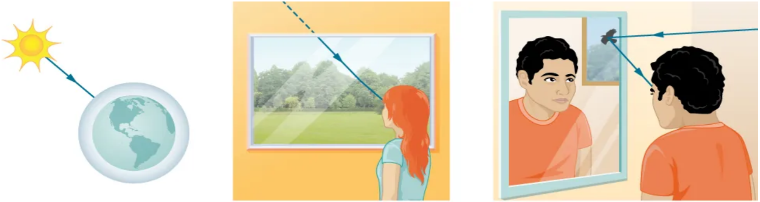
Ray Model of Light

3 ways light can travel from a source to another location



(a) (b) (c)

- a directly from source through vaccum . Sun to Earth
- b light can travel through various media like Air, glass, water to the observer
- c light can also arrive after being reflected such as mirrors

Ray of Light

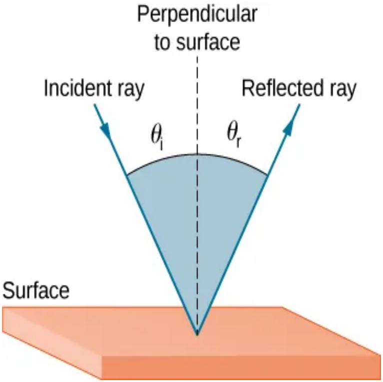
We model path of light as a straight line called ray

- Light behaves both as a particle and a wave
- When light interacts with an object several times larger than its wavelength($\approx 10^{-6}$), it travels in a straight line and acts like a ray.
- Light may change direction when it
  - reflection : encounters objects (such as a mirror)
  - refraction: passing from one material to another (such as in passing from air to glass)

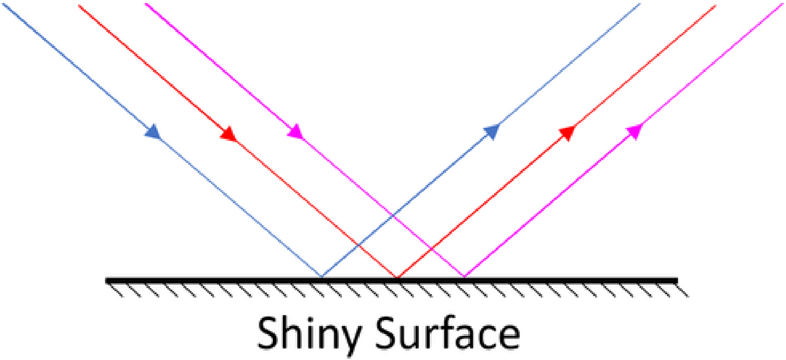
Law of Reflection

the law states that agle of reflection is equal to angle of incidence

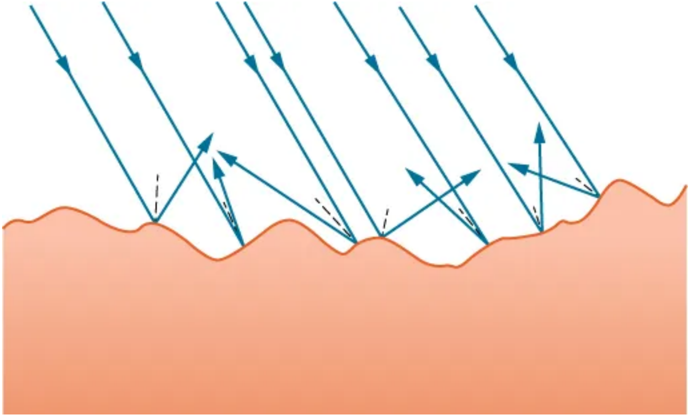
$$\theta_r = \theta_i$$

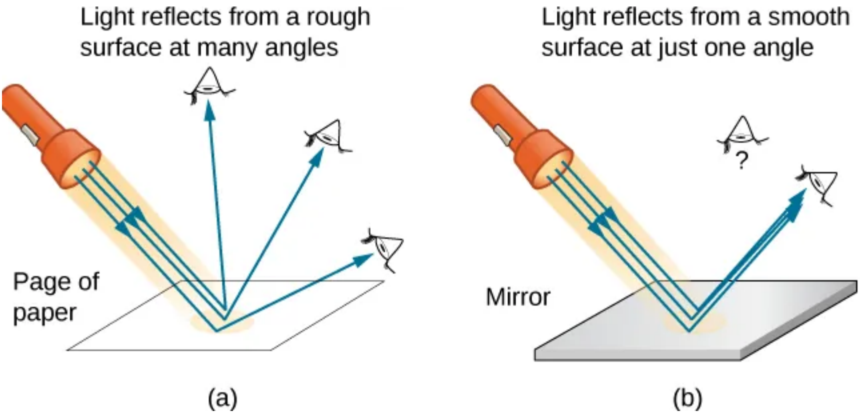


Specular Reflection

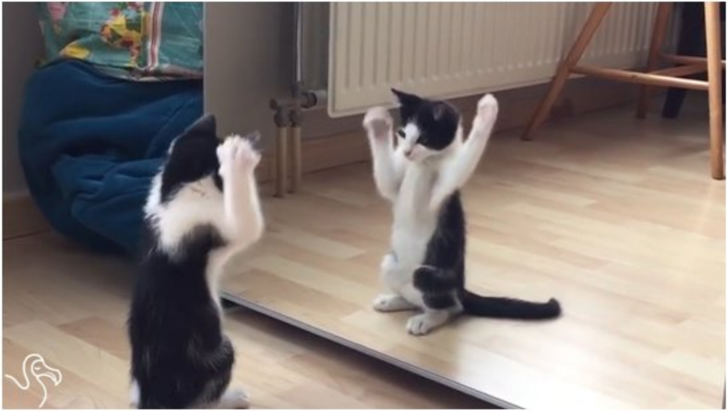


Diffused Reflection




Light reflects from a rough surface at many angles
Page of paper
(a)
Light reflects from a smooth surface at just one angle
?
Mirror
(b)

Reflections: Mirror



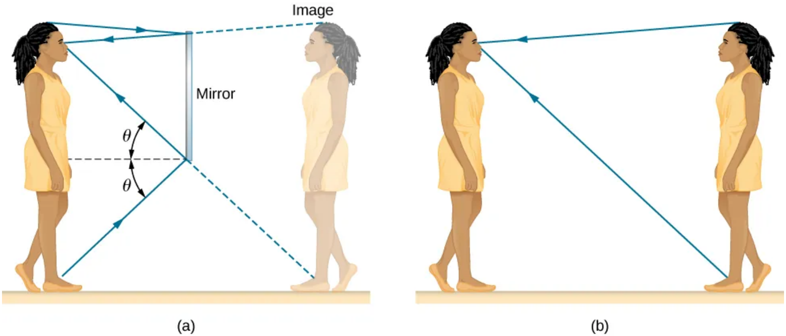


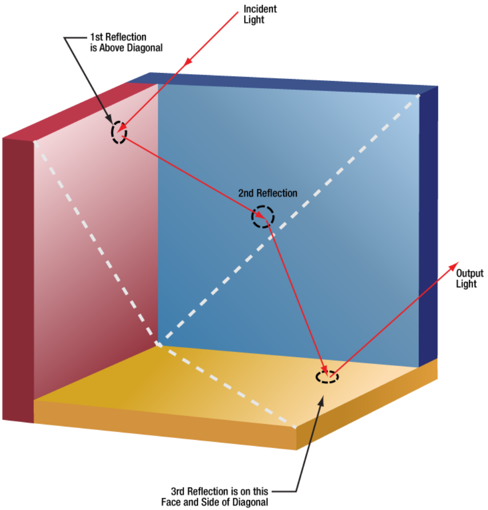
Image
Mirror
θ
θ
(a)
(b)

