

Thin lenses and optical instruments

Physics 114

Spring 2010 - S. Manly

References and photo sources:

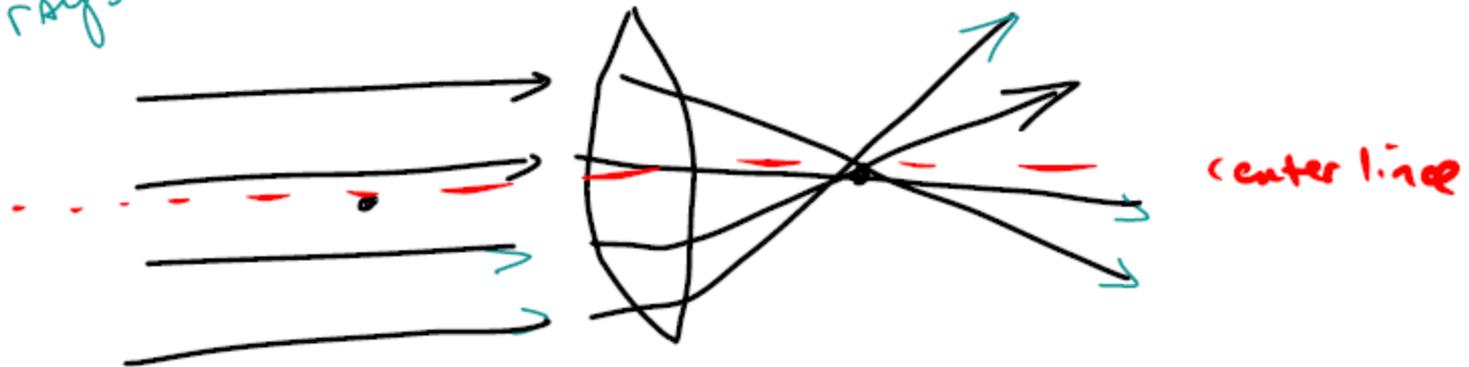
D. Giancoli, Physics for Scientists and Engineers, 3rd ed.,
2000, Prentice-Hall

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

<http://www.ebiomedia.com>

rays from ∞

converging lens

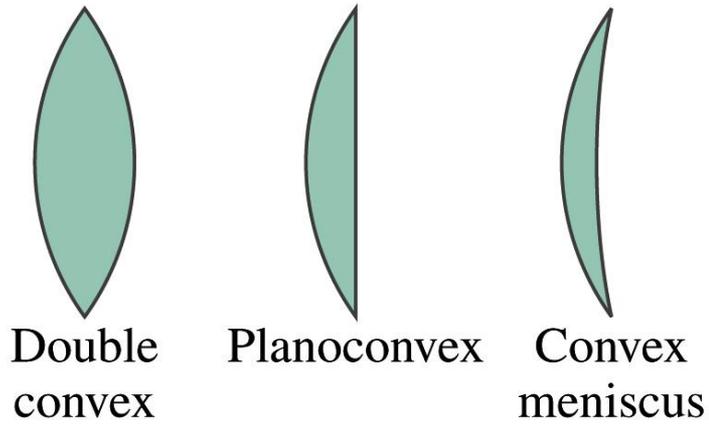


center line

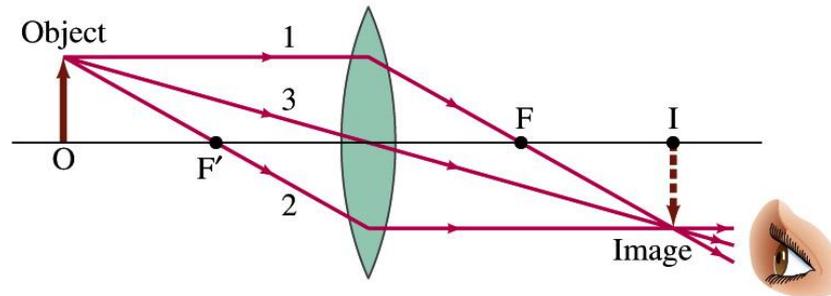
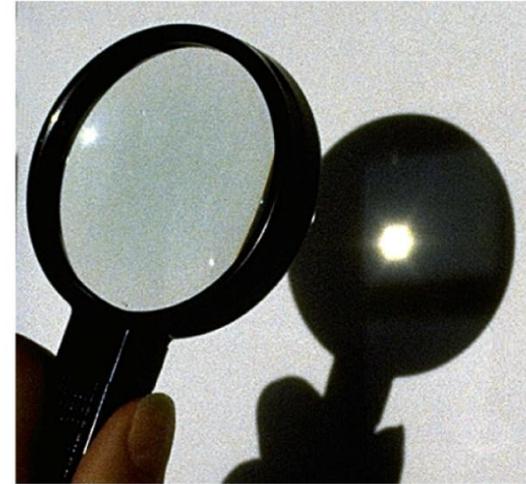
focal length

