# Visual Processing

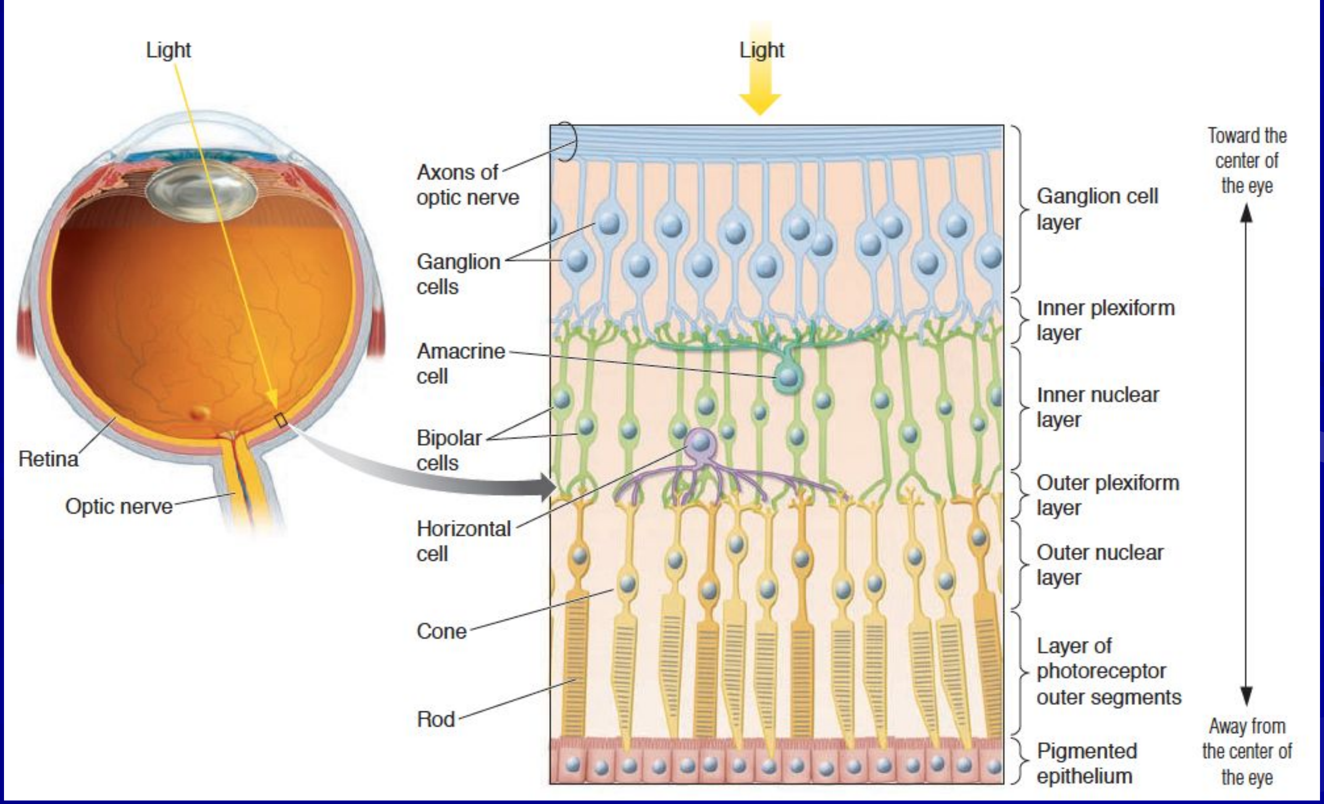
The topics:

- An overview of the basic elements of the visual system
- Processing of visual information through various steps until it reaches the cortex.
- Two main visual processing pathways in the cerebral cortex
- How information from different senses, such as vision and hearing, are integrated.

# Visual Processing

## The Retina

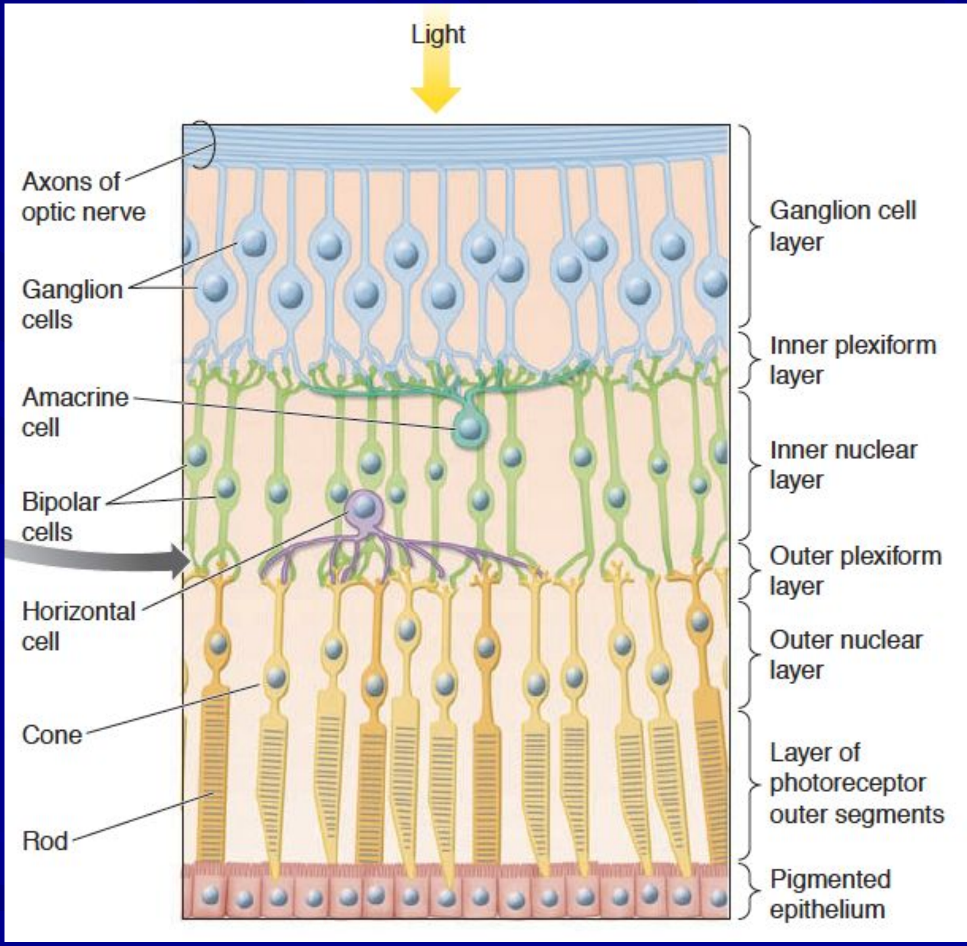
- The retina lies at the back of the eye
- Retinal tissue is derived from neural tissue during embryological development
- The retina acts as an information processor, much like the rest of the brain.



