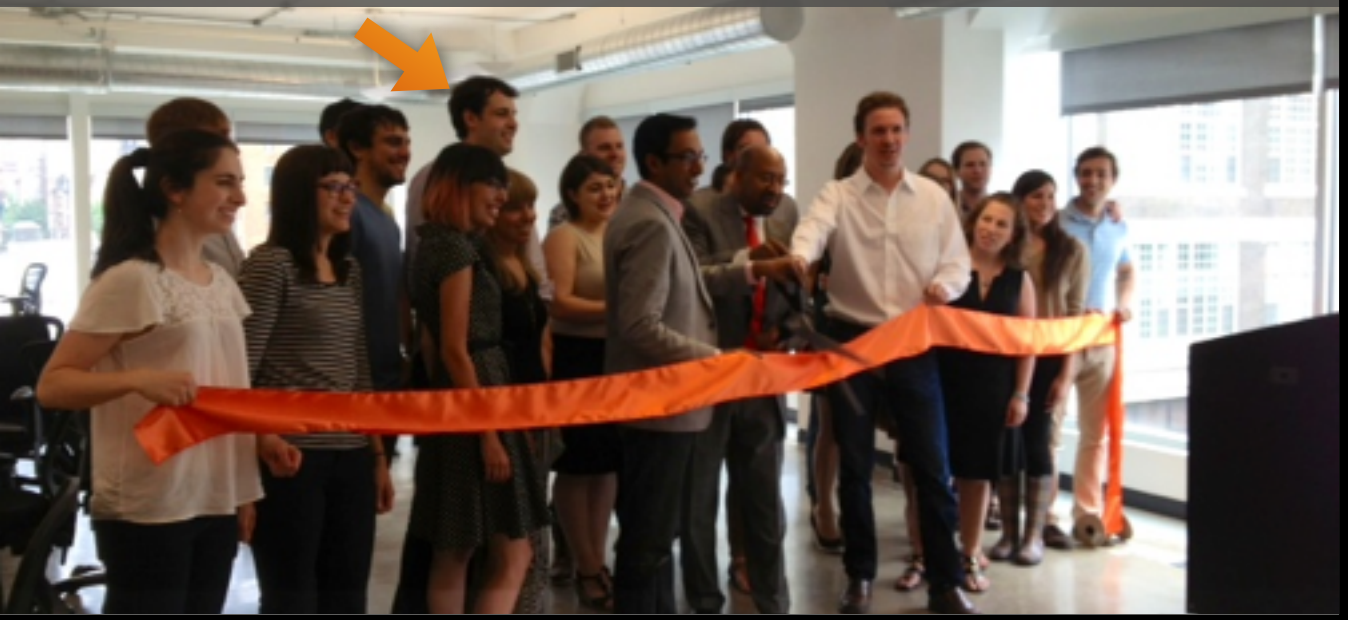
Computational Photography

Week 1, Spring 2016

Instructor: Lou Kratz

Software Engineer at



- computer vision
- machine learning
- big data

Who am I?

- Me:
  - Ph.D. from Drexel 2012; Advisor: Ko Nishino
  - Research on Computer Vision

  - lak24@drexel.edu
  - http://www.cs.drexel.edu/~lak24/

What will you learn?

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

- Textbook
  - **None** (many of the topics covered in Szeliski book)
  - 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 (20%x4=80%)
  - Details later
    - Project 1: HDR Imaging and Tone Mapping
    - Project 2: Seam Carving
    - Project 3: Image Morphing
    - Project 4: Fly Into the Image
- Final exam 20% (written test)

Administrivia

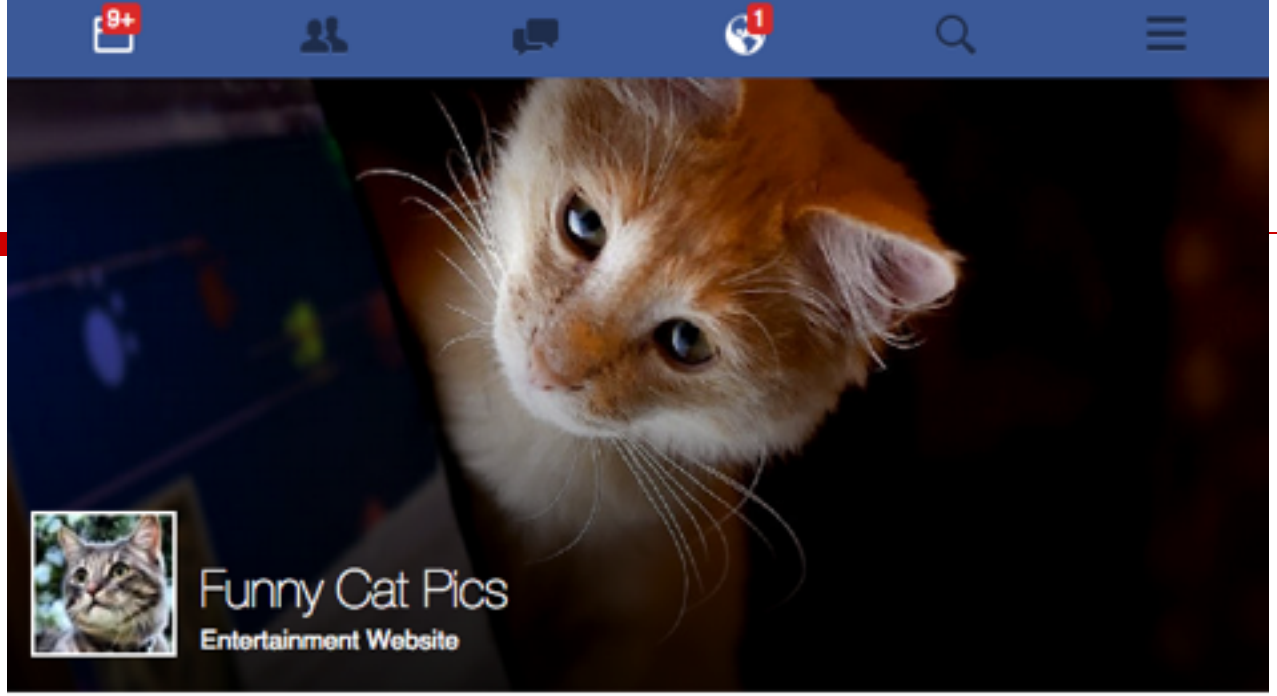
- Everything will be on Drexel Learn; Check it frequently
- Check your Drexel email frequently
- TA:
  - Leizer Teran
  - lt385@drexel.edu
  - Friday 4-6pm CLC (room 152?)
- Policy
  - Projects and assignments should be done independently
  - Zero tolerance for cheating.
  - Bring your own digital camera (cell phones)

Today

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

Computational Photography

PHOTO FROM CLEMENS SCHMILLEN



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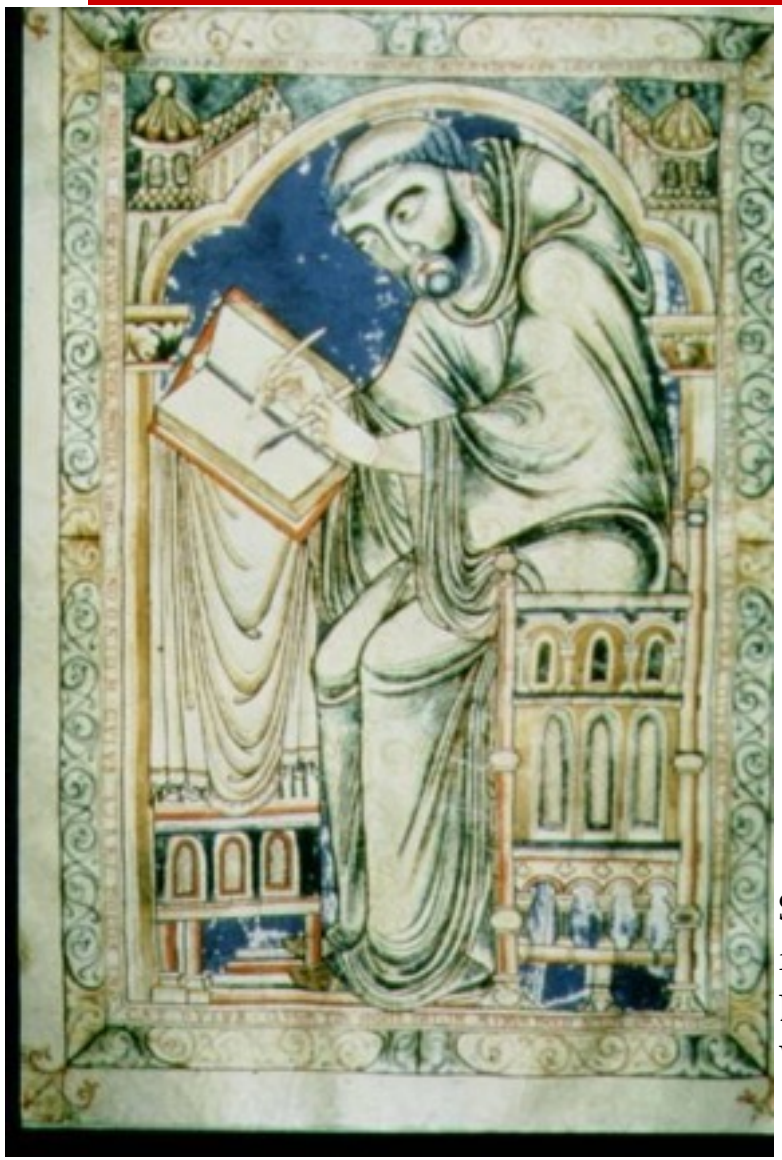
20k people like this

Funny Cat Pics added **7 new photos.**
April 25 at 5:54am ·

here you go guys some more pics from me~doglover

Depicting Our World: The Middle Ages



St. John
from the Gosp
Book of Abbot
Wedricus (114

Cimabue
Madonna
Enthroned (c.
1280-1290)

Depicting Our World: Renaissance

North Doors (1424)

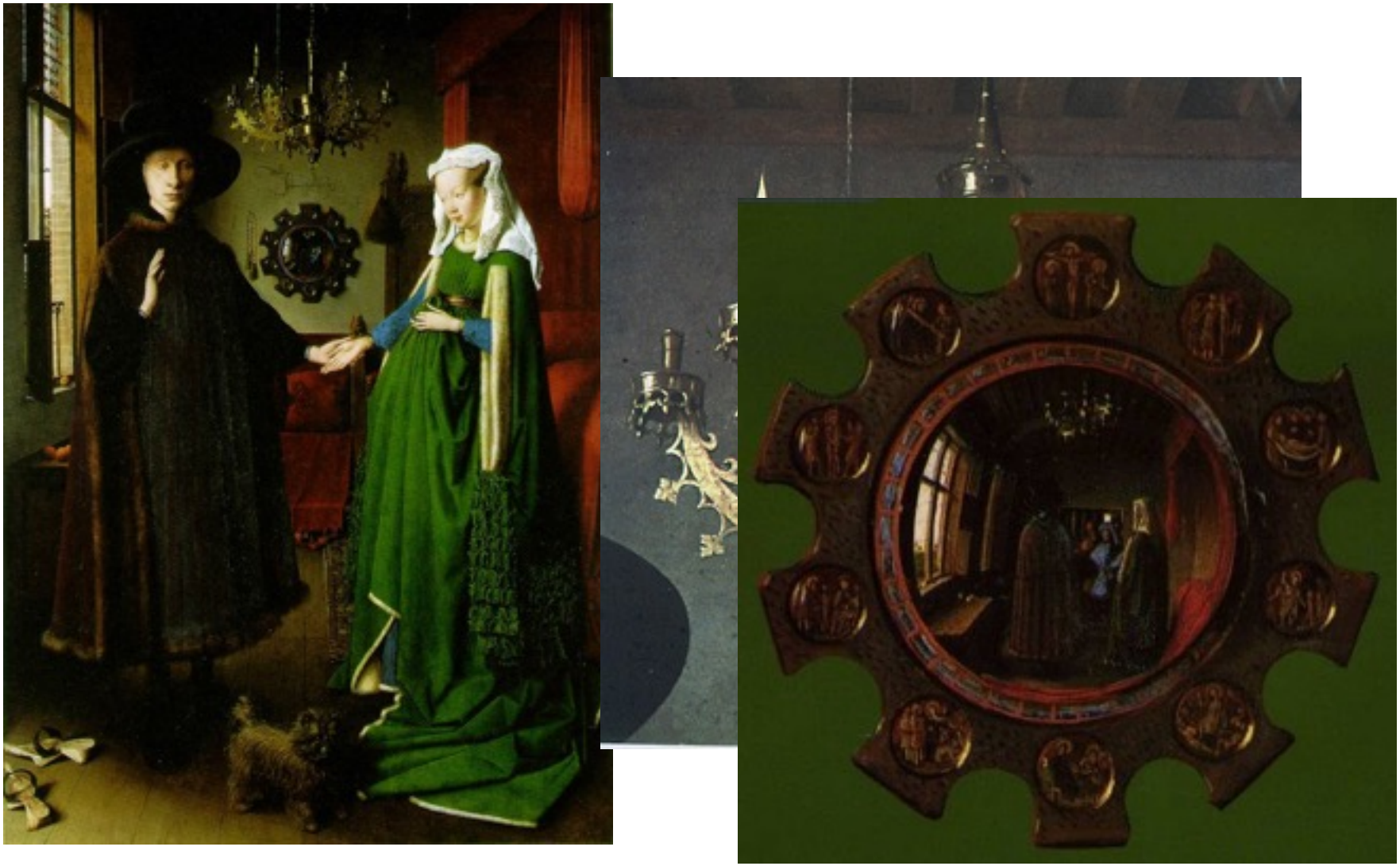
Lorenzo Ghiberti (1378-1455)

East Doors (1452)

Depicting Our World: Renaissance

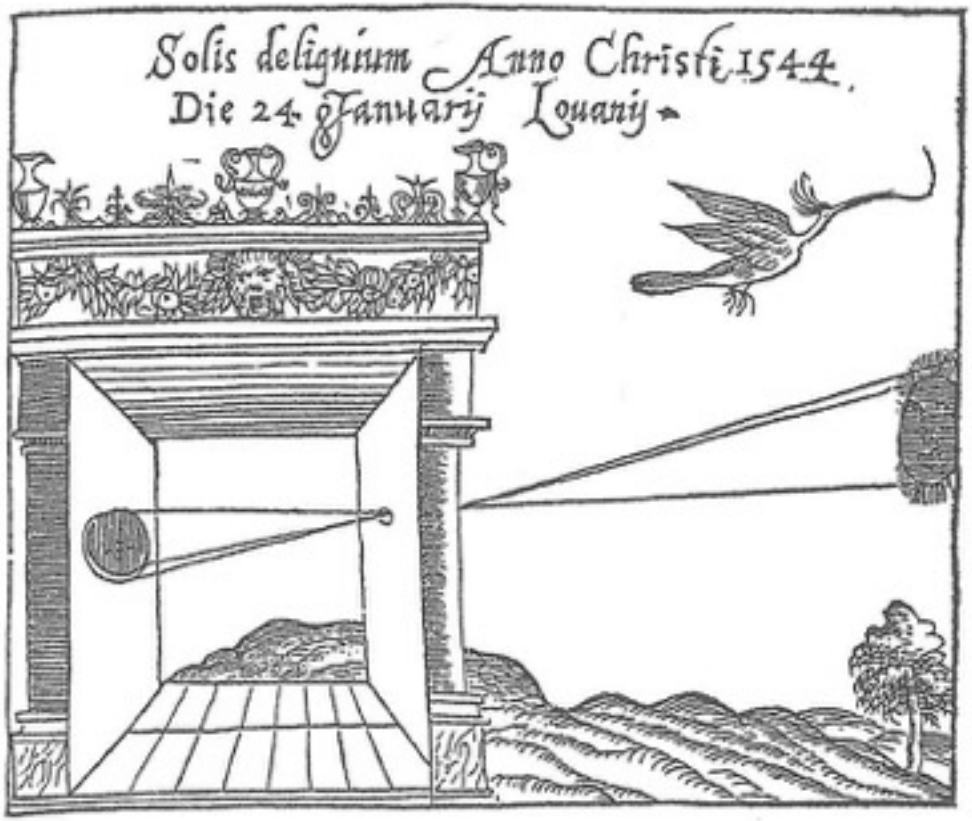
Piero della Francesca,
The Flagellation (c.1469)

