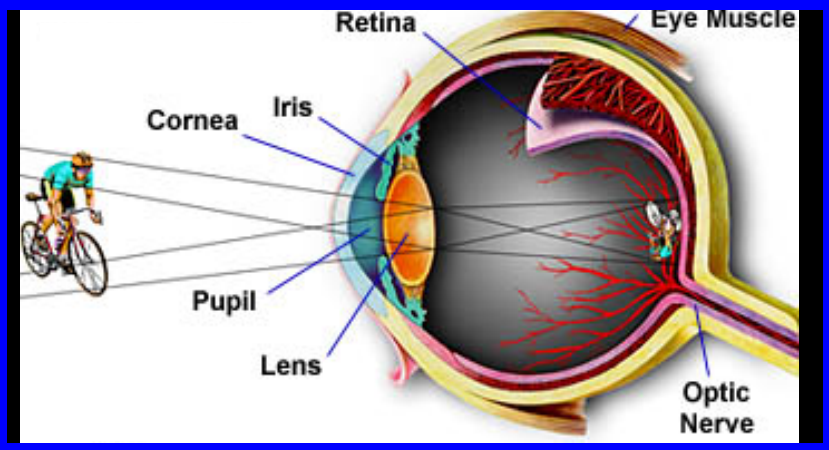
Biological vision

- Many slides adapted from
  - Ohad Ben-Shahar (http://www.cs.bgu.ac.il/~ben-shahar/Teaching/Computational-Vision/)LectureNotes/ICBV-Lecture-Notes-12-Sensing-2-The-Human-Eye-1SPP.pdf
  - Erik Learned-Miller (http://people.cs.umass.edu/~elm/Teaching/ppt/691a/CV%20UNIT%20Light/691A_UNIT_Light_1.ppt.pdf)
  - David Heeger (http://www.cns.nyu.edu/~david/courses/perception/lecturenotes/V1/lgn-V1.html)

Eye



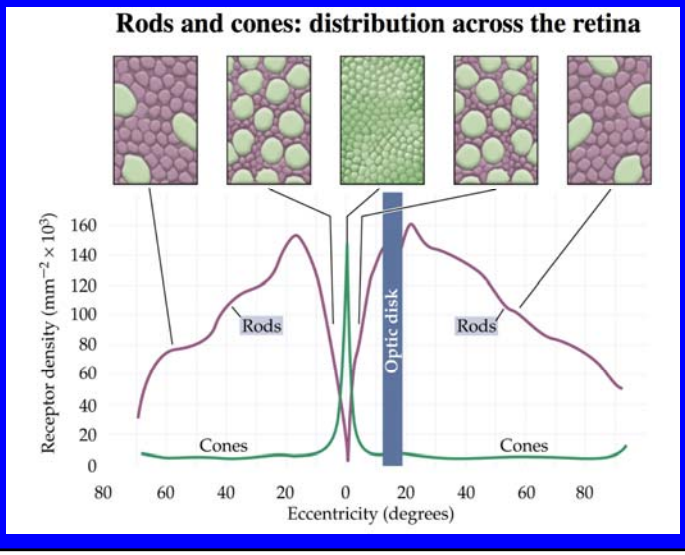
Blind Spot

a b c d e f g h

i j k l m n o p

q r s t u v w x

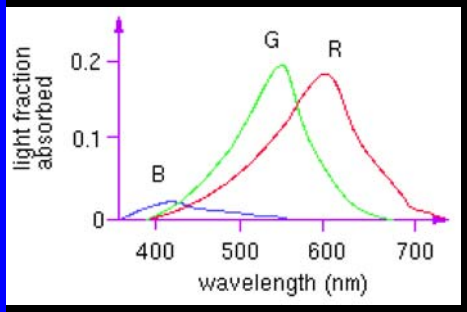
Rods and Cones



Rods and Cones

- Fovea –high resolution, color
  - See Island of the Colorblind, Oliver Sacks
- Three kinds of cones, tristimulus theory
  - (Almost) any color can be reproduced with three primary colors

