

Photonics



- ★ Photonics is the branch of the study of light where photons are important. Notably:
 - ▶ the detection of light
 - ▶ the generation of light
 - ▶ quantum optics
- ★ The name is commercially popular
- ★ This section concentrates on the detection of light and, in particular, methods involving the photoelectric effect

Photoelectric effect

★ The release of electrons upon bombardment with light

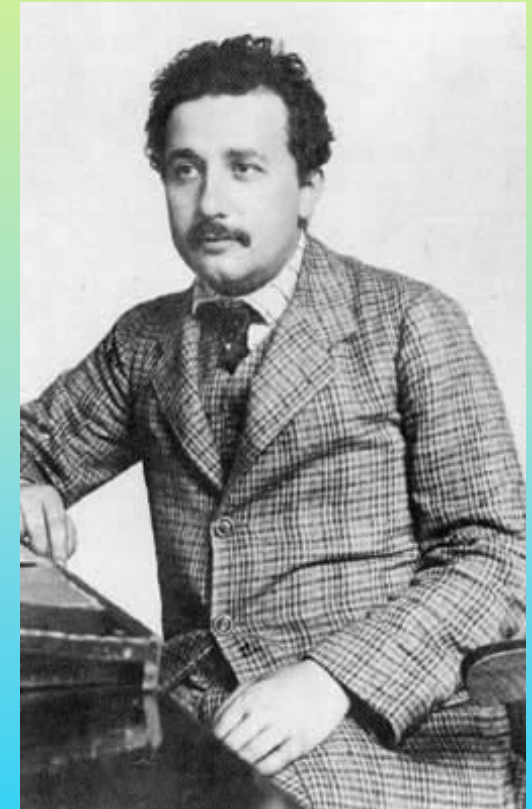
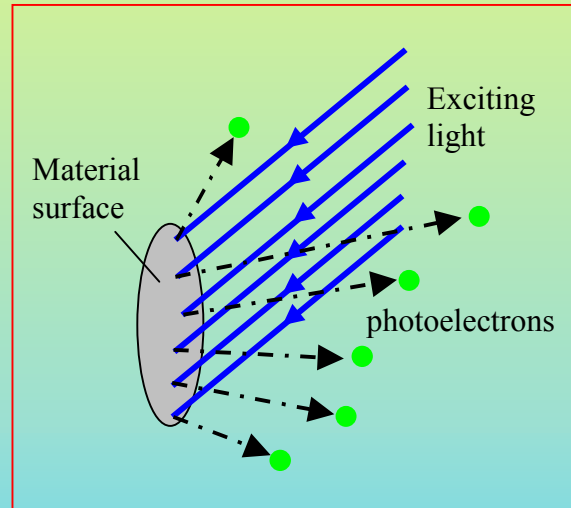
★ Einstein

▶ Nobel prize

★ 2 key properties:

▶ below a certain frequency no electrons are ever produced

▶ the kinetic energy of the electrons increases with light frequency

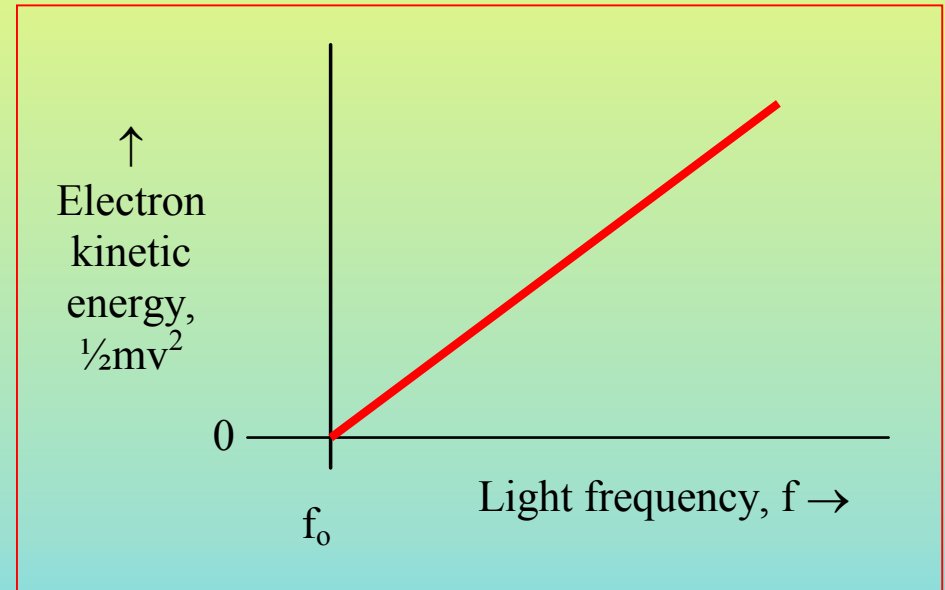


Albert Einstein 1879 - 1955

Quantitative results

- ★ Einstein postulated that light consisted of nothing but quanta – later called photons
- ★ Planck's formula

$$Energy = hf$$



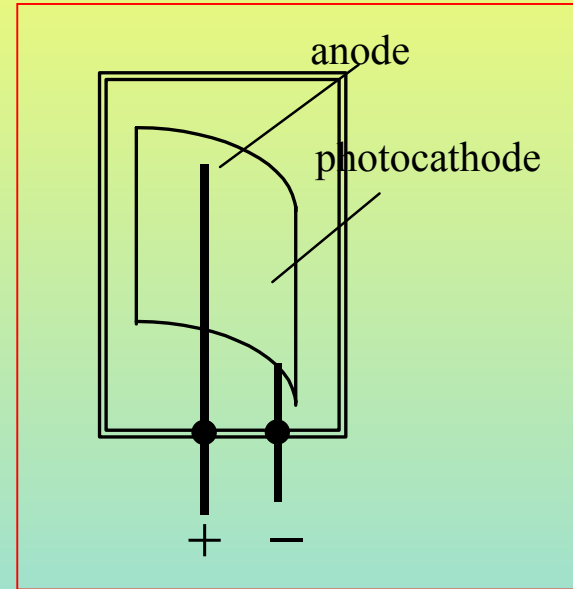
- ★ Einstein's interpretation: energy conservation

$$\frac{1}{2}mv^2 = hf - \Phi$$

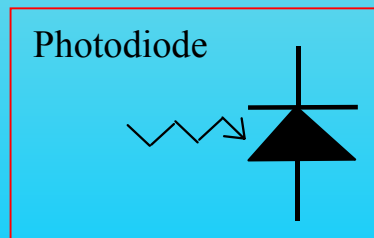
- ★ Φ is the work function of the material

Photocells

- ★ Photocells deliver a photocurrent when put into a circuit
 - ▶ the photocell is housed in a glass vacuum tube



- ★ Photodiodes are solid-state devices generating electrons in response to light

