Folien zur Vorlesung am 25.03.2025

3D Computer Vision

IMAGE FORMATION (BILDENTSTEHUNG)

Cameras

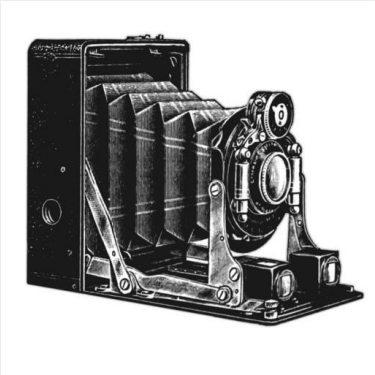
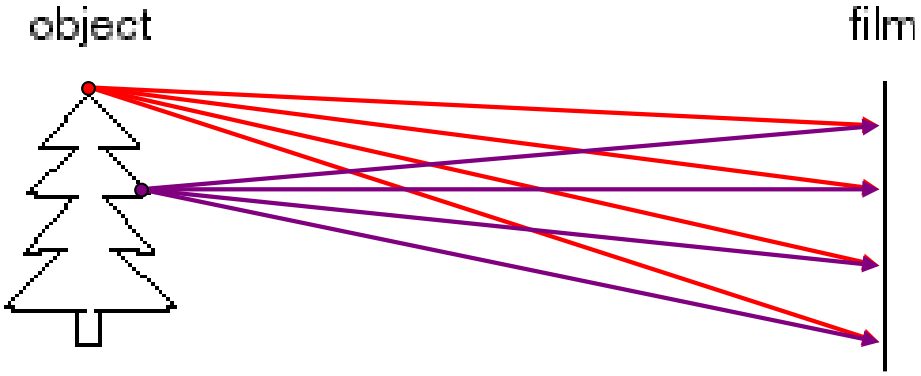


Image from https://www.apple.com/de/newsroom/2021/09/apple-unveils-iphone-13-pro-and-iphone-13-pro-max-more-pro-than-ever-before/

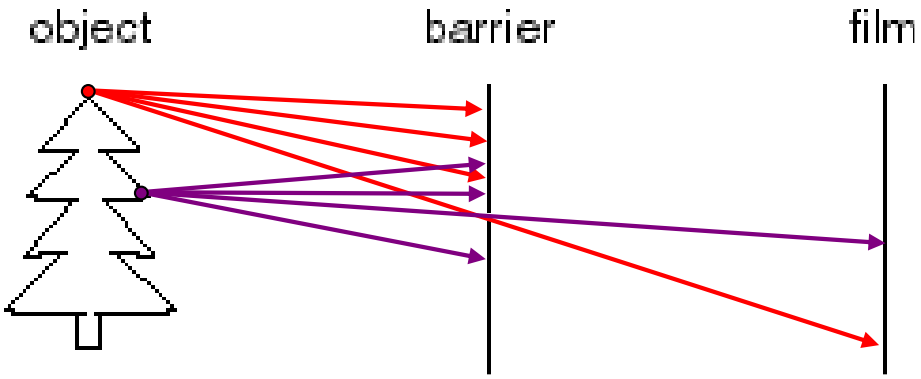
Image formation



Let's design a camera

- Idea 1: put a piece of film in front of an object
- Do we get a reasonable image?
- No. This is a bad camera.

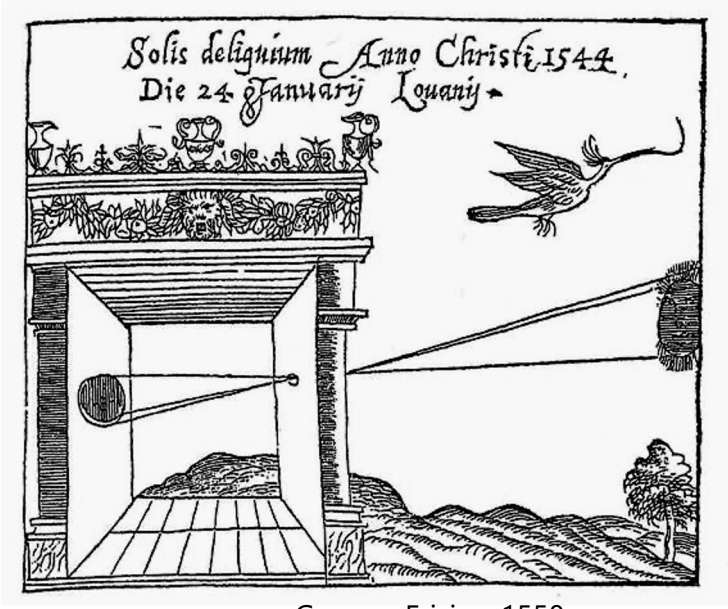
Pinhole camera



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



Gemma Frisius, 1558

- Basic principle known to Mozi (470-390 BC), Aristotle (384-322 BC)
- Drawing aid for artists: described by Leonardo da Vinci (1452-1519)

