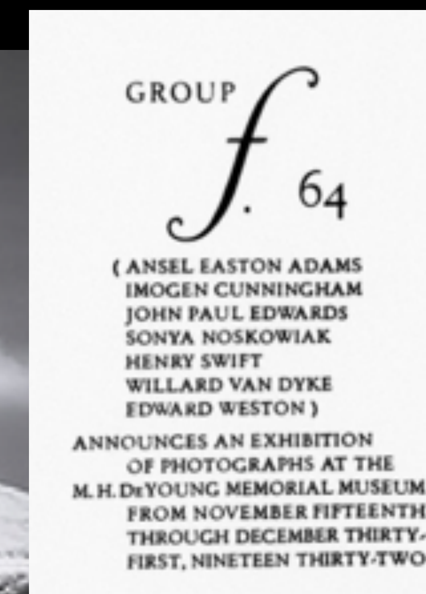
Vision

By Anette Smith Burgess, Opthamological Illustrator
(Student of Max Broedel, John’s Hopkins)

Straight Photography

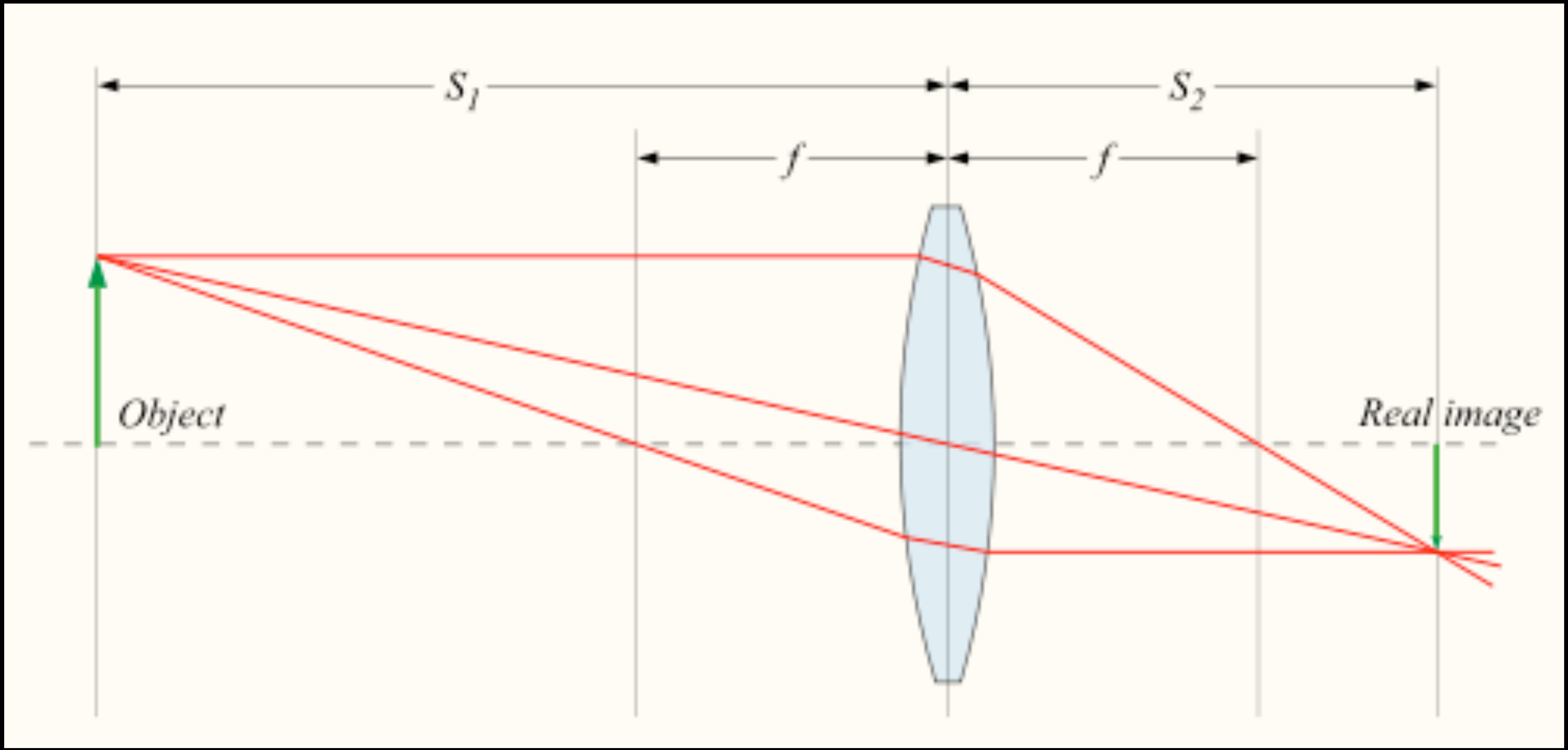


GROUP f. 64

(ANSEL EASTON ADAMS
IMOGEN CUNNINGHAM
JOHN PAUL EDWARDS
SONYA NOSKOWIAK
HENRY SWIFT
WILLARD VAN DYKE
EDWARD WESTON)

ANNOUNCES AN EXHIBITION
OF PHOTOGRAPHS AT THE
M. H. DeYOUNG MEMORIAL MUSEUM
FROM NOVEMBER FIFTEENTH
THROUGH DECEMBER THIRTY-
FIRST, NINETEEN THIRTY-TWO

Image Formation in a Single Lens



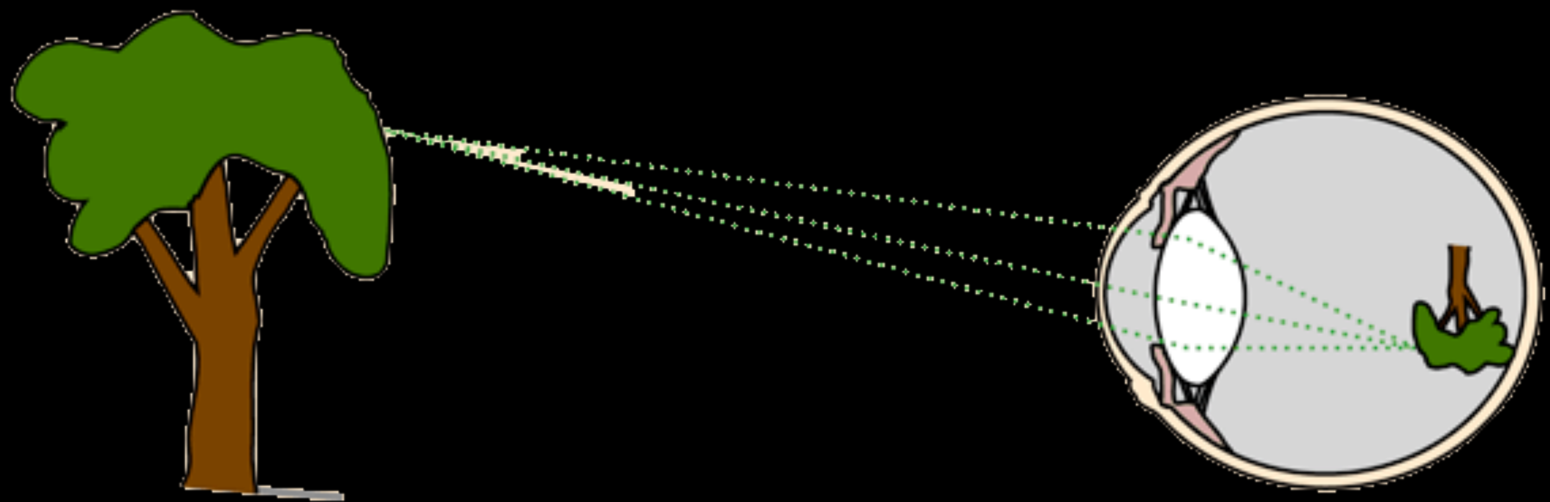
What is Light?

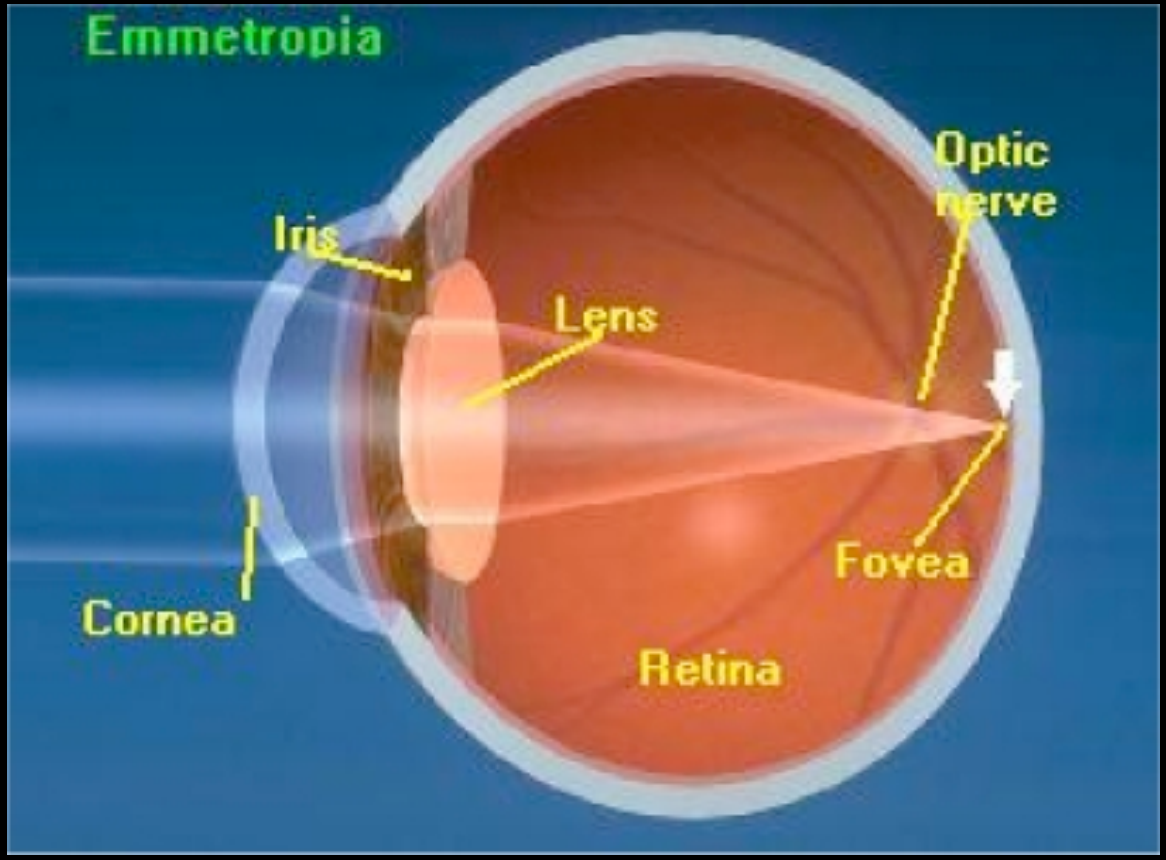
- Some useful ways to think of light:
  - Rays of light
  - Waves of light
  - Electromagnetic radiation that has both wavelike and particle-like properties, containing quanta of light: photons

What can happen to light?

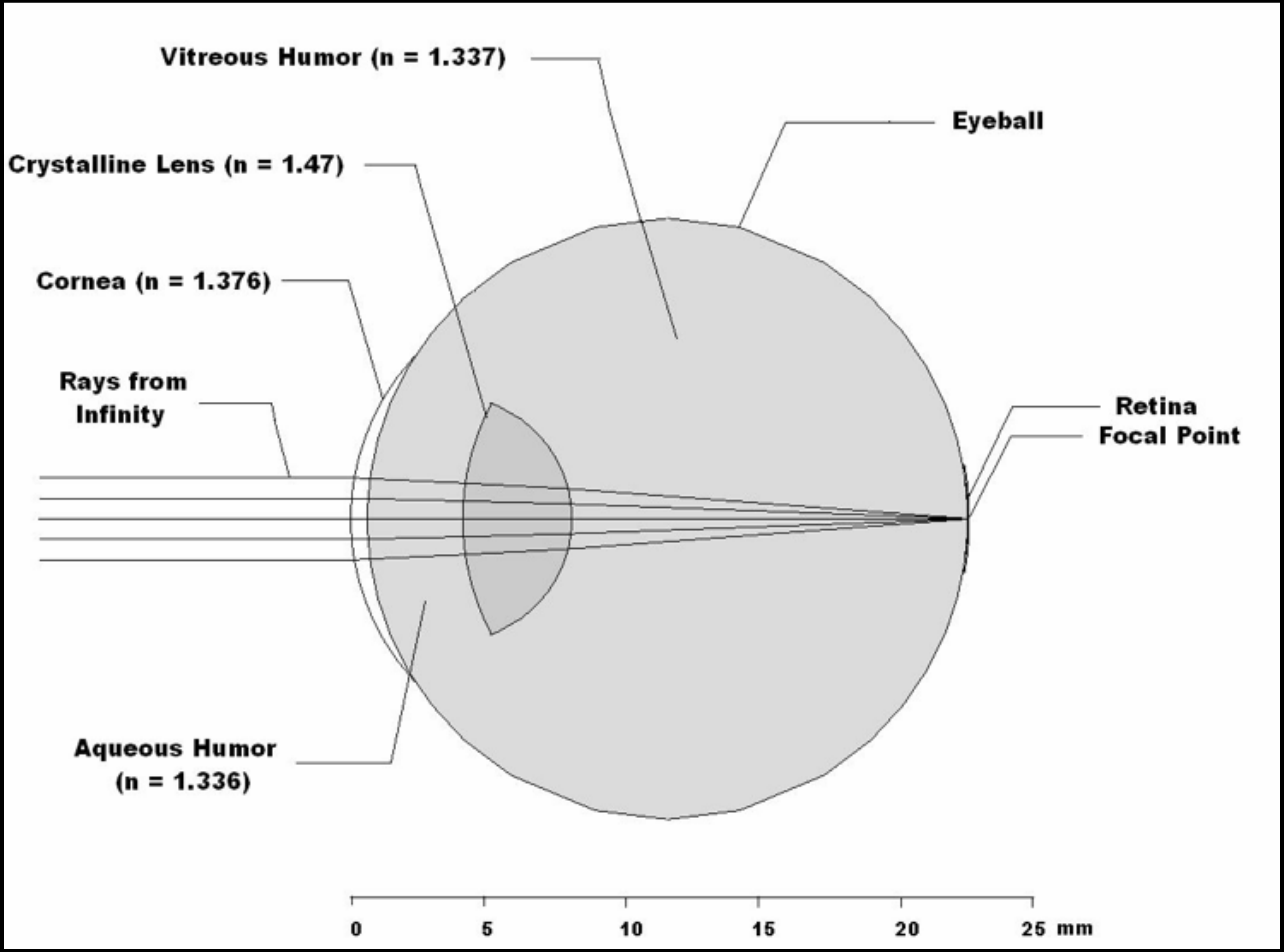
- **Refraction**
- **Reflection**
- Diffraction
- Scattering
- Absorption
- …

