Knowing and Protecting
MOTION PICTURE FILM

TIMELINE of MOTION PICTURE TECHNOLOGY

- 1889 ■ Cellulose nitrate film
- 1895 ■ First public projection
- ~1899 ■ Toning

- ~1900 ■ Tinting
- ~1905 ■ Pathé Color stenciling
- 1907 ■ 35mm format standardized
- 1908 ■ Kinemacolor, 2-color additive

- 1910 ■ Cellulose diacetate film
- 1912 ■ 28mm format
  - Chronochrome, 3-color additive
- 1917 ■ Technicolor, 2-color additive, process #1
  - Handschiegl, selective dye transfer coloring

- 1922 ■ Panchromatic film commercially available
  - 9.5mm format
  - Technicolor, 2-color subtractive, cemented positive, process #2
- 1923 ■ 16mm format
  - Reversal film
  - Phonofilm, variable density sound on film
- 1926 ■ Vitaphone, sound on disc
- 1927 ■ Movietone, variable-density sound on film
  - Technicolor, 2-color subtractive, dye transfer, process #3
- 1928 ■ RCA Photophone, variable-area sound on film
  - Kodacolor, 16mm, 3-color additive, lenticular
- 1929 ■ Sonochrome, pre-tinted stock for sound films

- 1931 ■ Dufaycolor, 3-color additive
- 1932 ■ Technicolor, 3-color subtractive, dye transfer, process #4
  - 8mm format
  - Cinecolor, two-color subtractive
- 1934 ■ Dufaycolor, 16mm
- 1935 ■ Kodachrome, 16mm, 3-color subtractive, non-incorporated dye coupler
- 1936 ■ Agfacolor Neu, 3-color subtractive, incorporated dye coupler
- 1939 ■ Agfacolor, 3-color subtractive, negative/positive system

- 1948 ■ Cellulose triacetate film

- 1950 ■ Eastman Color, 3-color subtractive, chromogenic color
- ~1950 ■ Xenon bulbs for theatrical projection
  - Nitrate stocks discontinued
  - Magnetic sound striping, 16mm
- 1952 ■ Cinerama, with synchronized full-coat magnetic soundtrack
- 1953 ■ Cinemascope, with 4-track magnetic sound on film
- 1955 ■ Todd-AO, 70mm, with 6-track magnetic sound on film
  - Technicolor, single-negative, dye transfer, process #5
  - Polyester film

- 1965 ■ Super 8 format
- 1969 ■ IMAX format

- 1973 ■ Ektasound, Super 8, magnetic sound stripe
- 1977 ■ Dolby A-Type Stereo with Noise Reduction (NR)
  - Polavision, 8mm, 3-color additive, instant process

- ~1982 ■ Industry conversion to low-fade color film

- 1992 ■ Dolby Digital Spectral Recording-Digital (SR-D), 5.1 channel sound
- 1993 ■ Digital Theater Systems (DTS), 5.1 channel sound
  - Sony Digital Dynamic Sound (SDDS), 7.1 channel sound

- 2003 ■ Cyan dye soundtrack conversion
  - 2K digital projection

Black-and-White

The image is formed by concentrations of filamentary silver particles suspended in a gelatin binder. This is supported on a clear plastic base, commonly nitrate, acetate, or polyester. Emulsions are orthochromatic or panchromatic.

Exists in negative/positive and reversal in all formats. Intermediate materials have a slight lavender hue.

i.d. tip

35mm negative on cellulose nitrate support

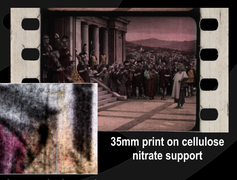
Silver particles are suspended in a gelatin binder layer on a plastic support.

Stenciled

Initial attempts to add color to the film image were made by hand painting. In the early 1900s, Charles Pathé introduced a stenciling technique to add color to films. A separate stencil was cut for each color to apply a dye precisely and rapidly to specific areas of each frame. Stenciling was first done by hand, then later mechanized, enabling large-scale production.

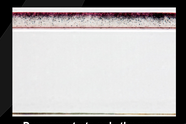
A black-and-white print with select areas of the image colored with dyes. Colors can be unnatural and often vivid, but limited in range.

i.d. tip



35mm print on cellulose nitrate support

Dye application may be imprecise.



