Thin lenses and optical instruments

Physics 142

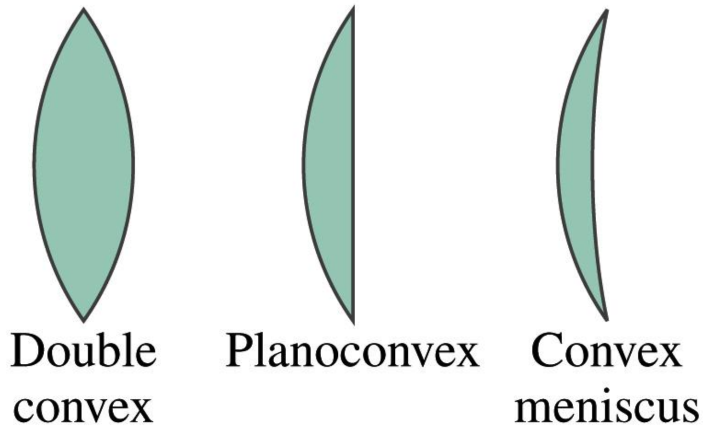
Fall 2008 - S. Manly

References and photo sources:

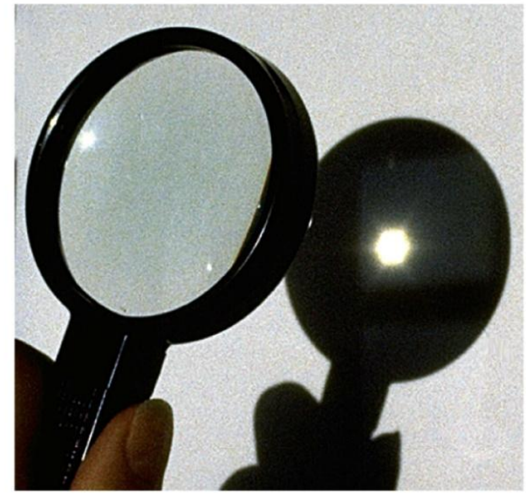
D. Giancoli, Physics for Scientists and Engineers, 3rd ed., 2000, Prentice-Hall

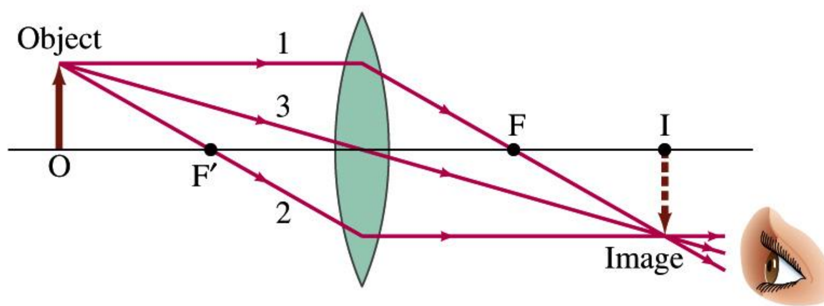
http://cvs.anu.edu.au (D. Denning and M. Kirk)

http://www.ebiomedia.com

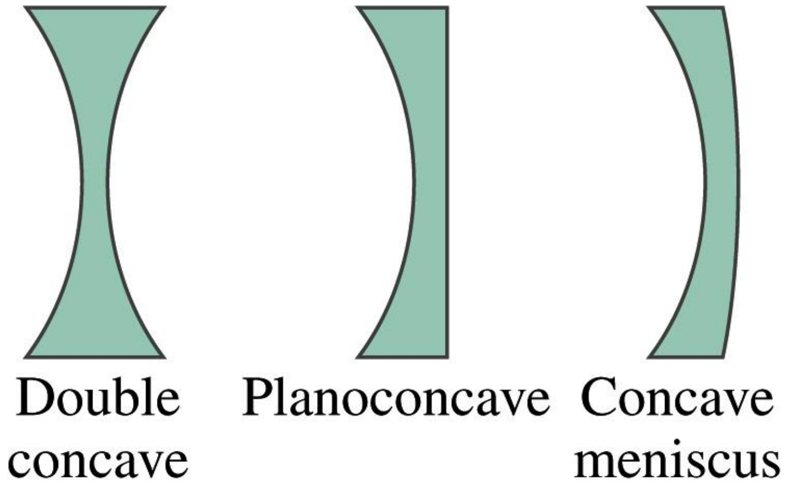


(a) Converging lenses

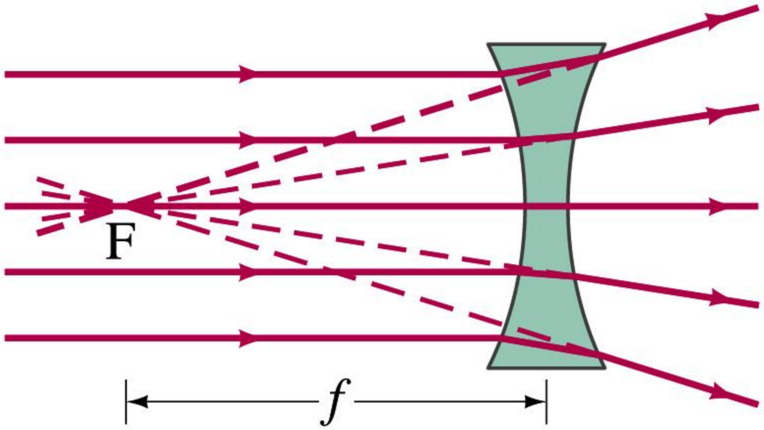


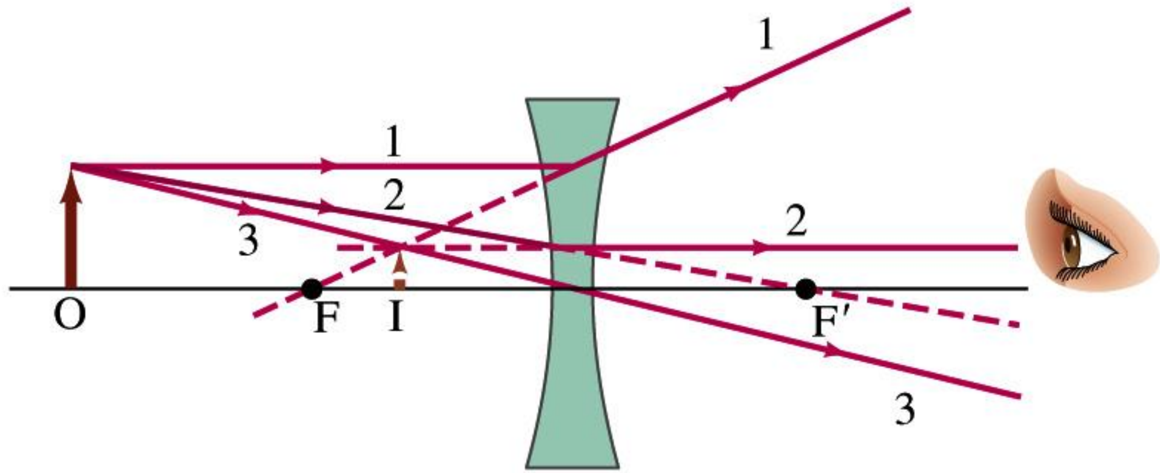


(c) Ray 3 passes straight through the center of the lens (assumed very thin).



(b) Diverging lenses



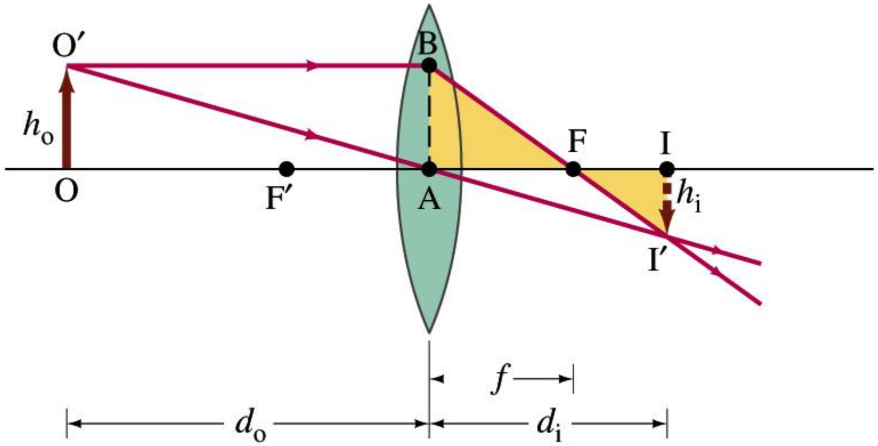

1
1
2
2
3
3
O
F
I
F′

Power of lens measured in diopters

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

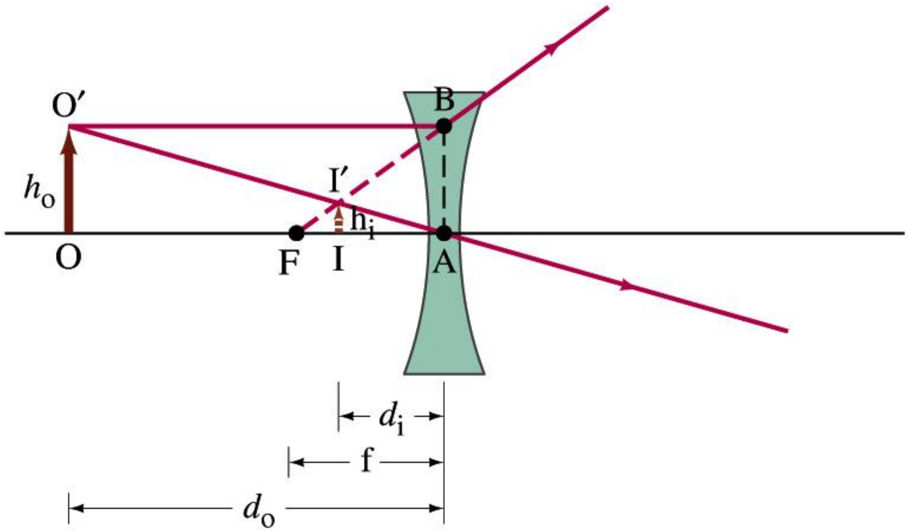
where f is focal length in meters

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:

