Lecture 11

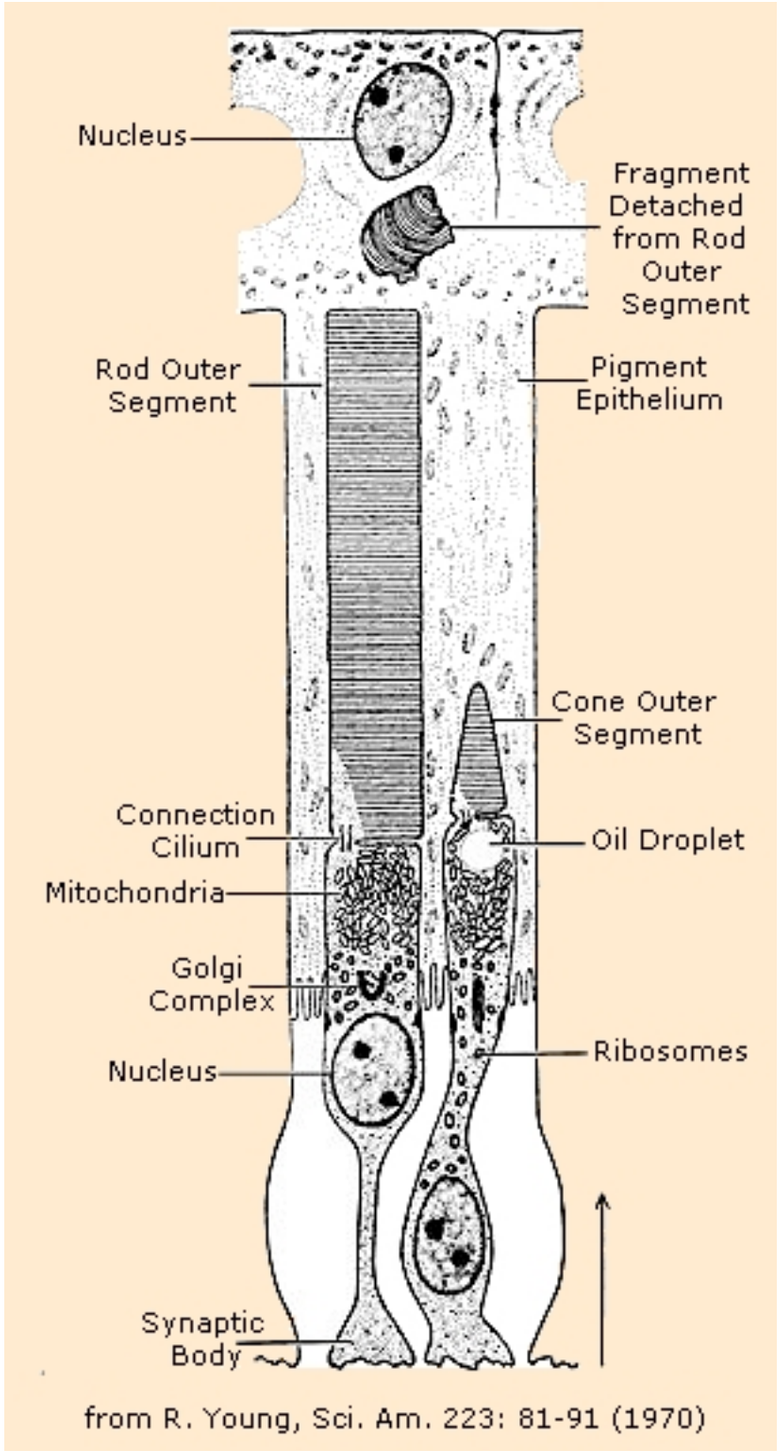
Colour Vision, f-stops and resolution

Rods and Cones

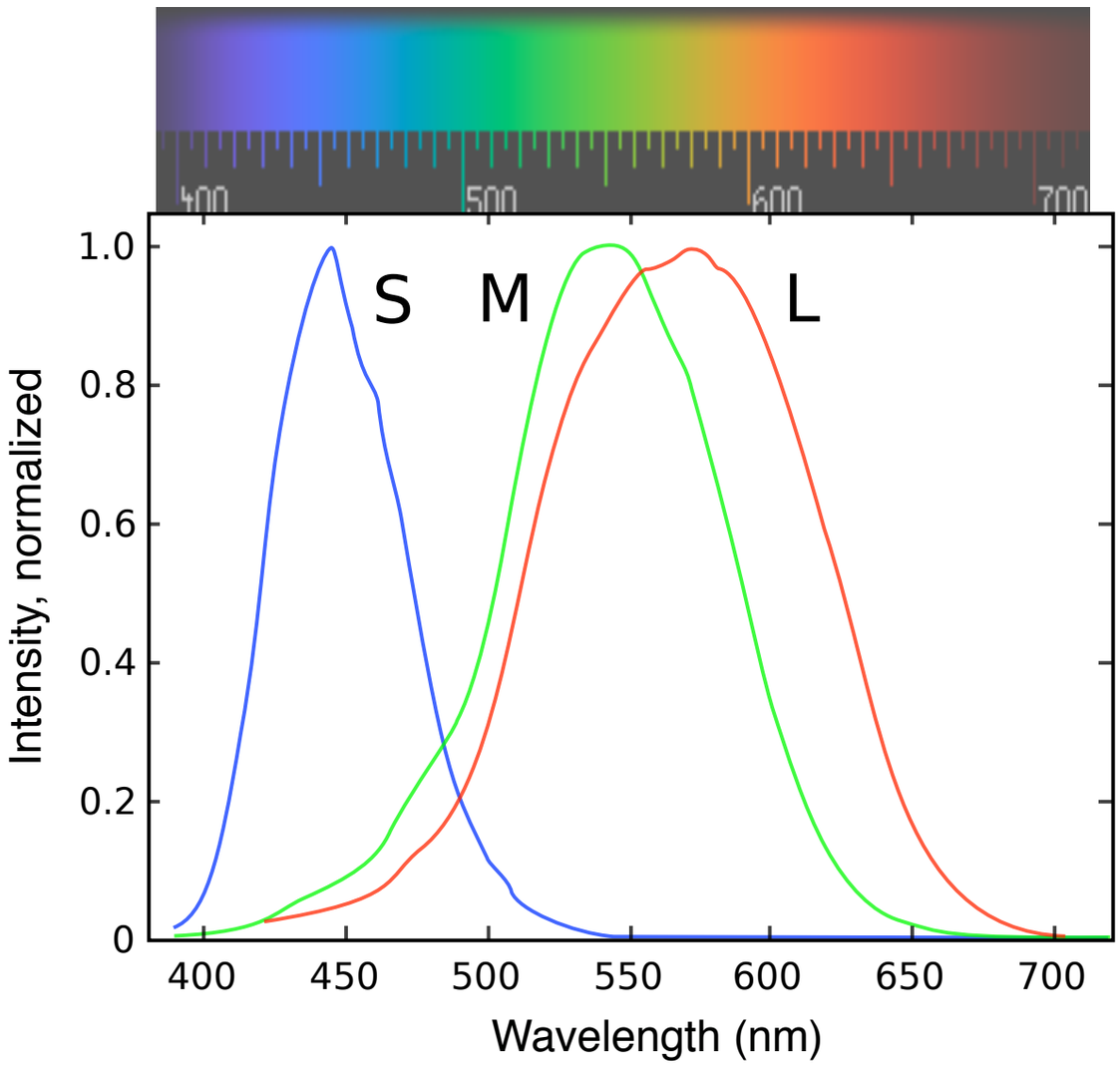
- There are two kinds of light-sensitive cells in the retina of the eye.

- Rods respond to light of any colour.

- Cones are less numerous and are colour-sensitive.



Opsins



- The cones contain three kinds of light-sensitive pigments called Opsins.

- Their absorption spectra show which wavelengths of light they are sensitive to.

