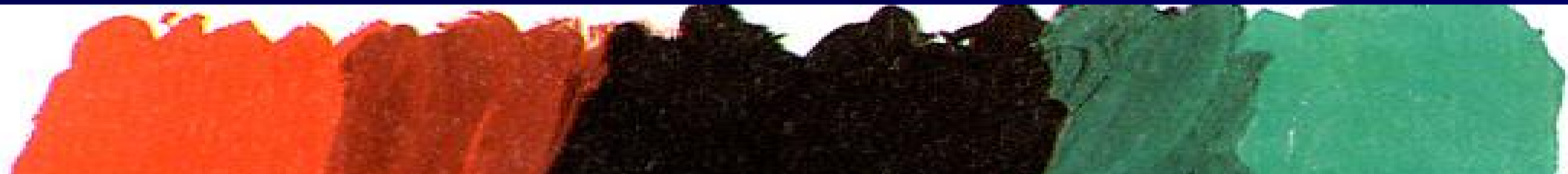
Color Theory

- Chapter 7
- Subtractive Color,
  Gamuts, Process Printing, Pantone…

A Review of the Basics of Subtractive Mixing

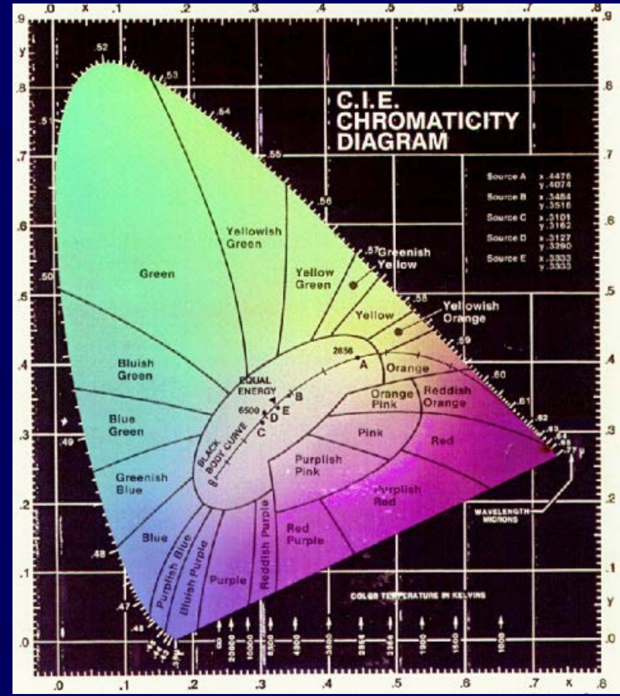
- The general principles of subtractive color mixing have already been introduced.
- Since *all of your paint-mixing experiences involve subtractive mixing*, you have a great deal of practical experience with the issues involved.
- We'll look at missing pieces — other media and applications that rely on colors mixed by pigments and dyes – subtractive mixtures.



Chapter 7

- Dyes
- Color Specification Systems
  - Munsell Notation System
  - C.I.E. System
  - Pantone Matching System
- Mixing Oils and Acrylics
- Ceramic Glazes
- Colored Glass
- Color Printing
- Color Photography
- Fiber Dyes
- Fading of Subtractive Color

C.I.E.



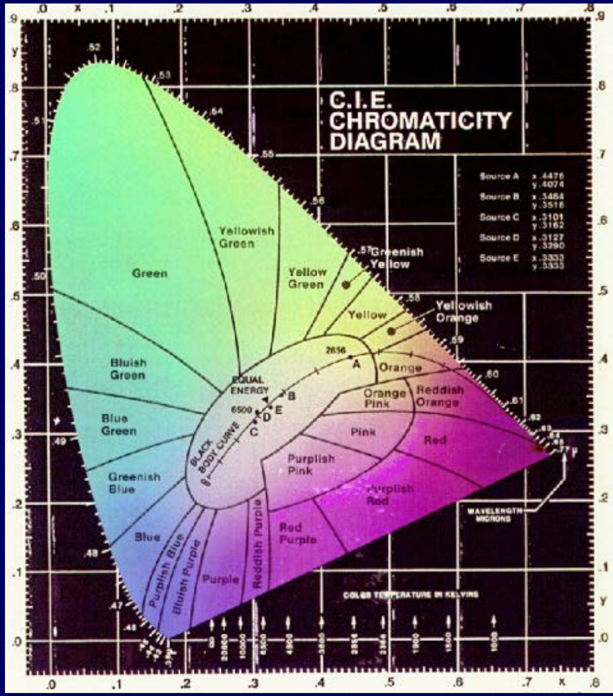
- “The CIE, or Commission Internationale de l’Eclairage (translated as the International Commission on Illumination), is the body responsible for international recommendations for photometry and colorimetry.”
- Measurements are based on light/wavelength traits, not on color swatches or samples.

Xrite/Guide to Understanding Color Communication

C.I.E.

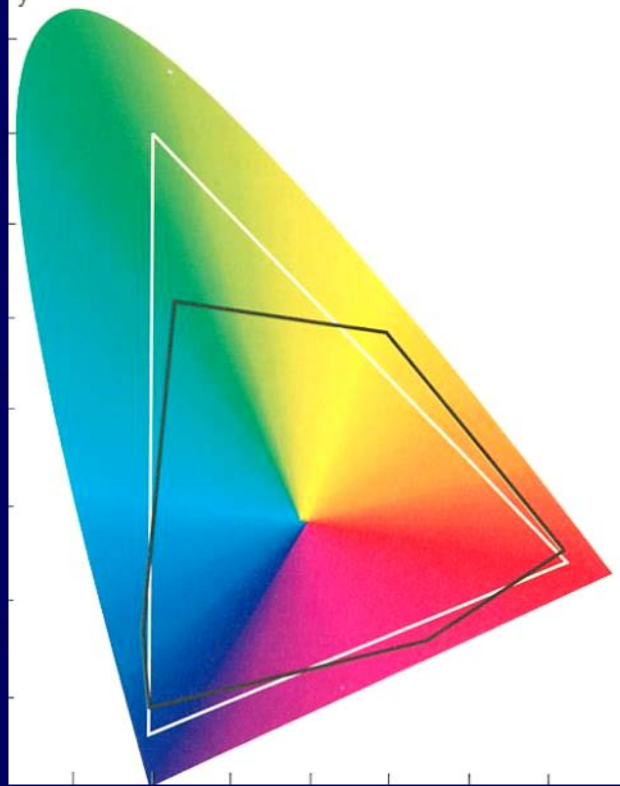
- In 1931 the CIE standardized color order systems by specifying the light source (or illuminants), the observer and the methodology used to derive values for describing color”

  Xrite/Guide to Understanding Color Communication



- Based on colored **light** (*not* pigments)

C.I.E Standard – measurable colors



- C.I.E. system offers a widely accepted standard which is objective – that is, *measurable and quantifiable*.

- Color swatches are *not* necessary – and since color swatches fade over time, thereby making the swatches unreliable standards, C.I.E. is often preferred in standard tight-tolerance color production.

Spectrophotometer

Today, the most commonly used instruments for measuring color are spectrophotometers.

Spectro technology measures reflected or transmitted light at many points on the visual spectrum, which results in a curve.

Hue/Wavelength Curve

The intensity of each hue or wavelength is measured thereby creating data points for the curve.

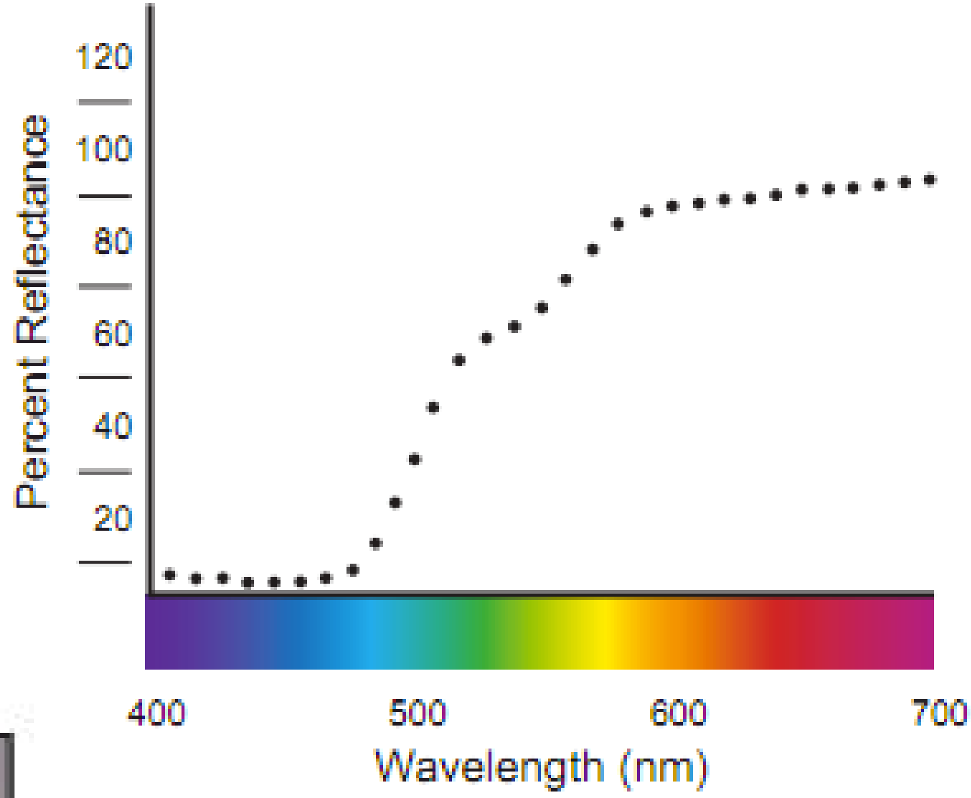


Figure 5: Spectral curve from a measured sample

Spectrophotometer

It measure three quantities.

Since each color sample's curve is as unique as a signature or fingerprint, the curve is an excellent tool for identifying, specifying and matching color

This method is accurate and widely available – try Wal-Mart house paint department paint mixer.

A portable sphere spectrophotometer measures the color of textile samples and other materials where the product's appearance is critical for buyer acceptability.

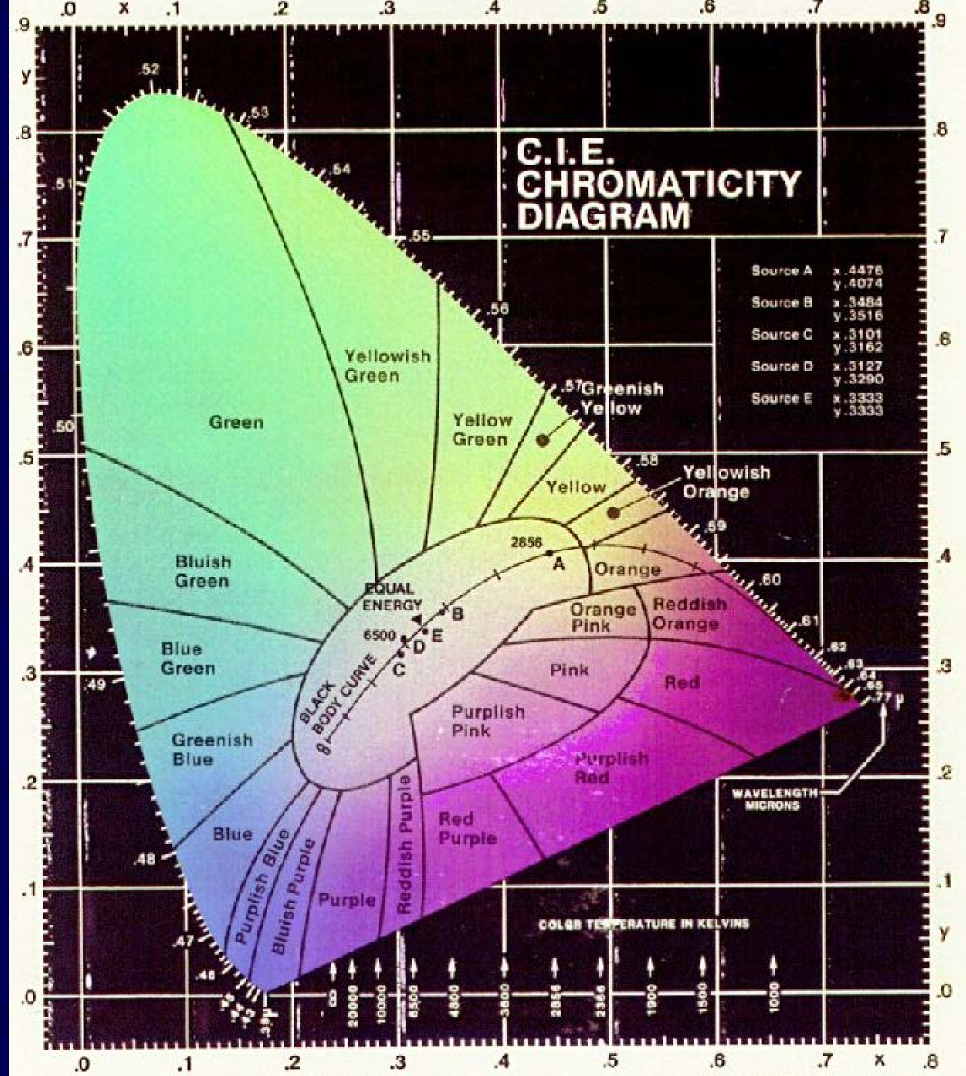
DENSITY (STATUS T)
V 1.84
C 1.39
M 1.55
Y 1.11

DOT AREA, 50% TINT
V 79%
C 77%
M 77%

A spectrodensitometer measures the color bar on a press sheet to monitor color reproduction. A typical printout (left) shows the visual, cyan, magenta and yellow values for density, dot area and other characteristics.

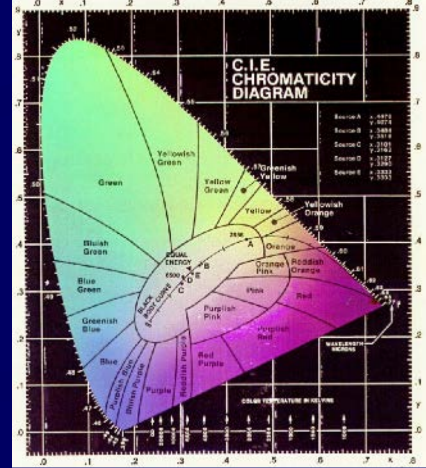
C.I.E. System — imaginary primaries

- "Chromaticity values depend on only *dominant wavelength (hue)* and *saturation (chroma)*, and are independent of the amount of luminous energy (value).
- For example, a brown color is not on the diagram; however, a brown is just a low-luminance orange-red…

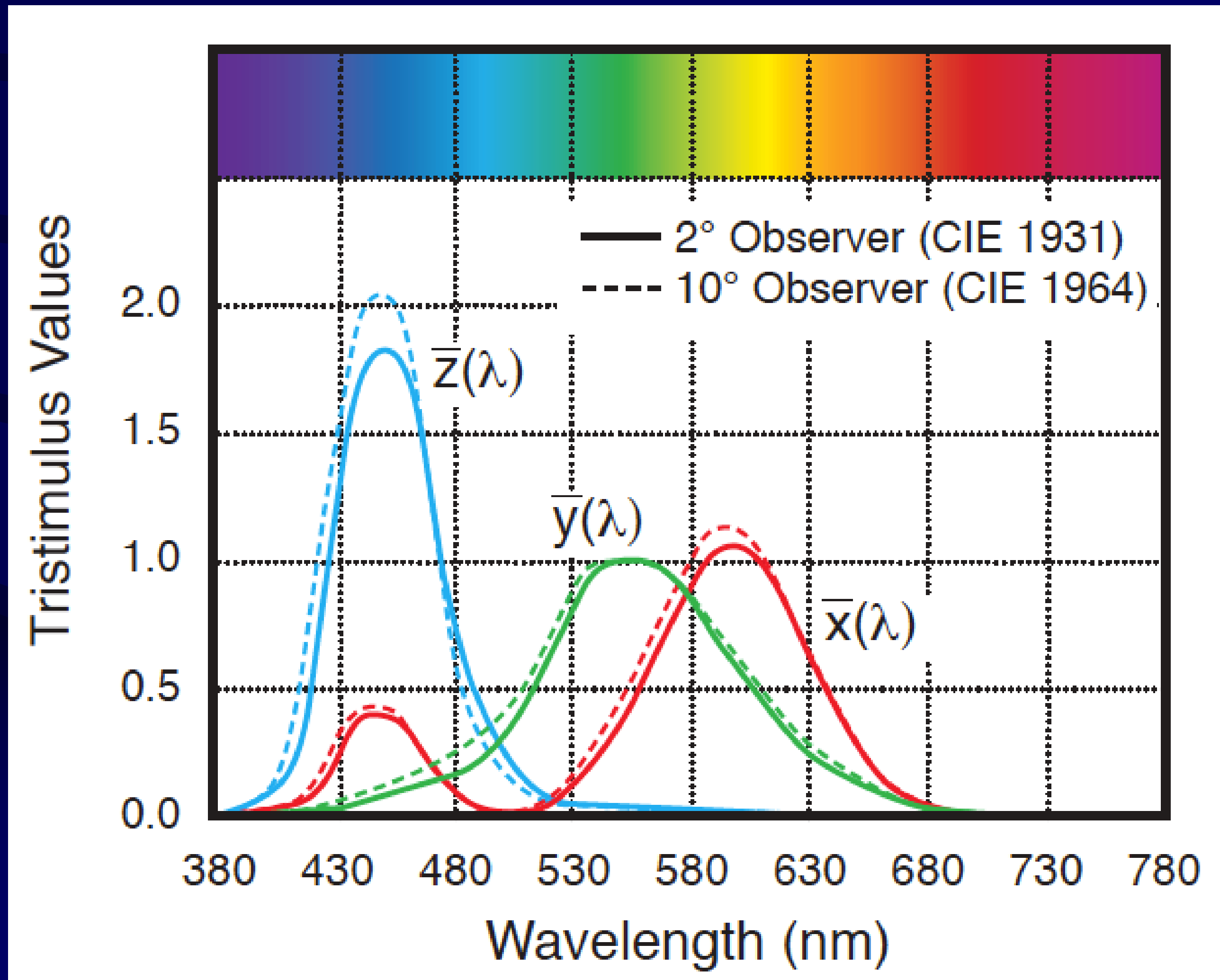


- Complementary colors are those that can be mixed to produce white light."
- http://www.cs.rit.edu/~ncs/color/t_chroma.html

C.I.E. System — imaginary primaries

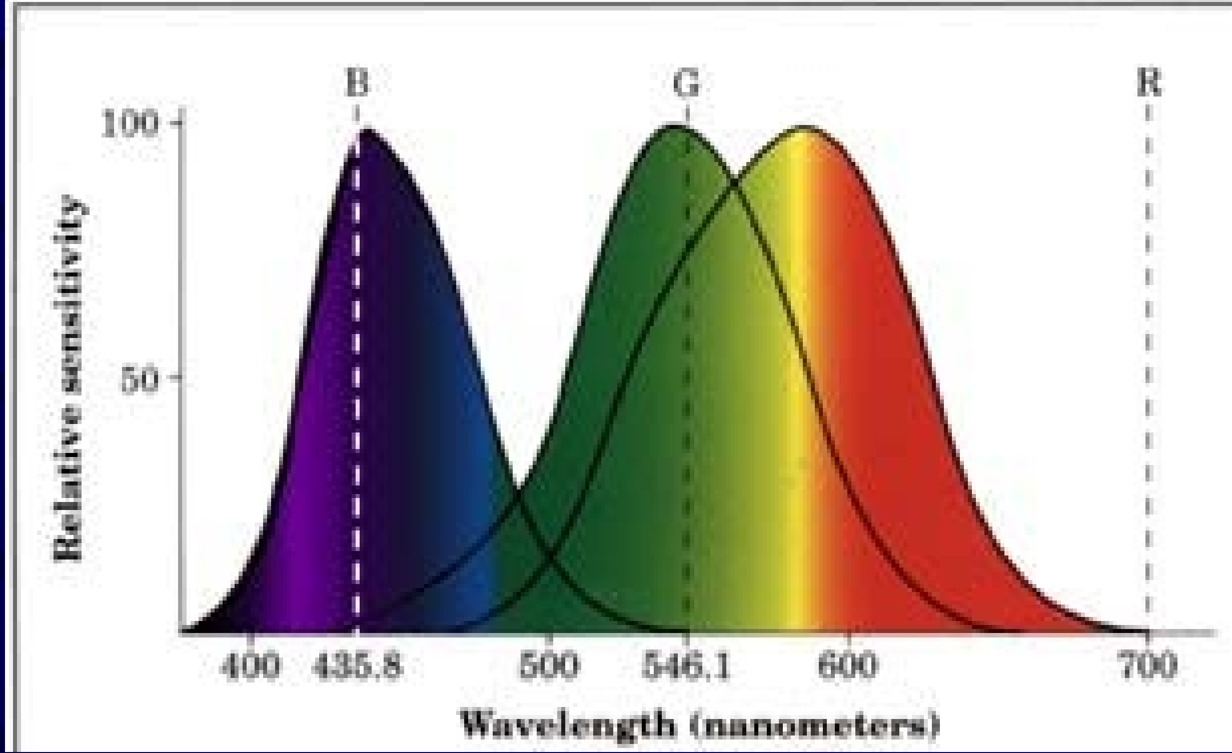


- The 3 "primary" colors are the *virtual* colors labeled A, B, and C.
- These are related to Red, Green and and Yellow light primaries.
- Yes.
- That’s confusing, but that’s just the outer edge of the technical jargon.
-



C.I.E.
X, Y, Z values.

The CIE definition of the standard observer is *based on three specific wavelengths* of light in the RGB regions respectively (435.8nm, 546.1nm and 700nm, see figure).



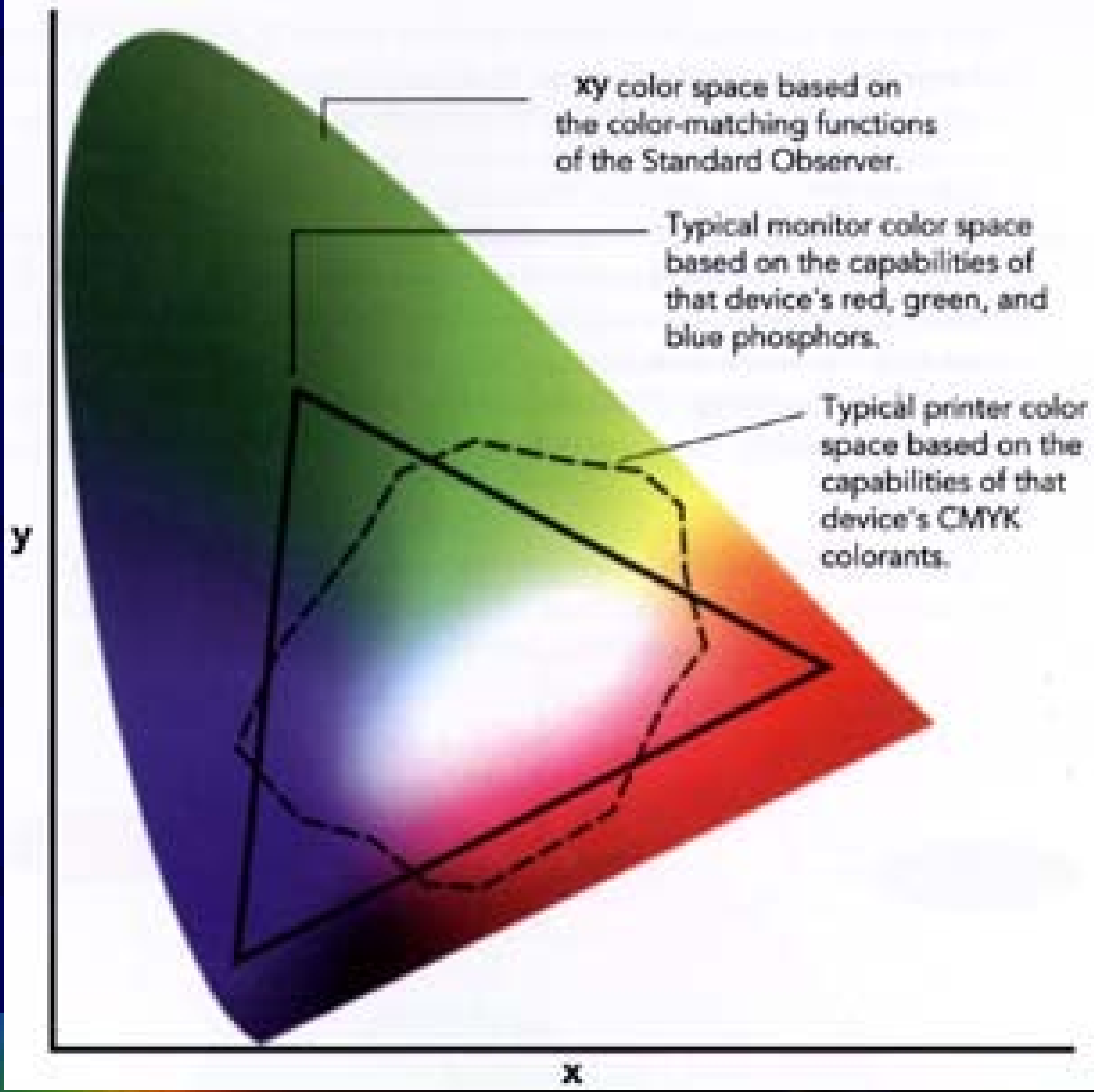
— The device independent tristimulus values (X,Y,Z) are *derived from the relative amounts of these characteristic wavelengths present* in a color.

http://www.wmich.edu/pci/colorspec/PP3.HTM

C.I.E.
X, Y, Z values.

— The X, Y and Z values are usually measured on a 0-100 scale. (Thus the luminance, Y, of the chromaticity scale is measured 0-100 by construction.)

Higher numbers are lighter, lower darker.

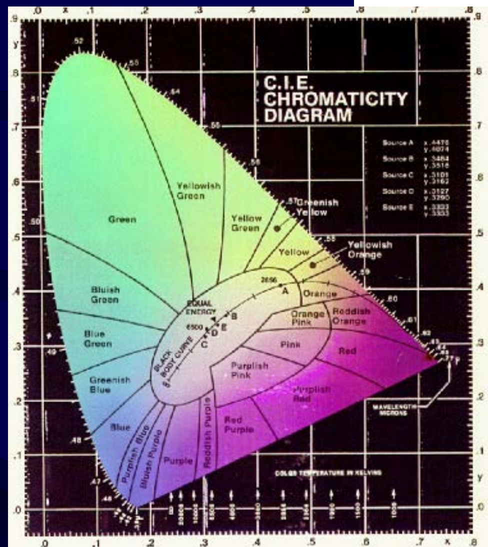


See interactive CIE model:
www.brucelindbloom.com/index.html?MunsellCalculator.html

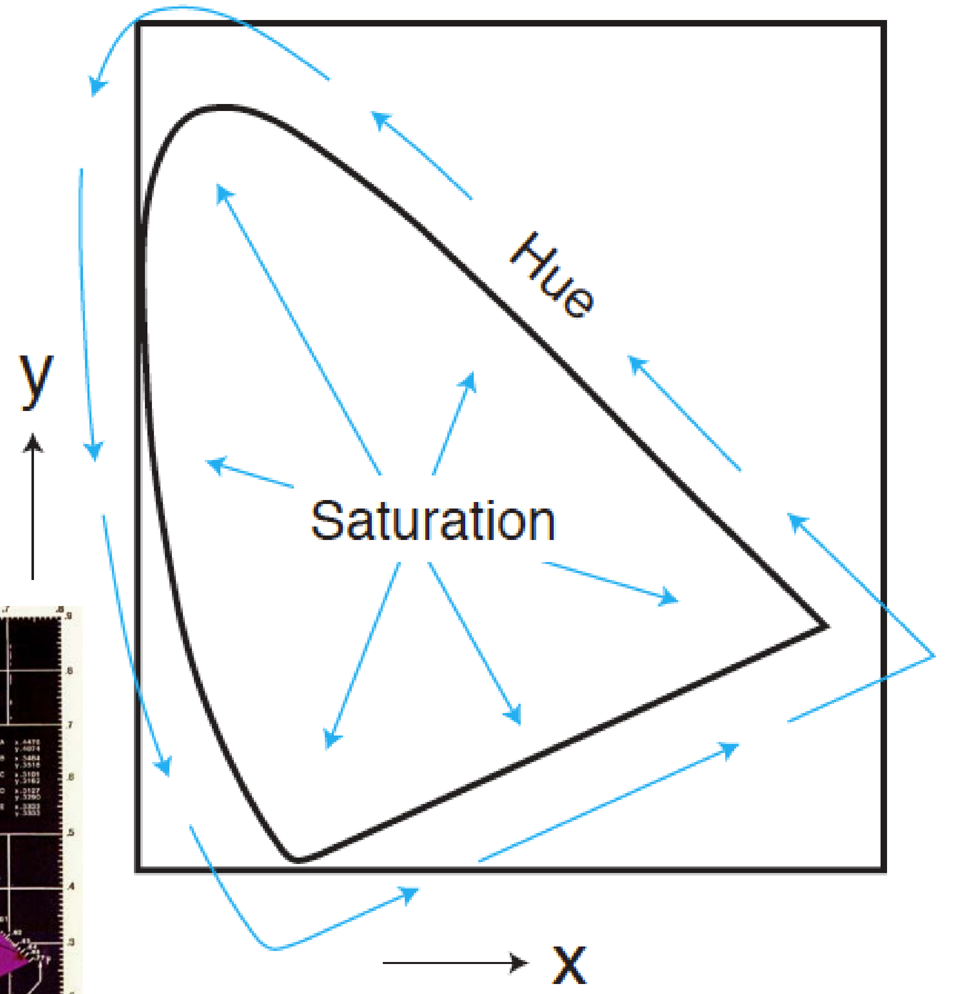
http://www.wmich.edu/pci/colorspec/PP3.HTM

C.I.E. System — imaginary primaries

- CIE plots X and Y values on the
- Chromaticity chart.
- For a given real color, its components with respect to the primaries are:



- $x = A/(A+B+C)$
- $y = B/(A+B+C)$
- $z = C/(A+B+C)$

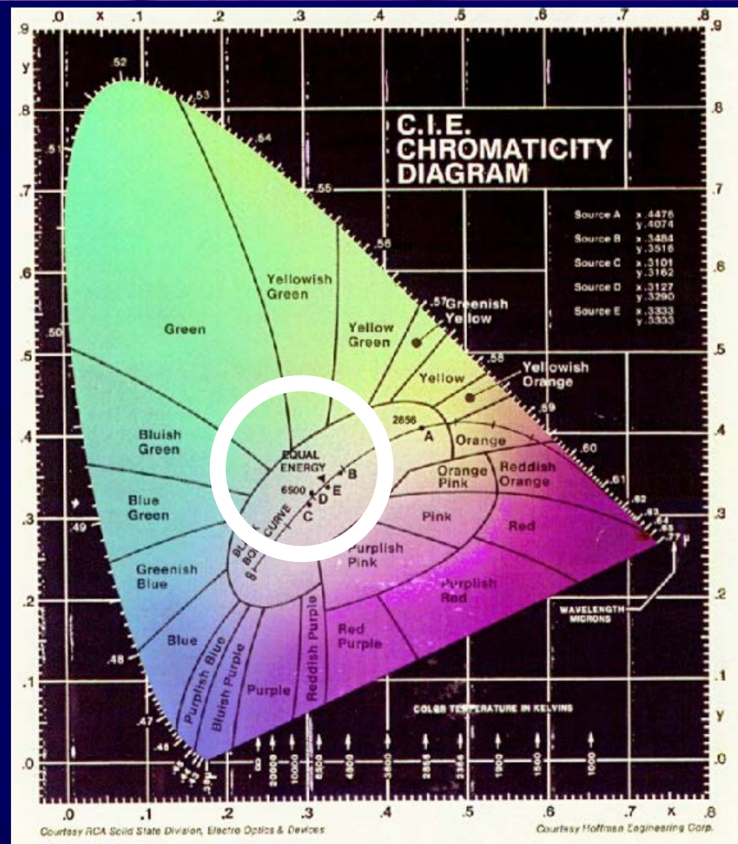


- Since $x + y + z = 1$, if x and y are known then z can be determined.
- *It allows all other colors to be defined as weighted sum of the three "primary" colors. There are no real three colors that can be combined to give all possible colors. Therefore the standard "primary" colors established by CIE don't correspond to real, but imaginary and ideal colors.*

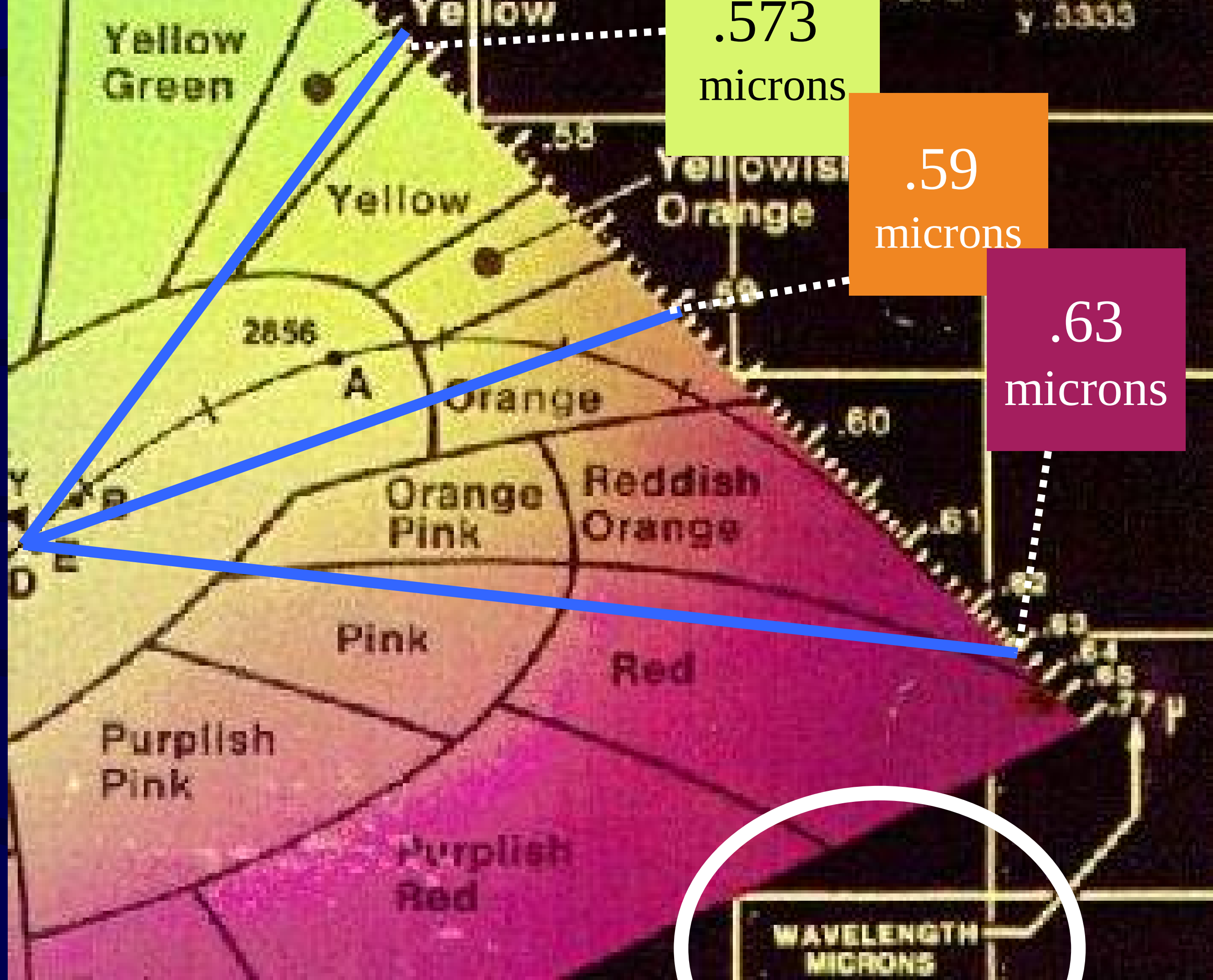
C.I.E. Diagram

- At the center is **white/neutral** -- the “**equal energy” point** at which all hues are equally present.

