Computational Photography

Week 1, Winter 2009

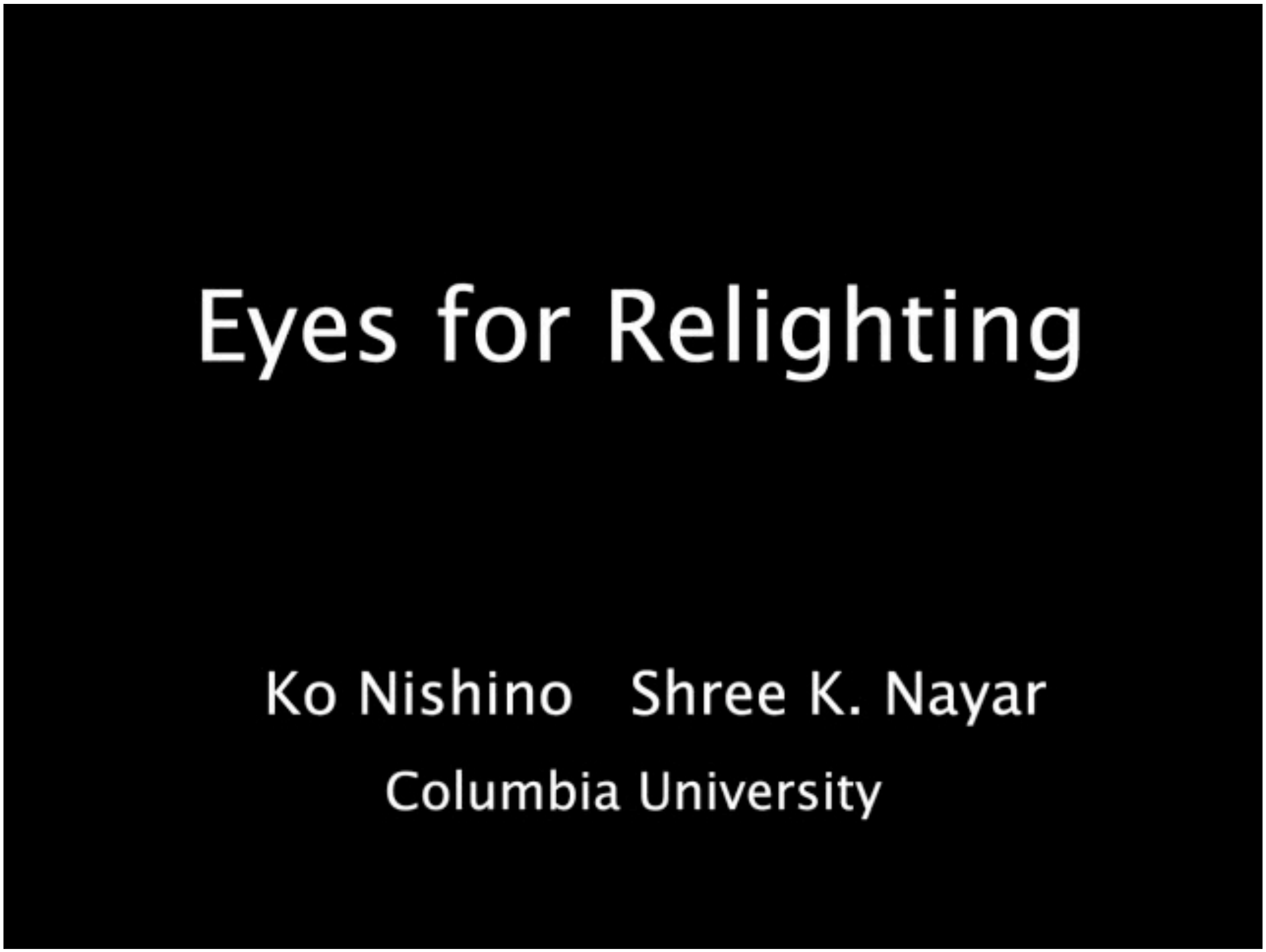
Instructor: Prof. Ko Nishino

Who am I?

- Ko Nishino
  - Assistant Professor since Fall 2005
  - Ph.D. from The Univ. of Tokyo, Postdoc at Columbia Univ.
  - Research on Computer Vision and Computer Graphics, mostly at their intersection
    - Physics-based Vision, Image-based Modeling/ Rendering, Color, Face Recognition, …

  - University Crossings 108
  - kon@cs.drexel.edu
  - http://www.cs.drexel.edu/~kon/

Research Example



What will you learn?

- Foundation of Computational Photography
  - Camera, image manipulation, warping,…
- Basic applications
  - Morphing, matting, 3D modeling, relighting,…
- **Implement fun applications**

- Textbook
  - **None**
  - General textbooks on Computer Vision, Graphics, Image Processing, and Photography may be useful along the way

Schedule

- Lectures
  - Foundation and applications of Computational Photography
- Projects (10%x1 + 20%x3=70%)
  - Details later
    - Project 0.5: Image Processing
    - Project 1: Intelligent Scissors
    - Project 2: Morphing
    - Project 3: Single-View Modeling
- Exams (Mid 10%+ Final 20%)
  - In-class (closed book)

Administrivia

- http://www.cs.drexel.edu/~kon/compphoto
- Office hours
  - Ko Nishino: Tuesday after class
- Policy
  - Projects and assignments should be done independently
  - No cheating, please!
  - Equipment
    - Bring your own digital camera
    - Otherwise, you can check out ours (strict return policy)

Today

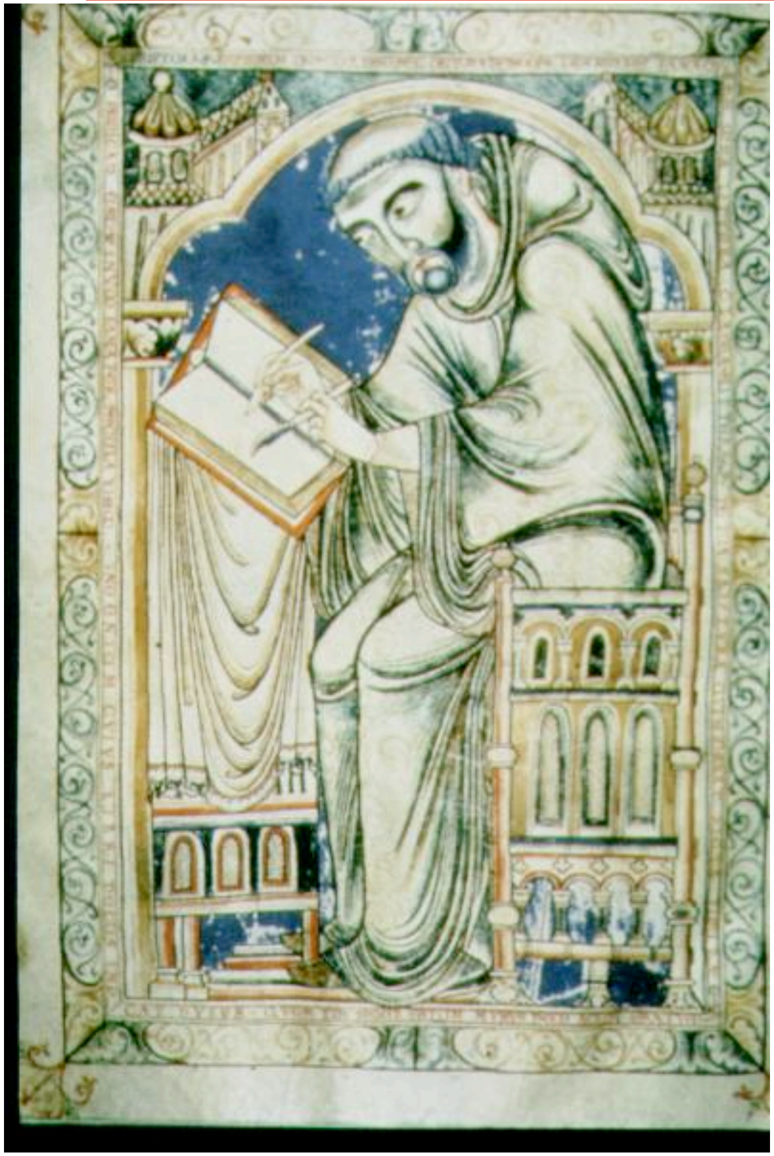
- What is Computational Photography?
  - Why you should learn it

Computational Photography

Depicting Our World

Prehistoric Painting, Lascaux Cave, France

Depicting Our World: The Middle Ages



St. John
from the
Gospel Book
of Abbot
Wedricus
(1147)

Cimabue
Madonna
Enthroned
(c.1280-1290)

Depicting Our World: Renaissance

North Doors (1424)

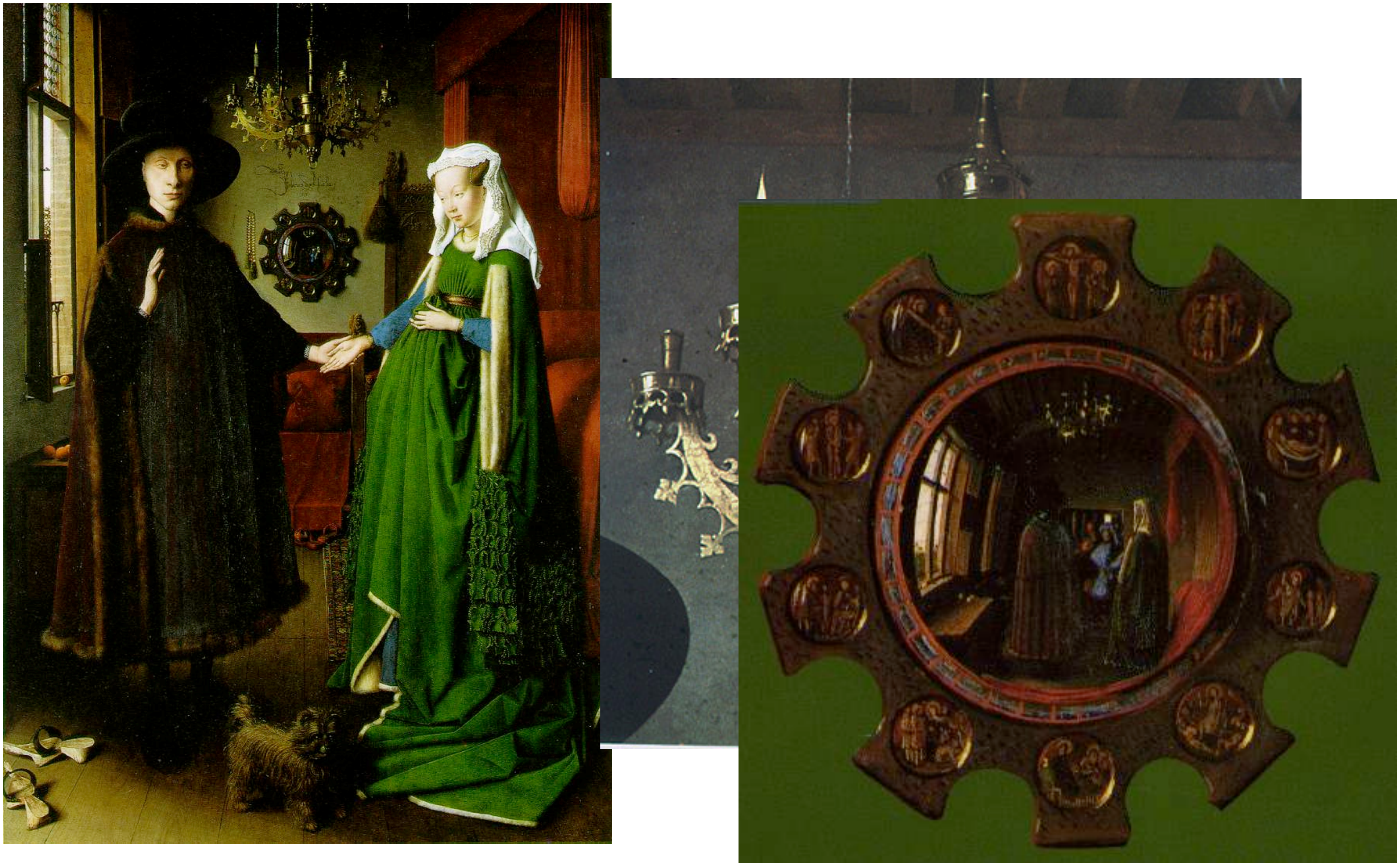
Lorenzo
Ghiberti
(1378-1455)

East Doors (1452)

Depicting Our World: Renaissance

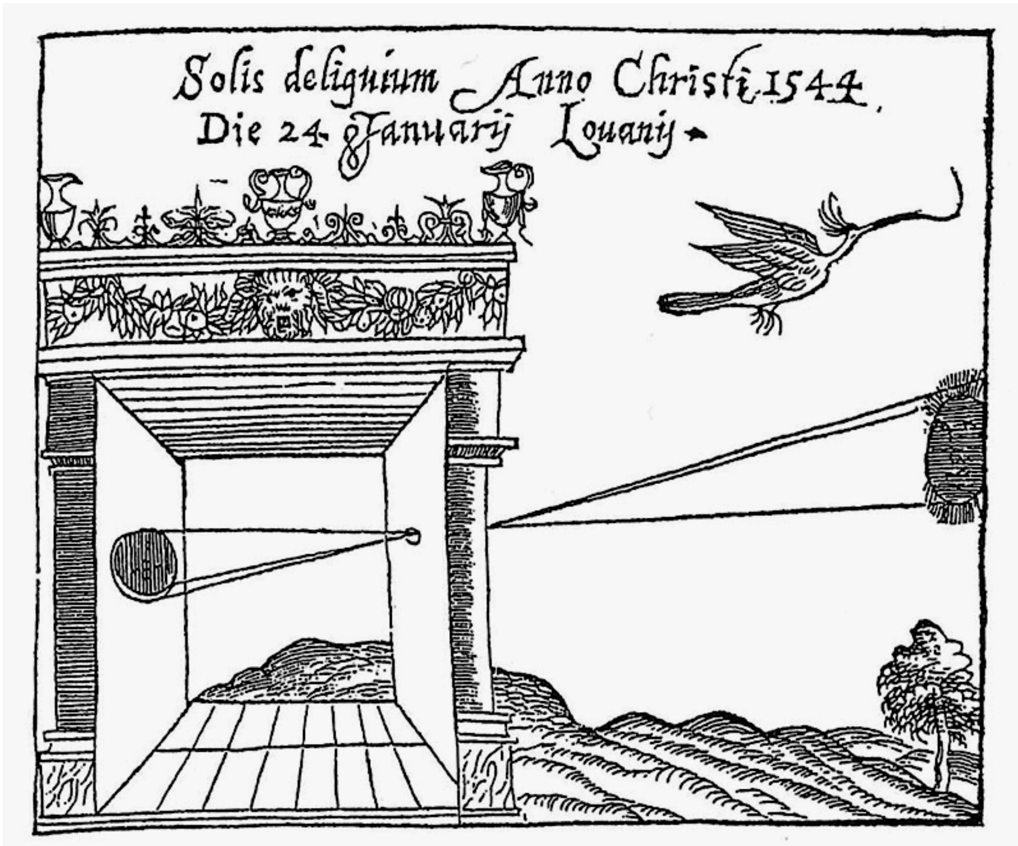
Piero della Francesca,
The Flagellation (c.1469)