# Visual Processing

## Photoreceptors

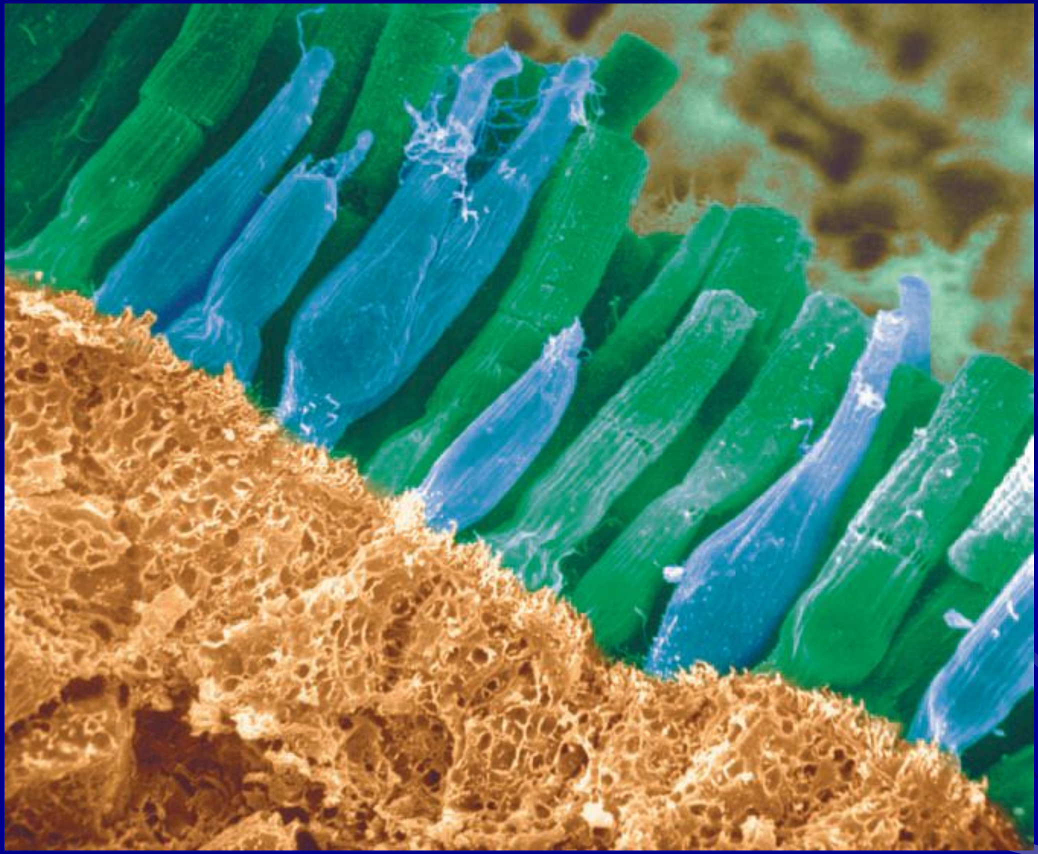
- Visual processing begins in the retina with the division of the sensory receptors into rods and cones – photoreceptor cells
- There are approximately 120 million rods and 6 million cones in the human eye.
- Both rods and cones contain pigments that absorb light.
- When photons of light are absorbed, a cascade of chemical changes inside the photoreceptors leads to changes in membrane polarization and the release of neurotransmitter, signaling to the next layer of cells within the eye.
- Therefore, rods and cones take light energy and transform it into the electrochemical energy used in the nervous system.



# Visual Processing

## Photoreceptors

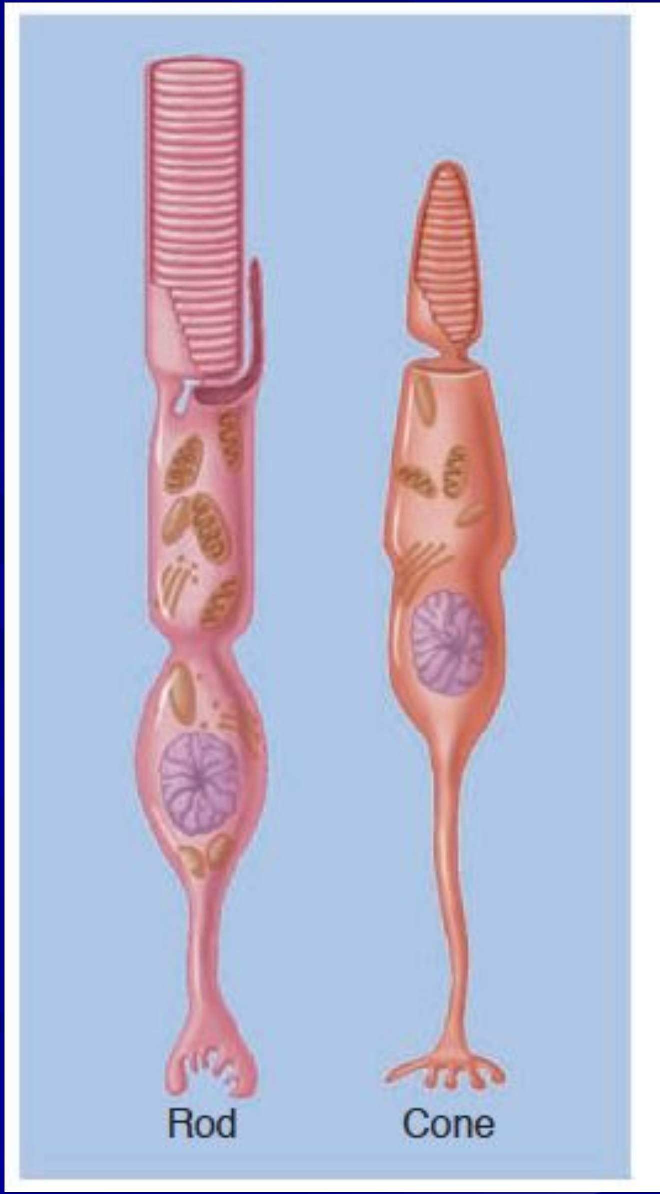
- The rods and cones differ in three main ways.
- First, they contain different pigments, which makes their response to light differ.
- The rods contain just one pigment (rhodopsin), which is sensitive to very small amounts of light.
- In broad daylight, this pigment becomes saturated and the rod system no longer functions. At that time, processing is taken over by the cones.



# Visual Processing

## Photoreceptors

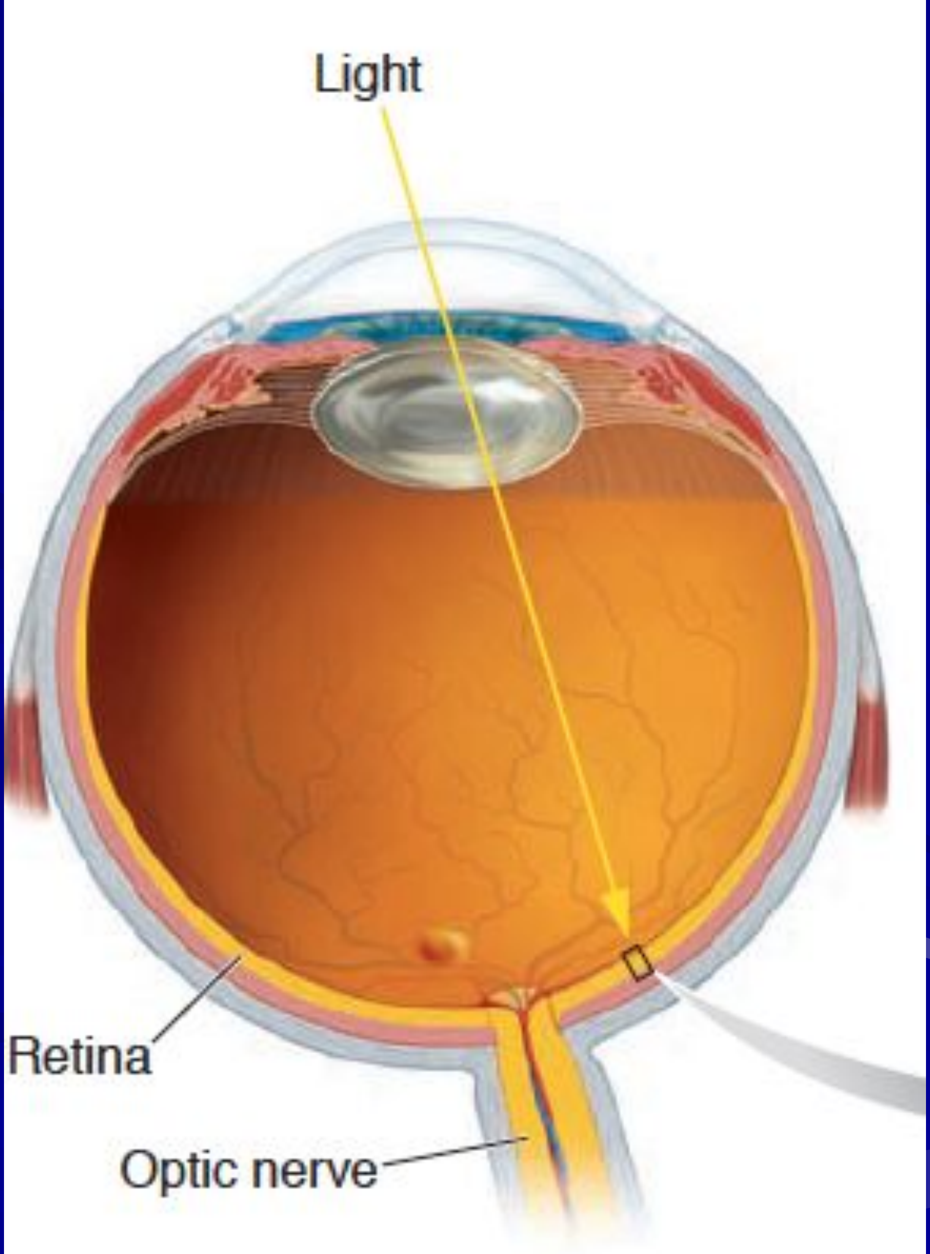
- There are three different types of cones, each containing a different pigment.
- The three types of cone pigment are sensitive to wavelengths in different portions of the light spectrum: short-wavelength, medium-wavelength, and long-wavelength light.
- Short-,medium-, and long-wavelength cone pigments are most sensitive to light that we perceive as blue, green, and red, respectively.
- It is the pattern of activity across these three types of receptors that ultimately enables color vision