Image Formation in the Eye

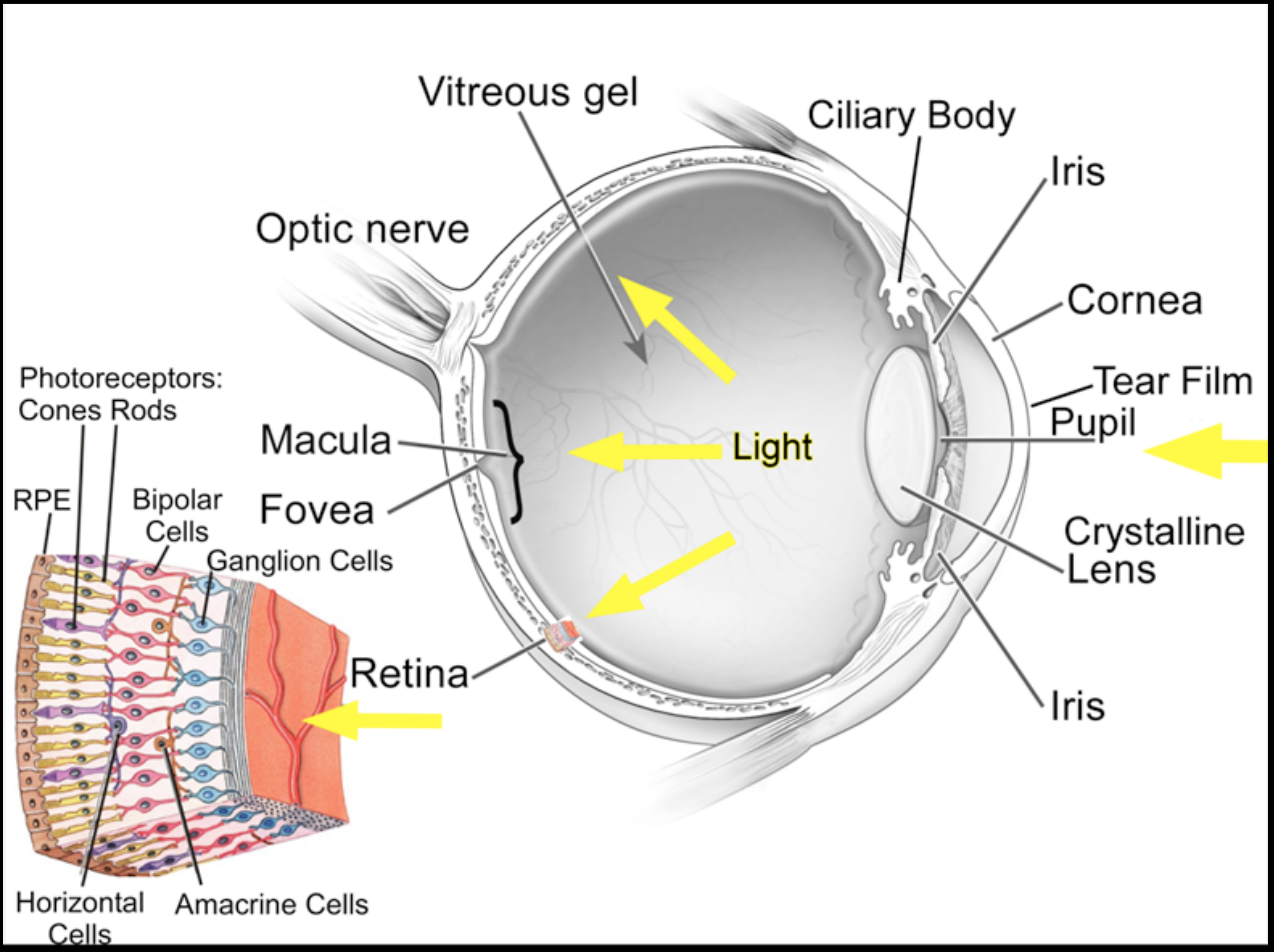




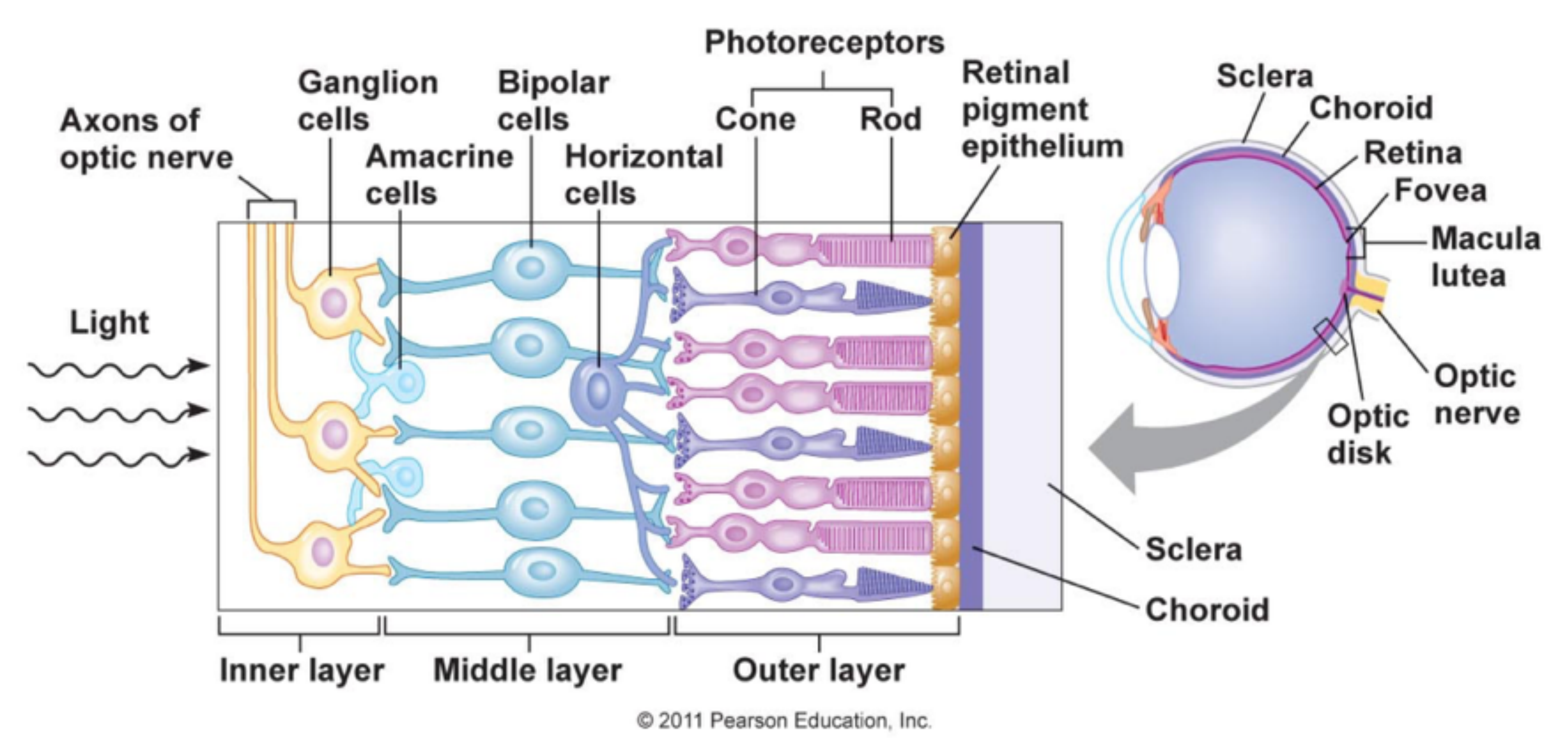
Refractive Index map



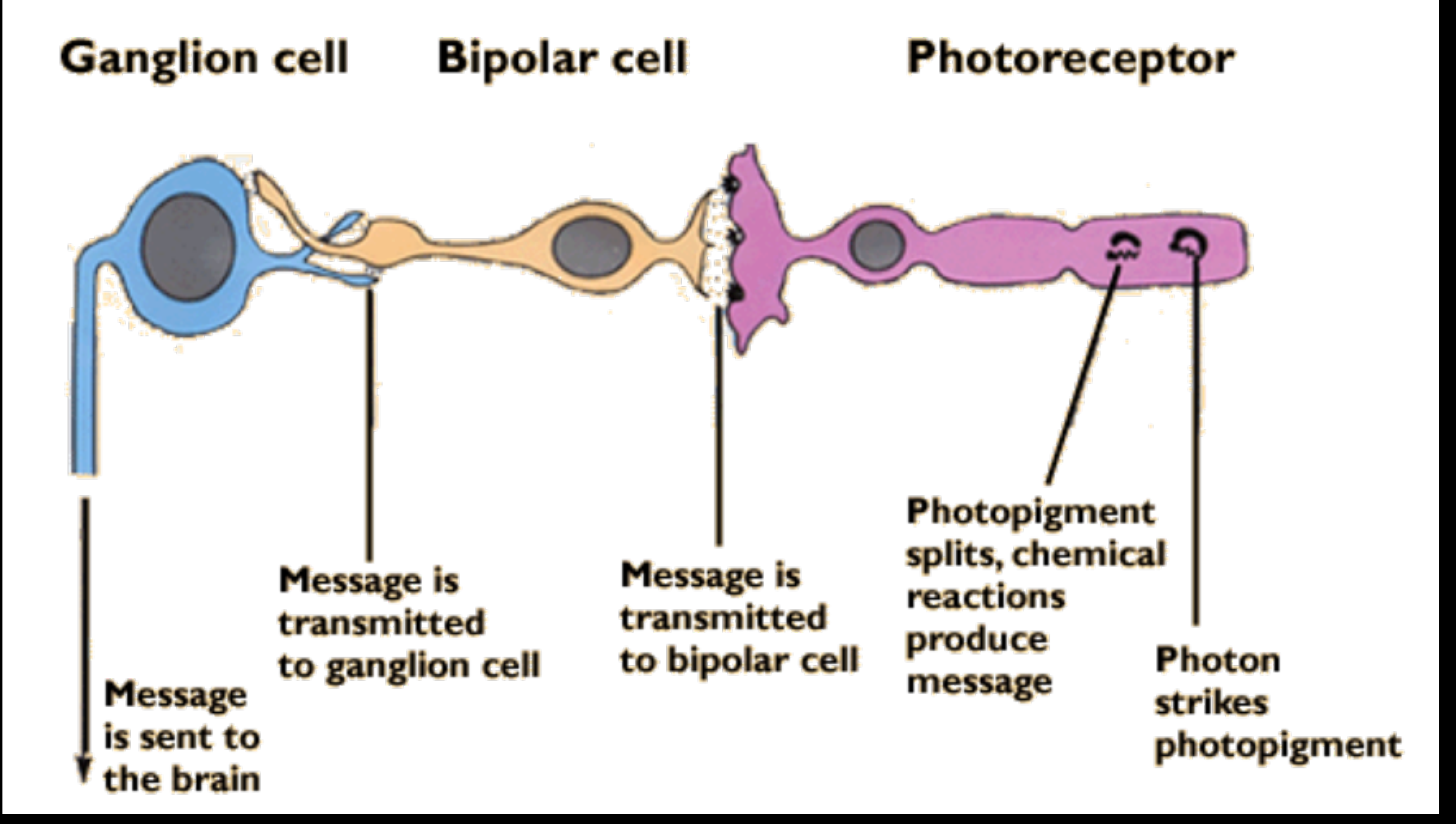
Anatomy of the Eye



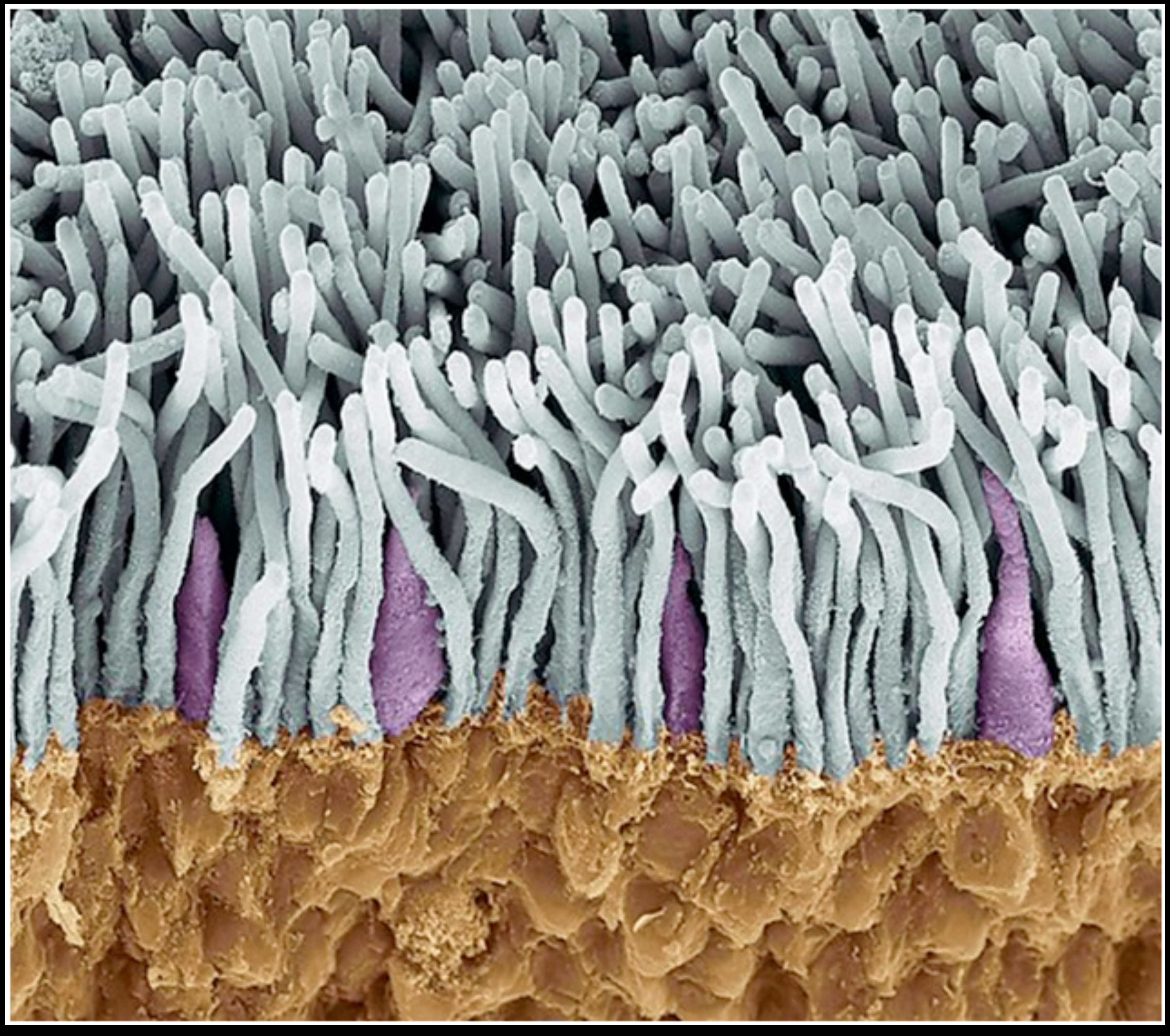
Phototransduction



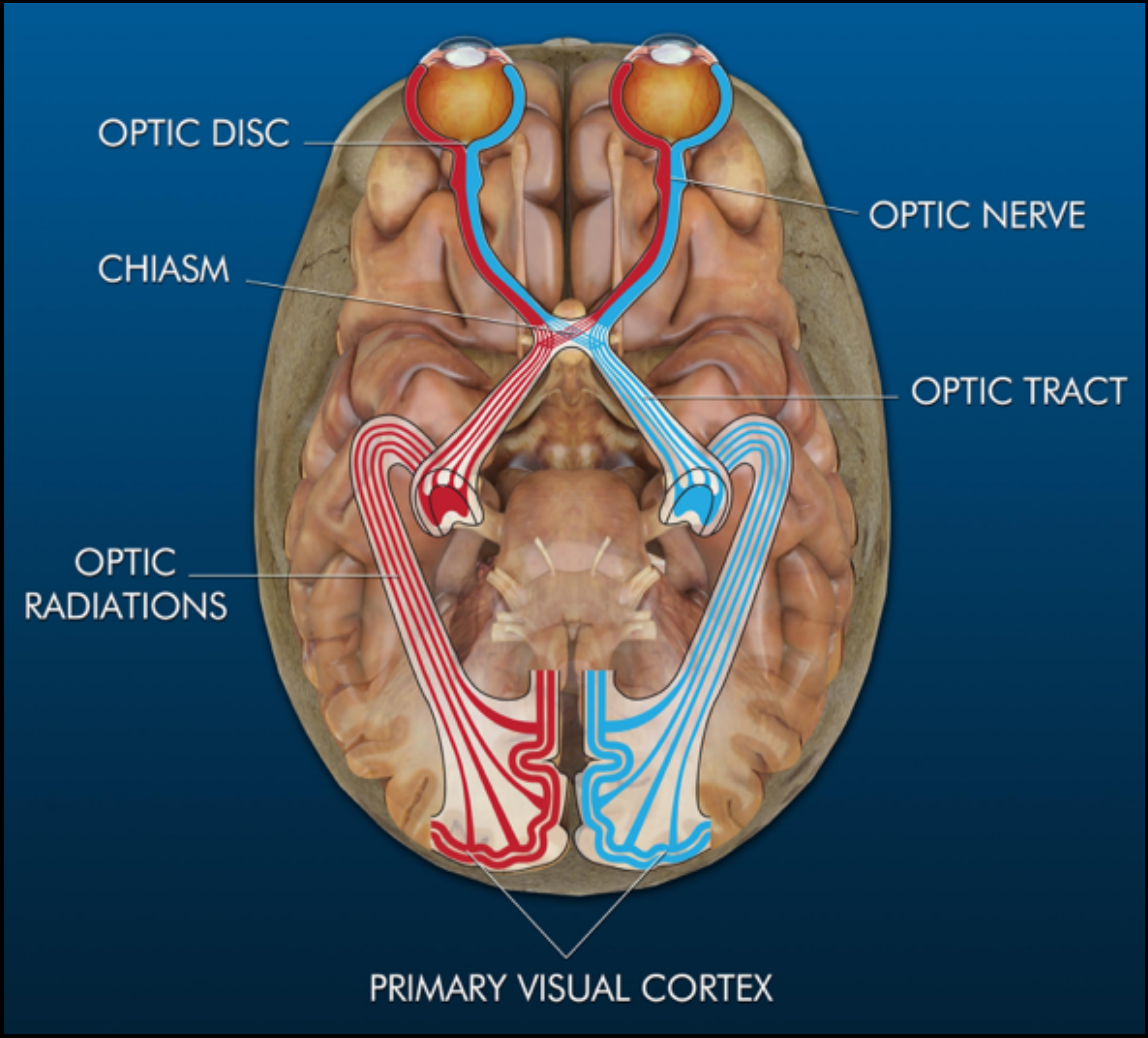
Bipolar Cells



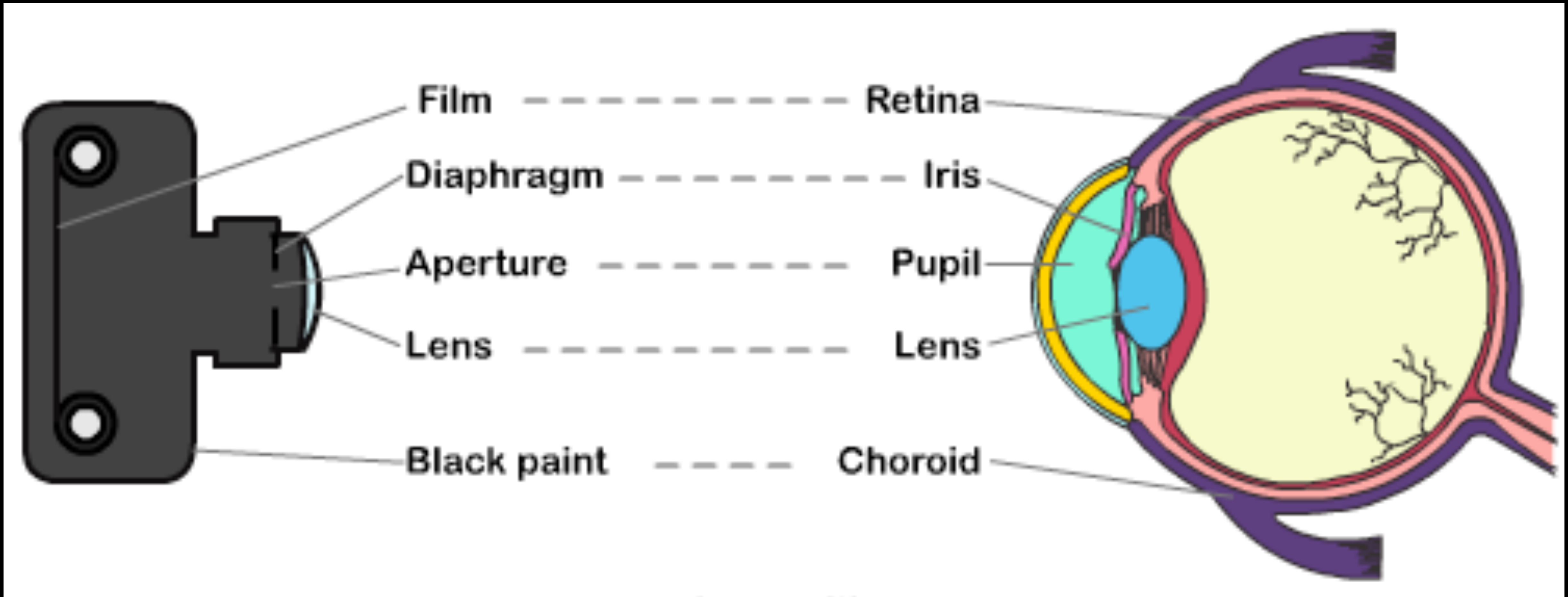
SEM of rods and cones



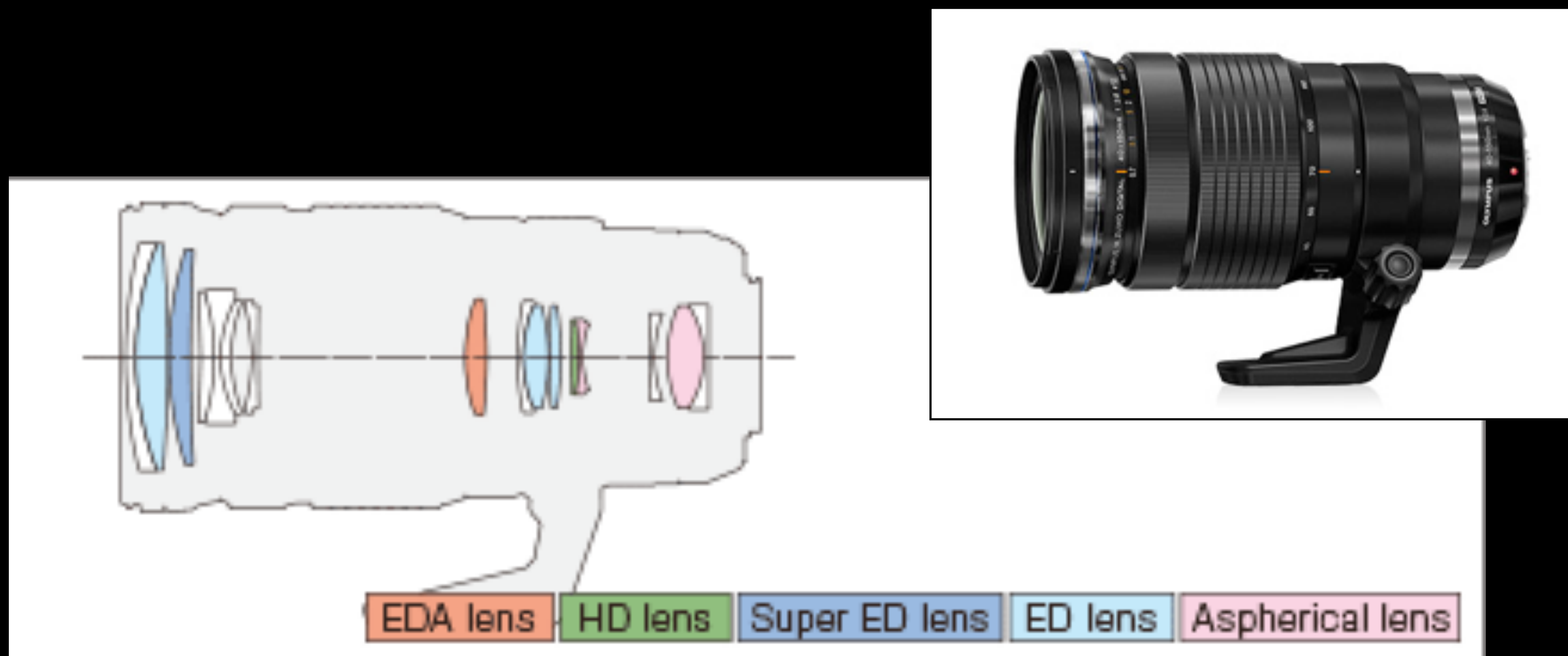
The Optic Nerves



Photographic Camera



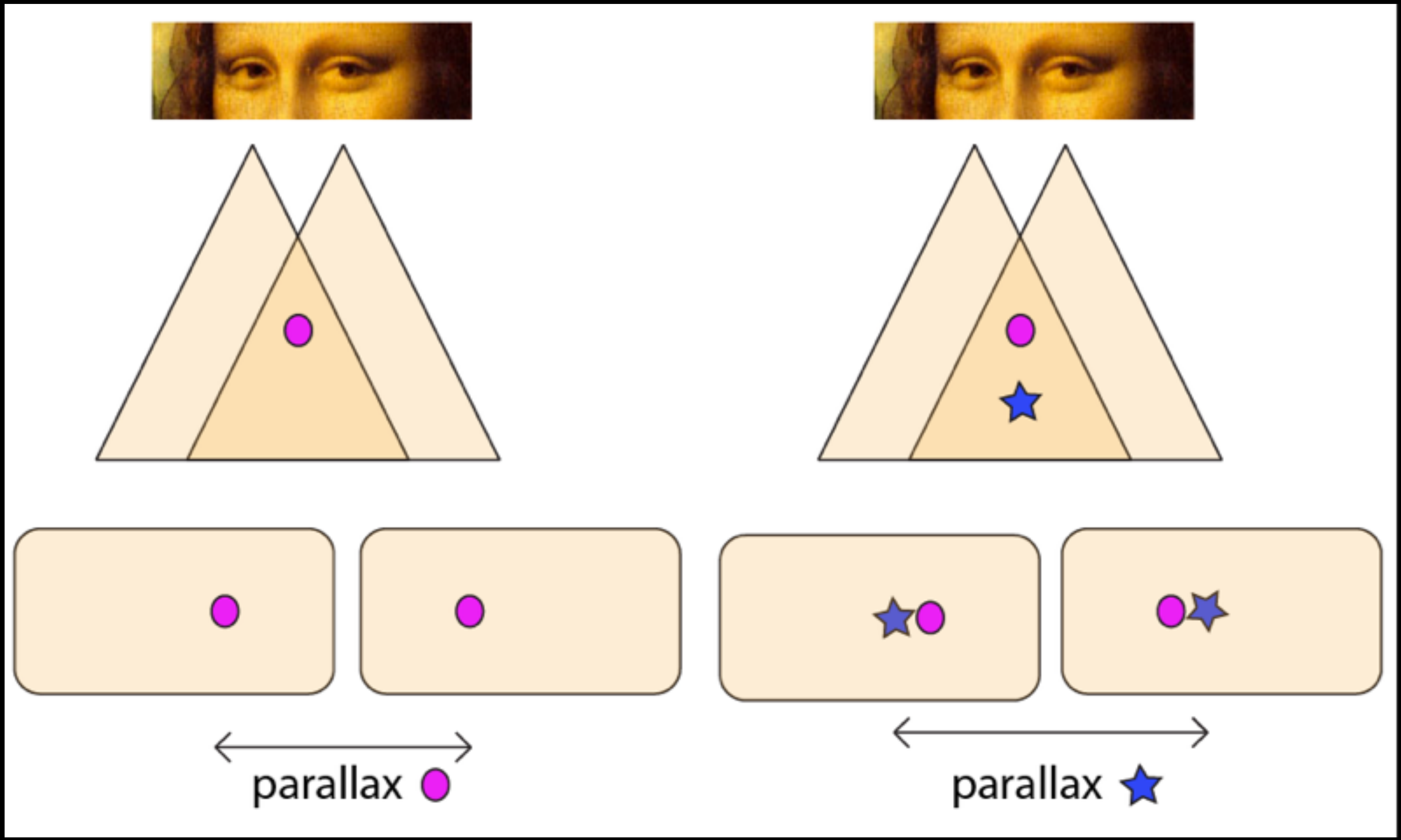
Camera Objective



Camera objectives contain many different lenses that act together as a single next-to-perfect lens

