Lecture 8
Vision II

PSYC 304

Announcements

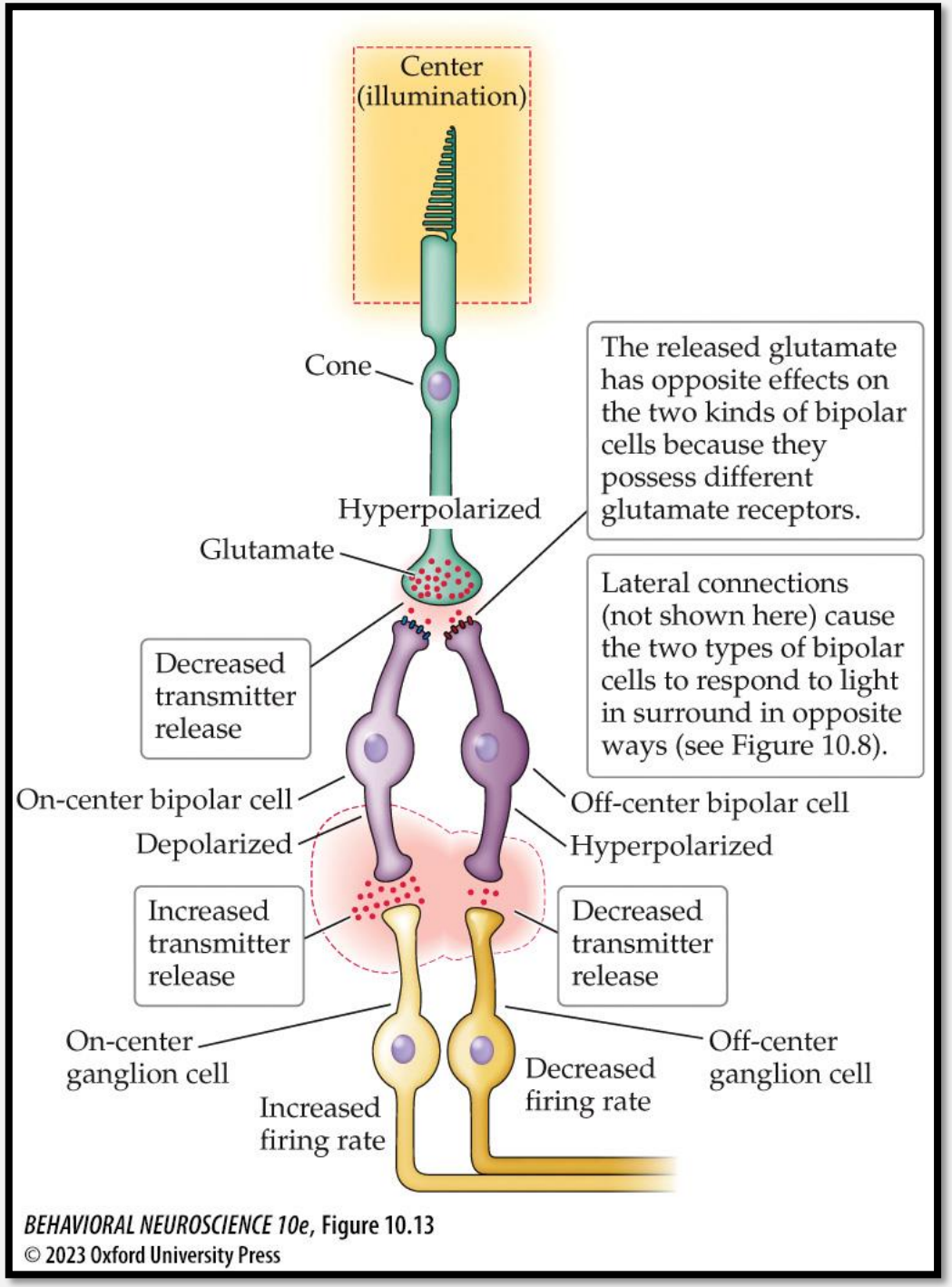
RC 2

- Next class! At the end of class.
- *Presentations due Friday 11:59pm*

Final exam

- June 26, 2026
- ***Swing floor 1 Room 121***
- ***7:00 PM***

Review


Center (illumination)
Cone
Hyperpolarized
Glutamate
The released glutamate has opposite effects on the two kinds of bipolar cells because they possess different glutamate receptors.
Lateral connections (not shown here) cause the two types of bipolar cells to respond to light in surround in opposite ways (see Figure 10.8).
Decreased transmitter release
On-center bipolar cell
Off-center bipolar cell
Depolarized
Hyperpolarized
Increased transmitter release
Decreased transmitter release
On-center ganglion cell
Off-center ganglion cell
Increased firing rate
Decreased firing rate
BEHAVIORAL NEUROSCIENCE 10e, Figure 10.13
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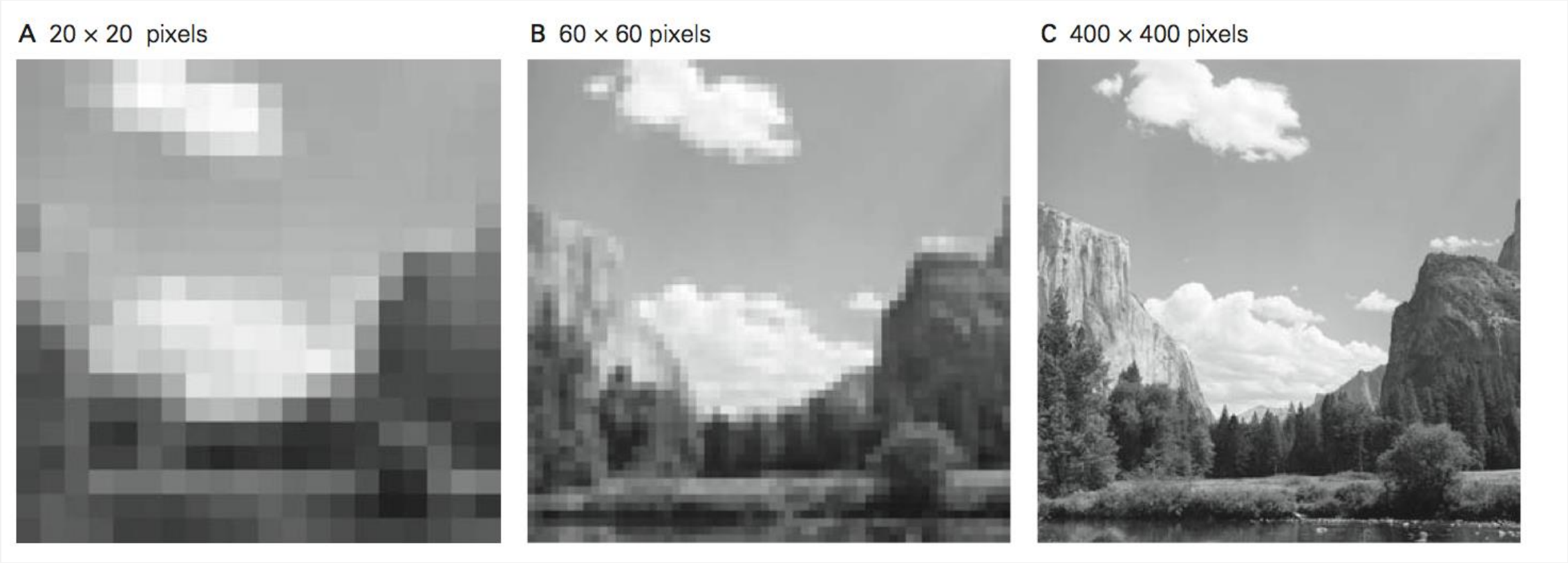
Receptive Field size – digital analogy



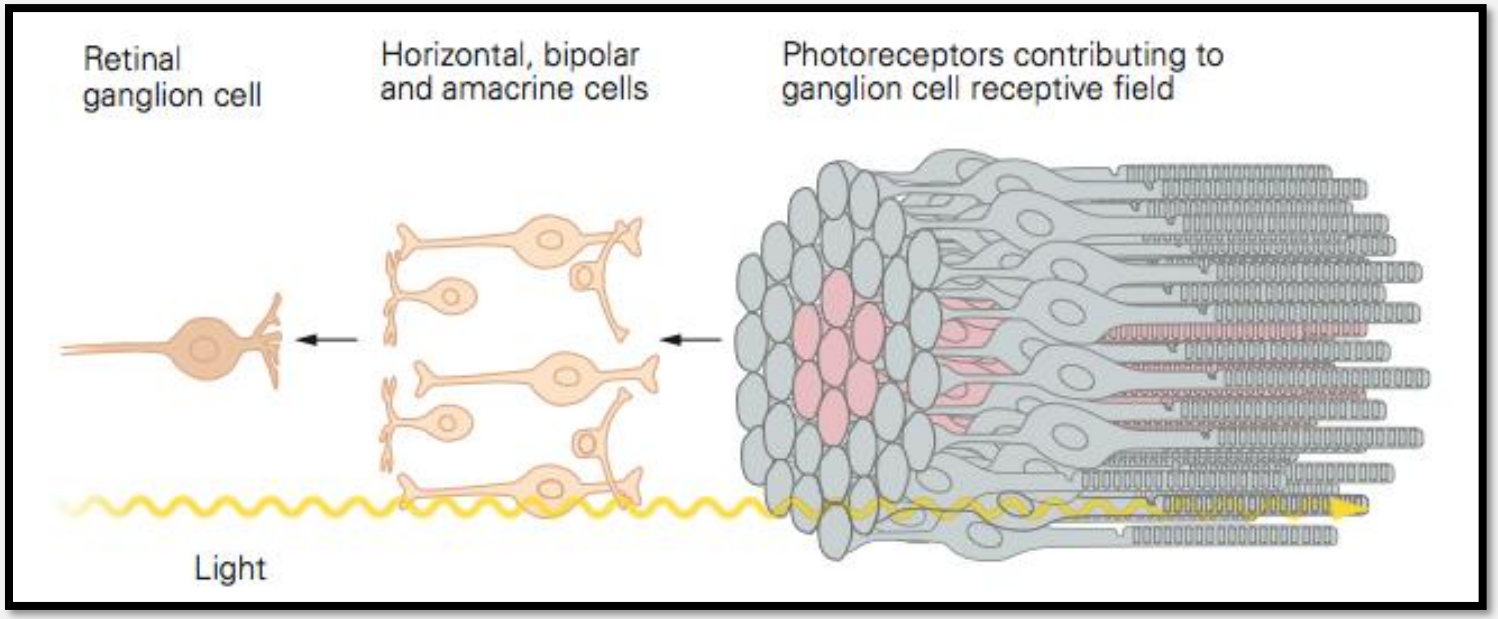
periphery

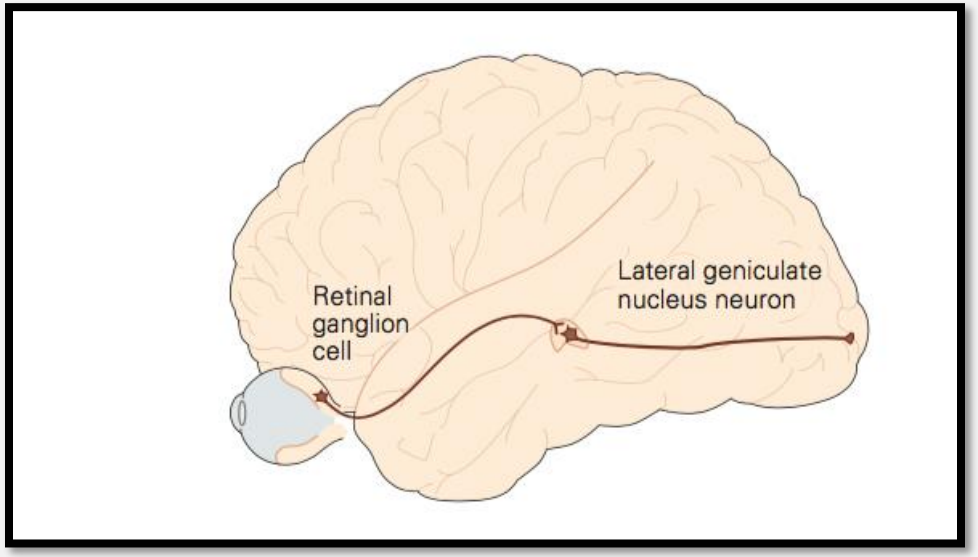
fovea

Kandel Fig 21-10

Ganglion cells – On-center receptive fields

On-center receptive fields

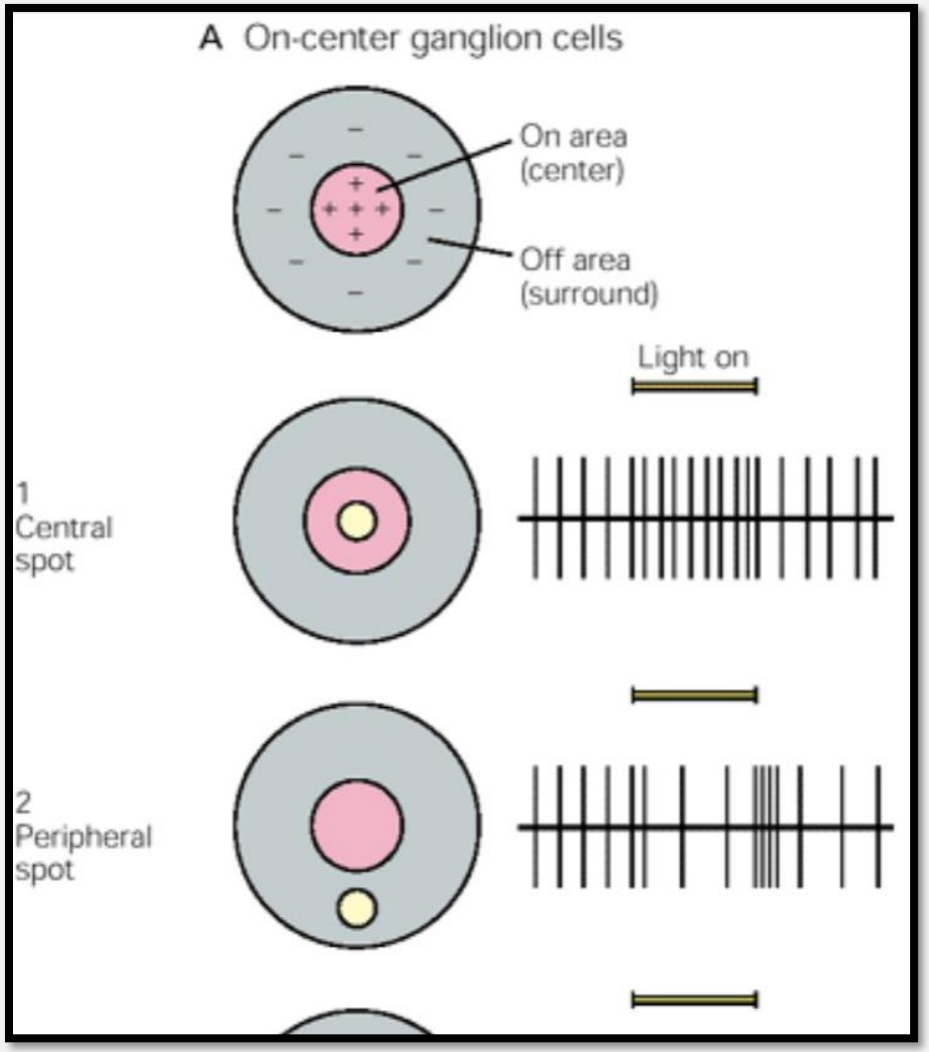


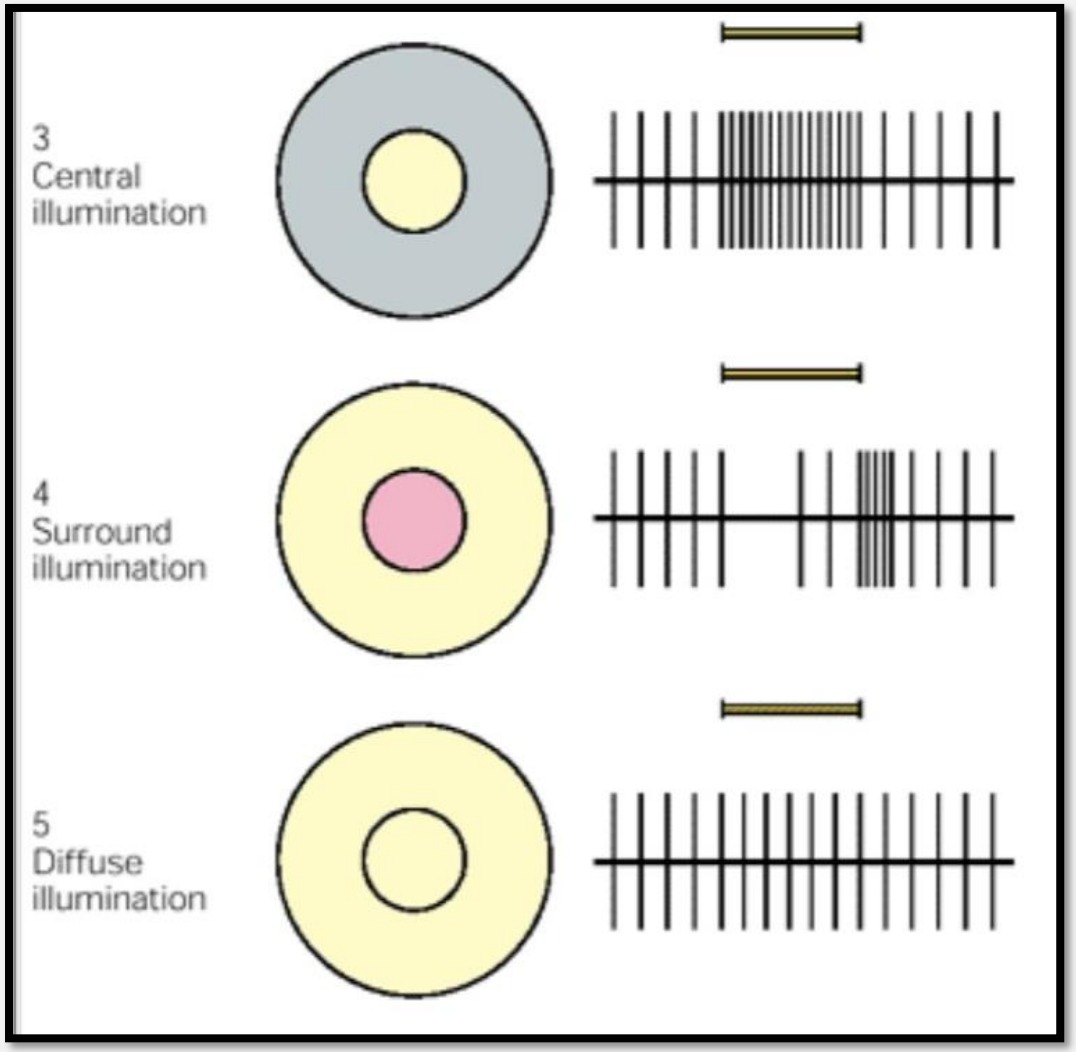


- Receptive fields – circular, smaller for the foveal portion, larger in periphery
- Often have both an excitatory region and inhibitory region

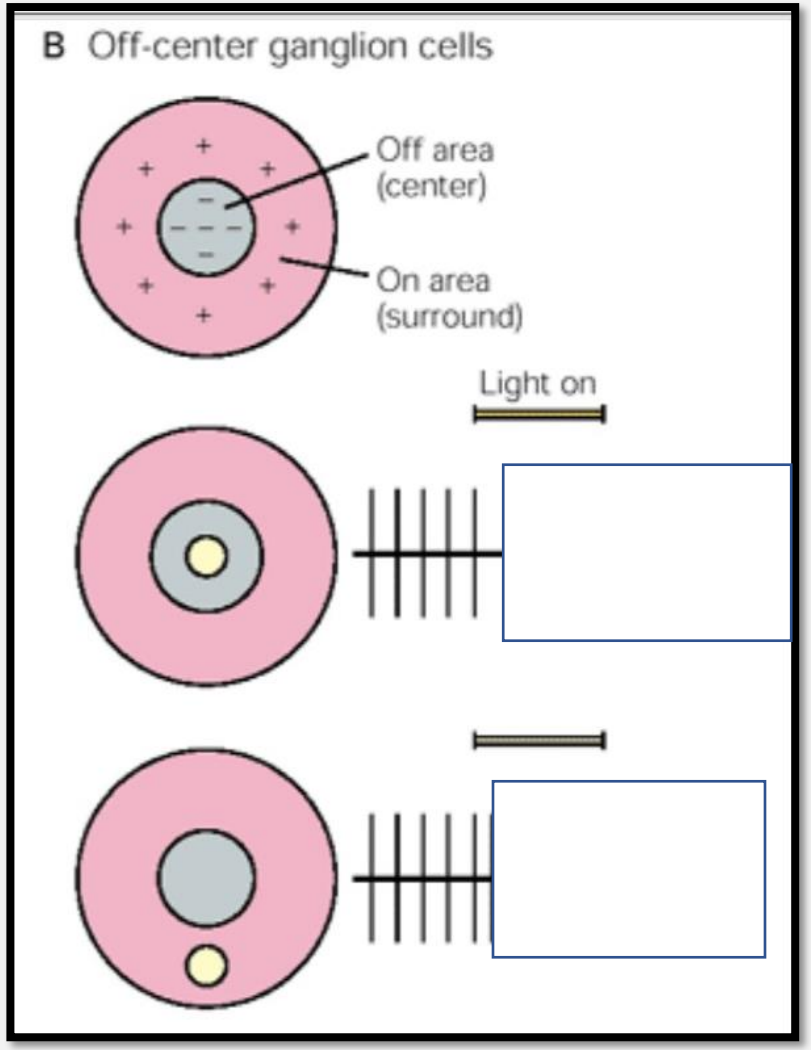
Kandel Fig 25-9

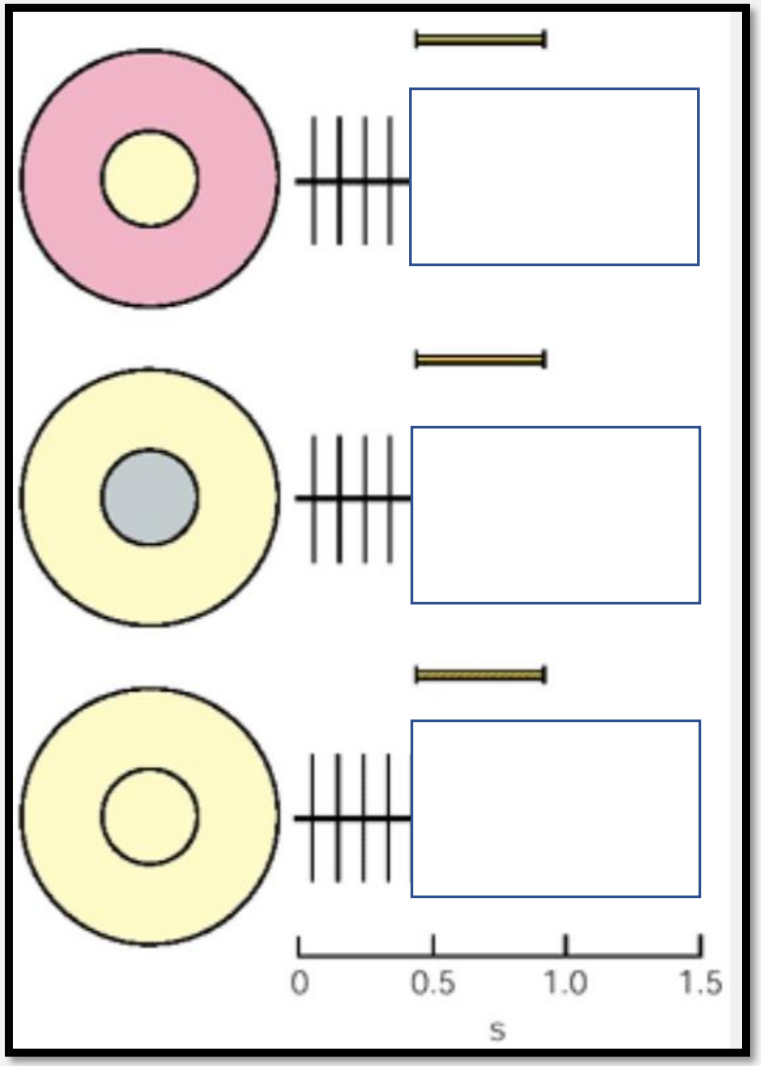
Receptive fields – Retinal Ganglion cells





Receptive fields – Off Center RGCs





Question?

- How can the same light, which causes the same graded response in a photoreceptor, which all release the same neurotransmitter (glutamate), have excitatory and inhibitory effects?

