# Physics 142 – December 2, 2014

Presentations

| | | |
|---|---|---|
| Dec 4 | grp 4 | EM in chem/med |
| | grp 3 | Supercond. |
| Dec 9 | grp 2 | Accel. /det |
| | grp 7 | EM + Music |
| Dec 11 | grp 5 | railgun |
| | grp 1 | relativity |
| | grp 6 | lasers |

optics ?

geometric ?

physical (interference + Diffraction ?)

$$y(x,t) = A e^{i(kx-\omega t)}$$

$$\psi(\vec{r}) = A e^{i(\vec{k}\cdot\vec{r} - \omega t)}$$

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}} \rightarrow v = \frac{1}{\sqrt{\epsilon \mu}}$$

$v < c$

$\frac{c}{v} \equiv n \equiv$ index of refraction   $n \geq 1$

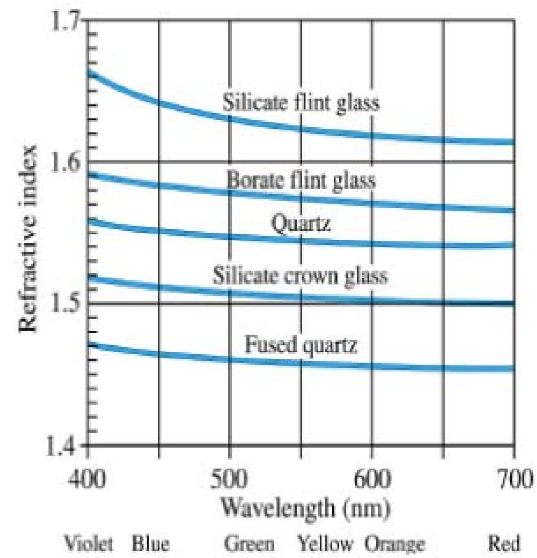
$c = \lambda \nu$

$v = \lambda_n \nu$

$$\lambda n = \lambda_0$$

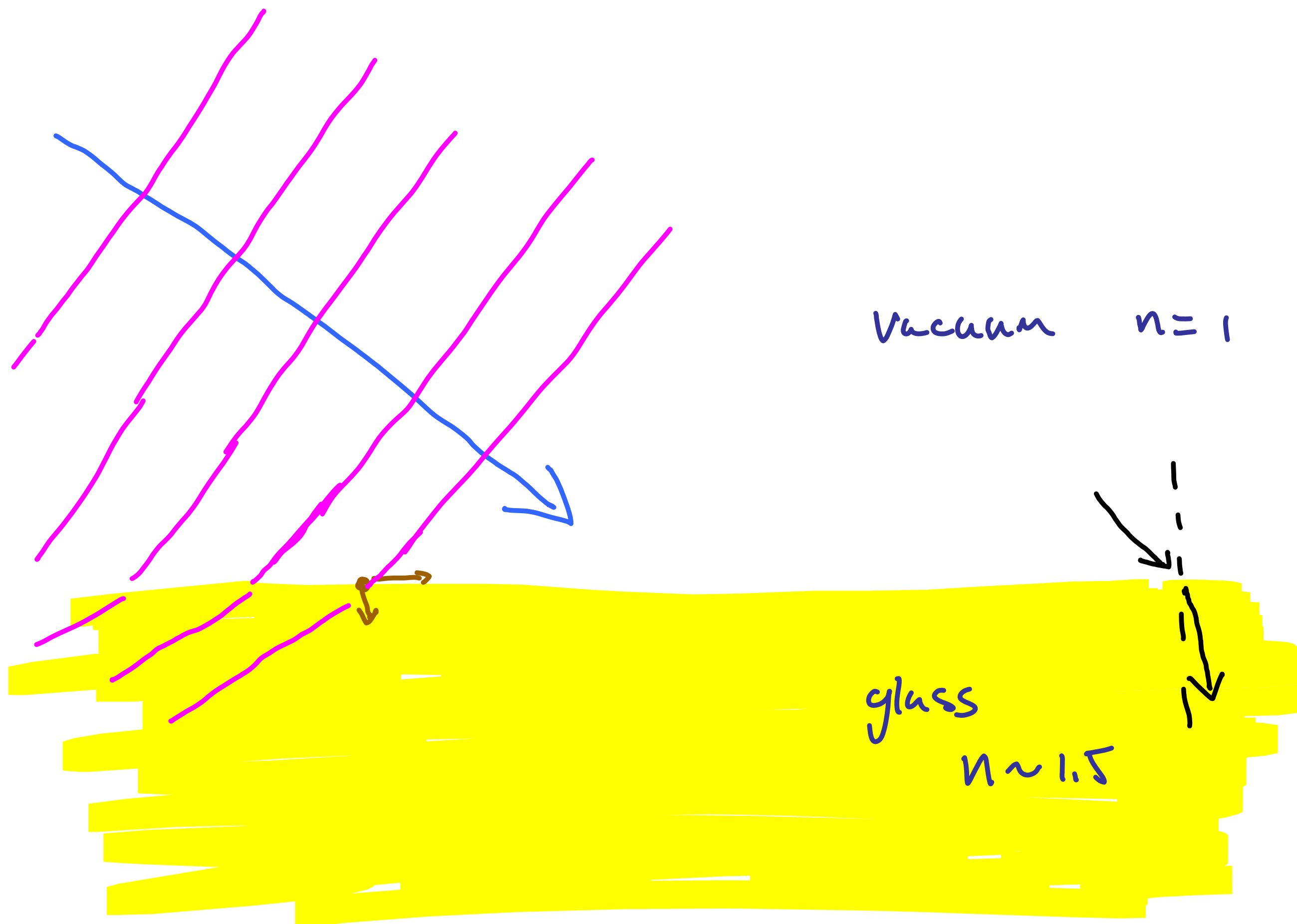
$\lambda$: in material; $\lambda_0$: in vacuum

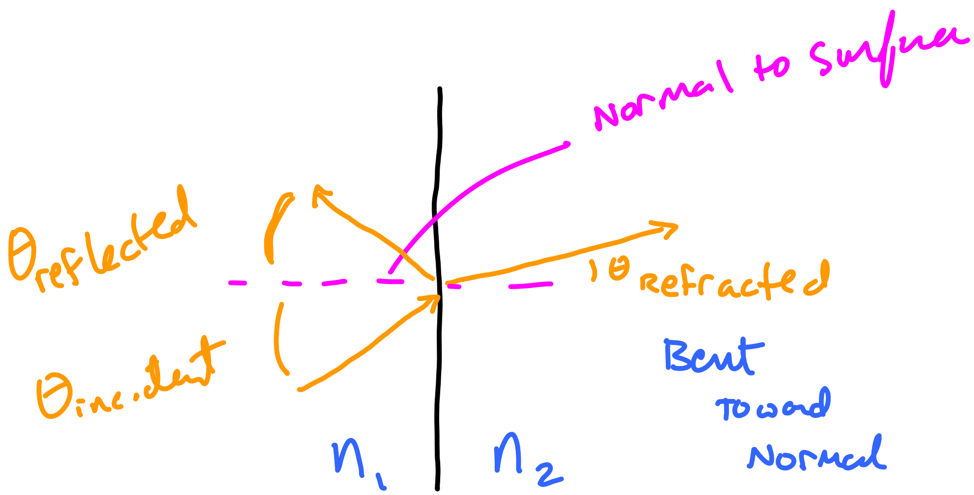
$$\frac{c}{v} = \frac{\lambda}{\lambda_n}$$



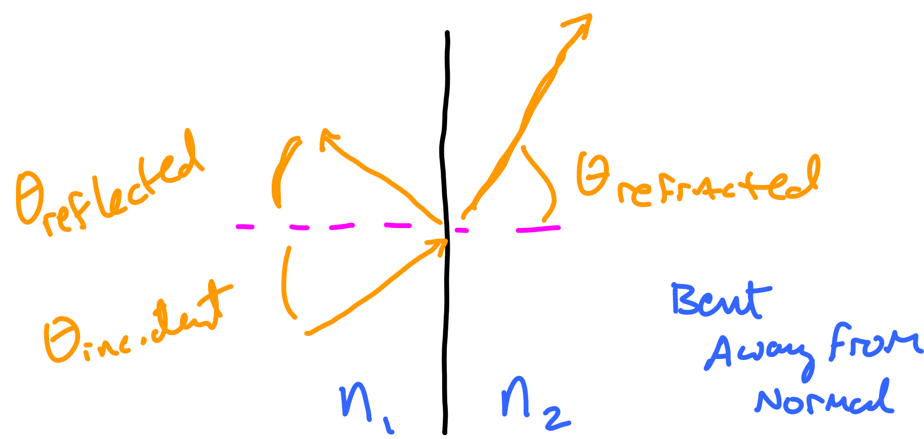

Note $n \rightarrow F(\lambda)$

"dispersion"


vacuum n = 1
glass
n ~ 1.5




$n_2 > n_1$



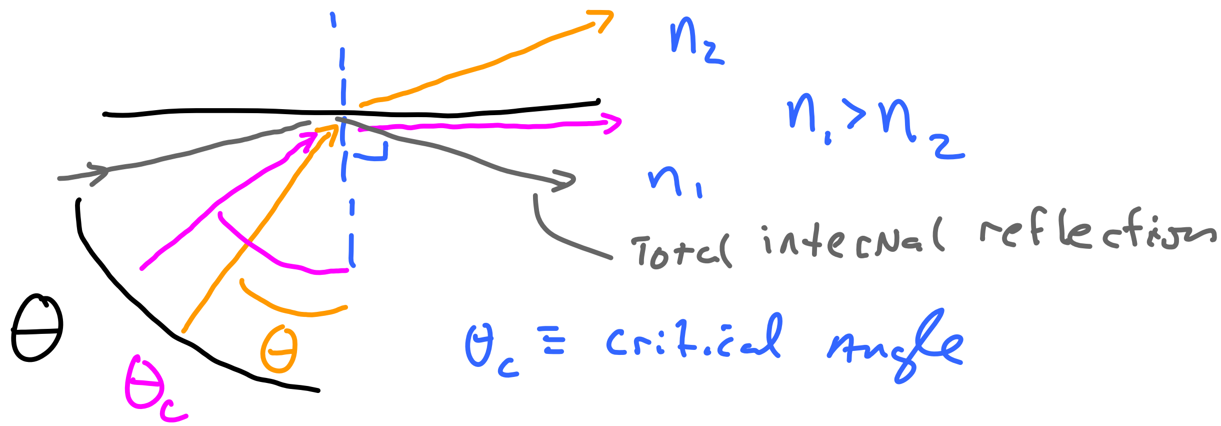

$n_2 < n_1$

$$\theta_{reflected} = \theta_{incident}$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$(1 \equiv \text{incident},\ 2 \equiv \text{refracted})$

# Critical Angle

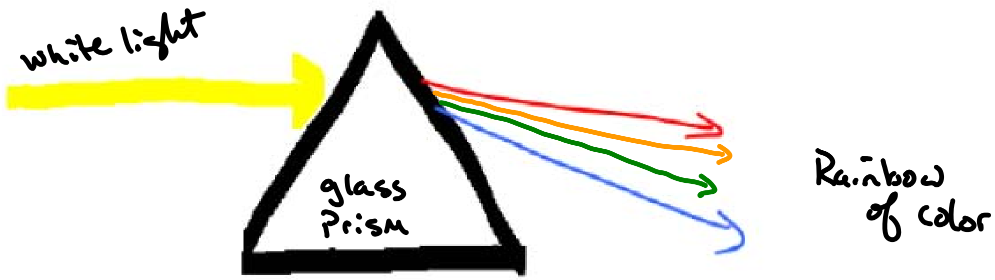



$\theta_c \equiv$ critical angle

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$n_1 \sin\theta_c \qquad \sin\theta_2 = 1$$

