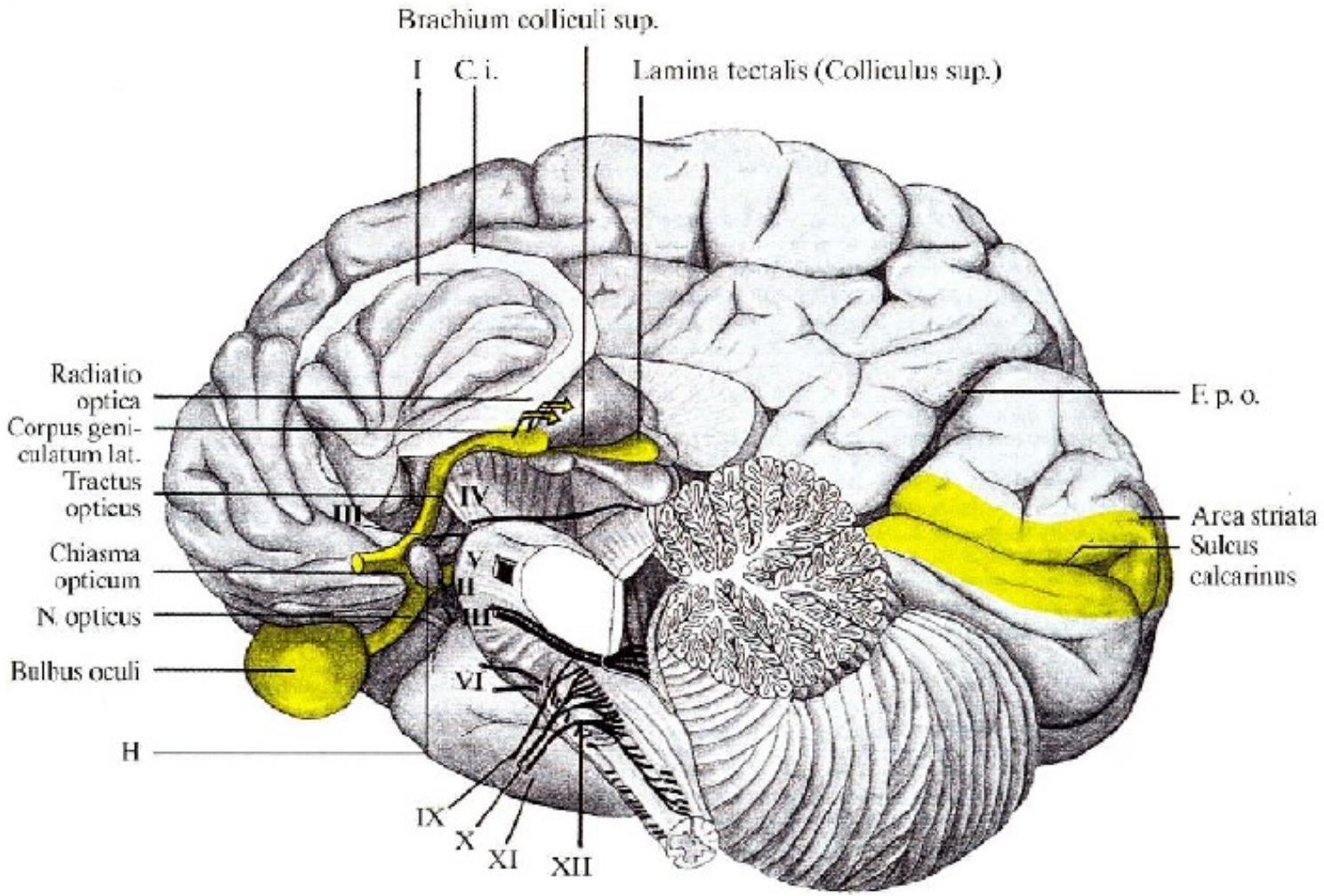
Early vision processing in the brain

November 10, 2011

Learning outcomes

- Recall parts of the eye and retina.
- Review the pathway from the retina to the thalamus.
- Recall an example of a retinal electronic chip.