This is necessary to correct for <u>optical aberrations</u>

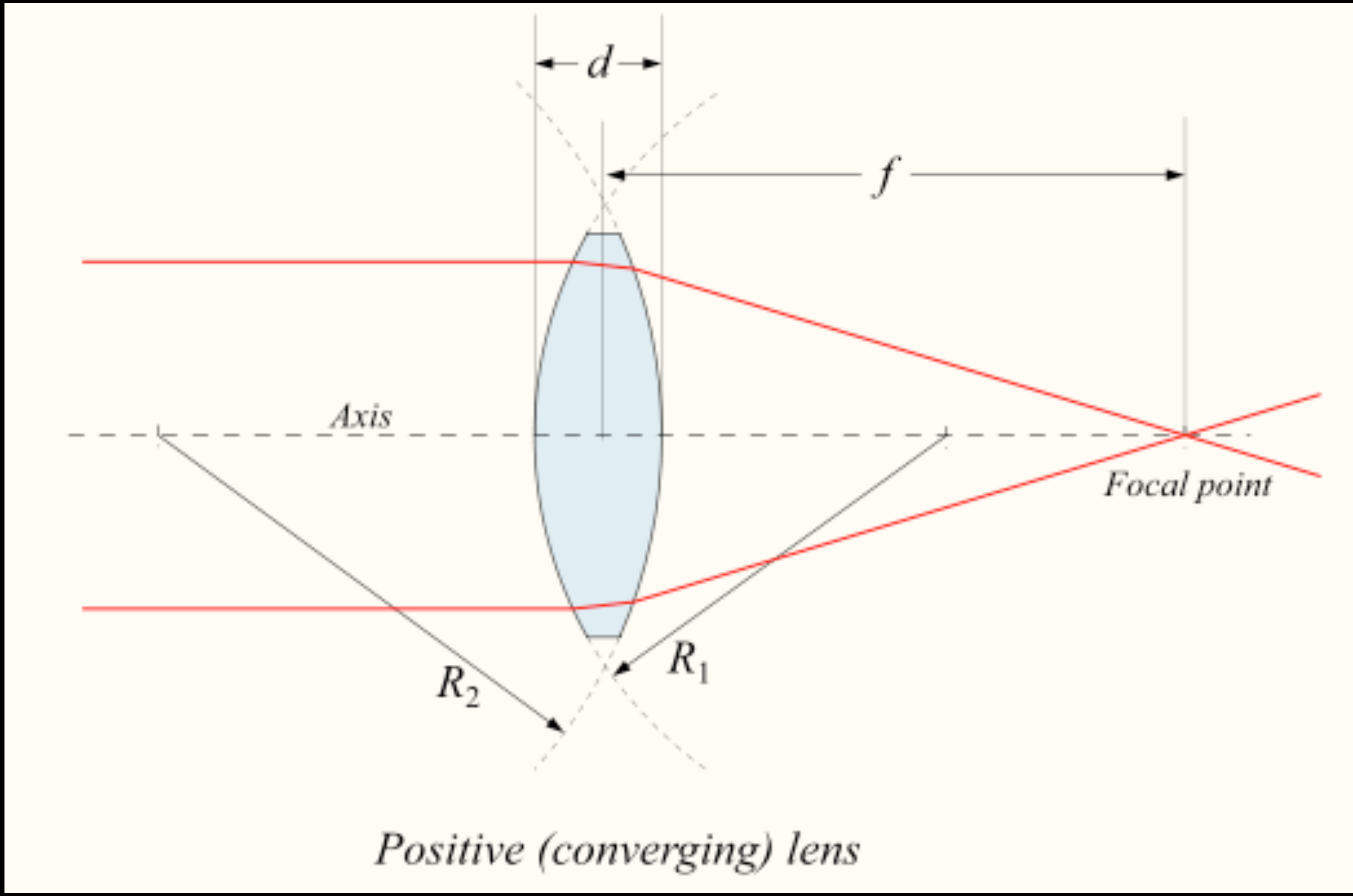
The Stereo Image



Optical Aberrations

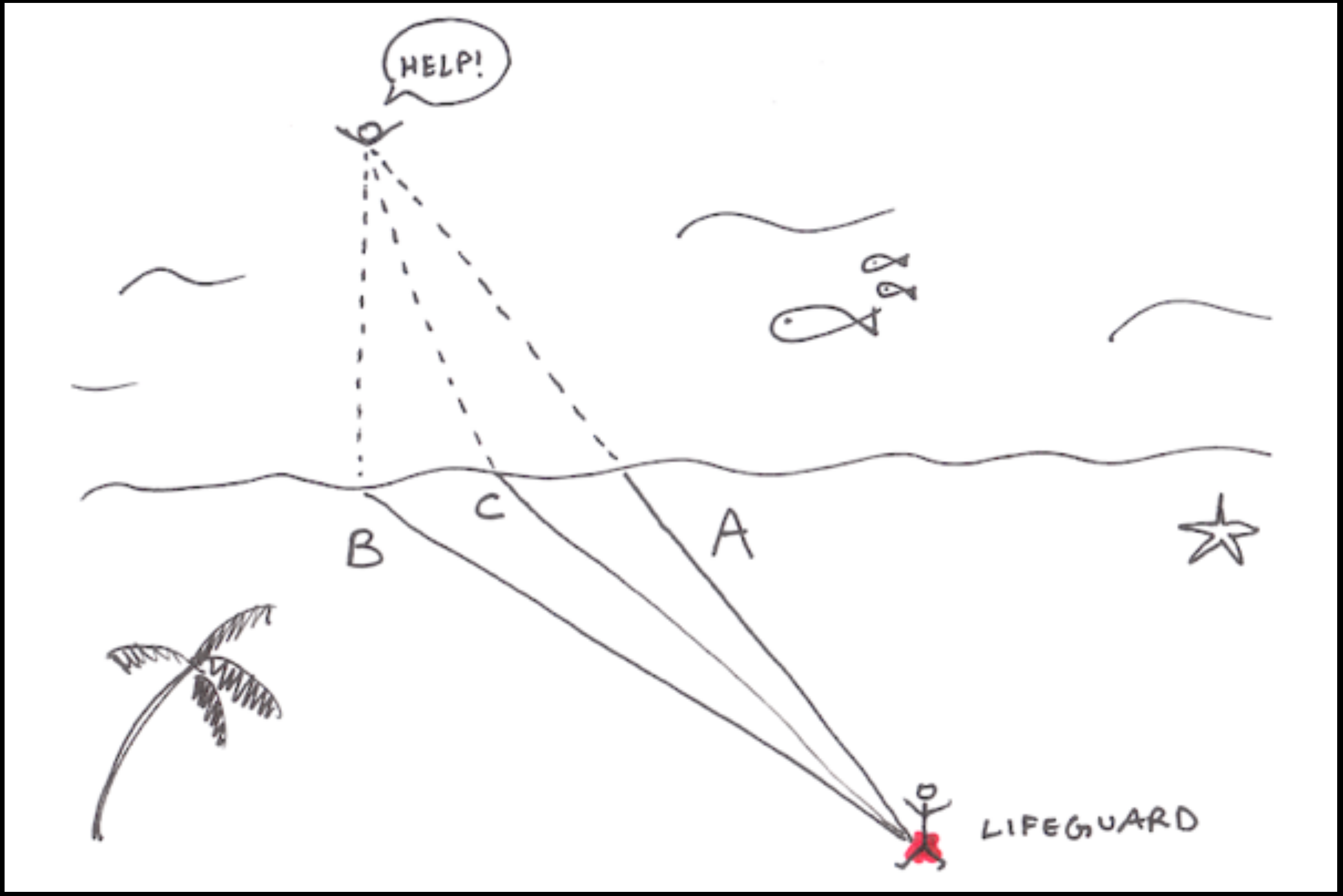
- Aberrations deteriorate image quality. Lens systems are designed to mimic a single, ideal, infinitely thin lens.

Refraction in a single Lens



Fermat’s Principle

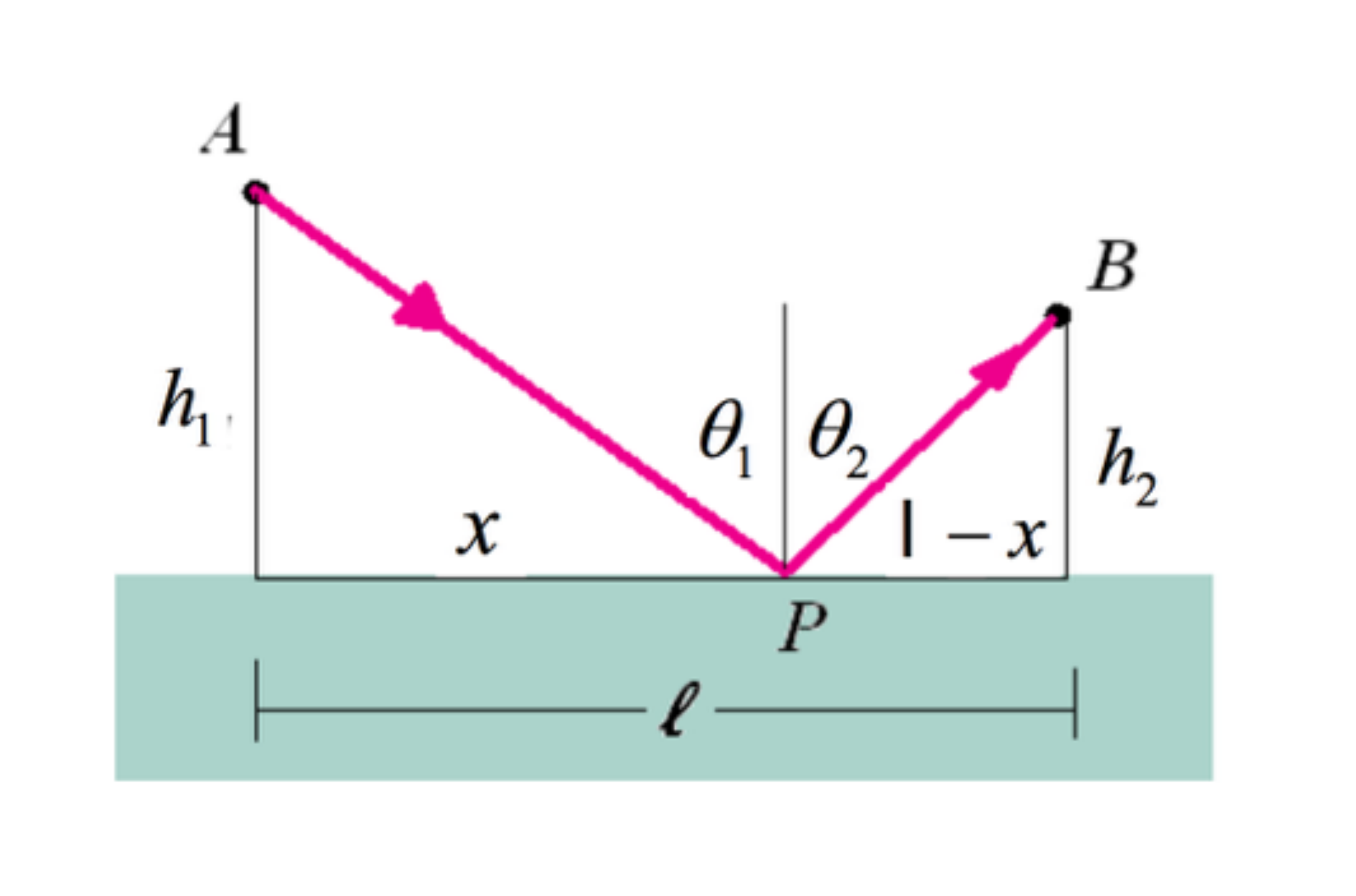
Light travels between two points along the path
that requires the least time,
as compared to other nearby paths



(Fermat = French mathematician, 1600s)

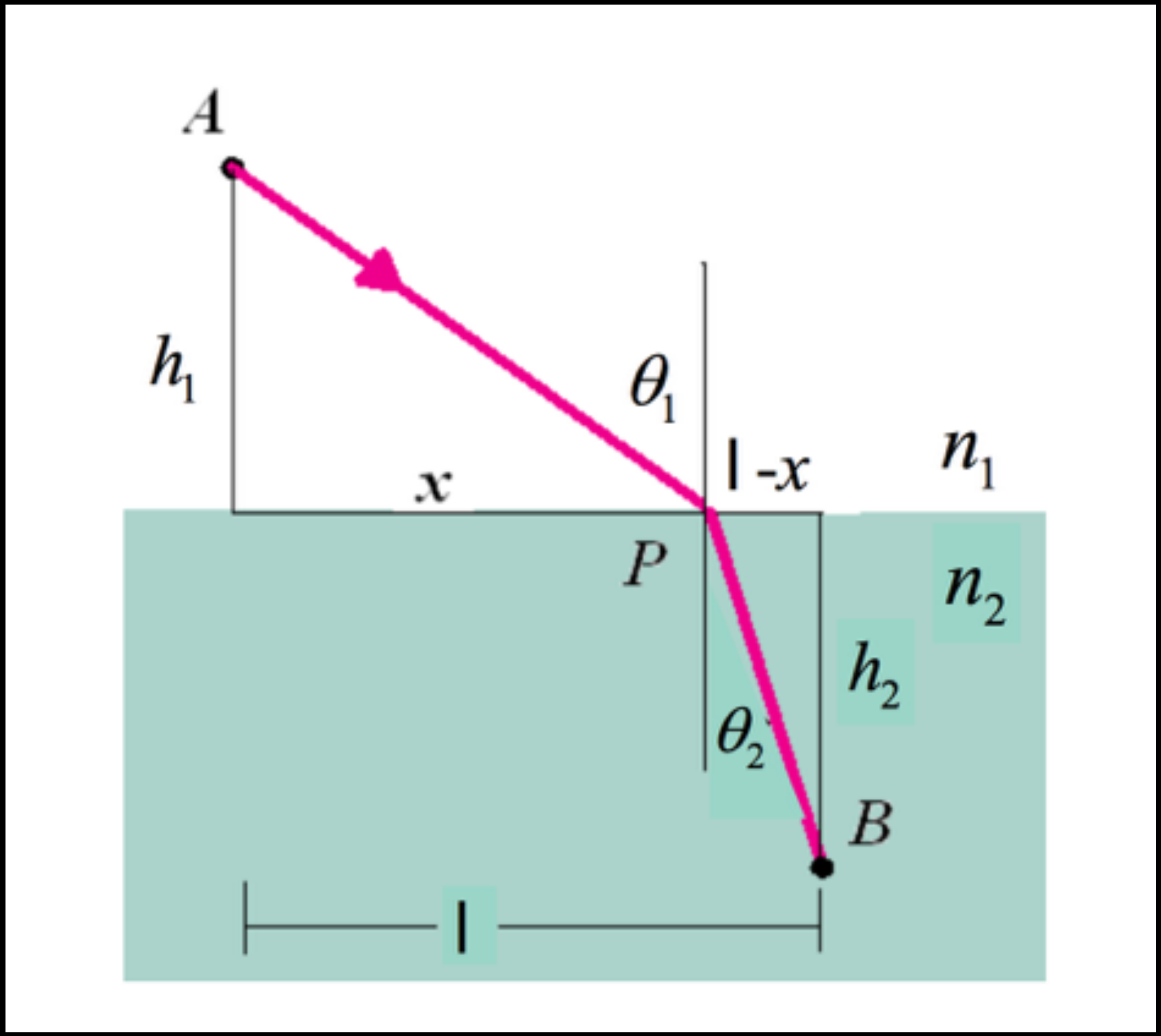
Law of Reflection

$$\theta_1 = \theta_2$$



Snell's Law (Refraction)

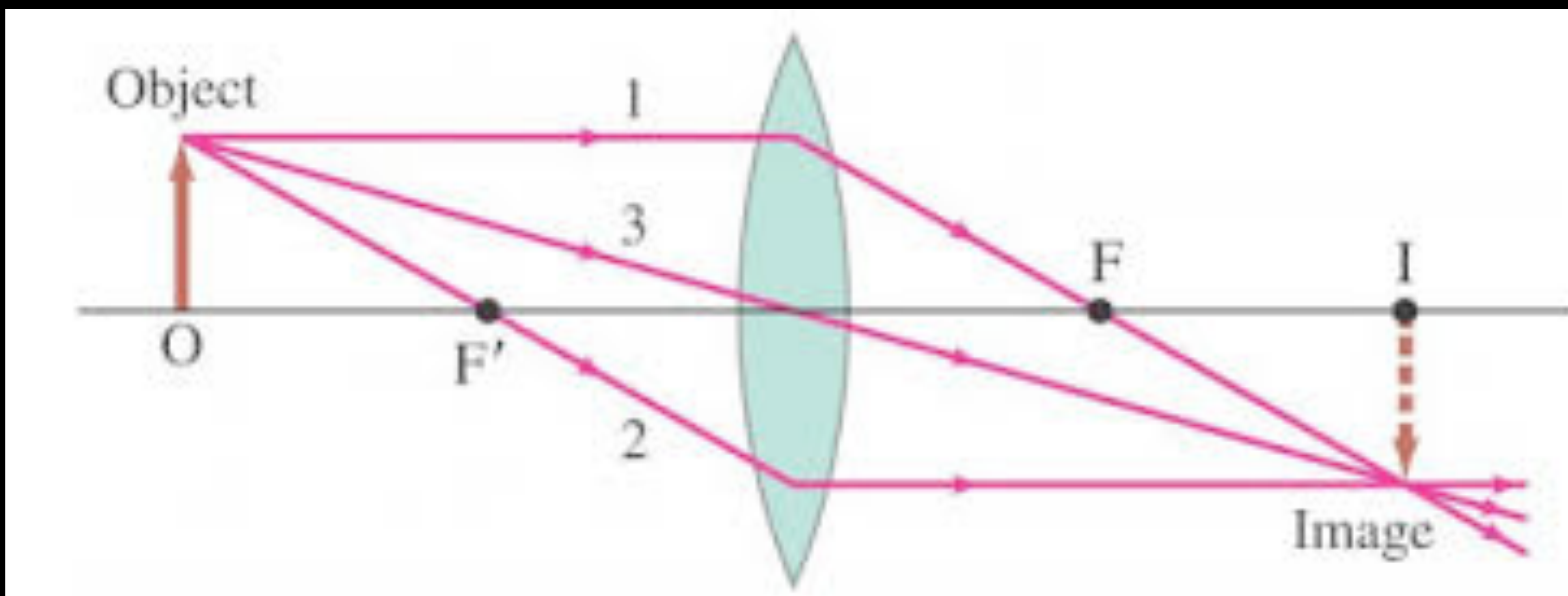
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$



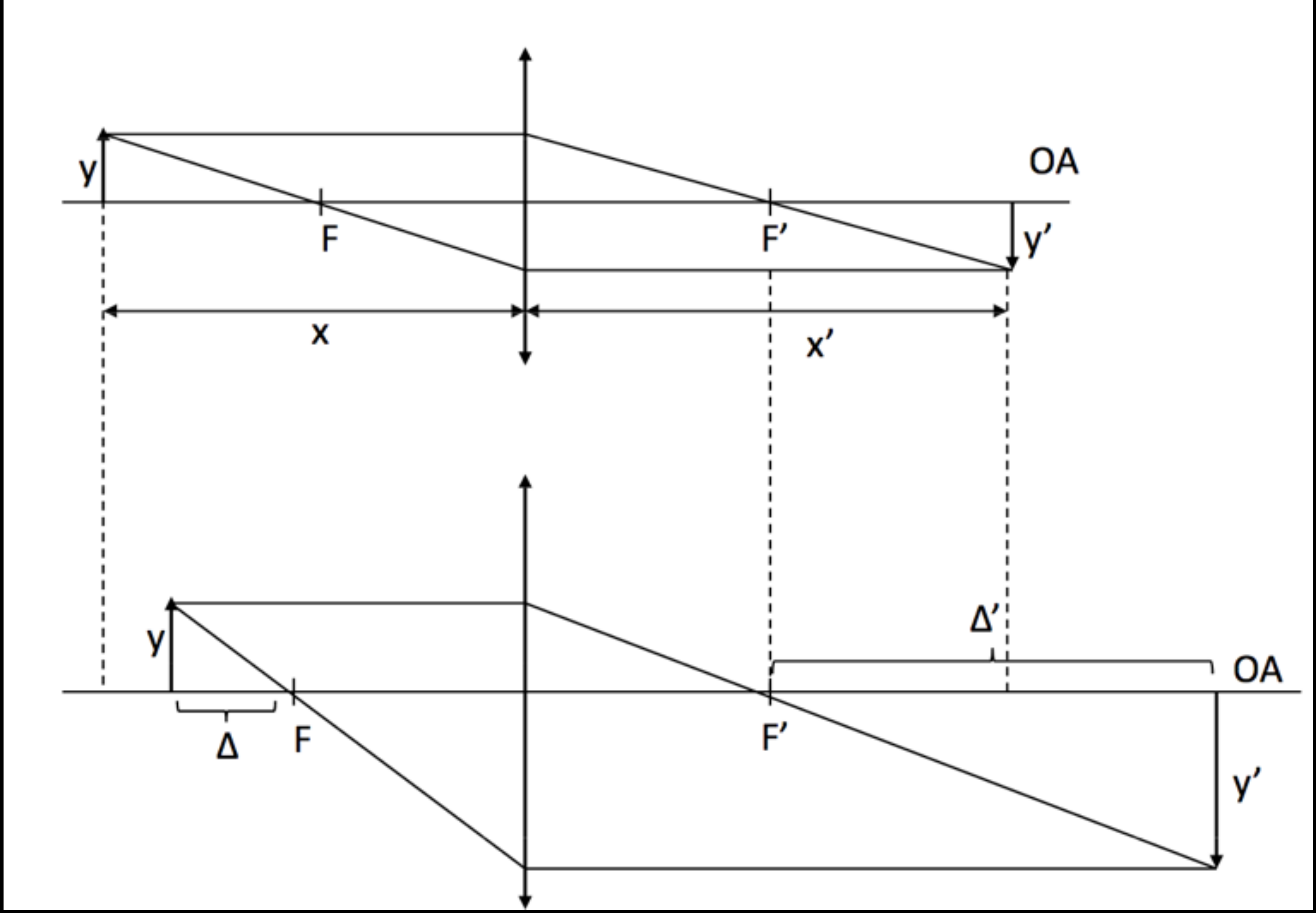
Total Internal Reflection

Geometrical Ray Optics

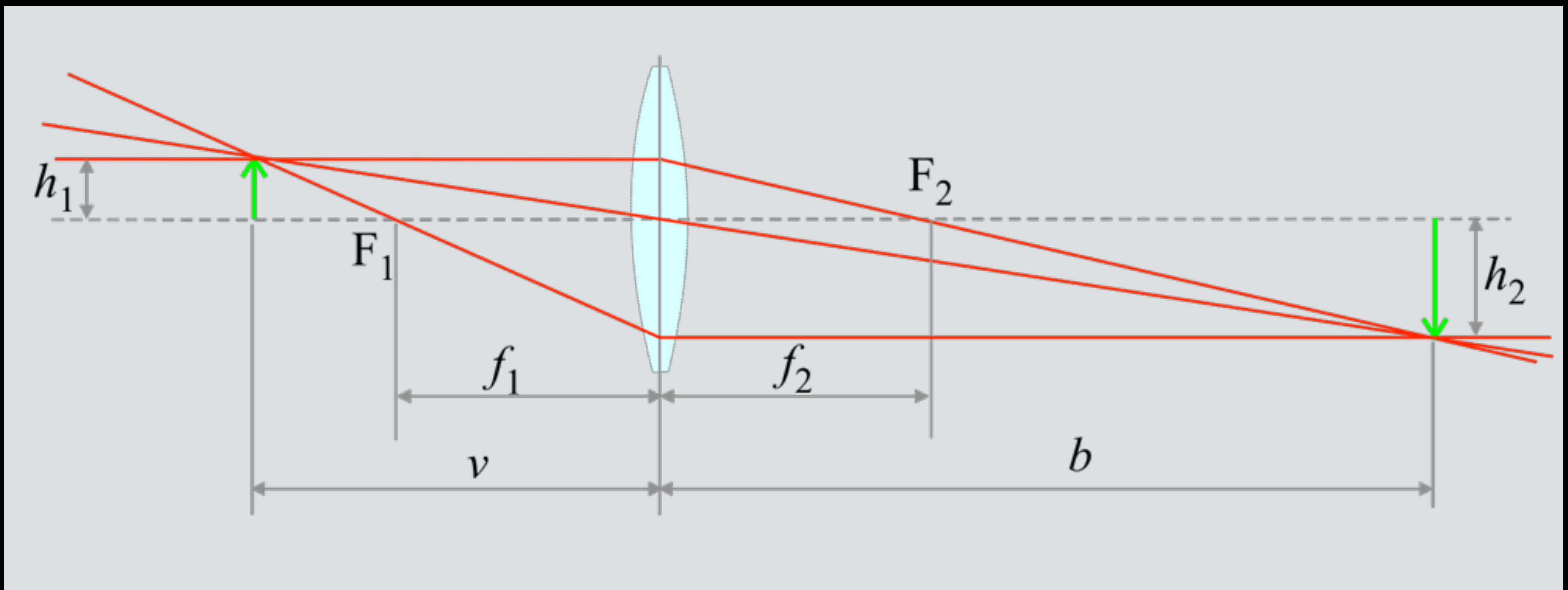
Three Principal Rays:



"4f system"

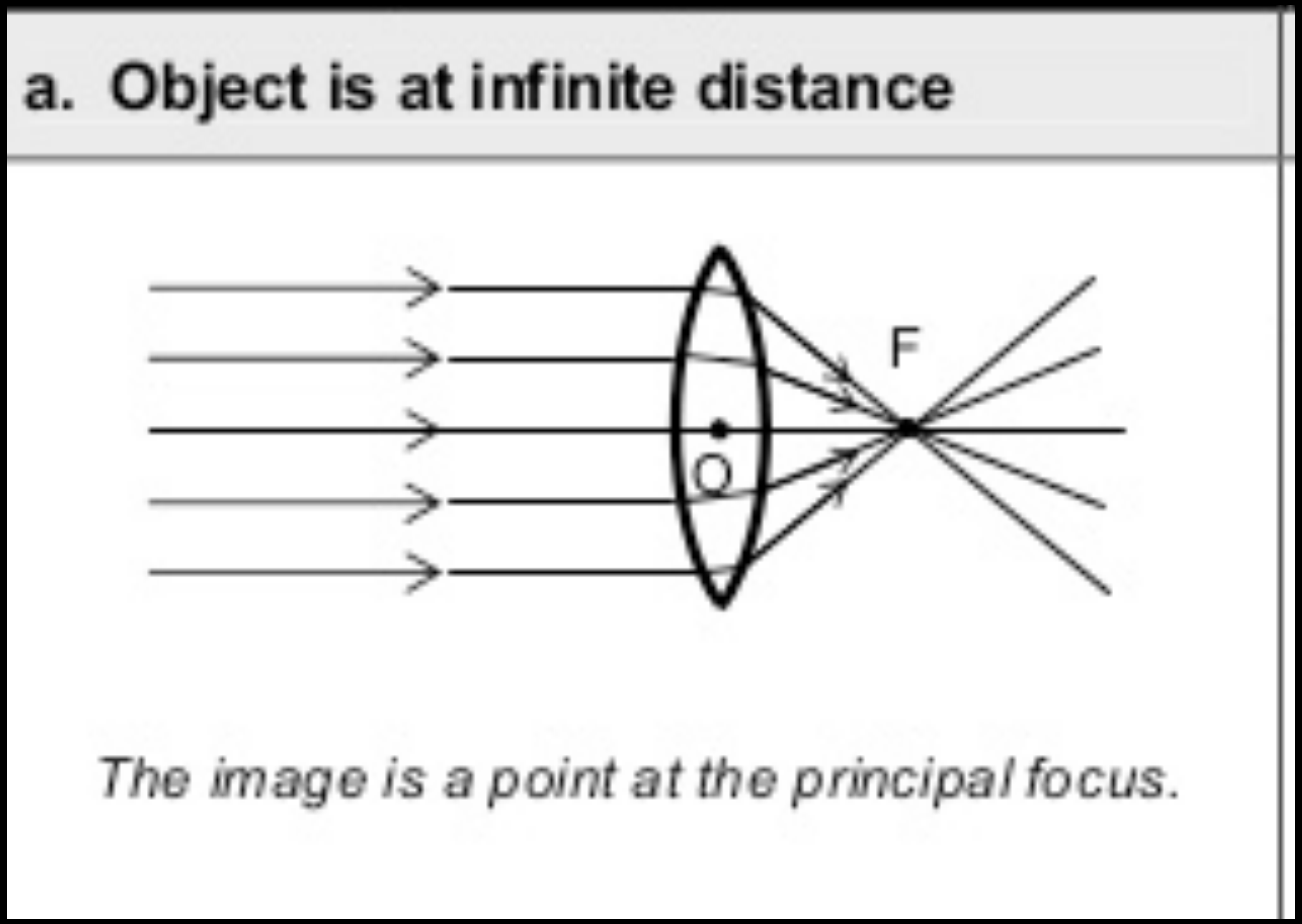


Magnification



$$M = f / (f-v)$$

Imaging at different focal positions



Imaging at different focal positions

b. Object is beyond twice the focal length (2F)

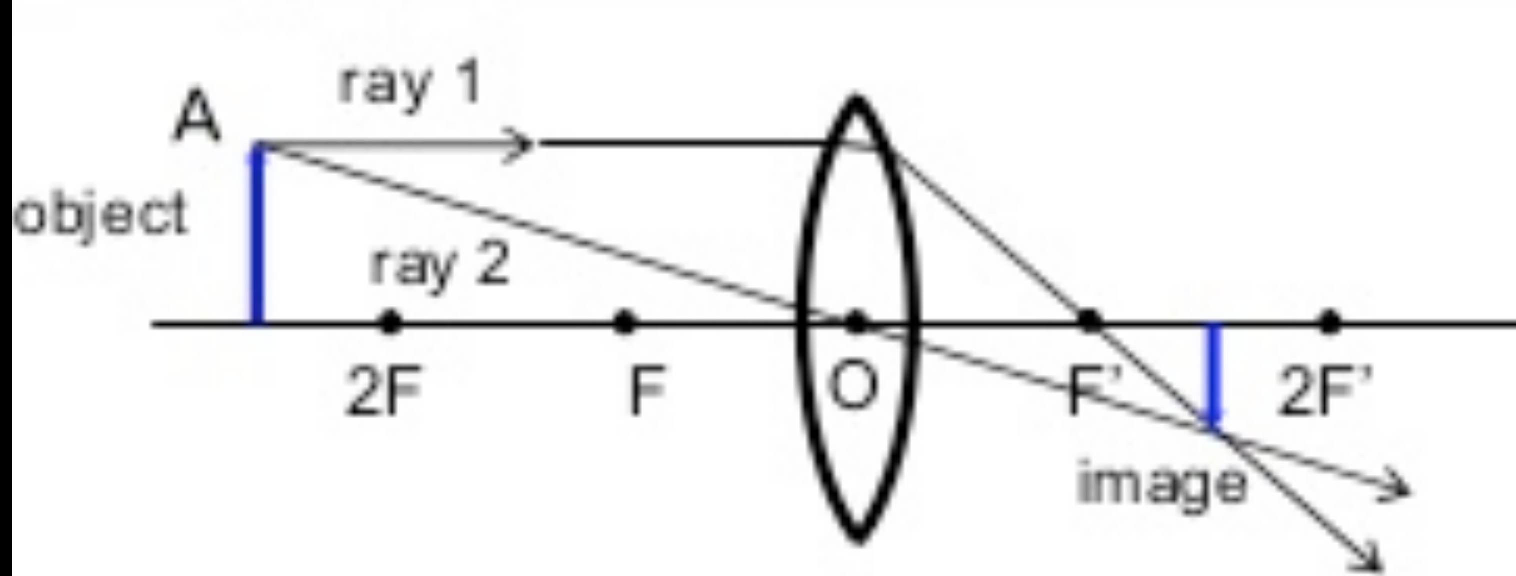


Image is real, inverted, diminished and located between F' and 2F'.

Imaging at different focal positions

c. Object is at twice the focal length (2F)

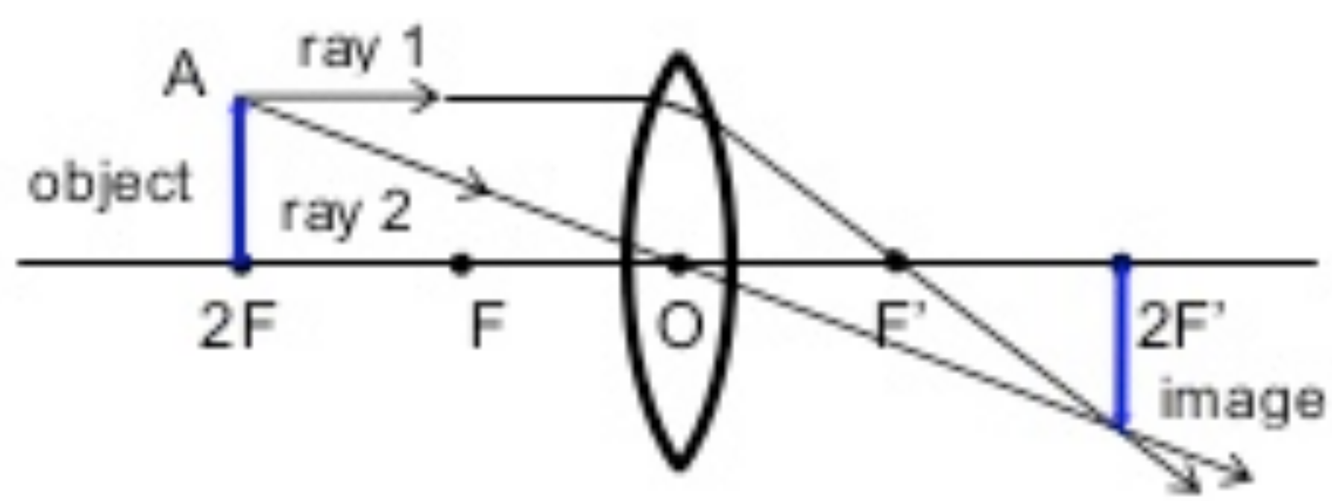
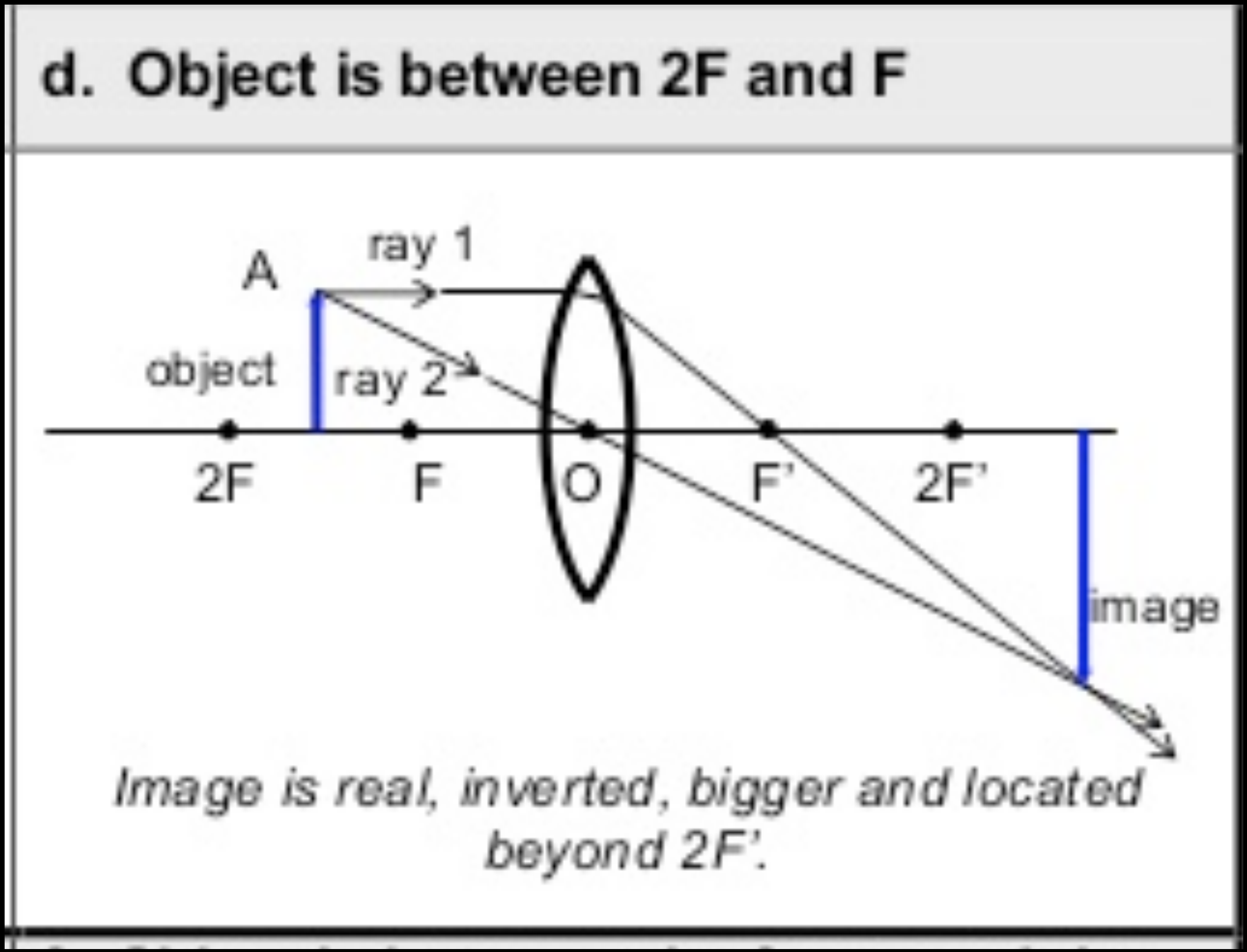
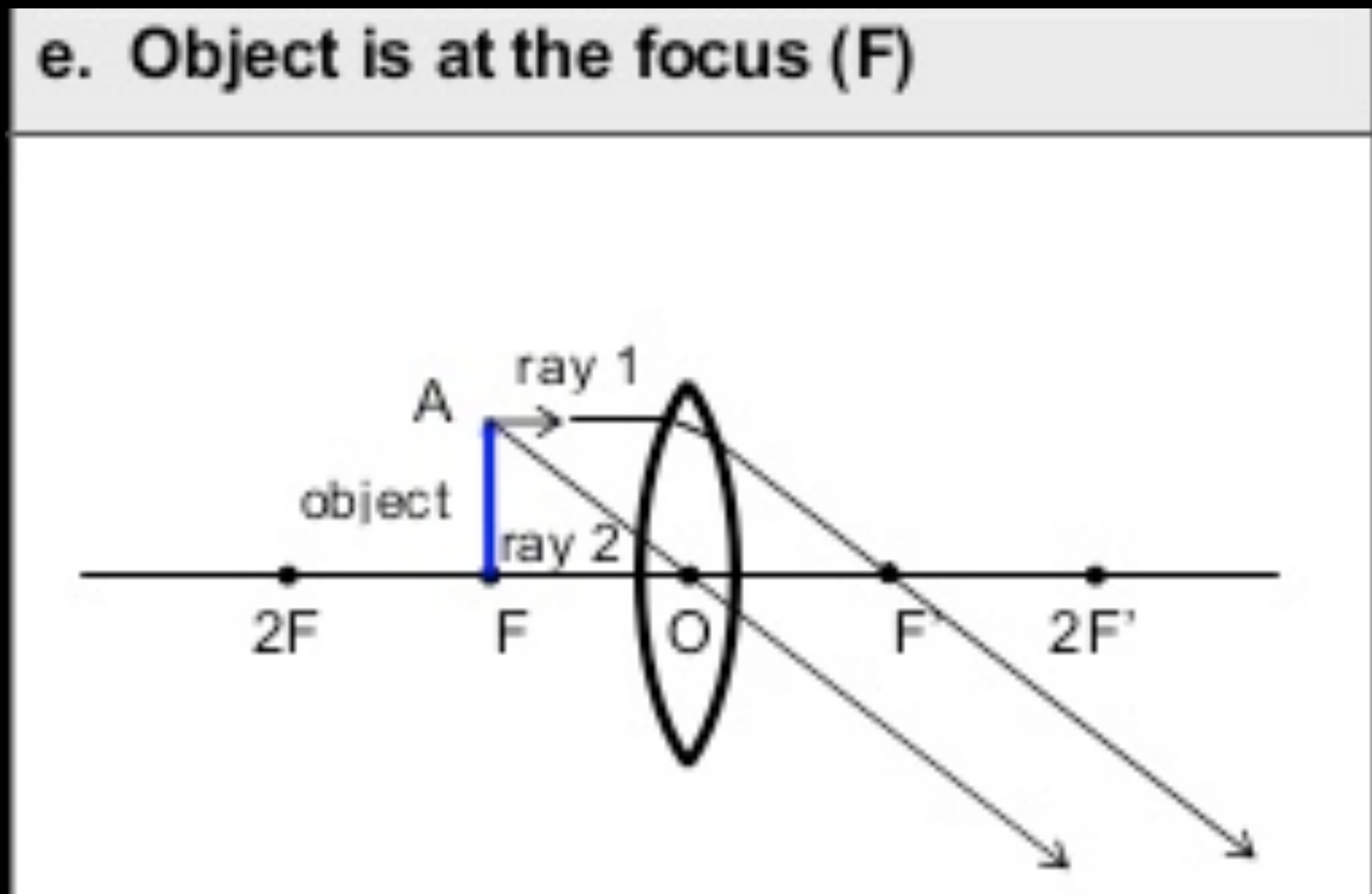


Image is real, inverted, of the same size and located at 2F'.

Imaging at different focal positions



Imaging at different focal positions



Refracted rays are parallel. No image is formed.

Imaging at different focal positions

f. Object is between the focus and the optical center

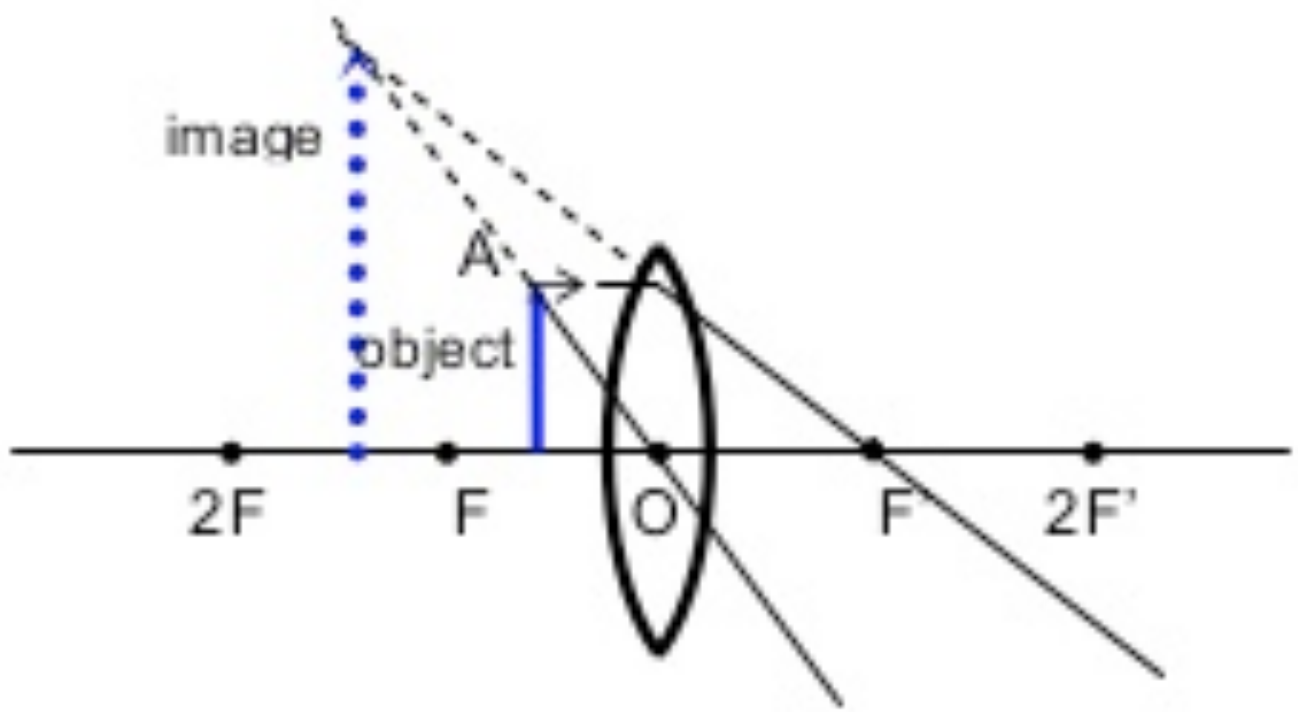
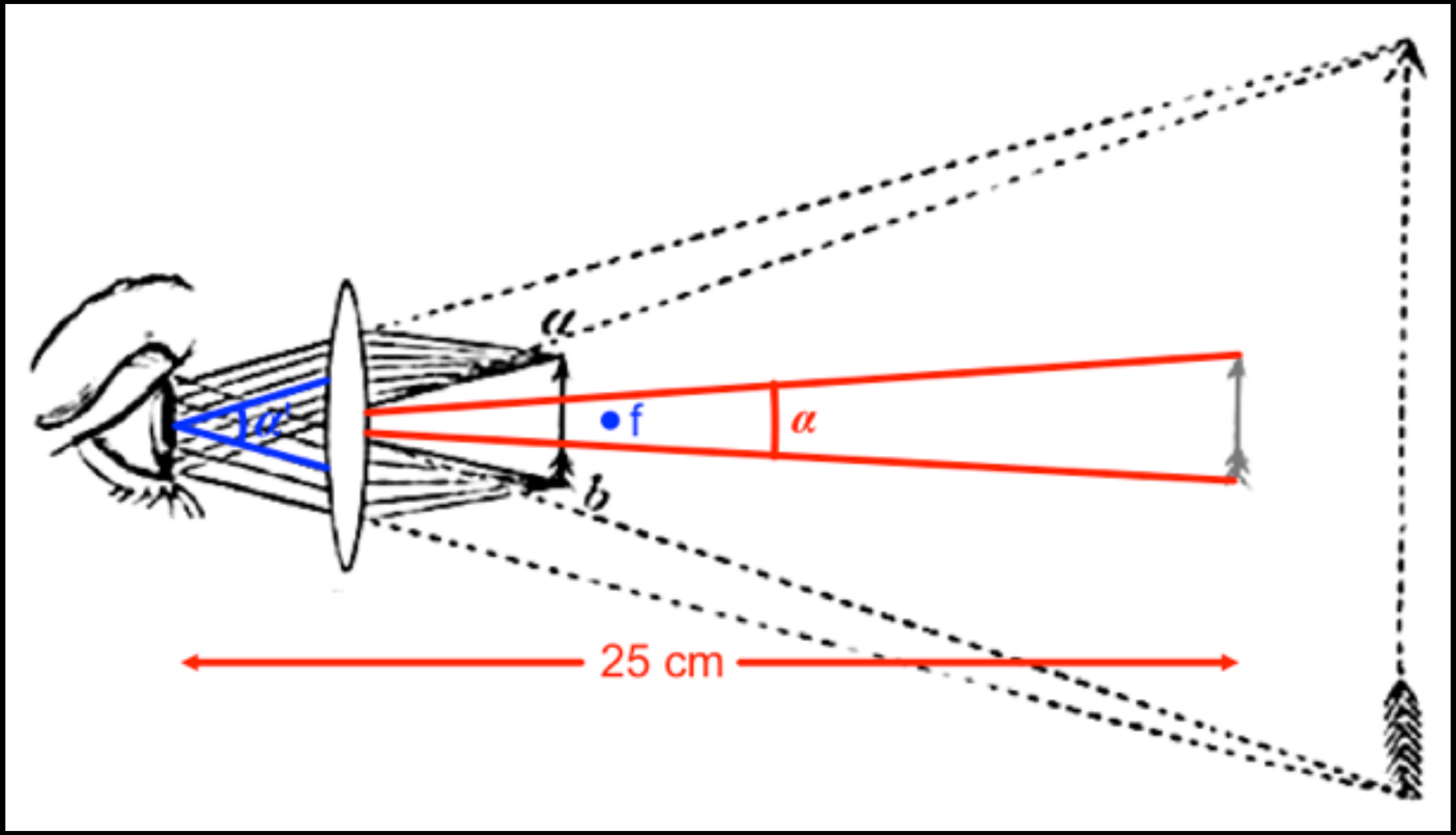


Image is virtual, erect, bigger and located between 2F and F.

