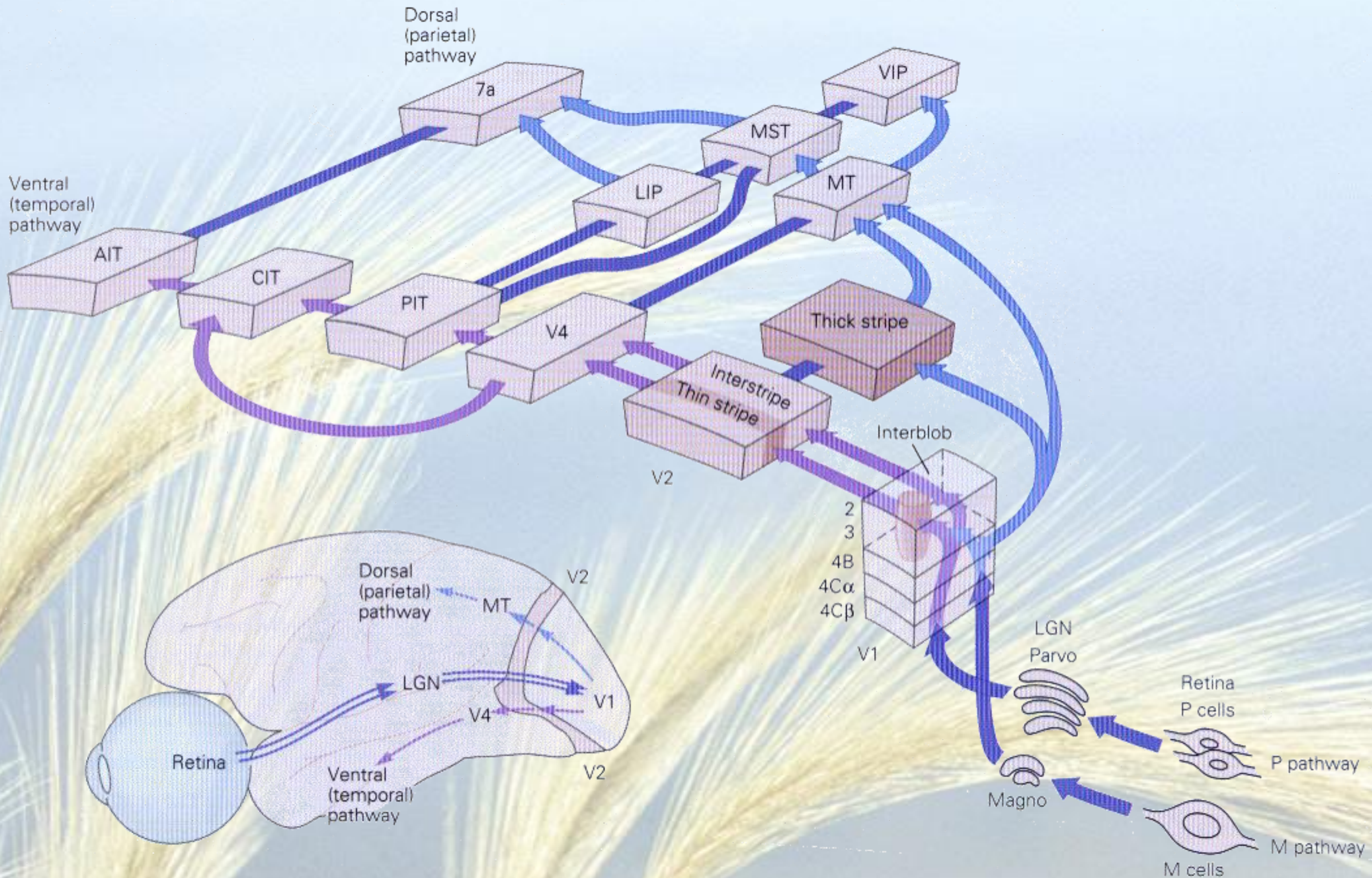
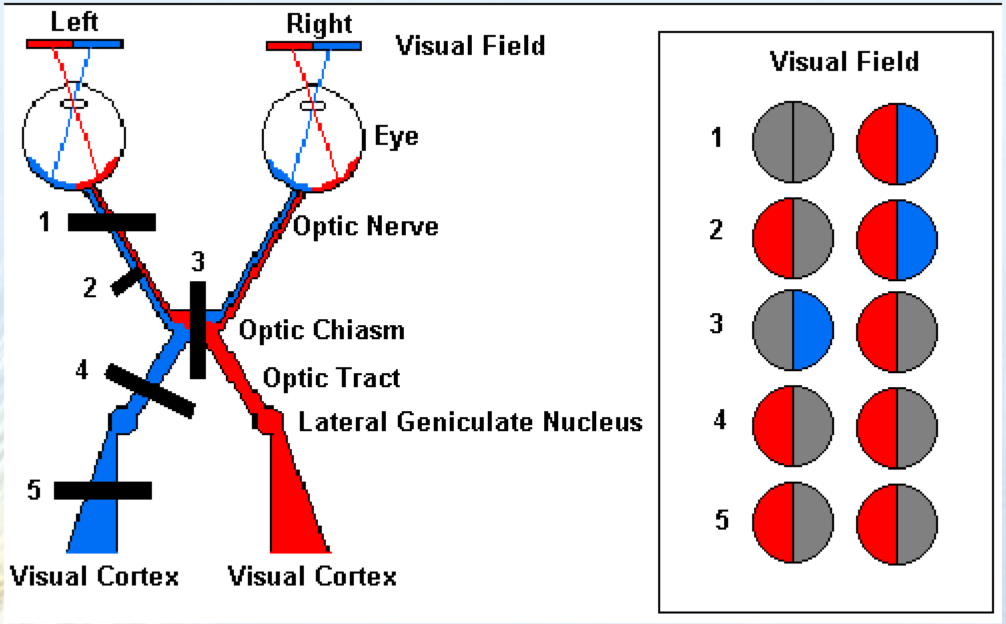
Primary Visual Cortex
V1-Striate Cortex


Dorsal
(parietal)
pathway
7a
VIP
MST
LIP
MT
Ventral
(temporal)
pathway
AIT
CIT
PIT
V4
Thick stripe
Interstripe
Thin stripe
V2
Interblob
2
3
4B
4Cα
4Cβ
V1
LGN
Parvo
Magno
Retina
P cells
P pathway
M pathway
M cells
Dorsal
(parietal)
pathway
MT
V2
LGN
V1
V4
Retina
Ventral
(temporal)
pathway
V2



Damage at site #1: this would be like losing sight in the left eye.
The entire left optic nerve would be cut and there would be a total loss of vision from the left eye.

Damage at site #2: partial damage to the left optic nerve.
Here, information from the nasal visual field of the left eye (temporal part of the left retina) is lost.

Damage at site #3: the optic chiasm would be damaged.
In this case, the temporal (lateral) portions of the visual field would be lost.
The crossing fibers are cut in this example.

Damage at site #4 and #5: damage to the optic tract (#4) or the fiber tract from the LGN to the cortex (#5) can cause identical visual loss.
In this case, loss of vision of the right side.

