Computational Photography

* Study the basics of computation and its impact on the entire workflow of photography, from capturing, manipulating and collaborating on, and sharing photographs.

Georgia Tech College of Computing

Cameras, Optics, and Sensors

* Cameras: Pinhole Camera and Optics

Lesson Objectives

1. Rays to pixels
2. A camera without optics
3. Lens in the camera system
4. The Lens Equation

Recall: Context of Computational Photography

Rays

3D Scene

Illumination

Optics

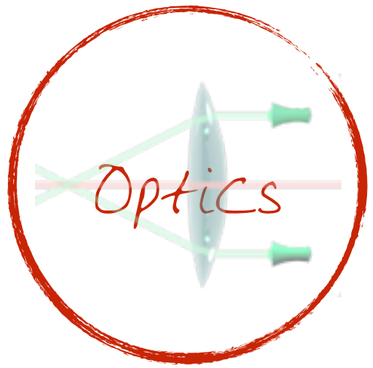
Sensor

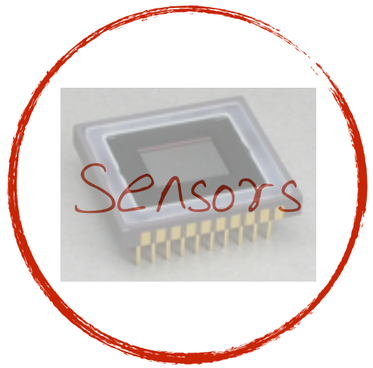
Processing

Display

User

Pixels





Pixels vs. Rays

http://commons.wikimedia.org/wiki/File:Sun_Rays.jpg

3D Scene

Illumination

Optics

Sensor

Processing

Display

User

* Scene via a 2D array of pixels
* Rays are fundamental primitives
* Illumination (Light Rays) follows a path from the source to the scene
* Computation can control the parameters of the optics, sensor and illumination

Evolution of the Camera

300 BC

1839

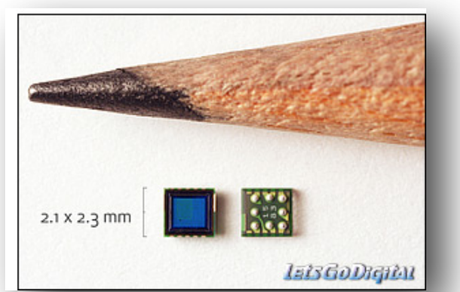
1907

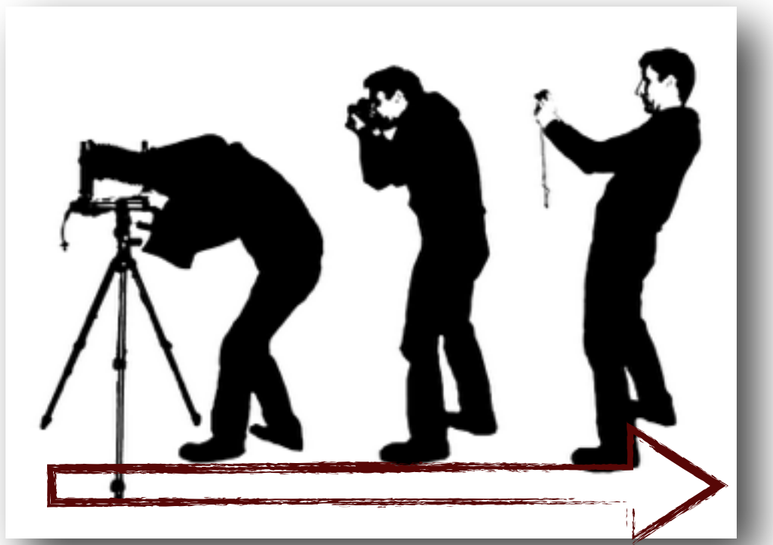
1948

1986

1991

2000

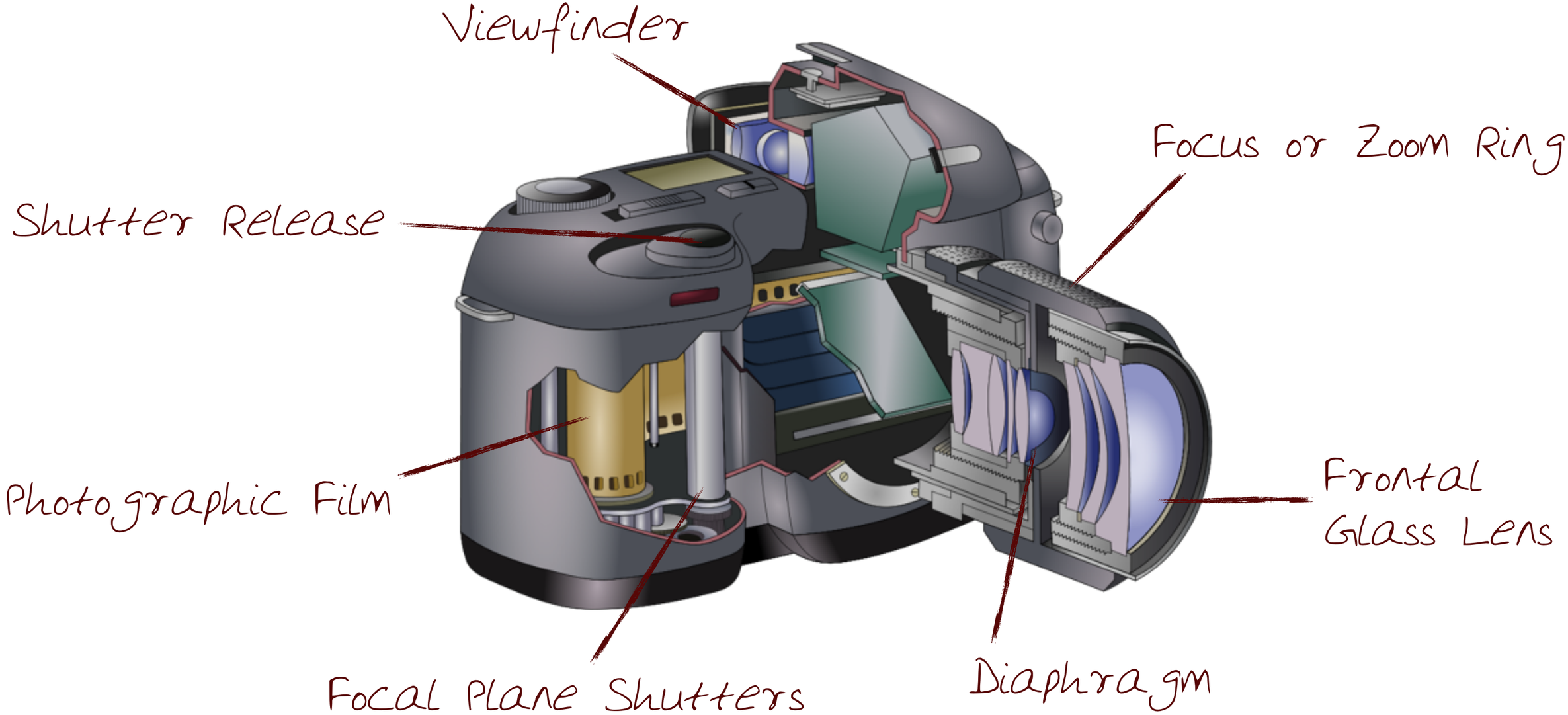




Formal to Casual

http://ericwilliamcarroll.com/blog/?p=23
http://simplevideoproduction.blogspot.com/
http://webdesign.njit.edu/2012/248/evolution.html