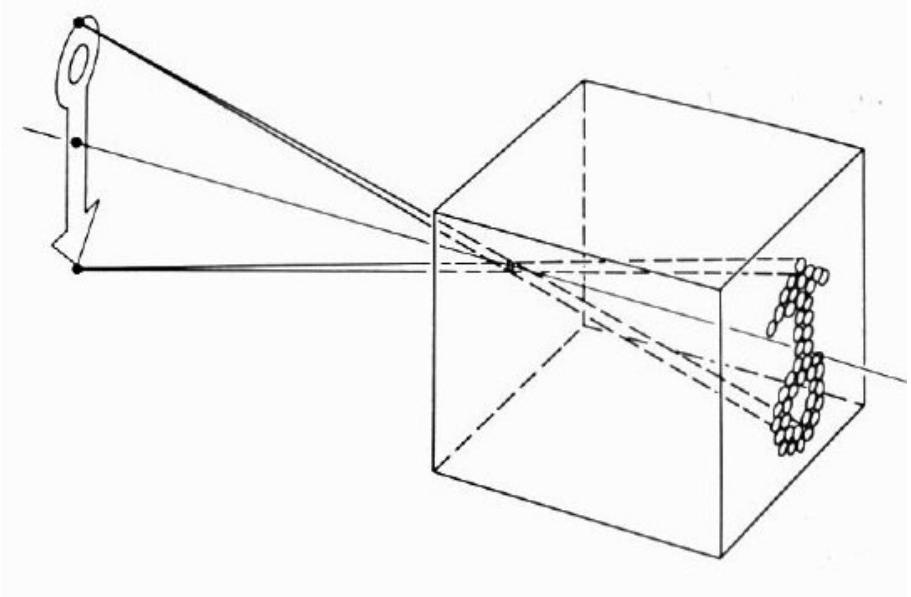
Source: A. Efros

Camera obscura

- Used by Canaletto in Venice (~1730)

Images from https://artsandculture.google.com/story/3QVhioQYNBkoJA

Camera Obscura



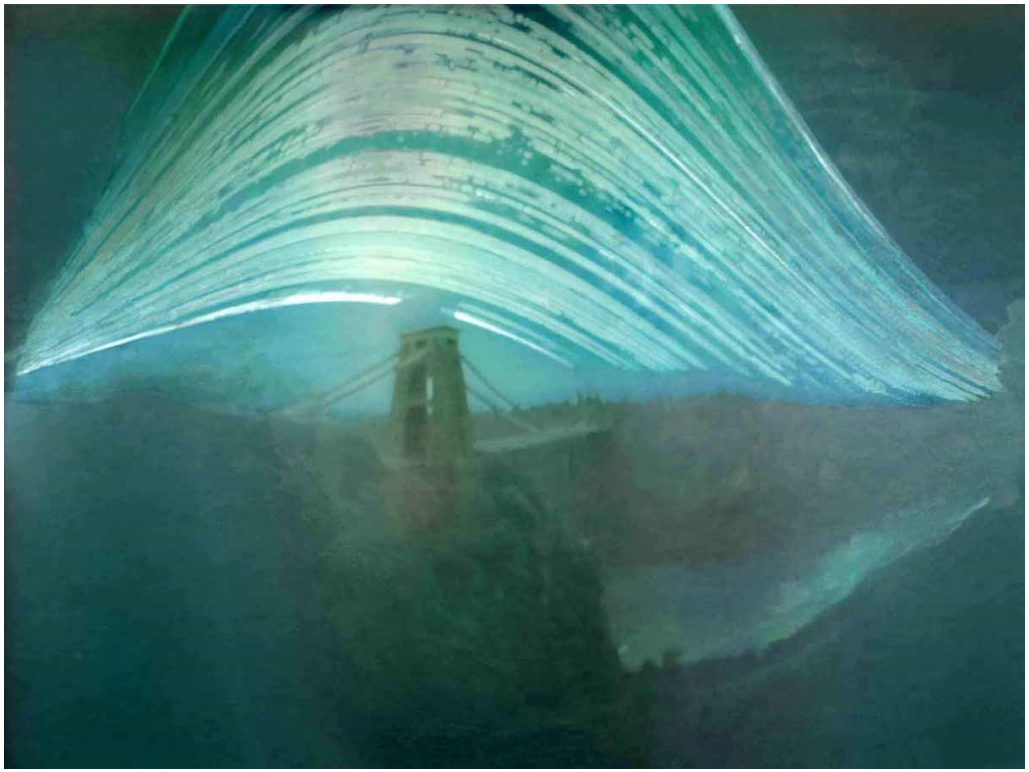
Home-made pinhole camera

Why so blurry?