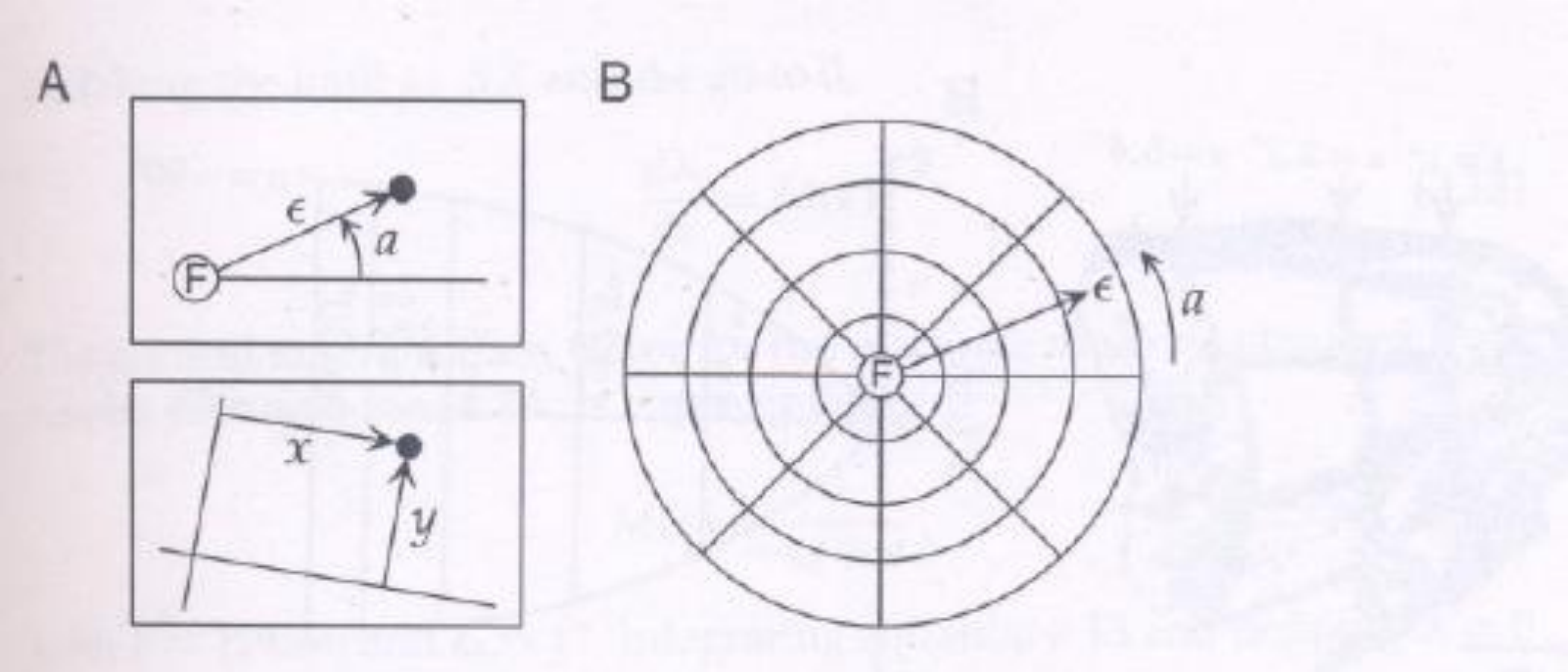
V1

- First stopover of visual information in cortex
- Retinotopic map:
  - Retinal information is mapped onto V1 such that nearby points are mapped onto nearby neurons in V1

Visual Field

- Consider the visual field as a sphere with the viewer at the center
- "North pole" of the sphere is the fixation point; this point is mapped onto fovea
- Latitude is called "eccentricity", ε (0–70^o)
- Longitude is called "azimuth," a (-90^o to 90^o)

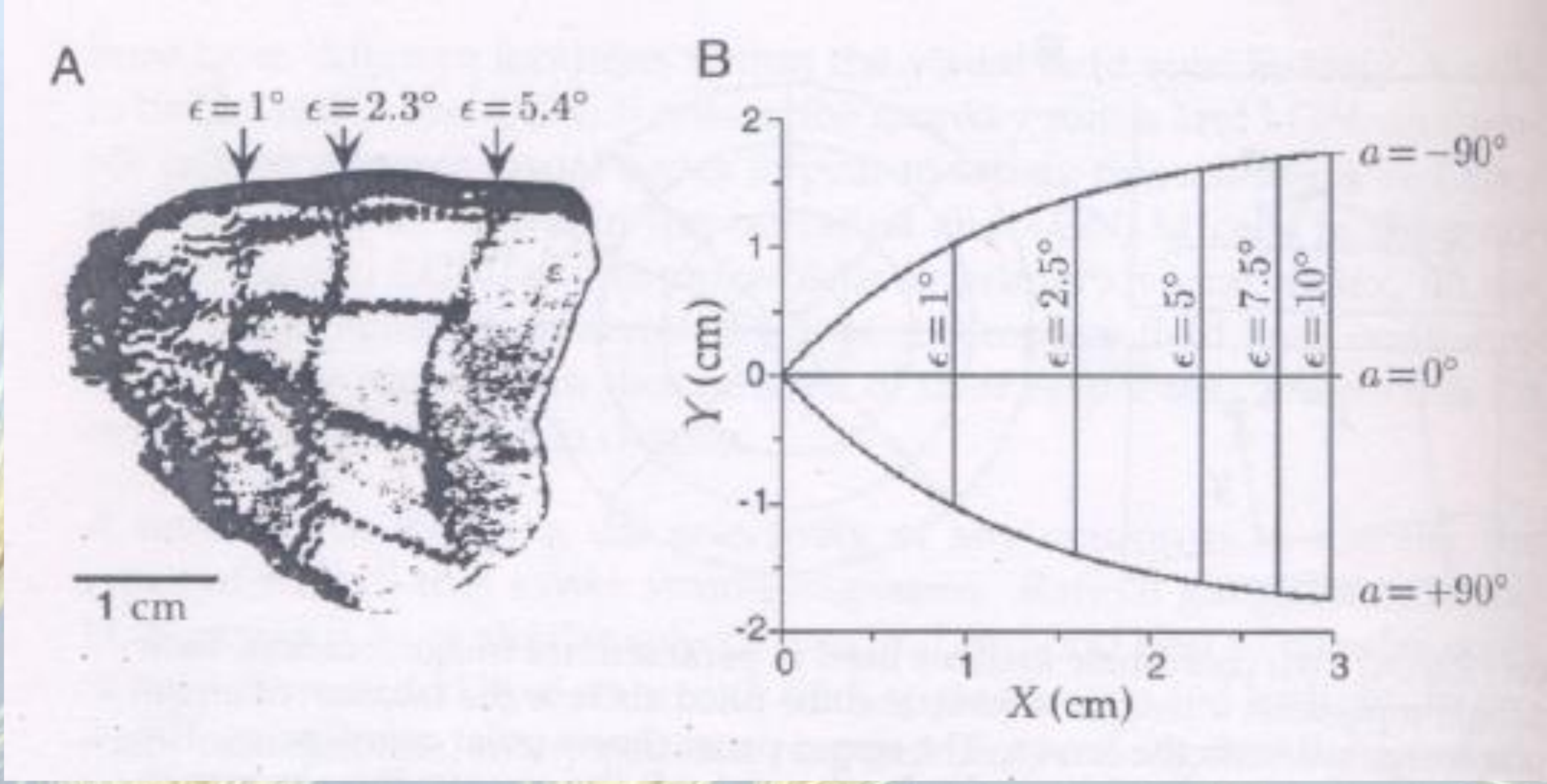
Visual field



Experiment to find Retinotopic Map

- “Bull’s-eye” pattern is displayed on a screen
- Pattern of activity in V1 is imaged by using a radioactive glucose; imaging reveals which neurons are active (taking up glucose)
- Experiment performed on monkey

Retinotopic Map



Retinotopic Map Features

- Vertical lines correspond to circles in the image
- Roughly horizontal lines correspond to radial lines
- Fovea is represented at the leftmost pole
- Azimuthal angles are positive in lower half, and negative in the upper half

Responses of neurons in V1

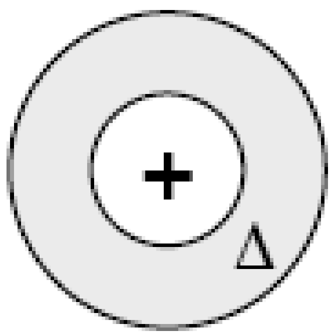
- Work of Hubel & Wiesel at Harvard in ’60s.
  - Neurons in V1 respond to oriented bars and edges and not to spots.
  - Some neurons also respond to moving bars.
  - Different neurons respond to different orientations.Within a dia of 1mm, all orientations are represented.

Simple and Complex Cells

- Simple cells: respond to an oriented line present in the center of their RF
- Complex cells: respond to an oriented line present almost anywhere in their RF
- End-stopping: some cells respond best when the line is not too long.

