

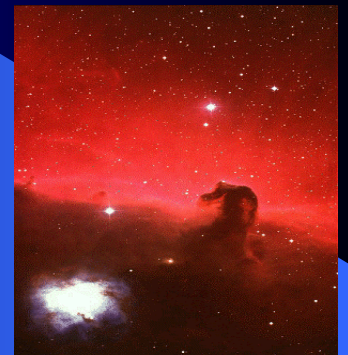
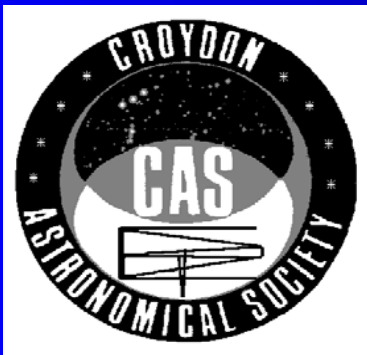
Croydon Astronomical Society

Eyes on the Universe

by

John Murrell

**Engineer at Work - Astronomer at
Play !**



Light Intensity

- Astronomical Magnitudes are logarithmic
- { Minus } One magnitude is 2.521 times brighter.
- 5 magnitudes is 100 times brighter / dimmer
- The logarithmic scale reflects the operation of the eye
- Typical Levels
- Sun = - 26.7
- Full Moon = - 12.5
- Venus = - 4.3
- Sirius = - 1.4
- Limit of Vision = + 6.5
???
- Binocular Limit = + 10
- Pluto = + 15
- Large Telescope Photographic Limit = + 25
- Dimmest object imaged $\approx +29$?

Exit Pupil

- Telescopes & Binoculars have an exit pupil.
- This is calculated from the Diameter of the Objective (mm) divided by the magnification.
- For 7 x 50 Binoculars = $50 / 7 = 7.14$ mm
- For 500 mm Telescope at 50 magnification = 10 mm
- For telescopes this determines the minimum useful magnification.

How the eye works

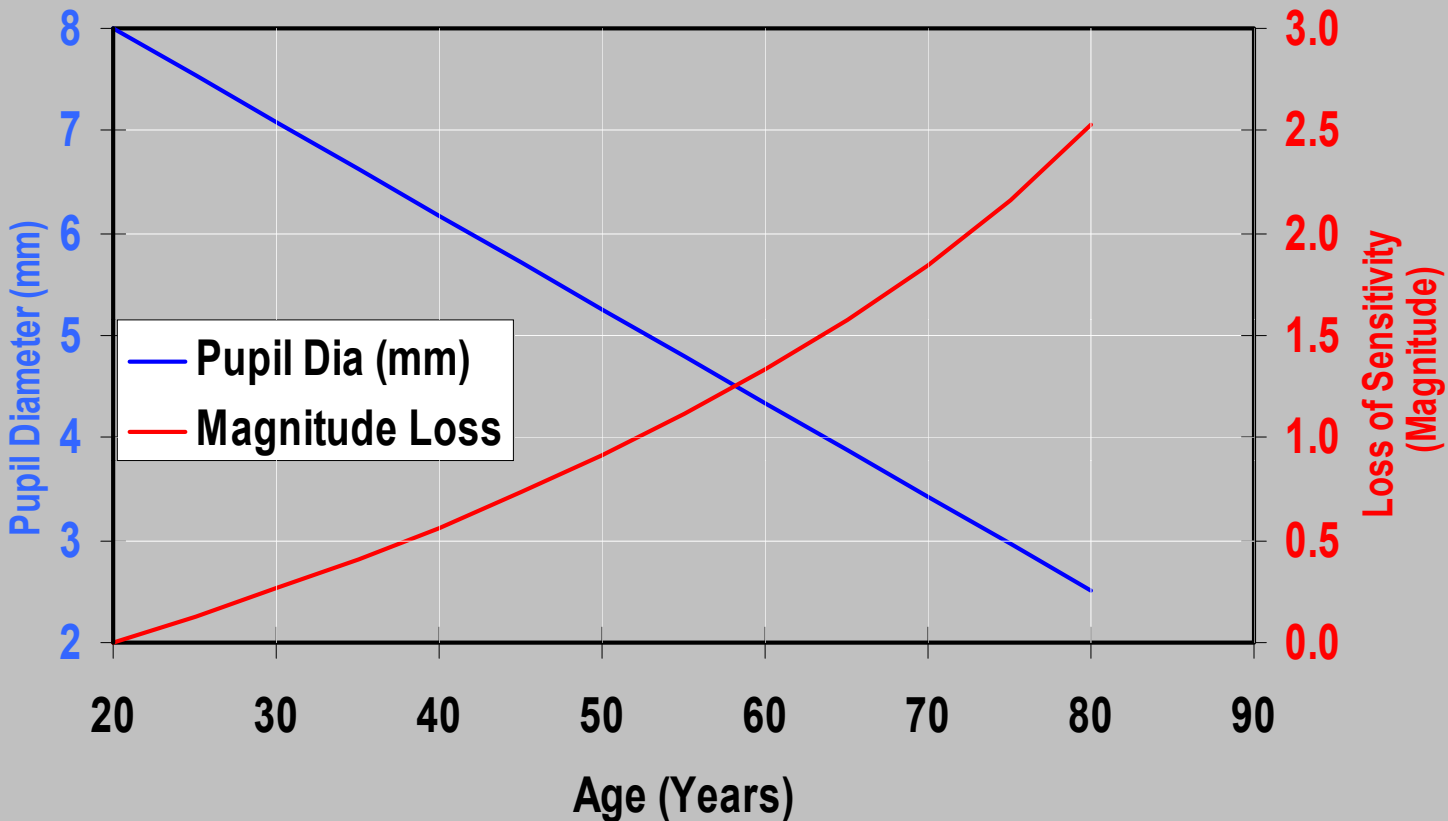
- It is very similar to a camera
 - At the front is a lens
 - The pupil adjusts the eyes sensitivity to light – much as the diaphragm does in a camera
 - The image is formed on the retina which is at the back of the eye – where the film would be in a camera
 - The ‘image’ is sent to the brain along the optic nerve – the brain does the clever bit !