$$\sin\theta_c = \frac{n_2}{n_1}$$

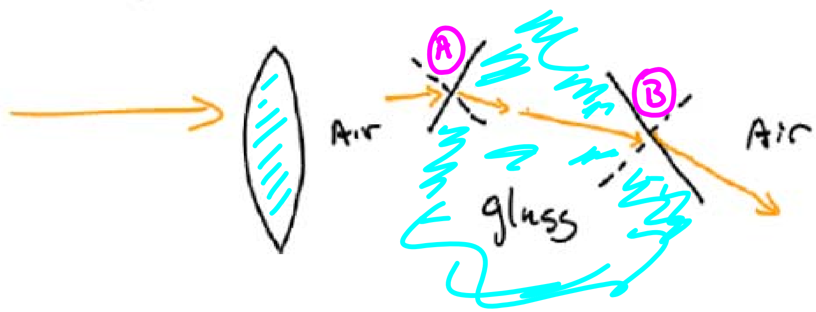


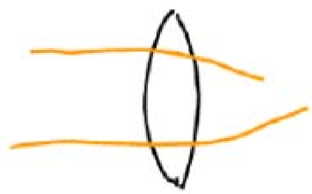


because $n_{red} < n_{blue}$

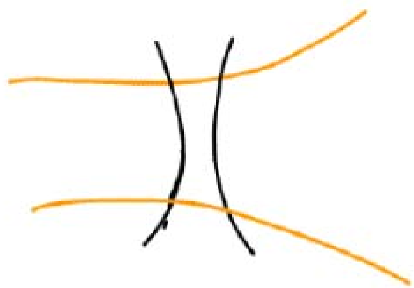
red bent less

operation of a thin convex lens



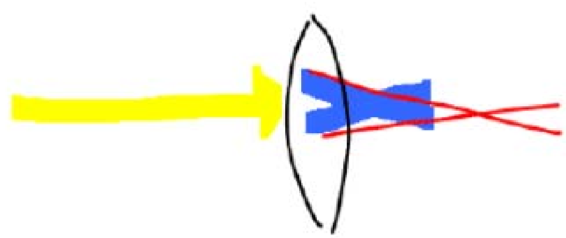


converging lens



diverging lense

abberation



chromatic dispersion

pulse broadening

# Thin lenses and optical instruments

Physics 142

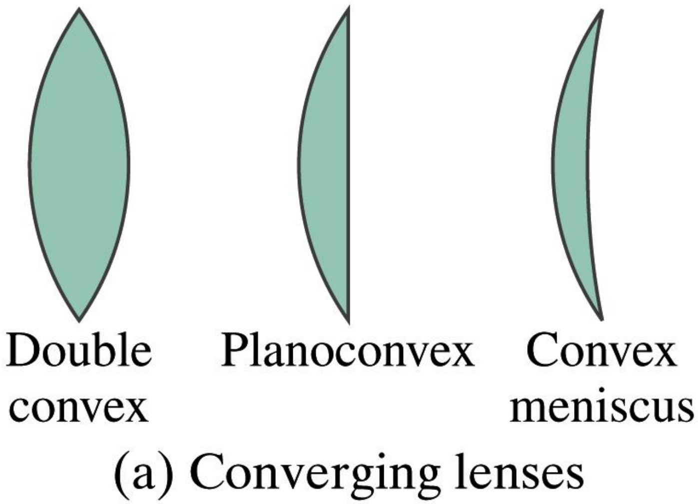
Fall 2014 - S. Manly

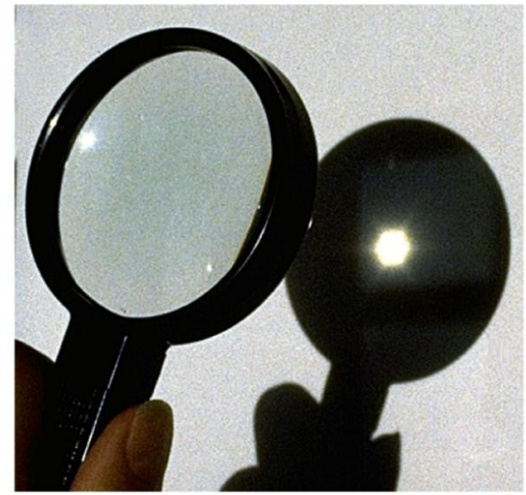
**References and photo sources:**

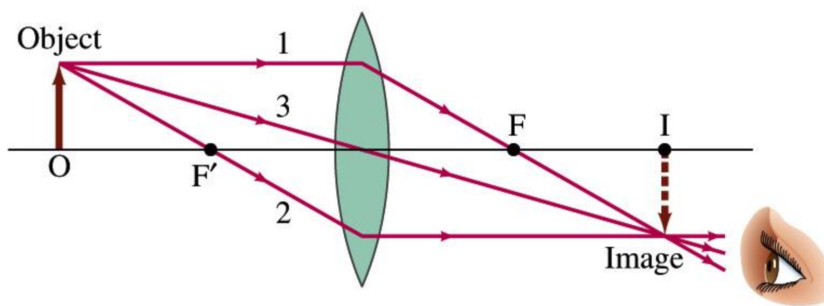
**D. Giancoli, Physics for Scientists and Engineers, 3rd ed., 2000, Prentice-Hall**

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

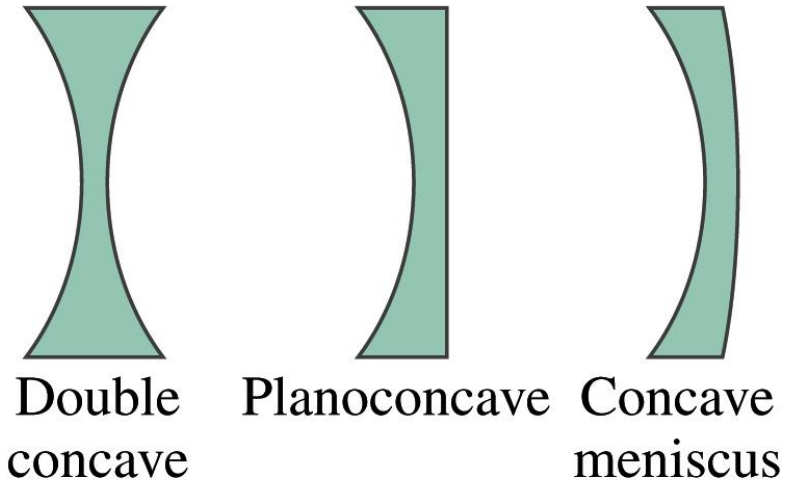
**http://www.ebiomedia.com**



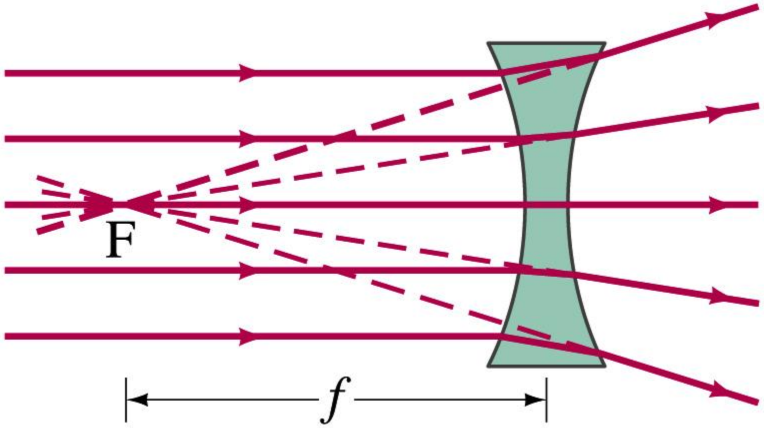



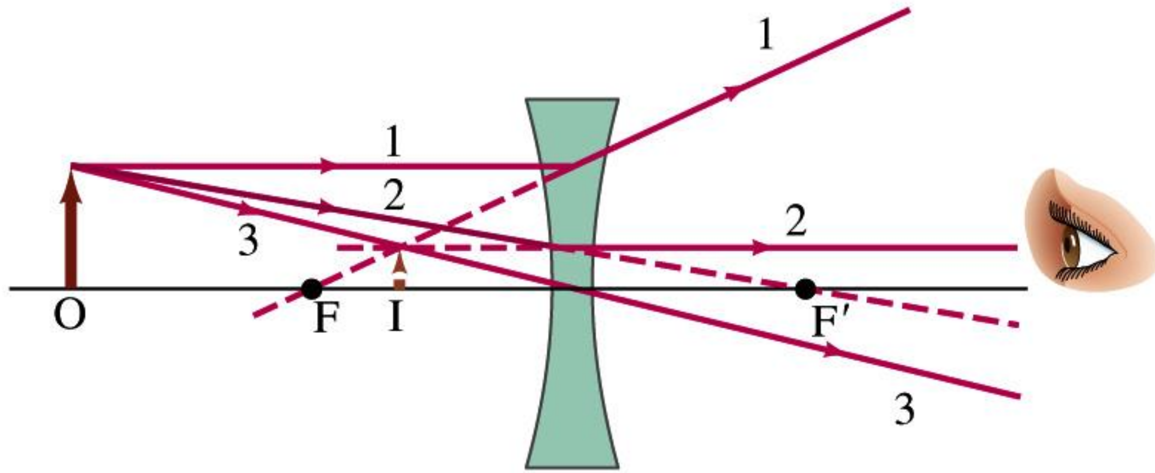



(c) Ray 3 passes straight through the center of the lens (assumed very thin).




(b) Diverging lenses

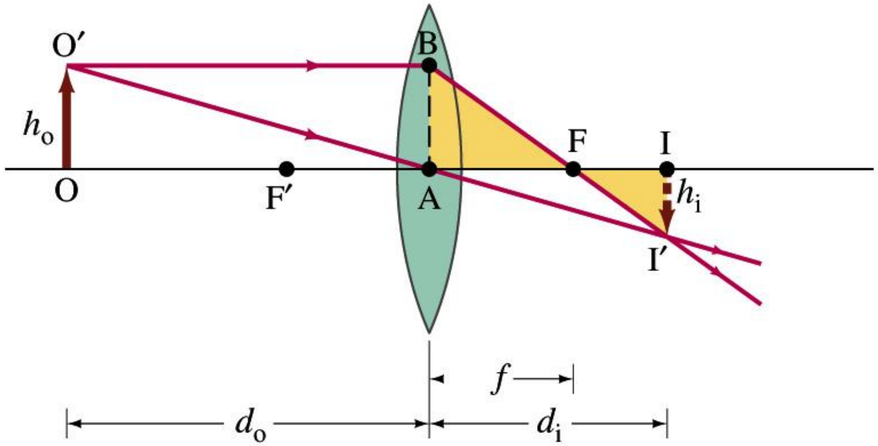



1
1
2
2
3
O
F
I
F′
3

# Power of lens measured in diopters

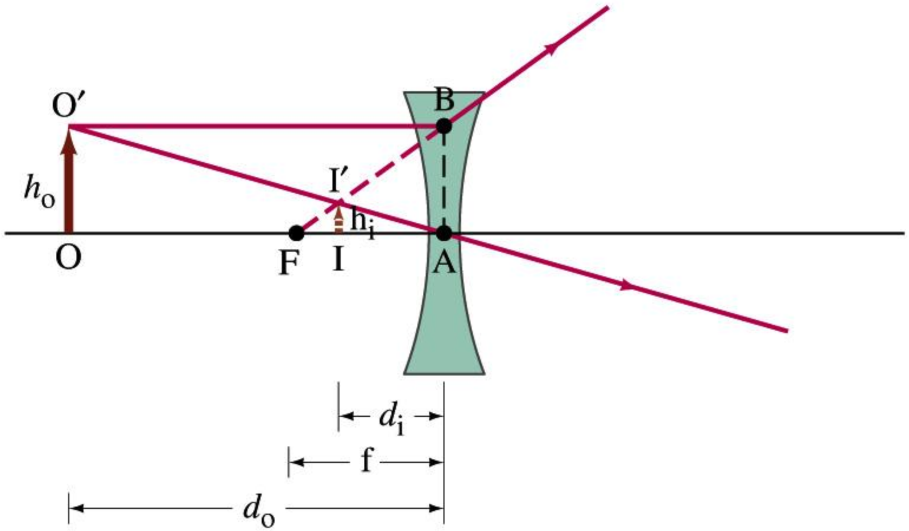
$$P = \frac{1}{f}$$ where f is focal length in meters

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:

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

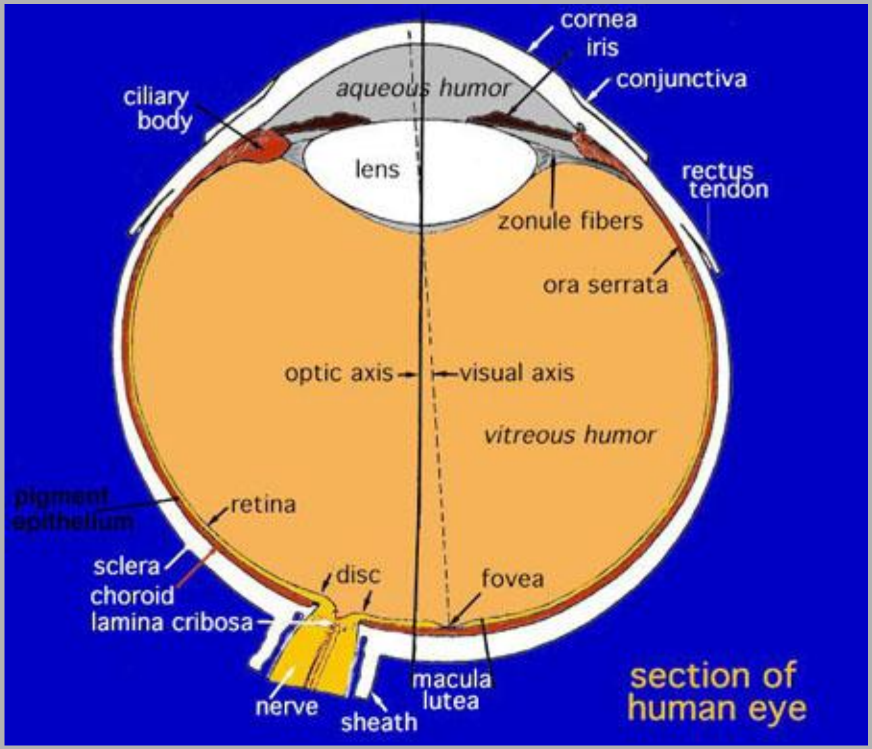
**Real image: rays actually pass thru image**