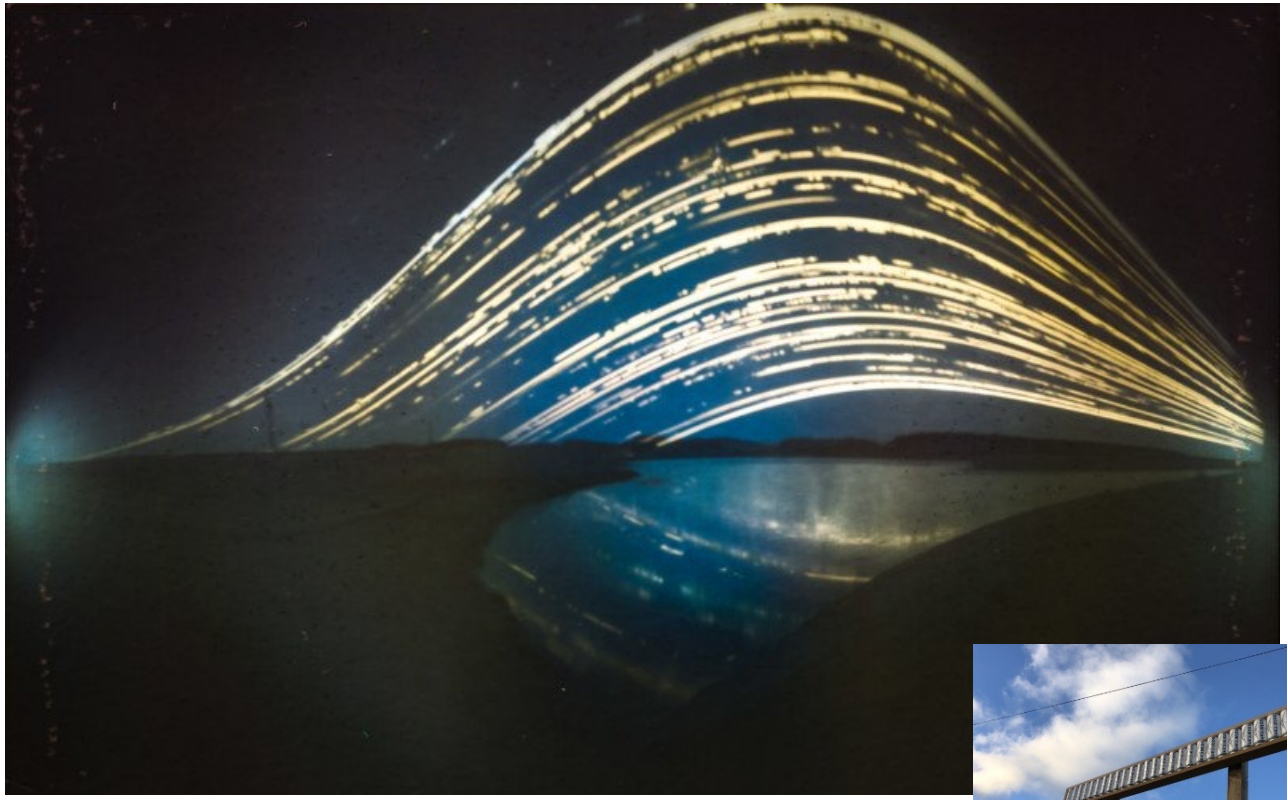
Slide by A. Efros

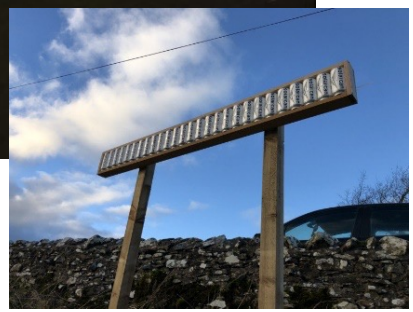
http://www.debevec.org/Pinhole/

Pinhole photography

