# Review,
# the visual and oculomotor systems

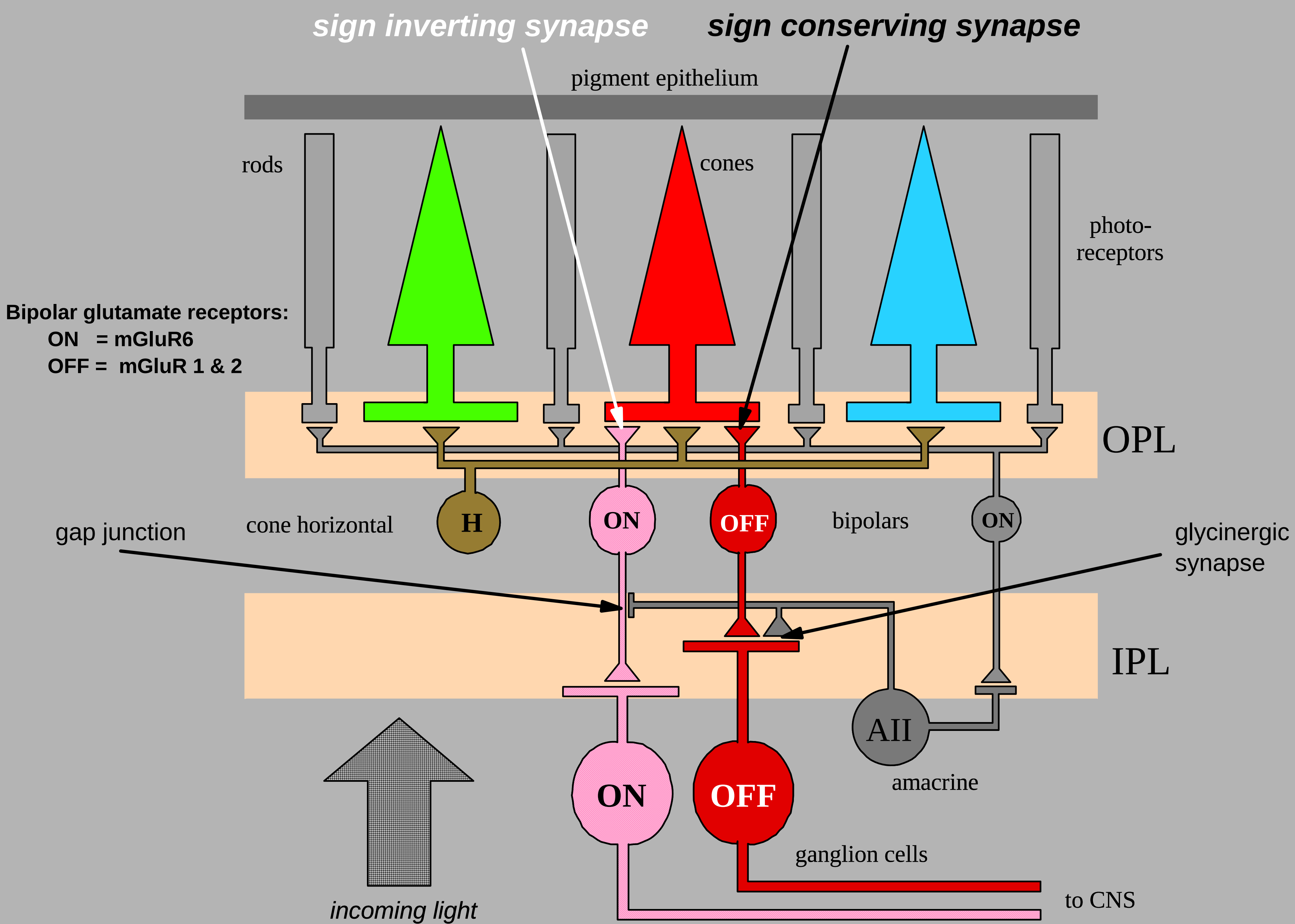
# Basic wiring of the visual system

# Primates

Image removed due to copyright restrictions.

Please see lecture video or Figure 3 from Schiller, Peter H., and Edward J. Tehovnik. "Visual prosthesis." *Perception* 37, no. 10 (2008): 1529.

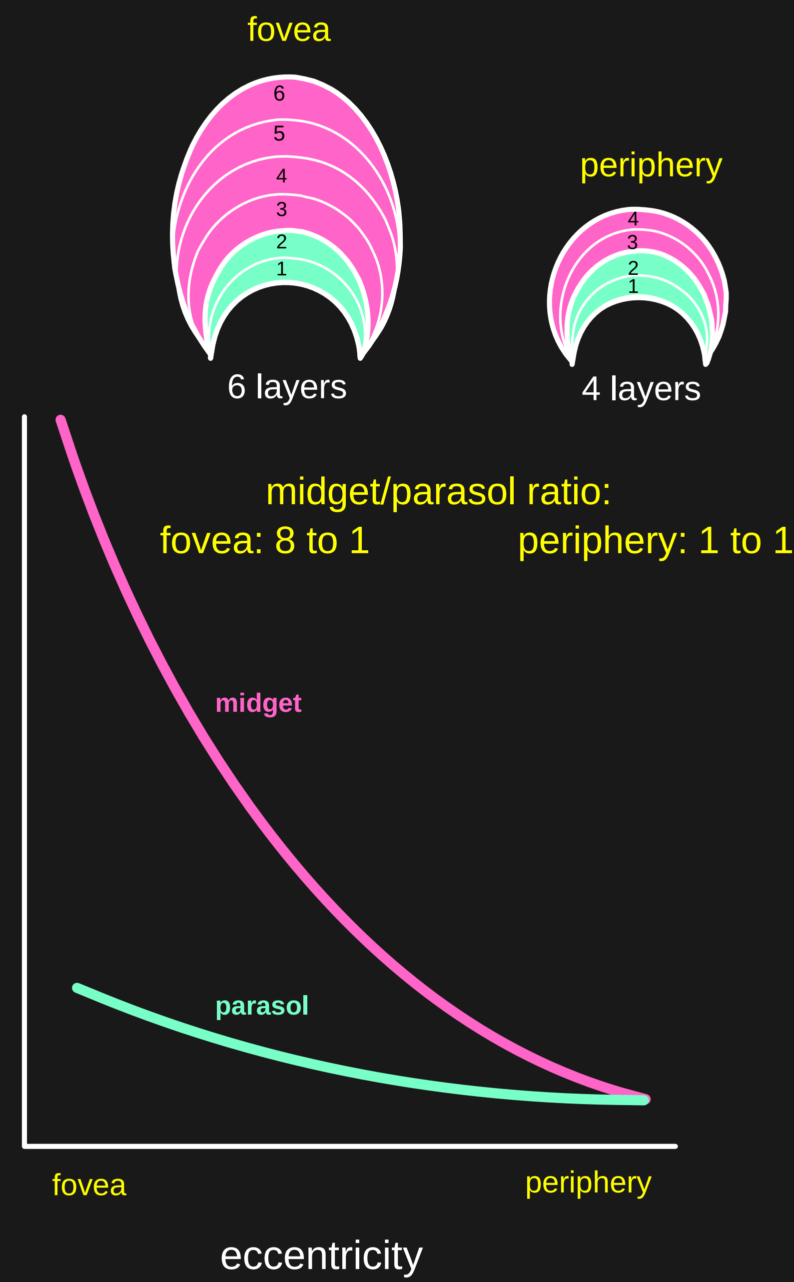
# Retina and LGN


sign inverting synapse
sign conserving synapse
pigment epithelium
rods
cones
photo-
receptors
Bipolar glutamate receptors:
ON = mGluR6
OFF = mGluR 1 & 2
OPL
H
ON
OFF
ON
gap junction
cone horizontal
bipolars
glycinergic
synapse
IPL
AII
amacrine
ON
OFF
ganglion cells
to CNS
incoming light

# Coronal section of monkey LGN

Figure removed due to copyright restrictions.

Please see lecture video or Figure 4A of Schiller, Peter H., and Edward J. Tehovnik. "Visual Prosthesis." *Perception* 37, no. 10 (2008): 1529.



