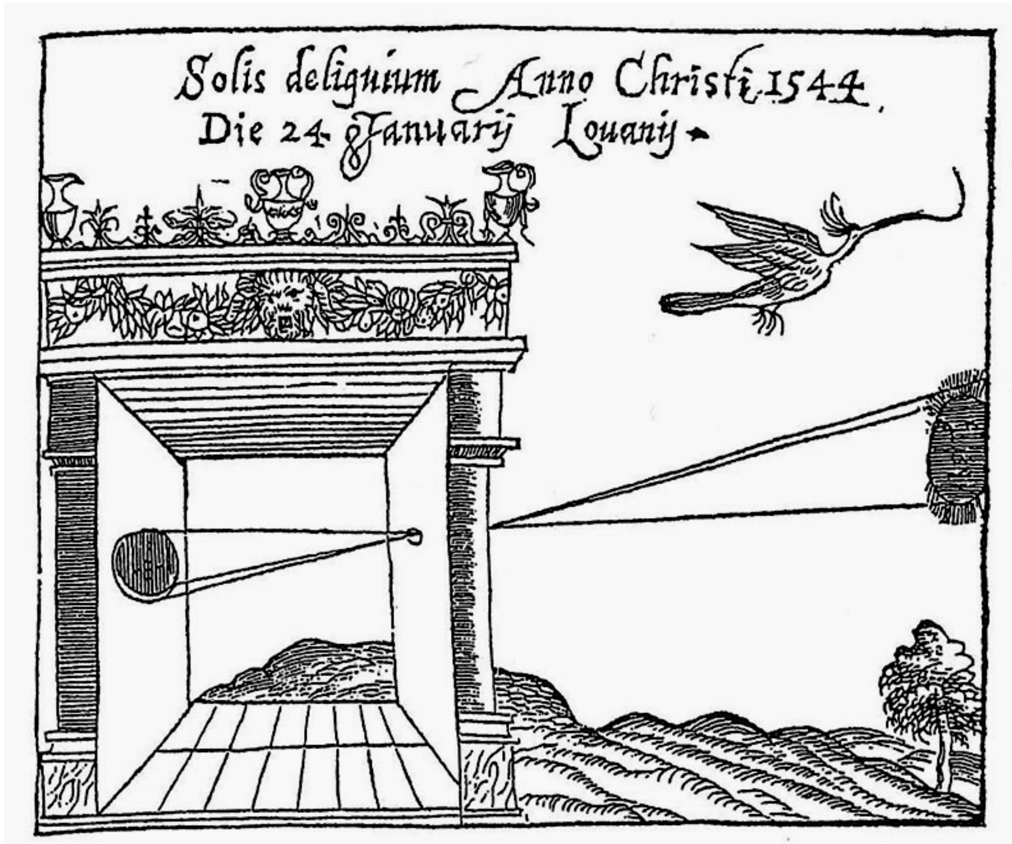
Cameras

15462: Computer Graphics

A Brief History of Images

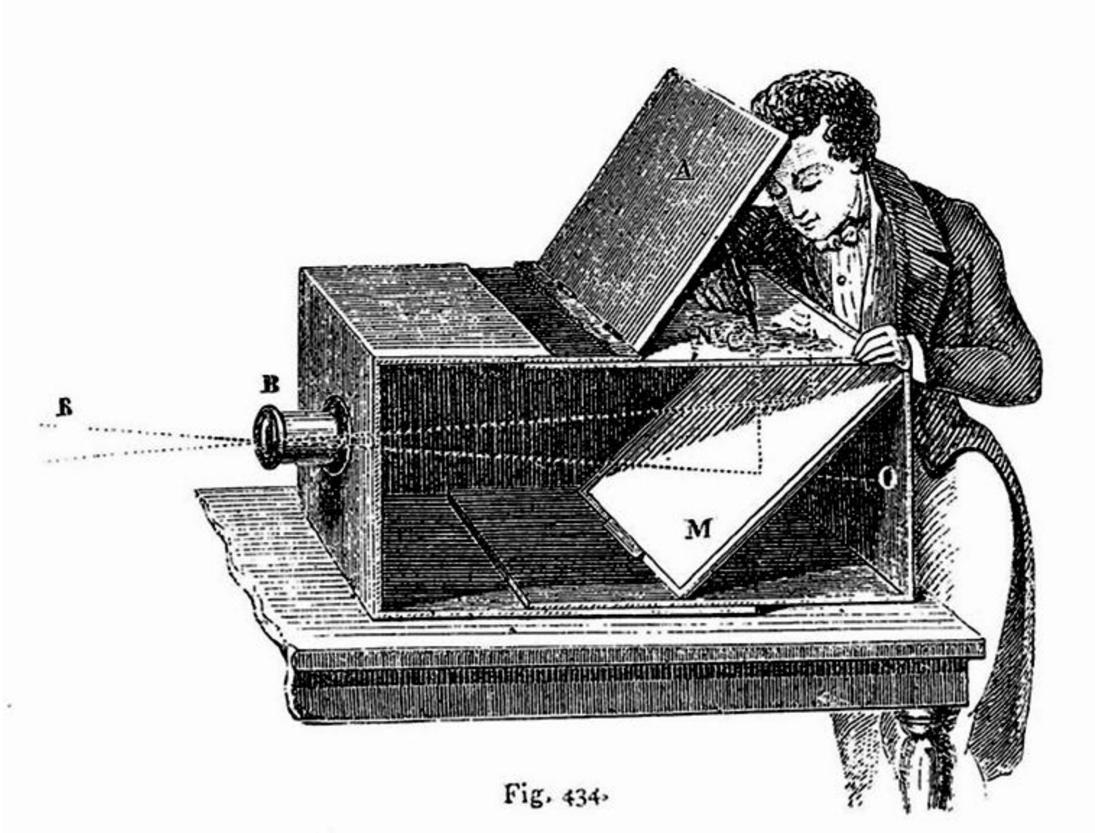
1558



Camera Obscura, Gemma Frisius, 1558

A Brief History of Images

1558
1568



Lens Based Camera Obscura, 1568

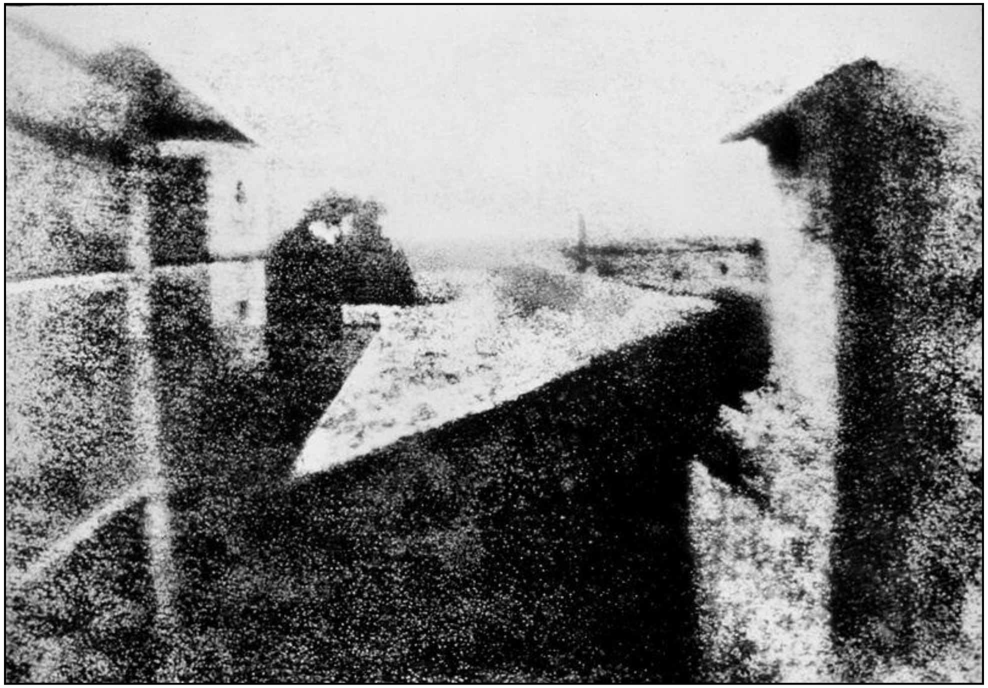
A Brief History of Images

Joseph Nicéphore Niépce (1765-1833)

The first negative (not original)
[Not fixed…quickly vanished]

A Brief History of Images

1558
1568
1816
1826



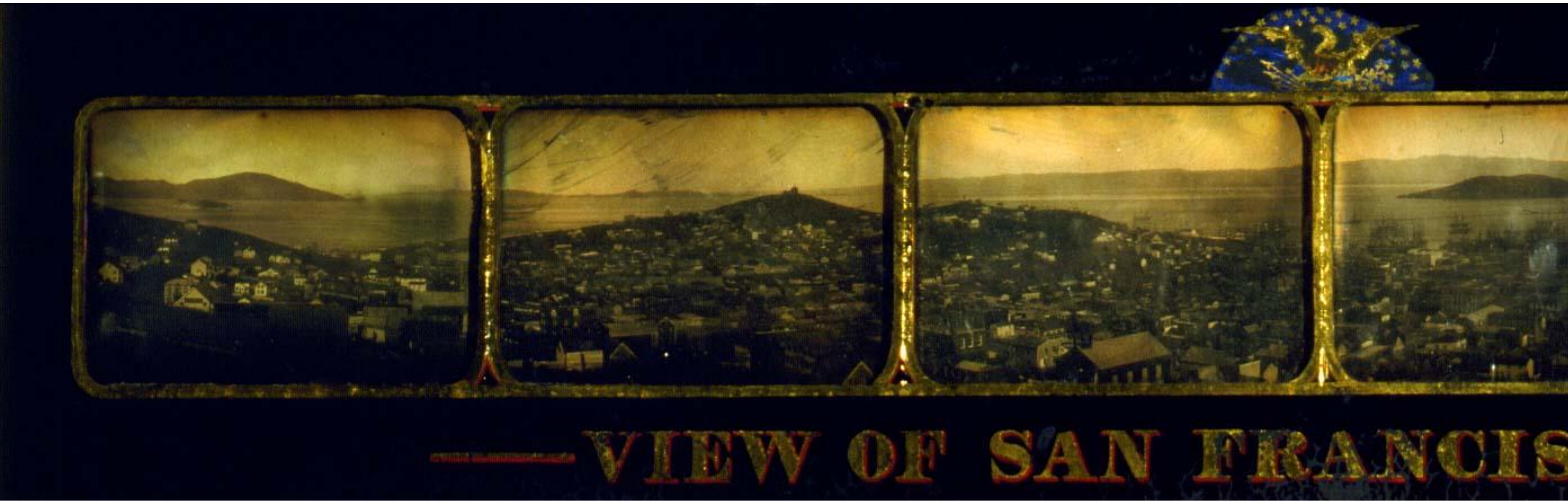
The first permanent photograph (8 hour exposure), Niepce

A Brief History of Images

Still Life, Louis Jaques Mande Daguerre, 1837

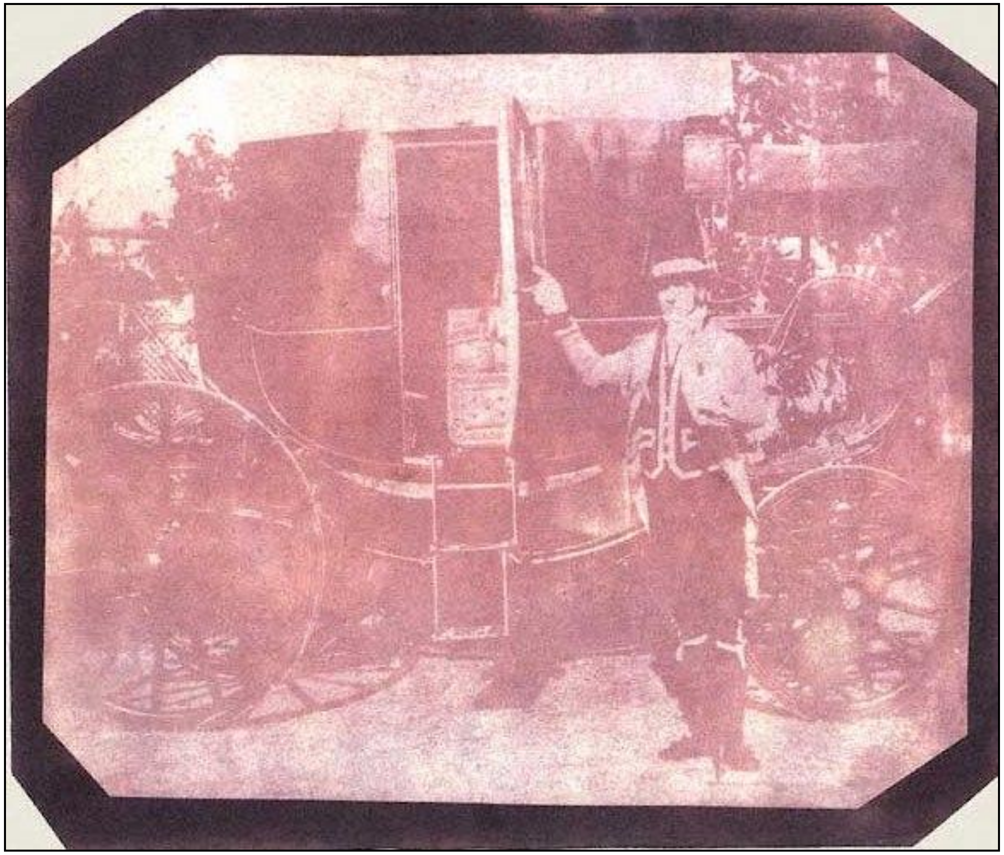
1558
1568
1816
1826
1837

A Brief History of Images

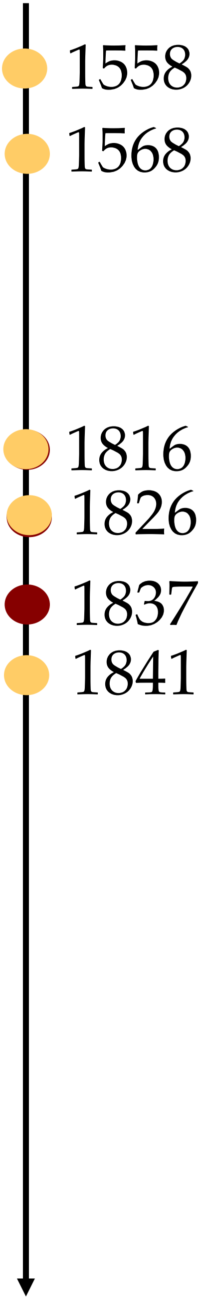


Daguerreotype Panorama (wiki)

