Thin lenses and optical instruments

Physics 114

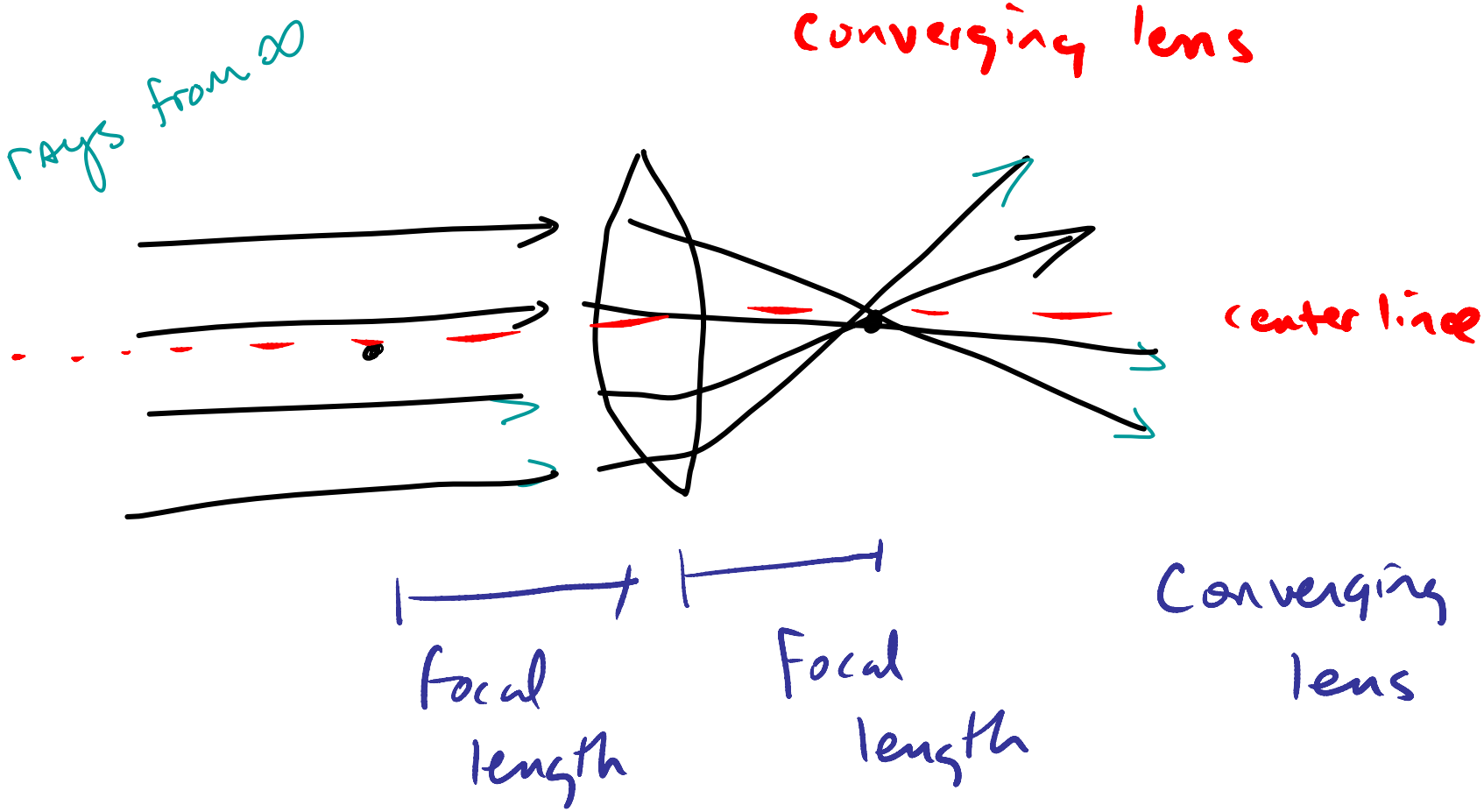
Spring 2006 – S. Manly

References and photo sources:

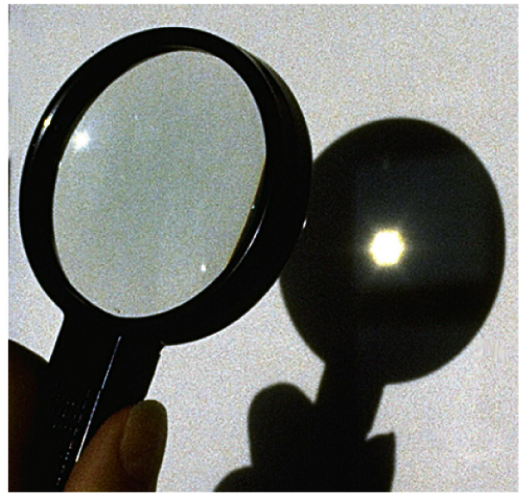
D. Giancoli, Physics for Scientists and Engineers, 3rd ed., 2000, Prentice-Hall

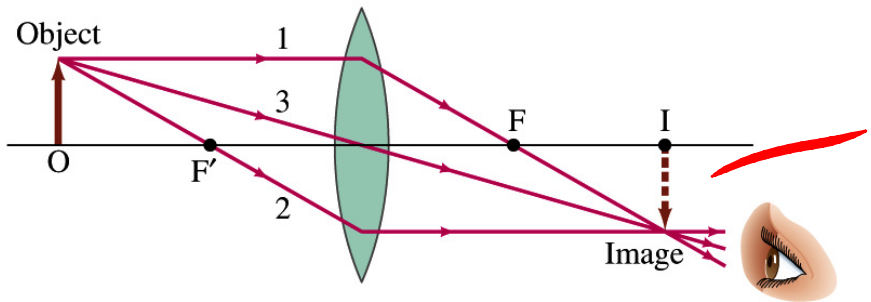
http://cvs.anu.edu.au (D. Denning and M. Kirk)

http://www.ebiomedia.com


Converging lens
rays from ∞
center line
Focal length
Focal length
Converging lens

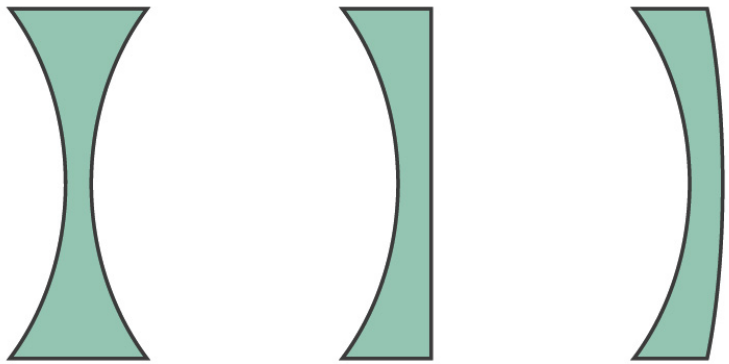
(a) Converging lenses



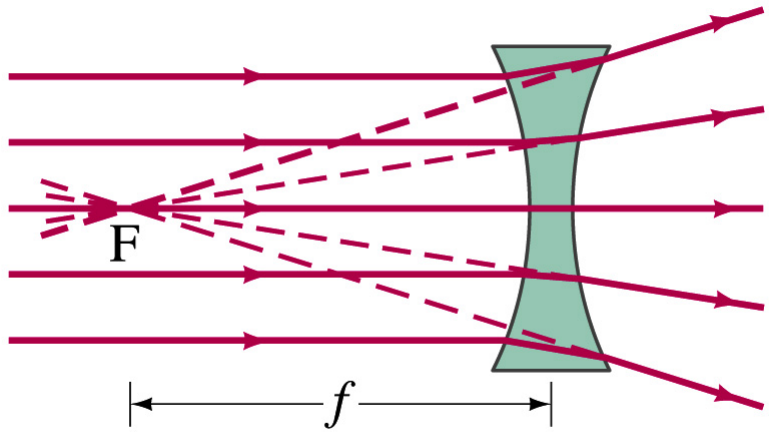


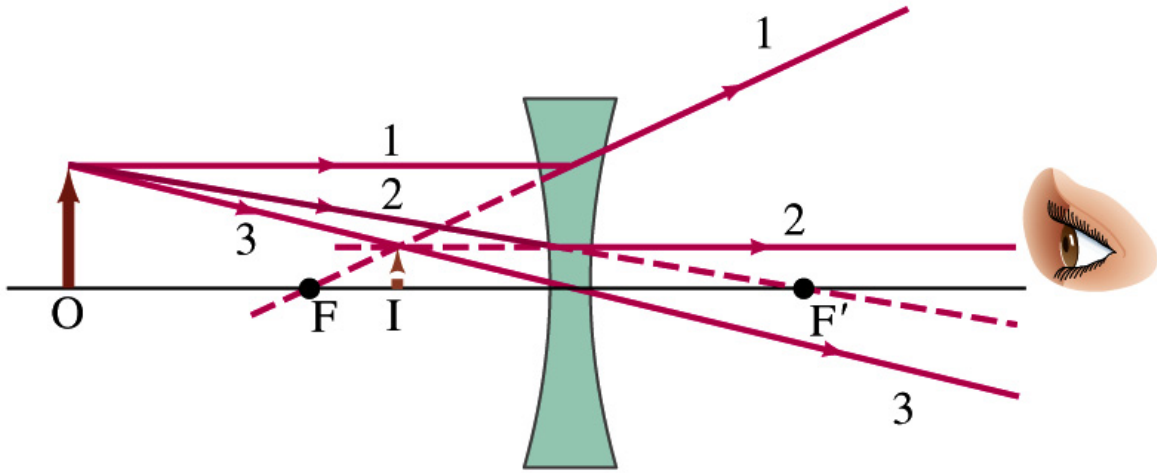
(c) Ray 3 passes straight through the center of the lens (assumed very thin).

