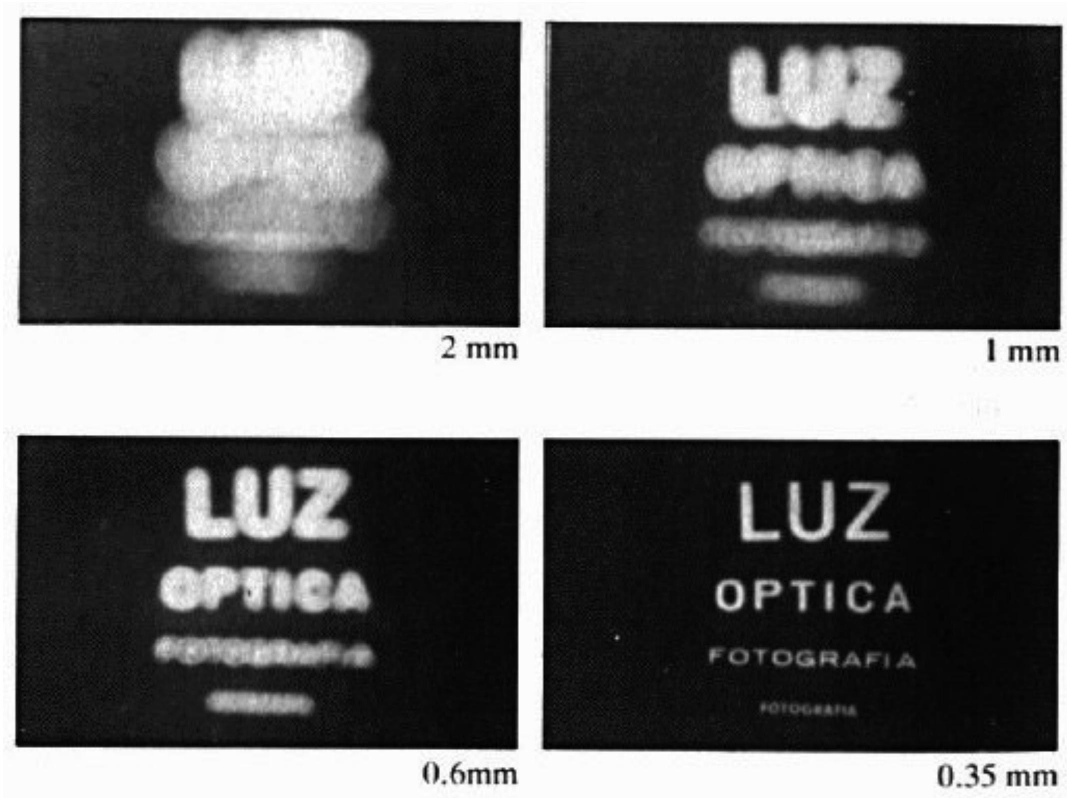
Building a Real Camera

Home-made pinhole camera

http://www.debevec.org/Pinhole/

Slide by A. Efros

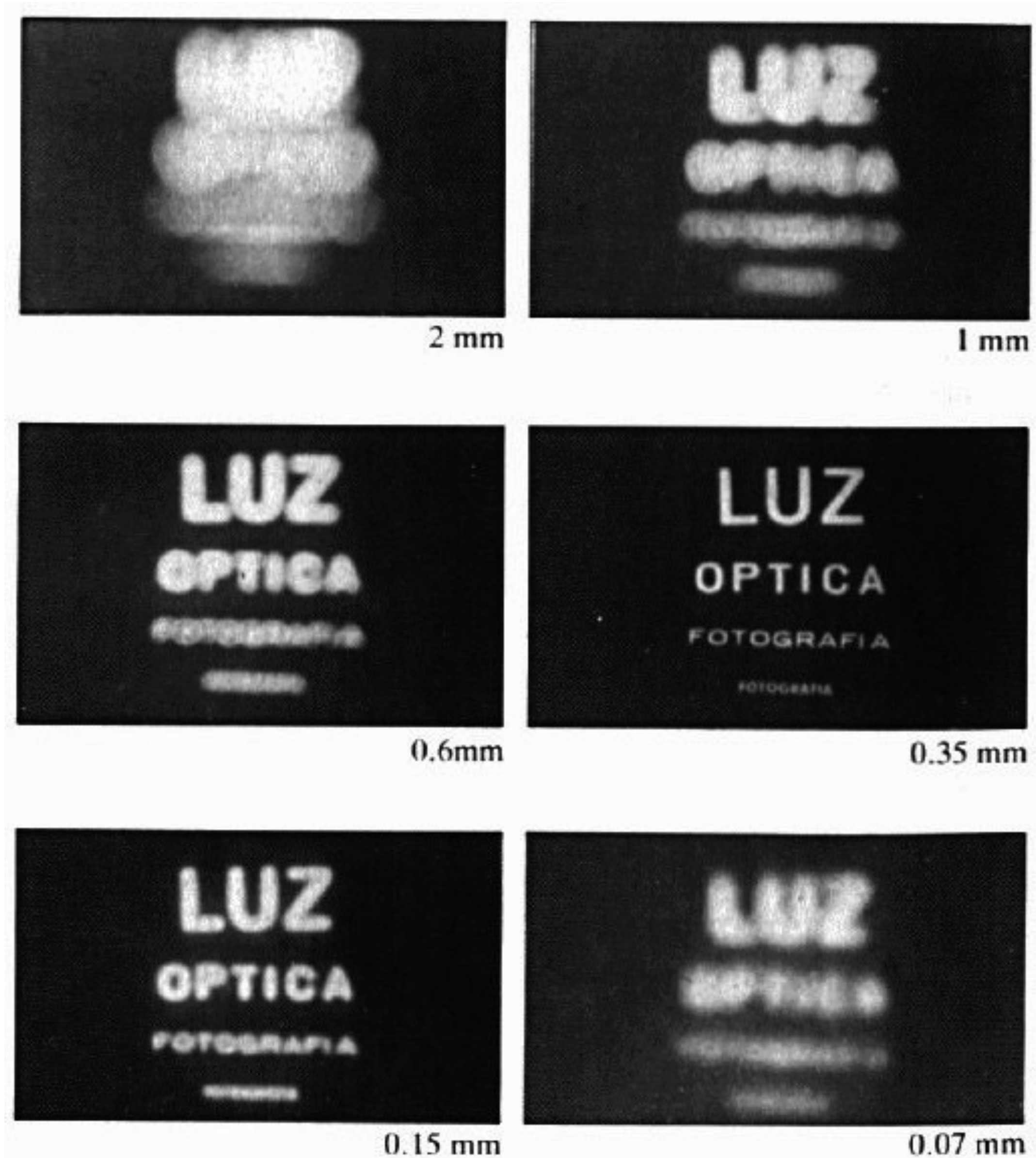
Shrinking the aperture



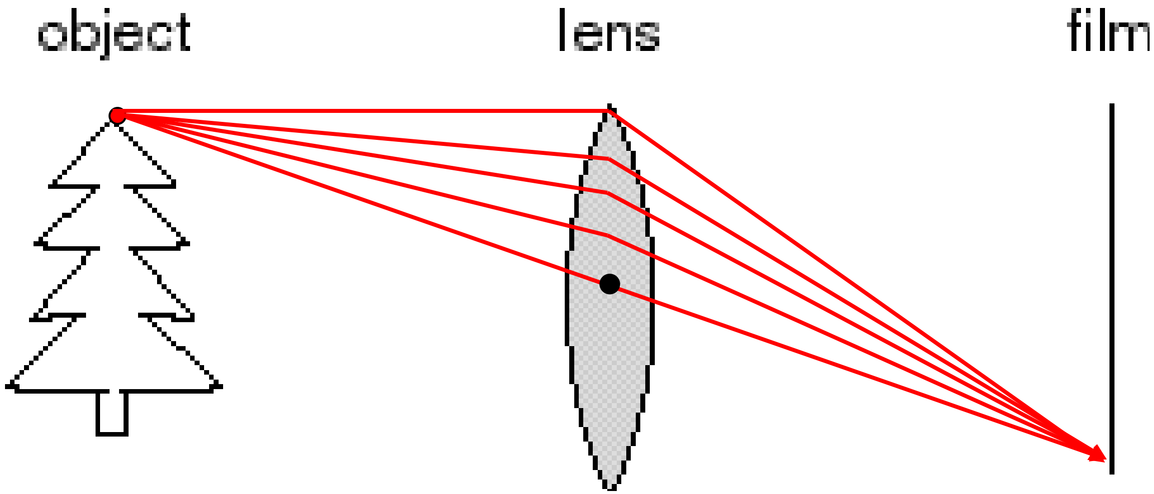
Why not make the aperture as small as possible?

