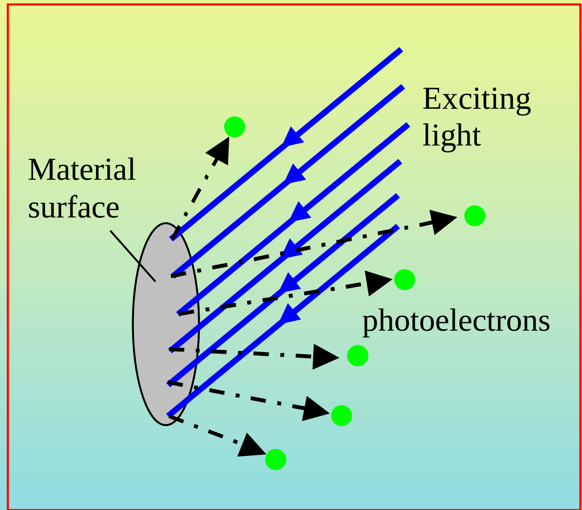
Photonics

- 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

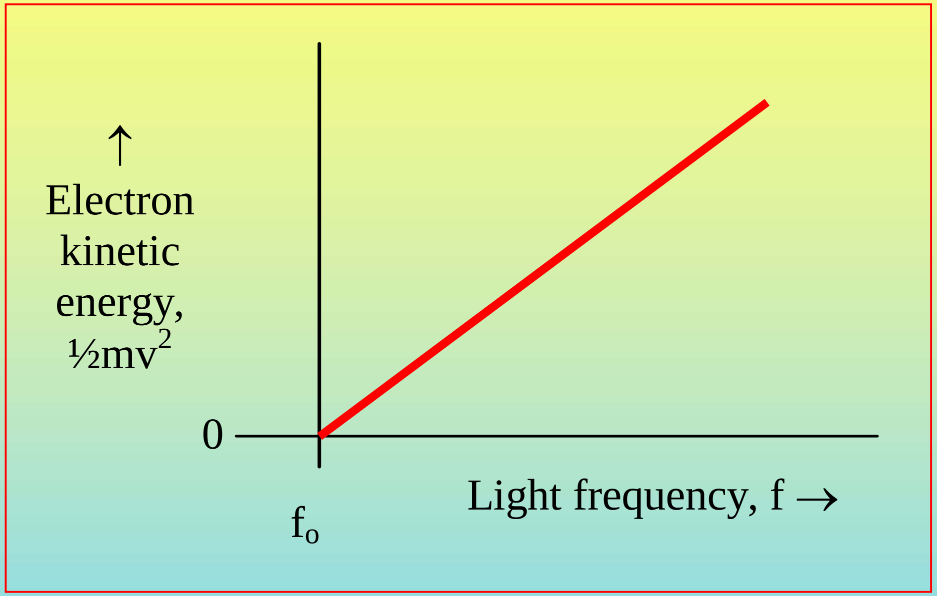
Photoelectric effect

- 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

$$\boxed{Energy = hf}$$

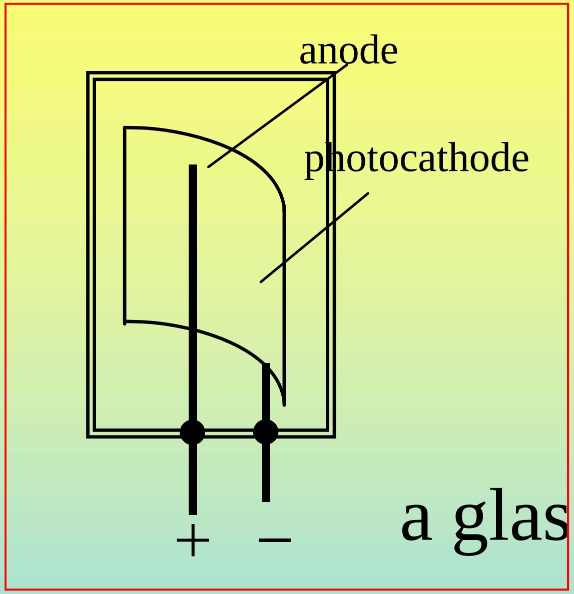
- Einstein's interpretation: energy conservation