inverted image



(b) Diverging lenses



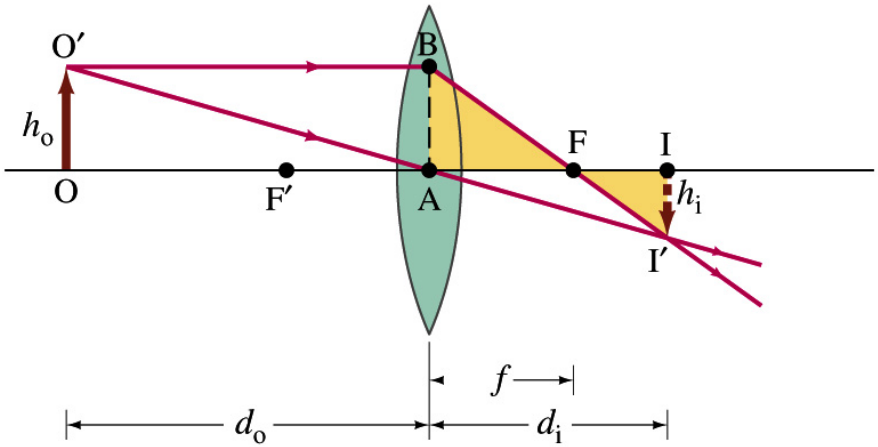

1
1
2
2
3
O
F
I
F′
3

Power of lens measured in diopters

$$P = \frac{1}{f}$$

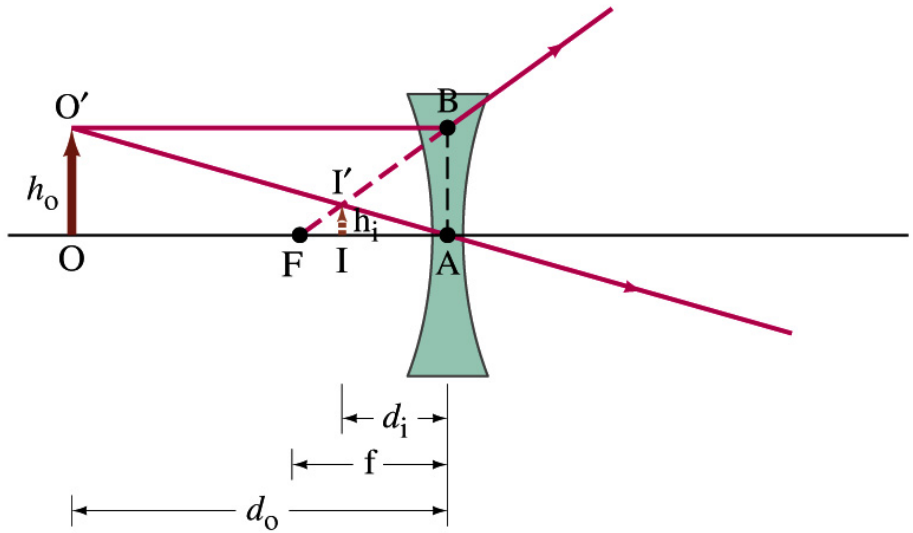
where f is focal length in meters

Power is positive for converging lenses
and negative for diverging lenses



Magnification:

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$



Lens equation:

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

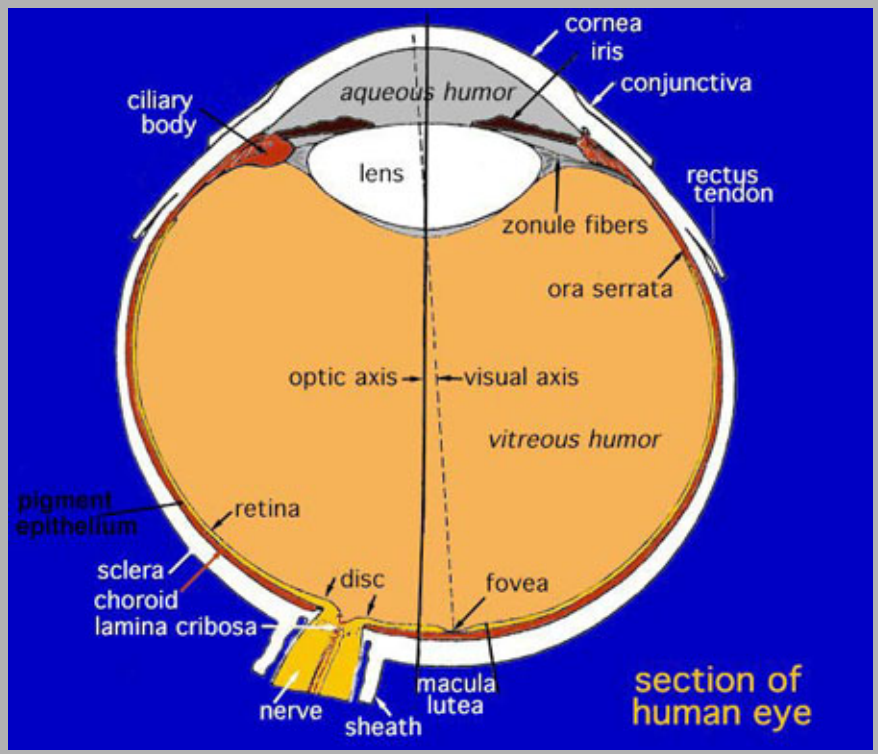
Real image: rays actually pass thru image

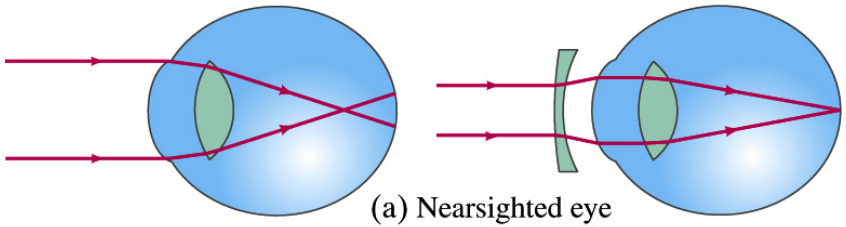
Virtual image: rays do not actually pass thru image

Sign convention is the tricky part, especially in multiple lens systems

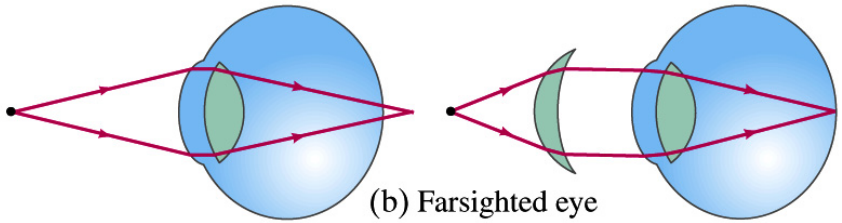
Convention from Giancoli p. 841:

- **Focal length is + for converging lens and - for diverging lens**
- **Object distance is + if on the side of the lens from which the light is coming (usual, unless in multi-lens system)**
- **Image distance is + if on the opposite side of the lens from where the light is coming, if on same side, image distance is –**
- **Image distance is + for real images and – for virtual images**
- **Height of image is + if image is upright and – if image is inverted. Height of object is always taken to be +.**