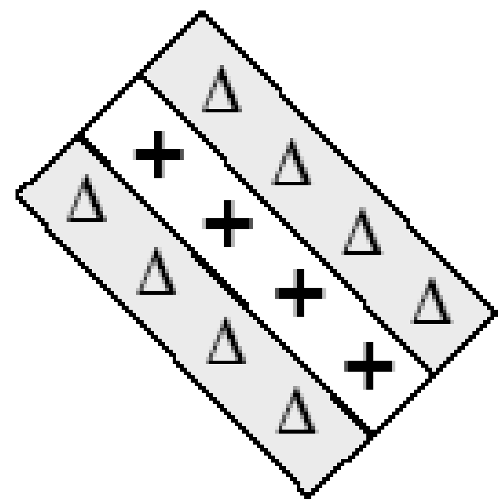
Transformation of Receptive Field Properties from LGN to Primary Visual Cortex

LGN Neuron



Circular Receptive Field
(e.g., on-center, off-surround)

"Simple Cell" in Cortex



Rectangular Receptive Field
(e.g., on-center, off-flanks)

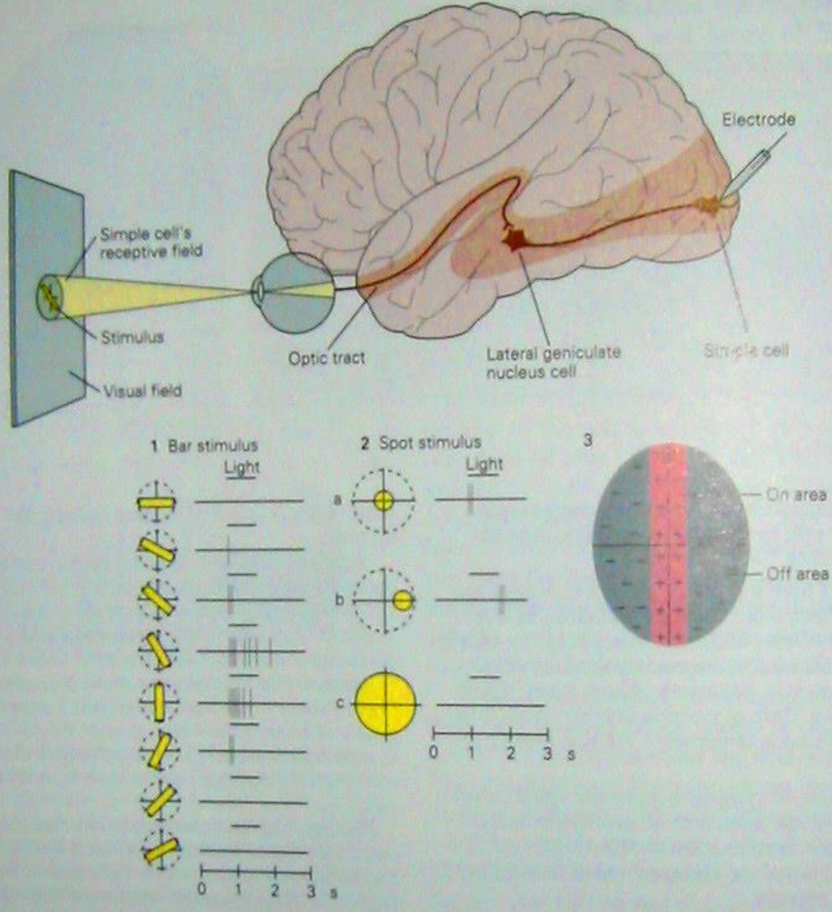


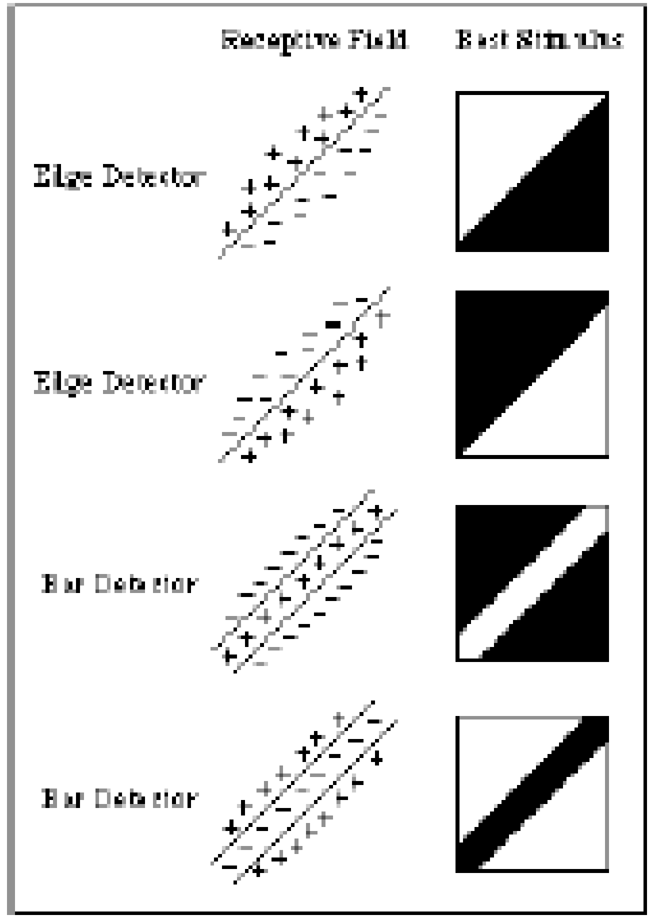
Figure 27-11 Receptive field of a simple cell in the primary visual cortex. The receptive field of a cell in the visual system is determined by recording activity in the cell while spots and bars of light are projected onto the visual field at an appropriate distance from the fovea. The records shown here are for a single cell. Duration of illumination is indicated by a line above each record of action potentials. (Adapted from Hubel and Wiesel 1959 and Zeki 1993.)

1. The cell's response to a bar of light is strongest if the bar of light is vertically oriented in the center of its receptive field.

2. Spots of light consistently elicit weak responses or no response. A small spot in the excitatory center of the field elicits only a weak excitatory response (**a**). A small spot in the inhibitory area elicits a weak inhibitory response (**b**). Diffuse light produces no response (**c**).

3. By using spots of light, the excitatory or "on" areas (+) and inhibitory or "off" areas (−) can be mapped. The map of the responses reveals an elongated "on" area and a surrounding "off" area, consistent with the optimal response of the cell to a vertical bar of light.

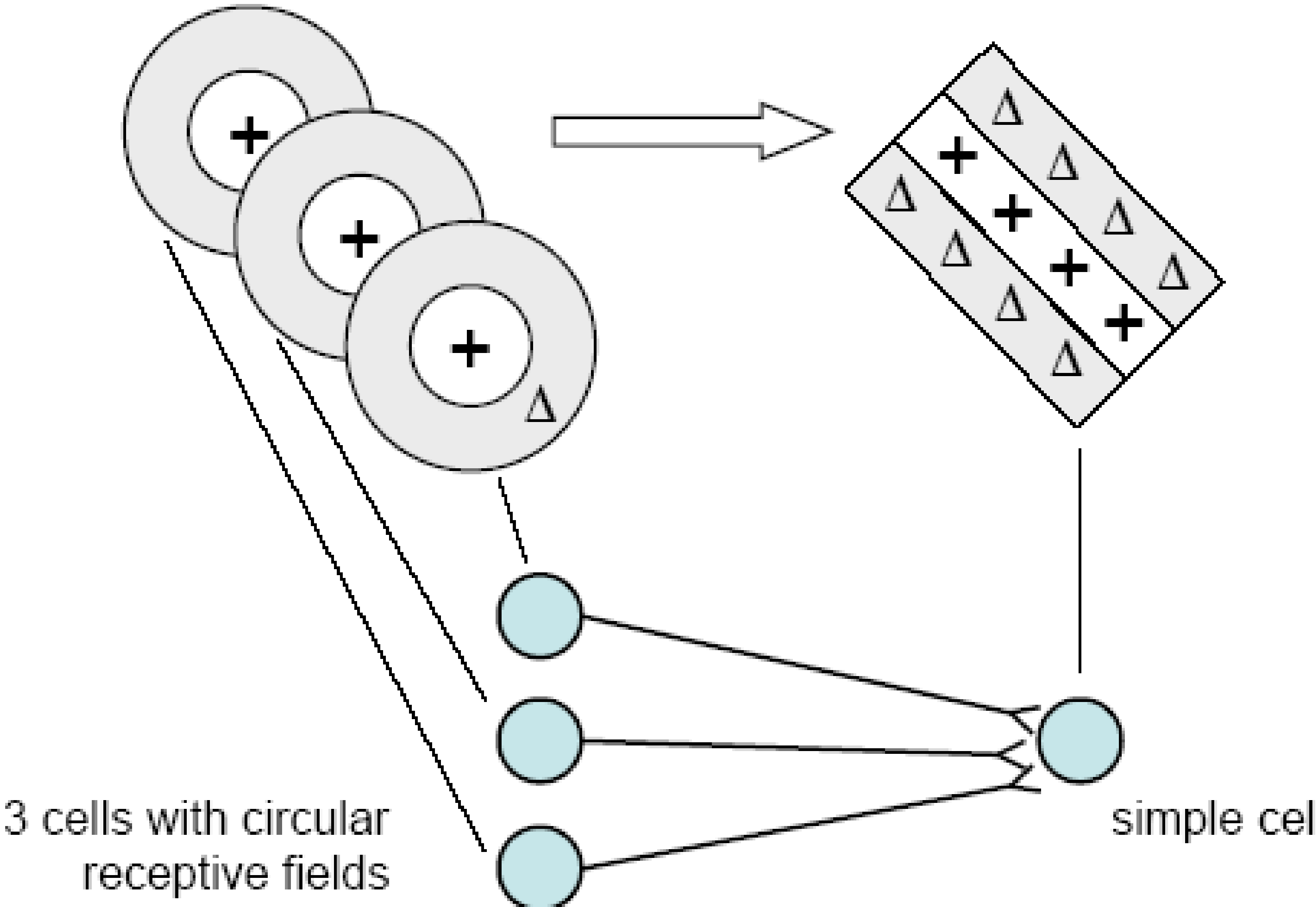
Examples of Simple Cell Receptive Fields



