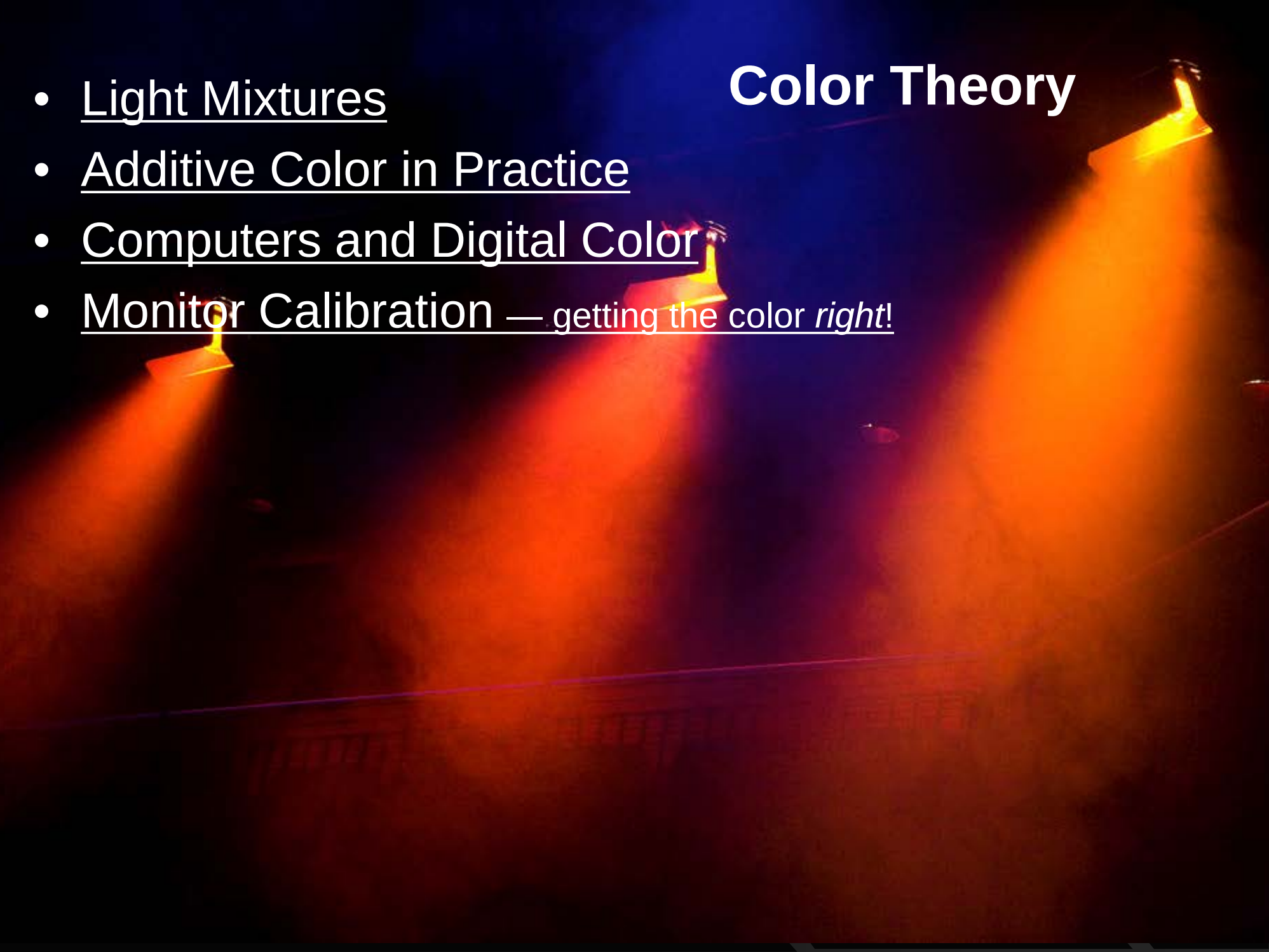


Color Theory

- Light Mixtures
- Additive Color in Practice
- Computers and Digital Color
- Monitor Calibration — getting the color *right*!

Light and Color

- Colored light has long been focused on relatively few areas of design:
- Theater/Stage Lighting
- Stained glass (though pigments are subtractive)
- General photographic lighting — both still, video and cinema
- Interior & (exterior) Architectural lighting
- Product display (showcases and specialty point-of-purchase displays)

Theater interiors are most often enclosed, without windows or natural light.

Thus all lighting is artificial, and can involve ongoing dramatic effects.

Today, digital control systems allow rapid, programmed changes and sequences in stage lighting.

Stage & Performance Lighting

- Concerts often harness rich-hued lighting to enhance the emotional range of music.

Stage & Performance Lighting

THE DECEMBERISTS TRAVELING STAGE SHOW

Theater Lighting

- Theater exteriors also take advantage of carefully controlled lighting — since theater performances are traditionally in the evening and light, does draw attention!

Architectural Lighting

- Urban architecture often leverages surface rhythms and details by vibrant lighting that accents relief in the architecture.
- London’s Albert Hall

Architectural Lighting

- Urban architecture often leverages rhythms and details by vibrant lighting that accents relief in the architecture.
- Royal College of Music, Kensington, London.

- Urban design and competition among architects motivate ever more dramatic nighttime illumination. Chicago’s skyline (from Adler Planeterium)

Theater & Architectural Lighting

Urban architecture often leverages dramatic façade by vibrant lighting, including programmed lighting that offers an ongoing animated display.

Theater & Architectural Lighting

Urban architecture often leverages dramatic façade by vibrant lighting, including programmed lighting that offers an ongoing animated display.

Architectural Lighting

- Contemporary skylines include dramatic geometric shapes/edges as well as intense color.
- (Frankfurt, Germany?)

Architectural Lighting

- Contemporary skylines include dramatic geometric shapes/edges as well as intense color.
- Hong Kong

Architectural Lighting

- LED and OLEDs on large panels enable architectural scale animated color imagery.
  Metamorphoses: performances by the Kopffarben Group/ 2015

- “Luminale” is an annual exhibit of architectural scale lighting technologies, art and design. (images from 2014 Frankfurt)

Client: Rafael Aragones and Sergio Kam, Acapulco, Mexico
Architect: Miguel Angel Aragones, Acapulco, Mexico
Lighting Designer: Lighteam Gustavo Avilés, Mexico City
http://www.archlighting.com/

Architectural Lighting

The hotel’s façade at night is a collage of color.

Client: Rafael Aragones and Sergio Kam, Acapulco, Mexico
Architect: Miguel Angel Aragones, Acapulco, Mexico
Lighting Designer: Lighteam Gustavo Avilés, Mexico City
http://www.archlighting.com/

Architectural Lighting

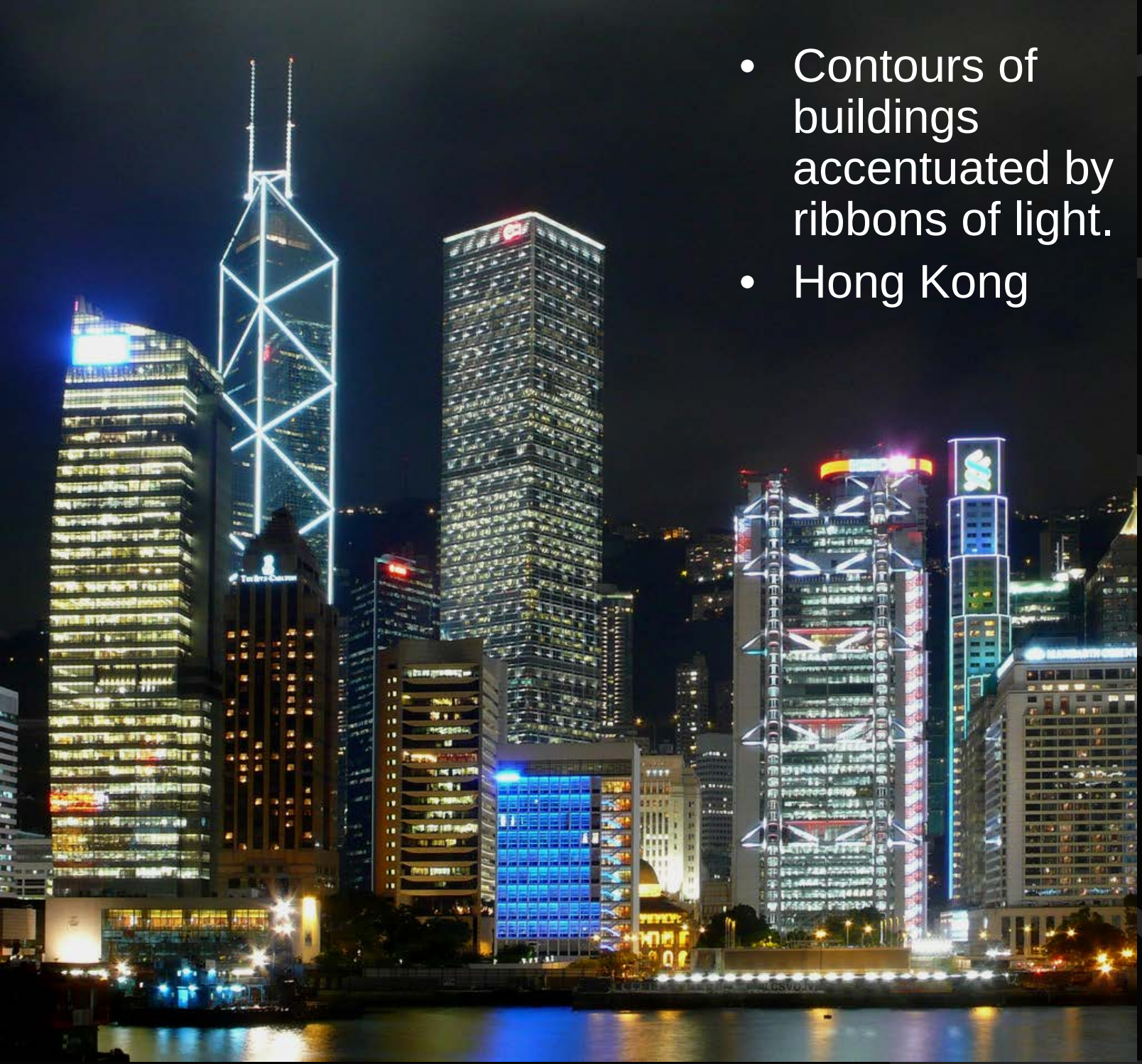
"Nestled in the hills of Las Brisas, overlooking Acapulco Bay in Acapulco, Mexico, Hotel Encanto is an architectural wonder for the senses."

Client: Rafael Aragones and Sergio Kam, Acapulco, Mexico
Architect: Miguel Angel Aragones, Acapulco, Mexico
Lighting Designer: Lighteam Gustavo Avilés, Mexico City
http://www.archlighting.com/

Architectural Lighting




Spaces illuminated by washes of chromatic lighting, changing over time.



- Contours of buildings accentuated by ribbons of light.
- Hong Kong

- The site of New York's World Trade Center is marked on 9/11, by beams of light.

In the pool area, lighting through vertical glass fins creates geometric patterns on the water, the floor and the ceiling.
Credit: Lighting Design International
ESPA Life at Corinthia

Interior Lighting

Structural Lighting

Infinity Bridge, Stockton-on-Tees, in northeast England

The structural design, with its sinuous form, required careful study to ensure that the bridge was properly and sensitively illuminated.

Lighting: Speirs+Major; Architect: Expedition Engineering

Structural Lighting

Infinity Bridge, Stockton-on-Tees, in northeast England
Concealment of fixtures, minimizing disability glare, and maintainability were all key issues.
Lighting: Speirs+Major; Architect: Expedition Engineering

Structural Lighting

Infinity Bridge, Stockton-on-Tees, in northeast England
Cantilevered brackets from the deck hold white metal-halide fixtures that carefully illuminate the majority of the arch with very fine rotatable, lenticular lenses to generate a very thin line of light.
Lighting: Speirs+Major; Architect: Expedition Engineering

Infinity Bridge, Stockton-on-Tees, in northeast England

Each fixture is carefully aimed onto the structure, overlapping the lines of light, ensuring that the form of the bridge is expressed, guaranteeing minimal light trespass.

Lighting: Speirs+Major; Architect: Expedition Engineering

Infinity Bridge, Stockton-on-Tees, in northeast England

Each fixture is carefully aimed onto the structure, overlapping the lines of light, ensuring that the form of the bridge is expressed, guaranteeing minimal light trespass.

Lighting: Speirs+Major;

Architect: Expedition Engineering

Infinity Bridge, Stockton-on-Tees, in northeast England

The trail of light changes from blue to white as a pedestrian crosses.

Lighting: Speirs+Major; Architect: Expedition Engineering

Structural Lighting

Lighting as Sculpture

- “$f5^3$ by LAB[AU] is an interactive kinetic light sculpture, extending the bi-dimensional screen space, by transposition of its pixel resolution to the physical space.

- Conceived as a modular infrastructure, 16n _ $f5^3$ is a communication and computation system, propagating in form of light and sound, the events it inhabits.

- Presence and motion create and alter the transmitted data, and propagation of this data becomes a space-time parameter.”

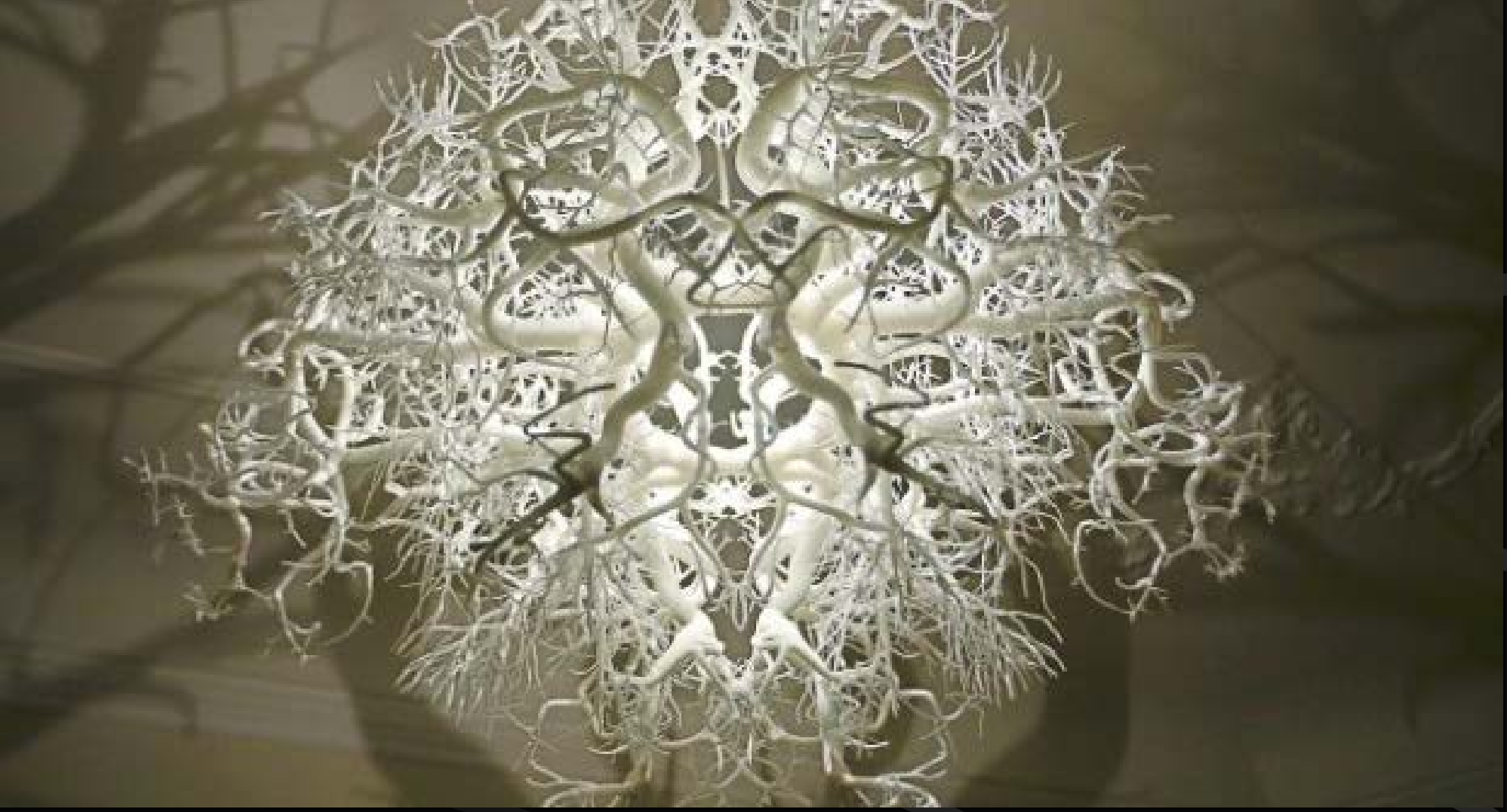
Lighting as Sculpture

- Mundy Hepburn
- Light Sculpture I
- 2006
- gas in glass

Light as Sculpture

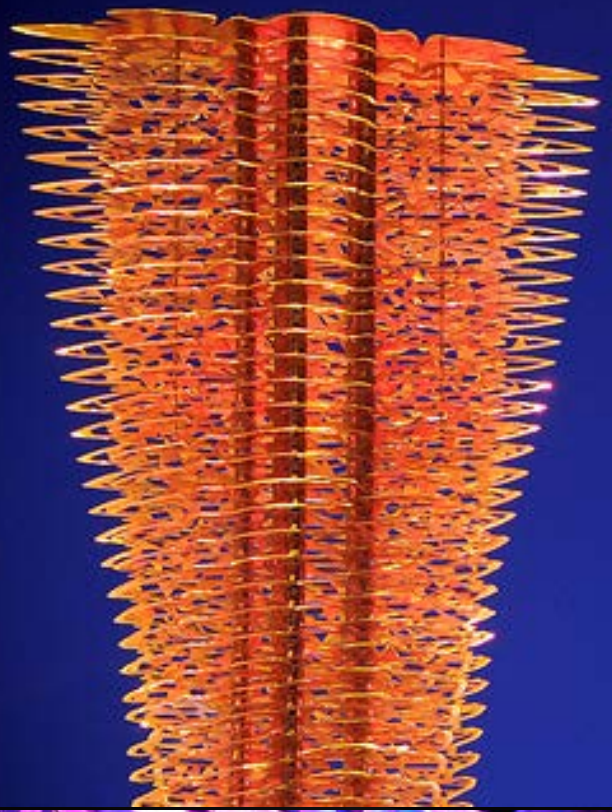
Web Site

Sydnye Cash Light as Sculpture



sculpture was created by artists
Thyra Hilden and Pio Diaz of
German design studio HildenDiaz.

