Computational Photography

Prof. Feng Liu

Spring 2022

http://www.cs.pdx.edu/~fliu/courses/cs510/

03/31/2022

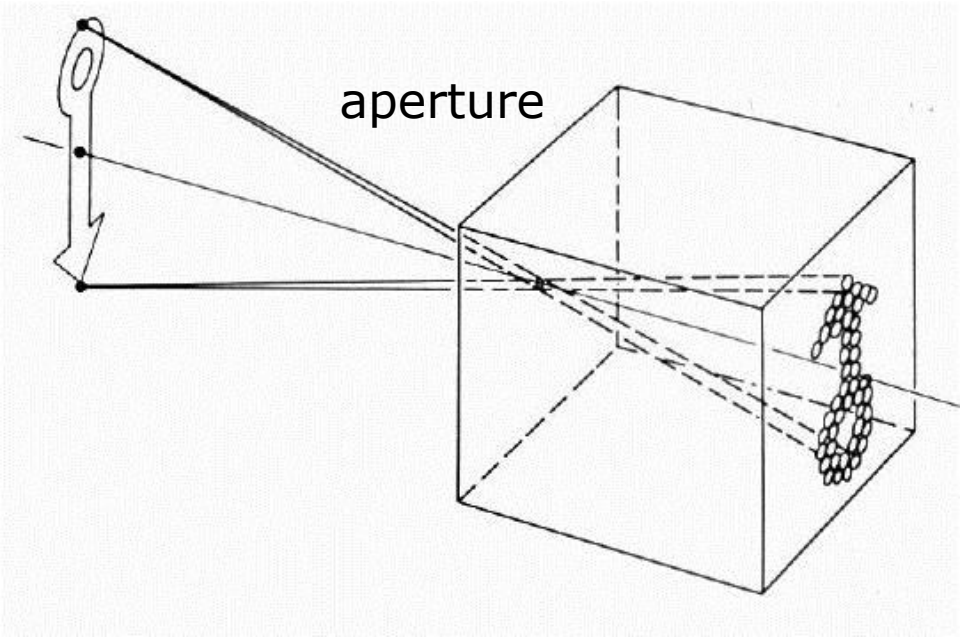
Last Time

- Course overview
  - Admin. Info
  - Computational Photography

Today

- Digital Camera
  - History of Camera
  - Controlling Camera
- Photography Concepts
- Reading assignment
  due 4 pm every Thursday
  - Email to lizhan@pdx.edu

Pinhole-Camera

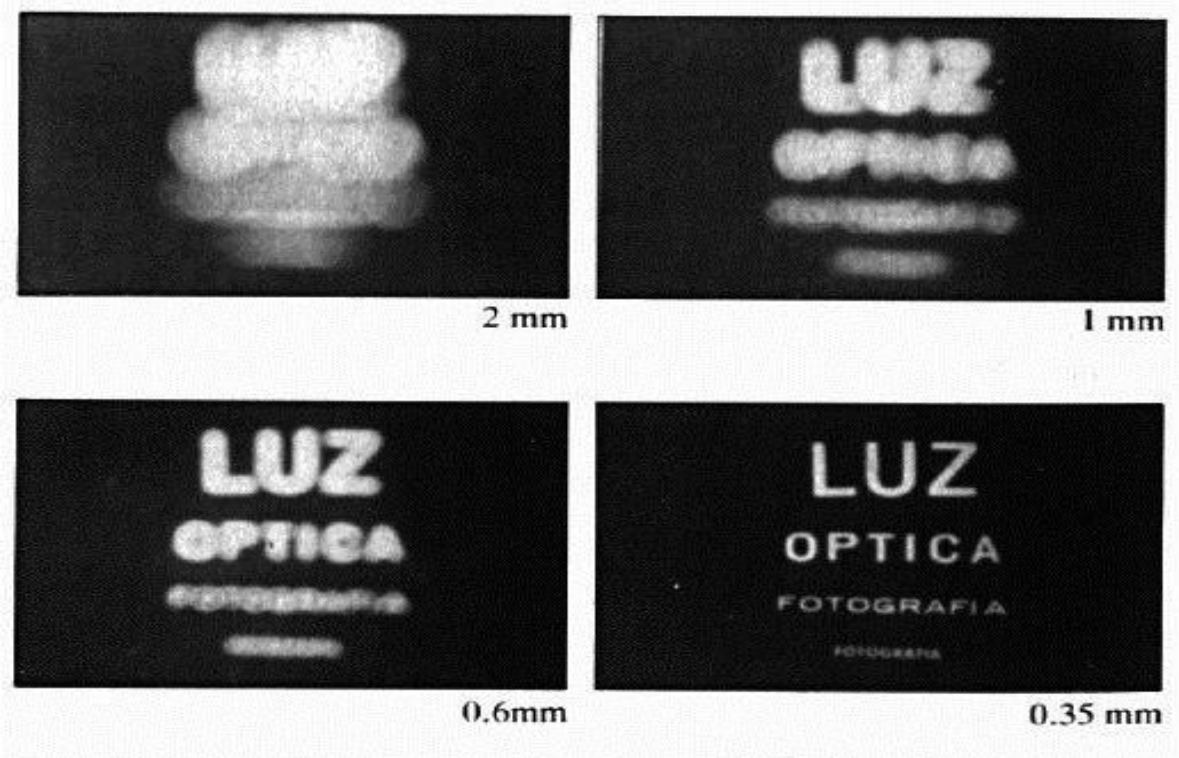


- The first camera
  - 5th B.C. Aristotle, Mozi (Chinese: 墨子)
  - How does the aperture size affect the image?

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

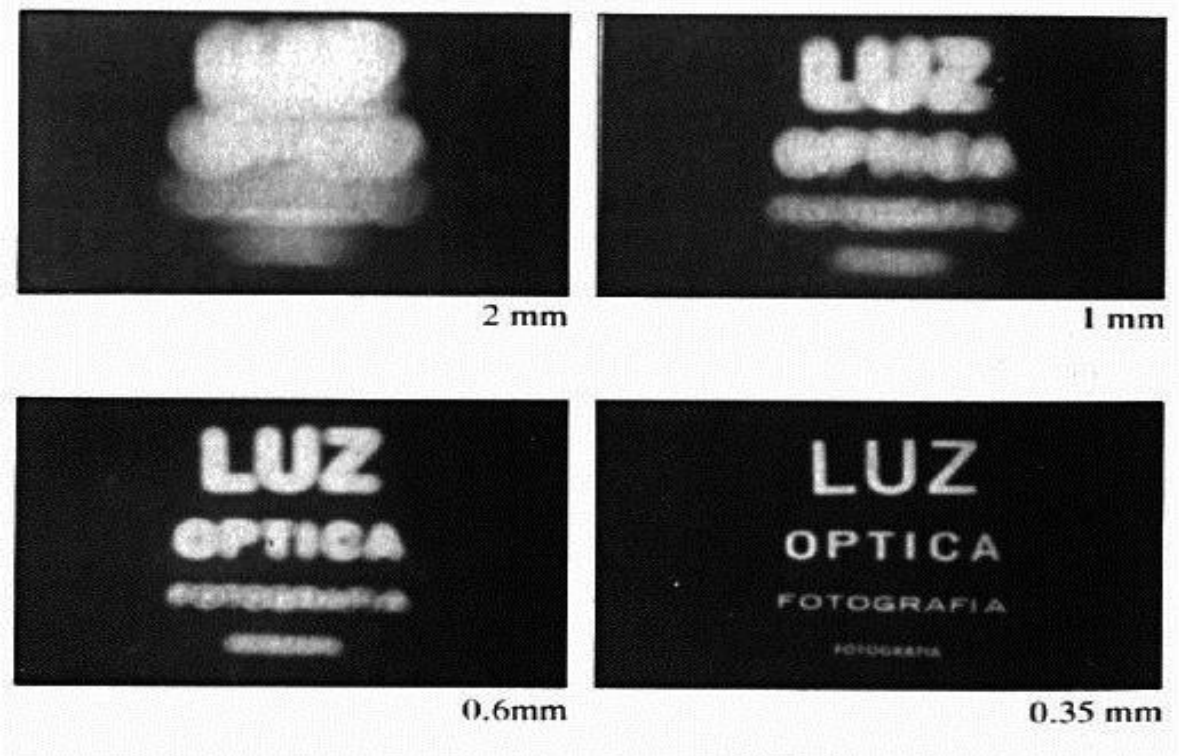
Modified from slides provided by L. Zhang

Shrinking the aperture



Slide credit: L. Zhang

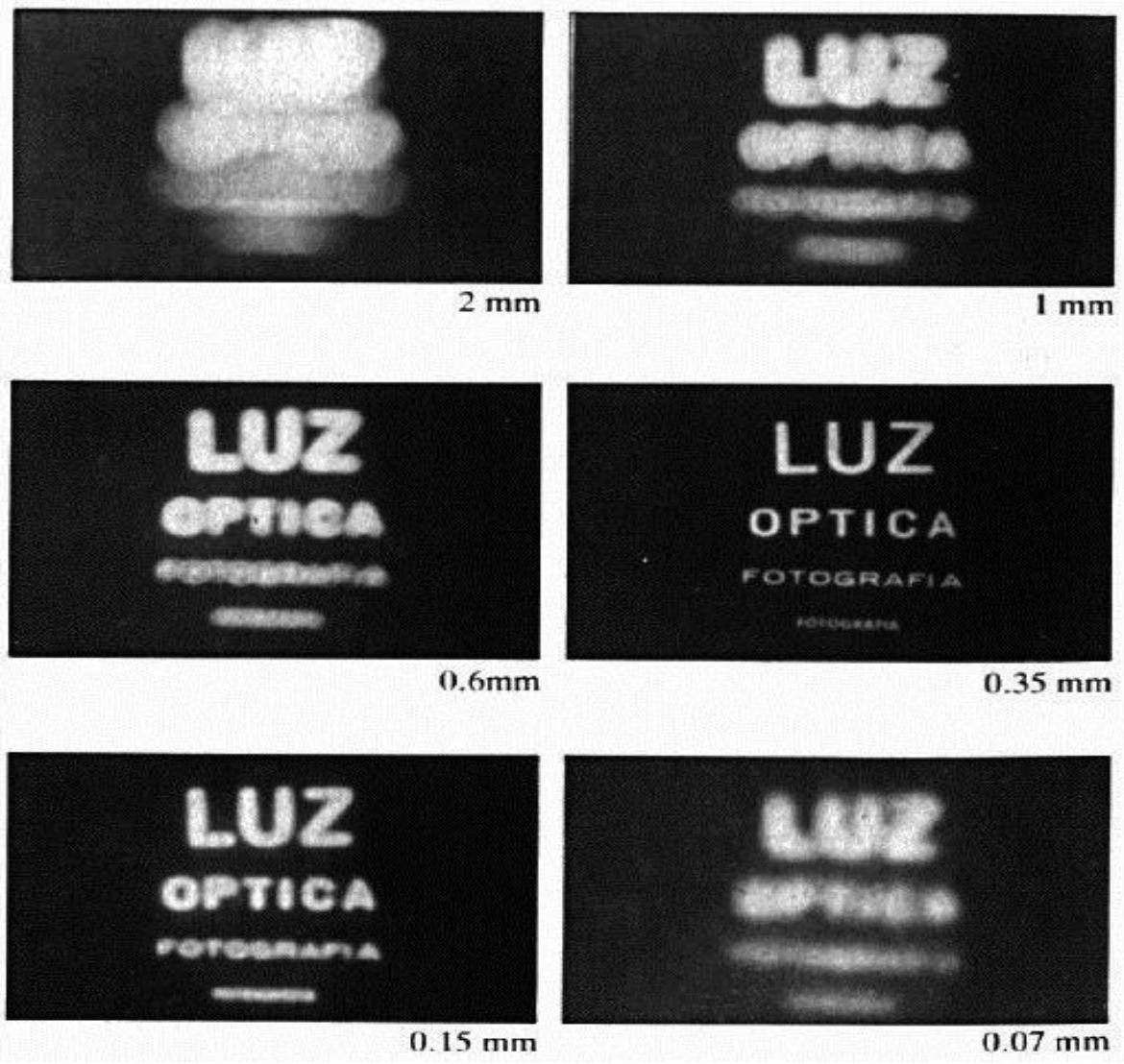
Shrinking the aperture



- Why not make the aperture as small as possible
  - Less light gets through
  - *Diffraction* effects

Slide credit: L. Zhang

Shrinking the aperture



Slide credit: L. Zhang

First production camera?