Reduction in size of Eye's Pupil

- As we get older the maximum size that our pupil will open becomes smaller
- Buying a Telescope or Binoculars with a larger exit pupil than this is of no benefit
- The lens on the eye also yellows & loses more light as it gets older
- The following graph shows how the maximum size of the pupil falls with age & how many magnitudes loss this causes

Reduction in size of Eye's Pupil

Loss of Eye Sensitivity (due to reduction in Exit Pupil) with Age

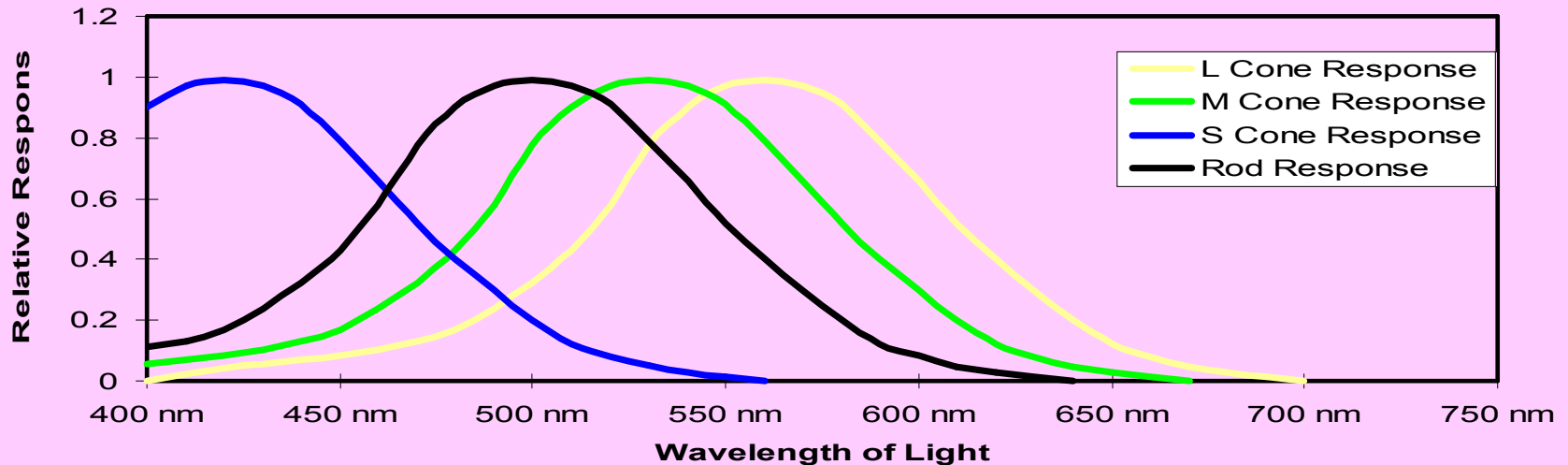


How the eye detects an image

- The retina at the back of the eye detects the image.
- There are two types of receptors in the retina.
- Cones for detailed vision in high light levels.
- Rods for low light levels but low resolution (they are not colour sensitive) .
- The Cones used for colour vision are subdivided into 3 types with different colour responses