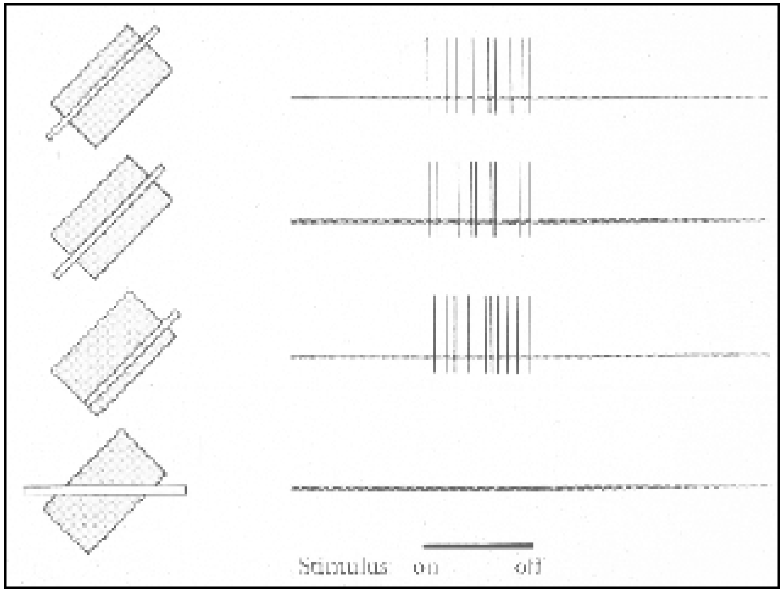
http://www.cquest.utoronto.ca/psych/psy280f/ch4/orientSelec.html

Simple cells can be used to detect edges and contours

Hypothetical Wiring Diagram for Generating a Simple Cell Receptive Field



Complex Cell Receptive Field Properties



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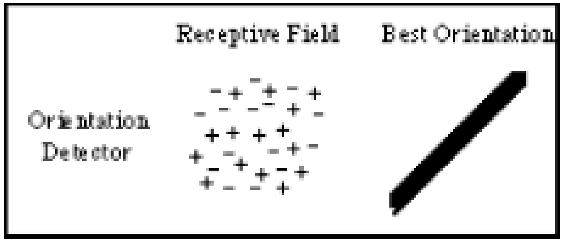
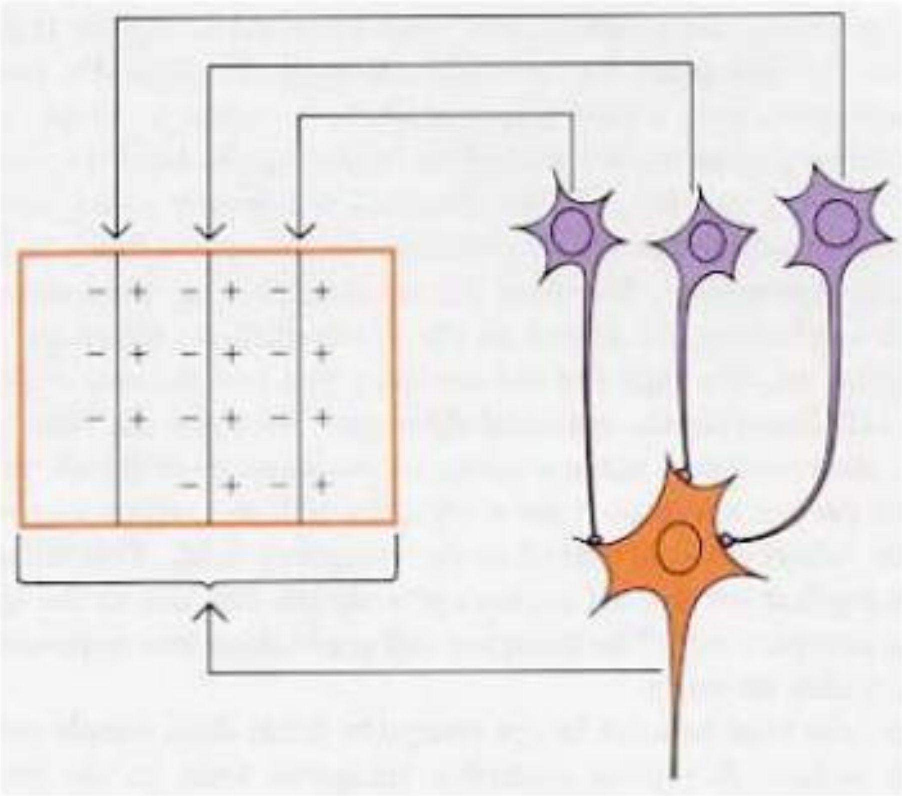


http://www.cquest.utoronto.ca/psych/psy280f/ch4/orientSelec.html

- "On" and "off" regions throughout receptive field
- Orientation selective

Hypothetical Wiring Diagram for Generating a Complex Cell's Receptive Field



http://neuro.med.harvard.edu/site/dh/b18.htm

Construction of complex cell receptive field via input from multiple simple cells

Schematic of Orientation Selectivity in the Primary Visual Cortex

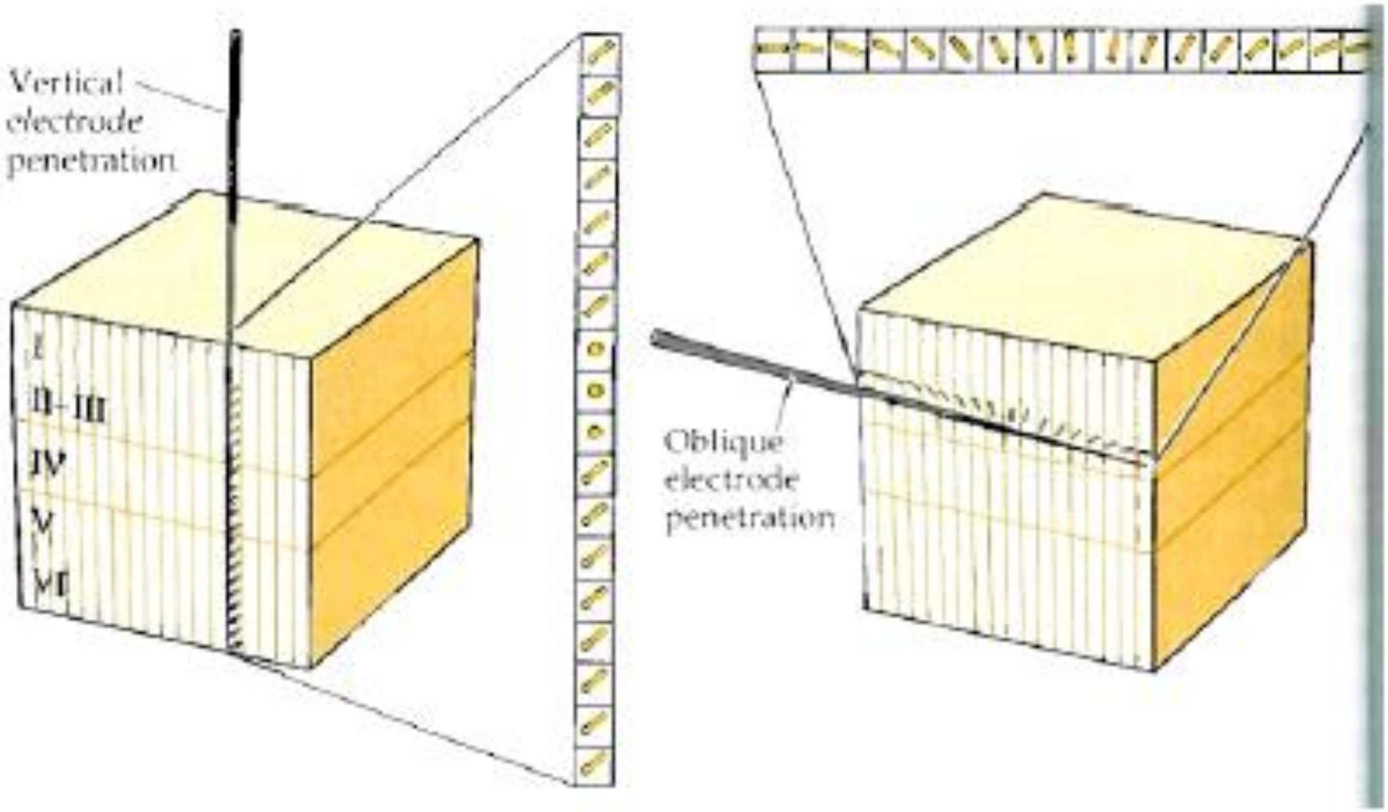
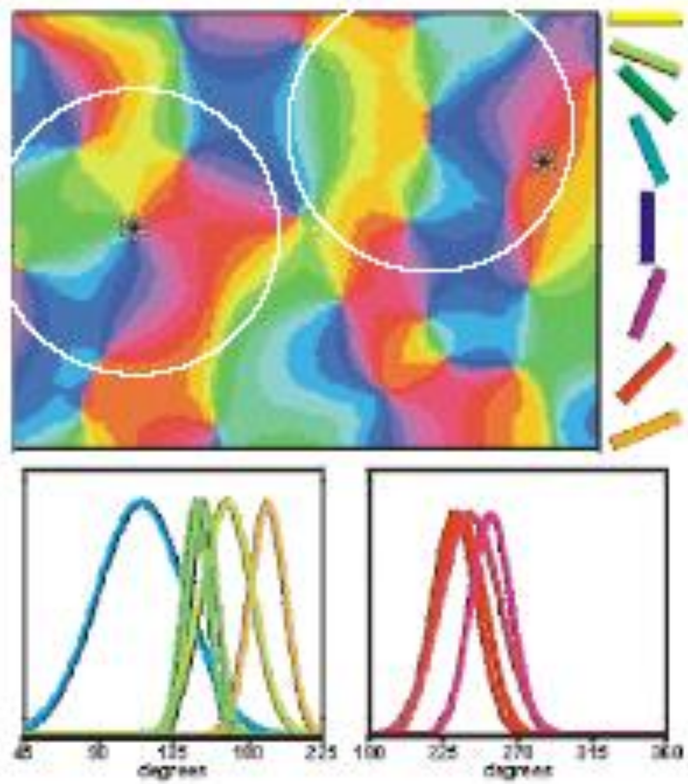