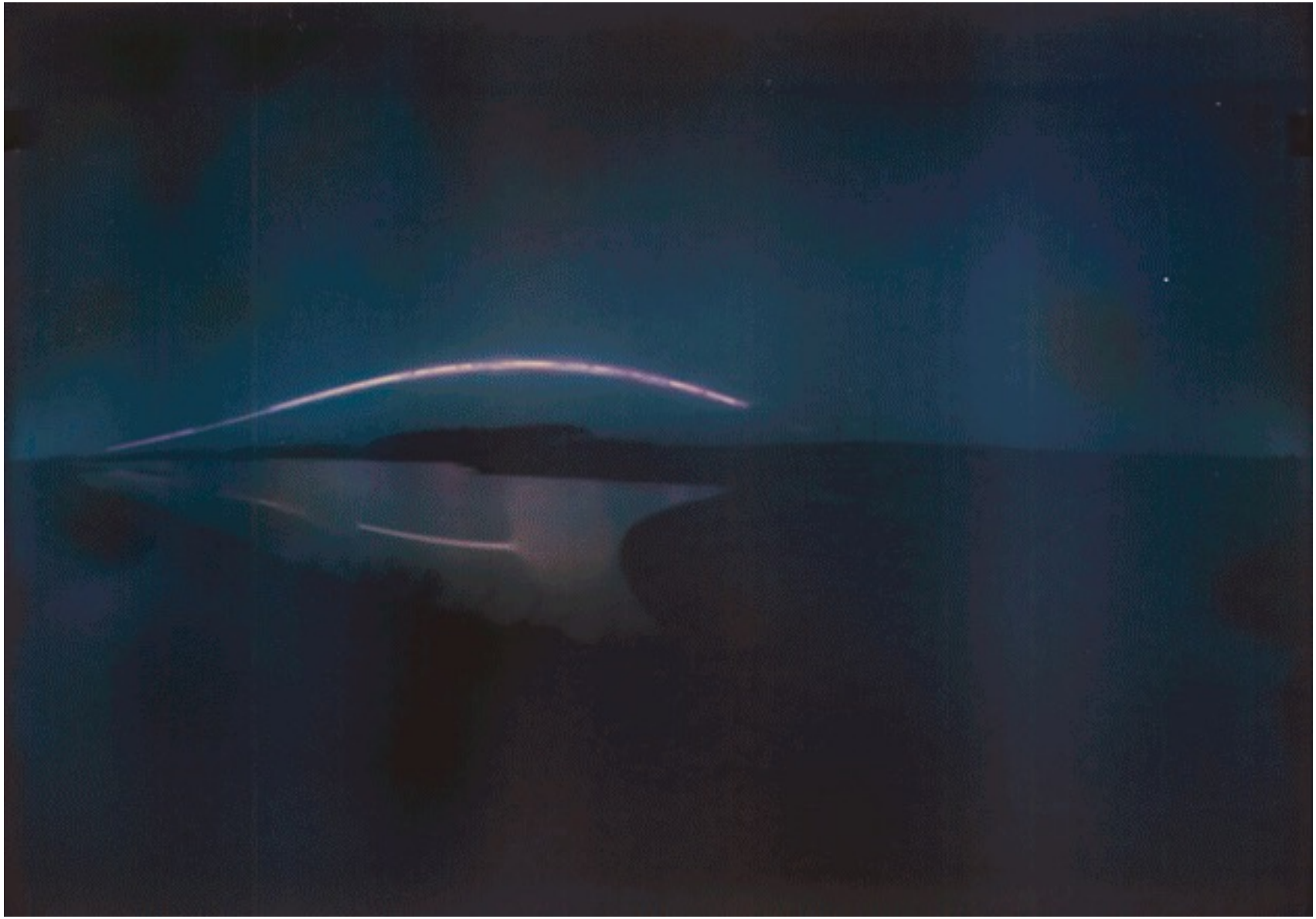


Justin Quinnell, The Clifton Suspension Bridge. December 17th 2007 - June 21st 2008
***6-month* exposure**



