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# Color Processing

15-463: Rendering and Image  
Processing  
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*...with most figures shamelessly stolen  
from Forsyth & Ponce and Gonzalez & Woods*

## Today

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A Touch of Color

## Causes of color

The sensation of color is caused by the brain.

Some ways to get this sensation include:

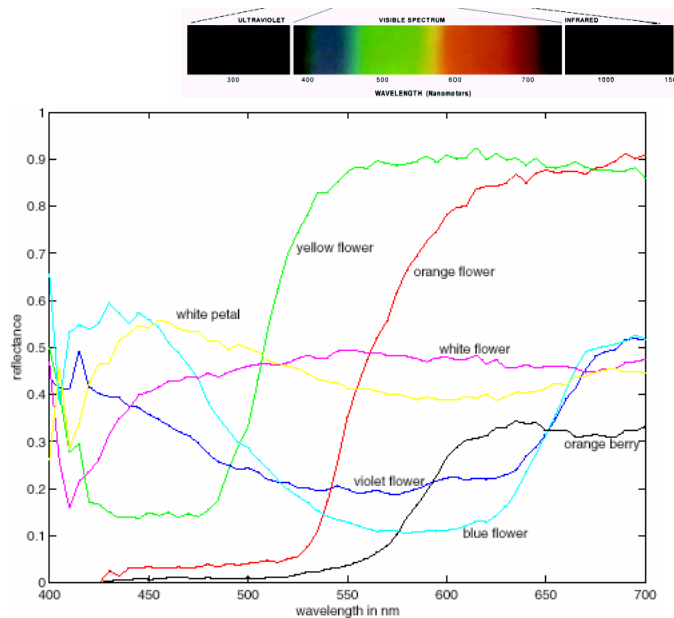
- Pressure on the eyelids
- Dreaming, hallucinations, etc.

Main way to get it is the response of the visual system to the **presence of light at various wavelengths.**

What causes this?

- Light could be produced in different amounts at different wavelengths (compare the sun and a fluorescent light bulb).
- Light could be differentially reflected (e.g. some pigments).
- It could be differentially refracted - (e.g. Newton's prism)
- Wavelength dependent specular reflection - e.g. shiny copper penny (actually most metals).
- Fluorescence - light at invisible wavelengths is absorbed and reemitted at visible wavelengths.

## Some Measured Spectral Albedoes



Spectral albedoes for several different leaves, with color names attached. Notice that different colours typically have different spectral albedo, but that different spectral albedoes may result in the same perceived color (compare the two whites). Spectral albedoes are typically quite smooth functions. Measurements by E.Koivisto.

## Why 3?

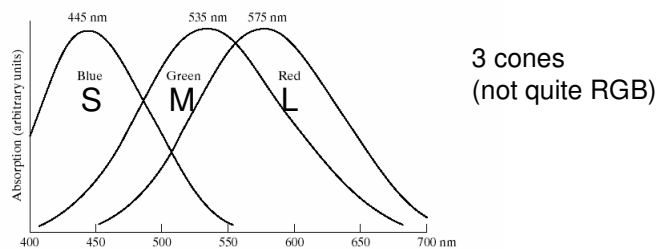
How should one represent spectral albedo?

- Distribution of light at various wavelengths (a histogram)

Then why do we represent color with a single R,G,B triplet?

No physical reason...

...but psychophysical:



Why is M cone not midway but closer to L?

## It's all in your head

So, color is psychological

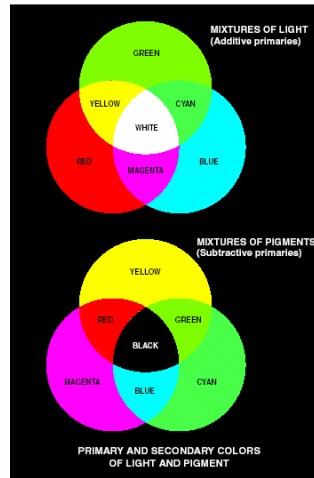
- Most people have the same cones, but there are some people who don't – the sky might not look blue to them (although they will call it "blue" nonetheless)
- But many people (mostly men) are colorblind, missing 1,2 or 3 cones (can buy cheaper TVs)
- Primary colors (R,G,B) related to cones, not physics

Describing Color

- Brightness: overall intensity
- Hue: dominant wavelength
- Saturation: how much other stuff mixed in with hue
- Hue + Saturation = Chromaticity

Almost like: sum, mean, and std. deviation...

## Additive and Subtractive Color

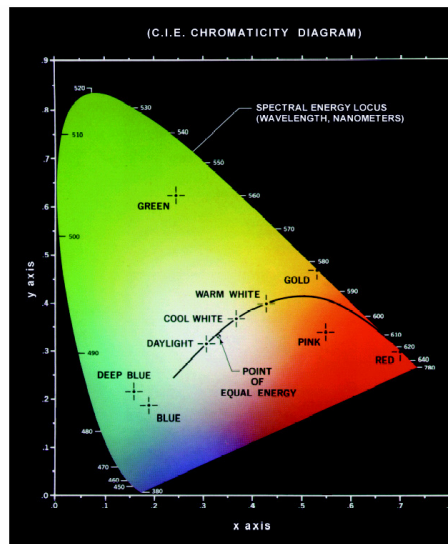


a  
b

**FIGURE 6.4** Primary and secondary colors of light and pigments. (Courtesy of the General Electric Co., Lamp Business Division.)

