- Light hits object, bounces off, scatters and then the human eye processes this
    - Objects reflect different percentages of incident light e.g. white paper 75%, black paper 5%
- Contrast
  - Difference in light and dark between objects is how the eye can identify them
  - Michelson contrast
  - Where the L_{max} and L_{min} are the largest and smallest luminance values respectively
  - Varies between 0 and 1

$$C = \frac{(L_{max} - L_{min})}{(L_{max} + L_{min})}$$

The eye

- The **cornea** is the transparent window through which light enters the eye
- It is curved and acts as a lens – ¾ of focusing power comes from cornea, ¼ from the actual lens
- Lenses focus light onto the retina
- At least one curved surface, and made of substance that bends light when hit due to light travelling slower than it does through air

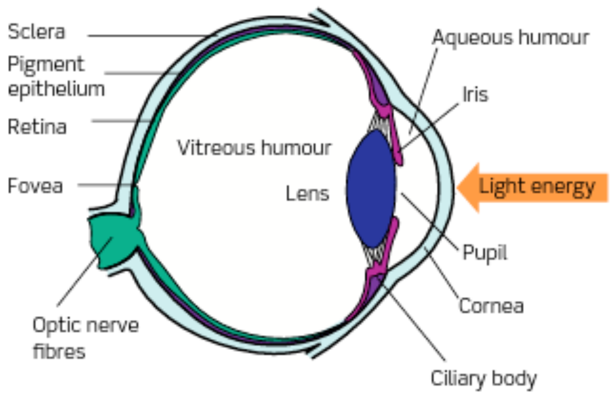
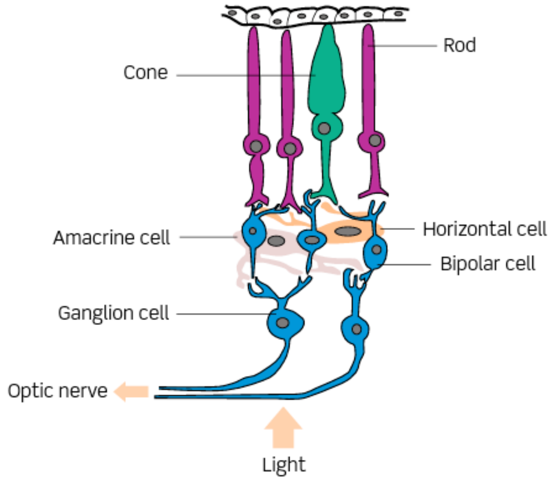


Figure 1.2 Horizontal cross-section through the human eye.

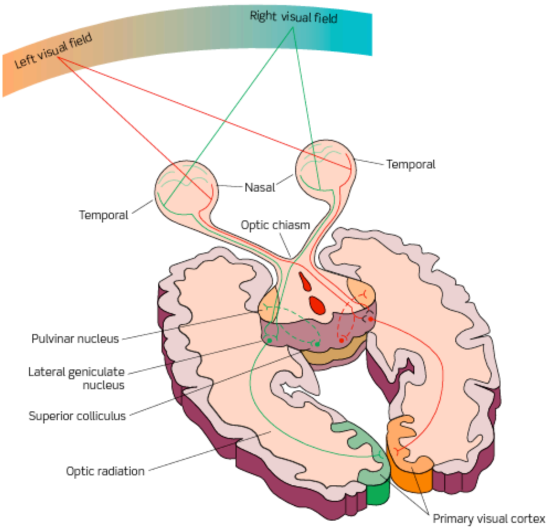
- Light travels at similar speeds through water and the cornea, therefore there is little deflection of light and focus is impossible
- A pair of goggles which insert an air-cornea boundary enable light to bend and the eye to see
- The chamber behind the cornea is filled with **aqueous humour**
- The **iris** is coloured and provides an adjustable aperture
  - When light levels are high, it constricts and pupil decreases in size to reduce amount of light passing through
  - When light is dim, iris relaxes and allows more light to pass
- **Pupils** dilate from excitement
  - When pupils constrict, the depth of focus increases
- **Lens** are adjustable, held between zonules of Zinn
  - This allows for accommodation i.e. focusing on objects of different distances from the eye
  - Focusing is recombining rays from various directions to form a single point on the imaging surface
  - When objects are far away, lens needs to be stretched and skinnier, achieved by tightening ciliary muscles
  - Close objects send diverging rays to the eye, so the lens needs to be fat and rounder to focus them on the retina, ciliary muscles relaxed