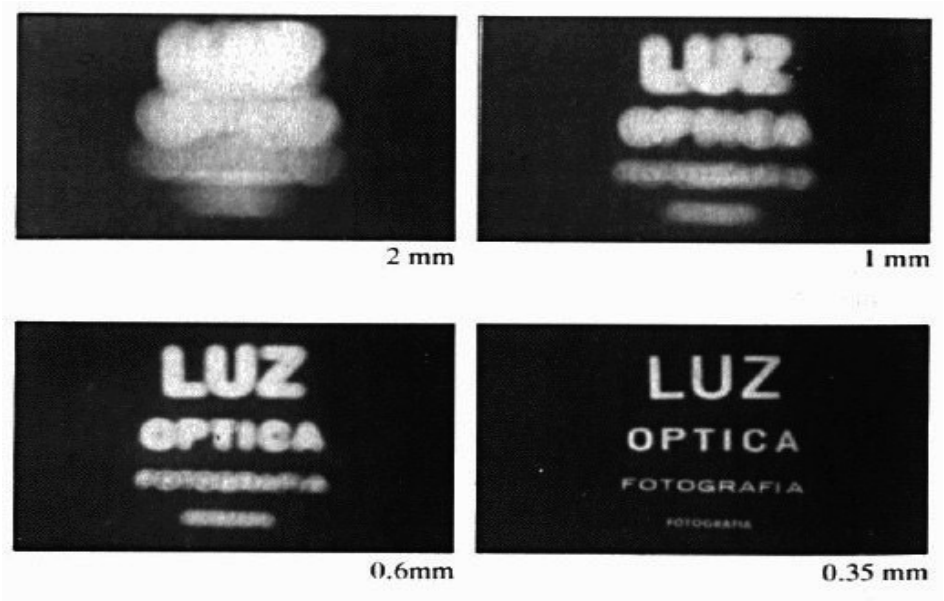


https://petapixel.com/2019/07/17/this-is-the-worlds-first-solargraphy-timelapse/



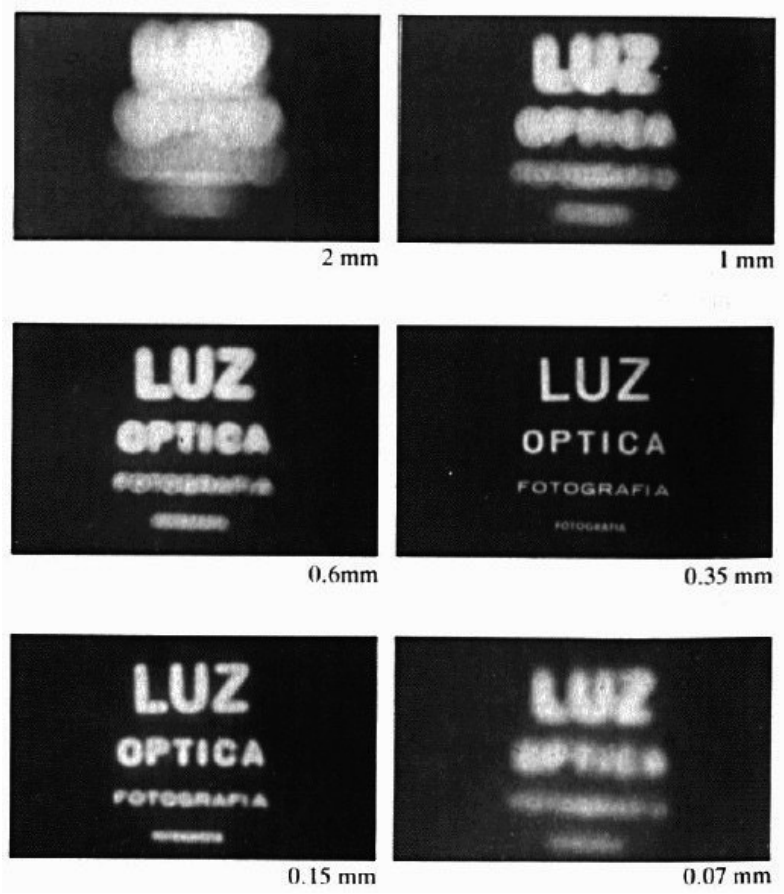
https://petapixel.com/2019/07/17/this-is-the-worlds-first-solargraphy-timelapse/

Shrinking the aperture

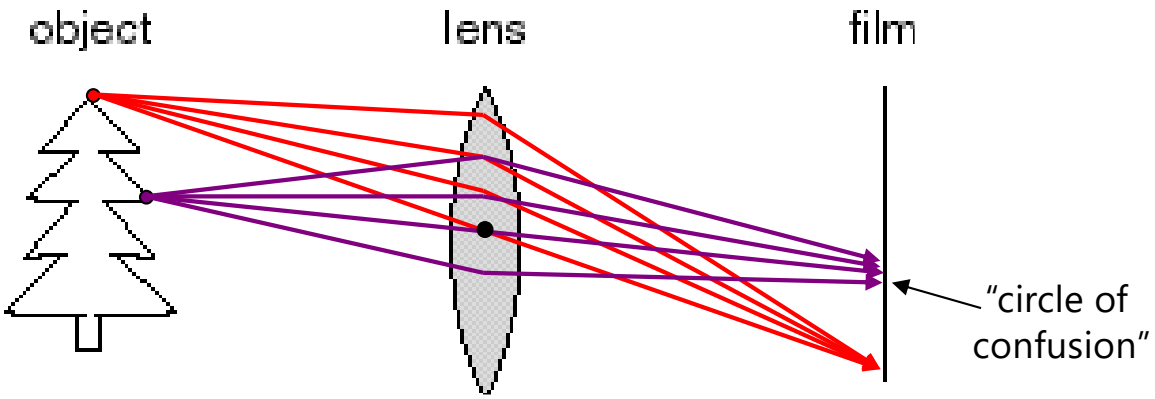


- Why not make the aperture as small as possible?
  - Less light gets through
  - *Diffraction* effects...