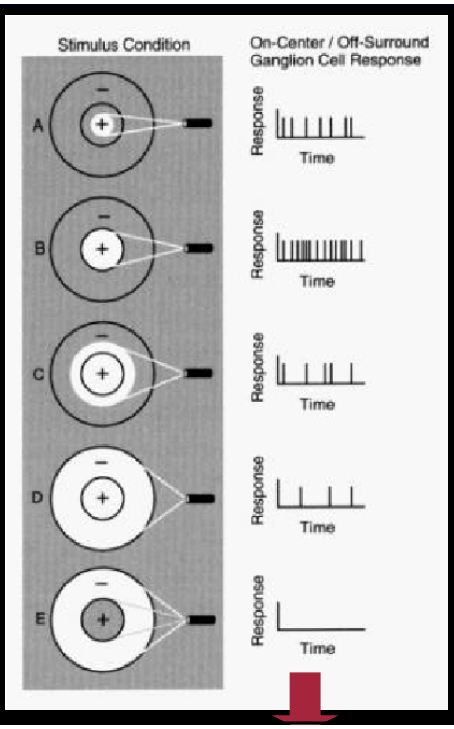
The different kinds of cells have different spectral sensitivities



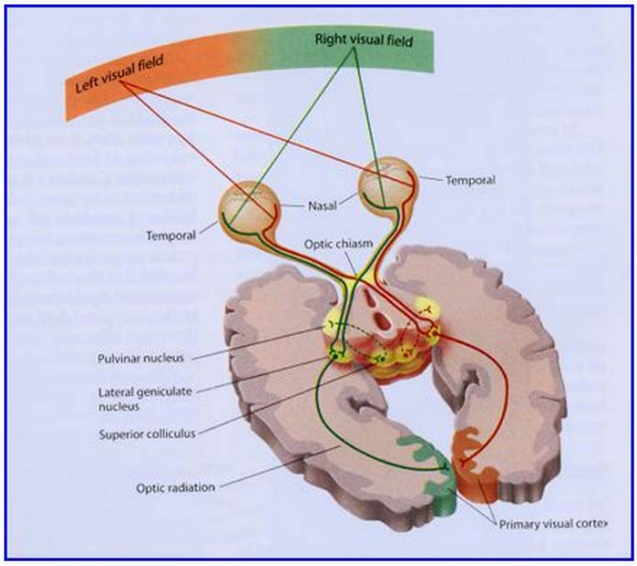
Peak sensitivities are located at approximately 437nm, 533nm, and 610nm for the "average" observer.

