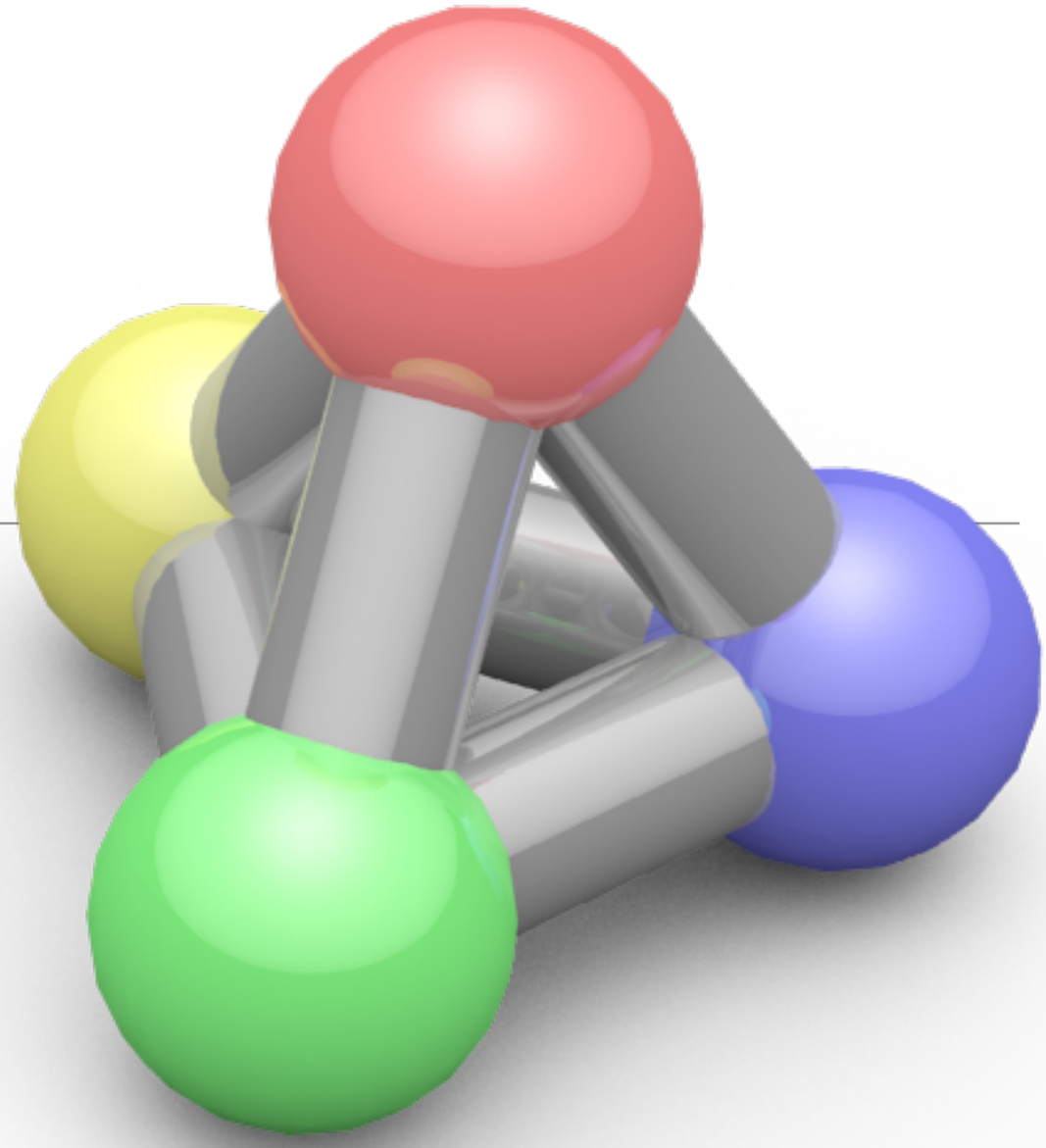
Image Formation



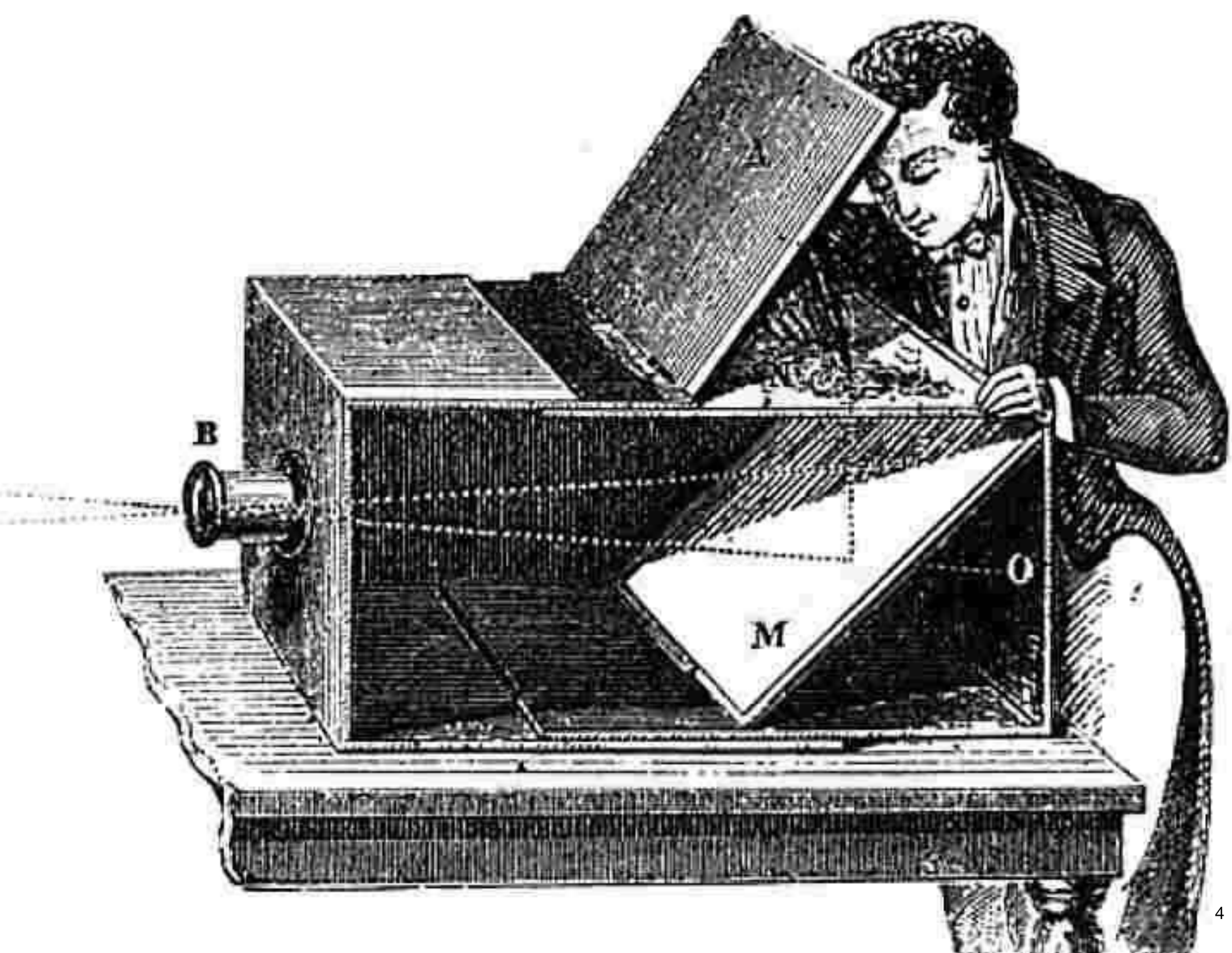
CPSC 453 – Fall 2016
Sonny Chan

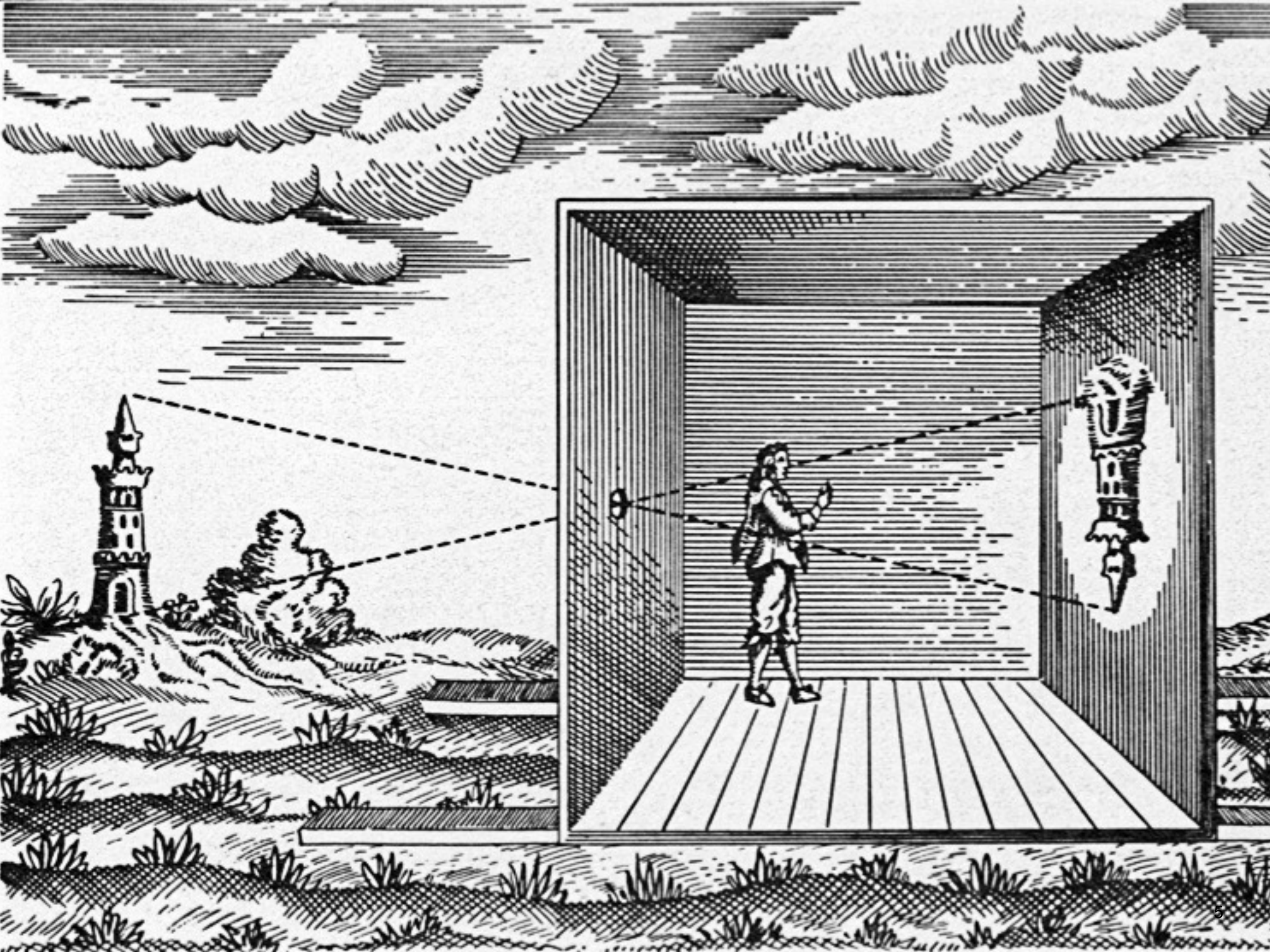
Outline for Today

- The Camera Obscura
- The modern camera
- Digital image formation

The Camera Obsura

ca. 4th century BC


A
B
M
O



Camera Obscura, 1946

San Francisco, California

Camera Obscura, 2012

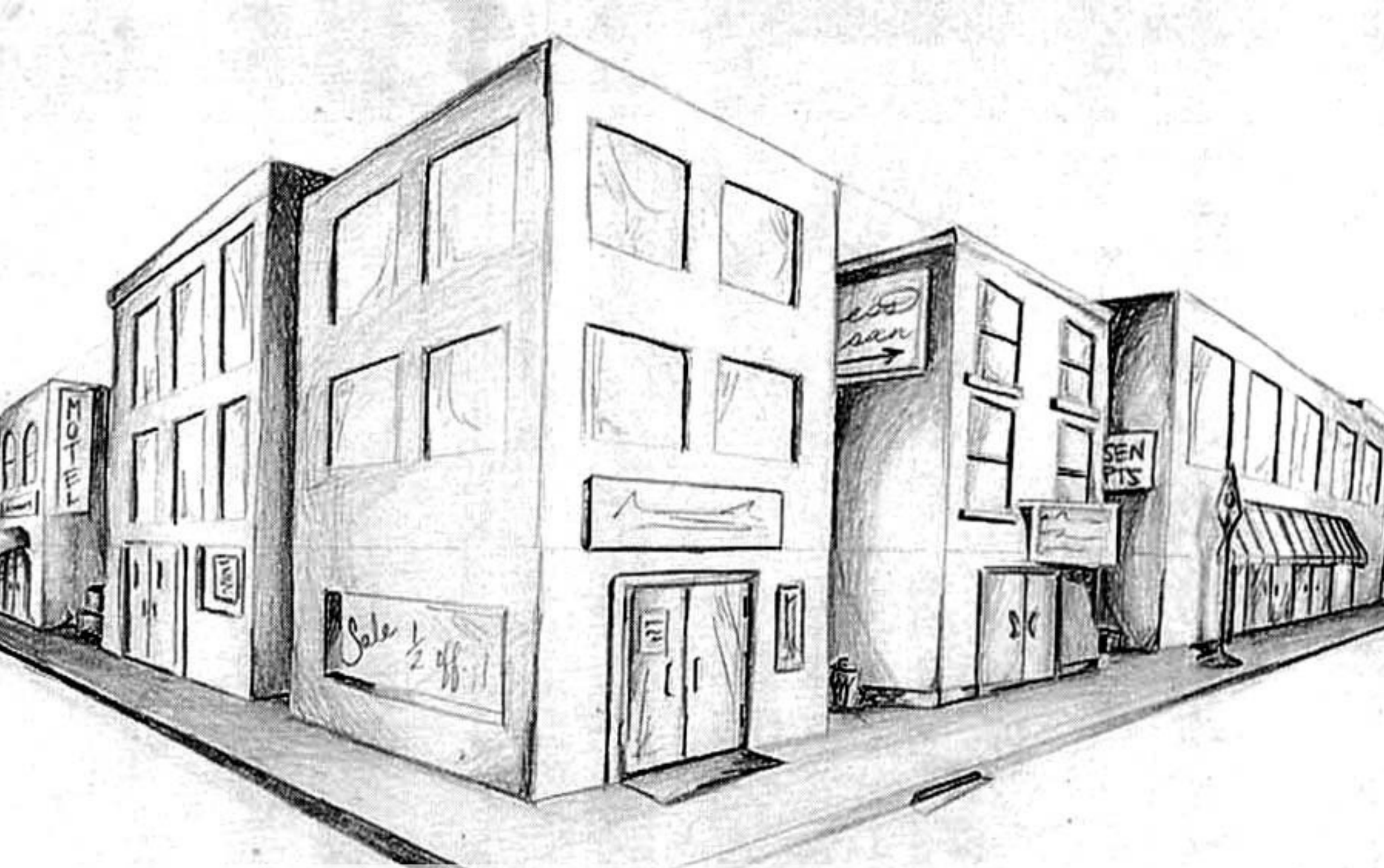
Cheverie, Nova Scotia

Why is the projected image upside down?