Depicting Our World: Toward Perfection



Jan van Eyck, *The Arnolfini Marriage (c.1434)*

Depicting Our World: Towards Perfection



Camera Obscura, Gemma Frisius, 1544

Camera = Latin for “room”
Obscura = Latin for “dark”

Depicting Our World: Towards Perfection

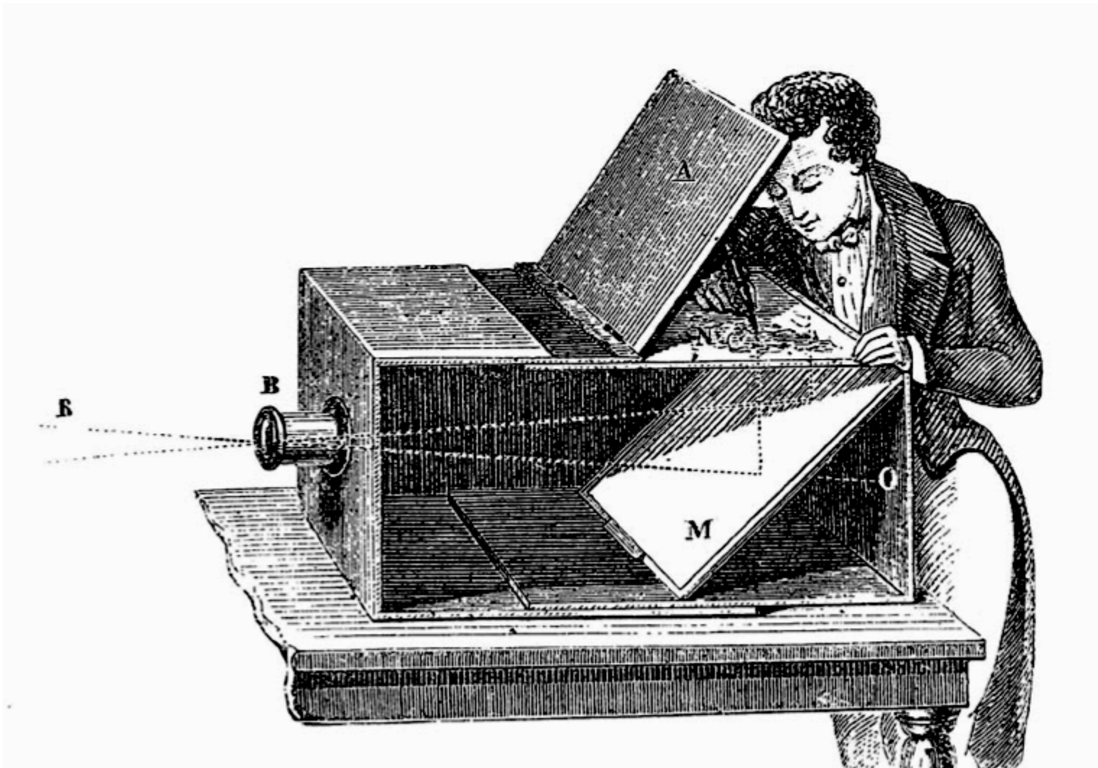


Fig. 434.

Lens Based Camera Obscura, 1568

Depicting Our World: Perfection!

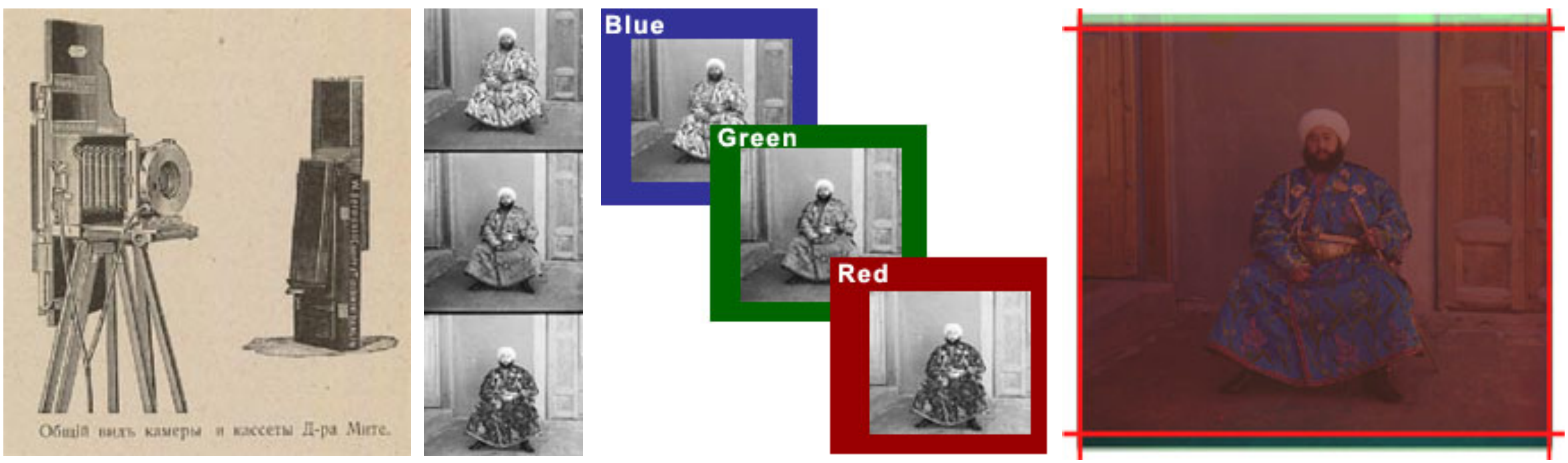
Still Life, Louis Jaques Mande Daguerre, 1837

Daguerrotype Camera

- 1839 first production camera

Color Photography

- 1861 by Maxwell
- Oldest color photos still preserved: Prokudin-Gorskii
  http://www.loc.gov/exhibits/empire/



Prokudin-Gorskii

- Digital restoration

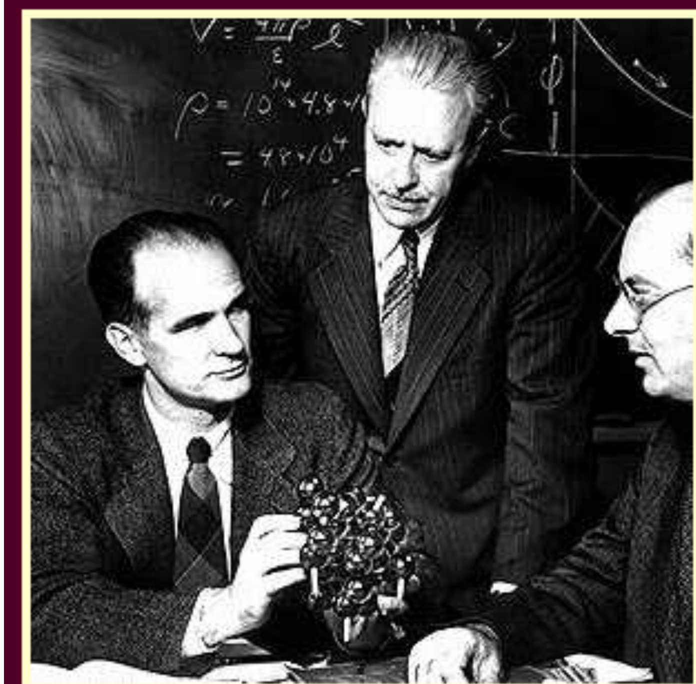
http://www.loc.gov/exhibits/empire/

Prokudin-Gorskii

Prokudin-Gorskii

Transistor

- 1947, Bell Labs (Nobel in 1956)
- William Shockley, John Bardeen and Walter Brattain



Shockley, Bardeen, and Brattain

The First Transistor
Click for Enlarged View

Integrated Circuit

- 1959 Bob Noyce of Fairchild Semiconductor
  (co-founded Intel Corporation in 1968)
  - One transistor, one capacitor

- Also Jack Kilby of Texas Instruments
  - Also inventor of portable calculator

Intel gang

Texas Instruments' first IC

http://www.pbs.org/transistor/background1/events/icinv.html

First Microprocessor in a Camera

- Canon AE-1 1976

CCD Technology

- 1969, Willard S. Boyle and George E. Smith, Bell Laboratories

First Digital Camera

- 1975, Steve Sasson, Kodak
- Uses CCD from Fairchild semiconductor, A/D from Motorola, .01 megapixels, 23 second exposure, recorded on digital cassette

Completely Digital Commercial Camera

- 1991 first completely digital Logitech Dycam 376x240

http://www.g4tv.com/1

Digital

- 1994 Apple quicktake, first mass-market color digital camera, 640 x 480 (commercial failure)

http://www-users.mat.uni.torun.pl/~olka/1

Digital SLR

- 1992 Kodak DCS 200, 1.5 Mpixels, based on Nikon body

Camera Phone

- In November 2000 Sharp and J-Phone introduced the first camera-phone in Japan

Traditional Photography

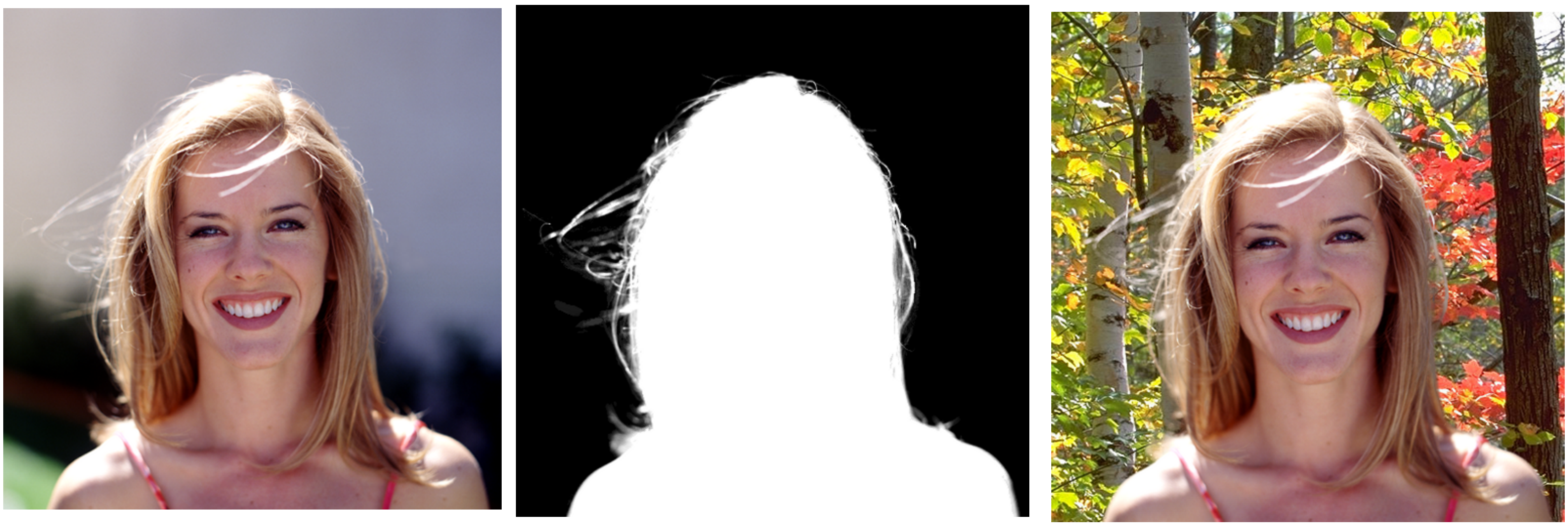
- Scene preparation
  - Make up, lighting, viewpoint
- Capture
  - Optics, film
- Post production
  - Dodge and burn, movie editing
- Viewing
  - Album, monitor, limited control (passive)

Computational Photography

- Scene preparation
  - Get rid of it!
- Capture
  - Active, feed-back
- Post production
  - Reconstruct image, automatic, creative scene manipulation
- Viewing
  - Additional dimensions (autostereoscopic, motion, HDR), interaction