Single-Lens Reflex Camera



When you take a picture

you try to capture

3D Scene

Illumination

Optics

Sensor

Processing

Display

User

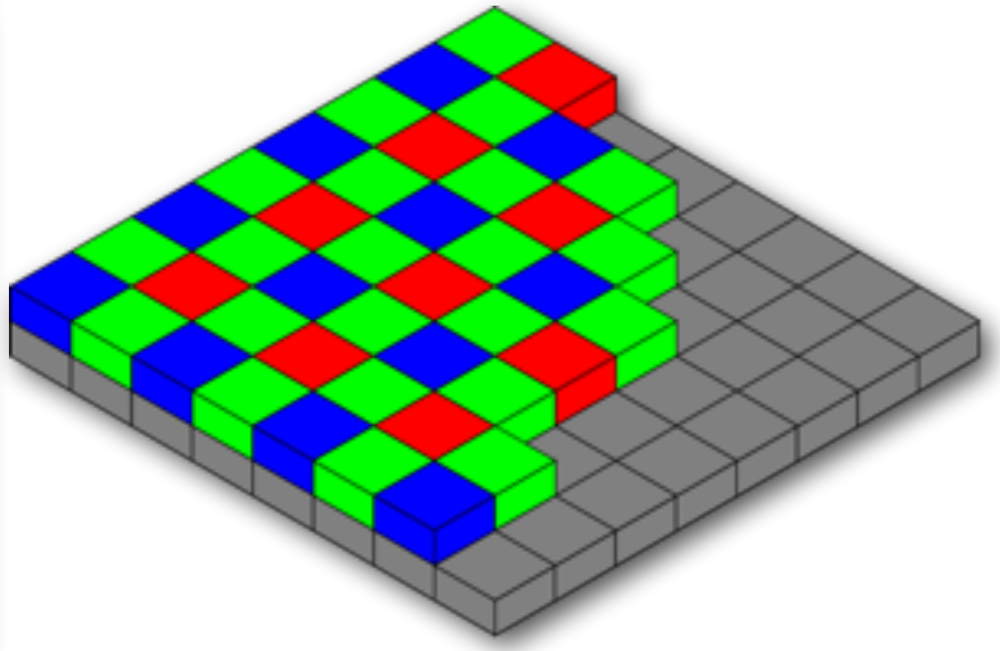
Geometry
(Perspective)

Light
Scattering

When you take a picture using

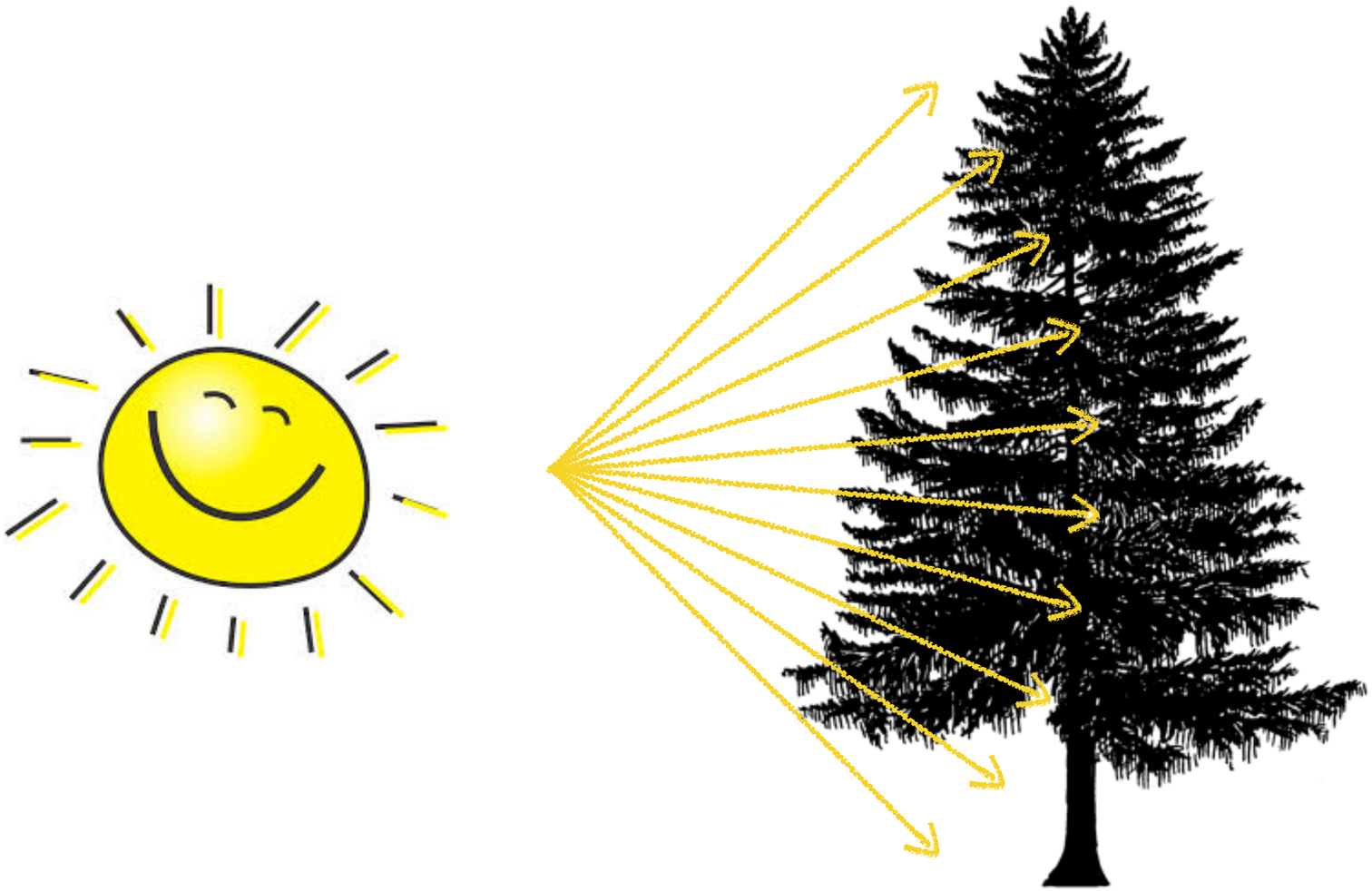
- 3D Scene
- Illumination
- Optics
- Sensor
- Processing
- Display
- User