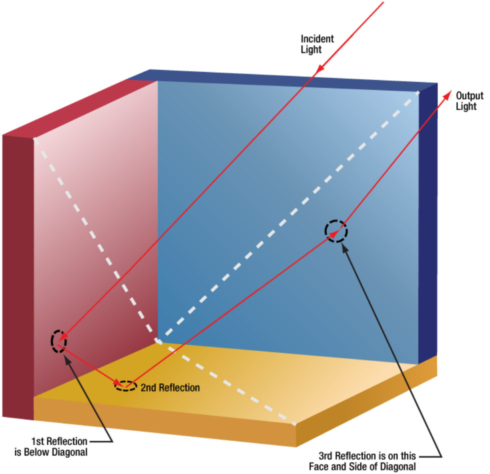
Defenition

A **retroreflector** is a device or surface that reflects radiation (usually light) back to its source with minimum scattering

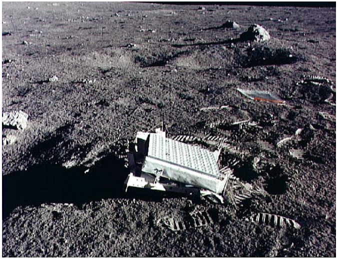
What is the difference from a **planar mirror** ?
This works in wide range of angle of incidence while mirror needs to be perpendicular to the wave front

Retroreflector: Corner Cube Reflector

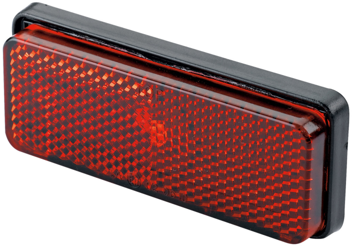



Incident
Light
Output
Light
2nd Reflection
1st Reflection
is Below Diagonal
3rd Reflection is on this
Face and Side of Diagonal

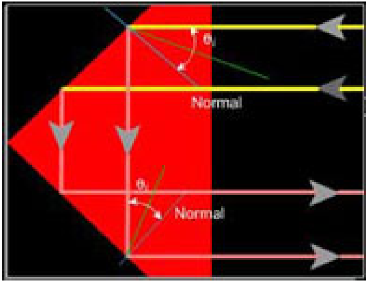
Retroreflector : Uses



- Astronauts placed a corner reflector on the Moon to measure its gradually increasing orbital distance. Laser signals from Earth can be bounced from that corner reflector to measure the gradually increasing distance to the Moon of a few centimeters per year.



(a) cycle reflectors



(b) working principle

- Retroreflection ensures high visibility if the driver and the light source are located together in case of cycle reflectors

Retroreflector : Radar

- Small boats made of fiberglass or wood do not strongly reflect radio waves emitted by radar systems. To make these boats visible to radar (to avoid collisions, for example), radar reflectors are attached to boats, usually in high places

The actual location of Mug ?

The actual location of Mug ?

Both are not the actual location !!!

Why two mugs ?

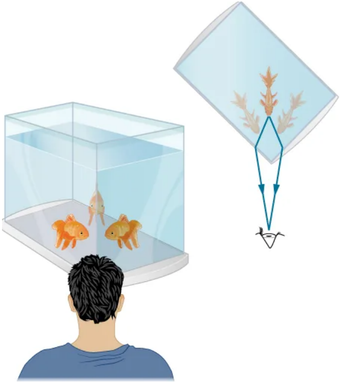
Refraction

The changing of a light ray's direction (loosely called bending) when it passes through substances of different refractive indices is called **refraction**

Why two mugs ?

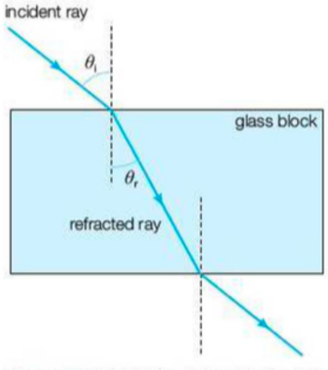
Refraction

The changing of a light ray's direction (loosely called bending) when it passes through substances of different refractive indices is called **refraction**

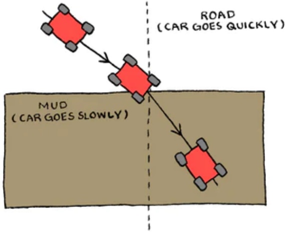


Velocity of Light

$$v = c/\eta$$



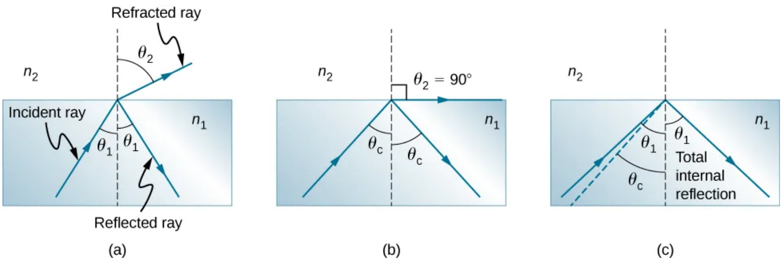
(a) Refraction through a glass block



(b) Direction of Bending

Snell's Law

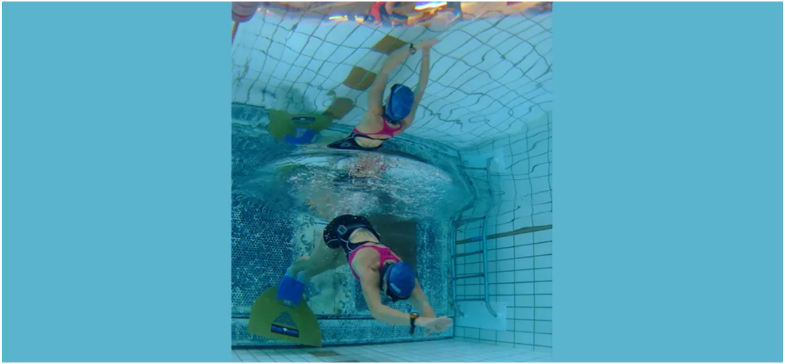
$$\eta_1 \sin \theta_1 = \eta_2 \sin \theta_2$$



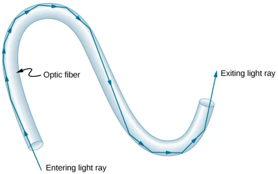
a. $\eta_1 > \eta_2 \implies \theta_2 < \theta_1$
b. $\theta_1 \uparrow \implies \theta_2 \uparrow$. At $\theta_1 = \theta_c, \theta_2 = 90°$
c. At $\theta_1 > \theta_c$, all of the light is reflected back in to medium = **total internal reflection**

$$\theta_c = \sin^{-1}\left(\frac{\eta_1}{\eta_2}\right) \text{ for } \eta_1 > \eta_2$$

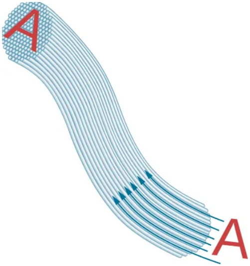
What is happening here?



