The Visual System

Central Projections, Parallel Pathways and Streams

Casagrande

February 18, 2004

Phone: 343-4538

Email: vivien.casagrande@mcmail.vanderbilt.edu

Office: T2302 MCN

- Required Reading for 2/13, 2/15, 2/18
  - Adler's Physiology of the Eye Chapters 28 and 29 chapter
  - Tovée Chapter 4 (short summary)
- Recommended Reading
  - McIlwain Chapters 7 & 8 (more complete overview)
  - Purves et al. Neuroscience (1997) Chapter 11
  - Hubel Eye, Brain, and Vision (1988) Chapter 9 pp 191-219.

Question?

The LGN contains at least three classes of cells. Name two of these classes.

Answer

Question?

- Visual information is processed by two broad parallel systems or streams. One called the ? stream is concerned with object identification. The other called the ? Stream is concerned with spatial relations or spatial location.

Answer

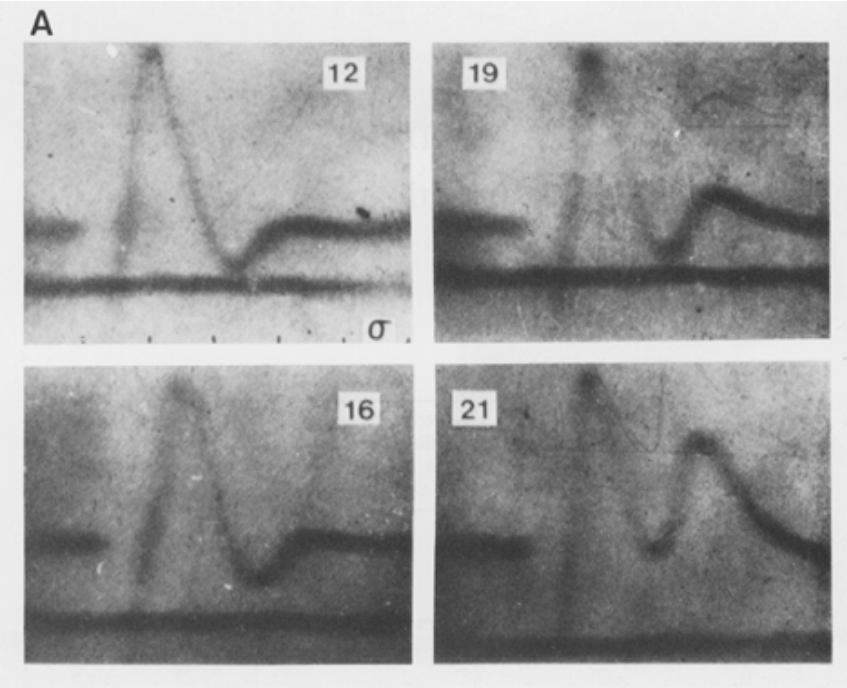
I. **Background (What is meant by parallel pathways?)**

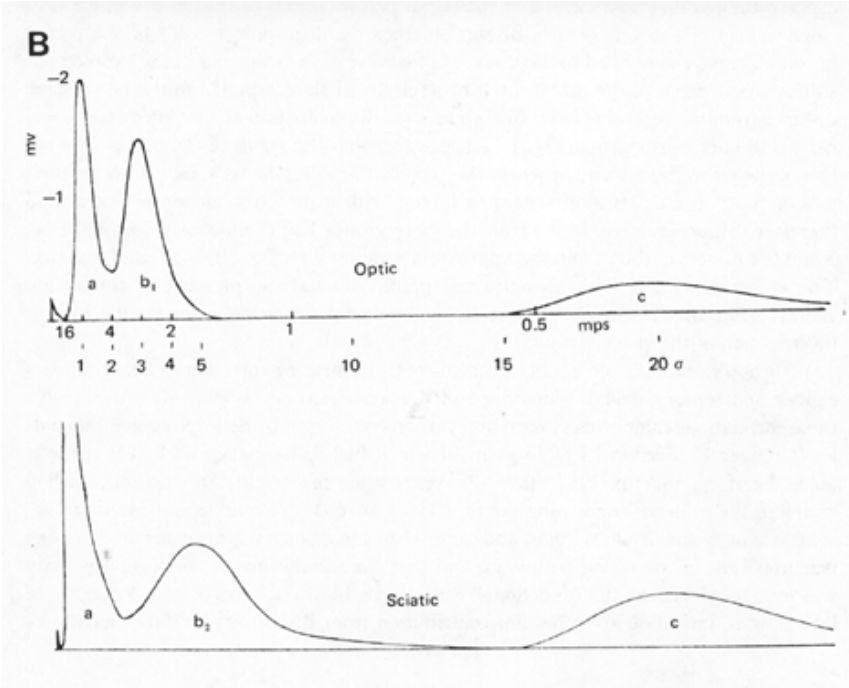
A. History: Original observations by Bishop in the late 1930's on conduction velocity in the optic nerve revealed 3 different groups of axons.

B. Retinotopic parallelism: At each level of the visual system adjacent points in visual space are mapped in adjacent cells. Cells that represent common points in visual space tend to be connected.

C. Functional parallelism: At each level of the visual system beginning in the retina cells are specialized to respond to different types of visual information (e.g. wavelength, spatial detail, fast verses slow movement). Using both retinotopic parallelism and functional parallelism the visual system encodes both object location and object identity.

Recordings from optic nerve in frog-Bishop





I. **There are different ways to classify cells.**

A. Essentialist: Cells are described based upon what the investigator believes the cells are doing. (e.g.,bug detectors, novelty detectors)

B. **Parametric:** Cells are classified based upon a number of features. (e.g., The collection of morphological, physiological, and neurochemical features that distinguish classes of cells from each other).

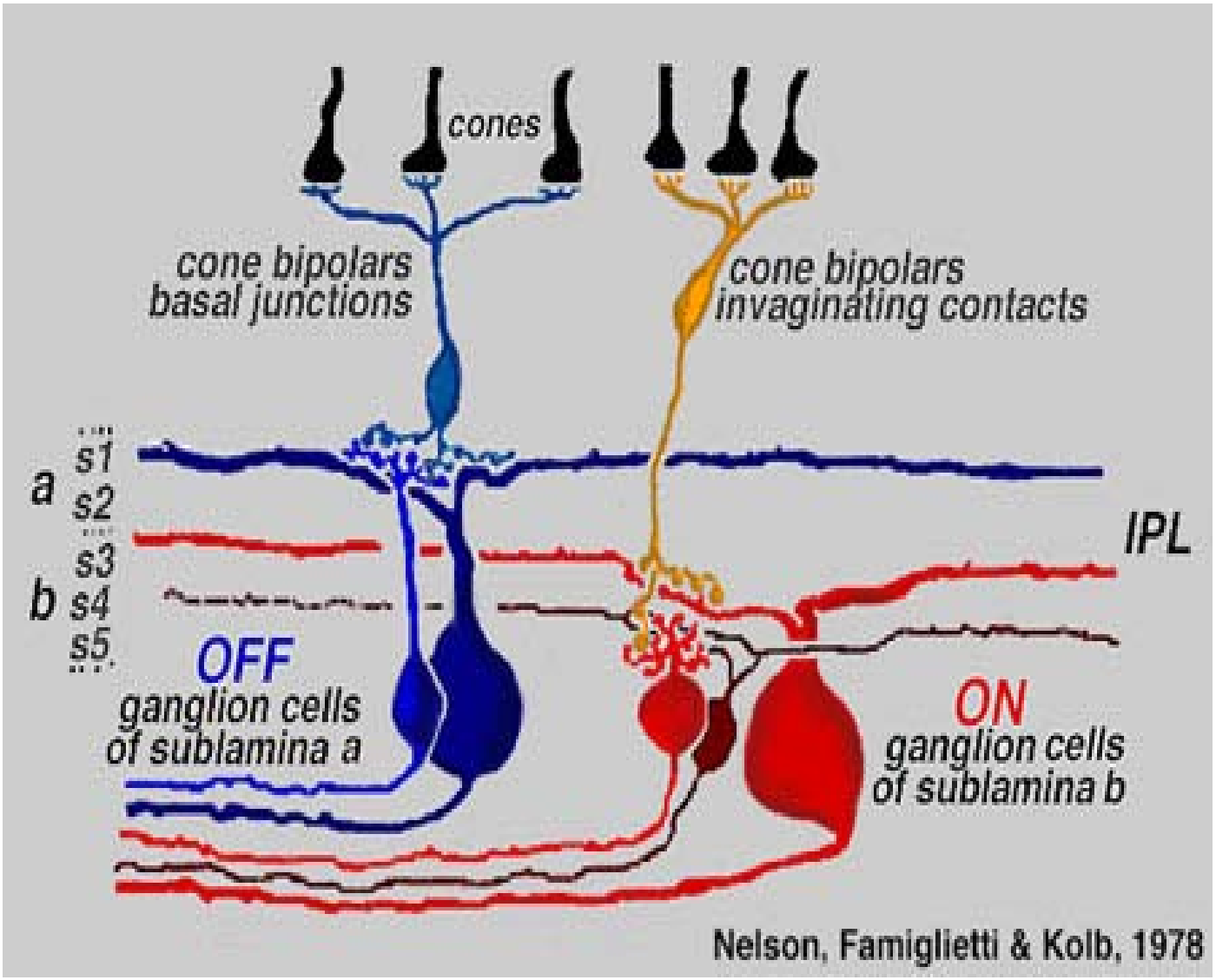
Underlying assumptions exist in cell classification. *Linking hypotheses* about the proposed links between cell characteristics (physiology /anatomy /neuro-chemistry) and behavior.