- Less light gets through
- Diffraction effects…

Shrinking the aperture



Adding a lens

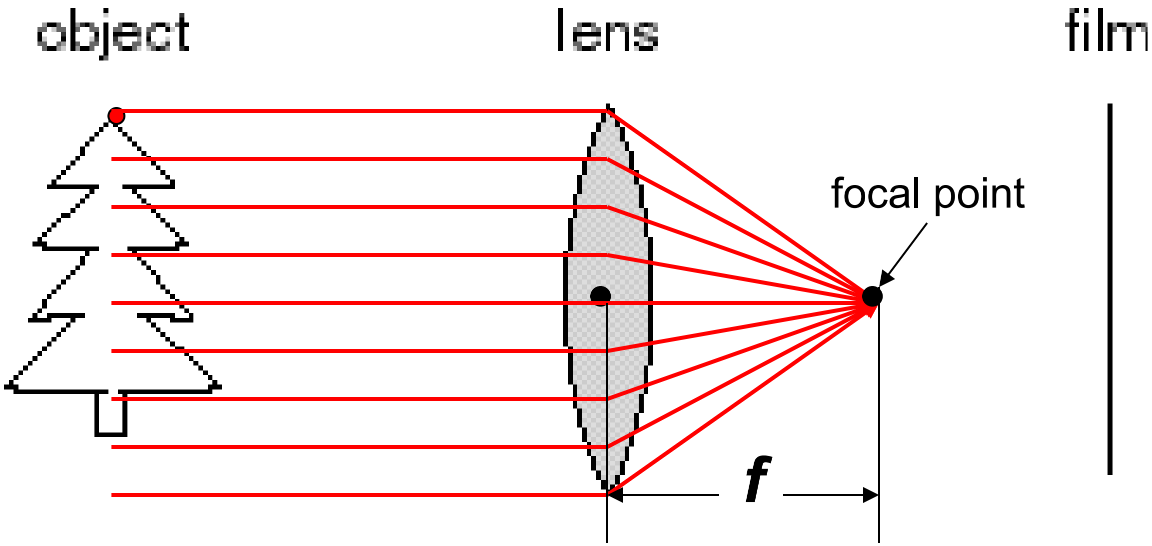


A lens focuses light onto the film

- Thin lens model:
  - Rays passing through the center are not deviated (pinhole projection model still holds)

Slide by Steve Seitz

Adding a lens

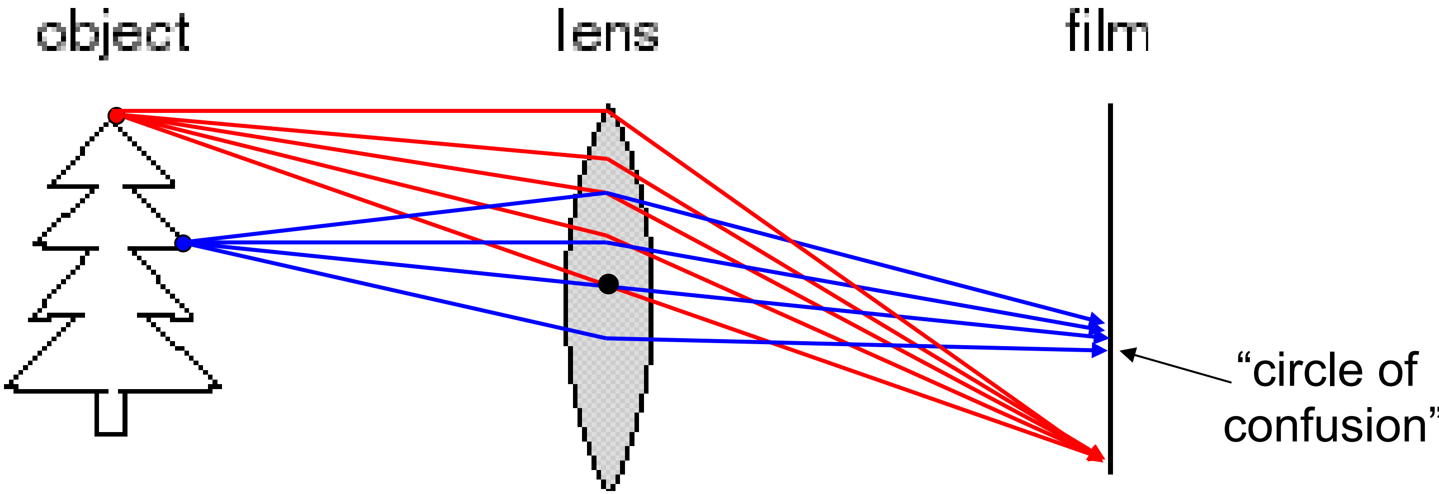


A lens focuses light onto the film

- Thin lens model:
  - Rays passing through the center are not deviated (pinhole projection model still holds)
  - All parallel rays converge to one point on a plane located at the *focal length f*