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"

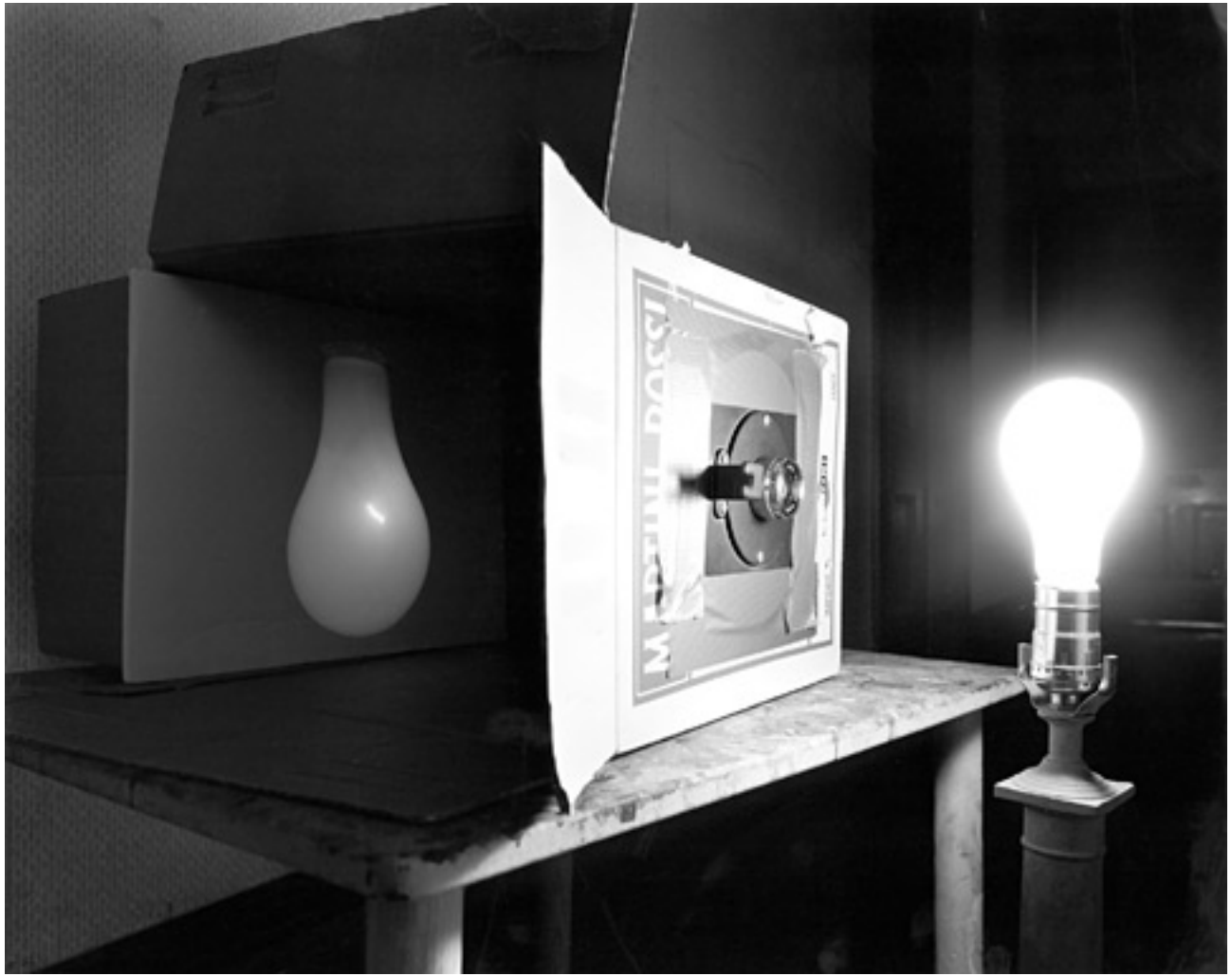
Abelardo Morell

http://www.abelardomorell.net/

Abelardo Morell

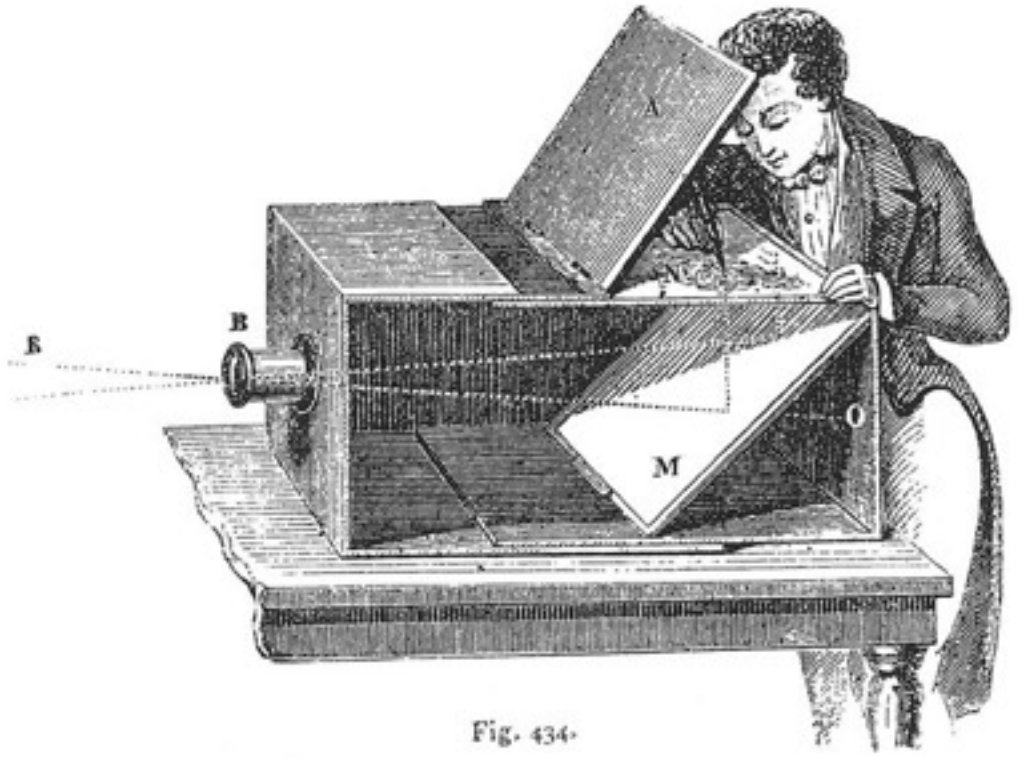
http://www.abelardomorell.net/

Abelardo Morell



http://www.abelardomorell.net/

Depicting Our World: Towards Perfection



Lens Based Camera Obscura, 1568

Depicting Our World: Perfection!

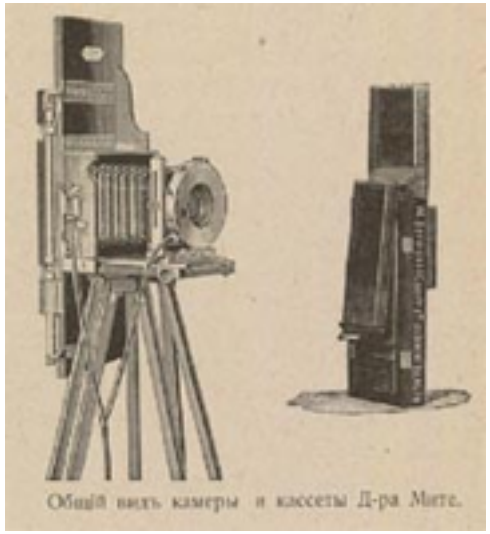
Still Life, Louis Jaques Mande Daguerre, 1837

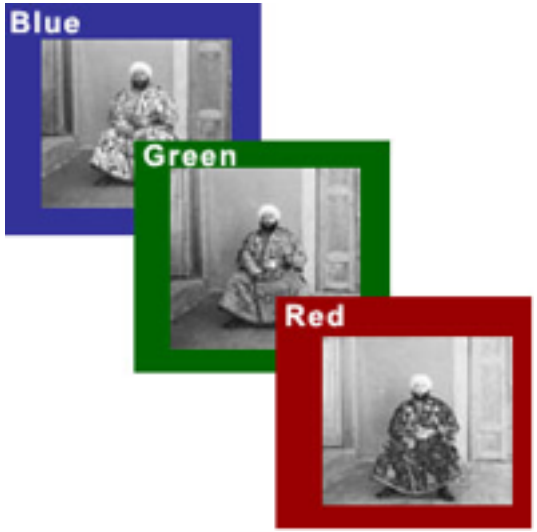
Daguerrotype Camera

- 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/

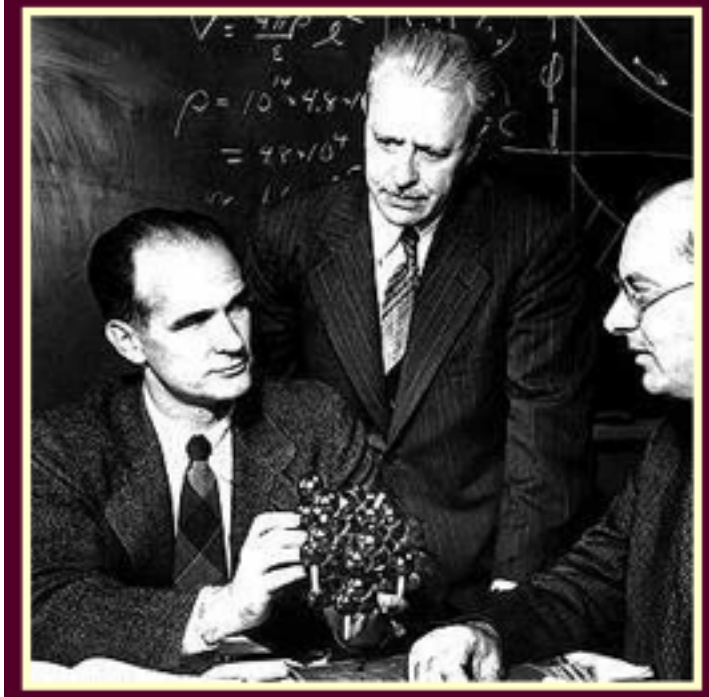
Prokudin-Gorskii

Prokudin-Gorskii

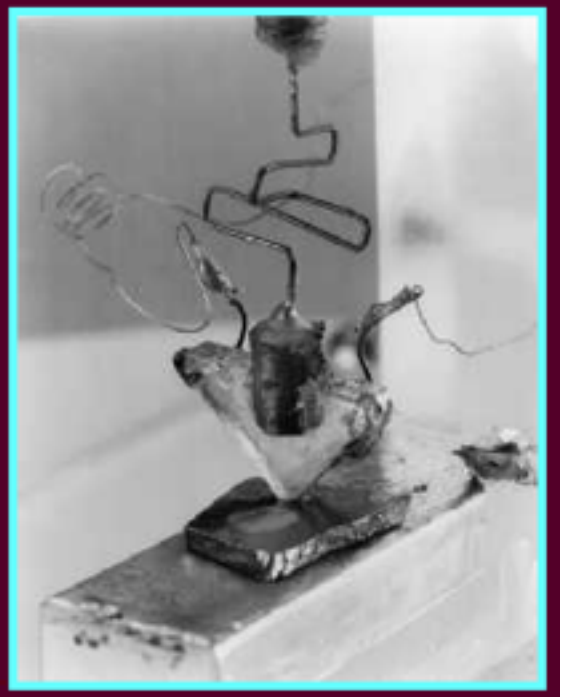
https://www.youtube.com/watch?v=sxPmQe6Lz6U

