Vision III: Cortical mechanisms of vision

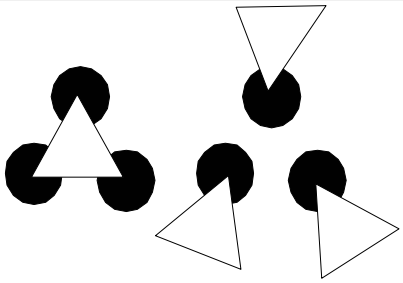
Please sit where you can examine a partner.

Michael E. Goldberg, M.D.

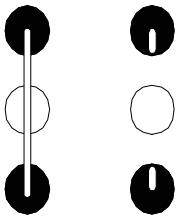
First you tell them what you're gonna tell them

- 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).

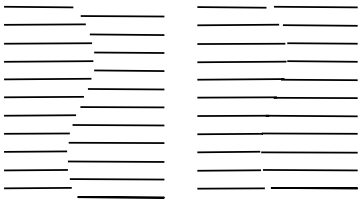
See the triangle?



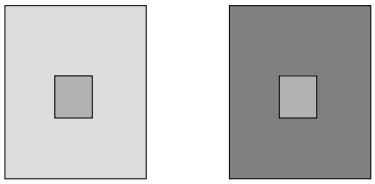
See the white bar?



See the wavy line?



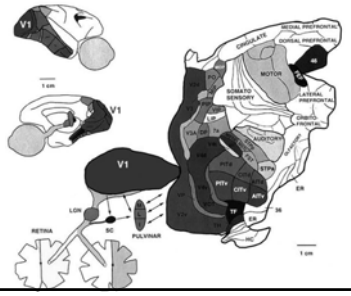
Which small square is darker?



So

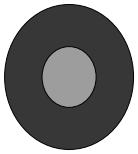
- Your visual system does not measure and report the exact physical nature of the visual world.
- It collects some data, and makes guesses.
- Optical illusions take advantage of the guessing strategies.

Roughly 40% of cerebral cortex is involved in vision



Remember

- Receptive fields in the retina and the lateral geniculate are circular, with center – surround organization.



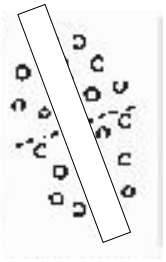
Off surround - inhibits

On center - excites

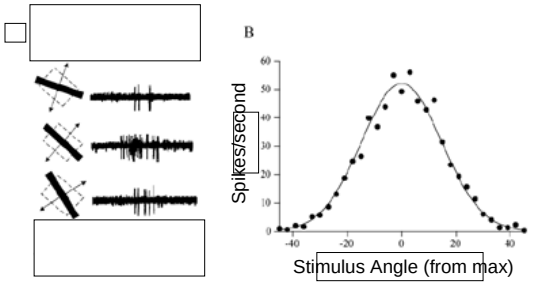
The striate cortex – V1 – builds more sophisticated receptive fields from these basic building blocks. Cells describe specific

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

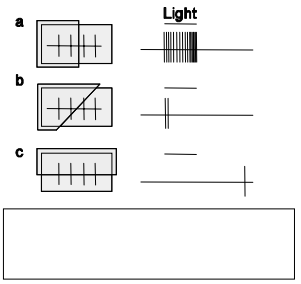
V1 simple cell is most responsive to an oriented line



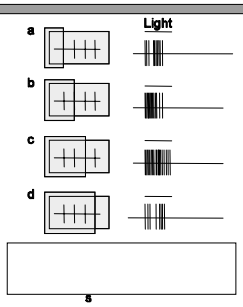
Orientation tuning in a V1 simple cell



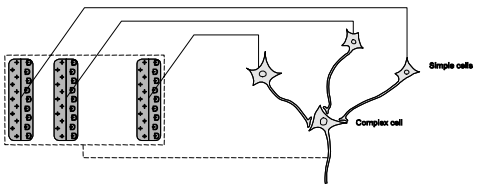
V1 complex cells are sensitive to orientation of stimuli