focal length

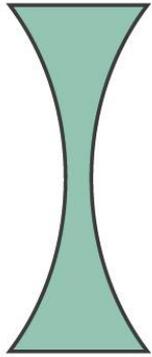
converging lens



(a) Converging lenses



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



Double
concave

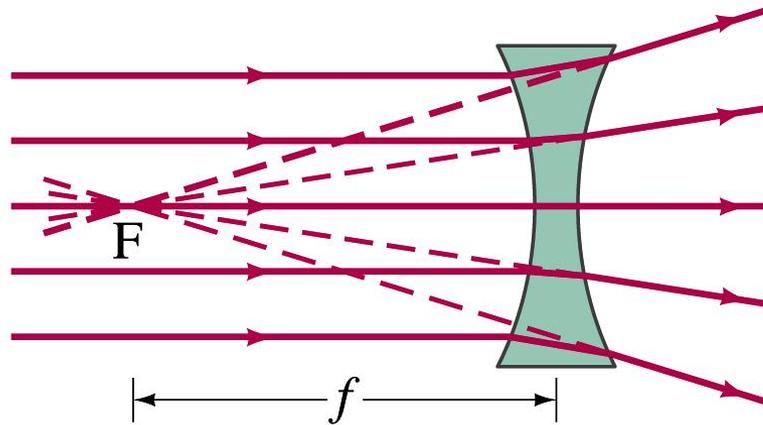


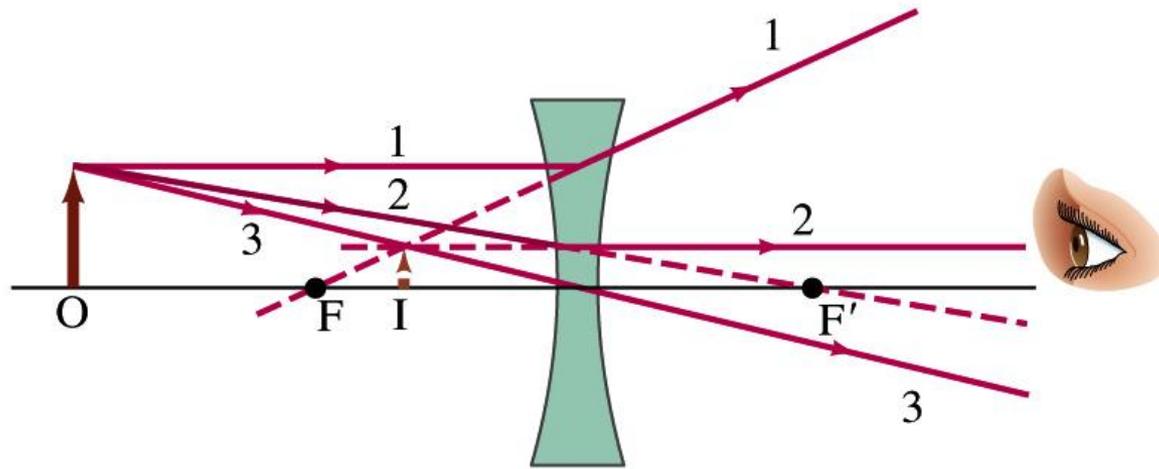
Planoconcave



Concave
meniscus

(b) Diverging lenses





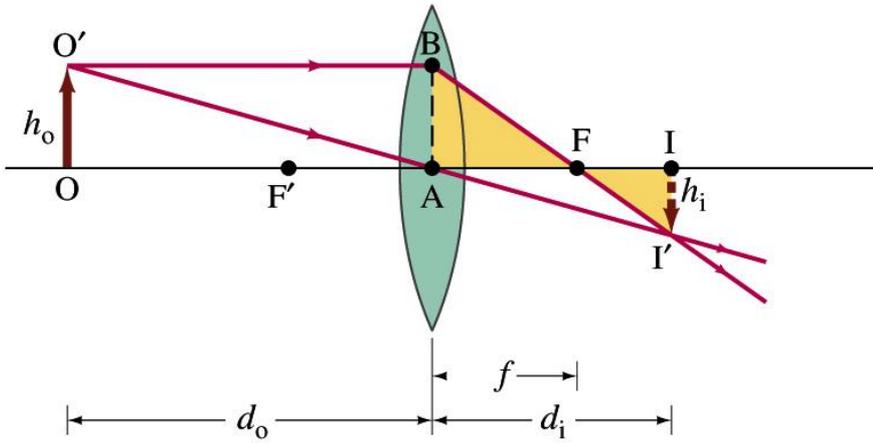
Power of lens measured in diopters

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

Power is positive for converging lenses
and negative for diverging lenses

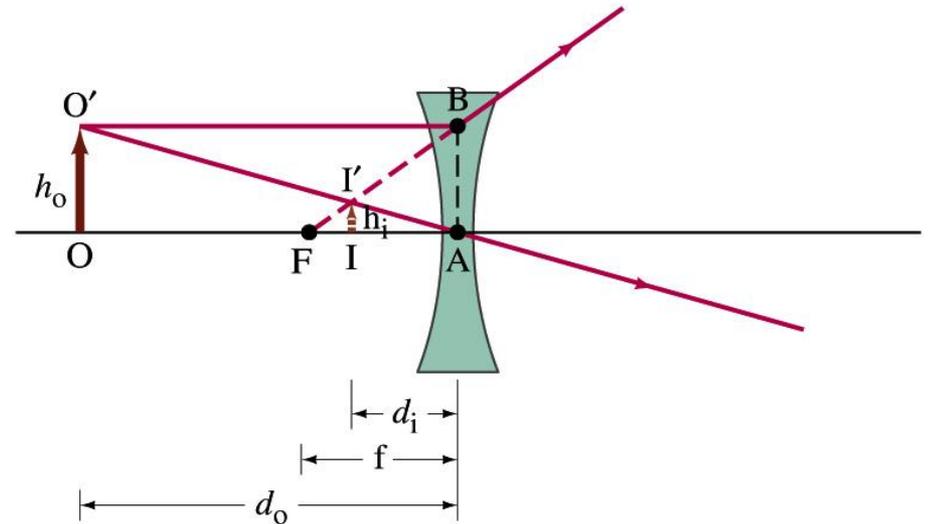
Magnification:

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



Lens equation:

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



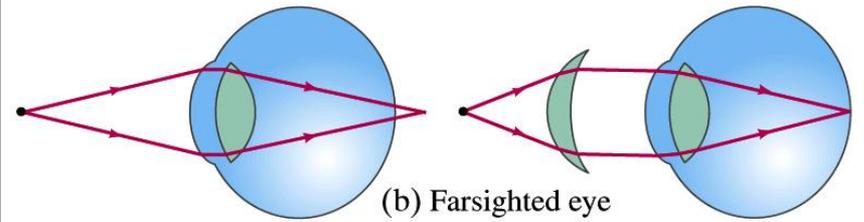
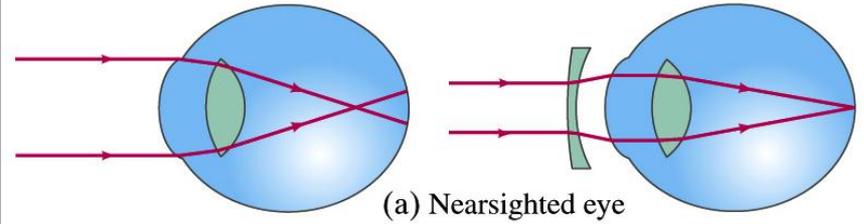
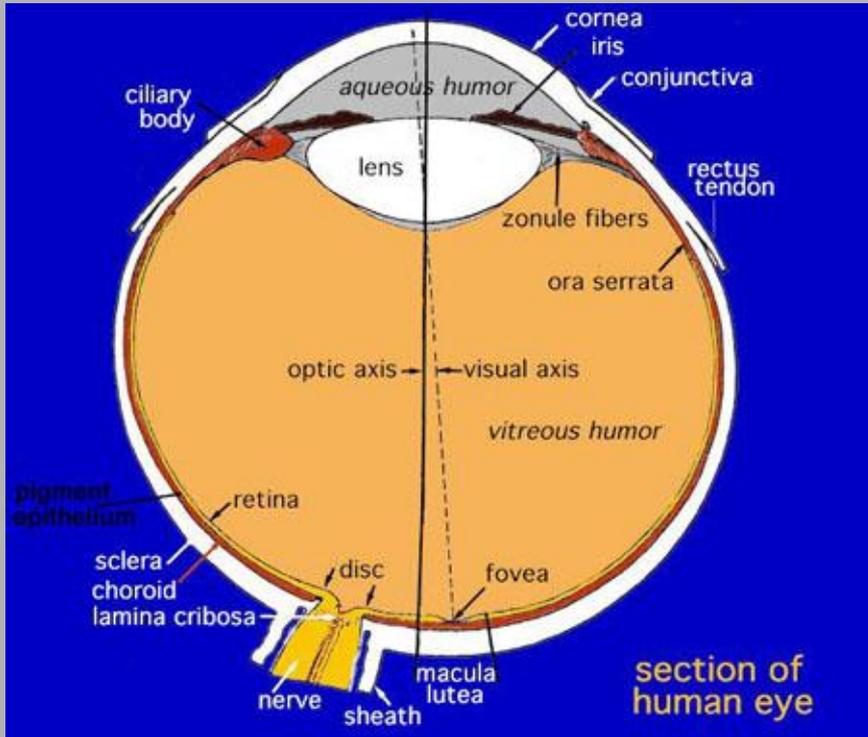
Real image: rays actually pass thru image

Virtual image: rays do not actually pass thru image

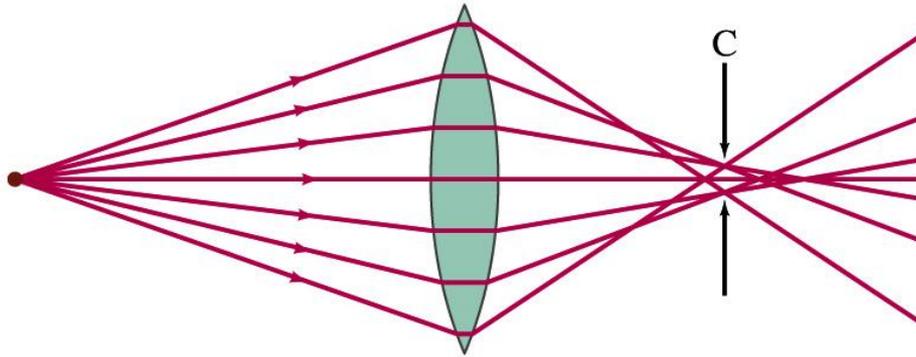
Sign convention is the tricky part, especially in multiple lens systems

Convention from Giancoli p. 841:

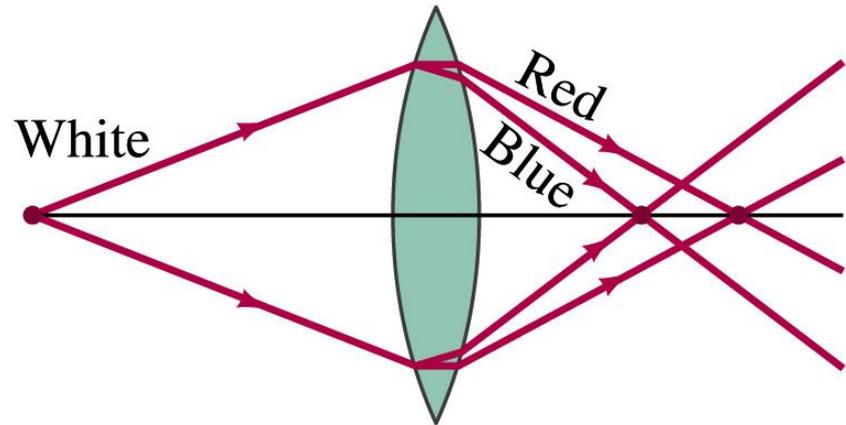
- **Focal length is + for converging lens and - for diverging lens**
- **Object distance is + if on the side of the lens from which the light is coming (usual, unless in multi-lens system)**
- **Image distance is + if on the opposite side of the lens from where the light is coming, if on same side, image 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 +.**



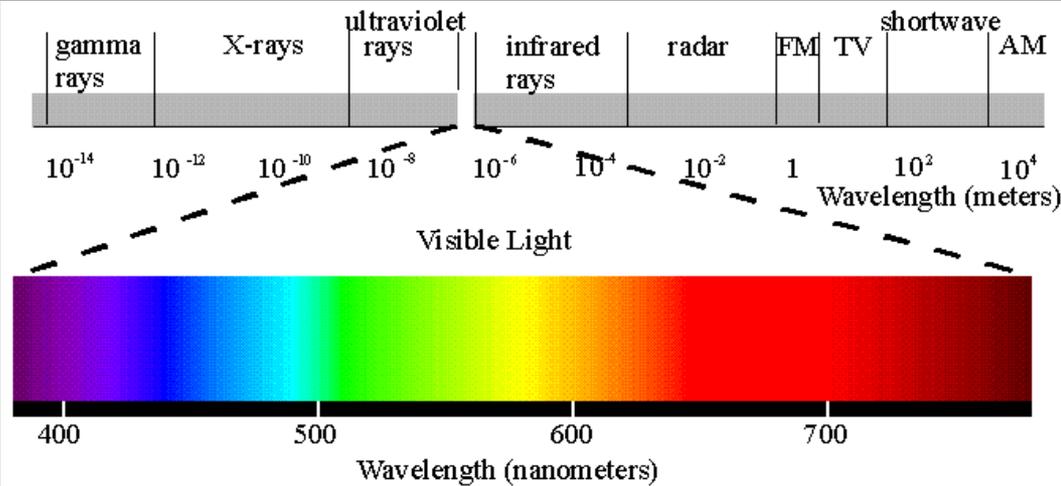
Aberrations



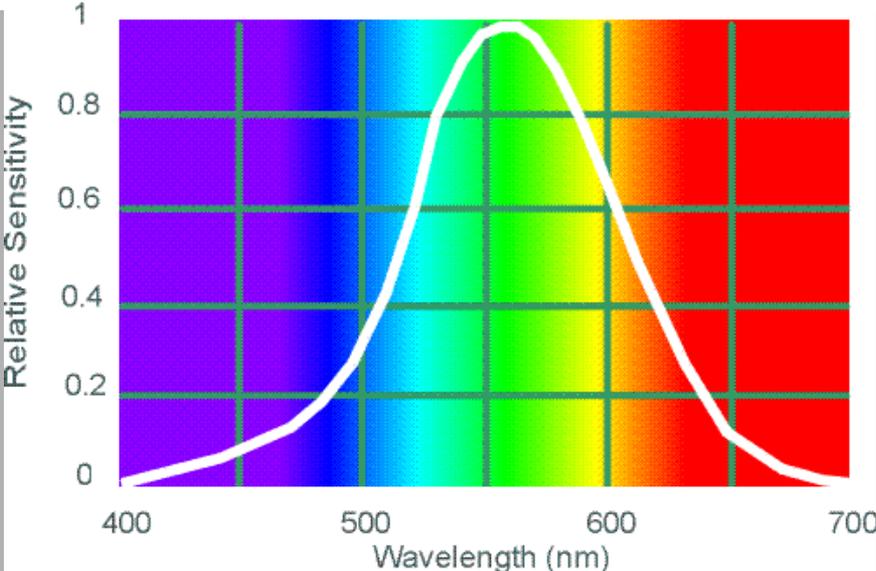
Spherical aberration

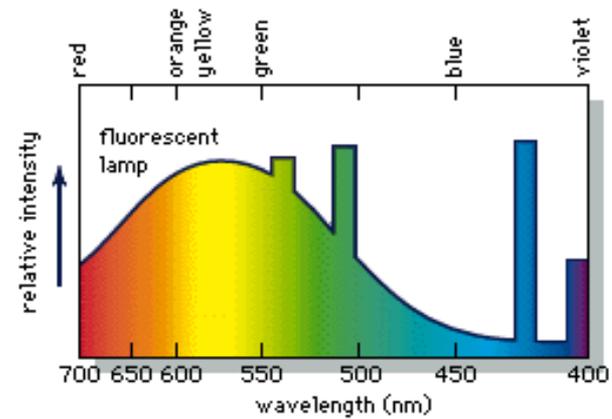
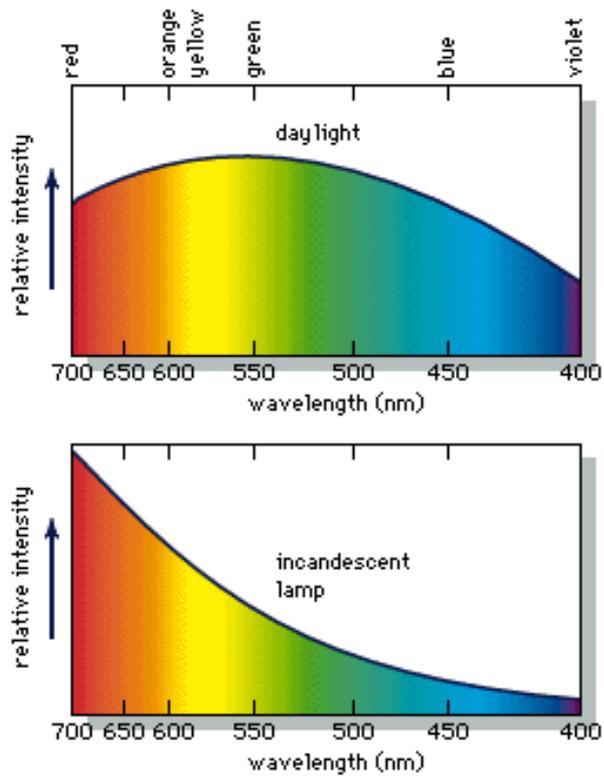


Chromatic aberration



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

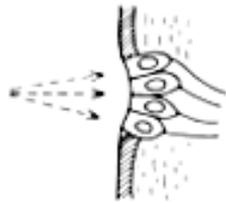




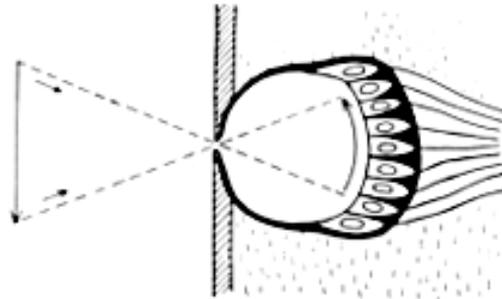
©1994 Encyclopaedia Britannica, Inc.