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

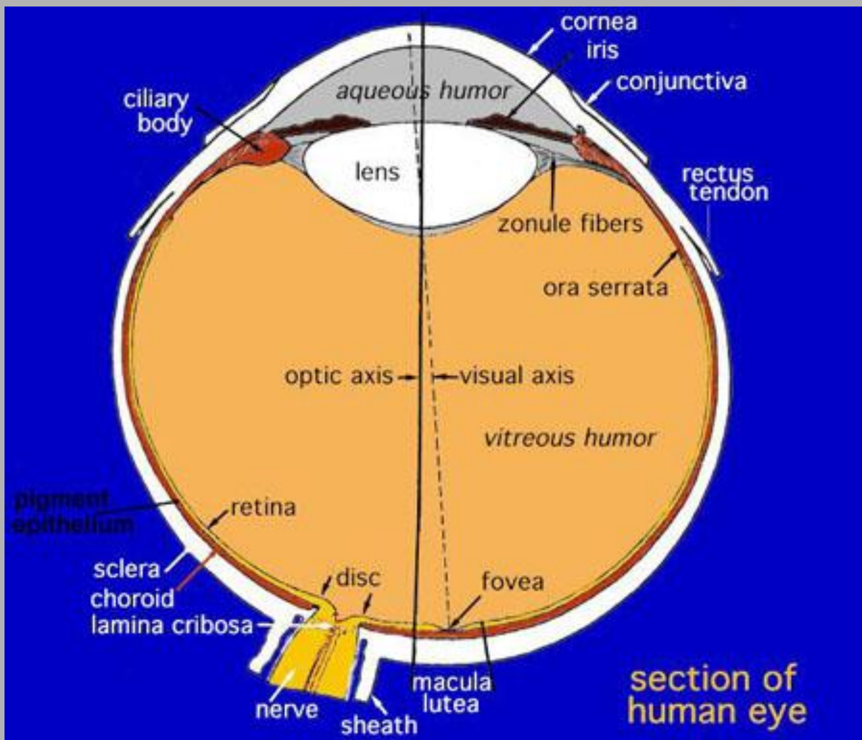
Real image: rays actually pass thru image

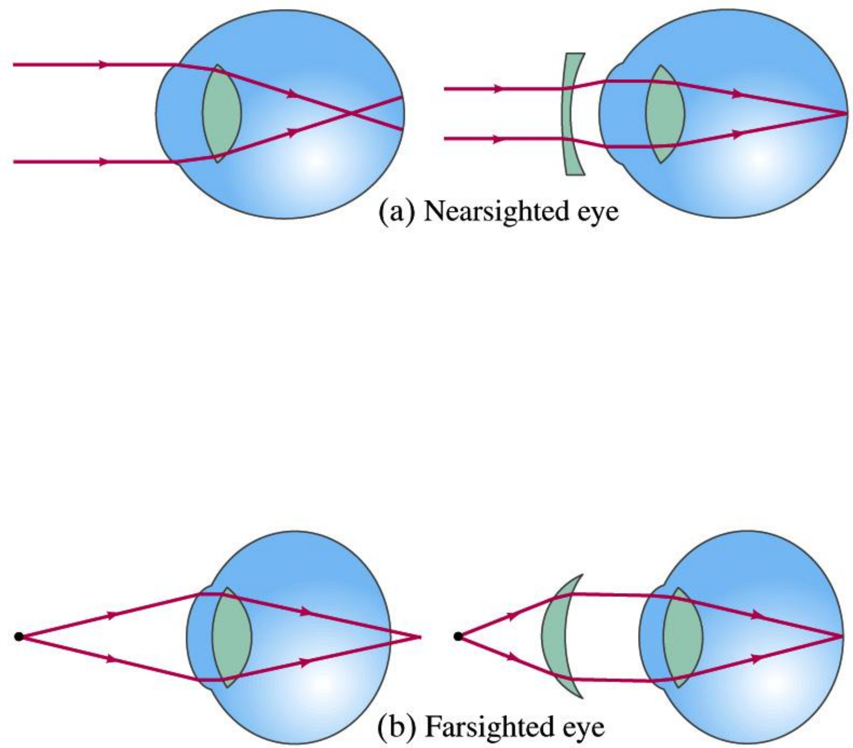
Virtual image: rays do not actually pass thru image