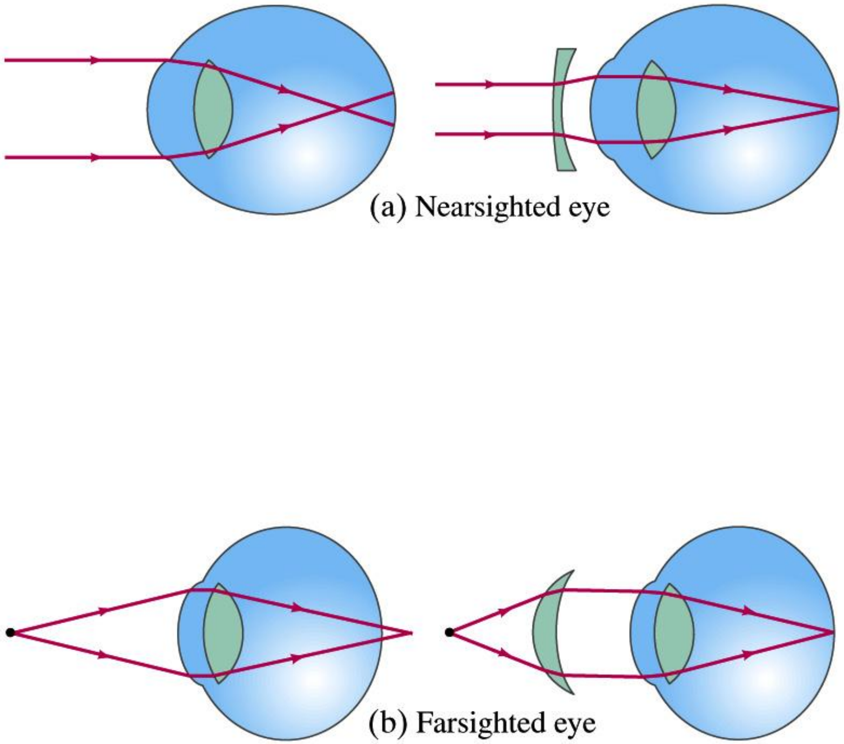
**Virtual image: rays do not actually pass thru image**

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

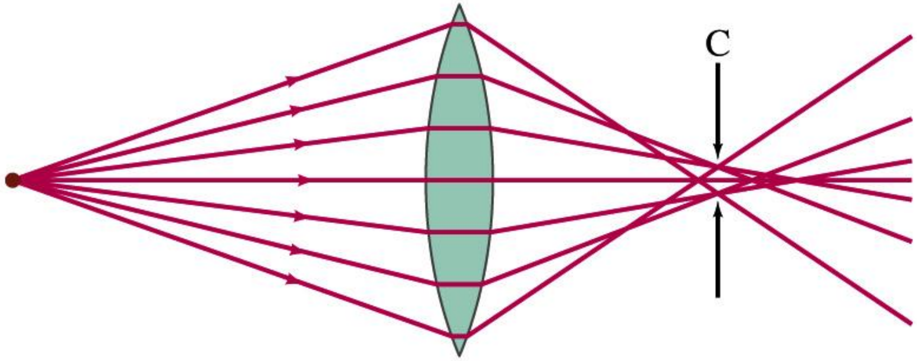
**Convention from Giancoli p. 841:**

- **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 +.**

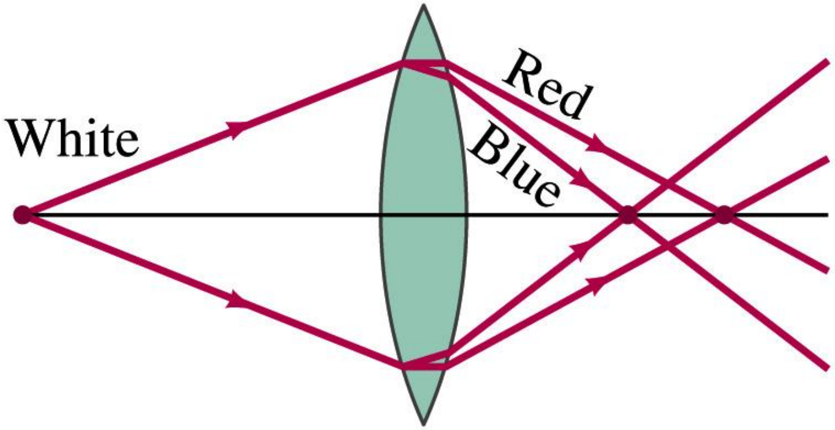

cornea
iris
conjunctiva
ciliary body
aqueous humor
lens
rectus tendon
zonule fibers
ora serrata
optic axis
visual axis
vitreous humor
pigment epithelium
retina
sclera
choroid
lamina cribosa
disc
fovea
macula lutea
nerve
sheath
section of human eye