Dyes penetrate only the upper surface of the gelatin layer.

Tinted

Produced by immersing a black-and-white print in a dye solution. The dye was absorbed by the gelatin, uniformly coloring the film. A wide range of color options were available. Release prints could be made of different color sections, which were individually dyed and joined together. First implemented in 1900, the technique reached its peak between 1908 and 1925, when approximately 85% of all features contained some amount of tinting.

Highlights are colored, while the positive image remains black. Color extends into the non-image area, directly affecting the emulsion layer. Dyes may have faded, sometimes unevenly.

i.d. tip

35mm print on cellulose nitrate support

Dyes are absorbed by the entire gelatin layer.

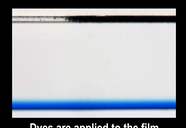
Tinted Base (or Pre-tinted Film)

The film base was impregnated with dye during film manufacture. As a result, color and depth of tints were standardized to a high degree of uniformity, eliminating uneven results that sometimes occurred with the dye bath method. In the 1910s, Kodak offered nine different color bases: red, pink, orange, amber, light amber, yellow, green, blue, and lavender.

The dye is evenly distributed across the film support. When examined closely, a clear separation is evident between the black-and-white image layer and the colored base.

i.d. tip

16mm print on cellulose acetate support



Dyes are applied to the film support. The black-and-white image layer is colorless.

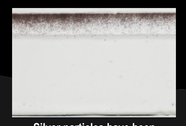
Toned

A toned film consists of a colored image embedded in a layer of colorless gelatin. The film was immersed in a metallic salt solution, which wholly or partially replaced the black silver image with an inorganic colored compound. The technique was used predominantly throughout the silent era, with some limited use in the 1930s. In combination, tinting and toning could achieve stunningly beautiful effects.

The positive image, consisting of mid-tones and shadows, is colored; highlights and non-image areas remain clear.

i.d. tip

35mm sulfide-toned print (sepia) on cellulose nitrate support



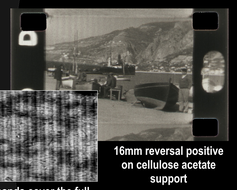
Silver particles have been chemically converted.

Kodacolor (1928 to mid-1930s)

A three-color additive process for amateur cinematography. The film base was embossed with microscopic cylindrical lenses. During shooting, light passed selectively through a banded color filter, which was focused by the camera lens onto the tiny embossed lenses and refocused onto black-and-white reversal emulsion as separate areas of red, green, and blue color information. The same banded filter was used during projection to reveal the natural color.

Black-and-white positive with black edges, most commonly found in 16mm. The embossed base is visible under magnification as a series of parallel lines. May have "KODACOLOR" edge markings.

i.d. tip



16mm reversal positive on cellulose acetate support

Lens bands cover the full width of the film

Microscopic lens elements are evident on the base

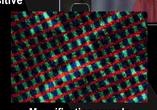
Dufaycolor (1931 to late 1940s)

The first additive reversal color process, which required no additional optical devices to reveal a color image. A microscopic, three-color mosaic grid, or *reseau*, imprinted and dyed onto the base, filtered light onto a black-and-white emulsion. Although it achieved reasonably good color results, the projected image was dim and marred by the obtrusive mosaic pattern. A negative-positive system was developed for professional 35mm production. Dufaycolor was available only in the United Kingdom.

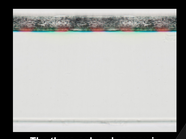
Can be on 9.5mm, 16mm, or 35mm. Dufaycolor reversal films and prints have a color positive image. The color mosaic pattern (*reseau*) is on the base and thus is seen, under magnification, across the full width of the film.

i.d. tip

35mm reversal positive on cellulose acetate support



Magnification reveals the colored mosaic pattern



The three-colored *reseau* is directly under the black-and-white emulsion.

FILM FORMATS

8mm 1932 · Super 8 1965 · 9.5mm 1922 · 16mm 1923 · 35mm 1892 · 70mm 1955 · IMAX 1969

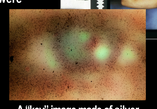
3-Color Technicolor Dye Transfer (1932 to 1977)

A three-color subtractive process utilizing dye transfer techniques, similar to lithography. Hardened gelatin relief matrices were created from separation negatives. Perfectly registered yellow-, cyan-, and magenta-dyed matrices were pressed into direct contact with a blank receiving film to create a full-color image print. Kodak manufactured all film elements for the Technicolor process.

