Basic principles of photography

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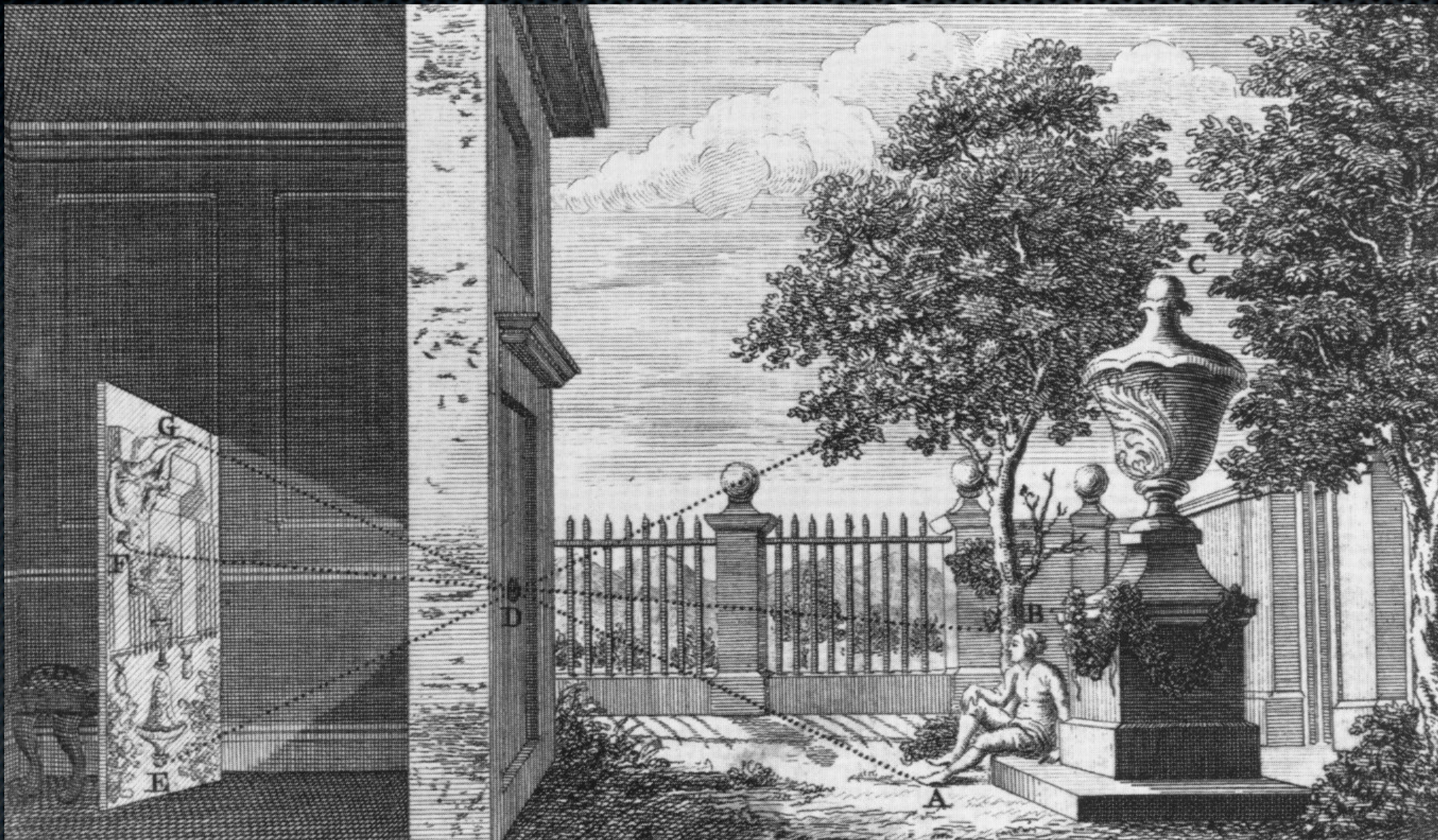
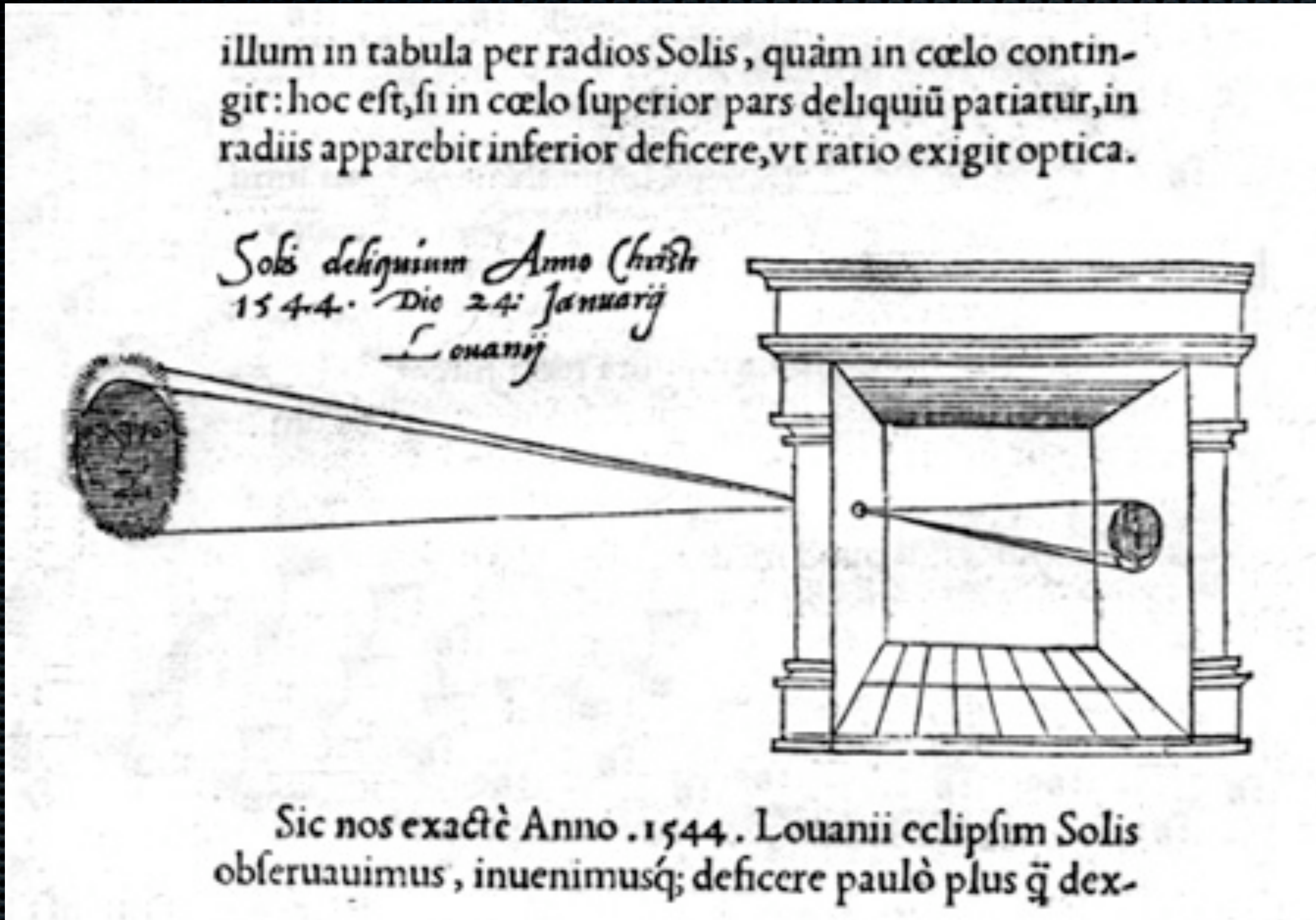
346B IST

Latin “Camera Obscura” = “Dark Room”



Light passing through a small hole produces an inverted image on the opposite wall

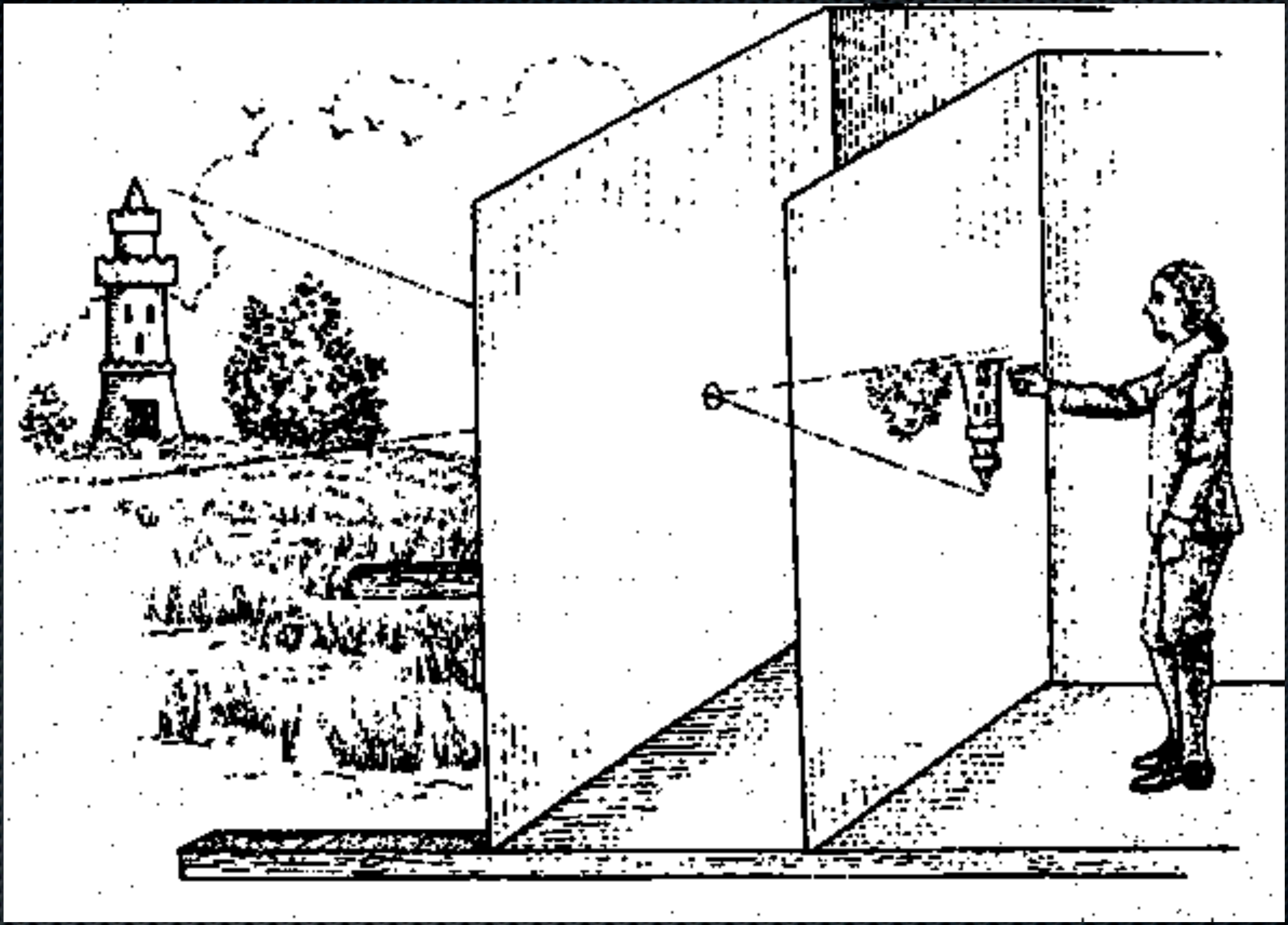


illum in tabula per radios Solis, quàm in cœlo contin-
git: hoc eſt, ſi in cœlo ſuperior pars deliquiū patiatur, in
radiis apparebit inferior deficere, vt ratio exigit optica.