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

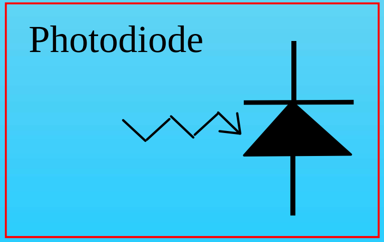
- Φ is the work function of the material

Photocells

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



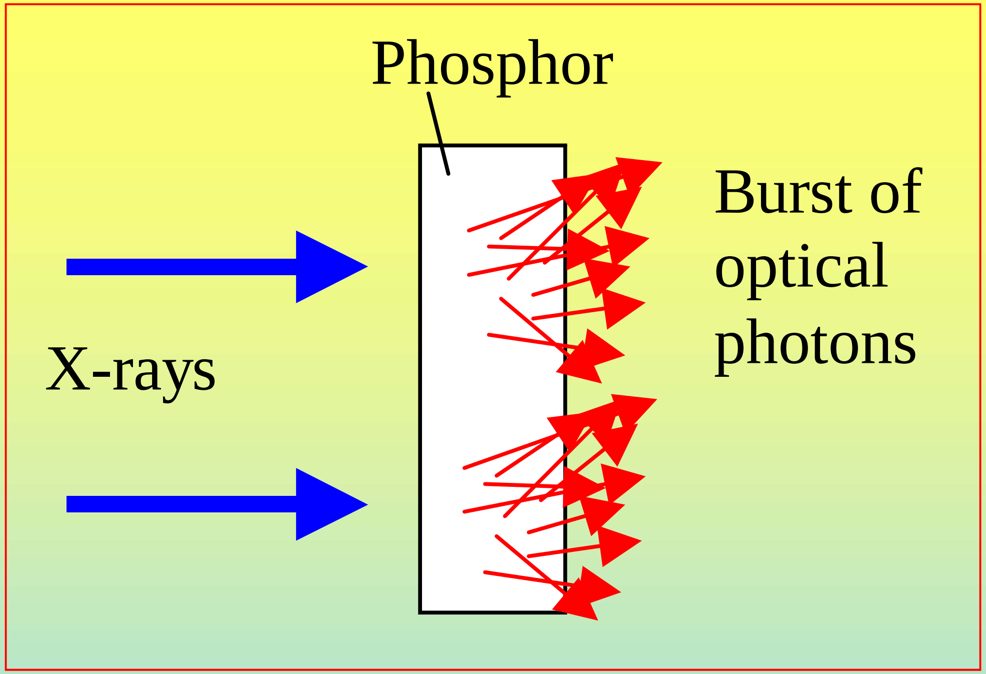
- Photodiodes are solid-state devices generating electrons in response to light



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 ~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 ~100V more positive giving a total amplification $>10^6$