May be found in 35mm and 16mm formats. Technicolor dye imbibition prints have a vibrant color image, with good dye stability, which appears softer than modern chromogenic prints. Soundtracks are printed in black-and-white emulsion.

i.d. tip

35mm print on cellulose nitrate support



A "key" image made of silver particles improves definition and contrast.

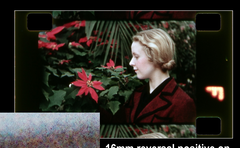
Dyes are absorbed into the gelatin layer.

Kodachrome (1935 to 2006)

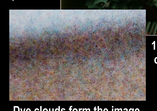
The first chromogenic color process—a subtractive color reversal process for amateur cinematography. The film had a multi-layered emulsion, sensitive to blue, green, and red. Beneath the top layer a yellow filter prevented blue light exposure in the bottom two layers. Processing was complex, originally involving 28 steps in development, with the dye couplers incorporated in the developer, not the emulsion.

A fine-grained color positive with black edges, notable for its vibrant saturated colors and dye stability. The image stands in strong relief on the emulsion side when viewed under reflected light. May have "KODACHROME" edge markings and can be found in 16mm, 8mm, Super 8, and occasionally 35mm.

i.d. tip



16mm reversal positive on cellulose acetate support



Dye clouds form the image.

The yellow dye layer is on top, followed by the magenta and cyan layers.

Chromogenic Negative (1939 to present)

A negative with three light-sensitive, color-sensitized emulsion layers coated on a single support, widely used in professional film production. Dye couplers in the emulsion layers react, when processed, to produce a separate dye image in each layer. An orange masking on the processed negative, formed by unreacted couplers in the red- and green-sensitive layers, helps preserve the color balance when making prints. Originating from principles first developed by Agfa in the 1930s, refined processes were later marketed under various trade names, such as Eastman Color, Ansco Color, Fujicolor, and Ferrania Color. The same principles remain in use for modern color emulsions.

The film has an overall orange cast. The colors of the image are opposite (complementary) to the colors of the scene filmed.

i.d. tip

35mm negative on cellulose acetate support

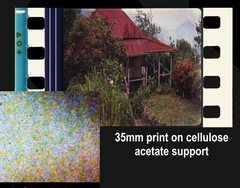
The yellow dye layer is on top, followed by the magenta and cyan layers.

Chromogenic Positive (1939 to present)

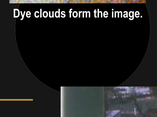
Images are reproduced subtractively via three light-sensitive emulsion layers with incorporated dye couplers. Prints can be made from either color negatives or black-and-white separation negatives. Chromogenic positives, like color negatives, have multi-layer characteristics but no orange masking. The dye couplers in each emulsion layer are colorless.

With a few early exceptions, chromogenic prints have been manufactured almost exclusively on acetate or polyester safety base. Scratches may appear colored, due to their penetration of certain emulsion layers.

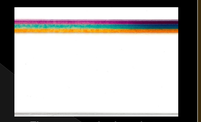
i.d. tip



35mm print on cellulose acetate support



Dye clouds form the image.



The magenta dye layer is on top, followed by the cyan and yellow layers.

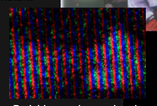
Polavision (1977-1979)

Polavision, an "instant" movie system by Polaroid, revived the concept of additive color cinematography. Light passed through a color screen composed of microscopic dyed parallel lines and recorded a filtered image onto a black-and-white emulsion. The film was encased in a special cartridge containing an instant processing reagent. Despite its technical accomplishment and "instant" appeal, Polavision was a commercial failure.

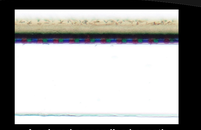
An 8mm film, identical in width and perforation to Super 8, encased in a cartridge labeled "Polaroid Phototape." Image often appears dark and murky. A rainbow banding effect is evident when viewed under reflected light. Exclusively on polyester safety stock.

i.d. tip

8mm reversal positive on polyester support



Red, blue, and green bands run vertically across the image.