Retina: Retinal Ganglion Cells

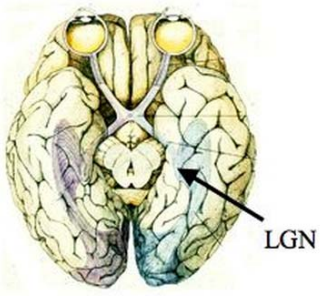
- Center Surround
- Receptive fields

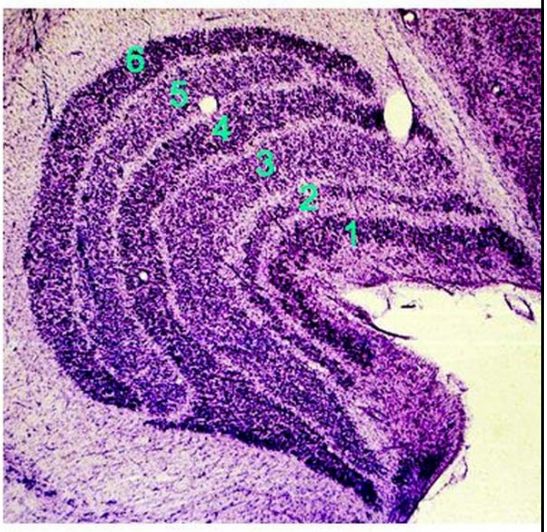


Lateralization



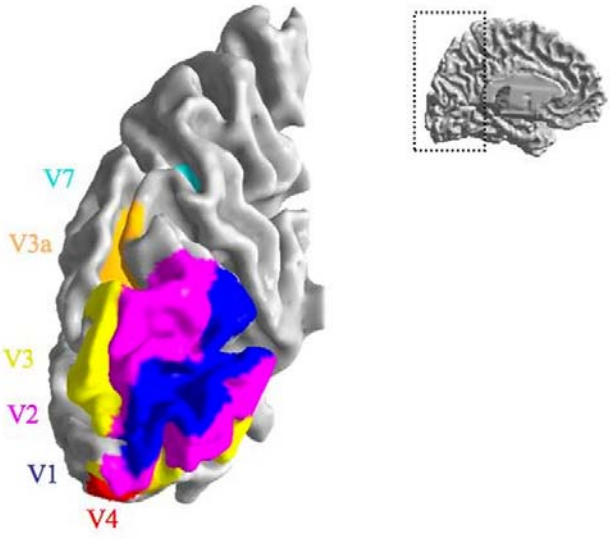
Lateral Geniculate Nucleus (LGN)



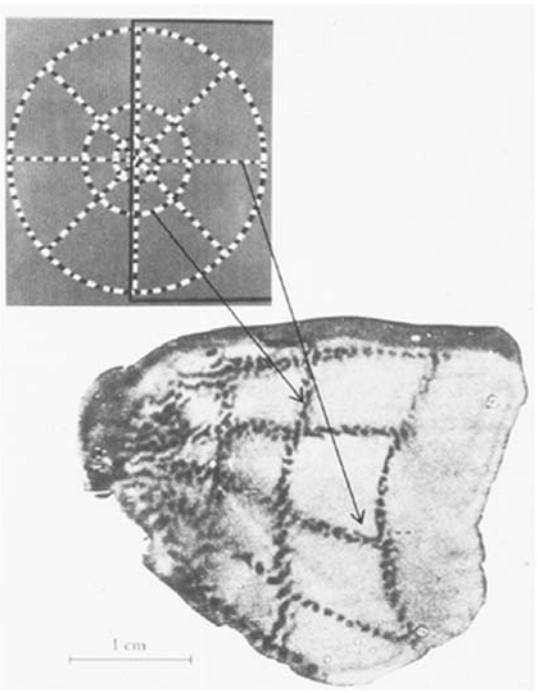


Retinotopic map
90% of inputs from cortex
Function not well understood

Primary visual cortex (V1)