Bipolar Cells

"On" bipolar cells

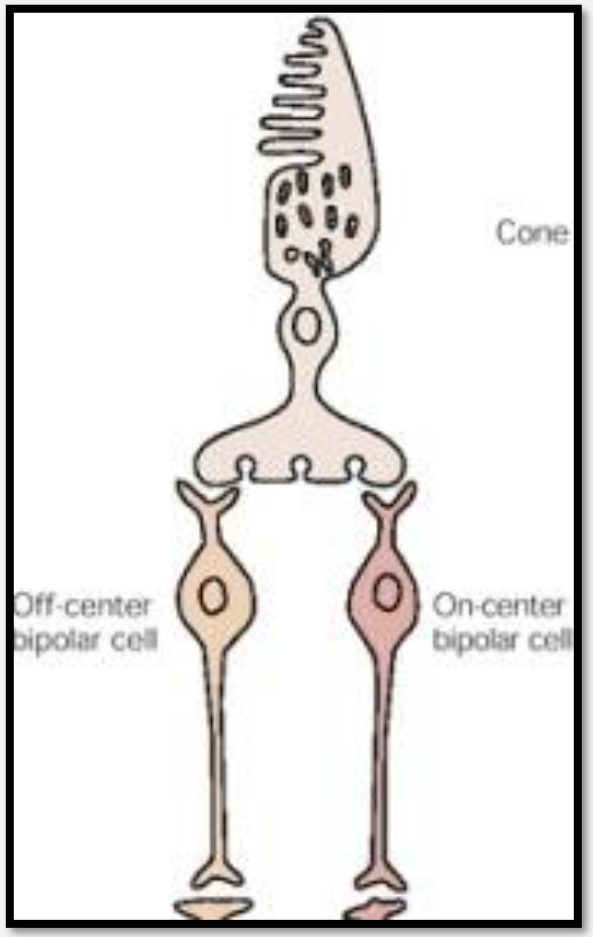
- Metabotropic Glutamate Receptors (mGluR)

In dark

- Continuous Glu release from photoreceptor hyperpolarizes the cell

Add light

- Add light – less Glutamate release from photoreceptors
- Depolarization effect



"Off" bipolar cells

- Ligand gated ionotropic glutamate receptors

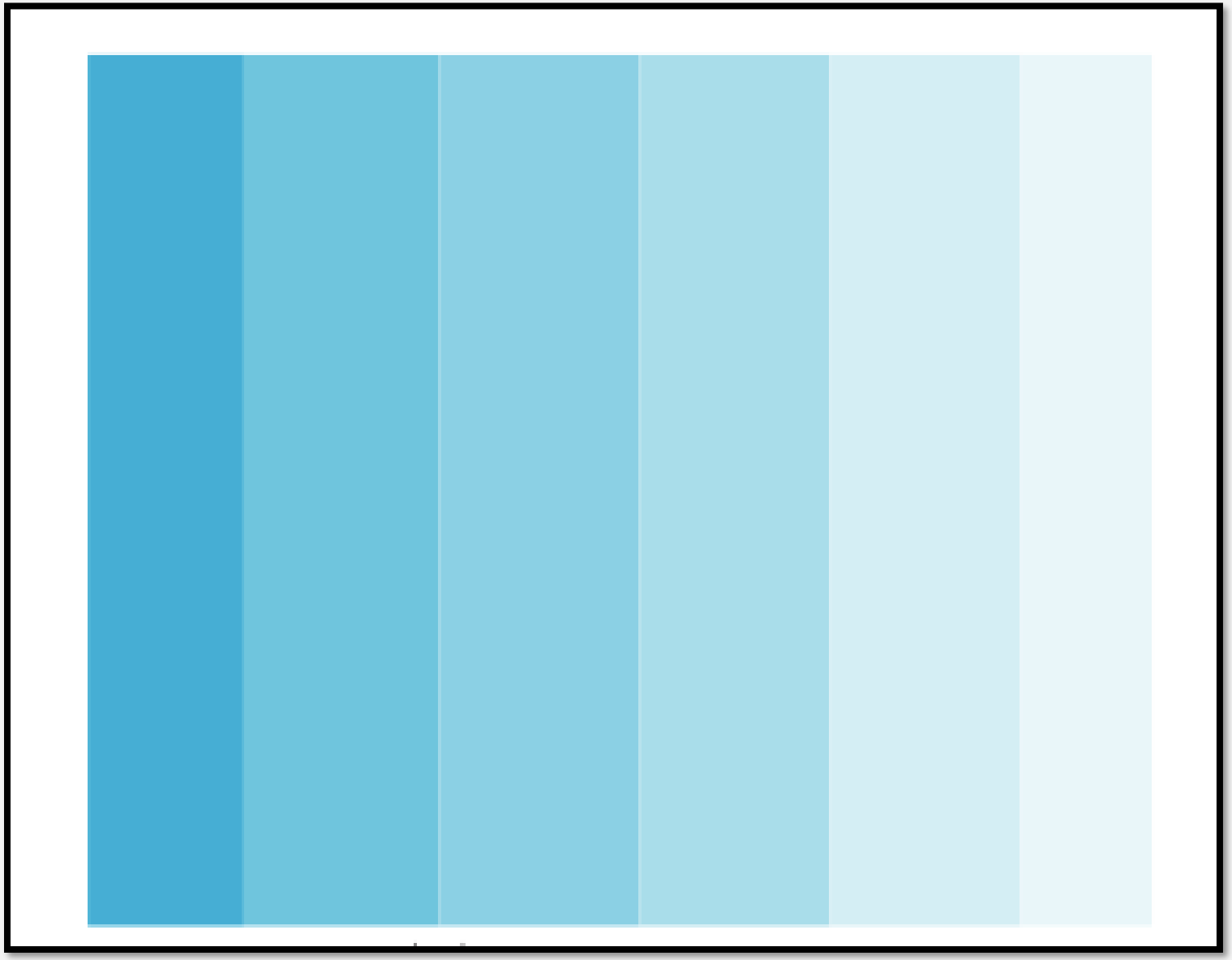
In dark

- Glutamate binds – opens cation channels – depolarizes the cell

Add light

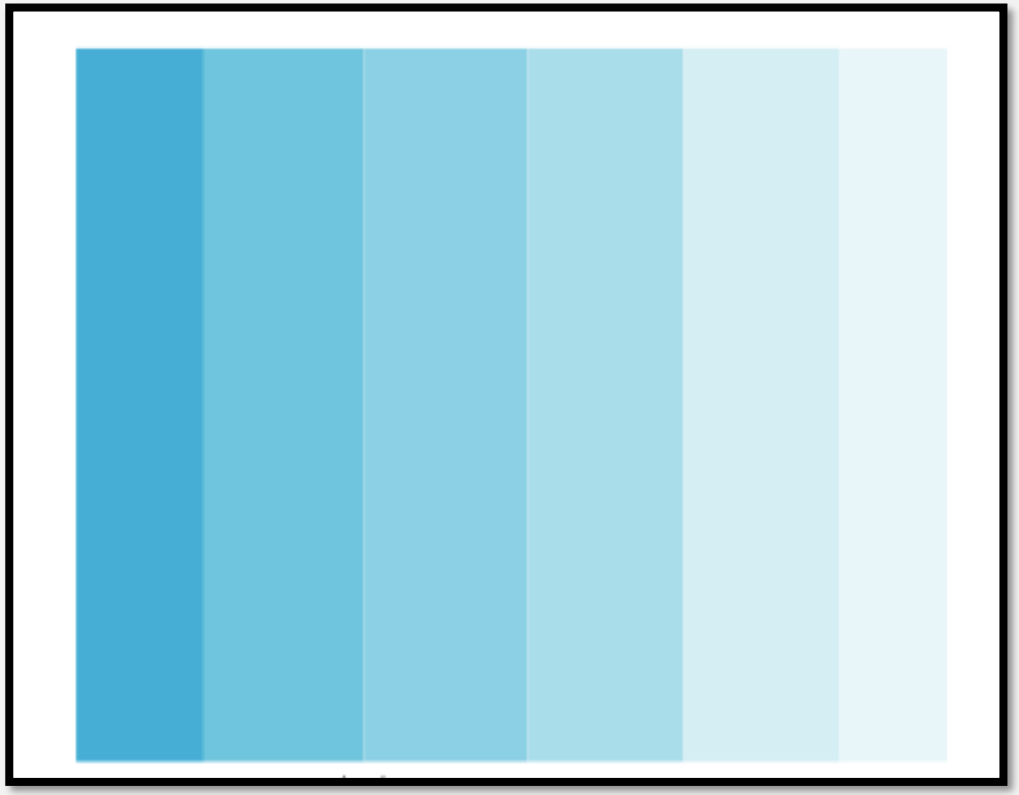
- Less glutamate release from photoreceptors – less bound ionotropic receptors, cell becomes more hyperpolarized

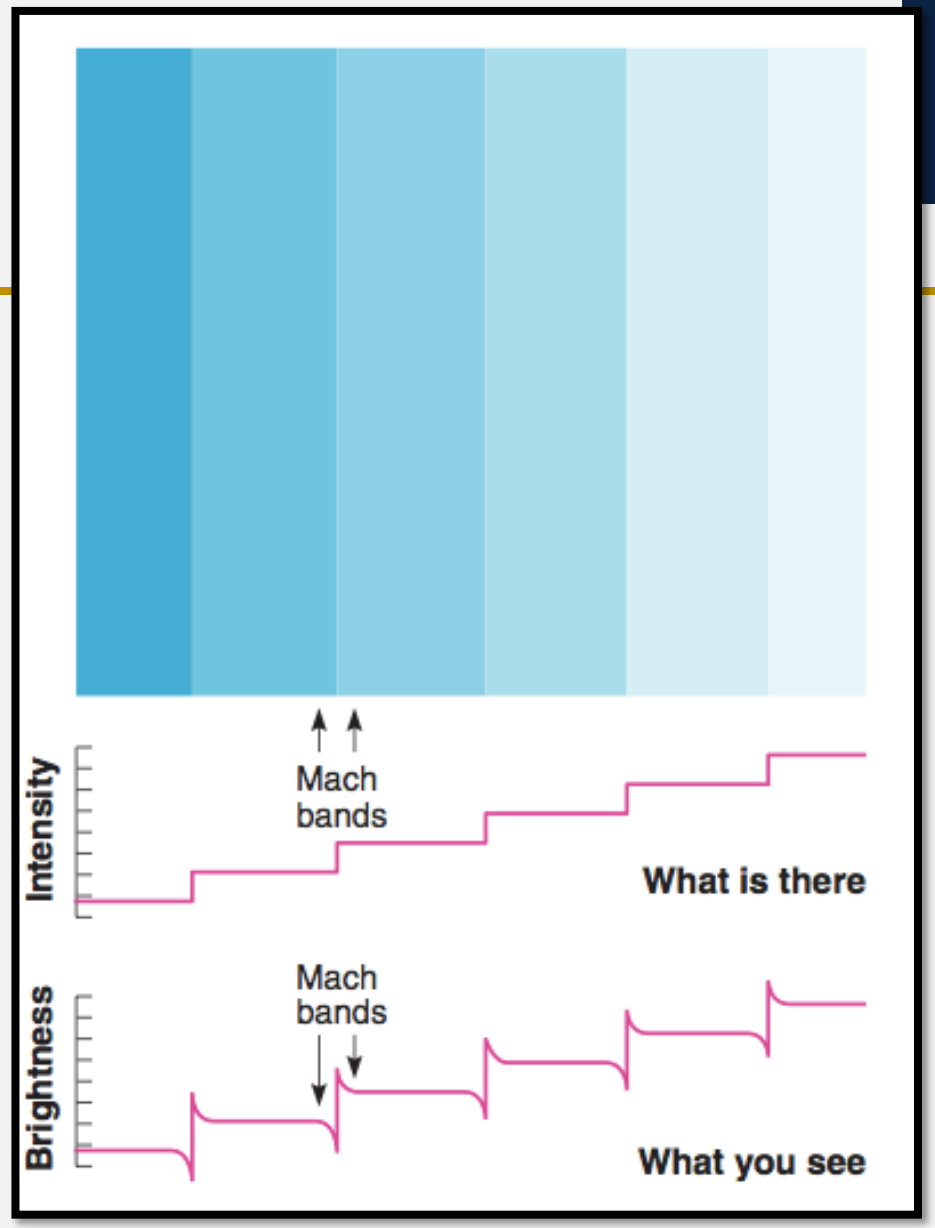
What do you see?