- This point is the “origin” of a polar chart — hues are identified by the *angle* of the wavelength from this white point.

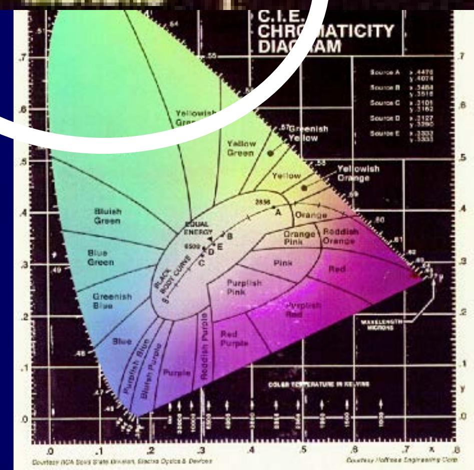


C.I.E. Diagram



Each spectrum hue is at a unique *angle* from the "equal energy" point.

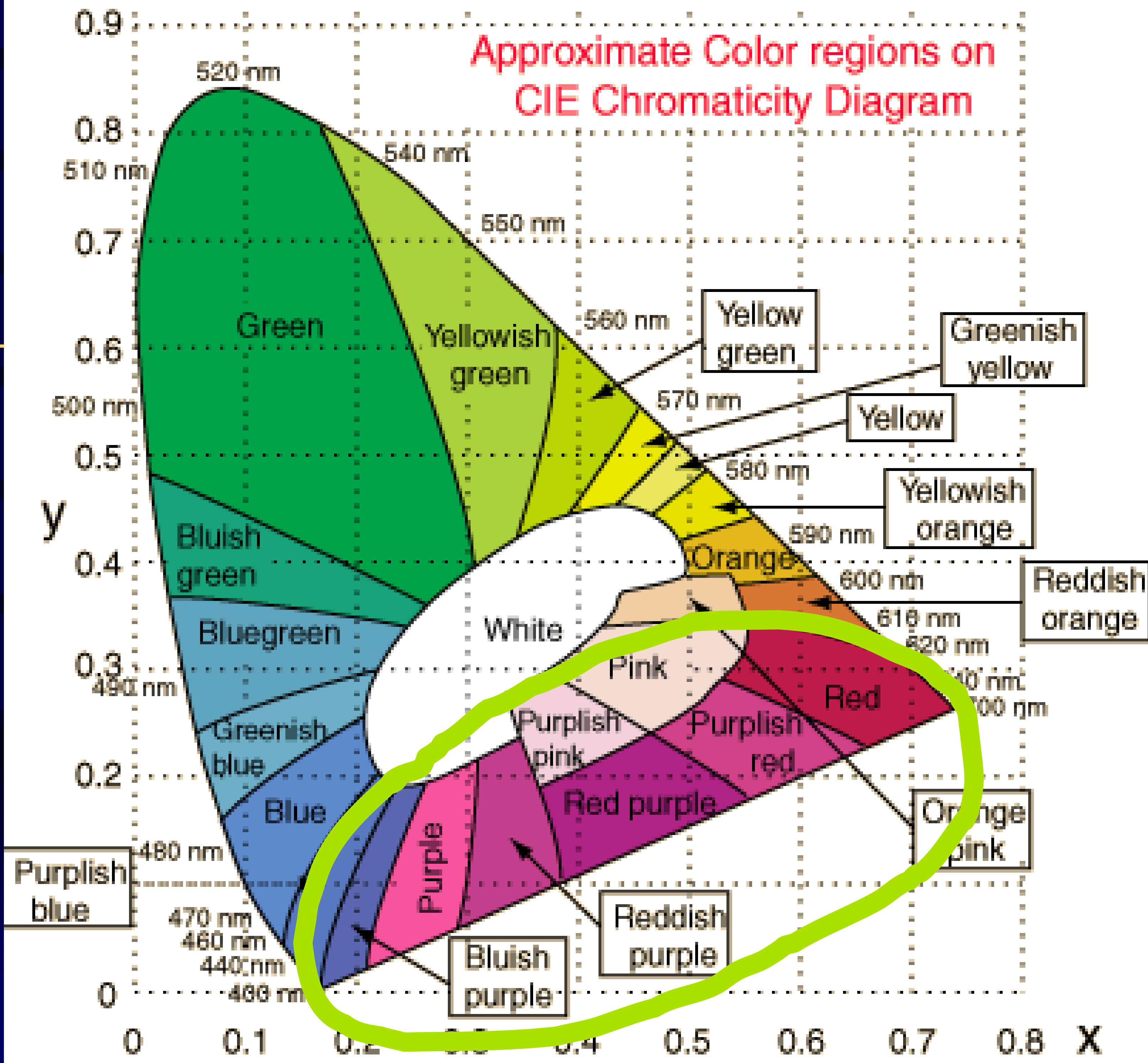
Each hue may be represented/described by its *wavelength* along the perimeter of the C.I.E. diagram.



CIE

Strictly speaking, *the hues of the red-purple range are NOT spectral hues*, but are *combinations* of the two extreme spectral hues, Indigo (BV) and Red (RV)

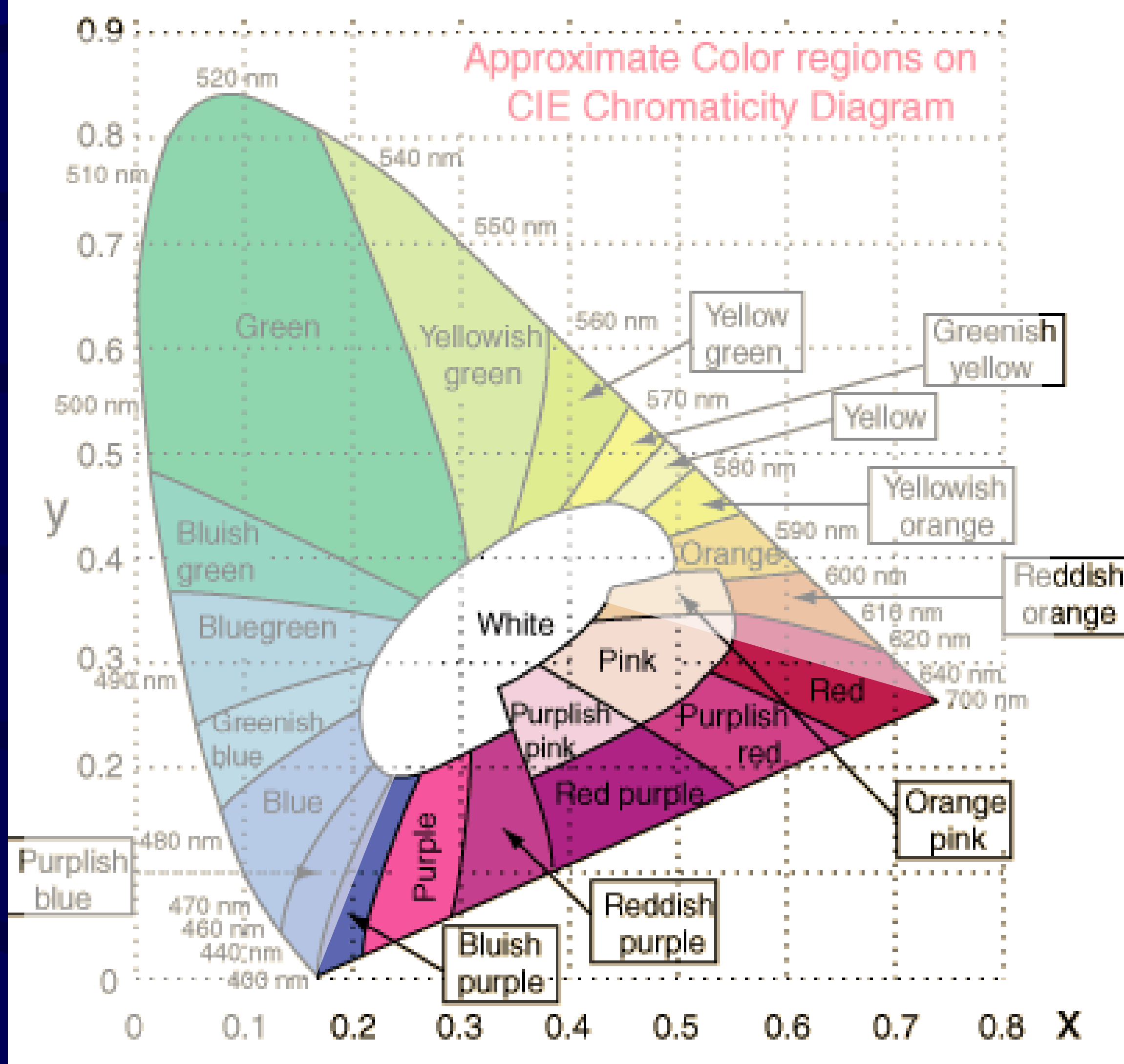
(recall that a rainbow begins and ends with Indigo and Red)

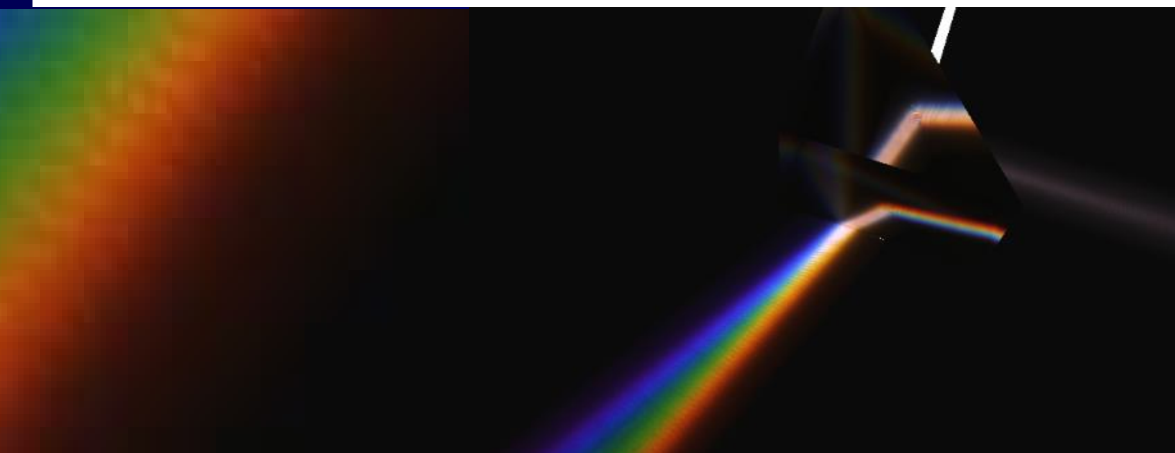


Non-Spectral Magenta

- Thus, hues "beyond the end of the rainbow" do not have angles/position — their X/Y position denotes proportions of indigo and violet.

- "If the line crosses the purple boundary, the dominant wavelength cannot be defined, and such color is called *nonspectral*.
Indeed, *there is no magenta in the rainbow.*"
http://www.cs.rit.edu/~ncs/color/t_chroma.html

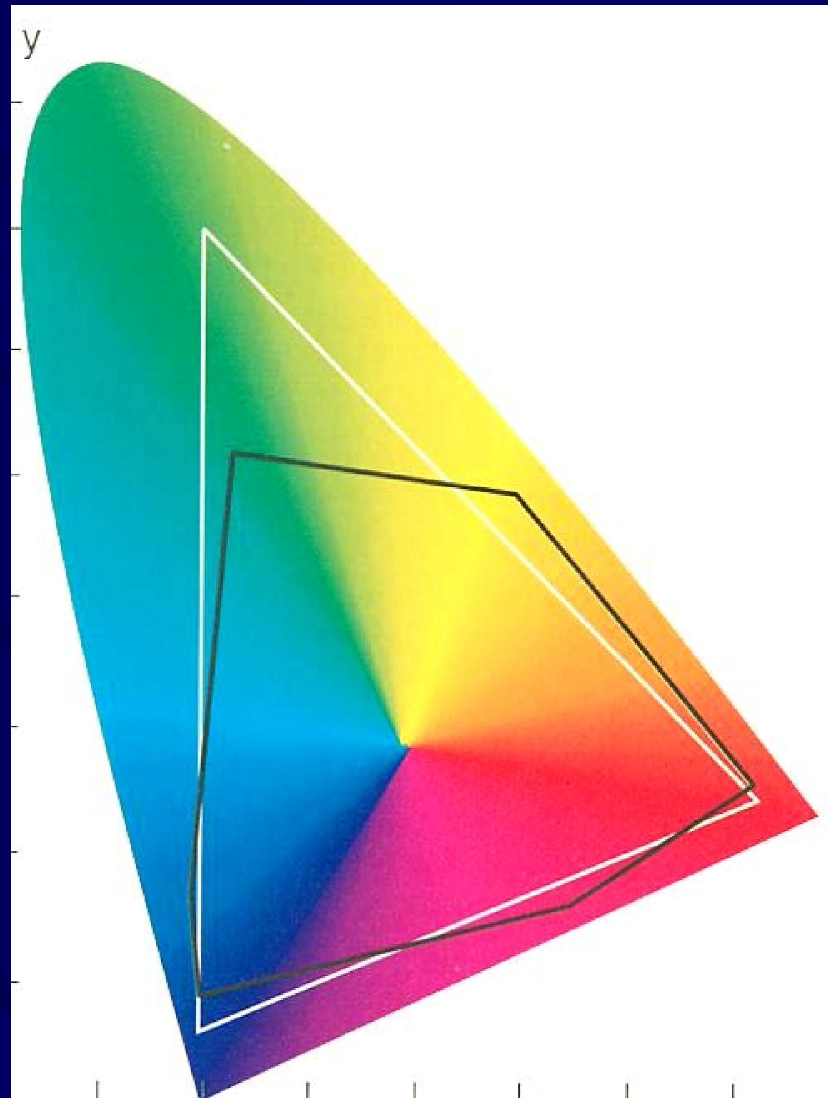


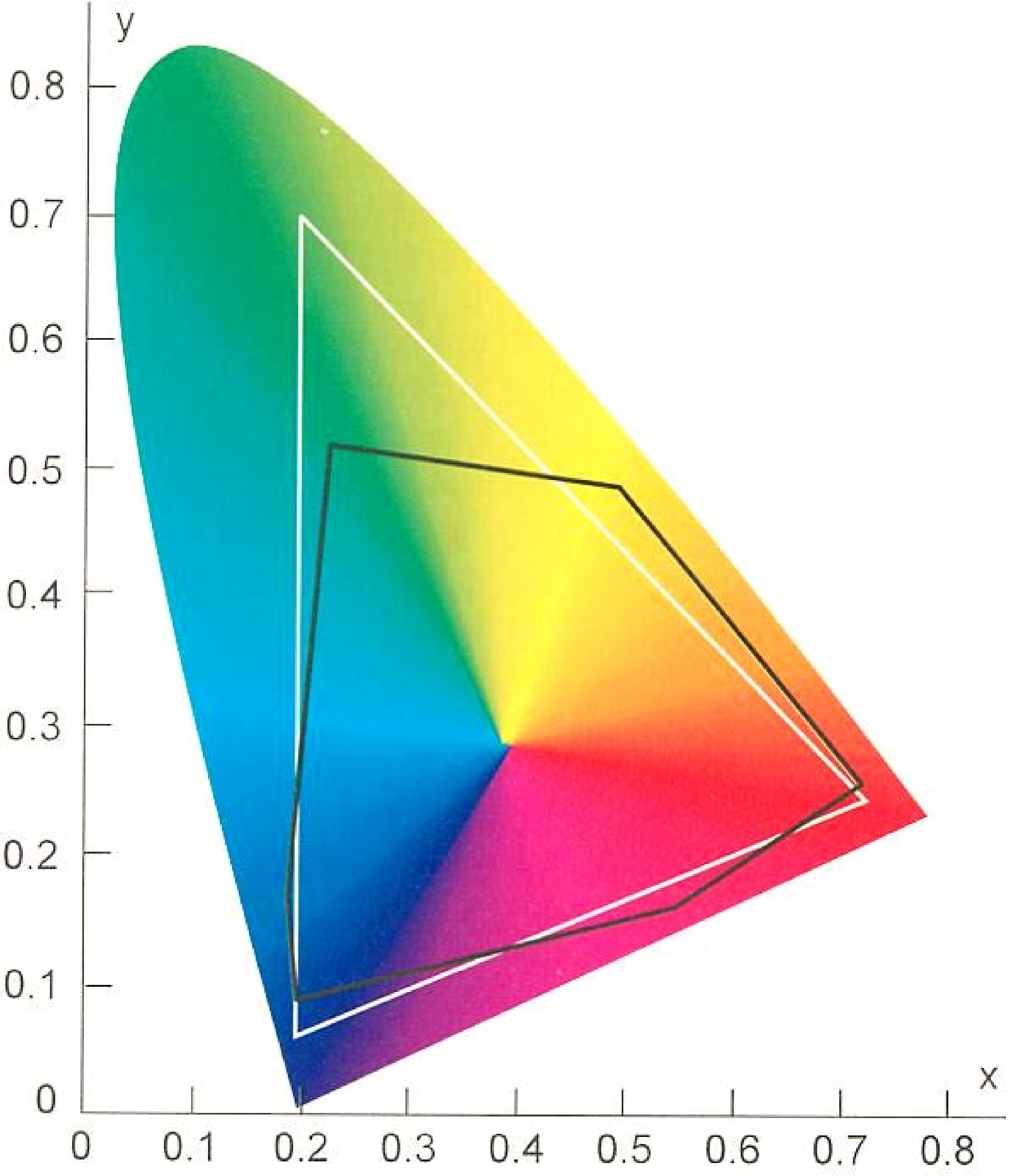


CIE basis:
"Just-noticeable-difference" Varies by Hue

- Note that hue regions are *not the same size* – that is, green colors dominate the diagram.

- This is because research on human vision indicates that the human eye can discriminate far more different greens than purple/magentas.





Color Gamut

C.I.E. diagram is typically used to represent the **full range of human-visible colors — the gamut of human vision.**.

"Gamut" is the range of colors that can be produced or discerned by an imaging device — in this case, the human eye.

Imaging Devices

- This term isn't in the book, but it needs to be.
- Its computer jargon that refers to *any device that*
  displays or
  prints ***or***
  captures an image.
- Printers, monitors, plotters, film, digital cameras and CCDs…

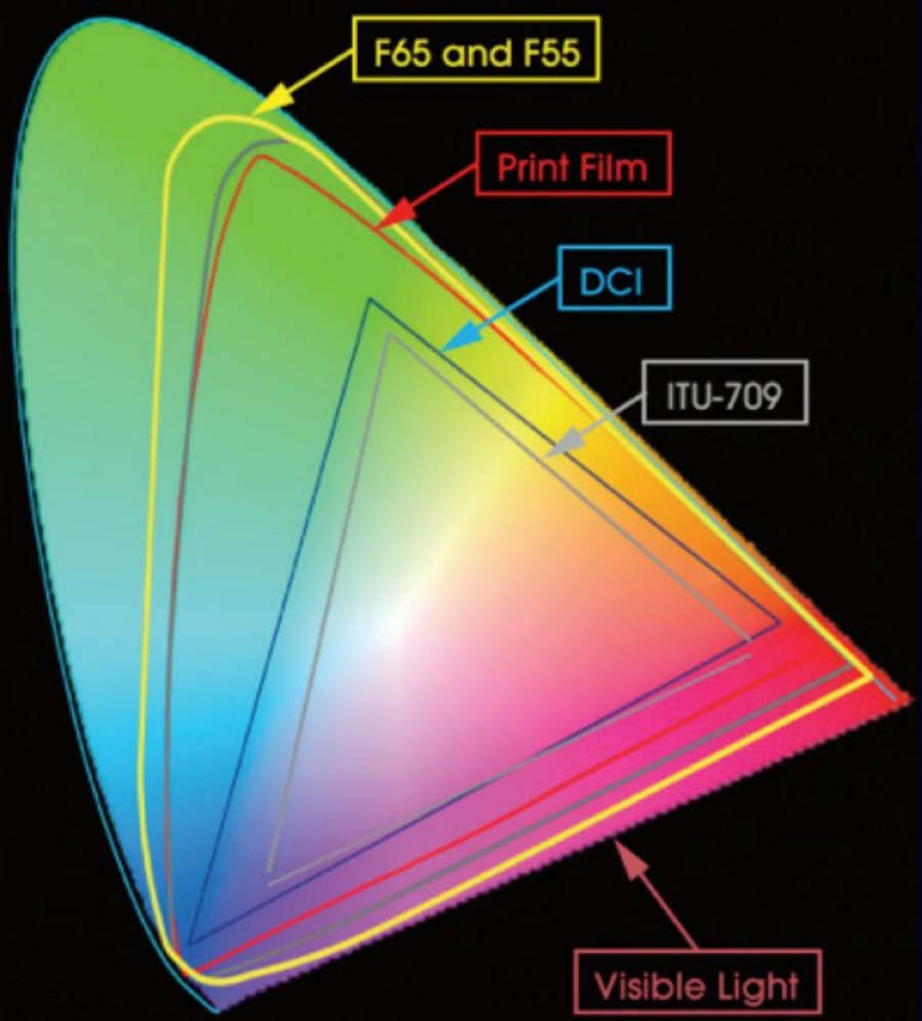
Common Imaging Devices

- Your *computer monitor* is an imaging device – whether you use an RGB cathode-ray tube (TV-like monitor) or an LCD flat panel display.

- *Any printer* is an imaging device – laser printers, inkjet printers, dot-matrix (remember those?), dye-sublimation, plotter, etc.

A device is a device..

- To the computer programmer, they’re all just devices that take a digital description of an image and create a “human-viewable” image.
- Just as every art-making medium has advantages and disadvantages, so do different imaging devices.



Device Color Gamut

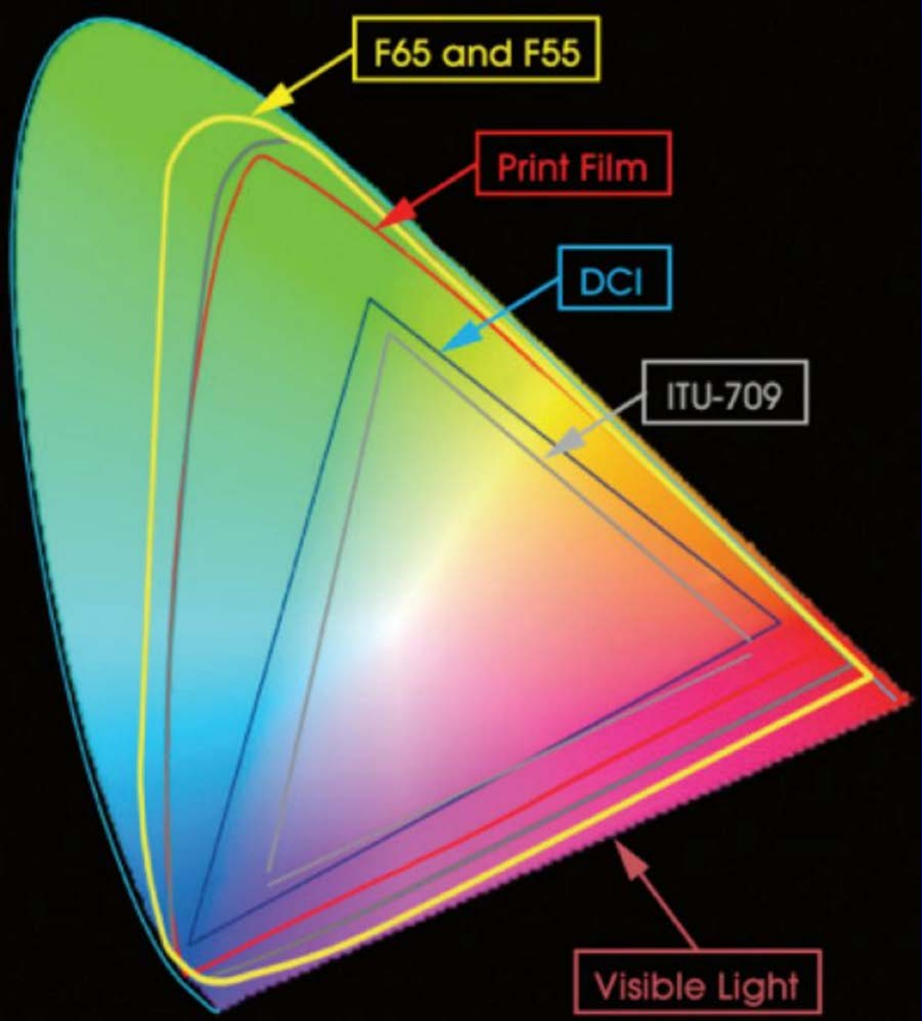
"The range of colors that can be formed by all combinations of a given set of light sources or colorants of a color reproduction system."

www.timesprintingco.com/Glossary.html

Every color imaging device (printer, TV, LCD, video projector, photo print film, transparency film) is capable of producing a different range of color

Thus every "device" and every (painter's) palette has its own, unique color gamut.

Sony F65 CineAlta digital motion picture camera.



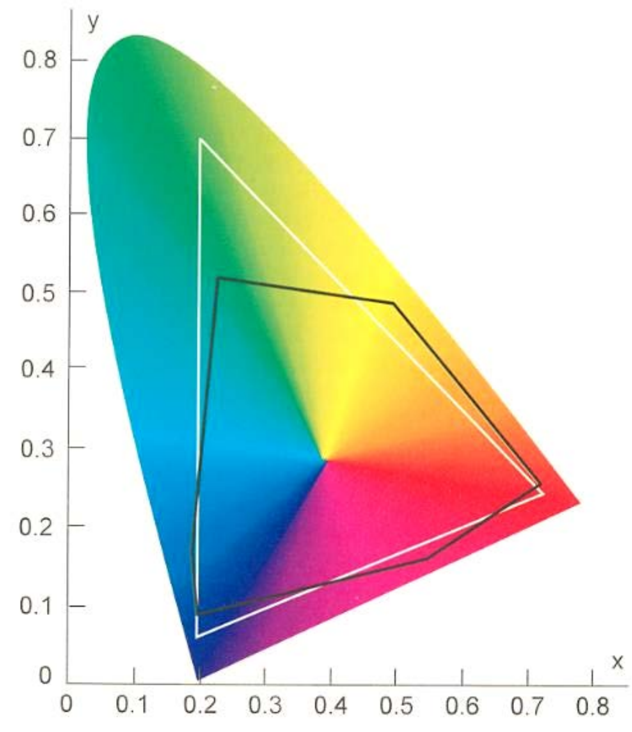
Device Color Gamut

In cinematic film-making there are evolving camera technologies, projection technologies and standards involving color gamuts.

DCI Specification
Commonly referred to as the "DCI Specification". The document describes overall system requirements and specifications for digital cinema.

ITU-R Recommendation BT.709, more commonly known by the abbreviations Rec. 709 or BT.709, standardizes the format of high-definition television, having 16:9 (widescreen) aspect ratio. The first edition of the standard was approved in 1990.

Sony F65
CineAlta digital motion picture camera.



Device Color Gamuts

Every **color sensing device** can capture, or recognize, only a limited range of colored light (digital cameras, film, human eye) -- thus, color gamut varies by device.

For Example:
'black and white' film does *not* capture hue or chroma at all — thus many colors that you can see, are ignored.