- 1839. Daguerrotype

Daguerreotype of Louis Daguerre in 1844
by Jean-Baptiste Sabatier-Blot

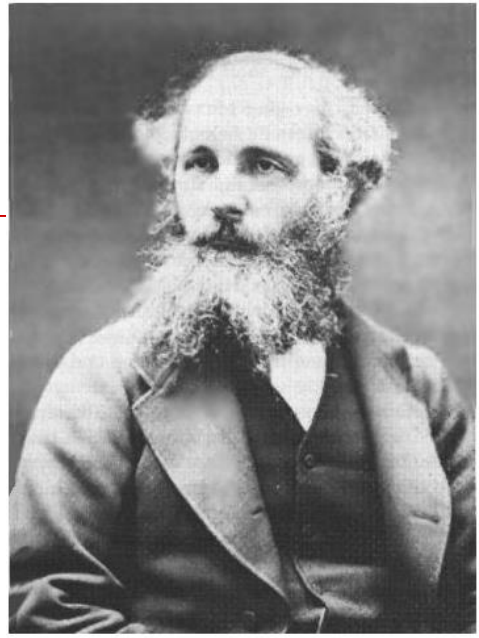
Slide credit: F. Durand

Beginning of hobby photography?

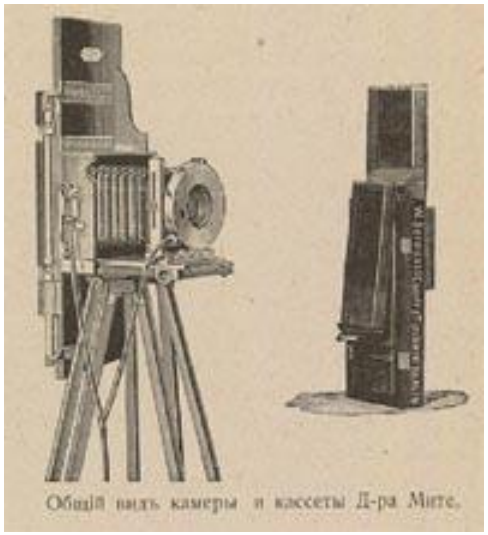
- 1900 Kodak Brownie

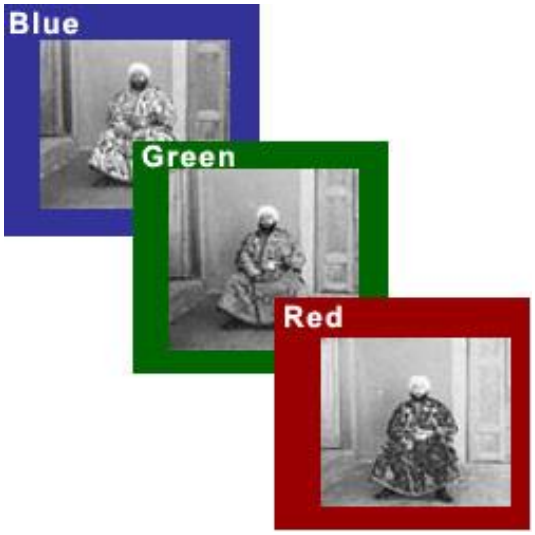
Slide credit: F. Durand

Color photography



- Who did the first color photography?
  - Maxwell (yes, the same from the EM equations)
- When? 1861
- Oldest color photos still preserved: Prokudin-Gorskii
  - http://www.loc.gov/exhibits/empire/





Slide credit: F. Durand

Prokudin-Gorskii

- Digital restoration

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

Slide credit: F. Durand

Prokudin-Gorskii

Slide credit: F. Durand

Prokudin-Gorskii

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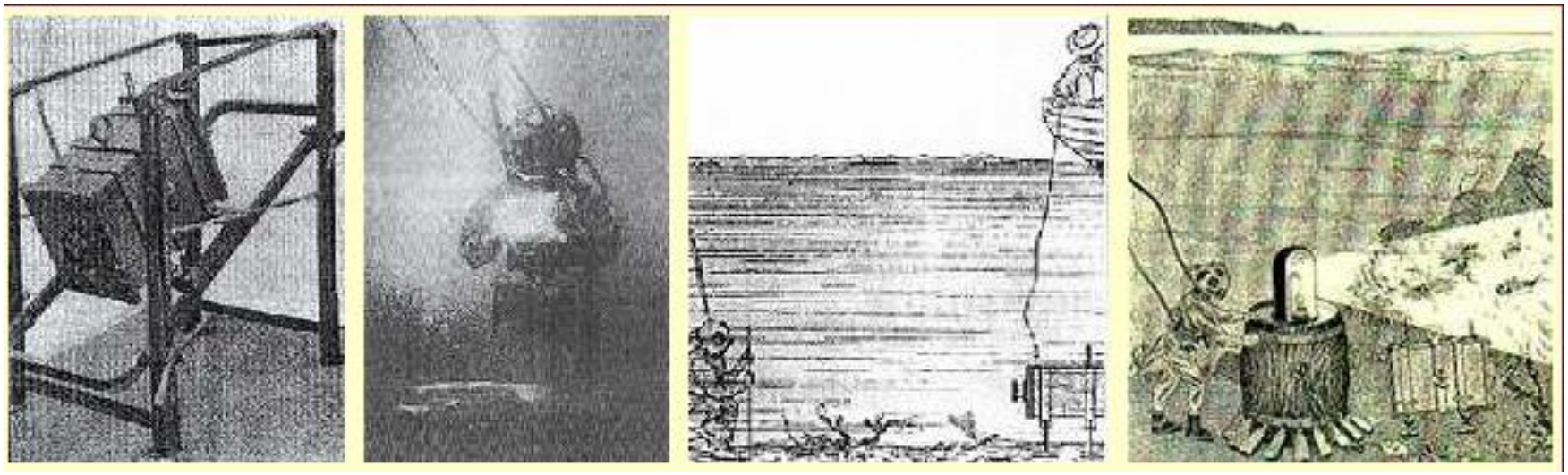
Flash bulb?

- As opposed to powder systems
- Boutan-Chauffour - 1893
- For underwater photography



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Instant photography?

- 1947, Edwin Land (Polaroid founder)

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Autofocus

- 1978, Konica

- 1981 Pentax ME-F.

- Canon T80 1985
  - Canon AL1 had focus assist but no actuator

- Minolta Maxxum 1985 (AF in body)

Slide credit: F. Durand

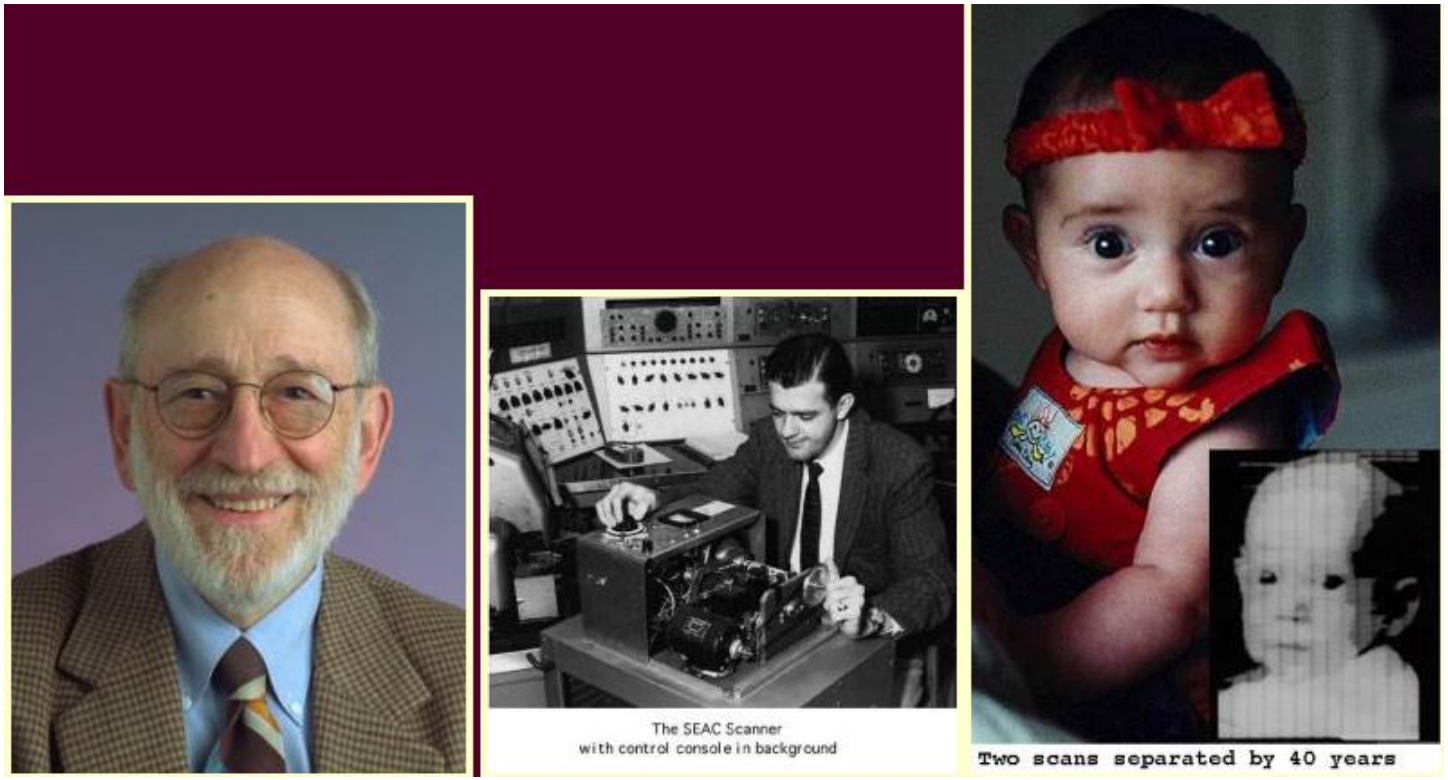
First microprocessor in a camera

- Canon AE-1 1976

Slide credit: F. Durand

First scanned photo?

- 1957, Russell A. Kirsch of the National Bureau of Standards, 176x176



Slide credit: F. Durand

CCD technology?