Spectral Response

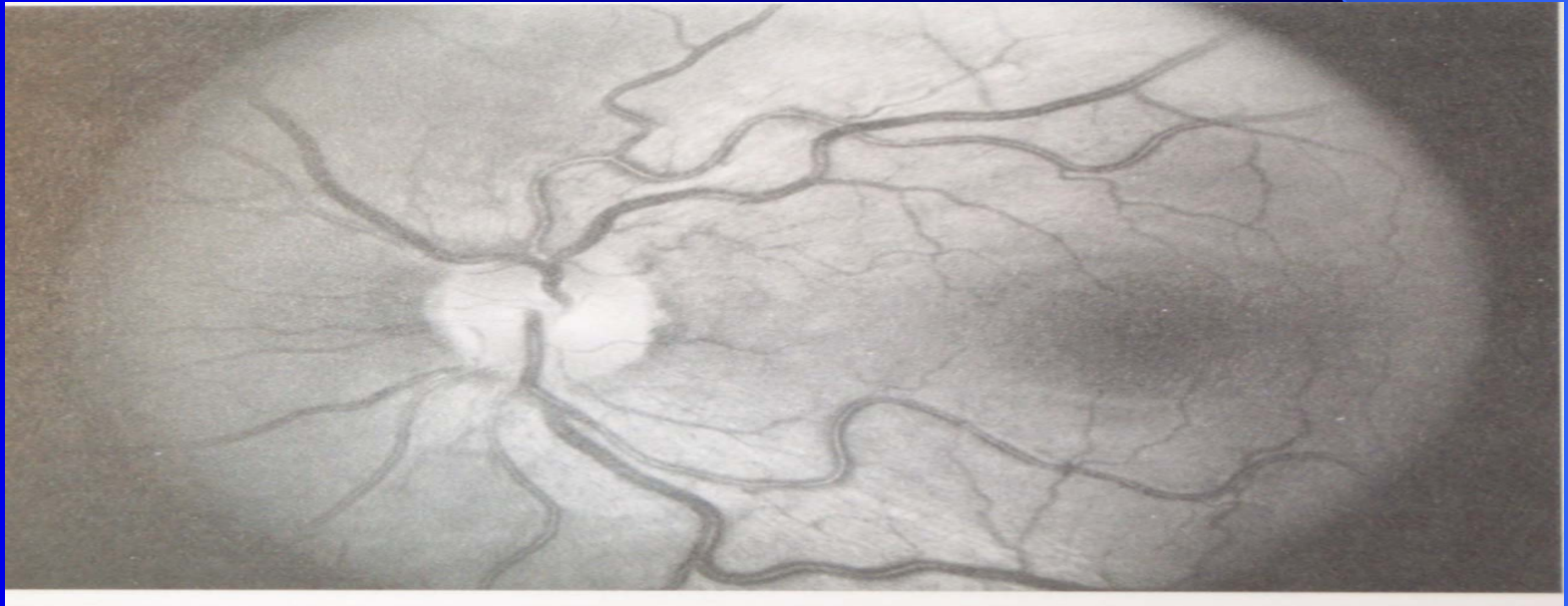
Eye Cone & Rod Response against Wavelength



