Imperial College London

Lecture 2

The Anatomy and physiology of Vision

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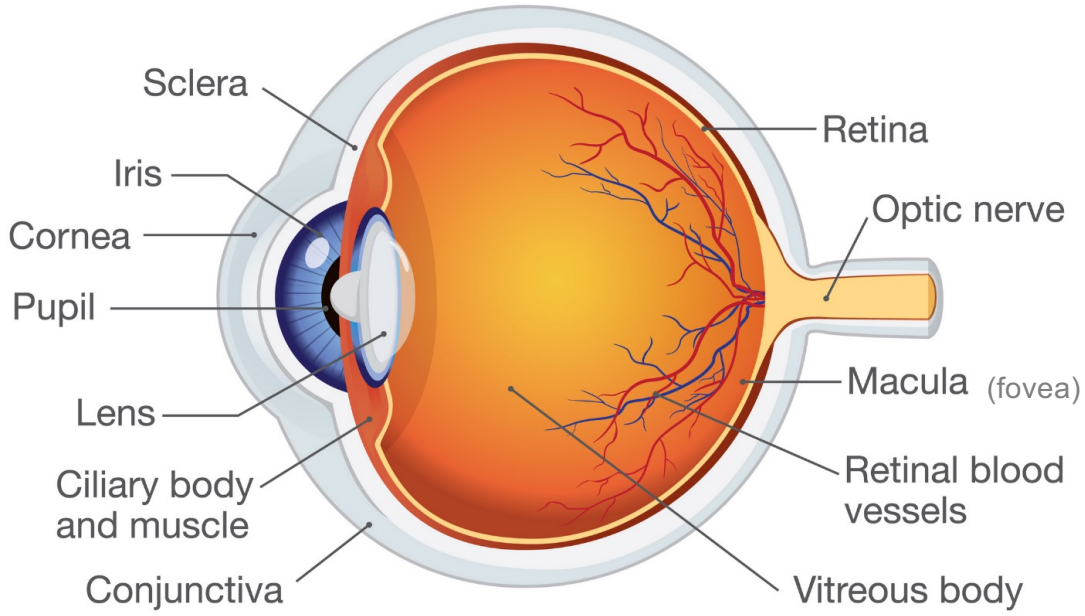
In this lecture, we will explore the anatomy and the physiology of the eye. This includes the structure of the eye, the functions of the various parts. This leads to how the different components of the eye works and how light energy is turned into electrical impulses which eventually reaches our brain. The topics we will cover in this lecture are:

- Structure of the eye
- The retina and its structure
- How cones and rods work?
- Neurons, Axons and Synapses – how information is transmitted
- How rods and cones turn photos to electrical impulses
- The function of other cell layers in the retina
- The receptive field of vision
- The visual pathway
- The visual cortex and how human “sees” (only in general terms)

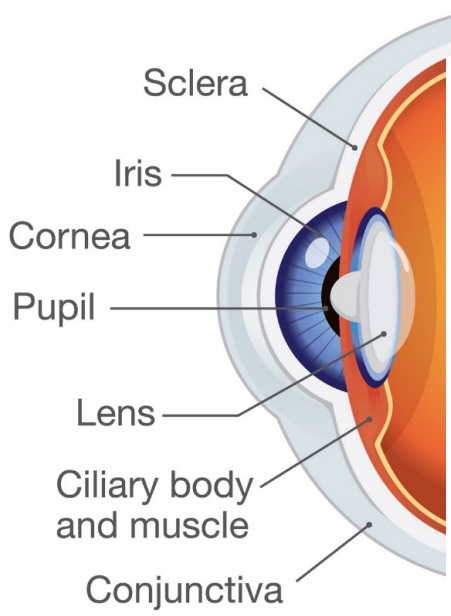
Anatomy of the Eye (1)



Source: Sight Research UK

The human eye consists of various parts. To develop some understanding about the anatomy of the eye is important to a design engineer because many visual systems are trying to mimic what we human sees and the eye is analogous to our image sensor (i.e. the camera). The various components found in an eye can also be found in a camera. They both have a lens. While human has a pupil to allow light through, a camera has aperture which also controls the amount of light is allowed through to the image senor. The image sensor is equivalent to the retina of the eye, although their structures are very different.

Anatomy of the Eye (2)



- Cornea – clear outer layer that is transparent and protects the eye
- Sclera – protective layer forming the white of the eye
- Pupil – opening at centre of iris where light passes through
- Iris – coloured part of the eye which dilates or constricts to adjust the amount of light passing through
- Ciliary body – circular structure that produces fluid in the eye and contains muscle to change the shape of the lens
- Lens – transparent structure that refracts and focuses light onto retina

The **CORNEA** is the outer front window of the eye which transmits and sharpens light into the eye.

The **SCLERA** forms the white of the eye. It is a tough and fibrous layer of the eyeball that protects the rest of the eye from dust and external matters. It consists of mostly collagen with small amount of elastic fibres. This helps to maintain the shape of the eyeball. It is well-supplied with blood, which when irritated, shows the blood shots appearance. The sclera can change its colour (from white). For example, a yellowish tint indicates the sign of a person suffering from jaundice (which indicates possible health issues with the liver, the gallbladder or blood disorder).

The **PUPIL** forms the hole in the middle of the colour part of the eye. Its diameter can be controlled, much like the aperture of a camera, and thus control the amount of light allowed through. It also helps to focusing on near objects, improving the sharpness of near-field vision.

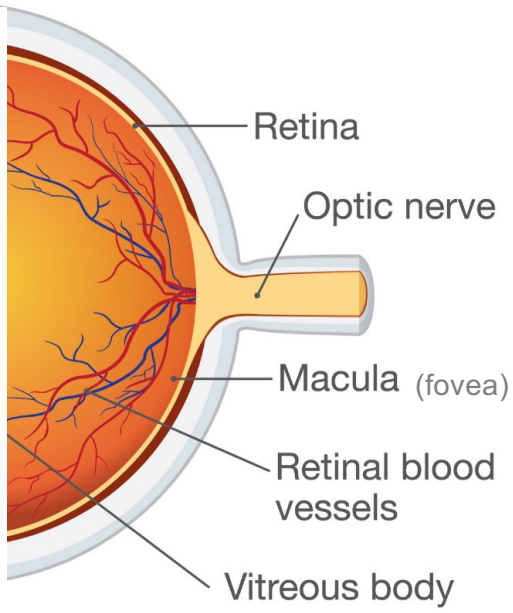
The **IRIS** control the size of the pupil and regulates the amount of light reaching the retina. It constricts and dilates the pupil with its muscles. It also determines the eye colour of the individual. The colour is determined by melanin and other pigments it contains.

The **LENS** provides the main method of focusing external image onto the retina. It is a clear and flexible disc whose shape can be adjusted to allow focusing to occur. This mechanism, known as ***accommodation***, is achieve using the ciliary muscles surrounding the lens.

The **CILIARY BODY** manufacture the clear fluid (called aqueous humor) that fills the eye. It also facilitates ***accommodation*** of the lens with its muscles.

Anatomy of the Eye (3)

- Retina – a layer of photoreceptor cells at the back of the eye that converst photons from light to signals for the brain
- Macular – a 5mm disc around 250 micron thick on the retina for detailed colour vision
- Fovea – a small indentation at the centre of the macula with the highest density of cone photoreceptor cells for colour vision.
- Optic nerve – bundle of over 1 million nerve fibres carrying the visual signals to the brain.
- Vitreous body – transparent gel-like substance under pressure to maintain shape of the eye.



The **RETINA** is like the film or the image senor in a camera. It captures the light through the eye to form the actual image. It contains millions of light sensitive cells known as photoreceptors which, through layers of other cells, turns photons into electrical signals. We will be examining the details of the retina and how it works in subsequent slides.