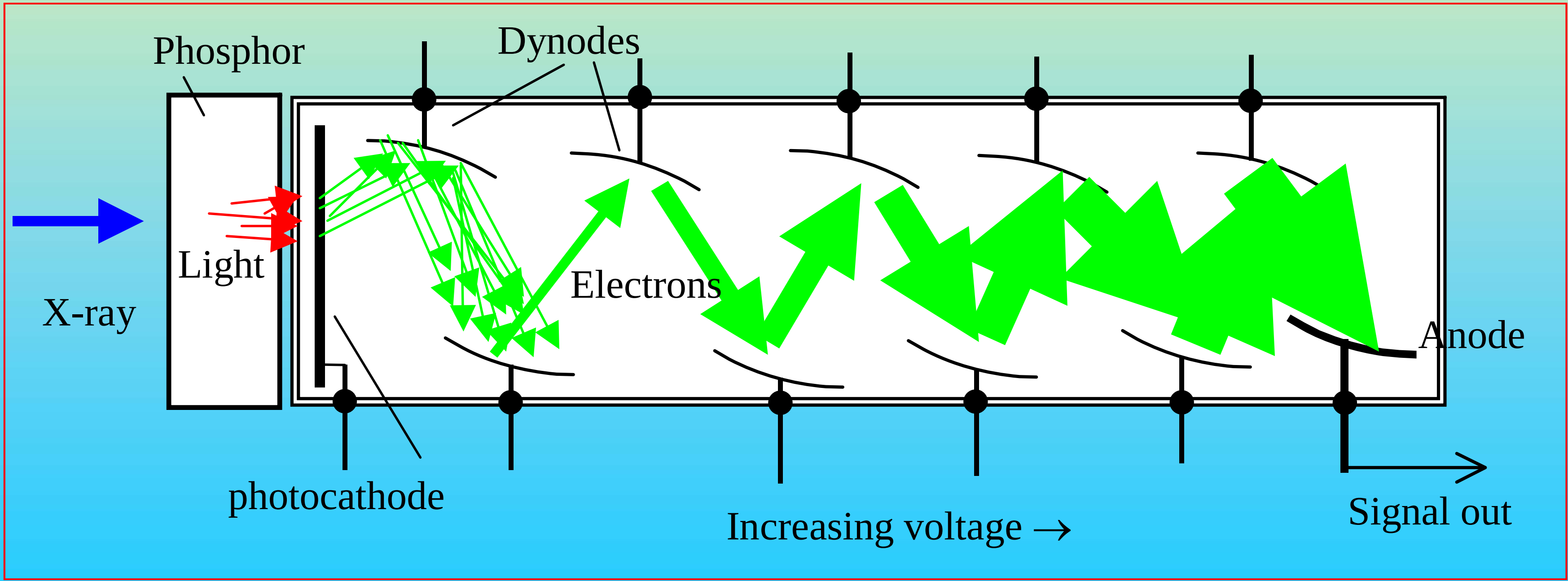
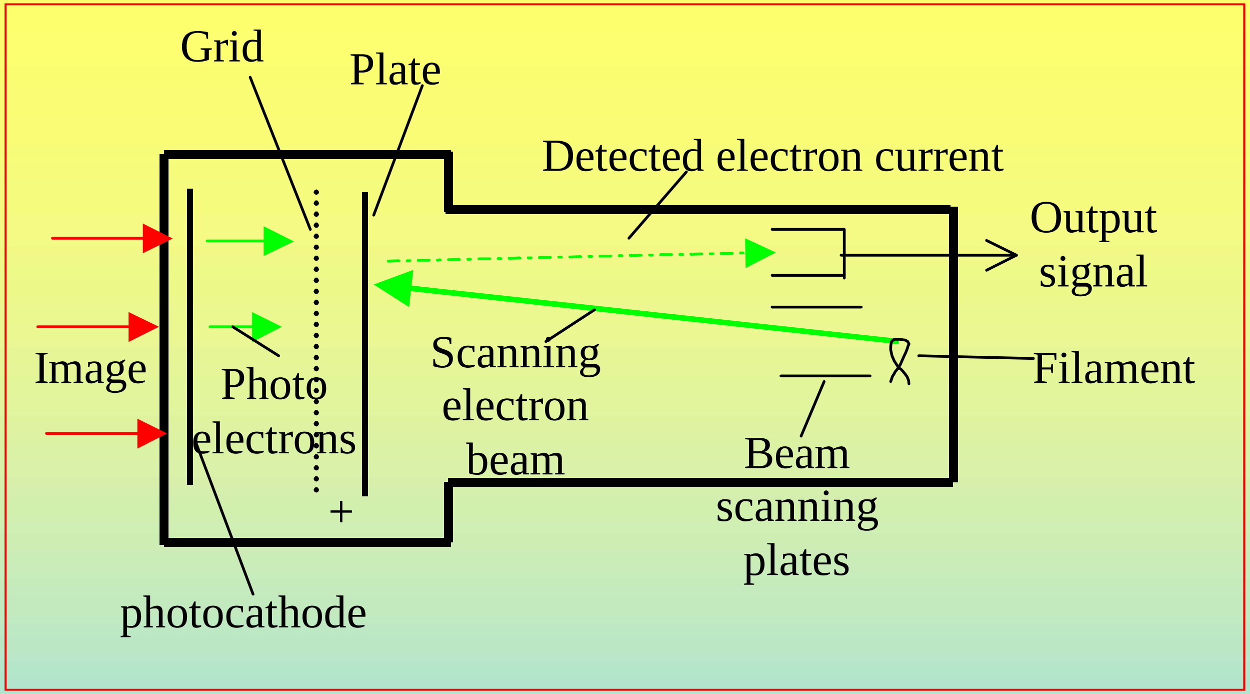
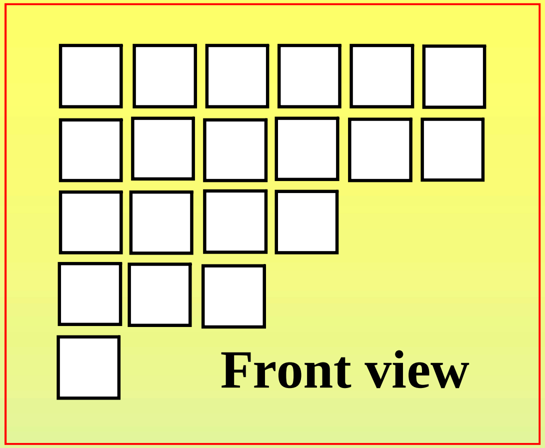