# Visual cortex

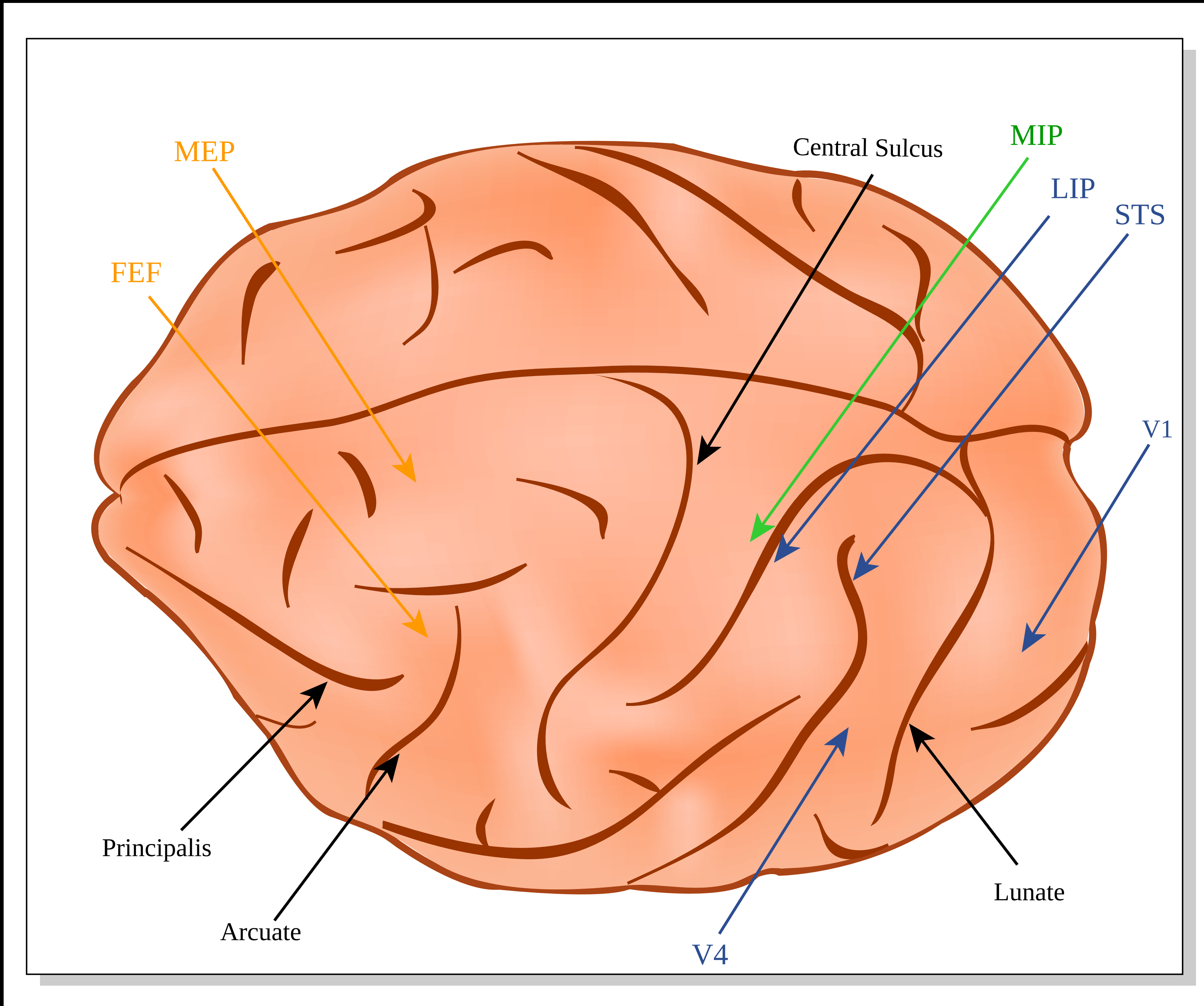
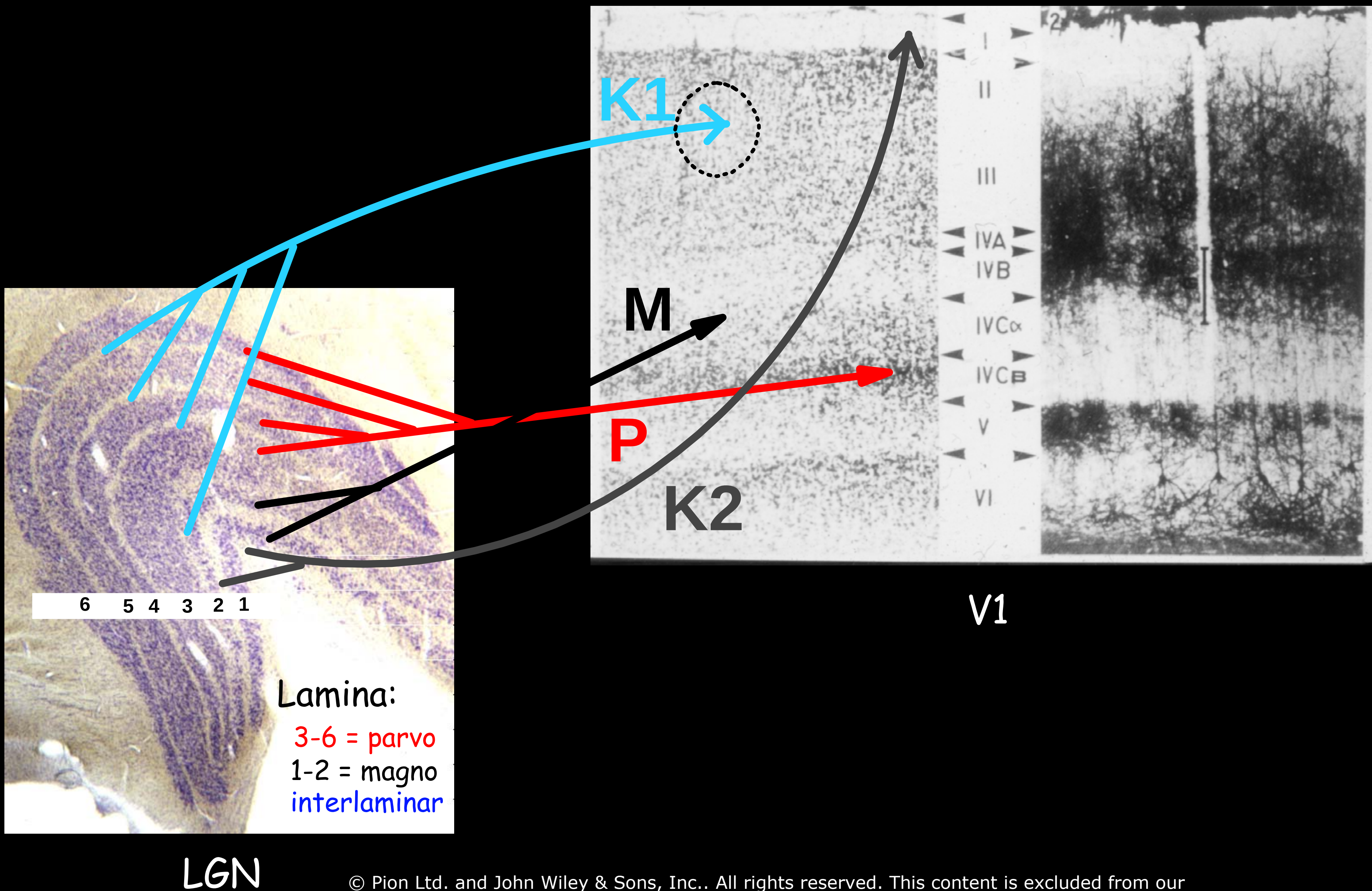



Image by MIT OpenCourseWare.

# Cortical projections from LGN



# Transforms in V1

Orientation

Direction

Spatial Frequency

Binocularity

ON/OFF Convergence

Midget/Parasol Convergence

# Three models of columnar organization in V1

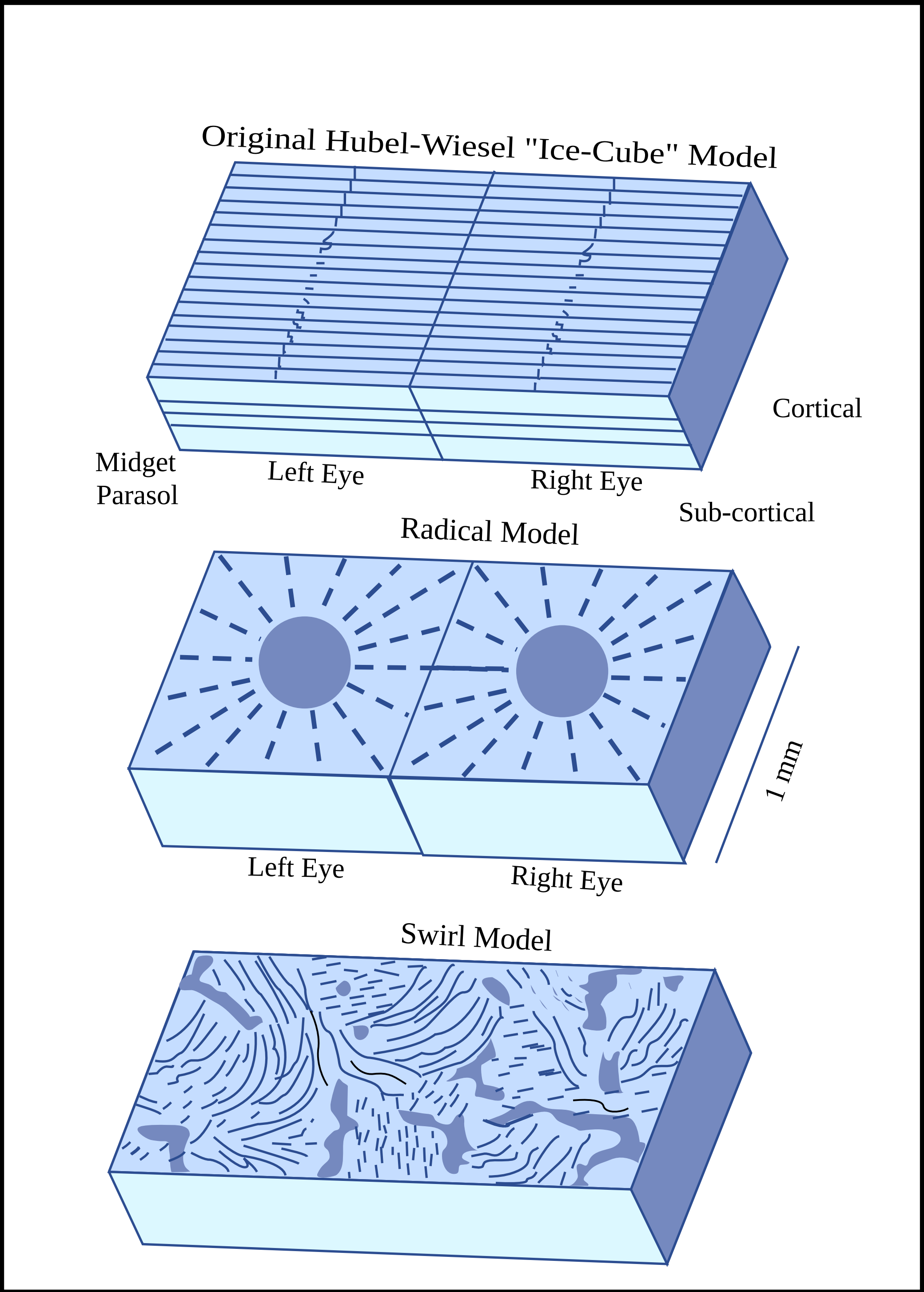
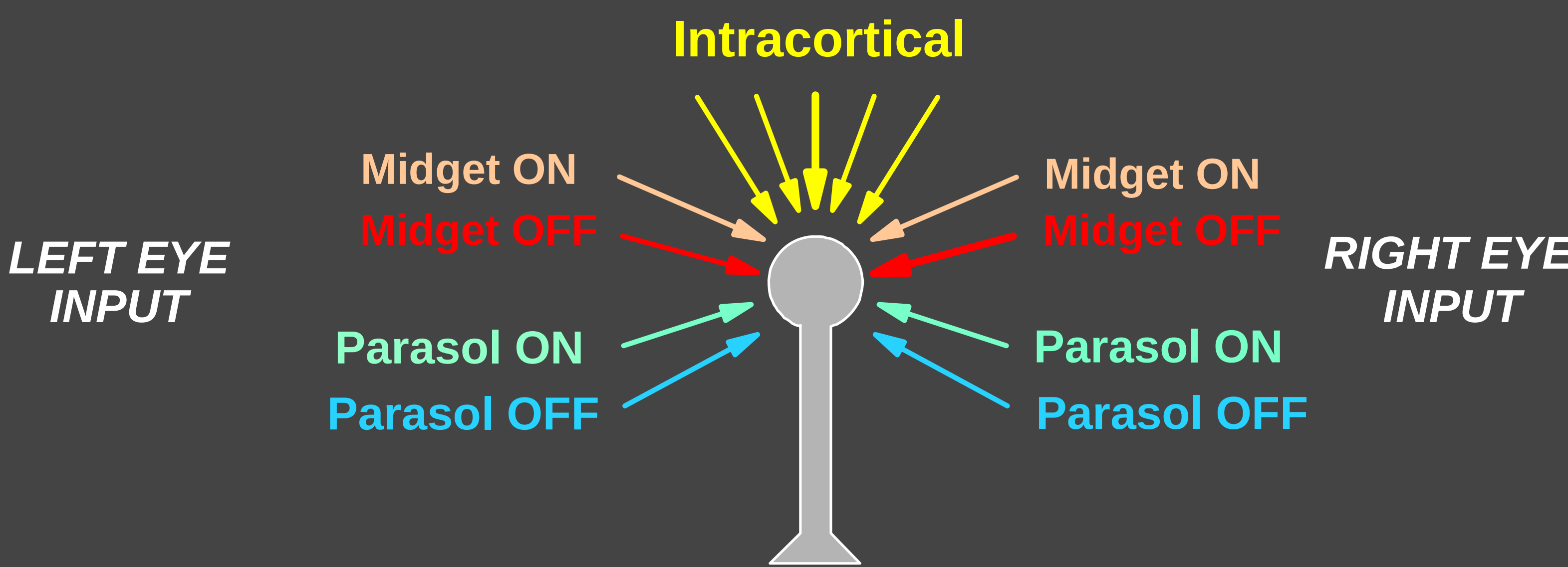


