COMPUTER VISION

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IMAGE FORMATION AND CAMERAS

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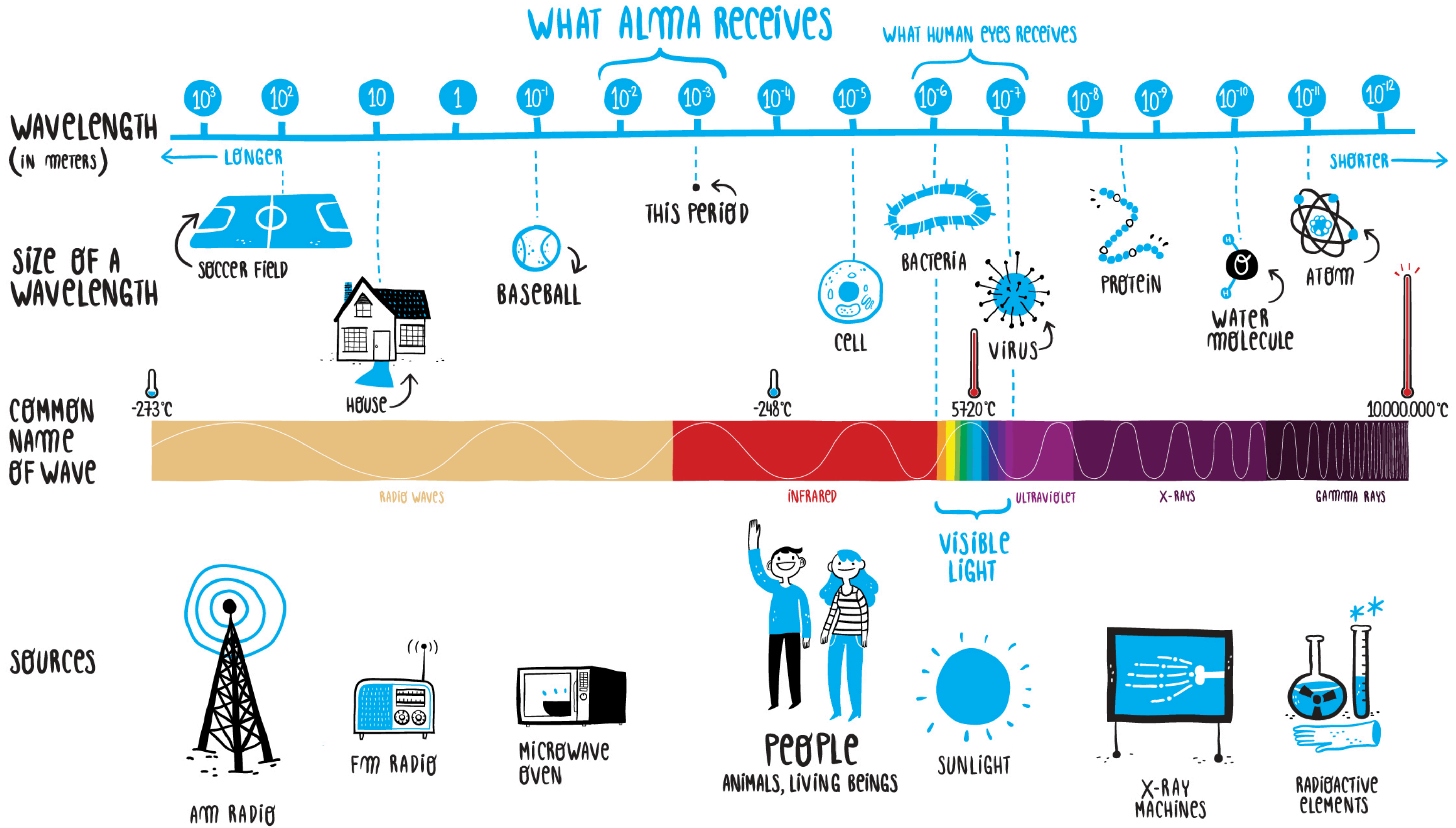
OUTLINE FOR THIS LECTURE

- Image Formation
- Cameras and Lenses
- Human Visual System
- Digital Cameras
- Digital Color Images, sampling and quantization
- Hyperspectral Camera

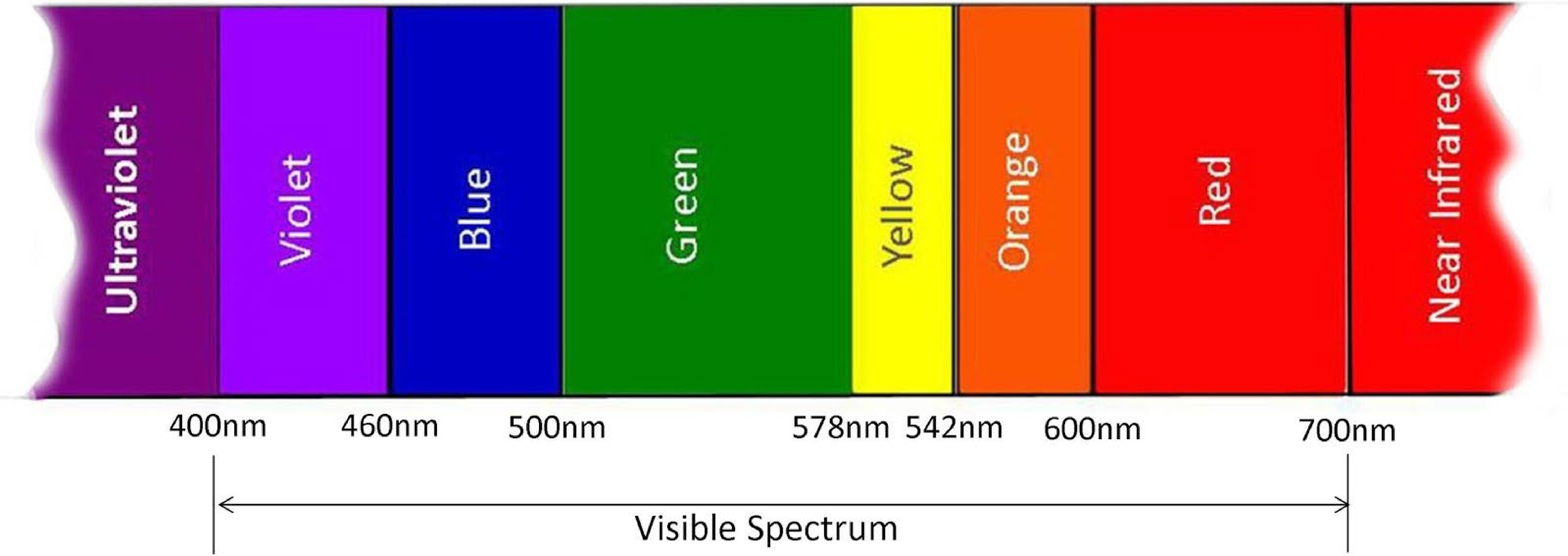
ELECTROMAGNETIC SPECTRUM



ELECTROMAGNETIC SPECTRUM

- Radio Waves-communication
- Microwaves-used to cook
- Infrared-“heat waves”
- Visible Light-detected by your eyes
- Ultraviolet-causes sunburns
- X-rays-penetrates tissue
- Gamma Rays-most energetic

