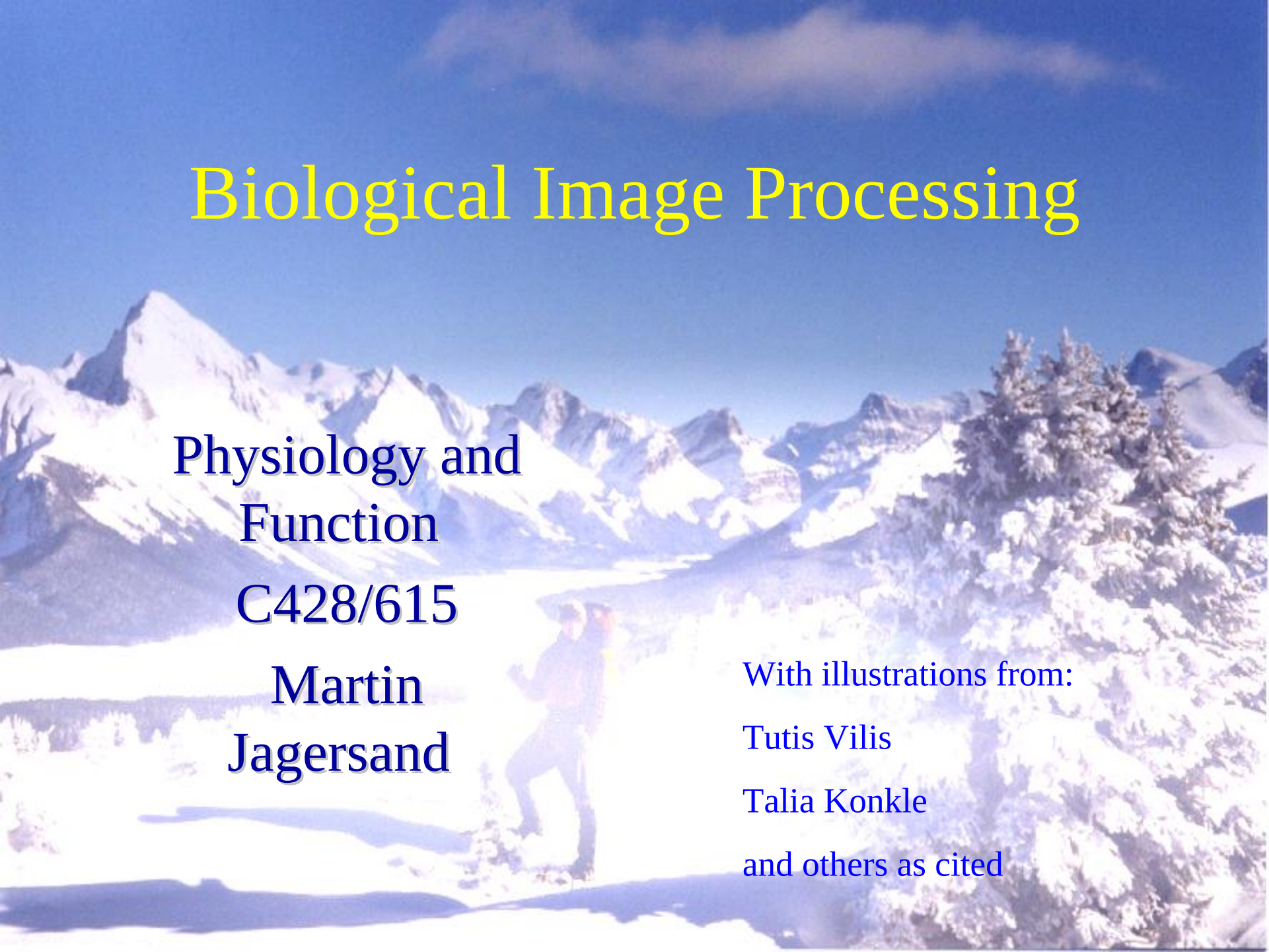


Biological Image Processing

Physiology and Function

C428/615

Martin Jagersand

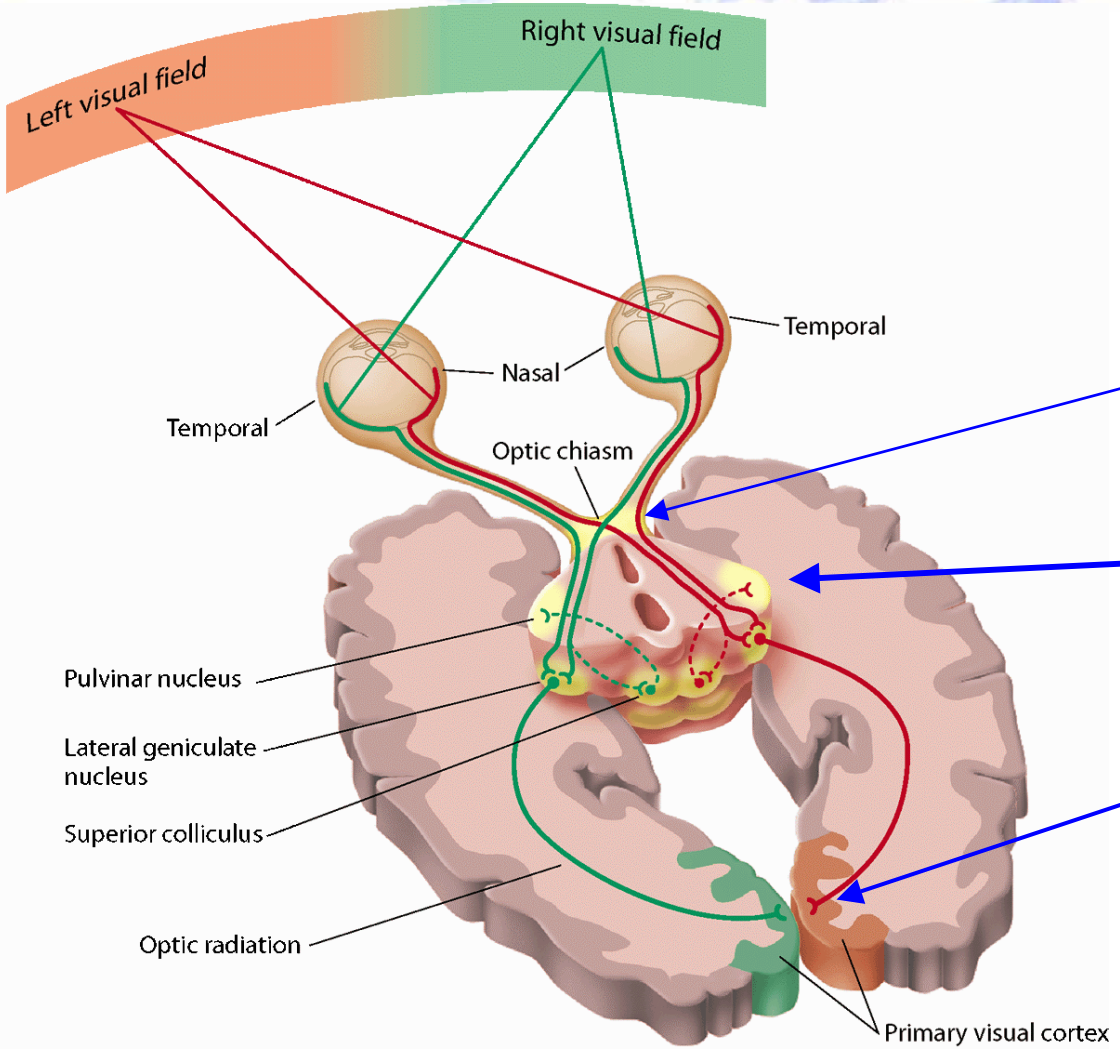
With illustrations from:

Tutis Vilis

Talia Konkle

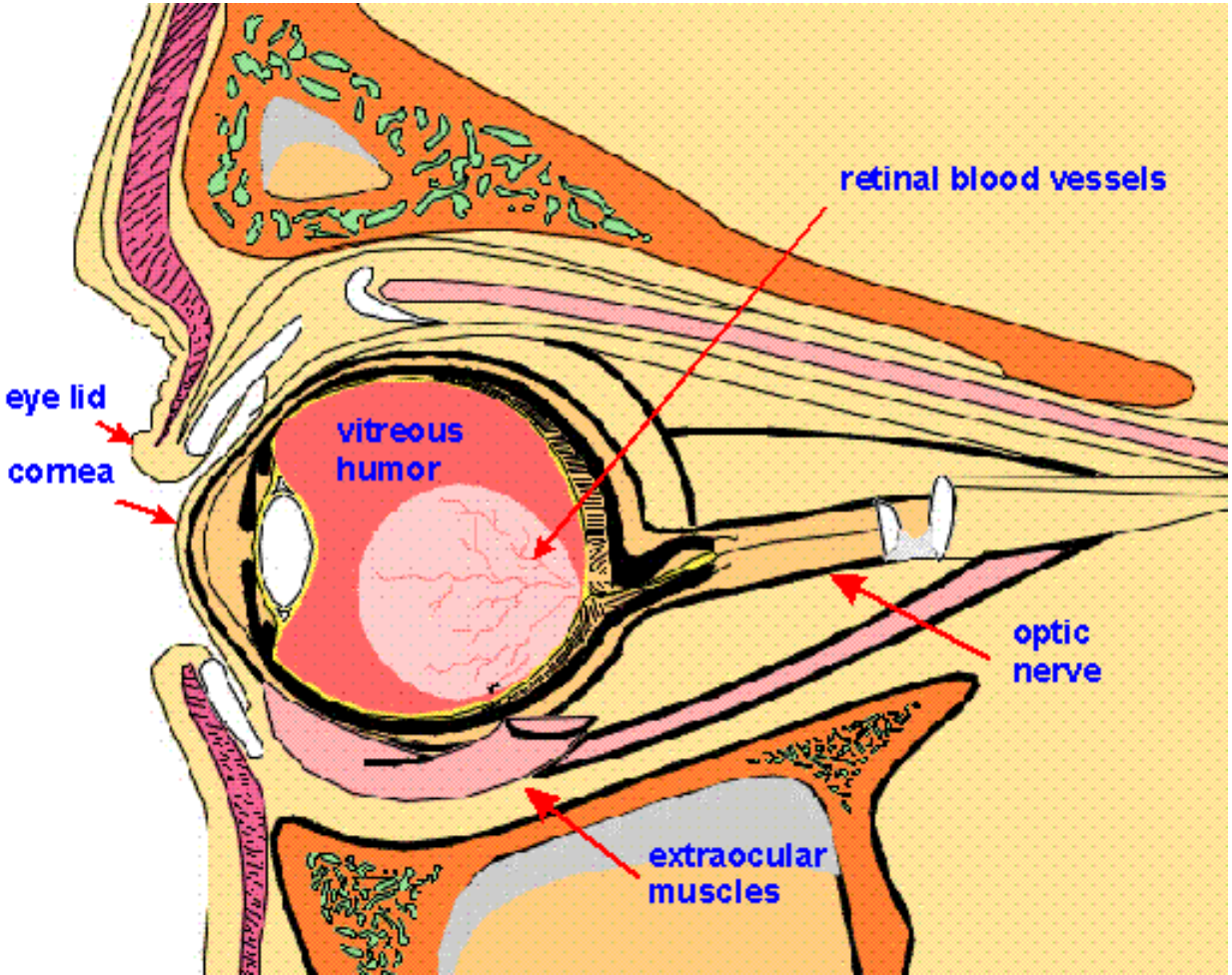
and others as cited

Visual Processing elements and Pathways



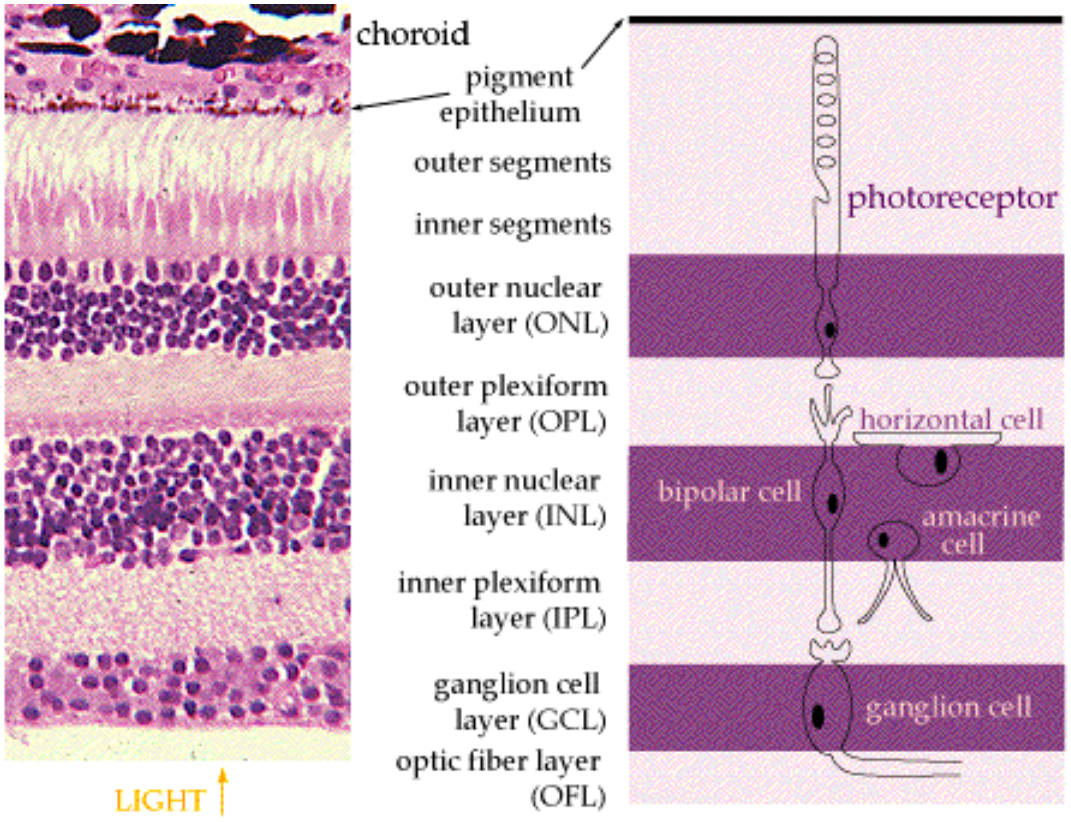
- Eye transforms light into nerve impulses
- Optic chiasm splits left and right visual fields
- LGN: Exact function unknown. May have to do with stereo.
- V1 (Striate cortex) performs spatial filtering / coordinate transforms

The Eye
The Biological Camera



- Lens, cornea and fluids focus light.
- Six eye muscles orient the eye
- Iris adjusts light
- Retina captures images

Retina
Converts light to nerve impulses



- Photoreceptor converts light
- Other cell layers perform image processing

Photoreceptors
Rods and cones

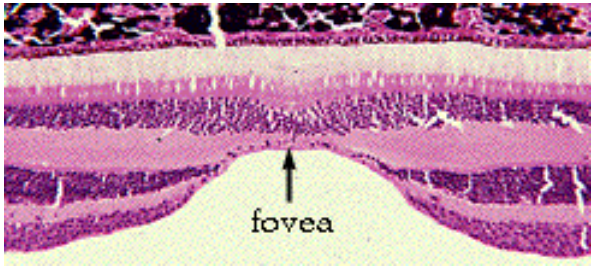
Rods: Night vision, but no color.

125million, none in fovea,

outnumber cones 20:1

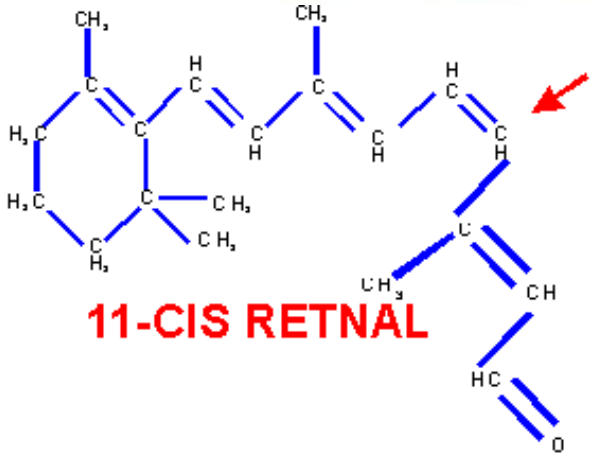
Cones: Color sensitive, but poor light sensitivity

6.4million, peak density in fovea



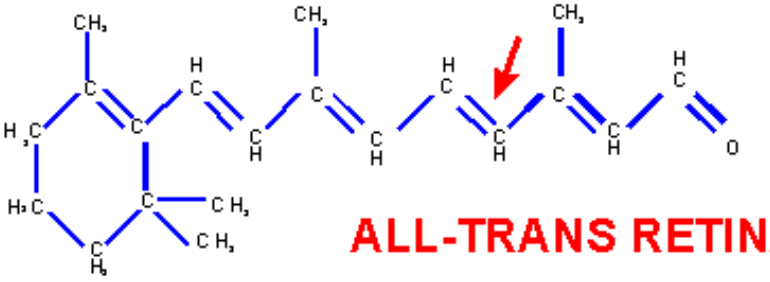
Large molecule with two energy levels Photopigment

- Cis retinal has low energy
- Trans slightly higher energy
- Incoming light photon adds energy => changes cis to trans state.



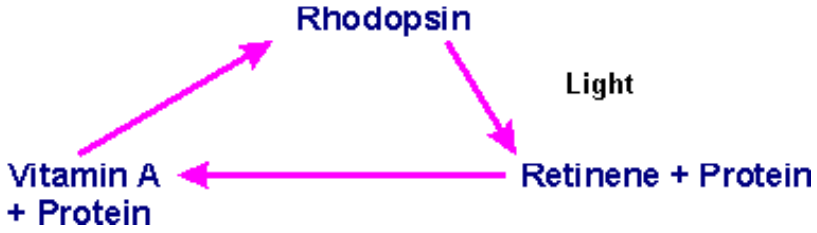
11-CIS RETNAL

Prior to light stimulation

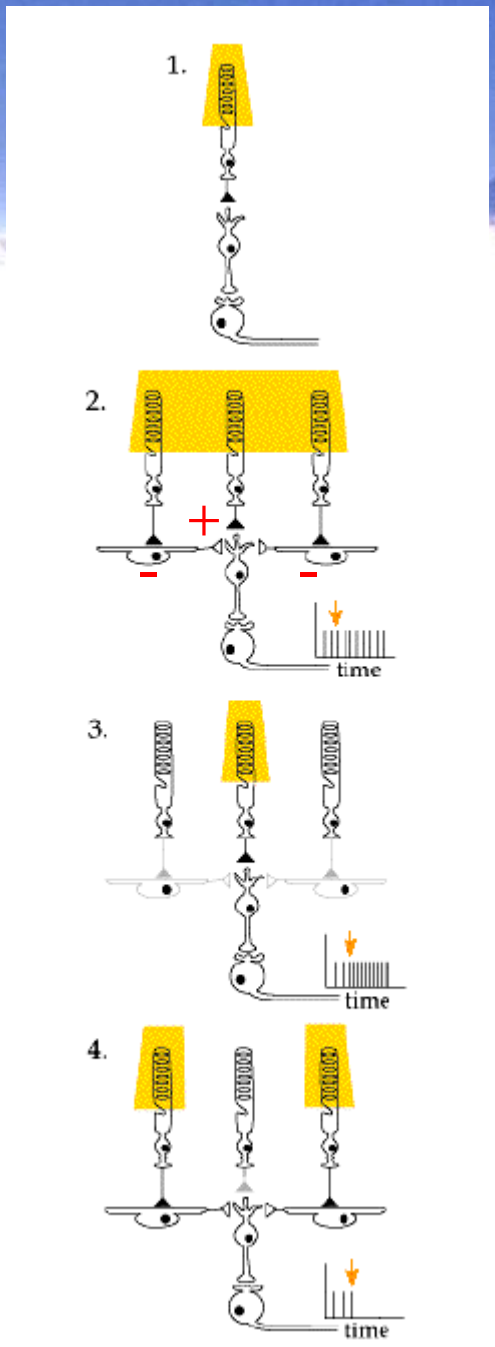


ALL-TRANS RETINAL

After light stimulation



Interneurons and Ganglion cells



Center-surround organization:

1. Light hyperpolarizes the rod and excites the bipolar cell below it
2. But inhibitory connections through horizontal cells suppress signals
3. Best response to localized “dot”
4. While stimulating surround only lowers firing rate

- What is this???

  Convolution!!! Im*[-1 2 –1]

Disappearing figure?