Fig. 11.12, Purves et al., Neuroscience, 3rd edition

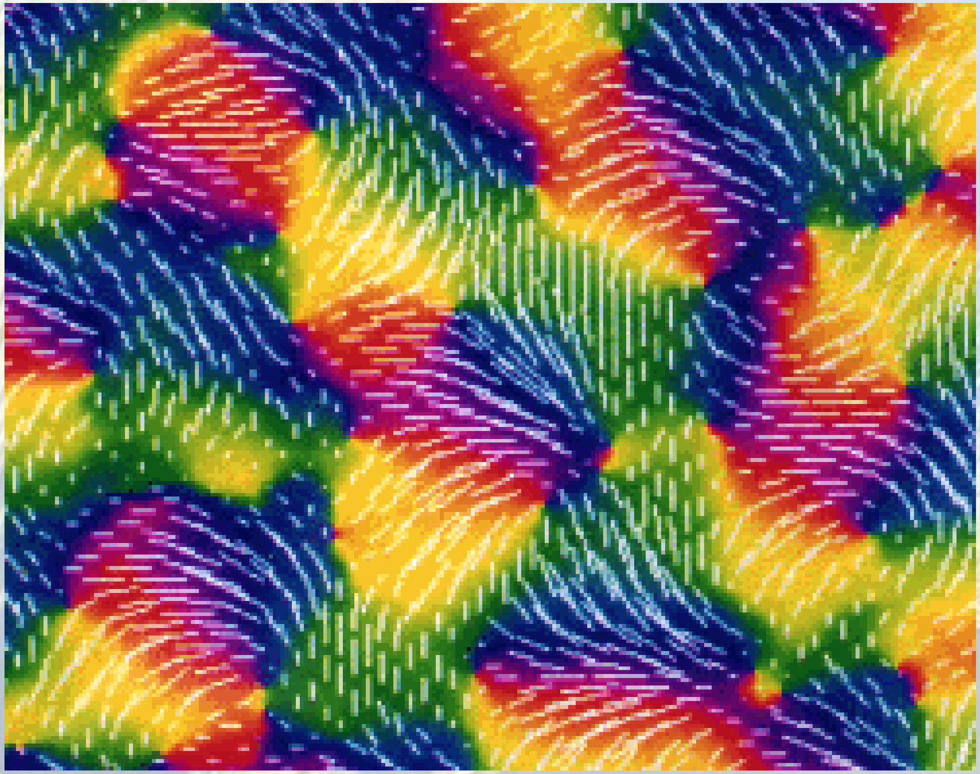
- Oblique/tangential penetration reveals progressive change in orientation selectivity
- Vertical penetration reveals columnar organization of orientation selectivity

Pinwheel Arrangement of Orientation Columns Revealed by Optical Imaging of Intrinsic Signals



http://www.neuro.mpg.de/ research/csn/pinwheel/

Orientation Columns



Schematic of Ocular Dominance Columns

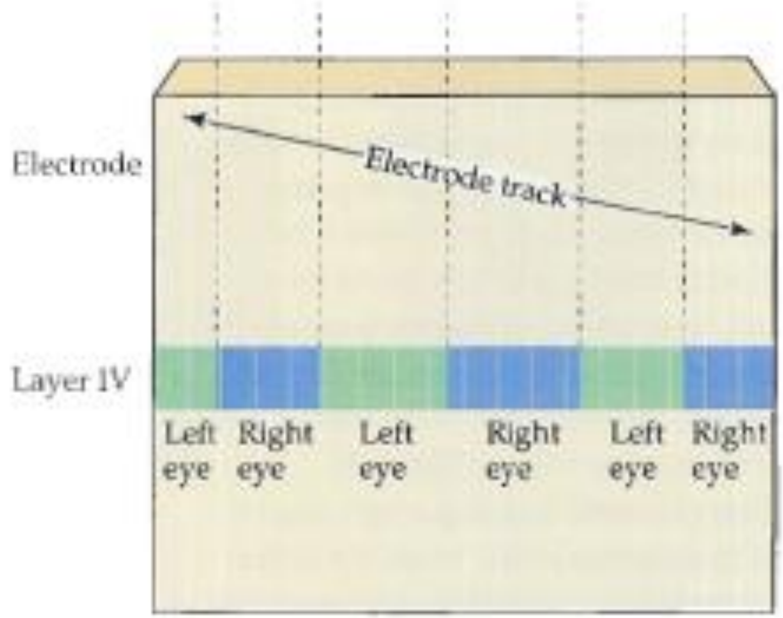


Fig. 11.13, Purves et al., Neuroscience, 3rd edition

- Alternating columns of cells showing preferential responses to right eye or left eye input
  - Monocular cells in layer 4
  - Binocular cells are found in other layers

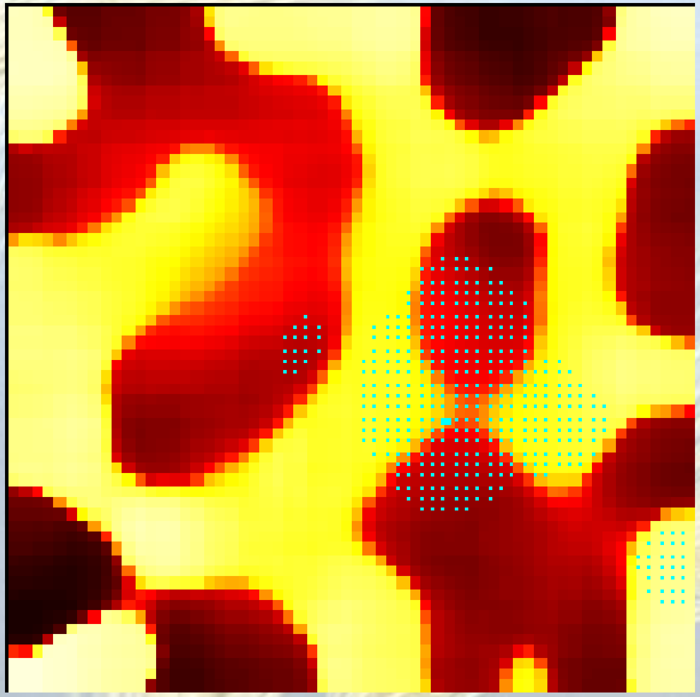
Ocular Dominance Columns in Primary Visual Cortex Revealed by Trans-Synaptic Labeling