Example: Project 1

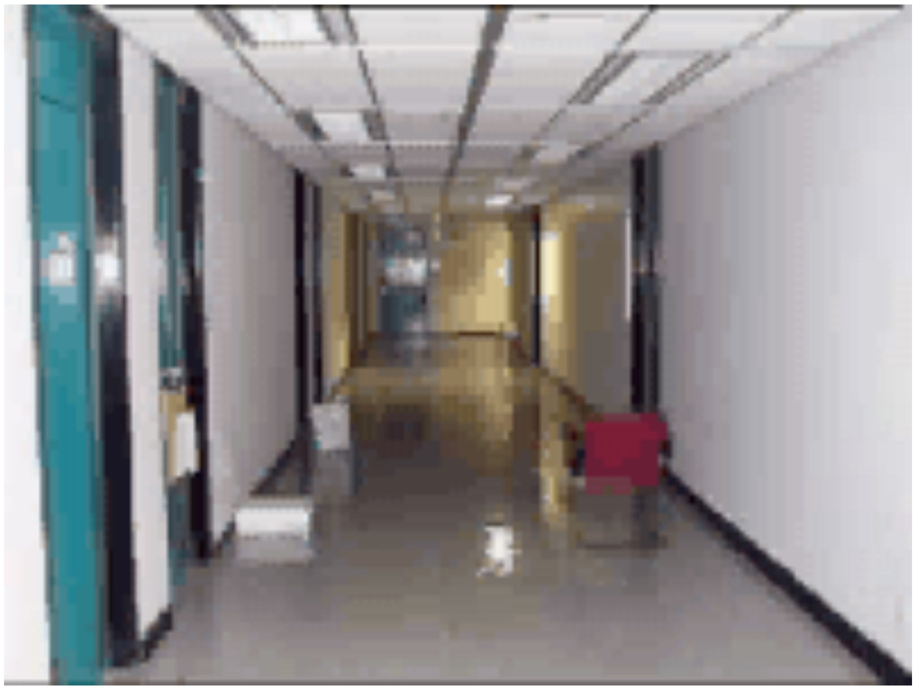
Example



Example: Project 2

Example

Example: Project 3



Nelson Chu

Computational Photography

Week 1, Winter 2009

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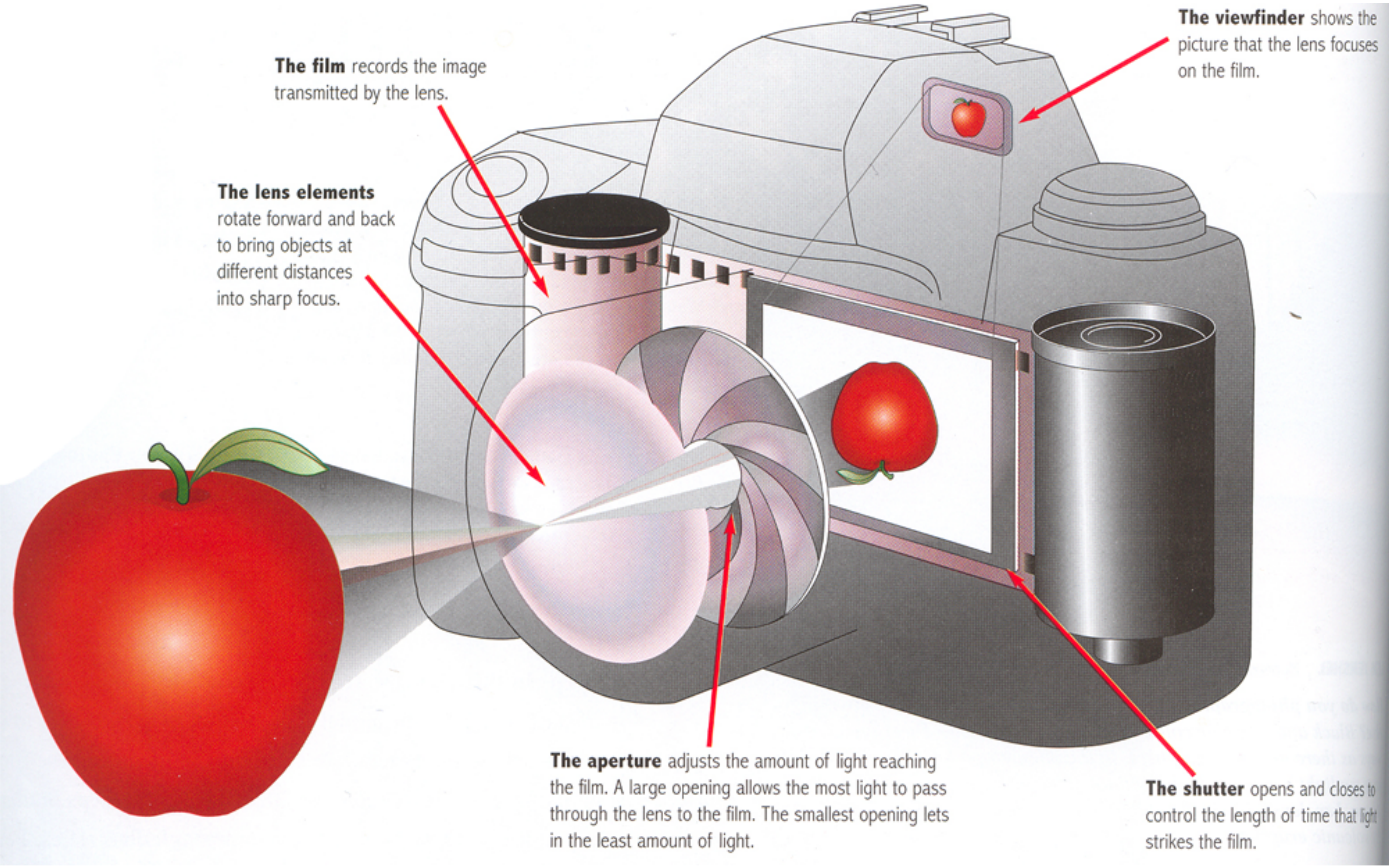
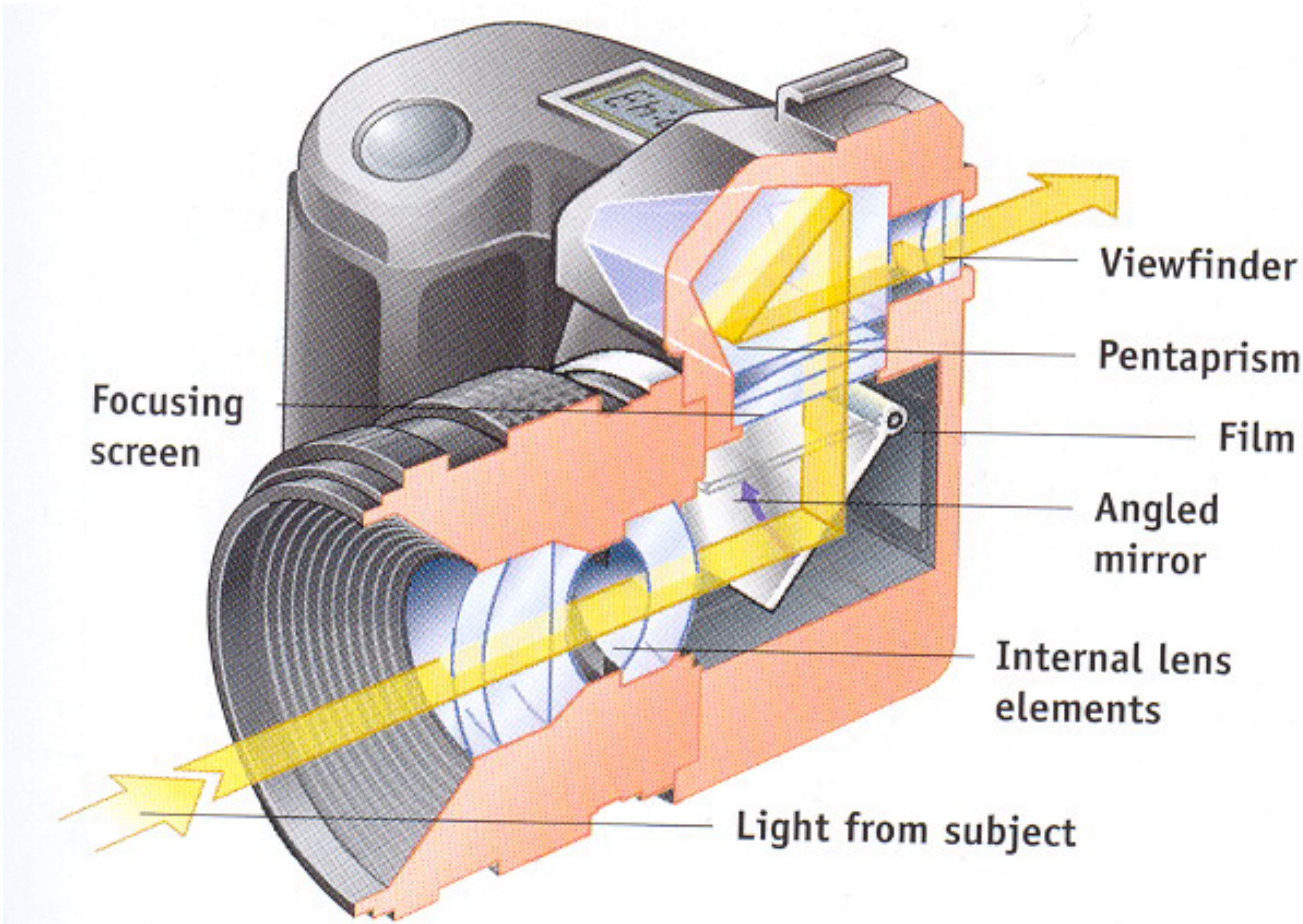
Computational Photography

?

Camera


The viewfinder shows the picture that the lens focuses on the film.
The film records the image transmitted by the lens.
The lens elements rotate forward and back to bring objects at different distances into sharp focus.
The aperture adjusts the amount of light reaching the film. A large opening allows the most light to pass through the lens to the film. The smallest opening lets in the least amount of light.
The shutter opens and closes to control the length of time that light strikes the film.

Single Lens Reflex (SLR)

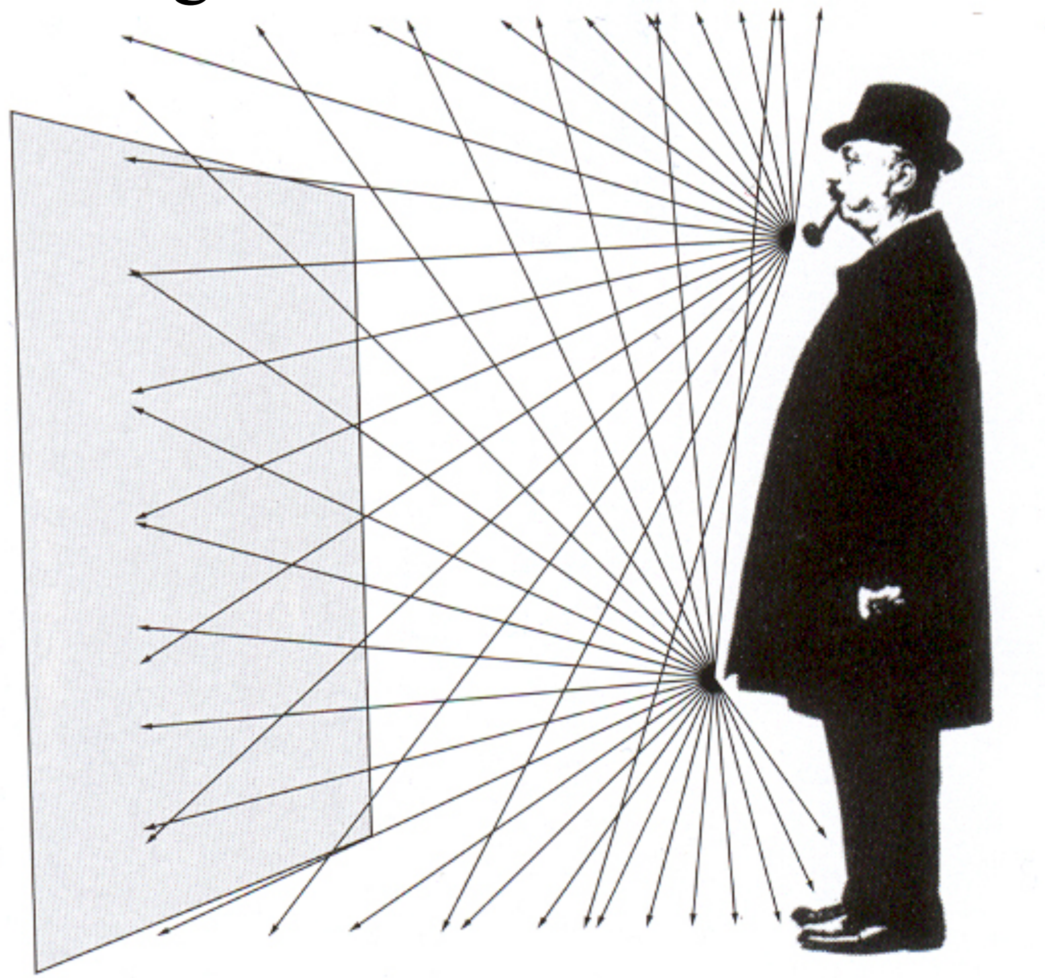


Question

- Why is there no image on a white piece of paper?
- Why do we need to put the film in the camera?

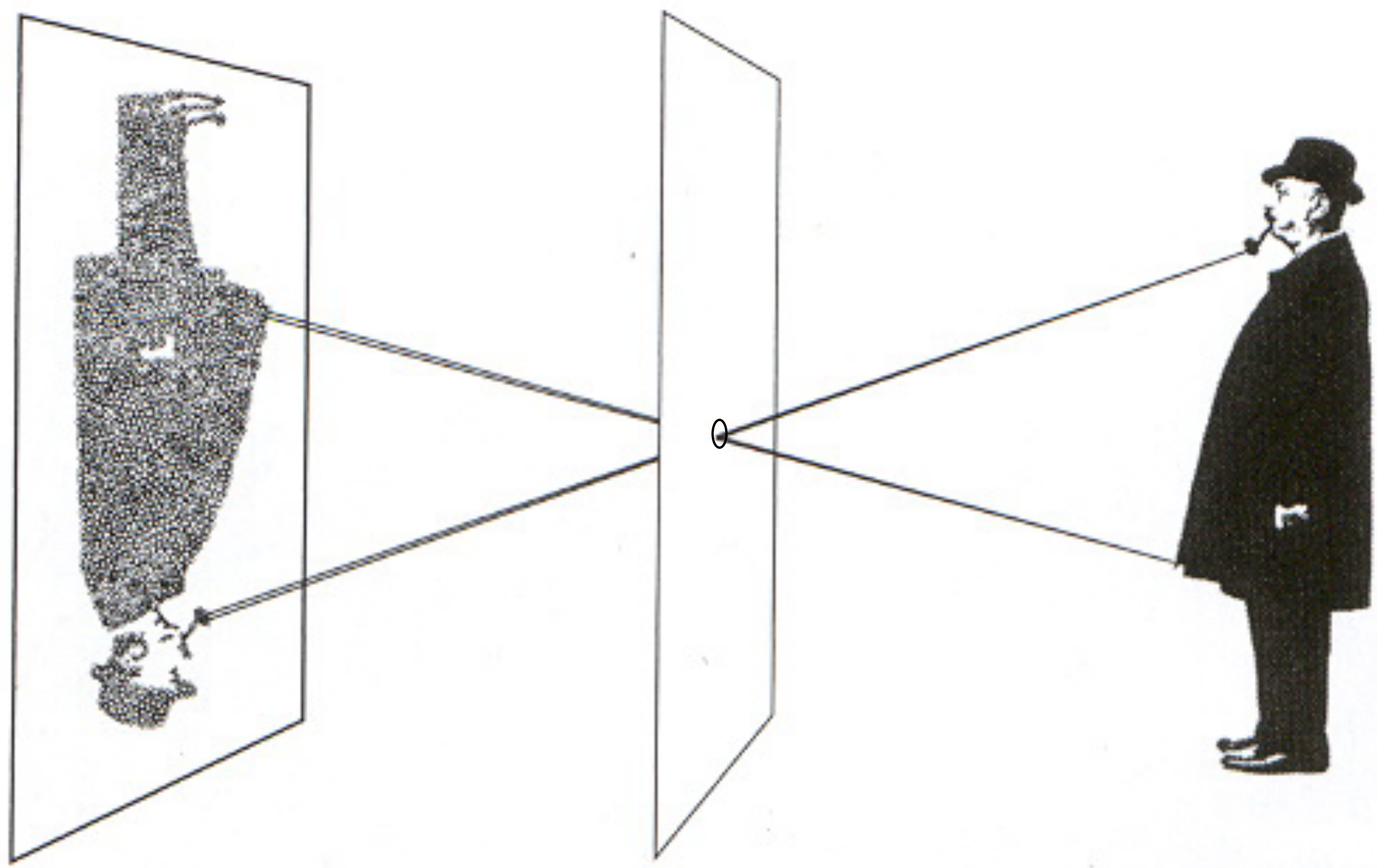
Answer

- It receives light from all directions



From Photography, London et al.