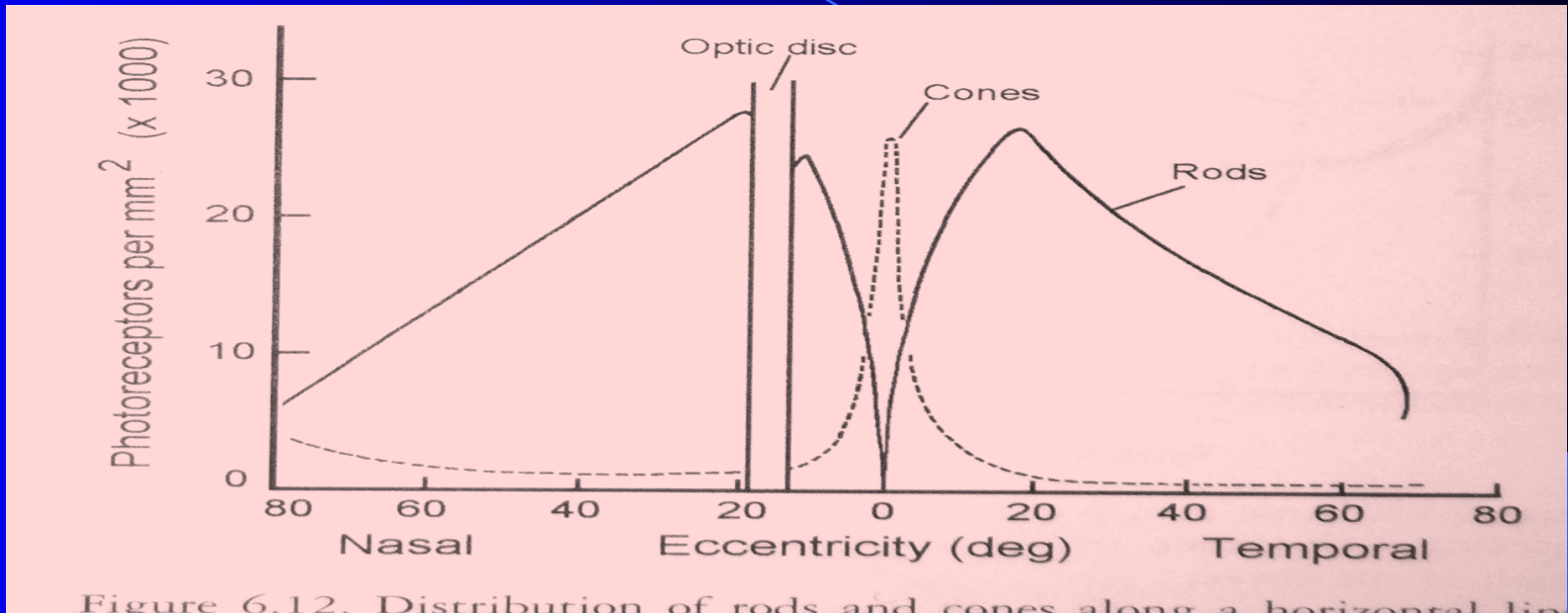
- As the eye has a logarithmic response the performance particularly in the red region is better than may be suggested by this graph
- **L Peak = 564 nm (Yellow Green)**
- **M Peak = 534 nm (Green)**
- **S Peak = 420 nm (Blue)**
- **Rod Peak = 498 nm (Blue Green)**

Distribution of Cones & Rods

- **Cones are in Centre**
- **Rods are around periphery**
- **Fovea is the highest resolution around One to Two Degrees (A thumbnail at arms length)**
- **Where the Optic nerve joins the retina there is a blind spot**