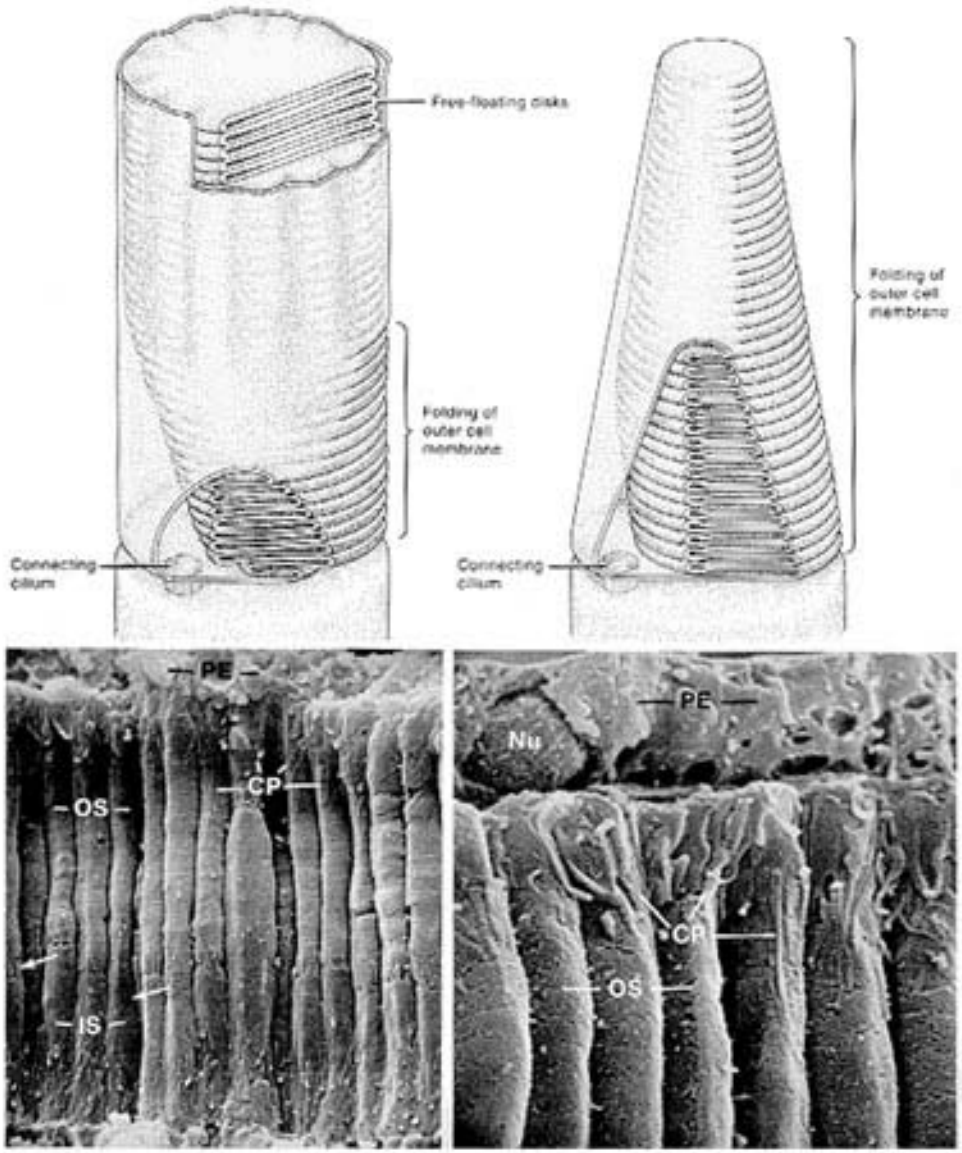
I. **How far do parallel pathways extend?** (i.e., can signatures of retinal ganglion cells be found at higher cortical levels?)

1. Are ON center and OFF-center ganglion cells part of a pathway?

2. What about Cone verses Rod pathways ?

3. Care must be taken in making assumptions about how the brain is wired simply based upon a single property.


cones
cone bipolars
basal junctions
cone bipolars
invaginating contacts
s1
a
s2
s3
b
s4
s5
IPL
OFF
ganglion cells
of sublamina a
ON
ganglion cells
of sublamina b
Nelson, Famiglietti & Kolb, 1978


Free-floating disks
Folding of outer cell membrane
Connecting cilium
Folding of outer cell membrane
Connecting cilium
PE
OS
CP
IS
PE
Nu
CP
OS

I. Several methods are used to distinguish cell classes

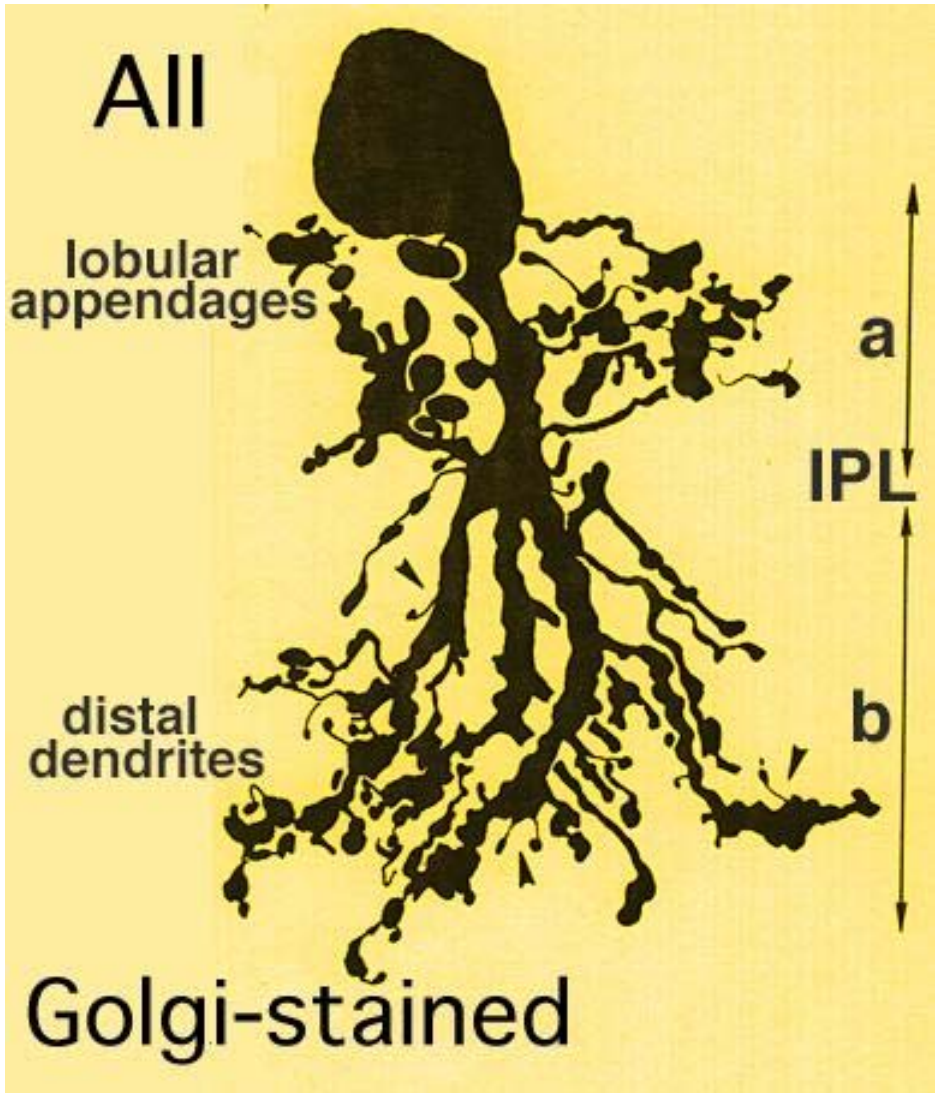
A. Cell **Morphology**: cell size, shape, dendritic field size (fill cell with a label, golgi, Nissl)

B. Connections: label axons or pathways

C. Neurochemistry: Neurotransmitters, other proteins and receptors: (e.g., GABA, GABAa or GABAb receptors, calcium binding proteins) use immunocytochemisty, physiology

D. **Physiology**: Receptive field size, spatial frequency selectivity etc. (record activity while stimulating the cell's receptive field).