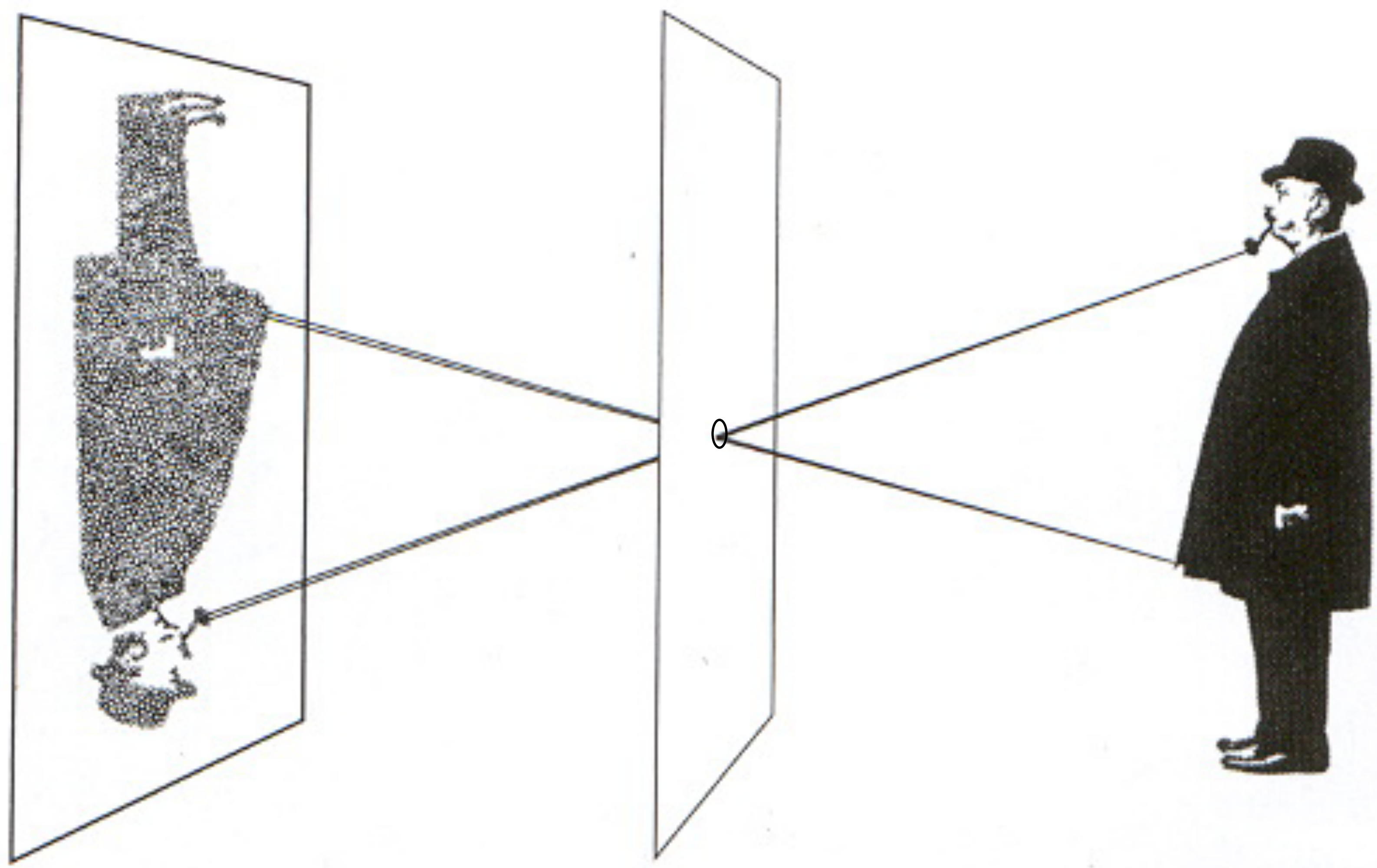
Pinhole



From Photography, London et al.

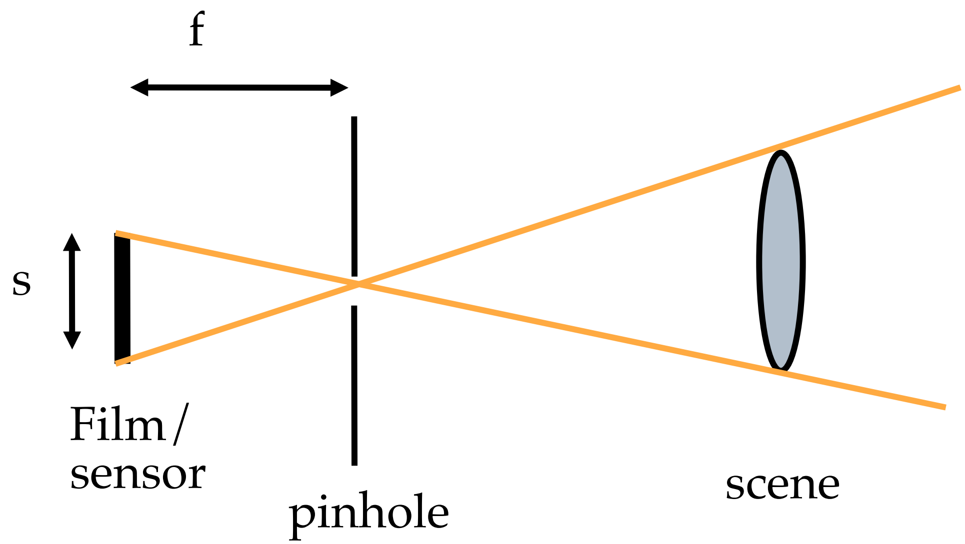
BW Pinhole Image

Pinhole



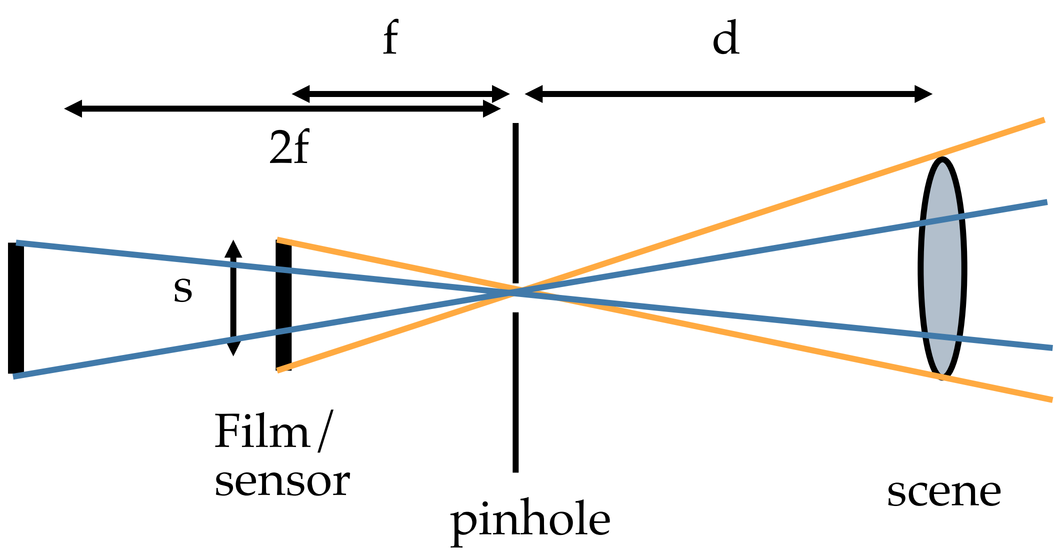
From Photography, London et al.

Focal Length



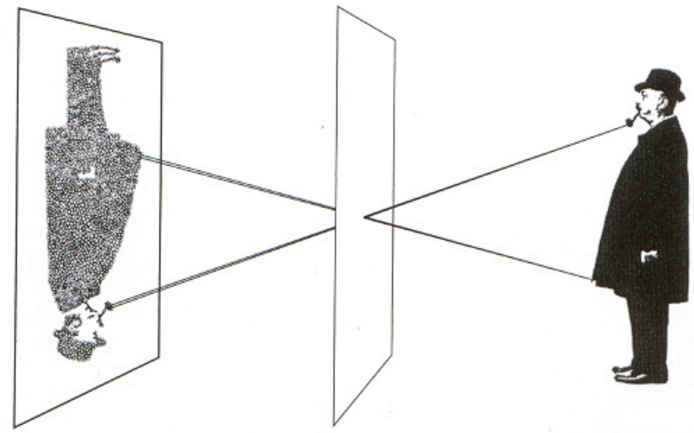
Focal Length: Pinhole Optics

- What happens when the focal length is doubled?
  - Projected object size is doubled
  - Amount of light gathered is divided by 4

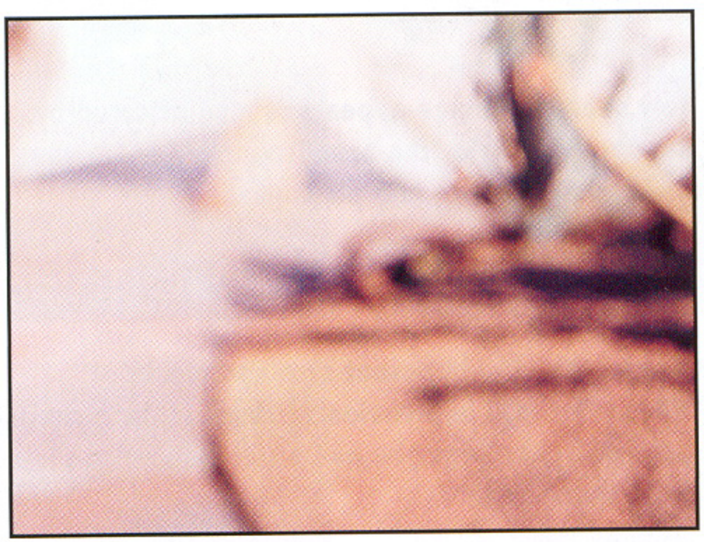


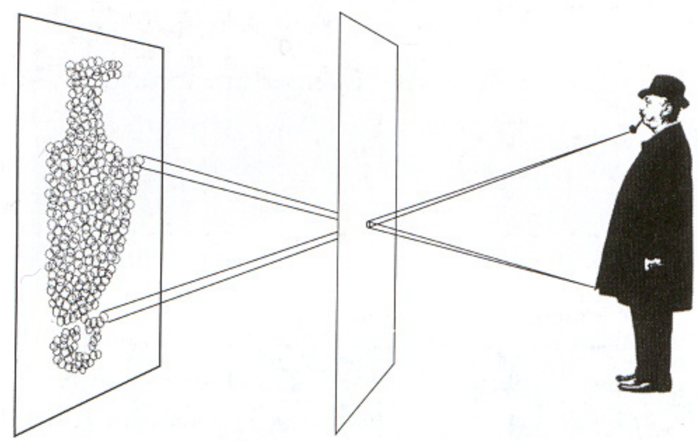
Pinhole Size?

Photograph made with small pinhole



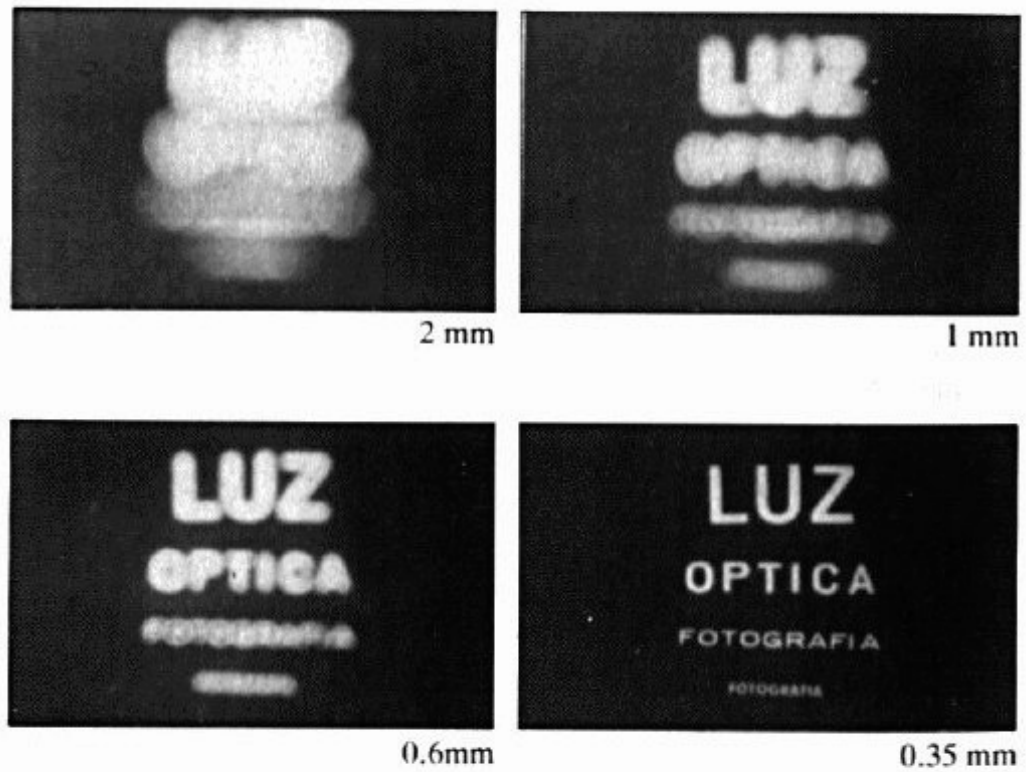
Photograph made with larger pinhole





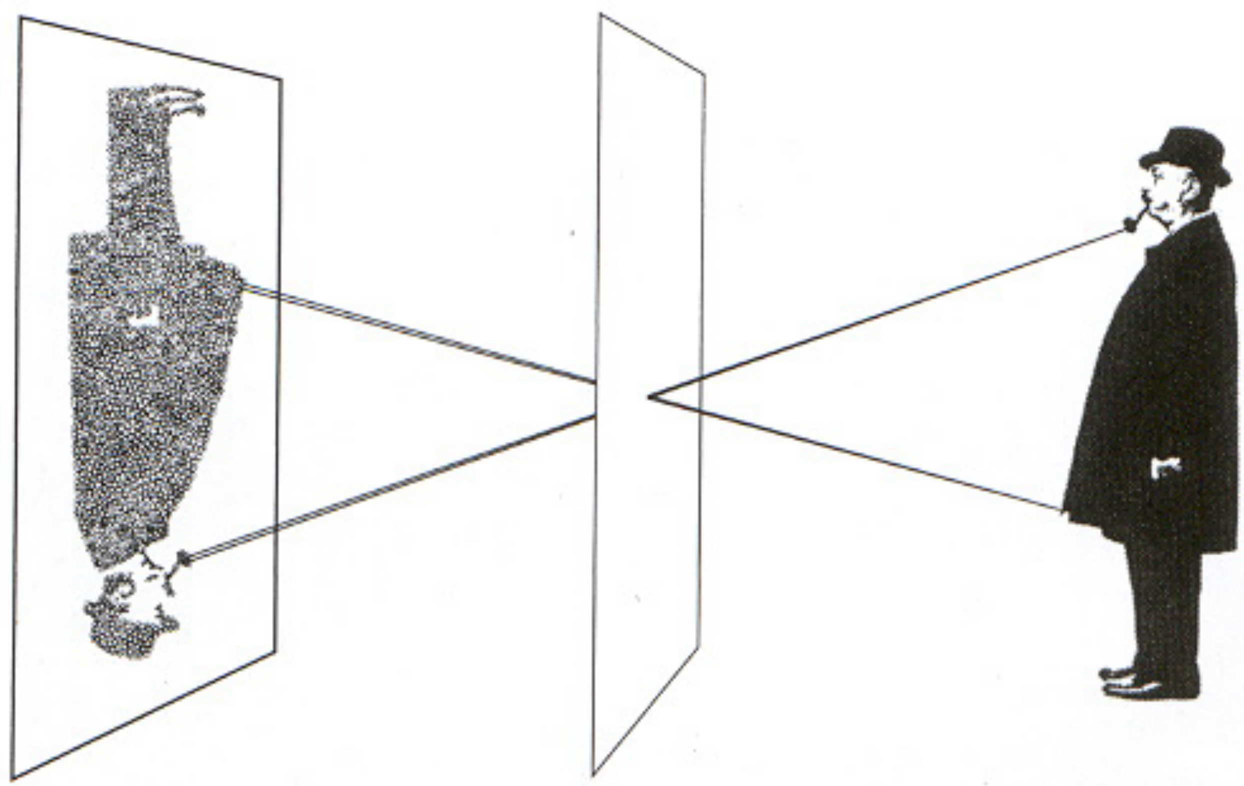
From Photography, London et al.