Optics / Lens

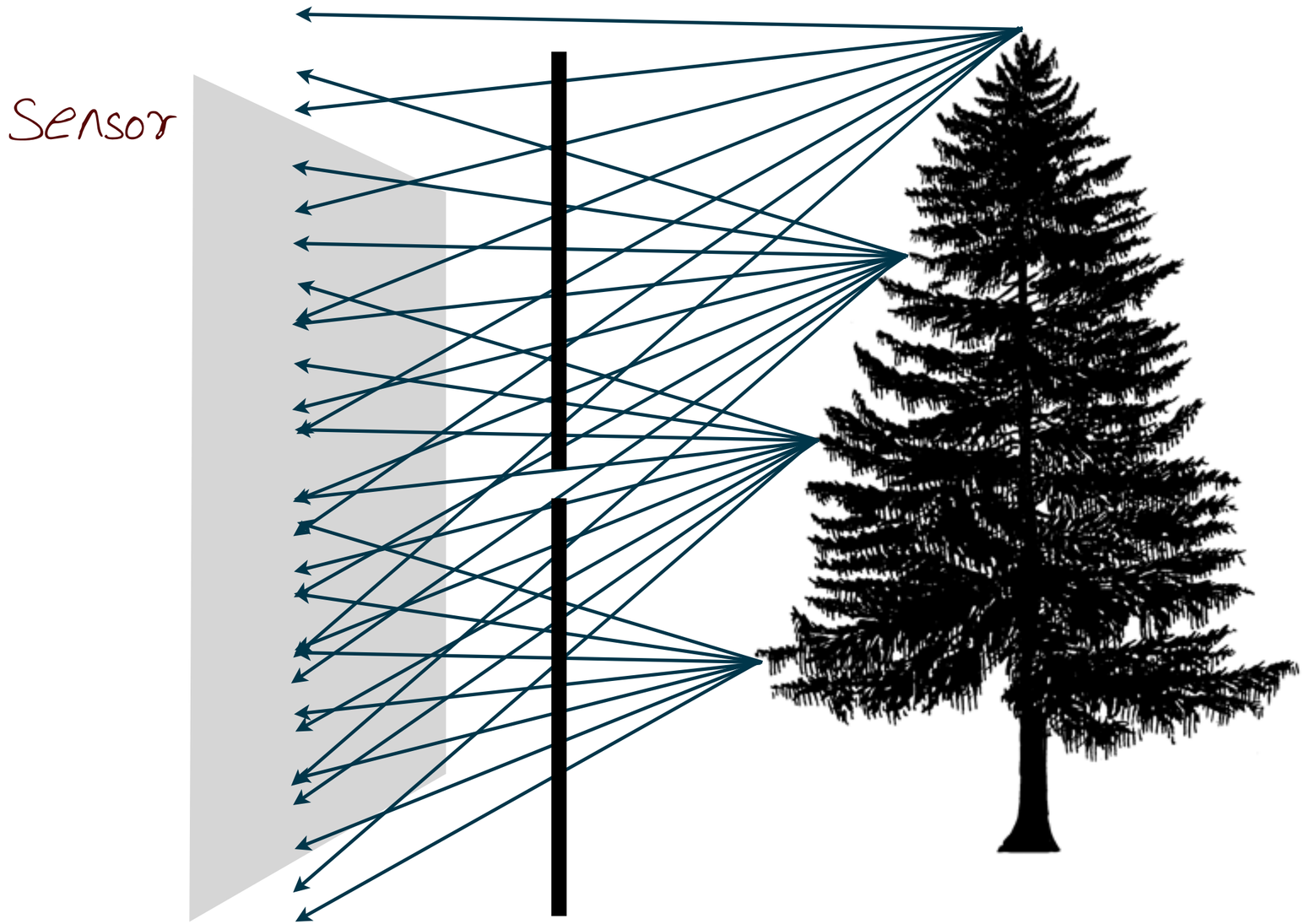


Sensor / Color Filter

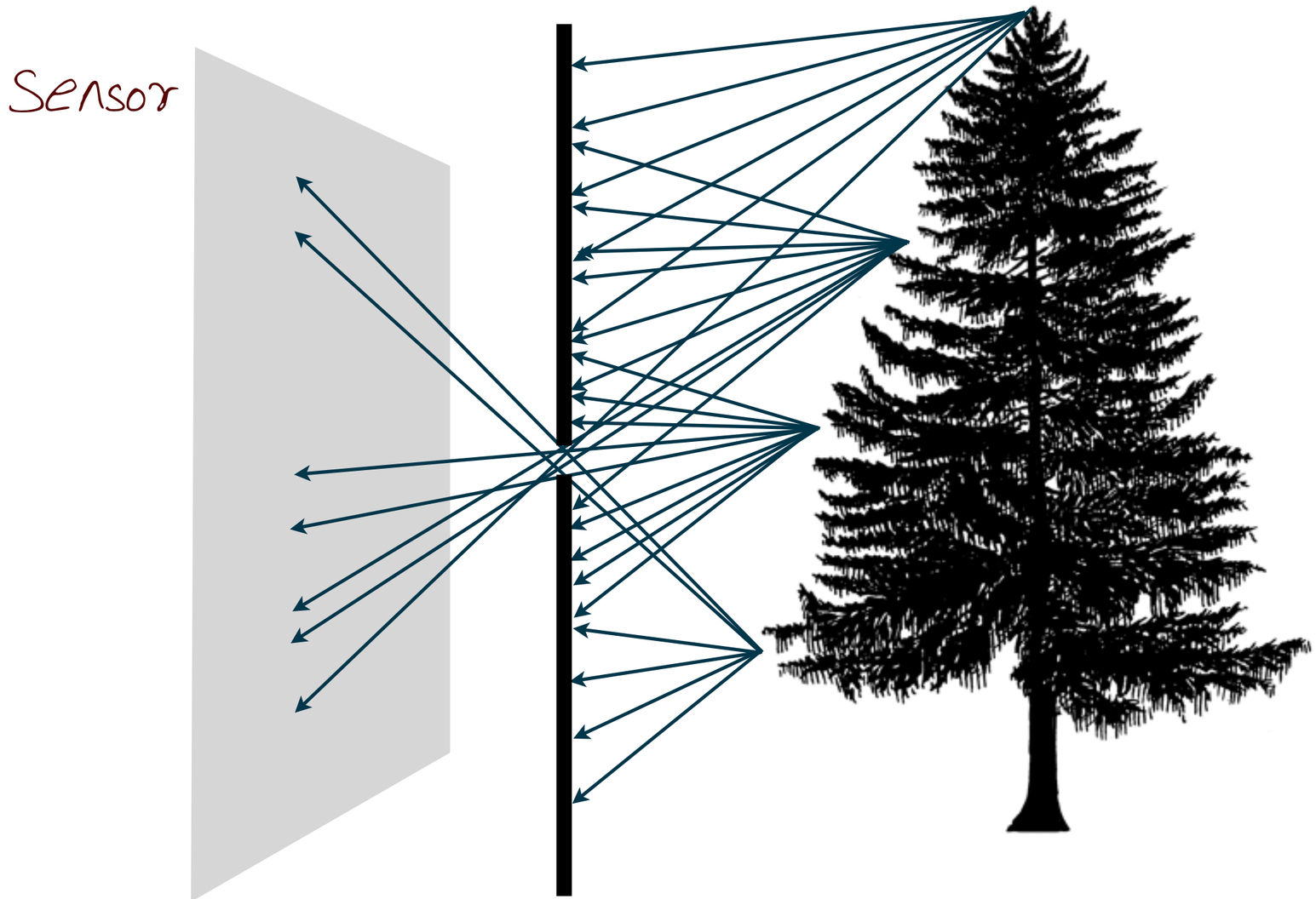
Cameras, without Optics



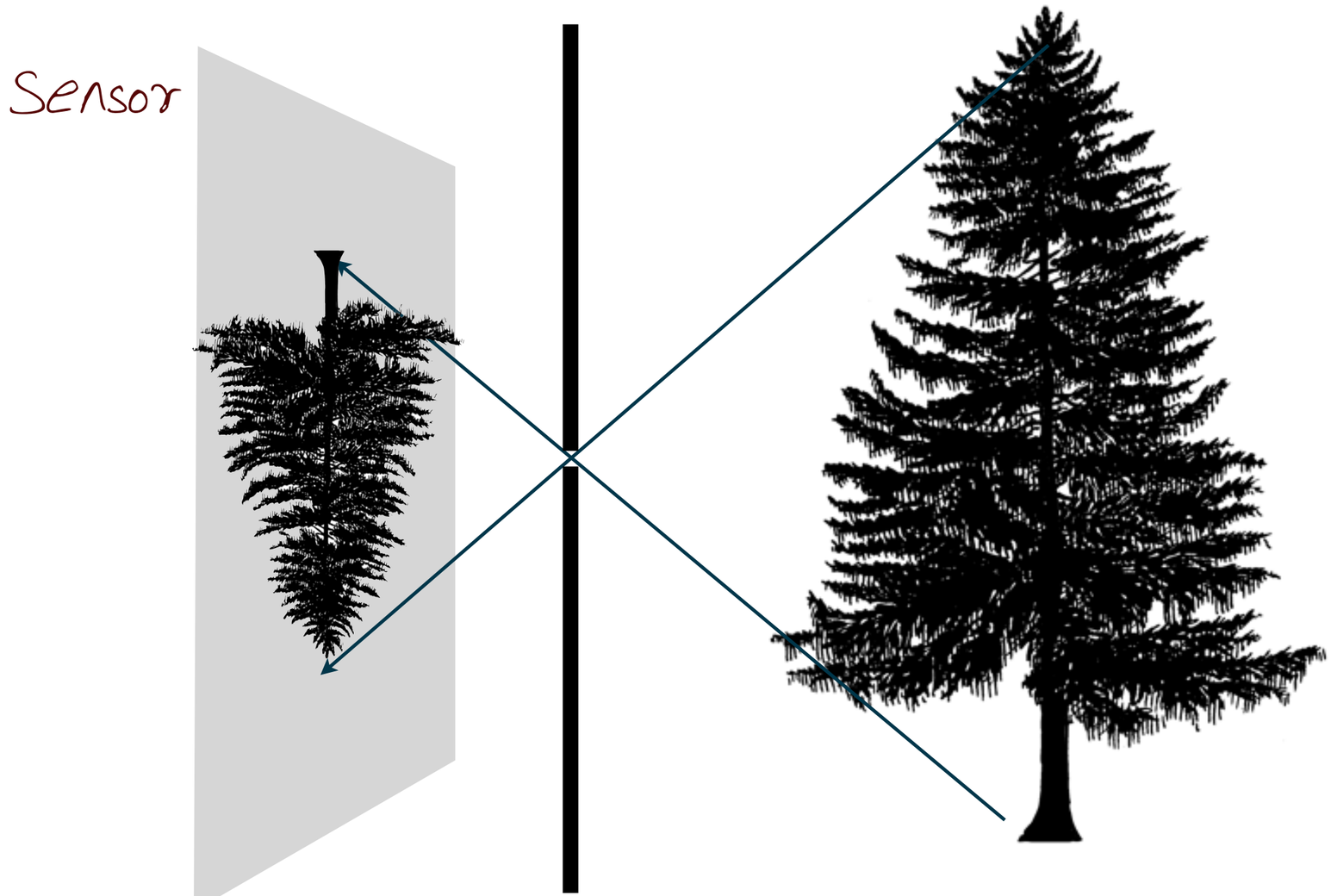