Cells can be classified based upon morphology



I. Several methods are used to distinguish cell classes

A. Cell **Morphology**: cell size, shape, dendritic field size (fill cell with a label, golgi, Nissl)

B. Connections: label axons or pathways

C. Neurochemistry: Neurotransmitters, other proteins and receptors: (e.g., GABA, GABAa or GABAb receptors, calcium binding proteins) use immunocytochemisty, physiology

D. **Physiology**: Receptive field size, spatial frequency selectivity etc. (record activity while stimulating the cell's receptive field.

Labels can be used to trace pathways by injecting molecules that are taken up and transported by nerve cells. These molecules can either be be fluorescent or can be visualized in other ways.

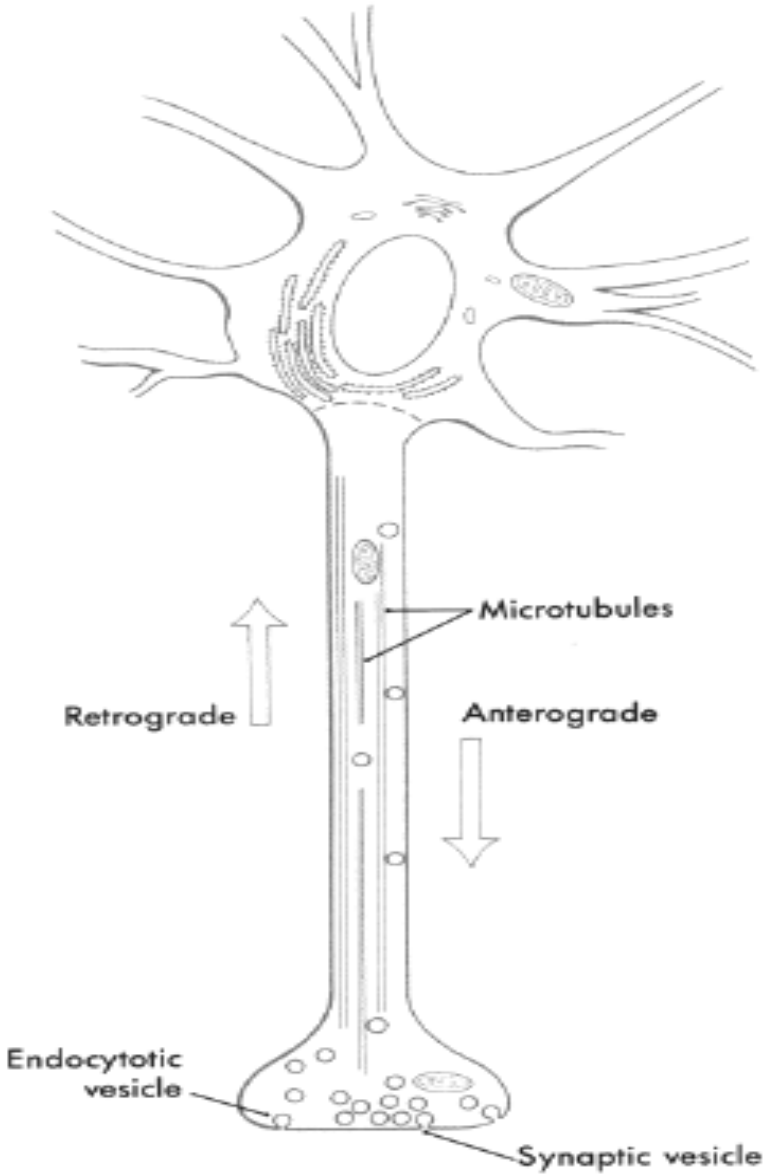


FIGURE 2-5 *Anterograde and retrograde axonal transport.*

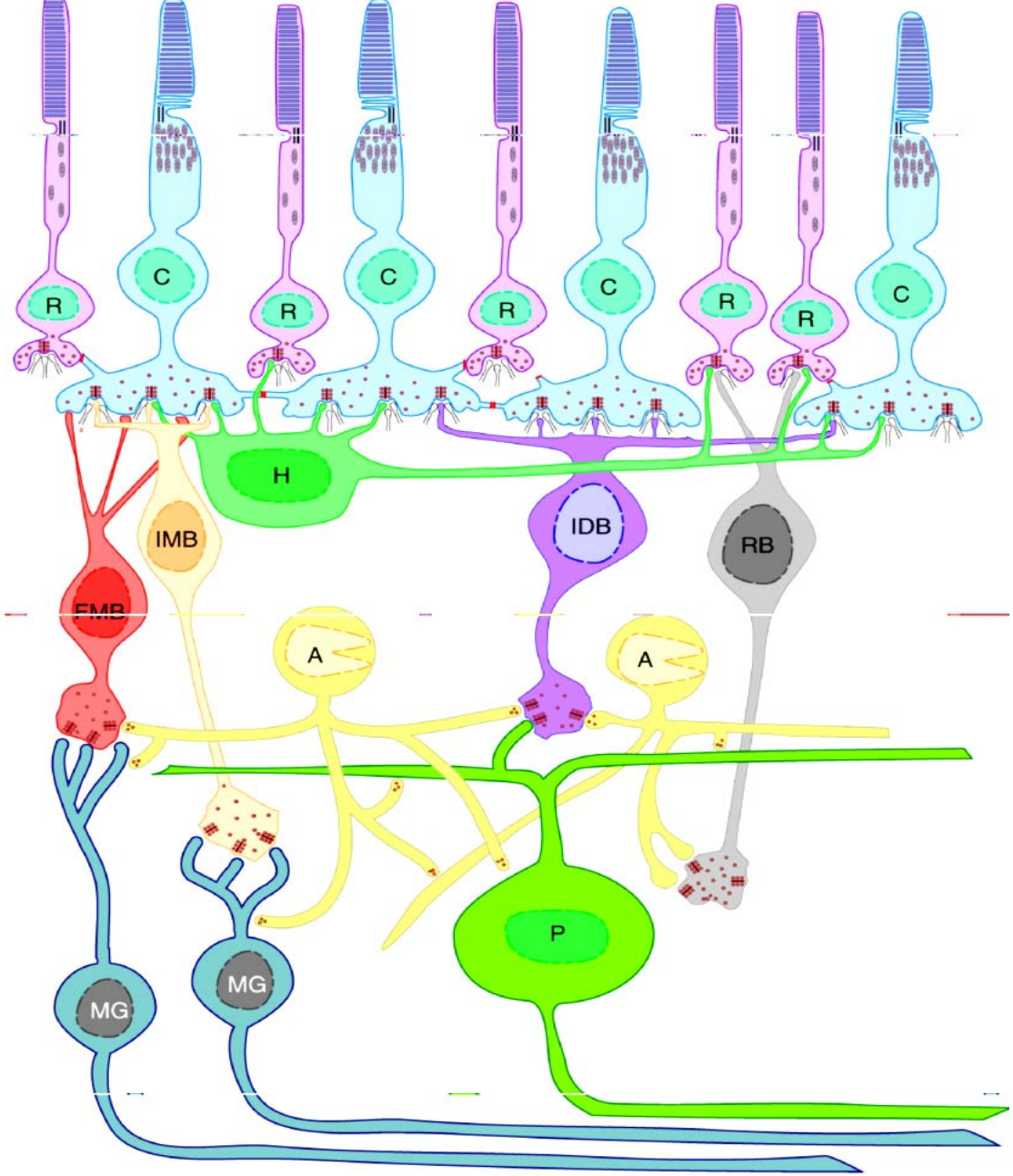
I. Several methods are used to distinguish cell classes

A. Cell **Morphology**: cell size, shape, dendritic field size (fill cell with a label, golgi, Nissl)

B. Connections: label axons or pathways

C. Neurochemistry: Neurotransmitters, other proteins and receptors: (e.g., GABA, GABAa or GABAb receptors, calcium binding proteins) use immunocytochemisty, physiology

D. **Physiology**: Receptive field size, spatial frequency selectivity etc. (record activity while stimulating the cell's receptive field.



