

# Perception of colour, form, depth and movement; organization of associative visual fields

Seminar

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# Perception of colour, form, depth and movement

- Motion, depth, form, and color - are coordinated into a single visual image
- The **magnocellular (M)** and **parvocellular (P)** pathways feed into two extrastriate cortical pathways: **a dorsal pathway** and **a ventral pathway**.
- **Motion and depth** are mediated in large part by the dorsal pathway to the **posterior parietal cortex**.
- Perception of **contrast and contours**, mediated largely by the ventral pathway extending to the **inferior temporal cortex**.

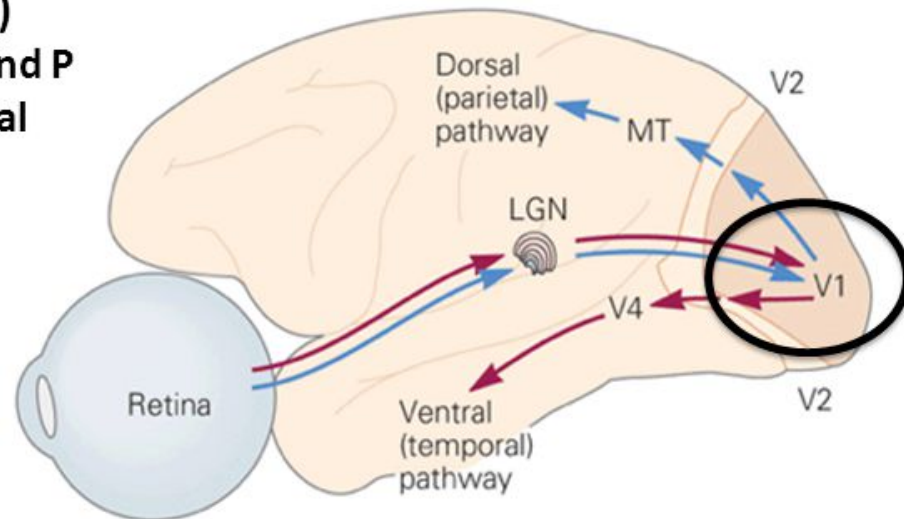
- binding problem in the visual system: how information conveyed in parallel but separate pathways is brought together into a coherent perception?

# **The Parvocellular and Magnocellular Pathways Feed Into Two Processing Pathways in Extrastriate Cortex**

- **P pathway** continues in the ventral cortical pathway that extends to the **inferior temporal cortex (IT)**.
- **M pathway** becomes the dorsal pathway that extends to the **posterior parietal cortex (PC)**.

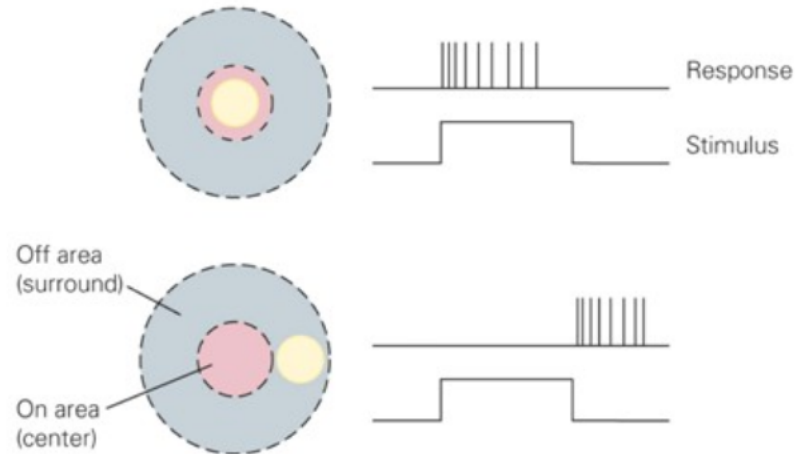
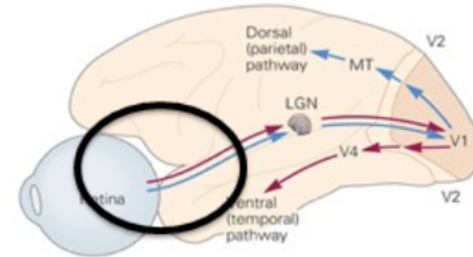
# Outline

- A. Subcortical pathways (retina, LGN)
  - Magno- & Parvo- streams
- B. **Primary visual cortex (V1)**
  - **Partial integration of M and P**
  - **Gateway to Ventral/Dorsal**
- C. Ventral pathway (V4, IT)
  - Object processing
- D. Dorsal pathway (MT, IP)
  - Motion processing
- E. Summary



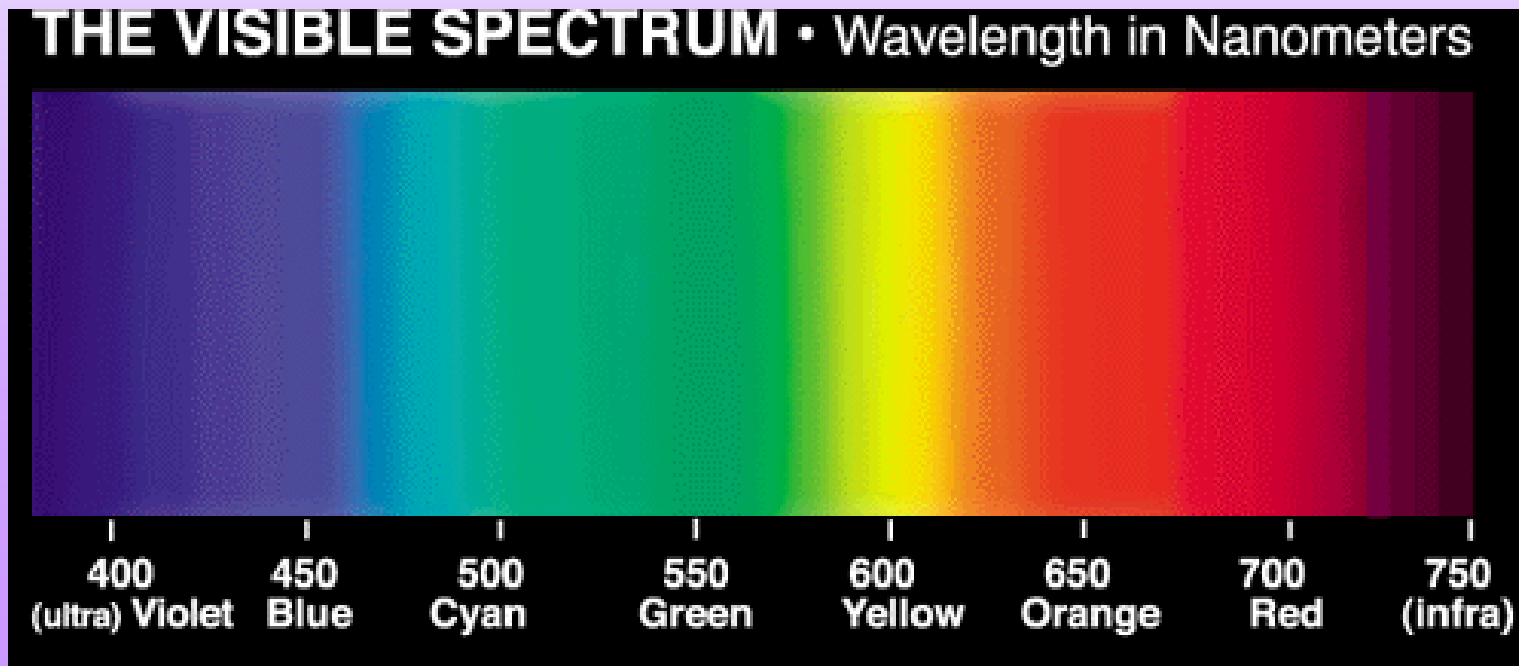
## Retinal ganglion cells (RGCs): Quick Summary

- **RGC's**
  - **Output of the retina**  
**("optic nerve")**
  - **Center-surround**  
**receptive fields**



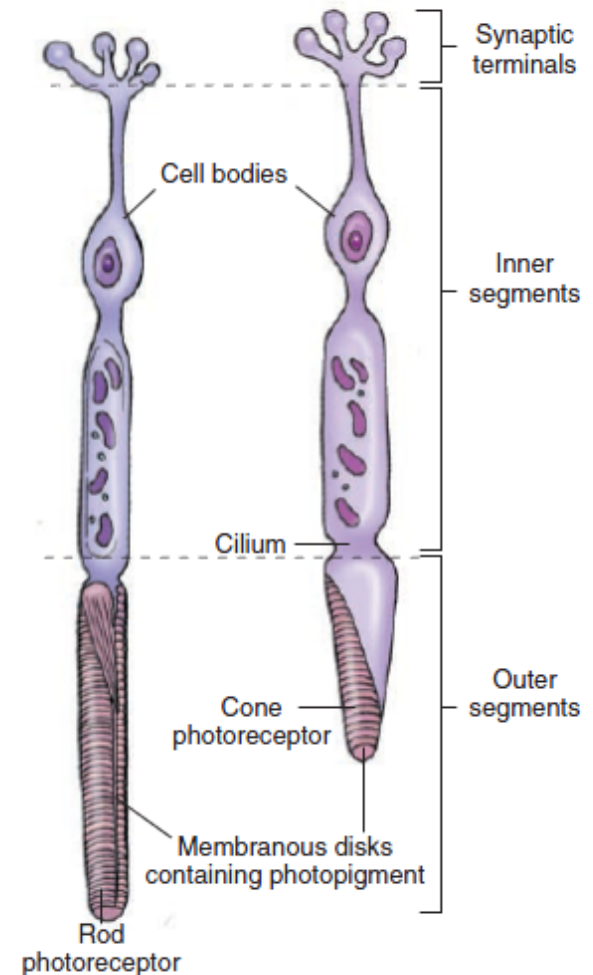
# Color Vision

- Color is subjective experience tied to the spectral composition of the light
- Starts with the fotoreceptors in retina



# The role of photoreceptors

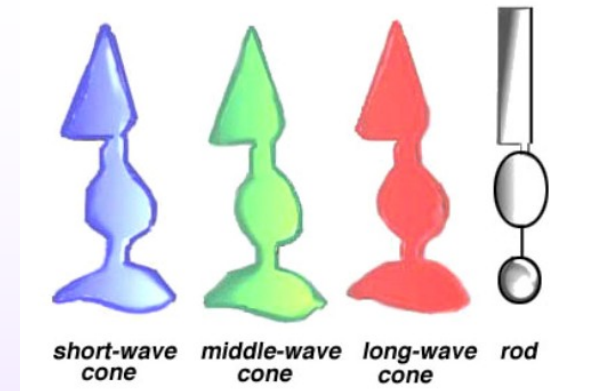
- human retina consists of two types of photoreceptors: **the rods and cones**
- functional regions: an **outer segment**, an **inner segment**, and a **synaptic terminal**





- The *outer segment* is located toward the outer surface of the retina and is involved in **phototransduction**
- contain light-absorbing photopigments
- The outer segments are constantly being renewed
- The *inner segment* contains the **nucleus** and most of the biosynthetic mechanisms.
- The synaptic terminal makes synaptic contact with the other cells.

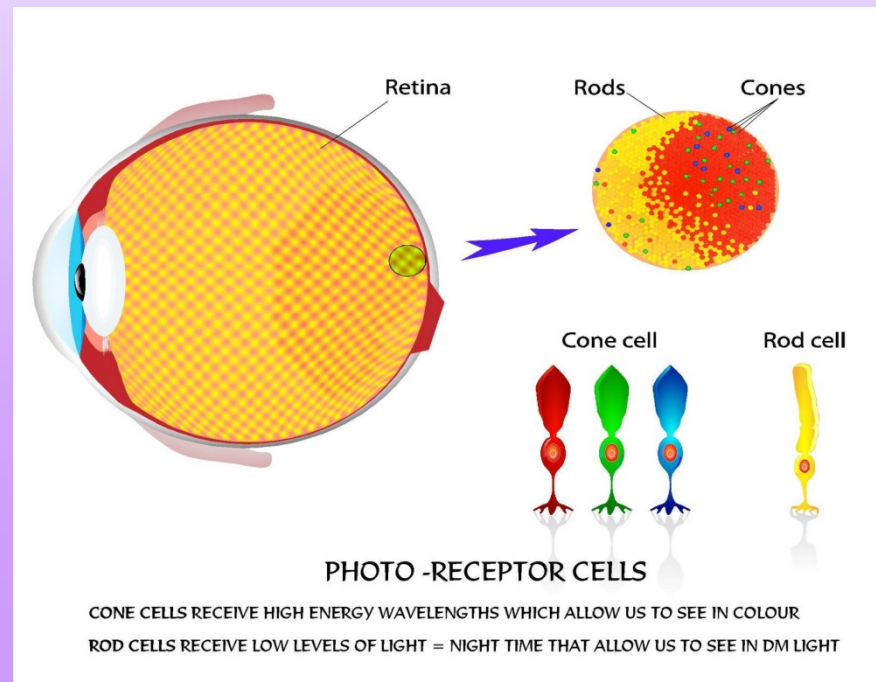
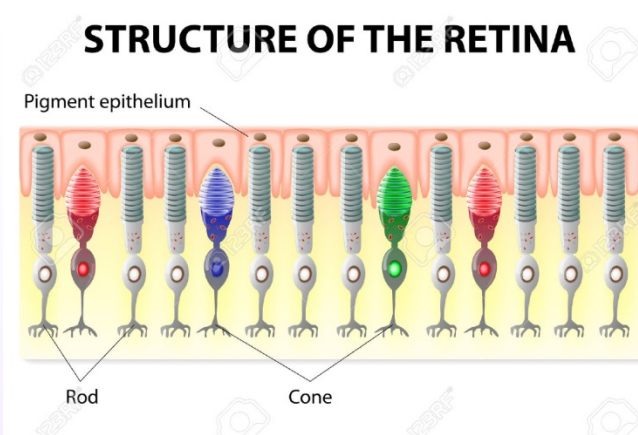
# Cones