Types of eyes in the animal kingdom

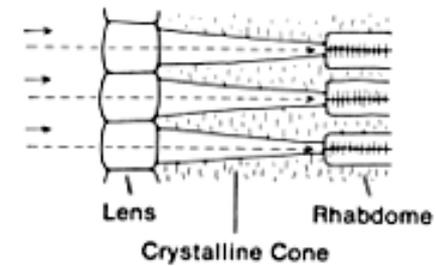
A. Ocellus



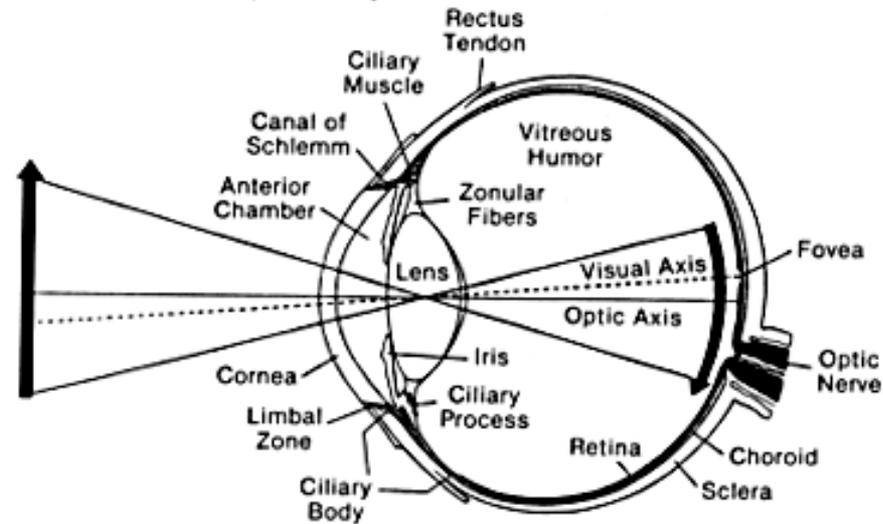
B. Pinhole Eye

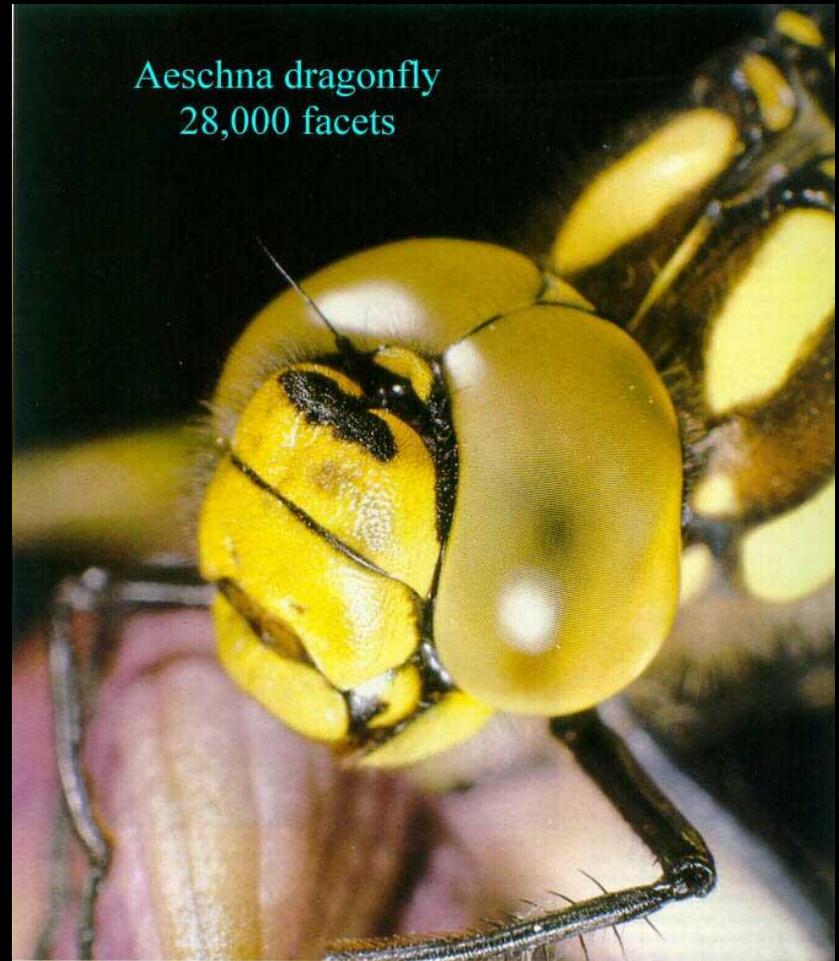
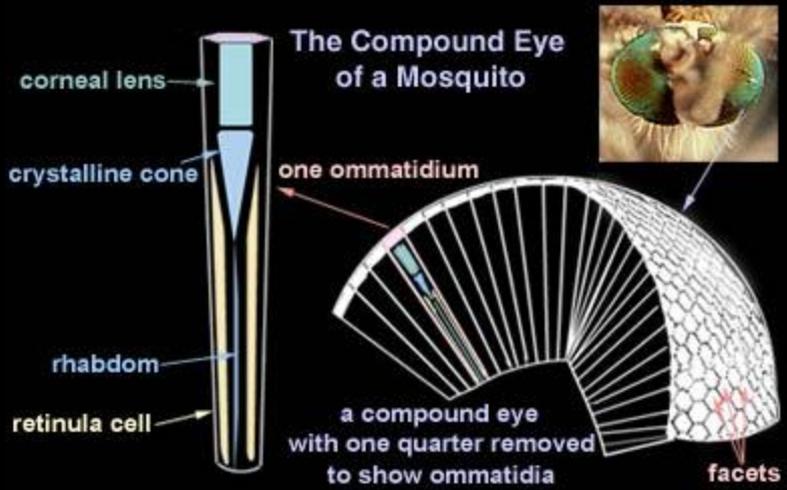