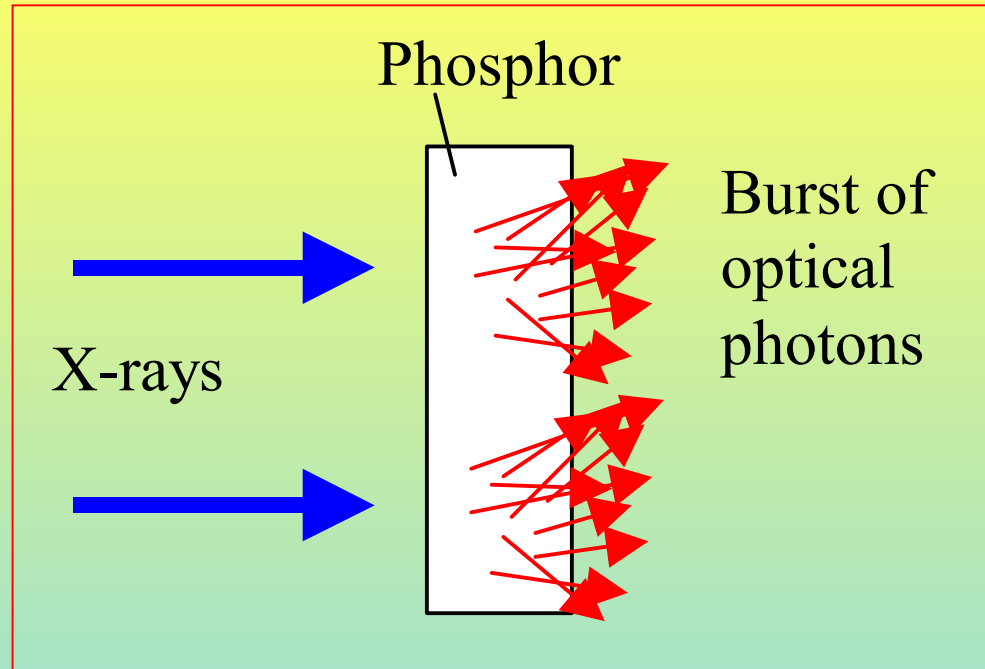


The photomultiplier

- ★ Photomultipliers are used to detect weak light sources
- ★ Photomultipliers are used to detect X-rays and γ -rays
 - ▶ the detection is a 2-stage process:
 - the radiation produces light via phosphors
 - the light is then detected by a photomultiplier

Phosphors

- ★ X-ray photons may have 10,000 times the energy of an optical photon



- ★ One X-ray photon creates several thousand optical photons

 - ▶ the time taken is very short $\sim 10^{-7} - 10^{-10}$ s

- ★ Suitable materials are some plastics and selected doped crystals

Working of the photomultiplier

- ★ The photomultiplier amplifies the initial photoelectron pulse by a succession of dynodes each $\sim 100\text{V}$ more positive giving a total amplification $>10^6$