(a) Nearsighted eye
(b) Farsighted eye

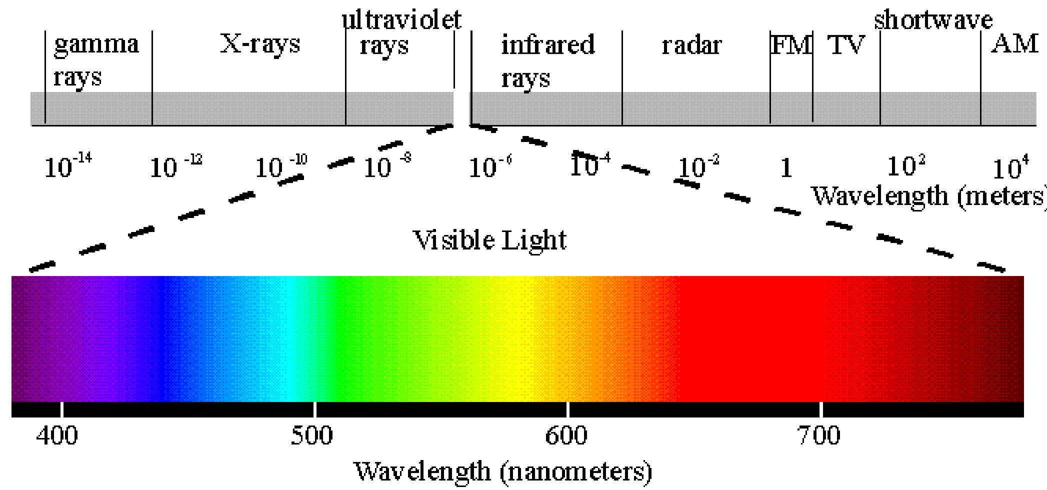
# Aberrations



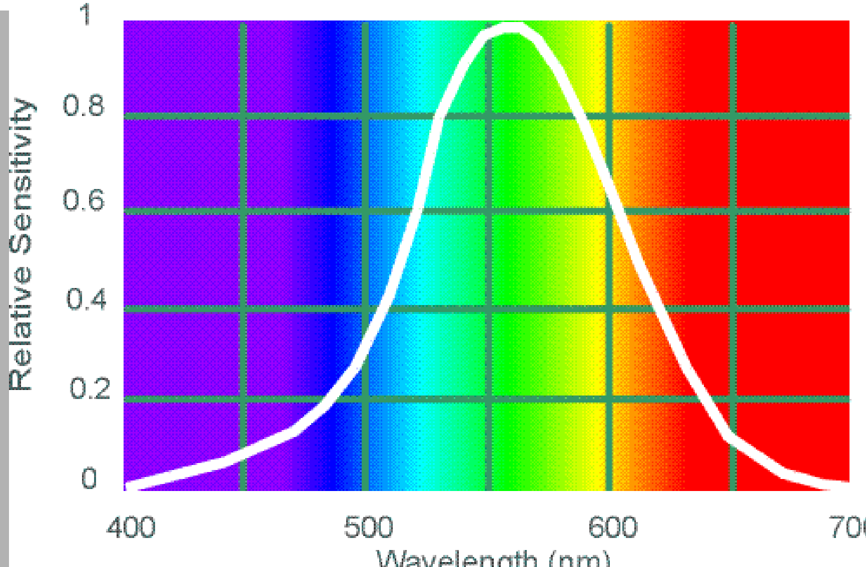

Spherical aberration

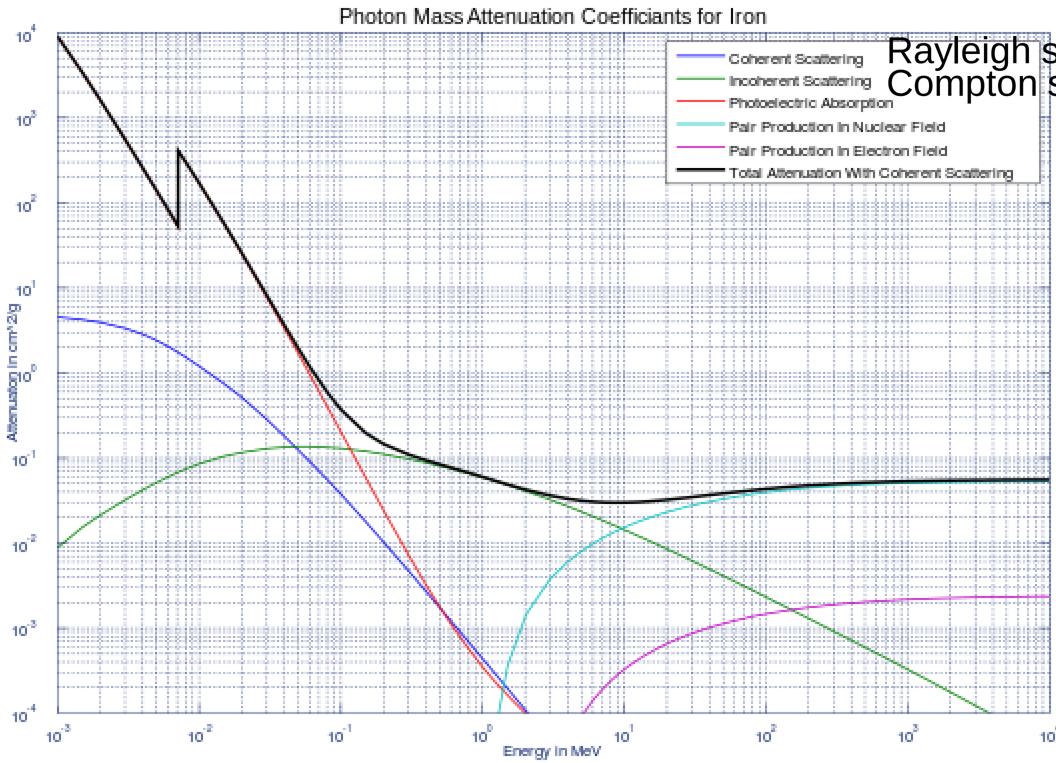



Chromatic aberration

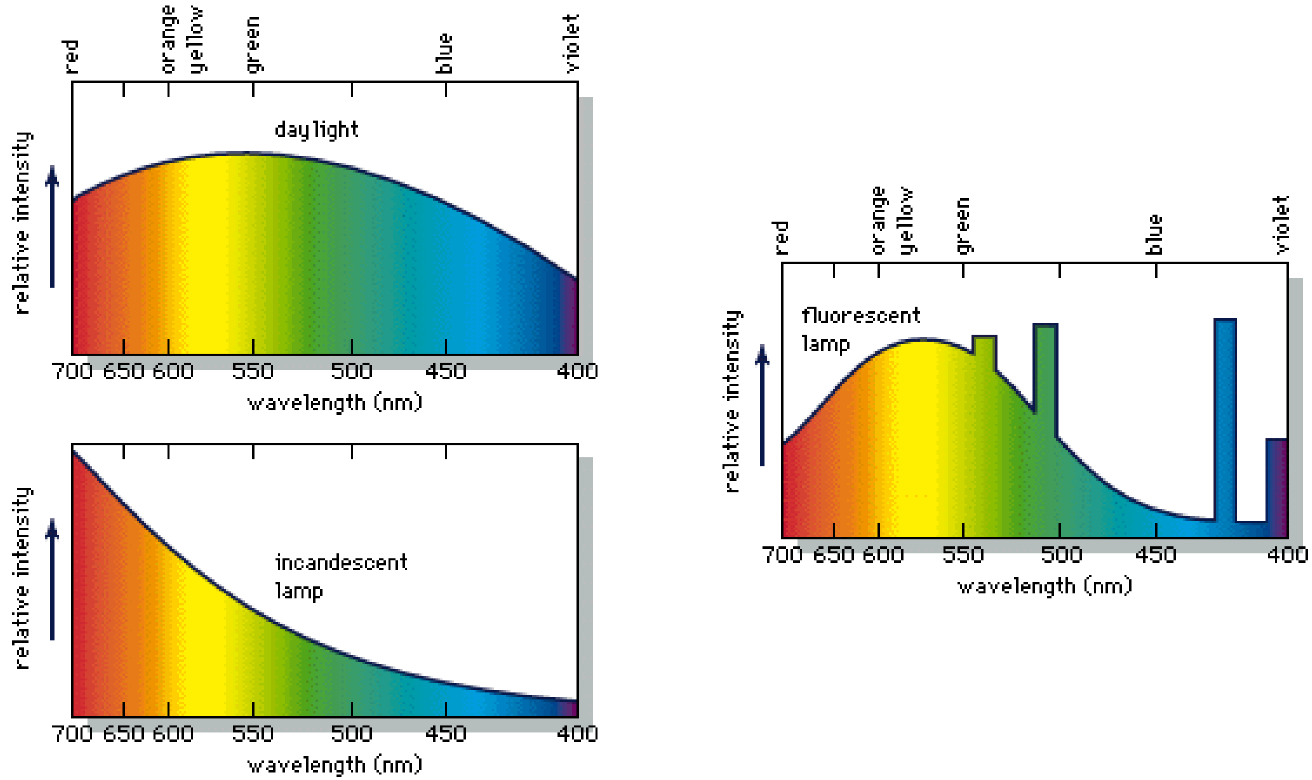



The electromagnetic spectrum
from "The Joy of Visual Perception: A Web Book"
http://www.yorku.ca/eye/



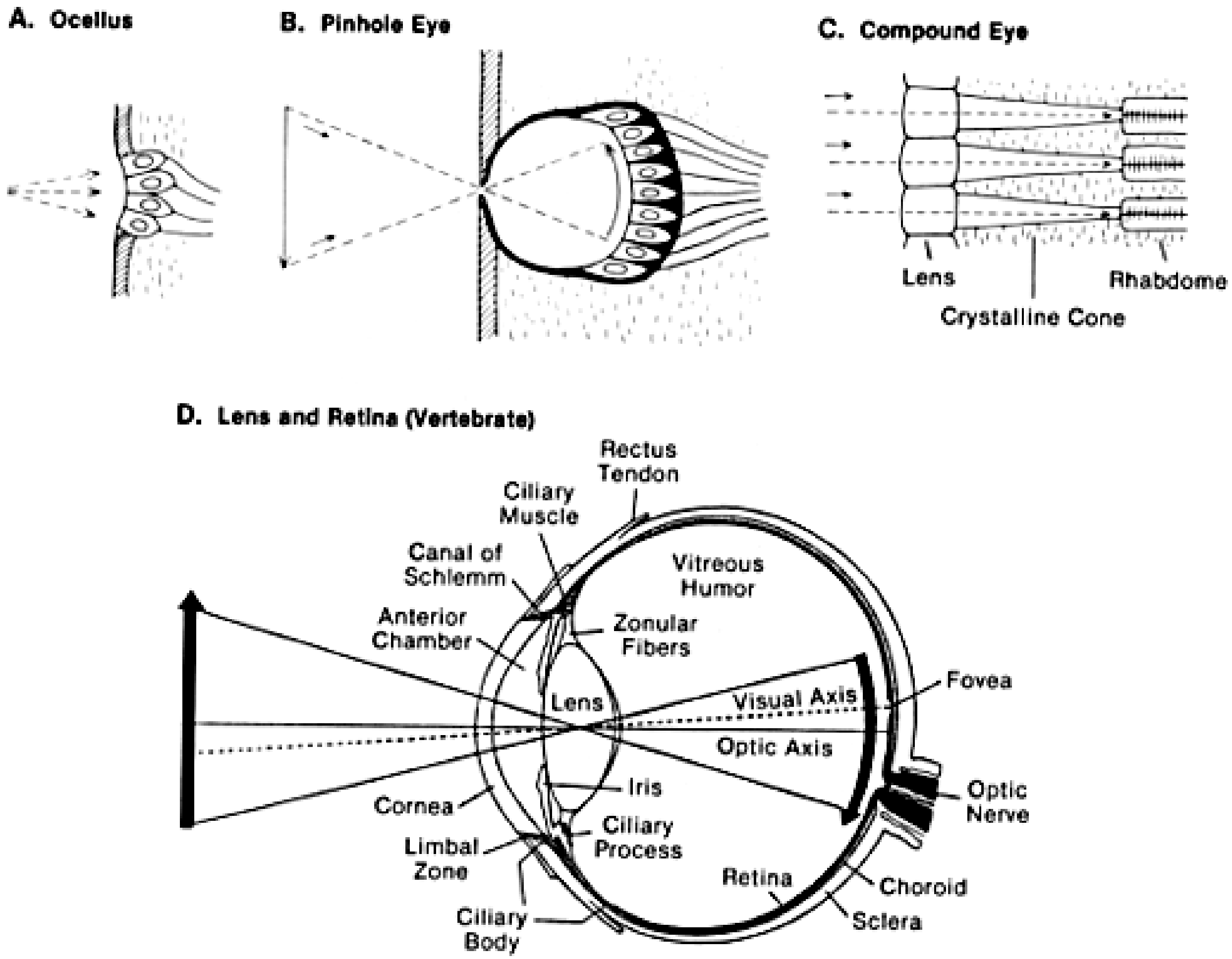


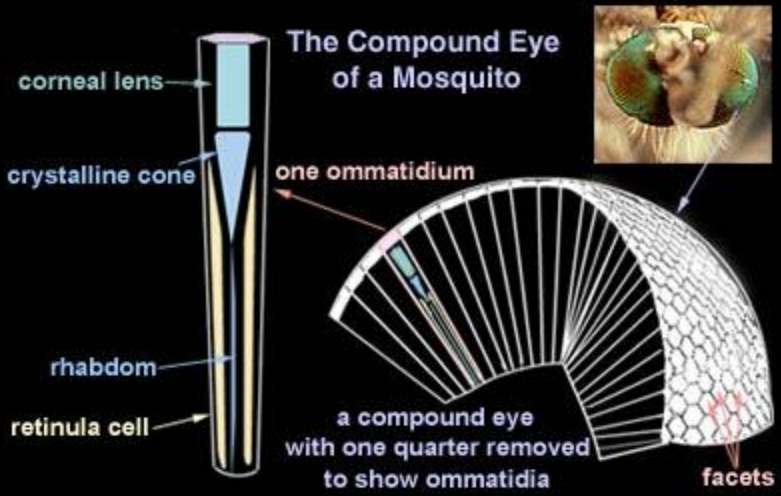

Rayleigh scatt.
Compton scatt.



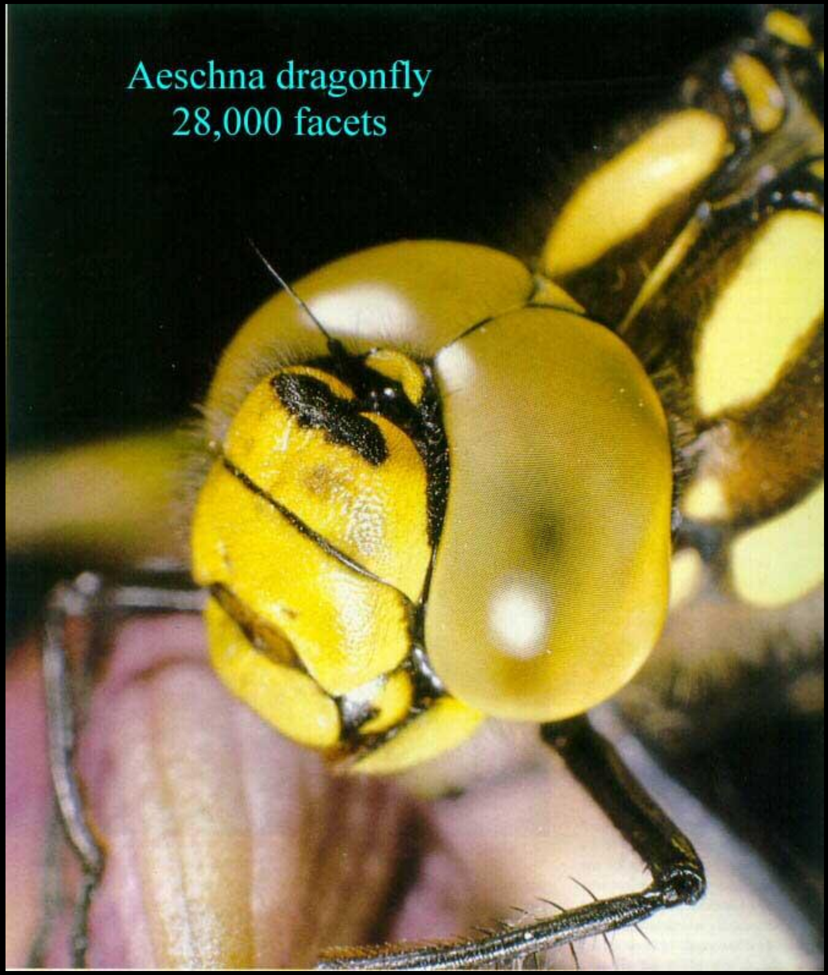
red
orange
yellow
green
blue
violet
daylight
relative intensity
700 650 600 550 500 450 400
wavelength (nm)
incandescent
lamp
relative intensity
700 650 600 550 500 450 400
wavelength (nm)
red
orange
yellow
green
blue
violet
fluorescent
lamp
relative intensity
700 650 600 550 500 450 400
wavelength (nm)

# Types of eyes in the animal kingdom



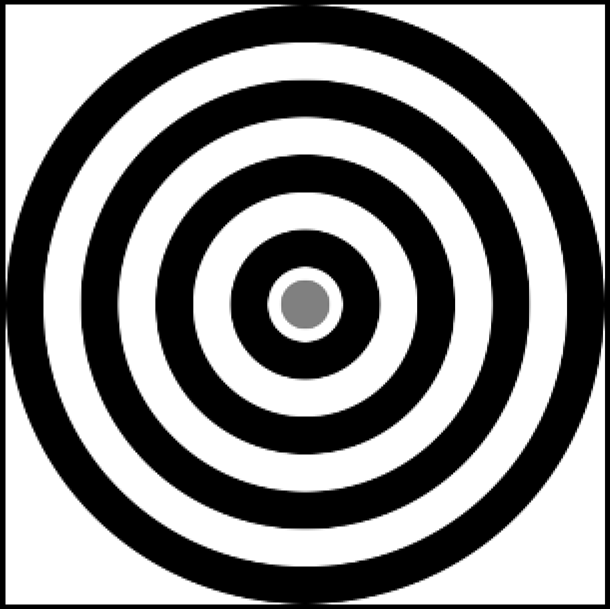


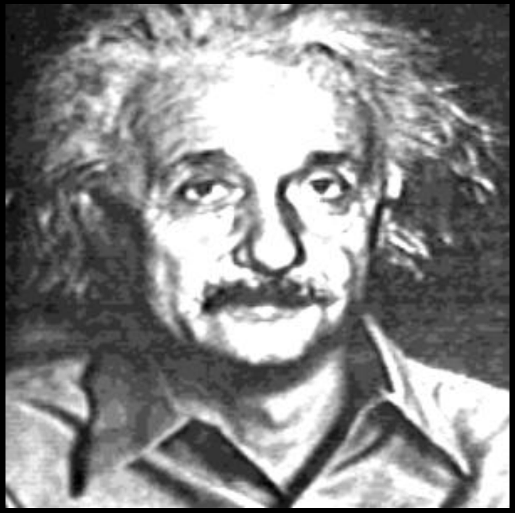
The Compound Eye
of a Mosquito
corneal lens
crystalline cone
one ommatidium
rhabdom
retinula cell
a compound eye
with one quarter removed
to show ommatidia
facets