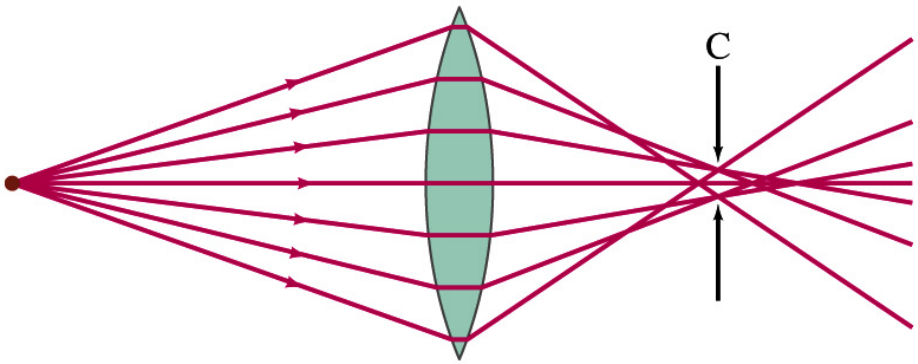


(a) Nearsighted eye

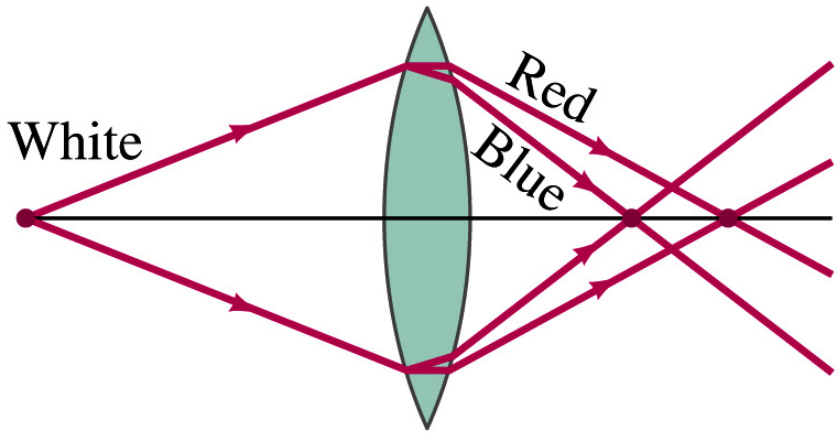


(b) Farsighted eye

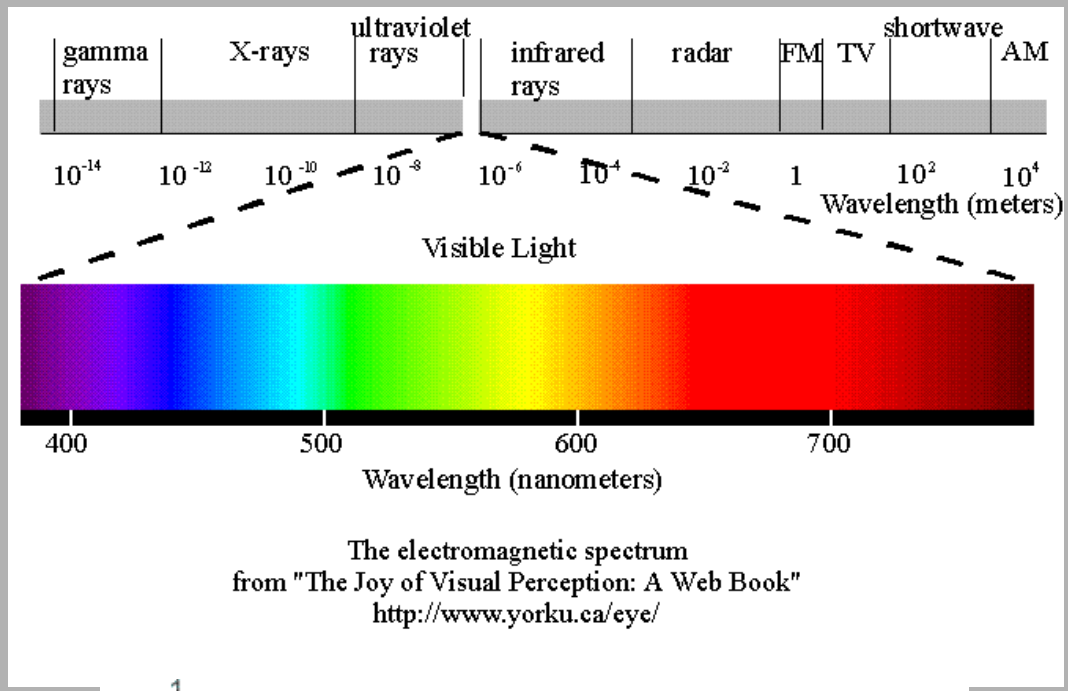
Aberrations



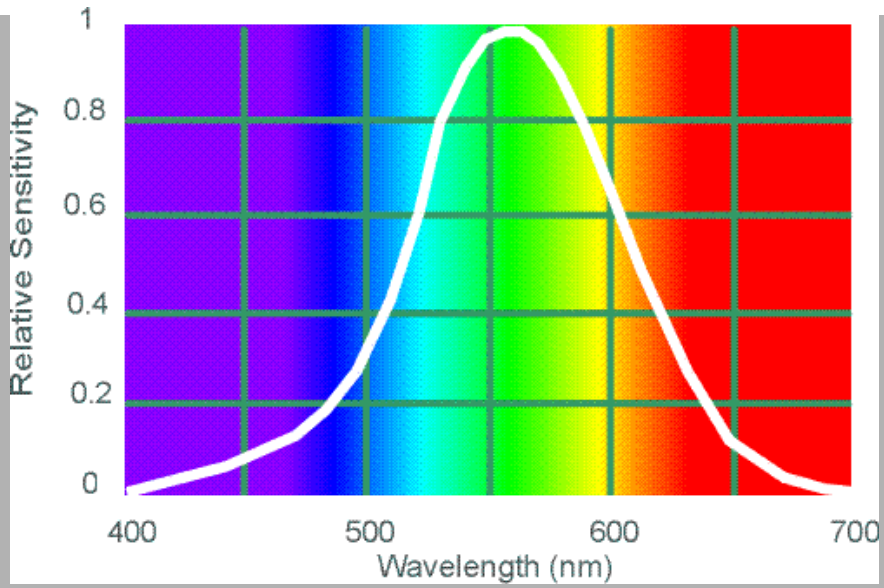
Spherical aberration

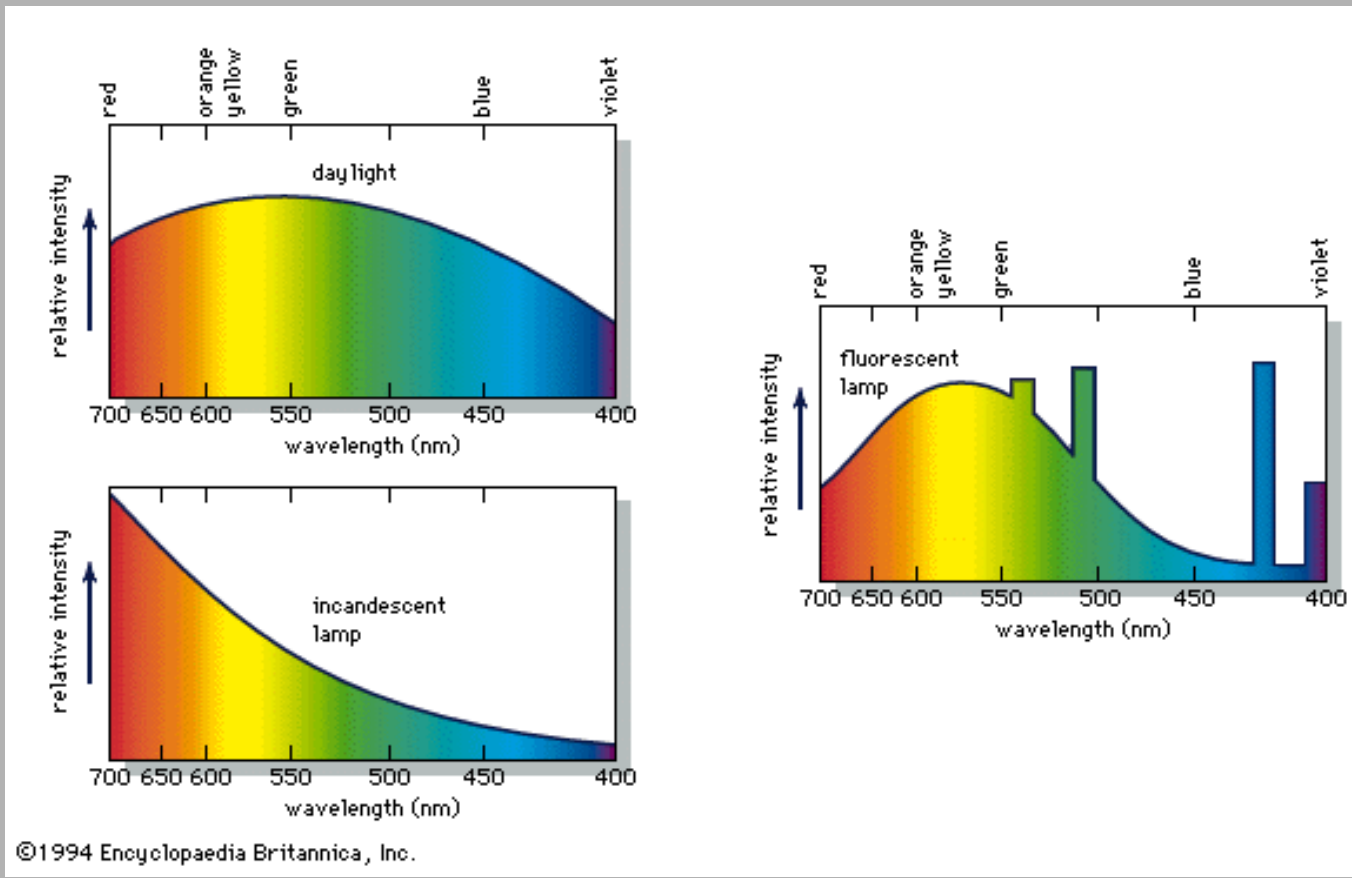


Chromatic aberration

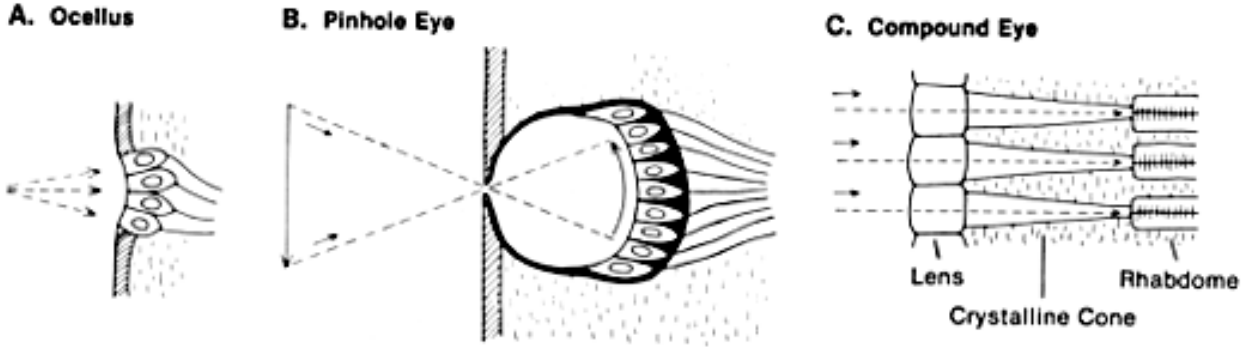


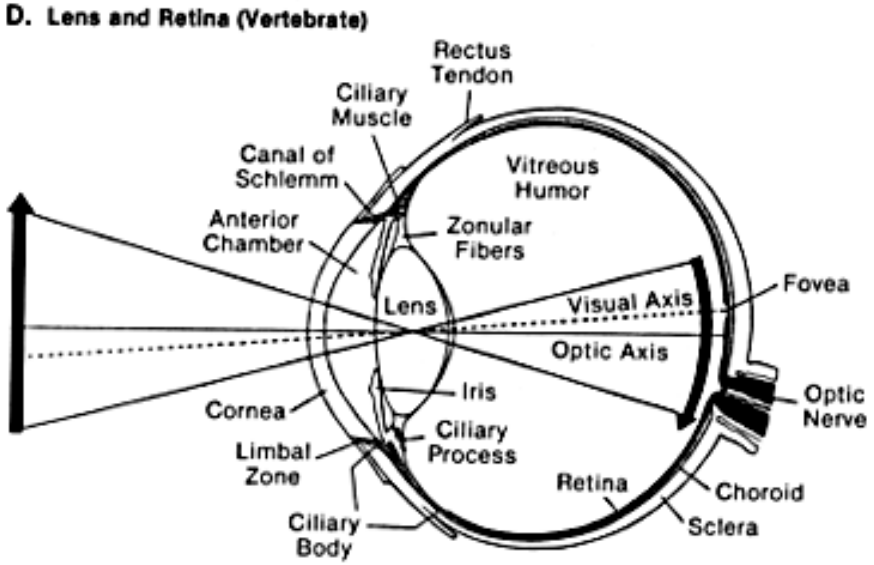
The electromagnetic spectrum