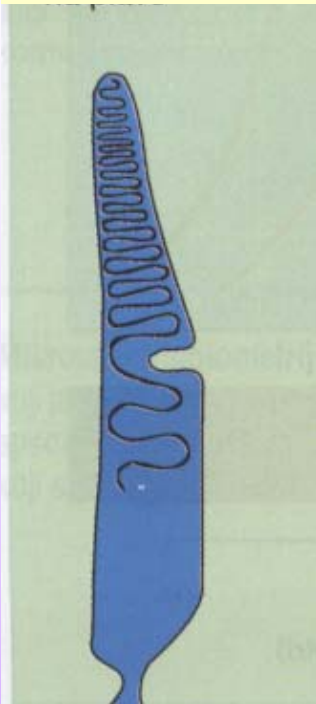
- Responsible for daylight vision
- Mediate color vision
- Have a fast response, and their integration time is short
- Concentrated in the fovea
- Color blindness

# Rods

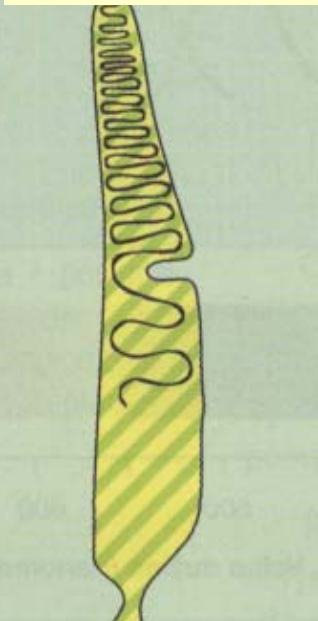
- highly sensitive and can detect dim light
- specialized for night vision
- The loss of rods results in night blindness and loss of peripheral vision.



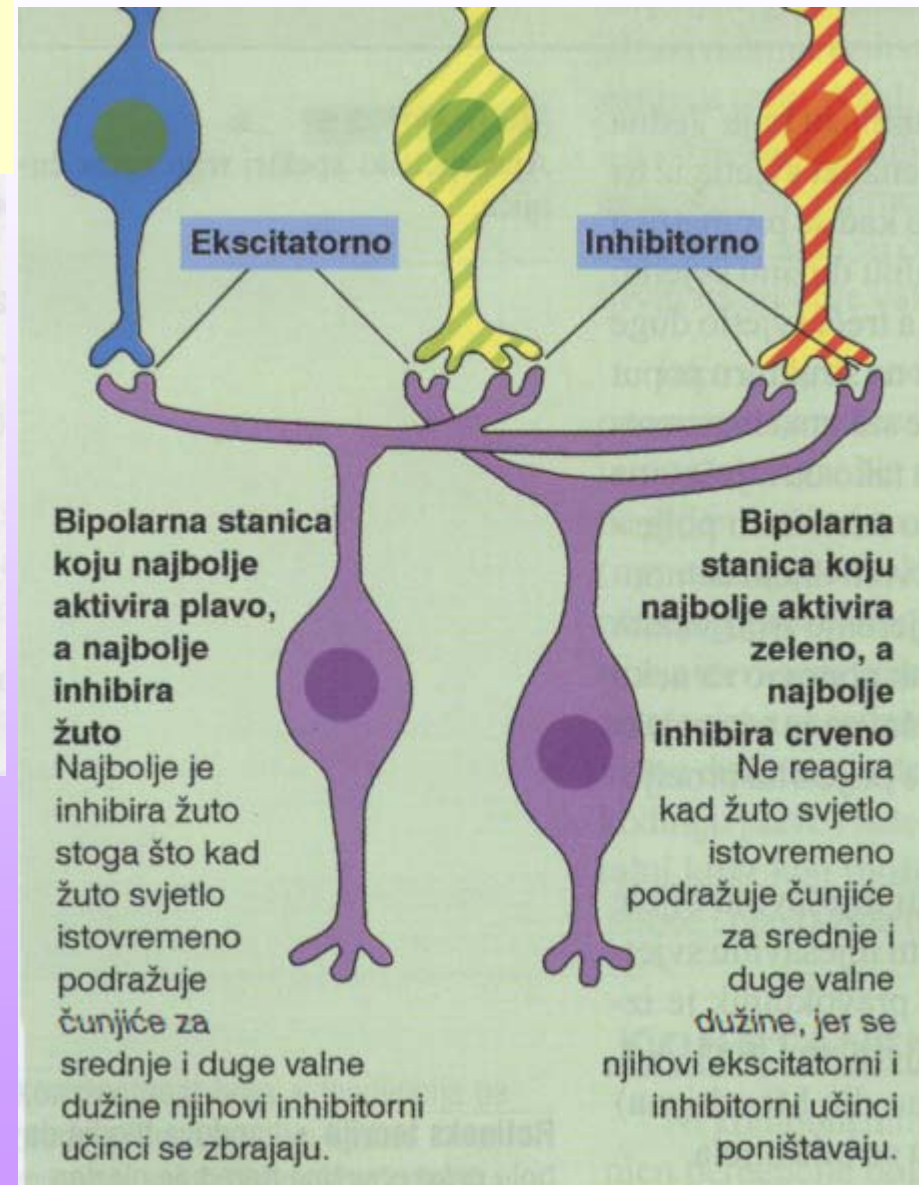
Cones for  
Short length  
waves - blue



Cones for  
Medium  
length waves  
– green and  
yellow

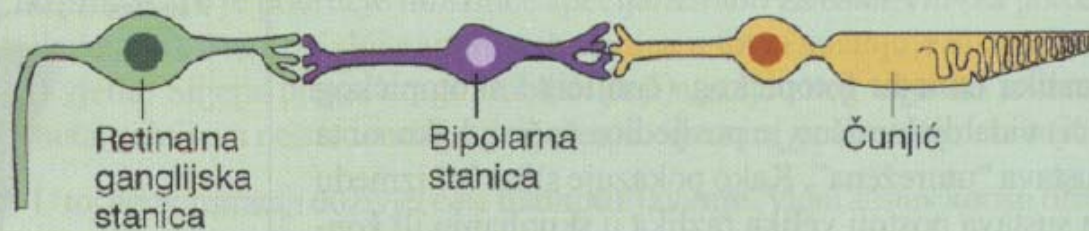


Cones for  
Long  
length  
waves -  
red

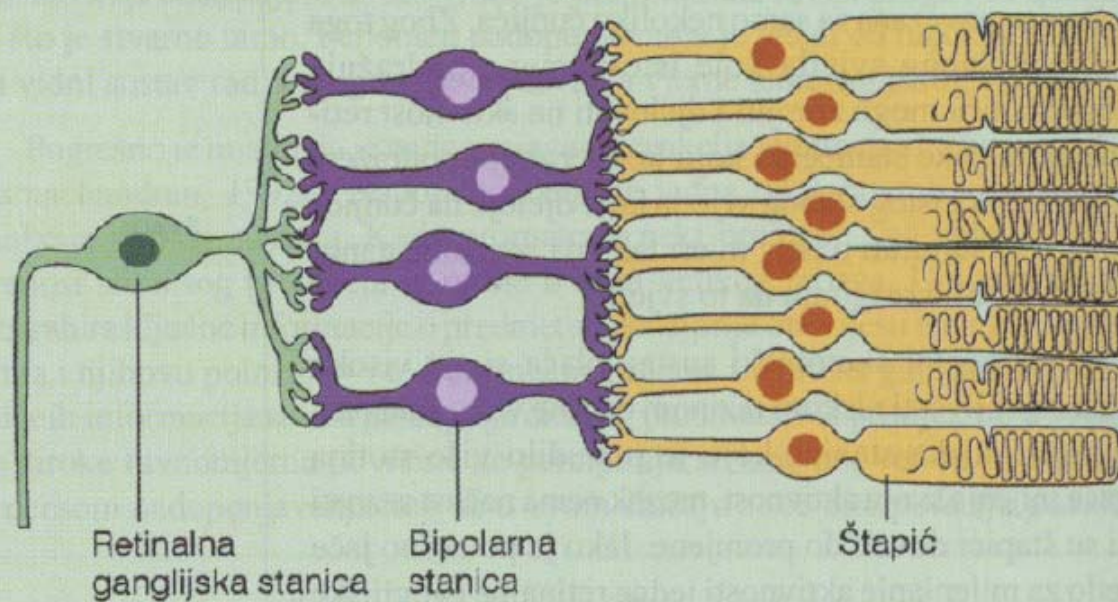




### Mala konvergencija putova iz čunjića



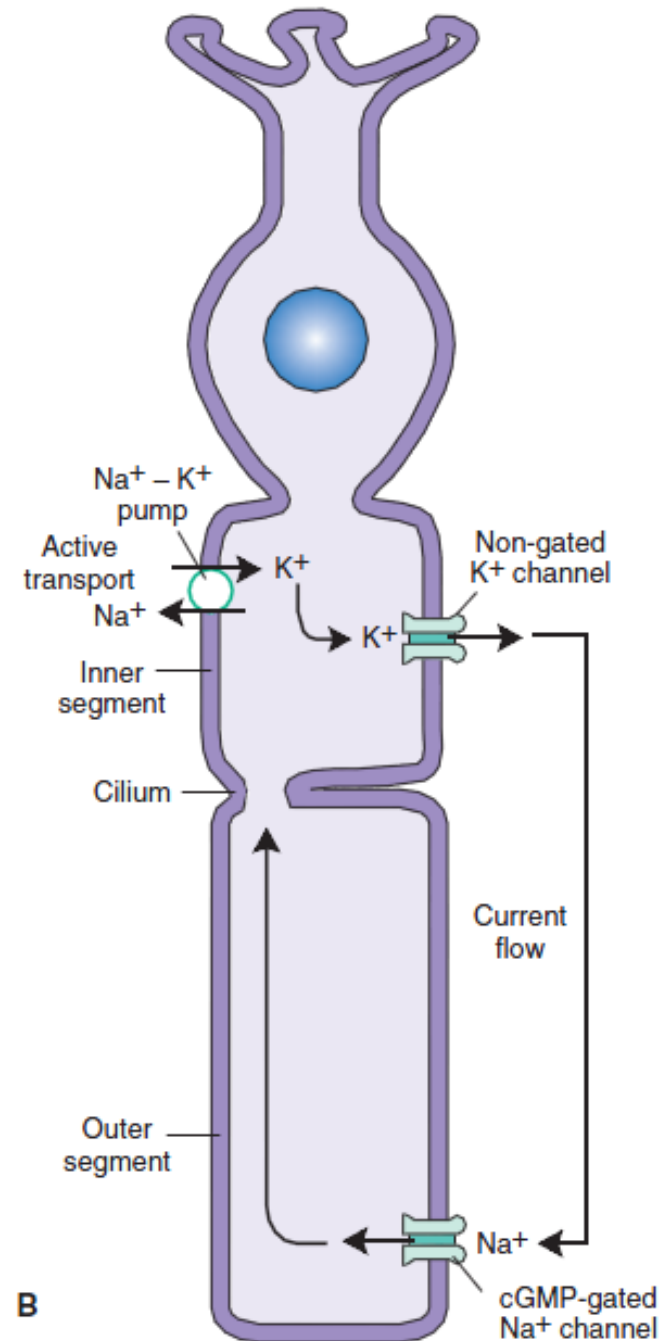
### Velika konvergencija putova iz štapića



# PHOTOTRANSDUCTION

- cyclic guanosine monophosphate (cGMP)–gated  $\text{Na}^+$  (sodium) channels
- cGMP binds directly to the cytoplasmic side of the channel, which causes it to open, allowing an influx of  $\text{Na}^+$

- During darkness, the presence of high levels of cGMP in photoreceptors results in opening of  $\text{Na}^+$  channels, and an inward current carried by  $\text{Na}^+$  flows into the outer segment of the photoreceptor.
- **photoreceptors remain depolarized during darkness**
- $\text{K}^+$  (potassium) flows out across the inner segment of the receptor membrane through nongated  $\text{K}^+$  (leakage) channels.