VISIBLE SPECTRUM

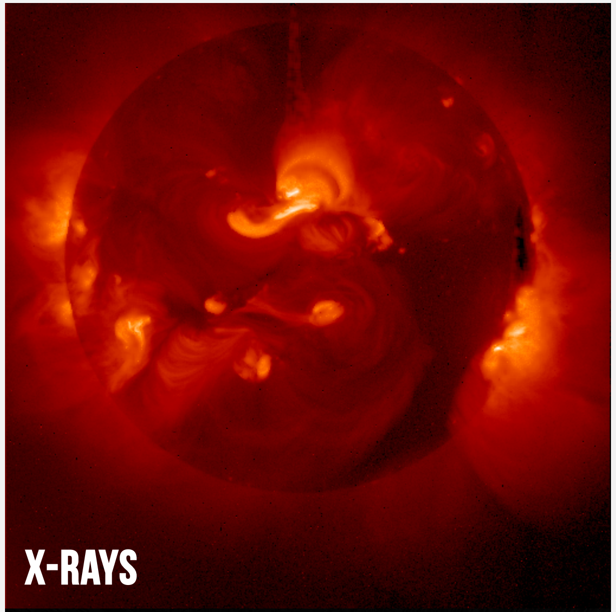


Light waves extend in wavelength from about 400 to 700 nanometers

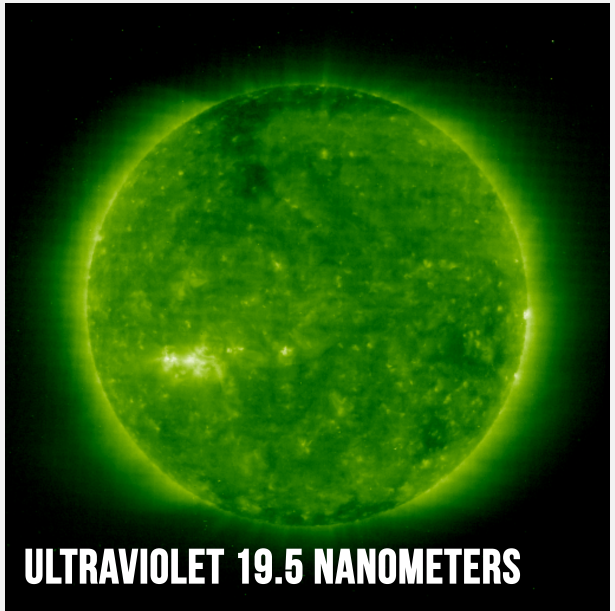
QUANTUM THEORY OF LIGHT

- Newton proposed that light is a stream of particles traveling in a straight line.
- Each particle is called a quantum and each quantum of light is a photon.
- Thus the intensity of light is measured in number of photons.
    - the visible spectrum is from 380 nm (violet) to 760 nm (red)
- Refraction occurs when light enters a different medium causing the velocity of the light to change, this change bends the direction of the light
- Short wavelengths (violet) of light are refracted more than longer wavelengths (red).
- This is why a spectrum is formed from white light passing through a prism and it also causes the problem of chromatic aberration