C. Compound Eye

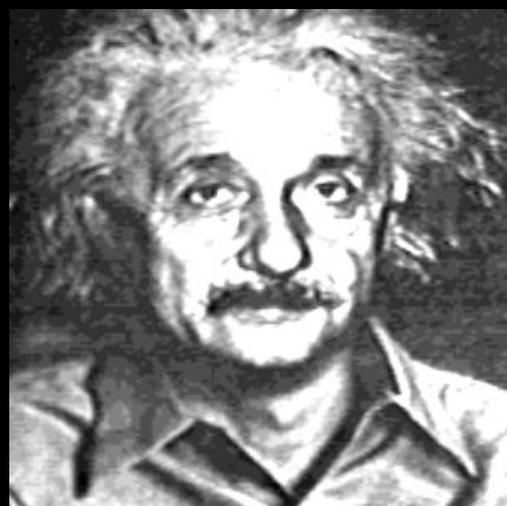


D. Lens and Retina (Vertebrate)





A bee's eye view



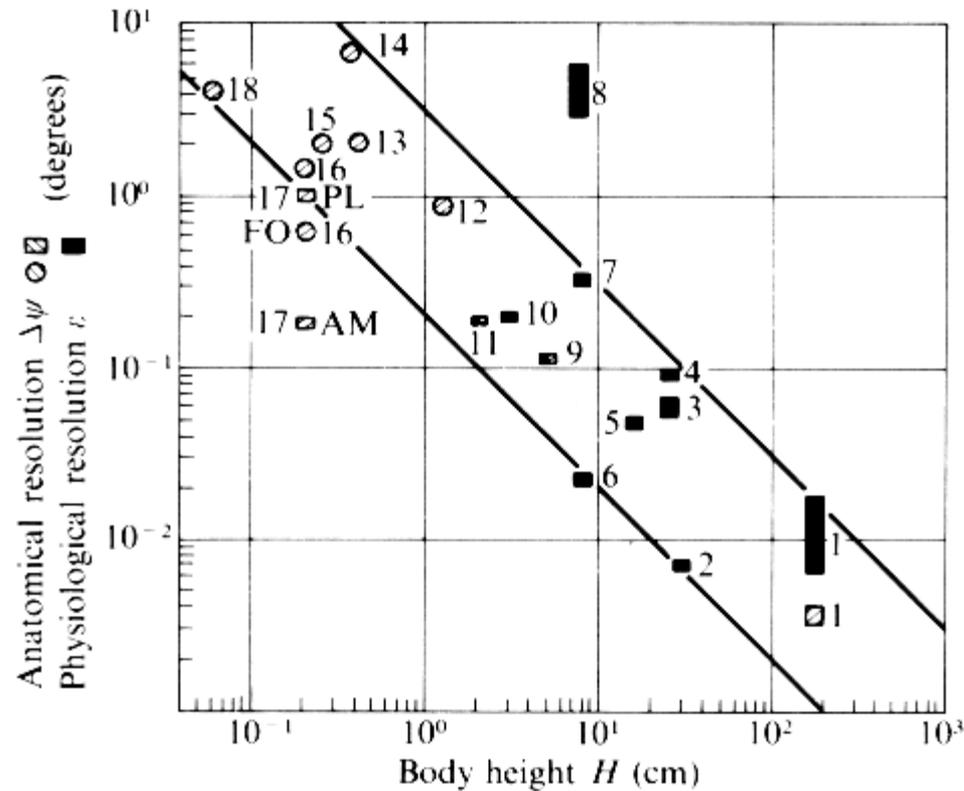
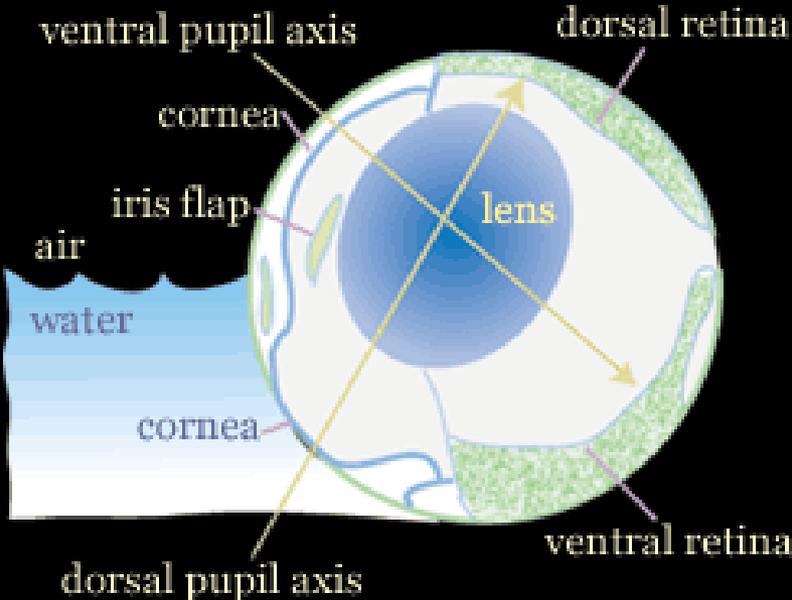
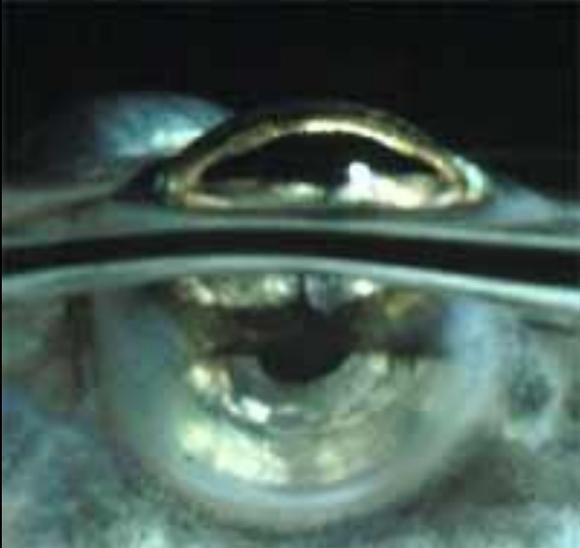


Fig. 2.9. Resolution of the eyes of various animals measured physiologically and deduced from anatomical criteria compared to body height: (1) man; (2) peregrine falcon; (3) hen; (4) cat; (5) pigeon; (6) chaffinch; (7) rat; (8) bat (*Myotis*); (9) frog; (10) lizard; (11) minnow; (12) dragonfly (*Aeschna*);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

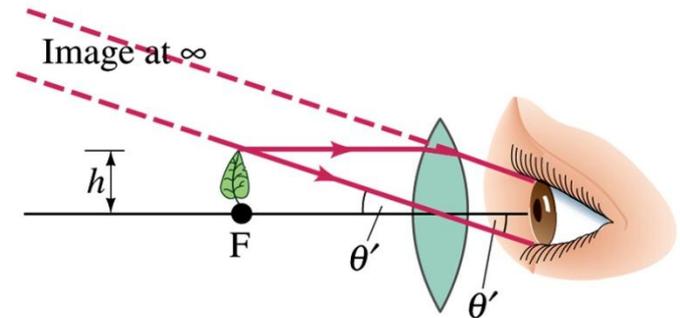
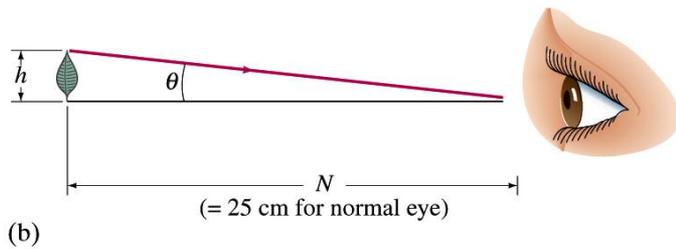
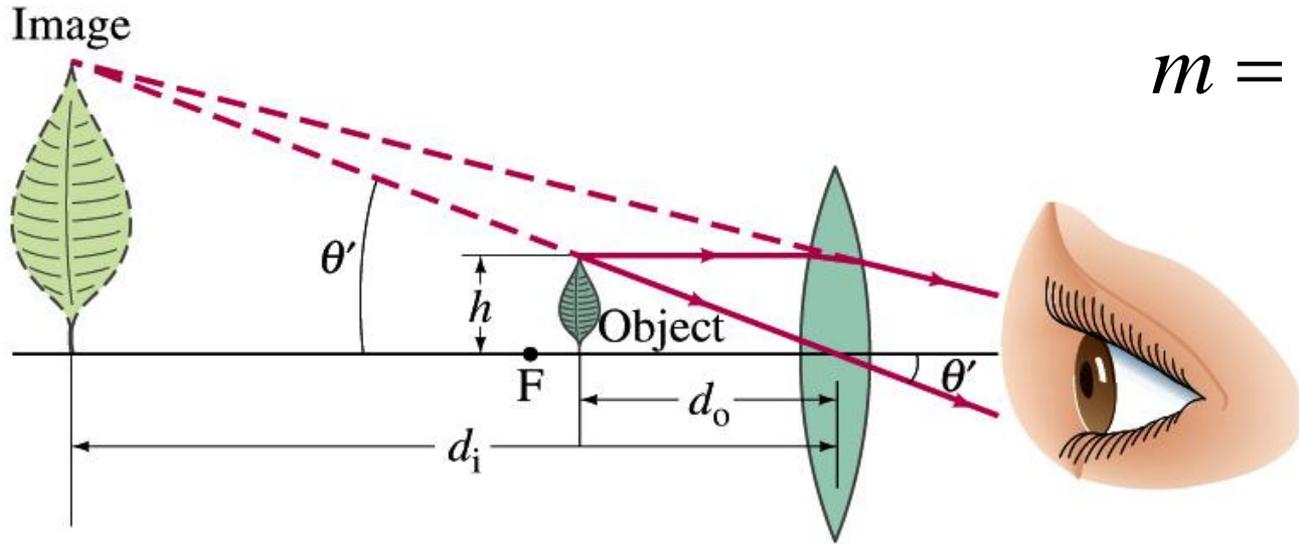