Cameras, without Optics



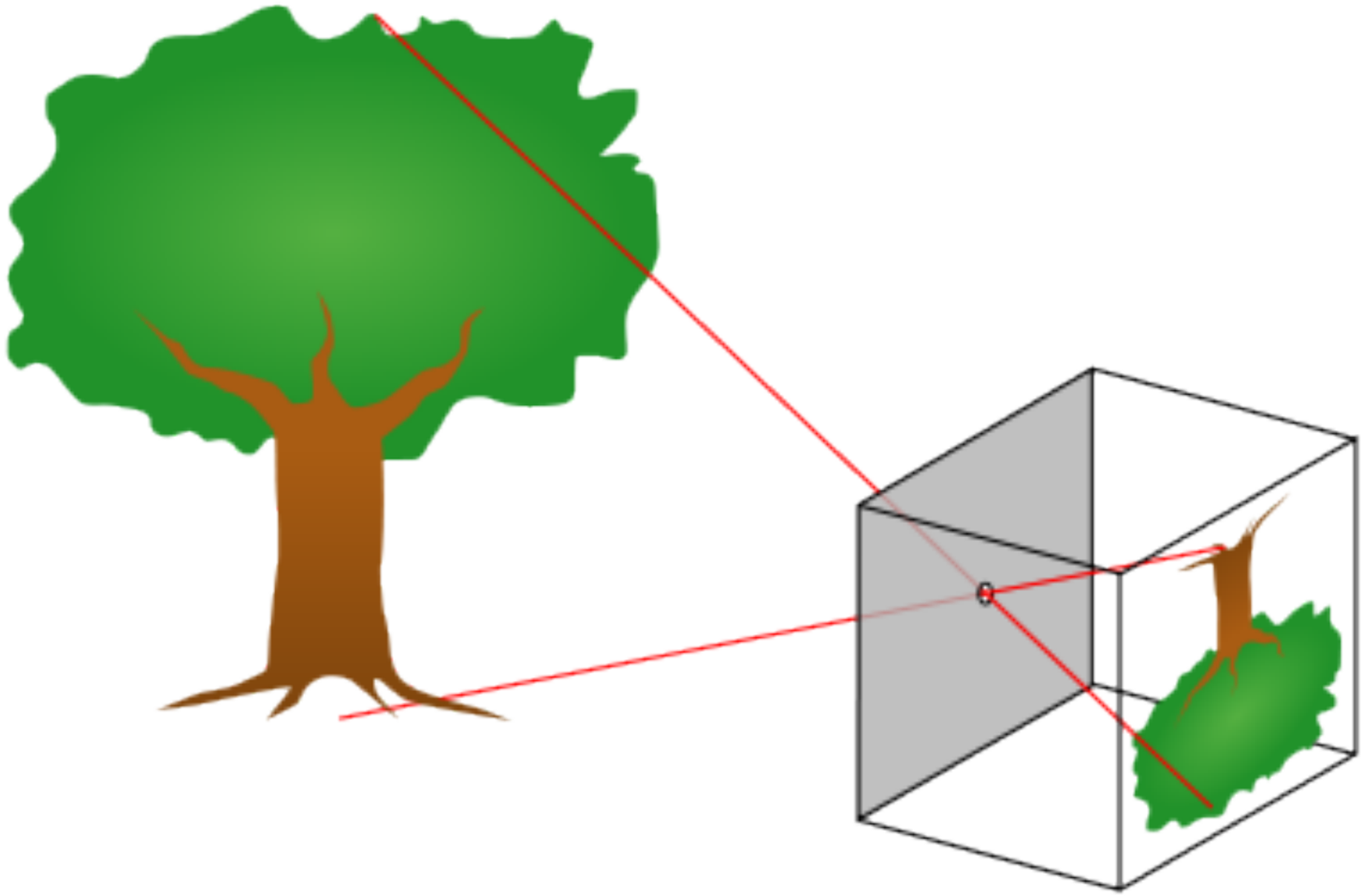
Cameras, without Optics



Cameras, without Optics



Camera Obscura
(Pinhole Camera)