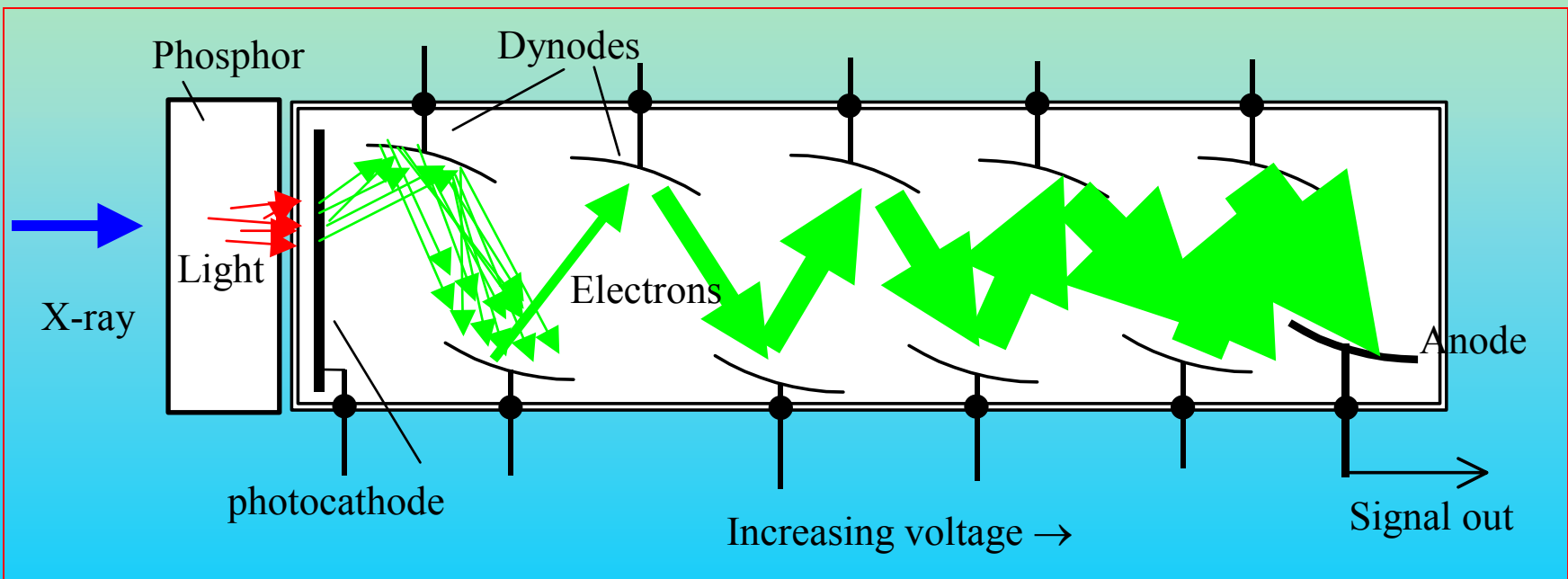
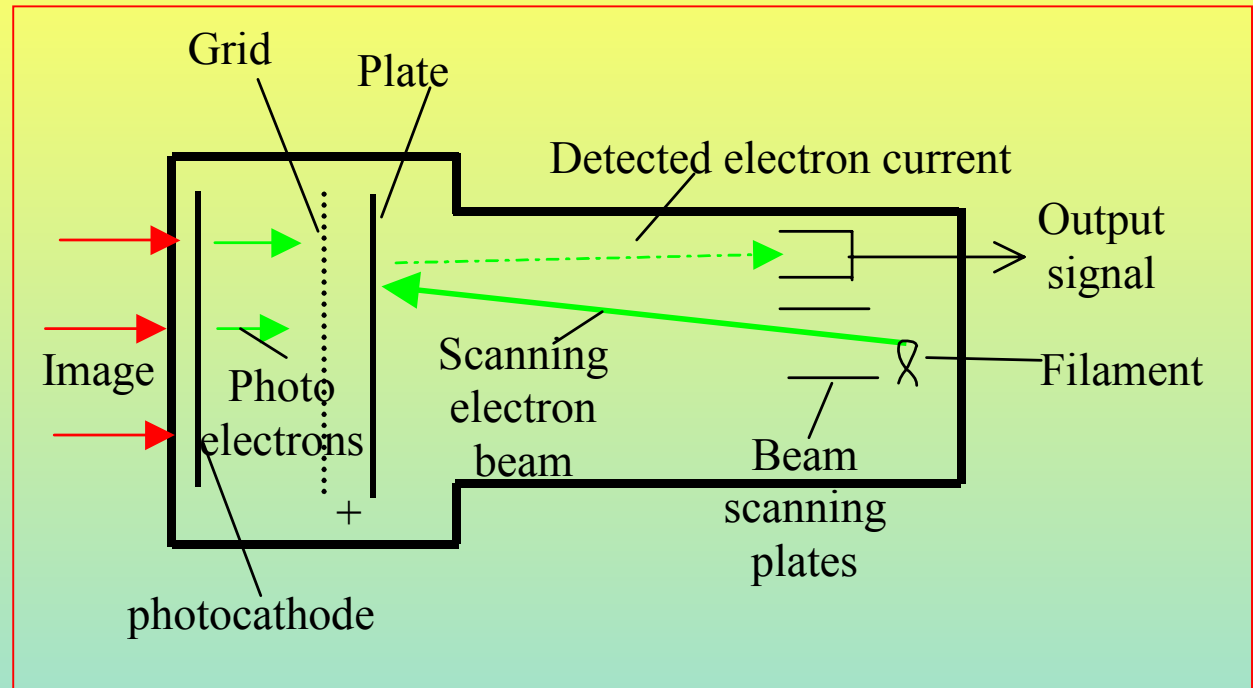
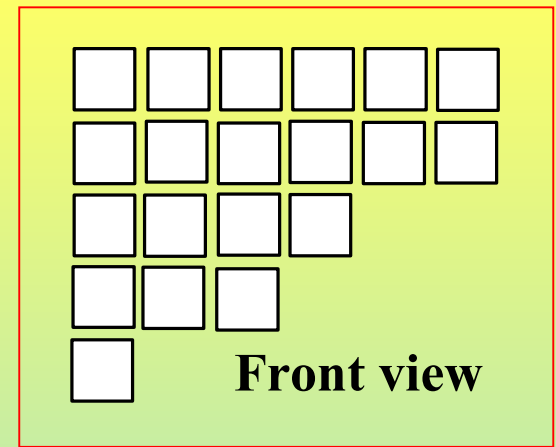


Image intensifiers

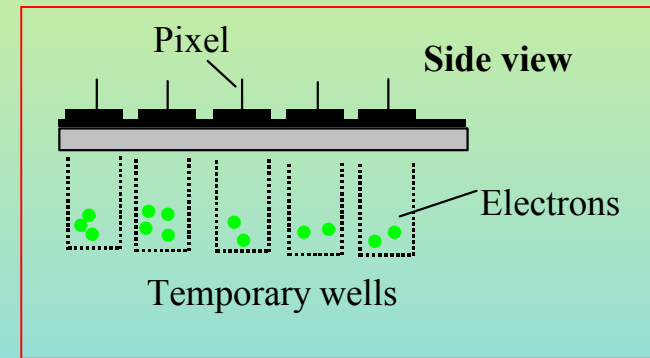


- ★ The image orthicon is based on photoelectron emission
- ★ The photoelectrons create a +ve replica of the image on the internal plate
- ★ This is scanned by an electron beam and the scattered electrons are measured

