One Hundred Years of Photo Physics

~~One~~ Two + Hundred Years of Photo Physics

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or:

“Professor Mitchell, people *still* do silver halide photography!”

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or:

"Professor Mitchell, people *still* do silver halide photography!"

Memorial Colloquium in Honour of J.W. "Jack" Mitchell

Keith Williams, UVa September 2007

One Hundred Years of Photo Physics

I. Introduction

II. Timeline from B.C. to 2007

III. The Contributions of J.W. Mitchell

IV. Silver Halide in the Modern Era

V. The Digital Future

One Hundred Years of Photo Physics

I. Introduction

II. Timeline from B.C. to 2007

(with particular emphasis on 1900-present)

III. The Contributions of J.W. Mitchell

IV. Silver Halide in the Modern Era

V. The Digital Future

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Pinhole cameras

- Mo Ti, China (500 B.C.) : pinhole camera
- Aristotle (330 B.C.) : pinhole observation of eclipse

A modern pinhole image
from Charlottesville (5x7”)

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Photosynthetic process …without glass lenses or photoemulsions??

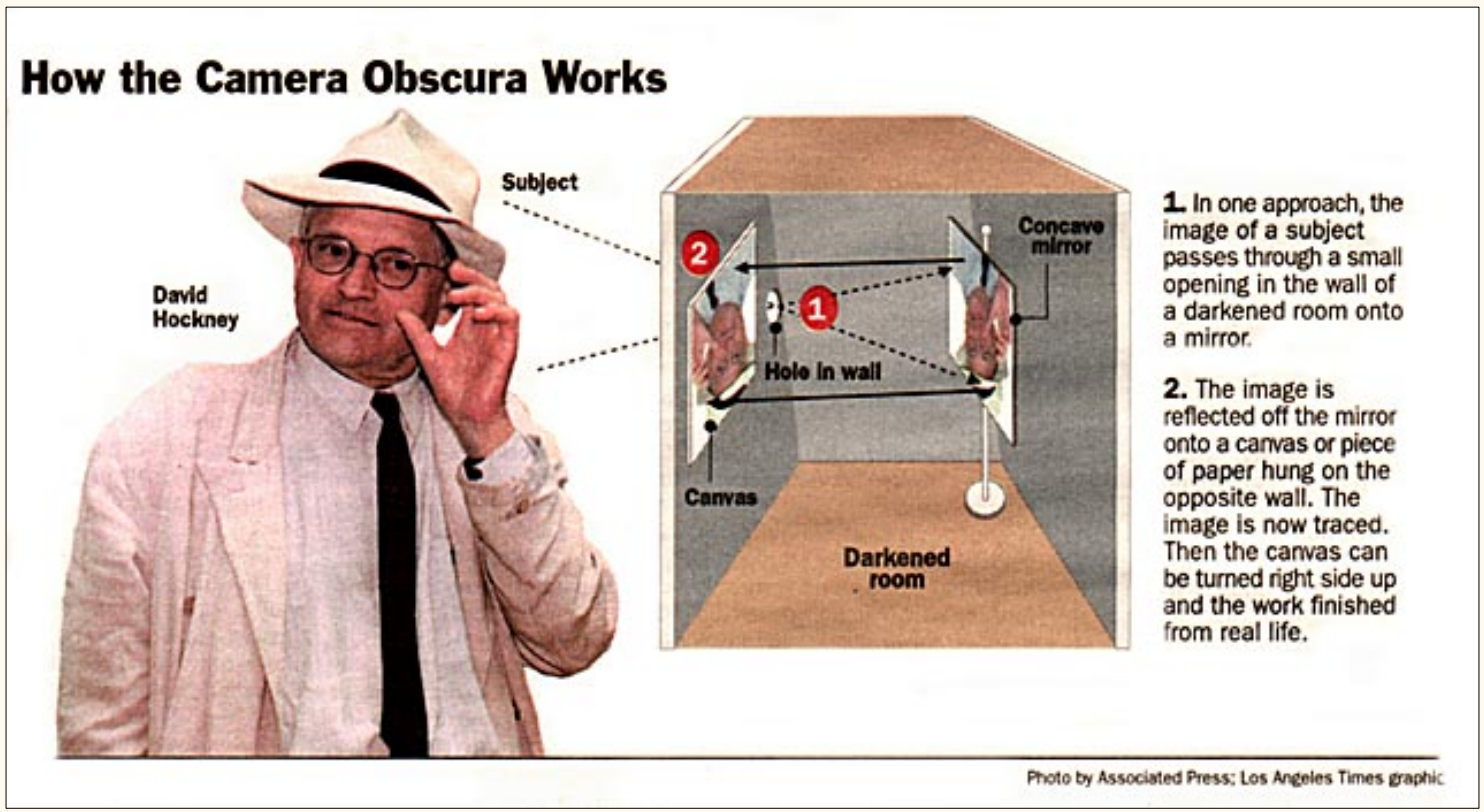
Binh Danh
Left: *The Leaf Effect: Study for Metempsychosis #7* (2006)
Above: *Untitled No.19* (2003)

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

James Pennell: Vermeer may have used a *camera obscura* (1891)
David Hockney: concave mirror could have been used…

Camera obscura used by Vermeer?



Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Philip Steadman's analysis

Camera obscura used by Vermeer?

Photography Timeline

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Philip Steadman's analysis

Camera obscura used by Vermeer?

Top: 1/6th scale model, plus camera…
Right: photograph reproduces the rays in Vermeer's composition

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

J. Schulze

C. Scheele

Schulze and Scheele's Photosensitive concoctions (chalk + nitric acid + silver)

Scheele's reactions (1777):

$Ag^+ + Cl^- + light \rightarrow Ag^+ + Cl + 1e^-$ } oxidation

$Ag^+ + 1e^- \rightarrow Ag\ (metal)$ } reduction

Photography Timeline

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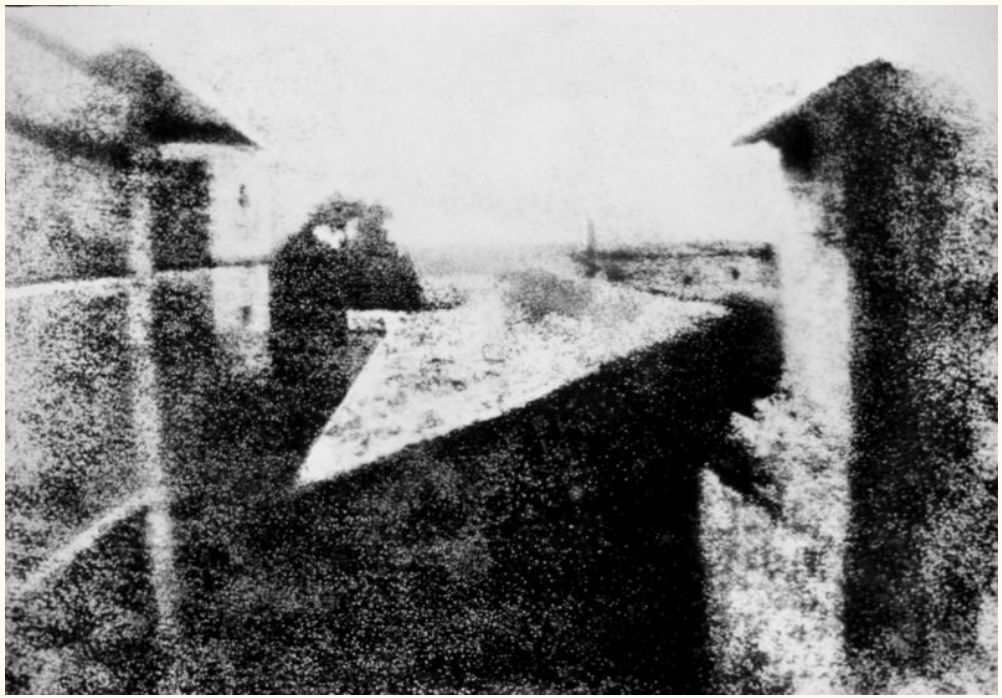
Remember this redox cycle !!!

Photography Timeline

1700 1750 1800 1850 // 1900 1920 1940 1960 1980 2000

T. Wedgwood's images were impermanent…

Nicéphore Niépce's photopaper and the "1st permanent image"



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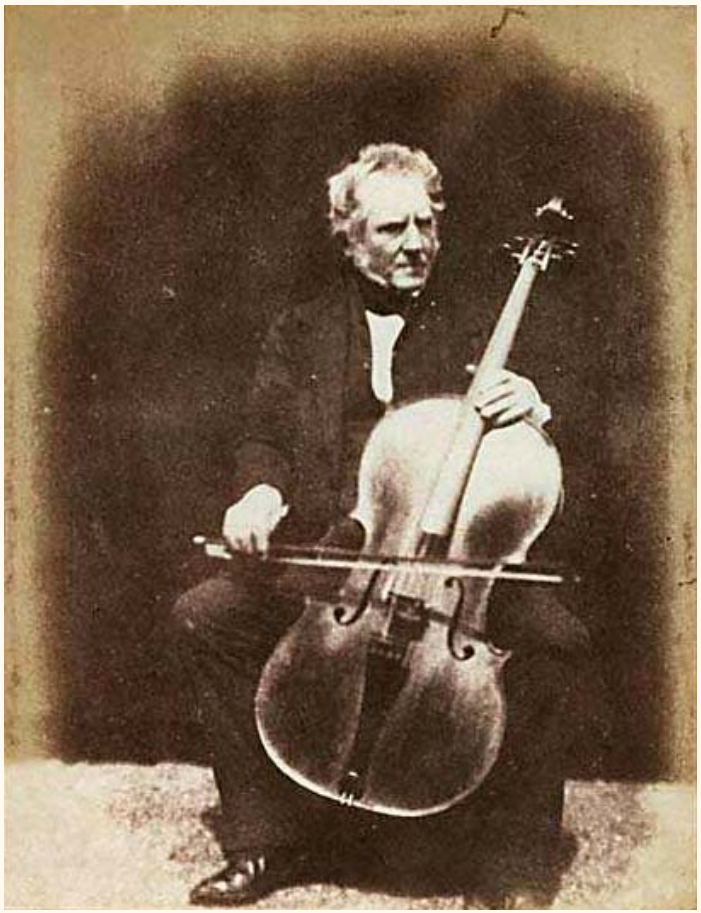


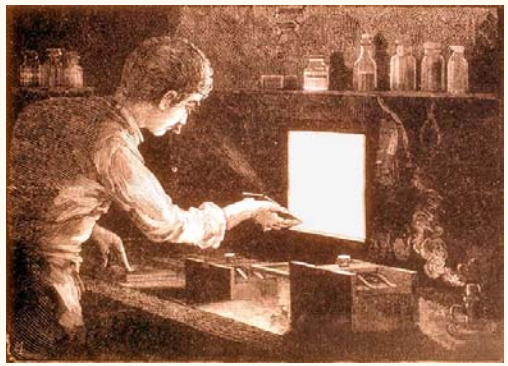
Henry Fox Talbot's calotype process

- Developed in 1841
- Paper coated with silver iodide
- Light exposure produces metal and liberates halide, and metal is then oxidized (turns black)
- KBr stabilizes the silver oxide
- salt prints made from calotype negative after washing