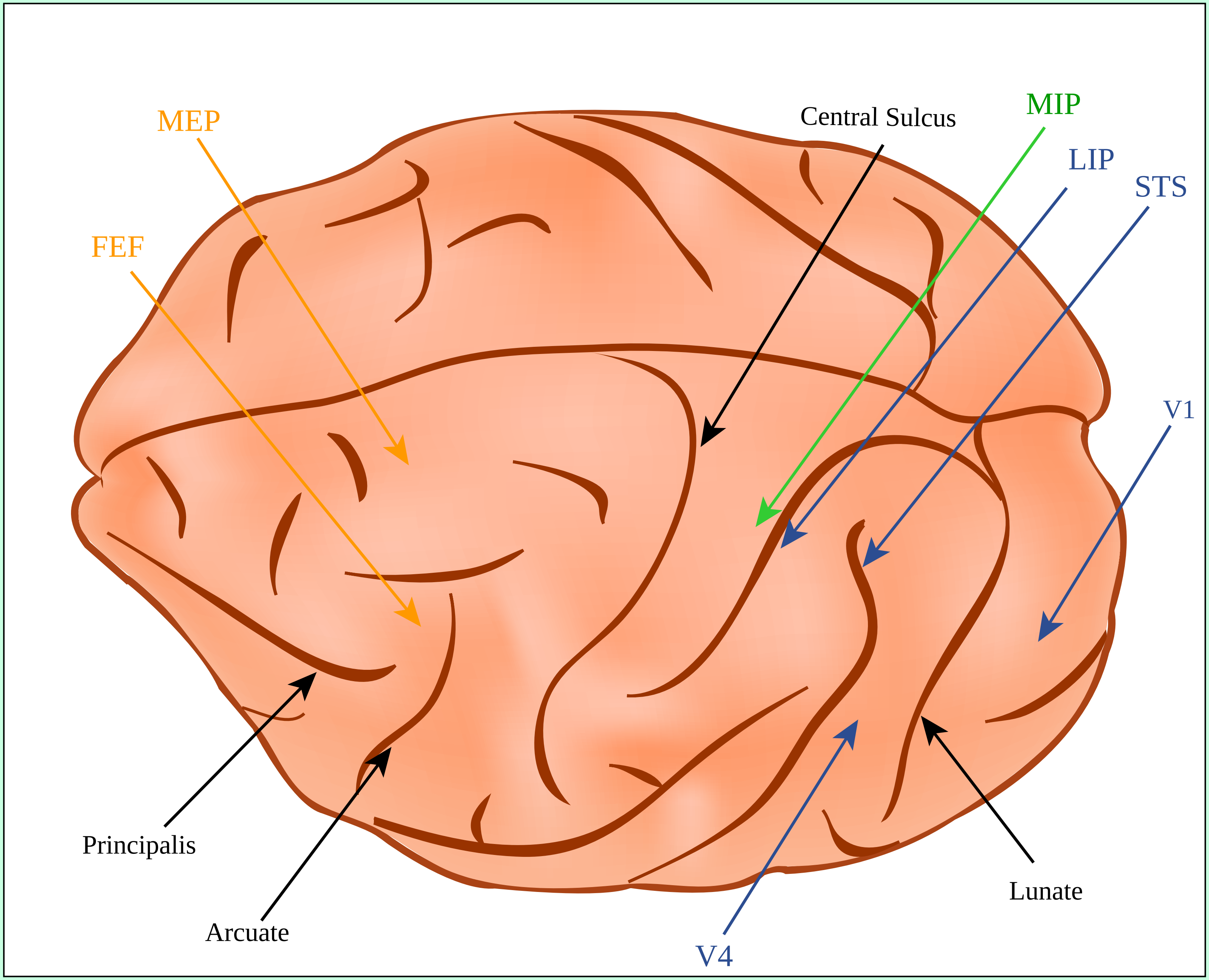

Image by MIT OpenCourseWare.

# Striate Cortex Output Cell




luminance
color
orientation
spatial frequency
depth
motion

# Extrastriate cortex


MEP
FEF
Central Sulcus
MIP
LIP
STS
V1
Principalis
Arcuate
V4
Lunate

# Major cortical visual areas:

| | | |
|---|---|---|
| Occipital | V1 | |
| | V2 | |
| | V3 | |
| | V4 | |
| | MT | (medial temporal) |
| Temporal | IT | (inferotemporal) |
| Parietal | LIP | (lateral intraparietal) |
| | VIP | (ventral intraparietal) |
| | MST | (medial superior temporal) |
| Frontal | FEF | (frontal eye fields) |

# The ON and OFF Channels

## The receptive fields of three major classes of retinal ganglion cells

# Action potentials discharged by an ON and an OFF retinal ganglion cell

Figure removed due to copyright restrictions.

Please see lecture video or Figure 2A of Schiller, Peter H., and Edward J. Tehovnik. "Visual Prosthesis." *Perception* 37, no. 10 (2008): 1529.

The 2-amino-4-phosphonobutyrate (APB) experiments blocking the ON channel:

1. No effect on center-surround antagonism and on orientation and direction selectivities in V1.

2. Deficit in detecting light increment but not light decrement.

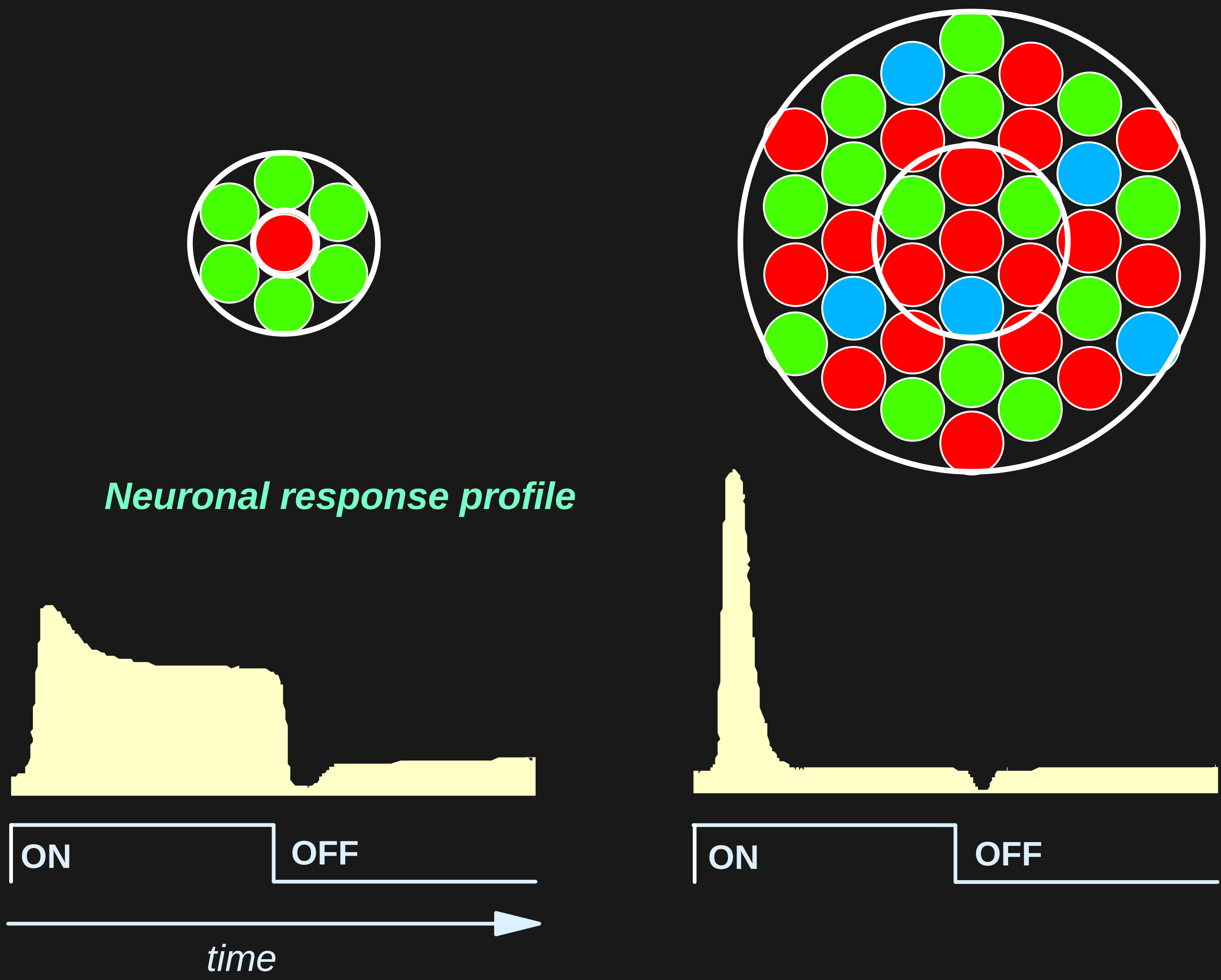
## The central conclusion:

The ON and OFF channels have emerged in the course of evolution to enable organisms to process both light incremental and light decremental information rapidly and effectively.

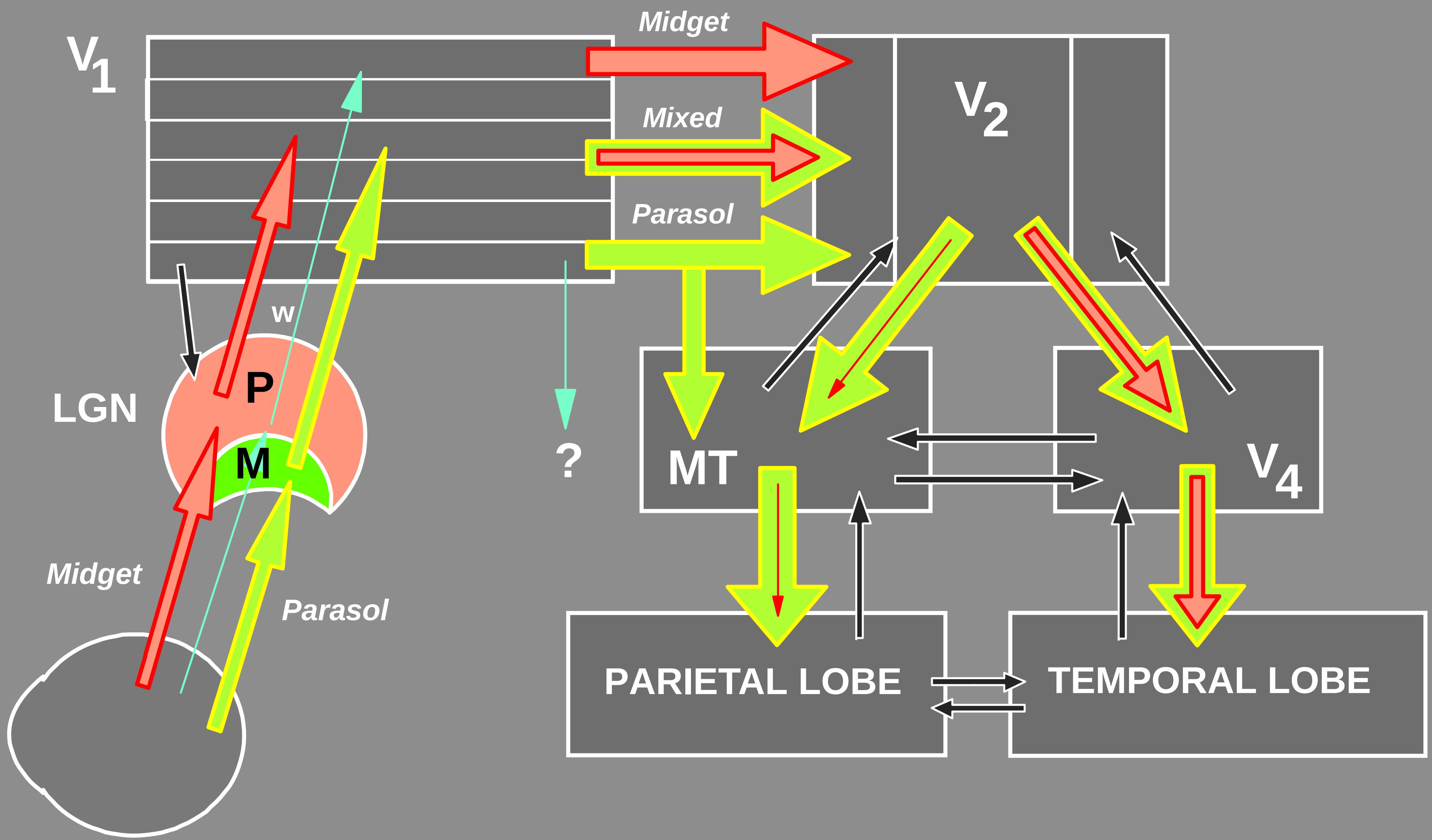
# The midget and parasol channels

## MIDGET SYSTEM

## PARASOL SYSTEM



# Projections of the midget and parasol systems



# *Summary of PLGN and MLGN lesion deficit magnitudes*

| | VISUAL CAPACITY | | PLGN | MLGN |
|---|---|---|---|---|
| BASIC VISUAL FUNCTIONS | color vision | | severe | *none* |
| | texture perception | | severe | *none* |
| | pattern perception | fine | severe | *none* |
| | shape perception | fine | severe | *none* |
| | | coarse | mild | *none* |
| | brightness perception | | *none* | *none* |
| | coarse scotopic vision | | *none* | *none* |
| | contrast sensitivity | fine | severe | *none* |
| | | coarse | mild | *none* |
| | stereopsis | fine | severe | *none* |
| | | coarse | pronounced | *none* |
| | motion perception | | *none* | moderate |
| | flicker perception | | *none* | severe |
| INTERMEDIATE | choice of "lesser" stimuli | | severe | *none* |
| | visual learning | | *not tested* | *not tested* |
| | object transformation | | *not tested* | *not tested* |

