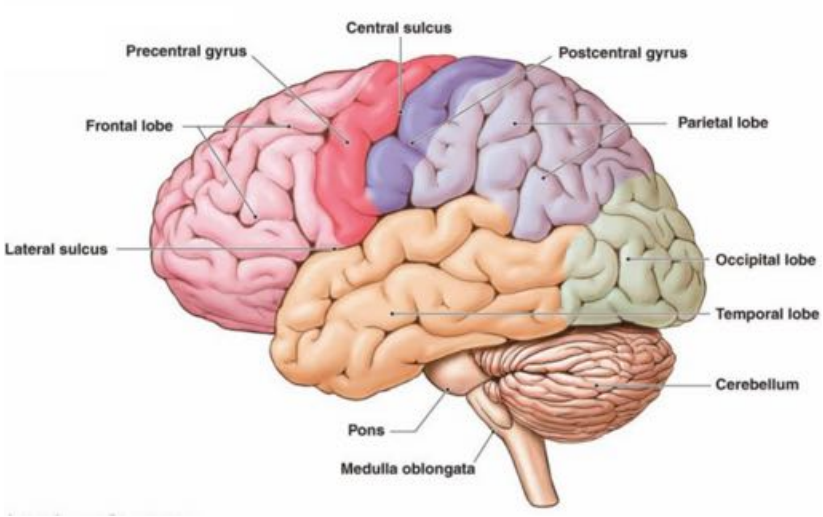
The Human Brain



cerebral hemispheres: two most important divisions of the brain, **separated by the longitudinal fissure**
corpus callosum: a large bundle of axons that constitutes the **major connection between the two cerebral hemispheres** (highly convoluted)
sulcus: an **indentation** between two gyri on the surface of the cerebral hemispheres
gyrus: an **elongated bump** on the surface of the cerebral hemispheres
cerebral cortex: the **outermost layer** of the cerebral hemispheres; about 2-4mm thick and constituting mainly of gray matter (neural cell bodies)
gray matter: the **cell bodies** of neurons **making up the cerebral cortex**
white matter: the **myelin covered axons** of cortical neurons, **making up the interior parts of the cerebral hemispheres**; these axons **connect neurons located in different parts of the cerebral cortex**
frontal lobe: one of the four lobe of each cerebral cortex (left and right); separated from the temporal lobe by the lateral sulcus and from the parietal lobe by the central sulcus
temporal lobe: one of the four lobes of each cerebral cortex (left and right); separated from the frontal lobe and the parietal lobe by the lateral sulcus
parietal lobe: one of the four lobes of each cerebral cortex (left and right) separated from the frontal lobe by the central sulcus, from the temporal lobe by the lateral sulcus, and from the occipital lobe by the parieto-occipital sulcus
occipital lobe: one of the four lobes of each cerebral cortex (left and right) separated from the parietal lobe by the parieto-occipital sulcus
thalamus: the most important subcortical structure involved in perception; most neural signals originating in the sensory organs pass through the thalamus on their paths to the cortex

Cognitive Neuropsychology

- Dependent on modularity, which is the **idea that human mind and brain consist of a set of distinct modules**, each of which carries out one or more specific functions e.g. typing to spoken dictation involves audition, language and finger movements.
- In cognitive neuropsychology, a pattern of brain **damage and impaired function in which damage to some specific brain region is associated with impairment of some specific function but not with another** is called **DISSOCIATION**
- **DOUBLE DISSOCIATION** (ideal when analysing brain lesions) is a pattern of brain damage and impaired function in which damage to some specific brain region is **associated with impairment of some specific function A but not with impairment of another function B**, along with a pattern (in a different patient) in which damage to a different region is **associated with impairment of function B but not with the impairment of function** A e.g. object recognition without face recognition, and face recognition without object recognition
- This requires the **ASSUMPTION OF COGNITIVE UNIFORMITY**, that the functional **organisation of human cognition and of the brain is essentially the same in everyone**

Functional Neuroimaging

- Measure brain activity in healthy volunteers
- Can encompass techniques for measuring the electrical or magnetic fields produced by populations of active neurons and techniques for measuring the changes in blood flow and blood oxygenation that accompany brain activity

Electroencephalography (EEG) and Magnetoencephalography (MEG)

- Both based on the **measurement of magnetic fields** associated with brain activity
- Allows **only approximate determination** of the locations in the brain of the neural activity being measured due to the **coarse resolution of EEG and MEG**

Position Emission Tomography (PET)