Different cell types contain different proteins that can be recognized with the use of immuno-cytochemistry.

I. Several methods are used to distinguish cell classes

A. Cell **Morphology**: cell size, shape, dendritic field size (fill cell with a label, golgi, Nissl)

B. Connections: label axons or pathways

C. Neurochemistry: Neurotransmitters, other proteins and receptors: (e.g., GABA, GABAa or GABAb receptors, calcium binding proteins) use immunocytochemisty, physiology

D. **Physiology**: Receptive field size, spatial frequency selectivity etc. (record activity while stimulating the cell's receptive field.

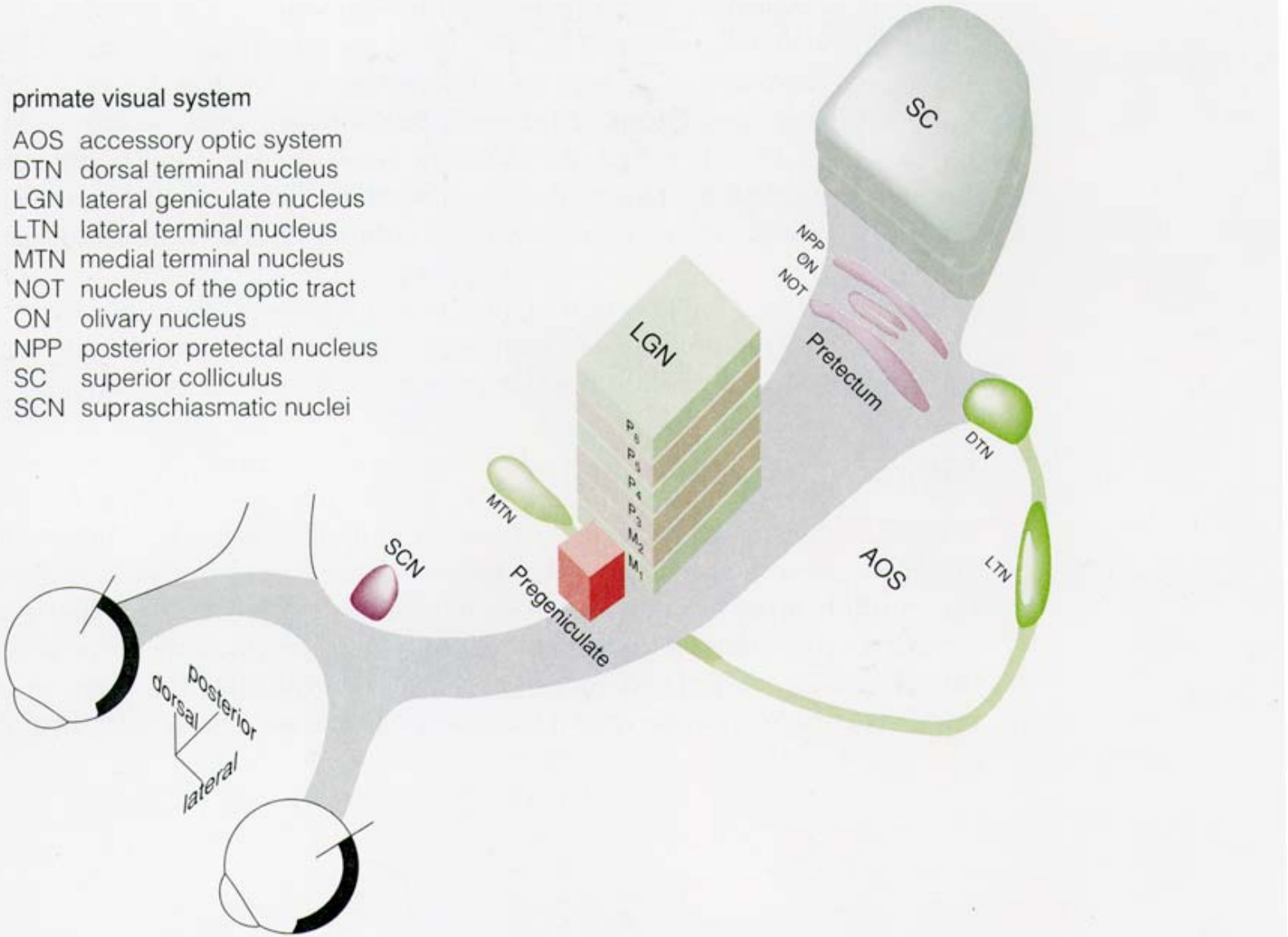
Central Projections of Retinal Ganglion cells

In primates separate morphological/physiological classes of ganglion cells project to the superior colliculus, pretectum, LGN, and other brain areas such as the suprachiasmatic nucleus of the hypothalamus

In many cases each target brain area (e.g., LGN) receives input from more than one type of retinal ganglion cell

primate visual system

AOS accessory optic system
DTN dorsal terminal nucleus
LGN lateral geniculate nucleus
LTN lateral terminal nucleus
MTN medial terminal nucleus
NOT nucleus of the optic tract
ON olivary nucleus
NPP posterior pretectal nucleus
SC superior colliculus
SCN supraschiasmatic nuclei



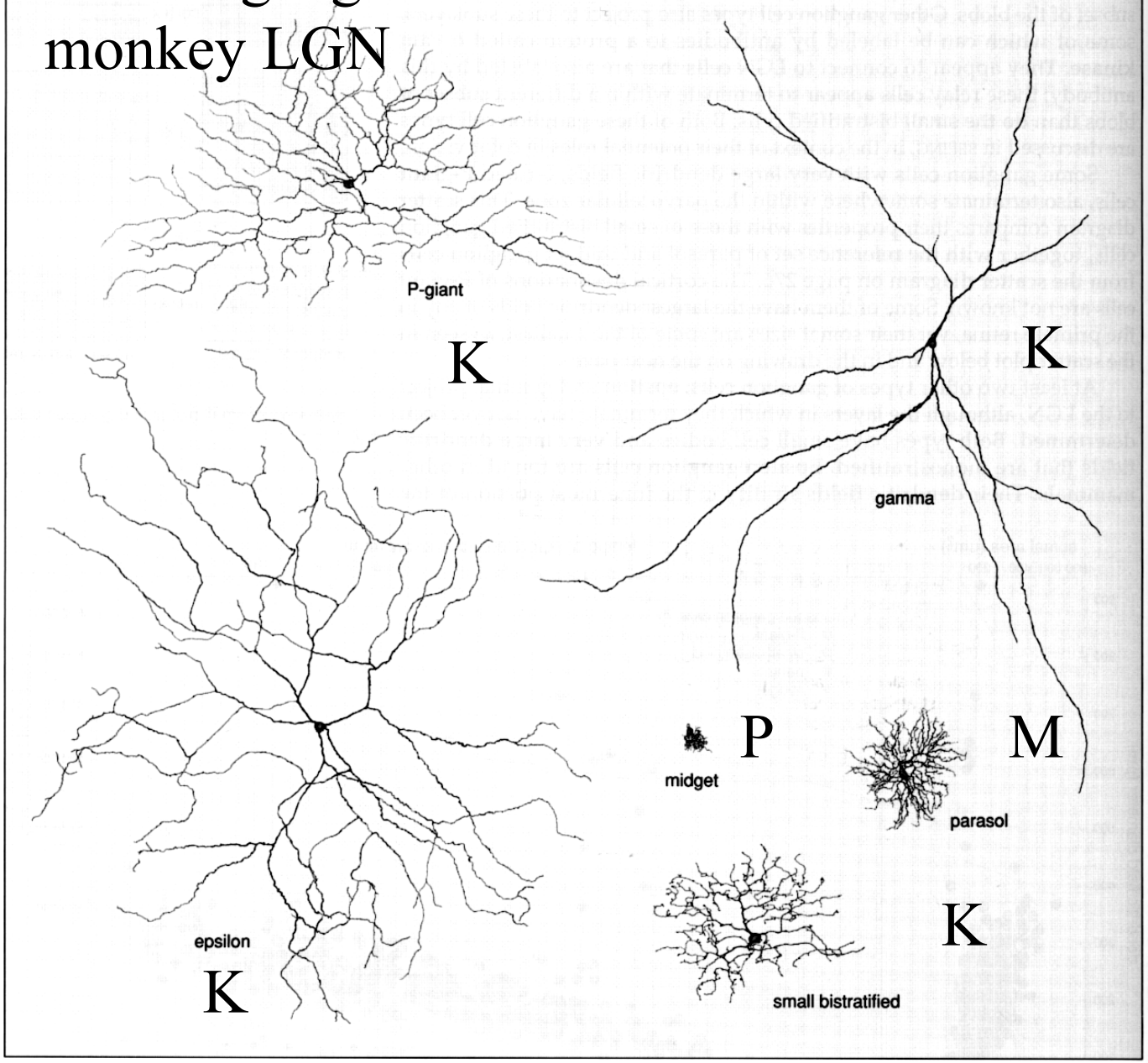
What are the advantages of parallel pathways?