Fiber Optical Cables and Endoscopes



(a) Total internal reflection in fiber optic cable



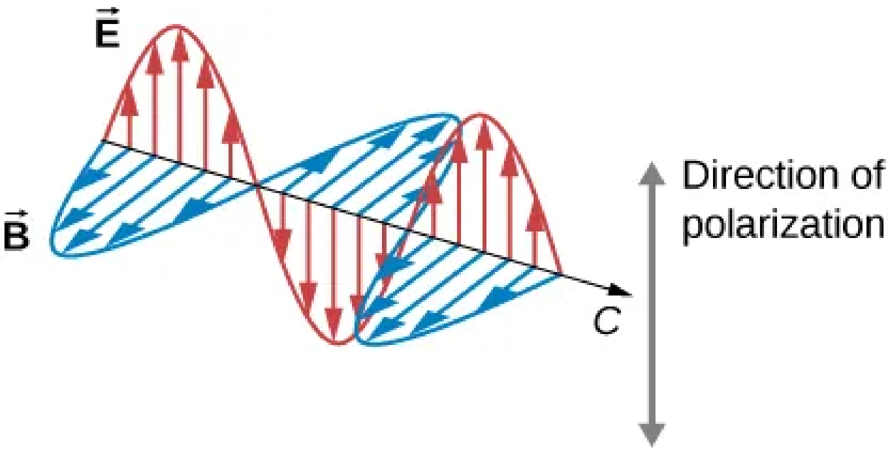
(b) Bundle of Fiber optic cables

(c) Endoscospic Camera

Premise

- Light behaves as both wave and particle
- Some optical phenomena require analysis based on wave characteristics of light when the wavelength is not negligible compared to dimension of optical device e.g. slit in case of diffraction

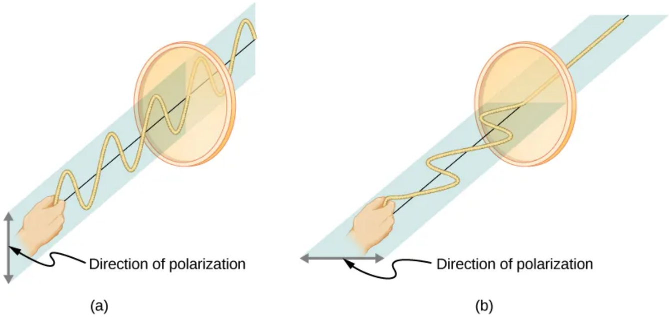
a. glare effect
b. using polarizing filter . this reduces the glare


$\vec{E}$
$\vec{B}$
C
Direction of polarization

EM wave propagation

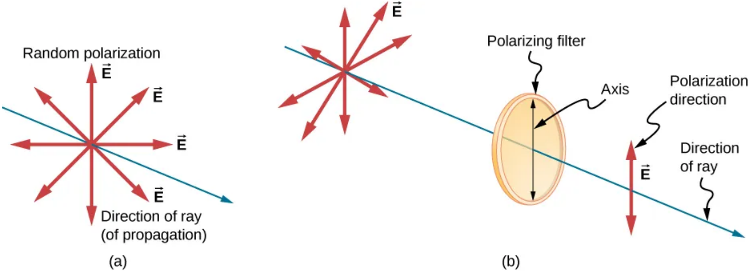
- EM waves are transverse waves consisting of varying Electric and Magnetic fields that oscillate perpendicular to the direction of propagation
- Polarization is the attribute that a wave's oscillations do have a definite direction relative to the direction of propagation of the wave
- For an EM wave, the direction of polarization is the direction parallel to the electric field.

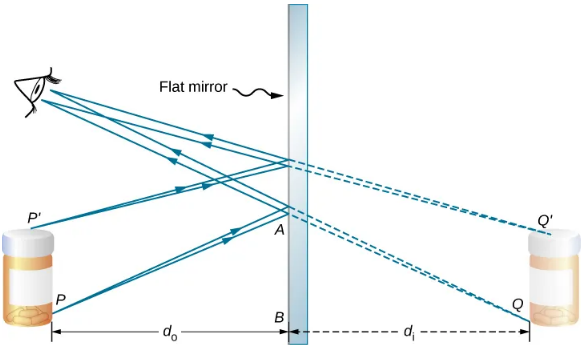
Vertical vs Horizontal Polarization



a. Vertical polarization . Effect of vertical slit placed on the rope and the waves will pass through
b. Horizontal polarization. Effect of horizontal slit where the wave propagation got blocked

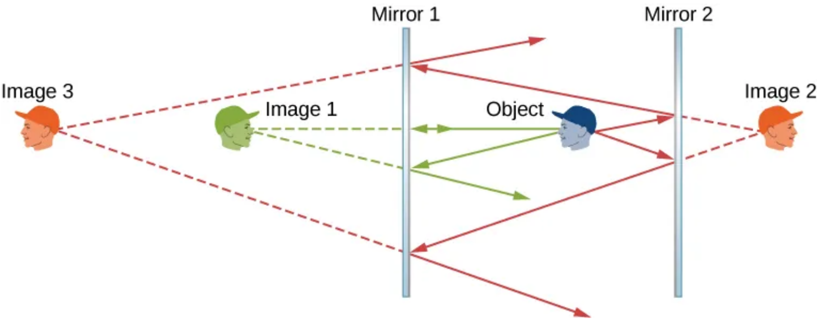
Polarizing filter



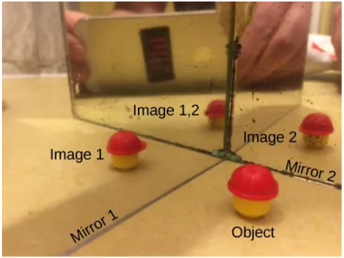


$$d_o = -d_i$$

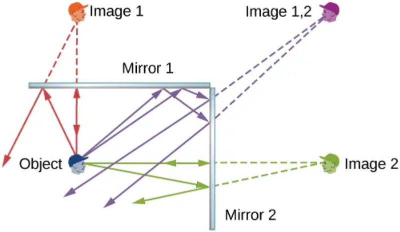
Multiple Images: infinite



Multiple Images: finite



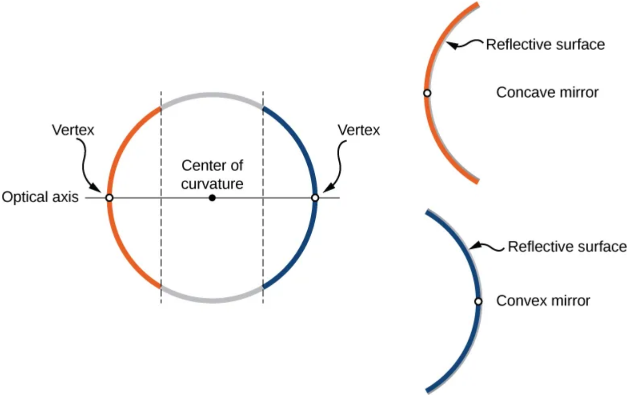
(a)