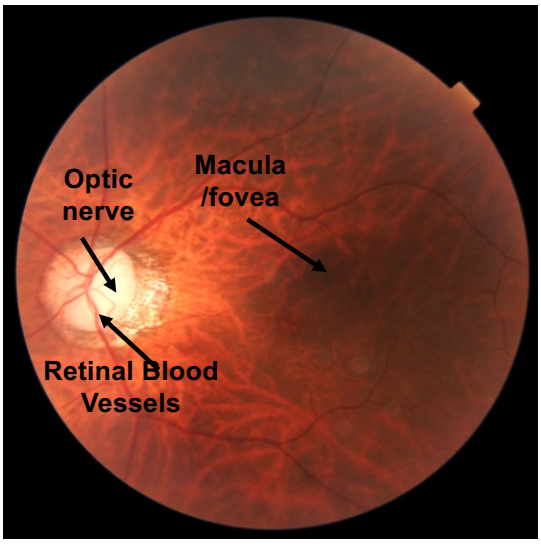
The **MACULA** is the small area near the centre of the retina responsible for high-definition vision because it contains the fovea in the middle.

The **FOVEA** is a very small dent in the middle of the macula area only 0.35mm in diameter. It contains densely packed colour photoreceptor cells called cones. It is responsible for our able to see in high definition of colour objects.

The **OPTIC NERVE** is the bundle of nerve fibres that carries the visual information as electrical impulses to the brain.

The **VITREOUS BODY** is the liquid filled cavity between the lens and the retina. It protects the retina from external disturbances, acting like a shock absorber. The transparent jelly allows light through with little attenuation so that most of the light focused by the lens reaches the retina. The fluid in the vitreous body help to kept the eyeball's spherical shape.

Function of the Retina



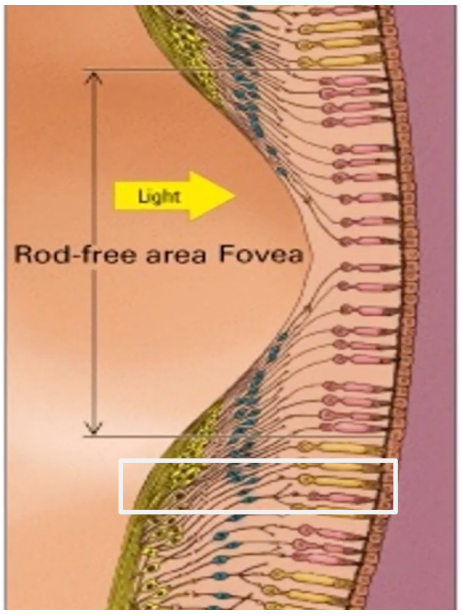
- To accept photons of light
- To translate photos into biochemical messages
- To translate biochemical messages into electrical impulses
- To transmit electrical impulses to the brain via the optic nerve bundle

The retina is responsible for **transducing** light energy into electrical impulses. It has three key functions:

1. **Capture photons**: the retina contains millions of light sensitive cells called photoreceptors. Two types of photoreceptors are found in the retina of a human eye: rods and cones. Photons hit rods and cones and start the process of transduction.
2. **Produce electrical signals**: The photoreceptors together with other layers of cells in the retina convert light energy into electrical signals. How this is done will be explained in later slides.
3. **Process visual signals**: There are layers of cells that perform various processing functions such as motion detection, image sharpening and balancing the colour.
4. **Transmit visual signals**: The ”output” of the retina is the optical nerve which carries the visual signals to the brain.
5. **Forming the image**: The collection of photoreceptors and various layer of neuron is responsible for forming the image that befalls the retina. Each retina receives a two-dimensional image that differs from each other. Together the brain is able to combine the two separate images to add visual depth to the 2D image.

In addition to the basic visual function, the retina contains special cells that detect light and darkness that help human to maintain the sleep-wake cycle and help to regulate **the Circadian rhythm**. That is the reason why exposing one’s vision to bright sunlight helps to overcome jet lack!

The Anatomy of the Retina (1)



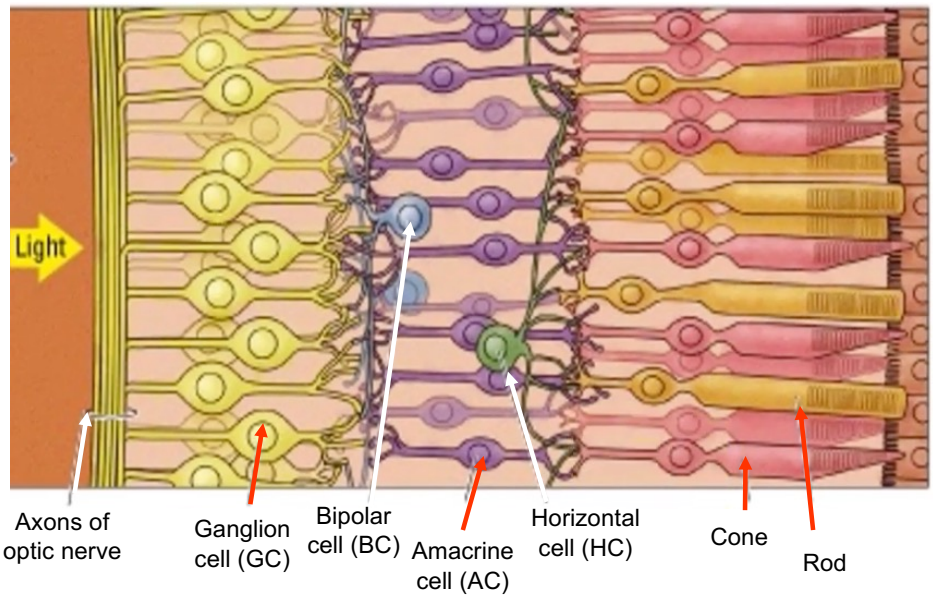
- The retina contains multiple layers of cells, each layer perform different functions.
- At the centre of the of the retina is a pitted region known as the fovea.
- The fovea contains only cones which are photoreceptors sensitive to bright colour lights.
- The density of the cones are very high, thus forming very high-definition image in this region.
- There are no rods in the fovea region.

Here is a small are of the retina around the centre of the retina where a small indentation is found. This is known as the fovea of the retina. The fovea is responsible for detailed colour vision. It contains no rods that is sensitive to low light. Instead, it has a very high density of cone cells.

The fovea region is small – sustaining no more than 6 degrees of the solid angle all the way around.

To understand how retina works, we shall focus on the cross section at the white rectangle.

The Anatomy of the Retina (1)



The retina is the most important part of the eye. It detects photons, convert them into electrical signals and eventually form the image of the what we see. It consists of many different layers of cells. Going from right to left, we have:

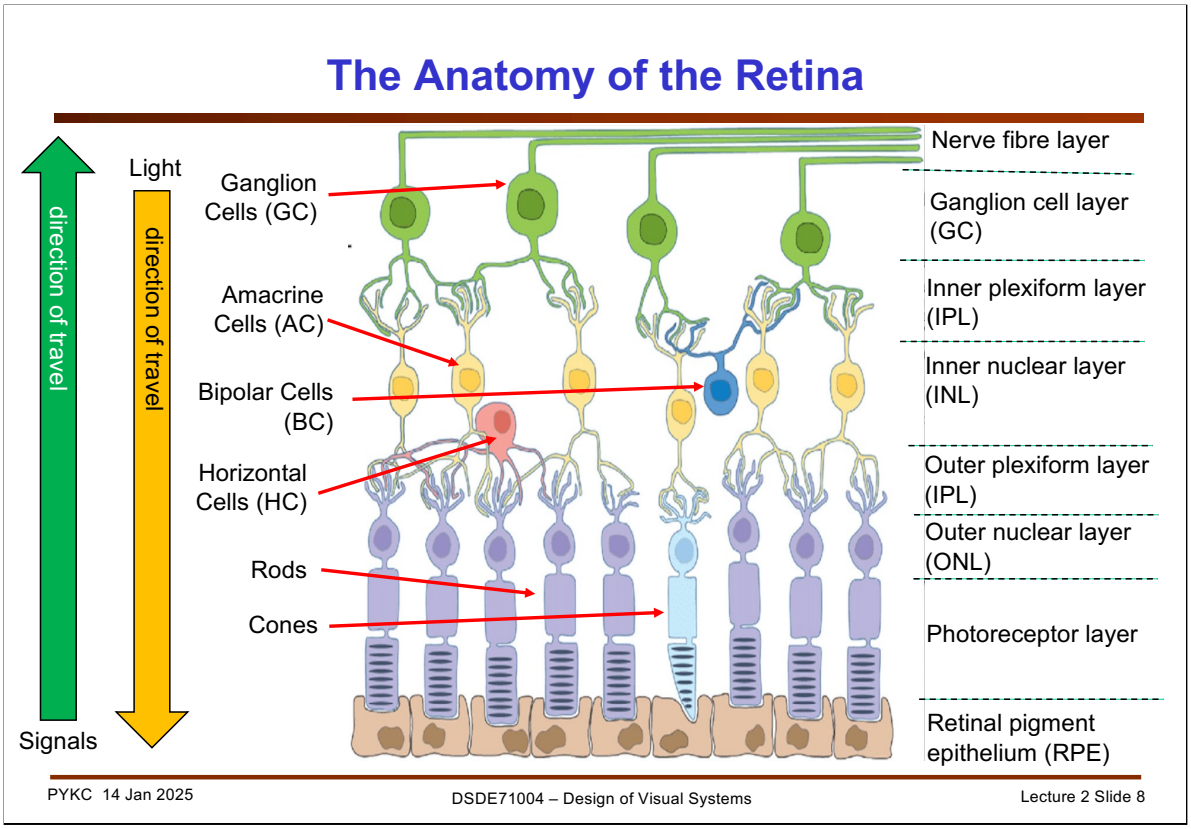
Rods & Cones: these are two different types of photoreceptor cells that are responsible for transducing (converting) photons to electrical impulses through some chemical process which we will discuss later. Rods are responsible for low light vision while cones are responsible for colour vision.

Horizontal Cell (HC): By its name, HC connects neighbouring receptors. When one receptor is activated by light, HC releases an inhibitory neurotransmitter to reduce the output of its neighbours. This improves the contrast between light and dark regions and enhancing the sharpness of edges. HC also helps to adapt to both bright and dim light conditions. It also helps in colour vision (details omitted here) and contributes to the development of receptive fields (later).

Bipolar Cell (BC): These are intermediate neurons that collects signals from the photoreceptors and relays them to the ganglion cells.

Amacrine Cell (AC): These are interneurons which refine signals from cells. They perform some aspects of spatial processing including sharpening edges, identifying changes such as movement, help processing colour and improve the transmission of signals from photoreceptors and bipolar cells.

Ganglion Cell (GC): This the output layer of cells that combines electrical signals from bipolar and amacrine cells and send this to the brain via the optic nerve fibres. There are many types of ganglion cells responsible for different type of vision such as direction of movement, sharp and detail central vision of the fovea, rapid change of light, edge, and colour. Some ganglion cells help to regulate the circadian rhythm (sleep-wave cycle).



This slide shows the different cell layers again with names of the layer shown. Remember: light enters from the top, travel towards the photoreceptor layer. However, electrical signals goes in the opposite direction from bottom to the top arriving at the nerve fibre layer. The nerve fibre then travel back to in the opposite direction through a hole in the retina, the blind spot, to the brain.

It seems somewhat counterintuitive that the cell layers are orgainised back to front in the sense that the photoreceptor cells are “behind” all other cells. The reasons are:

1. The rods and cods absorbs and detect light, but they can be damaged by UV rays. Being at the back of the retina help to protect these pigment epithelium from damage.
2. The photoreceptor layer being at the back allows its cells to be easily supplied with nutrient and oxygen.
3. Photoreceptors continually develop and regenerate. Being at the back of the retina allows these cells to grow and shed.
4. It allows efficient waste removal such as dead receptor cells.

A typical human eye has 0.7 to 1.5 million ganglion cells, funneling visual information collected by around 4.6 million cones and 92 million rod, to the brain!

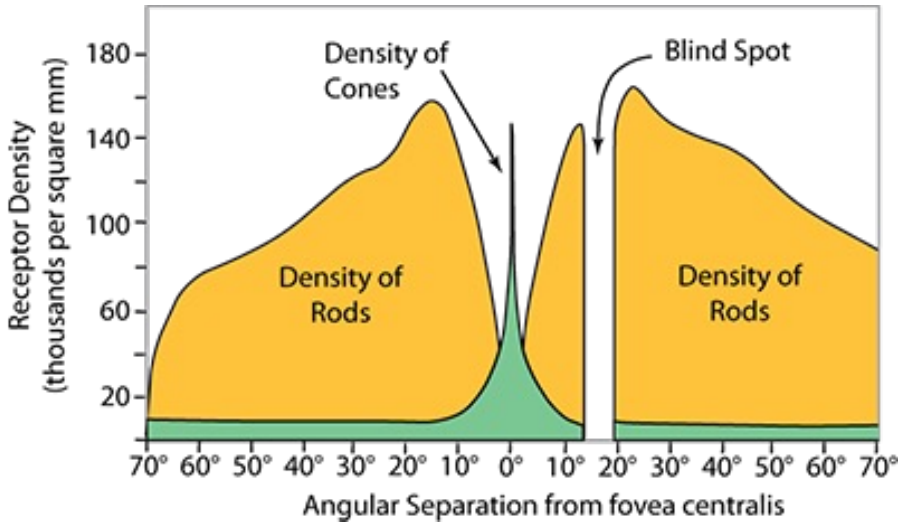
SEM Image of rods and cones

- Rods:
  - Scotopic vision
  - Night vision
  - Achromatic (i.e. BW only)
  - Peripheral vision
  - ~90 million/eye
- Cones:
  - Photopic vision
  - Daytime vision
  - Colour vision
  - Foveal vision
  - ~5 million/eye

Source: Omikron

Here is a Scanning Electron Microscope (SEM) photo of rods and cones with false colour. The shape of the receptors gave them their name!

Densities of rods and cones

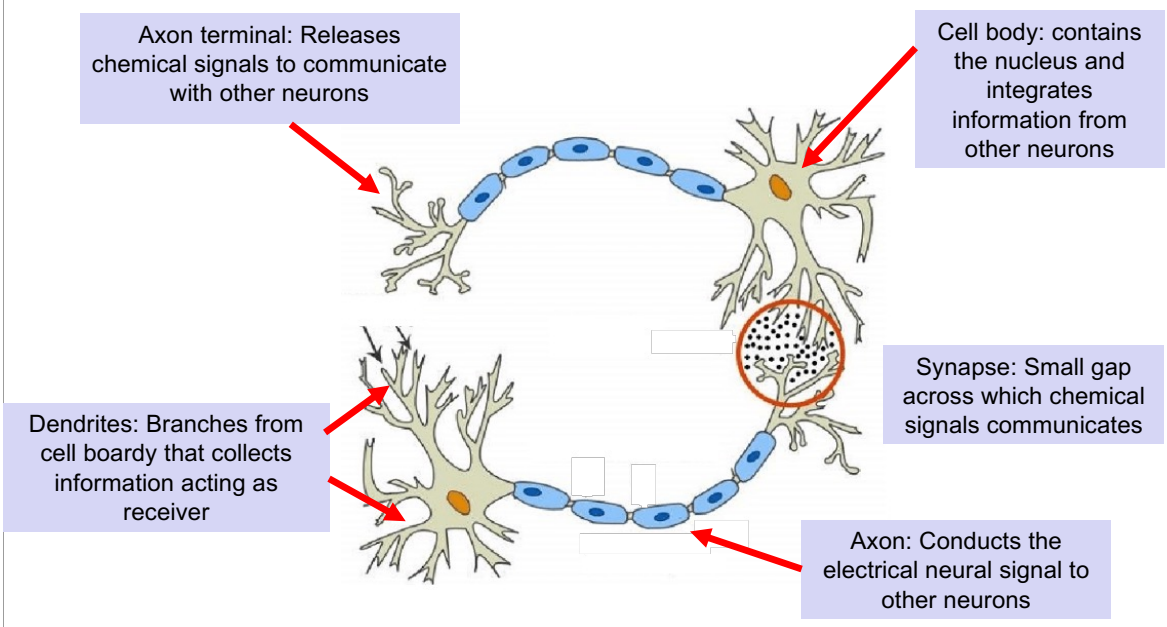


- Concentration of cones at very high density only in the fovea region, around ±6º around the centre of vision.
- Concentration of rod is spread out.