Diffraction Limit



Problem with pinhole?

- Not enough light!
- Diffraction limits sharpness

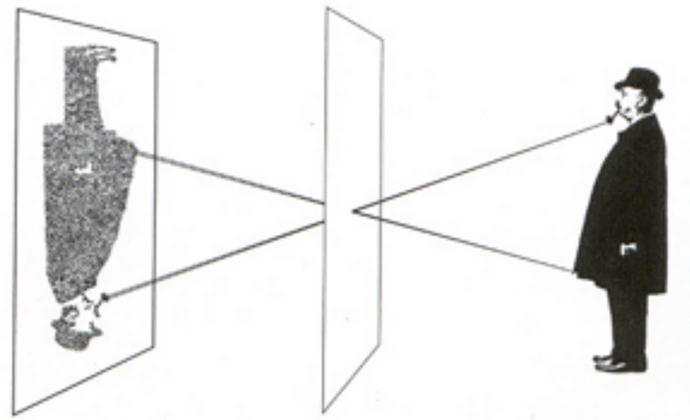


Solution: Refraction!

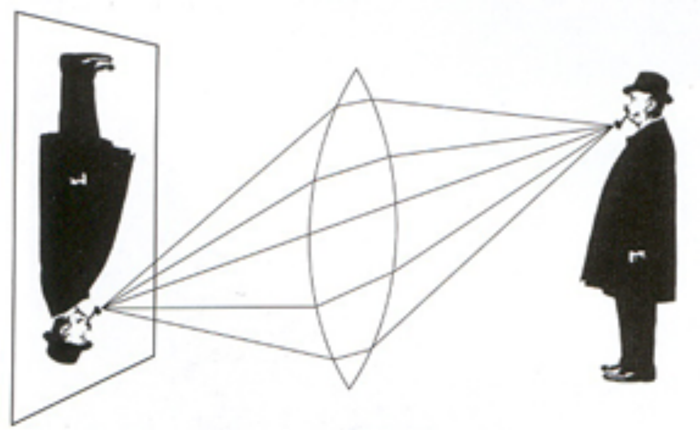
From Photography, London et al.

Lenses

Photograph made with small pinhole



Photograph made with lens



From Photography, London et al.

This time, using a simple convex lens with an f/16 aperture, *the scene appeared sharper than the*

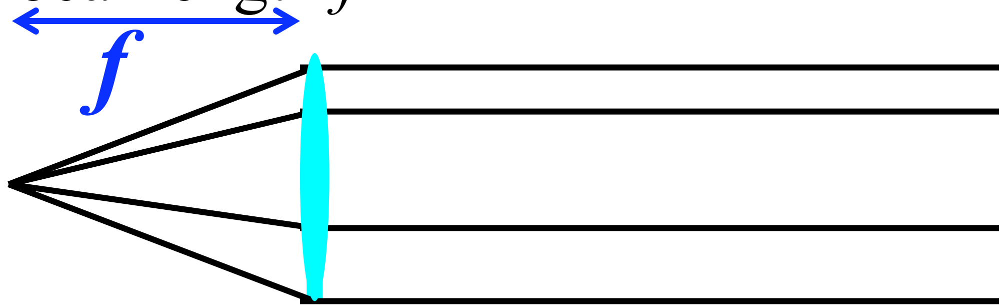
The lens opening was much bigger than the pinhole, letting in far more light, but it focused the

Lenses

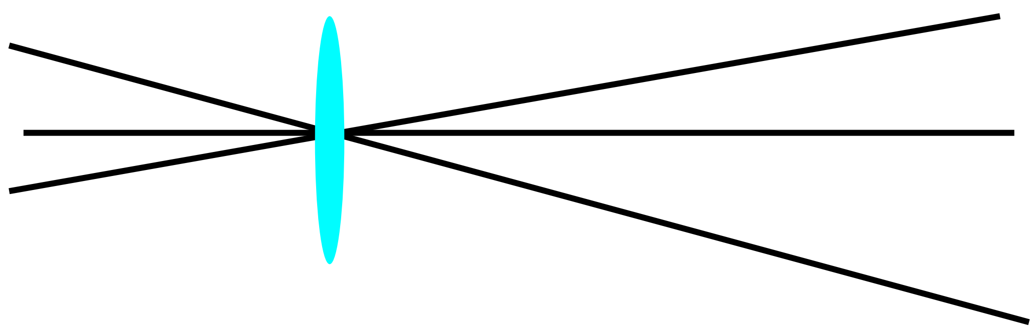
- Gathers more light
- But needs to be “focused”

Thin Lens Optics

- Simplification of geometrical optics for well-behaved lenses
- All parallel rays converge to one point on a plane located at the focal length f

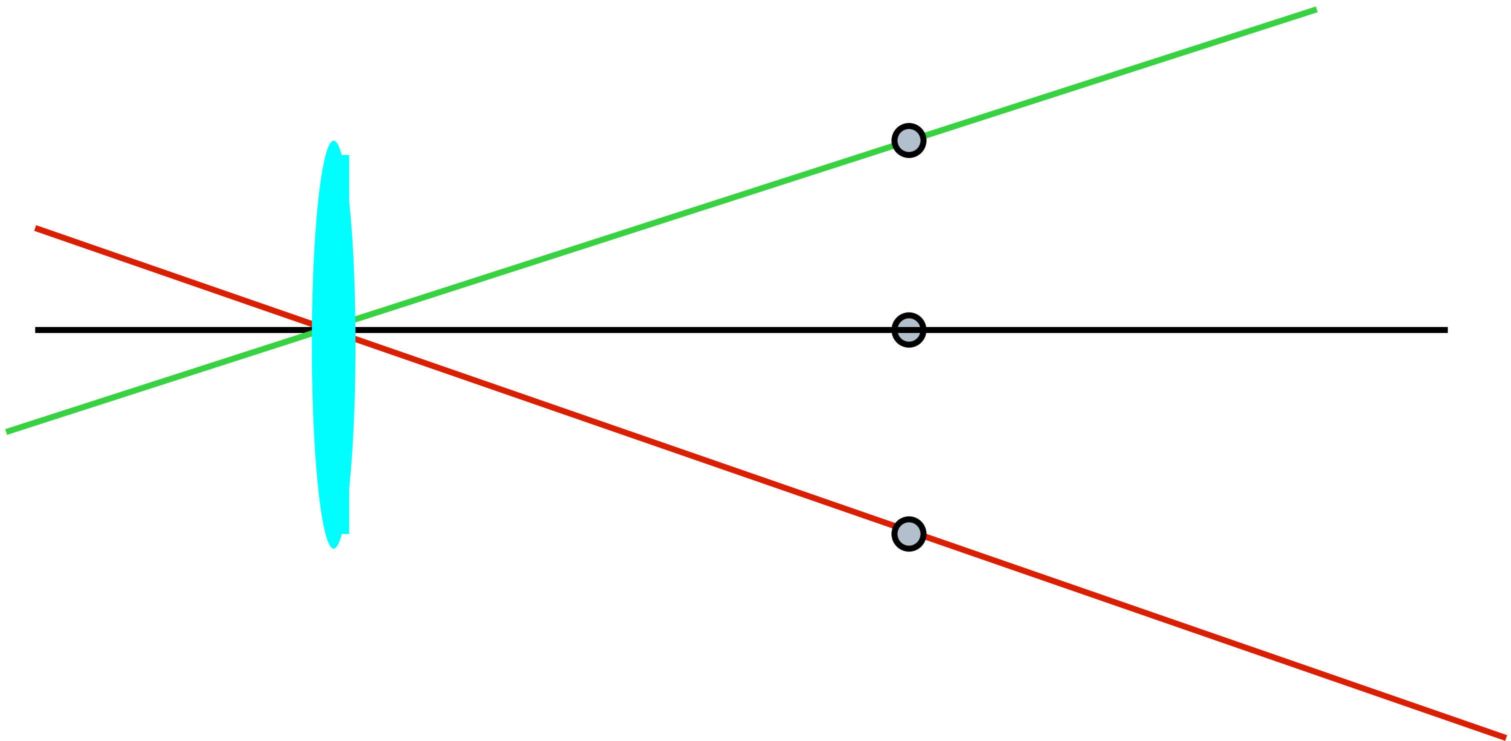


- All rays going through the center are not deviated
  - Hence same perspective as pinhole