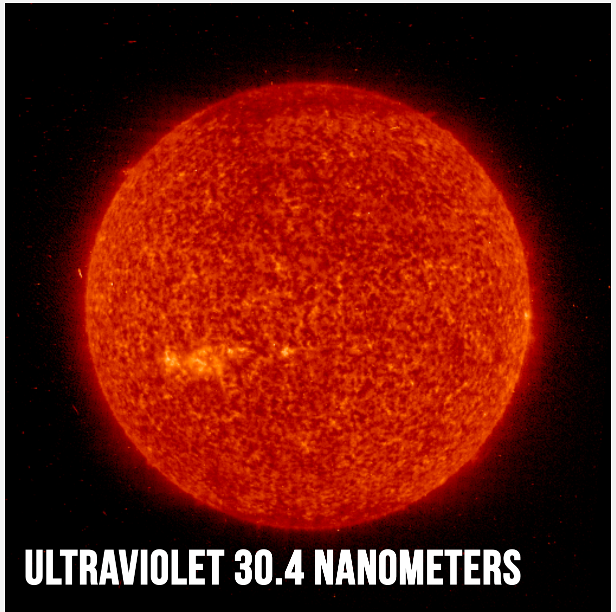
THE MULTI-WAVELENGTH SUN



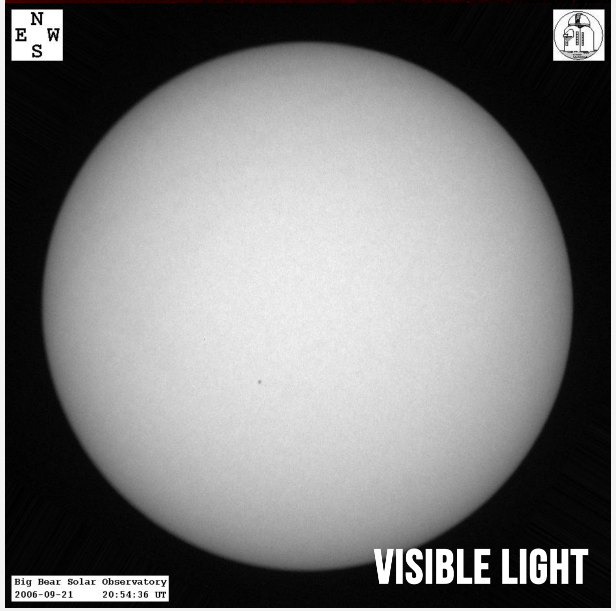
X-RAYS



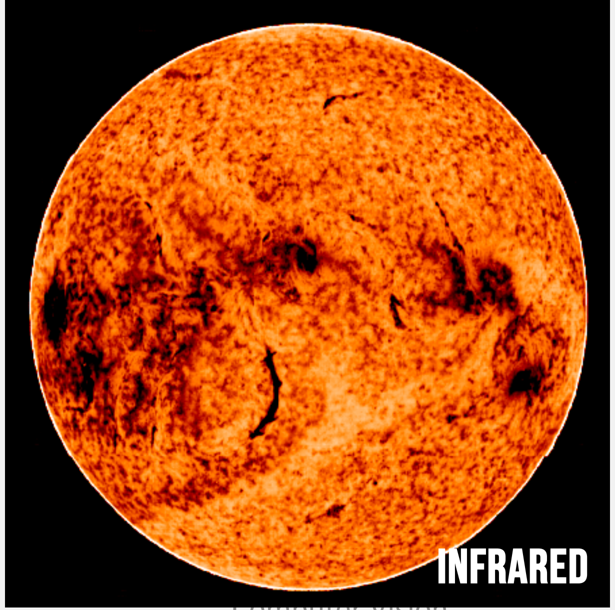
ULTRAVIOLET 19.5 NANOMETERS



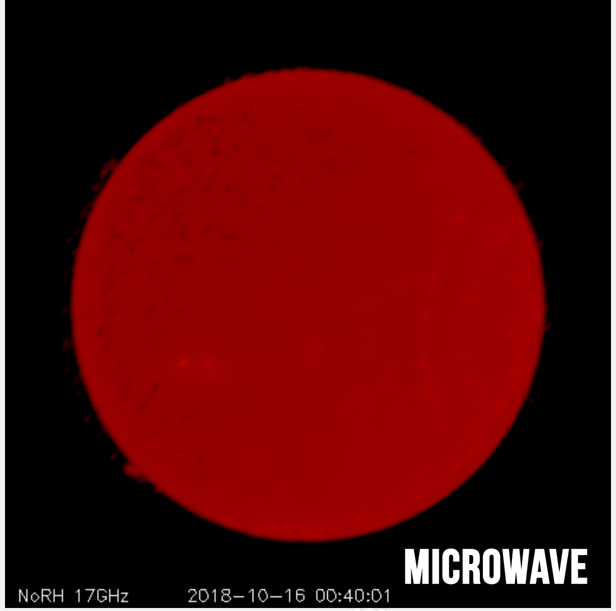
ULTRAVIOLET 30.4 NANOMETERS



VISIBLE LIGHT



INFRARED



MICROWAVE

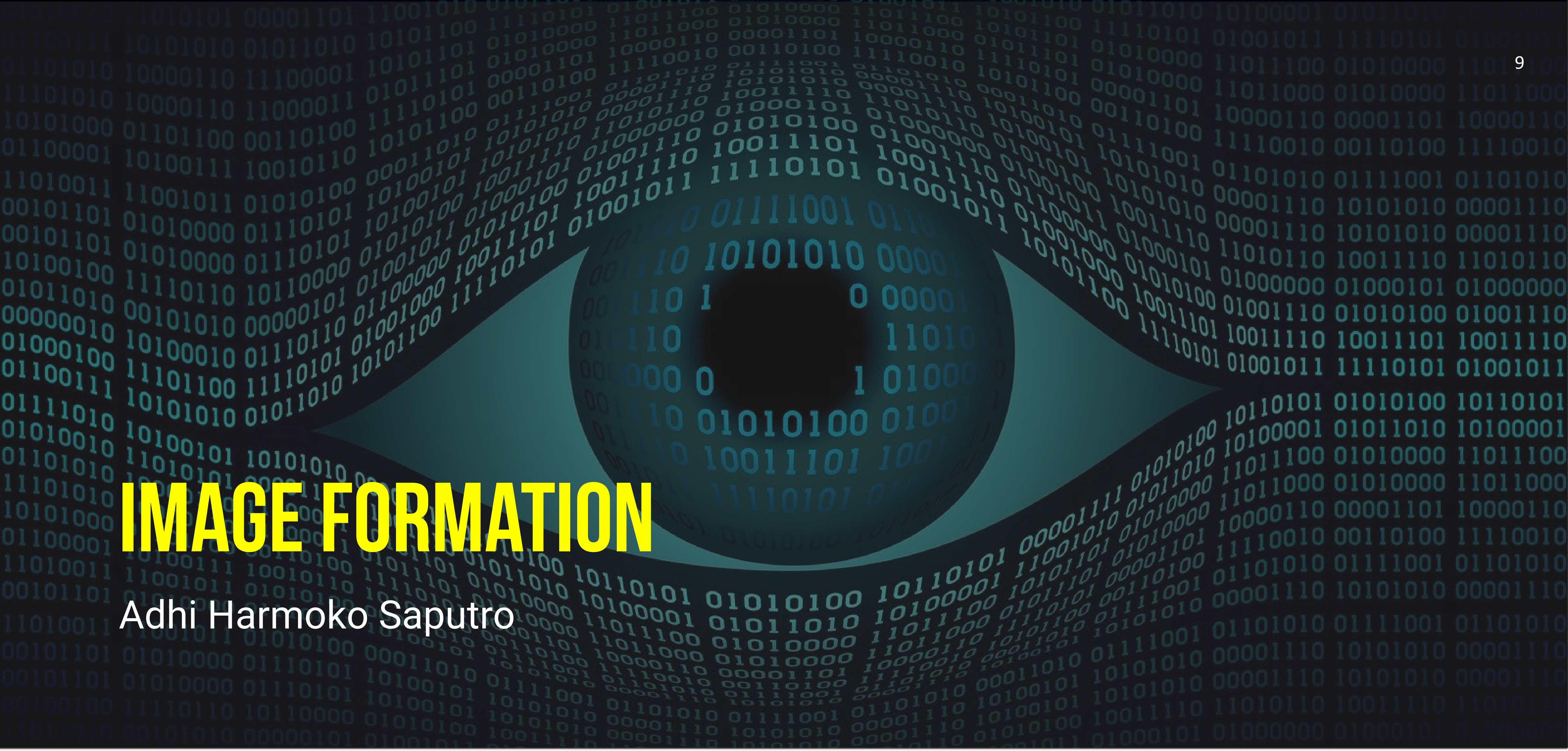


IMAGE FORMATION

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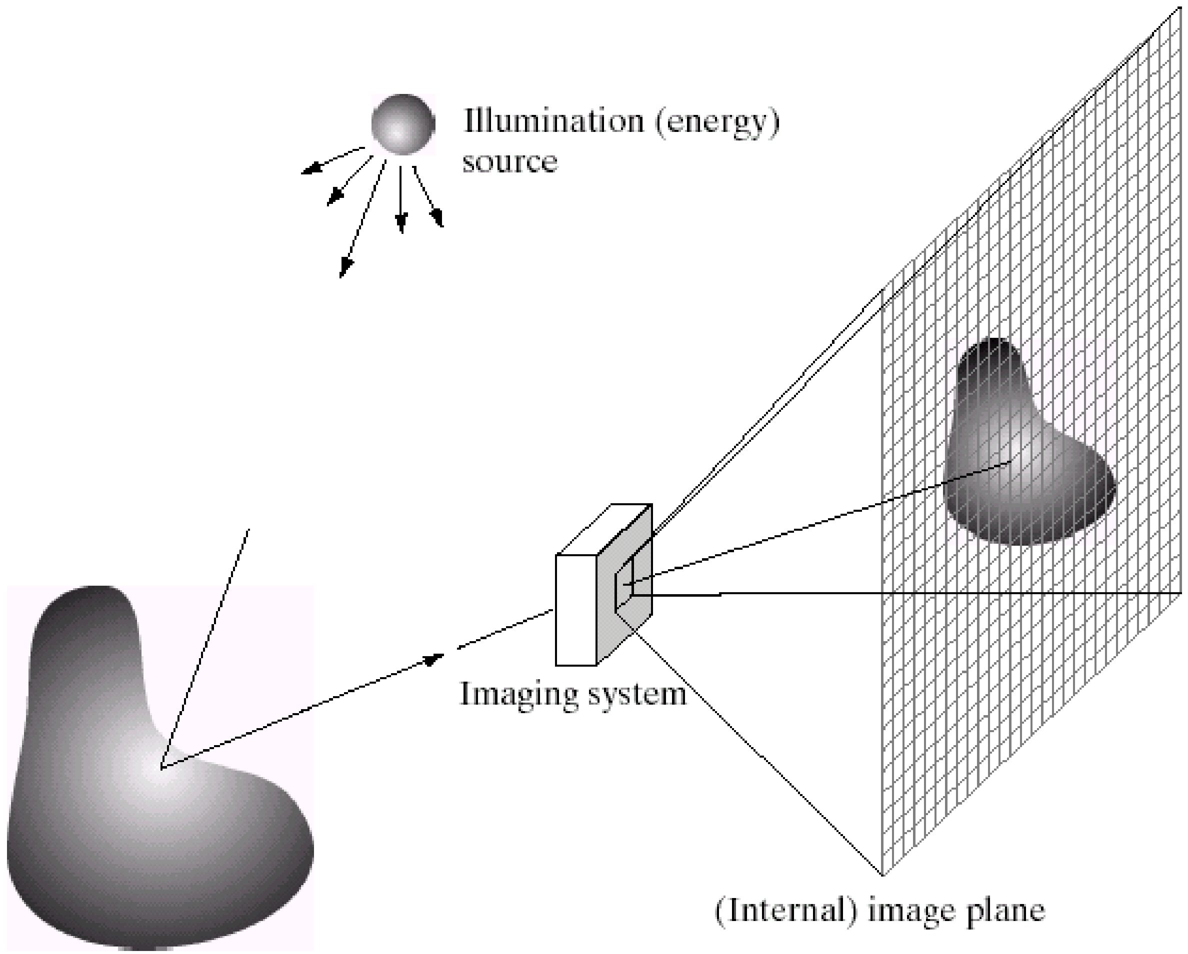
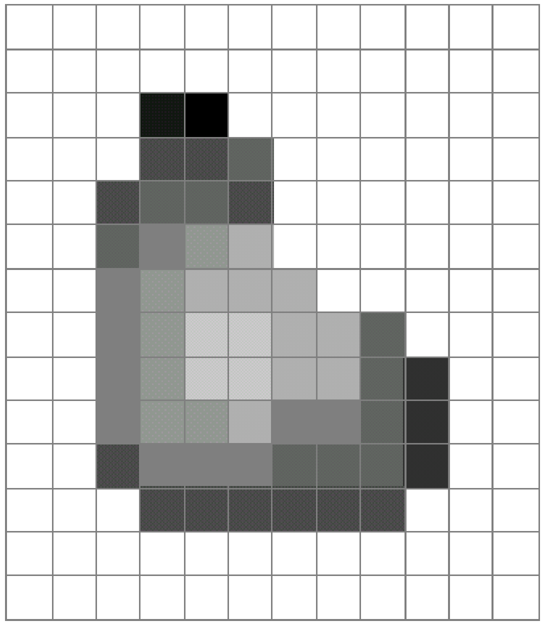
LIGHT IS EVERYWHERE