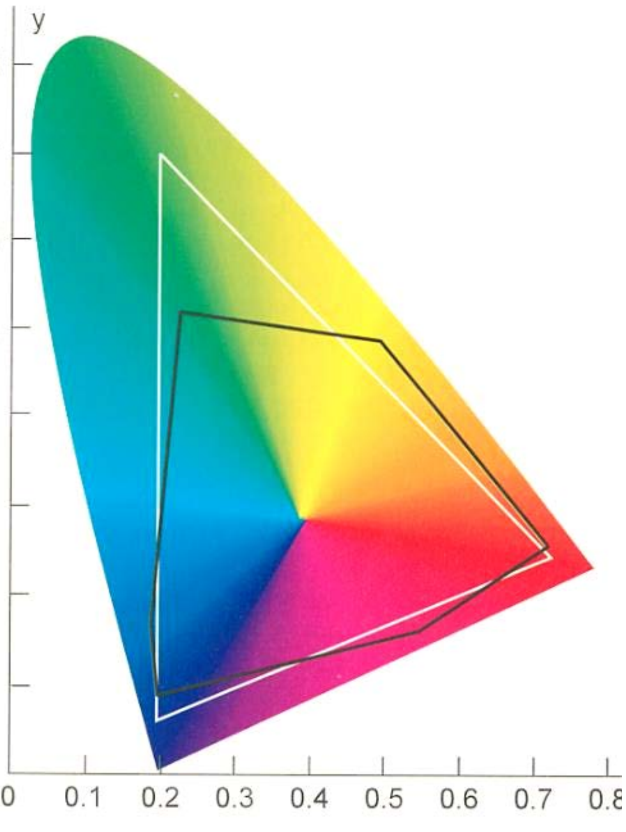
Infrared film captures infrared/heat radiance — "colors" beyond what you and I can see.

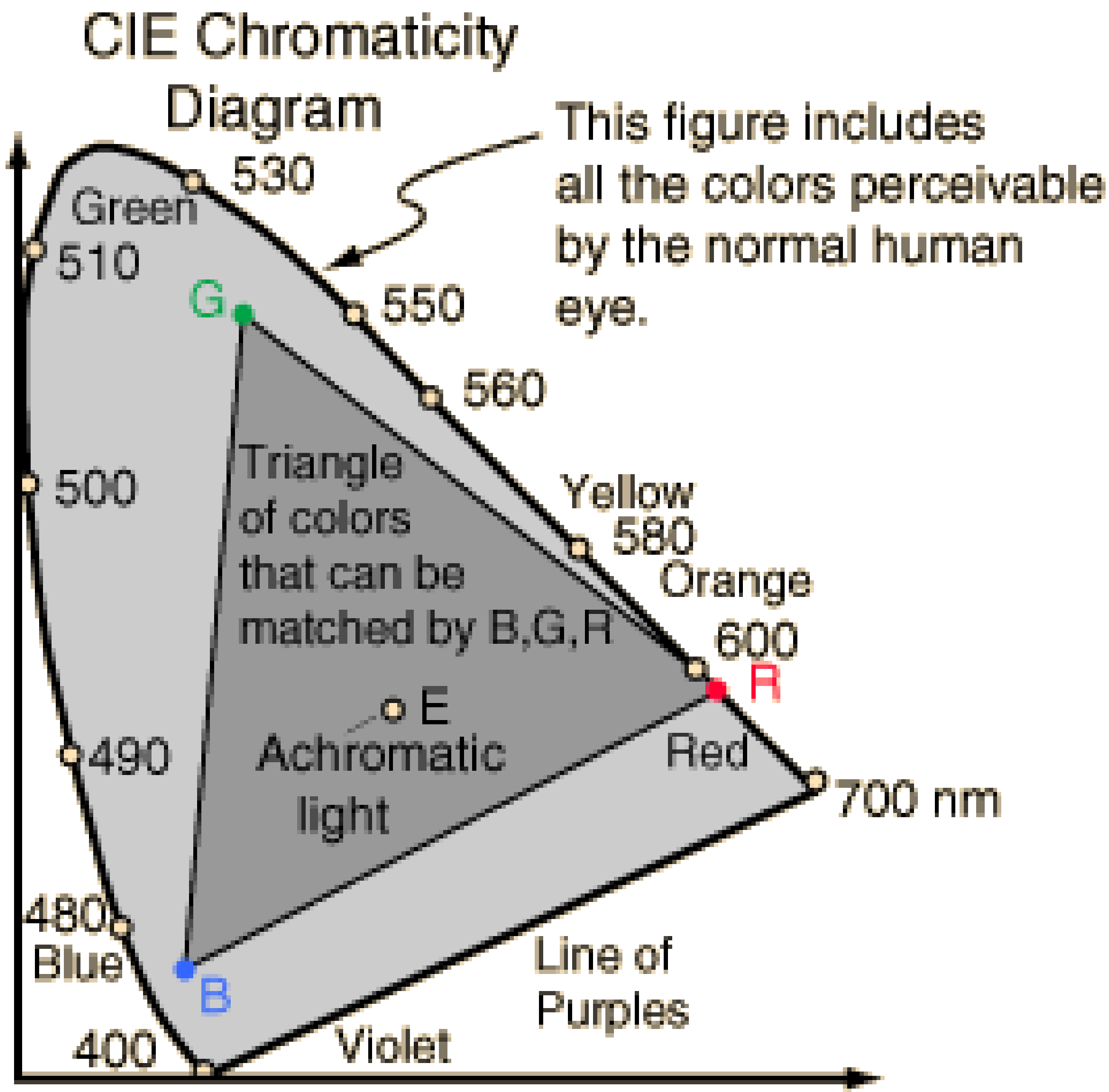
Color films **vary** in their capacity to capture particular hues -- Kodak tends enhance to warm/orange hues,
Fuji tends to enhance cools/greens.)

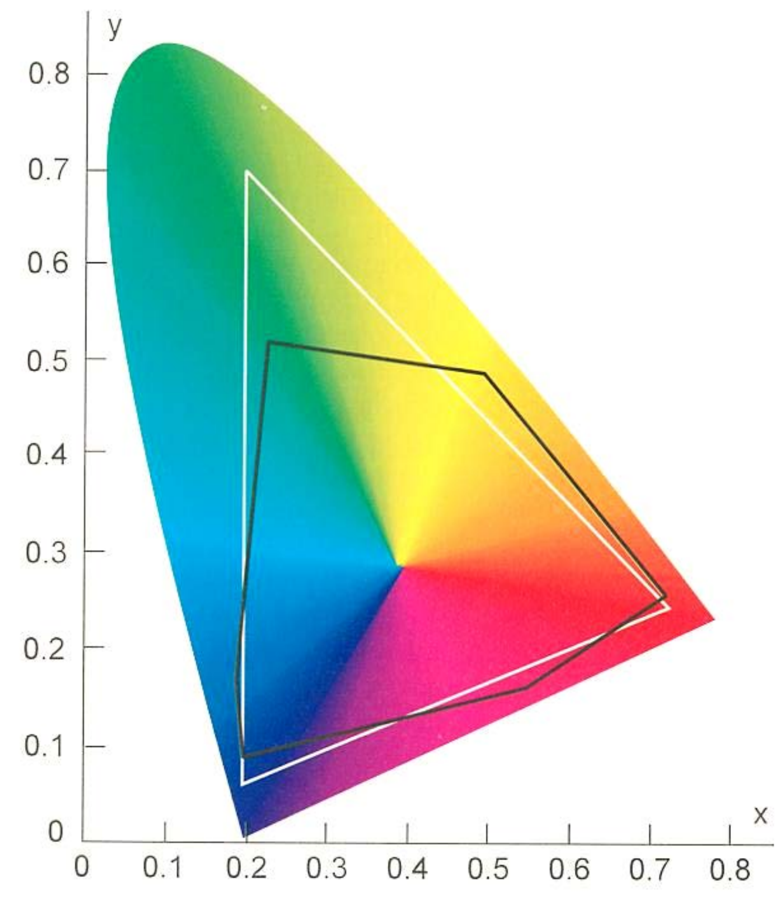
ary.html

CIE

- Visible colors vs. typical RGB monitor







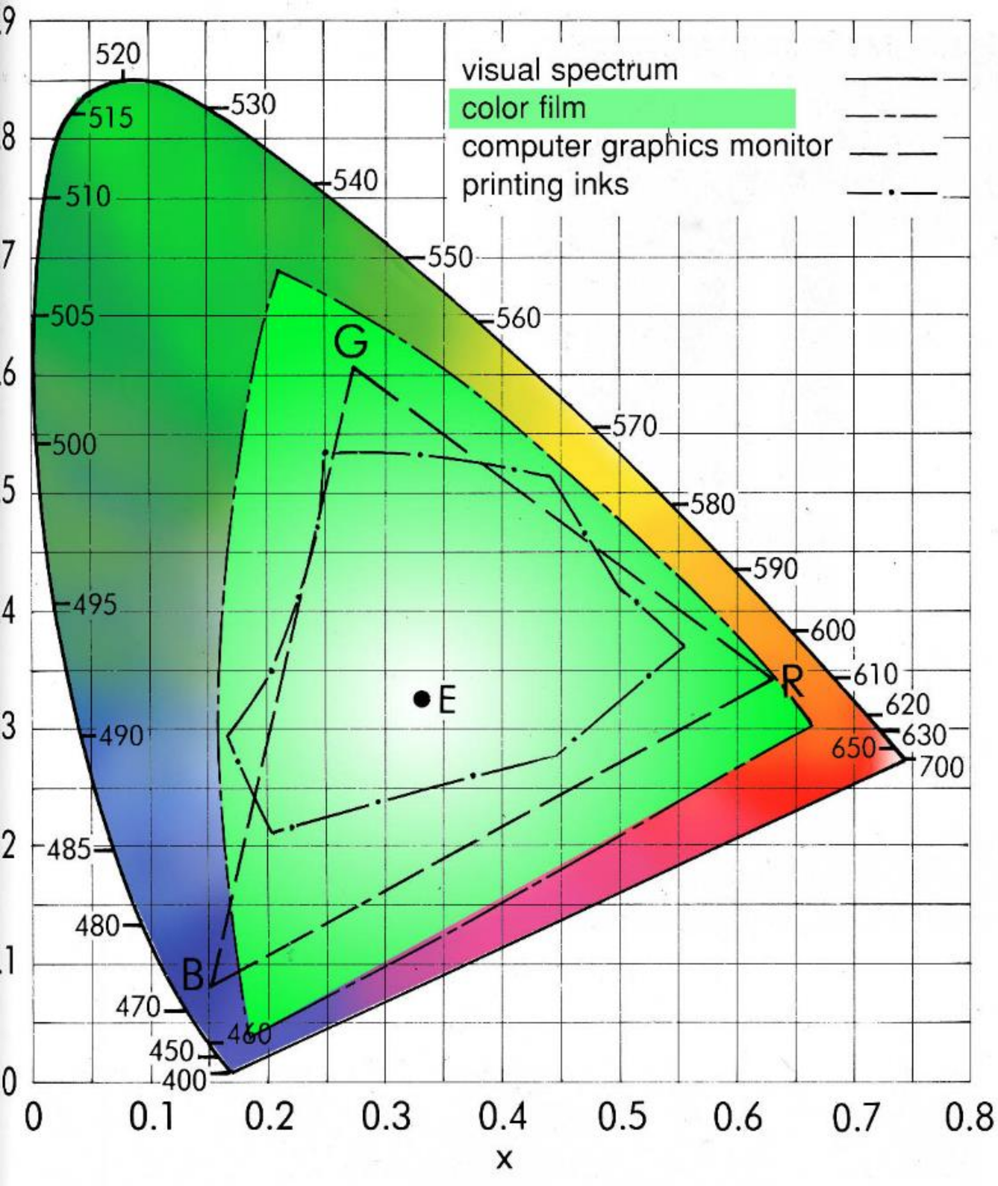
Compressing Color Gamuts

Transparencies and monitors, which display color using transmitted light, **also display only part of that visible color range, or gamut**.

Due to such limitations as reflected light, ink impurities, and paper absorption, a conventionally **printed image is limited to a much smaller range of colors**.

- Much of the work done in **color correction** arises from the **tonal compression of the color gamut that occurs during color separation** — basically, we compress one color gamut to best approximate another gamut.

www.timesprintingco.com/Glossary.html


visual spectrum
color film
computer graphics monitor
printing inks
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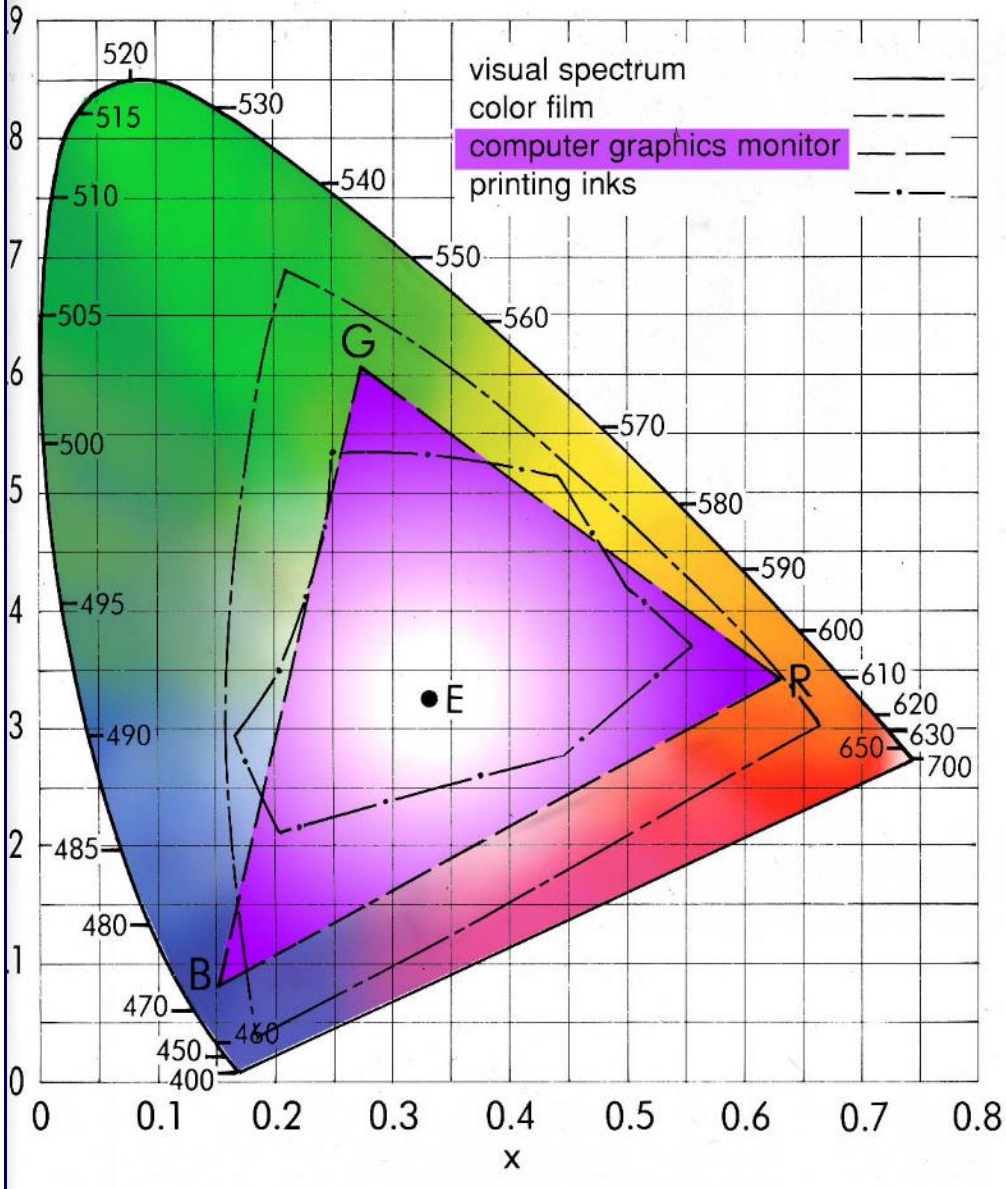
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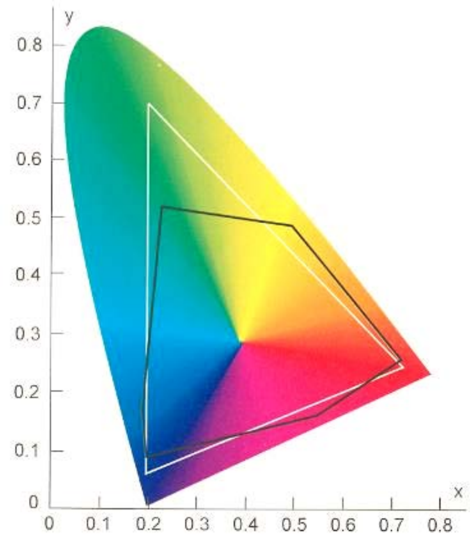
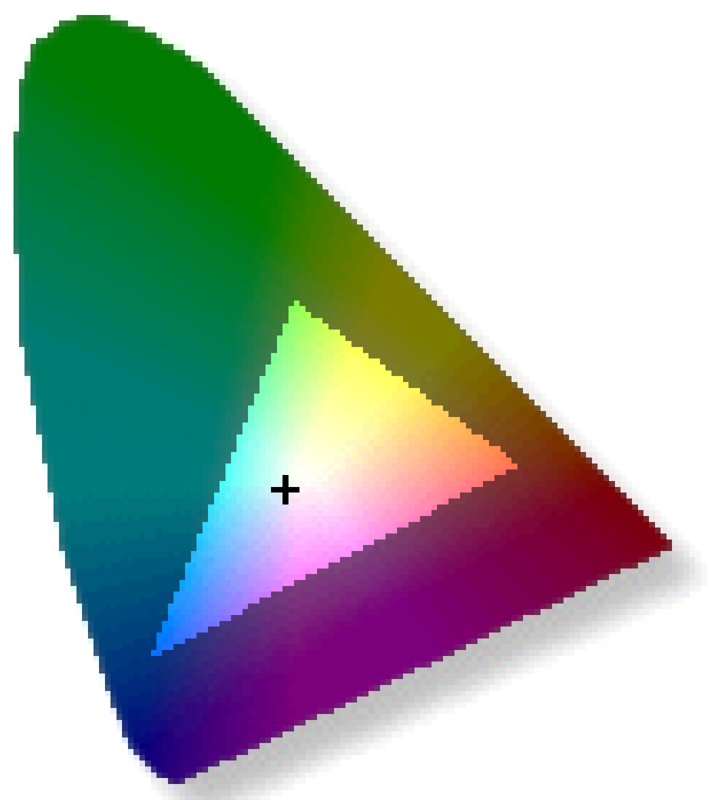
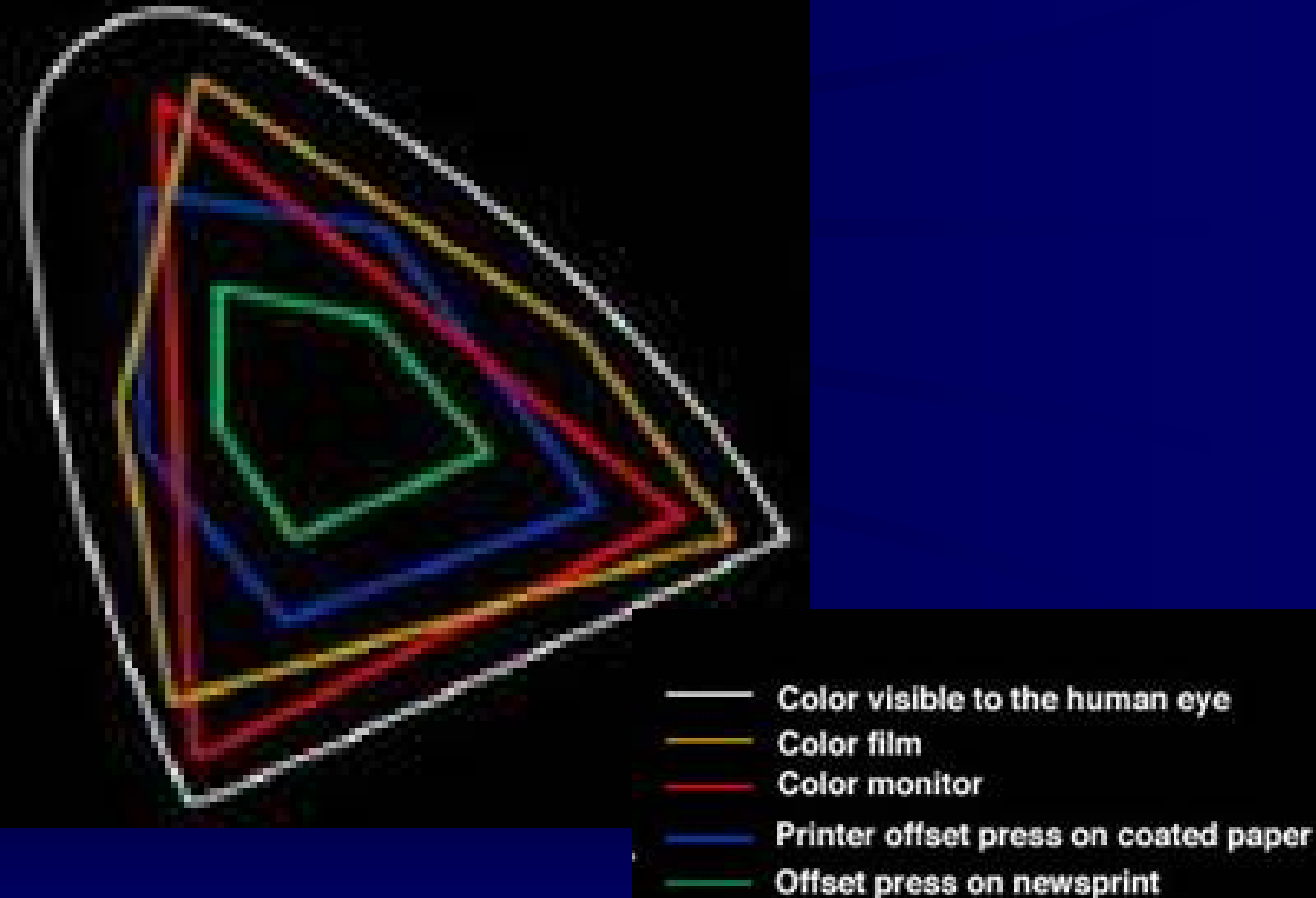


Color Gamuts

- Apple LCD (liquid crystal diode) (left)
- Apple Color Monitor (cathode ray tube/CRT) (right)




Color visible to the human eye
Color film
Color monitor
Printer offset press on coated paper
Offset press on newsprint

Color Printing

- A major industry today.
-
- Has exploded over the past 25 years due to the availability of desktop publishing, electronic prepress systems, direct-to-plate technologies, and… print-on-demand systems. (based on laser-print and ink-jet printers)

Types of Color Spec Options

- Two basic color printing strategies for graphic designers:

- **4-color-process printing**
- **Flat/Match/Spot colors.**

- (*more rare* - specialty ink separations)

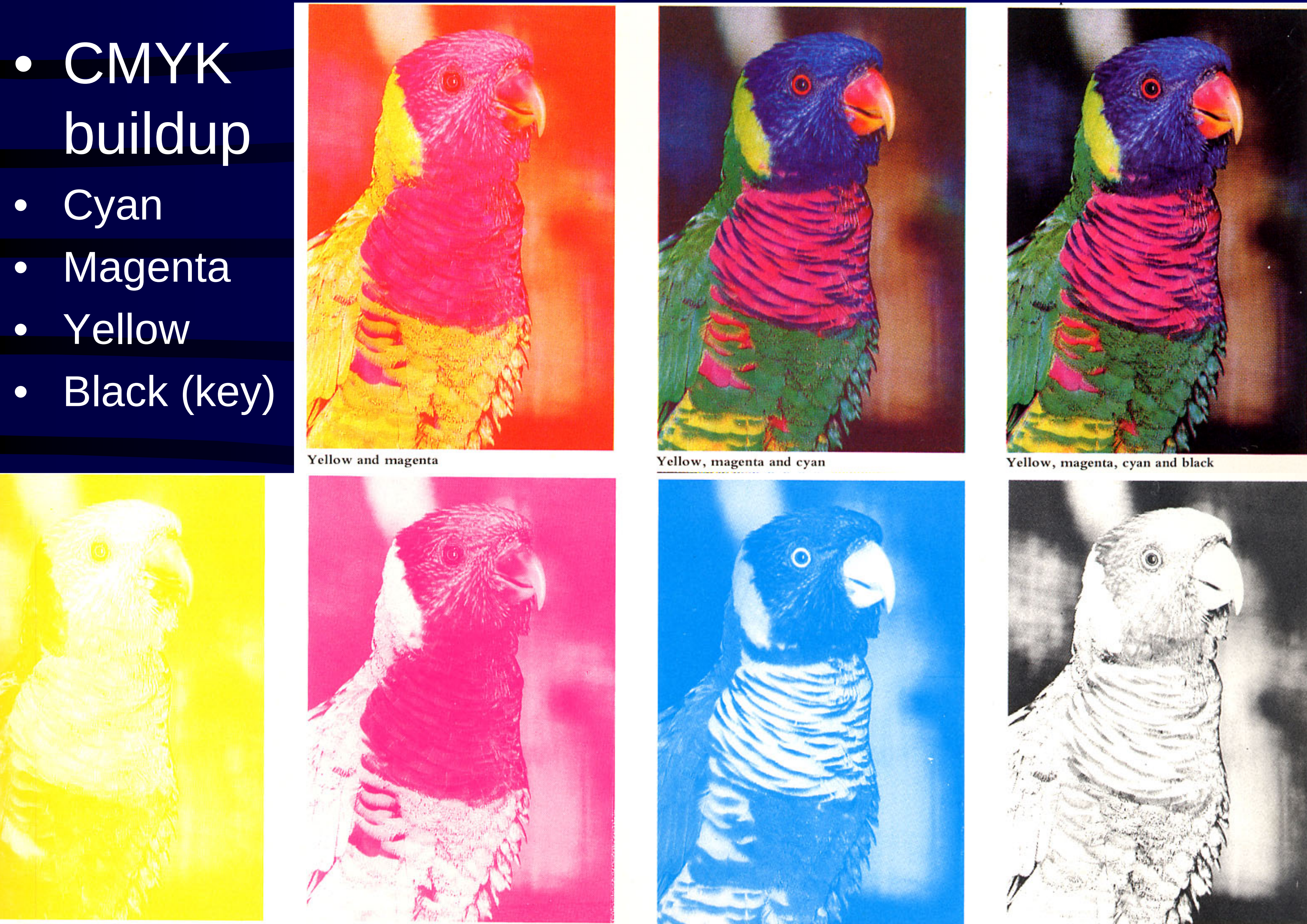
Four-Color Process Printing

- 4-color process is the most common system for rapid mass production of color.
- Many presses are designed specifically for process printing and pressmen are trained to deliver reliable color quality at a good price.
-
- However, *truly reliable color quality is still expensive, still requires the best presses and the most experienced and conscientious press operators* – automation has not yet fully solved color-quality control.

Optical Mixing in 4-Color Printing

- 4-color process colors are created by overlapping the four standard colors of ink, and allowing transparent overlap and optical mixing to produce the desired color.
-
- 4-color printing is rather limited in the range of colors that can be produced – that is, the color gamut is fairly narrow.

- CMYK buildup
- Cyan
- Magenta
- Yellow
- Black (key)



Yellow and magenta

Yellow, magenta and cyan

Yellow, magenta, cyan and black

separation

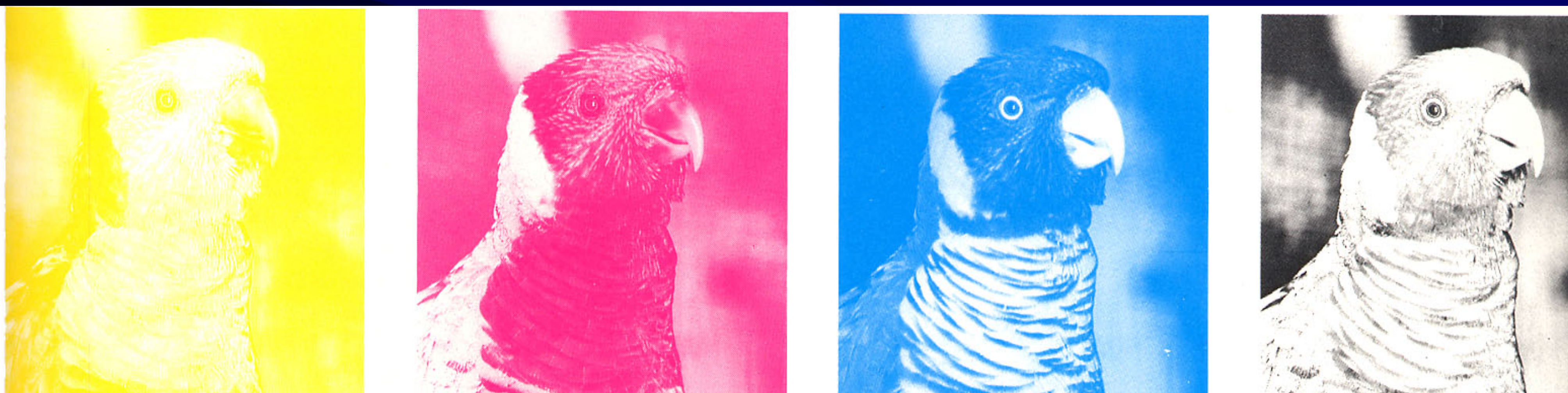
Magenta separation

Cyan separation

Black separation

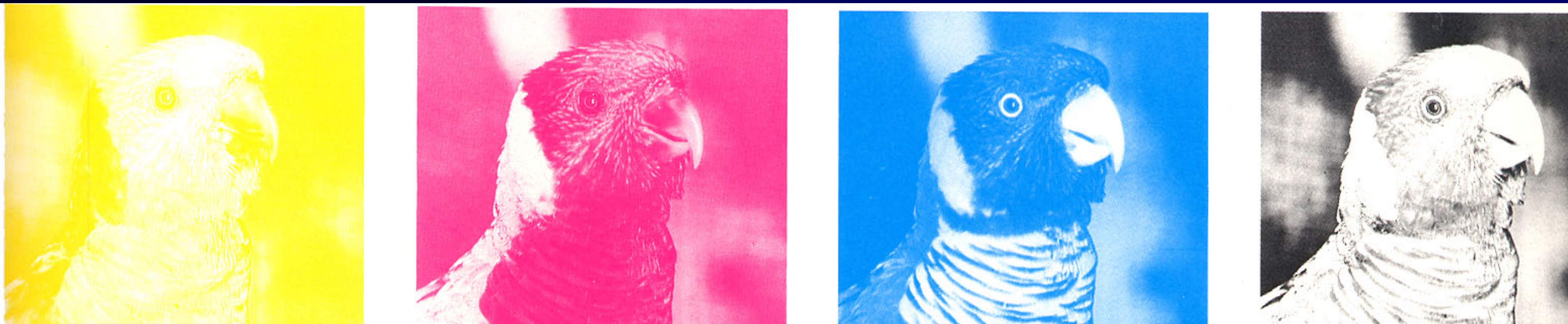
4- colors: CMYK

- Primaries plus Black
- C-Cyan (blue-blue-green) Cyan was a long time coming – only developed in 1940s?
- Y- Yellow
- M- Magenta (red-red-violet)

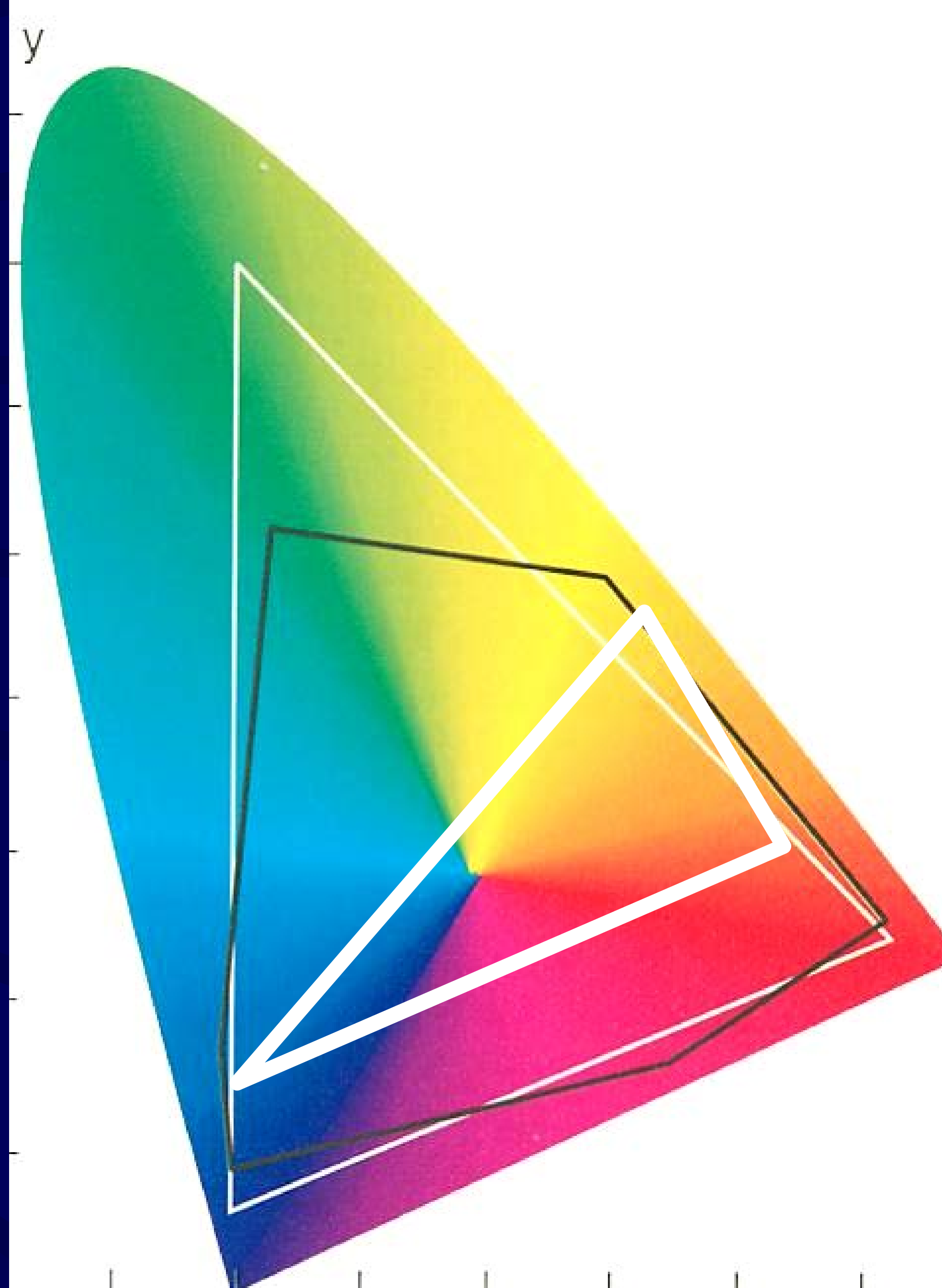


..Plus Black

- K- Black (“key”)
- Black is used to increase the value range. It is possible to create fairly dark grays – or near-blacks with CMY, but black makes sharp value contrast much easier to manage.