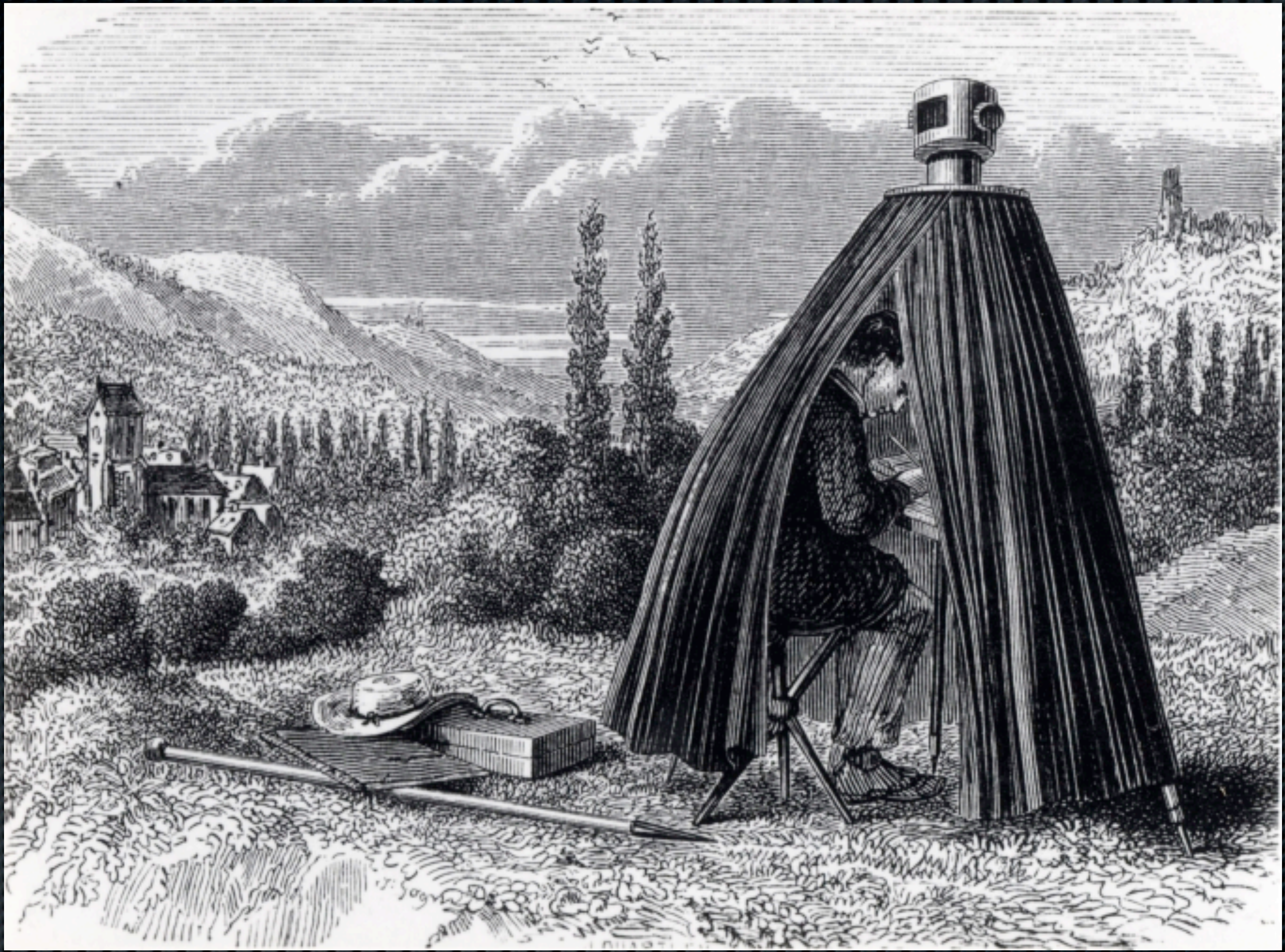
Sic nos exactè Anno .1544. Louanii eclipſim Solis
obſeruauimus, inuenimusq; deficere paulò plus q̃ dex-

Safely observing the solar eclipse

Alhazen (10th c.), Roger Bacon (13th c.)

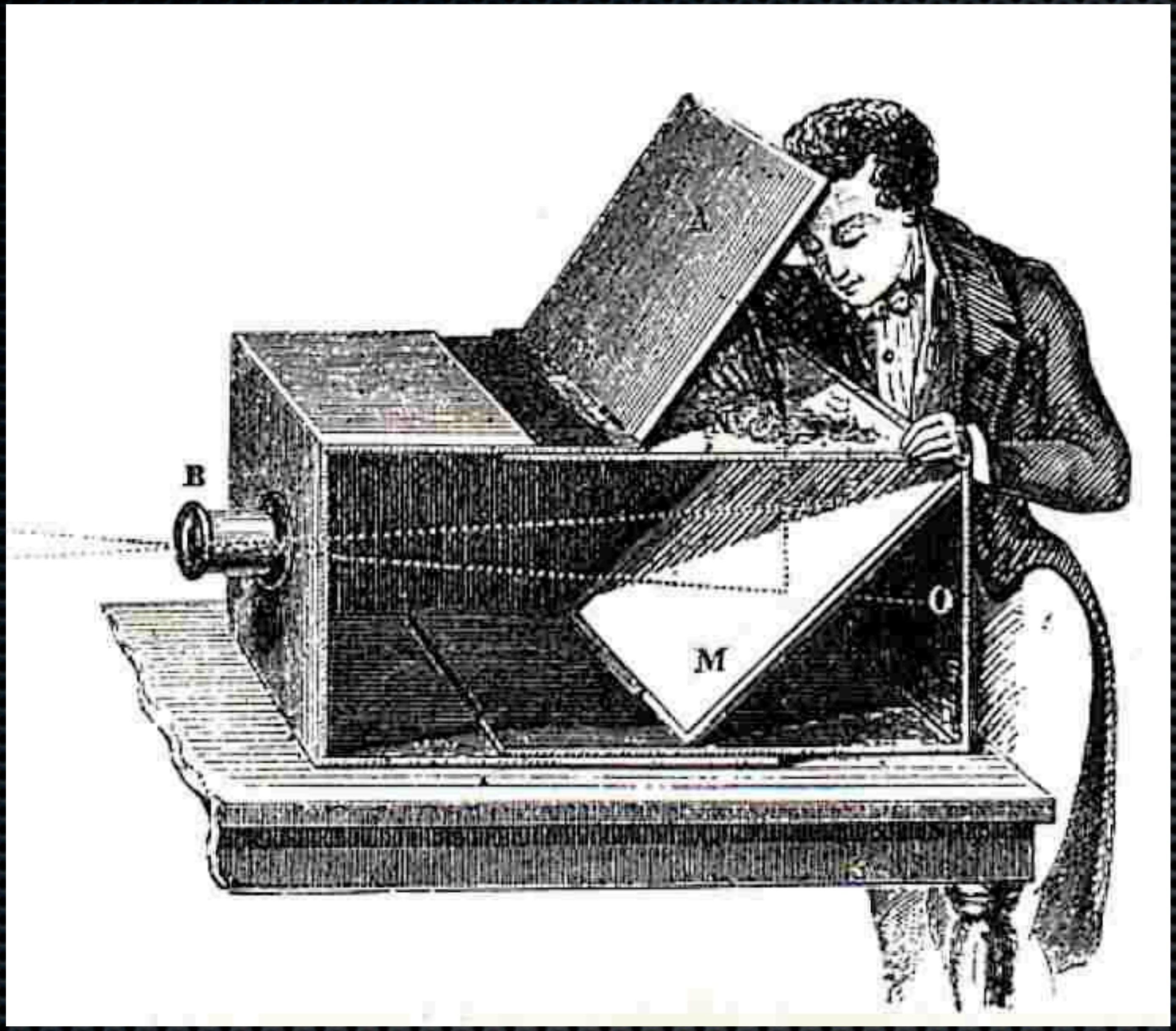


Early use by artists for true-life sketching
Leonardo DaVinci, 15th c.



The portable “tent” camera obscura

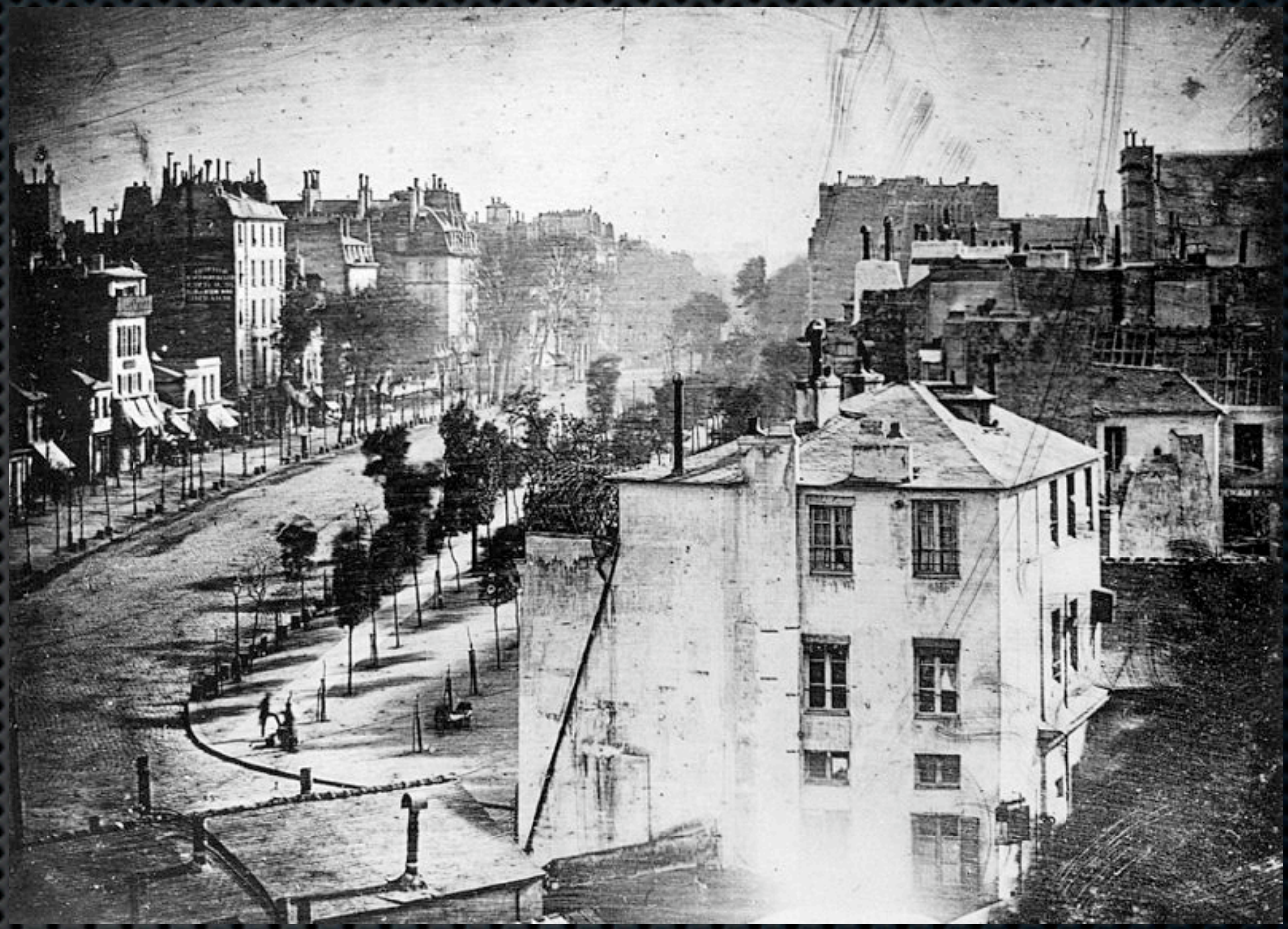
Johannes Kepler (1604)