Lateral inhibition

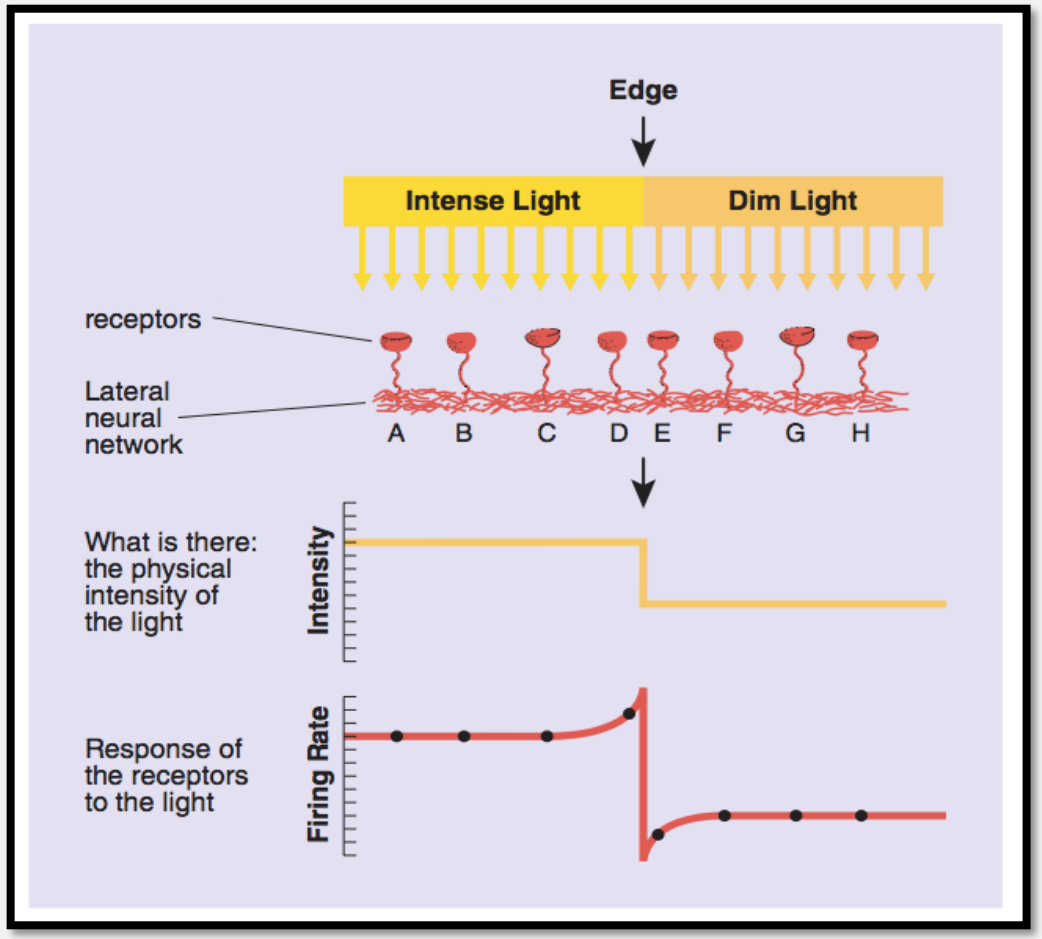
Contrast enhancement

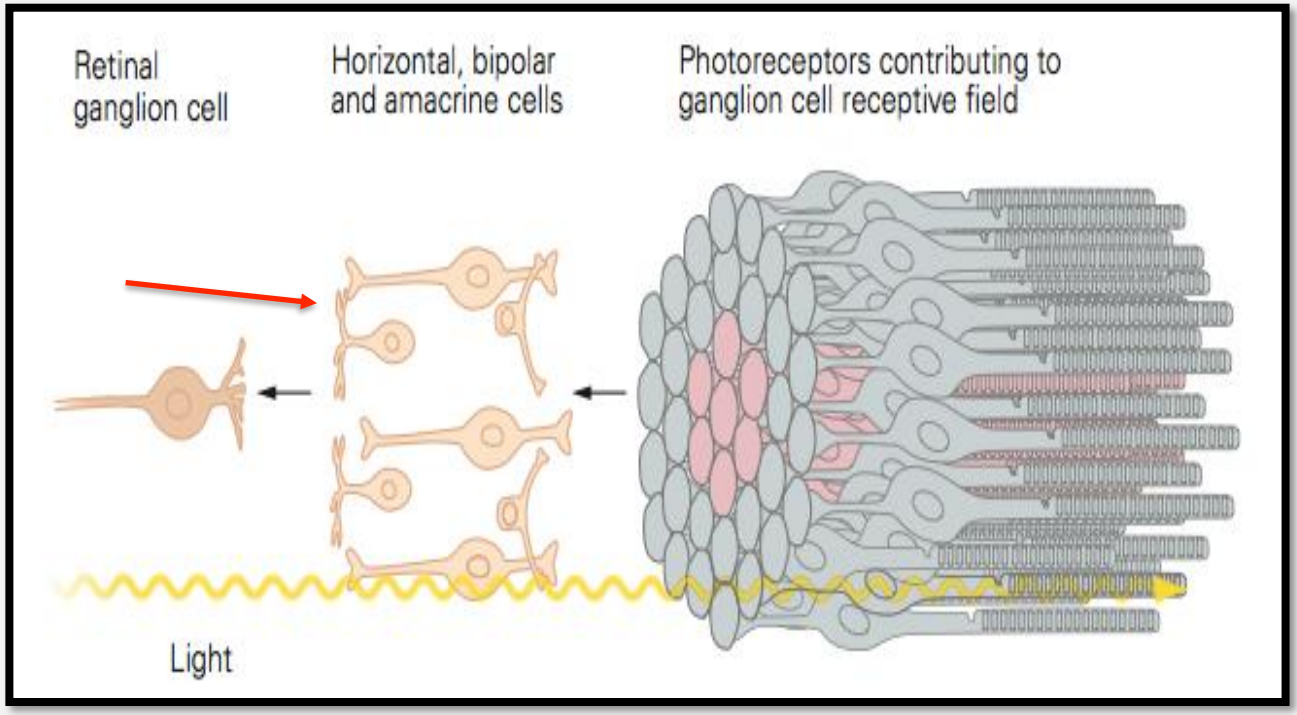




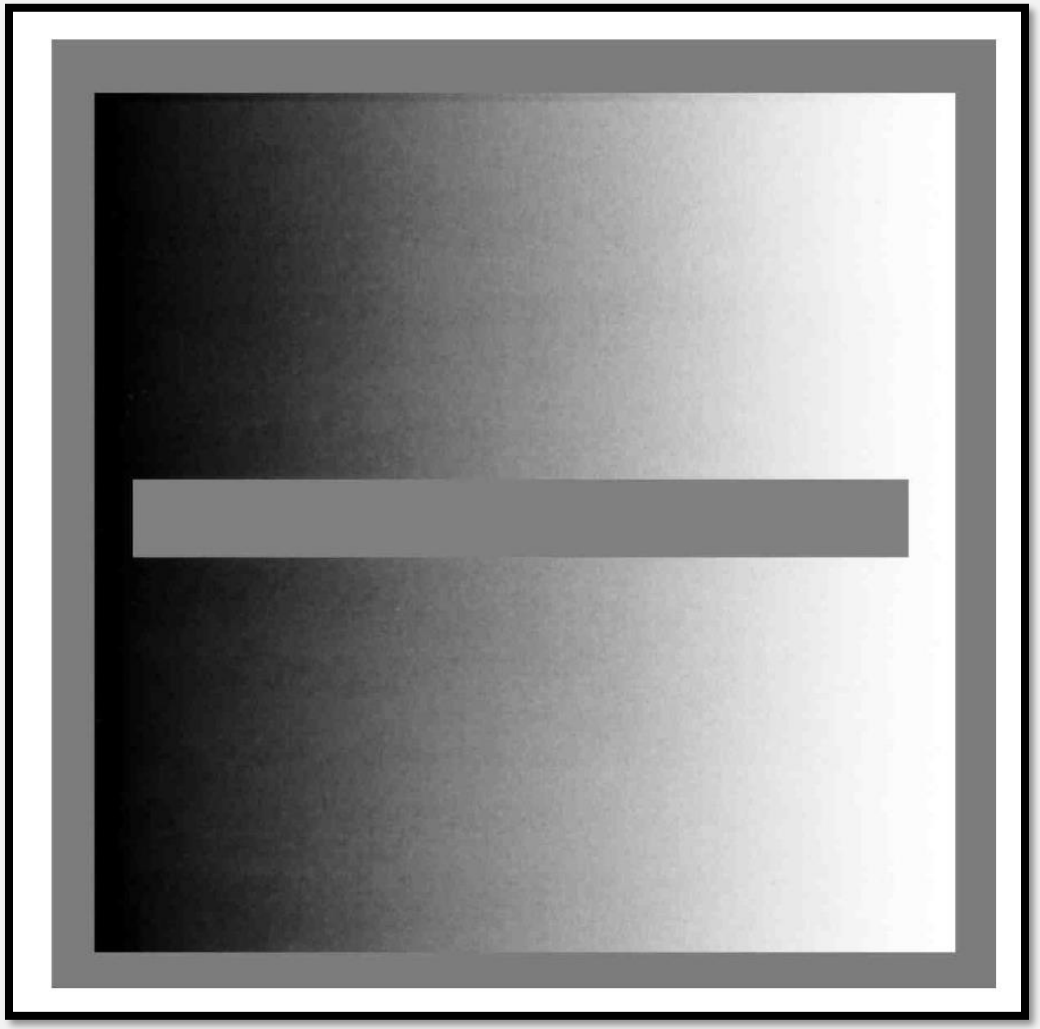
Lateral Inhibition

Contrast enhancement

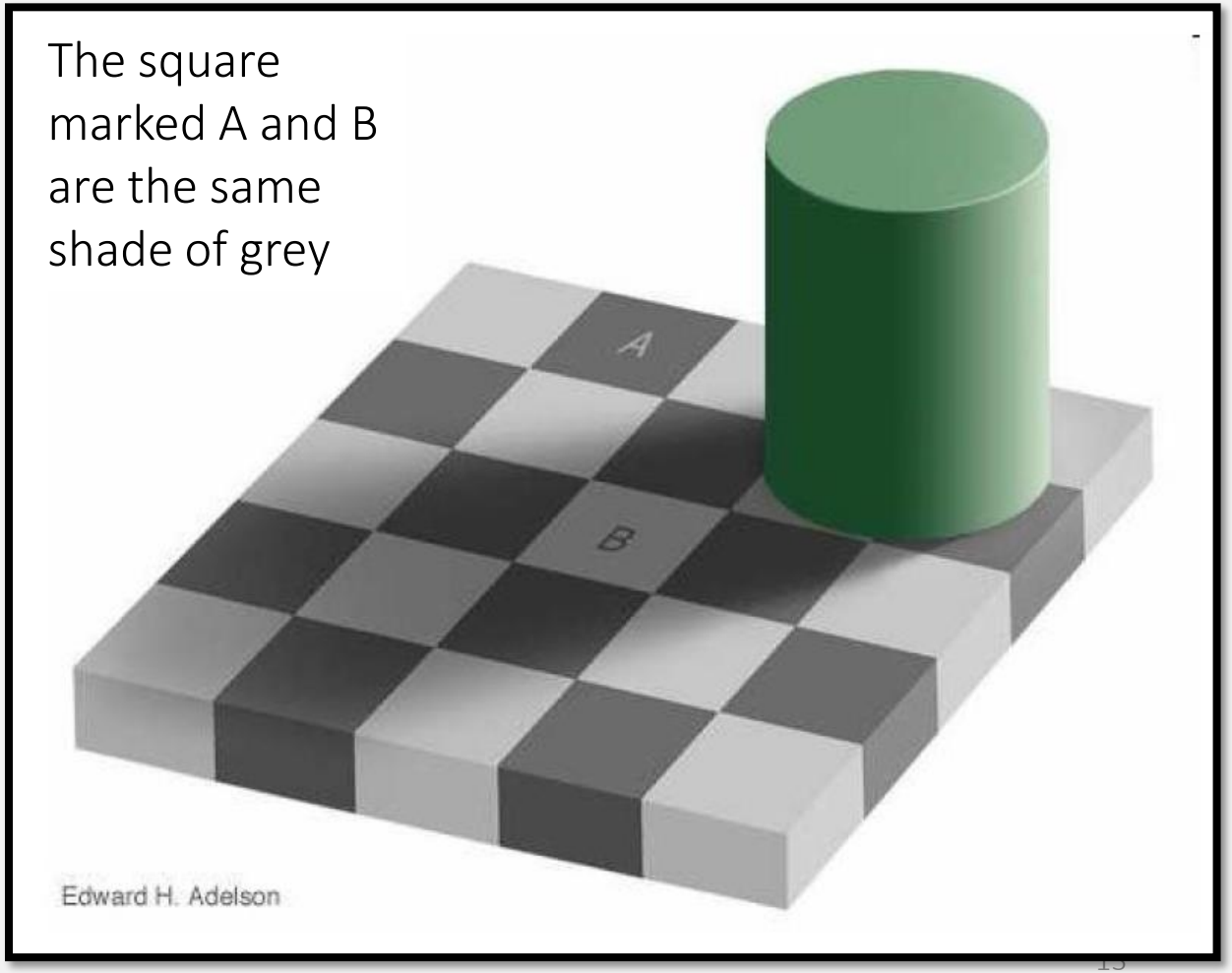




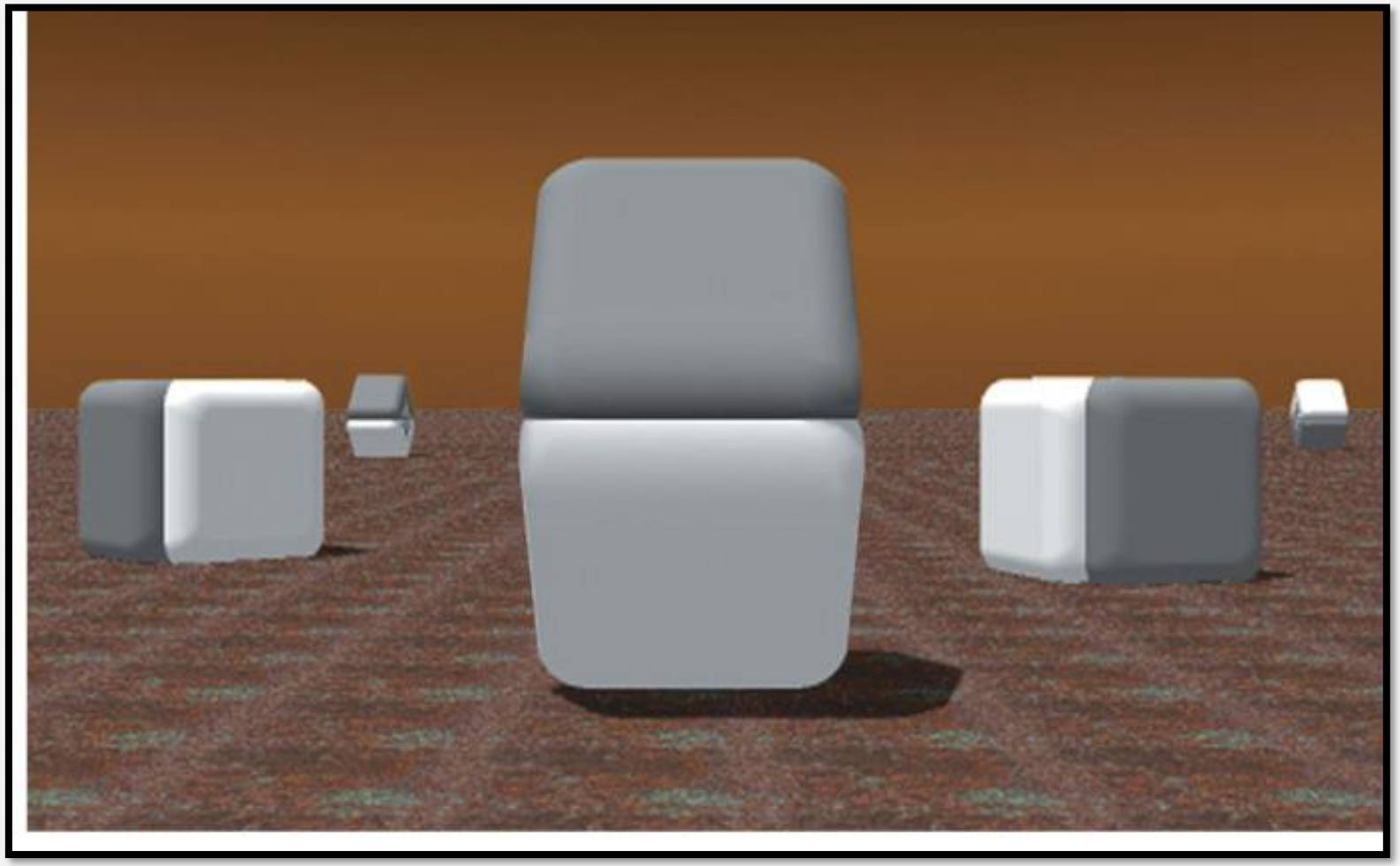
Simultaneous contrast illusion

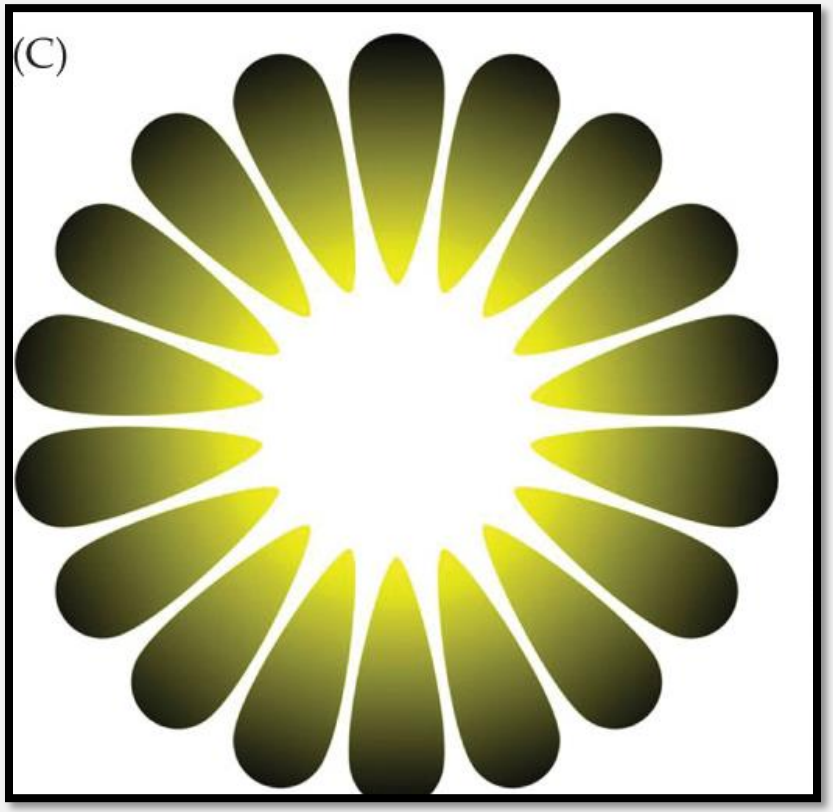


The square marked A and B are the same shade of grey



Context on brightness perception

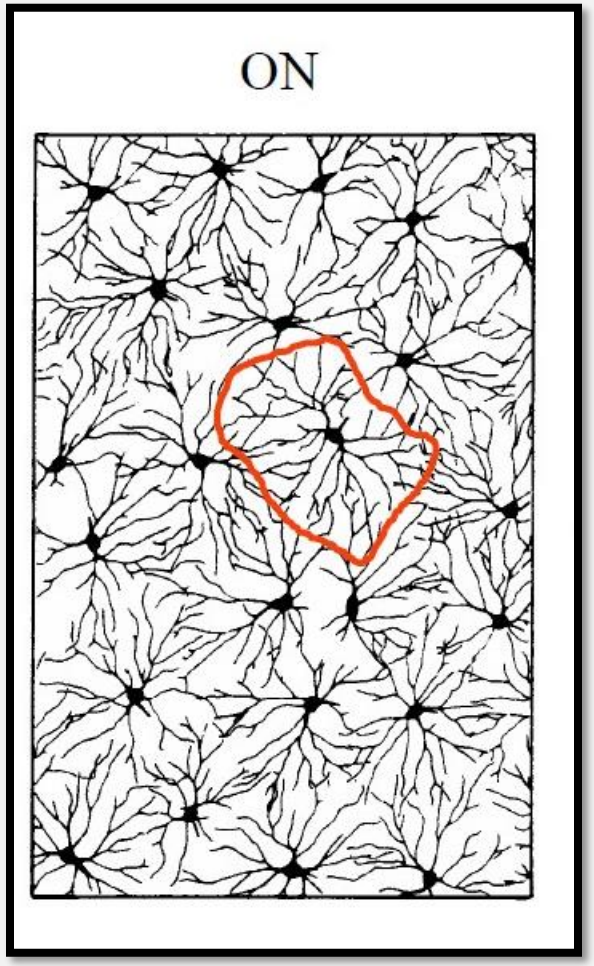




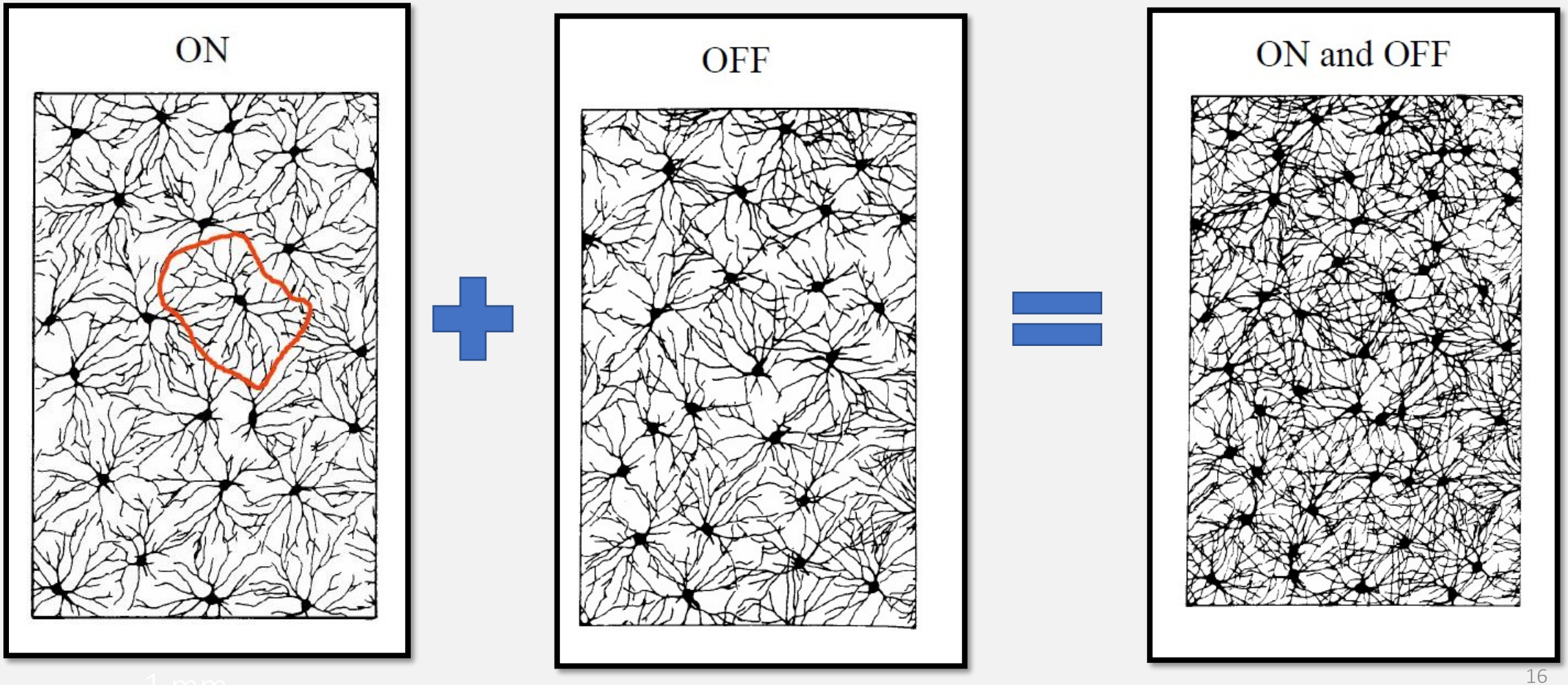
Retinal ganglion cells

Organization

- 20 types described
- Cover retina in tiled fashion
- Each send a unique representation of a certain area of the visual field
- Each point of the visual field hits *at least 1* retinal ganglion cell
- Optic nerve contains ~20 representations of the world (for a single spot in the visual field)
  - Polarity (on vs off)
  - Spatial resolution
  - Temporal responsiveness
  - Spectral filtering
  - Motion



Retinal ganglion cells in the cat retina



Summary

Photoreceptors

- Communicate with grade potentials to bipolar cells
- Light → hyperpolarization → less glutamate release to bipolar cells
- Magnitude of the hyperpolarization determines the reduction in neurotransmitter release.
- Remember that the visual system responds to *changes* in light.

Bipolar cells

- Broadly can be “on” or “off” center bipolar cells
- On cells become depolarized with light
- Off cells become hyperpolarized with light

Retinal ganglion cells

- RFs can vary in size based on eccentricity (distance from fovea)
- RFs tend to be circular and either have on center (with inhibitory surround) or off center (with excitatory surround)

Summary

Horizontal cells

- make contacts photoreceptors and bipolar cells.

Amacrine cells

- contact bipolar and ganglion cells.

All cell types *except* ganglion cells generate only graded local potentials; ganglion cells fire action potentials.

“In total about *20 ganglion-cell types* have been described. Each type covers the retina in a tiled fashion, such that any point on the retina lies within the receptive field center of at least one ganglion cell. One can envision each separate population as sending a distinct neural representation of the visual field to the brain, where the firing of an individual ganglion cell represents one pixel in the representation. In this view the optic nerve conveys about 20 neural representations of the world that differ in polarity (ON or OFF), spatial resolution (fine or coarse), temporal responsiveness (sustained or transient), spectral filtering (broadband or dominated by red, green, or blue), and selectivity for other image features such as motion.”

Kandel p 592

Vision: Cortical processing

Learning objectives

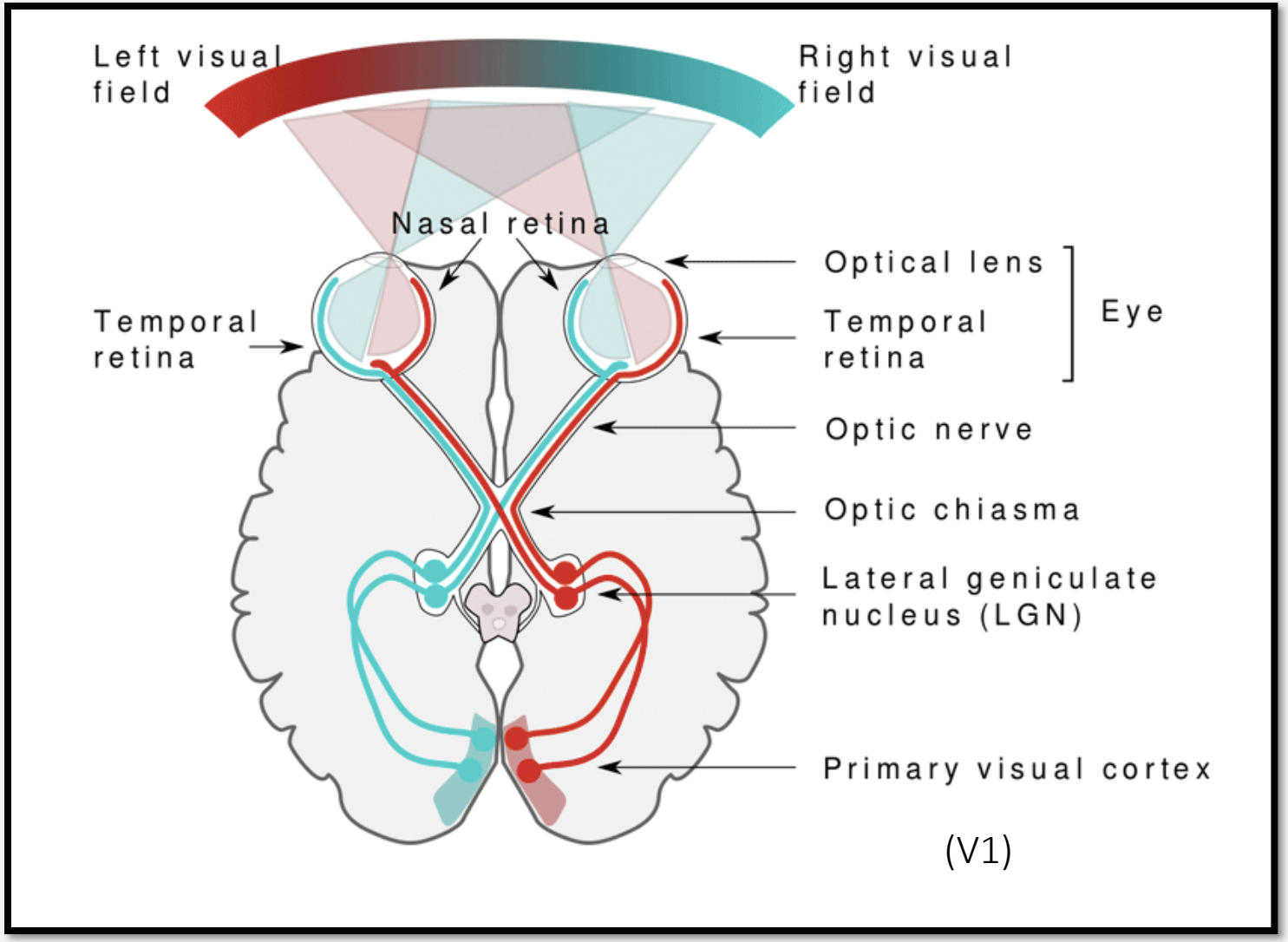
By the end of this lesson, you should be able to…

1. Trace the path of light through the eye, to where transduction occurs.
2. Trace the neural pathway of light information from the retina to the primary visual cortex
3. Describe the term retinotopic and visuo-topic map with respect to the retina, lateral geniculate nucleus and V1
4. Describe hierarchical processing with respect to a visual image
5. Understand the increasingly complex nature of receptive fields for retinal ganglion cells, V1 neurons, and IT neurons
6. Understand the concept of columnar organization with respect to the cortex
7. Describe the concept of a cortical hyper-column
8. Describe 2 routes that visual information takes in the brain and what each route is responsible for
9. Distinguish between optic ataxia and object agnosia

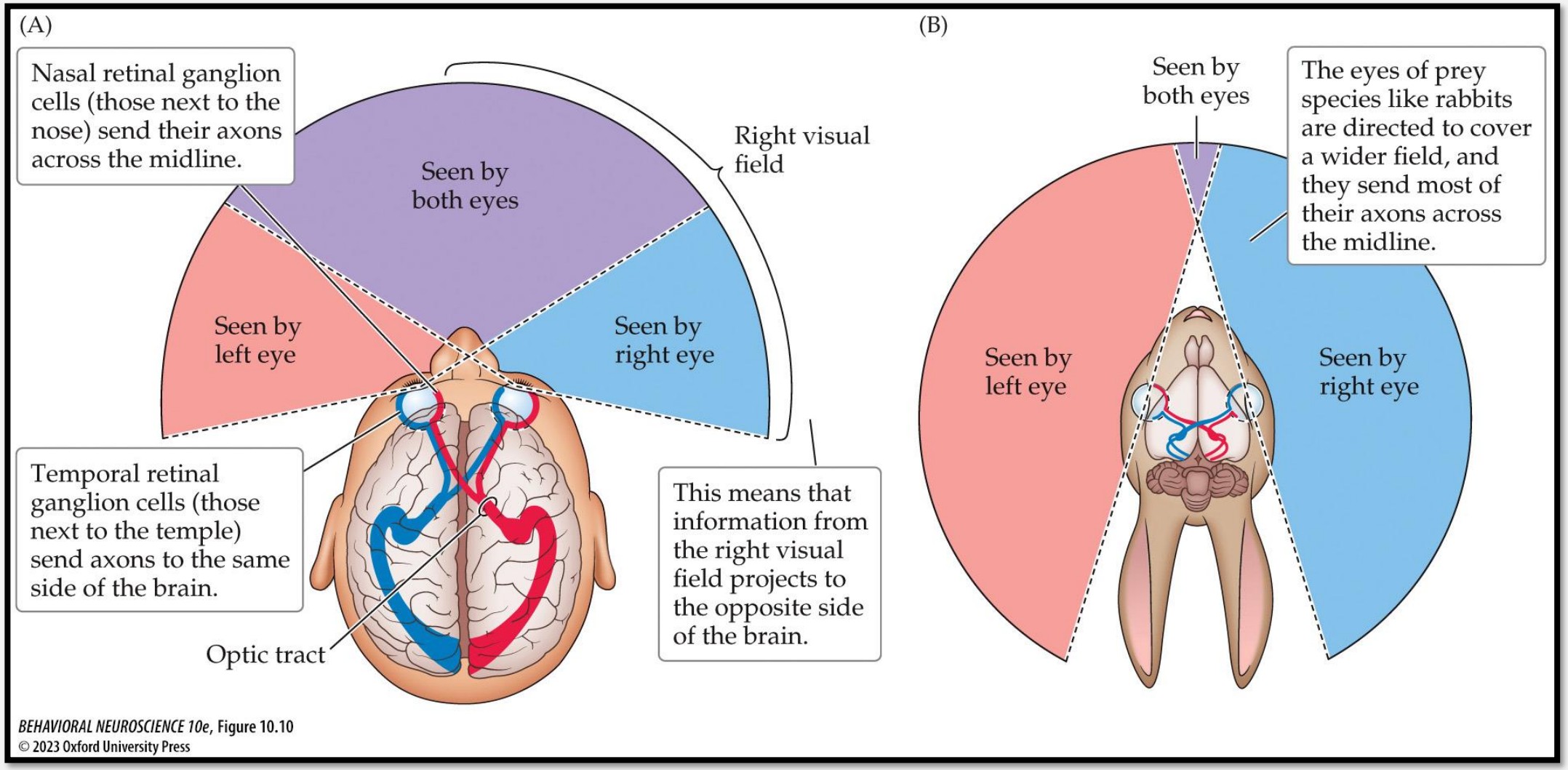
Cortical pathway

Retina – Thalamus – Visual cortex pathway

- Left visual field projected to right half of each retina then processed by right thalamus and right V1
- Right visual field projected to left half of each retina then processed by left thalamus and left V1



Visual fields across species

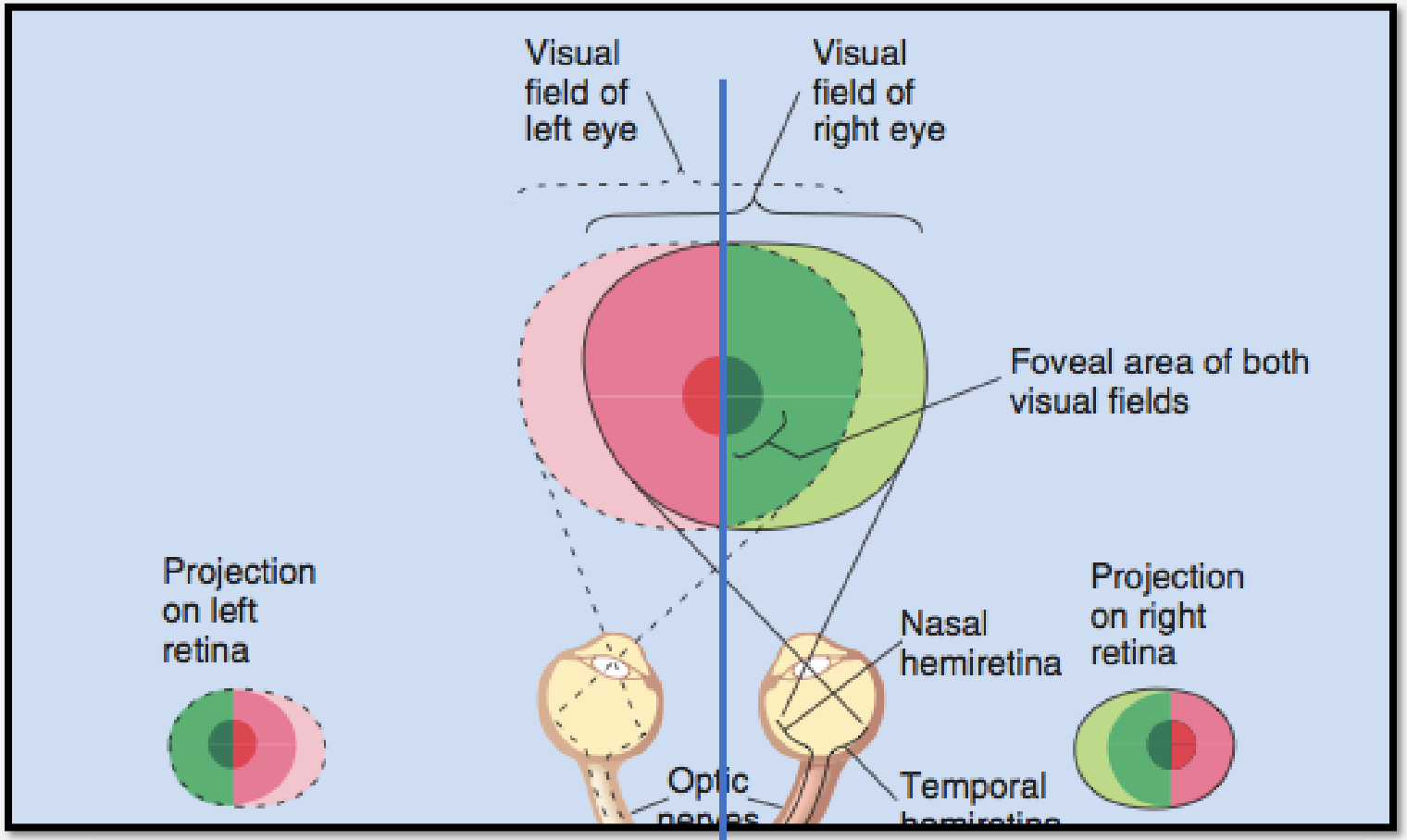


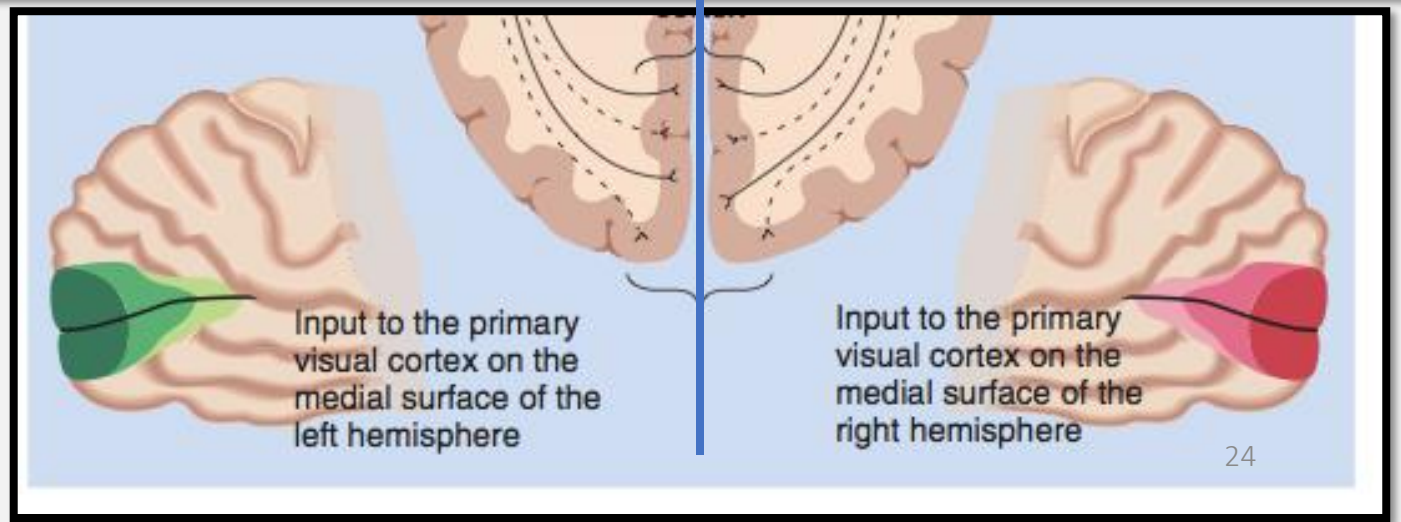
BEHAVIORAL NEUROSCIENCE 10e, Figure 10.10