# Visual Processing

## Photoreceptors

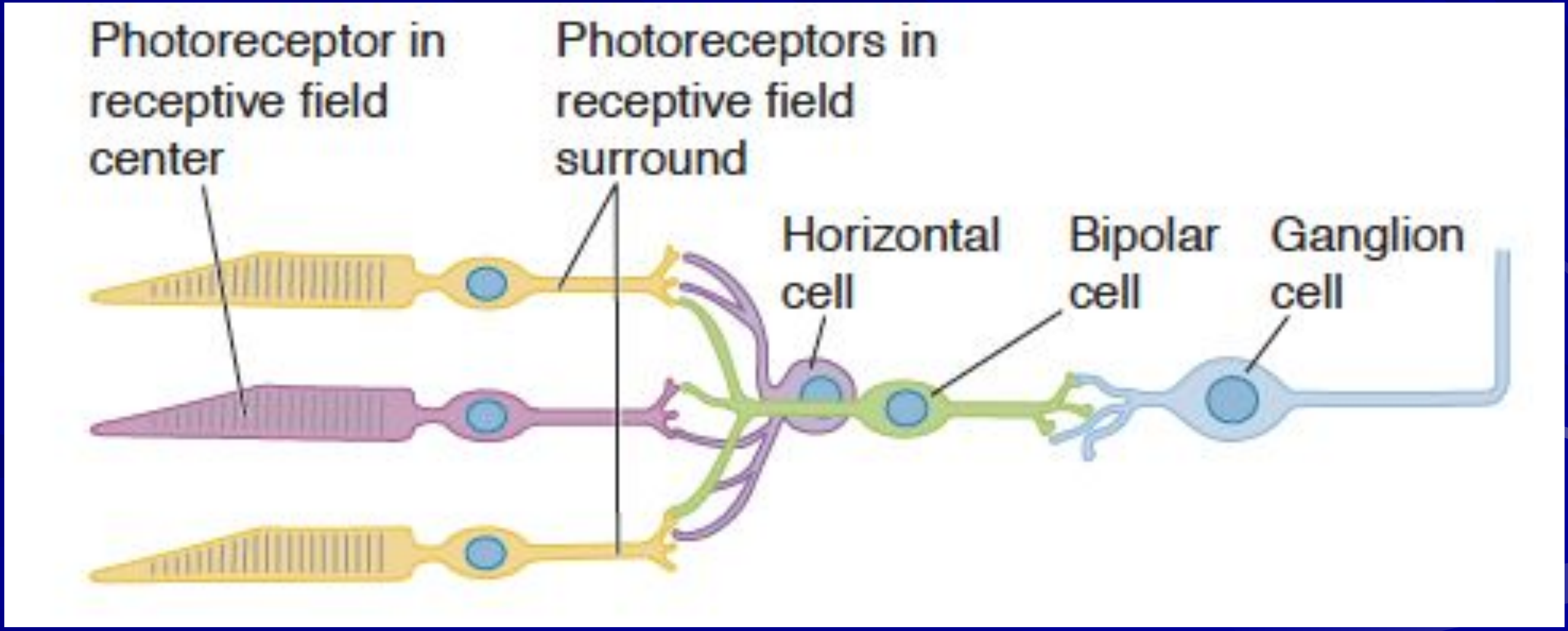
- Second, the distribution of rods and cones across the retina also differs.
- Cones are packed more densely in the center of the retina (a region known as the fovea), whereas rods are distributed more in the periphery.



# Visual Processing

## Photoreceptors

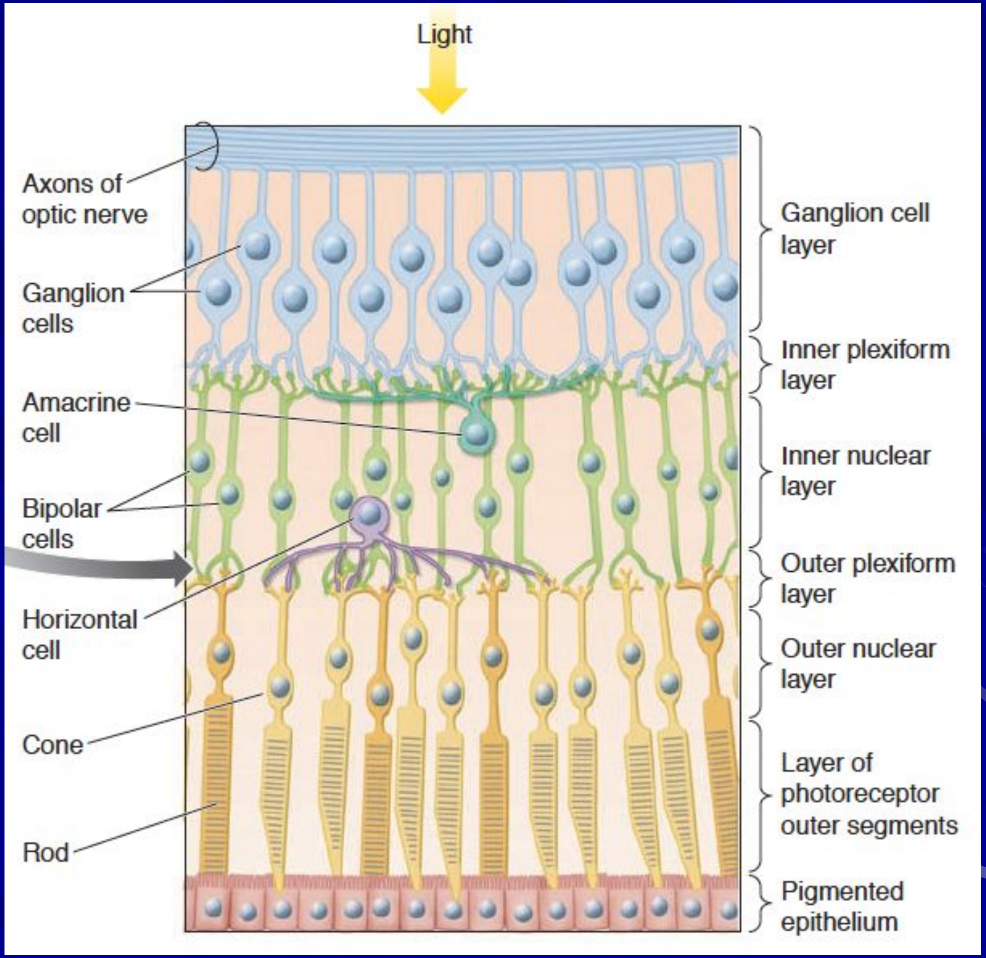
- Finally, rods and cones are hooked up to the retina's output layer of cells (ganglion cells), in somewhat different ways.
- Many rods feed into each ganglion cell, whereas only a few cones feed into each ganglion cell.