Photography Timeline

1700 1750 1800 1850 // 1900 1920 1940 1960 1980 2000

Polishing Cu/Ag plates

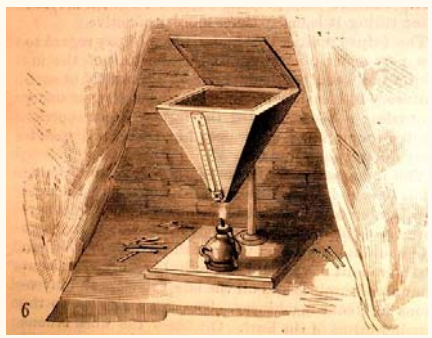


Sensitizing with I/Br

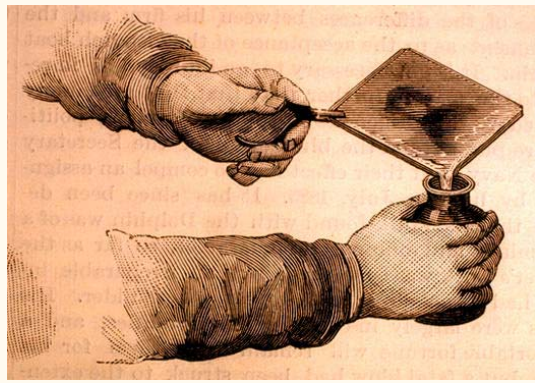
Louis Daguerre's "daguerreotypes"

- Image cast directly on polished plate coated with silver and silver halide from halide vapour (expensive and laborious)

Photography – *long* exposures!



Development of latent image over bath of heated Mercury



Fixing, then gilding / toning

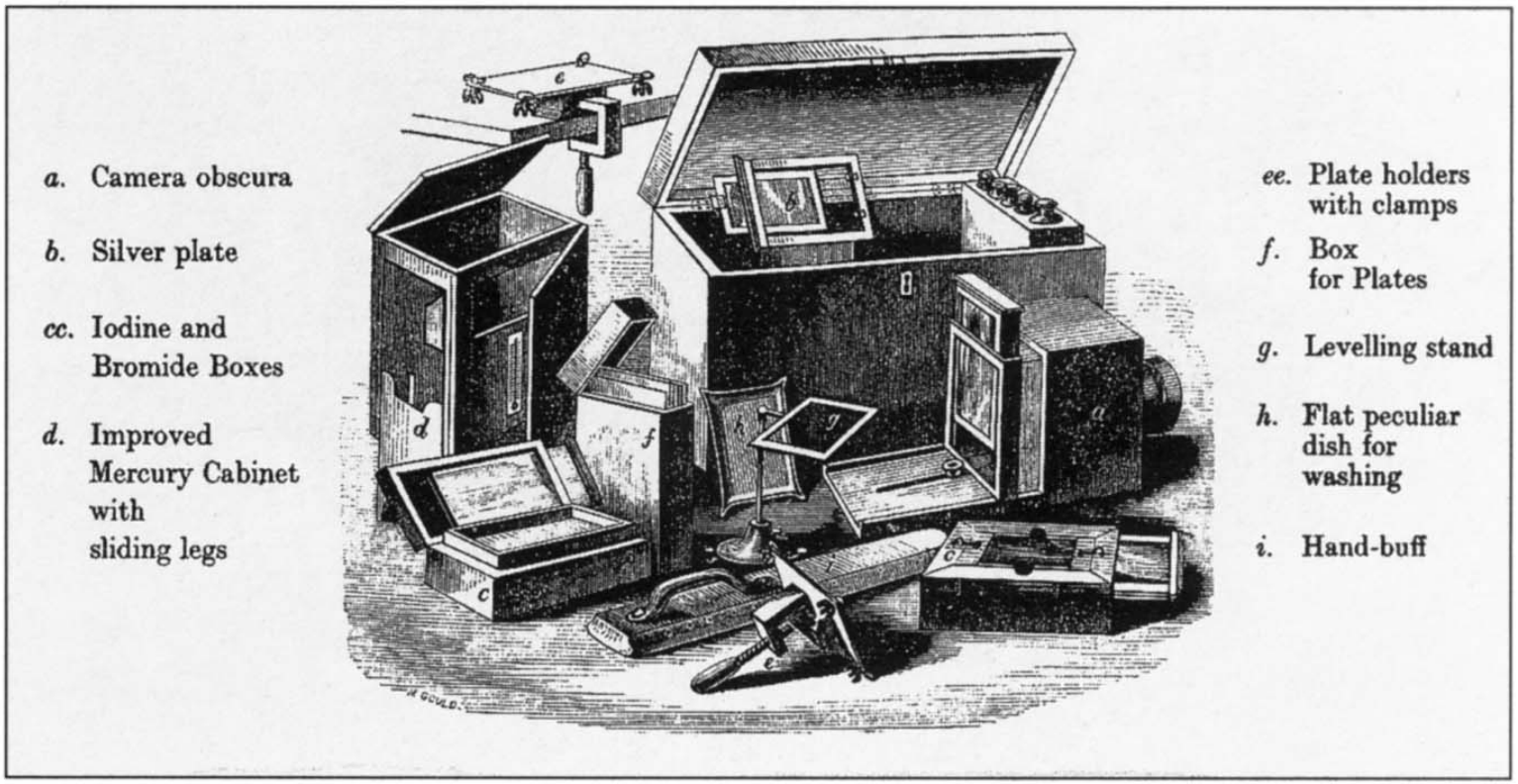
Source: *Scientific American* **56**(4), 47-52 (1887)

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

D-type kit, 1843*

Daguerreotypes

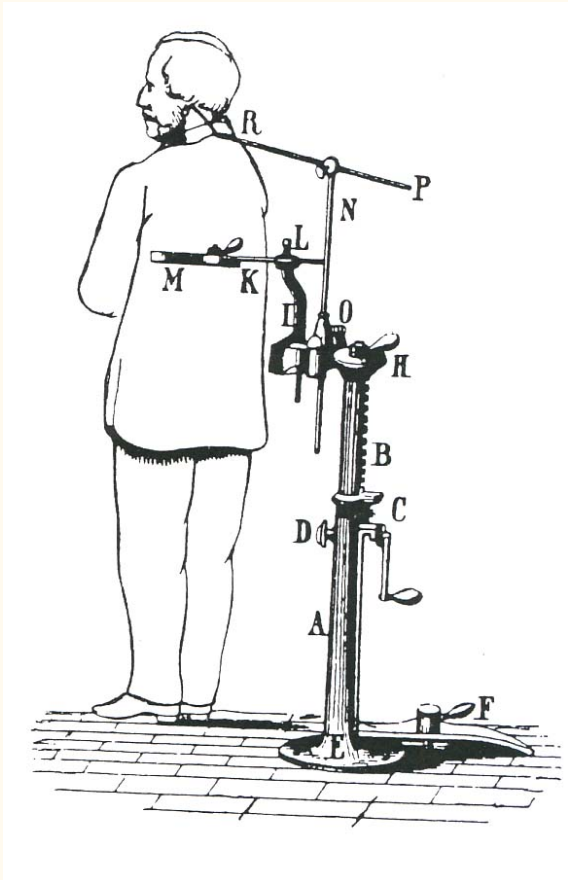


*http://www.photohistory-sussex.co.uk/dagprocess.htm

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Daguerreotypes



Posing stand *

- Image cast directly on polished plate coated with silver and silver halide from halide vapour (expensive and laborious)
- Image is a negative but appears positive if light orientation is correct
- Direct-print process: no negative is generated and so images cannot be duplicated

*http://www.photohistory-sussex.co.uk/dagprocess.htm

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Abraham Lincoln, ~1840 - “The Kaplan daguerreotype”

Daguerreotypes

- Image cast directly on polished plate coated with silver and silver halide from halide vapour (expensive and laborious)
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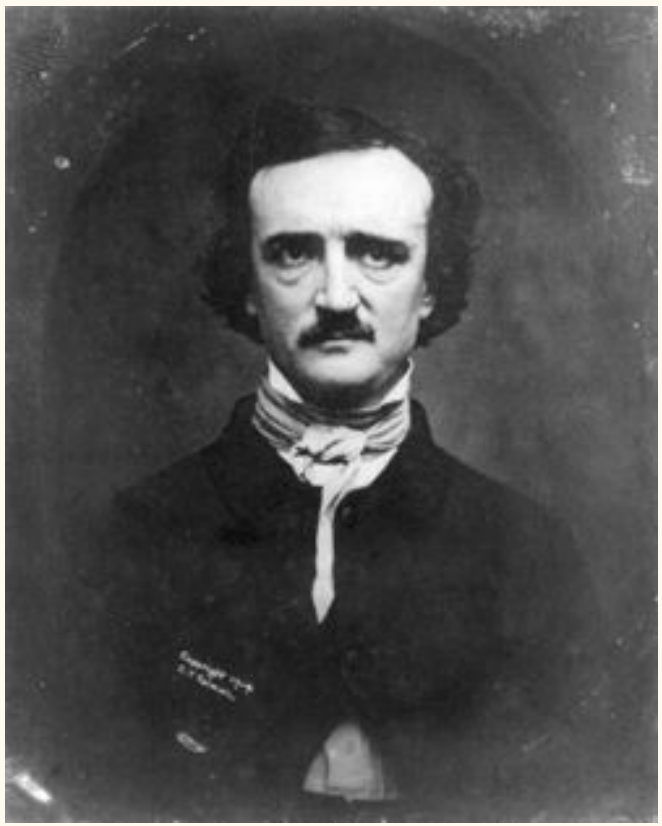

Edgar Allan Poe, ~1848

Daguerreotypes

- Image cast directly on polished plate coated with silver and silver halide from halide vapour (expensive and laborious)
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Photography Timeline

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Floral cyanotype; courtesy of Diwan Bhathal

Herschel and Atkin's cyanotype process

- Uses two primary aqueous chemicals, ammonium Fe(III) citrate and potassium ferricyanide, to form a photosensitive coat on paper
- UV exposure reduces Fe(III) to Fe(II), which then reacts with ferricyanide to form water-insoluble dye "Prussian blue" which stays on paper
- source of the term "blueprints" used in architecture & engineering
- Similar process: gum bichromate

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

James Clerk Maxwell's colour separation photography

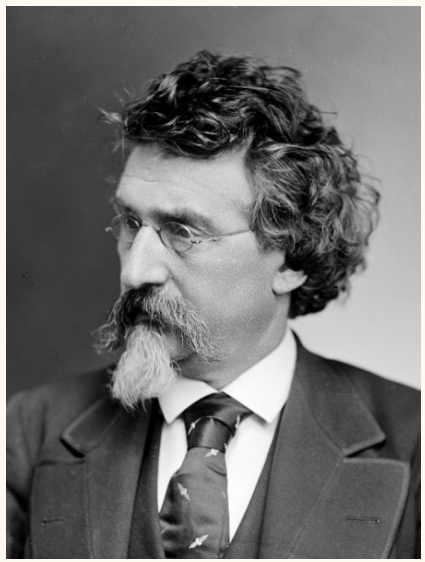
Young Master James with his colour wheel