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

Slide credit: F. Durand

CCD camera

"Michael Tompsett applied the Charge-Coupled Device CCD specifically to imaging application and, along with his team, developed a series of CCD Ccameras. The photo above, is the first color pixel image, probably of his Tompsett's wife."[1]

[1] http://www.bell-labs.com/about/awards/2009-nobel-prize-physics/

CCD in astronomy

- 1979, 1-meter telescope at Kitt Peak National Observatory, 320x512, great for dim light
- Nitrogen cooled

Slide credit: F. Durand

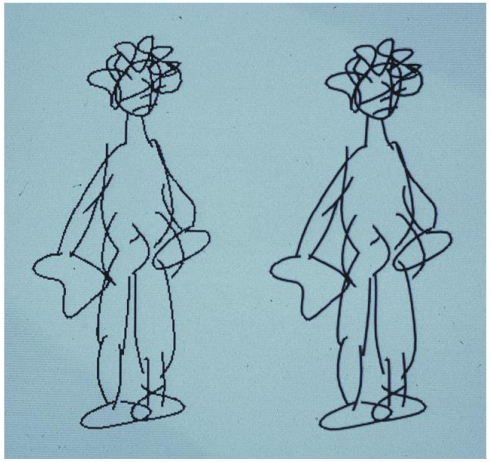
Computer graphics?

- Computers to create image
  - Sketchpad, 1961, Ivan Sutherland

Slide credit: F. Durand

Paint program

- Dick Shoup: SuperPaint [1972-73]
  - 8 bits
  - http://www.rgshoup.com/prof/SuperPaint/
- Alvy Ray Smith (Pixar co-founder): Paint [1975-77]
  - 8 bits then 24 bits
  - http://www.alvyray.com/Awards/AwardsMain.htm
  - http://www.alvyray.com/Bio/BioMain.htm
- Tom Porter: Paint



Slide credit: F. Durand

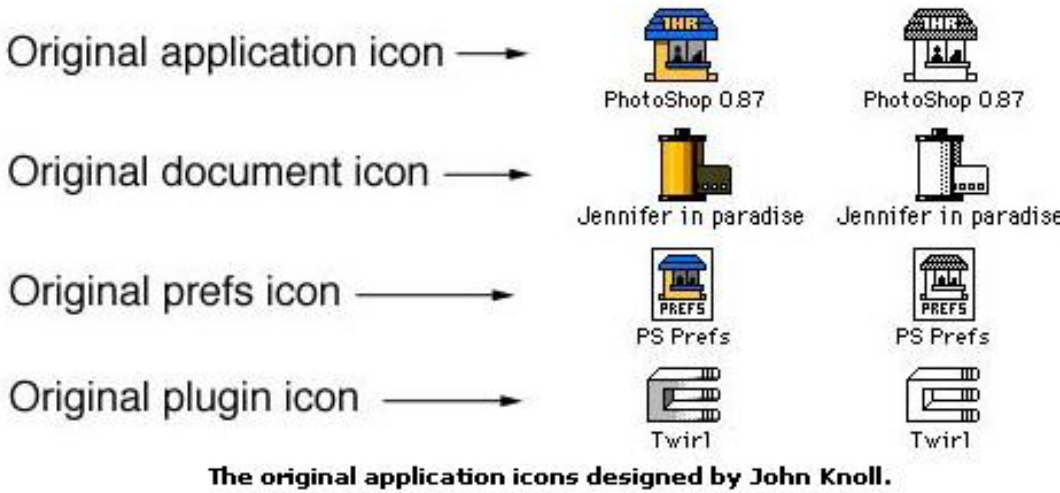
Photoshop

- Thomas Knoll and John Knoll began development in 1987
- Version 1.0 on Mac: 1990
- http://en.wikipedia.org/wiki/Photoshop#Development
- http://www.storyphoto.com/multimedia/multimedia_photoshop.html

Photoshop toolbar from version 1.07

John Knoll.
Photo by Jeff Schewe.

Thomas Knoll.
Photo by Jeff Schewe.



The original application icons designed by John Knoll.

Slide credit: F. Durand

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

Slide credit: F. Durand

Completely Digital Commercial camera

- 1991 first completely digital Logitech Dycam
  - 376x240

http://www.g4tv.com/

Slide credit: F. Durand

Digital

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

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

Slide credit: F. Durand

Digital SLR?

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

Slide credit: F. Durand

Consumer digital SLR?

- Canon D30, 2000 3MPixels

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Camera phone?

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

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Dual-lens phone

https://www.techradar.com/news/key-camera-features-on-the-iphone-xs

Triple-lens phone

Image from Apple.com

Consumer lightfield camera

- Lytro, founded in 2006 by Ren Ng
  - Acquired by Google in 2018



https://en.wikipedia.org/wiki/Lytro

VR cameras

Google Jump

Facebook VR Camera

Automatic Photography

Google Clips is "a new hands-free camera that automatically captures interesting moments in your life"[1]

Facebook Portal features a smart camera that "frames shots much as an experienced camera operator would, so that people using Portal feel like they are right beside each other"[2]

[1] https://ai.googleblog.com/2018/05/automatic-photography-with-google-clips.html
[2] https://ai.facebook.com/blog/under-the-hood-portals-smart-camera/

Google Clips

"A new hands-free camera that automatically captures interesting moments in your life"*

- All computations are performed on-device.
  - Extending battery life and reducing latency
  - Offering strong privacy control as clips stay in the device unless users save or share them
- Record short videos instead of still photographs.
  - "Moments with motion can be more poignant and true-to-memory, and it is often easier to shoot a video around a compelling moment than it is to capture a perfect, single instant in time" *
- Capture candid moments of people and pets
  - Not dedicated to optimize composition, color balance, light, etc
  - Focus on "selecting ranges of time containing people and animals doing interesting activities" *

*https://ai.googleblog.com/2018/05/automatic-photography-with-google-clips.html
https://www.youtube.com/watch?v=KPFPlVqGhyI

Facebook Portal

"Frames shots much as an experienced camera operator would, so that people using Portal feel like they are right beside each other"[1]

- **Follow action**
  - "No more "Wait... I can't see you." Portal's Smart Camera intelligently adjusts to stay with the action, whether you're moving around the kitchen or chasing the kids through the living room"[2]
- **Automatic framing**
  - "As more people enter a room, Smart Camera automatically widens to keep everyone in view, so you don't miss a moment" [2]
- **Privacy**
  - "Uses AI technology that runs locally on Portal, not on Facebook servers. Portal's camera does not use facial recognition and does not identify who you are" [2]

[1] https://ai.facebook.com/blog/under-the-hood-portals-smart-camera/
[2] https://portal.facebook.com/

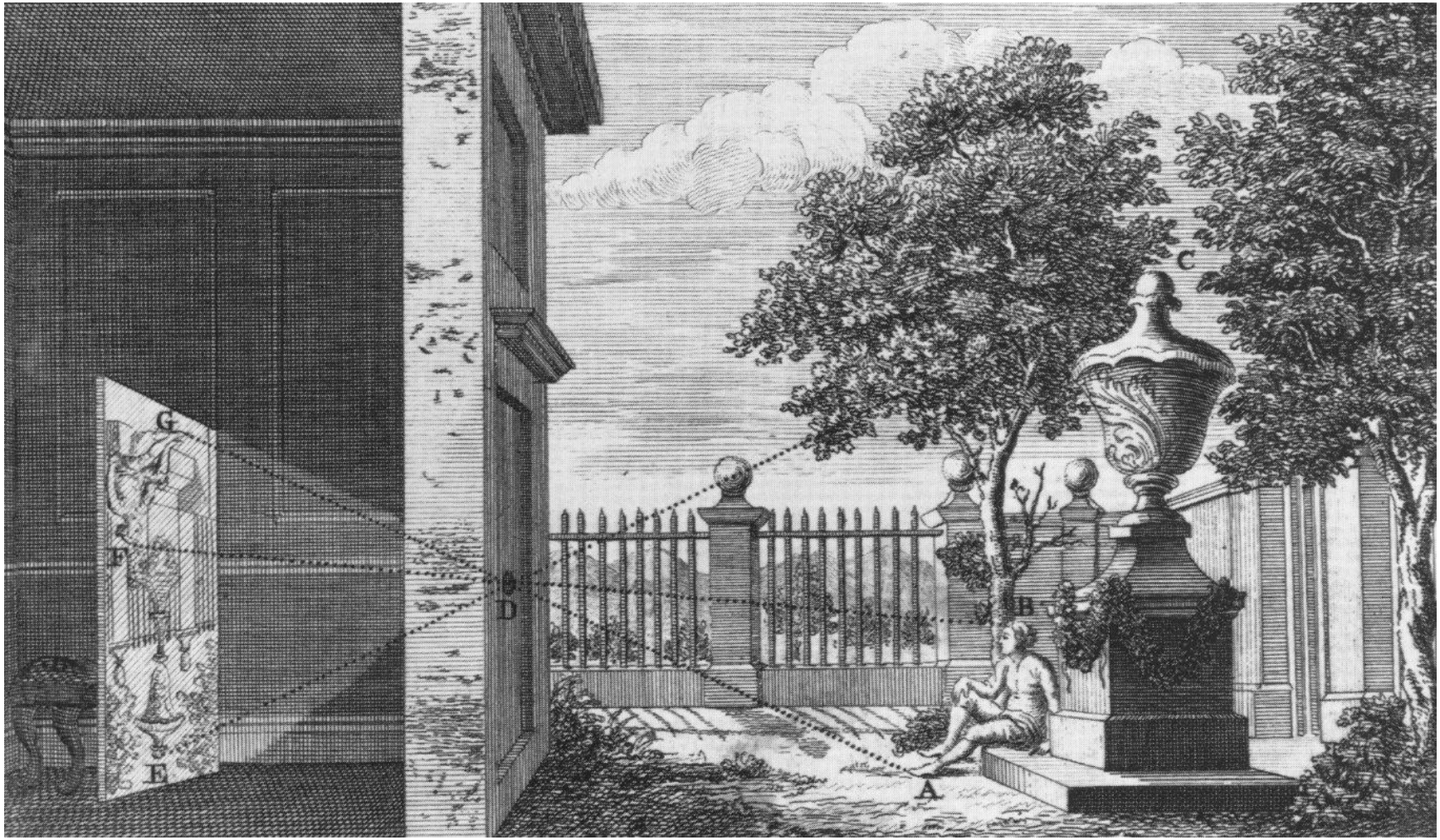
Outline

- History of Camera
- Controlling Camera

Camera specifics

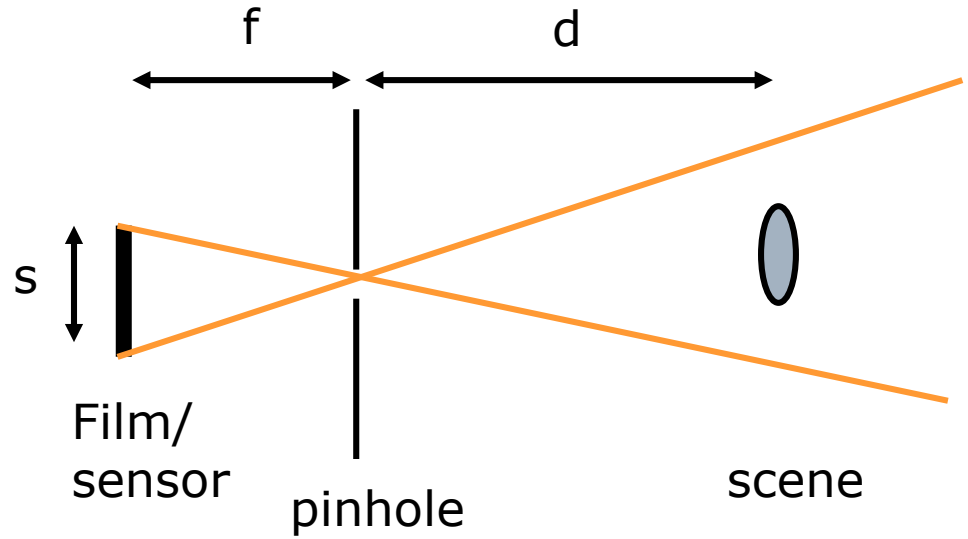
- Focal length
- Shutter
- Aperture
- Reciprocity
- Depth of field (focal)
- Motion
- ISO
- Metering