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 +.**

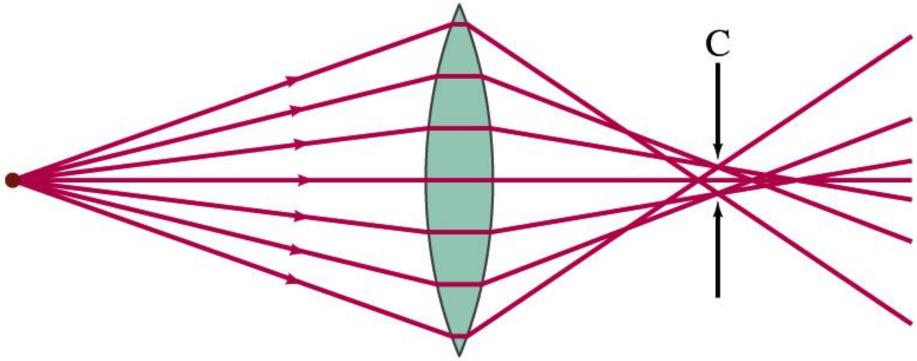




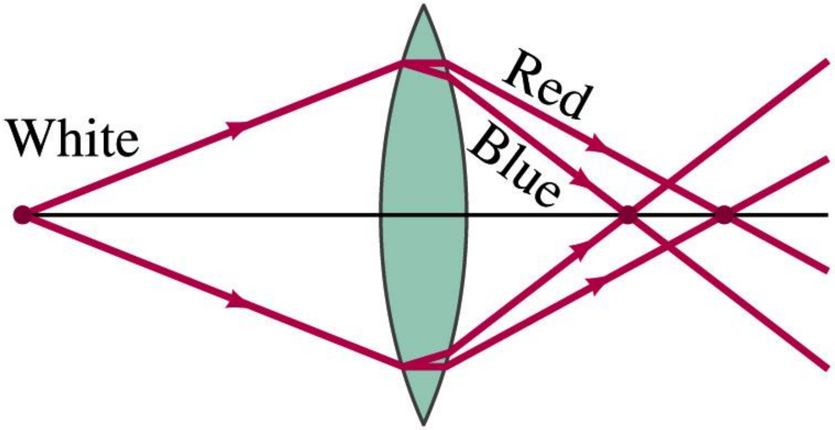
(a) Nearsighted eye

(b) Farsighted eye

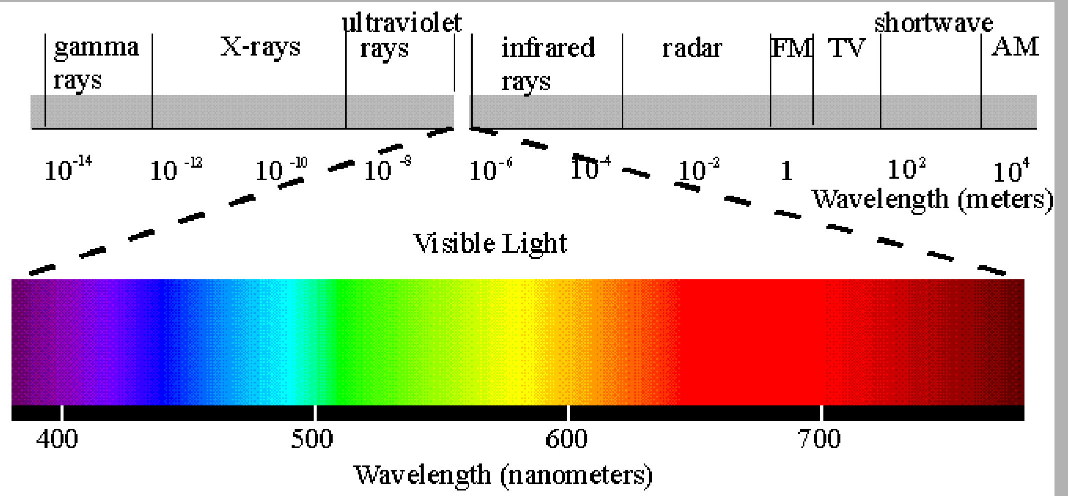
Aberrations



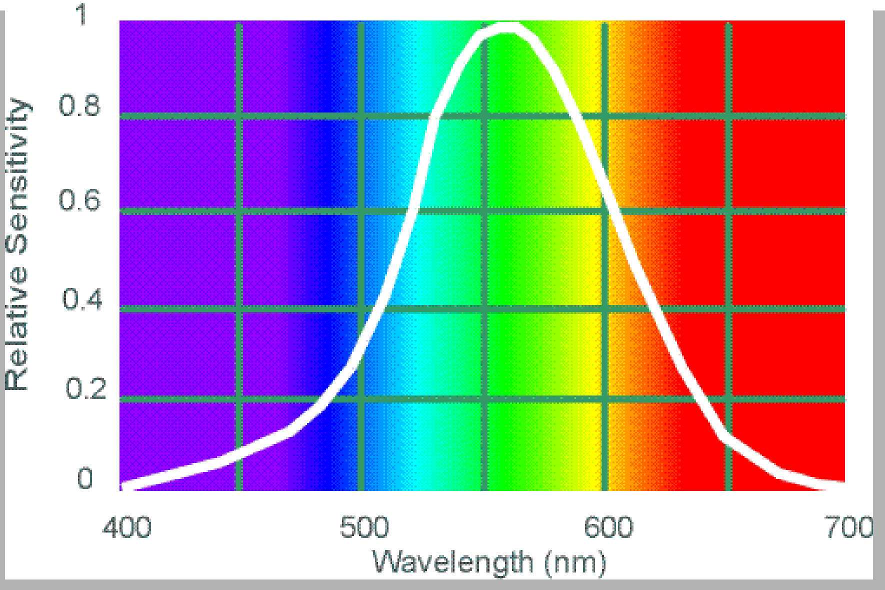
Spherical aberration

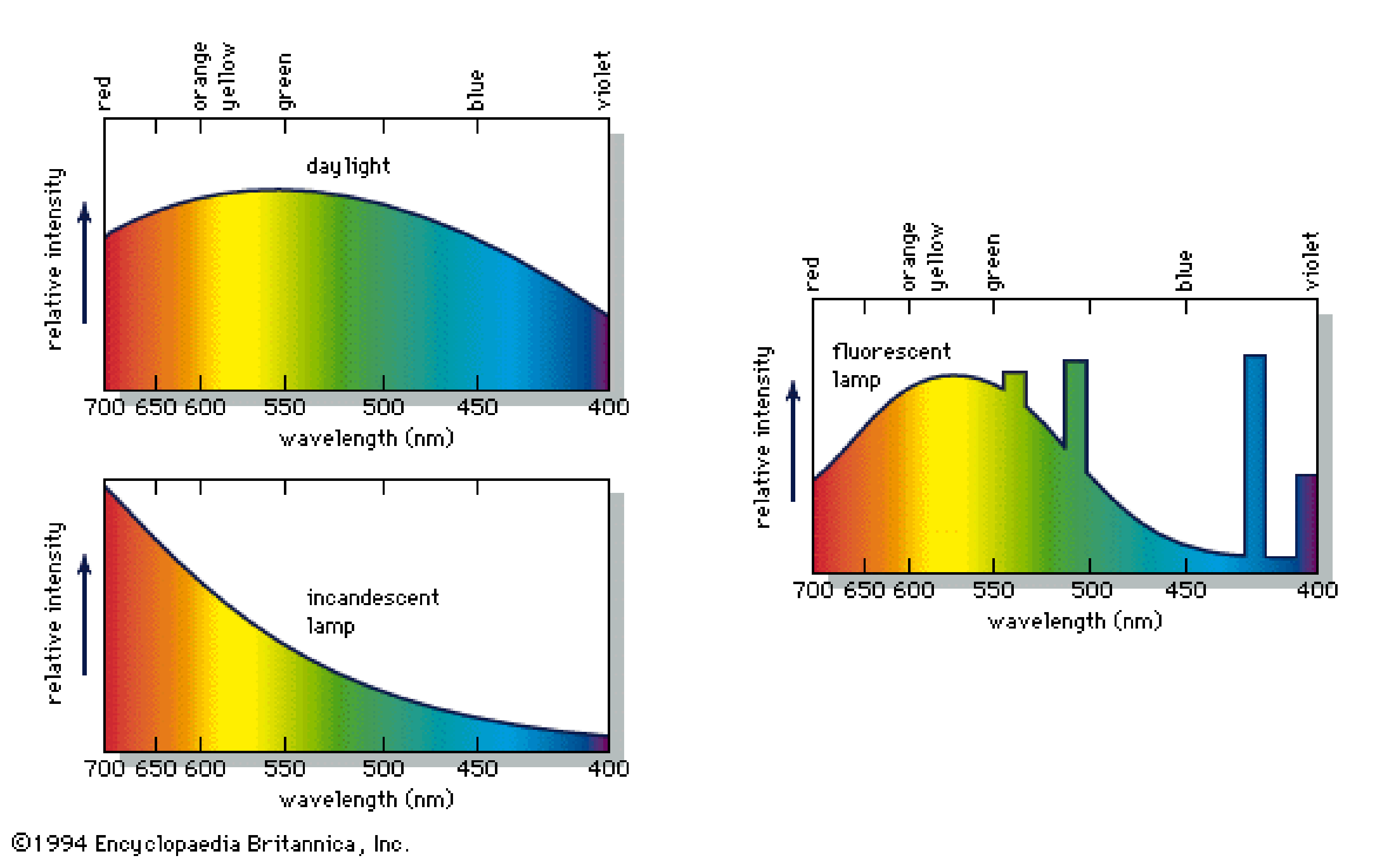


Chromatic aberration



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




red
orange
yellow
green
blue
violet
daylight
relative intensity
700 650 600 550 500 450 400
wavelength (nm)
incandescent
lamp
relative intensity
700 650 600 550 500 450 400
