

MSc in Digital Humanities



Image Processing/Analysis

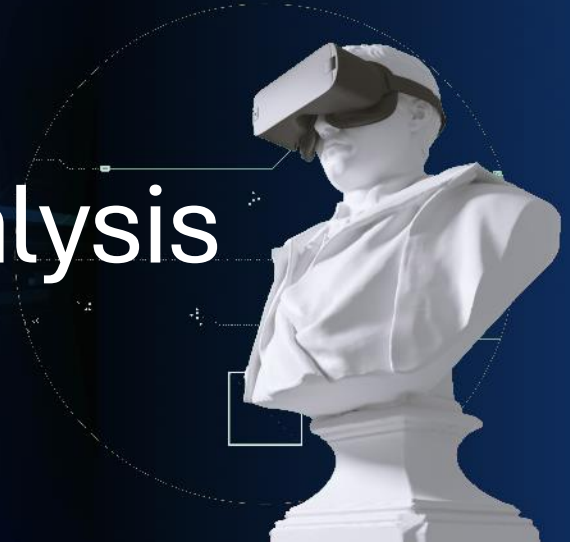


Image digitization technology

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Digital imaging technology

- The imaging technology
 - Photography
 - Image scanning
 - Digital creation
- Digital image representation
- Image processing
- Image analysis
- Image display

The imaging technology

Photography



Photography

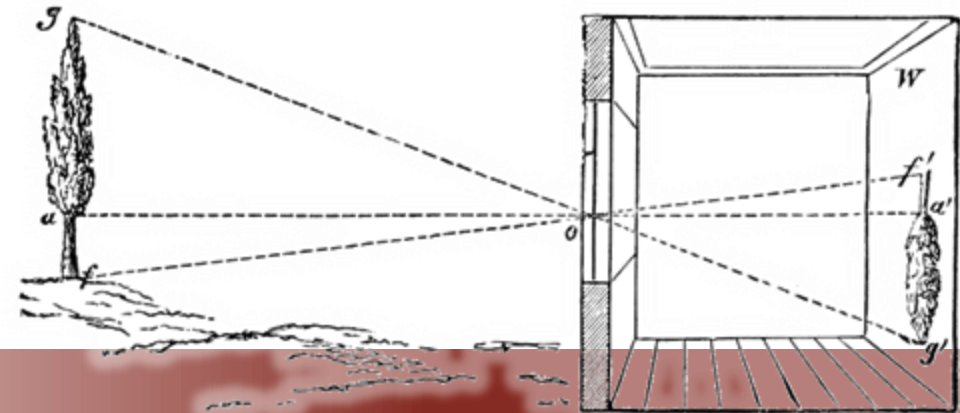
- The history of photography **in the form known today** is considered to have begun in the **early 19th century**
 - The first permanent photographs were made possible
 - ~1839 Sir John Frederick William Herschel
 - coined the term **photography**
 - from the Greek **φως + γράφω**
 - meaning to **inscribe, to write or to draw with light**



The camera obscura



- The **principle of the pinhole effect** was known (most probably) since prehistoric times
 - A confined dark structure with a small opening (hole) creates an inverted image of the world
 - The whole dark structure with the small hole is called a **camera obscura**
 - from the Latin **camara obscura** for the **dark room**
 - The word **camera** originates in the ancient Greek **καμάρα**
 - a structure with and arched cover or a vaulted construction
 - became **camara** or **camera** in Latin, a vault or arched chamber usually for a council or legislative chamber



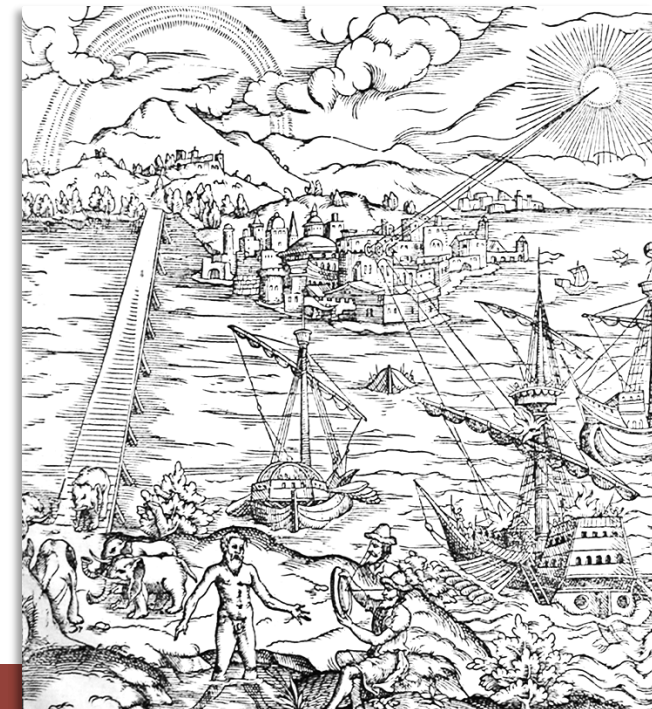
Milestones in photography



- **Palaeolithic** period (c.3.3 million to c.11.5 thousand years ago), Europe
 - projections on surfaces inside tents or caves through small holes or openings
 - this may be why cave paintings are distorted in a particular way
- **Neolithic** period (c. 12 thousand to 6.5 thousand years ago), Whales, Scotland
 - the distinctive architecture of Neolithic passage tombs served as a format of a camera obscura
- **4th ce. BCE**, China
 - the **Mozi**, or Mojing, or the Mohist Canon (Chinese text that describes the philosophy of Mohism)
 - might be the earliest written record of camera obscura
- **~6th-4th ce. BCE**, Greece
 - **Eleusinian Mysteries** in ancient Greece
 - exploited pinhole technology to immerse participants into a deep spiritual experience, by using the Telesterion (Initiation Hall) as a camera obscura to project large images of the goddess Demeter to the participants in a very dark room

Milestones in photography

- ~1020, Abu Alı al-Hasan ibn al-Hasan ibn al-Haytham, **Alhazen**
 - Published **Kitab al Manazir**
 - one of the most influential treatises in the science of the optics
- ~1200, Erasmus Ciołek Vitello, **Witelo**
 - Published **Vitellonis Thuringopoloni opticae libri decem** (Ten Books of Optics)
 - Alhazen's theories came to Europe, into Latin, and further extended
- ~1200, **Albertus Magnus**
 - is credited the discovery of the element **arsenic (As)**
 - is considered to have experimented with **photosensitive chemicals**,
 - including the salt silver nitrate AgNO_3 (precursor to other silver compounds useful in photography)



Milestones in photography

- 1566, Georg **Fabricius**
 - discovered the silver chloride (AgCl)
- 1568, Daniele Matteo Alvise **Barbaro**
 - is attributed the description of the integration of a lens with a diaphragm (aperture) in the camera obscura
- 1652-1715, Wilhelm (or Guillaume) **Homberg**
 - significant contribution to chemistry (founding figure of the modern chemistry)
 - experimented with silver salts (like silver nitrate) and their sensitivity to light
 - demonstrated the photochemical interaction
- 1664, Robert **Boyle**
 - one of the founders of modern chemistry and experimental scientific method
 - Published **Experiments and Considerations Touching Colours**
 - corpuscular nature of light
 - hypothesised that colours are some sort of modifications of light
 - documented various experiments with light and materials, chemical experiments with colour,
 - foundation work for photography



Milestones in photography

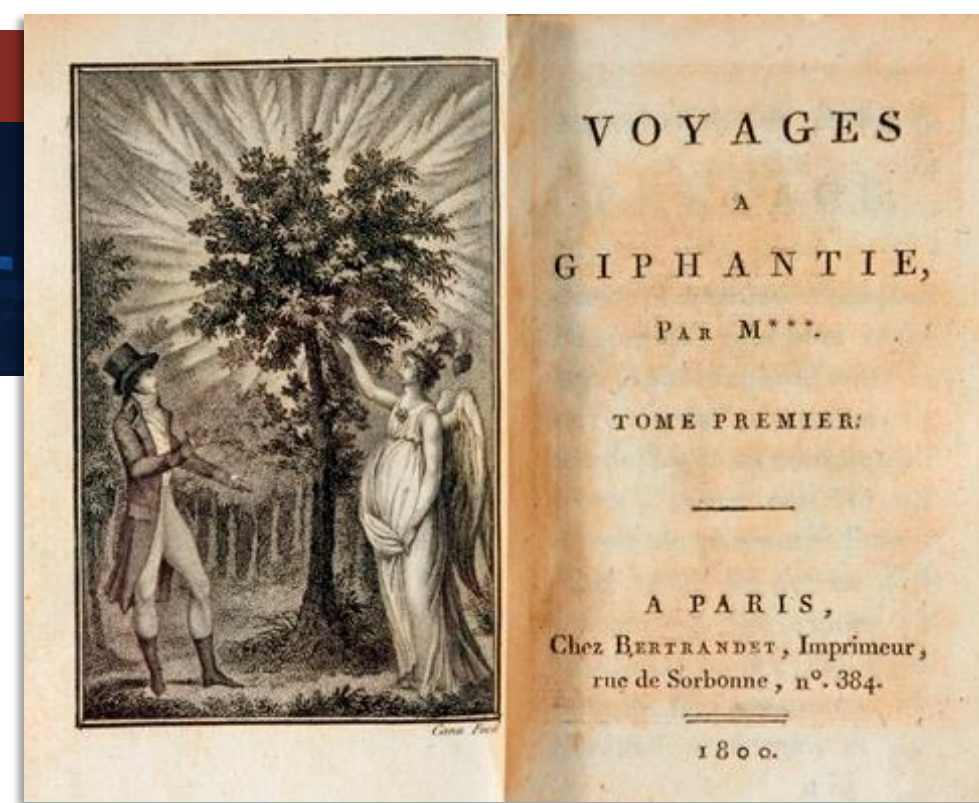


- 1614, Angelo **Sala** (1576-1637)
 - Published **Septem planetarum terrestrium spagirica recension** (The seven terrestrial planets)
 - Reported that powdered silver nitrate turns black in sunlight (→lapis lunaris)
 - Established the effect on paper, as he noticed that paper that wrapped silver nitrate for a year eventually turned black
- ~1717, Johann Heinrich **Schulze**
 - was the first to differentiate between **light** and **heat** in photo-chemical processes
 - like the darkening of various substances mixed with silver nitrate when exposed to sunlight
 - series of experiments that conclusively resulted in that the **darkening was caused by light and not by heat**
 - bibliography suggests should be attributed the discovery of photography
 - interesting demonstration covering silver salts mixtures with stencils of words and exposing to sunlight
 - the result was to produce copies of the text in dark characters
 - this was a **NOT permanent** photographic image imprint, but certainly a foundation work



Milestones in photography

- 1760, Charles-Francois **Tiphaigne** de La Roche
 - wrote the predictive novel “**Giphantie**”
 - contains hints to the possibility of producing **persisting photographic images**
 - probably used Schulze’s discoveries
 - provoked a great deal of discussion
- 1777, Carl Wilhelm **Scheele**
 - published his dissertation **Aeris atque ignis examen chemicum** (Chemical Observations and Experiments on Air and Fire)
 - based on Schulze's investigations, practically laid the foundation of photochemistry
 - verified the reaction of silver chloride in light
 - discovered the role of ammonia as a fixative for silver chloride images



Milestones in photography



- 1774, Joseph **Priestley**
 - is credited with the independent discovery of **oxygen**
 - his experiments demonstrated that **nitric acid turned red quickly in sunlight**,
 - kept its colour unchanged after several days in the dark, even though subjected to heat
 - postulated that light acted similarly to **phlogiston**
- 1783, Jean **Senebier**
 - was able to provide extensive evidence explaining the process of **photosynthesis**
 - published **Recherches sur l'influence de la lumiere solaire pour metamorphoser l'air fixe en air pur par la vegetation** (Research on the influence of solar light on the metamorphosis of fixed air into pure air by plants)
 - provided important data about the colour change of the different woods and many resins under sunlight
 - repeated Scheele's experiments, and provided data on the time needed for chloride of silver to darken under various spectrum ranges
 - under violet light it only required 15 seconds
 - under red light it requires 20 minutes
 - silver chloride assumes various colours
 - credited that with his work, the chemical action of light in the 18th century reached its climax

Milestones in photography



- 1802, Thomas **Wedgwood**
 - together with Humphry Davy published **An Account of a Method of Copying Paintings upon Glass, and of making Profiles by the Agency of Light upon Nitrate of Silver**
 - described the process for copying paintings
 - highlighted the issues and challenges
 - worked on creating “permanent” pictures
 - using materials coated with light-sensitive chemicals
 - was able to create non-permanent imprints (permanent in darkness)
 - “*shadow image photograms*”
 - ideas and partial success led historians to call him **the first photographer**

Milestones in photography



- 1810, Thomas Johann **Seebeck**
 - experimented with the interaction of light with silver chloride, and observed how the chemical would be coloured by the colour of light; also experimented with the ultraviolet light interactions; reported that
 - the violet rays rendered silver chloride brown
 - the blue rays resulted a shade of blue
 - the yellow rays a white
 - the red rays a red colour
 - contributed to Goethe's Theory of Colours, published in 1810

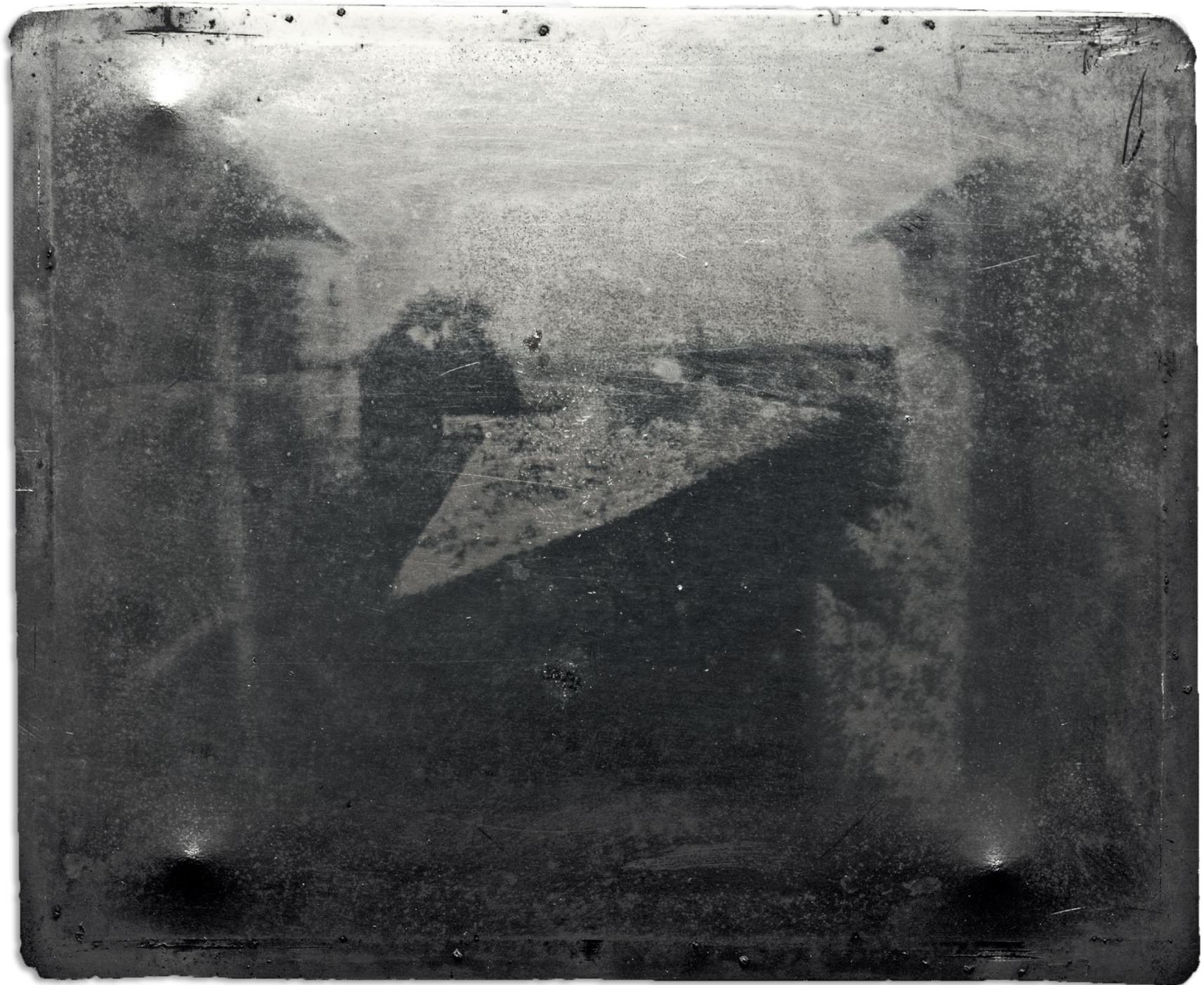
Milestones in photography



- 1822, Joseph Nicéphore **Niépce**
 - great inventor with many contributions in technology
 - 1807, the Niepce brothers invented and patented the **Pyréolophore**
 - the world's **first internal combustion engine** that was actually built and applied to a river boat
 - ten years later, they were the first to develop a **fuel injection system** and made an engine work with it
 - 1814, begun work on fixing photographs
 - 10 years of work and succeeded **the first permanent imprint of a photograph** using a material that hardened when exposed to light
 - the first photograph needed an **exposure to light for several hours**
 - named his discovery **heliography** (sun-drawing)
 - 1827, he was rejected to submit a paper to the Royal Society of London, as he kept his process a secret

- **1827, View from the Window at Le Gras**

- the earliest surviving photograph captured with a camera obscura
- Untitled “point de vue”, Heliograph on pewter
- 16.7 x 20.3 x .15 cm
- Process
 - dissolved light-sensitive bitumen in oil of lavender
 - applied a thin coating of it over a polished pewter plate
 - inserted the plate into a camera obscura
 - positioned it near a window
 - exposed to sunlight for several days



Milestones in photography



- Niépce invented a **contact method** to make copies of engraving
 - based on using simple sheets of paper printed with ink in a printing press, in which the plates were created photographically by the asphalt process
 - in essence, an early version of **photocopying**



The earliest surviving photocopy artifact by Niépce

Milestones in photography



- ~1839, Louis Jacques Mandé Daguerre
 - one of the fathers of photography, with the invention of his own permanent photographic process
 - painter and the developer of the **diorama theatre**
 - ~1820, conceived the idea of improving the **panorama**,
 - a variation in his invention of the diorama, considered precursor of modern cinema
 - 1829, his endeavour and contribution to photography was sealed by a contract with Nicéphore Niépce
 - 1831, suggests the use of **iodised silver plates** in the camera
 - 1839, publication of **La Daguerreotype, origine et histoire de cette decouverte** (The Daguerreotype, origin and history of this discovery)

Milestones in photography

Ten minutes exposure
Earliest protography of a person



1837, L'Atelier de l'artiste



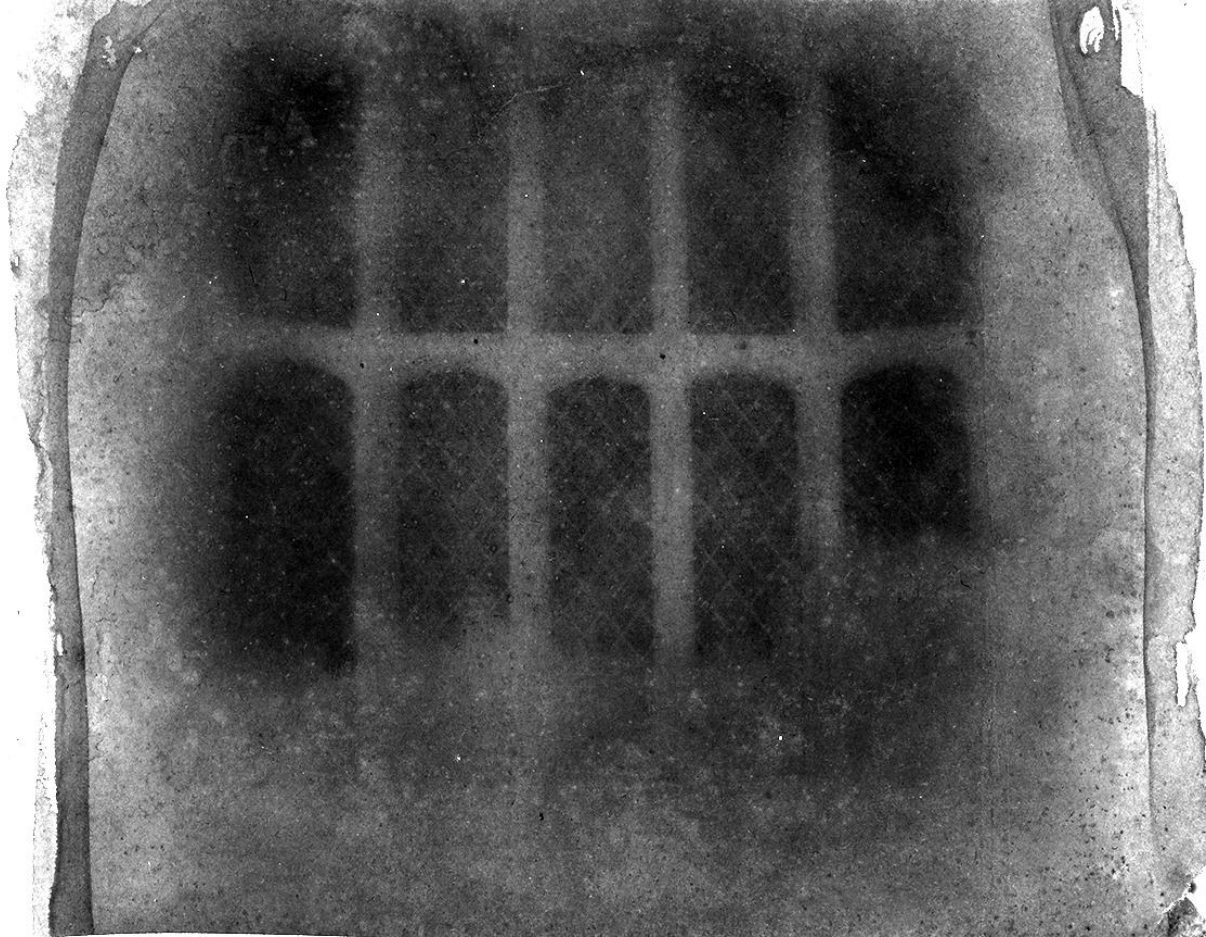
1838, Boulevard du Temple

Milestones in photography

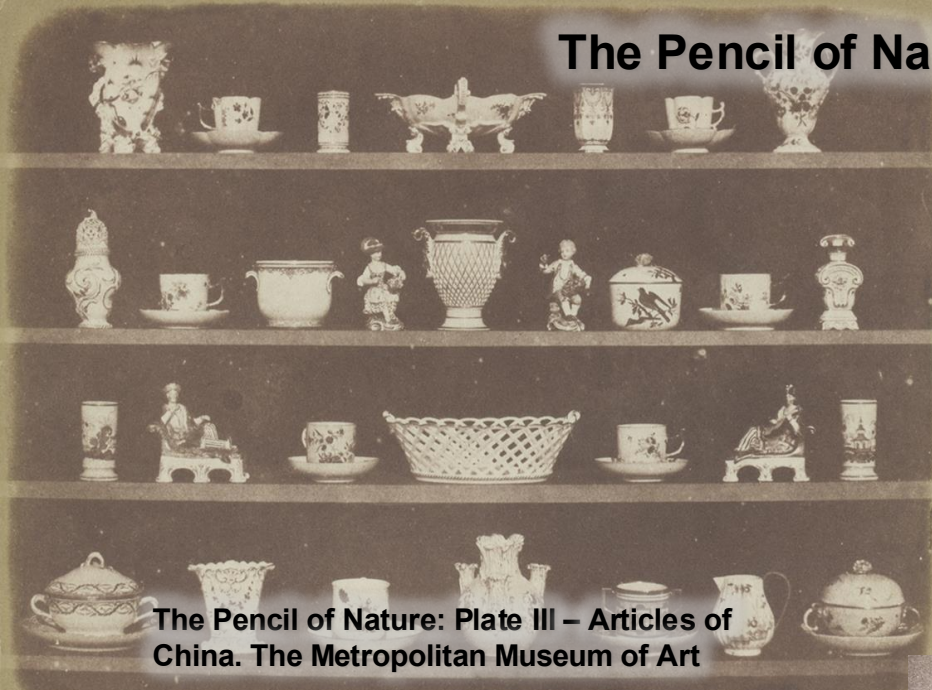


- ~1820s, William Henry Fox Talbot
 - invented the precursors (a) to contemporary photographic processes, and (b) to photogravure
 - is credited for the invention of a complete photographic process able to **work fast** and result **permanent imprints of negatives** of natural images and contact copies
 - as an artist contributed significantly to the **development of photography as an art form**
 - initial approach was called **photogenic drawing**
 - 1839, published his method and in 1841 he patented the **Calotype**