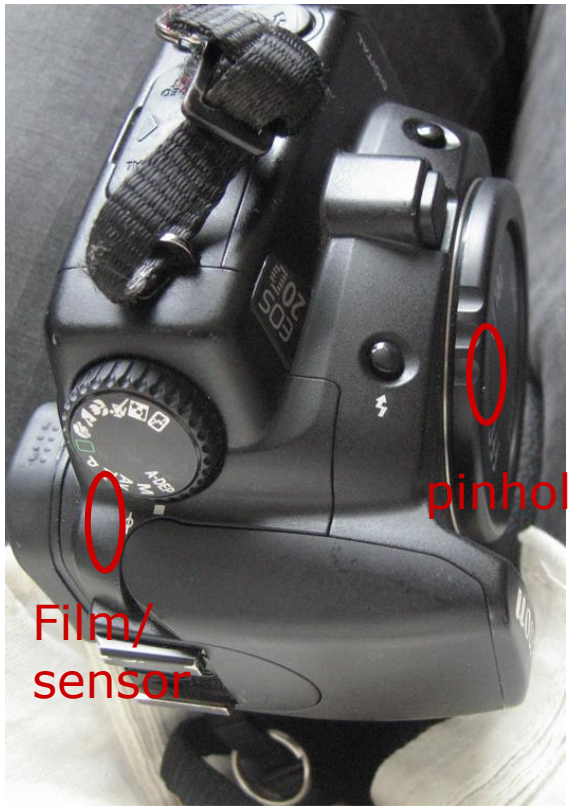
Pinhole imaging



Slide credit: F. Durand

Focal length: pinhole optics





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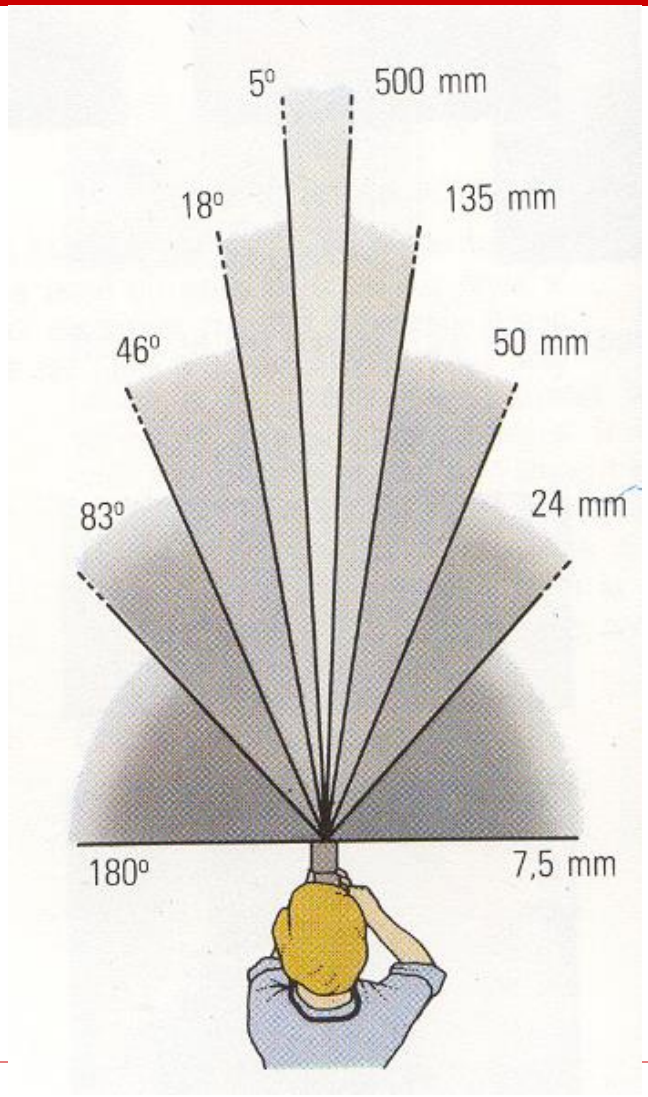
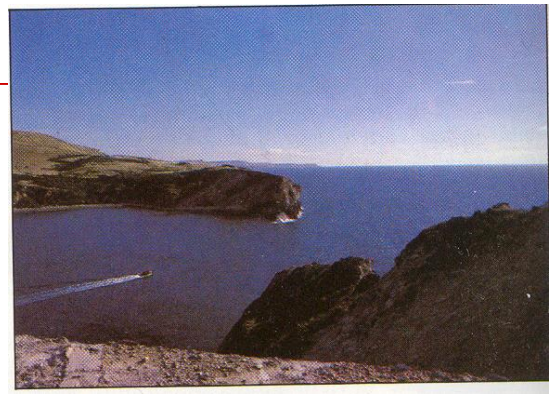
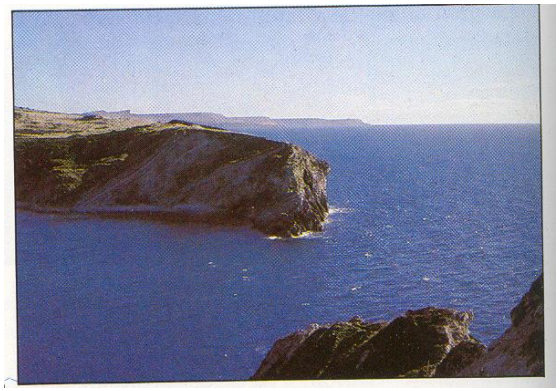
Field of View



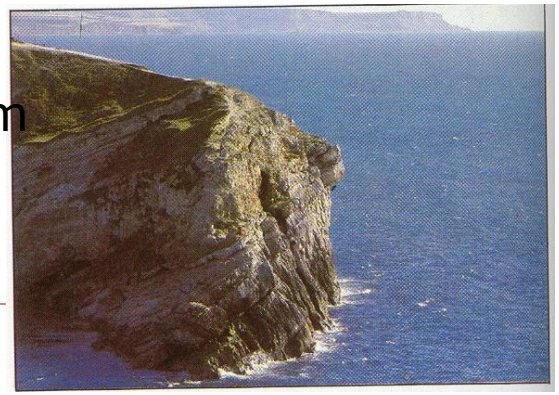
24mm



50mm



135mm



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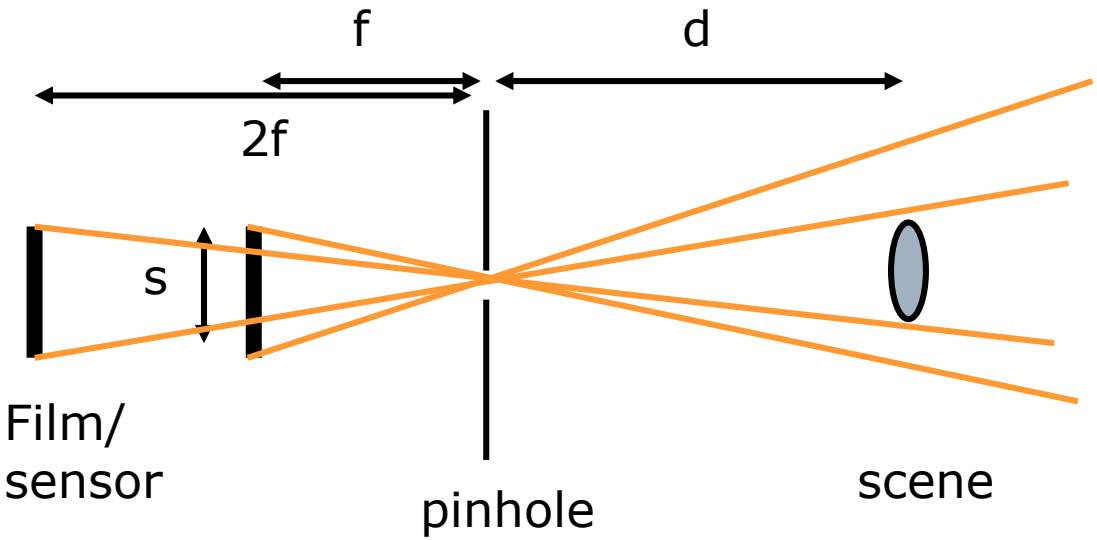
Focal length: pinhole optics

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



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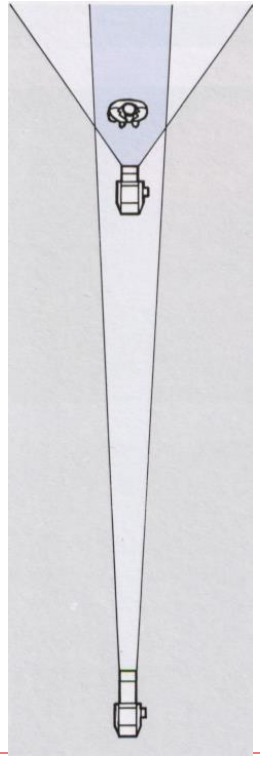
Perspective vs. viewpoint

- Focal lens does NOT ONLY change subject size
- Same size by moving the viewpoint
- Different perspective (e.g. background)



Slide credit: F. Durand

Perspective vs. viewpoint

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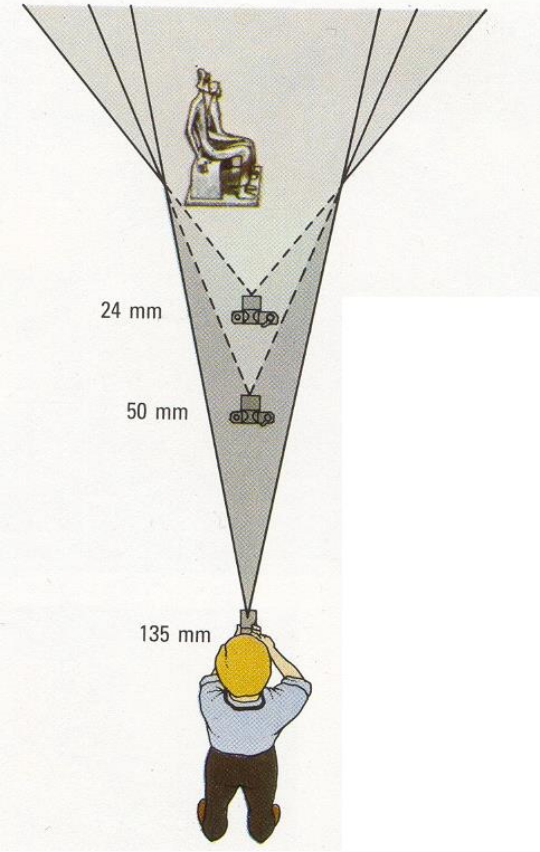
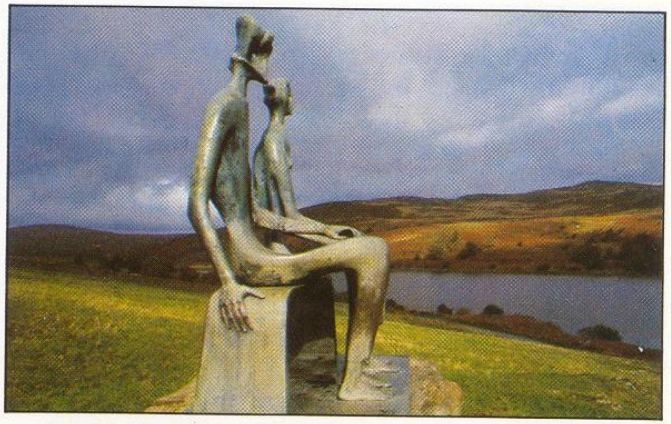
- Same size by moving the viewpoint
- Different perspective (e.g. background)

Slide credit: F. Durand

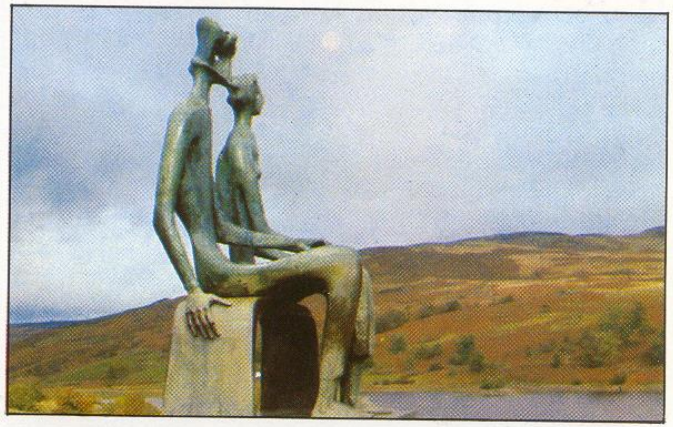
Perspective vs. viewpoint

- 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

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Perspective vs. viewpoint



Slide credit: F. Durand

Perspective vs. viewpoint

- Portrait: distortion with wide angle
- Why?