The CCD detector



- ★ **Charge Coupled Device**
- ★ Expose the detector to light, generating the photoelectrons
- ★ Store the photoelectrons in electrical 'wells' directly beneath their place of generation
- ★ Transfer the stored charges to the edge of the device
- ★ Read-out the charge and generate a suitable digital number to represent the light irradiance.

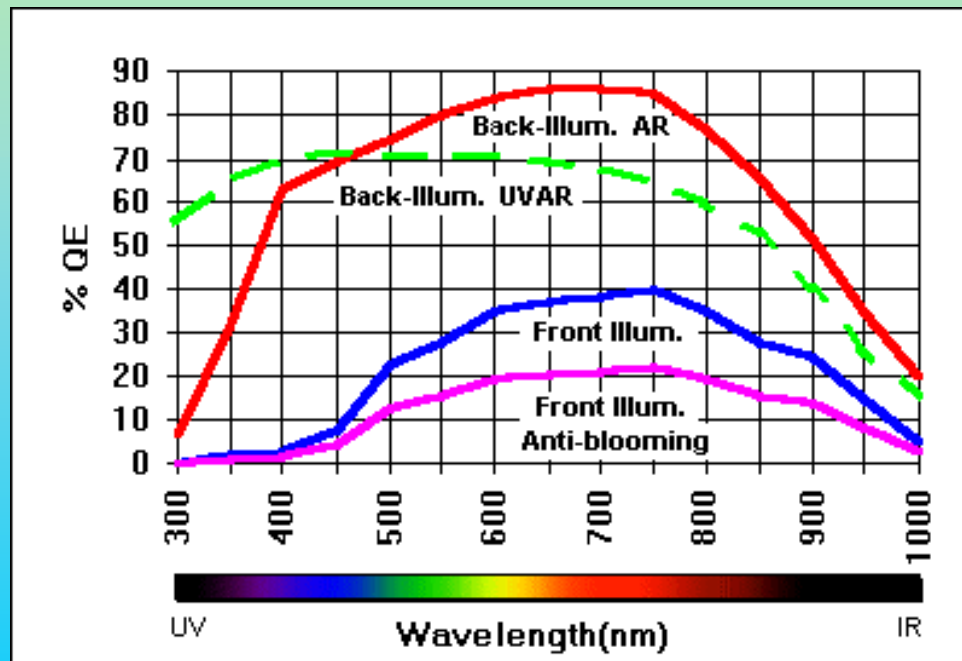


Advantages of the CCD

- ★ They are intrinsically digital
- ★ They're highly linear: twice the irradiance produces twice the output voltage
- ★ They have a large dynamic range (the maximum to minimum levels that can be detected)
- ★ They can integrate the light for many seconds, allowing the imaging of sources too weak to be seen by eye
- ★ They have a low 'noise', or dark signal, made even lower by cooling. A few electrons per pixel is achievable.