Camera Obscura
(Pinhole Camera)

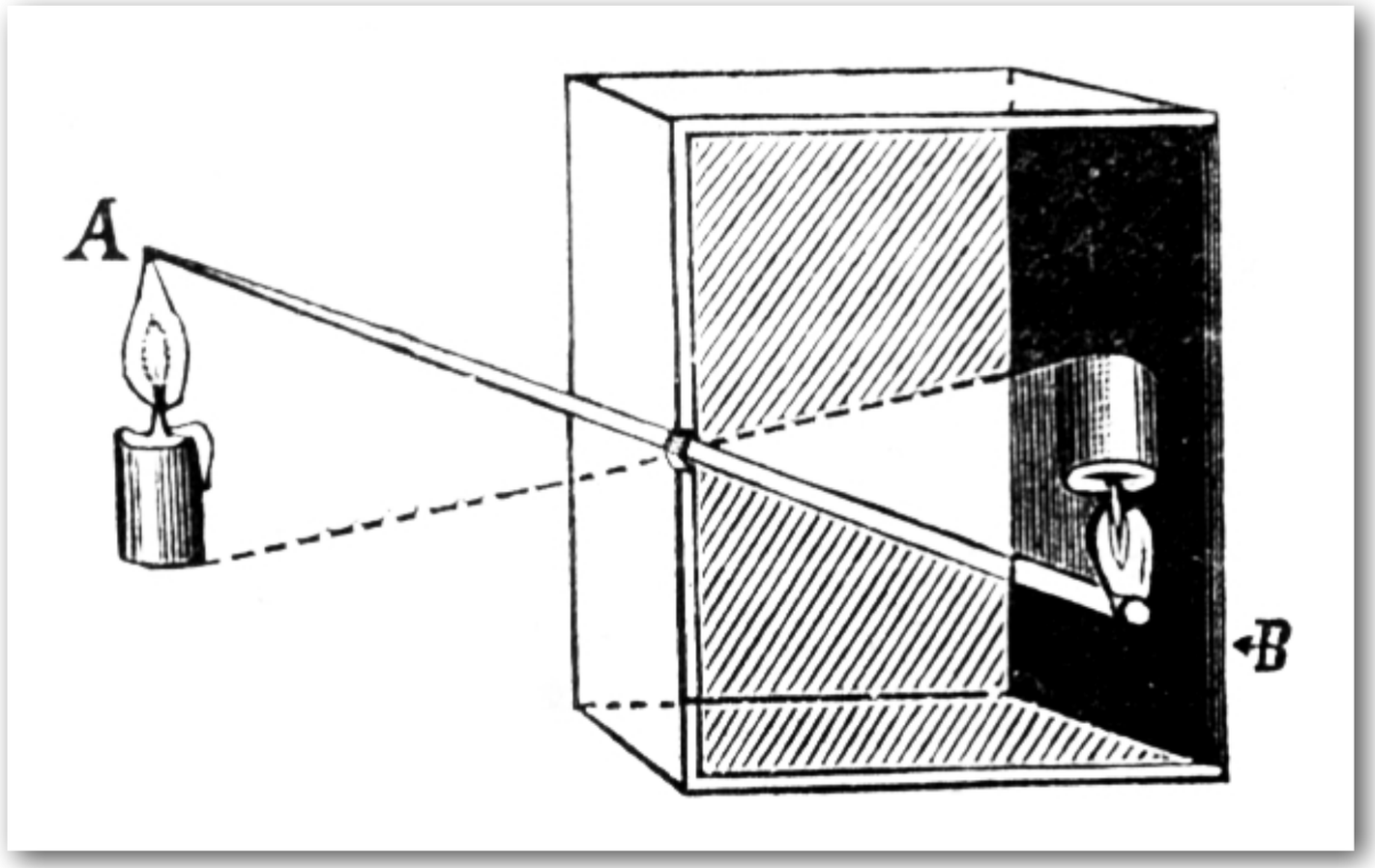


Illustration of camera obscura from "Sketchbook on military art, including geometry, fortifications, artillery, mechanics, and pyrotechnics"

Pinhole Photograph

Byelorussky Station: commons.wikimedia.org

Theoretically,

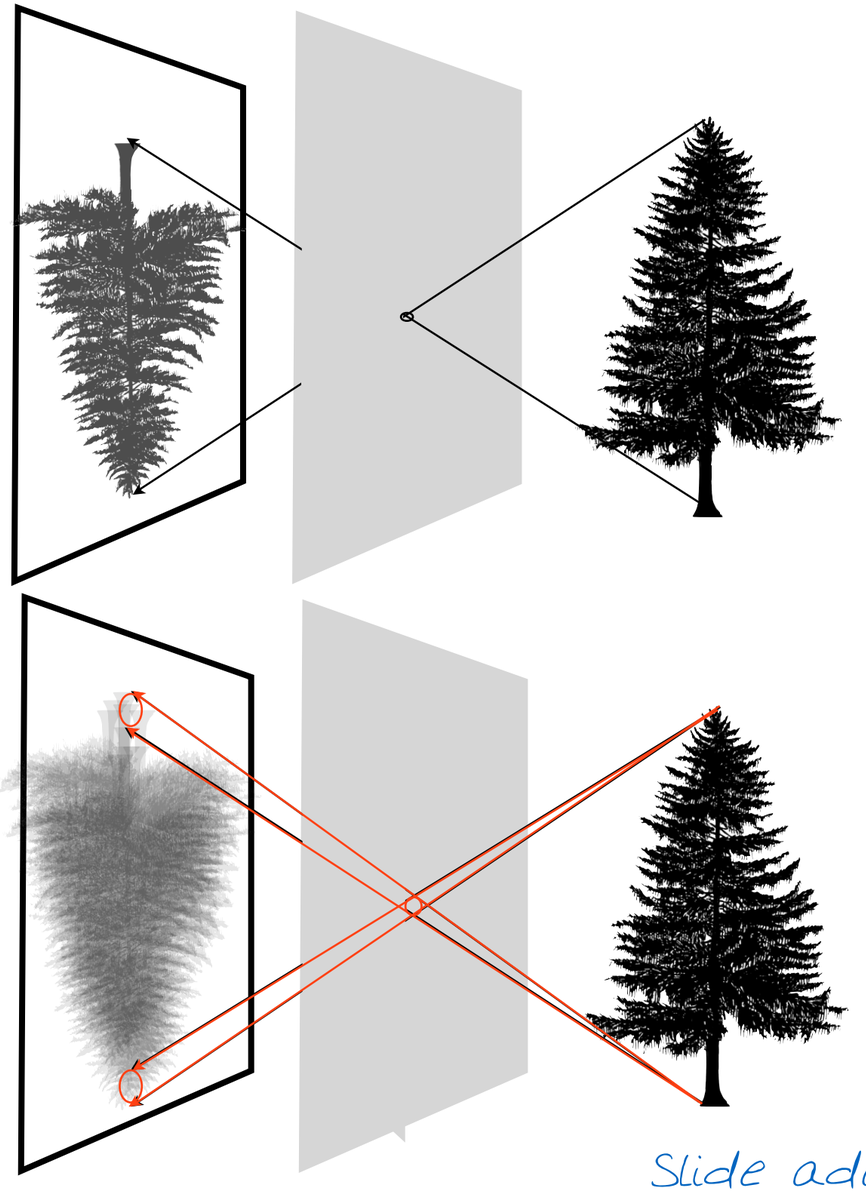
* No distortion! Straight Lines remain straight
* Infinite depth of field! Everything in focus (but there is optical blurring)

Slide adapted from Marc Levoy

This could be done as an explorational exercise. “What would happen if we increased the pinhole size?”, followed by four images that simulate different changes (sharper, blurrier, double image, color change, etc.).

