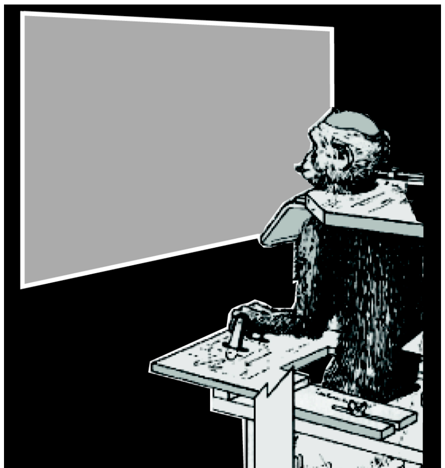
location
movement
spatial transformations
spatial relations
Attention

color
texture
pictorial detail
shape
size

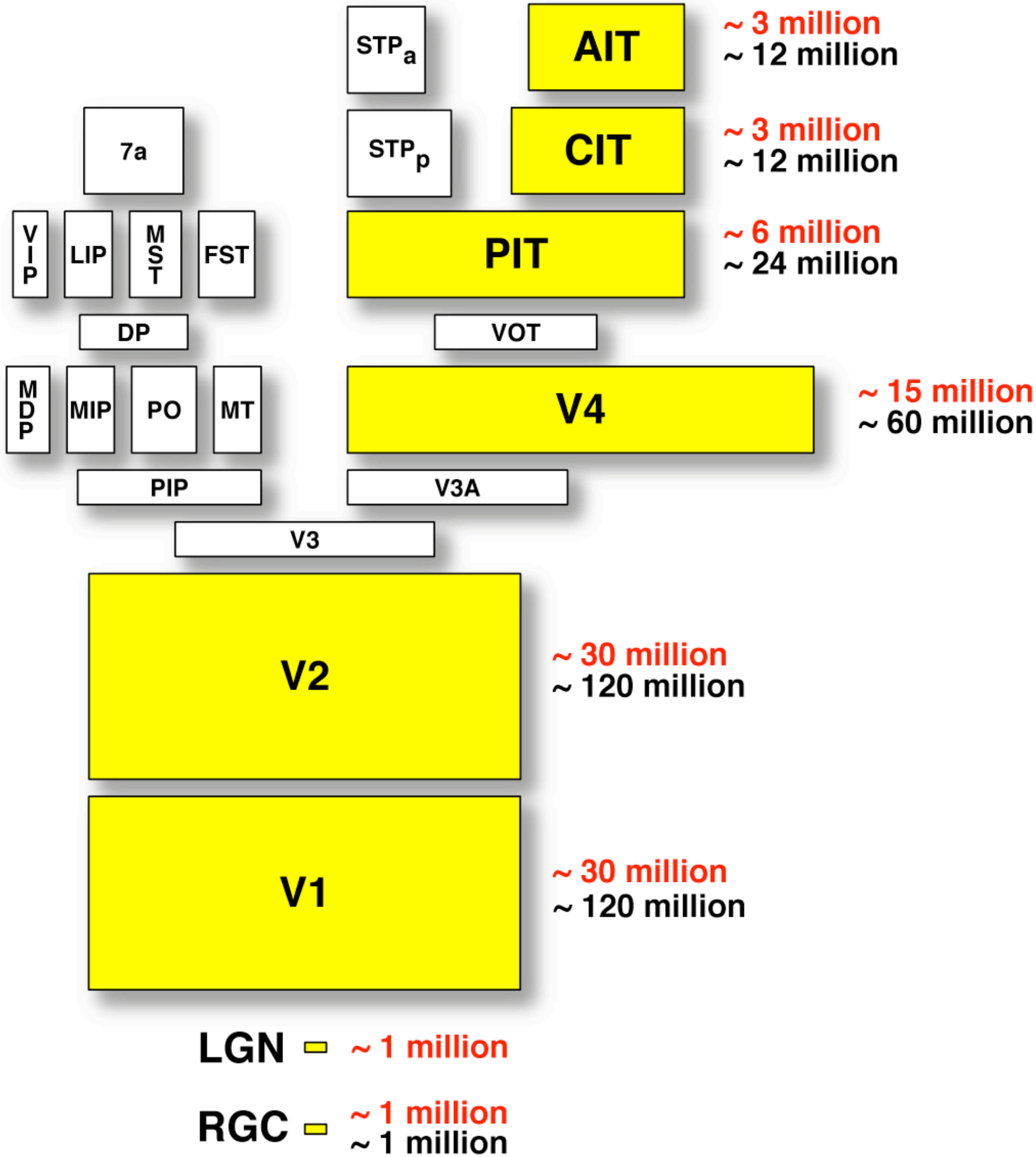
Object processing

Ventral or "what" stream

Monkey Visual Areas



Adapted from Motter and Mountcastle 1981



Total number of neurons

Total number of feedforward projection neurons

(both hemispheres)

Hierarchical Organization