- Focusing Errors
    - If this works, you are emmetropic
    - Short sighted (eye too long for optics) – myopic
        - Diverging lens – concave
    - Long sighted (eye too short for optics) – hypermetropic
        - Converging lens – convex
    - Presbyopia is the condition where our closest point we can focus on (near-point) gets progressively further away – reading glasses
    - Astigmatism – different focal lengths for different orientations
- Behind lens is the main cavity of the eye, the **vitreous humour** which maintains shape of the eye and pins retina to back of eye
- The **retina** is a light-sensitive layer at the back of the eye, where visual processing really begins
    - Receptors are at the very back, where light travels through other neural matter before reaching them – an accident?
    - This leads to a **blind spot** in each eye, where ganglion cell axons converge and leave the eye



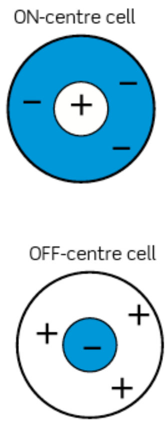
    - Receptors are connected to **bipolar cells** which synapse with **retinal ganglion cells**
    - The ganglion cells' axons carry information from the eye towards the visual cortex
- Photoreceptors in the eye: rods and cones
    - Rods contain the purple photopigment **rhodopsin** 'visual purple'
        - Respond well in dim light
        - Not useful in full daylight, with activity increasing as light levels increase
        - **Scotopic** vision
        - Most sensitive to green light
    - Cones
        - 'Red' cones contain photopigment sensitive to long wavelengths of light
        - 'Green' cones most sensitive to middle wavelengths
        - 'Blue' cones most sensitive to shorter wavelengths – none in fovea
        - Overall most sensitive to yellow light
        - Responsible for daytime vision
        - **Photopic** vision
        - When vision is a combination of rod and cones, it is **mesopic**
        - Most concentrated in the fovea
- Ganglion cell selectivity
    - Each ganglion cell has a receptive field, the area over your retina where stimulation in that area changes the firing rate of that cell
- Receptive fields & acuity
    - Receptive fields for foveal vision are smaller and densely packed
    - Further into the periphery, they are larger and less dense

- Larger cortical area for processing foveal vision than for peripheral i.e. more precision

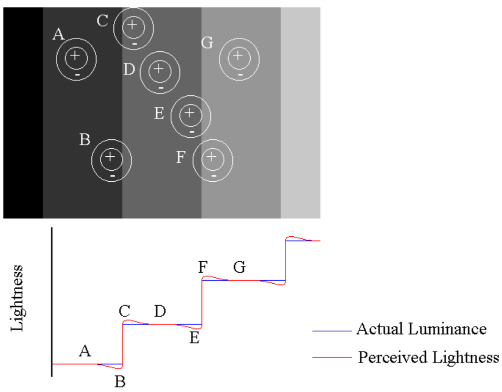


- Eye to brain
    - Optic nerve ➔ **retinal receptive fields ➔** crossover at **optic chiasm** ➔ retinal ganglion cell axons terminate in **Lateral Geniculate Nucleus (LGN)**
    - Images seen in the left visual field travels to the right LGN & vice versa – **partial decussation**
    - Lesion of optic nerve causes loss of vision in one eye
    - Lesion of optic tract causes loss of vision of half the world - **hemianopia**
    - **LGN** projects to **primary visual cortex (V1)** in occipital lobe via optic radiations (paths it travels along)
    - Then **V1** projects to other important extra-striate brain areas ➔ **V2, V3, V4** (colour), **V5/MT** (simple motion), **MST** (complex motion) – these areas have specialisations, not exclusivity
    - Each area is **retinotopic** except MST – adjacent cells have adjacent retinal receptive fields
    - As you progress along the processing stream, areas become more selective
    - Works in hierarchies but many connections are also lateral or backwards