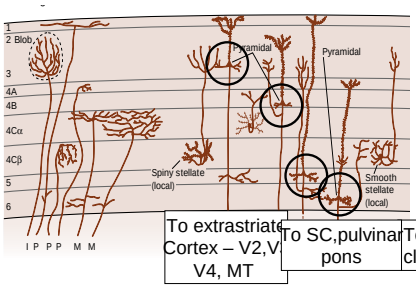
But not particularly to stimulus position within the receptive field



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



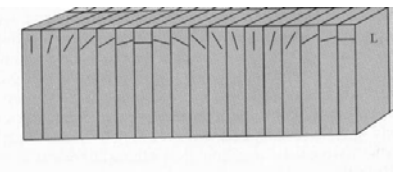
The cerebral cortex is organized in a columnar manner



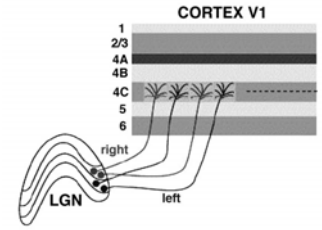
Within a column

- 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.

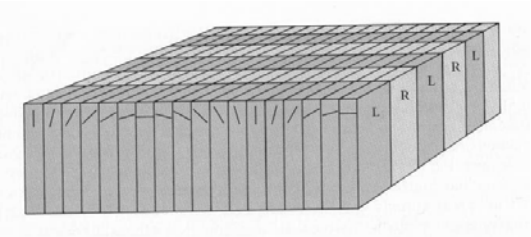
Cells with similar orientation preferences lie in the same column



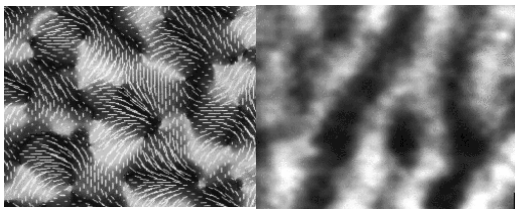
Geniculate cells representing the same area of the visual field but arising from different eyes project to adjacent areas of V1



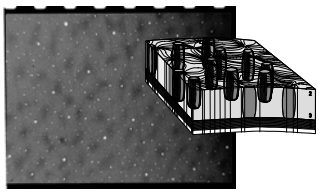
Orientation columns with the same monocular lateral geniculate input lie in the same ocular dominance column.



The actual topology of orientation and ocular dominance columns

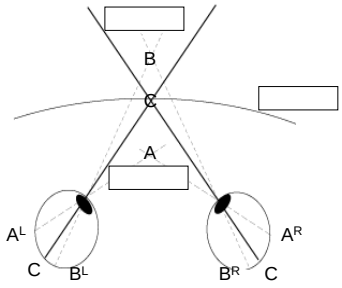


Color sensitive cells lie at the center of the pinwheels, in cytochrome oxidase containing 'blobs.'



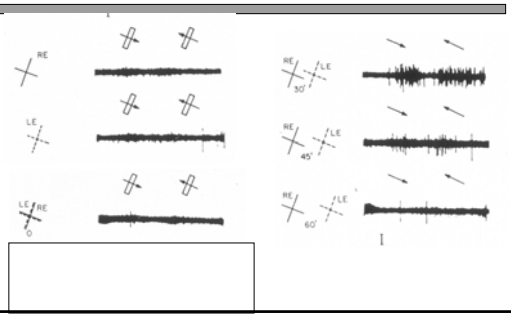
Color sensitive cells are mostly unoriented