from "The Joy of Visual Perception: A Web Book"
http://www.yorku.ca/eye/

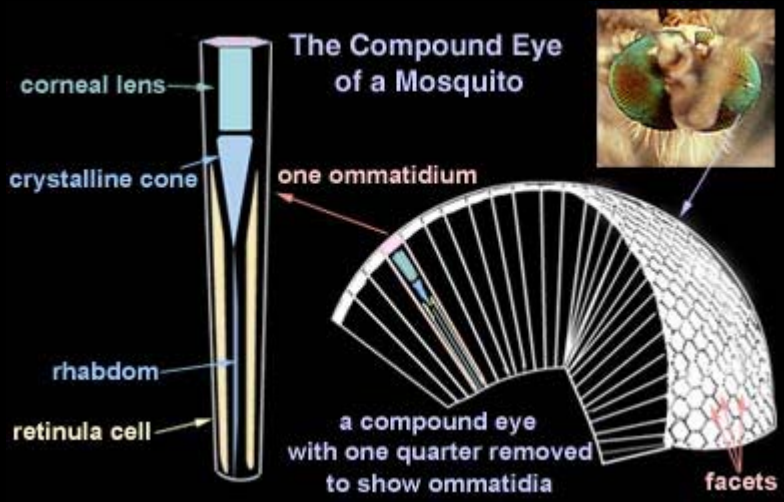


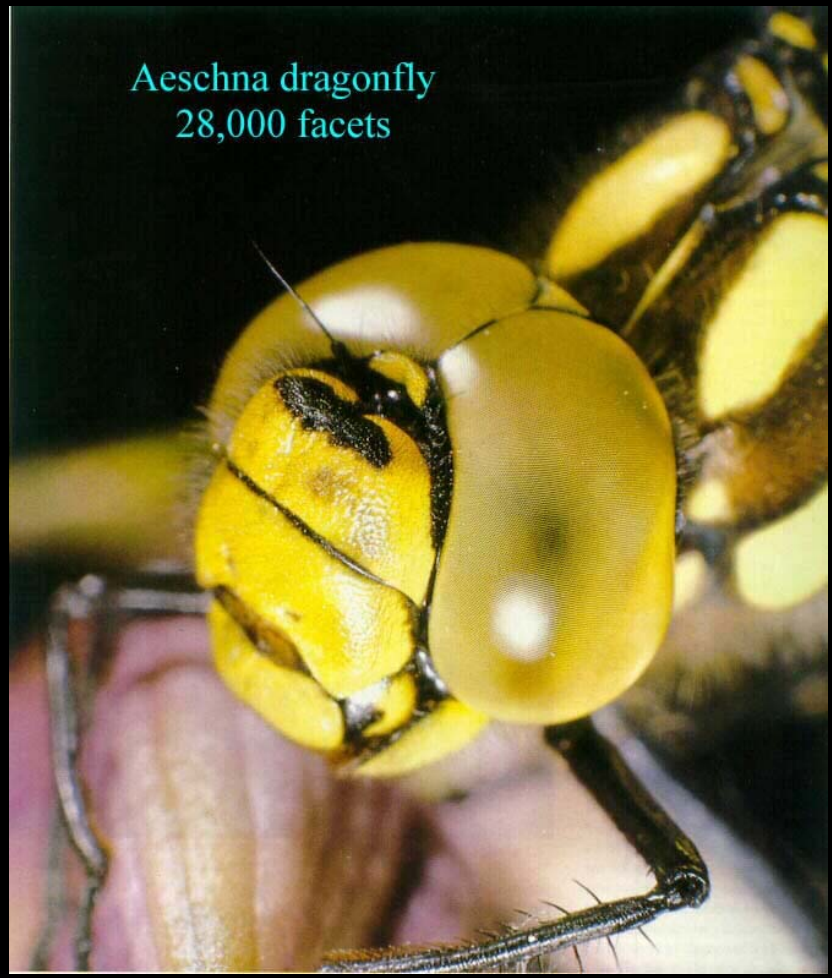


Types of eyes in the animal kingdom

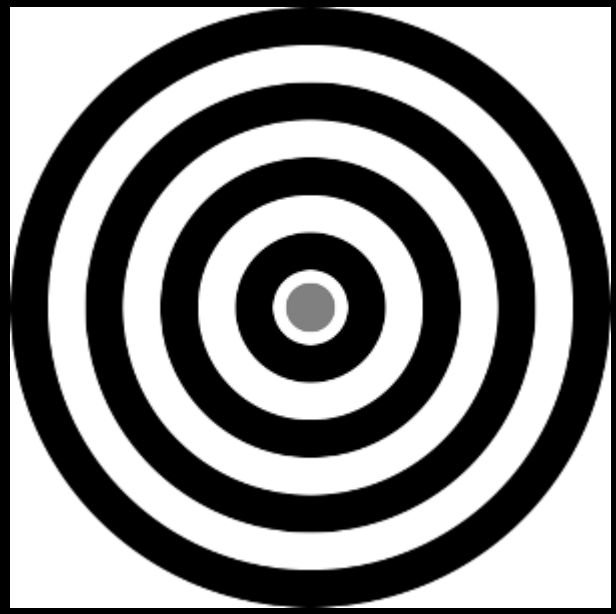


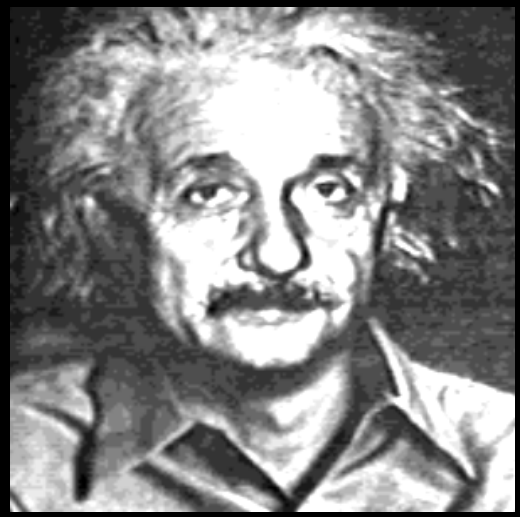



The Compound Eye
of a Mosquito
corneal lens
crystalline cone
one ommatidium
rhabdom
retinula cell
a compound eye
with one quarter removed
to show ommatidia
facets