- Pre-CYMK separations & printing (early 1880s?)
- Note yellow-orange, red-orange, blue-violet and sepia inks (dark brown) — *NOT* our primaries

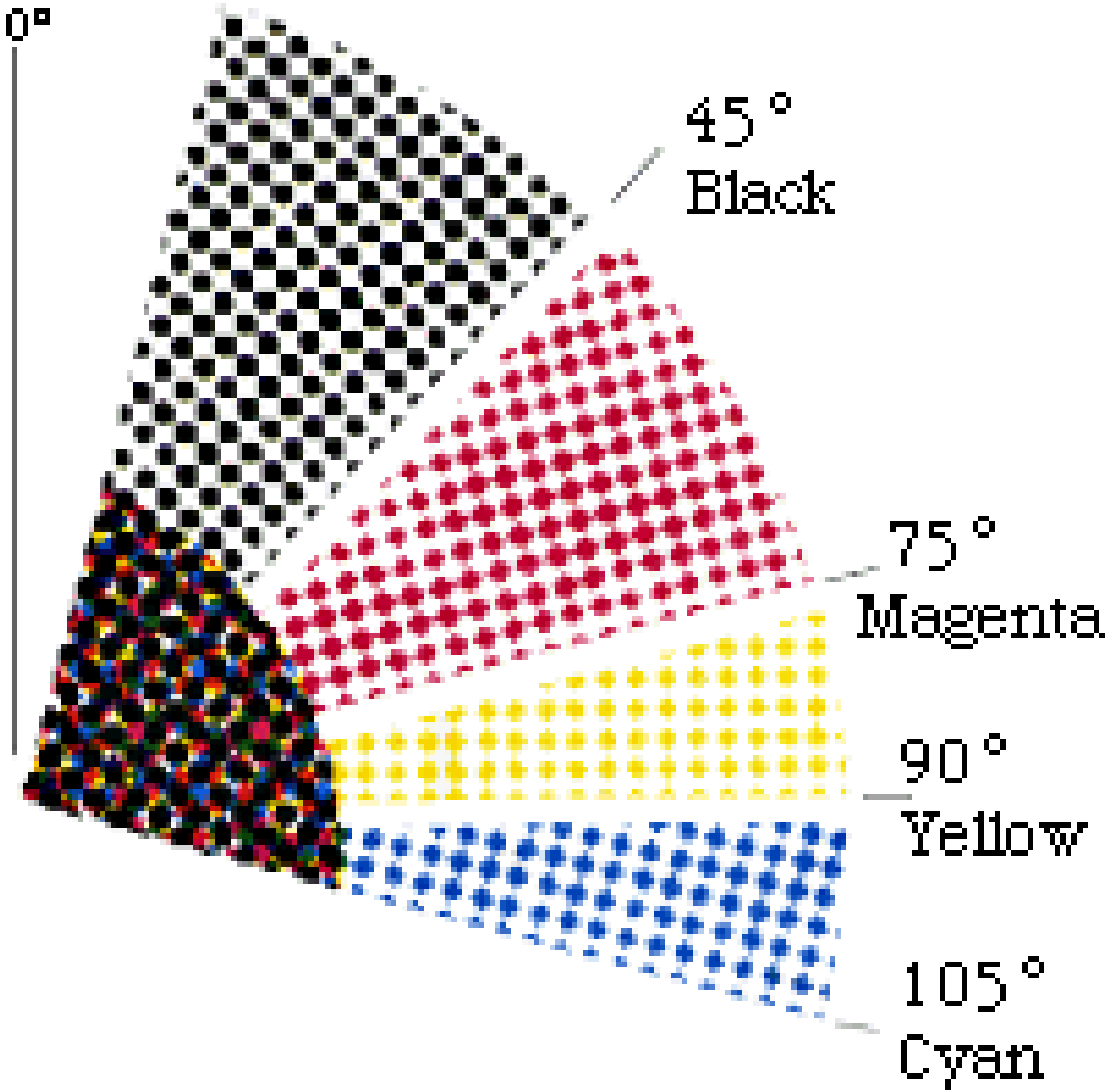


- The available inks *are* the primaries for this color system — they create the potential for color, a particular color gamut.

- Note that this gamut does not offer much potential for *greens*.

Where’s White?

- The paper – usually white — provides the base color.
  Where ink *isn’t*, the image is white.
- Process inks are *semi-transparent*, allowing *transparent-overlap-mixing*.
- For graphic designers, **paper selections are critical** to color fidelity because the paper color always influences the semi-transparent inks used in process, offset printing.



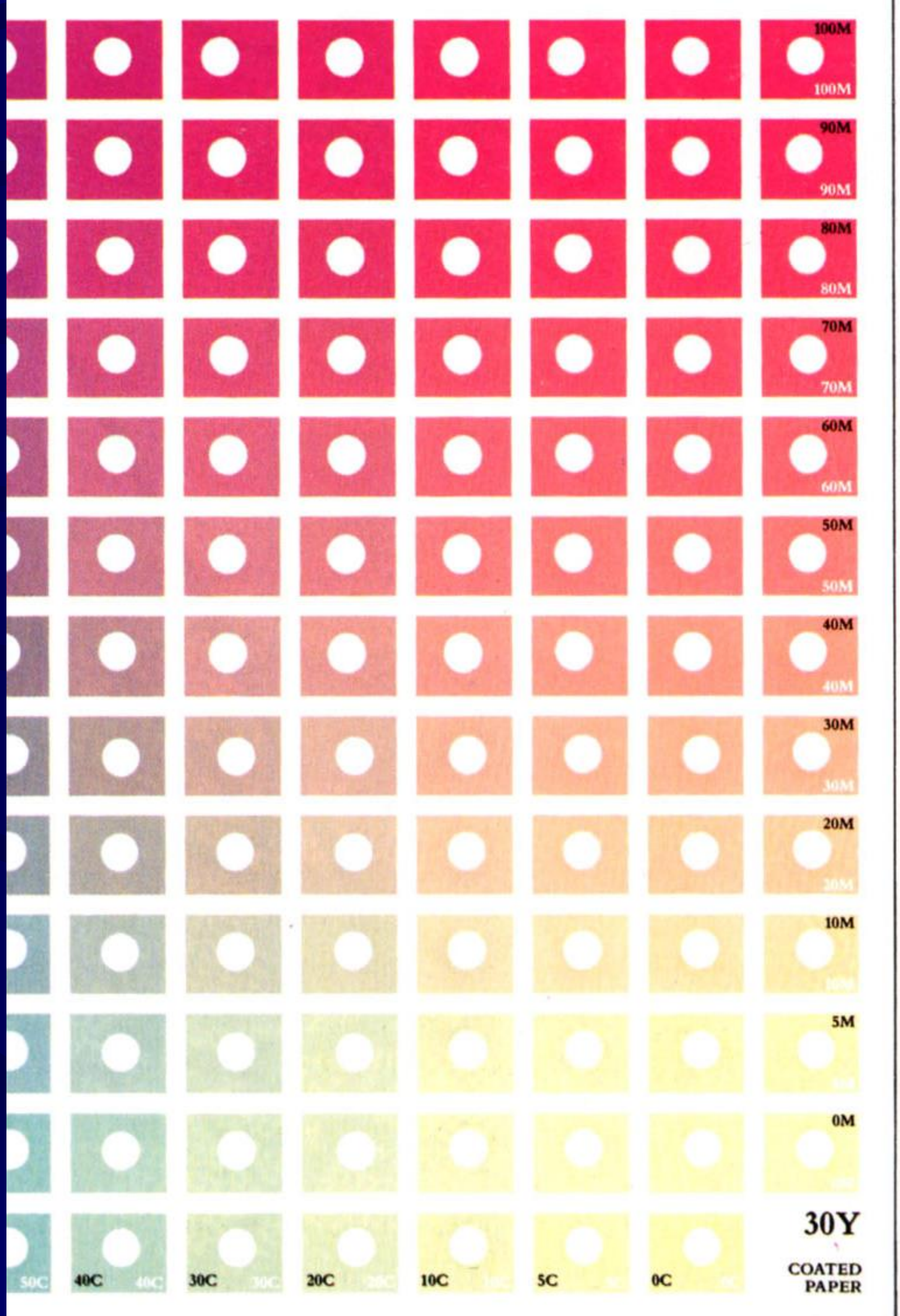
0°
45°
Black
75°
Magenta
90°
Yellow
105°
Cyan

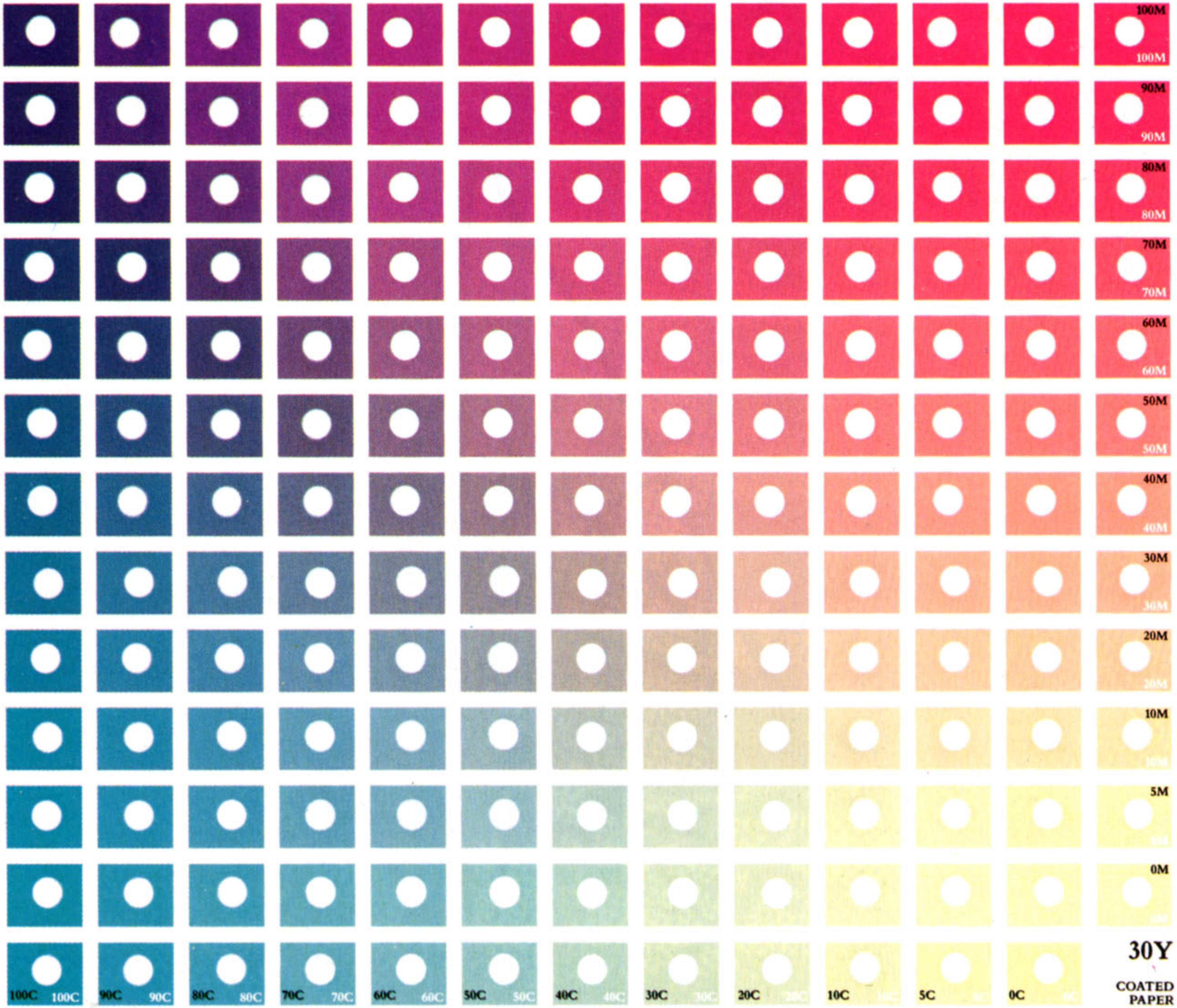
Four-Color Specification

- When individual “spot” colors must be specified for a print produced using process color, the color is specified in terms of percentages of each of the four colors:
- C - 40%, M - 80%, Y - 10%, K - 10% would produce medium chroma violet.
- Coverage of ink not to exceed 270% to keep from muddy buildup.

- In 4-color process separation, ***every color is separated, or divided, into its constituent primary colors*** -- every color is some combination cyan, magenta, yellow and black.

- This process color sample sheet shows colors based only on 30% yellow, and varied percentages of cyan and magenta




100M
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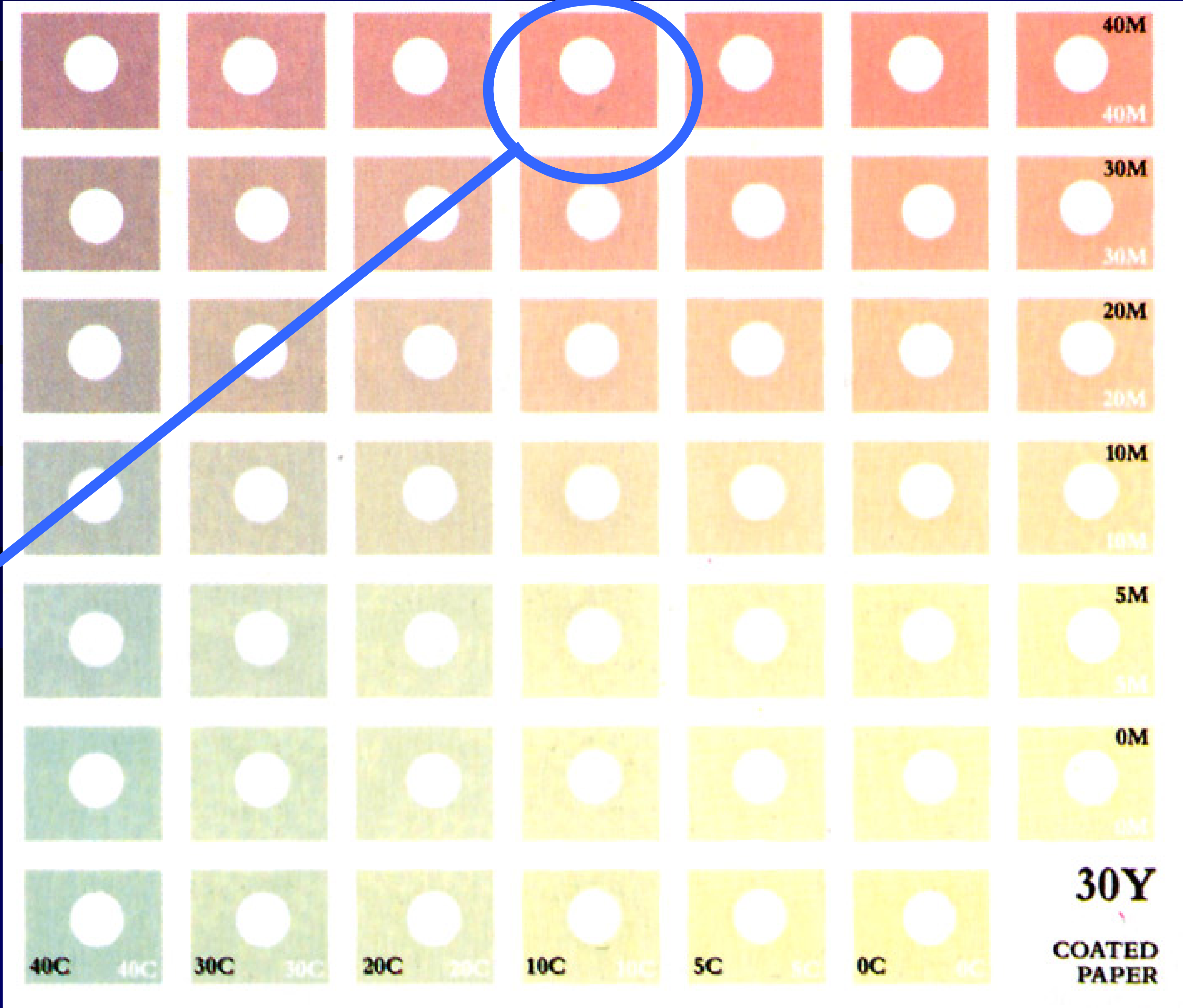
80M
70M
60M
50M
40M
30M
20M
10M
5M
0M
100C
90C
80C
70C
60C
50C
40C
30C
20C
10C
5C
0C
30Y
COATED PAPER

- Y
- M
- C

40%M
10%C
30%Y



- CMYK buildup

Expanding the Color Gamut

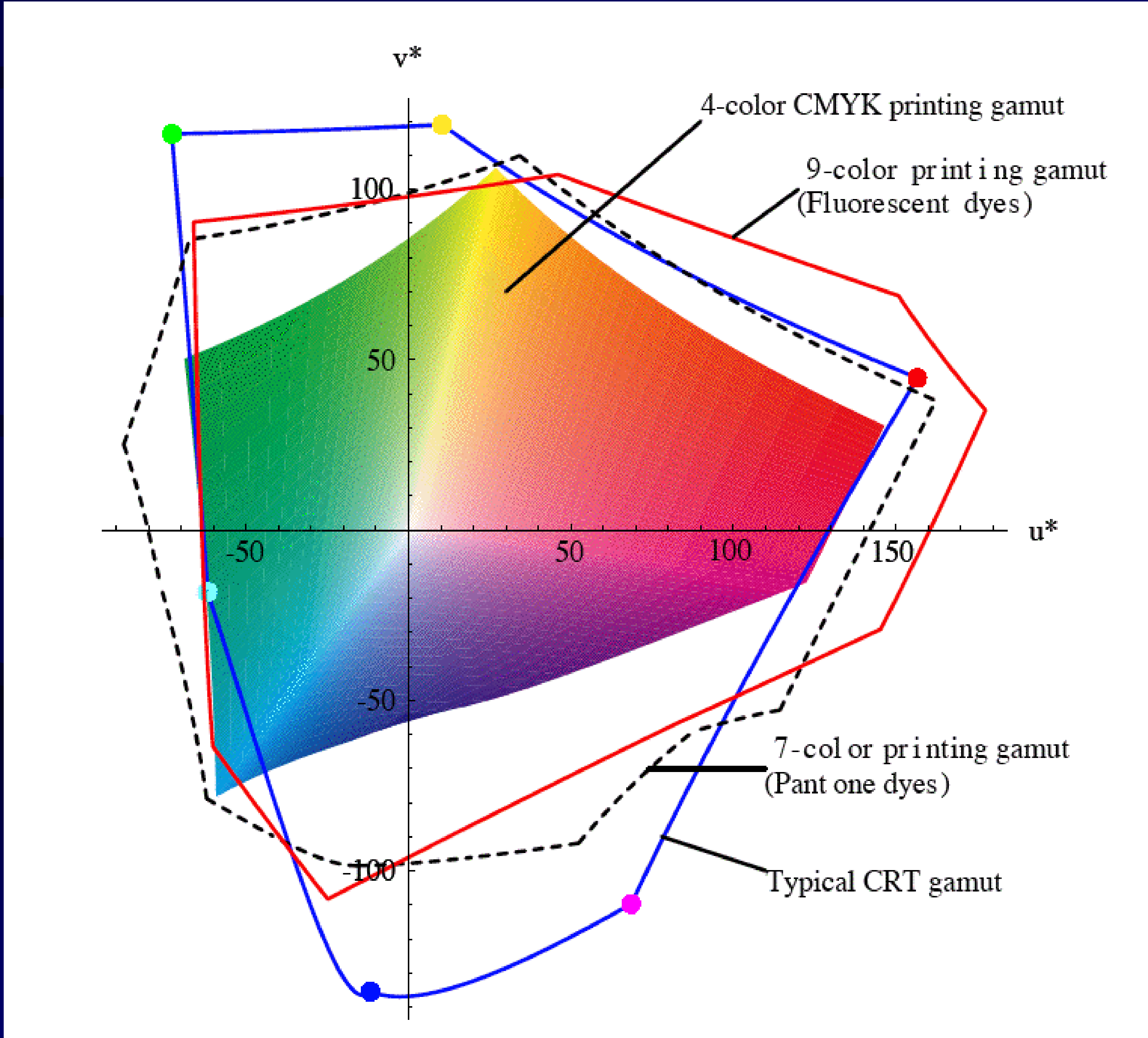
- Designers will sometimes print 4+1 colors – *process colors plus one spot color*.
- *Fine color reproductions can be printed in 6 or more colors in order to widen the color gamut*, to create more subtle variations in color, and to provide richness in particular colors important to a particular image.

High-End Offset Litho Printers

- In order to expand the color gamut of printing, some offset systems link 7 or more presses, each printing its own color – typically 4 process colors plus spot colors and laquers.

Relative Color Gamuts

- Varied Color Printing inks
- Heptatone (7-color) printing and 9-color printing gamuts compared to CMYK printing gamut

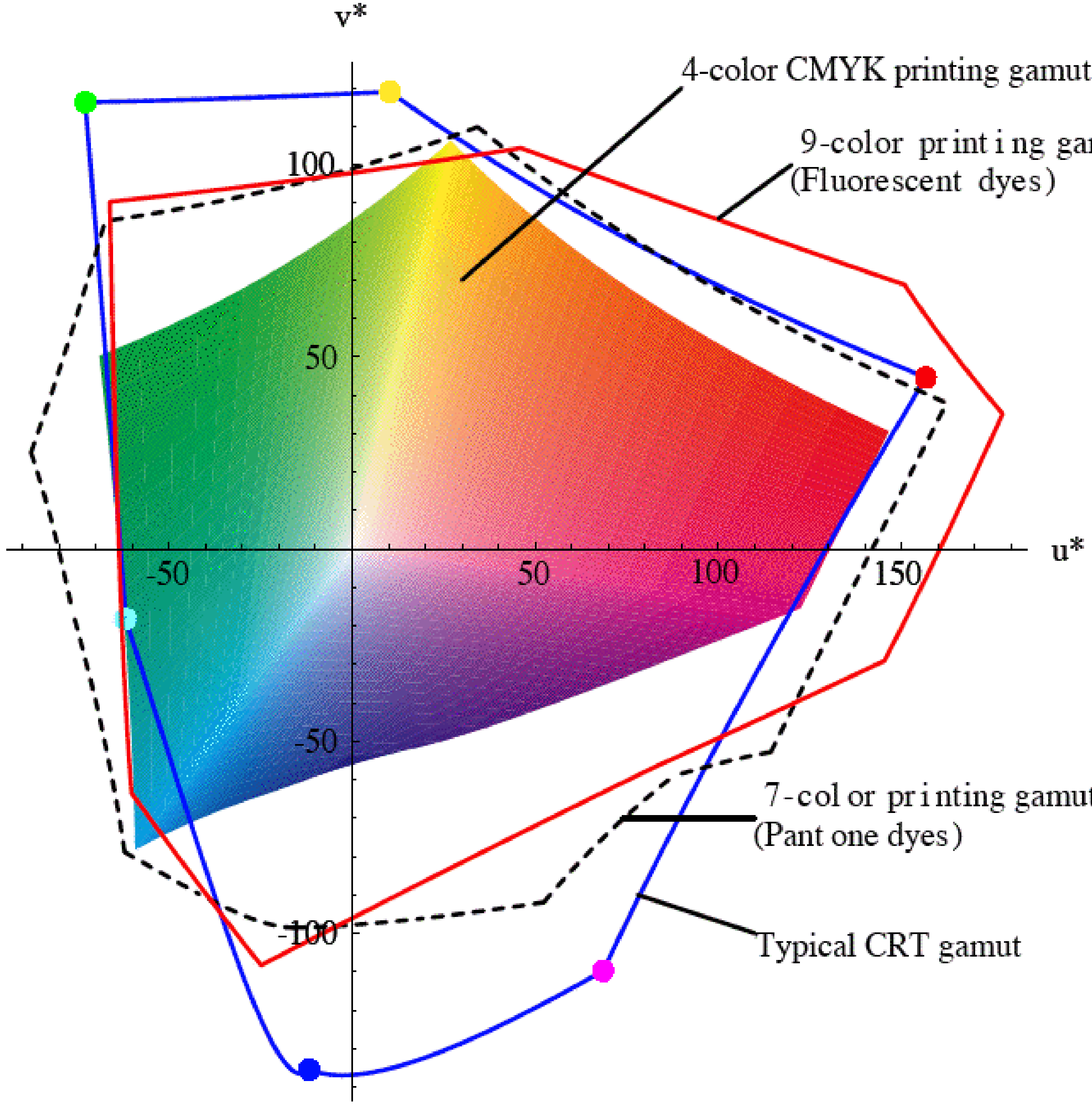


Relative

- Pantone's 9-color system includes Red, Green, Violet, Orange

9-color printing basic colors:

PANTONE 801C
PANTONE 802C
PANTONE 803C
PANTONE 804C
PANTONE 805C
PANTONE 806C
PANTONE 807C
PANTONE Blue072
PANTONE Process Black

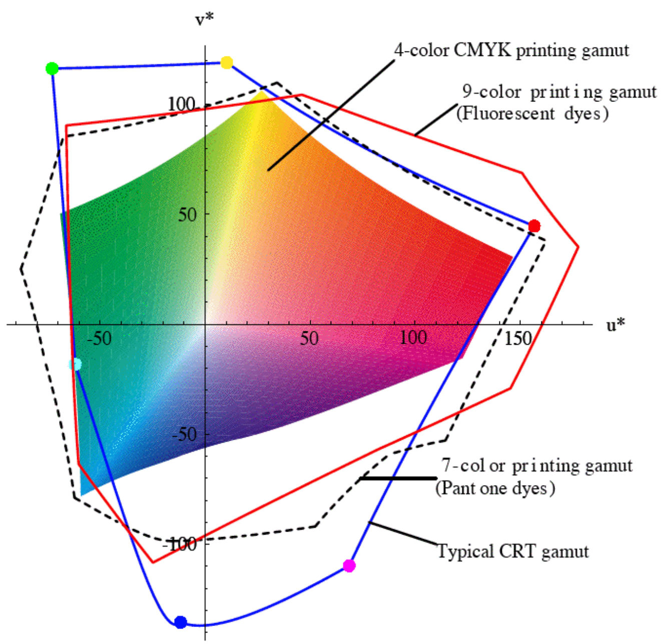


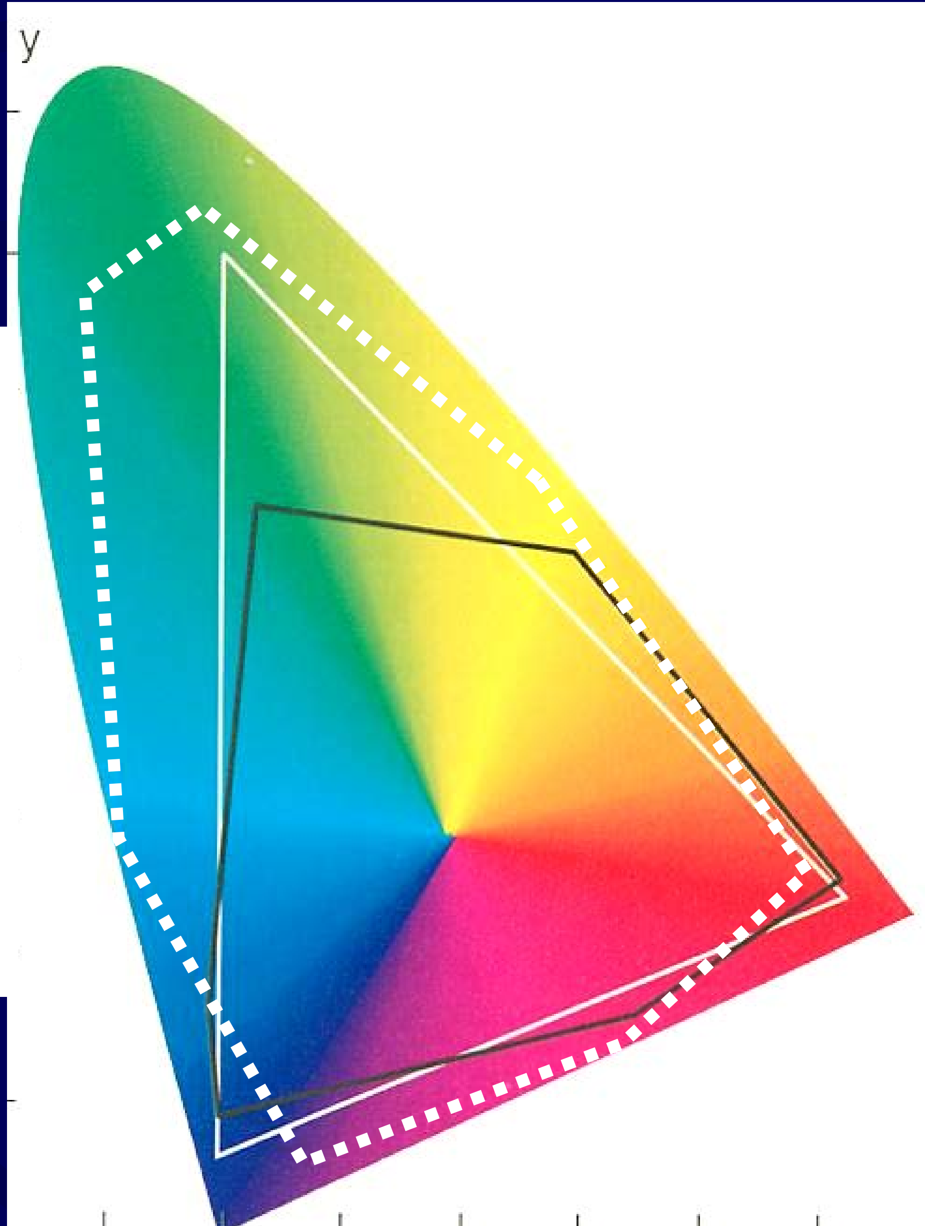
Relative Color Gamuts

- Varied Color Printing inks

9-color printing basic colors:

PANTONE 801C
PANTONE 802C
PANTONE 803C
PANTONE 804C
PANTONE 805C
PANTONE 806C
PANTONE 807C
PANTONE Blue072
PANTONE Process Black



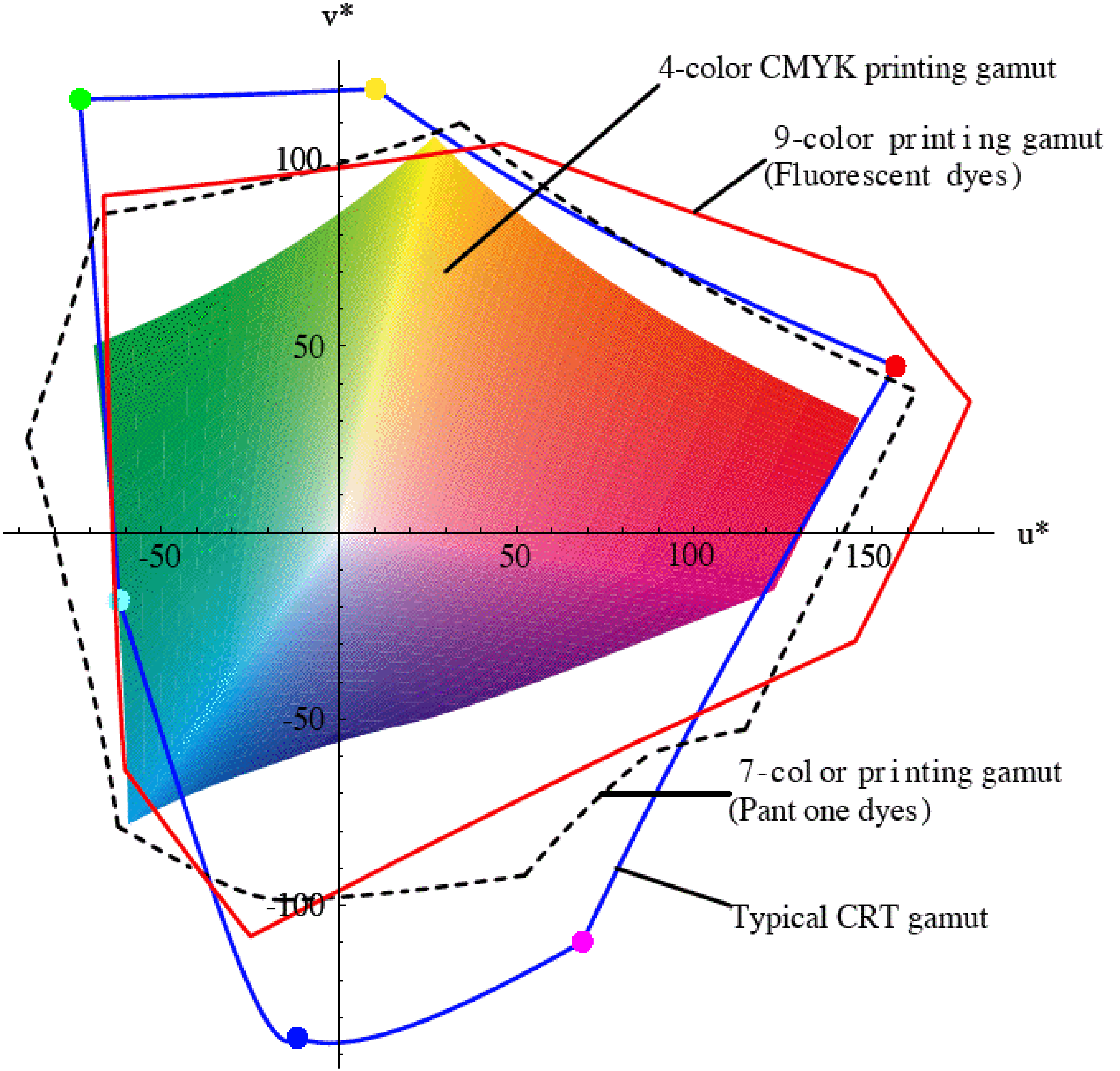


Relative C

- Varied Color Printing inks

Heptatone printing basic colors:

SICPA Process Yellow
SICPA Rhodamine Red
SICPA Purple
SICPA Blue
SICPA Process Cyan
SICPA Green
SICPA Process Black

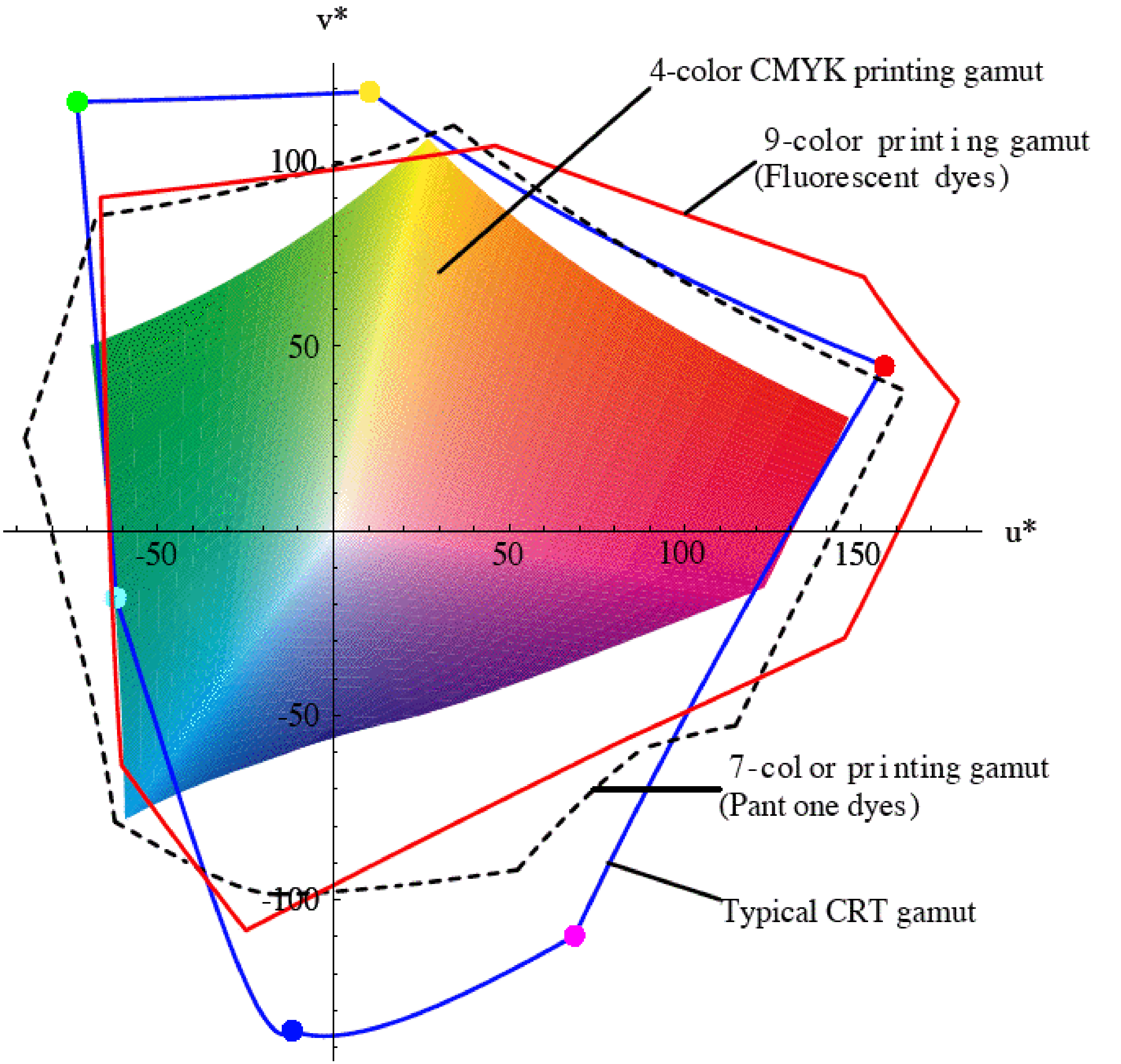


Relative (

- Varied Color Printing inks

CMYK printing basic colors:

SICPA Process Yellow
SICPA Process Magenta
SICPA Process Cyan
SICPA Process Black

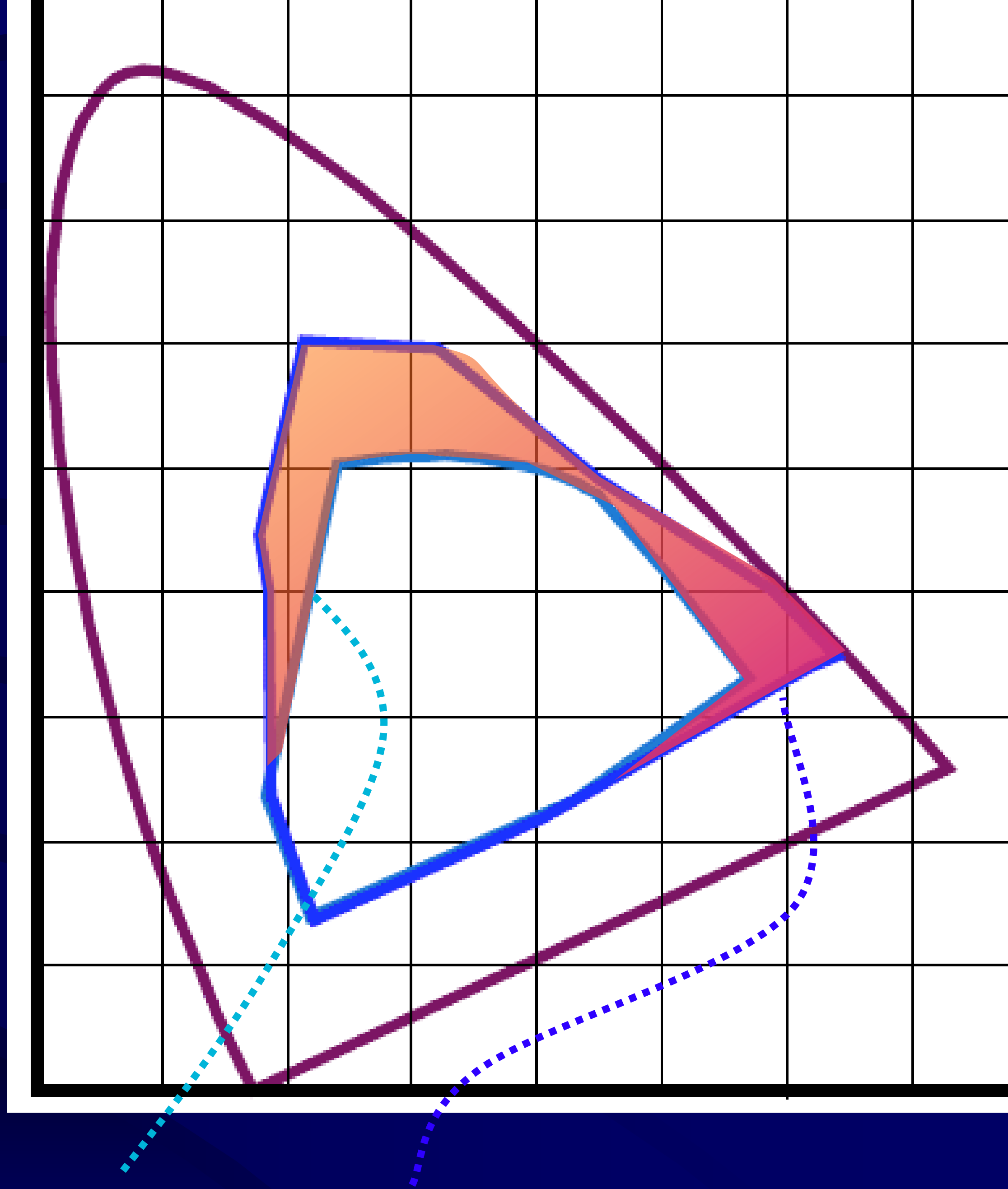


Hexachome

In addition to custom CMYK inks, Hexachrome adds orange and green inks to expand the color gamut, for better color reproduction.
It is therefore also referred as the CMYKOG process.

While the details of Hexachrome are not secret, use of Hexachrome is limited by trademark and patent to those obtaining a license from Pantone.

Note: Pantone discontinued their Hexachrome printing system in 2008, but some print services still offer it (e.g. RPImaging).



CMYK vs. CMYKOG Gamuts

Color Control of the Multi-Color Printing Device, by Wang et al., 2006

http://en.wikipedia.org/wiki/Hexachrome

Altering the Color Gamut

- Experiments in producing natural color using fewer colors of ink, and/or inks other than process inks.
- Images are digitally analyzed for prominent colors.
- Specific ink colors are selected to best produce the range of colors present in the particular image. (NEW primaries)
- How successful is each combination? What is lost?

two custom colors and black

Expanding the Color Gamut

- Original image mapped onto 4 different target color gamuts

process colors/inks to produce a satisfying, broad range of color.

- http://diwww.epfl.ch/w3lsp/pub/research/colour/

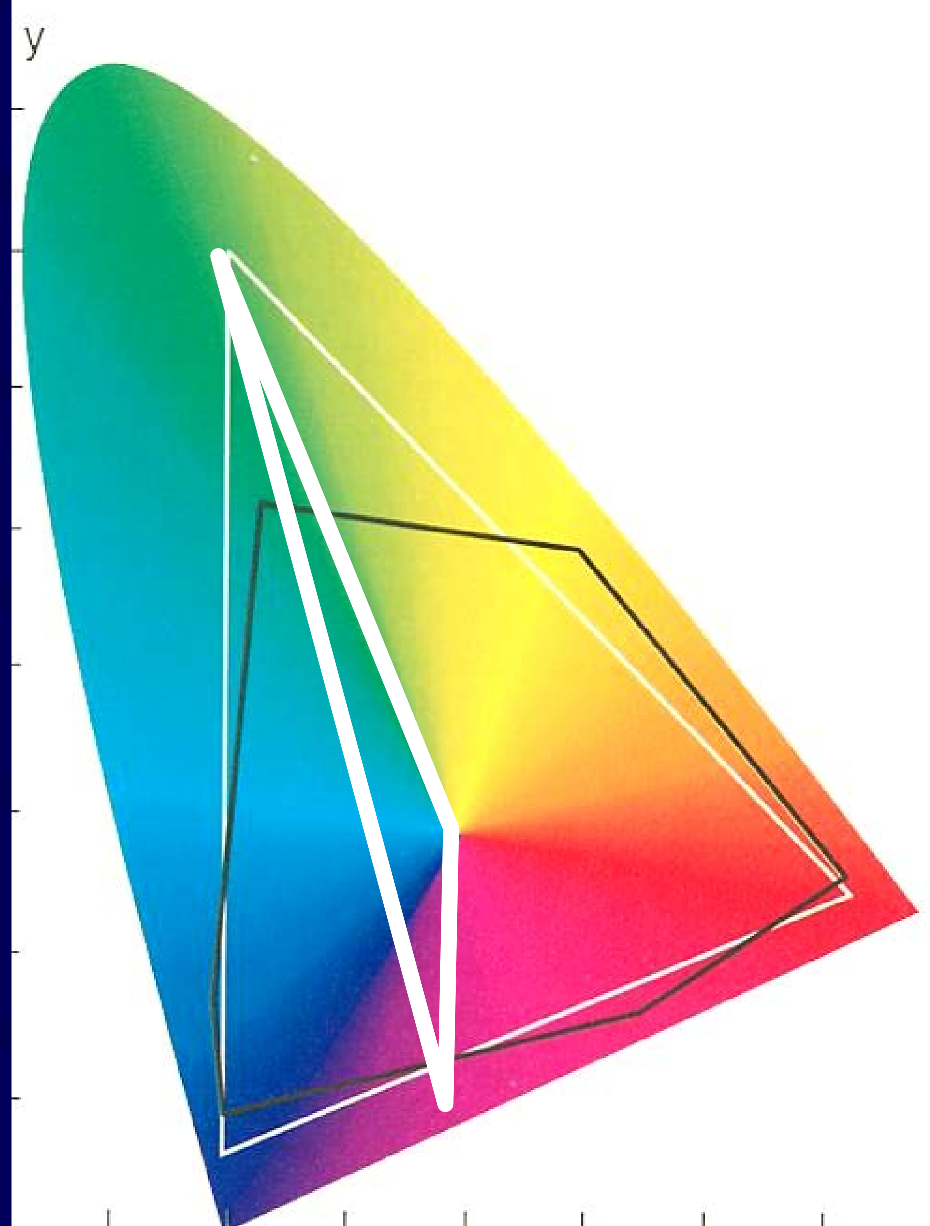
Expanding the Color Gamut

Original image mapped onto different color gamut

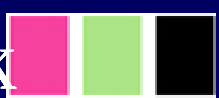
two custom colors and black

Expanding the Color Gamut

Original image mapped onto different color gamut



two custom colors and black



Neutral black offers suggestions of blue. Note no yellows — Flesh tones are all pinkish, but somewhat satisfactory.

No good blues, but some blue-violet.

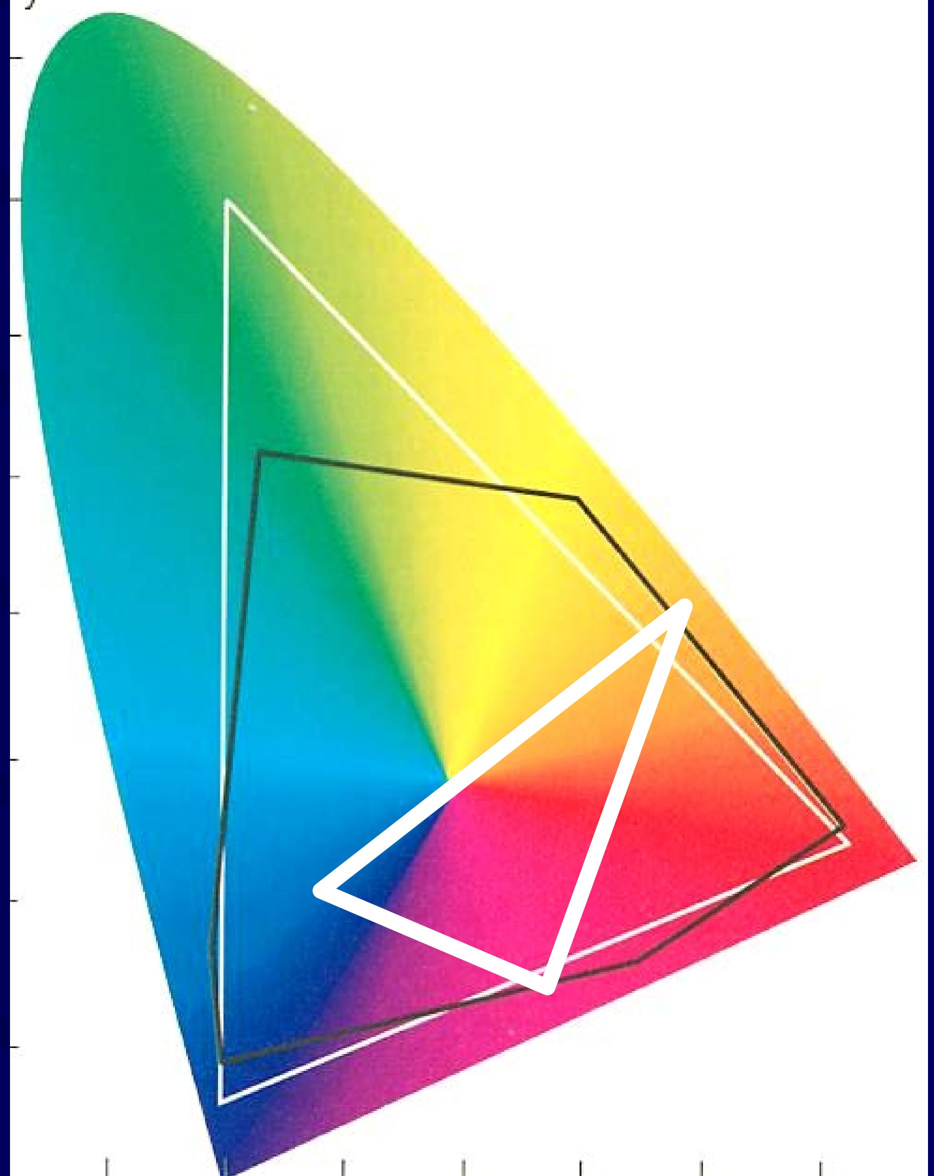
Expanding the Color Gamut

Original image mapped onto different color gamut

three custom colors &

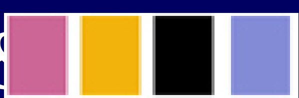
Expanding the Color Gamut

Original image mapped
onto different color gamut



Flesh tones now have Y/YO hues. Richer blues are present. Poor greens due to YO, BBV.

three custom colors &



Expanding the Color Gamut

Original image mapped onto different target color gamut

three custom colors *NC* k

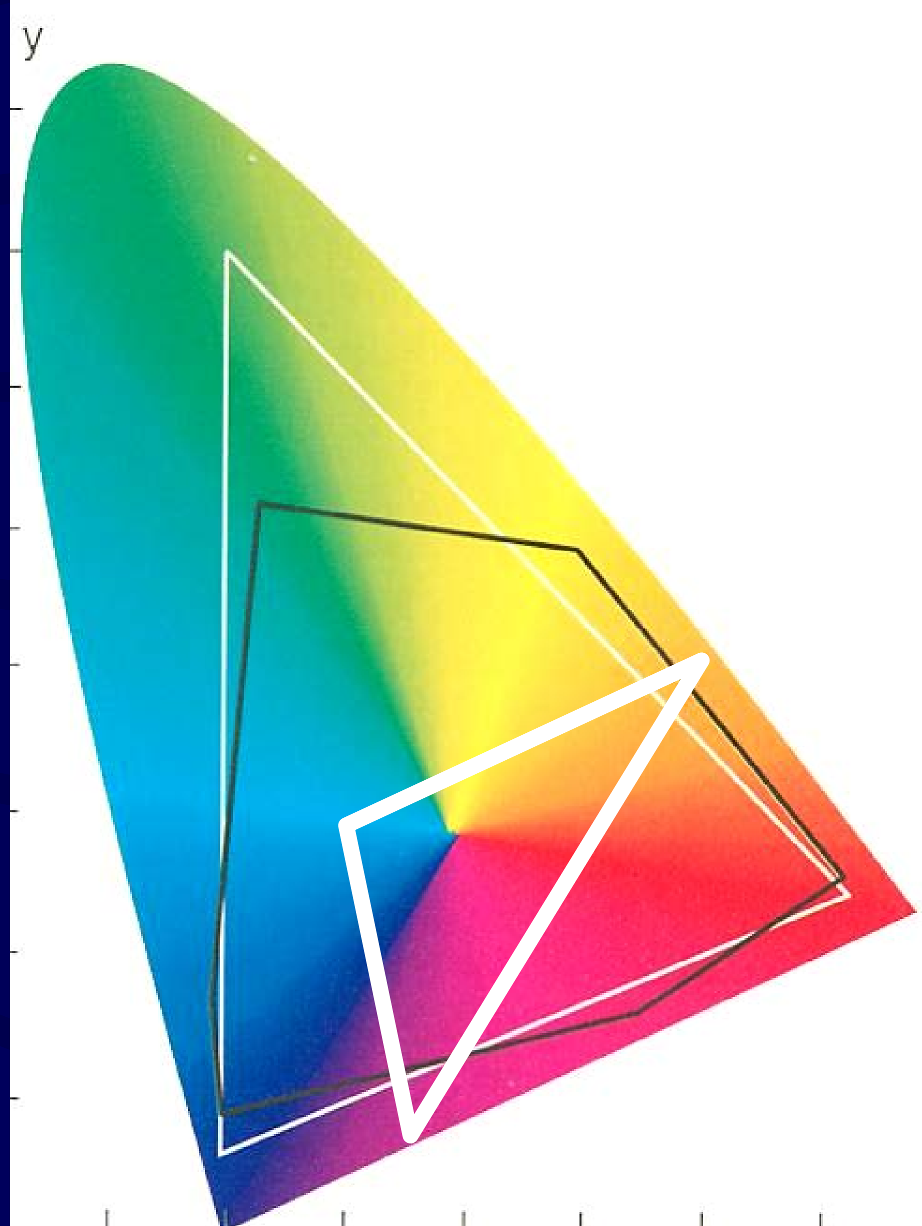
Expanding the Color Gamut

Original image mapped onto 4 different target color gamuts

three custom colors NC k

Expanding the Color Gamut

Original image mapped
onto different color gamut



Very poor greens, but flesh tones are fairly rich. Absence of black limits density/contrast of value.

three custom colors NC k

Expanding the Color Gamut

Original image mapped onto 4 different target color gamuts

Common Six-Color Printing Systems

- Note that there are now inexpensive inkjet "Photo" printers that print in **six-colors**, rather than the standard four process colors of ink.
- Lighter shades of cyan and magenta are added to enrich subtle tints and hue distinctions.
- CMYKcm –
- (Epson/HP offer 7-color printers: CMYKcmk)

CMYKcm — *CcMm?*

- C – standard cyan or darker – fairly dark and rich in color density.
- “c” – light cyan – a pale, soft, lighter cyan that can be used to mix subtle blues.
- “M” – standard magenta or darker – dark and rich in color density.
- “m” – a light magenta – pale, more transparent, lighter so subtle red and red-mixes can be created.

- “These ink sets provide smoother blends (less visible pixels), particularly in bright areas. They usually do not extend the limits of the color gamut of the device, which is still constrained by the cyan, magenta, yellow, and black inks. In special cases, however, they can slightly increase the color gamut in the near-white areas making the bright colors look "very clear and shiny".
  Some manufacturers call such printers 6-color-printers, but correctly it should still be considered as 4-C process.”
- http://en.wikipedia.org/wiki/Hexachrome

Refined-Color Subtleties via 7+ color Printing

- **Most of today's photo and fine-art-printing technologies produce refined color transitions by using "softer" versions of the usual CMYK process color.**
- **The printer, below, offers**
- **LIGHT BLACK**
- **LIGHT MAGENTA**
- **LIGHT CYAN**
  inks, as well as the standard process colors.

  This particularly helps the very fine transitions and subtleties of flesh-tone coloration.

Continuous Tone

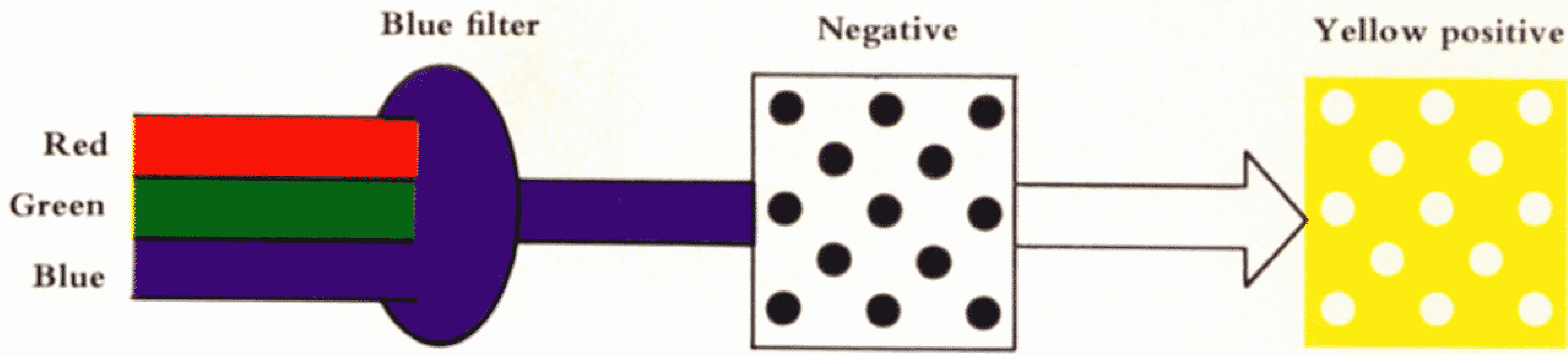
- Continuous tone images have a full range of color or value. Printing continuous tone images is much more difficult than “line art”.
- Continuous tone offers black, white and everything in between.

Photos are continuous tone

- Photographs are normally continuous tone images.
- We use the term “continuous tone” whether we’re speaking of “black-and-white” photos (grayscale) or color photos.

Color Separations

- A photographic or a digital process whereby the full range of colors in an image are separated in constituent colors – the colors are divided into their primary colors and black.
- Traditionally, photographic techniques used colored filters to “separate” each color from the original.



