PSYC 10004-6 – FOUNDATIONS OF PSYCHOLOGY
Introduction to Cognitive Psychology

Lecture 3 – Sensation and Perception

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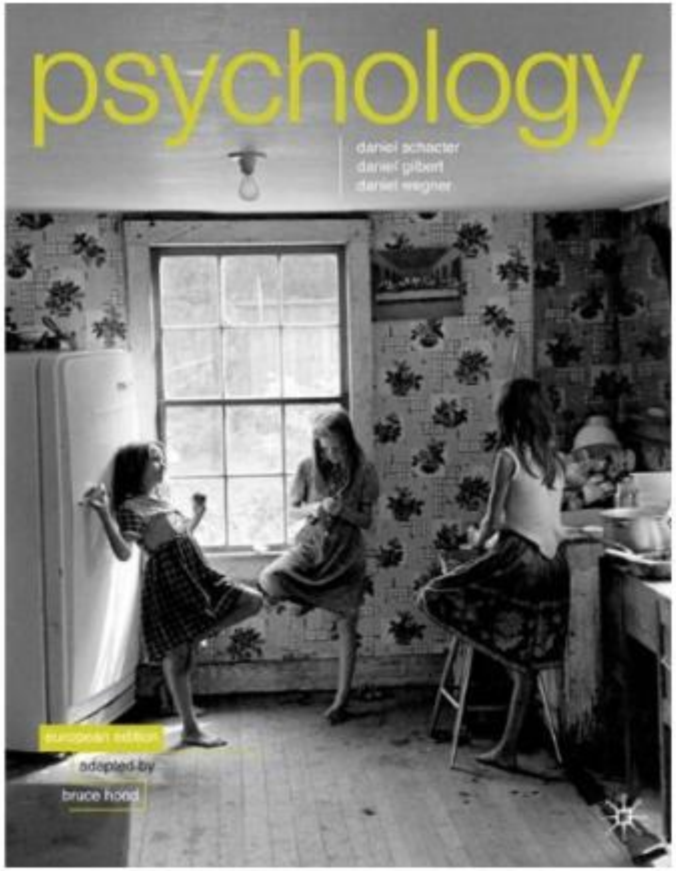
Aims of lecture

- How is information about the external world transmitted to the brain?
  - Sensory receptors, neural pathways, etc.
- How does our brain accomplish perception of the external world?
  - Via automatic (and inaccessible) low-level neural processes
- many of the processes involved in sensation/perception are innately determined, and/or automatic
- *interpretation* is an integral part of our sensory experience, with limited awareness of ‘raw’ sensory input

Required reading:

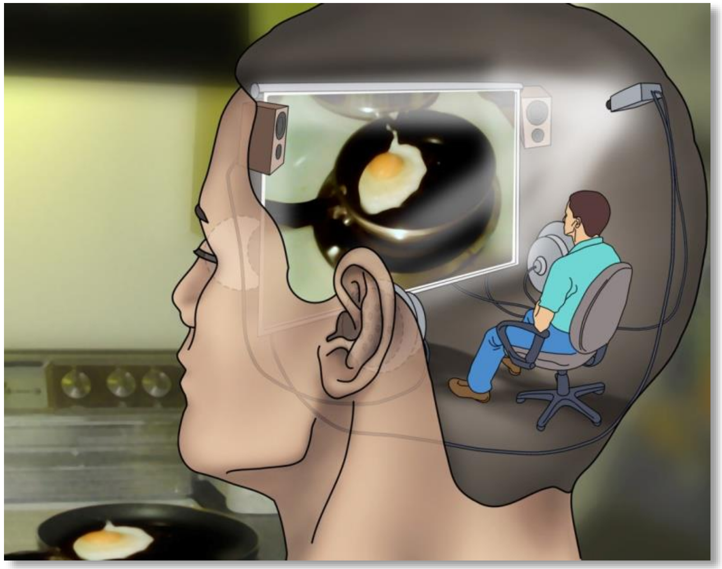
- Schacter, Gilbert, Wegner & Hood (2012), Psychology. Palgrave Macmillan. European Edition.
    - Chapter 4 (“Sensation and Perception”, pp. 120-129 and pp. 147-149 <u>only</u>)

- Recommended but not required: Chapter 3 (“Neuroscience & Behaviour“), pp. 80-92 (“Neurons: the origin of behaviour“)



Sensory perception

- do sensory systems provide an image that is a copy of the world?
- cognitive processes are based on *internal representations* (primarily of an external world)
- input from sensory systems is restricted to specific properties or attributes
- cognitive processes *construct* perceptual interpretations from data provided by sensory input



Sensation and perception – a conventional distinction

- Sensation
  - detection of simple properties, e.g.: brightness, colour, loudness, sweetness etc.

- Perception - *interpretation* of sensory signals
  - object recognition
  - identification of properties such as location, size, movement, etc.

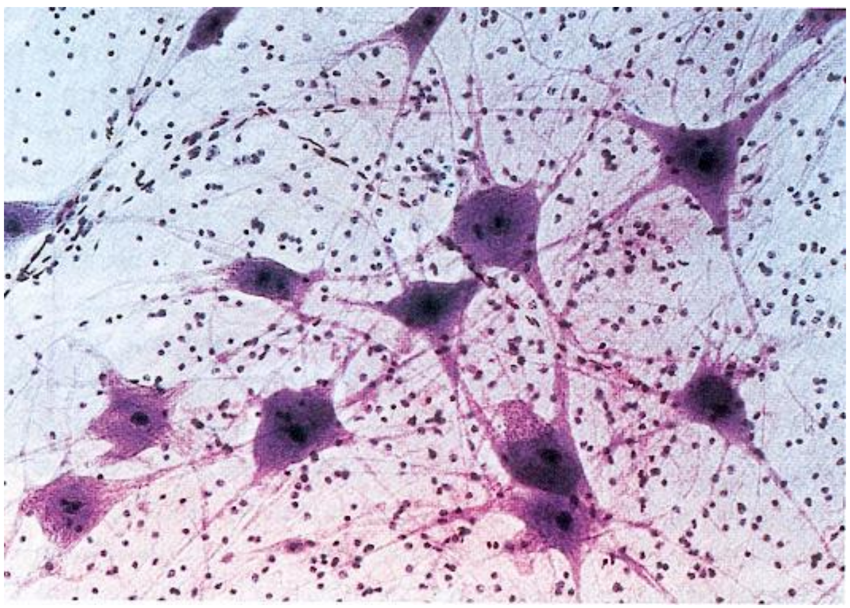
- but distinction is not always clear-cut – properties that can be directly “sensed” may be computationally complex

Requirements for sensory systems

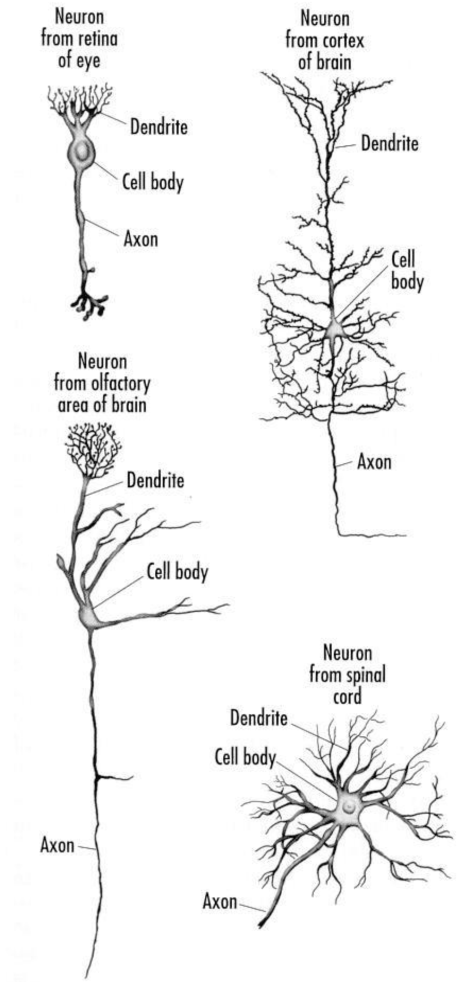
- the brain can't sense the external world directly – it relies on signals received from sense organs (eyes, ears, skin, etc.) via *afferent* nerves
- sensory systems therefore need
  - a biological mechanism for translating physical attributes into electrical signals (*receptors*)
  - mechanism for conveying this information to CNS

