La vision

1. **Introduction**

2. **Mécanismes périphériques**

   a) **L'organe récepteur : l'œil**
      - **Structure**
      - **Propriétés optiques**

   b) **La rétine**
      - **Données histologiques**
      - **Structure des photorécepteurs**
      - **La phototransduction**

   c) **Le message rétinien**

3. **Mécanismes centraux**

   a) **Le cortex visuel V1 (aire striée ou aire 17)**
      - **Les projections géniculées**
      - **Organisation anatomo-fonctionnelle de V1**

   b) **Les aires visuelles péristriées**

      - **Inféro temporal (IT) et forme/couleur du stimulus**
      - **Pariétal et localisation/mouvement du stimulus**

4. **Conclusion**

La vision

1. Introduction

2. Mécanismes périphériques

   a) L'organe récepteur : l'œil
      - Structure
      - Propriétés optiques

   b) La rétine
      - Données histologiques
      - Structure des photorécepteurs
      - La phototransduction

   c) Le message rétinien

3. Mécanismes centraux

   a) Le cortex visuel V1 (aire striée ou aire 17)
      - Les projections géniculées
      - Organisation anatomo-fonctionnelle de V1

   b) Les aires visuelles péristriées

      - Inféro temporal (IT) et forme/couleur du stimulus
      - Pariétal et localisation/mouvement du stimulus

4. Conclusion

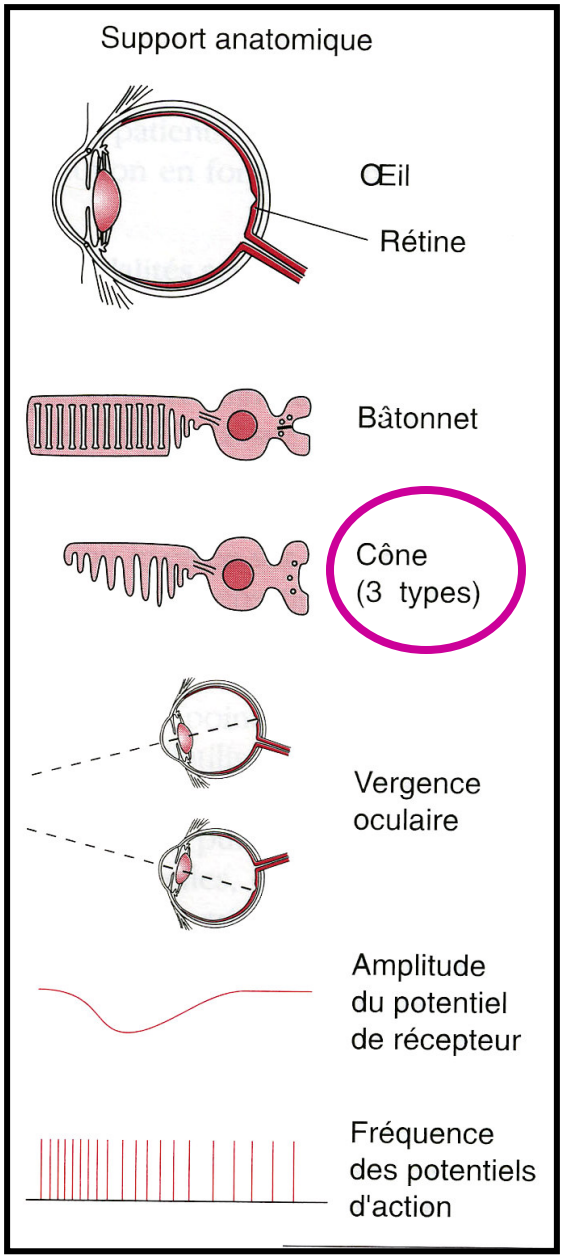
Modalité = Vue

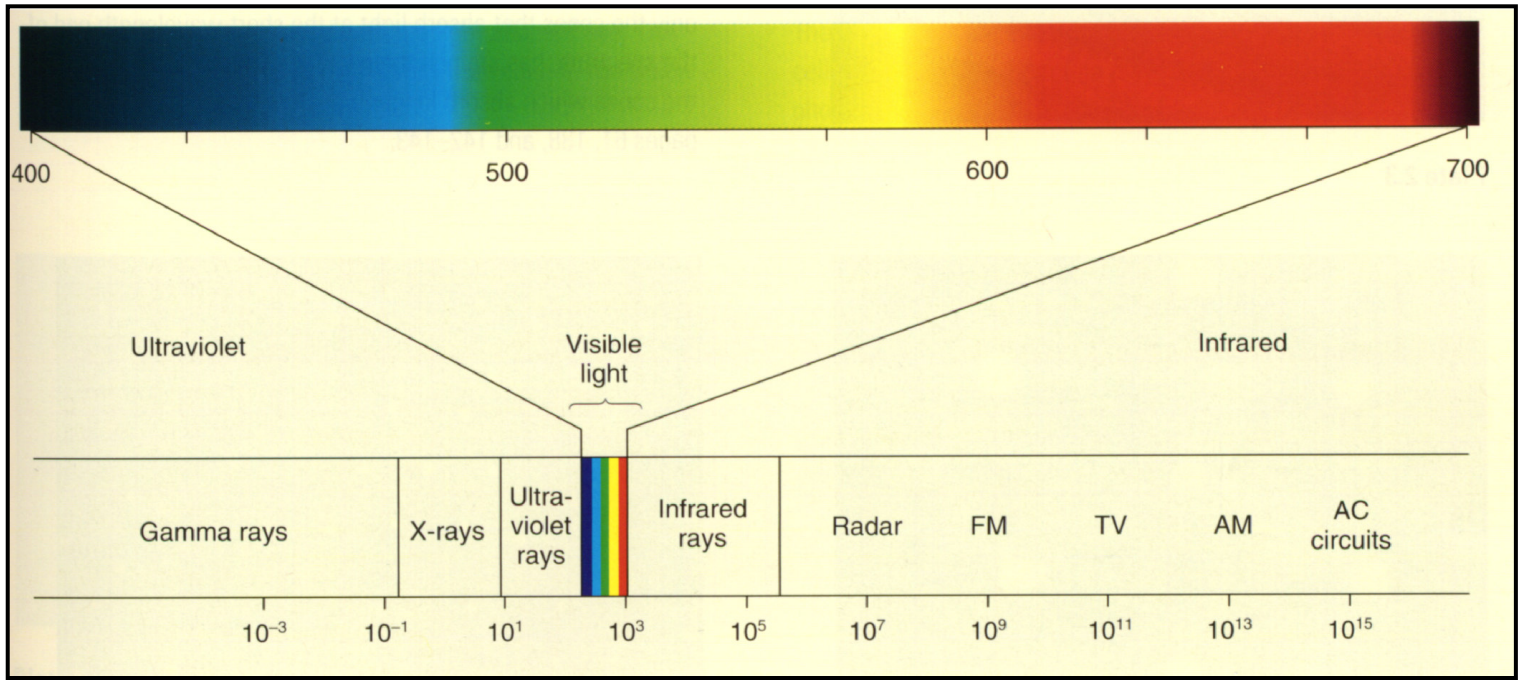
3 QUALITES

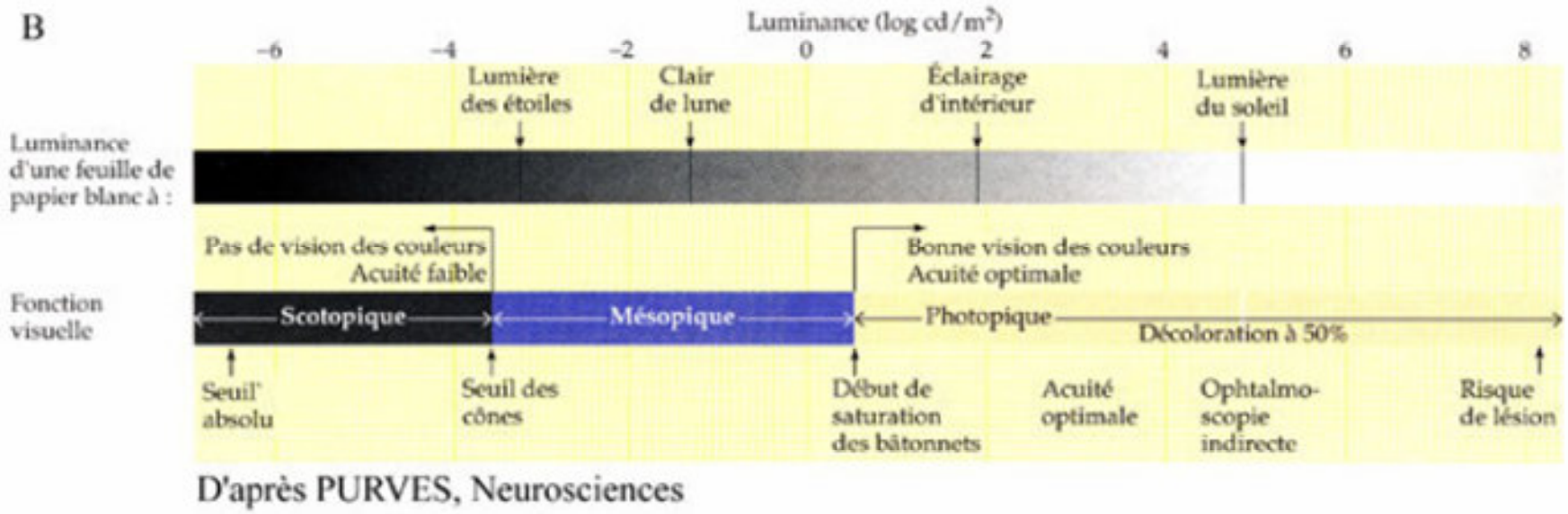
- Brillance
- Couleur
- Profondeur

QUANTITE

Intensité
de la sensation





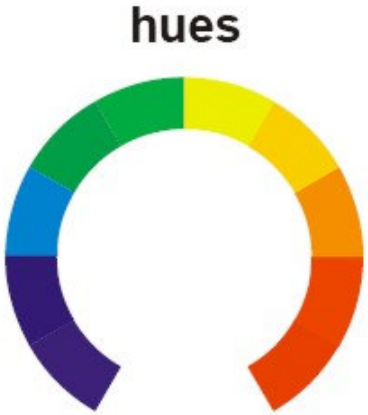


D'après PURVES, Neurosciences

How many gradations of color can the human brain distinguish?

a) 200 hues

The brain transforms the single wavelengths of light seen in rainbow into a color circle. Hues on opposite sides of the circle are complementary.



b) 20 levels of saturation

Combinations of two more wavelengths. When complementary wavelengths are combine equally one gets white.

c) 500 brightness levels

Any color on the circle can be made brighter or darker.

Remarkably with only 3 cones types we can see 500x200x20 = 2,000,000 gradations of color

La vision

1. Introduction

2. Mécanismes périphériques

   a) L'organe récepteur : l'œil
      - Structure
      - Propriétés optiques

   b) La rétine
      - Données histologiques
      - Structure des photorécepteurs
      - La phototransduction

   c) Le message rétinien

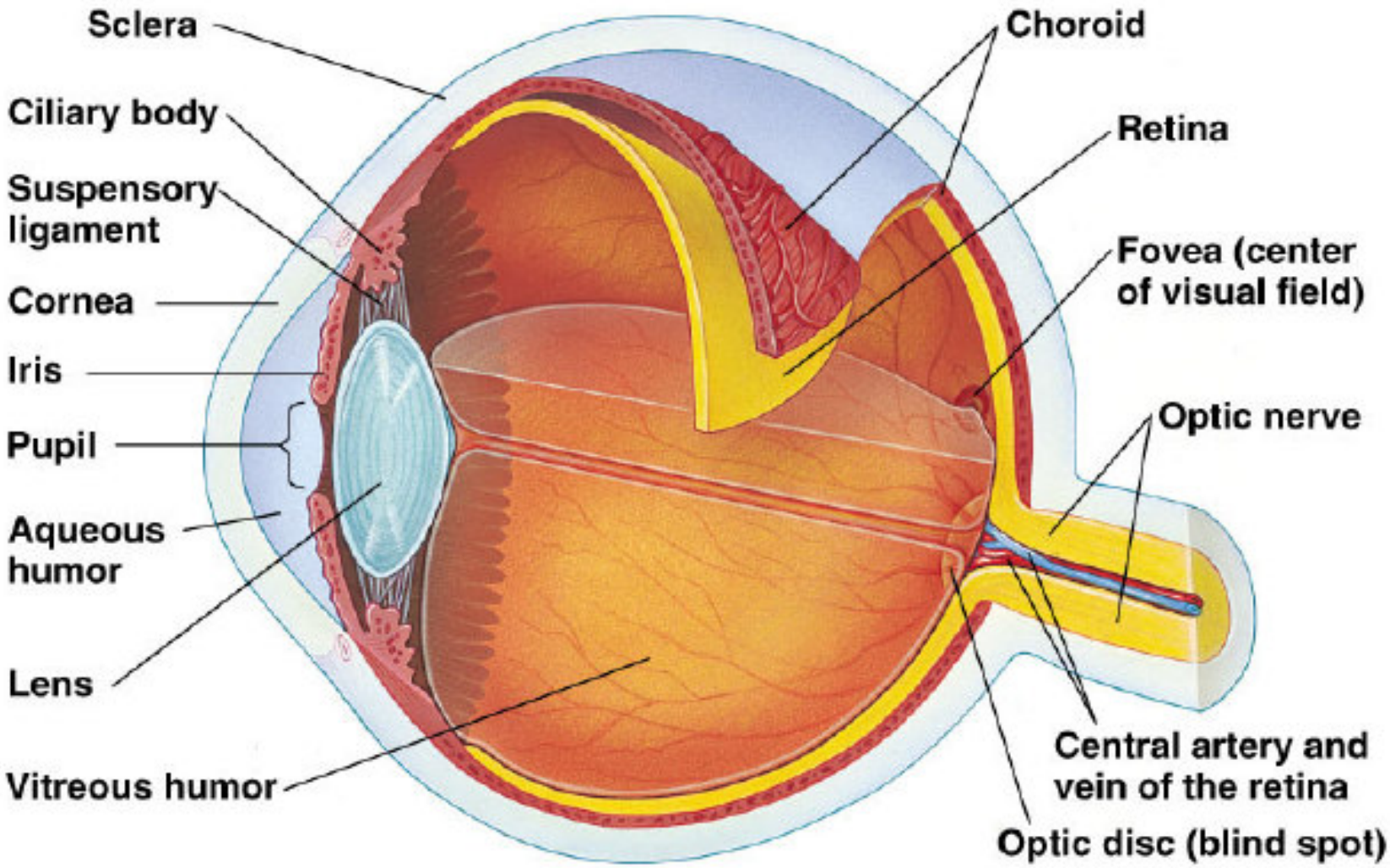
3. Mécanismes centraux

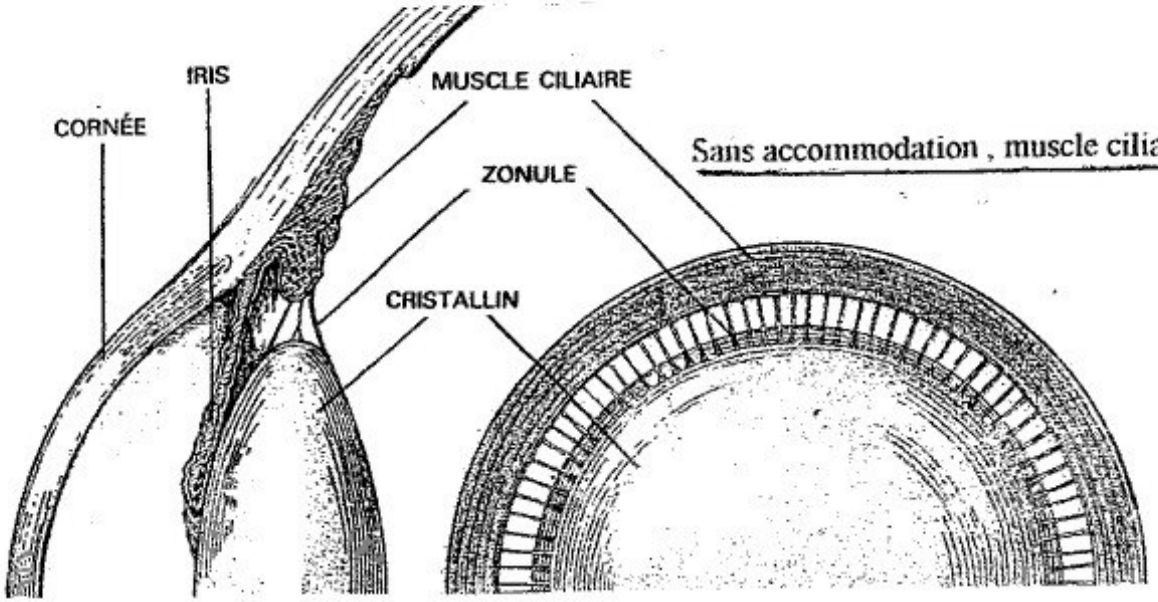
   a) Le cortex visuel V1 (aire striée ou aire 17)
      - Les projections géniculées
      - Organisation anatomo-fonctionnelle de V1

   b) Les aires visuelles péristriées

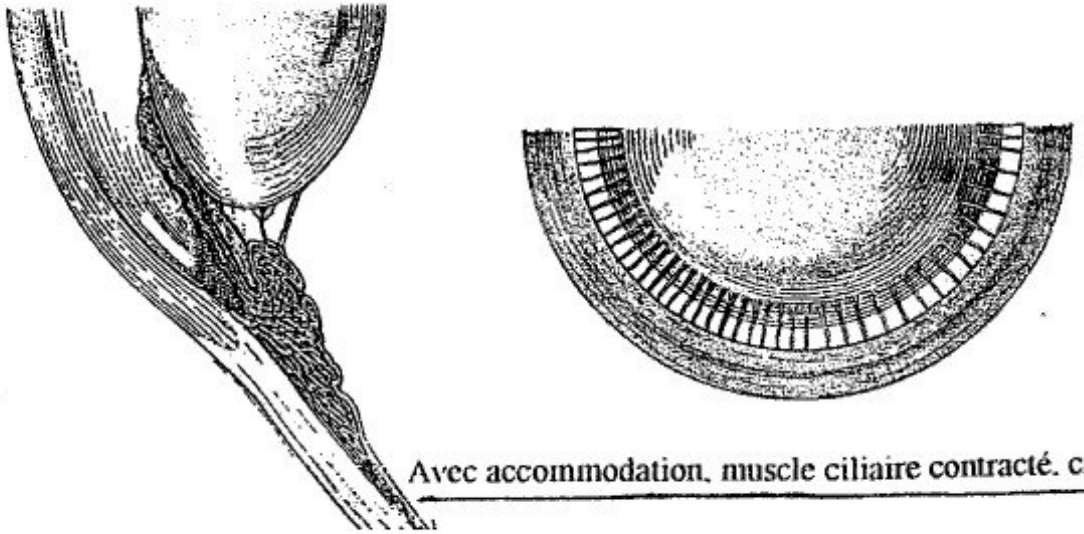
      - Inféro temporal (IT) et forme/couleur du stimulus
      - Pariétal et localisation/mouvement du stimulus

4. Conclusion

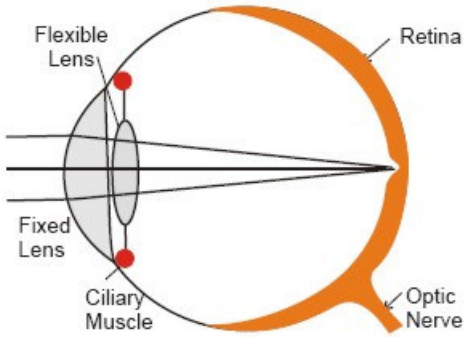

Sclera
Ciliary body
Suspensory ligament
Cornea
Iris
Pupil
Aqueous humor
Lens
Vitreous humor
Choroid
Retina
Fovea (center of visual field)
Optic nerve
Central artery and vein of the retina
Optic disc (blind spot)



Sans accommodation , muscle ciliaire détendu, cristallin aplati



Avec accommodation, muscle ciliaire contracté, cristallin détendu donc plus sphéri



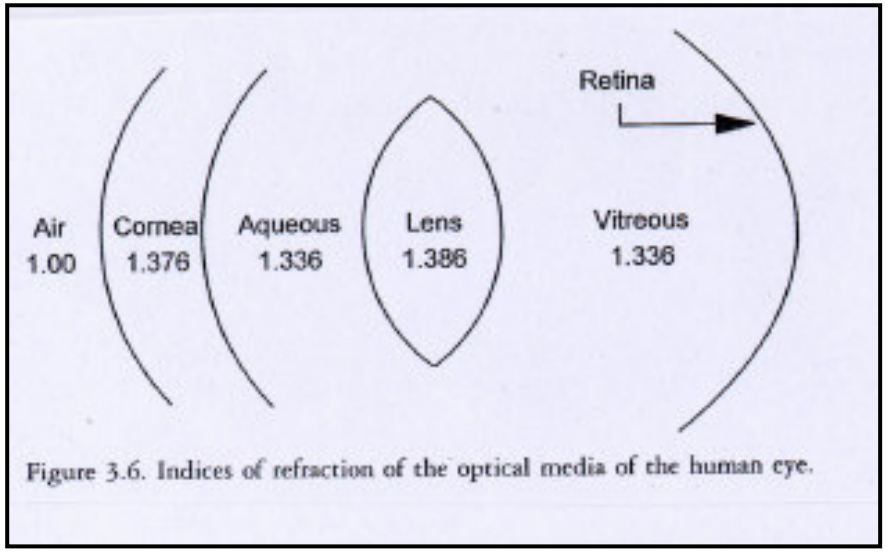
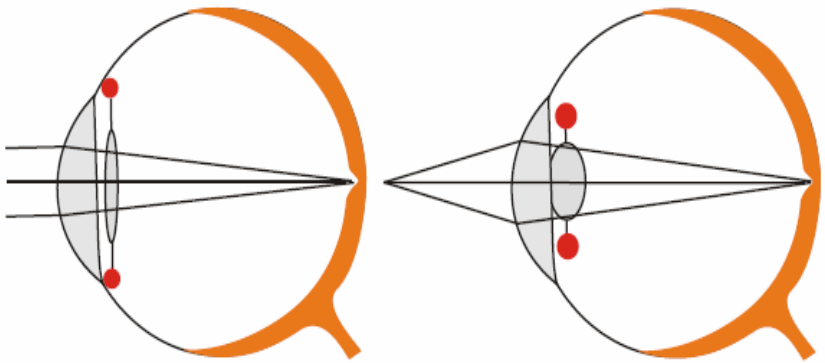
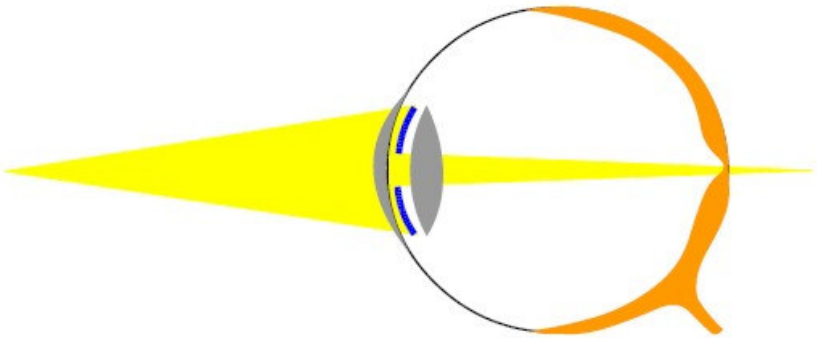


Figure 3.6. Indices of refraction of the optical media of the human eye.

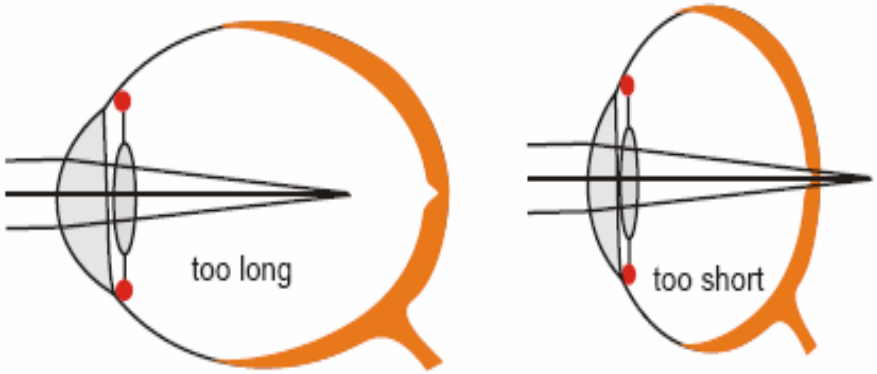


When the ciliary muscles are relaxed the lens is flat and distant objects are focused onto the retina

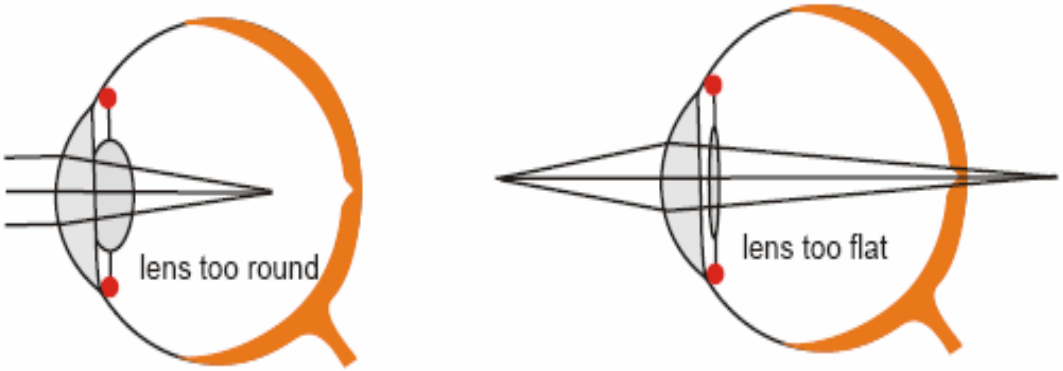
When the ciliary muscles are contracted, the lens becomes more round and a close object is focused onto the retina



a) The shape of the eye ball.

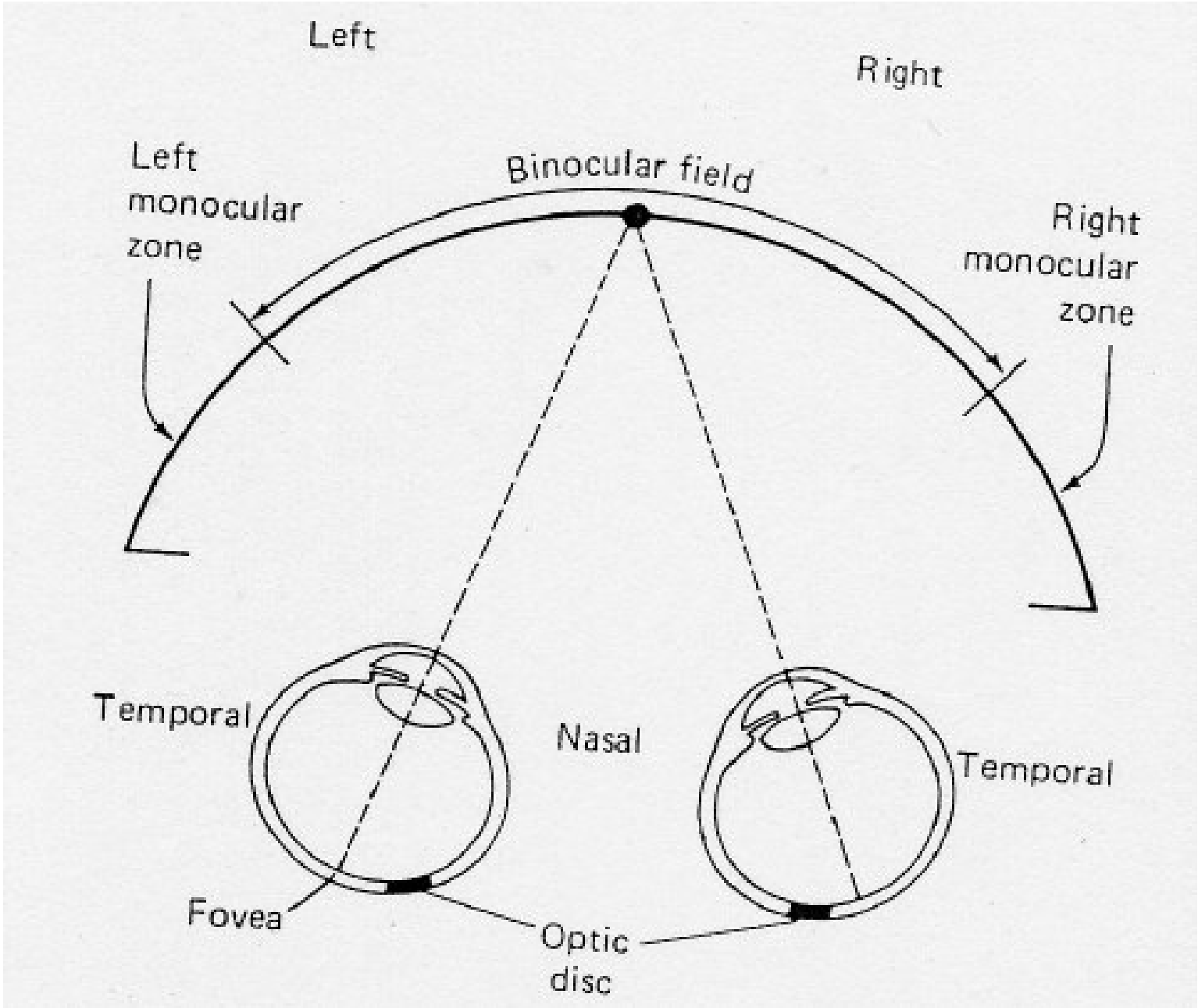


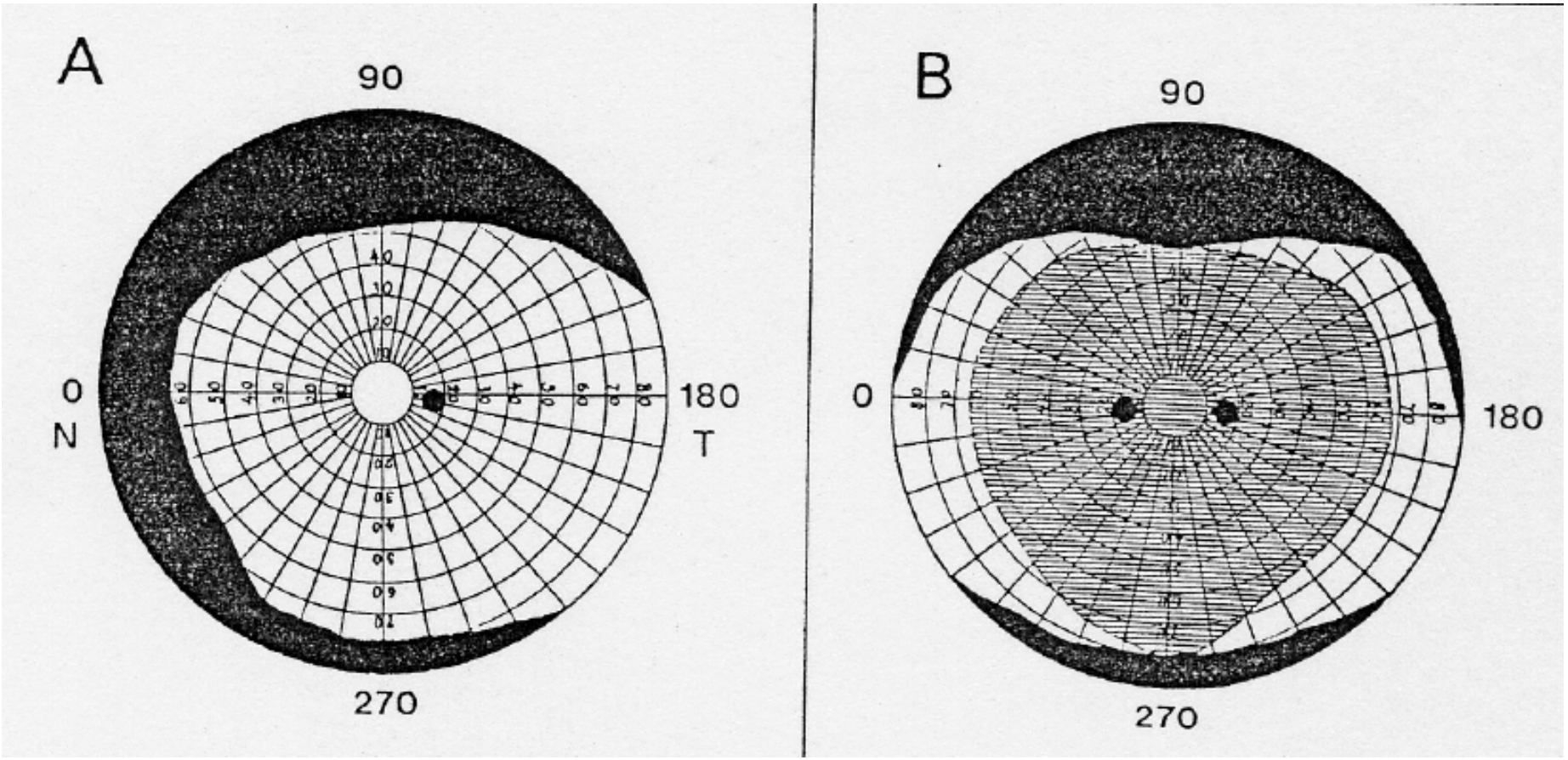
b) The shape of the lens



Here one cannot focus on far targets. One is near sighted & needs a concave lens.

