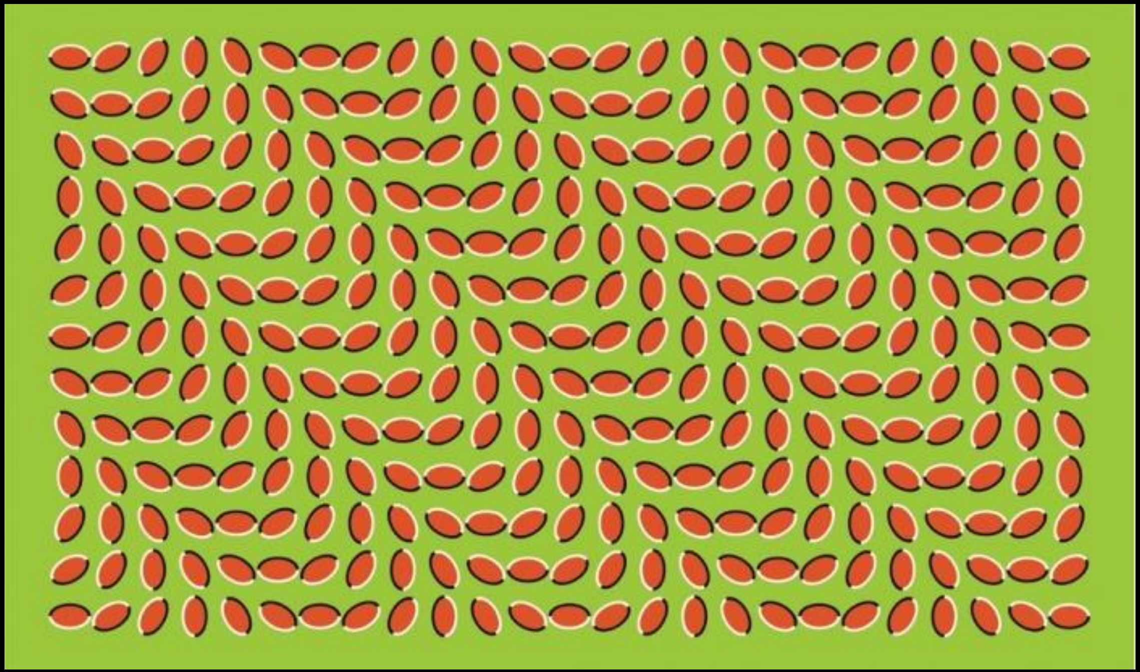
University of BRISTOL

PSYC10009: Biological Psychology

Vision



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From Early Vision To Social Vision In 3 Lessons

Lecture 1: Early Vision

- Retinal processing
- Early cortical visual processing

Lecture 2: Higher-Level Vision

- Beyond V1: colour, motion, form, objects
- Feature binding

Lecture 3: Social Vision

- Perceiving People
- Perceiving Minds

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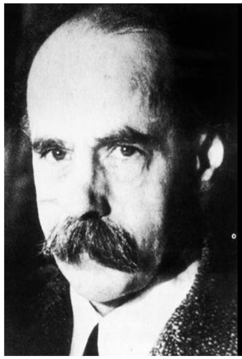
Relevant Readings

Schacter, D., Gilbert, D, & Wegner, D. (2012). Psychology. New York: Palgrave MacMillan. (Chapter 4, pp. 130 – 147)

Kalat, J. W. (2013). Biological Psychology. Wadsworth Cengage Learning. (Chapter 6, pp. 151 – 187).

Historic Views on Perception

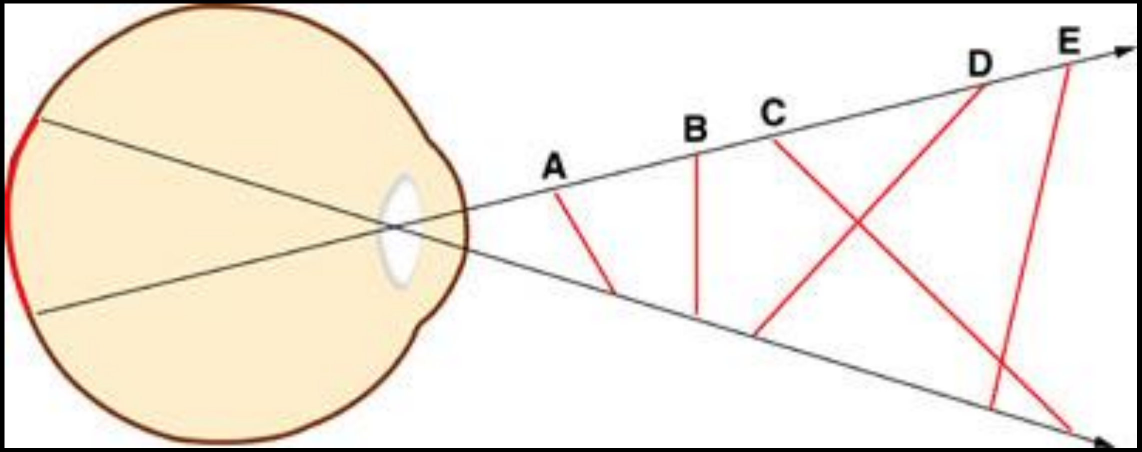
James Gibson et al.: Senses accurately reflect the physical world. (objectivist view)



Max Wertheimer et al.: Our senses organize the world. (subjectivist view)

David Heeger et al.: Senses/brain evolved to reflect some aspects of the world very accurately. (synthetic view)

What's The Goal of Vision?



- solve the inverse problem: given some sensation on the retina, what was out there?
- enable interaction with the visual environment

Important Basic Terms

<u>TRANSDUCTION:</u>

conversion of physical signals from the environment (e.g., light) into neural signals carried by sensory neurons into the central nervous system

<u>SENSATION:</u>

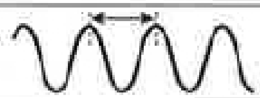
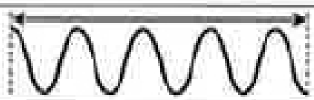
stimulation of a sense organ (e.g., retina)

<u>PERCEPTION:</u>

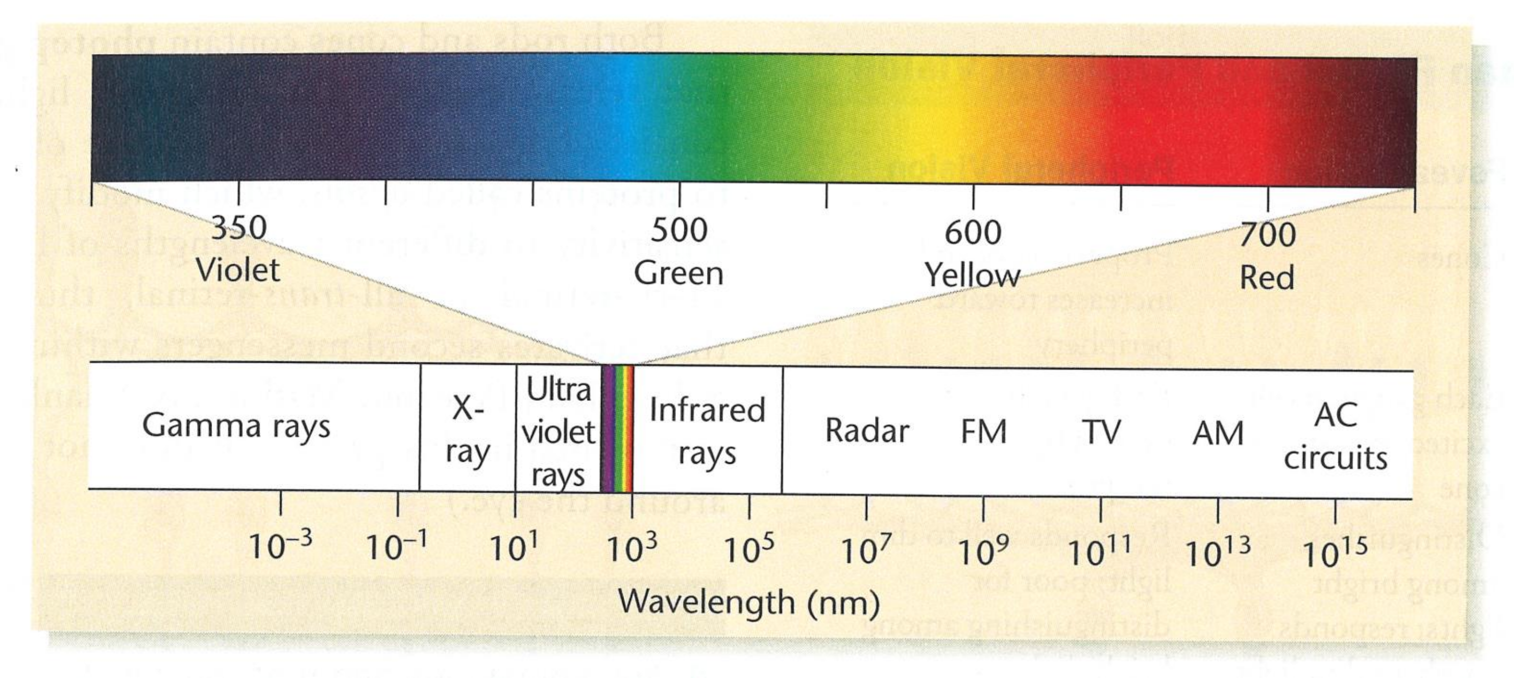
organization and interpretation of the stimulation at the level of the brain