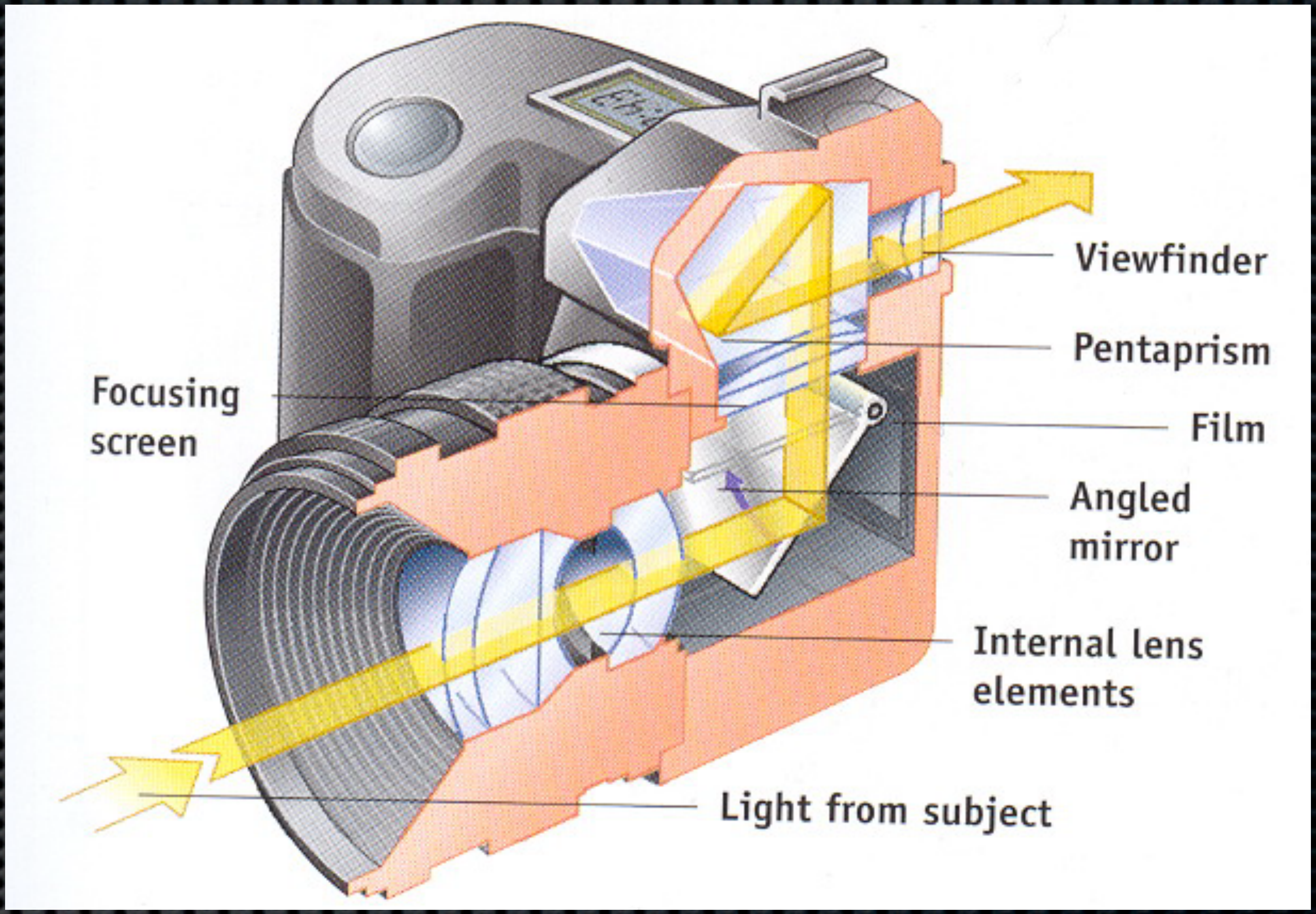
Further refinements, use by 18th century artists

Canaletto (18th c.)

First photo : Joseph Niépce (1825)
Light sensitive silver chloride plates



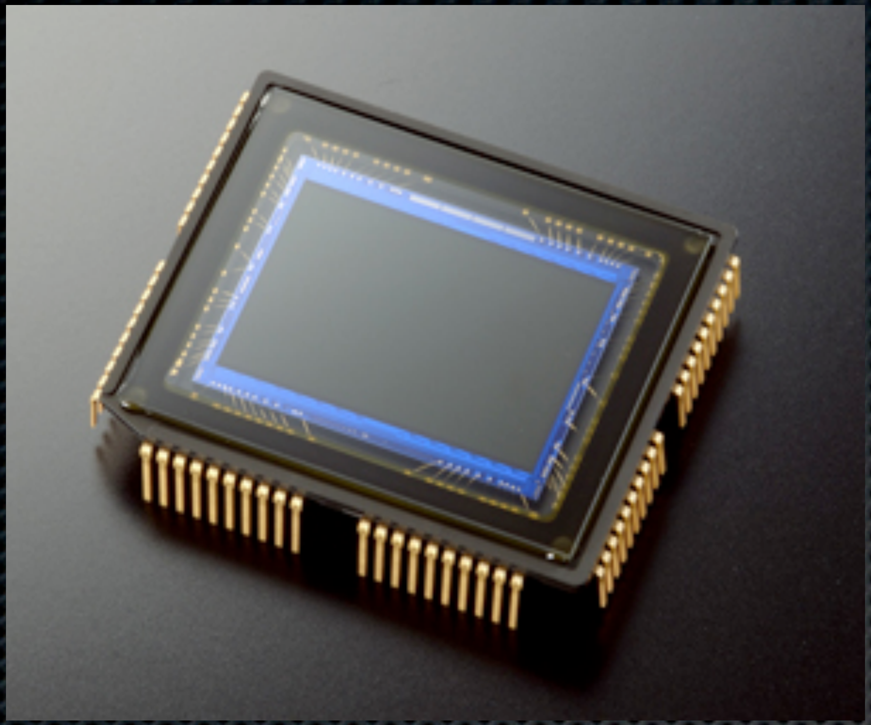
First production camera: Daguerreotype
Louis Daguerre (1840s)



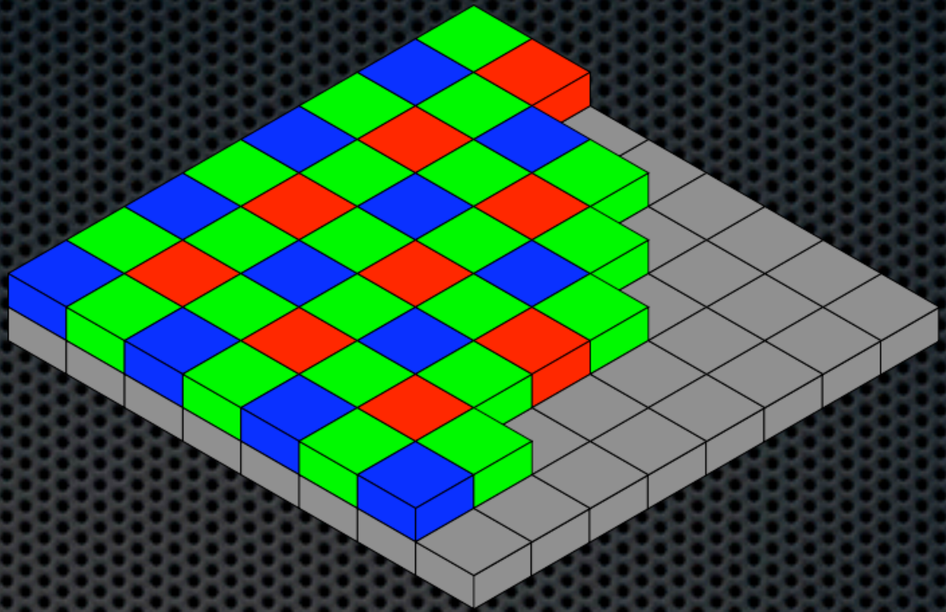
Fast-forward 150 years:
the digital single lens reflex camera (DSLR)

Modern film technology

- A substrate coated with light-sensitive chemicals
- Early photographers used silver halides on a mirror-polished hard surface
- Modern color film attaches dye molecules to achieve sensitivity to different wavelengths of light
- May employ over 200 chemicals and 12 different wavelength bands!



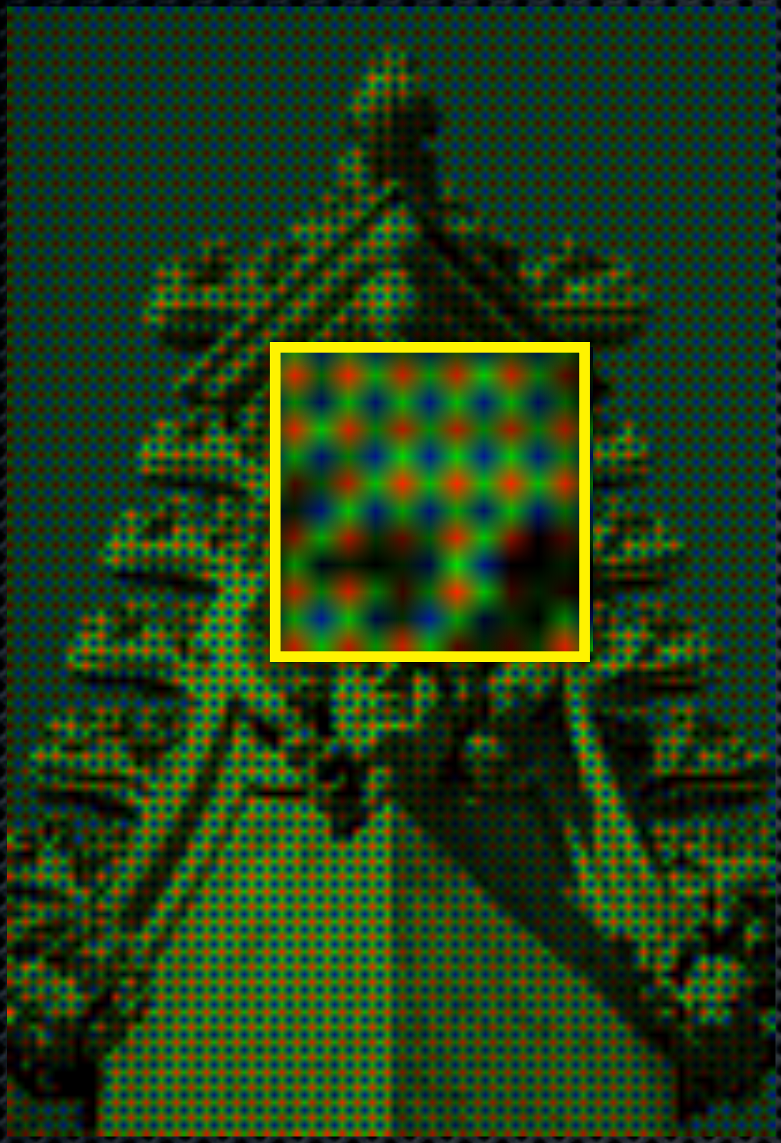
CCD or CMOS sensor



Color Filter Array

- Digital cameras employ an electronic sensor consisting of a large number of square cells or “pixels”
- Photons hitting a cell create an electrical charge
- Accumulated charge is proportional to amount of light
- Color sensors employ a mosaic of Red,Green,Blue dyed cells (Color Filter Array). Requires interpolation to recover the color image.