Biological components – Nerve cells (neurons)

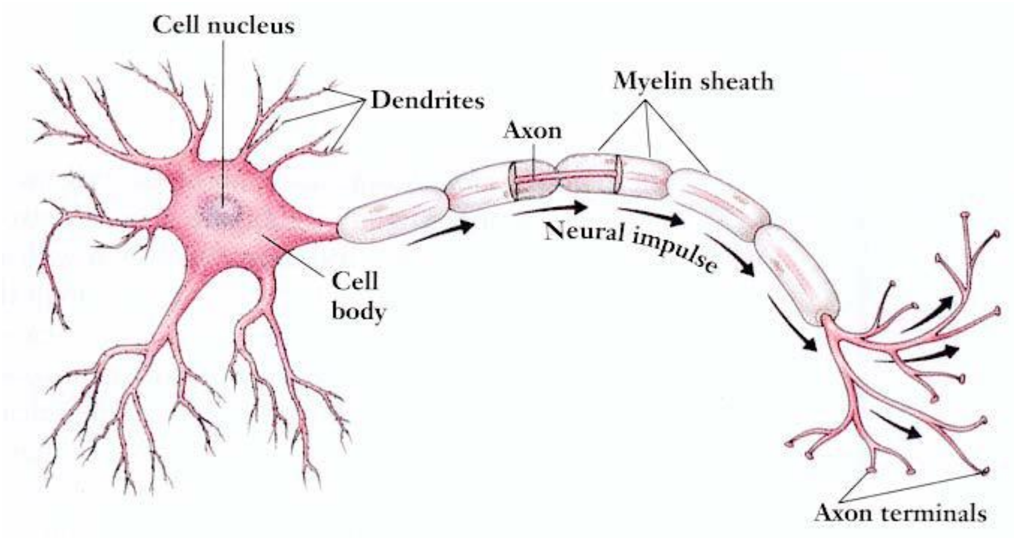
- neurons come in many shapes and sizes
- most sensory detectors are modified neurons



Neurons in the spinal cord



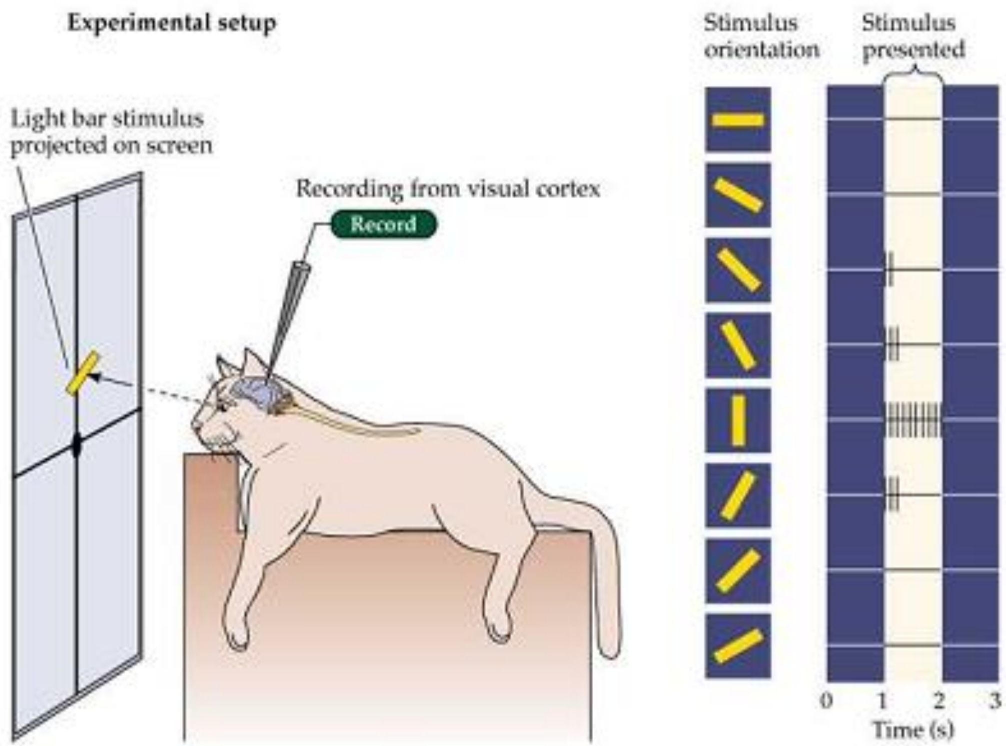
Neural computing - what can nerve cells do?



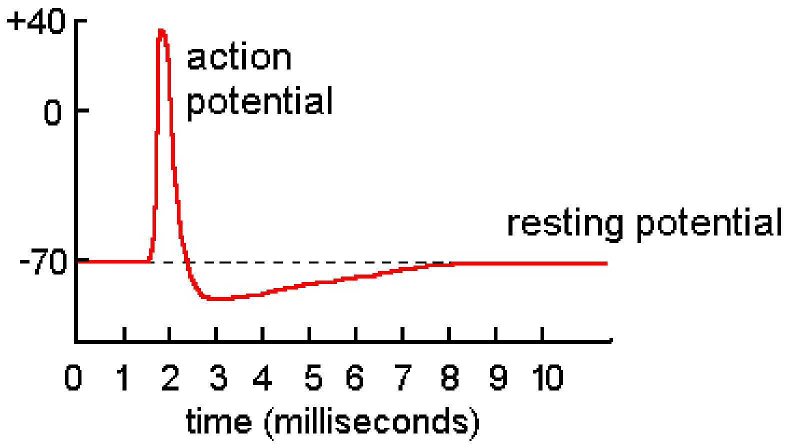
- neurons transmit brief electrical pulses with fixed amplitude and duration
- make excitatory or inhibitory connections with each other to create networks with one-to-many and many-to-one linkages

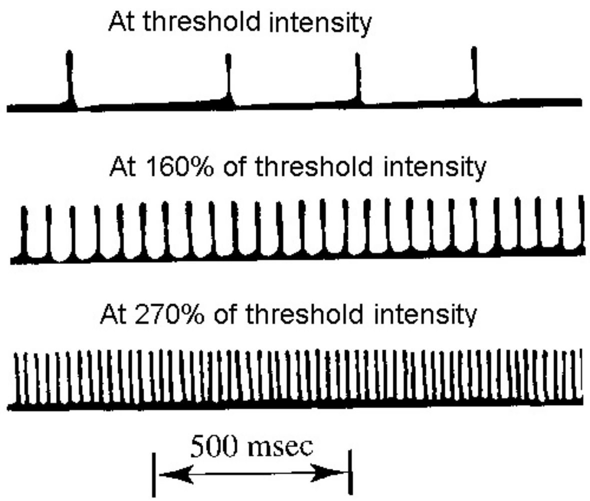
Single-cell recording

- Electro-physiological response of a single neuron can be observed by inserting a microelectrode (“single cell recording”)