Here one cannot focus on near targets. One is far sighted & needs a convex lens.


Left
Right
Left monocular zone
Binocular field
Right monocular zone
Temporal
Nasal
Temporal
Fovea
Optic disc


A
90
0
N
180
T
270
B
90
0
180
270

La vision

1. Introduction

2. Mécanismes périphériques

   a) L'organe récepteur : l'œil
      - Structure
      - Propriétés optiques

   b) La rétine
      - Données histologiques
      - Structure des photorécepteurs
      - La phototransduction

   c) Le message rétinien

3. Mécanismes centraux

   a) Le cortex visuel V1 (aire striée ou aire 17)
      - Les projections géniculées
      - Organisation anatomo-fonctionnelle de V1

   b) Les aires visuelles péristriées

      - Inféro temporal (IT) et forme/couleur du stimulus
      - Pariétal et localisation/mouvement du stimulus

4. Conclusion

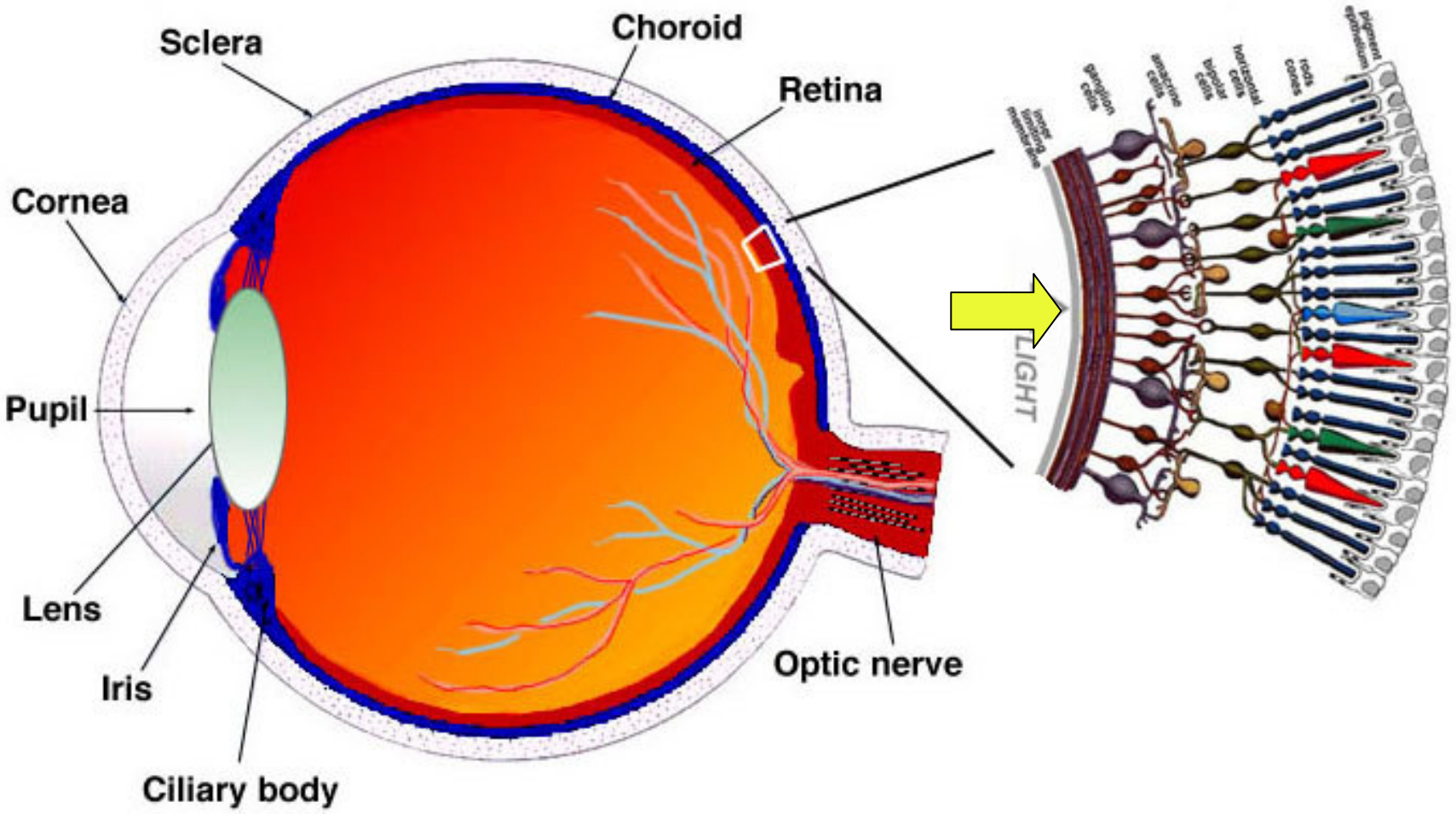


Fig. 1.1. A drawing of a section through the human eye with a schematic enlargement of the retina.

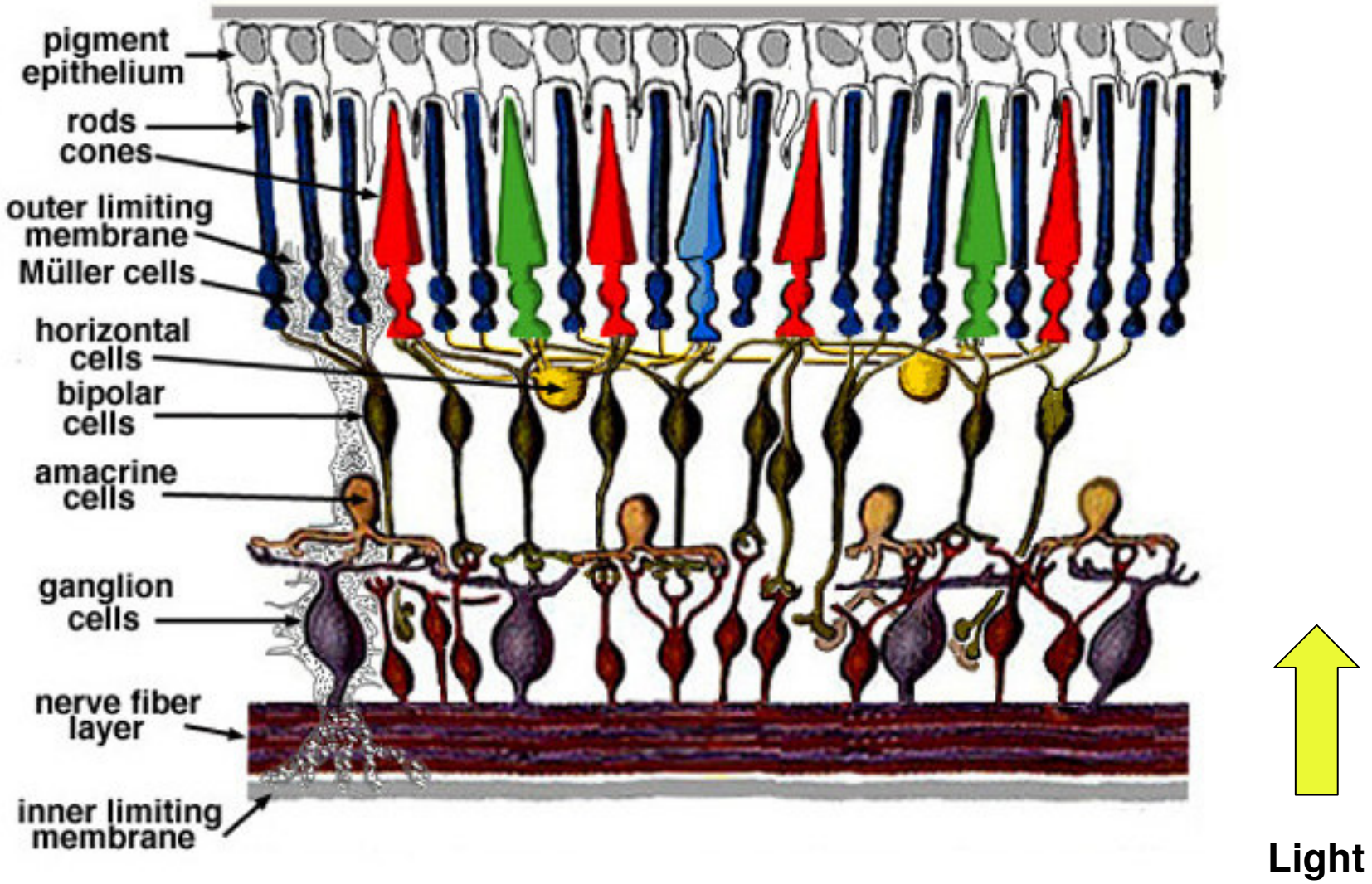
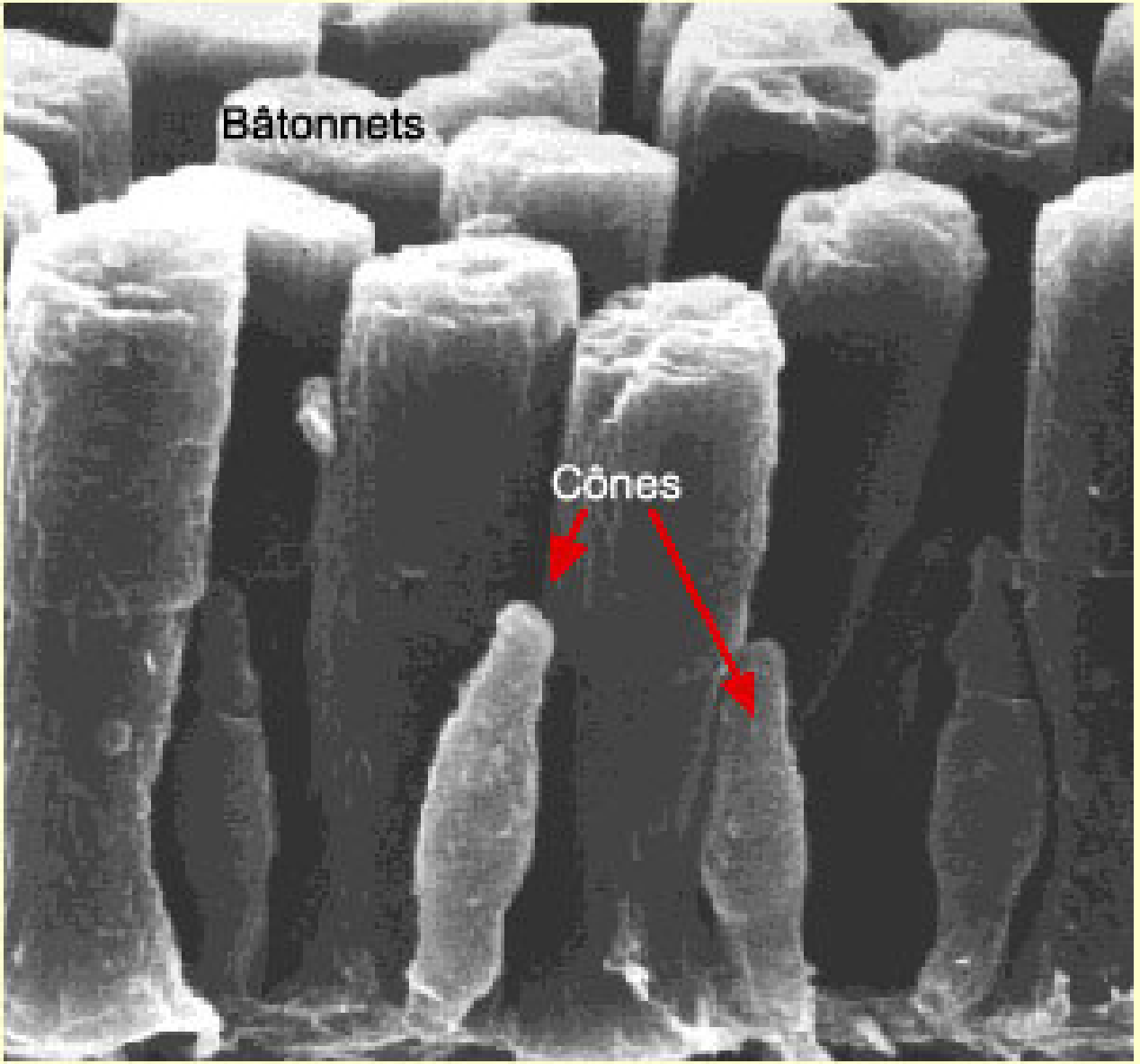


Fig. 2. Simple diagram of the organization of the retina.


Bâtonnets
Cônes

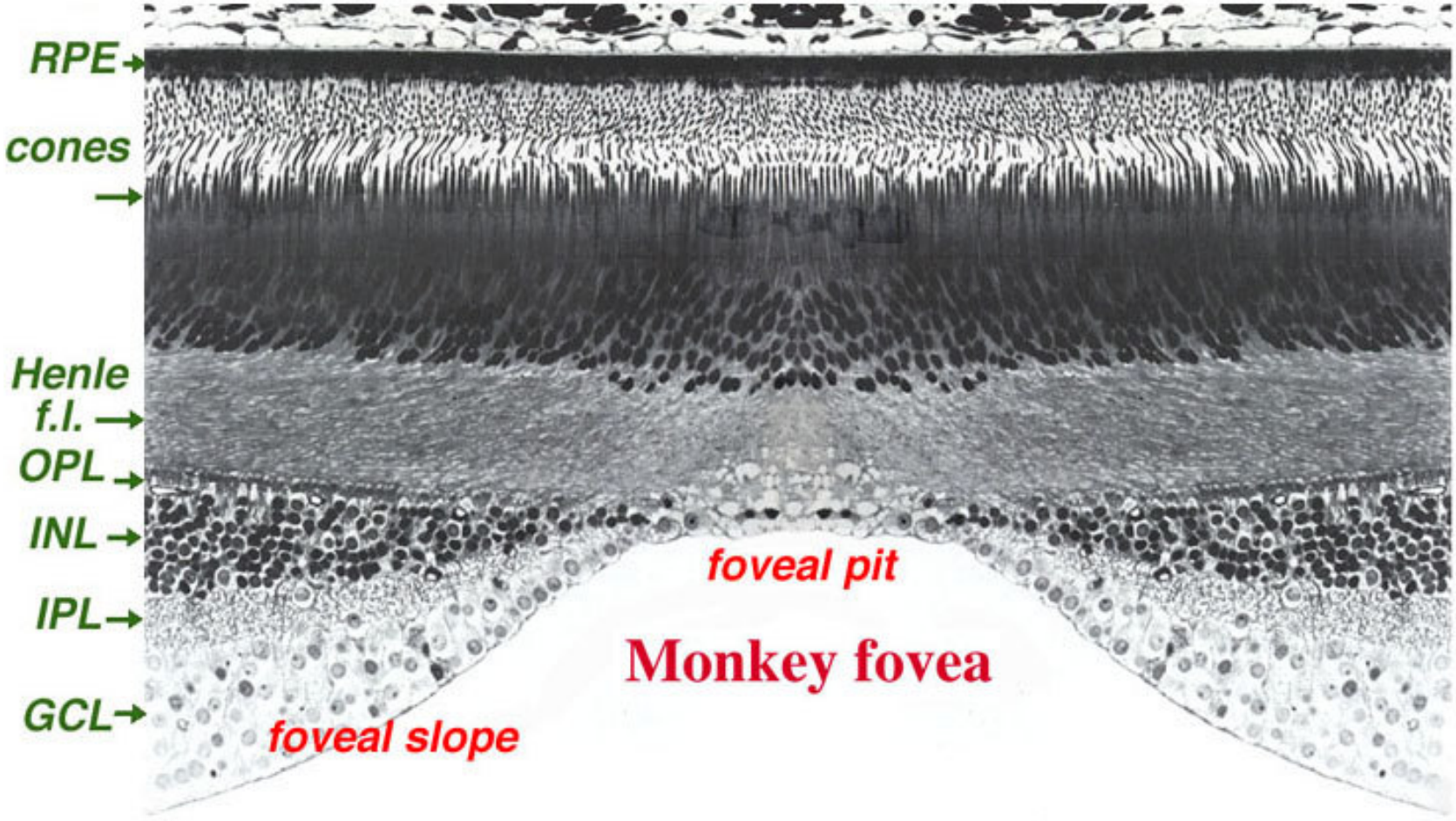


Fig. 12b. Vertical section of the monkey fovea from Hagerman and Johnson (1991).

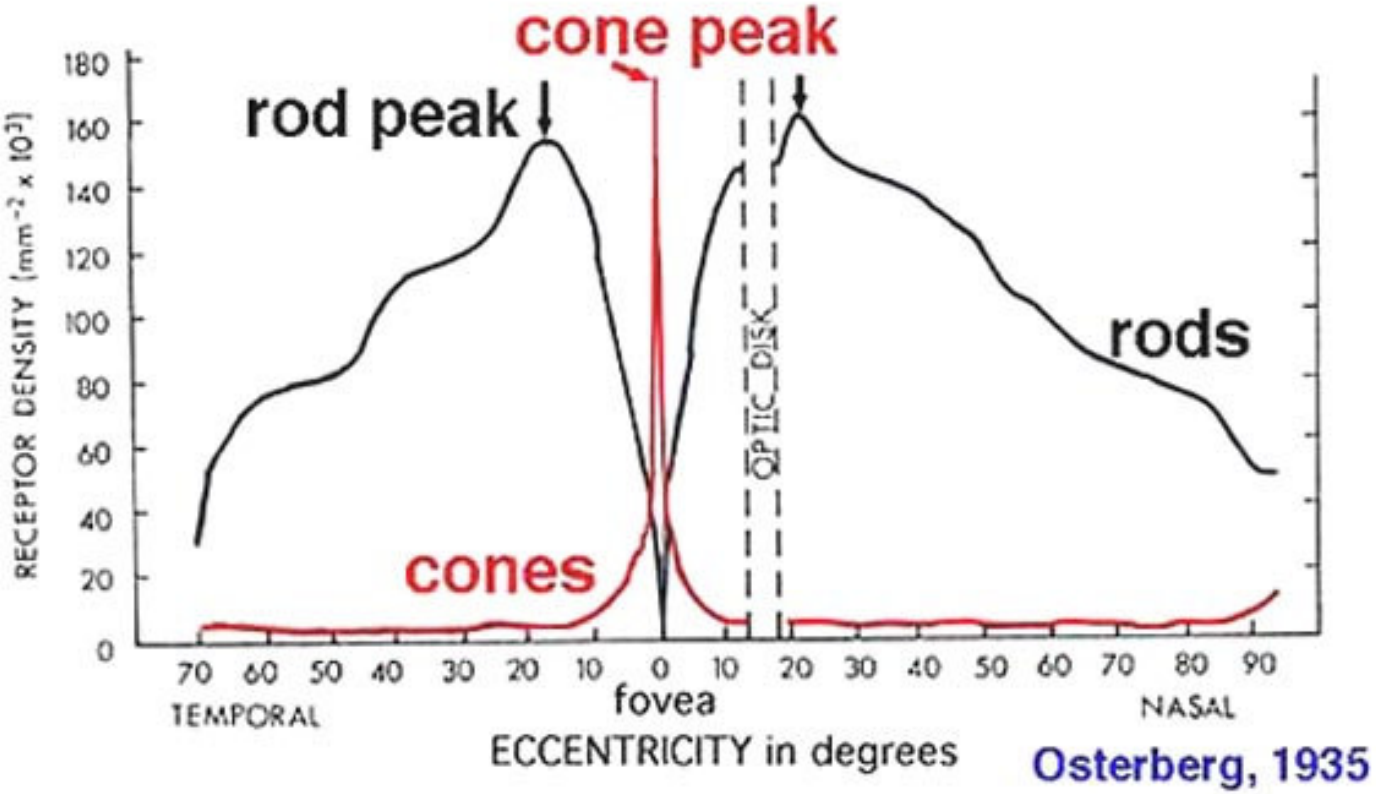


Fig. 20. Graph to show rod and cone densities along the horizontal meridian.

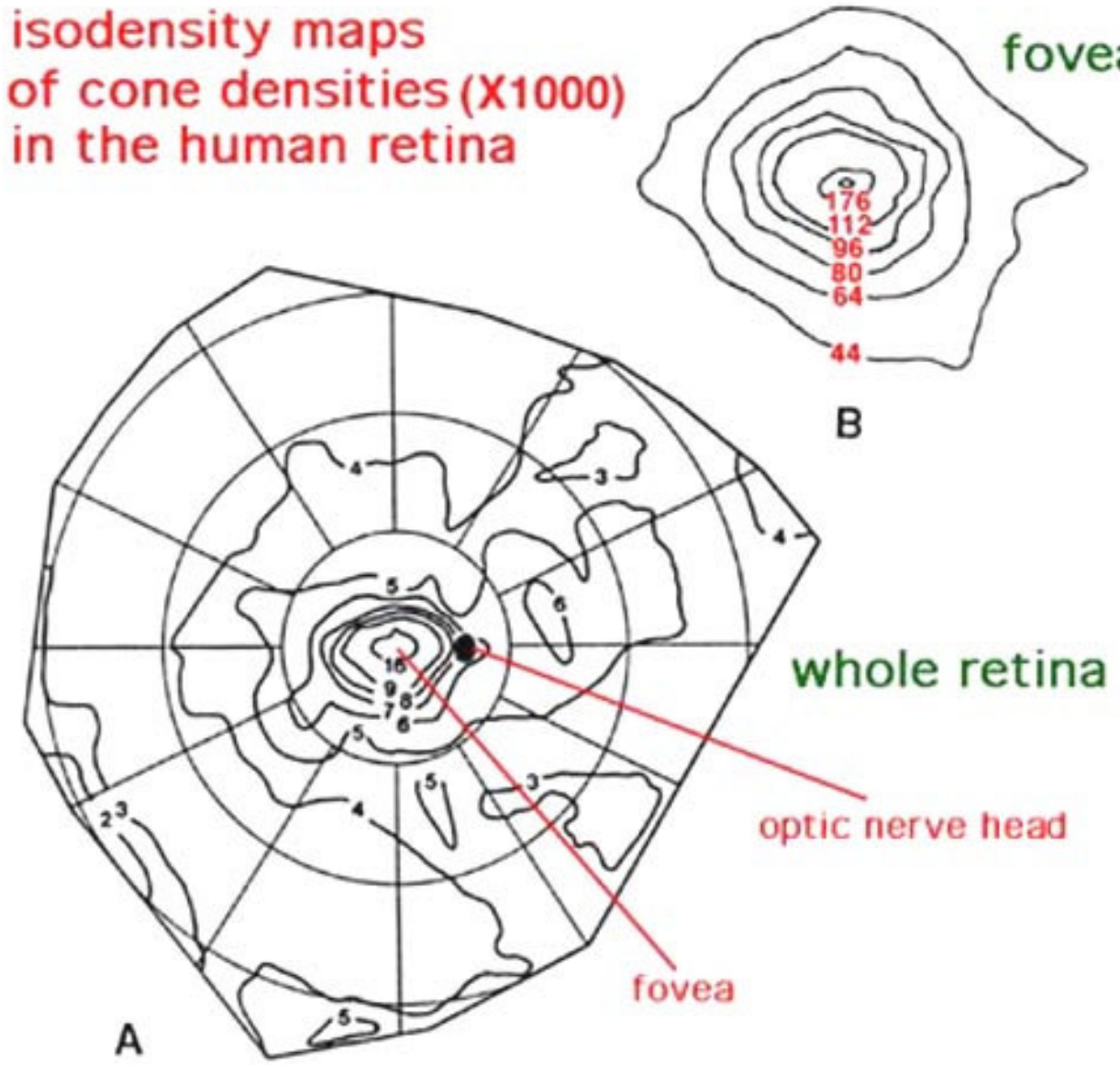
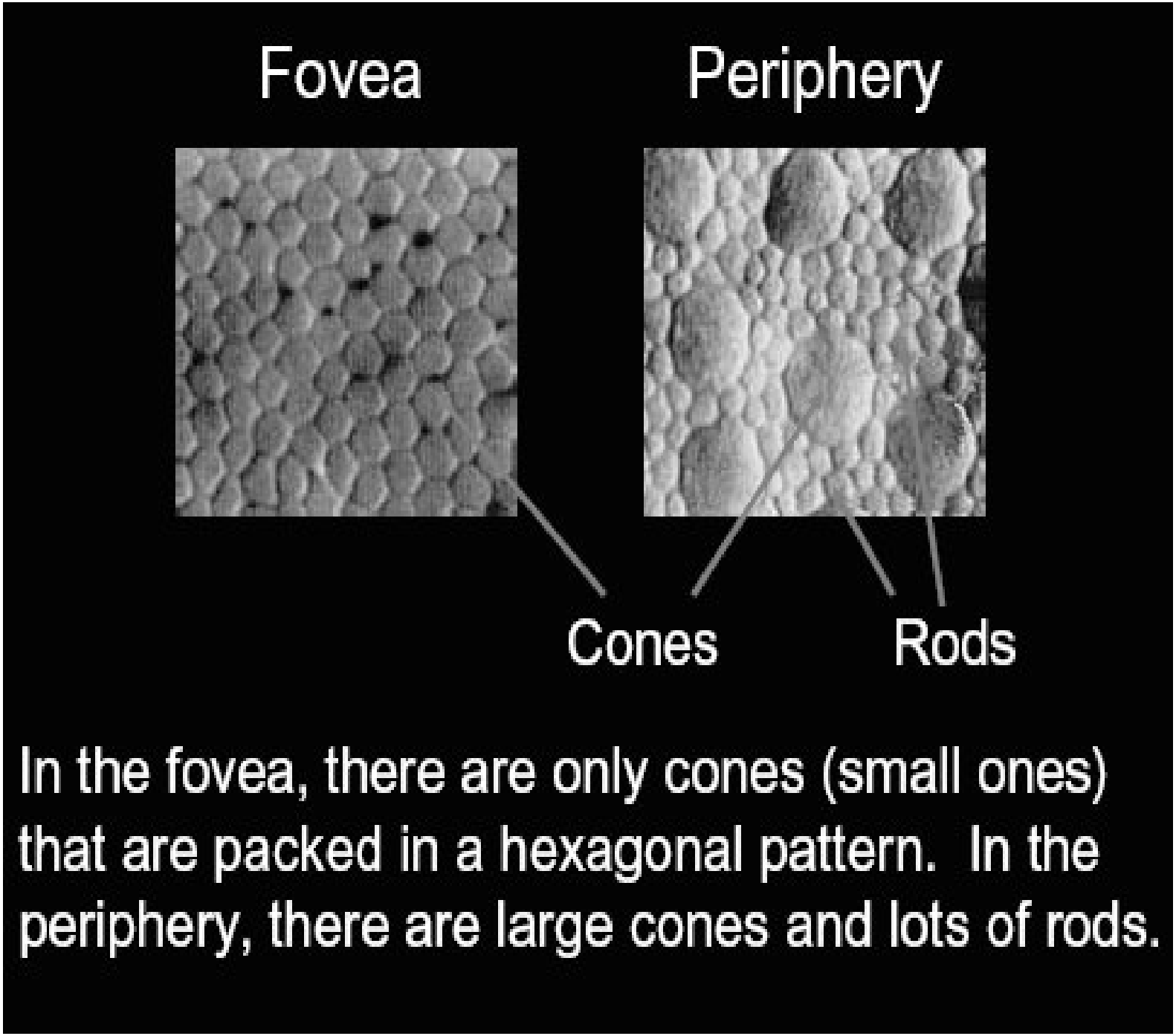
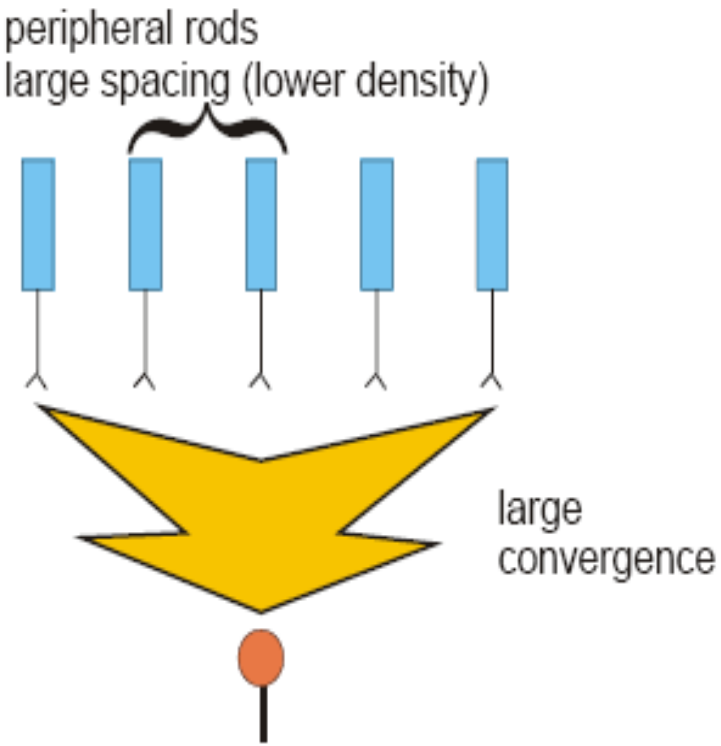
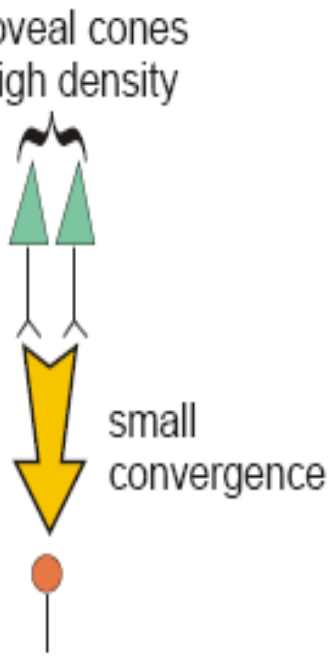


Fig. 21. Cone densities in human retina as revealed in whole mount. The foveal area is enlaged in B. (from Curcio et al., 1987).