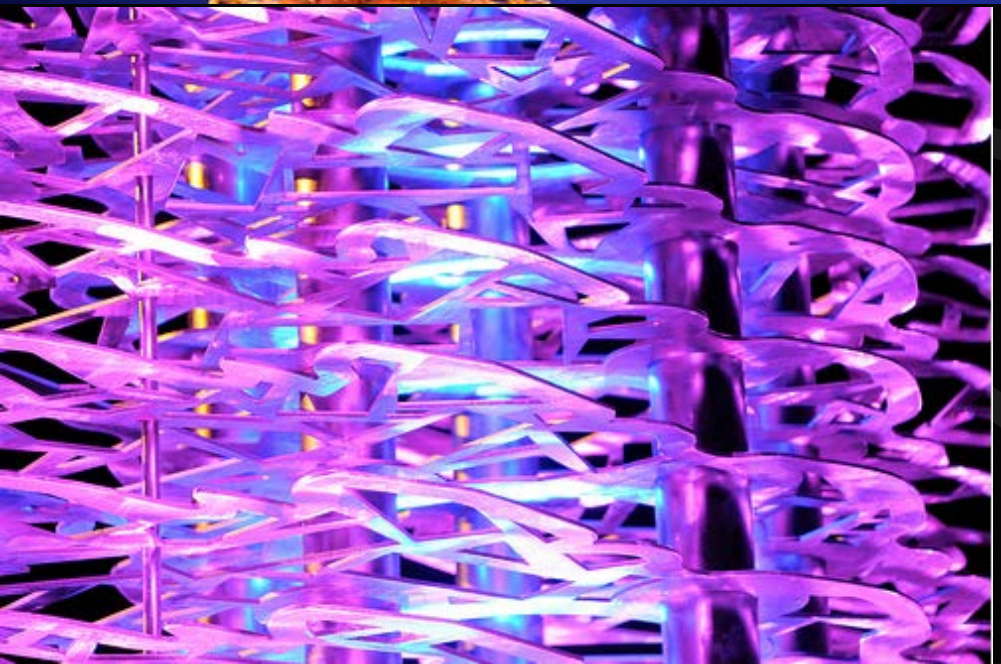
Thyra Hilden and Pio Diaz: as intensity and position of lights change, so cast shadows move & alter on surrounding surfaces.

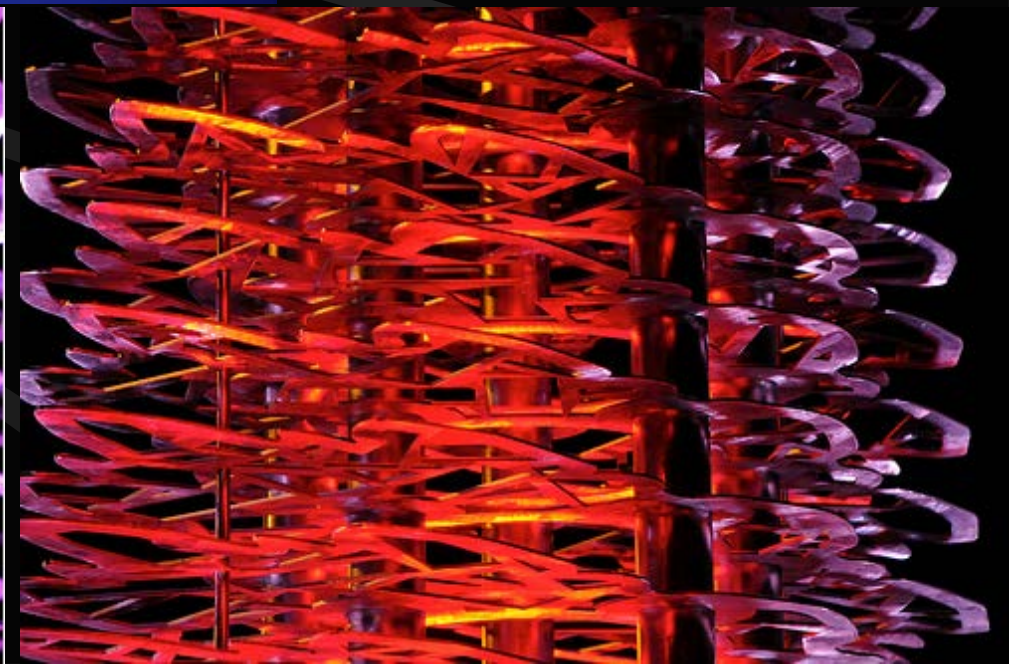


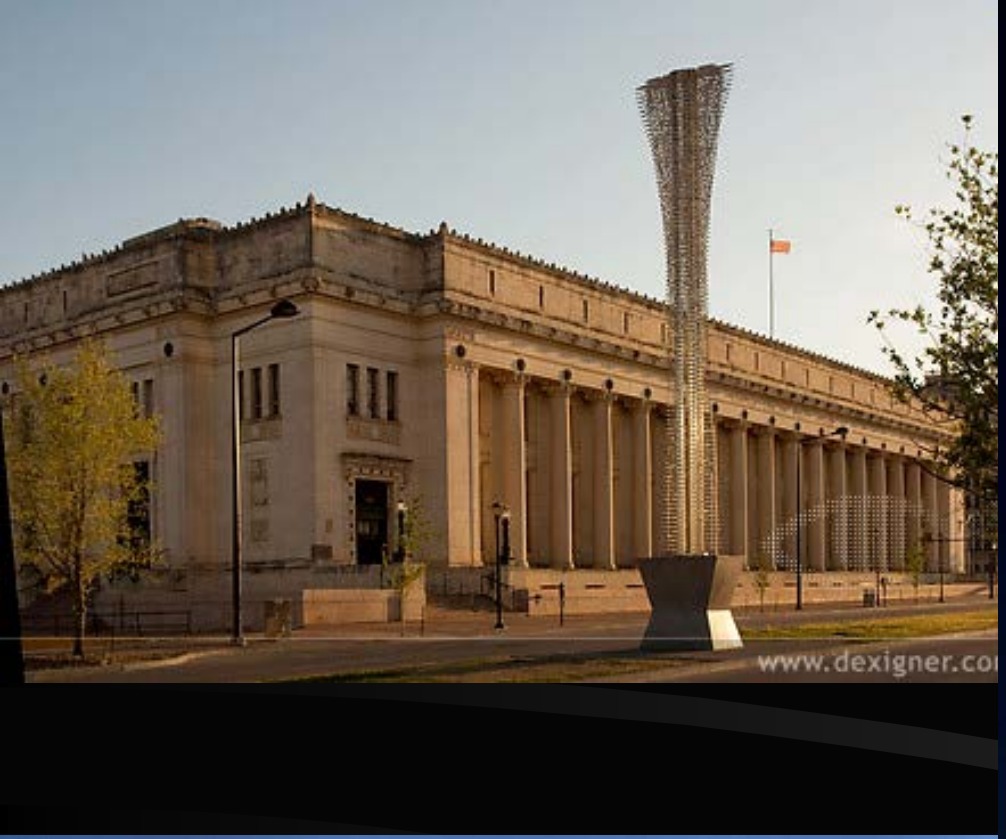
Light as Sculpture

- Various views/stages of Fort Worth's Avenue of Light, by Cliff Garten.
- 2009

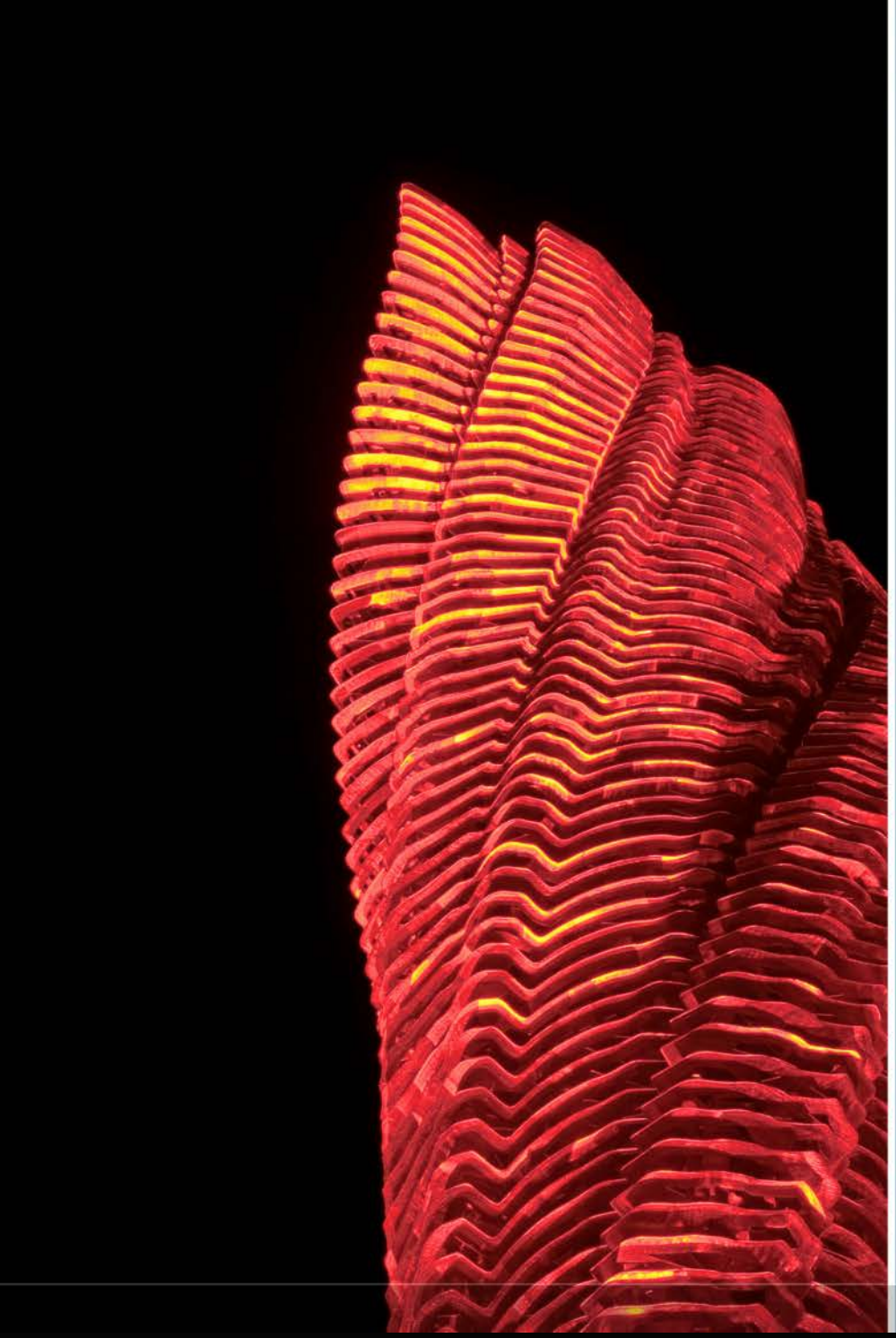
- Flicker Slide Show






www.dexigner.co

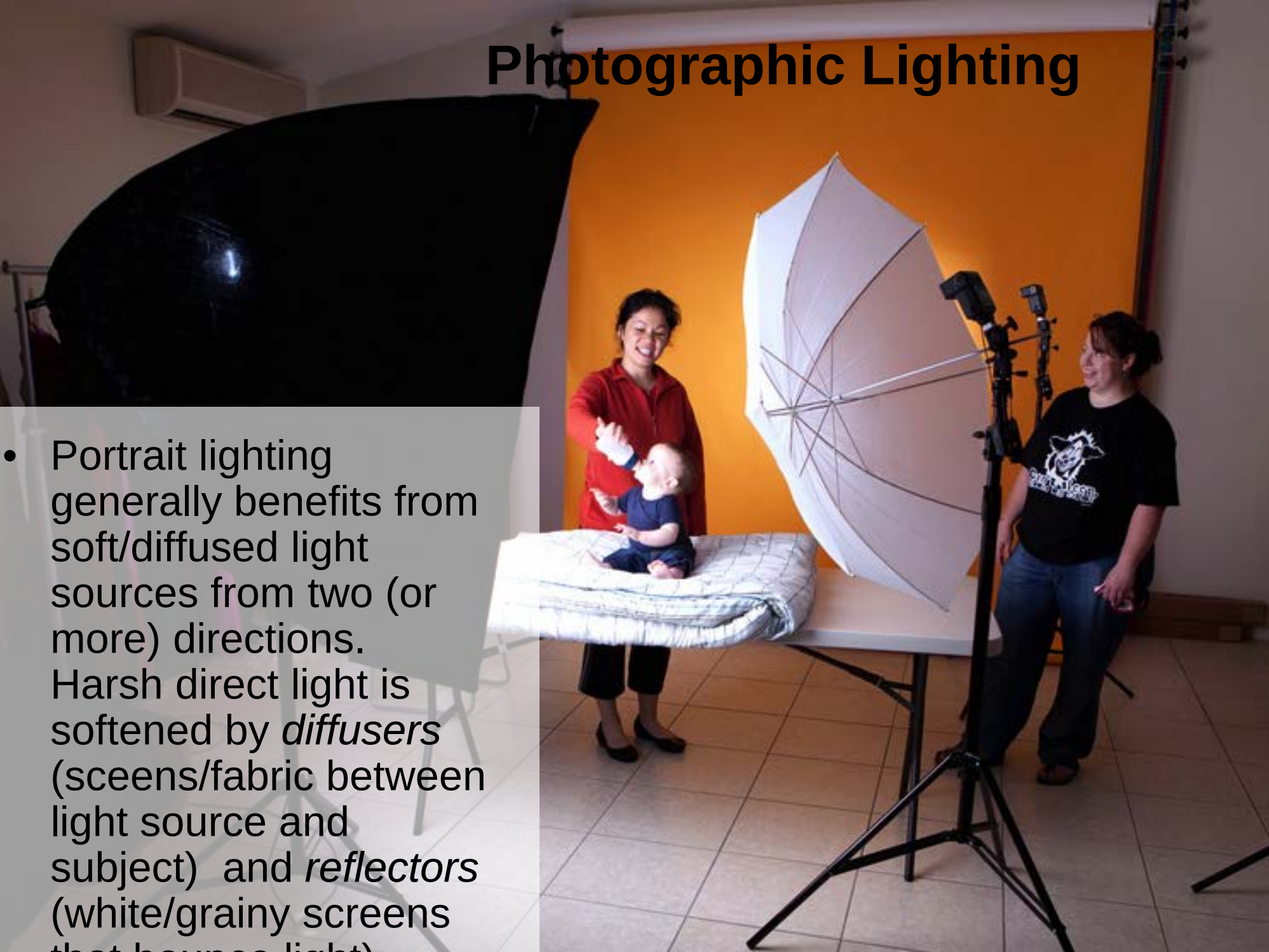

Throckmorton St
www.dexigner.com



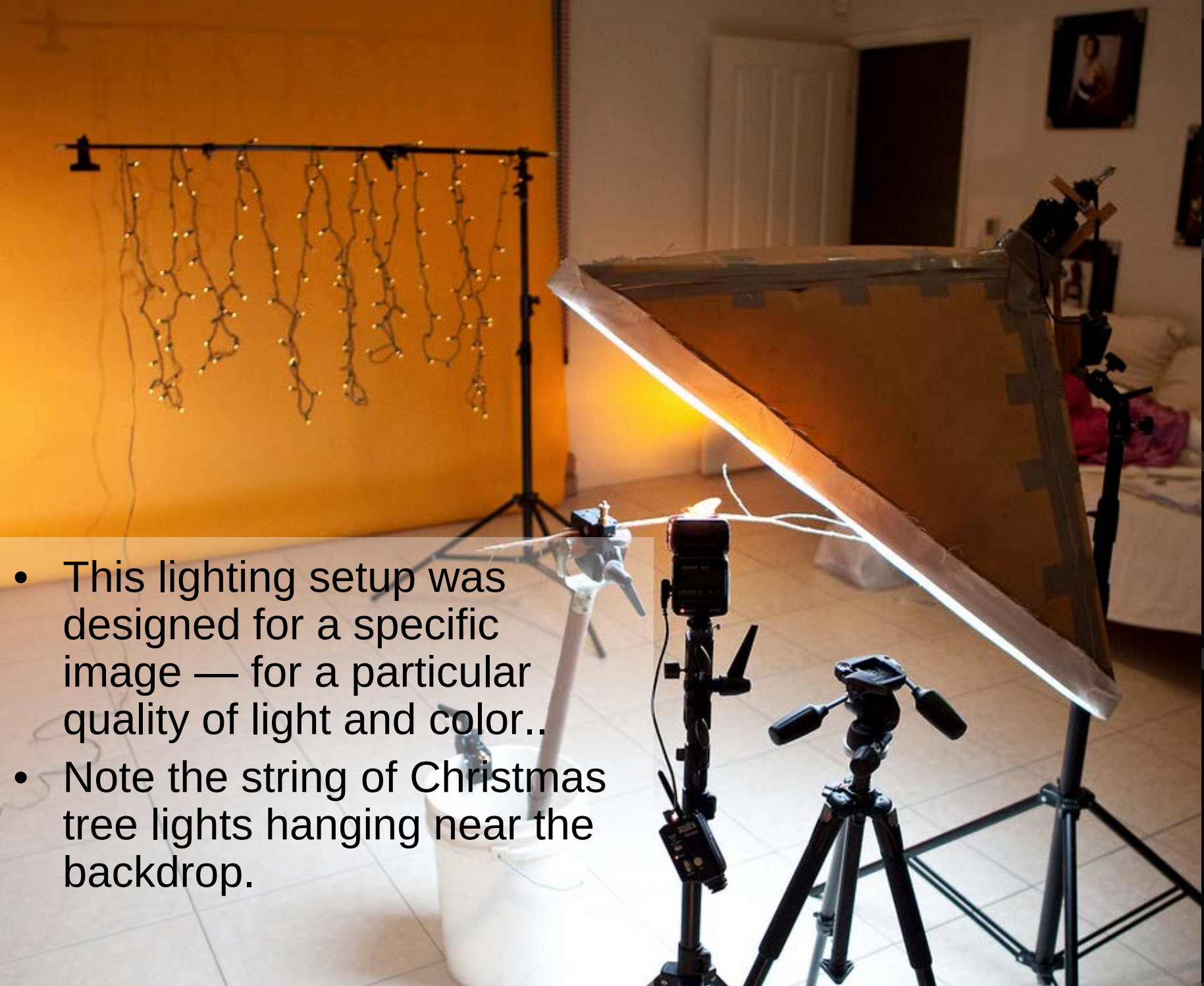
Photographic Lighting

- Photo, video and cinema involve careful planning of lighting, both for sake of illumination (control of value and contrasts) and for sake of color (hue) balance.