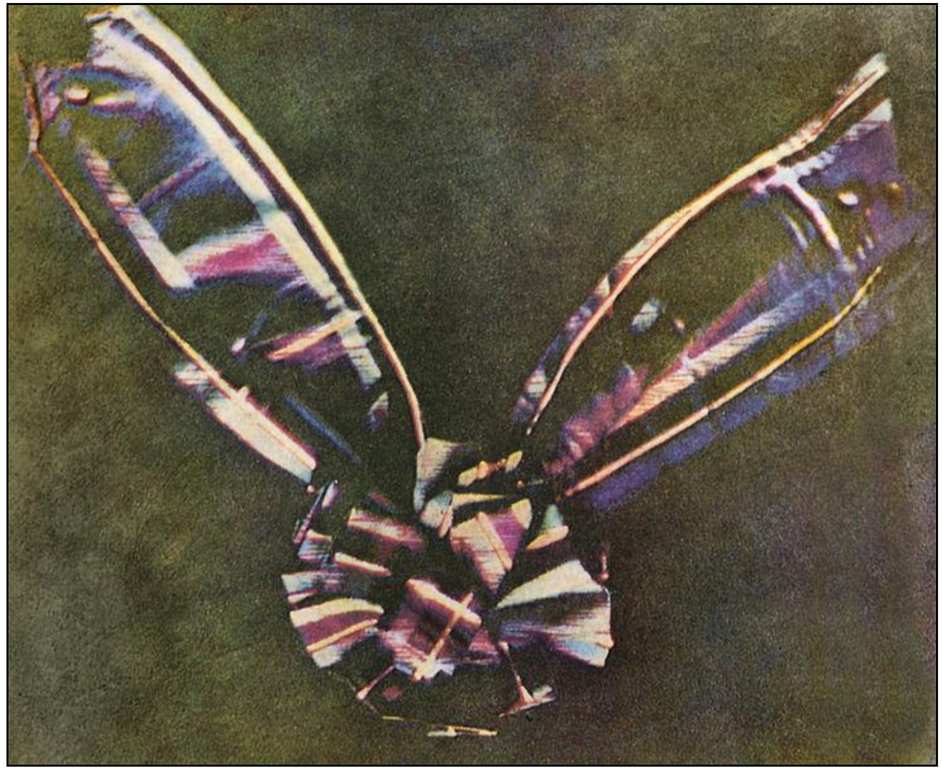
A Brief History of Images



William Henry Fox Talbot , negative to positive photographic process



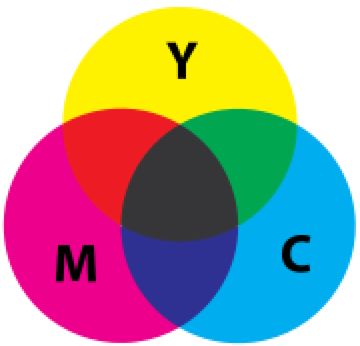
A Brief History of Images



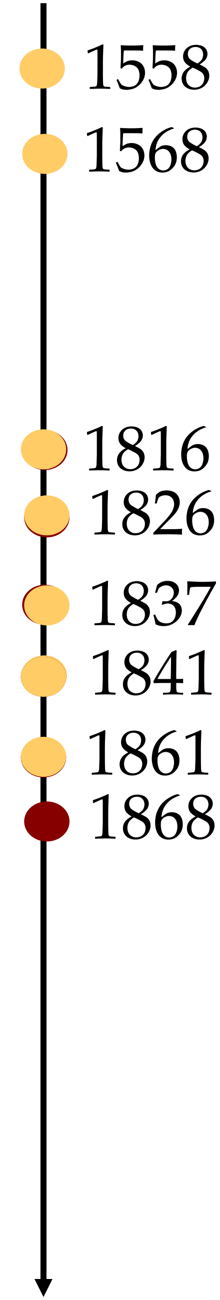
tartan ribbon, James Clerk Maxwell, additive color photograph

1558
1568
1816
1826
1837
1841
1861

A Brief History of Images



Louis Ducos du Hauron, subtractive color photograph

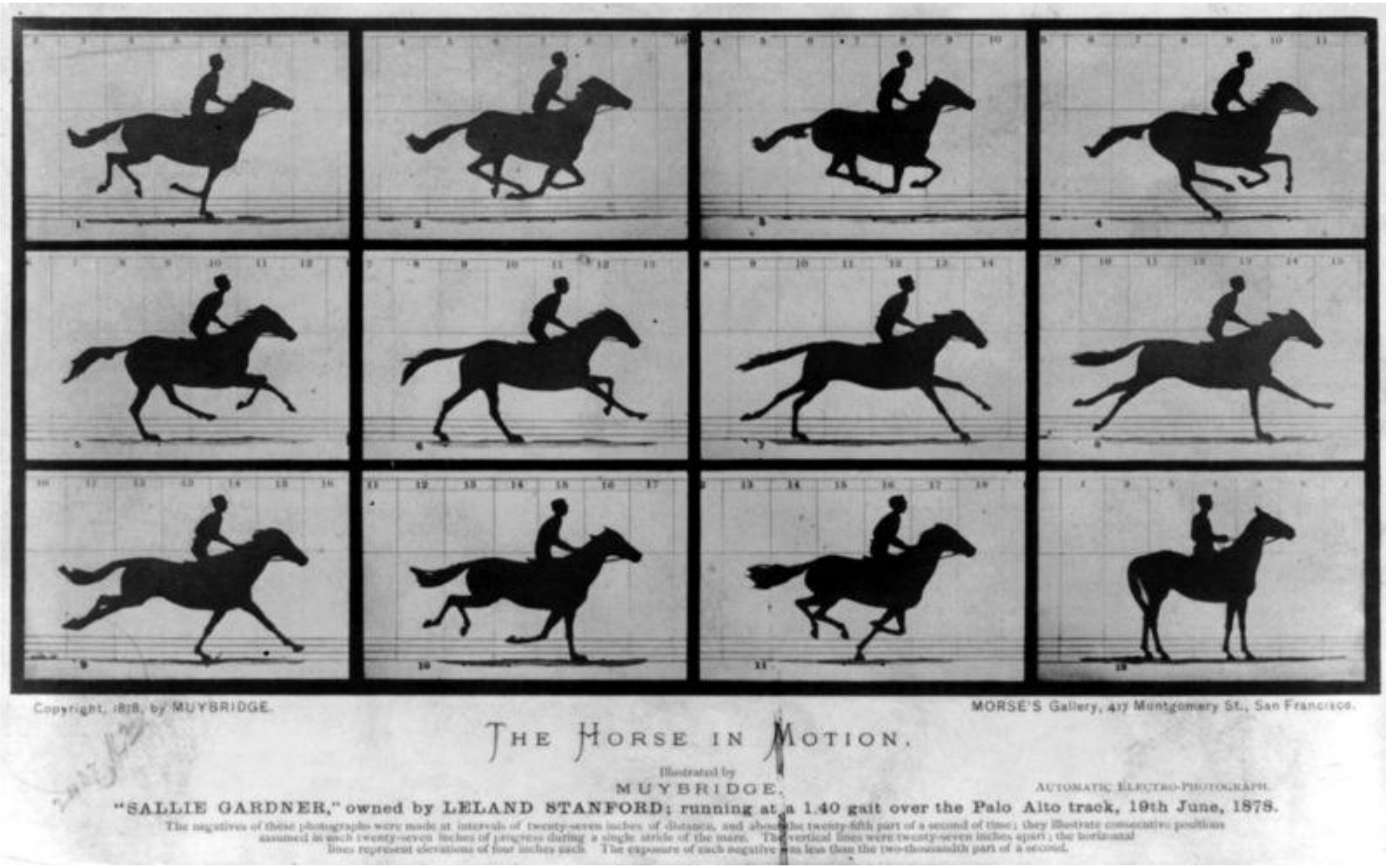


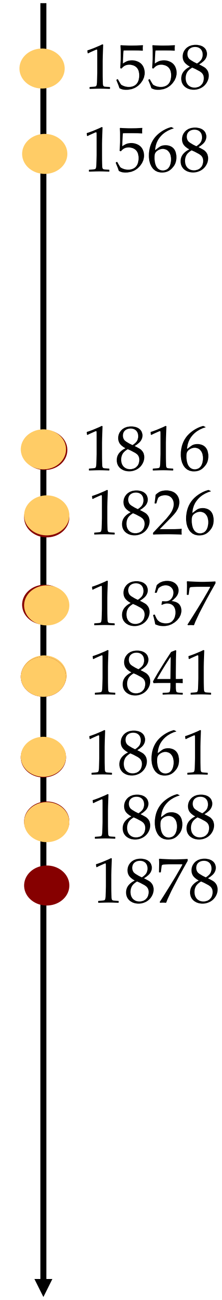
A Brief History of Images

The Horse in Motion, Muybridge, fast motion using 24 cameras.

1558
1568
1816
1826
1837
1841
1861
1868
1878

A Brief History of Images





A Brief History of Images

The Leica, the 35mm format in still photography.

The photographic film is cut into strips 35 millimeters wide.

1558
1568
1816
1826
1837
1841
1861
1868
1878
1925

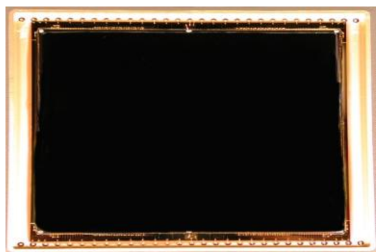
A Brief History of Images

Edwin H. Land

Poloroid instant image camera

1558
1568
1816
1826
1837
1841
1861
1868
1878
1925
1948

A Brief History of Images



Silicon Image Detector, 1973

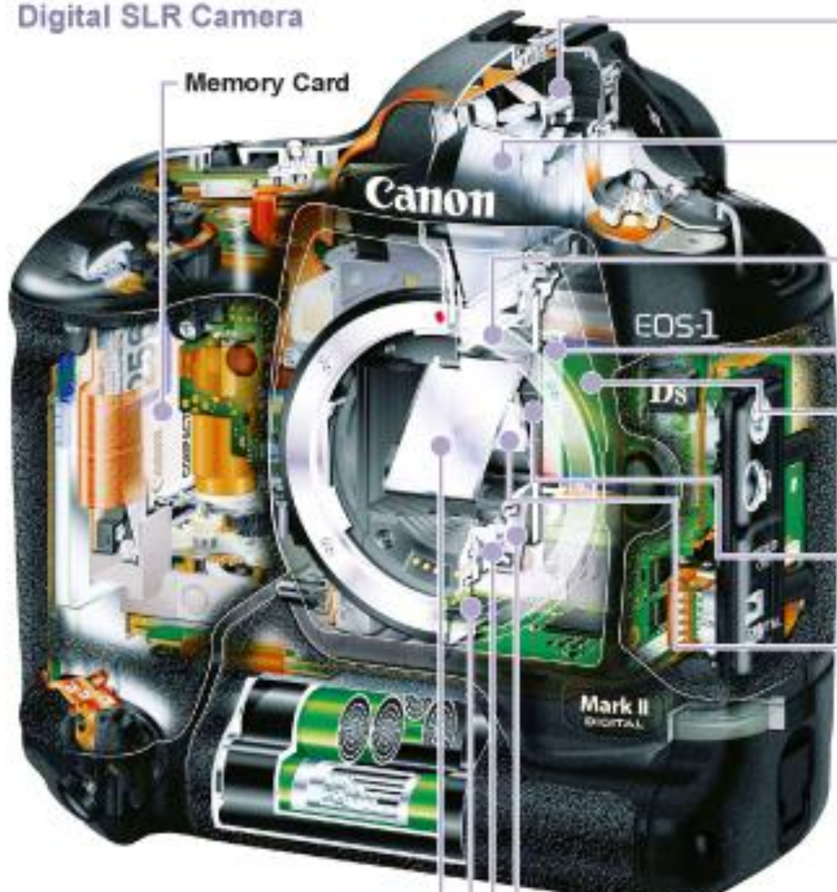
1558
1568
1816
1826
1837
1841
1861
1868
1878
1925
1948
1973