Aeschna dragonfly
28,000 facets

A bee's eye view





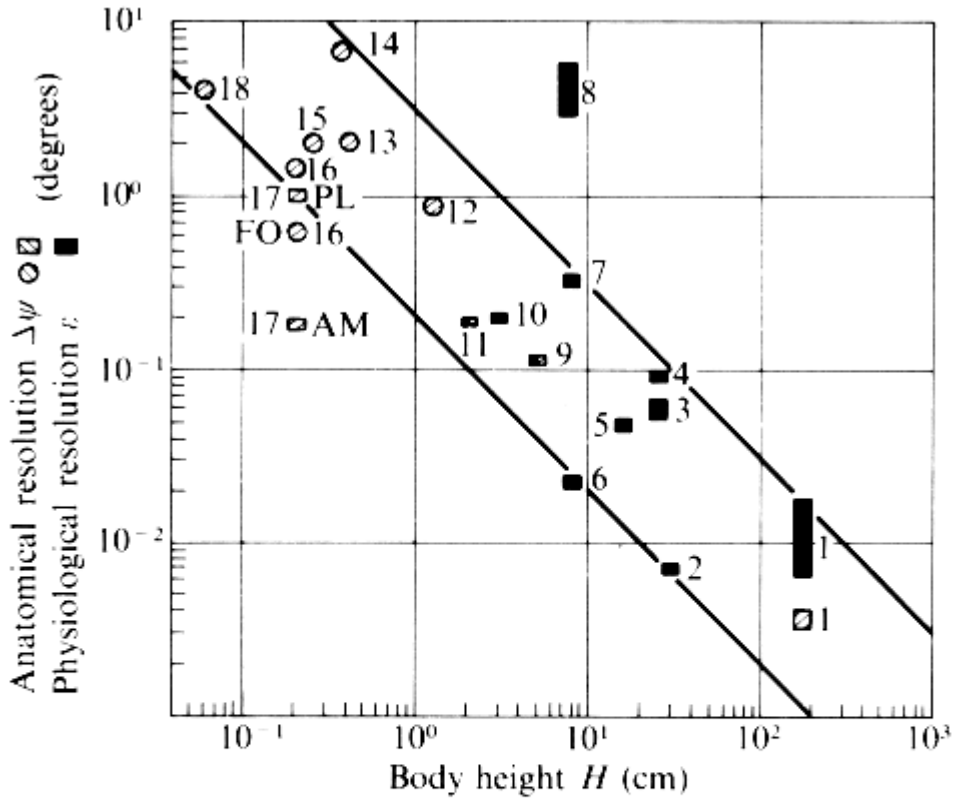
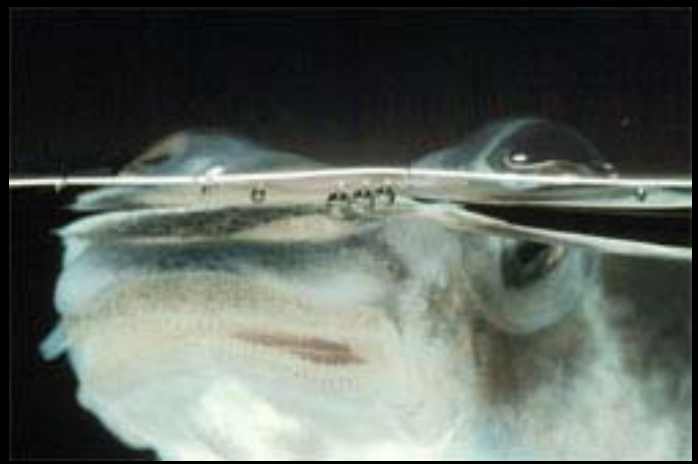
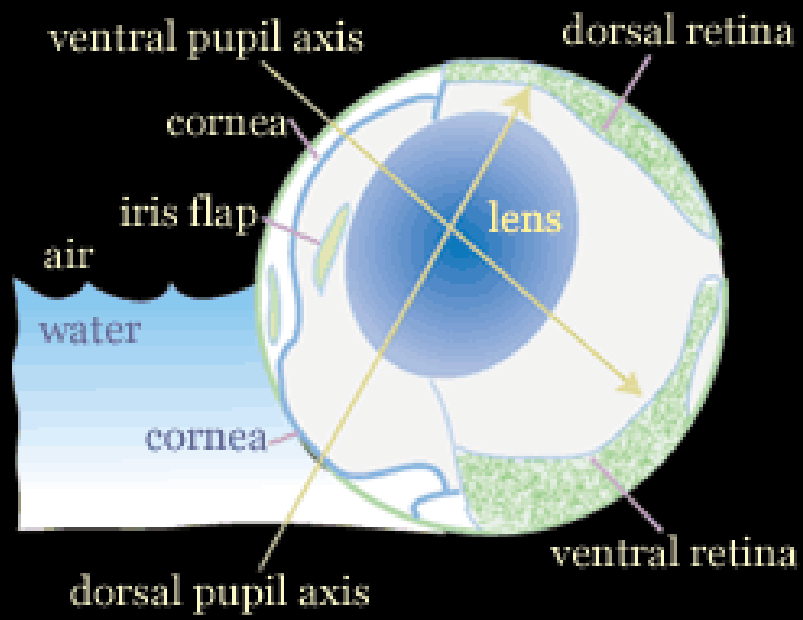


Fig. 2.9. Resolution of the eyes of various animals measured physiologically and deduced from anatomical criteria compared to body height: (1) man; (2) peregrine falcon; (3) hen; (4) cat; (5) pigeon; (6) chaffinch; (7) rat; (8) bat (*Myotis*); (9) frog; (10) lizard; (11) minnow; (12) dragonfly (*Aeschna*); (13) bee (Apis); (14) *Chlorophanus*; (15) housefly (*Musca*); (16) hover fly (*Syrrita*), frontal region FO; (17) jumping spider (*Methaphidippus*), anteromedian eye AM, postero-lateral eye PL; (18) fruit fly, *Drosophila*. (From Kirschfeld 1976.)