Retinotopic Map

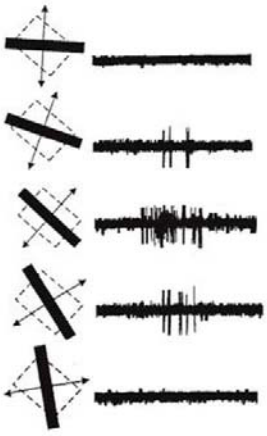


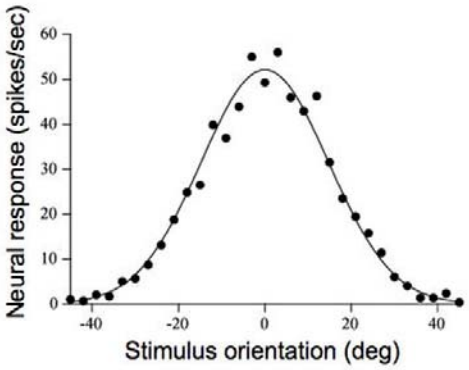
Cortical magnification

Retinal image

Cortical map

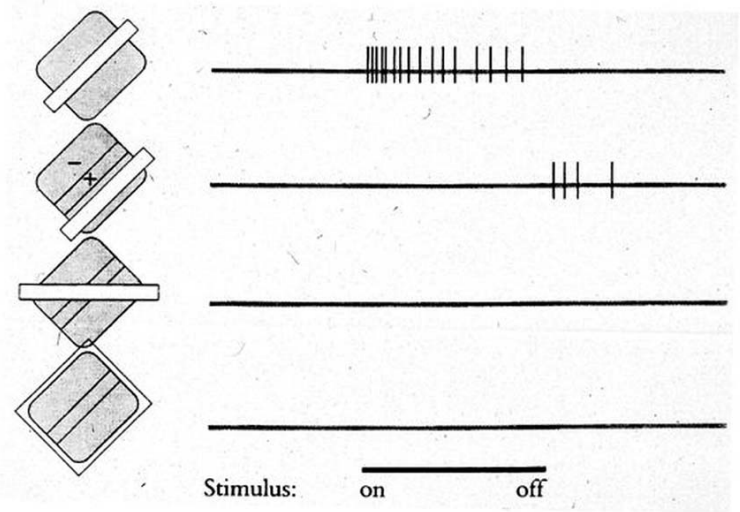
V1 physiology: orientation selectivity



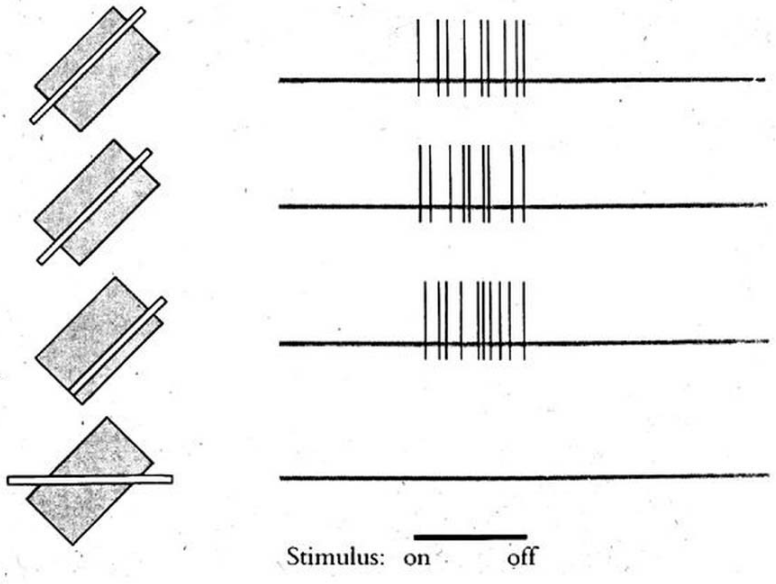


Hubel & Wiesel, 1968

Simple cell



Complex cell



Perceptual Grouping

- Perceptual grouping is about putting parts together into a whole:
  - Finding regions with a uniform property
  - Linking edges into object boundaries

  Surfaces and objects are critical.

  Also, simpler ``objects'' such as lines

Gestalt Principles of Grouping: some history

- Behaviorists were dominant psychological theorists in early 20th century.
  - To make psych scientific, wanted to view it as rules describing relation between stimulus and response, described as atomic elements.
  - No role for “mind”.
    - This meant no role for internal processing/inference/algorithms.
  - Influential early behaviorist was Pavlov

- Gestalt movement claimed atomic stimulus and response don't exist.

  -The mind perceives world as objects, as wholes, not as atomic primitives.

  - Can't understand psych without understanding how we perceive the world.

I stand at the window and see a house, trees, sky.

Theoretically I might say there were 327 brightnesses and nuances of colour. Do I *have* "327"? No. I have sky, house, and trees. It is impossible to achieve "327 " as such. And yet even though such droll calculation were possible and implied, say, for the house 120, the trees 90, the sky 117 -- I should at least have *this* arrangement and division of the total, and not, say, 127 and 100 and 100; or 150 and 177.