1. Speed (the brain is slow)

2. Can combine information in different ways at higher levels. (If it is already put together in the retina it can not be taken apart easily e.g., binocular information.

3. Extends the dynamic range of the system (i.e. one individual cell can not represent all stimulus qualities because of design conflicts)

Retinal ganglion cells that send axons to monkey LGN



Classes of Primate Retinal Ganglion Cells projecting to the LGN

Property	M cell (7-10%)	P cell (80%)	K cell (7-10%)
Morphology	Parasol	midget	variable
Soma size	large	medium	small
Receptive field **Dendritic field**	Center/surround medium	Center/surround small	Variable Avg. large
Spatial freq	low	high	low
Wavelength selective	no	yes	Some blue-ON
Contrast sensitivity	high	low	Intermediate
Temporal freq. Sustained/transient	High transient	Low sustained	Intermediate/variabl Both types
Axon speed	High (2.0msec)	Medium (4.0)	Low (>5.0)

Morphology

M>P>K in soma size

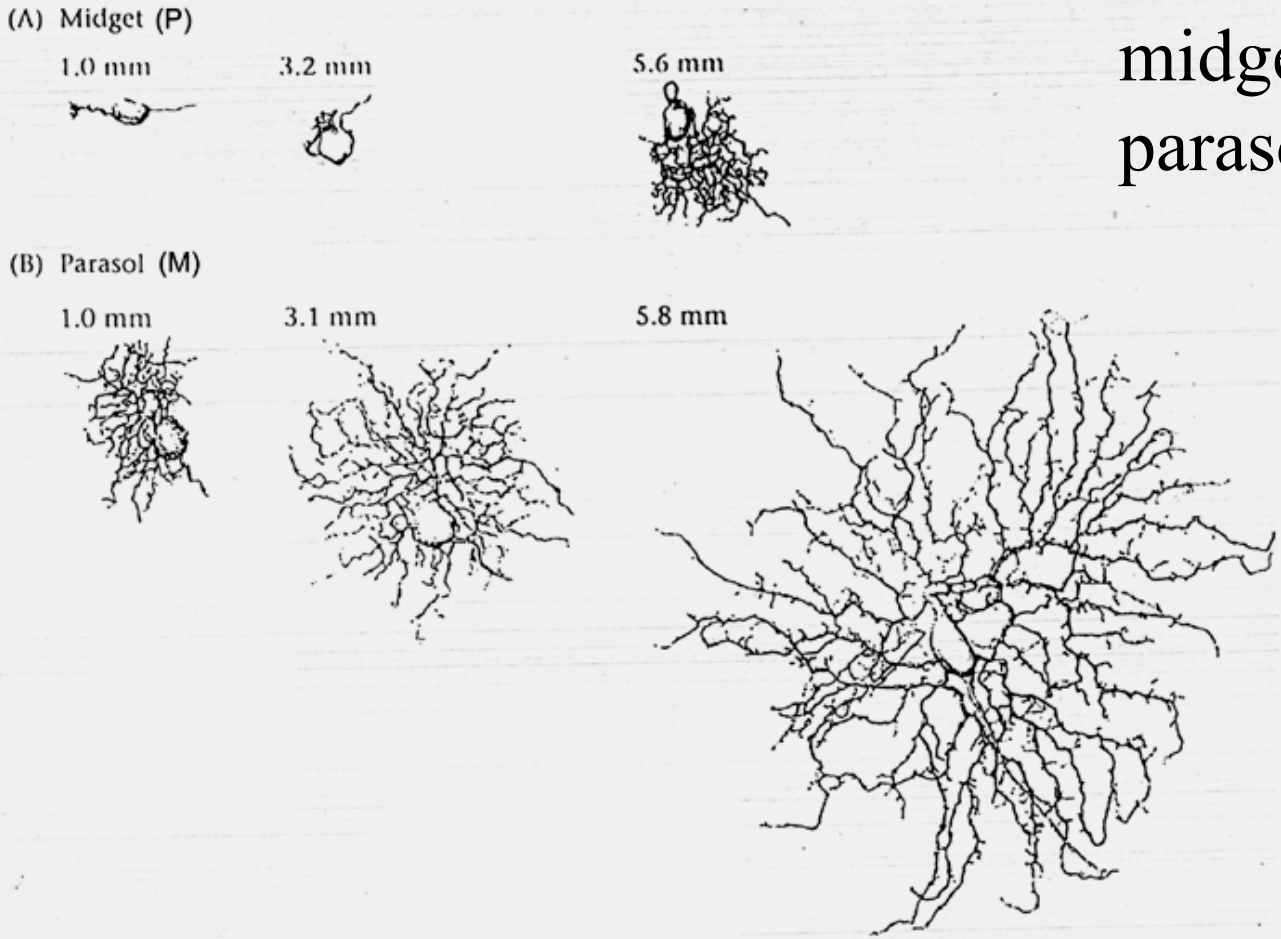
K>M>P dendritic field size

Dendritic field size correlated with receptive field center size.

BENEFITS/COSTS:
Since surround is ineffective in low illumination **larger receptive fields** are more **sensitive** at detecting stimuli at lower levels of light but have lower spatial resolution.

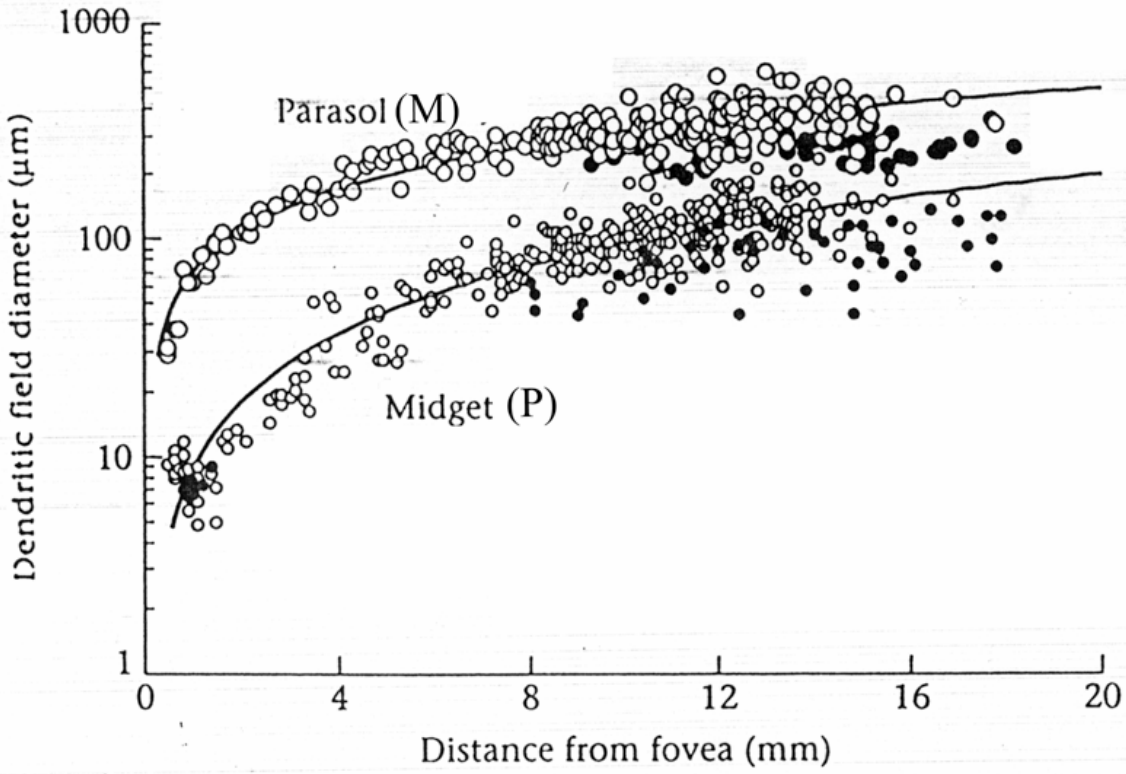
Smaller receptive fields have better **acuity** but less sensitivity