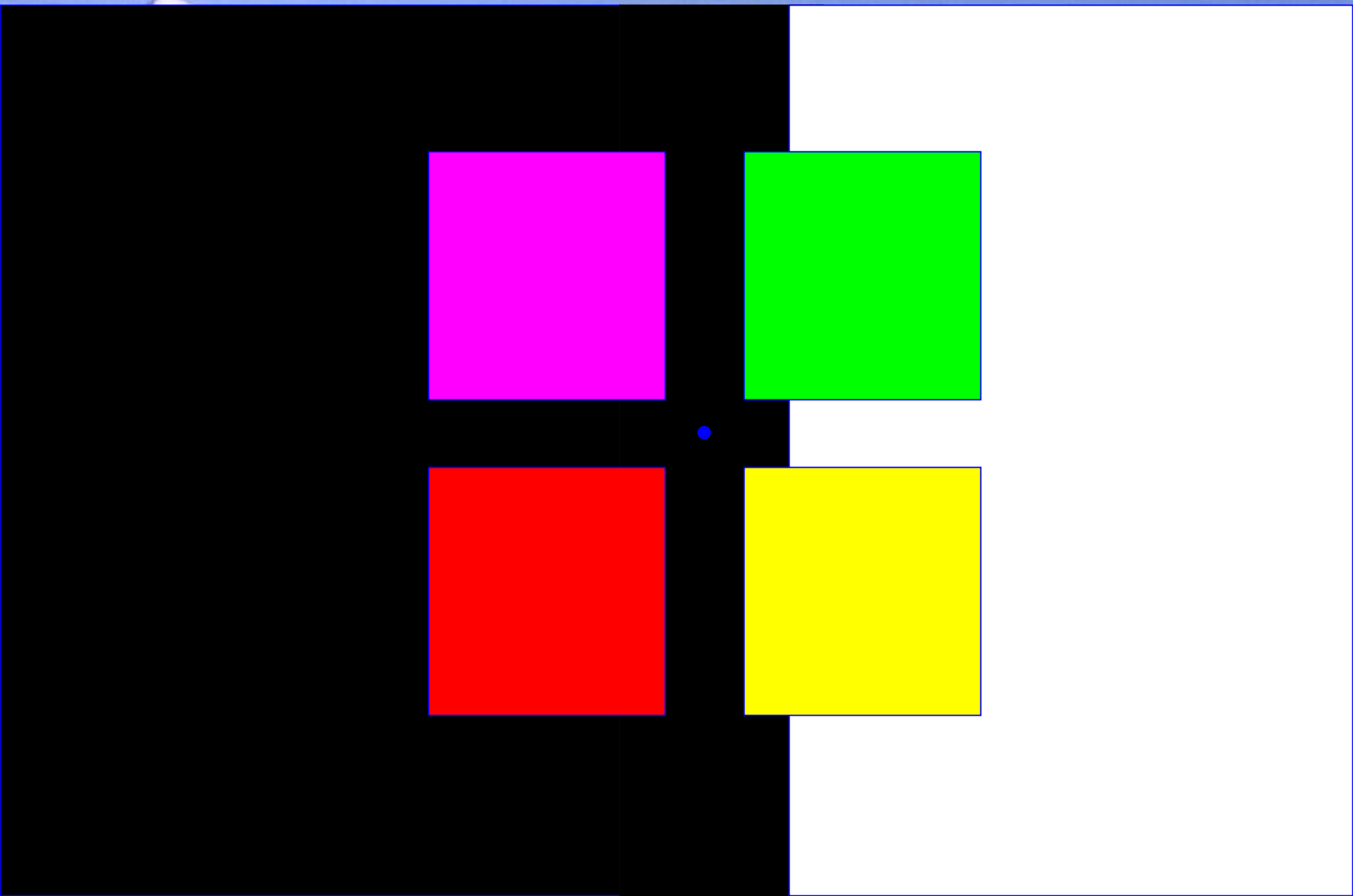
- Focus steadily on first the left then the right black dot

The visual system adjusts itself.

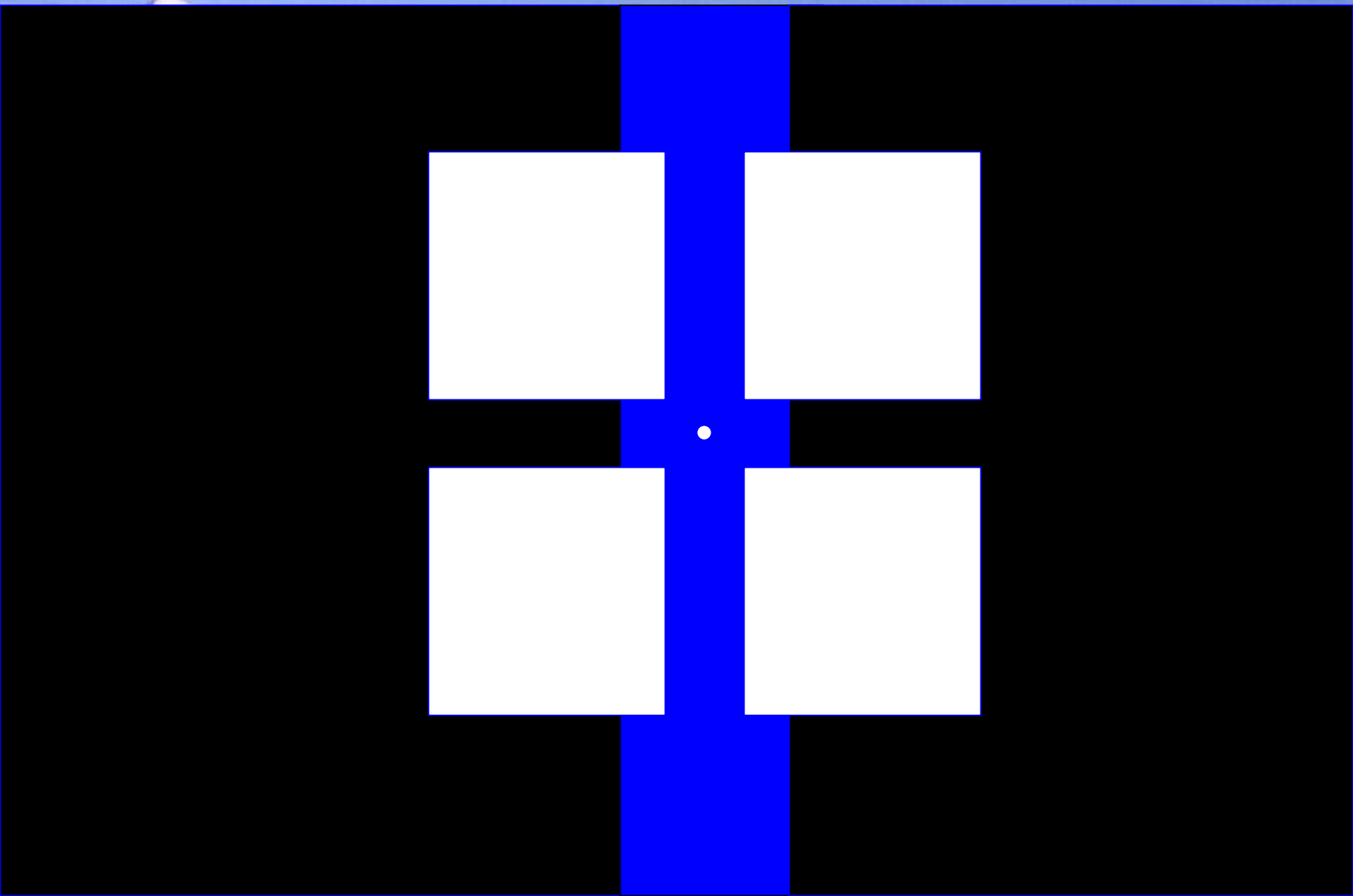
- In time.
- In space.

- Why does it adjust?
  - sensitivity and gain?
  - neural fatigue?
  - adjustment of priors? (effects in the opposite direction)
  - Error correction?

Color opponency, receptor adaptation



Color opponency, receptor adaptation



Color opponent ganglion cells

- Red-green and blue yellow

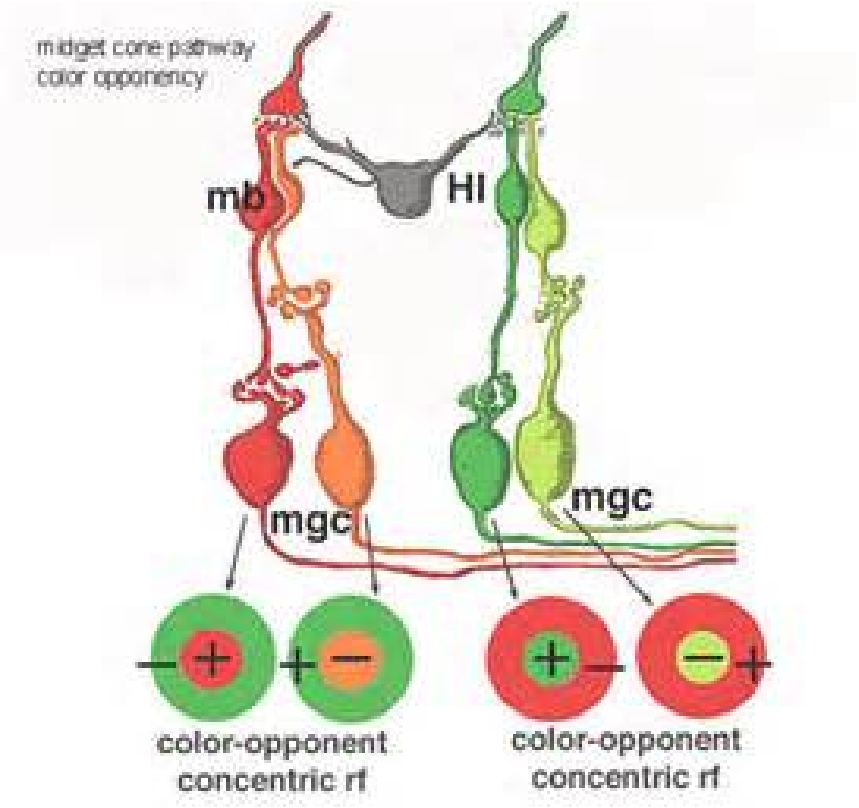
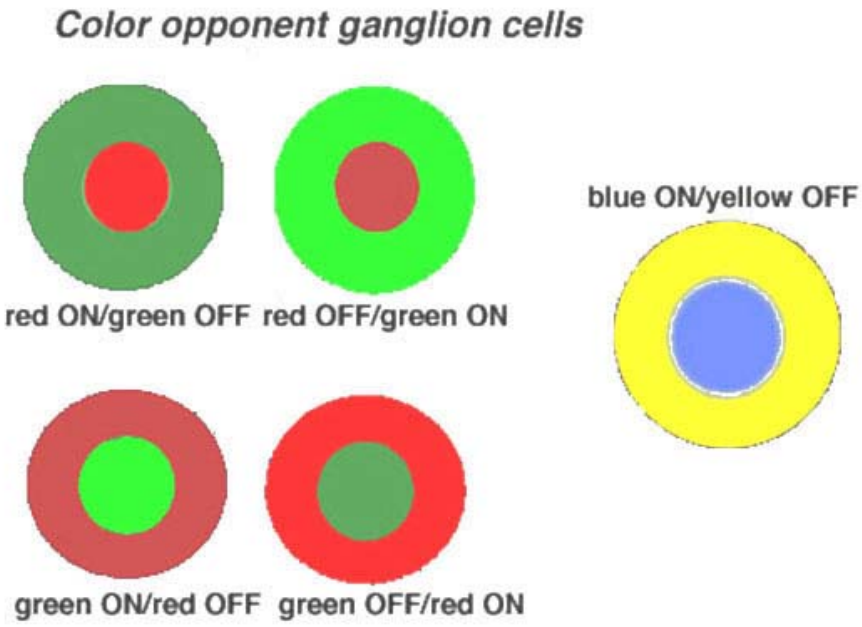
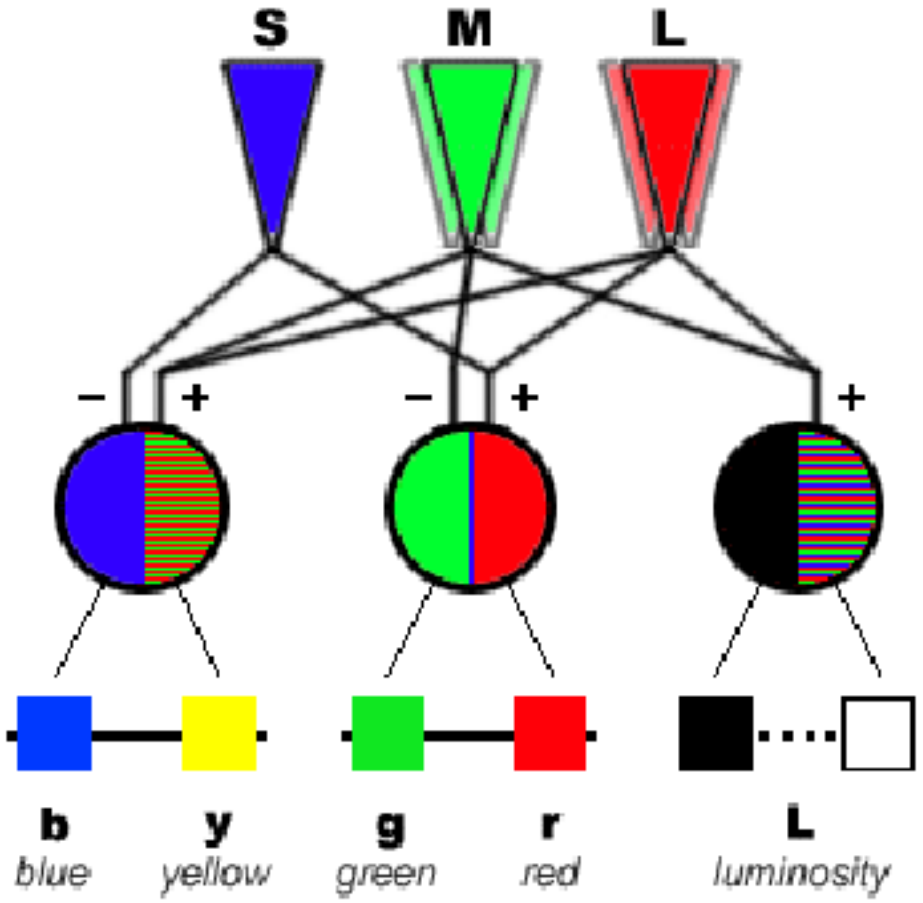