This diagram shows the density of photoreceptor on the retina from the centre of the fovea. Most of the cones reside within±6º around the fovea region. The rods are spread out throughout most of the retina.

In the area where the optic nerve goes to the brain, the retina has no photoreceptors and therefore there is a hole in the image that the retina can “see”. It is interesting how our brain interpolates our visual in such a way that the hole is generally not perceivable in our day-to-day vision.

Five Components in a Neuron



To understand how photons are turned into electrical signals, we need to understand how neurons work in general.

Neurons are the basic nerve cells that send and receive messages all over a human body. It consists of five components:

1. **Cell body**: this contains the nucleus which has the genetic materials and controls the neuron's function. It receives signals from other neurons and combines them together.

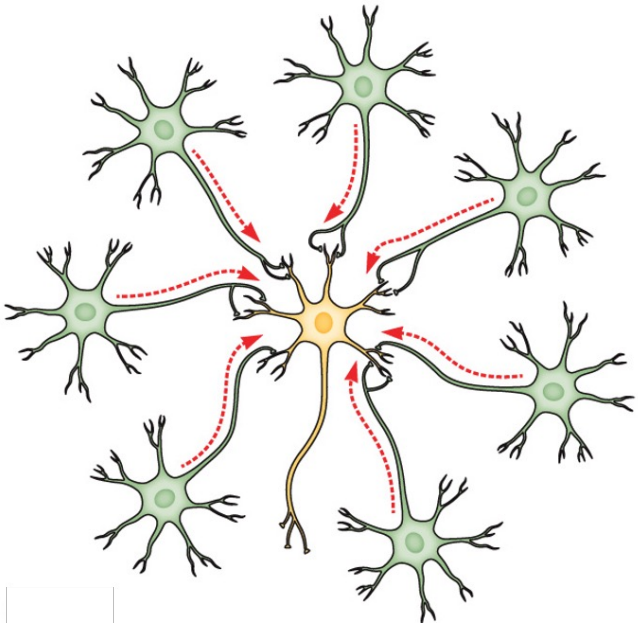
2. **Dendrites**: These are extensions from the cell body that collects electricals from neighbouring neurons.

3. **Axon**: This is the long thin fibre that carries the electrical signals from the cell body to other neurons. The axon is covered by a layer known as myelin, which insulates the axon from its surrounding biomaterials, and speed up the transmission of signals.

4. **Axon terminal**: The end of the axon is called the axon terminal. It is the "output" of the neuron. These connects to other neurons or other cells (e.g. muscle cells).

4. **Synapse**: This the gap between one neuron's axon terminal and another neuron's dendrites. It provides a chemical interface (via neurotransmitters) between two neurons through which signals can be transferred from one neuron to another.

Neuron connections

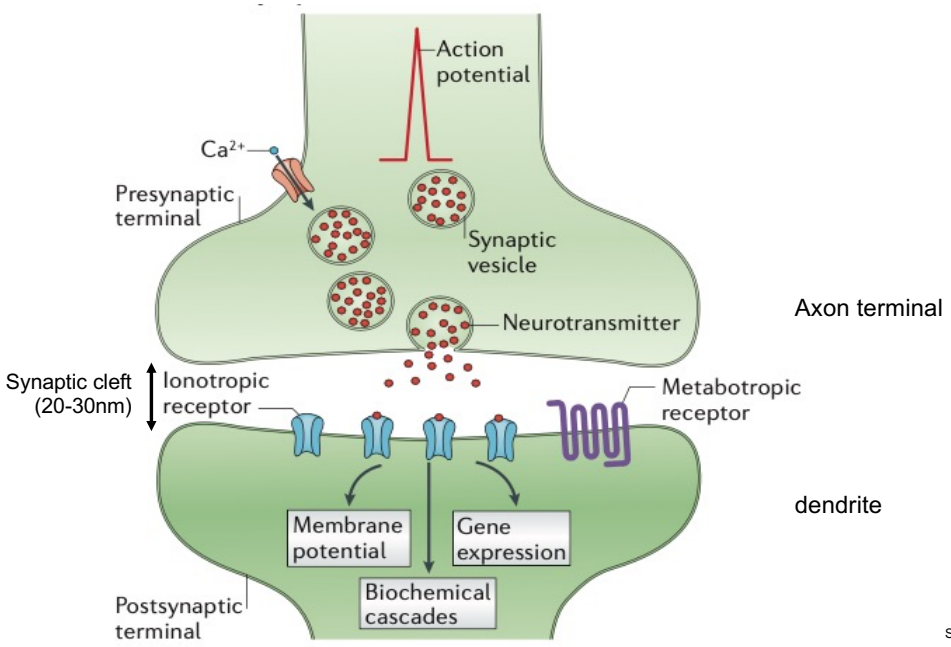


There are about 100 billion neurons and over 100 trillion synapses in an adult brain!!

Typically a neuron is connected to many other neurons, and receives signals from them. There can be as many as 100 billion neurons in human brain, and over 100 trillion synaptic connections. This means that there are 1,000 synaptic connections to every neuron! It is such connections that allows a human to see and think, and to form memory. The interconnection of neuron also forms the bases of AI: artificial neural network is our imitation of such neural connectivity of the brain.

Currently the largest artificial neural network implements around 16 million neurons with 530 billion parameters (i.e. synaptic connections) developed by Nvidia and Microsoft (as of 2023)!

Synapse

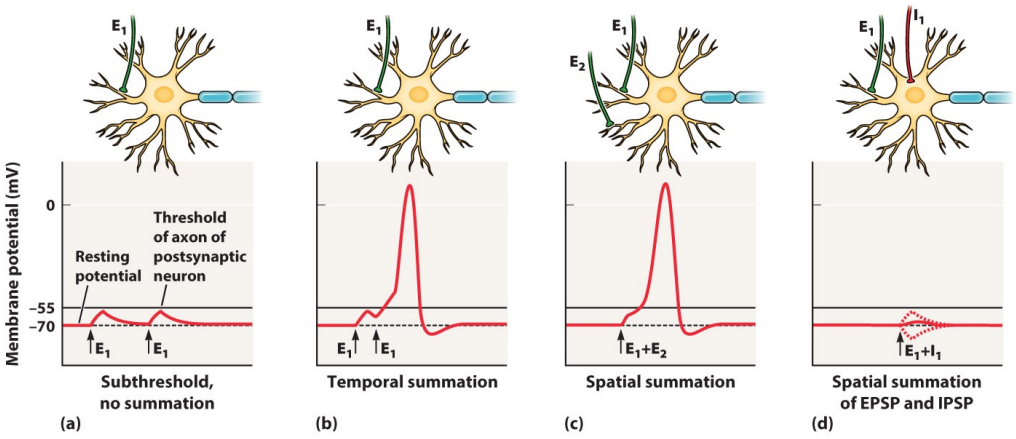


Synaptic connection is key to the ability for our neural system to function. Its function is to connect one neuron's **axon terminal** (transmitter) to another neuron's **dendrite** (receiver). The synapse works in the following way:

1. The axon transmit the electrical signal in the form of an action potential (nerve impulse), which triggers the axon terminal to release chemical messengers called neurotransmitters.
2. The neurotransmitters traverse a very small gap, known as the synaptic cleft (20-30 x nm), around 4,000 times thinner than a human hair to reach the dendrite of the receiving neuron.
3. The neurotransmitters bind to receptors on the postsynaptic terminal of the dendrite on the receiving neuron. This changes voltage potential at the membrane on the receptor side of the cleft.
4. In some cases, the change makes the target cell more likely to fire its own action potential. This is called an **excitatory postsynaptic poten**tial (EPSP)
5. In other cases, the change in voltage causes the target cell less likely to fire its own action potential. This is called an **inhibitory postsynaptic potential** (IPSP).
6. The postsynaptic neuron integrates all the excitatory and inhibitory potentials in space and time to create its own action potential.

