

## Vision III: Cortical mechanisms of vision

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Please sit where you can examine a partner.

Michael E. Goldberg, M.D.

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## First you tell them what you're gonna tell them

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- The cortical visual system is composed of multiple visual areas with different functions.
- V1 neurons describe object features.
- The principle of columnar organization.
- Two visual streams – 'what' and 'how' (or 'where').
- MT neurons describe motion and depth (dorsal stream).
- IT neurons describe objects (ventral stream).

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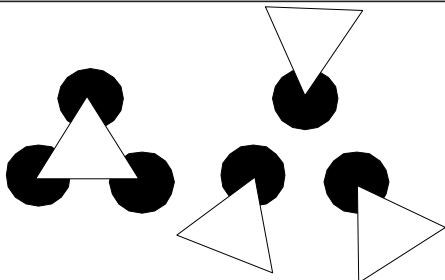
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See the triangle?

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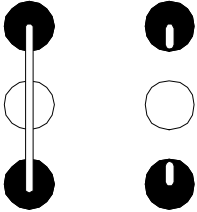
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See the white bar?



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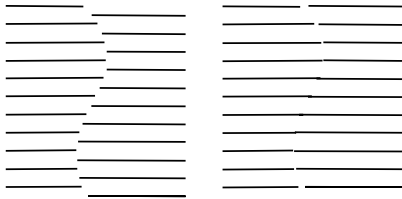
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See the wavy line?



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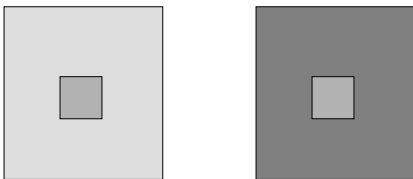
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Which small square is darker?



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The striate cortex – V1 – builds more sophisticated receptive fields from these basic building blocks. Cells describe specific

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- Contour orientations.
- Binocular interaction.
- Speed and direction of motion.
- Color.

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David Hubel and Torsten Wiesel won a Nobel Prize in 1981 for describing the properties of striate cortical neurons

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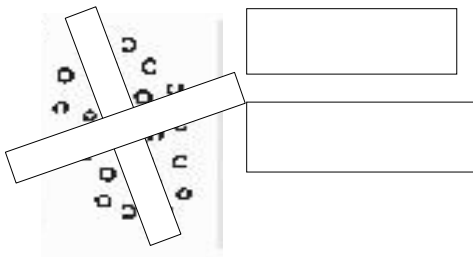
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V1 simple cell is most responsive to an oriented line

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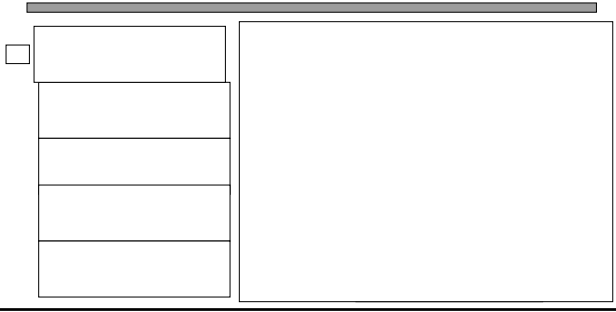
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### Orientation tuning in a V1 simple cell



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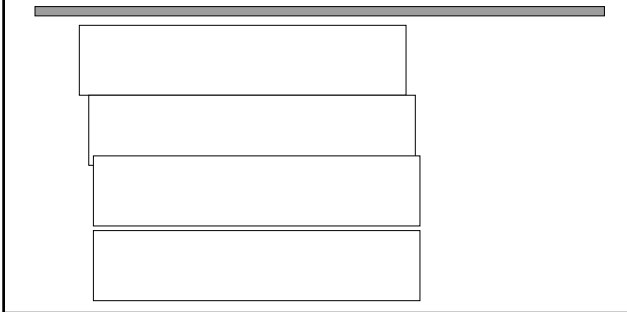
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### V1 complex cells are sensitive to orientation of stimuli