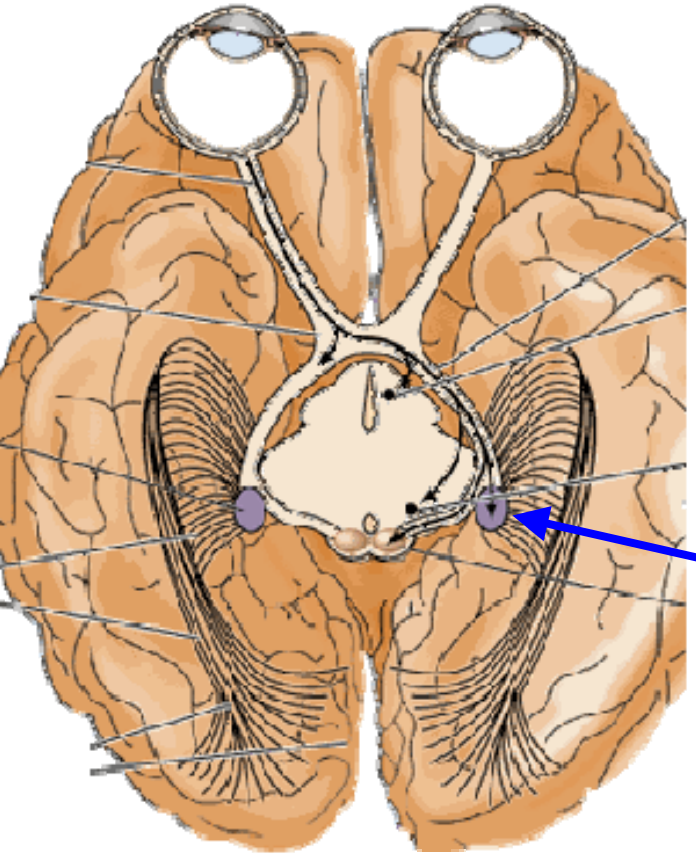
Fig. 22. Summary diagram of midget pathways of the primate retina with center and surround wiring.



Summary of color opponency

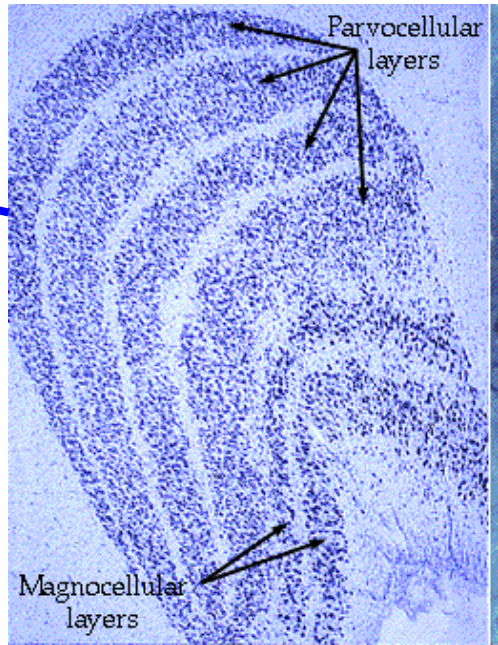


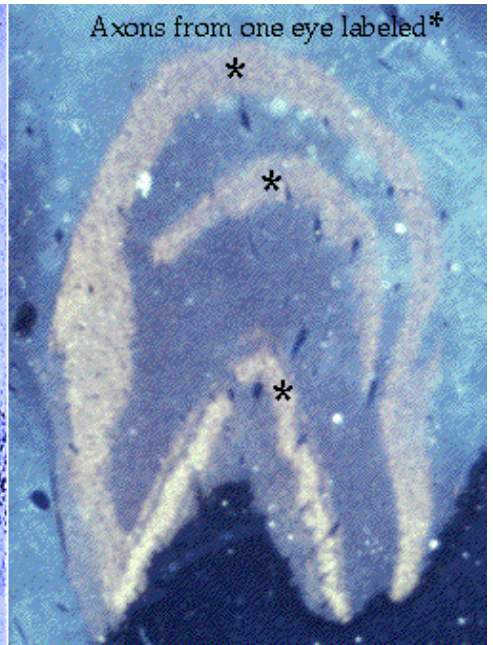
Laterate Geniculate Nucleus LGN:



LGN

- "Switchboard" between retina and visual cortex.
- Exact function unknown
- Retinotopic. Axons from left and right eyes in alternate layers.
- Cells with same spatial angle but different eye adjacent



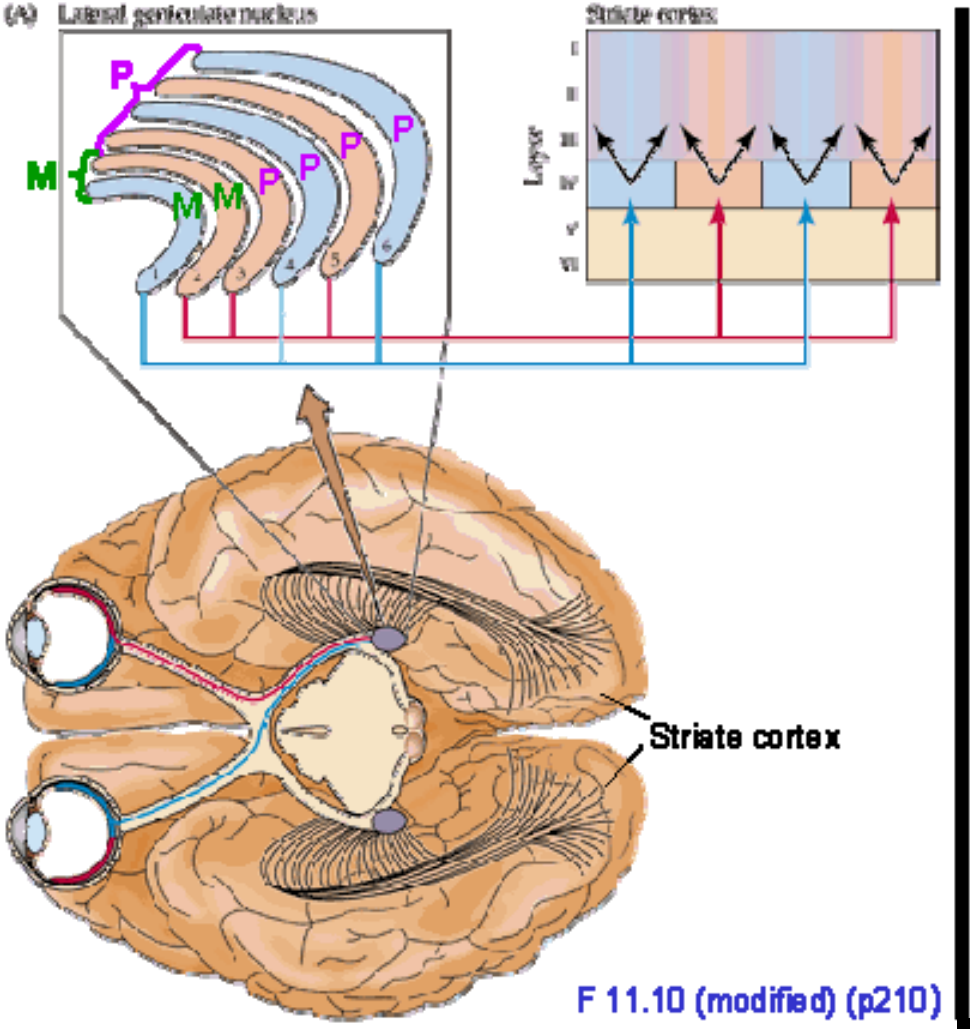


Visual Cortex: P and M cells

Projections of the lateral geniculate nucleus to the striate cortex

Magnocellular layers: 1 & 2 (motion)

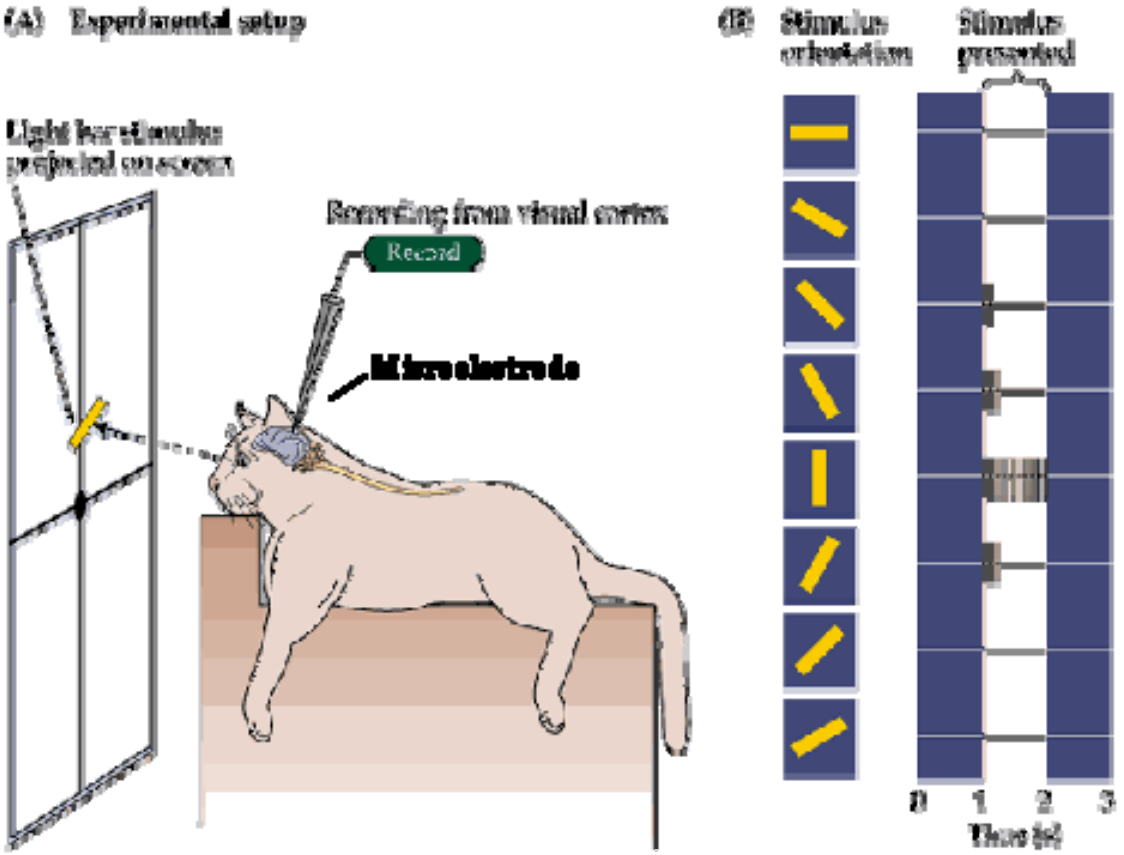
Parvocellular layers: 3 – 6 (form & color)



F 11.10 (modified) (p210)

Simple Cells in V1
Direction sensitive “line finders”??