wavelength (nm)
red
orange
yellow
green
blue
violet
fluorescent
lamp
relative intensity
700 650 600 550 500 450 400
wavelength (nm)
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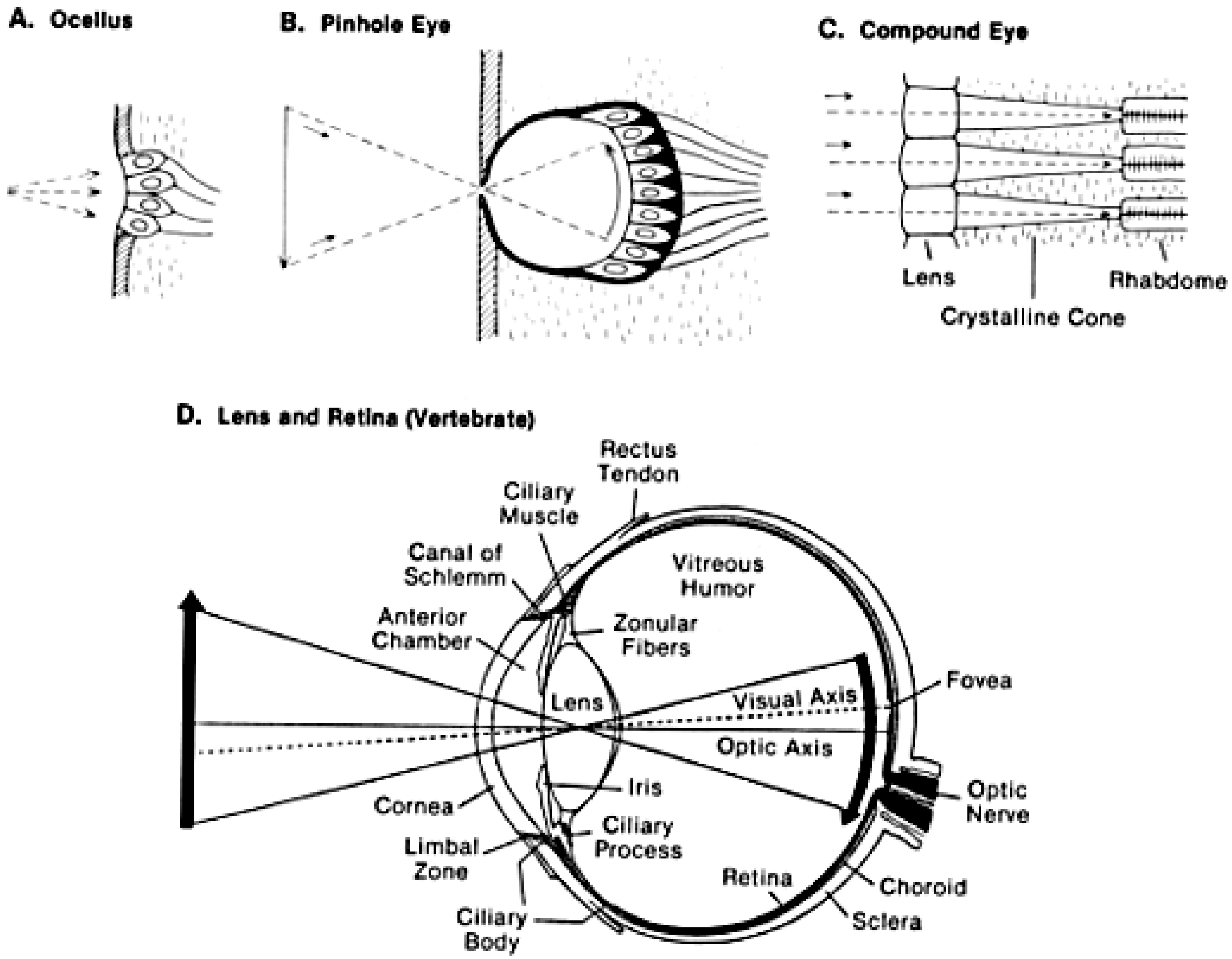
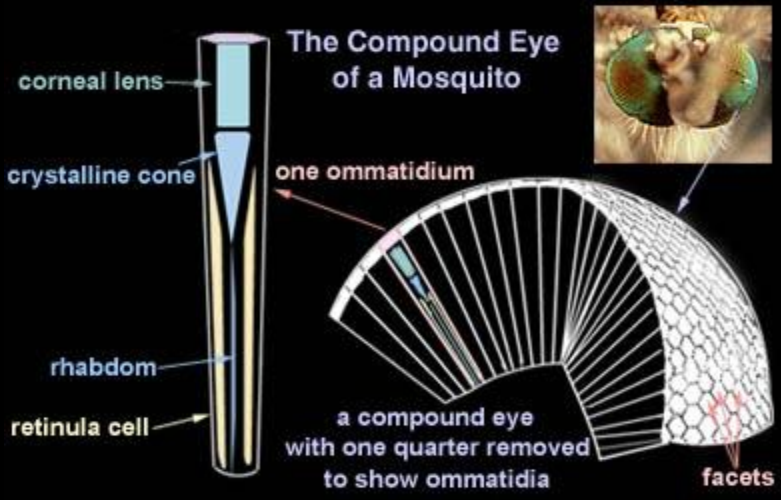
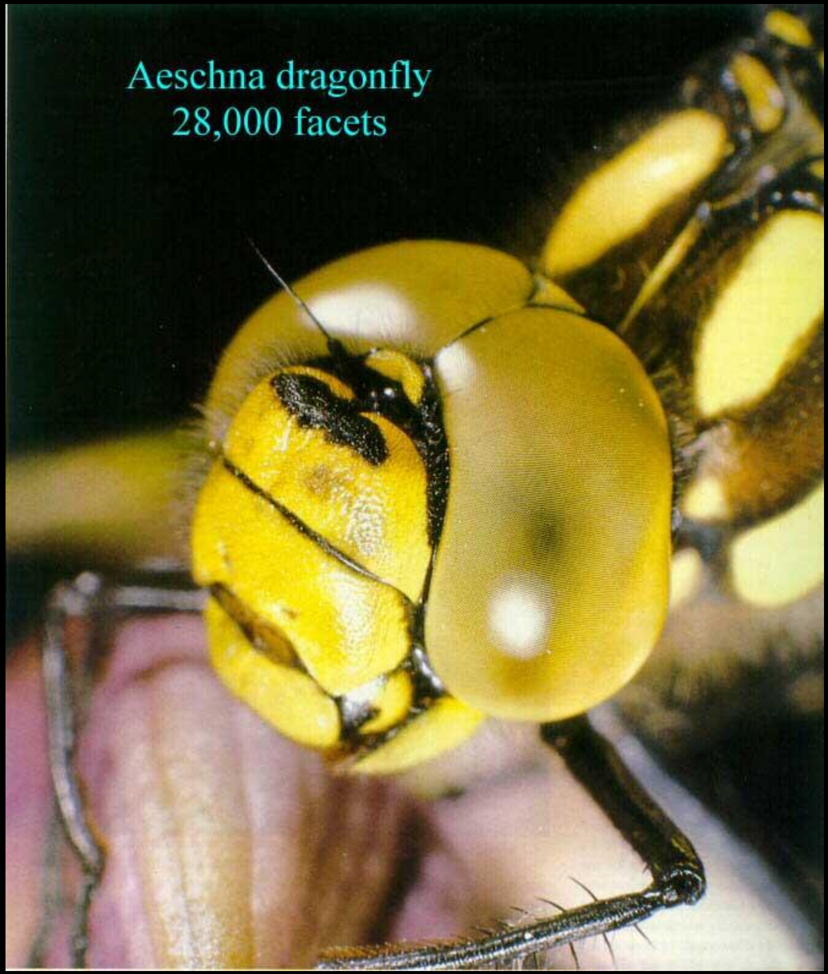
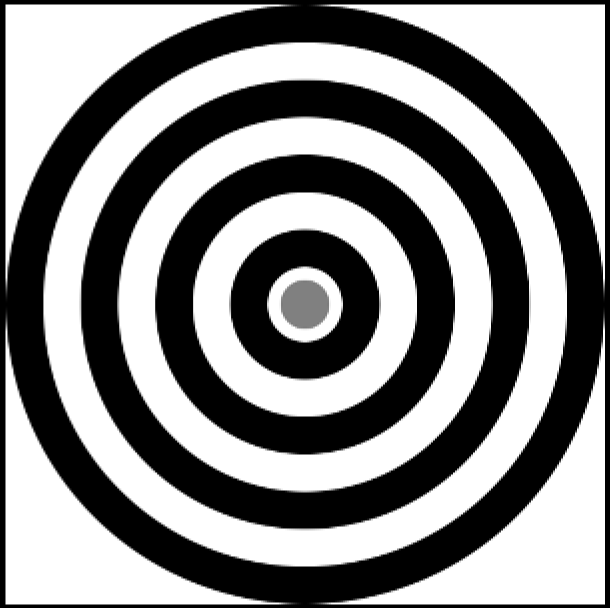
Types of eyes in the animal kingdom

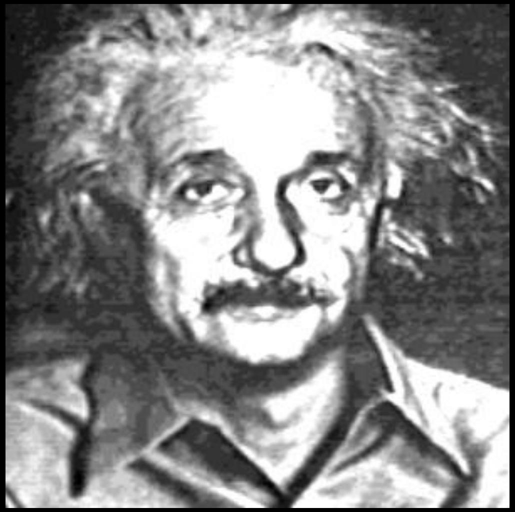



The Compound Eye
of a Mosquito
corneal lens
crystalline cone
one ommatidium
rhabdom
retinula cell
a compound eye
with one quarter removed
to show ommatidia
facets