Perspective

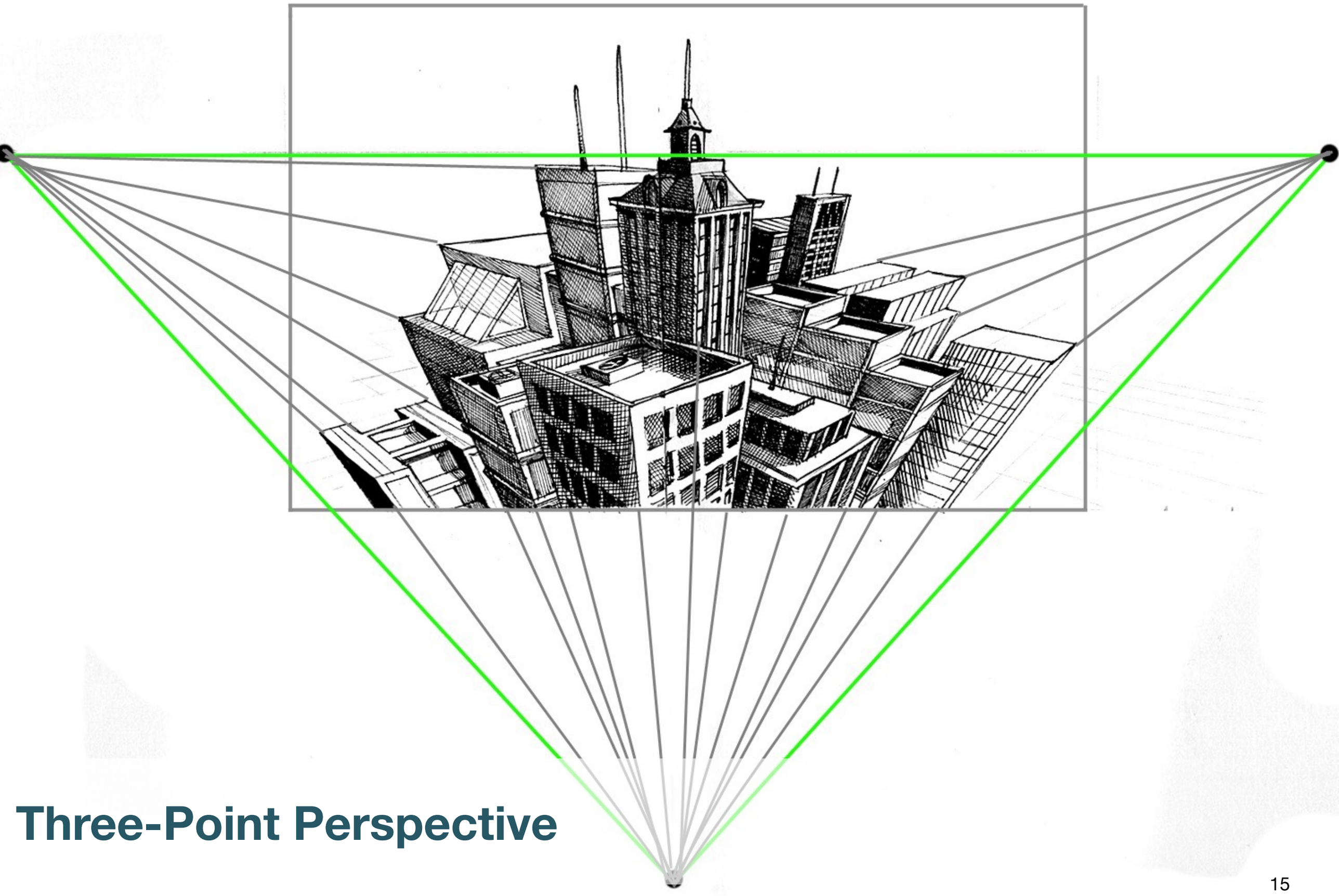
a geometric explanation

One-Point Perspective

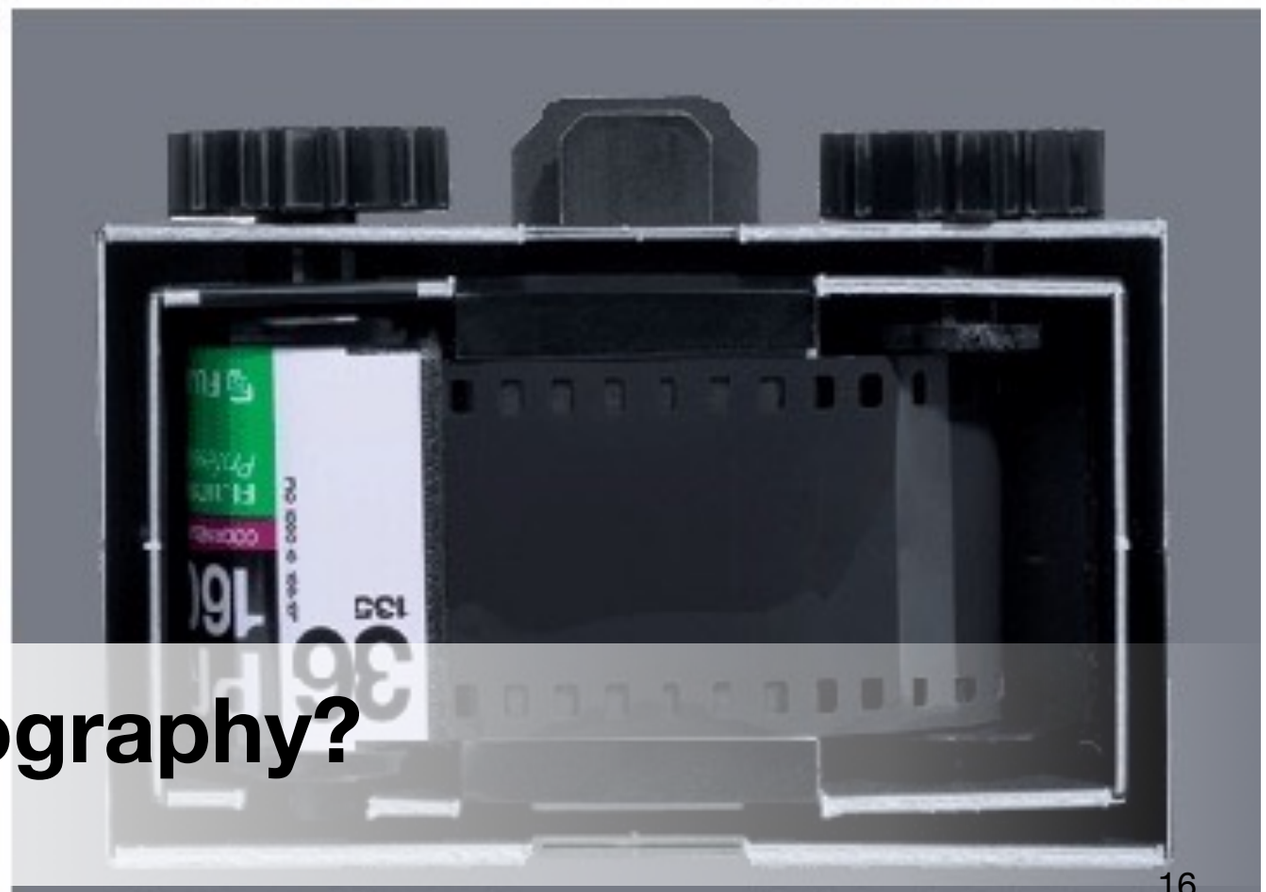


Two-Point Perspective

Three-Point Perspective

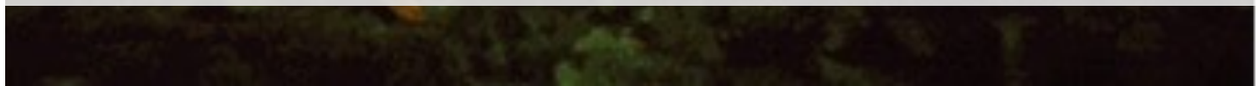


Three-Point Perspective



A Camera Obscura for photography?

Sharan Pinhole Cameras, Japan



The Pinhole Camera

What are its key advantages and disadvantages?

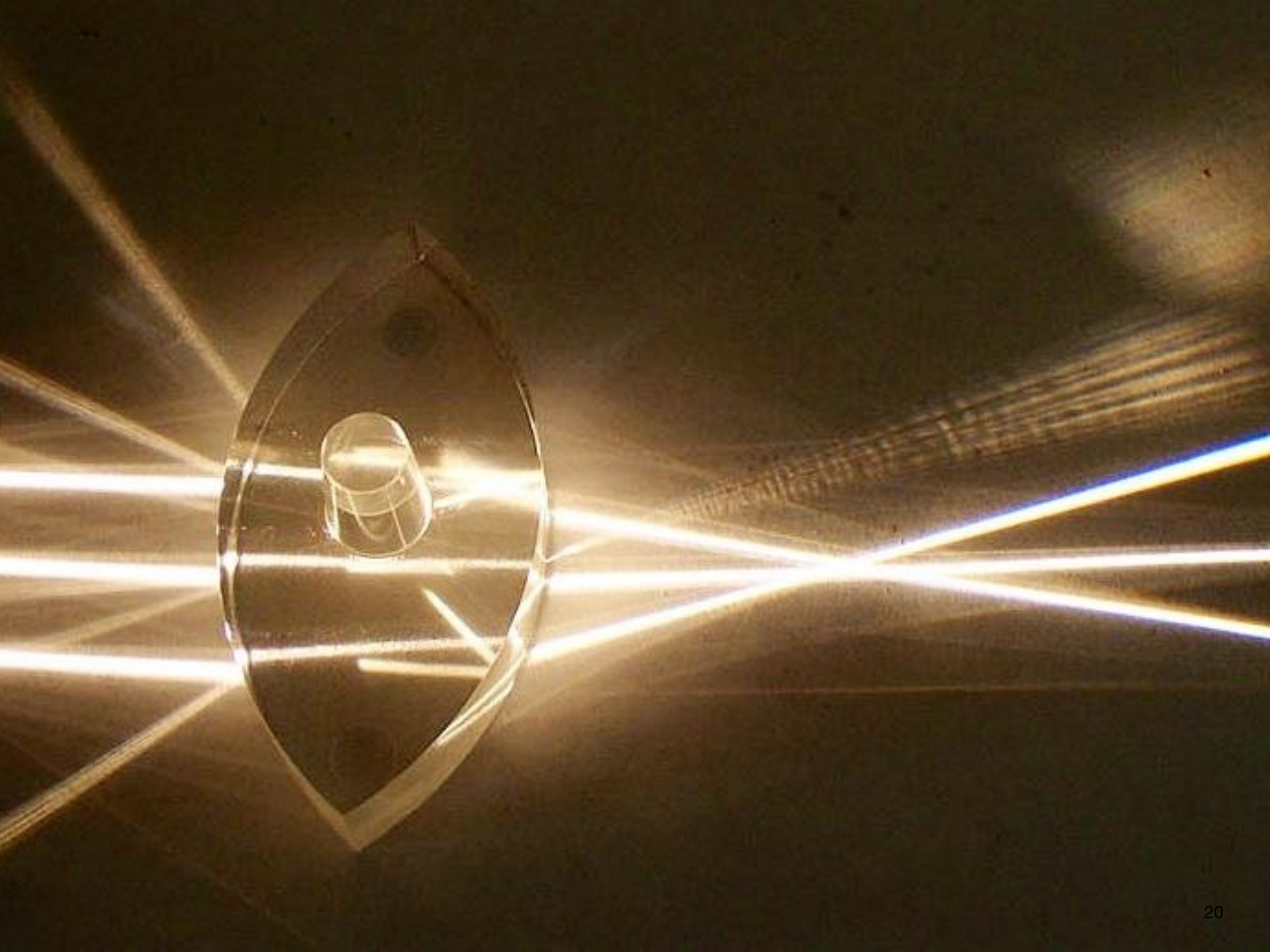
[from civilwar150pinholeproject.com]