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

(via collodion invented by Archer and Le Gray, 1850)

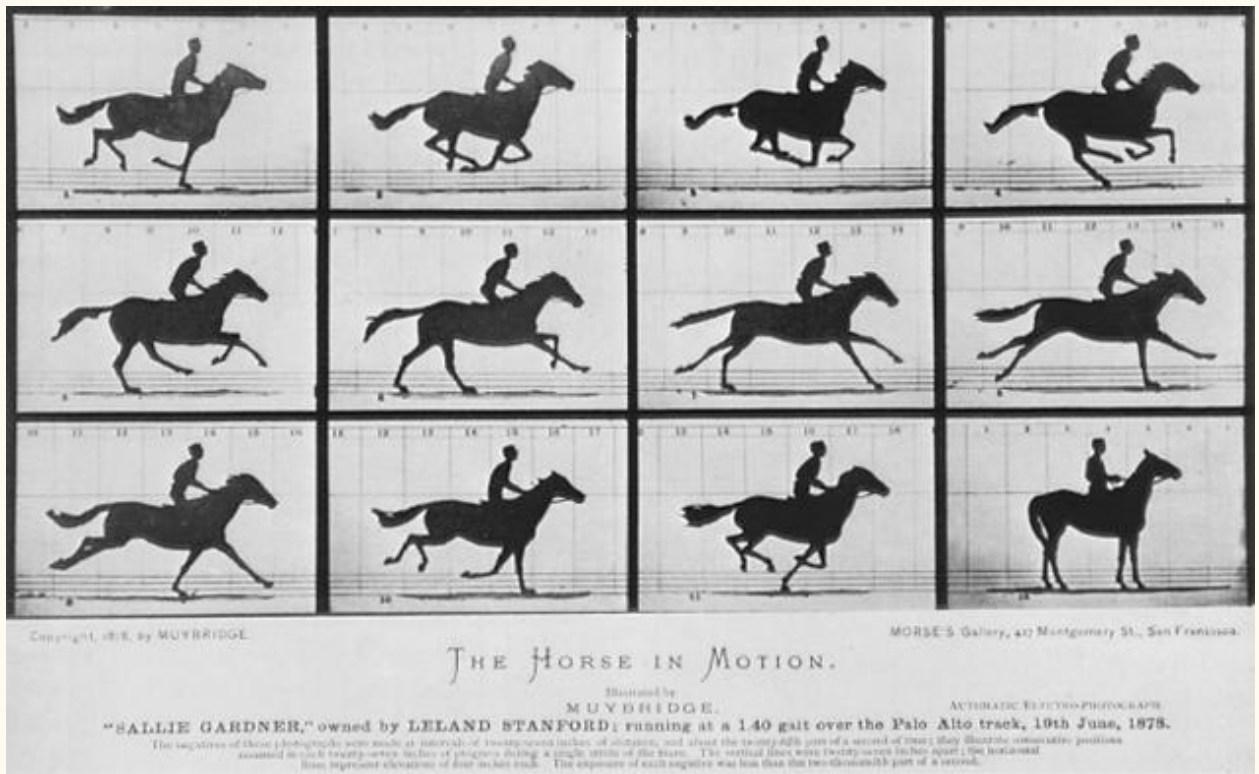
U.S. Civil War – first extensive wartime photojournalism (Mathew Brady et al)



Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Eadweard Muybridge- horses in motion

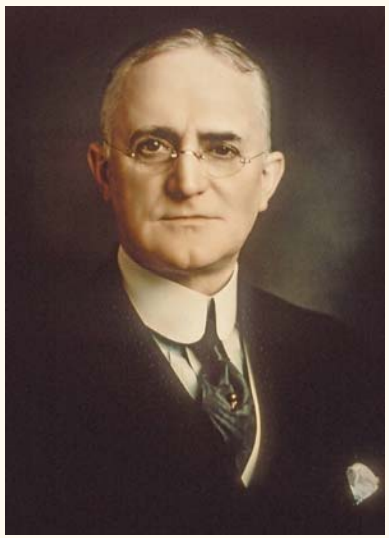


(Electronically triggered)

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

George Eastman's roll film



- Roll film patented in 1884
- Roll film camera patented in 1888; "Kodak" also created that year
- Sold 100,000 cameras in only ten years
- $1 Brownie introduced in 1900
- suicide in 1932
- Donated $100M in his life, anonymously, to Rochester University and to MIT

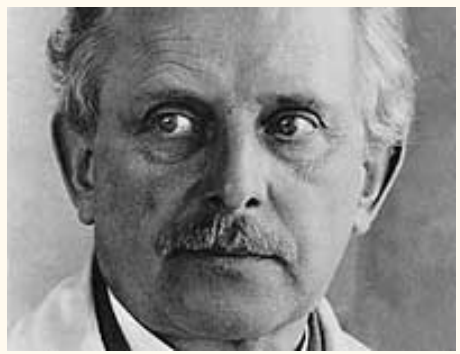
2007: 107th birthday of the brownie

See http://www.brownie-camera.com

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Oskar Barnack's Rangefinder
birth of Leitz Camera
(a.k.a. Leica)



Barnack

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

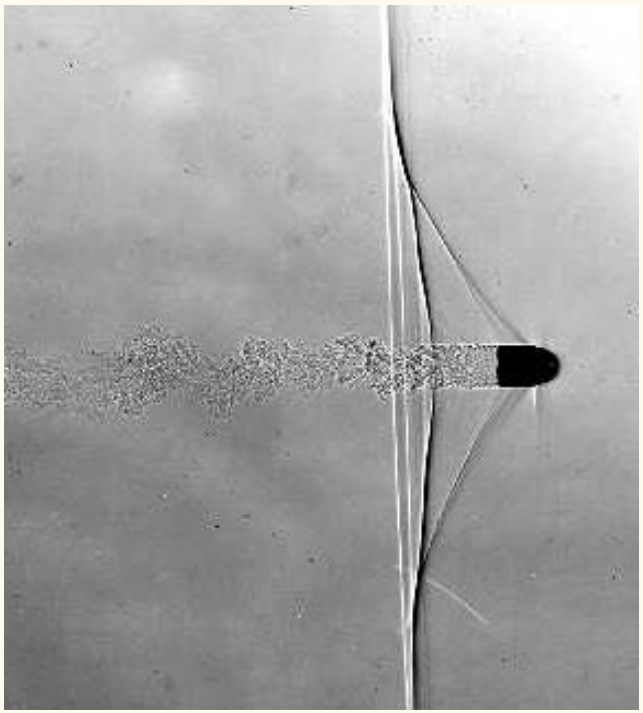
Oskar Barnack's Rangefinder
birth of Leitz Camera
(a.k.a. Leica)

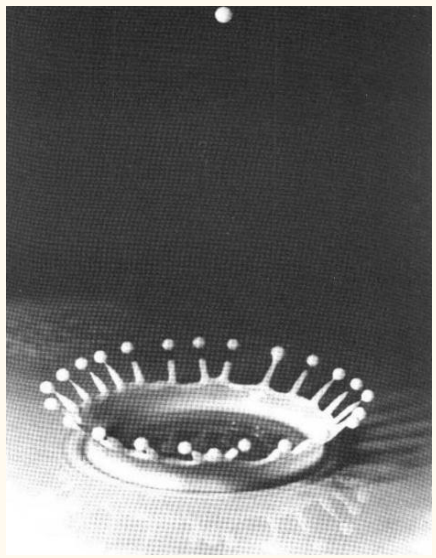
Leica M8 (2006), the first truly pro-grade digital manual focus RF

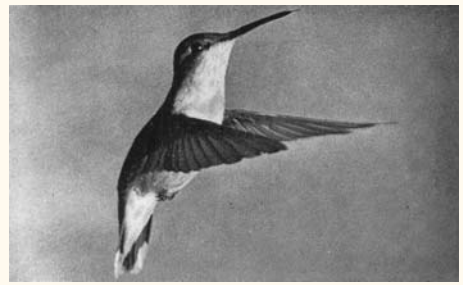
Photography Timeline

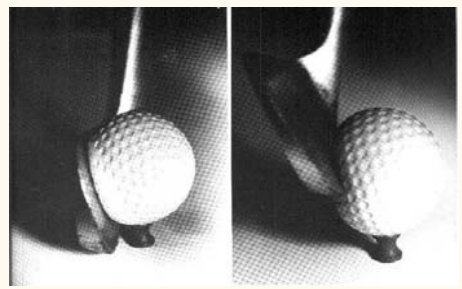
1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Harold ("Doc") Edgerton's strobe photography at MIT (late '20s on)









Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Ansel Adams, *Arches, North Court, Mission San Xavier del Bac* (1968) captured on Polaroid Type 55 “pos/neg” film

Edwin Land’s “polaroid”

- Patented in 1929
- Trivia: Land designed the optics for the U2 spy plane
- Trivia: Land was one of the richest scientists… ever.
- 20x24” polaroid cameras are still in operation

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

20x24” Celebrity Polaroid
Timothy Greenfield

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Photography Timeline

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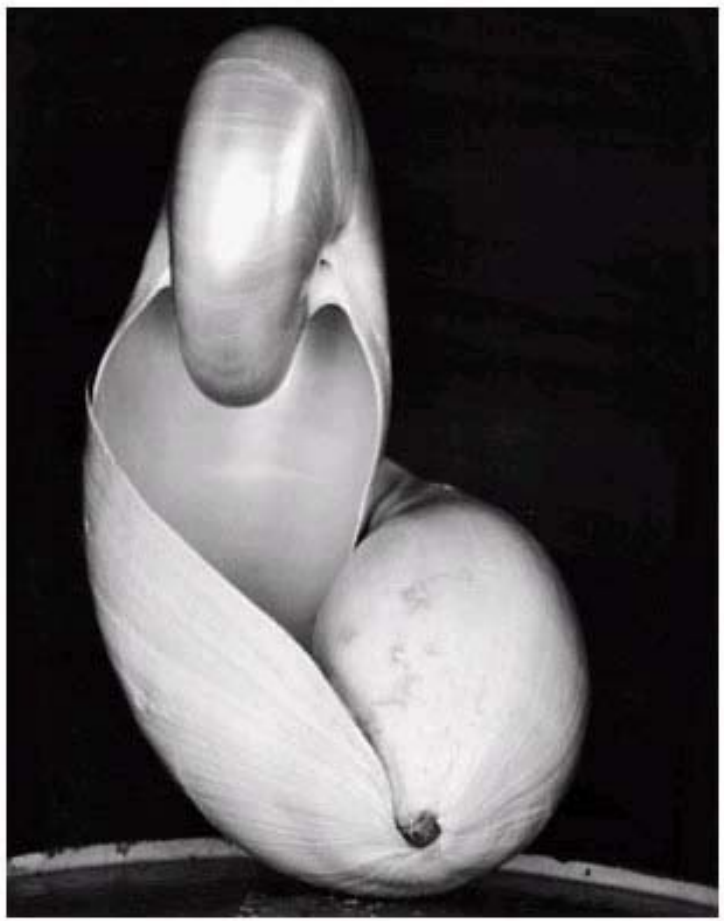
Formation of "Group f/64" by Weston, Adams, Cunningham, and Van Dyke