A Brief History of Images

Digital Cameras

1558
1568
1816
1826
1837
1841
1861
1868
1878
1925
1948
1973
1995

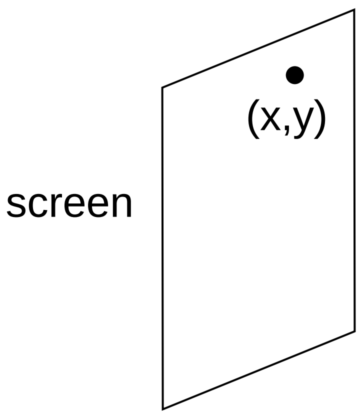
Digital SLR Camera



35mm SLR Film Camera

Canon.com

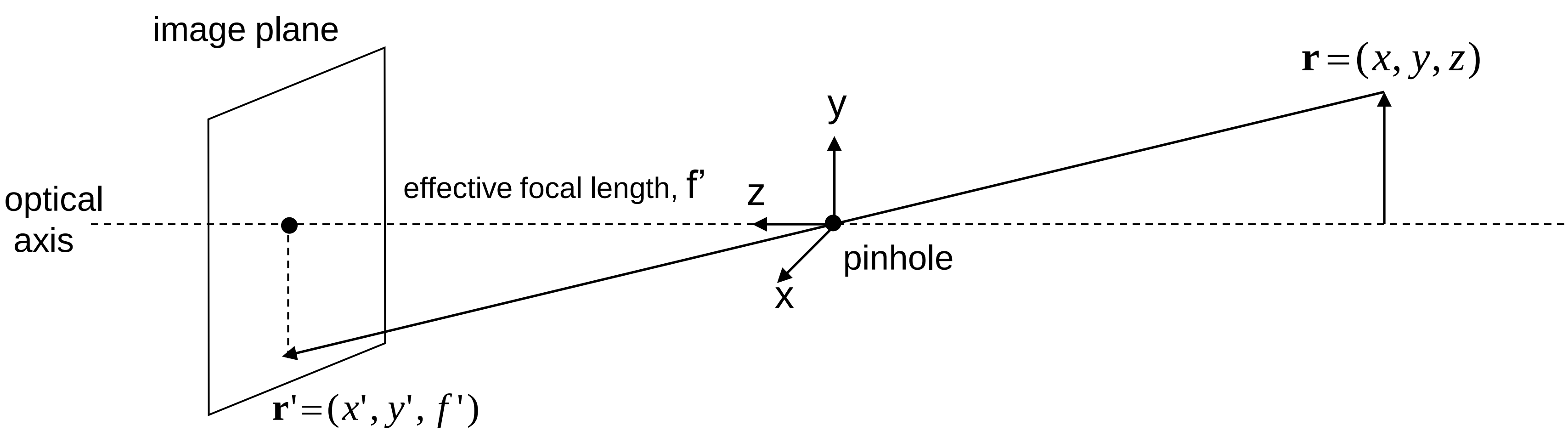
Pinhole and the Perspective Projection



scene

Is an image being formed on the screen?

YES! But, not a “clear” one.



$$\frac{\mathbf{r}'}{f'} = \frac{\mathbf{r}}{z} \quad \Rightarrow \quad \frac{x'}{f'} = \frac{x}{z} \qquad \frac{y'}{f'} = \frac{y}{z}$$

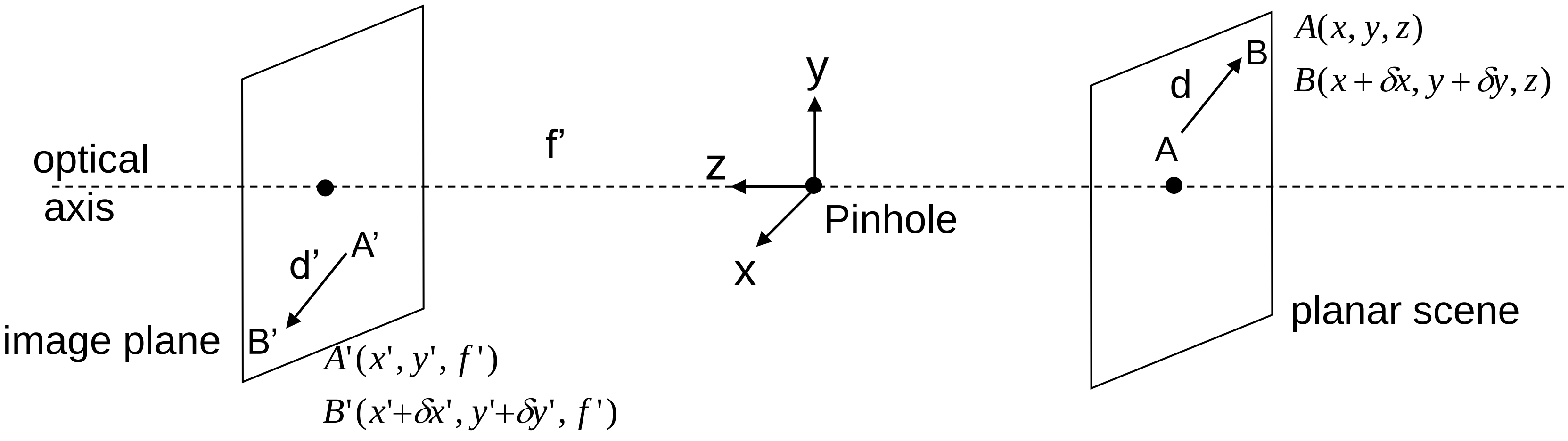
Pinhole Photography

©Charlotte Murray Untitled, 4" x 5" pinhole photograph, 1992

Image Size inversely proportional to Distance

Reading: http://www.pinholeresource.com/

Magnification



From perspective projection:

$$\frac{x'}{f'} = \frac{x}{z} \qquad \frac{y'}{f'} = \frac{y}{z}$$

$$\frac{x'+\delta x'}{f'} = \frac{x+\delta x}{z} \qquad \frac{y'+\delta y'}{f'} = \frac{y+\delta y}{z}$$

Magnification:

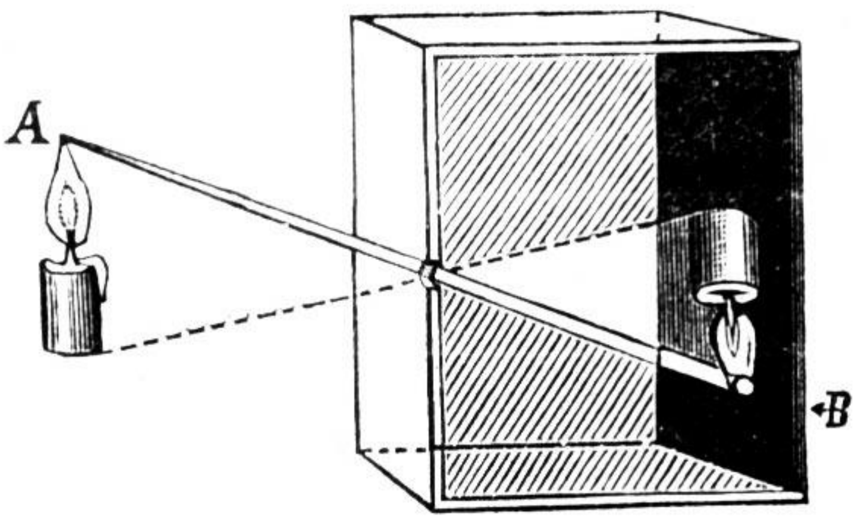
$$m = \frac{d'}{d} = \frac{\sqrt{(\delta x')^2 + (\delta y')^2}}{\sqrt{(\delta x)^2 + (\delta y)^2}} = \frac{f'}{z}$$

$$\frac{Area_{image}}{Area_{scene}} = m^2$$

Pinhole Photography

Wide Field of View and Sharp Image

Camera Obscura with a Pinhole



Contemporary artist Madison Cawein rented studio space in an old factory building where many of the windows were boarded up or painted over. A random small hole in one of those windows turned one room into a camera obscura.

Problems with Pinholes

- Pinhole size (aperture) must be "very small" to obtain a clear image.
- However, as pinhole size is made smaller, less light is received by image plane.
- If pinhole is comparable to wavelength λ of incoming light, DIFFRACTION blurs the image!
- Sharpest image is obtained when:

pinhole diameter $$d = 2\sqrt{f'\lambda}$$

Example: If *f'* = *50mm,*

= *600nm* (red),

d = *0.36mm*

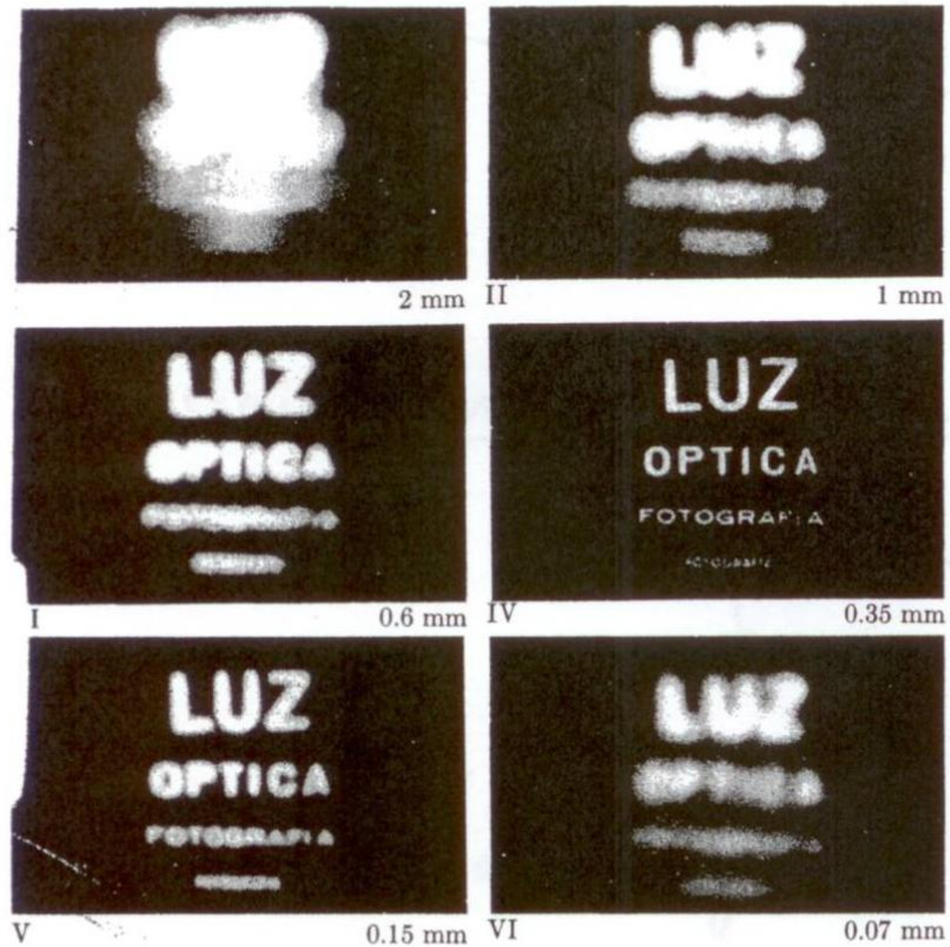
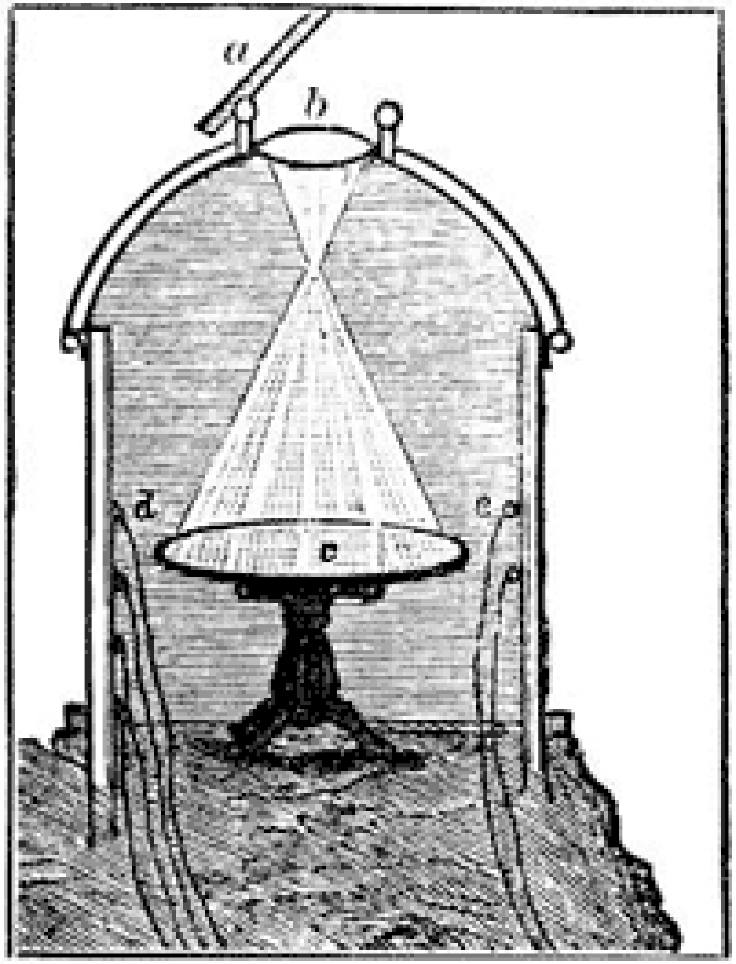


Fig. 5.96 The pinhole camera. Note the variation in image clarity as the hole diameter decreases. [Photos courtesy Dr. N. Joel, UNESCO.]