Action Potentials

- Action potentials are all or none.
- EPSPs and IPSPs combine to affect the membrane voltage.
- In temporal summation, PSPs arriving at the cell body at close to the same time are combined.



Source: Eagleman

Action potentials are all or none – a neuron either fires or not fires, just like a binary signal. The two types of ESPs: EPSPs and IPSPs combine to affect the membrane voltage. Neuron membrane is normally polarized at around -70mV at quiescent state. When the neuron membrane potential reaches above the threshold voltage of -55mV, an action potential is fired.

(a) Shows the membrane potential with two EPSPs happening at two different times. Neither are high enough to trigger the action potential to fire.

(b) Temporal summation - two EPSPs generated by the same neuron close together in time (temporal). They are summed to pass the threshold and trigger the action potential.

(c) Spatial summation - two EPSPs from two different neurons happen at more or less the same time. These are also added together to trigger an action potential.

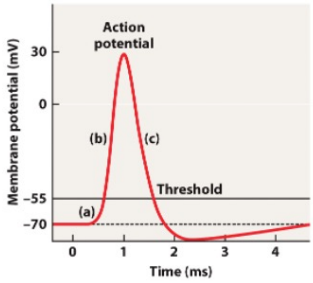
(d) Cancellation - one IPSP and another EPSP from two neurons occurs at the same time. They cancel each other out and therefore NO action potential is trigger.

A typical neuron receives 100s or 1000s of PSPs at a time from different sources..

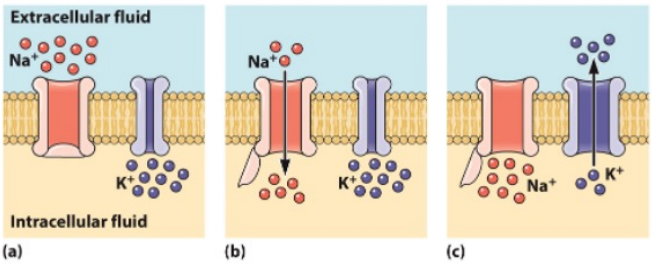
EPSPs sum together to depolarize the cell (move the voltage closer to 0).

If the membrane voltage reaches threshold (approximately -55 mV), an action potential is generated.

It is all chemistry!



- In neurons at rest, there are more Na+ ions outside the cell and more K+ ions inside the cell.
- At threshold, voltage-gated Na+ channels open, allowing Na+ ions to flow into the cell, down the chemical concentration and electrical gradients.
- Voltage-gated K+ channels open, allowing K+ ions to flow out of the cell.



- The current formed by the Na+ ions flows down the neuron, depolarizing the next part of the neuron.
- There is a refractory period after the action potential, when the voltage-gated Na+ ion channels are less likely to open.
- Calcium and chloride ions also contribute to the action potential.

The firing of neuron is the result of chemistry in the cell. The sequence of events is:

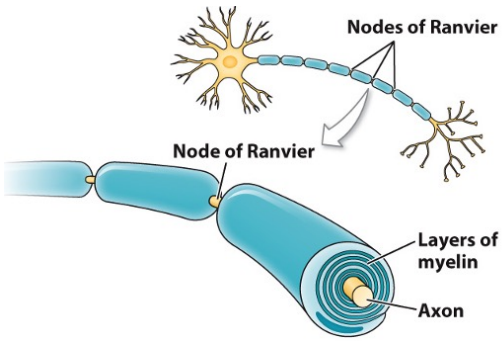
(a) At rest, there are more Na+ sodium ions outside the cell than inside and more K+ potassium ions inside the cell than outside.

(b) When voltage-gated Na+ channels open, Na+ ions rush from the outside to the inside—both because of the concentration differences and because of the electrical field.

(c) The depolarization caused by Na+ influx triggers the opening of K+ channels, which cause K+ ions to rush out, thus making the outside more positive again (repolarization).

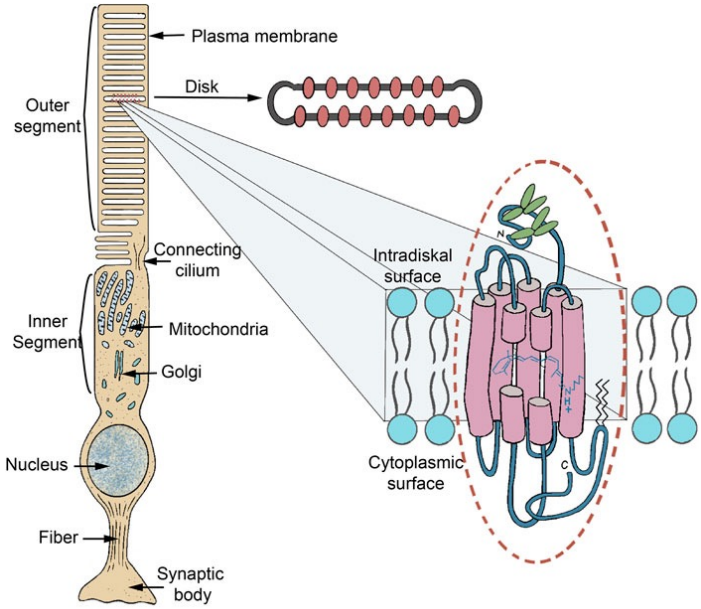
How an Action Potential Travels

- Myelin is interrupted by gaps, known as nodes of Ranvier, where the action potential is regenerated.
- The action potential jumps from node to node, greatly speeding up transmission.
- Myelination decreases the amount of energy used by the neuron.



Axons are insulated by a fatty sheath called myelin. The myelin is not a continuous sheath like the insulation of a wire. Instead, there are gaps in between known as nodes of Ranvier at around 1-2mm intervals. This exposes the axon membrane to the extracellular fluid. The result of this structure is that the action potential effectively “jumps” from one node to the next, thus speeding up the transmission of the electrical signal. This is known as “saltatory” conduction. In this way, the nodes of Ranvier acts as repeater of the traveling signals. This not only preserves the “strength” of the action potential, it also reduces the energy required for transmission.

How does a photoreceptor works?



Source: Hargrave 1995

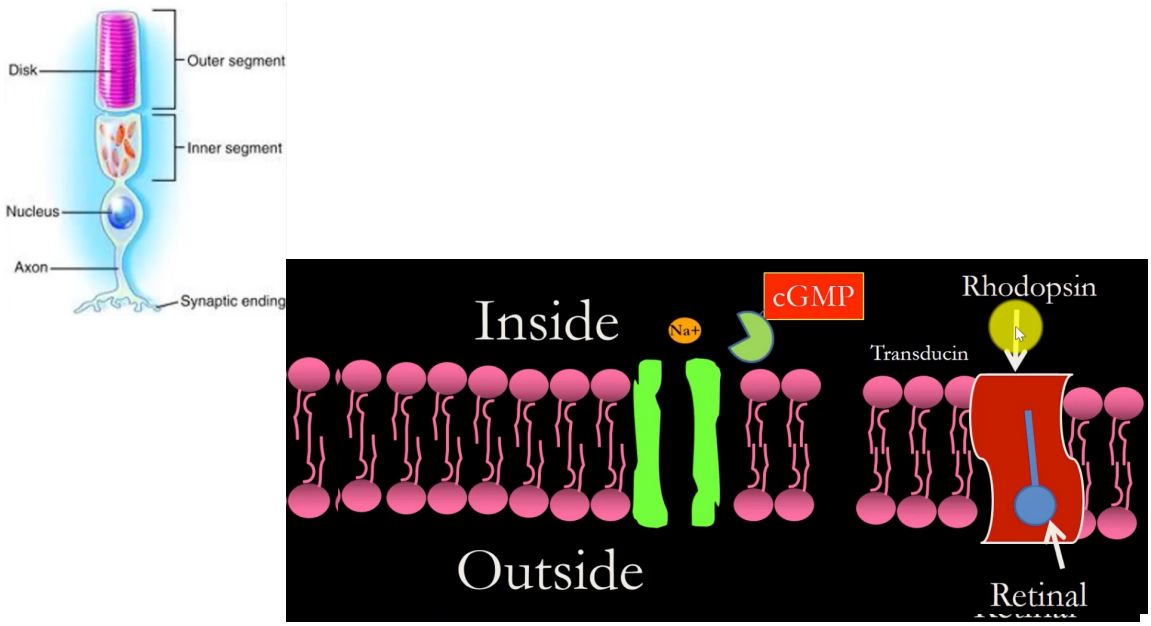
Both types of photoreceptor cells (rods and cones) work in a similar way. They have four primary structures and functional regions: the outer segment, the inner segment, the cell body which has the nucleus and the synaptic terminal.