Aeschna dragonfly
28,000 facets

A bee's eye view





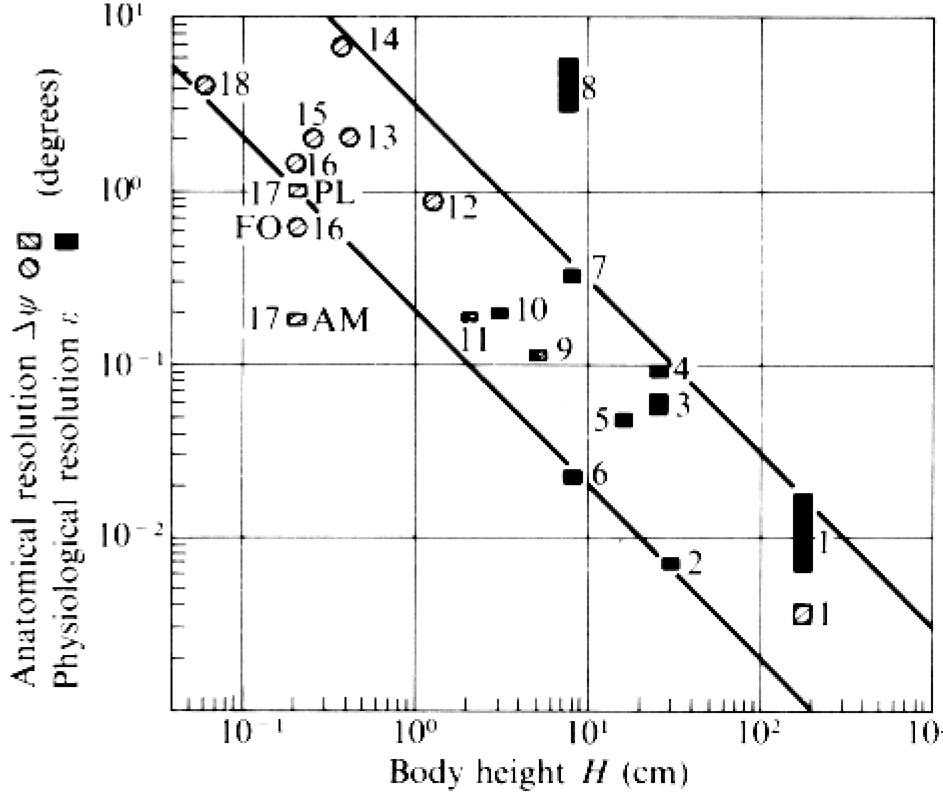
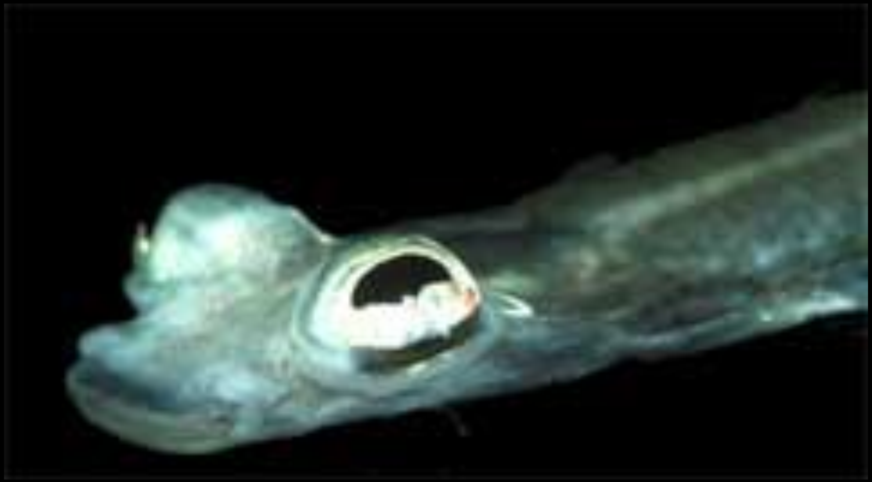
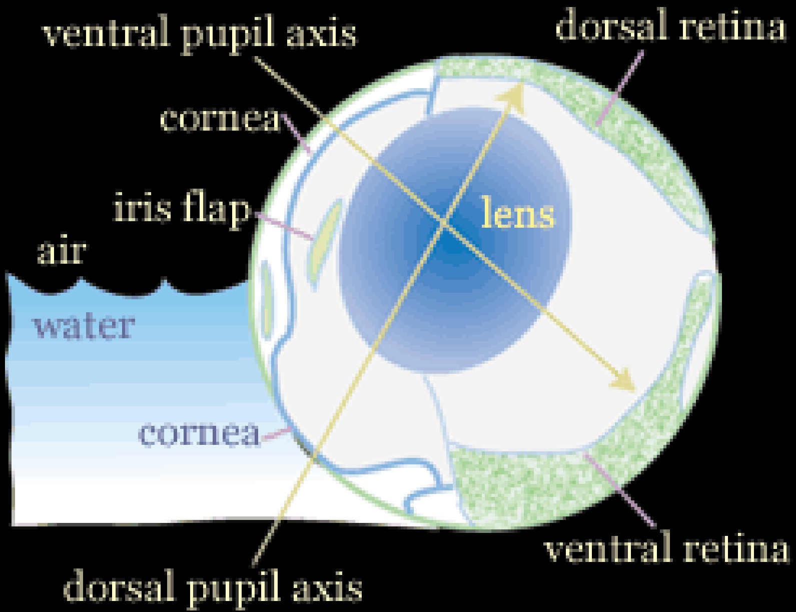


Fig. 2.9. Resolution of the eyes of various animals measured physiologically and deduced from anatomical criteria compared to body height: (1) man; (2) peregrine falcon; (3) hen; (4) cat; (5) pigeon; (6) chaffinch; (7) rat; (8) bat (*Myotis*); (9) frog; (10) lizard; (11) minnow; (12) dragonfly (*Aeschna*); (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.)