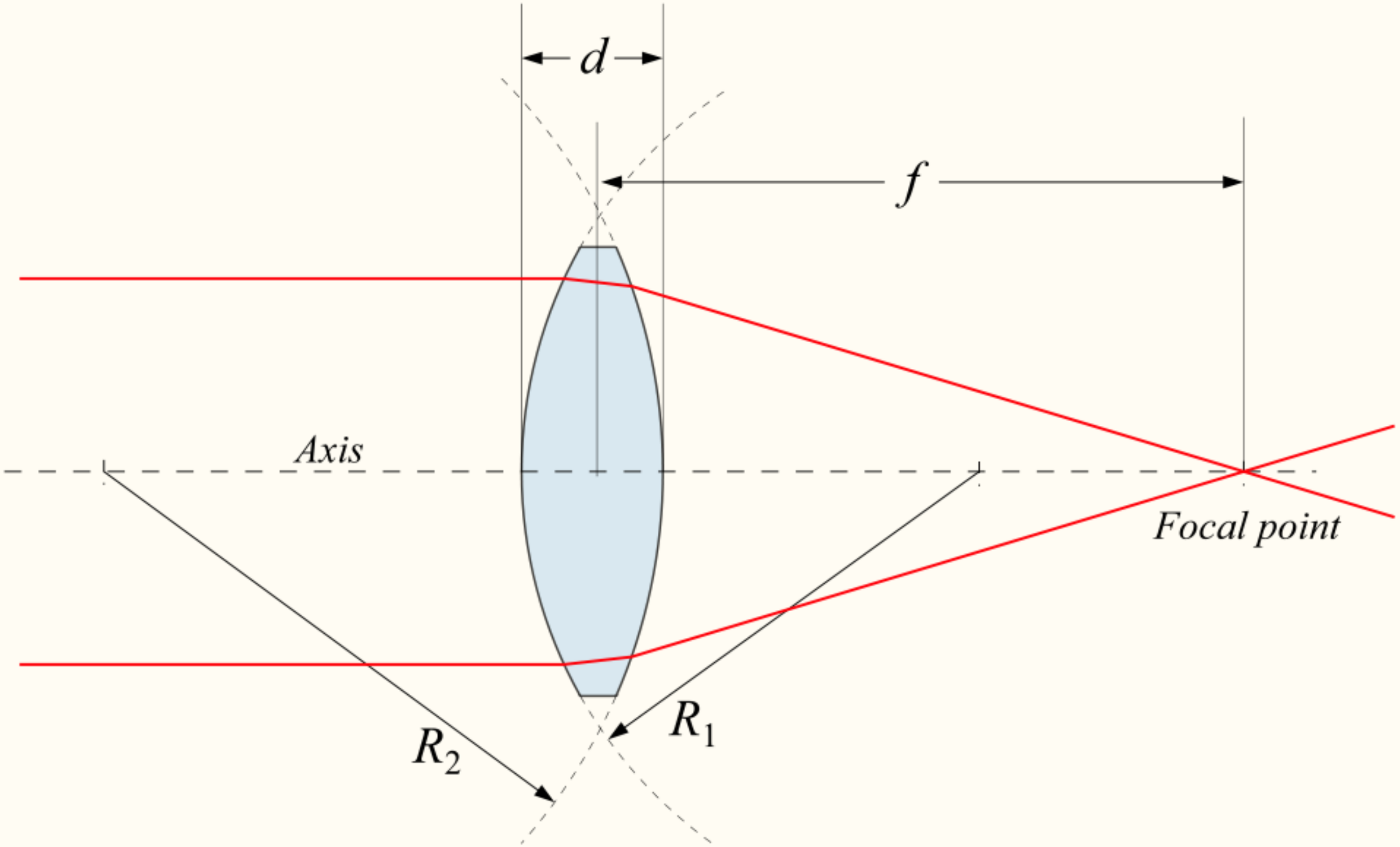
The Modern Camera

Pentax Spotmatic, ca. 1960s

Lenses

They let us get more light!!!





Positive (converging) lens

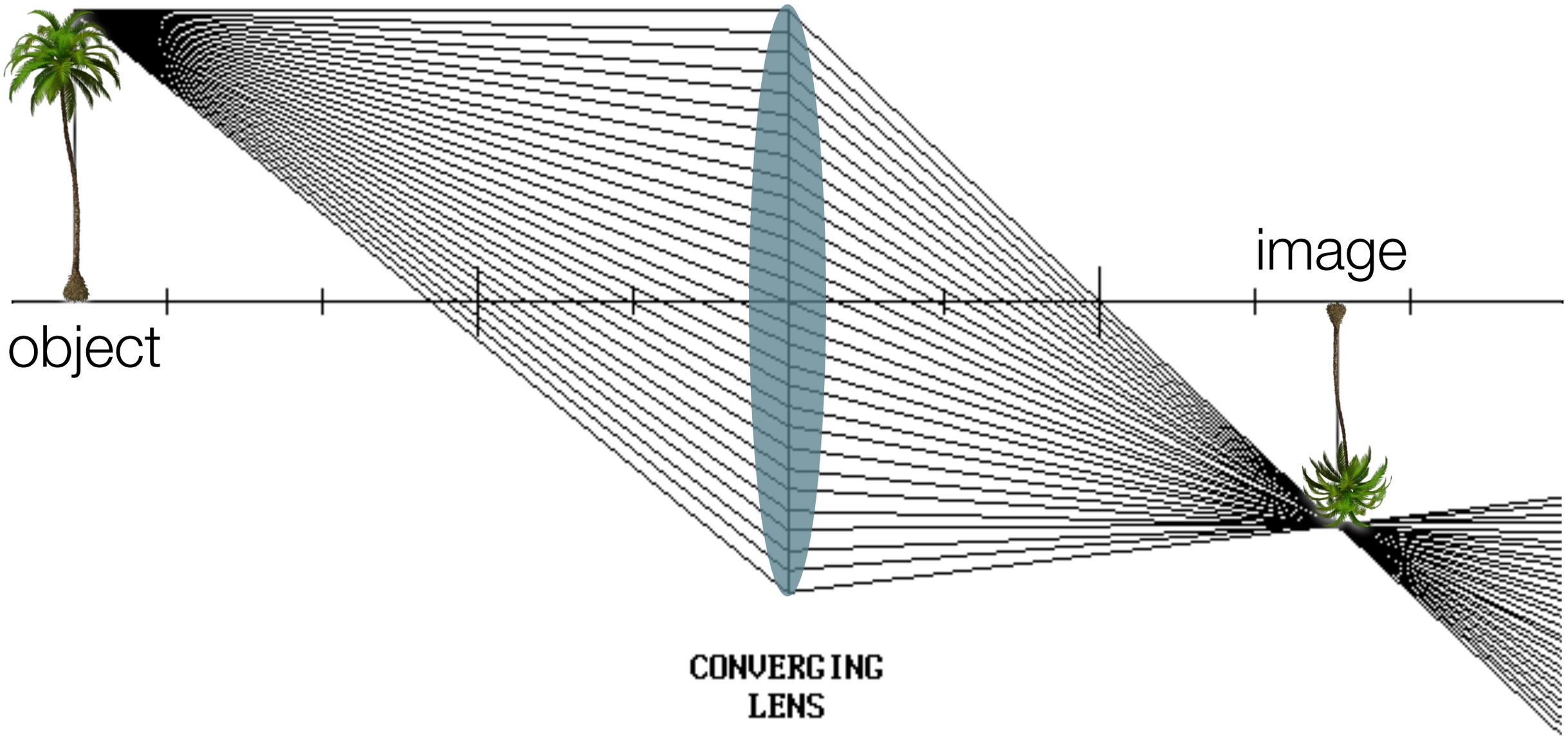
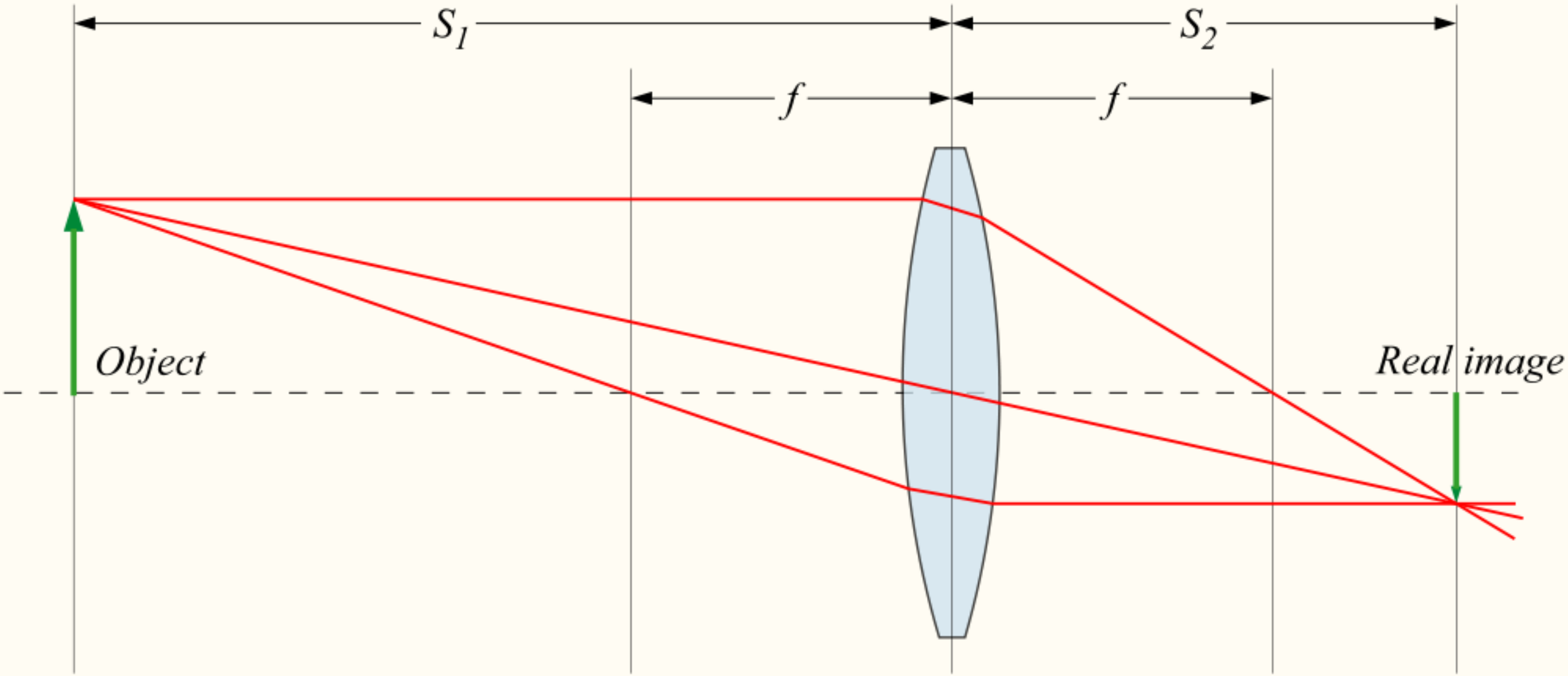


image
object
CONVERGING
LENS

Try taking a picture…

of this “Prairie Chicken”