Wide angle

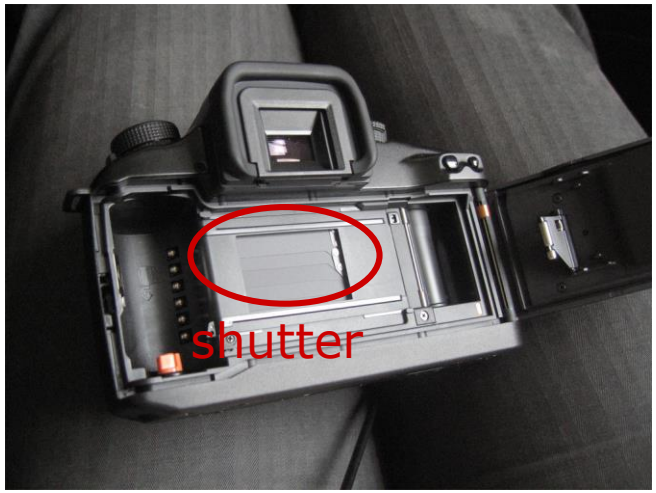
Standard

Telephoto

Slide credit: F. Durand

Shutter

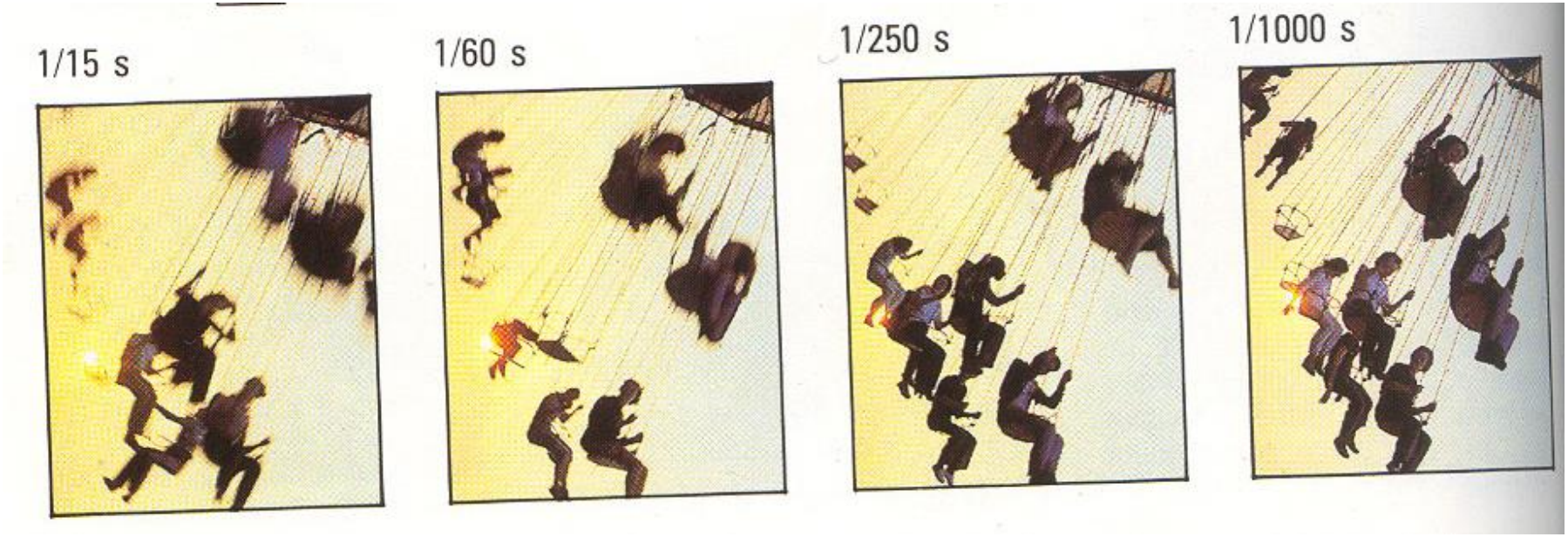
- Most of the time, the film/sensor is protected from light
- When we take a picture, the shutter opens and closes, thereby exposing the film.
- Exposure is proportional to the time the shutter is open
- Expressed in fraction of a second (1/60s, 1/125s, 1/250s, 1/500s, etc.)



Slide credit: F. Durand

Effect of shutter speed

- Longer shutter speed => more light, but more motion blur
- Faster shutter speed freezes motion



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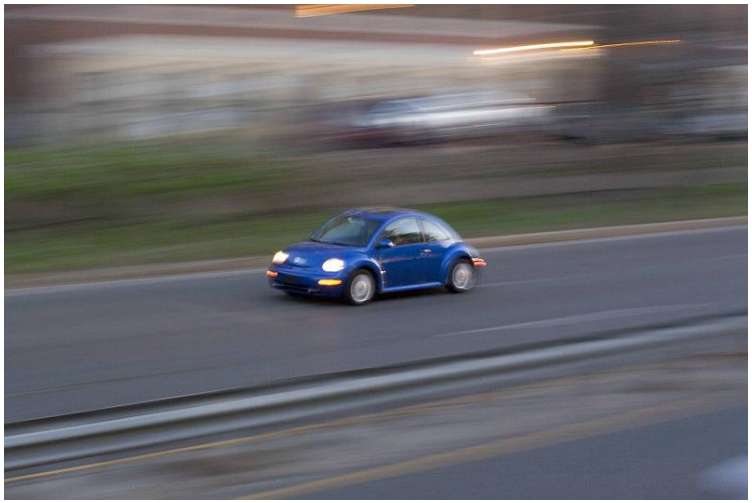

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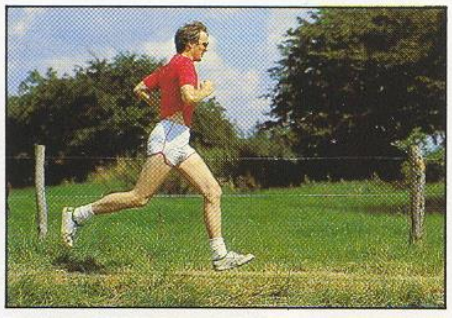
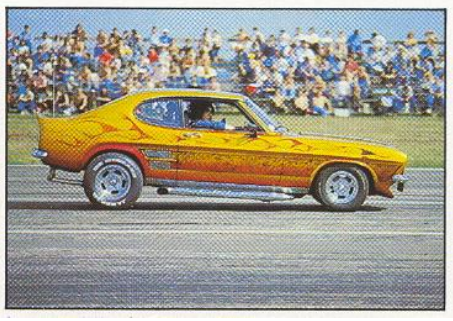
Effect of shutter speed

- Freezing motion

Walking people	Running people	Car	Fast train
			
1/125	1/250	1/500	1/1000

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Shutter speed and focal length

- Because telephoto “magnify”, they also magnify your hand shaking
- Telephotos therefore require faster shutter speed
- Rule of thumb:
  - The slowest shutter speed where normal human can hand-hold and get a sharp picture is 1/f
  - E.g., a 500mm requires 1/500 s or higher.
- Solution: Image stabilization
  - mechanically compensates for vibration
  - Can gain 2 or 3 shutter speeds (1/125 or 1/60 for a 500mm)