Photographic Lighting



- Portrait lighting generally benefits from soft/diffused light sources from two (or more) directions. Harsh direct light is softened by *diffusers* (sceens/fabric between light source and subject) and *reflectors* (white/grainy screens

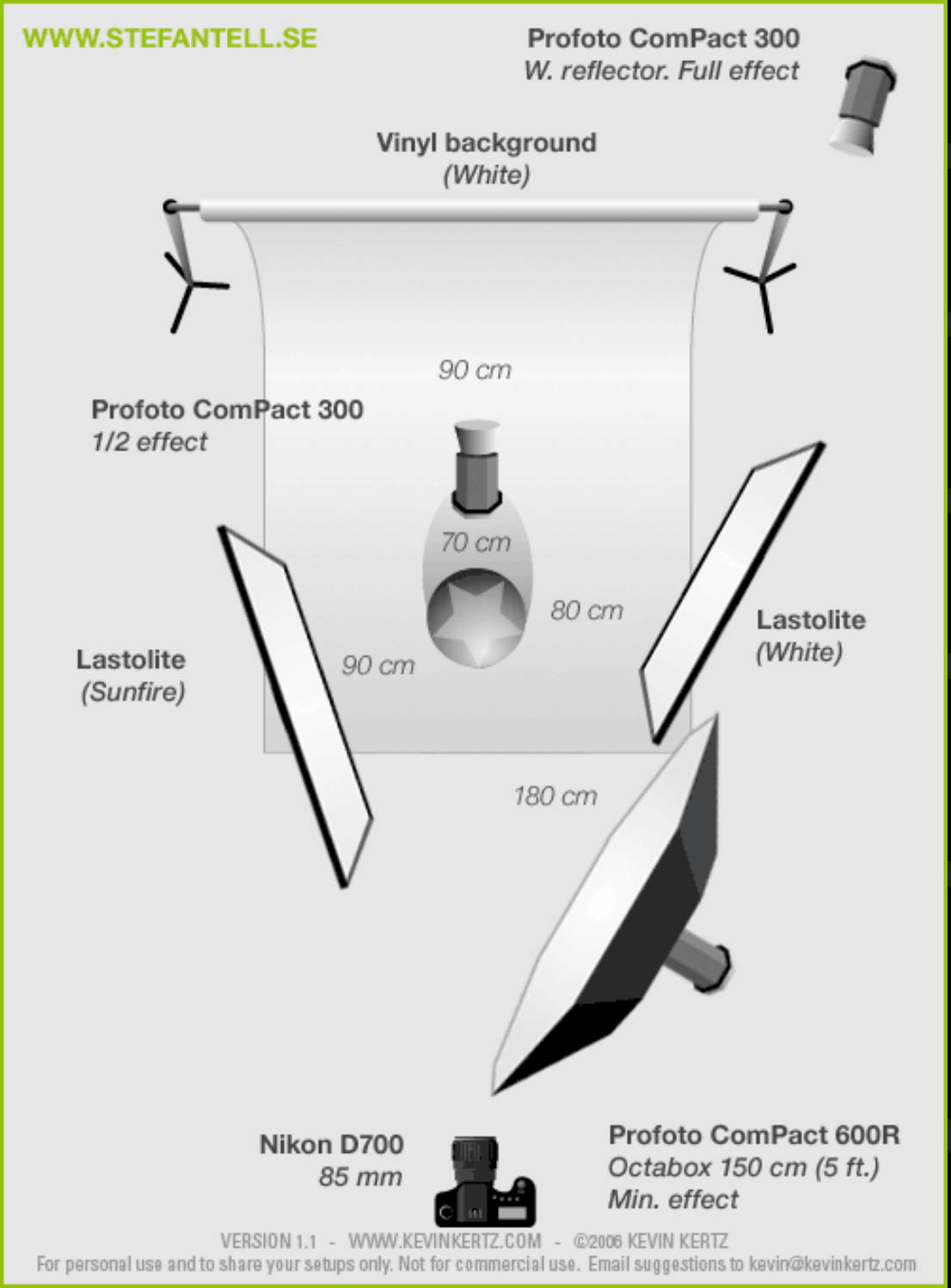


- This lighting setup was designed for a specific image — for a particular quality of light and color..
- Note the string of Christmas tree lights hanging near the backdrop.

- Shallow depth-of-field on the wide-aperture lens causes the small, distant lights to distort into a bokeh effect. The Christmas lights are dim compared to the main illuminating floods.

- Problem: how do you get a live butterfly to hold still for a studio photo?

- Solution: butterfly collectors “ship” butterflies in a chilled, semi-hybernated state. So, get a chilled butterfly, and shoot photos before he wakes up fully.


WWW.STEFANTELL.SE
Profoto ComPact 300
W. reflector. Full effect
Vinyl background
(White)
90 cm
Profoto ComPact 300
1/2 effect
70 cm
80 cm
Lastolite
(White)
Lastolite
(Sunfire)
90 cm
180 cm
Nikon D700
85 mm
Profoto ComPact 600R
Octabox 150 cm (5 ft.)
Min. effect
VERSION 1.1 - WWW.KEVINKERTZ.COM - ©2006 KEVIN KERTZ
For personal use and to share your setups only. Not for commercial use. Email suggestions to kevin@kevinkertz.com

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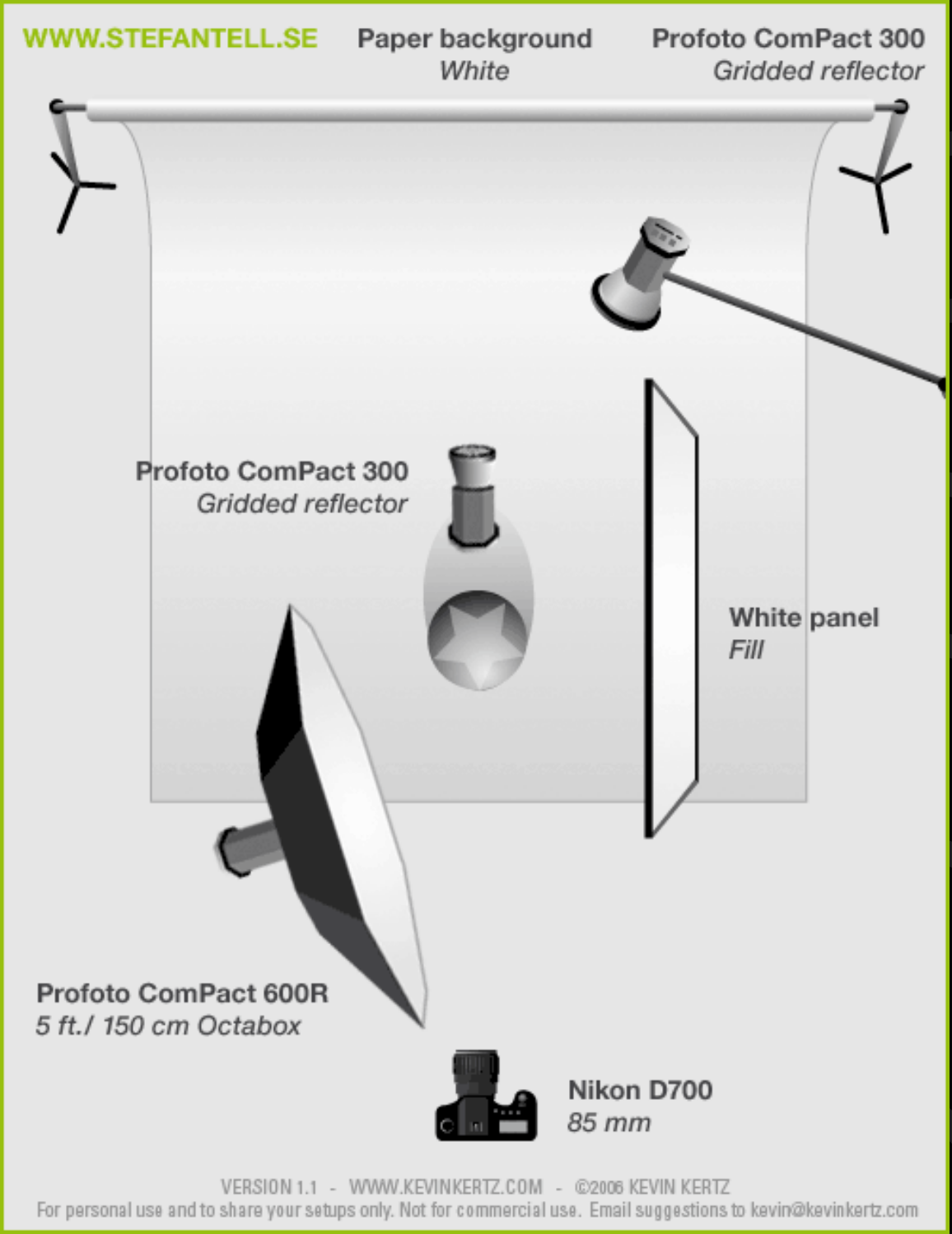


Recall...

Subtractive (pigment) vs. Additive (light)

RYB (or CMYb)

Red-to-RV (Magenta)

Yellow

Blue-to-BG (Cyan)

RGB

Red (RRO)

Green

Blue (BBV)

Recall...

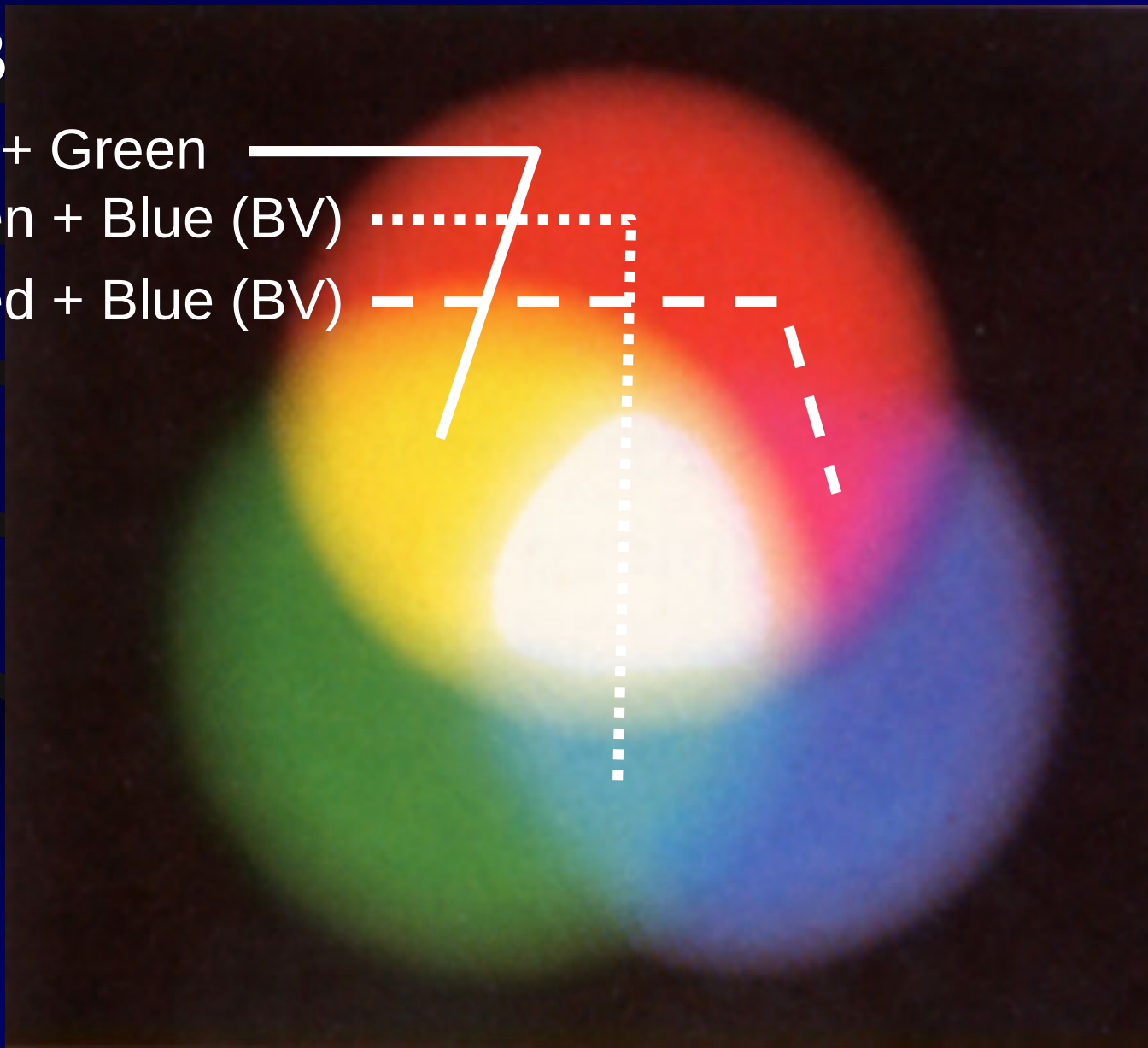
Additive Secondaries

RGB

Yellow = Red + Green

Blue (Cyan) = Green + Blue (BV)

Magenta (RV) = Red + Blue (BV)