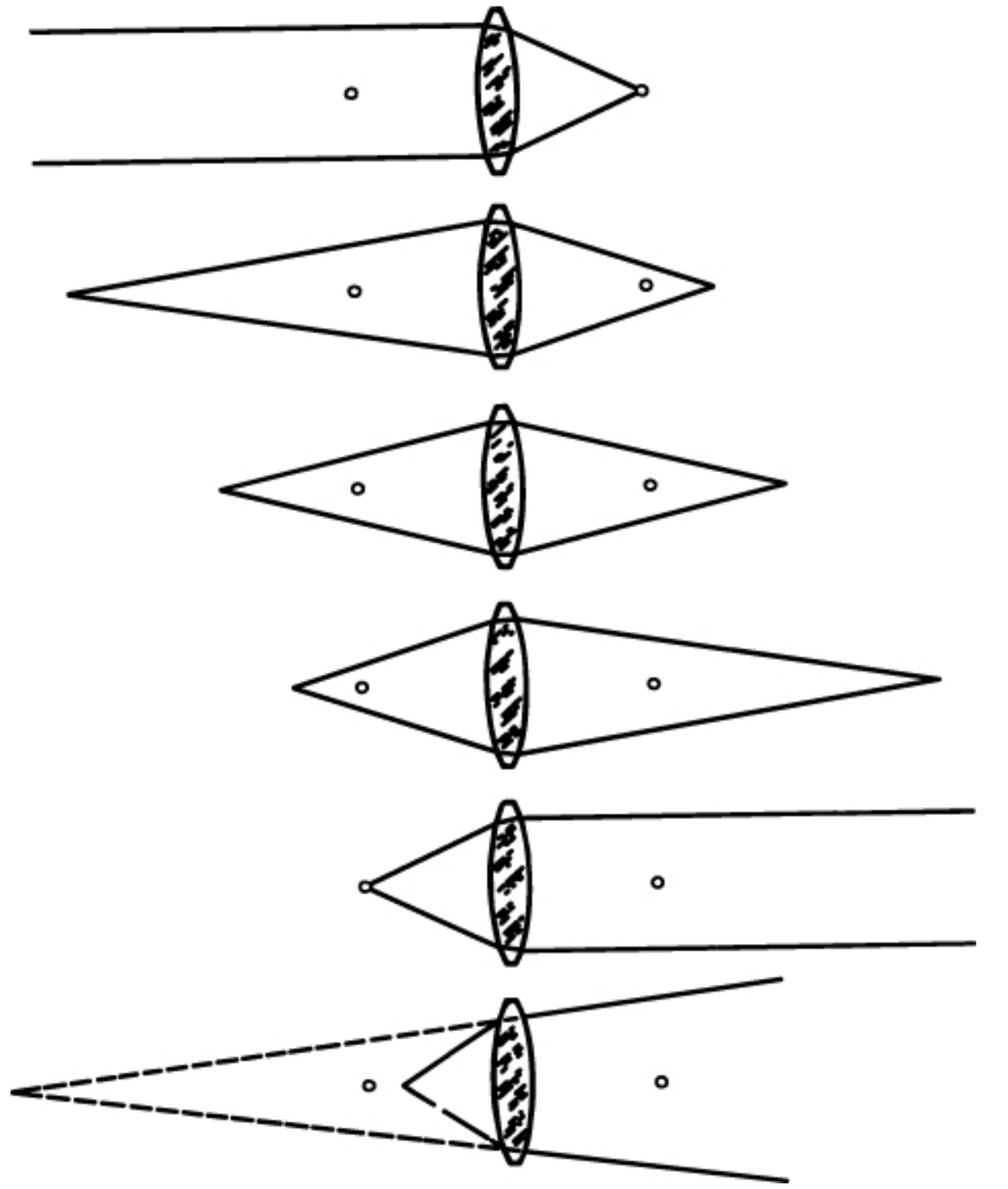
Thin Lens Equation

$$\frac{1}{S_1} + \frac{1}{S_2} = \frac{1}{f}$$

Circles of Confusion

Focusing

To focus on objects at various distances, move the lens relative to the image/film plane.



[courtesy of P. Hanrahan, Stanford University]

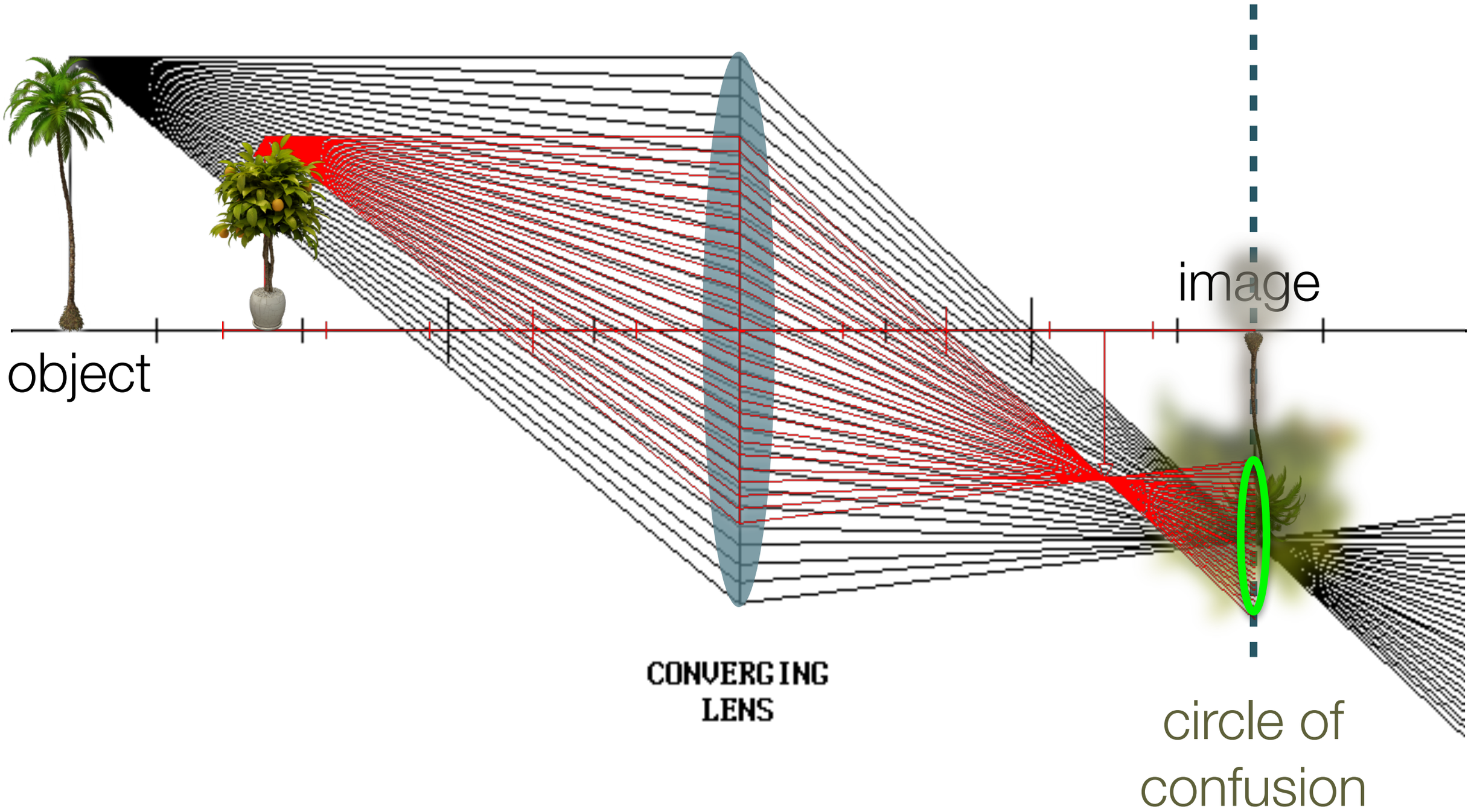


image
object
CONVERGING
LENS
circle of
confusion

How big is your picture?

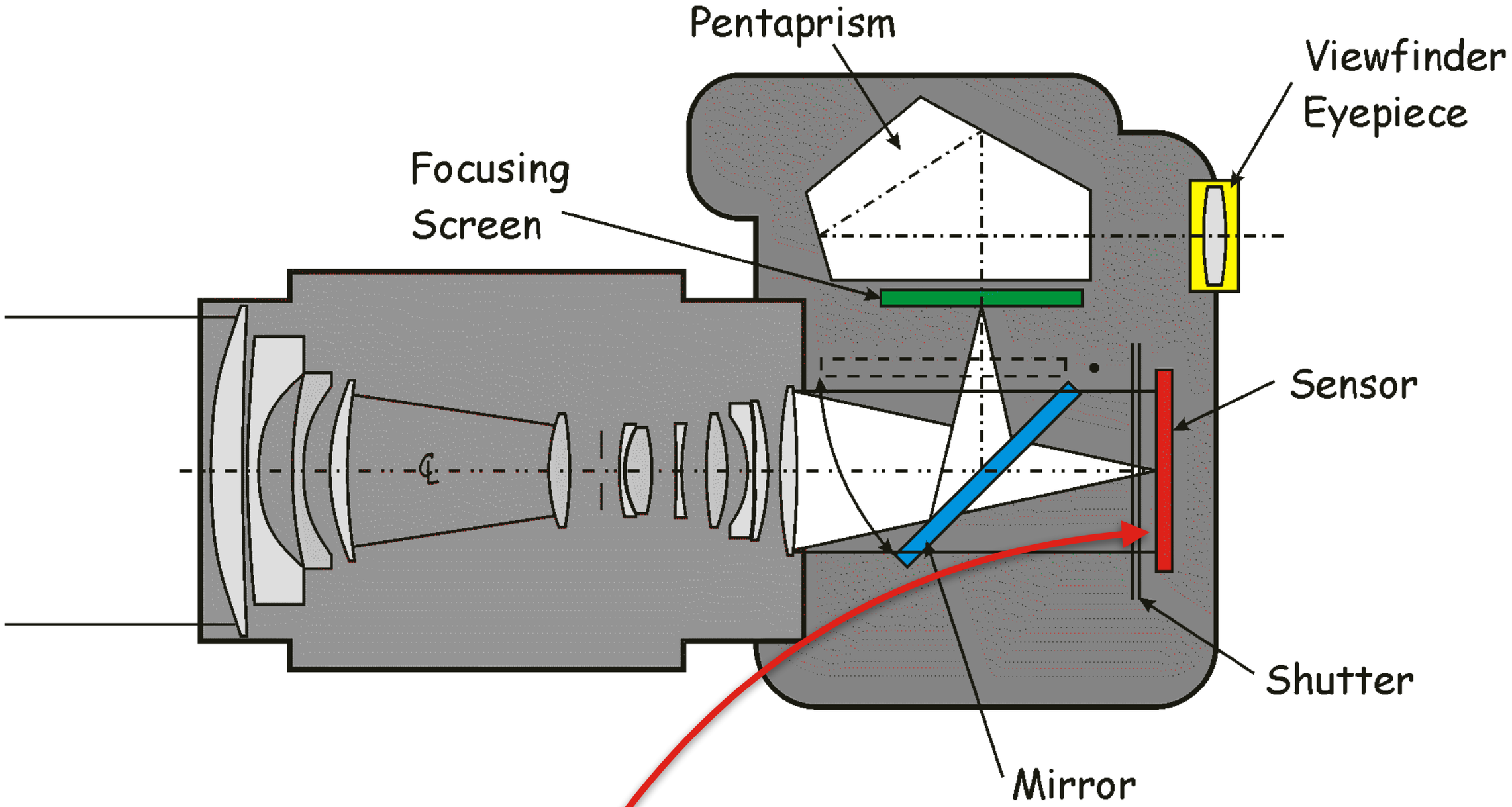
$$\frac{1}{S_1} + \frac{1}{S_2} = \frac{1}{f}$$

What determines your field of view?

Putting it all together…

Nikon D3 cutaway

The Goal



Get as much light onto here as possible!

[from 1derful.info]

[from pierretoscani.com]