DARK

LIGHT

1

Rhodopsin is not activated

1

Light affects rodopsin

2

cGMP keeps  $\text{Na}^+$  channels open

2

cGMP is degraded and  $\text{Na}^+$  channels are closed

3

Sodium ( $\text{Na}^+$ ) ions enter the cone and depolarization occurs

3

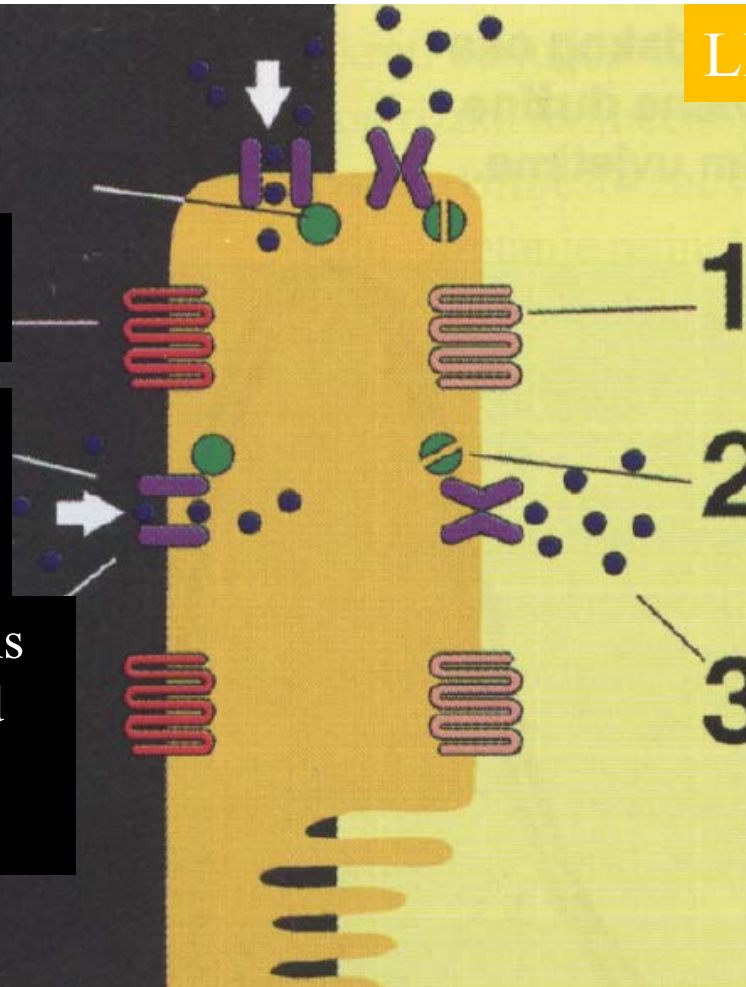
$\text{Na}^+$  does not enter so cones are hyperpolarized

4

Cones release glutamate

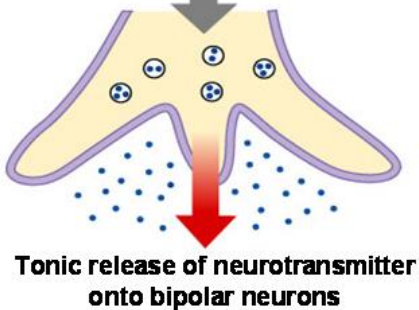
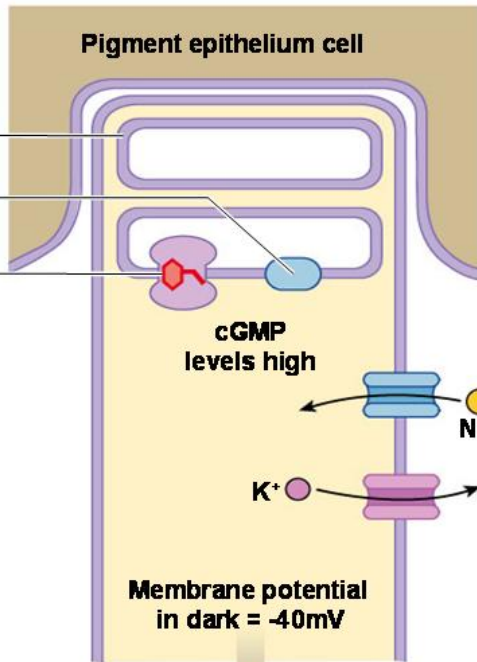
4

Release of glutamate is decreased

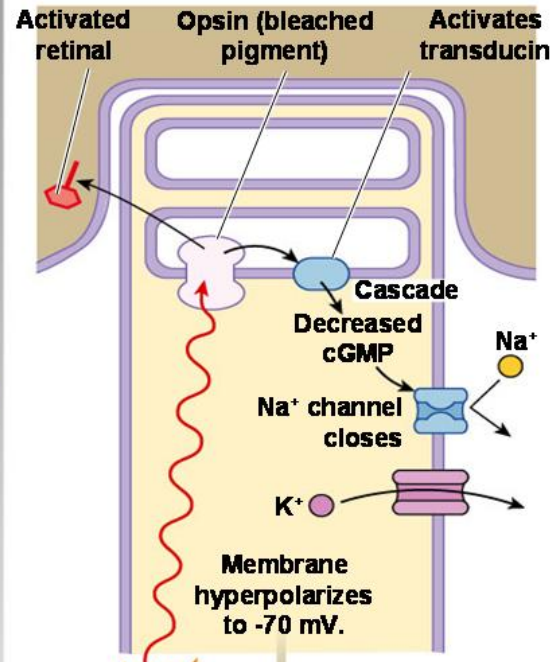




**(a) In darkness, rhodopsin is inactive, cGMP is high, and ion channels are open.**

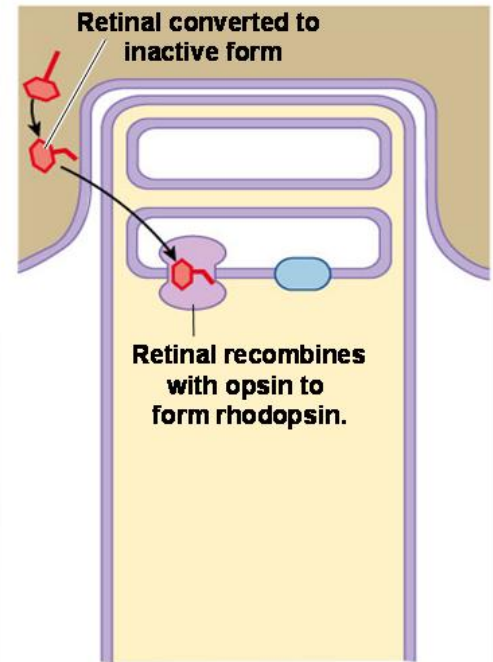


**(b) Light bleaches rhodopsin. Opsin decreases cGMP, closes Na<sup>+</sup> channels, and hyperpolarizes the cell.**

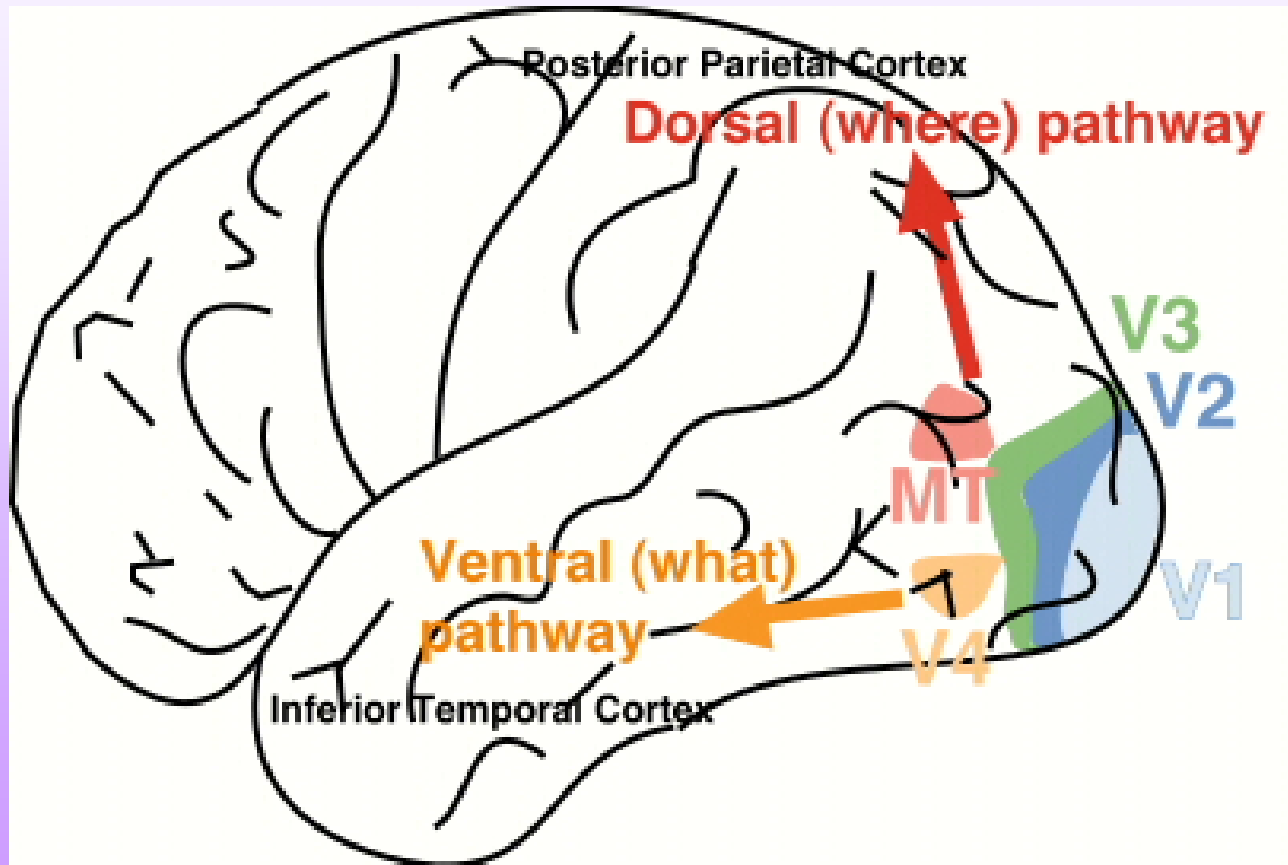


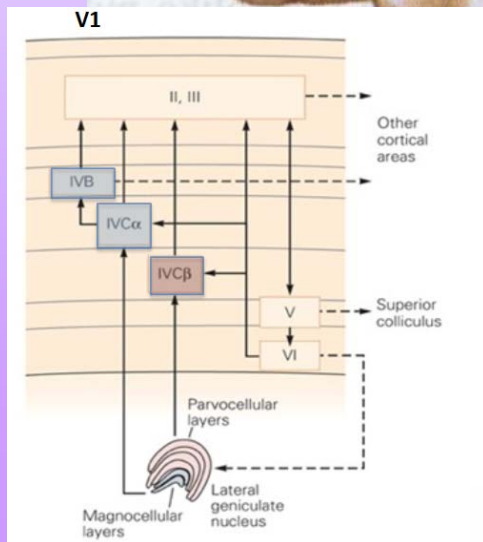
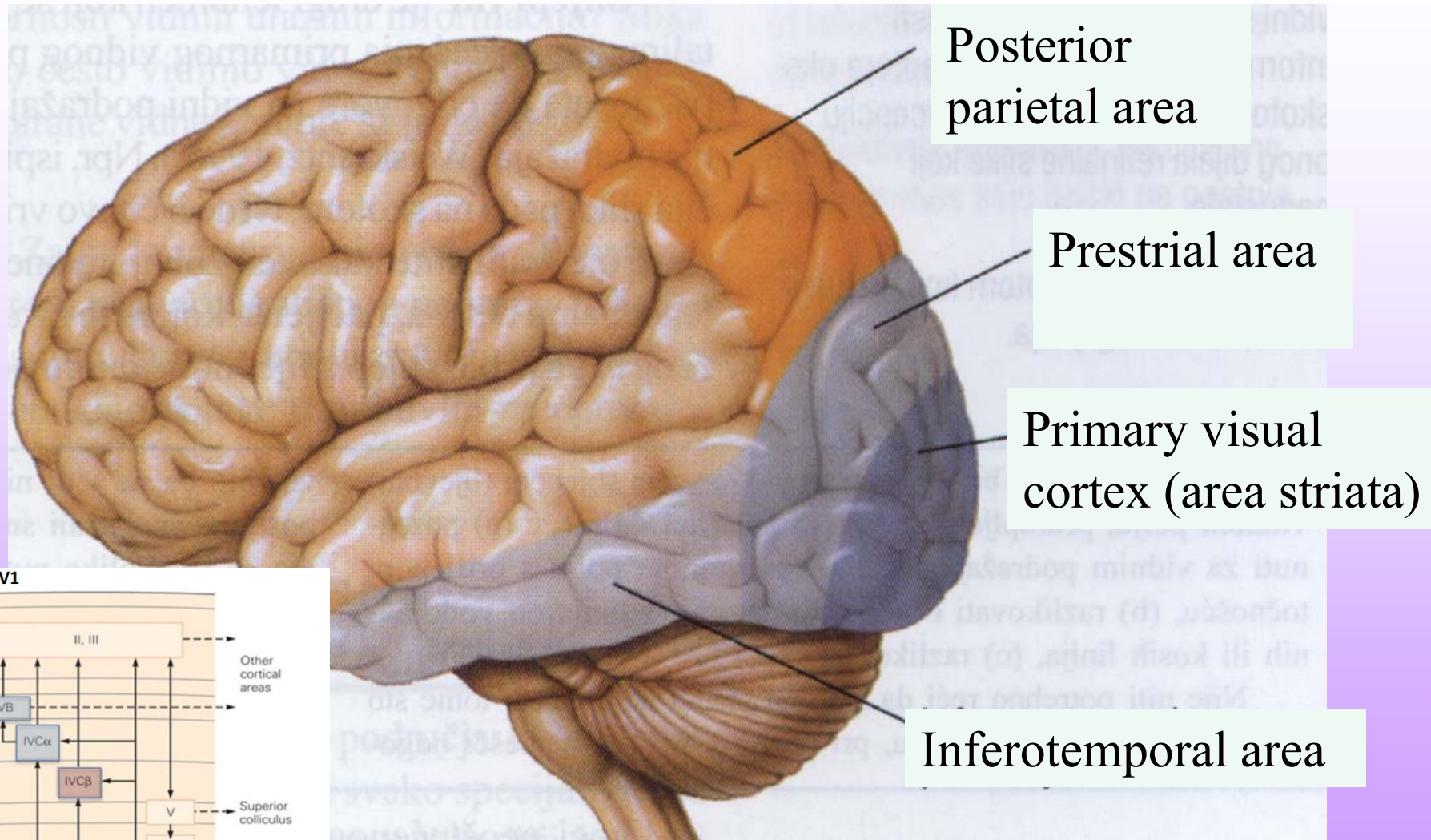
Neurotransmitter decreases in proportion to amount of light.