In the fovea, there are only cones (small ones) that are packed in a hexagonal pattern. In the periphery, there are large cones and lots of rods.





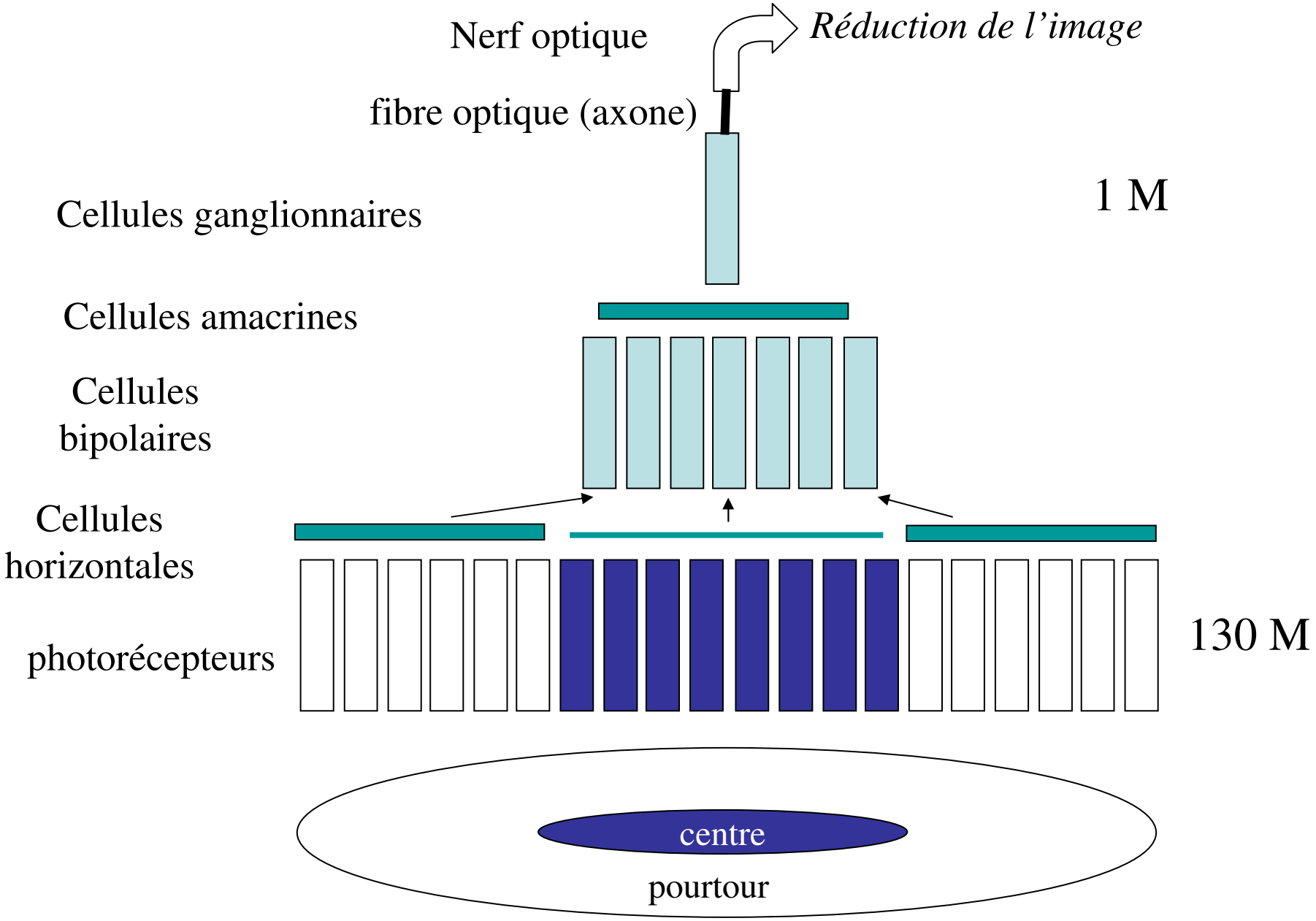
Ganglion cells integrate information from a large area of retina (3 deg)

large spacing and large convergence results in low acuity

Ganglion cells integrate information from a small area of retina (.03 deg)

small spacing and low convergence results in high acuity.

Compression de l'information ou convergence



La vision

1. Introduction

2. Mécanismes périphériques

   a) L'organe récepteur : l'œil
      - Structure
      - Propriétés optiques

   b) La rétine
      - Données histologiques
      - Structure des photorécepteurs
      - La phototransduction

   c) Le message rétinien

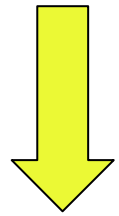
3. Mécanismes centraux

   a) Le cortex visuel V1 (aire striée ou aire 17)
      - Les projections géniculées
      - Organisation anatomo-fonctionnelle de V1

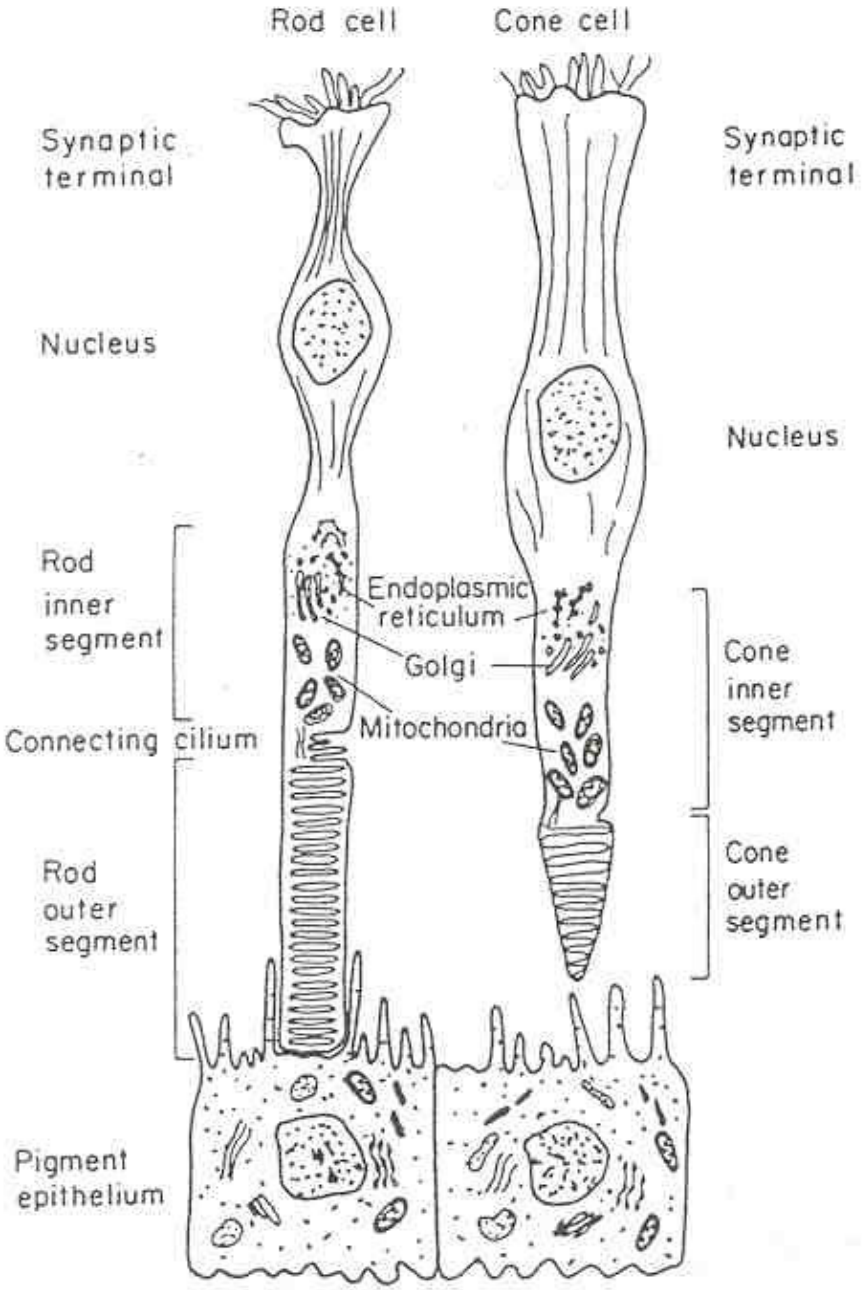
   b) Les aires visuelles péristriées

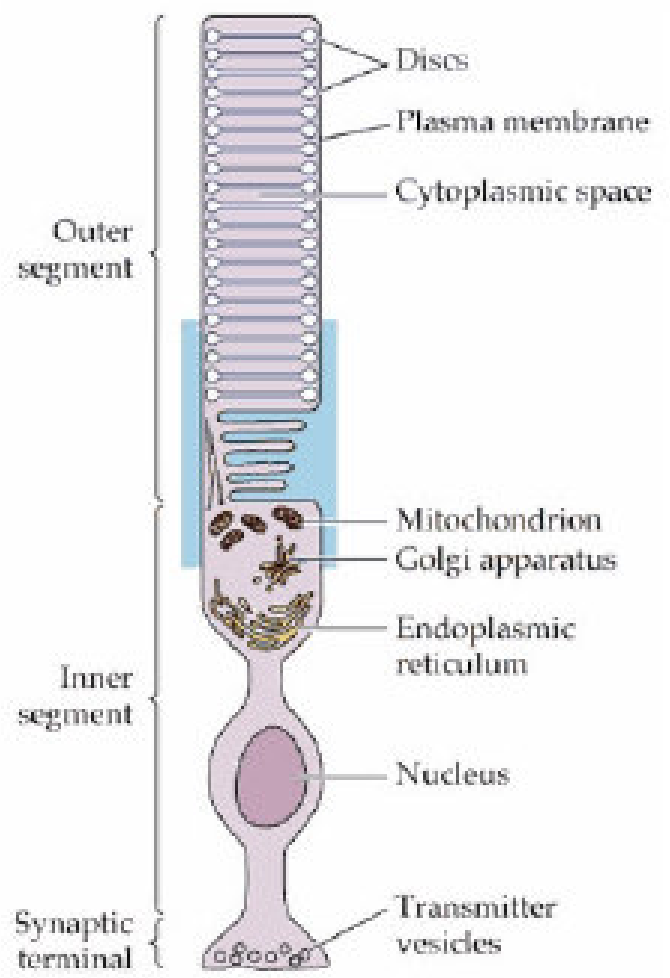
      - Inféro temporal (IT) et forme/couleur du stimulus
      - Pariétal et localisation/mouvement du stimulus

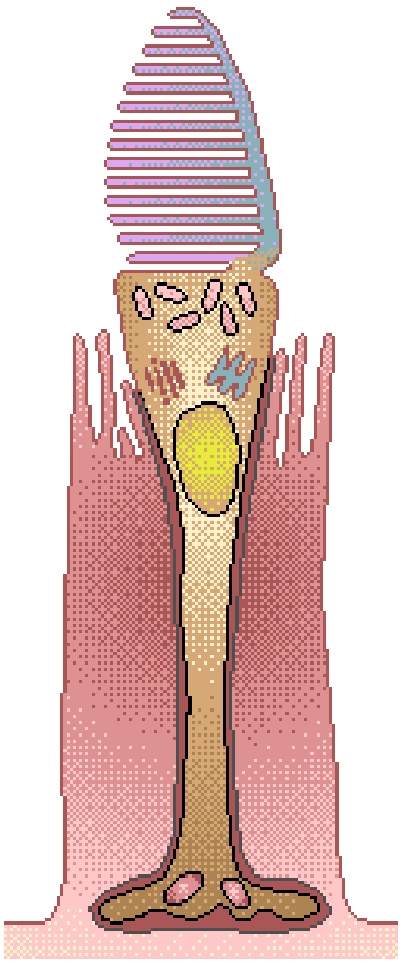
4. Conclusion



Light


Rod cell
Cone cell
Synaptic terminal
Synaptic terminal
Nucleus
Nucleus
Rod inner segment
Endoplasmic reticulum
Golgi
Mitochondria
Connecting cilium
Cone inner segment
Rod outer segment
Cone outer segment
Pigment epithelium


Discs
Plasma membrane
Cytoplasmic space
Outer segment
Mitochondrion
Golgi apparatus
Endoplasmic reticulum
Inner segment
Nucleus
Transmitter vesicles
Synaptic terminal



La vision

1. Introduction

2. Mécanismes périphériques

   a) L'organe récepteur : l'œil
      - Structure
      - Propriétés optiques

   b) La rétine
      - Données histologiques
      - Structure des photorécepteurs
      - La phototransduction

   c) Le message rétinien

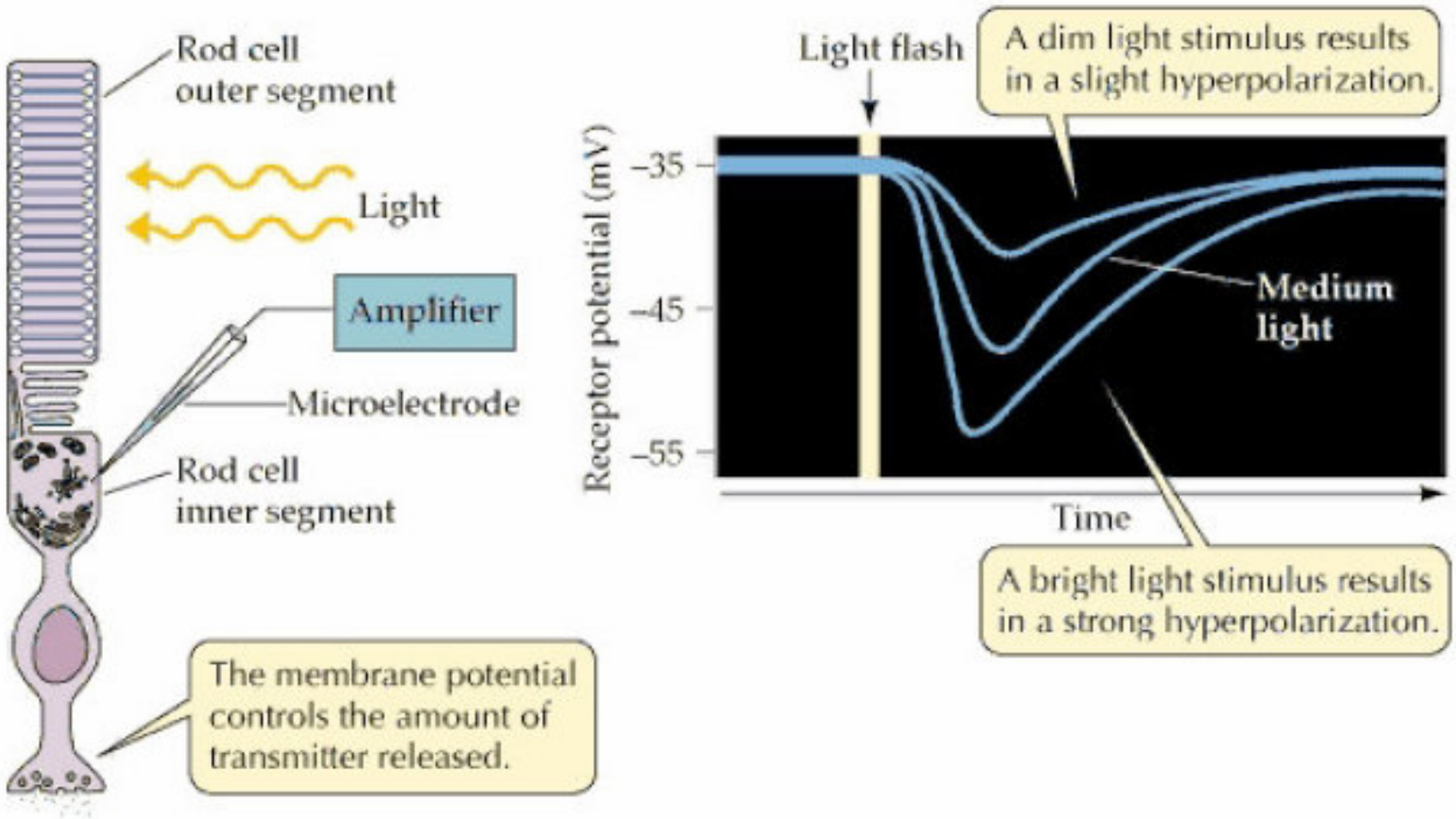
3. Mécanismes centraux

   a) Le cortex visuel V1 (aire striée ou aire 17)
      - Les projections géniculées
      - Organisation anatomo-fonctionnelle de V1

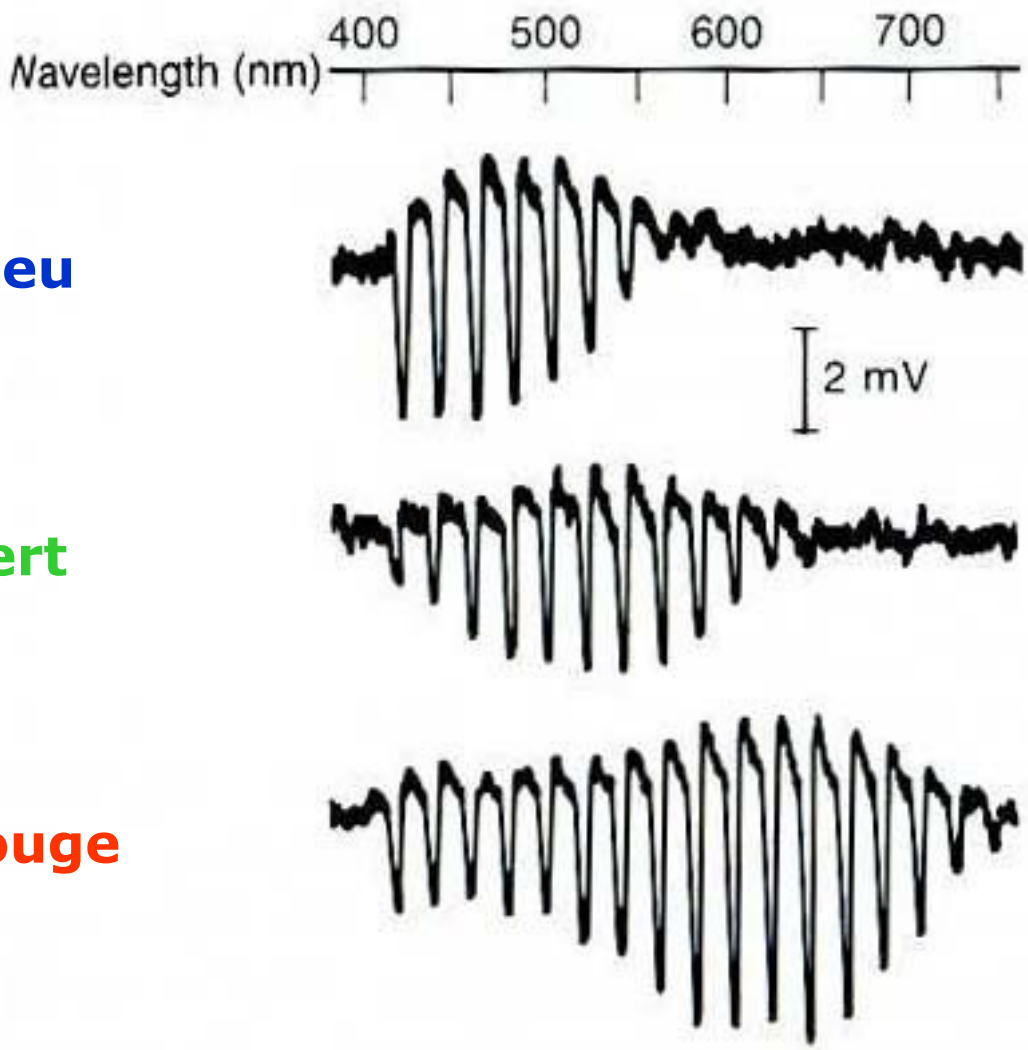
   b) Les aires visuelles péristriées

      - Inféro temporal (IT) et forme/couleur du stimulus
      - Pariétal et localisation/mouvement du stimulus

4. Conclusion


Rod cell
outer segment
Light
Amplifier
Microelectrode
Rod cell
inner segment
The membrane potential controls the amount of transmitter released.
Light flash
A dim light stimulus results in a slight hyperpolarization.
Receptor potential (mV)
–35
–45
–55
Medium light
Time
A bright light stimulus results in a strong hyperpolarization.

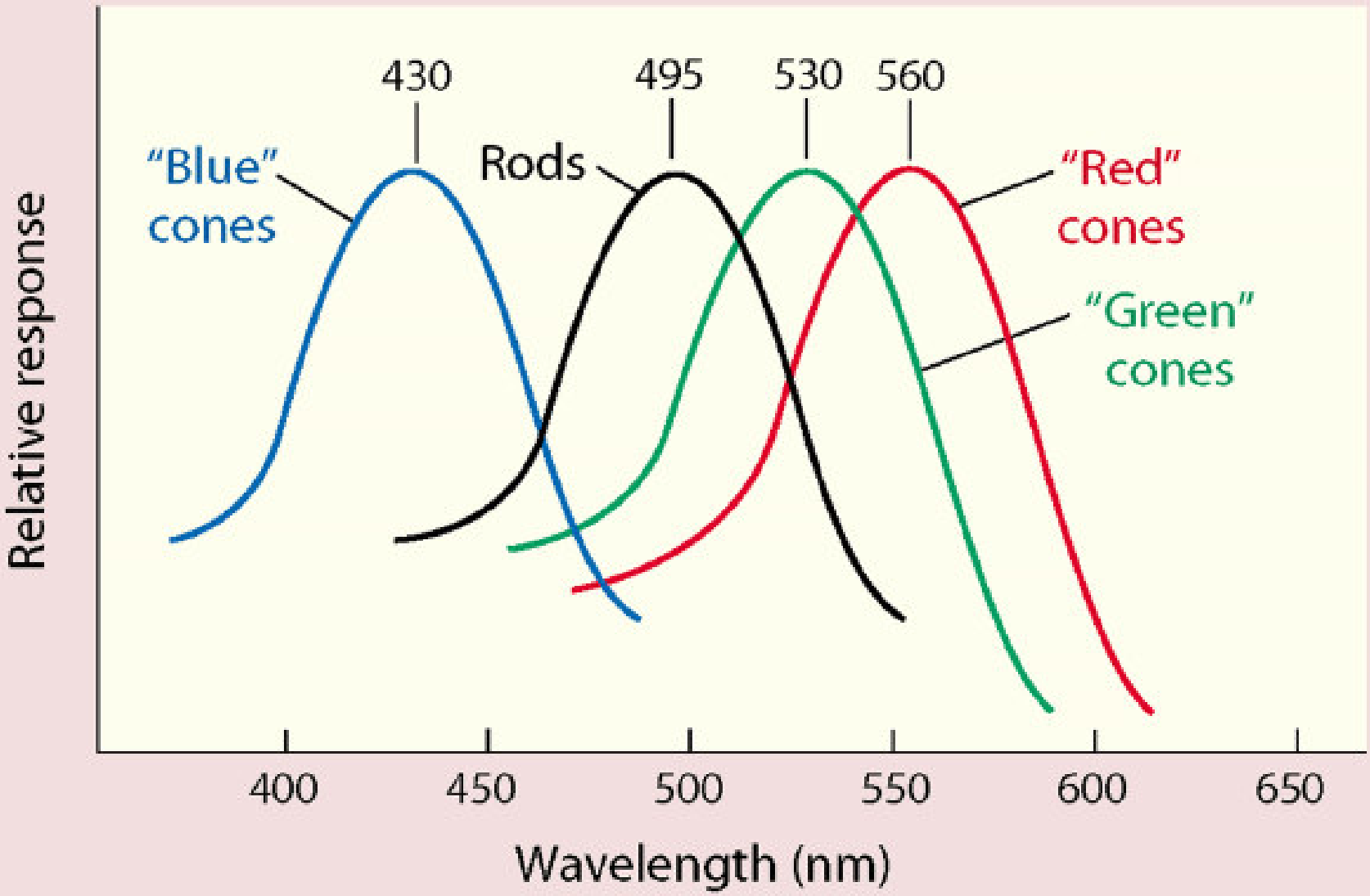
Les cônes

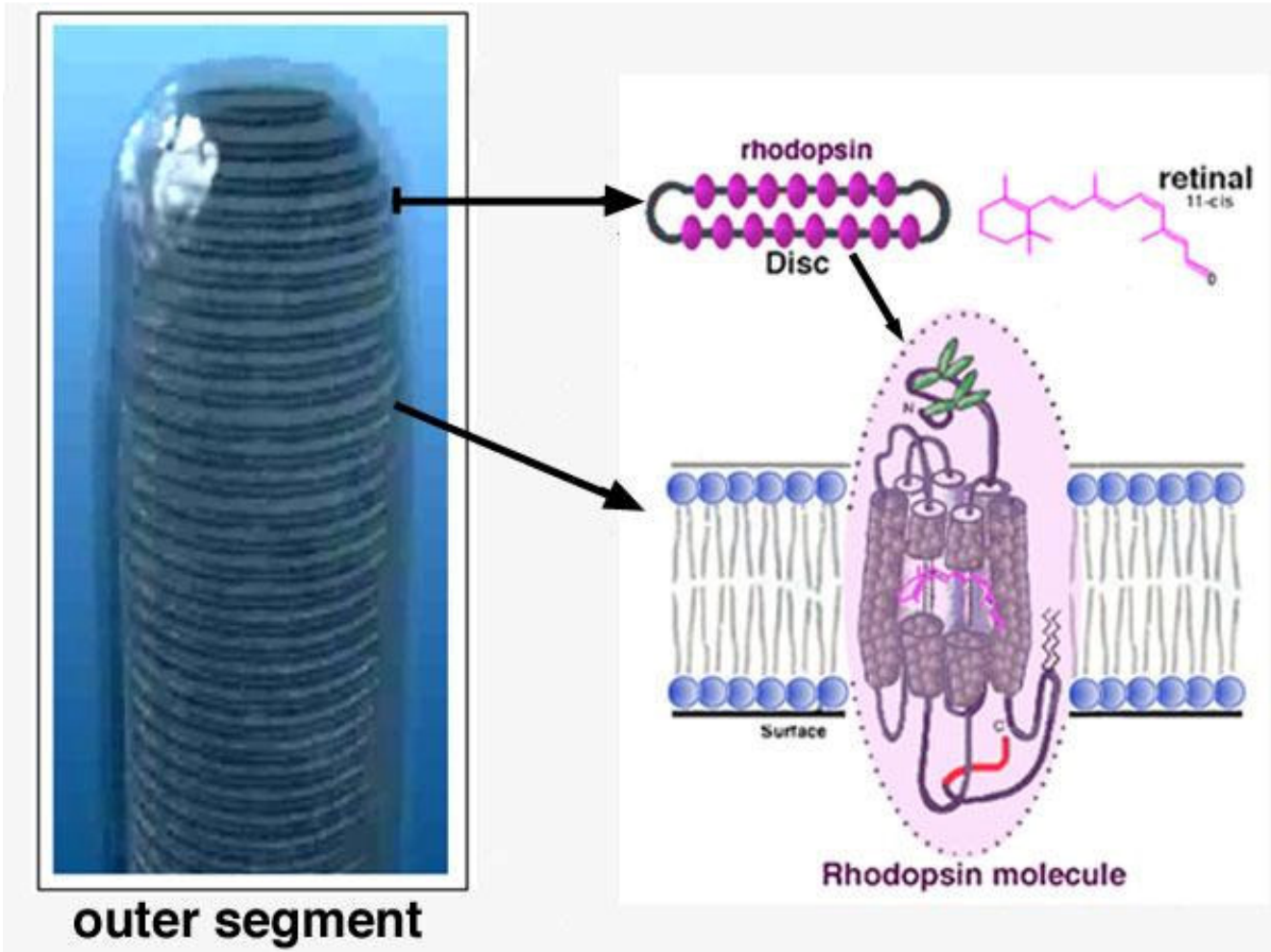


bleu

vert

rouge


430
495
530
560
"Blue" cones
Rods
"Red" cones
"Green" cones
Relative response
400
450
500
550
600
650
Wavelength (nm)