Coding of stimulus intensity

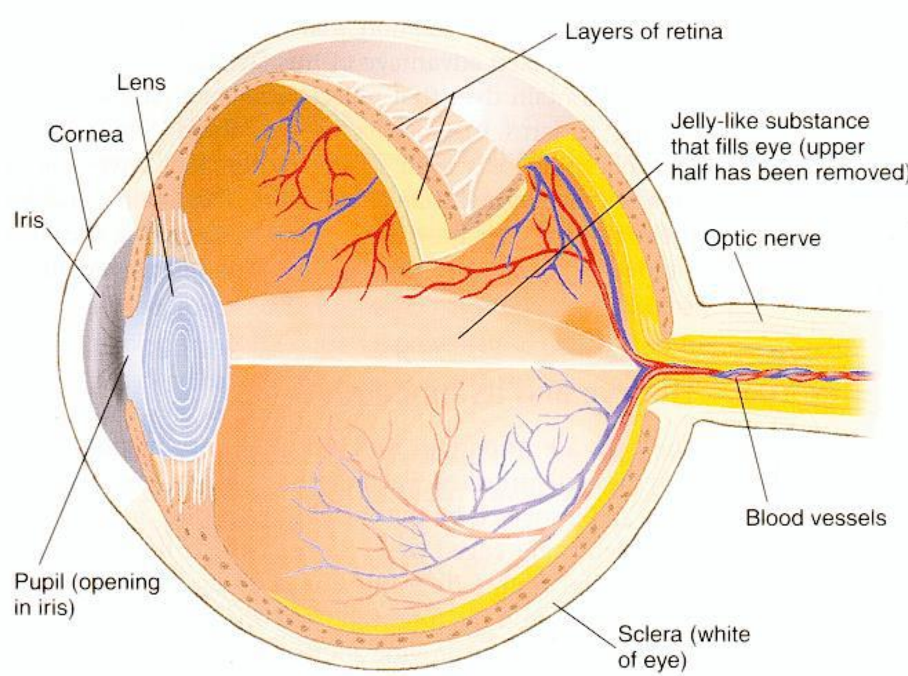




- electrical ‘spike’ has *fixed amplitude*, regardless of stimulus intensity – signal is one-dimensional (i.e., can only encode one stimulus dimension)
- for most sensory systems, intensity is signaled by the *rate* at which neurons fire

Vision

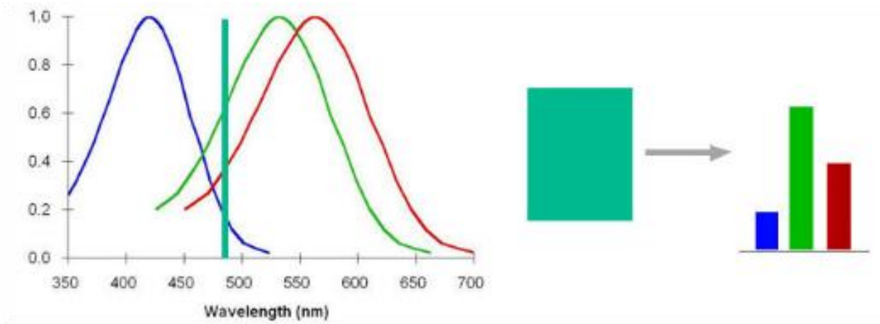
- receptors in the retina of the eye are *rods* and *cones* – modified neurons containing photosensitive pigment (rhodopsin)
- rods function at low light levels, cones in bright light
- cones are colour-tuned – peak sensitivity to either red, green or blue (different rhodopsins)



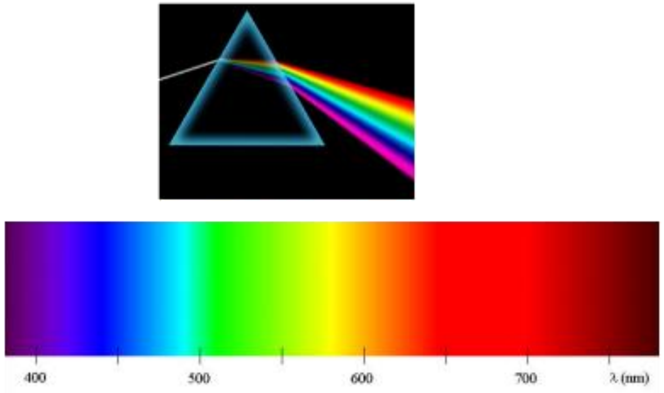
Perception of colour

- cones are colour-sensitive – output depends on wavelength of light
- for any *single* wavelength, colour is uniquely coded by output pattern
- principle extends to light that contains a mixture of wavelengths

sensitivity of three types of cone

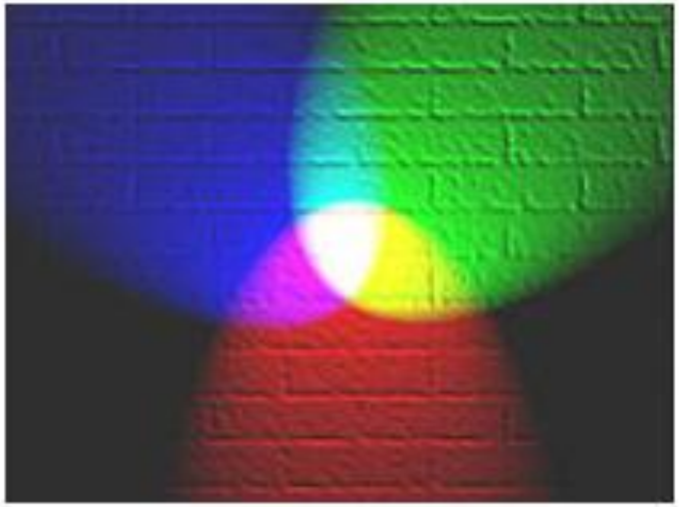


- white light is a mix of all visible wavelengths, all at the same intensity
- “white” is therefore coded as equal output of red, green, blue receptors

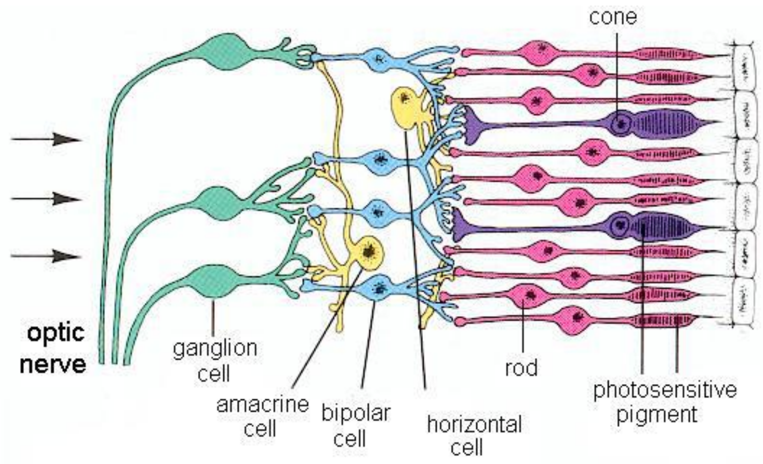


Perception of colour

- the perception of white can be created by mixing *pure* red, green and blue light at equal intensities
- this is the basis of colour mixing (makes colour TV possible)