Cell Class characteristics vary with eccentricity



midget=P
parasol=M

5.6 A COMPARISON OF MIDGET AND PARASOL RETINAL GANGLION CELL MORPHOLOGY at various distances from the fovea. Camera lucida drawings of (A) midget ganglion cells and (B) parasol ganglion cells from a series of positions within the retina. At comparable positions within the retina, the dendritic tree of the midget ganglion cell is smaller and denser than that of the parasol cell. For each types of cells, however, the absolute size of the dendritic field increases with distance from the fovea. Source: Watanabe and Rodieck, 1989.



5.7 DENDRITIC FIELD SIZE AS A FUNCTION OF ECCENTRICITY in the human retina. The graph shows the dendritic field size of midget and parasol neurons. Filled symbols represent neurons in the nasal retina and open symbols represent neurons in the temporal retina. The dendritic field size increases with eccentricity for both types of neurons, but at each eccentricity the cells are easily classified. Source: Dacey and Petersen, 1992.

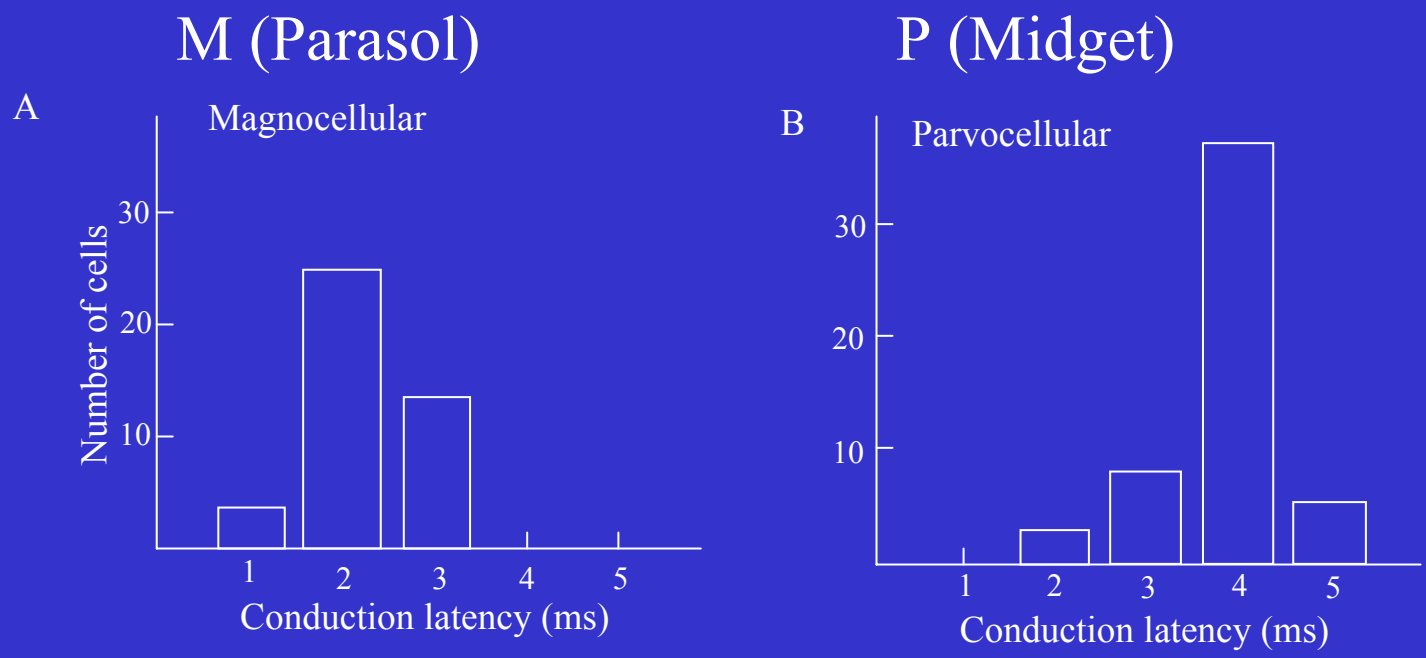
Classes of Primate Retinal Ganglion Cells projecting to the LGN

Property	M cell (7-10%)	P cell (80%)	K cell (7-10%
Morphology	Parasol	midget	variable
Soma size	large	medium	small
Receptive field Dendritic field	Center/surround medium	Center/surround small	Variable Avg. large
Spatial freq	low	high	low
Wavelength selective	no	yes	Some blue-on
Contrast sensitivity	high	low	Intermediate
Temporal freq. **Sustained/transient**	High transient	Low sustained	Intermediate/variable Both types
Axon speed	High (2.0msec)	Medium (4.0)	Low (>5.0)

Temporal properties

M = high temporal sensitivity, transient response
benefit: good detection cost: poor identification

P = low temporal sensitivity, sustained response
benefit: good identification cost: poor detection of change or movement.