Max Wertheimer, 1923

I. A row of dots is presented upon a homogeneous ground. The alternate intervals are 3 mm. and 12 mm.

Normally this row will be seen as *ab/cd*, not as *a/bc/de*. As a matter of fact it is for most people impossible to see the whole series simultaneously in the latter grouping.

Max Wertheimer

Gestalt Movement

- Perceptual organization was a big issue.
  - How we perceive the world in terms of things/objects, not pixels.
- This was part of broader attack on behaviorism.
  - Gestalt viewed mind as constructing *representations* of the world, no learning/behavior could be understood without understanding this.
  - These representations were constructing by inferences of the mind.

Issues in Perceptual Organization

- What is the role of an edge in an image? To what object (if any) does it belong?

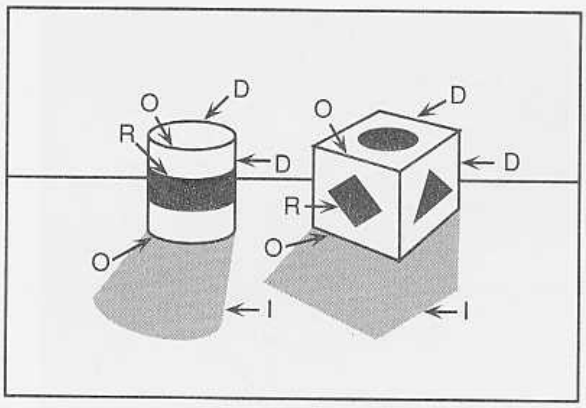
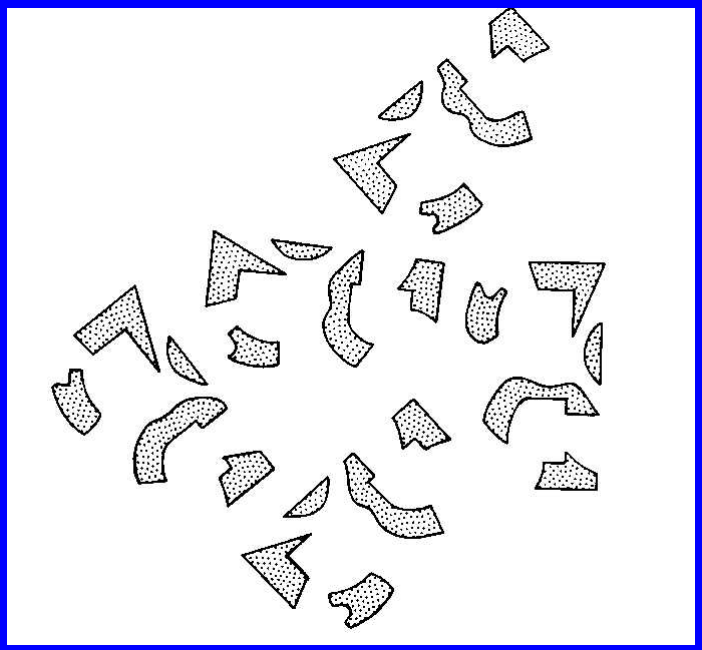
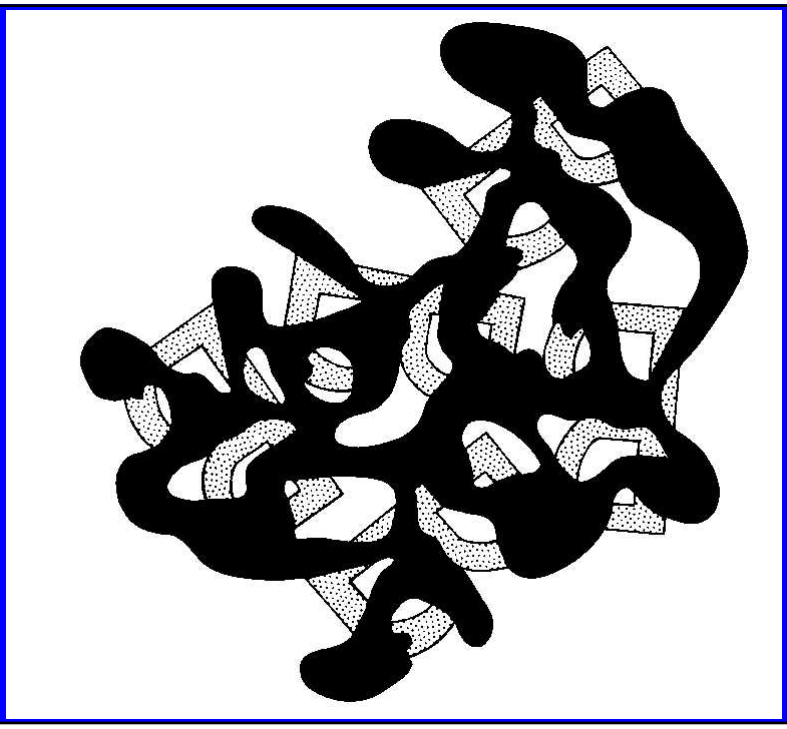