Image intensifiers

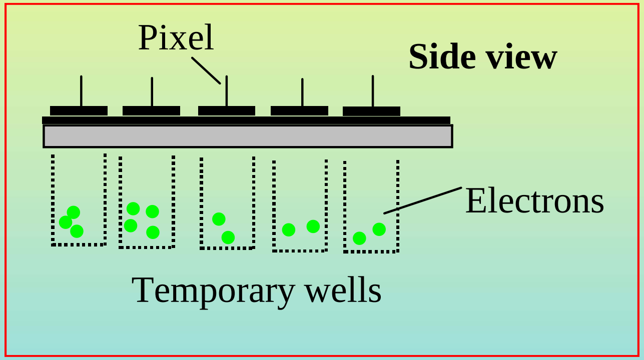


- The image orthicon is based on photoelectron emission
- The photoelectrons create a +ve replica of the image on the internal plate
- This is scanned by an electron beam and the scattered electrons are measured

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



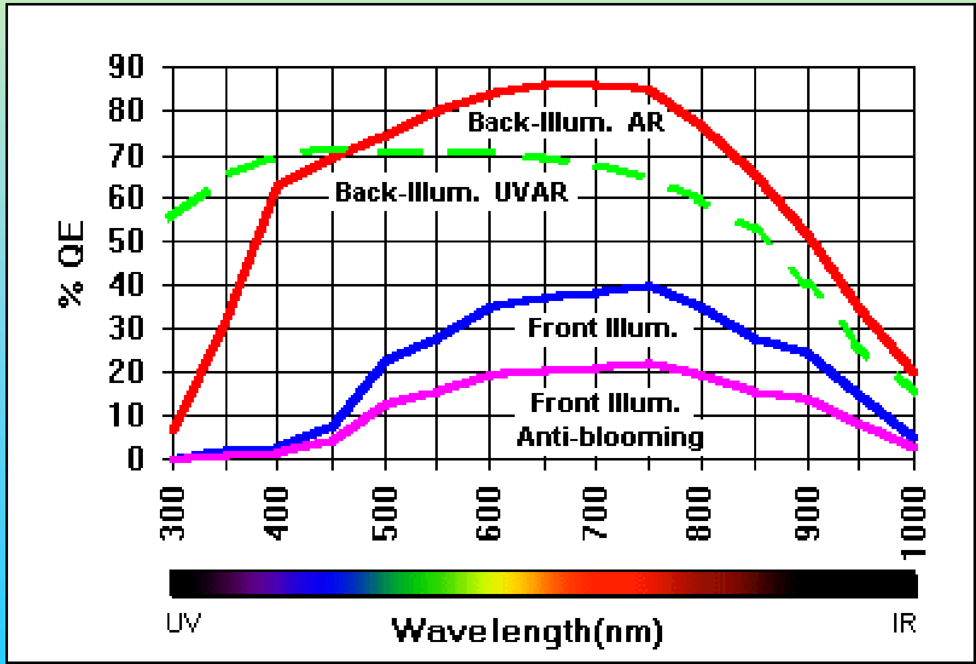
- Transfer the stored charges to the edge of the device
- Read-out the charge and generate a suitable digital number to represent the light irradiance