- Injection of ^3H amino acid tracer into one eye
- Tracer is transferred trans-synaptically from retina to LGN to cortex
- Autoradiography of flattened cortical sheet reveals interdigitating regions of left eye vs. right eye inputs

Autoradiogram of V1

www.utoronto.ca/psy280sh/ PSY_Lecture_4_jpgs.html

Ocular Dominance Columns in Simulations



Orientation sensitivity AND Ocular Dominance

Properties of OrientationMaps:

- The maps of O.S. and O.D. are highly repetitive
- Orientation changes continuously as a function of cortical location except at isolated points.
- Orientation changes by 180 deg around singularities
- Both types of singularities appear in equal numbers
- There exist line-like regions (fractures), across which orientation preferences change rapidly with distance.
- (Obermeyer, Blasdel & Schulten 1992)

Orientation sensitivity AND Ocular Dominance

- Properties of Ocular Dominance Maps
  - Ocular dominance changes continuously as a function of cortical location.
  - The ocular dominance pattern is locally organized into parallel strips, which sometimes branch and terminate.
  - **Iso-orientation slabs often cross the borders of ocular dominance bands at approximately right angles.**
  - **The singularities tend to align with the center of the ocular dominance bands.**

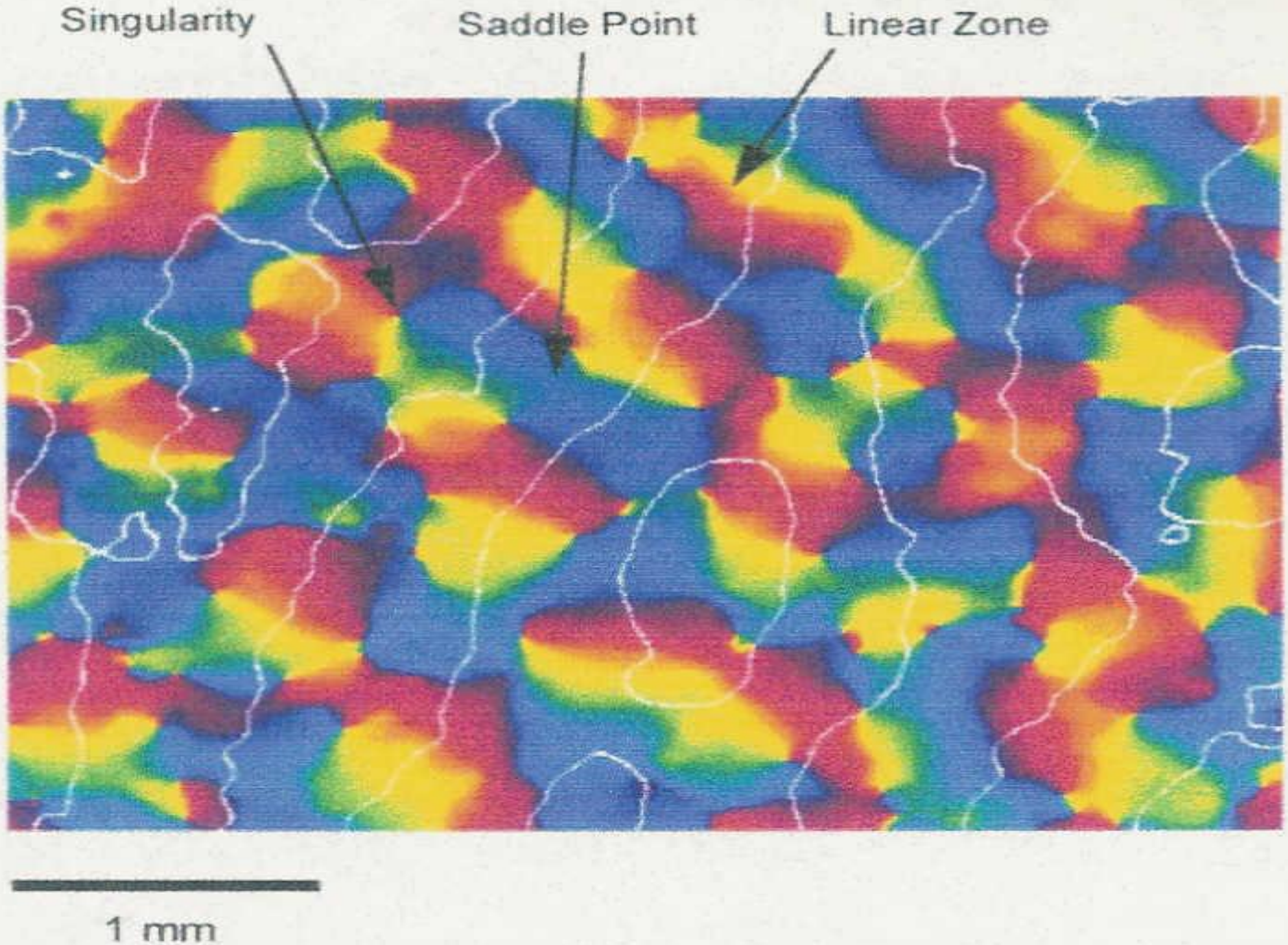
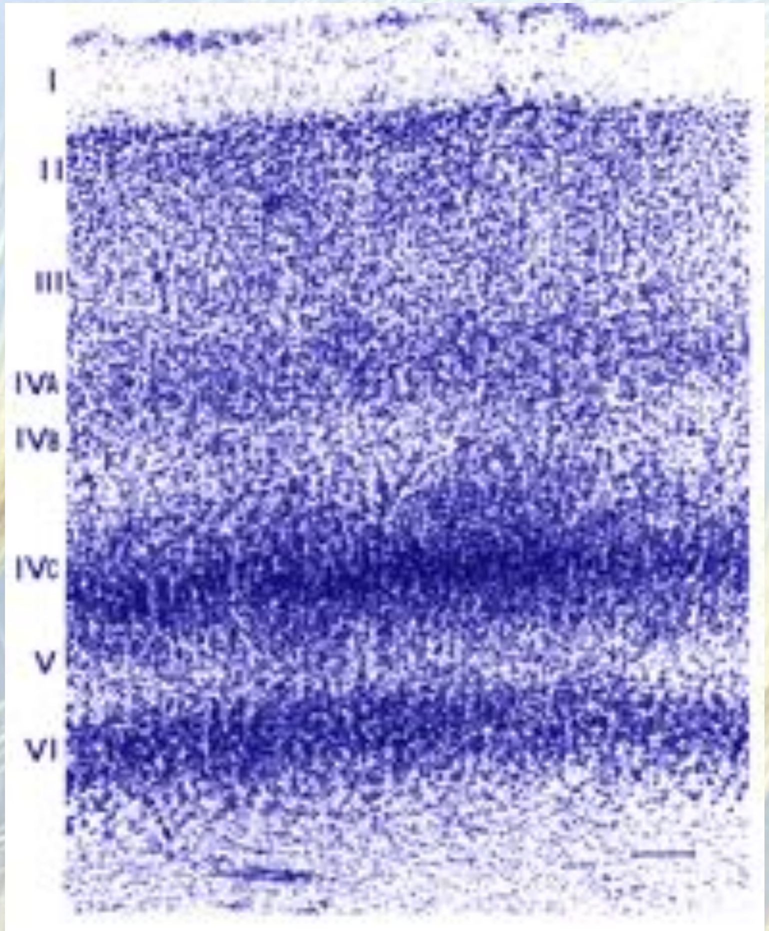