Structure of the retina



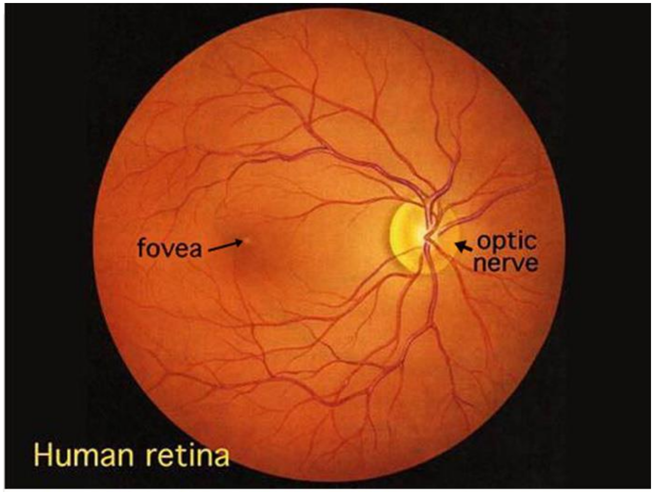
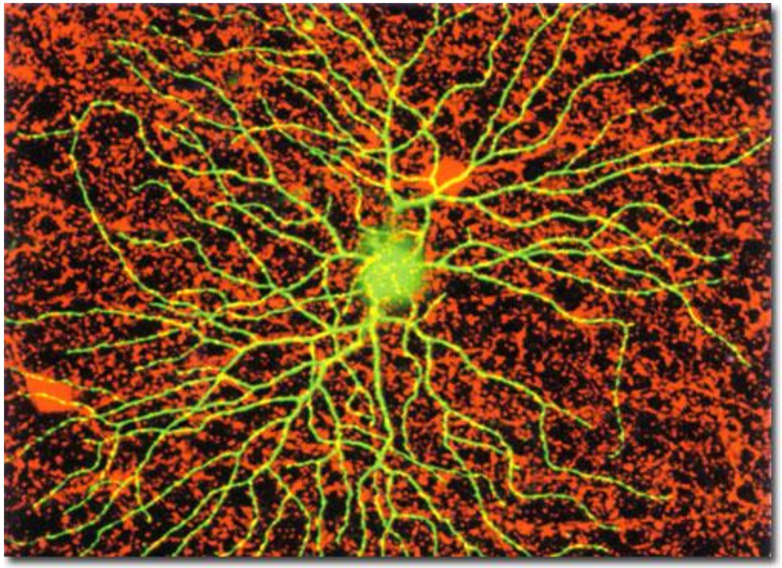


Fig. 1. Human retina as seen through an opthalmoscope.

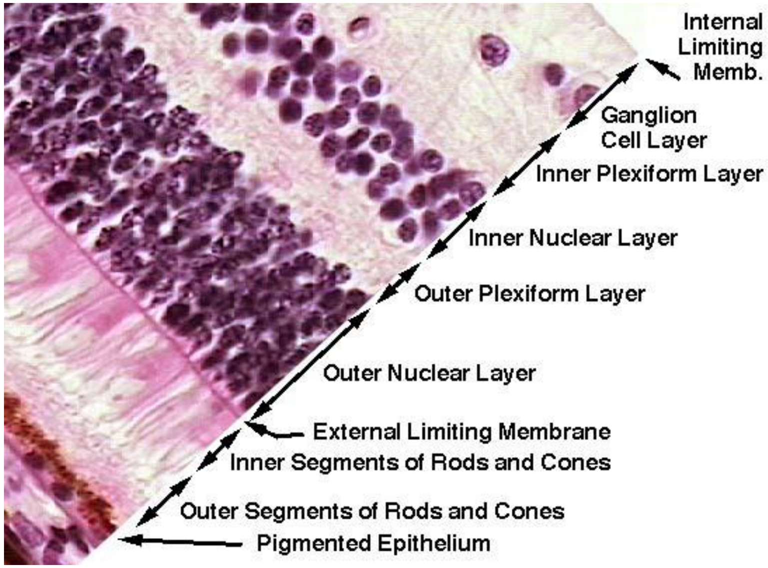
- network of connections between receptors and optic nerve *performs local computations*
  - response of photoreceptors and bipolar cells to illumination is graded
  - amacrine cells and horizontal cells combine and contrast signals from adjacent photoreceptors
  - ganglion cells generate action potentials and form the *optic nerve*

Retinal complexity

- retina contains around 120 million rods and 7 million cones, richly interconnected
- optic nerve is formed from axons of approximately one million ganglion cells

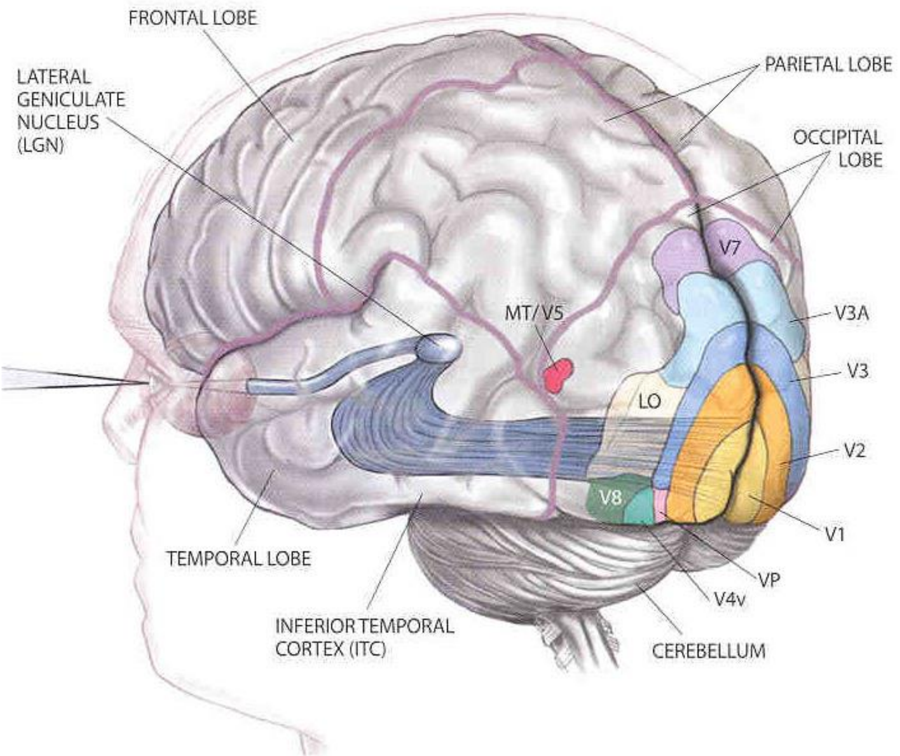


A single ganglion cell



Early processing of visual information

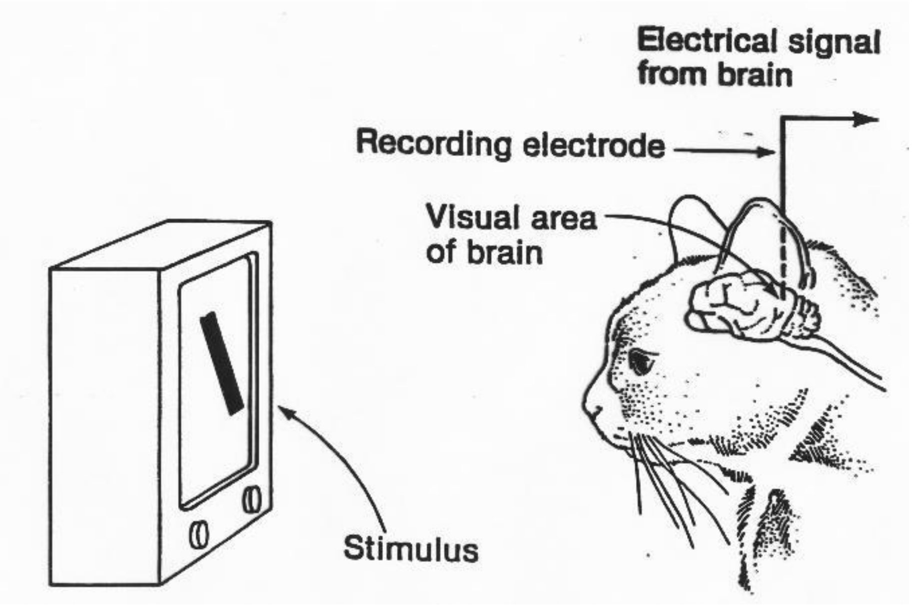
- interconnections mean that retina does not function as a simple light detector
  - retinal processing involves ‘cleaning up’ of image and beginnings of feature extraction
- separate structures exist in *visual cortex* for extracting information about shape, colour, position, motion, etc.