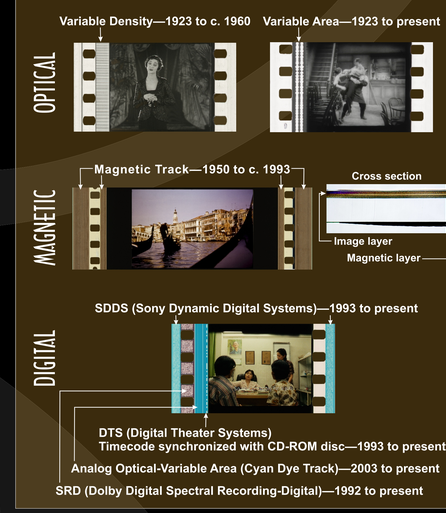
A colored screen lies beneath the black-and-white emulsion.

THREE CRITICAL STEPS in the LONG-TERM CARE of FILM COLLECTIONS

1. ***IDENTIFYING and UNDERSTANDING*** the nature of film materials is key to determining vulnerability. Nitrate, acetate, and chromogenic film elements require cold storage to significantly decrease the rate of film decay.
2. ***ASSESSING*** condition will help organize preservation priorities and develop better storage practices. A-D Strips® are a vital tool for surveying acetate film in motion picture collections. The more advanced the decay, the colder the storage temperature should be.
3. ***STORING*** film under proper environmental conditions prolongs film life. Cold storage and reduced relative humidity drastically improve film stability. The Image Permanence Institute has published several guides and management tools to help institutions plan the best storage for their collections.

For more information visit www.imagepermanenceinstitute.org

SOUNDTRACKS



EXAMINING FILM

Special examination techniques can be useful in identifying motion-picture film materials and in understanding their nature.

- Lighting and magnification are key to obtaining a film's identifying characteristics. Transmitted light from a LIGHT BOX will reveal the film image, immediately displaying whether it is black-and-white or color, and any edge markings.
- Tilting a film under reflected light from OVERHEAD or AT A RAKING ANGLE can reveal color process components (e.g., lenticules on the film support) and can help the viewer differentiate the base from the emulsion. Typically, the emulsion will appear textured, it will look dull compared to the shiny base, and the image will be slightly raised.
- Examining a film under a LOUPE or other magnification tool will ensure accuracy in readings of edge markings and understanding of base or emulsion structure.
- CROSS-SECTION VIEWS clearly display the physical structure of the film element and can reveal emulsion layer structure and additive color components on the base.

GLOSSARY

ADDITIVE COLOR—A method of reproducing natural colors by mixing colored light. Filtered light is captured on a black-and-white emulsion when photographed and recombined in projection. Additive primary colors for three-color systems are red, green, and blue.

CHROMOGENIC—Describes a color image generated by dyes formed in development.

DYE COUPLER—An organic compound in the emulsion that reacts with an oxidized developer to form a dye.

ORTHOCHROMATIC—An emulsion sensitive to all colors except red.

PANCHROMATIC—An emulsion sensitive to all colors of the visible spectrum.

REVERSAL—A camera film, which is processed into a unique direct positive, and can be identified by its black edges.

SEPARATION NEGATIVES—Separate color records filtered on black and white emulsion, which can be recombined during printing to create a full color positive.

SUBTRACTIVE COLOR—A method of reproducing natural colors on a print by removing certain colors from the spectrum, and transmitting those remaining. Subtractive primary colors for three color systems are cyan, magenta and yellow.

This poster was developed at the Image Permanence Institute with the help of a number of individuals working in the field of film preservation: recipients of the AMIA Image Permanence Institute Internship in Preservation Research Award, James Layton (2008) and Tim Wilson (2007); recipients of the Image Permanence Institute L. Jeffrey Selznick School of Film Preservation Internship award, Rachel Bauer (2009) and Jennifer Miko (2008); and Paul Pichon from the Université Michel de Montaigne Bordeaux 3, France, during his 2009 IPI internship. Our thanks go to the Motion Picture Department at George Eastman House for its continuing support. Technical and content assistance: Zach Long and Kristin Smith. Poster design: Karen Santoro. Project coordinator: Jean-Louis Bigourdan.

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