Photographic separation and halftone screening

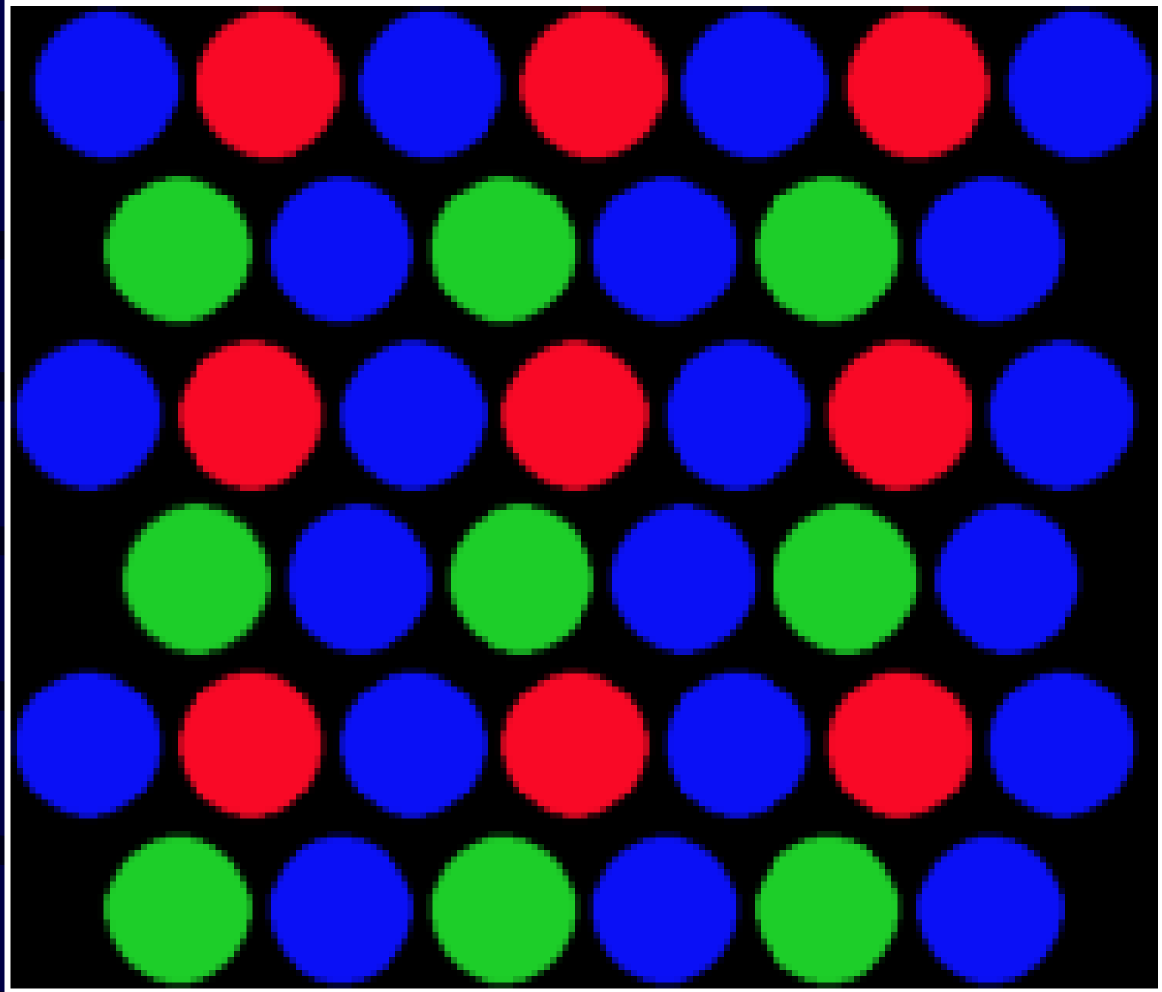
- Blue filter “removes” all but yellow range of light in original image. (color separation)
- Halftone screen is also used to create the negative. (screening)
- Negative is used to make positive printing plate—which applies yellow ink. (platemaking)
- Plate is inked and printed on paper (printing)

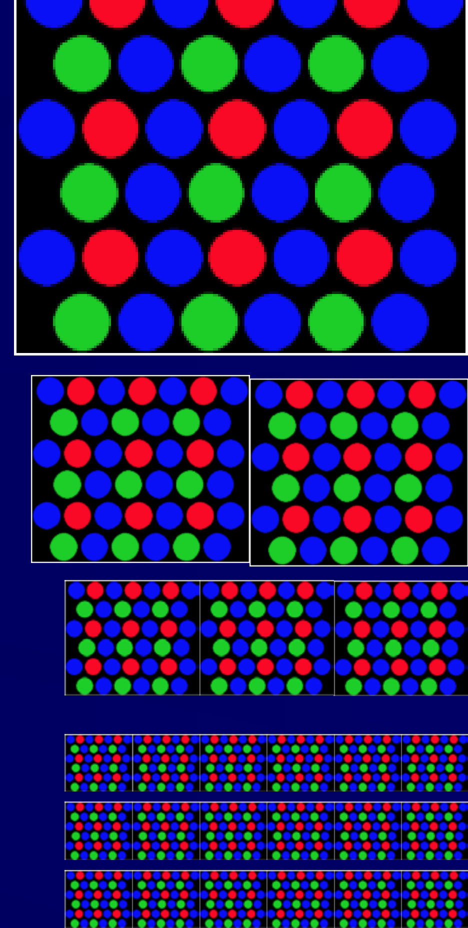
Digital Separations

- Today, most separations are done digitally.
- Any time you use a color scanner or a digital camera, the colors of your subject are being separated into the optical primaries – red, green, and blue.
- Further digital conversions are necessary to create a CMYK separation.

Computers Store Separate Color Channels

- Whenever you view colors on a computer, you are looking an image that is divided (separated) into its (additive) primaries -- RGB.
- The computer monitor has red, green and blue phosphors that glow.
- Your eye recombines those three colors -- Optical Mixing at work!





- Computer monitor/television RGB phosphors
- Optically mixed additive colors (light)

Digital Conversions

- Graphics Prepress Software Uses Many color specification systems -- or color models.
- Most graphics applications allow you to work with RGB (native to the computer) or CMYK color definitions. (Photoshop, Illustrator, etc.)

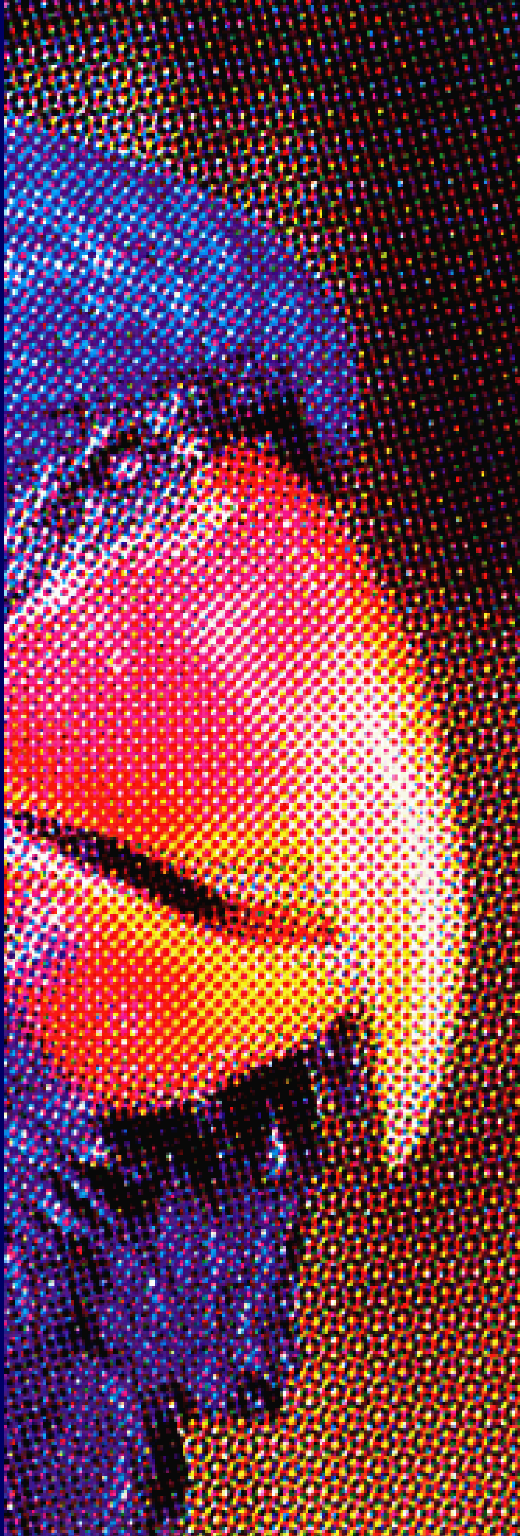
- Imaging devices (all printers, monitors and, yes, palettes of acrylic colors) have a **gamut** — a range of potential colors.
- **Color mapping** translates colors from one gamut to another, aiming to offer an adequate translation within the limits of the final imaging device.

Production Printing Technologies

- Offset lithographic presses are the most common printing technology used in graphic production printing.
- Flexography, engraving, serigraphy are also widely used, but are specialty options – appropriate for special situations, but not for general, low-cost, high-volume printing.

Offset Lithography

- Offset litho prints line art that pretends to be continuous tone art.
- That is, litho only produces “ink”, never “50% ink” to create a medium gray or “10% ink” to create a pale gray.
- We must rely on *screened images* to create the illusion of continuous tone images when printing technologies do not produce true continuous tone colors.



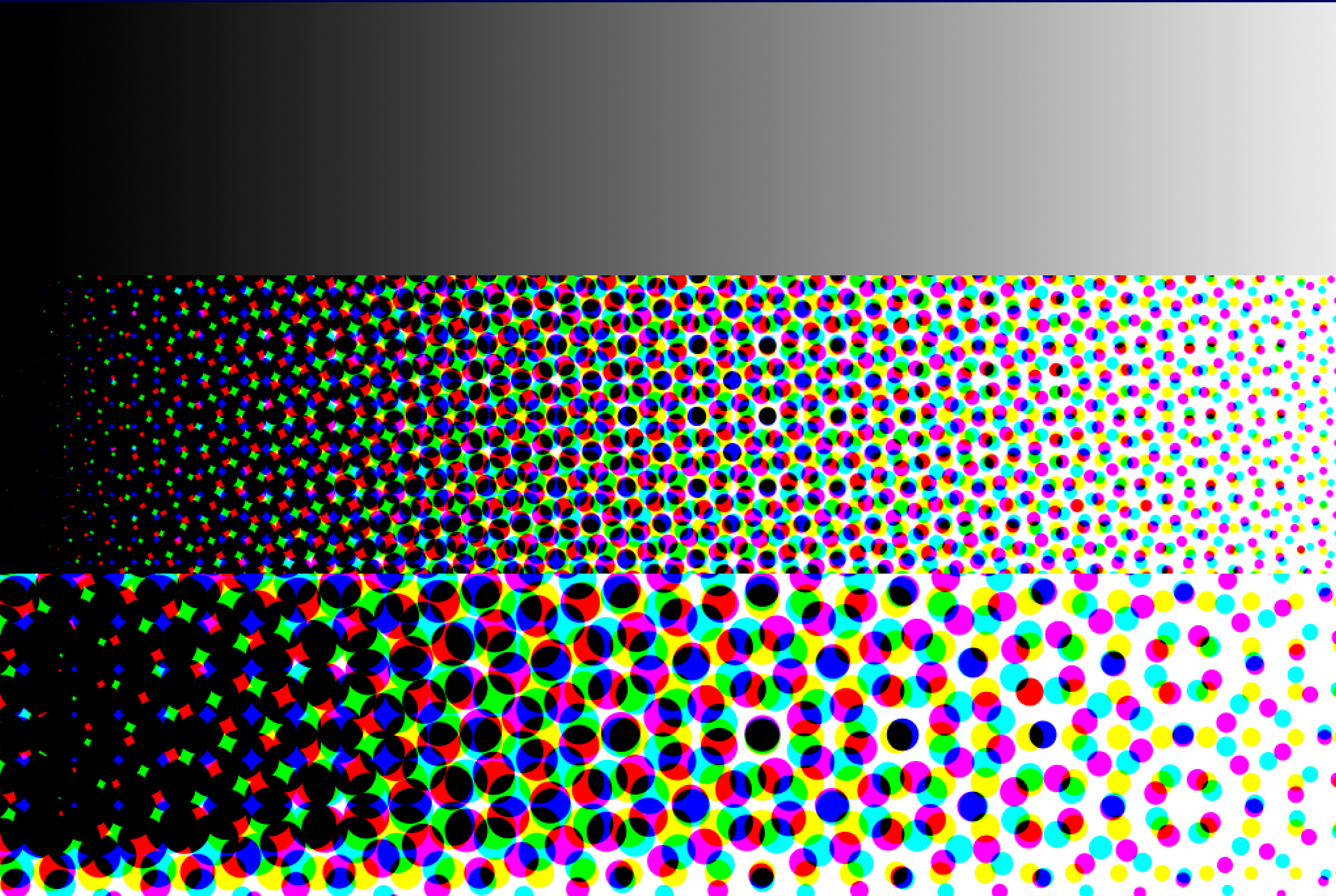
Screening or Halftoning

- *Continuous tone images must be* ***converted*** *to line art before printing.*
- **Halftones** create the illusion of continuous tones on line-art printing devices.
- The screening process breaks up the image into fine dots – the smaller the dots, the lighter the apparent tone.
- The larger the dots, the closer to full ir coverage and so the darker the appar tone.

Screening -- “auto-stippling”

- Screening is a bit like automatically stippling thousands and thousands of tiny ink dots so that black ink can thereby render varied values of gray.
- Screening is absolutely essential to 4-color process work – if we didn’t use screened color, we have only 4 flat colors to pick from.   Dull.

Screening or Halftoning



Screening or Halftoning

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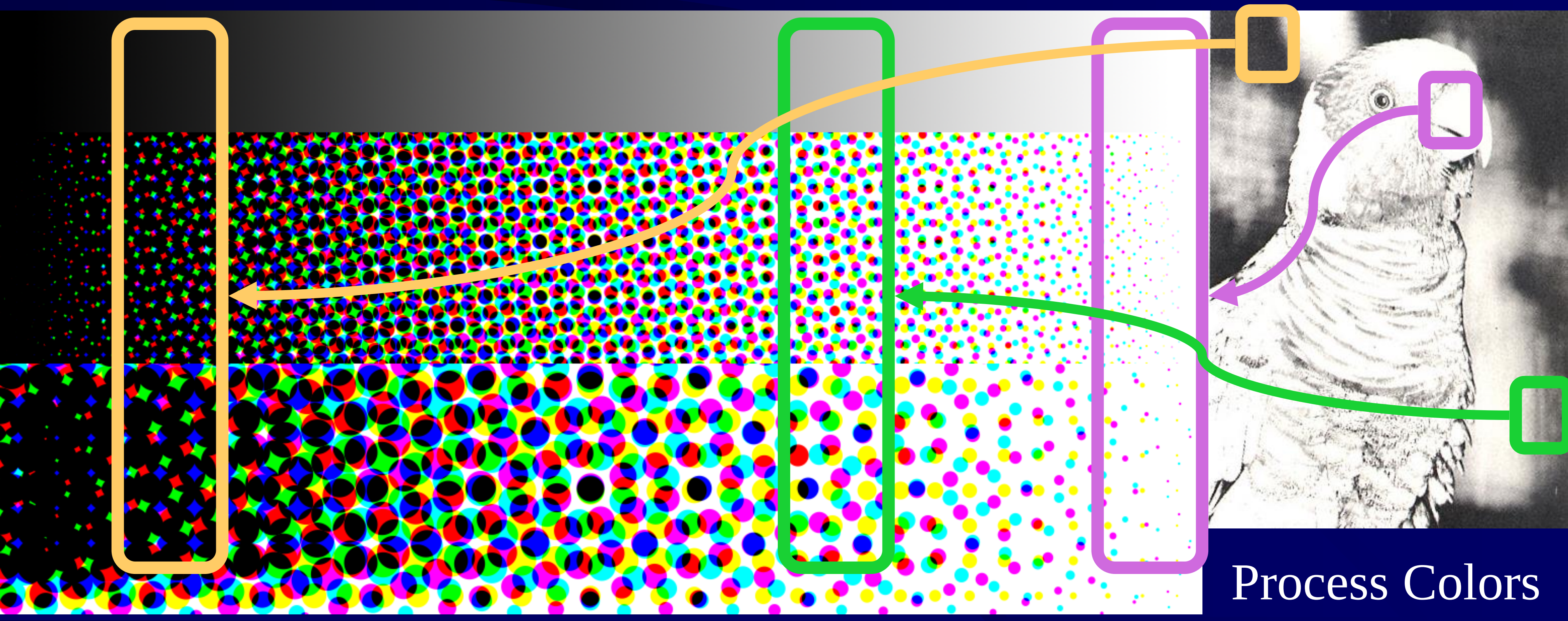
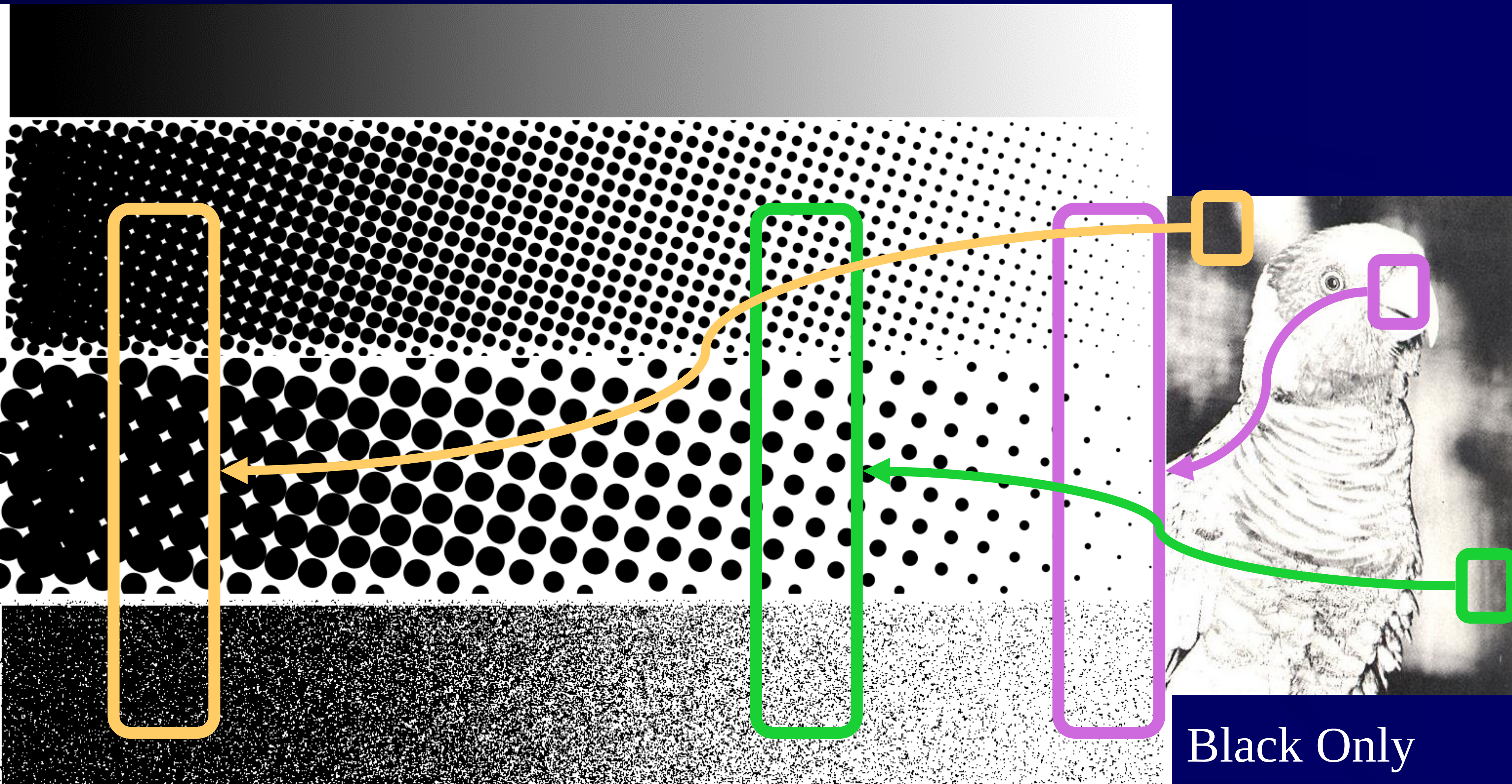


Screens

- There are many *types of screens* (dots, diamonds, ellipses, line screens, mezzotint, etc.)
- With Postscript, you can create your own screen.



Black Only

Technical Issues in Print Production

- There are many technical issues involved in preparing and managing 4-color printing. But this is such a widely practiced technique that prepress operators and pressmen are well trained to handle most problems.
- Graphic designers, however, need to understand technical printing issues in order to anticipate the problems their designs can create during production, *and…*
- …to be able to imagine ways to fully exploit the technical possibilities of production processes.

Process Color Issues include…

- Screen angles
- Screen type/dot types/ line screens
- Screen frequency (lines per inch)
- Trapping (overlapping of color areas)
- Ink spread (ink soaks into paper)
- Paper-ink interaction (gloss vs. textured)
- Press variations, humidity, temperature, moisture in ink…
- Varnishes, specialty inks, fluorescents, etc.

Spot/Match/Flat Color

- Spot colors offer designers the option of selecting **a specific ink** to satisfy the need for a particular color in a design.
- Can be combined with 4-color process jobs when one color is must be either very accurate or very brilliant.

Spot, Match, or Flat Colors

- Different terms for the same technique.
- The press uses a color of ink mixed to match exactly the color required by the designer.
- This produces accurate, bold, sharp color -- richer than process can provide.
- However, spot colors are difficult to plan in combination with process colors -- and so are usually isolated in the design.

Matching "Match" Colors

- Often called "match" colors because the pressman must "match" a particular color sample, specification of a color swatch by mixing an ink to match the color sample.

Spot Colors

- Often called “spot” colors because the designer will often use such colors only in isolated spots or regions of a design.
- A company logo and a headline, for instance, might be printed in IBM-blue, while the rest of the ad is printed only in black, or in process color.

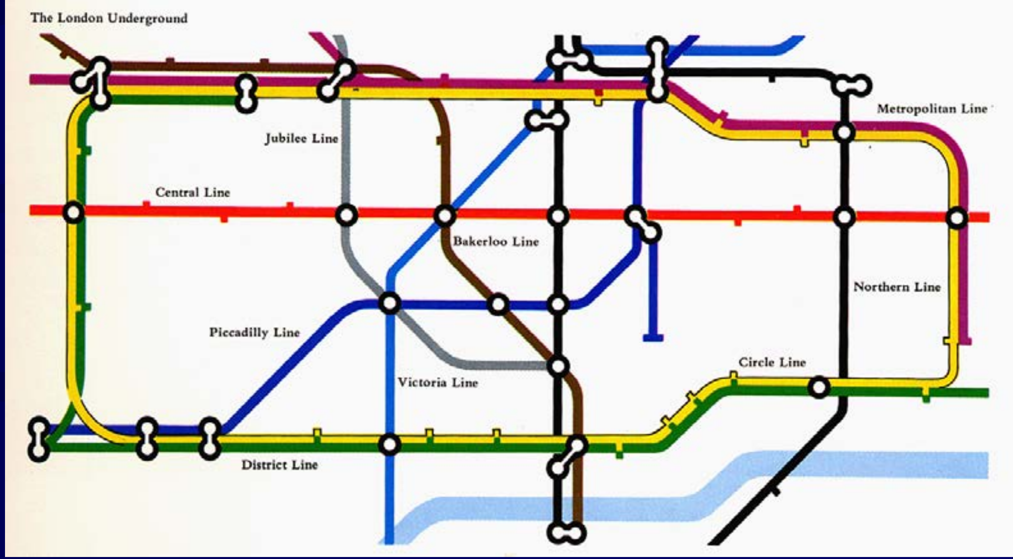
Flat Colors

- Sometimes called “Flat” colors because, until recently, it was awkward or difficult to print such colors in anything but flat, continuous tone regions.
- Gradations were difficult or impractical – so flat fields of color would be used.
- However, since desktop design systems make varied-color regions easy to define, spot colors can be applied much more freely.

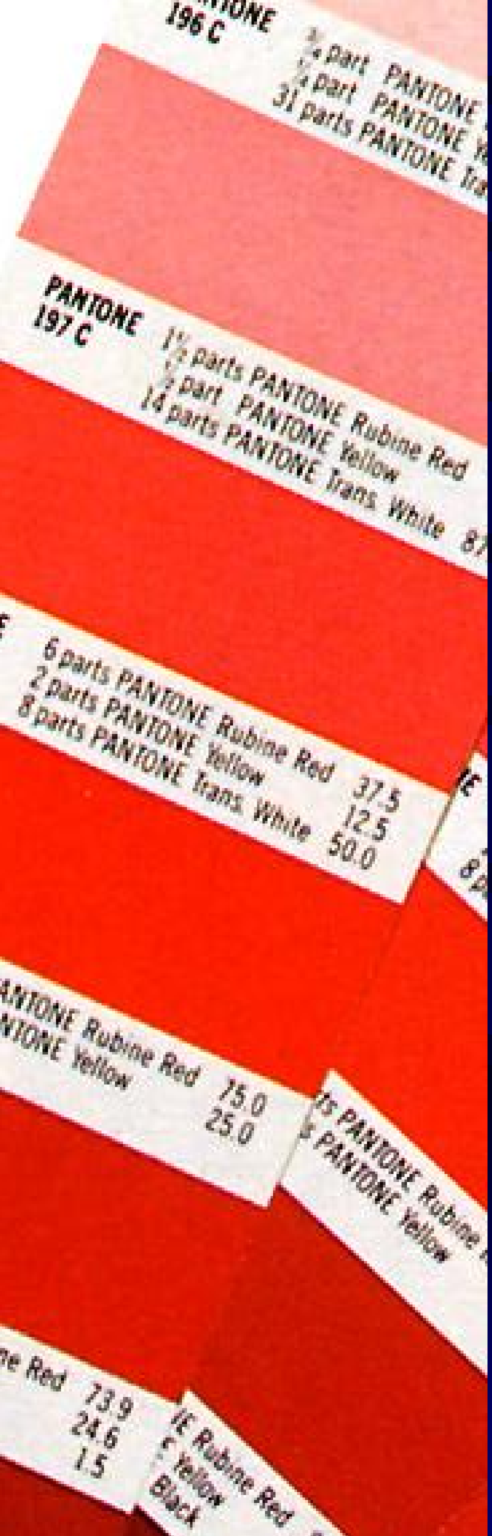
Line Art

- In graphic design we distinguish between continuous tone images and line-art images.
- Line art has no grays, no in-between values – just ink, or non-ink (paper).

Common Line Art



- The printed text of your text book is black-on-white, with no grays – the ink is stark.
- A woodblock print, for instance, is *not* continuous tone – every part of the image is either ink or paper – usually black or white.
- All early methods of printing relied on line art – no true photographs could be produced by Gutenberg's press.



Color Matching Systems

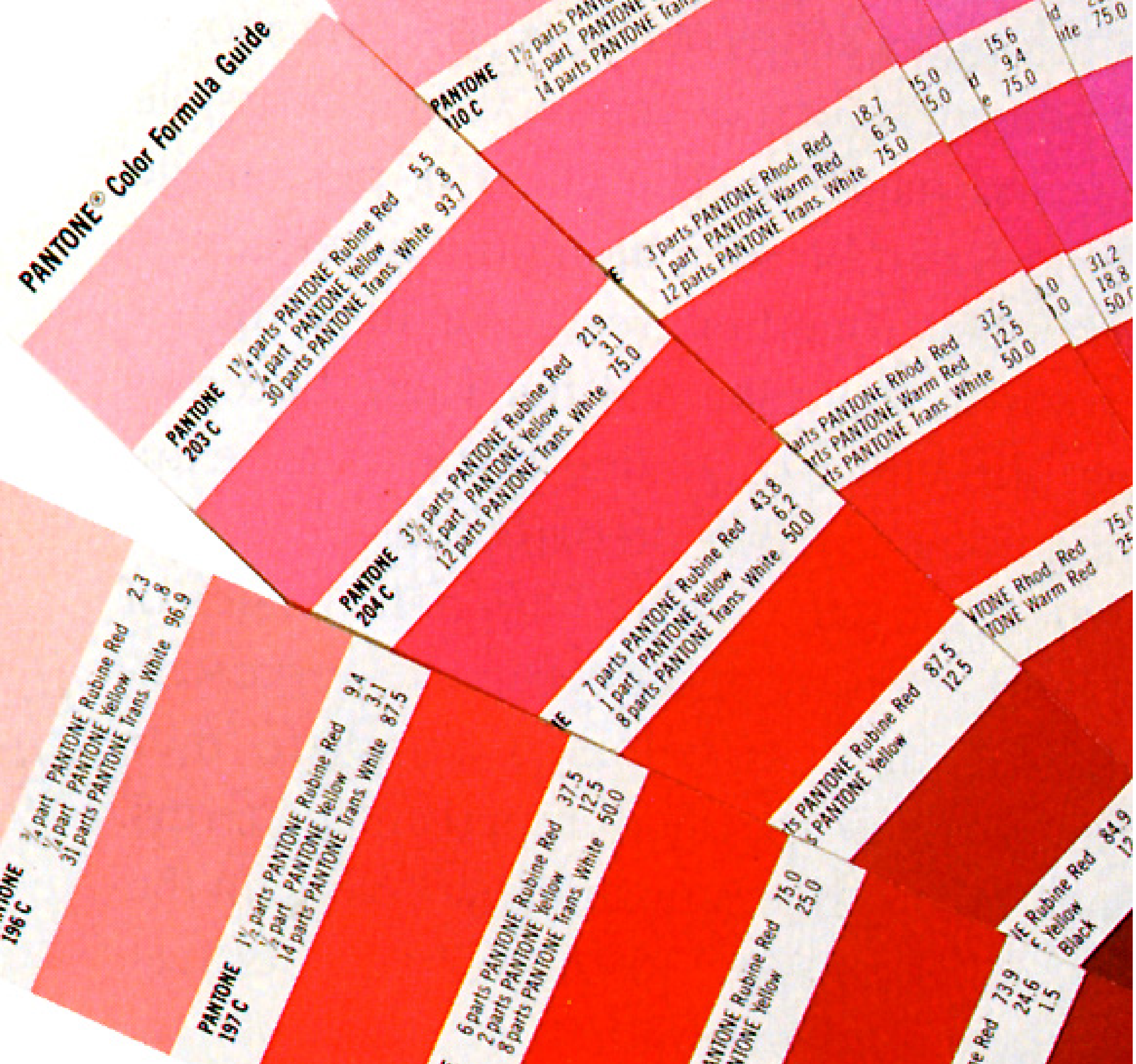
- A color matching system offers a way for designers, clients, and press-production people to communicate about specific colors.
- They offer the designer a way to say "this is the color I want!" – over the phone and across an ocean, and *still get* the color he wants.

Color Matching Systems

- While Pantone is well-accepted internationally, there are other legitimate competitors. Japan is one of the worlds biggest exporters of printed materials – the Toyo system is widely used there. Each system has some advantages and some weakness.
- Toyo
- Pantone

Pantone Matching System (PMS)

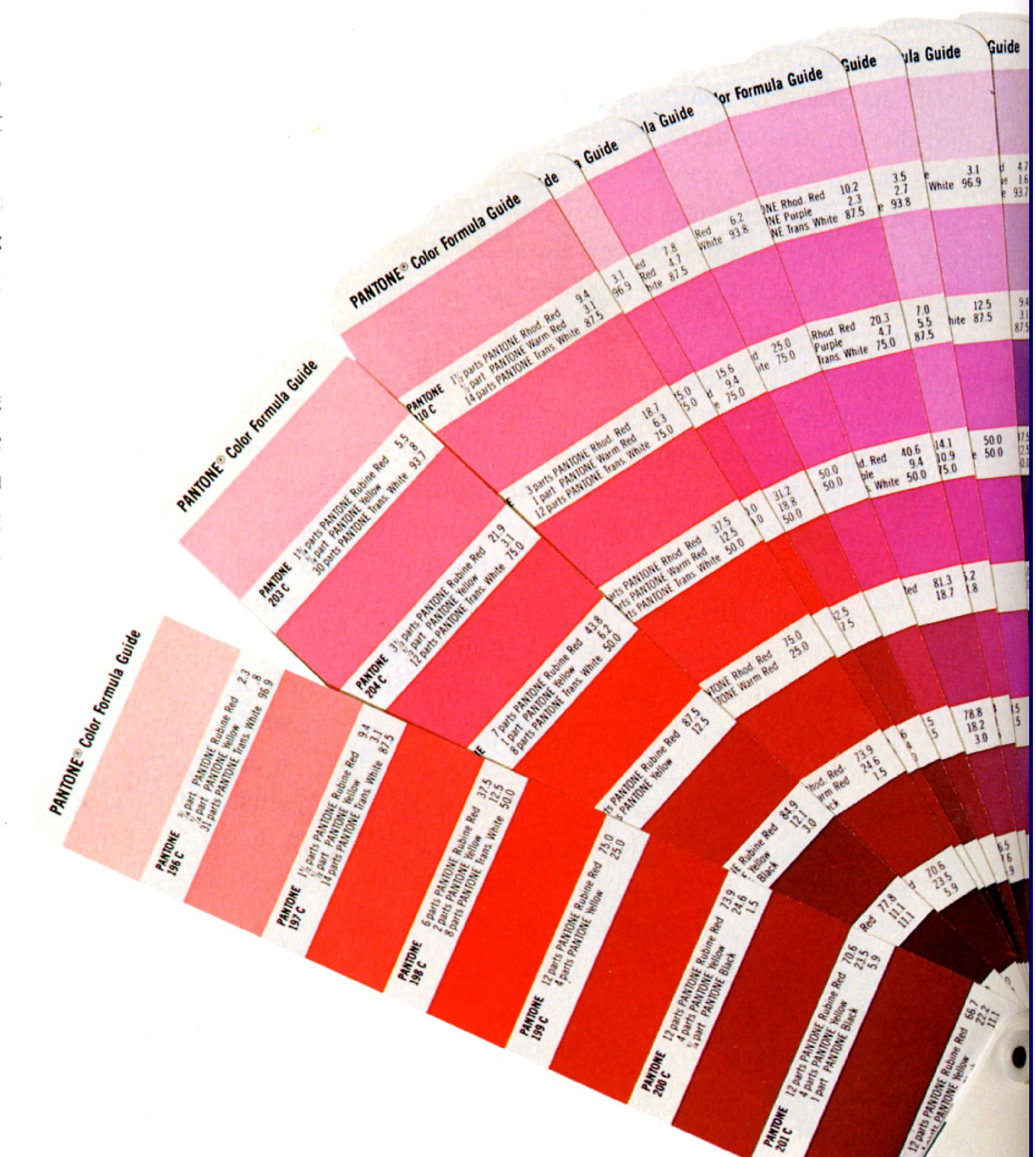
- Based on **nine** carefully controlled inks – the “primaries” of the Pantone System.
- Plus black and transparent white.
- All other colors are mixed by recipe which any pressman can mix.