Cortical processing of visual information

- feature processing structures in visual cortex arranged in layers
- early stages of processing detect elementary visual features - ‘simple cells’ discovered by Hubel and Wiesel in the 1960s (Nobel prize in 1981)

- identified via single-cell recordings from neurons in visual cortex
- collections of ‘simple cells’, each responding to a line or edge in illumination reaching a particular region in the retina



Feature detection – neurophysiological evidence

- electrical responses monitored in a single cell when bright lines in different orientations are projected onto a small area of the retina
- particular cells are selective active in response to a particular stimulus (say, a line) in a particular orientation (e.g., vertical) – “feature detectors”

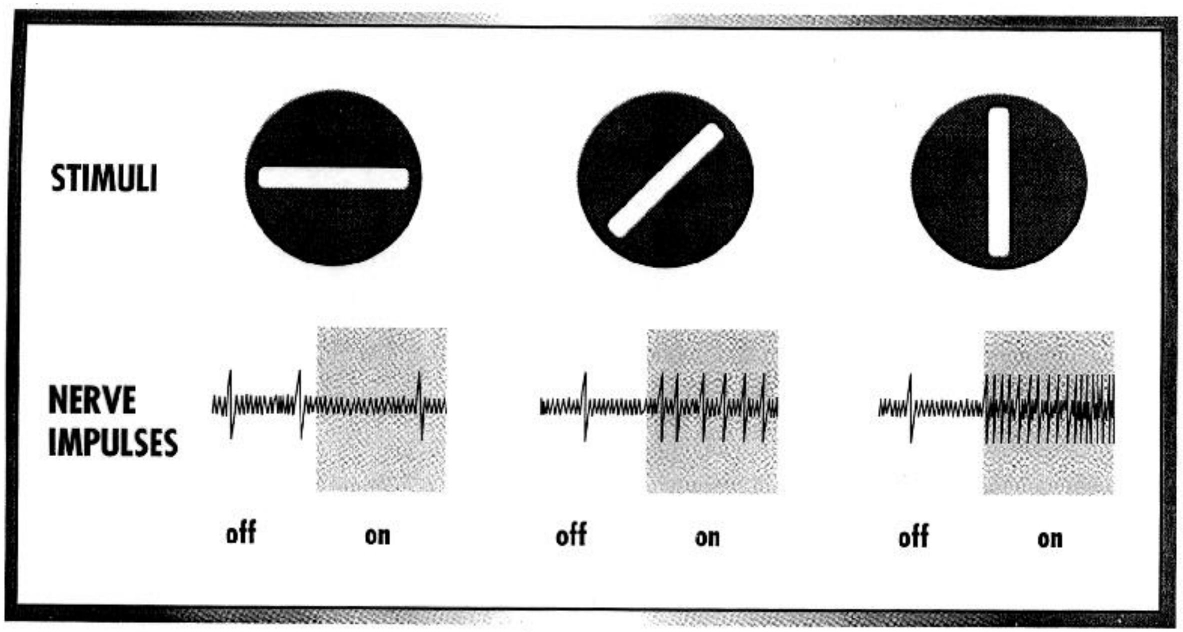


FIGURE 5-11

Response of a Simple Cell *This figure illustrates the response of a simple cortical cell to a bar of light.*

Perception

- perception involves *interpretation* of sensory input as information about an external world
- requires computational processing of sensory data, including
  - segmentation and object recognition
  - construction of 3-dimensional representation
- many of the processes involved in this are automatic and/or innately determined
  - interpretation is an integral part of our sensory experience, with limited awareness of "raw" sensory input

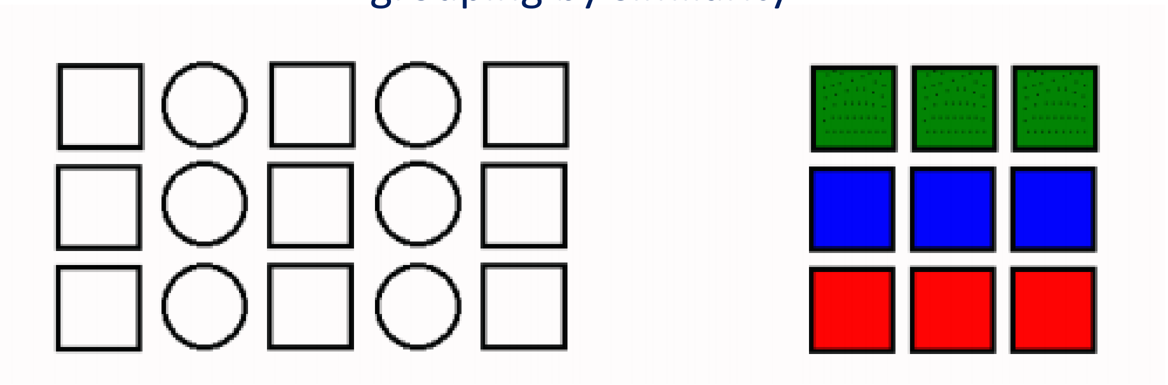
Segmentation ("parsing") of the visual scene

- first stage of object recognition – visual features that belong to the same object are grouped together
- "Gestalt" principles of perceptual organization, such as
- fundamental distinction between figure and ground
  - a prerequisite for object recognition (applies to *all* objects in visual field)
  - assignment of figure and ground can be ambiguous or reversible (but distinction must always be made)

Gestalt principles of grouping (e.g., Wertheimer, 1923)

- grouping of elements to make a “figure” is determined by a set of heuristic* principles
  - based on processes that are automatic, and *innate* (evidence from studies of infants)
  - principles include grouping by similarity, proximity, goodness of form, etc.

grouping by similarity



*heuristics are simple, efficient rules to solve problems - typically when incomplete information is available or there is too much information for all possibilities to be fully considered

Gestalt principles of grouping

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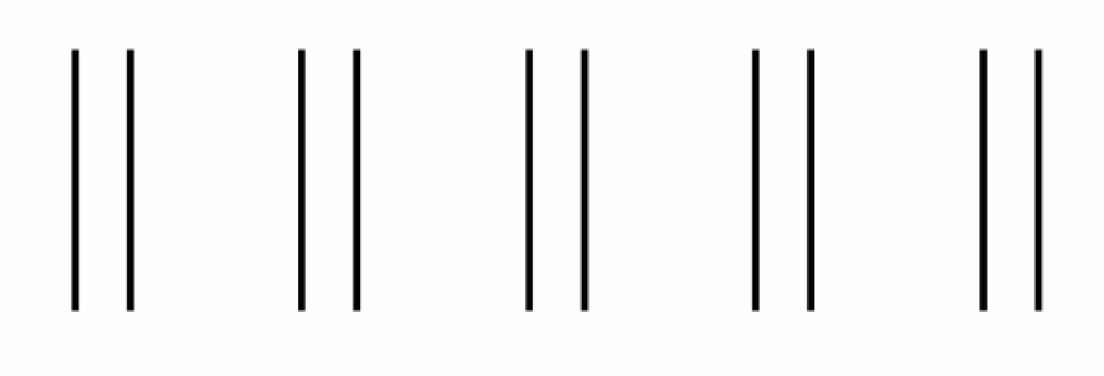
grouping by proximity