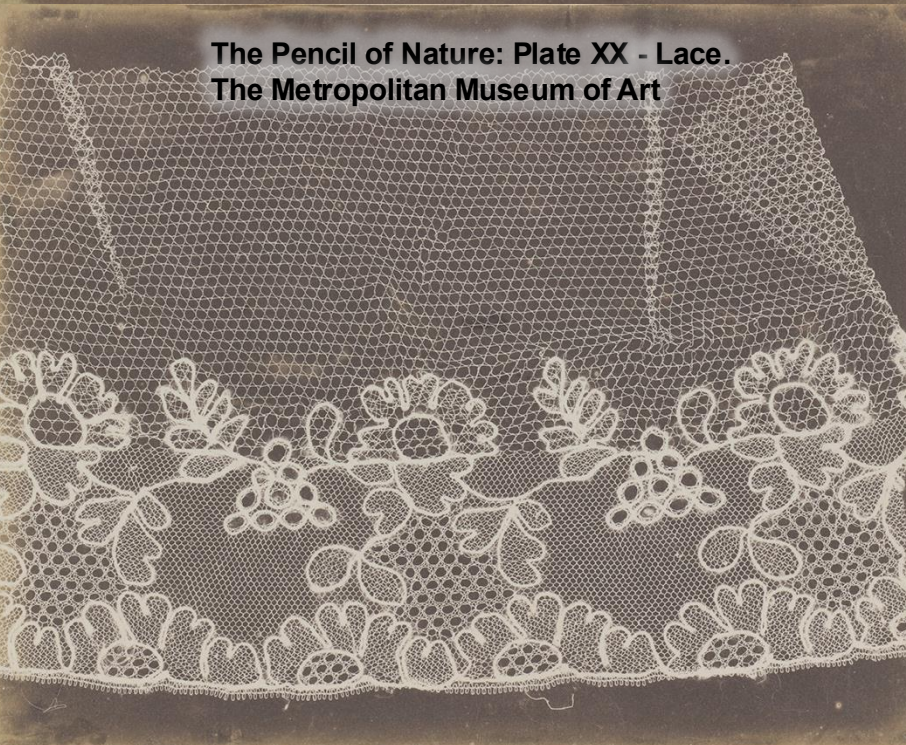
Milestones in photography



The Pencil of Nature (1844) and Sun Pictures in Scotland (1845)



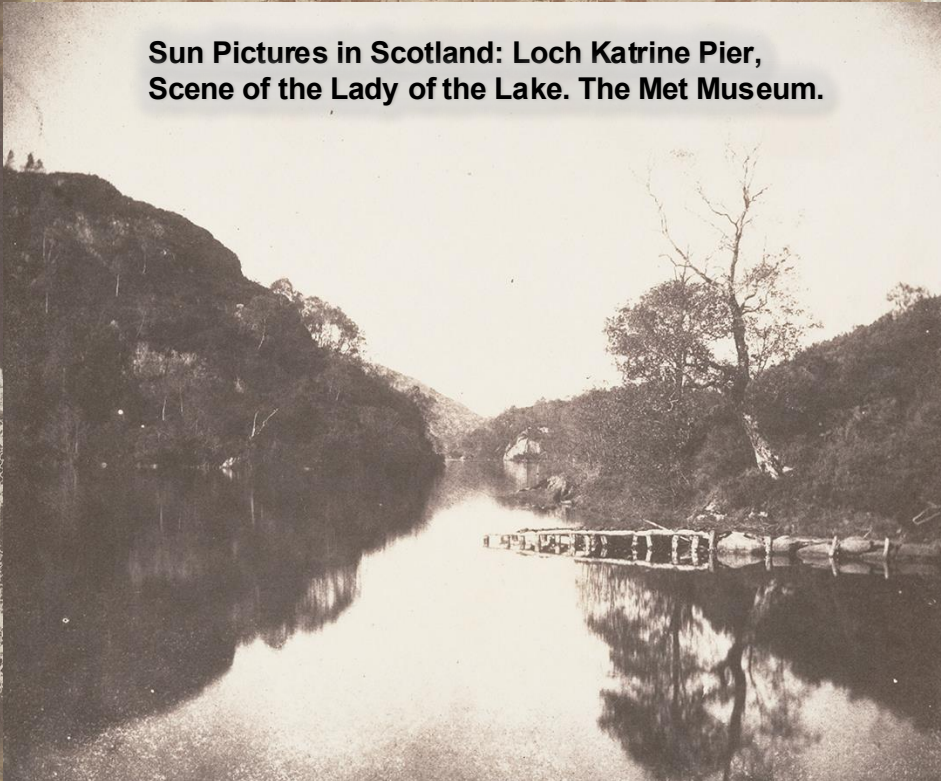
The Pencil of Nature: Plate III – Articles of China. The Metropolitan Museum of Art



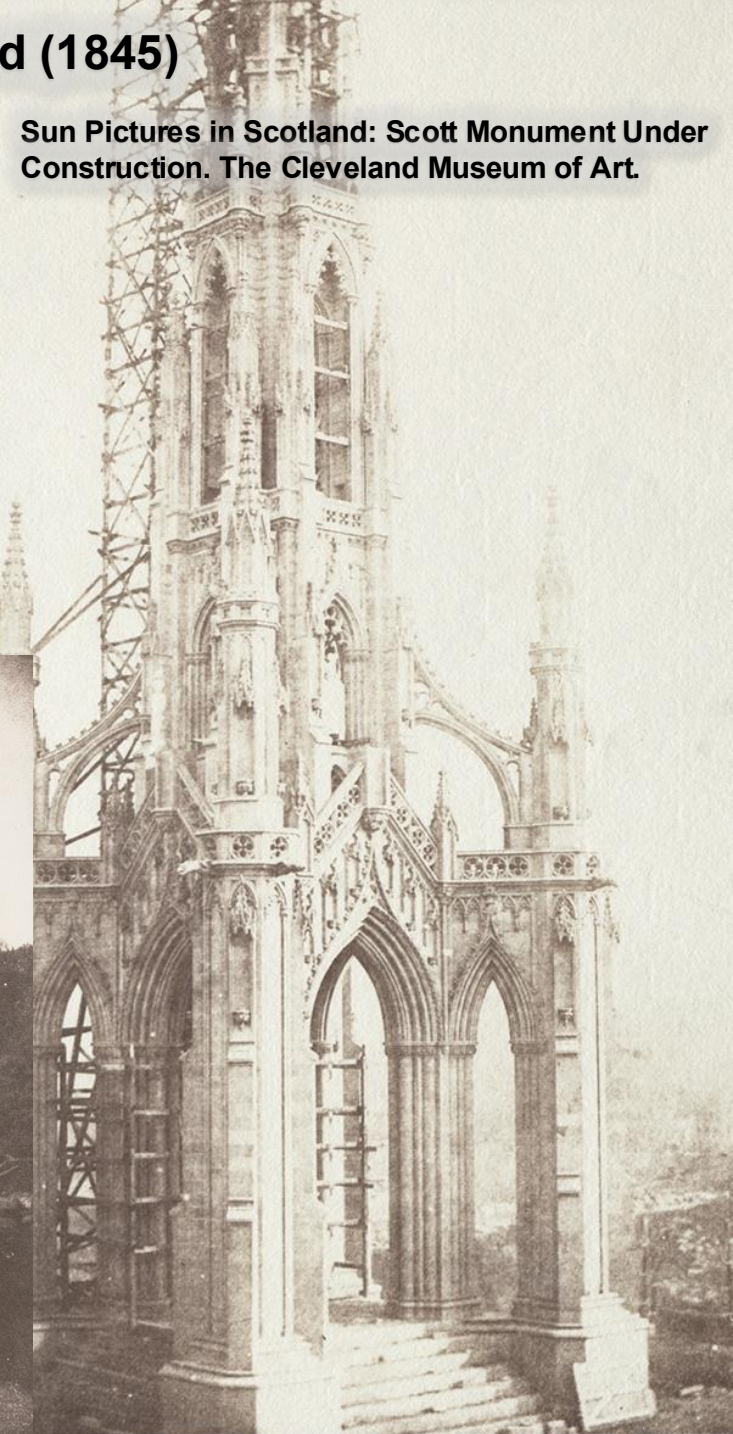
The Pencil of Nature: Plate XX - Lace. The Metropolitan Museum of Art



The Pencil of Nature: Plate XIII - Queen's College, Oxford, Entrance Gateway. The Metropolitan Museum of Art



Sun Pictures in Scotland: Loch Katrine Pier, Scene of the Lady of the Lake. The Met Museum.



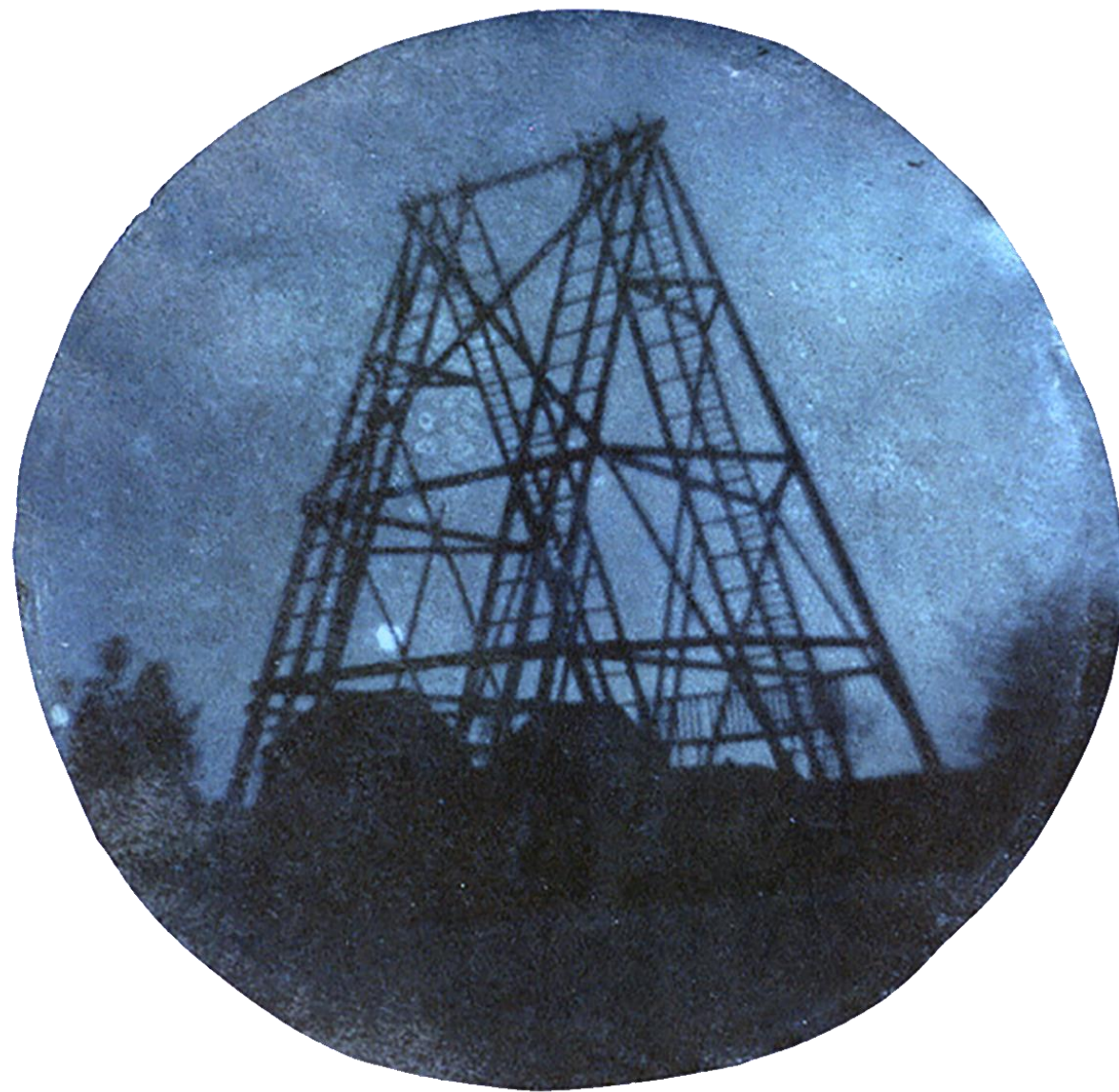
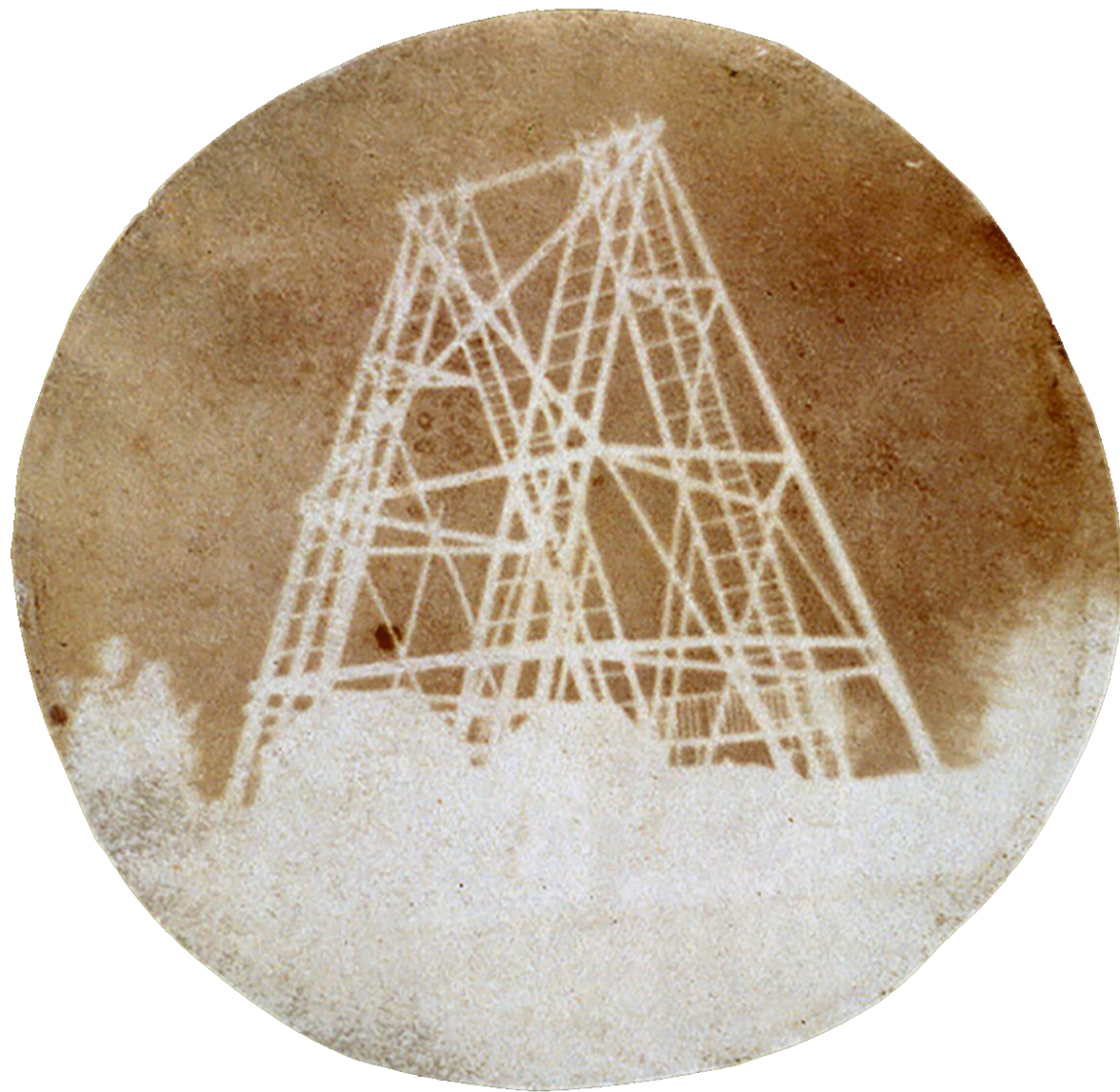
Sun Pictures in Scotland: Scott Monument Under Construction. The Cleveland Museum of Art.

Milestones in photography

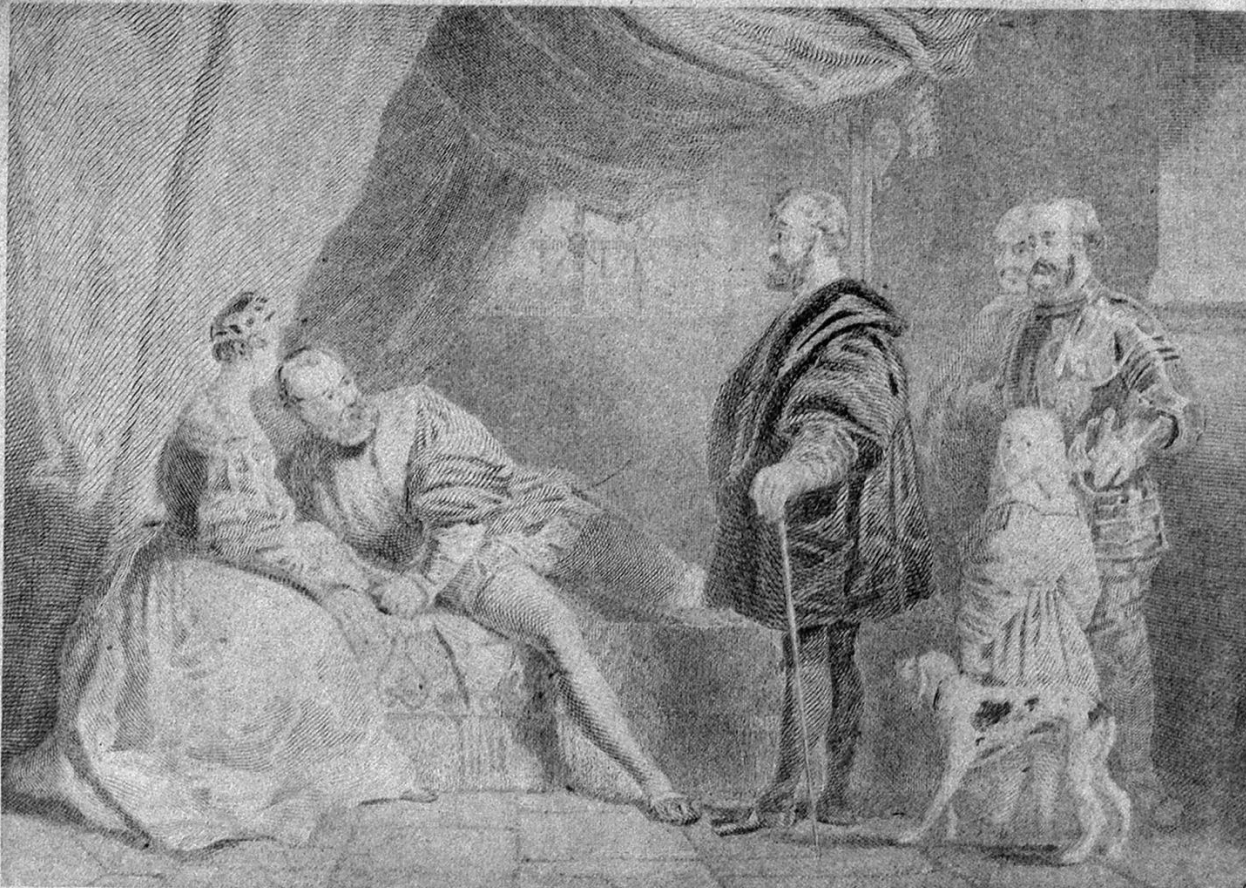


- 1839, Sir **John** Frederick William **Herschel** (son of Sir Frederick William Herschel)
 - primarily concerned with the investigation of the **physical laws in photography**, not the artistic expression
 - studied the **photographic properties of chemicals** like mercury, ferro-tartrate of silver, and colouring substances of flowers
 - was able to invent new and interesting photographic processes, including **cyanotype, chrysotype, amphitype, phytotype, and anthotype**
 - 1819, discovered sodium thiosulfate, or hyposulphite of soda, or simply **hypo** ($\text{Na}_2\text{S}_2\text{O}_3 \cdot x\text{H}_2\text{O}$) to be a solvent of silver halide (AgX) and **fixative for silver chloride-based photographic processes**
 - published it in **On the hyposulphurous acid and its compounds**
 - only in 1839 Daguerre finally adopted its use
 - 1839, photograph on glass, the earliest surviving such photograph

1839, First glass-plate photograph of William Hersel's telescope



Herschel's 1840s experimental chrysotypes

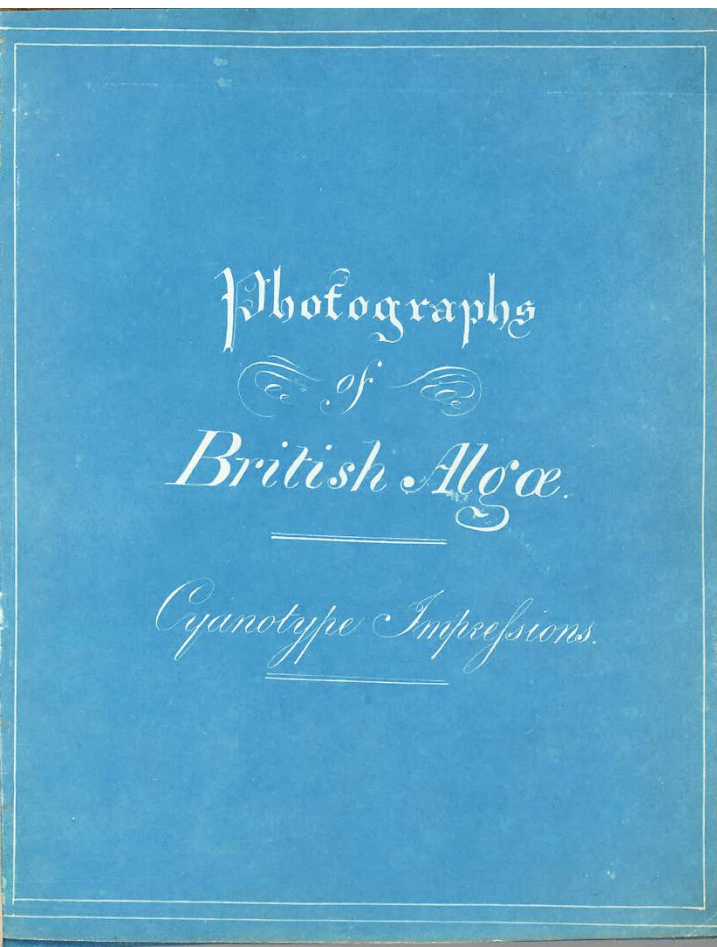


c.1841, Direct positive contact-copy phytotype
of the engraving Grecian lady looking at the
moon by Herschel.