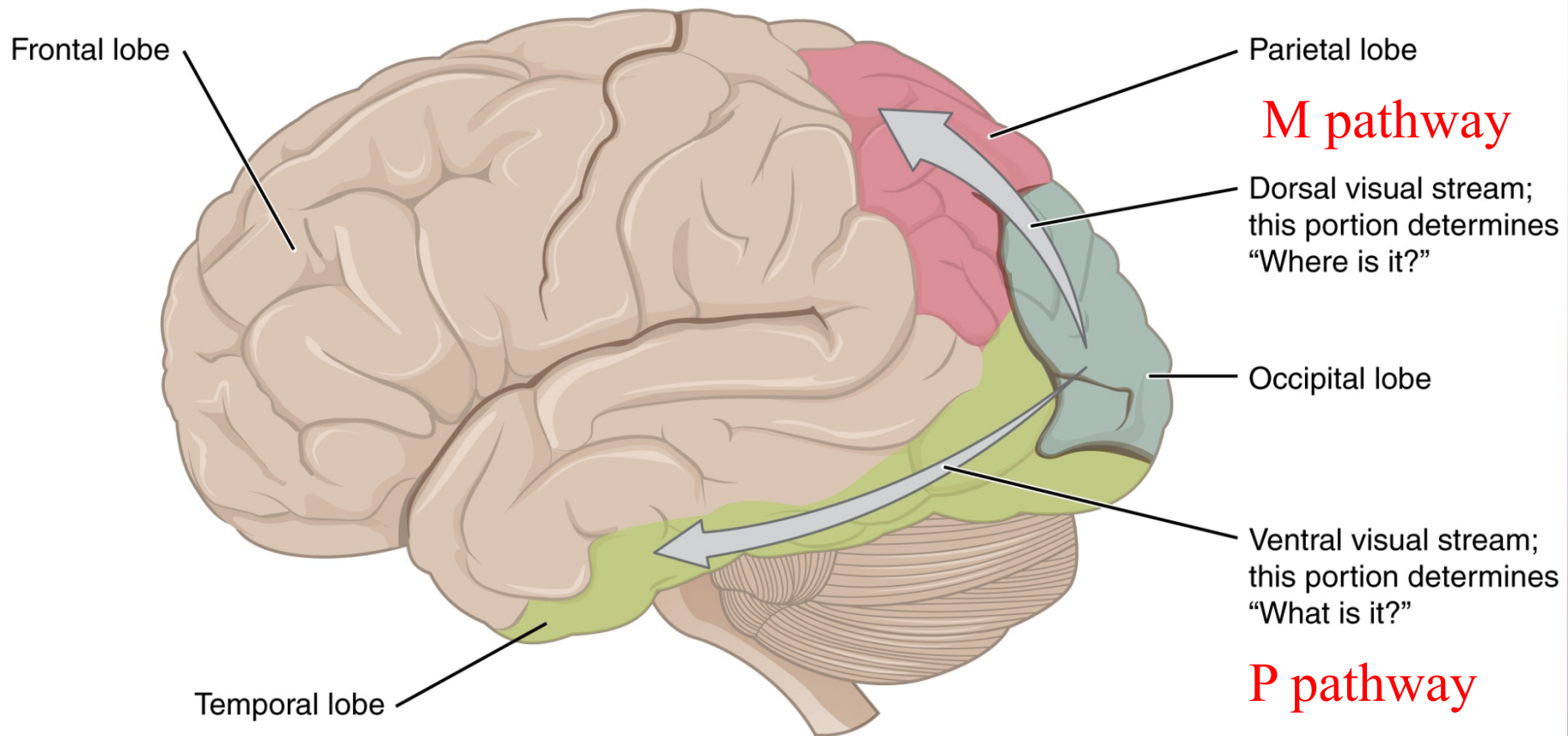
**(c) In the recovery phase, retinal recombines with opsin.**



# P and M system – perception of color and form

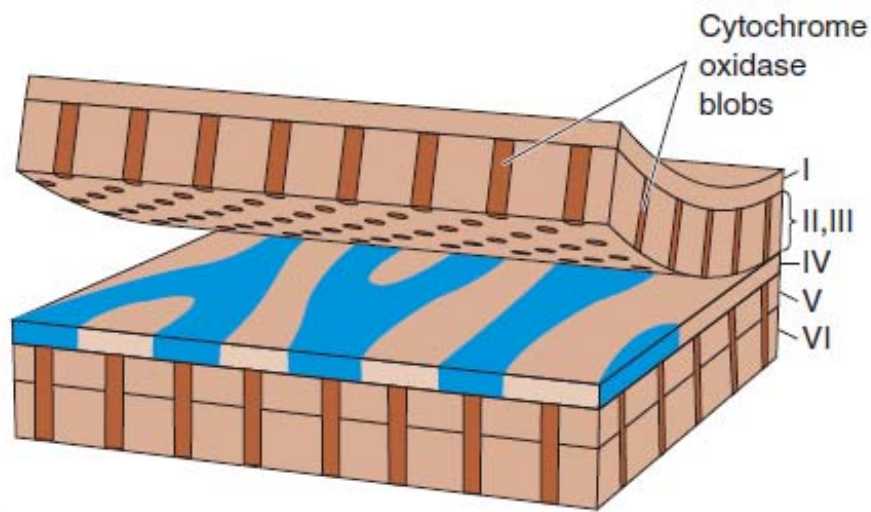




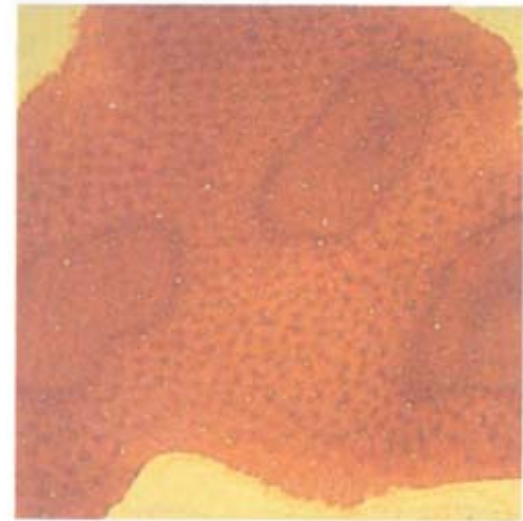


- When a special stain (**cytochrome oxidase**) for identifying mitochondrial enzymes is applied to the visual cortex, it reveals two types of **staining patterns**.
- **Electrophysiology** experiments reveal **different function** in different staining patterns.



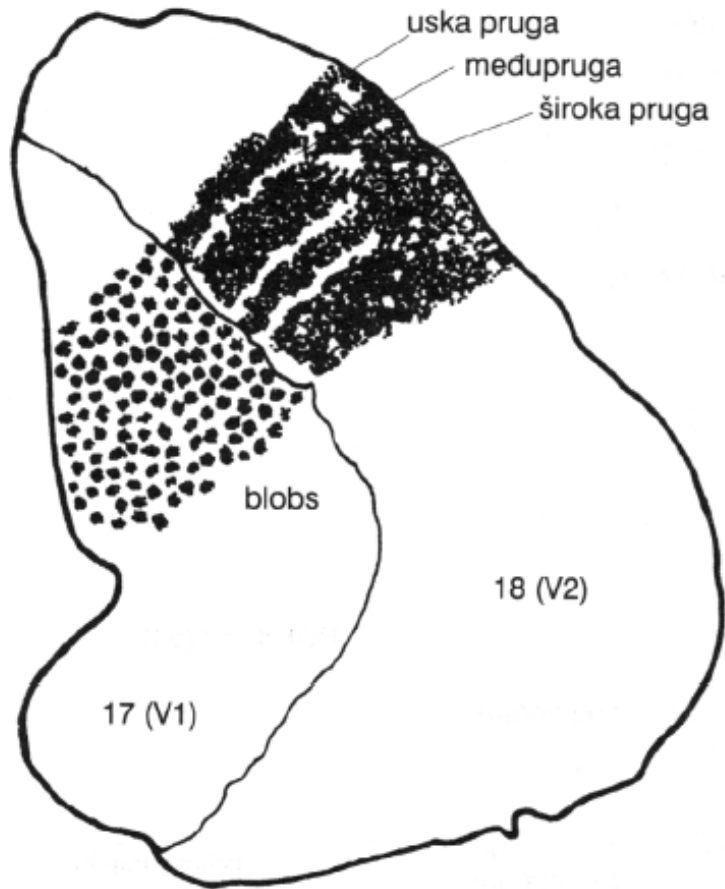


A



B

**FIGURE 26-12** Blobs shown with cytochrome oxidase staining. (A) Diagram illustrates the distribution of the enzyme cytochrome oxidase in blob areas of the visual (also called "striate") cortex of a monkey. (B) Photomicrograph taken from the blob area in layer III (as shown in A) revealing intense positive staining for cytochrome oxidase. (From Bear MF, et al.: Neuroscience: Exploring the Brain, 3rd ed. Philadelphia: Lippincott Williams & Wilkins, 2007, p. 324.)



**Slika 29-18.** Histokemijskom metodom za prikaz reaktivnosti citokrom-oksidade u polju V1 prikazujemo »blobs« i »interblobs«, a u polju V2 široke pruge, uske pruge i međupruge. Nacrtano prema mikrofotografiji preparata primarne i sekundarne vidne moždane kore rezus majmuna (tangenijalni rez kroz III. sloj moždane kore polja V1 i V2), u radu Livingstone i Hubel (1987a). Uočite da su pruge u polju V2 usmjerene okomito na granicu polja V1 i V2.

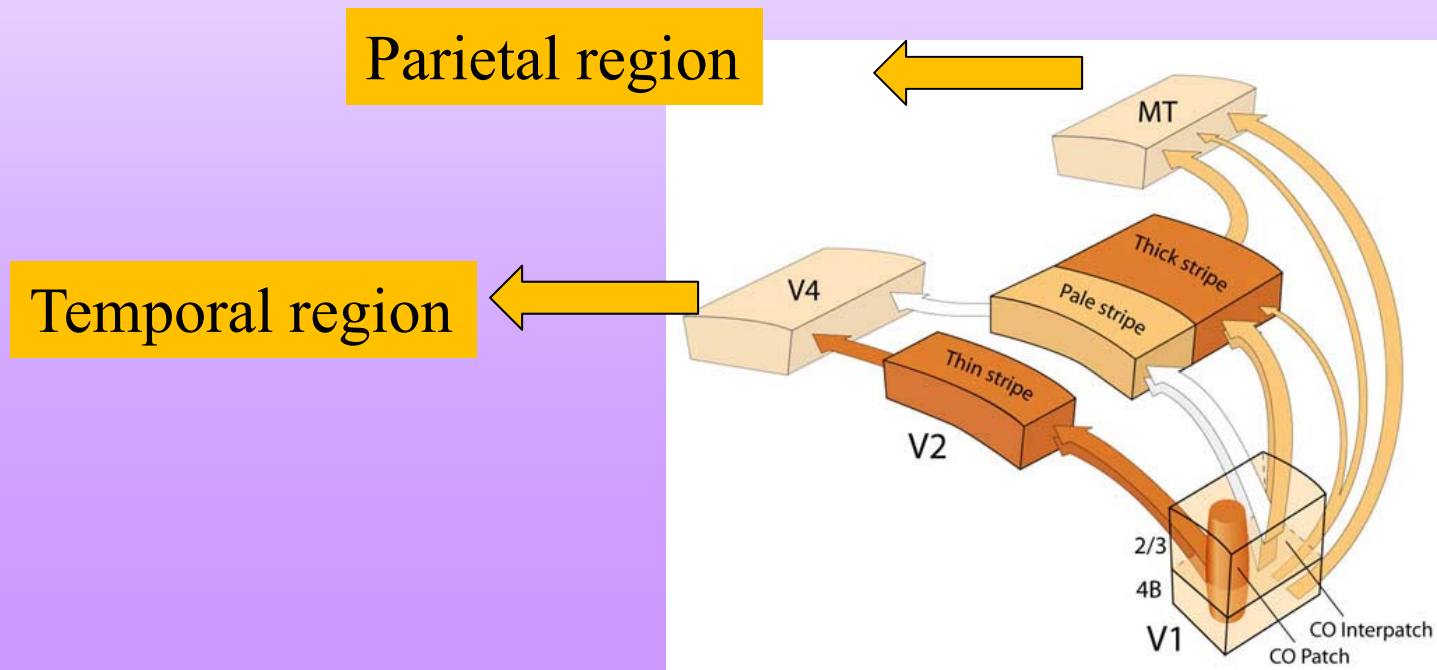
- “blobs” (V1) and narrow lines (V2) are part of P system for color and form
- wide lines (V2) are part of M system for perception of movement

# Role of visual cortex

- 1) **V1**: separation of visual information for color, form, movement and depth.
- 2) **V2**: sending visual information to the parietal or temporal pathway
- 3) Associative visual fields involved in color and form perception (**P-system**); associative visual fields involved in movement perception (**M-system**)

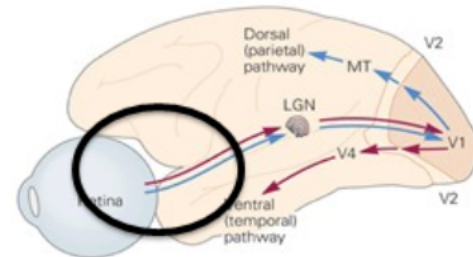


- 4) Associative visual field **V4** mediates the information from P-pathway into the **temporal region**; field **V5** mediates information from M-pathway into the **parietal region**.