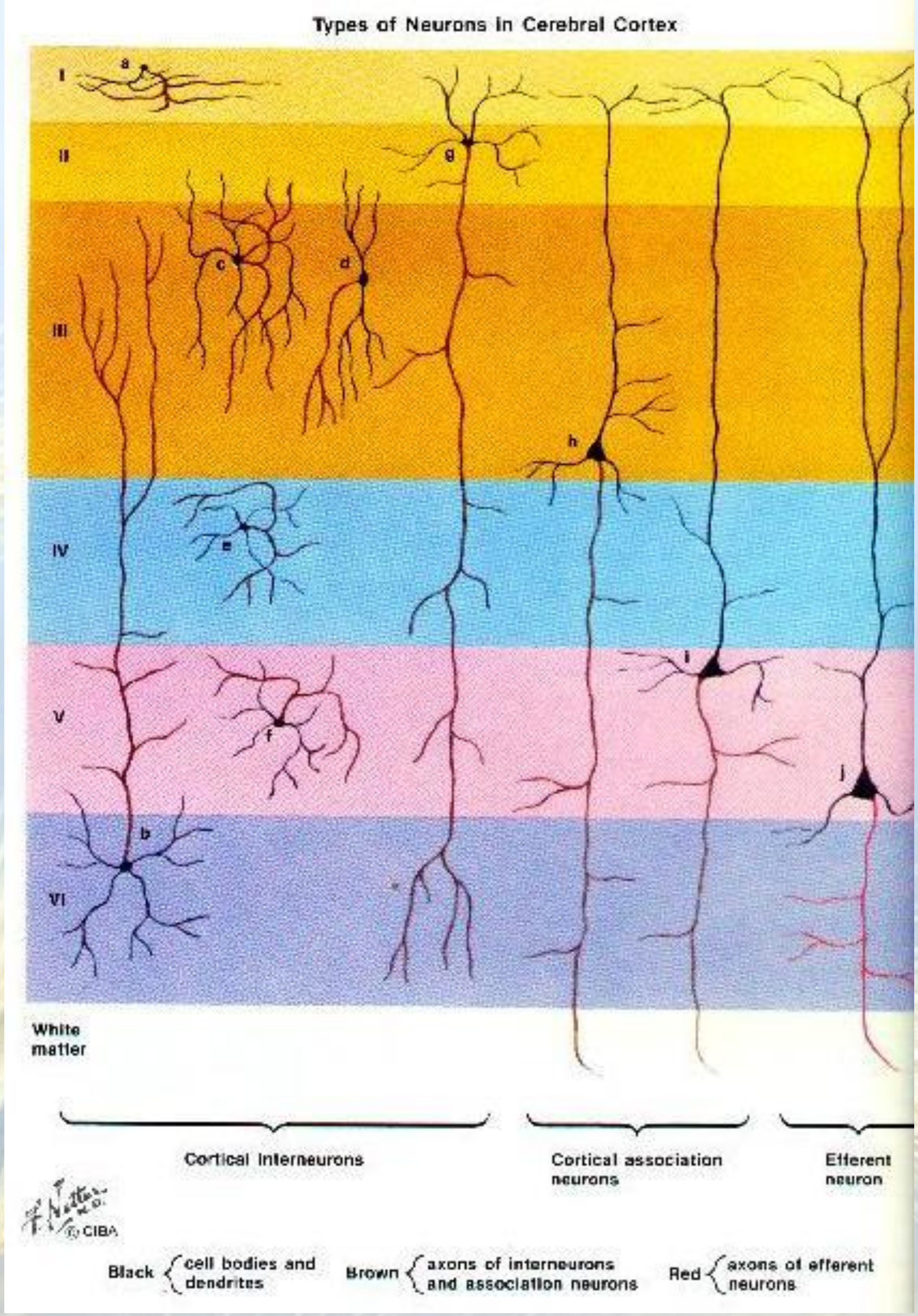
Figure 3. Composite figure showing the arrangement of orientation domains (a single colour represents a unique range of orientation preferences) and their relationship with ocular dominance column boundaries (white lines). The images were obtained by optical recording in macaque monkey striate cortex. Note that the iso-orientation domains tend to intersect ocular dominance column borders at right angles. (Figure supplied by K Obermayer, from data presented in Blasdel (1992b).)

Blobs

- Peg-shaped regions of cells
- In layers 2 and 3 of V1
- These cells respond to color, not orientation
- About 0.2 mm dia

Cortical Layers





Blob regions

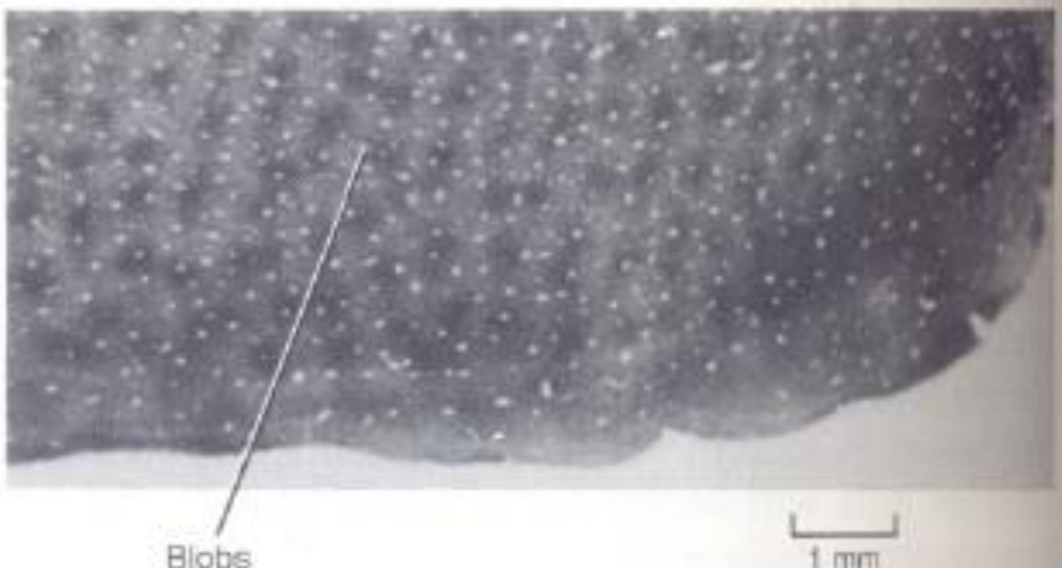


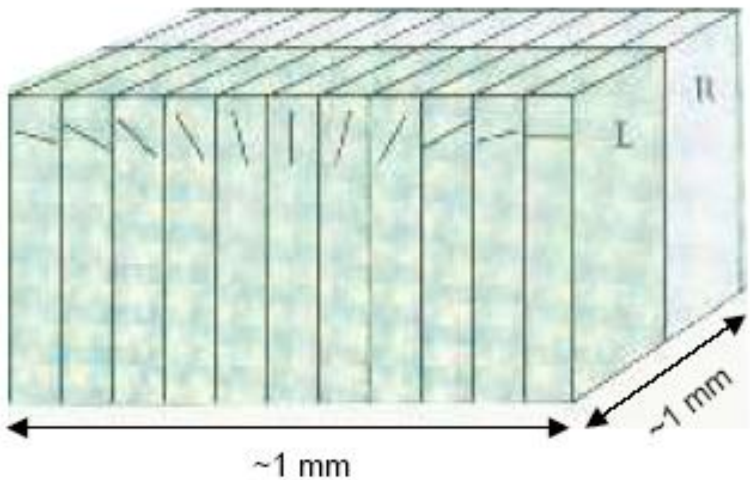
FIGURE 29–13

The distribution of the mitochondrial enzyme cytochrome oxidase in the superficial layers of the visual cortex, as seen in tangential sections of area 17 of the macaque monkey. The rows of dark patches or *blobs* represent areas of heightened enzymatic activity. This is thought to represent heightened neural activity in the blobs because of the lower response selectivity of these cells. (Courtesy of D. Ts'o, C. Gilbert, and T. Wiesel.)

Hypercolumn

- Smallest unit in V1 necessary to analyze all aspects of a region of visual field.
- Area = 1 sqmm
- Complete set of orientation columns (180^o)
- Inputs from both eyes.
- Several blobs