Anableps - minnow

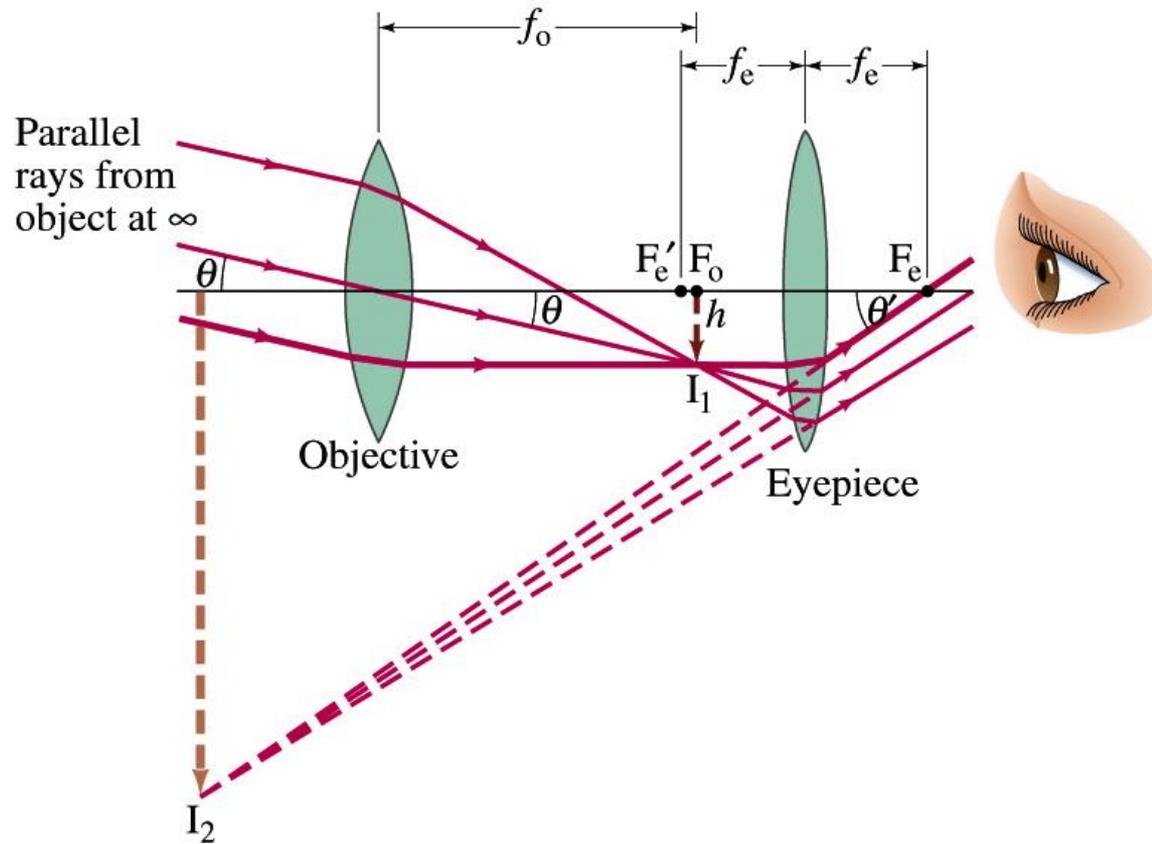


Magnifying glass

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



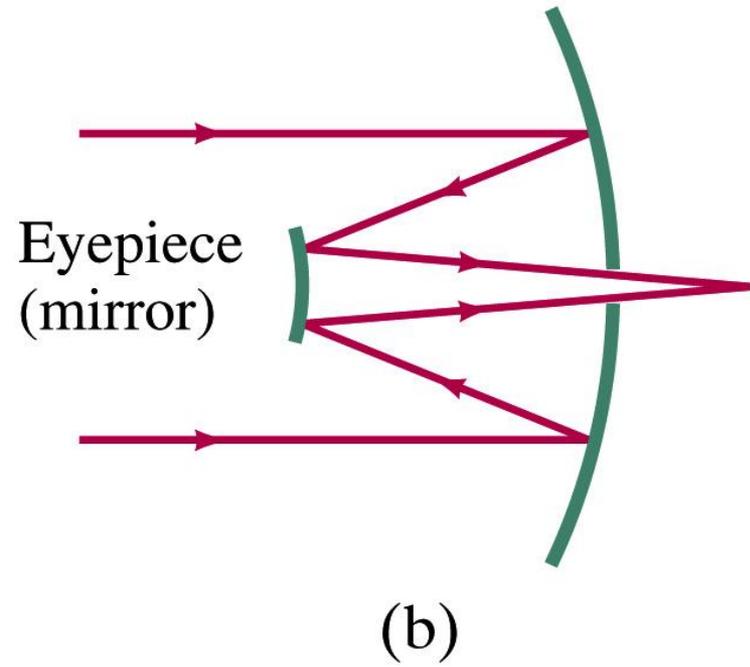
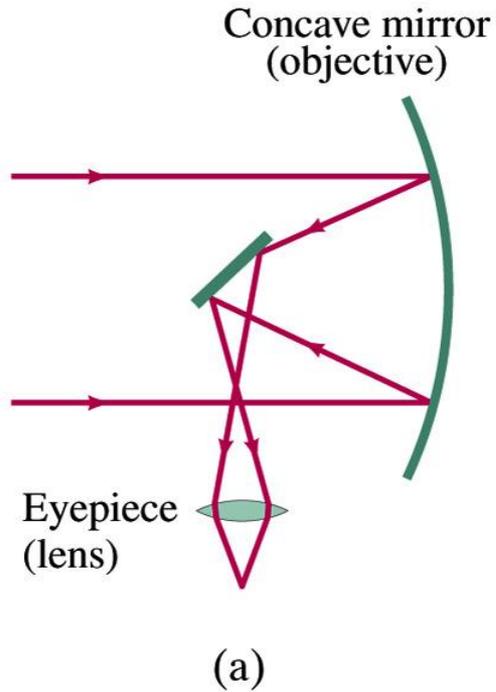
Refracting telescope