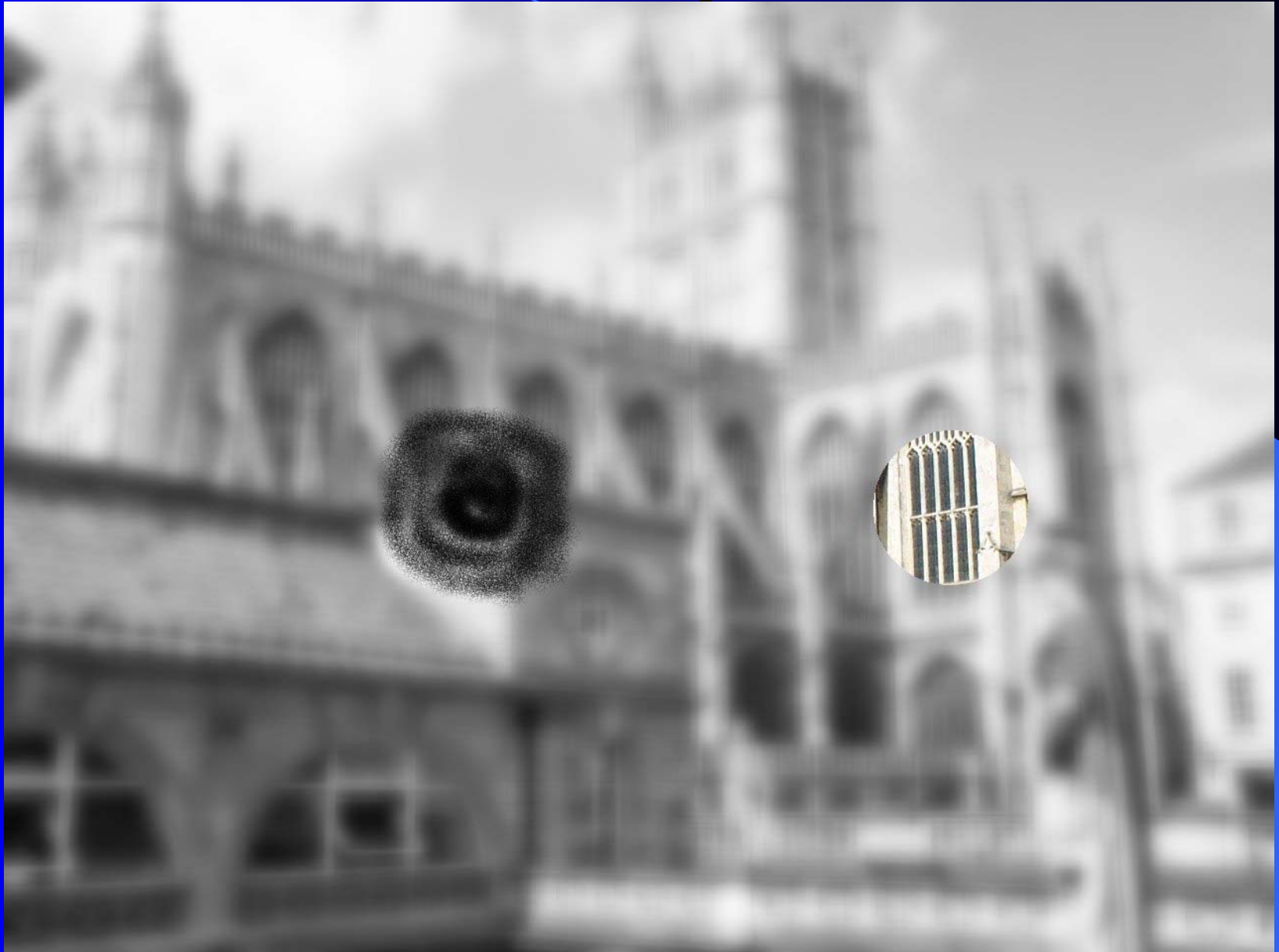


Resolution of the Retina



- The optic disk is where the optic nerve connects
- The rods work in groups (like binning a CCD) – this is part of the motion detection system so the resolution of the rods is lower than shown in this diagram

What the eye sees



What the brain sees



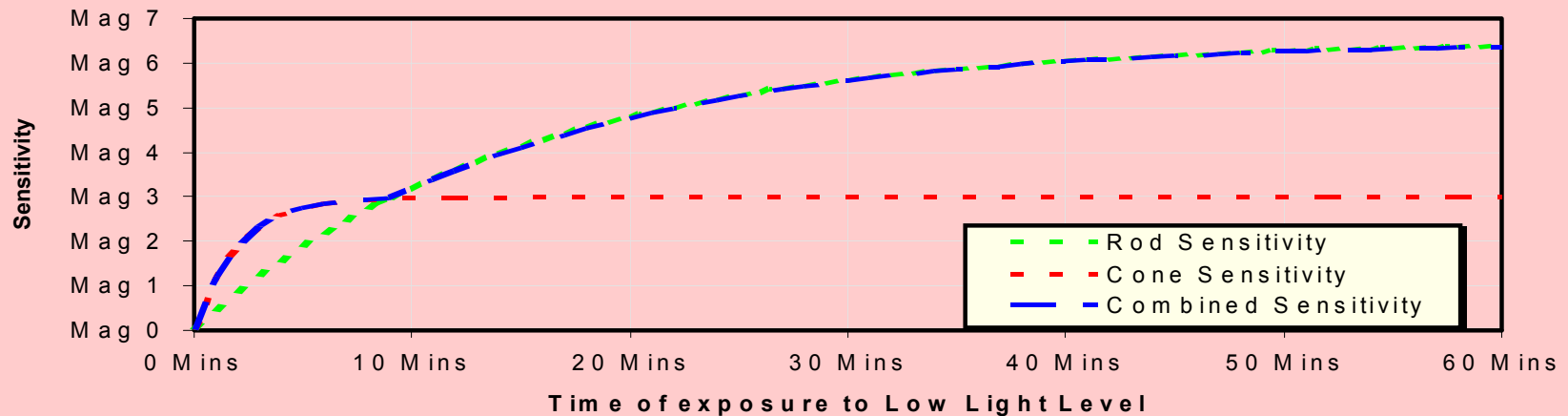
Dark Adaptation

Three Stage Process

- 1- The pupil opens gives about 3 magnitudes in 2-3 seconds.
- 2 - The Cones adapt to the low light level.
- 3 - The Rods adapt to the low light level.
- The Cones & Rods adapt at different rates as shown on the next graph.