Additive (RGB) Neutrals/Grays

White = Full intensity RGB

100% Gray = 100% R + 100%G + 100% B

RGB(255, 255, 255) ; Hex: #FFFFFF

~80% Gray = 80% R + 80%G + 80% B

RGB(208, 208, 208) ; Hex: #D0D0D0

~50% Gray = 50% R + 50%G + 50% B

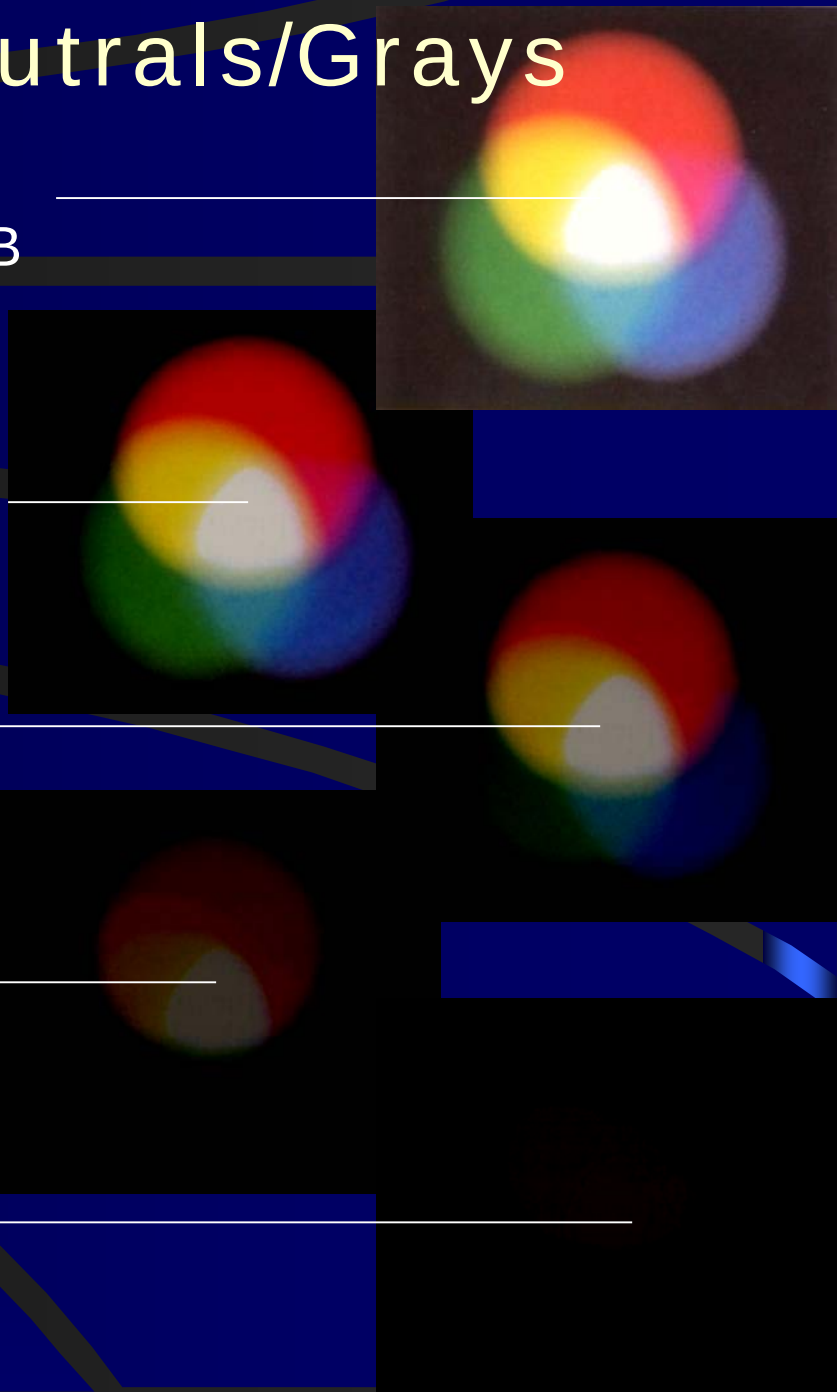
RGB(128, 128, 128) ; Hex: #808080

~20% Gray = 20% R + 20%G + 20% B

RGB(48, 48, 48) ; Hex: #303030

Black = 0% R + 0%G + 0% B

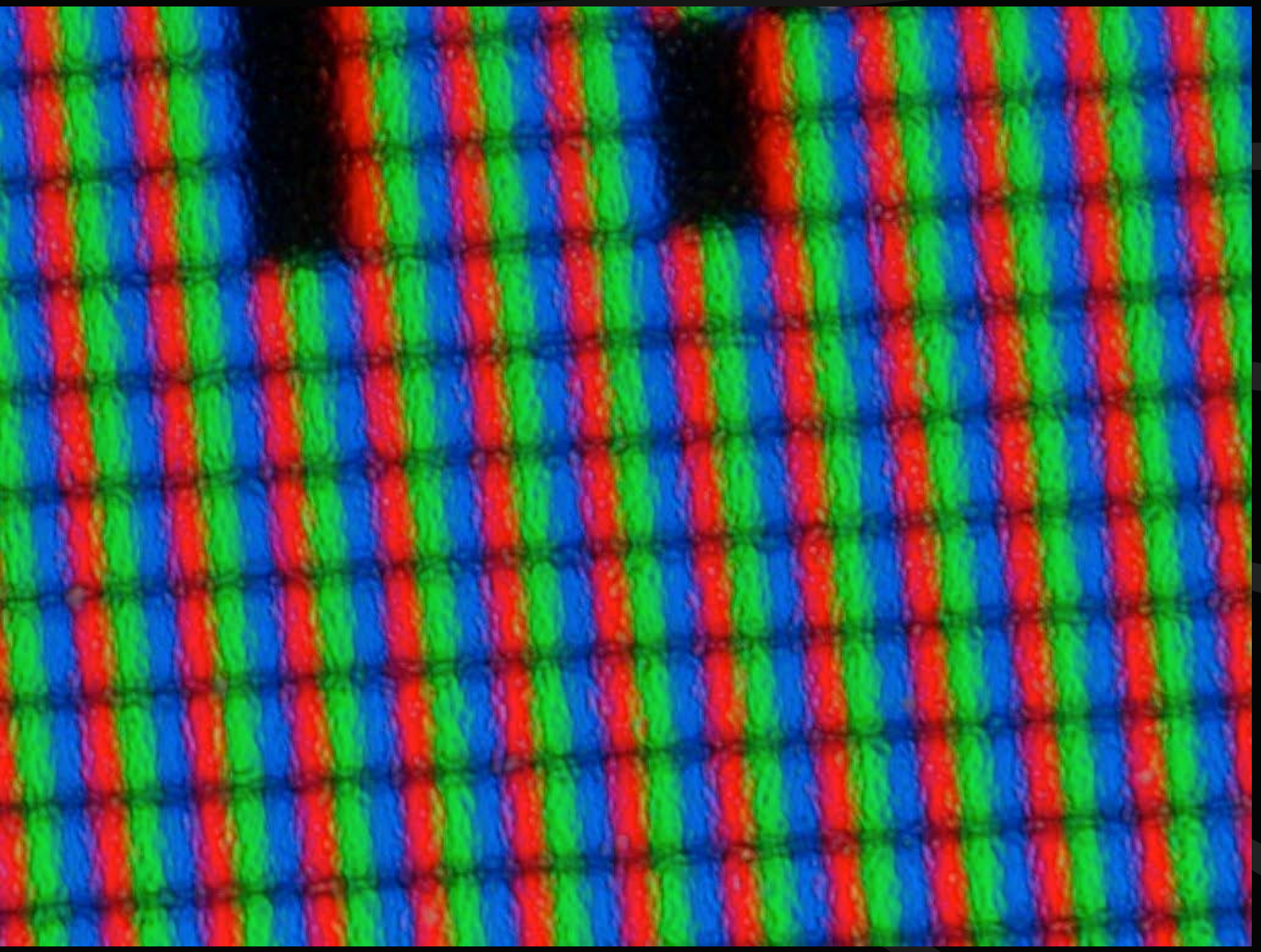
RGB(0, 0, 0) ; Hex: #000000



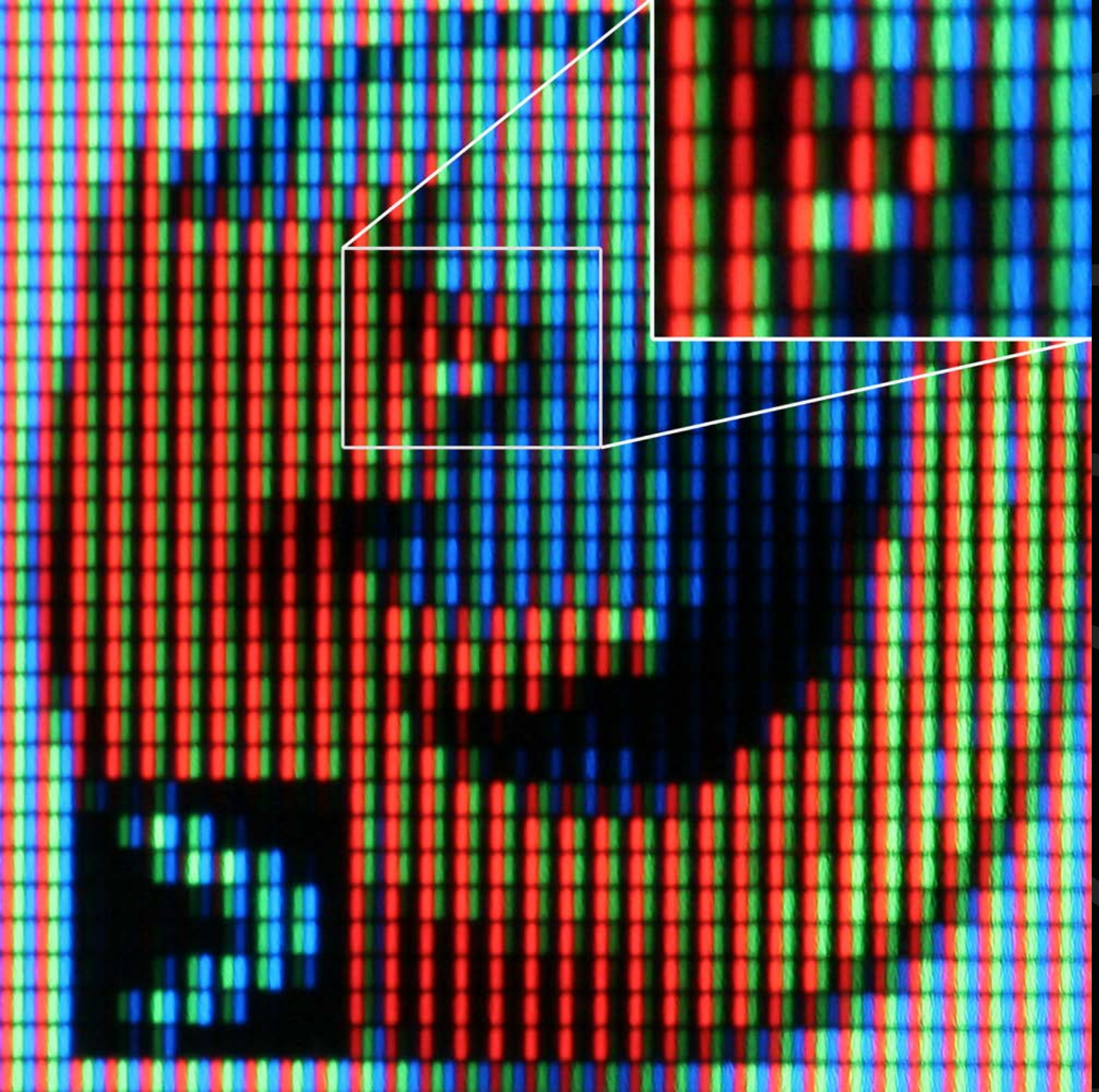
www.w3schools.com/html/html_colors.asp

- RGB color: the everyday digital spectrum
- Most of the onscreen color we see is generated by optically mixed RGB colors.

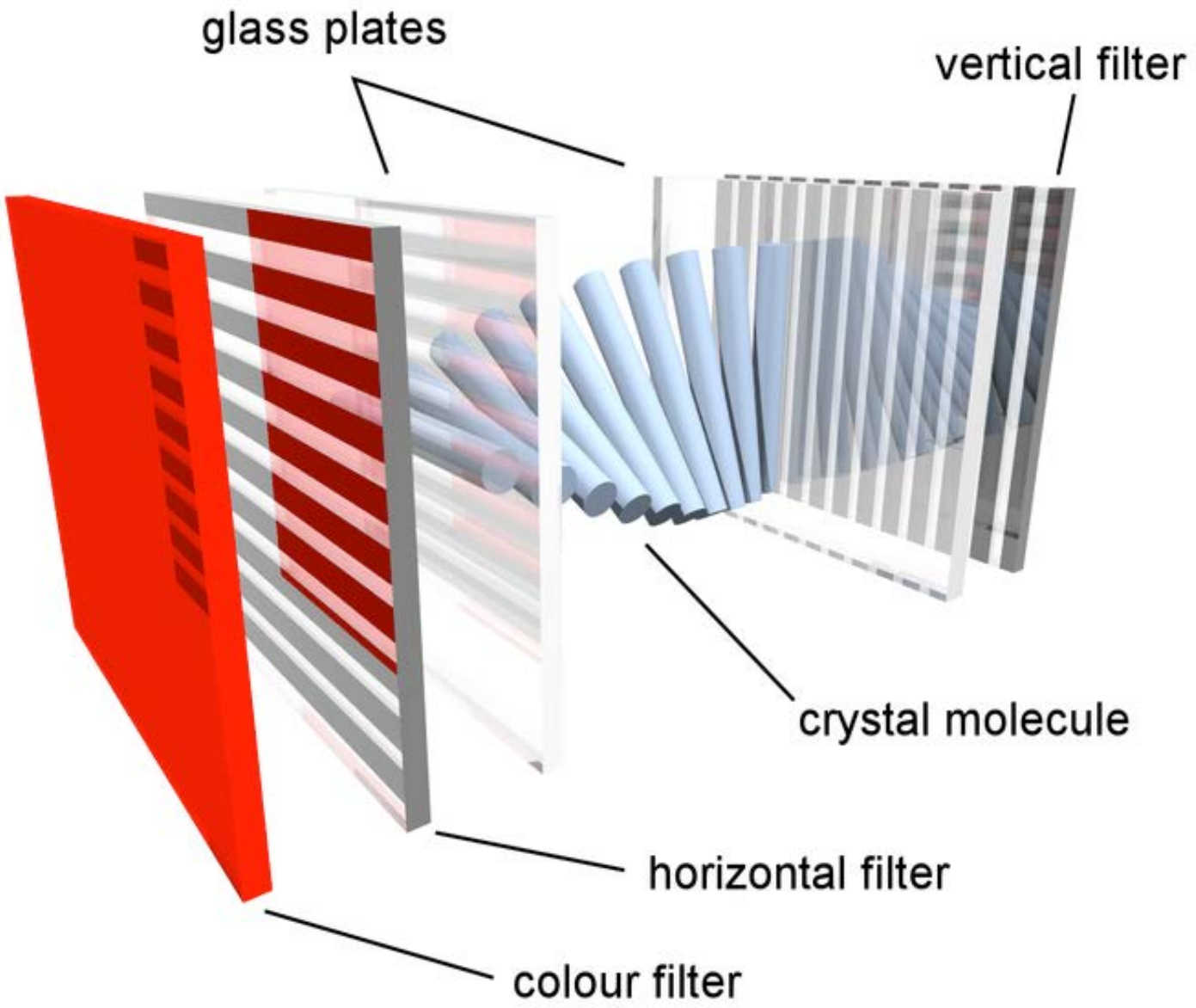
Digital Flat Screen RGB



- Cathode Ray tubes (CRTs) are no longer the standard solution for digital displays.
- LCD, Plasma screens, etc. each divide the screen into small discrete segments.
- Red, Green and Blue are obvious in macro photos.



LCD (red) subpixel

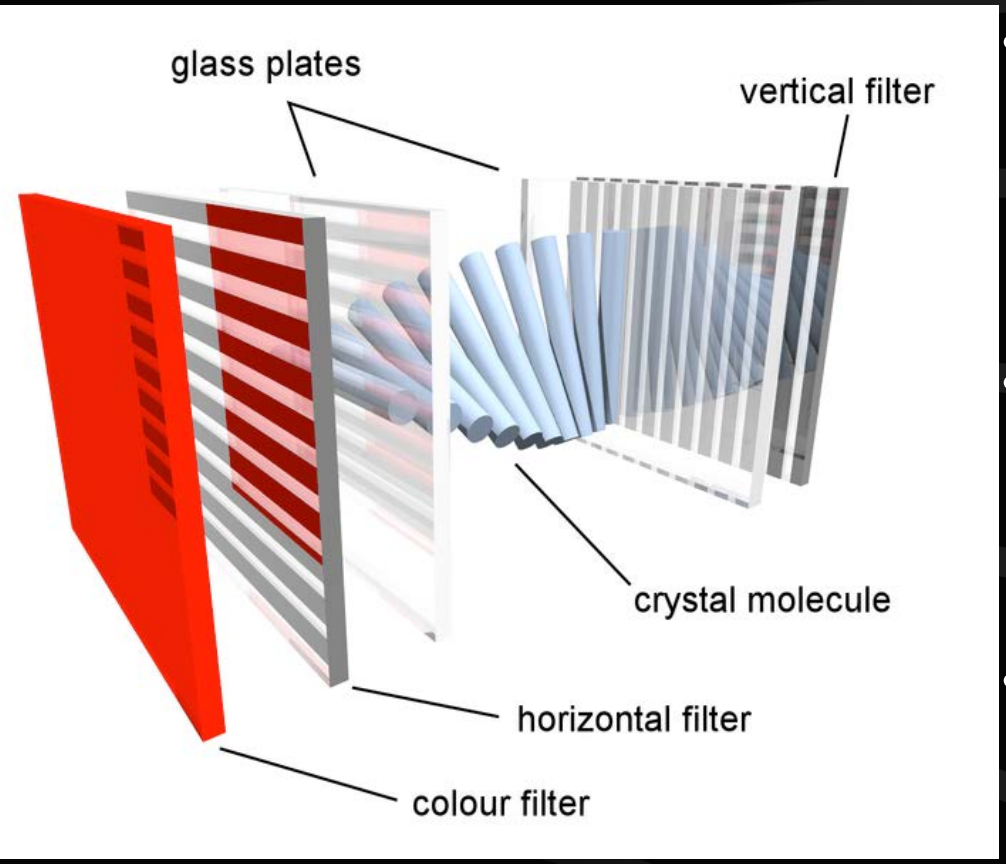


Basically, *a liquid crystal can either block light, or allow light to pass through fully or partially.*

The light itself us usually a behind the LCD.

Each pixel has a colored (R, G or B) filter.

LCD (red) subpixel

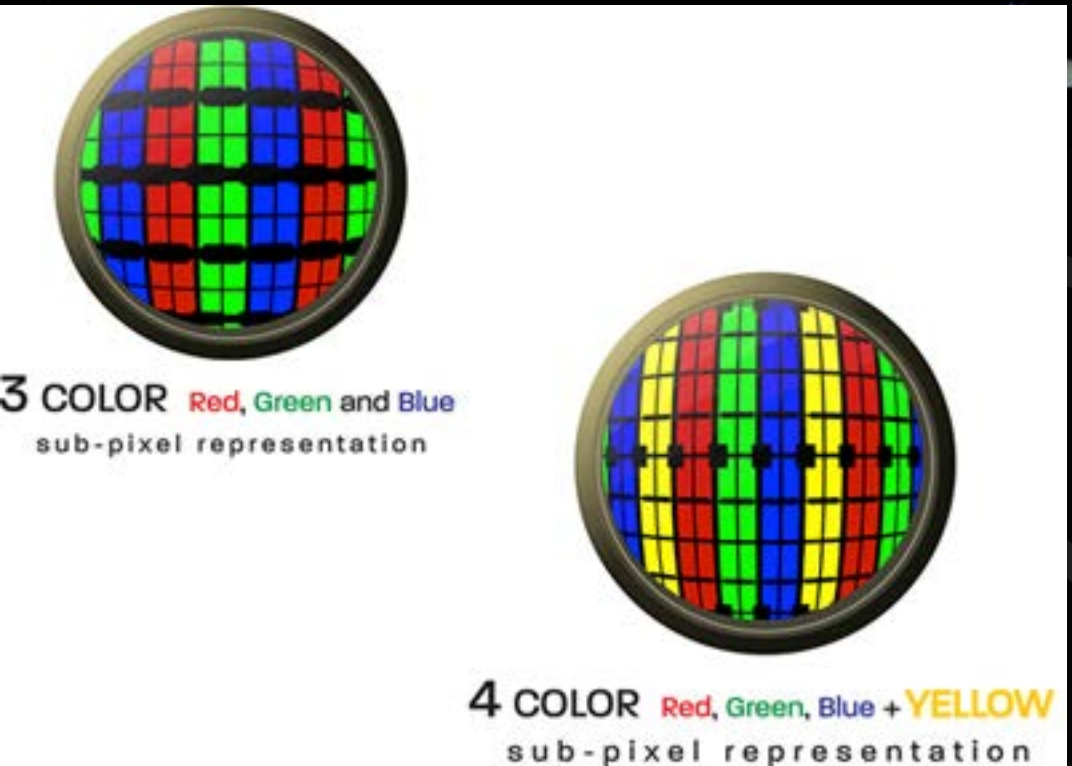


… a liquid crystal can either block light, or allow light to pass through.

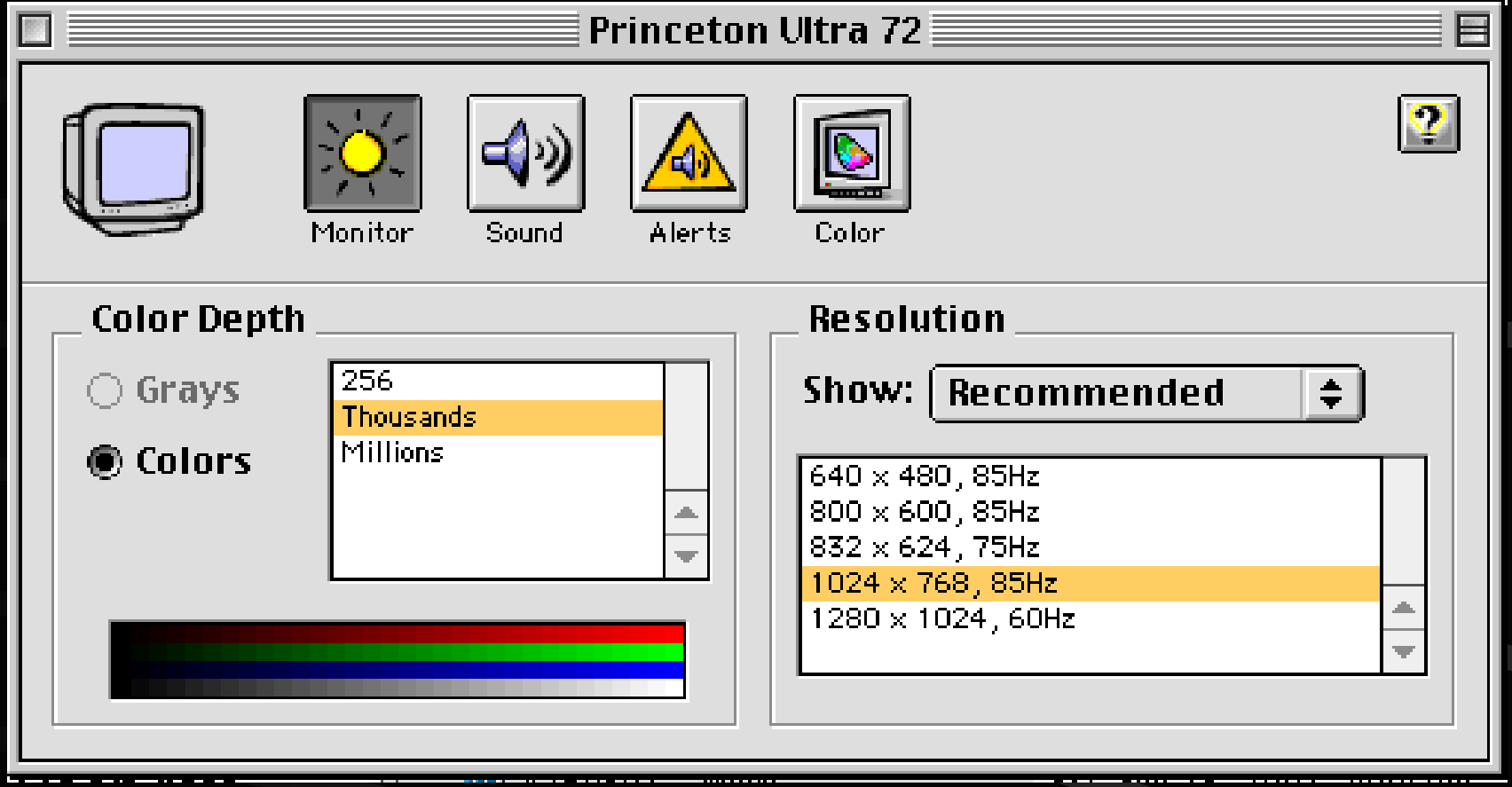
- Each pixel of an LCD typically consists of a layer of molecules aligned between two transparent electrodes, and two polarizing filters, the axes of transmission of which are (in most of the cases) perpendicular to each other.
- With no actual liquid crystal between the polarizing filters, light passing through the first filter would be blocked by the second (crossed) polarizer.
- ***By controlling the voltage applied across the liquid crystal layer in each pixel, light can be allowed to pass through in varying amounts thus constituting different levels of intensity for that (sub)pixel.***
- http://en.wikipedia.org/wiki/Liquid_crystal_display