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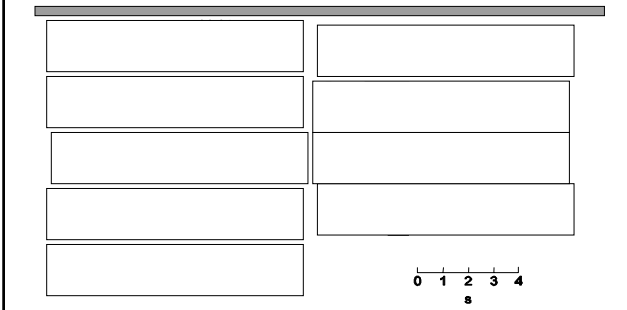
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### But not particularly to stimulus position within the receptive field



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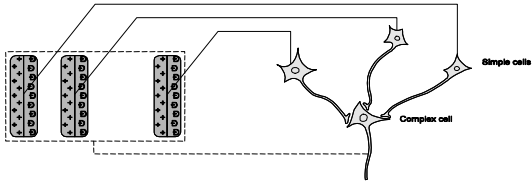
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Complex cells can be constructed from an array of similarly oriented simple cells




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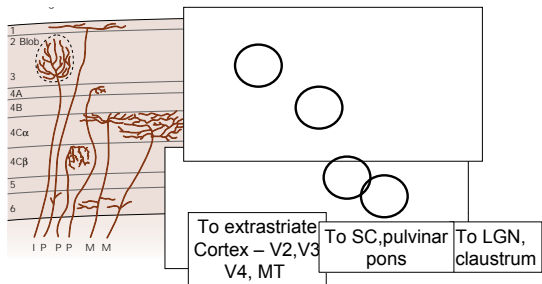
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The cerebral cortex is organized in a columnar manner




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Within a column

- Information is processed and transformed from monocular, center-surround, non-directionally selective input to
  - Orientation-
  - Binocular disparity-
  - Direction-selective output
- Processed information is distributed
  - Layers 2-3 to other cortical areas
  - Layer 5 to the superior colliculus
  - Layer 6 to the lateral geniculate nucleus
- This general arrangement of columnar processing is maintained throughout the cortex, not just visual cortex.

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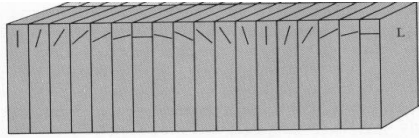
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Cells with similar orientation preferences lie in the same column



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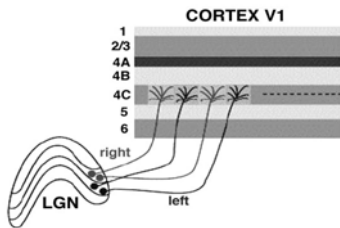
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Geniculate cells representing the same area of the visual field but arising from different eyes project to adjacent areas of V1



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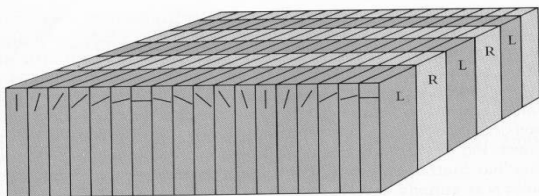
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Orientation columns with the same monocular lateral geniculate input lie in the same ocular dominance column.



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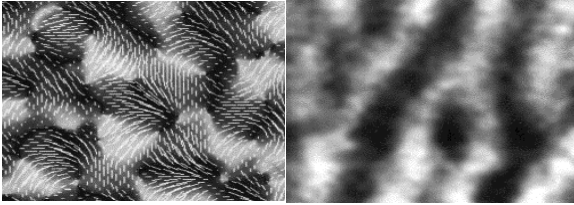
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# The actual topology of orientation and ocular dominance columns



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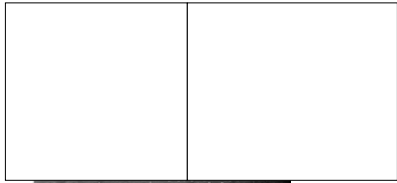
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Color sensitive cells lie at the center of the pinwheels, in cytochrome oxidase containing 'blobs.'