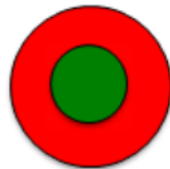


# Perception of the color

## RGCs: Two principal cell-types



**Midget** RGC receptive field tiling



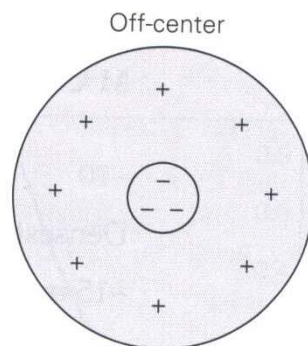
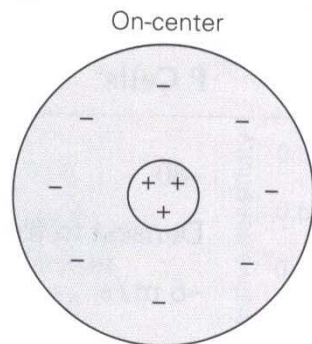
- P pathway characteristics:**
- Smaller RFs, so better spatial resolution
  - Selective for color (red-green opponency)

**Parasol** RGCs receptive field tiling

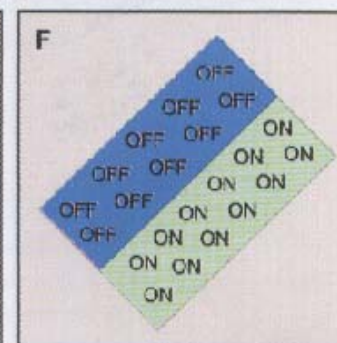
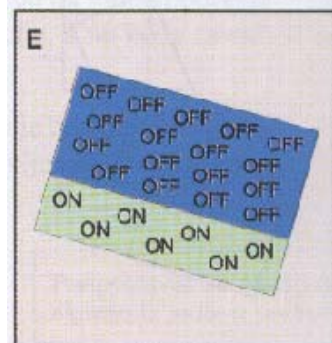
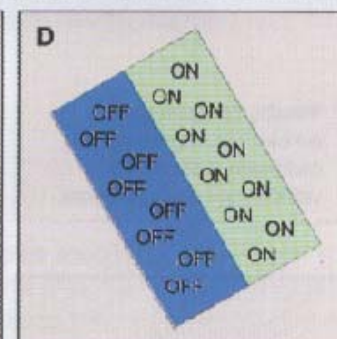
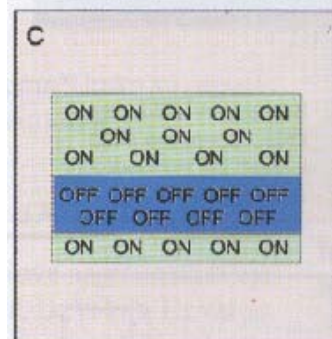
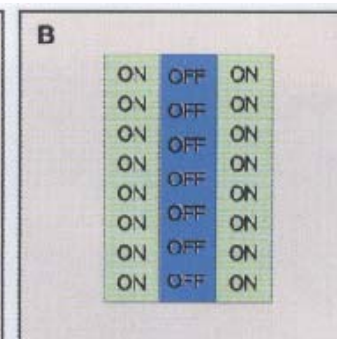
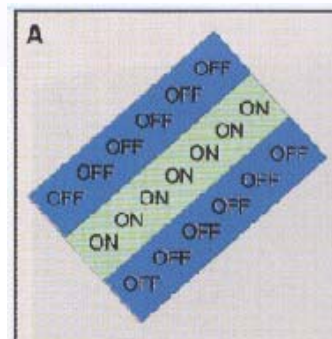
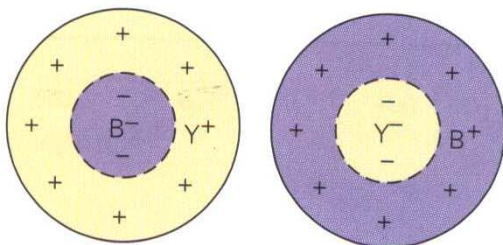
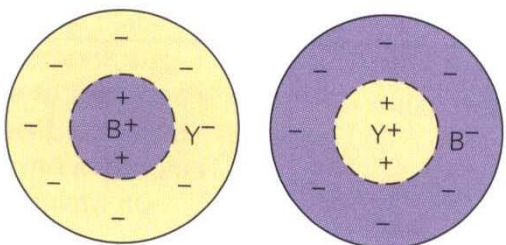
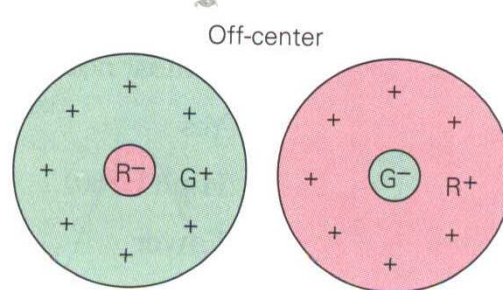
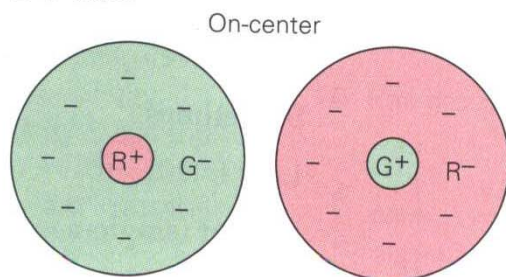


- M pathway characteristics:**
- Better temporal resolution
  - More sensitive to low light levels
  - Monochromatic (black-white opponency)

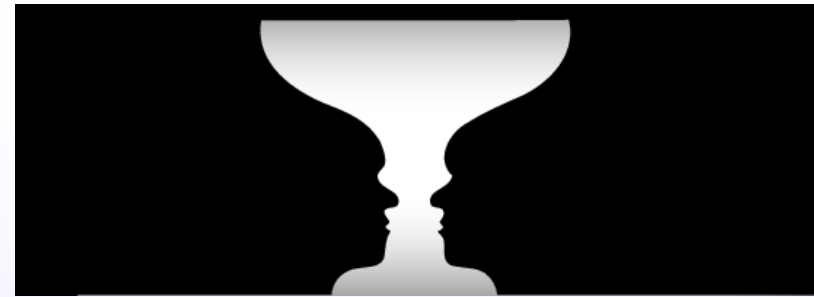
## A M cells



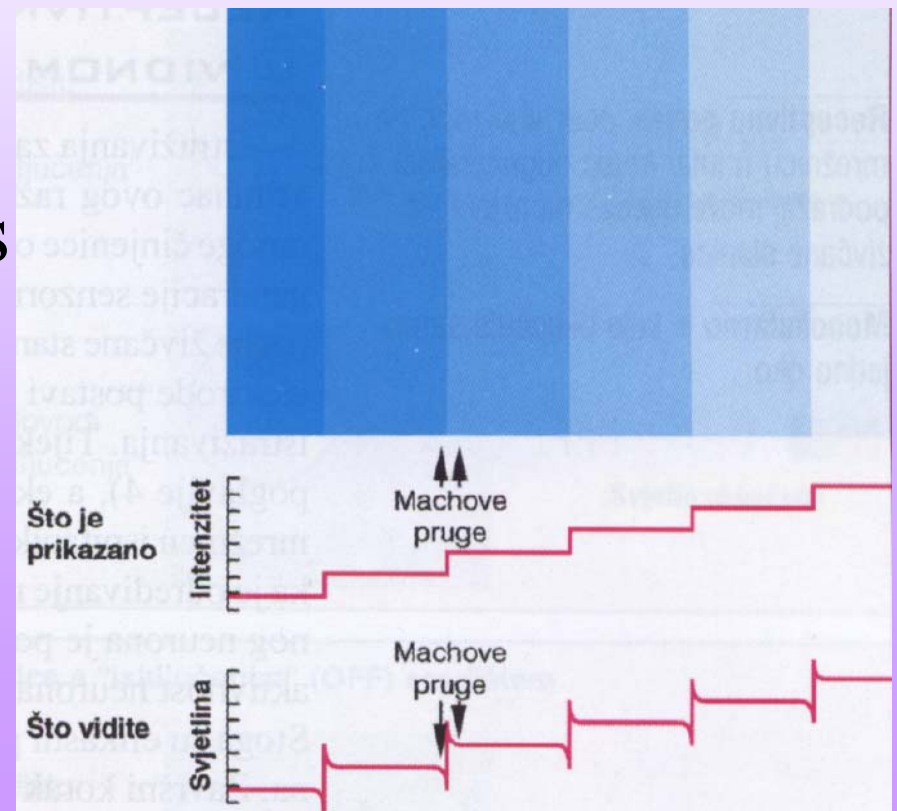
## B P cells



# Perception of Form

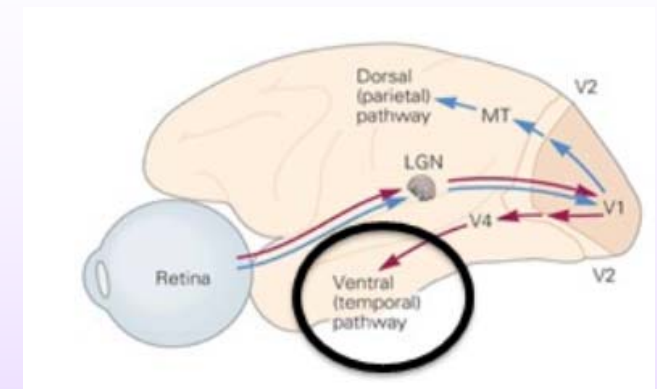
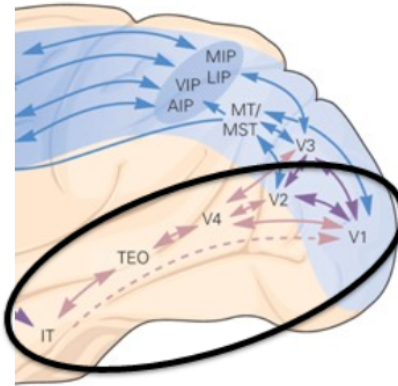


- Distinction between the form and the background
- Gestald psychology
- Perception of the edges

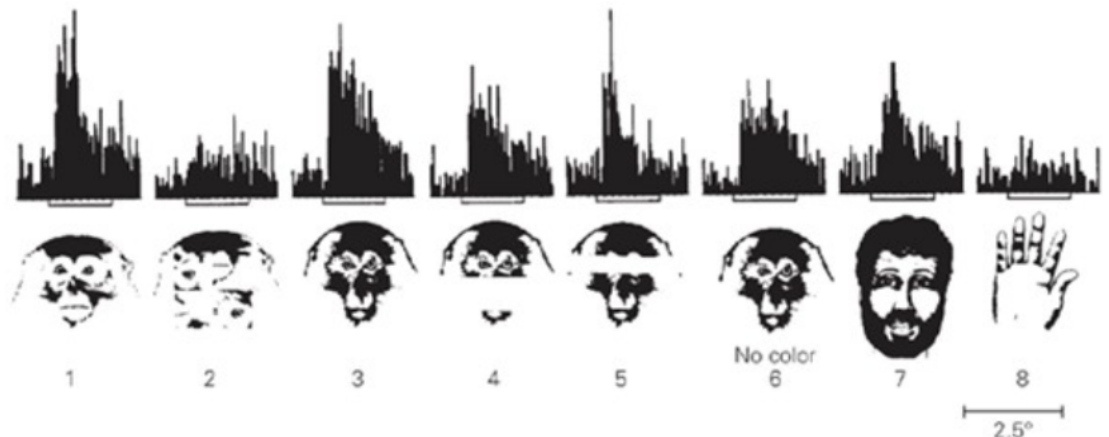


## Ventral pathway: Preview

- Two principal paths:
  - 1) V1-V2-V4-TEO-IT
  - 2) V1-V4-TEO-IT
- Involved in object identification  
Called the “what” pathway.
- Late stages of inferior temporal (IT) cortex contain the celebrated “face cells”