Slide by Steve Seitz

Adding a lens



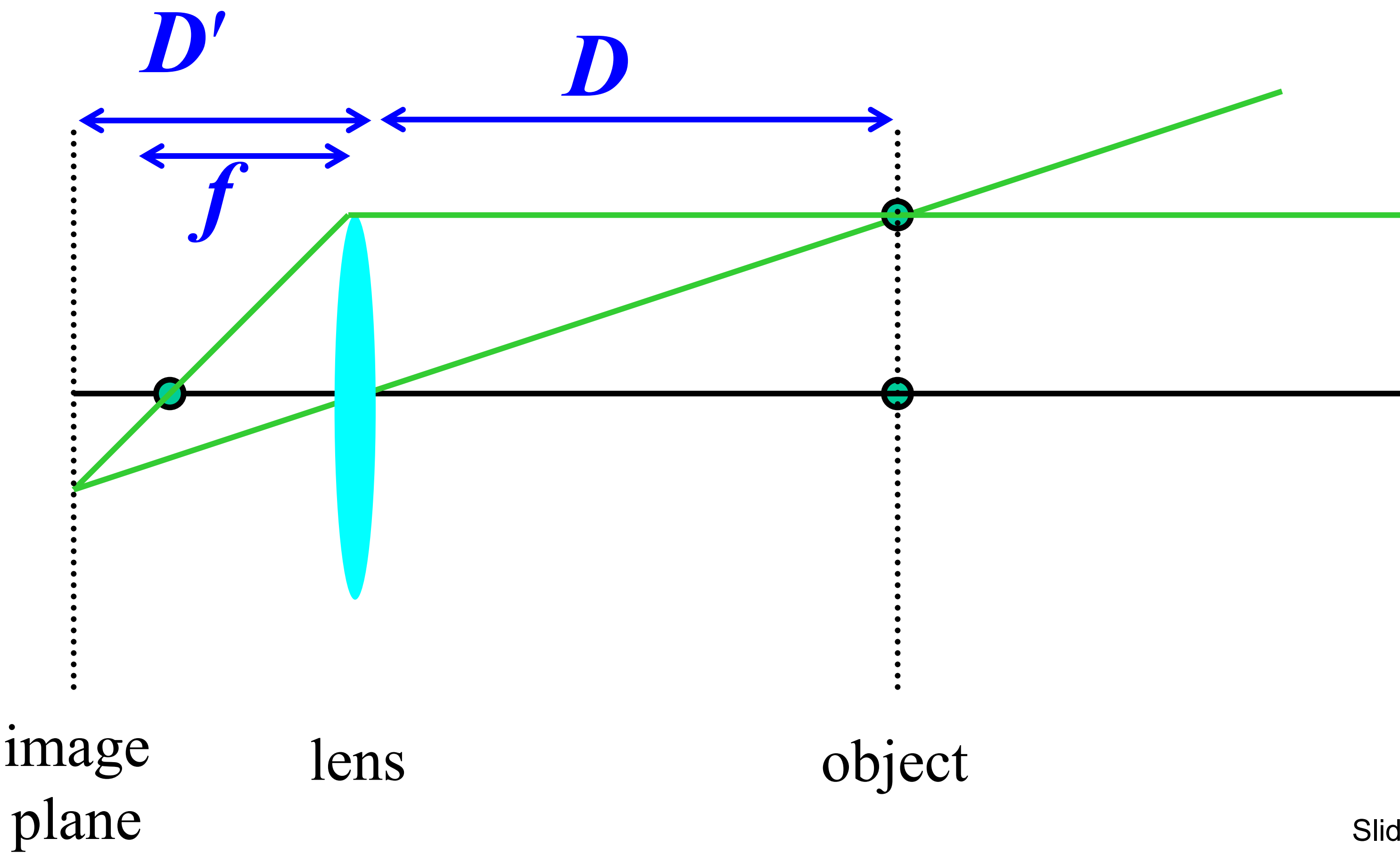
A lens focuses light onto the film

- There is a specific distance at which objects are “in focus”
  - other points project to a “circle of confusion” in the image

Slide by Steve Seitz

Thin lens formula

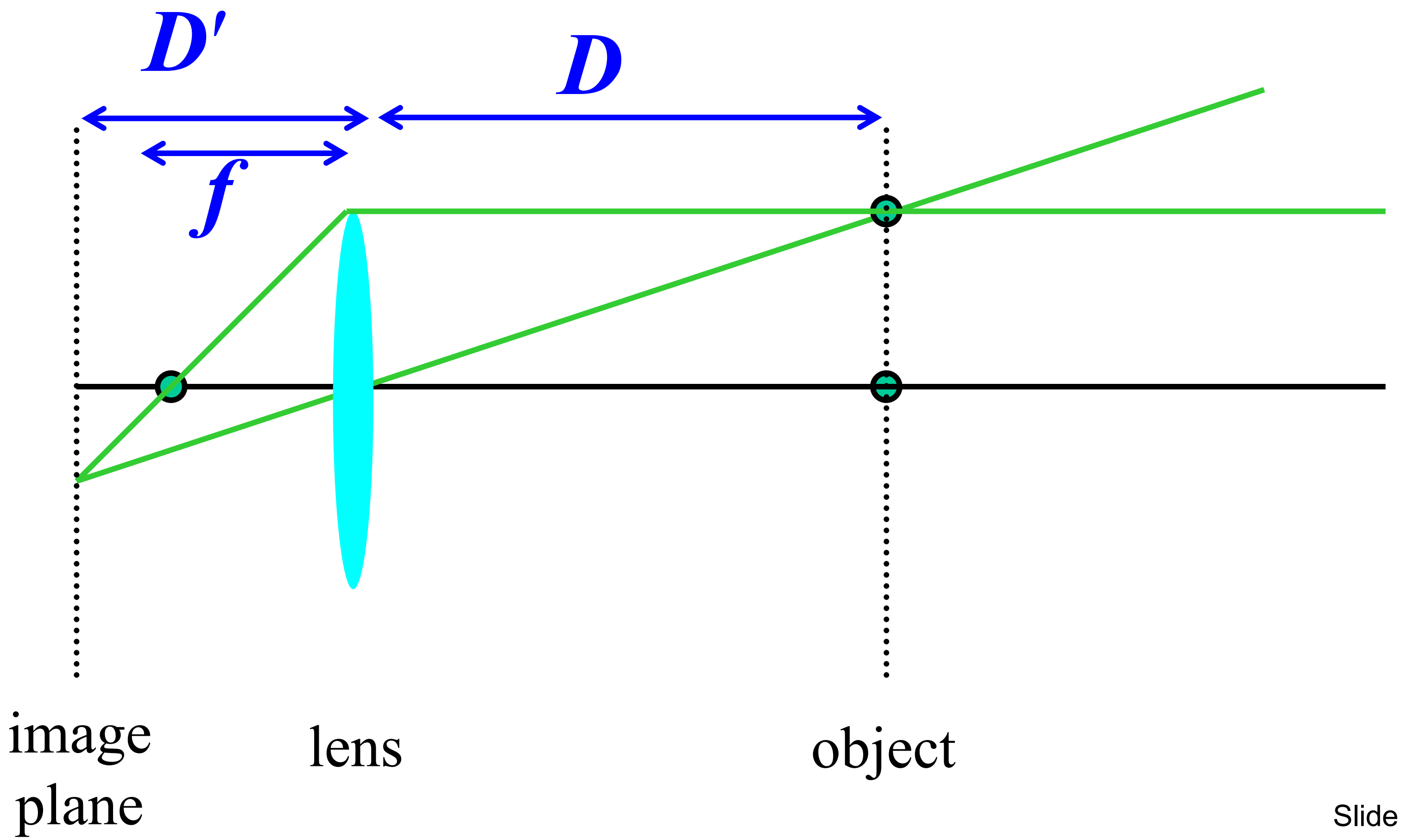
- What is the relation between the focal length (f), the distance of the object from the optical center (D), and the distance at which the object will be in focus (D')?



Slide by Frédo Durand

Thin lens formula

Similar triangles everywhere!