Slide credit: F. Durand

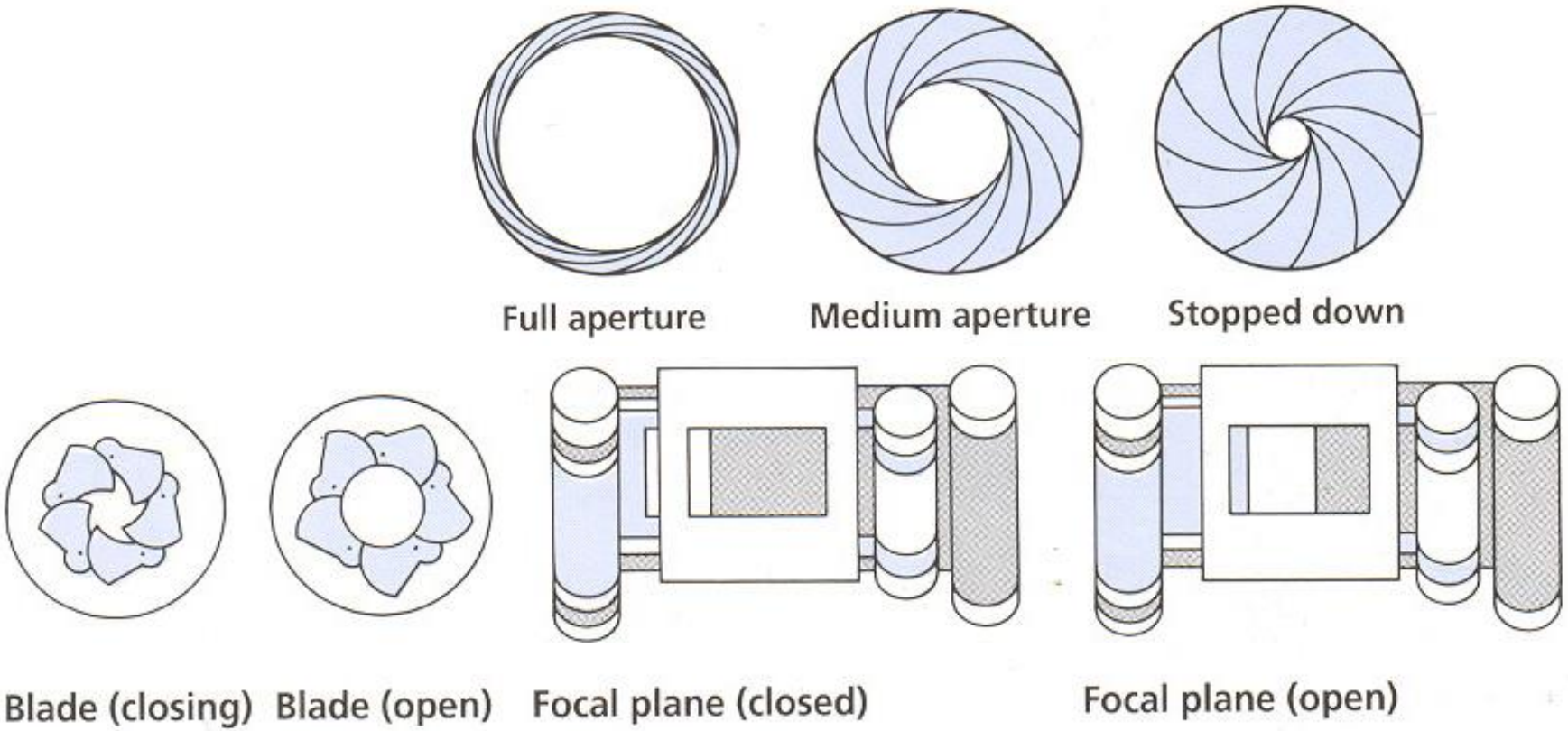
Your best friend

- Use a tripod! It will always enhance sharpness

Slide credit: F. Durand

Exposure

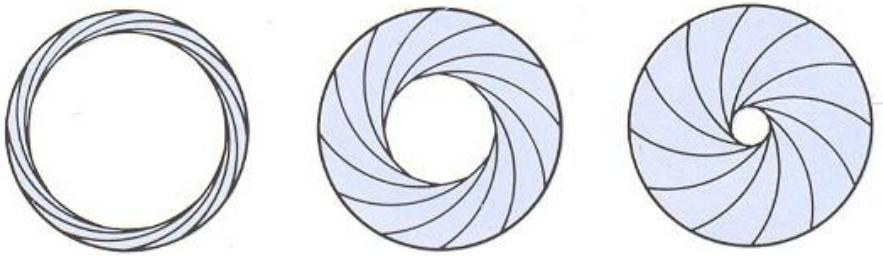
- Two main parameters:
  - Shutter speed
  - Aperture (in f stop)



Slide credit: F. Durand

Aperture

- Diameter of the lens opening (controlled by diaphragm)
- Expressed as a fraction of focal length, in f-number
  - f/2.0 on a 50mm means that the aperture is 25mm
  - f/2.0 on a 100mm means that the aperture is 50mm
- Disconcerting: small f number = big aperture
- What happens to the area of the aperture when going from f/2.0 to f/4.0?
- Typical f numbers are
  f/2.0, f/2.8, f/4, f/5.6, f/8, f/11, f/16, f/22, f/32



Slide credit: F. Durand

Exposure

- Two main parameters:
  - Aperture (in f stop)
  - Shutter speed (in fraction of a second)
- Reciprocity
  - **The same exposure is obtained with an exposure twice as long and an aperture area half as big**
  - Reciprocity can fail for very long exposures

Slide credit: F. Durand

Exposure & metering

- The camera metering system measures how bright the scene is
- In Aperture priority mode, the photographer sets the aperture, the camera sets the shutter speed
- In Shutter-speed priority mode, the photographers sets the shutter speed and the camera deduces the aperture
  - In both cases, reciprocity is exploited
- In Program mode, the camera decides both exposure and shutter speed (middle value more or less)
- In Manual, the user decides everything (but can get feedback)

Slide credit: F. Durand

Pros and cons of various modes

- Aperture priority
  - Direct depth of field control
  - Cons: can require impossible shutter speed (e.g. with f/1.4 for a bright scene)
- Shutter speed priority
  - Direct motion blur control
  - Cons: can require impossible aperture (e.g. when requesting a 1/1000 speed for a dark scene)
    - Note that aperture is somewhat more restricted
- Program
  - Almost no control, but no need for neurons
- Manual
  - Full control, but takes more time and thinking

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Metering

- Photosensitive sensors measure scene luminance
- Most cameras then use a center-weighted average
  - Can fail if scenes are very white or very black
  - Nikon has a more advanced system (3D matrix)

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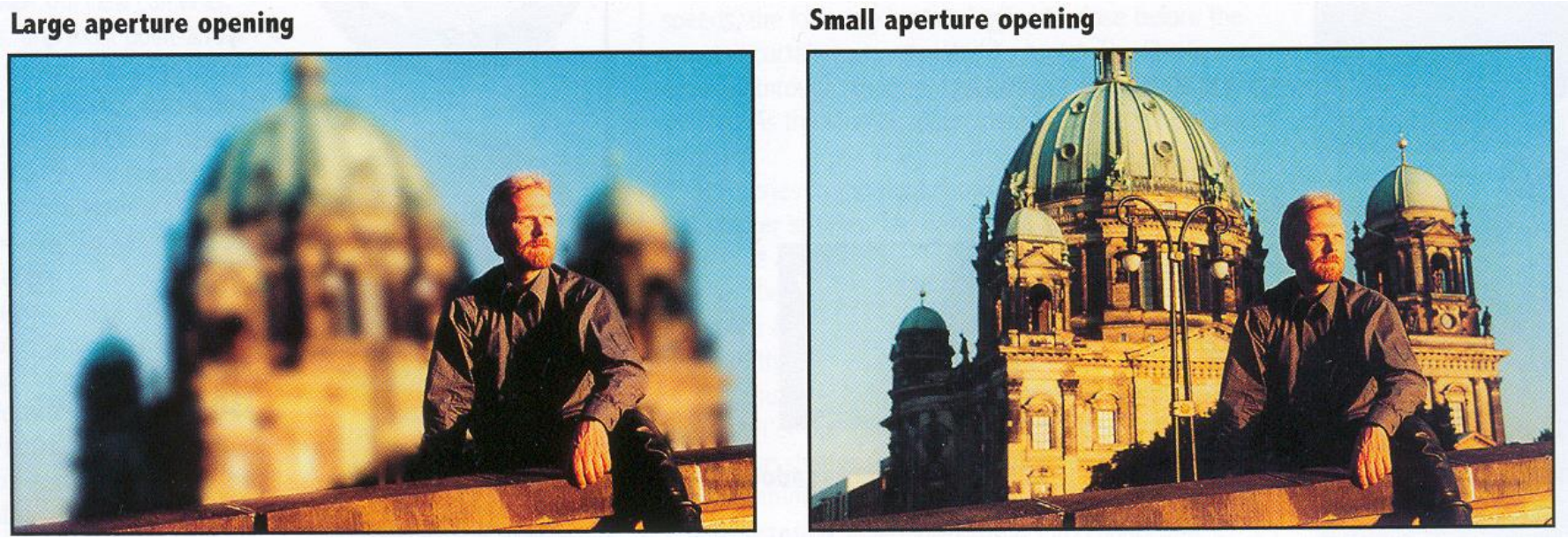
Main effect of aperture

- Depth of field



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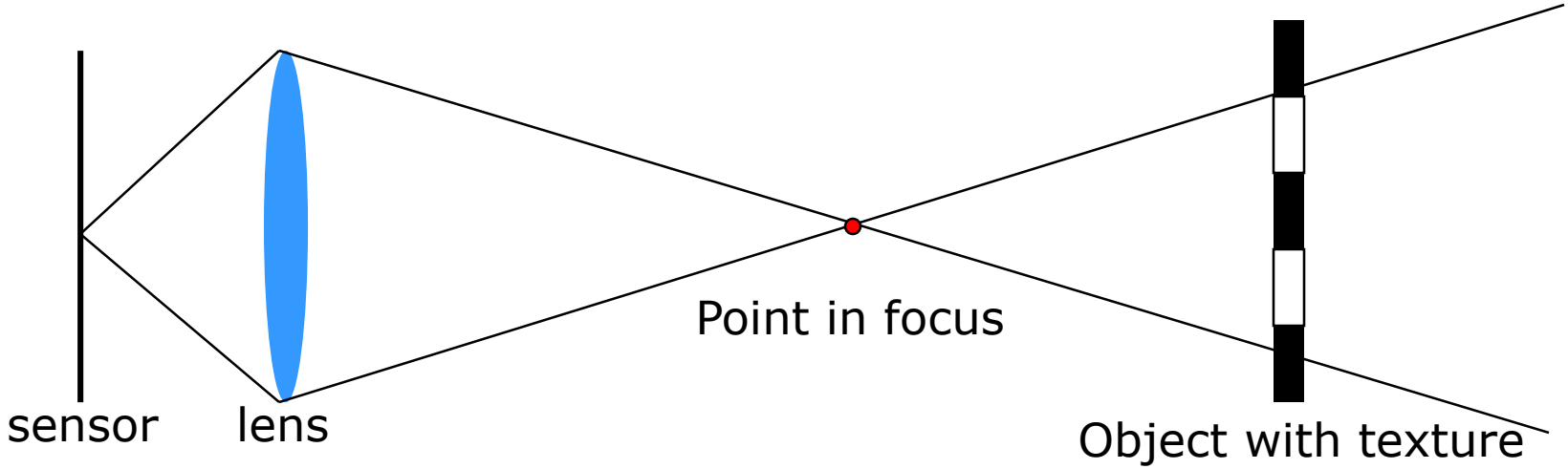
From Photography, London et al.