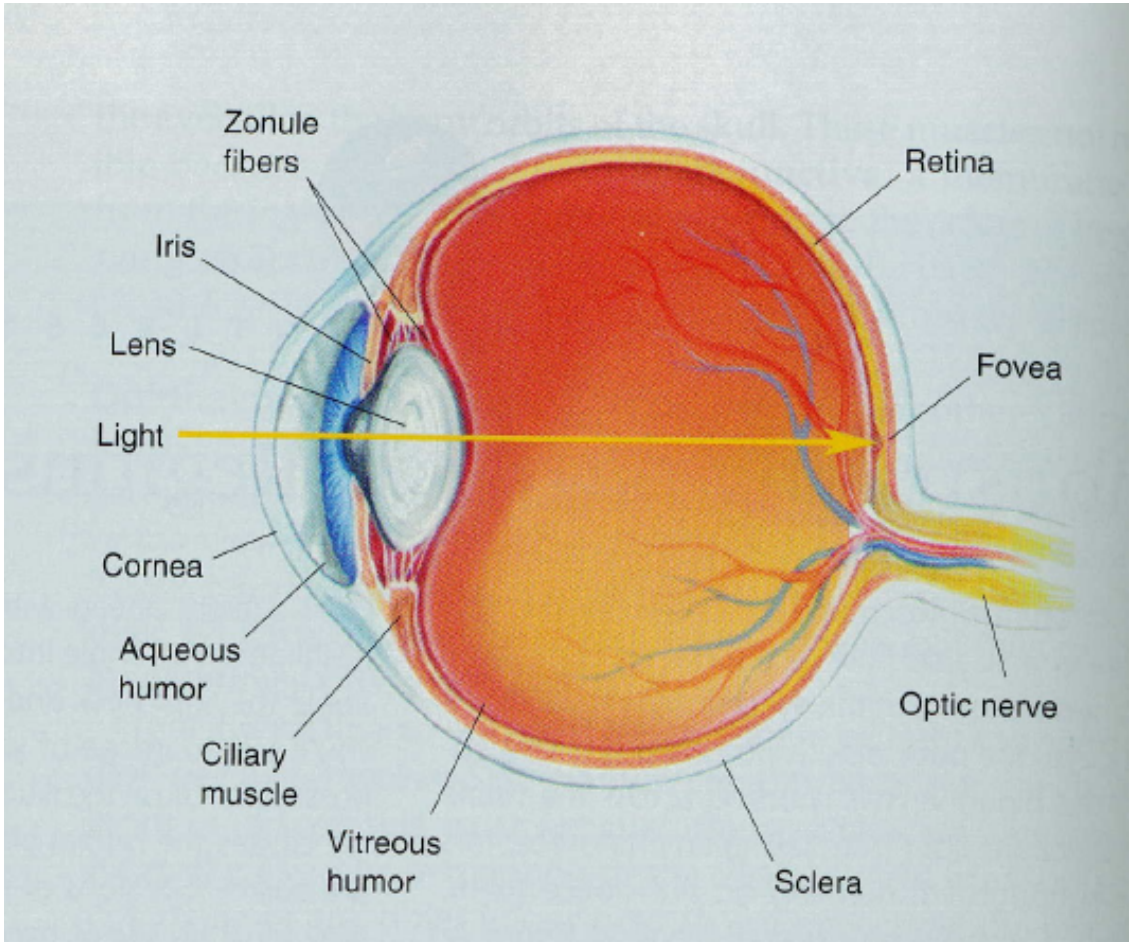
Eye to cortex



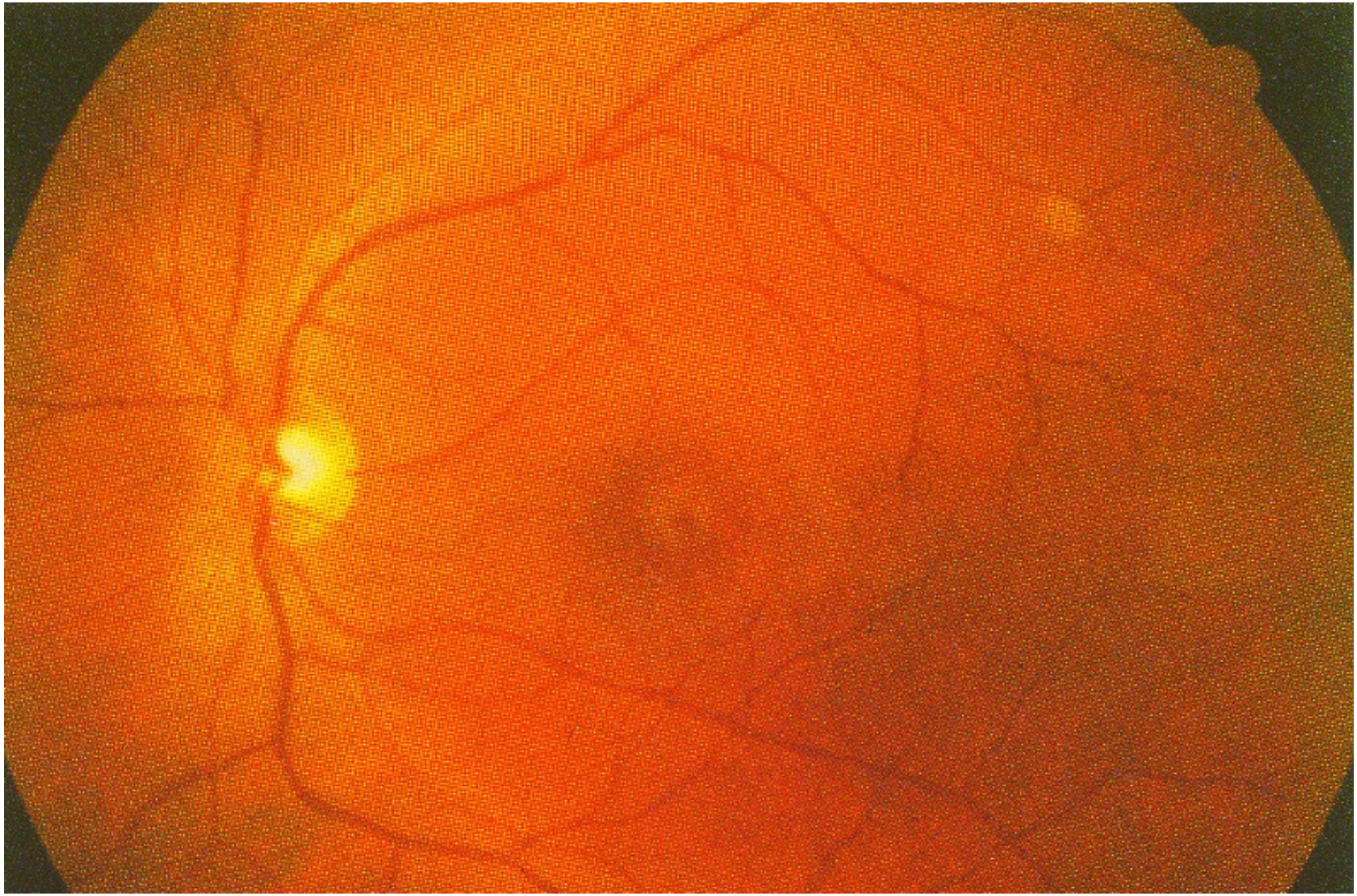
Section 1

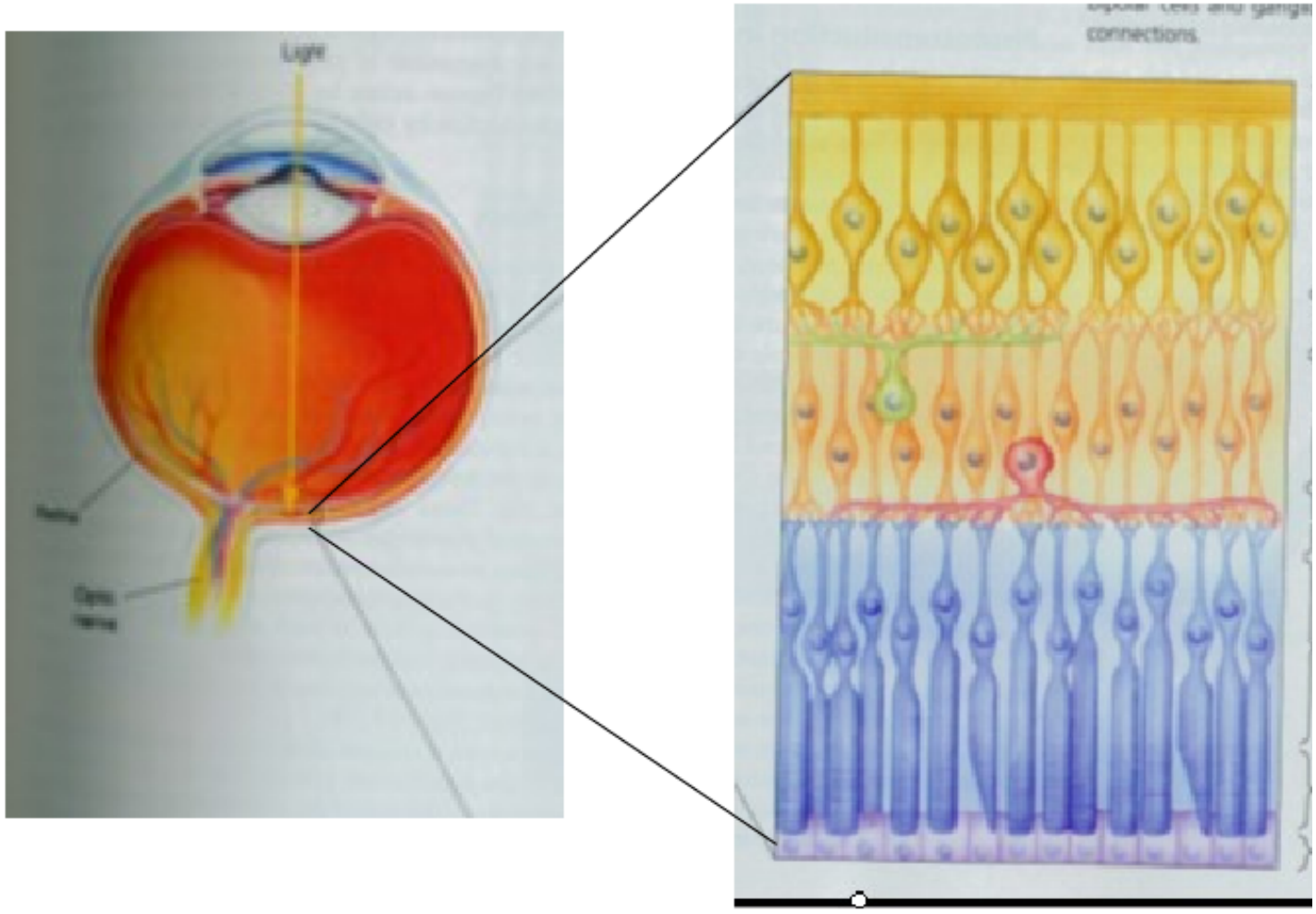
Eye

Eye


Zonule fibers
Iris
Lens
Light
Cornea
Aqueous humor
Ciliary muscle
Vitreous humor
Retina
Fovea
Optic nerve
Sclera