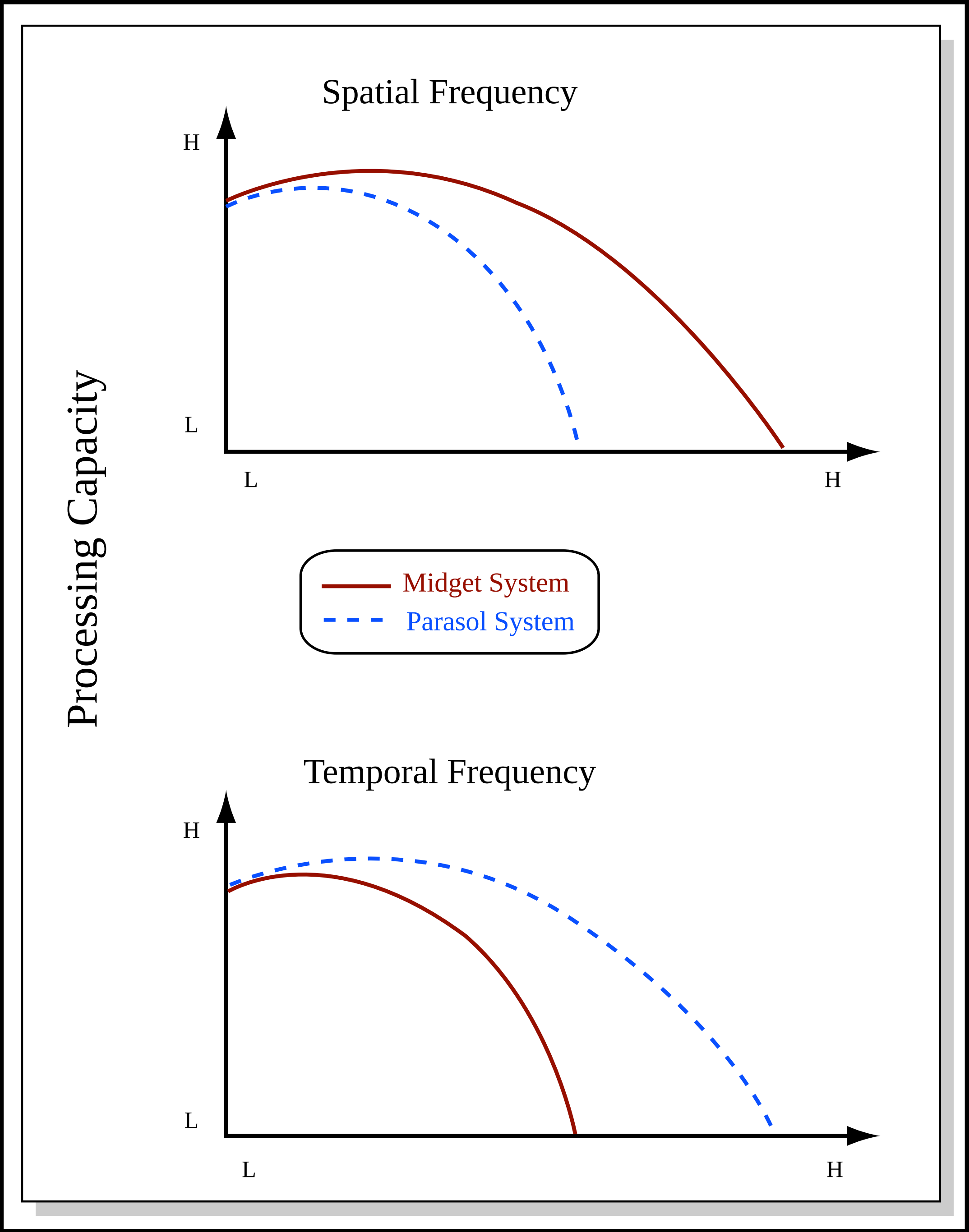



Image by MIT OpenCourseWare.

The midget system extends the range of visual processing in the spatial frequency and wavelength range.

The parasol system extends the range of visual processing in the temporal frequency range.

# Color vision and adaptation

# The color circle

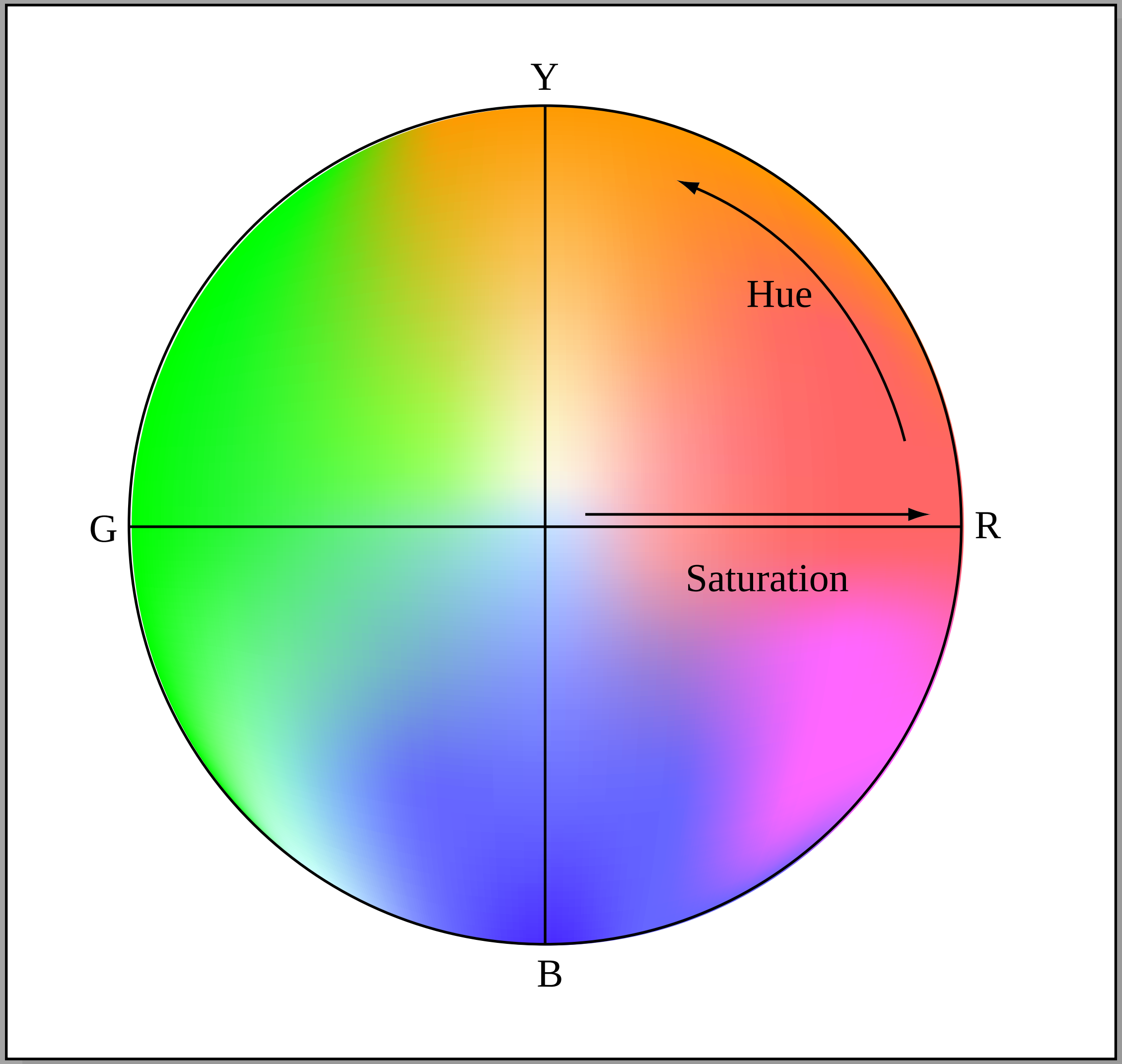



Image by MIT OpenCourseWare.

# Basic facts and rules of color vision

1. There are three qualities of color: hue, brightness, saturation

2. There is a clear distinction between the physical and psychological attributes of color: wavelength vs. color, luminance vs. brightness.