rhodopsin
retinal
11-cis
Disc
N
Surface
C
Rhodopsin molecule
outer segment

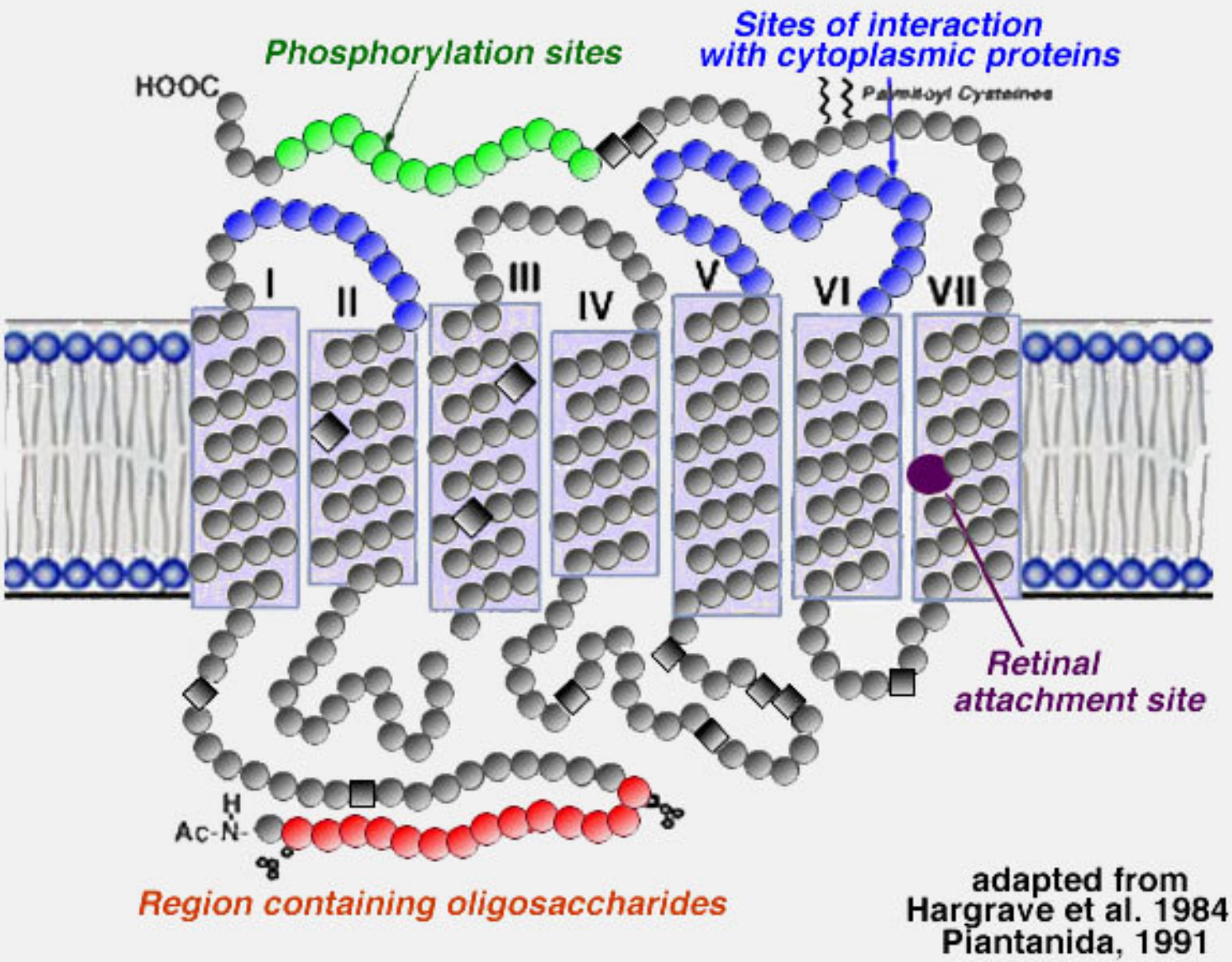


Fig. 9. Structural model of rhodopsin showing seven transmembrane components and the attachment site for retinal.

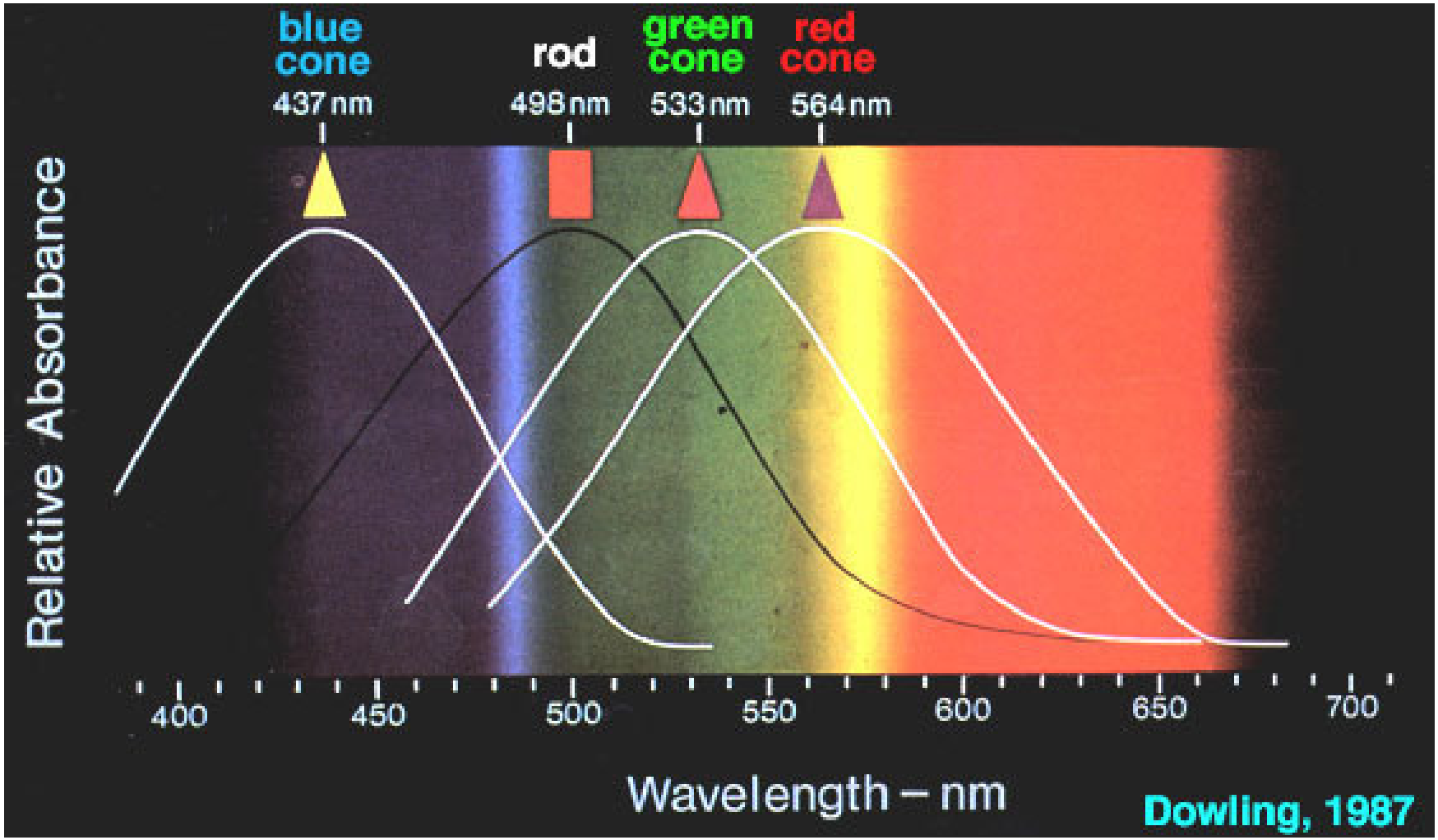
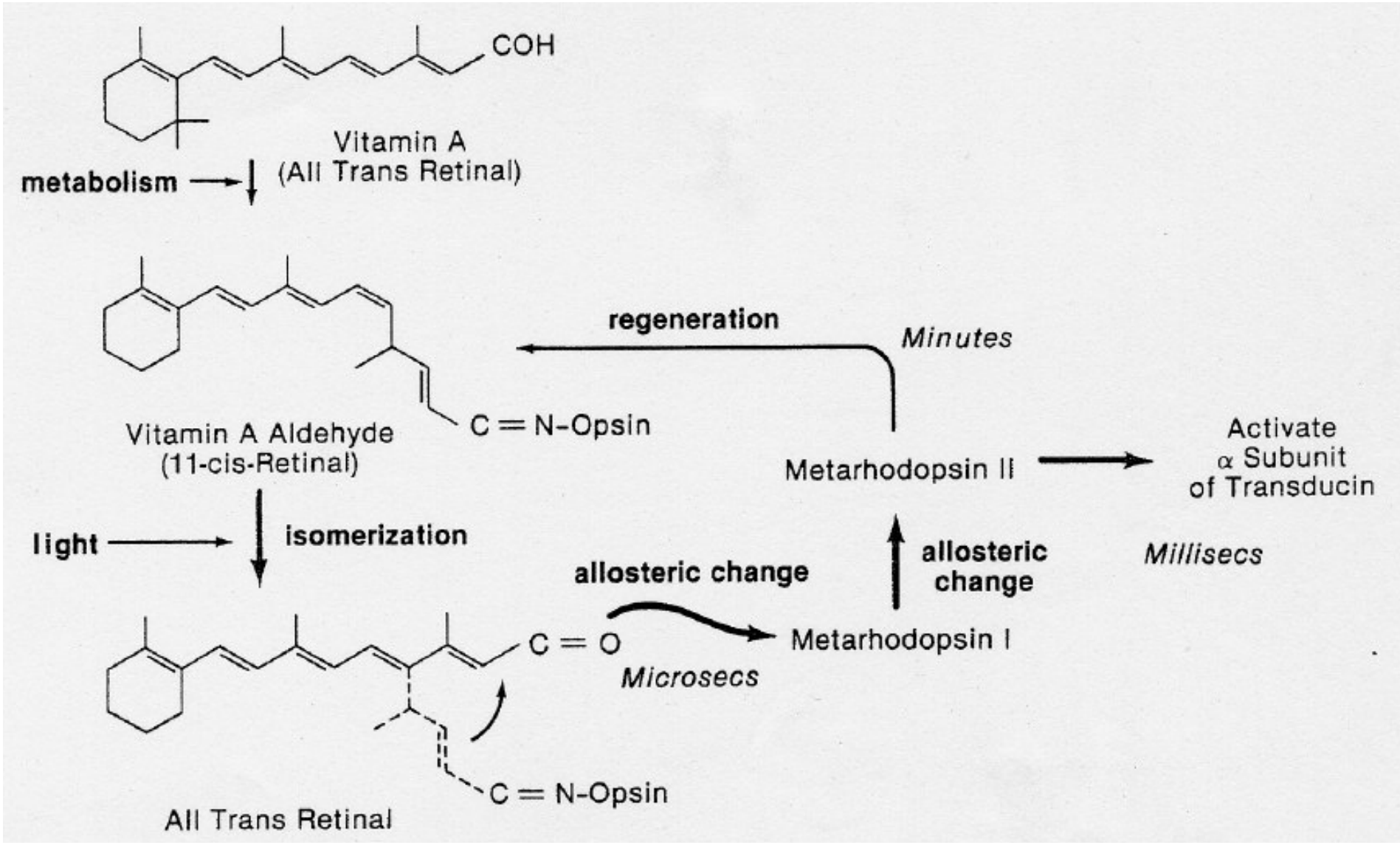
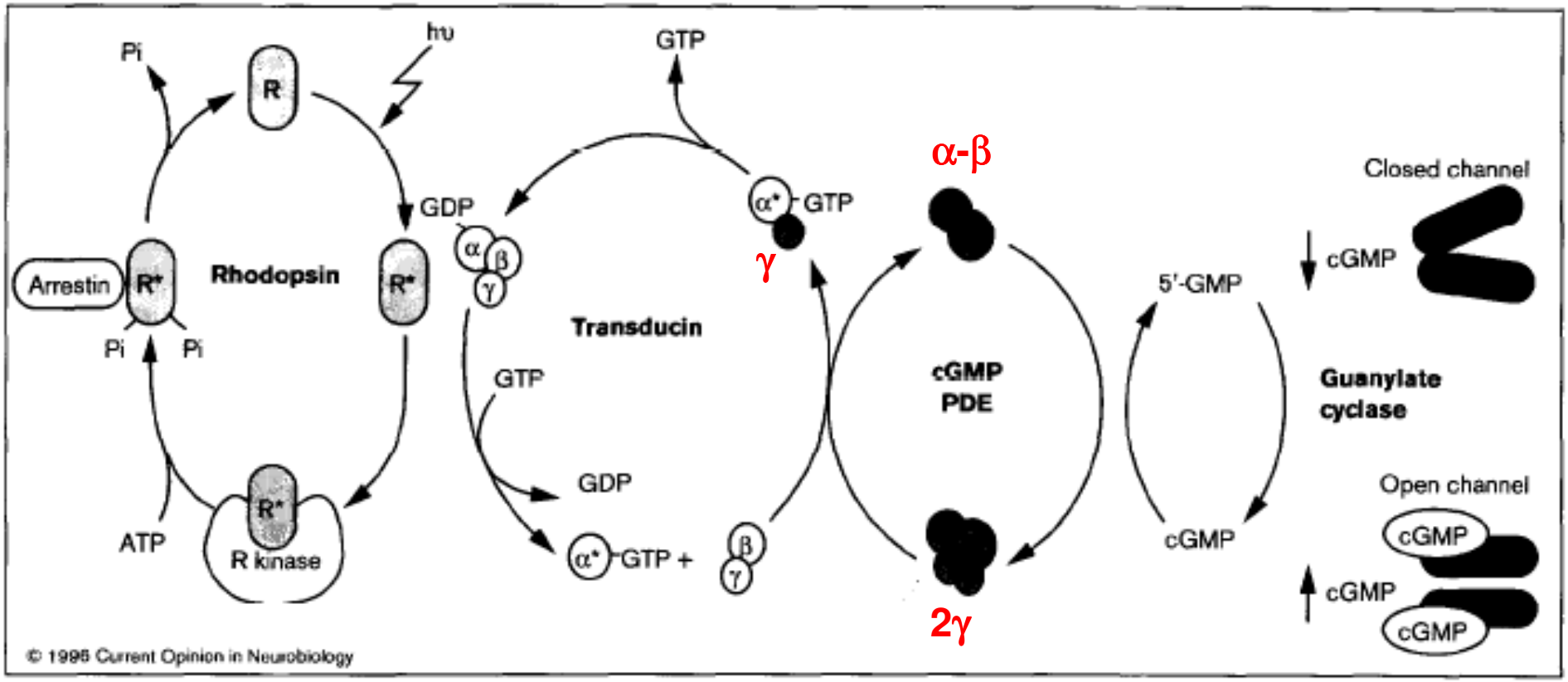


Fig. 14. The peak spectral sensitivities of the the 3 cone types and the the rods in the primate retina (Brown and Wald, 1963). From Dowling's book (1987).


COH
Vitamin A
(All Trans Retinal)
metabolism
regeneration
Minutes
Vitamin A Aldehyde
(11-cis-Retinal)
C = N-Opsin
Metarhodopsin II
Activate
α Subunit
of Transducin
light
isomerization
allosteric change
allosteric
change
Millisecs
C = O
Microsecs
Metarhodopsin I
C = N-Opsin
All Trans Retinal


Pi
R
hυ
GTP
α-β
Closed channel
GDP
α*-GTP
γ
cGMP
Arrestin
R*
Rhodopsin
R*
Transducin
5'-GMP
Pi
Pi
GTP
cGMP
PDE
Guanylate
cyclase
GDP
Open channel
ATP
R*
R kinase
α*-GTP +
cGMP
cGMP
cGMP
2γ
© 1996 Current Opinion in Neurobiology

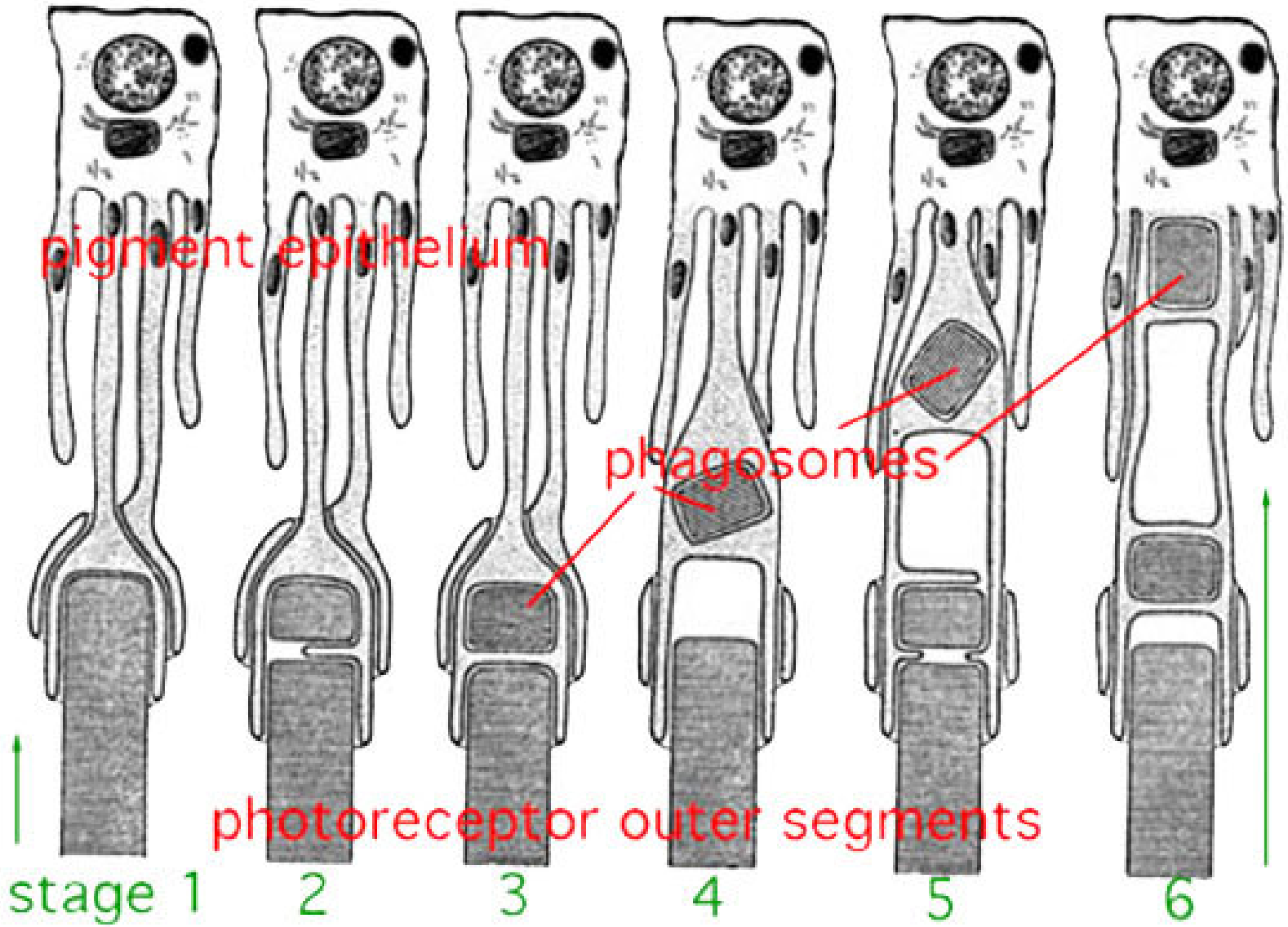
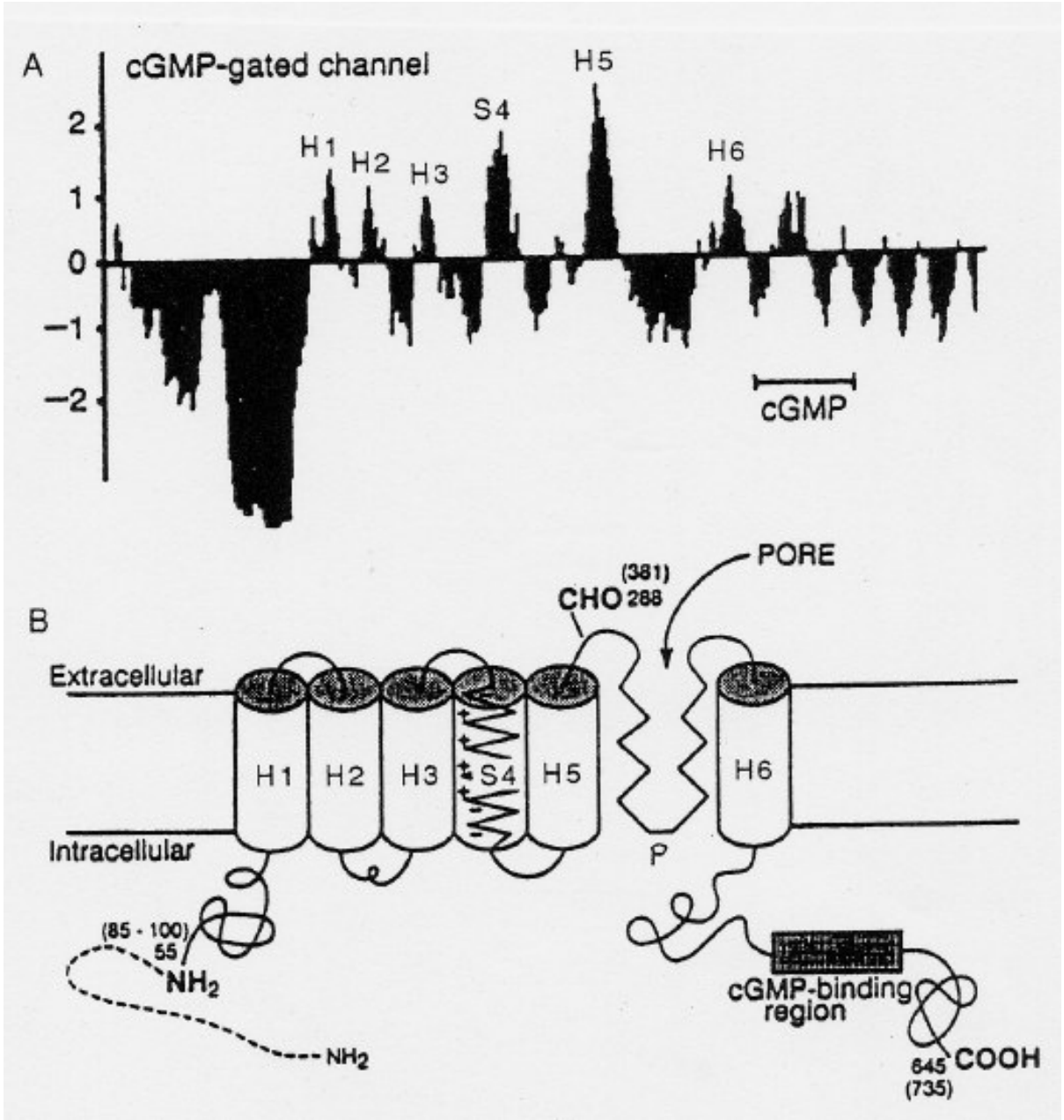
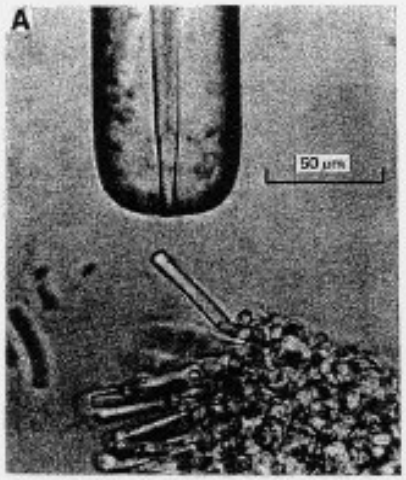


Fig. 12. Diagrammatic representation of disc shedding and phagosome retrieval into the pigment epithelial cell.


A
cGMP-gated channel
H5
S4
H1
H2
H3
H6
2
1
0
−1
−2
cGMP
B
PORE
(381)
CHO 288
Extracellular
Intracellular
H1
H2
H3
S4
H5
H6
P
(85 - 100)
55
NH2
NH2
cGMP-binding
region
645
(735)
COOH



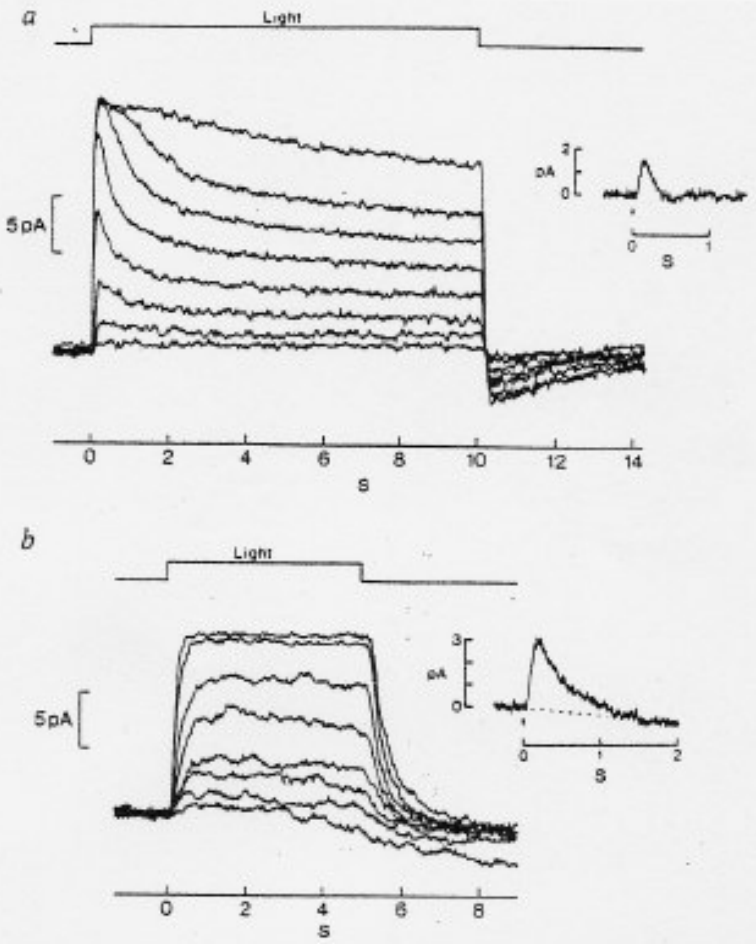
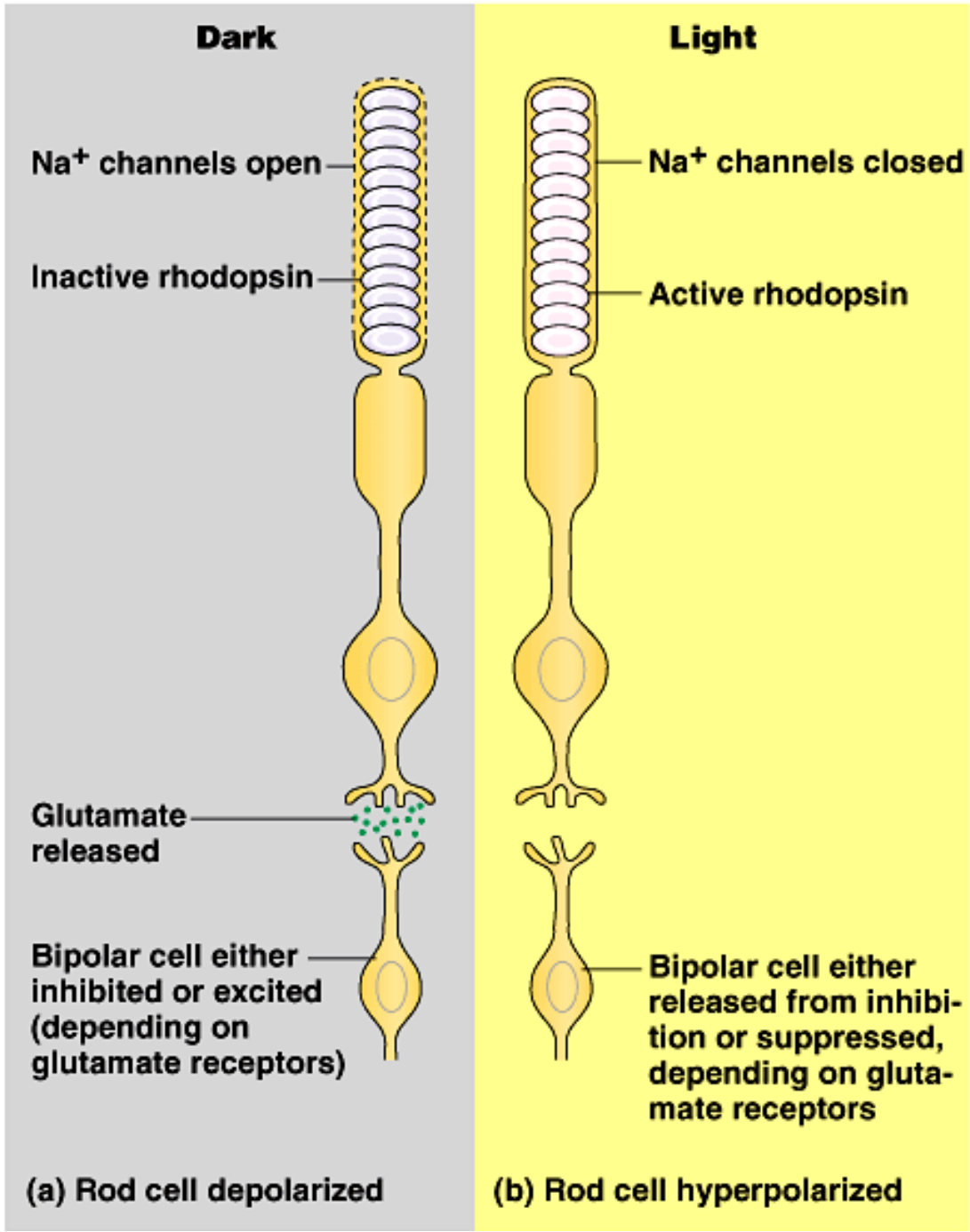


Fig. 3 Response-intensity families recorded from two cones, one in normal Ringer's solution (*a*) and the other in the test solution with the Ca^{2+} feedback removed (*b*). Single trials in all traces, 620 nm light throughout. The dark current in *a* was very stable throughout the experiment, but that in *b* showed some variations between light steps. To compensate for these variations in dark current, each response amplitude plotted in Fig. 4 has been normalized against the dark current amplitude at the time the response was elicited. Insets, averaged responses of the cones to dim flashes in the control and the test solutions. From calculations, the normalized flash sensitivity (k_f) and the response integration time (t_i) are 3.0×10^{-4} photon^{-1} μm^2, 0.19 s in *a* and 5.8×10^{-4} photon^{-1} μm^2, 0.45 s in *b*.