Retina

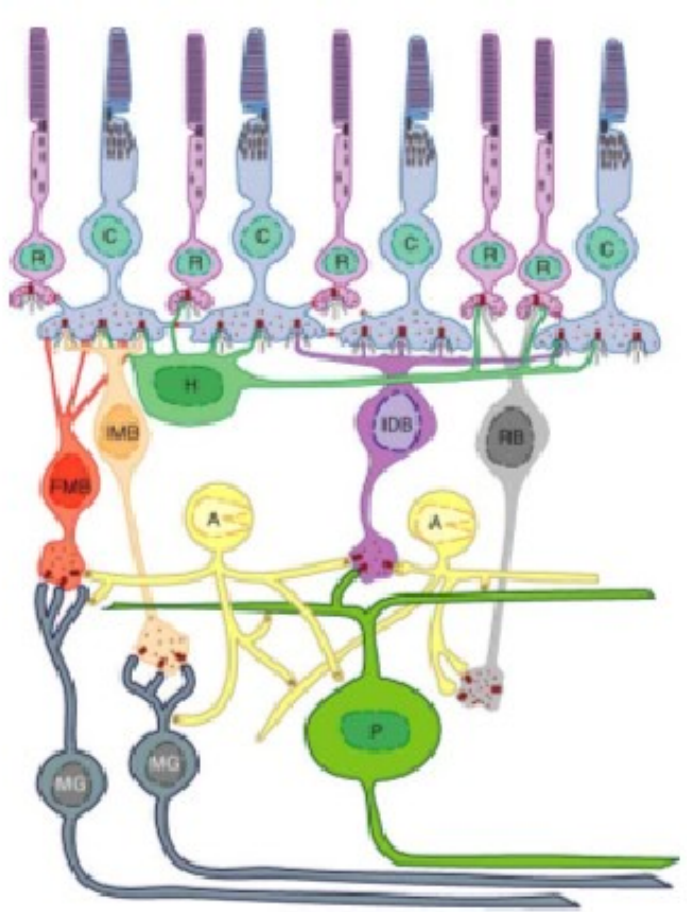




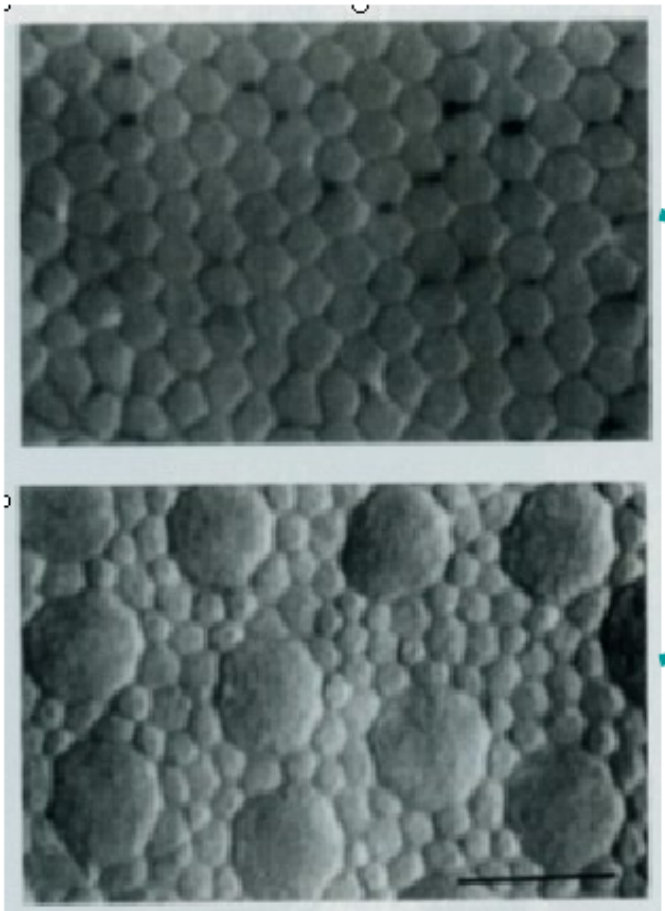
A cross-section through the retina showing the different cell layers.

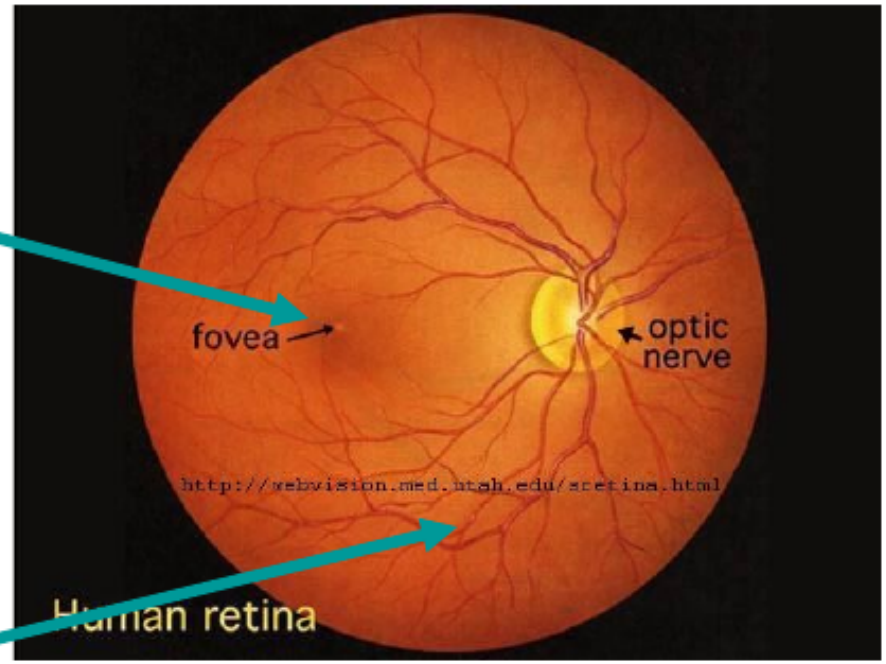
Cell types in the retina

- **Photoreceptor cells** are responsible for phototransduction
- **Horizontal cells** extend their dendrites horizontally integrating the input from many photoreceptor cells. Input from horizontal cells is fed back into photoreceptors and forward into **bipolar** cells.
- **Bipolar cells** extend their dendrites and axons vertically communicating signals to **amacrine** and **ganglion** cells
- **Ganglion cells** are spiking neurons that convey their information to other neural centres in the brain. The conglomeration of ganglion cell axons make up the optic nerve.



Retinal surface





The retinal surface – the mosaic of rods and cones

Structure of photoreceptors

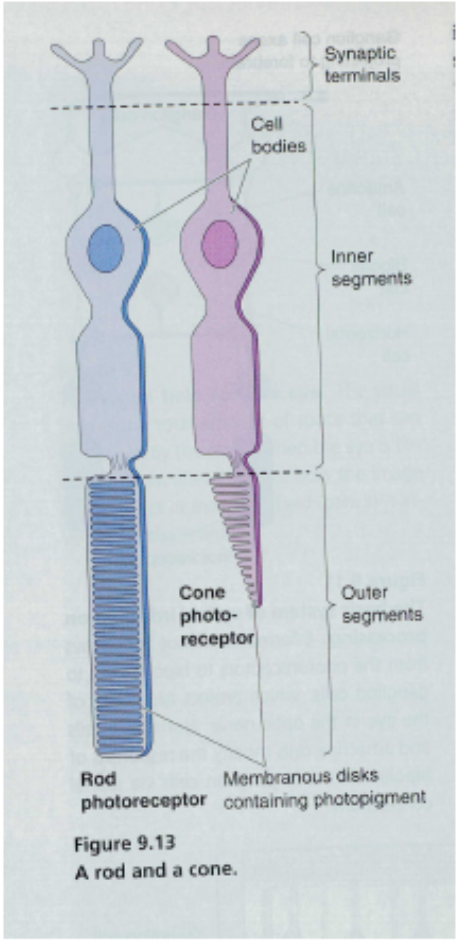
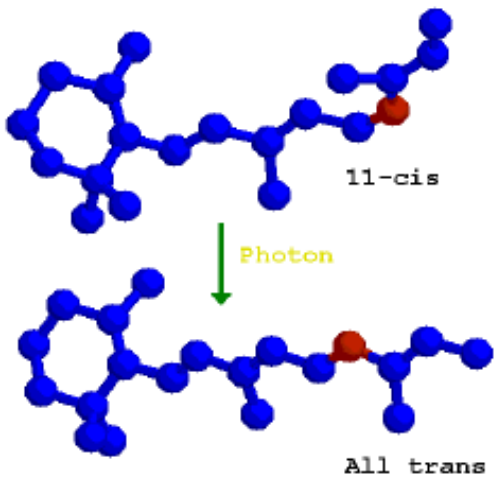


Figure 9.13
A rod and a cone.