Aeschna dragonfly
28,000 facets

## A bee's eye view





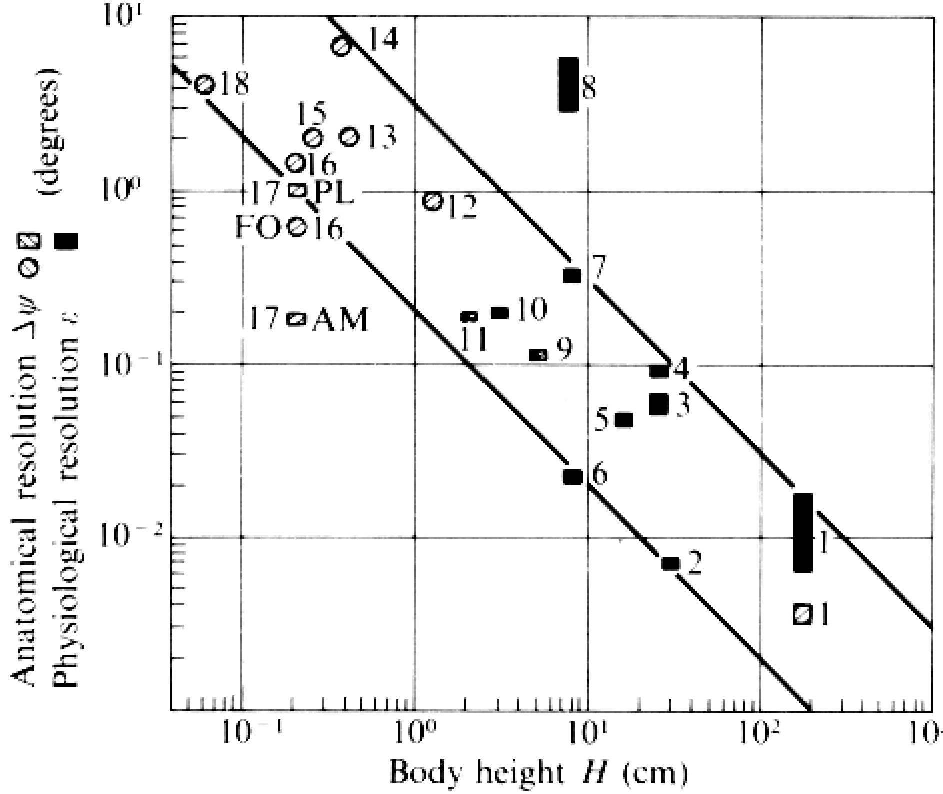
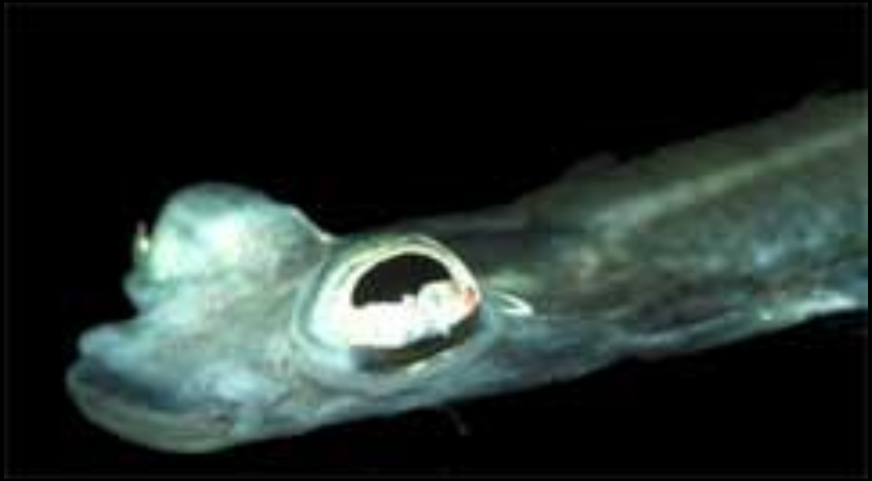
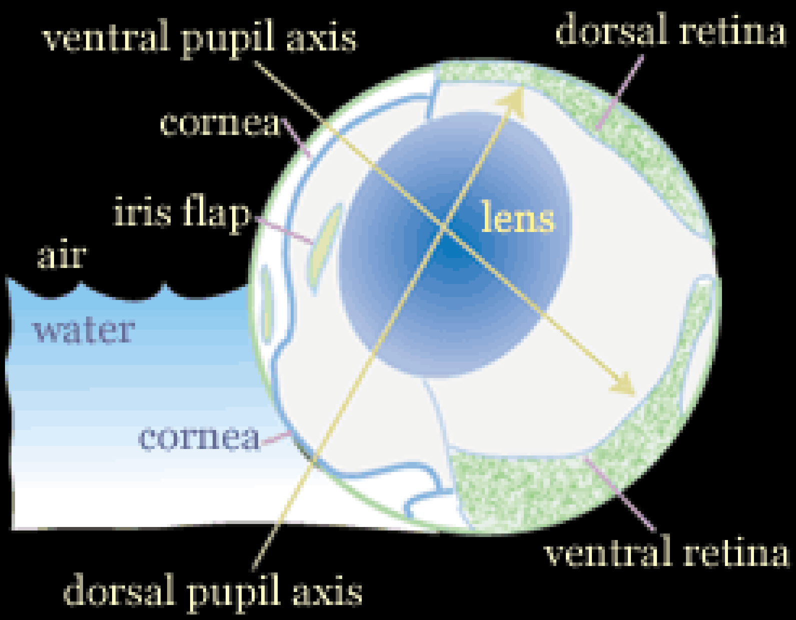



Fig. 2.9. Resolution of the eyes of various animals measured physiologically and deduced from anatomical criteria compared to body height: (1) man; (2) peregrine falcon; (3) hen; (4) cat; (5) pigeon; (6) chaffinch; (7) rat; (8) bat (*Myotis*); (9) frog; (10) lizard; (11) minnow; (12) dragonfly (*Aeschna*);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

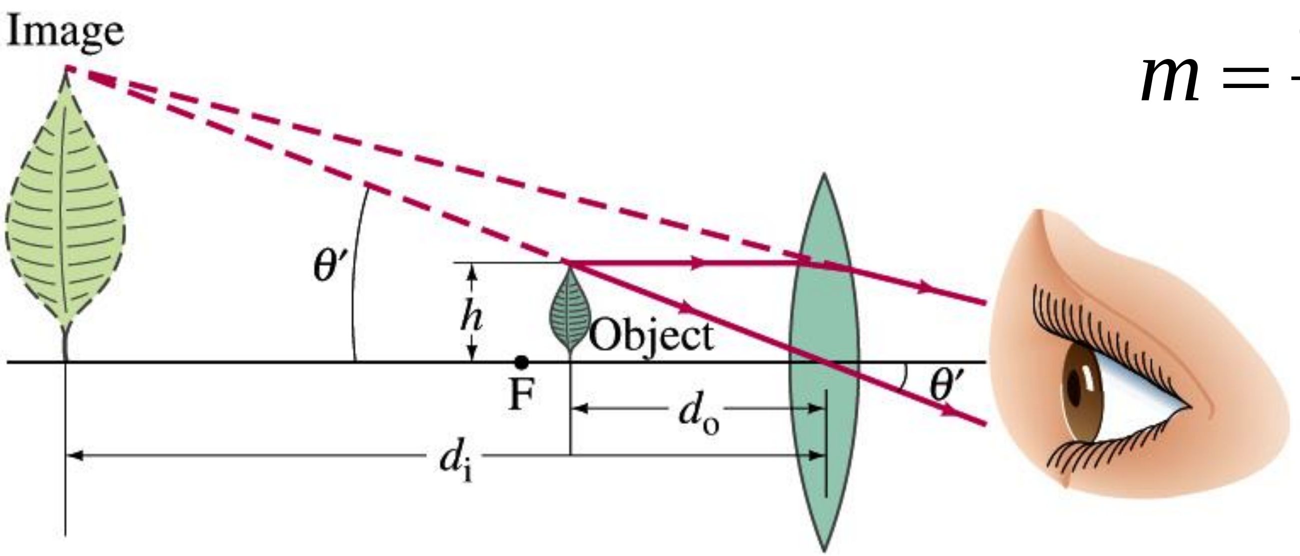
# Anableps - minnow

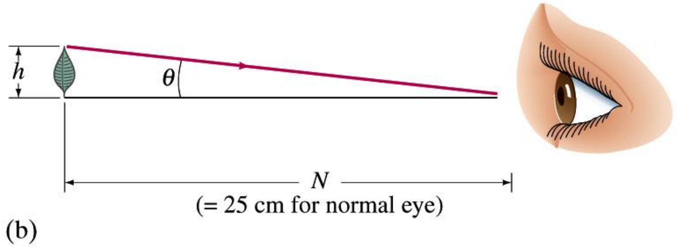


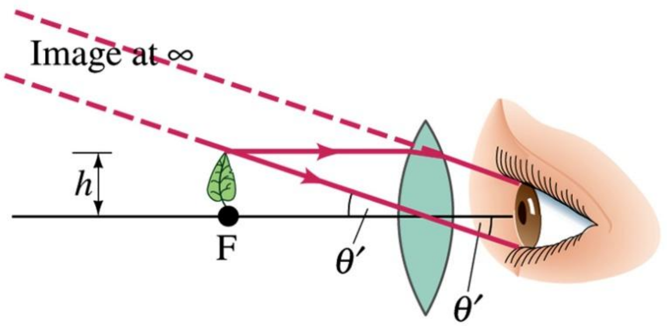


# Magnifying glass

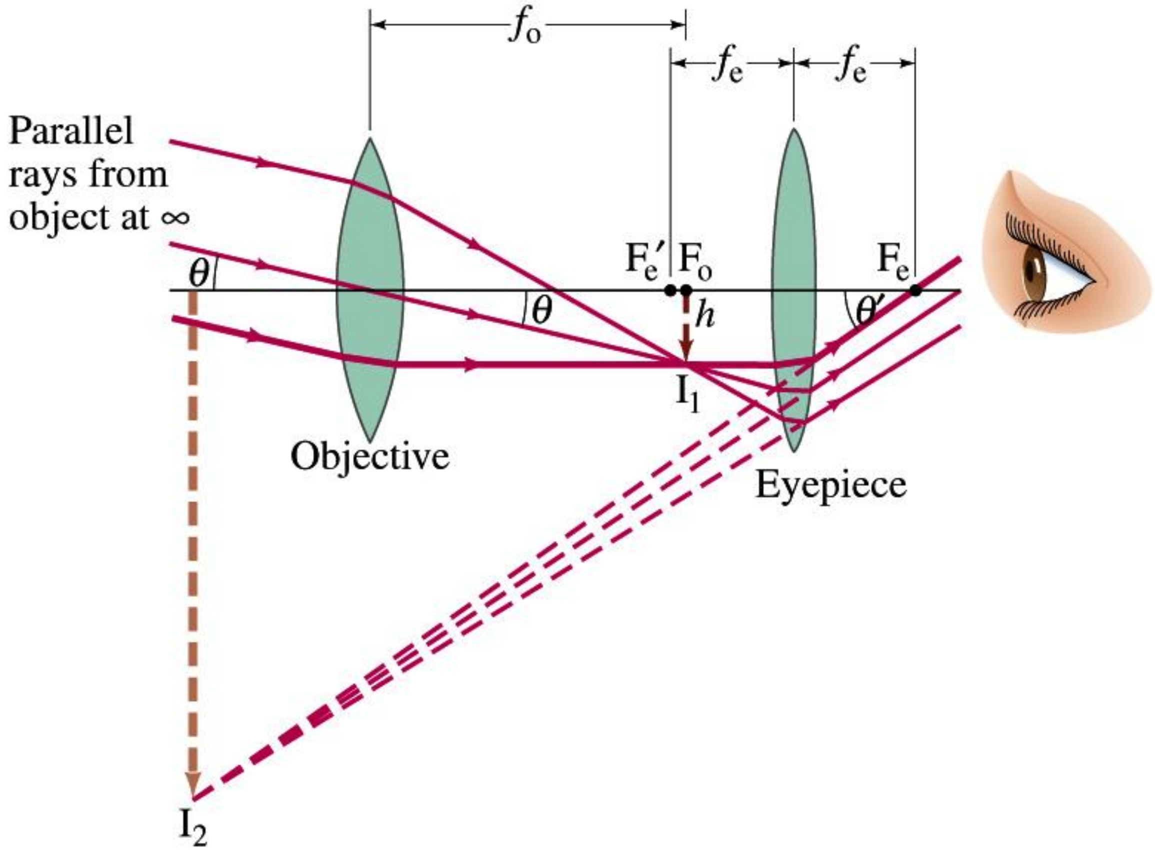
$$m = \frac{\theta'}{\theta} = \frac{N}{f}$$