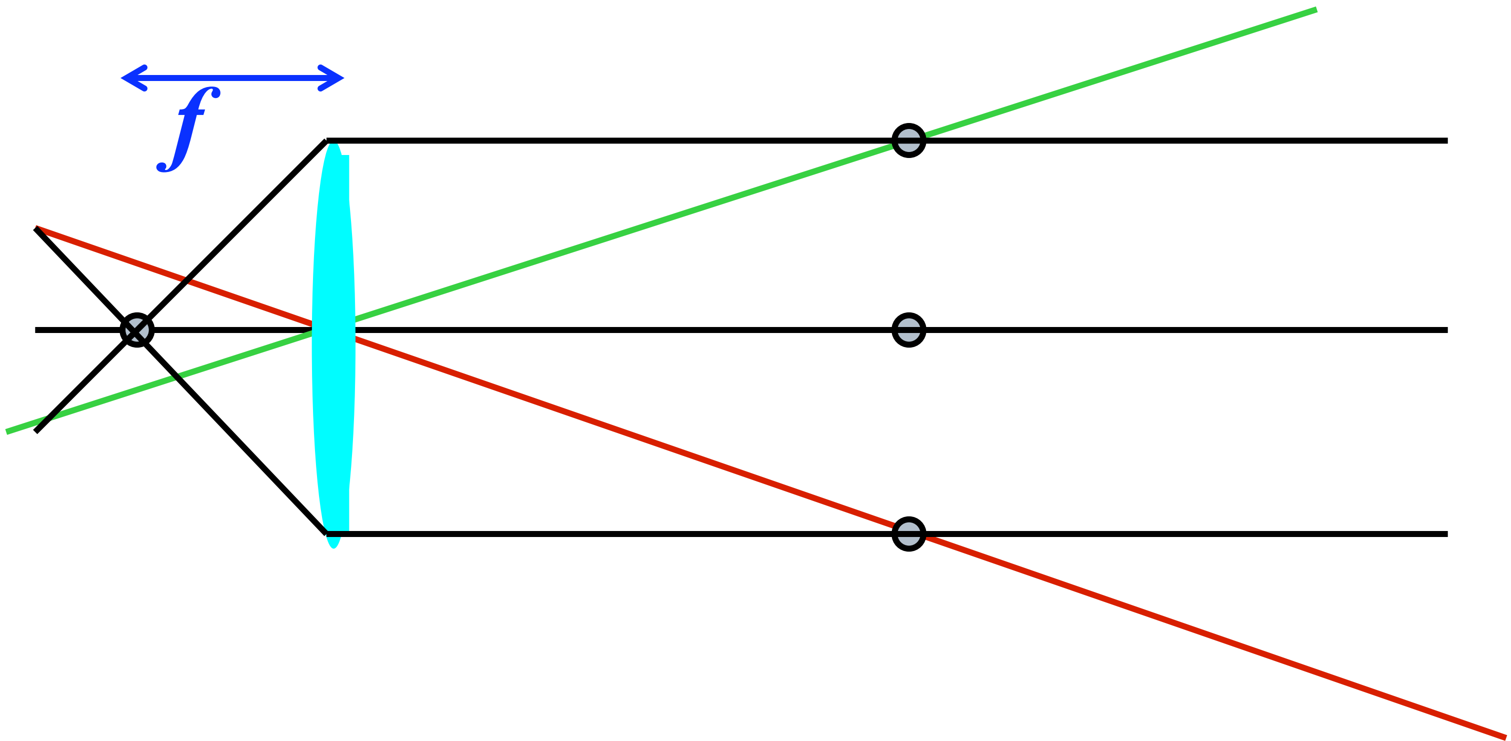
How to Trace Rays

- Start by rays through the center



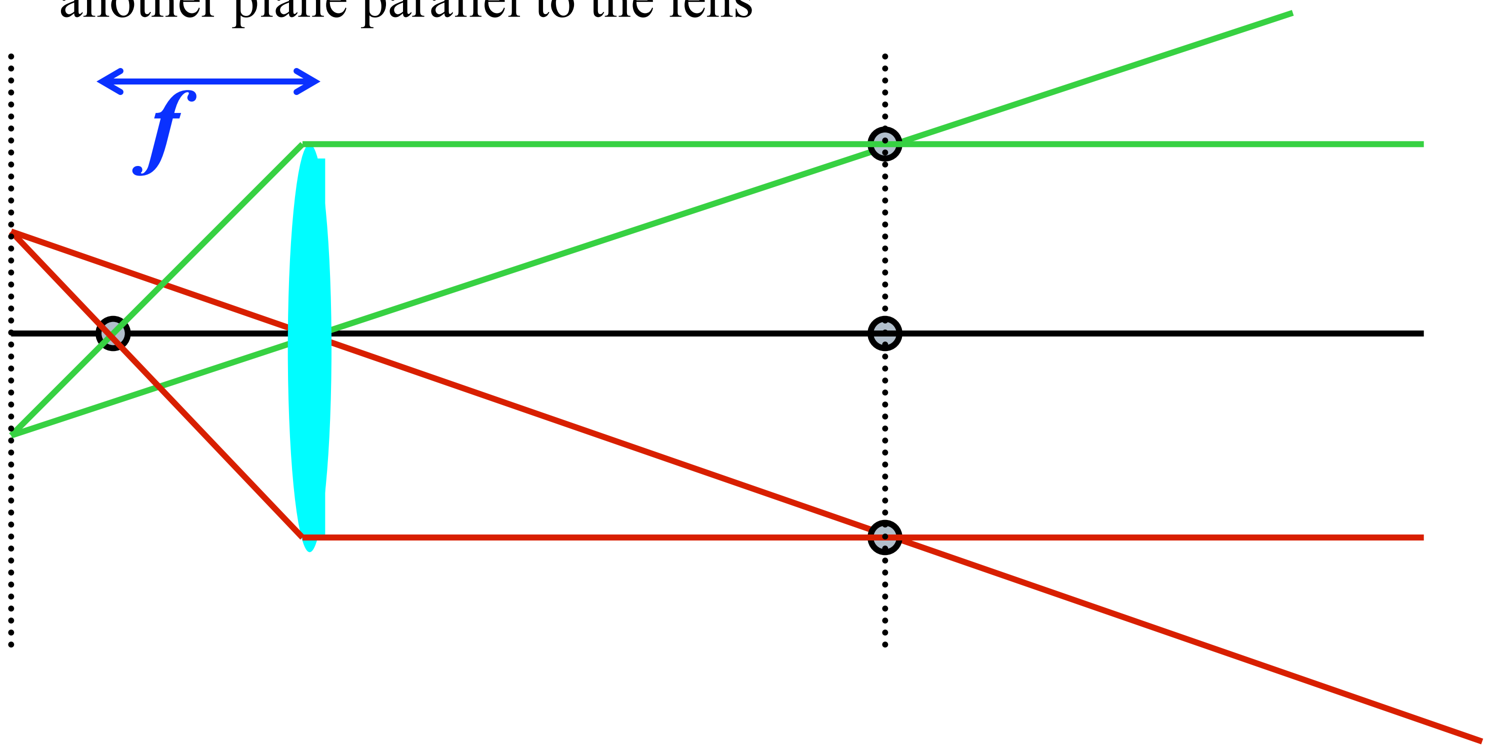
How to Trace Rays

- Start by rays through the center
- Choose focal length, trace parallels



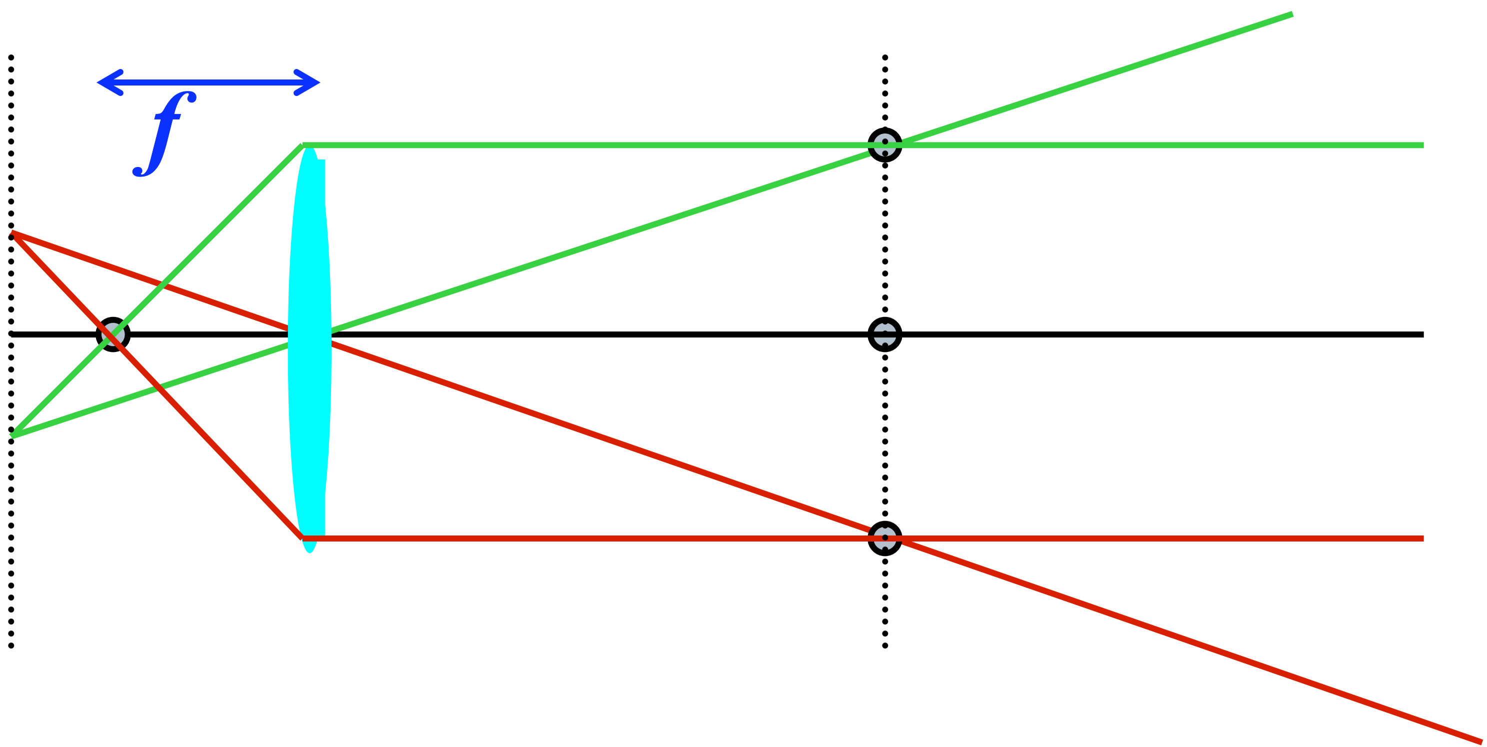
How to Trace Rays

- Start by rays through the center
- Choose focal length, trace parallels
- You get the focus plane for a given scene plane
  - All rays coming from points on a plane parallel to the lens are focused on another plane parallel to the lens

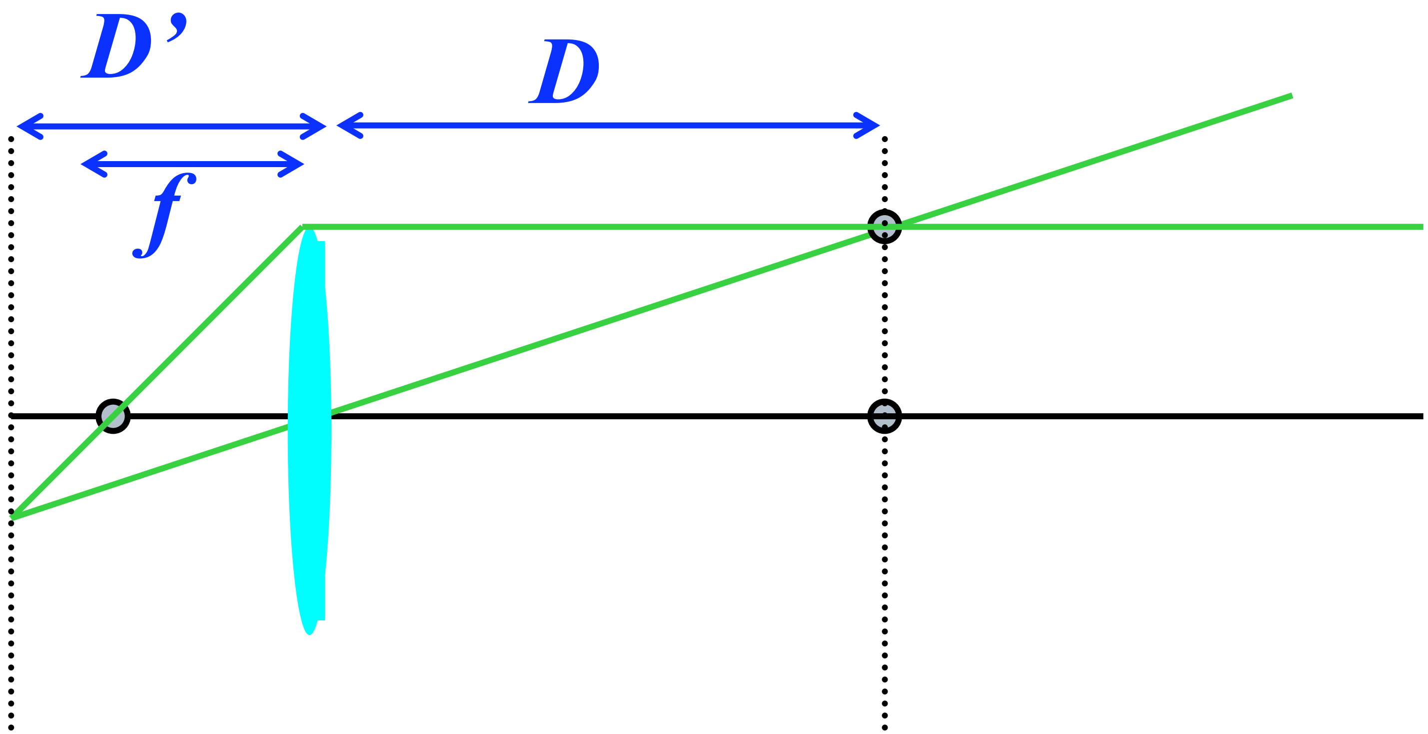


Focusing

- To focus closer than infinity
  - Move the sensor/film ***further*** than the focal length

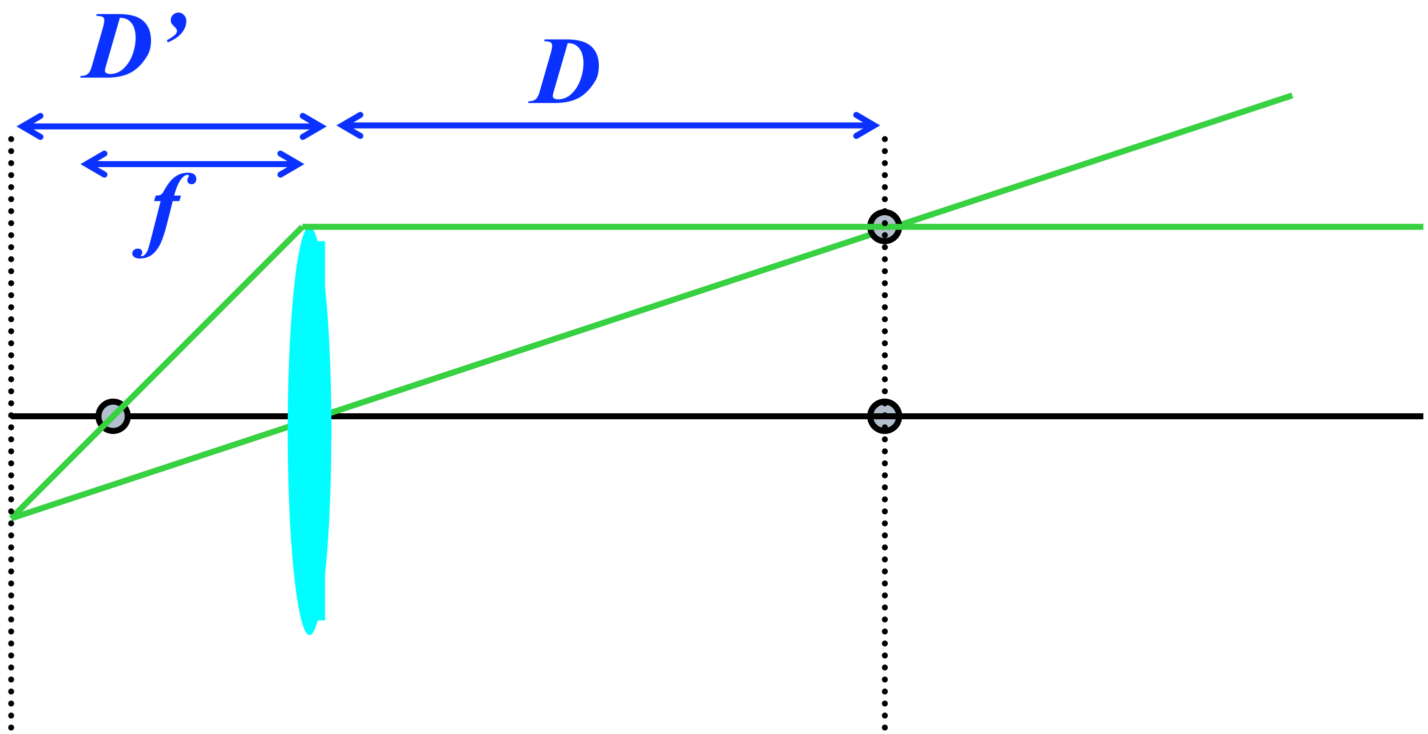


Thin Lens Formula



Thin Lens Formula

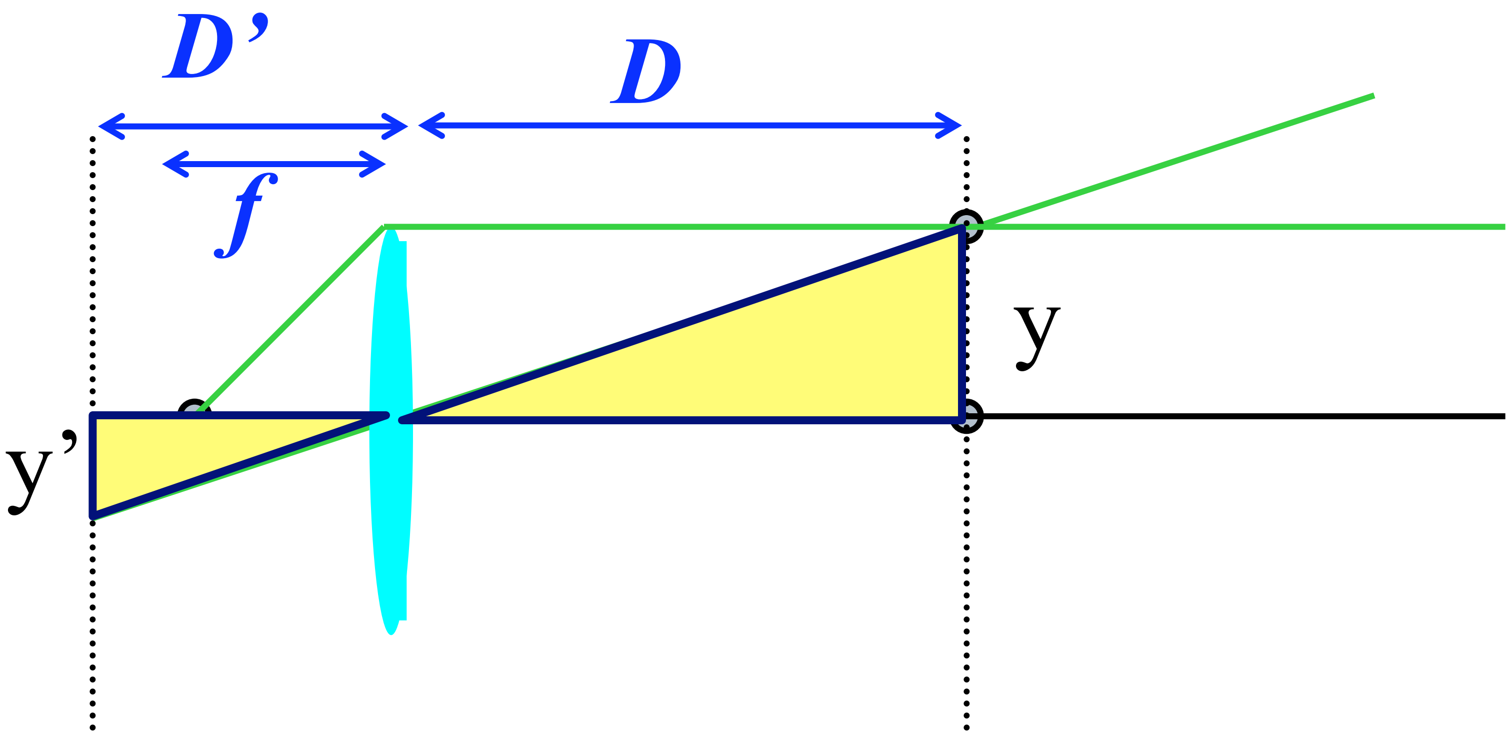
Similar triangles everywhere!