Basic Properties of Light Waves

TABLE 4.2 Properties of light waves

Physical dimension		Psychological dimension
Length		Hue or what we perceive as colour
Amplitude		Brightness
Purity		Saturation or richness of colour

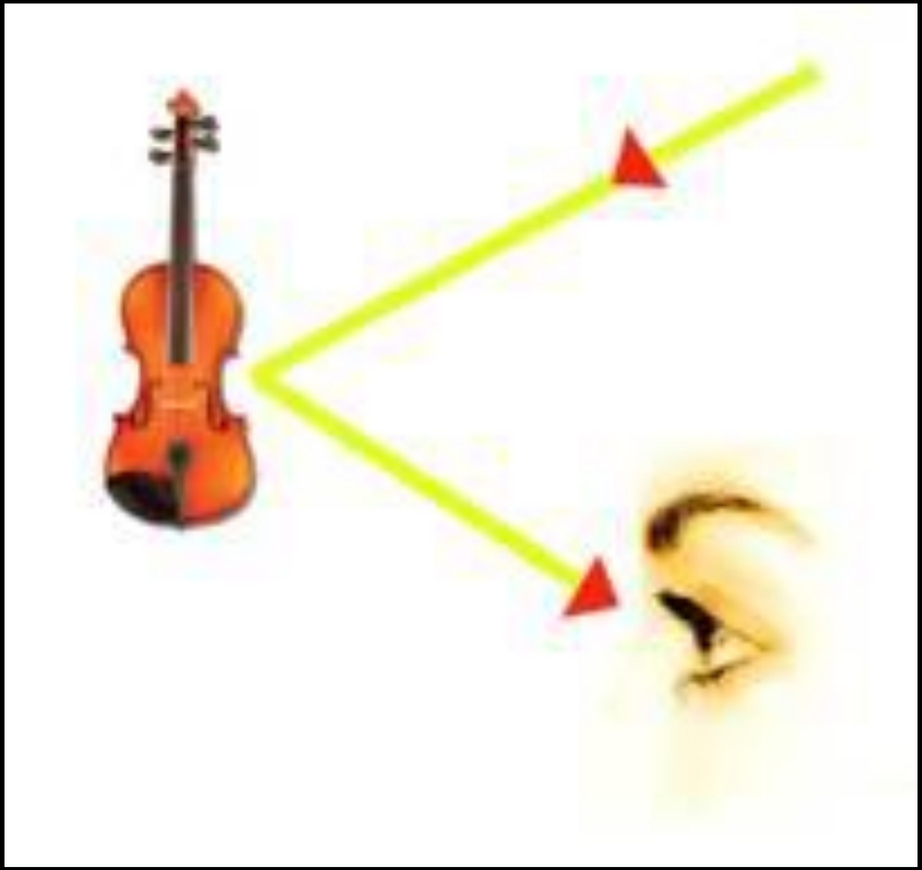
The Electromagnetic Spectrum



Humans perceive the shortest wavelengths as violet, longest one as dark red.

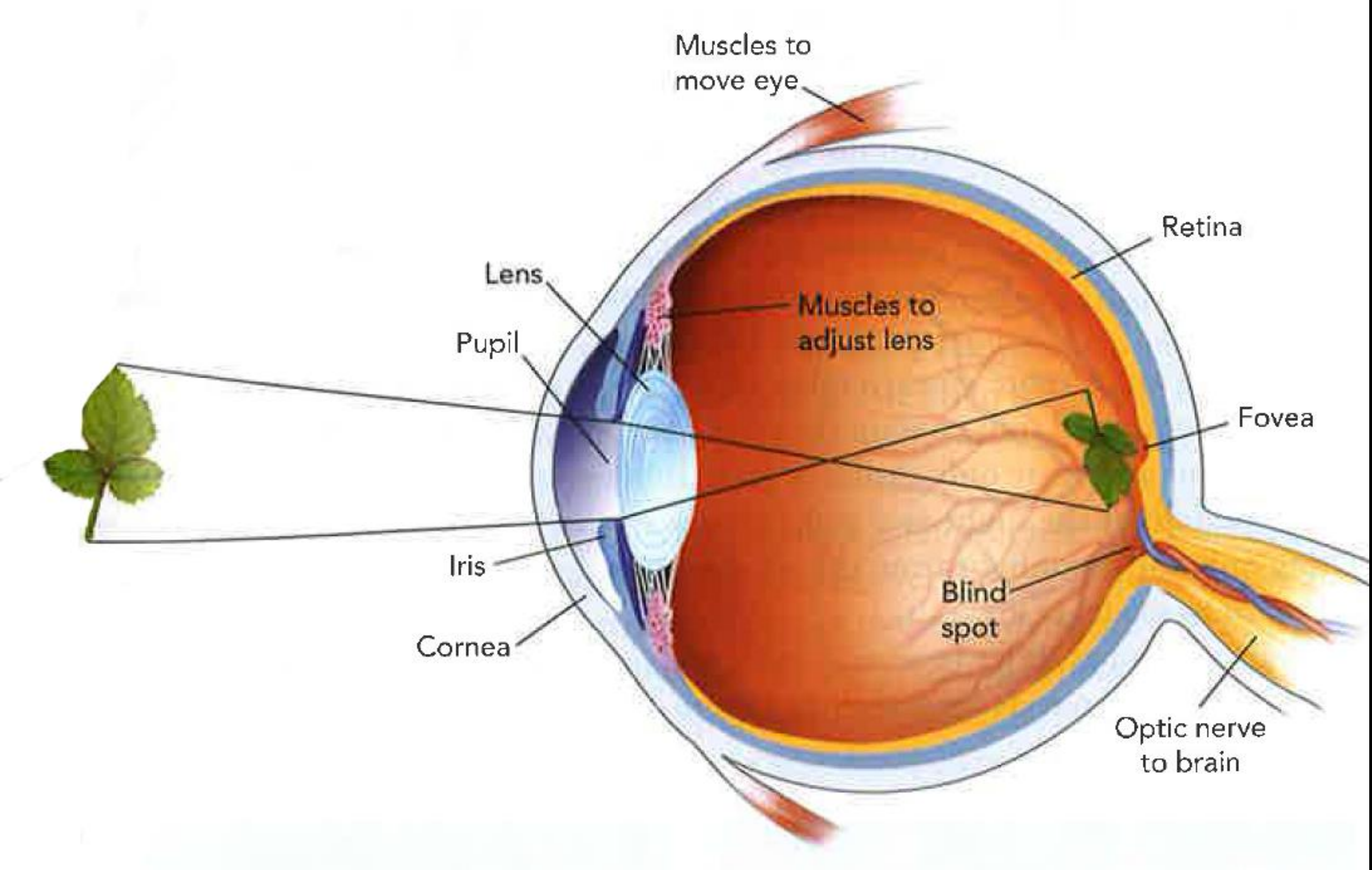
Even shorter wavelengths (i.e., ultraviolet radiation) can be seen by some non-human species such as bird, fish, and insects. Thus, to us the male and female bird of some species may look alike, but to them they look different, because one reflects more ultraviolet light.

