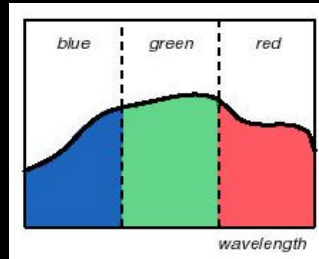# Color Reproduction

Principles

- ❑ Capture image as "RGB" components
- ❑ Reproduce each component
- ❑ Metameric match to the "original"

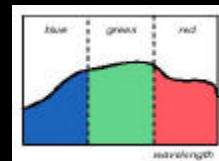The Reproduction of Colour
R.W.G Hunt

Image Capture

Process image through R, G, B filters

- ❑ Filters act as color matching functions
- ❑ Ideally, exact match to human vision
- ❑ Ideal is rarely practical

Encode the R, G, B components

- ❑ Primaries plus linearity
- ❑ Density, companded intensity
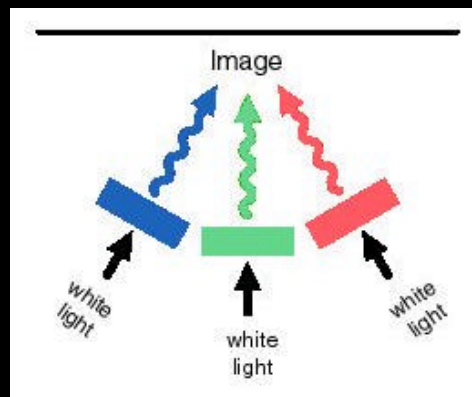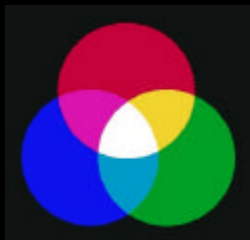- ❑ Digital data will be quantized

Additive Reproduction
Combine red, green, blue lights

Primaries
- red
- green
- blue

Additive Displays

CRT Displays
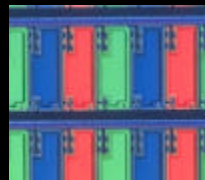- RGB phosphor dots
- Electron gun

LCD Displays
- Backlight
- RGB filters

Video Projectors
- RGB separations
- Three lights

Television/Video

Camera captures separations
- Encode as standard RGB
- Encode as companded intensity (gamma)

Reproduced on RGB display
- Map RGB input to RGB pixels
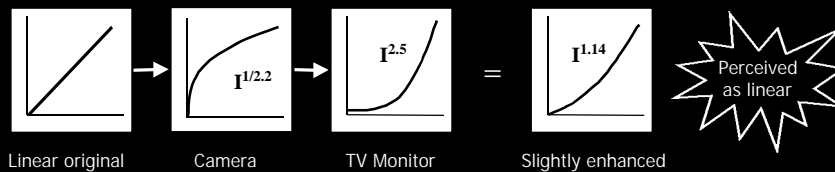- Decode linearity to give correct appearance

Digital photography

Digital Video
Charles Poynton

Television Pipeline

RGB Encoding

Spectral lights and surfaces → RGB camera → RGB monitor = Phosphor emissions

Perceived as original colors

Intensity Encoding (ITF)

$I^{1/2.2}$ → $I^{2.5}$ = $I^{1.14}$

Perceived as linear

Linear original   Camera   TV Monitor   Slightly enhanced
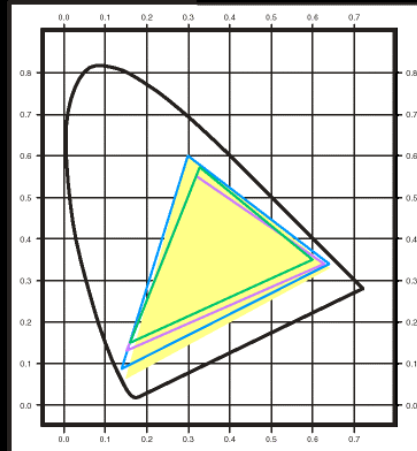
Monitors vs. LCDs

Monitors are similar
- ITU-R BT.707
- Yellow triangle

LCD's still evolving
- Filters, backlights
- Colored triangles

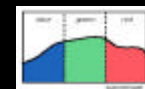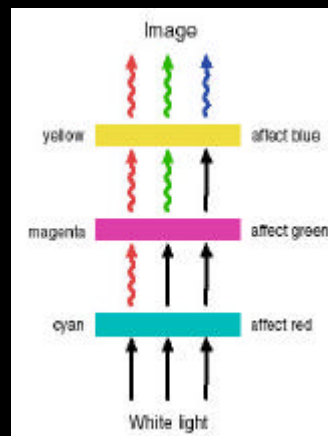RGB_1 to RGB_2
- Linear transform
- 3x3 matrix

Data courtesy of Tom Fiske

Subtractive Reproduction
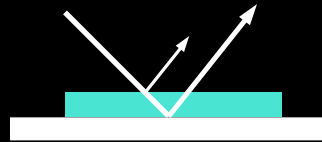## Filter white light to modulate R, G, B
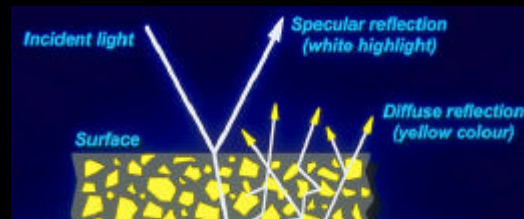
Primaries
- cyan
- magenta
- yellow

Reflection Prints

Subtractive process
- Layers of colors
- Ambient light
- Reflects off paper

Problems
- Contrast
- Saturation

Incident light

Specular reflection
(white highlight)

Diffuse reflection
(yellow colour)
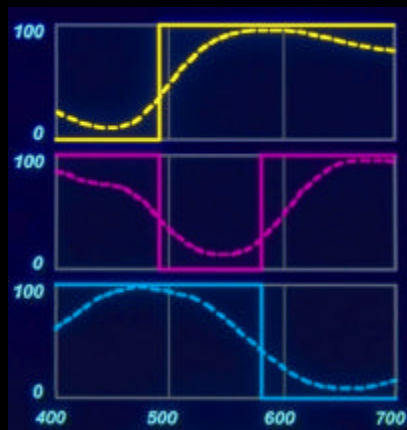
Surface

Ideal vs. Real CMY

Ideal filters
- Solid lines
- Block filters

Real filters
- Impurities
- Cross-talk

Result
- Non-linear
- Dark, muddy colors

Subtractive Media

Photographic slides and prints
- ❏ Film/emulsion layers encode separations
- ❏ Density encodes grayscale

Ink on paper printing technologies
- ❏ Standard CMY plus black (K)
- ❏ Patterns encode grayscale
- ❏ Halftone/dither, black algorithms

IS&T publications

CMYK Separations
red = magenta + yellow
green = yellow + cyan
blue = cyan + magenta
black for contrast

Issues

Specifics of media
- Each has its own science and art
- Make it work in its market

Limited gamut
- Brightness compression
- Color compression

Gamut demo

Digital Media

Integrating traditional media
- Scanners, video cameras
- Monitors, video recorders
- Printers, film recorders

All computer controlled

How do we manage color across them?

Cross-media Color

Device-independent color
- ❑ Based on color psychophysics
- ❑ CIE standards and extensions

Color management systems
- ❑ Standard color specification
- ❑ Calibrated devices (media)
- ❑ Make colors/images "look the same"

Digital Color Management
Giorgianni & Madden