- Some of the light is reflecting off surfaces, some is absorbed, and still more light may be transmitted through mediums
- Different materials respond differently to light

IMAGE FORMATION: SIMPLE MODEL





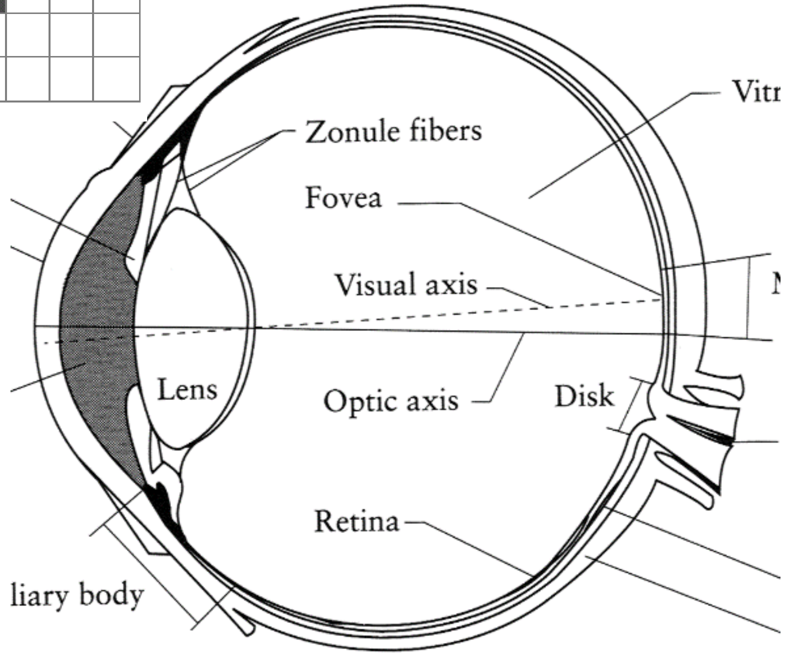


IMAGE FORMATION: SIMPLE MODEL

- There are two parts to the image formation process:

  - The **geometry**, which determines where in the image plane the projection of a point in the scene will be located.

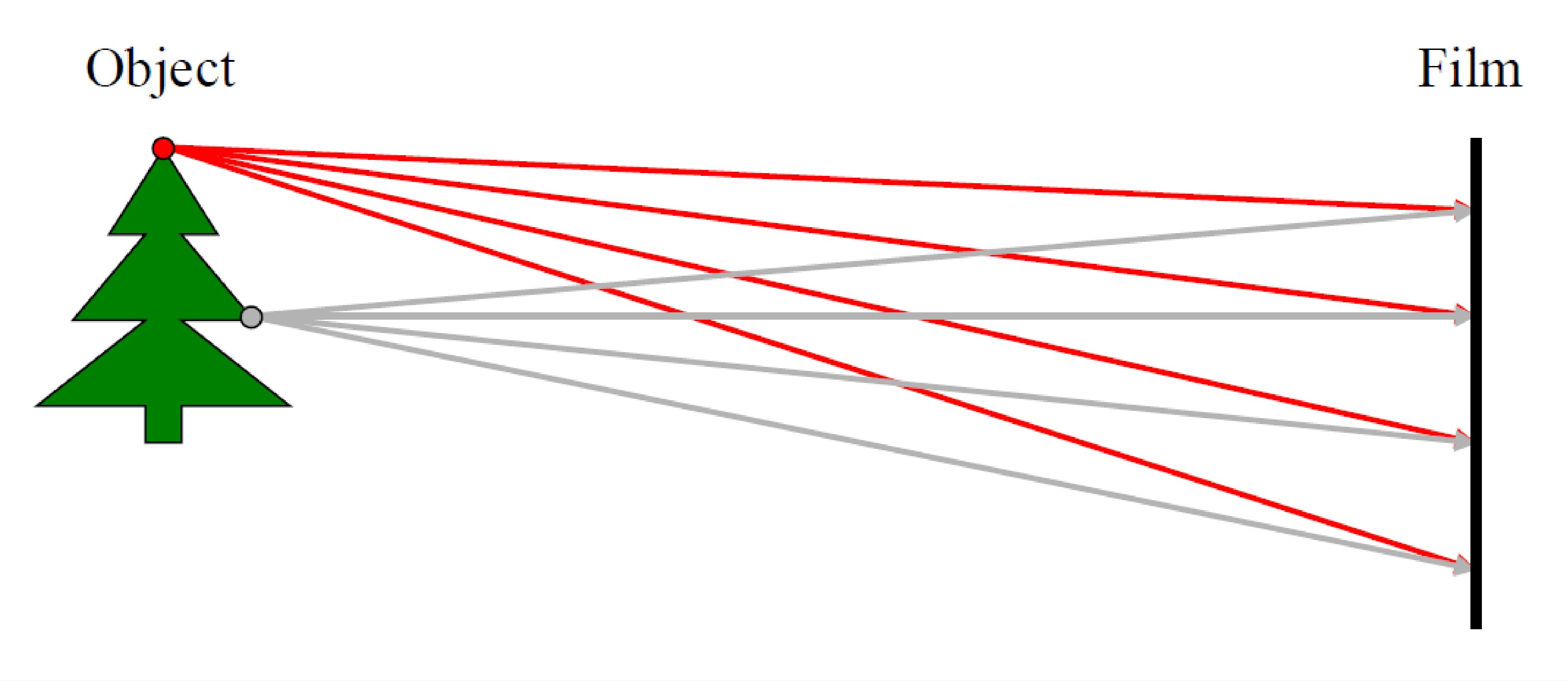
  - The **physics of light**, which determines the brightness of a point in the image plane.
    - Simple model