Camera Obscuras with Lenses



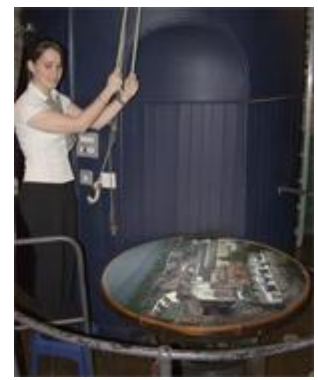
 

Charles Schwartz Private Camera Obscura, New York City The optics are housed in a copper turret on the roof and project through a hole in the ceiling onto a 42 inch round white table. At the side of the table are controls for the shutters, the tilt of the mirror and rotation of the turret. It is equipped with an 8-inch lens with a 12 1/2 foot focal length and a 12-inch mirror and brings in a 15-degree slice of the world outside. Sharp focus is possible from infinity to 400 feet. The optics were designed and built by George Keene of California.

Eastbourne, England

Kirriemuir, Scotland

Edinburgh, Scotland



1836, Dumfries, Scotland

Aberwystweth, Wales

Knighton, Wales

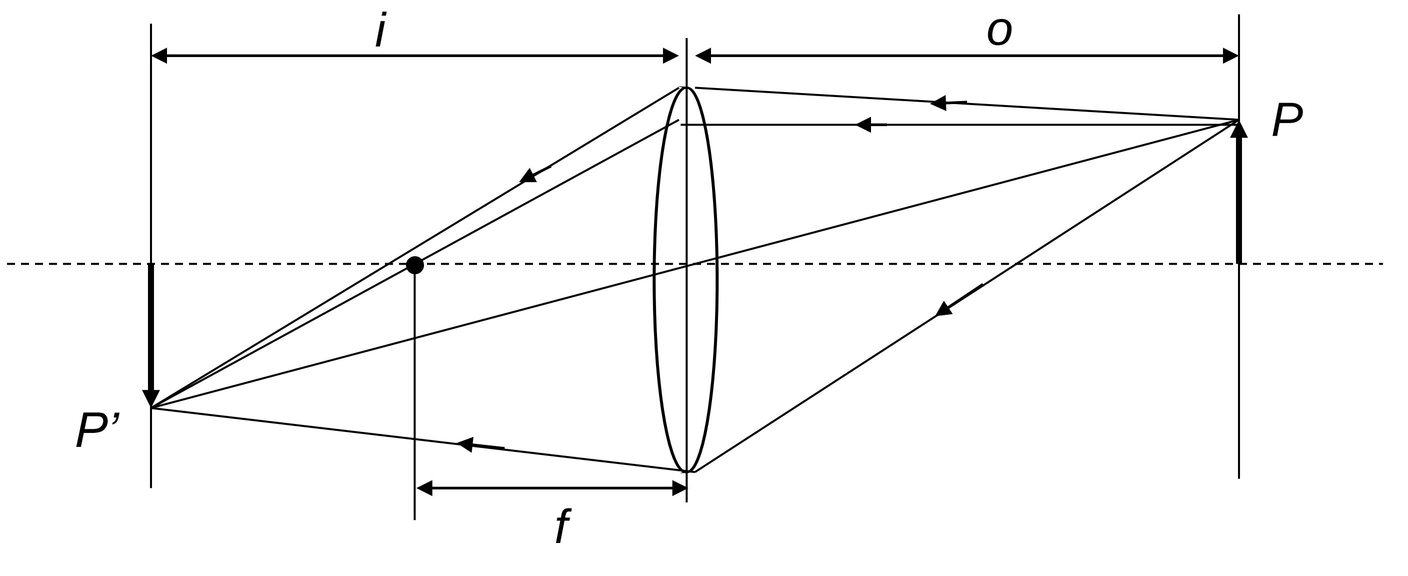
Giant Camera, San Francisco, California

Discovery Park, Safford, Arizona

George Eastman House, Rochester, New York

Image Formation using Lenses

- Lenses are used to avoid problems with pinholes.
- Ideal Lens: Same projection as pinhole but gathers more light!



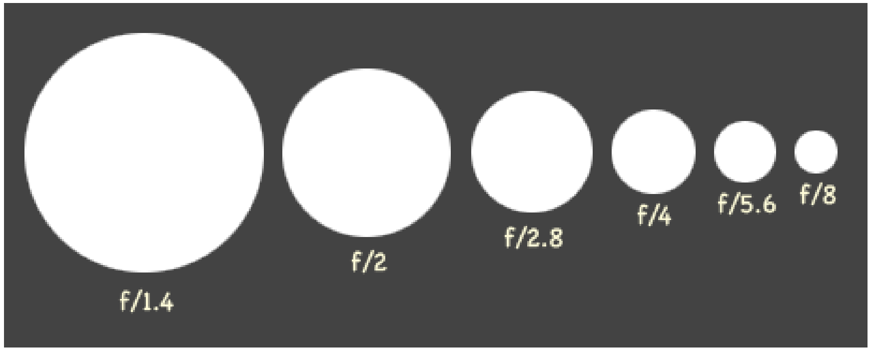
- Gaussian Thin Lens Formula: $$\frac{1}{i} + \frac{1}{o} = \frac{1}{f}$$
- *f* is the focal length of the lens – determines the lens's ability to refract light
- *f* different from the effective focal length ***f'*** discussed before!

Aperture, F-Number

• Aperture : Diameter ***D*** of the lens that is exposed to light.

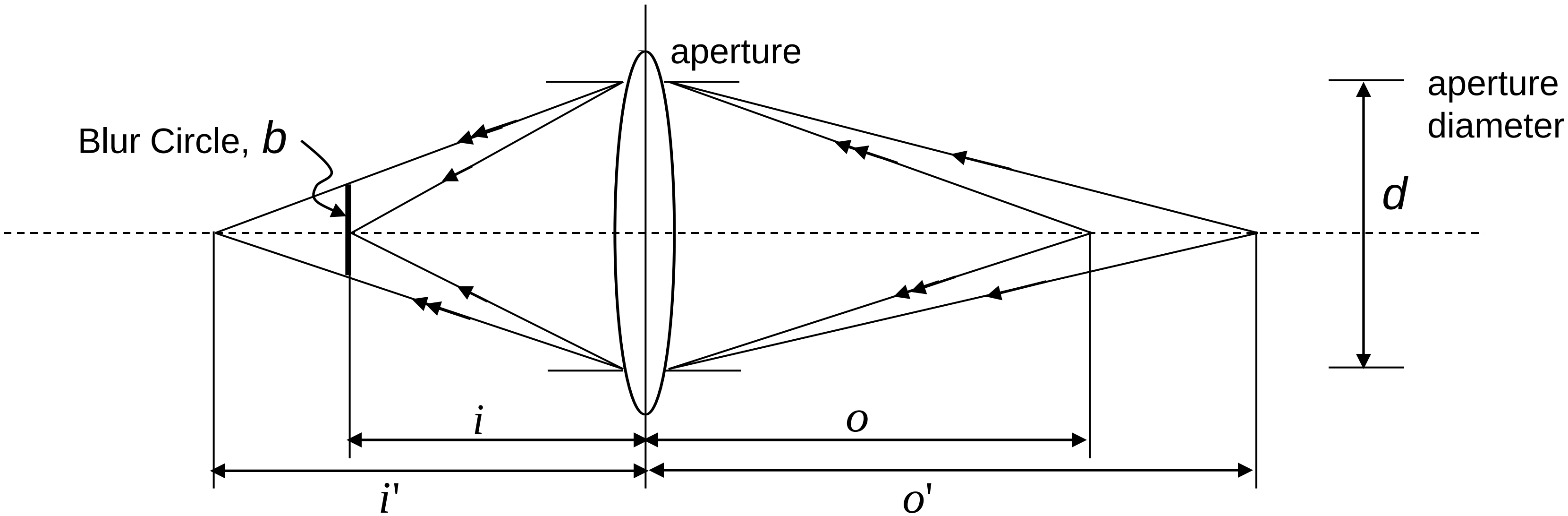
• F-Number **(f/#):**

$$f/\# = \frac{f}{D} \ ,$$



- For example, if ***f*** is 16 times the pupil diameter, then **f/#=f/16.**
- The greater the **f/#**, the less light per unit area reaches the image plane.
- f-stops represent a convenient sequence of f/# in a geometric progression.

Focus and Defocus



- Gaussian Law:

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

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

$$\Rightarrow \quad (i' - i) = \frac{f}{(o' - f)} \frac{f}{(o - f)} (o - o')$$

- In theory, only one scene plane is in focus.

Depth of Field

- Range of object distances over which image is sufficiently well focused.
- Range for which *blur circle* is less than the resolution of the sensor.

http://images.dpchallenge.com/images_portfolio/27920/print_preview/116336.jpg

Depth of Field

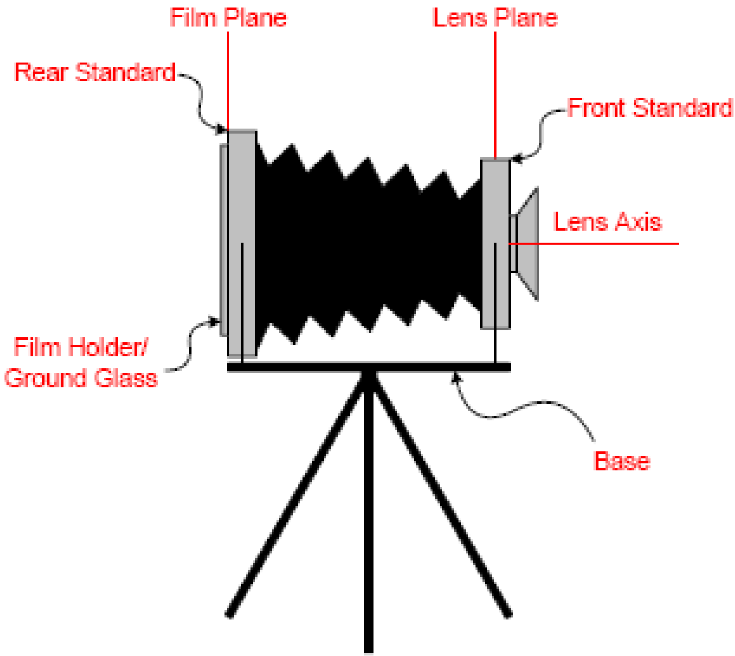
Both near and farther scene areas are blurred

Controlling Depth of Field

Increase Aperture, decrease Depth of Field

www.cambridgeincolour.com/.../depth-of-field.htm

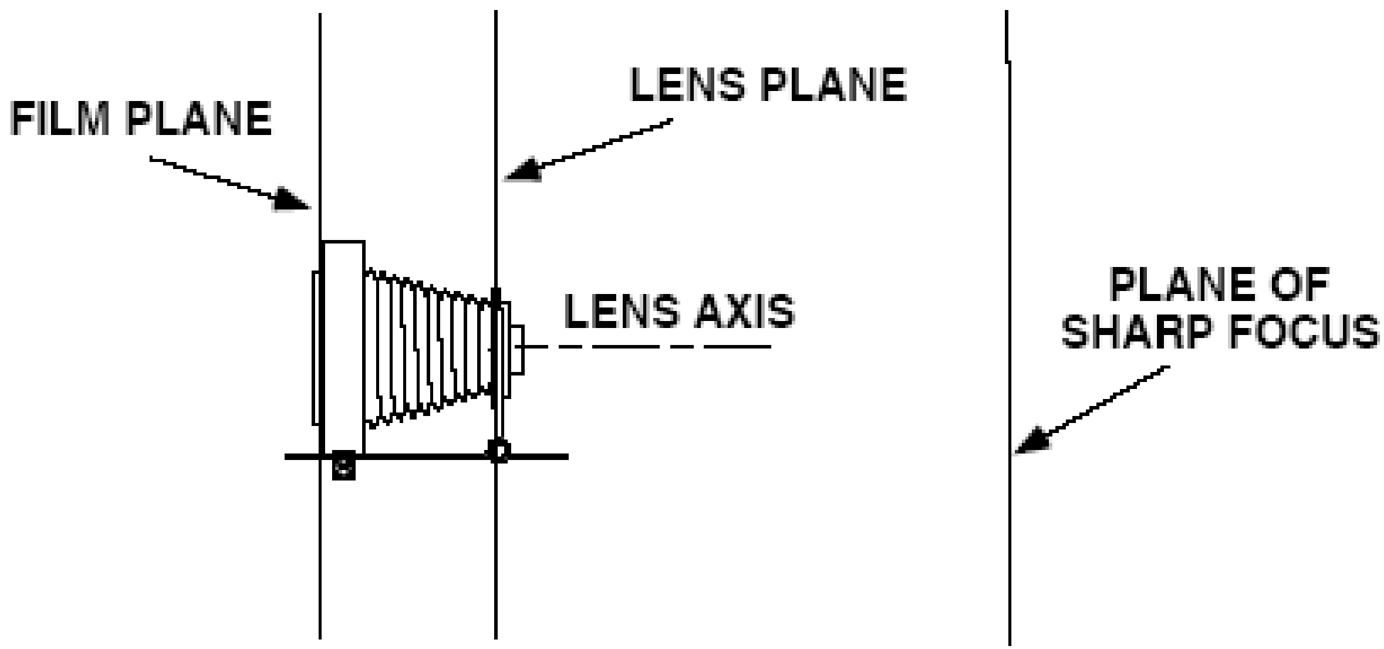
Large Format (View) Camera




Rockcliffe Parkway
Promenade Rockcliffe
East
Est
West
Ouest

[Harold M. Merklinger]