The image is controlled by

focal length

aperture

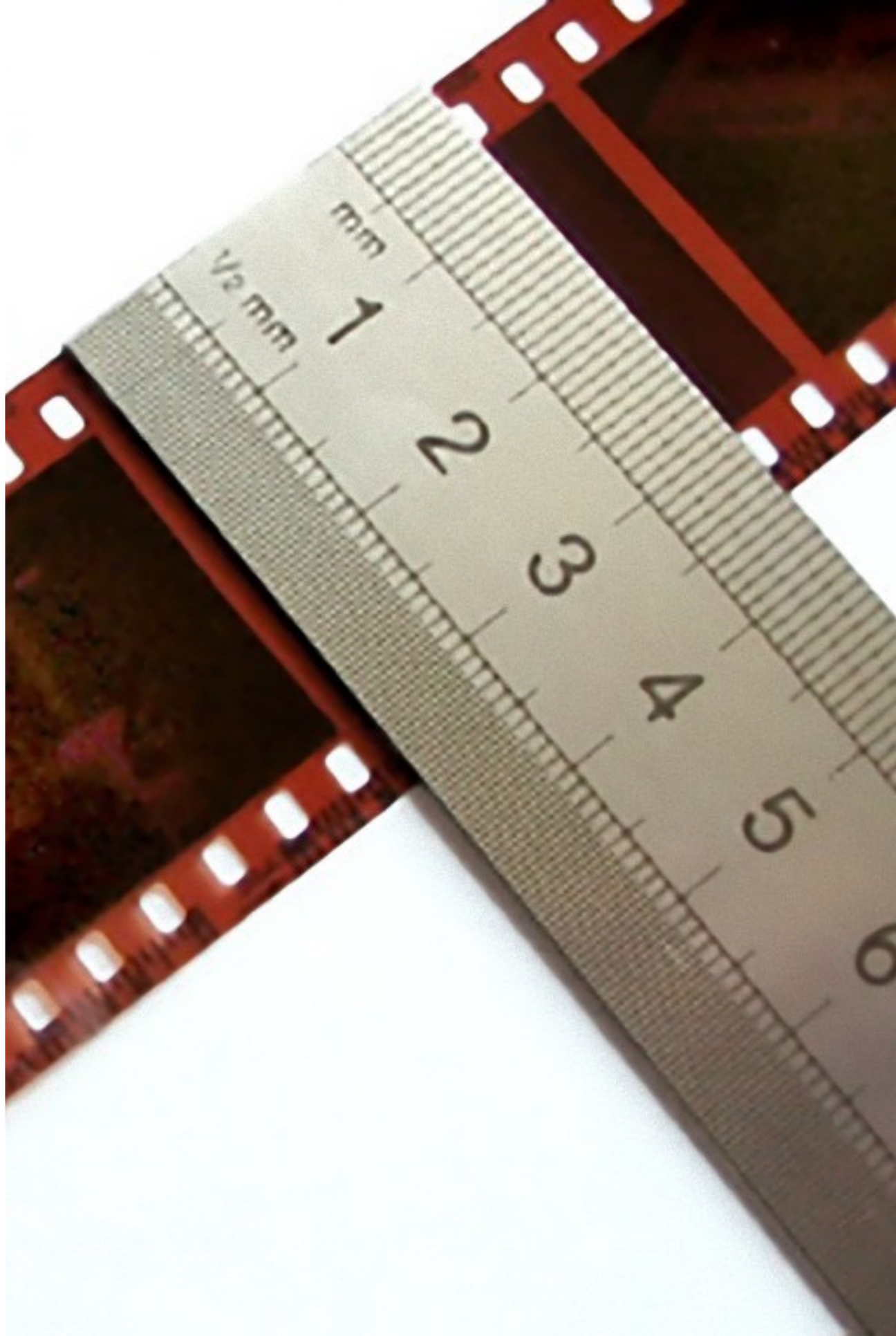
shutter speed

film sensitivity

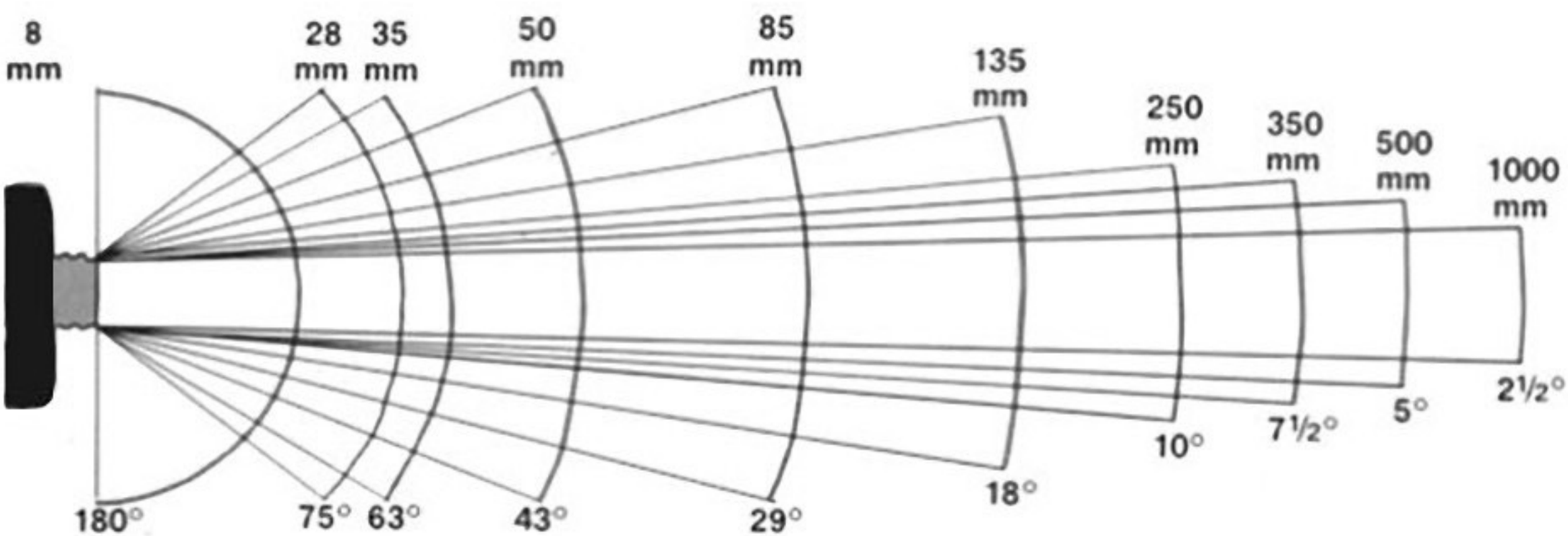
lens characteristics

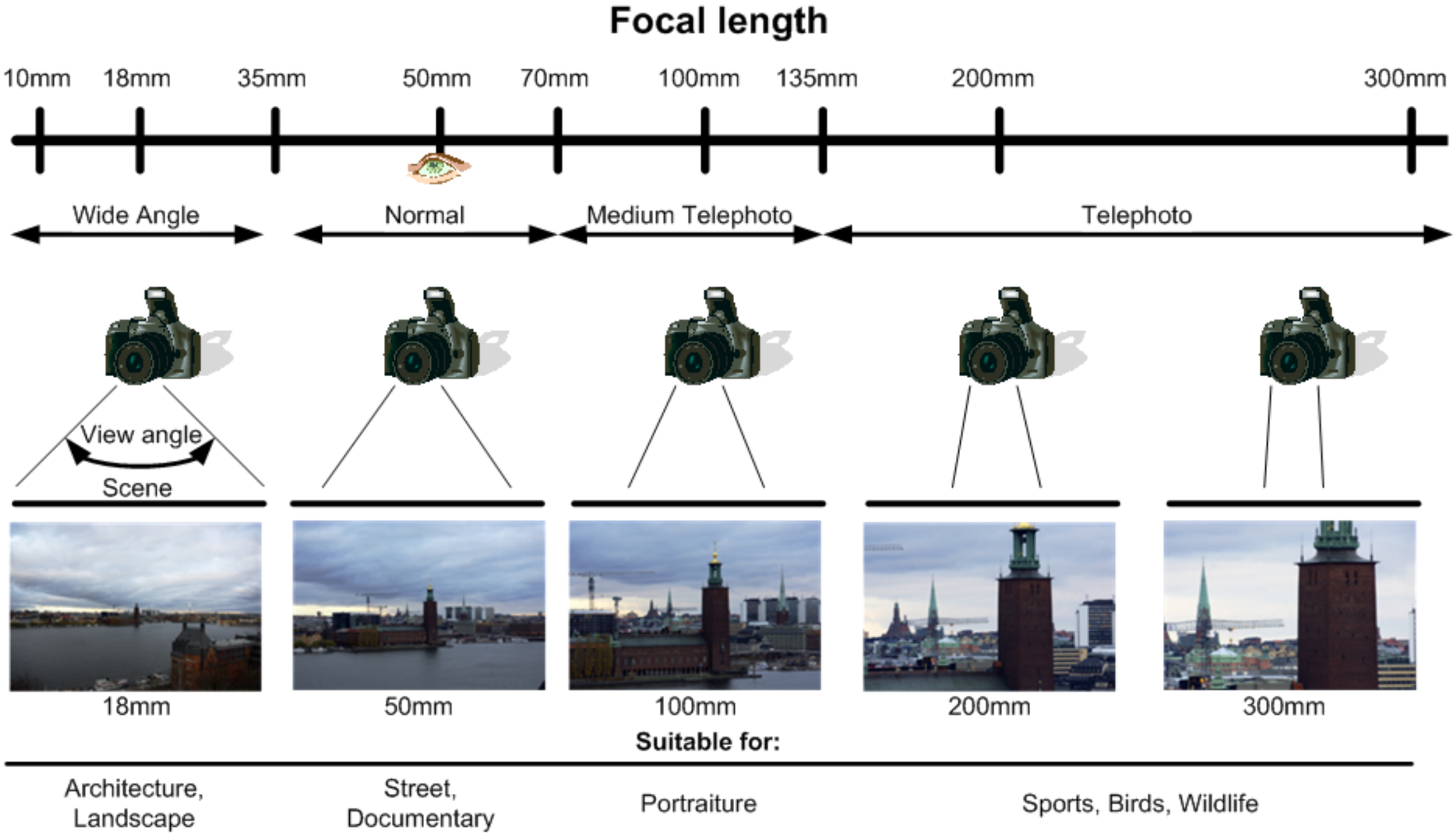
Focal Length

- You can’t change the size of your film!
  - nor your image sensor
- Longer focal length means moving the film back more
- Lens pupil gets smaller
- Longer focal length = smaller field of view



Focal Length on a 35mm Frame

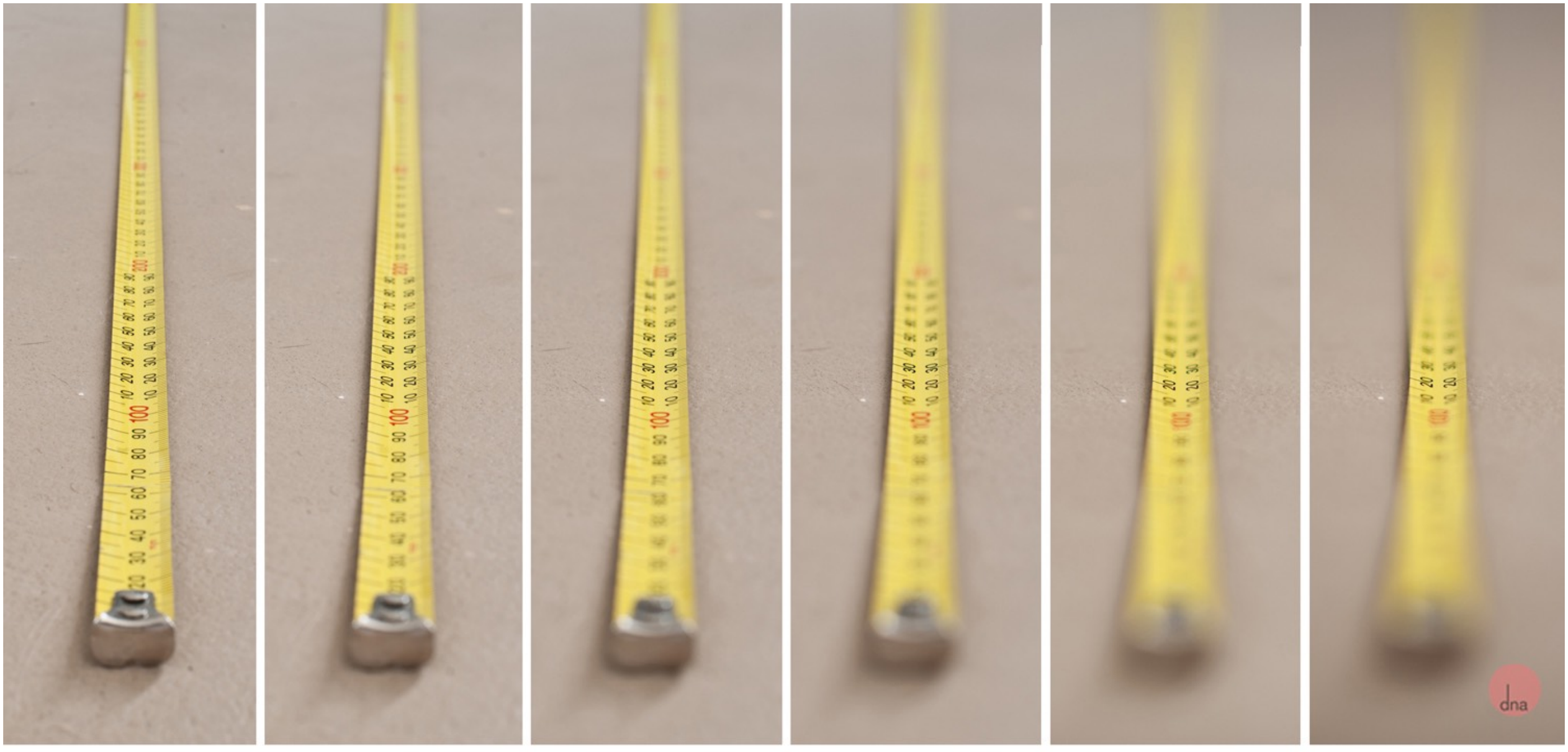


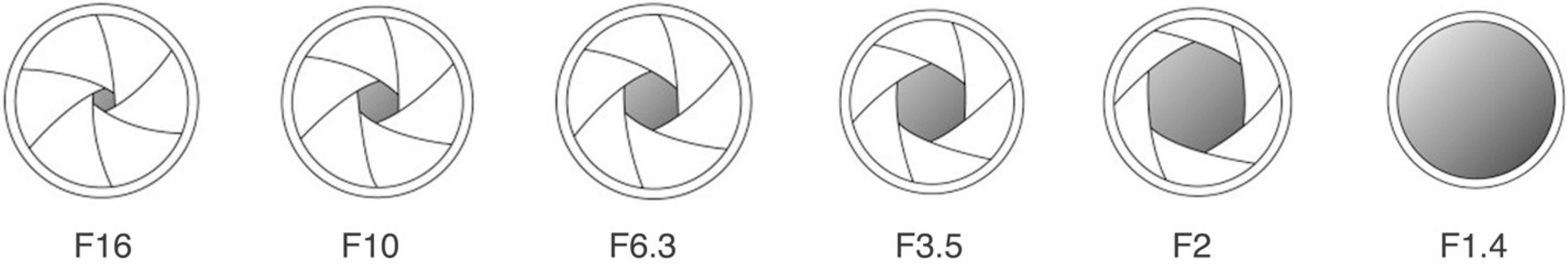


[from digital-photography-student.com]

Aperture

- Measured in *f-number*:
  - ratio of lens focal length to diameter of lens aperture
- Larger aperture lets more light in, but circle gets bigger
  - result is “depth of field” effect