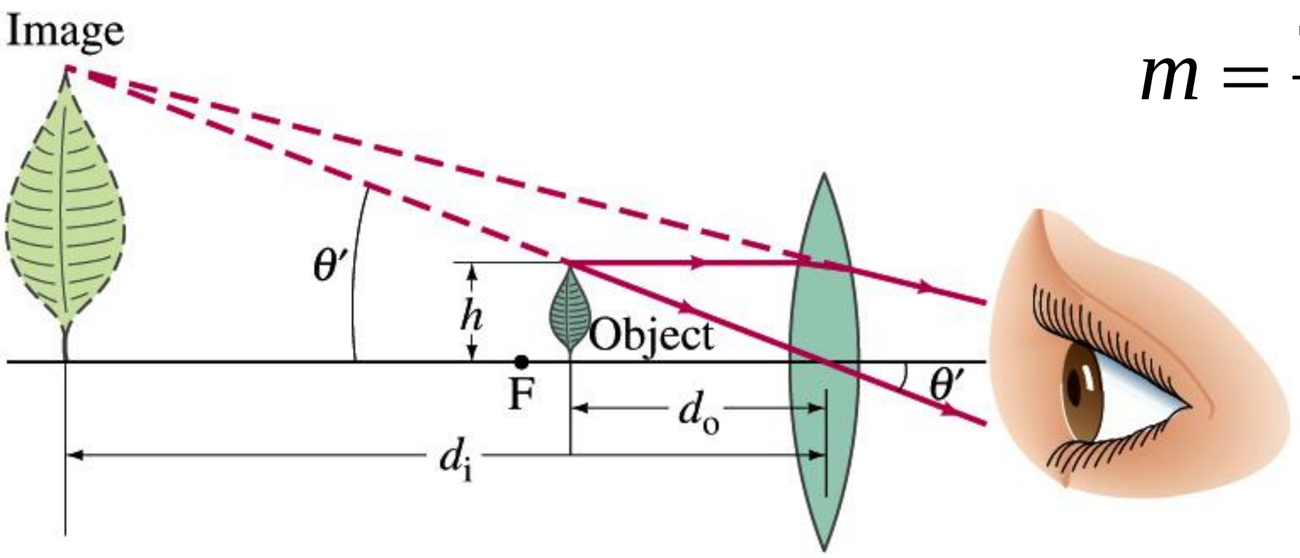
Anableps - minnow

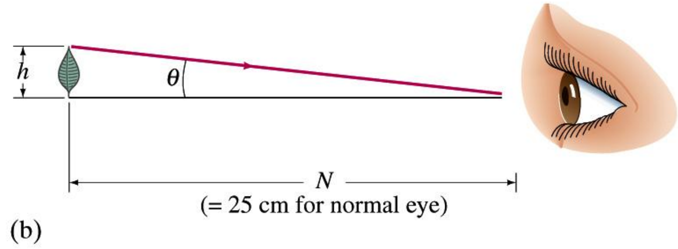


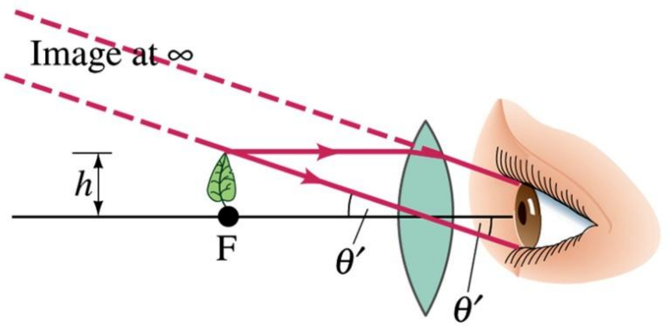


Magnifying glass

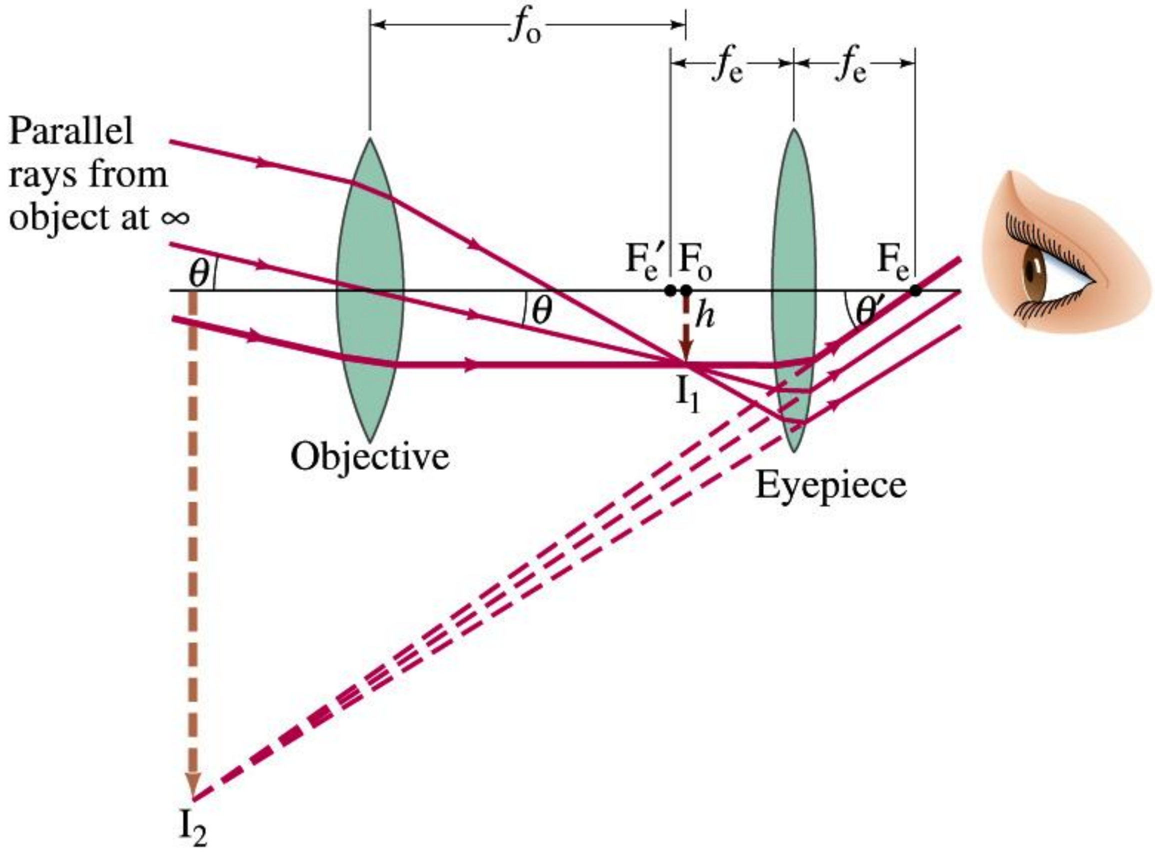
$$m = \frac{\theta'}{\theta} = \frac{N}{f}$$