$$f(x,y) = i(x,y)\ r(x,y)$$

    - i: illumination, r: reflectance

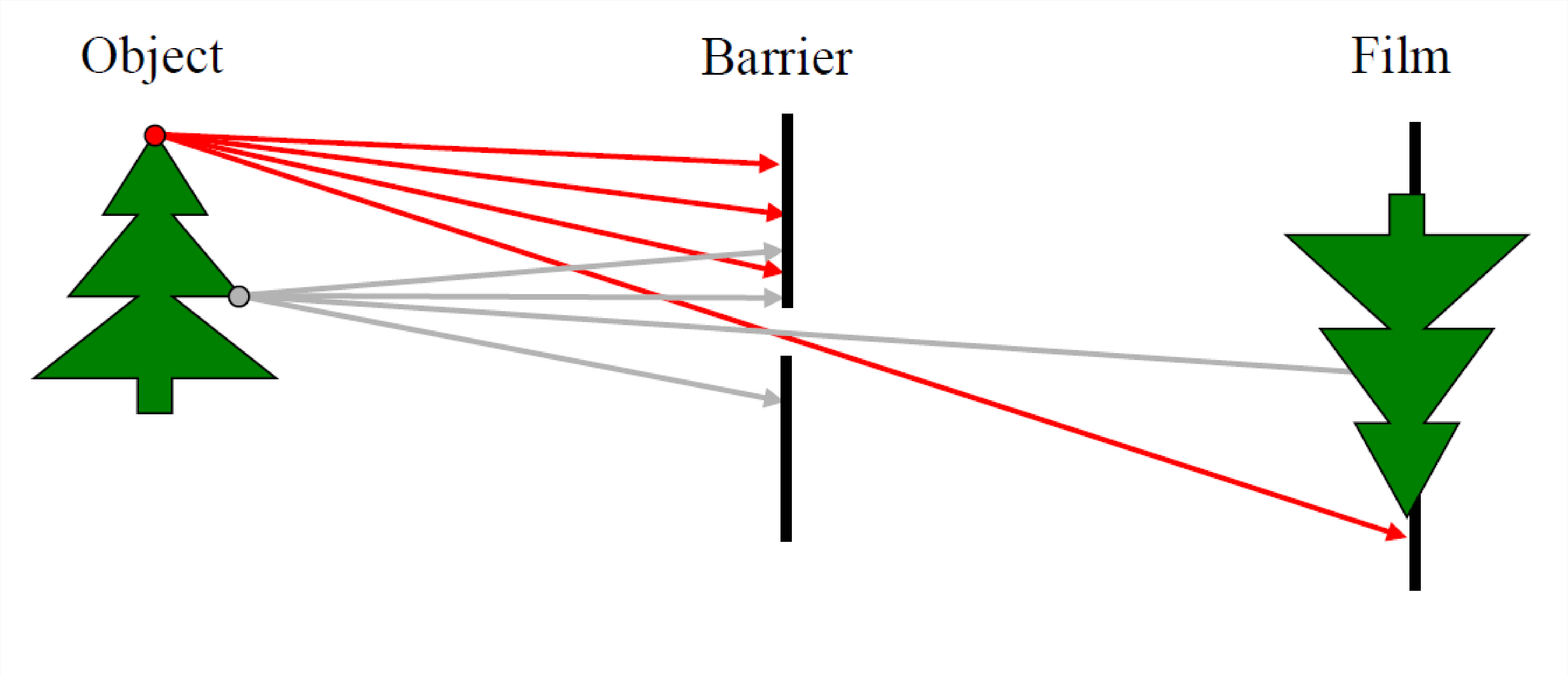
IMAGE FORMATION

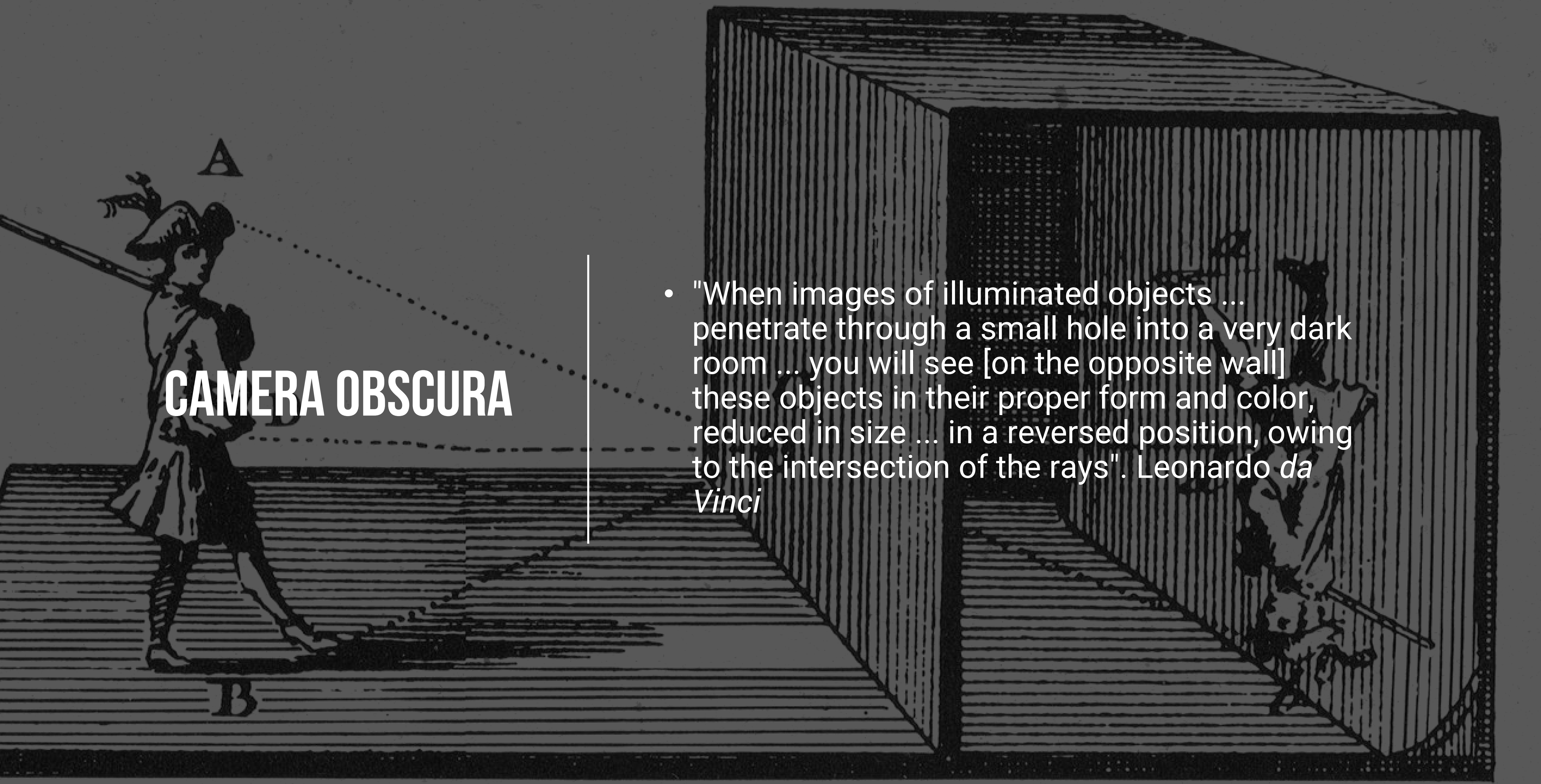
- Let’s design a camera
  - Idea 1: put a piece of film in front of an object
  - Do we get a reasonable image? Blurring …



PINHOLE CAMERA

- Add a barrier to block off most of the rays
  - This reduces blurring
  - The opening known as the **aperture**
  - How does this transform the image?