Dark
Light
Na+ channels open
Inactive rhodopsin
Glutamate released
Bipolar cell either inhibited or excited (depending on glutamate receptors)
(a) Rod cell depolarized
Na+ channels closed
Active rhodopsin
Bipolar cell either released from inhibition or suppressed, depending on glutamate receptors
(b) Rod cell hyperpolarized

La vision

1. Introduction

2. Mécanismes périphériques

   a) L'organe récepteur : l'œil
      - Structure
      - Propriétés optiques

   b) La rétine
      - Données histologiques
      - Structure des photorécepteurs
      - La phototransduction

   c) Le message rétinien

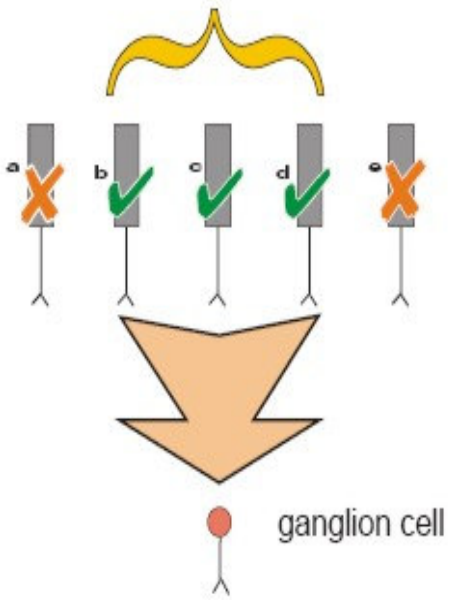
3. Mécanismes centraux

   a) Le cortex visuel V1 (aire striée ou aire 17)
      - Les projections géniculées
      - Organisation anatomo-fonctionnelle de V1

   b) Les aires visuelles péristriées

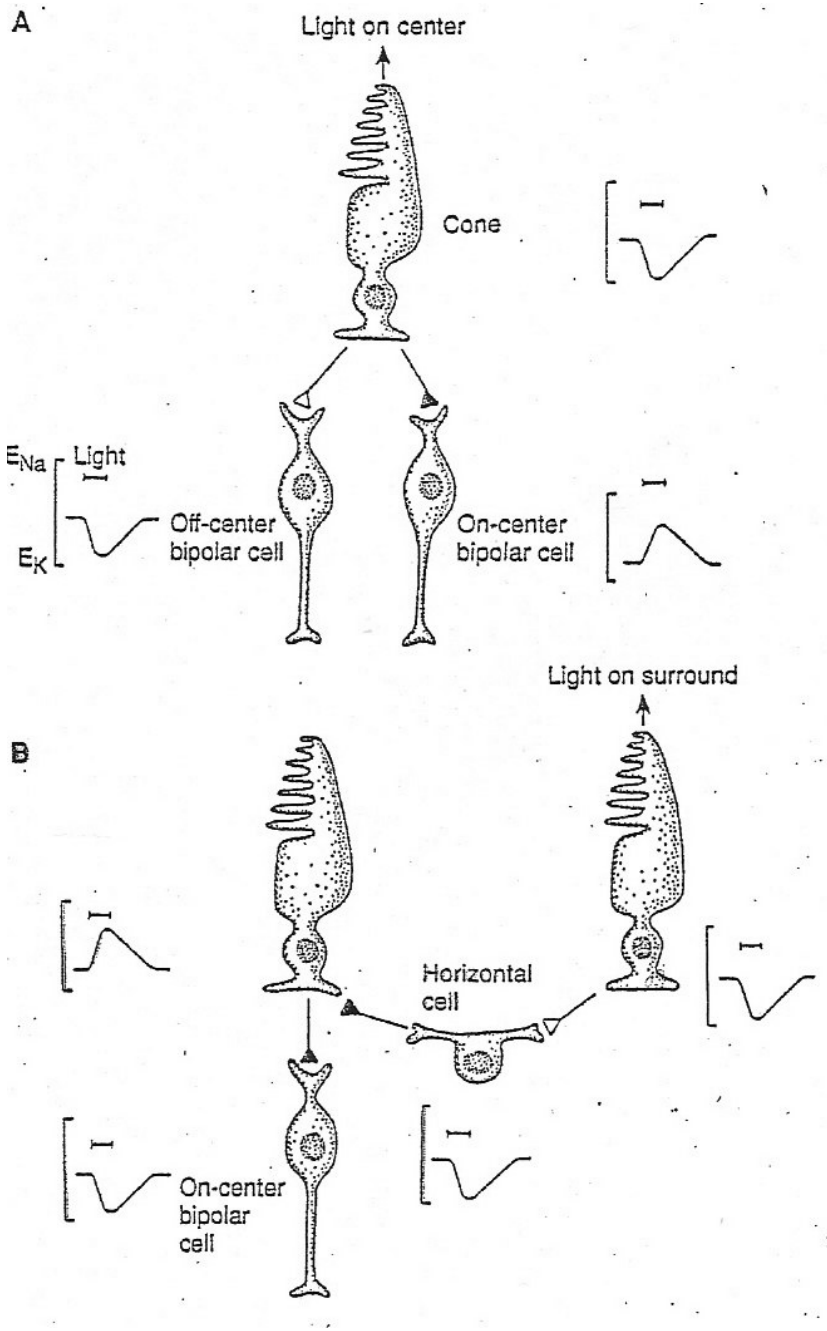
      - Inféro temporal (IT) et forme/couleur du stimulus
      - Pariétal et localisation/mouvement du stimulus

4. Conclusion



b, c, and d are in the receptive field of this ganglion cell

a, and e are out of the receptive field of this ganglion cell


A
Light on center
Cone
I
E_{Na}
Light
I
E_K
Off-center bipolar cell
On-center bipolar cell
I
B
Light on surround
I
Horizontal cell
I
I
On-center bipolar cell
I

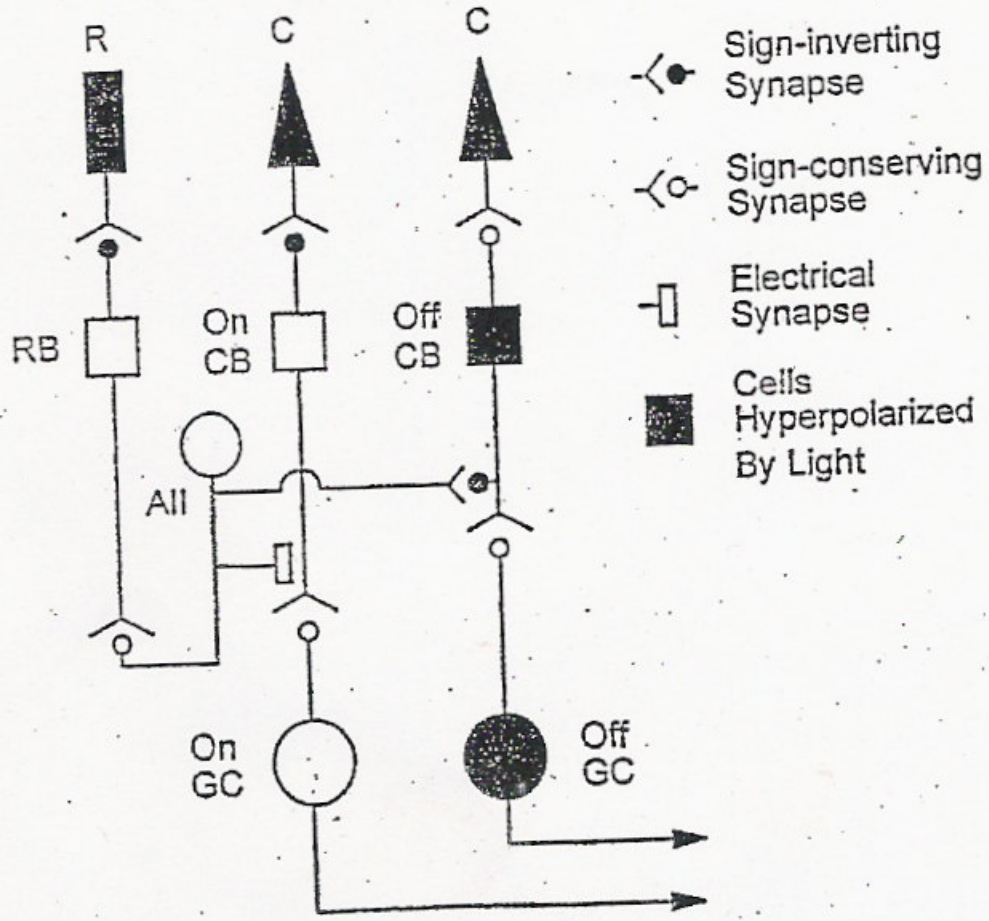
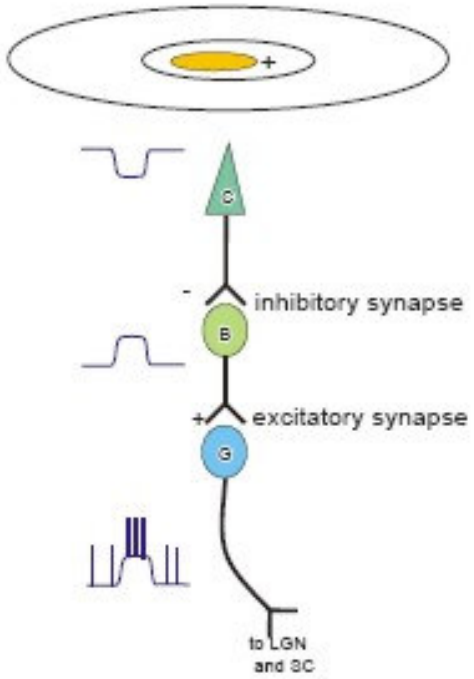


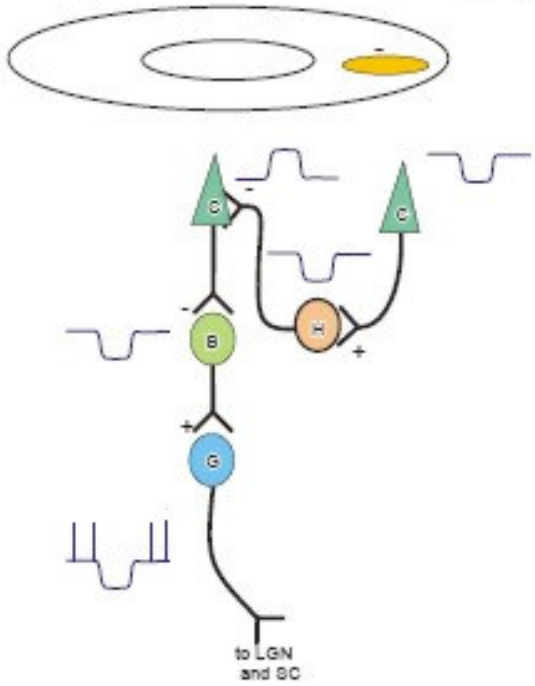
Figure 6.9. Circuitry of the mammalian rod pathway. R, rod; C, cone; RB, rod bipolar; CB, cone bipolar; AII, a specific type of amacrine cell; GC, ganglion cell.

Light to a cone in the centre
produces excitation of the ganglion cell.

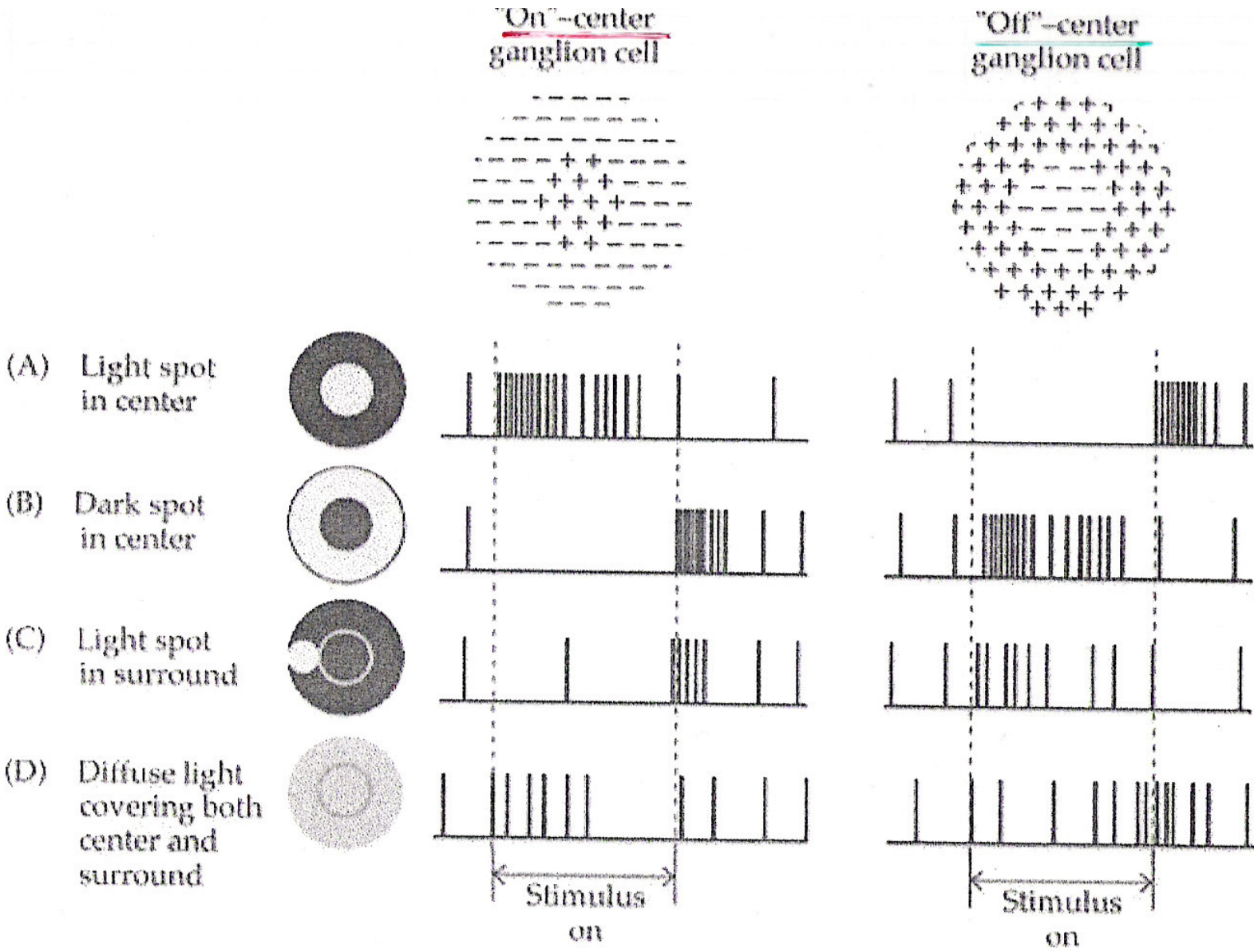


This is because:
1) light decreases the cone voltage
and the cone releases less inhibitory
transmitter
2) the voltage inside the bipolar cell
increases
and it releases more transmitter
3) the ganglion cell is excited
and it fires more often.

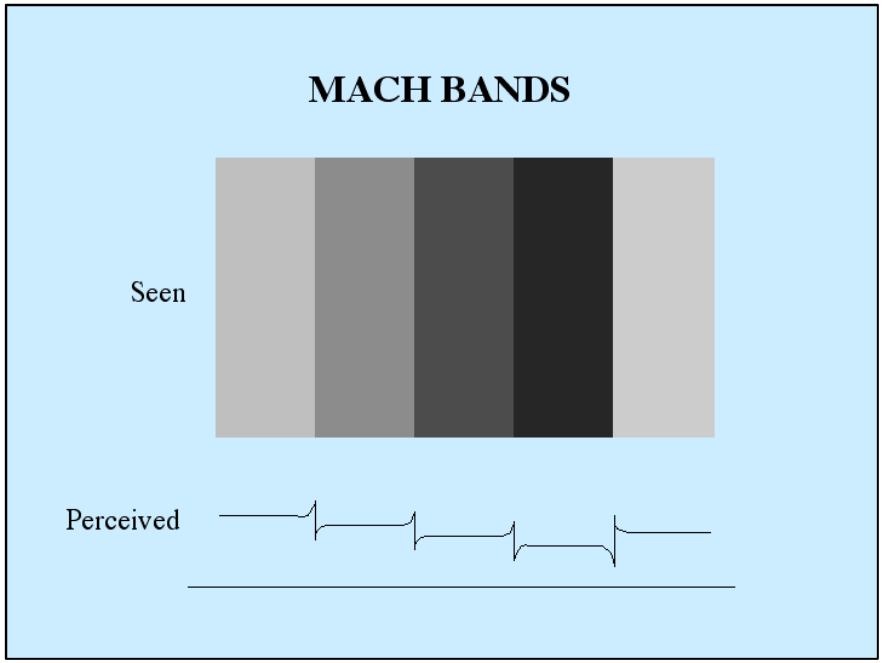
Light to a cone in the surround
produces inhibition of the ganglion cell.

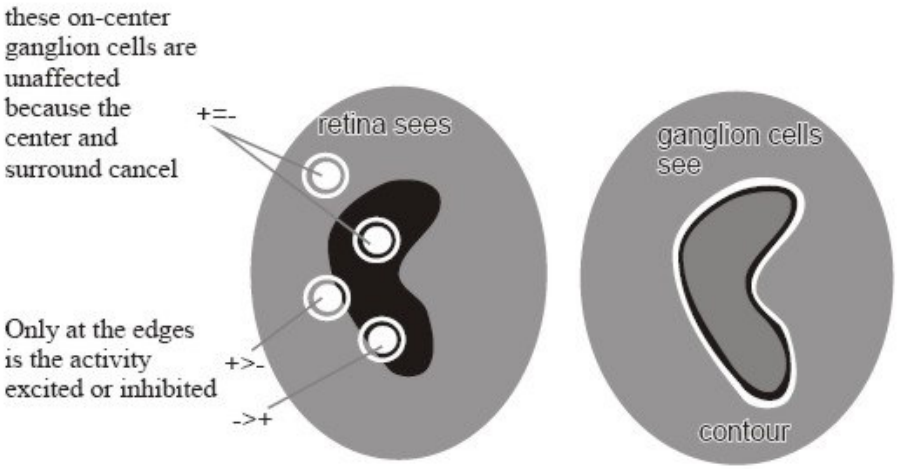


This is because:
1) light decreases the surround cone's voltage
and the cone releases less excitatory transmitter
2) the voltage inside the horizontal cell decreases
and it releases less inhibitory transmitter
3) the voltage inside the center cone increases
and it releases more inhibitory transmitter
4) the voltage inside the bipolar cell decreases
and it releases less excitatory transmitter
5) the ganglion cell is inhibited
and it fires less often.

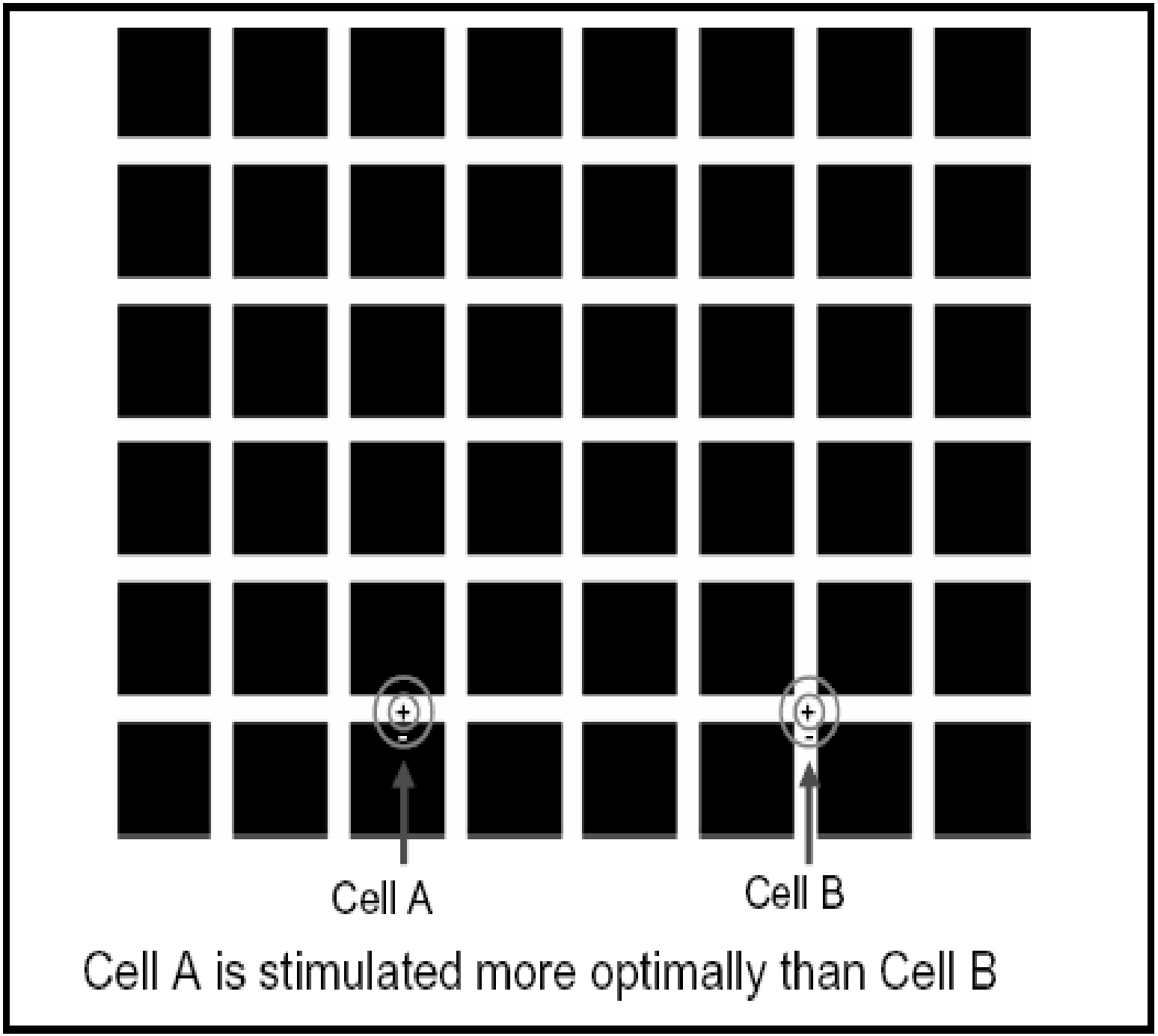


The response of "on"-center and "off"-center retinal ganglion cells to stimulation of different regions of their receptive fields.


MACH BANDS
Seen
Perceived

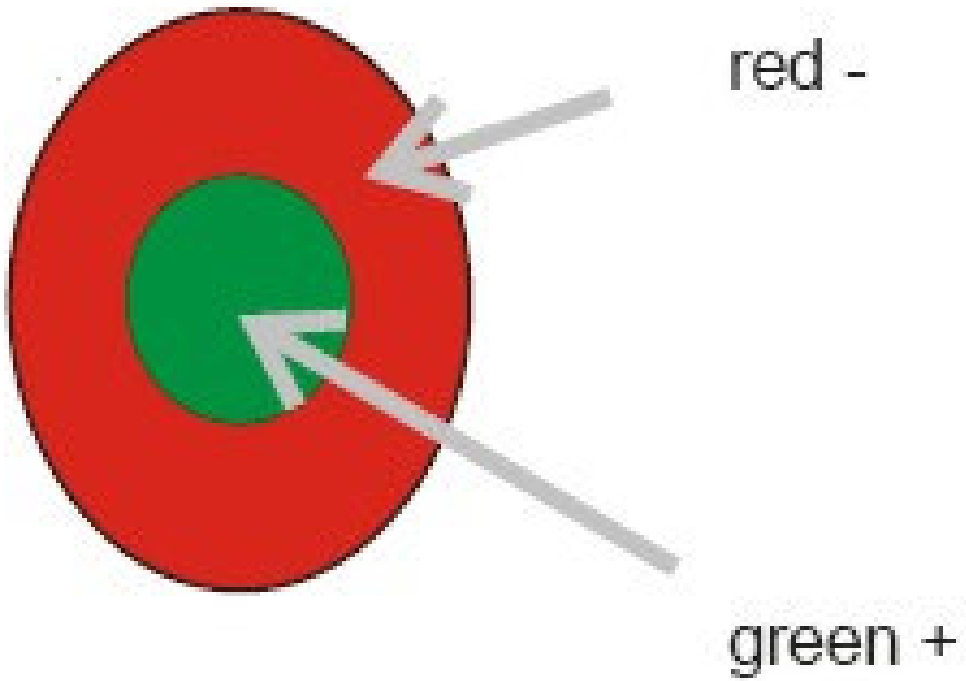

these on-center ganglion cells are unaffected because the center and surround cancel
+=-
retina sees
ganglion cells see
Only at the edges is the activity excited or inhibited
+>-
->+
contour


A
B



Cell A is stimulated more optimally than Cell B

ganglion cell single opponent



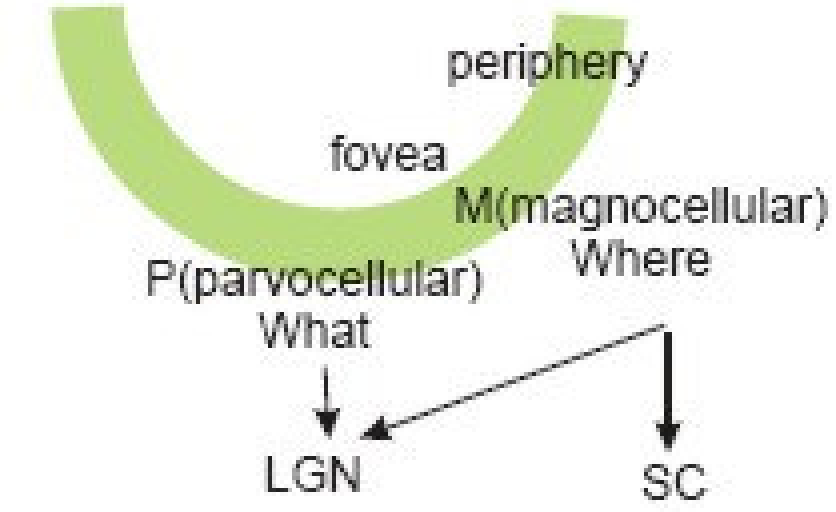
Rouge/Vert

Jaune (rouge+vert)/Bleu

Blanc/Noir

M- & P-cell properties

- M-cells
  - Large receptive fields
  - Respond well to rapid changes (mouvement)
- P-cells
  - Outnumber M-cells
  - Smaller receptive fields
  - Respond selectively to specific wavelengths (couleur)



Retinal Ganglion Cells

- Respond to simple visual stimuli (spots of light) in their receptive field
- Come in “On-center” and “Off-center” flavors
- Another functional categorization: M-cells (‘magno’ = large) & P-cells (‘parvo’ = small).