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

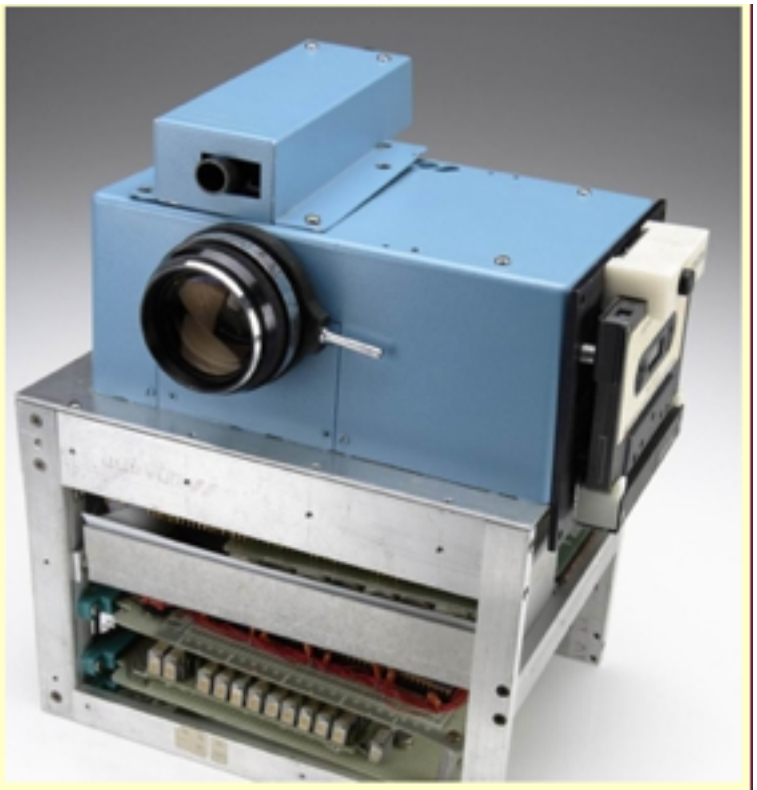
- Canon AE-1 1976

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/l

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

Today

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

Project 1: HDR and Tone Mapping

Project 2: Seam Carving

Scaled Input Seam Carving

Project 2: Seam Carving

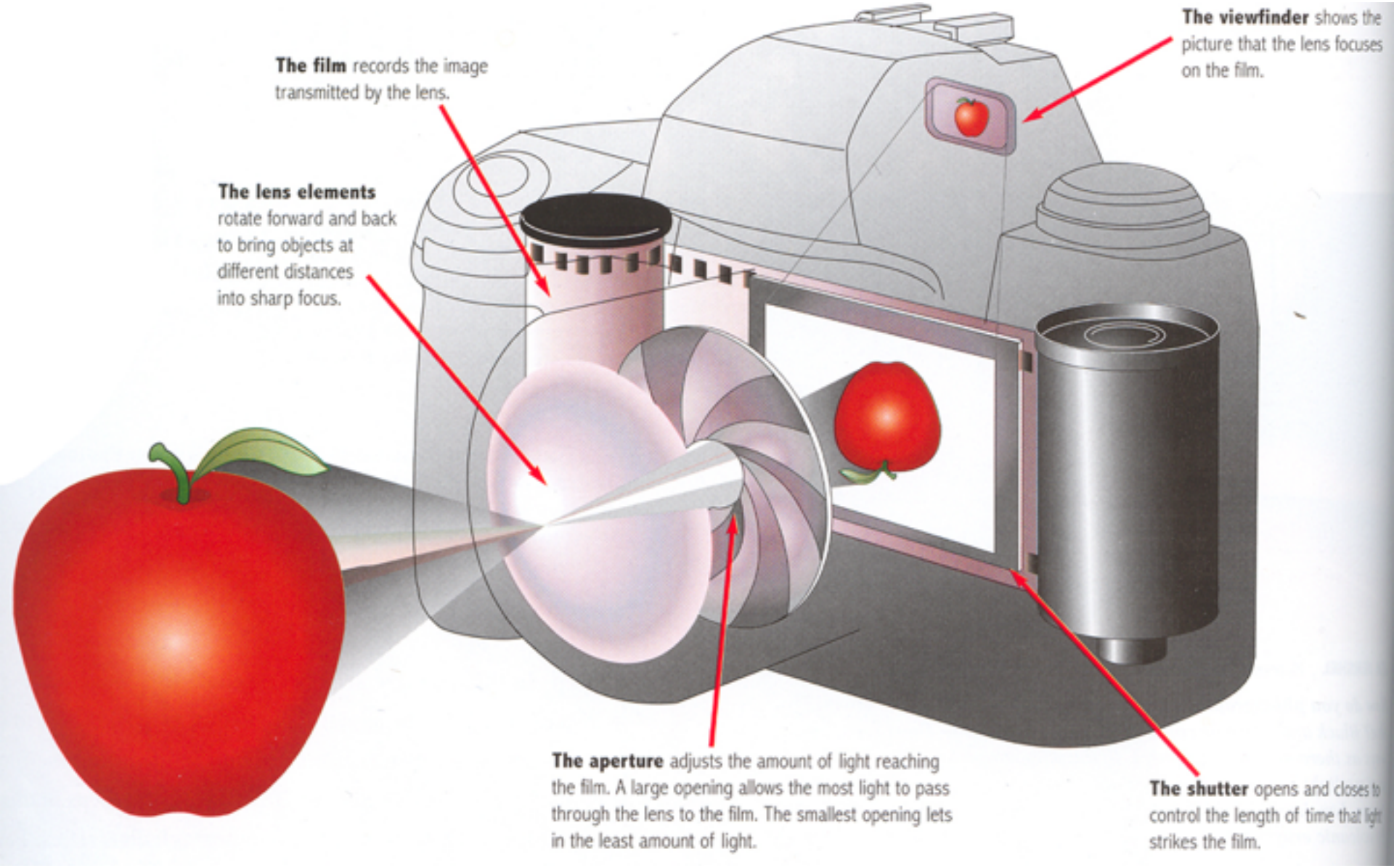
Project 3: Image Morphing

Example

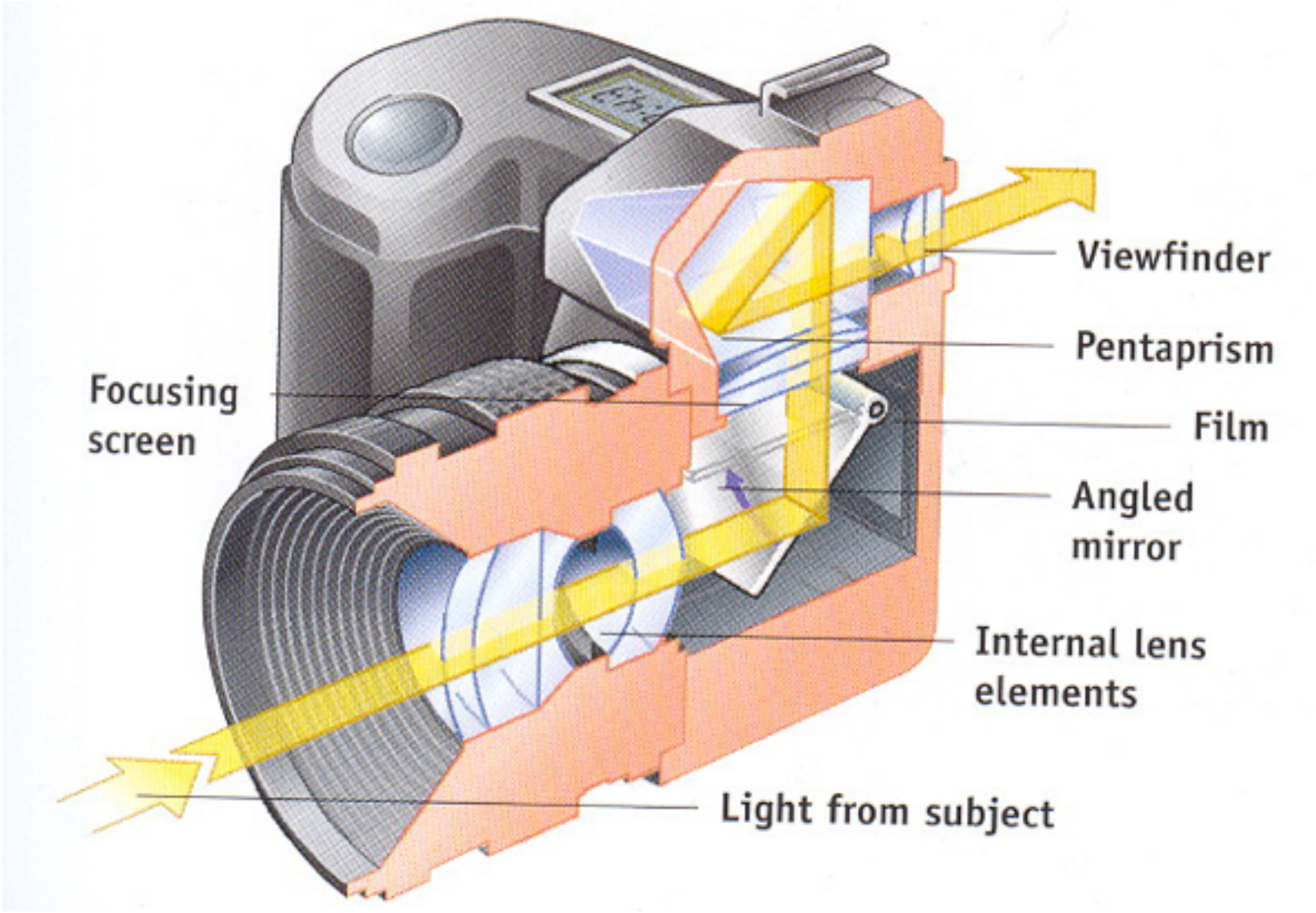
Project 4: Fly Into Painting

Nelson Chu

Camera


The film records the image transmitted by the lens.
The viewfinder shows the picture that the lens focuses on the film.
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)

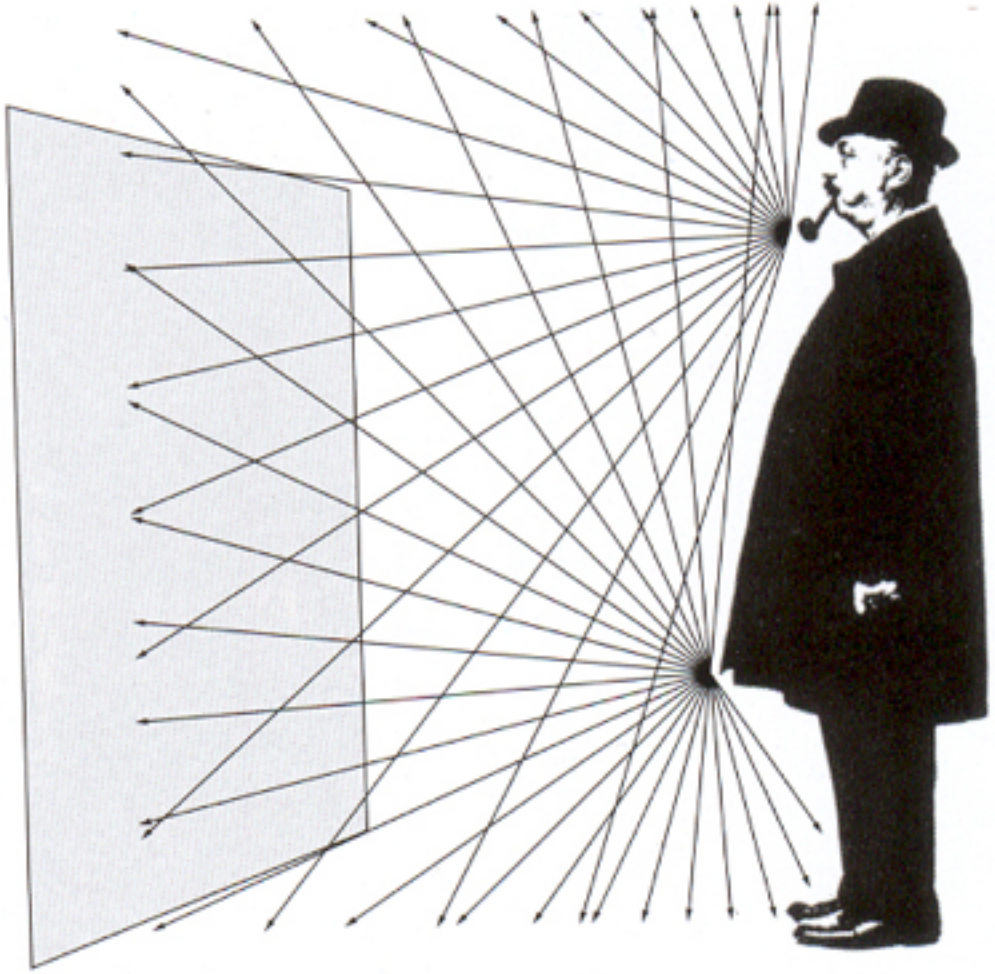


Question

- Why do we need to put the film in the camera?

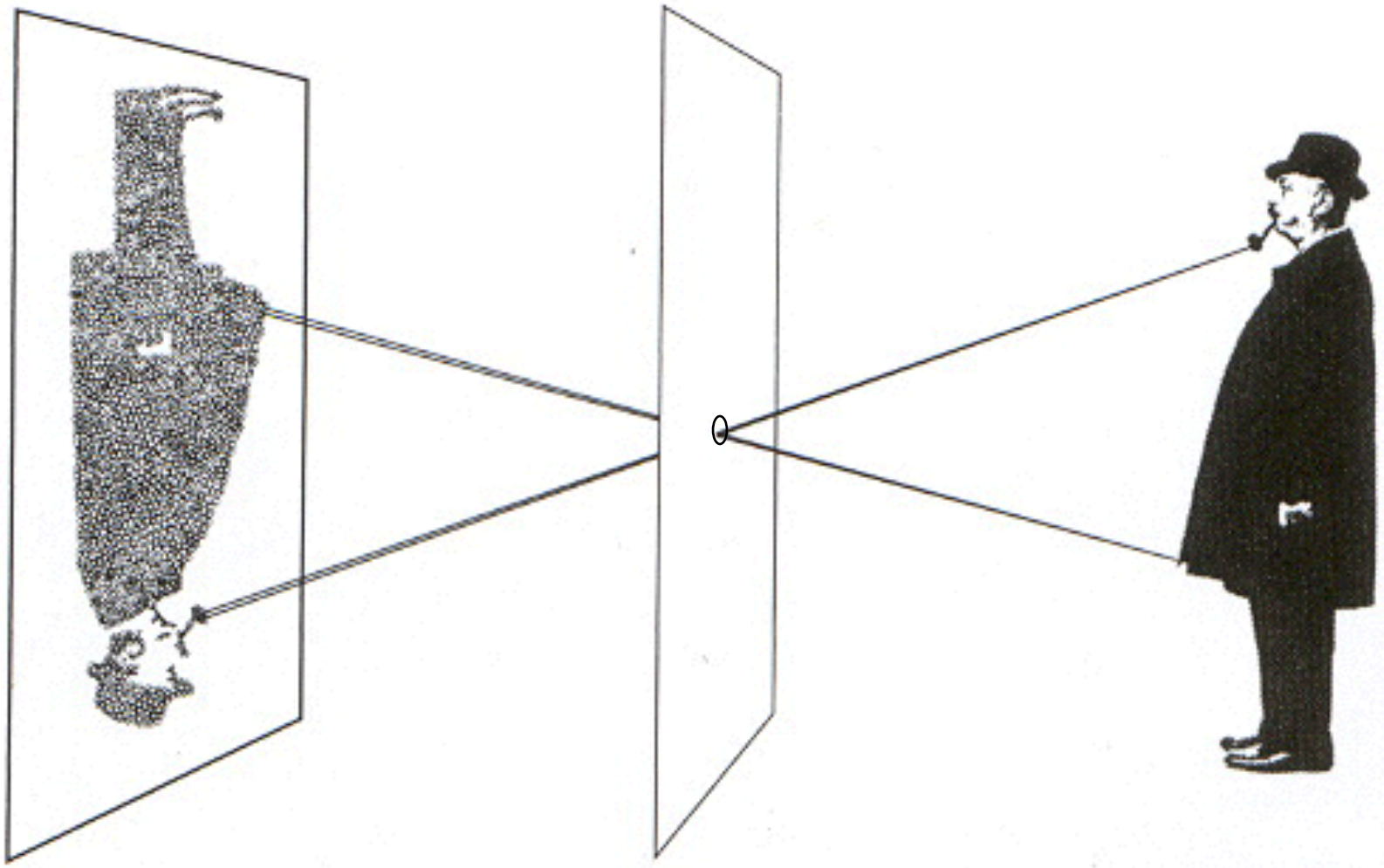
Answer

- It receives light from all directions



From Photography, London et al.

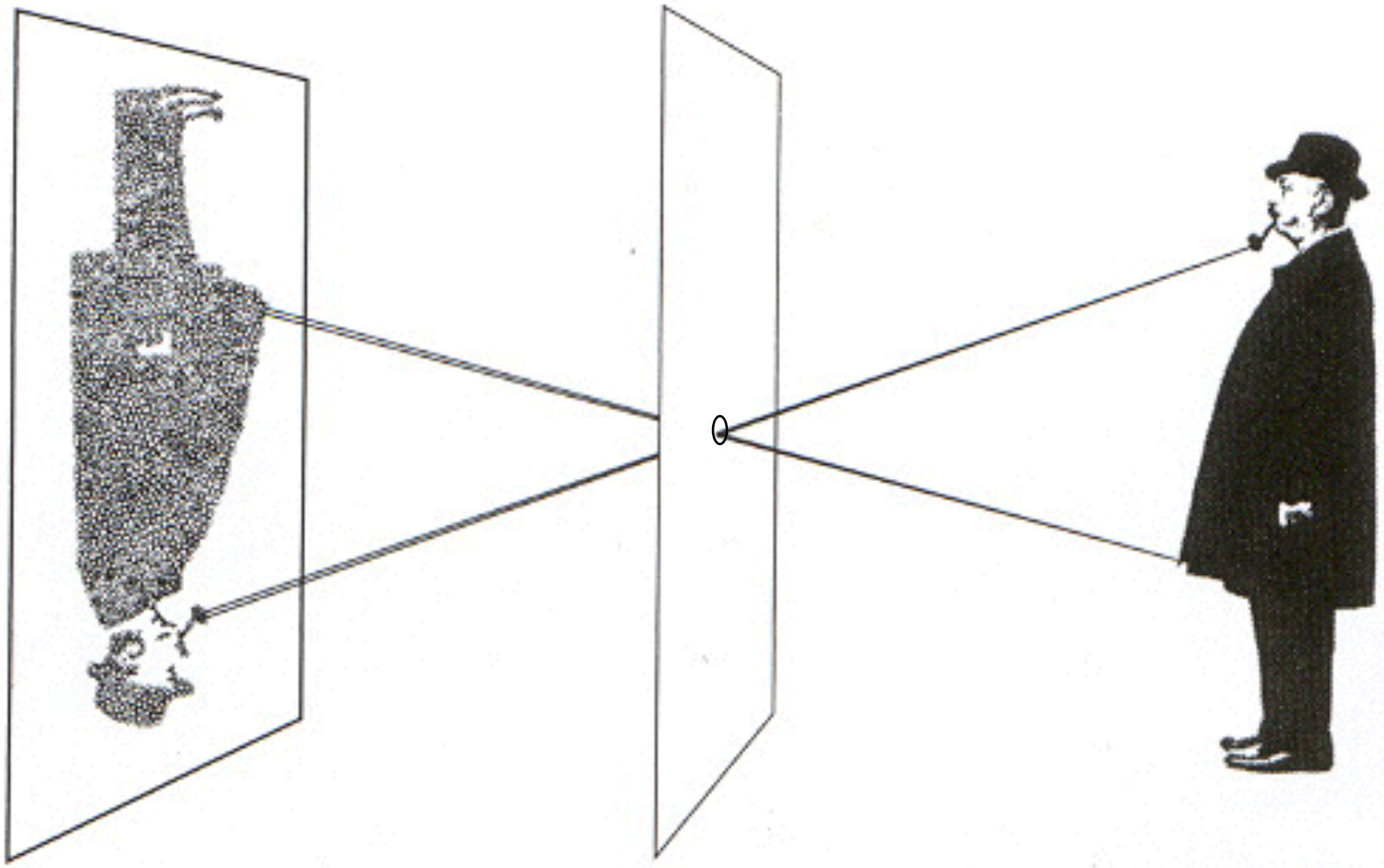
Pinhole



From Photography, London et al.