Shrinking the aperture



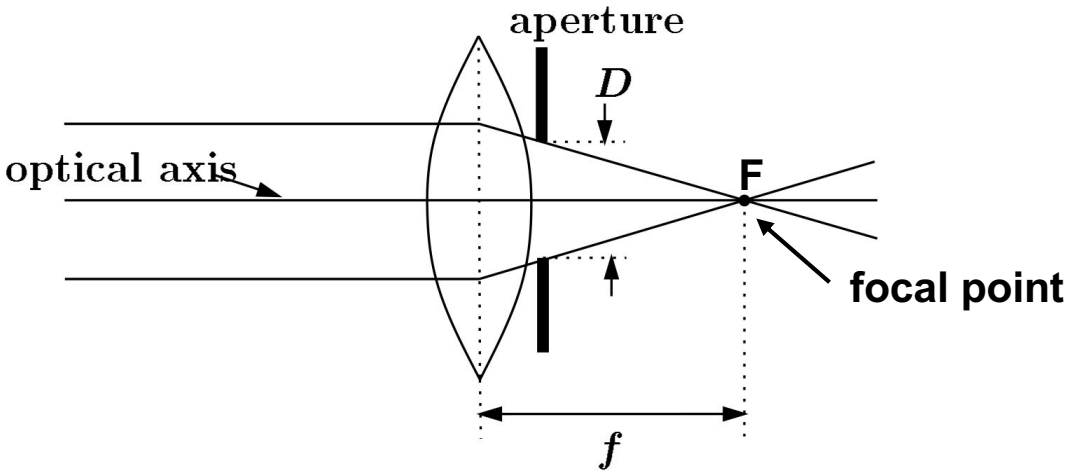
Adding a lens



A lens focuses light onto the film

- There is a specific distance at which objects are "in focus"
  - other points project to a "circle of confusion" in the image
- Changing the shape of the lens changes this distance

Lenses



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

Human visual perception

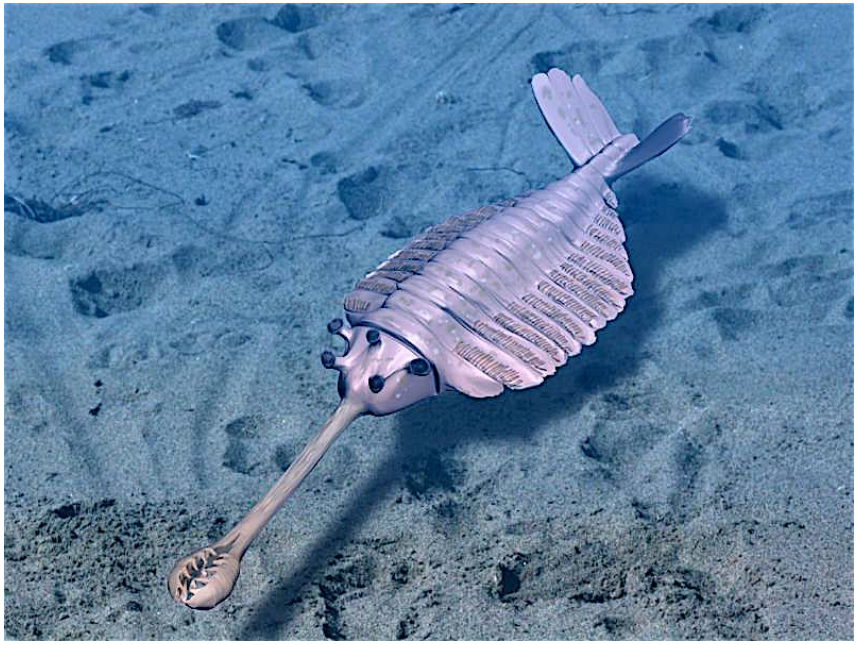
- “It turns out that roughly 60% of your brain is in one way or the other involved in the process of visual perception.” (Shree Nayar in What is Computer Vision?)

Motivation

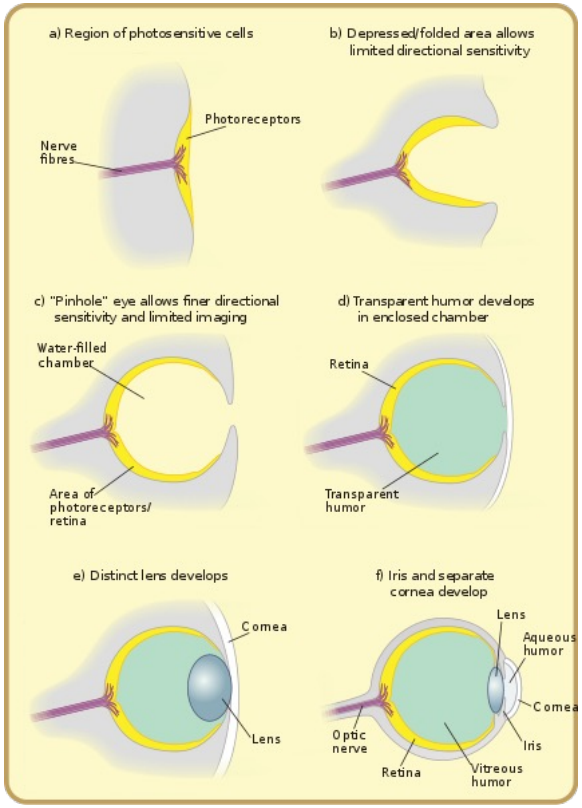
- Vision is the dominant human sense.
- It is important to understand what people perceive if you want to process images for them.