And What Do Light Waves Do?



Arab scholar Ibn al-Haytham (965 -1039). By some considered father of modern science.
Demonstrated that light rays bounce off any object in all directions.

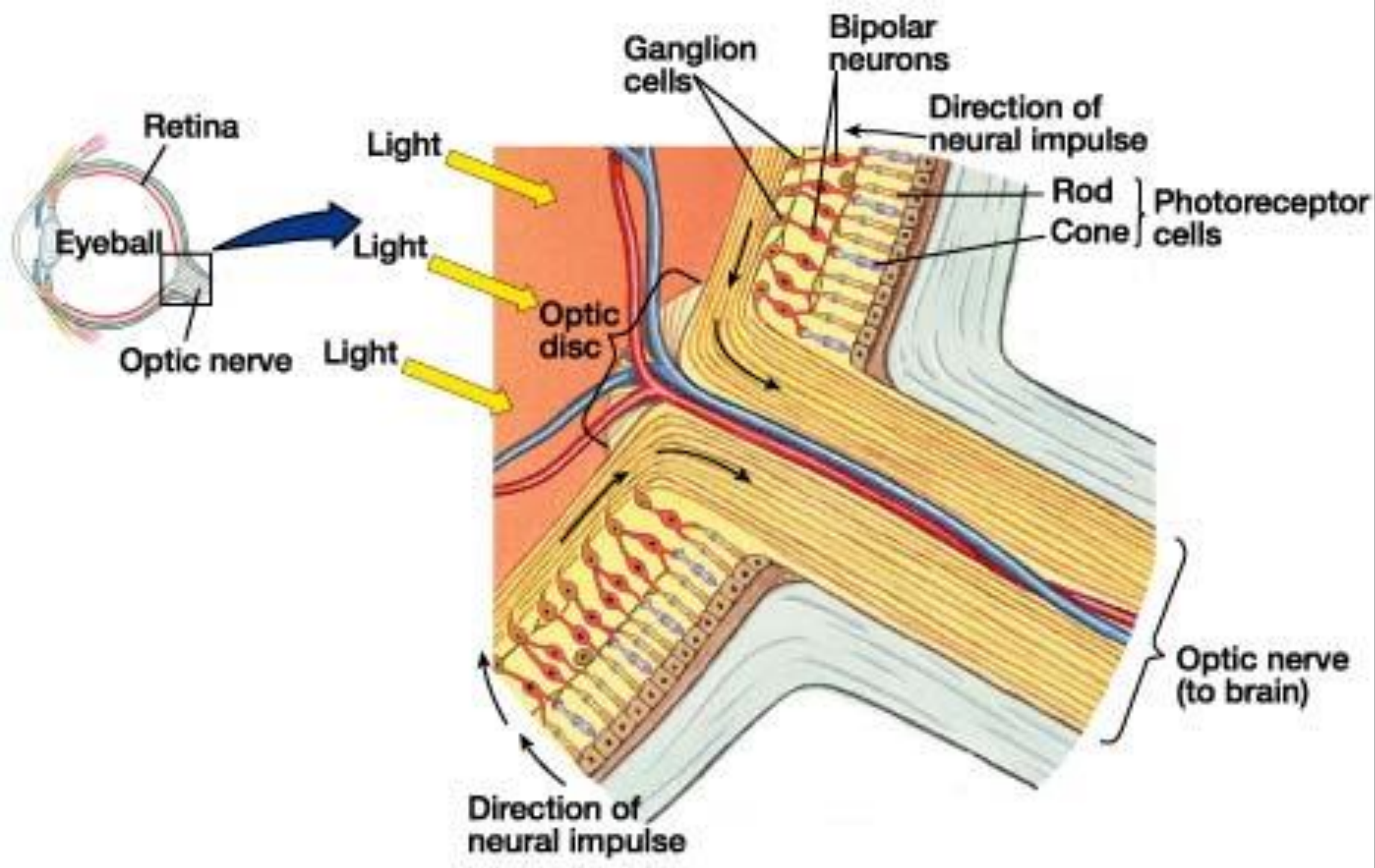
The Human Eye I



The Human Eye II

- **light enters eye through pupil**
- **light is focused by the lens** (adjustable) **and cornea** (not adjustable)
- **light is projected on rear surface of eye, the retina**
- **retina is lined with visual receptors**
- **light from above strikes the bottom half of the retina, light from below strikes the top half** (resulting in an inversion of the image)
- **anything that excites visual receptors in eyes is perceived as light** (even if it was actually mechanical pressure from rubbing your eyes)

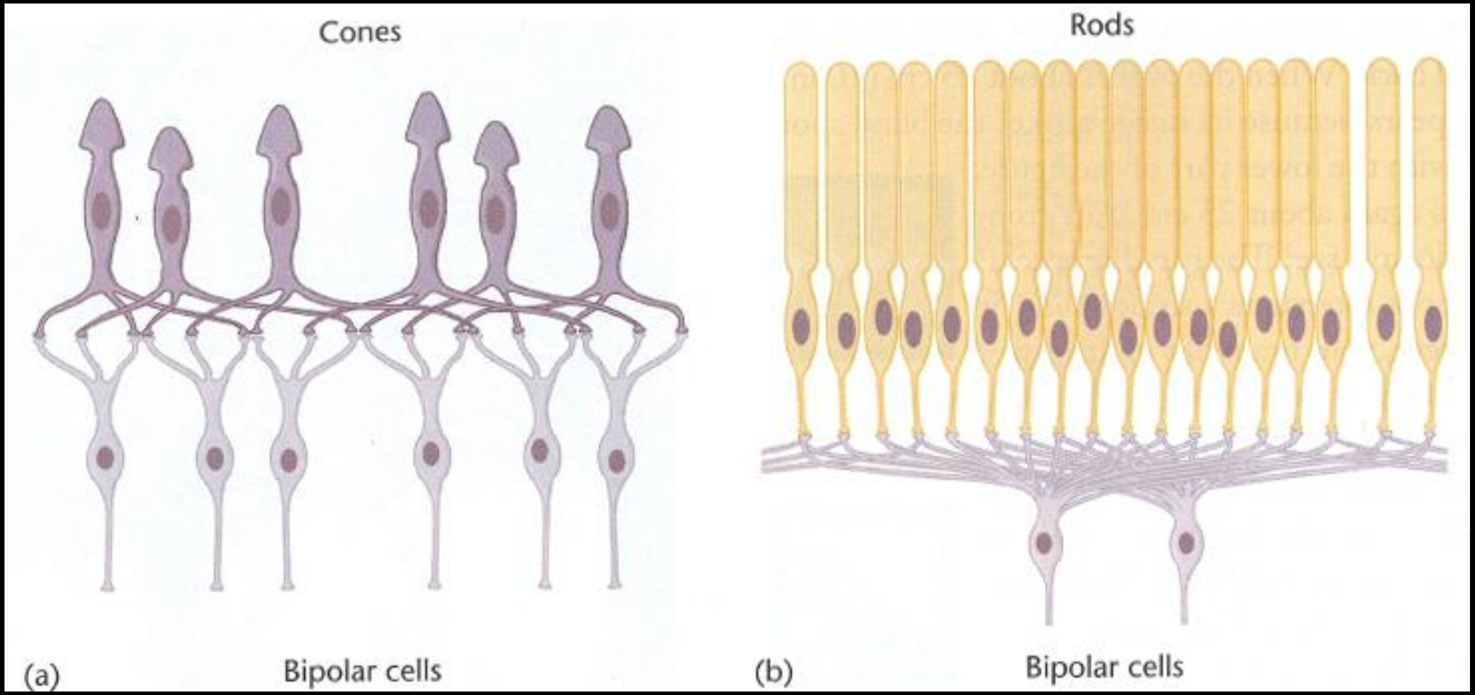
The Retina I


Ganglion cells
Bipolar neurons
Direction of neural impulse
Retina
Light
Eyeball
Light
Rod
Cone
Photoreceptor cells
Optic disc
Optic nerve
Light
Optic nerve (to brain)
Direction of neural impulse