- When neurons in some part of the brain become active, more blood flow goes to that area
- PET can be used to **measure changes in blood flow** and thus, measure neural activity
- PET introduces **radioactive substance into the blood** (disadvantage)
- Substance is carried to the brain and the PET scanner provides a 3D image of the amount of radioactivity at different locations of the brain

- ***Invasive procedure as a radioactive substance must be introduced in the body***
- Image provides a record of the **average brain activity over 30-60min**, which means that changes in **brain activity that happen over shorter periods of time can not be measured** (disadvantage)

Functional Magnetic Resonance Imaging (MRI)

- Takes advantage of naturally occurring magnetic properties of the body
- Produces **high resolution**, 3D images of bodily structures
- Structural MRI takes a snapshot of organs, bones and joints and can be effective in finding brain tumor or brain damage
- **Based on the changes of levels of oxygen in the blood** (more oxygen is needed in areas of higher neural activity)
- fMRI – based on the measurement of changes in blood oxygenation associated with brain activity and **relies on the production of magnetic fields in the brain**
- diffuse optical tomography (DOT) - based on the measurement of changes in blood oxygenation associated with brain activity and **relies on measurement of light absorbed and reflected by the brain.** DOT is advantageous because it **doesn't require the introduction of radioactive substances into the body and it can be used in patients that have metal inserted into their body** (unlike fMRI which is affected by magnetic fields). DOT equipment is relatively compact, has similar temporal resolution to fMRI but lower spatial resolution

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Face to Face Discussion

What would be benefit of using one neuroimaging technique over another?

Advantage of mRI that is dis of PET → during a PET scan, you have to inject with radioactive materials. However, both are slow techniques because they rely on the blood flow

- *fMRI- increase of consumption of O2 in blood that comes from the fact that neurons become more active*
- *fMRI how does it measure indirectly? Haemoglobin in blood has in 2 stated oxyhaem and de oxy. What the mri does it, (the 2 varieties have different magnetic signatures) the types of molecule distort the magnetic field in a certain way. So the mri detects how dark the blood becomes in a particular spot using the magnetic properties of the molecule.*

The Martrix

- ***The law of specific nerve energies***
- *Dr Wilder Penfield, surgeon, wanted to remove tumor from brain, didn't want to affect part of the brain that controls language, patient was awake, stimulated vivid recollections of past*

Learning how to see (video case)

- *Trouble with audio/visual integration – for us, we look and hear an object at the same time (helps us detect where something is)*
- *Bottom up (bottom up processing was repaired by fixing his eyes,), top down (the occipital lobe hasn't*
- *His visual system developed up to a certain point and was delayed*
- *He has the ability to detect colour because that part of the brain may have already developed before he lost his vision*
- *Face recognition and depth perception modules did not have the opportunity to develop by the time he lost his vision*
- *We have developed heuristics through experience that have allowed us to use object recognition mechanisms*

Light and the Eyes

Retina

- The retina **transforms images into neural signals** to be sent to the brain
- Retina is soft, textured, living tissue that is made up of different classes of neurons
- Retinal image = **a clear image on the retina of the optic array**
- The retinal image becomes inverted because of the way that the light rays are reflected
- The pupil of ones eye looks black because most of the light entering the eye is absorbed by the retina and not reflected back out through the pupil
- The retina has **3 nuclear layers** including the **outer nuclear layer, inner nuclear layer and ganglion cell layer**. They are called nuclear layers because they contain the various types of retinal neurons described below

Classes and Types of Neurons	*Main functions*
Photoreceptors	Transduce light into neural cells Send signals to bipolar cells Send signals to and receive signals from horizontal cells
Rods	Provide black and white vision in dim light
Cones	Provide high-accuracy vision in bright light
S-cones	Most sensitive to shorter wavelengths of light
M-cones	Most sensitive to medium wavelengths of light
L-cones	Most sensitive to longer wavelengths of light
Horizontal Cells	Receive signals from and send signals to photoreceptors and other horizontal cells
Amacrine cells	Receive signals from and send signals to bipolar cells and other amacrine cells
Retinal ganglion cells	Receive signals from bipolar cells and amacrine cells Send action potentials to the brain via the optic nerve