Evolution

- Eyes evolved 540 million years ago, as main part of the Cambrian Explosion, a.k.a. **The Biological Big Bang**

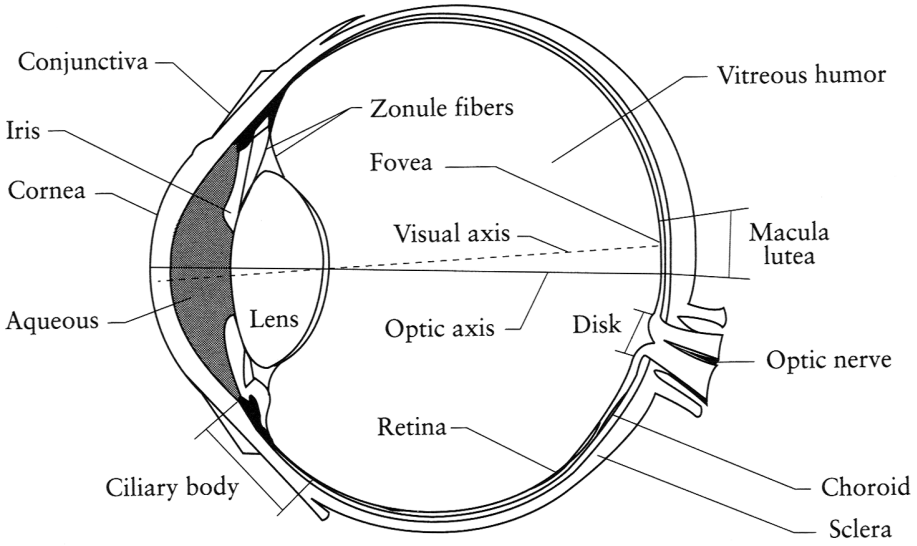


By Nobu Tamura (http://spinops.blogspot.com) - Own work, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=19460186



https://commons.wikimedia.org/wiki/File:Diagram_of_eye_evolution.svg Matticus 78

The eye

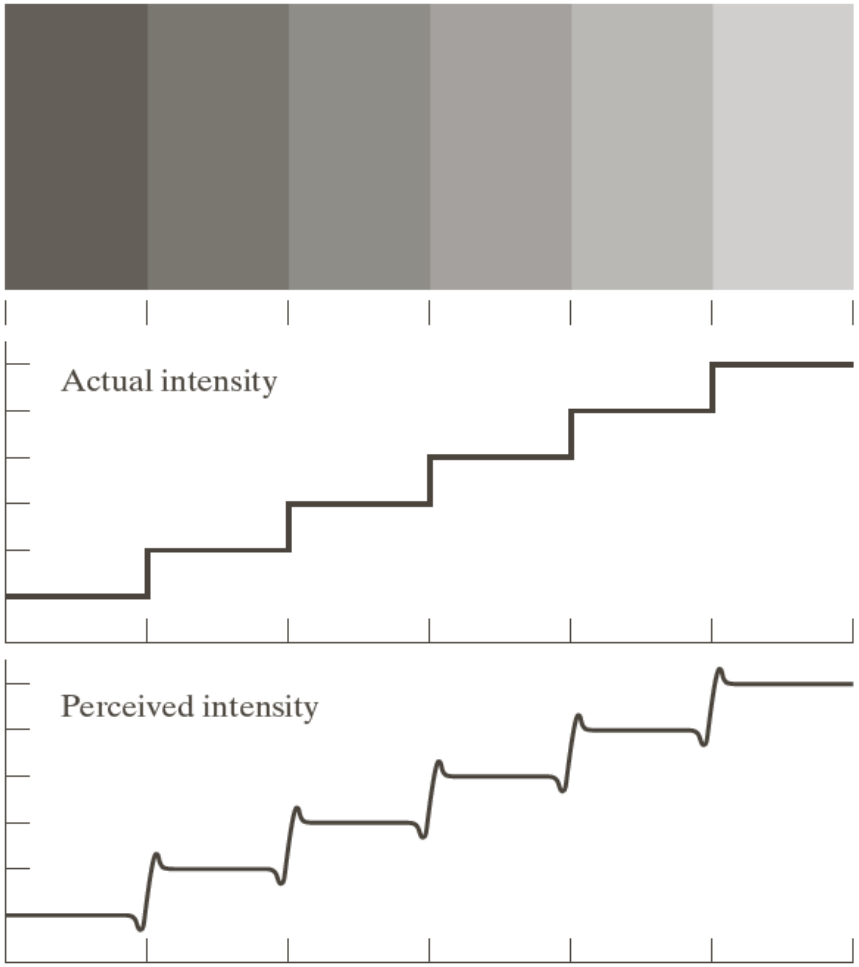


The human eye has elements of a camera but works differently

- **Iris** - colored annulus with radial muscles
- **Pupil** - the hole (aperture) whose size is controlled by the iris
- What's the "film"?
  - photoreceptor cells (rods and cones) in the **retina**