# Visual Processing

## Photoreceptors

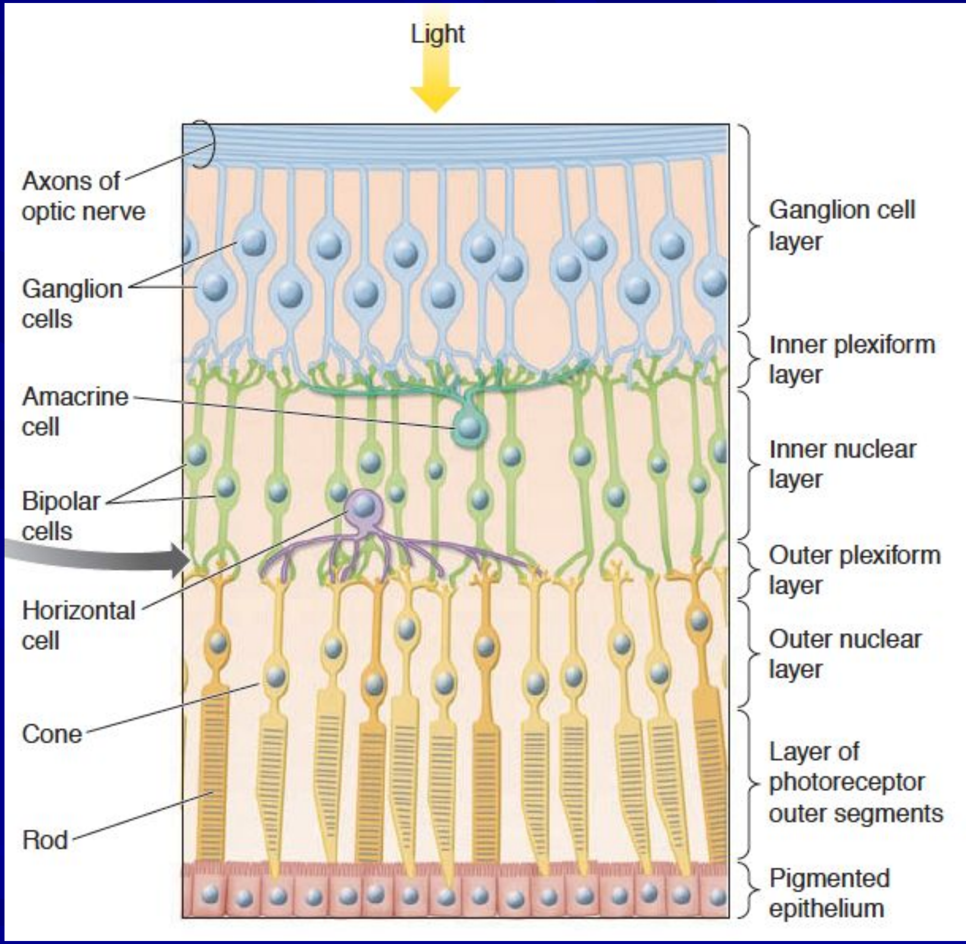
- The differences in how rods and cones are wired up to other cells is partly what gives the rod and cone systems different properties
- The rod system is more useful under low light levels, such as at night.
- However, it is less sensitive to fine details. Because so many rods feed into one ganglion cell, information about the precise location of the light is lost.



# Visual Processing

## Photoreceptors

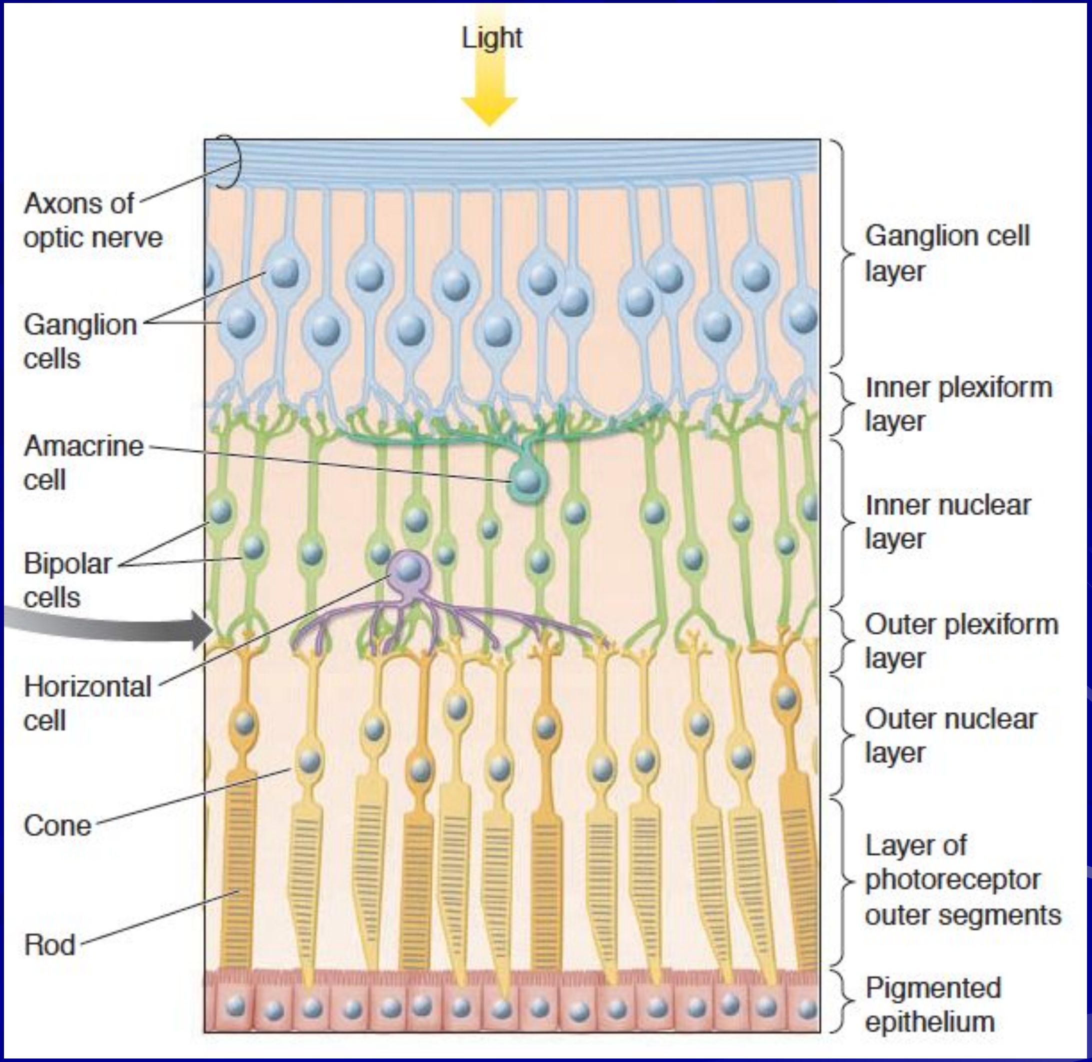
- By having less summation across multiple photoreceptors, the cone system preserves more fine-grained information about where on the retina light has been detected.
- However, it cannot function under low light conditions (because the summation of information from the cones is not sufficient to make a ganglion cell fire).
- Thus, the rod and cone systems have evolved to serve different aspects of vision.



# Visual Processing

## Ganglion Cells

- Whereas the rods and cones are the "input" part of the retina, the ganglion cells are the "output," sending information along from the eye to the brain
- The ganglion cell bodies are located in the retina, and their axons stretch out from the retina toward the brain, forming the optic nerve.



# Visual Processing

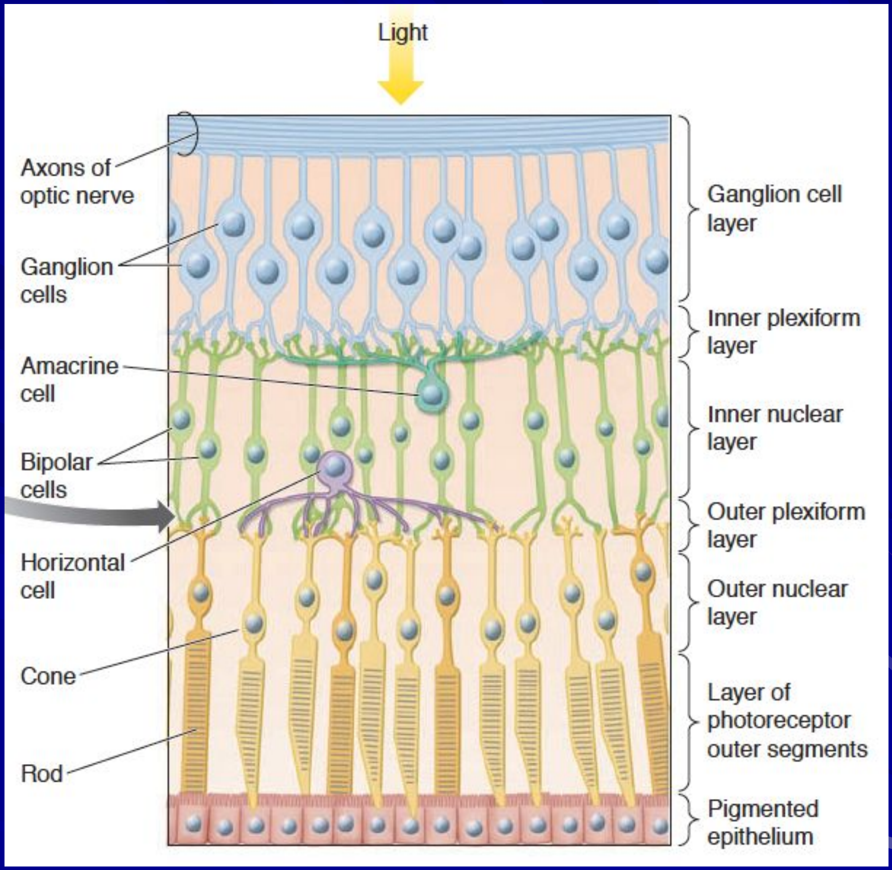
## Ganglion Cells

- Retinal ganglion cells come in two main types

1. M (midget) cells
2. P (parasol) cells

- M cells are tuned to detect rapid motion.
- P cells, in contrast, preserve color information that is coded by the cone system.