Quatron 4-primary-color LCDs

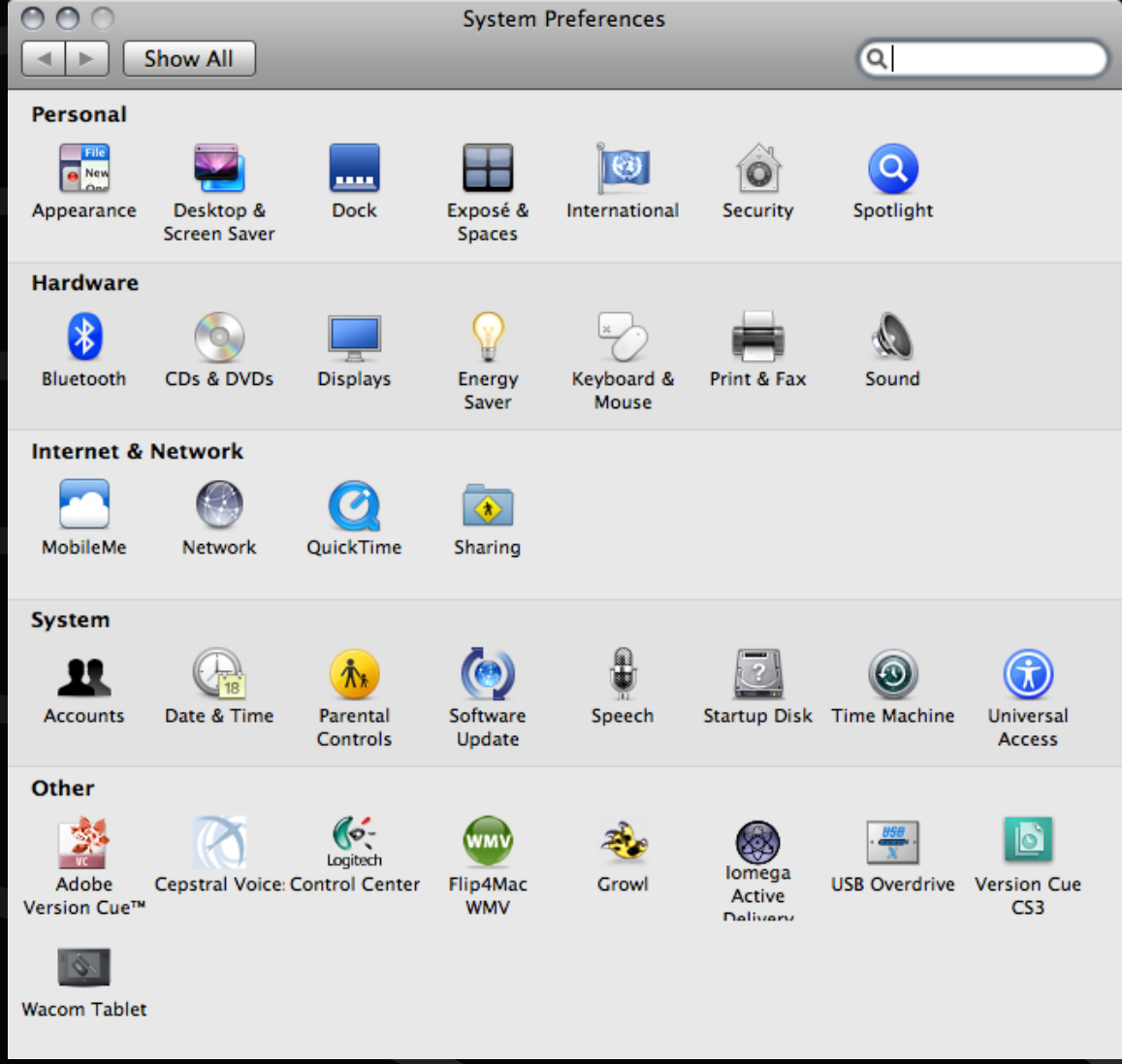
- In Spring 2010 at the Consumer Electronics Show, Sharp announces their advance in color display technology — not mere RGB, but RGBY. Yellow light is added to expand the gamut of color displayed, enabling more than 1 trillion HD colors. (which is about 999 billion more than your eye can distinguish).



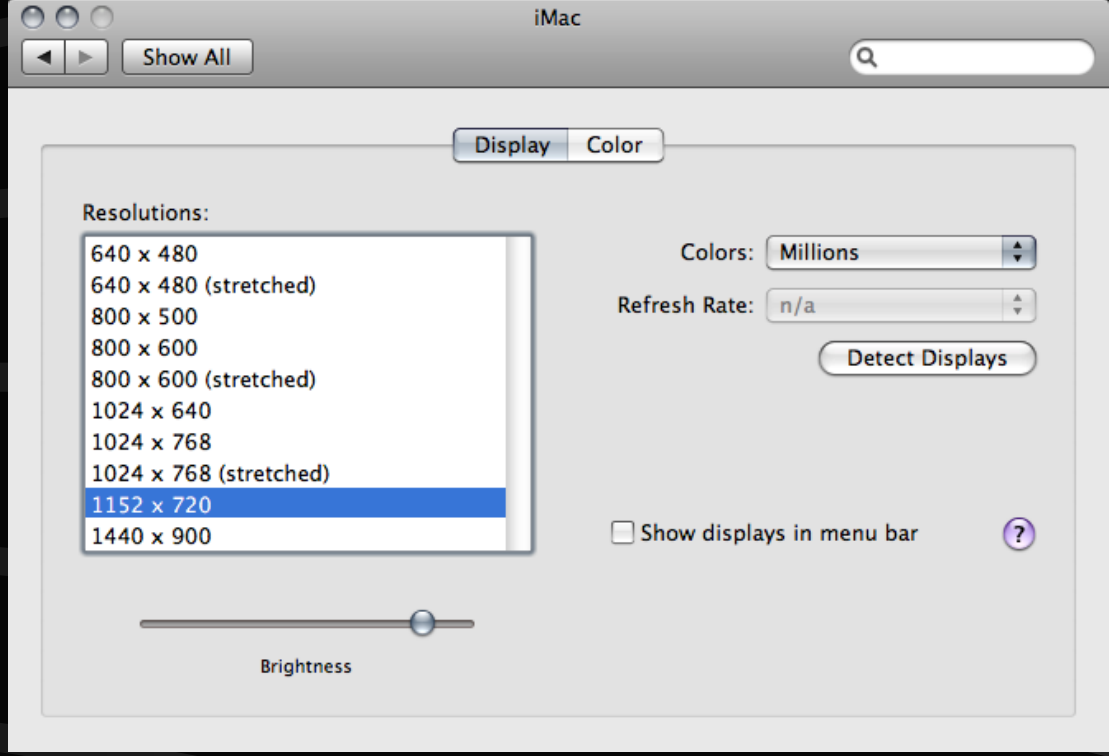
Takei Ad/YouTube
SharpUSA/Quatron


Princeton Ultra 72
Monitor
Sound
Alerts
Color
Color Depth
Grays
Colors
256
Thousands
Millions
Resolution
Show:
Recommended
640 x 480, 85Hz
800 x 600, 85Hz
832 x 624, 75Hz
1024 x 768, 85Hz
1280 x 1024, 60Hz

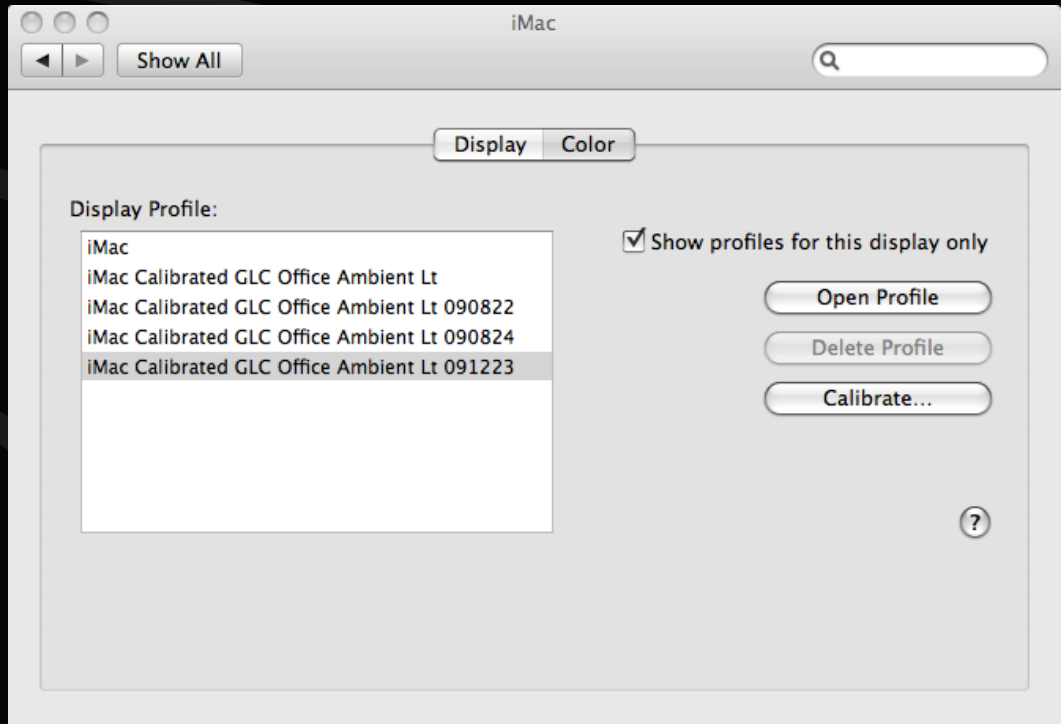
- Mac: Go to System Prefs (Apple Menu)



- Select the “Color” tab…



- Then the “Calibrate” button….



- Then follow the instructions to create an up-to-date monitor/display profile…

Color Gamut Limits

- No color outside of a device’s color gamut can be displayed by that device.
- A device: a monitor, a printer, a camera, film, a scanner, etc.
- Each is capable of either displaying or sensing a certain set of colors.
- A digital camera or a scanner will “see” and record only the colors within a certain range – within the device’s color gamut.

Color Gamut Limits

- A printer can only print a certain range of colors and a monitor can only display a certain range of colors.
- And every device has a different color range – a different color gamut.

RGB Monitor gamut problems

- A high chroma yellow is impossible.
- High chroma cyan and magenta are also impossible – though needed to represent CMYK color expected by print designers.

CMYK Gamut Limits

- Printing inks cover a fairly small area of the visible spectrum

Color Film

- Color Film superior to either Monitors or Printing Inks

RGB – 16 million colors

- Most Computers and Graphics Software allow you to *specify* 16.7 million colors. (256x256x256 = RGB range at 8-bits per channel)
- “24-bit color”
- 8-bits for specifying red, 8 bits for specifying Green, and 8 for Blue.
- $(2)^8 = 256$ $(256)^3 = 16.7$ mil.
- (what we can specify, what the monitor can display, and what we can see are *each* different color gamuts)

Color Management

- CMYK 0nly about 5,000 distinct colors possible
- Calibration

Gamma Correction

- Gamma correction is the process of pre-compensating for the nonlinear voltage-to-light intensity function of the CRT of a video monitor or a computer monitor, in order to obtain correct reproduction of intensity. Gamma correction is important if you want to obtain good picture quality and accurate color reproduction.

Gamma – one value to set contrast adjustments

- In video, computer graphics and image processing, *gamma* represents a numerical parameter that describes the nonlinearity of intensity reproduction. Having a good understanding of the theory and practice of gamma will enable you to get good results when you create, process and display pictures.
- *Gamma* characterizes the reproduction of tone scale in an imaging system. Gamma summarizes, in a single numerical parameter, the nonlinear relationship between code value - in an 8-bit system, from 0 through 255 - and luminance. Nearly all image coding systems are nonlinear, and so involve values of gamma different from unity.
- Owing to poor understanding of tone scale reproduction, and to misconceptions about nonlinear

- Device calibration is an important first step in the desktop color management process as monitor and output device (printers and scanners) performance capabilities can change over time. Calibration ensures that all devices conform to an established state or condition, often specified by the manufacturer.

Calibration really makes a big difference in monitors.

- Calibrating a monitor adjusts and corrects the monitor's gamma, white and black points, and color balance. Calibration software is used with hardware to send a series of colors to the screen, and the instrument reports back the value of the colors that actually arrive there. Profiling software then builds a corrective profile that is used by ColorSync to drive the monitor.

Monitors should be calibrated on a regular basis.

- (●) D50 — Warm yellowish lighting – standard for graphic arts work.
- ( ) 6500 — Cooler – equivalent to midday sunlight.
- ( ) 9300 — Coolest indoor lighting – the default white point of most monitors and televisions.
- ( ) None — No white point correction performed.

- ( ) D50 — Warm yellowish lighting – standard for graphic arts work.
- (●) 6500 — Cooler – equivalent to midday sunlight.
- ( ) 9300 — Coolest indoor lighting – the default white point of most monitors and televisions.
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- (●) 9300 — Coolest indoor lighting – the default white point of most monitors and televisions.
- ( ) None — No white point correction performed.

Color Profile – what color do you *see*?

- In order to accurately render colors from one device's color space to another, some resource must exist that *describes each device's color capabilities*. Today's digital color management systems use **color profiles**.

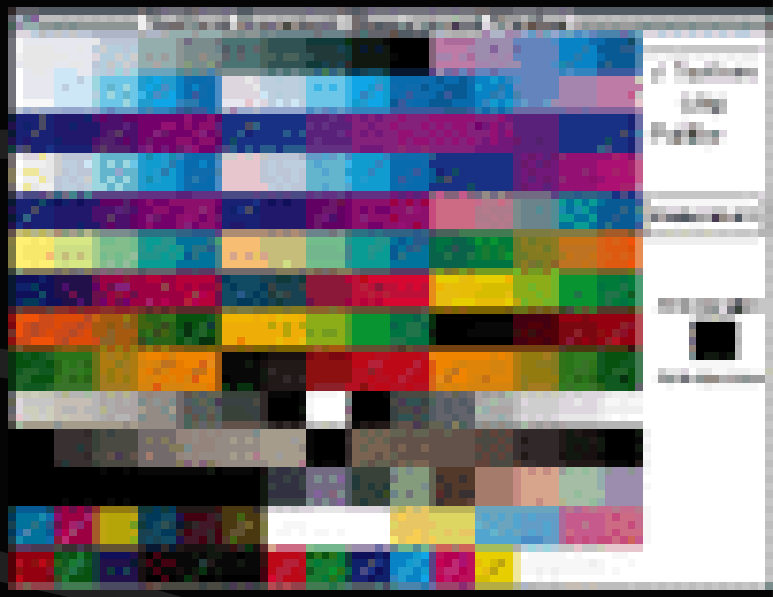
Color Profile – what color do you *see*?

- “A profile is simply a file that describes how a given printer / ink / paper *combination* combine to accurately display colours.

  Almost all contemporary printers ship with profiles for their inks and that manufacturer's popular papers. These are usually installed automatically when you install the printer driver. You can also buy third party profiles, or obtain them online from paper maker's web sites.

Profile a Printer

- Profiling a printer involves creating a testform document (often a Photoshop, Illustrator or PDF document with swatches of specific colors defined), printing it on a printer or printing press, then reading the printed color patches with an instrument, such as a spectrophotometer (or, in a pinch, a scanner)
  The colors that were described in the testform are compared to the colors observed by the spectrophometer. (software handles this)
- Then a color profile is created for the printer, adjusting color descriptions so that prints can better match the original document.



Color Profile – what color do you *see*?

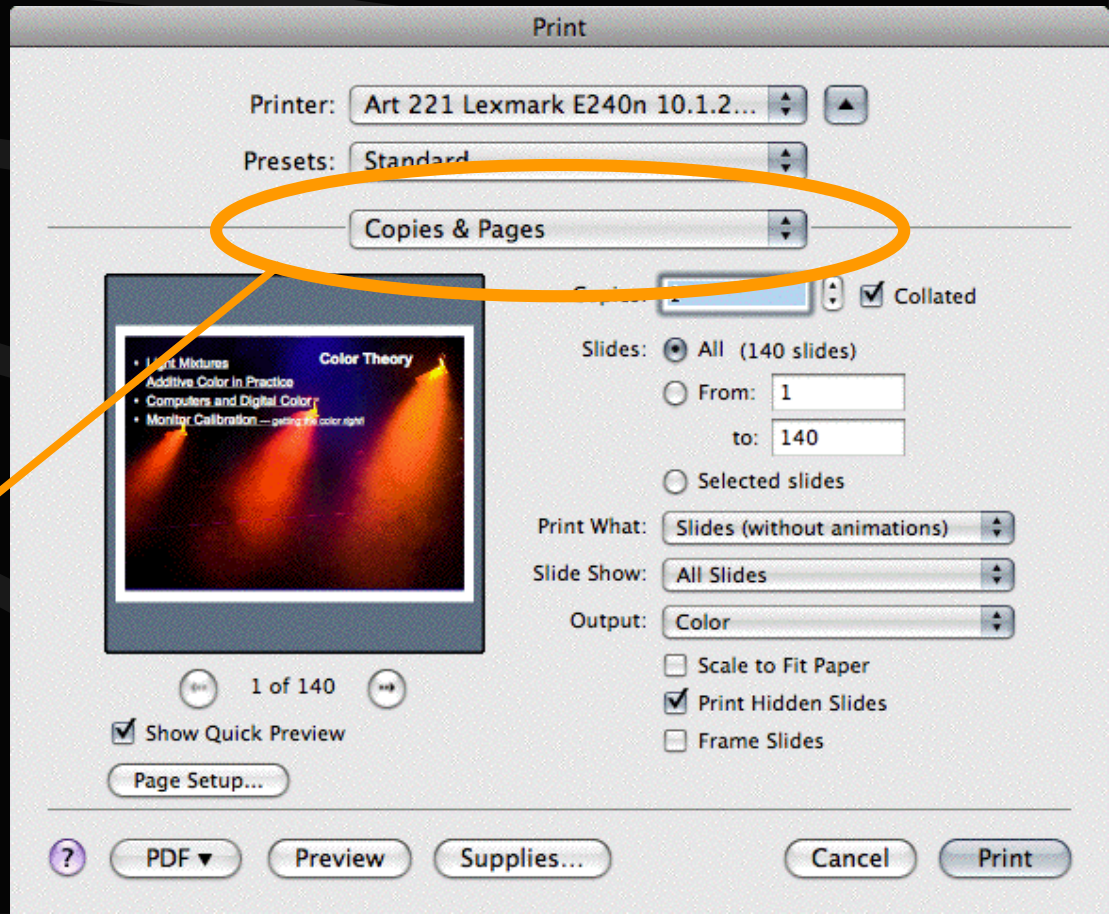
- “A third method, and often the best, is to make them yourself, but this requires that you have quality equipment and software… and usually only makes sense if you are using odd combinations of inks and papers that no one has prepared profiles for.

Color Profile – what color do you *see*?

- "Profiles have either an .ICC or .ICM extension, (depending on whether they are for a PC or a Mac; you can easily find them on your computer by searching for files with either of those extensions.)

•In practice, you select color profiles when you print your document. The Print dialog box on Macs and Windows usually offers access to profiles.