Anna Atkins (1799-1871)

- botanist and photographer
- the first woman photographer
- used cyanotype to create the earliest book illustrated with photographic images, the **Photographs of British Algae: Cyanotype Impressions**, 1843



1849, Anna Atkins' cyanotype of *Dictyota dichotoma*



Milestones in photography



- It is evident from Herschel's 1837 **Note on the art of photography, or the application of the chemical rays of light to the purposes of pictorial representation**, published in the Proceedings of the Royal Society London, that
 - he is the first to have formally used the term **photography** in a publication
 - *** Hércules Florence supposedly independently invented photography in Brazil and coined the term **photographie** (French) in 1834, but he never published formally for this invention and terminology
- Herschel was also the first to produce **photographs on glass plates** and to apply the terms **negative** and **positive**

Milestones in photography



- **Herschel**

- completely **solved the question of perfect fixation** with sodium thio-sulphate (hypo)
- his cyanotype become the first process for photocopying, the blueprinting

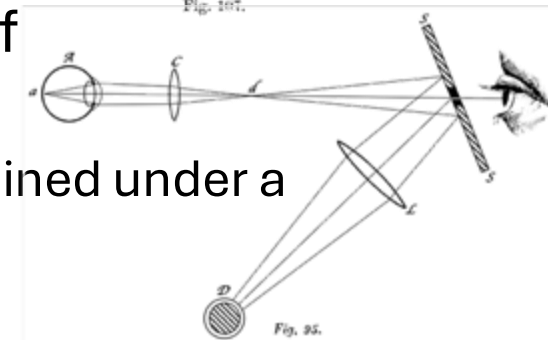
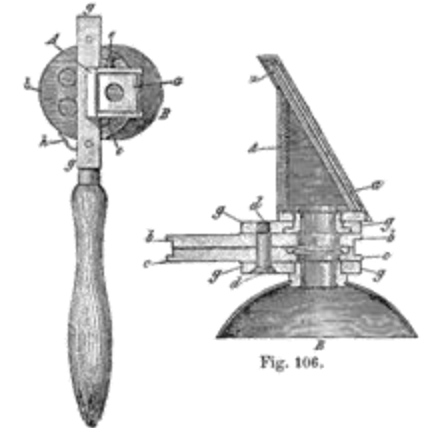
- **Talbot**

- laid the foundation for our **photographic printing** methods with bromide and chloride of silver
- pursued **commercial success in photocopying**

Milestones in photography



- 1851, Hermann Ludwig Ferdinand von **Helmholtz**
 - invention of the ophthalmoscope
 - particularly intrigued by the physics of perception and focused on optics and acoustics
 - known for his theories of vision and visual perception
- 1860s, **Handbuch der physiologischen Optik** (Handbook of Physiological Optics)
 - old and new experimental observations have been unified and explained under a single theory
 - the **Young-Helmholtz theory** of colour vision,
 - some argue that it should be the **Young-Helmholtz-Maxwell theory** of colour vision



Milestones in photography



- ~1851, Frederick Scott **Archer**
 - was familiar with the calotype
 - but not so satisfied by the low resolution and contrast attained, during rather long exposures
 - motivated by those imperfections of the previous processes and pursued a different approach
 - ~1848 he started experimenting with **collodion** (from the Greek κολλώδης [kollodis], gluey)
 - a flammable, syrupy solution of nitrocellulose ($C_6H_7O_2(ONO_2)_3$ (Tri_n itrat)) in ether ($(C_2H_5)_2O$) and alcohol (C_2H_5OH).
 - 1851, published **On the use of collodion in photography**
 - presenting the newly discovered **wet collodion process**
 - 1852, detailed it in **A Manual of the Collodion Photographic Process**
 - 1854, refined it in **The Collodion Process on Glass**

Castle, c.1851, by Frederick Scott Archer



The Grand Entrance, Kenilworth, c.1851, by Frederick Scott Archer, left; Castle, Kenilworth, 1851, by Frederick Scott Archer, right





The c.1860 Portrait of man; sitting with left hand stuck inside coat by Mats Landin, left, and



The c.1860 Veteran and his wife by an Anonymous creator, right

Milestones in photography



- ~1850s, Jean-Baptiste Gustave **Le Gray**
 - considered to be the most influential French photographer of the 19th ce.
 - credited to have **theoretically proposed the wet collodion process**
 - was outrun by Archer in practically applying it
 - was the first to employ, in June 1850, a solution of collodion cotton in ether, which when poured on glass furnished a transparent film that served as a carrier for the photographic image
 - described obscurely in his 1850 **Traité pratique de photographie sur papier et sur verre**
 - experts deduce this theory could not be applicable
 - more contributions included
 - improvements on **paper negatives**
 - his **waxing method** before exposure preserved the paper and enabled finer details
 - a method to achieve **combination printing** (blending)

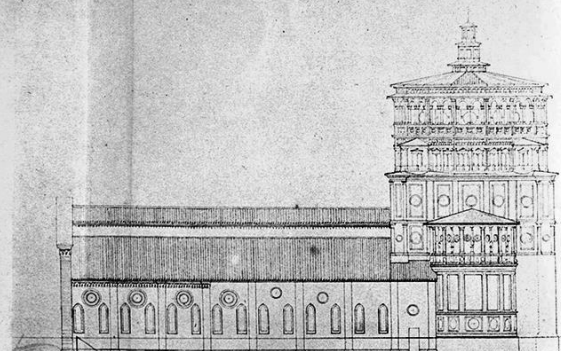
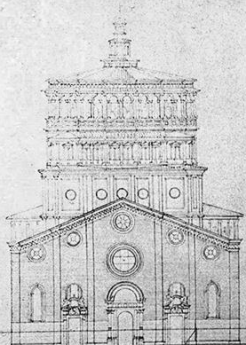


Le Gray's 1856 La Reine Hortense - Yacht de l'empereur, Havre, Albumen silver print from glass negative

Milestones in photography

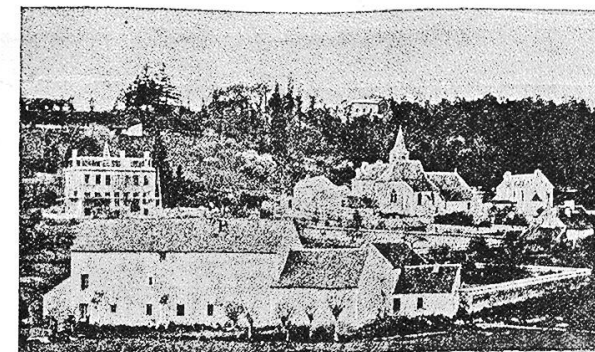


- ~1850s, Aimé **Laussedat**
 - considered the **father of photogrammetry**, the metrology of three-dimensional spaces based on photographs
 - originally, worked with the **camera lucida** in topographic studies
 - among the first to adopt photography directly into survey and cartography
 - he even constructed his own photographic equipment
 - named his process **iconometry** and **metrophotography** and applied it in the reconstruction of architecture and mapping
 - was able to produce **a map of Paris by 1861**
 - demonstrated the technique to a commission of the French War Ministry at the village of Buc, near Versailles
 - **within four hours**, he was able to select the proper camera locations and expose eight photographic plates
 - **within four days** he completed and presented the plan of Buc with success

*Élévation latérale libre.*Echelle approximative $\frac{1}{200}$ *Élévation de la façade.*Echelle approximative $\frac{1}{200}$ *Plan.*Echelle approximative $\frac{1}{400}$

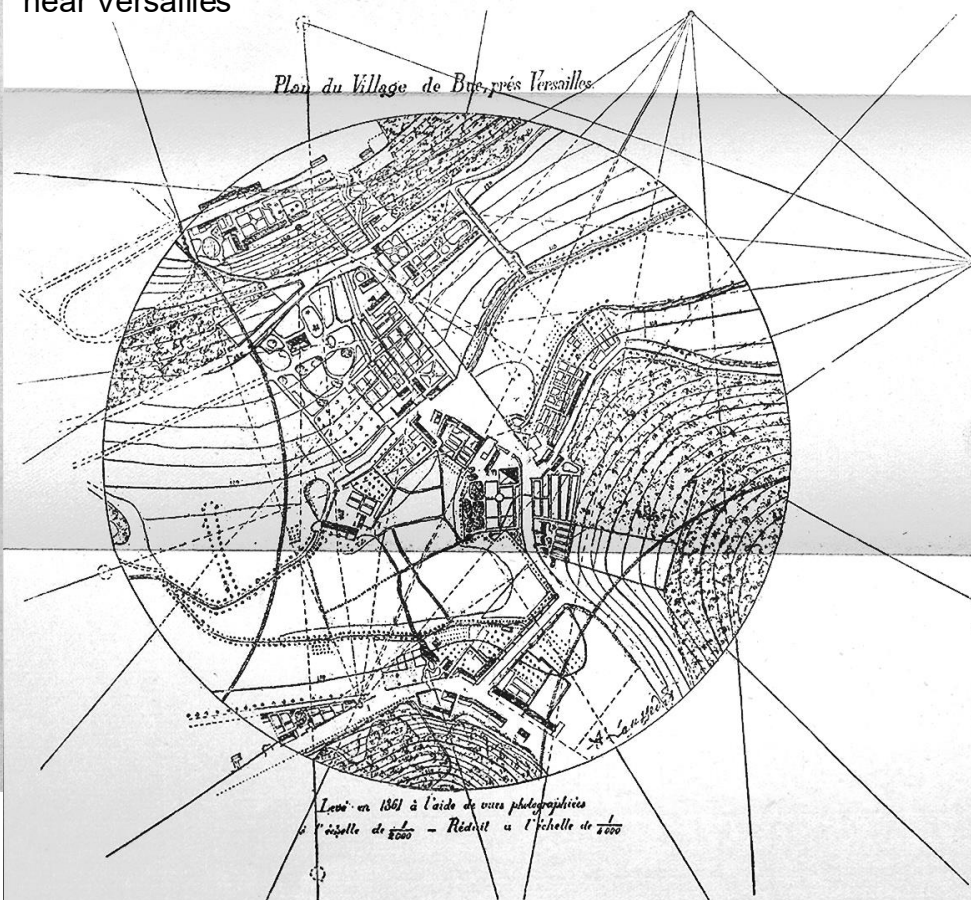
*Restitution
du plan, de la façade et de
l'élévation latérale libre
de
Santa Maria delle Grazie
à Milan.*

ÉCHELLE 1/3 DE L'ORIGINAL



Vue prise de la station n° 1 du plan ci-dessous.

1861, Laussedat's photogrammetric plan of the Village of Buc,
near Versailles

*Plan du Village de Buc, près Versailles.*

*Levé en 1861 à l'aide de onze photographies
à l'échelle de $\frac{1}{4000}$ - Réduit à l'échelle de $\frac{1}{1000}$*

Plan d'un village levé en 1861 à l'aide de la Photographie.

1899, Laussedat's photogrammetric rectification of Santa Maria delle Grazie in Milan

Milestones in photography



- 1871, Richard Leach **Maddox**
 - made a considerable contribution to photography by inventing the **gelatine negative plates**
 - due to his training as a physician was particularly interested in using photography to capture images of the micro-world
 - was an established and respected **photomicrographer** using the microscope
 - had been using Archer's collodion process
 - but noticed that **his health deteriorated due to the ether vapour** in the process, and quickly began searching for an alternative
 - 1871, published his findings with gelatine in **An Experiment with Gelatino-Bromide**

Pango Pango (sic) Harbour, 'Sauimatani' & Bloomfield, 1884, by Burton Brothers,
Museum of New Zealand, gelatin silver dry plate process



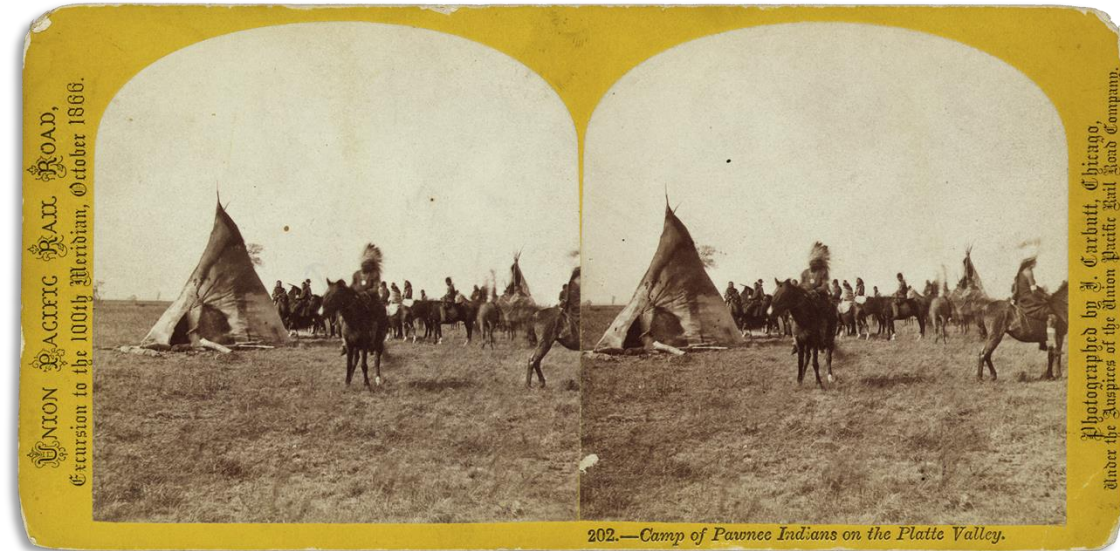
Milestones in photography



- 1856, Alexander **Parkes**
 - credited for creating the first man-made **plastic**, the “parkesine”
 - the world’s first fully synthetic plastic, in particular, thermoplastic, a celluloid based on nitrocellulose
 - filed 80 patents related to metallurgy, electroplating and plastics
 - Celluloid represents a family of materials crucial for the development of the photographic film
- 1862, parkesine was showcased in a variety of shapes and colours
- 1869, due to failures in the production of parkesine it was renamed as **xylonite**
- 1869, John Wesley Hyatt patented it at the US Patent Office as **celluloid**
 - It is considered by many that celluloid was actually invented by Parkes
 - Hyatt should be credited for refining and simplifying its production and transforming it to a marketable product

Milestones in photography

- ~1879, John **Carbutt**
 - the first to use celluloid for photographic film
 - the first to market dry-plate glass negatives
 - 1879, founded the Keystone Dry Plate Works in Philadelphia
 - 1888, resulting, after years of perfection, into celluloid film
 - was particularly interested in stereo-photography
 - produced a number of stereographs and stereographic cards



Milestones in photography



- 1880s, George **Eastman**
 - co-founder of the Eastman Kodak Company
 - a significant figure in photography with multiple contributions and patents
 - helped in the development and marketing of the **roll film**
 - 1884, first **practicable roll film** patent
 - 1885, patent for a **roll film holder**
 - 1888, patent, in which Eastman presented the **Kodak camera**
 - the first camera to utilise the roll film
 - 1889, Eastman marketed film stock
 - transforming Kodak to the leading supplier of film stock internationally by 1896
- The **Kodak camera** eventually became the first of the **box cameras**
 - a simple and portable type of cameras widely adopted by the public
 - apart from the benefit of using the roll film, did not necessitate the use of a tripod
 - Kodak marketed the whole package
 - a roll film pre-loaded camera and the processing and printing service
 - **“You press the button – we do the rest”**



1889, Kodak camera photographs

Left: Two boys on horses at corner of 14th St. and I St. N.W., Washington, D.C. view looking east on I St.

Right: Market scene, Washington, D.C., snow view (right)
by Uriah Hunt Painter, the Library of Congress

Milestones in photography

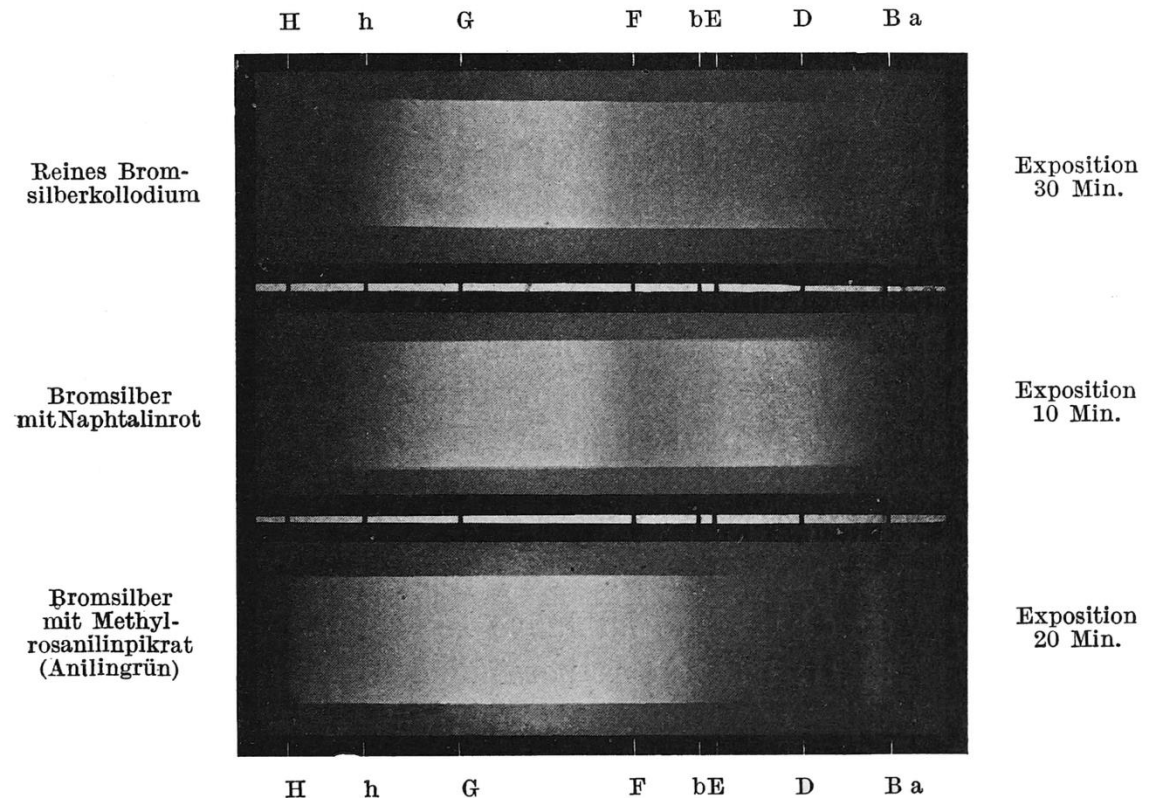
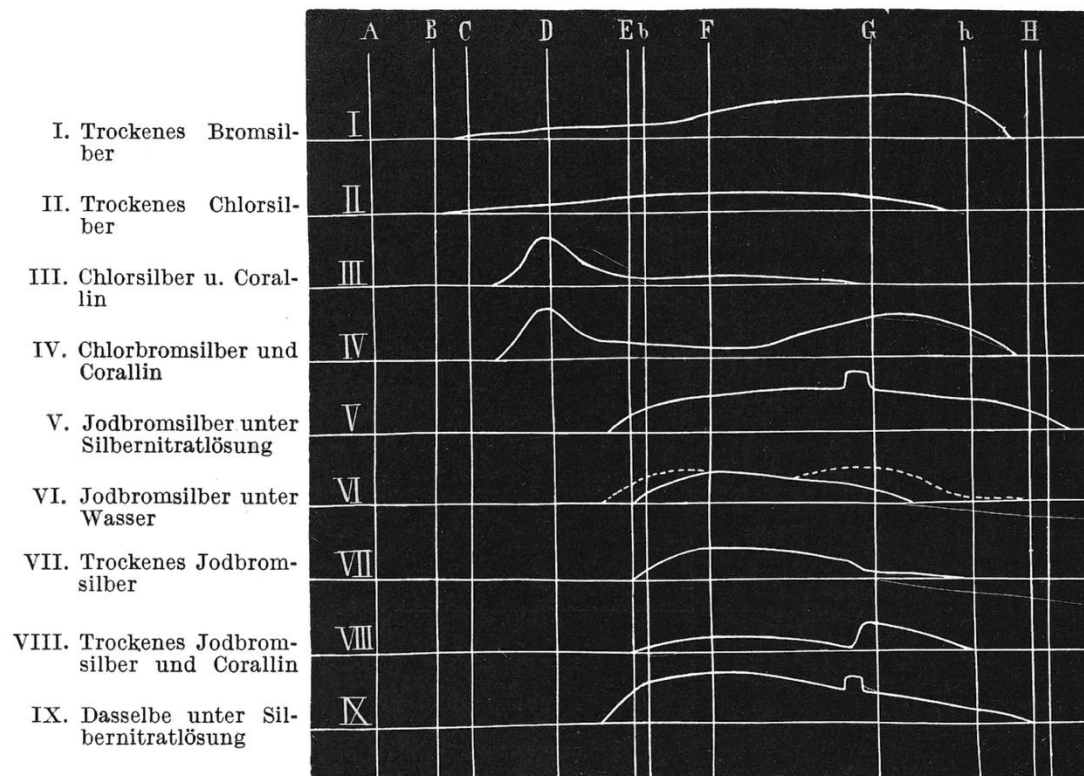