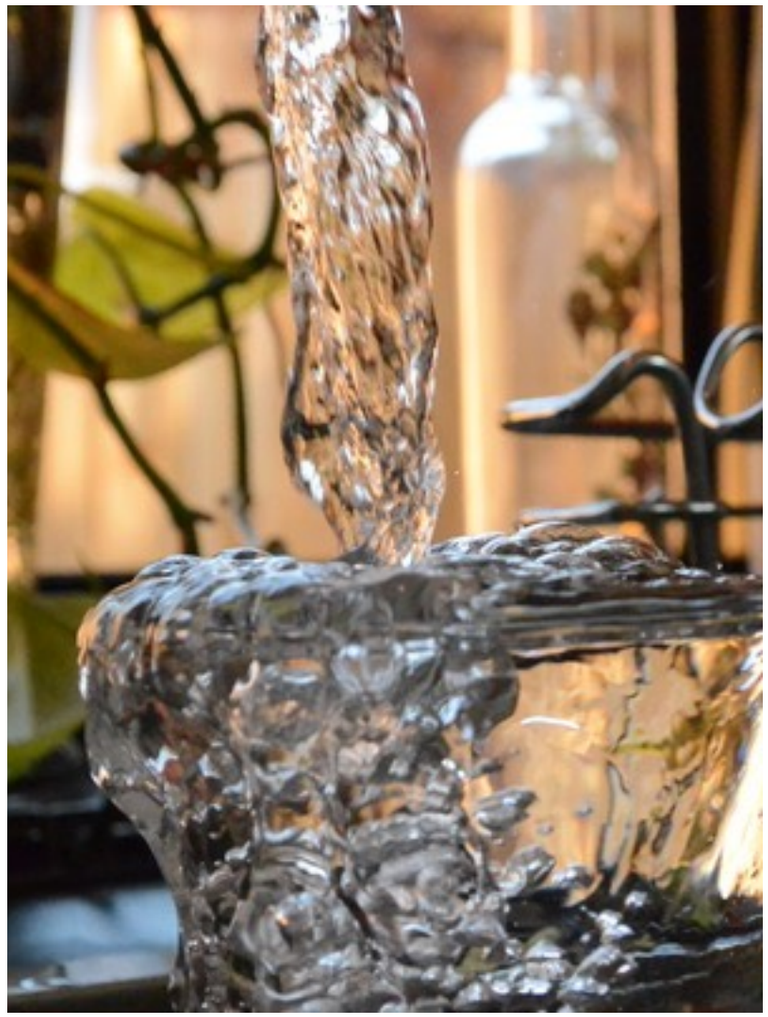


[from ormsdirect.co.za]

Shutter Speed

1/10 s

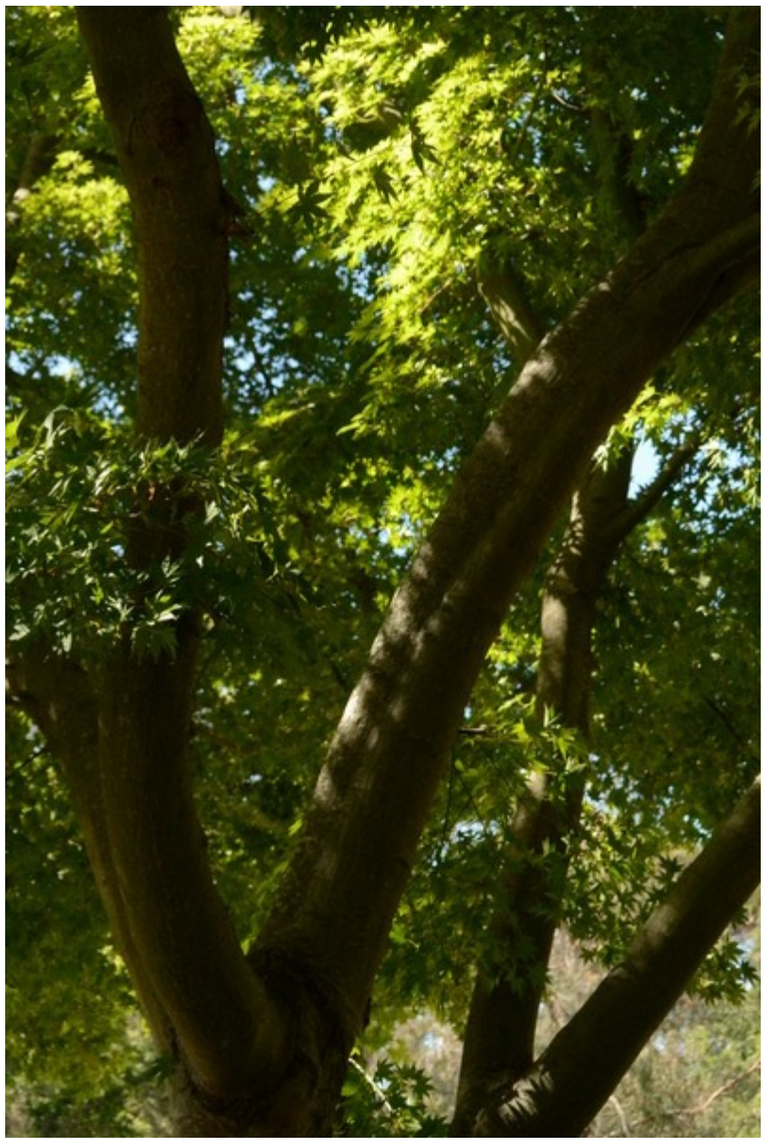
1/125 s



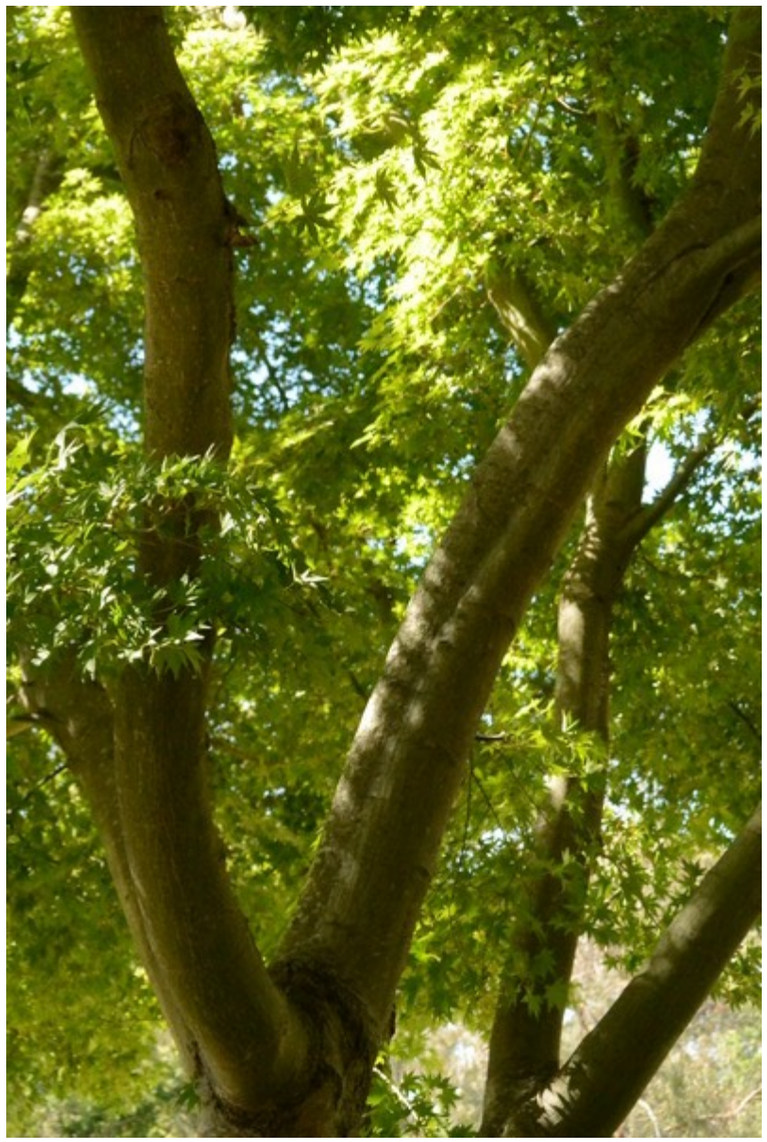
1/1000 s

[courtesy of K. Breeden, Stanford University]

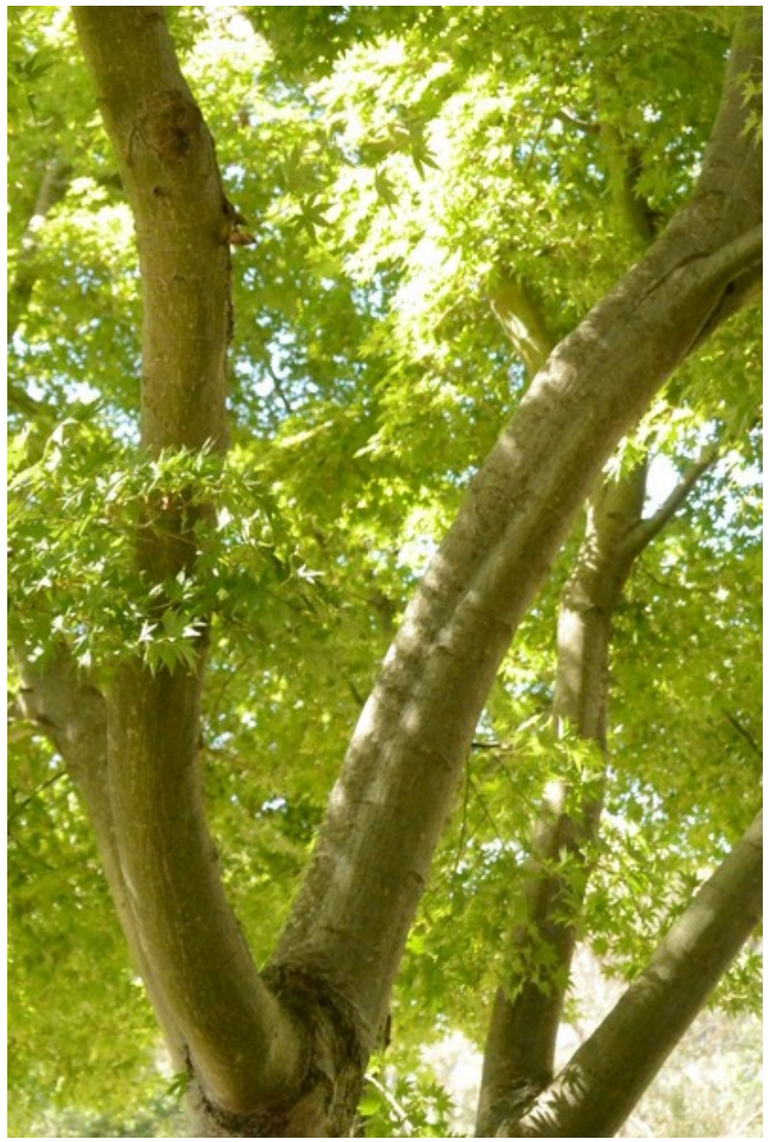
Film Sensitivity



ISO 800



ISO 1600



ISO 3200

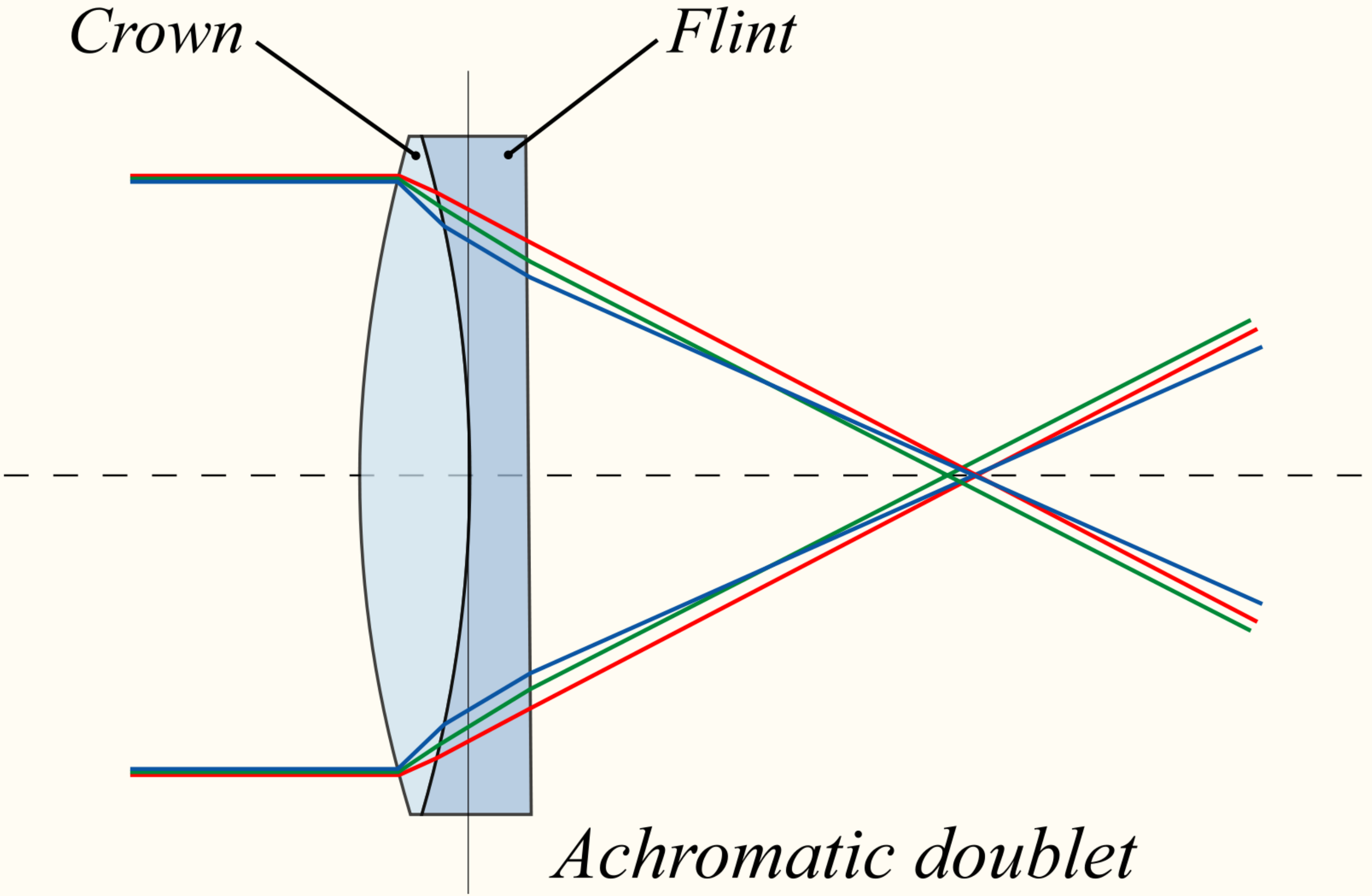
[courtesy of K. Breeden, Stanford University]