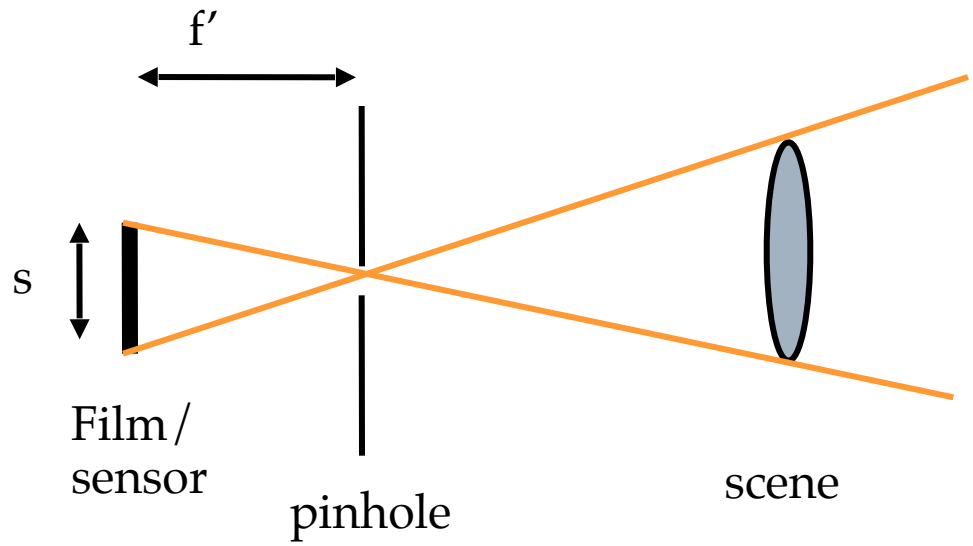
BW Pinhole Image

Pinhole



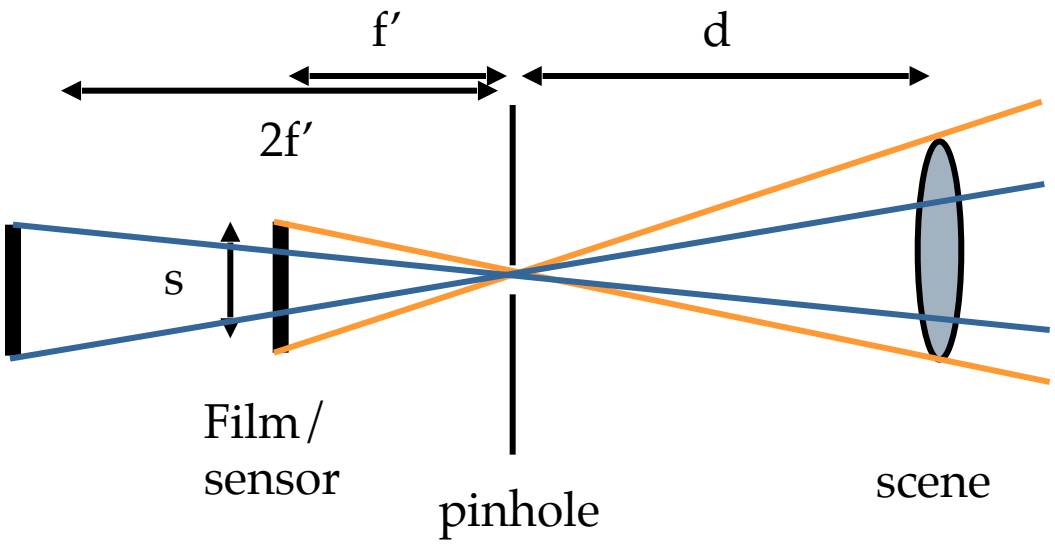
From Photography, London et al.

Effective Focal Length



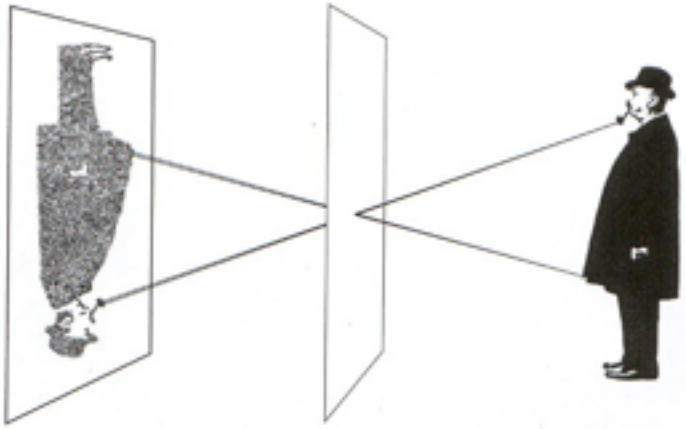
Effective Focal Length: Pinhole Optics

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

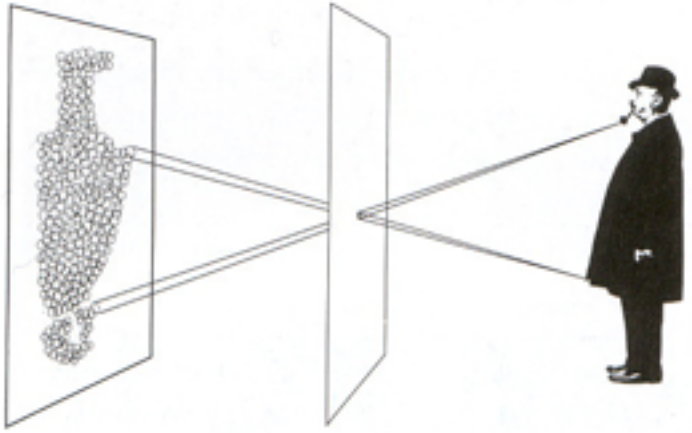


Pinhole Size?

Photograph made with small pinhole

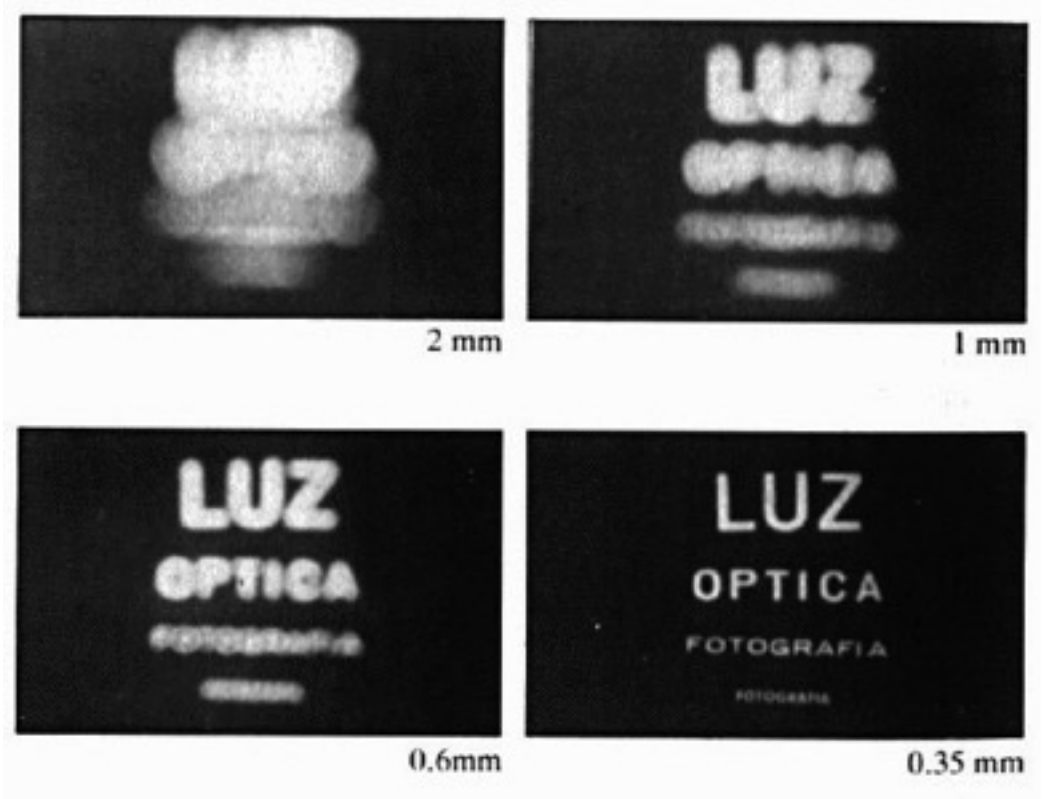


Photograph made with larger pinhole



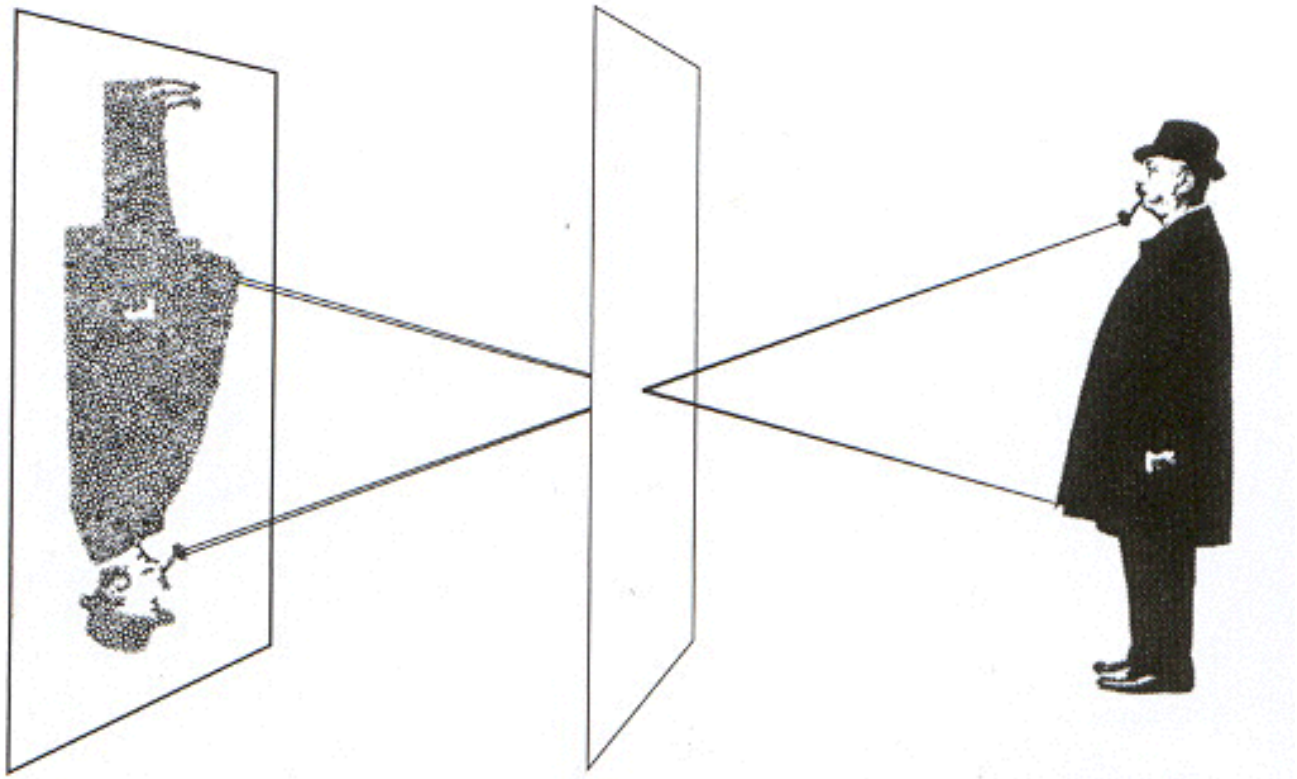
From Photography, London et al.

Diffraction Limit



Problem with pinhole?

- Not enough light!
- Diffraction limits sharpness



Solution: Refraction!

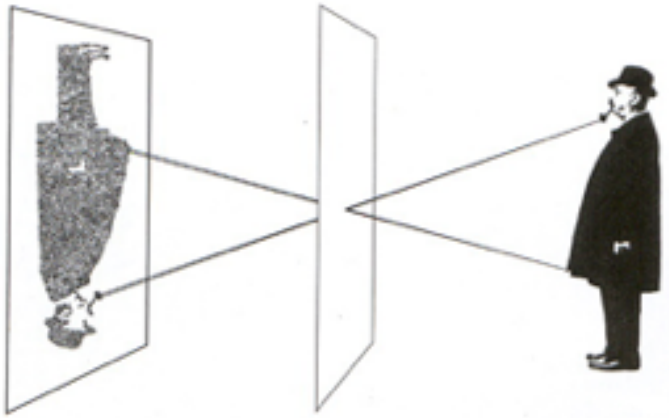
From Photography, London et al.

Before Diving into Those...

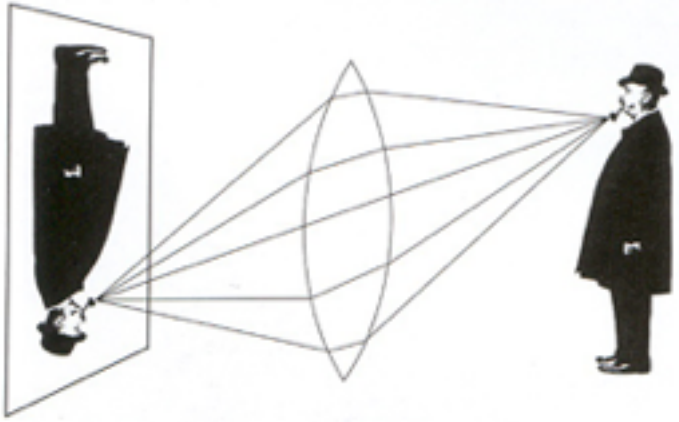
- Accidental Pinhole Cameras:
- http://techtalks.tv/beta/talks/accidental-pinhole-and-pinspeck-cameras-revealing-the-scene-outside-the-picture/56216/

Lenses

Photograph made with small pinhole



Photograph made with lens



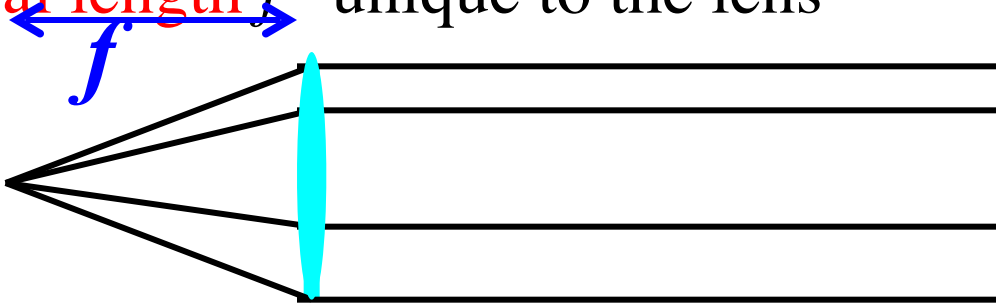
From Photography, London et al.