(b)

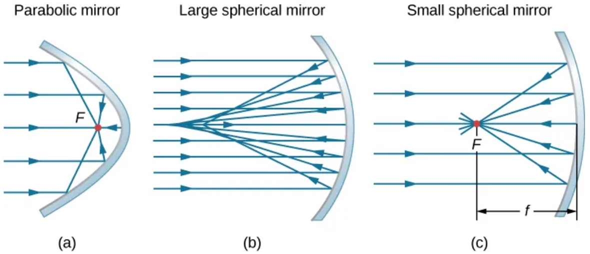
Curved Mirrors

- A **curved mirror** can form images that may be larger or smaller than the object and may form either in front of the mirror or behind it.



Curved Mirrors

a. Rays parallel to the optical axis of a parabolic mirror converges at the point called **focal point**
b. If the mirror is large compared to radius of curvature then rays will not converge
c. If the mirror is small compared to radius of curvature, then it can be approximated to parabolic mirrors

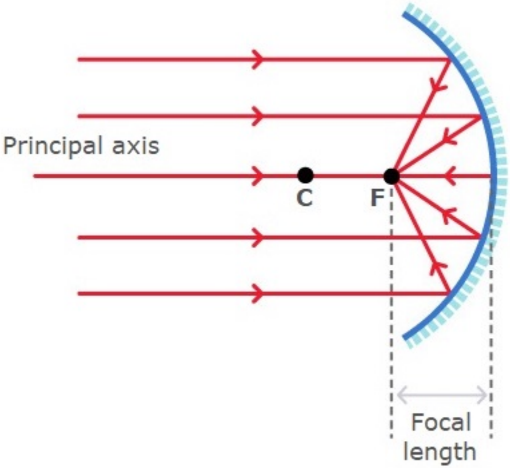


Walkie Talkie Building

(a) Walkie Talkie Building

(b) Egg Fry

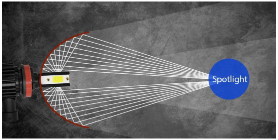
Reflection of light on a concave mirror



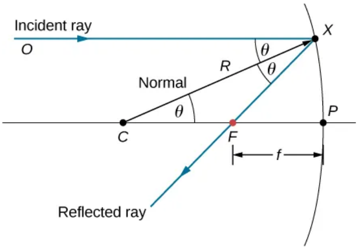
Concave Mirror Applications

(a) Microscope

(b) Dish TV



(c) Reflector Headlight



$$R = CF + FP$$

$$\triangle XCF, CF = XF$$

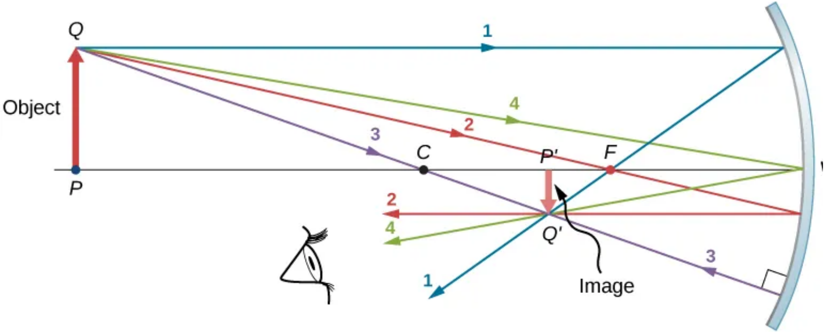
$$\triangle XFP, \cos 2\theta = \frac{FP}{FX}$$

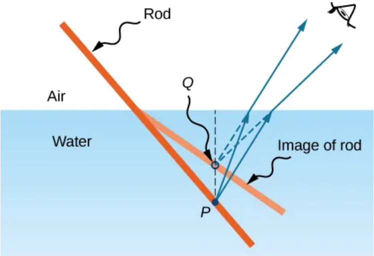
$$\text{for small angles}, FP = FX$$

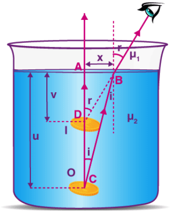
$$R = 2 \times FP$$

$$R = 2f$$

Image Formation in Concave Mirror

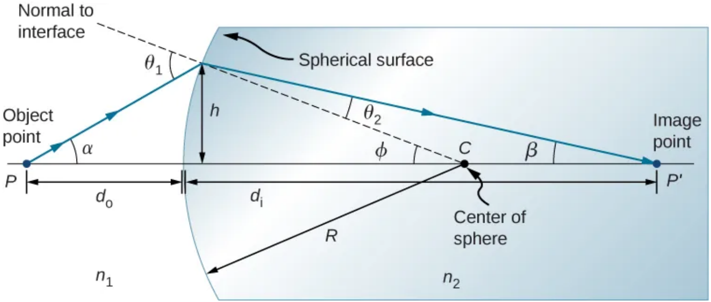



Rod
Air
Water
Q
Image of rod
P



$$\mu_1 \sin i = \mu_2 \sin r$$
For paralaxial rays, $\sin i = \tan i$
$$\triangle ACB, \tan i = \frac{x}{u}$$
$$\triangle ADB, \tan r = \frac{x}{v}$$

$$\frac{\mu_2}{\mu_1} = \frac{u}{v}$$

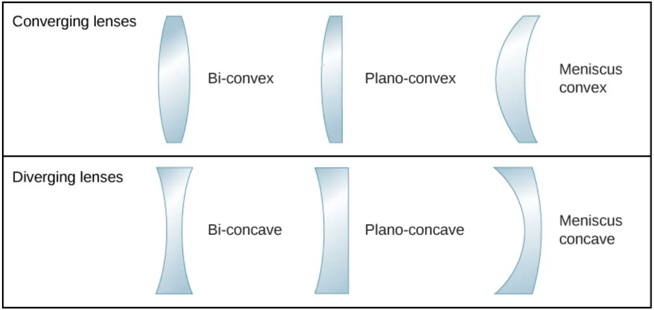


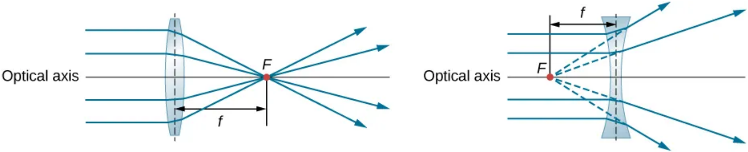
For paralaxial rays,

$$\eta_1 \theta_1 = \eta_2 \theta_2$$
$$\theta_1 = \alpha + \phi, \theta_2 = \phi - \beta$$
$$\tan \alpha \approx \frac{h}{d_0}, \tan \beta \approx \frac{h}{d_i}, \tan \phi = \frac{h}{R}$$
$$\alpha \approx \frac{h}{d_o}, \beta \approx \frac{h}{d_i}, \phi = \frac{h}{R}$$

title

$$\frac{\eta_1}{d_o} + \frac{\eta_2}{d_i} = \frac{n_2 - n_1}{R}$$

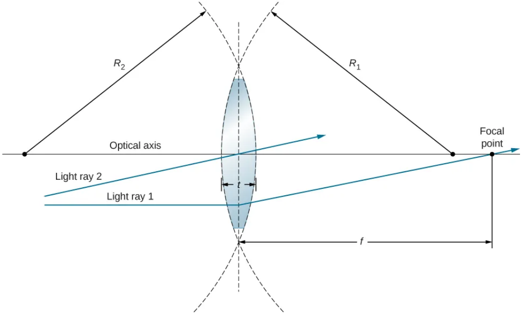




Converging lens
(a)