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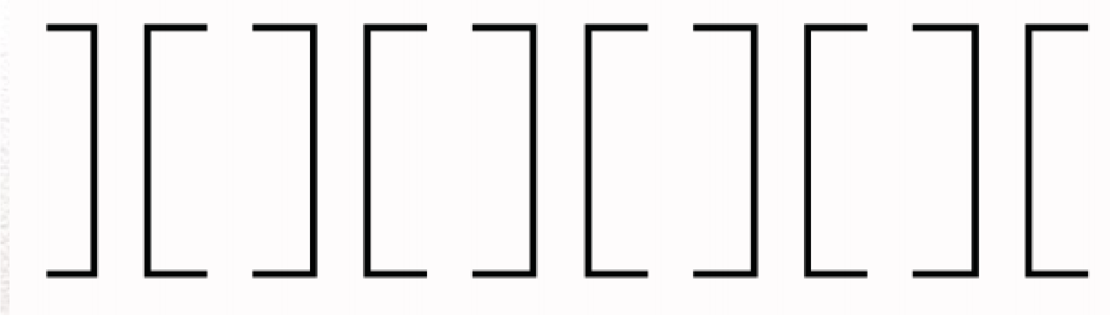
grouping by goodness of form

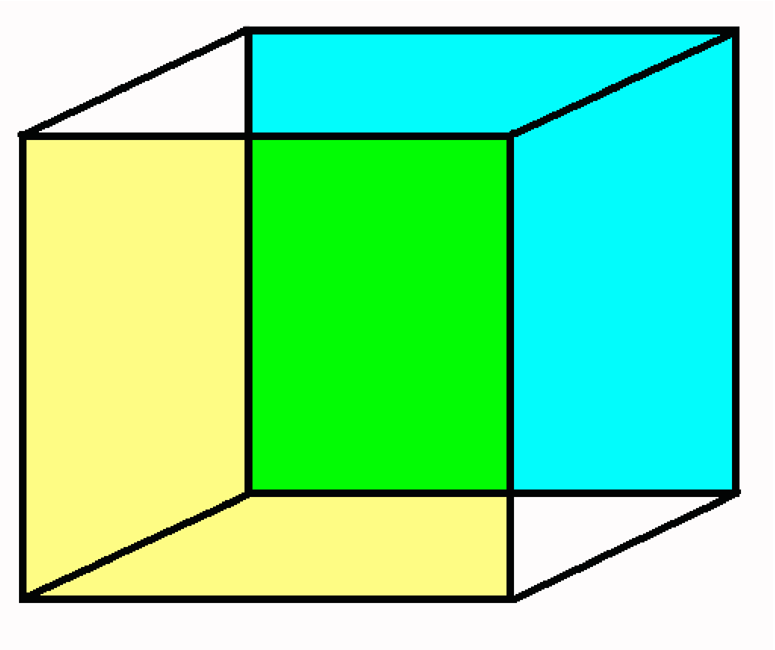


Living in a 3-D world

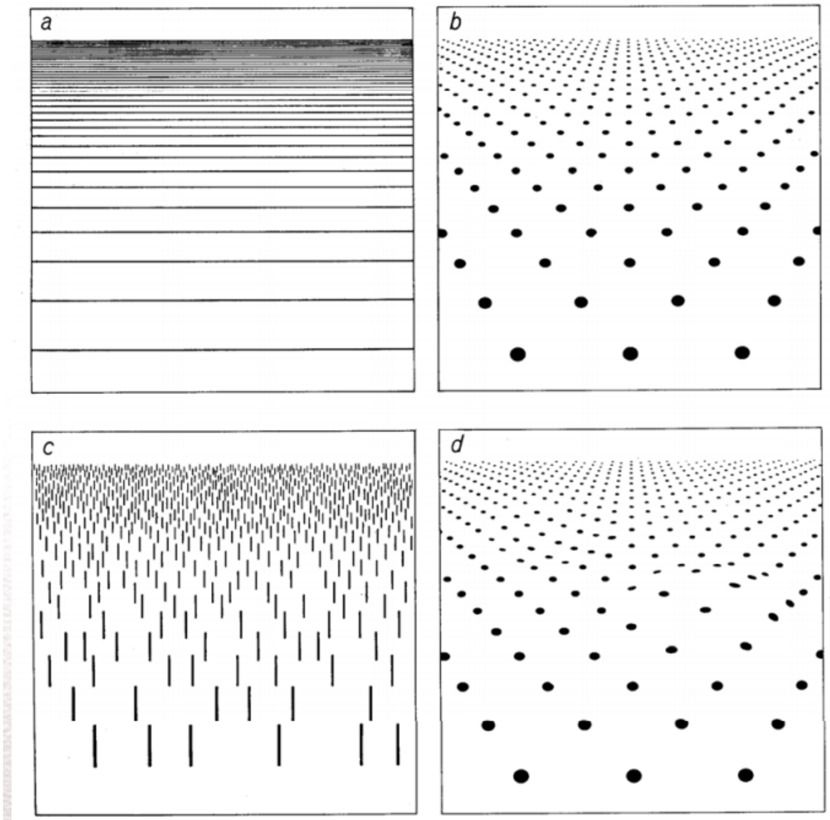
- visual images are two-dimensional - but the world is three-dimensional!

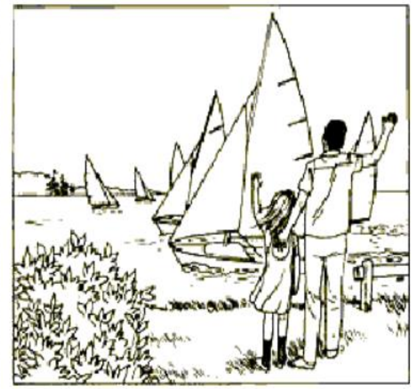
The ‘Necker cube’

- demonstrates that we automatically construct a 3-D world from a two-dimensional image
- an ambiguous figure – yellow in front of blue, or vice versa?
- either is possible, but at any given moment, *must* be one or the other (not both)
- hollow faces illusion:



Cues for depth perception

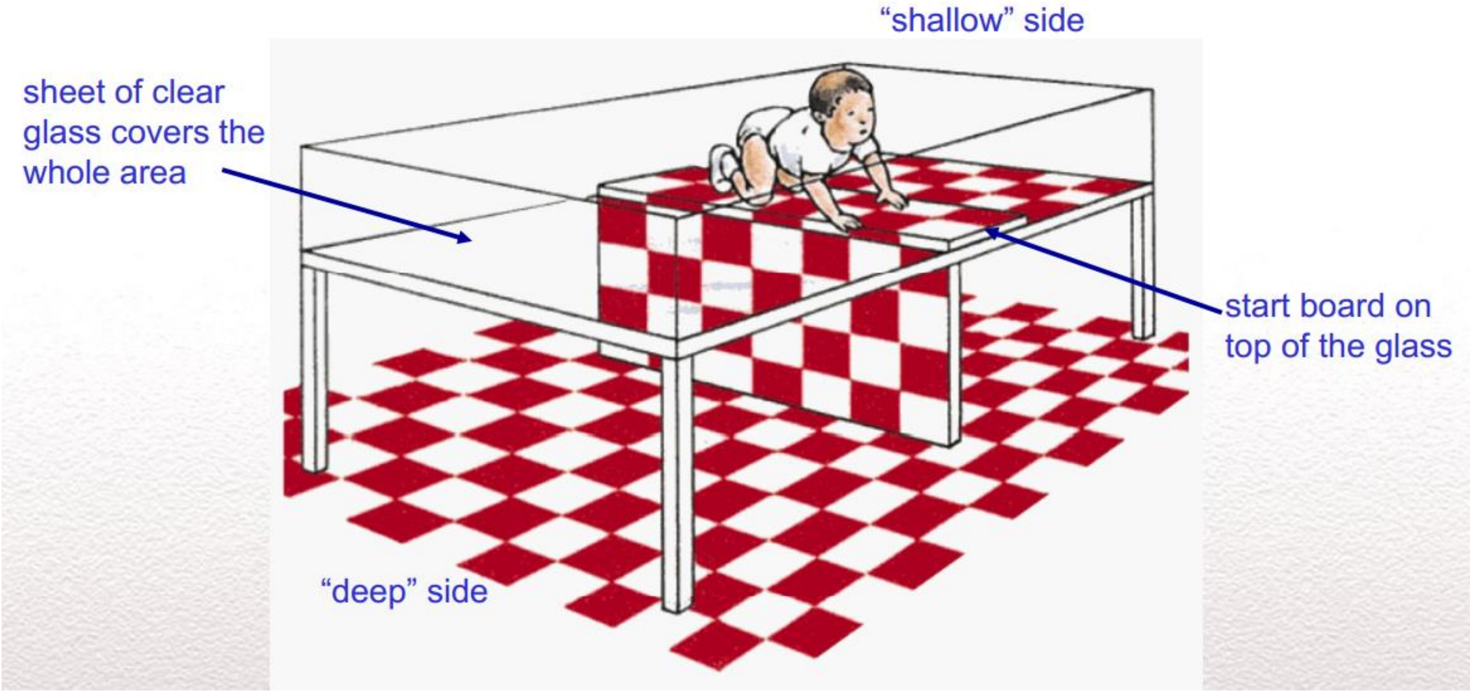




- texture gradient
- relative size
- superposition
- height in field

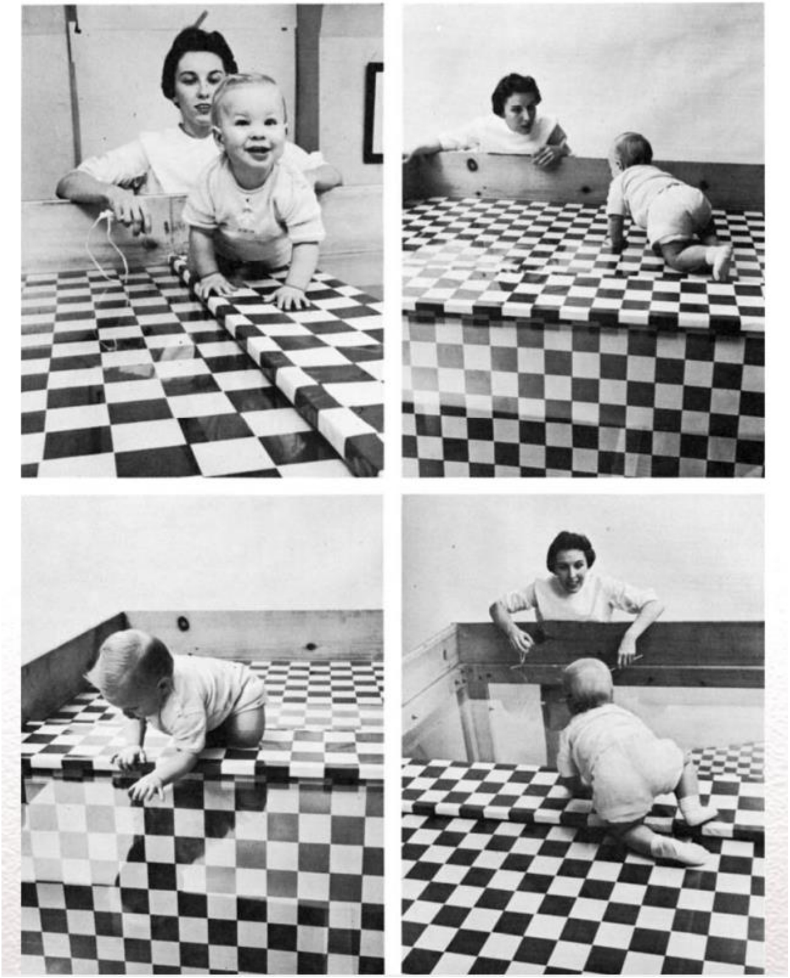
Is depth perception innate? The “visual cliff”

- Gibson and Walk (1960): apparatus for testing whether animals or infants are able to interpret these kinds of cues to depth

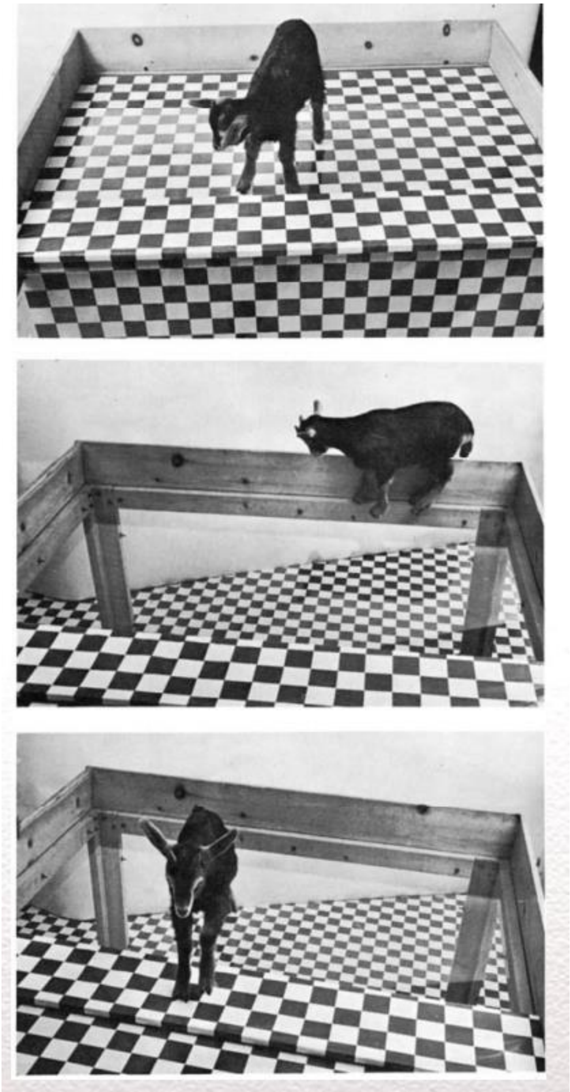


The "visual cliff"

- Gibson & Walk (1960) tested 36 infants old enough to crawl (6 – 14 mths)
- 27 were willing to move onto the shallow side, but only 3 onto the deep side



The “visual cliff”

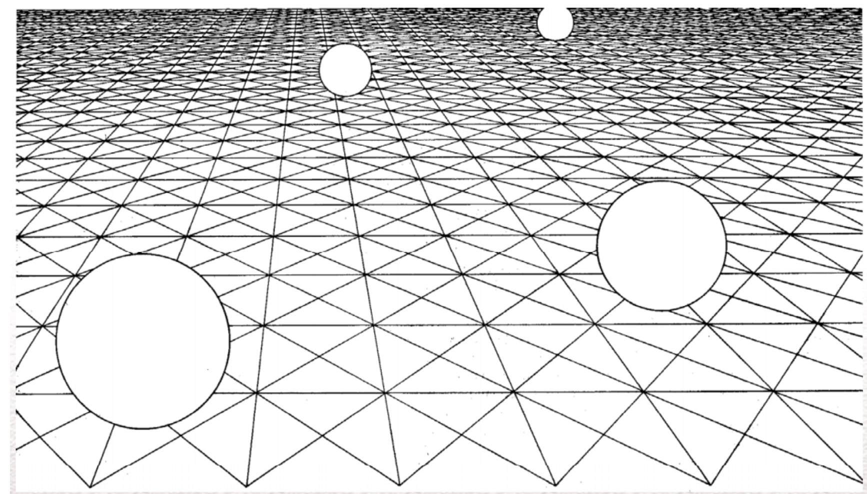


- for some animals, depth perception appears to be innate - when placed on the deep side, a one-day old goat jumps to the safety of the start board