Magnifying glass and loupe

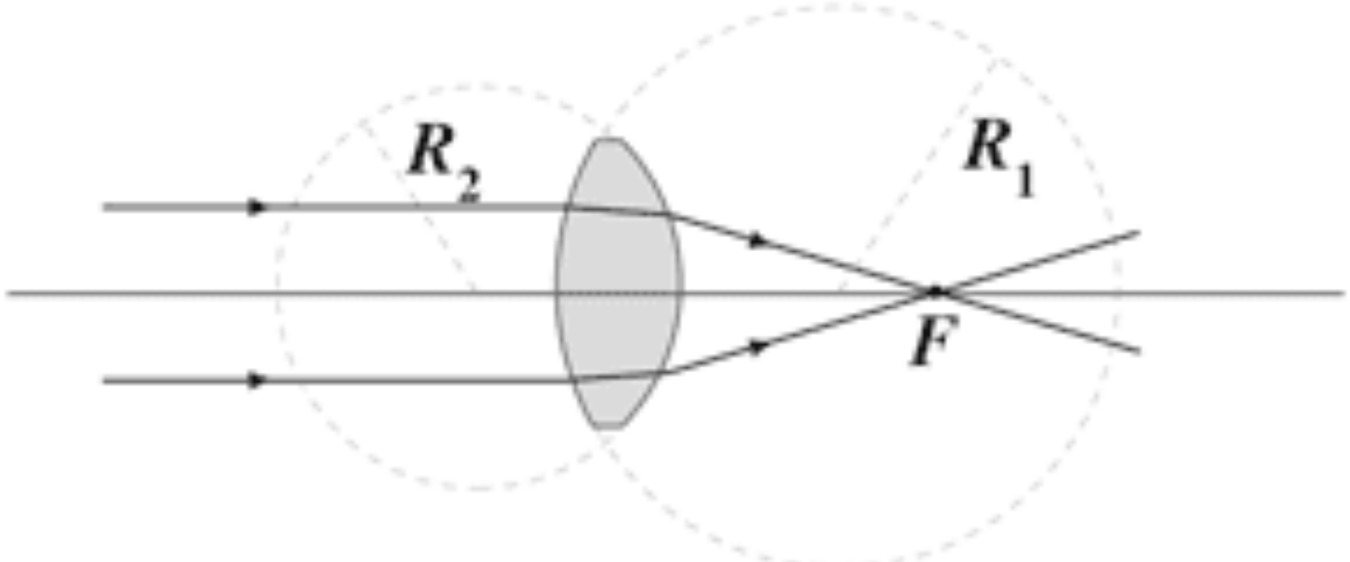


IT’S BREAK TIME

Lens-Maker's Equation

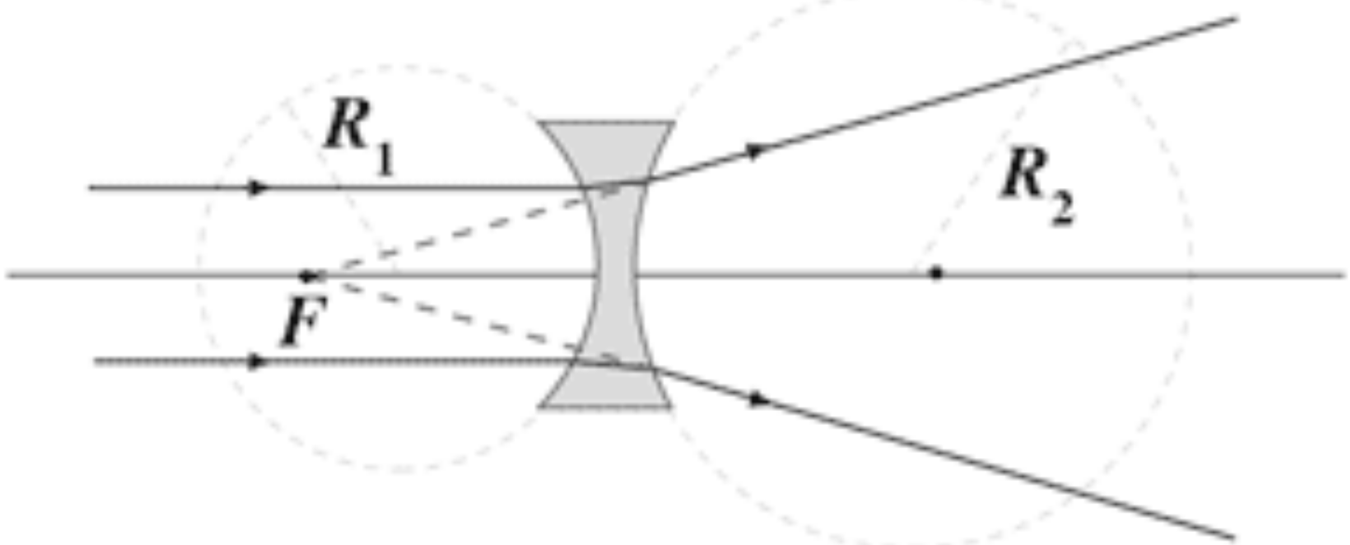
$$\frac{1}{F} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

F = focal length (1/2 C)
n = refractive index
R = radius of curvature



Positive (Converging) Lens

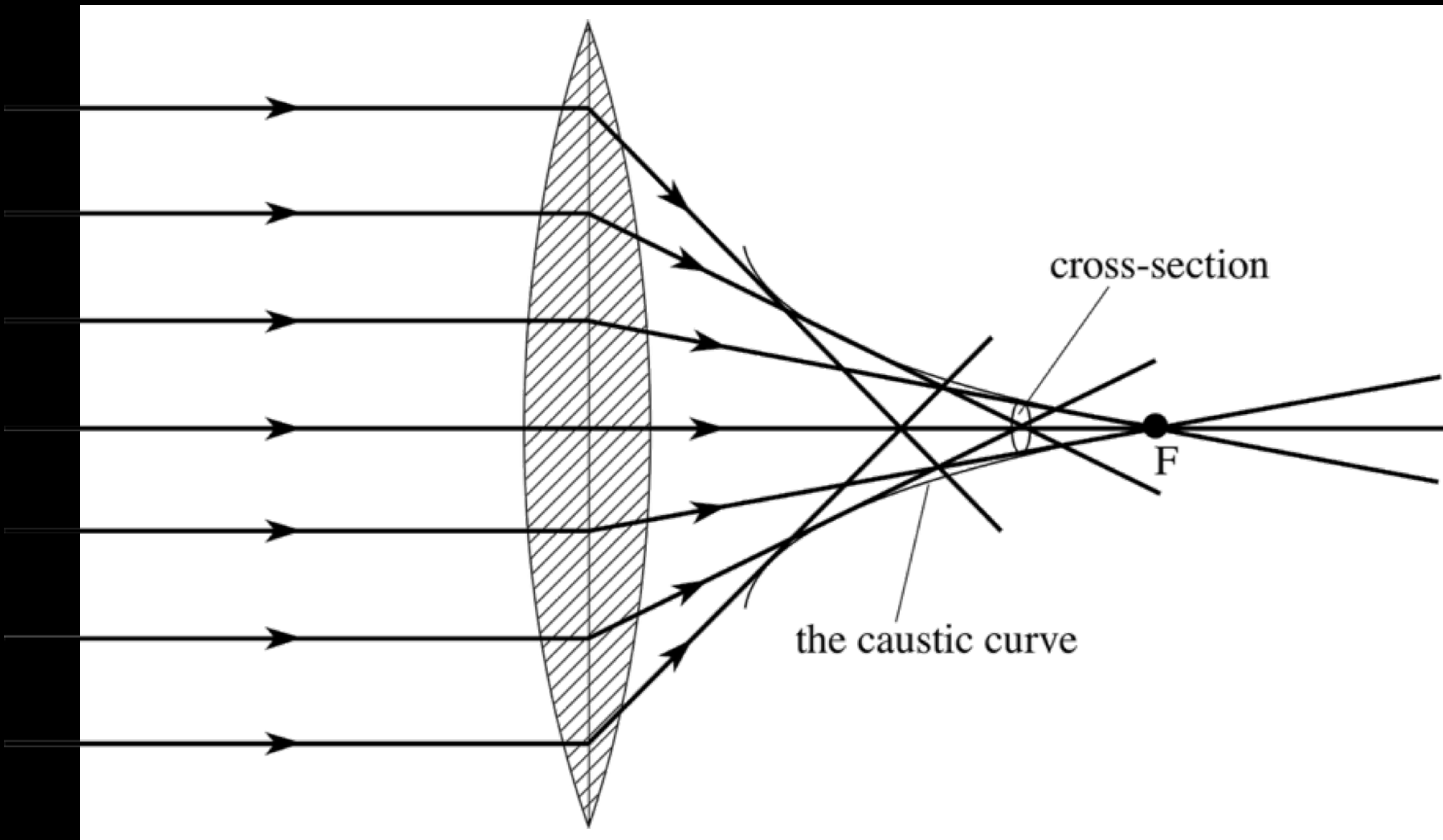
R_1 – positive
R_2 – negative
F – positive



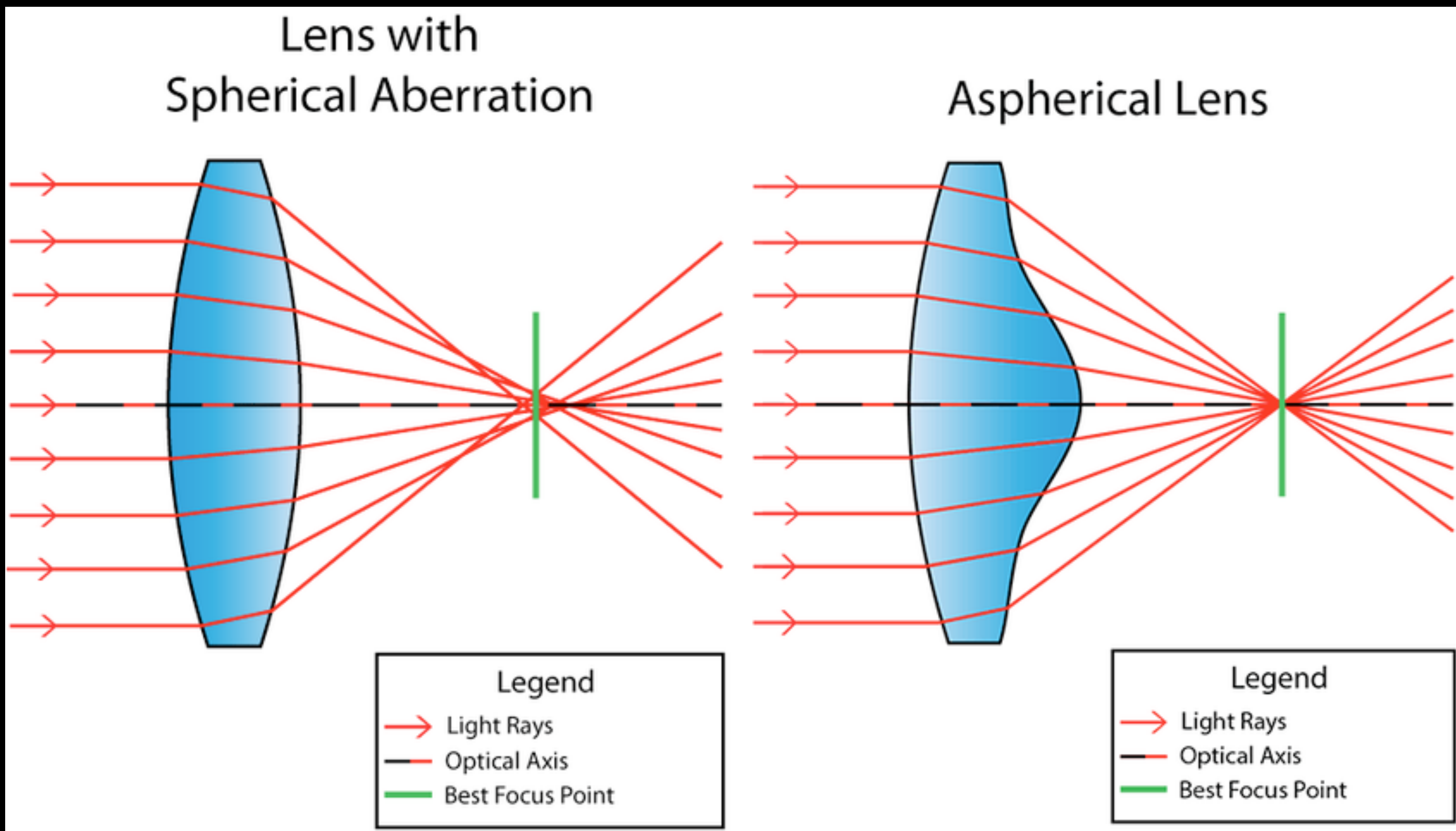
Negative (Diverging) Lens

R_1 – negative
R_2 – positive
F – negative

Spherical Aberration



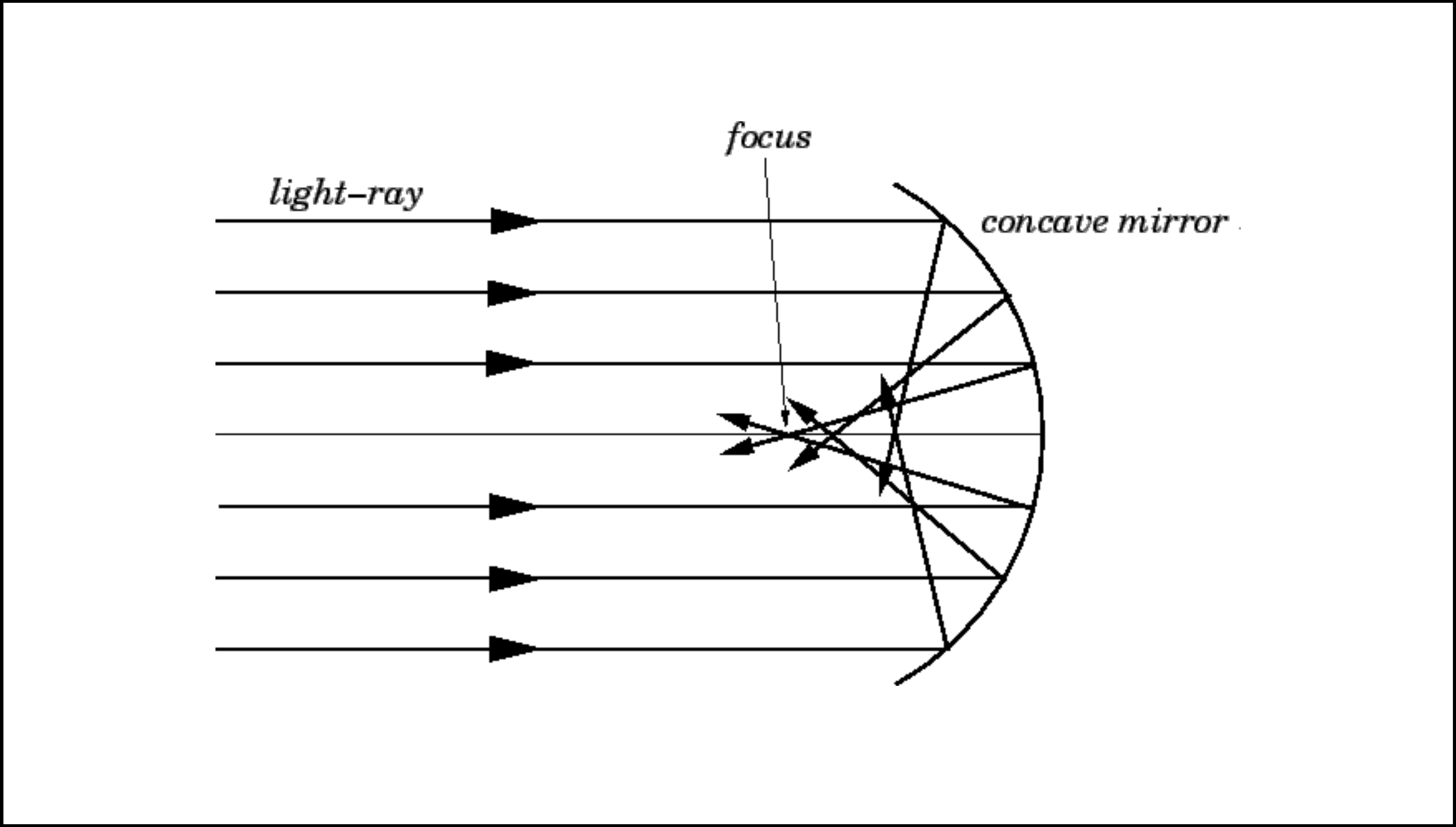
Spherical Aberration



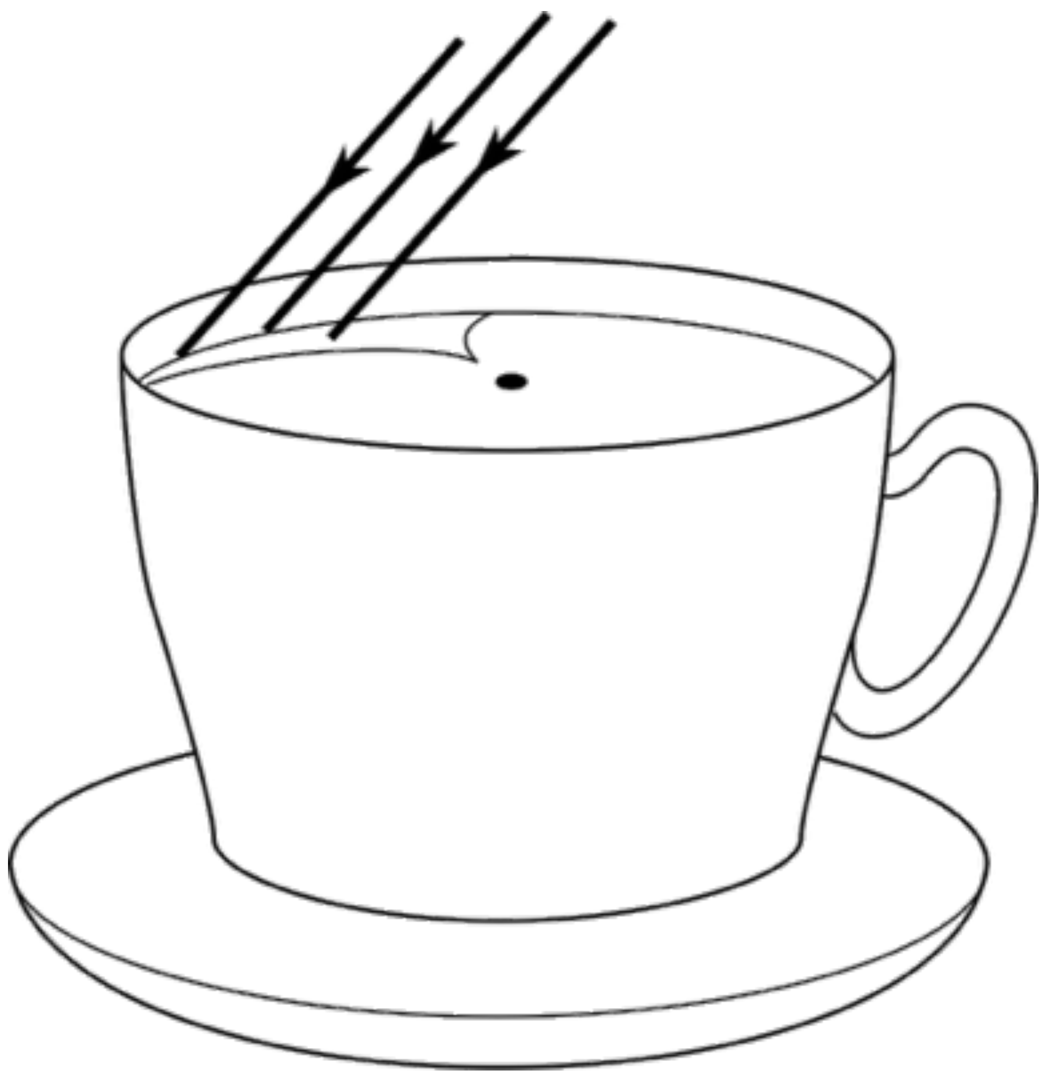
Aspherical Lenses

Earliest preserved optical quality lenses (~10th century Visby, Sweden)