Figure 5.5.16 Four kinds of edges. This scene contains four different kinds of luminance edges: orientation edges (O) due to abrupt changes in surface orientation, depth edges (D) due to gaps between surfaces at different distances, reflectance edges (R) due to different surface pigments or materials, and illumination edges (I) due to shadows.

If you know what is in the next image, silently raise your hand. Don't call out.



(Bregman)

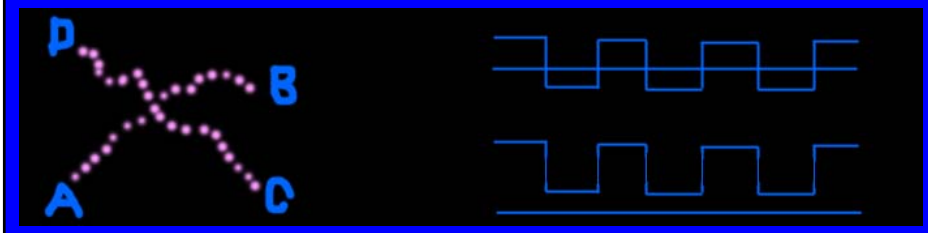


Issues in Perceptual Organization

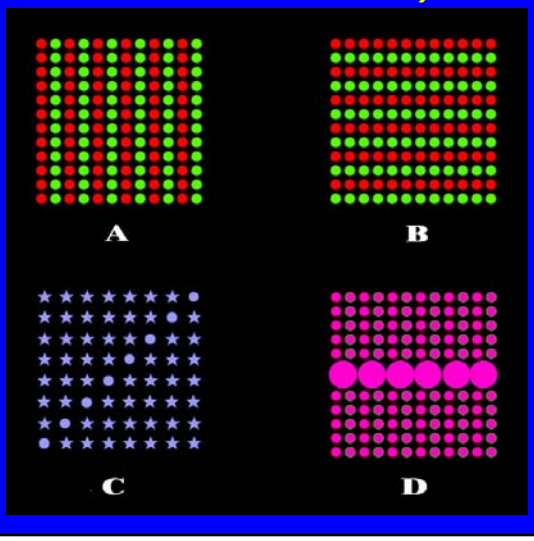
- What factors determine which parts of an image are combined in the same object?