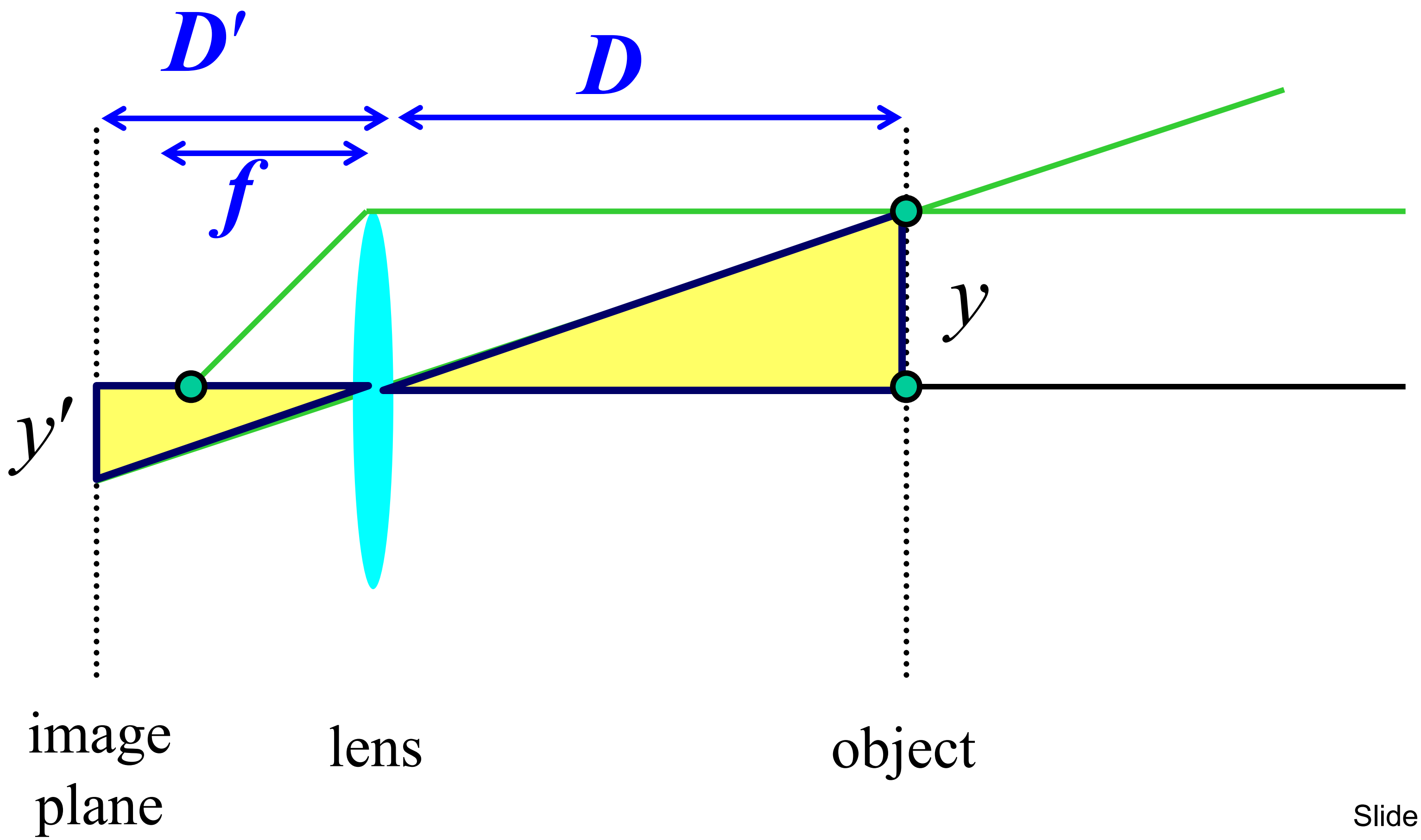


Slide by Frédo Durand

Thin lens formula

Similar triangles everywhere!

$$y'/y = D'/D$$



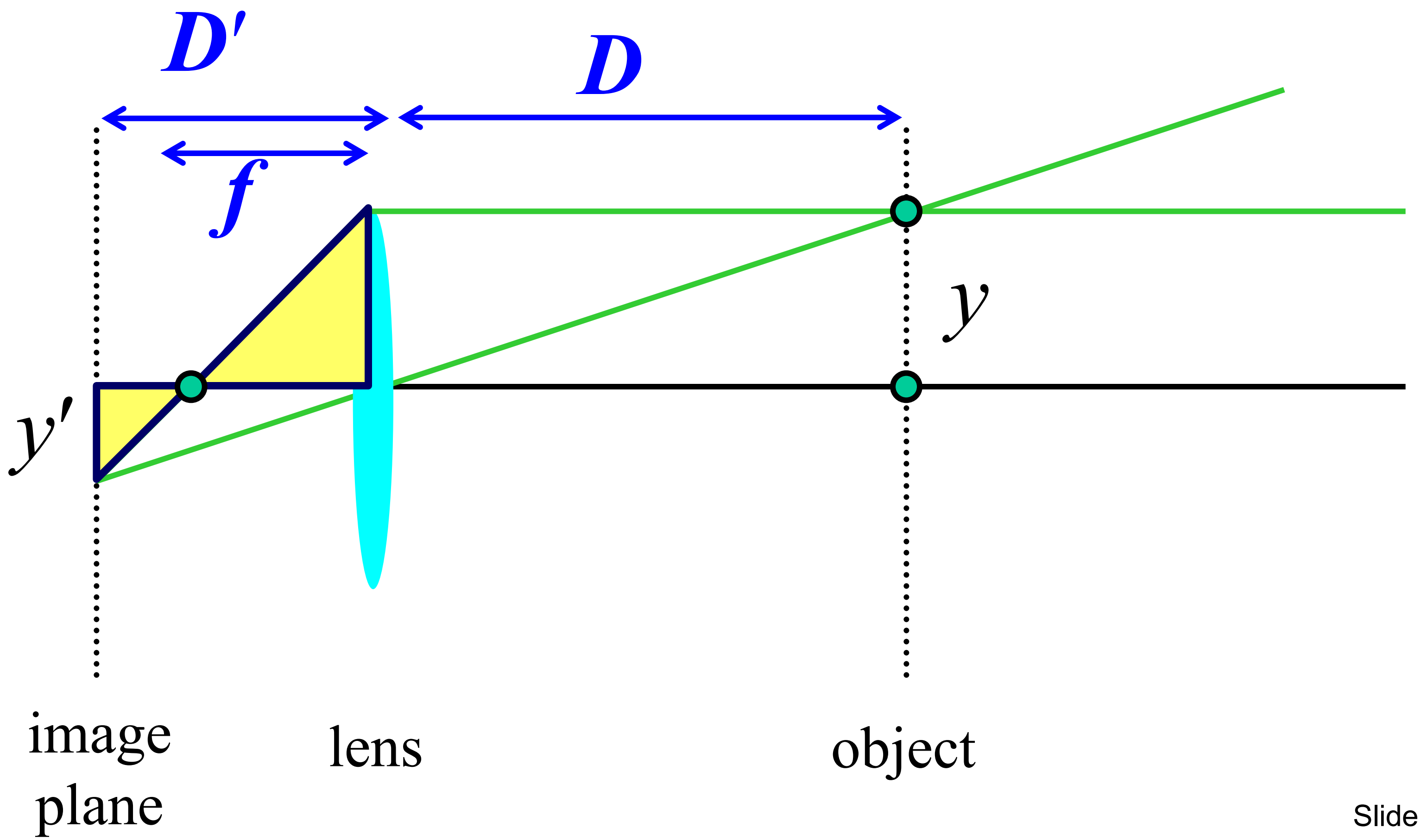
Slide by Frédo Durand

Thin lens formula

Similar triangles everywhere!