Schematic of a Cortical Hypercolumn: A Unit of Information



http://www-psych.stanford.edu/~lera/psych115s/notes/lecture3/figures.html

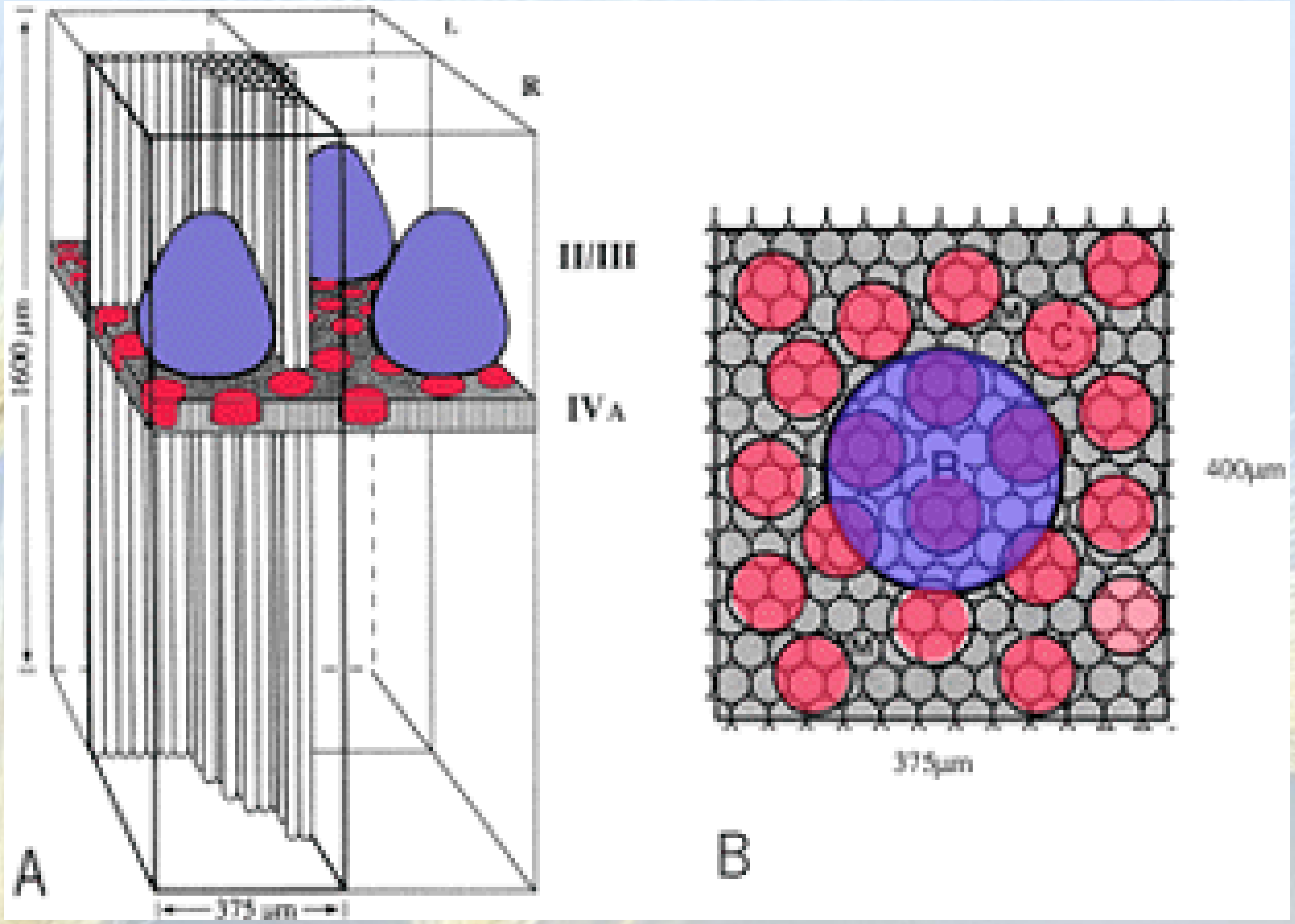
Each column
= 30 – 100 μm

<u>~1 mm x ~1 mm</u>

180° orientation

one L + R pair

Hypercolumns



Horizontal connections among hypercolumns

- Axon collaterals of pyramidal cells in layers 3 and 5 run long distances parallel with layers
- They give rise to clusters of axon terminals at regular intervals that approximate the width of hypercolumn

Blob regions form a horizontal network

- (Lund and Rockland)
- Injected horseradish peroxidase into restricted regions within cortical layers 2 and 3
- Found elaborate honeycomb-like lattice of labeled cells and axons that formed walls around unlabeled patches about 500 μm dia

Orientation sensitive cells form a horizontal network

- Tso, Gilbert, Wiesel
- Recorded cells that respond to a given orientation
- Many cells fire simultaneously
- Injected fluorescently labeled microbeads which were taken up axon terminals at the site of injected and transported to cell bodies.
- Injected radio-labeled 2-deoxyglucose, which revealed active cells
- Anatomical and metabolic patterns coincide well

Other visual areas

- One in area 17 – V1 (striate cortex)
- Two in area 18 – V2, V3
- Three in area 19 – V3a, V4, V5 (Middle Temporal area)
- Parietal cortex – V5a (Medial Superior Temporal area)

Functions of visual areas

- V1 – primary visual analysis
- V2 – more visual analysis
- V3 – dynamic form
- V4 – color and form
- V5 - motion

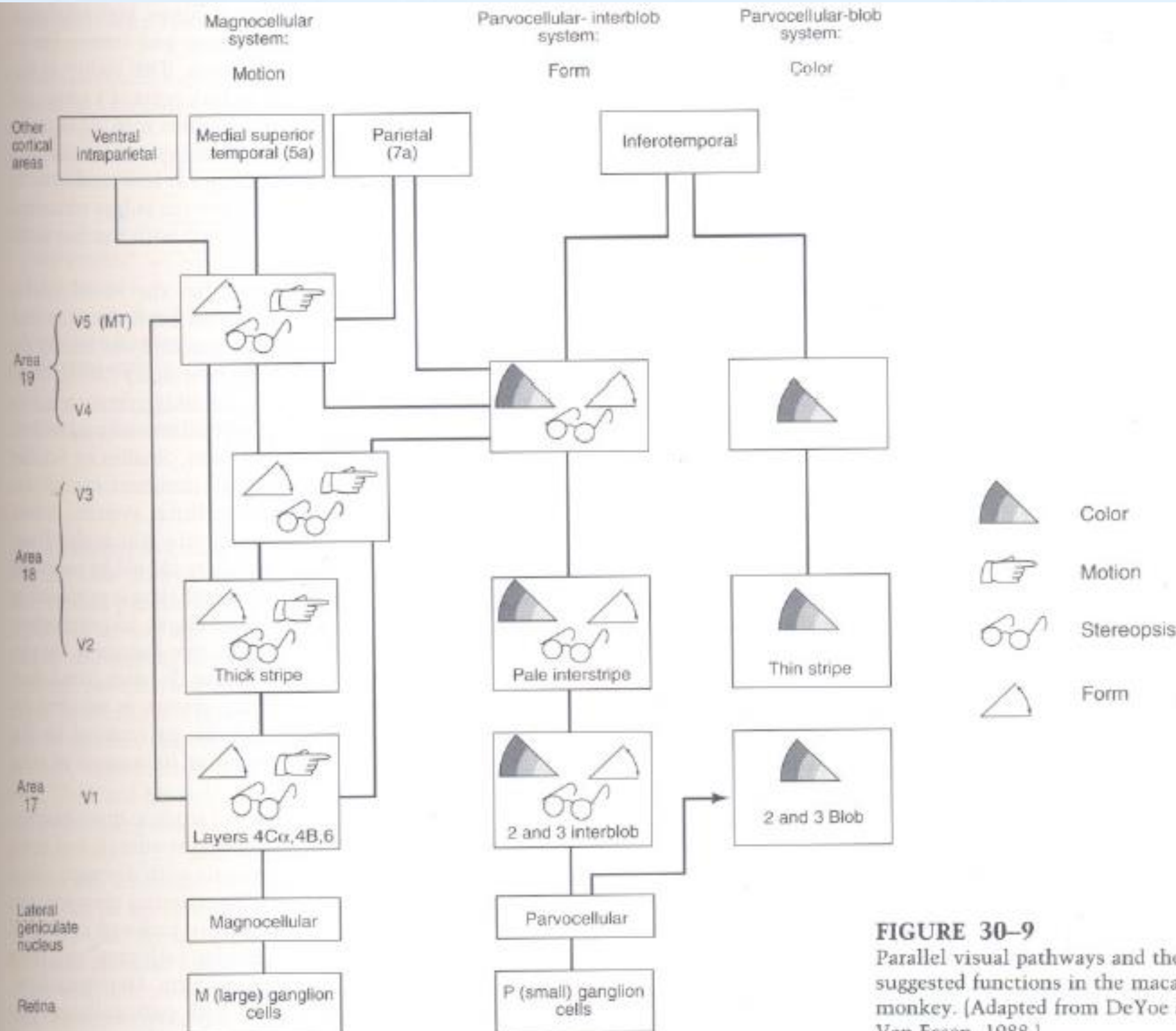


FIGURE 30–9
Parallel visual pathways and their suggested functions in the macaque monkey. [Adapted from DeYoe and Van Essen, 1988.]

Visual streams at V1

- Beginning of segregation of visual streams in V1
  - Magnocellular system
  - Parvocellular-interblob system
  - Parvocellular-blob system

Magnocellular system

- Specialized for: motion, spatial analysis, stereo vision etc
- Relatively insensitive to color
- Neurons respond rapidly but transiently
- Layers 4Ca, 4B, 6 in V1

Parvocellular-interblob system

- Specialized for form (and to some extent color)
- Area 2 and 3 interblob
- Neurons here respond to orientation of edges

Parvocellular-blob system

- Specialized for color
- 2 and 3 layer in blob regions

Structure of V2

- Located in area 18
- Staining revealed 3 patches:
  - Thick stripes
  - Thin stripes
  - Pale interstripes