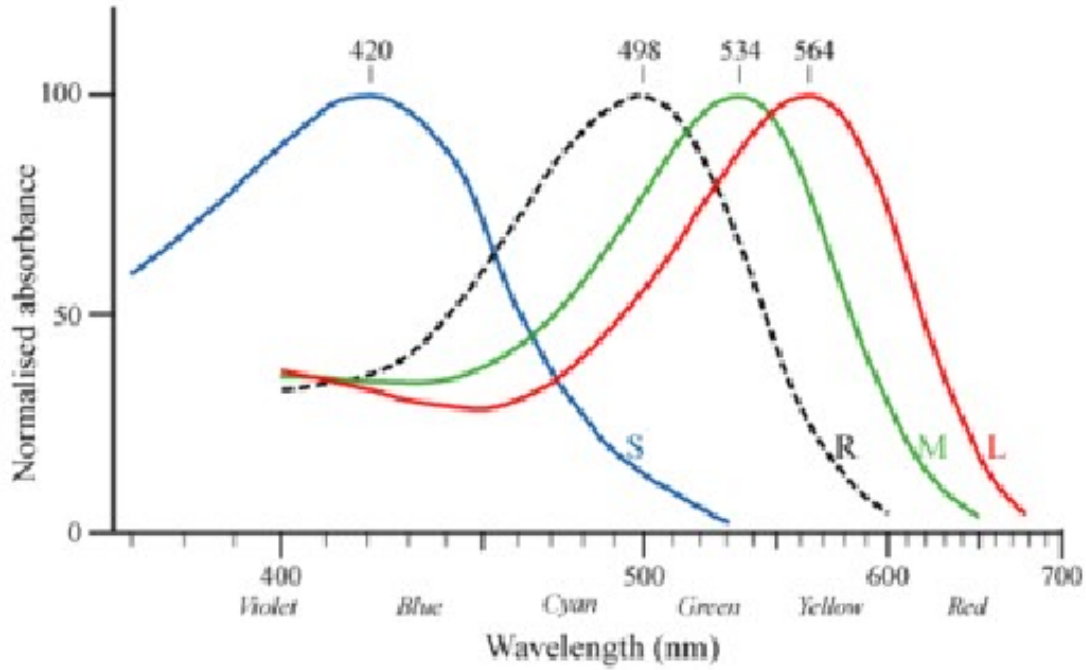
These cells have elongated segments that contain the biochemical machinery respondible for **phototransduction**.
Rods contain within their outer segments thousands of **discs** that host millions of photosensitive molecules (**photopigments**).
The size of both types of photoreceptor increases with increasing eccentricity (distance from the fovea towards the periphery of the retina).

Operation of photoreceptors



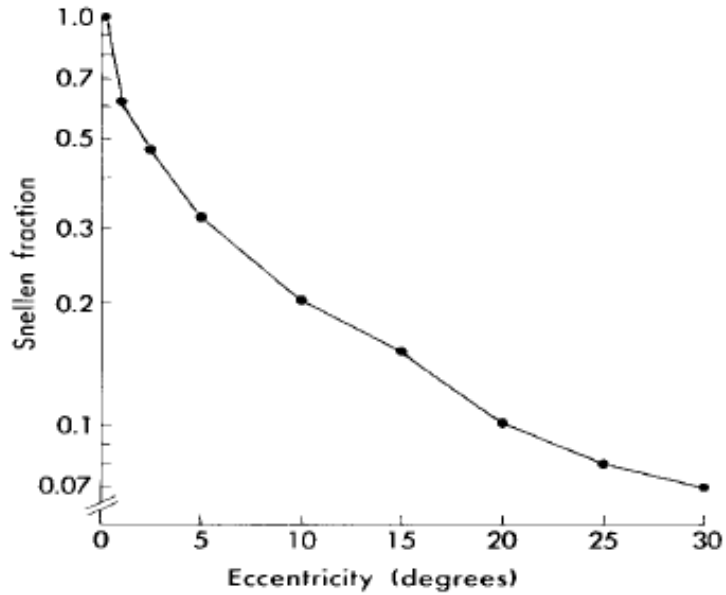
This depends on a photosensitive molecule **retinal** which exhibits a conformational change by the absorption of a photon by the 11th carbon atom.
Retinal is attached to a protein known as **opsin**; the complex is known as **visual pigment**. Four types of opsins are expressed in the human retina.

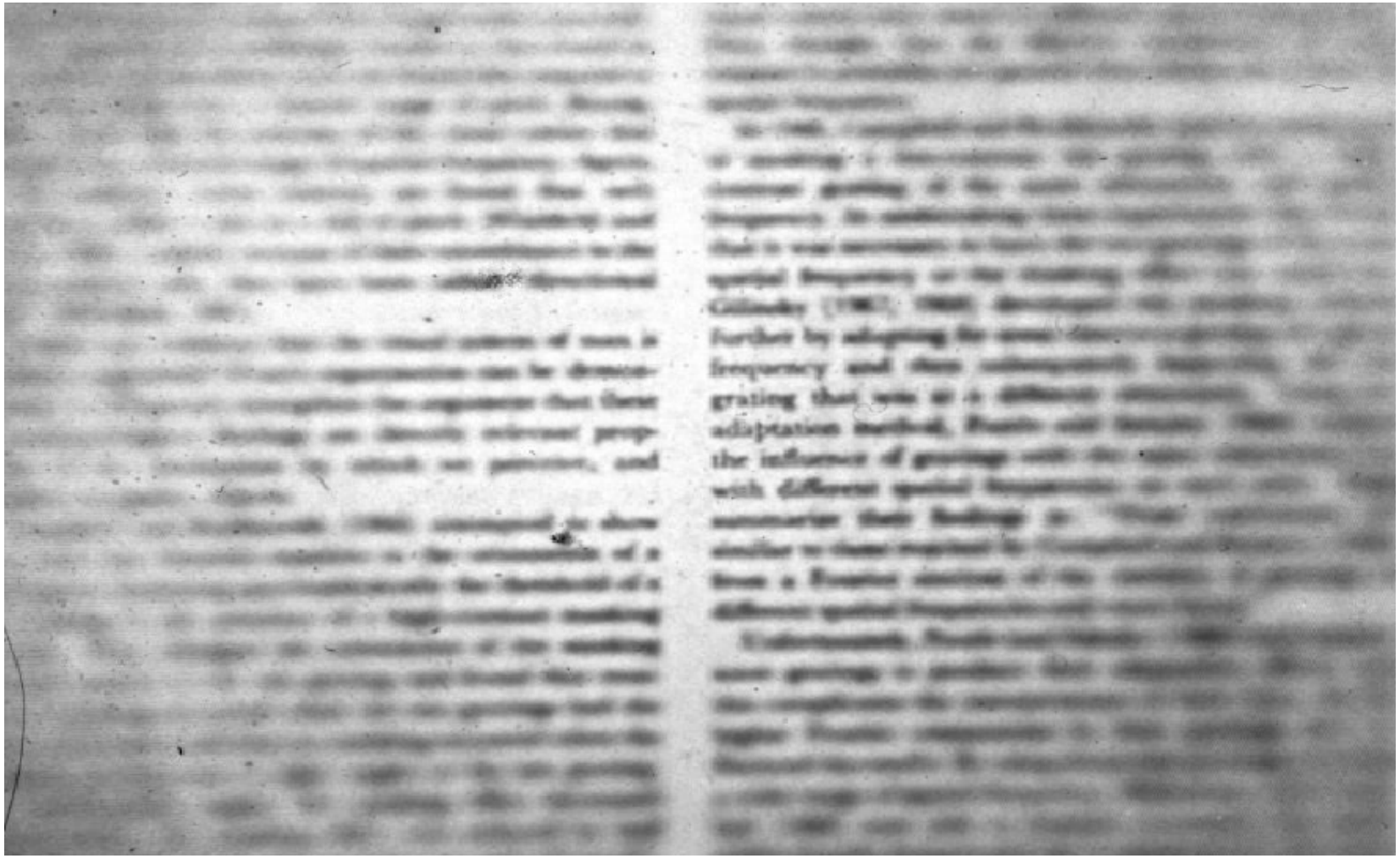
- **Rhodopsin** is found in rod photoreceptors.
- The other three are expressed within cone receptors: **blue**, **green** and **red** opsin.



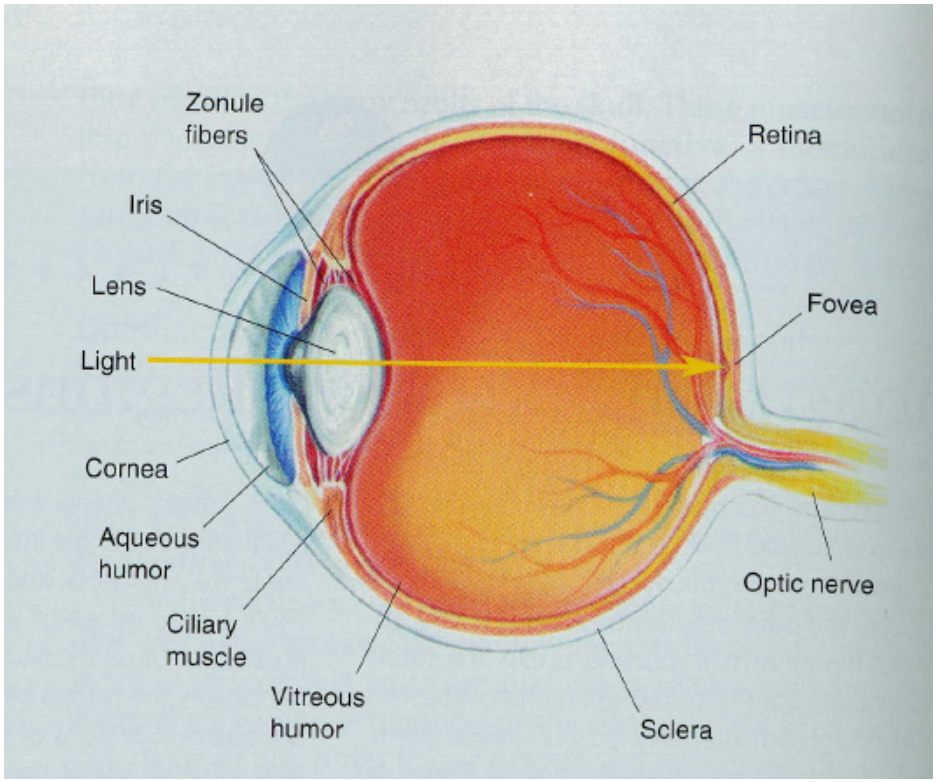
Each cone pigment shows particular **spectral preferences**. This means that every type has a well defined range of photon energies, or electromagnetic wavelengths, to which it responds with higher probability of absorption.