$$y'/y = D'/D$$

$$y'/y = (D'-f)/f$$

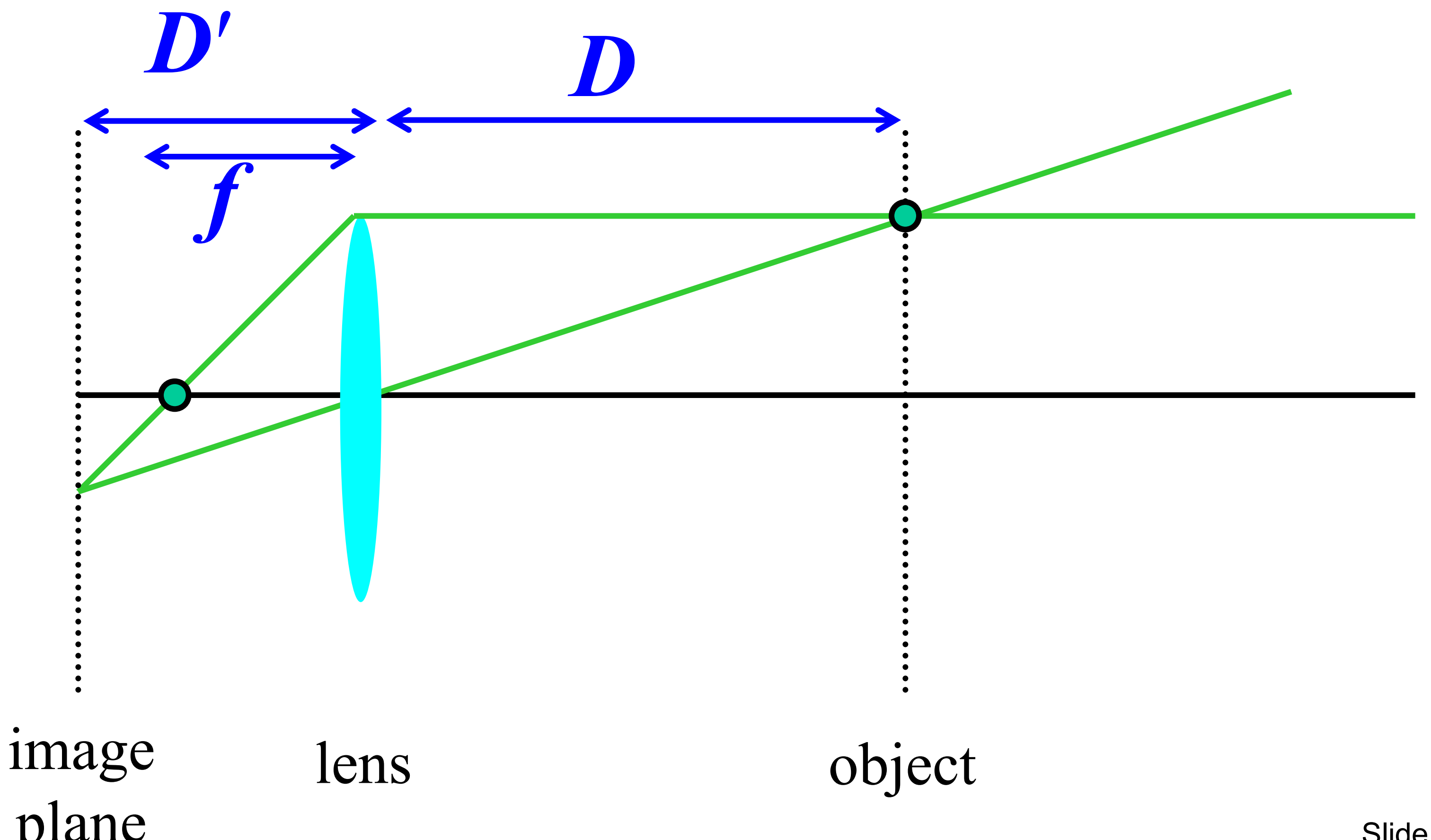


Slide by Frédo Durand

Thin lens formula

$$\boxed{\frac{1}{D'} + \frac{1}{D} = \frac{1}{f}}$$

Any point satisfying the thin lens equation is in focus.



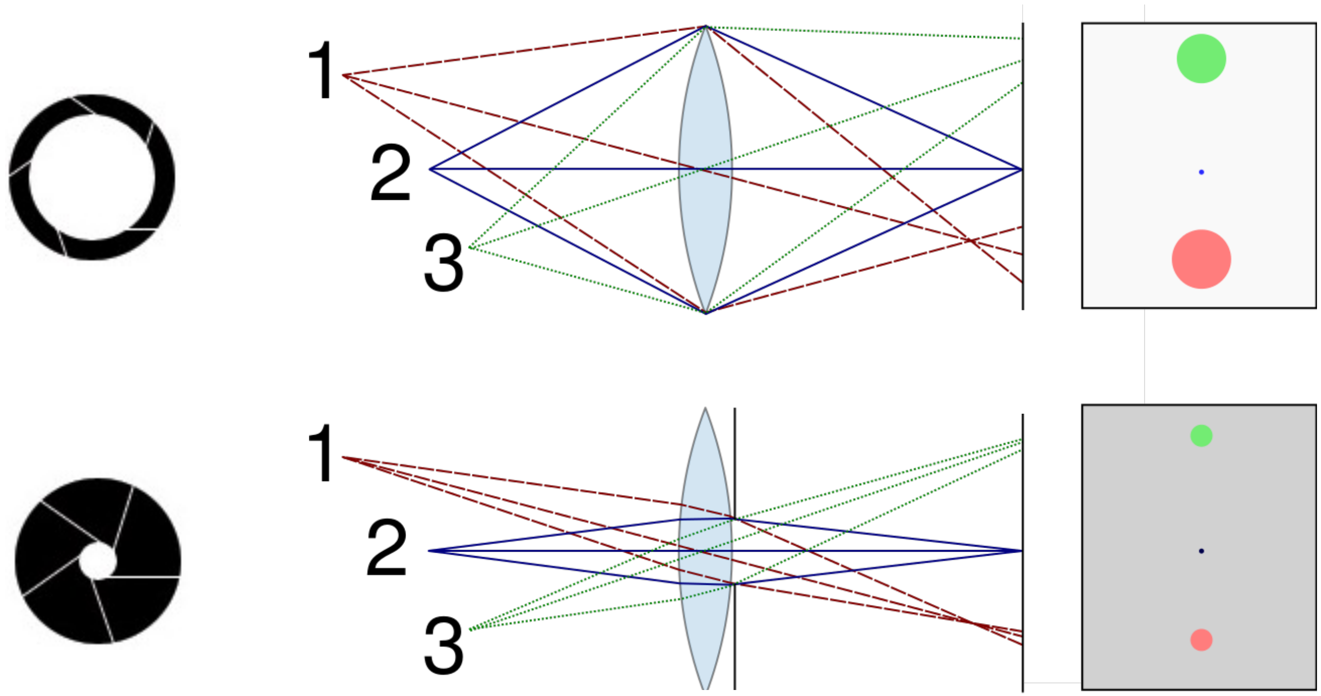
Slide by Frédo Durand

Depth of Field

http://www.cambridgeincolour.com/tutorials/depth-of-field.htm

Slide by A. Efros

Controlling depth of field



Changing the aperture size affects depth of field

- A smaller aperture increases the range in which the object is approximately in focus
- But small aperture reduces amount of light – need to increase exposure

http://en.wikipedia.org/wiki/File:Depth_of_field_illustration.svg

Varying the aperture

Large aperture = small DOF
DOF：depth of focus

Small aperture = large DOF

Slide by A. Efros

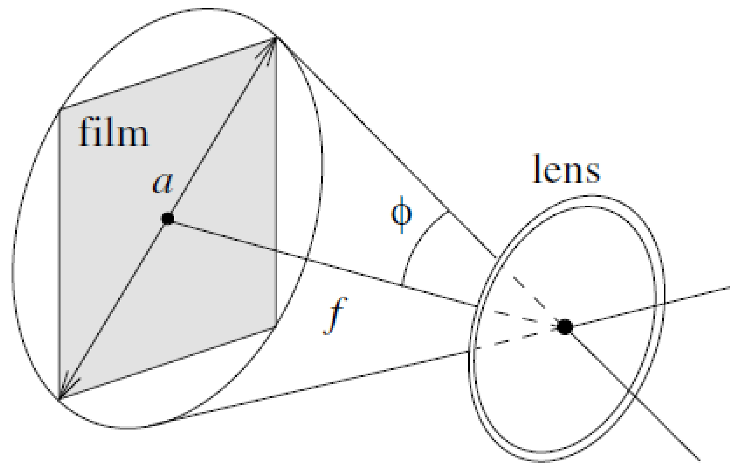
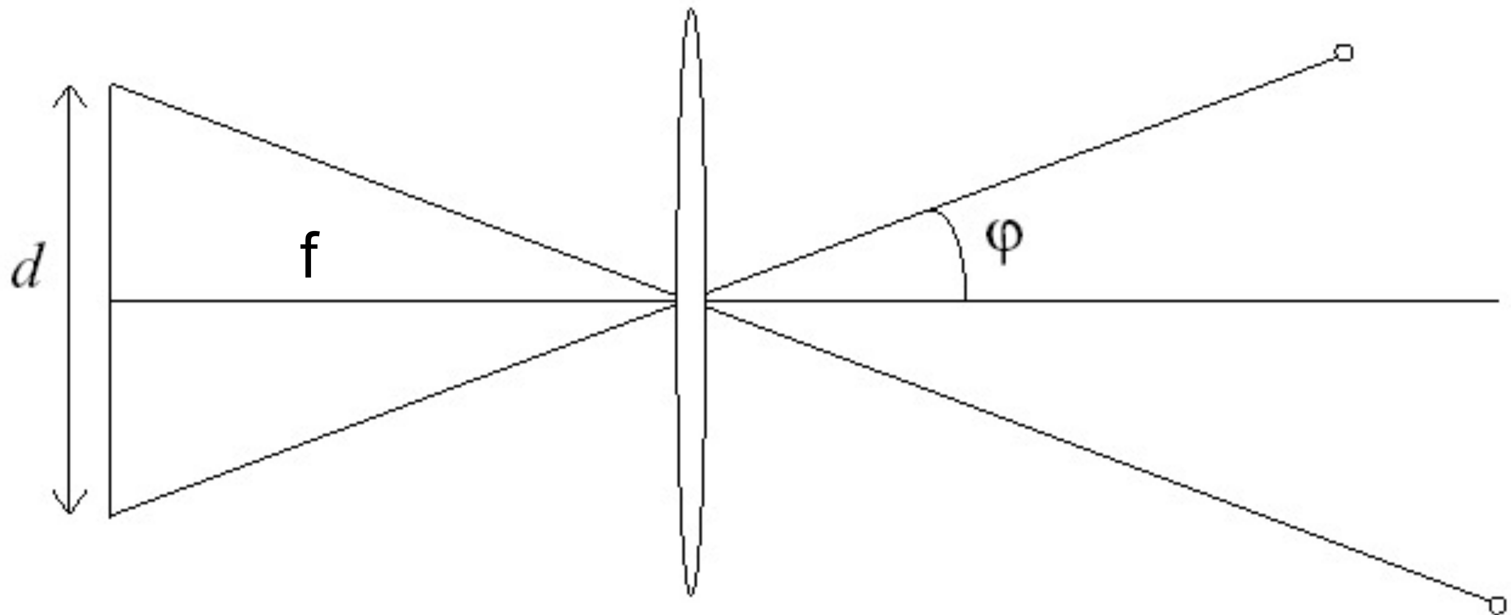