- 1873, Hermann Wilhelm Vogel
 - discovered **dye sensitisation** (colour-sensitising of photographic films)
 - published in numerous separate publications, particularly in the **Photographische Mitteilungen** (Photographic Communications)
 - 1870s, his **Handbuch der Photographie** (Handbook of Photography) appeared in four Parts and various editions
 - 1871, Handbook of the Practice and Art of Photography
 - 1875, The Chemistry of Light and Photography
 - in trying to solve the halation in collodion plates with particular chemicals he observed an increased sensitivity in specific parts of the spectrum
 - Corallin (yellowish-red dye) → sensitivity to yellow and green
 - Green aniline → sensitivity to red

Milestones in photography



- Verification of Vogel's color sensitization



Milestones in photography



- 1855, James Clerk Maxwell
 - Maxwell's work was crucial for the formation of what is accepted today as the Young-Helmholtz-Maxwell **three-primary colour theory** (trichromacy)
 - This theory suggests that **any three independent colours** may serve as the basis for the representation of any other perceivable colour
 - 1855, following this line of reasoning, he proposed that **three photographs with filters** may be combined or superimposed to project a full colour image
 - proposed the use of a red, a green and a violet glass filters
 - 1861, demonstrated the idea at the Royal Institution of Great Britain

Milestones in photography



- Maxwell collaborated with the established photographer **Thomas Sutton** to acquire these photos
 - Sutton photographed a tartan ribbon three times
 - through red, green, and blue filters
 - also making a fourth photograph through a yellow filter, not used in the demonstration
 - The photos were printed on glass so that projection would be relevant using the same filters used in capturing the photographs
- Maxwell should be credited for the first attempt at tri-colour separation and not the first colour photograph



A digital reconstruction of the famous
tartan ribbon colour photograph

Milestones in photography

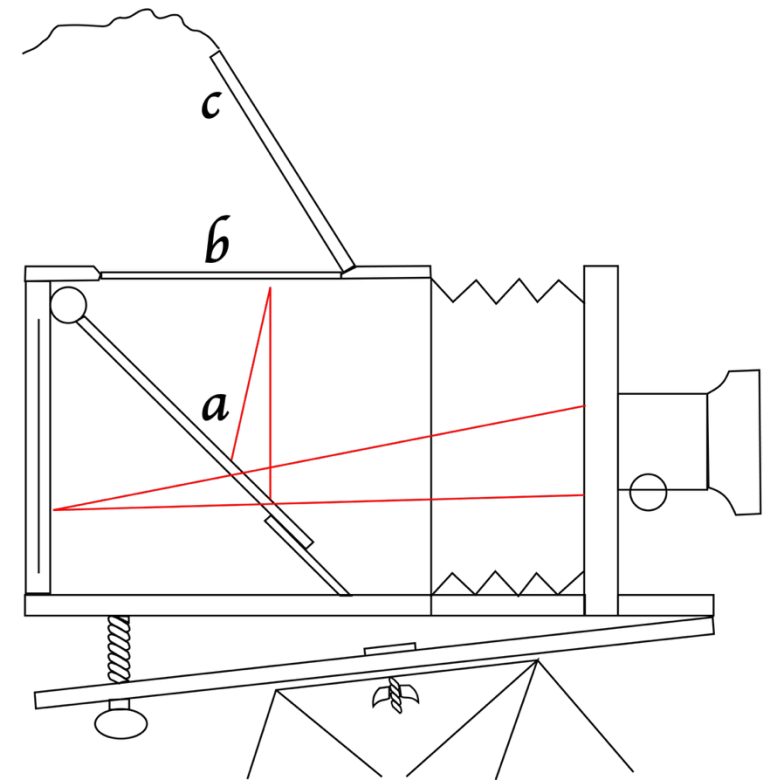


- 1859, Thomas **Sutton**
 - developed the earliest panoramic camera, using his patented wide-angle lens (initially of 120°)
 - the lens projected images onto a curved plate at the back of the camera



Milestones in photography

- 1861, Thomas Sutton
 - created and patented the first **Single Lens Reflex (SLR)** camera with glass plates
 - **Single lens**: for using just one and the same lens for focusing, composition and exposure
 - **Reflex** (from reflection): for using a mirror to reflect the incoming light to the viewfinder during composition



Milestones in photography



- ~1875, Louis Arthur Ducos **du Hauron**
 - credited progress on three-colour printing and the successfully application of Vogel's colour sensitisation into photographic practice
 - 1864, he patented an early type of cinematography
 - 1868, he proposed a patent on three-colour process based on three photographs
 - applied the three-colour principles using both **additive** and **subtractive** methods for photography and printing respectively
 - ~1875, adopted Vogel's invention of colour sensitisation and dyed his plates accordingly and significantly improved the results
 - his concept for colour photography, **heliochromy**, was based on the superimposition of three photographs, taken using blue, yellow, and red filters
 - invented a **three-colour camera**, in which **the three-colour separations could be made simultaneously by a single exposure**

Du Hauron's 1877 View of Agen three-colour photograph



Milestones in photography

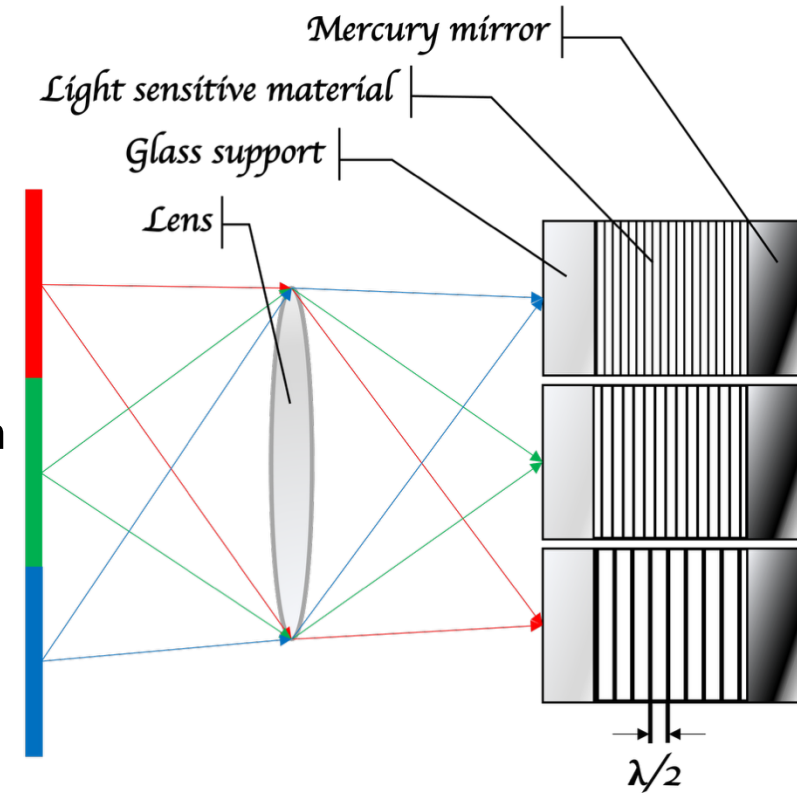


- 1869, Émile-Hortensius-Charles **Cros**
 - proposed various technological innovations, like the transmission technology for the telegraph, the reproduction of recorded sound, colour photography, even extraterrestrial communications
 - 1869 he published his concept of three-colour negative photography
 - use the typical negative photography through green, violet, and orange glass filters
 - subsequently would be transformed into red, yellow, and blue positives
 - The positive impressions, superimposed on gelatin using sufficiently transparent pigments, transferred onto a single support sheet, would recompose the original colours of the photographed scene
 - used the **subtractive color** approach
 - accepted a **red-yellow-blue colour basis** and expressed the classic mixing approach by using three greyscale photographs that correspond to the brightness of the three primary colours

Milestones in photography



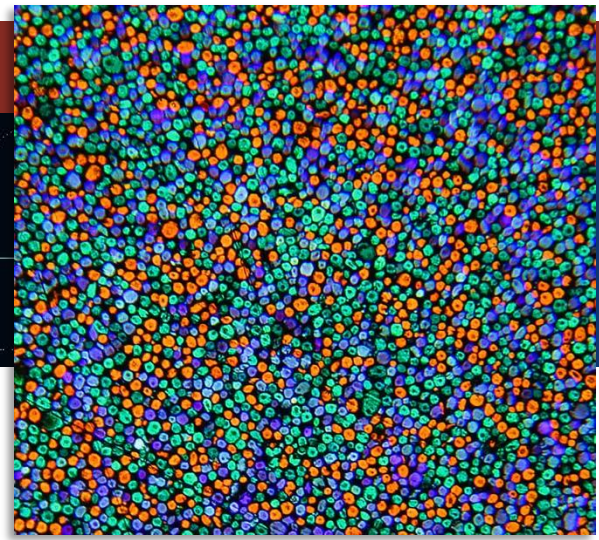
- 1891, Jonas Ferdinand Gabriel **Lippmann**
 - developed an entirely different method of permanent colour photography
 - he was awarded the 1908 Nobel in physics
 - *“For his method of reproducing colours photographically based on the phenomenon of interference”*
 - interference photography soon disappeared from photographic practice
 - still remains a culminating point of scientific solutions to the problem of permanent colour photography by direct exposure in the camera
 - 1891, presented his interference photography method to the Paris Academy of Sciences
 - more related to **holography**
 - **Significant limitations:** difficulty in creating the emulsion, the need for long exposures, the good reproduction only of spectral colours, the inability to create prints, and the particular conditions for viewing the photograph





A 1906 interferential photograph by Auguste Ponsot, Lippmann's student and colleague

Milestones in photography



- 1907, Auguste Marie Louis Nicolas and Louis Jean Lumière (**Lumière brothers**)
 - known for two major contributions in photography and cinematography, with their invention of the **autochrome** and the **cinématographe** motion picture system respectively
 - Sons to Antoine Lumière, who owned a firm that manufactured dry plates
 - 1895, patented their **cinématographe** and started producing and displaying films
 - 1903, patented their colour photographic process, **the Autochrome Lumière**
 - ~1905 gave up cinematography and film business, and **focused on colour photography**
 - 1907, successful marketing of **autochrome plates**
 - autochrome plates carry mixed red, green, and blue potato starch grains on a glass plate, on which a thin film of panchromatic gelatine emulsion is applied
 - an autochrome is **the very first single colour photograph**, the result of an additive colour process, a positive transparency on a glass support

Alfred Stieglitz, 1907, Kitty Stieglitz,
The J. Paul Getty Museum



Constantin Mitrofanovitch Flórinsky, 1907, Officer
of His Majesty Tzar Nicholas II (Jaeger
Regiment), The Metropolitan Museum of Art





Mervyn O'Gorman, 1913, Christina in red cloak, PICRYL.



Mervyn O'Gorman, 1913, Christina on the beach, PICRYL

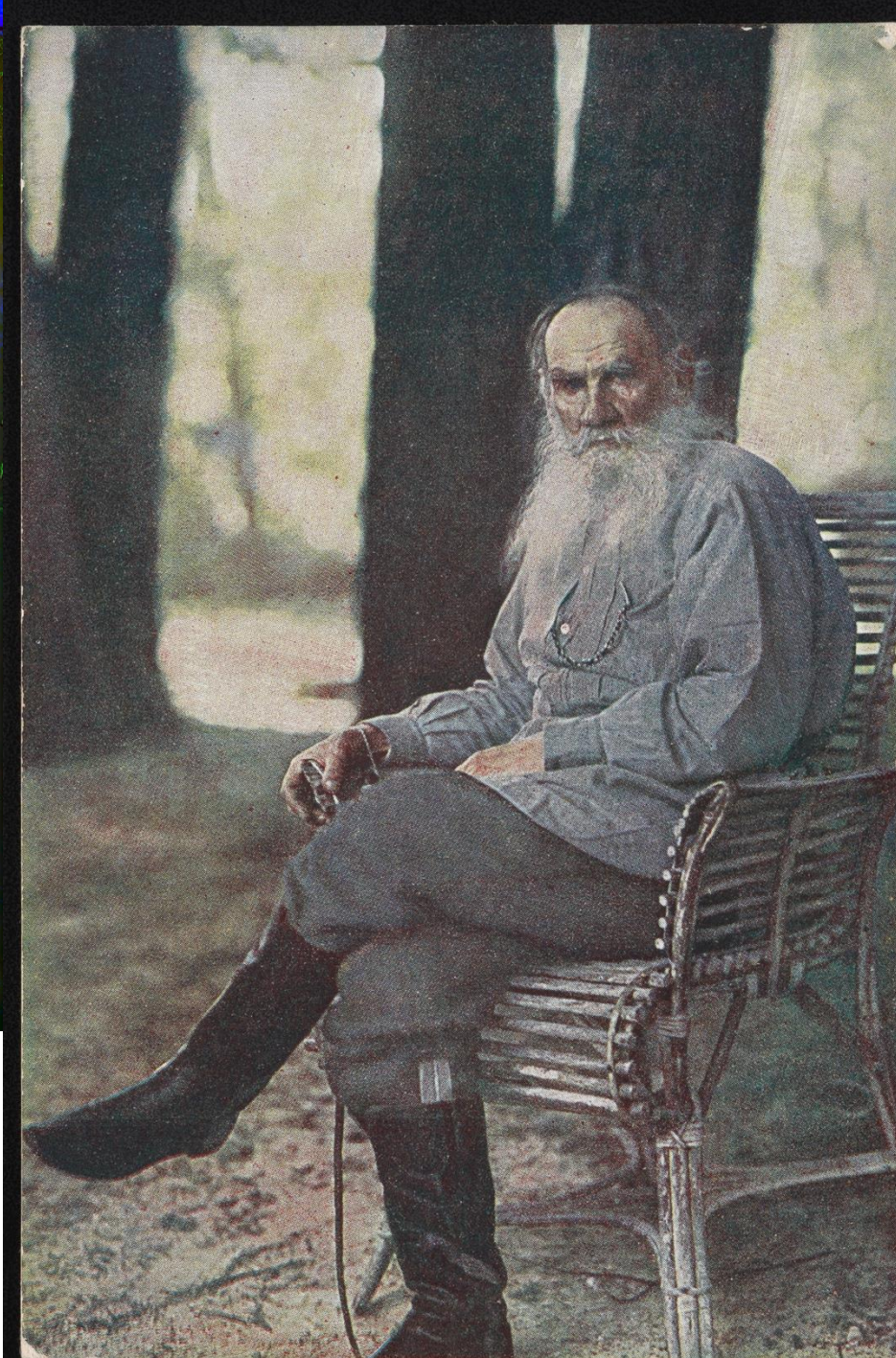
Milestones in photography



- 1905, Sergei Mikhailovich Prokudin-**Gorskii**, (Sergey Mikhaylovich Prokudin-Gorsky)
 - left an important legacy through his pioneering work in colour photography
 - have been influenced and inspired by his teacher, the world-known chemist Dmitri Ivanovich **Mendeleev** (the creator of the periodic table of elements)
 - 1905, presented his first result on the development of new colour sensitive photographic plates
 - three-colour photography, three exposures taken sequentially about one second apart
 - imprint three monochromatic greyscale negatives using filters to block selected parts of the spectrum
 - as the three photographs were not exposed concurrently, only non-moving subjects could be captured successfully
 - viewing involved the projection of the three monochromatic plates, registered so that they form a single image



Digital reconstruction of Gorskii's, 1911, V Borodinskom muzei e, Borodino (In the Borodino Museum, Borodino)



Sergei Gorskii, 1908, Leo N. Tolstoi in Iasnaia Poliana

Milestones in photography



- The years following the era of the frantic photographic developments of the 19th c., came the era of the optimisations and improvements, many of which are due to major players, like Kodak
 - ~1909, Kodak replaced the highly flammable nitrate base of films with a safer acetate base
 - 1912-1926, Kodak marketed the foldable **Vest Pocket camera** (127 film, 72 mm lens, f/6.8 - f/11)
 - known as the **Soldiers Camera**, due to small size
 - 1914, Kodak marketed the **Autographic film system**
 - allowed photographers to add written information on the film at the time of exposure



Milestones in photography



- Modern history of reflex cameras kickstarted with **Twin Lens Reflex (or TLR) cameras** as practical, portable, and easy to use
 - 1928, the German optical instruments manufacturer Rollei was the first to create and market a practical TLR camera, the medium format **Rolleiflex**



Milestones in photography

- 1934, introduced the **135 film cartridge**, popularizing the 35 mm film
- 1935, Kodak introduced the Kodachrome multi-layered colour reversal film
 - **first successfully marketed colour film that used a subtractive colour approach**
- 1936, Ihagee Kamerawerk Steenbergen GmbH, created and marketed the **Kine Exakta**
 - **first 35 mm single-lens reflex (SLR) photographic camera**



Milestones in photography



- 1939, Agfa, introduced the **35 mm Agfacolor negative film for motion picture**
- 1942, Kodak's **Kodacolor** became the world's first true colour negative film intended for making paper prints
- 1947, Harold Edgerton created the **rapatronic camera**, a **high-speed camera** capable of capturing images with a really short exposure time, **in the scale of nanoseconds**,
 - to capture the rapid changes of matter during nuclear explosions
- 1948, the Hasselblad camera was introduced
 - later named the **Hasselblad 1600F**
 - a breakthrough in photographic cameras
 - modular design: exchanging lenses, viewfinders, film magazines
- 1962, NASA started using Hasselblad cameras in space flight
- 1965, NASA's requests brought new innovations
 - like **the motor drive**, which appeared in the Hasselblad 500 EL



Two of the most iconic photographs to have been ever captured.