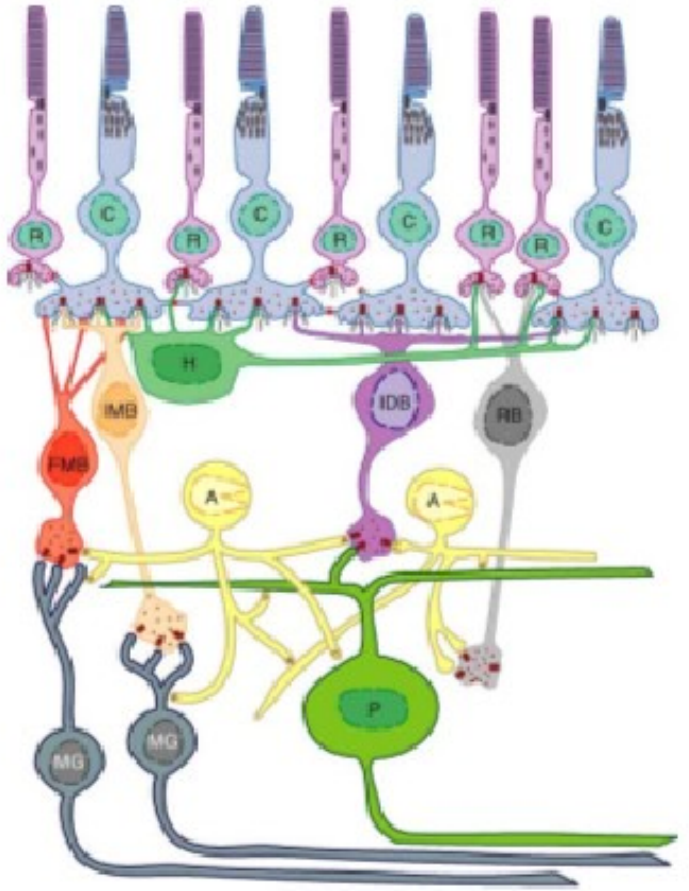
Acuity vs Foveal Eccentricity





Summary

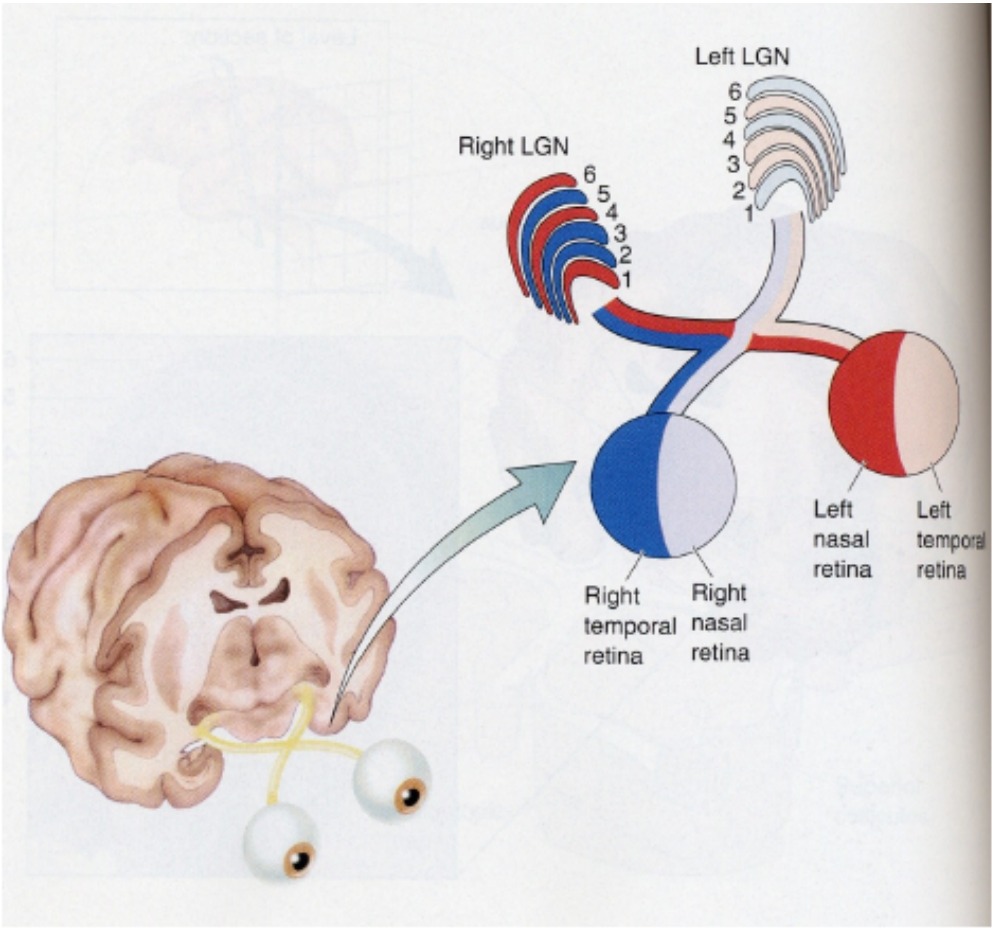

Zonule fibers
Retina
Iris
Lens
Fovea
Light
Cornea
Aqueous humor
Optic nerve
Ciliary muscle
Vitreous humor
Sclera


C
R
H
IMB
IDB
RB
FMB
A
P
MG

Section 2

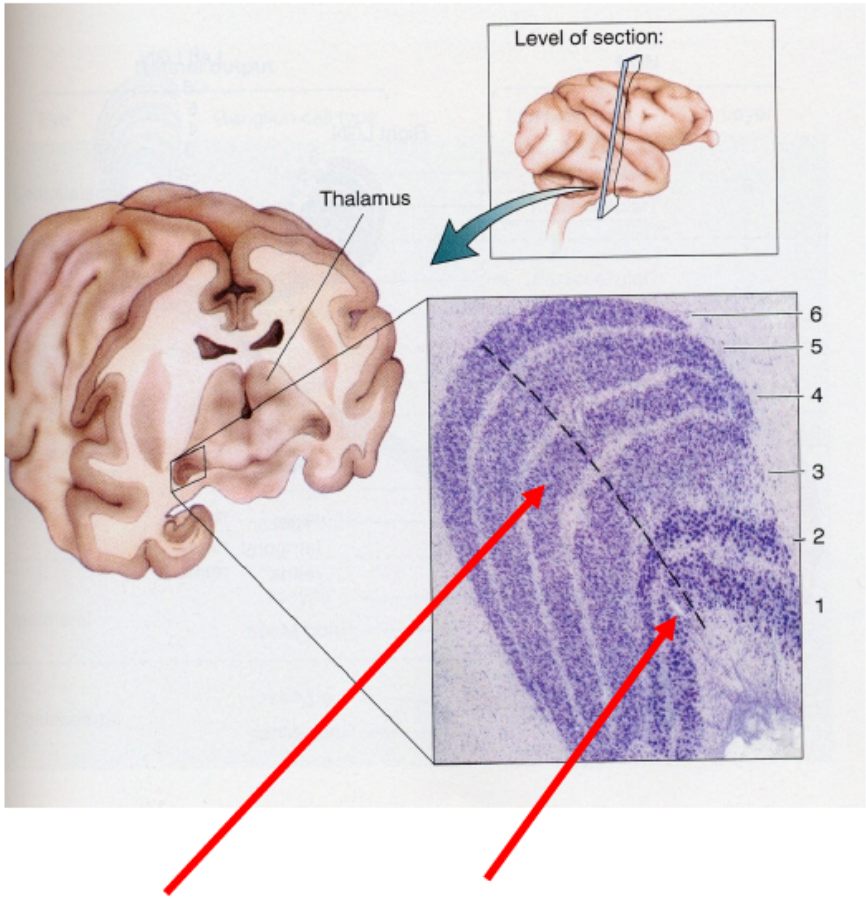
Retina to thalamus

Retinal projections to the LGN



The **right LGN** gets input from the **left visual field**, alternating on successive layers between input from the left eye and fromn the right eye. The **left LGN** gets input from the **right visual field**, alternating on successive layers between input from the right eye and from the left eye.