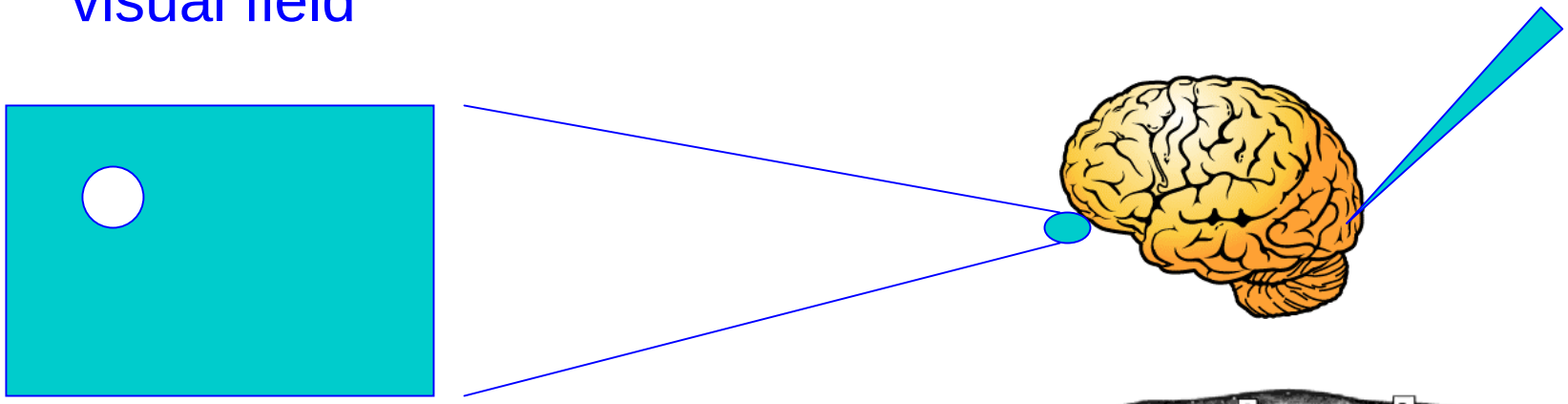
- Responds best to edge segments of particular orientation
- Like convolving image with line filters?!?



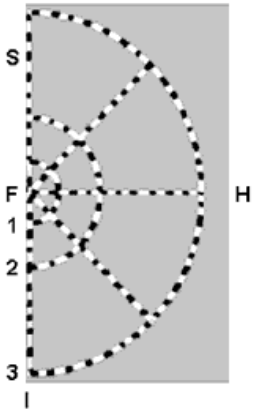
Receptive Field

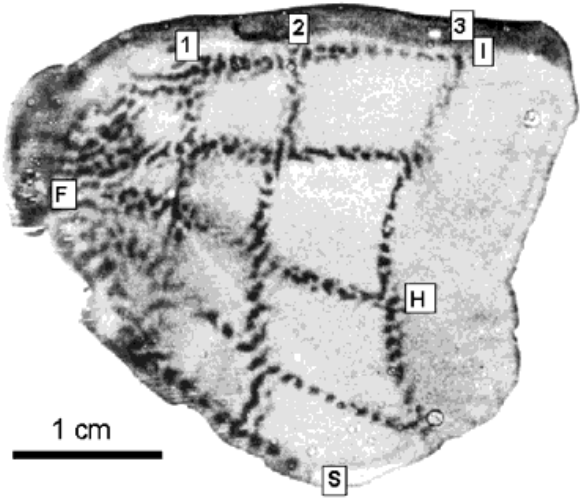
visual field

neuron in V1



Retinotopy



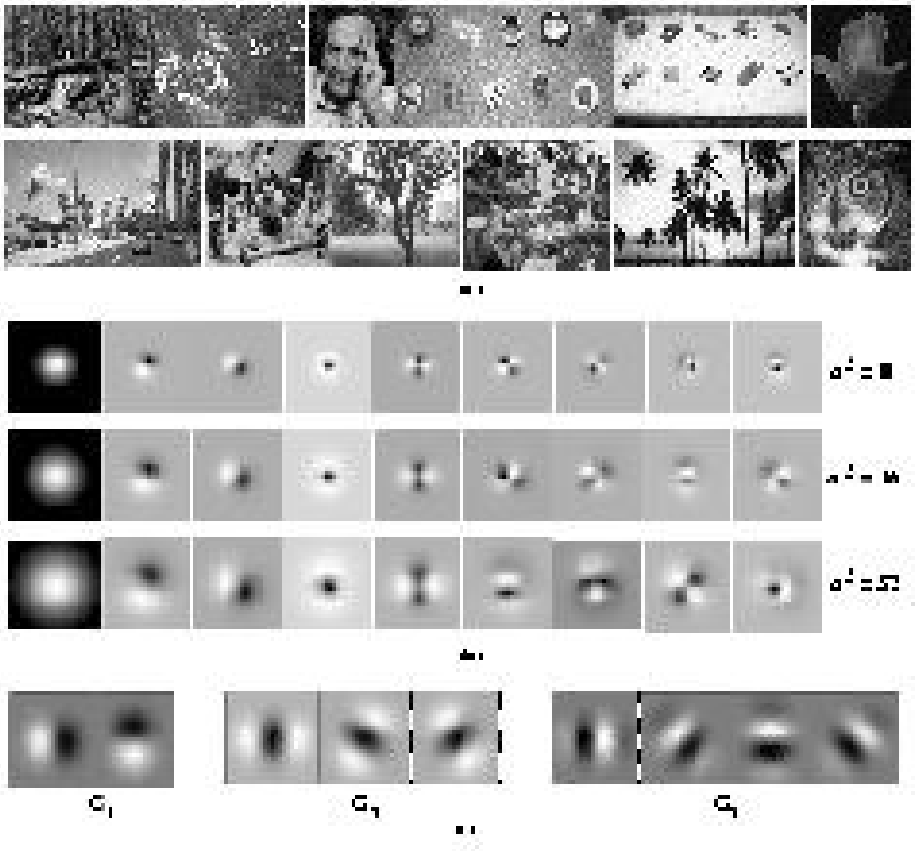


V1 Simple cells
What are they for?

- Spatially localized filters can be found with

1. Many (all needed) orientations.
2. Many scales.

- Perhaps performing localized spatial frequency analysis?



Complex and Hyper-complex cells More cells in V1:

- Complex cells: No specific retinotopic region. Responds to particular orientation or direction over a wide area.
- Hypercomplex cells:End stop. Only responds to a terminating line.

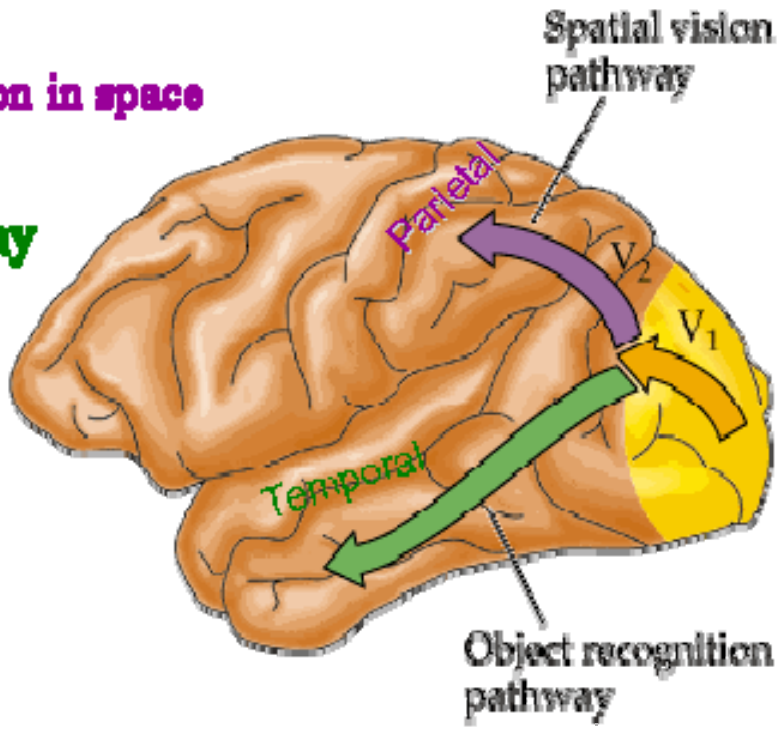
Dorsal and Ventral Pathways Where/What or Action/Perception?

Dorsal (magno) Pathway

- to parietal lobe
- spatial vision – localization in space
- "WHERE"

Ventral (parvo) Pathway

- to temporal lobe
- object recognition
- "WHAT"

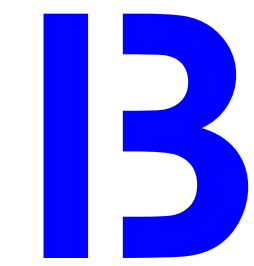


Example responses
Higher cells in the M pathway

- Follower neurons: Responds to particular object moving regardless of where in the visual field.
- Reach neurons: Responds when reaches to contact a specific 3D location.
- Attention neurons: Responds when gaze is directed to a specific object.
- Gaze neurons: Responds when gaze is directed to a specific 3D location.