La vision

1. Introduction

2. Mécanismes périphériques

   a) L'organe récepteur : l'œil
      - Structure
      - Propriétés optiques

   b) La rétine
      - Données histologiques
      - Structure des photorécepteurs
      - La phototransduction

   c) Le message rétinien

3. Mécanismes centraux

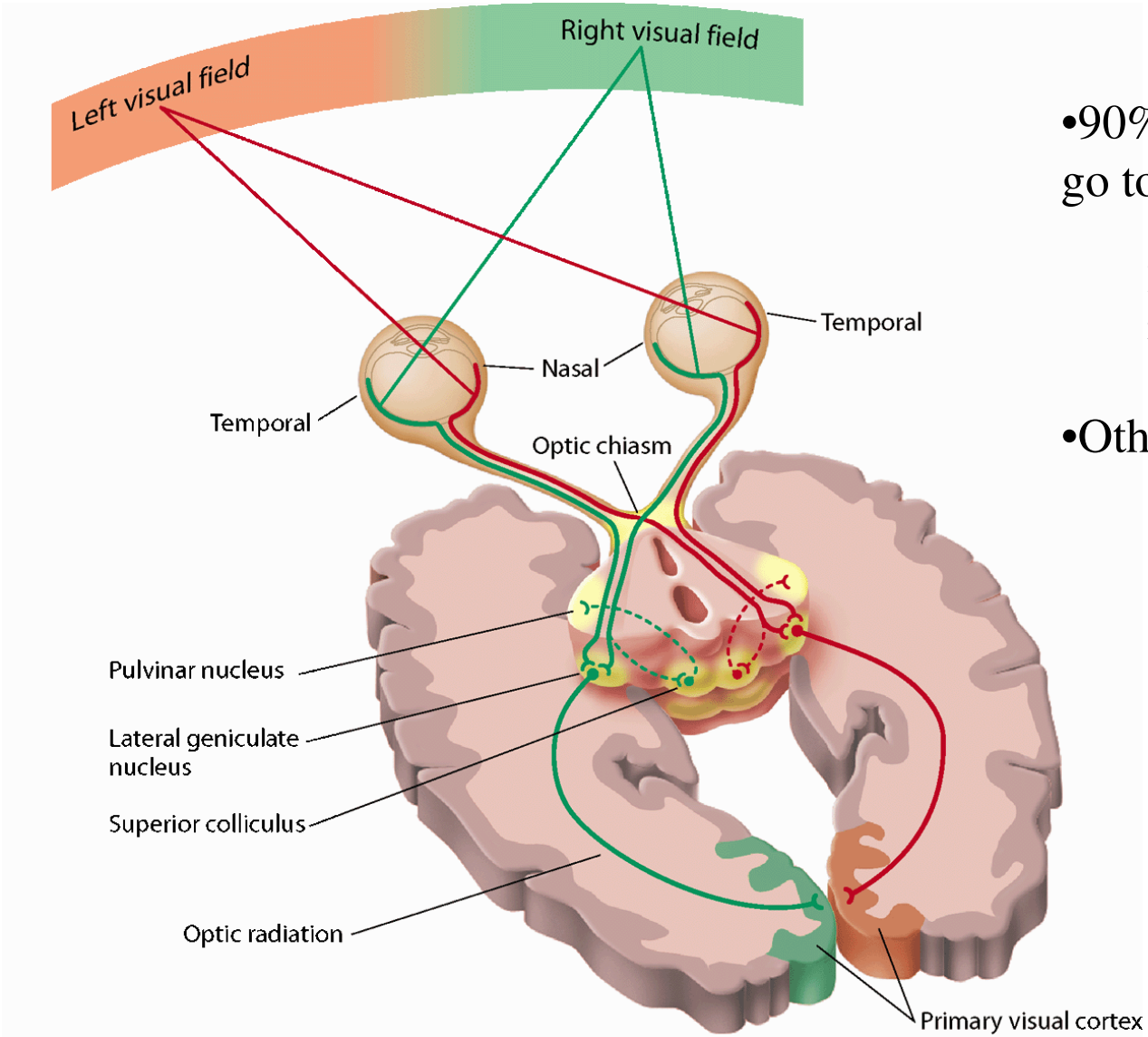
   a) Le cortex visuel V1 (aire striée ou aire 17)
      - Les projections géniculées
      - Organisation anatomo-fonctionnelle de V1

   b) Les aires visuelles péristriées

      - Inféro temporal (IT) et forme/couleur du stimulus
      - Pariétal et localisation/mouvement du stimulus

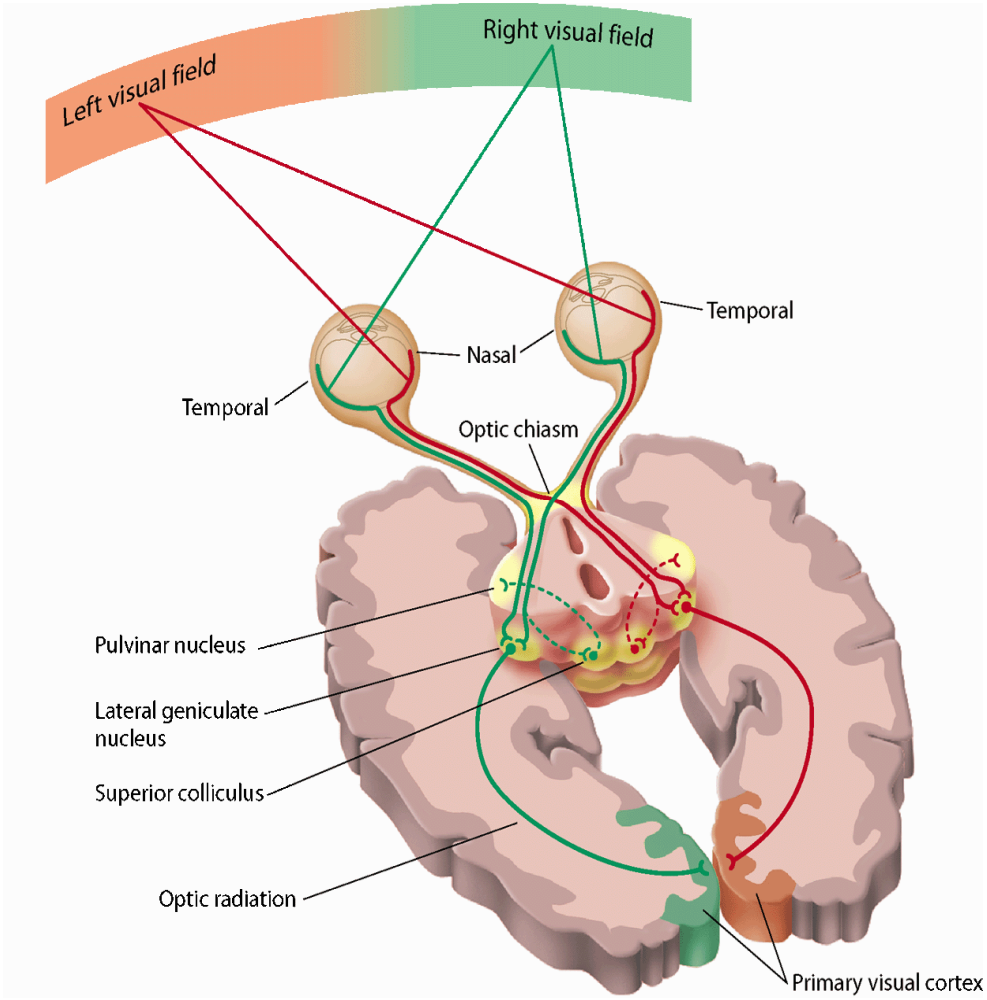
4. Conclusion

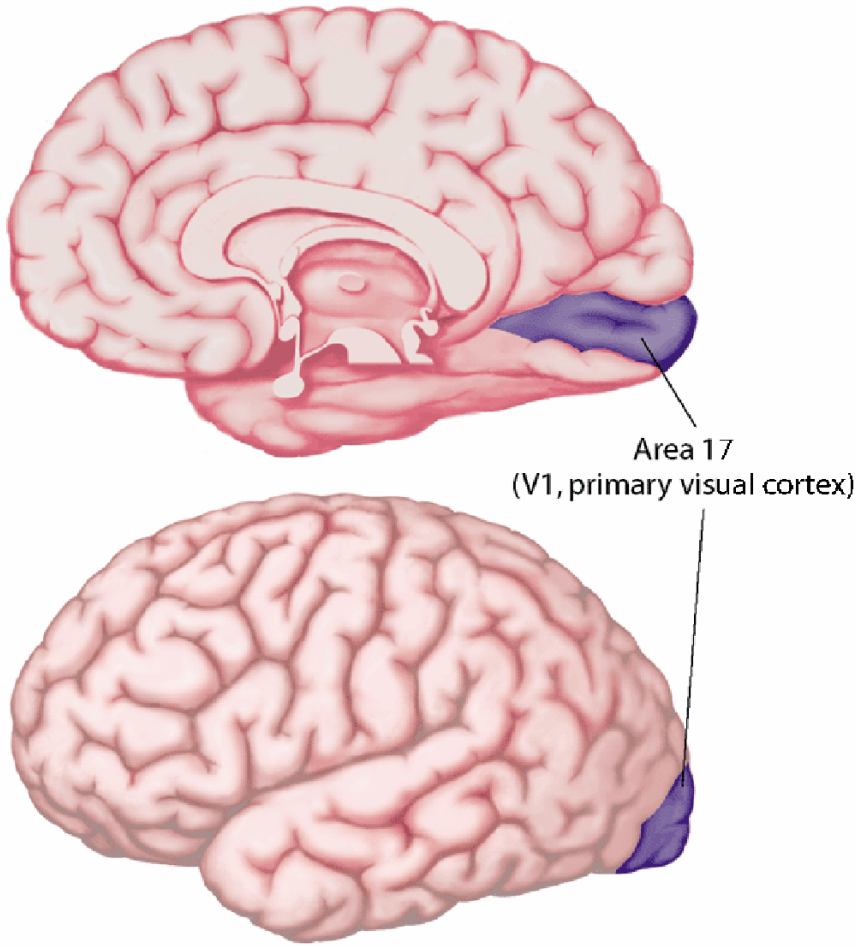
Visual Pathways



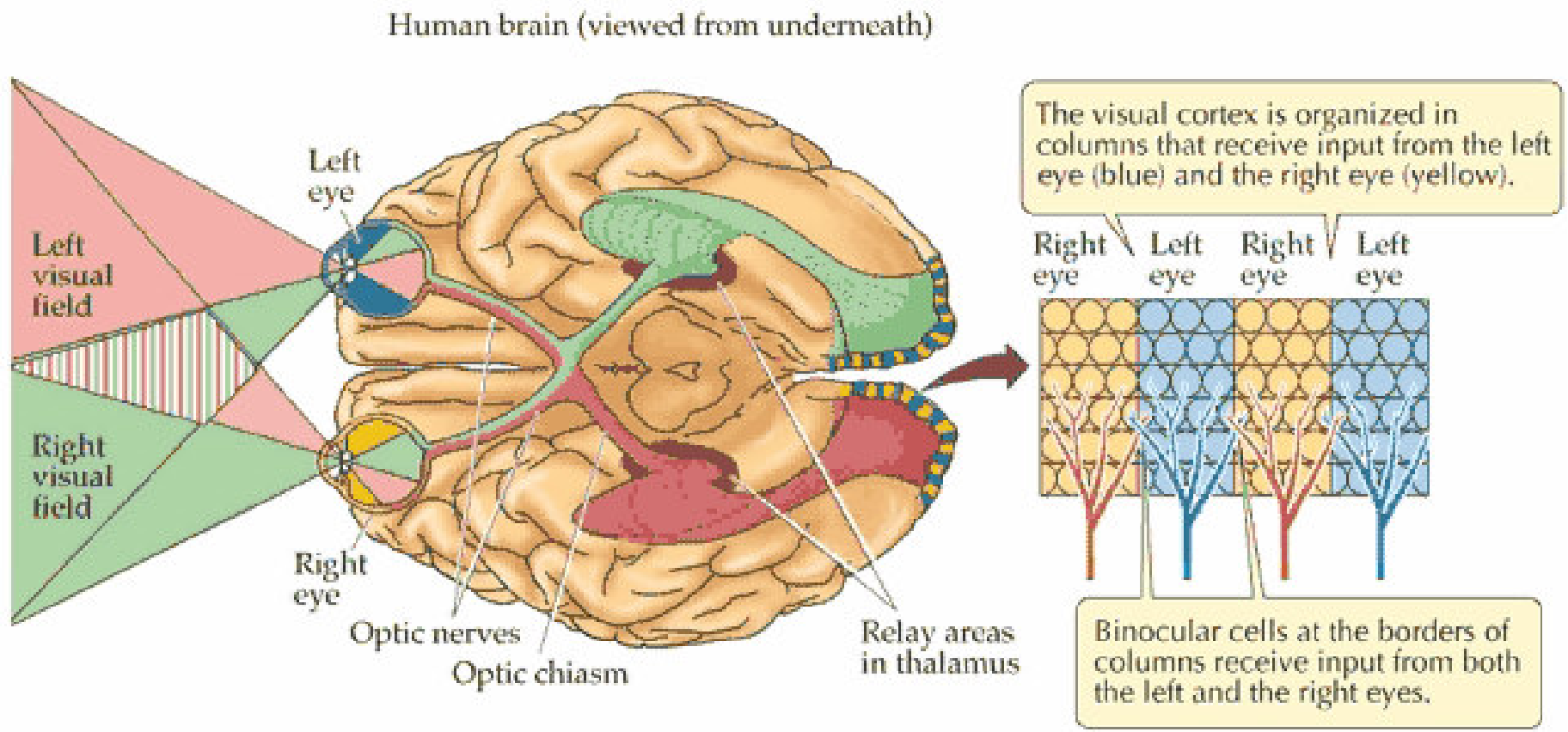
- 90% of retinal projections go to LGN
  - (but only 10-20% of the LGN's input comes from the retina!)
- Other targets:
  - SC (controls eye mvmts)
  - Pre-tectum (controls pupillary responses)

Cortex visuel primaire

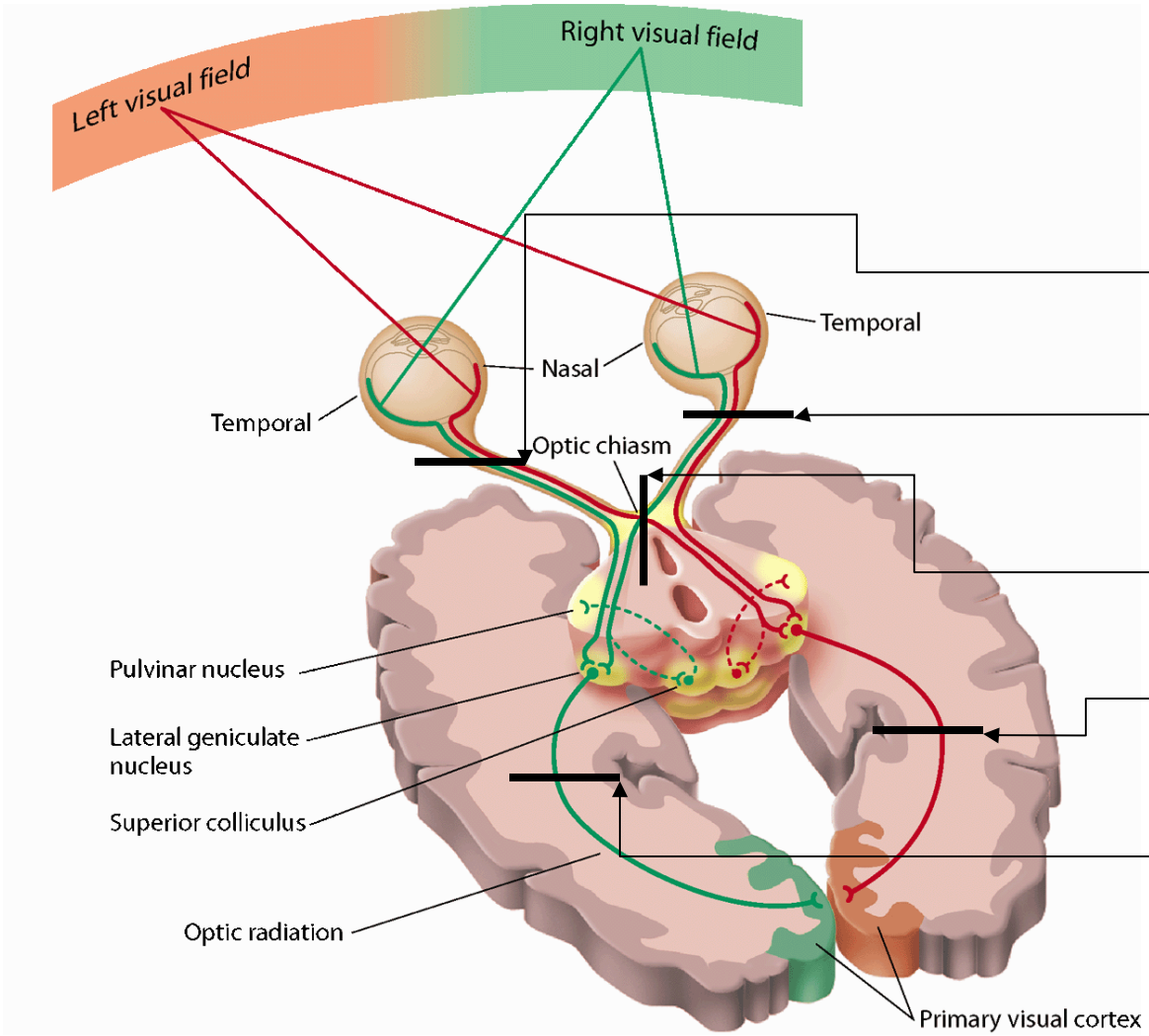




The visual pathways



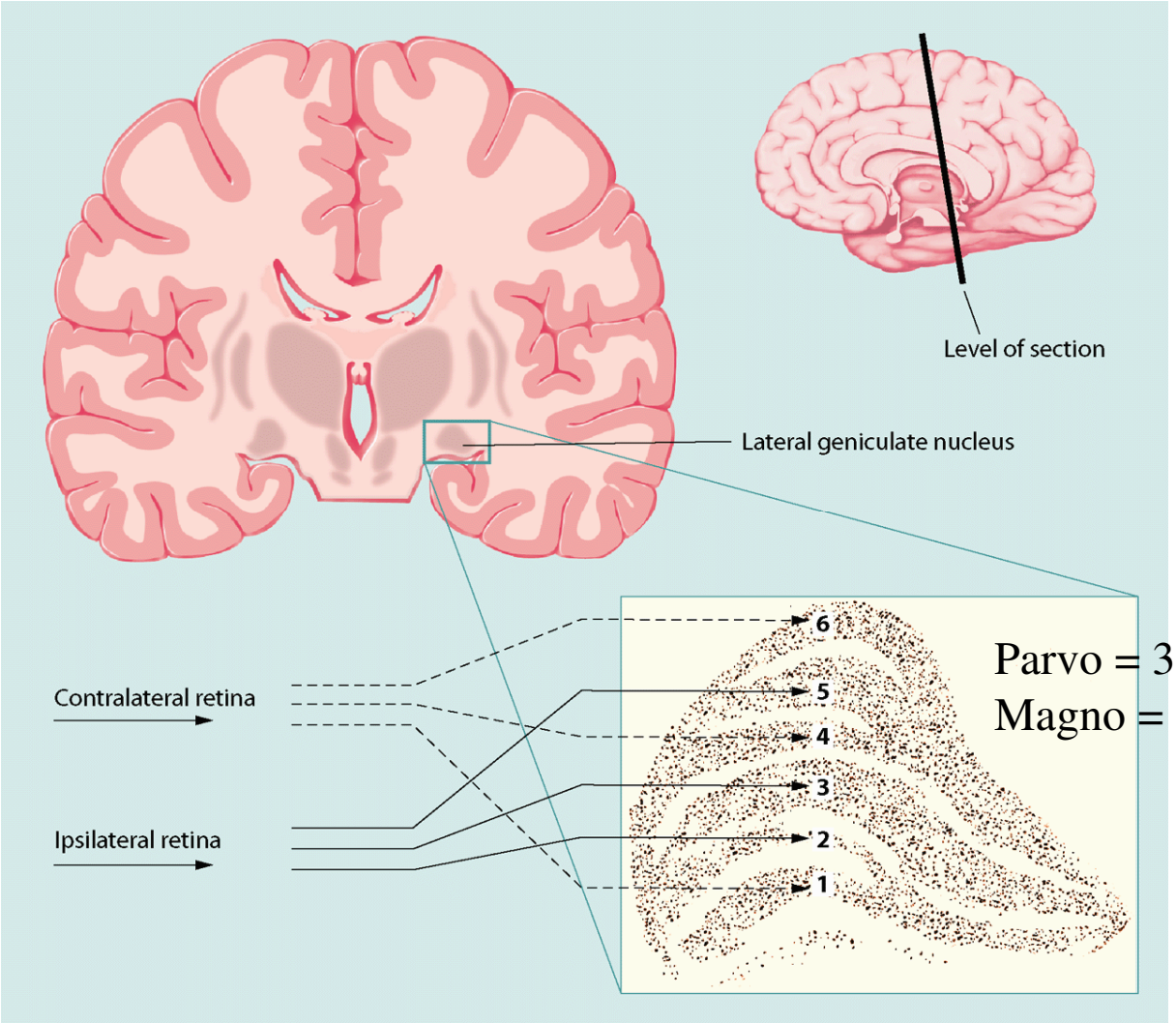
Visual Pathways: Homework!



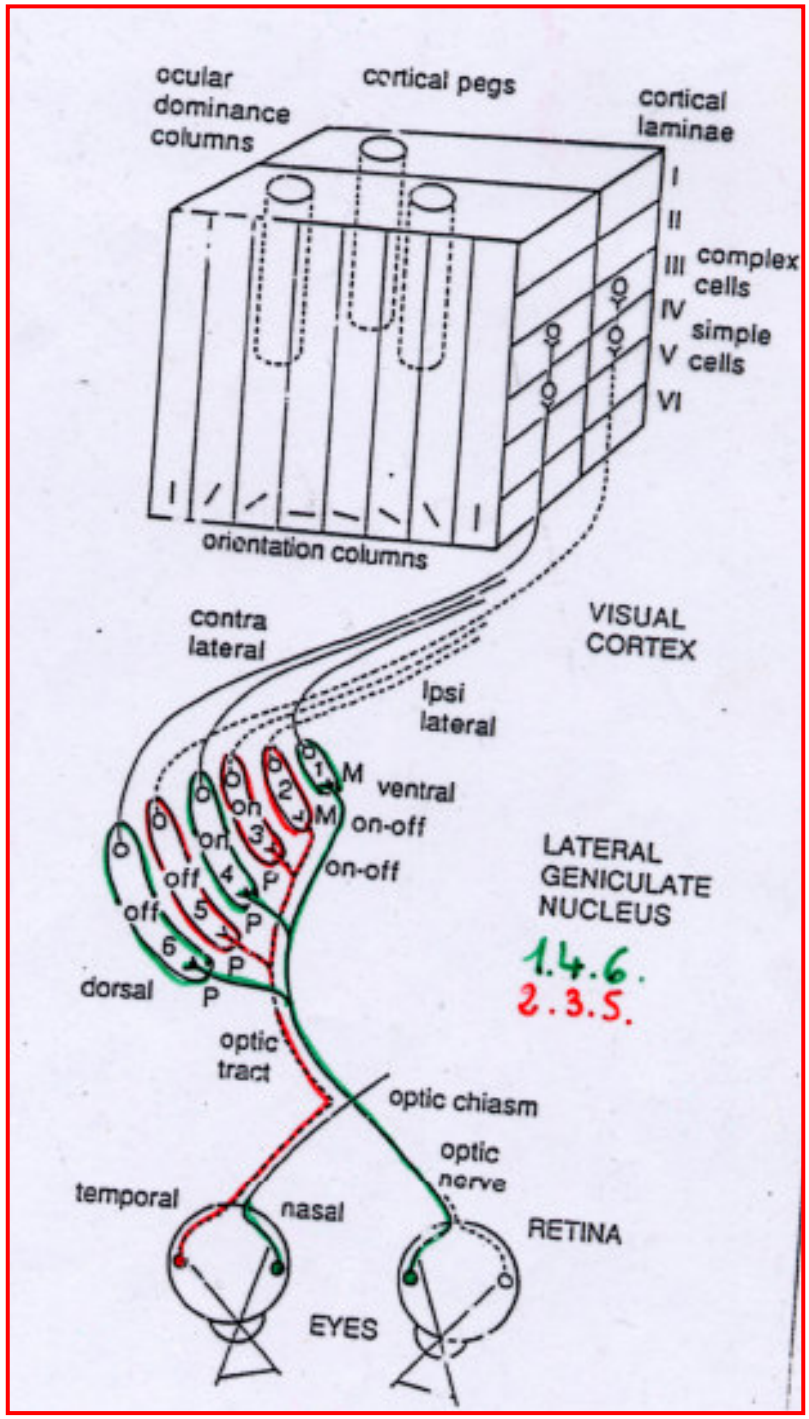
	Left Eye		Right Eye	
	LVF	RVF	LVF	RVF
1.				
2.				
3.				
4.				
5.				

LGN

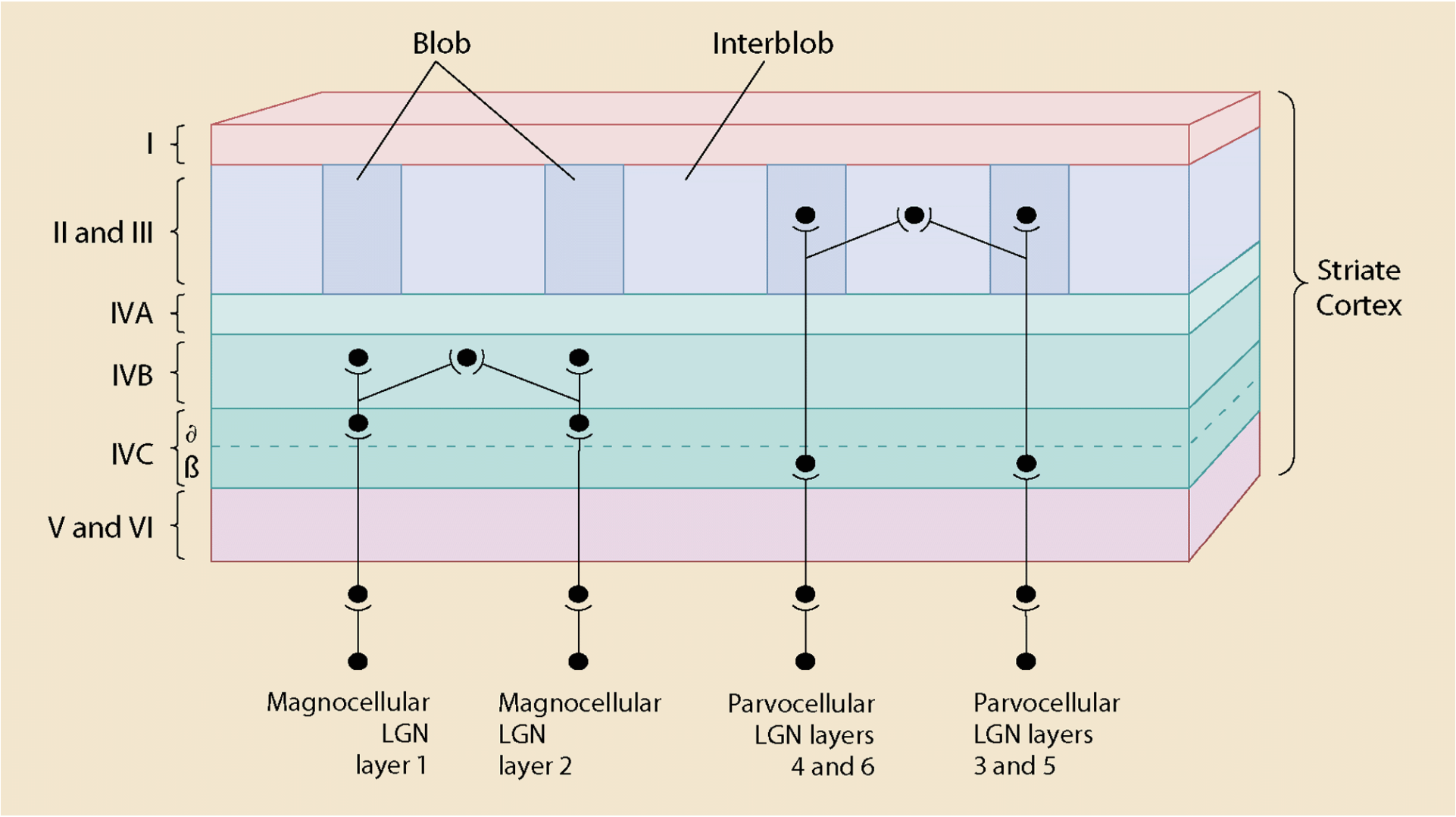
- Part of the thalamus
- There are two, one in each hemi
- A 6-layered structure
- Projections from the two eyes are segregated
- Magno and Parvo type retinal ganglion cells project to different LGN layers
- Neurons have receptive field properties like ganglion cells
- Retinotopic organization w/in each layer