Mach bands

- Perception is not linear

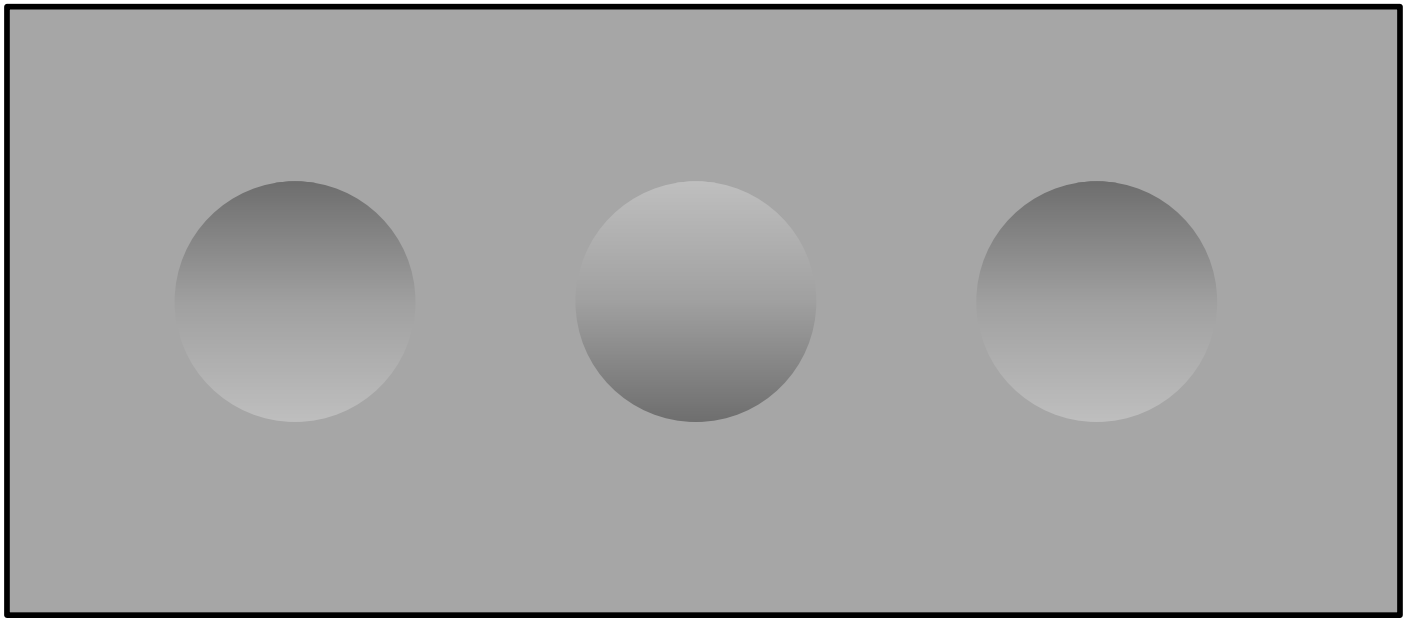


a
b
c

FIGURE 2.7 Illustration of the Mach band effect. Perceived intensity is not a simple function of actual intensity.

Ambiguity in perception

- 3D Perception by shading → Assumption: Light comes from above.

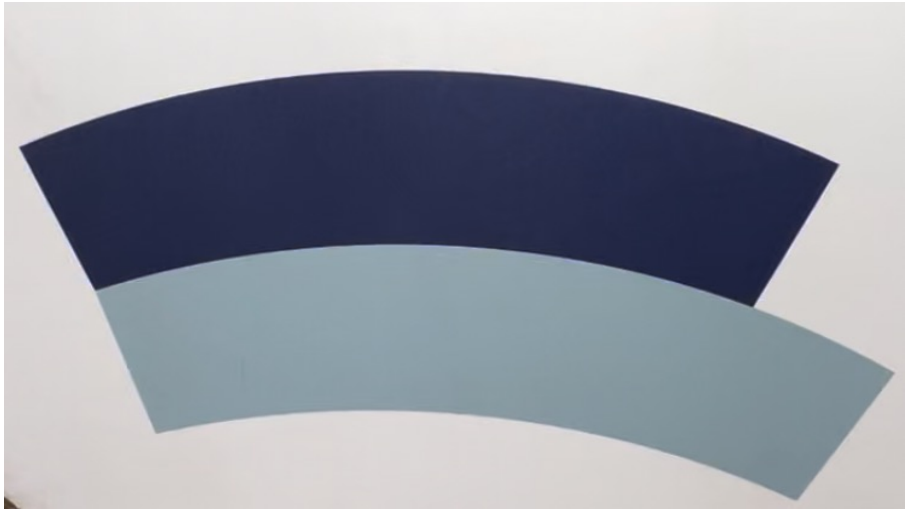


Halluzination - Movement

- Image source: https://giphy.com/gifs/miron-miron-ocxtBHVQaS2fC
- Giphy user miron

Wrong measurements

- Jastrow Illusion



- Humans lack intuition in measuring visually.

Summary

- Visual perception is complex and not fully understood.
- We do not see everything in pictures.
- We see things in pictures that are not there.

- Inspiration: How Do Humans Do It? (Shree Nayar)