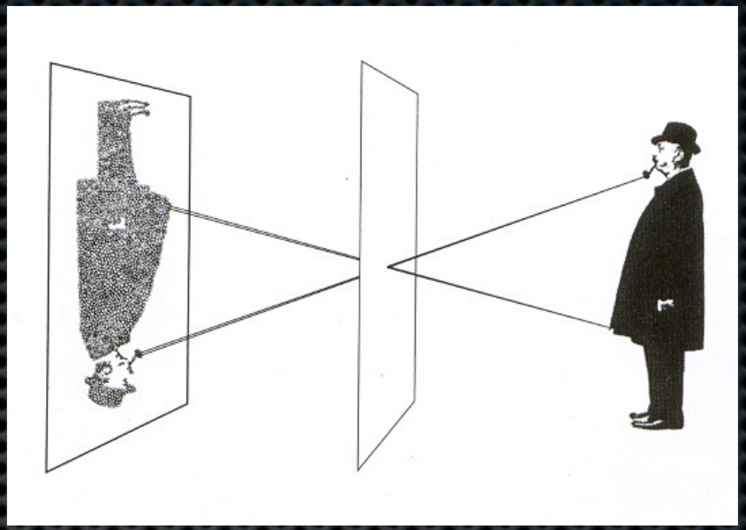
Color Filter Demosaicking

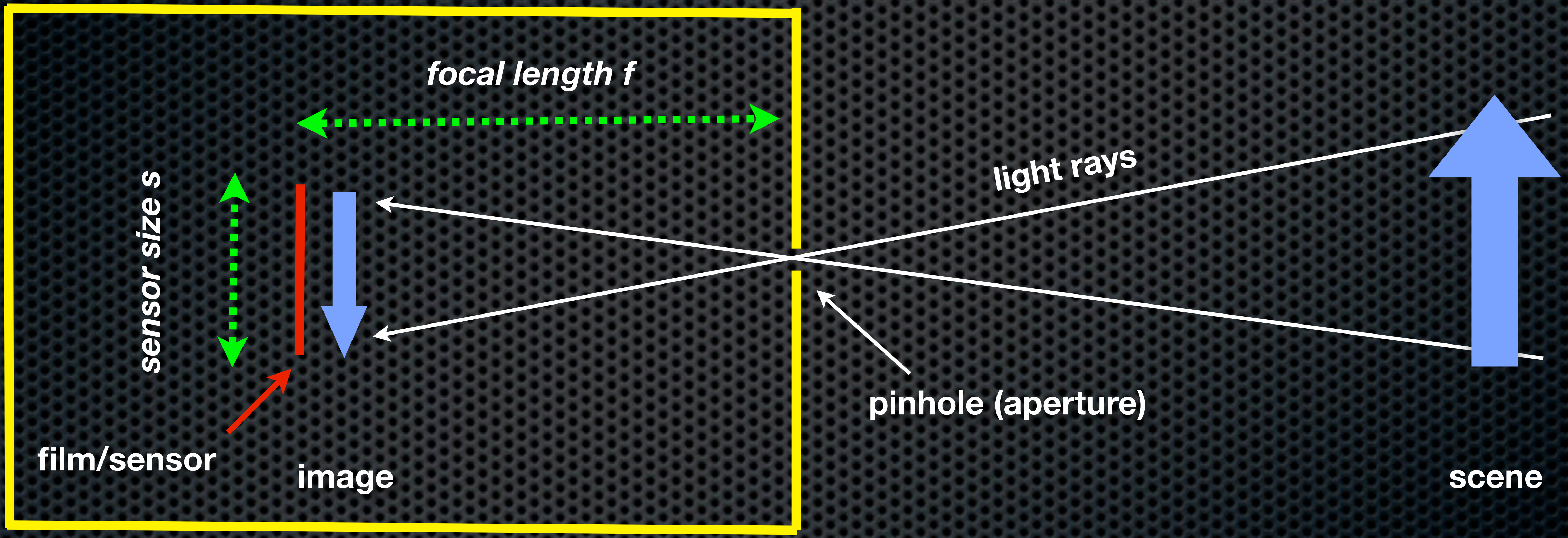


interpolate
between
samples

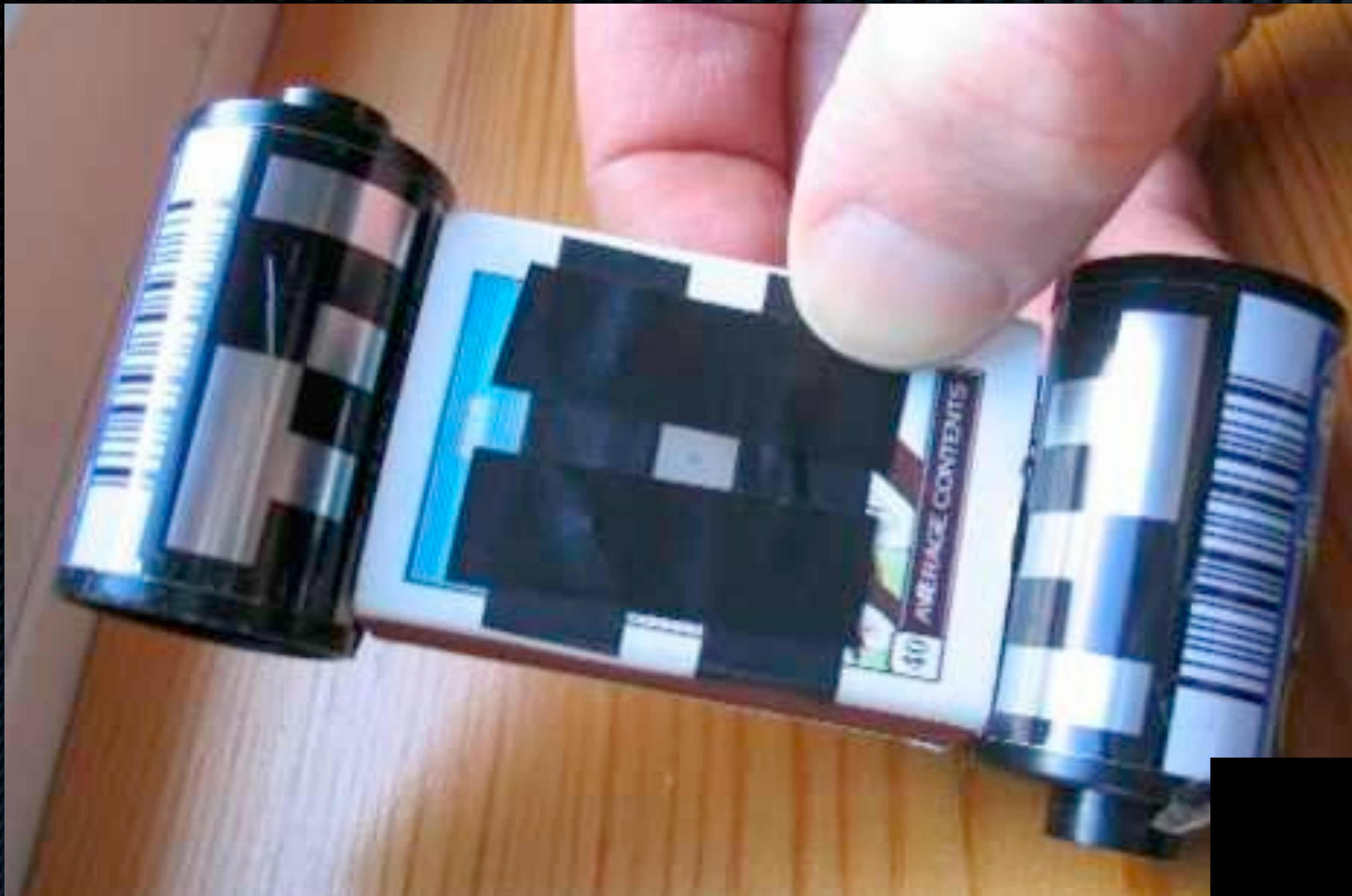
combine
color
channels

Pinhole cameras



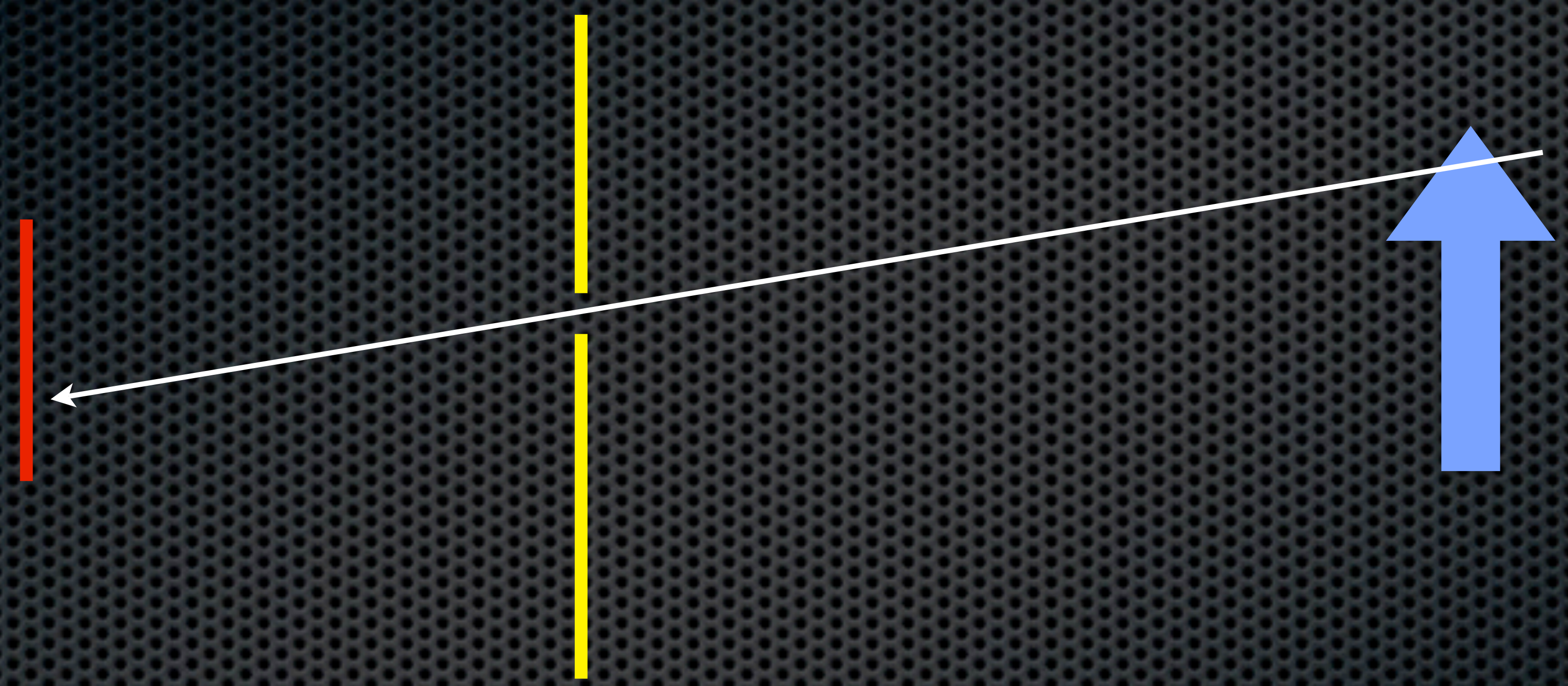


- The camera obscura is an example of a "pinhole camera"
- Each point on the film is illuminated from a single direction
- Simplest and earliest practical camera