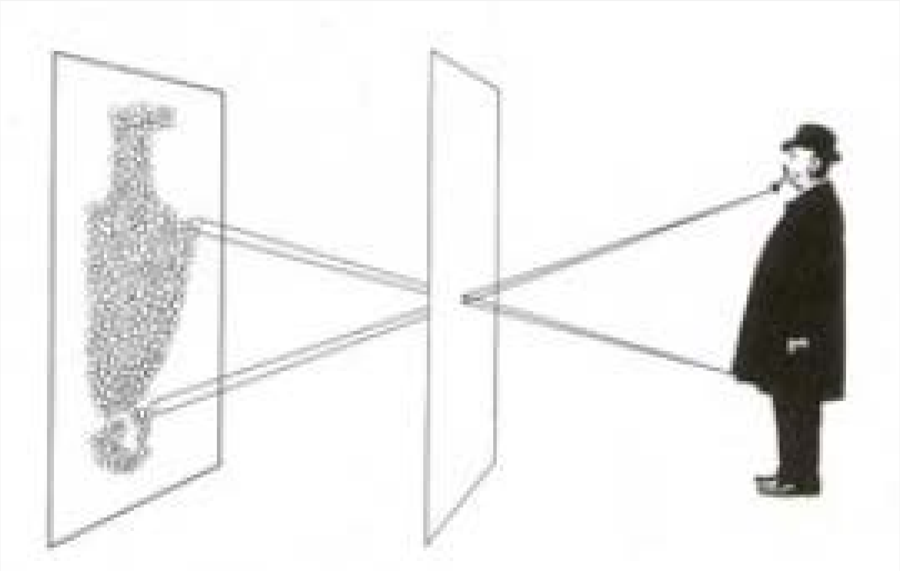


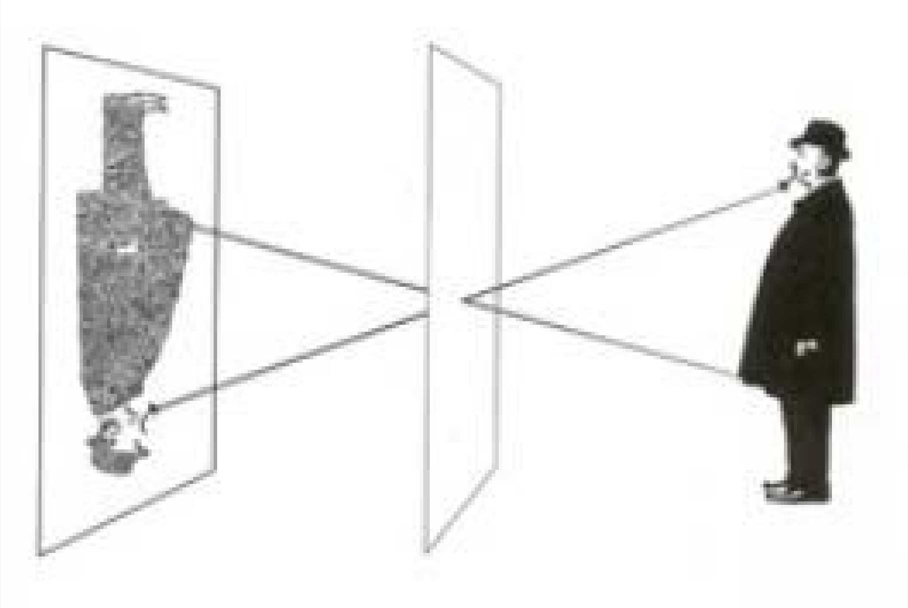
CAMERA OBSCURA

- "When images of illuminated objects ... penetrate through a small hole into a very dark room ... you will see [on the opposite wall] these objects in their proper form and color, reduced in size ... in a reversed position, owing to the intersection of the rays". Leonardo *da Vinci*

WHAT IS THE EFFECT OF APERTURE SIZE?

- Large aperture: light from the source spreads across the image (i.e., not properly focused), making it blurry!
- Small aperture: reduces blurring but (i) it limits the amount of light entering the camera and (ii) causes light diffraction.

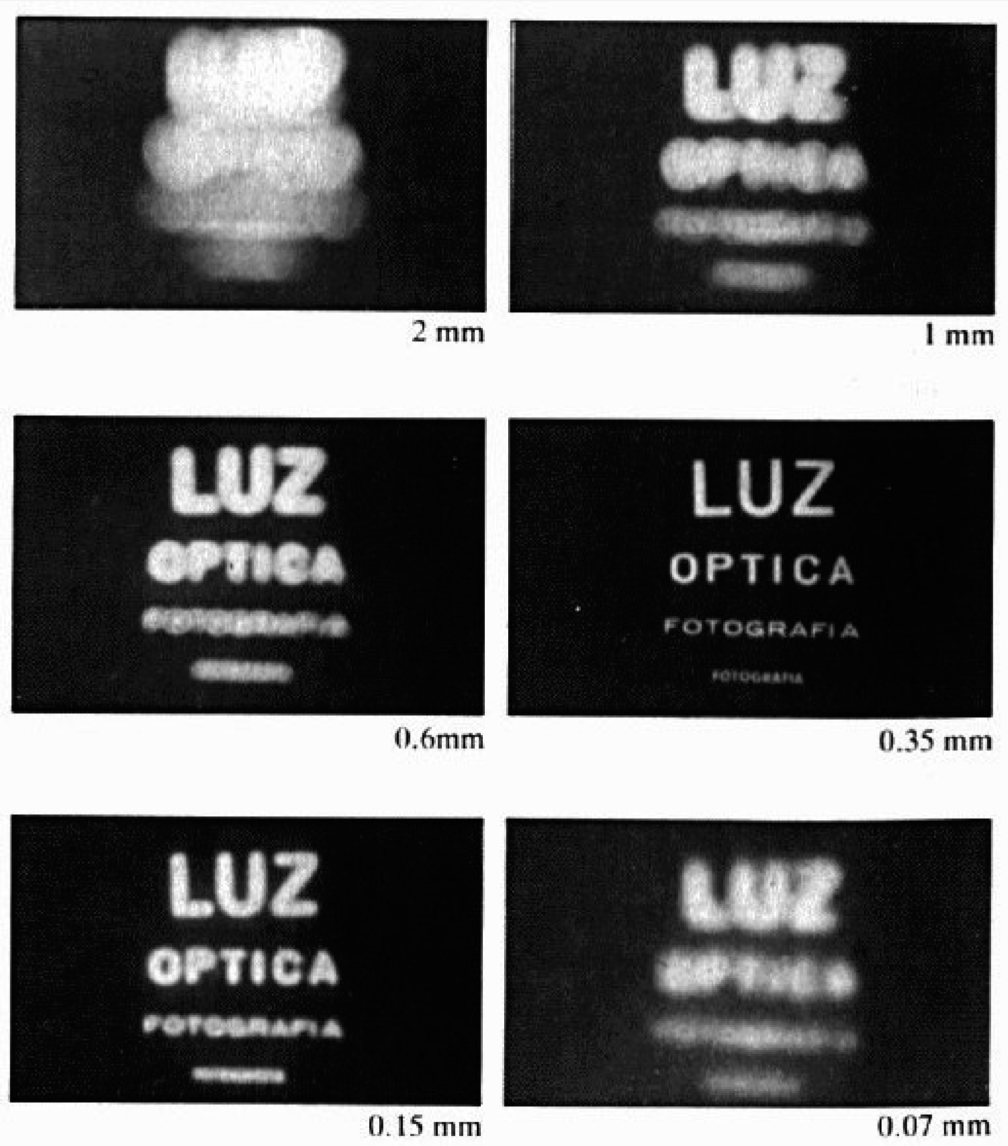




SHRINKING THE APERTURE

- Why not make the aperture as small as possible?
    - Less light gets through

- What happens if we keep decreasing aperture size?
- When light passes through a small hole, it does not travel in a straight line and is scattered in many directions (i.e., diffraction)