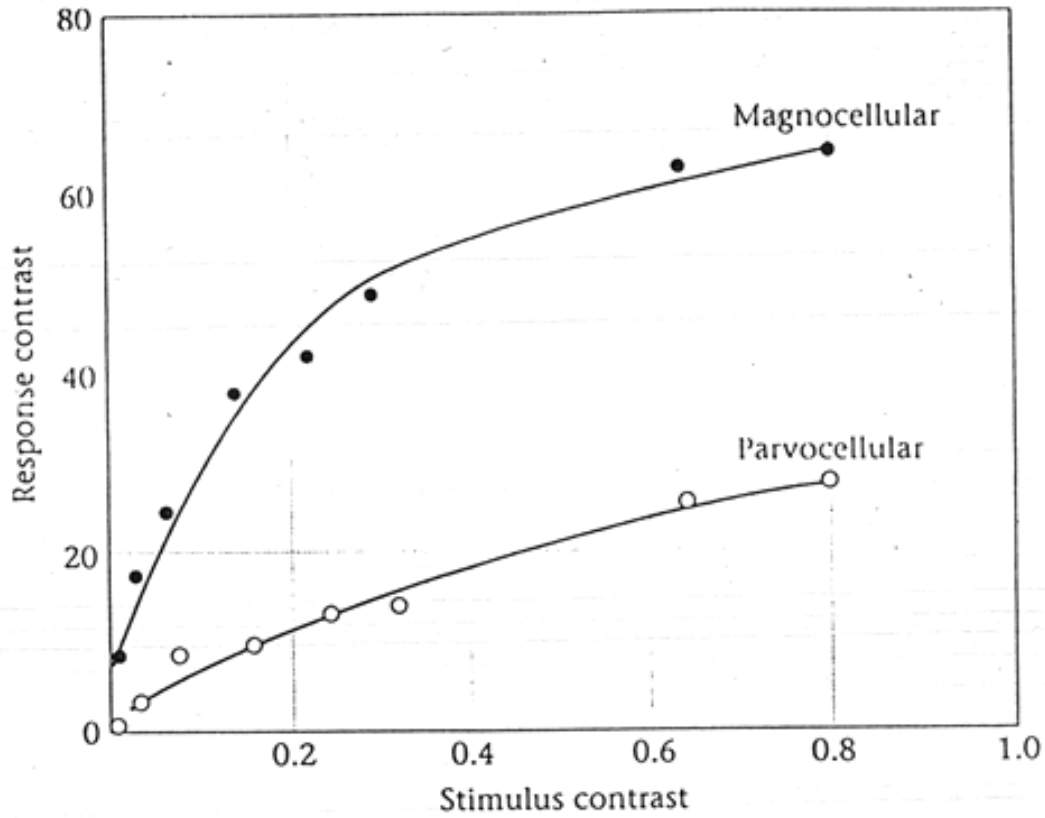


K=very slow small fibers

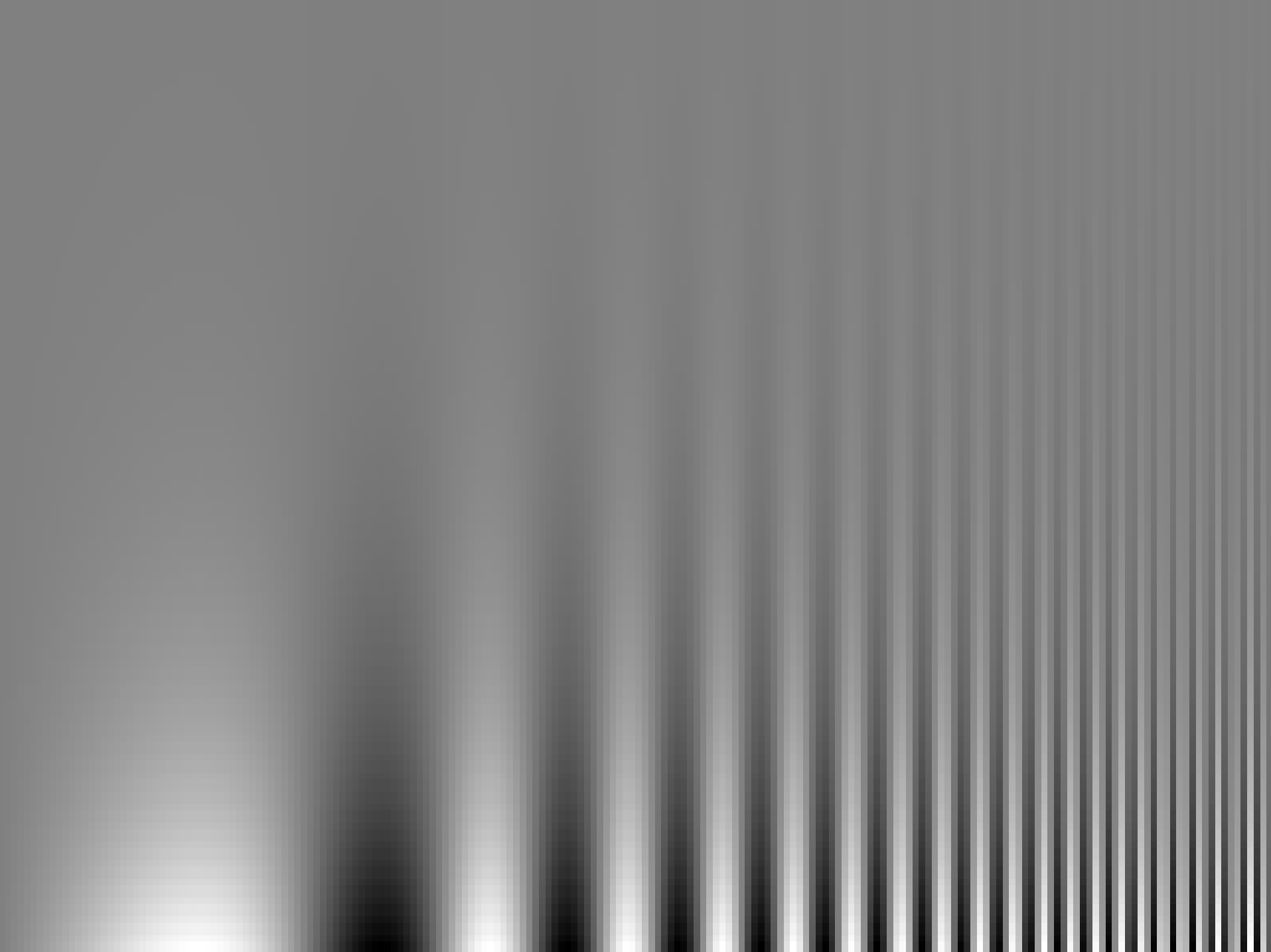
Schiller & Malpeli, 78

Classes of Primate Retinal Ganglion Cells projecting to the LGN

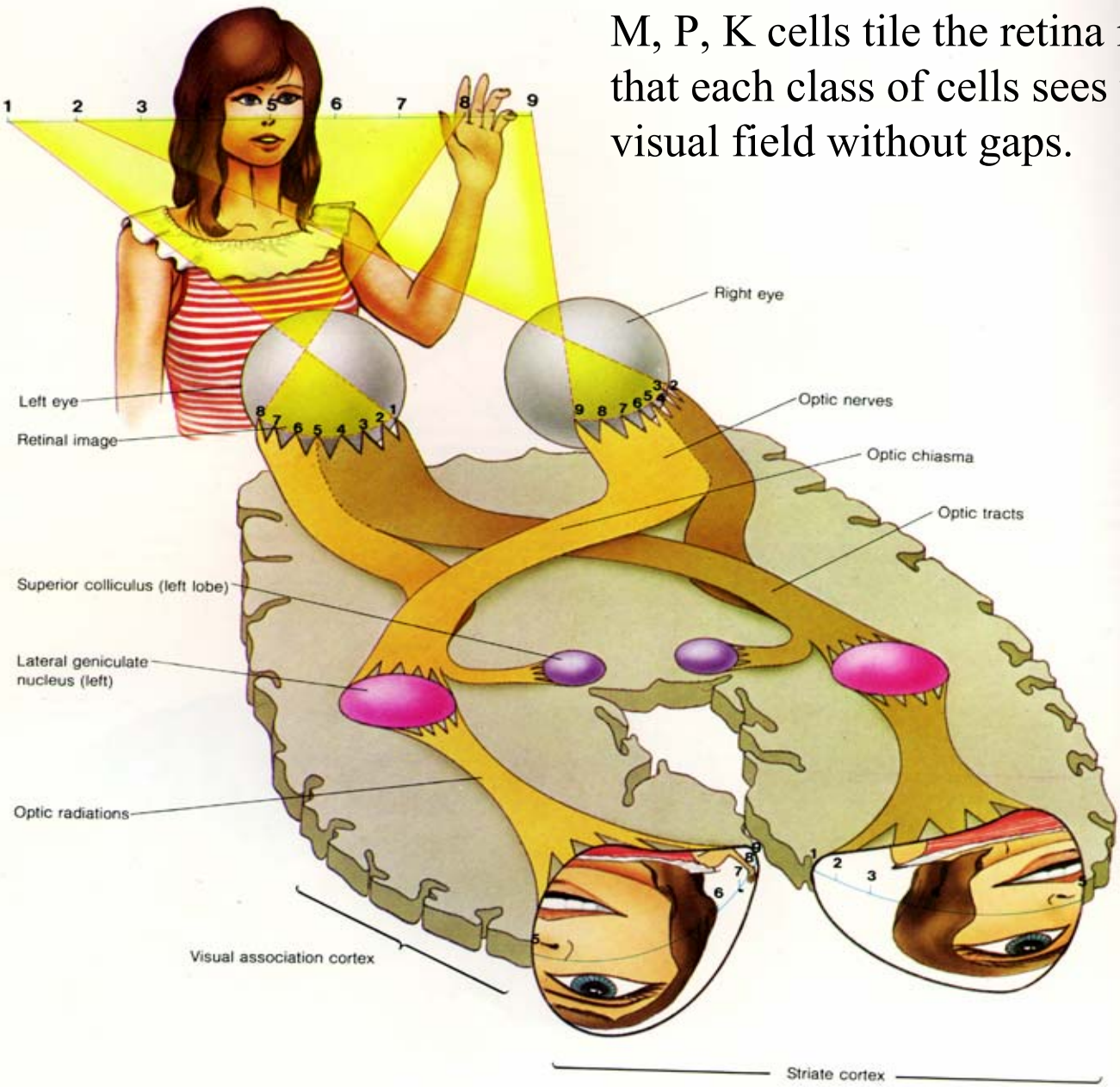
Property	M cell (7-10%)	P cell (80%)	K cell (7-10%
Morphology	Parasol	midget	variable
Soma size	large	medium	small
Receptive field Dendritic field	Center/surround medium	Center/surround small	Variable Avg. large
Spatial freq	low	high	low
Wavelength selective	no	yes	Some blue-on
Contrast sensitivity	high	low	Intermediate
Temporal freq. Sustained/transient	High transient	Low sustained	Intermediate/variabl Both types
Axon speed	High (2.0msec)	Medium (4.0)	Low (>5.0)