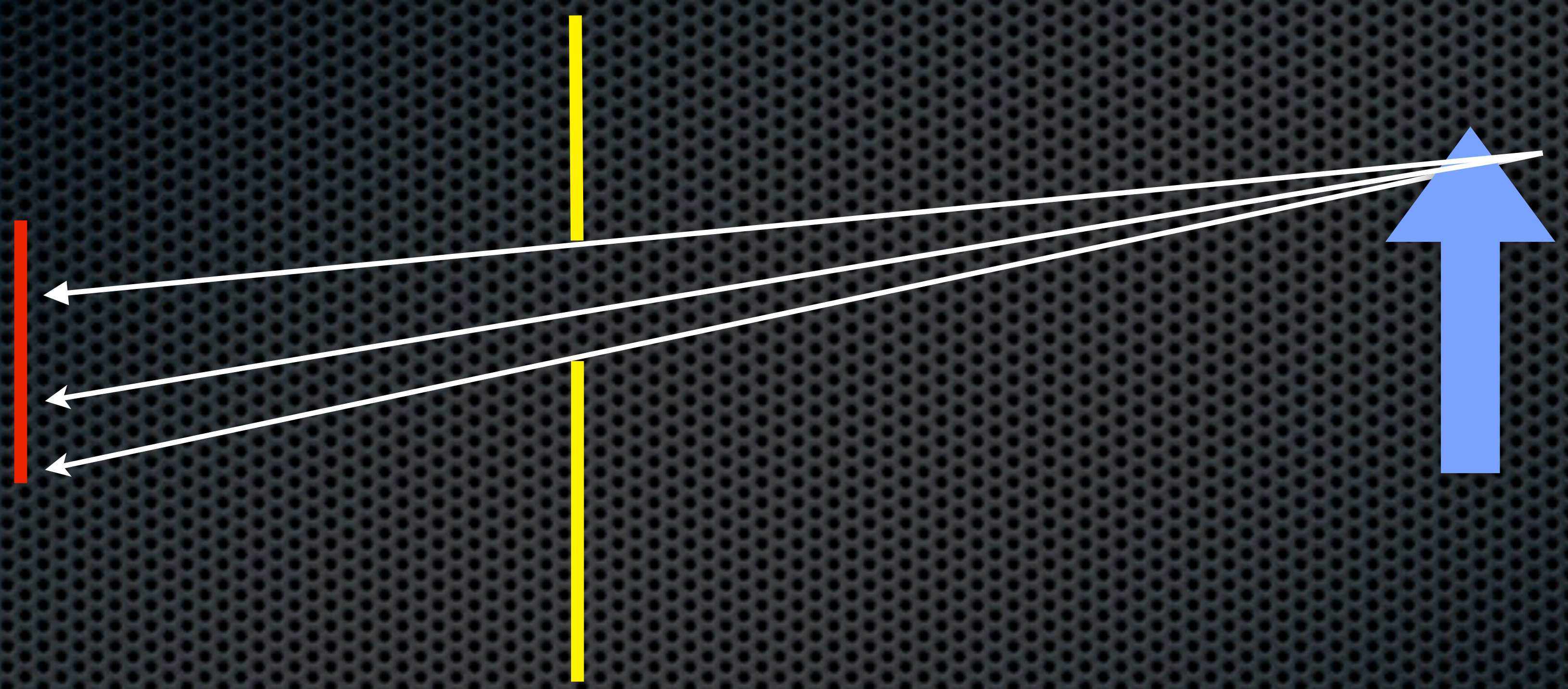
A working pinhole camera!

Problem: Tiny aperture means little light hits film



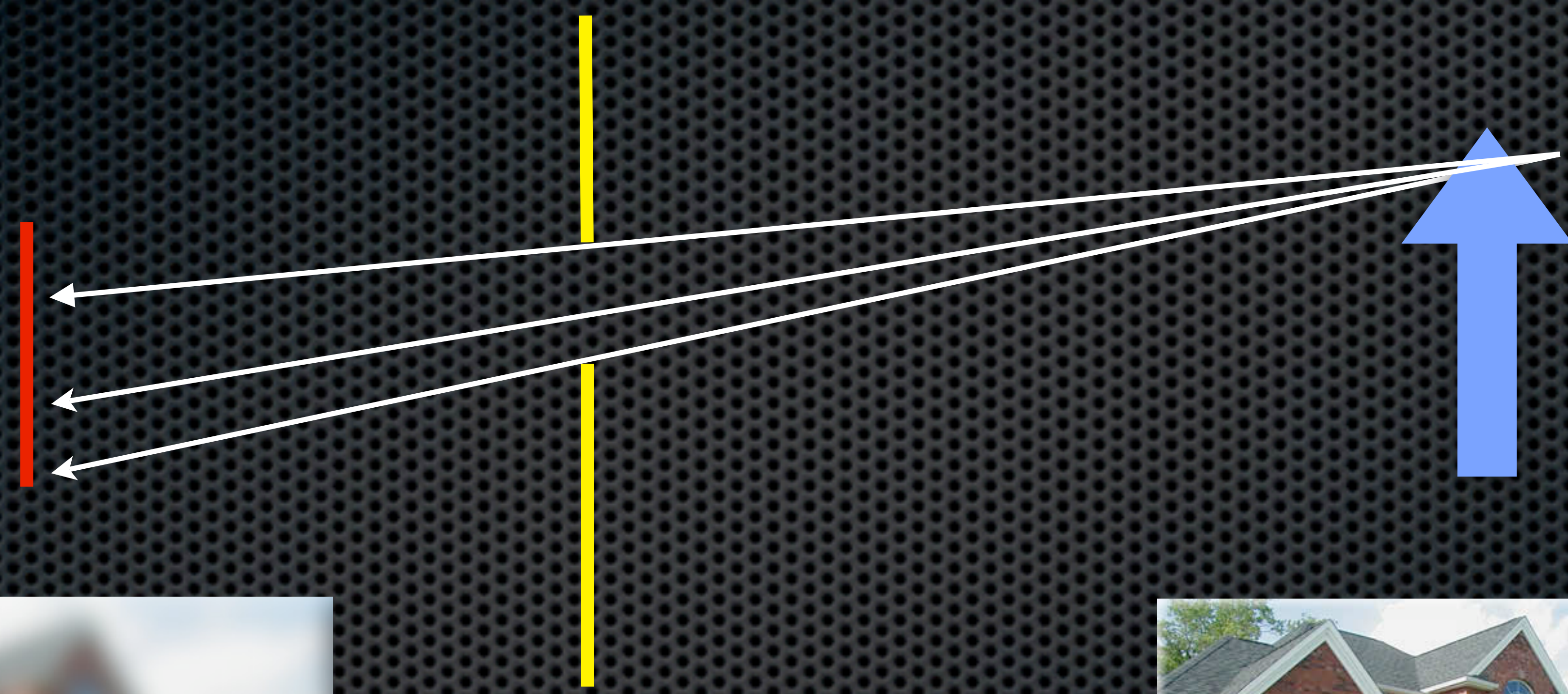
Problem: Tiny aperture means little light hits film

So use a bigger pinhole?



Problem: Tiny aperture means little light hits film

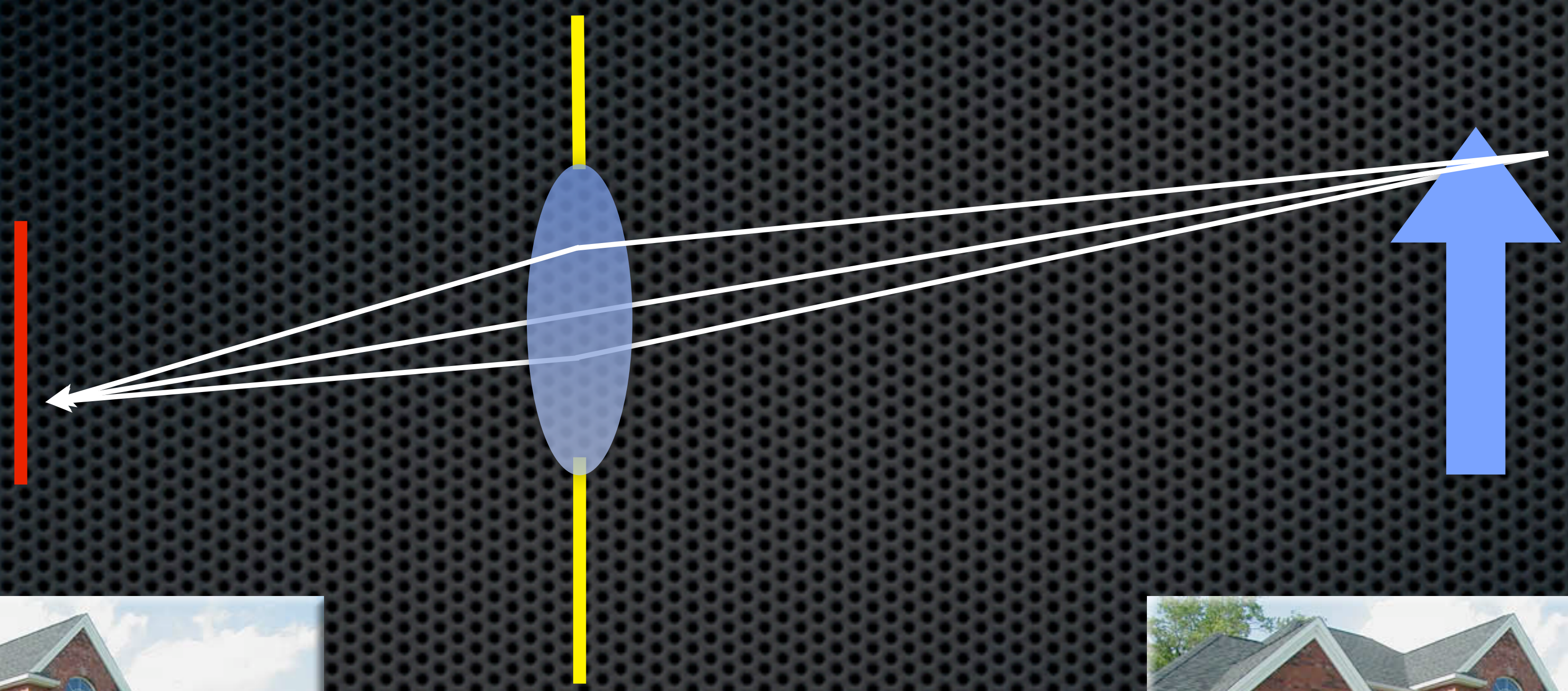
So use a bigger pinhole?



Each point on film sees rays from multiple directions

Result: a blurry image!