- S: Short wavelenth
  M: Medium wavelength
  L: Long wavelength

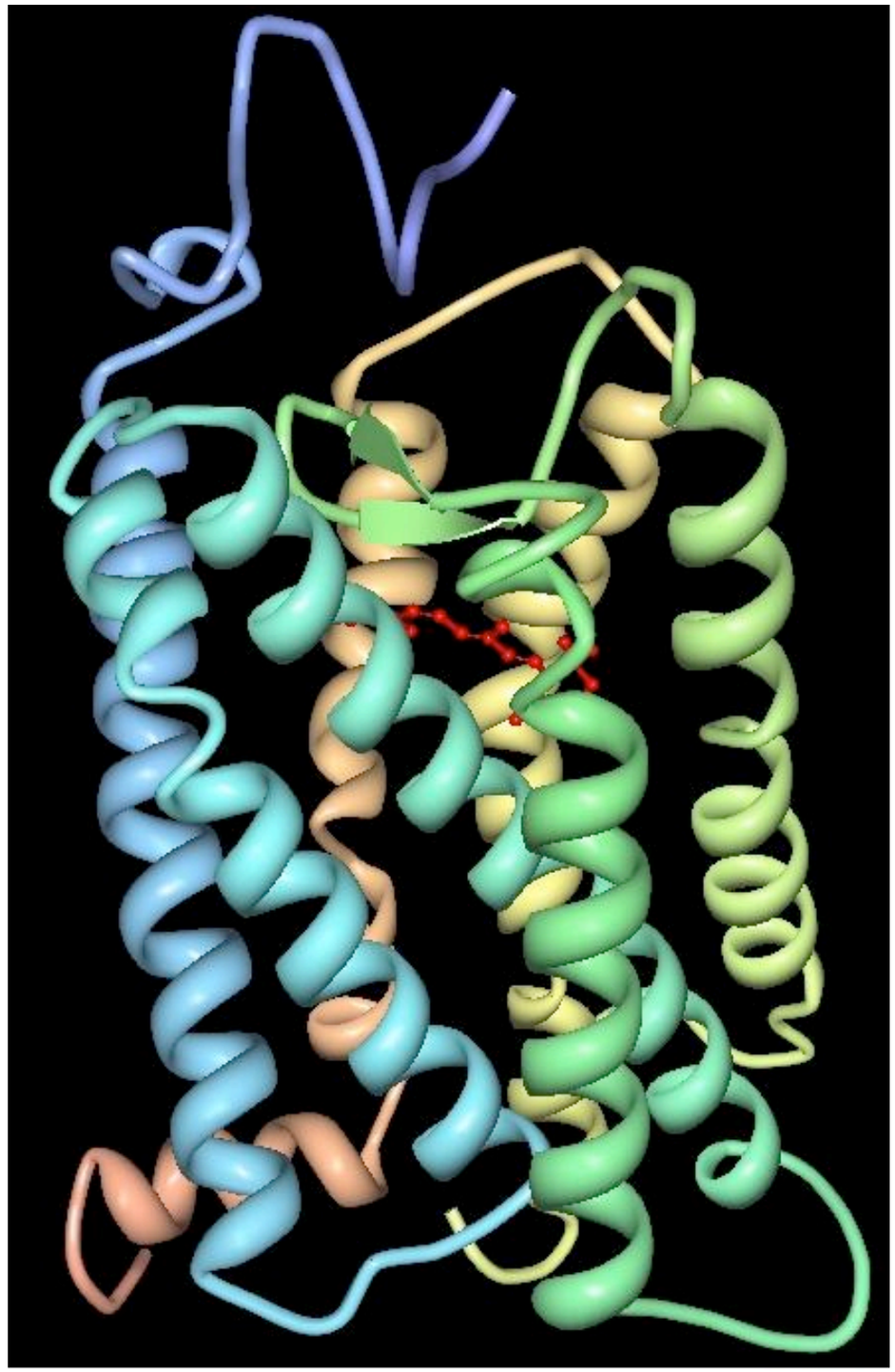
Rhodopsin

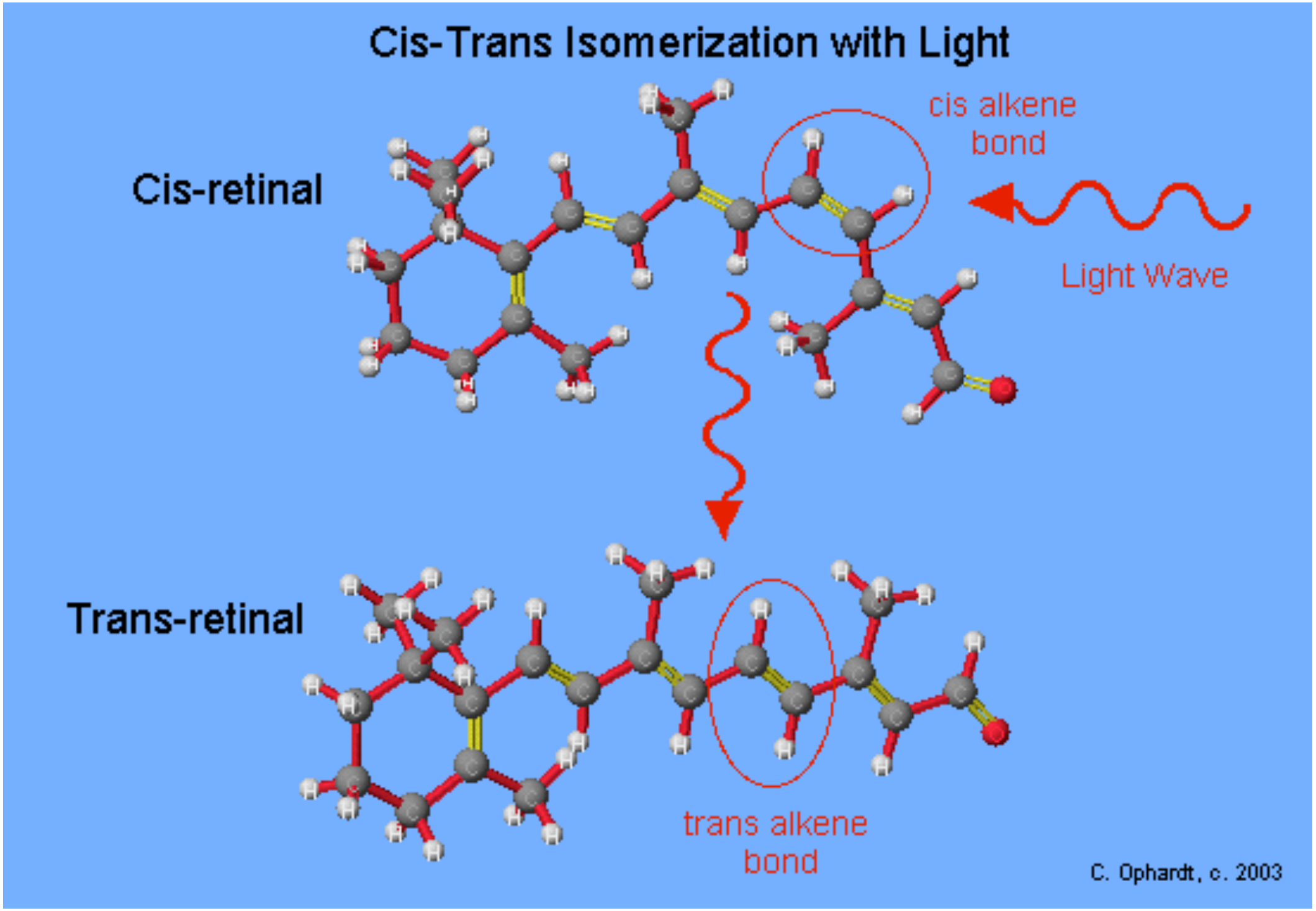
- Rhodopsin is the opsin in the rods