Cortical pathway

Retinotopic map

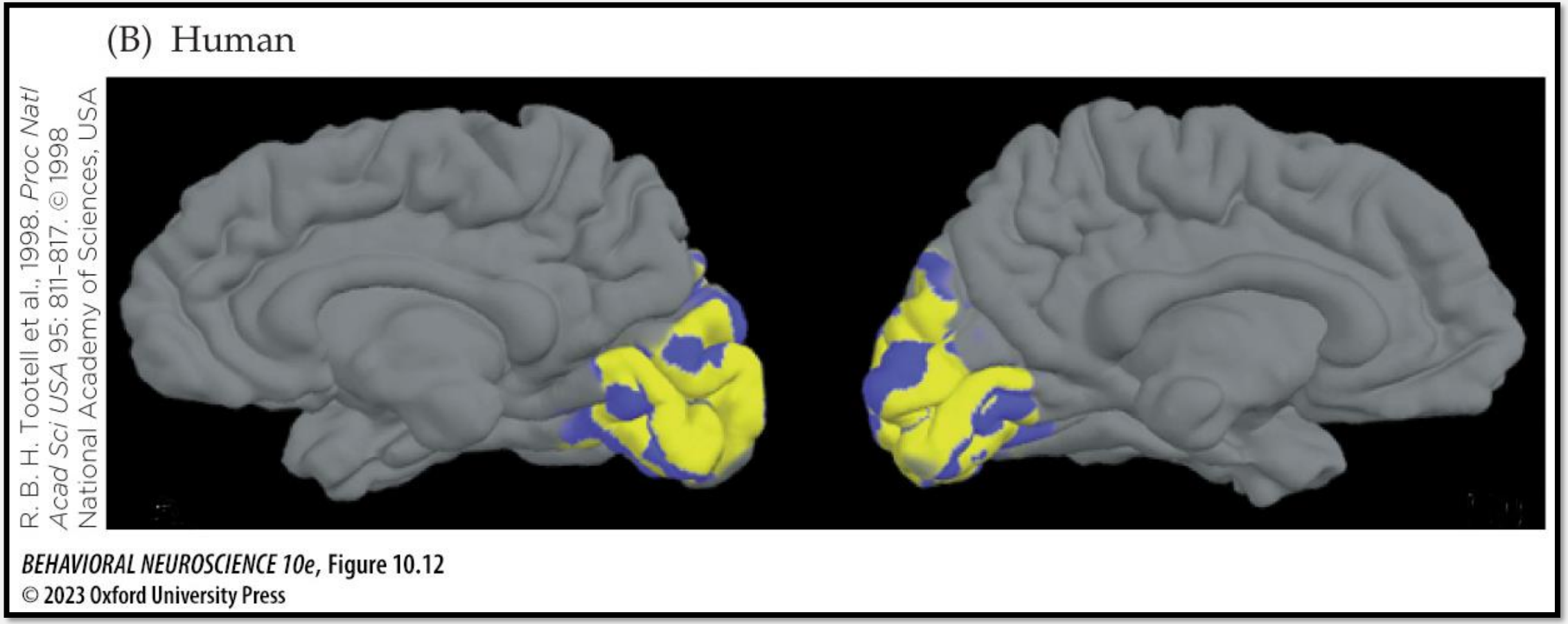
- Adjacent areas of visual field represented by adjacent areas of retina
- Spatial relationship preserved in thalamus and V1 (adjacent neurons represent adjacent areas in visual field)
- More cortical real estate given to fovea



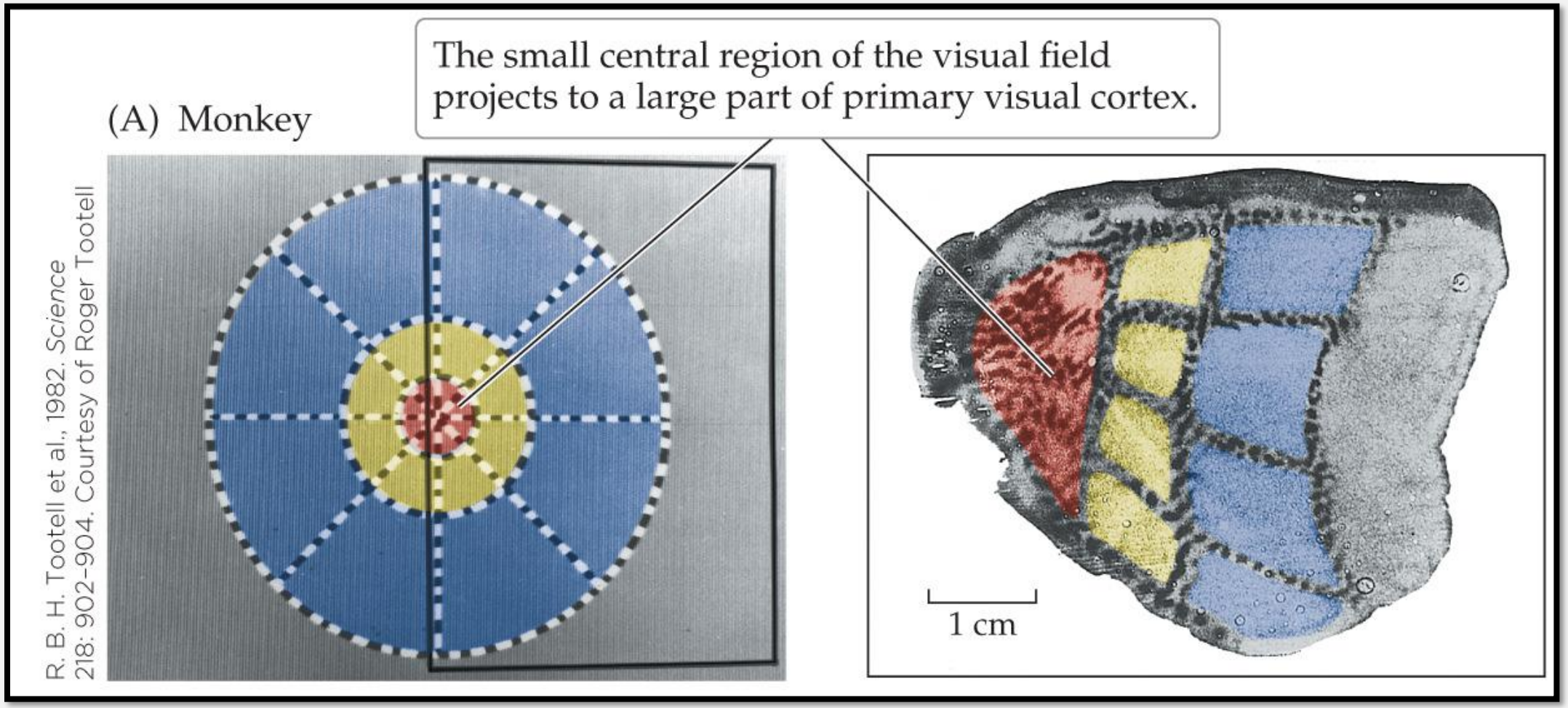


*aka retina-geniculate-striate/V1 pathway

Another view

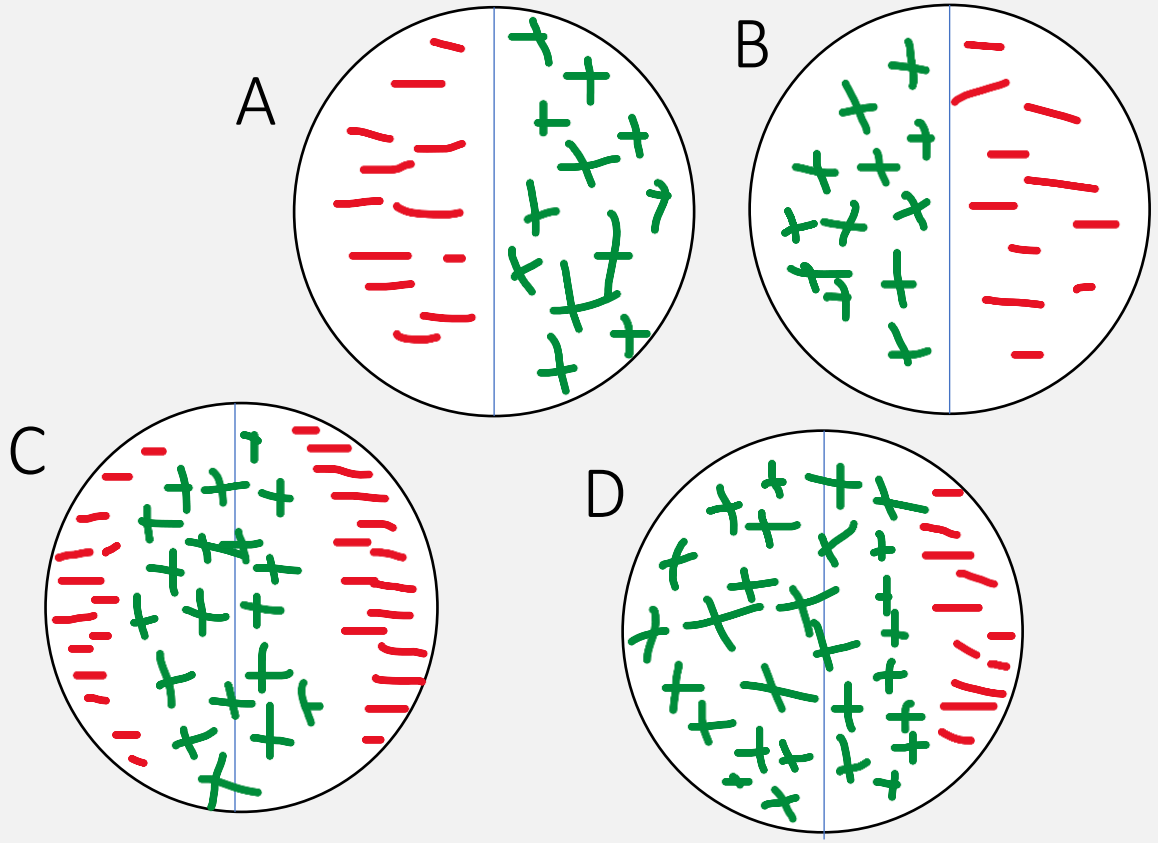


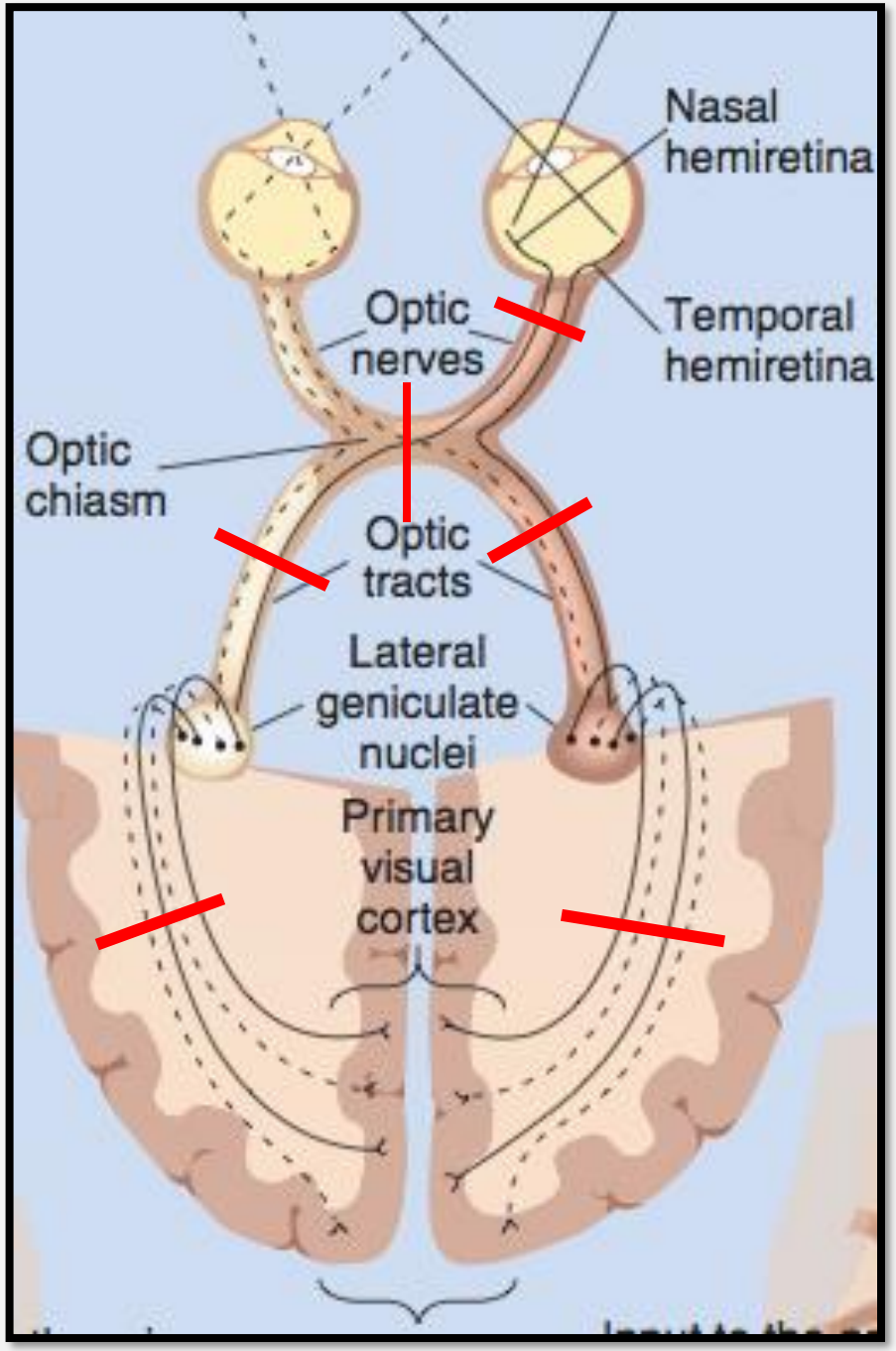
Another view



Exercise – Cortical Lesions

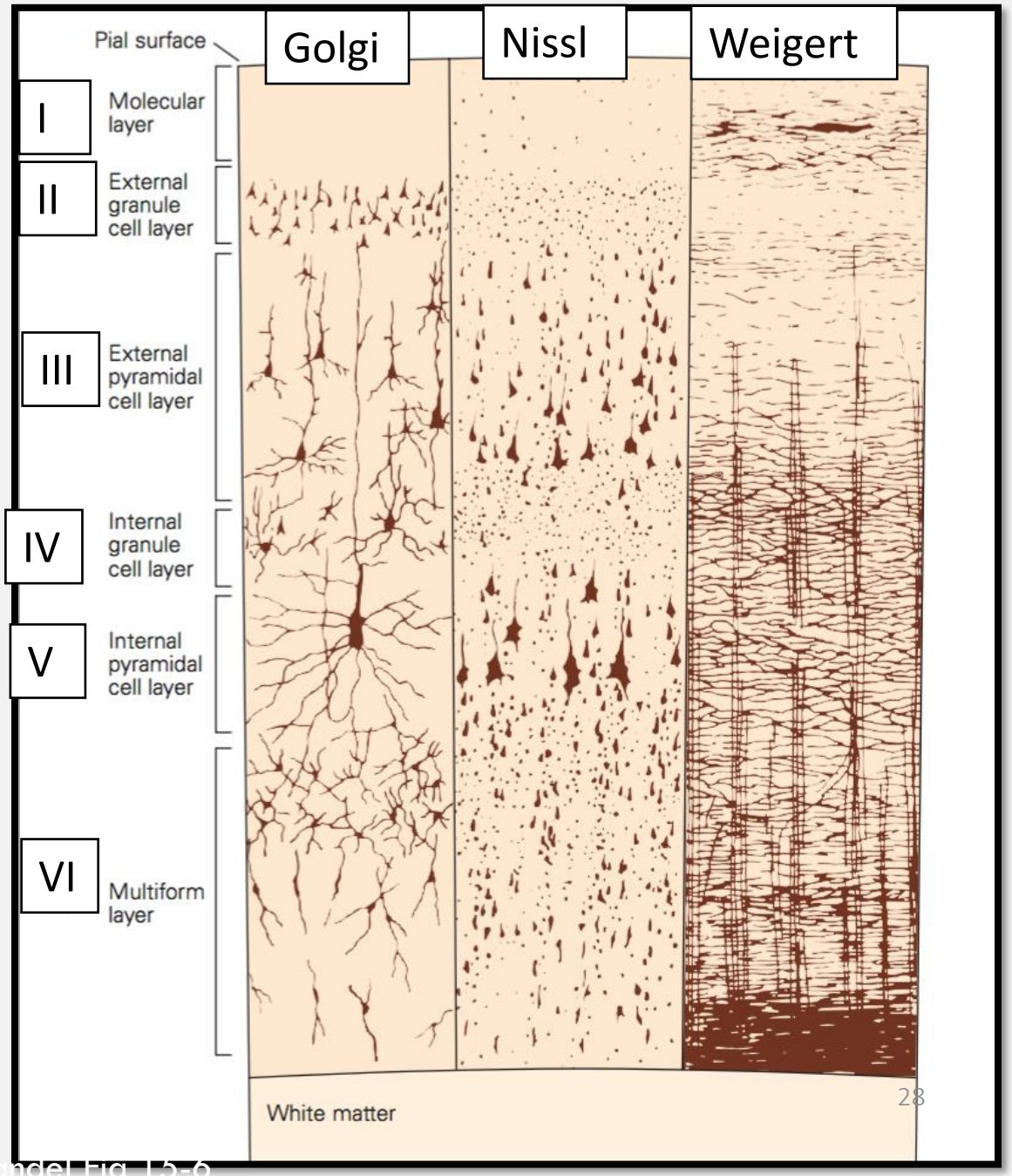
For each visual field deficit, locate the possible lesion site





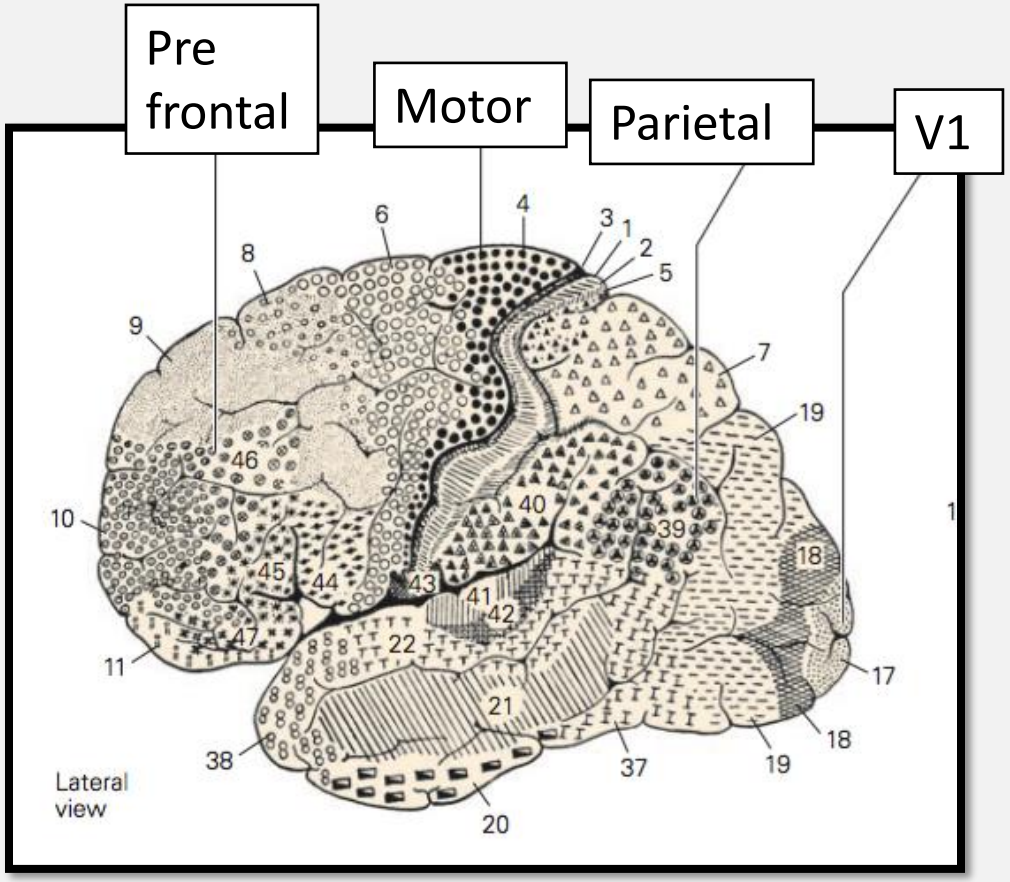
Neocortex

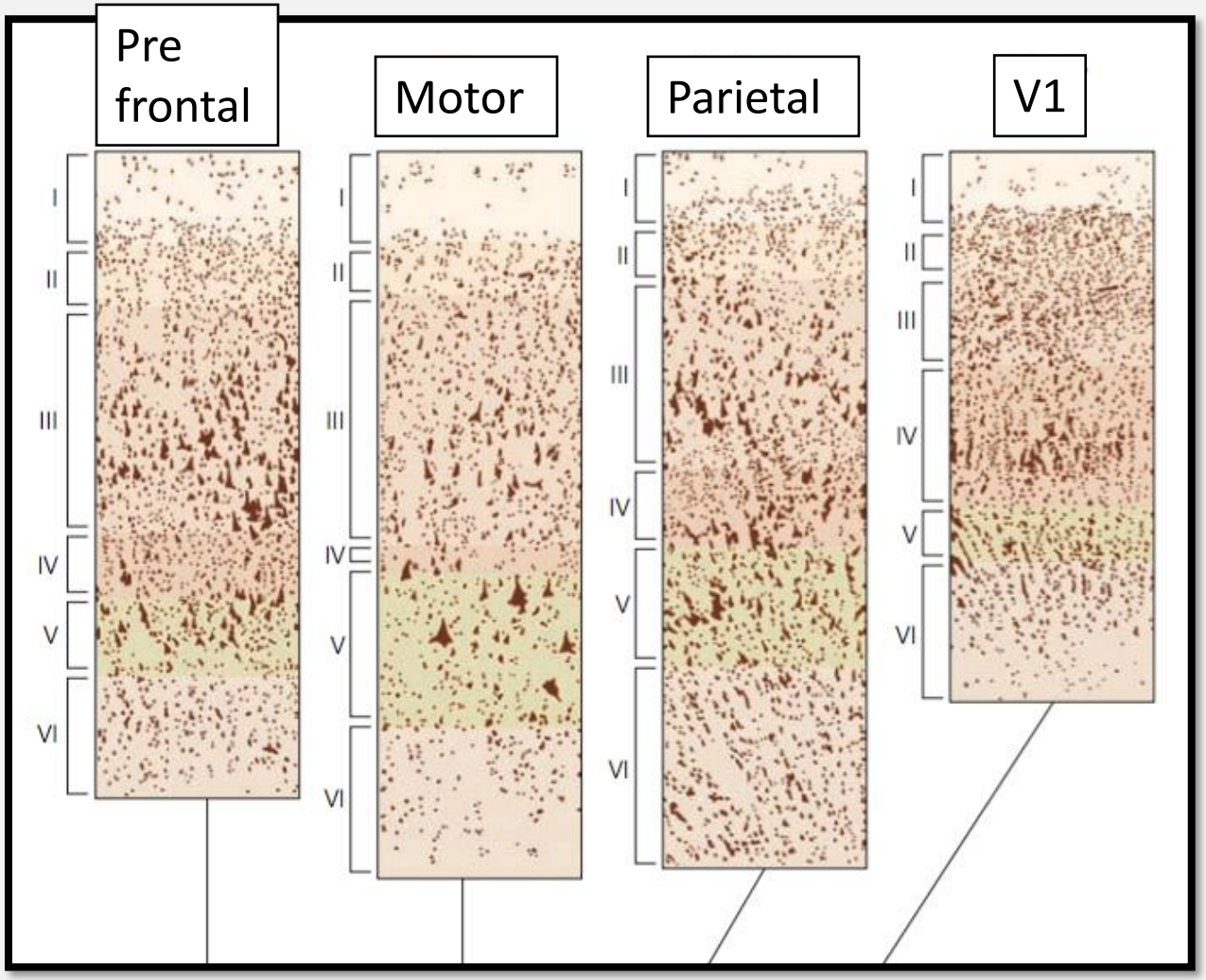
- Columnar organization
- Organized into 6 layers