Outer segment: It is filled with a dense stack of membrane discs spaced at intervals of around 30nm. The discs contains photopigments, rods have rhodopsin and cones have cone pigment. These discs are where the main phototransduction process occurs. The dense stacking of the discs increases the probability of capturing photons that enter the eye.

Inner segment: this is where much of metabolism and regulation of membrane potential takes place. It contains structure that contracts when exposed to bright light, and relaxes in dim light, thus regulating the among of light captured by the outer segment.

Synaptic connection: this performs the usual function of synapses in a neuron. It transmits electrical signals from the photoreceptor cell to other retinal neurons.

How light is turned into electrical signal (1)



This slide shows how photons (light) is turned into electric potentials. Here is a diagram showing the disc found in the outer segment of a rods.

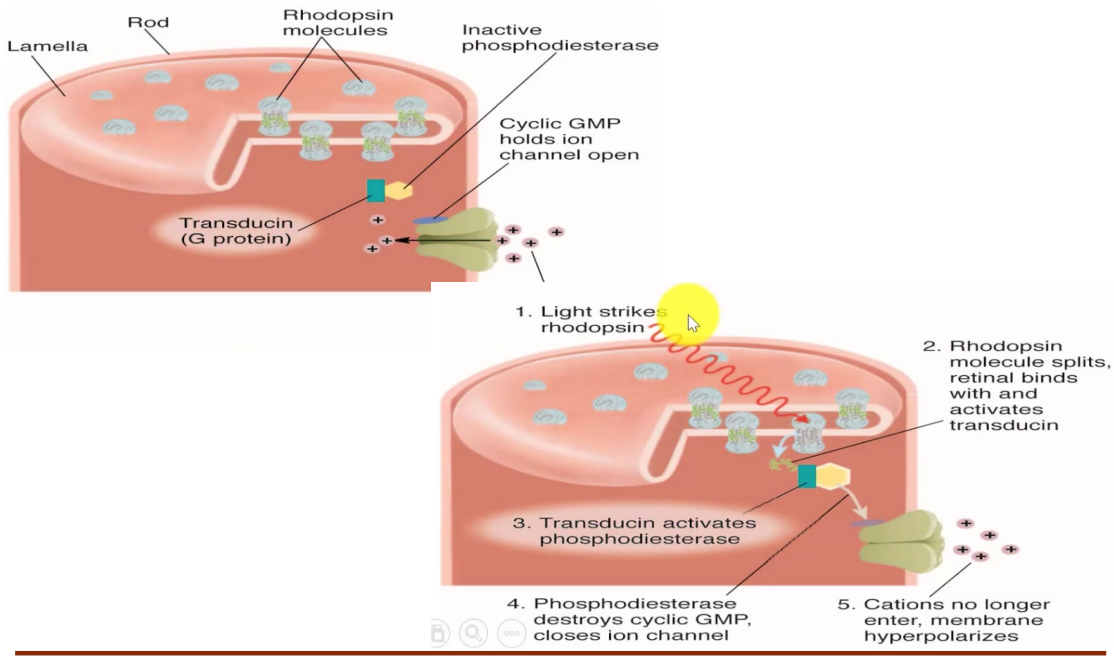
A rod disc contains photopigment known as rhodopsin. When there is no light received, the sodium channel kept opened by a chemical called cyclic GMP (cGMP). Na+ ions flows freely across the membrane through the channel and constantly depolarizing the cell.

When even a photon hits the rhodopsin molecule, it changes its shape and releases a messenger called transducin. This messenger causes cGMP to close off the sodium ion channel. The results in the rod becoming hyperpolarized and thus producing an electrical signal that was not there before the light hits.

In short, electrical signal is produced by the change in the sodium ions due to the closing of the ion channel by the messenger (tranducin) produced by the photosensitive pigment cell, the rhodopsin.

Cones operate in a similar manner. The photo pigment of cones are like rhodopsin, but they have different colour sensitivity characteristics. But cones' phototransduction mechanism is essentially the same as that for rods.

How light is turned into electrical signal (2)



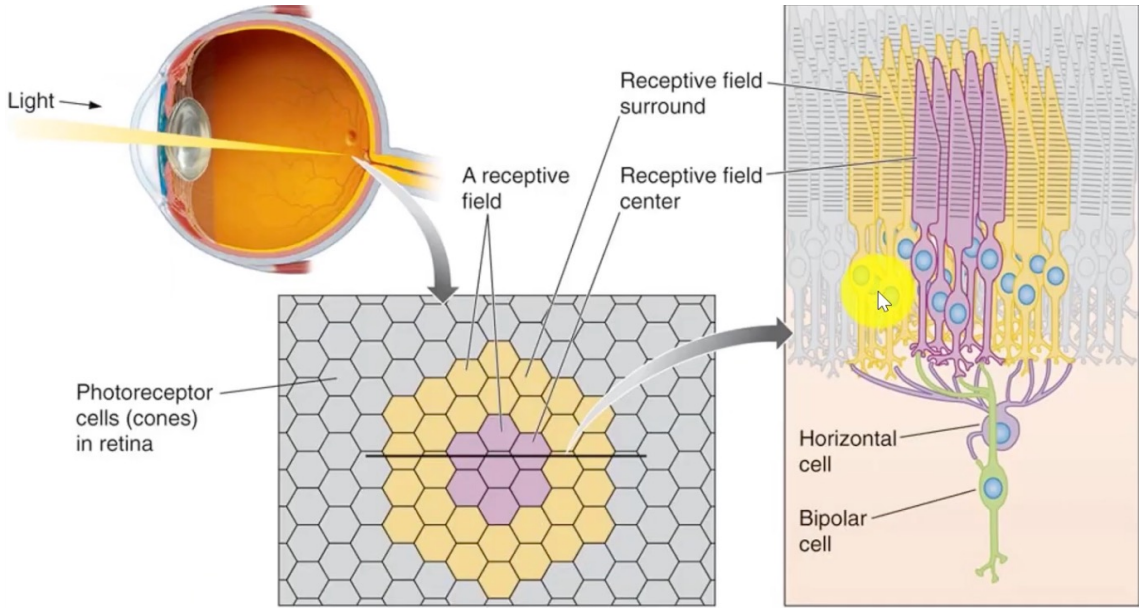
Here is another step-by-step diagram showing how rods perform the phototransduction process.

Here is the summary:

- Transduction is the conversion of a physical stimulus (e.g. light) into nerve impulses
- When no light (i.e. dark)
    - Opsin and retinal (rhodopsin) are bound together as the photopigment
    - Rod membrane is depolarised
    - Dark current – Na+ ions constantly moving through channel
    - cGMP keep the channel open

- When light hits
    - Photon of light causes rhodopsin to break into opsin and retinal again
    - Creates the messager called transducing which denature cGMP
    - This closes the channel and Na+ ions are now blocked
    - Rod becomes hyperpolarized and an electrical signal is thus produced

Receptive Field of retinal cells



Now let us consider the concept of RECEPTIVE FIELD in vision.