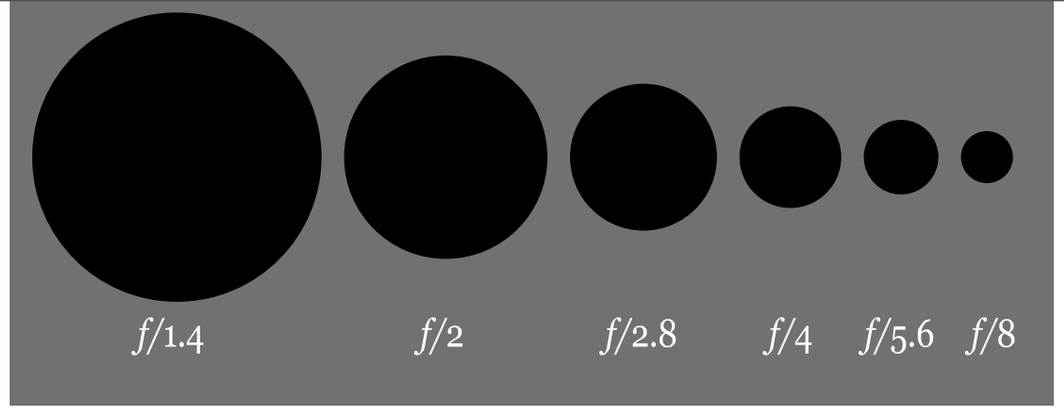
- It consists of a protein chain with 7 α-helices and a chromophore in the middle (red).

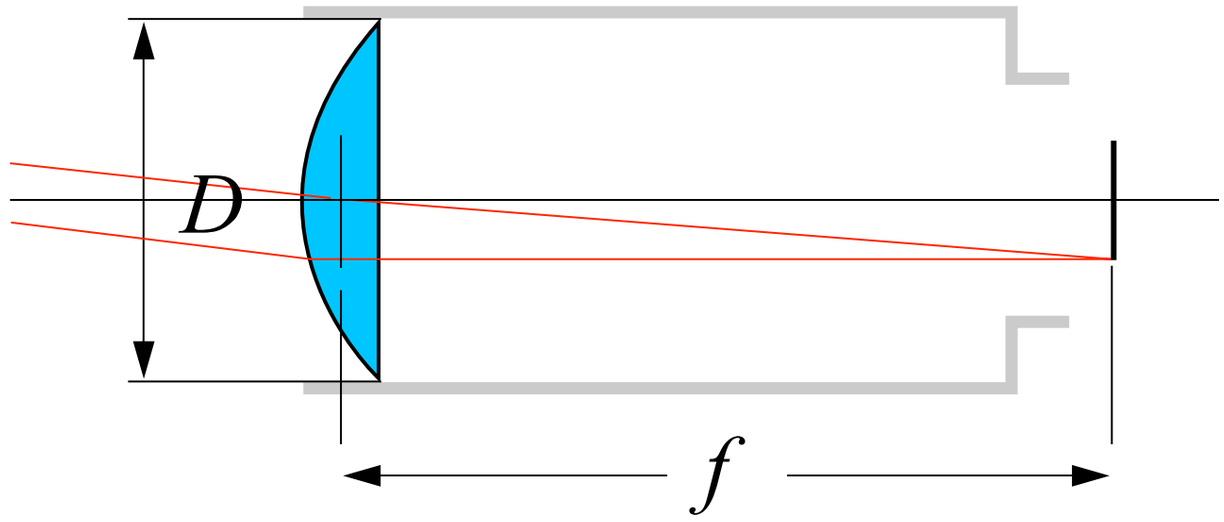
- The chromophore is retinal. It changes shape when it absorbs a photon.

- Then the protein changes shape and causes a nerve impulse.




Cis-Trans Isomerization with Light
Cis-retinal
cis alkene bond
Light Wave
Trans-retinal
trans alkene bond
C. Ophardt, c. 2003