Pinhole Size and Image Quality

Pinhole “blur” simulated

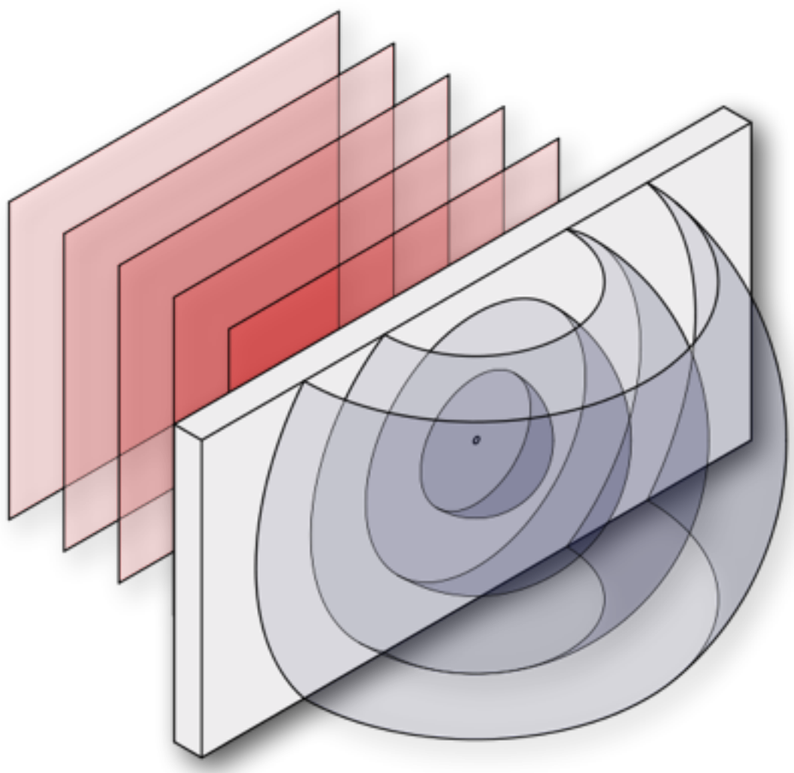


Pinhole Size = Aperture!