- M and P cells send their output to different destinations within the brain.



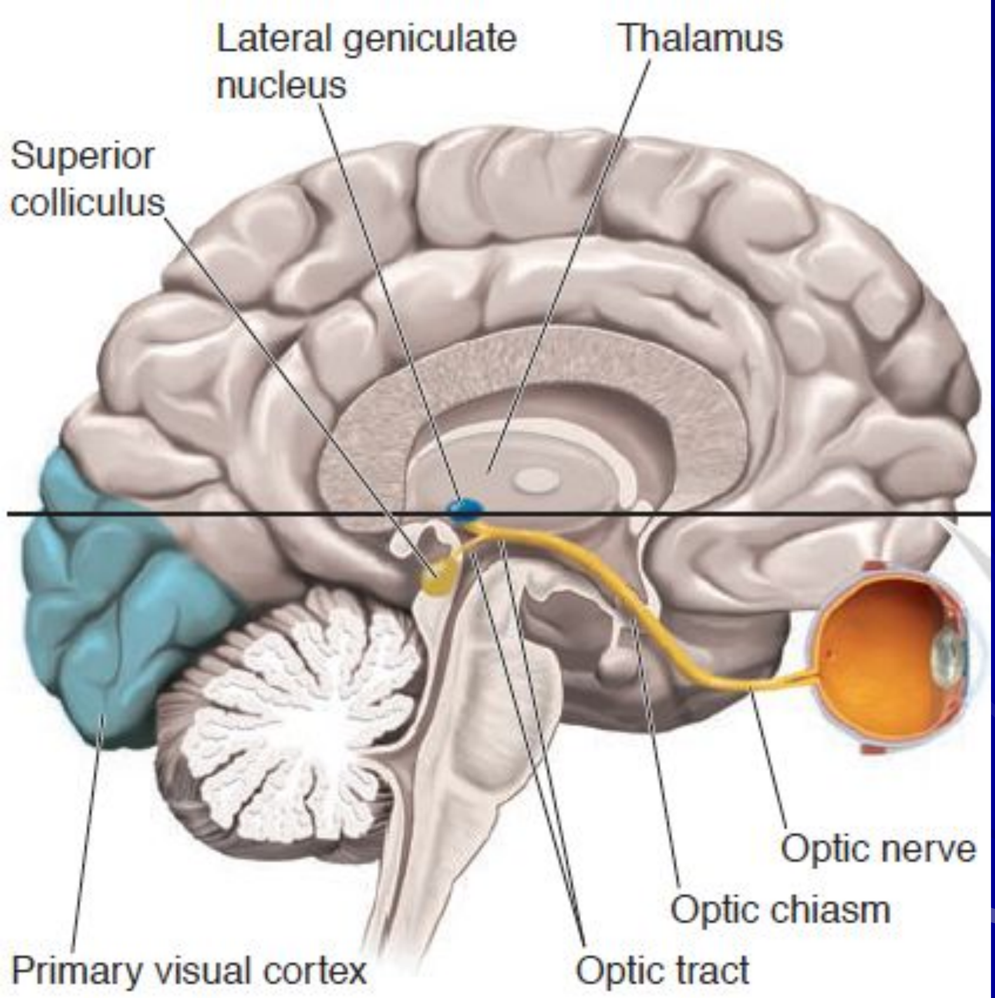
# Visual Processing

Pathways from the Retina to the Brain

- There are two main destinations for visual information that travels out of the eye along the optic nerve:

1. the superior colliculus (midbrain region)
2. the lateral geniculate nucleus (in the thalamus, which then extends to *primary visual cortex*).

- In addition, minor projections extend to other brain regions (for example, the suprachiasmatic nucleus of the hypothalamus).

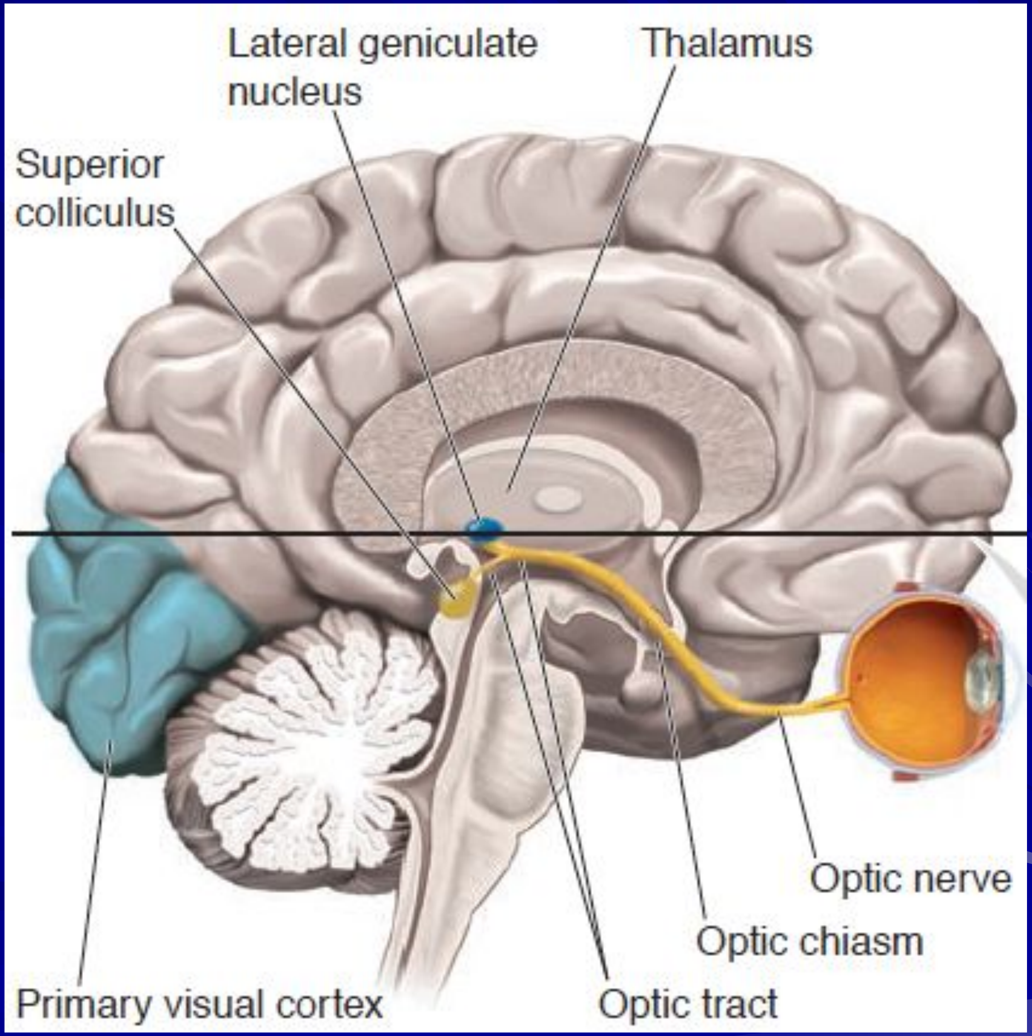


# Visual Processing

Pathways from the Retina to the Brain

The Tectopulvinar Pathway

- The tectopulvinar path allows people to orient quickly to important visual information.
- This path is very fast-acting and is especially sensitive to motion and appearances of novel objects in the visual periphery.
- It receives most of its input from M ganglion cells.