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

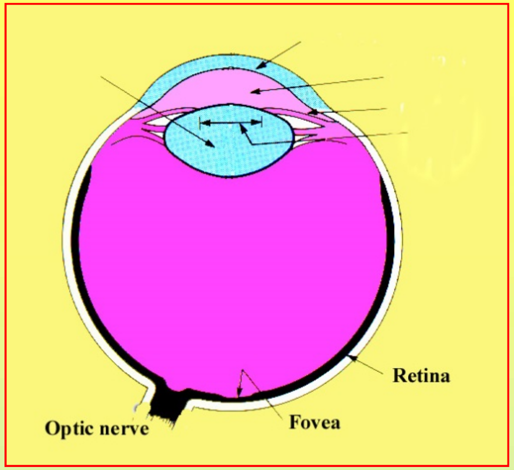
- The quantum efficiency is the success at creating a signal for incident quanta. It is very high indeed for CCD detectors

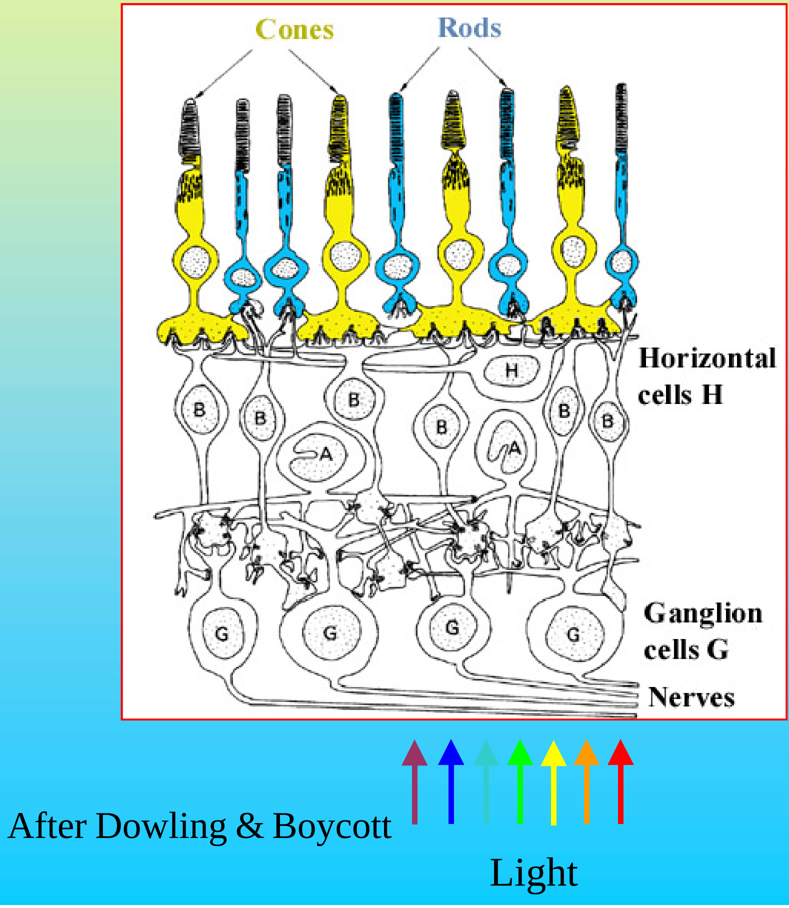


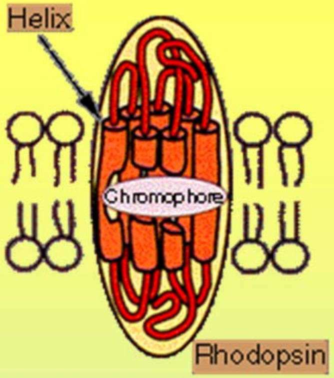
Courtesy:
apogee-ccd.com

Detecting light by eye

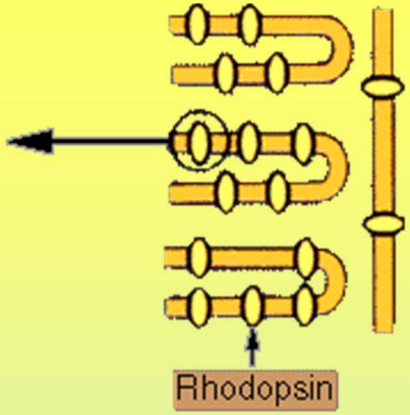
- The eye takes in light and produces electrical signals
- The crucial molecule is a protein called rhodopsin
- Within rhodopsin is a chromophore that absorbs light, called retinal