Lens Characteristics

good lens

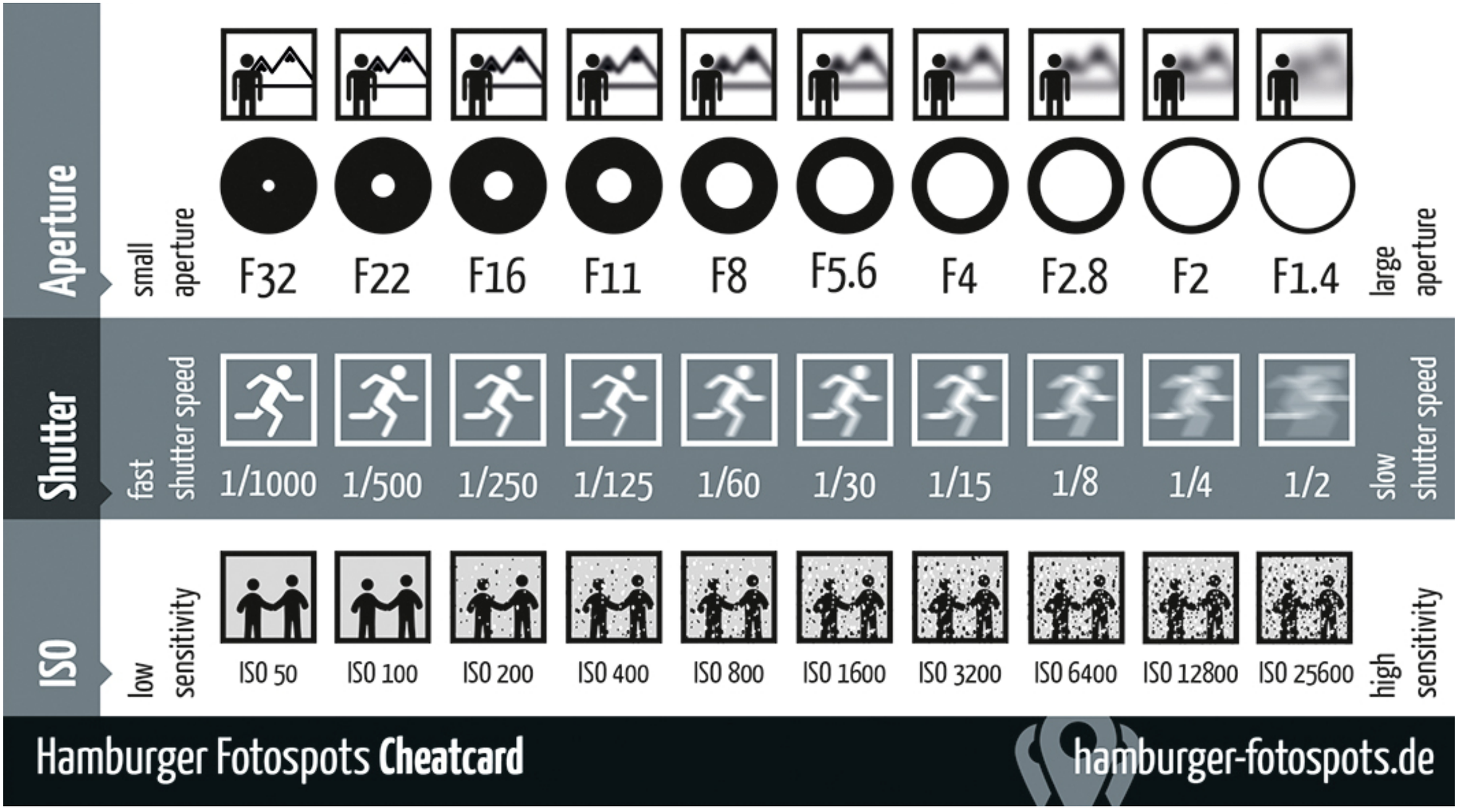
bad lens

Chromatic Aberration



Achromatic doublet

In Summary


Aperture
small aperture
F32
F22
F16
F11
F8
F5.6
F4
F2.8
F2
F1.4
large aperture
Shutter
fast shutter speed
1/1000
1/500
1/250
1/125
1/60
1/30
1/15
1/8
1/4
1/2
slow shutter speed
ISO
low sensitivity
ISO 50
ISO 100
ISO 200
ISO 400
ISO 800
ISO 1600
ISO 3200
ISO 6400
ISO 12800
ISO 25600
high sensitivity
Hamburger Fotospots Cheatcard
hamburger-fotospots.de

The Digital Revolution

ca. 1990s

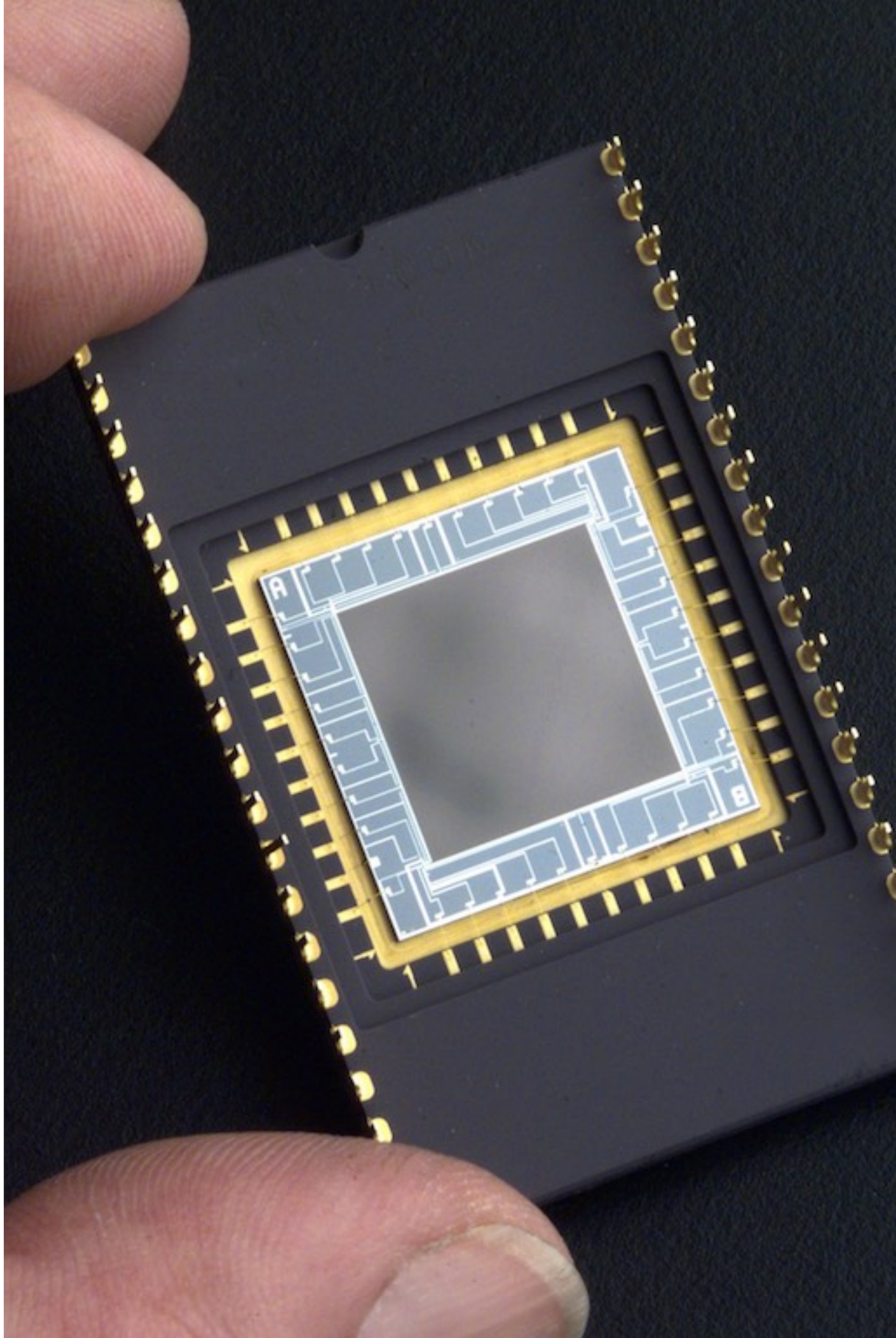
Is it always better to have more megapixels?

W. Boyle & G. Smith

AT&T Bell Labs, 1969

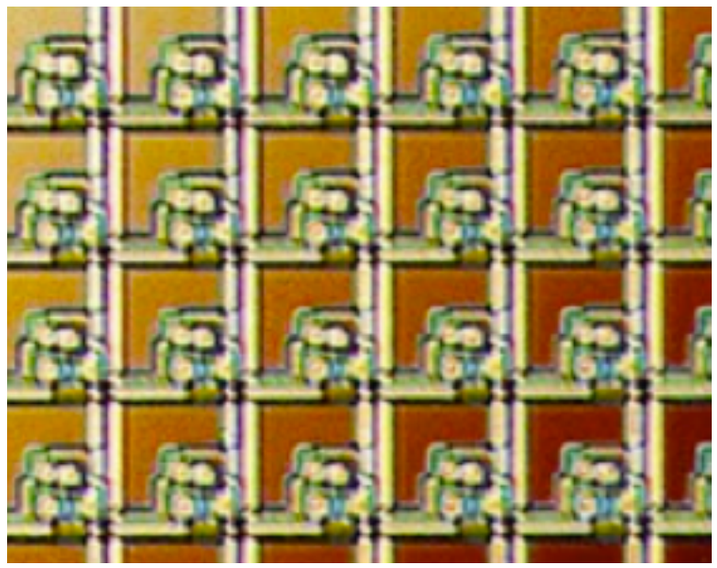
Charge-Coupled Devices

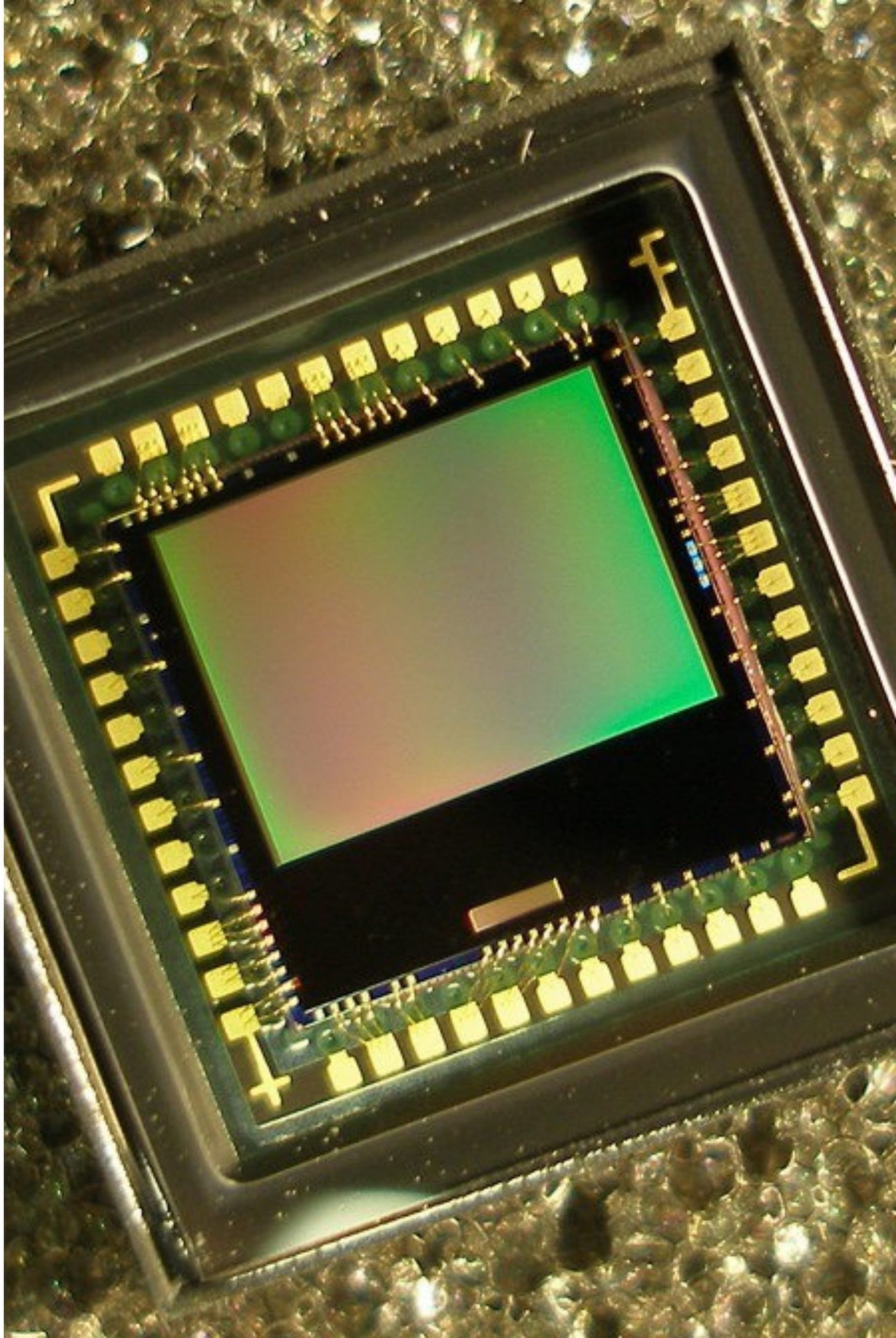
- Photons converted to electrical charge
- Stored in capacitor array
- More photons = greater charger
- Charges read from array to produce an image
- 2009 Nobel Prize in Physics