Anableps - minnow

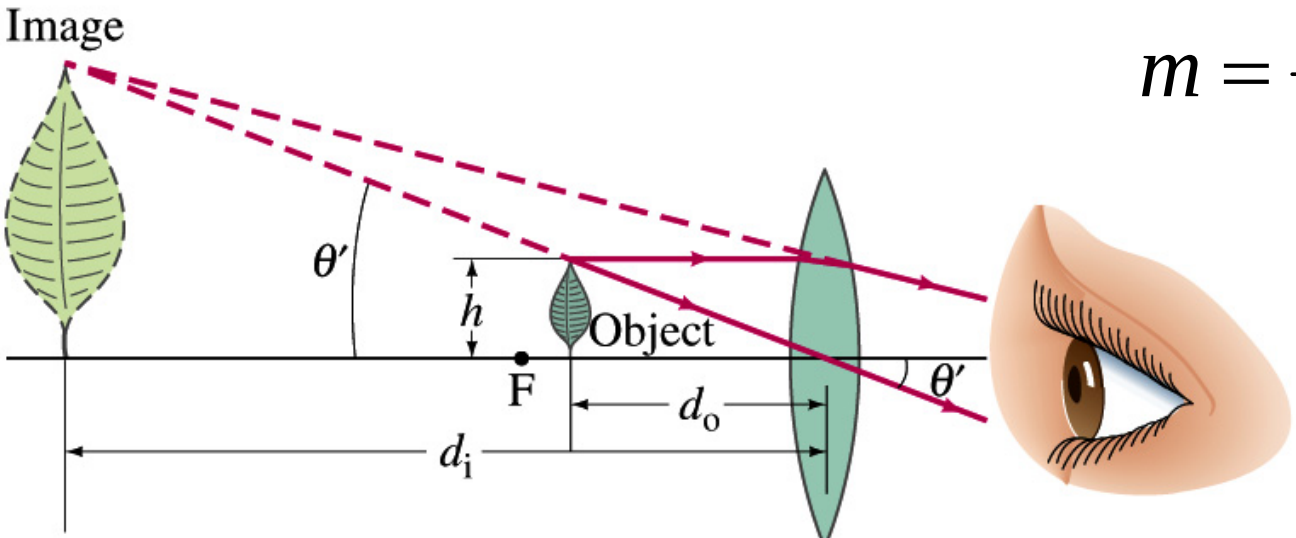


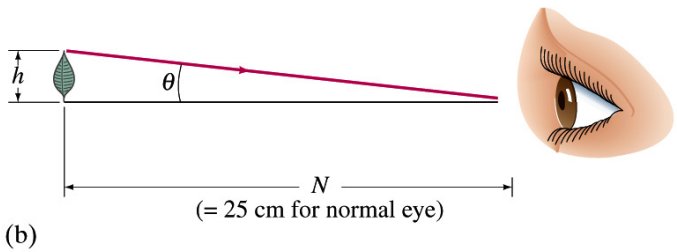


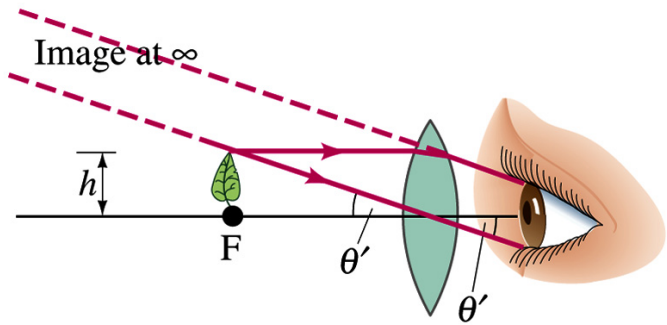
Virtual

Magnifying glass

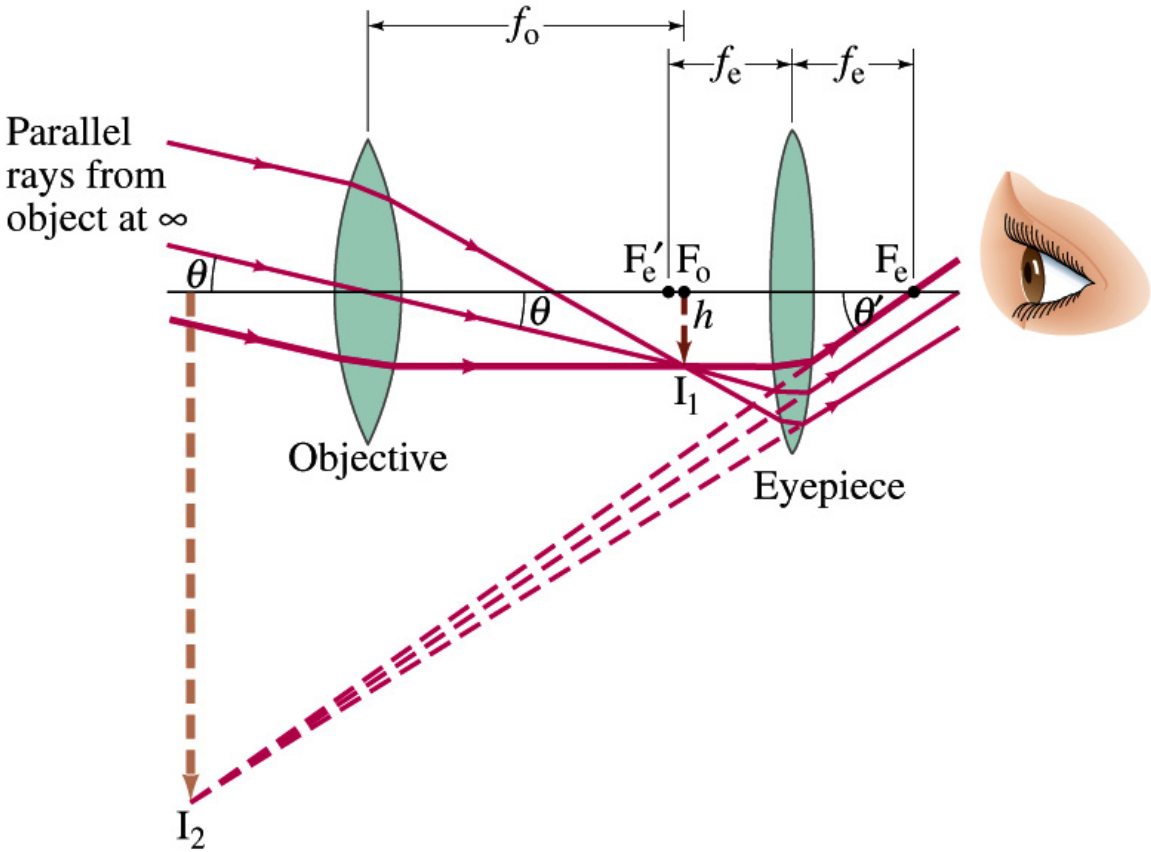
$$m = \frac{\theta'}{\theta} = \frac{N}{f}$$