Milestones in photography

- 1937, Edwin H. Land co-founded the **Polaroid Corporation**
 - invented inexpensive polarising filters, a practical instant photography method, and developed the retinex theory of colour vision
- 1948, Land marketed the **first Polaroid instant camera**
 - made it possible to photograph and develop a picture in about one minute
- 1949, VEB Zeiss Ikon introduced and marketed the **Contax S camera**
 - the **first 35 mm SLR camera with a pentaprism-based viewfinder** and the M42 lens mount
 - critical breakthrough in the 35 mm SLR technology
- 1957, the Asahi Optical Company created the **Pentax 35 mm SLR camera**
 - a highly successful market model that had a significant impact in the 35 mm SLR design throughout the world
 - Asahi Optical Company changed its name to Pentax due to the world-acceptance



Milestones in photography



- Late 1940s, early 1950s, the U.S. National Bureau of Standards undertook the development of a first-generation electronic computer
 - The **Standards Eastern Automatic Computer (SEAC)**
 - SEAC was in operation until 1964
 - one of its major contributions was in the development of digital imaging
 - 1957, **Russell A. Kirsch** worked in the creation of the SEAC and is recognised as the developer of the **first digital image scanner**
 - an invention of enormous importance for digital imaging
 - first scan: 176×176 array, a total of 30976 picture elements, in an area 5×5 cm, with a resolution of a 1 bit per picture element



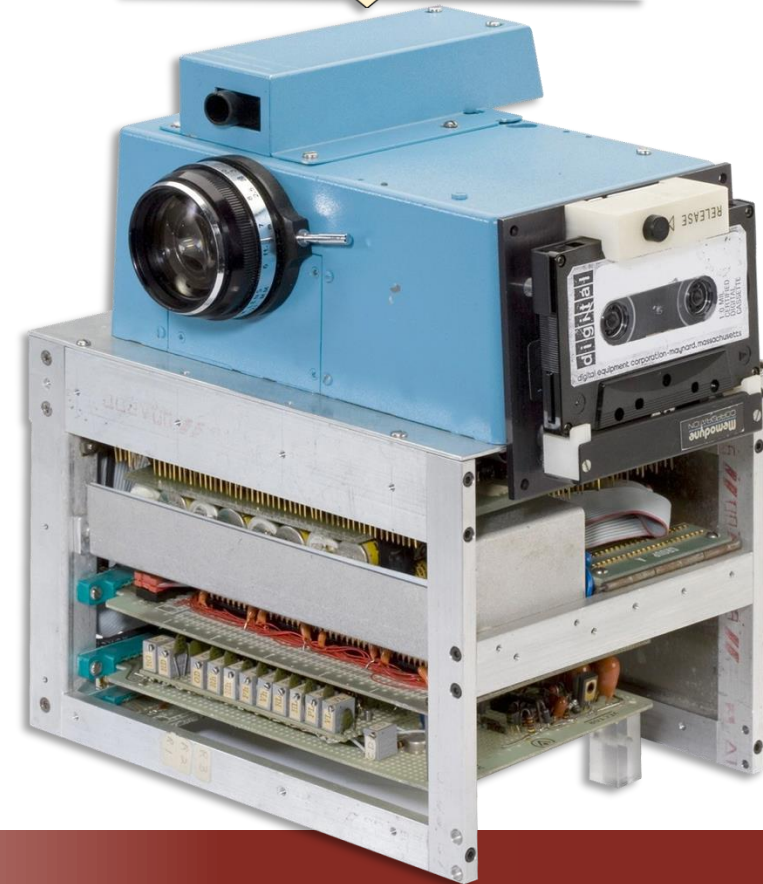
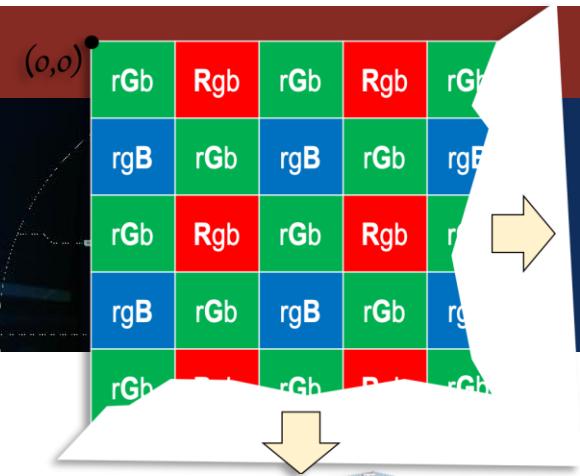
Milestones in photography



- 1965, Frederic Crockett Billingsley, deeply involved in digital image processing for space missions, coined the term **pixel**
- 1968, Peter Noble presented the basic principle of operation of a matrix of **image detectors** and the required digital electronics
- 1969, Willard Sterling Boyle and George Elwood Smith were awarded the Nobel Price in Physics 2009, for the invention of an imaging semiconductor circuit—**the CCD sensor**

Milestones in photography

- 1975, Bryce E. **Bayer**, at Kodak
 - invented the **Bayer filter**
 - a filter for digital imaging sensors that made colour photography possible for digital cameras
- 1978, Steven J. **Sasson**, at Kodak
 - assigned in 1975 to attempt and build an electronic camera using a CCD
 - used the Fairchild 100×100 CCD
 - managed to create a self-contained electronic camera
 - the **first portable digital camera**



Milestones in photography



- 1988, Fuji created the **first fully digital camera**, the **Fuji DS-1P**, with 16 MB storage space
- 1990, **Dycam Model 1** was the **first commercially available digital camera**
- 1991, Kodak released **DCS-100 the first Digital SLR**, or simply **DSLR** camera with 1.3 megapixel resolution enclosed in a Nikon F3 body, requiring a large companion storage unit
- 1993, Eric R. Fossum, NASA, developed a new CMOS active pixel sensor to tackle the problems of CCDs for space missions, the **CMOS Image Sensor or CIS**.
- 1994, SanDisk defined and manufactured the **CompactFlash** flash memory mass storage device to be used mainly in portable electronic devices, one of the most successful storage media in digital photography
- 1995, Casio created the **first consumer digital camera with a liquid crystal display (LCD)** for previewing and viewing photographs, the **Casio QV-10**.
- 1996, Kodak created the **Kodak DC-25**, the **first camera to have used CompactFlash** memory for storage
- 1988, **JPEG** and **MPEG** became the international standards for digital image and video interchange
- 1995, Ricoh marketed the **Ricoh RDC-1 the first camera with video capture** capability
- 1999, Nikon released **Nikon D1**, a 2.74 megapixels camera, a camera **completely created by Nikon** with a price under \$6,000 and compatibility with Nikon F lenses
- 2006, DALSA Semiconductor announced a CCD of **111 megapixels targeting astronomy applications**, the first sensor to pass the 100 megapixels mark
- 2009, Kodak announced that **Kodachrome film that has been manufactured since 1935, was discontinued**

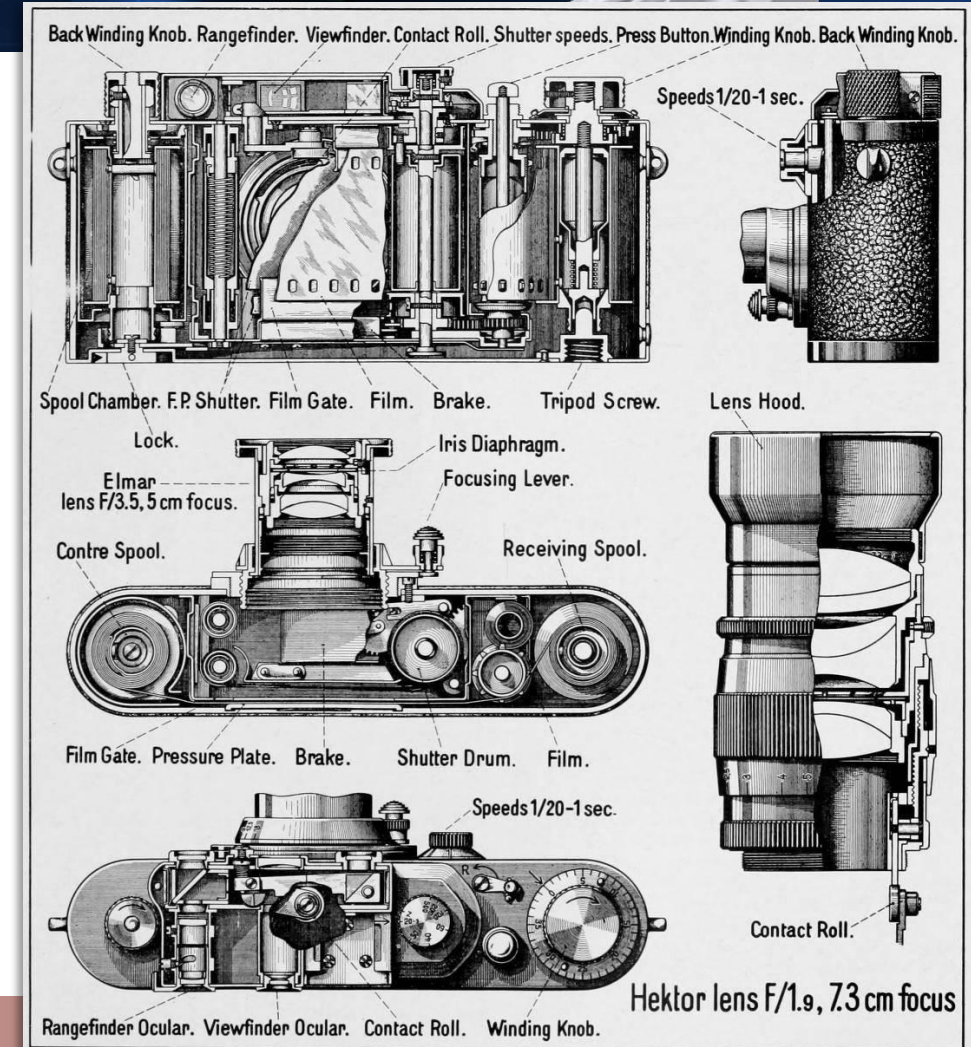
Lets get back to today

What do we have in our hands?



The analog photographic camera

- Initially a purely optical instrument relying on the photo-chemistry of certain materials
- Later evolved into a complex mechanical-optical instrument
- Became an intelligent electro-mechanical-optical instrument



Photographic camera

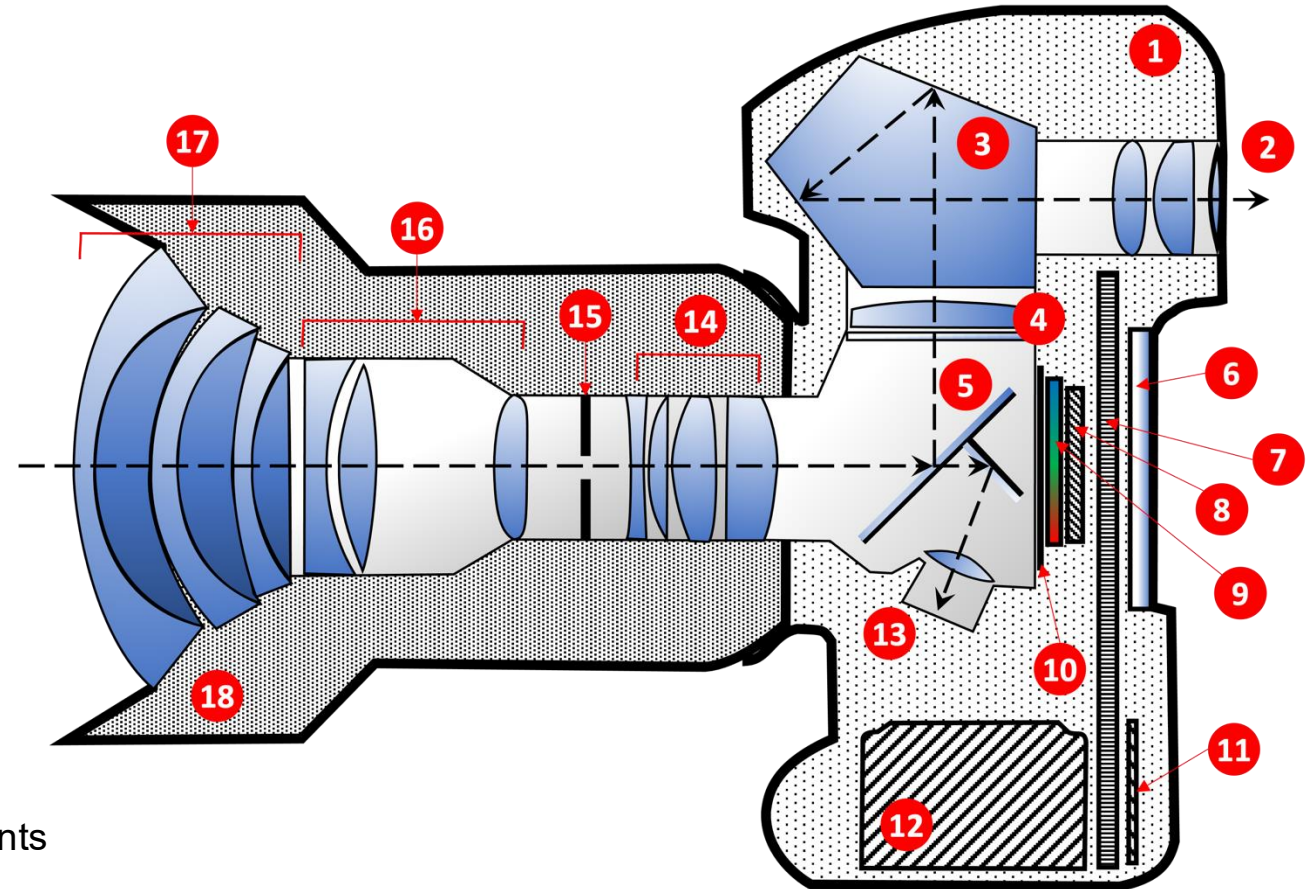


(1) Camera Body

- (2) viewfinder, (3) pentaprism, (4) focusing screen
- (5) reflex and relay mirror
- (6) display
- (7) electronics (digital camera)
- (8) sensing surface (sensor/film)
- (9) filters (Bayer, Infrared)
- (10) shutter
- (11) storage media drive (digital camera)
- (12) Battery

(18) Lens

- (13) autofocus system
- (14) focusing lens elements
- (15) aperture
- (16) zoom lens elements, (17) light gathering lens elements



Photography

- Analog or digital?

- Traditional analog photography (films)

- No restrictions in chromatic resolution
 - Dynamic range around 1000:1
 - Mosaic of different chemical elements
 - Good standard film $\sim 7000 \times 5000$ elements
 - General estimate of ~ 20 - 30 MPixels in a black and white film and 8-12 MPixels in a color 35 mm in ISO 50-100 settings
 - Additionally:
 - Medium format films correspond to ~ 50 MPixels
 - 4x5 inch films correspond to ~ 200 MPixels
 - 8x10 inch files correspond to ~ 800 MPixels



Photography

- A Comparison
 - film scanned at 2700 bpi

JACK RUSSEL TERRIERS—Absolutely adorable. Fun family pet. M's, 12 wks. Shots & wormed. Health guar. \$250. 703-402-3402

JACK RUSSELL PUPPIES—Mini's, parents JRTC, health guar. shots & wormed, \$275+. 410-231-4125

JACK RUSSELL PUPS—M & F, shots/wormed, 3 litters to choose from, raised w/kids, \$350. 540-338-3535

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277 Tickets—Travel

Many airline tickets are not transferable. Please check before buying.

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Many airline tickets are not transferable. Please check before buying.

TERMS OF SALE: A deposit of \$ shall be required at the time of sale price with interest at 8.875% per the date of payment will be paid at ratification of the sale. Adjustments and special or regular assessments sale and thereafter assumed by minimum and/or homeowner association

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Photography

- Comparison
 - Film scanned at 4000 bpi



Photography

- Factors that differentiate analog to digital photography
 - Quality
 - spatial resolution, noise level, dynamic range, sensor size
 - Usability and processing capabilities
 - Cost
 - Robustness (resistance to wear and heavy use)
 - Storage/management
 - Security/authenticity

Digital photography



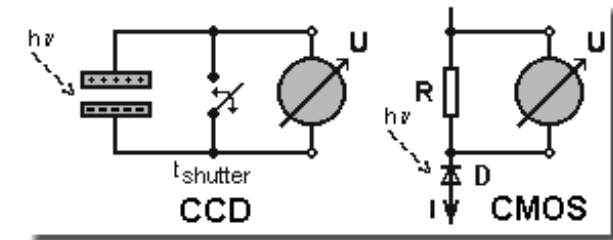
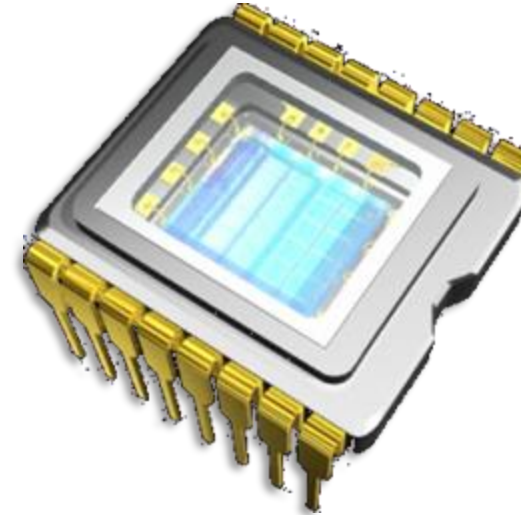
- Main types of photosensors

- **CCD**

- Older technology
 - Good quality under difficult conditions
 - High power consumption

- **CMOS**

- Newer technology
 - Medium/bad quality under difficult conditions
 - Low power consumption
 - Lower cost



Digital image

- **Pixels**

- [Pict]ure [El]ements are the elementary units of optical information in digital images
- Digital image sizes in computers are measured in pixels

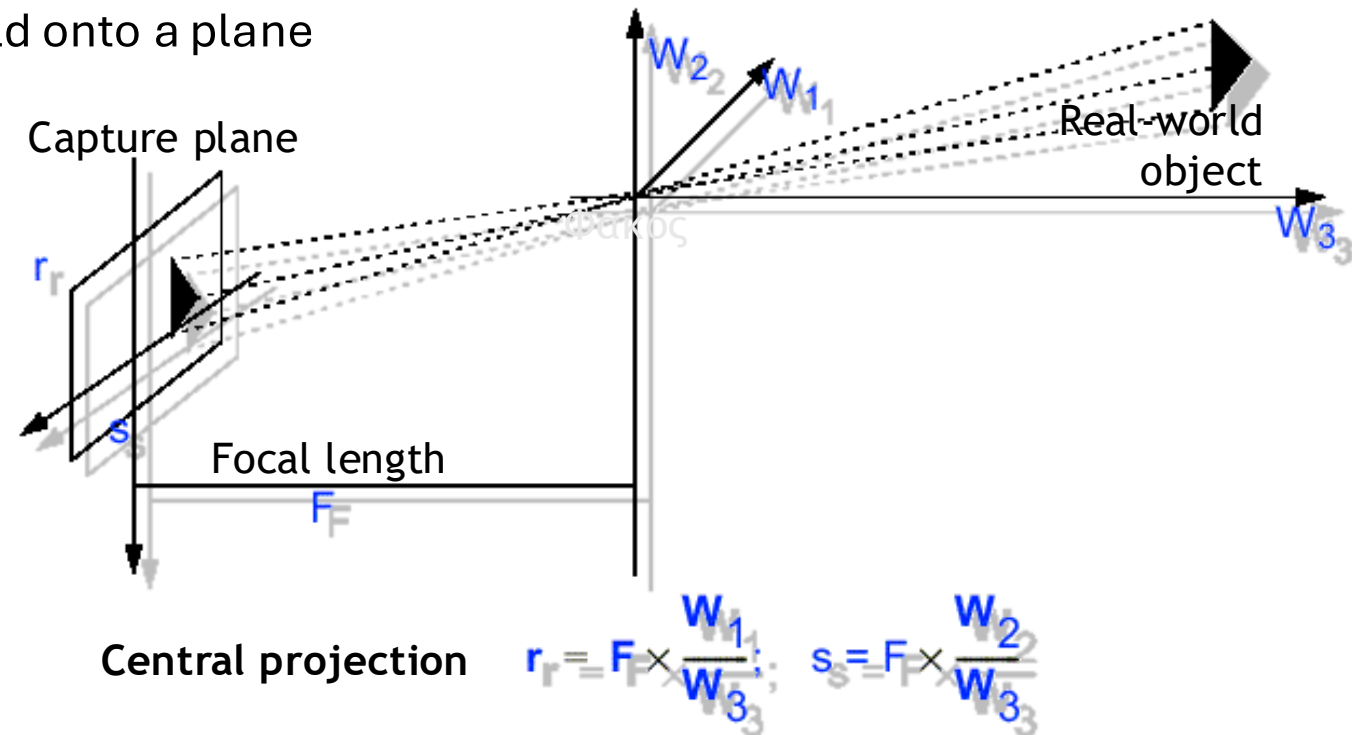
- **MegaPixels (MPixels)**

- The total number of pixels in a digital image
- Expressed as the product of the width and height of the image in pixels
- When MP and the ratio (i.e. 4:3, 16:9) are known then the actual dimensions can be deduced

Digital images & graphics

- Digital image
 - Array (or matrix) with N rows and M columns that contain
 - $N \times M$ pixel values
 - Represents a projection of the real world onto a plane

- Graphics
 - Design elements
 - Lines, circles, ... etc.
 - Properties
 - Color, depth, texture, ..., etc.



Digital image technologies



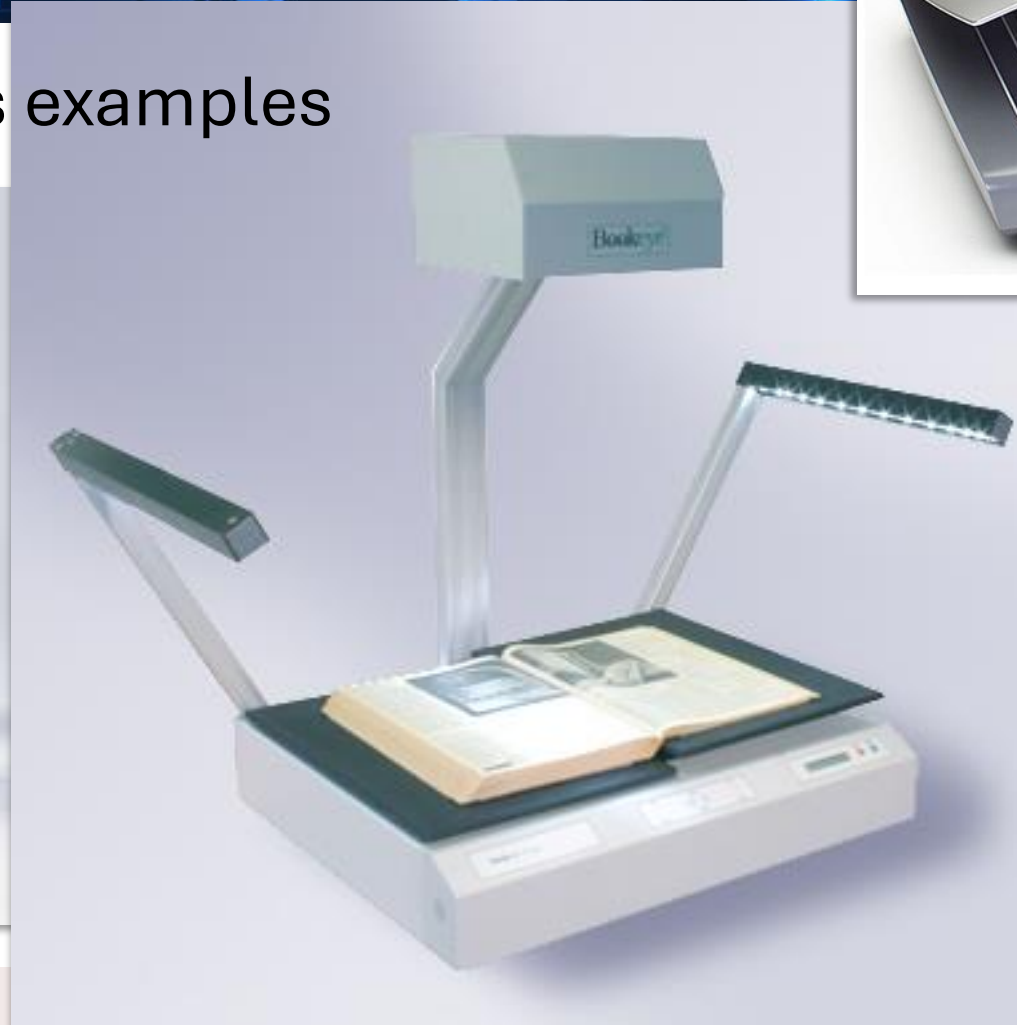
- Scanners
 - Desktop, handheld
 - Film, slides, microfilm scanners
 - Book scanners
- Digitizers
- Digital photographic cameras
 - In the visible, infrared, multispectral
- Digital ultrasound imagers
- Digital tomographers