Depth perception starts with the detection of binocular disparity

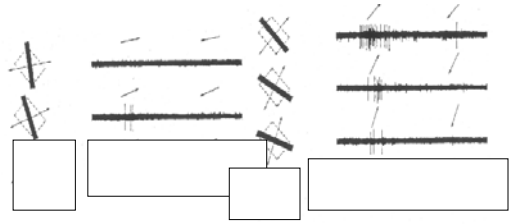


Random dot stereograms generate structure from disparity

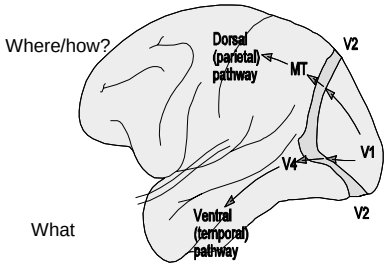
Disparity selectivity in a V1 neuron



Motion selectivity in a V1 neuron



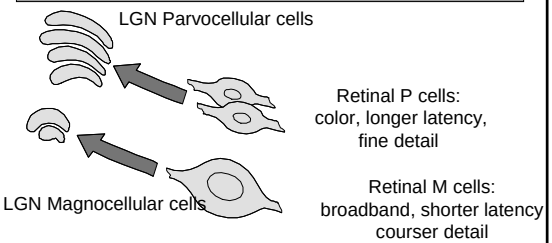
Two cortical visual streams subserve two different visual functions.



Patients demonstrate this functional segregation

- Patients with V1 lesions generally have total visual field deficits in the affected field.
- Patients with dorsal stream lesions have deficits in sensory location (and attention), motion perception, color perception, and the performance of visually-guided movements.
- Patients with ventral stream lesions have visual agnosia, the inability to associate a visual stimulus with a name or function.

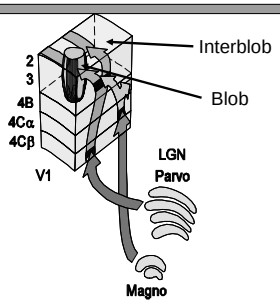
Functional separation begins in the retina and continues through the LGN



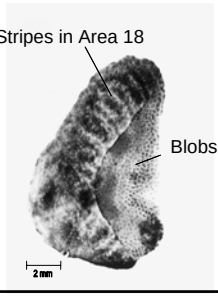
Retinal P cells: color, longer latency, fine detail

Retinal M cells: broadband, shorter latency courser detail

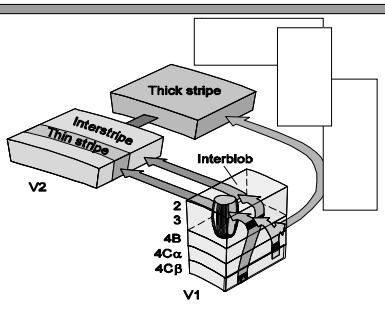
And continues in V1



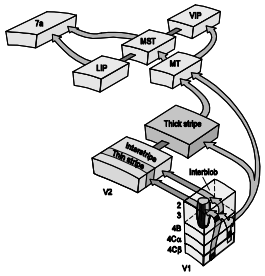
V2 (Area 18) also is divisible by cytochrome oxidase staining



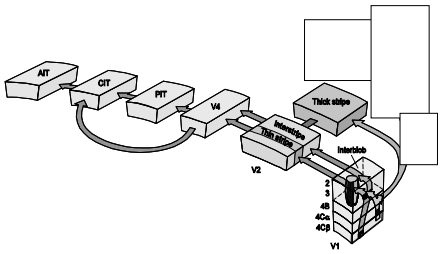
Functional separation continues in V2



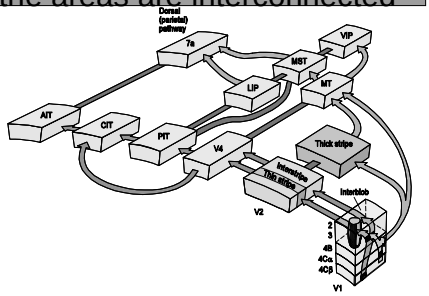
After V2, different functions are performed by anatomically different areas: The dorsal stream provides vision for action –"where and how"



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



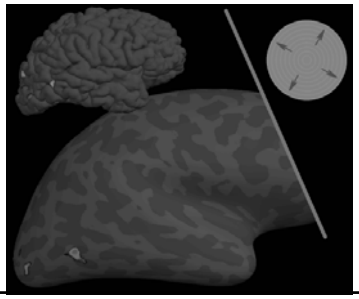
After V2, different functions are performed by anatomically different areas: But the areas are interconnected



