The Visual System: Higher Visual Processing

Primary visual cortex

The primary visual cortex is located in the occipital cortex. It receives visual information exclusively from the contralateral hemifield, which is topographically represented and wherein the fovea is granted an extended representation.

Like most cortical areas, primary visual cortex consists of *six layers*. It also contains, however, a prominent stripe of white matter in its layer 4 - the *stripe of Gennari* - consisting of the myelinated axons of the lateral geniculate nucleus neurons. For this reason, the primary visual cortex is also referred to as the *striate cortex*.

The LGN projections to the primary visual cortex are segregated. The axons of the cells from the magnocellular layers terminate principally within *sublamina 4Ca*, and those from the parvocellular layers terminate principally within *sublamina 4Cb*.

Ocular dominance columns

The inputs from the two eyes also are segregated within layer 4 of primary visual cortex and form alternating *ocular dominance columns*. Alternating ocular dominance columns can be visualized with *autoradiography* after injecting radiolabeled amino acids into one eye that are transported transynaptically from the retina.

Although the neurons in layer 4 are monocular, neurons in the other layers of the same column combine signals from the two eyes, but their activation has the same ocular preference.

Bringing together the inputs from the two eyes at the level of the striate cortex provide a basis for *stereopsis*, the sensation of depth perception provided by binocular disparity, i.e., when an image falls on non-corresponding parts of the two retinas.

Some neurons respond to disparities beyond the plane of fixation (*far cells*), while others respond to disparities in front of the plane of the fixation (*near cells*). These disparity sensitive neurons are “*depth detectors*”.

Primary visual cortex receptive fields

Unlike the small, concentric (center-surround) receptive fields of retinal and lateral geniculate nucleus cells, the receptive fields of primary visual cortex neurons are large, rather rectangular and come in three main classes: *simple*, *complex* and *hypercomplex*.

Simple cells have narrow, elongated excitatory and inhibitory zones that have a specific axis of *orientation*. These cells are "*line detectors*". Their receptive fields can be built from the convergent connections of lateral geniculate nucleus cells.

Complex cells have large receptive fields without clear excitatory or inhibitory zones. They respond best to a *moving edge* of specific orientation and direction of motion. These direction selective neurons are powerful "*motion detectors*". Their receptive fields could be built from the convergent connections of simple cells.

Hypercomplex cells have very large receptive fields that may combine complex cells' signals. Many of them respond best to an oriented edge that is *stopped*, i.e., its end does not extend beyond a specific part of the receptive field. Neurons with such a pattern of response act as "*angle detectors*".

Simple, complex and hypercomplex cells can work together to decompose the outlines of a visual image into short segments, the basis of simple and complex object recognition.

Orientation columns

Within the topographical organization of visual field in the primary visual cortex, *simple cells* with the same orientation preference are grouped together into *orientation columns*, organized with an orderly shift in orientation preference. The orientation preference of neurons with similar receptive fields changes in a continuous fashion to form a pinwheel-like area (1-mm diameter). The map of orientation preference is then repeated for neurons with adjacent receptive fields.

Blob regions

The systematic shifts in orientation preference from one column to another is occasionally interrupted by *blobs*, peg-shaped regions of cells in layers 2-3, which contain neurons responsive to *brightness* and *color* but not to orientation. Blobs can be revealed by examining the density of *cytochrome oxydase*, a mitochondrial enzyme involved in energy production. The heightened enzymatic activity in the blobs is thought to represent heightened neural activity.

Hypercolumns

A hypercolumn is a set of columns responsive to lines of all orientations from a particular region in the visual field and viewed by both eyes.

Ventral and dorsal processing streams

The parvocellular and magnocellular pathways that originate in the retina remains segregated within the striate cortex and feed into two processing pathways in extrastriate cortex.

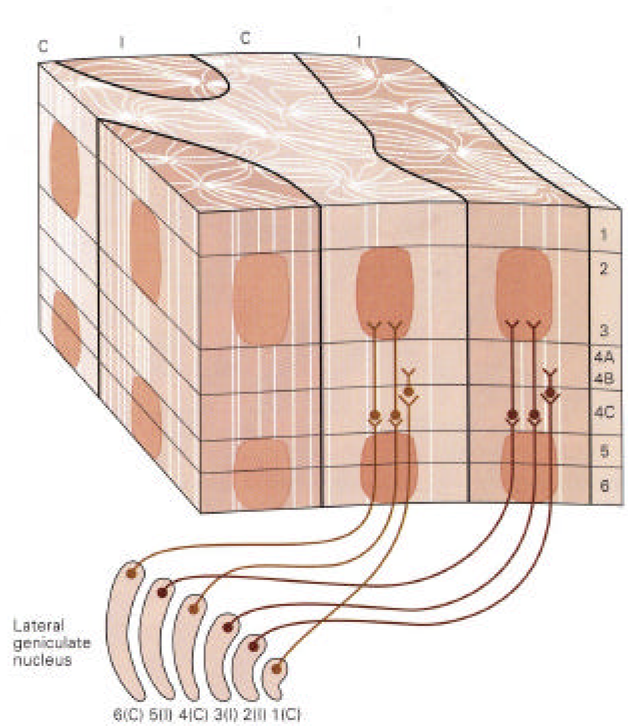
Motion processing is accomplished within the dorsal pathway: LGN magno layers → V1 layer 4Cα → V1 layer 4B → V2 thick stripes → MT
Color processing is accomplished within the ventral pathway: LNG parvo layers → V1 layer 4Cβ → V1 blobs → V2 thin stripes → V4