The Retina II

- **signal transmitted from photorecepter cells => bipolar cells => ganglion cells** (latter most closely to the center of the eye)
- **thus: light passes through ganglion and bipolar cells en route to photoreceptors** (luckily, these cells are transparent)
- **ganglion cells' axons join together** (forming the optic nerve) **and travel to brain**
- **point where optic nerve leaves the eye has no receptors (= 'blind spot')**
- **people vary in number of axons from retina to brain** (those with more show greater ability to detect brief or faint stimuli)

The Fovea And Periphery of the Retina I



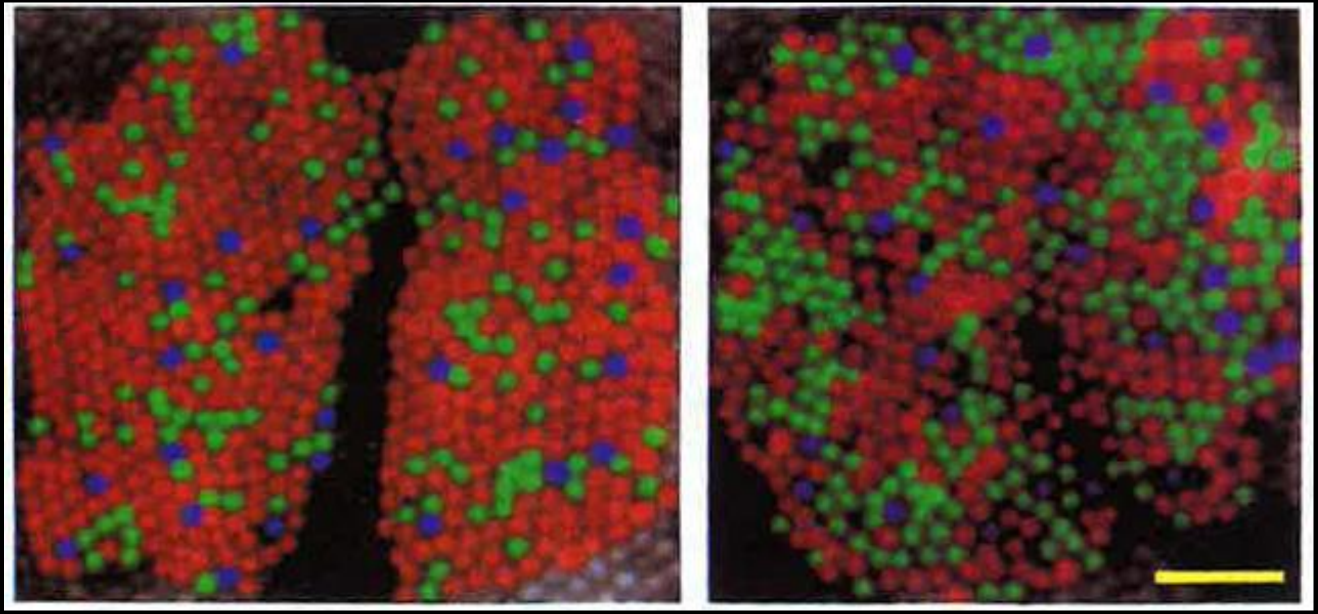
The Fovea And Periphery of the Retina II

- **central portion of retina: fovea**
- **fovea: point of most accurate, detailed vision**
- **in fovea each receptor connects to a single bipolar cell, which in turn connects to a single ganglion cell => high acuity** (sensitivity to detail)
- **toward periphery, more and more receptors converge onto common bipolar and ganglion cells** (brain can no longer detect the exact location of shape of a light source) **=> but summation of light** (peripheral vision has better sensitivity to dim light)

Visual Receptors: Rods and Cones

- **human retina contains two types of photoreceptors: rods and cones**
- **both contain photopigments** (i.e., chemicals that release energy when struck by light, the energy release activates second messengers within the cell)
- **rods: abundant in periphery, responsive to faint light**
- **cones: abundant in in/near fovea, responsive to bright light, essential for color vision**
- **in retina, rods outnumber cones (20 : 1) but cones provide about 90% of the brain's input**

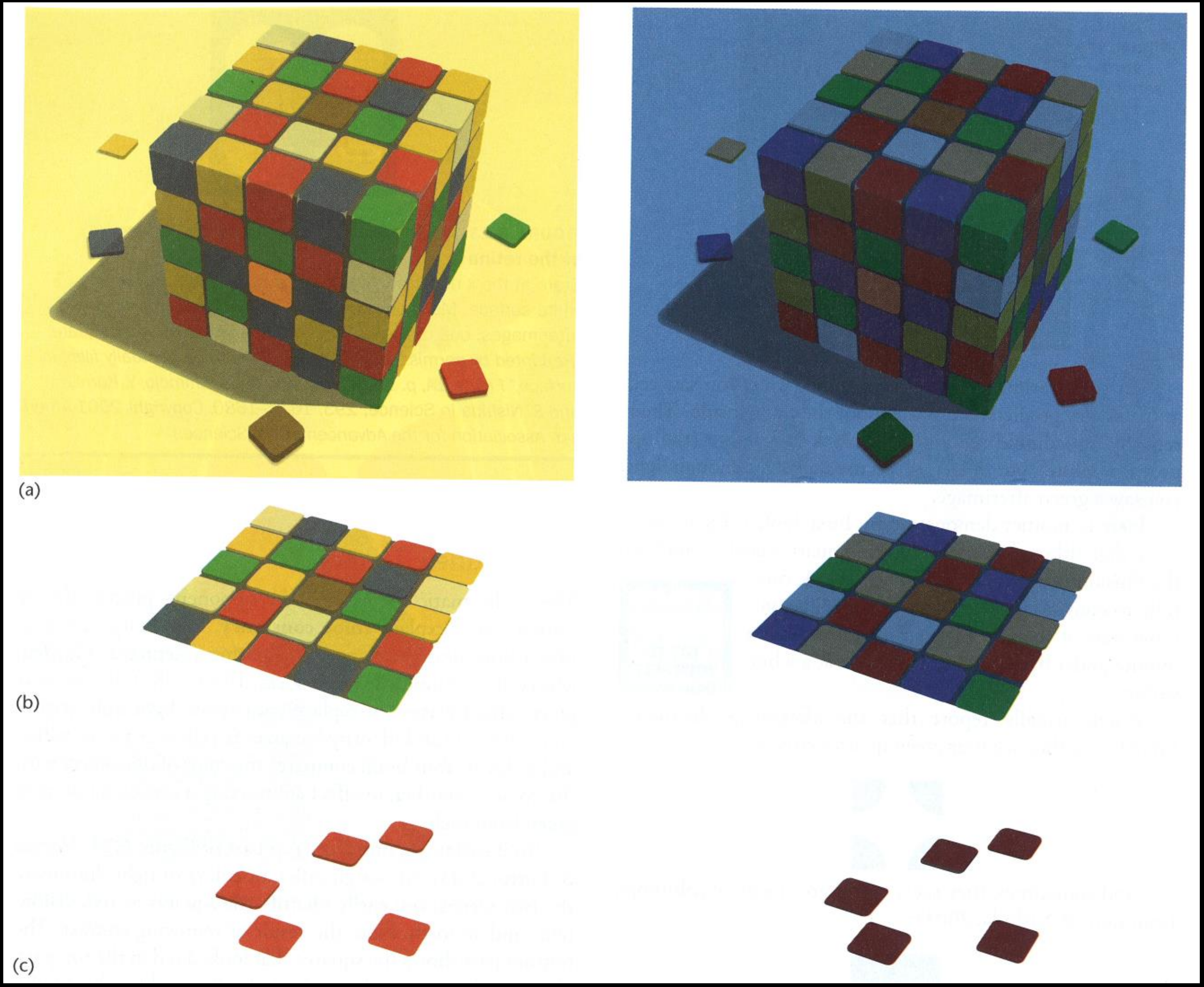
Colour Vision: Distribution of Cones in 2 Human Retinas