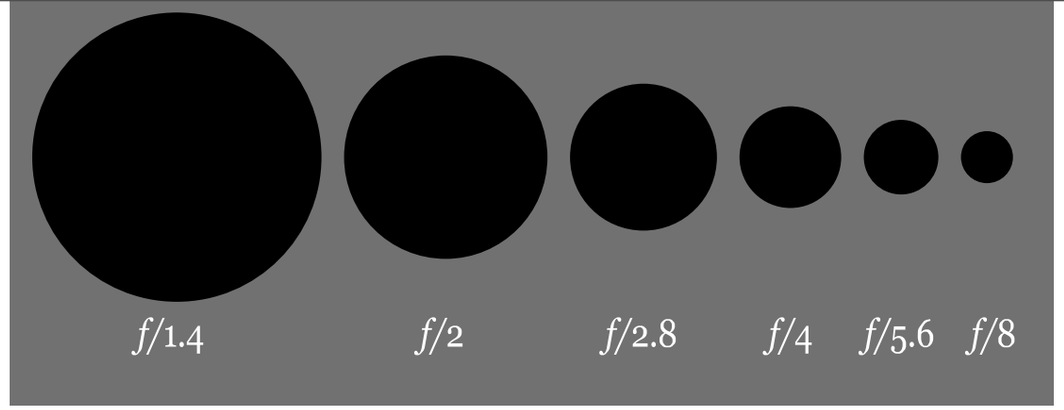
f-numbers

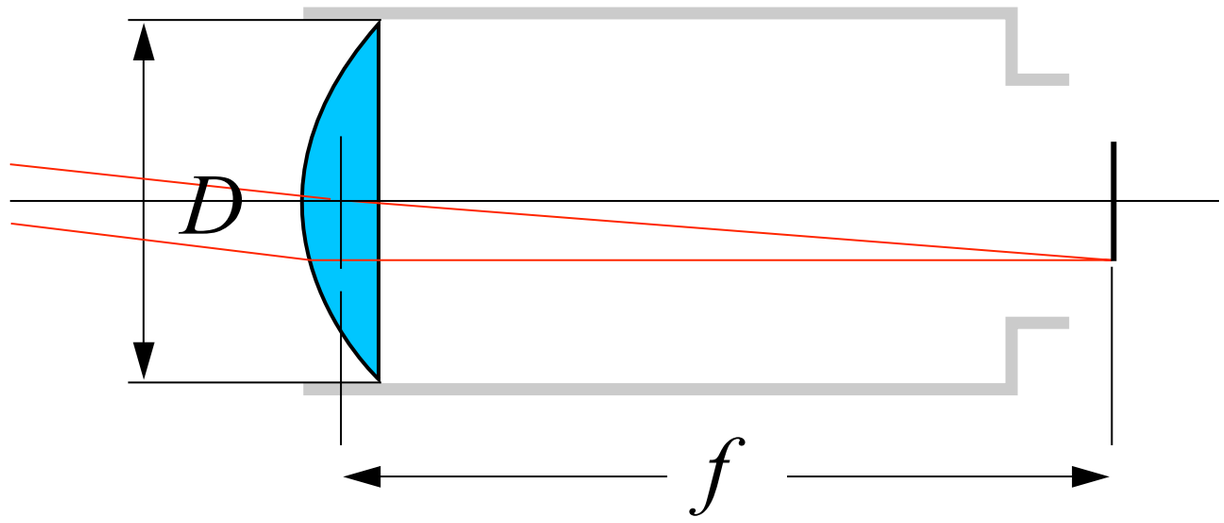
- The amount of light that an optical instrument lets in is proportional to the square of the aperture diameter, D^2

- The aperture size is stated in f-numbers.

  f-number = $\frac{f}{D}$

- f-numbers are traditionally written *f*/#





f-numbers

- The aperture diameter is got by
  D = (focal length)/(*f*-number)
- For example *f/2* on a 50 mm lens means that D = 25 mm
- *f*/2.8 lets in one-half as much light as *f*/2.

f-numbers

- A higher *f*-number decreases the amount of light that is let in.

- When taking a photo, one compensates by increasing the exposure time.

- A higher *f*-number also increases the Depth of Field of the picture.

- *f*-numbers are sometimes called *f*-stops.