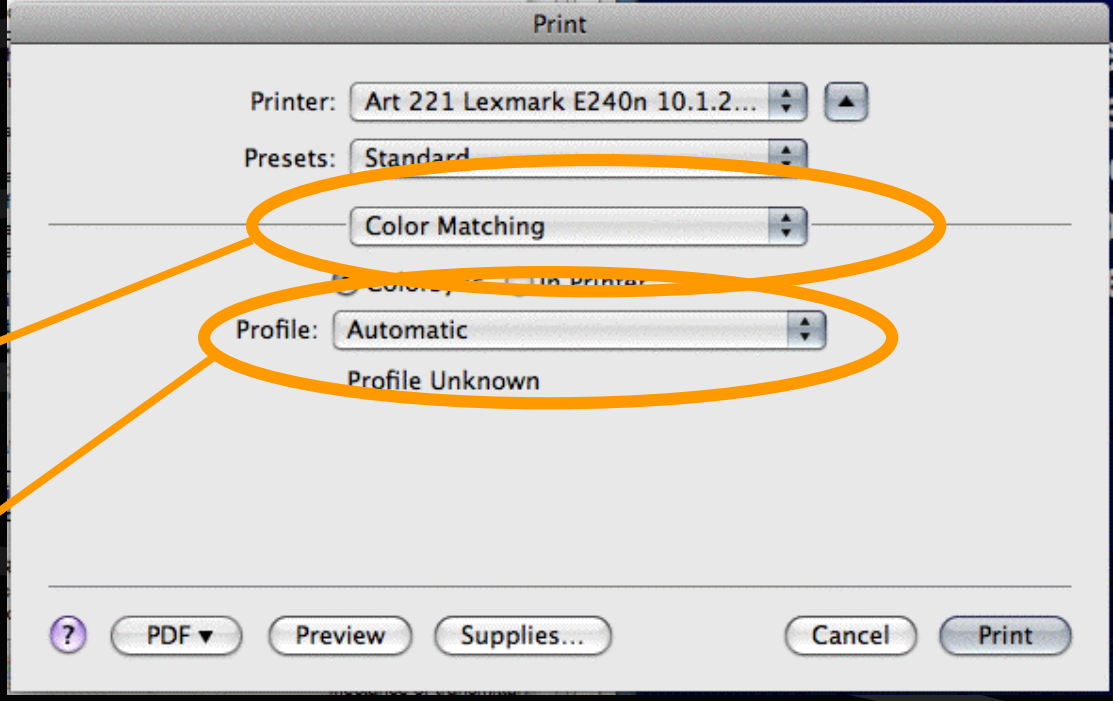
Here, pull down the (default) "Copies & Pages" menu…



Color Profile –
Using for Printing

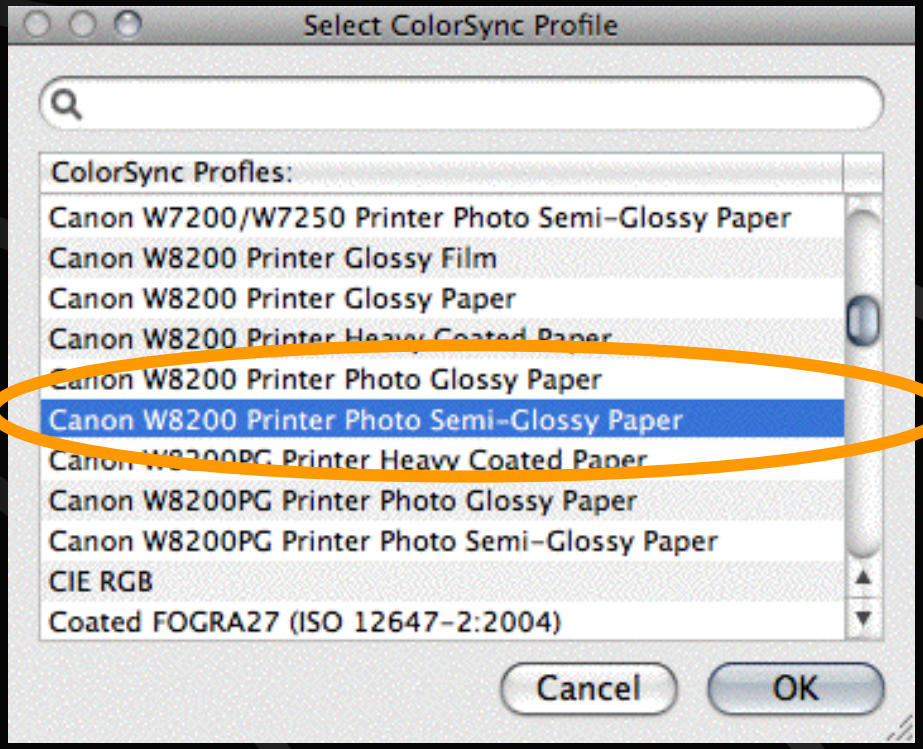
•Select “Color Matching”

•…then Select “Other Profiles…” in the Profile menu…



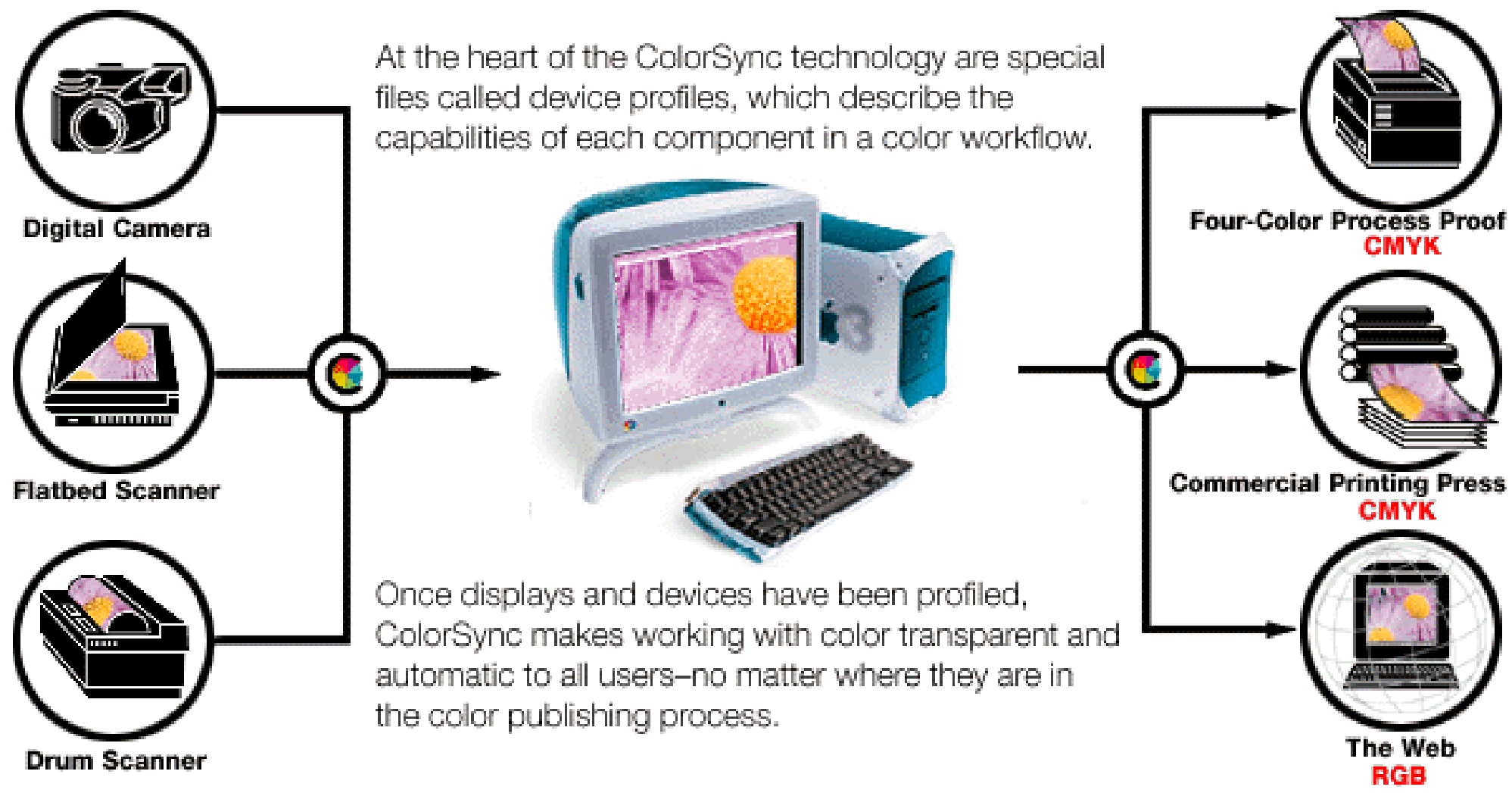
You’ll then see a list of all of the installed profiles on your computer.

You can download or create others.



ColorSync – Apple's Color Calibration Solution

- **ColorSync** provides a built-in framework for implementing and managing these device profiles. ColorSync profiles follow the International Color Consortium (ICC) profile format. This format provides a single cross-platform standard for translating color data across devices and across operating systems. A profile created for a particular device is usable on systems running different operating systems.



- Each imaging device can be profiled. Once done, reliable color can be transferred from one device to another…say, from camera, to monitor to printer.

Monitor Calibration Assistant

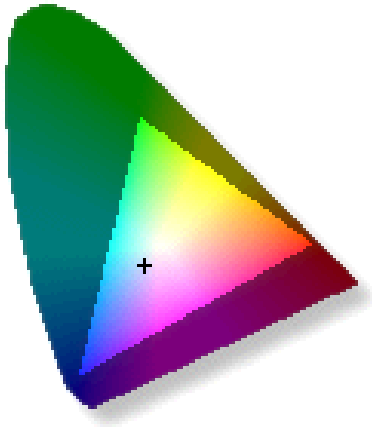
Select your monitor's color characteristics

Your monitor has chemical phosphors (or similar physical characteristics) that determine the range of colors you see on your screen.

Select the description that best fits your monitor.

Twentieth Anniversary Macintosh

Generic Apple Monitor
Generic Hitachi-EBU



er you have done this step, click the right arrow.

5

Monitor Calibration Assistant

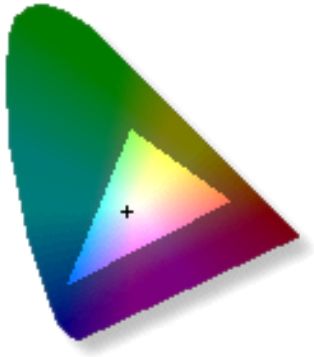
Select your monitor's color characteristics

Your monitor has chemical phosphors (or similar physical characteristics) that determine the range of colors you see on your screen.

Select the description that best fits your monitor.

Twentieth Anniversary Macintosh

Generic Apple Monitor
Generic Hitachi-EBU
Generic Hitachi-Ikegami
Generic LCD Color
Generic NEC Monitor
Generic Radius Pivot
Generic Sony Monitor
Generic sRGB Monitor
Generic Trinitron Monitor
Generic ViewSonic Monitor



After you have done this step, click the right arrow.

5

Every Device is Different and Changing

- It is important to recognize that a device profile represents the device in its factory condition. In reality, devices of the same type will deviate, resulting in inconsistencies, and require device calibration. Device calibration should be performed on a regular basis to ensure accuracy.

Device-specific Gamuts

- When an image is output to a monitor or printer, the device displays only those colors that are within its gamut. Likewise, when an image is created by scanning, only those colors within the scanner's gamut are saved. Devices with different gamuts cannot reproduce each other's colors exactly, but careful shifting of the colors used on one device can improve the visual match when the image is displayed on another.

Color Conversion

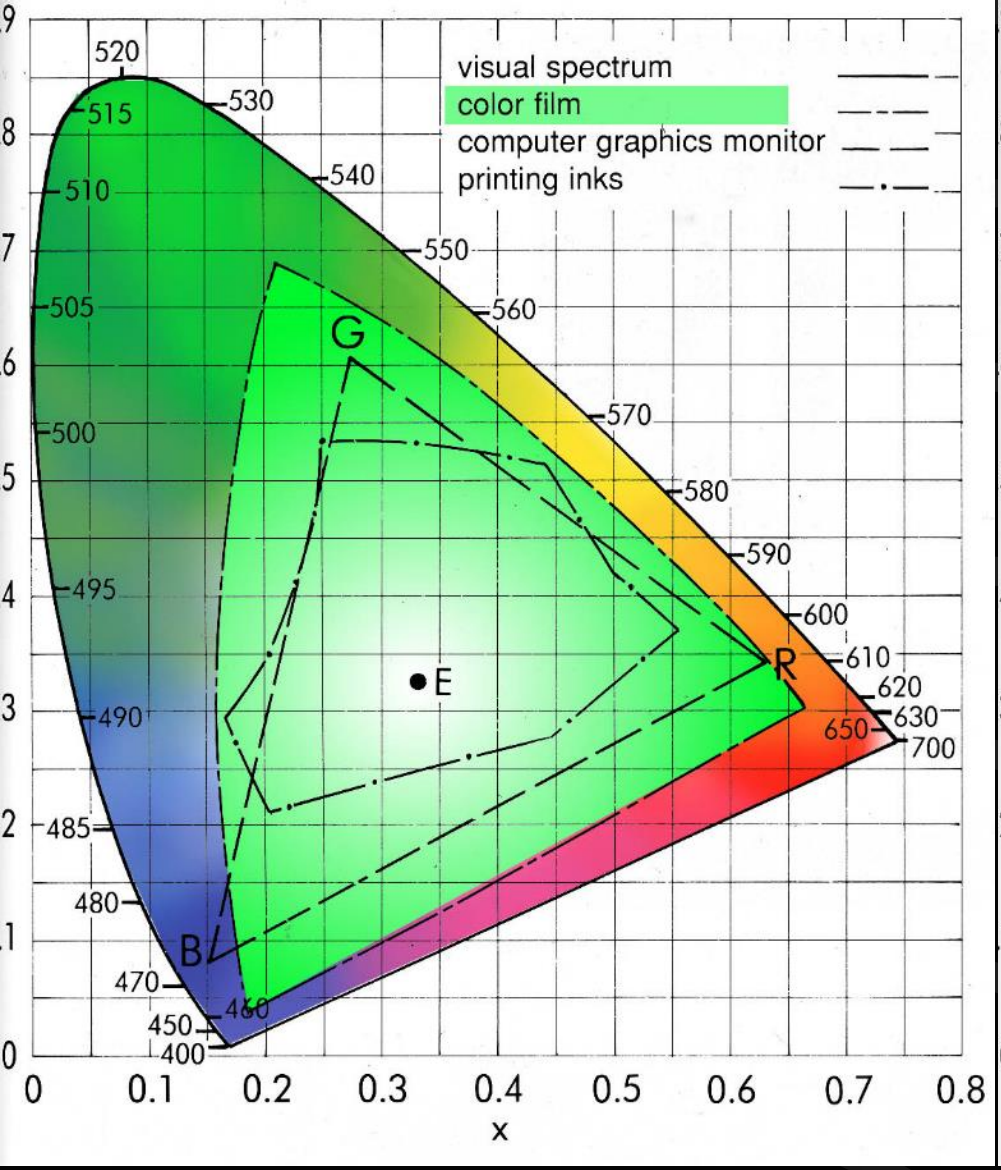
- Color conversion is the process of translating colors from one color space to another.
- Different imaging devices (scanners, displays, printers) work in different color spaces, and each can have a different **gamut**, or range of colors that can be generated. For example, color displays from different manufacturers all use RGB colors but may have different RGB gamuts
- Sophisticated algorithms convert color specs from one space to another.

Color Matching

- Printers that work in CMYK space vary drastically in their gamuts, especially if they use different printing technologies. Even a single printer's gamut can vary significantly with the ink or type of paper it uses.
- Color matching is the process of adjusting converted colors to achieve maximum similarity from the gamut of one color space to the other.

Gamut Mapping

- Since it is not possible to have perfect color matches between devices due to the differences in each device's gamut the Color Matching Module (CMM) performs **gamut mapping**, a process by which the next closest reproducible color is selected.


visual spectrum
color film
computer graphics monitor
printing inks
520
515
530
540
510
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505
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570
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580
590
495
600
610
620
630
650
700
490
485
480
470
460
450
400
G
R
B
E
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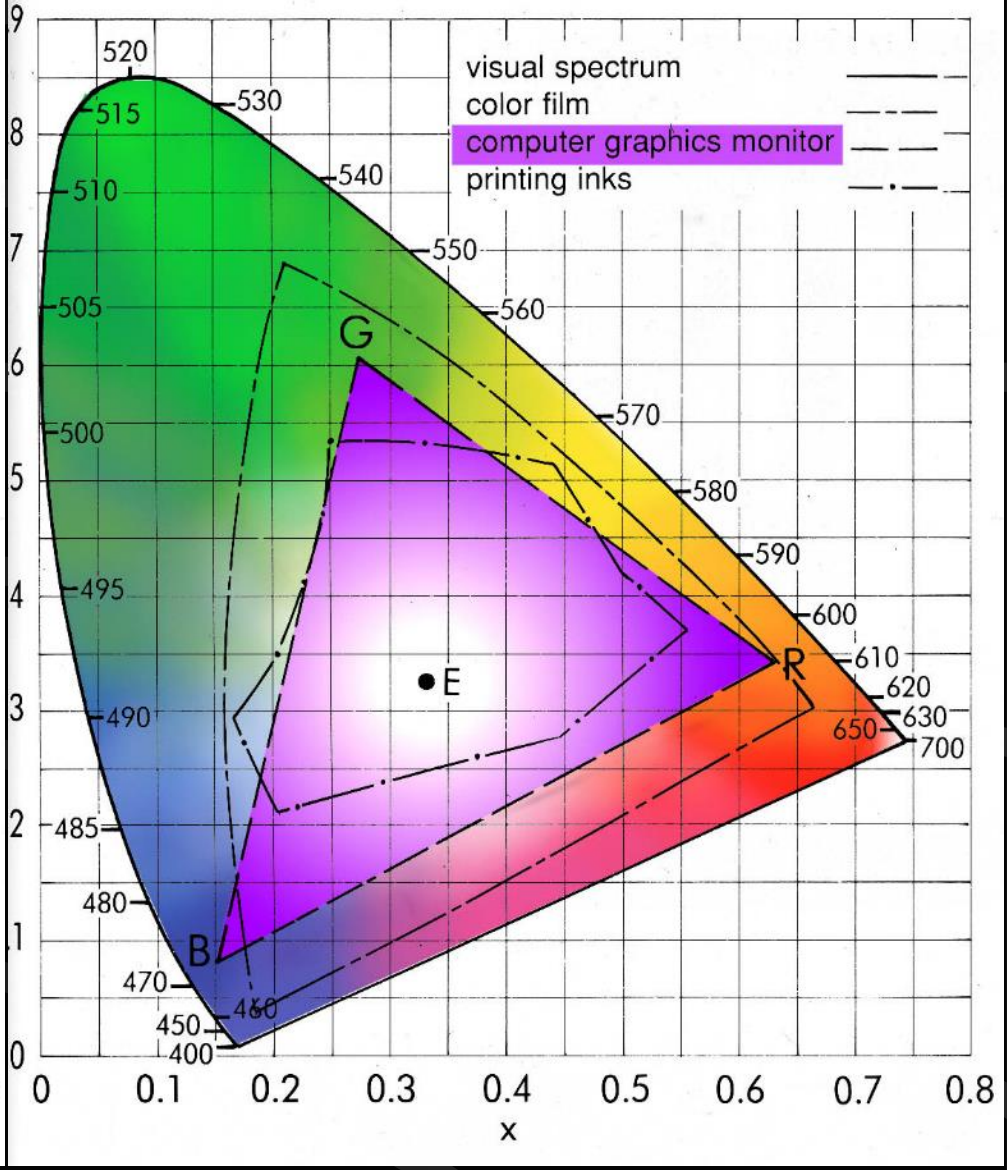
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
x


visual spectrum
color film
computer graphics monitor
printing inks
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485
480
470
460
450
400
G
R
B
E
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
x