Shell
Edward Weston

Edward Weston

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Aspens, New Mexico
Ansel Adams

Formation of "Group f/64" by Weston, Adams, Cunningham, and Van Dyke

Ansel Adams

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Henri Cartier-Bresson begins work with Leica

Henri Cartier-Bresson

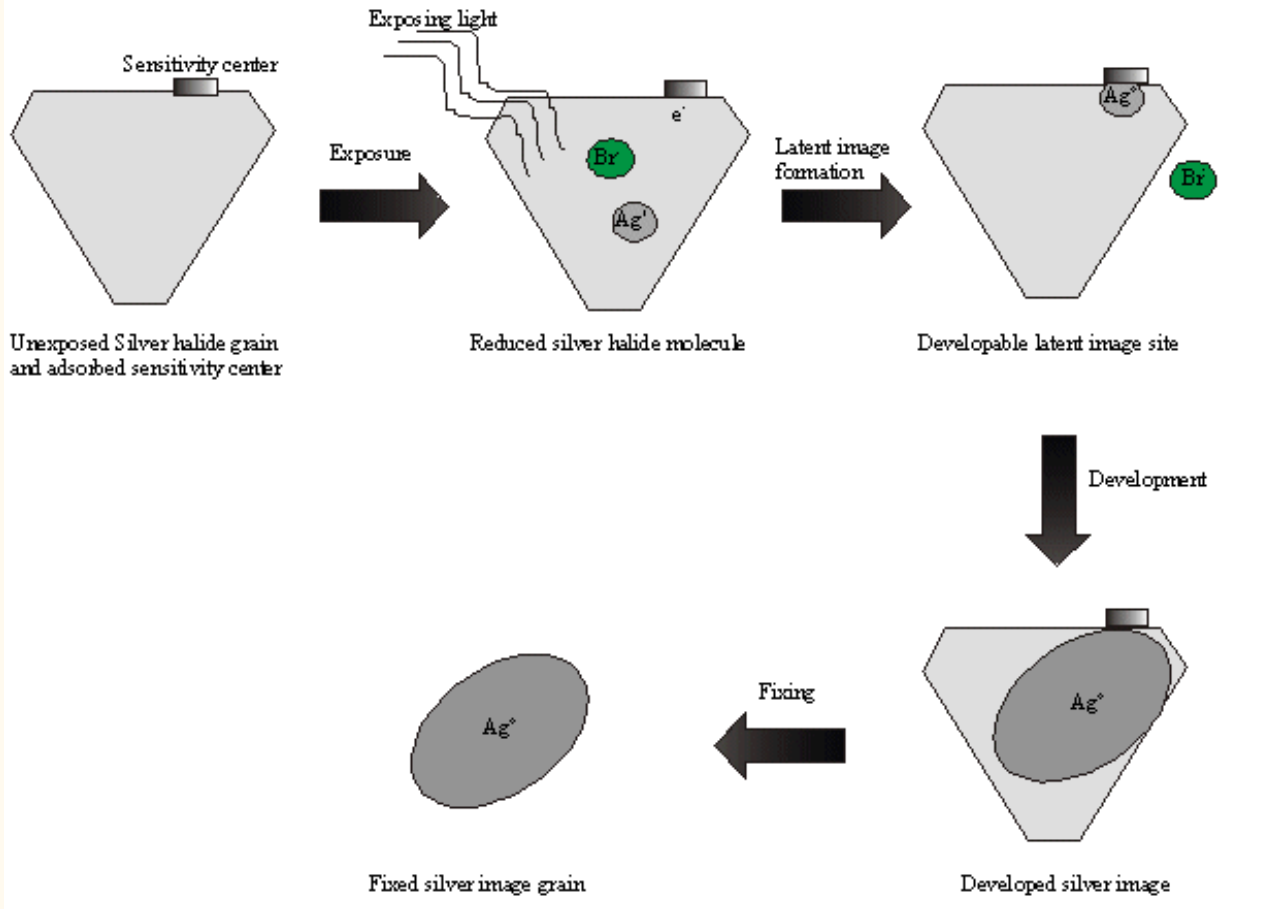
Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

HCB

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000



Theory of Latent Image Formation - Gurney & Mott (1938)

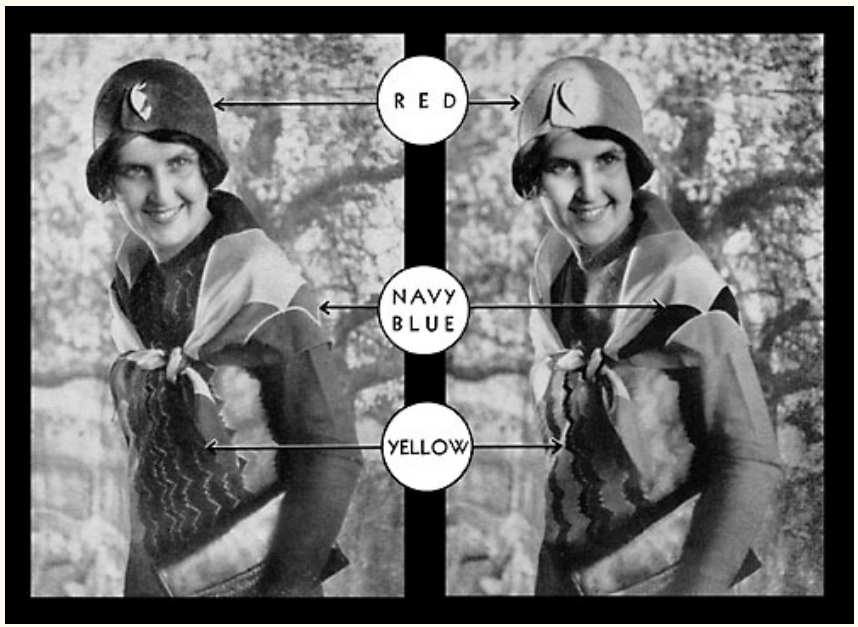
*http://www.cheresources.com/photochem.shtml

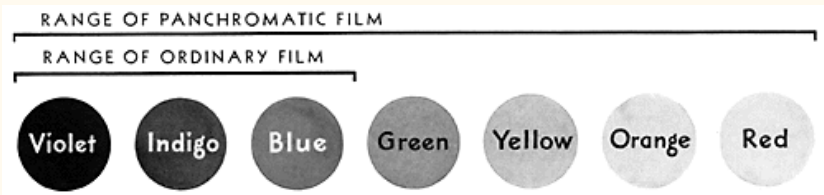
Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

"Beauty heretofore impossible"

Pan films
Kodak ~1930





Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

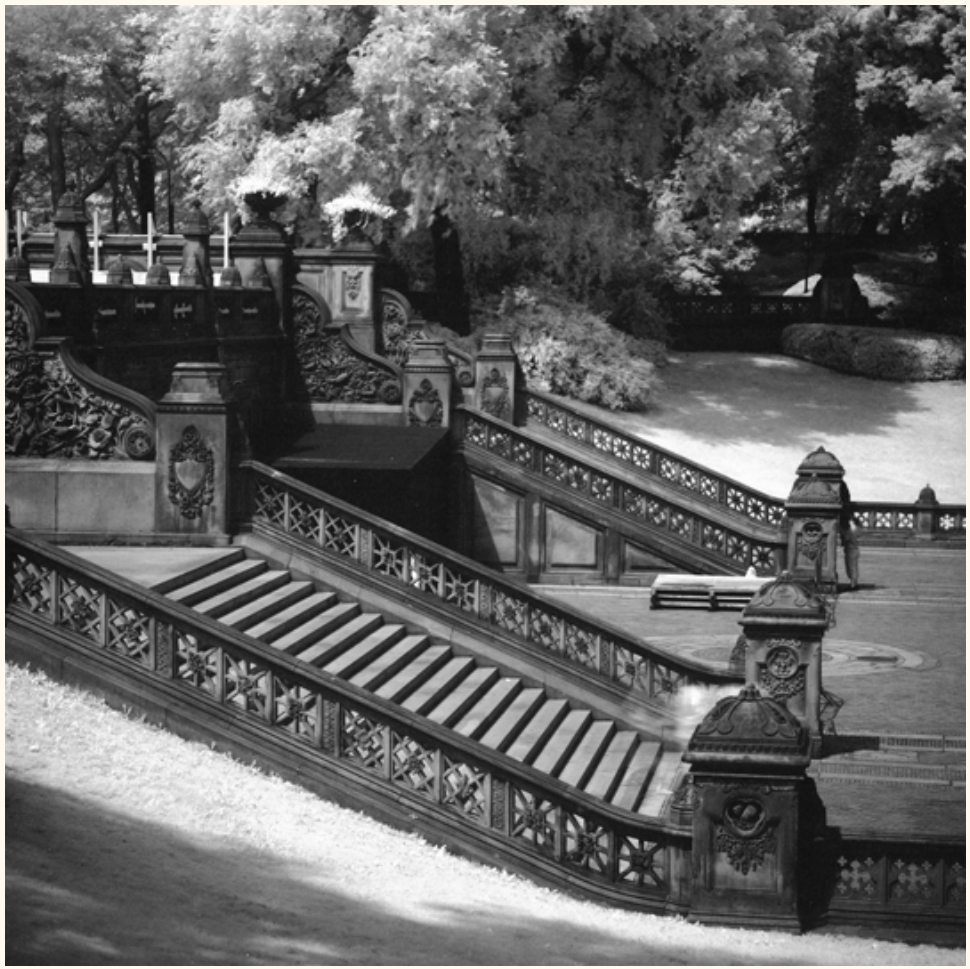
UV and IR photography- Robert Williams Wood

- Sensitizers had been previously discovered
- Developed “Wood’s glass” to block visible light
- proposed use of UV for secret communication
- First to do UV fluorescence
- Glowing of trees in IR photos is called the Wood effect
- Less atmospheric scatter in IR; $1/\lambda^4$ (Rayleigh)

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Modern IR photography



Central Park (2006)

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Modern IR photography

Albemarle (2007)

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Modern IR photography

Mares and Foals (2006)

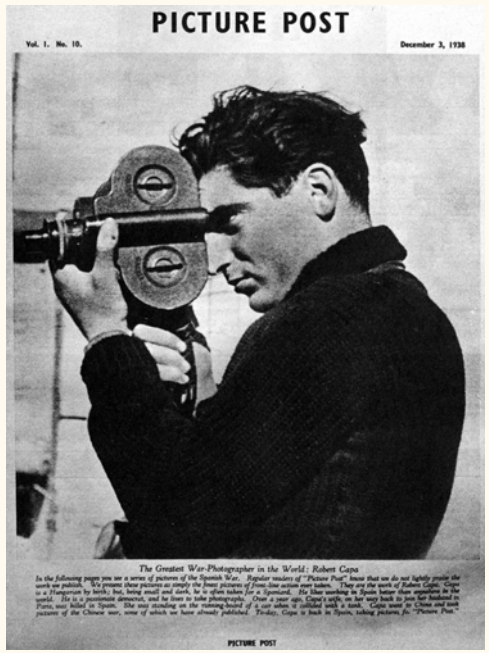
Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Loyalist Militiaman at the Moment of Death,
Cerro Muriano, September 5, 1936.