The quantum efficiency

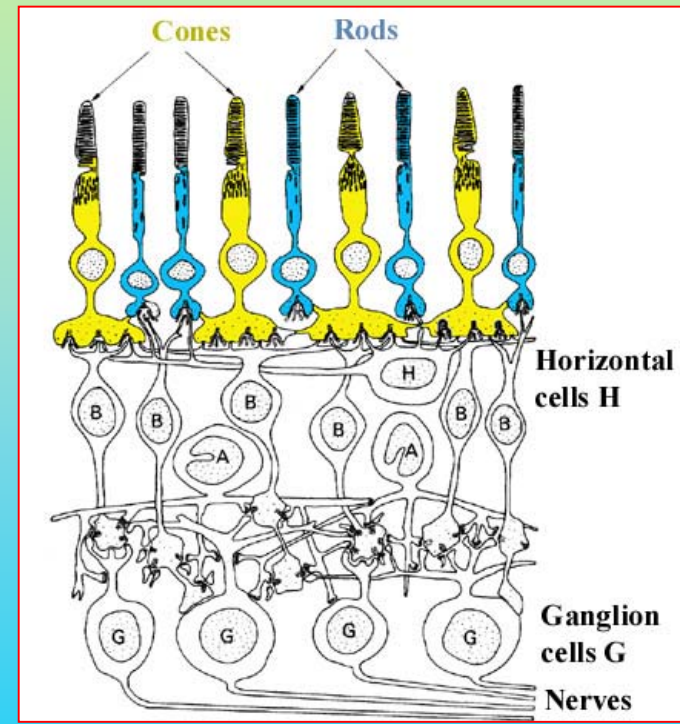
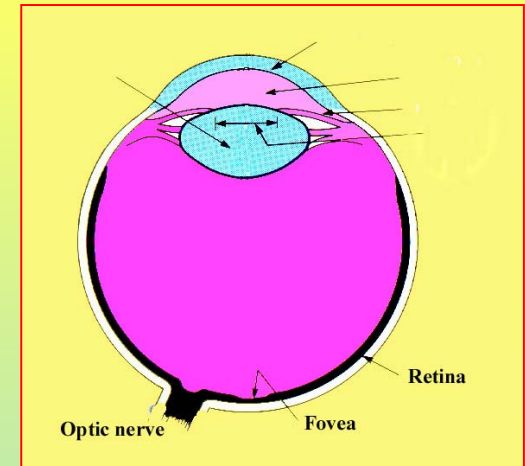
- ★ The quantum efficiency is the success at creating a signal for incident quanta. It is very high indeed for CCD detectors



Courtesy:
apogee-ccd.com

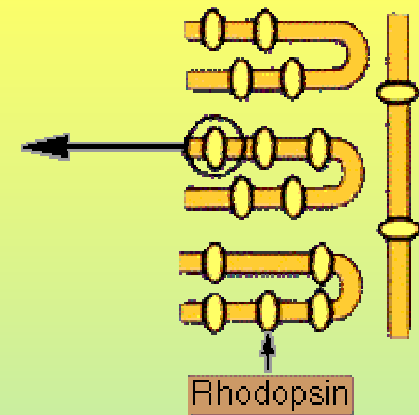
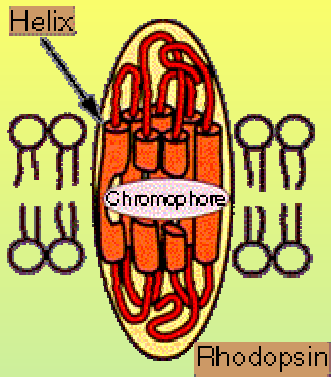
Detecting light by eye

- ★ The eye takes in light and produces electrical signals
- ★ The crucial molecule is a protein called rhodopsin
- ★ Within rhodopsin is a chromophore that absorbs light, called retinal