Perceptual constancy

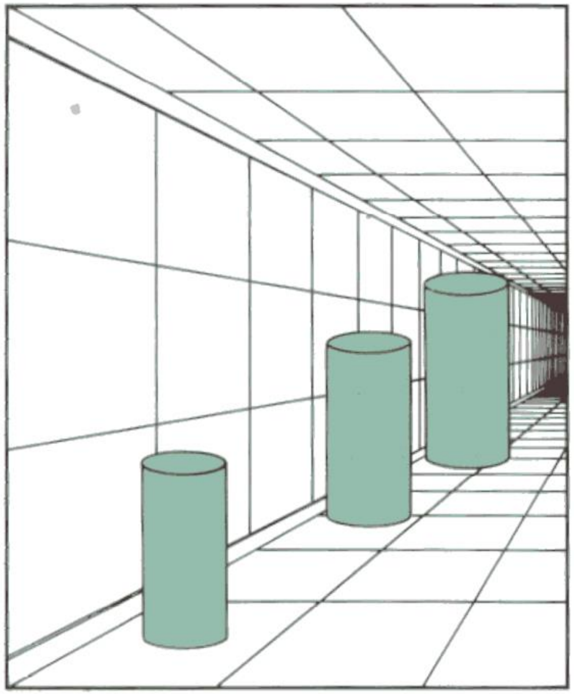
- visual images are *ambiguous* in many aspects – e.g.:
  - size vs. distance
  - shape vs. rotation/orientation
  - colour/brightness vs. illumination
- Our brains resolve this ambiguity via implicit assumption that objects are stable and unchanging ("perceptual constancy")
  - size, shape, colour, brightness constancy
- The brain automatically computes "true" size, shape etc. of objects by taking into account viewing conditions

Objects the same (real) size seen at different distances



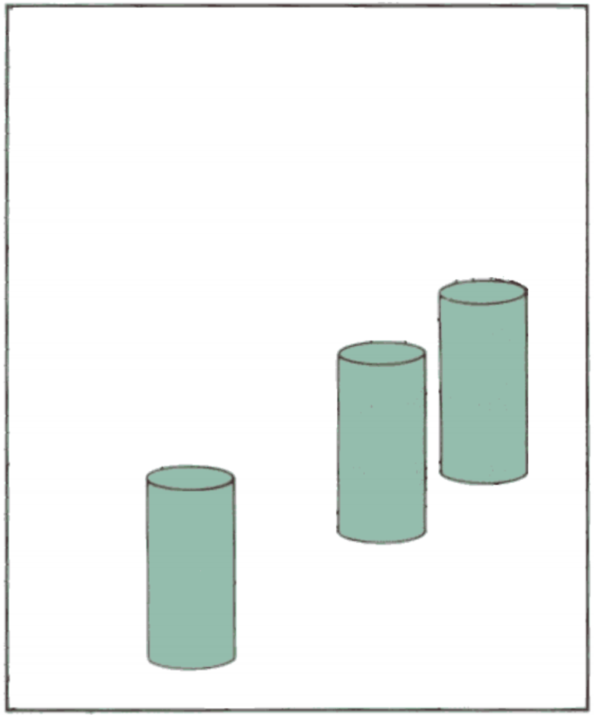
Objects with the same image size at different apparent distances

…produce a visual illusion!



Objects with the same (image) size at different distances

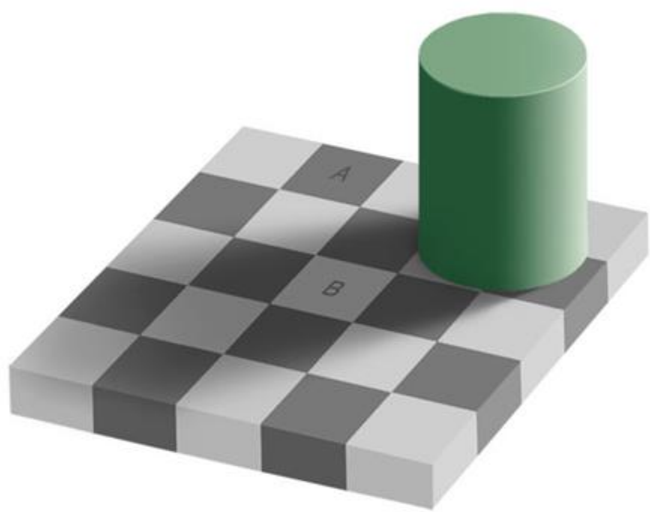
- judgments of image size are influenced by perceptual processes that produce awareness of “real” size



Size/distance illusion in a real world scene

Brightness constancy

- when painting a picture of this scene, what shades of grey would I need for squares A and B?



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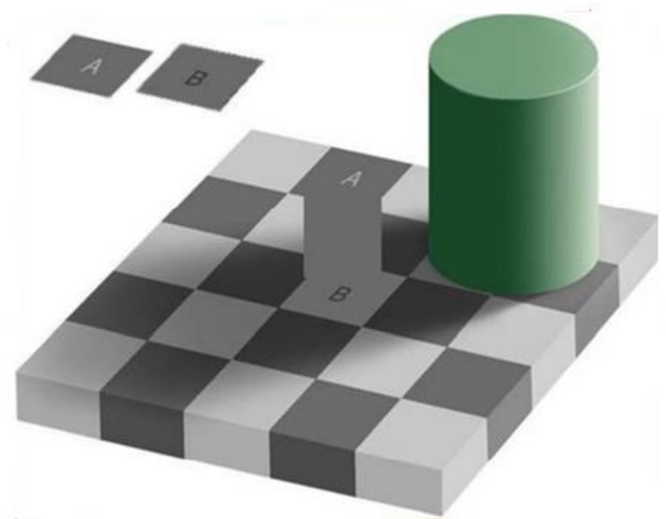
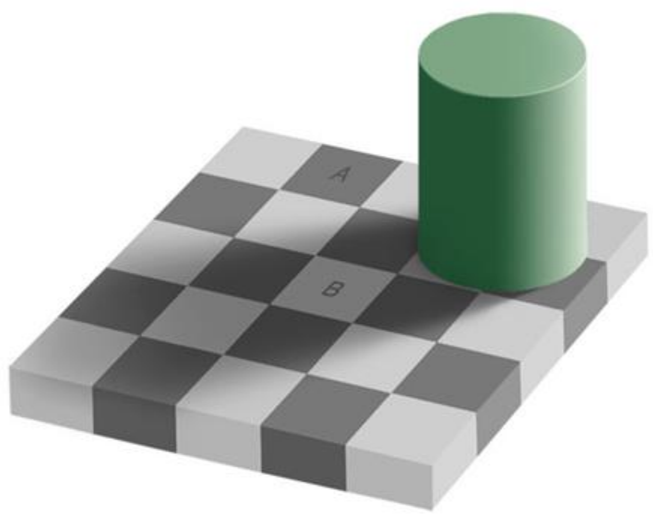


Brightness constancy

- when we view this scene, we automatically compensate for differences in illumination from an unseen light source (somewhere off to the right of the picture)



Perceptual constancy

- perceptual mechanisms are designed to provide awareness of physical reality, rather than appearance
- cues extracted from the scene provide information about viewing conditions and observer's relation to the object
- perceptual experience is shaped by this interpretation - observers do not have direct access to sensory data

Summary and key points

- Sensation - involves conversion of physical energy into signals in sensory neurons ("transduction")
  - requires specialised sense organs, containing receptors which convert physical energy to neural signals
- Perception - perceptual processing is based not on passive reception of sensory information from an external world, but rather involves interpretation
- Interpretation is based on:
  - innate principles of perceptual organisation
  - procedures acquired through perceptual learning
  - memory (stored knowledge)
- Perceptual experience (i.e. what we see) is shaped by these computational processes – can produce powerful "visual illusions"

References

Gibson, E. J., & Walk, R. D. (1960). *The "visual cliff"*. WH Freeman Company.

Hubel, D. H., & Wiesel, T. N. (1962). Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. *The Journal of Physiology*, *160*, 106.

Wertheimer, M. (1923). Untersuchungen zur Lehre von der Gestalt. *II.Psychological Research, 4*, 301-350.