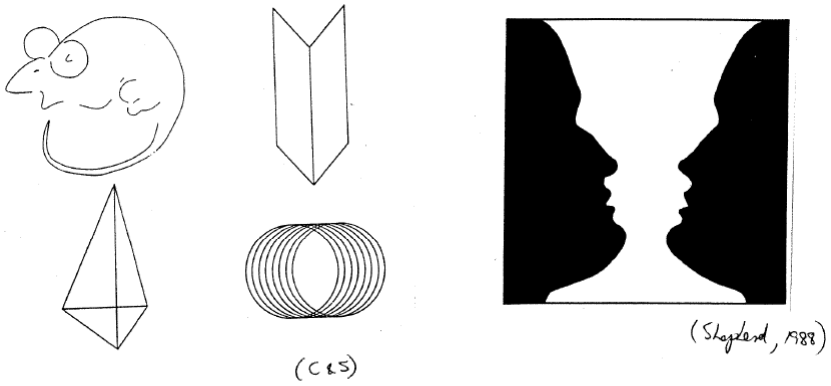
The Visual System

Computing and the Brain

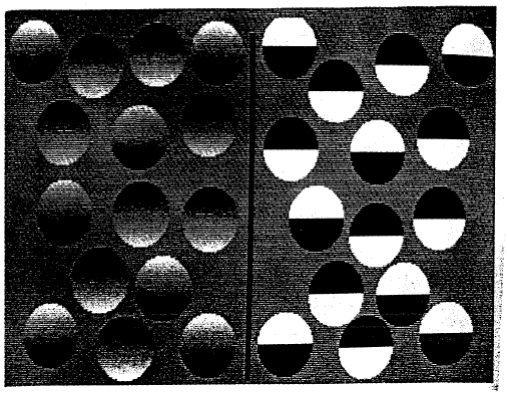
Visual Illusions

- Give us clues as to how the visual system works
  - We see what we expect to see
  - http://illusioncontest.neuralcorrelate.com/



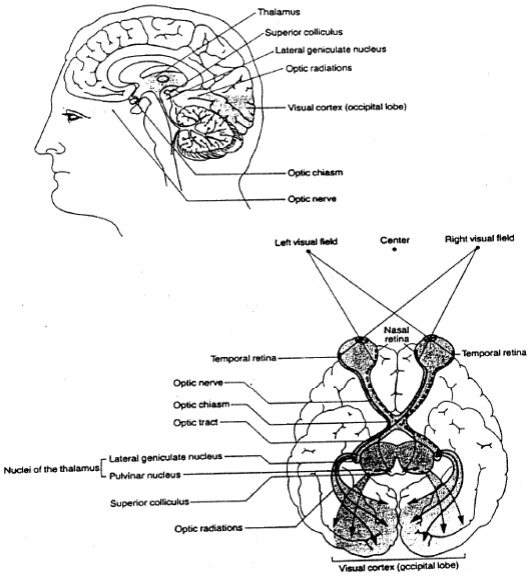
Visual Illusions (2)

- We interpret shading as depth information



(CS92 Fig 4.5)

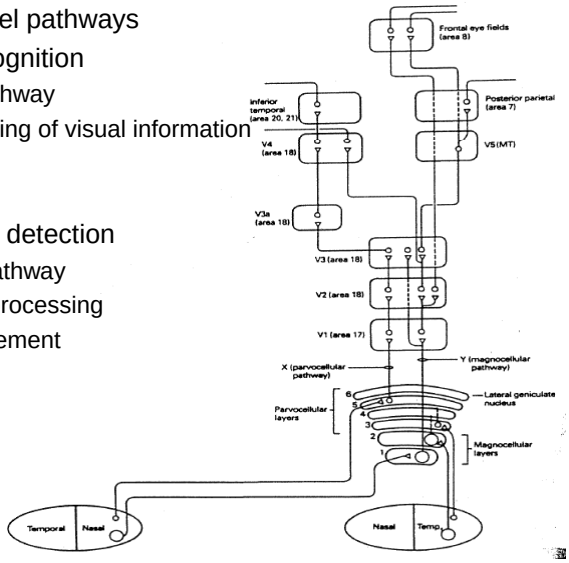
Structure of the Visual System



(CS92 Fig 4.7)

Visual Pathways

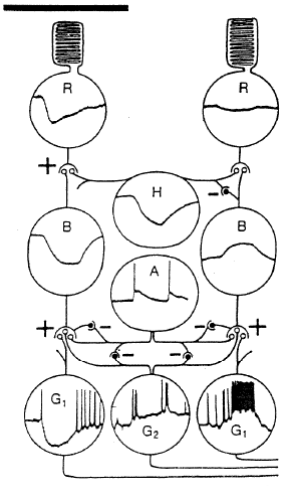
- Roughly two parallel pathways
- One for object recognition
  - Parvocellular pathway
  - Detailed processing of visual information
  - Colour
  - Binocularity
- One for movement detection
  - Magnocellular pathway
  - Quick and dirty processing
  - Direction of movement
  - Binocularity



(CS92 Fig 4.6)