Lenses

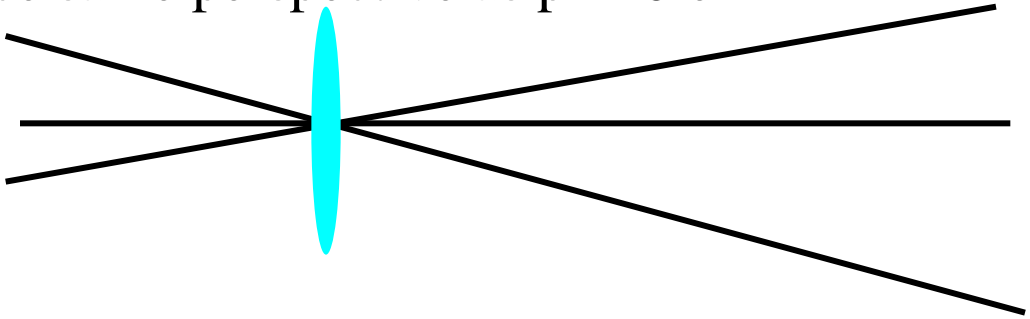
- Gathers more light
- But needs to be “focused”

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 unique to the lens

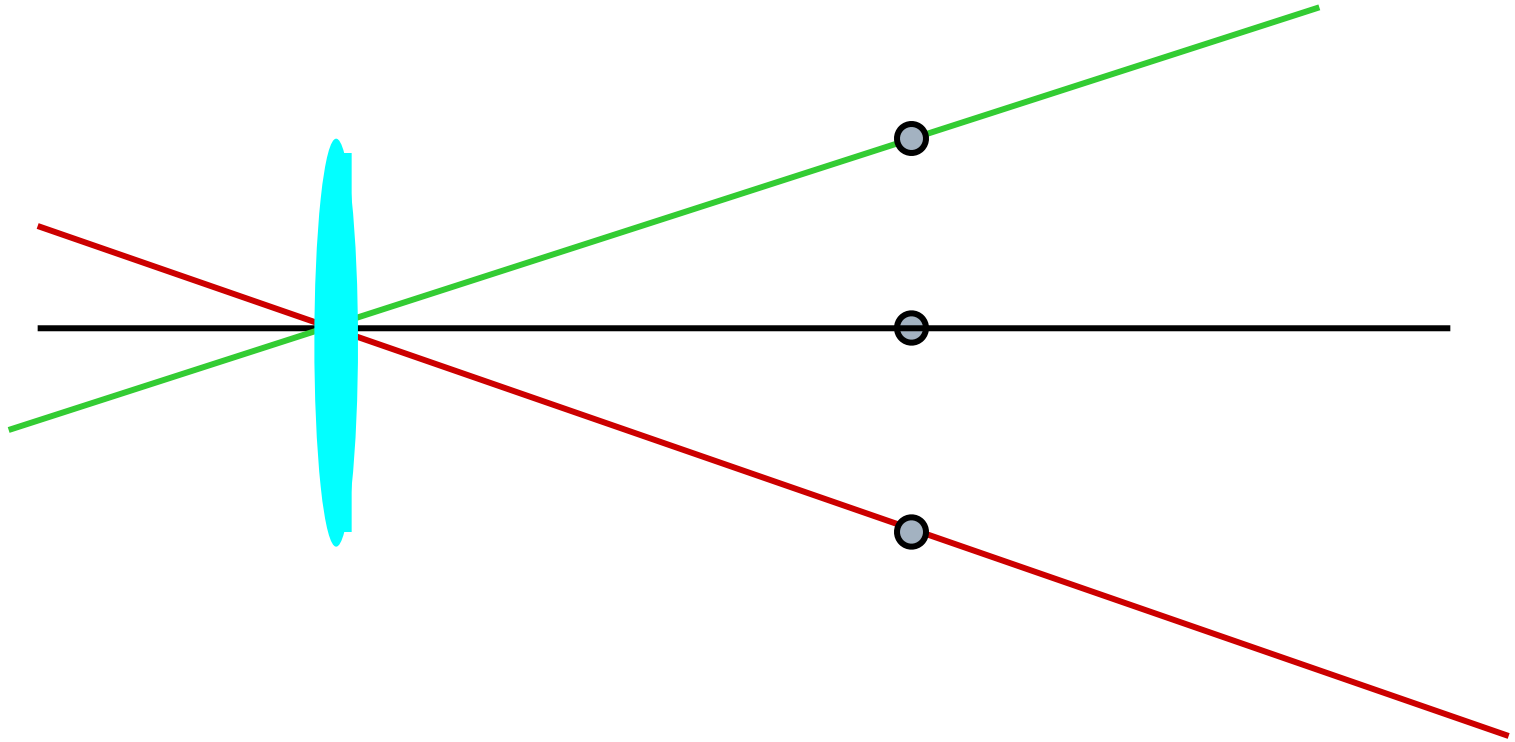


- All rays going through the center are not deviated
  - Hence same perspective as pinhole