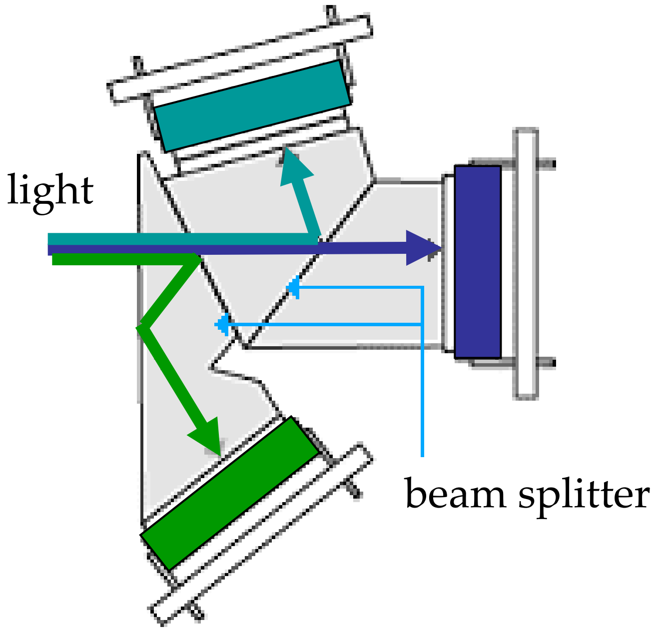
Regular Camera: Image, Lens & Object Planes are Parallel



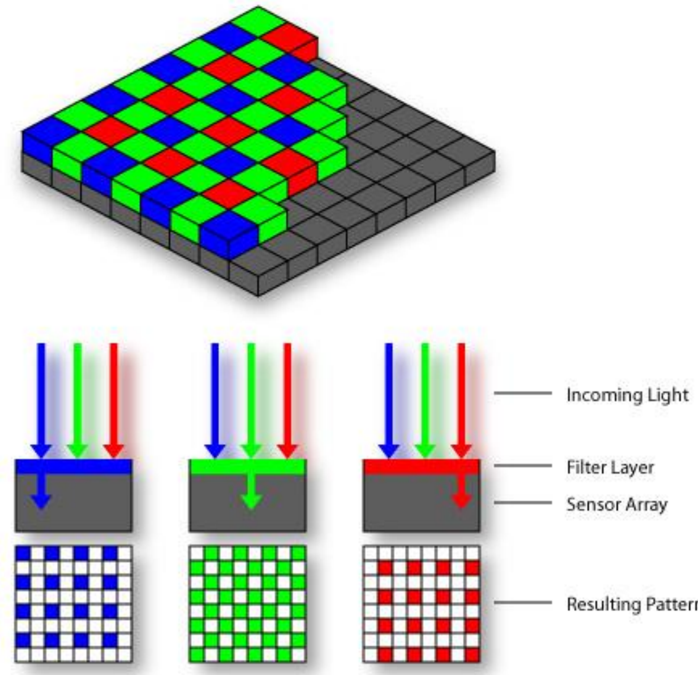
View camera: The image and lens planes can be shifted/tilted

[Harold M. Merklinger]

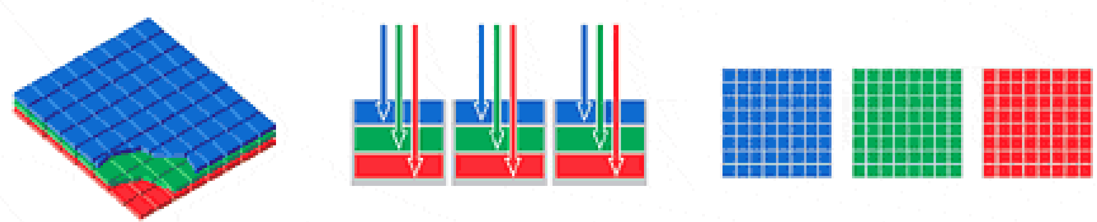
Sensing Color



3 CCD

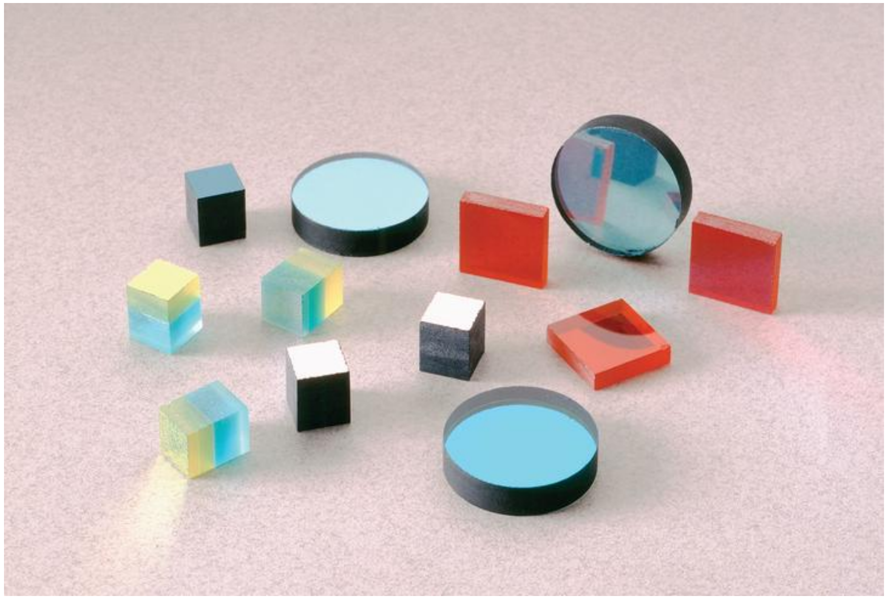


Bayer pattern



Foveon X3™

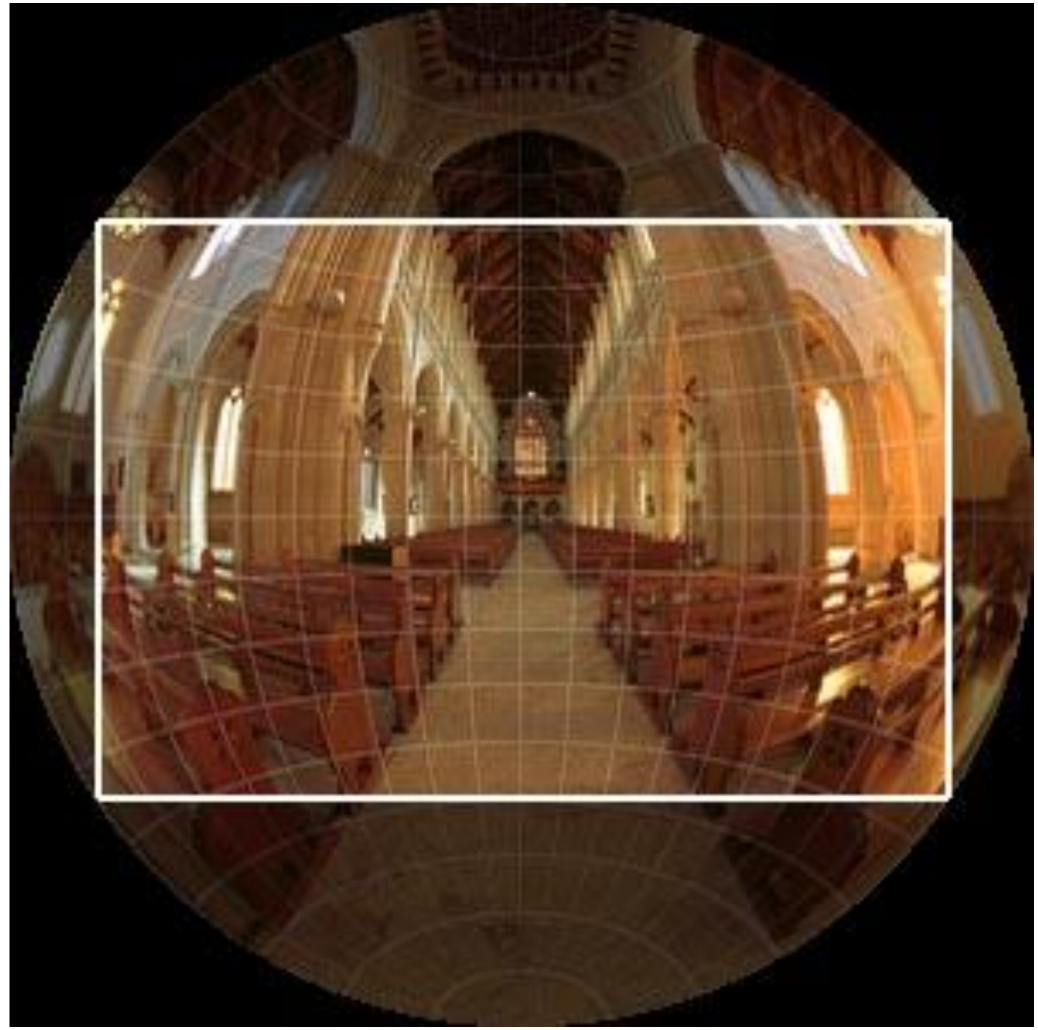
Optical Elements in an Imaging System



Lens Distortions

Wide angle Lenses

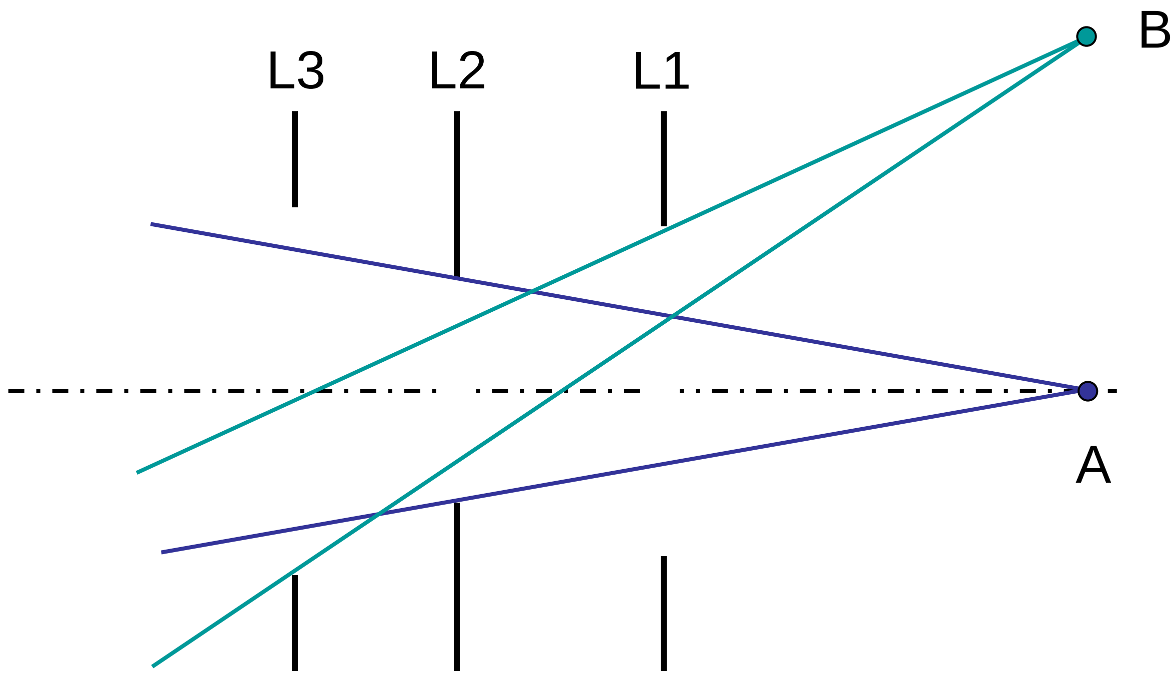
Circular Fisheye



Full Frame Rectangular Fisheye

Common lens related Issues

Vignetting



More light passes through lens L3 for scene point A than scene point B

Results in spatially non-uniform brightness (in the periphery of the image)