1957

Image digitization

- Digitization systems examples



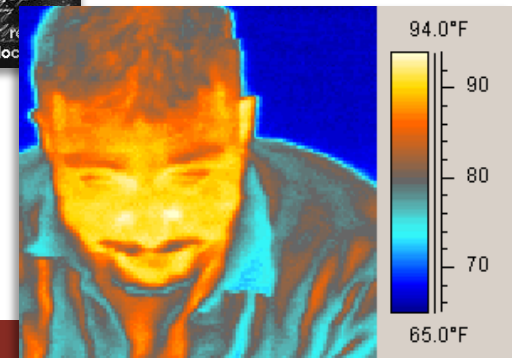
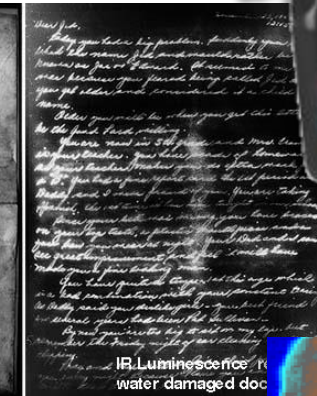
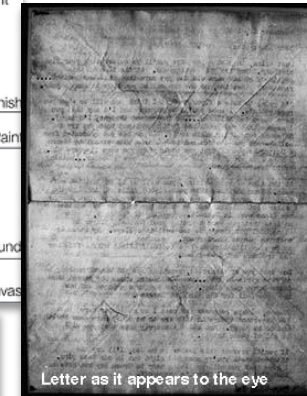
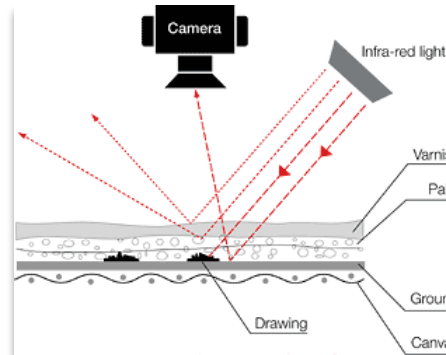
Digital cameras

1. **DSLR cameras:** widely accepted standard for advanced amateur and professional photography
2. **Mirrorless cameras:** dynamic type of camera currently in the market due to certain benefits
3. **Compact cameras:** point-and-shoot cameras, easy to use, small and lightweight for automated photography
4. **Bridge cameras:** fill the gap between compact and DSLRs
5. **Instant cameras:** compact, automated cameras, point-and-shoot scenario, instant filtering, instant print
6. **Action cameras:** outdoor activities with fast movement and action
7. **Panoramic (360°) cameras:** recording of spherical panoramic views
8. **Smartphone cameras:** specific limitations still, with significant photography functionalities
9. **Medium and large format cameras:** the elite group of cameras targeting professional photography users and applications

Camera type	Pros	Cons
DSLR	Complete manual control; optical viewfinder; various interchangeable lens options; high quality output; customisation and gear; dedicated auto-focusing system	Large size; heavy; expensive; knowledge demanding
Mirrorless	Practically, DSLRs without the pentaprism-mirror-viewfinder system; less mechanical noise; less vibration; complete manual control; compact design; various interchangeable lens options; high quality output; customisation and gear	Slow and energy consuming electronic viewfinder; shorter battery life; higher cost in entry level cameras
Compact	Easy to use; increased automation; low cost; compact design	Limited control; small sensor size; low quality output; no or limited lens options
Bridge	Easy to use; compact design; low cost; lens options	Small sensor size; decreased lens quality; increased energy consumption; medium quality output
Instant	Easy to use; compact design; instant print; low cost	No lens options, very limited manual control; specific applications
Action	Easy to use; ultra compact and lightweight; weatherproof; mountable on various surfaces	Small sensor size; virtually no manual control; typically no viewfinder; very limited customisation; decreased battery duration
360°	Easy to use; ultra compact and lightweight; weatherproof; mountable on various surfaces; special immersive captures	Small sensor size; virtually no manual control; typically no viewfinder; very limited customisation; decreased battery duration; difficult to control the orientation
Smartphones	Ultra compact; lightweight; easy to use; always available; readily cloud and media integrated	Typically, limited manual control; very small sensors; lower quality output; limited or no lens options
Medium/large format	Large sensor size; high quality output; lower noise; interchangeable lens options; large dynamic range	Very high cost, large size; heavyweight; challenging depth of field setting

Digital photography special cases

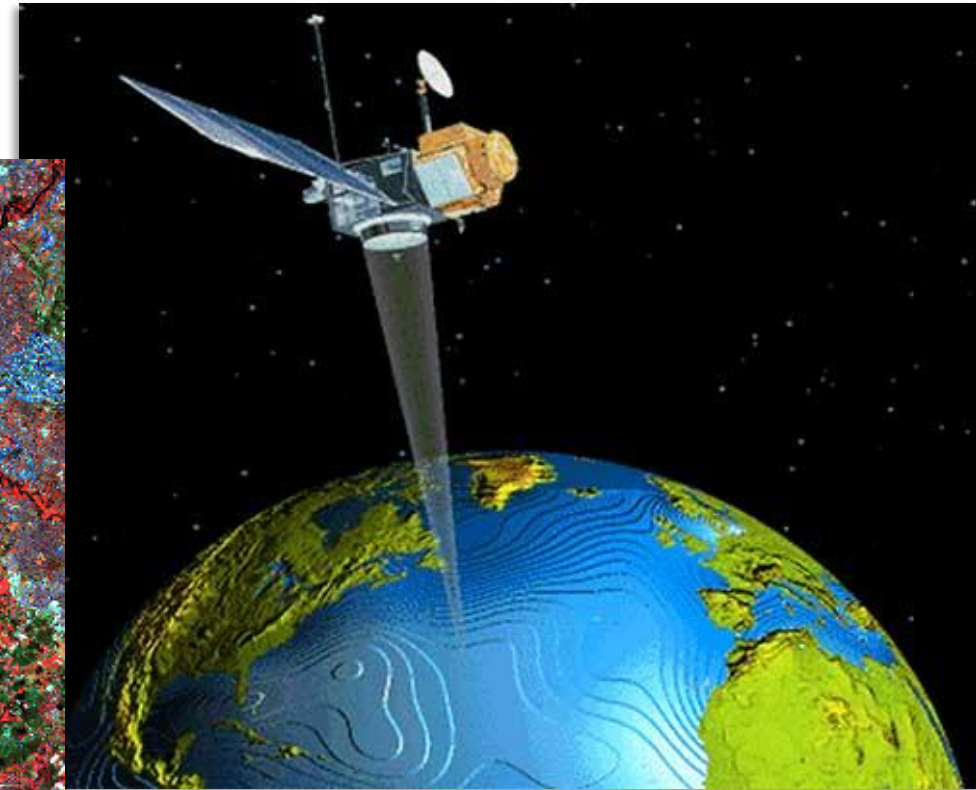
- Multispectral capture and X-ray capture
 - Multispectral 3CCD Color/CIR cameras
 - Thermal cameras



Digital photography special cases



- Multispectral satellite imaging



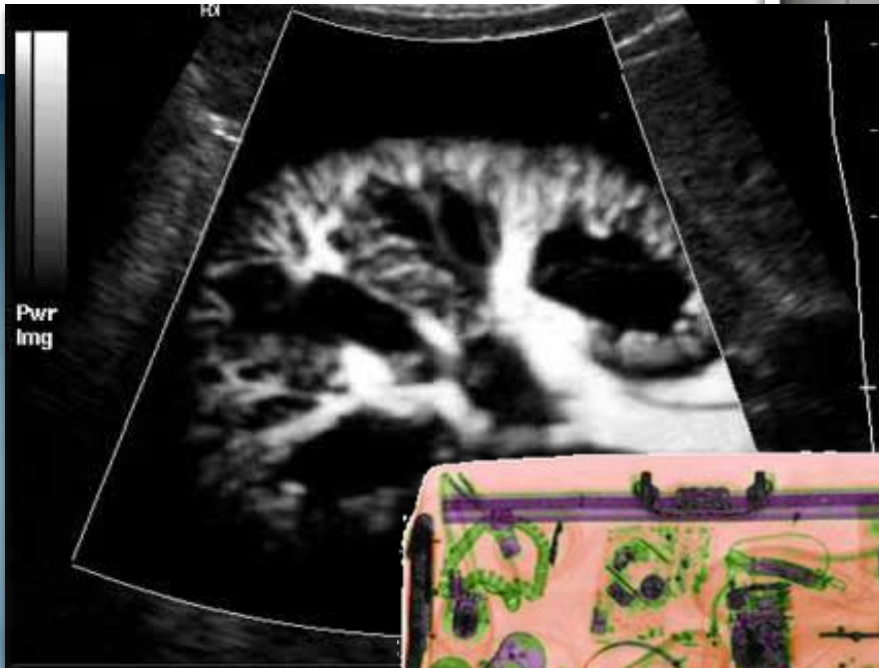
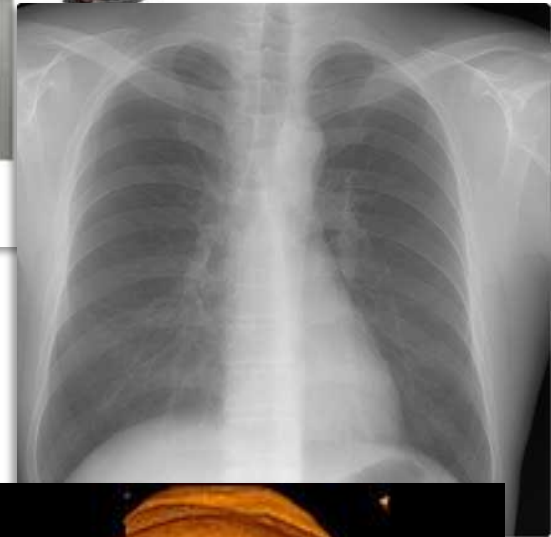
Scanning

- Color scanning of film, microfilm and slides
 - Support for multiple film types like 35mm, E6, C-41



Special digital imaging

- X-rays, ultrasound imaging



Digital image creation

- Special equipment
 - Digitizers – drawing tablets
- Special software
 - Image processing
 - Vector graphics
 - Raster graphics



Representation of digital images



Typical true color image (24 bpp)



Red color channel (8 bpp)

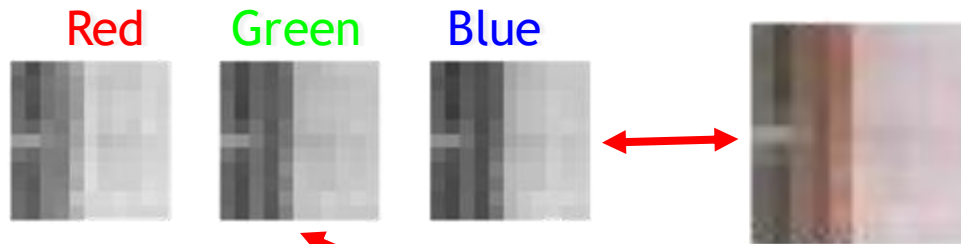


Blue color channel (8 bpp)

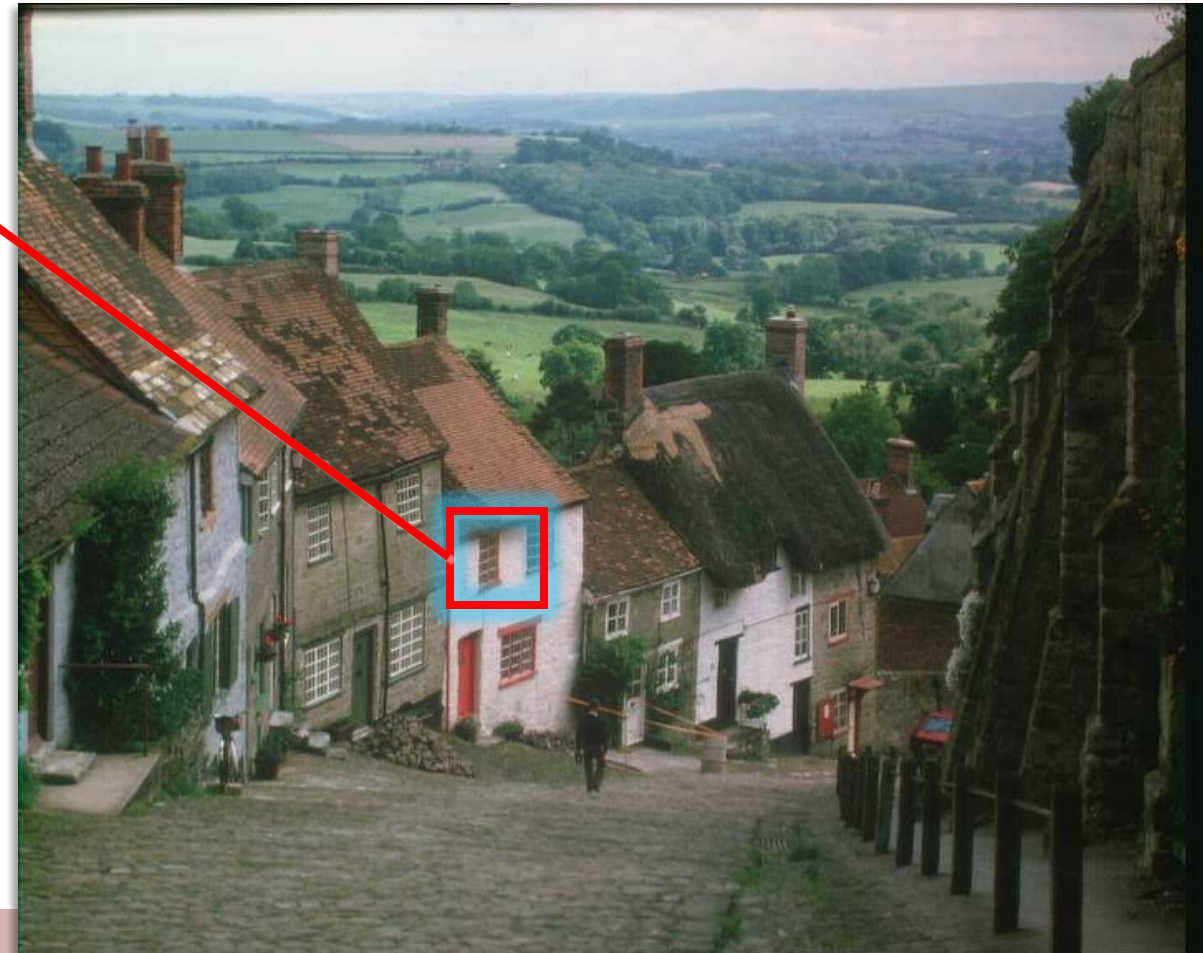


Green color channel (8 bpp)

Representation of digital images



113	77	112	135	166	208	201	200	199	212	212
99	88	118	130	156	204	194	199	197	212	210
107	84	116	124	155	210	199	207	206	215	208
108	78	114	125	153	213	201	209	207	214	210
112	100	129	121	164	213	199	207	202	220	213
153	158	136	129	162	208	188	195	199	208	210
117	106	125	125	173	215	199	203	205	211	212
99	97	127	123	181	220	204	207	208	215	215
103	91	130	130	173	222	207	206	207	219	217
109	95	131	135	196	215	215	222	216	224	220
111	96	129	139	179	213	212	217	213	213	213



Representation of digital images



- Each pixel conveys information about
 - **Color**
 - eg. amount of red, green, blue, for a color image
 - **Graylevel**
 - brightness between black and white, for graylevel images
 - **0 or 1**
 - 0=black, 1=white, for binary images

Representation of digital images

- Representations with reduced colors
 - 16 colors



Representation of digital images

- Representations with reduced colors
 - 256 grays



Representation of digital images

- Representations with reduced colors
 - 4 grays



Representation of digital images

- Representations with reduced colors
 - Black and white (binary)
 - Halftoning applied



Pixels and image dimensions



- Image dimensions in Pixels
 - Reveal the sampling array, the positions with color information
 - ex. 1024 x 768
 - The display size depends on the viewing device
 - Display: display resolution, ex. 72 or 96 dpi (ppi)
 - Printing: printer resolution, ex. 300 or 600 dpi
 - Example
 - A 6 MPixels 3:2 image → dimensions = 3000 x 2000 pixels
 - Printing at 300 dpi ~ 25 x 17 cm (~A4-4 cm margin)
 - Full screen display (at 96 dpi, 16:9) requires ~42 inch display
 - The image corresponds to 94 x 53 cm

Formats of digital images



- Characteristics of capturing formats
 - Spatial resolution (pixel rows and columns)
 - Chromatic resolution (bits/pixel - bpp)
- Characteristics of storage formats
 - 2D matrix of pixel values
 - For color images
 - Color space for true color images
 - Ex. Three values representing the Red, Green, Blue contribution in the RGB color space
 - Index to a color table for indexed color images, color lookup table (CLUT)

Postscript format

- Introduced by Adobe around 1980
- Functionality
 - Integration of high-quality text, graphics and images
 - Usage of a specific “programming language”
- Two major types
 - Postscript Level-1
 - Introduces the concept of a scalable font
 - Drawback: the medium quality
 - Postscript Level-2
 - High quality sketch filling
 - Large number of elementary graphics
 - Color can be defined depending (or not) on the device

Graphics Interchange Format (GIF)



- Introduced by CompuServe
- Goal: to interchange image in cross-platform environments
- Main elements
 - Header: identifier and versioning metadata
 - Software: metadata regarding the software and creator
 - Data
 - Trailer: end of data marker
- Compression based on the Lempel-Ziv algorithm
 - Focuses on using bit patterns
 - Variable length coding (VLC)
- Suitable for animations
 - A GIF file may include more than one images

Joint Photographic Experts Group (JPEG)



- Introduced by the Joint Photographic Experts Group
- Goal
 - *High efficiency image interchange for cross-platform environments*
- Became the standard for Web image interchange
- Compression
 - Support for multiple color models
 - Primarily for RGB color images
 - Supports graylevel, etc
 - Support for various compression methods
 - Primarily lossy compression
 - Supports also lossless compression

Tagged Image File Format (TIFF)



- Introduced by Aldus and Microsoft
- Goal
 - *High quality image interchange for cross-platform environments*
- Widely used due to suitability for scanning and faxing
- Compression
 - Support for multiple color models
 - Binary, graylevel, RGB, CIE (perception-based)
 - Support for various compression methods
 - Lempel-Ziv, run-length encoding, JPEG, Huffman encoding

Image processing

An introduction to basic functions



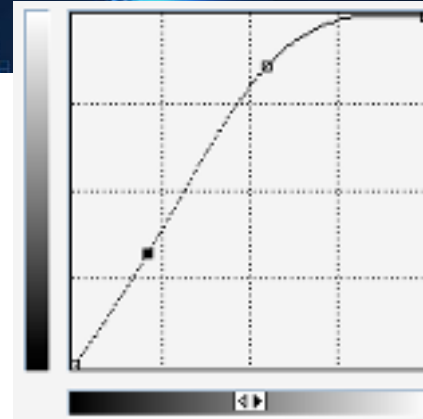
Image processing

- Simple transformations
 - brightness, contrast



Image processing

- Simple transformations



Non-linear brightness transform



Color replacement

Image processing

- Histogram
 - Distribution of light intensity per color channel
 - Number of pixels at a specific intensity

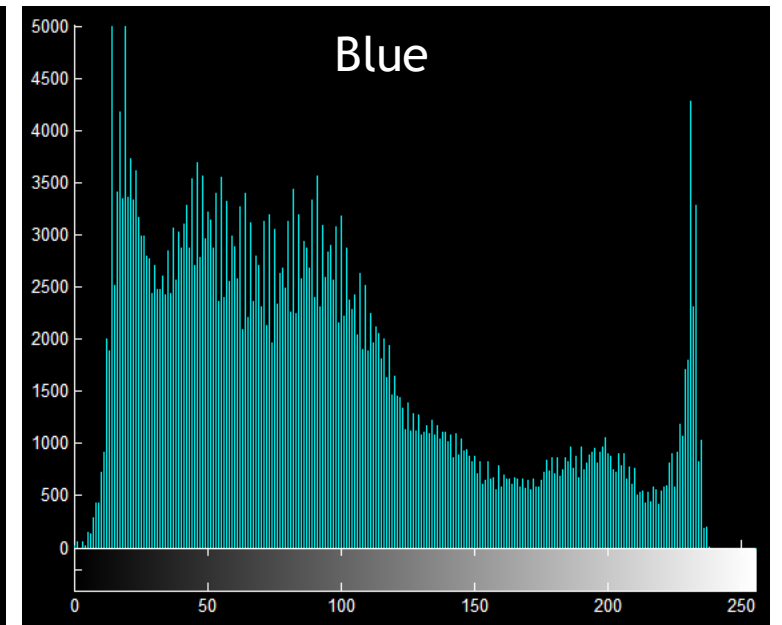
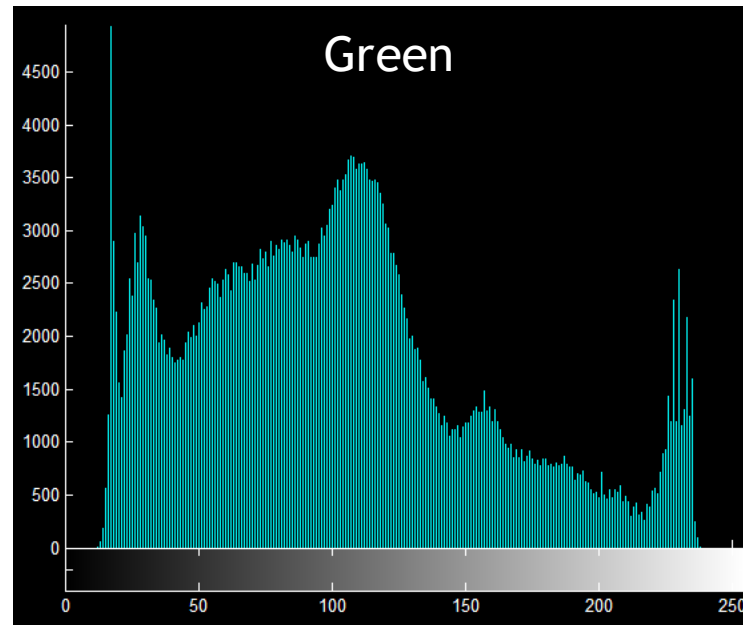
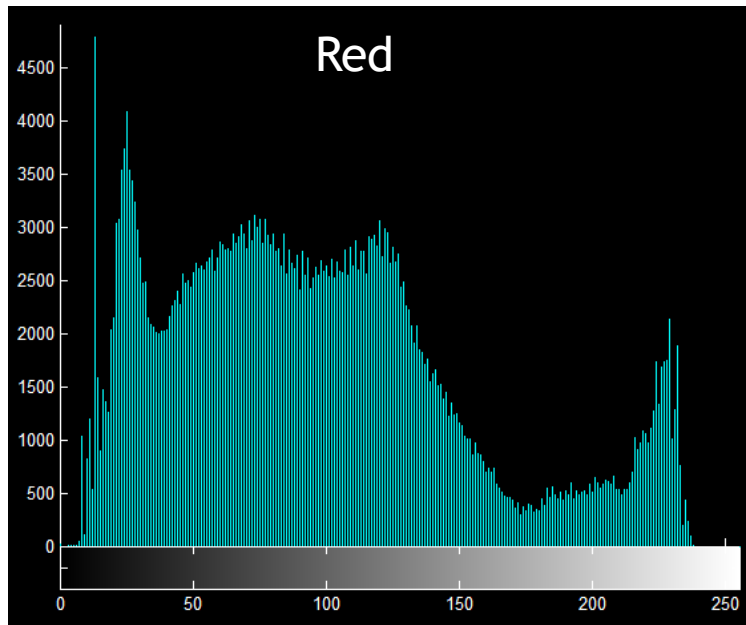