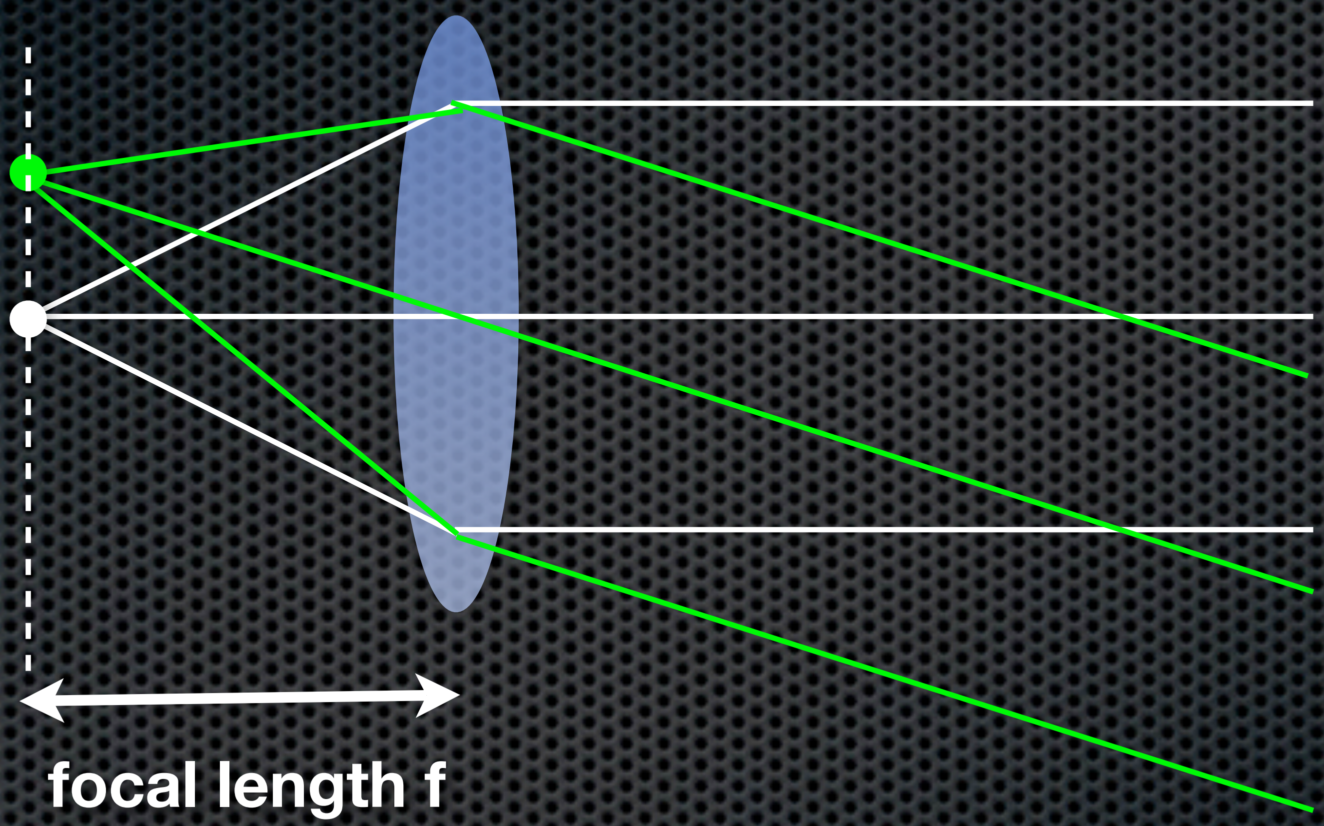
Answer: add a lens!



Rays from a single point are focussed at a point

Result: a sharper image

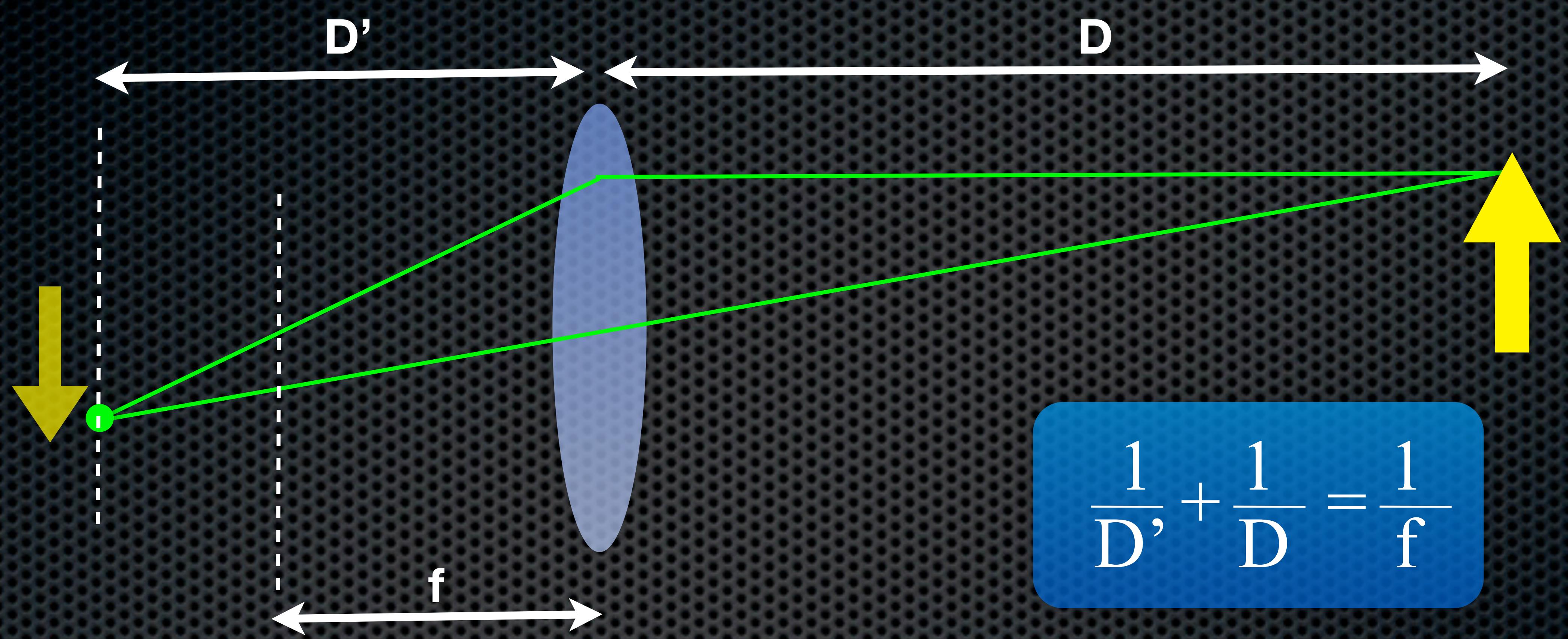
Thin lens optics



Parallel rays converge on a plane at focal length f

To focus on objects at “infinity”, place film at distance f behind lens

Thin lens optics



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

Points at distance D are focussed on a plane at D’

To focus on objects at distance D, place film at distance D’ behind lens

When you turn the focus ring ...

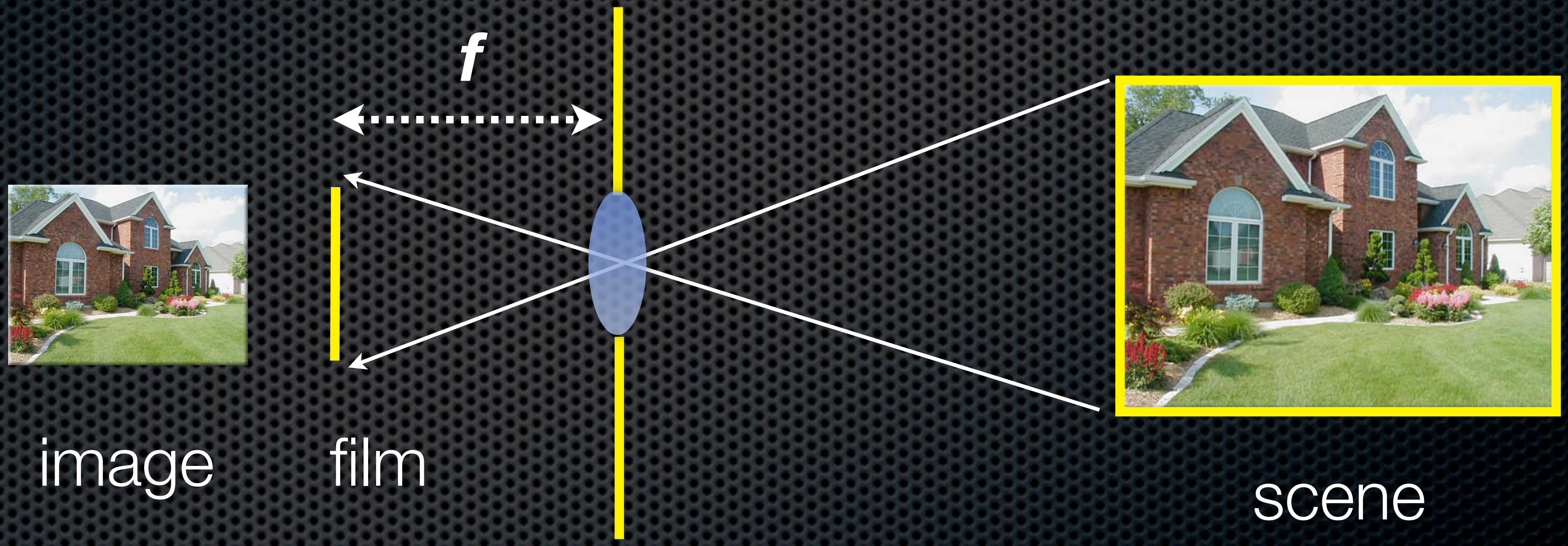
... you move the focal plane

out of focus

in focus

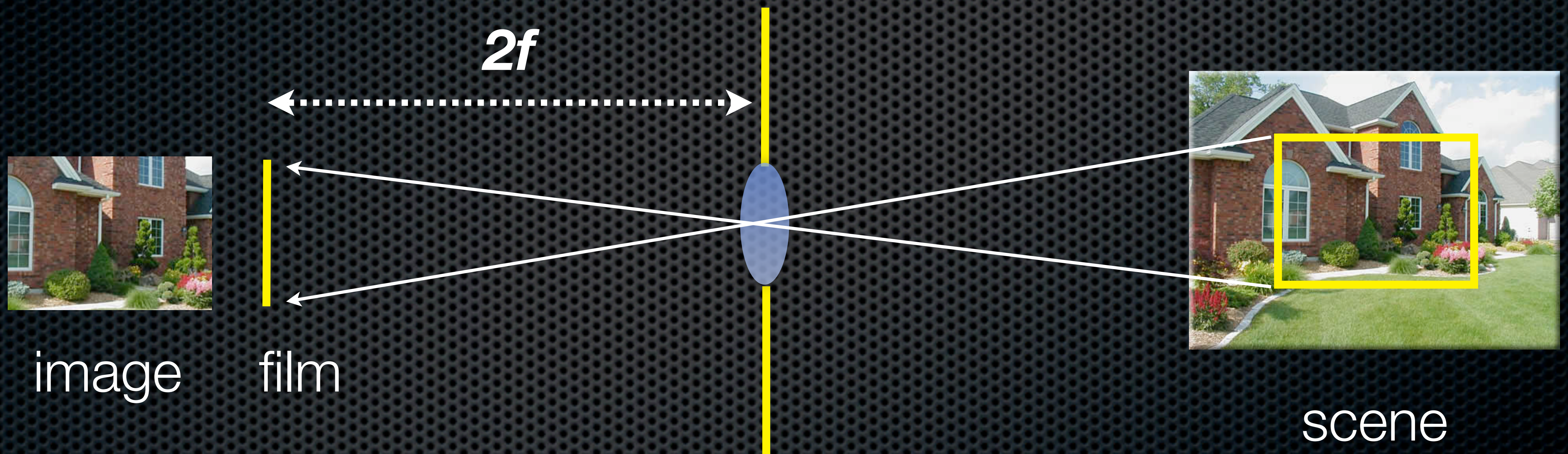
Field of view

For a given film or sensor size, the field of view depends on the focal length **f**