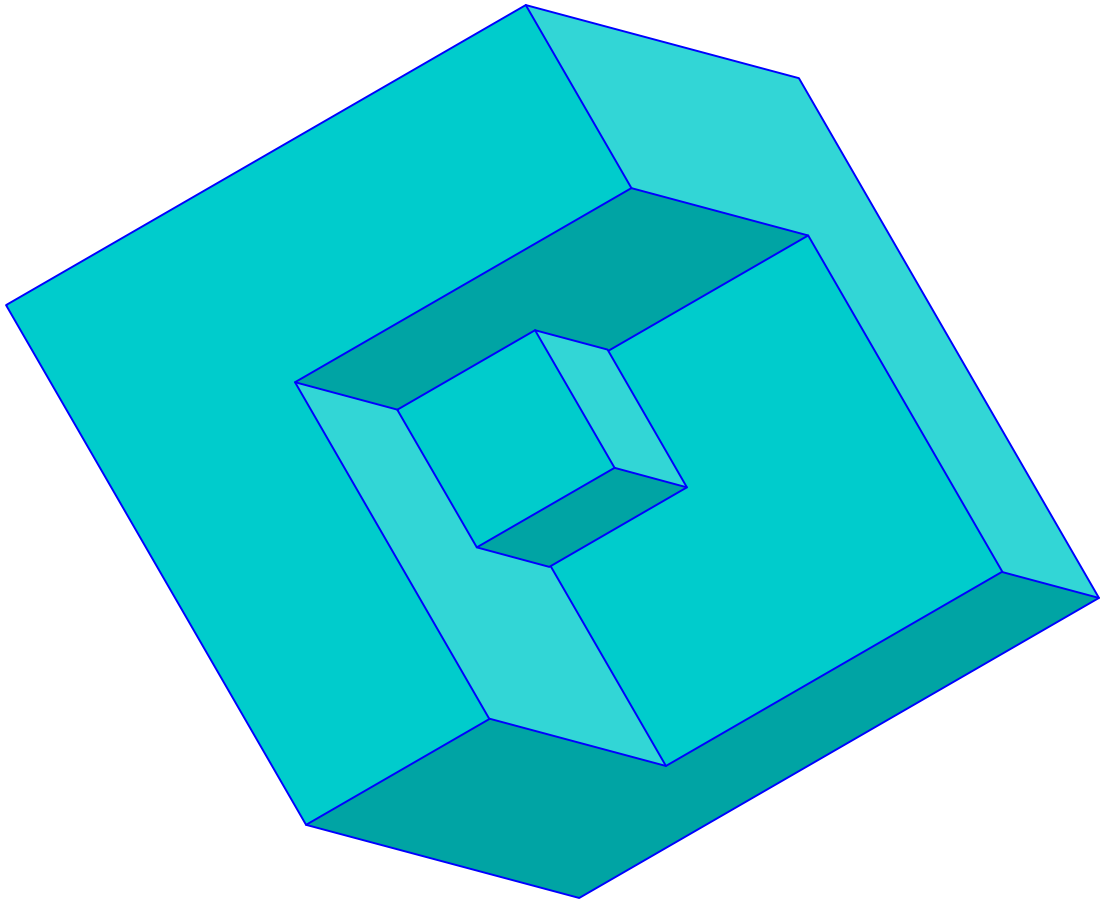
Kaniza triangle

A stimulus in context



B or 13?

Only reasonable 3D interpretations come to mind….



Change blindness

What does this say about our perception and memory of the world?

Get Ready…

I’m going to show you a picture

and I want you to **remember** it!

(you’ll have 3 seconds)

Which One Did You See?

A

B

C

D

Which One Did You See?

correct answer

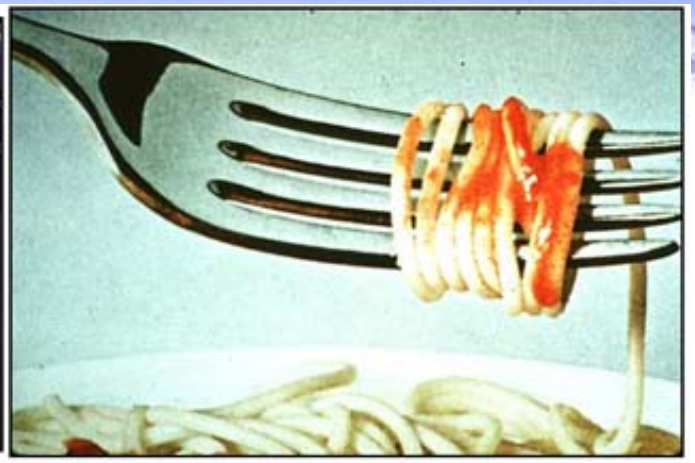
A **B** **C** **D**

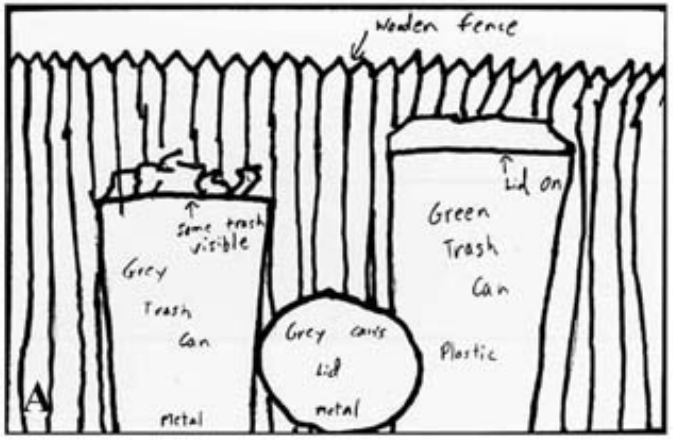


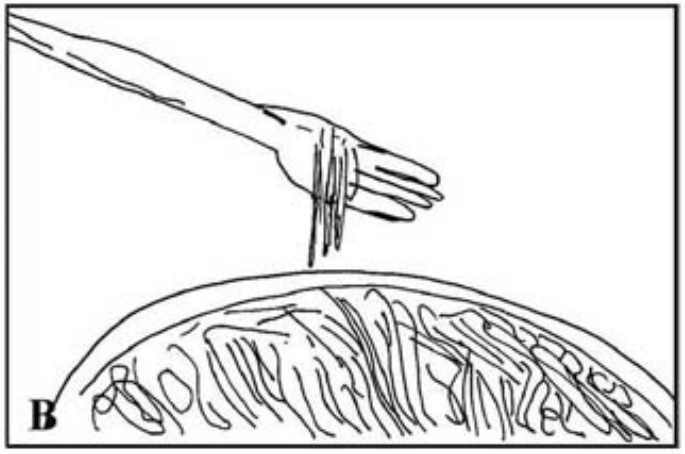

too close ⟷ **too far**

Boundary Effect

Background







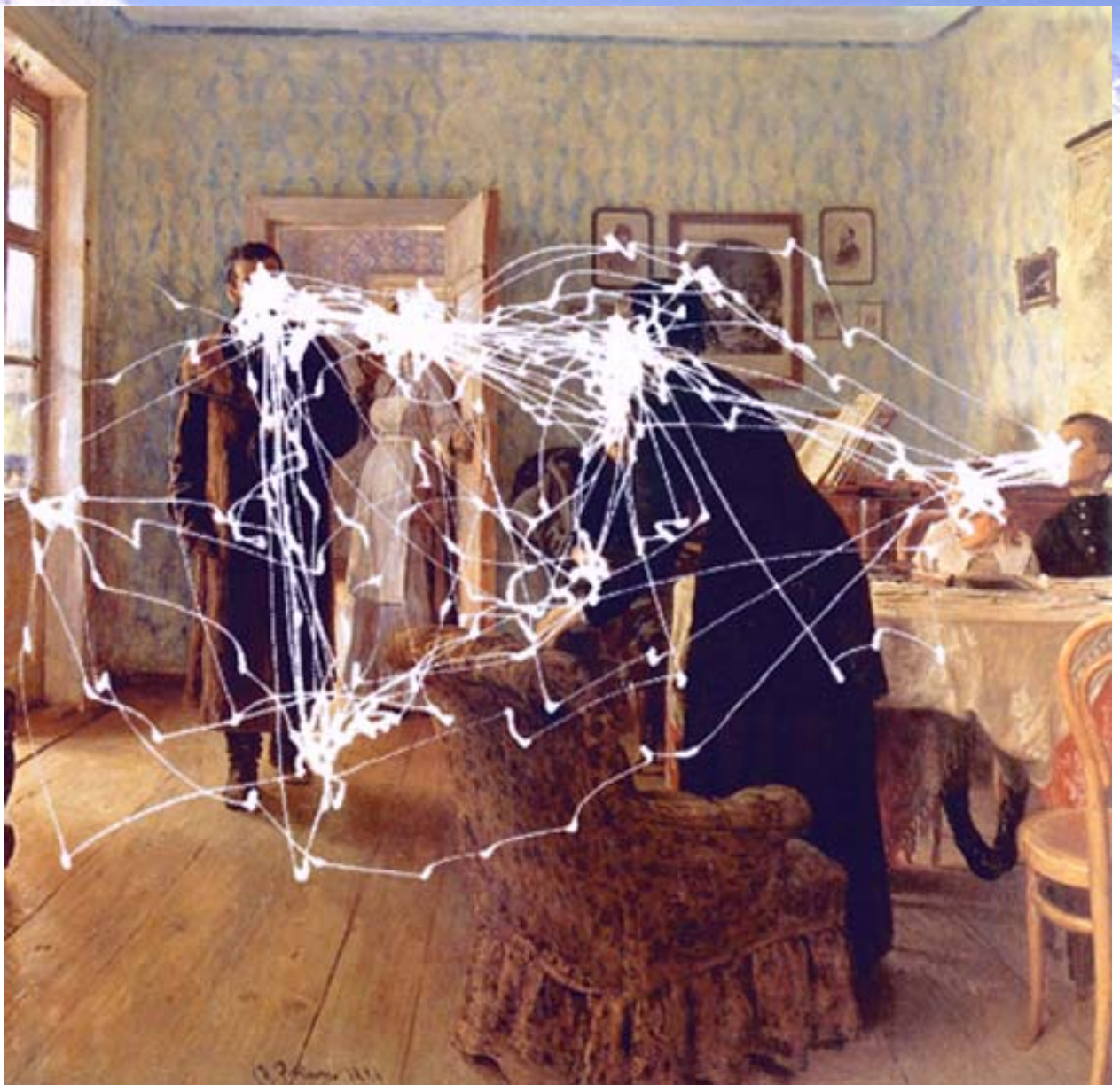
Intraub and Richardson (1989)
Intraub and Bodamer (1993)
Intraub (2002)
Bertamini (2005)