Retinal Circuits

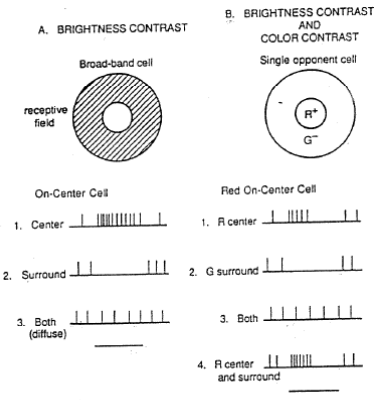
- Photoreceptors (R)
- Bipolar (B), Horizontal (H) and Amacrine (A) cells
  - Graded responses to photons of light
- Ganglion cells
  - Output cells from retina
  - Spiking output (action potentials)
- Feedforward excitation
- Lateral inhibition
- 100 million photoreceptors converge onto 1 million ganglion cells



(SH88)

Retinal Circuits (2)

- Receptor fields
  - Portion of visual space that a cell responds to
  - Very small for photoreceptors
  - More receptors in fovea than in periphery
  - Ganglion cells have much larger receptive fields, due to convergence of photoreceptors
- Ganglion cell types
  - X cells in fovea respond to colour
  - Y cells in periphery respond to motion
  - On-centre / off-surround
    - Lateral inhibition
  - Off-centre / on-surround



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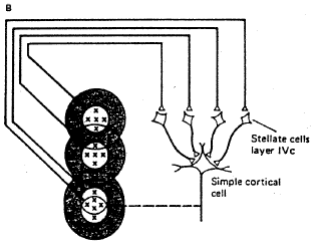
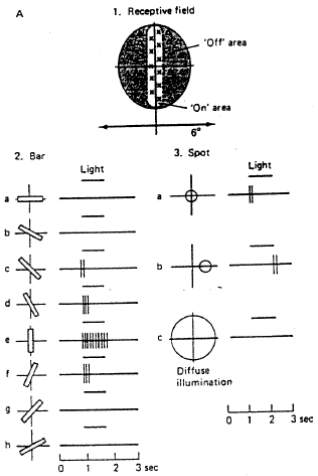
Early Visual Processing in the Cortex

- Cortical area V1
  - Retinotopic mapping preserved
  - *Simple* and *complex* cells
- Simple cells
  - Respond to bars of light of particular orientation in middle of their receptive field
- Complex cells
  - Oriented bars of light anywhere in their receptive field
  - And/or moving in a particular direction
  - Bars of particular length: *end-stopped* cells





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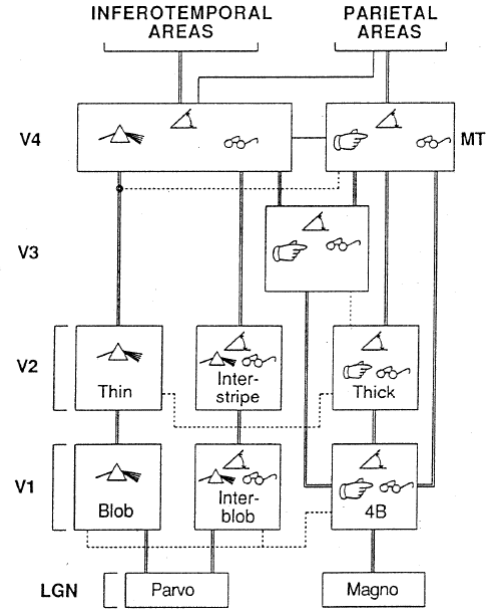
Hierarchy of Visual Processing

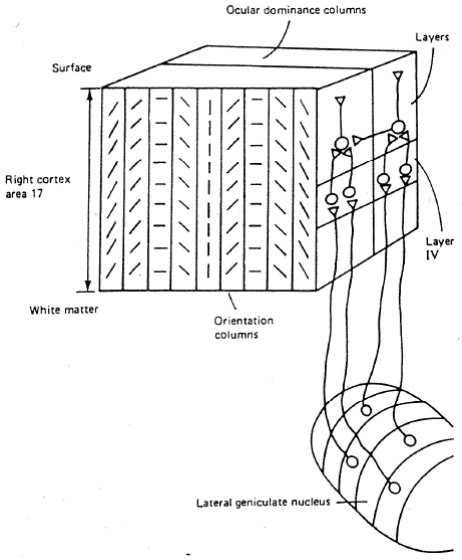
- Dual pathways
  - Colour processing and object detection
  - Motion detection

Prism: colour
Angle: orientation
Hand: direction
Spectacles: binocular



Hypercolumns

- Columns of cells that respond to same value of particular features
- Ocular dominance
  - Respond mostly to left or right eye
- Orientation
  - Respond to bars of same orientation



Higher Visual Processing

- Higher-order receptive fields
  - Cells respond to more complex features in the visual field
- Object detection results from integration of line (bar) detecting cells by downstream neurons
- Cells respond to objects of particular size, orientation and position in the visual field
- View cells respond to a particular view of an object
  - Frontal or side views of faces
  - May be independent of size and location
- Object categorization cells
  - Respond to objects of a particular type e.g. faces, coffee cups
- Object recognition cells
  - Respond to particular object e.g. grandmother

Speed of Visual Processing

- Object recognition within 150msecs in humans
- Implies feedforward processing
  - One or two action potentials per neuron in the hierarchy
- Quicker at recognizing objects we expect to see
- Implies feedback processing
  - Higher levels in the visual system *prime* lower levels to expect particular visual stimuli