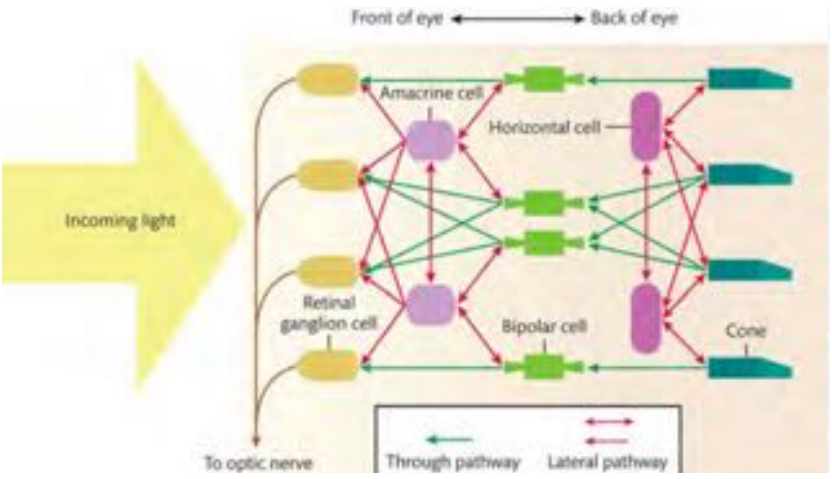
- The nuclear layers are separated by two **synaptic layers**- the outer synaptic layer and inner synaptic layer- where the retinal neurons make synapses with each other.
- Closest to the back of the eye is a layer consisting of the inner and outer segment of the **photoreceptors**, the retinal neurons that transduce light into neural signals.
- The 'business ends' of the photoreceptors, where transduction occurs, are embedded in a layer of cells called the **pigment epithelium**, which is itself attached to the choroid.
- The **outer nuclear layer** consists of the photoreceptors (but not including their inner and outer segments); the **inner nuclear layer** contains **bipolar cells, horizontal cells and amacrine cells**; and the **ganglion cell layer** consists of **retinal ganglion cells (RGCs)**.
- The synapses among the photoreceptors, bipolar cells, and horizontal cells are contained in the **outer synaptic layer** and the synapses among the bipolar cells, amacrine cells, and RGCs are contained in the **inner synaptic layer**.
- The **axons of the RGCs** exit the eye at the optic disk (or blind spot, so called because there are no photoreceptors in this part of the retina), forming a bundle called the **optic nerve**.

Fovea

- Optic axis passed through the fovea at the center of the retina
- **No rods (vision at low light levels, low visual acuity) in the fovea and the density of cones (colour vision, best in bright light) is very high**
- Cones in the fovea are thinner so can be packed densely in a hexagonal grid
- **Ganglion cell and inner nuclear layers are pushed off to the side of the fovea to let the light reach the foveal cones without being scattered as much. This contributes to maximizing high-acuity vision at the center of gaze**

Pathways of Neural Signals in the Retina: An overview

- Incoming light passes through the outer layers of neurons in the retina and **strikes the outer parts of the photoreceptors**, where it is **transduced into neural signals**, **expressed as changes in the membrane potential of the photoreceptors**
- The changes in photoreceptor membrane potential **alter the amount of**



neurotransmitter molecules that the photoreceptors release

- A "through" pathway transmits signals **from photoreceptors to RGC's via bipolar cells**; this is the principle flow of signals through the retina
    - The flow of neurotransmitter molecules released by rods and cones **affects the membrane potential** of bipolar cells, which changes their release of neurotransmitter molecules (any individual bipolar cell receives signals from cones only or rods only)
    - The change in bipolar cell neurotransmitter release **affects the membrane potential of RGCs**, which in turn **affects their firing rates**
- A **lateral pathway** involving **horizontal cells and amacrine cells allows the presence of light at one location on the retina to affect the responses of photoreceptors, bipolar cells, and RGCs at adjacent locations on the retina** (these lateral influences **provide a way for the neural signals to transmit information about luminance contrast**- differences in the intensity of illumination at adjacent retinal locations – and this plays a critical role in detecting edges and boundaries)
    - **Horizontal cells receive signals from photoreceptors and other horizontal cells** and send signals back to photoreceptors and other horizontal cells
    - **Amacrine cells receive signals from bipolar cells and other amacrine cells**, send signals back to bipolar and other amacrine cells, and **send signals to RGCs**.
- Retinal ganglion cells receive signals from bipolar cells and amacrine cells and send action potentials to the brain via the optic nerve.