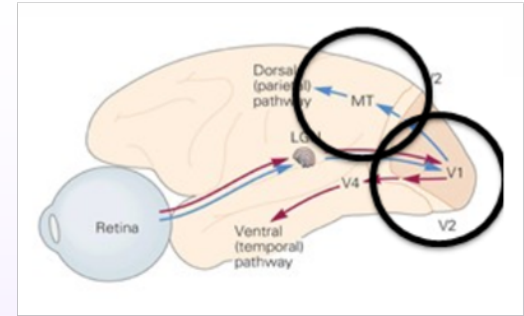


IT represents complex objects, such as faces



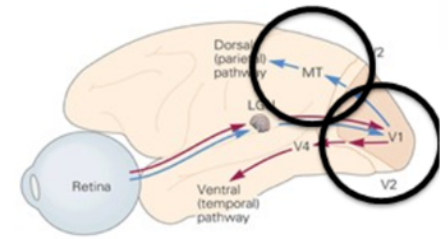


# Perception of the motion



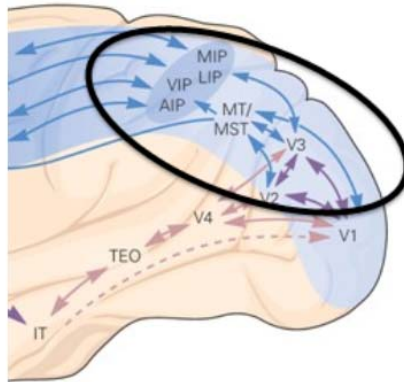
- Peripheral retina can only see moving object
- Motion is analysed in the **Dorsal Pathway** to the Parietal Cortex
- Motion is represented *in the Middle Temporal Cortex (MT)*
- Visual system perception of the motion :
  - a) based on the movement of the object
  - b) based on the neural signals from the moving eyes and head

## Medial Temporal Area (MT): Motion Selectivity



### Dorsal pathway (preview)

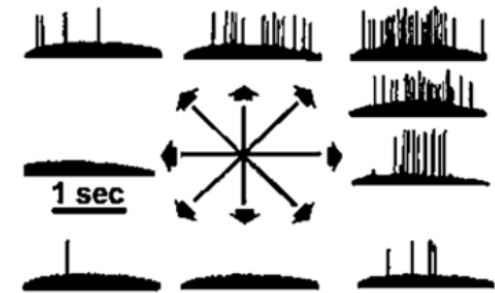
- The “where” pathway
- Main input from M-pathway circuits within V1.
- V1-to-MT-to-IP
- MT (aka V5) neurons are highly selective to direction of motion.
- IP neurons tell the motor system how to respond to the environment.



Motion selectivity seen at **2 stages of dorsal hierarchy:**

- 1) Neurons in **layer IVB of V1**
- 2) Neurons in **MT** (IVB of V1 is major MT input)

So what is MT doing??

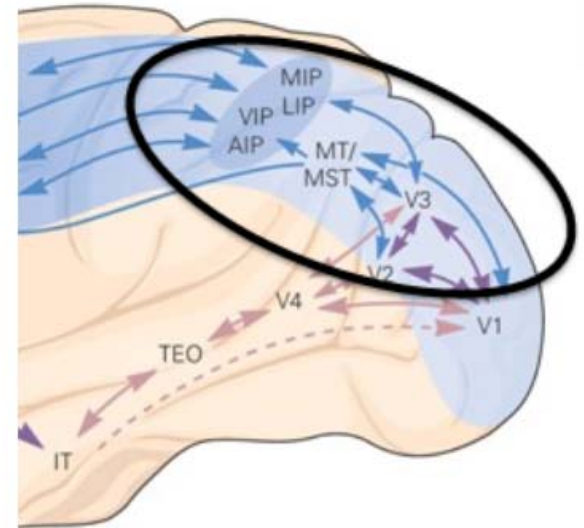


IVB of V1  $\longrightarrow$  MT

Both stages are direction selective

## Parietal cortex: A ridiculously brief summary

- MT passes its output to the intraparietal cortical areas. Each IP area is responsible for a different “class” of movement.
- In addition to unparalleled object recognition (ventral pathway), primates have great hand-eye coordination so that we can use tools, or hit a baseball (dorsal pathway).
- IP uses visual input to tell the motor system how to interact with the environment.

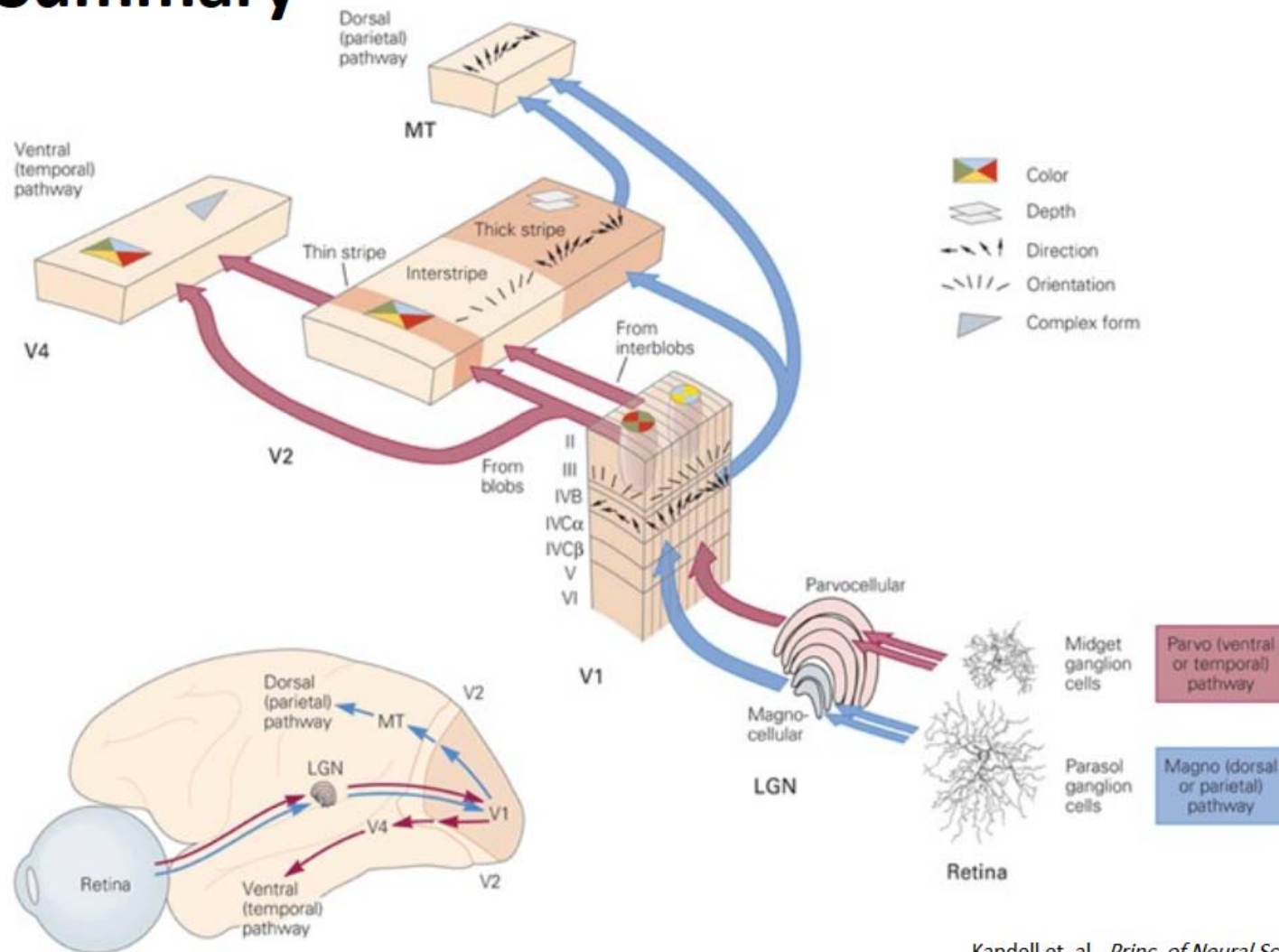




## Differences between dorsal and ventral pathway, summarized by lesion examples

- Patients with lesions of the parietal cortex cannot properly adjust their grip (width or angle) to grab an object. But they can describe the shape of the object in detail.
- Patients with lesions of the ventral path cannot describe the object but can easily adjust their grip to grab it.

# Summary



# Color Blindness

- CAUSE: congenital, hereditary
- 8% men and about 0.05% women
- Coupled to the x-chromosome – mothers give it to their sons
- HEALTHY cones are trichromate

## 3 types of *dichromates*

- 1) *Protanopia*: loss of the L cones (red)
- 2) *Deuteranopia*: loss of the M cones (green)
- 3) *Tritanopia*: loss of the S cones (blue)

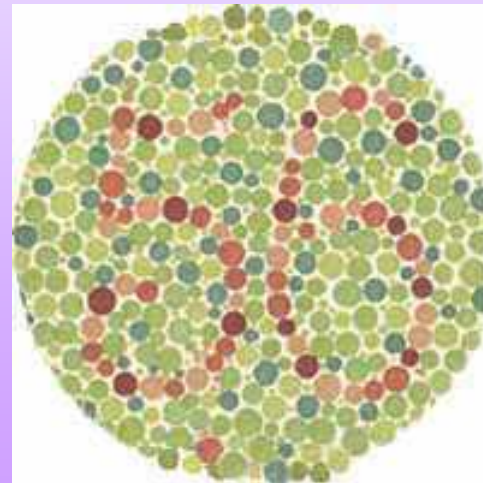
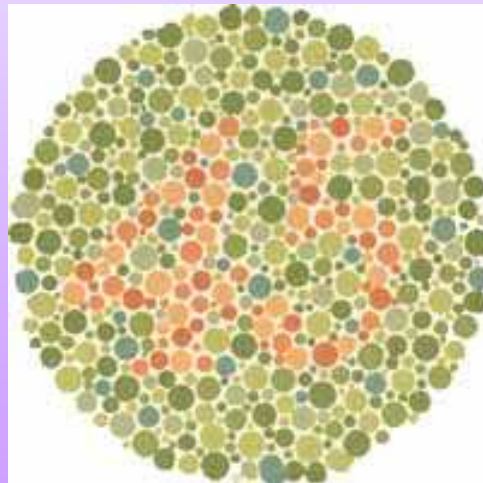
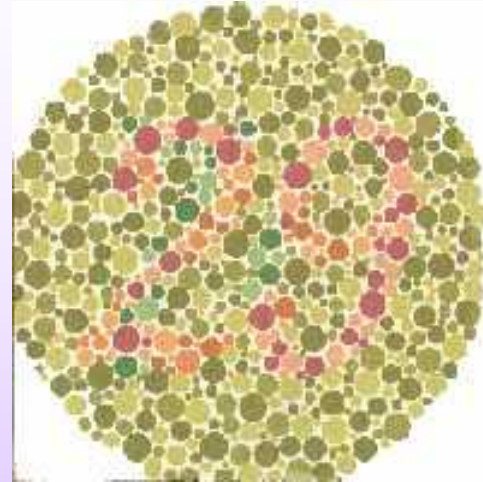
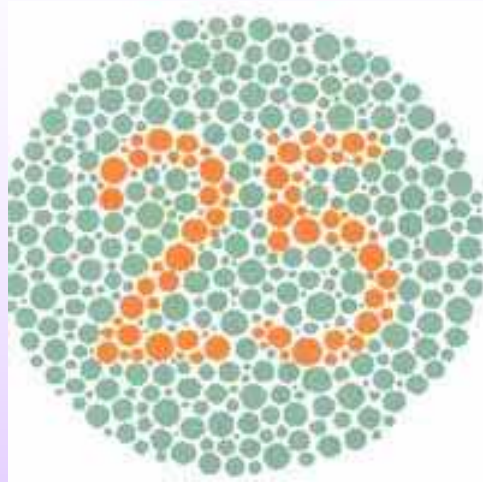
# Milder impairments

- 1) *Protanomalopia*: damage of the L cones (green)
- 2) *Deuteranomalopia*: damage of the M cones (green)
- 3) *Tritanomalopia*: damage of the S cones (green)

# ***Monochromate* color blindness**

- Completely color blind

# Ishihara Test for Color Blindness



# Effects of Lesions of the Occipital and Temporal Regions of the Cortex

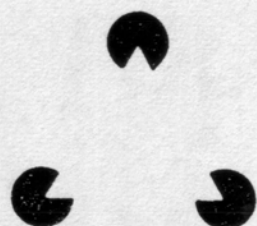
- *Primary Visual Cortex*
- a total lesion of the visual cortex will produce a **contralateral homonymous hemianopsia**
- lesion restricted to the inferior bank of the calcarine sulcus will cause an **upper quadrantanopsia**



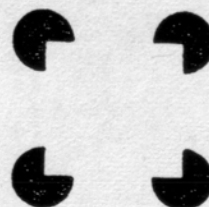
- *Secondary Visual Areas (in Occipital Cortex)*
- **visual agnosia** (failure to understand the meaning or use of an object)
- **color agnosia** (inability to recognize color)

- *Inferotemporal Cortex*
- **prosopagnosia** = the loss of the ability to recognize familiar faces
- *Middle Temporal Cortex*
- **movement agnosia** = the patient cannot distinguish between objects that are stationary and those that are moving.