Color sensitive cells are mostly unoriented

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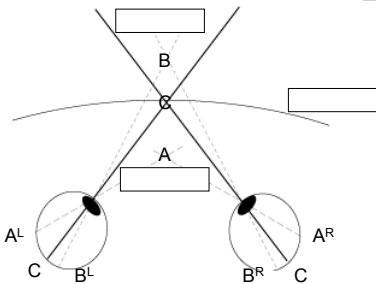
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# Depth perception starts with the detection of binocular disparity



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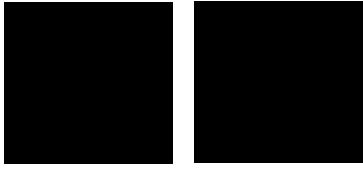
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Random dot stereograms generate structure from disparity



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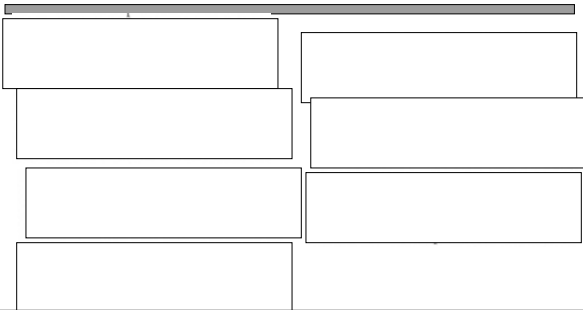
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Disparity selectivity in a V1 neuron



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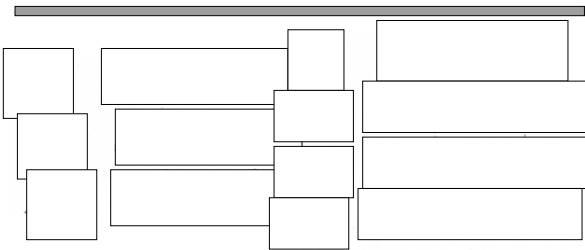
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Motion selectivity in a V1 neuron



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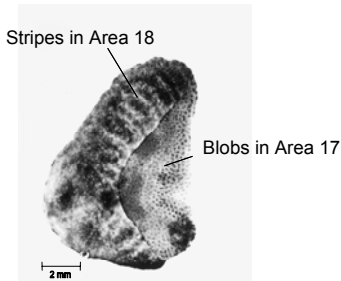
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## V2 (Area 18) also is divisible by cytochrome oxidase staining



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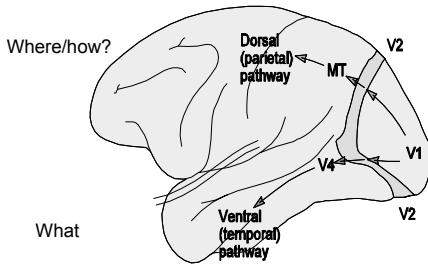
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## Two cortical visual streams subserve two different visual functions.



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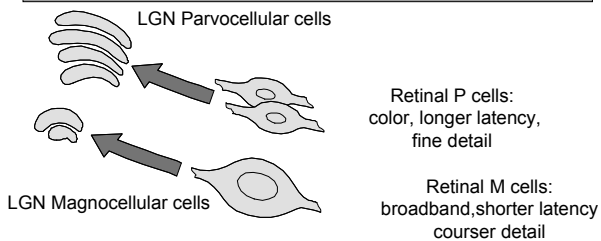
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## Functional separation begins in the retina and continues through the LGN



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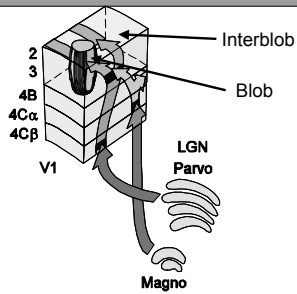
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And continues in V1




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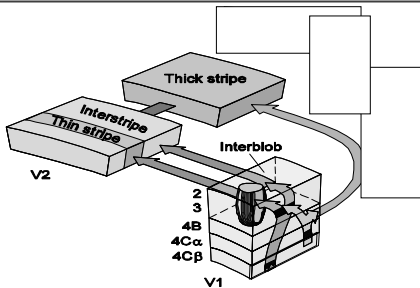
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And V2




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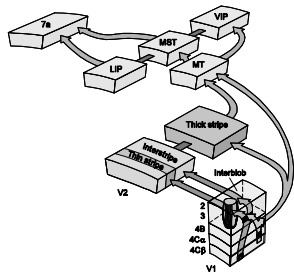
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After V2, different functions are performed by anatomically different areas:  
The dorsal stream provides vision for action – "where and how"