Diverging lens
(b)

Thin Lens



- If thickness t is much less than radius of curvature of both surfaces
- In this case parallel rays will bent only once at the centre of the lens and go through the focal point
- rays passes through the centre of the lens undeviated

Ray Tracing and Thin Lenses

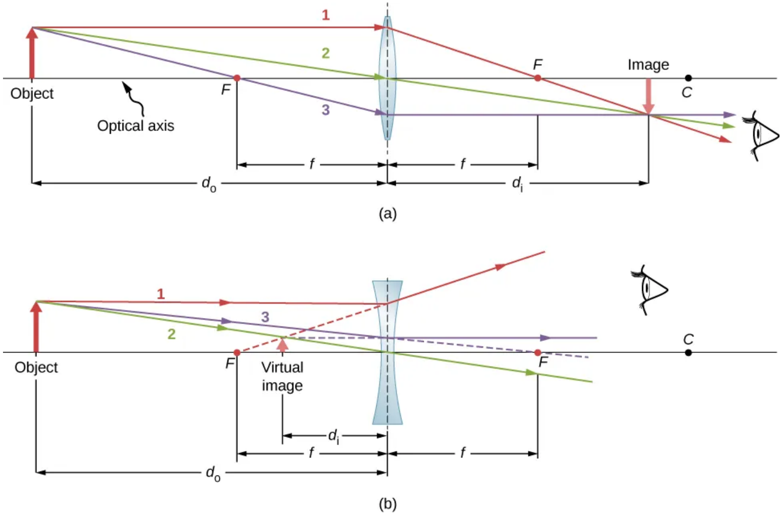
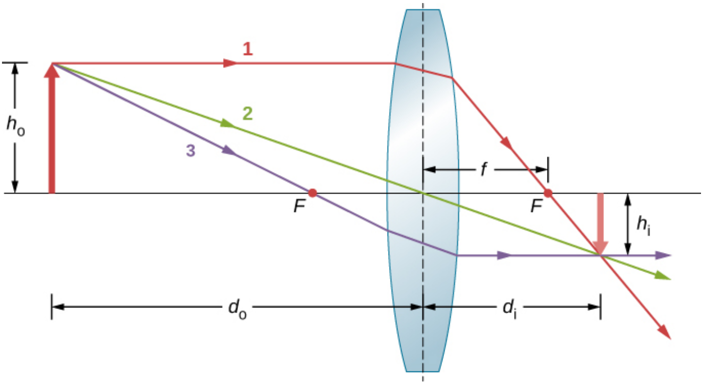
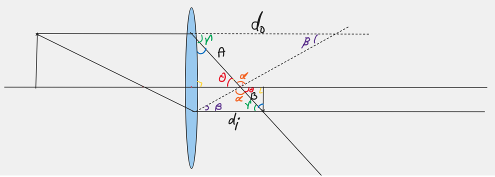


Image formation by Lenses





from similar triangles

$$\frac{d_o}{d_i} = \frac{A}{B} = \frac{f}{d_i - f}$$

Thin-Lens Equation

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

A History of Photography

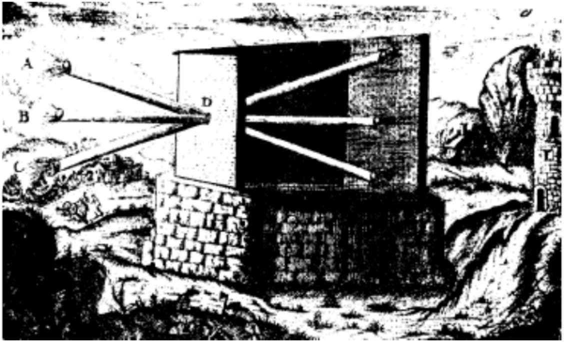
It could be said that photography was not "invented"…but that it evolved over time.

Ms. Scales

- A camera obscura (from Latin 'dark chamber') is a darkened room with a small hole or lens at one side through which an image is projected onto a wall opposite the hole
- A camera obscura without a lens but with a very small hole is referred to as a pinhole camera

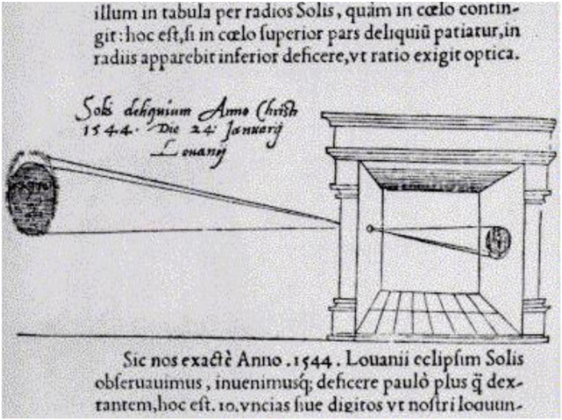
The word photography came from two Greek words that mean "writing with light." The first time the word "photography" was used was in 1839, the year the invention of the photographic process was made public, by Sir John Herschel.

The Chinese were the first people that we know of to write about the basic idea of the pinhole camera or *"camera obscura"* (Latin words meaning "dark room"). About 2,500 years ago (5th Century B.C.) they wrote about how an image was formed upside down on a wall from a pinhole on the opposite wall.

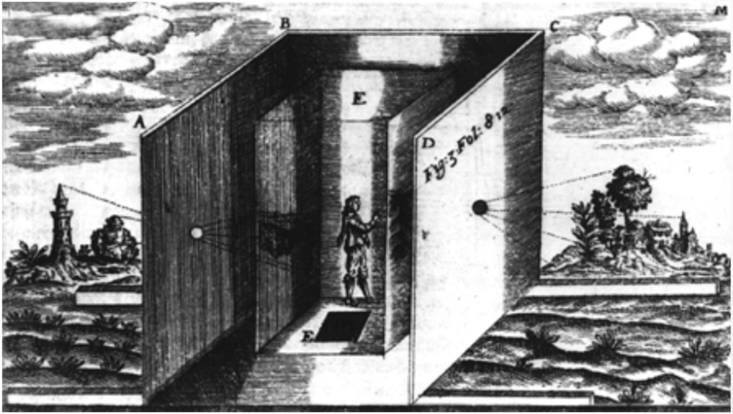


About 2,400 years ago (4th Century B.C.) the famous philosopher Aristotle talked about a pinhole image formation in his work. He wondered why "when light shines through a rectangular peep-hole, it appears circular in the form of a cone?" He didn't find an answer to his question and the problem wasn't answered until about 2,000 years later in the 1500s.