Lens Vignetting

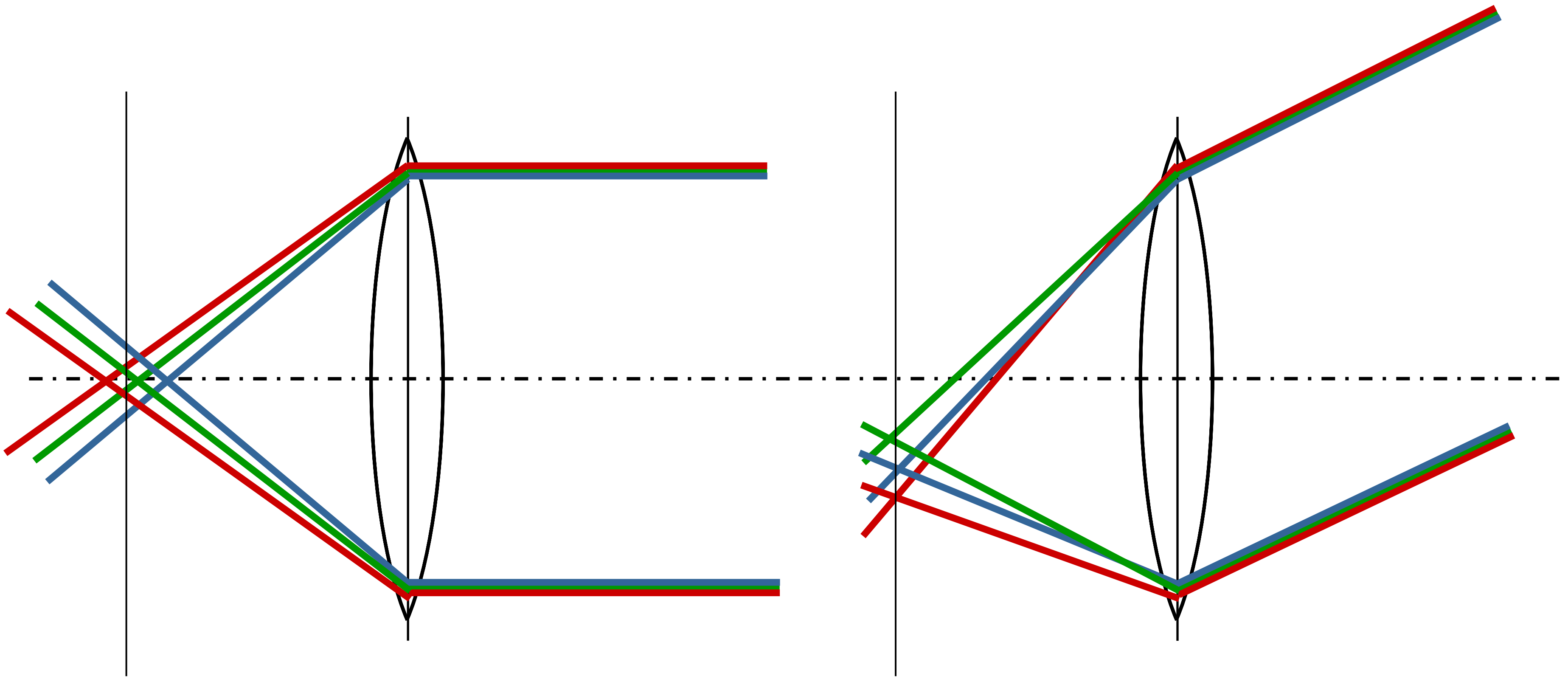
- Usually brighter at the center and darker at the periphery.

Reading: http://www.dpreview.com

Vignetting

photo by Robert Johnes

Chromatic Aberration



longitudinal chromatic aberration (axial)

transverse chromatic aberration (lateral)

Chromatic Aberrations

longitudinal chromatic aberration
(axial)

transverse chromatic aberration
(lateral)

Chromatic Abberations

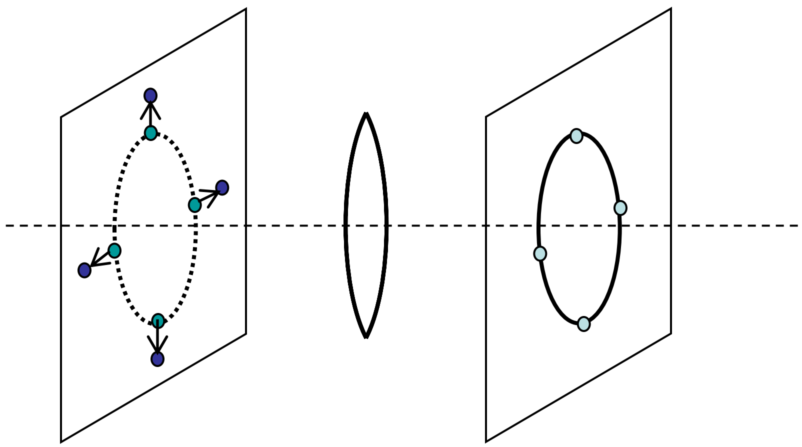
Reading: http://www.dpreview.com

Lens Glare

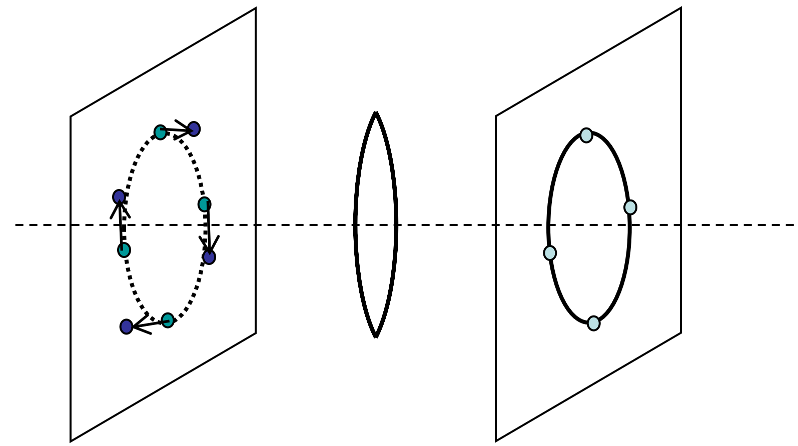
- Stray interreflections of light within the optical lens system.
- Happens when very bright sources are present in the scene.

Reading: http://www.dpreview.com

Geometric Lens Distortions



Radial distortion



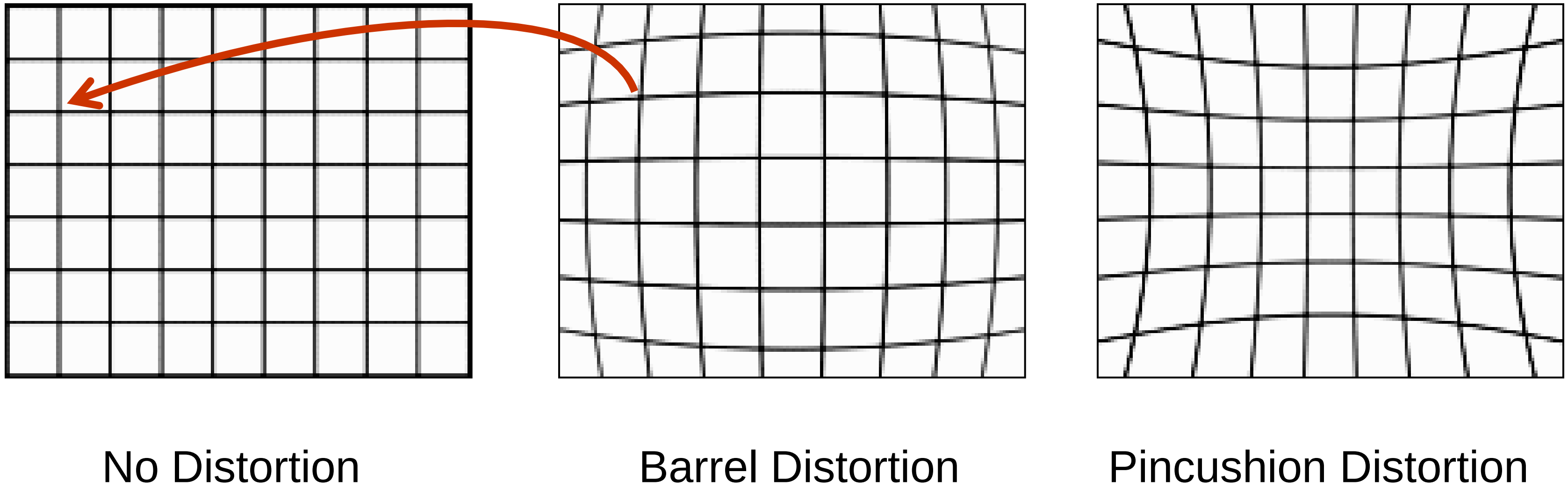
Tangential distortion

Photo by Helmut Dersch

Both due to lens imperfection

Rectify with geometric camera calibration

Radial Lens Distortions



- Radial distance from Image Center:

$$r_u = r_d + k_1 r_d^3$$

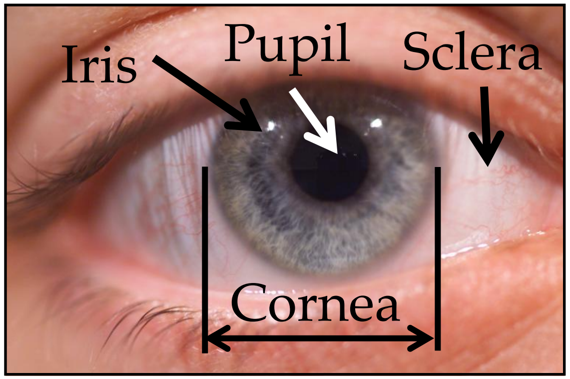
Correcting Radial Lens Distortions

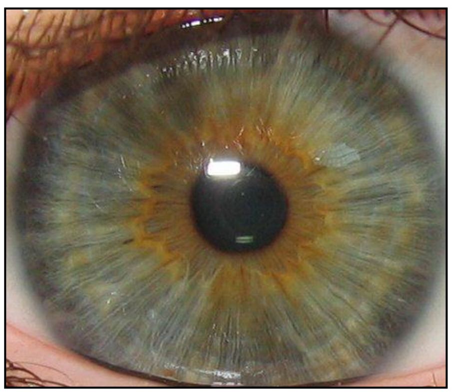
Before

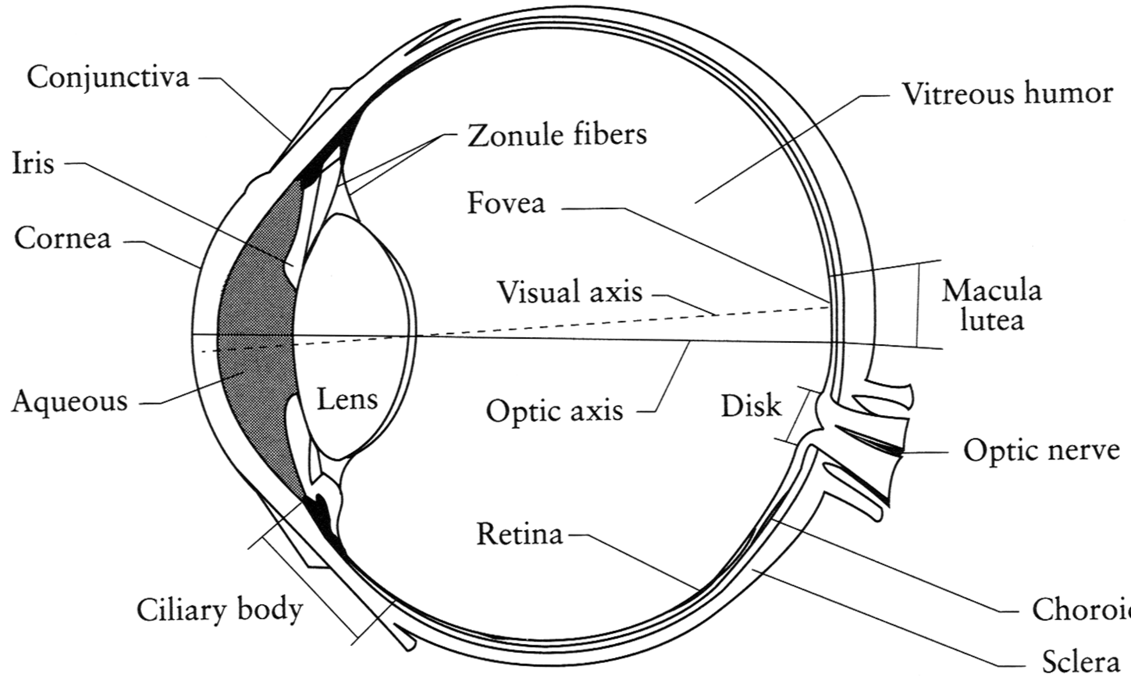
After

http://www.grasshopperonline.com/barrel_distortion_correction_software.html

Our Eyes

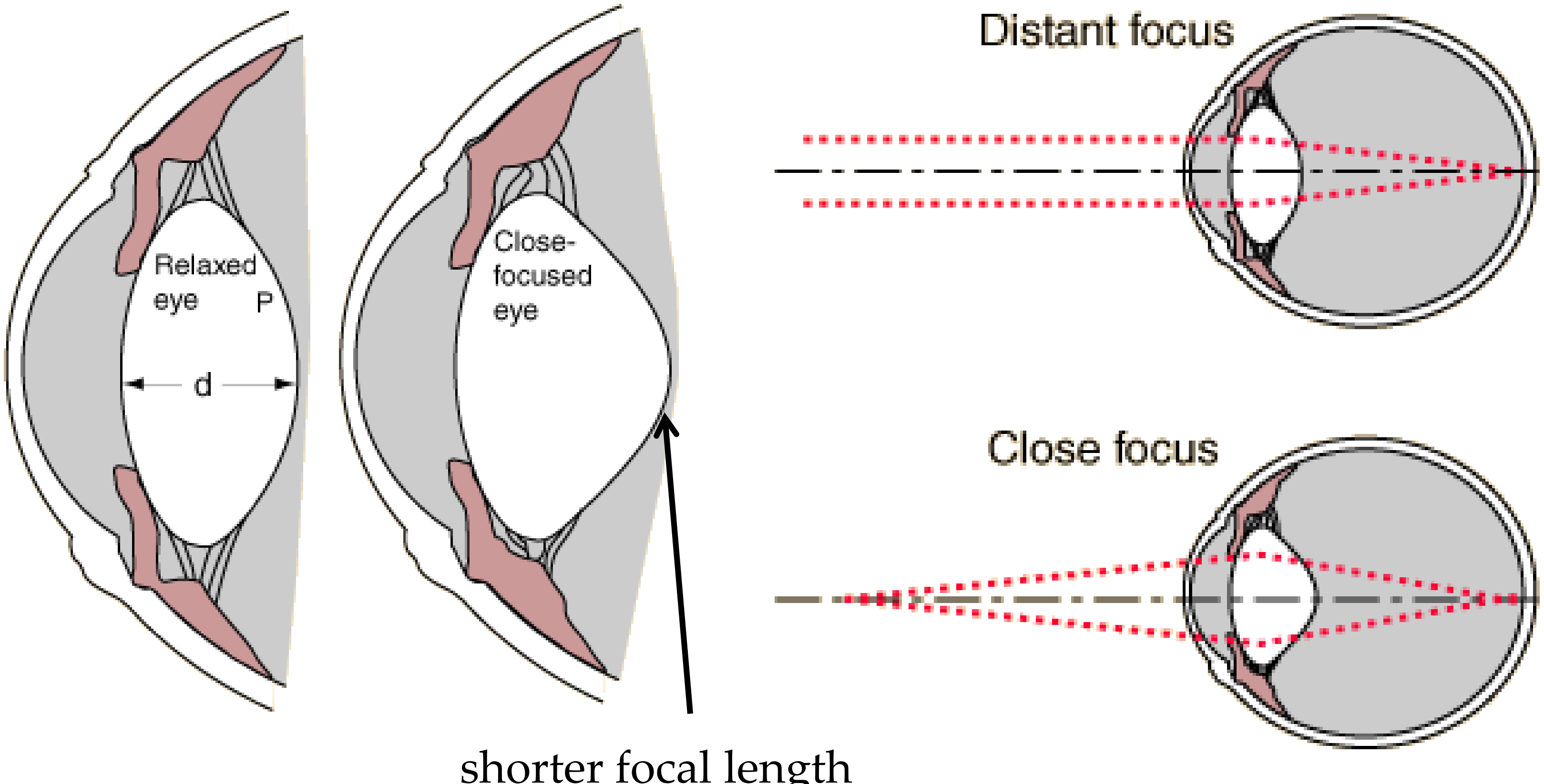






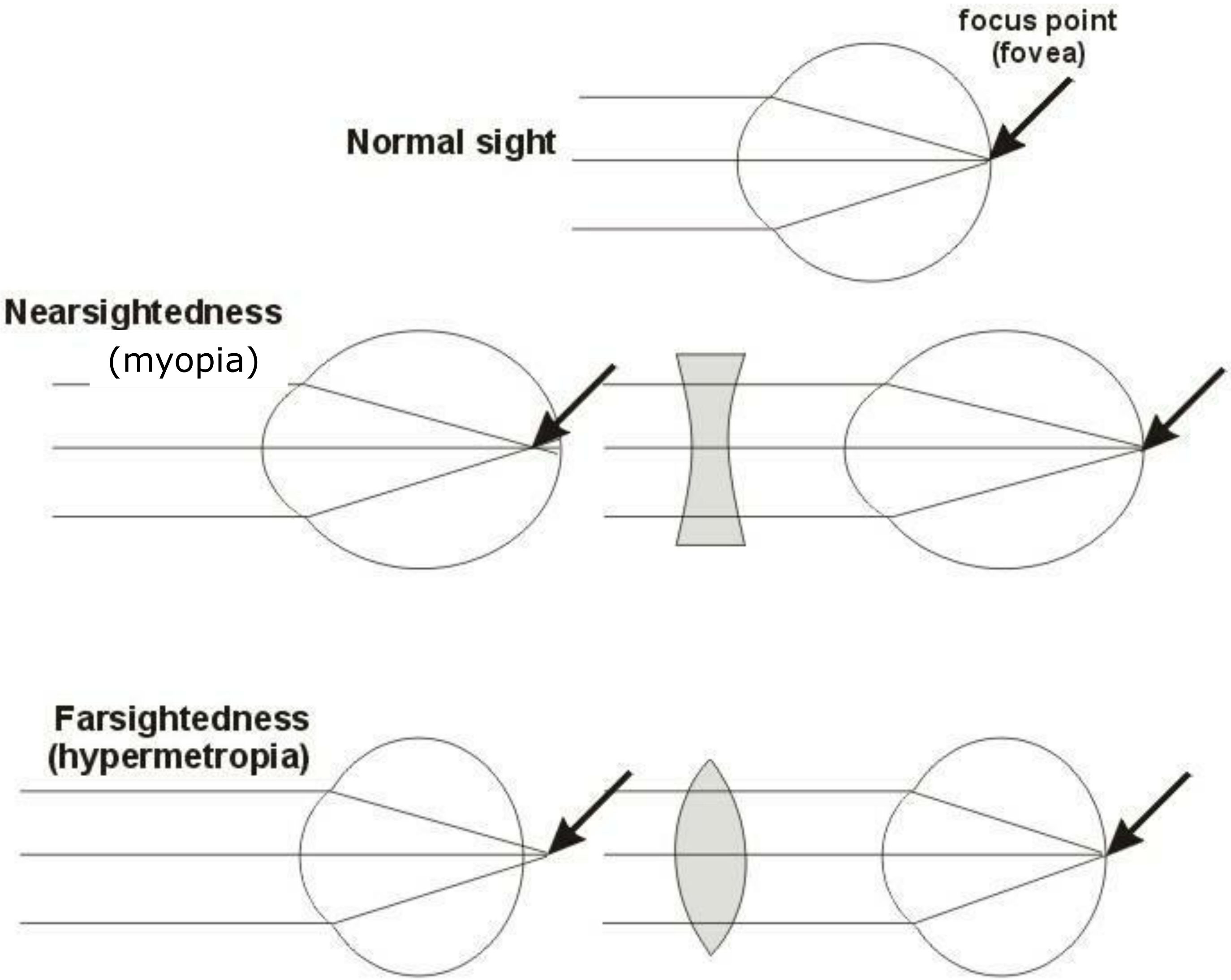
- Index of refraction: cornea 1.376, aqueous 1.336, lens 1.406-1.386
- Iris is the diaphragm that changes the aperture (pupil)
- Retina is the sensor where the fovea has the highest resolution

Accommodation

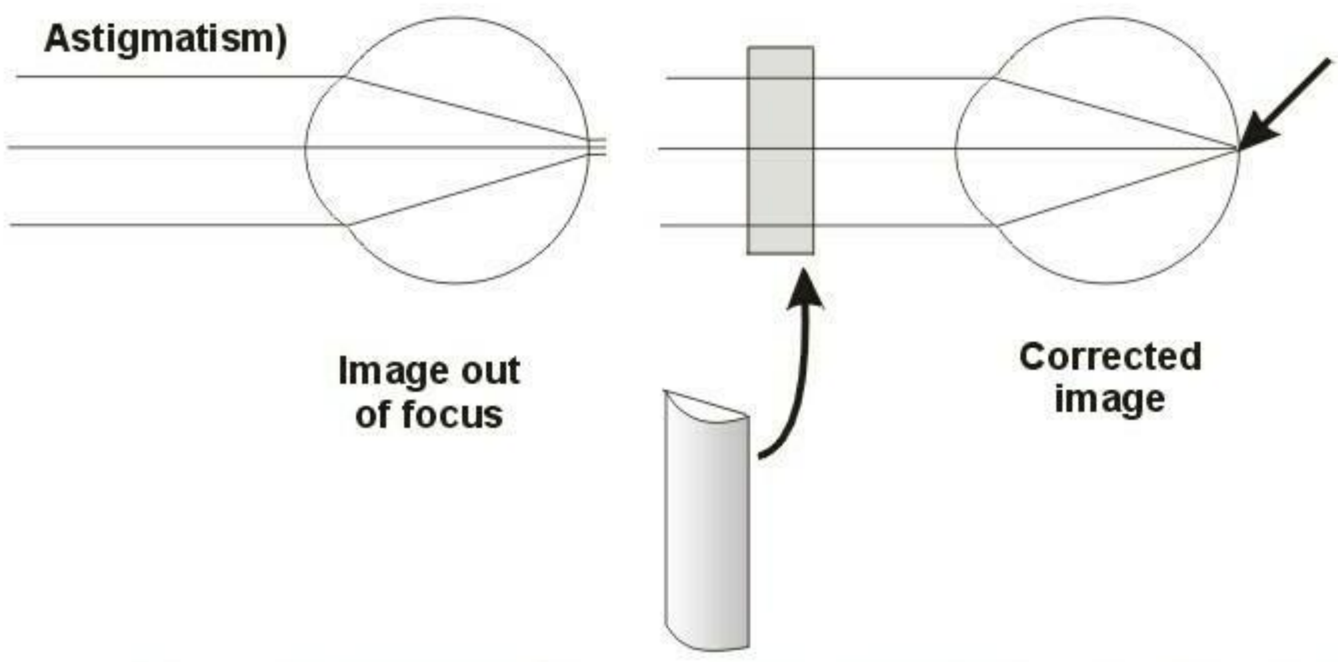


Changes the focal length of the lens

Myopia and Hyperopia



Astigmatism

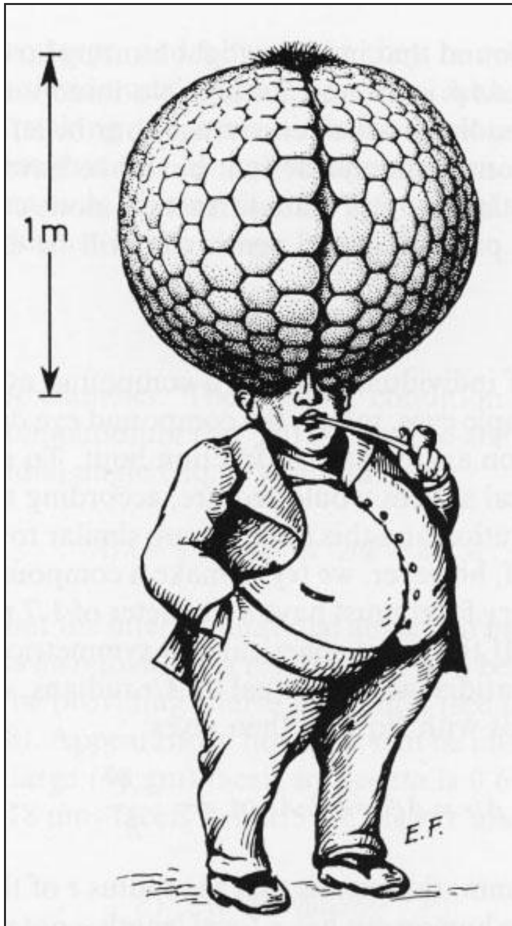


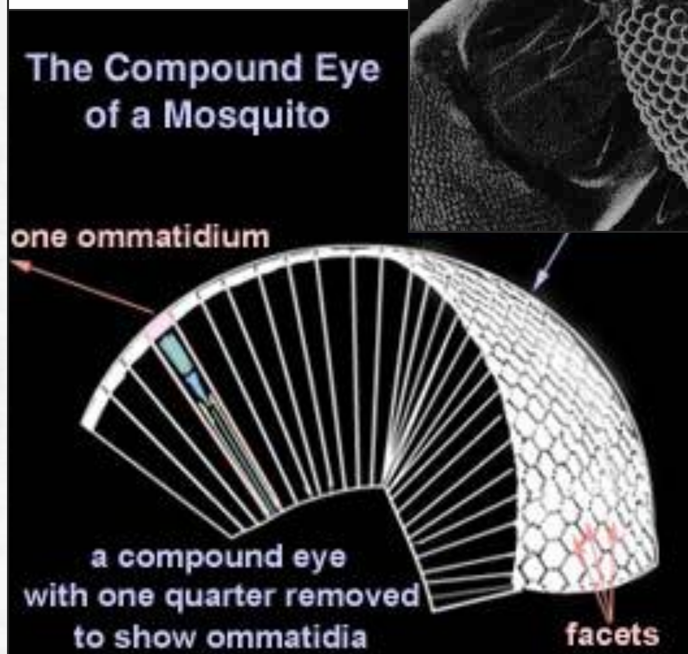
The cornea is distorted causing images to be un-focused on the retina.