D-day landings, 1944

Robert Capa
War-time photography


PICTURE POST

Vol. 1. No. 10. December 3, 1938

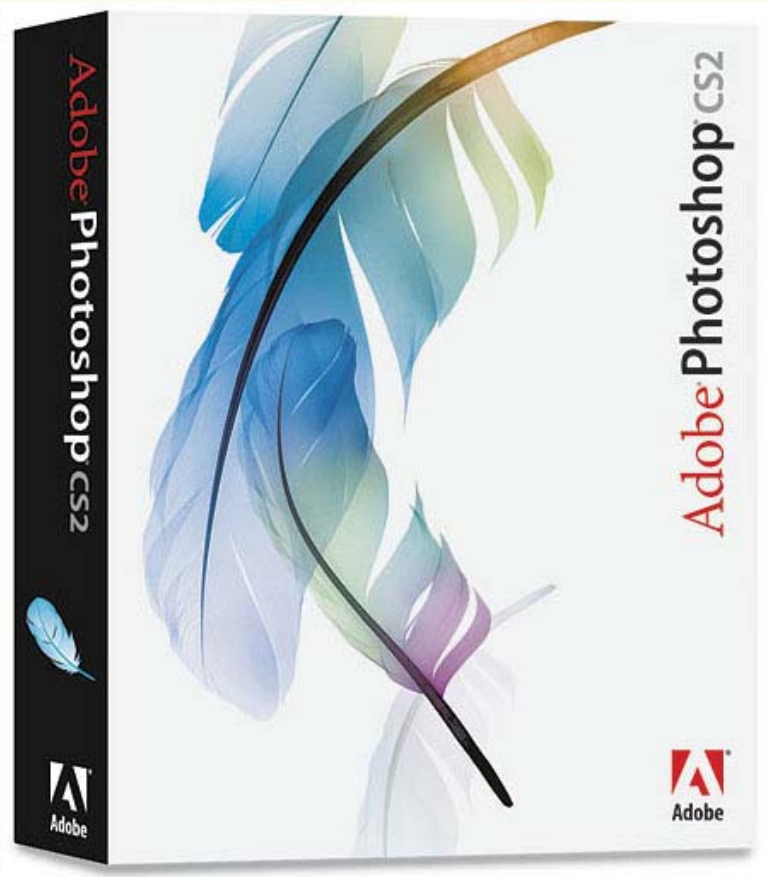
The Greatest War-Photographer in the World: Robert Capa

PICTURE POST

"The desire of any war photographer is to be put out of business." - Capa

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000



Adobe Photoshop (1988)

the digital darkroom emerges…

Photography Timeline

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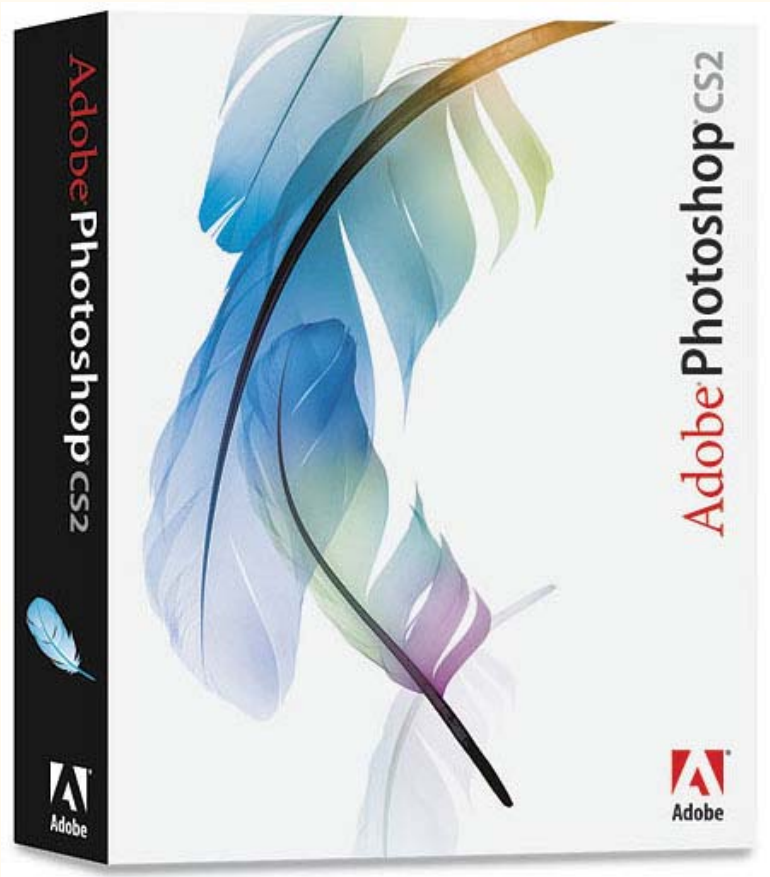


Adobe Photoshop (1988)

the digital darkroom emerges…

… and hybrid photography is born.

Photography Timeline

1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

First “pro” DSLR- Introduced by Kodak, 1991

- Based on Nikon F3 body
- 1.3 megapixel
- 3.5” hard drive
- External module to visualize images

Photography Timeline

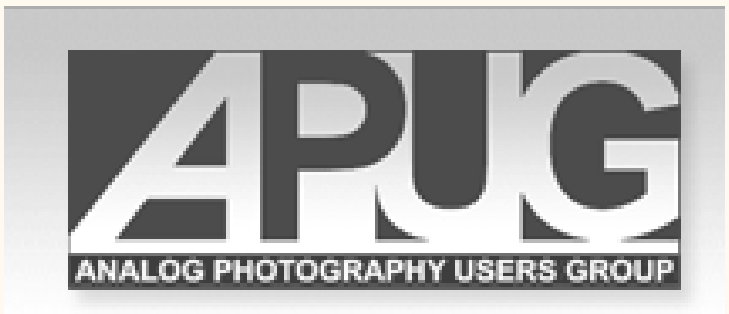
1700 1750 1800 1850 1900 1920 1940 1960 1980 2000

Canon and Nikon full-frame DSLRs

Epson RD1 and Leica M8 DRFs

Photography Timeline

2007: Lots of people still use film!



www.apug.org

http://www.apug.org/forums/portfolios.php?u=16571

One Hundred Years of Photo Physics

I. Introduction

II. Timeline from B.C. to 2007

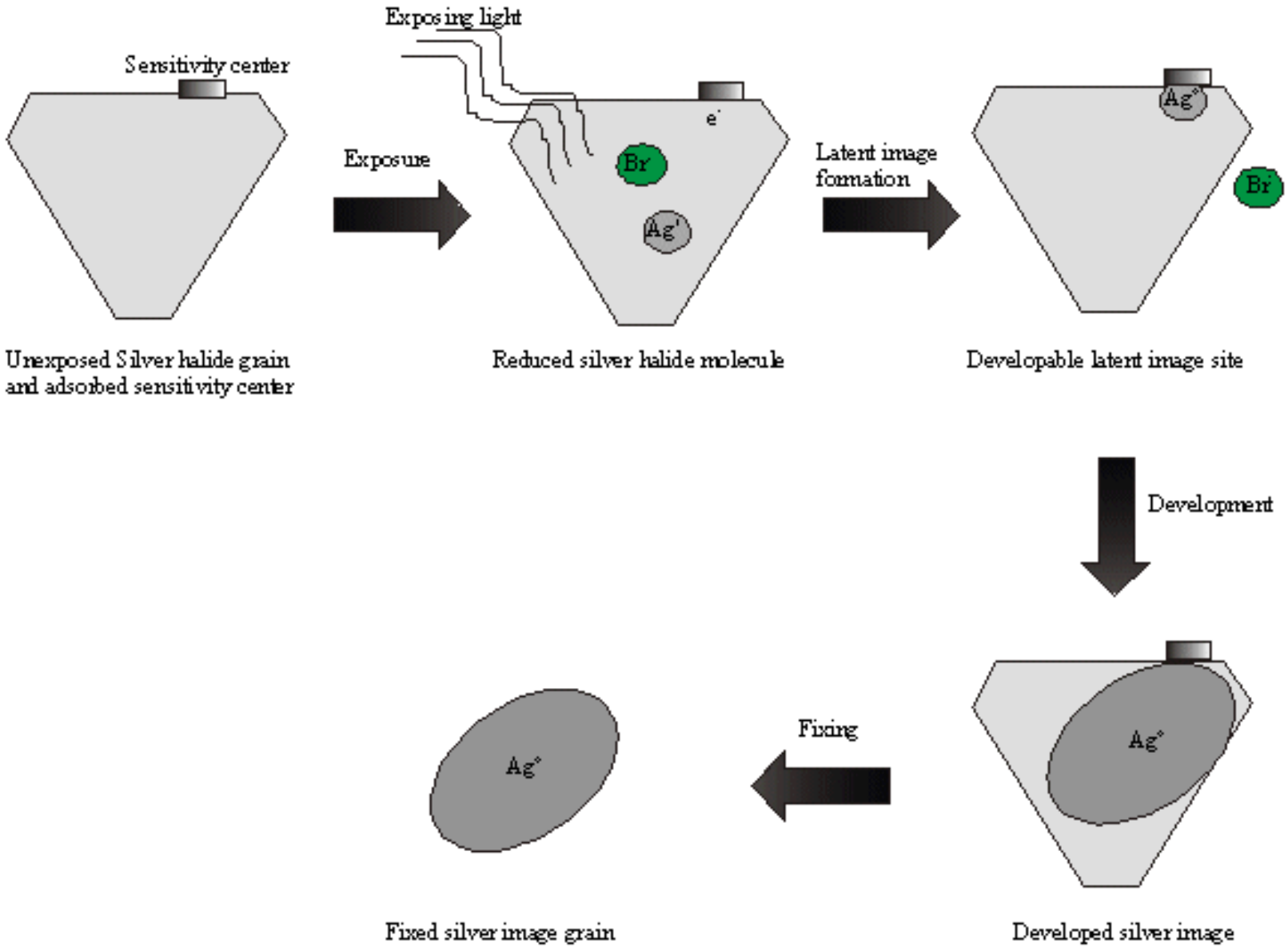
III. [Some of the] Contributions of J.W. Mitchell