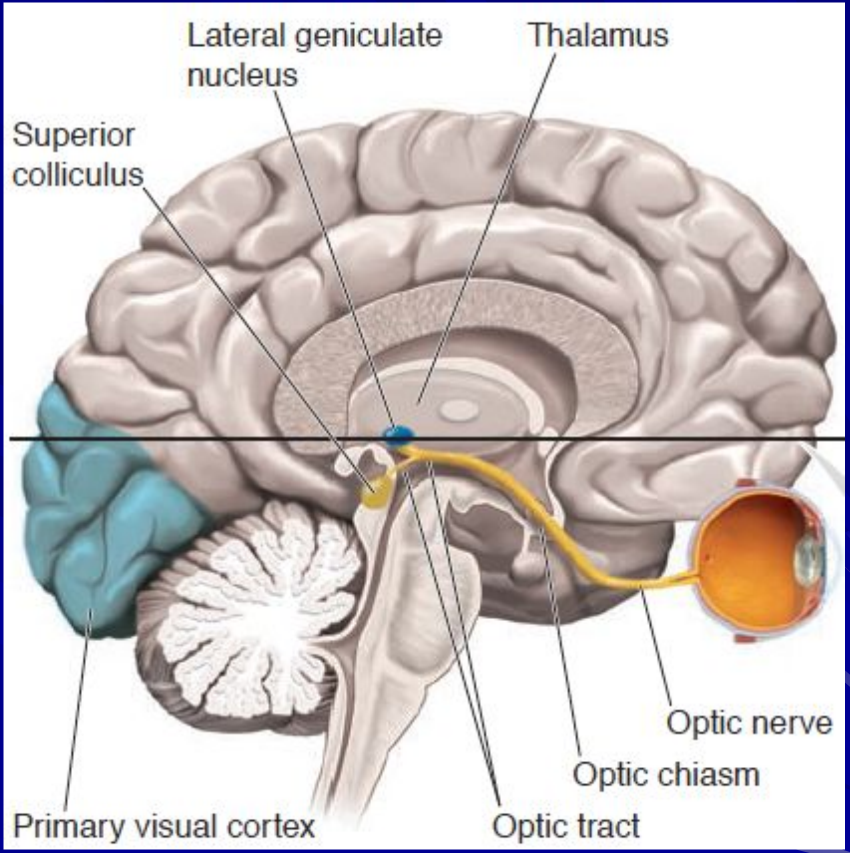


# Visual Processing

Pathways from the Retina
to the Brain

The Tectopulvinar Pathway

- It is also a site for integration of the auditory and visual senses. Some individual neurons within deep layers of the superior colliculus are responsive to both auditory and visual inputs in a synergistic way.
- From the superior colliculus, the tectopulvinar pathway extends "upstream" to the pulvinar nucleus in the thalamus and to cortical areas that govern eye and head movements.
- The superior colliculus also sends projections "downstream" to brainstem areas that control eye muscles.

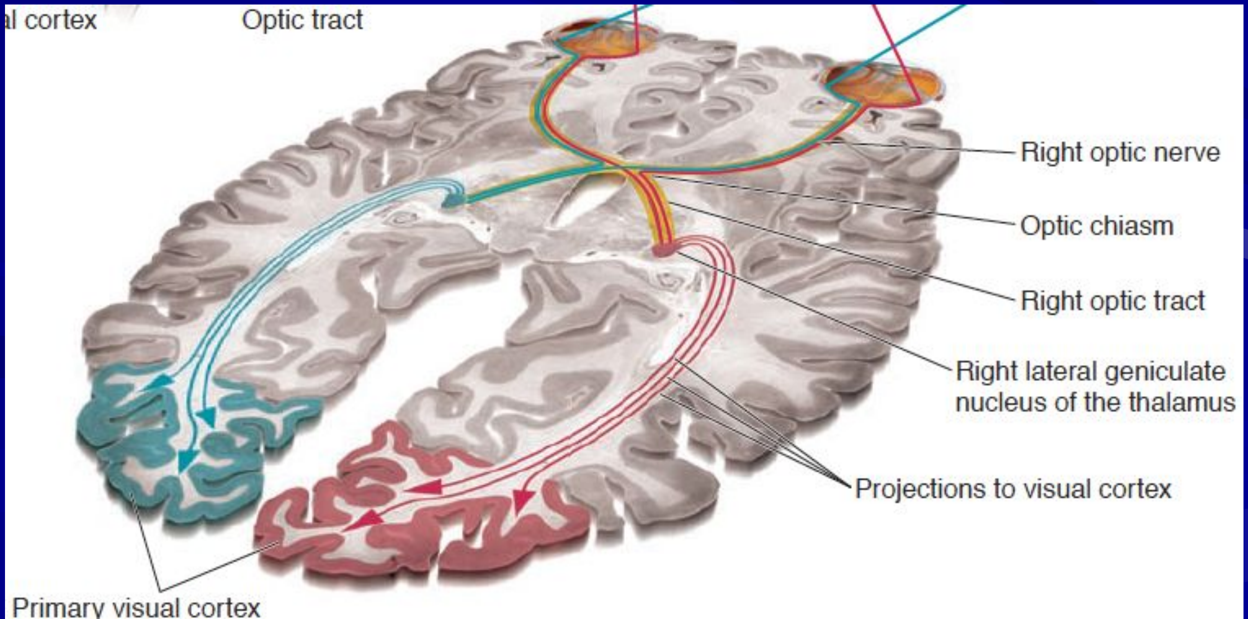


# Visual Processing

Pathways from the Retina to the Brain

The Geniculostriate Pathway

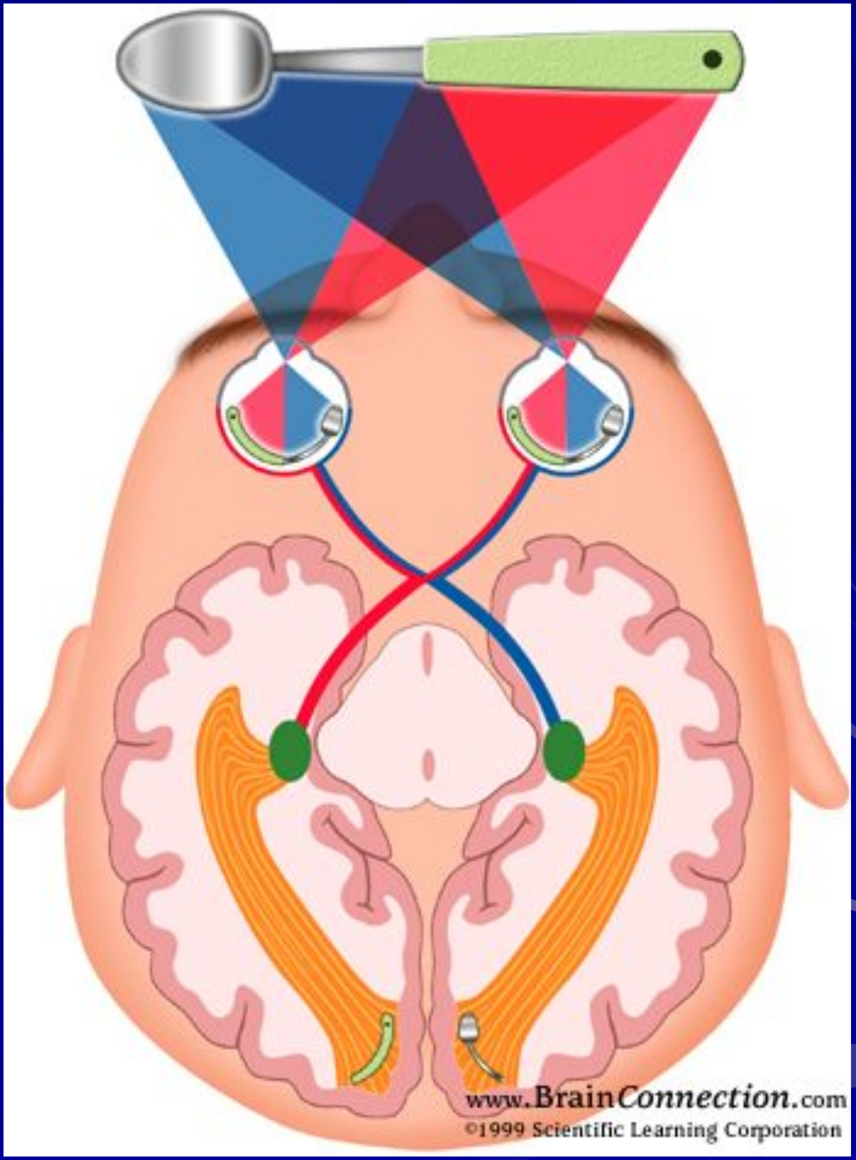
- Approximately 90% of optic nerve fibers project to the geniculostriate pathway.
- Through this path, we are able to perceive color and all the fine-grained features of objects.
- The axons in the optic nerve terminate in the lateral geniculate nucleus (in the thalamus).
- From there, the information continues to the primary visual cortex



# Visual Processing

The Geniculostriate Pathway

- Information from the right sides of both retinas is sent on to the LGN on the right side of the brain, while information from the left sides of both retinas is sent on to the LGN on the left side of the brain.
- The crossover point is called the optic chiasm.
- Once the optic nerve fibers cross at the optic chiasm, they are referred to as the optic tract.
- As a result, the right LGN receives information only about the left half of the world (from both eyes) whereas the left LGN receives information only about the right half of the world (from both eyes).