FIGURE 1.9: The field of view of a camera. It can be defined as 2ϕ, where $\phi \stackrel{\text{def}}{=} \arctan \frac{a}{2f}$, a is the diameter of the sensor (film, CCD, or CMOS chip), and f is the focal length of the camera.

Field of View



FOV depends on focal length and size of the camera retina

$$\varphi = \tan^{-1}\left(\frac{d}{2f}\right)$$

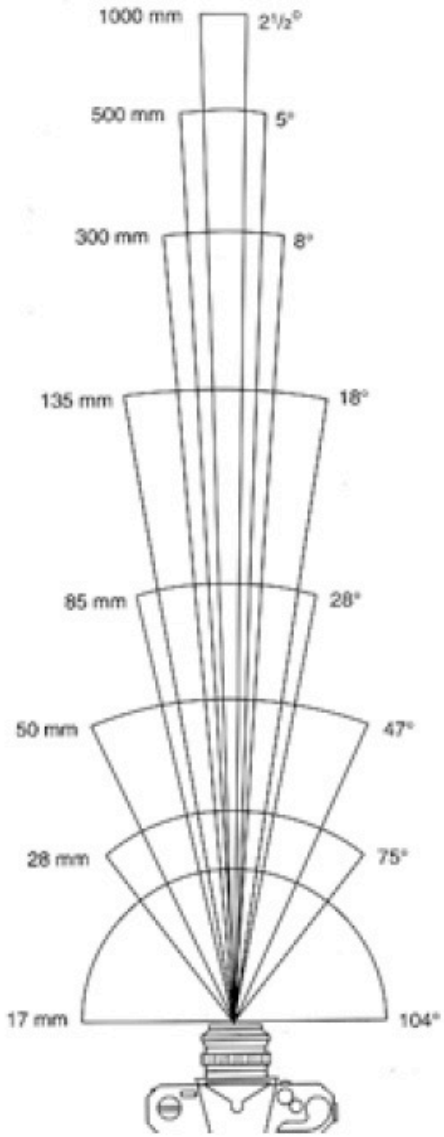
Larger focal length = smaller FOV

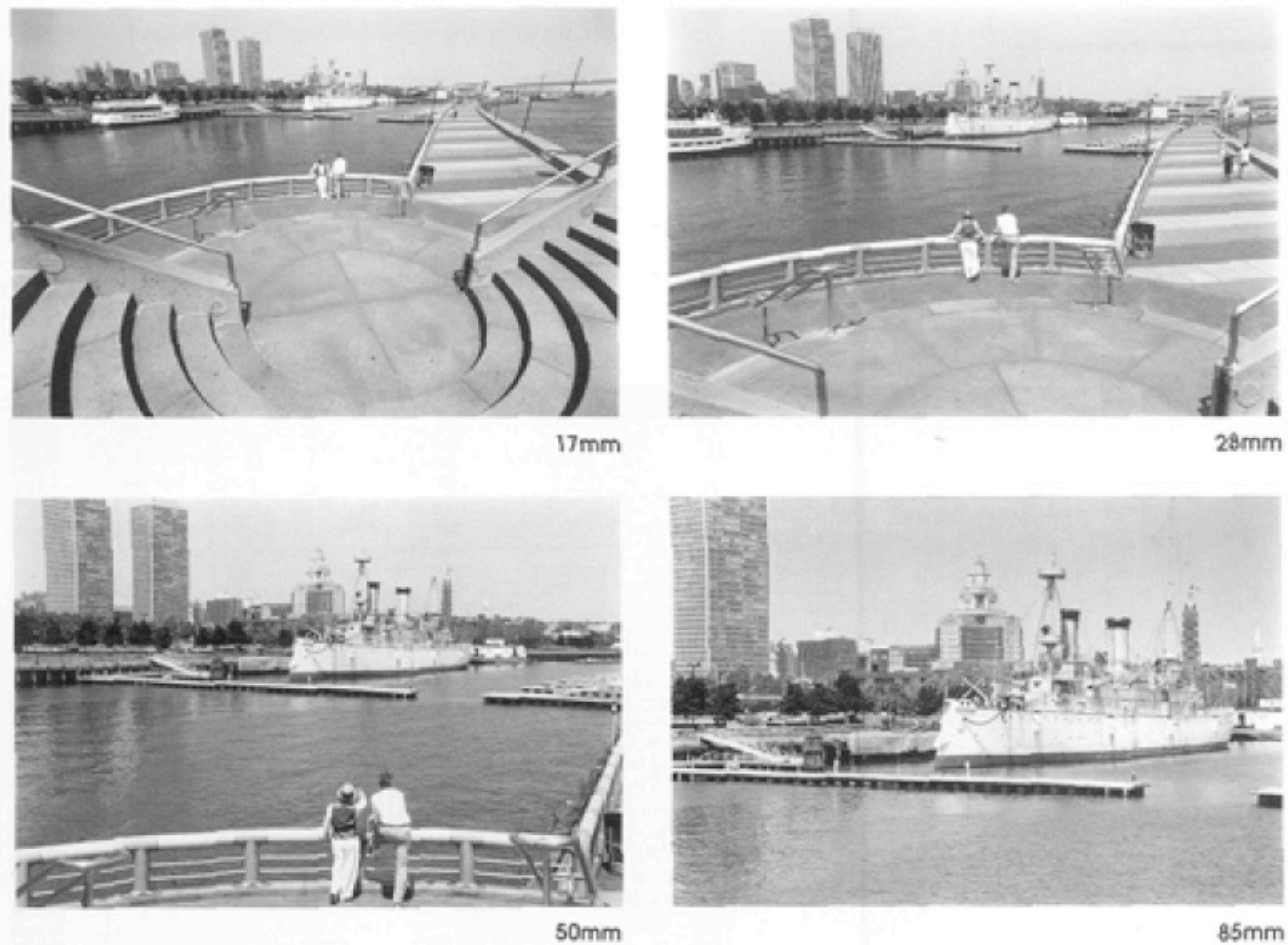
Slide by A. Efros

正常人視野

青光眼
(逐漸縮小的視野)