Thin Lens Formula

Similar triangles everywhere!

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

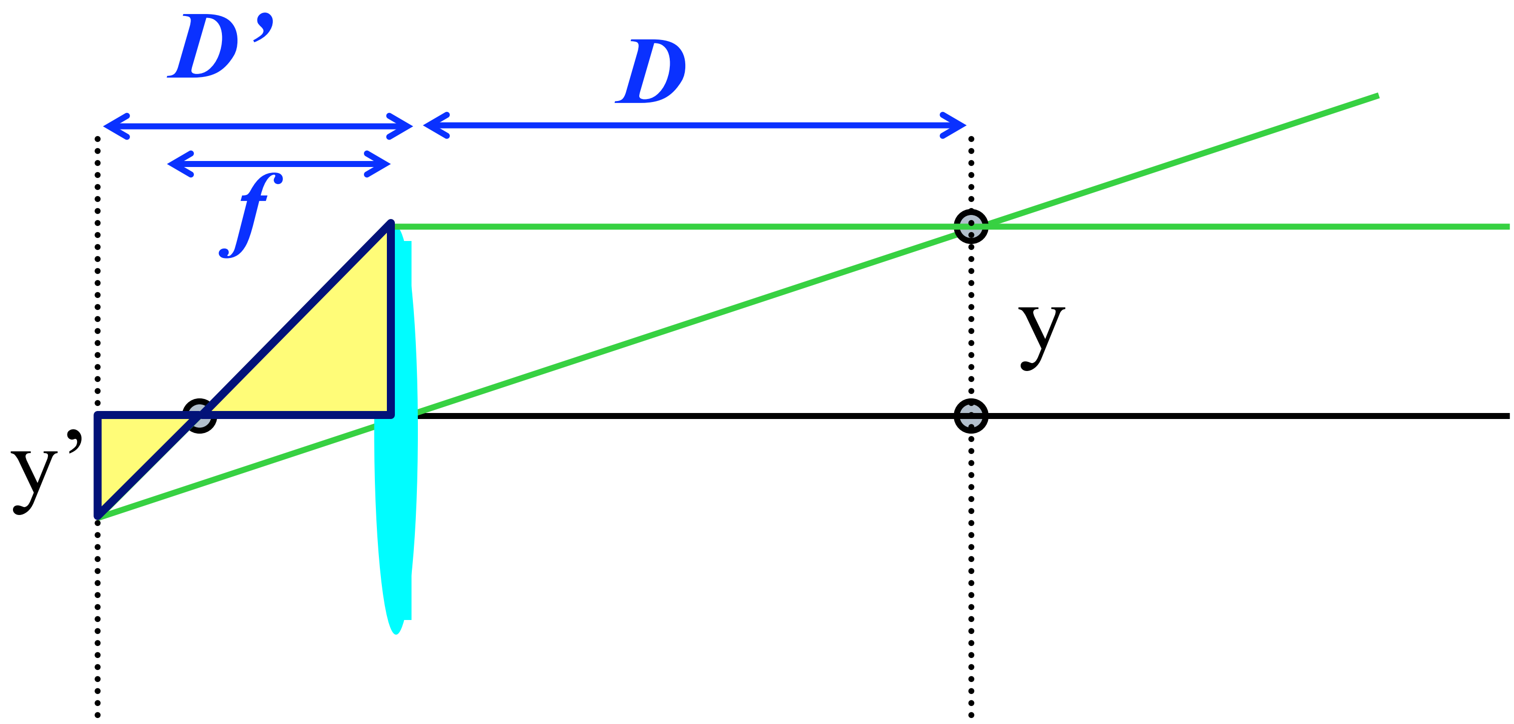


Thin Lens Formula

Similar triangles everywhere!

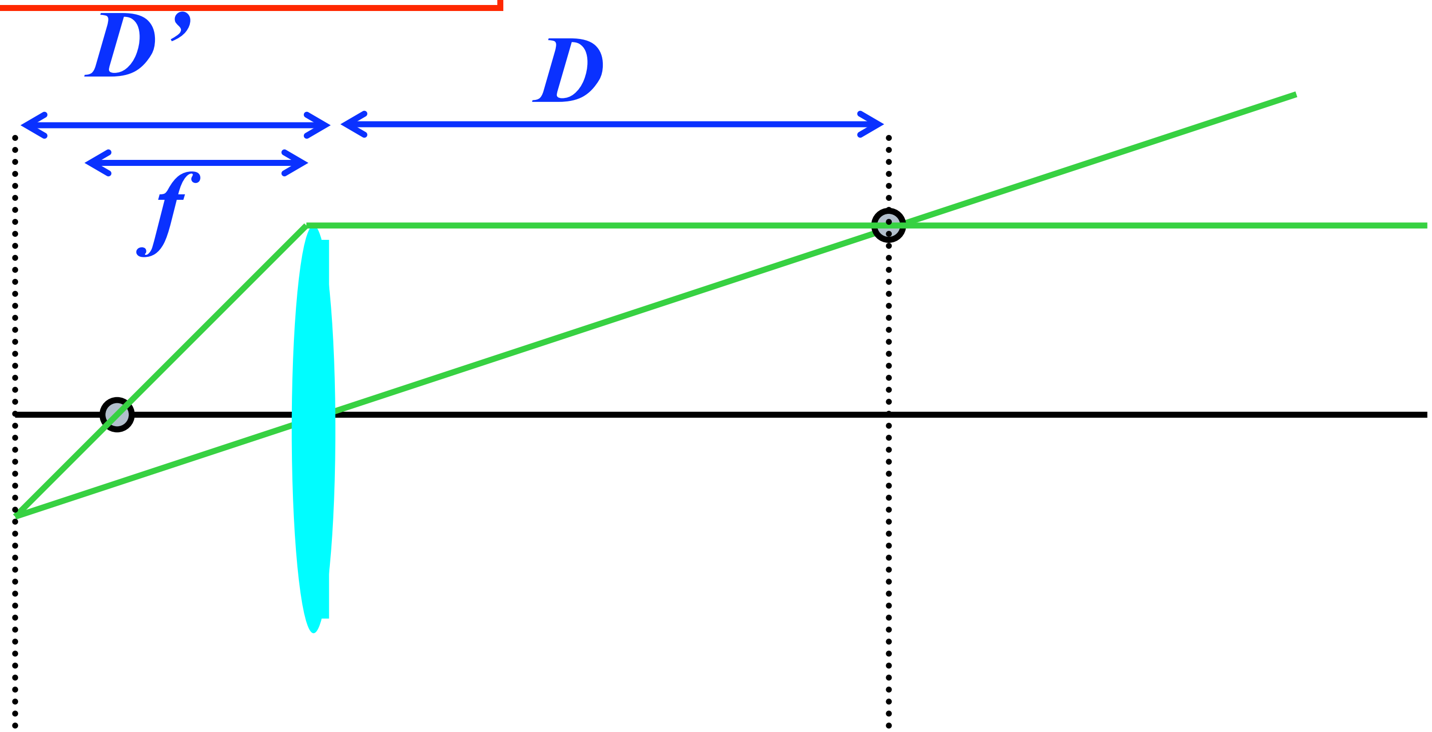
$$y'/y = D'/D$$

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



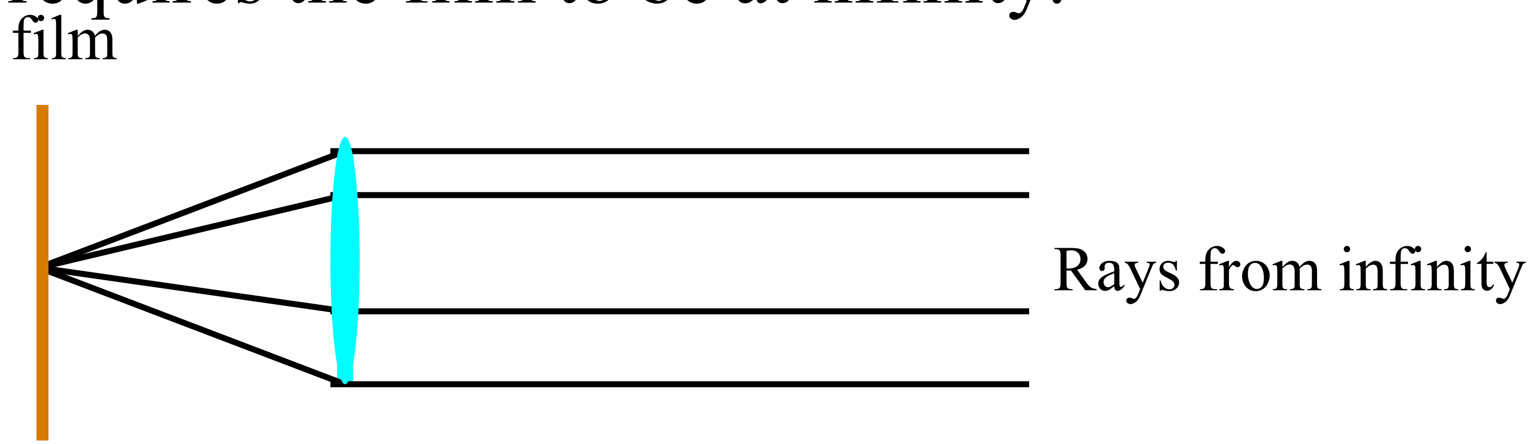
Thin Lens Formula

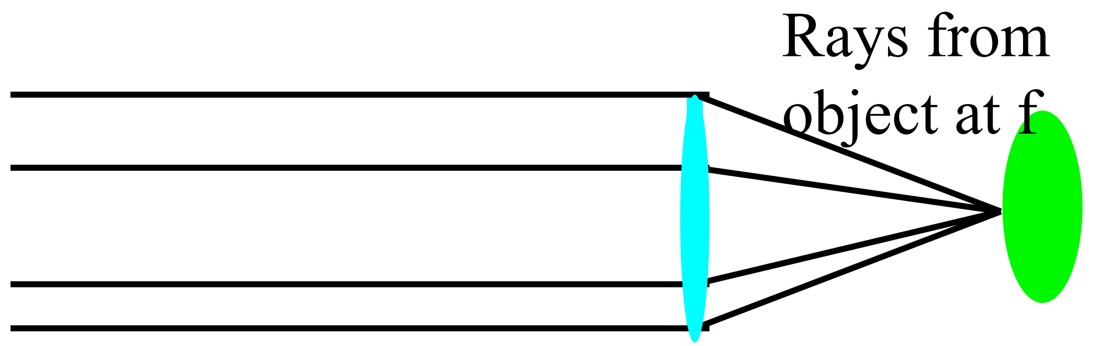
$$\frac{1}{D'} + \frac{1}{D} = \frac{1}{f}$$



Minimum Focusing Distance

- By symmetry, an object at the focal length requires the film to be at infinity.