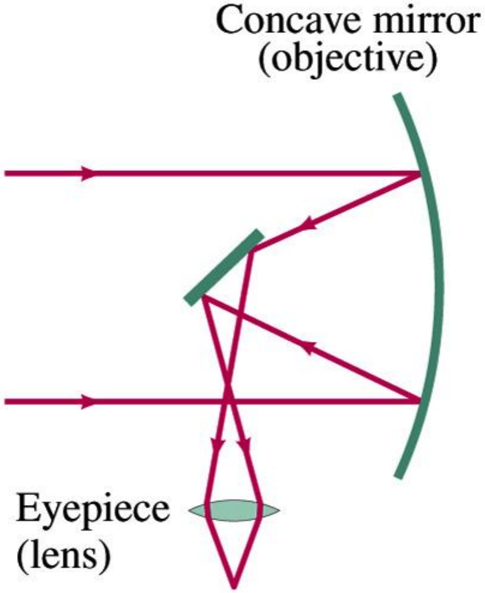



# Refracting telescope

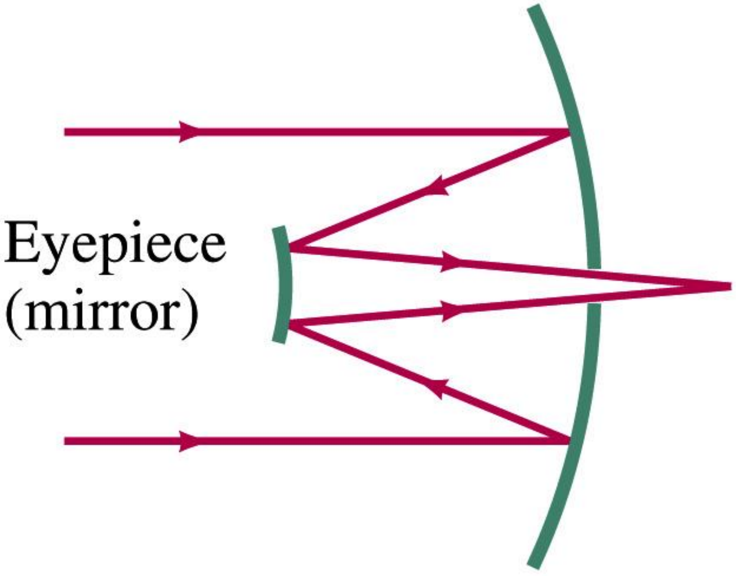



40 inch refractor – Yerkes Observatory

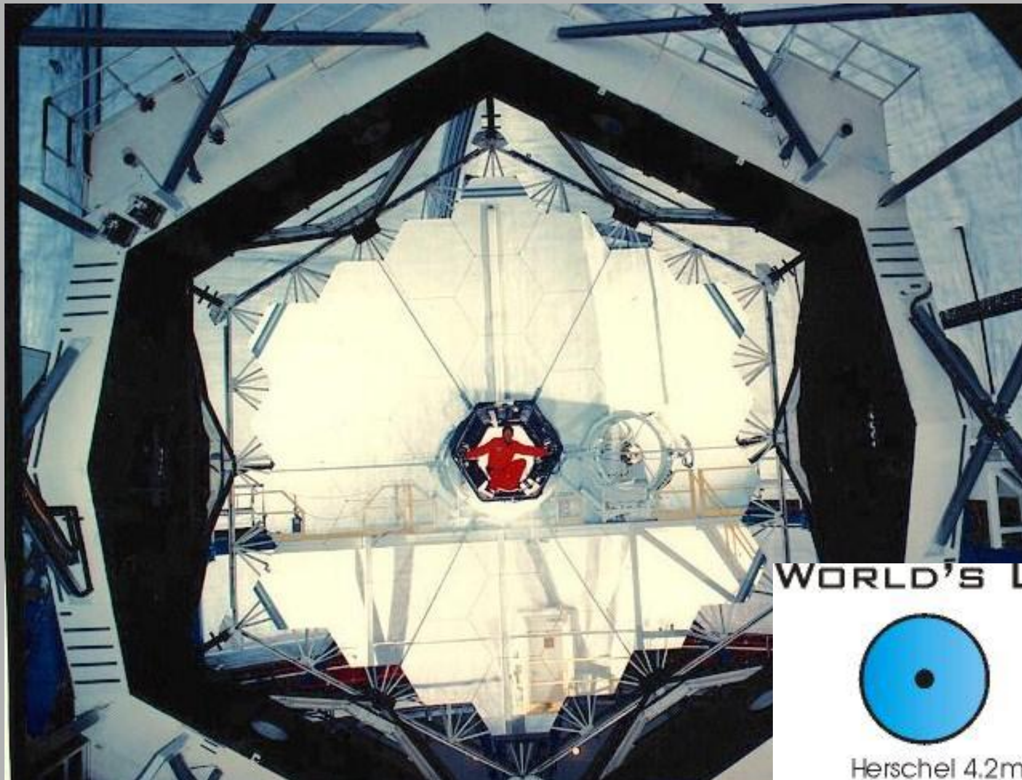
# Reflecting telescope

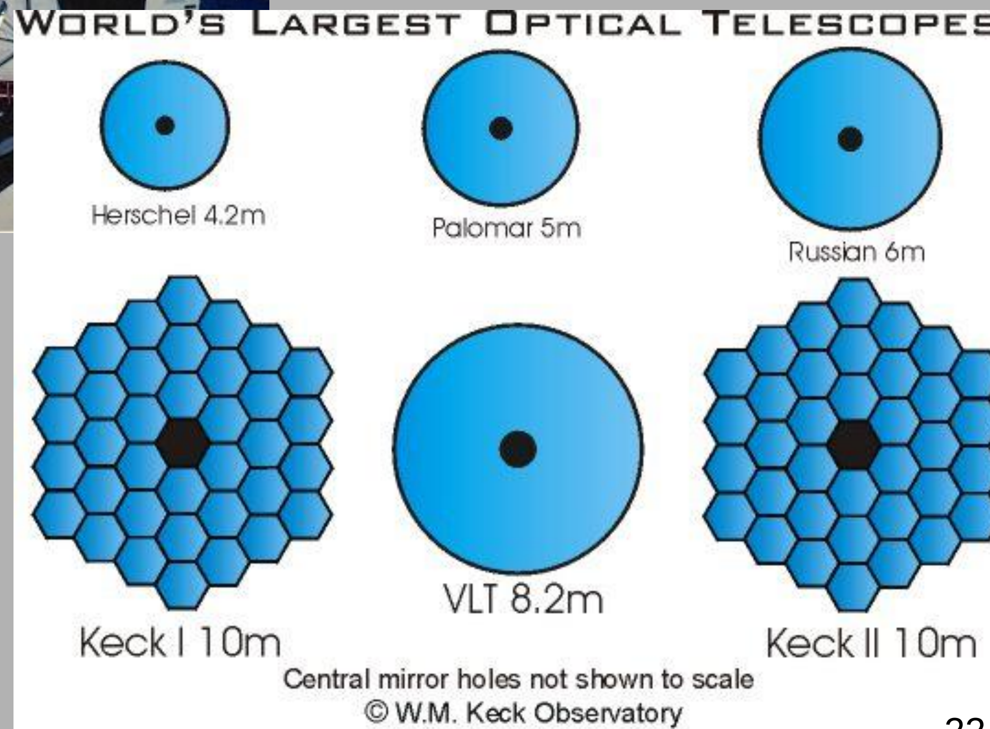


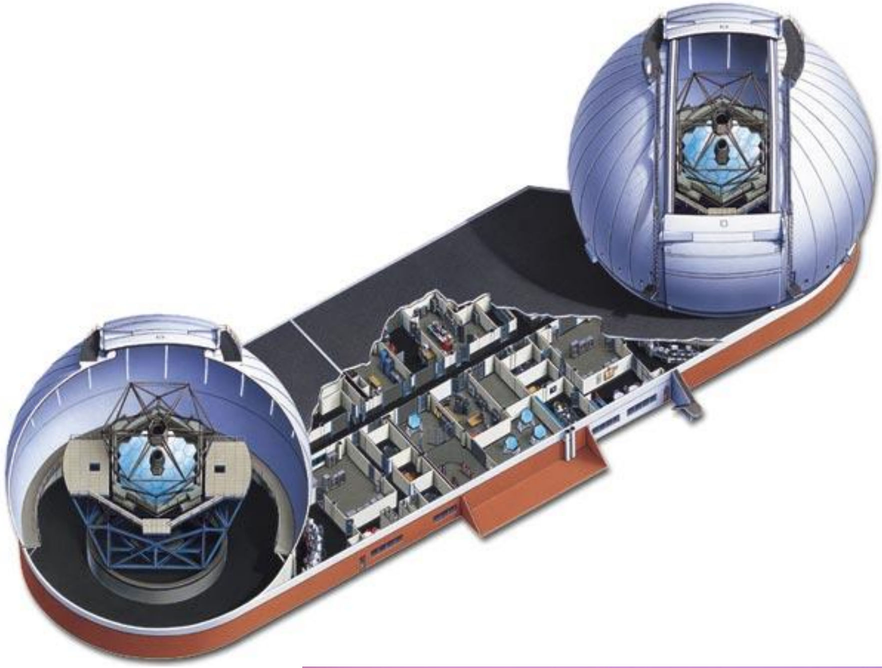

(a)

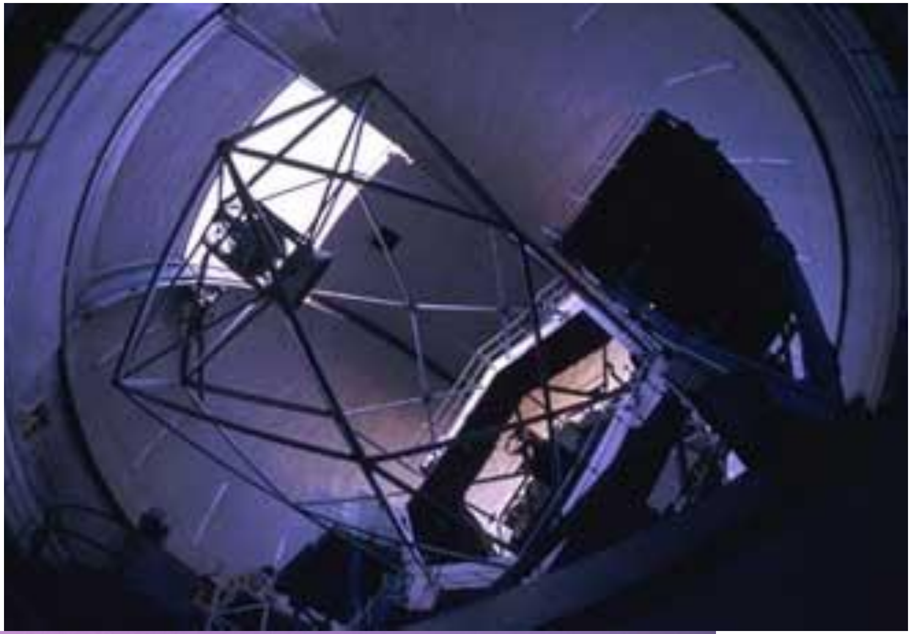



(b)



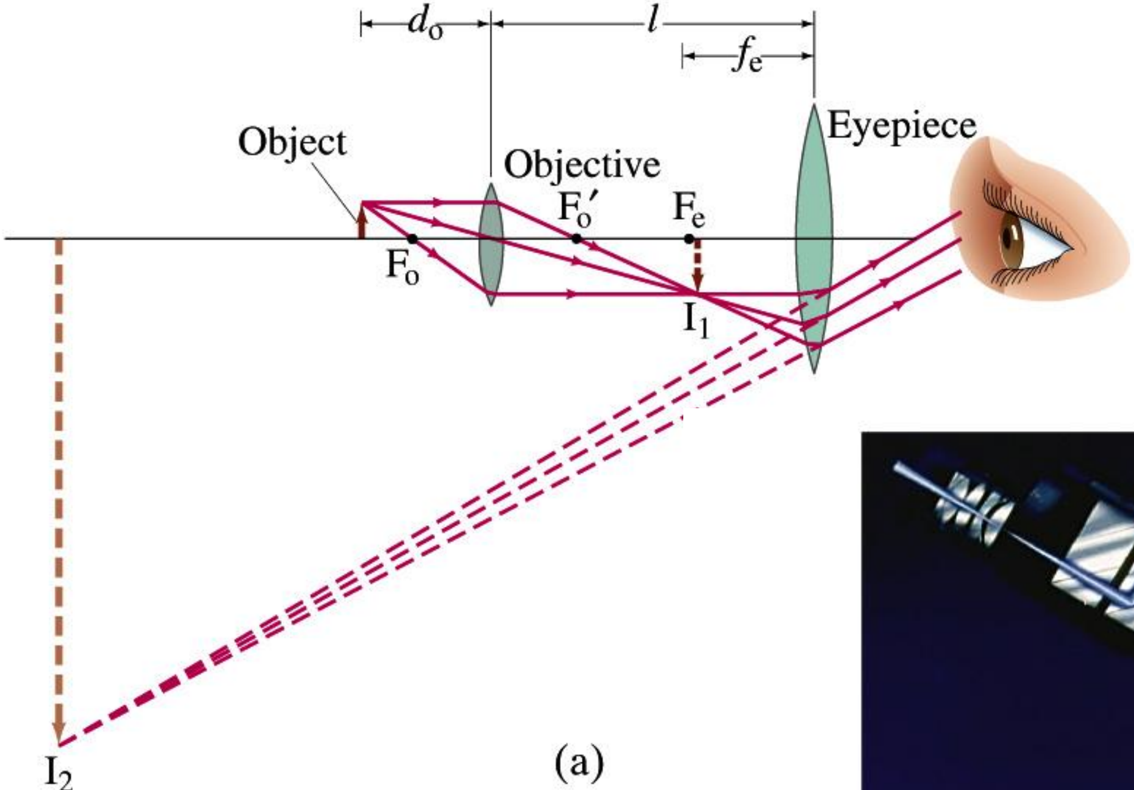

WORLD'S LARGEST OPTICAL TELESCOPES
Herschel 4.2m
Palomar 5m
Russian 6m
Keck I 10m
VLT 8.2m
Keck II 10m
Central mirror holes not shown to scale
© W.M. Keck Observatory