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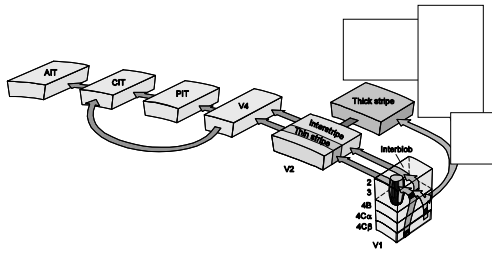
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After V2, different functions are performed by anatomically different areas:  
The ventral stream provides vision for object identification




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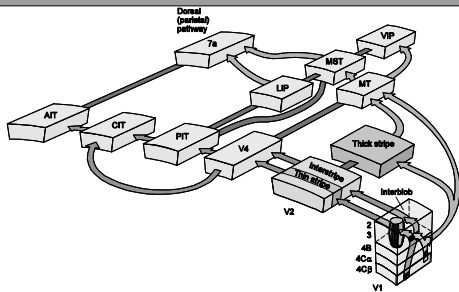


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After V2, different functions are performed by anatomically different areas:  
But the areas are interconnected




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## MT – the analysis of motion

- Neurons in MT are selective for speed and direction of motion, and retinal disparity.
- Neurons in MT report the perceptual aspects of motion.
- Electrical stimulation of MT affects the perception of motion.

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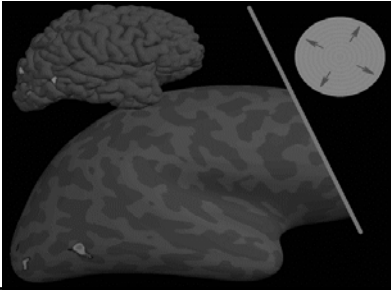


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# Human MT



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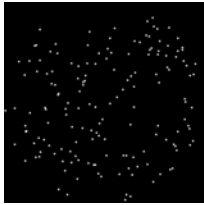
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# Structure from motion



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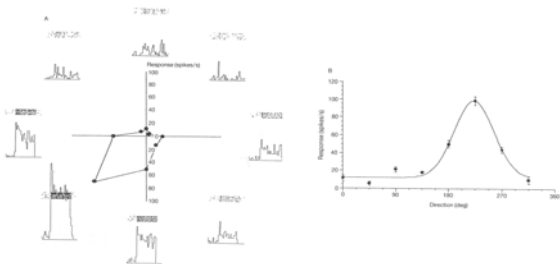
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# MT Cells are tuned for direction



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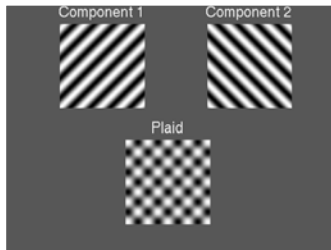
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## Perceived motion in a plaid



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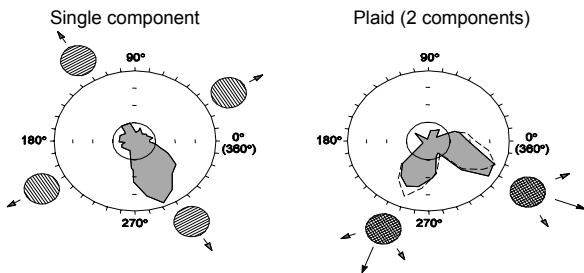
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## Striate neurons respond to the components of the plaid



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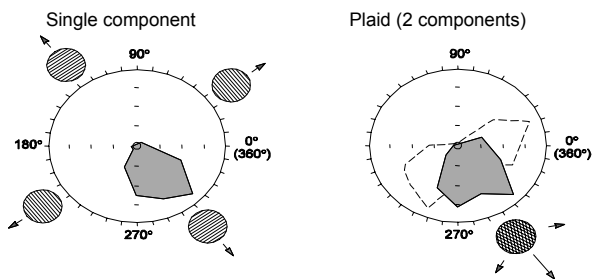
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## MT responds to the direction of the plaid, and not the components



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MT has columns for direction of motion



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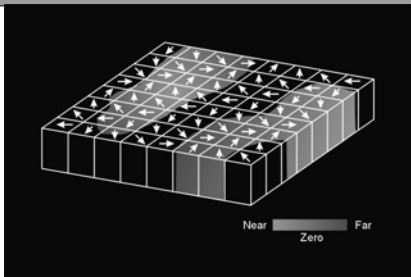
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MT has disparity columns



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Electrically stimulating an orientation column  
in MT induces the perception of motion  
described by that column