Spherical mirror

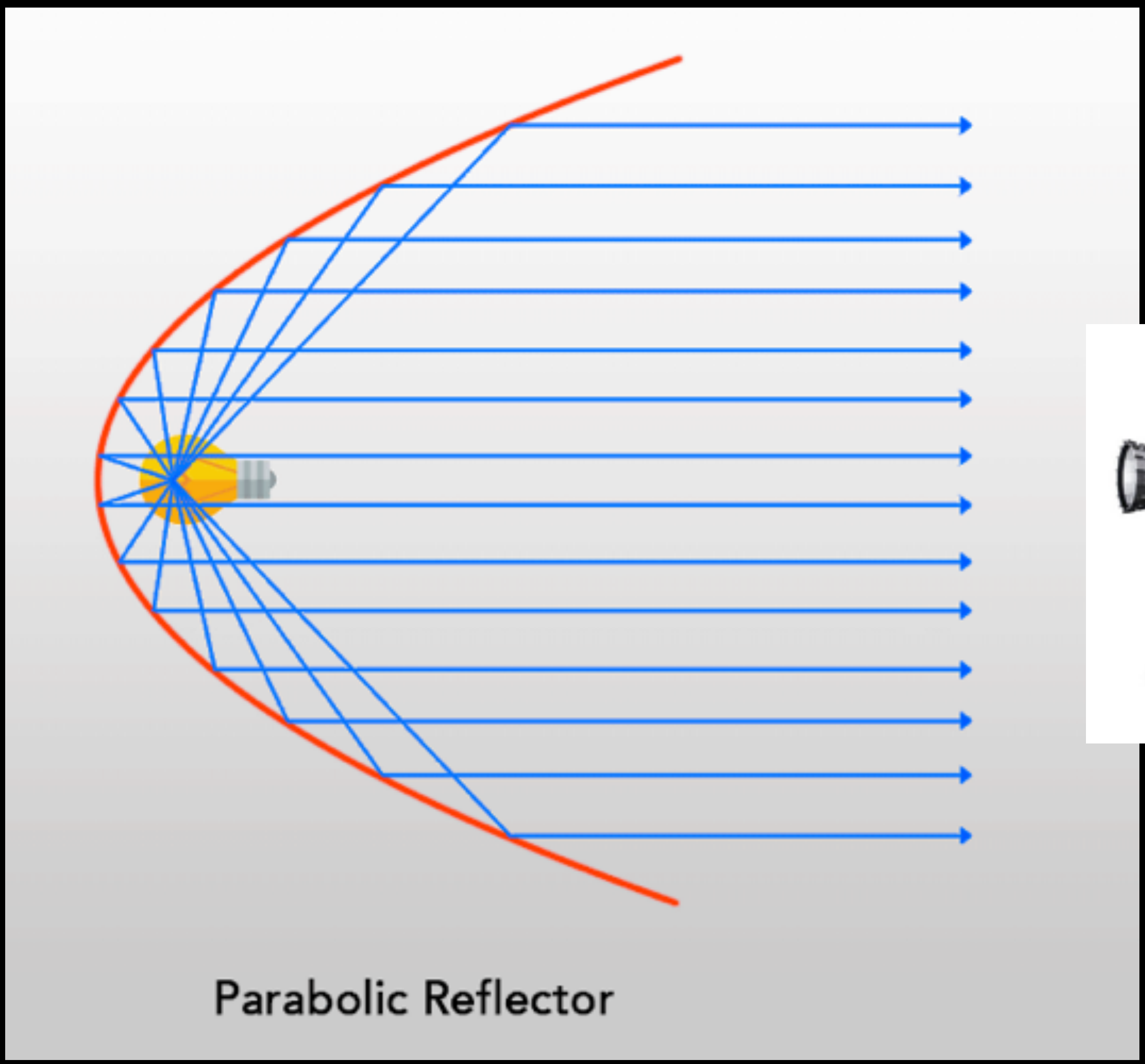


Caustic Curve

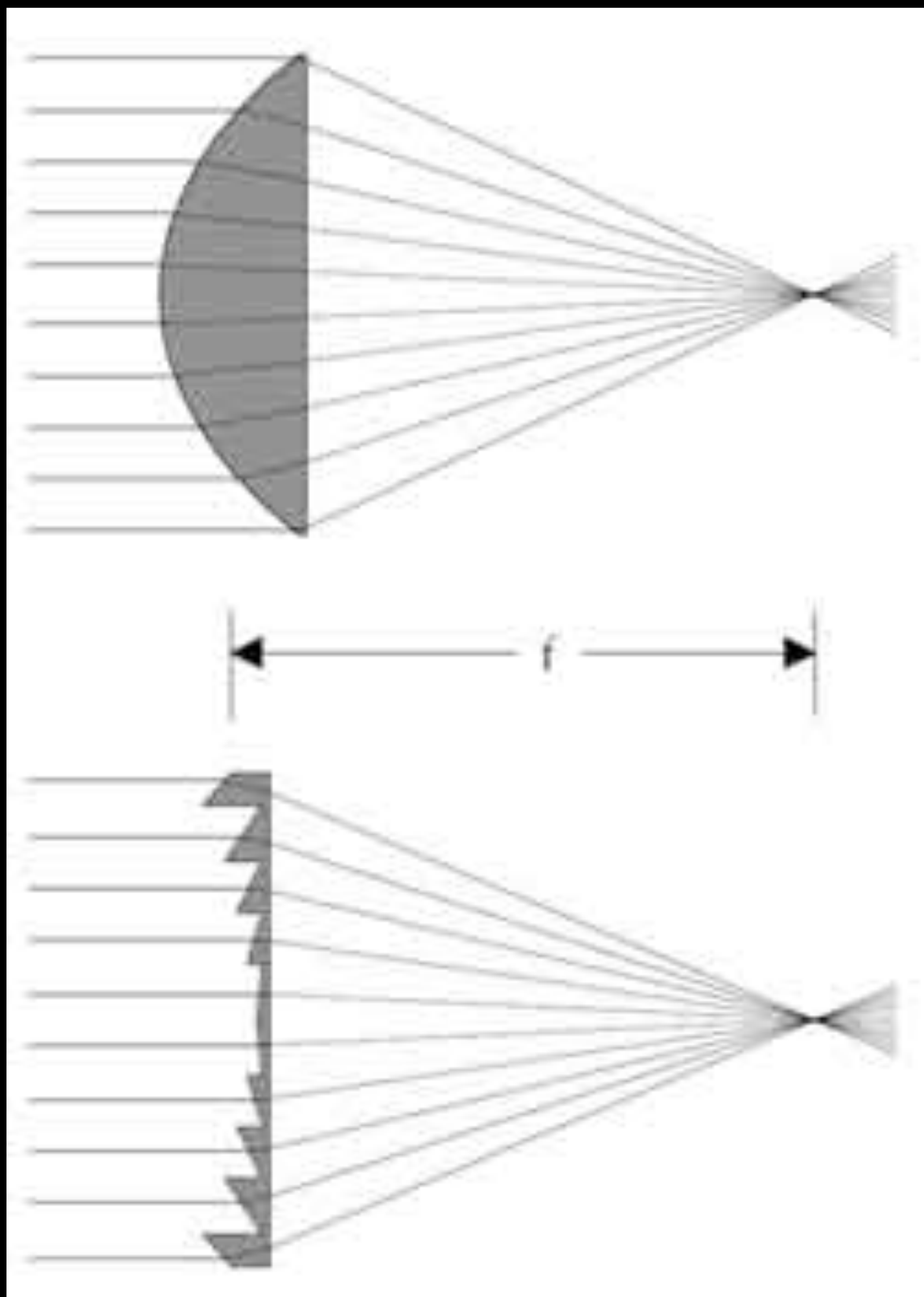


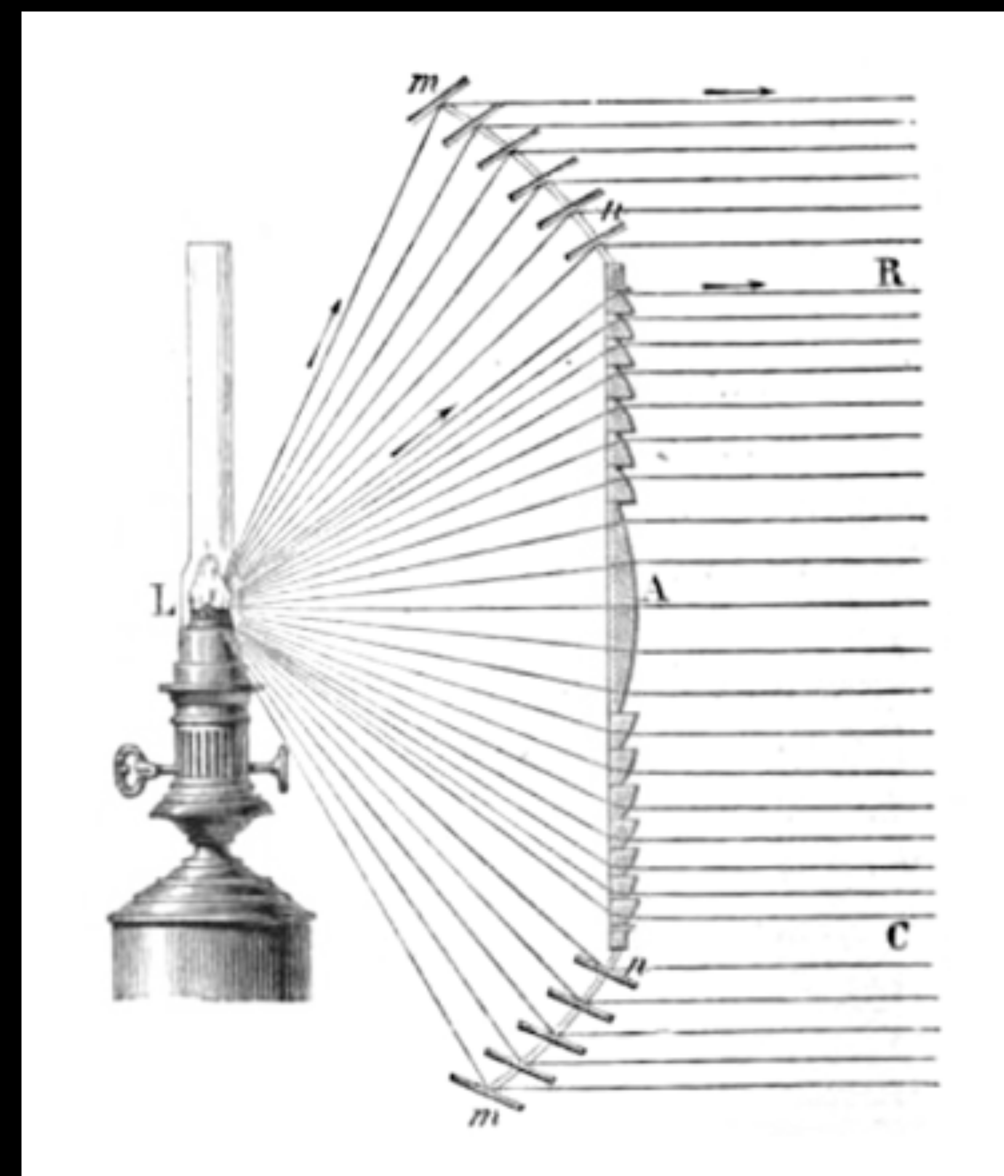
Spherical aberration
in a cup of tea

Parabolic Reflector



The Fresnel Lens





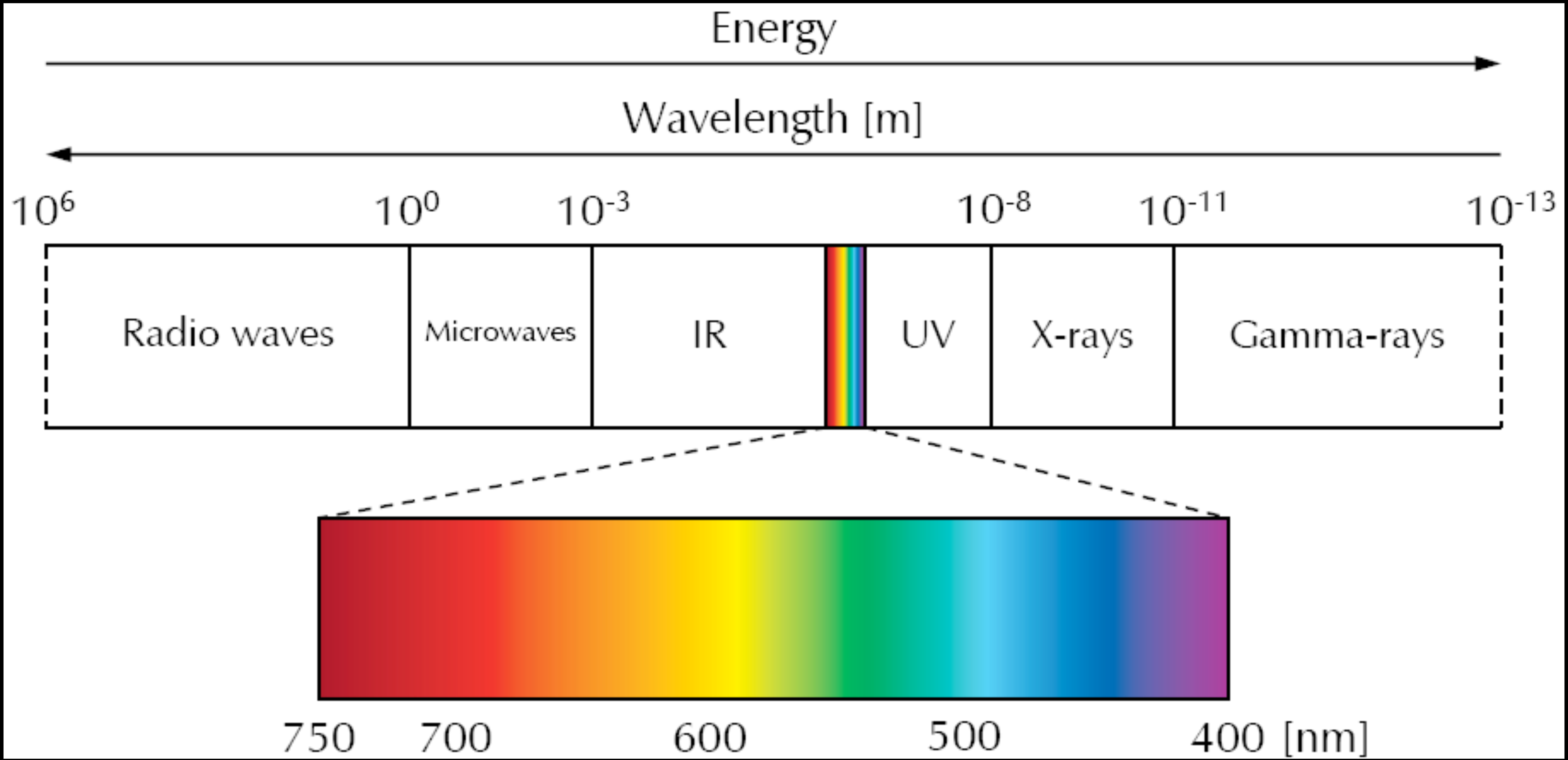
Fresnel Lenses

John Ford using a 24" Fresnel lens
shooting John Wayne

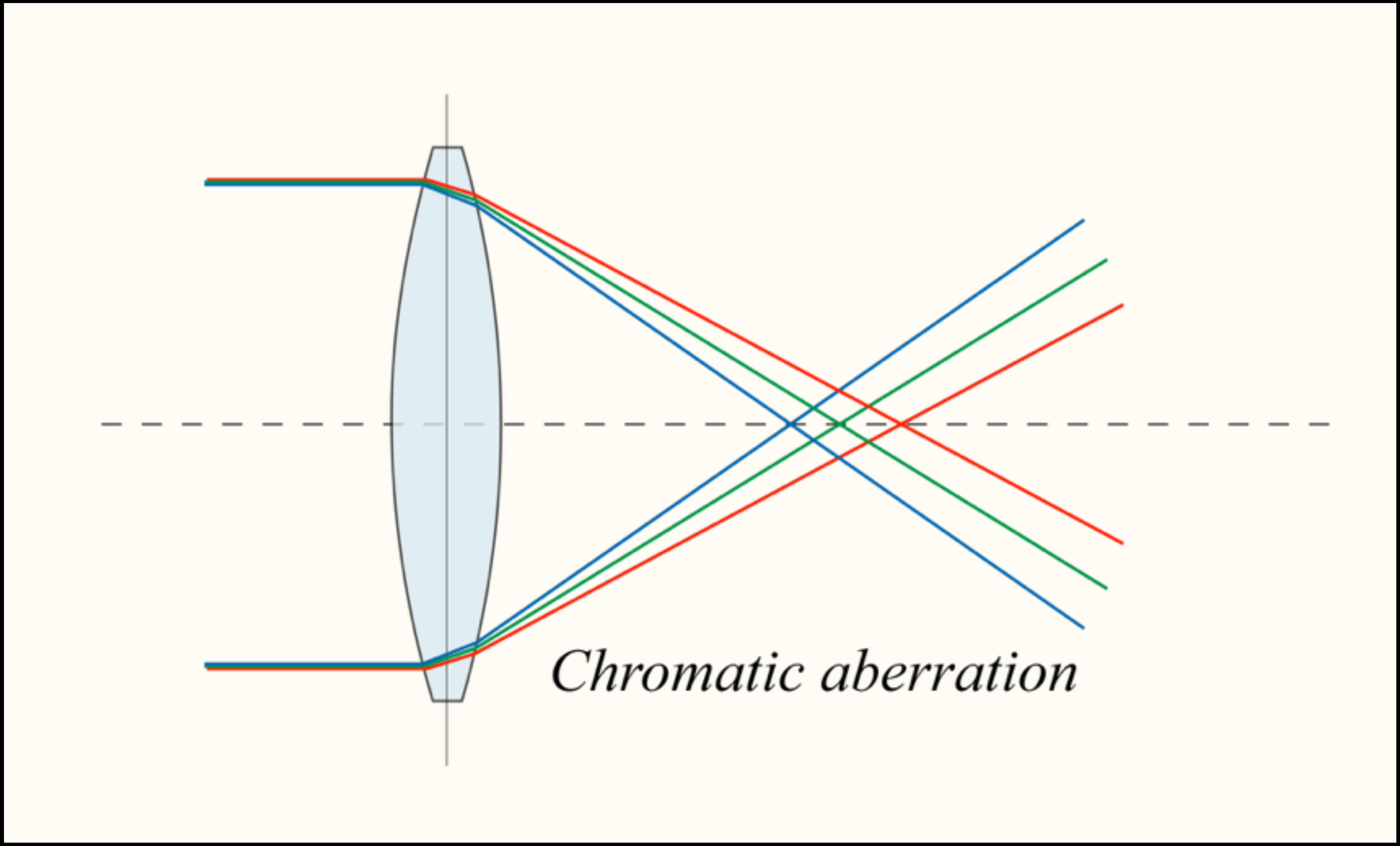
Fresnel lens in lighthouse

Refraction in a Prism

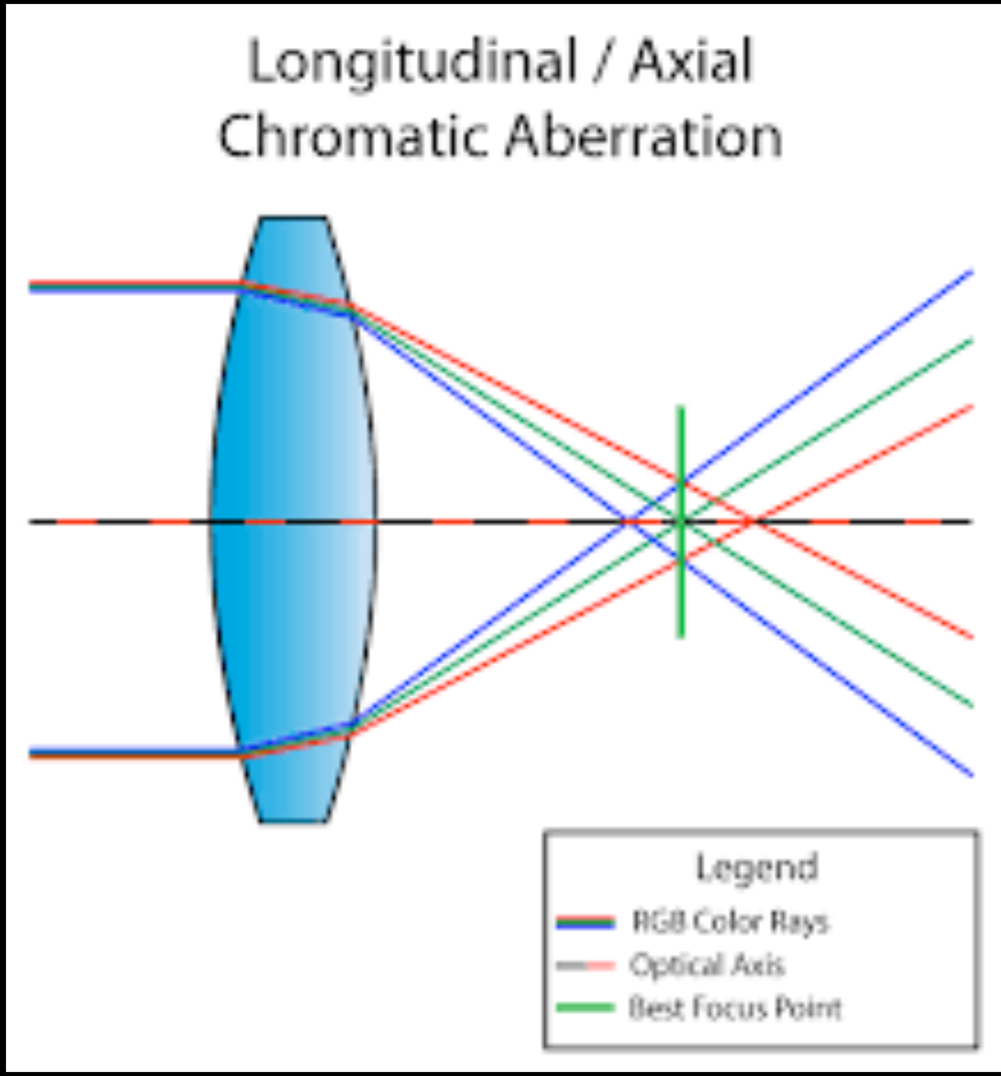