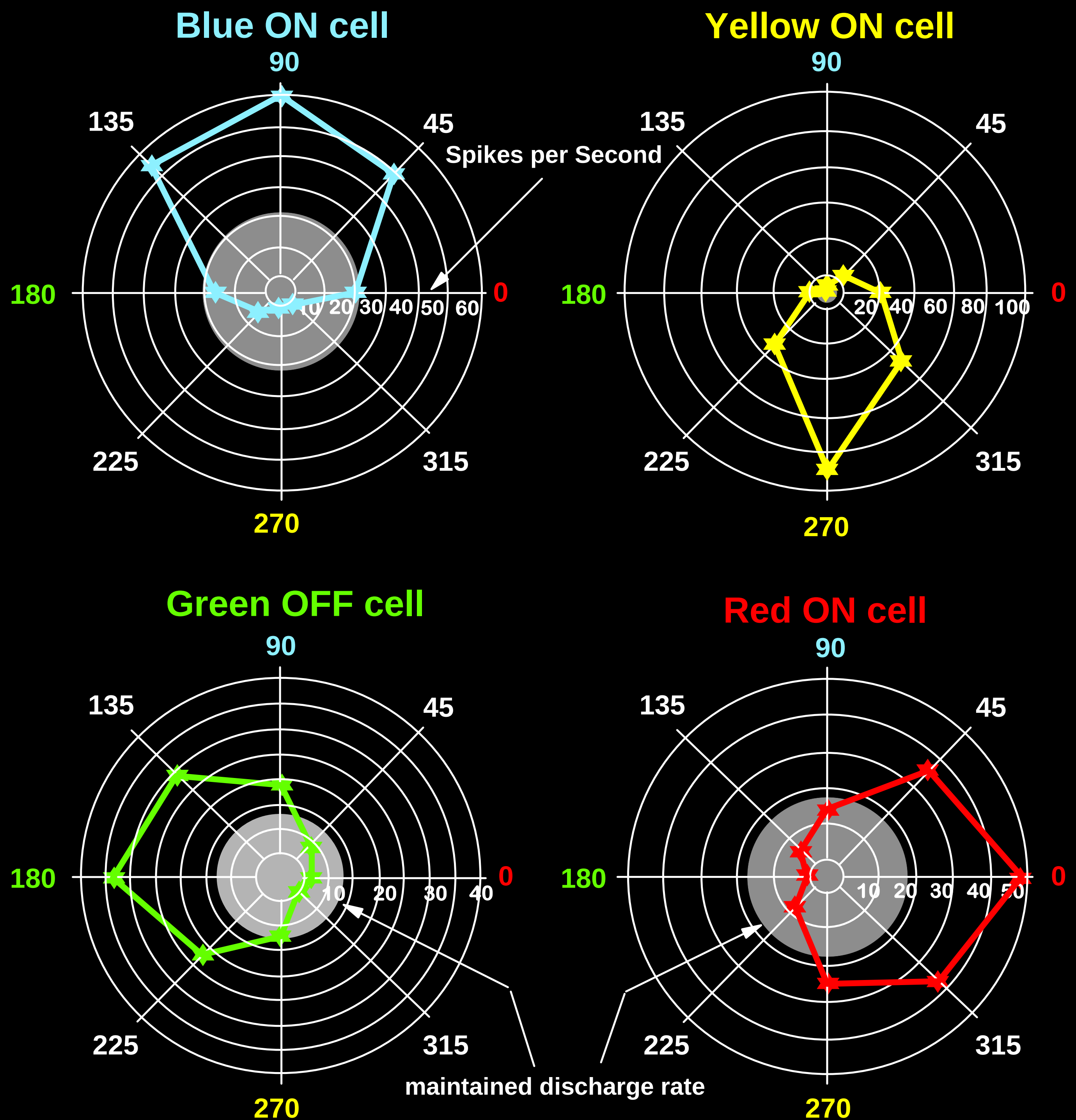
3. Peak sensitivity of human photoreceptors (in nanometers):
   S = 420, M = 530, L = 560, Rods = 500

4. Grassman's laws:
   1. Every color has a complimentary which when mixed propery yields gray.
   2. Mixture of non-complimentary colors yields intermediates.

5. Abney's law:
   The luminance of a mixture of differently colored lights is equal to the sum of the luminances of the components.

6. Metamers: stimuli producing different distributions of light energy that yield the same color sensations.

# Response to Different Wavelength Compositions in LGN



# Response of a retinal ganglion cell at various background adaptation levels

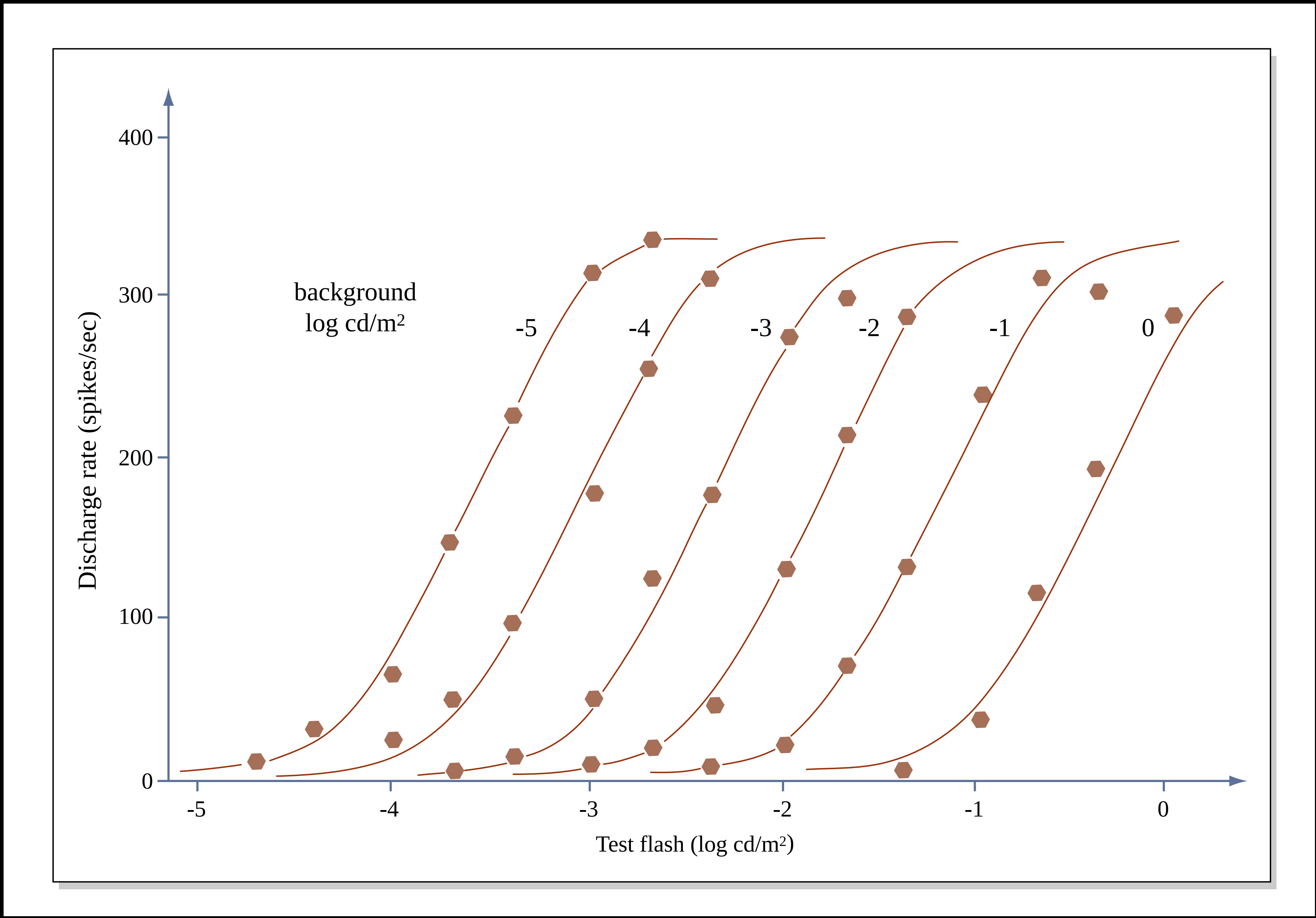



Image by MIT OpenCourseWare.

# Basic facts about light adaptation

1. Range of illumination is 10 log units. But reflected light yields only a 20 fold change (expressed as percent contrast).

2. The amount of light the pupil admits into the eye varies over a range of 16 to 1. Therefore the pupil makes only a limited contribution to adaptation.

3. Most of light adaptation takes place in the photoreceptors.

4. Any increase in the rate at which quanta are delivered to the eye results in a proportional decrease in the number of pigment molecules available to absorb those quanta.

5. Retinal ganglion cells are sensitive to local contrast differences, not absolute levels of illumination.

# Depth perception

# Cues used for coding depth in the brain

| Oculomotor cues | Visual cues |
| --- | --- |
| accommodation<br>vergence | *Binocular*<br>stereopsis |
| | *Monocular*<br>motion parallax<br>shading<br>interposition<br>size<br>perspective |

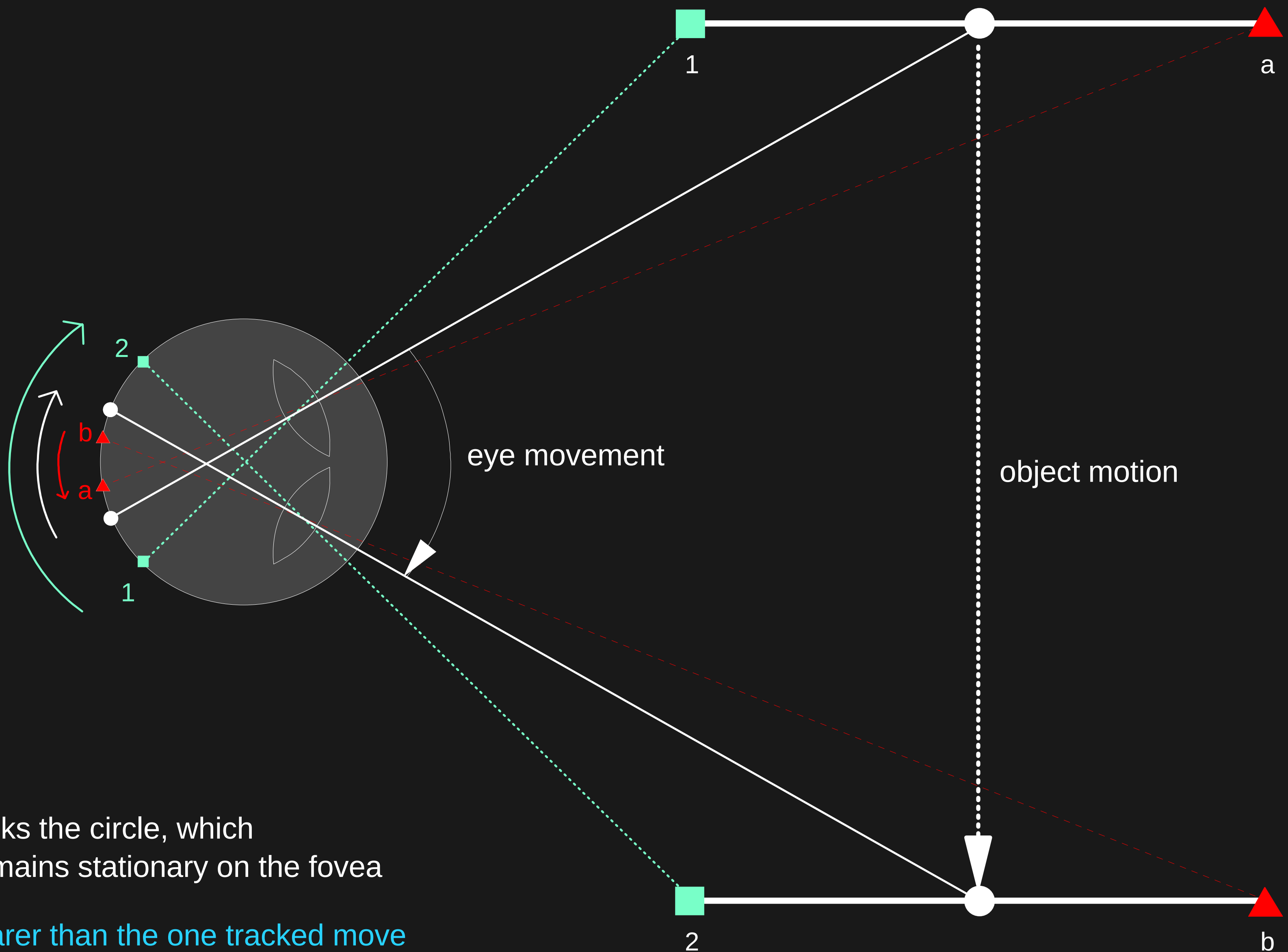
# Autostereogram

Image removed due to copyright restrictions.

Please see lecture video or the autostereogram from The Magic Eye, Volume I: A New Way of Looking at the World. Andrews McMeel Publishing, 1993.