Retinal projections to the LGN



Parvocellular layers 3 - 6

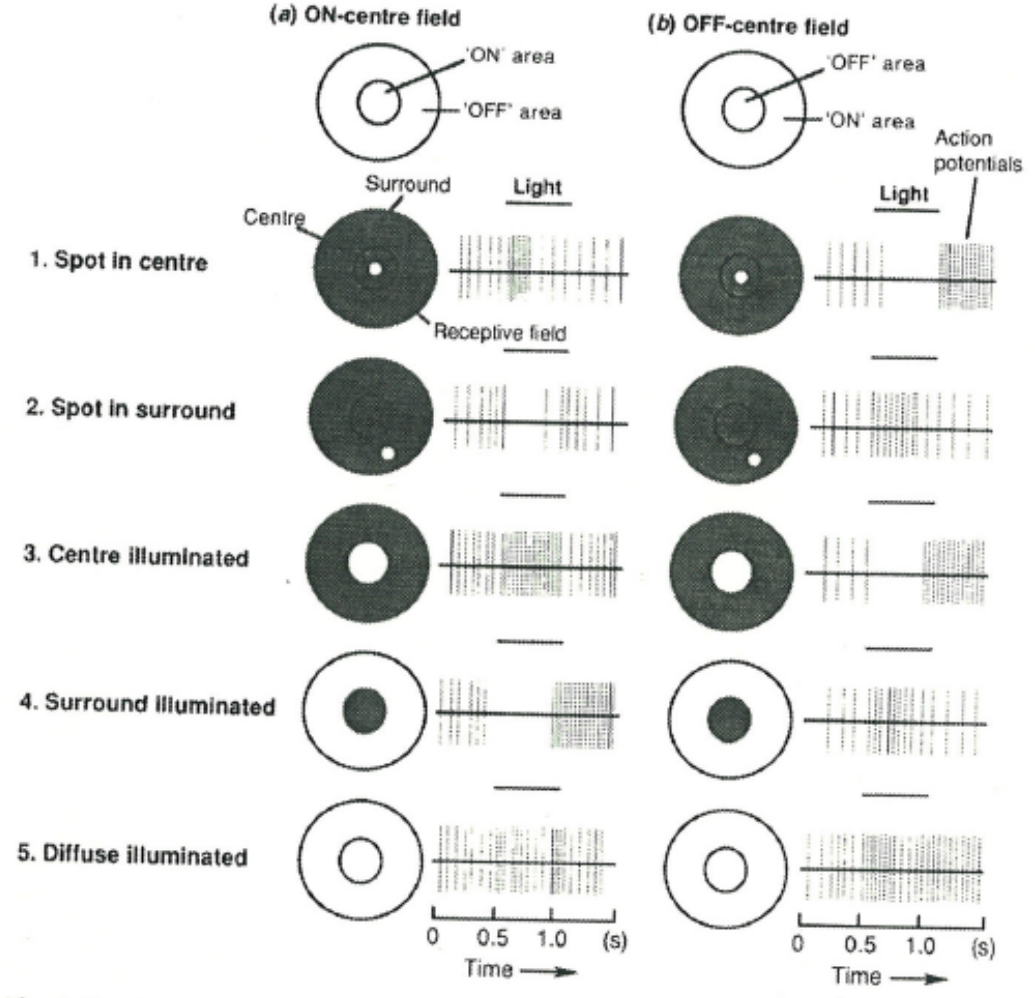
Magnocellular layers 1 & 2

The axons of the retinal ganglion cells forms synapses on the neurons of the **lateral geniculate nucleus (LGN)** of the **thalamus**.

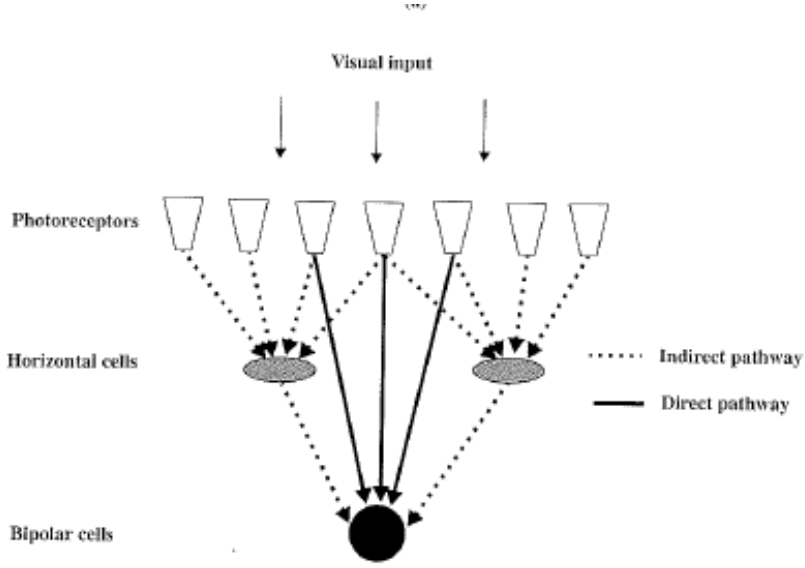
Structure of the LGN

- About 80% of the LGN excitatory neurons are in the parvocellular layers.
- About 10% are in each of the magnocellular and koniocellular layers.
- In addition there are inhibitory neurons in all layers (about four times as many in the magnocellular as in the parvocellular layers).
- Only about 10% of the synaptic inputs to the LGN neurons comes from the retinal ganglion cells — another 30% comes from feedback inputs from the cortex. The rest are the interconnections between excitatory and inhibitory cells in the LGN.

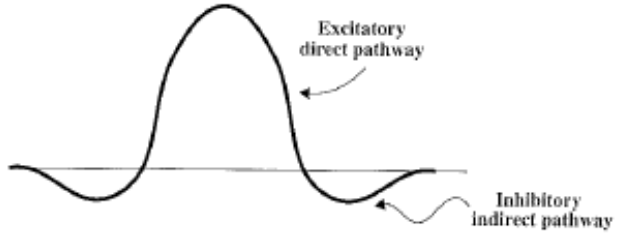
Receptive fields



Receptive fields cntd.



(b)