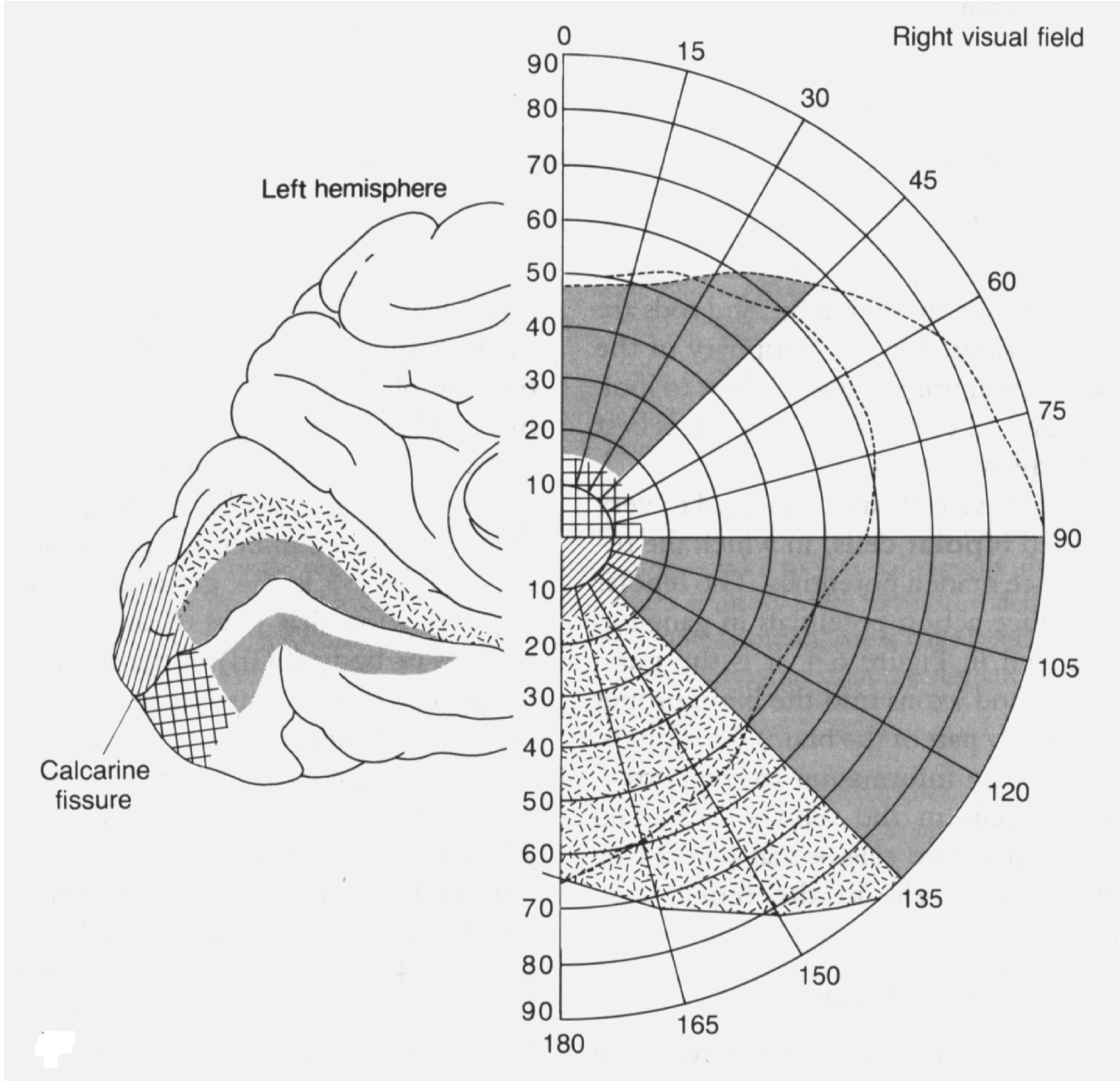
W. W. Norton

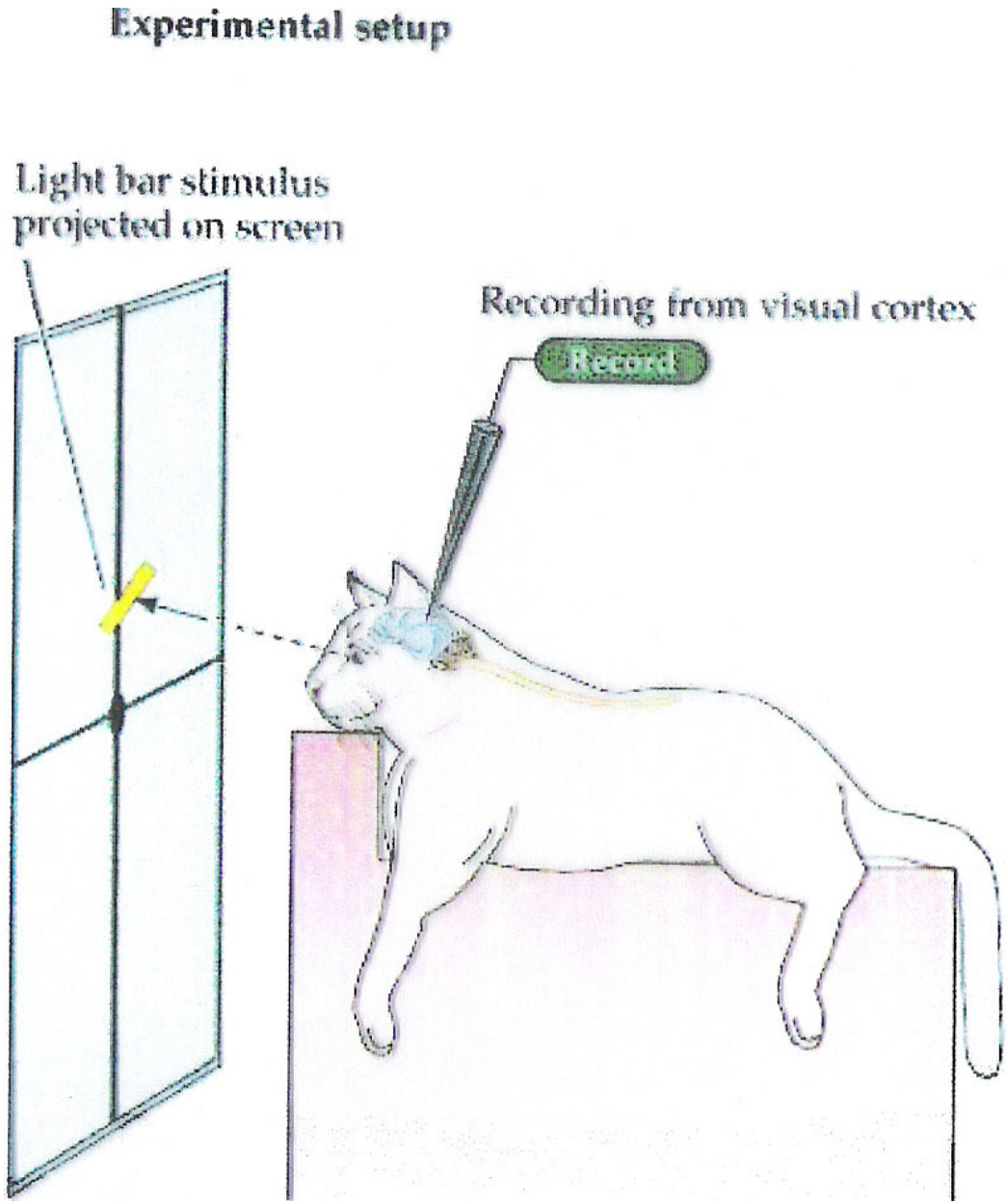

ocular dominance columns
cortical pegs
cortical laminae
I
II
III
IV
V
VI
complex cells
simple cells
orientation columns
contra lateral
VISUAL CORTEX
Ipsi lateral
M
ventral
on-off
on-off
LATERAL GENICULATE NUCLEUS
1.4.6.
2.3.5.
dorsal
P
optic tract
optic chiasm
optic nerve
temporal
nasal
RETINA
EYES

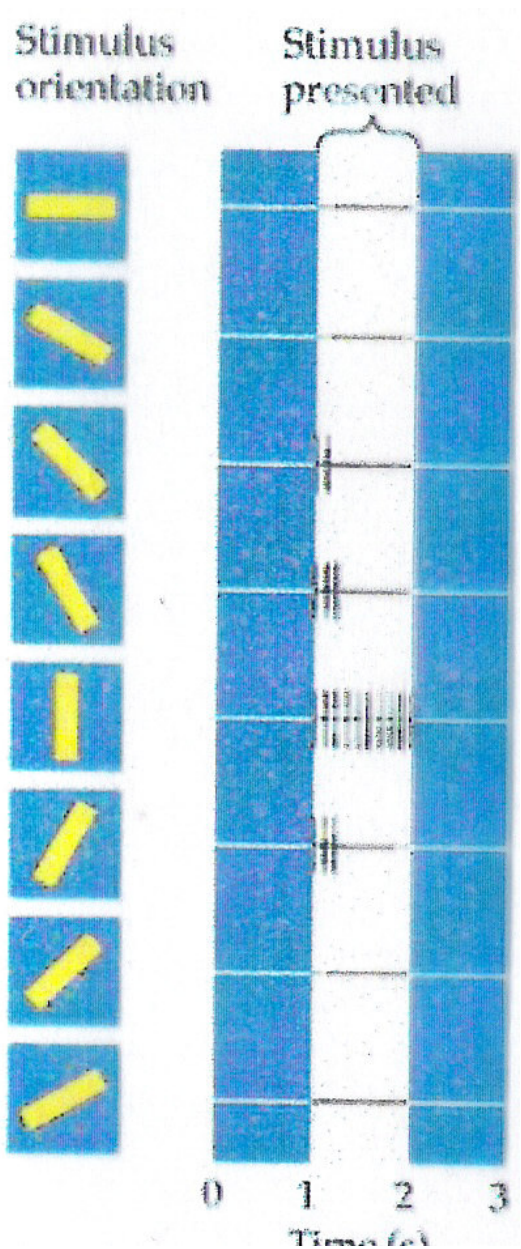
Segregated M & P projections



Rétinotopie




Experimental setup
Light bar stimulus
projected on screen
Recording from visual cortex
Record


Stimulus
orientation
Stimulus
presented
0
1
2
3

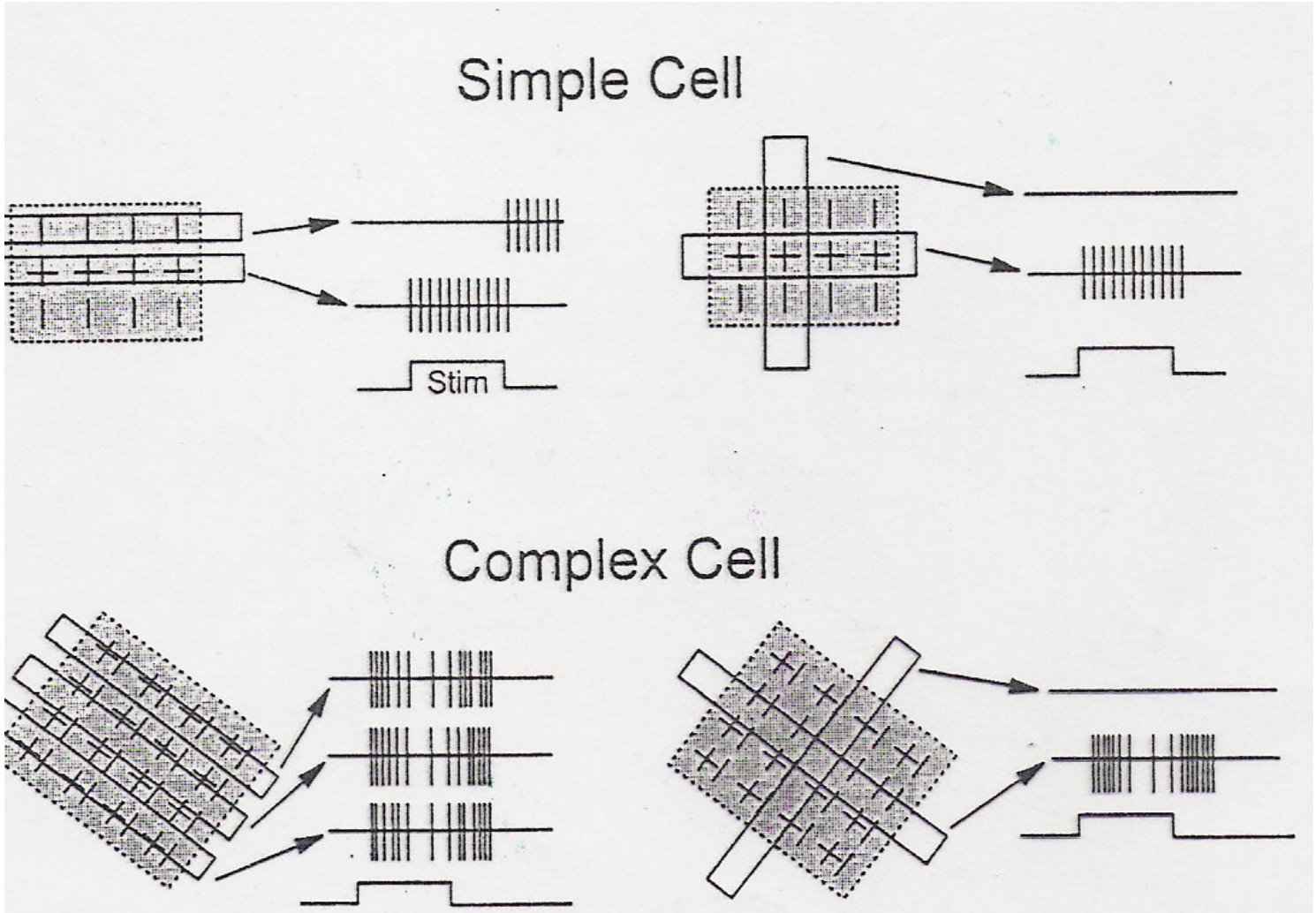
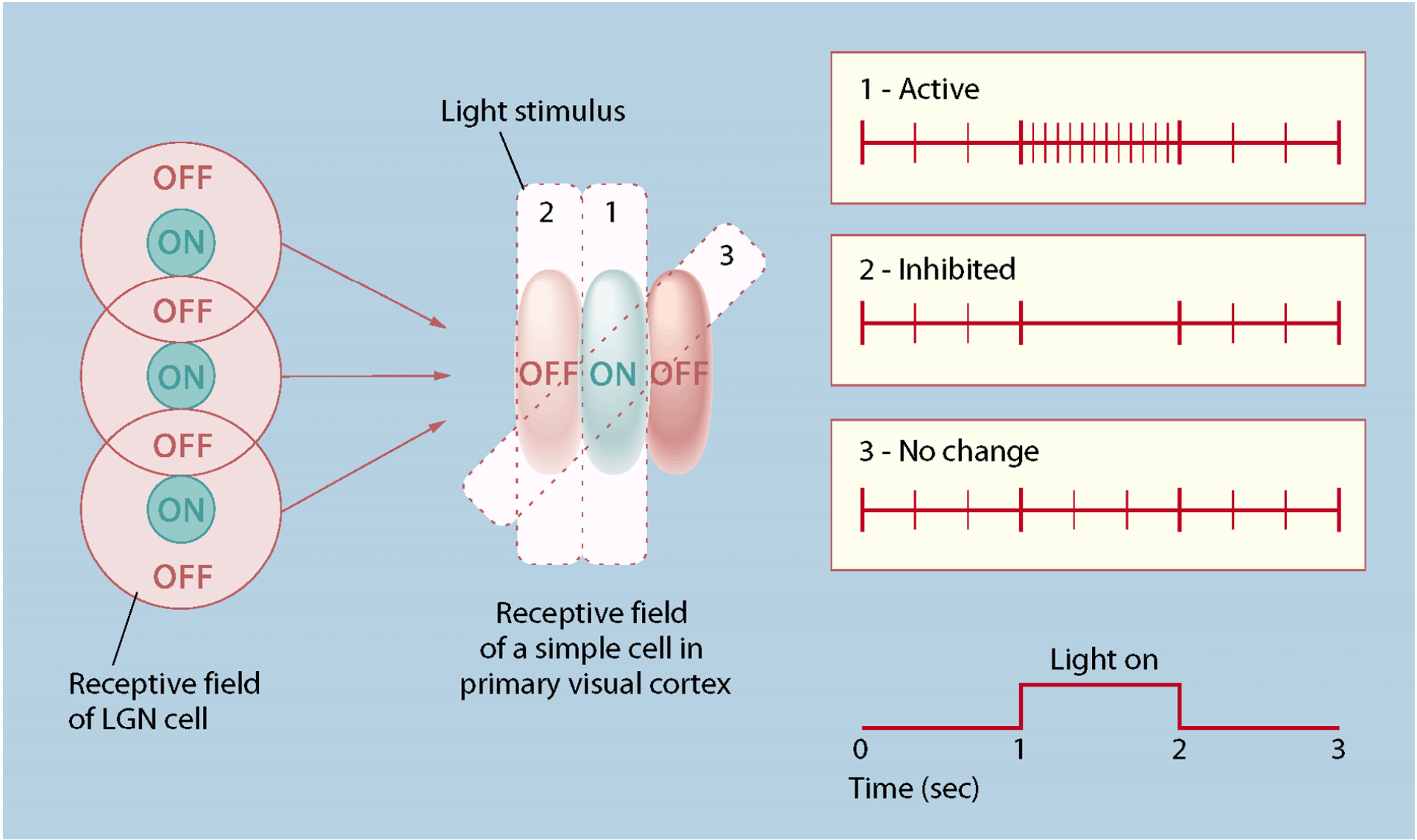
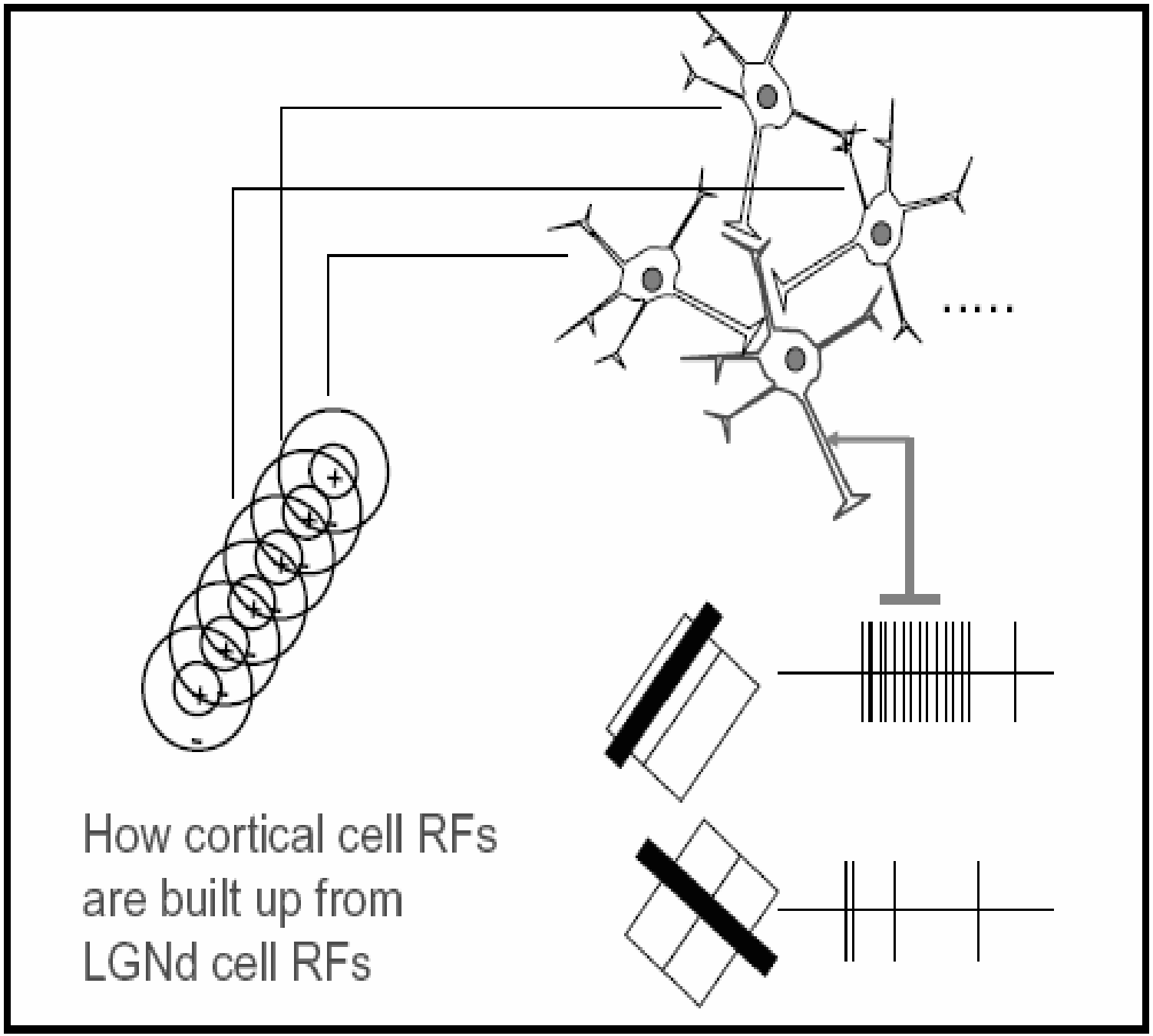
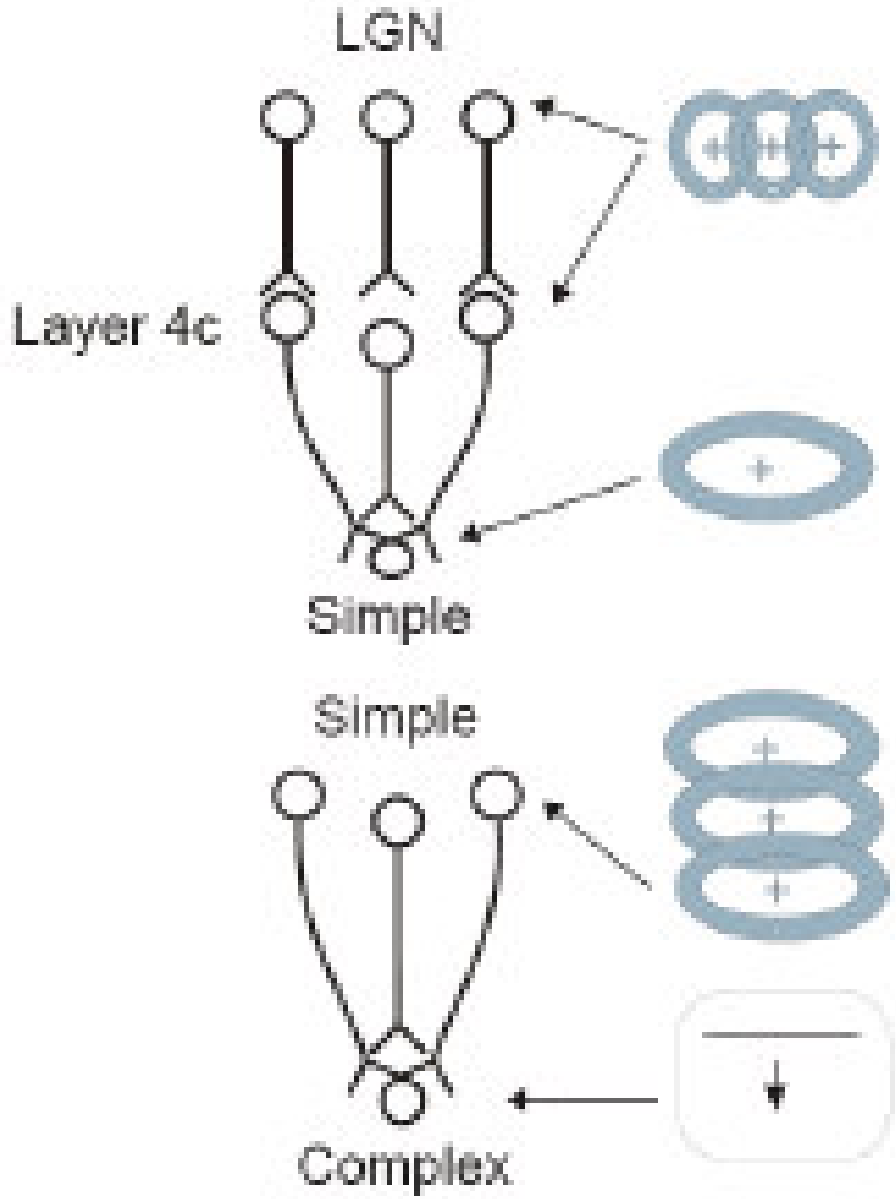
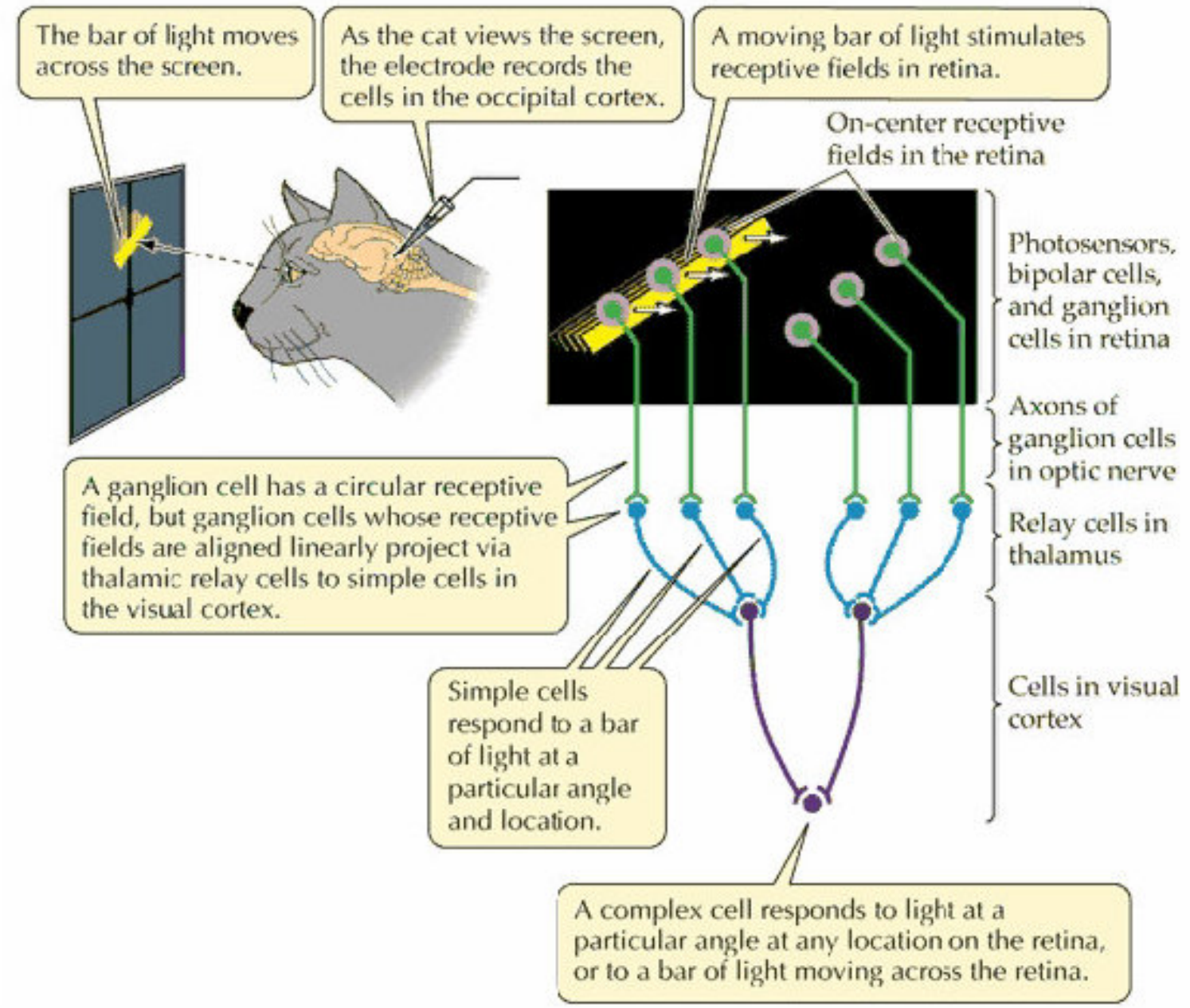


Figure 8.9. Schematic examples of simple (top) and complex (bottom) cortical receptive fields. The on areas (plus signs) and off areas (minus signs) are spatially separate in the receptive fields of simple cells, and superimposed in complex cells. The position of the stimulus in the receptive field is critical for the simple cell, but not for the complex cell (left). Changing the orientation of the elongated stimulus from its optimum reduces the responses of both kinds of cells (right).

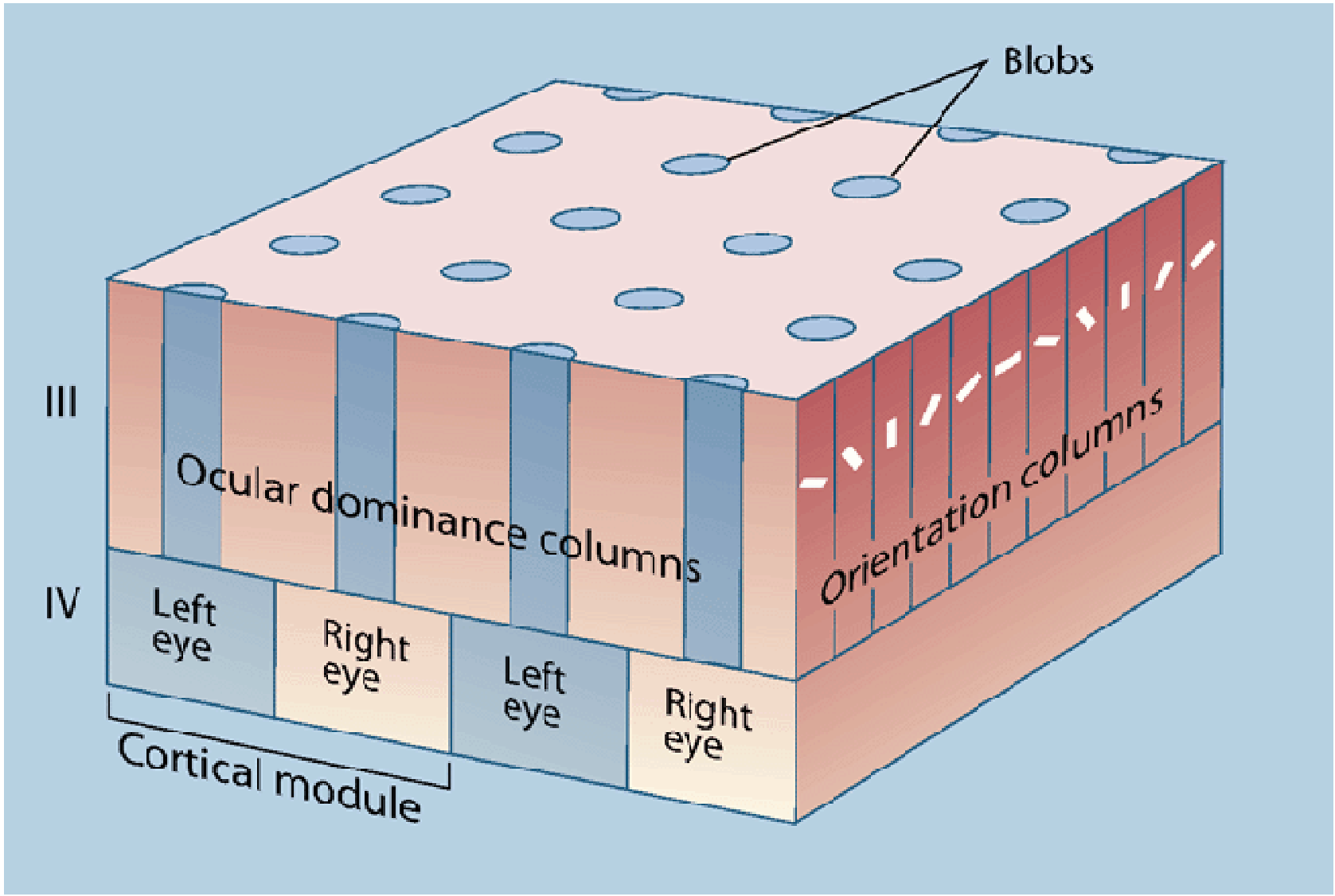

Light stimulus
OFF
ON
OFF
ON
OFF
ON
OFF
2
1
3
OFF
ON
OFF
Receptive field
of LGN cell
Receptive field
of a simple cell in
primary visual cortex
1 - Active
2 - Inhibited
3 - No change
Light on
0
1
2
3
Time (sec)

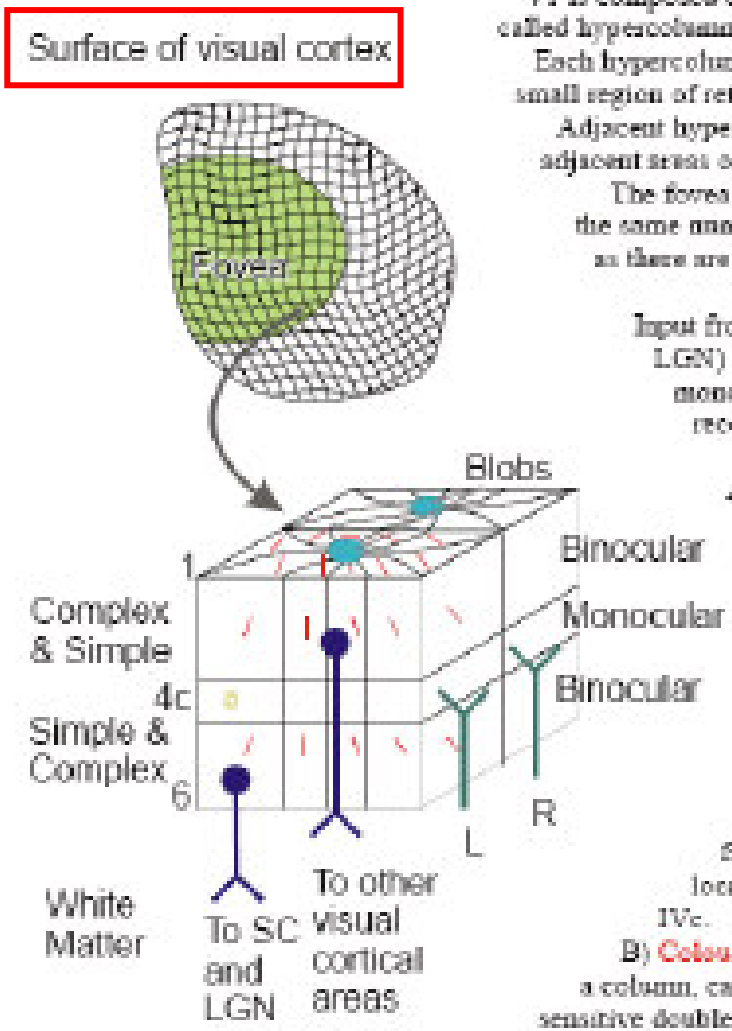

How cortical cell RFs
are built up from
LGNd cell RFs


LGN
Layer 4c
Simple
Simple
Complex


The bar of light moves across the screen.
As the cat views the screen, the electrode records the cells in the occipital cortex.
A moving bar of light stimulates receptive fields in retina.
On-center receptive fields in the retina
Photosensors, bipolar cells, and ganglion cells in retina
Axons of ganglion cells in optic nerve
Relay cells in thalamus
Cells in visual cortex
A ganglion cell has a circular receptive field, but ganglion cells whose receptive fields are aligned linearly project via thalamic relay cells to simple cells in the visual cortex.
Simple cells respond to a bar of light at a particular angle and location.
A complex cell responds to light at a particular angle at any location on the retina, or to a bar of light moving across the retina.