Spatial Vision

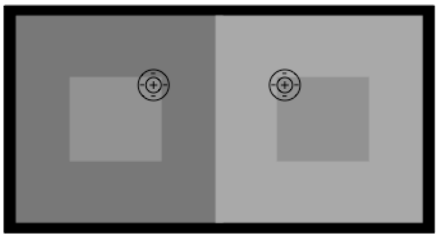


- A lot of information is received by the ganglion cells, so the irrelevant information must be discarded and only important information retained to regulate data load to the brain
- **Centre-Surround Antagonism** (aka lateral antagonism, lateral inhibition, spatial opponency)
    - Ganglion cell RF has 2 concentric areas
    - ON Centre Cell
        - Light falling on inner portion causes excitation – more ganglion cell activity
        - Light falling on outer portion causes inhibition – less activity
    - OFF Centre Cell
        - Work in opposite manner
        - Tell us how dark an area is, help detect local luminance decrements

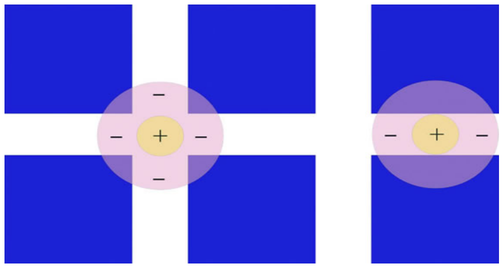


    - Optimal stimulus is a central spot of light on central zone, causing high activity levels
    - Light all over, or not light, causes only spontaneous activity
    - Stimulation of just the surround causes a reduction in firing rate
    - These processes are important for you to determine where changes are in an image – to

exaggerate edges
    - Allows compensation for intensity of light source
    - Cells prioritise contrast, not the overall brightness
- Simultaneous Brightness Contrast Illusion
    - There is less inhibition of the on-centre cell in the square on the left, therefore more ganglion cell firing
    - Thus, central square is perceived to be brighter



- Hermann Grid
    - Less noticeable closer to the fovea
    - More light at the intersections ie more inhibition (less firing) so makes it appear darker
      Less inhibition at white bars, so it appears brighter



- Why are grey patches more pronounced in periphery?
    - RFs are larger at periphery
- LGN
    - Like ganglion cells with centre-surround antagonism
    - Concentric receptive field will produce the same level of response to lines of all orientations
    - 6 major layers
    - All cells are monocular – only take input from one eye
        - Layers 1, 4 & 6 from contralateral eye (on opposite side)
        - Layers 2, 3 & 5 from ipsilateral eye (same side)
    - Retina ganglion cells send signals to LGN
        - Large **M cells** (magnocellular) – Low resolution, fast response, high sensitivity, process motion, coarse features, V5
        - Small **P cells** (parvocellular) – High resolution, slow response, low sensitivity, R-G colour, finer features, V4
        - Koniocellular (between M/P layers) – unclear purpose, process blue/yellow colour?

Lecture 6

- Optical imaging is an invasive method to observe activity in V1
- Selectivity for orientation – many channels selective to different angles
- Selectivity for eye-of-origin
    - Ocular dominance ranges 1-7
    - 1 & 7 monocular
    - Others binocular (2-6)
    - Binocular neurons have a role in estimating depth
- V1 Cell Properties
    - Orientation tuning – cells respond to edge or bar with a preferred orientation within its RF, with activity reducing as orientation departs from preferred
    - Range of orientation which cell fires to is a measure of its bandwidth
    - Small bandwidth ➔ sharp tuning
    - Large bandwidth ➔ broad tuning
    - Similar to auditory filters, olfactory receptors etc.
- V1 Organisation ("ice cube model")
    - Organised into orientation column – in a column, cells have same preferred orientation
    - Columns of ocular dominance – in a column, cells take inputs from same eye