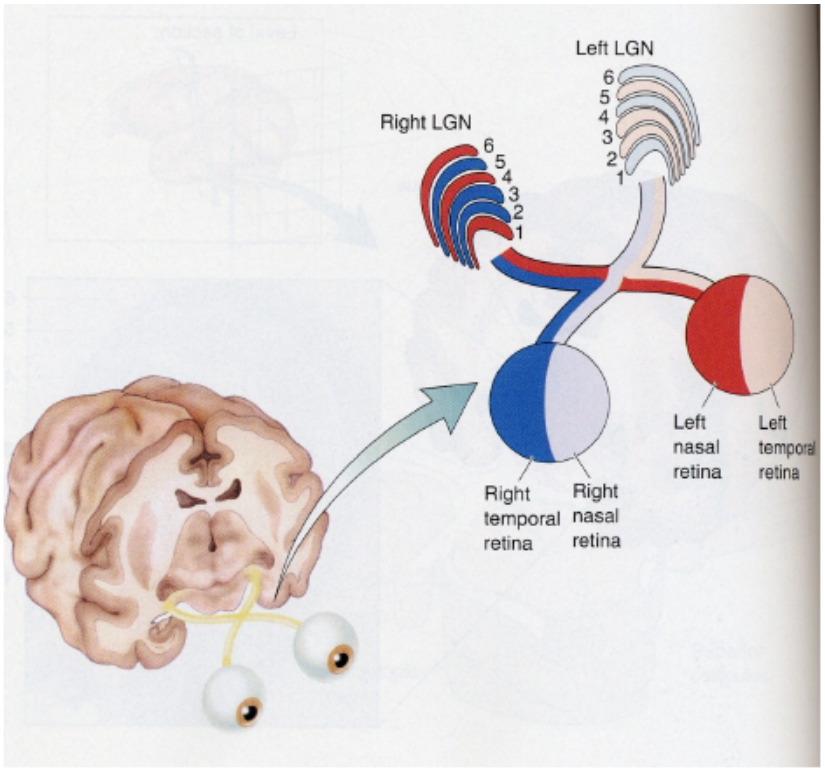


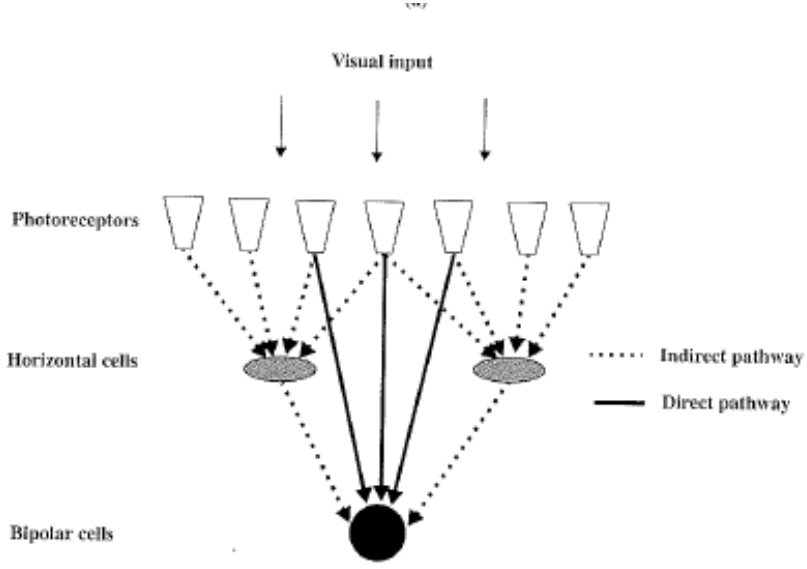
Mexican hat receptive field of an on-centre/off-surround bipolar cell

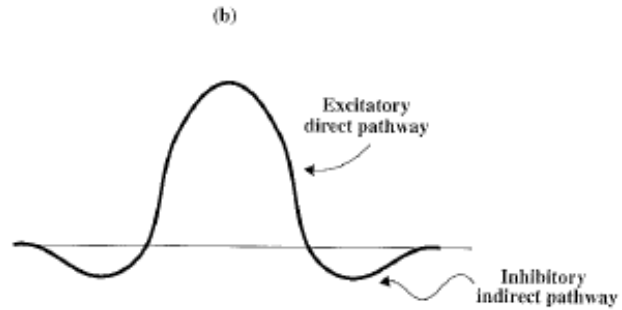
Differences in response properties between magnocellular and parvocellular LGN cells

- Receptive fields are larger in magnocelluar than parvocellular cells.
- The receptive field sizes of both increase with distance from fovea.
- The axons of the magnocellular cells **conduct action potentials much faster** than the axons of the parvocellular cells.