Optic disk (or blind spot): Location on the retina **where the axons of RGCs exit the eye**; contains no photoreceptors
Optic nerve: Nerve formed by the **bundling together of the axons of RGCs**; it exits the eye through the optic disk
Fovea: Region in the center of the retina where the light from objects at the center of our gaze strikes the retina; contains no rods and a very high density of cones

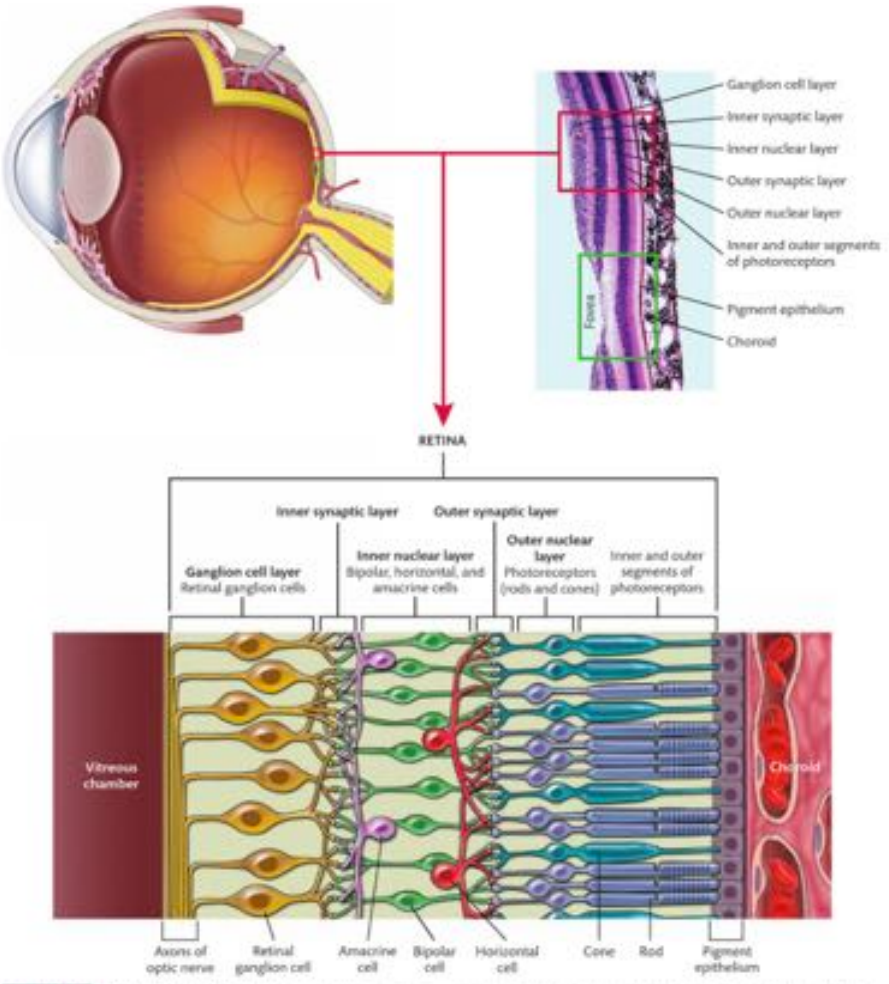


Figure 2.15 Anatomy of the Retina The retina is structured in three main nuclear layers—the outer nuclear layer, inner nuclear layer, and ganglion cell layer—separated by two synaptic layers containing synaptic connections among the cells in the nuclear layers. A layer at the back of the eye consists of the inner and outer segments of photoreceptors, with the outer segments embedded in the pigment epithelium, from which the photoreceptors receive nourishment. The outer nuclear layer consists of the photoreceptors (not including their inner and outer segments), and the inner nuclear layer consists of horizontal cells, bipolar cells, and amacrine cells, which form a network connecting the photoreceptors to the ganglion cell layer, which consists of retinal ganglion cells. The axons of the retinal ganglion cells come together at the optic disk and exit the eye in a bundle, the optic nerve. The micrograph shows a cross section of the retina: the part in the red box corresponds to the part of the retina illustrated below; the part in the green box is the retina at the fovea, where the ganglion cell layer and inner nuclear layer are "pushed to the side" to minimize interference with the image at the fovea by giving incoming light more direct access to the photoreceptors. [Courtesy of Dr. Deborah W. Vaughan, Histology Learning System, Boston University]

Photoreceptors: Rods and Cones

- Rods and Cones both transduce light into neural signals
- **CONES** = carry information about differences in wavelength (colour) and support greater acuity (especially the densely packed cones in the fovea). There are 3 types of cones.
- **RODS** = rods are more sensitive than cones to low levels of light and thus, they are used to see in dim light. There is only one type of rods.
- Both rods and cones have a different kind of photopigment- a molecule with the ability to absorb light and initiate the transduction of light into neural signals. These photopigment molecules **differ in their spectral sensitivity**, which is the degree to which they absorb different wavelengths of light