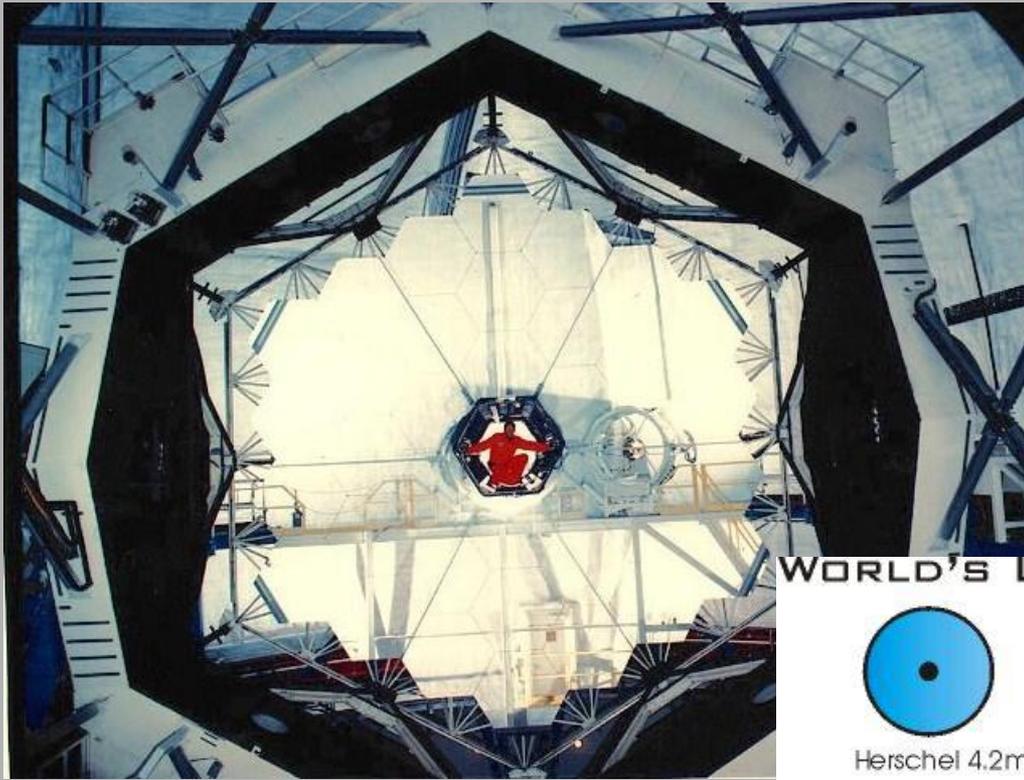


40 inch refractor – Yerkes Observatory



Reflecting telescope

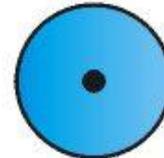




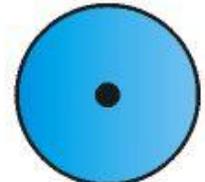
WORLD'S LARGEST OPTICAL TELESCOPES



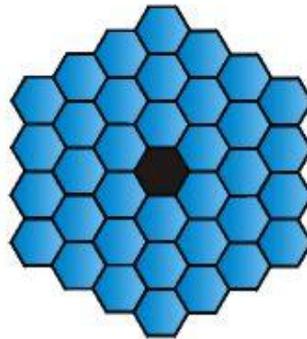
Herschel 4.2m



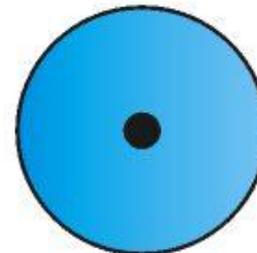
Palomar 5m



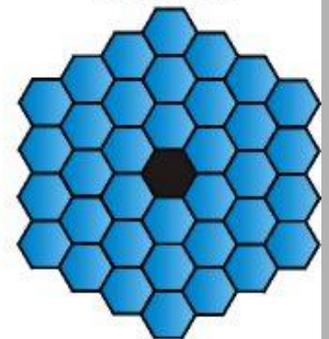
Russian 6m



Keck I 10m



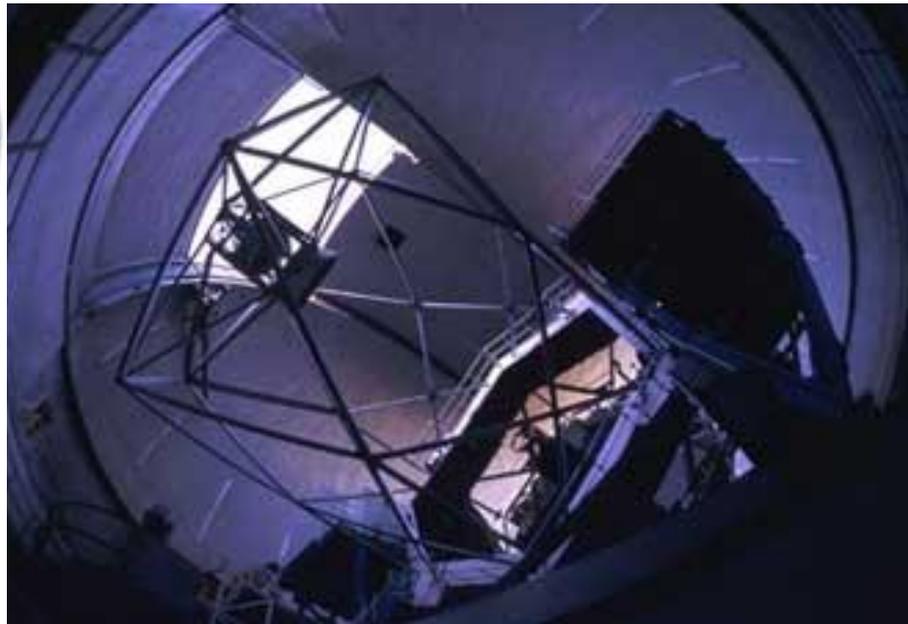
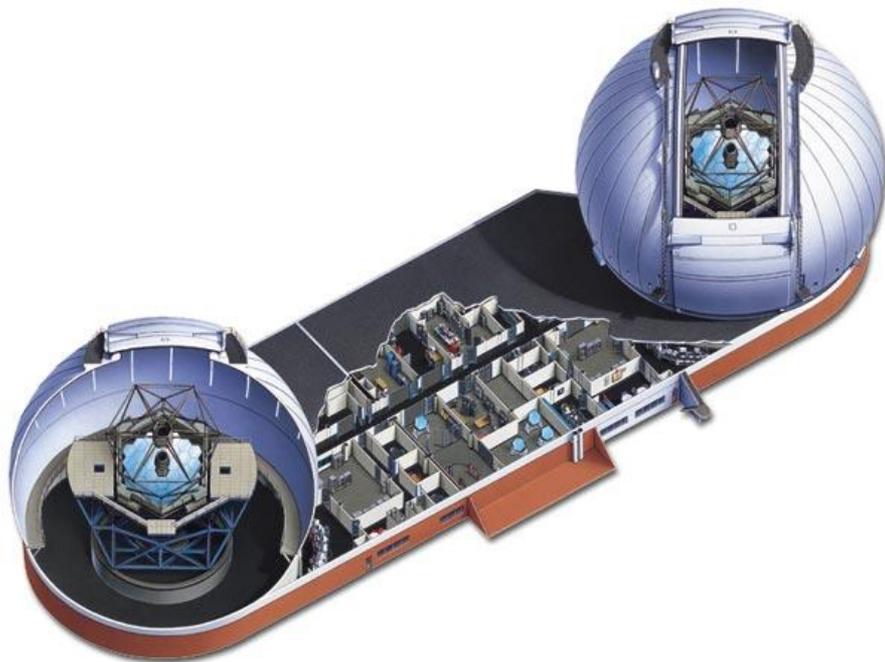
VLT 8.2m