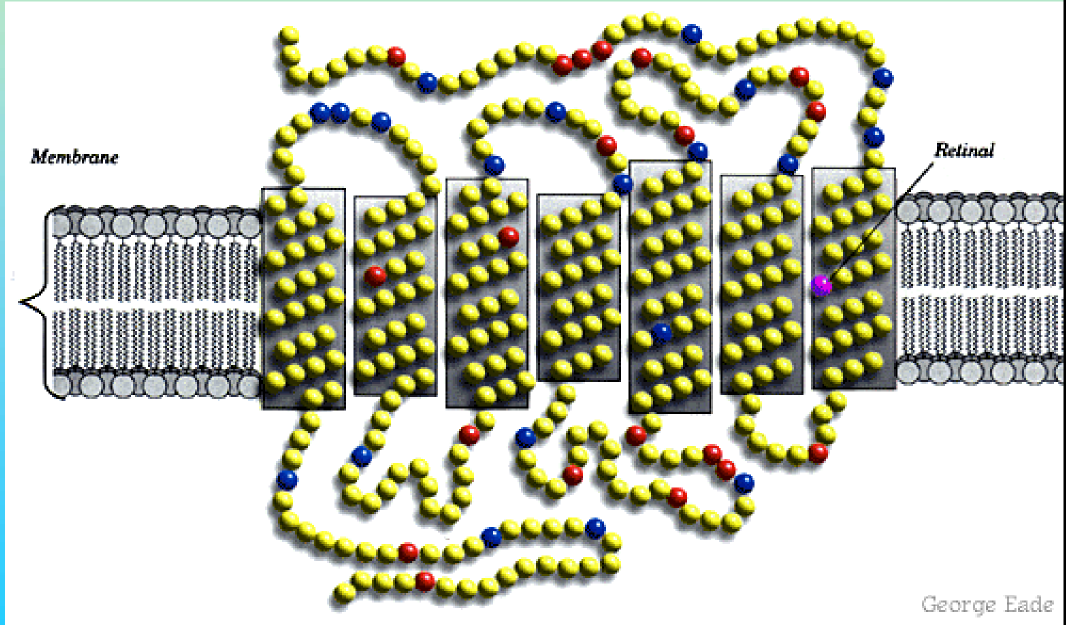


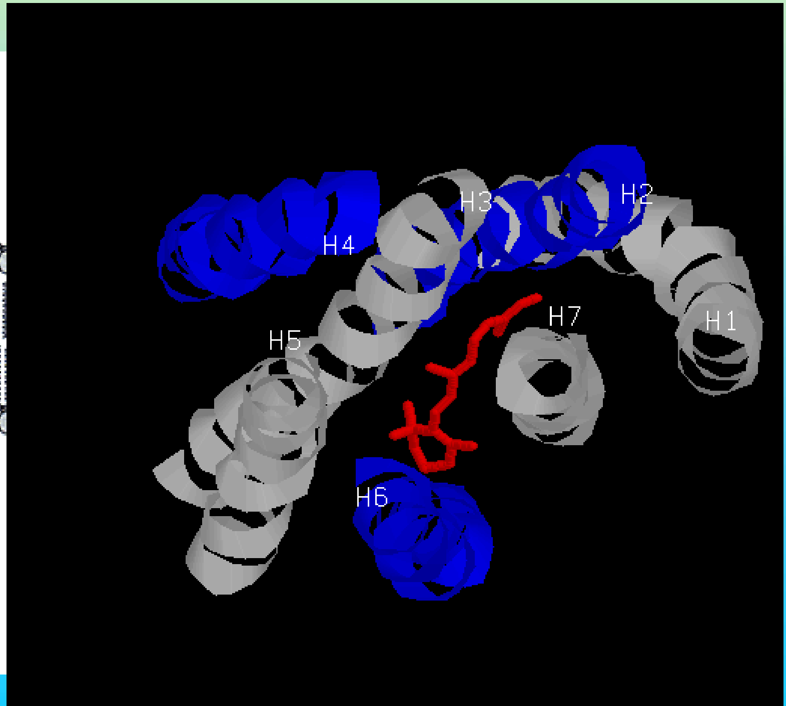


Rhodopsin in rods



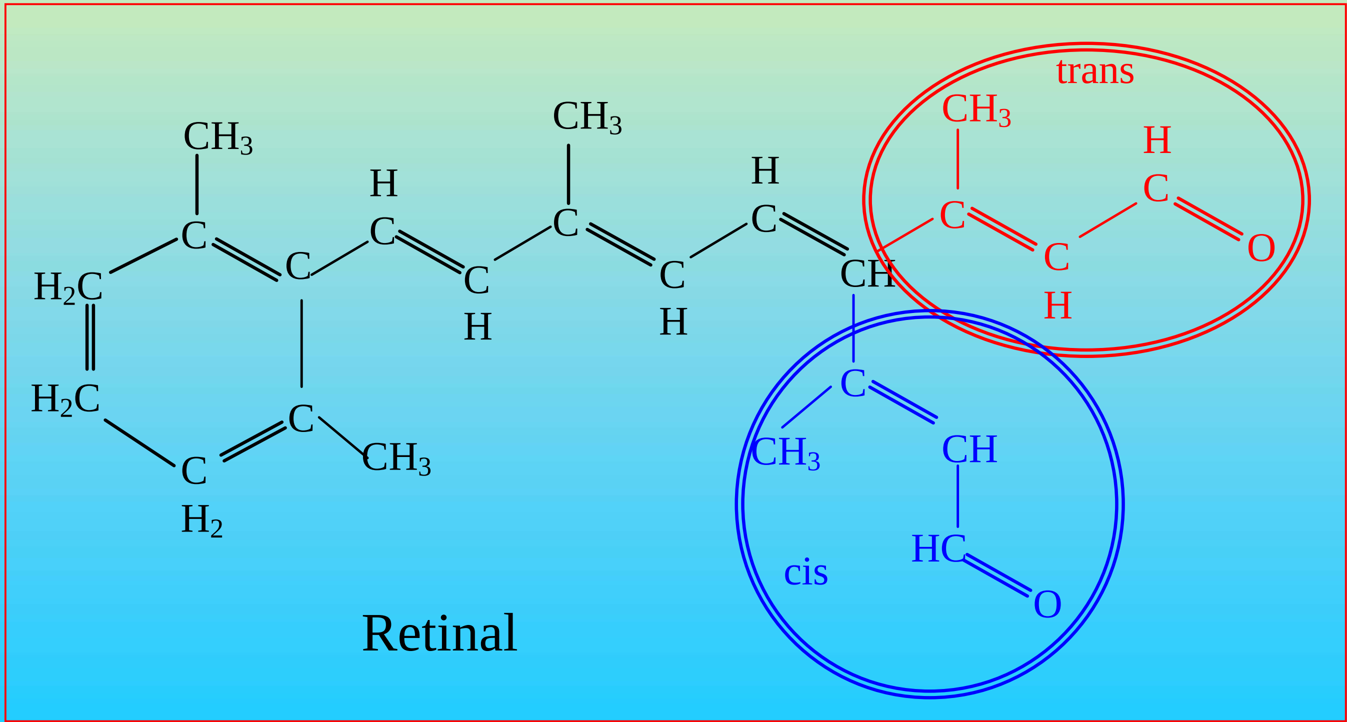
- Rhodopsin winds up and down a rod
- Notice the retinal





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