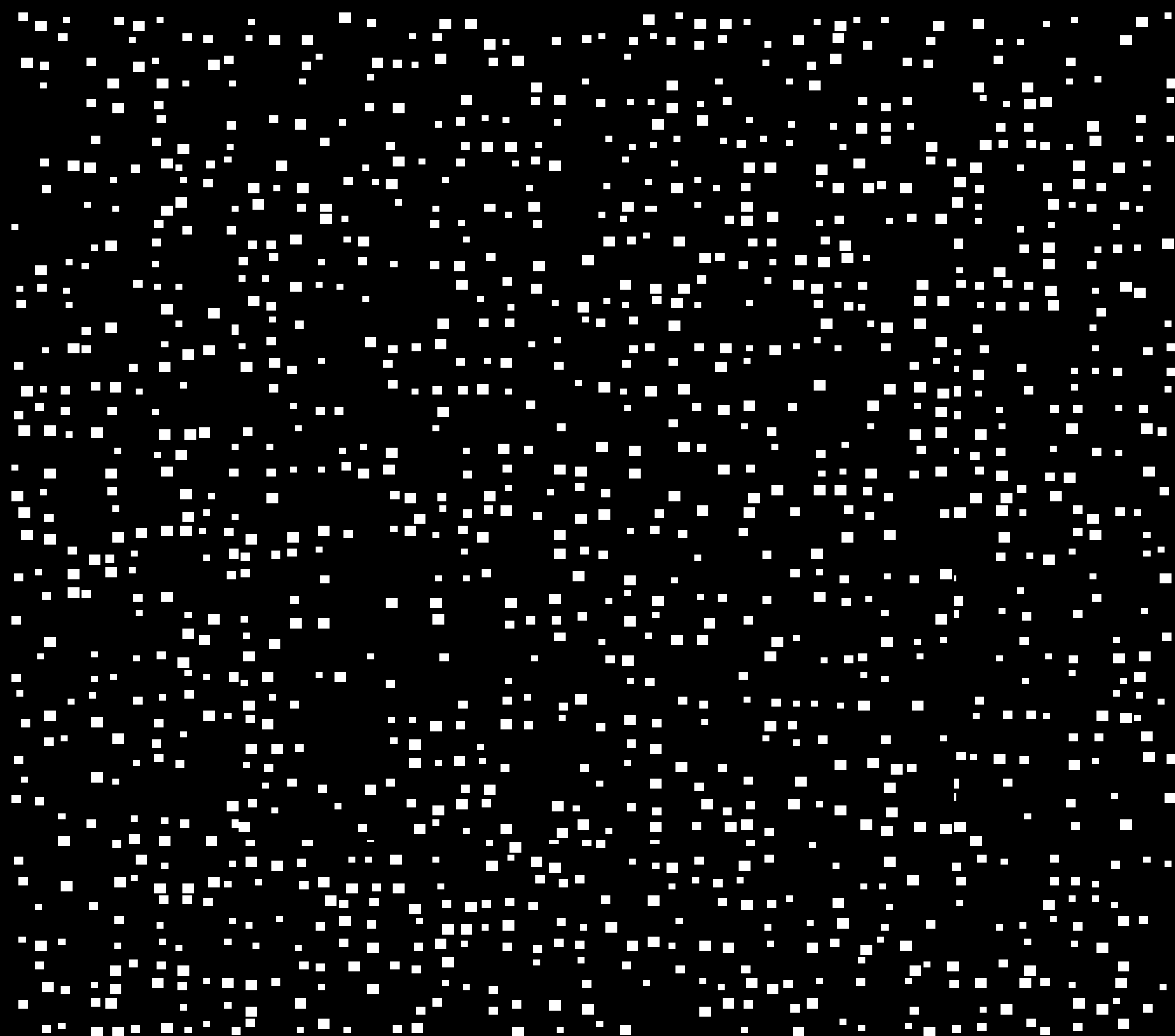
Masayuki Ito, 1970, Chris Tyler, 1990

# MOTION PARALLAX, the eye tracks



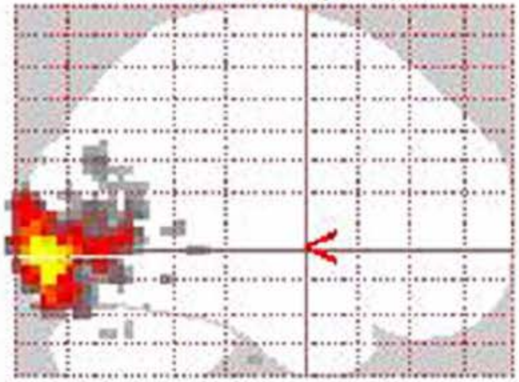

The eye tracks the circle, which
therefore remains stationary on the fovea

Objects nearer than the one tracked move at greater velocities on the retinal surface than objects further; the further objects actually move in the opposite direction on the retina.

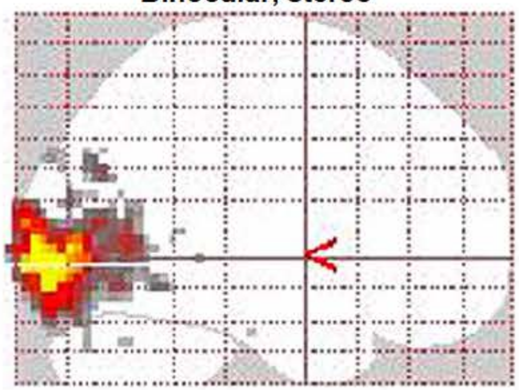


# Normal subject

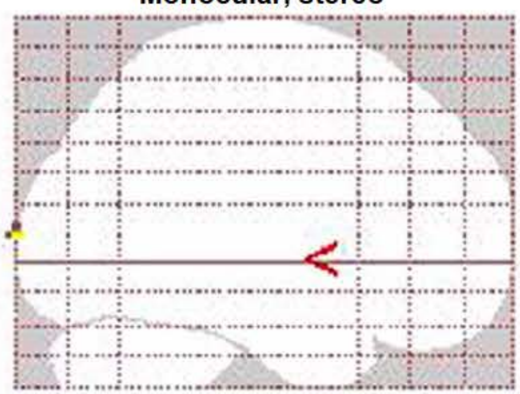
**Binocular, motion parallax**



**Binocular, stereo**

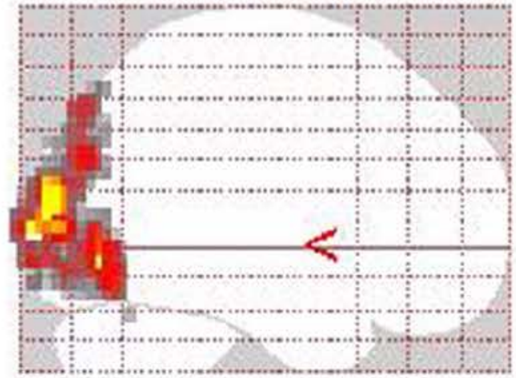


**Monocular, stereo**

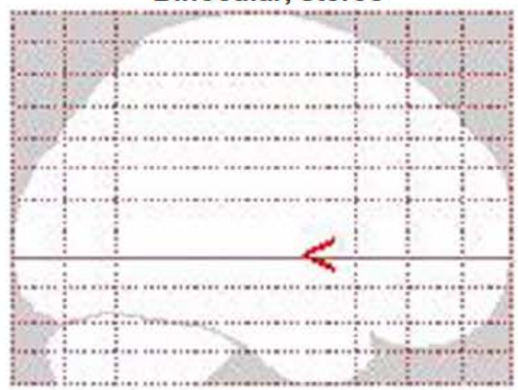


# Stereoblind subject

**Binocular, motion parallax**



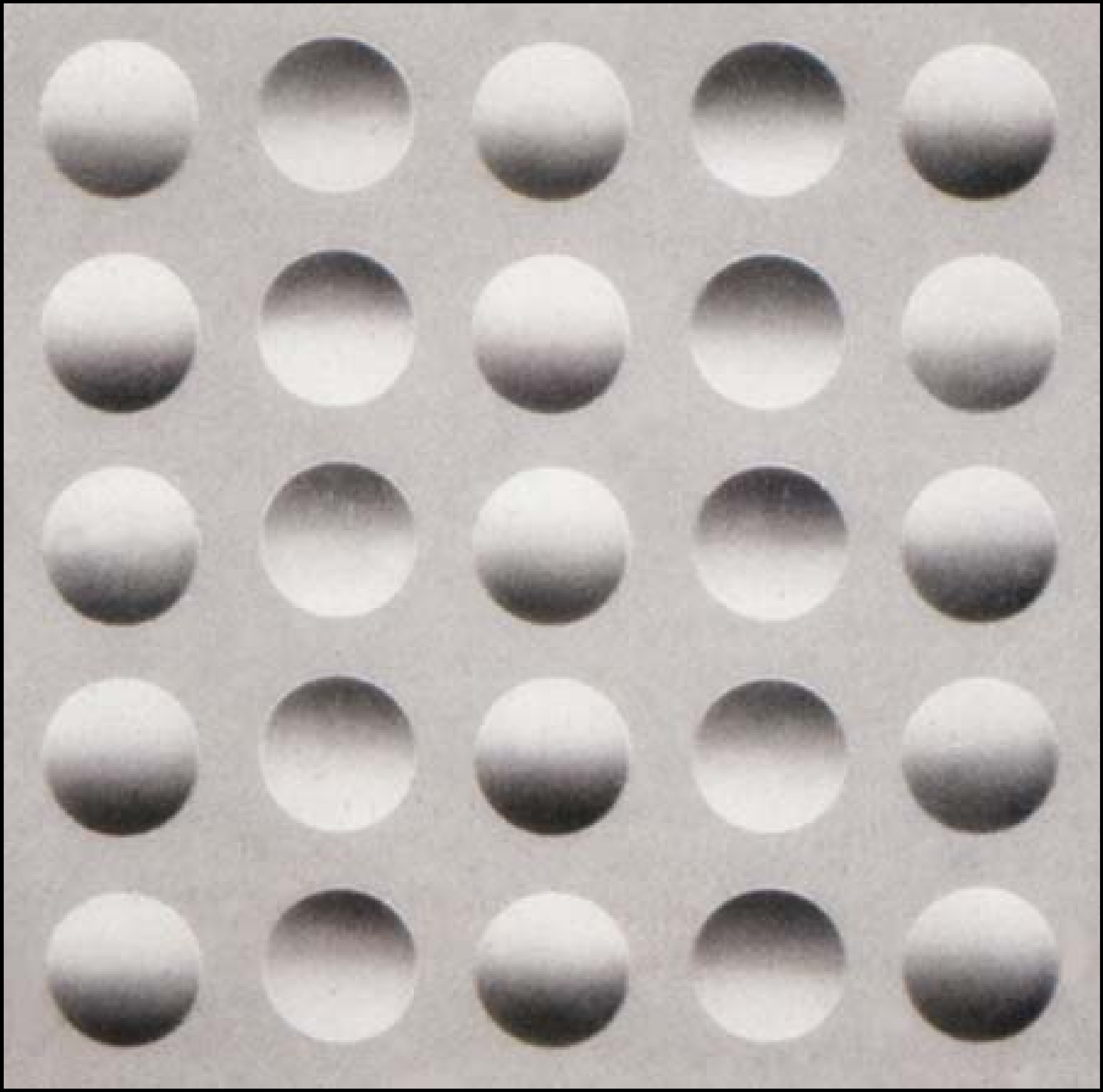
**Binocular, stereo**



**Four conditions:**

1. No depth cues
2. Stereo only
3. Parallax only
4. Stereo and parallax

50 and 60 trials each



# Form perception

# Three general theories of form perception:

1. Form perception is accomplished by neurons that respond selectively to line segments of different orientations.

2. Form perception is accomplished by spatial mapping of the visual scene onto visual cortex.

3. Form perception is accomplished by virtue of Fourier analysis.

# Form perception with little information about orientation of line segments

Image removed due to copyright restrictions.

Please refer to lecture video.