Kandel Fig. 15-6

Neocortex





Kandel Fig 15-8

Neocortex

Layer 4

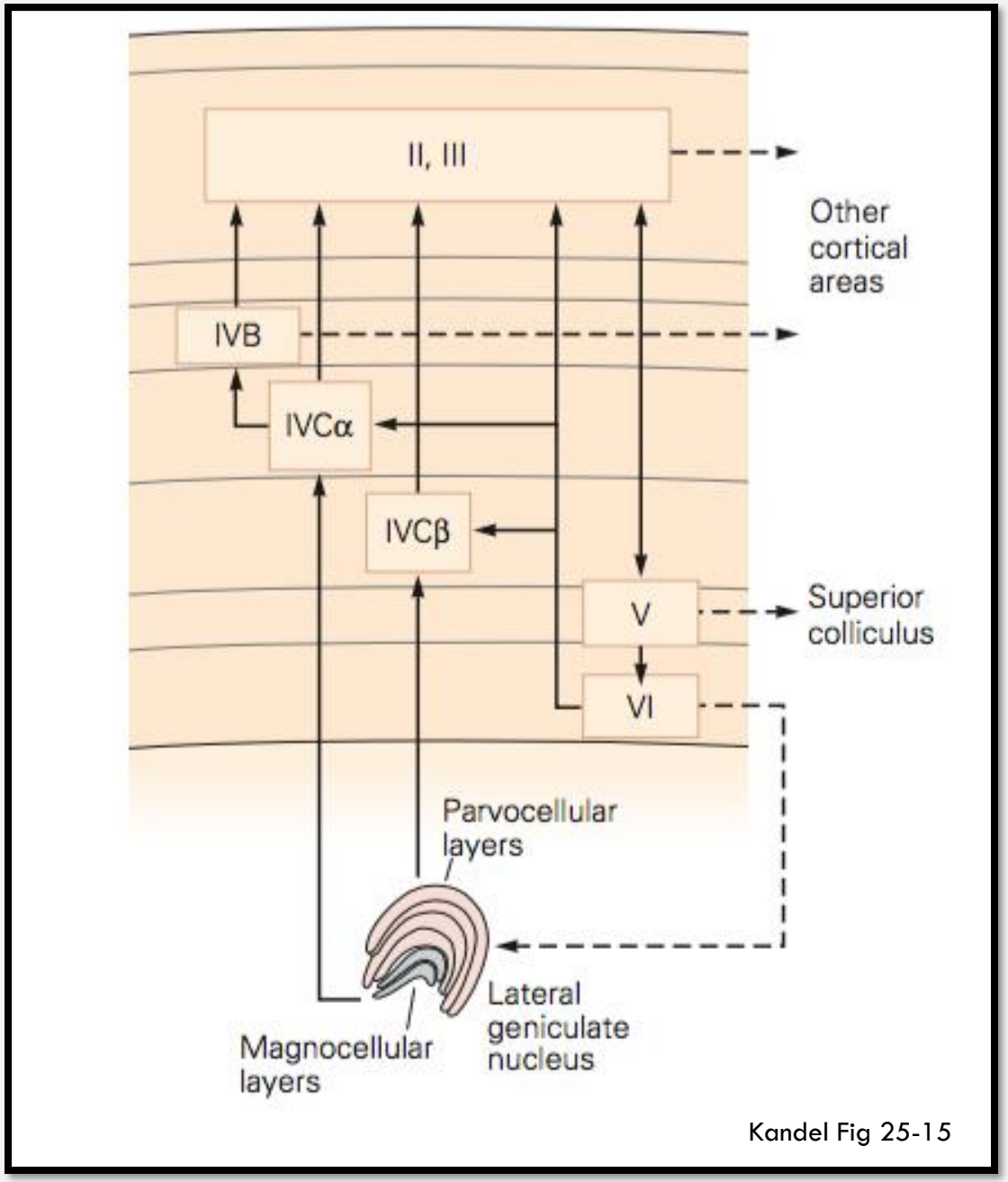
- Receives inputs from thalamus (lateral geniculate nucleus)

Layer 2/3

- Inputs from layer 4
- Cortico-cortical outputs

Layer 5

- Subcortical outputs



Kandel Fig 25-15

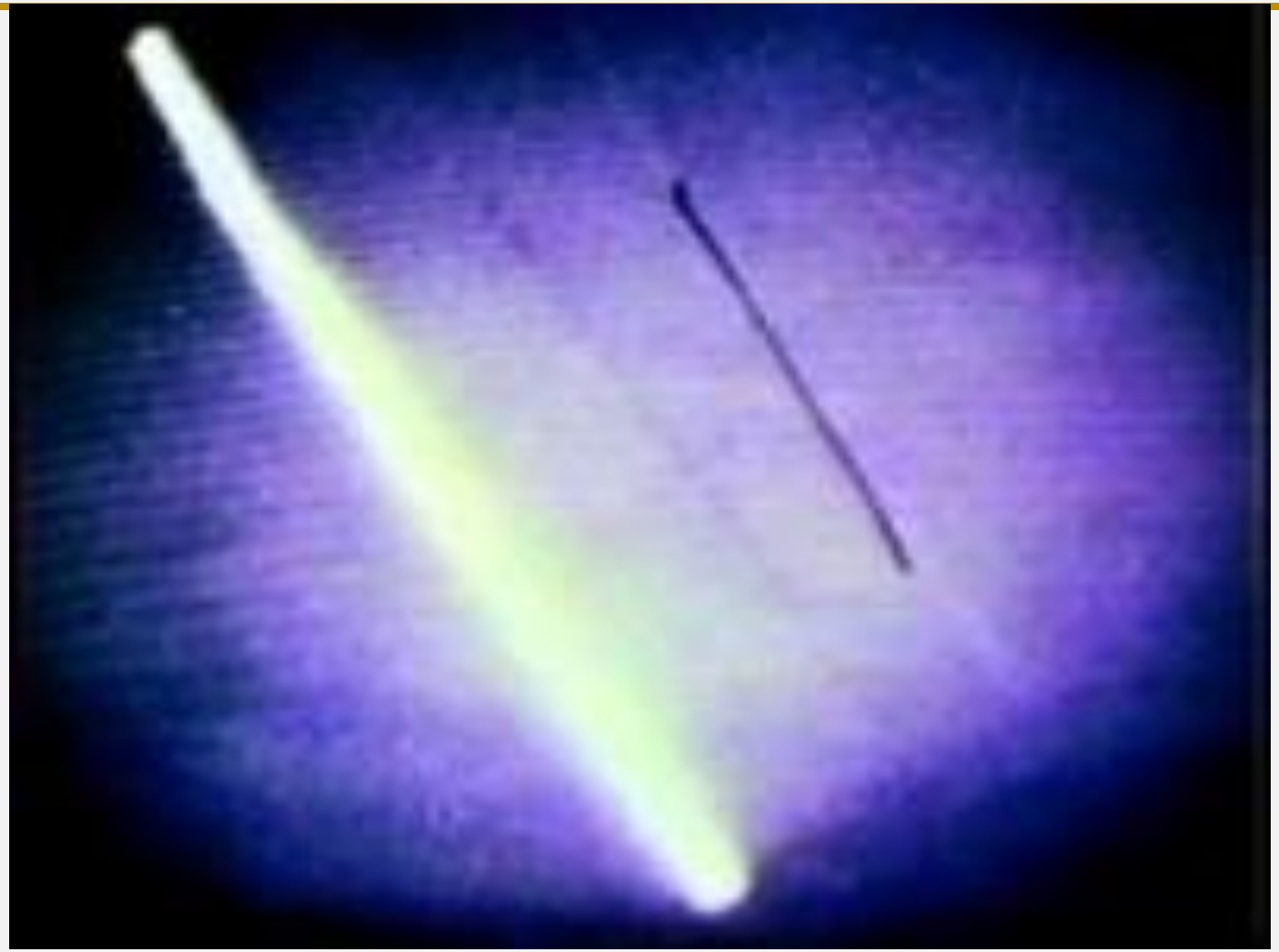
Primary visual cortex V1

Striate cortex (striped)

Orientation selective cells in V1

Electrophysiological evidence

- “Simple” cells
- Neurons in V1 tuned to specific orientations of bars of light



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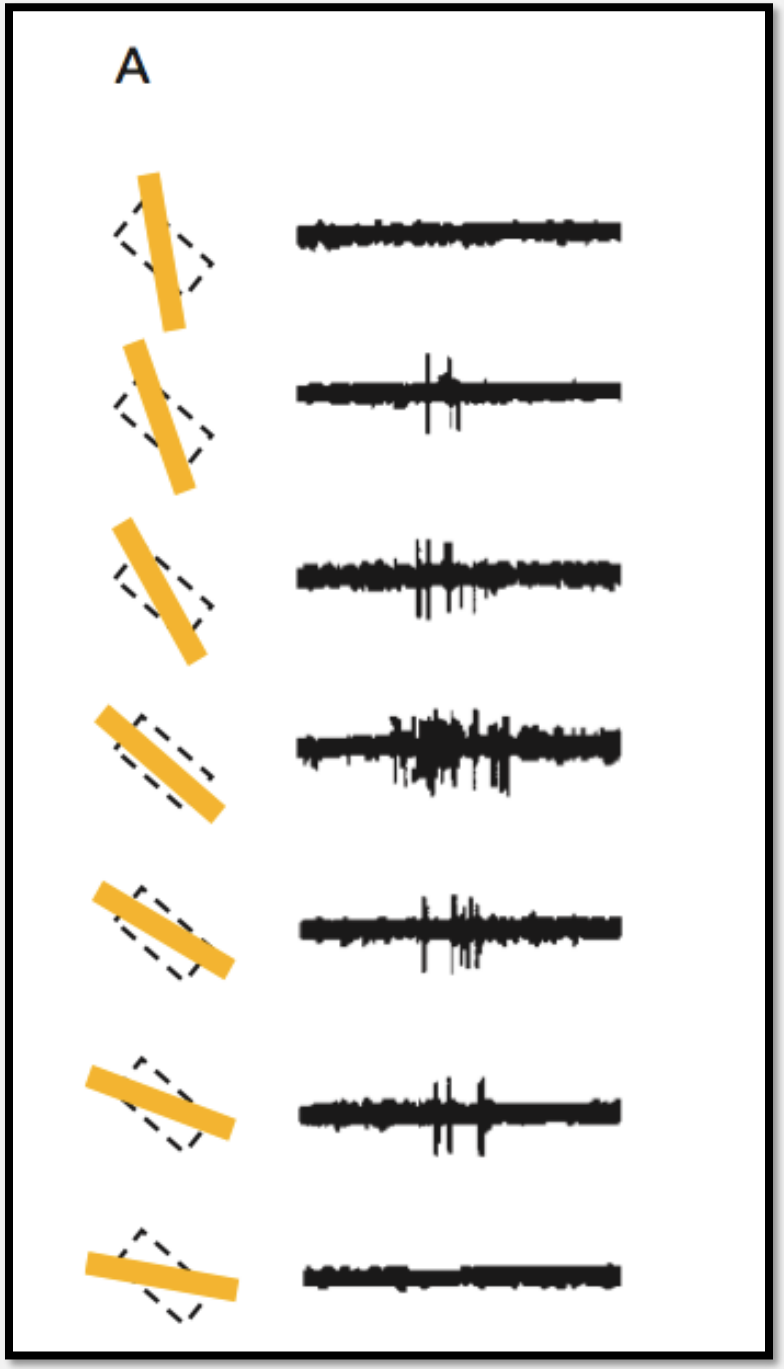


Kandel Fig 27-3

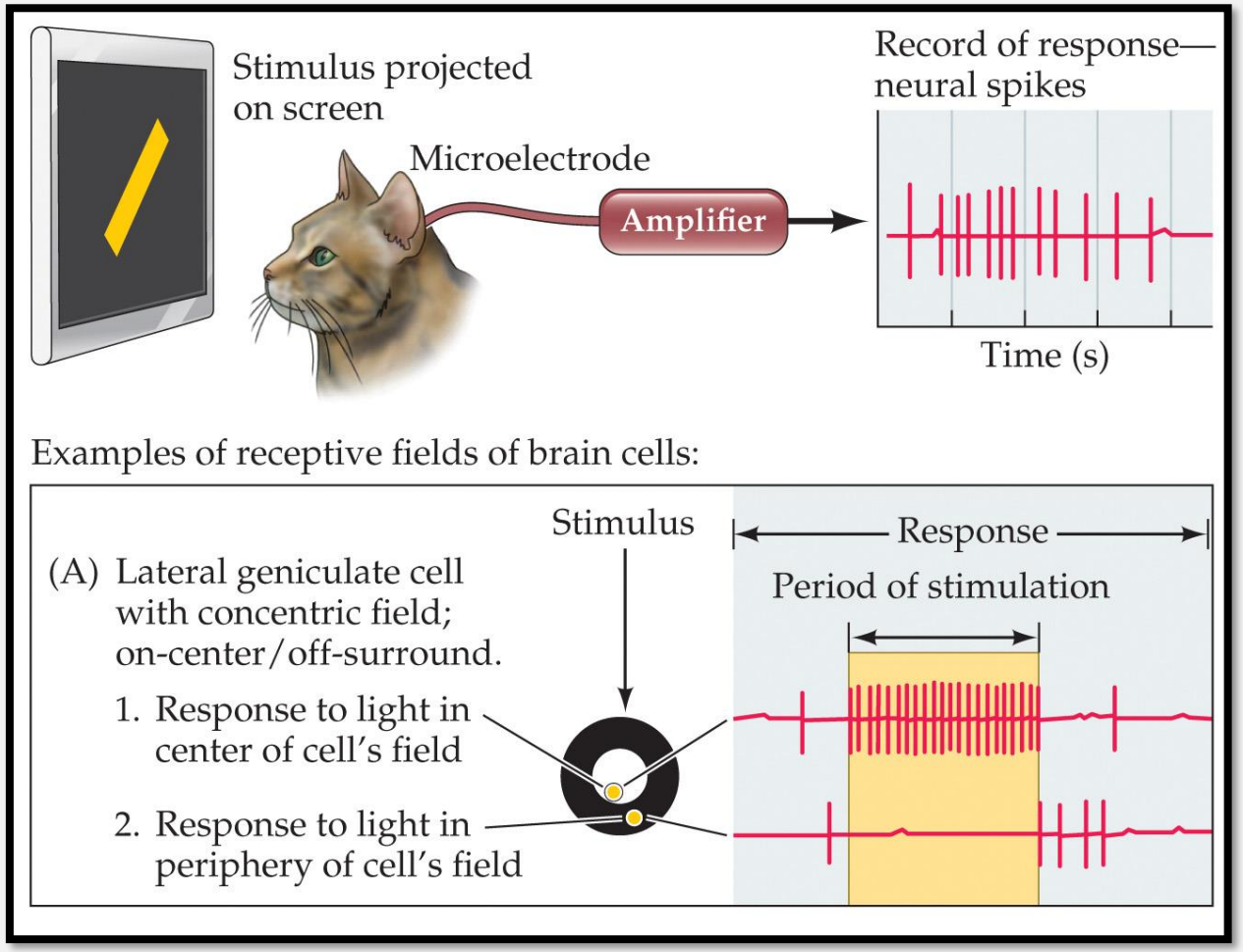
Orientation selective cells in V1

RGCs, LGN, and layer 4 neurons

- Circular receptive fields

Layer 3 neurons

- Bar-of-light receptive fields
- Convergence of ON-center cells from layer 4 neurons in a neocortical collumn



Kandel Fig 27-3

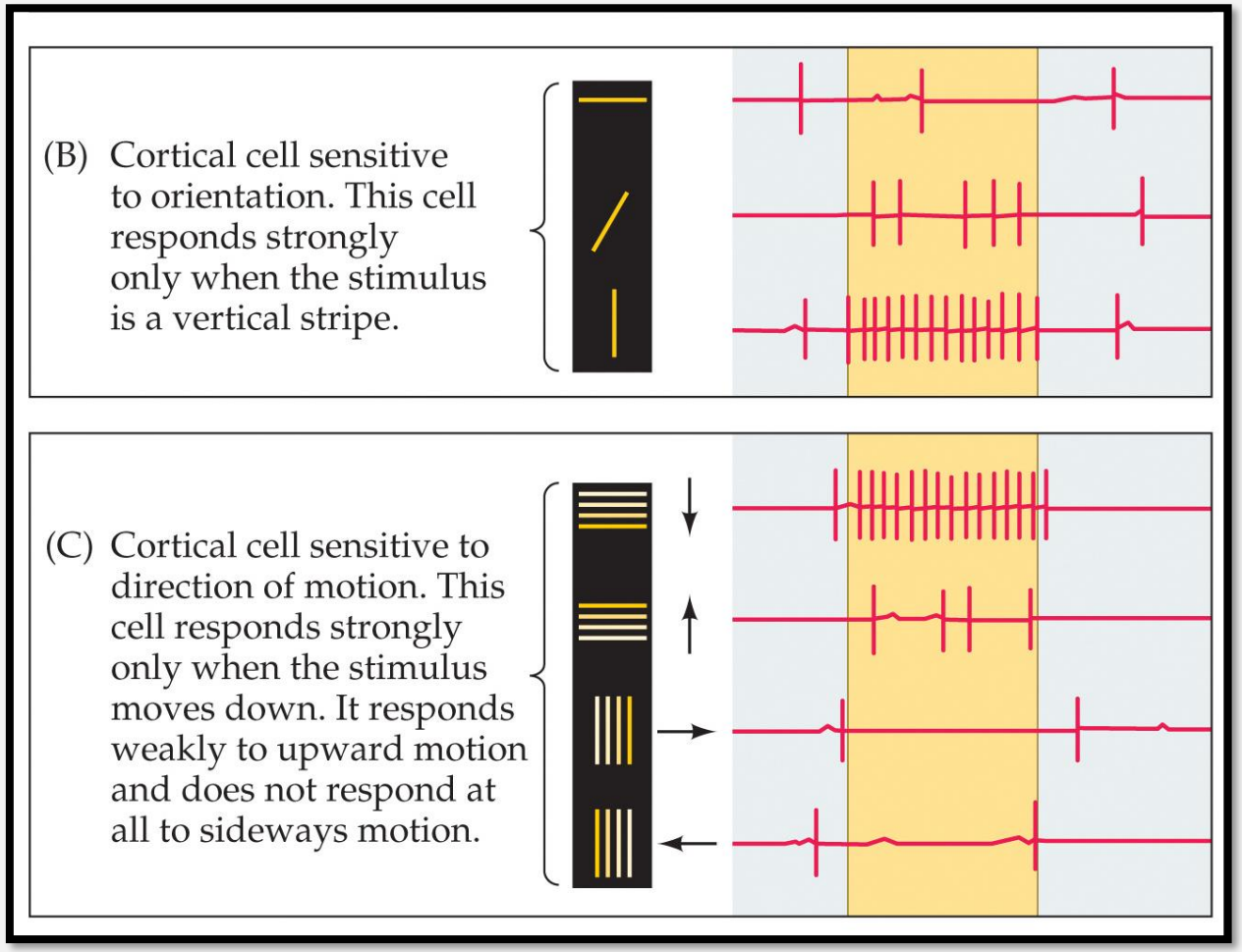
Orientation selective cells in V1

RGCs, LGN, and layer 4 neurons

- Circular receptive fields

Layer 3 neurons

- Bar-of-light receptive fields
- Motion selective receptive fields



Kandel Fig 27-3

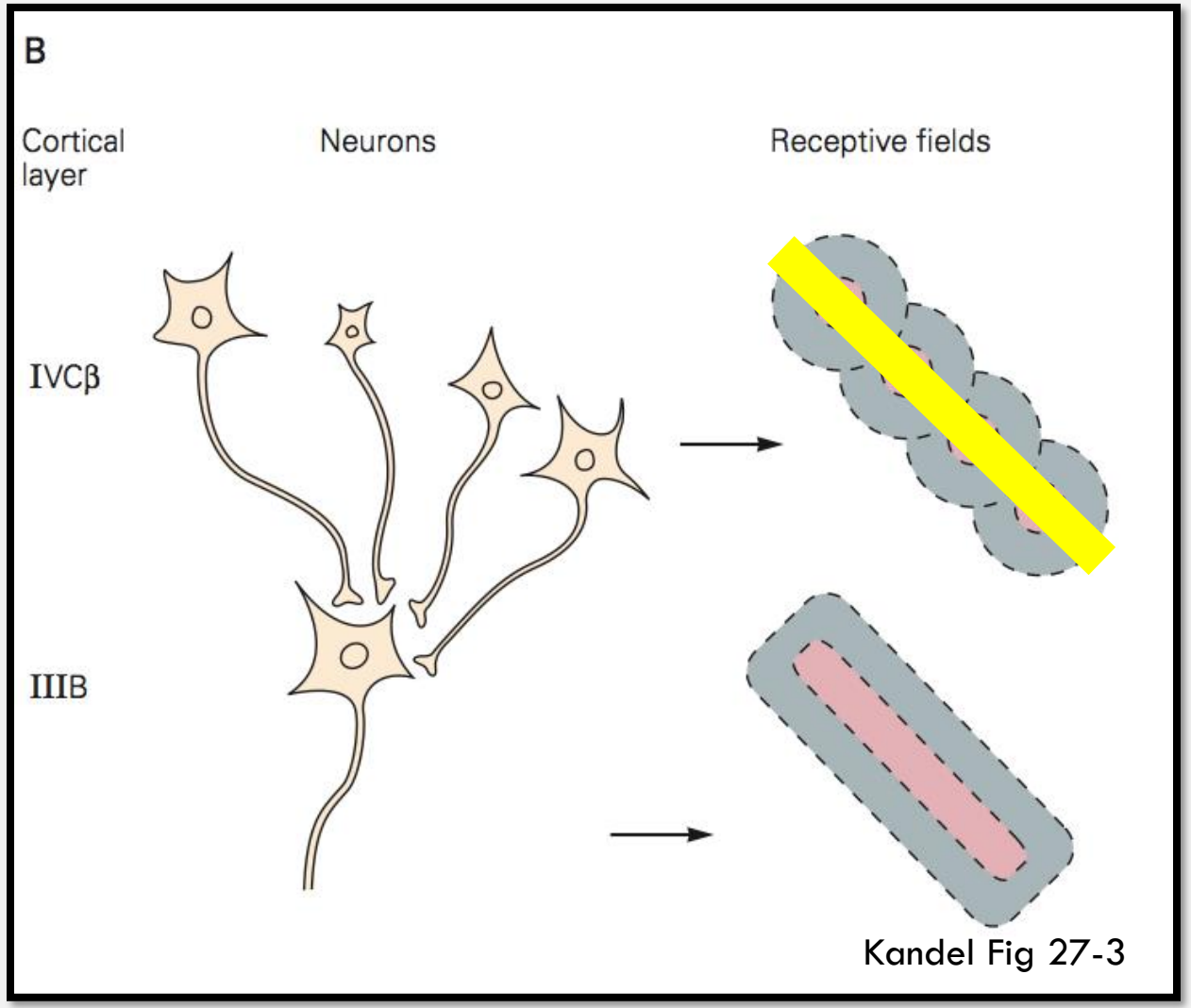
Orientation selective cells in V1

RGCs, LGN, and layer 4 neurons

- Circular receptive fields

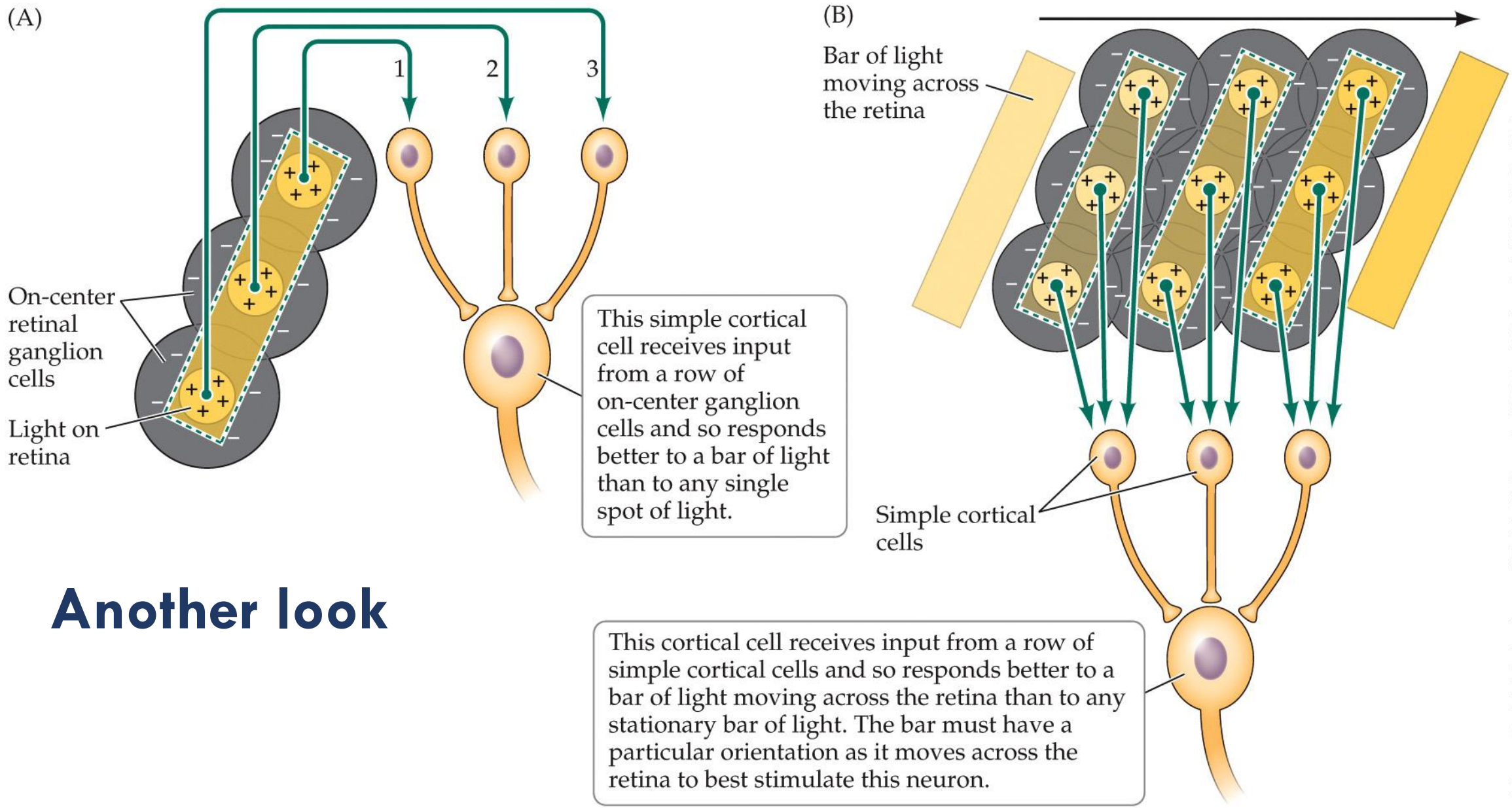
Layer 3 neurons

- Bar-of-light receptive fields
- Convergence of ON-center cells from layer 4 neurons in a neocortical column



Kandel Fig 27-3

Another look



BEHAVIORAL NEUROSCIENCE 10e, Figure 10.17

Receptive Fields

Neurons in the visual cortex

- have more complicated receptive fields.