MT – the analysis of motion

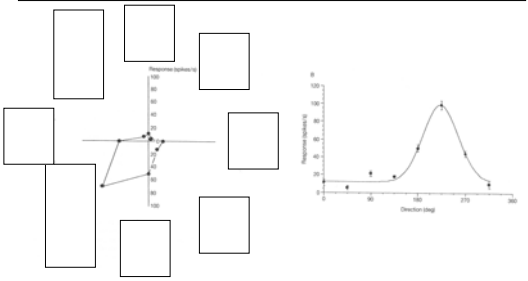
- Neurons in MT are selective for speed and direction of motion, and retinal disparity.
- Neurons in MT report the perceptual aspects of motion.
- Electrical stimulation of MT affects the perception of motion.

Human MT

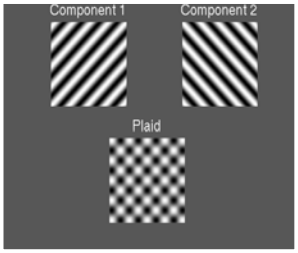


Structure from motion

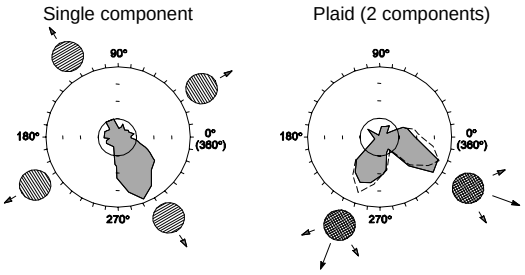
MT Cells are tuned for direction



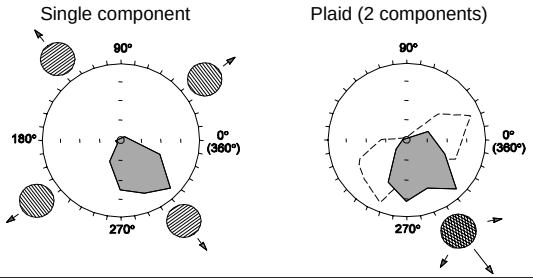
Perceived motion in a plaid



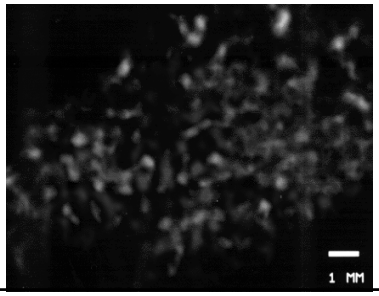
Striate neurons respond to the components of the plaid



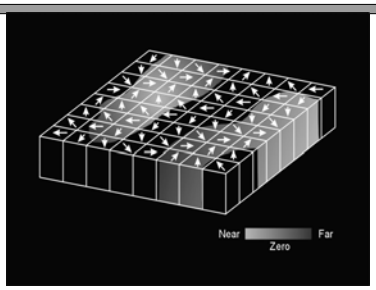
MT responds to the direction of the plaid, and not the components



MT has columns for direction of motion



MT has disparity columns



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

100% coherence

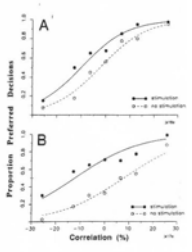
Electrically stimulating an orientation column in MT induces the perception of motion described by that column

50% coherence

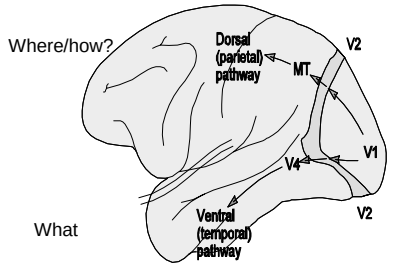
Electrically stimulating an orientation column in MT induces the perception of motion described by that column