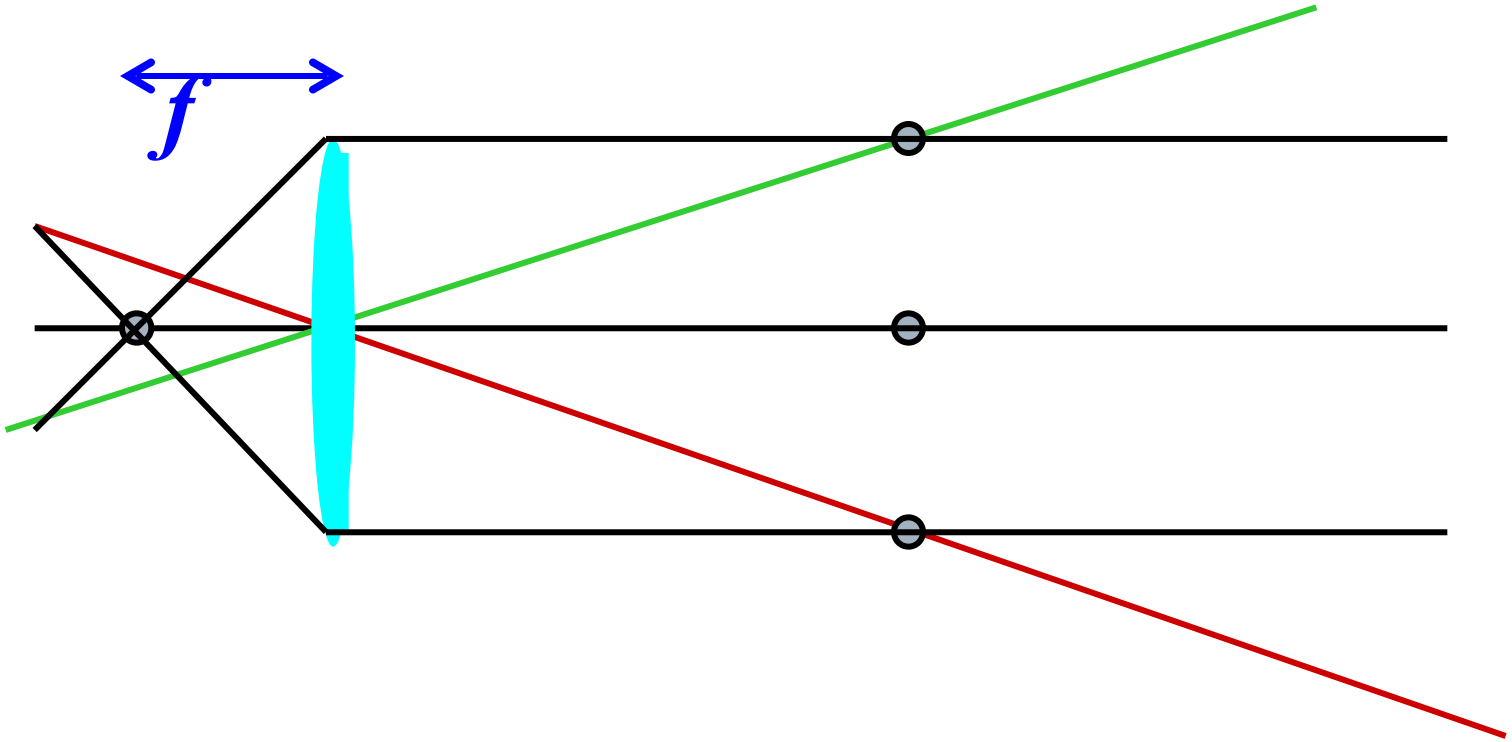
How to Trace Rays

- Start by rays through the center



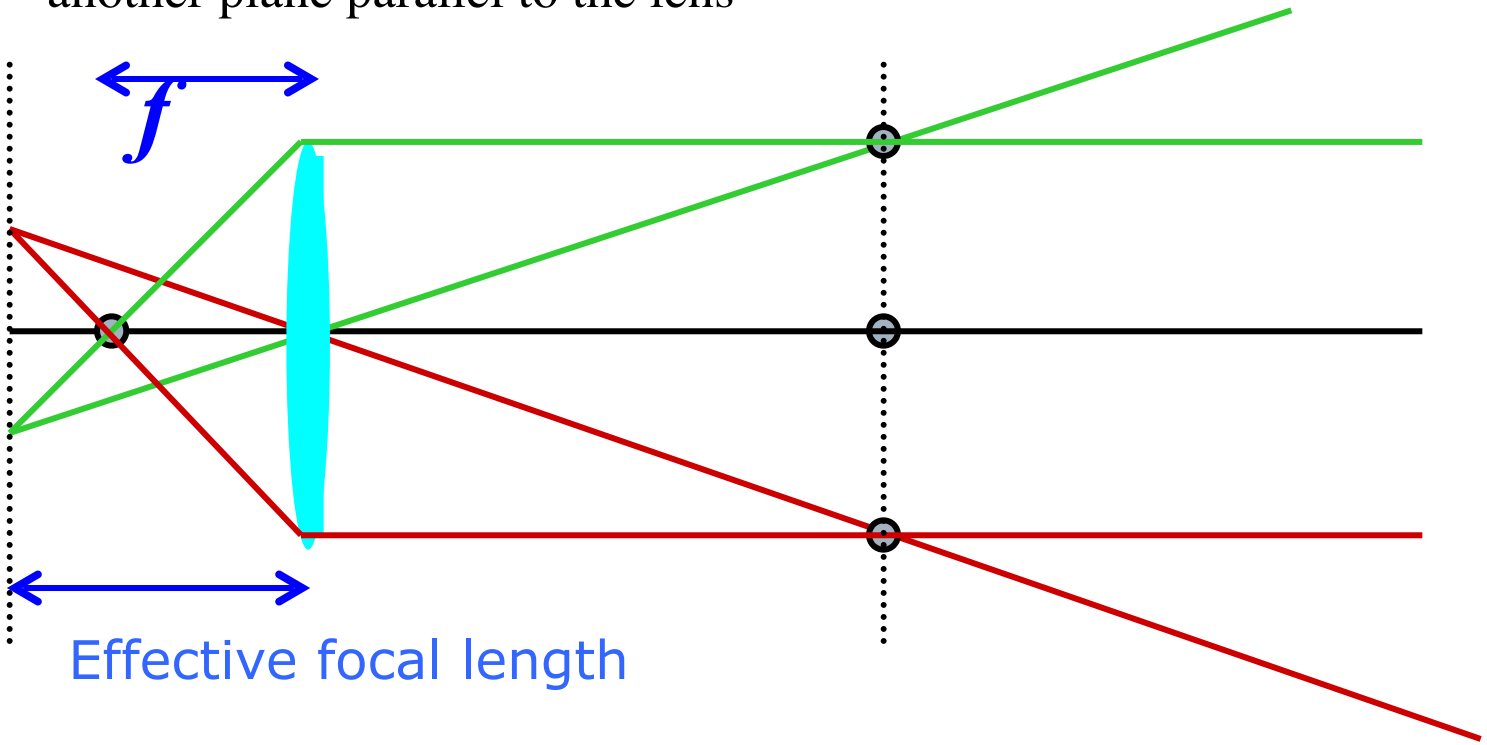
How to Trace Rays

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



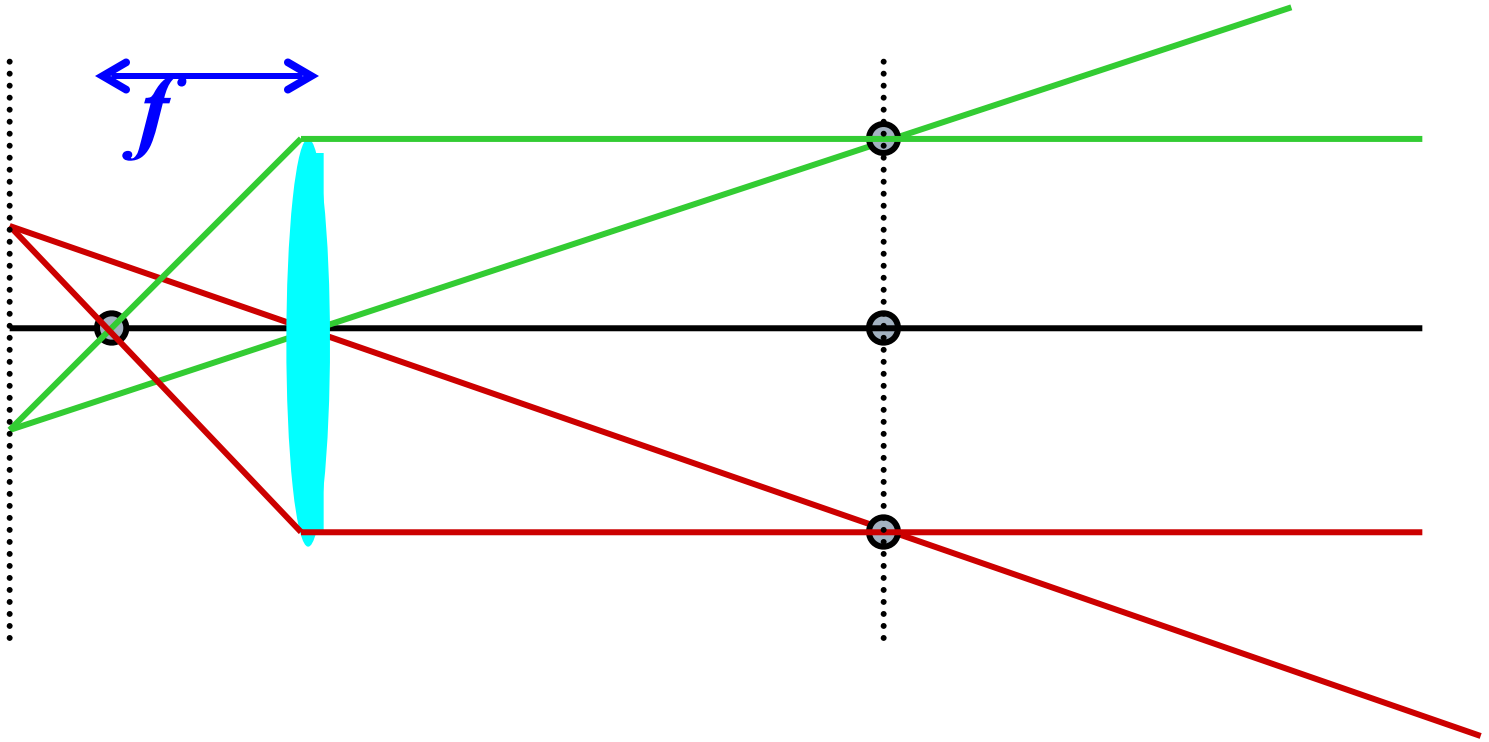
How to Trace Rays

- 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

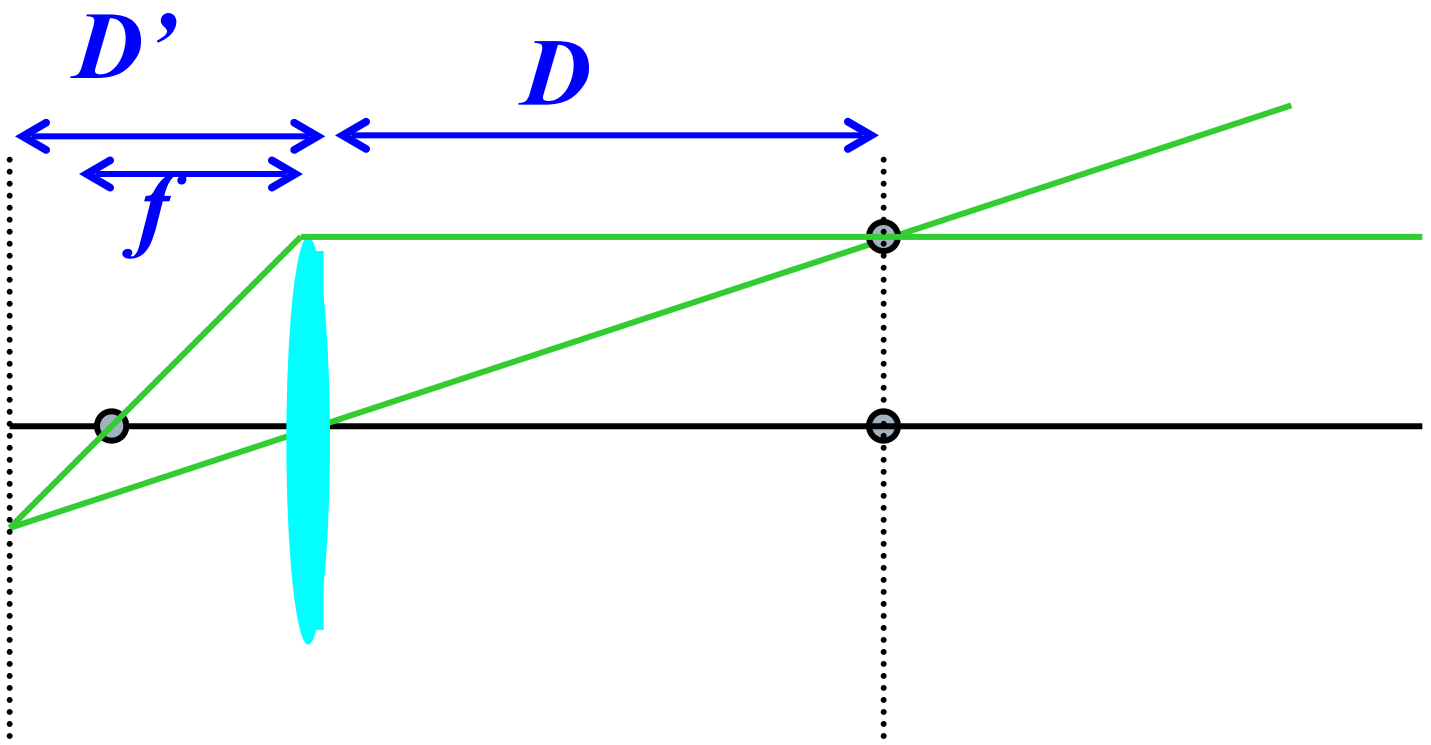


Focusing

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

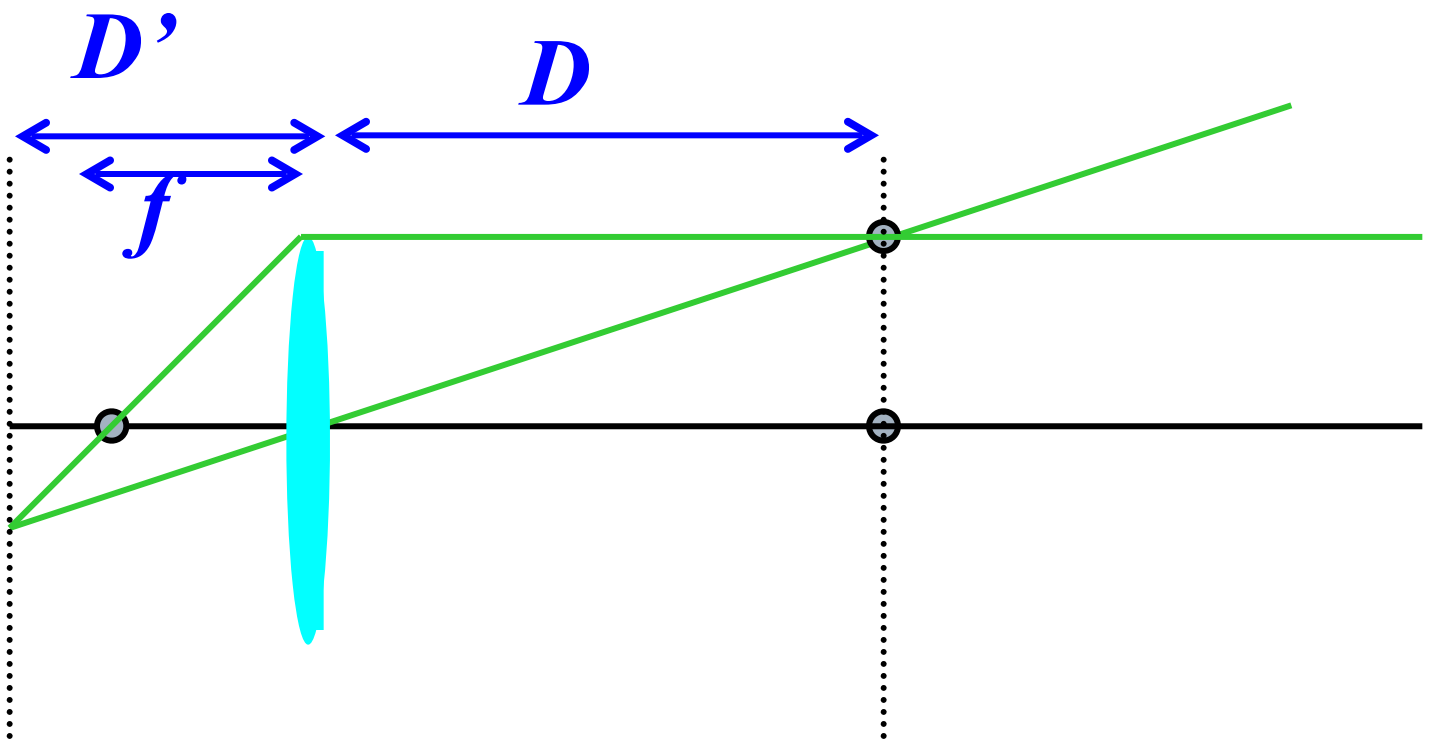


Thin Lens Formula



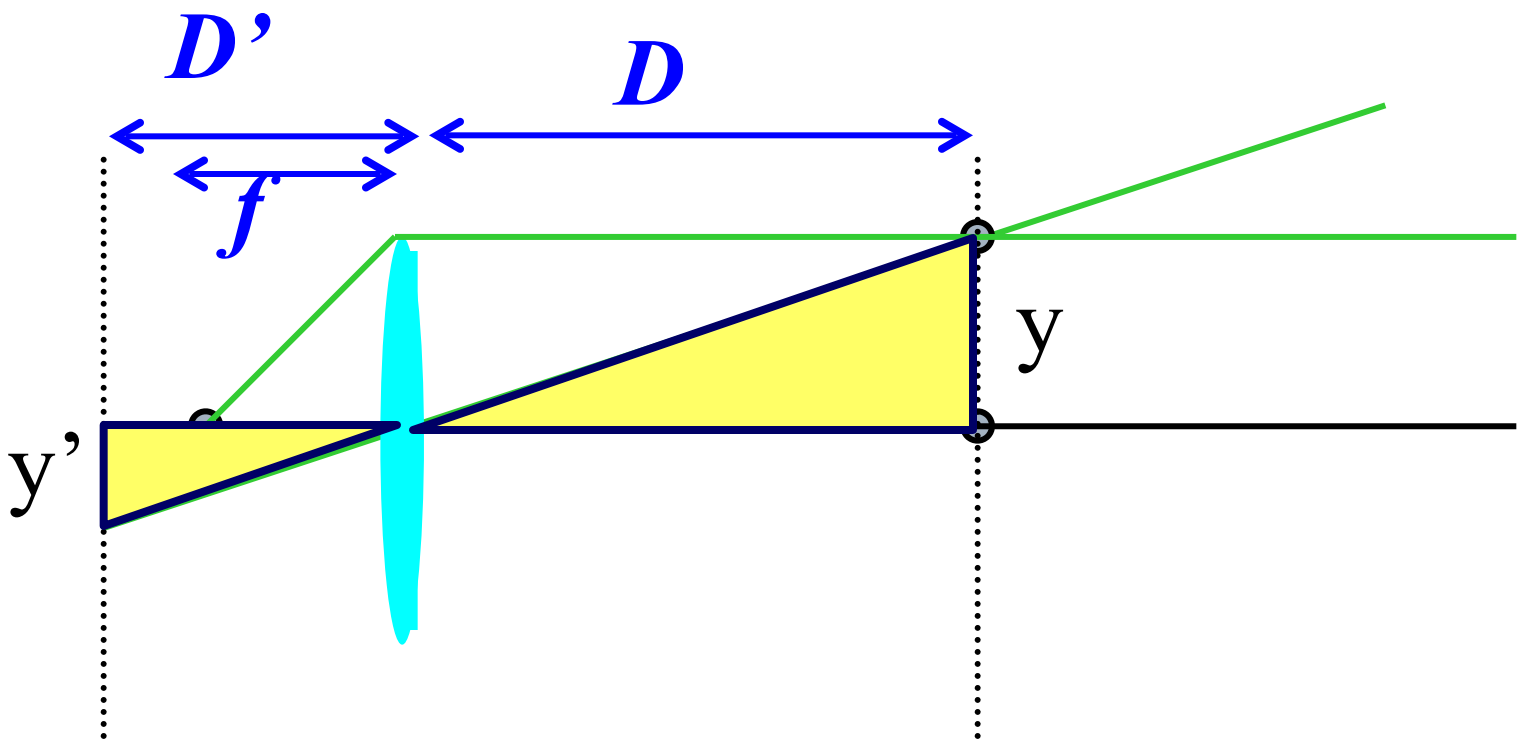
Thin Lens Formula

Similar triangles everywhere!



Thin Lens Formula

Similar triangles everywhere! $y'/y = D'/D$

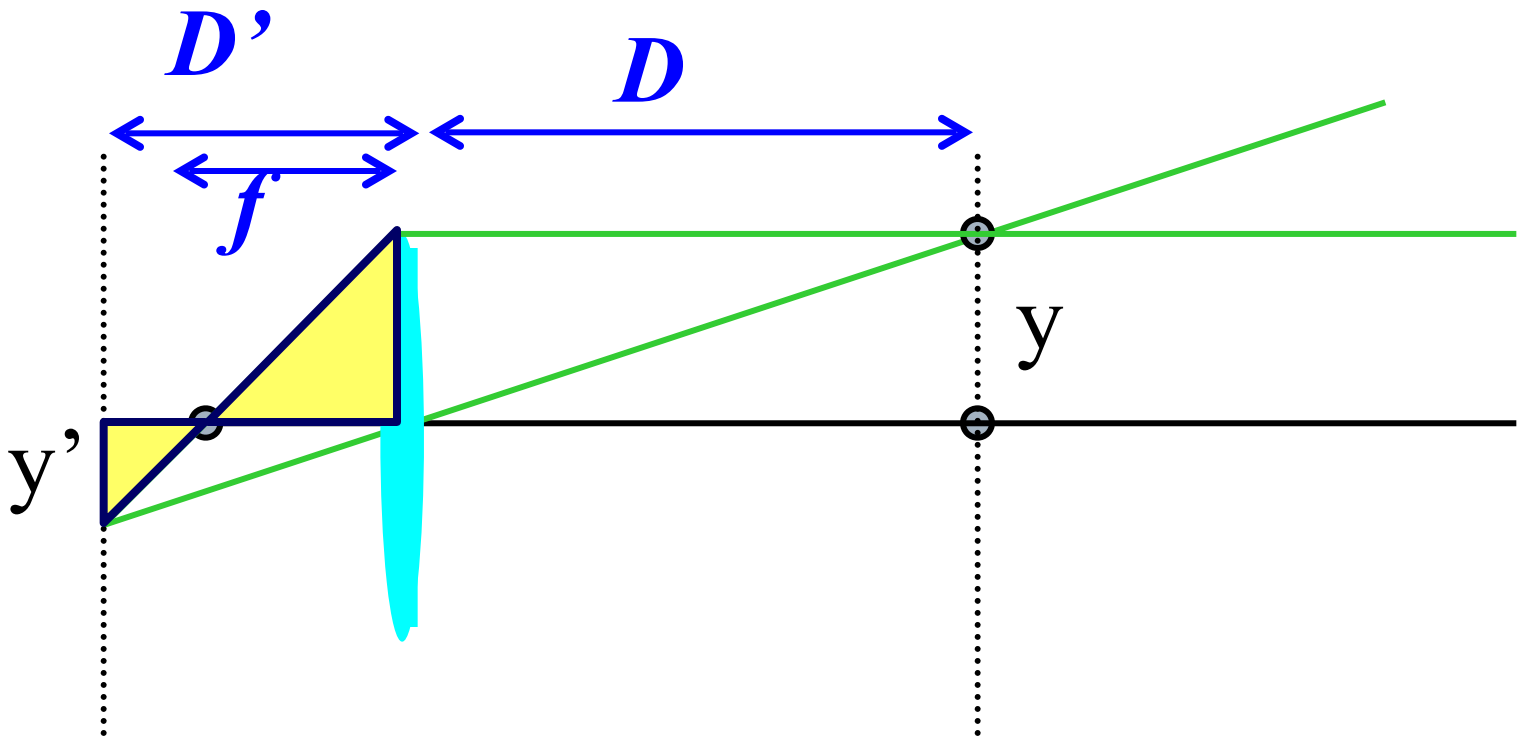


Thin Lens Formula

Similar triangles everywhere!