Colour Vision

- **3 cone types: sensitivity for short (‘blue’), medium (‘green’), or long wavelengths (‘red’)**
- **colour perceived based on <u>relative</u> response of all three**
- **white is seen when all three types are equally active**
- **short-wavelength cones are rare but most evenly distributed across the retina**
- **other two distributed haphazardly, with big differences across individuals**
- red-green color deficiency: medium- and long-wavelength cones have same photopigment instead of different ones

The Color Constancy Challenge I



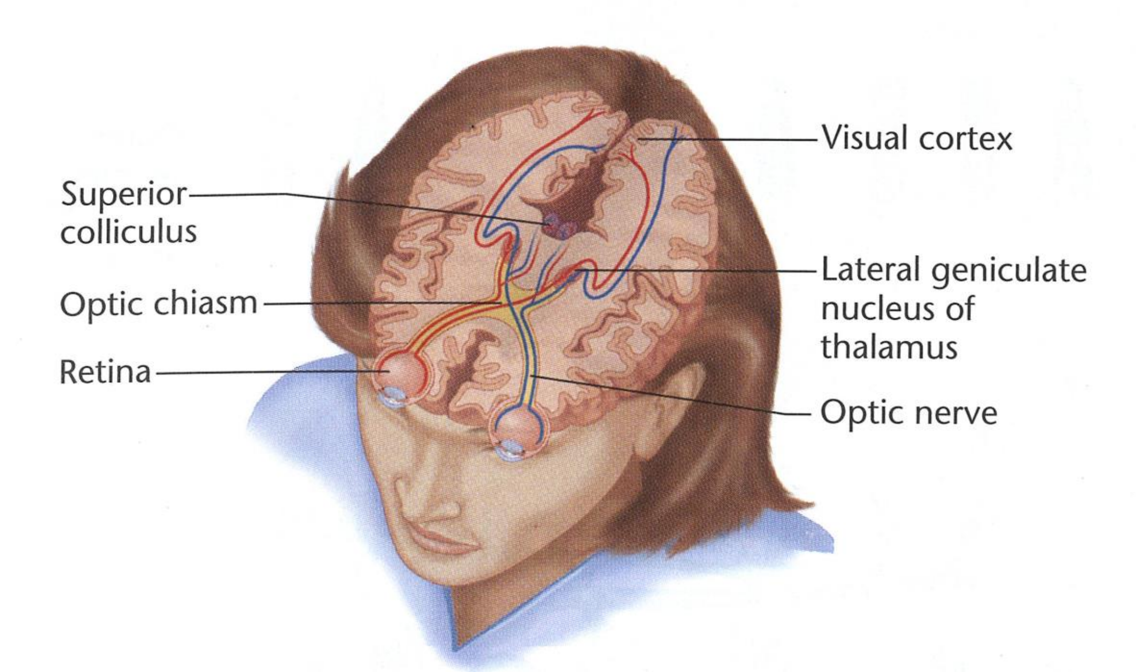
The Color Constancy Challenge II

- color constancy: ability to recognize colors despite changes in lighting
- a certain wavelength of light can appear as different colors depending on background
- => reflected wavelength ≠ perceived colour
- Retinex Theory (Land, 1983): cortex compares information from various parts of retina to determine color
- early visual neurons respond to wavelength, later neurons respond to perceived colour

Interim Summary I

- light passes through pupil and stimulates photoreceptors lining the retina at the back of the eye
- photoreceptors can be rods or cones (3 types of cones allow for color vision)
- visual acuity is greatest when light stimulates cones in the fovea (central area of retina)
- axons from retina form the optic nerve that goes to the brain

From The Eye To The Primary Visual Cortex I



From The Eye To The Primary Visual Cortex II

- optic nerves from the 2 eyes meet at the optic chiasm
- there, half of axons from each eye cross to opposite side of brain
- minority of ganglion axons go to superior colliculus
- majority of ganglion axons go to lateral geniculate nucleus (LGN) in the thalamus
- LGN sends axons to other parts of the thalamus and the primary visual cortex
- primary visual cortex returns many axons to thalamus
  (information is fed back and forth)

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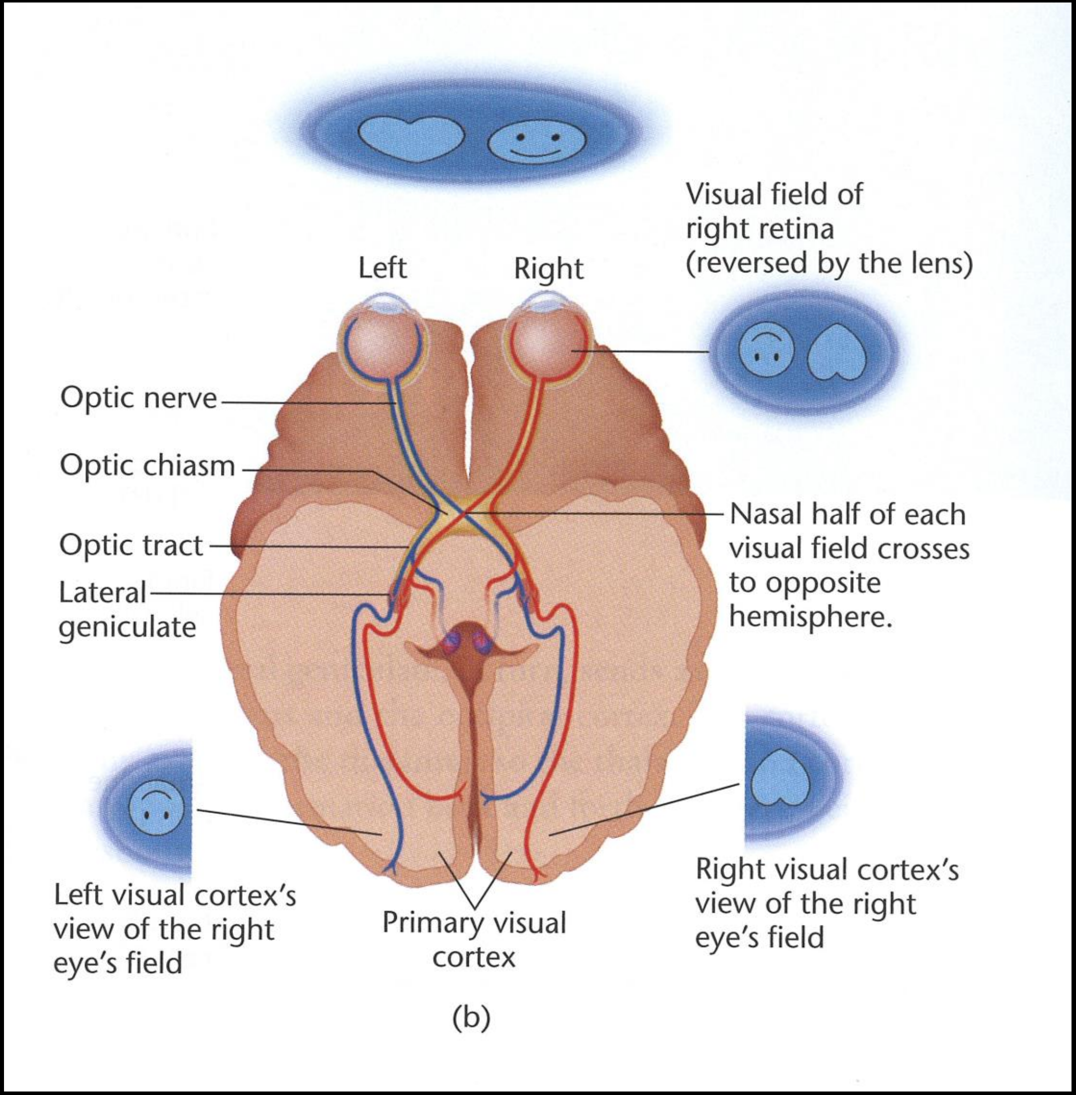
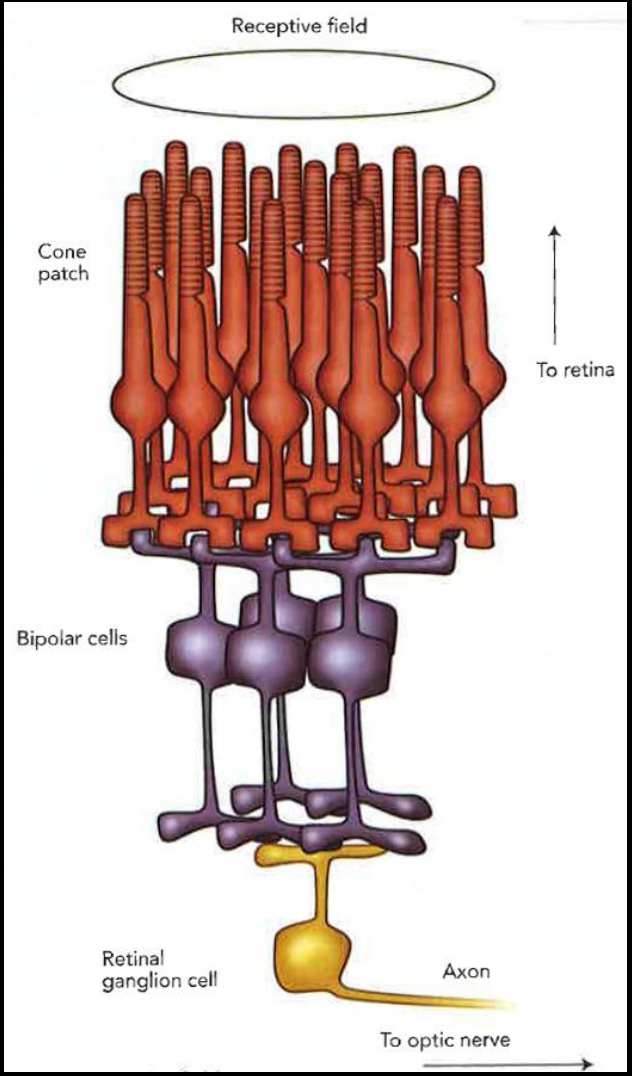
From The Eye To The Primary Visual Cortex III