high *f*/#

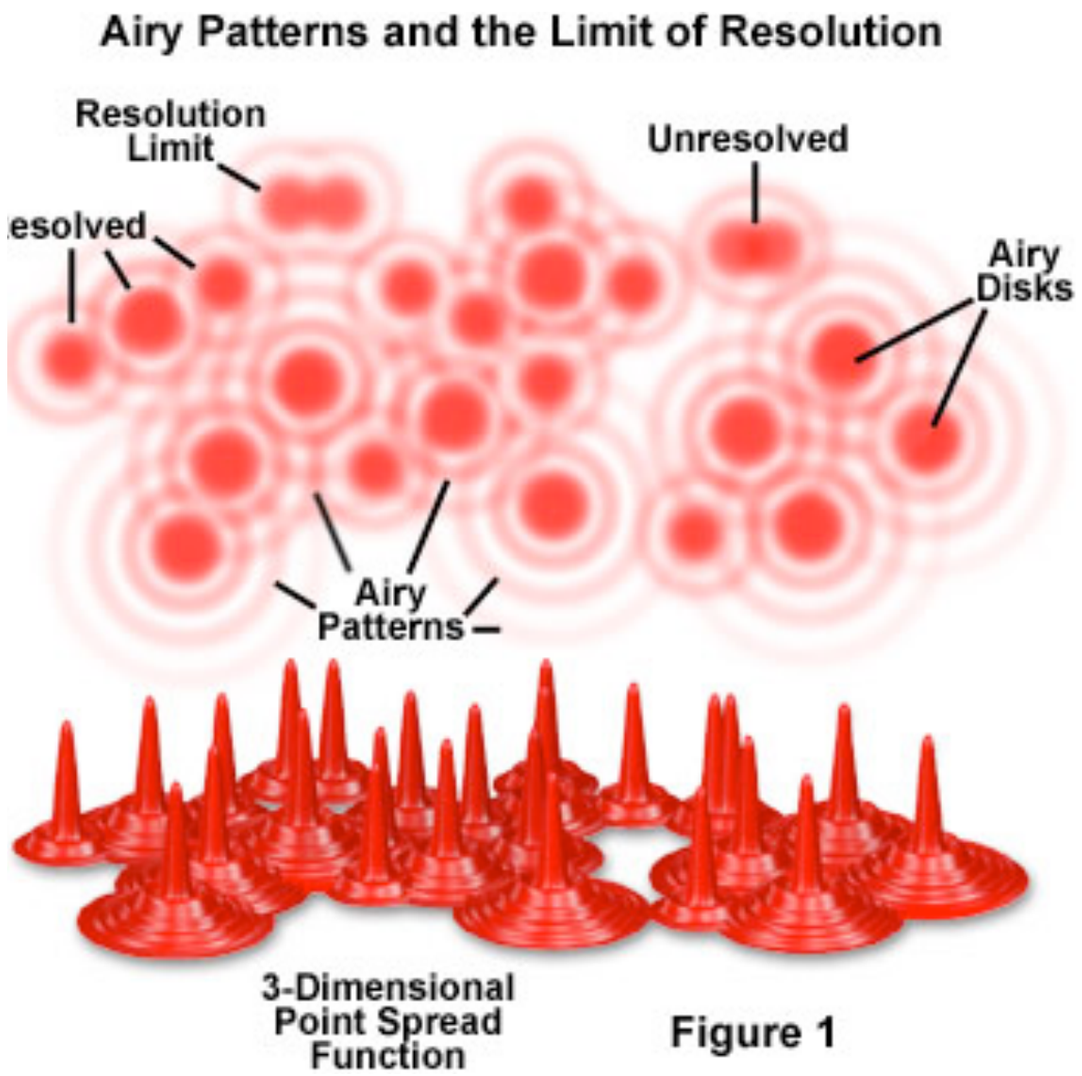
low *f*/#

Resolving Power

- You would think that if you decreased the aperture of a microscope, or other optical instrument, the image would get sharper and sharper.

- Not true. Diffraction limits the ability to resolve two closely-spaced dots.