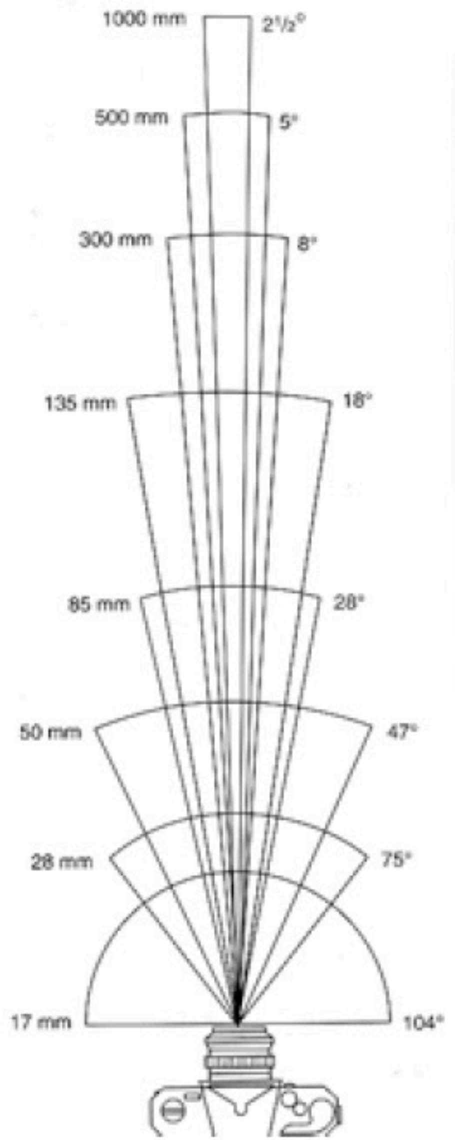
Field of View

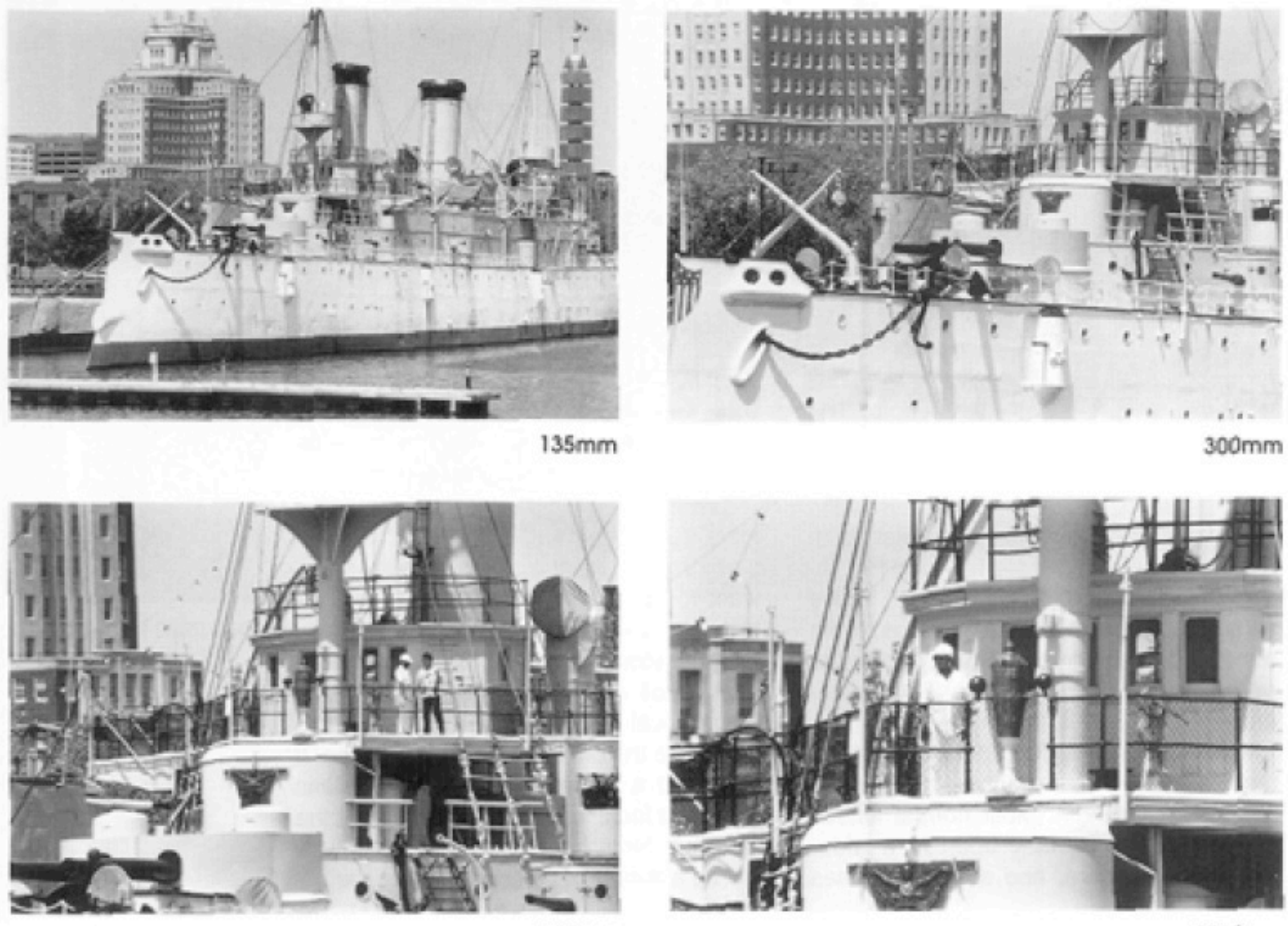




Slide by A. Efros

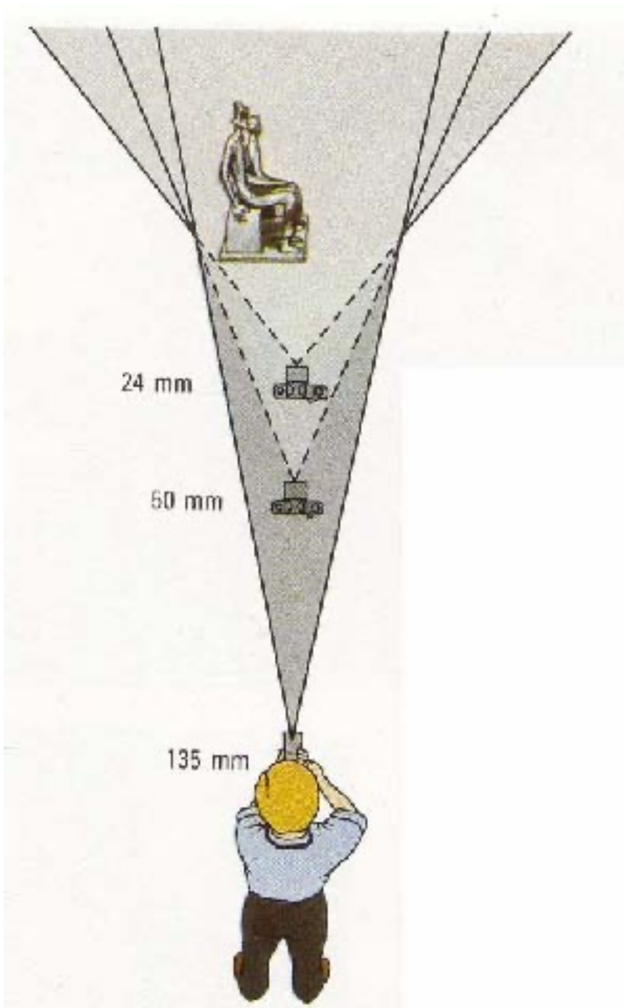
Field of View





Slide by A. Efros

Field of View / Focal Length



Large FOV, small *f*
Camera close to car

Small FOV, large *f*
Camera far from the car

Sources: A. Efros, F. Durand

Same effect for faces

wide-angle

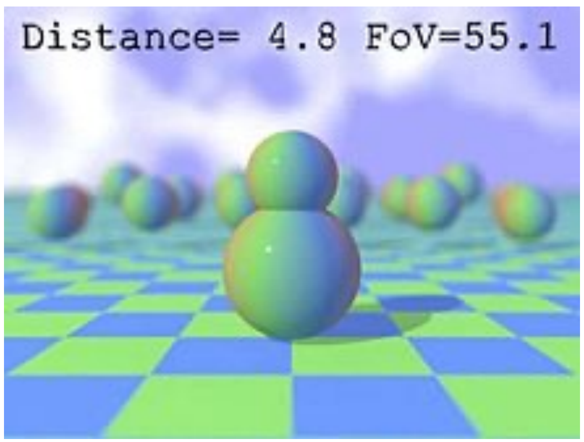
standard

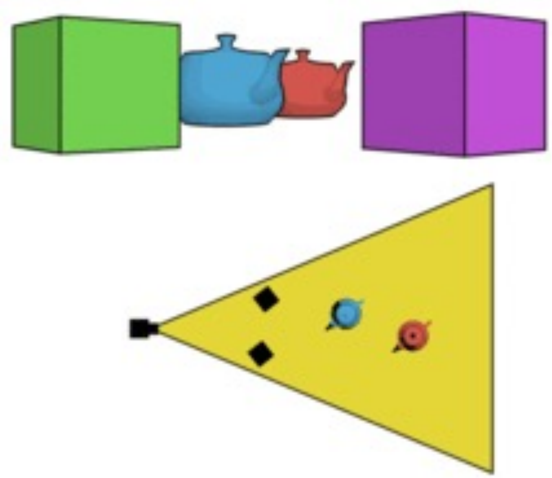
telephoto

Source: F. Durand

The dolly zoom(滑动变焦)