Field of view

If we double focal length, we halve the field of view

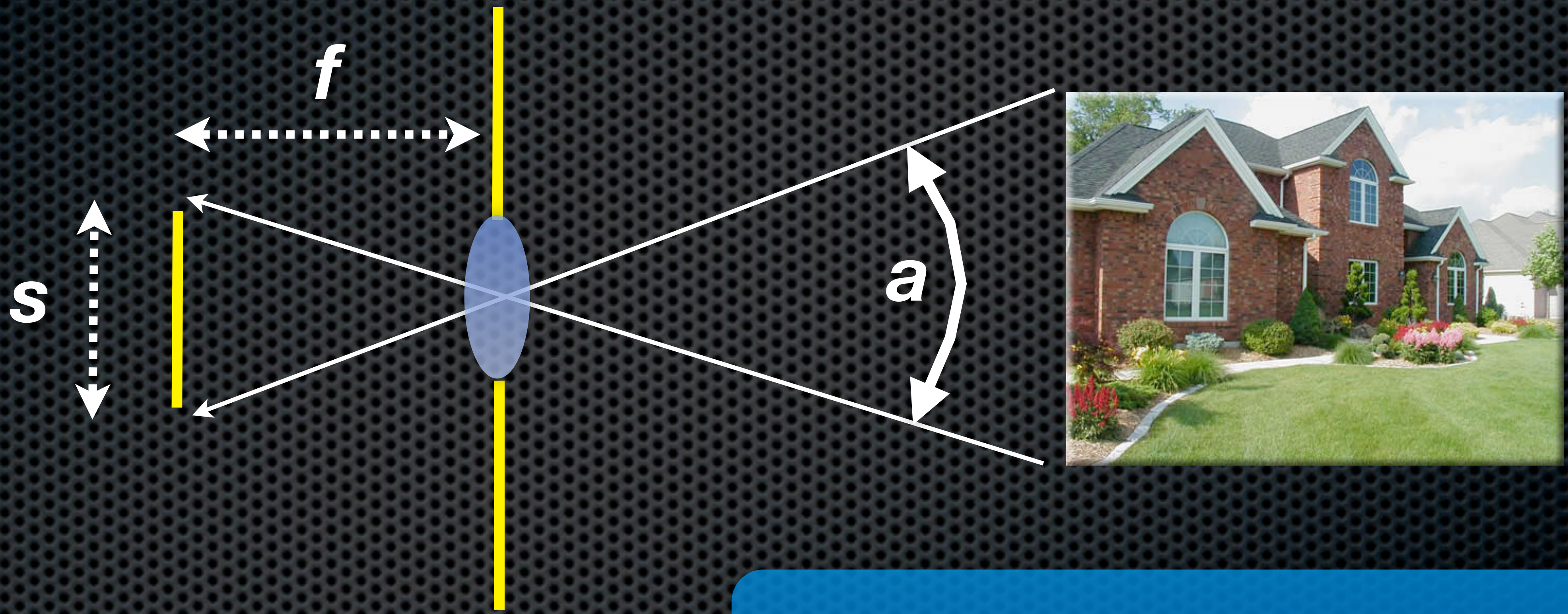


Short focal length = wide field of view

Long focal length = narrow field of view

Field of view

For known film size **s** and focal length **f** ...



Angular field of view

$$a = 2 \arctan \frac{s}{2f}$$

35 mm film (aka 135)

35mm is by far the most common film format

Each recorded image is actually 36 x 24 mm

Examples: 35mm film, various focal lengths ...

28 mm focal length, 65.5° × 46.4°

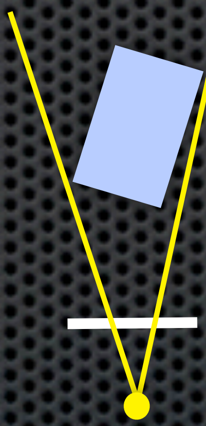
50 mm focal length, 39.6° × 27.0°

70 mm focal length, 28.9° × 19.5°

210 mm focal length, 9.8° × 6.5°

Perspective convergence

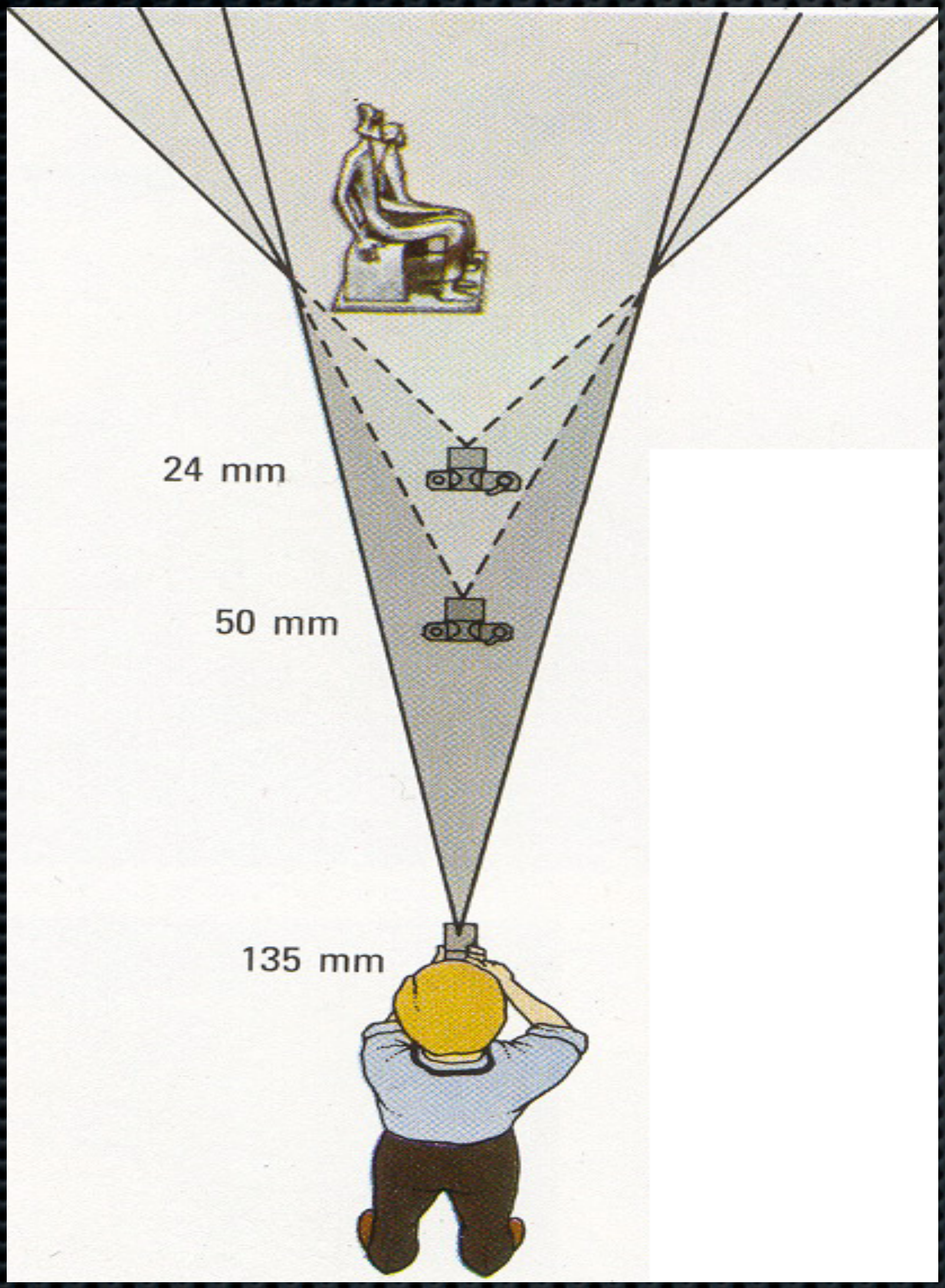
Short focal length (wide FoV) images tend to exhibit pronounced perspective effects

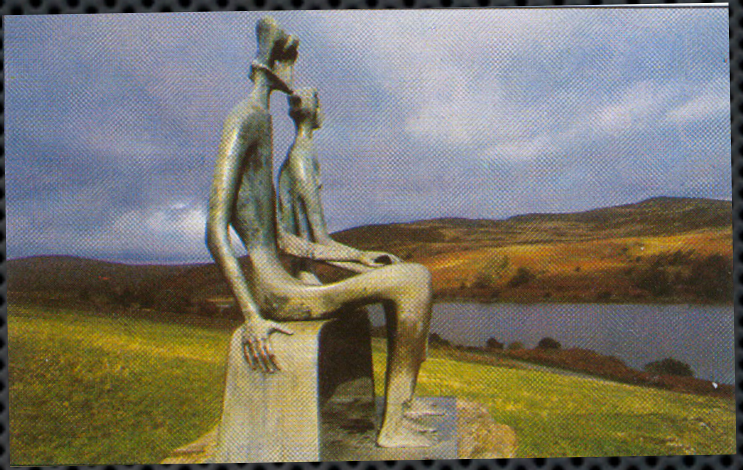


Wide FoV, near to subject:
parallel lines converge

Narrow FoV, far from subject:
parallel lines remain parallel

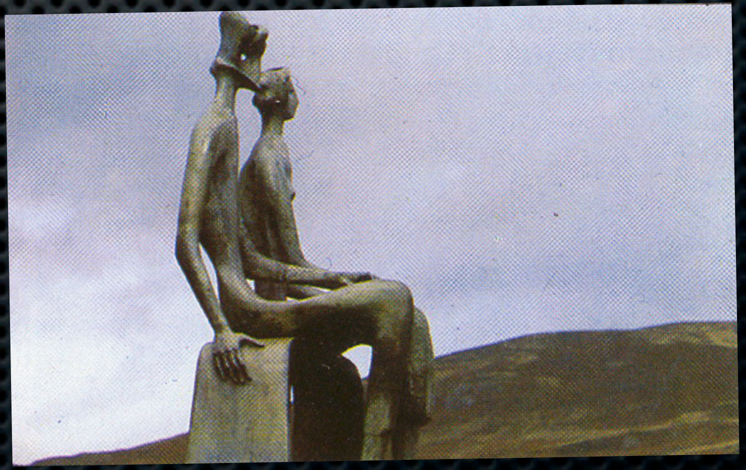
By increasing focal length and moving further from subject, we can drastically change the composition





f = 24 mm

f = 50 mm



f = 135 mm

Move-in, zoom-out

Move-in, zoom-out

In practice, different lenses are required in order to allow focussing at different focal lengths ...

Short focal lens
(wide FoV)

Long focal lens
(narrow FoV)

Zoom lens
(variable FoV)

These are complex, compound optical devices, but the previous principles still apply most of the time

Exposure

Taking a good photo requires getting the right amount of light to the sensor or film

Under-exposed

Correct exposure

Over-exposed

There are two main parameters we can control:

- Shutter speed
- Aperture area

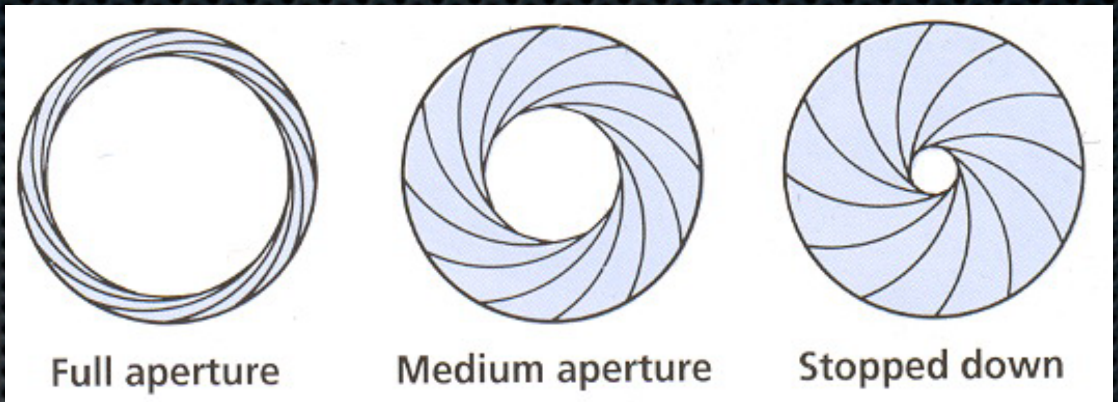
Shutter speed

- Controls how long film is exposed for
- Measured in fractions of a second
  - e.g. 1/30, 1/60, 1/125, 1/250, 1/500
- Fast shutter reduces motion blur BUT admits less light

Slow shutter speed
(long exposure time)

Fast shutter speed
(short exposure time)

Aperture



- Diameter of lens opening
- Expressed as fraction of focal length (called *f-number*)
  - e.g. f/2 on 50mm lens = 25 mm aperture
- **Big** f-number means **small** aperture
- Large aperture = more light, but shallow "depth of field"