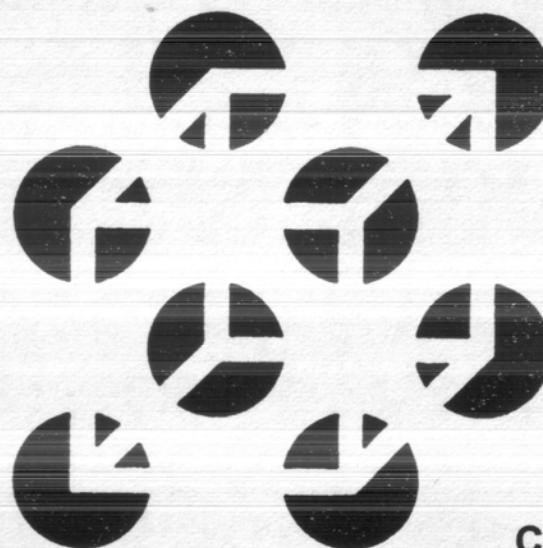
# Visual ilusions



A



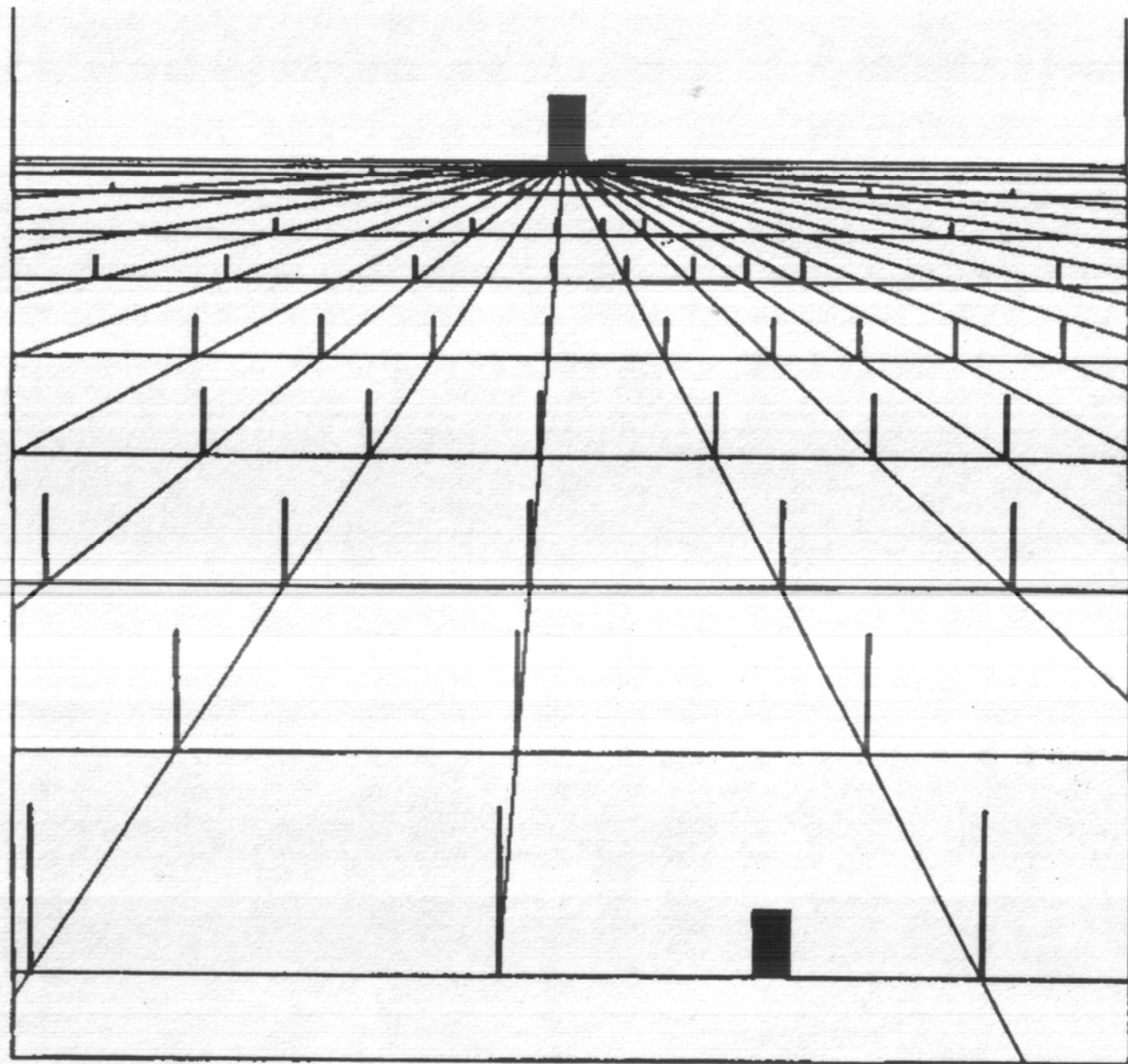
B



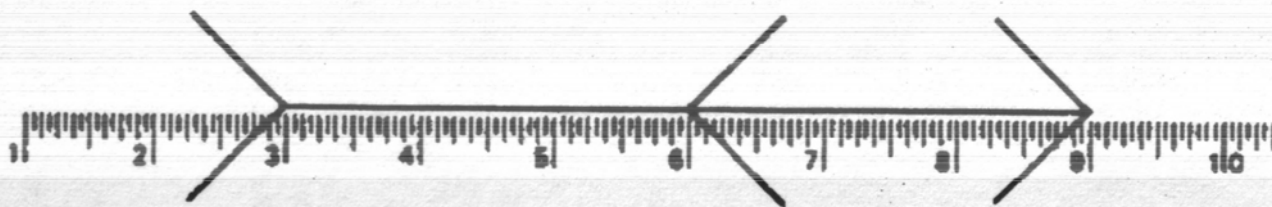
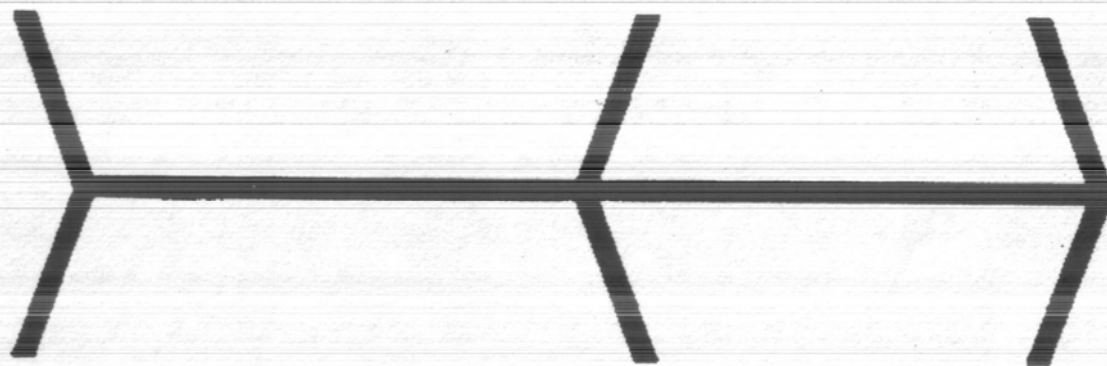
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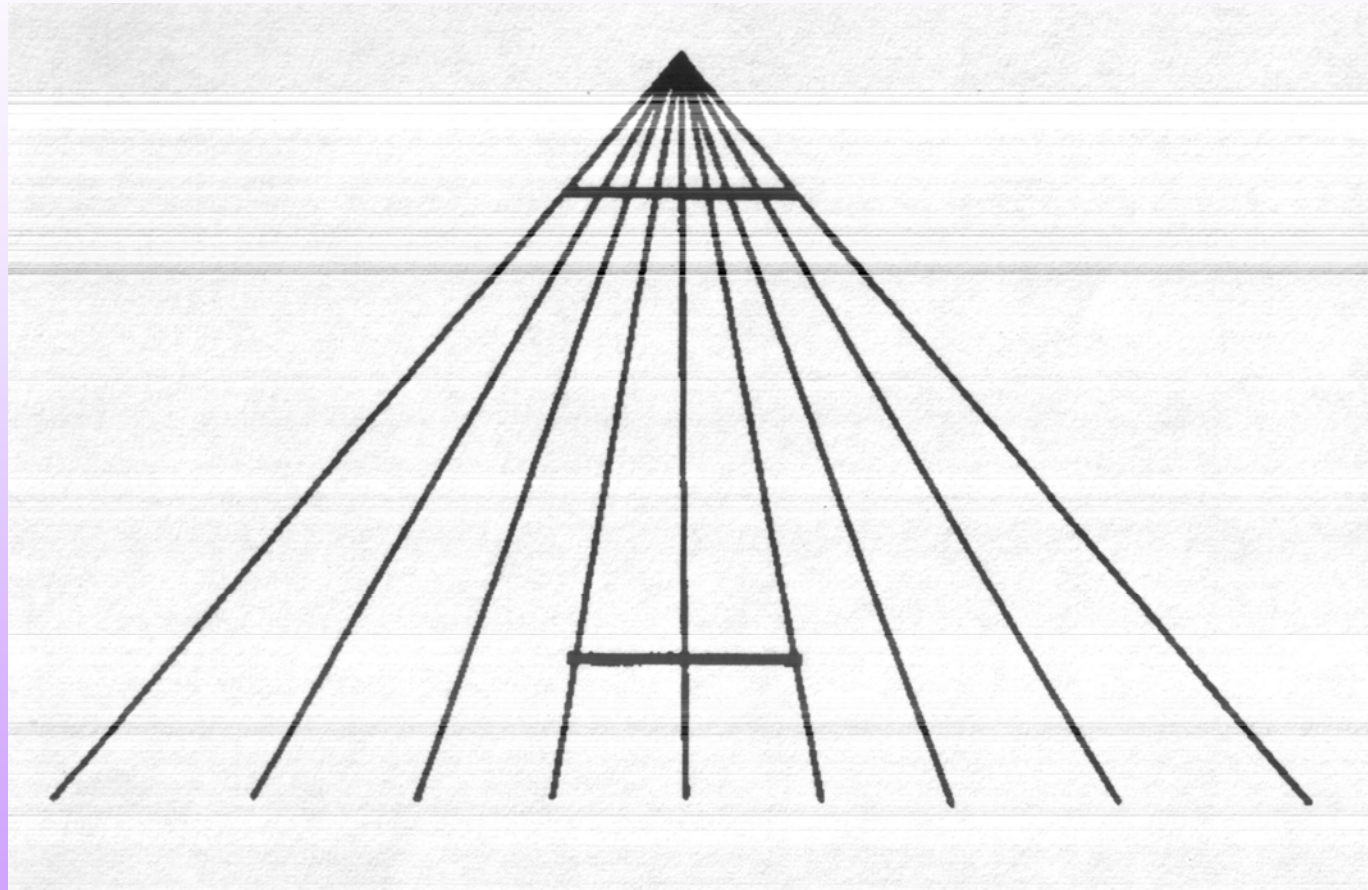
I1 I2 I3 I4