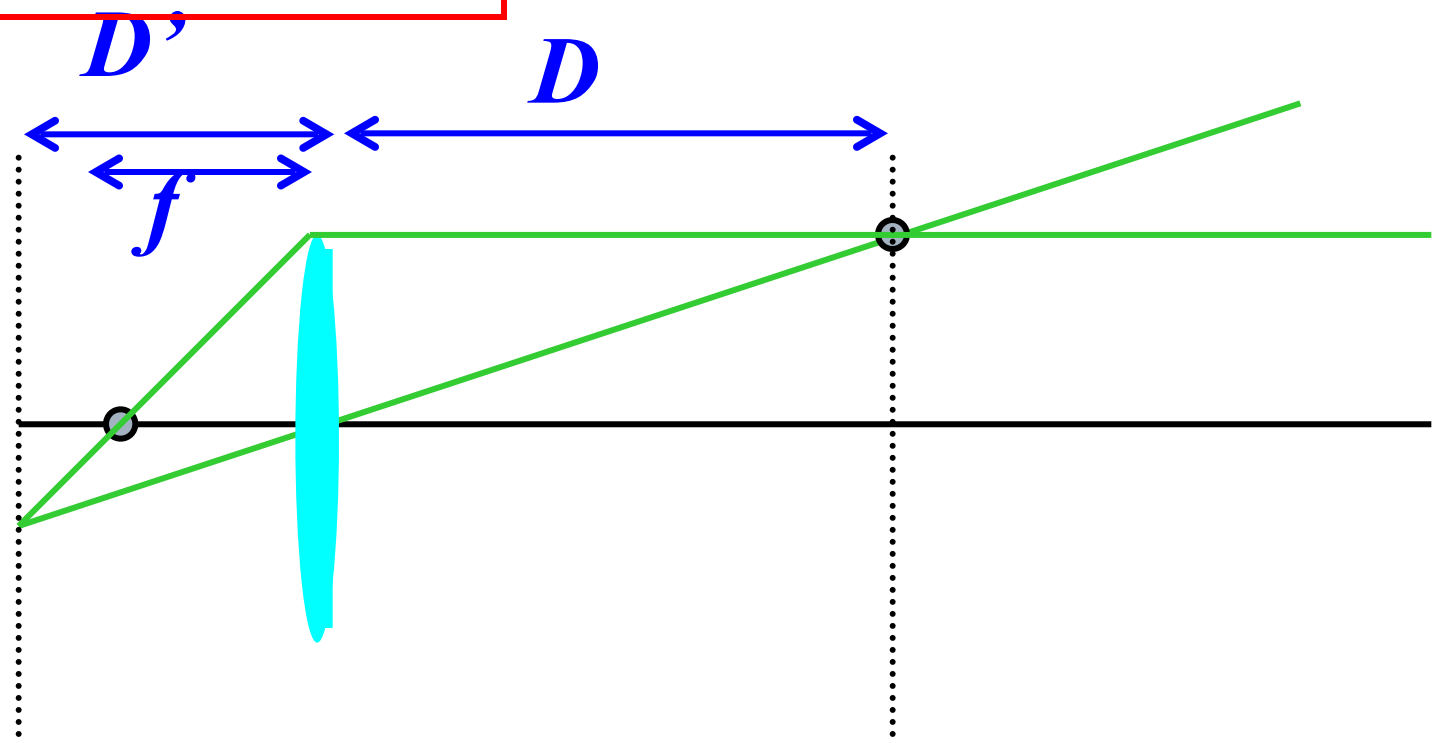
$$y'/y = D'/D$$

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



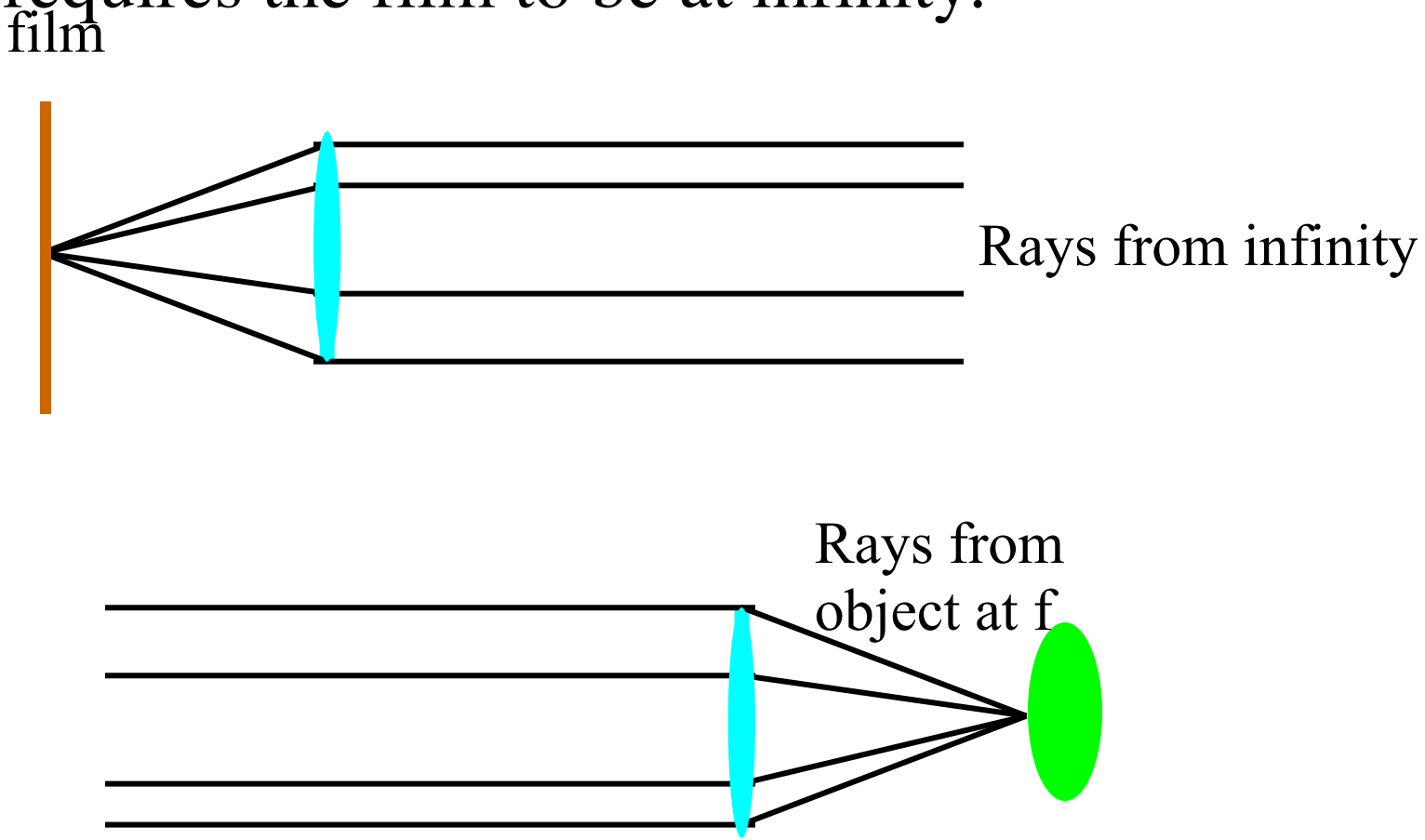
Thin Lens Formula

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



Minimum Focusing Distance

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

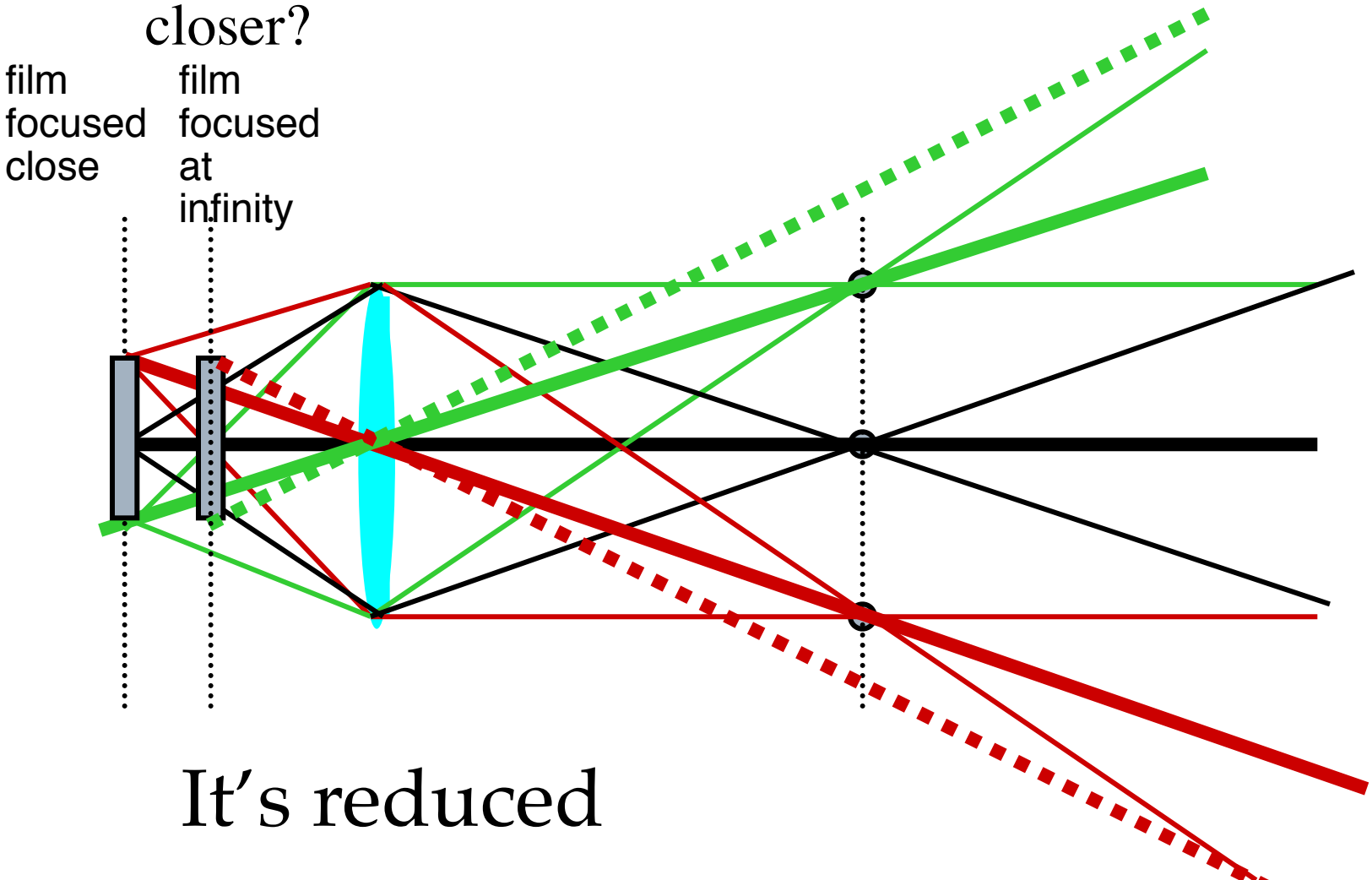


Ray Drawings for Convex Lenses

HTTPS://WWW.YOUTUBE.COM/WATCH?V=C6MLLAQLDVG

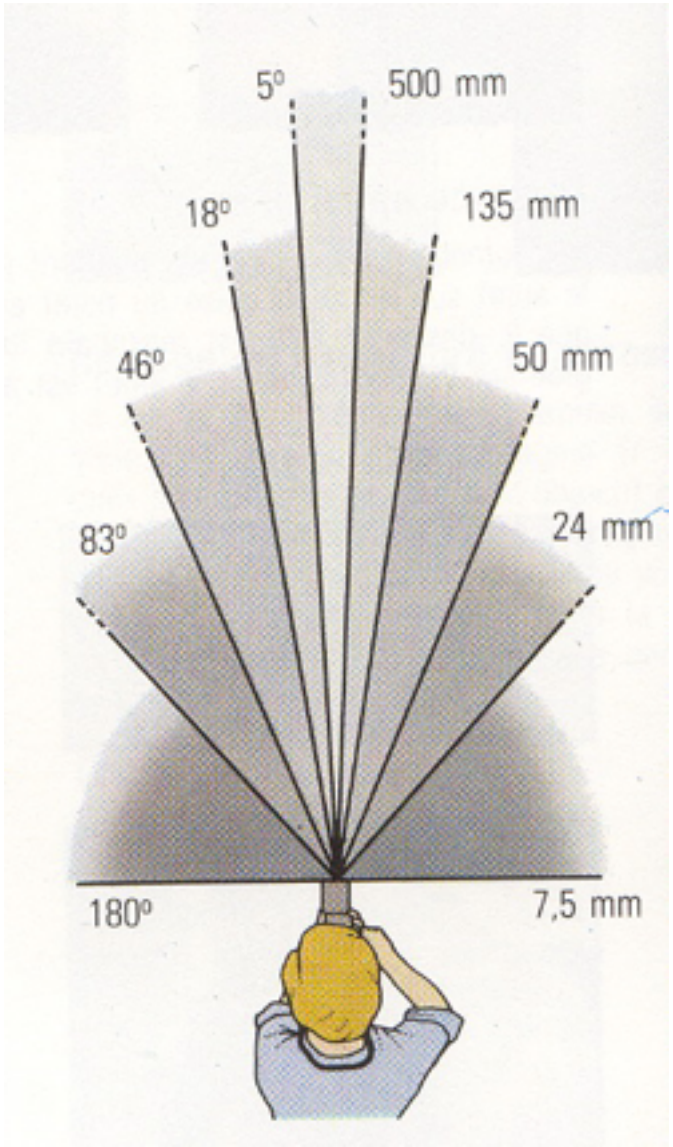
Field of View & Focusing

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



It's reduced

Focal Length in Practice



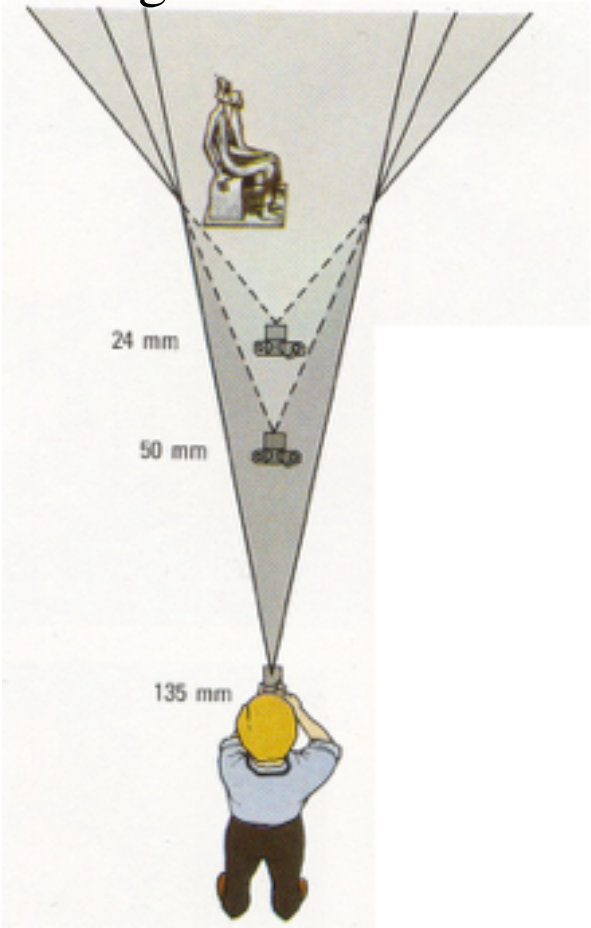
24mm

50mm

135mm

Perspective vs. Viewpoint

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

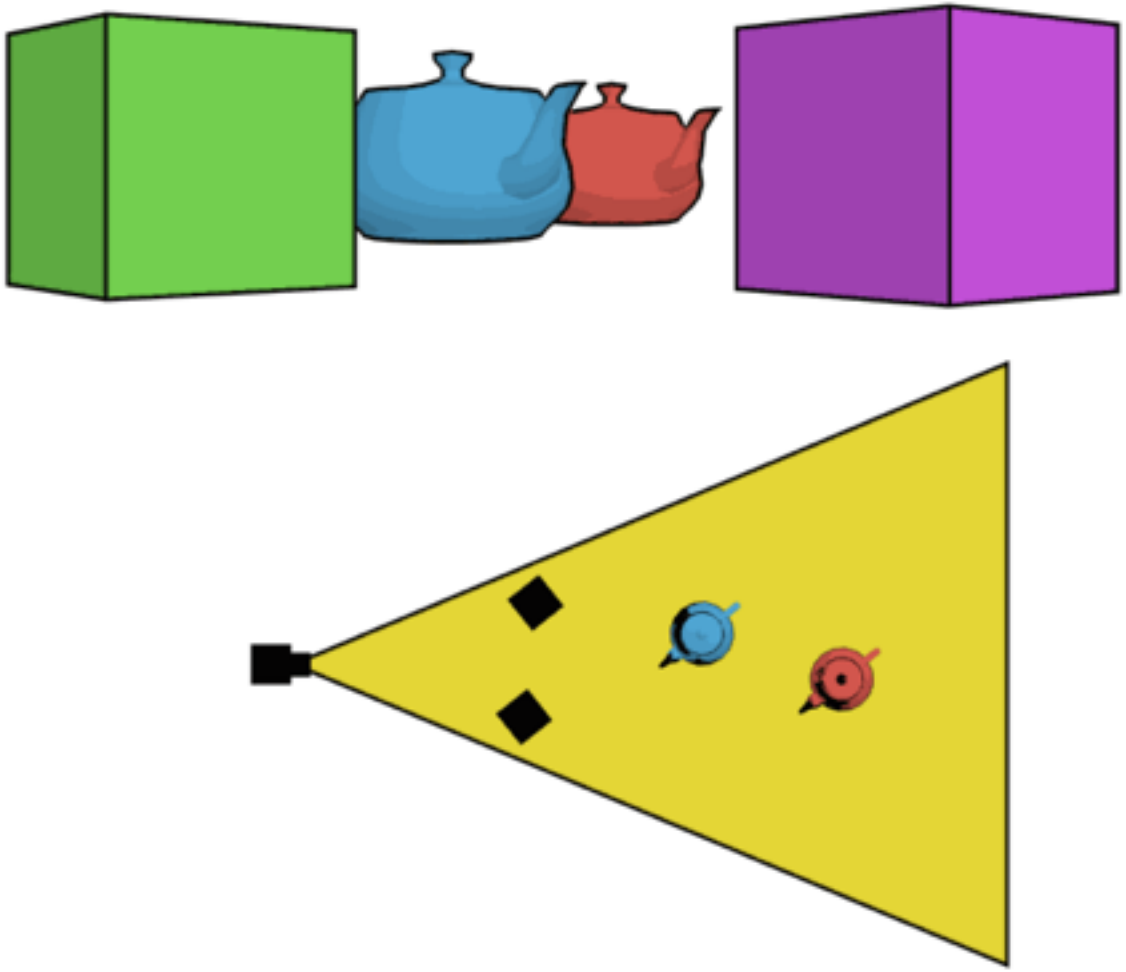


Grand-angulaire 24 mm

Normal 50 mm

Longue focale 135 mm