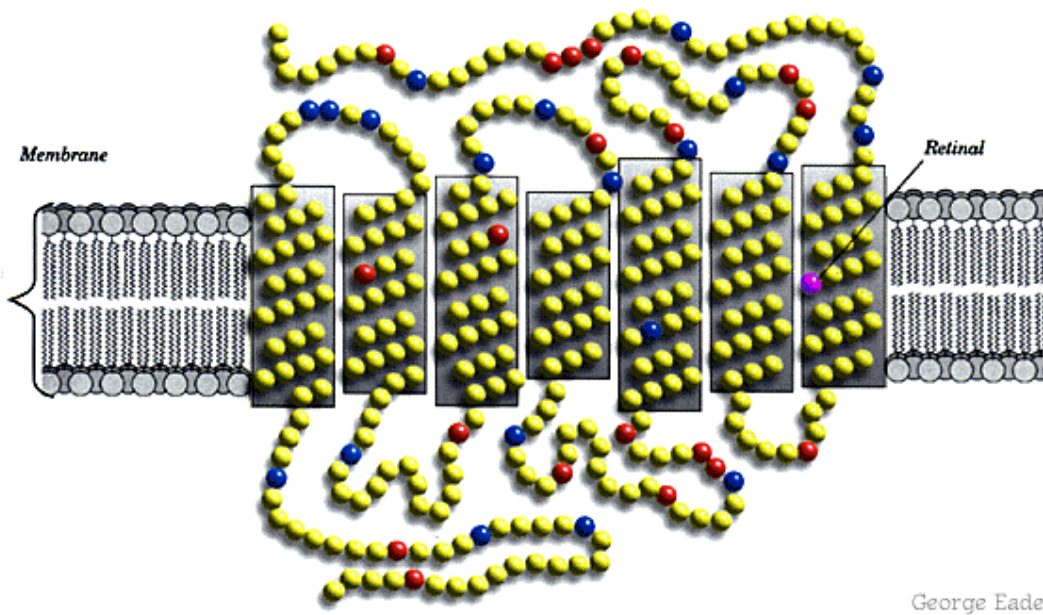


After Dowling & Boycott
↑ ↑ ↑ ↑ ↑ ↑ ↑
Light

Rhodopsin in rods



- ★ Rhodopsin winds up and down a rod
- ★ Notice the retinal

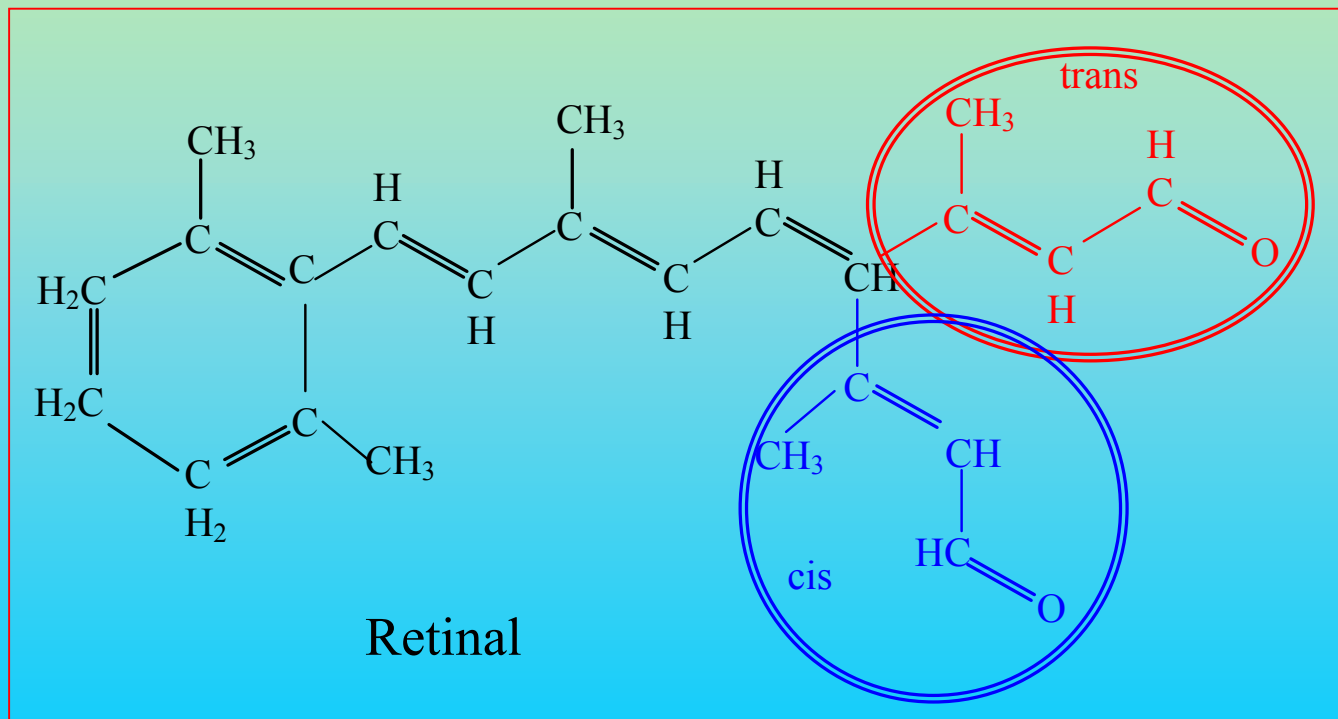


George Eade



The working of retinal

- ★ Upon absorbing light, retinal changes from the *cis* to the *trans* configuration, releasing an electron
- ★ This is the start of a cascade process, leading to generation of an optic nerve signal



The end