Gamut Mapping – Color Transformation – Color Translation

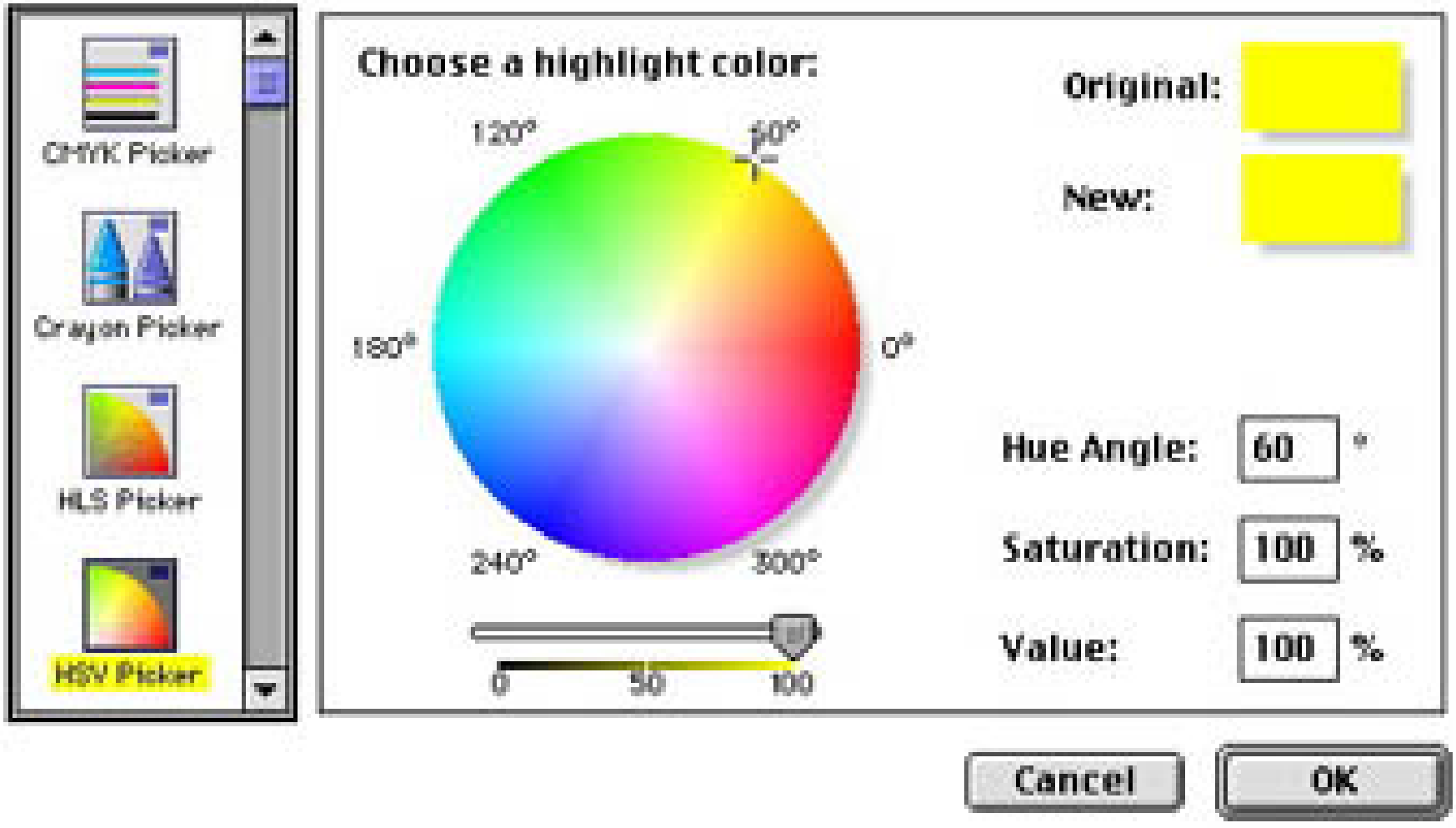
- ColorSync profiles are used by the CMM, or color transformation engine, in ColorSync-savvy applications. The CMM translates data from one device's colors to another, via an independent color space.
- The CMM receives the necessary information from the profiles , so that it can accurately transform a color from one device to another.
- The result is color that is consistent from device to device.

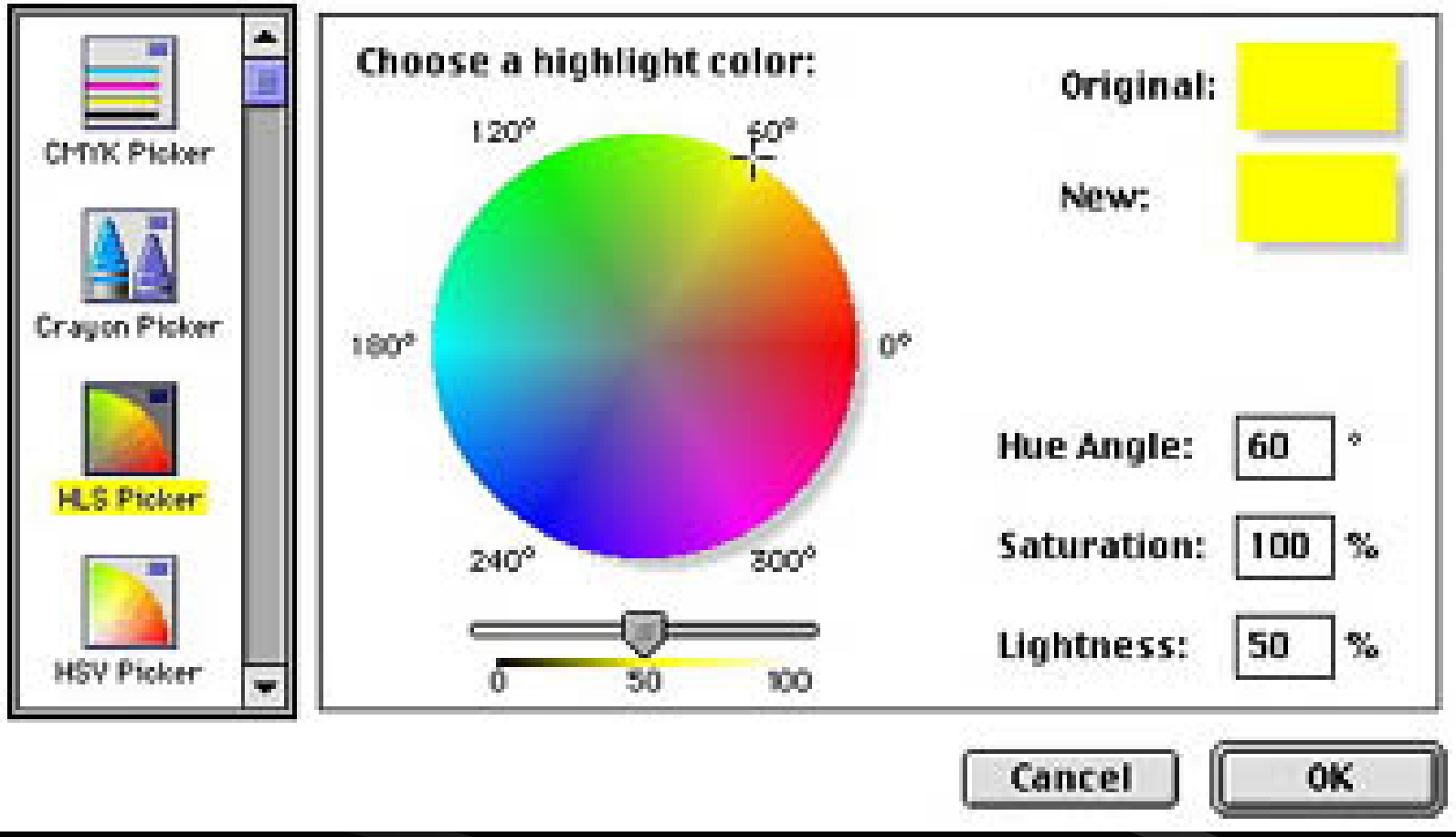
Calibration

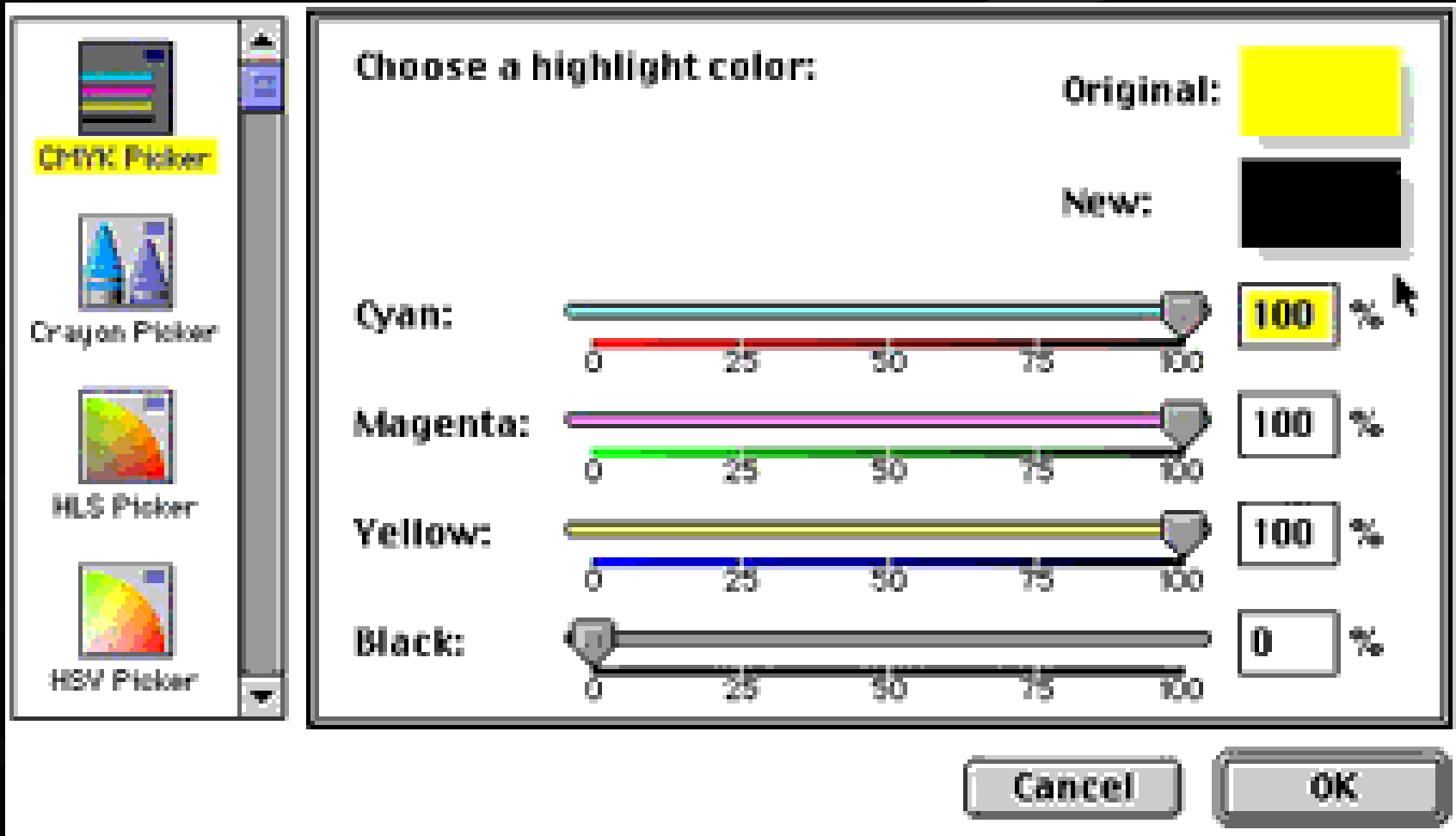
- **Calibration.** The process of ensuring that all color production devices (scanners, monitors, printers) conform to an established state, specified by the manufacturer, user, or an industrywide specification or standard.

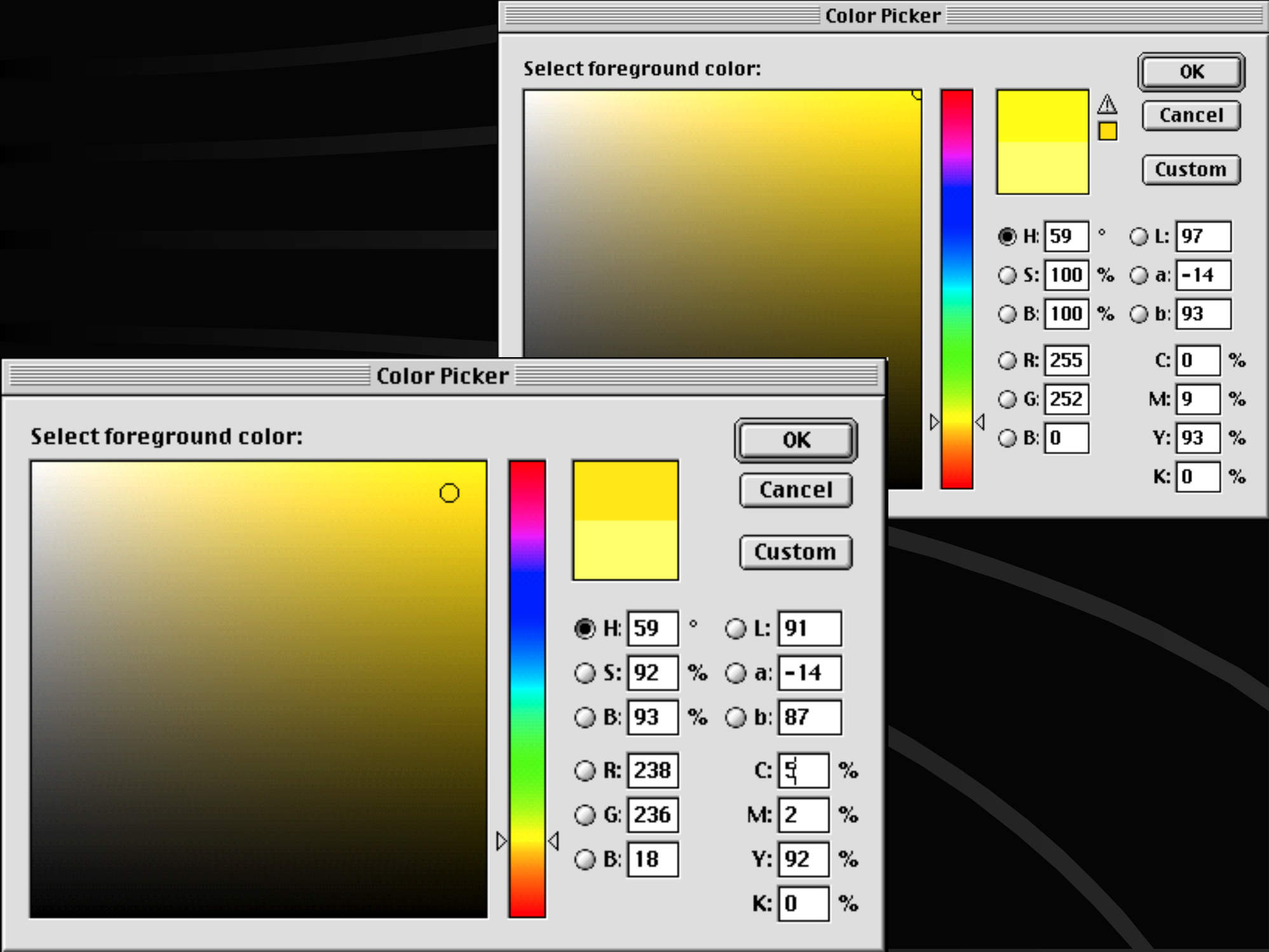
Alternate Color Spaces

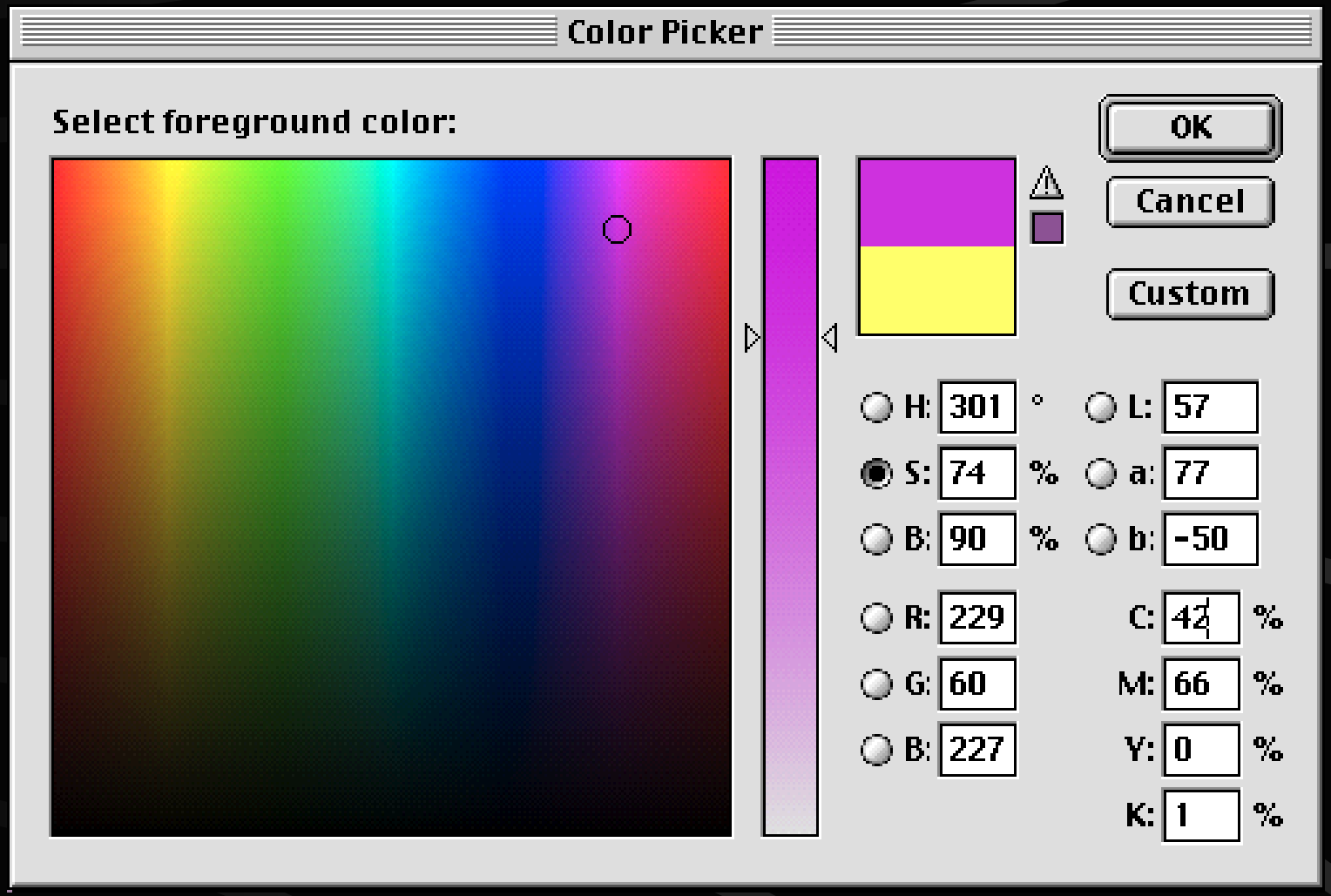
- **HSV and HLS Spaces** - transformations of RGB space that allow colors to be described in terms more natural to an artist. The name HSV stands for hue, saturation, and value. HLS stands for hue, lightness, and saturation.