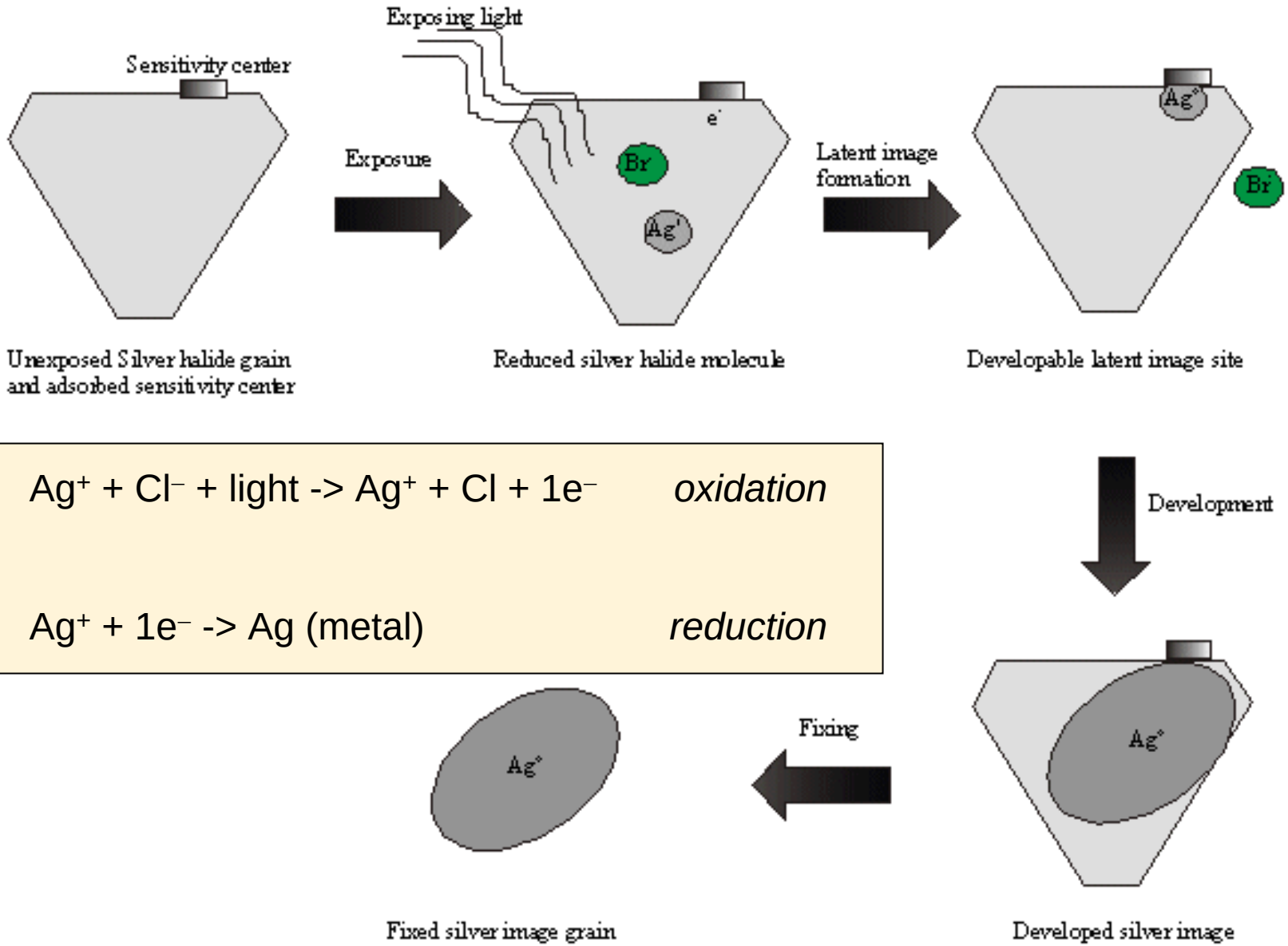
- photographic sensitivity
- hole migration
- role of dislocations
- control of fogging

IV. Silver Halide in the Modern Era

V. The Digital Future

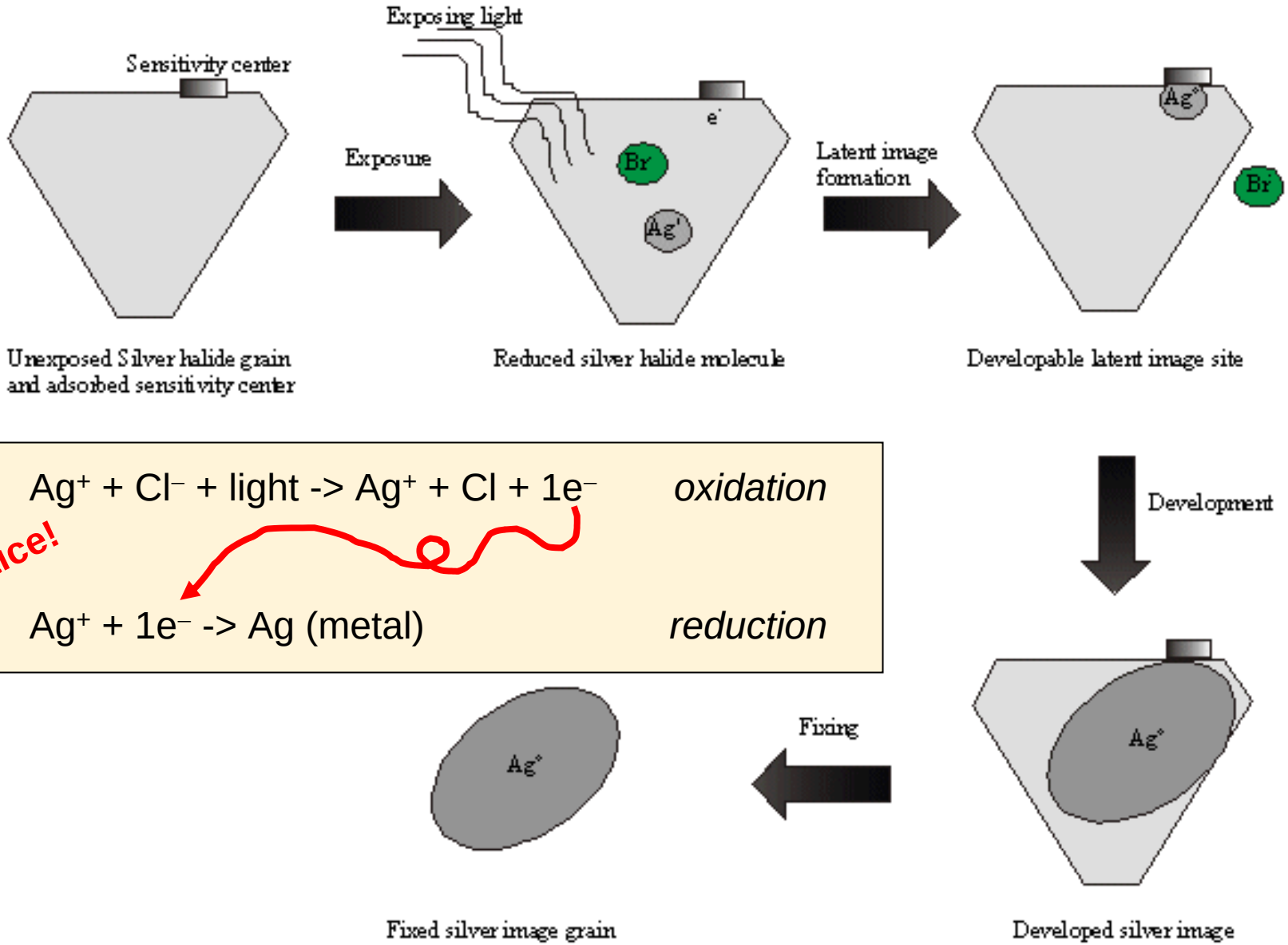
Keith Williams, UVa September 2007


Exposing light
Sensitivity center
e⁻
Exposure
Br
Ag⁺
Latent image formation
Ag°
Br⁻
Unexposed Silver halide grain and adsorbed sensitivity center
Reduced silver halide molecule
Developable latent image site
Development
Ag°
Fixing
Ag°
Fixed silver image grain
Developed silver image



$Ag^+ + Cl^- + light \rightarrow Ag^+ + Cl + 1e^-$ *oxidation*

$Ag^+ + 1e^- \rightarrow Ag$ (metal) *reduction*


Exposing light
Sensitivity center
Exposure
e⁻
Br
Ag°
Latent image formation
Ag°
Br
Unexposed Silver halide grain and adsorbed sensitivity center
Reduced silver halide molecule
Developable latent image site
Ag⁺ + Cl⁻ + light -> Ag⁺ + Cl + 1e⁻ oxidation
Lattice!
Ag⁺ + 1e⁻ -> Ag (metal) reduction
Development
Ag°
Fixing
Ag°
Fixed silver image grain
Developed silver image

The Silver Halide Process: where and what is the **latent image**, actually?

Gurney and Mott (1938):

Photoelectrons migrate to traps (sensitivity centers), where they form a silver speck- this is the latent image.

Berg (1948):

There are external (surface) and internal latent images.

Mitchell (1955-):

A hole is also generated upon photoexcitation, recombination is avoided because holes are trapped by surface halide ions or adsorbed sensitizer molecules.

Silver sulfide sensitivity centers are formed preferentially where dislocations meet the crystal surface.

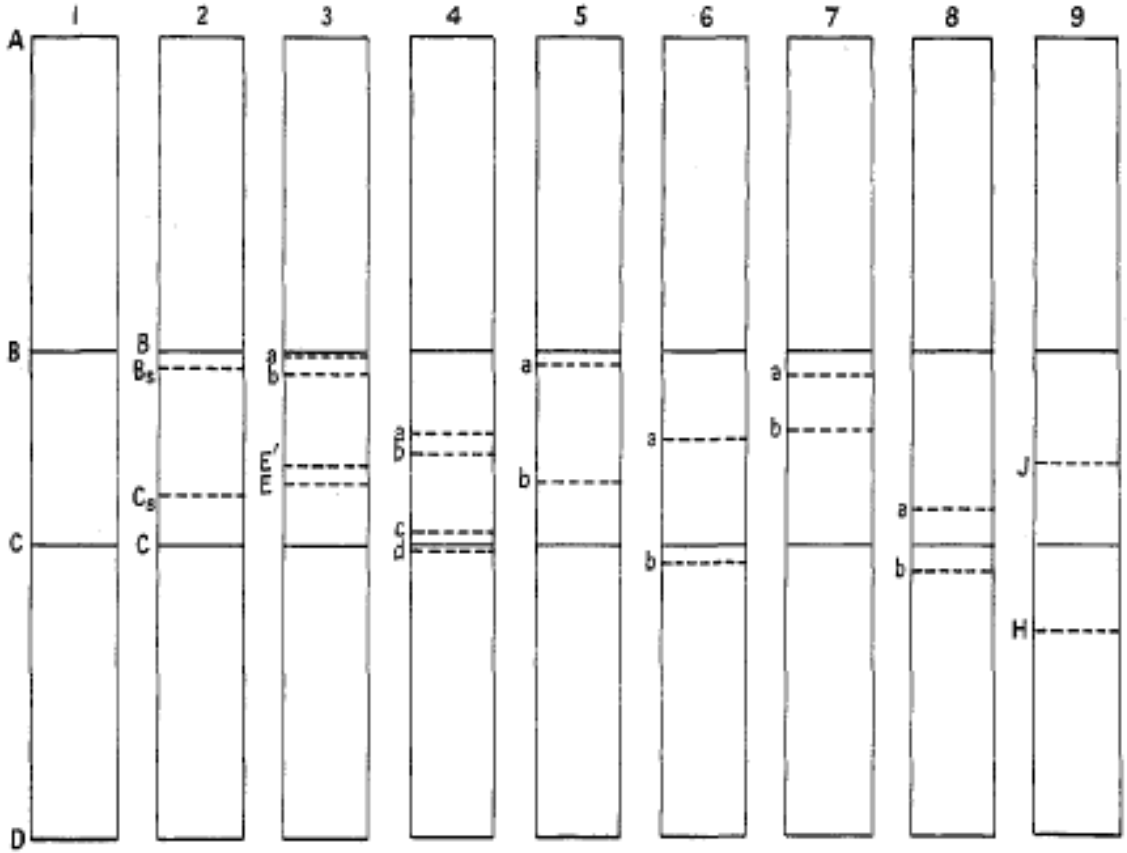
Internal latent image is formed by separation of silver atoms along dislocation lines.