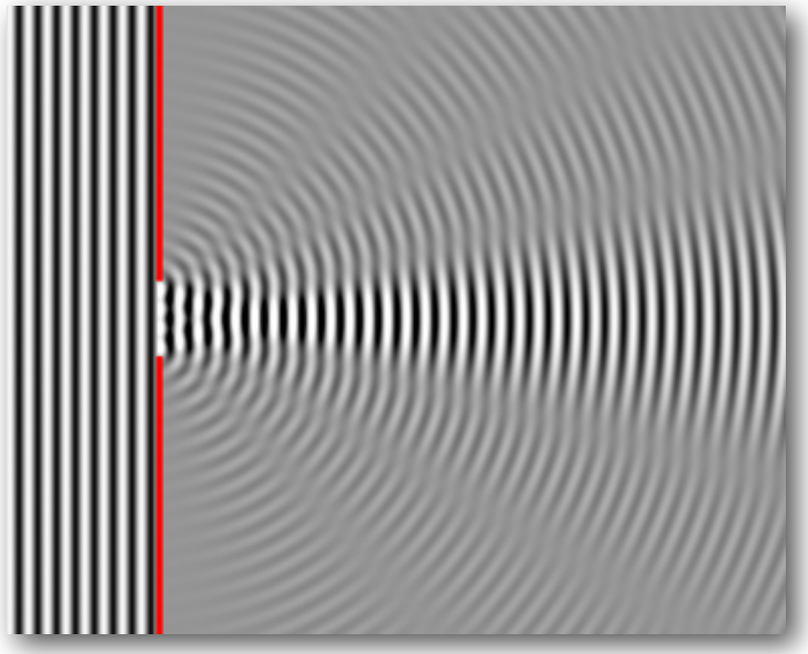
Slide adapted from Marc Levoy

Light Diffracts

* Wave Nature of Light
* Smaller Aperture means more Diffraction



3D Schematic



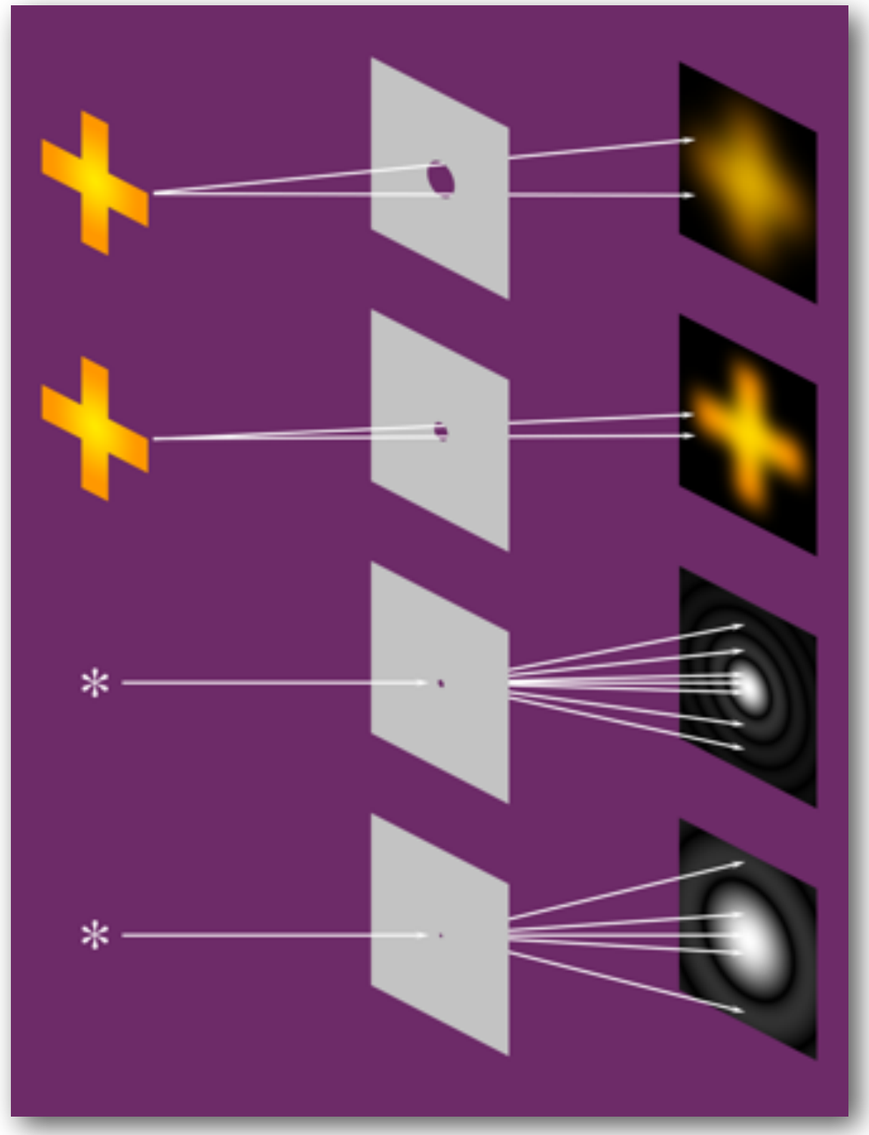
Actual Diffraction Pattern

Effect of Pinhole Size

Large Pinhole = Geometric Blur

Small Pinhole = Diffraction Blur

Best Pinhole = Very Little Light



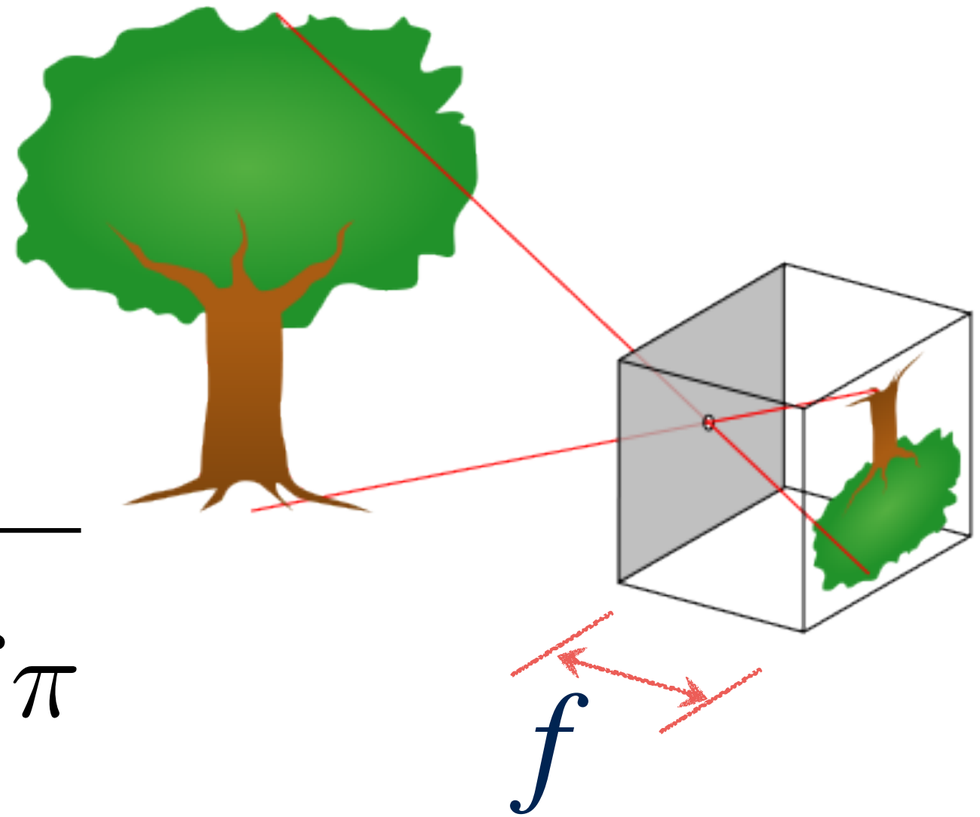
Slide adapted from Marc Levoy

Effect of Pinhole Size

For d (pinhole diameter),

f (distance from pinhole to sensor),

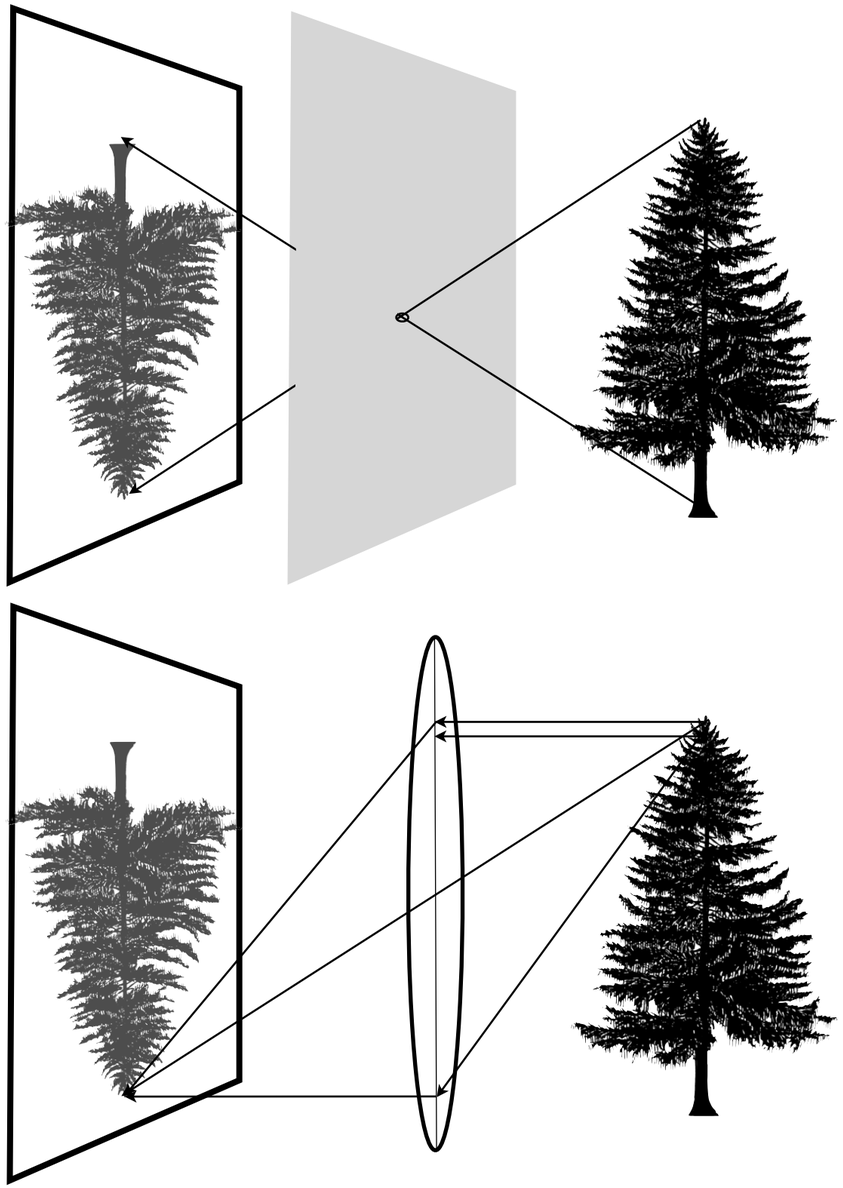
and π (wavelength of light):