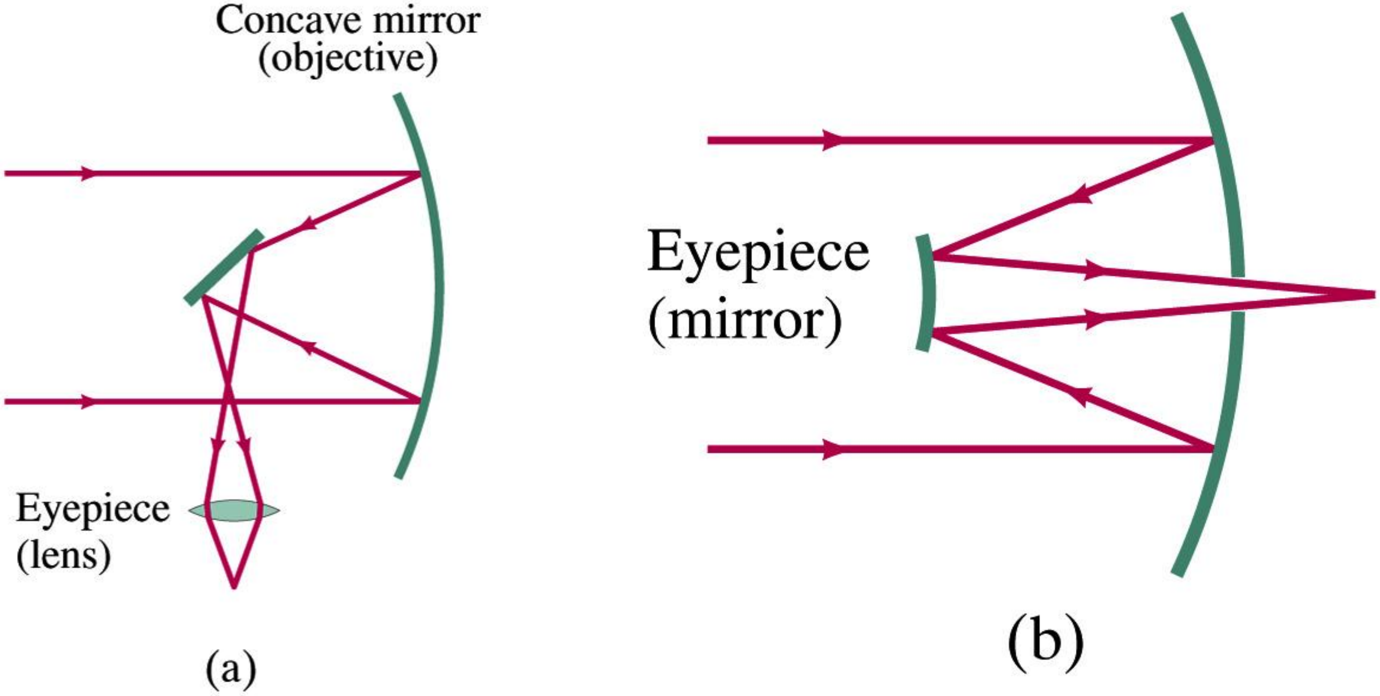


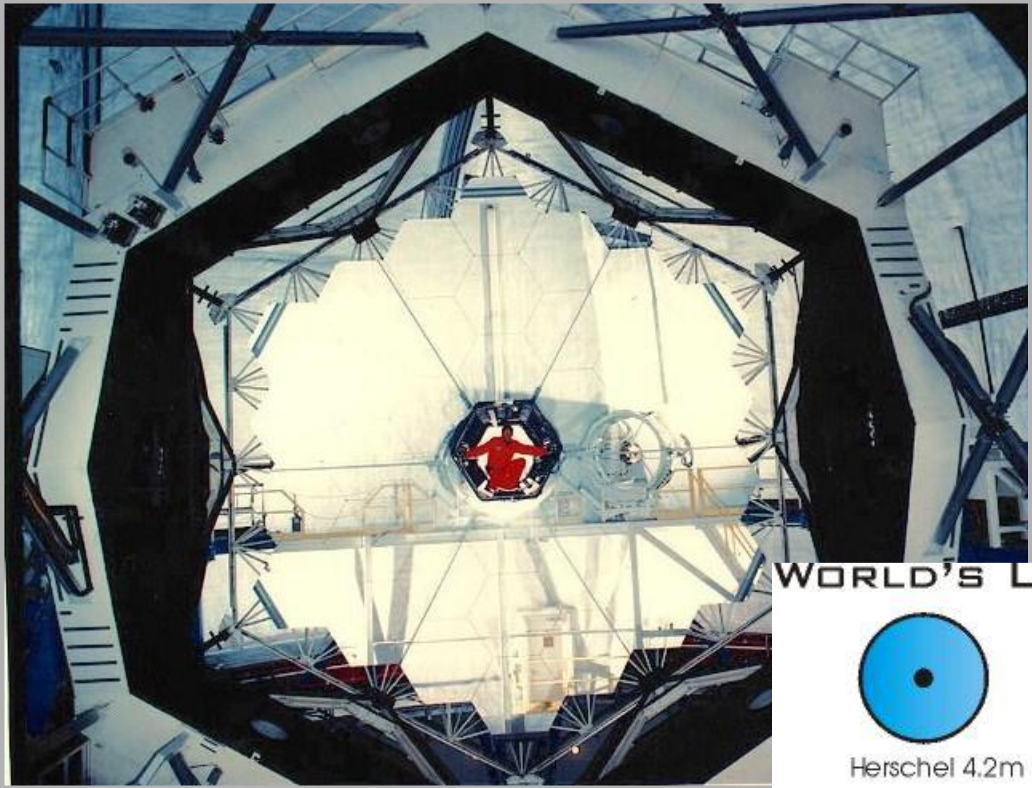
Refracting telescope

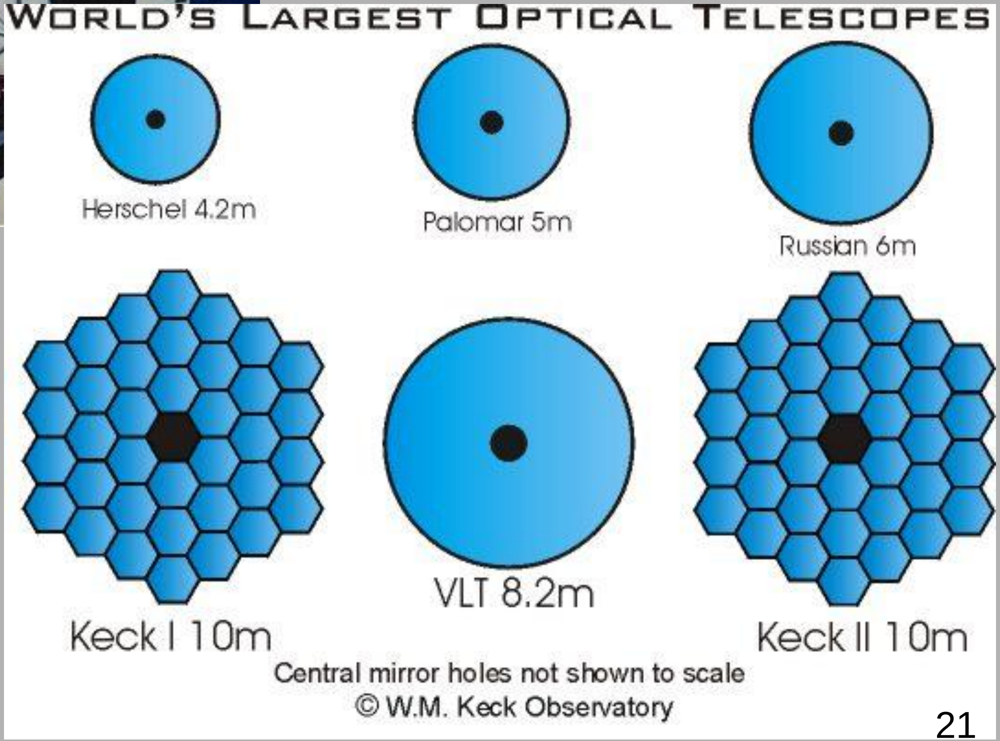


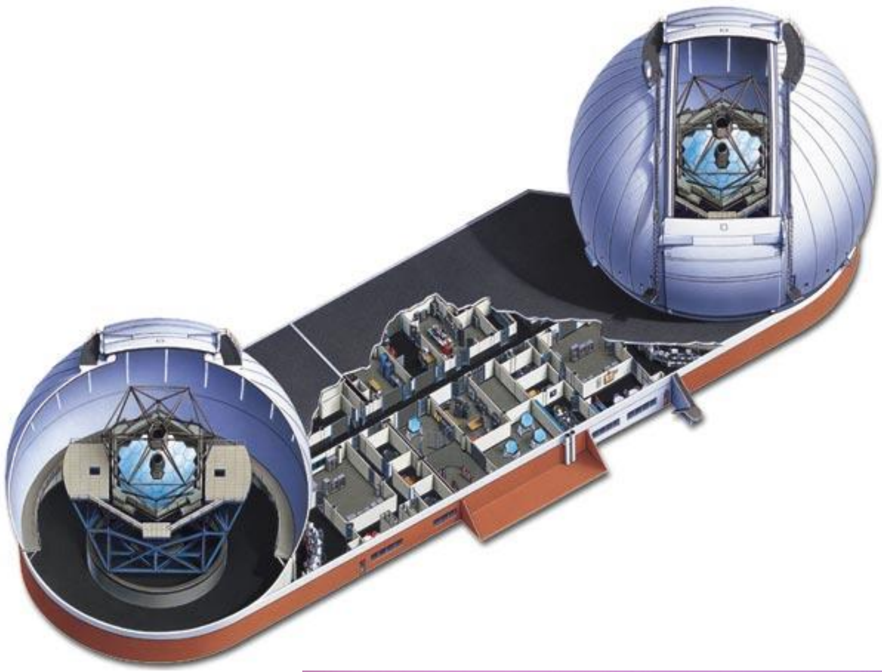
40 inch refractor – Yerkes Observatory

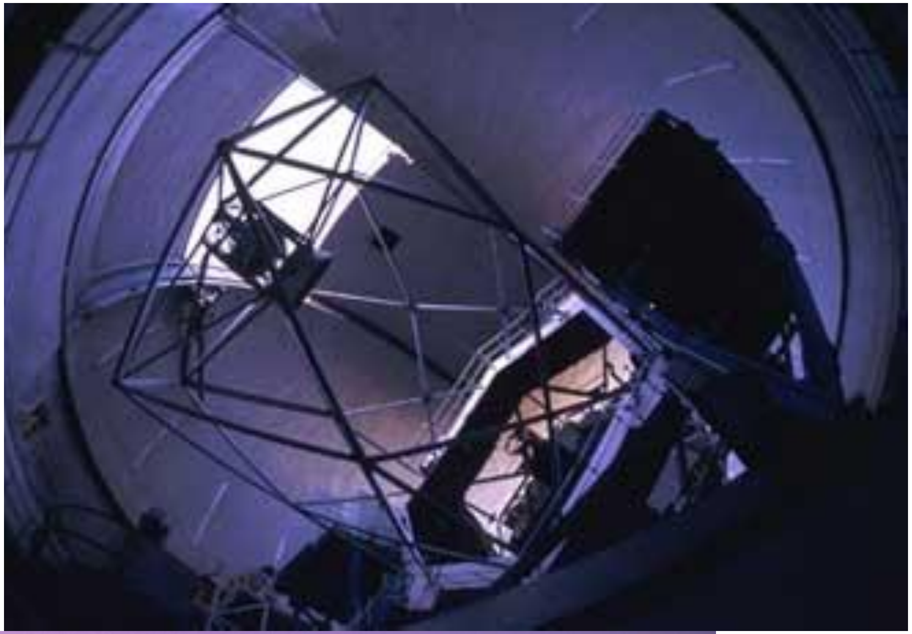
Reflecting telescope





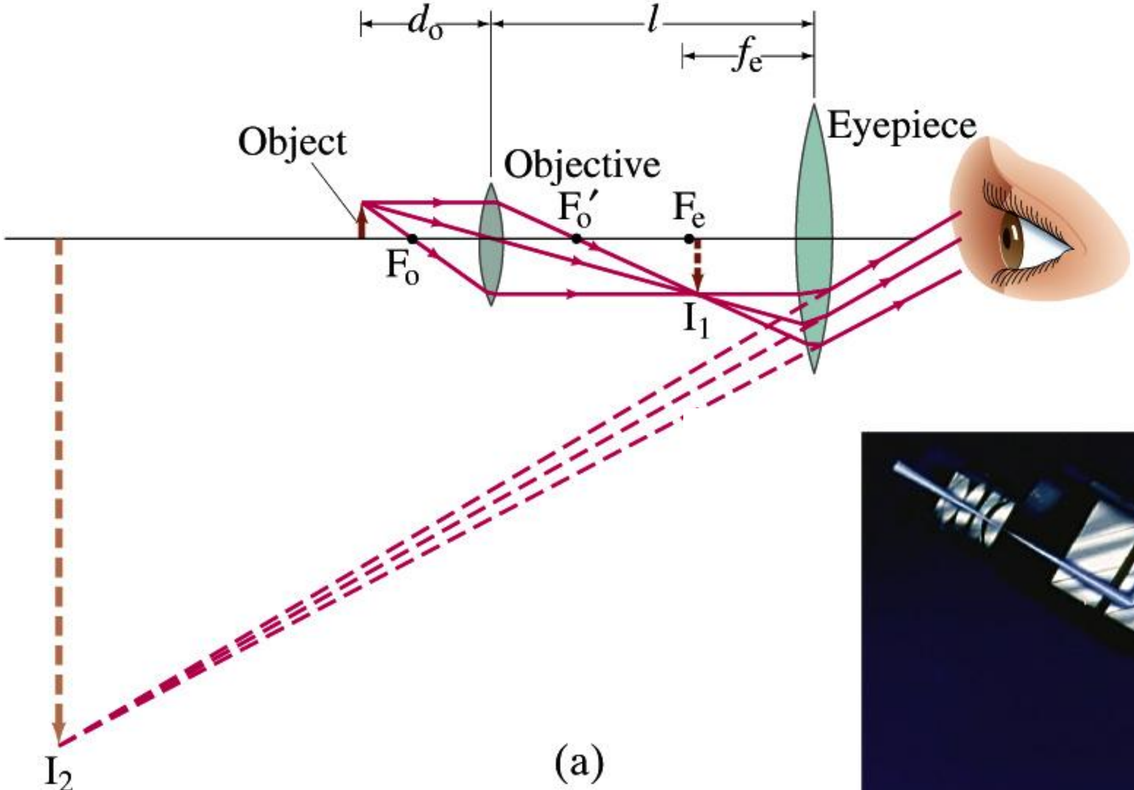

World's Largest Optical Telescopes
Herschel 4.2m
Palomar 5m
Russian 6m
Keck I 10m
VLT 8.2m
Keck II 10m
Central mirror holes not shown to scale
© W.M. Keck Observatory