No coherence

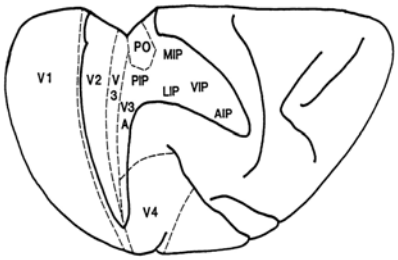
Electrically stimulating an orientation column in MT induces the perception of motion described by that column



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



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



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 for reaching.
- AIP is specialized for providing visual. information for grasping.
- VIP is specialized for providing visual. information for mouth and head

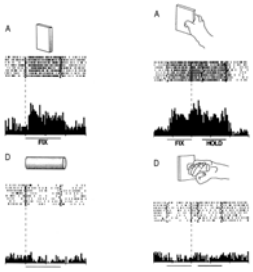
An example of a dorsal stream function

- When you reach for something, your grip opens to accommodate the size of your target.
- Patients with dorsal stream lesions can't do this.
- They can, however, describe the size of the object.

A patient with a dorsal stream lesion cannot orient her hand with respect to a slot

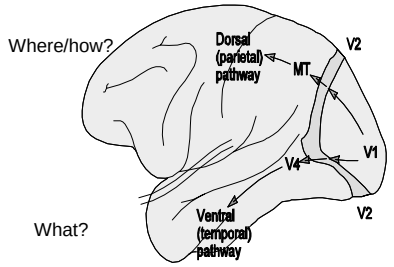
Neurons in AIP specialized for grip

Look at the object

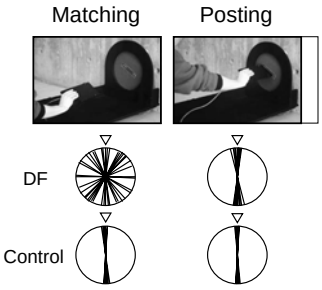


Reach for the object

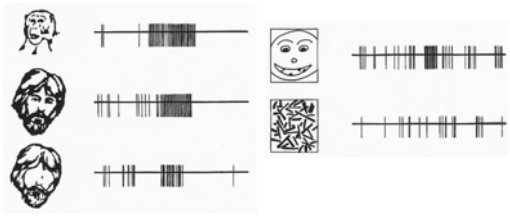
The inferior temporal lobe describes the visual world for object recognition



A patient with a ventral stream lesion can move her hand to a slot, but can't mimic the position.

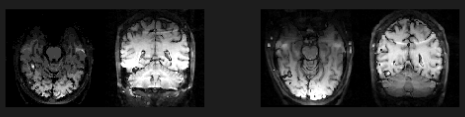


Neurons in inferior temporal cortex are selective for complex patterns like faces



The Fusiform Face Area (FFA)

Kanwisher, McDermott, & Chun (1997)

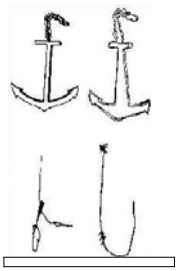


- Responds during passive viewing of faces > objects.
- Cannot be explained in terms of
  - differences in low-level features
  - attentional confounds
  - subordinate - level categorization of any stimulus class
  - generalized response to anything animate/human
- Is selectively involved in perception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

Patients with inferior temporal lesions have visual agnosia

Copy the drawing
Visuomotor function Intact – but patient can't name the object

Draw an anchor.
Patient cannot conceptualize the anchor



Ventral stream patients

- Cannot identify objects
- But they can make appropriate visually-guided movements.
- The patient who could not set her grip can still tell you which cylinder is thicker.
- The patient who cannot tell you which cylinder is thicker can set still her grip.

Prosopagnosia "face blindness" is the most dramatic ventral stream deficit

- 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.

Finally, you tell them what you told them

- The striate cortex (V1) uses unoriented, monocular input from the lateral geniculate to assemble cells selective for orientation,motion, and retinal disparity. Complex cells generalize the orientation information found in simple cells.
- 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