Keck II 10m

Central mirror holes not shown to scale

© W.M. Keck Observatory

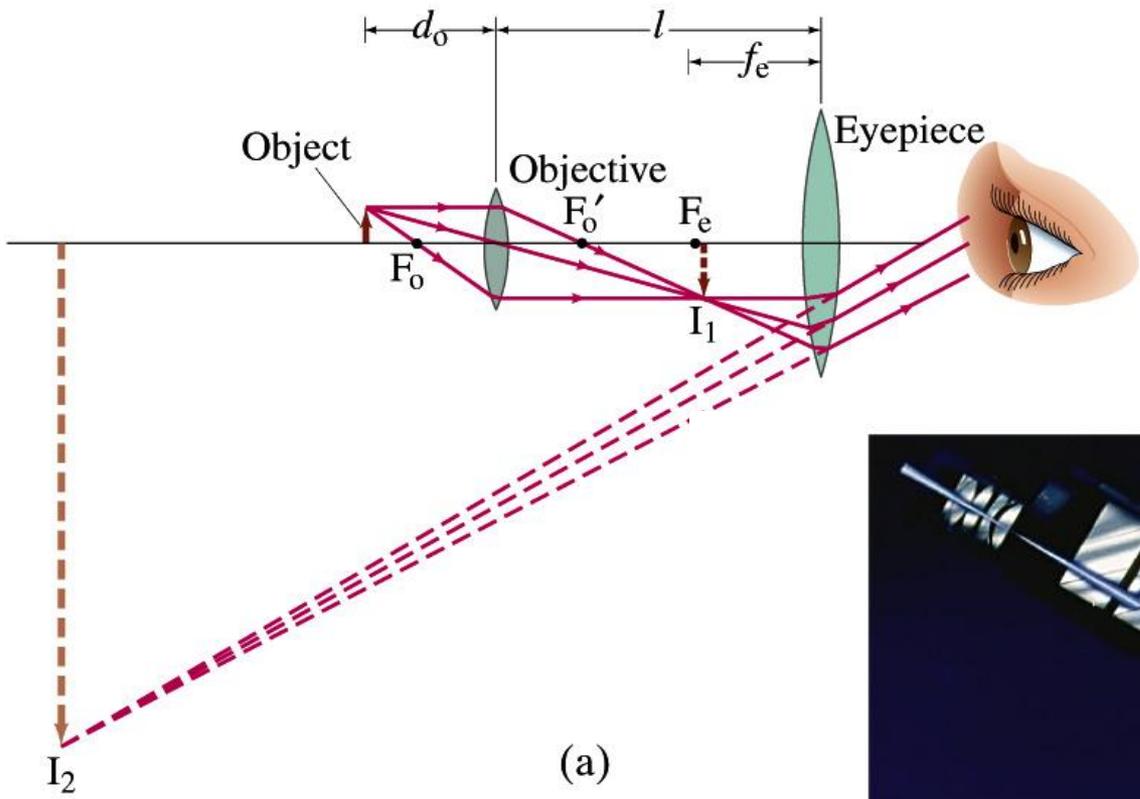


Keck Observatory



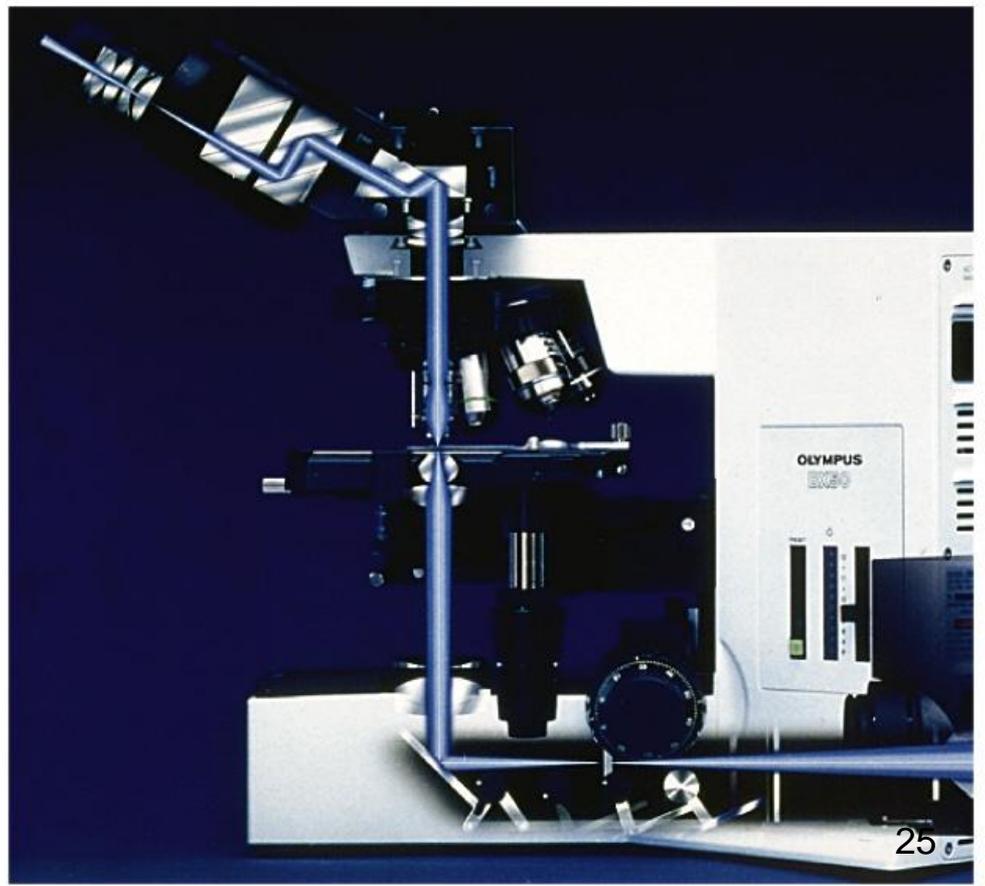
Hubble Space Telescope





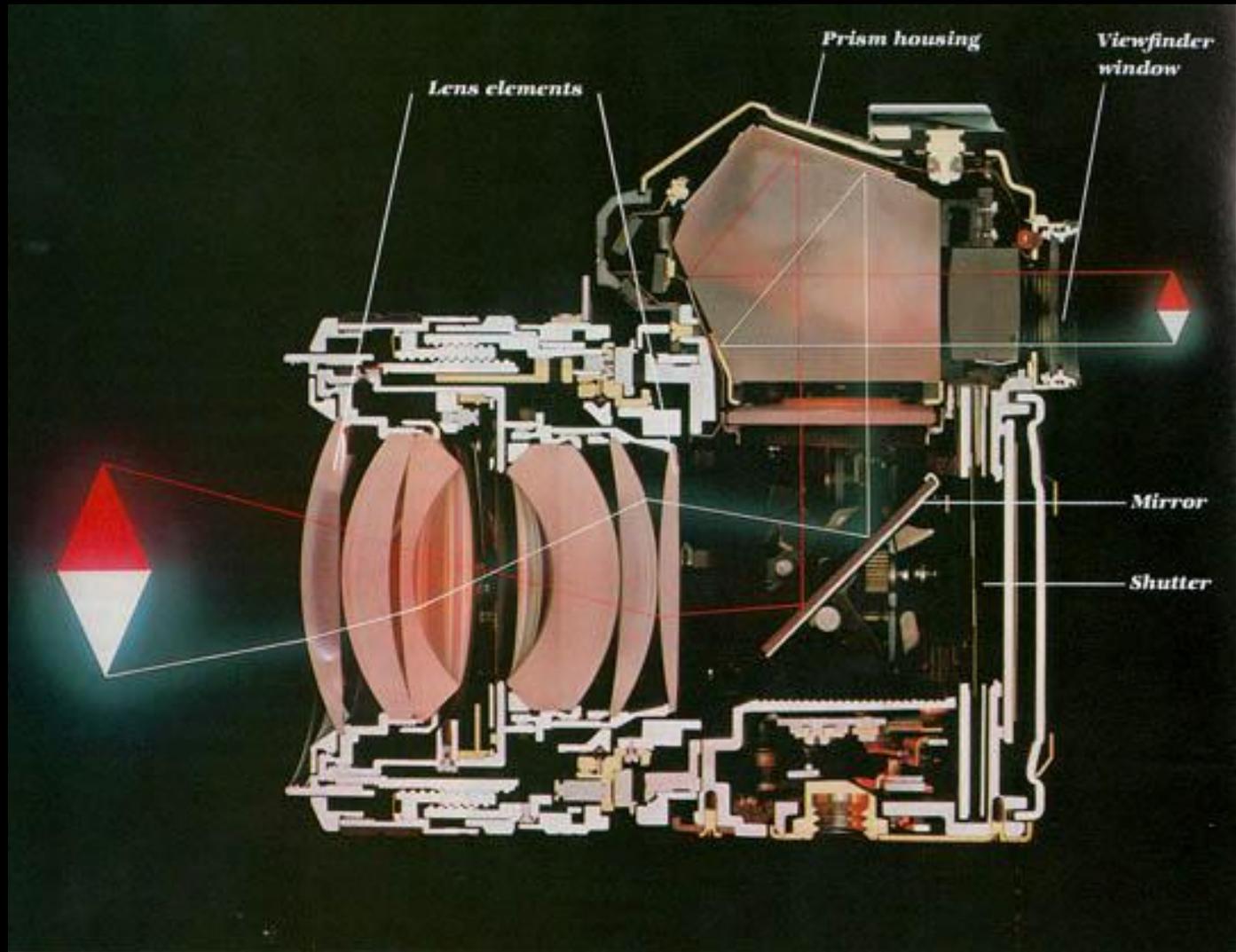
(a)

Compound microscope



(b)

Camera



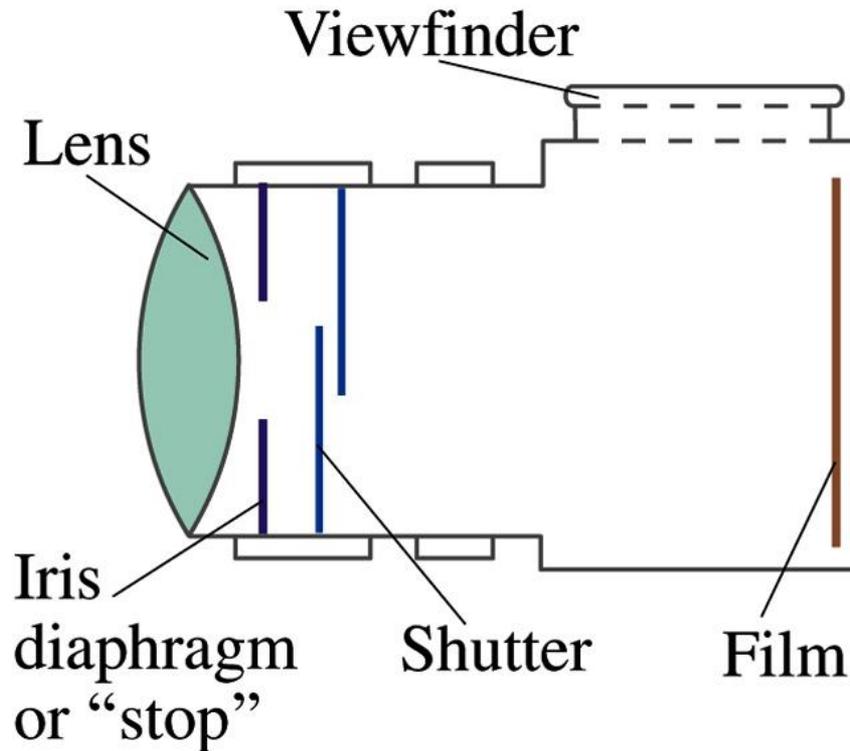
Light vs. depth of field

Shutter speed

$f\text{-stop} = f/D$, 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