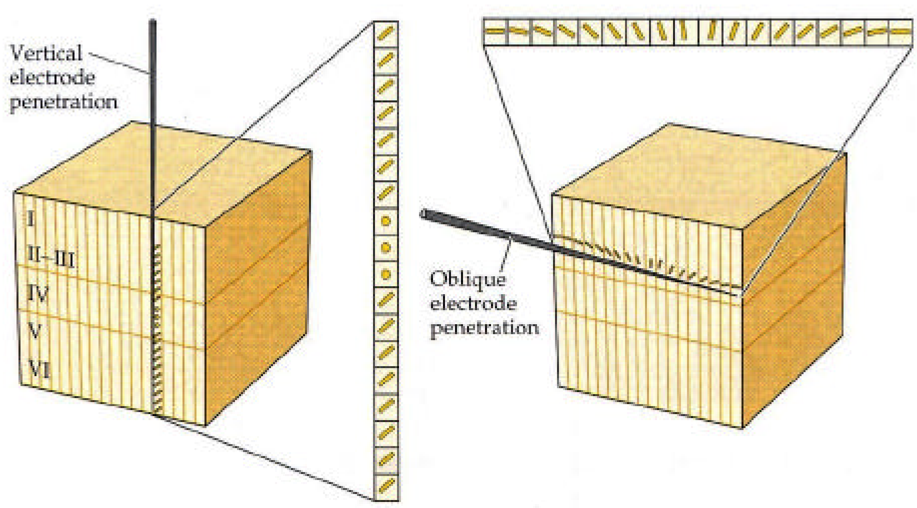
Color processing is accomplished within the ventral pathway: LGN parvo layers → V1 layer 4Cβ → V1 interblobs → V2 interstripes → V4 & IT

Positron emission tomographic (PET) scans in human subjects show increase in cerebral flow in: 1) *area MT* (V5) while they view a monochromatic scene in motion, and 2) *area V4* while they view a stationary colorful scene.

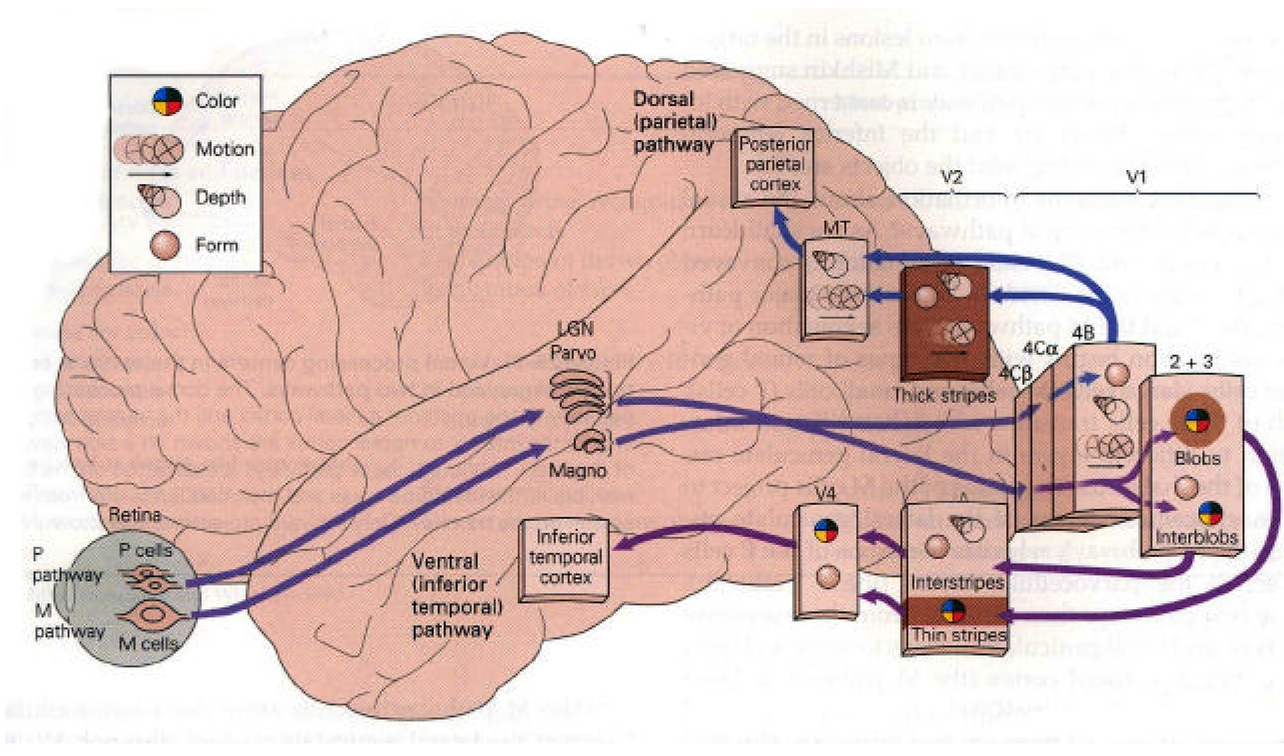
Neurons in the ventral stream exhibit properties that are important for object recognition. At the highest levels in this pathway, neurons in the inferior temporal cortex respond preferentially to faces. Furthermore, lesions to these areas produce prosopagnosia, a deficit in face recognition.

It should be kept in mind that within these ventral and dorsal streams of visual processing, visual neurons are not passively responding to visual stimulation. Their responses are constantly modified by *selective attention*.





Vertical electrode penetration
I
II–III
IV
V
VI
Oblique electrode penetration



Color
Motion
Depth
Form
Dorsal (parietal) pathway
Posterior parietal cortex
V2
V1
MT
Thick stripes
4Cα
4B
4Cβ
2 + 3
Blobs
Interblobs
LGN
Parvo
Magno
Retina
P pathway
P cells
M pathway
M cells
Ventral (inferior temporal) pathway
Inferior temporal cortex
V4
Interstripes
Thin stripes