## CIE perceptual space

**FIGURE 6.5**  
Chromaticity  
diagram.  
(Courtesy of the  
General Electric  
Co., Lamp  
Business  
Division.)



Which colors can RGB monitor display?

## Monitor Gamut

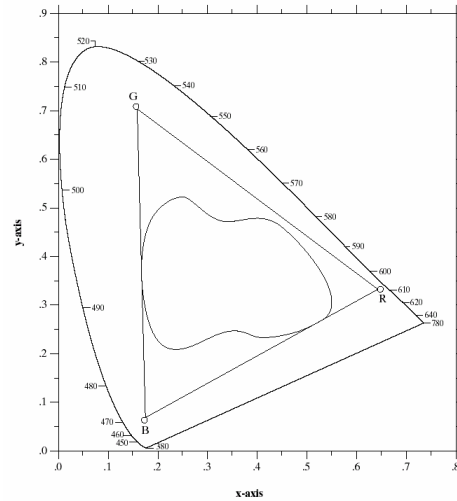


FIGURE 6.6 Typical color gamut of color monitors (triangle) and color printing devices (irregular region).

## RGB color space

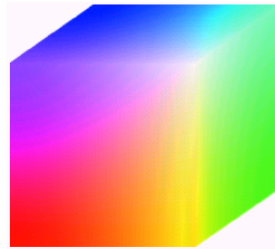
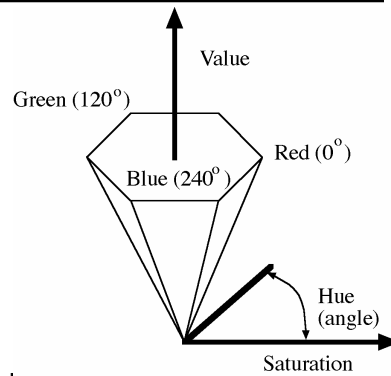
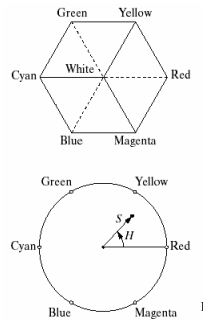


FIGURE 6.8 RGB 24-bit color cube.

### RGB cube

- Easy for devices
- But not perceptual
- Where do the grays live?
- Where is hue and saturation?

# HSV



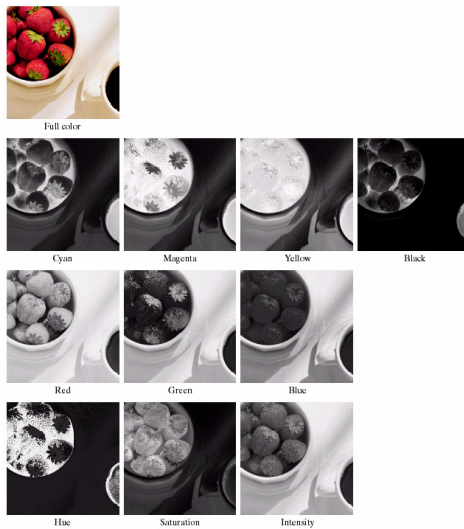
## Hue, Saturation, Value (Intensity)

- RGB cube on its vertex

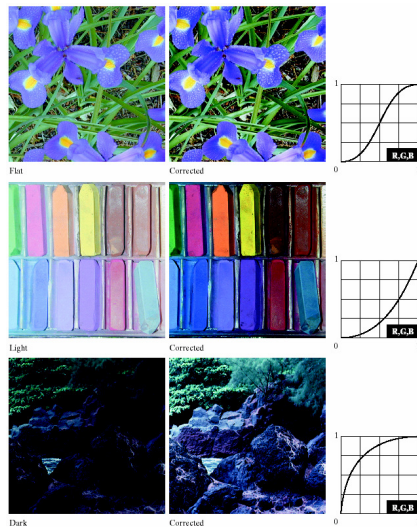
Decouples the three components (a bit)

Use `rgb2hsv()` and `hsv2rgb()` in Matlab

## Color Channels



## Color Point Processing

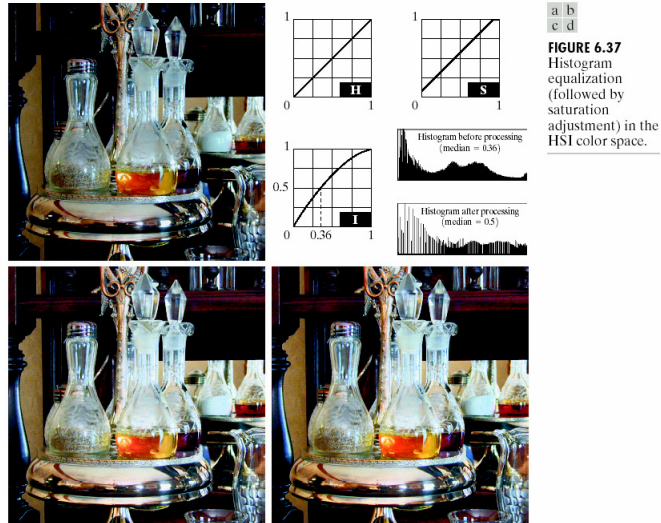


## White Balance



White World / Gray World assumptions

## Histogram Equalization



## Neighborhood Processing (filtering)

Q: What happens if I reshuffle all pixels within the image?



A: It's histogram won't change. No point processing will be affected...

Need spatial information to capture this