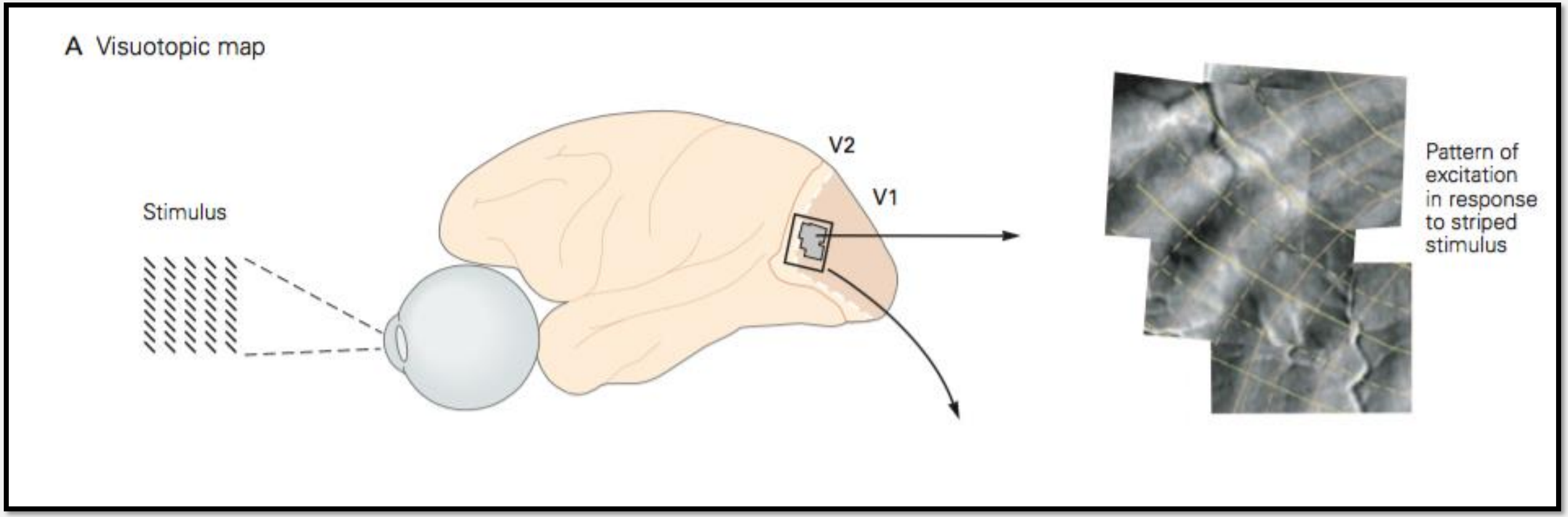
Simple cortical cells

- *bar* or *edge detectors*—respond to an edge or bar of a particular width, orientation, and location.

Complex cortical cells

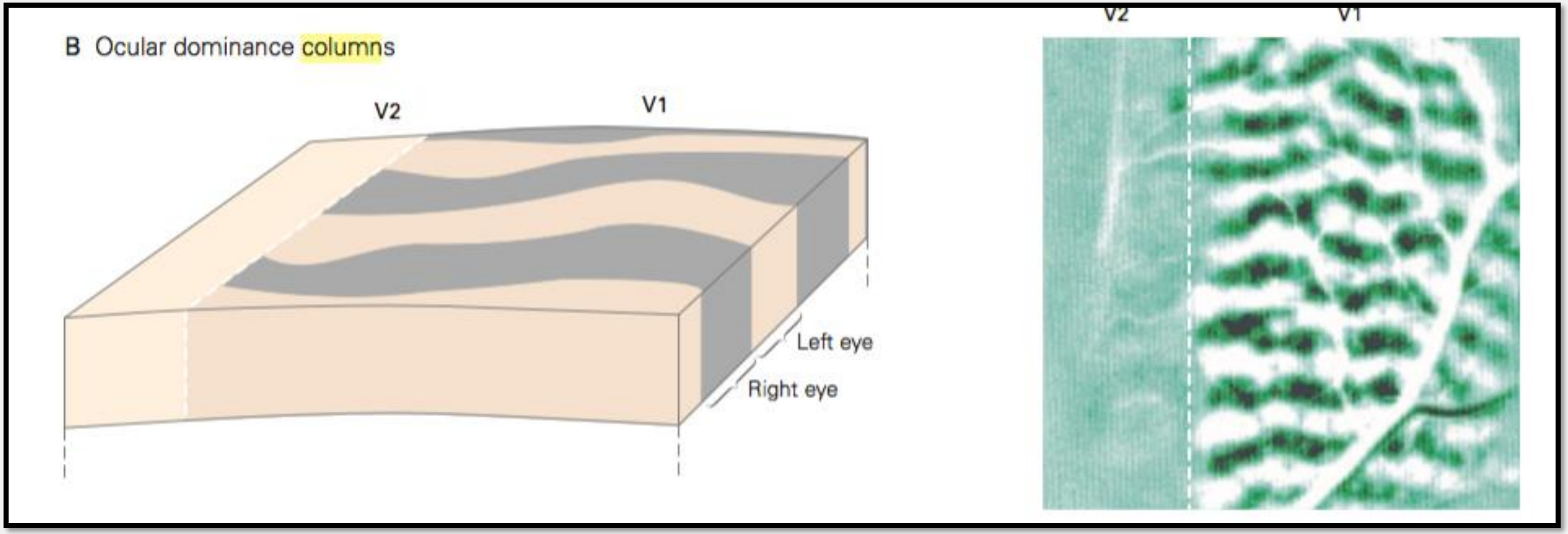
- also respond to a bar of a particular width and orientation but it may be located within a larger area of the visual field.

V1 Receptive field properties



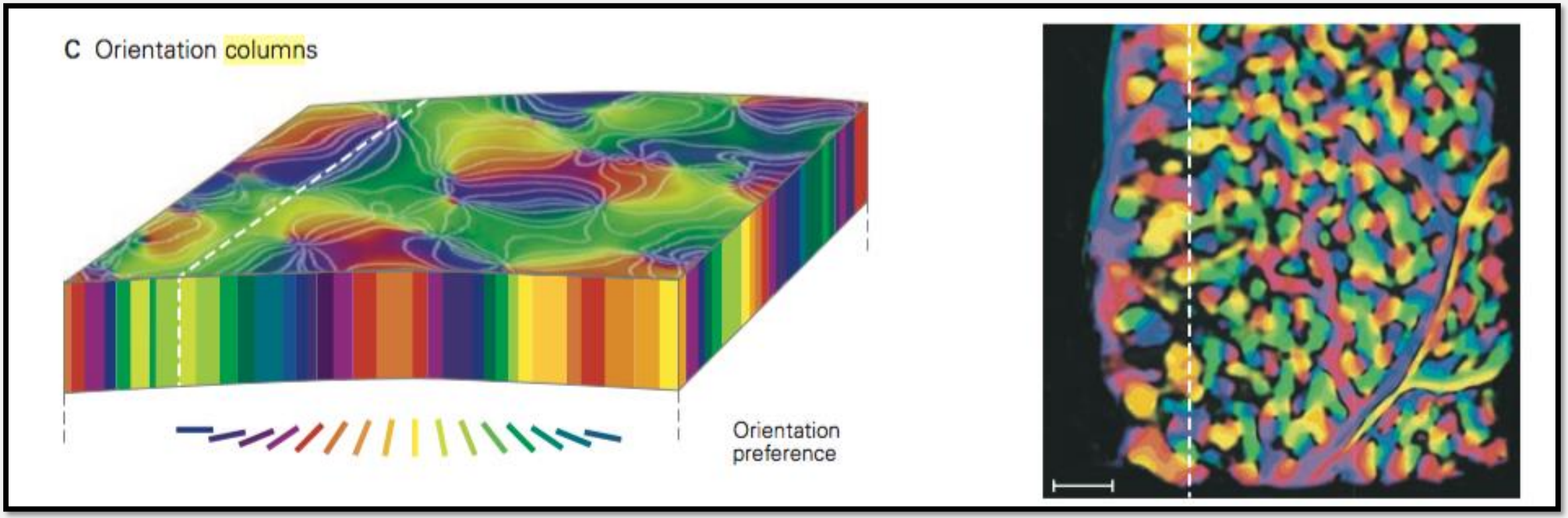
Kandel Fig 25-11

V1 Receptive field properties



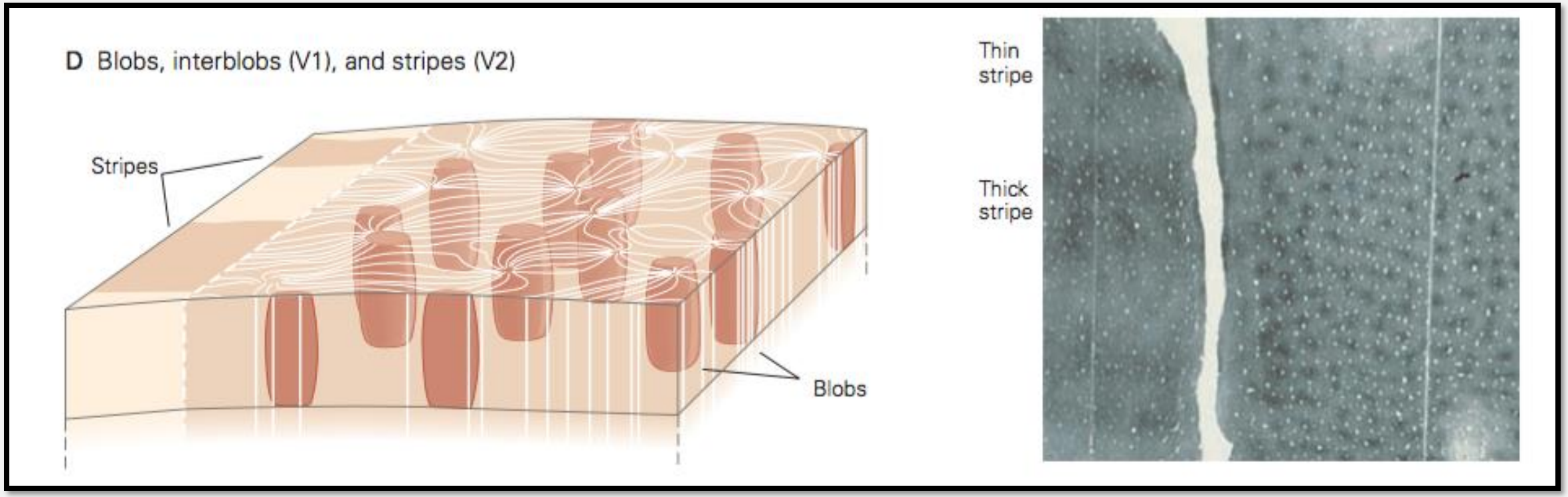
Kandel Fig 25-11

V1 Receptive field properties



Kandel Fig 25-11

V1 Receptive field properties



Kandel Fig 25-11

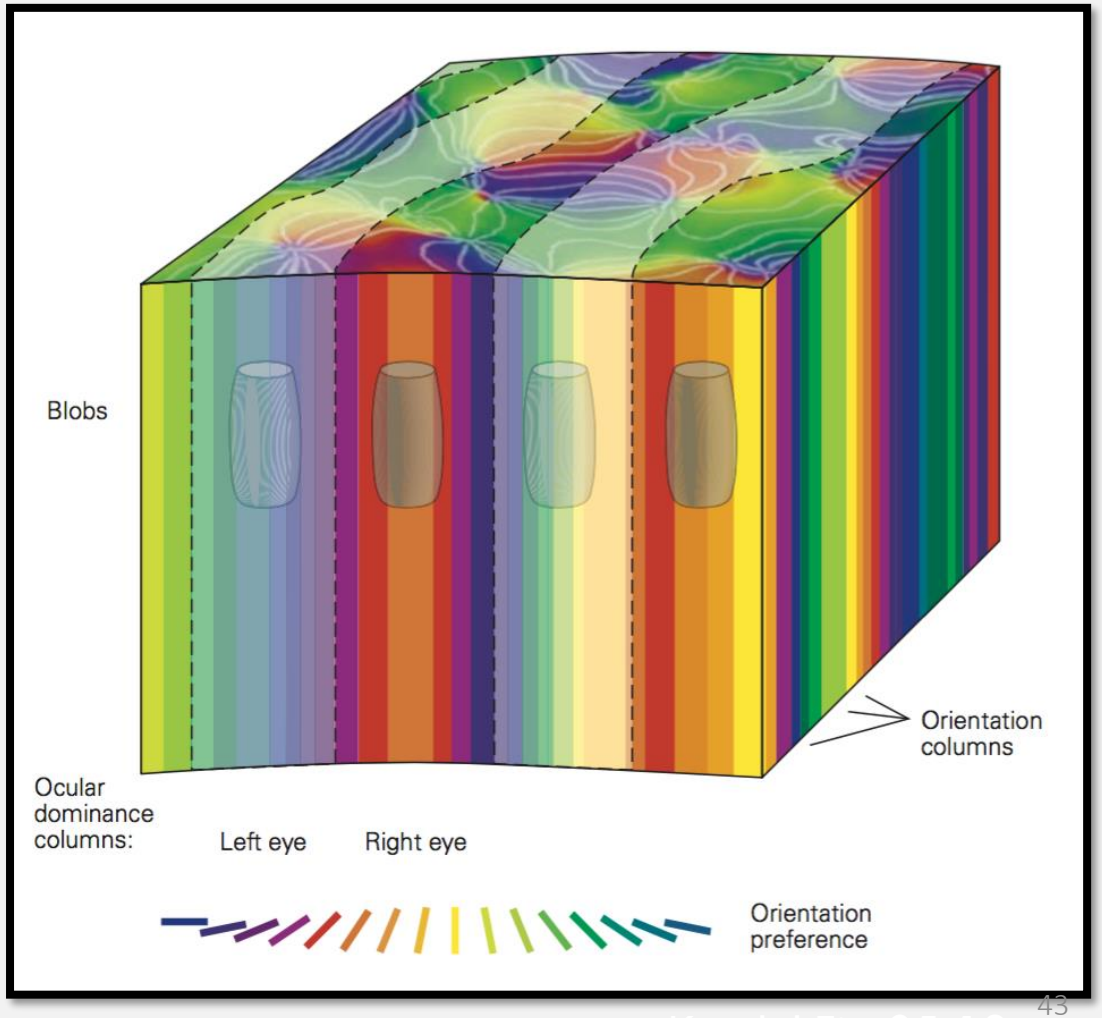
Cortical hyper-column

Contains

- Full range of orientation selective columns
- Blobs (colour responsive neurons)
- On cycle of left and right ocular dominance columns

Covers

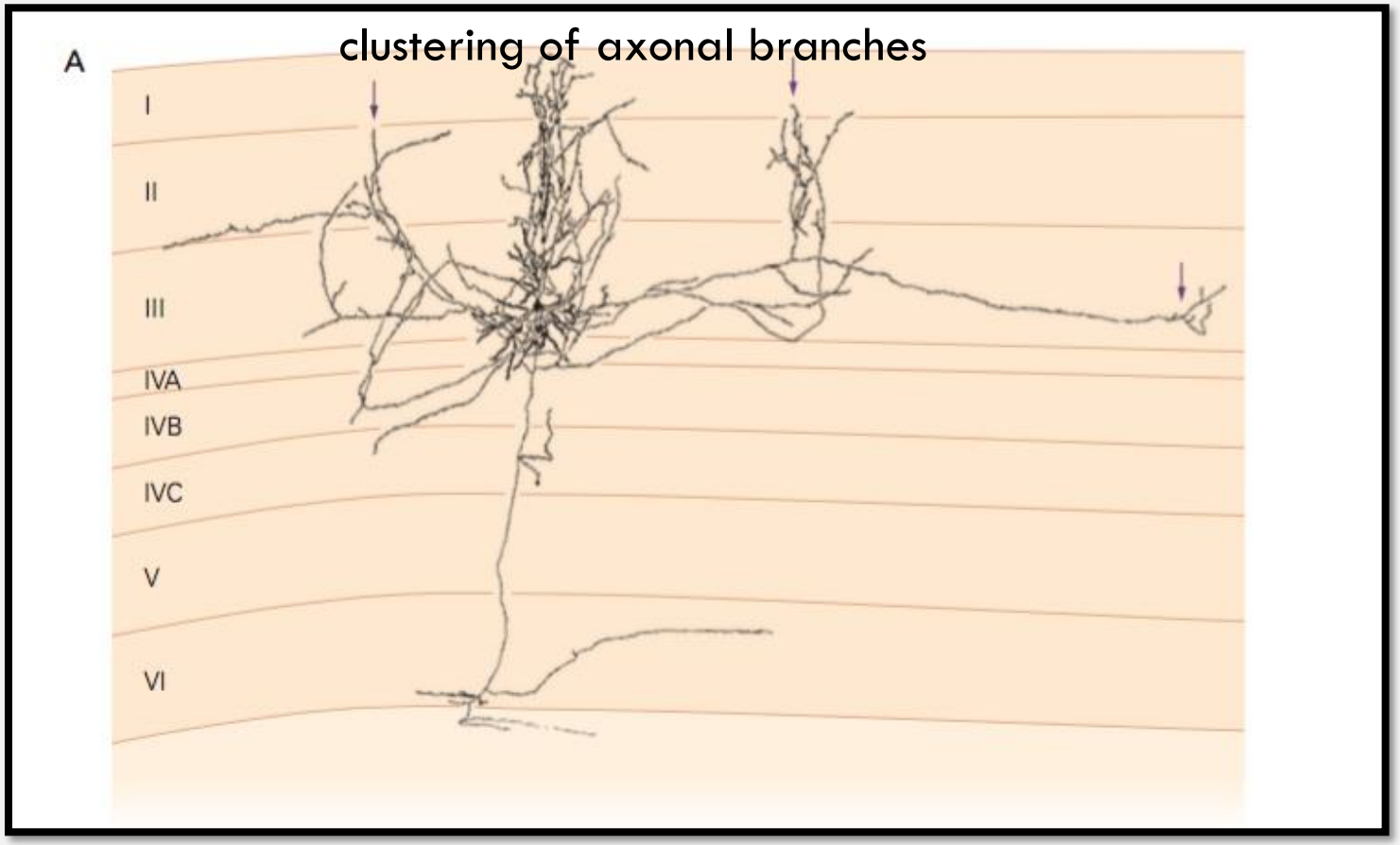
- One portion of the visual field
- ~ 1 mm diameter



Kandel Fig 25-13

Functional linking of cortical columns

Anatomical evidence

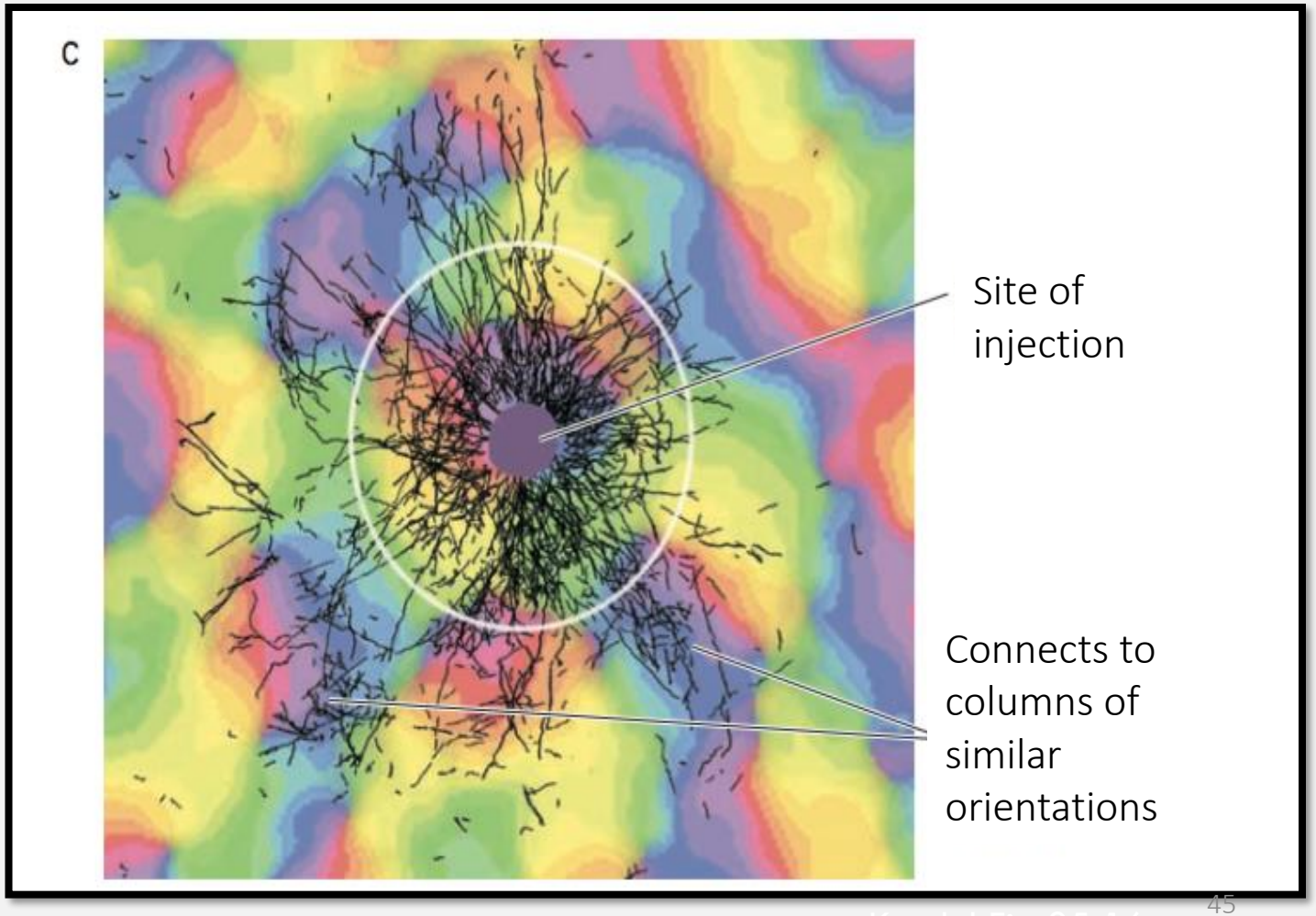


Kandel Fig 25-16

Functional linking of cortical columns

Anatomical + functional evidence

- Inject adenoviral vector with GFP into one orientation column
- Superimpose on map of all orientation columns (different colours)

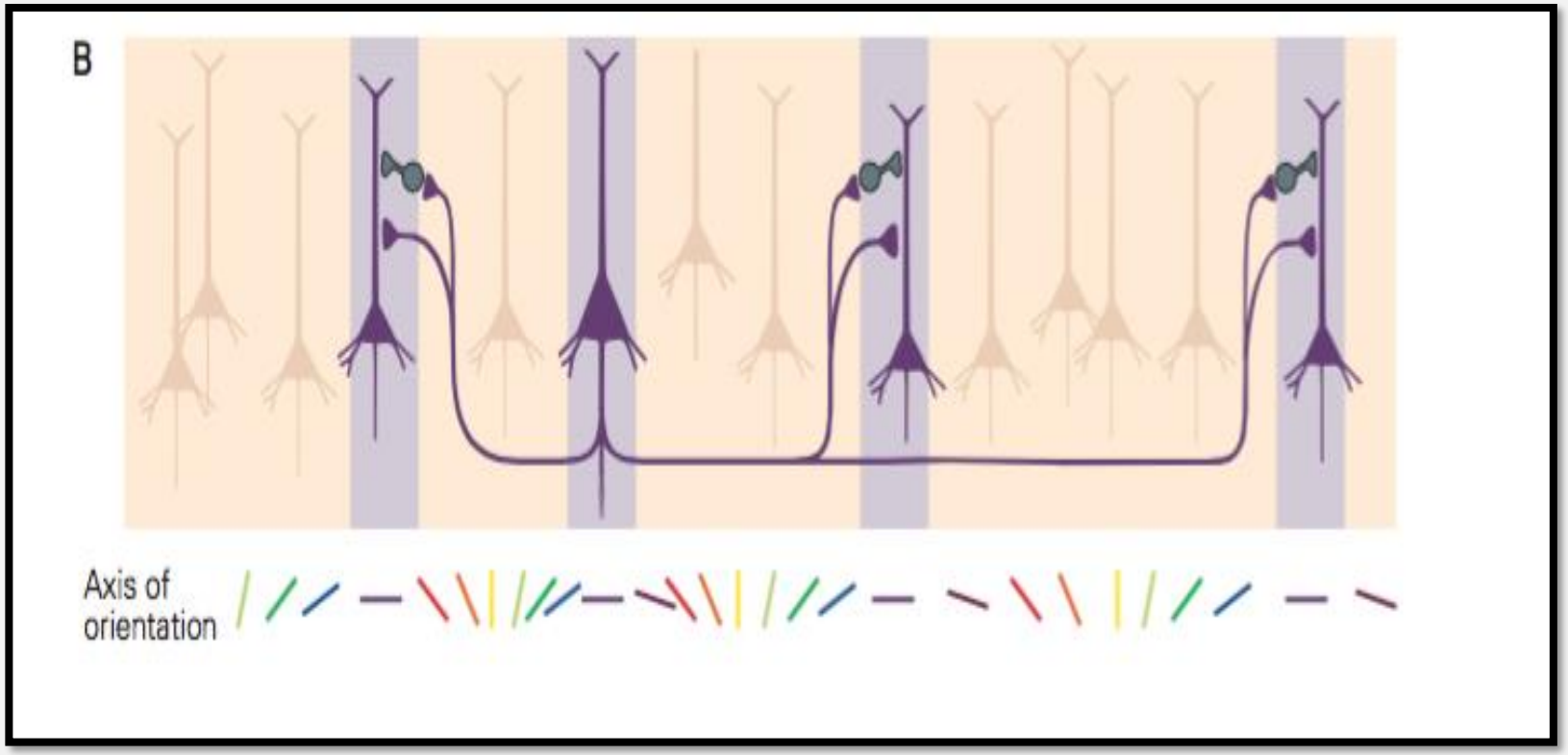


Kandel Fig 25-16

Functional linking of cortical columns

Population Coding

- Complex representations formed through integrating activity across a population



Kandel Fig 25-16

Building an image

Categorization

- receptive fields can be described as hierarchical. More complex events are built up from inputs of simpler ones.