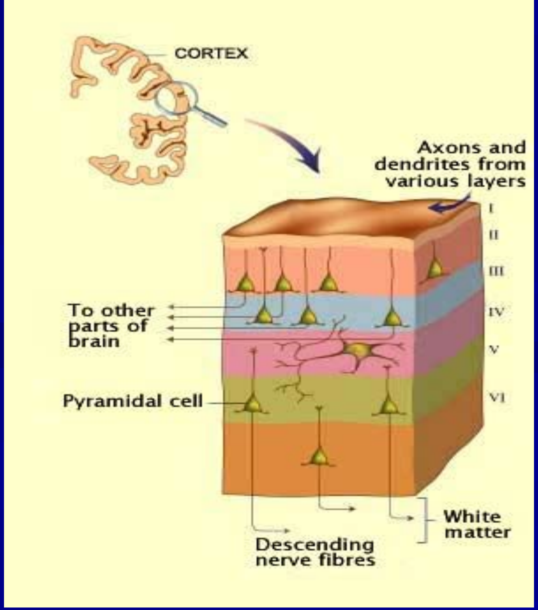


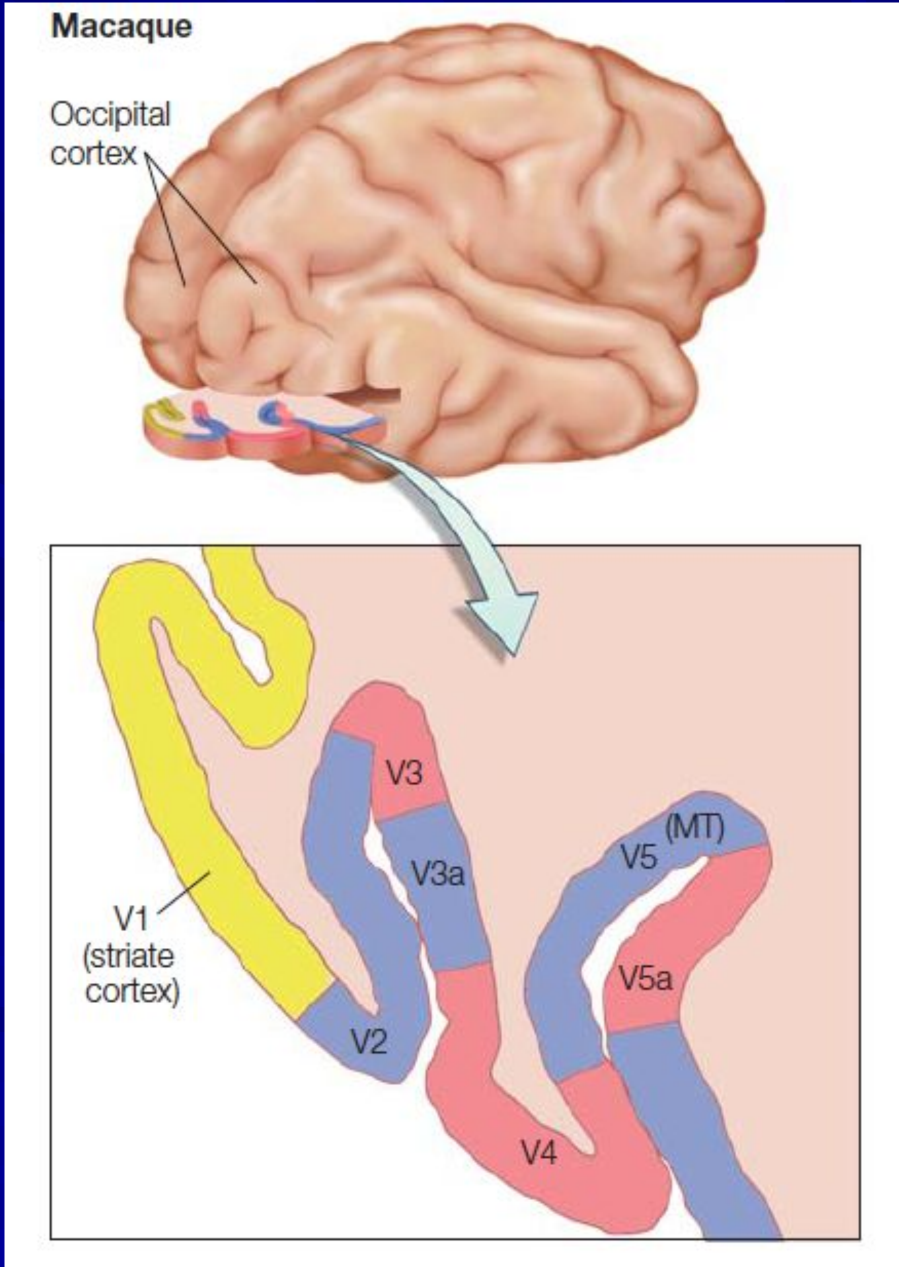
# Visual Processing

Primary Visual Cortex

(Striate Cortex or V1)

- The first destination within the cortex is the primary visual cortex in the occipital lobe.
- Specifically, projections from the parvocellular and magnocellular LGN layers enter layer 4 within the six-layered cortex.