PMS basic colors

The Swatch Books

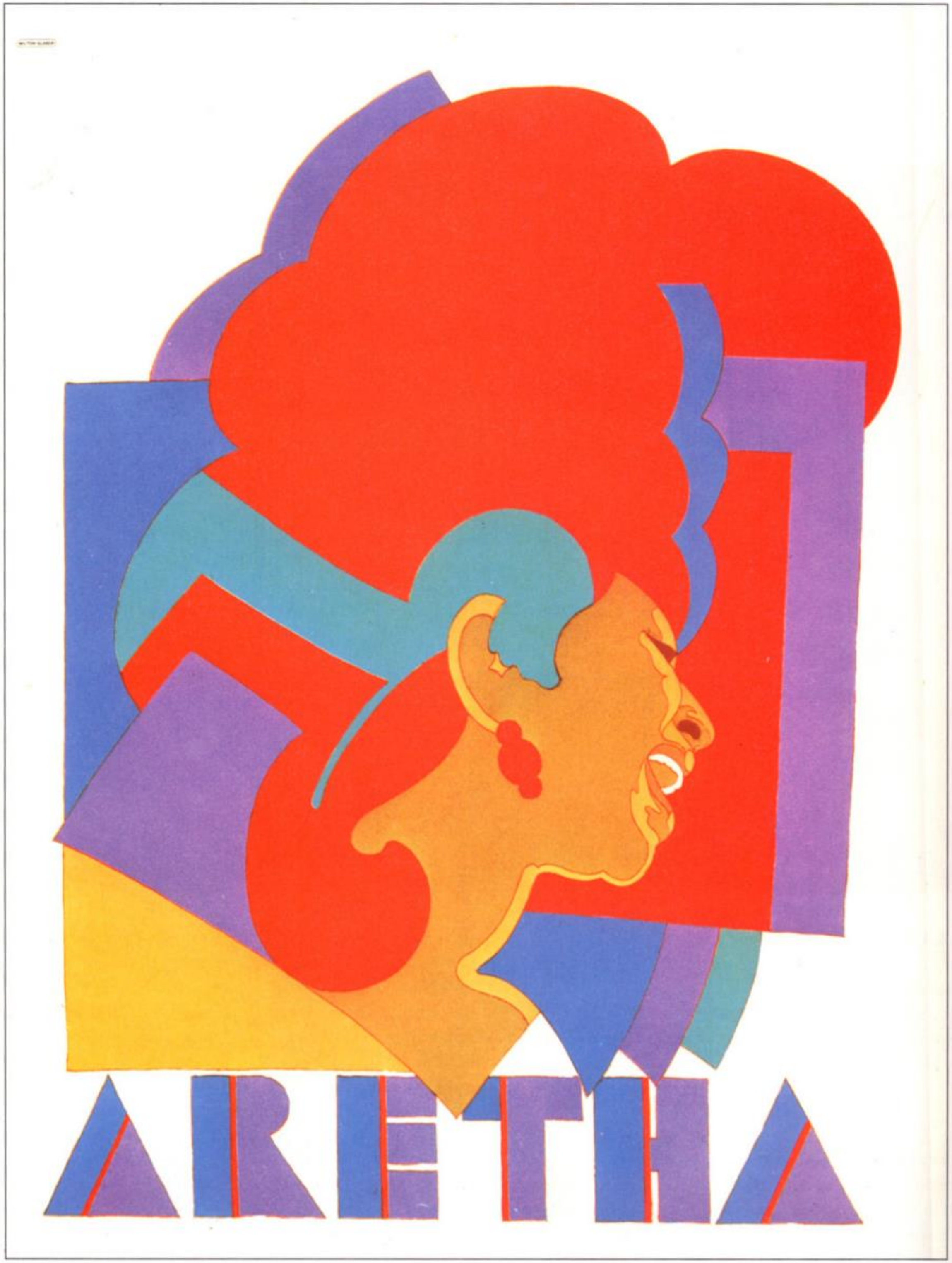
- Designers rely on color swatch books that have hundreds of color variations printed on both coated and uncoated paper.
- Ink behaves differently on absorbent uncoated paper than it does on glossy, coated paper – so color recipes sometimes differ for the same color)



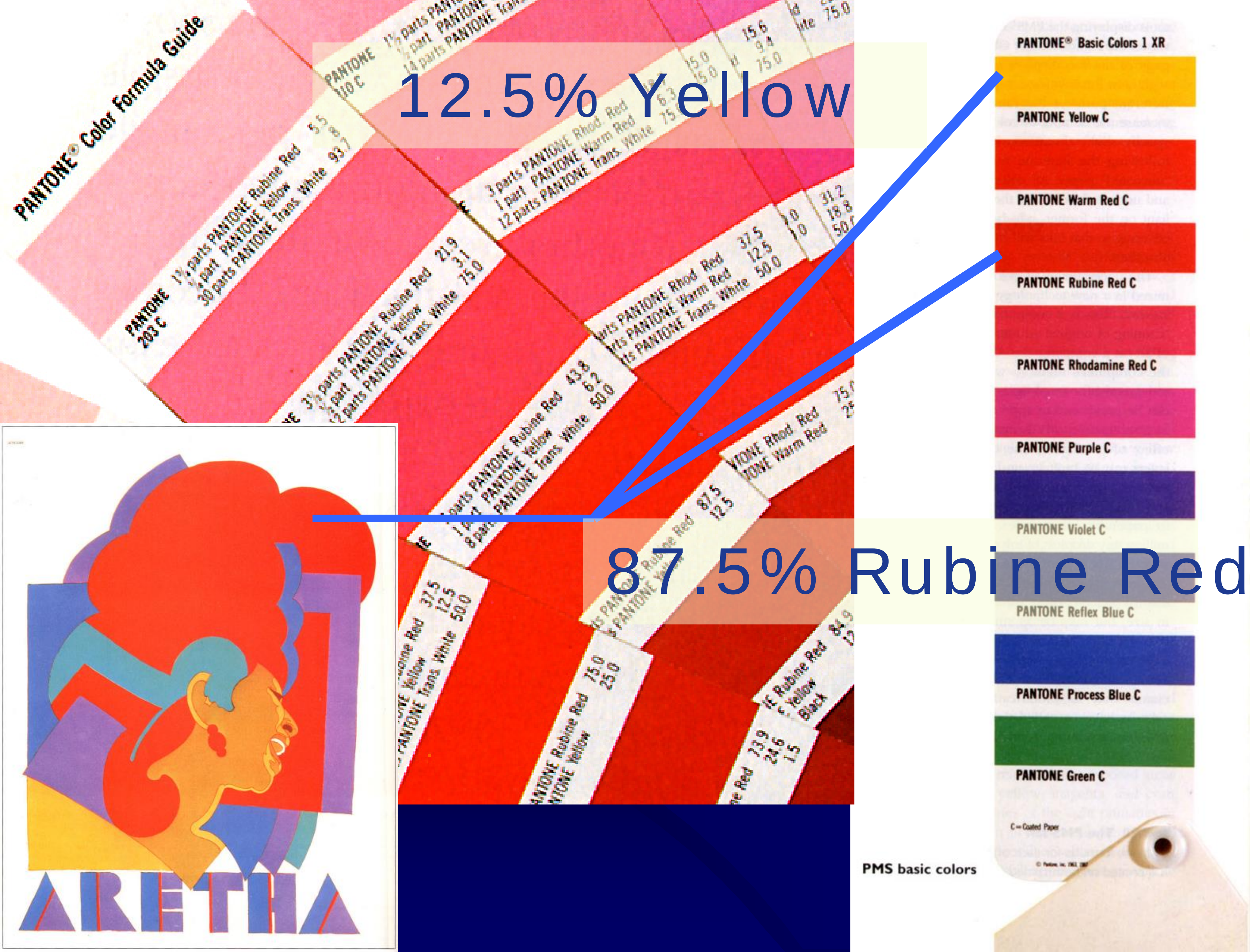
PMS basic colors

Pantone color specifications

- Colors are specified by number: 540C is a rich, midnight blue intended for coated paper.
- 389U is a bright lime green designed for uncoated paper.
- Pantone also offers a selection of metallic inks and fluorescent inks – usually used in flat color applications.



- Glaser poster
- Flat colors can be printed as line art
- (Your textbook illustration is 4-color process, and so does *not* use flat/spot colors.)


PANTONE® Color Formula Guide
PANTONE 203 C
1½ parts PANTONE Rubine Red 5.5
½ part PANTONE Yellow .8
30 parts PANTONE Trans White 93.7
12.5% Yellow
87.5% Rubine Red
ARETHA
PANTONE® Basic Colors 1 XR
PANTONE Yellow C
PANTONE Warm Red C
PANTONE Rubine Red C
PANTONE Rhodamine Red C
PANTONE Purple C
PANTONE Violet C
PANTONE Reflex Blue C
PANTONE Process Blue C
PANTONE Green C
C=Coated Paper
PMS basic colors

Opaque Inks

- Not all printing involves transparent ink.
- Opaque inks can be specified and in some printing processes are common (serigraphy/silkscreen, flexography).
-
- Opaque inks – more nearly paint – can provide *reliable flat color since the final color does not depend on the color of the paper nor the colors of underlying inks* -- so spot colors are sometimes opaque.

Fading Color

- Sunlight and bright indoor lighting can be extremely harmful to colors. (p. 90)
- Color inks fade over time.
  The energy within ultraviolet light produces a chemical breakdown of many pigments, causing them to fade – in much the same way that ultraviolet light can damage human skin.

Ars Longa, Photo Brevis

- Common color photographs may last only 12-15 years.

- There are more expensive color photographic papers and processes that last longer – ordinarily used only be photo-artists or the best portrait photographers. (Cibachrome (Ilfochrome Classic) 500 yrs when light-protected; Fuji Crystal Archive — dye-based photos)

- Archival Black & White photographic printing processes include: silver gelatin prints, Platinum and Palladium prints.

- [look for **archival pigment-based inks**, **acid-free paper** or other archival materials]

Throw away printing

- Most 4-color process prints fades quickly -- and will be tossed even quicker. Ink pigments quickly breaks down due to ultraviolet light and acid content of most newsprint (paper).
- USA-Today, for instance, will fade within a few weeks, particularly if left in sunlight.
- For the vast majority of printed materials, fading is fine – we produce tons of "temporary" graphics that become trash within days or weeks. (which may *not* be so fine)

Lasting Printed Color

- However, artists and printmakers demand that their image colors remain stable for a very long time.
- Giclee currently claims 75 years of color fidelity.
- Epson now provides "archival" pigment-based inks that claim color fidelity of 300 years if the print is protected from ultraviolet light – sunlight.
- This is a fast-evolving technical issue in color print production.

Add-on Specs to add color durability

- Specialty inks and U/V inhibitors are available for most printing technologies. (a clear coating that helps colors keep from fading)
- Designers can specify ultraviolet-absorbing varnishes over prints – this extends the life of printed pigments. (like UV sunglasses…sort of)

Giclee Printing

- http://www.gicleemaster.com/html/faq.html
- Giclée (pronounced "zhee-clay") reproductions were originally developed in 1989 as a plateless method of fine art printing.
- The word Giclée is French for "to spray "and is a registered trade name of The 'IRIS' Printer - a high-end ink-jet printer.

Giclee Printing

- Images are **high resolution digital** scans printed with **archival quality inks onto various substrates** including canvas, fine art, and photo-base paper.
- The giclee printing process claims **better color accuracy** than other means of reproduction.
- As for quality, the giclee print now **rivals many traditional silver-halide and gelatin printing processes and is commonly found in museums, art galleries, and photographic galleries.**
- Numerous examples of giclee prints can be found in New York City at the Metropolitan Museum, the Museum of Modern Art, and the trendy Chelsea Galleries.

Giclee Printing

- **The Advantages** : Giclee prints are advantageous to artists who do not find it feasible to mass produce their work, but want to *reproduce their art as needed, or on-demand*.
- Once an image is digitally archived, additional reproductions can be made with minimal effort and reasonable cost - the prohibitive up-front cost of mass production for an edition is eliminated.
- Another tremendous advantage of giclee printing is that digital images can be *reproduced to almost any size and onto various media*, giving the artist the ability to customize prints for a specific client.
- These digital images *will not deteriorate in quality* such as negatives and film because the information is archived digitally.
- http://www.gicleeprint.net/abtgclee.asp

Geclée Claims

- With a resolution of 1800 dpi, the IRIS printer uses a continuous stream of minute ink droplets about the size of red blood cells to deposit the ink.
- Results are close to continuous tone prints.
- When printed on archival art papers and canvas, the IRIS Giclée has the look and feel of original fine art.

Resolution

- Digital artists and designers have a couple of types of resolution to be concerned with – and they tend to be confusing.
- How small are the dots used to render the image? (device resolution)
- How small are the dots used to define the digital image (as stored in the computer)? (image resolution)

Getting Finer

- Not long ago 300dpi was considered pretty good printer resolution.
- Now you can go to Wal-Mart and buy inkjet printers at 1200dpi, even 2400 or 2740 dpi.
- Epson claims their high-end photo printers achieve 4700+ dpi.

The higher, the better

- The higher the resolution, the smaller the dots used to create the image – the smaller the stipples used to build up tones.
- And so, higher the dpi, *the more convincing the continuous tone illusion is* – the image looks *more and more photographic*. (up to a point -- at some point, the eye can no longer distinguish finer resolution)

Metamerism

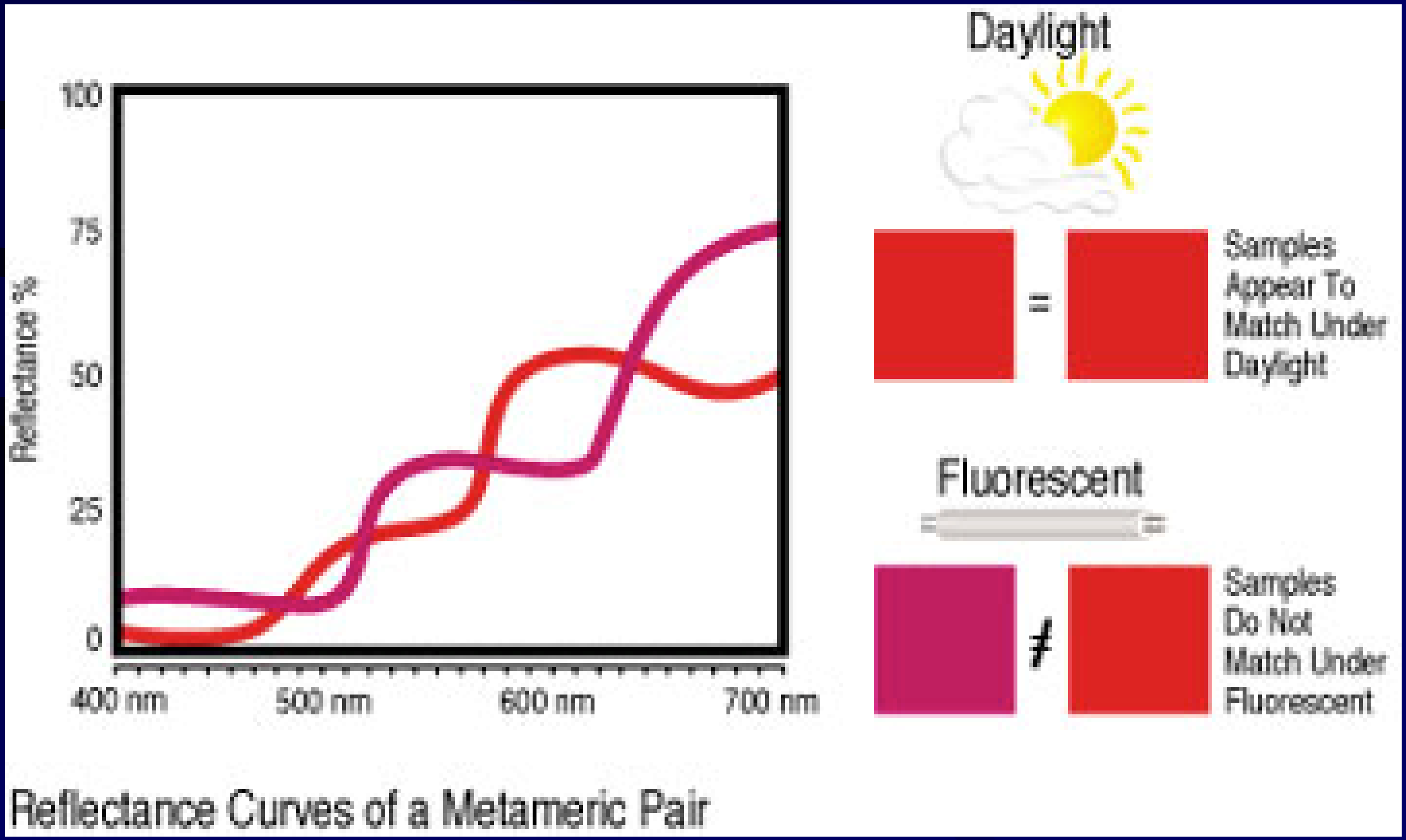
- Have you ever compared two garments in a store and decided they matched, only to find that when you left the store and went out into daylight they no longer matched and instead looked quite different?

- If so, you have seen an optical phenomenon called metamerism. Strictly speaking, metamerism occurs when you see two samples match under one light source (illuminant) and not match under another.

http://www.photoshopnews.com/?p=248

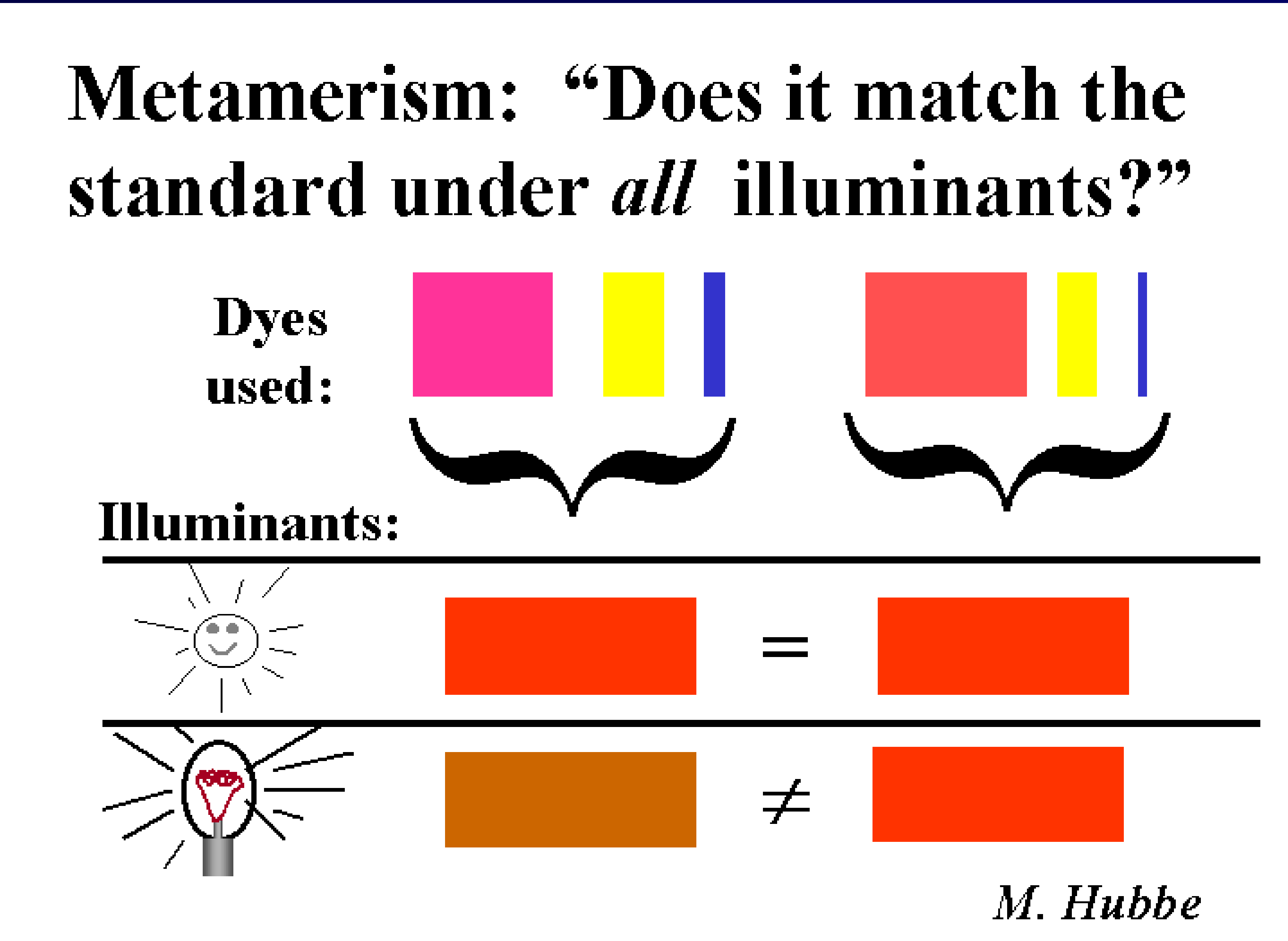
Metamerism

- Metamerism Has Three Forms: colorimetric, observer and geometric.
- Metamerism occurs when two samples appear identical under one set of viewing conditions, but not under another set of conditions. When this occurs, we call the two samples a metameric pair. Metamerism occurs very frequently in plastics.



http://www.gecolorxpress.com/jsp/extranet/user/start/basics10.jsp

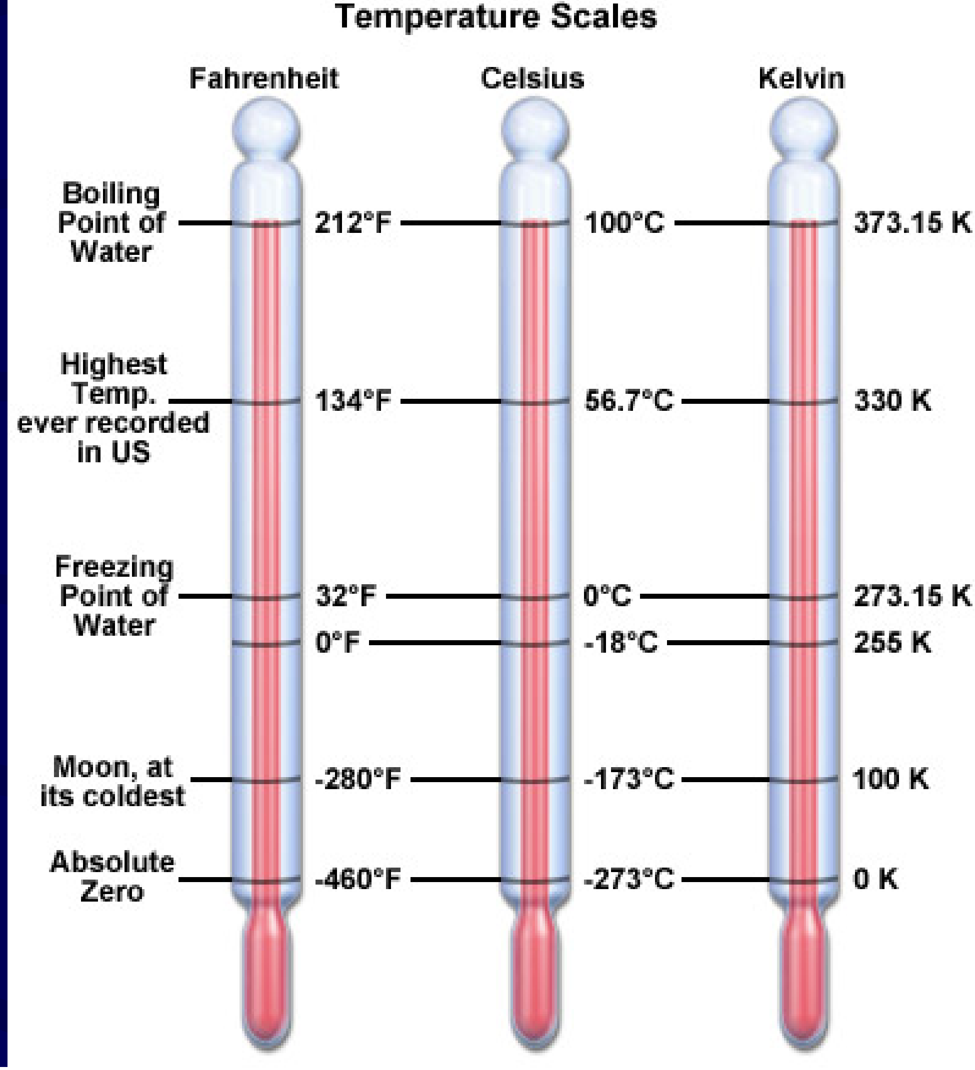
- When dying fabrics or papers, there are many combinations of color that will produce the target color under a given light source. However, under a different light source, colors may shift due to the colors that were used to create the mixture.

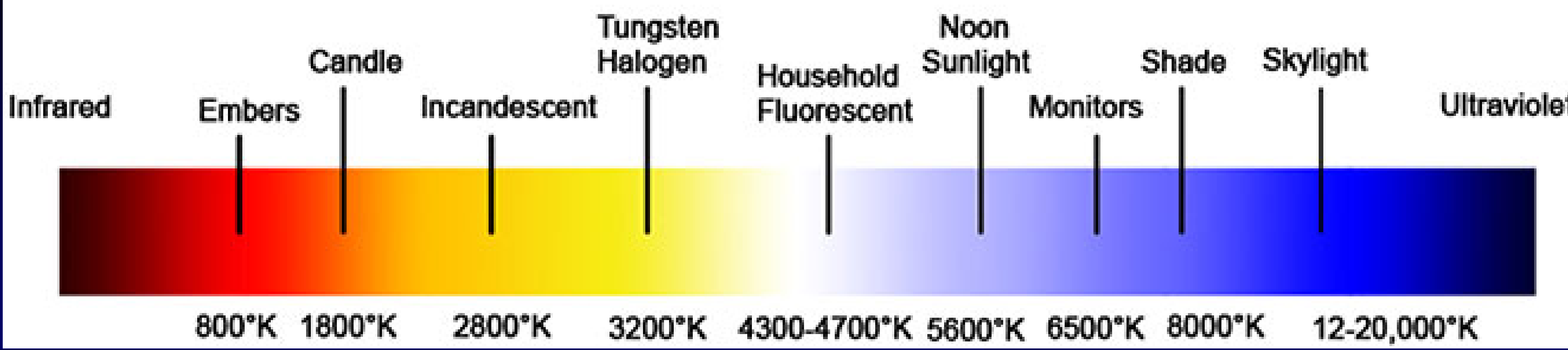


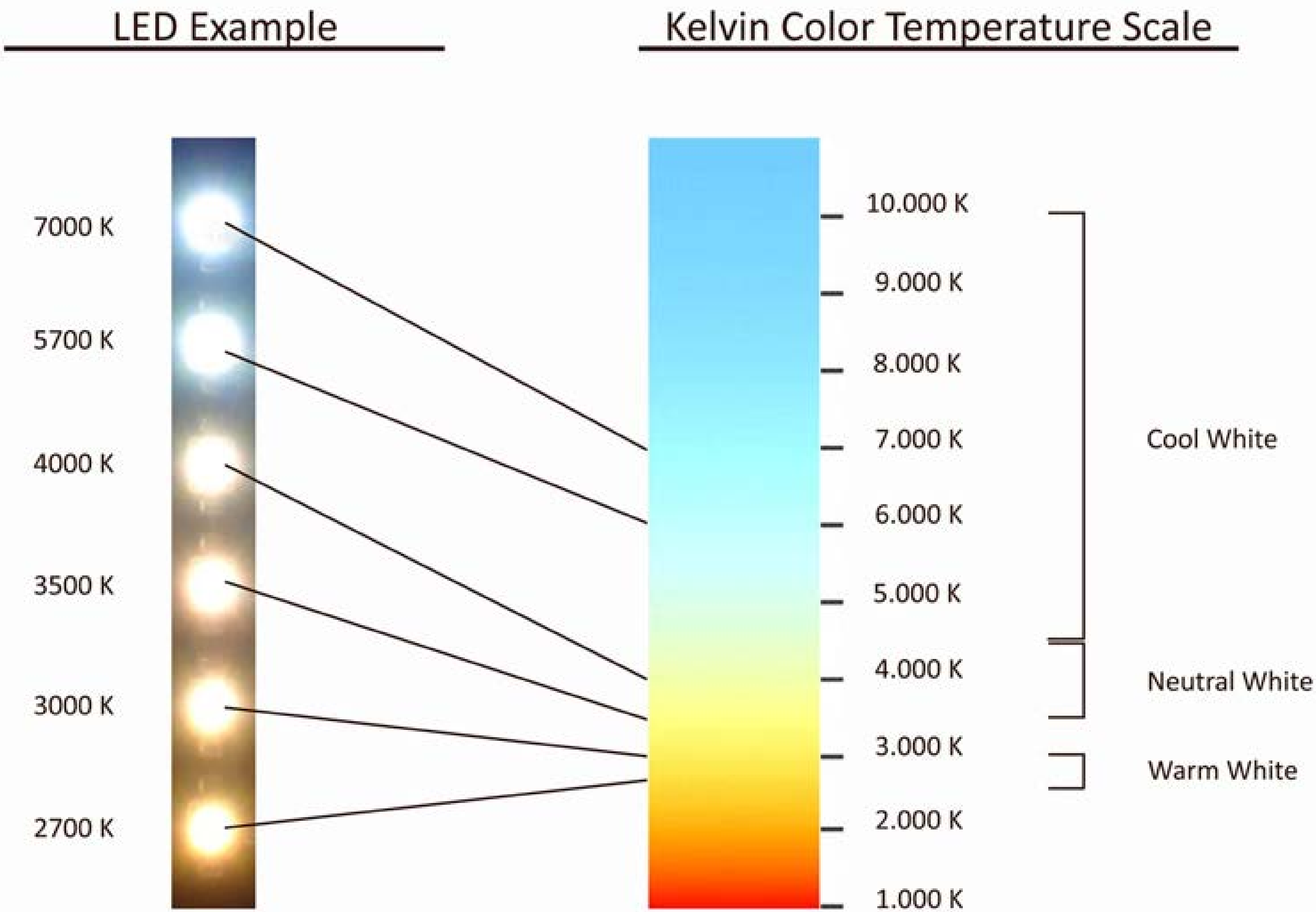
Metamerism

http://www4.ncsu.edu/~hubbe/Defnitns/Metamrsm.htm

The color of light sources is usually measured in degrees Kelvin. Kelvin is an alternative to Fahrenheit or Celsius temperature scales.
It is a physicist-preferred temperature scale that begins at absolute zero – 450f.
The colors associated with these Kelvin temperatures are derived from “black body radiation” – all objects radiate energy depending on their temperature. Physics again.