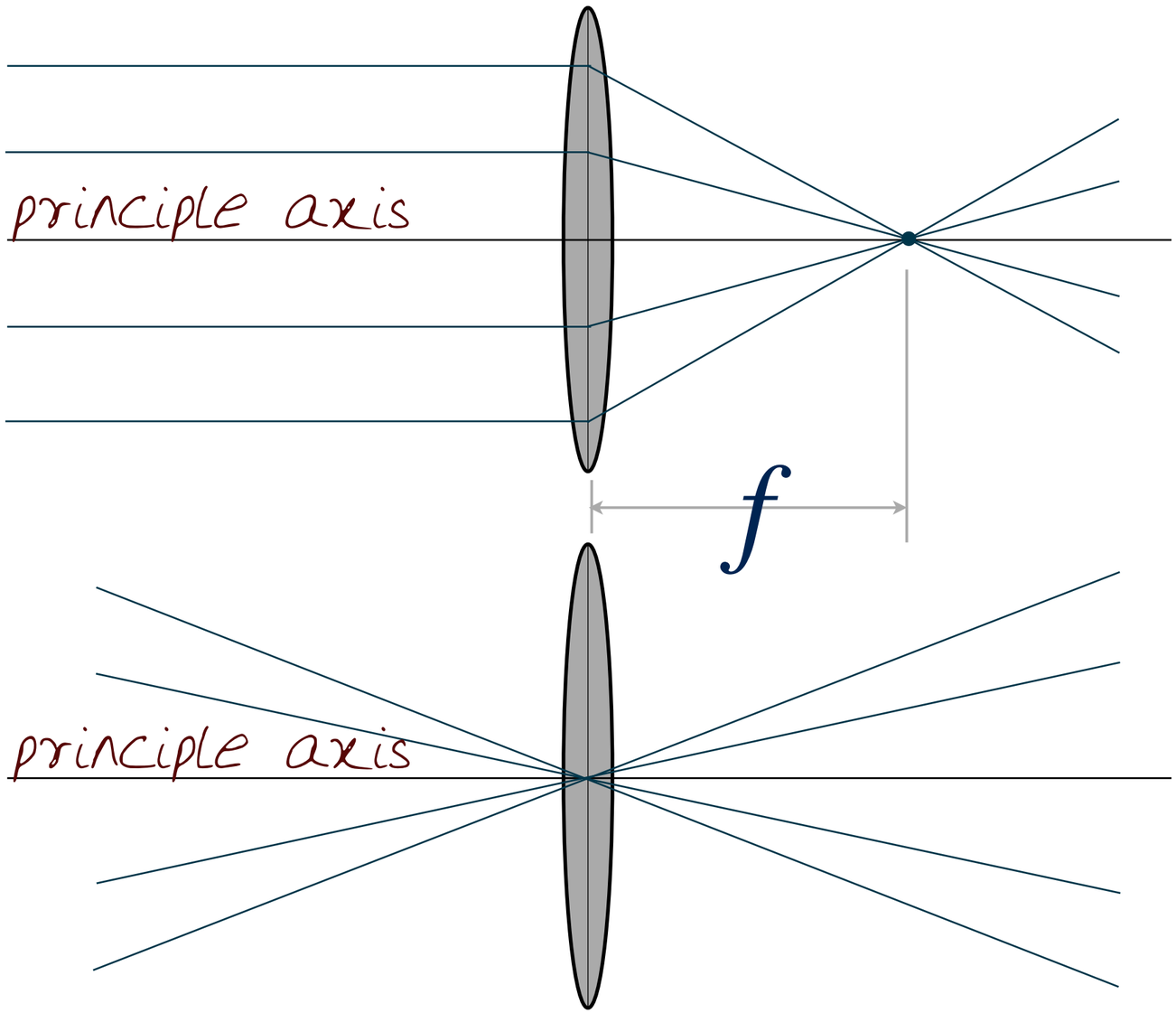
$$d = 2\sqrt{\frac{1}{2} f \pi}$$

Slide adapted from Marc Levoy

Replacing the Pinhole with a Lens

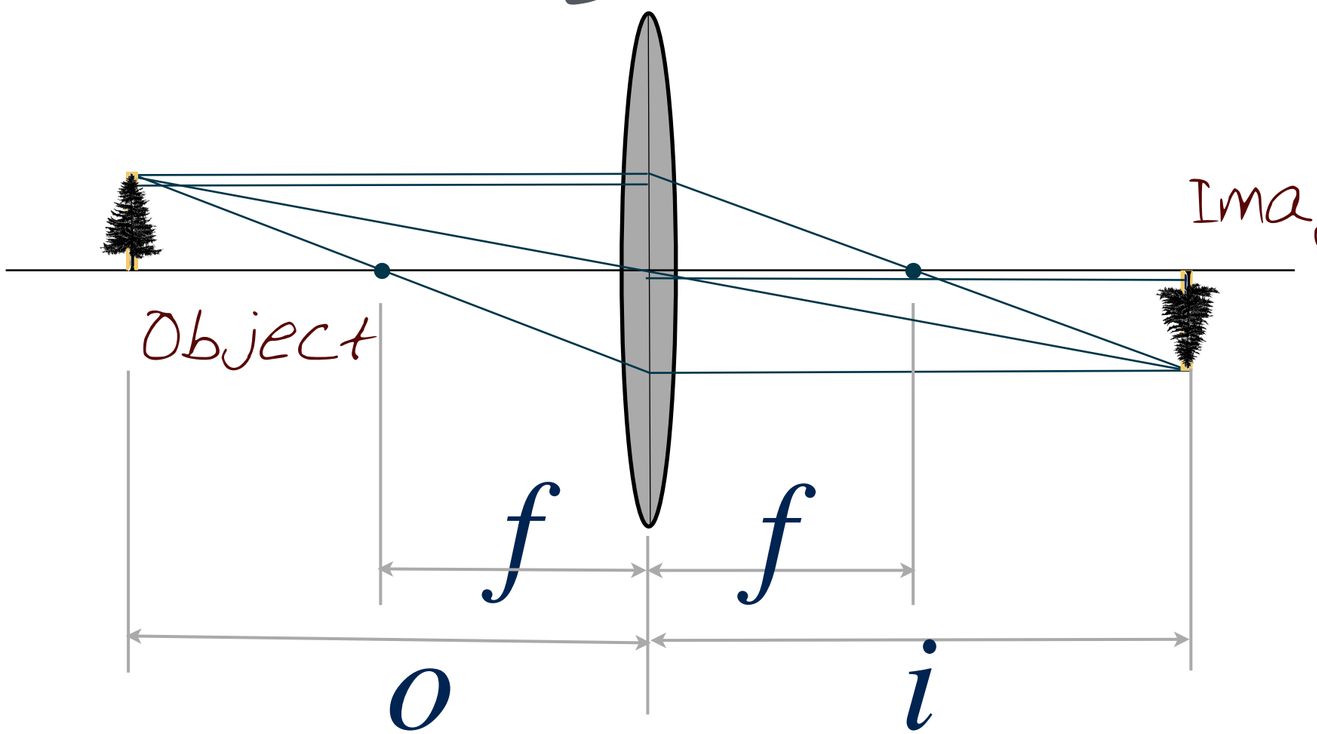


Geometrical Optics



* Parallel rays converge to a point located at focal length, f from lens
* Rays going through center of lens do not deviate (functions like a pinhole)

Ray Tracing with Lenses



$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

* Rays from points on a plane parallel to the lens, focus on a plane parallel to the lens on the other side (and upside down).

* Lens Equation

Summary

* Discussed the Foundations of How a Camera works
* Presented the Concept of a Pinhole Camera
* Introduced Optics and Lenses and the Role they play in a Camera

Next Class

* Cameras: Changes in Focal Length, Aperture, Shutter and Sensor

Credits

- For more information, see
  - Hecht, E. Optics, 4th ed. Reading, MA: Addison-Wesley and
  - London, B., Stone, J., & Upton, J., Photography, 10th ed. Upper Saddle River, NJ: Prentice Hall.
- Images retrieved from
  - http://commons.wikimedia.org/
    - http://commons.wikimedia.org/wiki/File:Sun_Rays.jpg
  - List will be available on website
- Some Slides adapted from Mark Levoy

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