Image processing

- Histogram
- Equalization

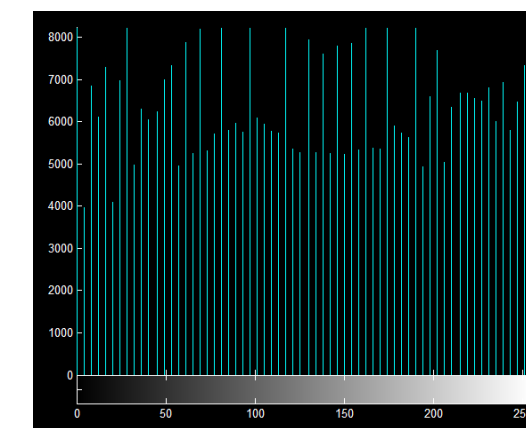
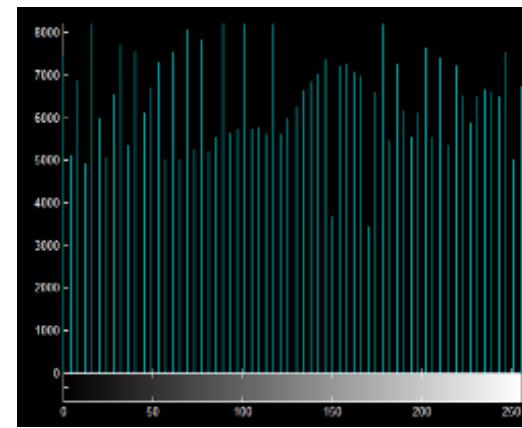
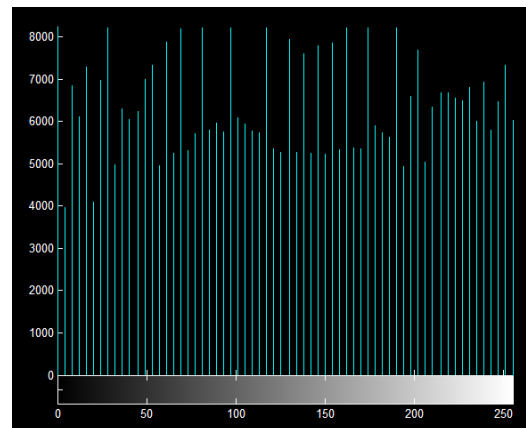
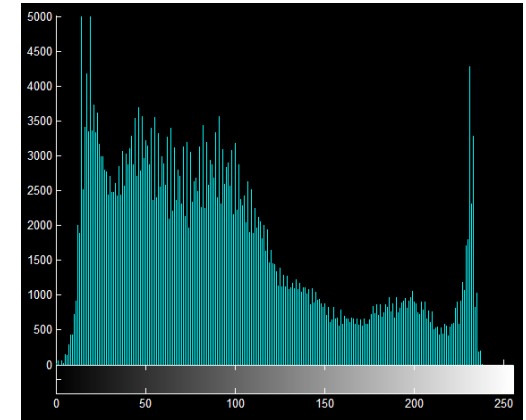
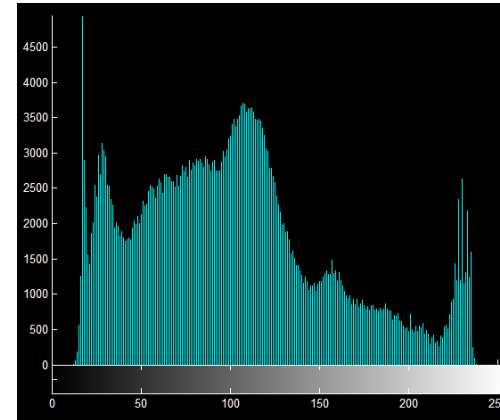
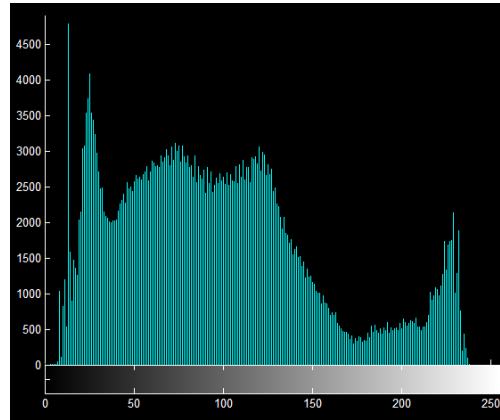


Image processing

- Histogram equalization



Image processing



- Image enhancement
 - Noise reduction



Image processing

- Image enhancement
 - Sharpening



Image processing

- Aesthetic/artistic filtering



Image processing

- Gamma correction

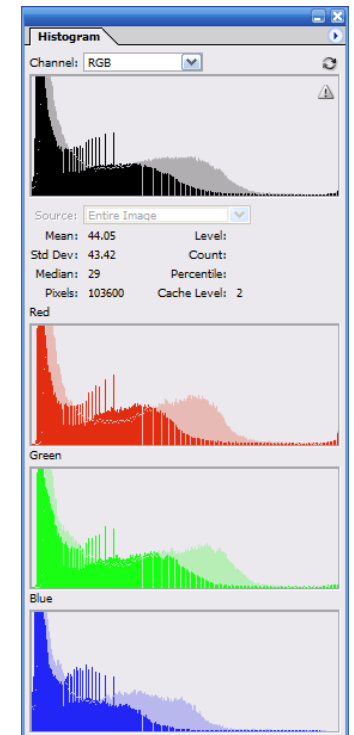
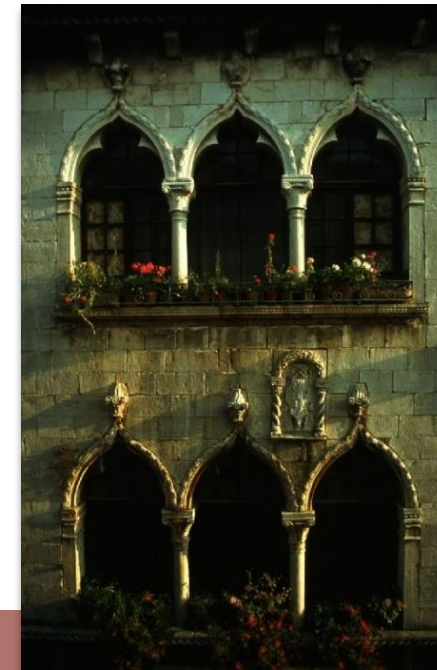
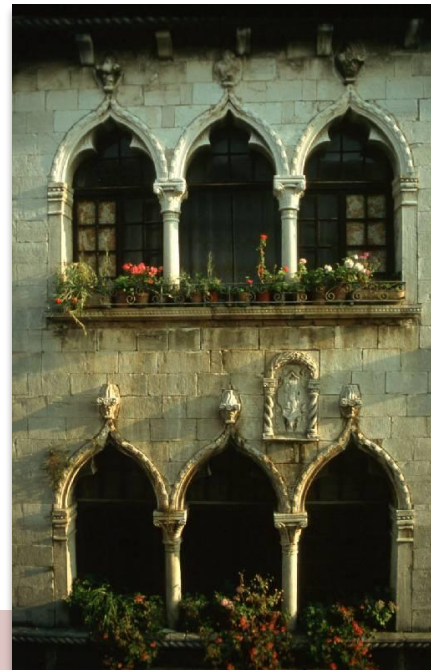
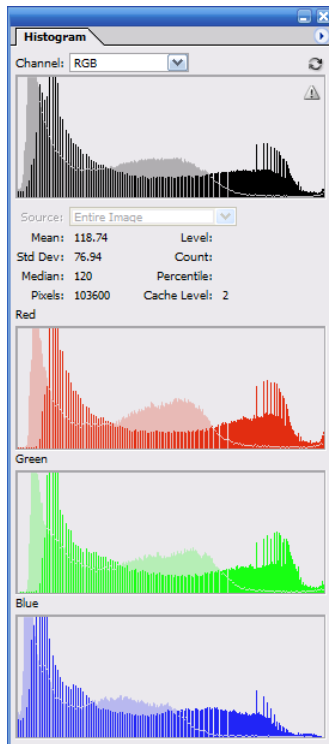
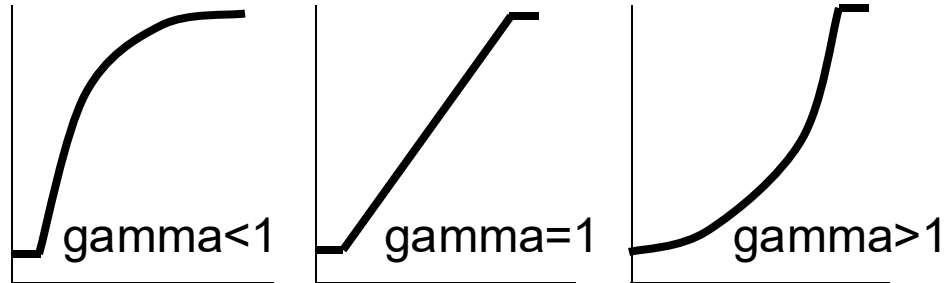


Image processing

- Brightness/Contrast correction

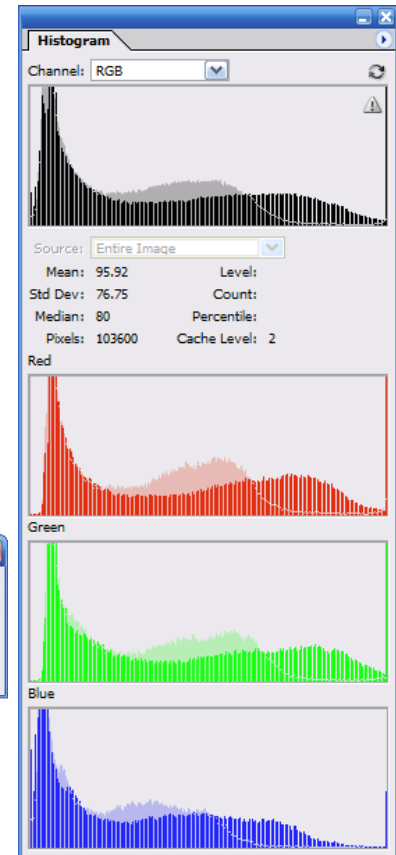
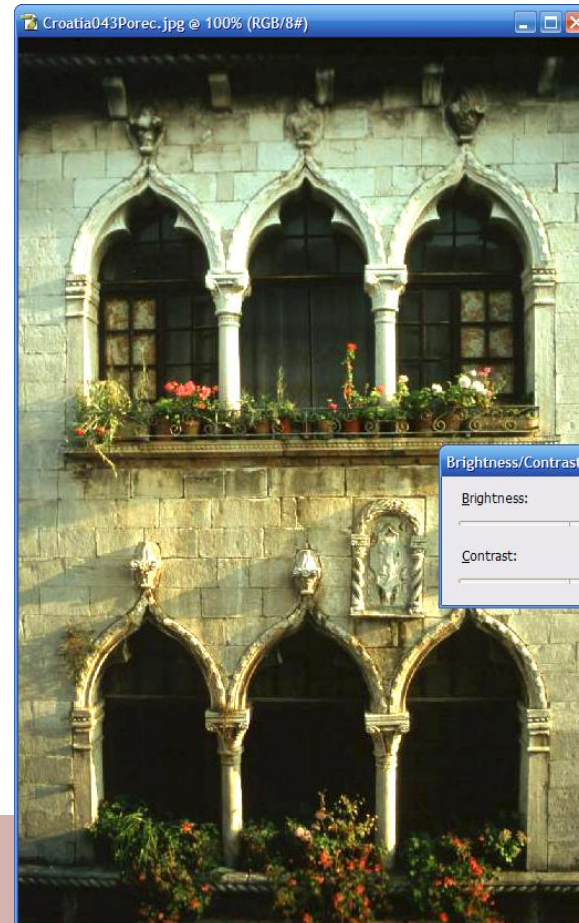
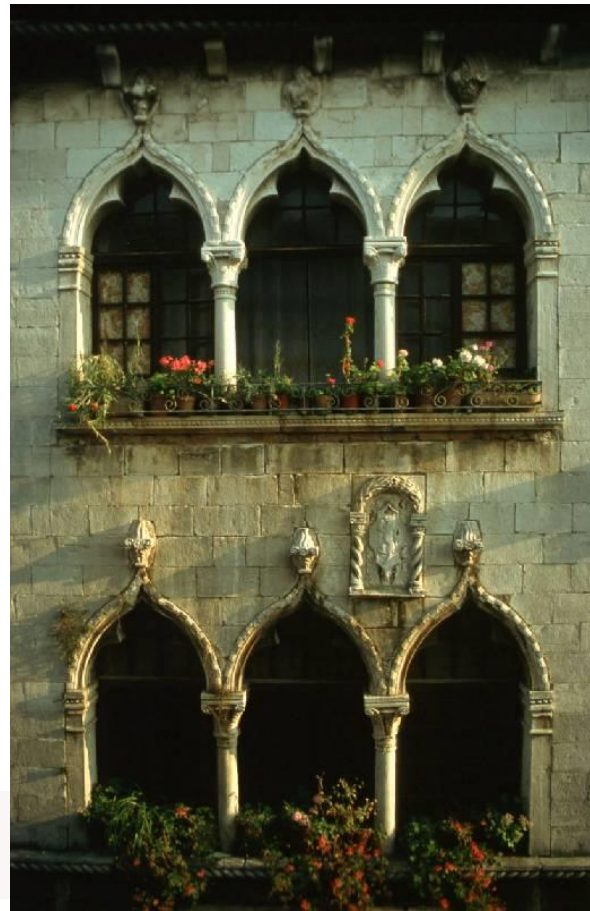
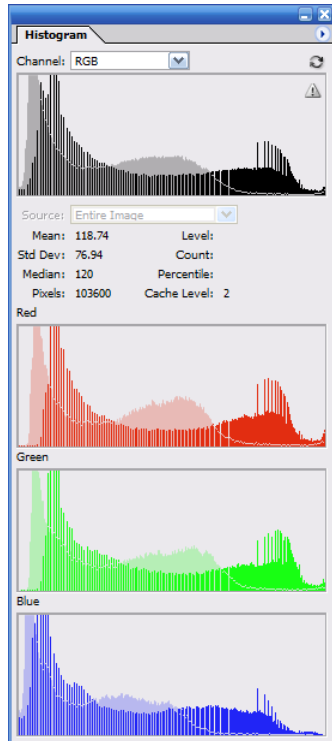


Image processing

- Histogram correction

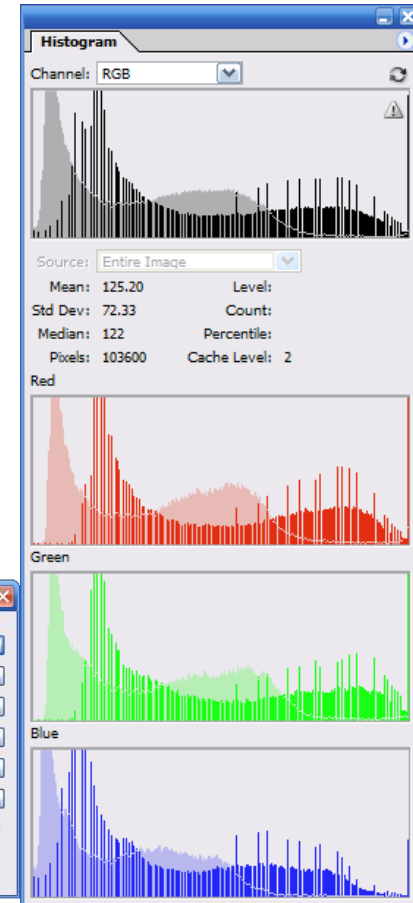
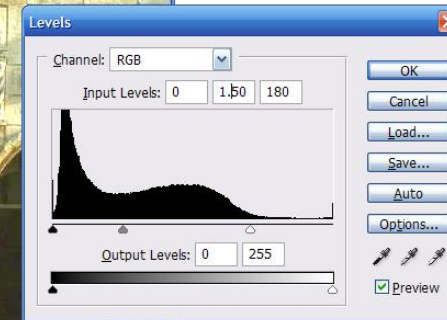
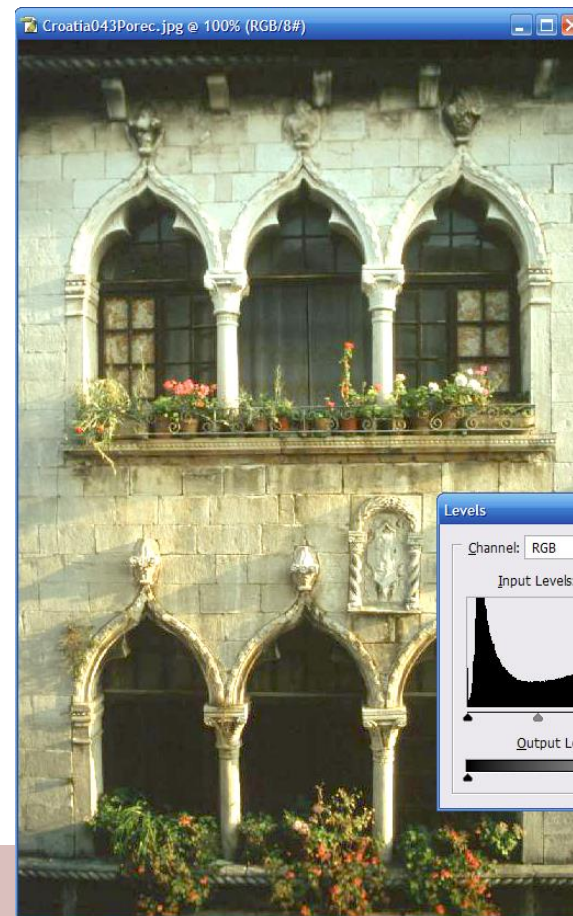
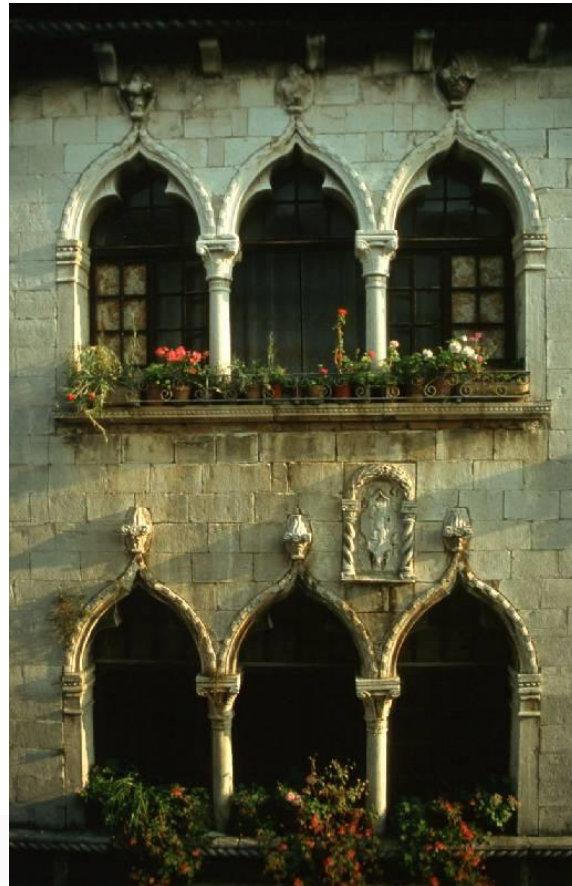
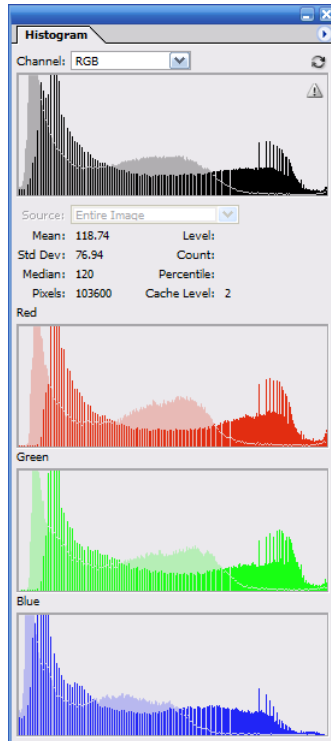