Adaptation Response Time

Graph showing the approximate increase in sensitivity of the Human Eye when exposed to low light conditions. The values of sensitivity are only approximate.

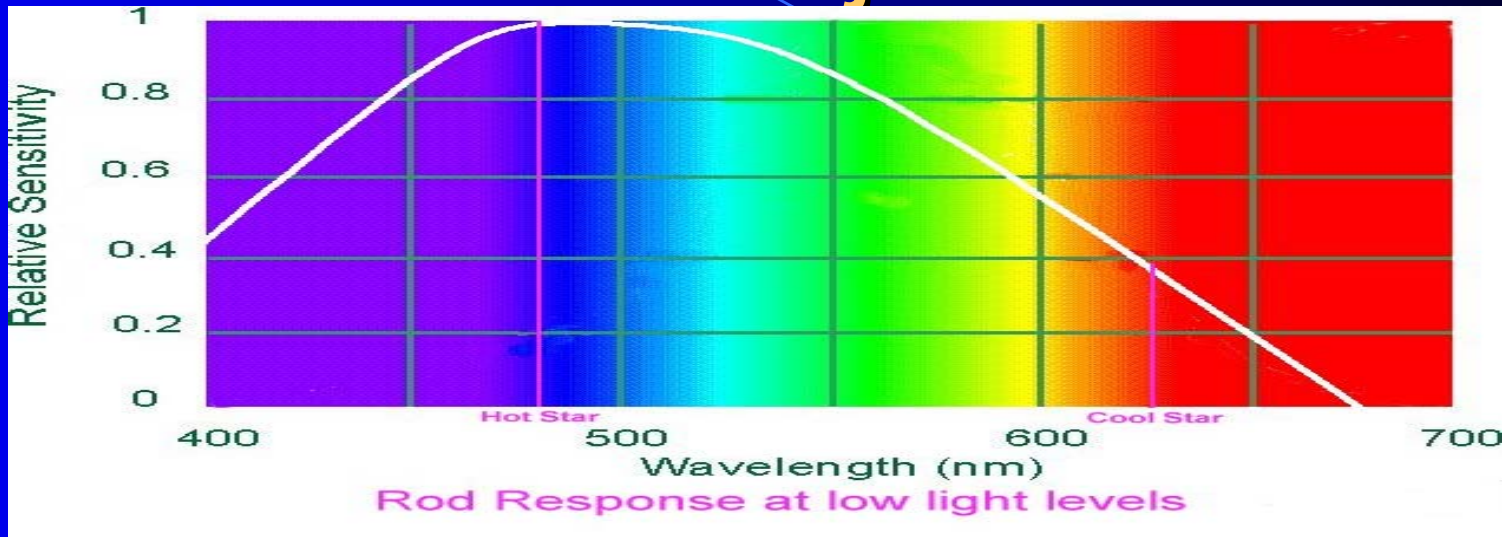


- The Blue Dashed Line shows the combined response.
- The point where the Rods become more sensitive is known as the 'Rod - Cone Break'.

Averted Vision

- The centre of the Eye has no rods so does not work at low light intensities.
- To see dim objects you need to use the periphery of the eye - this is averted vision
- However the blind spot stops the use of one side.
- Best response is opposite the Blind Spot (Temporal Side)
- Above & Below are quite good

The Purkinje Effect



- **Dim stars only activate the rods**
- **A red star will appear dimmer than a blue star even if they are the same intensity due to the response curve shown above**
- **This causes errors in visual estimates of star brightness**
- **It is known as the Purkinje effect**

Summary

- Wait 30 - 50 minutes before looking for dim objects.
- Use low levels of deep red light to look at charts – this does not effect the dark adaptation of the rods.
- Use averted vision
- Beware of the blind spot
- Don't expect to see colour in dim objects.
- Rod vision has low resolution so you will not see detail.
- The larger the image the better provided that it is above the detection threshold.

and Finally

- Lack of Oxygen reduces the sensitivity of the retina – if you observe from a mountain take your oxygen !
- ☹ Alcohol also reduces the sensitivity to light ☹