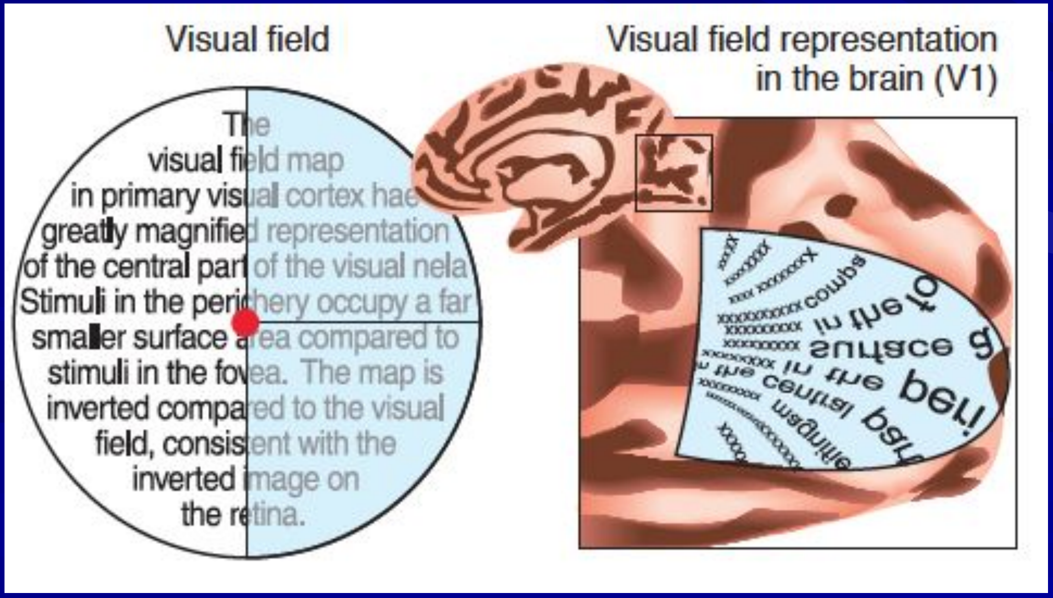


# Visual Processing

## Primary Visual Cortex (Striate Cortex or V1)

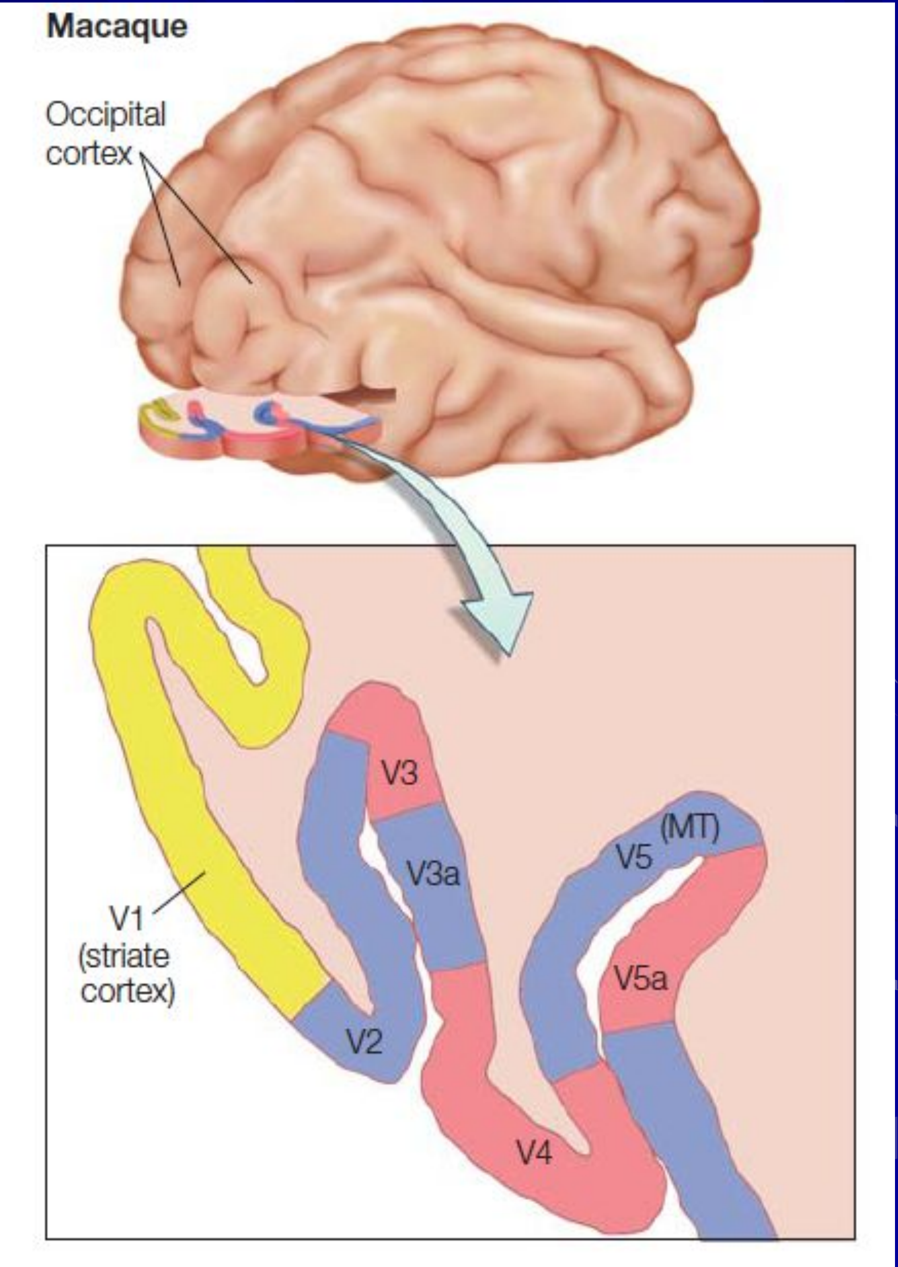
- The V1 contains a map that is retinotopically organized:
- Neighboring cells in an V1 receive input from neighboring ganglion cells in the retina, so they code for neighboring regions of the visual world, preserving the spatial organization of light patterns in the world.
- Cortical magnification factor - much more of primary visual cortex is devoted to representing information from the center of the visual field than from the periphery



# Visual Processing

## Visual Areas beyond the Striate Cortex

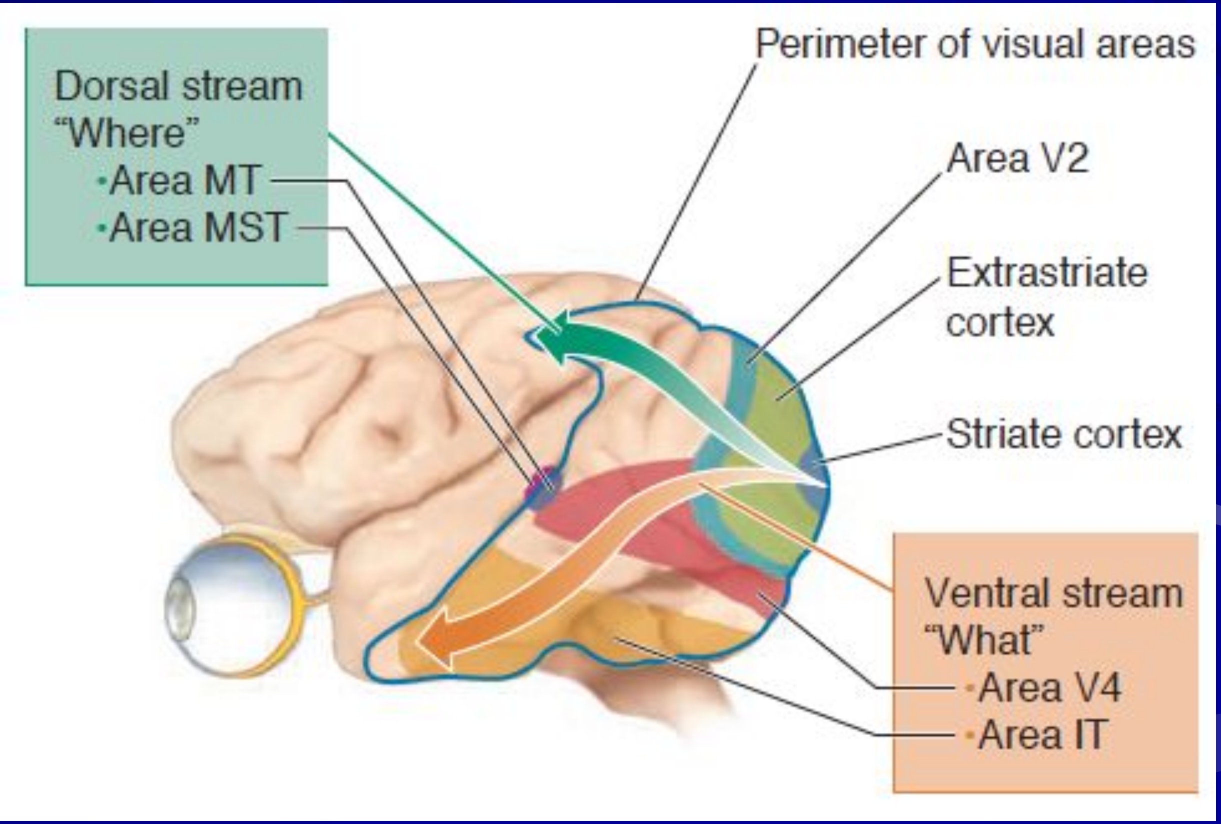
- Striate cortex provides a representation of numerous features of the visual world, but that information must be further processed and transformed before it can be fully useful in understanding and acting upon the world
- Figure illustrates the location of several of additional regions, named V2, V3, and V4, V5 in the macaque monkey brain.
- We do not really know the functions of all these areas.
- Area V5 has been linked to motion perception
- Area V4 has been posited to play a special role in color perception.



# Visual Processing

Dorsal and ventral streams for visual information

- The striate cortex projects both "downward," (ventrally), in the brain toward the inferior temporal cortex, and also upwards (dorsally), in the brain toward the parietal lobe
- As information travels along either of these two pathways out of the striate cortex, it undergoes further transformations to serve the goals of higher level vision.



# Visual Processing

Dorsal and ventral streams for visual information

- Processing that occurs along these two paths, the ventral and dorsal paths, is thought to serve two main goals of vision:

1. identifying objects ("what" function) – ventral path
2. representing spatial locations ("where" function) - dorsal path