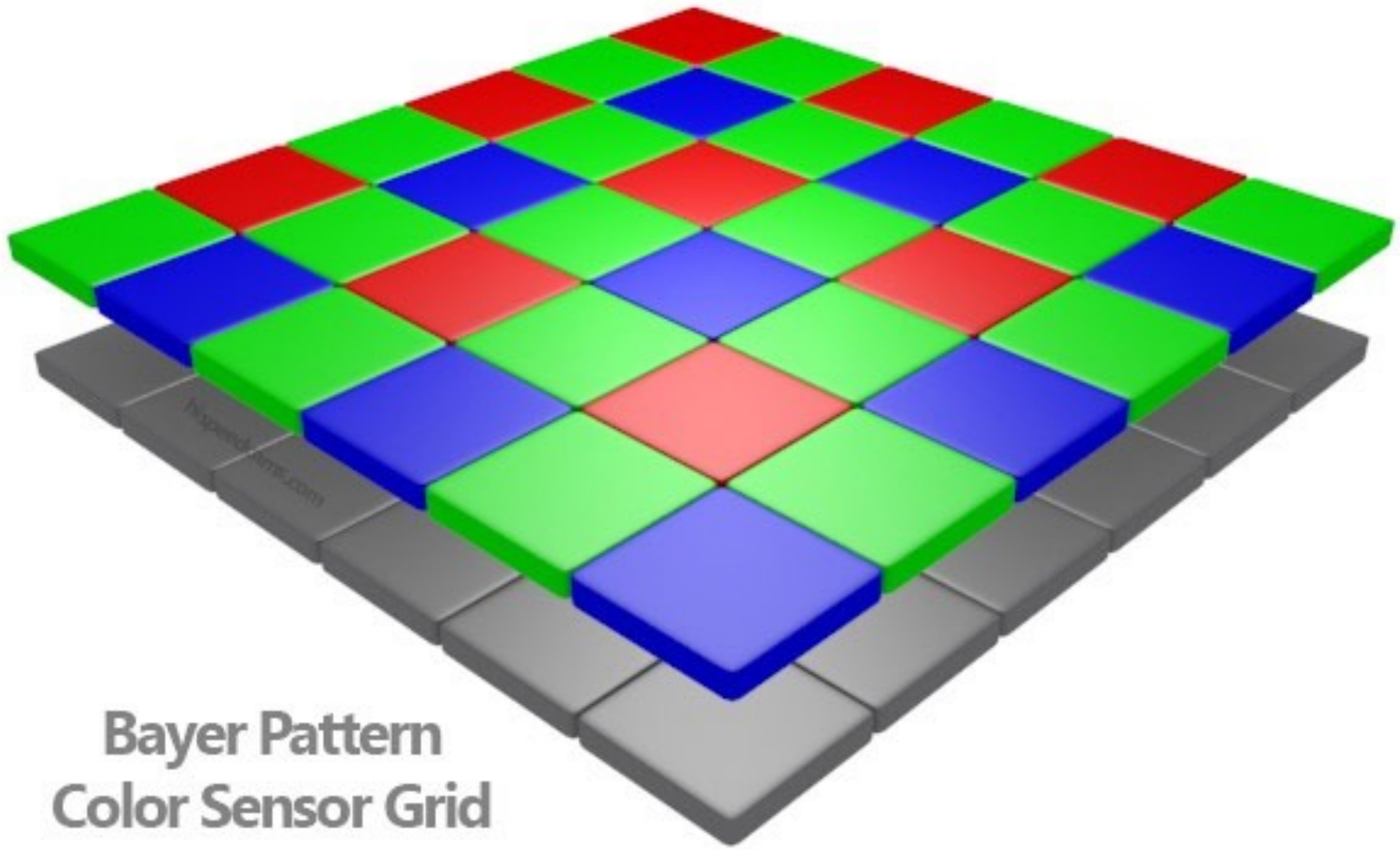
Active Pixel Sensors

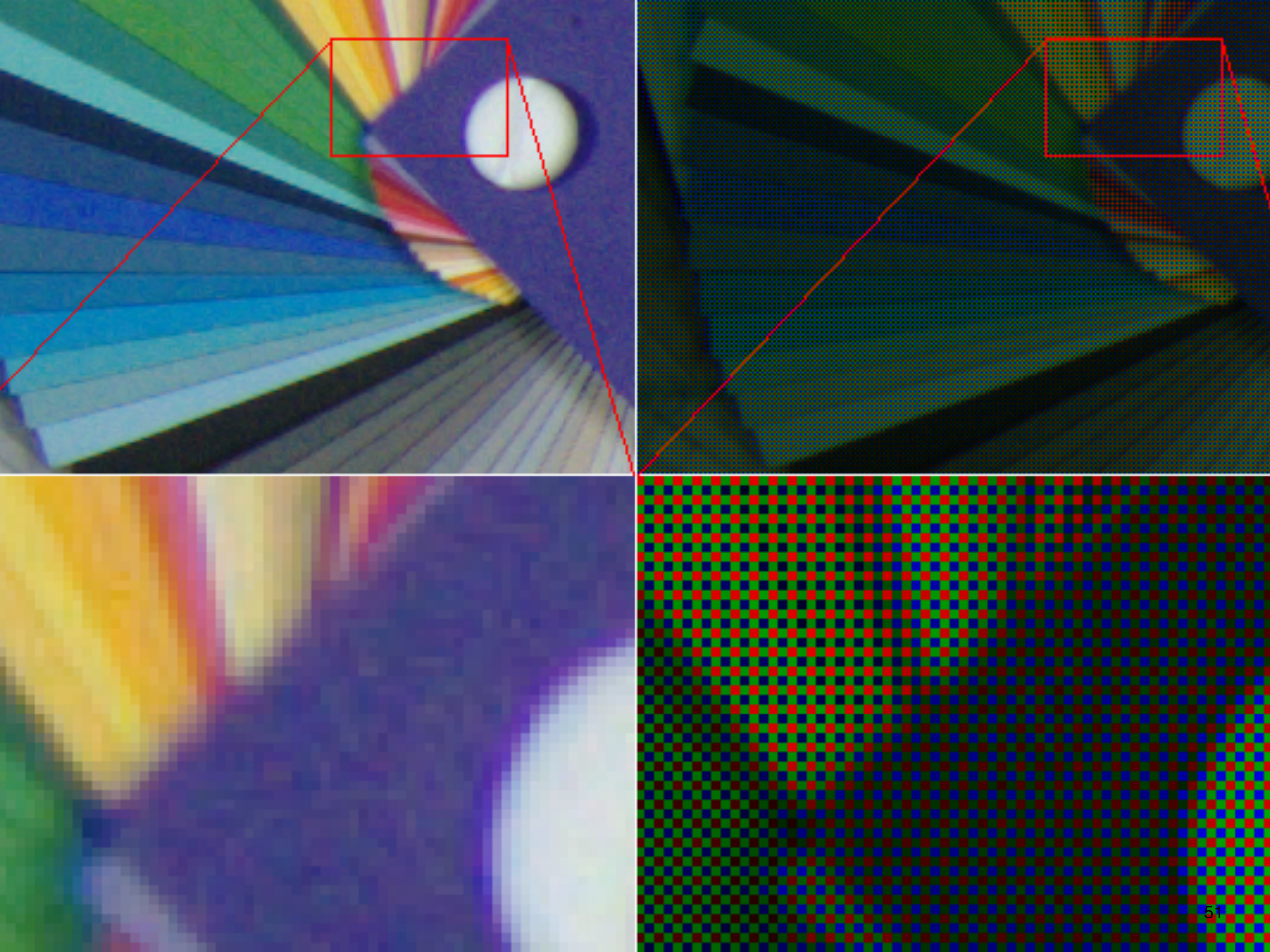
- CMOS sensors
- Each pixel has its own active amplifier
- Ability for continuous read
- Cheaper than CCD





Colour Images: Bayer Mosaic





Which one takes a better picture?

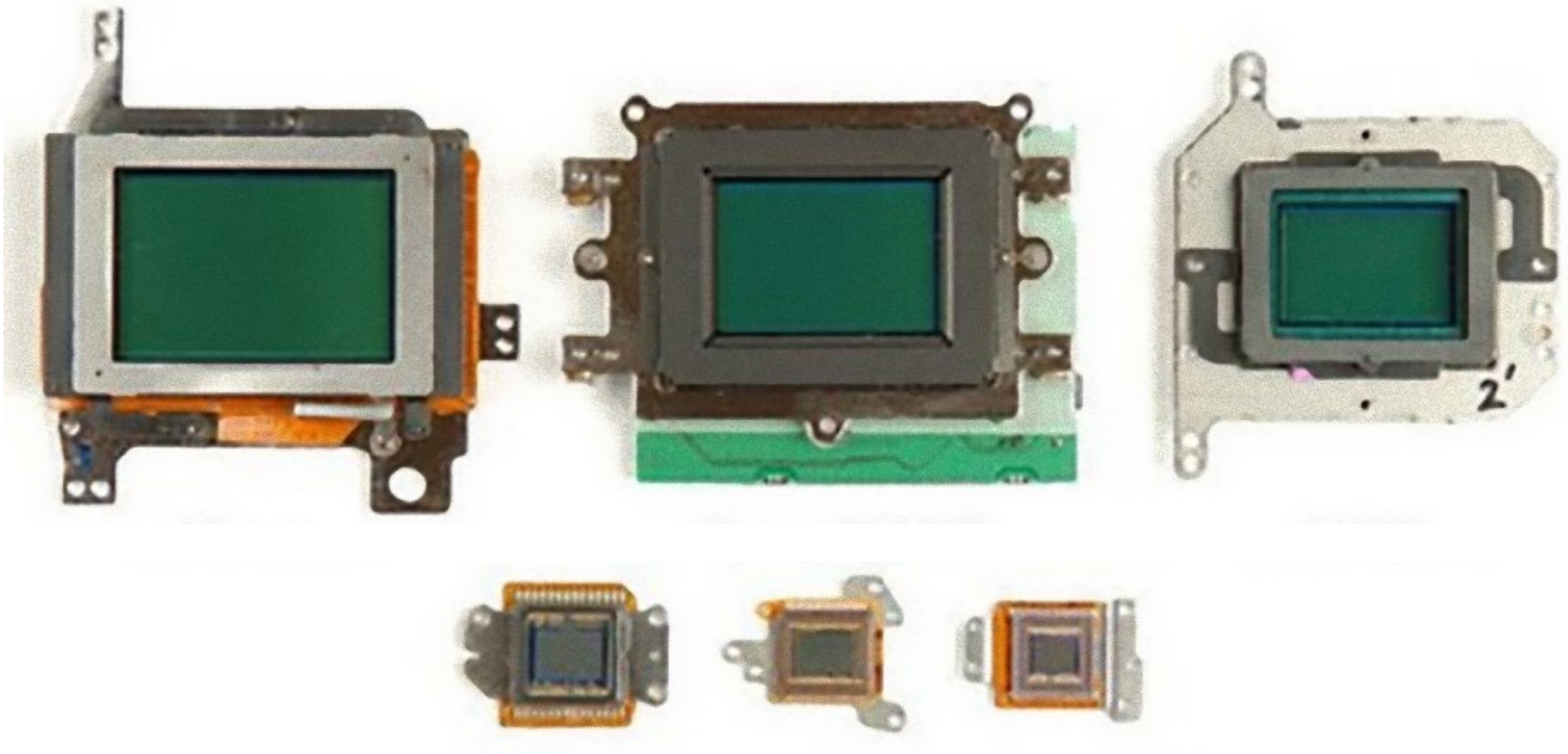
Nikon D100

6.1 megapixels

iPhone 6s

12 megapixels

Digital Camera Image Sensors



[from rickclinephotography.com]

Lytro Illum - where did all the dials and buttons go?

Things to Remember

- The **camera obscura**, or pinhole camera, allows us to capture images of the world in **perspective**

- Using a **lens** allows us to gather **more light**
  - but introduces a plethora of variables to account for

- CCD/CMOS **sensors** allow us to capture **digital images**

- Understanding how real-world images are formed helps us to synthesize artificial, but realistic digital images