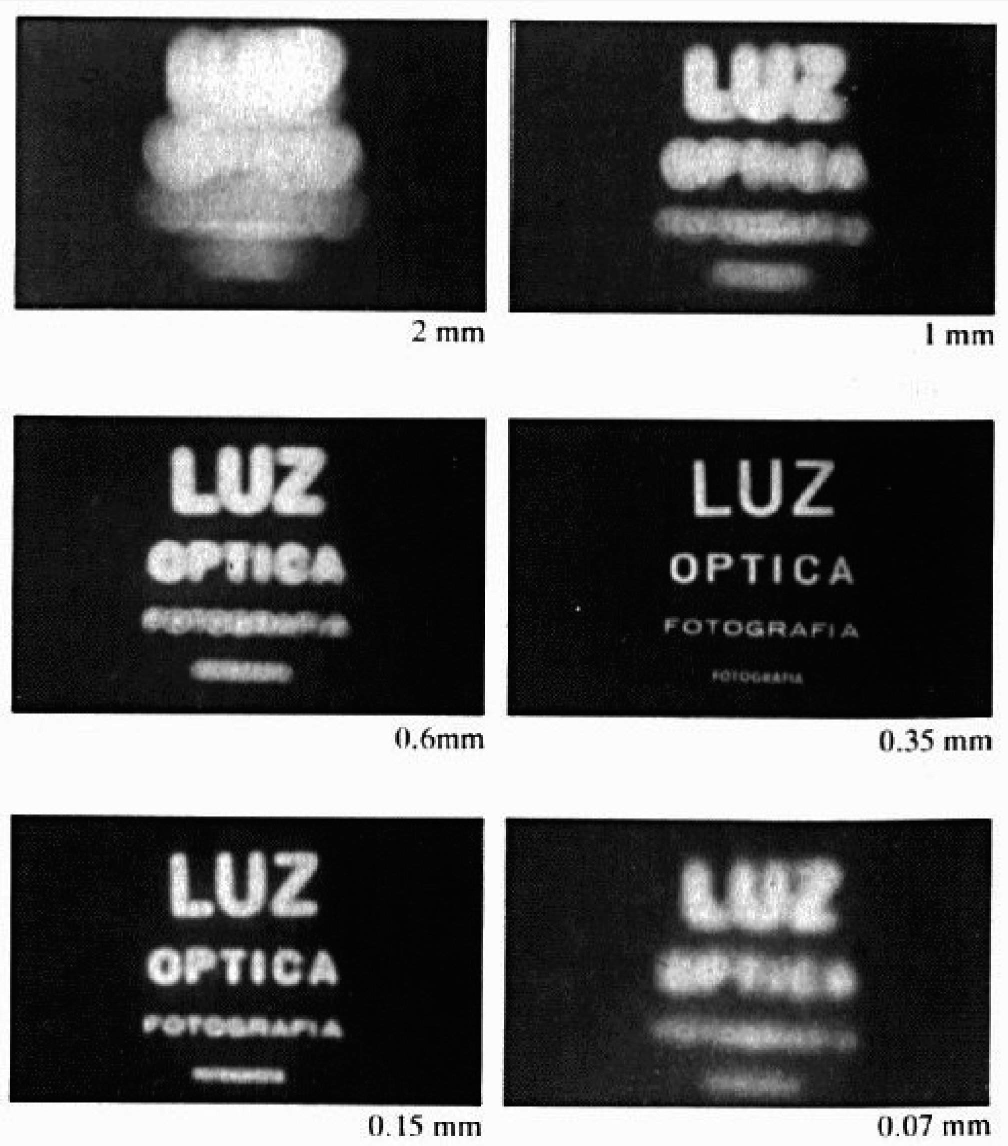


Shrinking the aperture

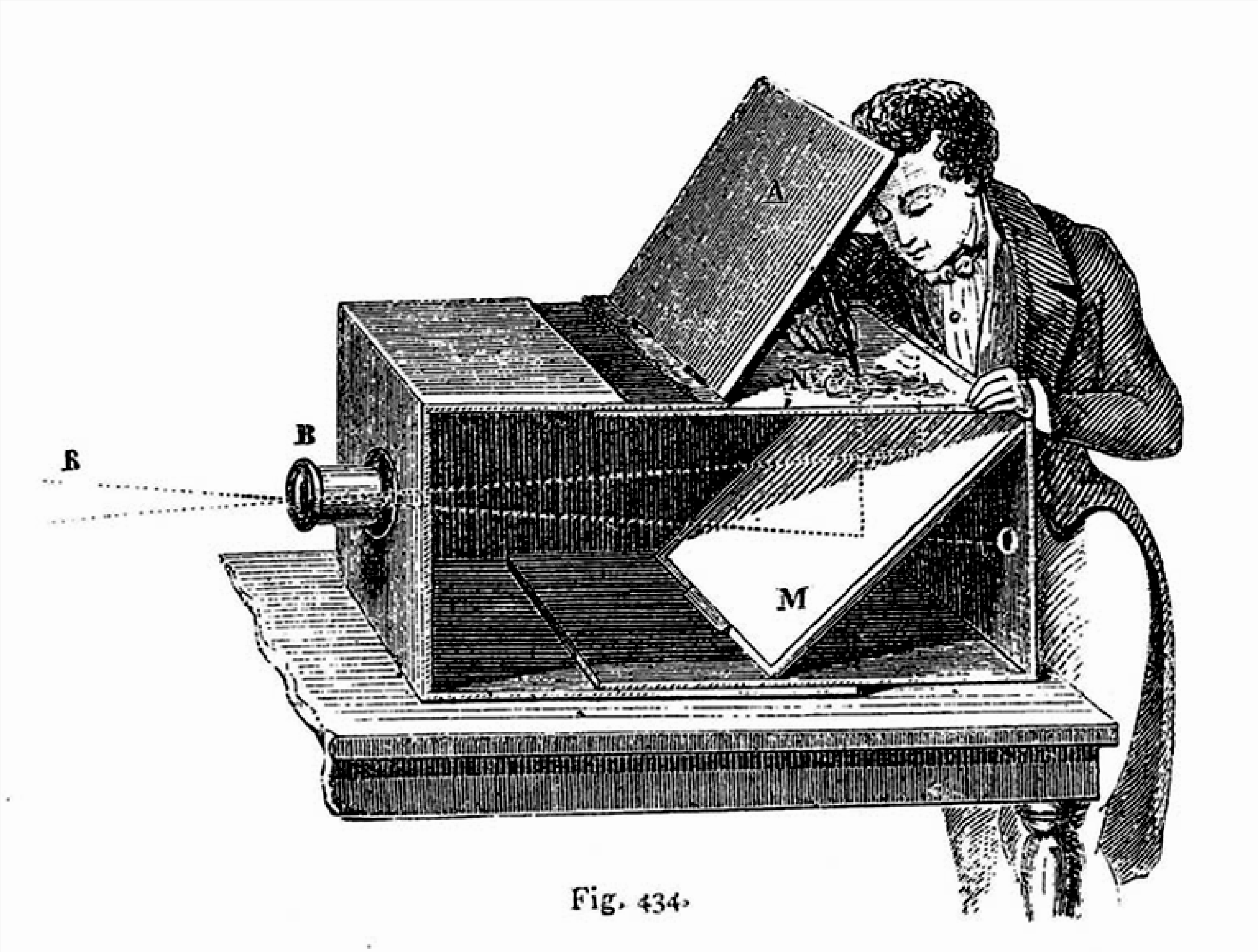
- Pinhole too big -many directions are averaged, blurring the image

- Pinhole too small -diffraction effects blur the image

- Generally, pinhole cameras are *dark*, because a very small set of rays from a particular point hits the screen.