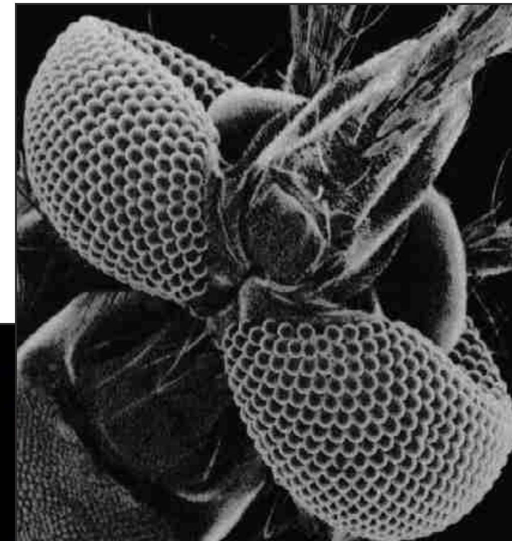
Blind Spot in Eye

Close your right eye and look directly at the “+”

Eyes in Nature







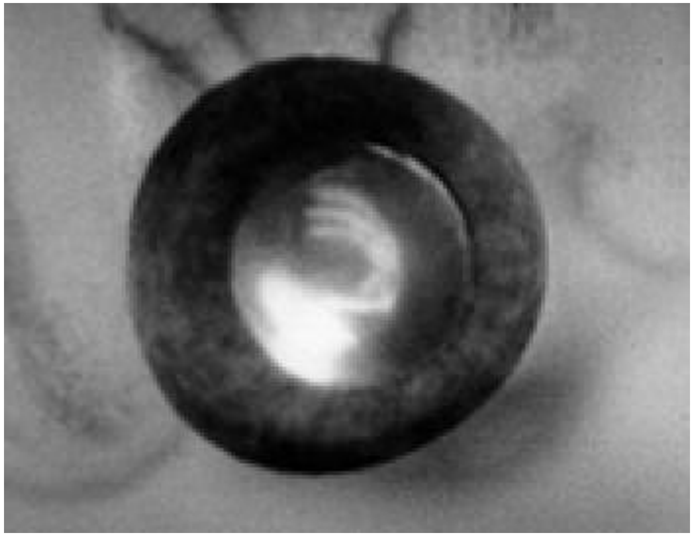
Mosquito

http://ebiomedia.com/gall/eyes/octopus-insect.html

Mosquitos have microscopic vision, but to focus at large distances the eye would need to be 1 m!

Curved Mirrors in Scallop Eyes

Telescopic Eye



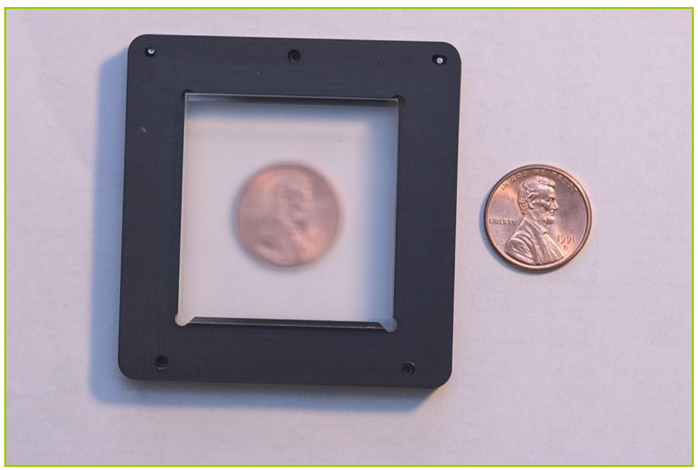
(by Mike Land, Sussex)

… More in the second part of the course

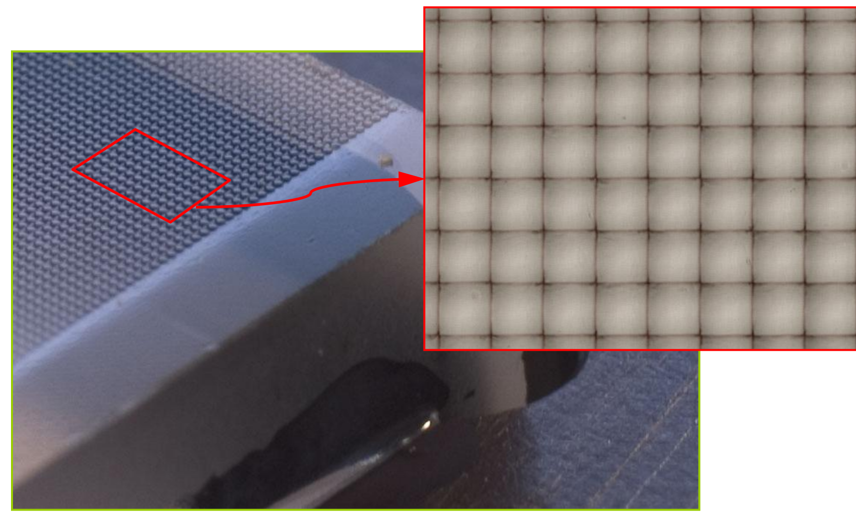
Light Field Cameras - Lens Arrays

Contax medium format camera

Kodak 16-megapixel sensor



Adaptive Optics microlens array



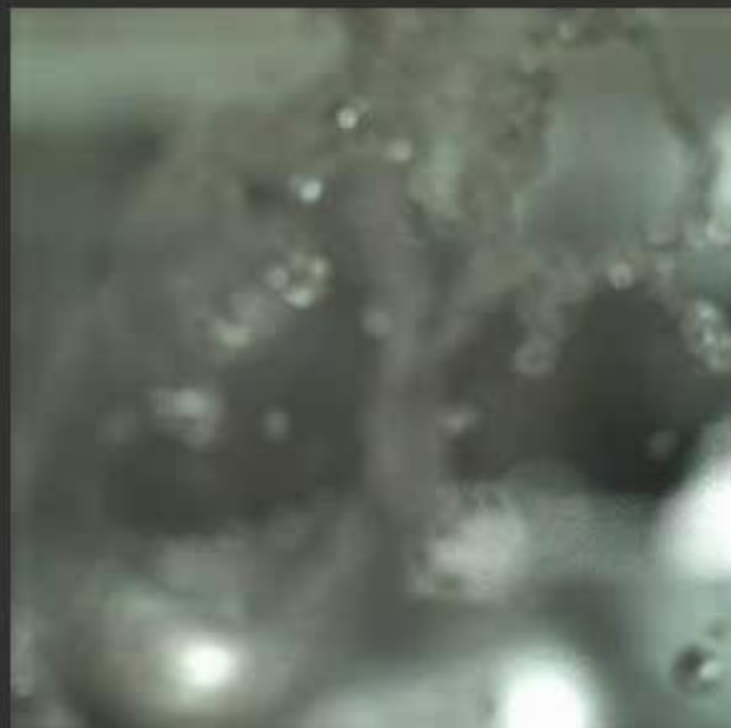
125μ square-sided microlenses

4000×4000 *pixels* $\div$ 292×292 *lenses* $=$ 14×14 *pixels per lens*

Refocusing using Lens Arrays

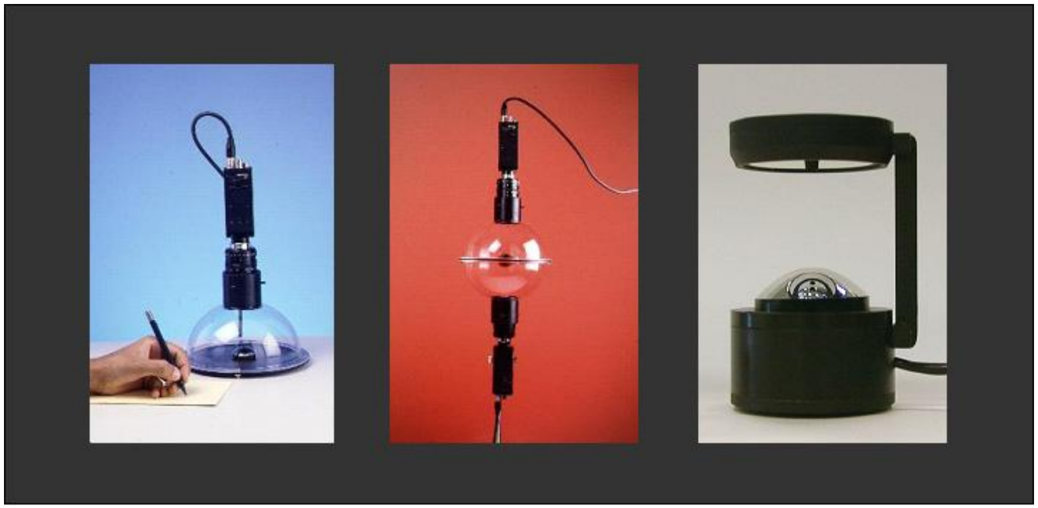
Refocusing using Lens Arrays

Refocusing using Lens Arrays



Focusing through a splash of water

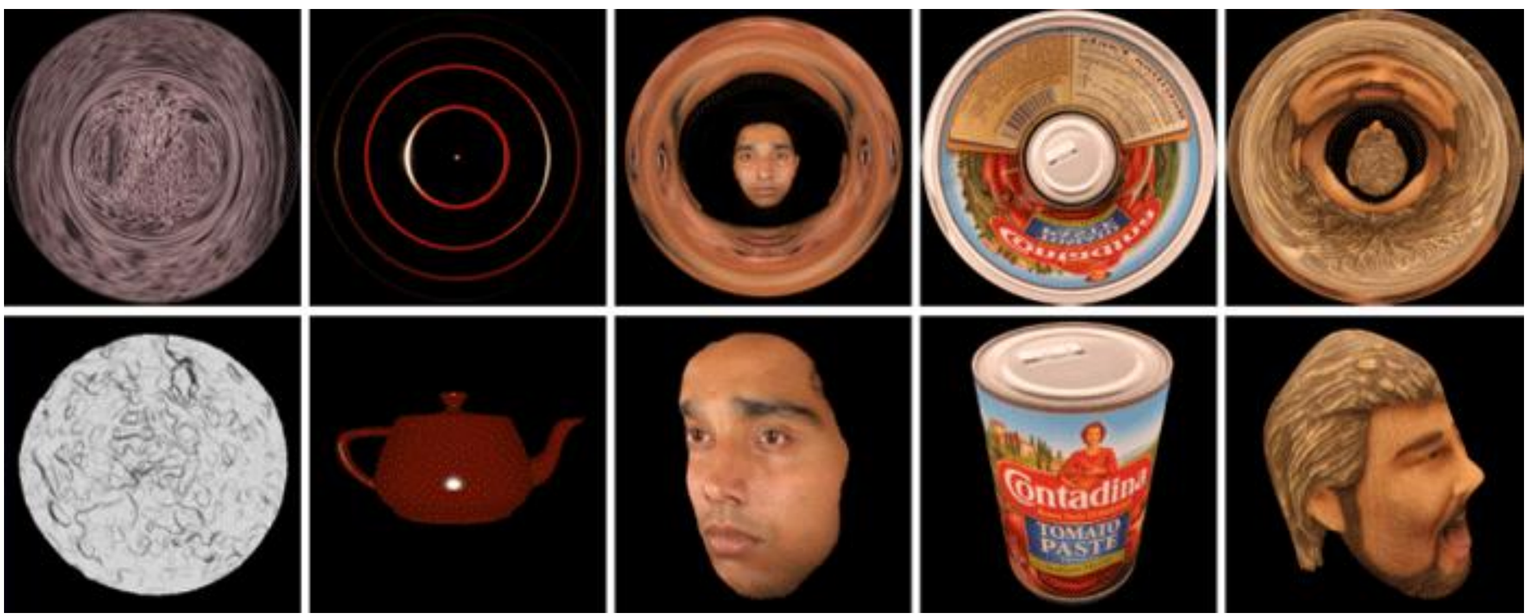
Cameras with Lenses and Mirrors




COOLPIX
990

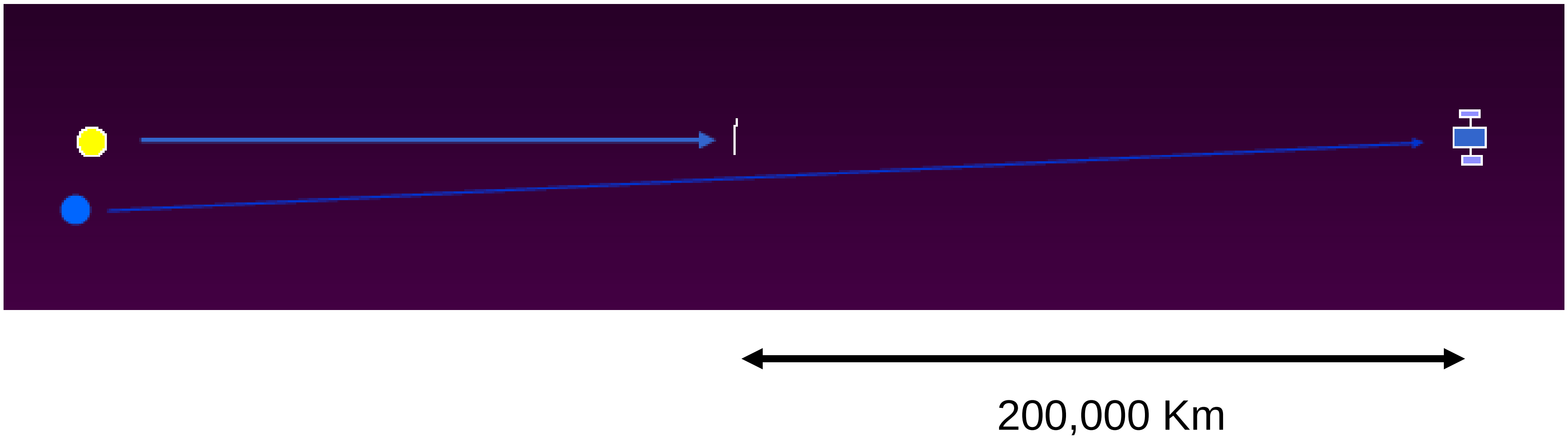

COOLPIX

Cameras with Lenses and Mirrors - Applications



Astronomical Camera Obscura?

New World Mission - NASA



http://en.wikipedia.org/wiki/New_Worlds_Mission
http://www.nasa.gov/lb/vision/universe/newworlds/new_worlds_imager.html