# Keck Observatory

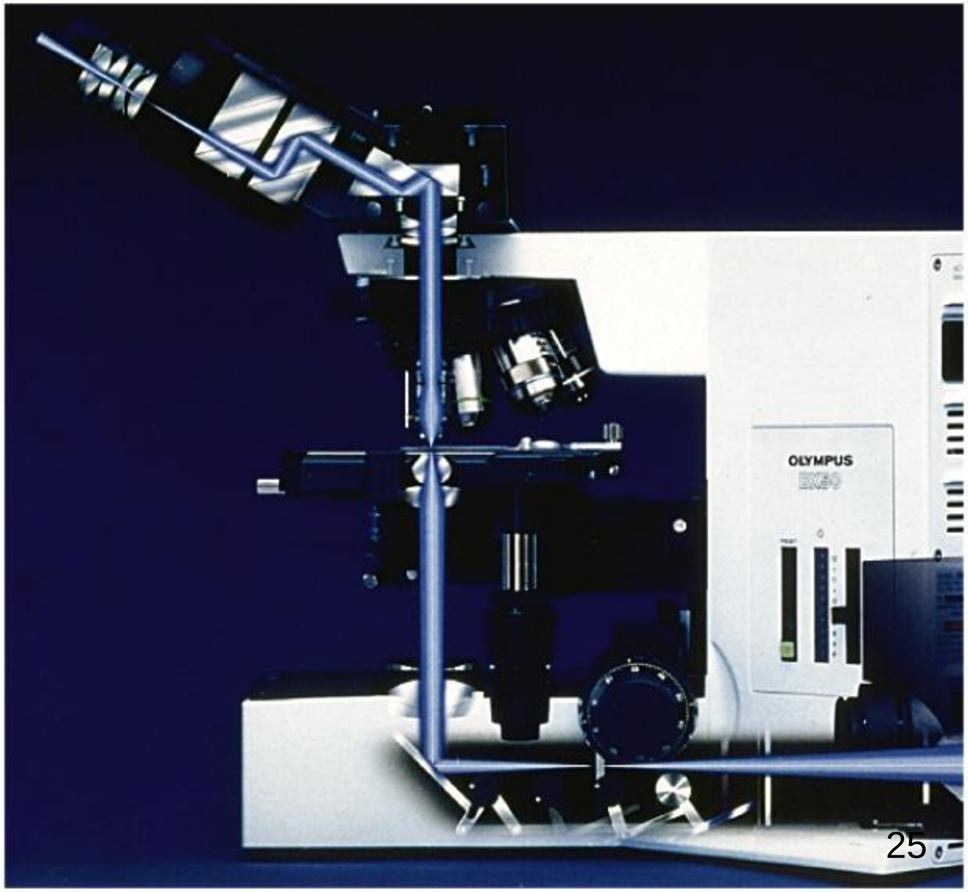

Hubble Space Telescope



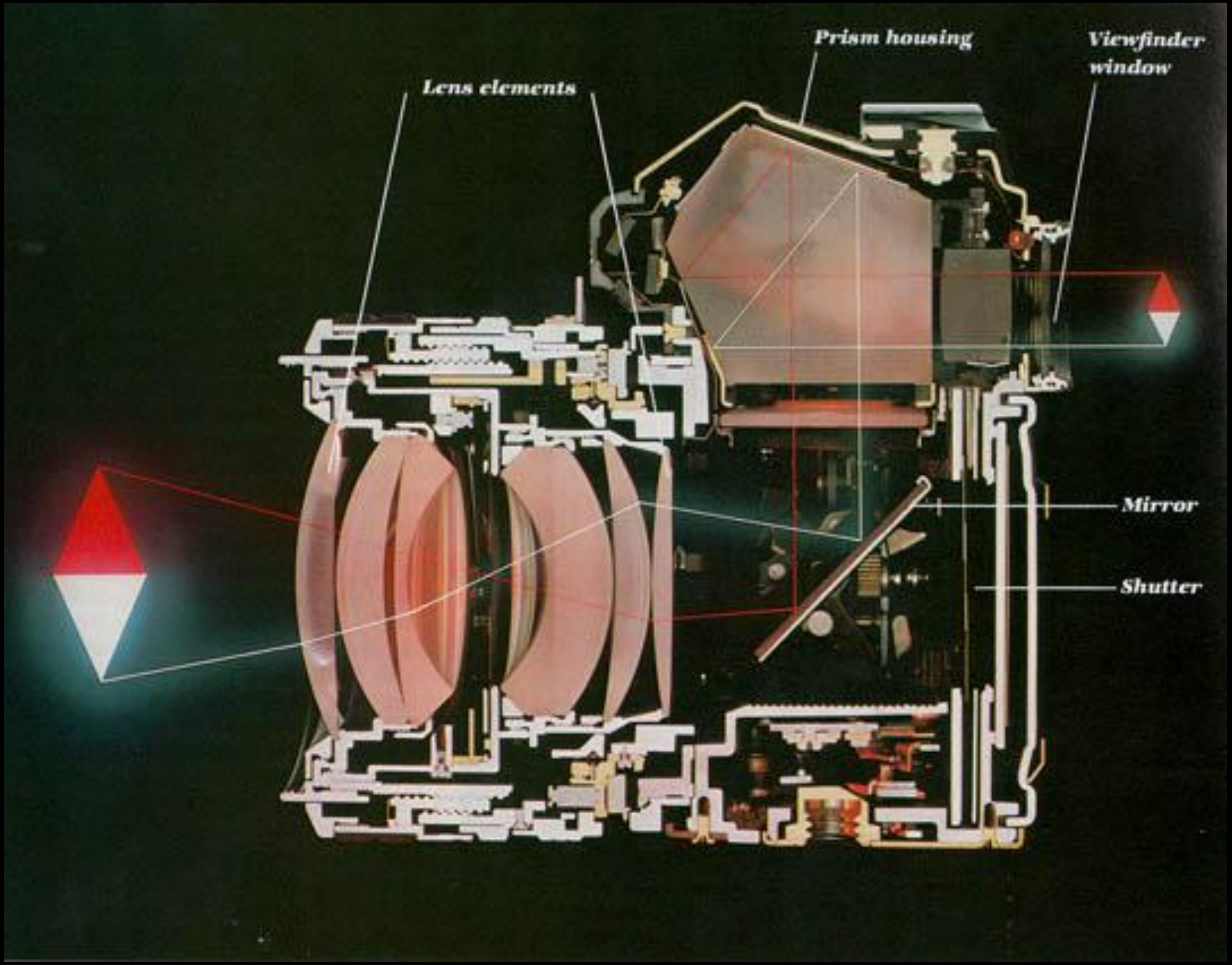
(a)

**Compound microscope**

(b)