Condition for a stable latent image: 4 silver atoms per crystal.

Minimum requirements for a stable (developable) latent image:

traps for conduction electrons at room temperature but do trap positive holes and may therefore suffer regression. The latent sub-image specks are transformed into stable latent image specks of minimum size by combination with an interstitial silver ion and conduction electron. At this stage, a critical change in the mechanism takes place: the group of three silver atoms, which has been formed from interstitial silver ions and electrons by the processes which have been outlined, can adsorb a silver ion from the surface of the silver halide crystal and thus become positively charged in thermal equilibrium at room temperature, the compensating negative charge being provided by a vacant silver ion lattice site in the neighbourhood. These and all larger groups of silver atoms which are positively charged repel positive holes, and are therefore protected from regression. They trap conduction electrons and the positive charge is then immediately restored to the uncharged speck by the adsorption of a further silver ion from the surface and the formation of a vacant silver ion lattice site. The potential differences arising from the trapping of the positive holes and electrons at separated sites are eliminated by the motion of silver ions and, through a succession of such processes, the silver specks increase in size until they become visible particles of photolytic silver.

Mitchell (1957)



Energy levels involved in the formation of the latent image in crystals of silver bromide

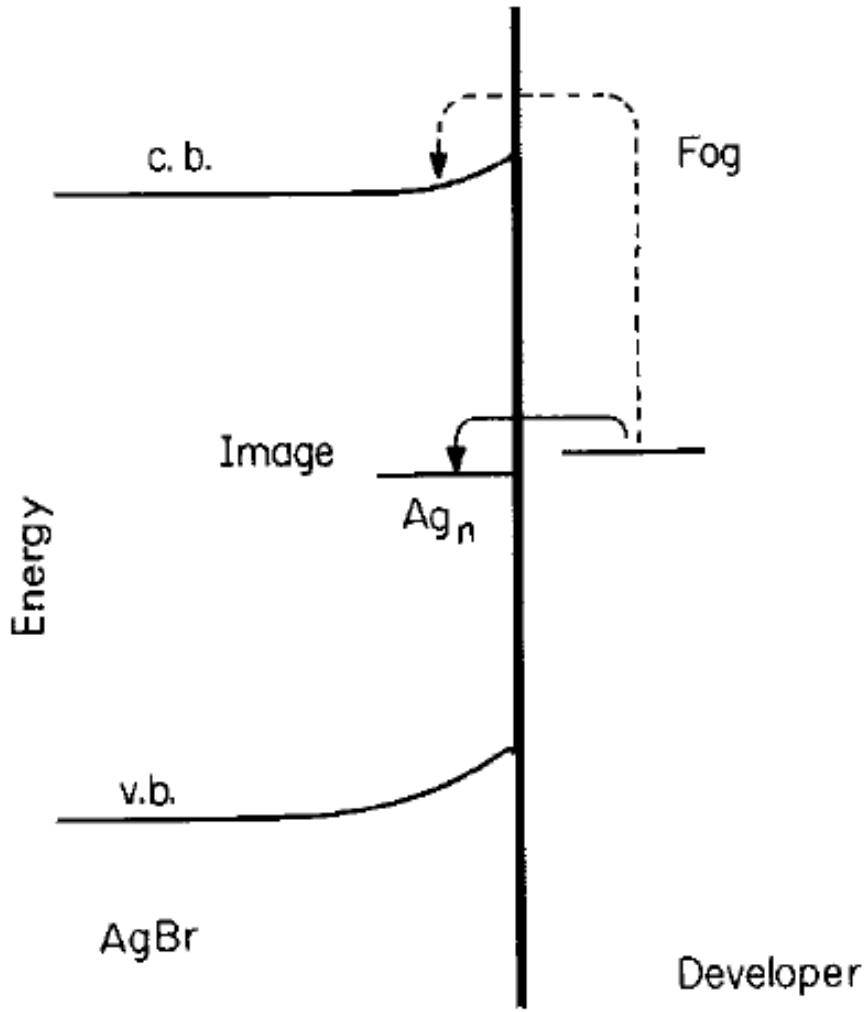
1. Energy levels within the crystals : AB, the conduction band ; BC, the forbidden band ; CD, the full band.

2. Localized energy levels at the surfaces of the crystals : BB_s, range of unoccupied levels associated with surface silver *ions* ; C_sC, range of occupied levels associated with surface halide *ions*.

3. Localized levels associated with molecules of silver sulphide *adsorbed at sites adjacent to surface silver ions* : ab, acceptor levels which provide very shallow traps for conduction electrons ; E′E, range of highest occupied levels which furnish traps for positive holes.

Mitchell (1957)

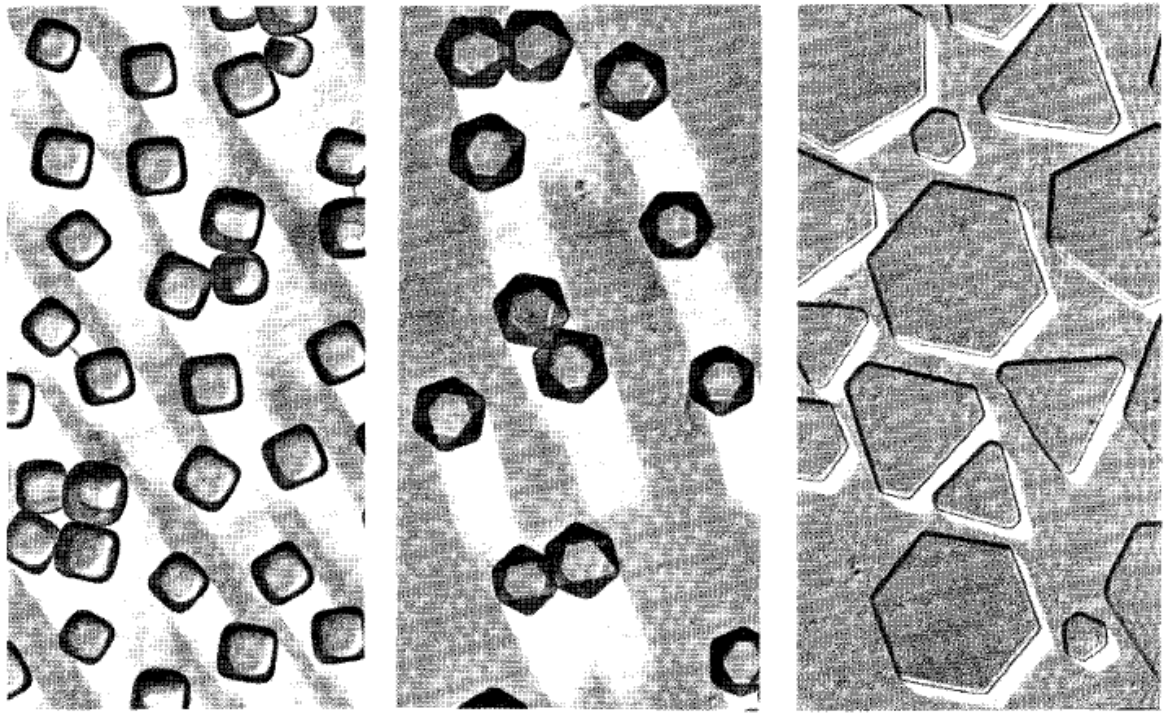
The Silver Halide Process: how not to fog the image



Hamilton (1978)

The Silver Halide Process: grain

cubic *octahedral* *tabular*



Ilford delta films: epitaxial (core shell) grains

Hamilton (1978)

One Hundred Years of Photo Physics

I. Introduction

II. Timeline from B.C. to 2007

III. The Contributions of J.W. Mitchell

IV. Silver Halide in the Modern Era

- equipment diversity
- resolution
- camera movements
- output options

V. The Digital Future

Keith Williams, UVa September 2007

Camera Movements- the **Scheimpflug** principle ~1904

Toyo
view camera

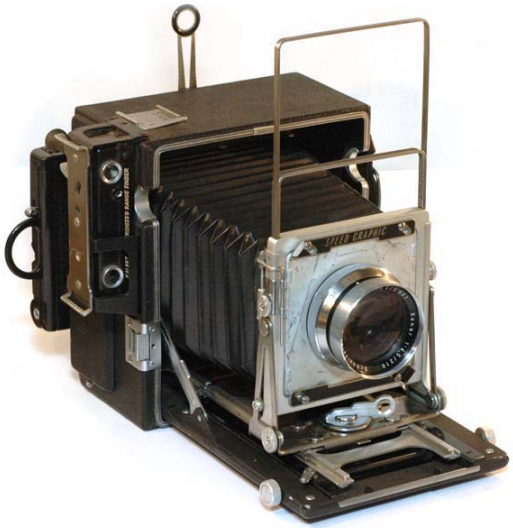
Lensbaby

Canon t&s lens

Lensbaby

But… poor reproducibility,
low resolution, few focal length options,
severe falloff etc.