Attention


WINDSOR CAPITAL
KITCHENS Plus
1-800-466-6093
CABO VERDE APARTMENTS
GIANT SALE

Attention

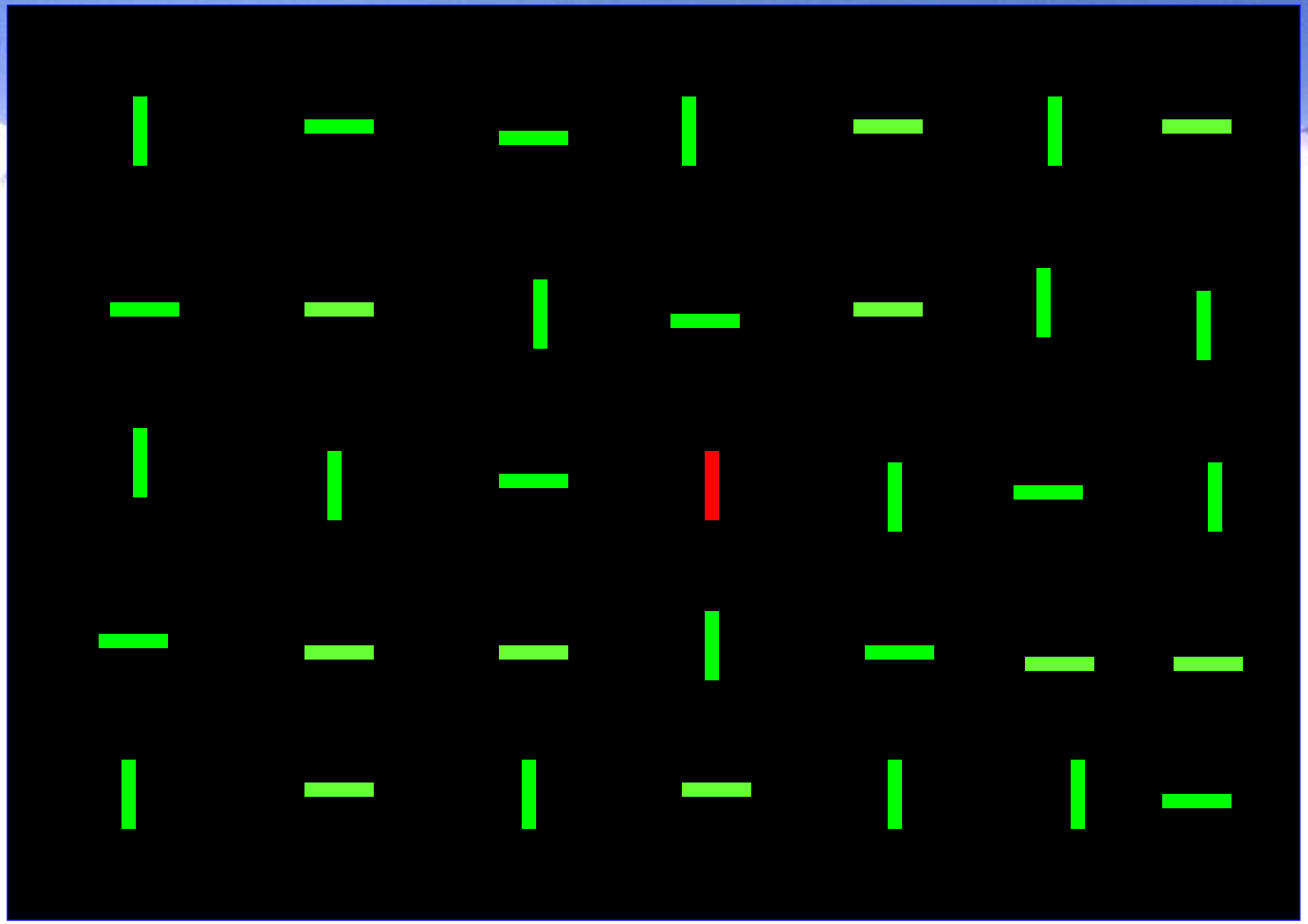
Attention



Yarbus
1967

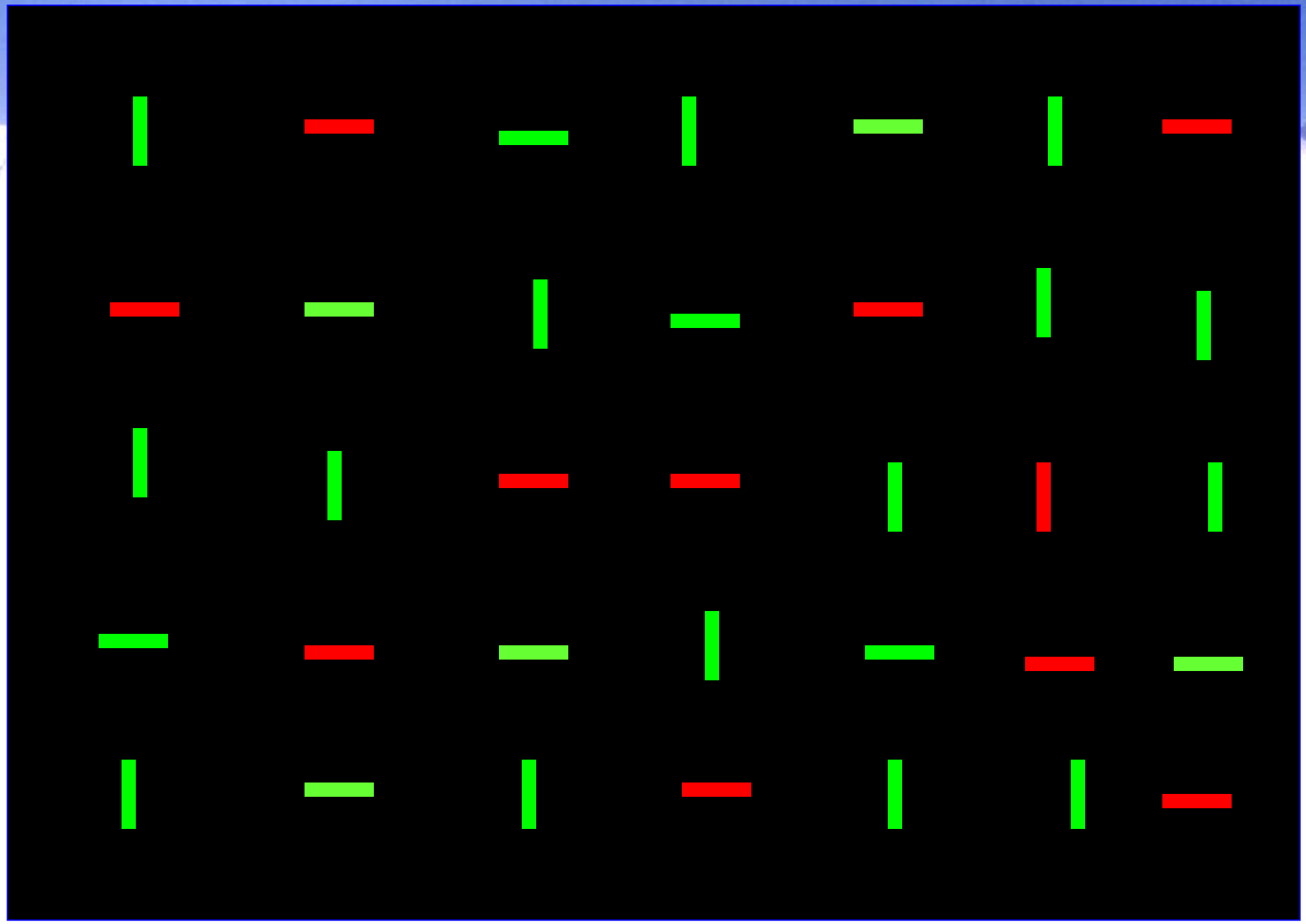
Visual Search

Search for the red vertical



Pretty easy.

Search for the red vertical again

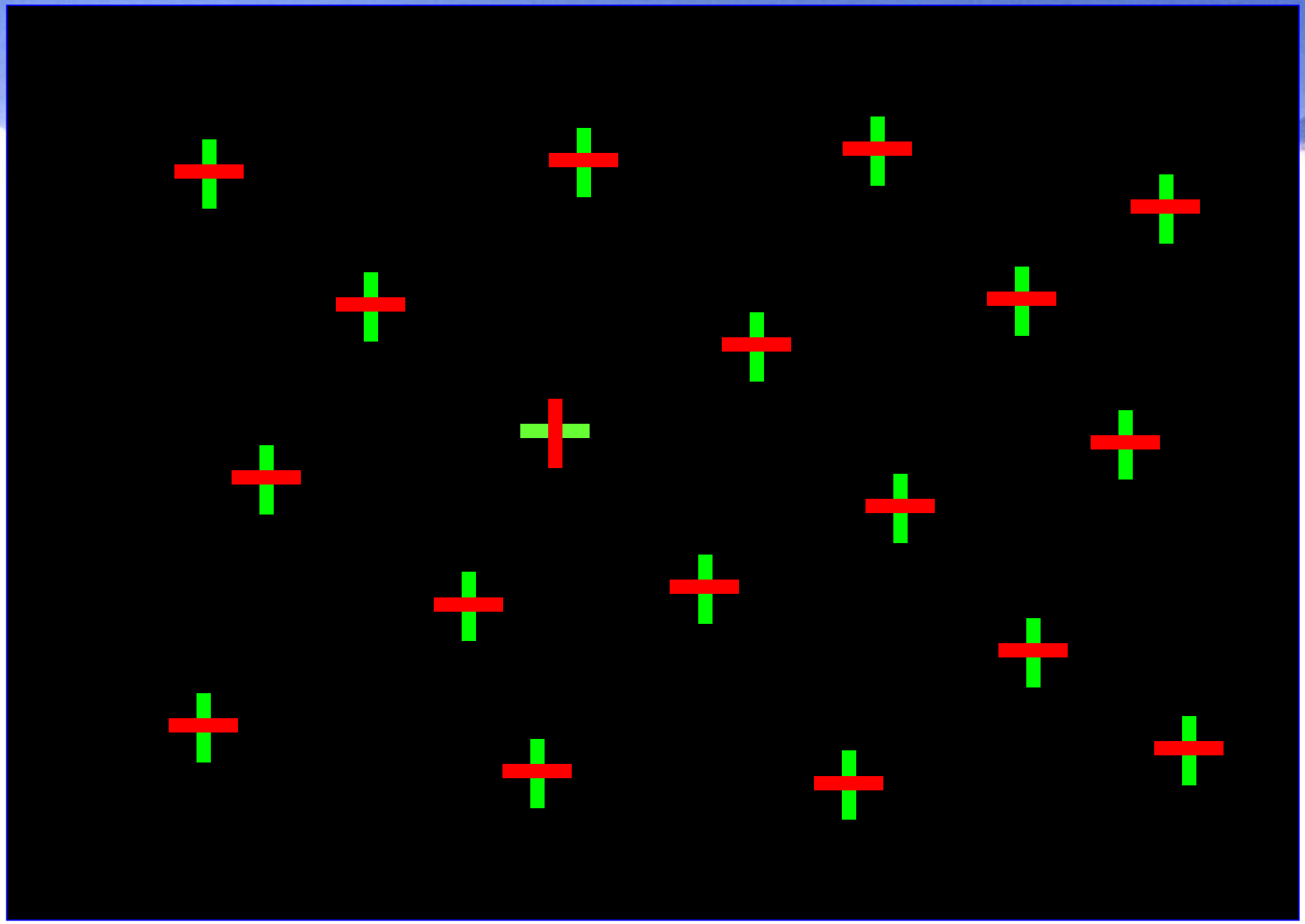


Harder?