# Cortical layout of neurons activated by disks

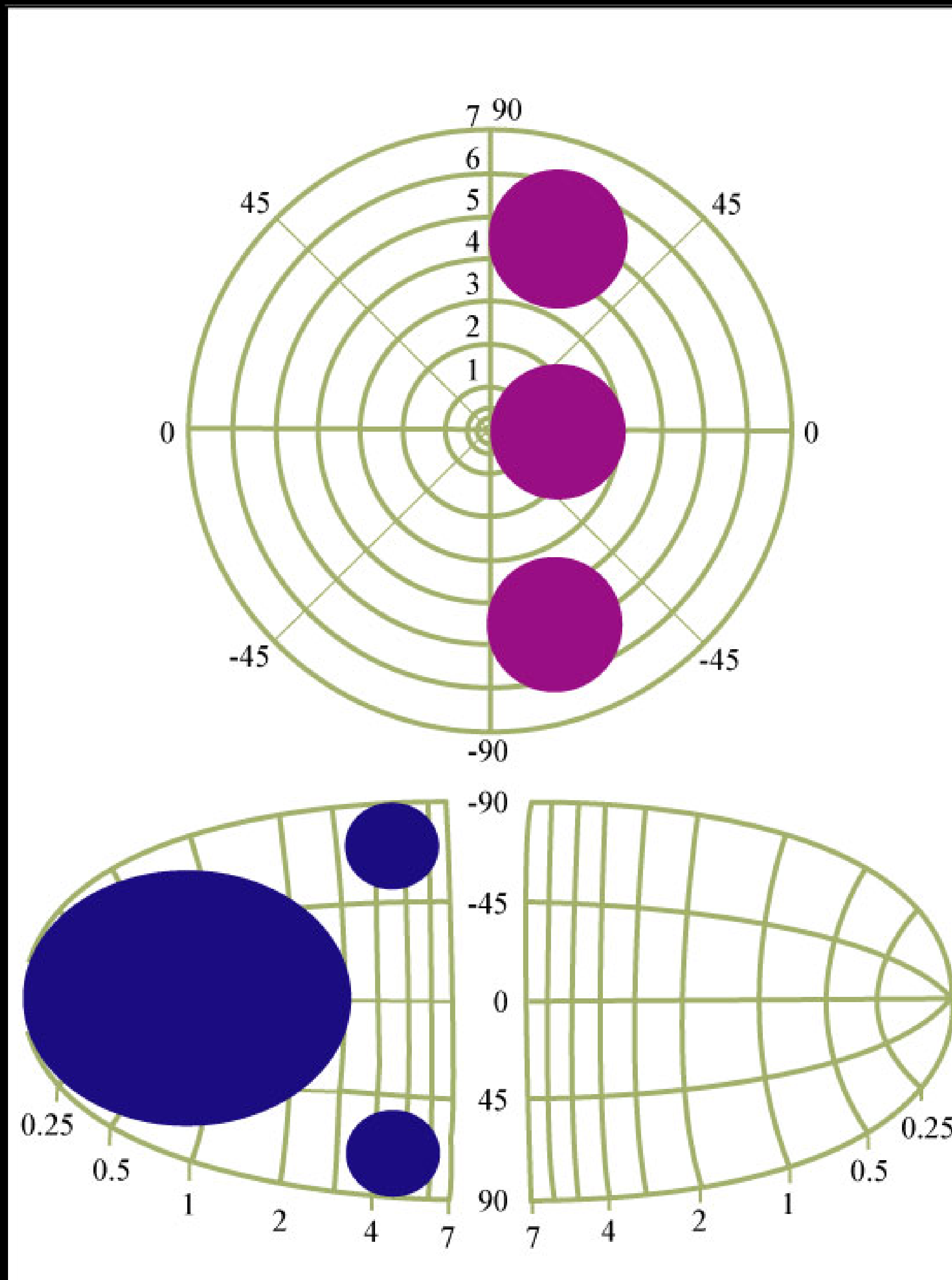



Image by MIT OpenCourseWare.

disks in one hemifield

# Cortical layout of neurons activated by disks

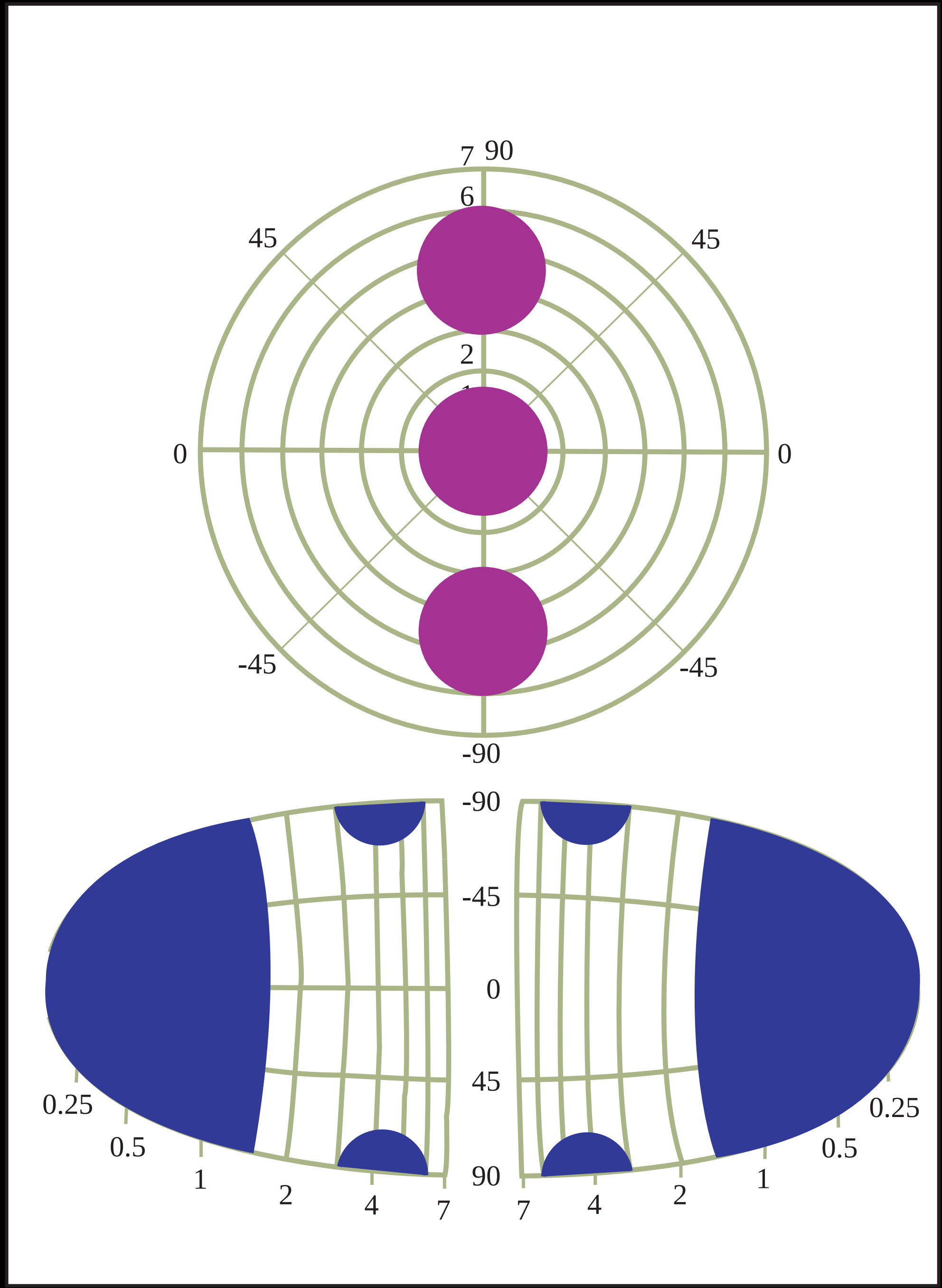



Image by MIT OpenCourseWare.

disks across midline

# Prosthetics

Image removed due to copyright restrictions.

Please see lecture video or Figure 5 from Schiller, Peter H., and Edward J. Tehovnik. "Visual prosthesis." *Perception* 37, no. 10 (2008): 1529.

Image removed due to copyright restrictions.

Please see lecture video or Figure 7 from Schiller, Peter H., and Edward J. Tehovnik. "Visual prosthesis." *Perception* 37, no. 10 (2008): 1529.

Image removed due to copyright restrictions.

Please see lecture video or Figure 9 from Schiller, Peter H., and Edward J. Tehovnik. "Visual prosthesis." *Perception* 37, no. 10 (2008): 1529.

# Illusions

# The Hermann grid illusion

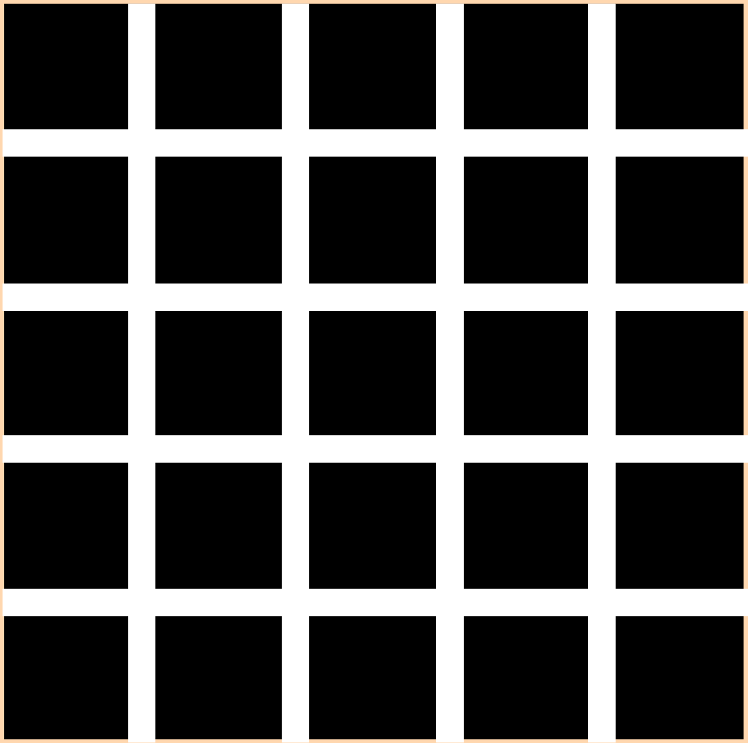
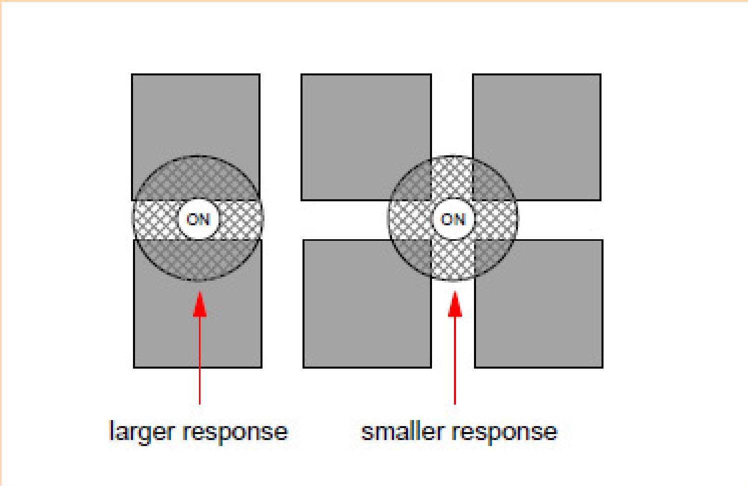


Image is in public domain.

**The most widely cited theory purported to explain the illusion:**




Due to antagonistic center/surround organization, the activity of ON-center retinal ganglion cells whose receptive fields fall into the intersections of the grid produces a smaller response than those neurons whose receptive fields fall elsewhere.