The last layer of neuron cells in the retina are ganglion cells, which receive signals from intermediate cells including bipolar and other cells, which in turn receive signals from the photoreceptor cells. Each ganglion cell is connected to a number of neighbouring rods and cones, and therefore its firing is affected by a "region" in the retina, not just individual receptors. This is called the **receptive field** of the neuron.

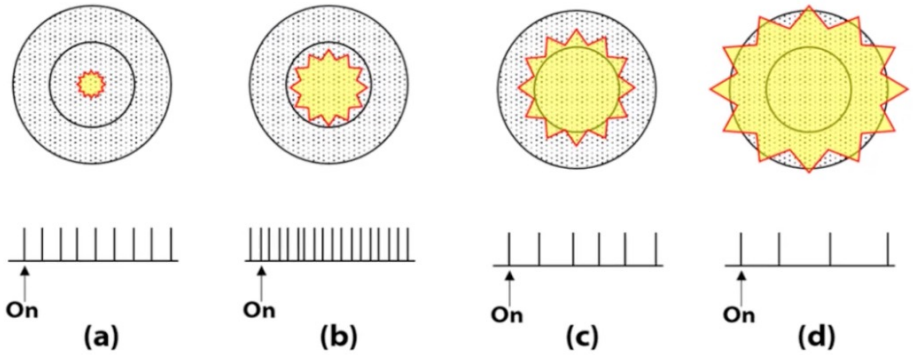
In general, receptive fields in the fovea region are small , while receptive fields in the peripheral regions are larger.

This diagram shows how rods and cones are connected to horizontal and bipolar cells to effect receptive fields. Some cells are inhibitive and others are excitative. Together, it forms a receptive fields that has a centre region and an off-centre region.

In other words, the structure of the multiple layers of cells and how they are connected provide a spatial processing capability (and also temporal) within the retina.

Receptive Field – Retinal Spatial Processing

- On-centre receptive field: Fires most when light hits the centre and dark on the periphery



- Off-centre receptive field: Fires most when light hits the periphery of the receptive field and dart on the centre

Here it shows the signals from a ganglion cell which fires when light is in the central region of the receptive field. What happens to its output signal when we shine lights onto the receptors linked to the on-centre and off-centre area of the receptive fields.

(a) Light is received in a small area of the on-centre part of the receptive field of this ganglion cell. The cell fires a sequence of action potentials which are transmitted by the optic nerve for this cell to the visual cortex of the brain.

(b) Light is received in nearly all of the on-centre region and the density of spikes increases because this ganglion cell is receiving firing from photoreceptors corresponding to the on-centre region.

(c) Light now spread outside the receptive field to the off-centre region. Cells linked to off-centre part of the receptive field have inhibitive effective and the frequency of spikes reduced to even lower than that of case (a).

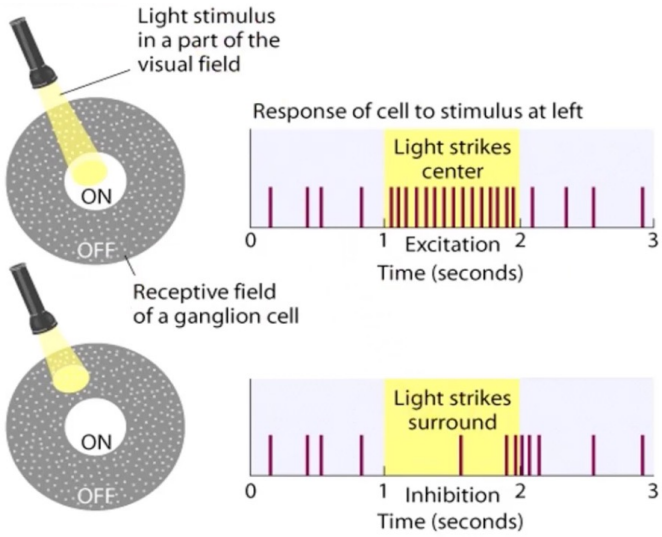
(d) When the entire field is illuminated, the spike density becomes very low because of the strong inhibit effect cancelling the excitative effect over the entire receptive field.

Consider lots of ganglion cells with overlapping receptive fields sending different signals to the brain. The combination of these signals allows dark and light features (such as edges) to be perceived and interpreted by the brain.

Therefore, the retinal cells perform some local spatial and temporal signal processing that produce complex sequences of spikes that allow our brain to “see” things. As will be seen later, many of our designs that process visual information are mimicking the way that biology works!

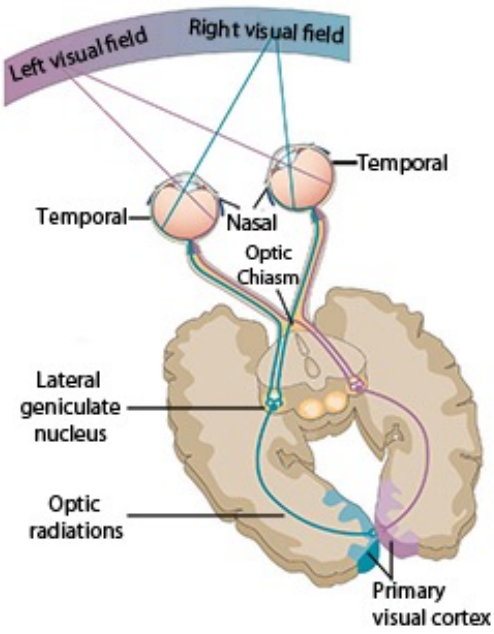
On-centre Ganglion Cell

- On-centre receptive field: Fires most when light hits the centre and dark on the periphery



Here is another view of how an on-centre ganglion cell will fire with on-centre and off-centre light situation.

Visual Pathway – from eye to brain



- Right visual field is processed by the left side of the visual cortex, and the left visual field by the right.
- The optic chiasm is the X-like structure in the optic nerves where the cross-over happens.
- The lateral geniculate nucleus (LGN) is the destination of the optic nerve its primary function is to relay and dispatch information to the primary visual cortex. It also perform some pre-processing functions.

Source: Paresh Malhotra, ICL

Visual pathway shows how visual information outside the eye reaches the visual cortex in the brain.

This slide shows the right visual field with pathway in BLUE enters the left side of the retina in both eyes. The signals generated by the right visual field eventually reach the left side of the brain and is processed by the left part of the primary visual cortex.

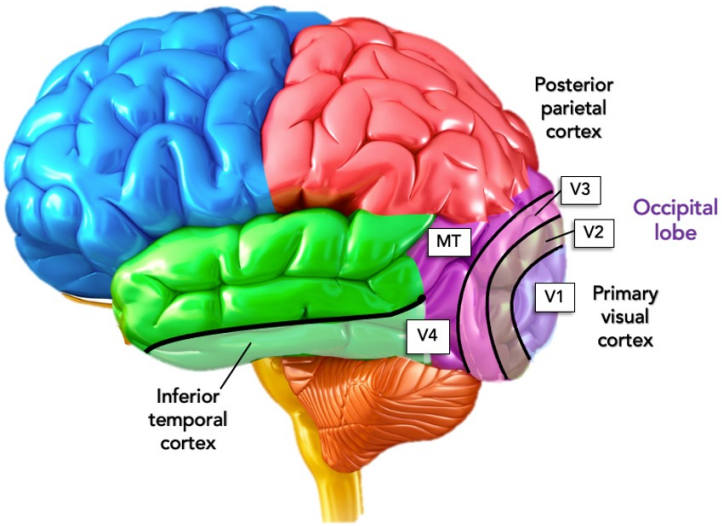
In a similar way, the left visual field shown in purple is processed by the right side of the visual cortex.

There is a cross over point in the optic nerve bundle where right and left side signals cross each other. That is called the optic chiasm. This is the place where nerve fibres from each eye converge and the optic nerve that carries signals for right or left visual field get sent to the corresponding side of the visual cortex.