Proximity

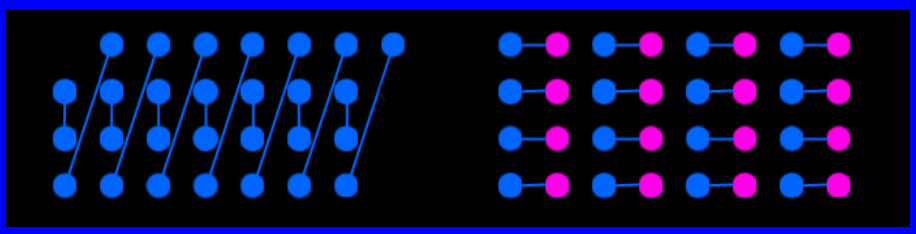
Good Continuation



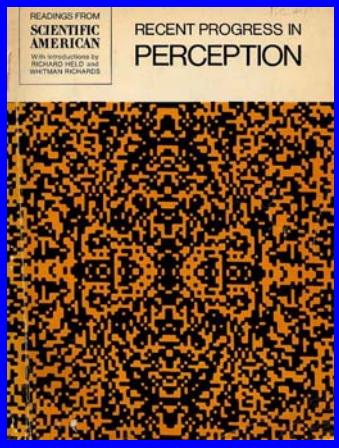
Common Form: (includes color and texture)



Connectivity



Symmetry



Symmetry

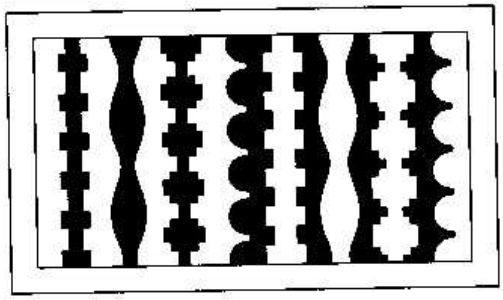
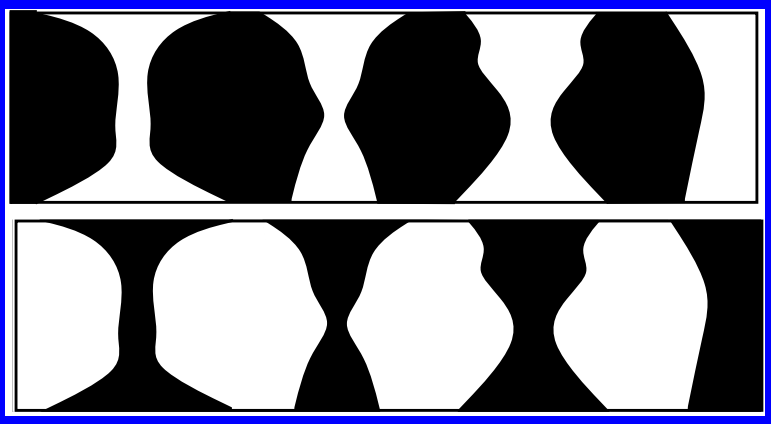


Figure 7.25
Symmetry and figure ground. Look to the left and to the right, and observe which colors become figure and which become ground. (Adapted from Hochberg, 1971.)

Convexity (stronger than symmetry?)



Good continuation also stronger than symmetry?

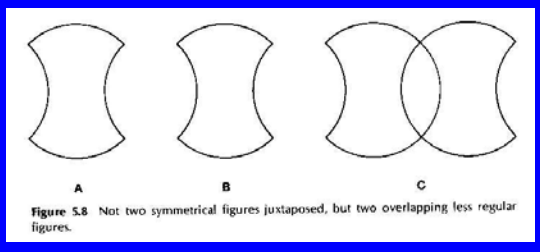


Figure 5.8 Not two symmetrical figures juxtaposed, but two overlapping less regular figures.

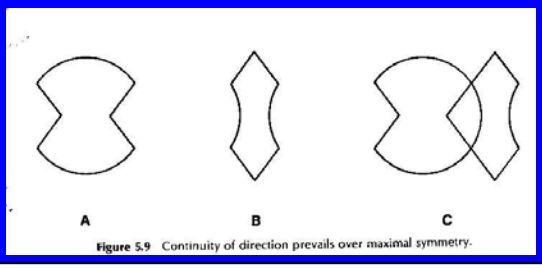


Figure 5.9 Continuity of direction prevails over maximal symmetry.