Camera Movements –a Renaissance

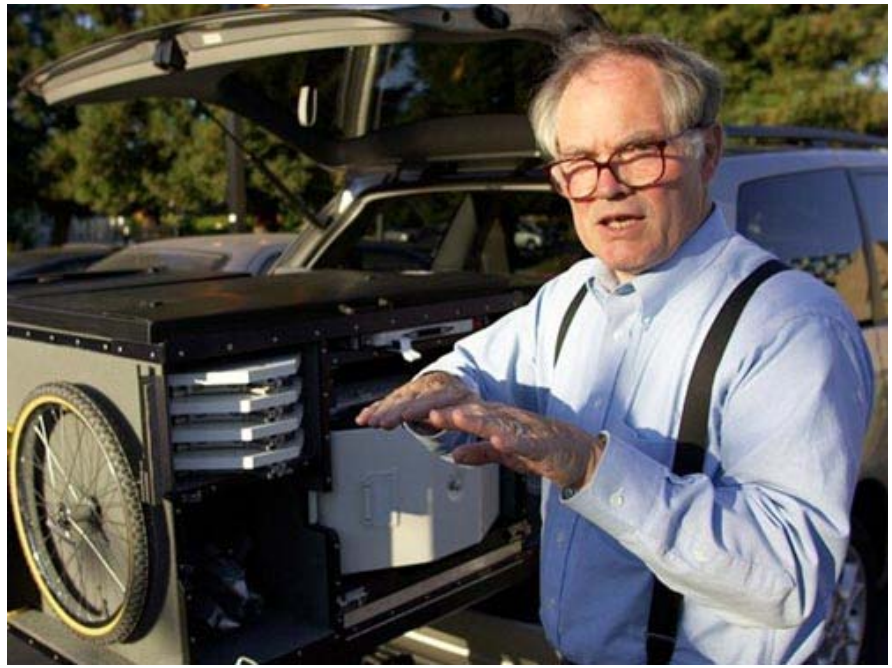


~1950s era press camera

David Burnett, *Nat. Geo.*

Gigapixel Project

- ULF 9x18 inch plate camera (same as used in U2 spy plane)
- Kodak aerial roll film, resolution: 4000 pixels per inch



Graham Flint*

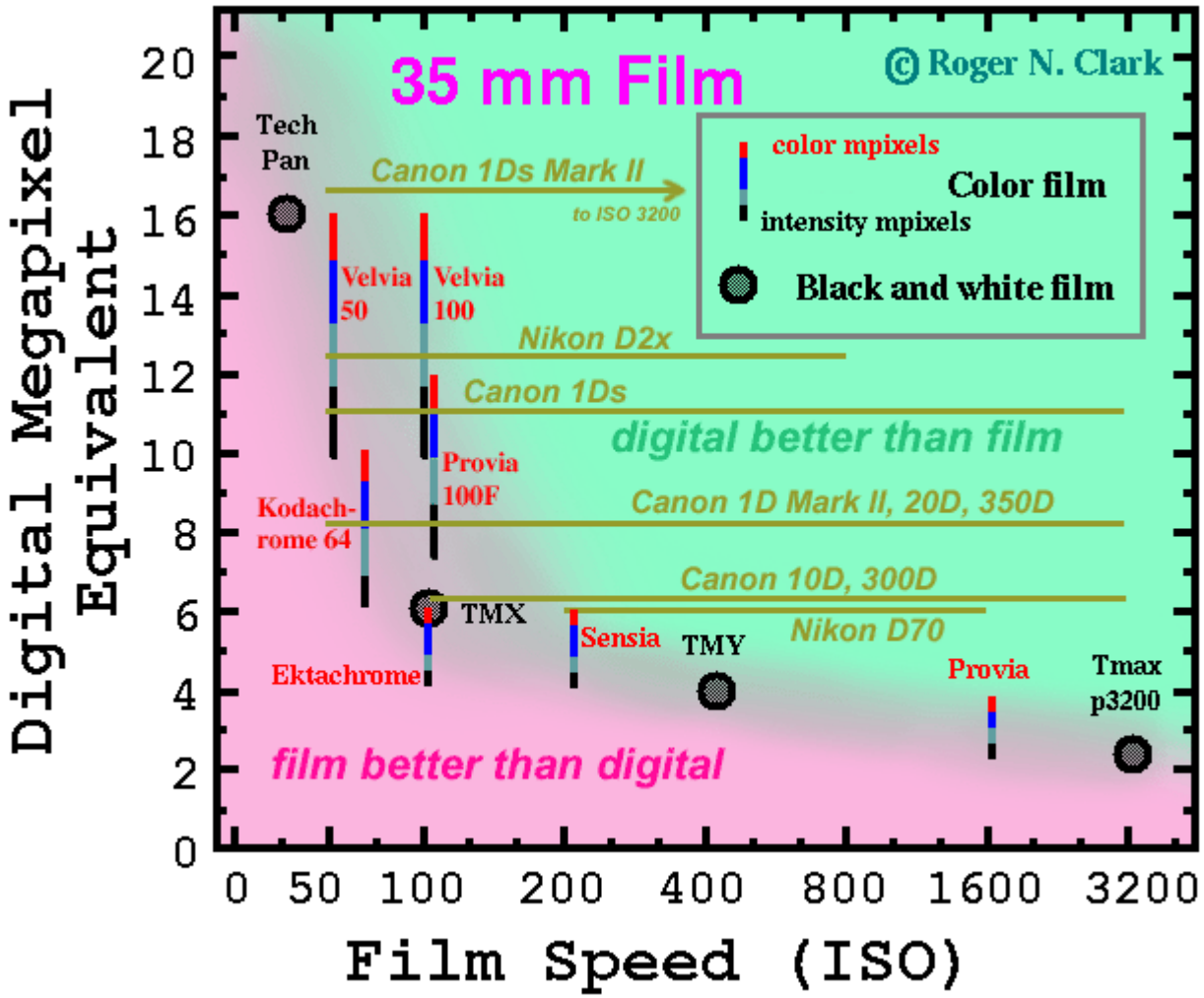
*http://www.wired.com/gadgets/digitalcameras/news/2005/02/66498

Gigapixel Project

Gigapixel Project

Gigapixel Project

Gigapixel Project


35 mm Film
© Roger N. Clark
Digital Megapixel Equivalent
Film Speed (ISO)
0
2
4
6
8
10
12
14
16
18
20
0 50 100 200 400 800 1600 3200
color mpixels
Color film
intensity mpixels
Black and white film
Tech Pan
Canon 1Ds Mark II
to ISO 3200
Velvia 50
Velvia 100
Nikon D2x
Canon 1Ds
digital better than film
Provia 100F
Kodach-rome 64
Canon 1D Mark II, 20D, 350D
Canon 10D, 300D
TMX
Sensia
TMY
Nikon D70
Ektachrome
Provia
Tmax p3200
film better than digital

Film vs. digital:
Image detail comparisons…

39 mp digital back

drum-scanned velvia 4x5”

http://www.luminous-landscape.com/essays/Cramer.shtml

Digital 39mp system: ~$30k!!!

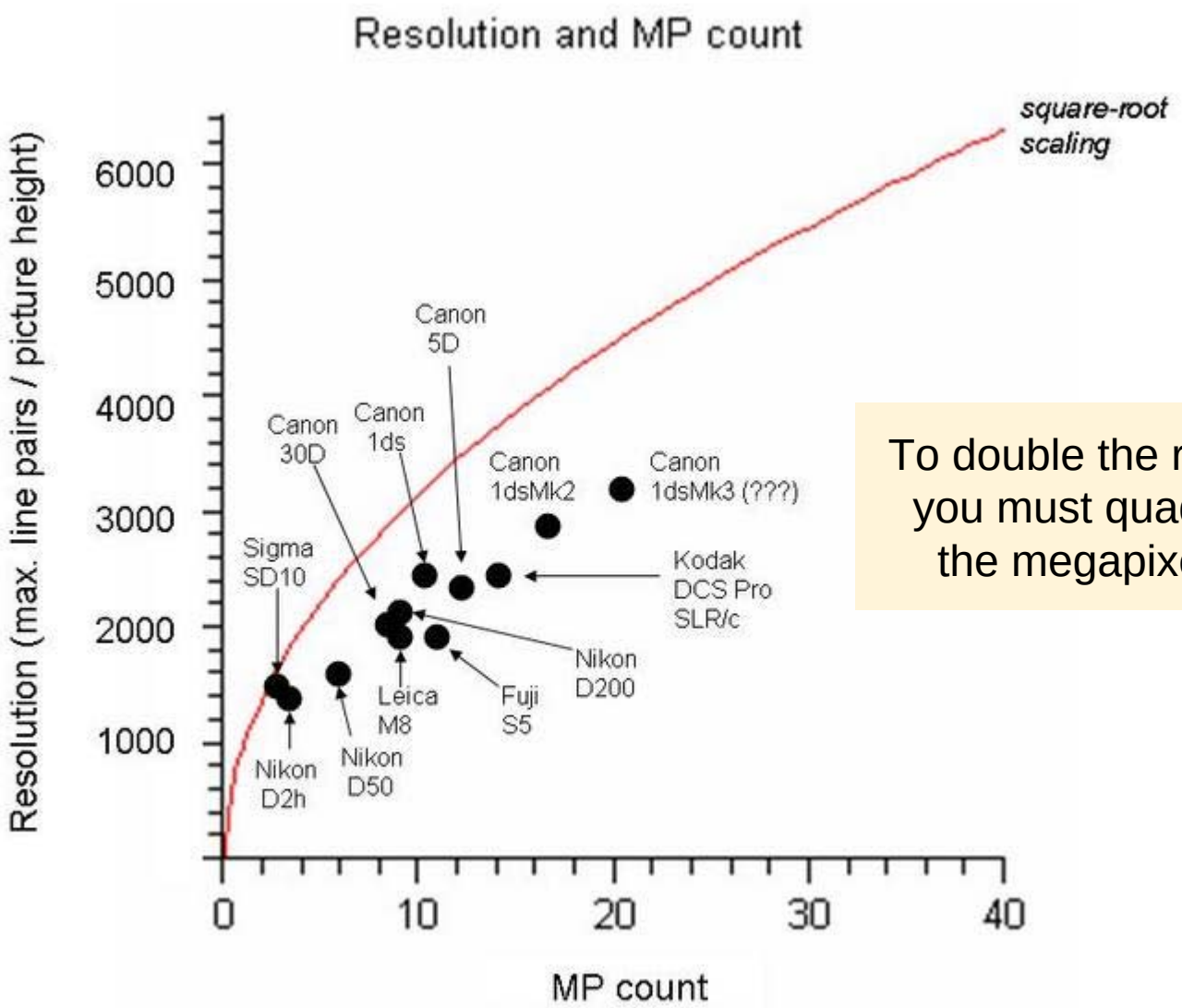
4x5 system: ~$500

39 mp digital back

drum-scanned velvia 4x5”

http://www.luminous-landscape.com/essays/Cramer.shtml

Who do we care about megapixels?!



To double the resolution, you must quadruple the megapixel count !

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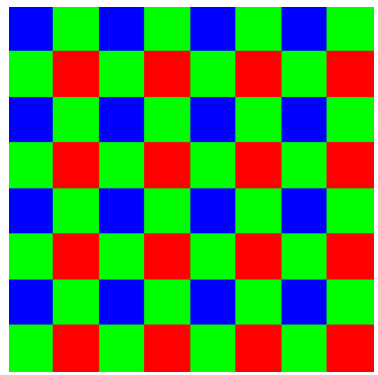
- Full(er) frame DSLRs at lower cost
- Digital backs at lower cost
- Foveon architecture as opposed to Bayer
- The camera of the future?



Keith Williams, UVa September 2007


ALARM
OFF
TIME
SET
MENU
SELECT
DISPLAY
Canon
FOLDER
FILE
CLEAR
WB
USM
WB +/-
SAT
ON OFF
CALL SPOCK
Batt
Null
ON
OFF
PEE BREAK NOW
ADAMS MODE
OFF
ON
L
MOOD
CALL
WINE
BEER
GIN
COKE
IDEAS
JOBS
SEX
MONEY
PIZZA

“I am sure the next step will be
the electronic image, and I hope
I shall live to see it.
I trust that the creative eye
will continue to function,
whatever technological innovations
may develop.”

- Ansel Adams

Examples: The Making of 40 Photographs (1983)