After the optic chiasm, the optic nerve terminates at the lateral geniculate nucleus, or LGN. This acts as a rely and amplification station for the visual signals. It also acts as a selective filter, amplify details such as edges, contrast and movements, while suppressing background noise.

Higher-order Visual Pathway

- Information from the contralateral eye goes to layers 1, 4 and 6
- Information from the ipsilateral eye goes to layers 2, 3 and 5



Source: Banich & Compton, 2018

Signals from the optic nerve are processed by the visual cortex – the part of the brain that is responsible for us seeing and interpreting visual information.

The visual cortex consists of various regional cortices labelled as V1 to V5. They each has special functions:

V1 or Primary Visual Cortex – This is responsible for basic feature recognition such as edges, lines and orientations. It builds a rough outline of the visual image.

V2 – This processes colour, texture and motion.

V3 – This analyses shapes and other complex objects.

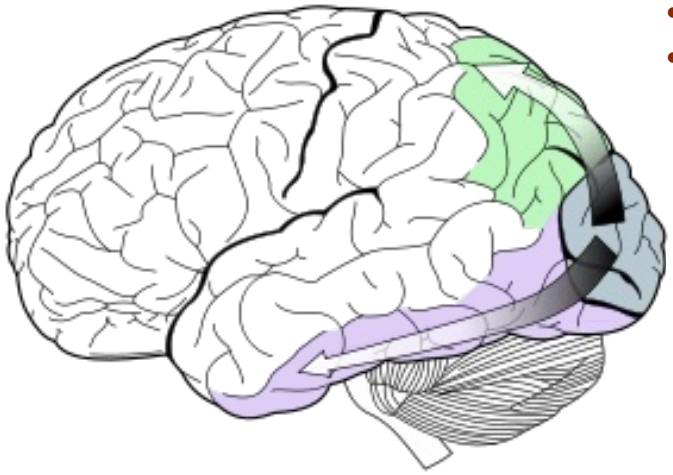
V4 – This is responsible for colour perception and object recognition.

V5 (MT) – This is responsible for movement detection and object tracking.

The V1 to V5 communicate with each other and interact with each other.

The visual cortex also interacts with other regions of the brain for tasks such as memory, attention and decision-making.

Visual Area



- Dorsal 'Where' Stream
  - Spatial awareness
  - Visually-guided behaviour
- Ventral 'What' Stream
  - Recognition & discrimination of visual shapes & objects
  - Perception & recognition of faces

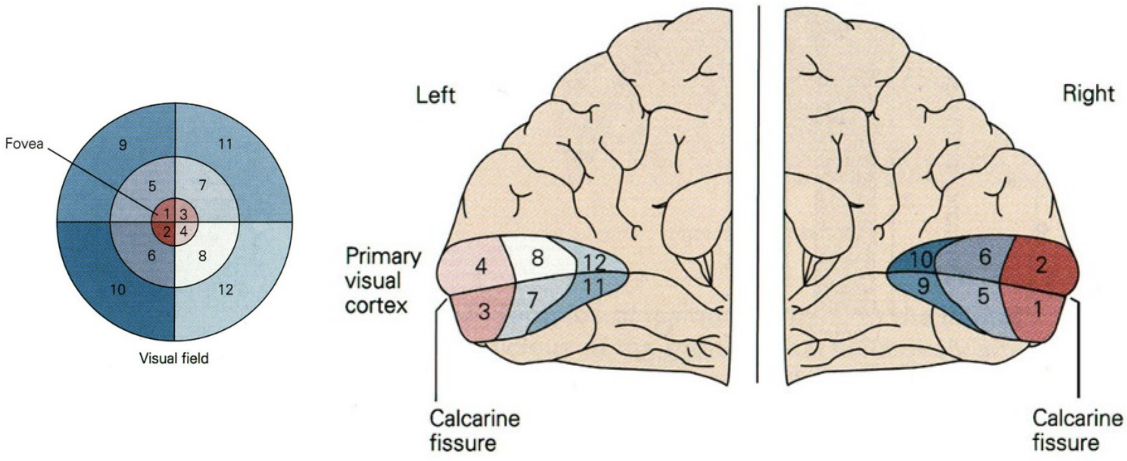
Source: Banich & Compton, 2018

Visual information is processes by the visual cortex (V1– V5) and also by other part of the brain. There are two pathways for visual information flowing from the visual cortex, each specializing in different aspect of the visual processing. They are called "Dorsal" and "Ventral" streams.

Dorsal Stream: In this stream, information flows from V1 towards the top of the brain. This is sometimes called the "where" pathway because it is responsibility for spatial awareness such as finding your way around or reading maps, and generally handles visually-guided behaviour.

Ventral Stream: Information for this stream flows downwards as shown. It is often called the "what" pathway because it is responsible for object recognition and identification, perception of colour, texture, features and general object understanding. It also contribution to facial recognition and emotional processing.

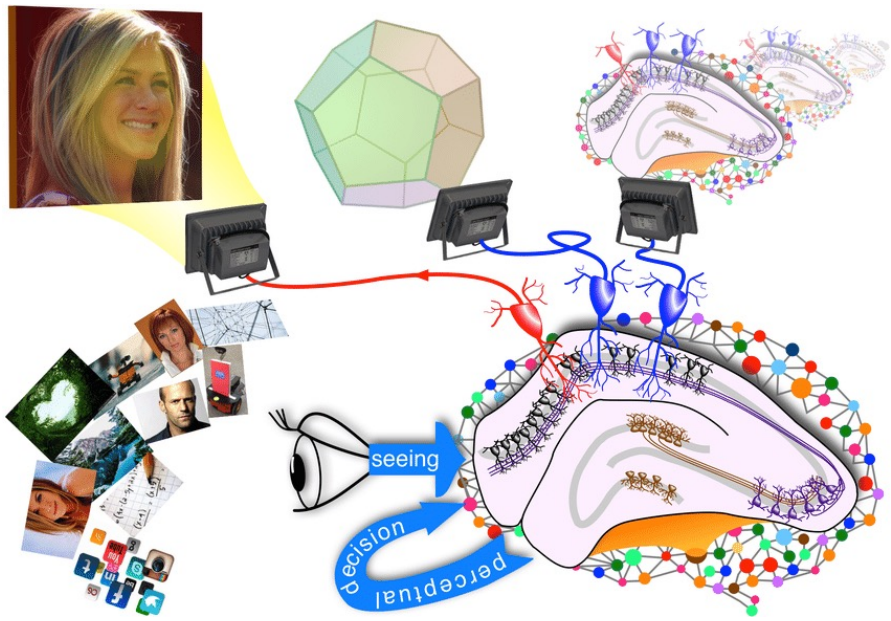
Retinotopic mapping



Source: Paulun et al, 2018.

Retinotopic mapping refers to a characteristics where visual field is mapped to the surface of the visual cortex as shown in the slide here. The right visual field is mapped to the left primary visual cortex. Further, the different part of the retina is mapped to specific part of V1 as shown. (And similarly for the left visual field.)
In this way, spatial relationship between the visual field, the retina an the visual cortex that processes the signals are preserved. In this way, our perception of space matches the actual physical layout of the image captured by the retina.

High dimension perception – Jennifer Aniston Cell



Source: Gorban et al, 2018

In 2005, a team of scientist from University of Leicester published a paper in nature entitled 'Invariant visual representation by single neurons in the human brain'. It reports how they recorded brain activity in an epileptic patient and found some neurons fired specifically when the patient was shown Jennifer Aniston's picture, but not other faces. This suggests that some neurons are highly tuned to recognize very specific high-level information such as a person's face. Current understanding of the brain and how it retains information suggests that this is probably not due to a single neuron, but a group of neurons that are adapted to recognize complex images and concepts. This is currently still just a theory – the existence of such cells is yet to be scientifically proven.

Such cells are also called the "Grandmother" cells.

The article can be found here: https://doi.org/10.1038/nature03687