V1 (primary visual cortex)

- perceives objects and events and is necessary in forming the building blocks for mental images.

V2

- Starts to combine the building blocks of V1

V4 cells

- have a strong response to concentric and radial stimuli.
- Some V4 cells also respond to color.

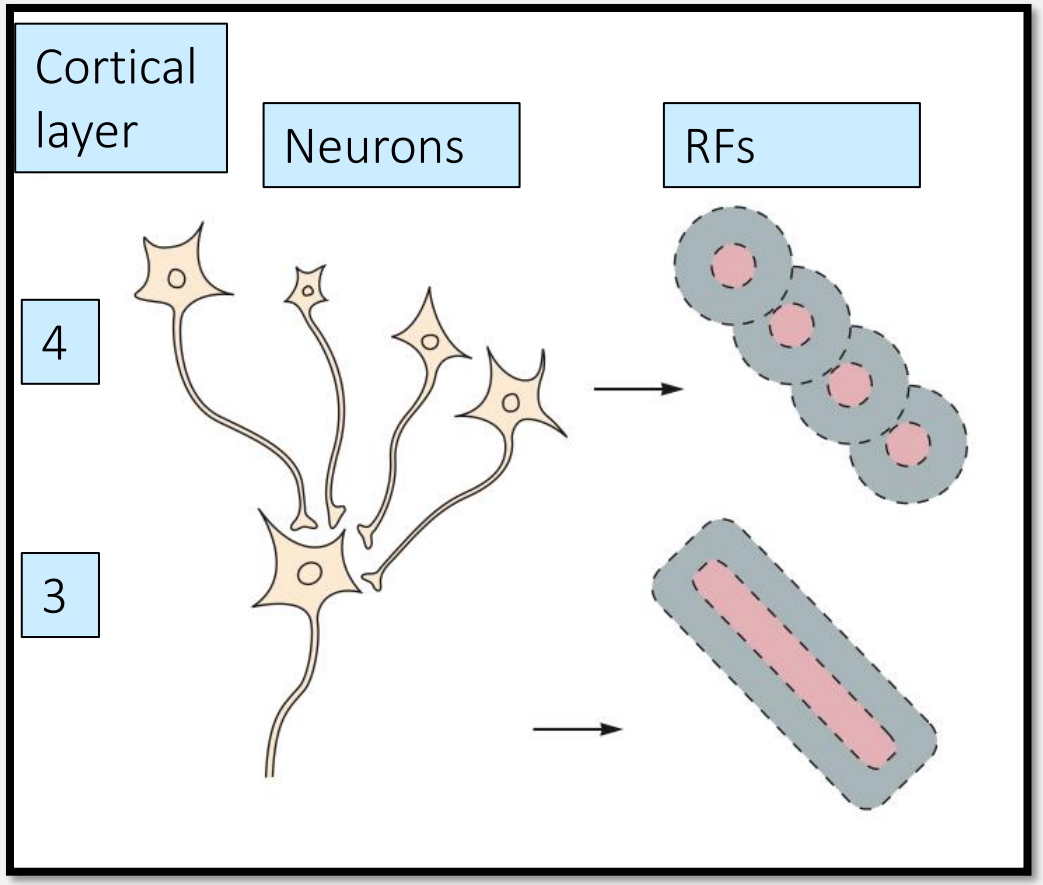
V5, also called the *medial temporal area* (*MT*)

- is specialized for motion perception.

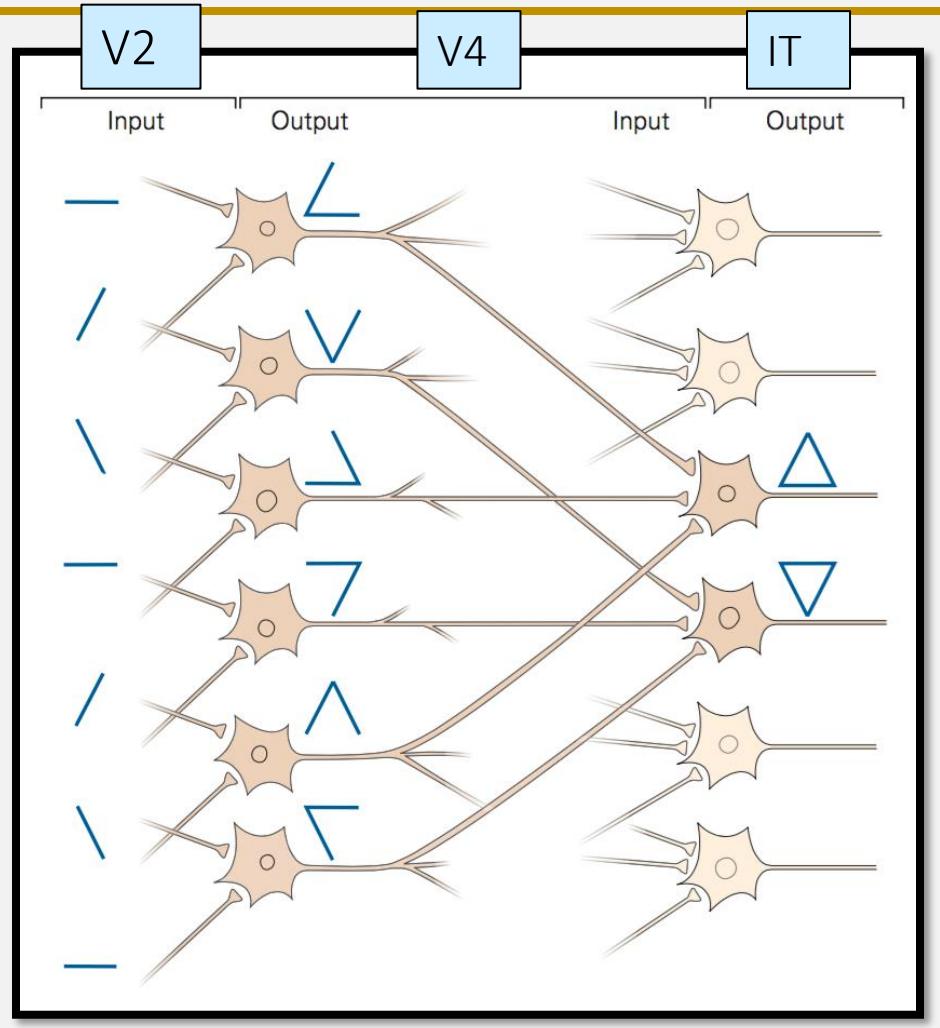
Cells in the inferior temporal cortex (IT)

- respond to complex shapes, sometimes combined with color or texture

Building an image



Kandel Fig 27-3



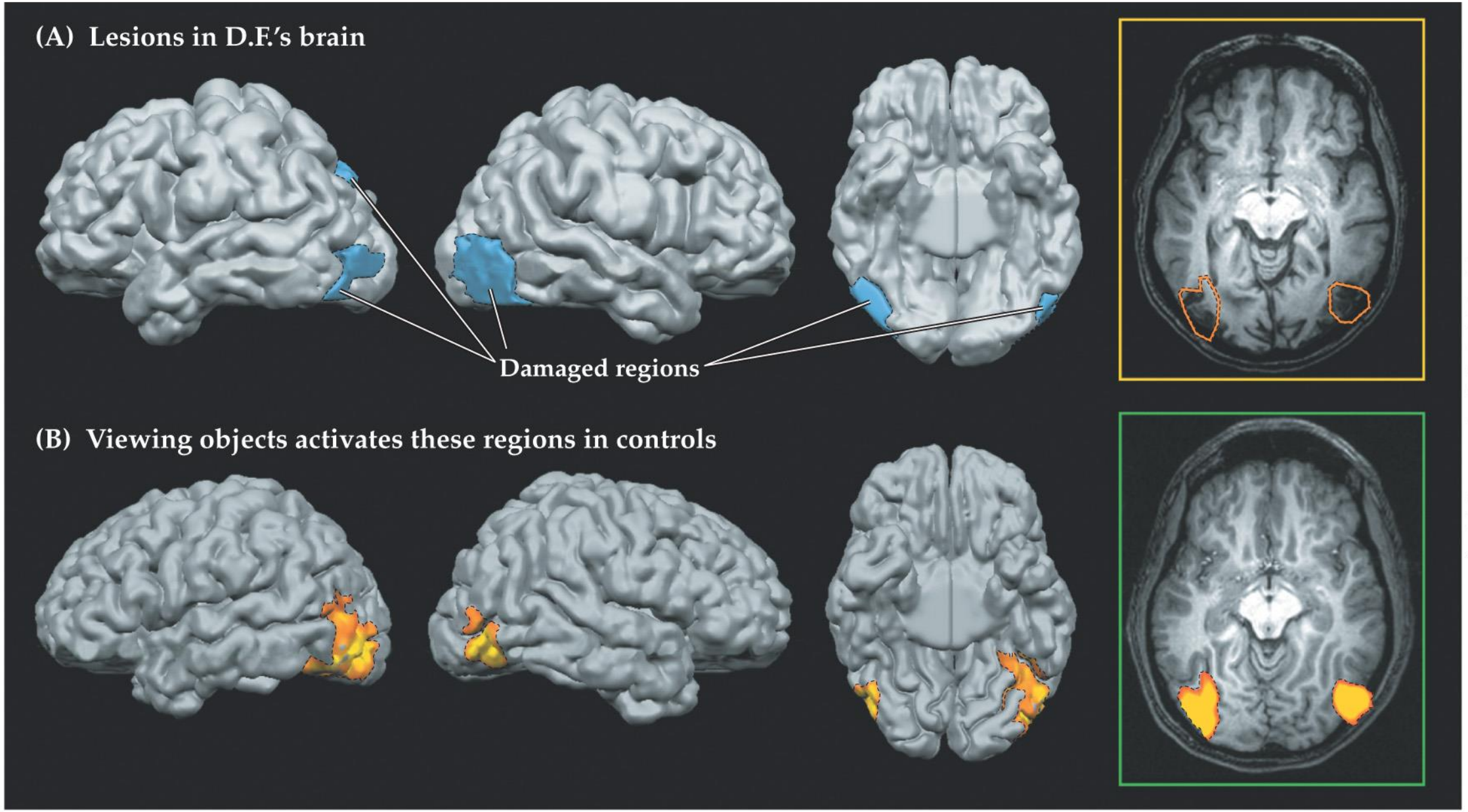
Kandel Fig 21-13

Processing streams

Case study

D.F.

- Fell unconsciousness during a shower due to a malfunctioning space heater in the bathroom
- She suffered from carbon monoxide poisoning which deprived a part of her brain from oxygen for an extended period of time
- After the accident, her symptoms included:
  - Loss of ability to recognize objects
  - Loss of ability to recognize people
  - Hand her an object and she can use it no problem: e.g. flashlight, keys, utensils
  - Show her a mail slot – no idea what it is or what orientation it is
  - Hand her mail – she can slide it through the slot, even with changes to the slot's orientation?
- What can we learn from DF?



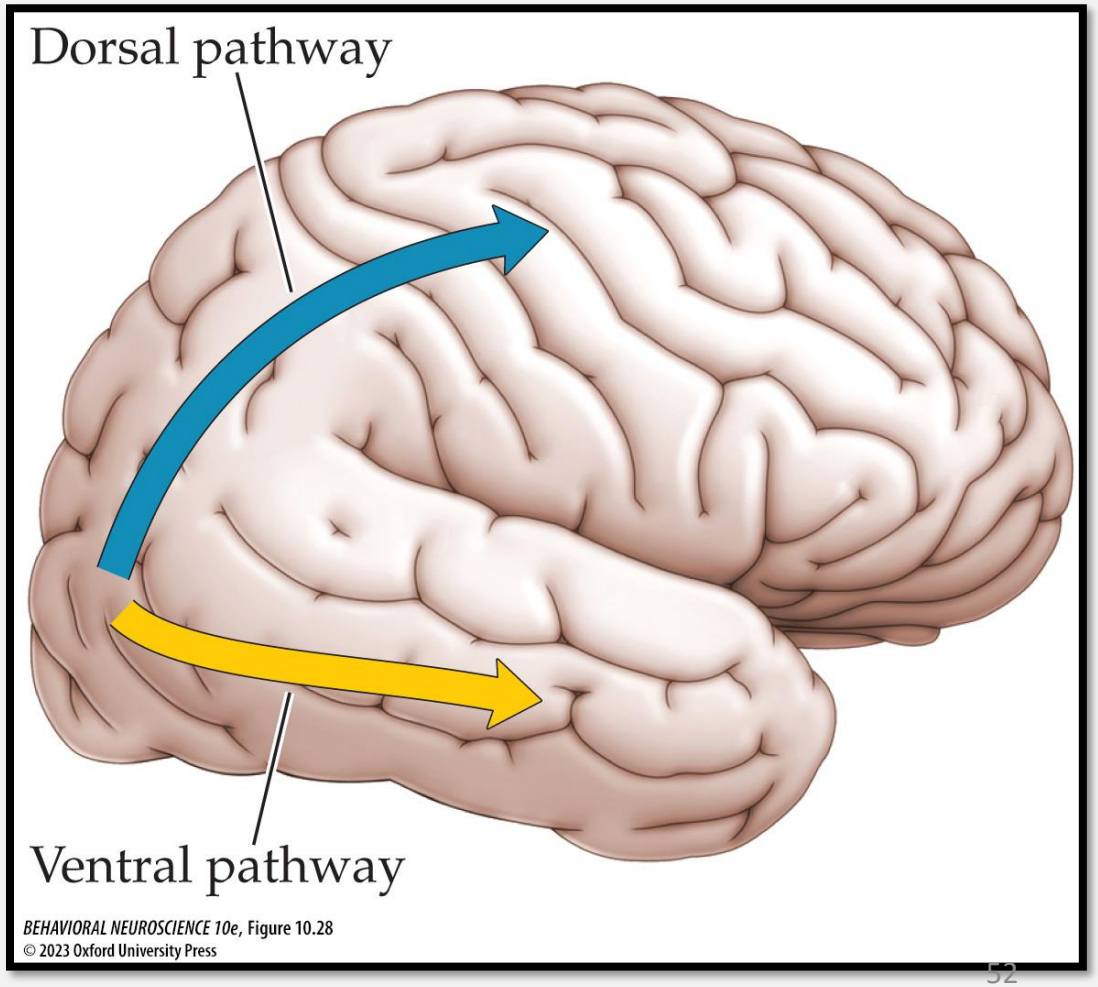
From T. W. James et al., 2003. *Brain* 126: 2464–2475. Courtesy of Thomas James

BEHAVIORAL NEUROSCIENCE 10e, Figure 10.29

Processing streams

Two main processing streams originate in primary visual cortex:

- A ventral processing stream, for identifying objects (*what*).
- A dorsal stream for assessing the location of objects (*where*).
    - Both originate in primary visual cortex.



Processing streams [2]

Damage to either processing stream can result in impairment.

Optic ataxia

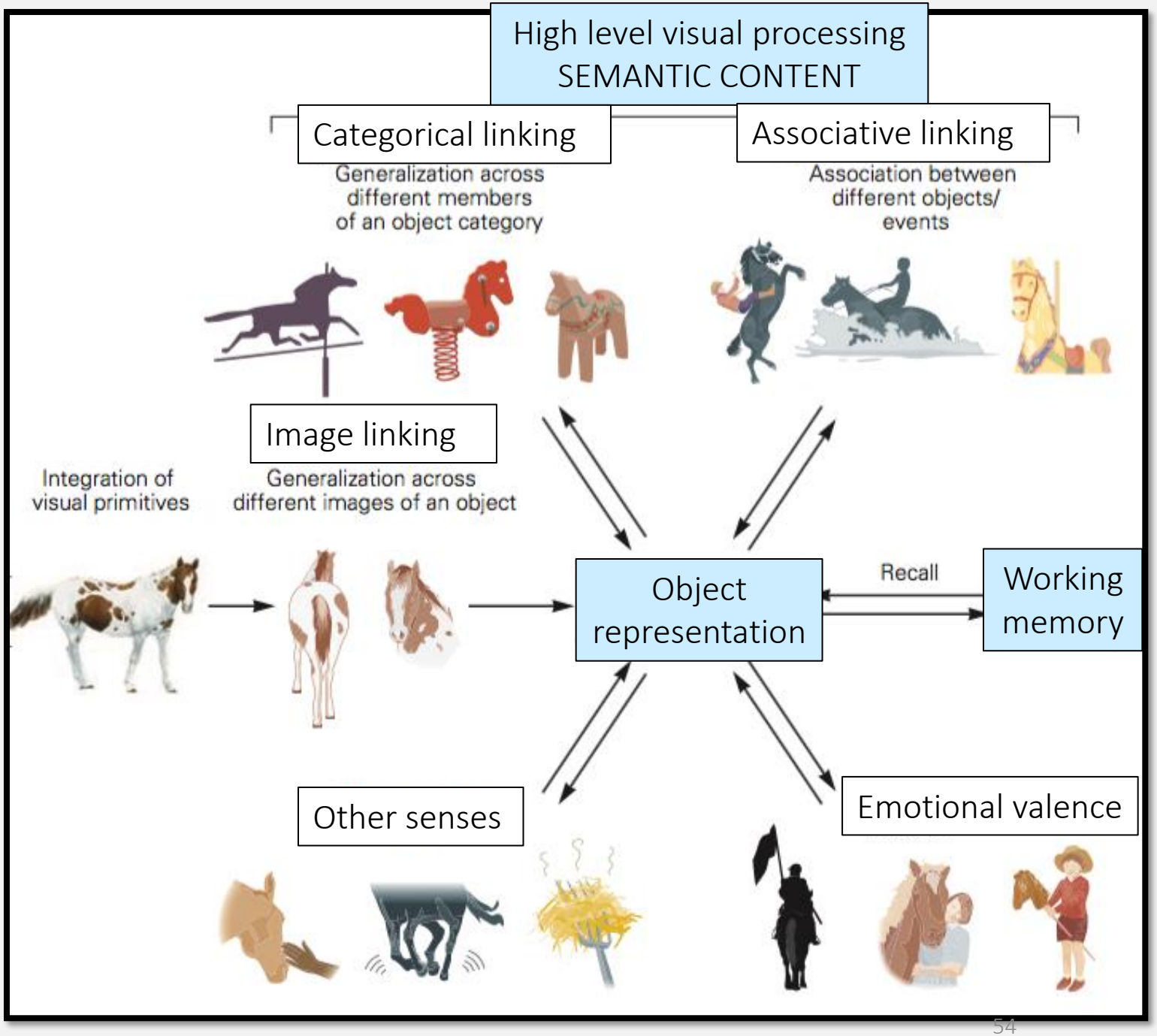
- due to damage in the posterior parietal cortex (dorsal stream)
- difficulty using vision to reach for an object.

Visual agnosia

- Damage to the ventral stream (such as in the occipitotemporal and inferior temporal areas)
- problems in identifying faces and objects.

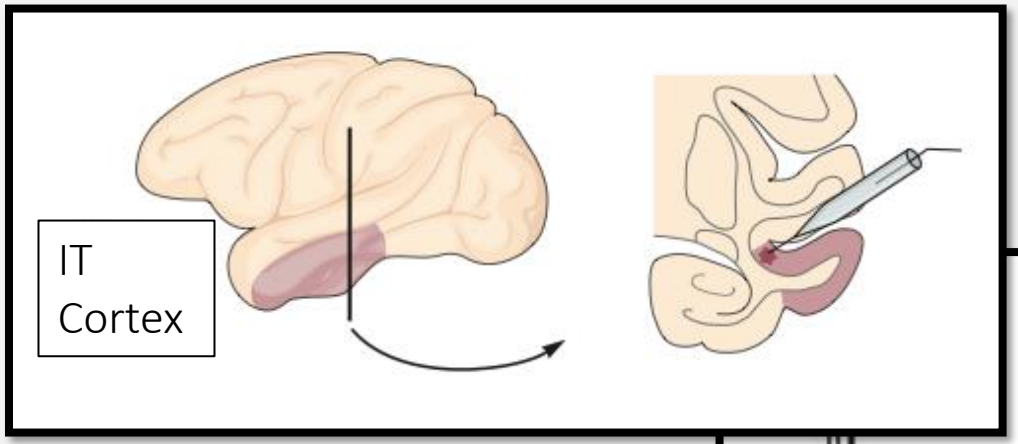
Objects

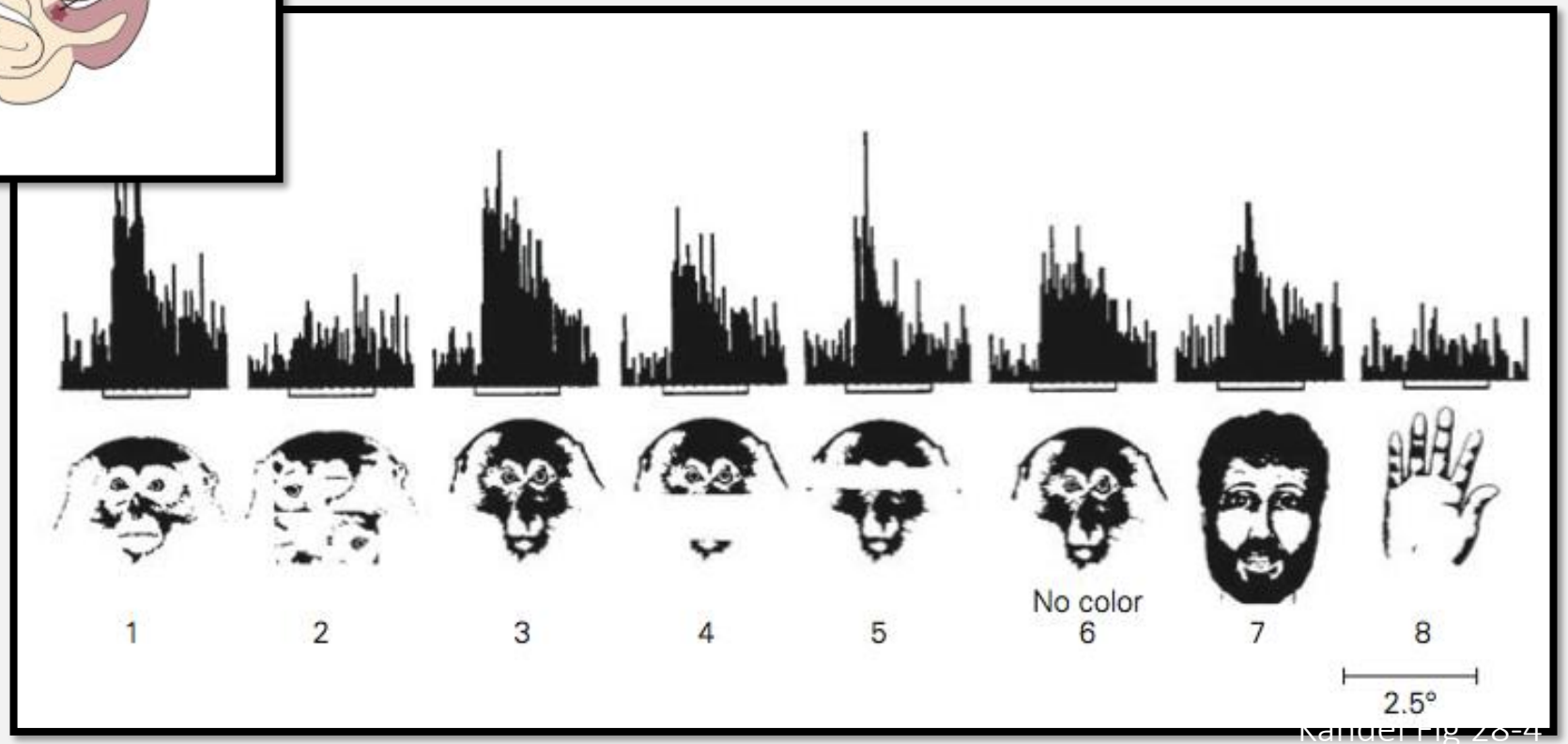
A sophisticated task



Kandel Fig 28-1

Receptive Fields - IT





Kandel Fig 26-4

Discussion: which brain area is likely implicated in each form of agnosia. How could you test a patient without brain imaging for each type of agnosia?