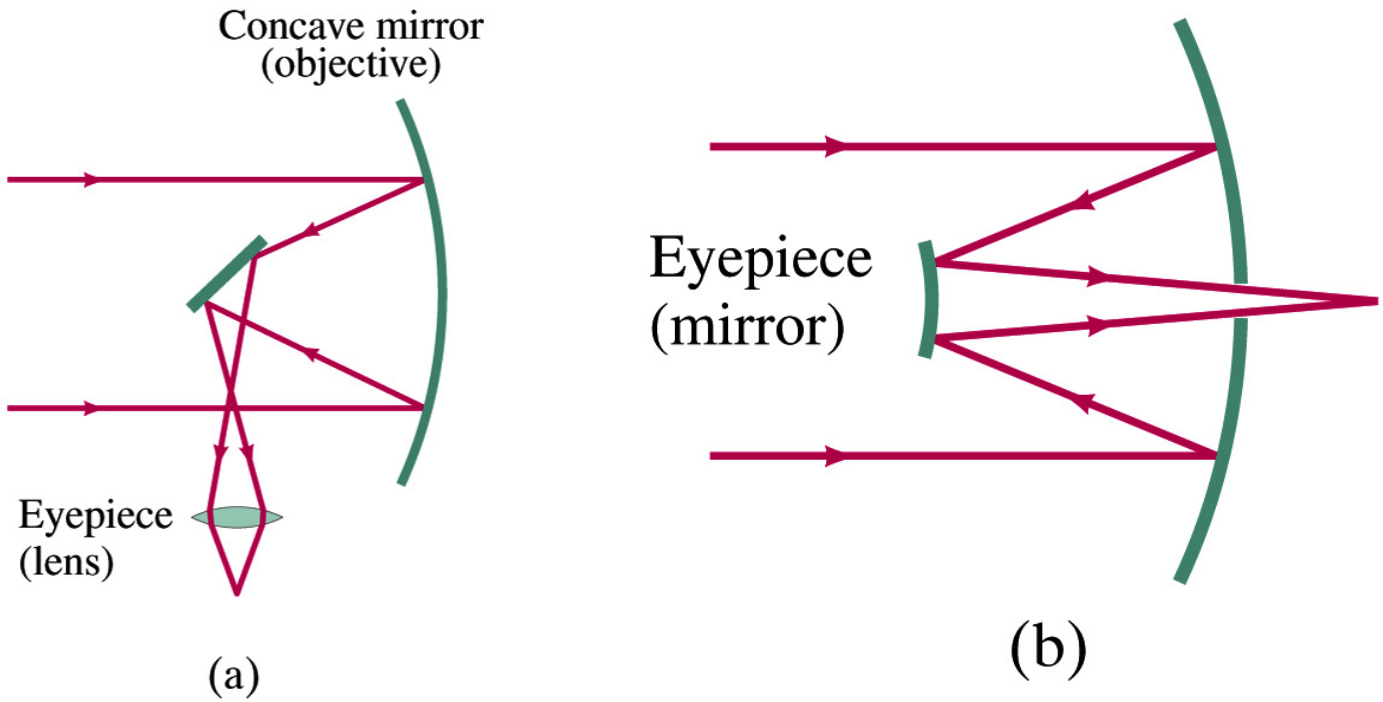


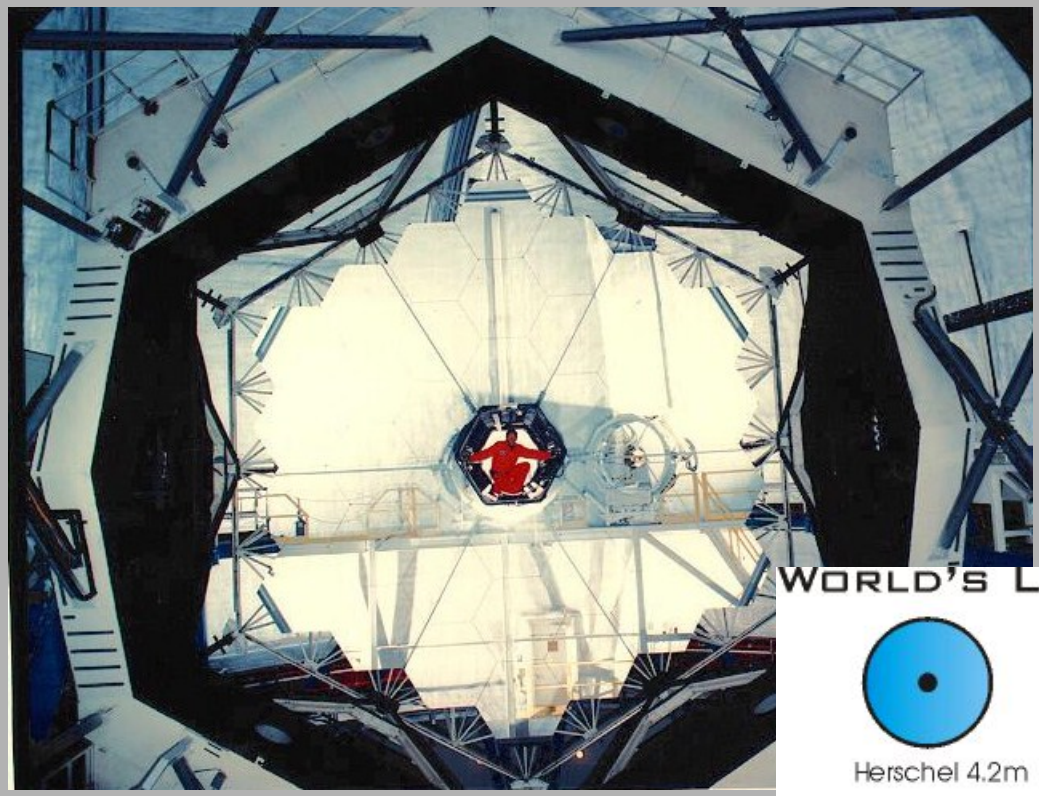
Refracting telescope

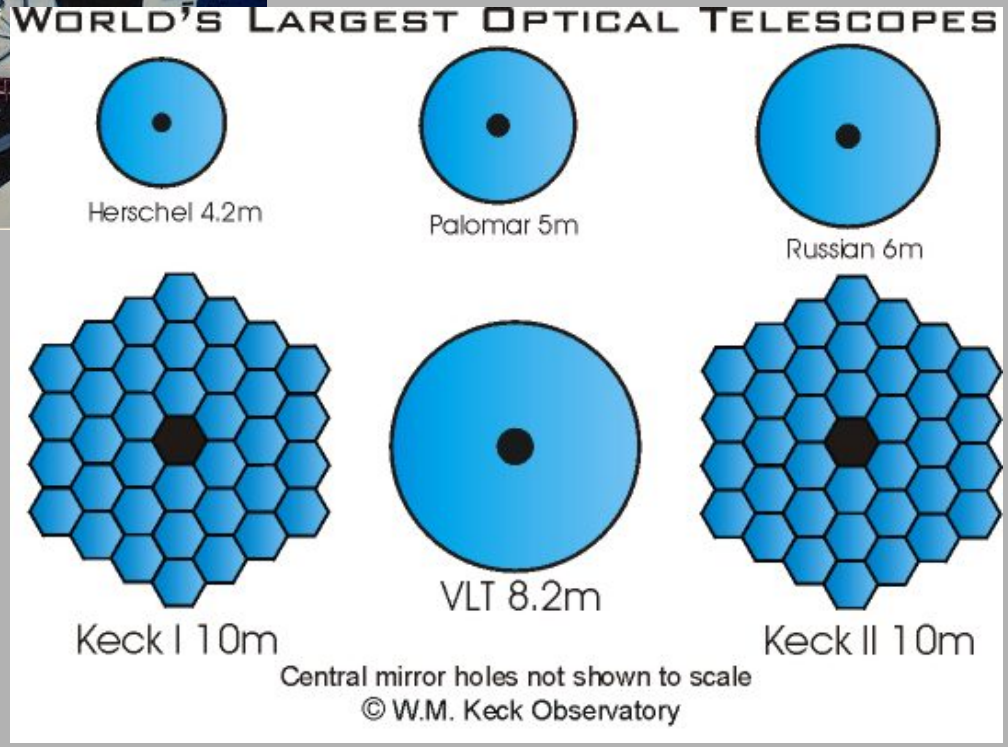


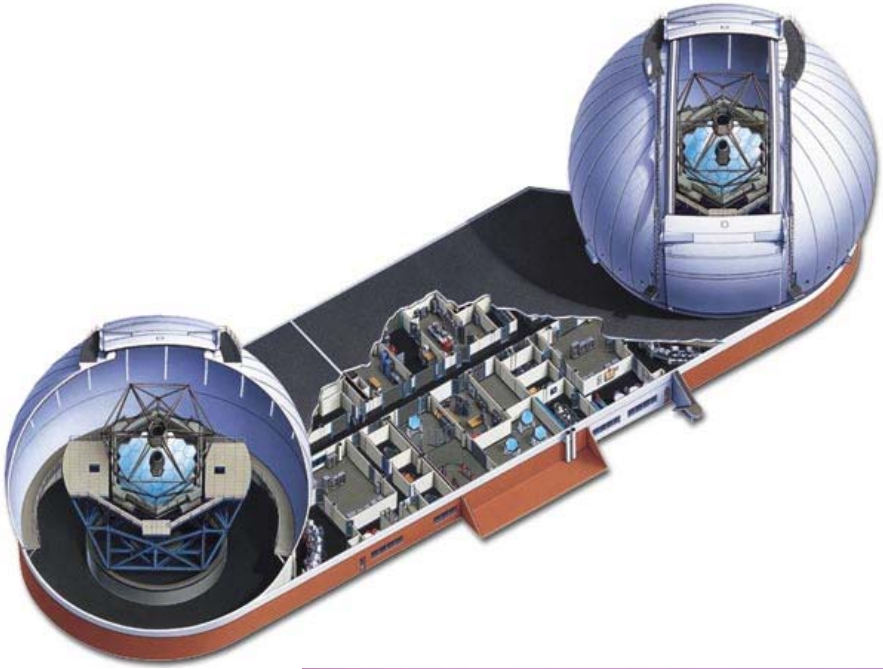
40 inch refractor – Yerkes Observatory

Reflecting telescope



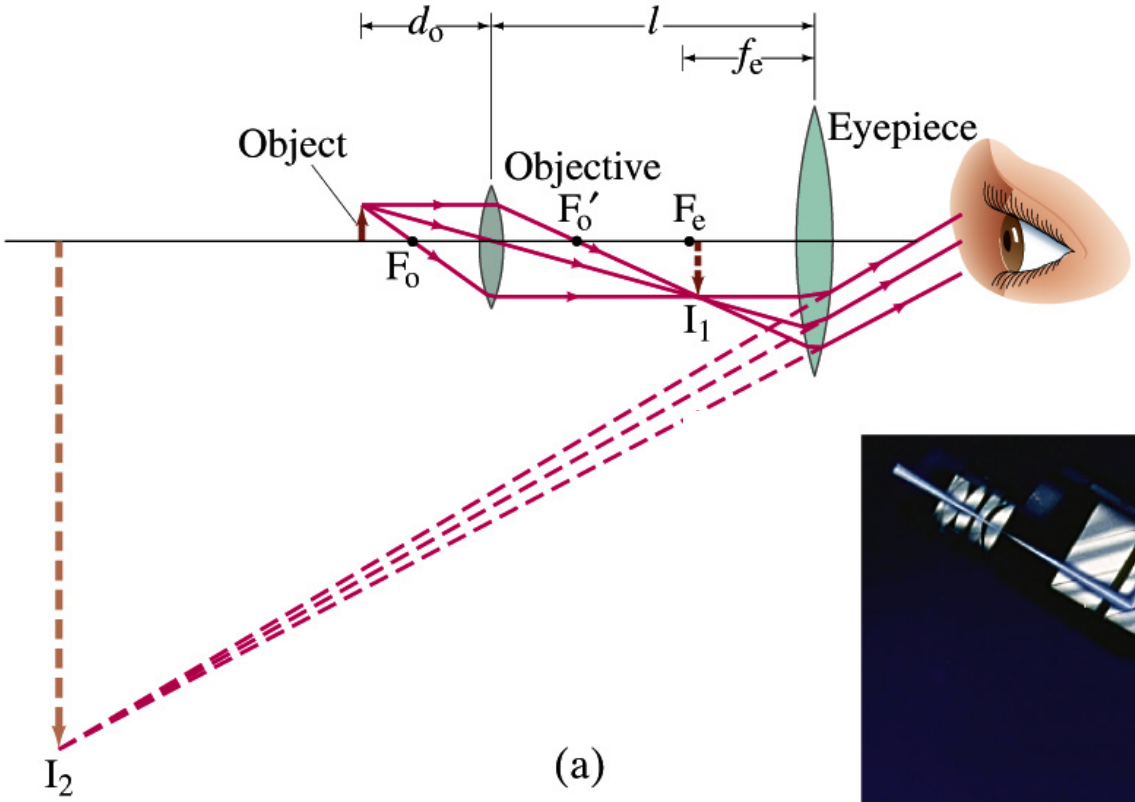



WORLD'S LARGEST OPTICAL TELESCOPES
Herschel 4.2m
Palomar 5m
Russian 6m
VLT 8.2m
Keck I 10m
Keck II 10m
Central mirror holes not shown to scale
© W.M. Keck Observatory