Depth of field

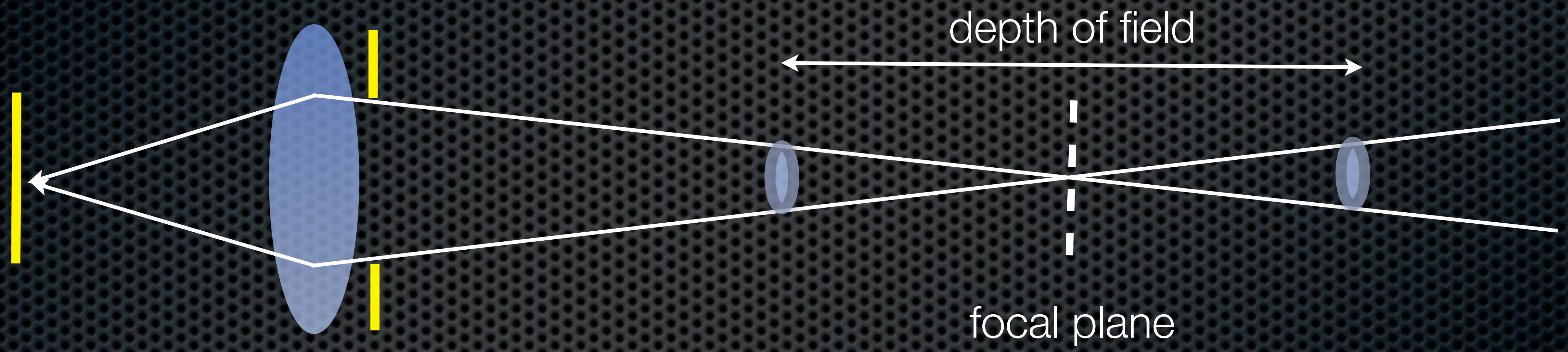
Range of distance that is acceptably "in focus"

Small aperture
= large depth of field

Large aperture
= shallow depth of field

Recall: lens can precisely focus points at only one distance (the focal plane)

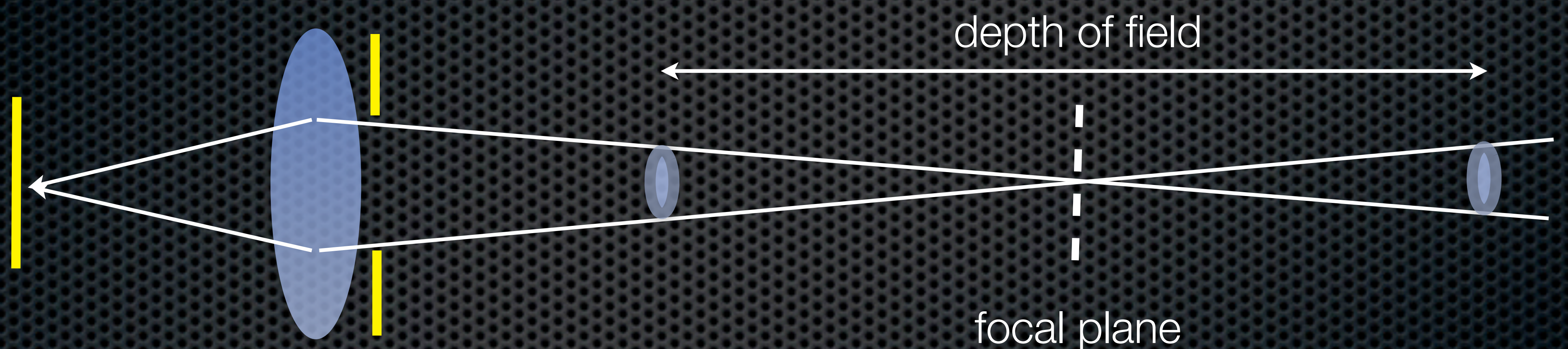
Sharpness decreases away from the focal plane



Points within the depth of field produce an acceptably sharp image

Recall: lens can precisely focus points at only one distance (the focal plane)

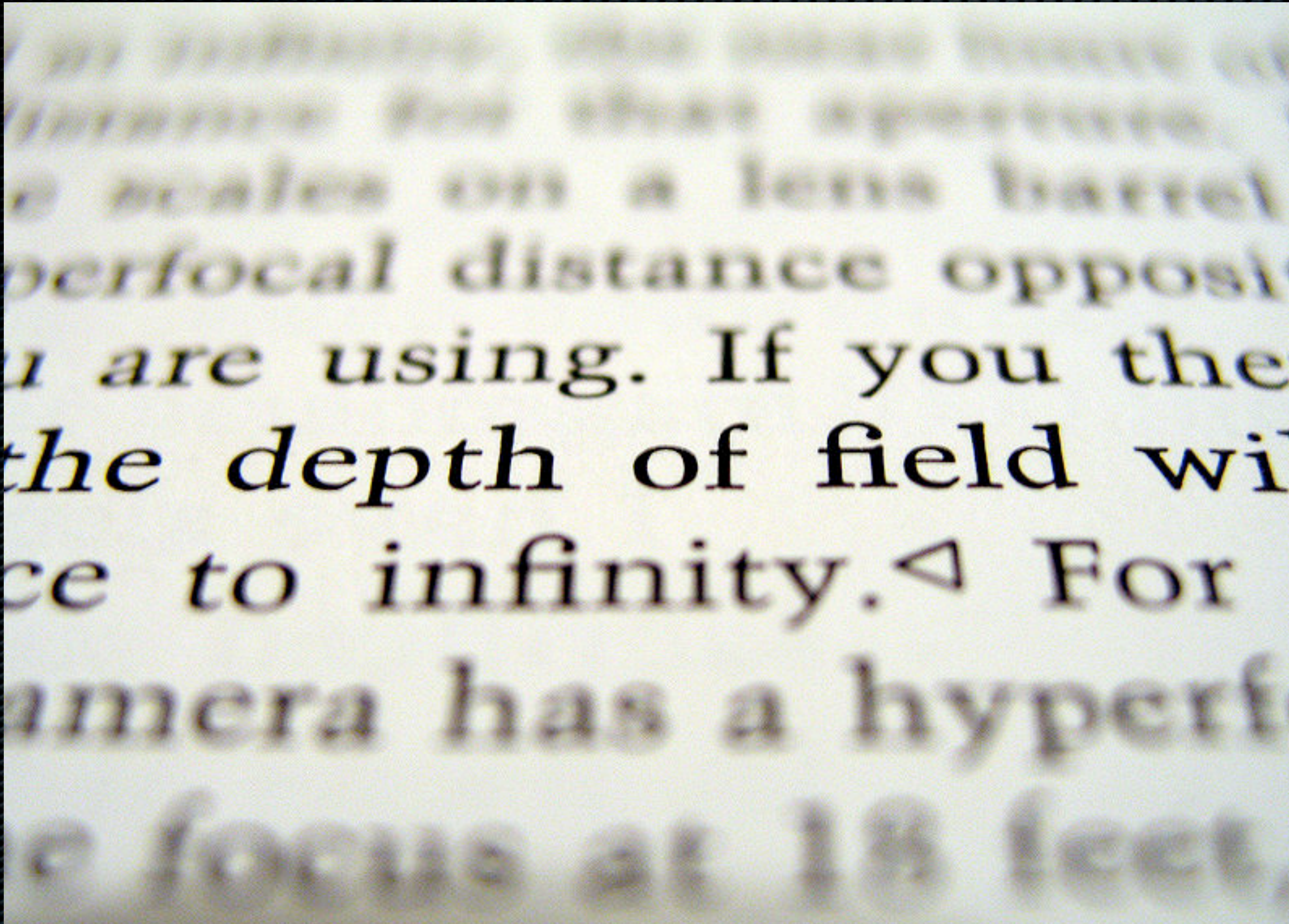
Sharpness decreases away from the focal plane



The rate of decrease depends on the aperture

Smaller aperture = larger depth of field

Pinhole camera = infinite depth of field!



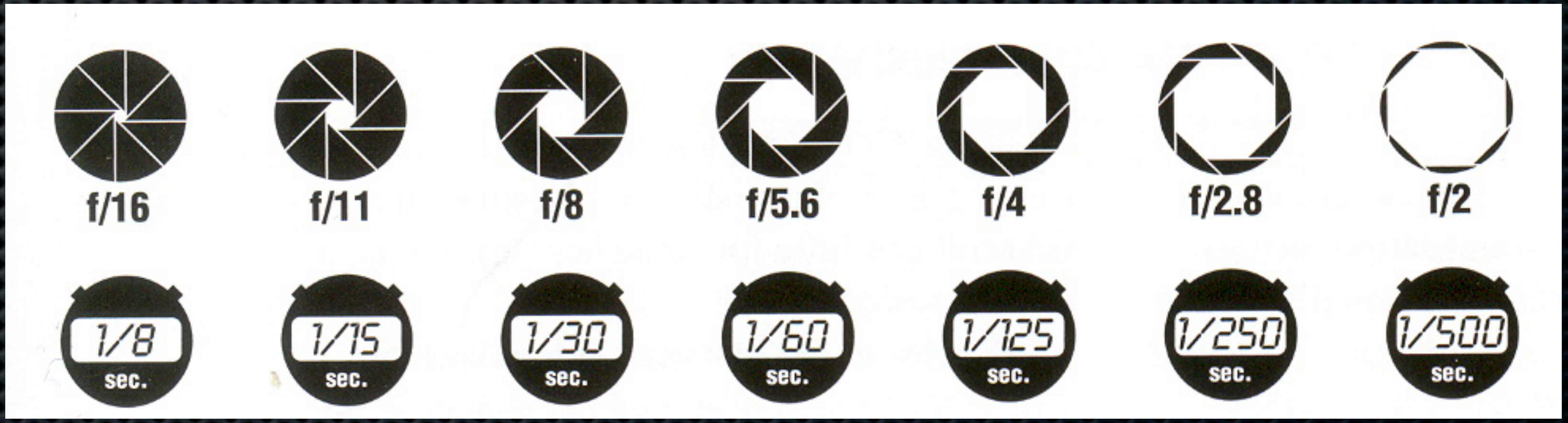
e scales on a lens barrel
perfocal distance opposi
u are using. If you the
the depth of field wil
ce to infinity.◁ For
amera has a hyperf
e focus at 18 feet,

Exposure: Reciprocity

Same exposure is obtained with shutter interval **twice** as long and aperture area **half** as big

$$\text{exposure} = \frac{\text{shutter speed}}{\text{f-number}^2}$$

For a given exposure, we have a number of possible choices of shutter and aperture:



Note the convenient step sizes!

Sensitivity (ISO scale)

- Additional variable affecting exposure
- ISO scale indicates chemical film sensitivity to light:
  - **ISO 100** - low sensitivity, good for bright conditions, static scenes, wide aperture, slow shutter
  - **ISO 1600** - high sensitivity, good for low light, dynamic scenes, small aperture, fast shutter
- Digital camera equivalent is electronic gain level
- Penalty for high sensitivity is noise or "graininess"

Example of film grain at high ISO numbers

Digital cameras exhibit similar noise at high gain levels

Camera modes

- Modern DSLR cameras typically have several shooting modes:
  - Program mode (P) - Camera intelligently chooses shutter speed and aperture to achieve correct exposure
  - Shutter priority (S) - User sets shutter speed, camera chooses appropriate aperture
  - Aperture priority (A) - User sets aperture, camera chooses appropriate shutter speed
  - Manual mode (M) - User sets both aperture and shutter speed

Depth of field preview

- When using “aperture priority” mode, the camera still uses the widest aperture for the view-finder
    - Ensures a bright image
    - Shallow depth of field helps with manual focussing
- BUT - use the “aperture preview” button to temporarily stop-down the aperture and see the true effect