Dolly Zoom



Dolly Zoom

Lisa Zoom

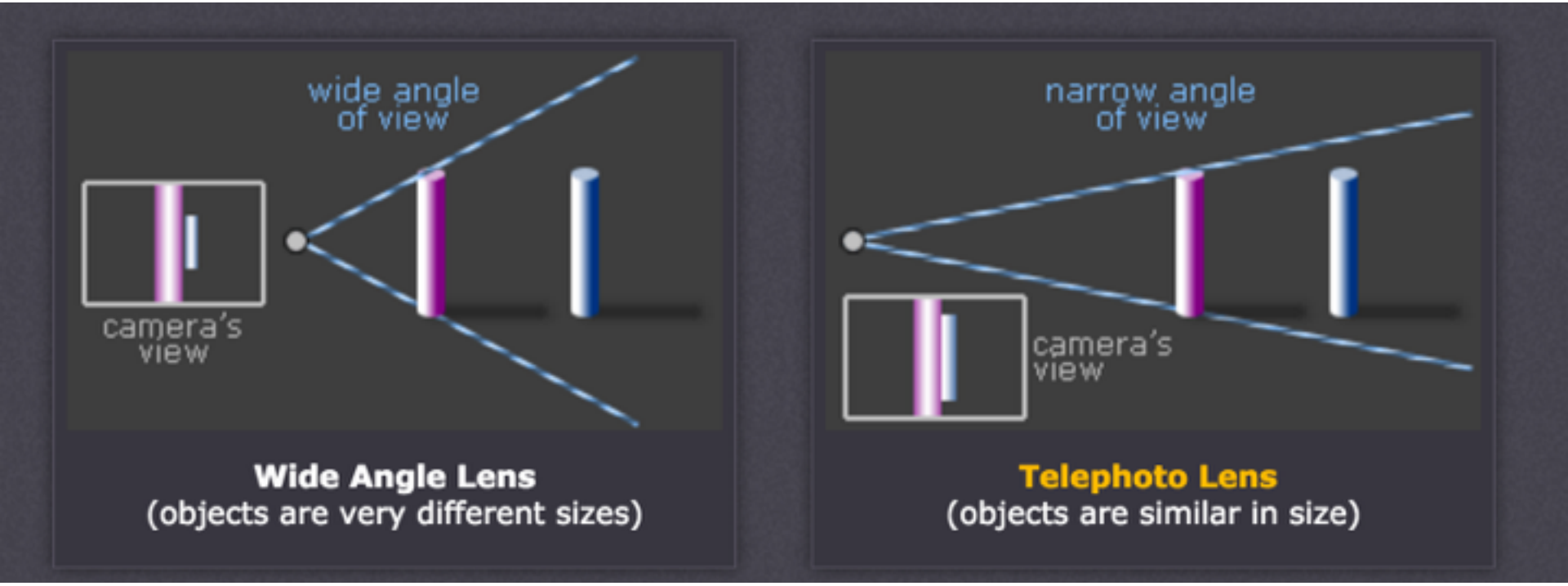
Perspective vs. Viewpoint

- Portrait: distortion with wide angle
- Why?

Wide angle

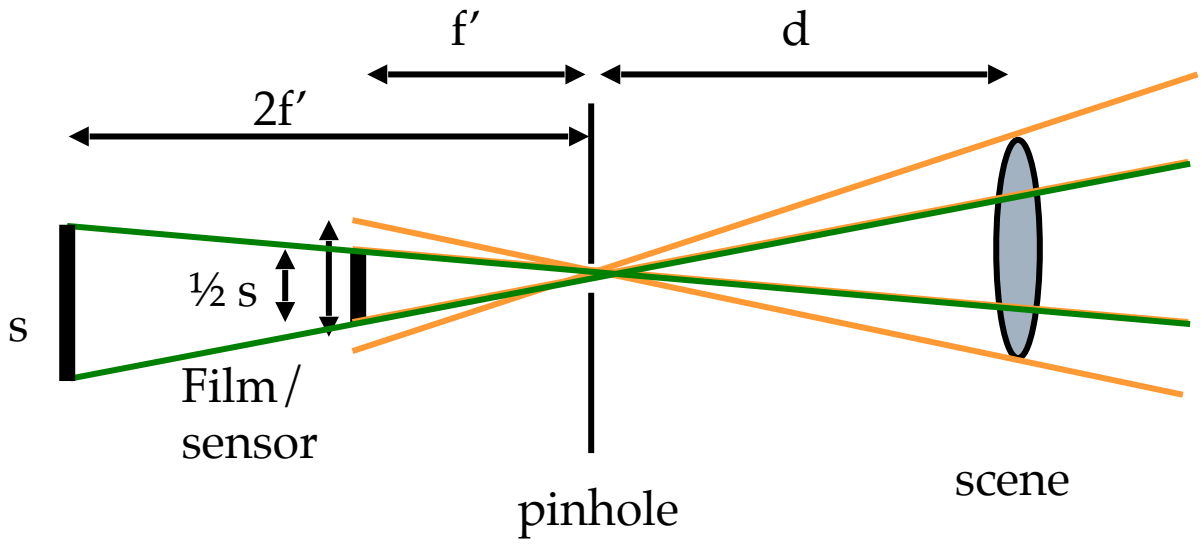
Standard

Telephoto


wide angle
of view
camera's
view
Wide Angle Lens
(objects are very different sizes)
narrow angle
of view
camera's
view
Telephoto Lens
(objects are similar in size)

Focal Length & Sensor

- What happens when the film is half the size?

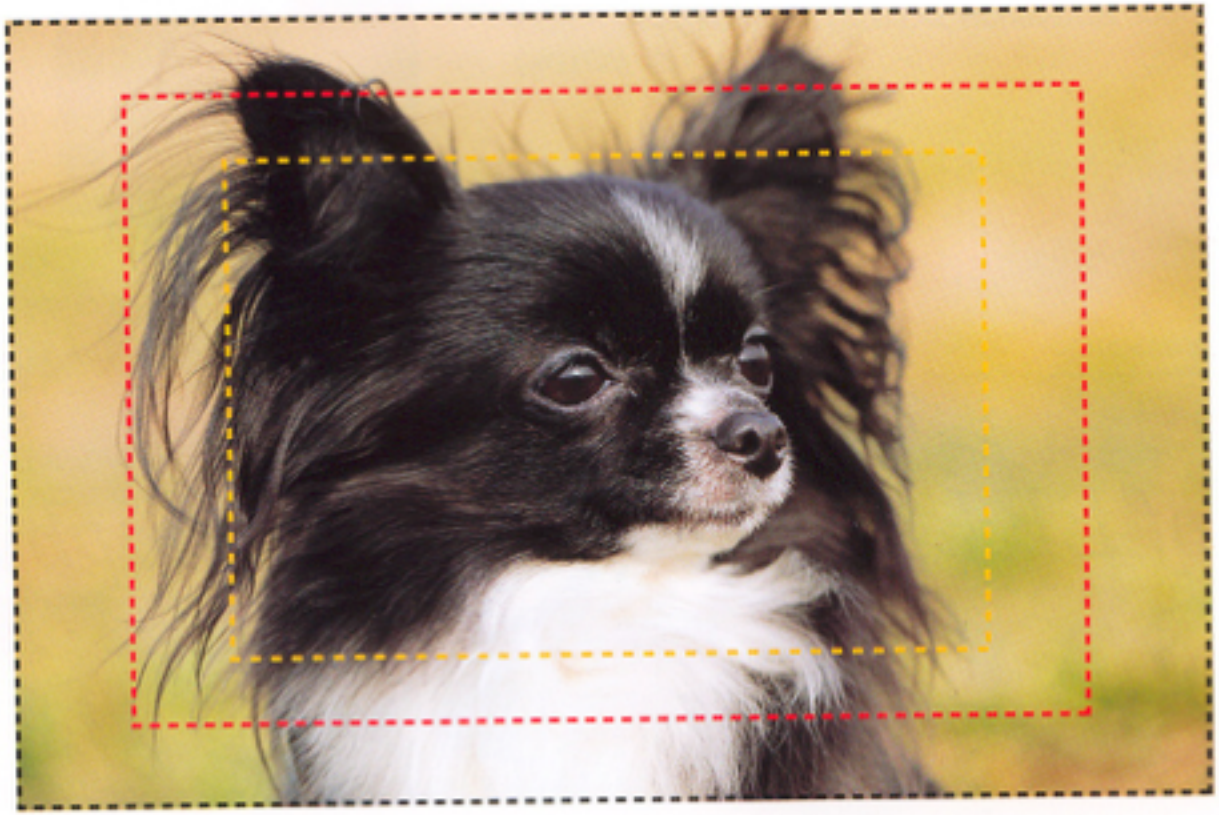


Need to convert focal length
between cameras of different film size!

Sensor Size

- Similar to cropping

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



— EOS-1Ds / — EOS-1D/ — EOS 10D

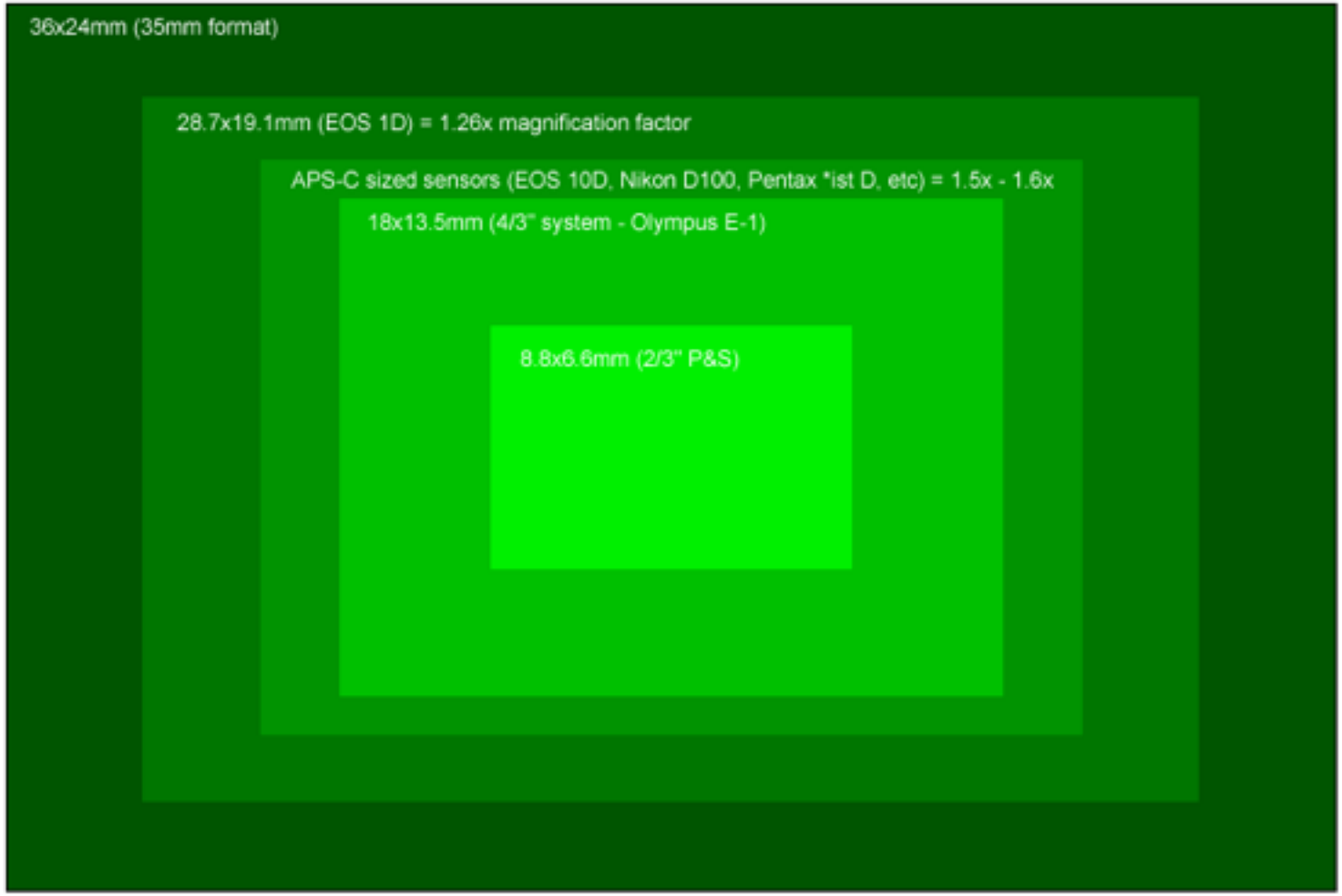
EOS-1D

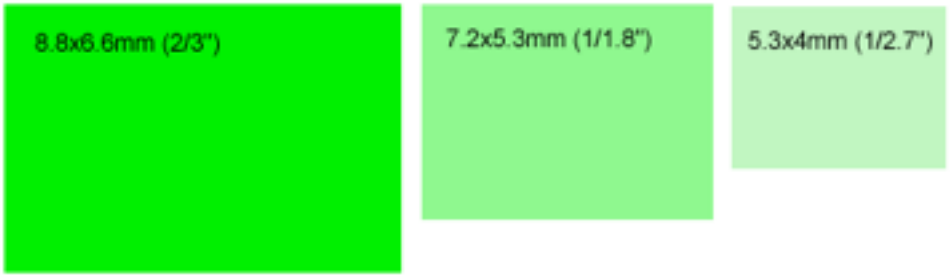
EOS 10D

(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