Visible Light Wavelength Spectrum

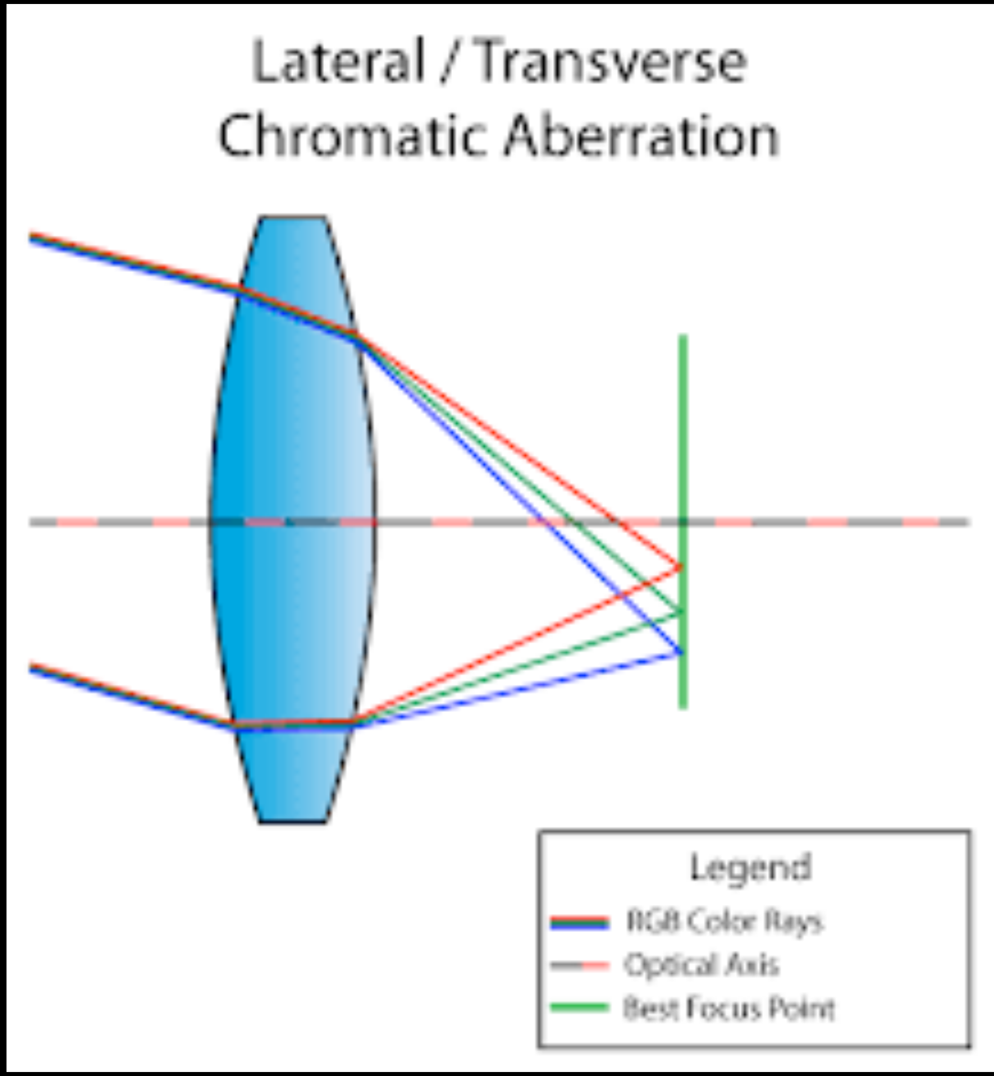


Refractive index ~ wavelength

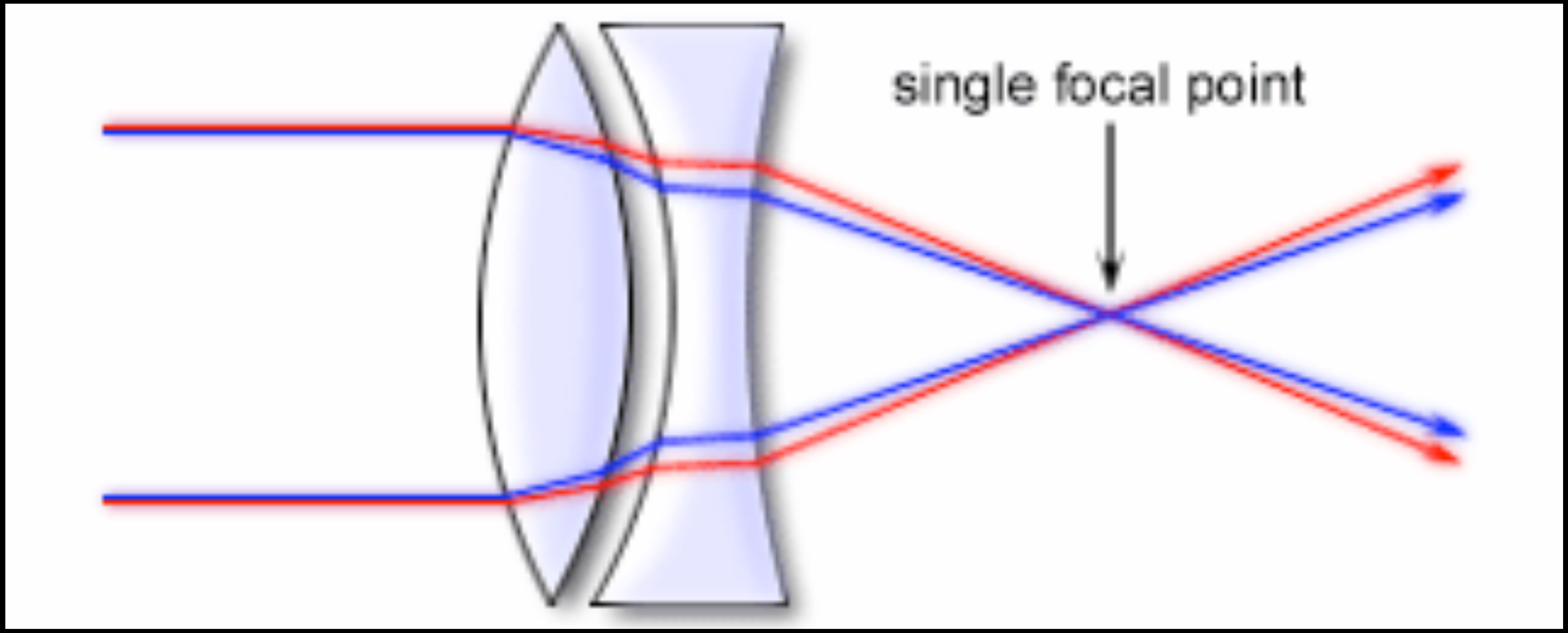


Chromatic Aberration



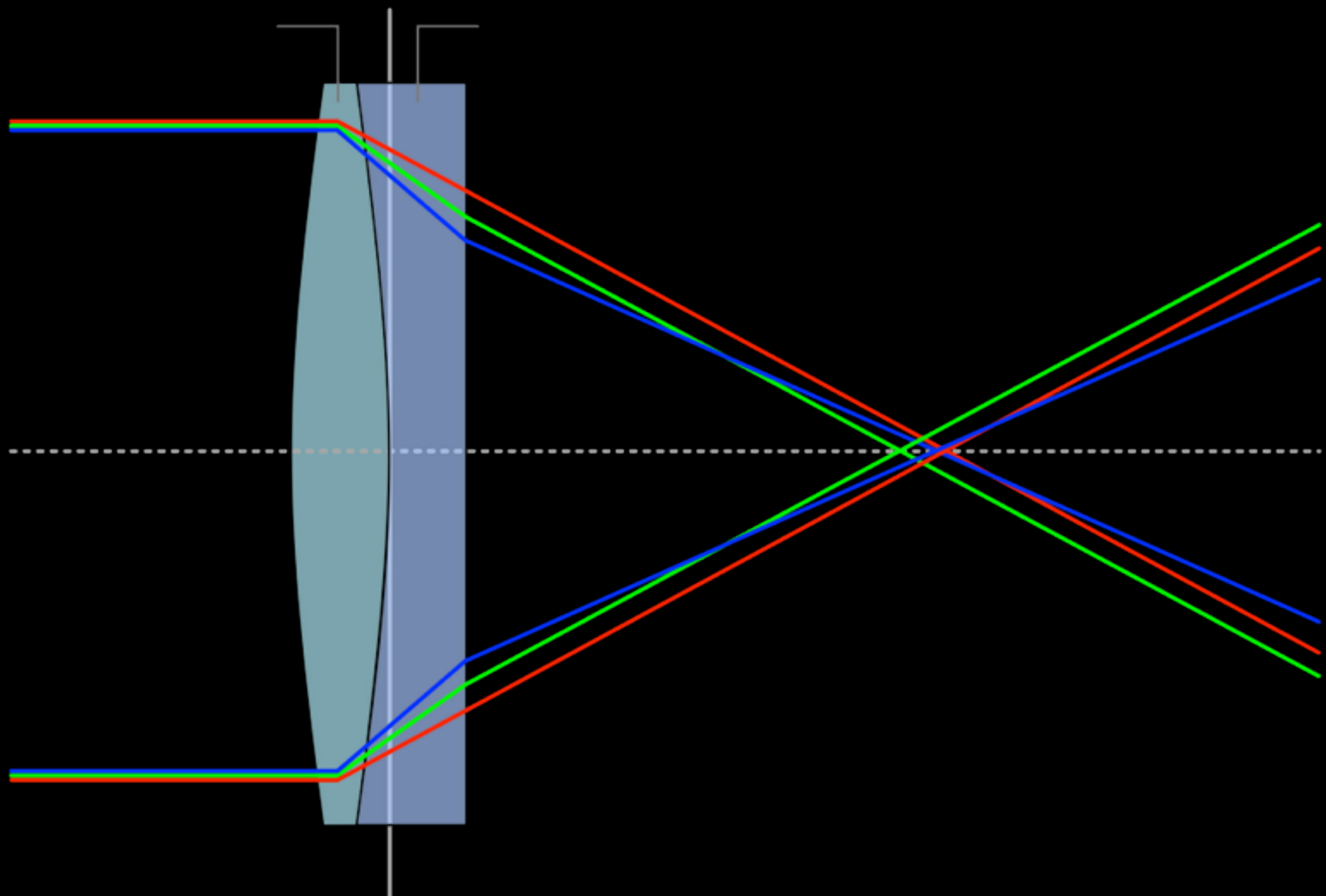


Achromatic Doublet



First lens: Crown glass   Second lens: Flint glass

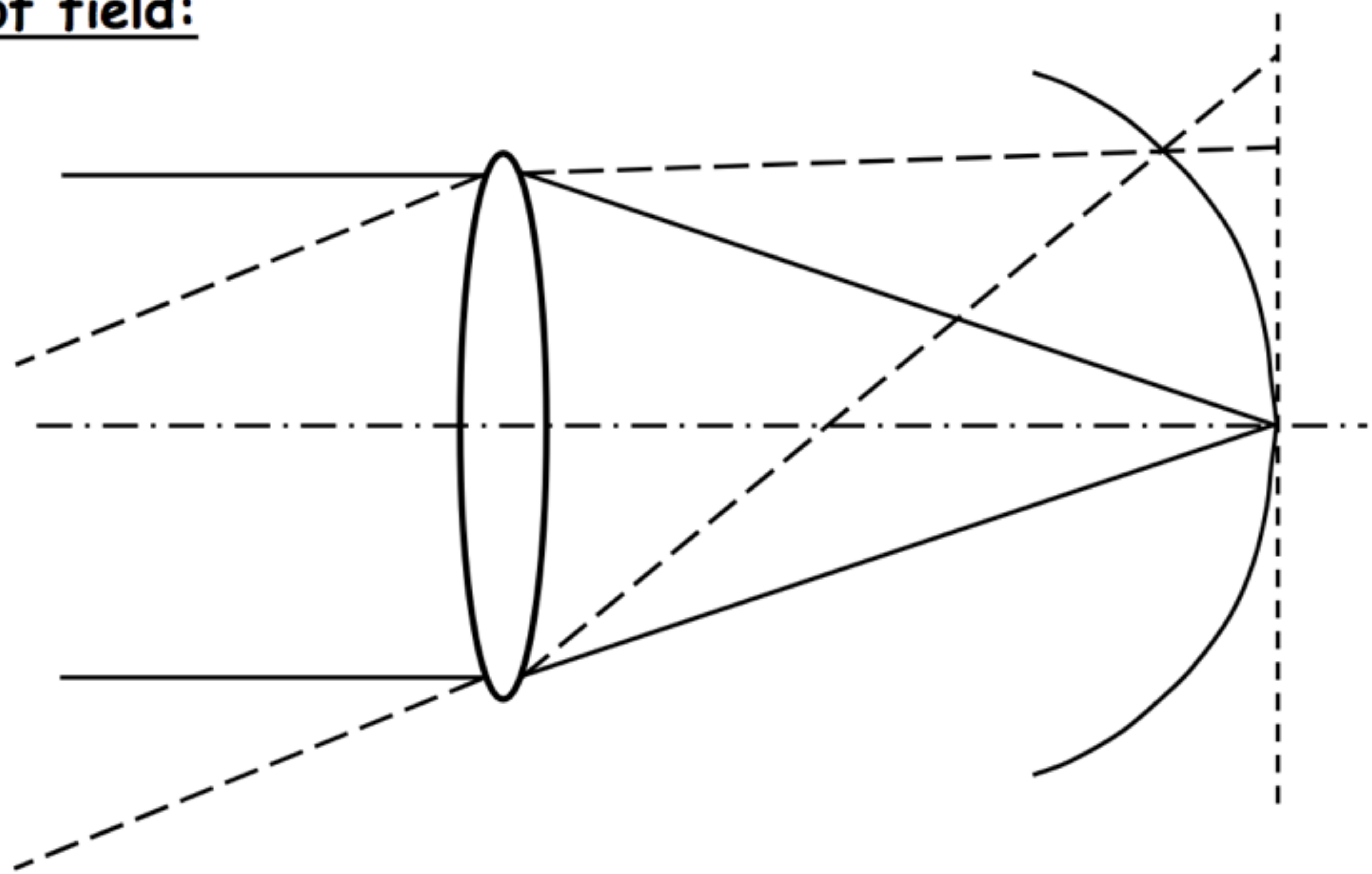
Not perfect



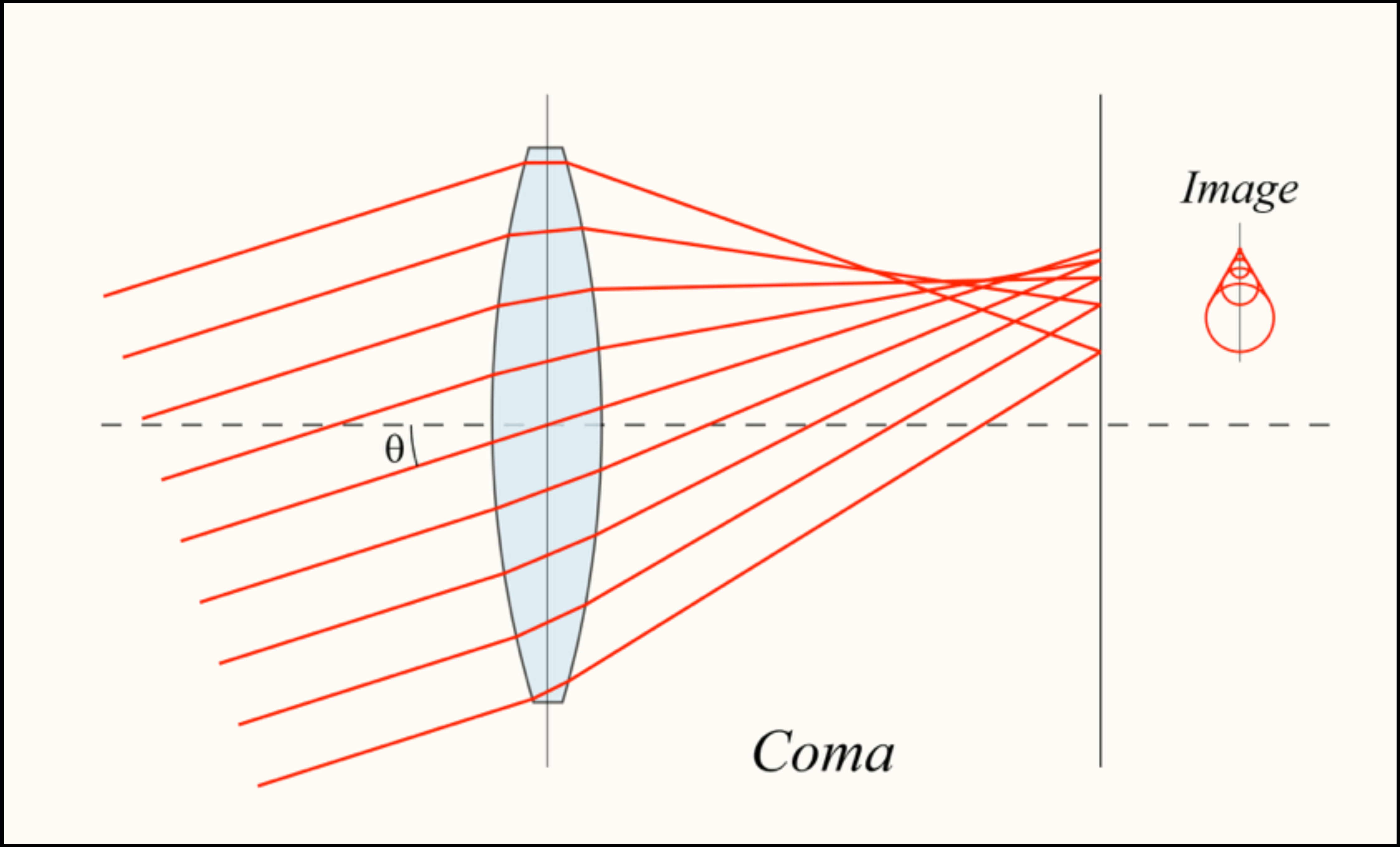
(Mirrors don't have chromatic dispersion)

Field Curvature

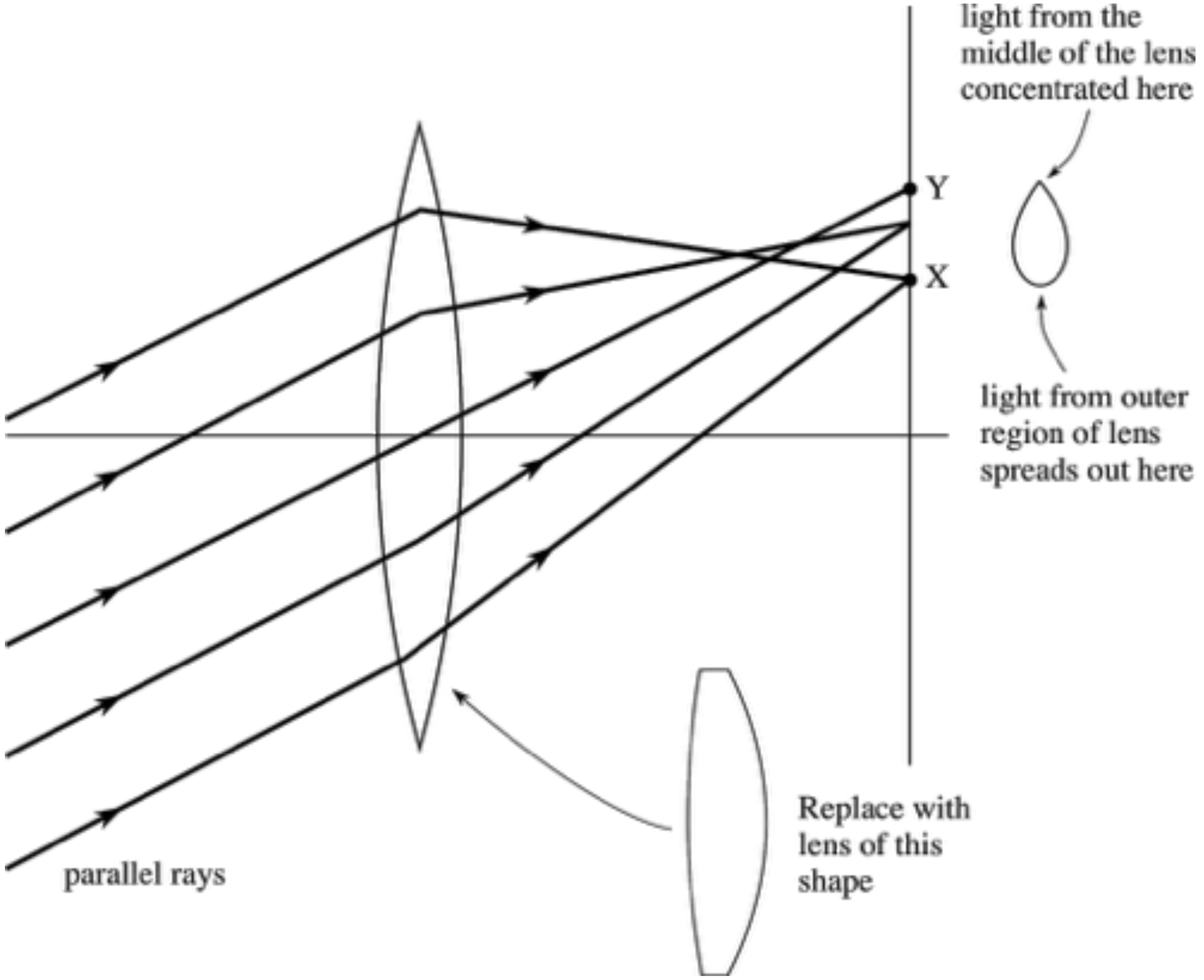
Curvature of field:



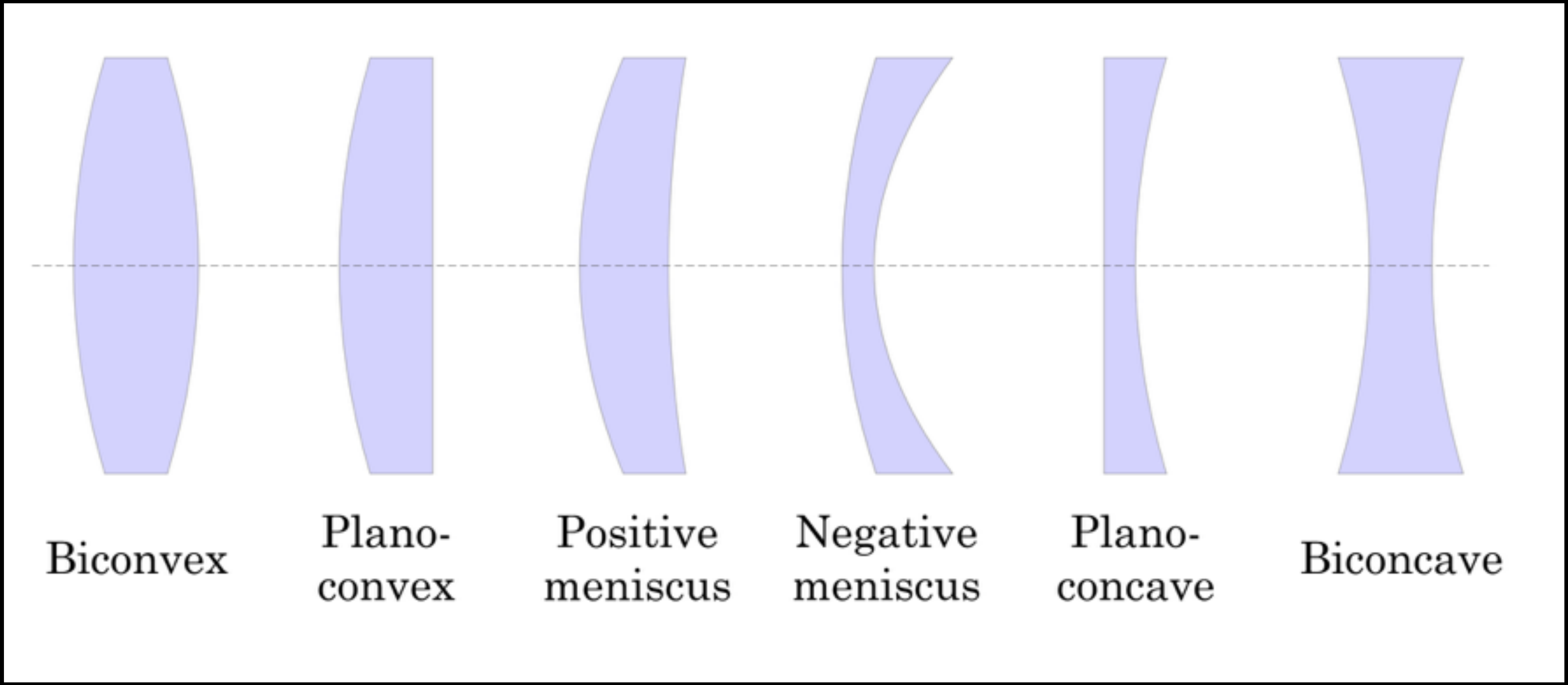
Coma



Correcting Coma



Simple Lenses



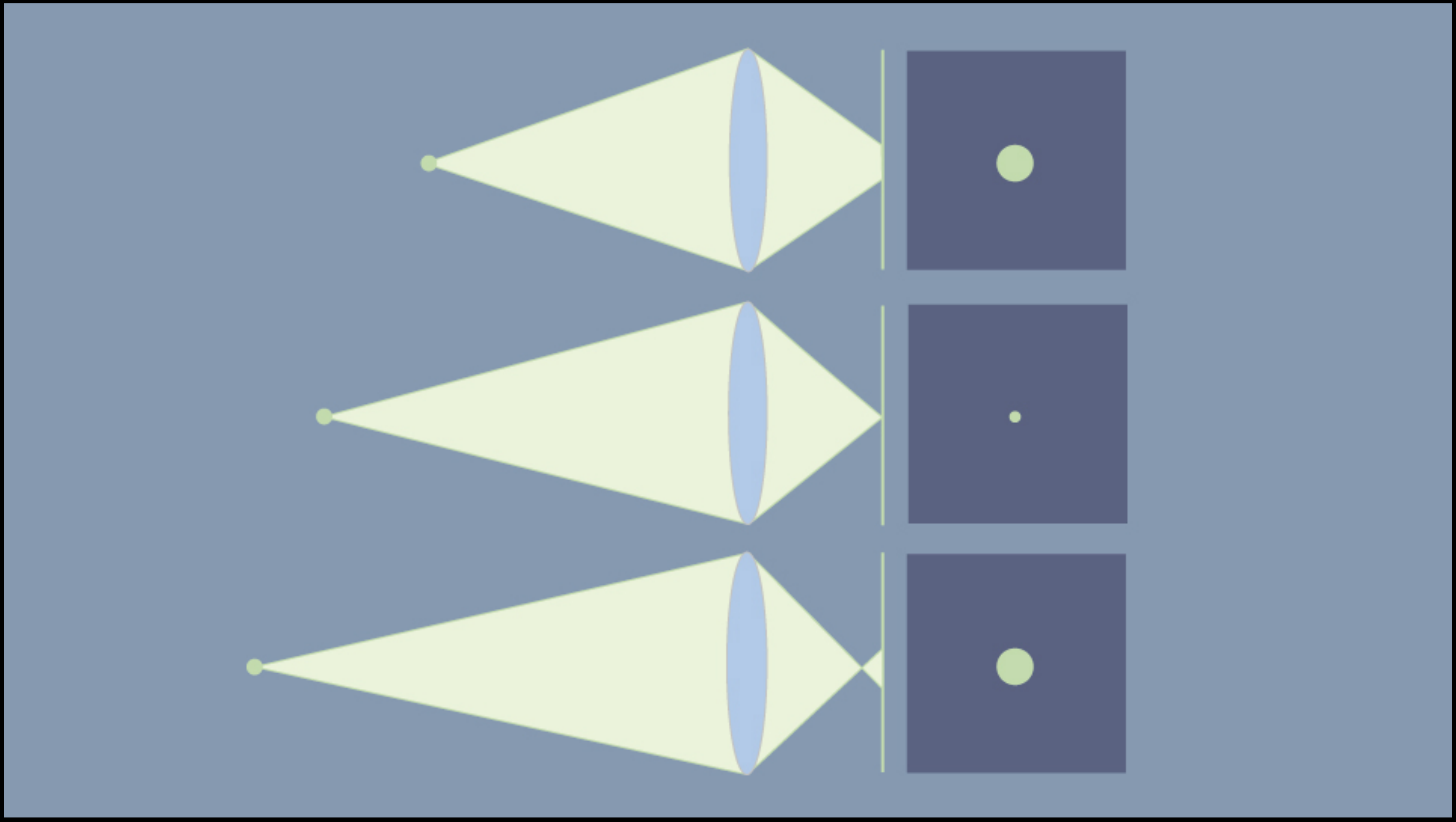
Single Element Spherical Lenses

Depth of Field/Focus

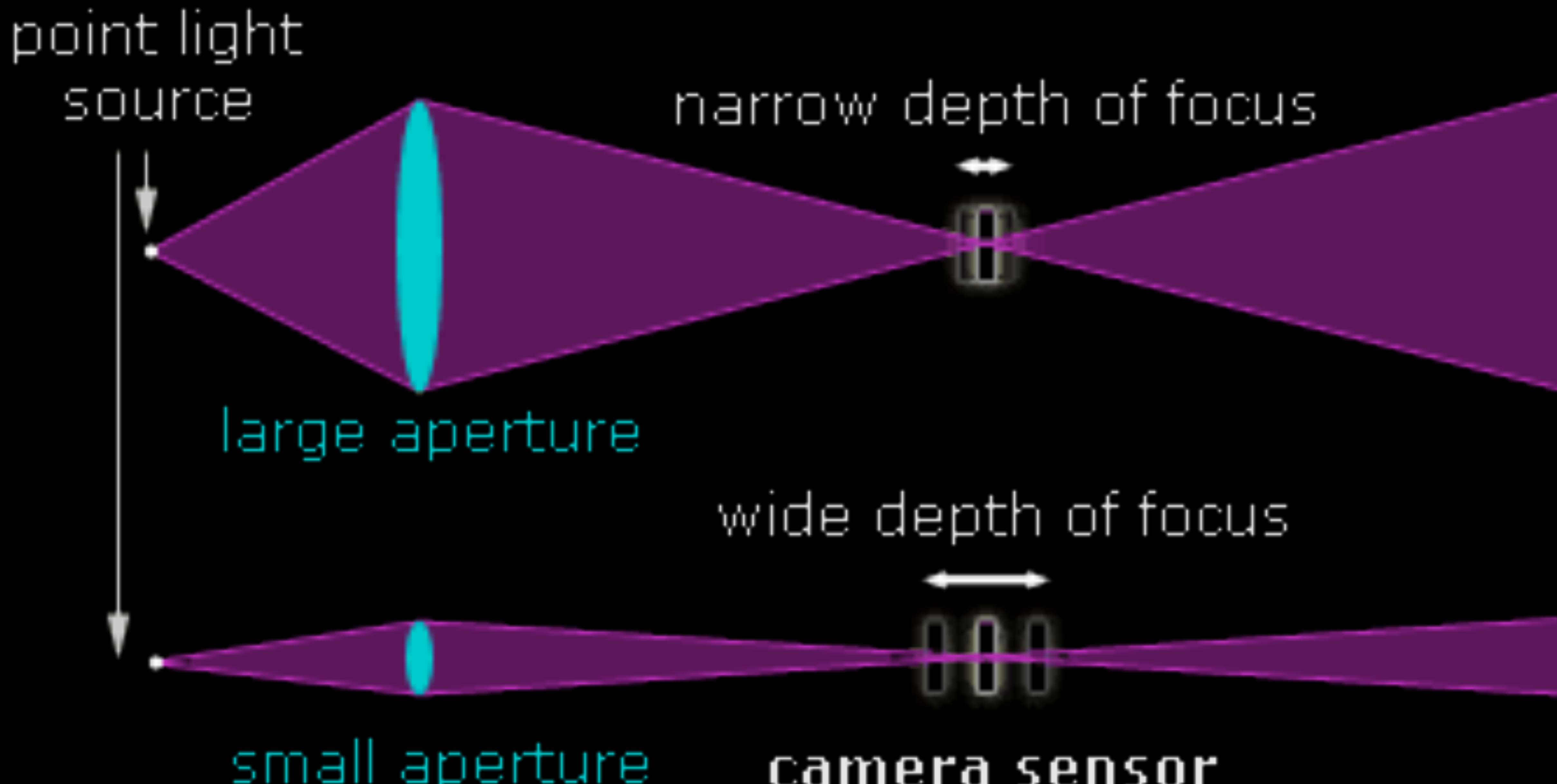
Large depth of field

Small depth of field

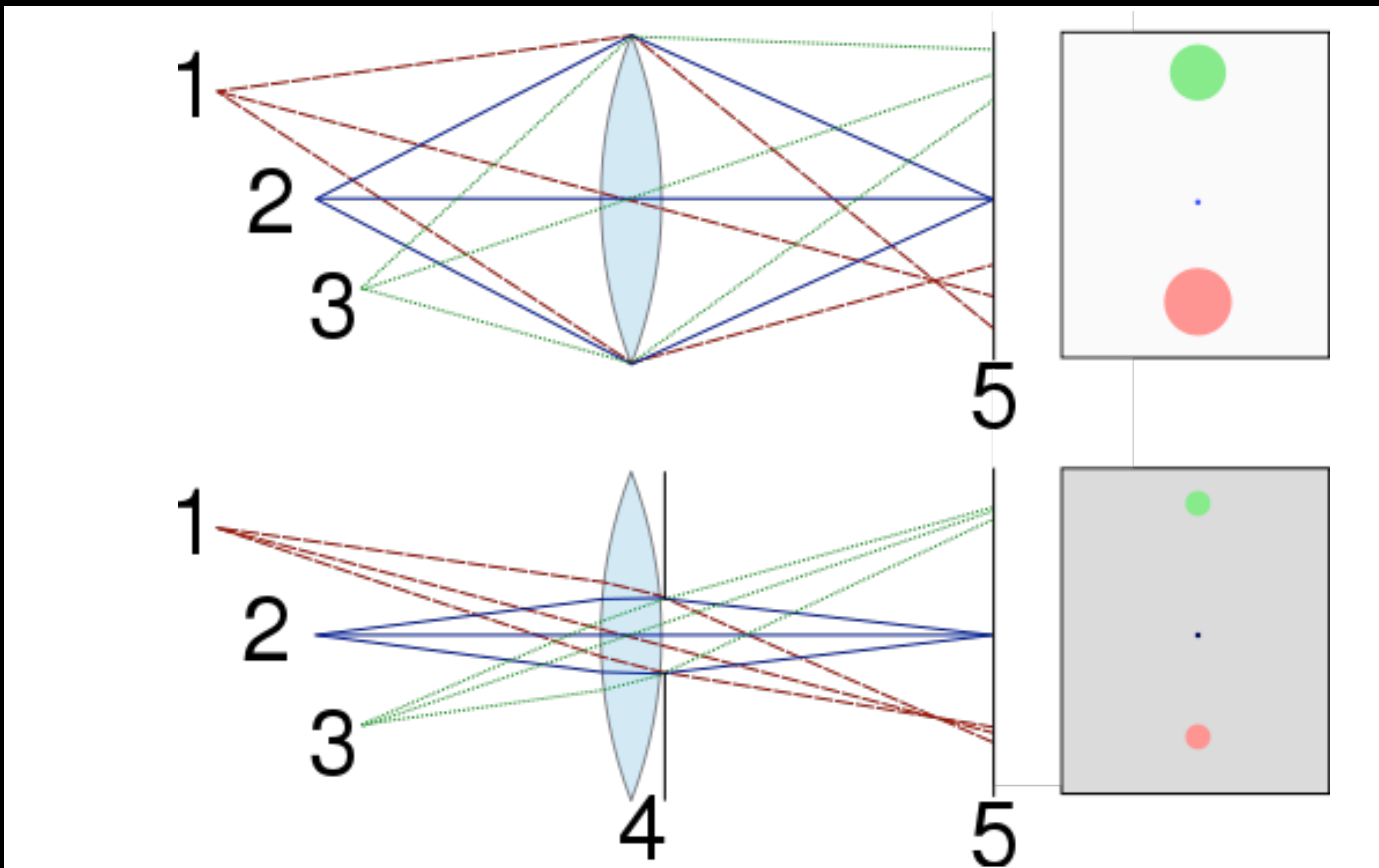
Circle of Confusion



Small aperture = more DOF



Large aperture = less DOF



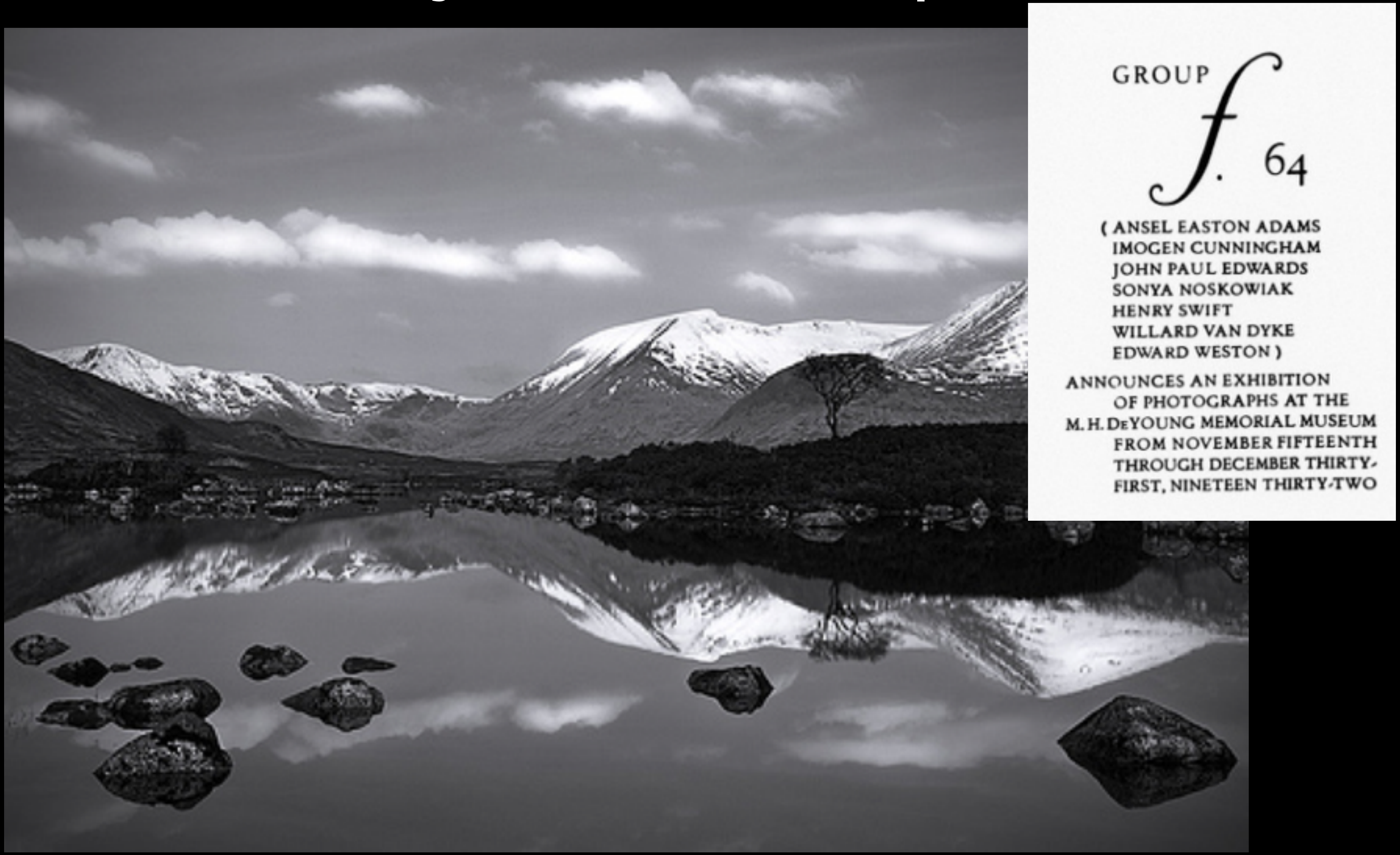
Did I use a small or large aperture here?

Monarch butterfly (*Danaus plexippus*) on its favorite food, the milkweed plant

“Bokeh” 暈け

Say’s Phoebe (*Sayornis saya* named after the American naturalist Thomas Say) in Moore Creek Preserve shot at F# 2.8

Extremely small aperture



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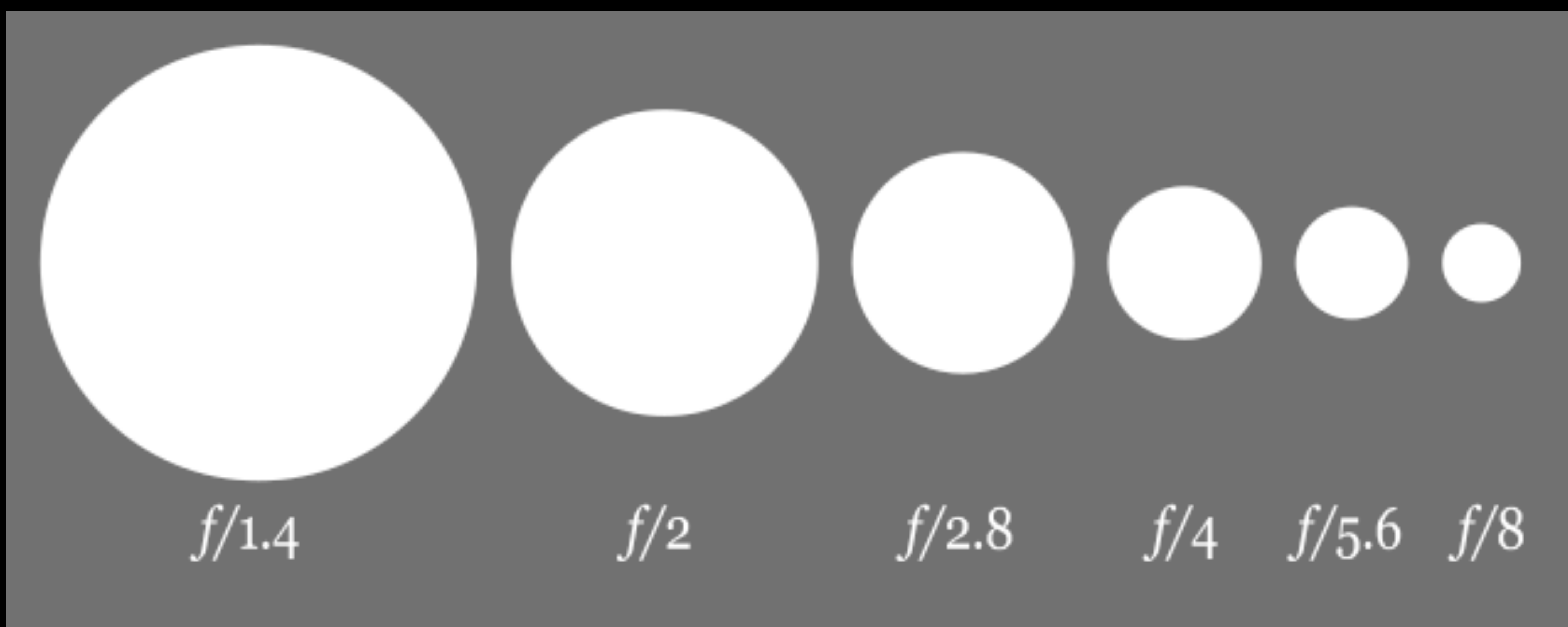
Ansel Adams shooting in the High Sierra

F# ("F-number") = f/D

Determined by ratio of lens focal length *f* and lens aperture Diameter *D*



$$f/1 = f/(\sqrt{2})^0,\ f/1.4 = f/(\sqrt{2})^1,\ f/2 = f/(\sqrt{2})^2,\ f/2.8 = f/(\sqrt{2})^3\ \ldots$$

Again…

Large depth of field

Small depth of field

F# also affects resolution
(we will talk about this next time)

High resolution


Low resolution

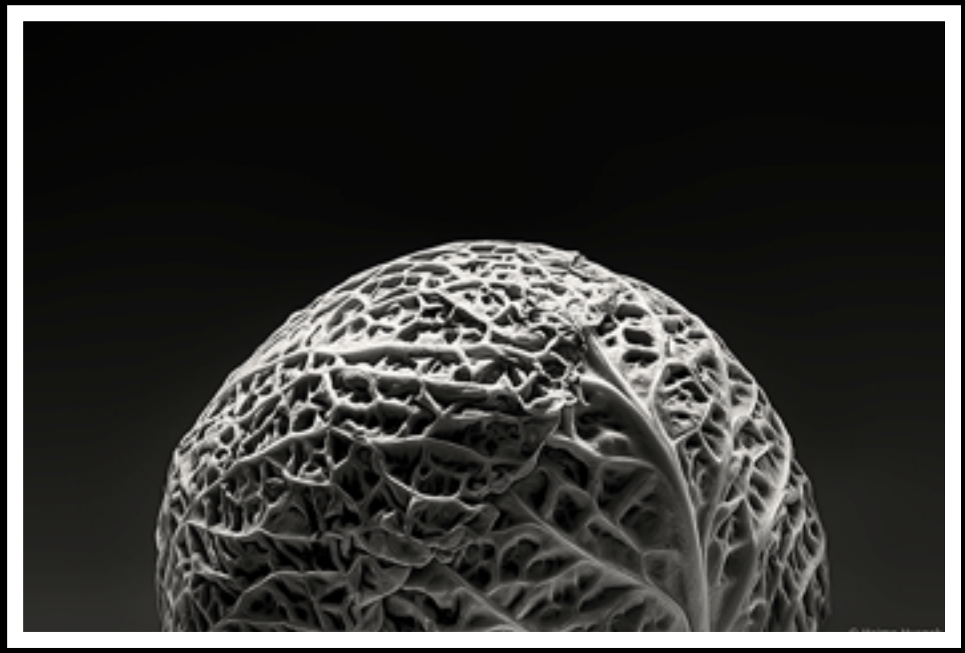
Next time, we will also talk about two-lens imaging systems

- Modern microscopes use this layout
- Possible to control both field and aperture stop

First Homework is due Thursday!

- Homework is due at the beginning of class
- If you cannot attend class on Thursday, please email me the homework (same deadline)





(Straight photography vegetables, shot by Edward Weston, F64 group)