Columns and Cortical Modules





V1 is composed of a grid (1 mm by 1mm) of what are called hypercolumns.

Each hypercolumn analyses information from one small region of retina.

Adjacent hypercolumns analyse information from adjacent areas of retina.

The fovea is over represented. There are about the same number of columns devoted to the fovea as there are to the rest of the retina.

Input from the left and right eyes (via the LGN) enters at layer 4c. Here one finds monocular cells with circular surround receptive fields.

As one moves to higher or lower layers one finds binocular cells, first simple then complex.

Each hypercolumn extracts the following features:

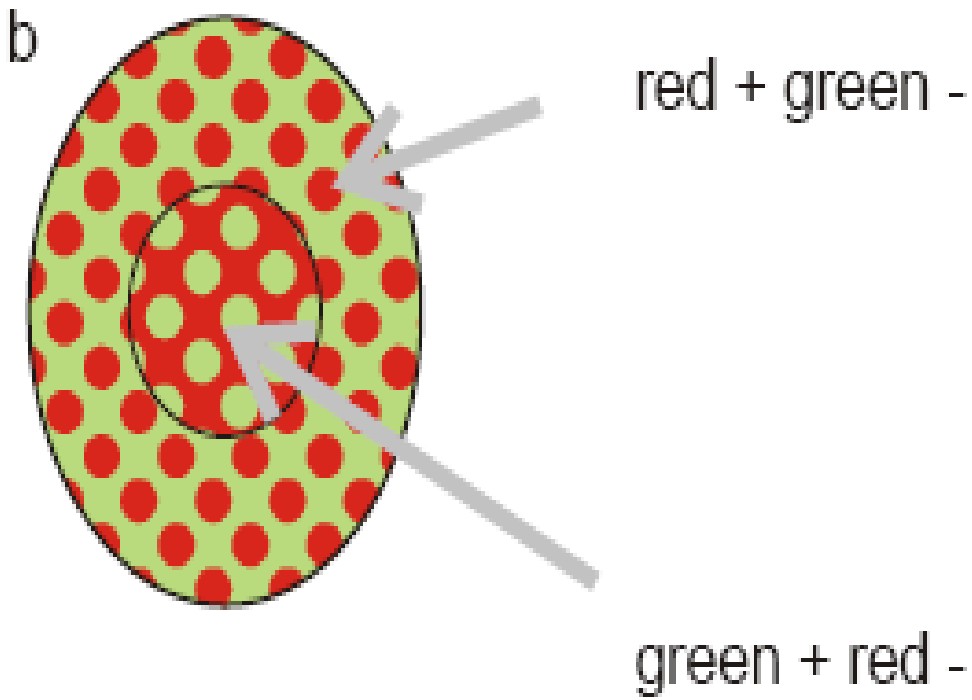
A) **Stereopsis**: In each half, one or the other eye dominates. One sees in stereo by combining information from the two eyes in binocular cells located above and below the input layer, IVc.

B) **Colour**: In the center of each cube one finds a column, called a blob, which contains colour sensitive double opponent cells with circular surround receptive fields.

C) **Orientation of line segments**: Radiating from the blobs, like spokes from the centre of a wheel, one finds simple and complex cells ordered into pin wheels of the same orientation.

Note that this arrangement allows cells with similar receptive fields to be grouped together. This is an important organizing principle shared by all the cortex. Neurons like to be near their own kind. It minimizes the length and # of axons.

cortical cell double opponent



La vision

1. Introduction

2. Mécanismes périphériques

   a) L'organe récepteur : l'œil
      - Structure
      - Propriétés optiques

   b) La rétine
      - Données histologiques
      - Structure des photorécepteurs
      - La phototransduction

   c) Le message rétinien

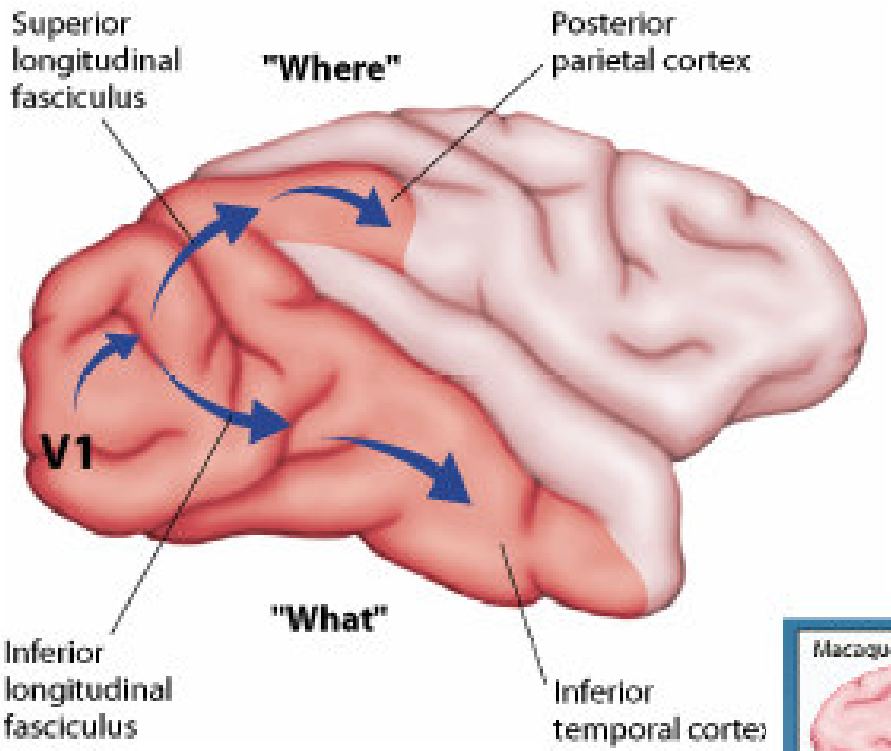
3. Mécanismes centraux

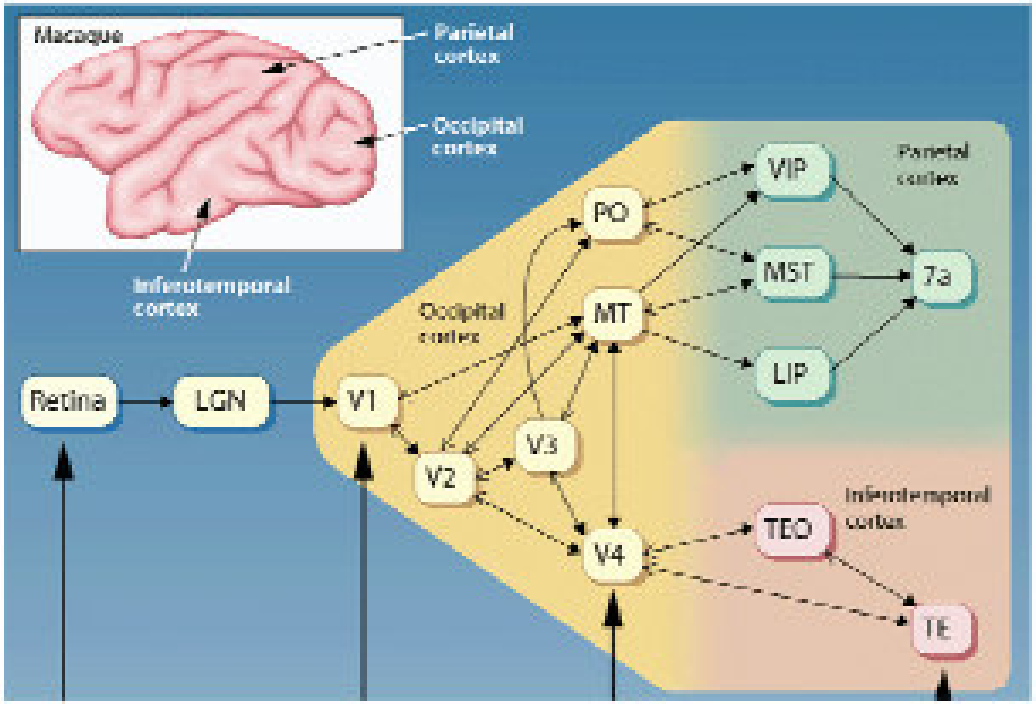
   a) Le cortex visuel V1 (aire striée ou aire 17)
      - Les projections géniculées
      - Organisation anatomo-fonctionnelle de V1

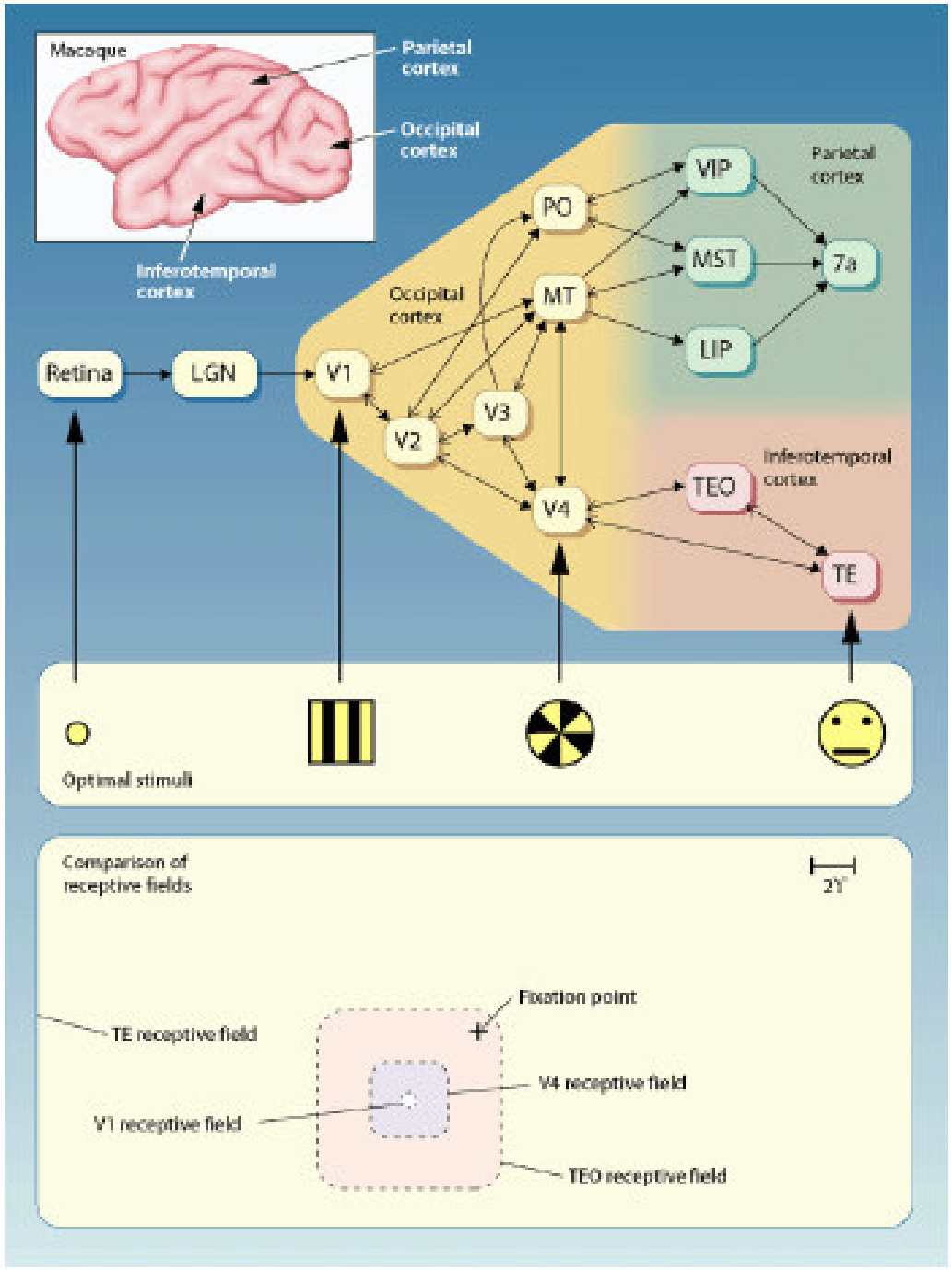
   b) Les aires visuelles péristriées

      - Inféro temporal (IT) et forme/couleur du stimulus
      - Pariétal et localisation/mouvement du stimulus

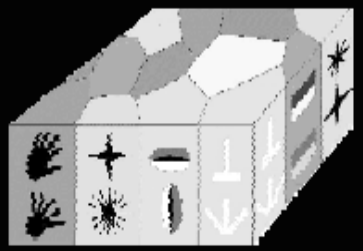
4. Conclusion


Superior
longitudinal
fasciculus
"Where"
Posterior
parietal cortex
V1
"What"
Inferior
longitudinal
fasciculus
Inferior
temporal cortex

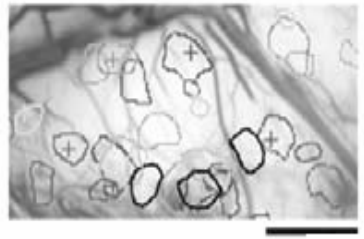

Macaque
Parietal cortex
Occipital cortex
Inferotemporal cortex
Occipital cortex
Parietal cortex
Retina
LGN
V1
V2
V3
V4
PO
MT
VIP
MST
LIP
7a
TEO
TE
Inferotemporal cortex


Macaque
Parietal cortex
Occipital cortex
Inferotemporal cortex
Retina
LGN
V1
V2
V3
V4
PO
MT
VIP
MST
LIP
7a
Parietal cortex
Occipital cortex
TEO
TE
Inferotemporal cortex
Optimal stimuli
Comparison of receptive fields
2°
Fixation point
TE receptive field
V4 receptive field
V1 receptive field
TEO receptive field

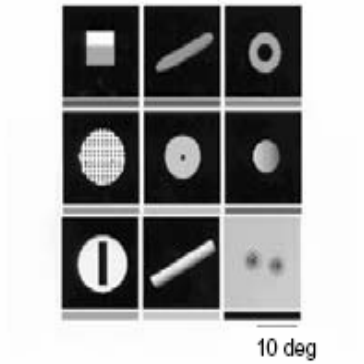
Neurons that code for similar objects or object features are organized in columns in inferotemporal cortex



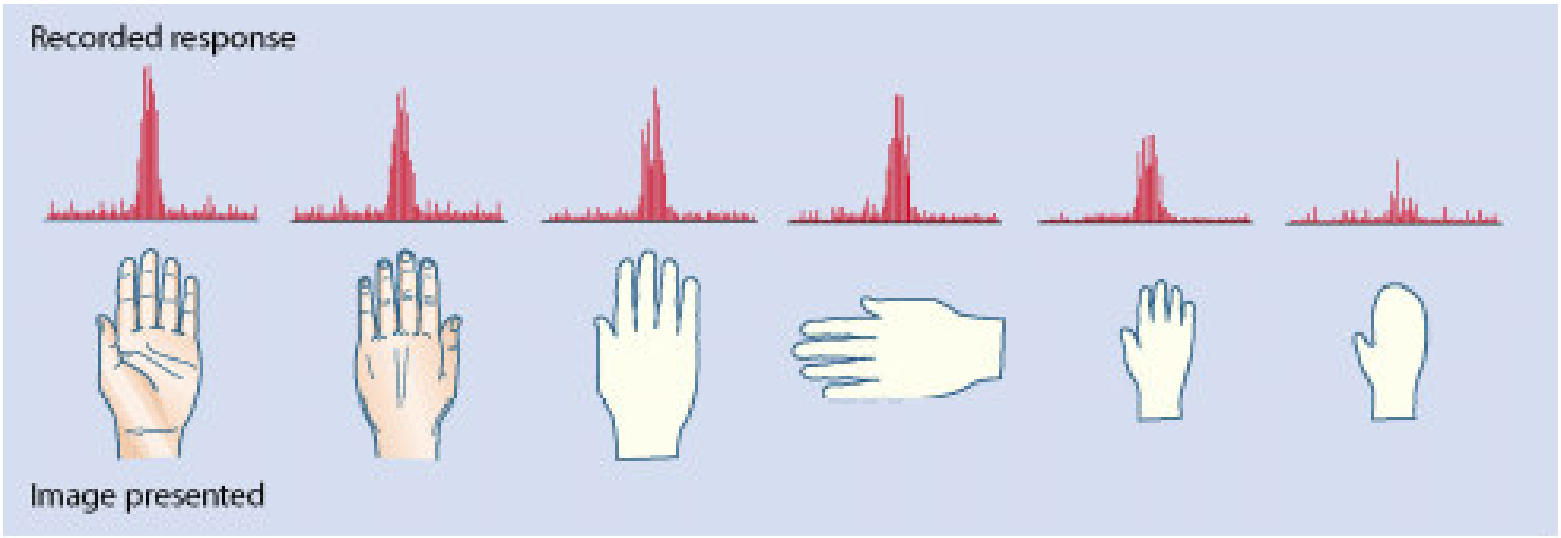
Optical Imaging

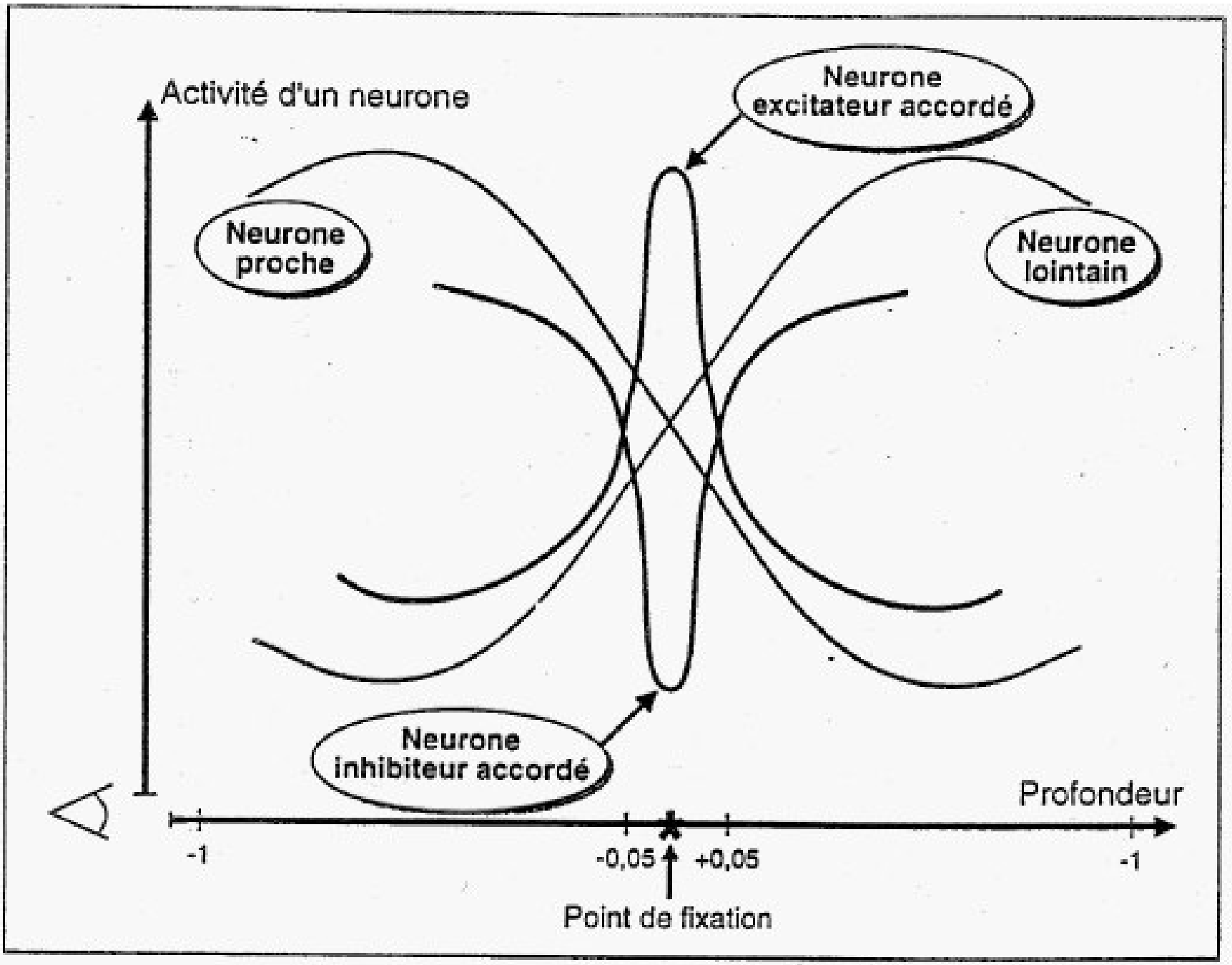


Optical imaging of monkey inferotemporal cortex has also shown patches (columns) that are tuned to specific object features



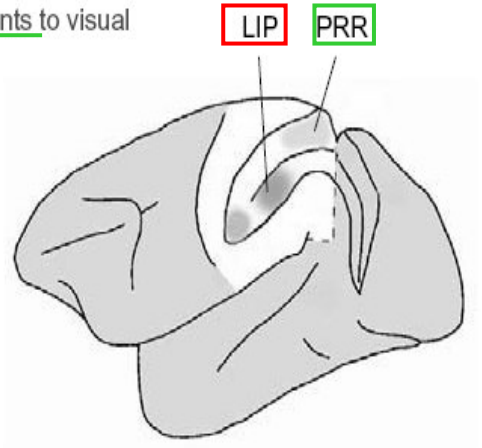
response in IT to complex stimulus



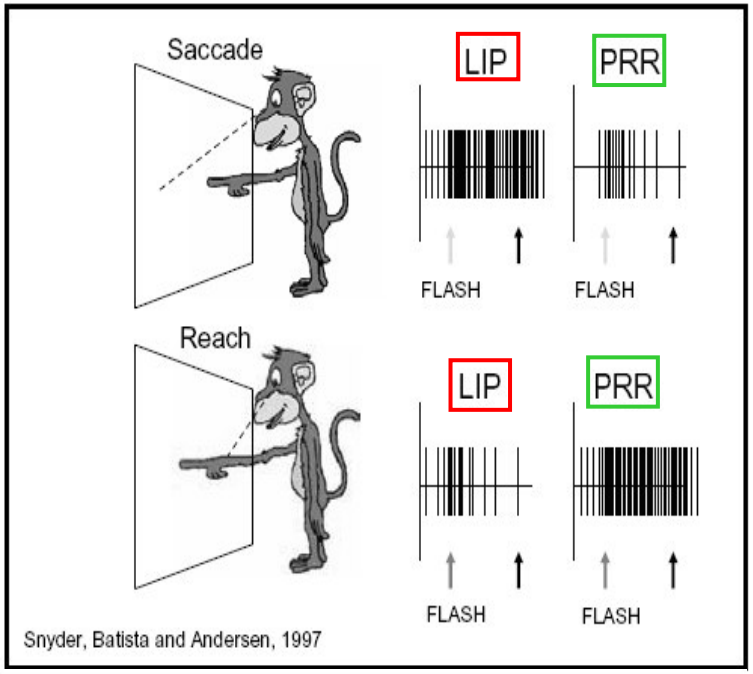

Activité d'un neurone
Neurone excitateur accordé
Neurone proche
Neurone lointain
Neurone inhibiteur accordé
Profondeur
-1
-0,05
+0,05
-1
Point de fixation

LIP plays a role in the initiation of voluntary saccades to visual targets

PRR plays a role in the initiation of reaching movements to visual targets

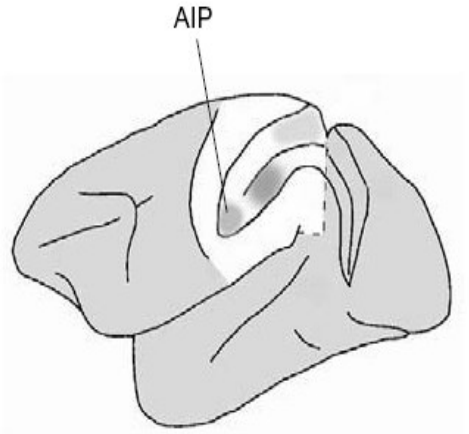


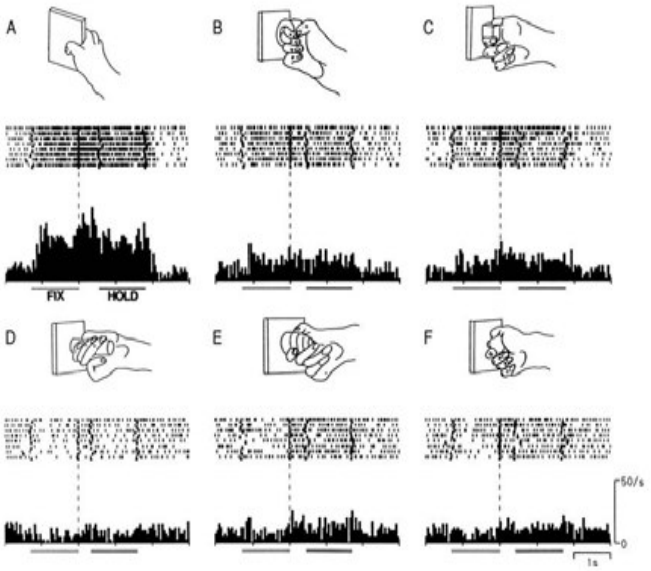
Snyder, Batista and Andersen, 1997



Snyder, Batista and Andersen, 1997

Recording from anterior intraparietal sulcus (AIP) Visual control of grasping





Gallese et al. (2000)

Ventral Stream	Dorsal Stream
Scene parsing and object identification	Visual control of motor output
Scene-based frame of reference	Effector-based frames of reference
Relational metrics	Absolute metrics
Long-term representations	Moment-to-moment computations
Contents of visual consciousness	Visuomotor transformations for (un)conscious acts

Goodale, M.A. & Humphrey, G.K. (1998). *Cognition*

Goodale, M.A. & Milner, A.D. (2004). *Sight Unseen* (Oxford University Press)

La vision

1. **Introduction**

2. **Mécanismes périphériques**

   a) **L'organe récepteur : l'œil**
      - **Structure**
      - **Propriétés optiques**

   b) **La rétine**
      - **Données histologiques**
      - **Structure des photorécepteurs**
      - **La phototransduction**

   c) **Le message rétinien**

3. **Mécanismes centraux**

   a) **Le cortex visuel V1 (aire striée ou aire 17)**
      - **Les projections géniculées**
      - **Organisation anatomo-fonctionnelle de V1**

   b) **Les aires visuelles péristriées**

      - **Inféro temporal (IT) et forme/couleur du stimulus**
      - **Pariétal et localisation/mouvement du stimulus**

4. **Conclusion**

CONCLUSION

- Fonction sensorielle dont on connaît le fonctionnement à plusieurs échelles : moléculaire, du neurone et des systèmes.
- Rôle des propriétés intrinsèques et de réseau dans le traitement de l'information
- Complexité du traitement à tous les niveaux (extraction de composantes abstraites de l'environnement dès le niveau rétinien).
- Principes communs de fonctionnement des systèmes sensoriels : traitement en parallèle (rapidité: 100-150 ms pour identifier un objet) et en série (complexification) des informations, divergence et convergence (compression de l'image), inhibition latérale (contraste), etc.
- Contrôles en retour des informations visuelles et mécanismes attentionnels (filtrage).
- Relations étroites avec la motricité (contrôle visuo moteur).
- Plasticité fonctionnelle