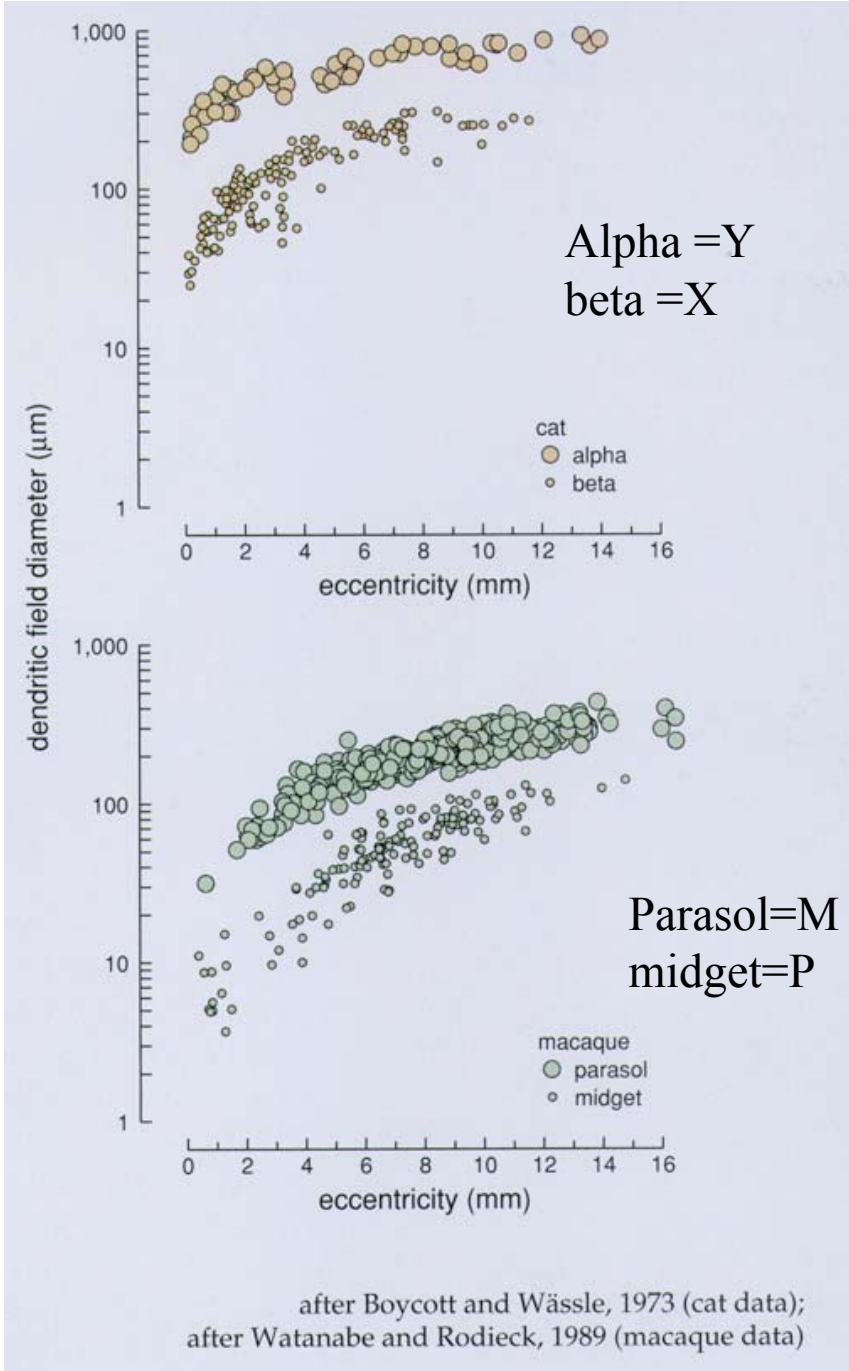
5.11 CONTRAST-RESPONSE FUNCTIONS of neurons in the LGN. The contrast responses of magnocellular neurons (filled circles) increase more rapidly than the contrast responses of parvocellular neurons (open circles). Source: Shapley, 1990.



M, P, K cells tile the retina in such a way that each class of cells sees the whole visual field without gaps.



There are many similarities between classes of cells that project to the LGN in cats and primates. M, P, and K cells share features in common with Y, X, and W cells, respectively.



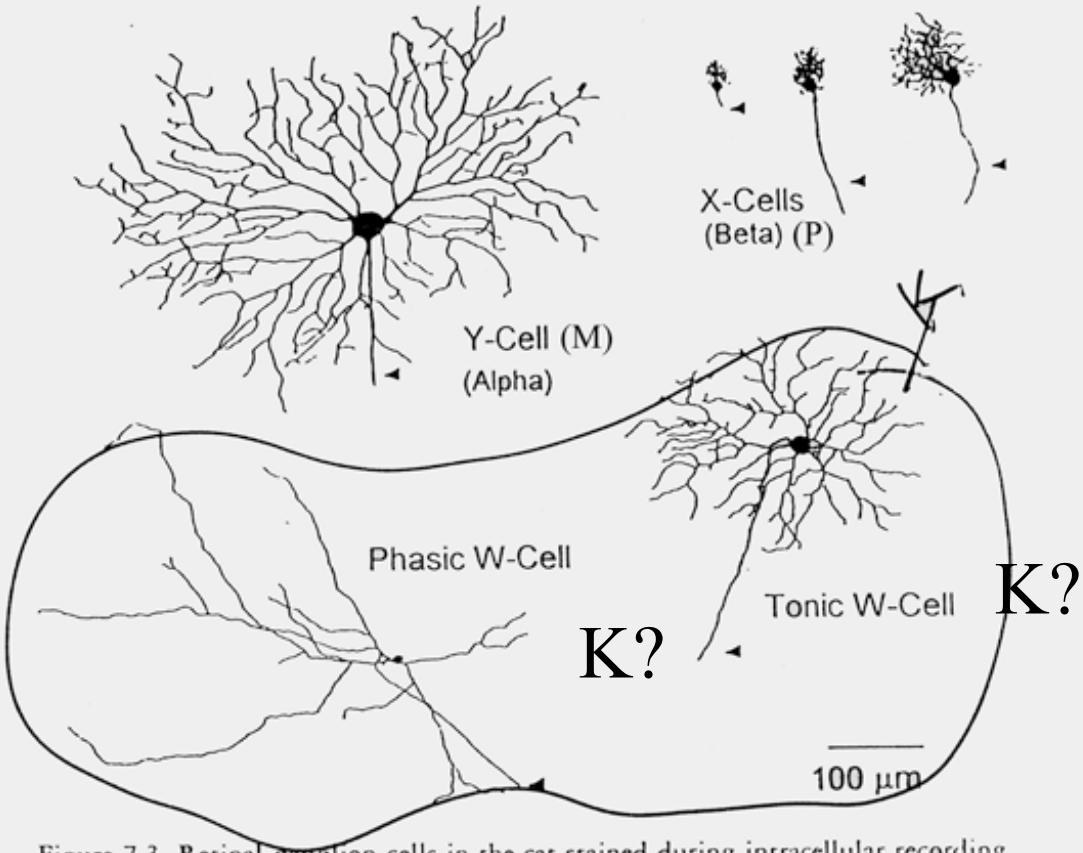


Figure 7.3. Retinal ganglion cells in the cat stained during intracellular recording and classified according to their physiologic responses. Physiologic Y cells correspond to morphologic alpha cells of the retina. The X cells, morphologic beta cells, were collected at three retinal locations of increasing distance from the area centralis, the smallest cell being located most centrally. The heterogeneous class of W cells is associated with an equally heterogeneous group of morphologic types designated gamma, delta, epsilon, and so forth. Arrowheads indicate axons. (Courtesy of Dr. L. R. Stanford. The two W cells are illustrated in L. R. Stanford: W-cells in the cat retina: correlated morphological and physiological evidence for two distinct classes. *Journal of Neurophysiology* 57:218–44, 1987. Reproduced with permission of the American Physiological Society.)