Image processing

- Histogram equalization

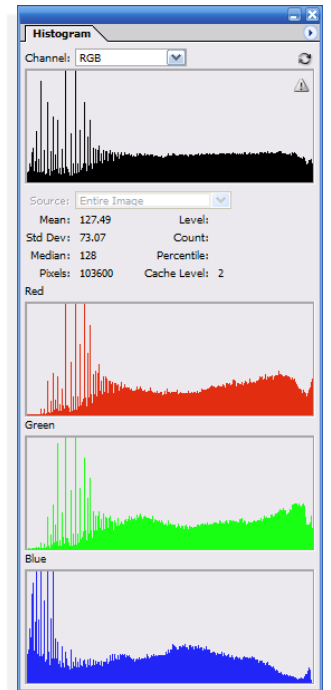
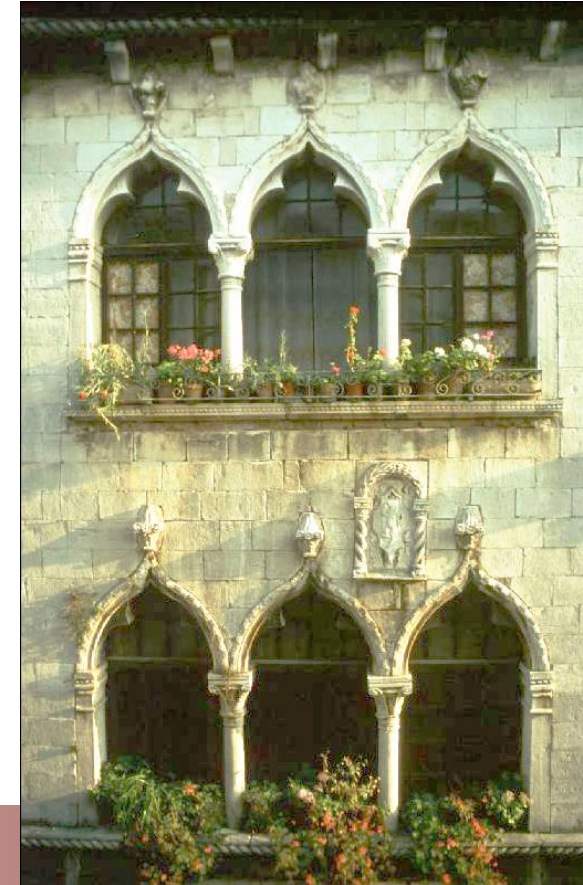
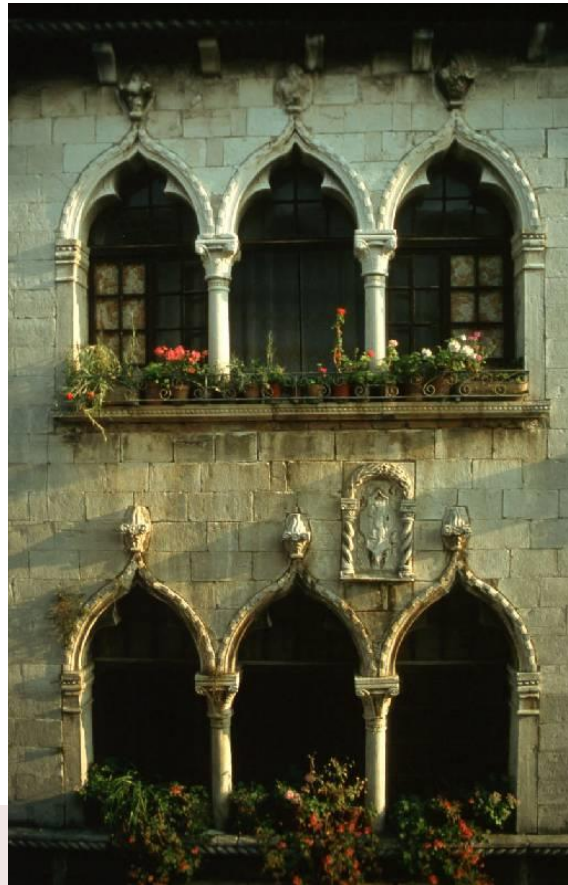
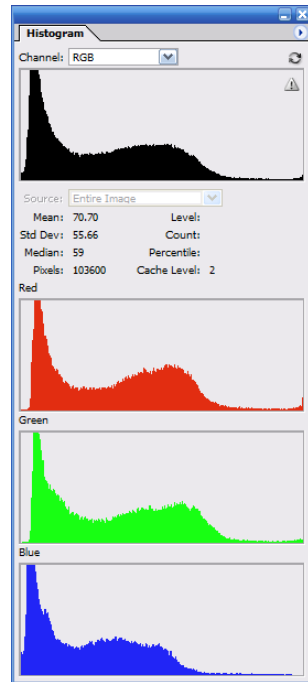


Image processing

- Color balance/correction

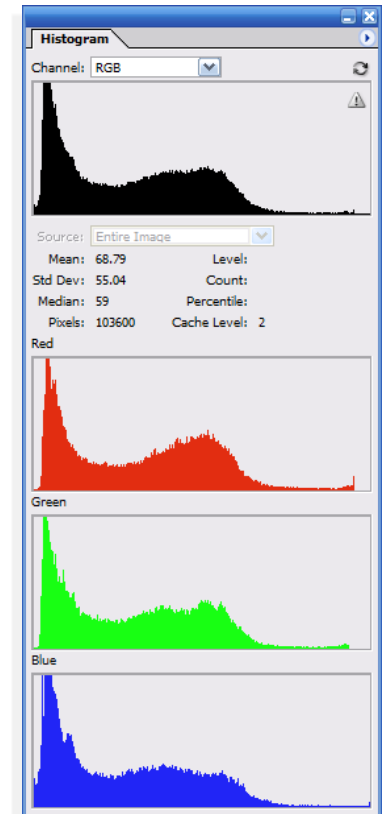
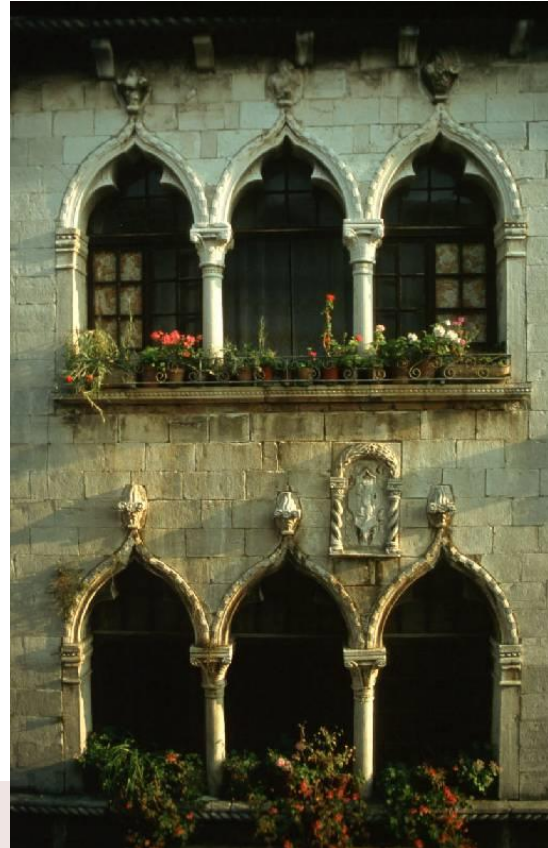
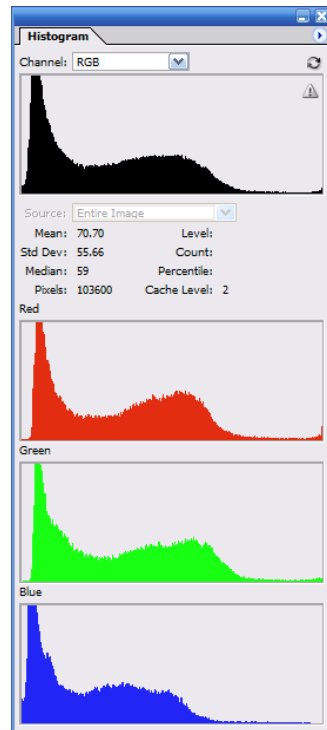


Image processing

- Color space transformation

- RGB
- HLS/HSV
- CMYK
- YUV, YIQ
- YCbCr
- YPbPr
- CIE Lab/Luv
- sCIELab

$$R = Y + 1.4075 * (V - 128)$$

$$G = Y - 0.3455 * ((U - 128) - (0.7169 * (V - 128)))$$

$$B = Y + 1.7790 * (U - 128)$$

$$Y = R * .299000 + G * .587000 + B * .114000$$

$$U = R * -.168736 + G * -.331264 + B * .500000 + 128$$

$$V = R * .500000 + G * -.418688 + B * -.081312 + 128$$

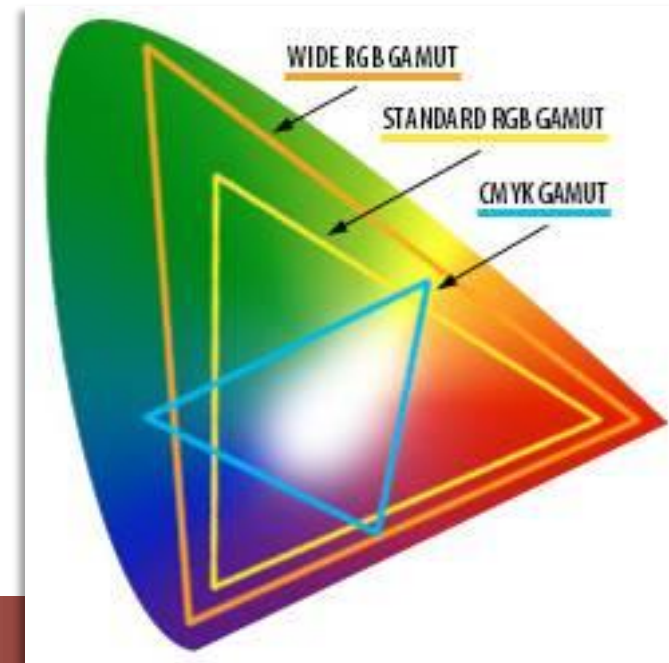
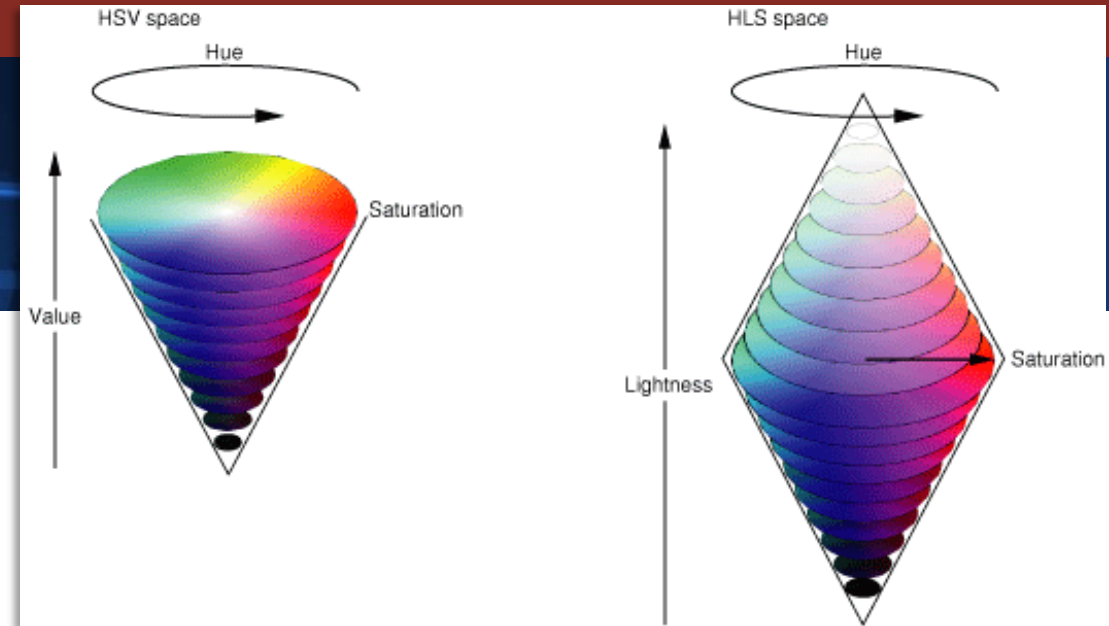


Image analysis

An introduction



Image analysis

- Incorporates notions like
 - Content recognition
 - Content enhancement
 - Pattern recognition
 - Scene understanding
 - Machine vision

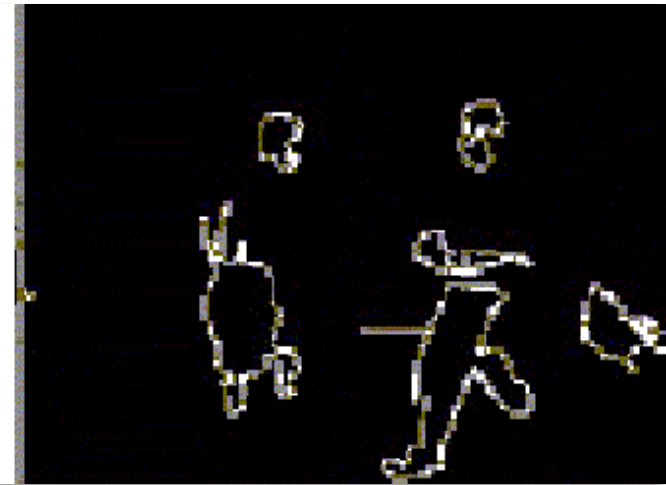


Image analysis

- Edge detection

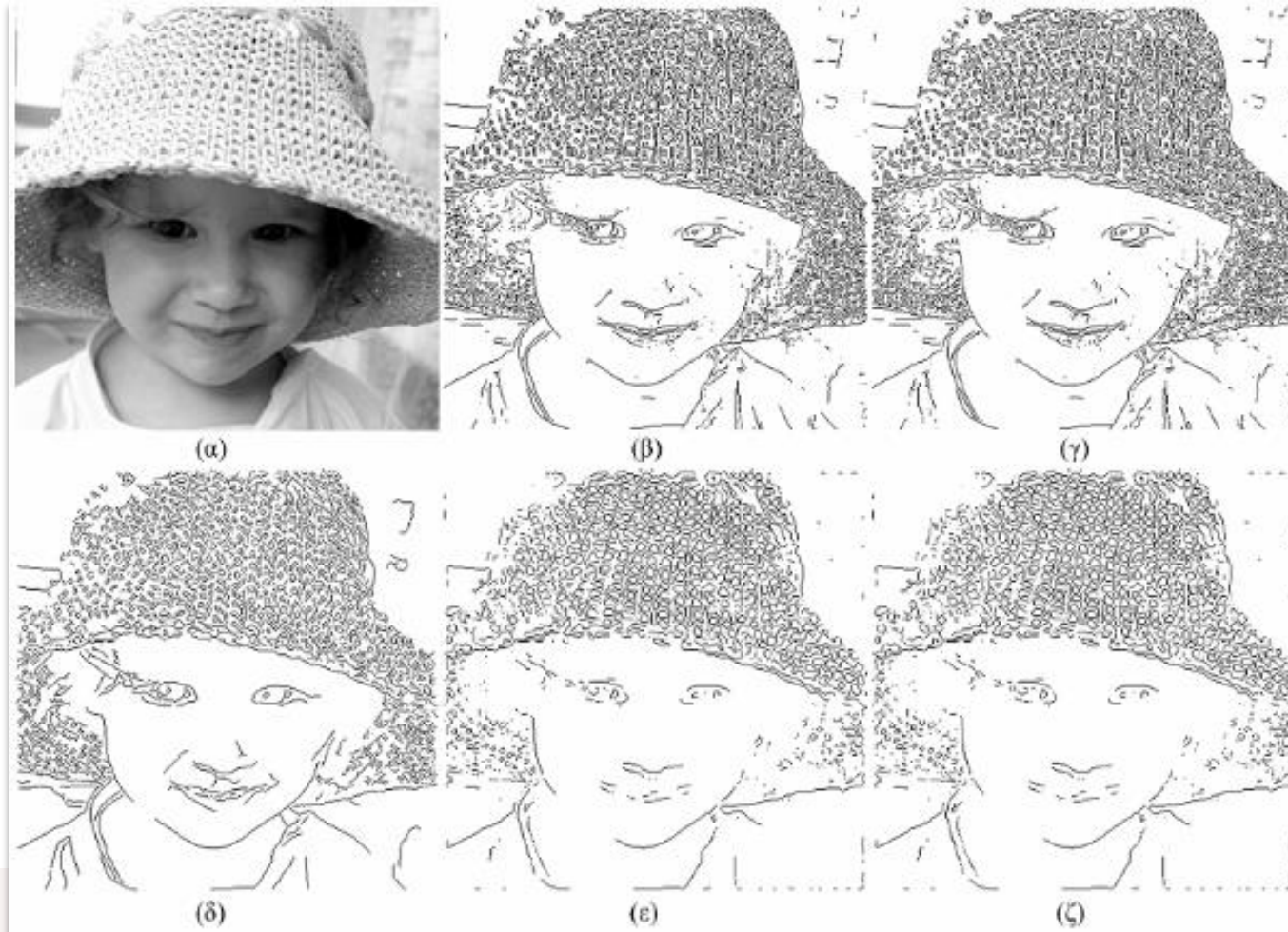


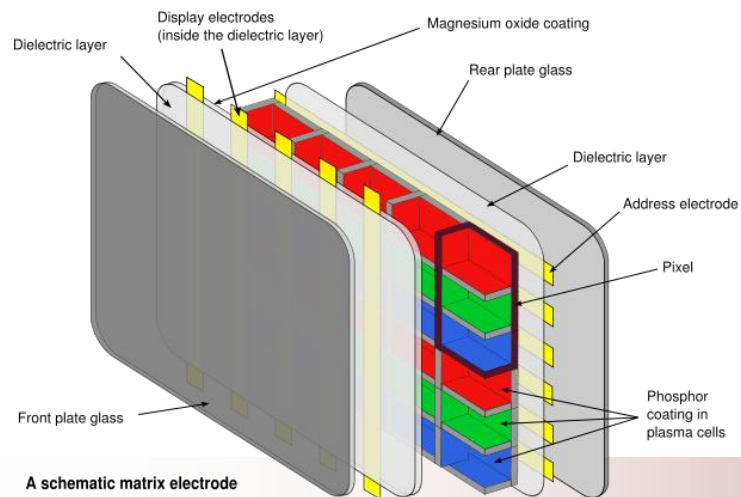
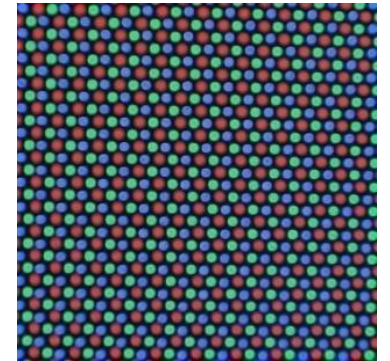
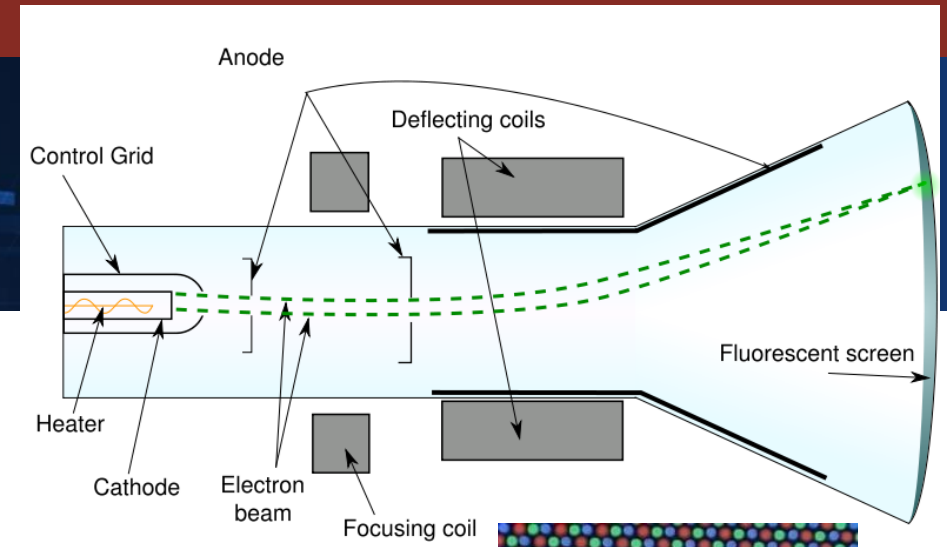
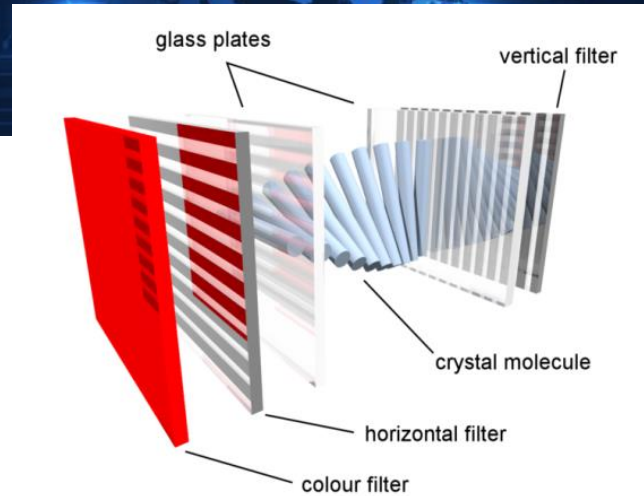
Image display

Basic technology

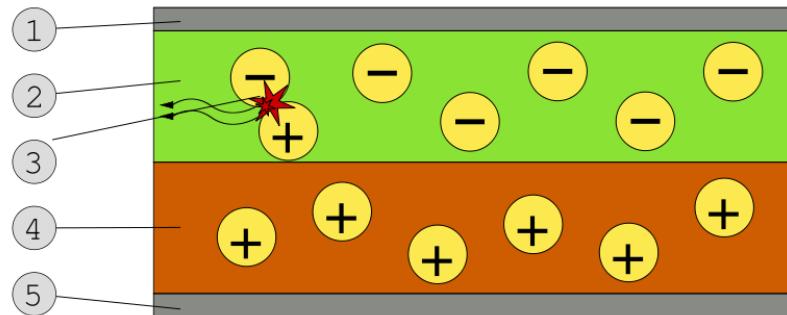


Image display

- Display technology
 - CRT
 - LCD
 - Plasma
 - OLED



A schematic matrix electrode configuration in an AC PDP



Bibliography