100% coherence

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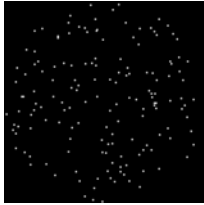
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Electrically stimulating an orientation column in MT induces the perception of motion described by that column



50% coherence

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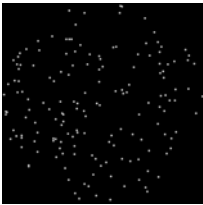
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Electrically stimulating an orientation column in MT induces the perception of motion described by that column



No coherence

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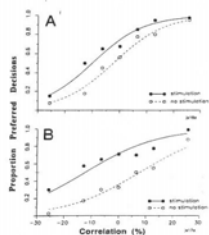
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Electrically stimulating an orientation column in MT induces the perception of motion described by that column



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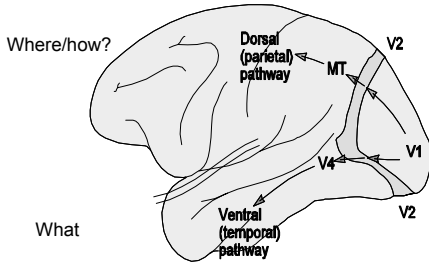
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The parietal lobe describes the world for action, location, and attention.



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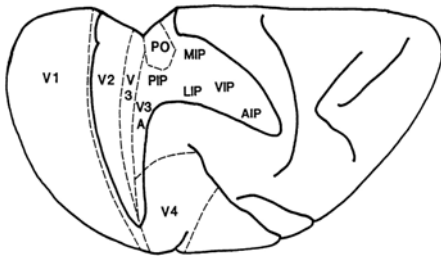
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There are multiple representations of the visual field in the intraparietal sulcus



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Within the dorsal stream there is further functional segregation –

- MT is specialized for depth and motion.
- LIP is specialized for attention in far space.
- MIP is specialized for providing visual information to the arm-reaching area.
- AIP is specialized for providing visual information for grasping.
- VIP is specialized for providing visual information for mouth and head movements.

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## Patients demonstrate this functional segregation

- Patients with V1 lesions generally have total visual field deficits in the affected field.
- Patients with more anterior lesions can have loss of specific functions:
  - Color agnosia
  - Blindness for motion
  - Dissociation of object vision and vision for action
  - Neglect

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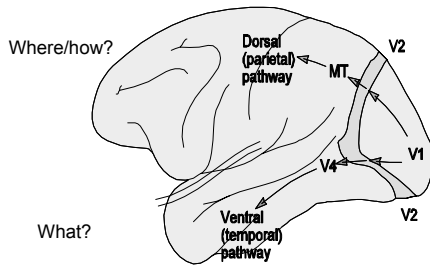
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## The inferior temporal lobe describes the visual world for object recognition



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## Neurons in inferior temporal cortex are selective for complex patterns like faces


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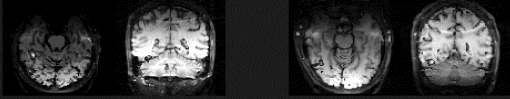
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## The Fusiform Face Area (FFA)

*Kanwisher, McDermott, & Chun (1997)*



- Responds during passive viewing of faces > objects.
- Cannot be explained in terms of
  - » differences in low-level features
  - » attentional confounds
  - » subordinate - level categorization of any stimulus class
  - » generalized response to anything animate/human
- Is selectively involved in perception of faces.

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## Patients with inferior temporal lesions have visual agnosia



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## Prosopagnosia "face blindness"

- Term first used by Bodamer, 1947
- Inability to recognize familiar faces
- Visual acuity is normal
- Caused by lesion to right inferior temporal lobe
- May be congenital ("developmental prosopagnosia")
- Patients compensate by using other recognition cues: clothing, gait, voice, etc.

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## Finally, you tell them what you told them

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- The striate cortex (V1) uses unoriented, monocular input from the lateral geniculate to assemble cells selective for orientation, motion, and retinal disparity.
  - Striate cortex is organized in columns with similar orientation and ocular dominance.
  - Two visual streams emanate from V1: a dorsal stream concerned with analyzing the visual world for location and action, and a ventral stream concerned with analyzing the nature of objects in the visual world. Different areas subsume different spatial and object attribute functions.
  - Clinical deficits include specific deficits for color, faces, motion, visual targeting of motion, and spatial localization.

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