- http://www.microscopyu.com/tutorials/java/imageformation/airyna/index.html



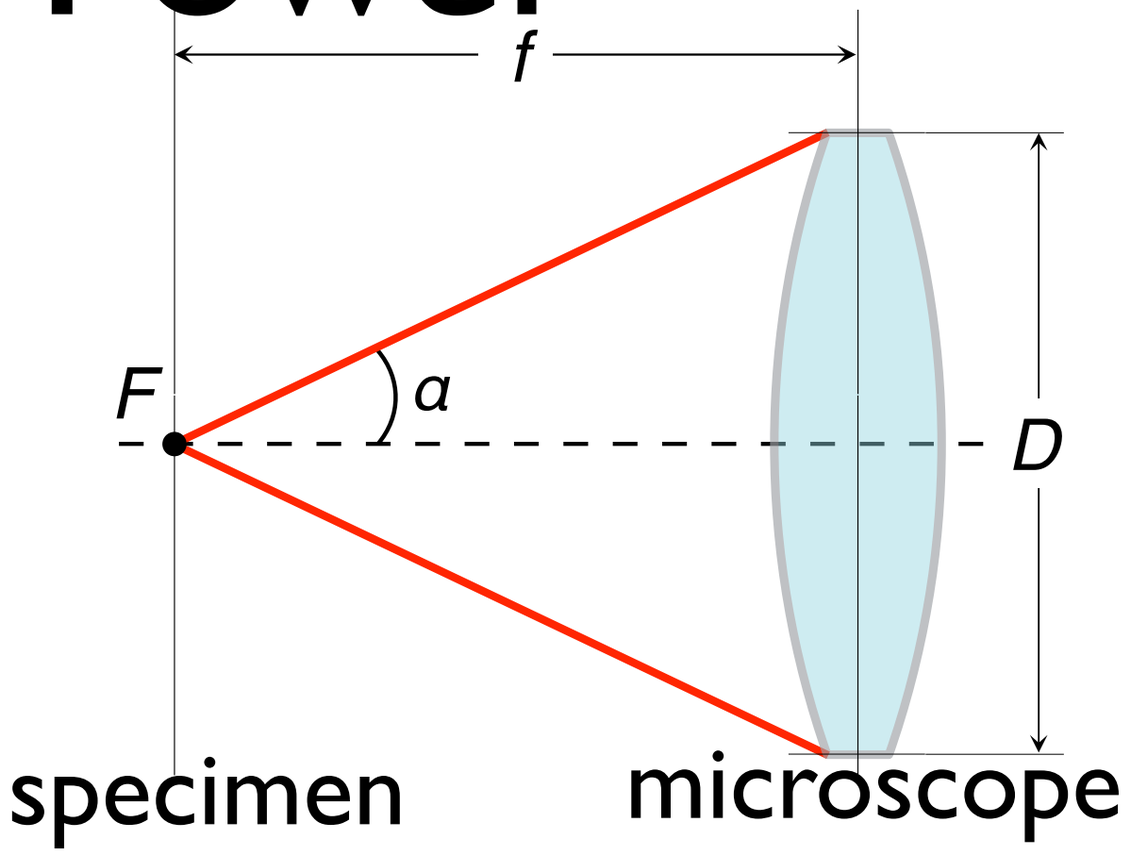
Resolving Power

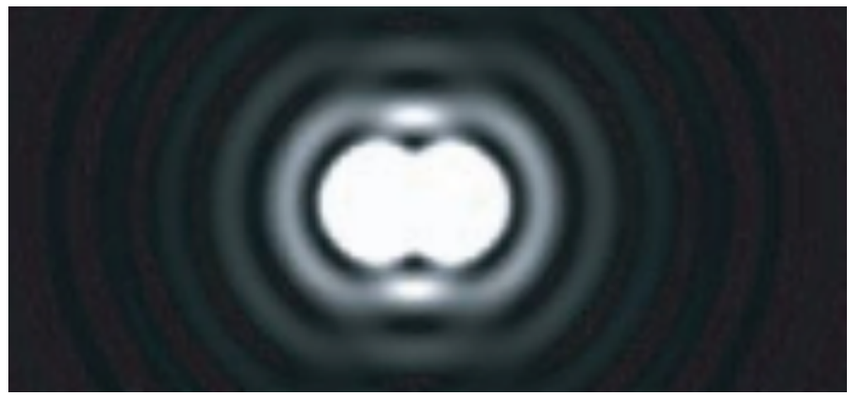
- In microscopes the Numerical Aperture (N.A.) is used to measure the light-gathering ability.

- N.A. = $n \sin \alpha \approx 1/(2f)$
  where n is the refractive index of the medium that the object is in.

- The spatial resolution of the microscope is the minimum distance between two dots that you is clearly distinguishable

- $d_{min} = 0.61\ \lambda/\text{N.A.}$
  (Rayleigh's criterion)





Aberrations

- Aberrations in optical systems cause fuzzyness

- Chromatic aberration occurs when light of different colours focus at different points

- Spherical aberration occurs when light hitting different parts of the lens focus at different points.

- Good (i.e., expensive) optics minimize these aberrations.