- Continuously adjusting the focal length while the camera moves away from (or towards) the subject





http://en.wikipedia.org/wiki/Dolly_zoom

The dolly zoom

- Continuously adjusting the focal length while the camera moves away from (or towards) the subject
- “The Vertigo shot”

Example of dolly zoom from *Goodfellas* (YouTube)

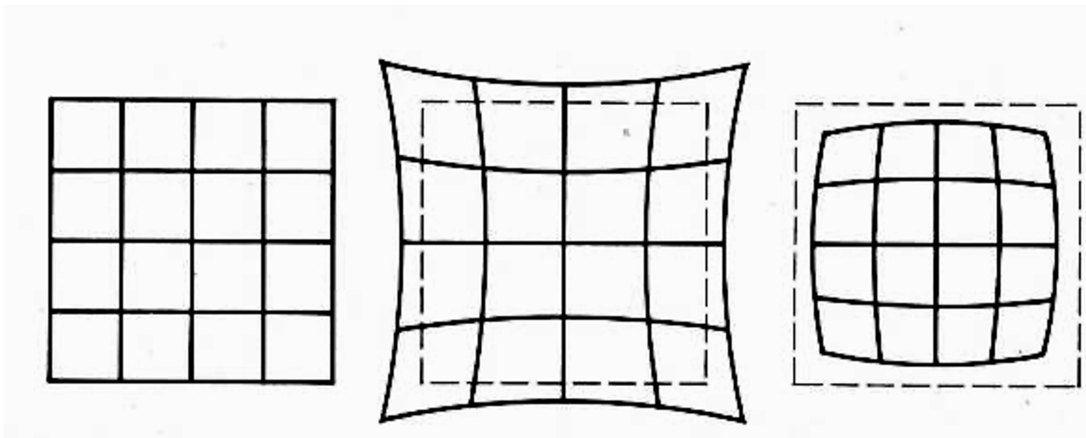
Example of dolly zoom from *La Haine* (YouTube)

Lens flaws: Vignetting（光暈）

A photograph whose edges shade off gradually

Radial Distortion

- Caused by imperfect lenses.
- Deviations are most noticeable near the edge of the lens

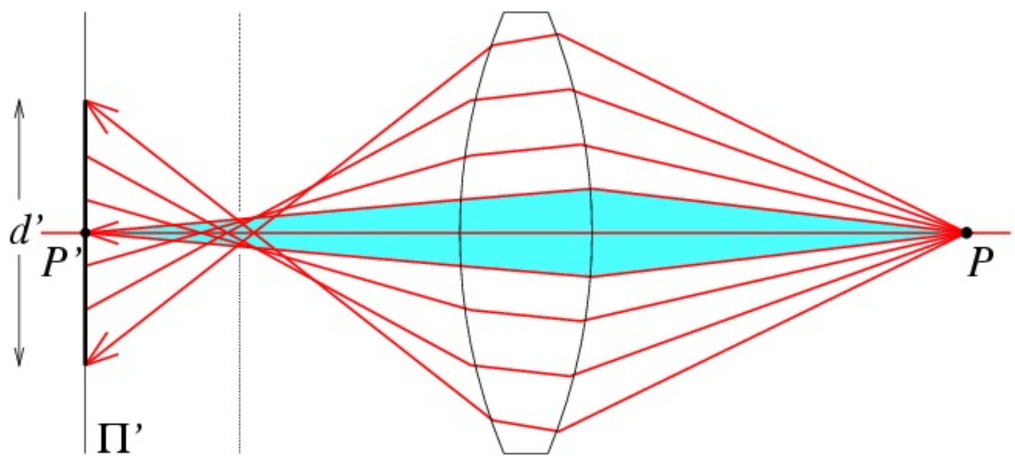


No distortion Pin cushion Barrel

Lens flaws: Spherical aberration

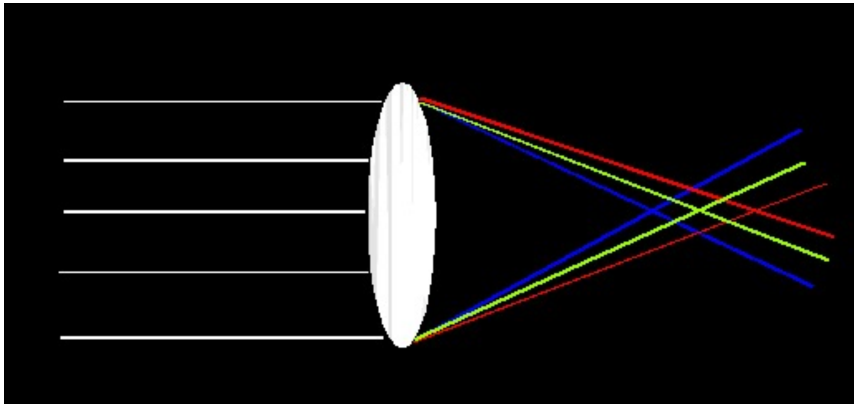
Spherical lenses don't focus light perfectly

- Rays farther from the optical axis focus closer

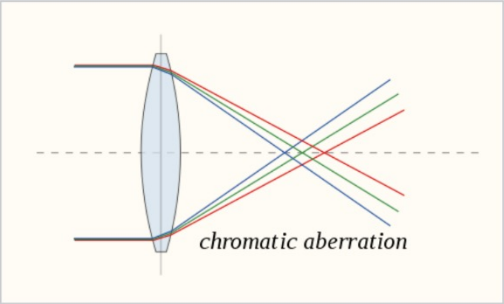


Lens Flaws: Chromatic Aberration

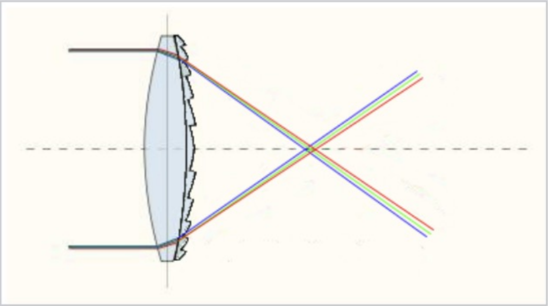
Lens has different refractive indices for different wavelengths: causes color fringing



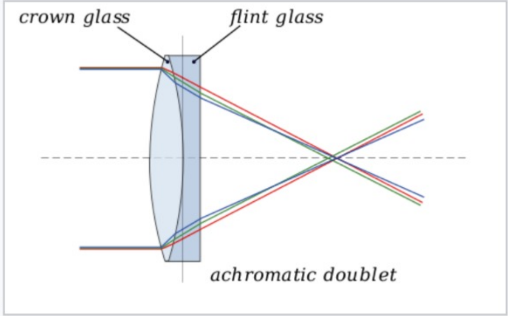
How to avoid CA



Chromatic aberration of a single lens causes different wavelengths of light to have differing focal lengths



Diffractive optical element with complementary dispersion properties to that of glass can be used to correct for color aberration



For an achromatic doublet, visible wavelengths have approximately the same focal length