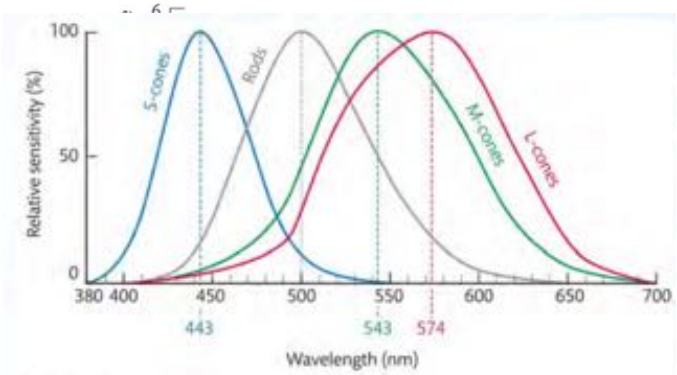


Figure 2.17
Yantis/Abrams, *Sensation and Perception*, 2e, © 2016 Worth Publishers
Data from Stockman et al., 1993

cones-only curve is obtained by making sure that the spot of light falls only on the fovea, where there are no rods. The green rods-only curve is obtained by having a rod monochromat as the participant (rod monochromats have no cones in their retina).

Transduction of Light Process

- Photopigments have 2 possible shapes, isomers
- **When a photopigment absorbs light, it undergoes photoisomerization** (its shape changes from 1 1-cis retinal to all-trans retinal)
- This initiates a cascade of **biochemical reactions that reduces membrane potential of the photoreceptors** (the first step of transducing the light)
- This reduction in membrane potential **changes the number of neurotransmitter molecules released by the photoreceptor at the synaptic terminals**
- Leads to **change in membrane potential of bipolar/horizontal** cells to which the photoreceptor is connected
- Neural signals propagated **through the retina to the RGC's** which send APs to the optic nerve and then the brain

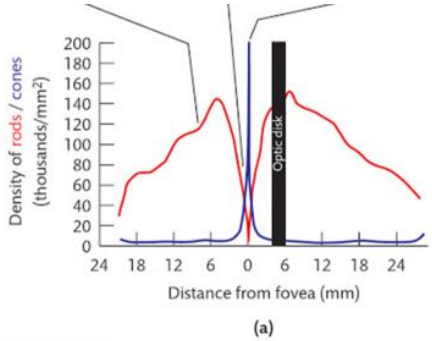
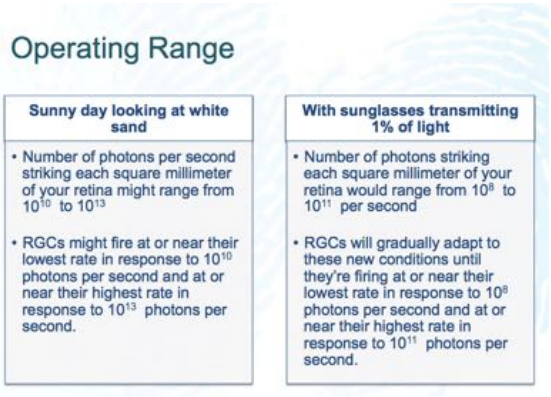


Figure 2.20 Distribution of Rods and Cones Rods and cones are distributed across the retina very differently. (a) Graph of rod (red) and cone (blue) densities and their variation with distance from the fovea. The inset photos show top views of the retina at three distances from the fovea. (b) Contour maps depicting rod and cone

Distribution of Rods and Cones

- **No rods in fovea**
- Concentration of **cones in fovea is very high- and lessens further away from the fovea**
- **Density of rods rises rapidly within a short distance of the fovea**
- Blind spot- total absence of both rods and cones. This is where the optic nerve leaves the eye

Operating range: the **visuals system's sensitivity to the range of light intensities within the current scene**- the visual system adjusts its operating range according to current conditions



Adapting to Changes in Lighting

- Highest level of light commonly experienced is at least a million times as great as the lowest level.
- Light adaptation
  - Light adaptation **takes place in only a few minutes** (in approximately one minute you are doing quite well, although the process takes about 10 minutes to become fully light-adapted).
- Dark adaptation
  - Dark adaptation is a **slower process** (it takes up to 30 minutes to become fully dark-adapted). It is the process of adjusting retinal sensitivity (changing the operating range) as a person moves from a bright environment to a darker one; the reverse process is called light adaptation.

Dark Adaptation

- The retina adjusts its sensitivity to deal optimally with the light that is present in the current scene
- Pupils dilate to admit as much light as possible
- Rods and cones have two different dark adaptation curves
- **During the first eight minutes** when the lights still needs to be fairly bright to be visible, **the combined dark adaptation curve matches the cone curve**. The reason for this is that during this period, **cones are more sensitive than rods** (shown by the fact that the cone curve is below the rod curve, which means that cones can respond to dimmer lights than rods).