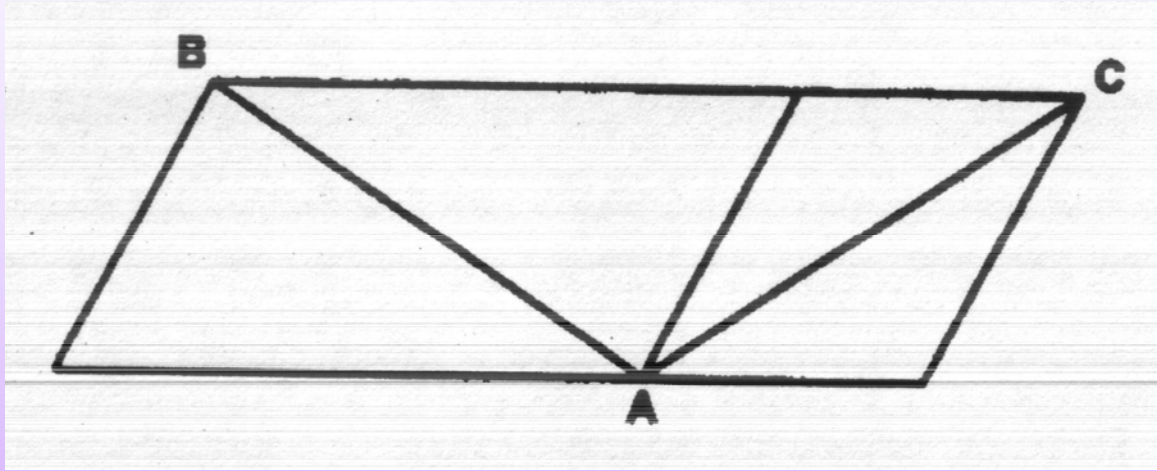
A B C D

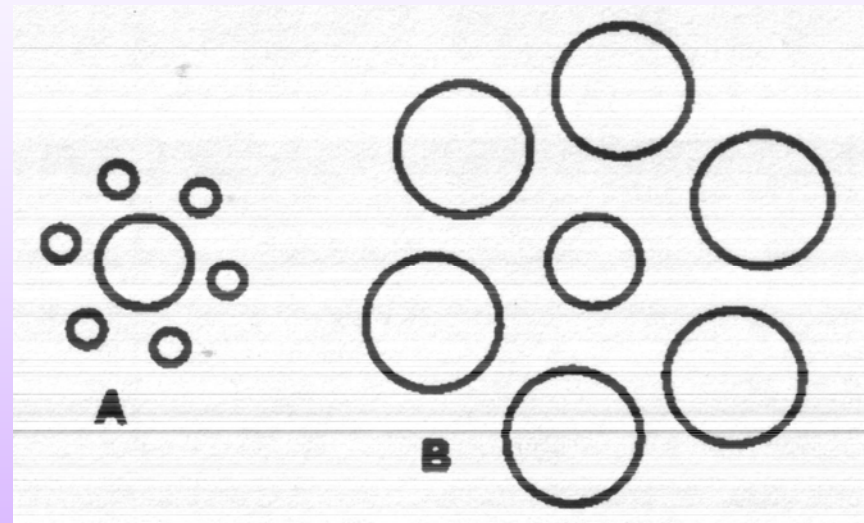


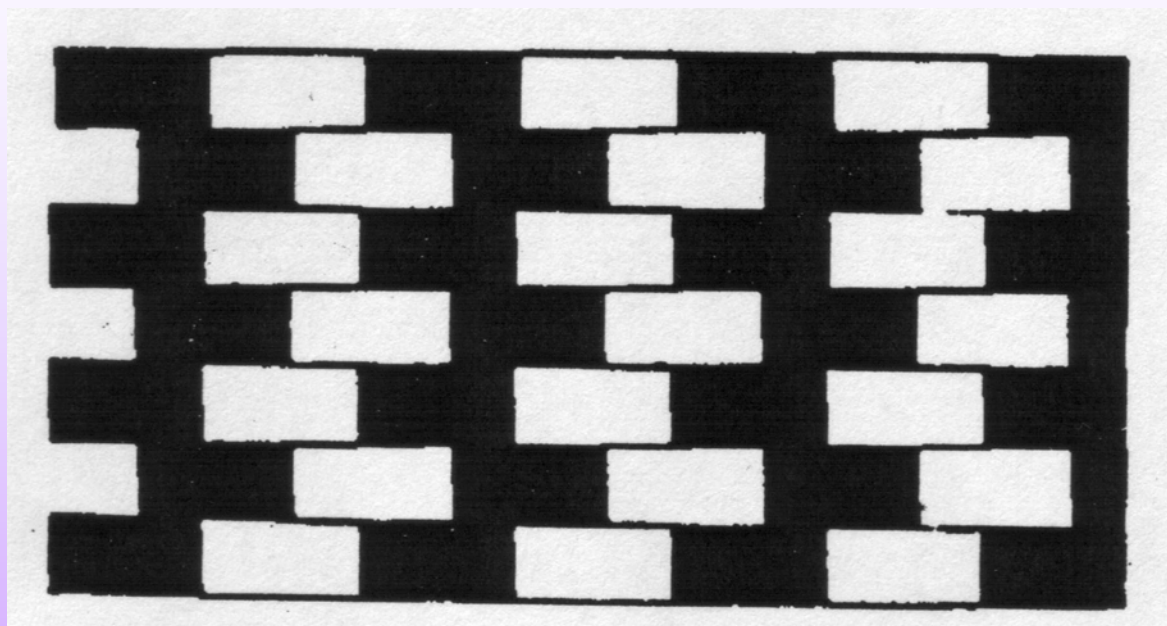


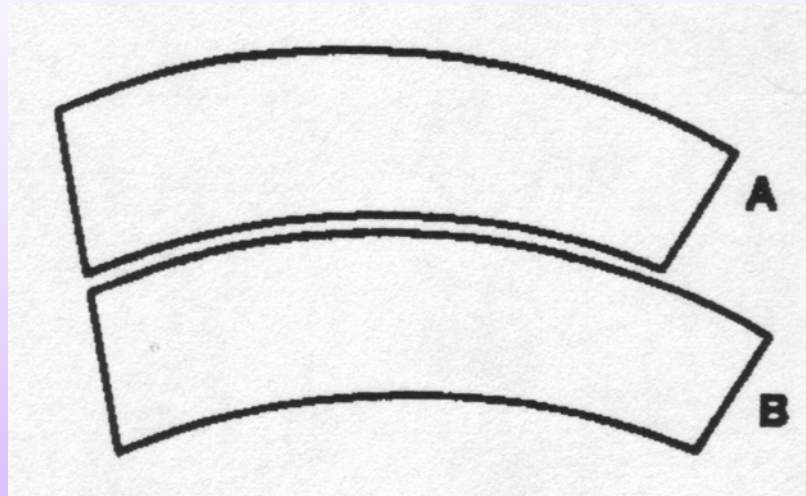




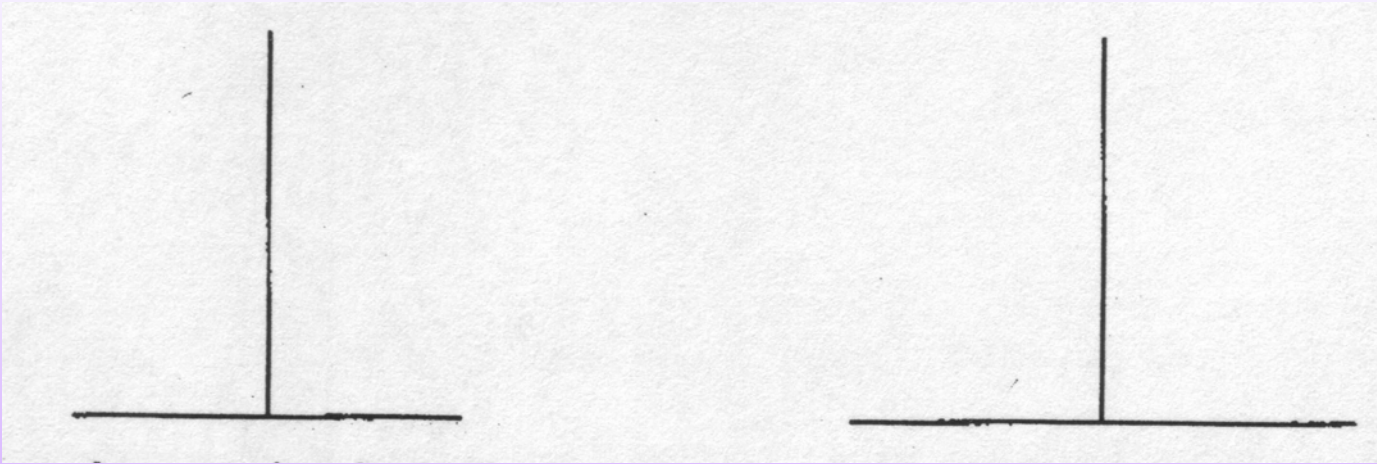


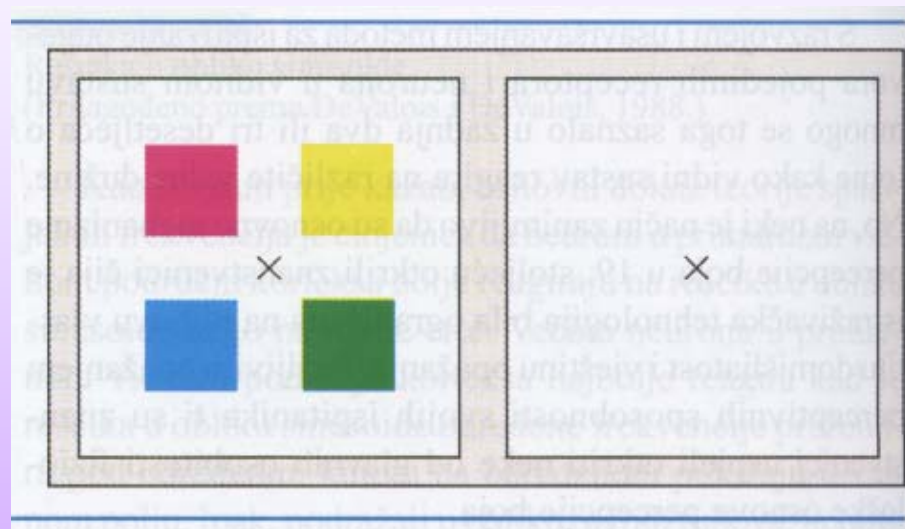


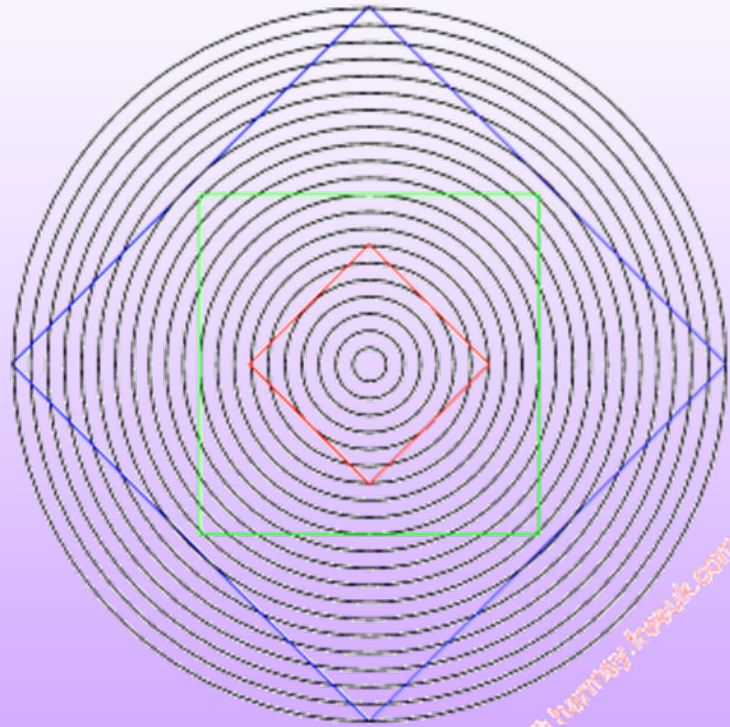




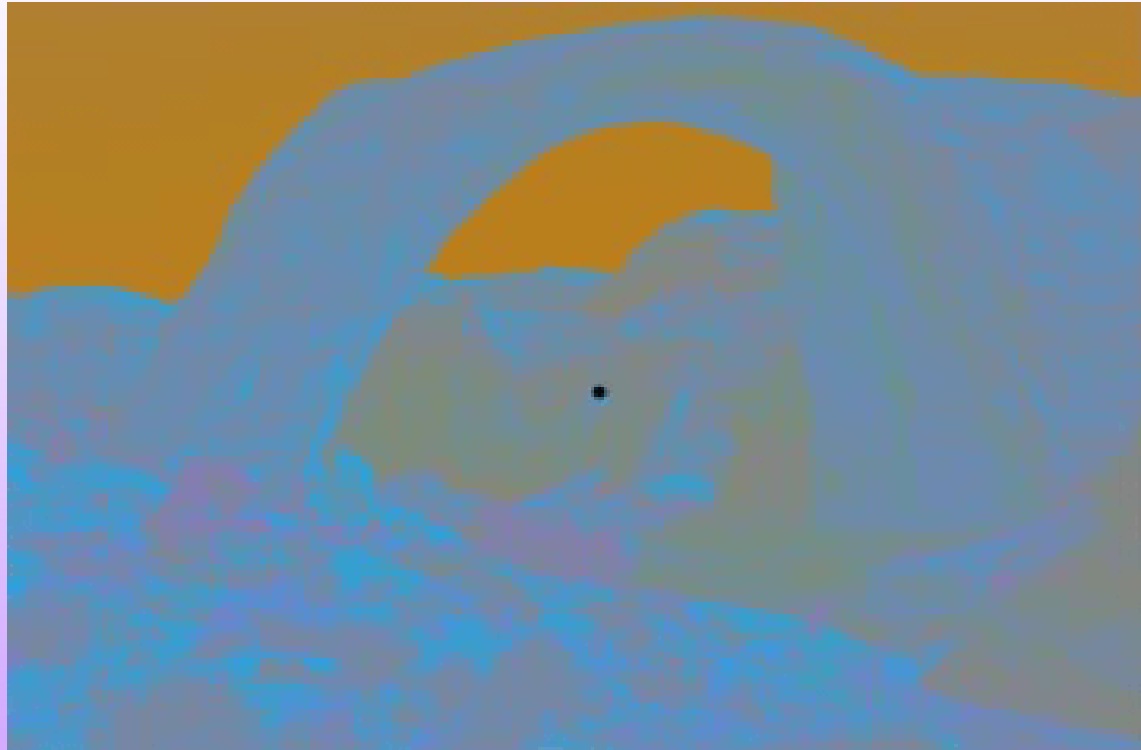








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Thank you!