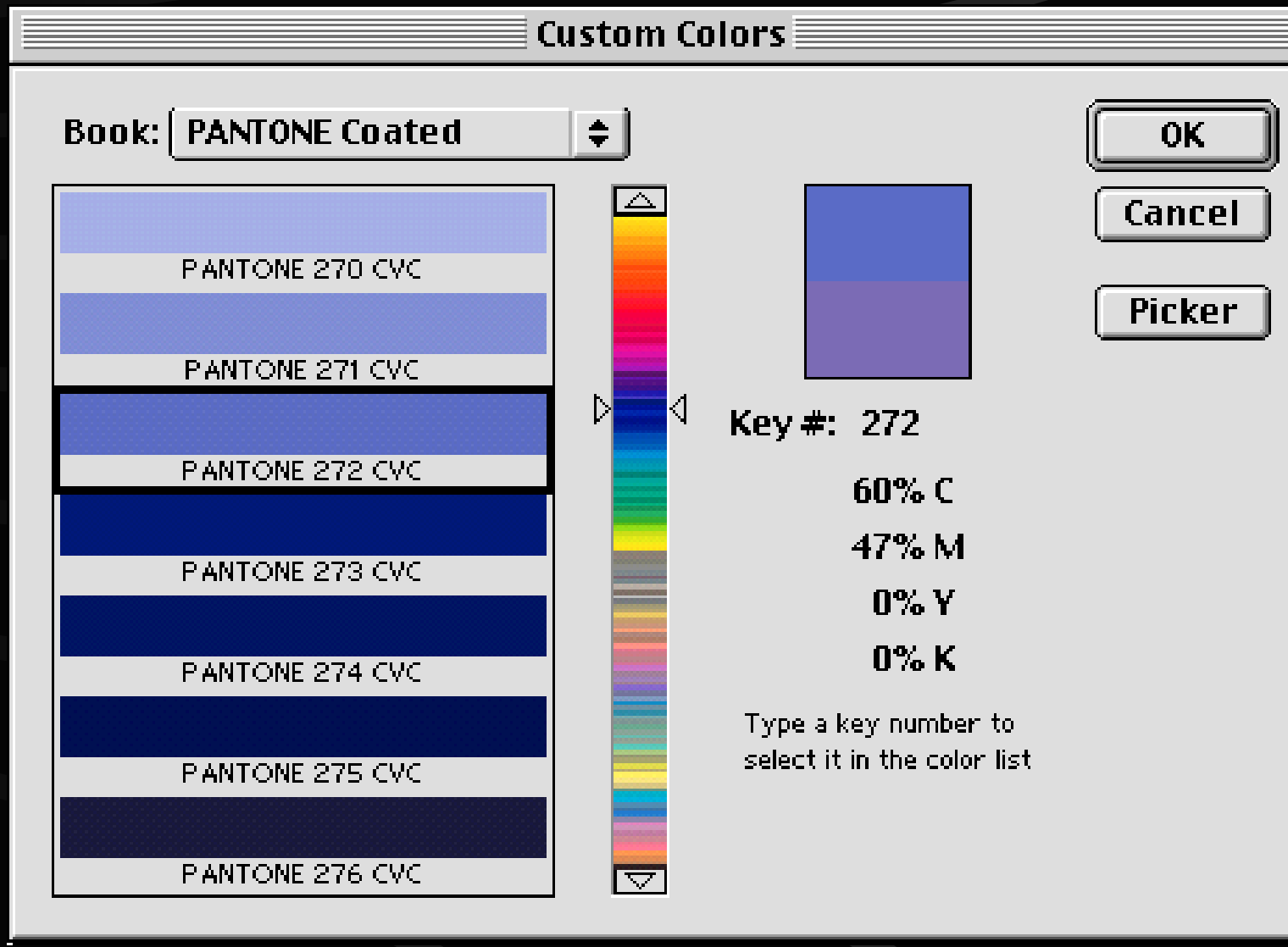

CMYK Picker
Crayon Picker
HLS Picker
HSV Picker
Choose a highlight color:
120°
60°
180°
0°
240°
300°
0
50
100
Original:
New:
Hue Angle:
60
°
Saturation:
100
%
Value:
100
%
Cancel
OK

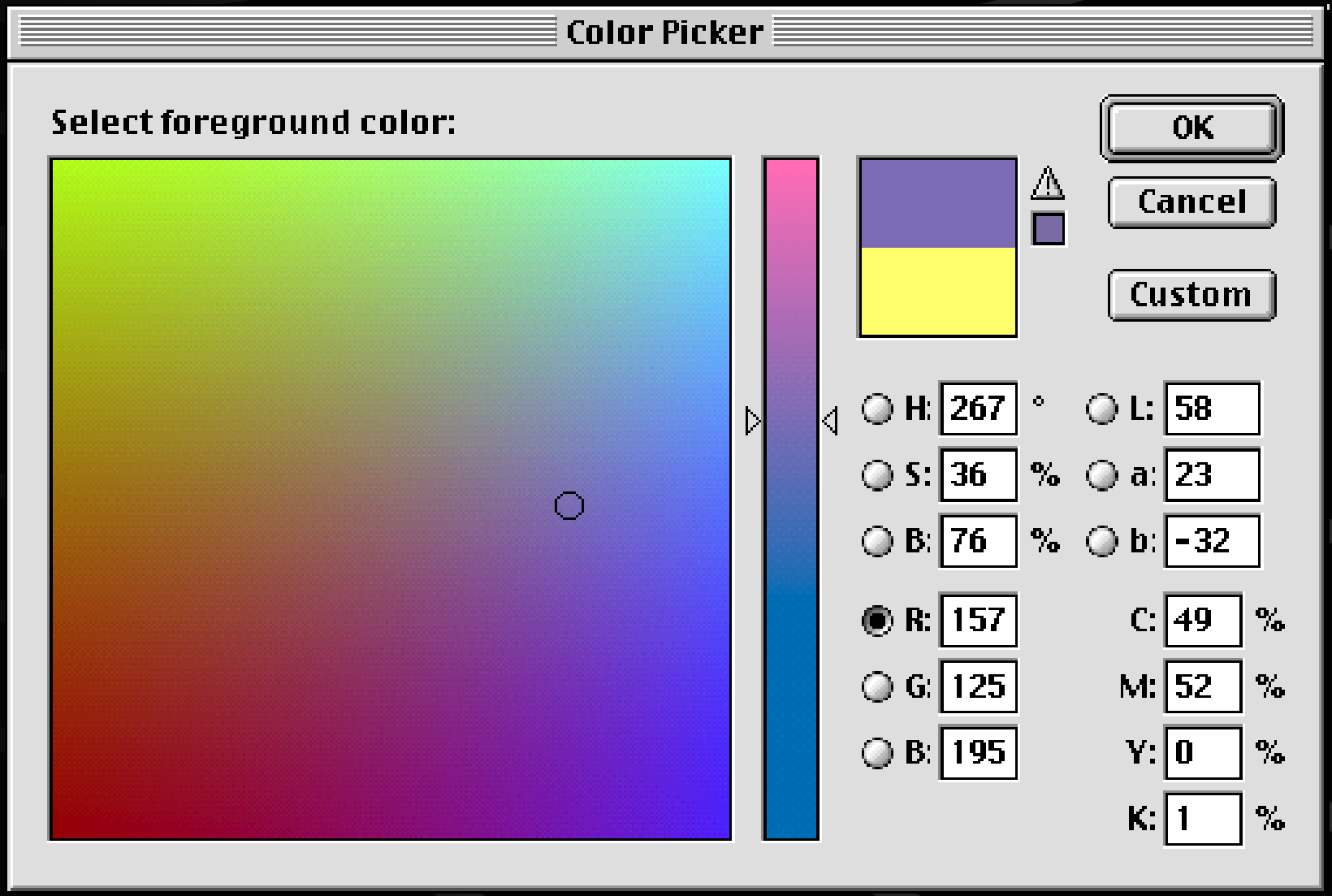

CMYK Picker
Crayon Picker
HLS Picker
HSV Picker
Choose a highlight color:
120°
60°
180°
0°
240°
300°
0
50
100
Original:
New:
Hue Angle:
60
°
Saturation:
100
%
Lightness:
50
%
Cancel
OK

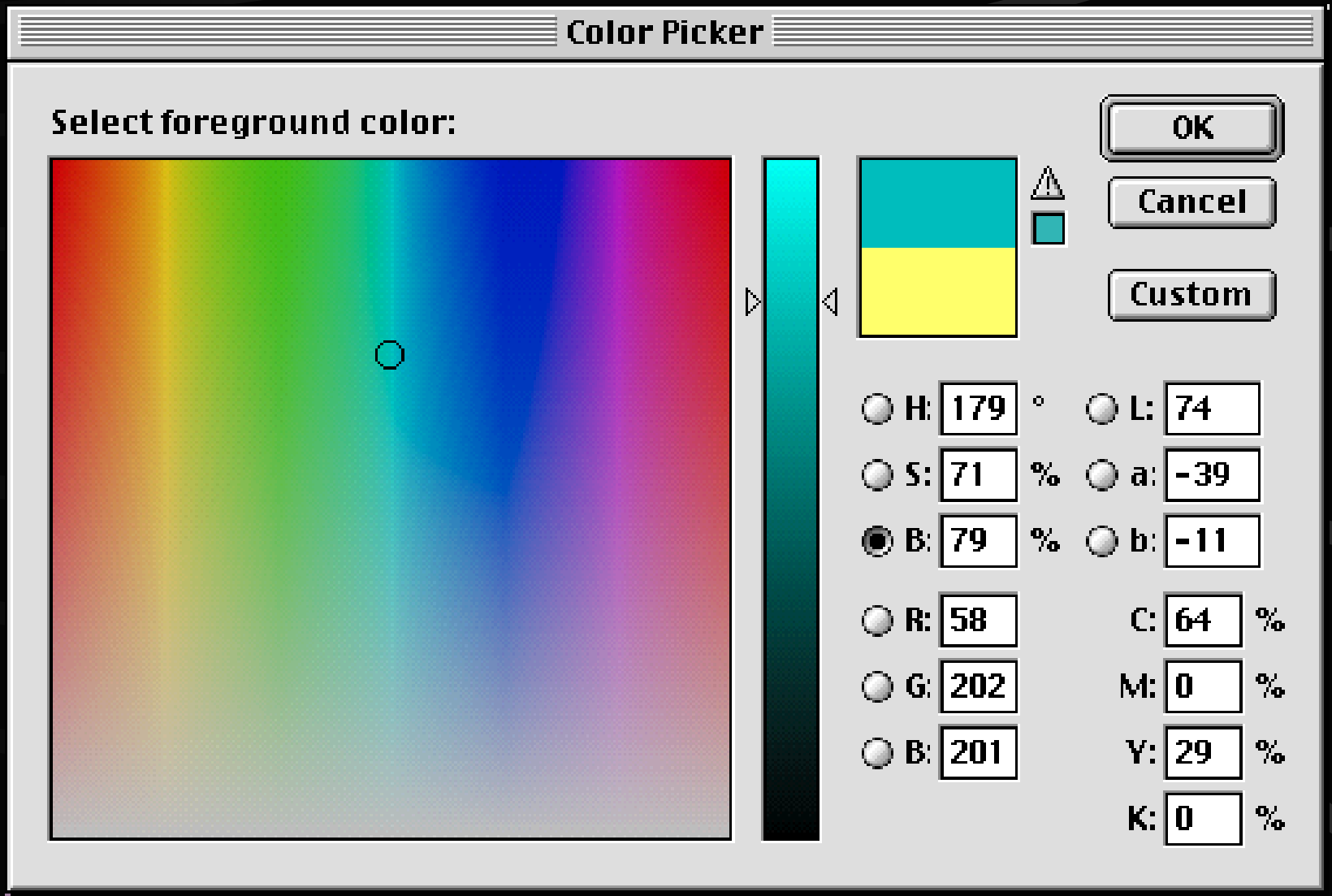

CMYK Picker
Crayon Picker
HLS Picker
HSV Picker
Choose a highlight color:
Original:
New:
Cyan:
100
%
0
25
50
75
100
Magenta:
100
%
0
25
50
75
100
Yellow:
100
%
0
25
50
75
100
Black:
0
%
0
25
50
75
100
Cancel
OK


Color Picker
Select foreground color:
OK
Cancel
Custom
H: 59 °
S: 100 %
B: 100 %
R: 255
G: 252
B: 0
L: 97
a: -14
b: 93
C: 0 %
M: 9 %
Y: 93 %
K: 0 %
Color Picker
Select foreground color:
OK
Cancel
Custom
H: 59 °
S: 92 %
B: 93 %
R: 238
G: 236
B: 18
L: 91
a: -14
b: 87
C: 5 %
M: 2 %
Y: 92 %
K: 0 %

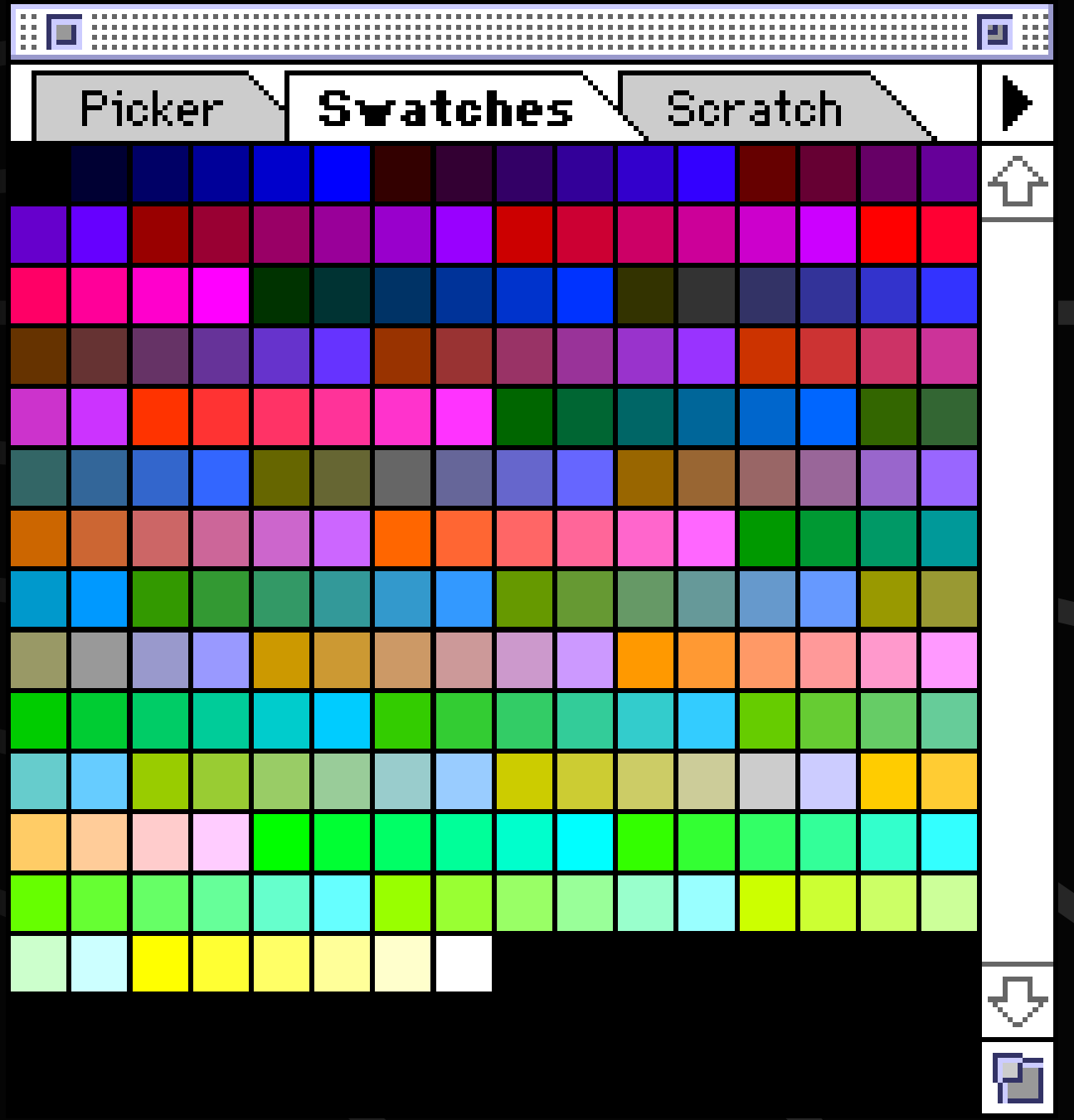

Color Picker
Select foreground color:
OK
Cancel
Custom
H: 301 °
S: 74 %
B: 90 %
R: 229
G: 60
B: 227
L: 57
a: 77
b: -50
C: 42 %
M: 66 %
Y: 0 %
K: 1 %

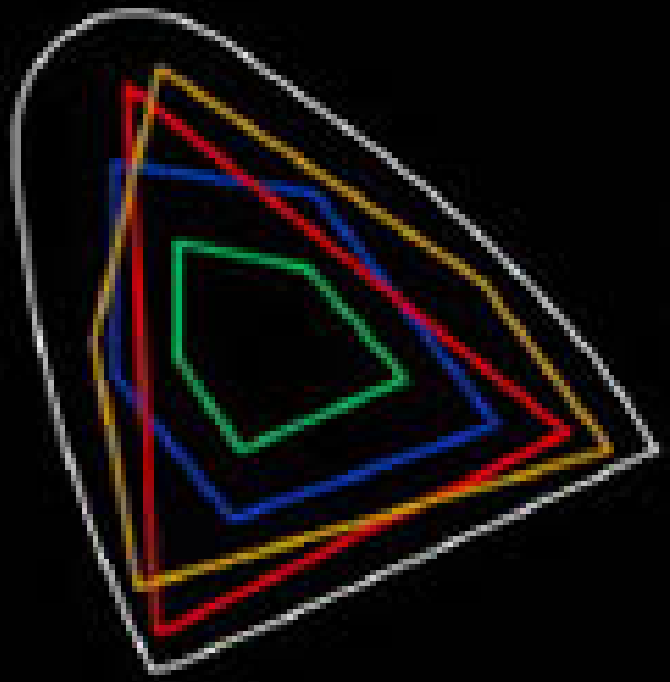

Custom Colors
Book:
PANTONE Coated
OK
Cancel
Picker
PANTONE 270 CVC
PANTONE 271 CVC
PANTONE 272 CVC
PANTONE 273 CVC
PANTONE 274 CVC
PANTONE 275 CVC
PANTONE 276 CVC
Key #: 272
60% C
47% M
0% Y
0% K
Type a key number to
select it in the color list


Color Picker
Select foreground color:
OK
Cancel
Custom
H: 267 °
S: 36 %
B: 76 %
R: 157
G: 125
B: 195
L: 58
a: 23
b: -32
C: 49 %
M: 52 %
Y: 0 %
K: 1 %


Color Picker
Select foreground color:
OK
Cancel
Custom
H: 179 °
S: 71 %
B: 79 %
R: 58
G: 202
B: 201
L: 74
a: -39
b: -11
C: 64 %
M: 0 %
Y: 29 %
K: 0 %

- HTML “color safe” palette.
- 216 cross platform browser colors.





Color visible to the human eye

Color film

Color monitor

Printer offset press on coated paper

Offset press on newsprint