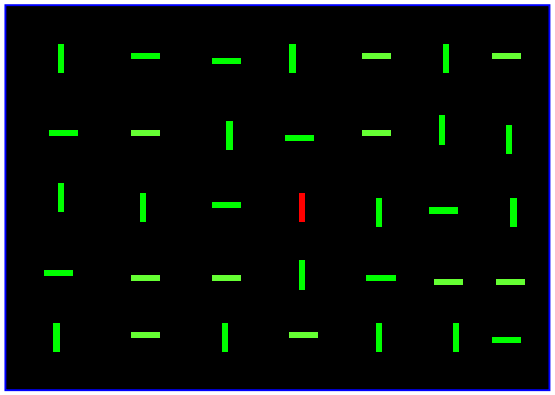
Guiding attention by color… pretty easy

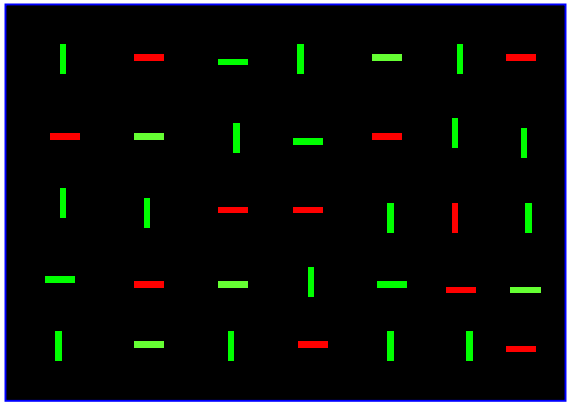
Guiding attention by color AND orientation, more difficult

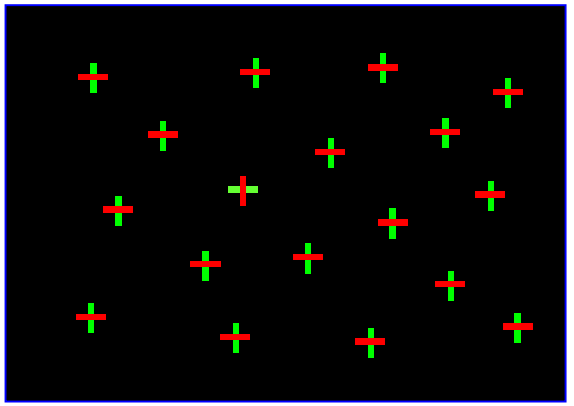
one more time, find the red vertical

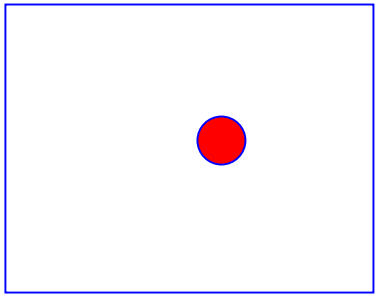


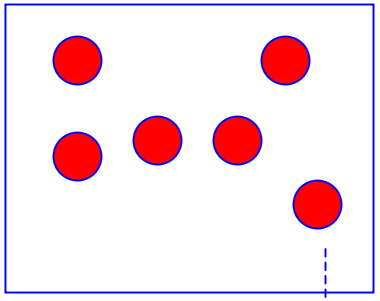
How do we explain this?
feature maps

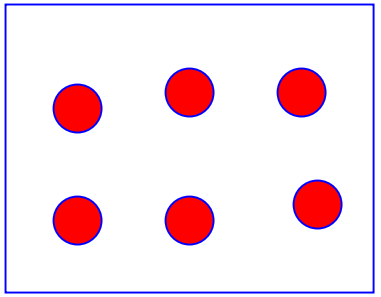


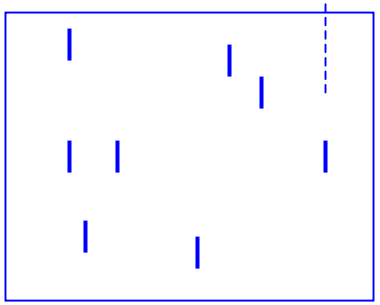


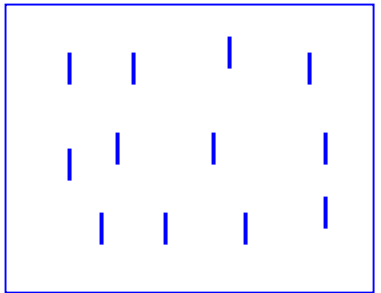












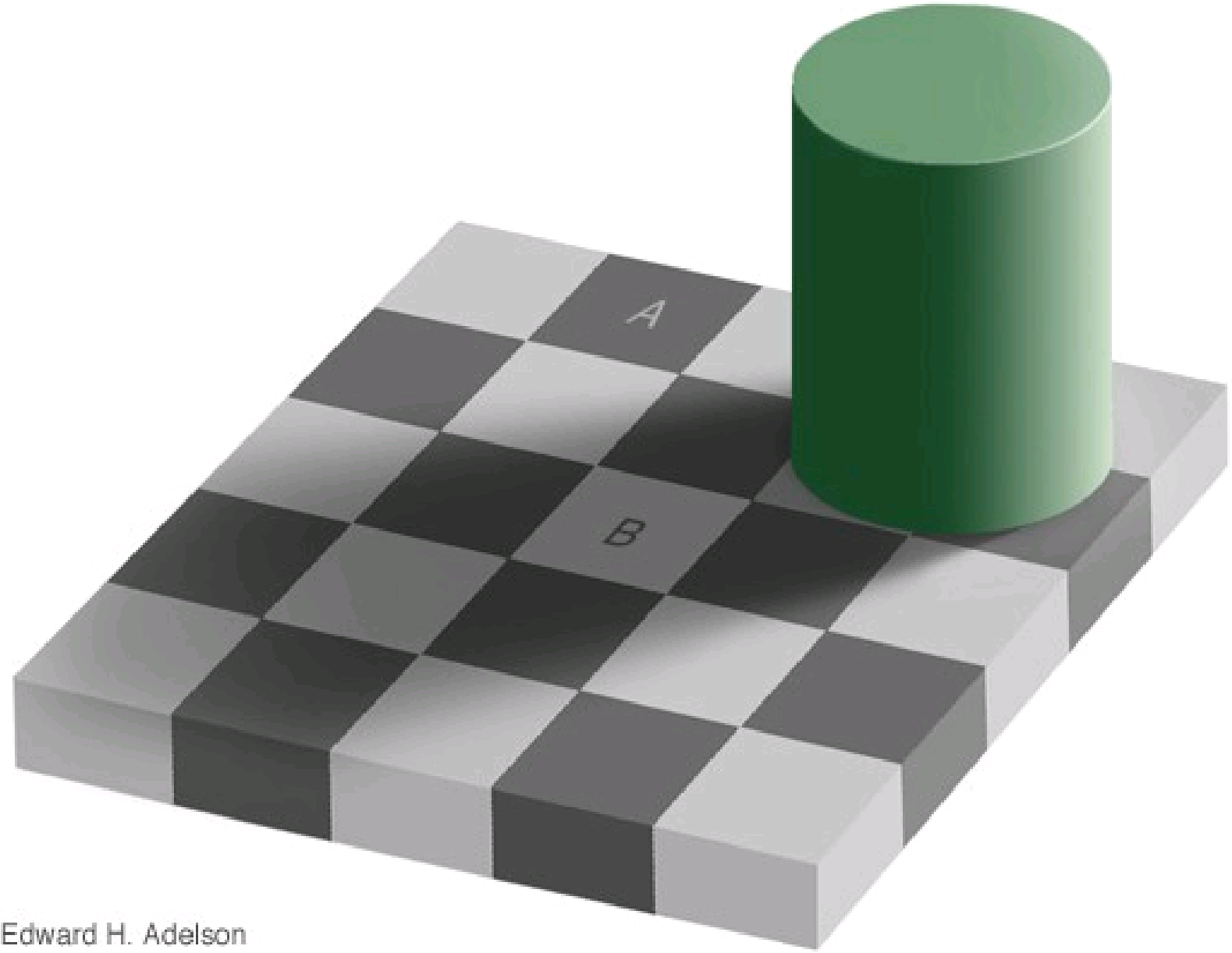
Bottom-up

“pop-out” processing

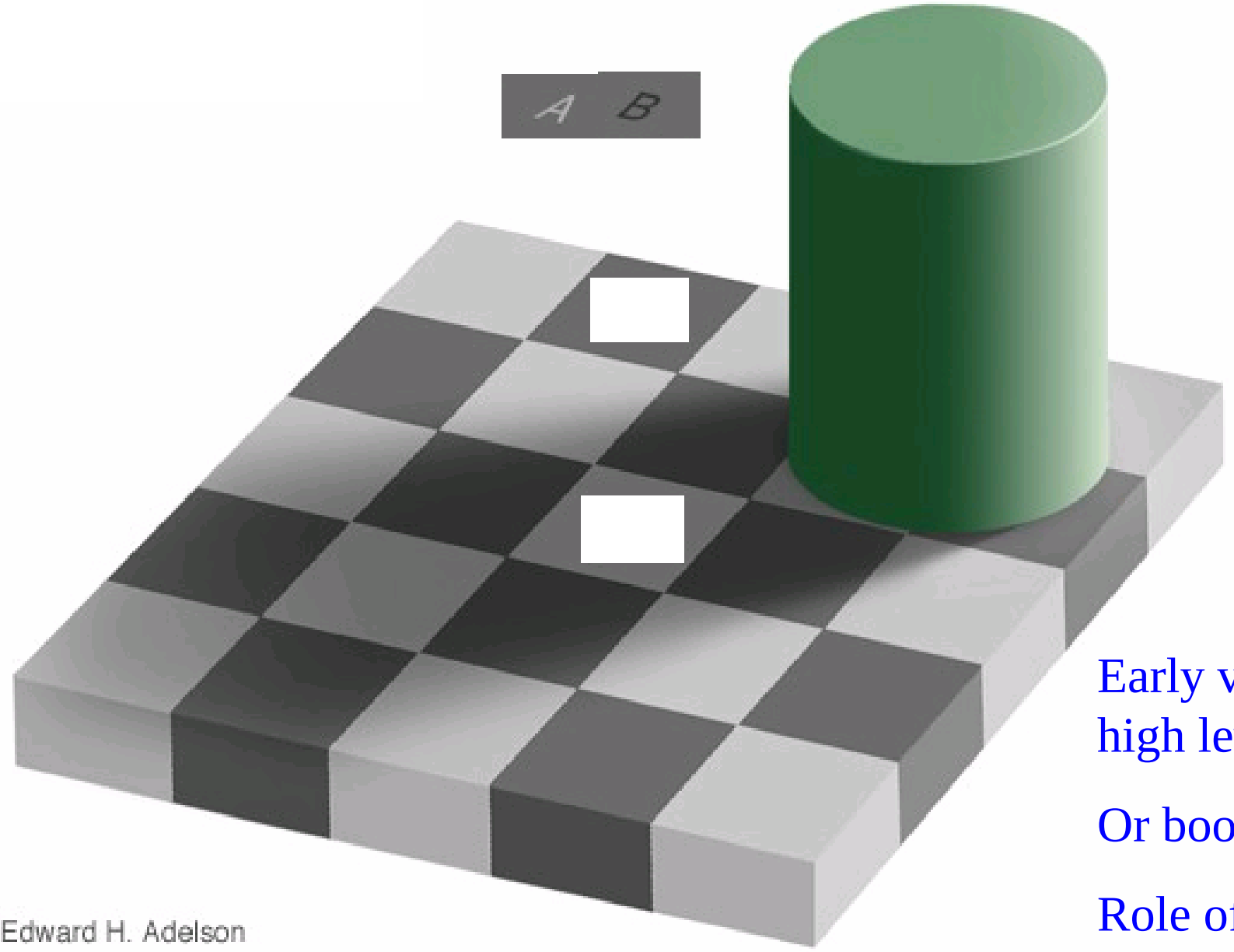
(Anne Treisman)

Bio motion
(Gestalt, or expectations?)

- http://www.biomotionlab.ca/Demos/BMLwalker.html



Edward H. Adelson



Edward H. Adelson

Early vision or high level?

Or booth?

Role of feedback

Conclusions: Biological vision

- The visual system provides researchers with a window into the brain.
- A fair amount is known about the eye, retina and early retinotopic areas like striate cortex (V1).
- Less is known about the function of higher areas.

Questi