In the 1500s many artists, including Michelangelo and Leonardo da Vinci, used the "camera obscura" to help them draw pictures. A person or object would be outside the dark room and their image was reflected on a piece of paper and the artist would trace it.



This is a drawing of a camera obscura done in 1646. This drawing shows an outer shell with lenses in the center of each wall and an inner shell with transparent paper for drawing. The artist needed to enter by a trap door in the bottom.

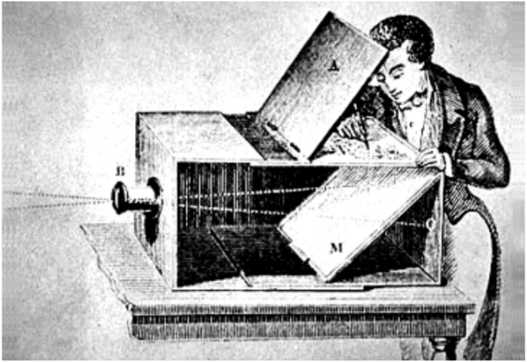


"View of Delft"

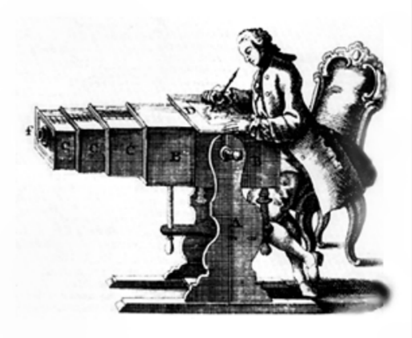
The camera obscur
was used in the pai
of this picture. It was
painted about 1660
Jan van der Meer v
Delft (aka Jan Verm
His paintings are kn
for their "camera-like
detail and quality - b
were painted 150 ye
before the invention
the camera

The camera obscura is believed to have been used in this painting by Jan Vermeer. He painted this in 1665. He was a great master who made paintings that to this day still amaze people with how much they look like a photograph.

The camera obscura was made portable by the 1700s by putting it in a box with a pinhole on one side and a glass screen on the other. Light coming through this pinhole projected an image onto the glass screen, where the artist could easily trace it by hand. Artists soon discovered that they could obtain an even sharper image by using a small lens in place of the pinhole.



Two types of portable cameras obscura.



Drawing of "portable" camera obscura from 1769 (right)

Extremely important to the invention of photography was knowledge of how sensitive to light certain materials were. More than 2,000 years before the invention of the camera obscura, the ancient Phoenicians (the first civilized nation in the world) knew that a certain snail left a yellow slime that turned purple in sunlight.

The Phoenicians came from the eastern shore of the Mediterranean Sea in land we now call Lebanon.

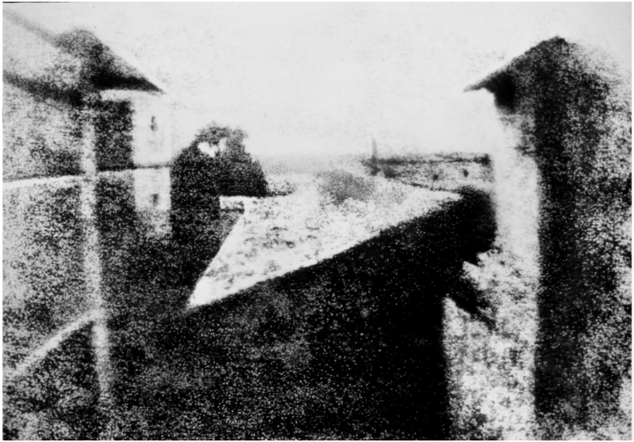
In 1727 a German professor, Johann Heinrich Schulze, observed that silver salts darkened when exposed to light. But the idea of making pictures using this information did not occur to him. That invention required the talents of a later generation of scientists.

In 1800 a young English chemist, Thomas Wedgewood, was making "sun pictures" by placing leaves on leather that he had treated with silver salts, but he couldn't find a way to stop the darkening action of light and his leaf images faded into blackness

For the birth of photography to happen two key discoveries were still needed: a way to combine light-sensitive material with the camera obscura device and a way to make an image permanent.

"View from the Window at Le Gras, France"

The birth of photography happened in 1826 when a French scientist, Joseph Nicephore Niepce, put a plate coated with bitumen (an asphalt used in ancient times as a cement or mortar) in a camera obscura. He put the camera obscura facing his house for eight hours and made a photograph. It is the earliest camera photograph that we still have today. Here is that first photograph.



Niepce (left) began sharing his findings with Louis Jacques Mande Daguerre (right), an artist who owned a theatre in Paris. They became partners three years later. Daguerre's most important discovery came in 1835, two years after Niepce died.

Daguerre found that the chemical compound silver iodide was much more sensitive to light than Niepce's bitumen. He put a copper plate coated with silver iodide in a camera obscura, exposed this plate to light for a short time, then to fumes of mercury and an image appeared! One problem remained, the image darkened over time. Two years later he solved this problem by washing away remaining silver iodide with a solution of warm water and table salt.

Daguer

Still life

1837

Daguerre's process, which he named the daguerreotype, was announced to the world on January 7, 1839. Half a year later the French government gave Daguerre and Niepce's son, Isidore, lifetime pensions in exchange for all rights to their invention. The daguerreotype was to become France's gift to the world.

Here is one of the first daguerreotypes that was taken in 1839. It is a picture of Port Ripetta, Rome in Italy.

"I was first!"

Three weeks after Daguerre's announcement an English amateur scientist, William Henry Fox Talbot, read about the daguerreotype and realized that this invention was a lot like his own unpublicized process that he called photogenic drawing. He quickly tried to claim priority over Daguerre and presented his process in a paper to the Royal Society in London, England.

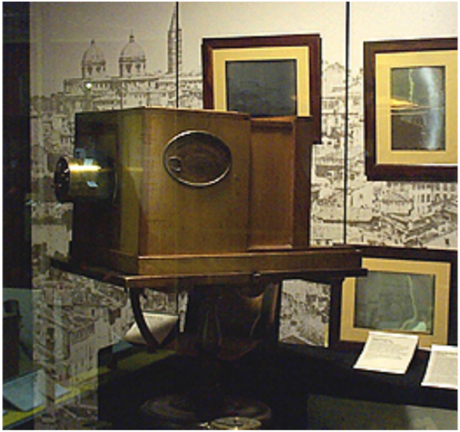
In Talbot's process he first coated a sheet of drawing paper with the chemical compound silver chloride, then he put it in a camera obscura where it produced an image with the tones reversed (a negative). He then placed the negative against another coated sheet of paper to produce a positive image. Talbot did not find a way to make the image permanent until a month after Daguerre's announcement, but his process, later improved and renamed the calotype, is the basis for most modern film technology which relies on negatives to produce many positive prints.