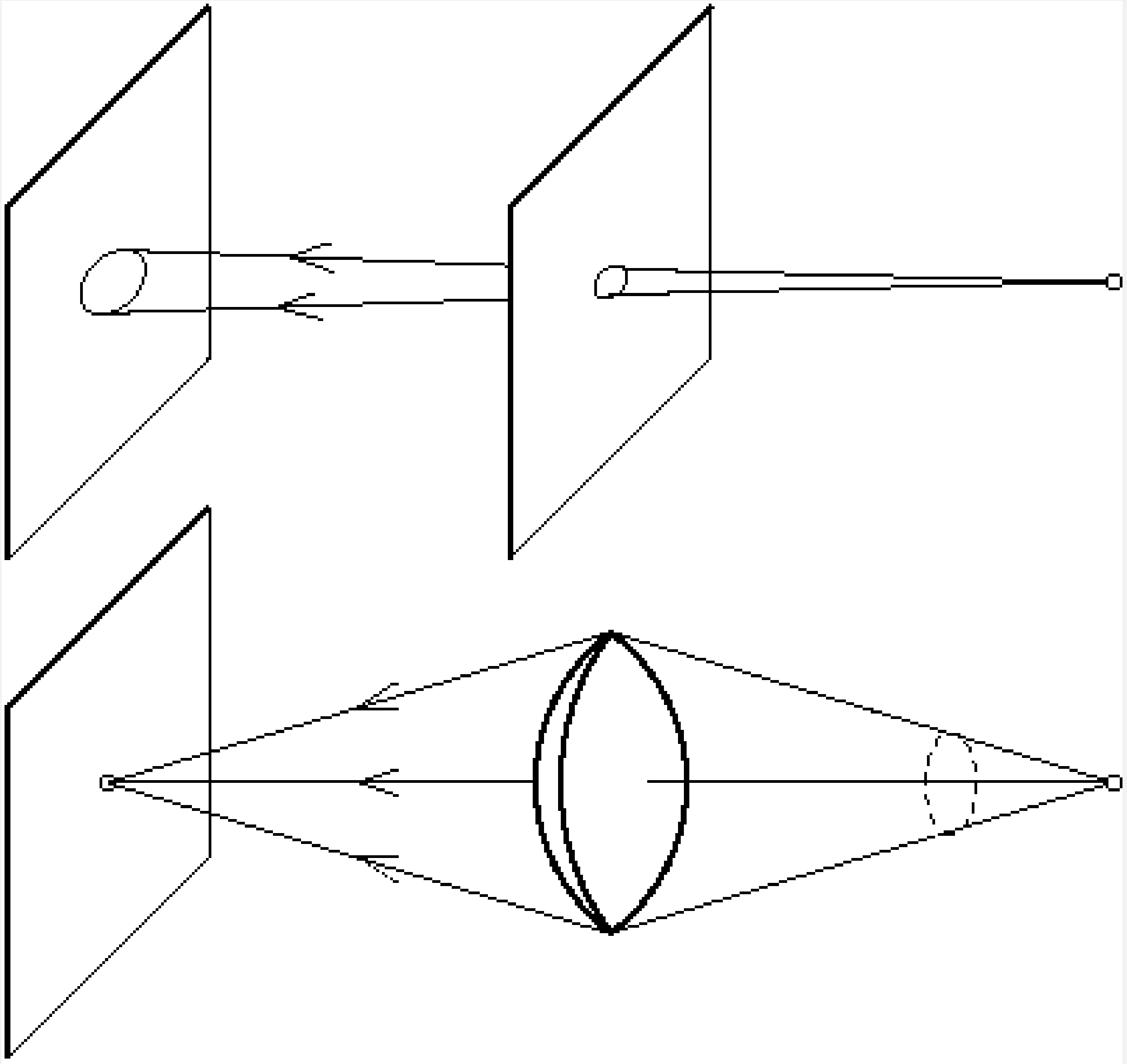


HISTORY OF IMAGING: ADDING A LENS



Lens Based Camera Obscura, 1568

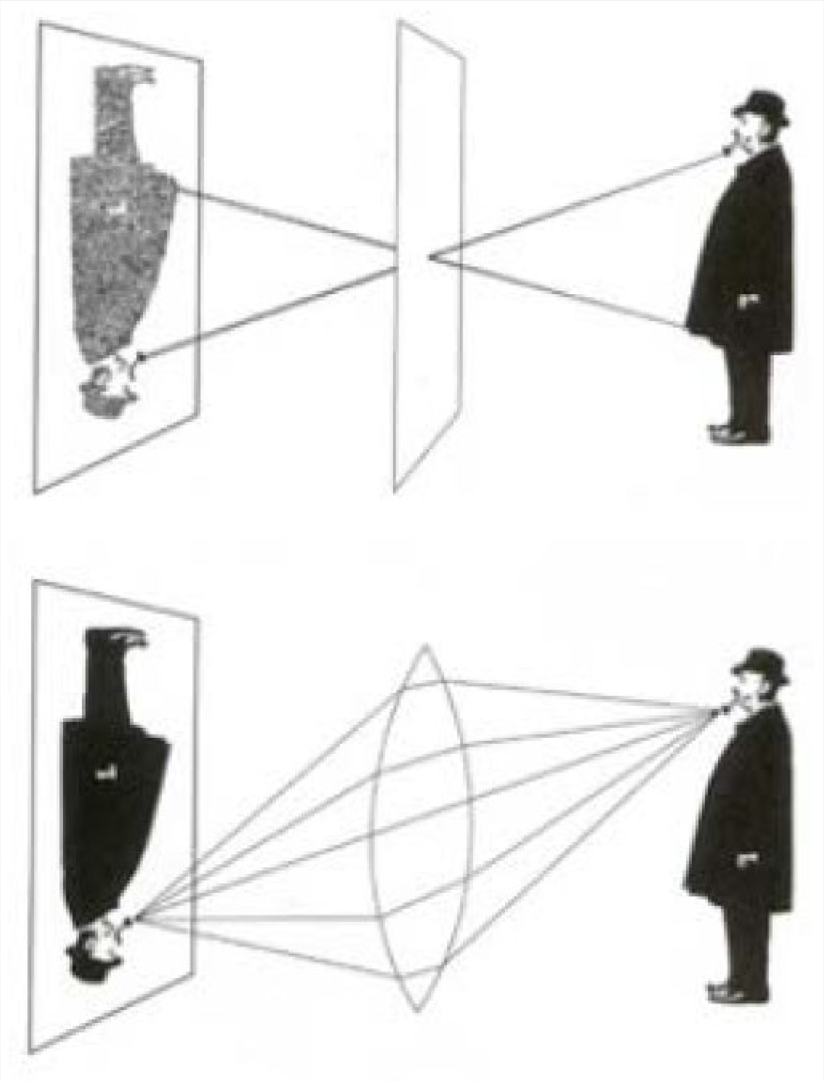
THE REASON FOR LENSES



Gather more light from each scene point

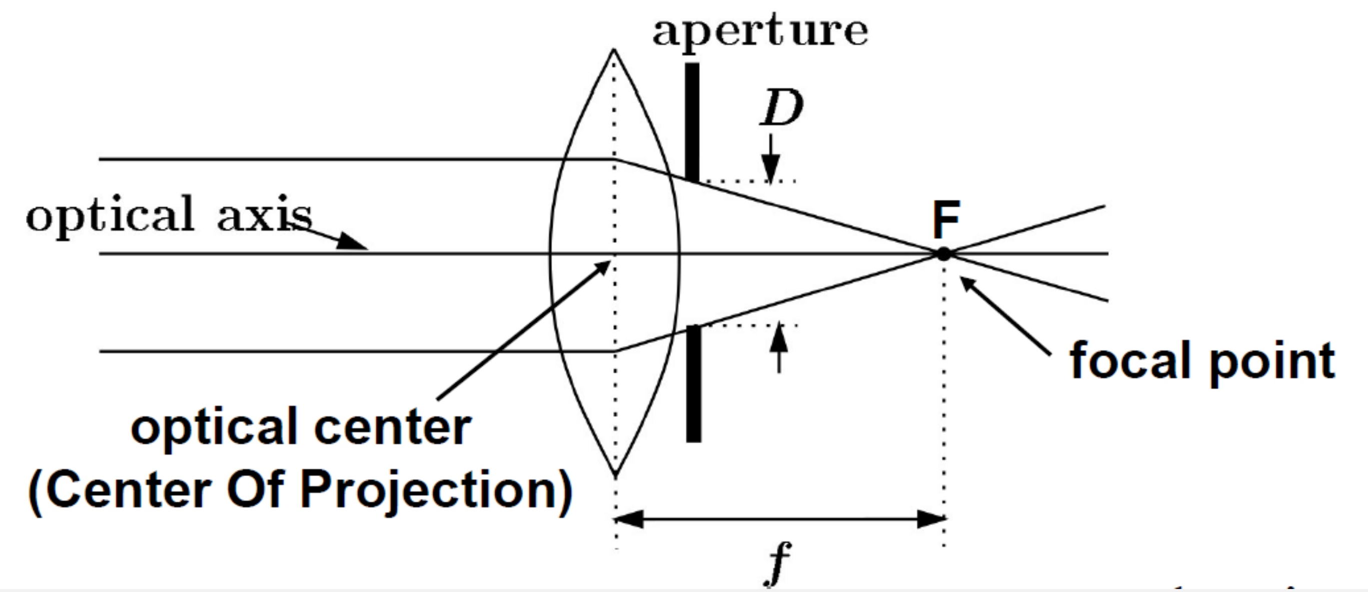
ADDING A LENS

- Pinhole replaced by a Lens
- Lens redirect light rays emanating from the object
- Lens improve image quality, leading to sharper images.



LENSES

- A lens focuses parallel rays onto a single focal point
  - focal point at a distance *f* beyond the plane of the lens
    - *f* is a function of the shape and index of refraction of the lens
  - Aperture of diameter D restricts the range of rays
    - aperture may be on either side of the lens
  - Lenses are typically spherical (easier to produce)



TERIMA KASIH

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