# Differently oriented vertical and horizontal lines reduce illusion

Figure removed due to copyright restrictions.

Please see lecture video or Schiller PH, Carvey CE (2005). "The Hermann Grid Illusion Revisited." *Perception* 34 (11): 1375–97.

# Retinal ganglion cell receptive field layout at an eccentricity of 5 degrees

Figure removed due to copyright restrictions.

Please see lecture video or Schiller PH, Carvey CE (2005). "The Hermann Grid Illusion Revisited." *Perception* 34 (11): 1375–97.

# After-effect illusions explained by the facts and rules of adaptation.

interocular experiments

# Effects of lesions on vision

# Summary of lesion deficit magnitudes

| | VISUAL CAPACITY | | PLGN | MLGN | $V_4$ | MT |
|---|---|---|---|---|---|---|
| BASIC VISUAL FUNCTIONS | color vision | | severe | none | mild | none |
| | texture perception | | severe | none | mild | none |
| | pattern perception | fine | severe | none | mild | none |
| | shape perception | fine | severe | none | mild | none |
| | | coarse | mild | none | none | none |
| | brightness perception | | none | none | none | none |
| | coarse scotopic vision | | none | none | none | none |
| | contrast sensitivity | fine | severe | none | mild | mild |
| | | coarse | mild | none | none | mild |
| | stereopsis | fine | severe | none | none | none |
| | | coarse | pronounced | none | none | none |
| | motion perception | | none | moderate | none | moderate |
| | flicker perception | | none | severe | none | pronounced |
| INTERMEDIATE | choice of "lesser" stimuli | | severe | none | severe | none |
| | visual learning | | not tested | not tested | severe | none |
| | object transformation | | not tested | not tested | pronounced | not tested |

# Eye-movement control

# Electrical stimulation triggering eye movements:

Figure removed due to copyright restrictions.

Please see lecture video or Figure 2 from Schiller, Peter H., and Edward J. Tehovnik. "Look and See: How the Brain Moves Your Eyes About." *Progress in Brain Research* 134 (2001): 127-42.

# Electrical stimulation triggering eye movements:

Figure removed due to copyright restrictions.

Please see lecture video or Figure 3 from Schiller, Peter H., and Edward J. Tehovnik. "Look and See: How the Brain Moves Your Eyes About." *Progress in Brain Research* 134 (2001): 127-42.

# Summary of the effects of the GABA agonist muscimol and the GABA antagonist bicuculline

## Target selection

| | muscimol | bicuculline |
|---|---|---|
| V1 | INTERFERENCE | INTERFERENCE |
| FEF | INTERFERENCE | FACILITATION |
| LIP | NO EFFECT | NO EFFECT |
| SC | INTERFERENCE | FACILITATION |

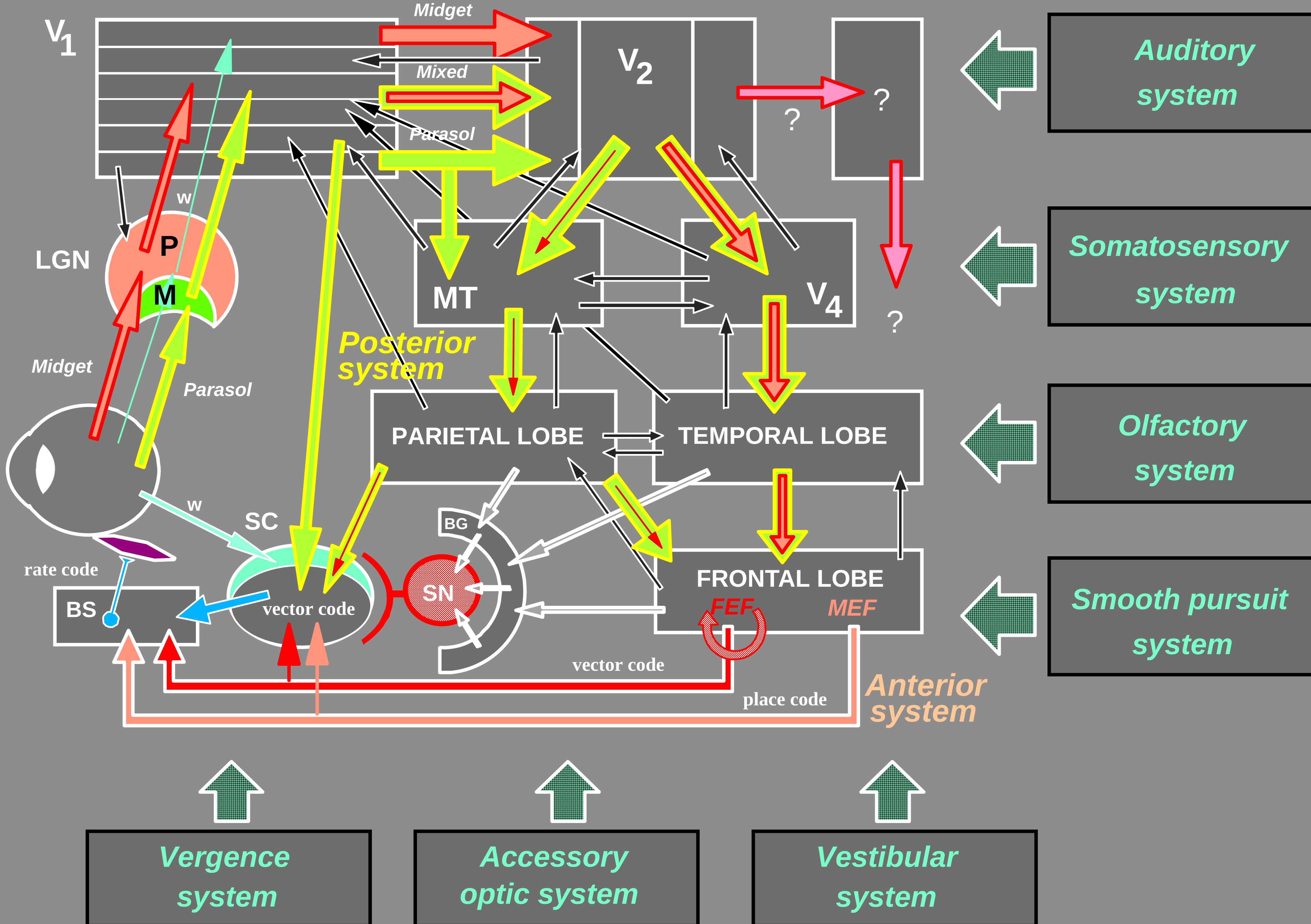
## Visual discrimination

| | muscimol | bicuculline |
|---|---|---|
| V1 | DEFICIT | DEFICIT |
| FEF | MILD DEFICIT | NO EFFECT |
| LIP | NO EFFECT | NO EFFECT |

***Hikosaka and Wurtz***

Figure removed due to copyright restrictions.

Please see lecture video or Figure 17 from Schiller, Peter H., and Edward J. Tehovnik. "Look and See: How the Brain Moves Your Eyes About." *Progress in Brain Research* 134 (2001): 127-42.


V1
Midget
Mixed
Parasol
V2
?
?
?
LGN
P
M
W
Midget
Parasol
MT
V4
Posterior system
PARIETAL LOBE
TEMPORAL LOBE
SC
W
BG
SN
rate code
BS
vector code
vector code
FRONTAL LOBE
FEF
MEF
place code
Anterior system
Auditory system
Somatosensory system
Olfactory system
Smooth pursuit system
Vergence system
Accessory optic system
Vestibular system

# Motion perception

# Summary of cell types in V1

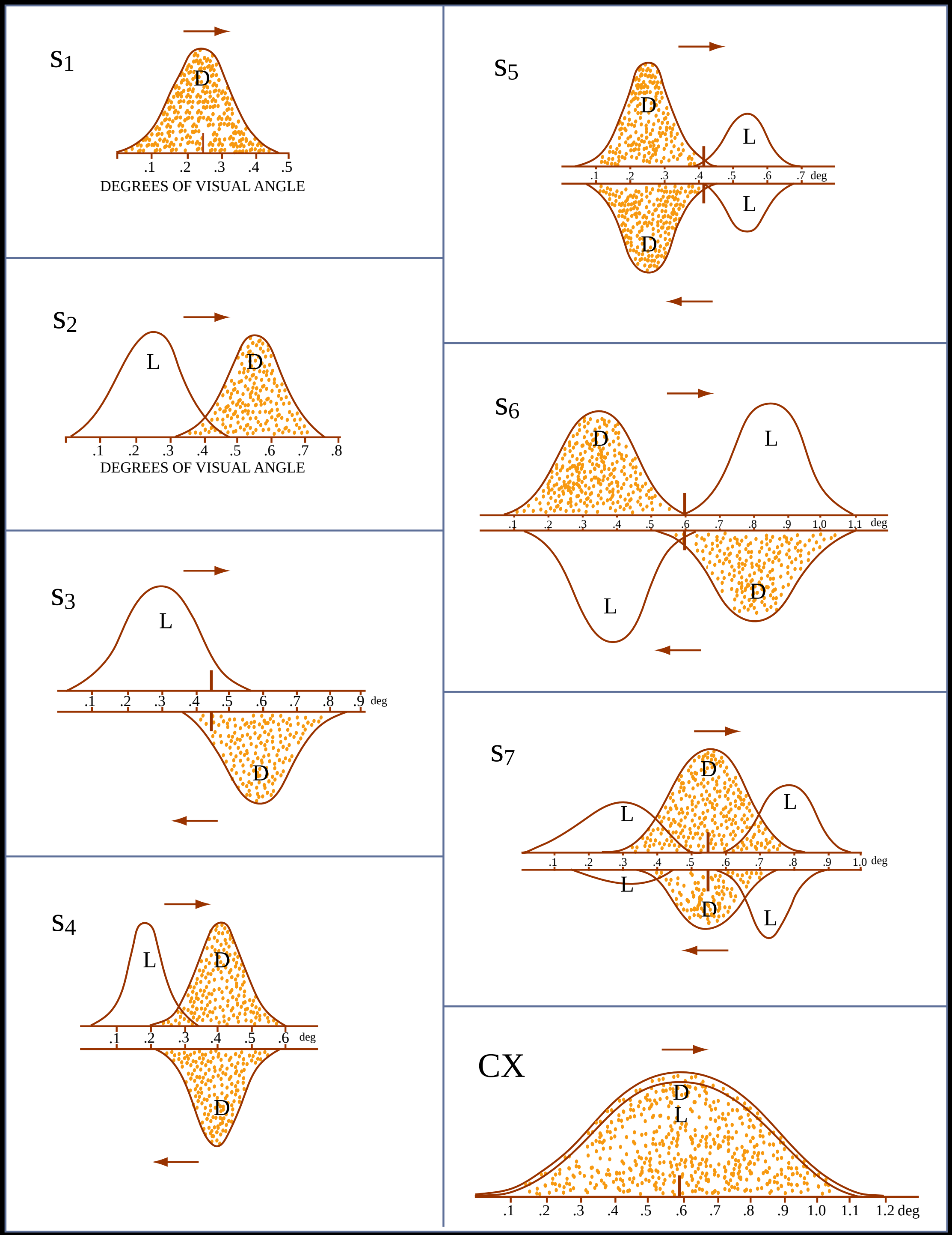



Image by MIT OpenCourseWare.

**The central role of the parasol system in motion processing and in the perception of apparent motion.**

# Major Pathways of the Accessory Optic System (AOS)

Velocity response of AOS neurons = 0.1-1.0 deg/sec

Number of AOS RGCs in rabbit = 7K out of 350K