Because of a few problems of Talbot's process, the daguerreotype was the method of photography that firs took the world by storm. With improvements the daguerreotype quickly proved a great way to make portraits of people.

One year after the daguerreotype was invented, daguerreotype studios throughout Europe and America were producing detailed likenesses. People gazed in amazement at their own image in these "mirrors with a memory."

This is a picture of one of the first commercially made daguerreotype cameras that was made in 1839. It was designed by Mr. Daguerre, the inventor of the daguerreotype.

Another picture of a daguerreotype. Notice it is quite large.



A daguerreotype portrait made the year the daguerreotype was invented.

Portrait of the photographer, Rob Cornelius

Photography arrived in America because the man who invented the telepgraph system, Samual F. B. Morse, was so excited about it. He saw a demonstration of the daguerreotype in Paris and returned to America and spread the news. Daguerreotypes remained popular in America into the 1850's, long after European photographers had switched to the improved process developed from Talbot's positive/negative method.

Daguerreotype of Samuel Morse

Most pictures of the California Gold Rush of 1849 are daguerreotypes.

Portraits of people were the most popular type of photographs taken in the 1800's. Photographic portraits were much less expensive than painted ones, they took less time and were more accurate. People who painted people's portraits quickly went out of business or became daguerreotypists themselves.

Army Post Office tent in Virginia during the Civil War. Collodian picture taken April 1863 by Timothy O'Sullivan.

Another improvement...

In 1851 English photographer Frederick Scott Archer invented a wet-plate process called collodion. This was like Talbot's process but the negatives were made of smooth glass instead of paper. This produced sharper images and lasted longer than paper so it was easier to produce many paper prints from one glass negative.

A less expensive process was the *tintype* which used an iron plate instead of a glass plate. During the Civil War tintypes were the type of photography that was used the most. Tintype photographers often worked from the back of horse-drawn wagons photographing pioneer families and Union soldiers.

Picture of a photographer's wagon during the Civil War in 1863 in Virginia. Timothy O'Sullivan took this photograph.

Tintype of Civil War Soldiers

The Civil War in America was the first war to be thoroughly recorded by photography. American photographer Mathew Brady saw the importance of documenting the conflict at its beginning and organized a team of photographers to cover different battlefronts. They took 7,000 pictures!

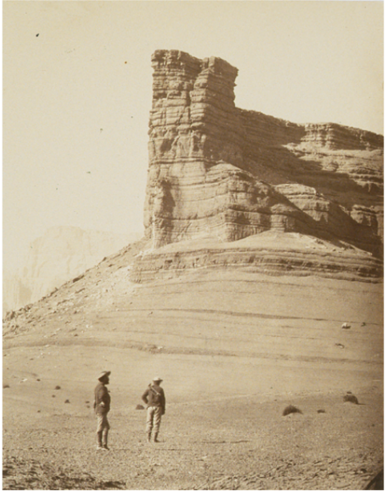
Photograph of George Armstrong Custer (on right) and a Confederate prisoner during the Civil War.

Two of Mathew Brady's employees went on to become two of the best-known photographers of the American West, Timothy O'Sullivan and Andrew J. Russell. They produced large prints of spectacular land forms and people of the west.

Timothy O'Sullivan

Other well known photographers are William Bell, John Hillers and William Henry Jackson.

William Bell



William Henry Jackson

Photographers hauled their large cameras, tripods and portable darkrooms all over the world.

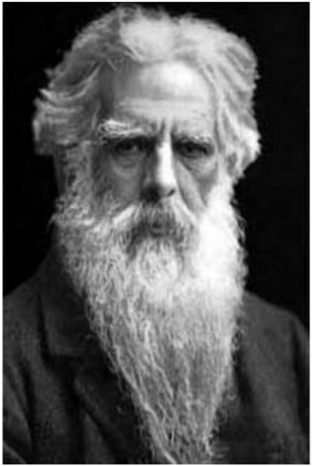
They photographed India, China and Japan. People were eager to see what these far off countries looked like.

Driving of the golden spike

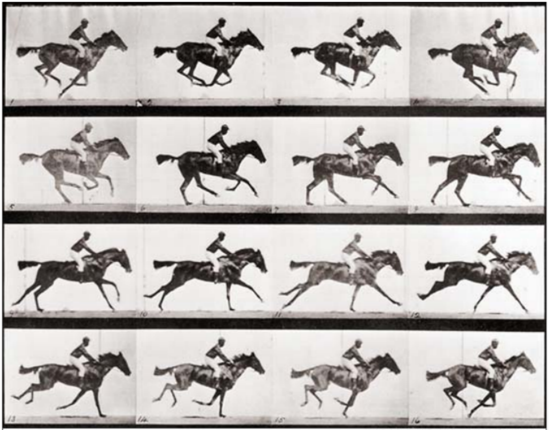
In the 1800's industries hired photographers to photograph the great things they did like building ships, railroads, buildings and bridges. In Utah the completion of the transcontinental railroad in 1869 was celebrated with a photograph of the two steam locomotives facing each other. This photograph was taken by Andrew J. Russell who had worked for Mathew Brady during the Civil War.

Birth of “Motion” Pictures

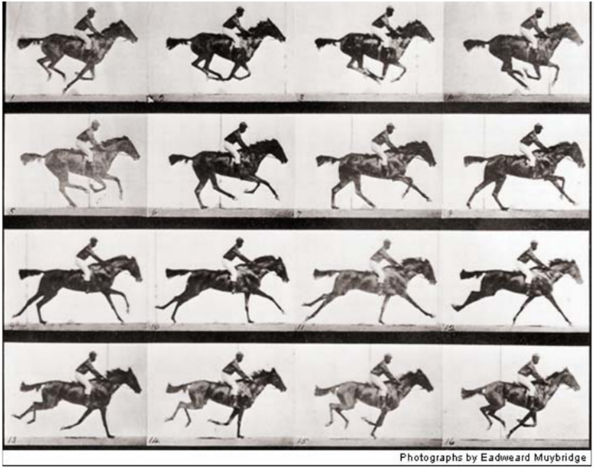
Leland Stanford unwittingly started a chain of events that contributed to the development of motion pictures. To settle a wager regarding the position of a trotting horse's legs, he sent for Eadweard Muybridge, a British photographer who had recently been acclaimed for his photographs of Yosemite.



Although Muybridge initially considered the task impossible, he made history when he arranged 12 cameras alongside a race track. Each was fitted with a shutter working at a speed he claimed to be "less than the two-thousandth part of a second." Strings attached to electric switches were stretched across the track; the horse, rushing past, breasted the strings and broke them, one after the other; the shutters were released by an electromagnetic control, and a series of negatives made.