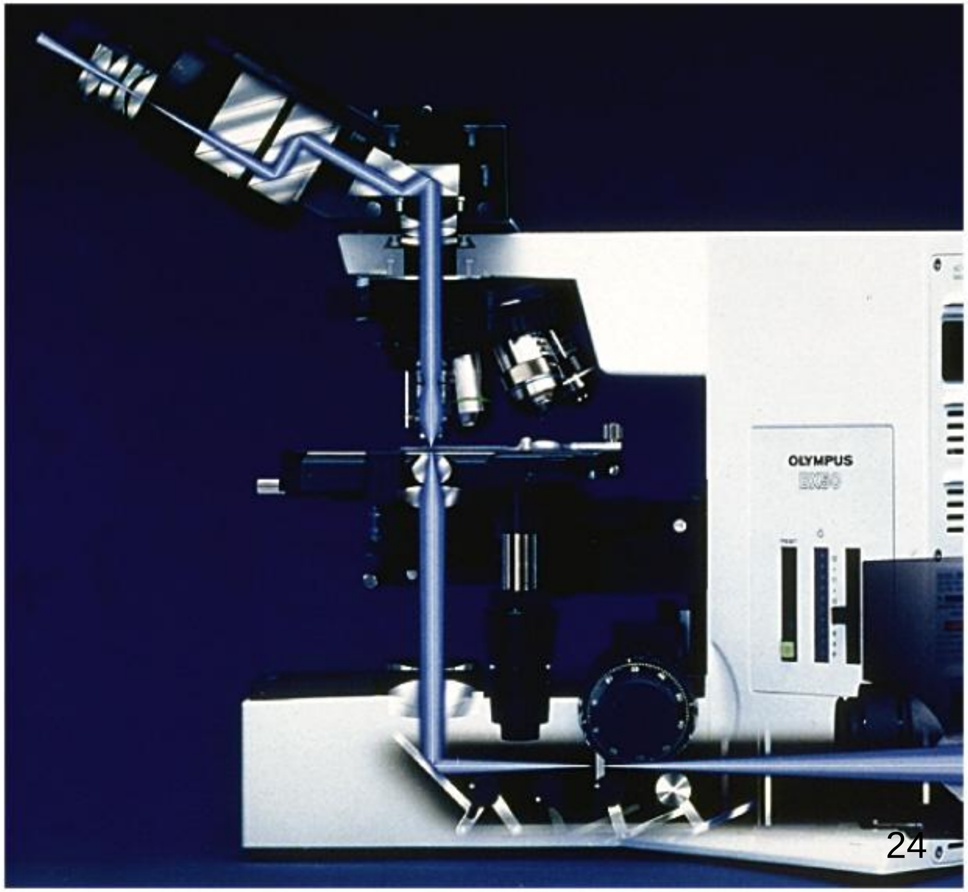
Keck Observatory


Hubble Space Telescope



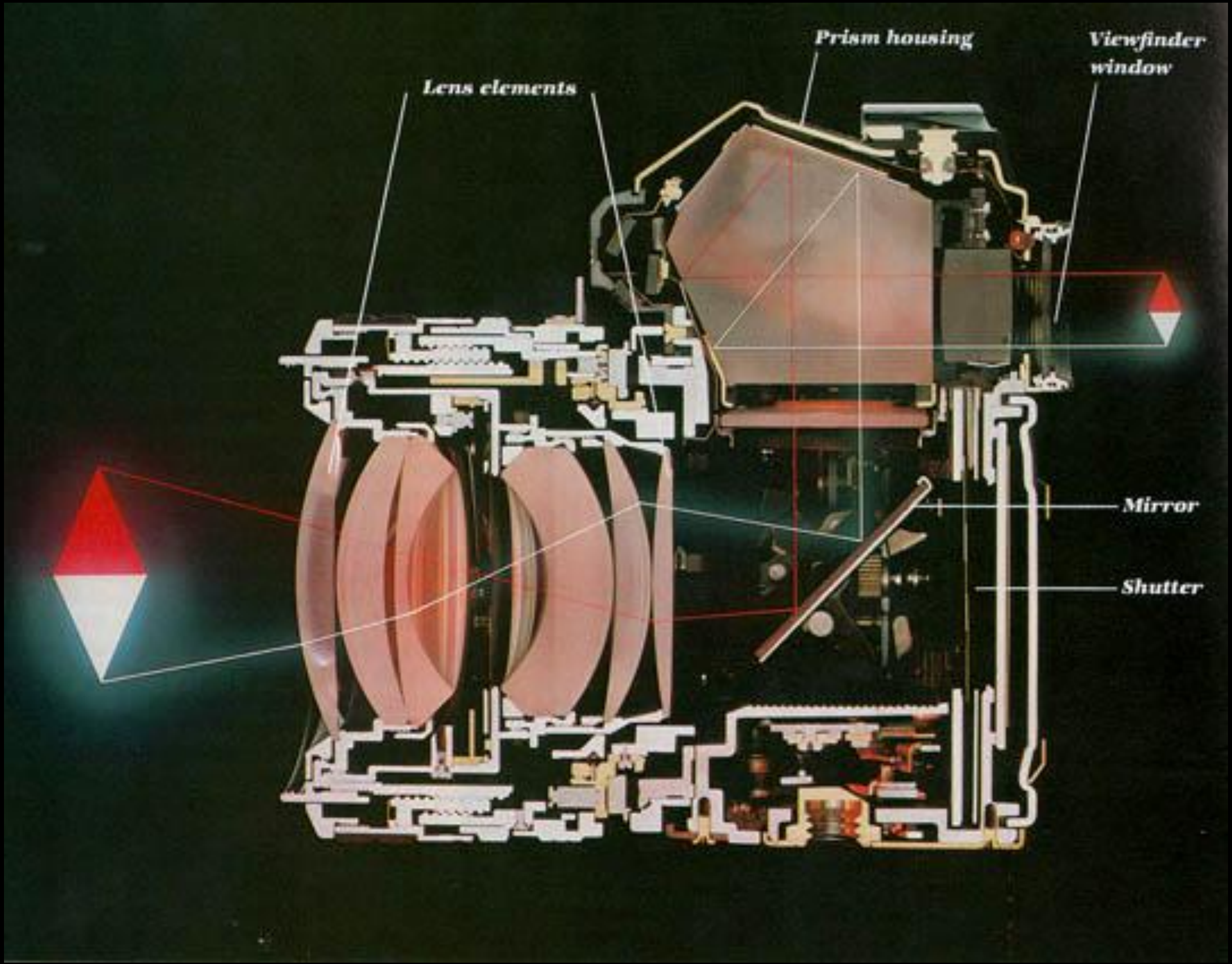
(a)

Compound microscope



(b)

Camera



Prism housing
Viewfinder window
Lens elements
Mirror
Shutter

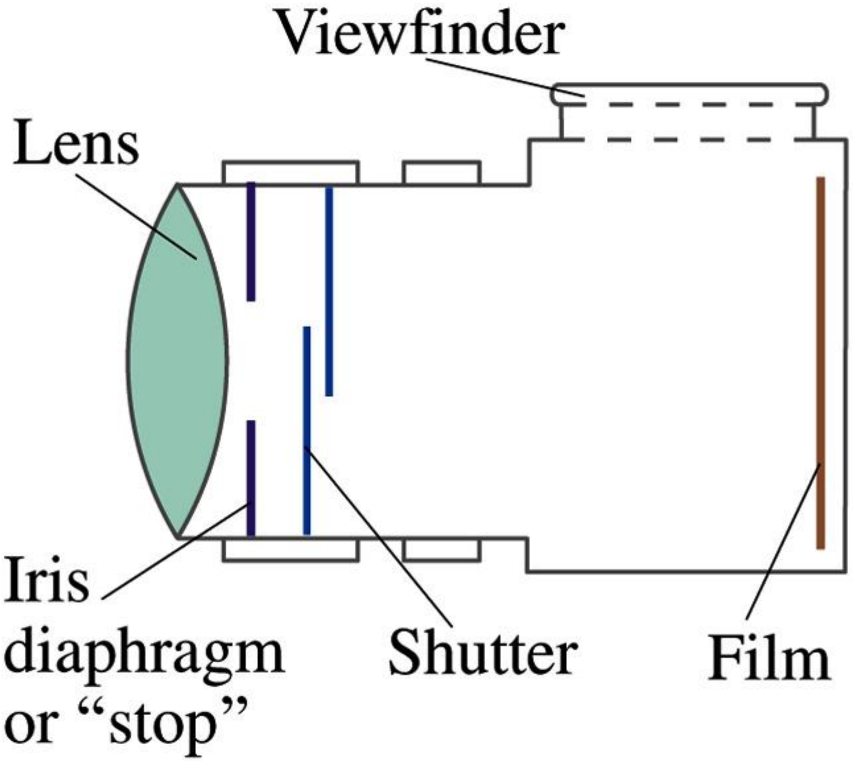
Light vs. depth of field

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