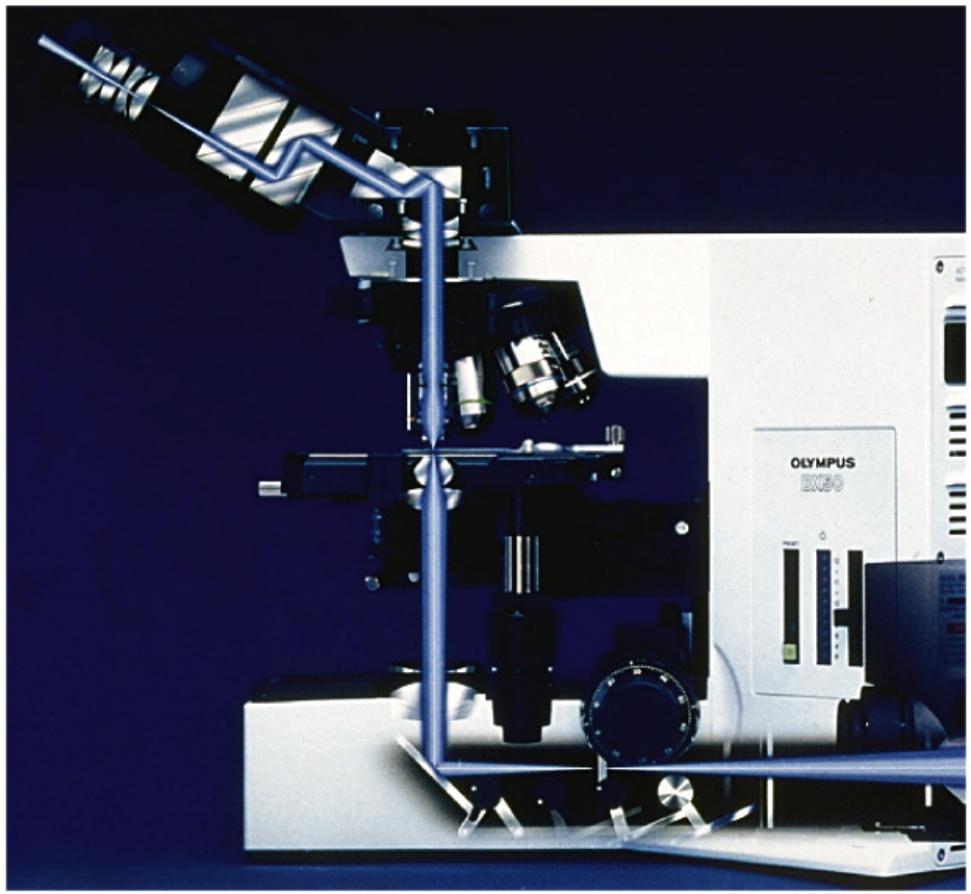


Keck Observatory

Hubble Space Telescope

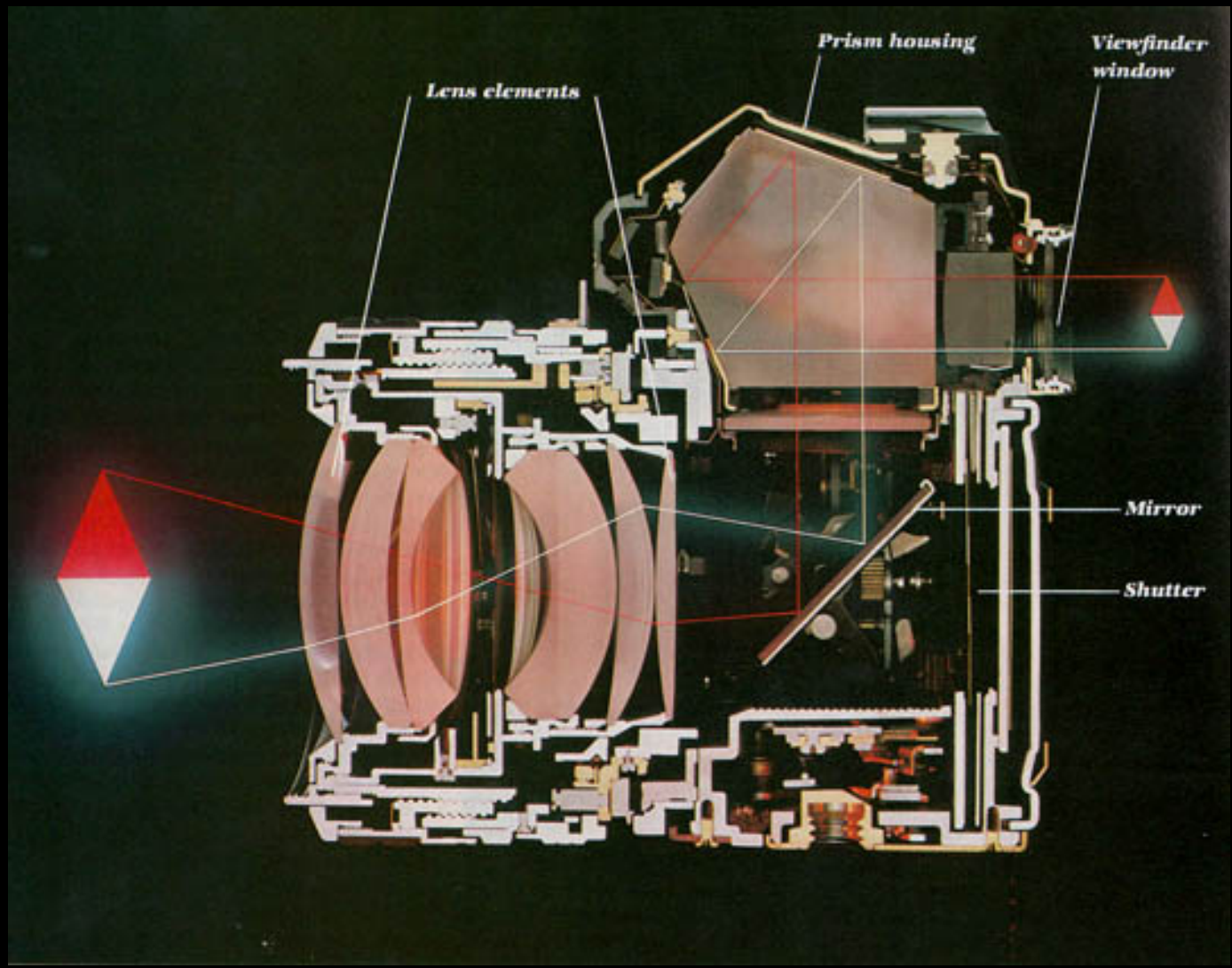


Compound microscope



(b)

Camera


Prism housing
Viewfinder window
Lens elements
Mirror
Shutter

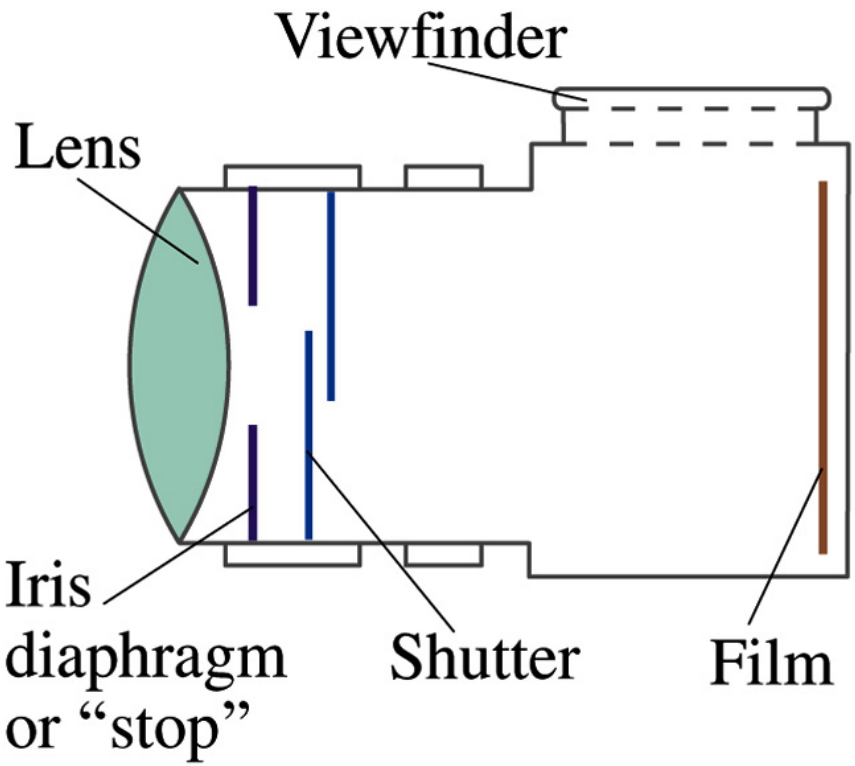
Light vs. depth of field

Shutter speed

f-stop=f/D, each f-stop=factor of 2 in light intensity

Faster the object or darker the day, need slower speed and/or larger D

Larger D means narrower depth of field



Slow exposure time
(Note hand Motion)

Small opening

large depth of field
of focus

fast Time

large opening

Narrow field of focus