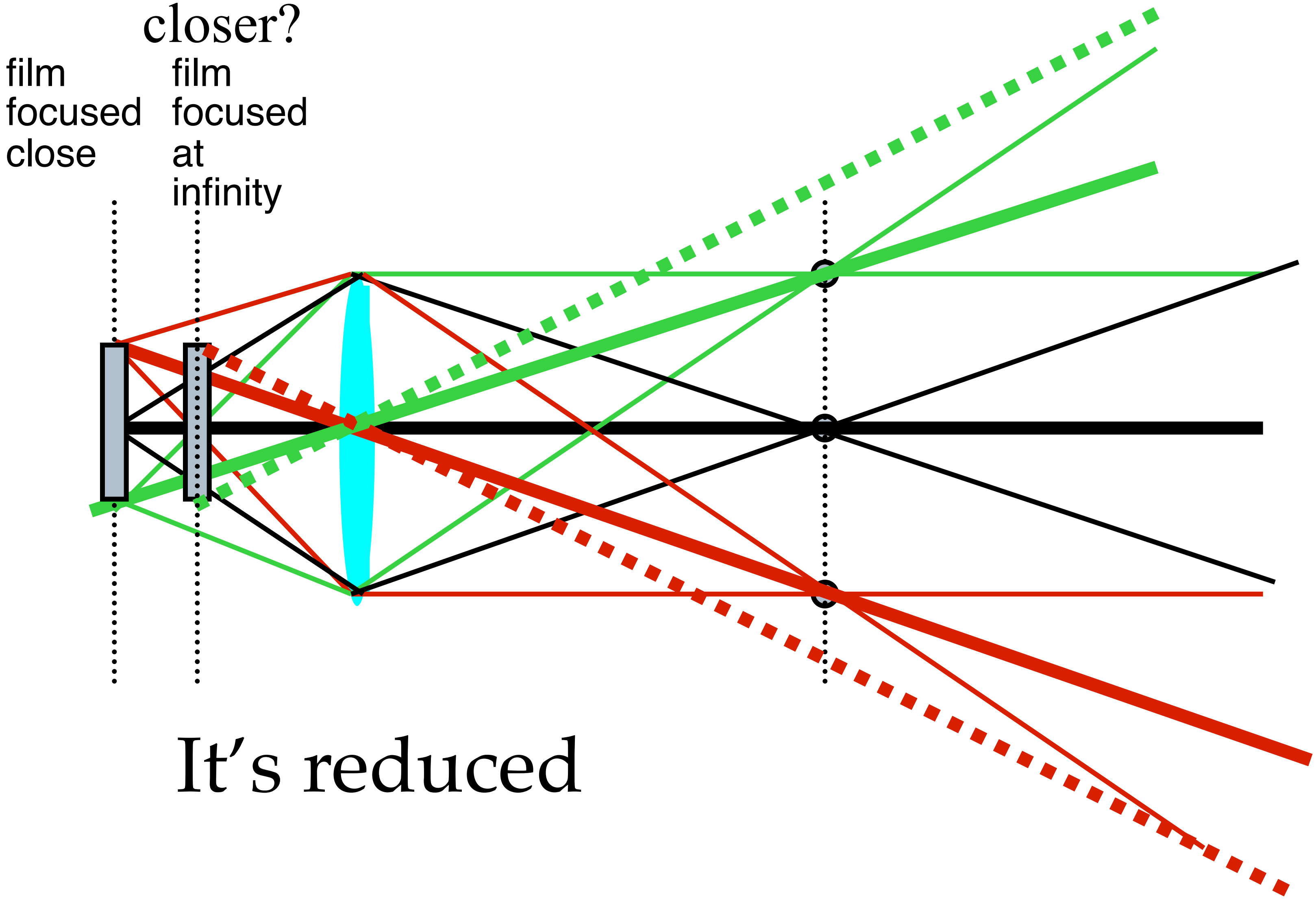
Extensions Tubes

- Allow us to put sensor/film farther

  → focus closer

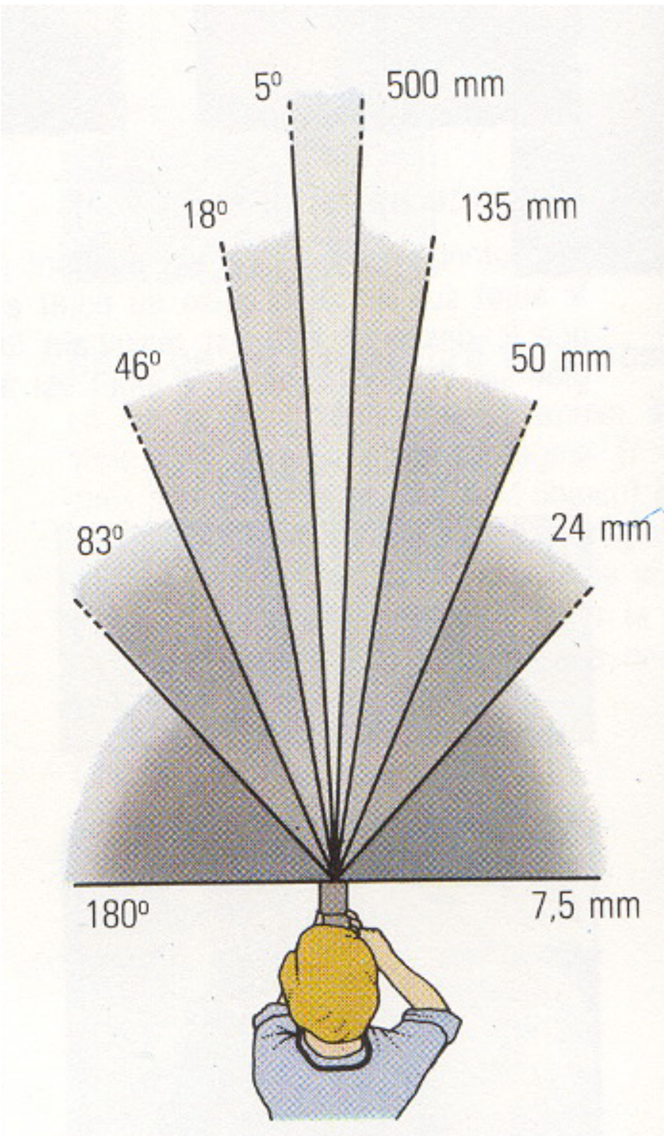
Field of View & Focusing

- What happens to the field of view when one focuses closer?



It's reduced

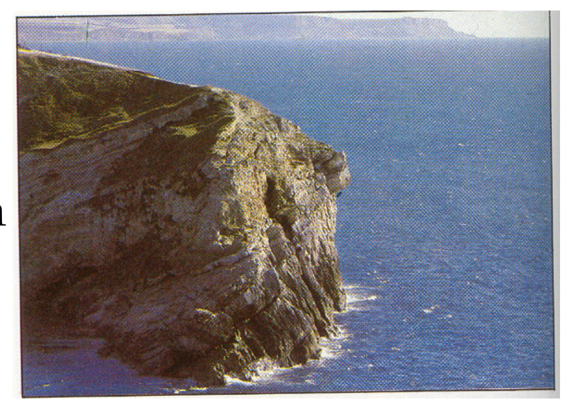
Focal Length in Practice



24mm

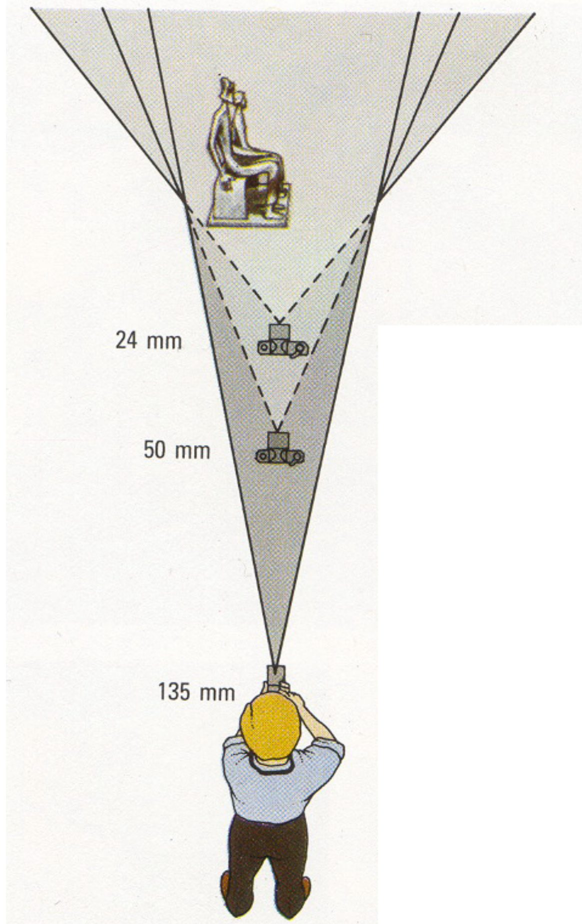
50mm

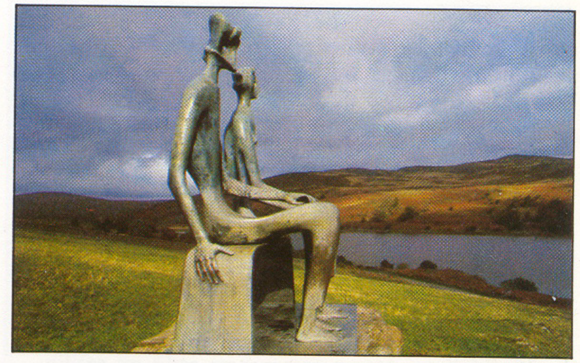
135mm



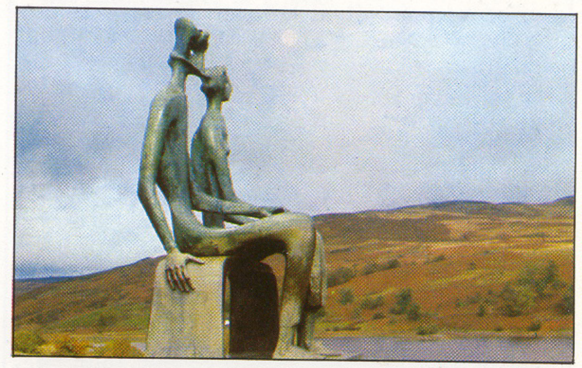
Perspective vs. Viewpoint

- Telephoto makes it easier to select background (a small change in viewpoint is a big change in background.

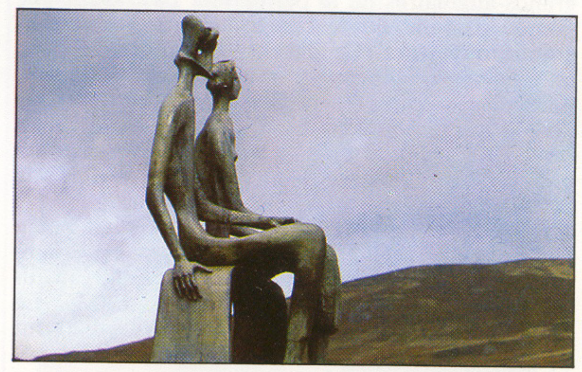




Grand-angulaire 24 mm



Normal 50 mm



Longue focale 135 mm

Perspective vs. Viewpoint

- Portrait: distortion with wide angle
- Why?

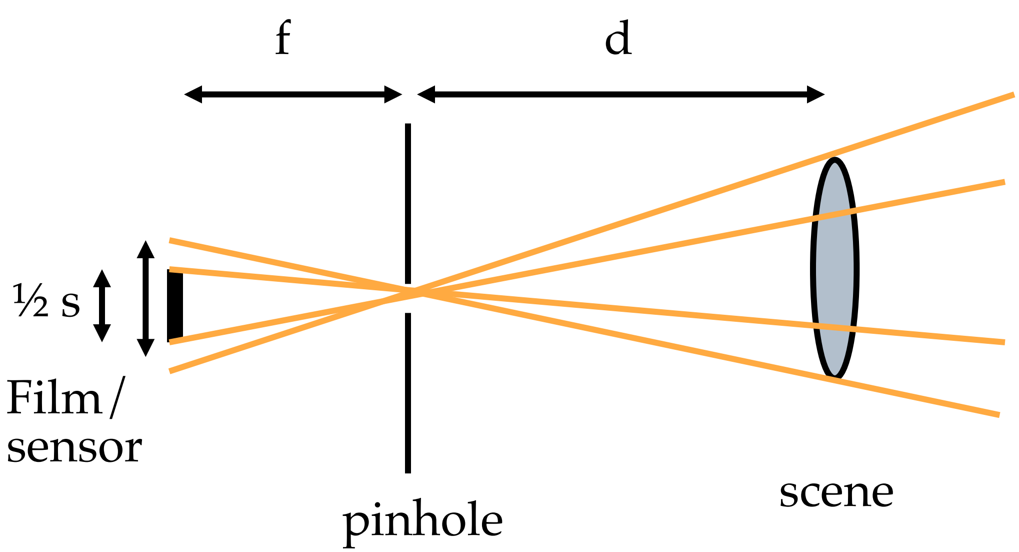

Wide angle


Standard


Telephoto

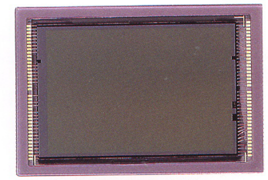
Focal Length & Sensor

- What happens when the film is half the size?
- Application:
  - Real film is 36x24mm
  - On the 20D, the sensor is 22.5 x 15.0 mm
  - Conversion factor on the 20D?
  - On the SD500, it is 1/1.8 " (7.18 x 5.32 mm)
  - What is the 7.7-23.1mm zoom on the SD500?

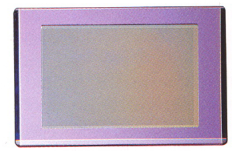


Sensor Size

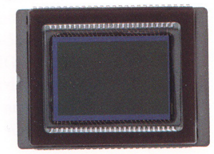
- Similar to cropping



EOS-1Ds : 35.8 x 23.8mm

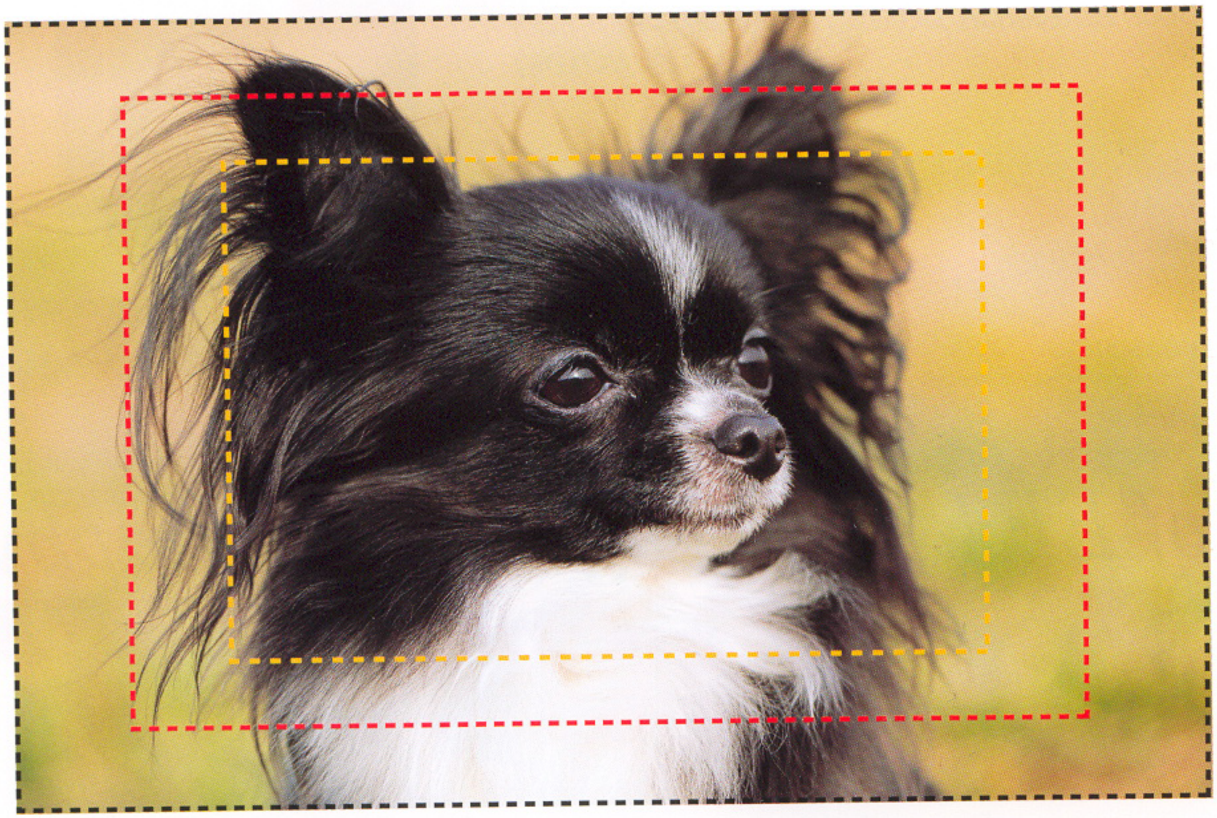


EOS-1D : 28.7 x 19.1mm



EOS 10D : 22.7 x 15.1mm

35mm full size and digital shooting range image size (picture dimensions) and lens selection



— EOS-1Ds / — EOS-1D/ — EOS 10D

EOS-1D

EOS 10D
(The EOS Kiss Digital/EOS DIGITAL Rebel/EOS 300D DIGITAL SLR camera has the same image size as the EOS 10D.)

source: canon red book

http://www.photozone.de/3Technology/digital_1.htm

Recap

- Pinhole is the simplest model of image formation
- Lenses gather more light
  - But get only one plane focused
  - Focus by moving sensor/film
  - Cannot focus infinitely close
- Focal length determines field of view
  - From wide angle to telephoto
  - Depends on sensor size