# Camera



Prism housing
Viewfinder window
Lens elements
Mirror
Shutter

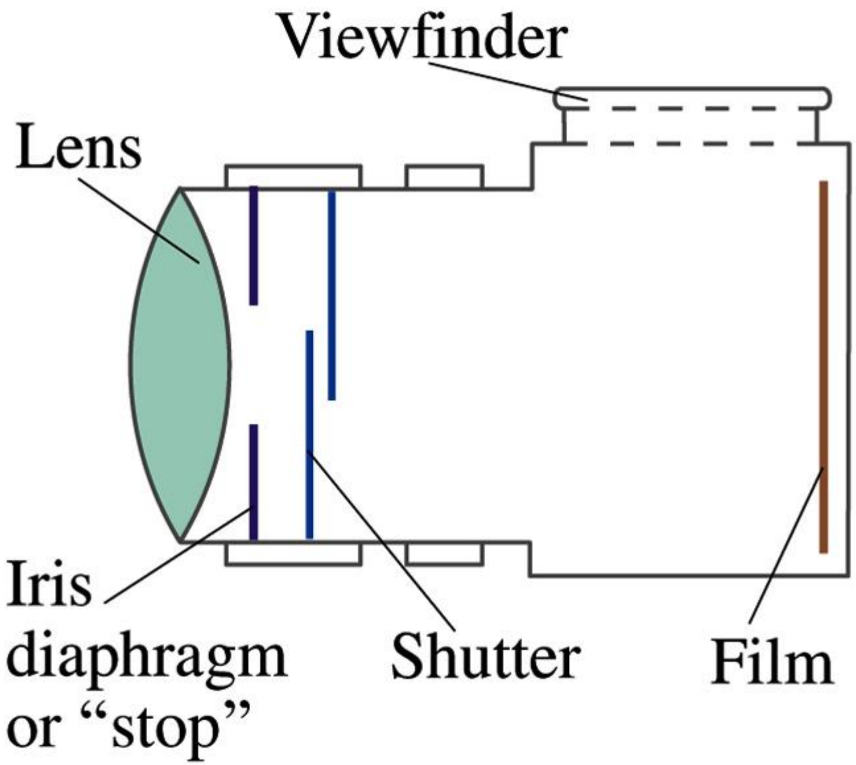
Light vs. depth of field

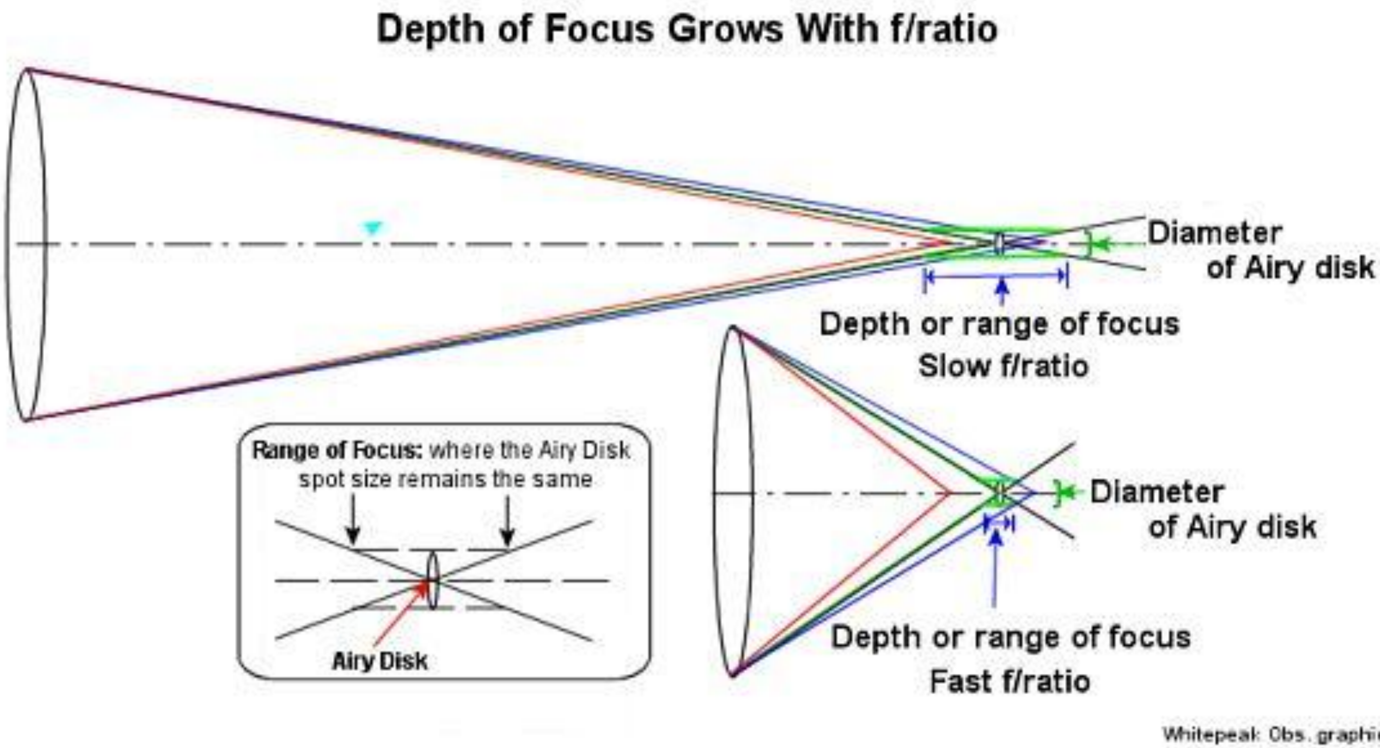
Shutter speed

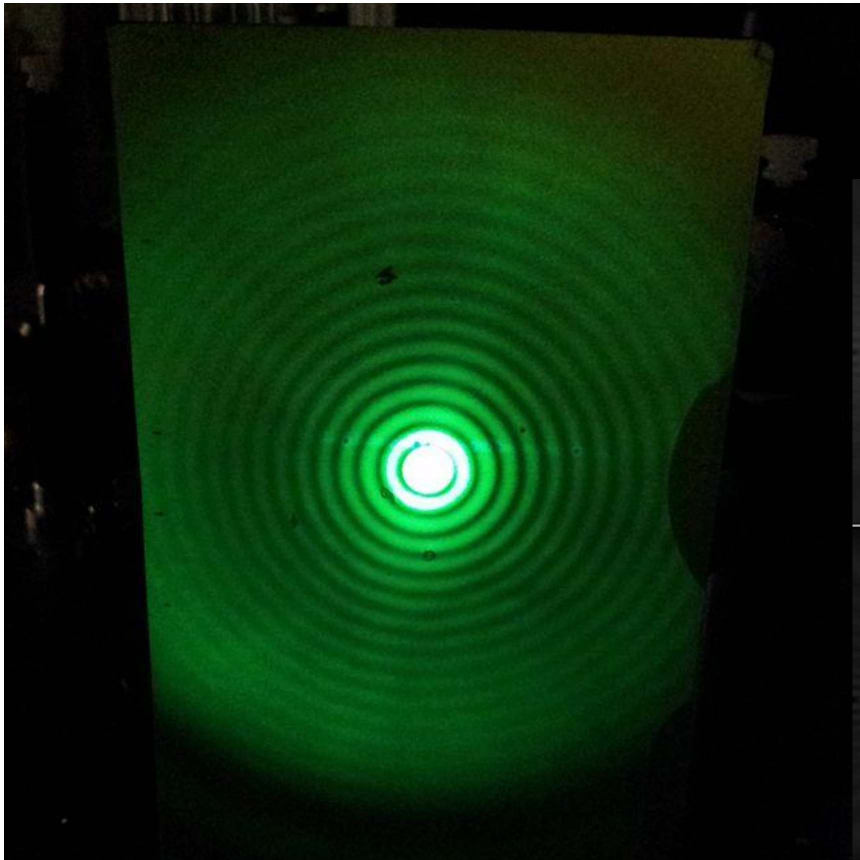
f-stop=f/D, each f-stop=factor of 2 in light intensity

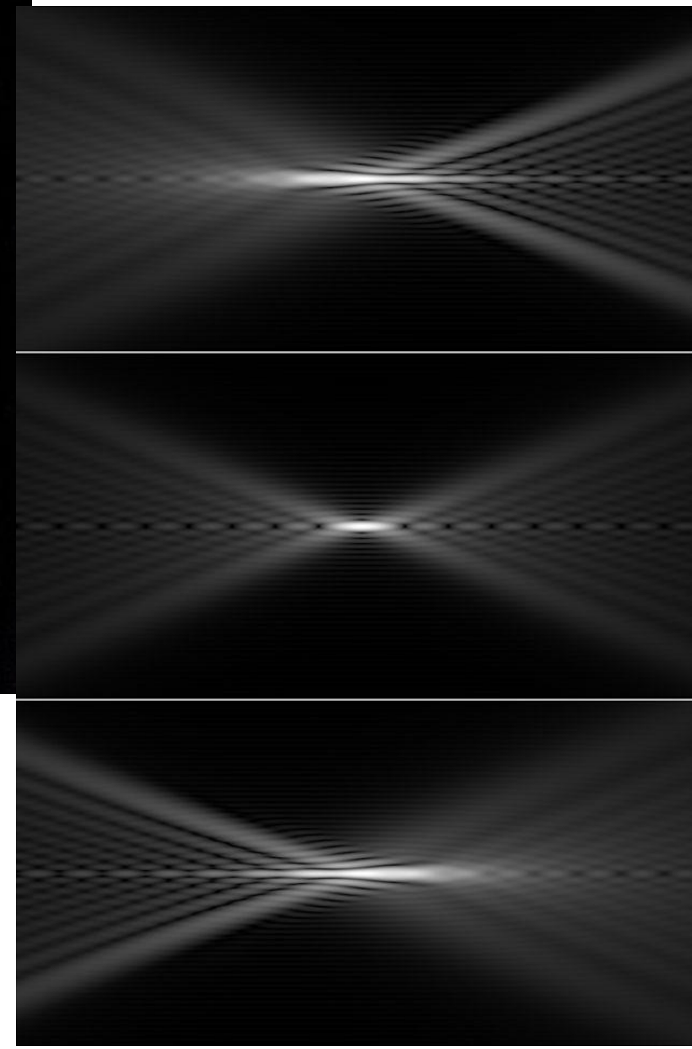
Faster the object or darker the day, need slower speed and/or larger D

Larger D means narrower depth of field




Depth of Focus Grows With f/ratio
Diameter of Airy disk
Depth or range of focus
Slow f/ratio
Range of Focus: where the Airy Disk spot size remains the same
Airy Disk
Diameter of Airy disk
Depth or range of focus
Fast f/ratio
Whitepeak Obs. graphic





Slow exposure time
(Note hand Motion)

Small opening

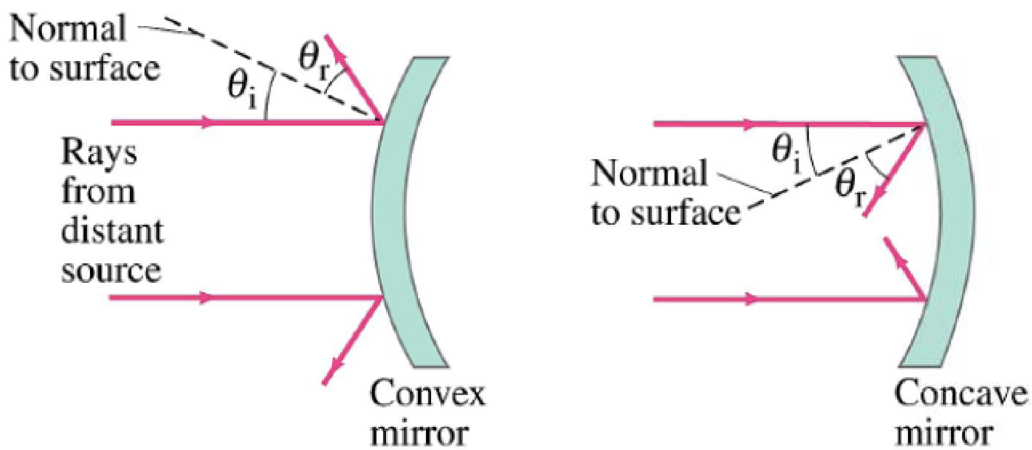
large depth of field
of focus

fast Time

large opening

Narrow Field of focus

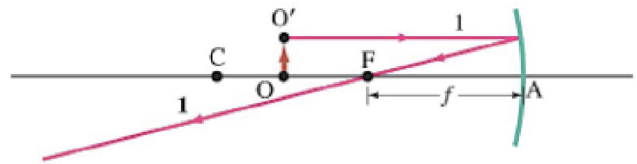
Spherical mirrors



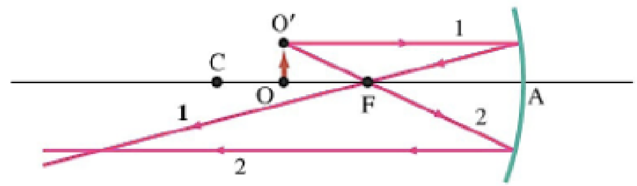

We will NOT cover
Spherical Mirrors
in Phy 142.
Rather similar
to thin lenses

# Ray Tracing – Spherical mirrors

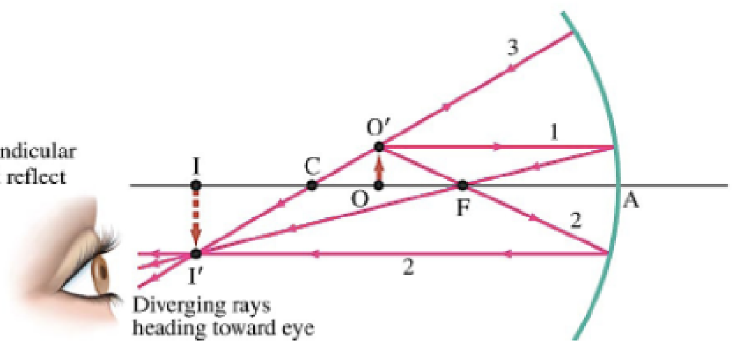
(a) Ray 1 goes out from O′ parallel to the axis and reflects through F.



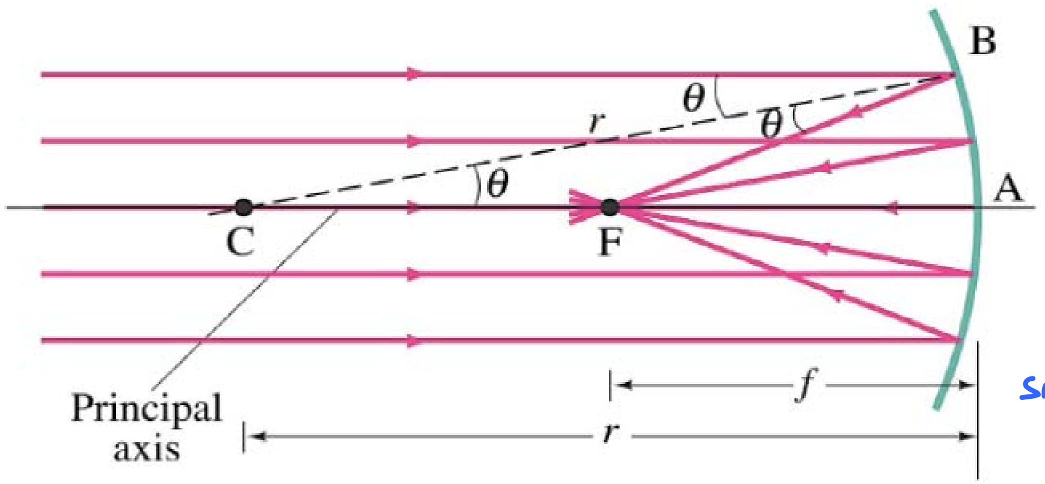

(b) Ray 2 goes through F and then reflects back parallel to the axis.




(c) Ray 3 is chosen perpendicular to mirror, and so must reflect back on itself and go through C (center of curvature).

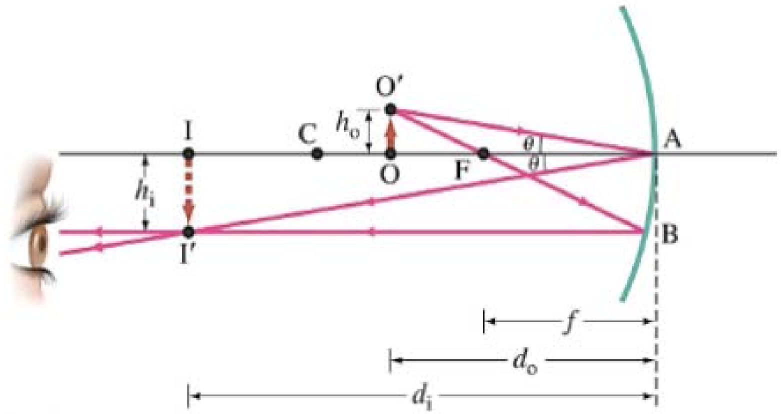


Source
Far
away




small curvature

$f = r/2$




Mirror Equation

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

magnification, $m \equiv \dfrac{h_i}{h_o} = -\dfrac{d_i}{d_o}$

image inverted