Face recognition

Apperceptive Agnosia

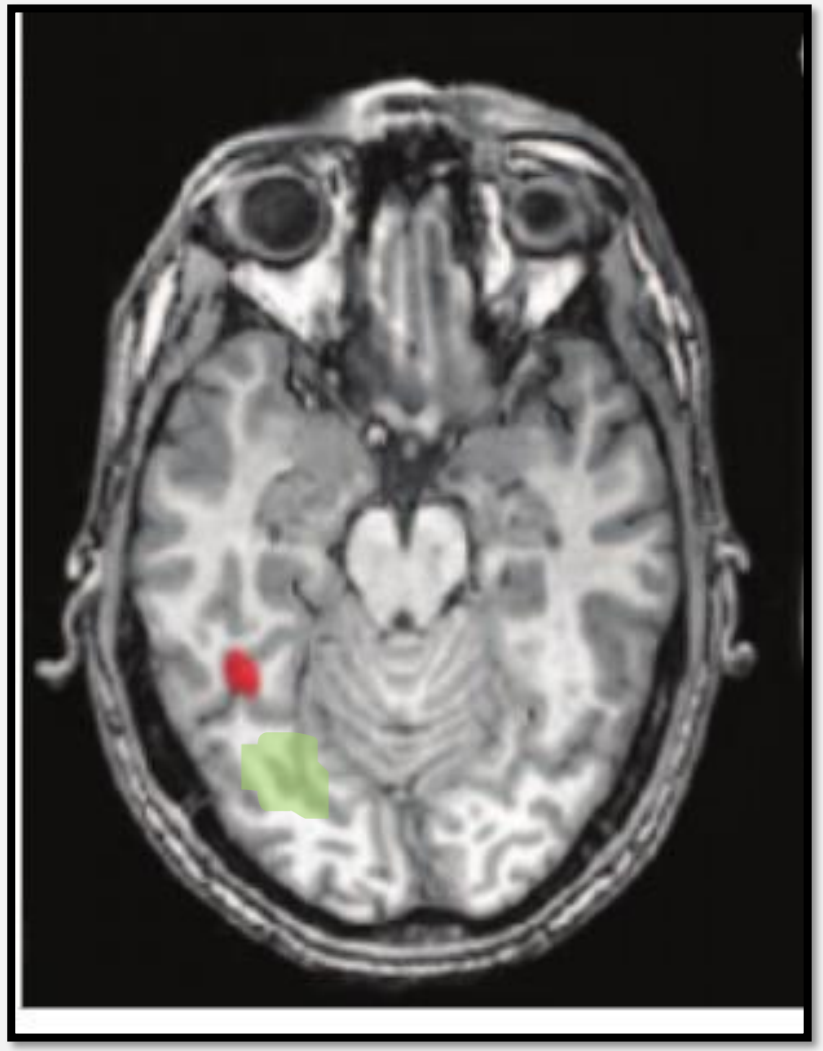
- Difficulty forming a complete conscious percept of an image
- Difficulty recognizing shape, cannot recognize or name objects

Associative Agnosia

- Difficulty recognizing objects
- Difficulty assigning meaning or individual identity to an object

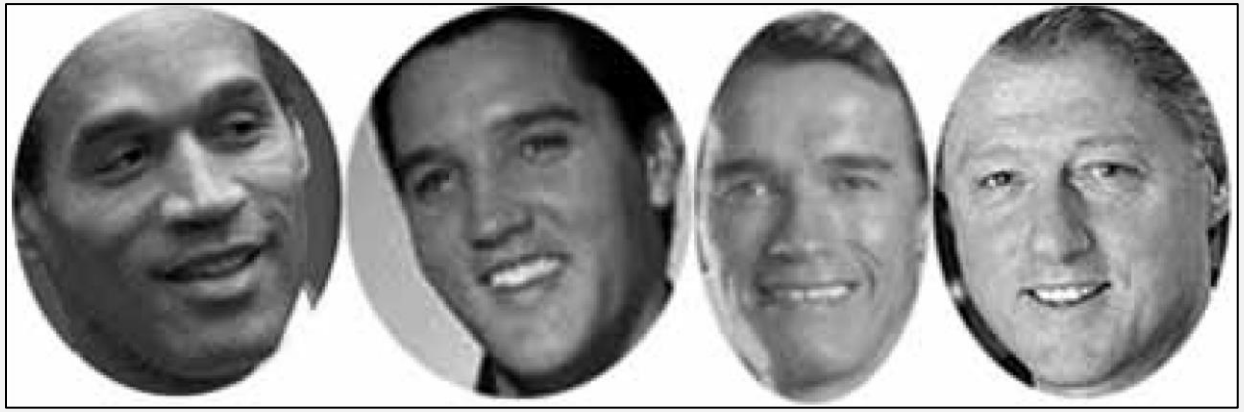
Fusiform Gyrus

Occipitotemporal area

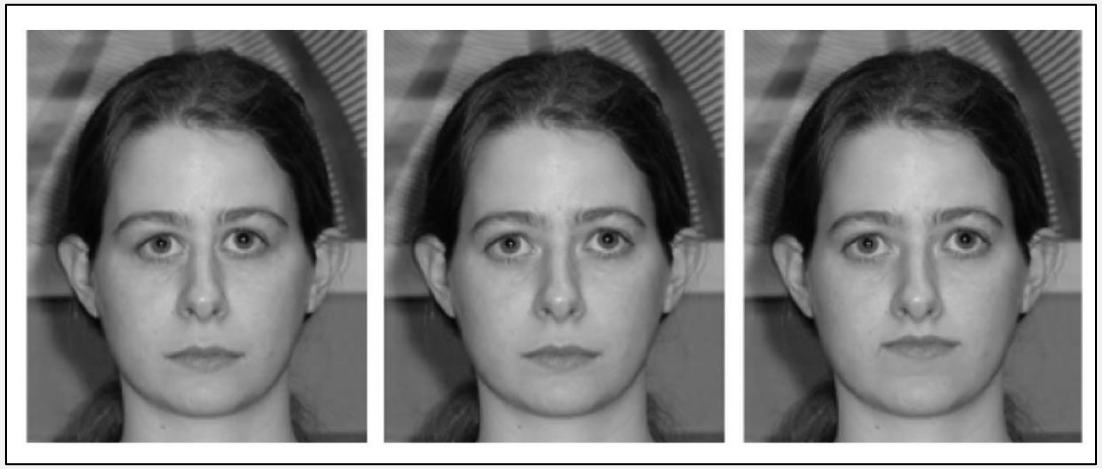


Journal of Neuropsychology, Barton, 2008

Face recognition and IT



Duchaine, Parker & Nakayama, 2003



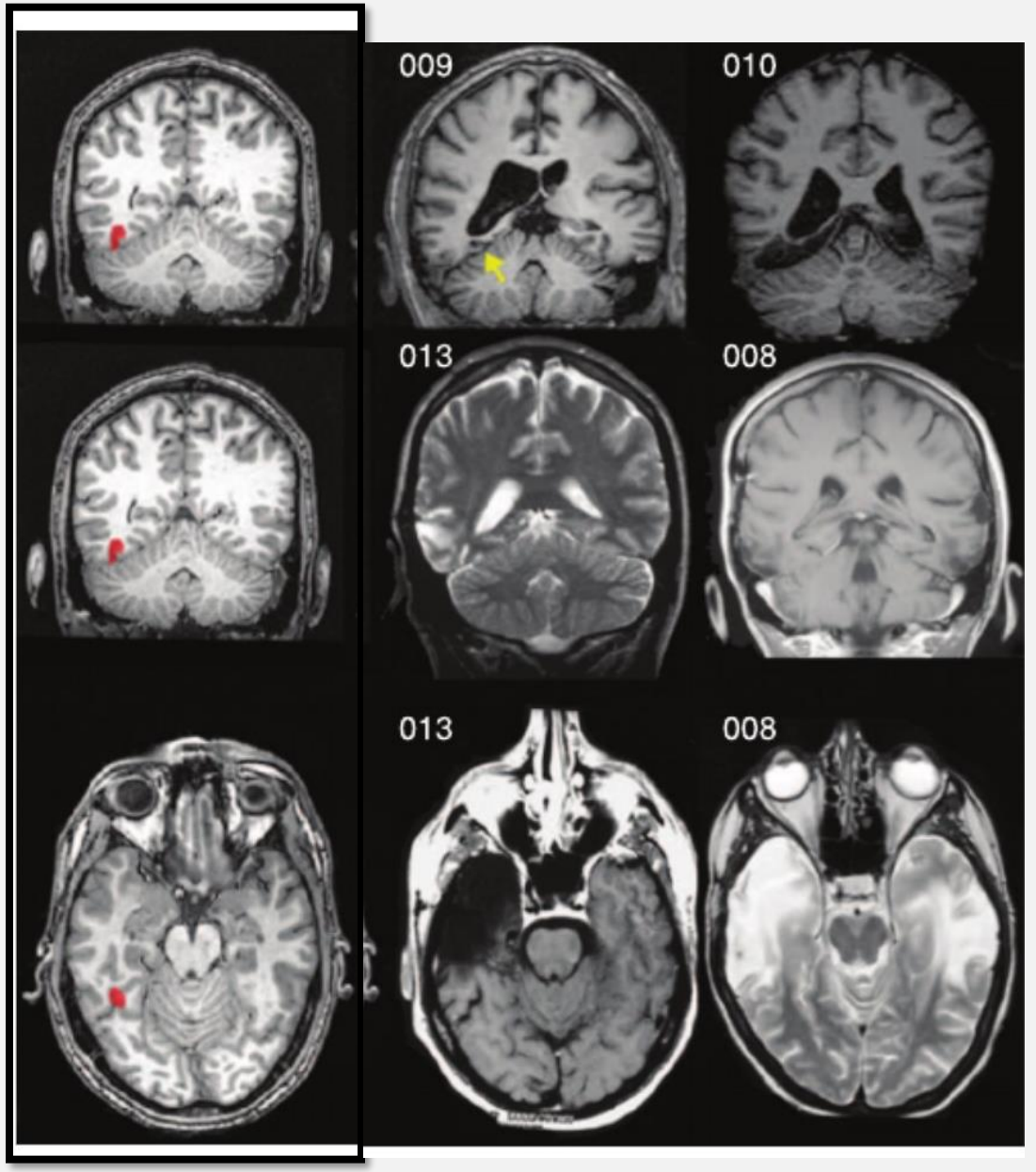
Barton, 2008

Journal of Neuropsychology, Barton, 2008

Face recognition and IT

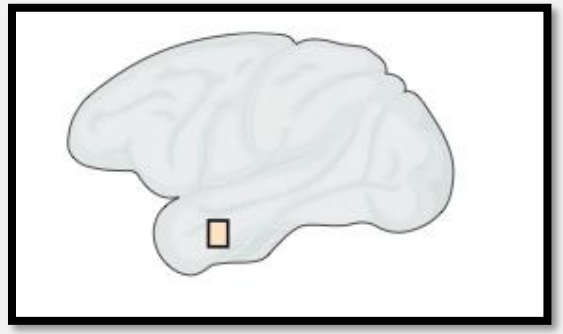
Coronal slices

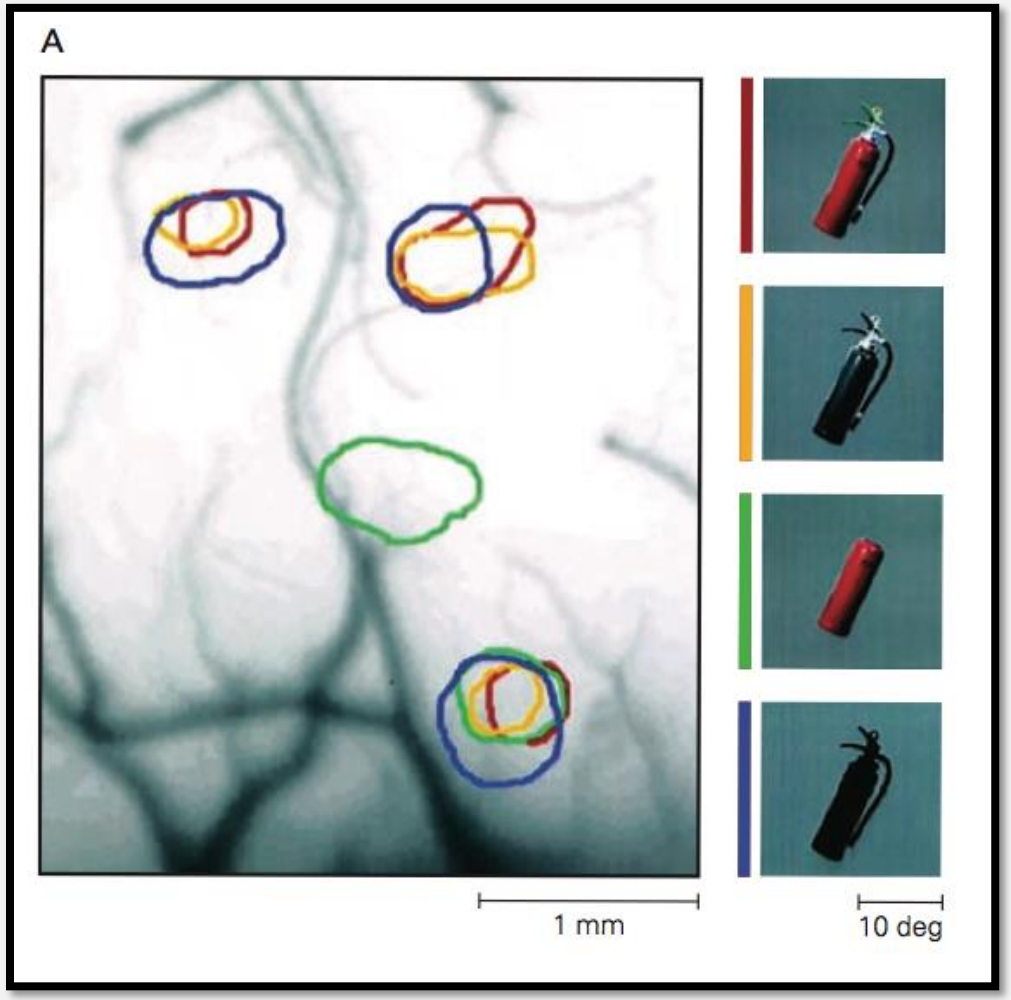
Horizontal slices

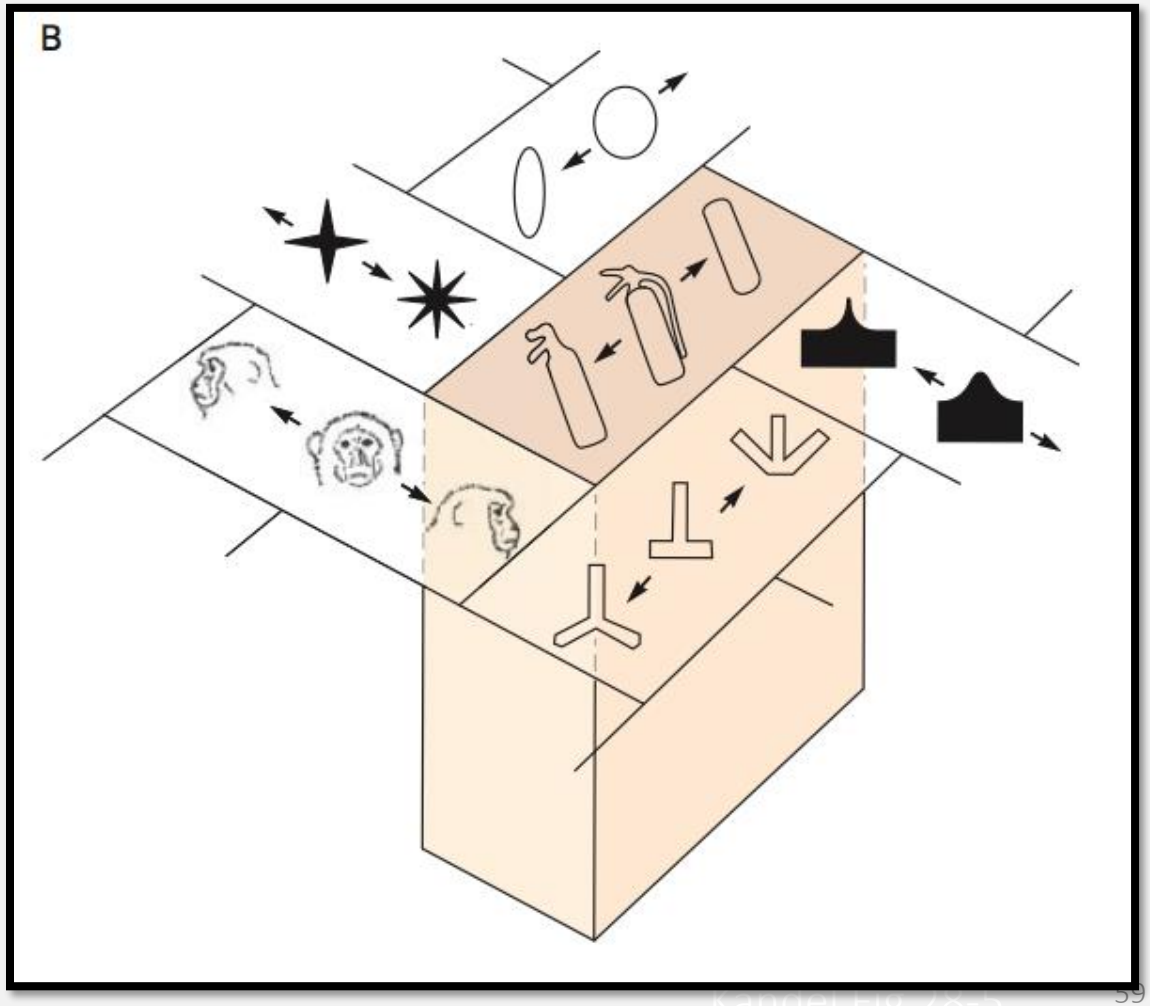


Journal of Neuropsychology, Barton, 2008

Temporal cortex representations





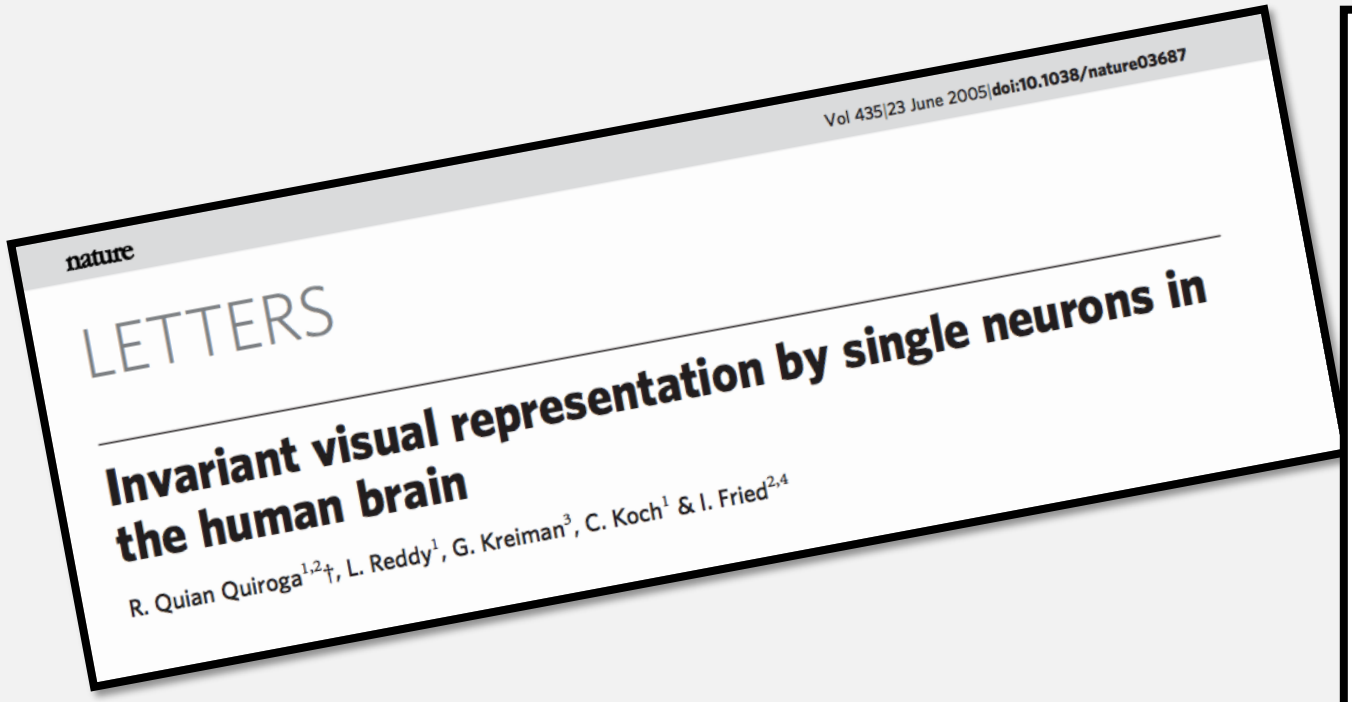


Kandel Fig 28-5

How far does the hierarchy go?

Is there a ‘super’ single neuron responsible for 1 specific item somewhere down the line?

The Jennifer Aniston neuron



nature

Vol 435|23 June 2005|doi:10.1038/nature03687

LETTERS

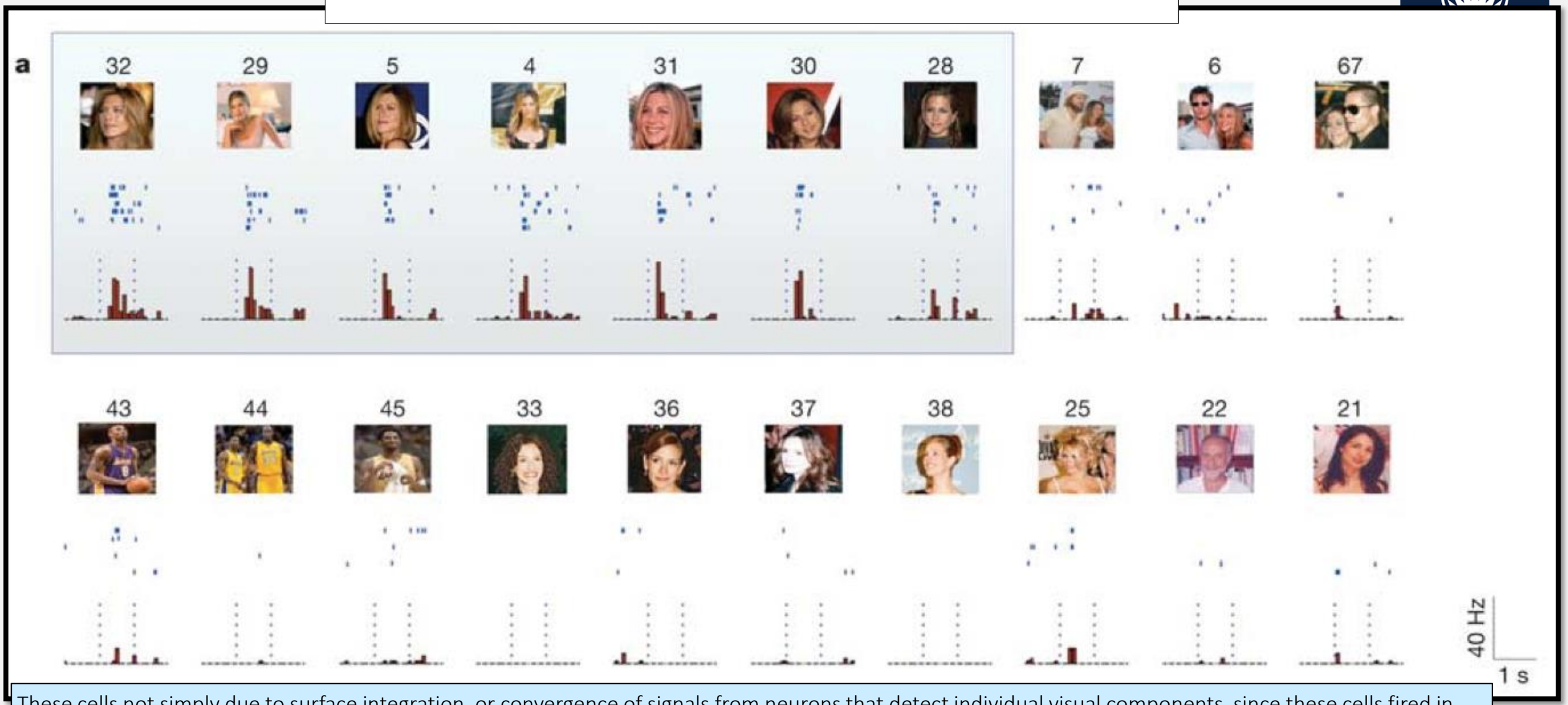
Invariant visual representation by single neurons in the human brain

R. Quian Quiroga[1,2]†, L. Reddy[1], G. Kreiman[3], C. Koch[1] & I. Fried[2,4]

The subjects were eight patients with pharmacologically intractable epilepsy who had been implanted with depth electrodes to localize the focus of seizure onset. For each patient, the placement of the depth electrodes, in combination with micro-wires, was determined exclusively by clinical criteria[13]. We analysed responses of neurons from the hippocampus, amygdala, entorhinal cortex and parahippocampal gyrus to images shown on a laptop computer in 21 recording sessions. Stimuli were different pictures of individuals, animals, objects and landmark buildings presented for 1 s in pseudo-random order, six times each. An unpublished observation in our previous recordings was the sometimes surprising degree of invariance inherent in the neuron's (that is, unit's) firing behaviour. For example, in one case, a unit responded only to three completely different images of the ex-president Bill Clinton. Another unit (from a different patient) responded only to images of The Beatles, another one to cartoons from *The Simpson's* television series and another one to pictures of the basketball player Michael Jordan. This suggested that neurons might encode an abstract representation of an individual. We here ask whether MTL neurons can represent high-level

*medial temporal lobe, downstream of inferotemporal cortex

Receptive Field = Jennifer Aniston



These cells not simply due to surface integration, or convergence of signals from neurons that detect individual visual components, since these cells fired in response to sketches & strings of letters (i.e. J-E-N-N-I-F-E-R A-N-I-S-T-O-N). Much more abstract, higher level and multimodal representation, though still dependent on convergence and integration of lower-level representations