Receptive Fields

- **each axon in optic nerve originates in individual retinal ganglion cell (RGC)**
- **RGC often integrates signals of adjacent cones or rods**
- **i.e., RGC will respond to light falling anywhere within this small patch = its receptive field**
- definition receptive field: region of the sensory surface that causes a change in the firing rate of a neuron when stimulated

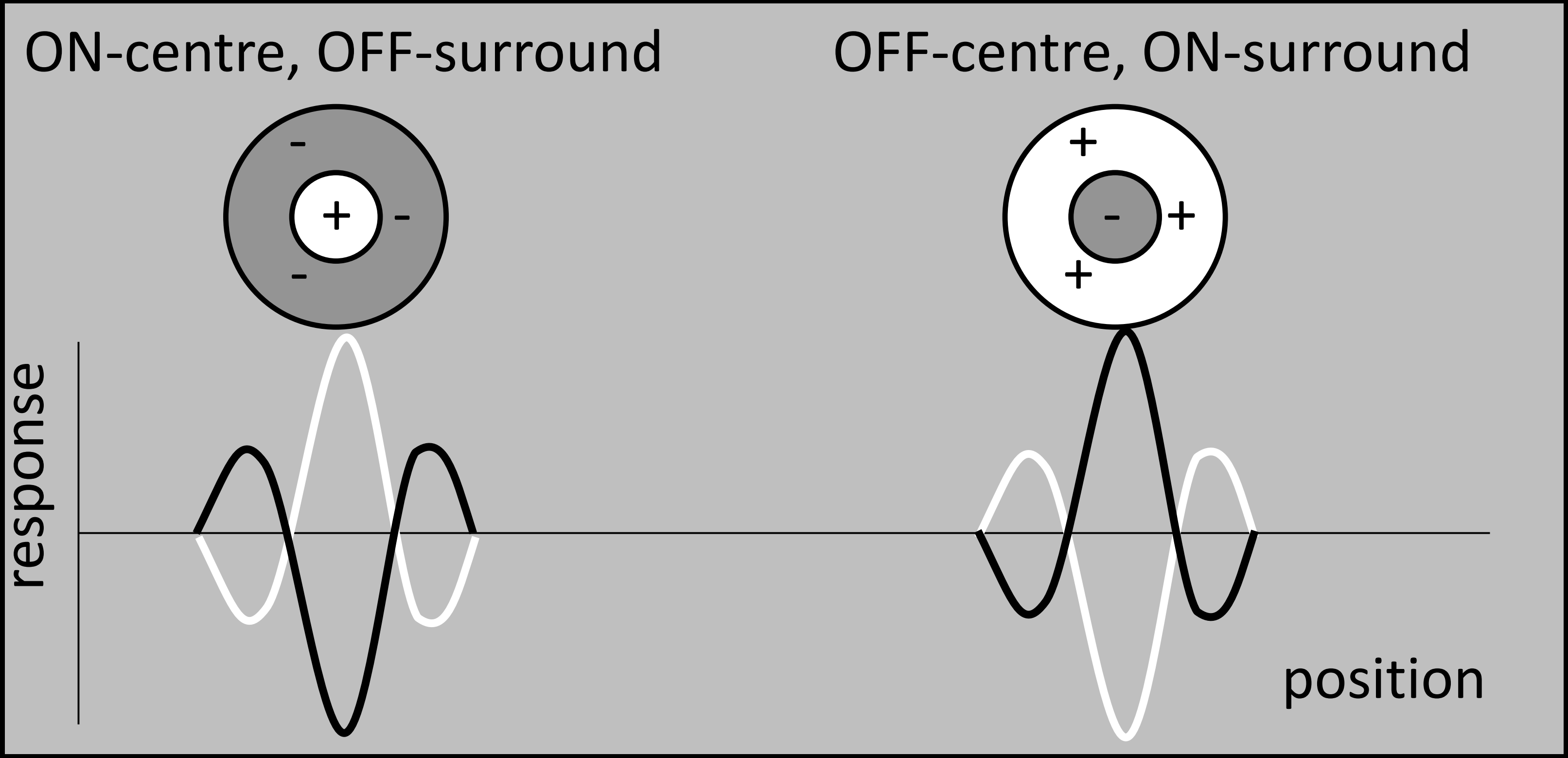


Excitatory and Inhibitory Responses

- if light detected by a particular spot in the retina excites a cell, then this location is part of the neurons excitatory receptive field
- if light detected by a particular spot in the retina inhibits a cell, then this location is part of the neurons inhibitory receptive field

Receptive Fields of Ganglion Cells

- are organized in a center-surround fashion
- Version A: light in the center excites the cell, light in the surround inhibits the cell
- Version B: light in the center inhibits the cell, light in the surround excites the cell