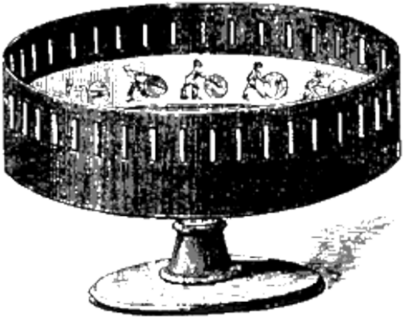


Photographs by Eadweard Muybridge

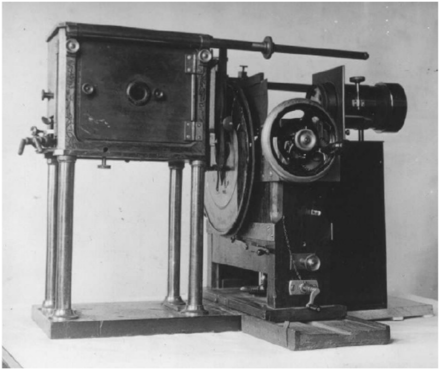


Though the photographs were hardly more than silhouettes, they clearly showed that the feet of the horse were all off the ground at one phase of the gallop. Moreover, to the surprise of the world, the feet were bunched together under the belly. None of the horses photographed showed the "hobbyhorse attitude" - front legs stretched forward and hind legs backward -so traditional in painting. The photos were widely published in America and Europe.

The *Scientific American* printed eighteen drawings from Muybridge's photographs on the first page of its October 19, 1878 issue. Readers were invited to paste the pictures on strips and to view them in the popular toy known as the zoetrope, a precursor of motion pictures. It was an open drum with slits in its side, mounted horizontally on a spindle so it could be twirled. Drawings showing successive phases of action placed inside the drum and viewed through the slits were seen one after the other, so quickly that the images merged in the mind to produce the illusion of motion.



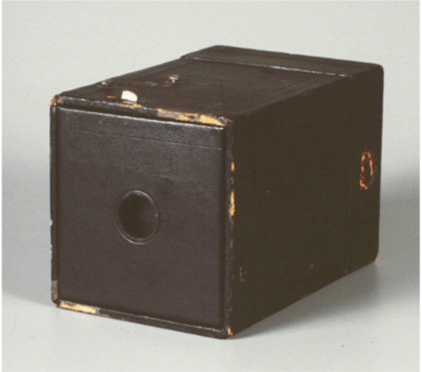
In 1880, using a similar technique with a device he named the zoogyroscope, or zoopraxiscope, Muybridge projected his pictures on a screen at the California School of Fine Arts, San Francisco." Motion pictures were born.



Kodak Cameras

George Eastman, was only 24 years old when he set up his Eastman Dry Plate Company in New York in 1880 and the first half-tone photograph appeared in a daily newspaper. In 1888 he introduced the first Kodak camera that cost $25.00 (a great deal of money then). It had a 20 foot roll of paper, (enough for 100 pictures) already put in it. To get the film developed you had to return the camera to the Eastman Dry Plate Company in Rochester, New York. For $10.00 they would develop the photographs, put more film in your camera and mail everything back to you. One year later an improved Kodak camera with a roll of film instead of a 20 foot roll of paper appeared.

Mr. Eastman wanted everybody to be able to take photographs. He worked hard to develop a camera that everybody could afford to buy. He did it in 1900. It was the Kodak Brownie box roll-film camera. It cost $1.00. Now everyone could take photographs, not just professional photographers.

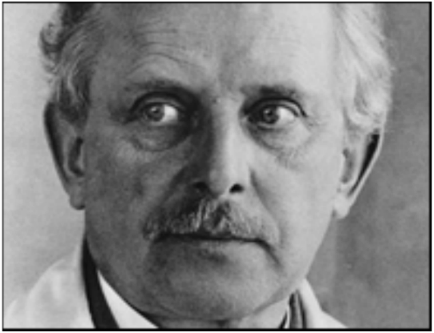


Photograph taken with a Brownie camera. Notice how the photograph is round, just like the camera opening.

Color Photographs

People had tried to make color photographs since 1860. It wasn't until 1906 that a film sensitive to all colors called "panchromatic film" was produced. You had to take three separate negatives and then use a special viewer so you could see all three slides layed on top of each other.
The first color plates were invented in 1907 by Auguste and Louis Lumiere. They named it Autochrome. The colors appeared in delicate pastel.

The cameras that we have now use film with "sprockets" (holes along both sides of film). This film was developed in 1914 by Oscar Barnack.

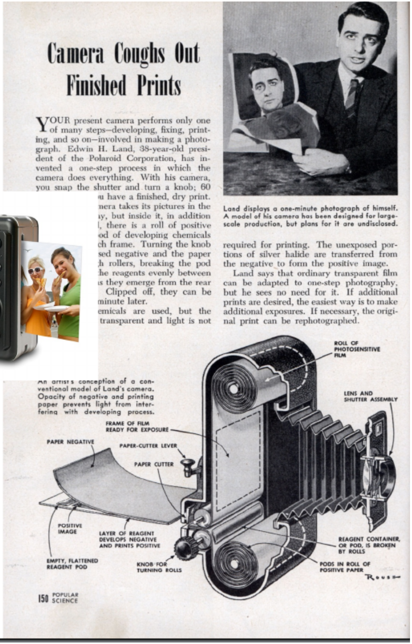


Oscar Barnack, the inventor of the world-renowned Leicca camera was the first to utilize the new 35mm format with the production of the Ur-Leica in 1924.

Kodachrome

It was the first color film that had more than one layer of film - it had many layers of film. Now you didn't need to take three separate photographs and put them on top of each other to get one color photograph, you could just take one photograph! Kodachrome was developed in 1936.

The first instant color film is developed in 1963 by Polaroid.



Camera Coughs Out Finished Prints

YOUR present camera performs only one of many steps—developing, fixing, printing, and so on—involved in making a photograph. Edwin H. Land, 38-year-old president of the Polaroid Corporation, has invented a one-step process in which the camera does everything. With his camera, you snap the shutter and turn a knob; 60
ɪu have a finished, dry print.
nera takes its pictures in the
ıy, but inside it, in addition
l, there is a roll of positive
ɪod of developing chemicals
ch frame. Turning the knob
sed negative and the paper
h rollers, breaking the pod
he reagents evenly between
ıs they emerge from the rear
Clipped off, they can be
minute later.
emicals are used, but the
transparent and light is not
required for printing. The unexposed portions of silver halide are transferred from the negative to form the positive image.

Land says that ordinary transparent film can be adapted to one-step photography, but he sees no need for it. If additional prints are desired, the easiest way is to make additional exposures. If necessary, the original print can be rephotographed.

Land displays a one-minute photograph of himself. A model of his camera has been designed for large-scale production, but plans for it are undisclosed.

An artist's conception of a conventional model of Land's camera. Opacity of negative and printing paper prevents light from interfering with developing process.

150 POPULAR SCIENCE

The disk camera, the predecessor to the digital camera was introduced in 1981 by Sony called the Sony Mavica. It used a charge coupled device elimnating the need for film.

Digital Cameras

Nikon introduced the DSC 100 in 1991. It was 1.3 megapixels and had a separate shoulder box to store the files. It was quite expensive so only photojournalist had them originally.

The Photo CD was introduced in 1992 by Kodak.