Summary



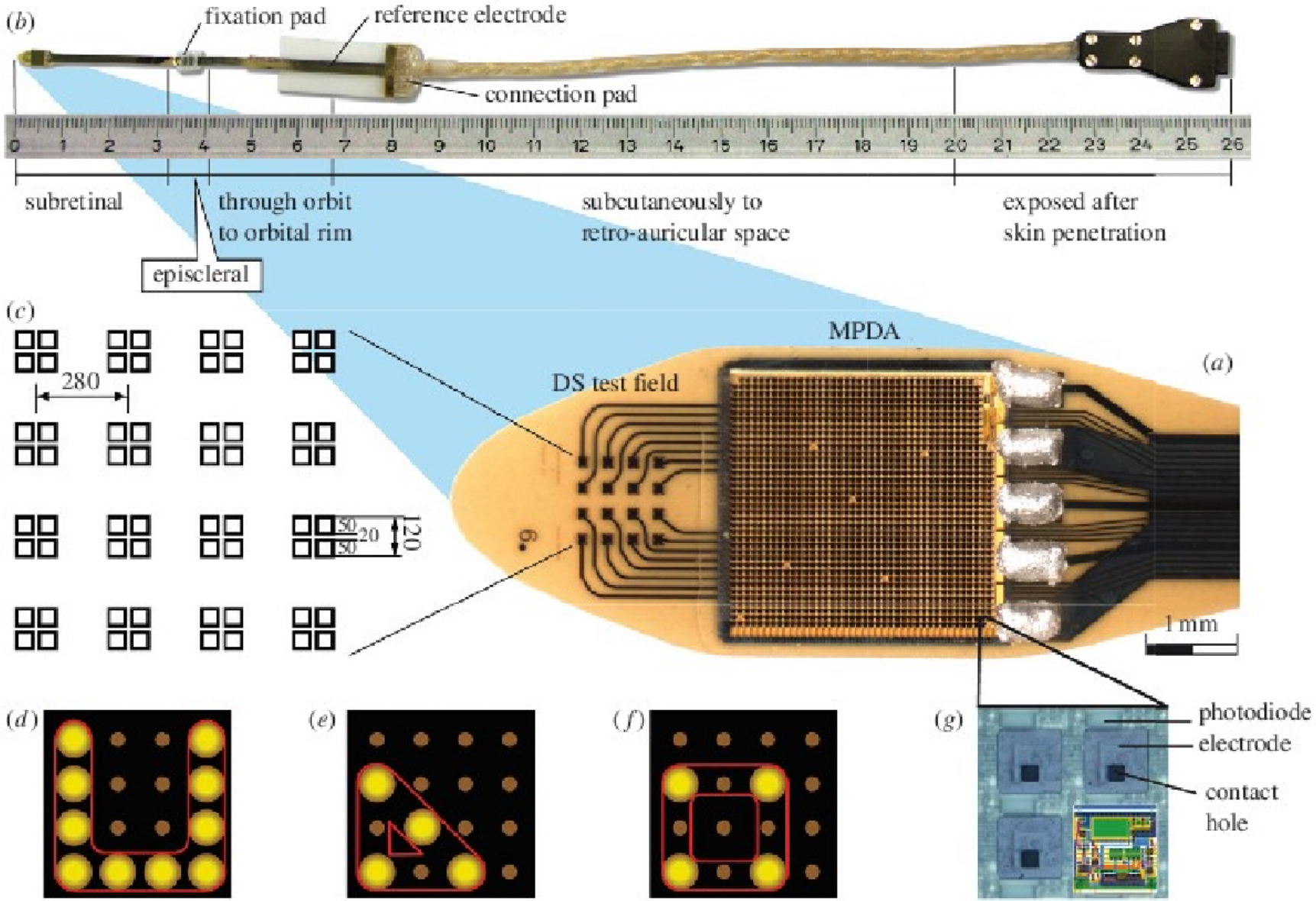


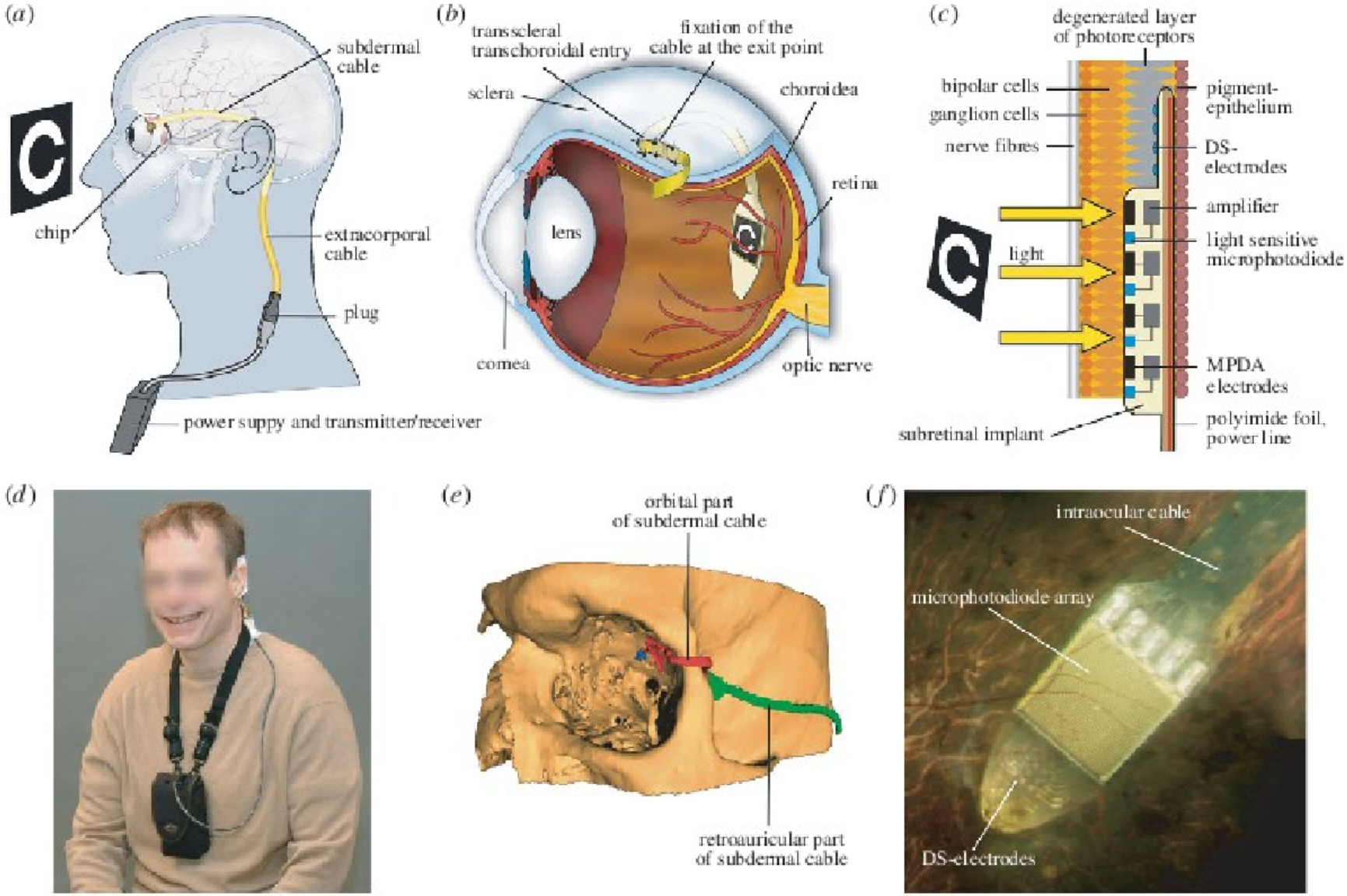


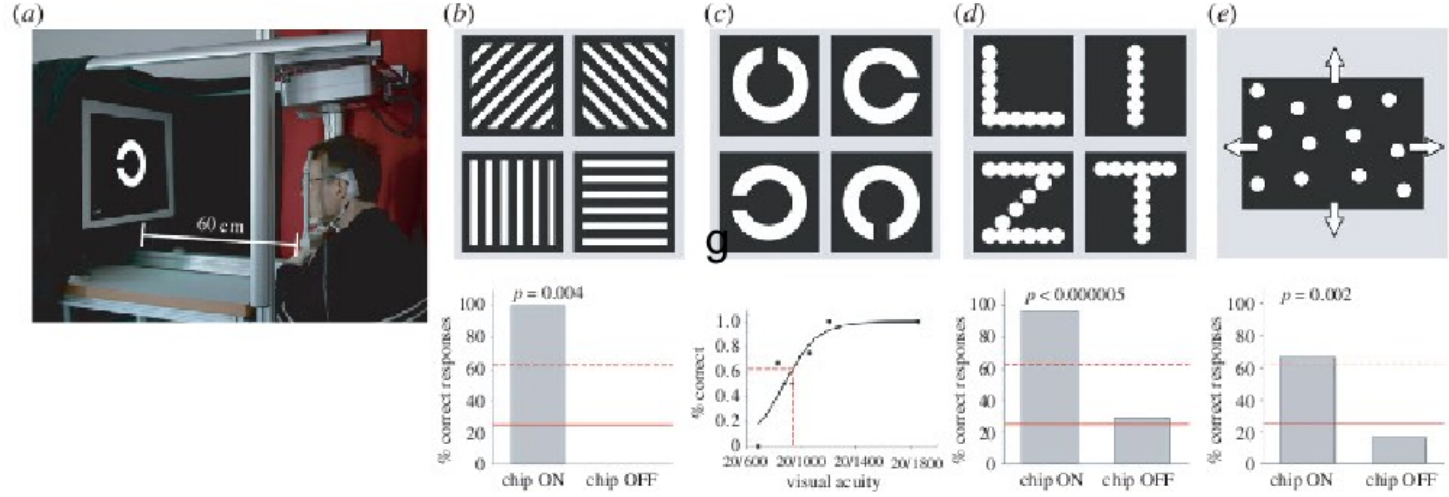
Mexican hat receptive field of an on-centre/off-surround bipolar cell

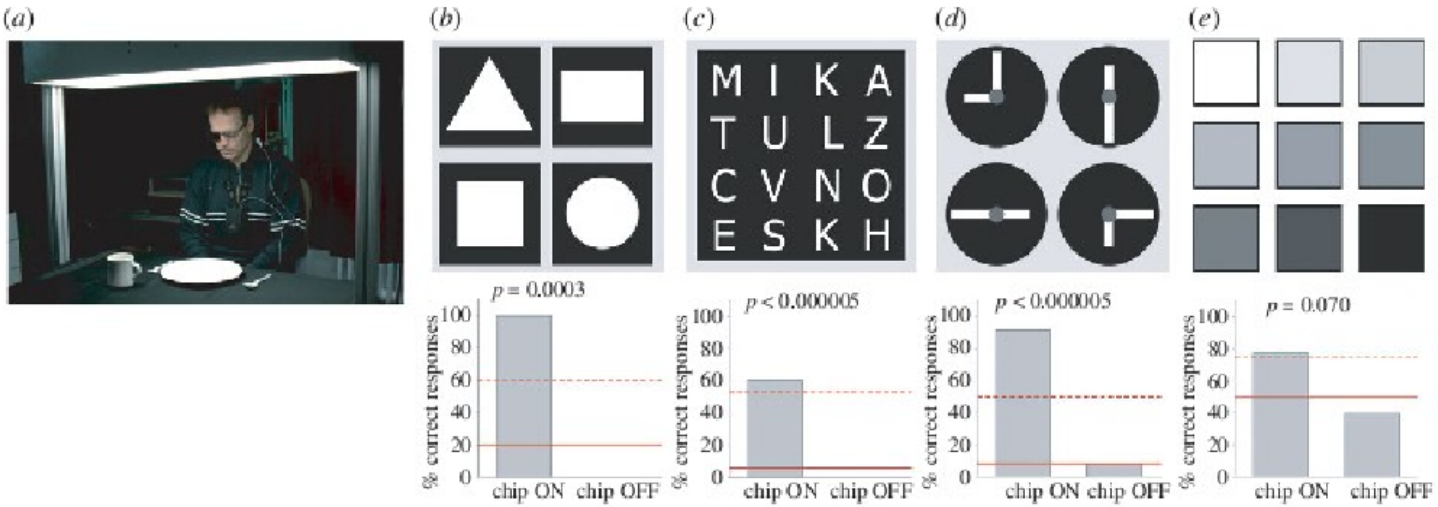
Section 3

Artificial retinas?


(b)
fixation pad
reference electrode
connection pad
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
subretinal
episcleral
through orbit
to orbital rim
subcutaneously to
retro-auricular space
exposed after
skin penetration
(c)
280
80
20
80
120
MPDA
DS test field
(a)
1 mm
(d)
(e)
(f)
(g)
photodiode
electrode
contact
hole


(a)
subdermal cable
chip
extracorporal cable
plug
power suppy and transmitter/receiver
(b)
transscleral transchoroidal entry
fixation of the cable at the exit point
sclera
choroidea
retina
lens
cornea
optic nerve
(c)
degenerated layer of photoreceptors
bipolar cells
ganglion cells
nerve fibres
pigment-epithelium
DS-electrodes
amplifier
light sensitive microphotodiode
light
MPDA electrodes
polyimide foil, power line
subretinal implant
(d)
(e)
orbital part of subdermal cable
retroauricular part of subdermal cable
(f)
intraocular cable
microphotodiode array
DS-electrodes


(a)
60 cm
(b)
(c)
(d)
(e)
p = 0.004
% correct responses
chip ON
chip OFF
% correct
visual acuity
20/600
20/1000
20/1400
20/1800
p < 0.0000005
p = 0.002


(a)
(b)
(c)
(d)
(e)
M I K A
T U L Z
C V N O
E S K H
p = 0.0003
p < 0.000005
p < 0.000005
p = 0.070
% correct responses
chip ON
chip OFF

Learning outcomes

- Recall parts of the eye and retina.
- Review the pathway from the retina to the thalamus.
- Recall an example of a retinal electronic chip.