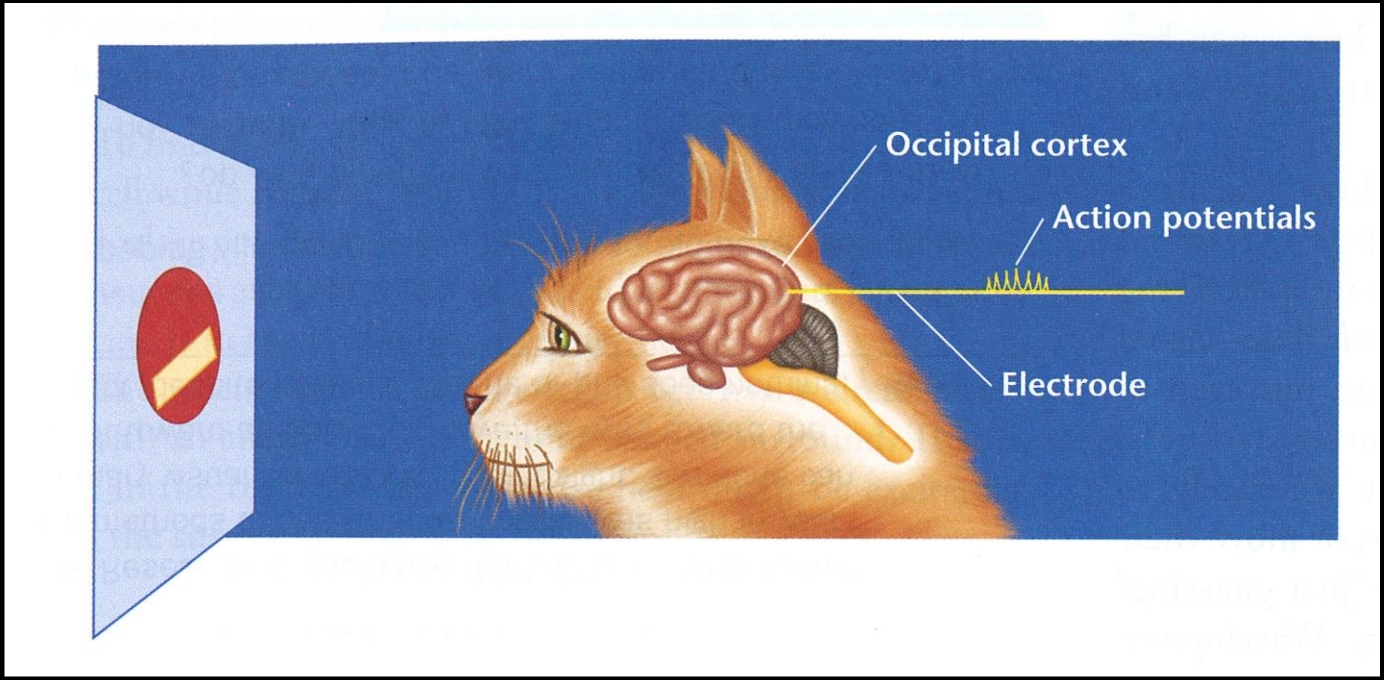


Receptive Fields of Increasing Complexity

- **cells of the LGN have receptive fields that resemble those of ganglion cells**
- **but receptive fields in the primary visual cortex (V1) can be more complicated**
- **their size/organization depends on the connections they receive (i.e., combination of the receptive fields of several ganglion cells)**

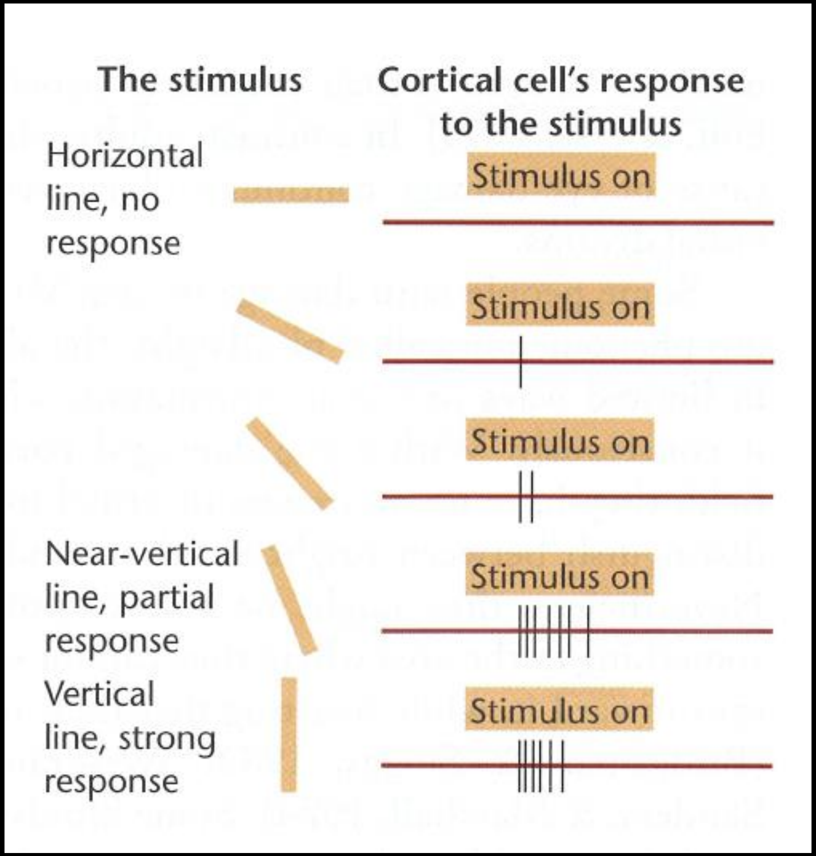
Hubel & Wiesel (1959)

- **Hubel & Wiesel (1959) recorded neural activity from cells in cats' and monkeys' visual cortex while shining light patterns on the retina** (cf. microelectrode recordings)



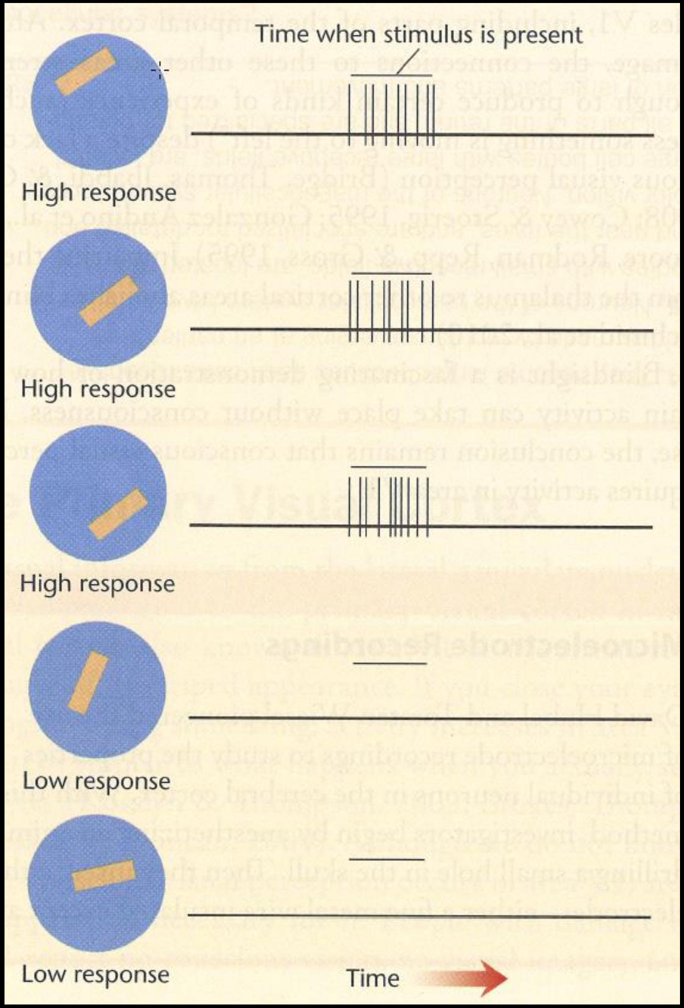
Simple Cells at V1

- **receptive field of relative small size**
- **receptive field usually bar- or edge-shaped**
- **fixed excitatory and inhibitory zones** (i.e., the more light shines in an excitatory zone, the more the cell fires)