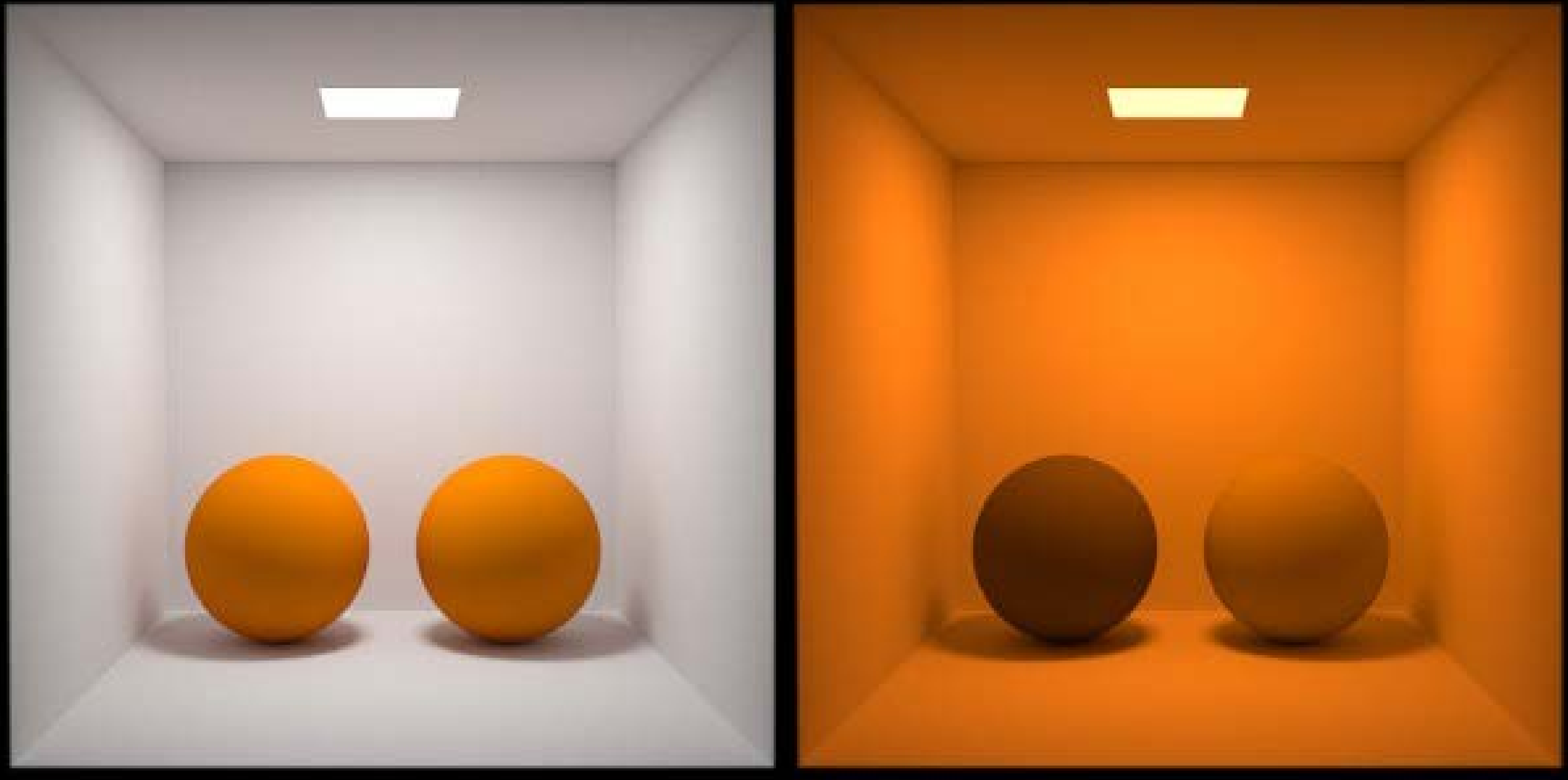



LED Example
Kelvin Color Temperature Scale
7000 K
5700 K
4000 K
3500 K
3000 K
2700 K
10.000 K
9.000 K
8.000 K
7.000 K
6.000 K
5.000 K
4.000 K
3.000 K
2.000 K
1.000 K
Cool White
Neutral White
Warm White

fluorescent lamp (F11)
4100Kelvin
(warm)

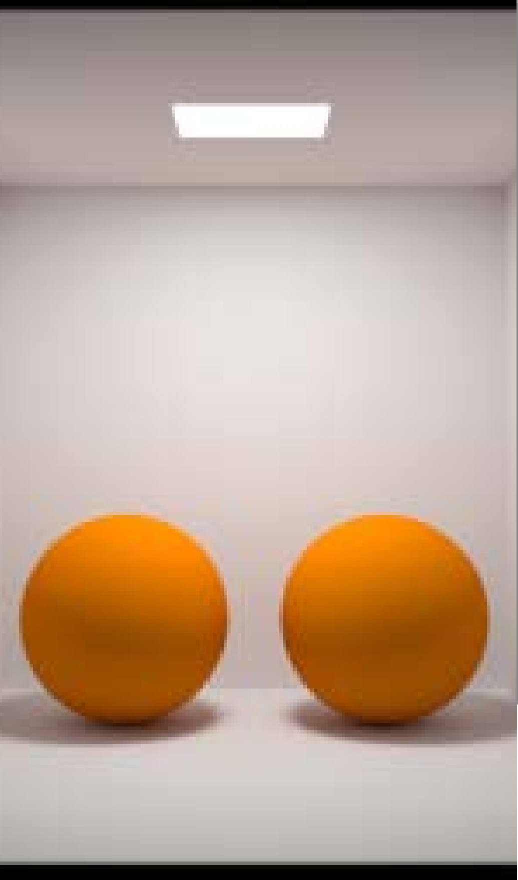
D65 (F7)
6500Kelvin
(daylight)

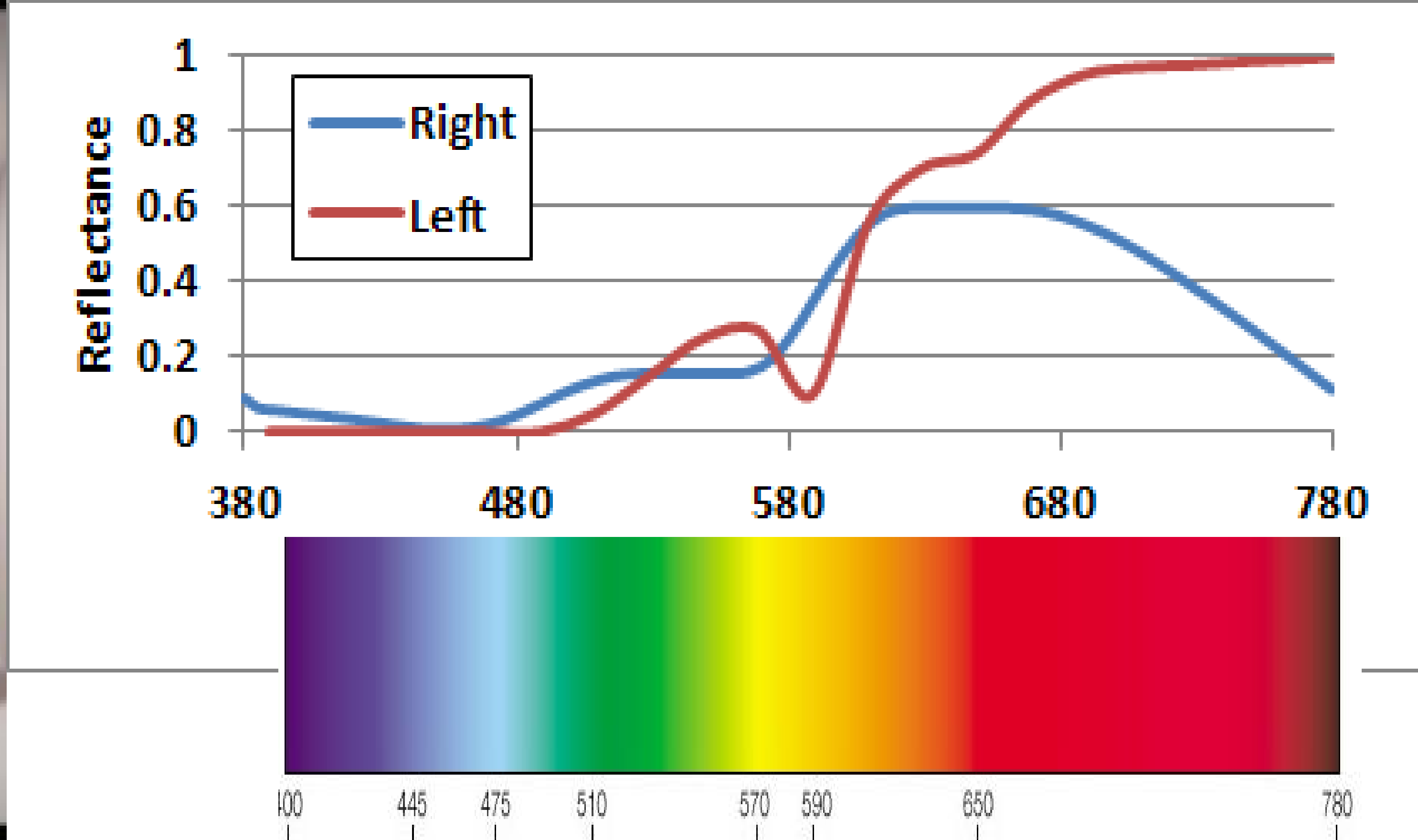
Incandescent light bulb (A)
2856Kelvin
(very warm/yellow)



Metameric surfaces under D65 (daylight) light source, with distinct colors illuminated by sodium arc lamp

http://www.eclat-digital.com/metamerism/





The two YO surfaces look identical under daylight, but each surface is actually reflecting a different spectrum of colors.
The left sphere has stronger red reflectance and no blue.
The right sphere has modest red, strong orange and a bit of blue and green.
To our tri-stimulus eyes, these traits "average" to the same color – the spheres look virtually identical.

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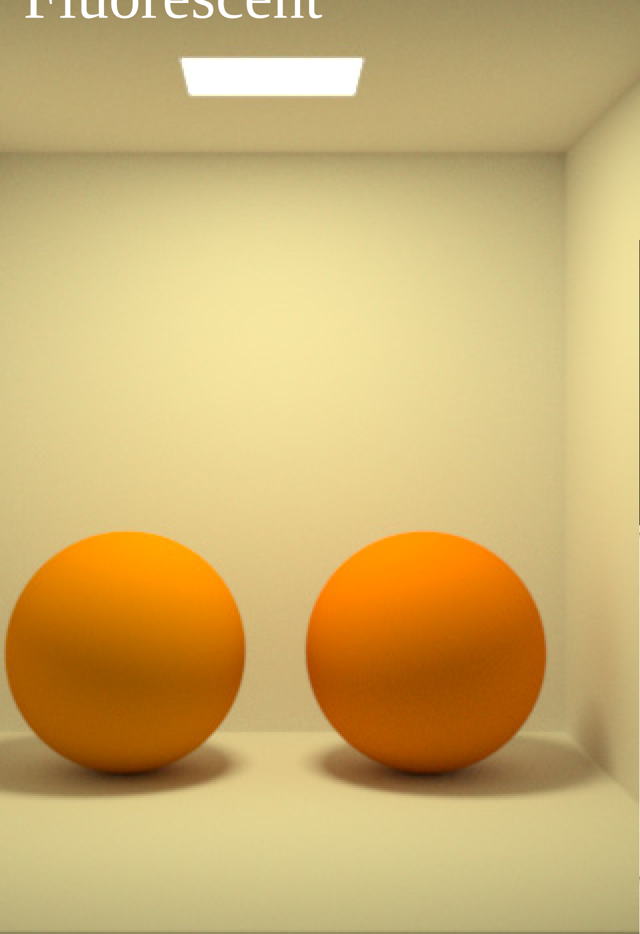

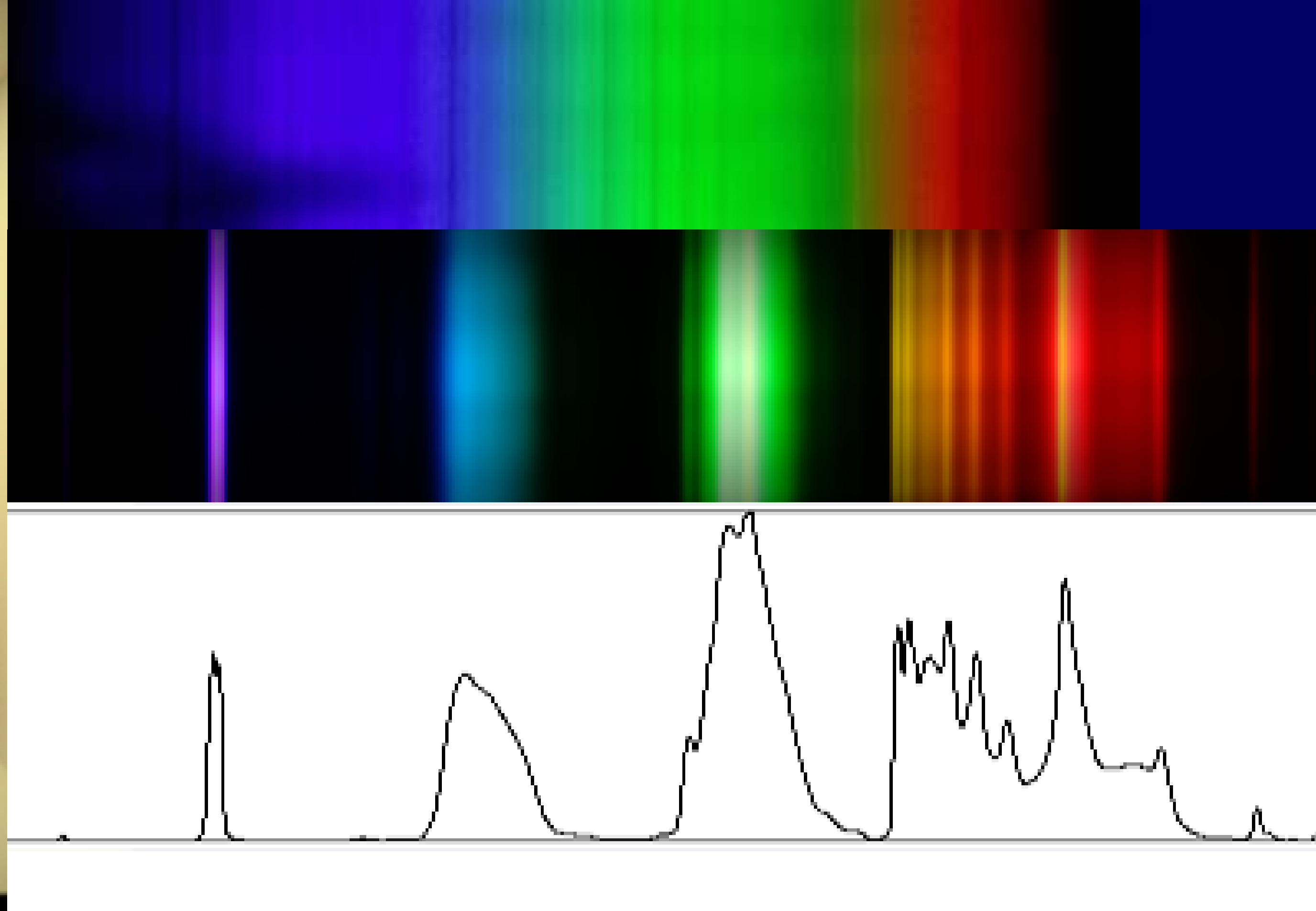

Under fluorescent light, colors begin to shift. The reason is that the wavelengths of light emanating from the fluorescent bulb are more sporadic or divided into peaks and gaps. Note the difference between a particular fluorescent lamp and sunlight's spectrum.

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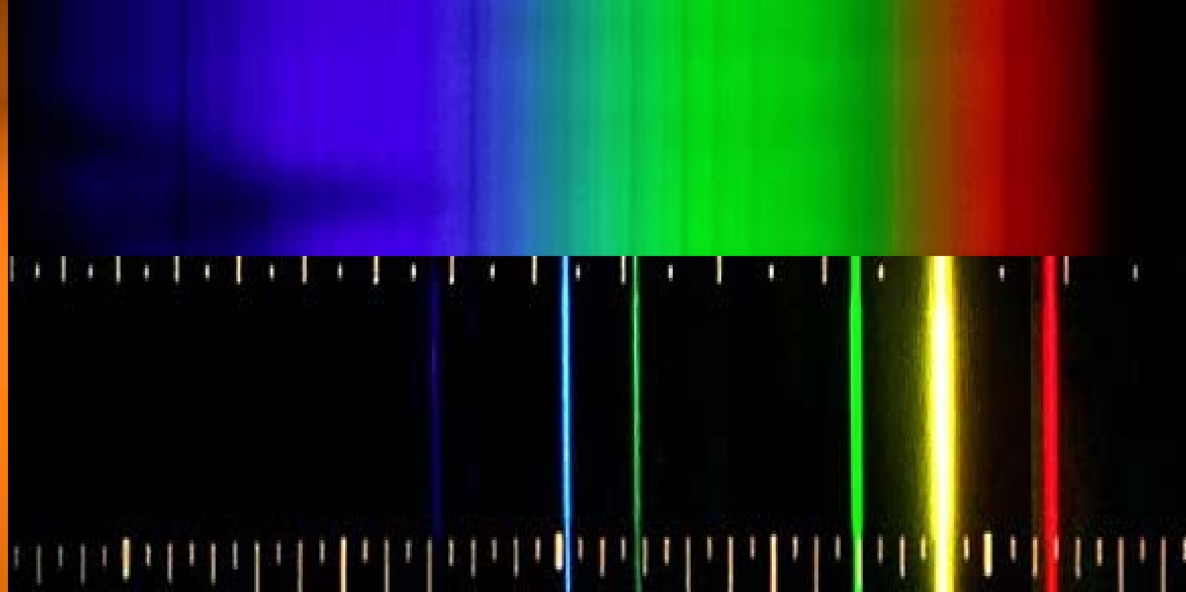

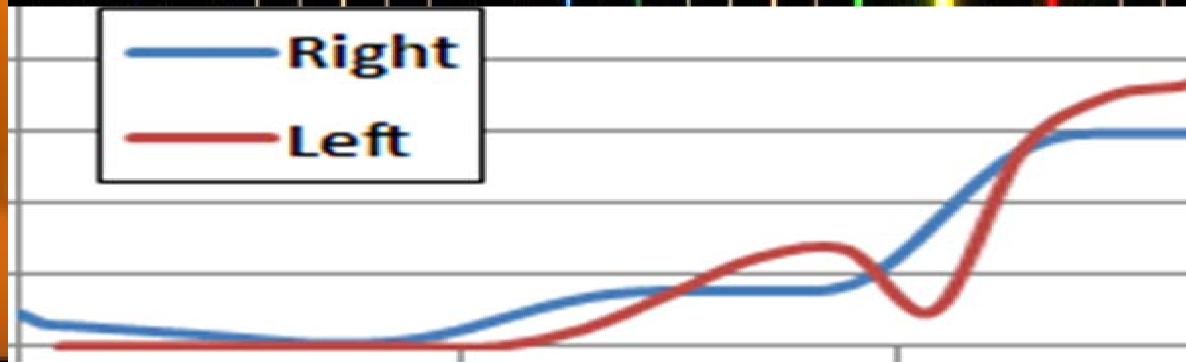

Under a sodium vapor lamp, colors shift dramatically.
The left sphere becomes darker since the lamp has an intense yellow spike just at the point that the left-sphere's reflectance dips.

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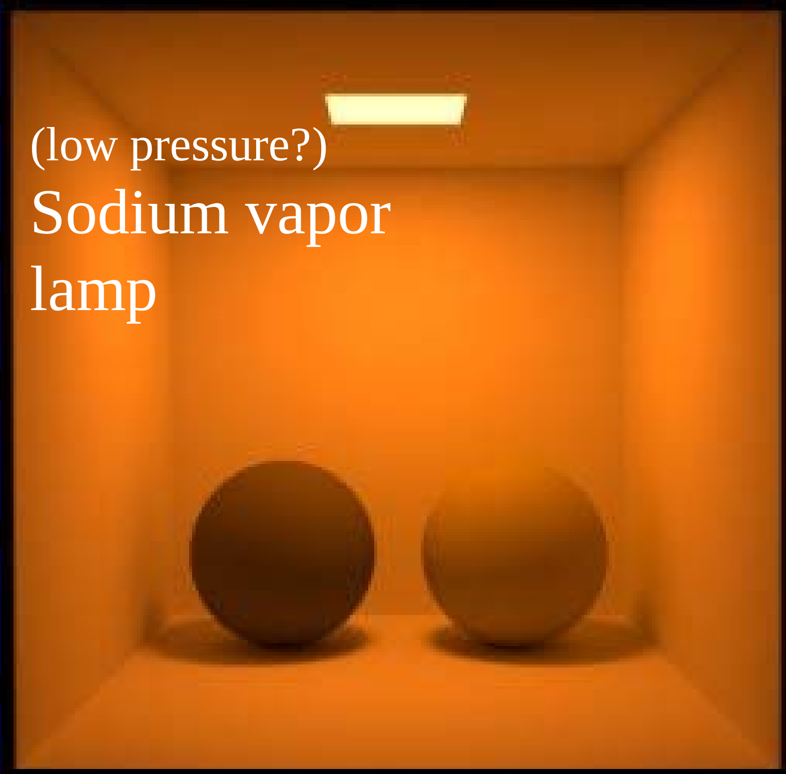
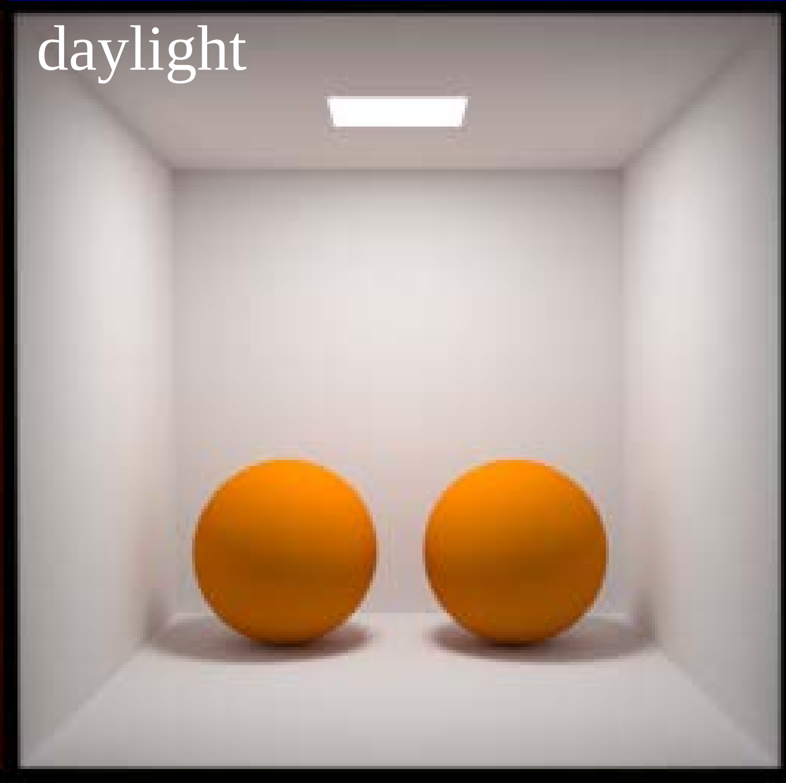
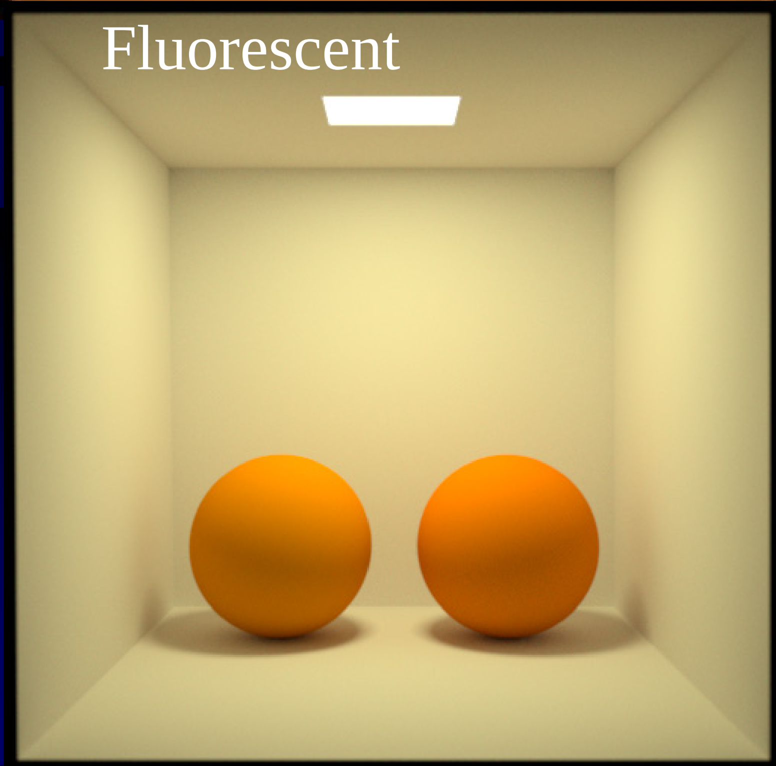






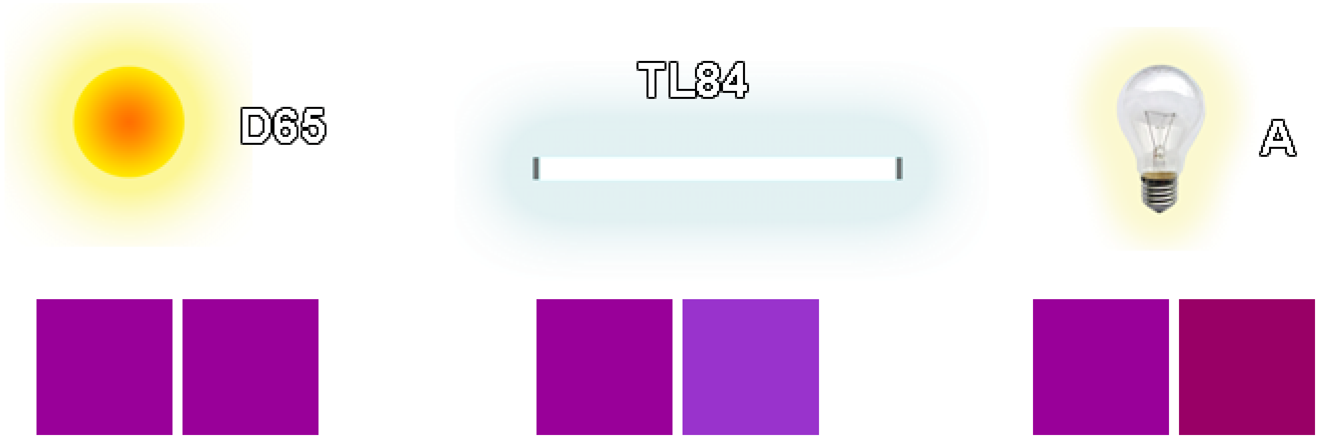
Metamerism occurs because of the many differences in the specific spectrum of colors provided by varied light sources, along with…

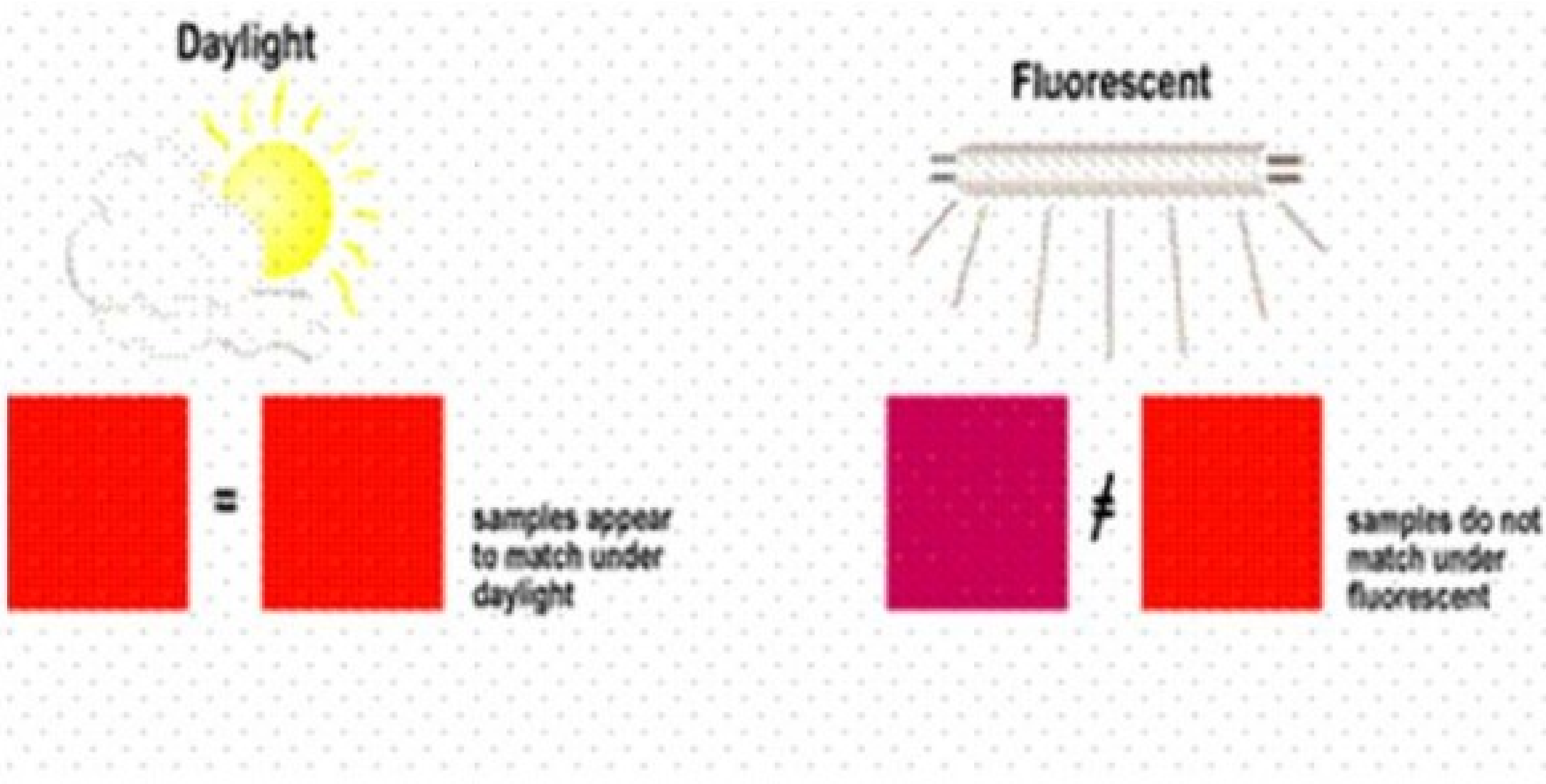
…the many differences in the reflectance spectrums of various dyes, paints and surfaces.

Lights vary. Pigments vary.

Together, color varies.

http://www.eclat-digital.com/metamerism/


D65
TL84
A


Daylight
Fluorescent
samples appear to match under daylight
samples do not match under fluorescent

Summary Topics include…

- C.I.E. "just noticeable difference" gamut of visible colors
- Device Color Gamut
- CMYK process printing
- Spot/Flat/Match colors
- Screening, angles, linescreen
- Halftones vs. line art
- Resolution
- Color Calibration