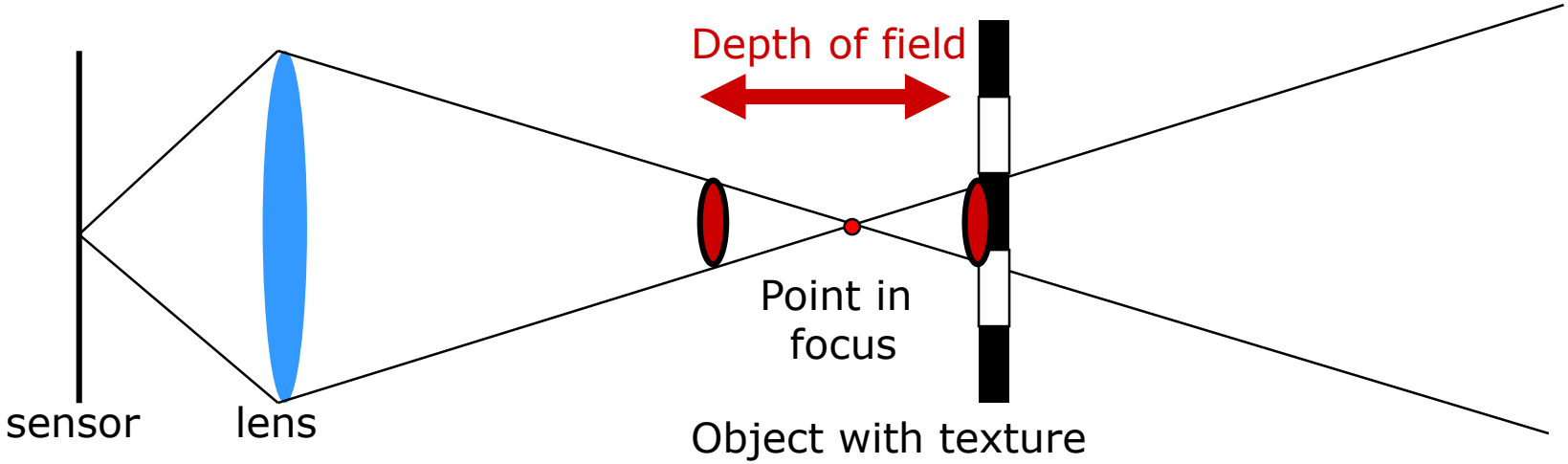
Depth of field

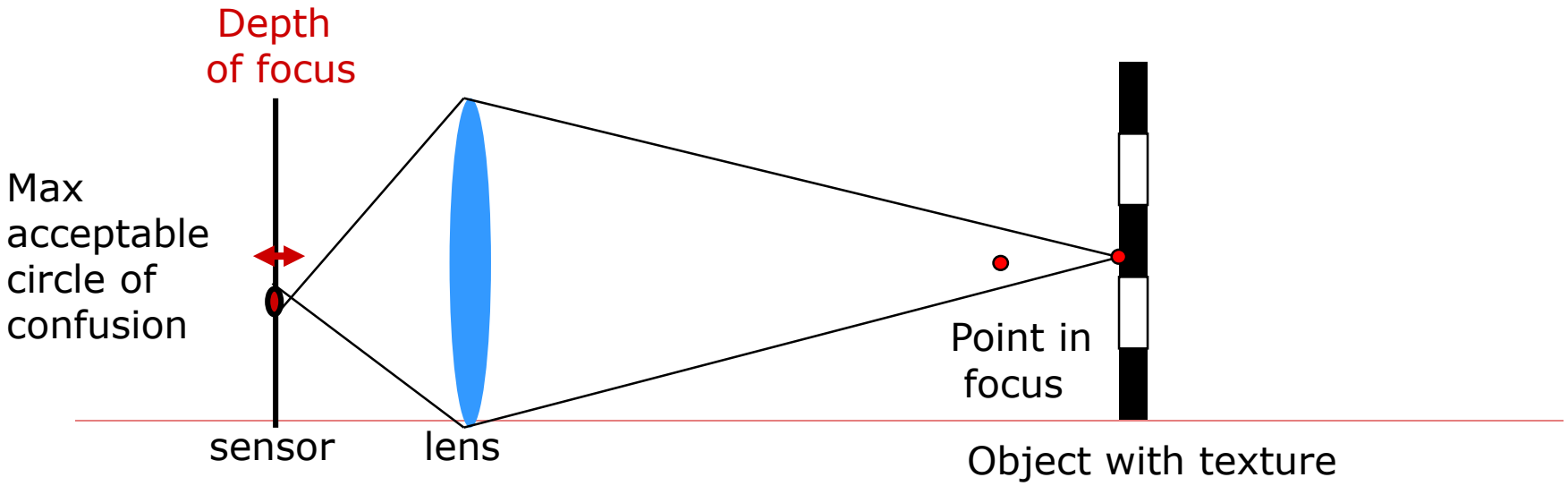


Slide credit: F. Durand

Depth of field

- We allow for some tolerance





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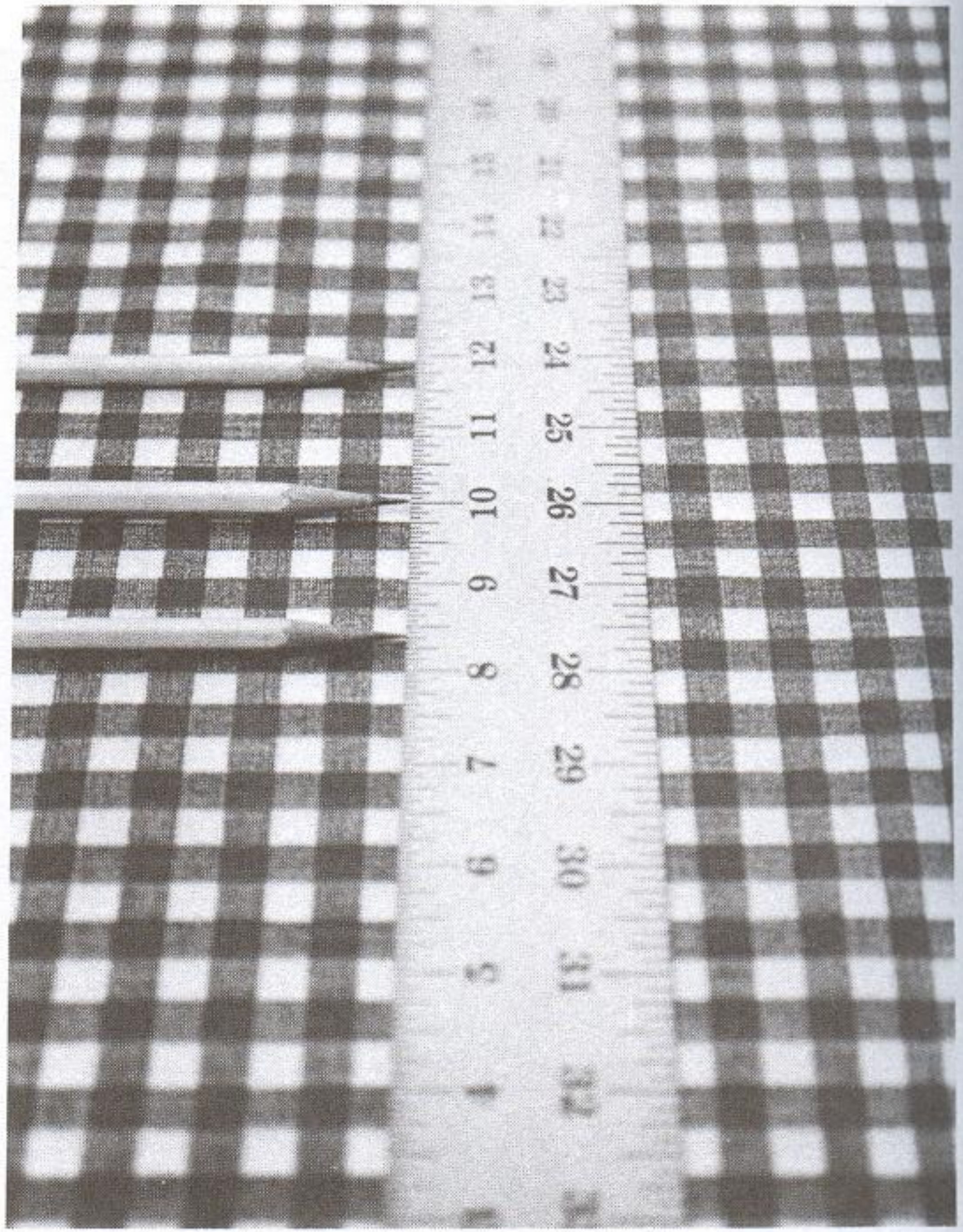
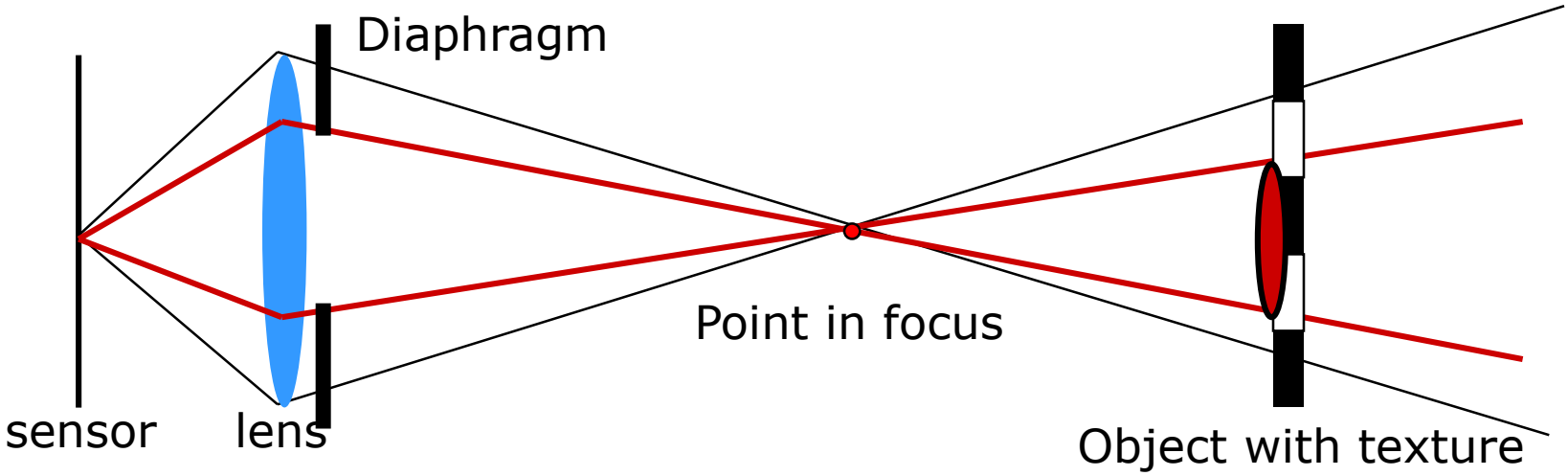


Slide credit: F. Durand

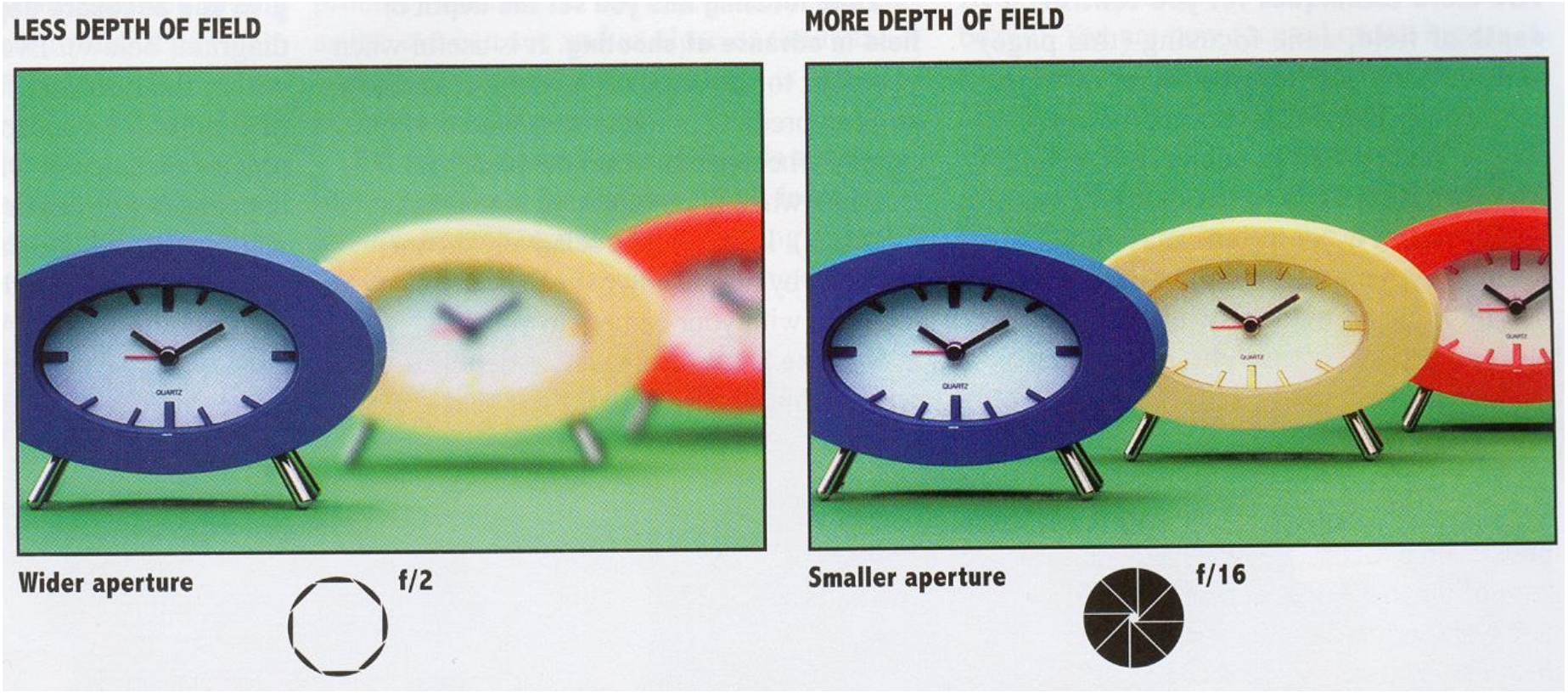
Depth of field

- What happens when we close the aperture by two stop?
  - Aperture diameter is divided by two
  - Depth of field is doubled