Complex Cells at V1

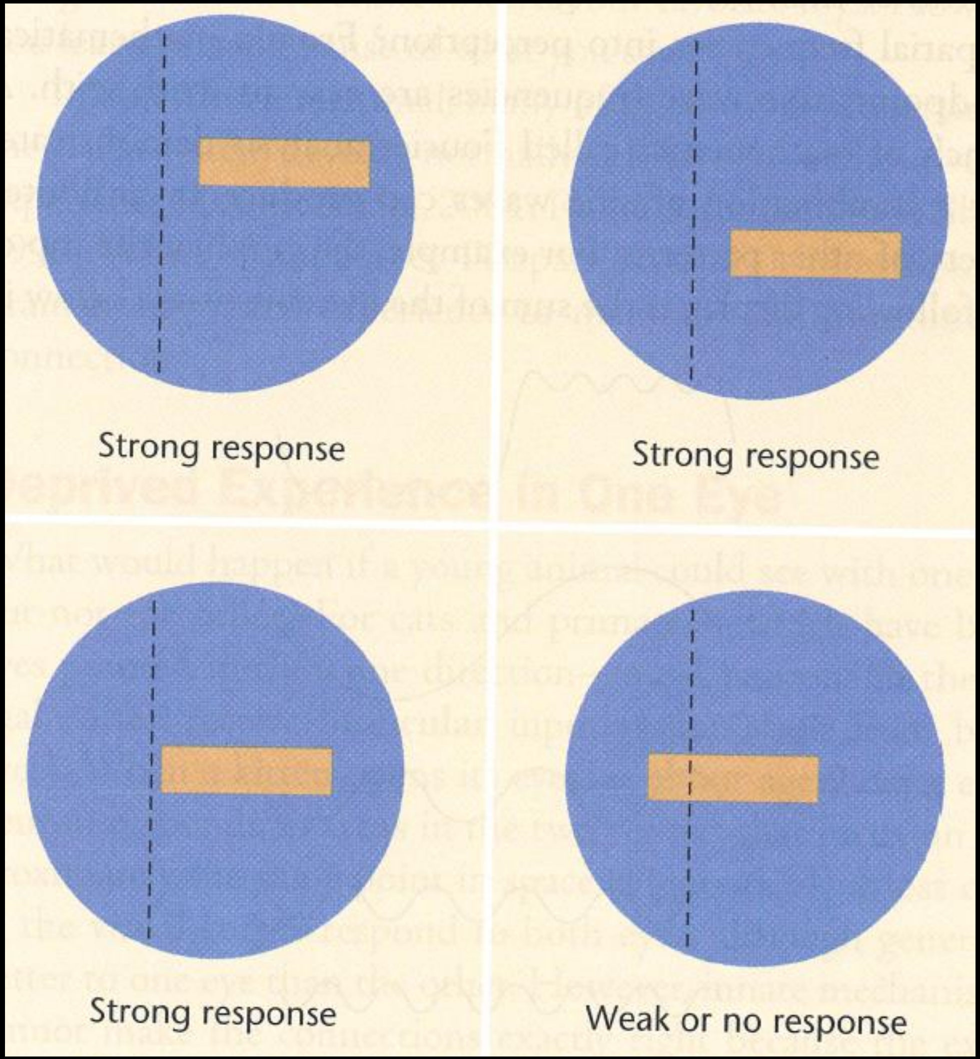
- **receptive field of medium size**
- **bar-/edge-shaped but without fixed excitatory or inhibitory zones**
- **cells respond to moving light patterns**



Best way to classify a cell as simple or complex: A cell that responds to a stimulus in only one location is a simple cell. One that responds to a stimulus equally throughout a large area is a complex cell.

Hypercomplex Cells at V1

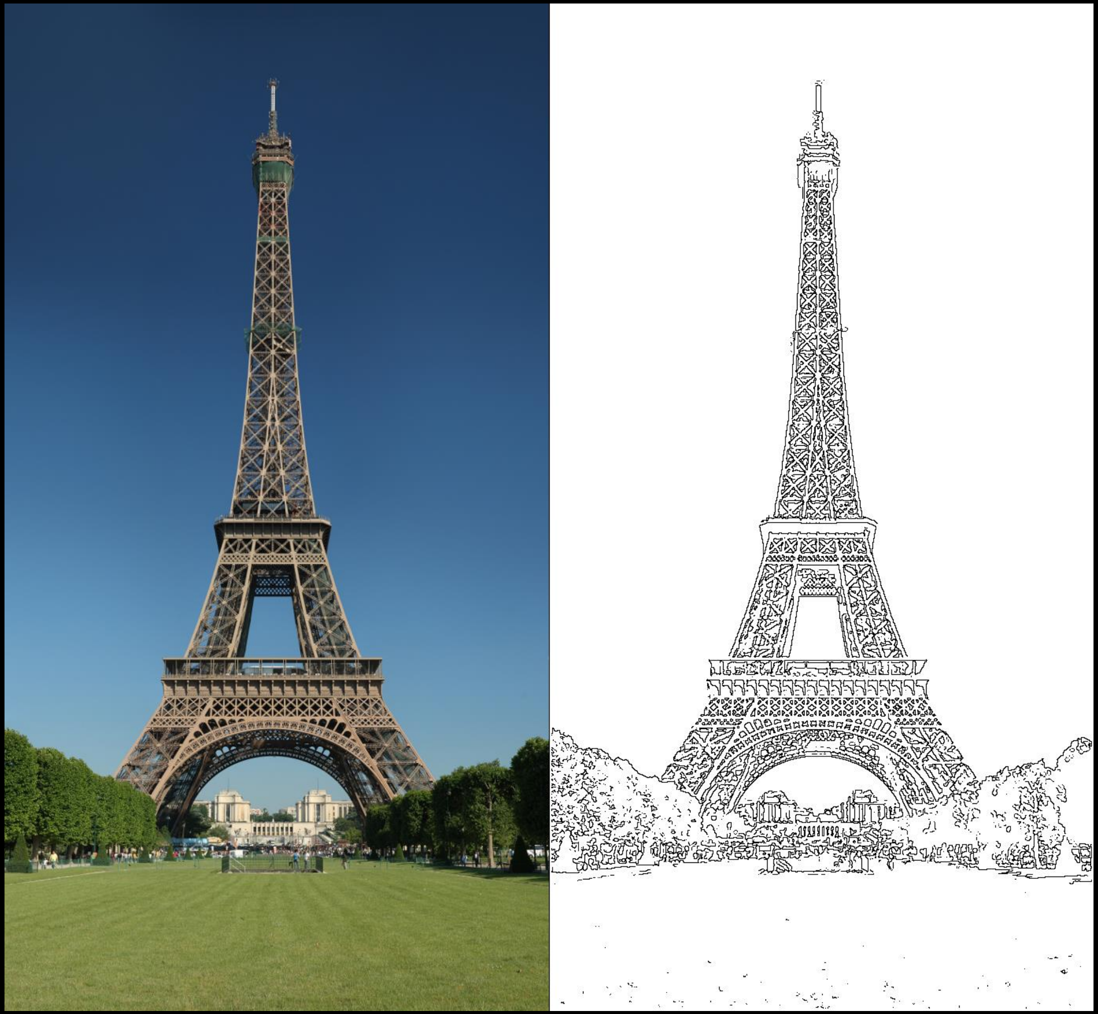
- receptive field of large size
- bar-/edge-shaped but strong inhibitory area on one end



Summary Primary Visual Cortex (V1)

- **contains many neurons tuned to bars in different positions of the visual field => specialized for encoding edge orientation**
- **cells of similar properties** (e.g., with similar receptive fields and/or coding information from the same eye) **are grouped together in columns (=> alternative name: Striate Cortex)**
- **columns follow topographic organization: adjacent neurons process adjacent portion of the visual field**

Edge Encoding Across Many Populations of Neurons



Interim Summary II

- a receptive field describes the spatial pattern of light to which a cell responds
- across the visual processing stream receptive fields grow progressively more complex
- receptive fields can be probed with behavioural experiments
- early visual cortex detects basic features in images: edges!
- edge detection depends on the activity of many populations of neurons