Higher level Knowledge

If you know what is in the next image, silently raise your hand. Don't call out.

Other Factors

- Closure
- Common fate (ie., common motion).
- Good continuation in time.
- Parallelism
- Collinearity

Kanizsa's Subjective Contours

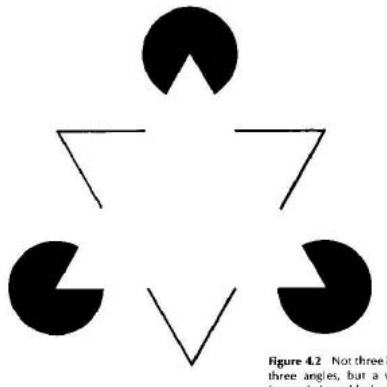
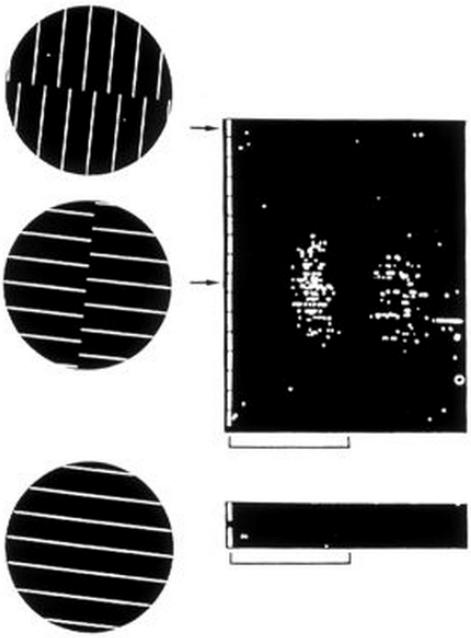


Figure 4.2 Not three black sectors and three angles, but a white triangle in front of three black disks and an outlined triangle.

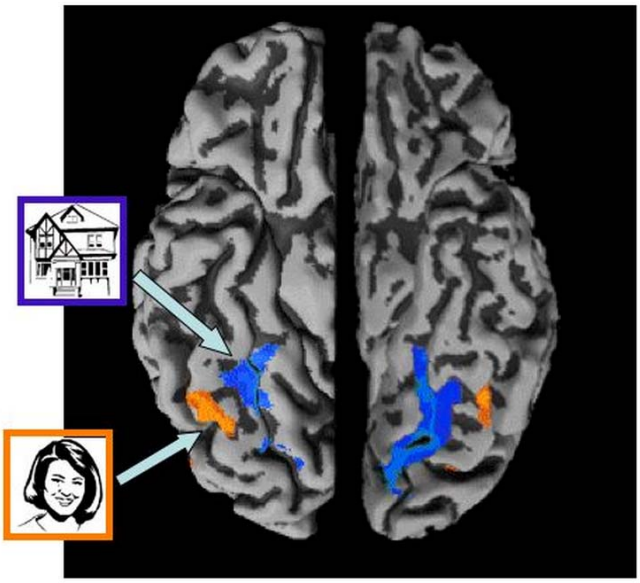
Cells in V2 sensitive to illusory contours



Inattentional Blindness

- http://www.youtube.com/watch?v=y6qgoM89ekM

Faces (FFA) and Places (PPA)



Reading and letter recognition

Aoccdrnig to rscheearch at Cmabrigde Uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are. The olny iprmoetnt tihng is taht the frist and lsat ltteer be at the rghit pclae. The rset can be a total mses and you can sitll raed it wouthit porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe. Amzanig huh?

Face Recognition

- Some figures from *Face Recognition by Humans: 20 results all Computer Vision Researchers Should Know* by Pawan Sinha