Slide credit: F. Durand

Depth of field

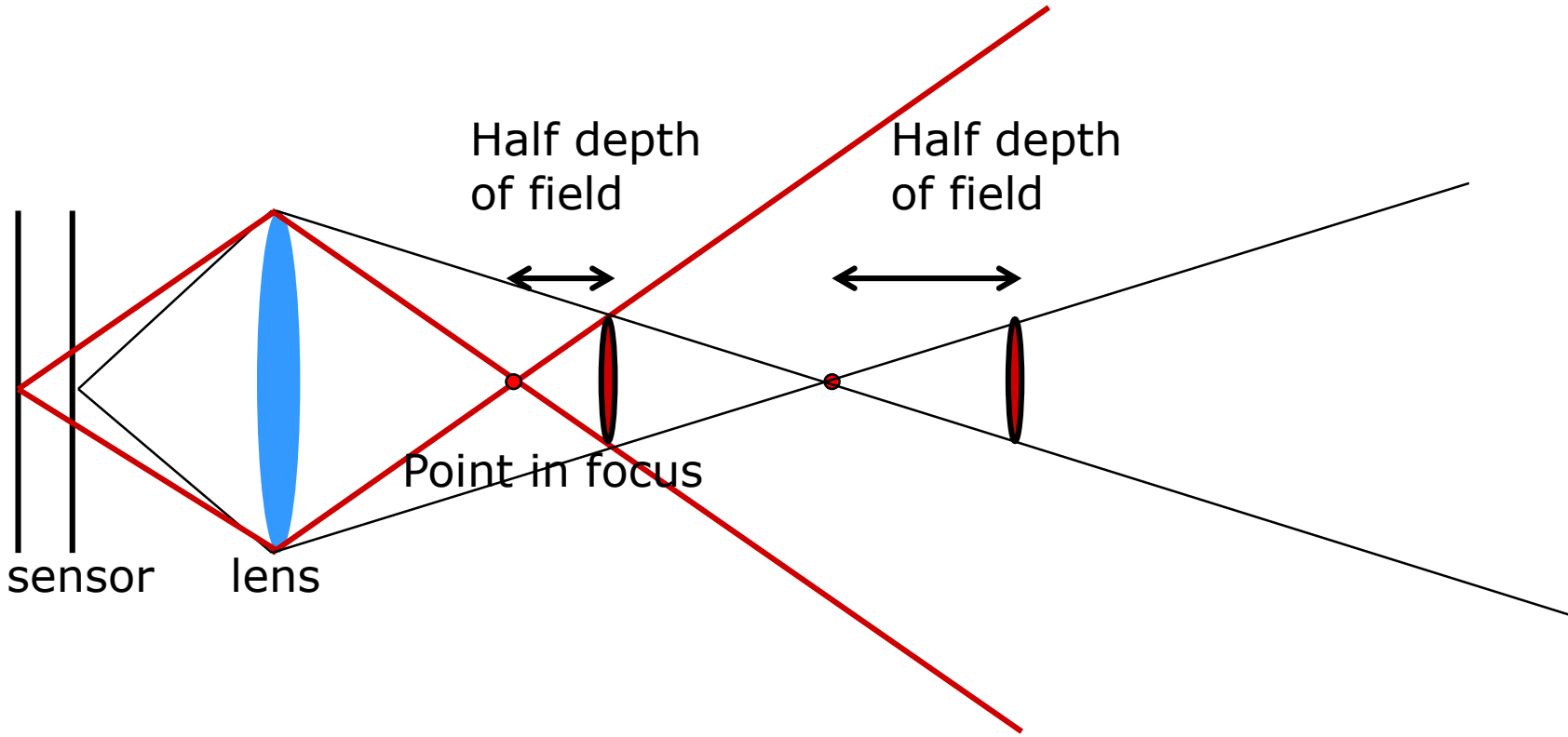


Slide credit: F. Durand

From Photography, London et al.

Depth of field & focusing distance

- What happens when we divide focusing distance by two?
  - Similar triangles => divided by two as well



Slide credit: F. Durand

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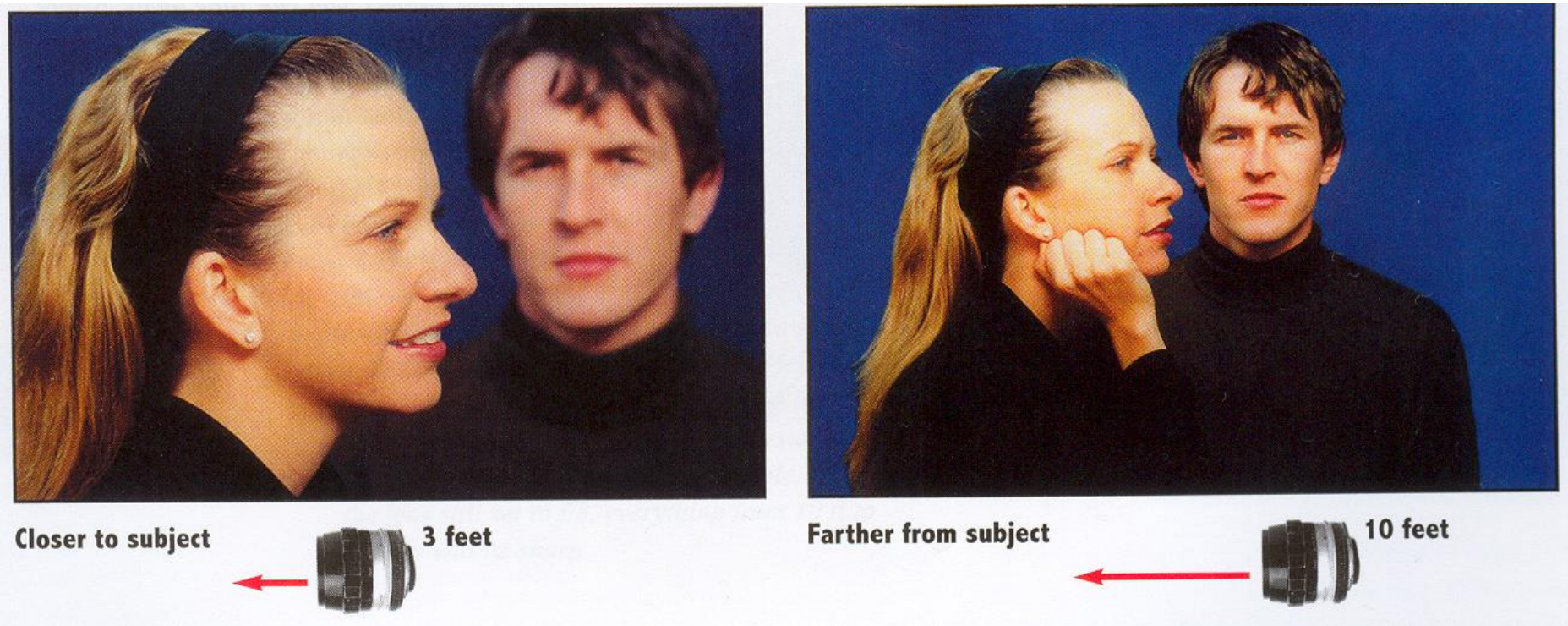
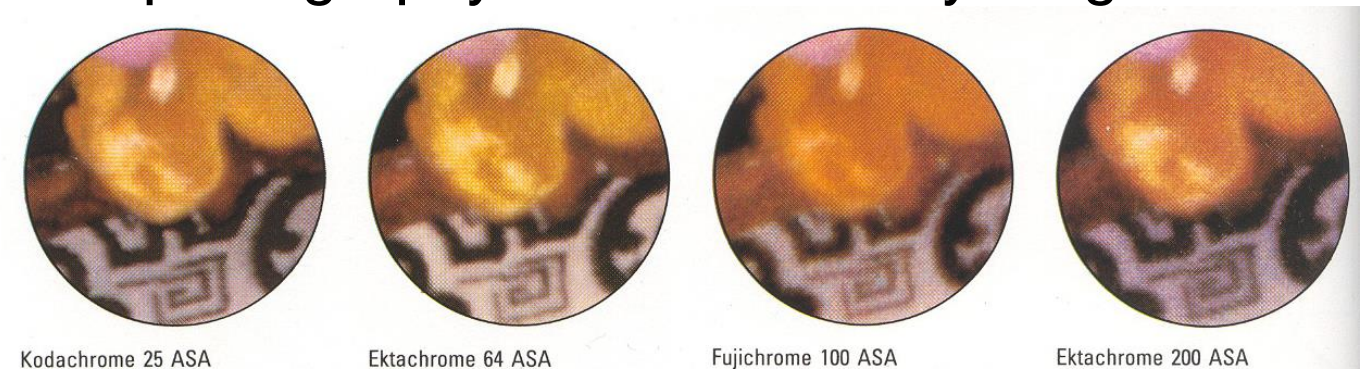


Slide credit: F. Durand

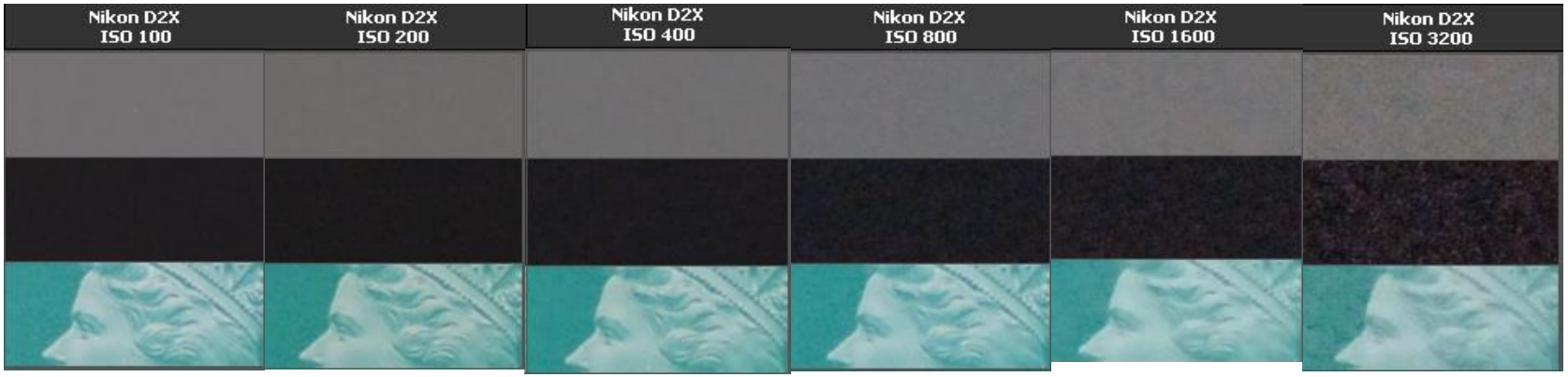
From Photography, London et al.

Sensitivity (ISO)

- Third variable for exposure
- Linear effect (200 ISO needs half the light as 100 ISO)
- Film photography: trade sensitivity for grain



- Digital photography: trade sensitivity for noise



From dpreview.com

Slide credit: Y. Chuang

Next Time

- Filter