Lecture 6 Cogsci 109

Tues. Oct. 10, 2006

Announcements

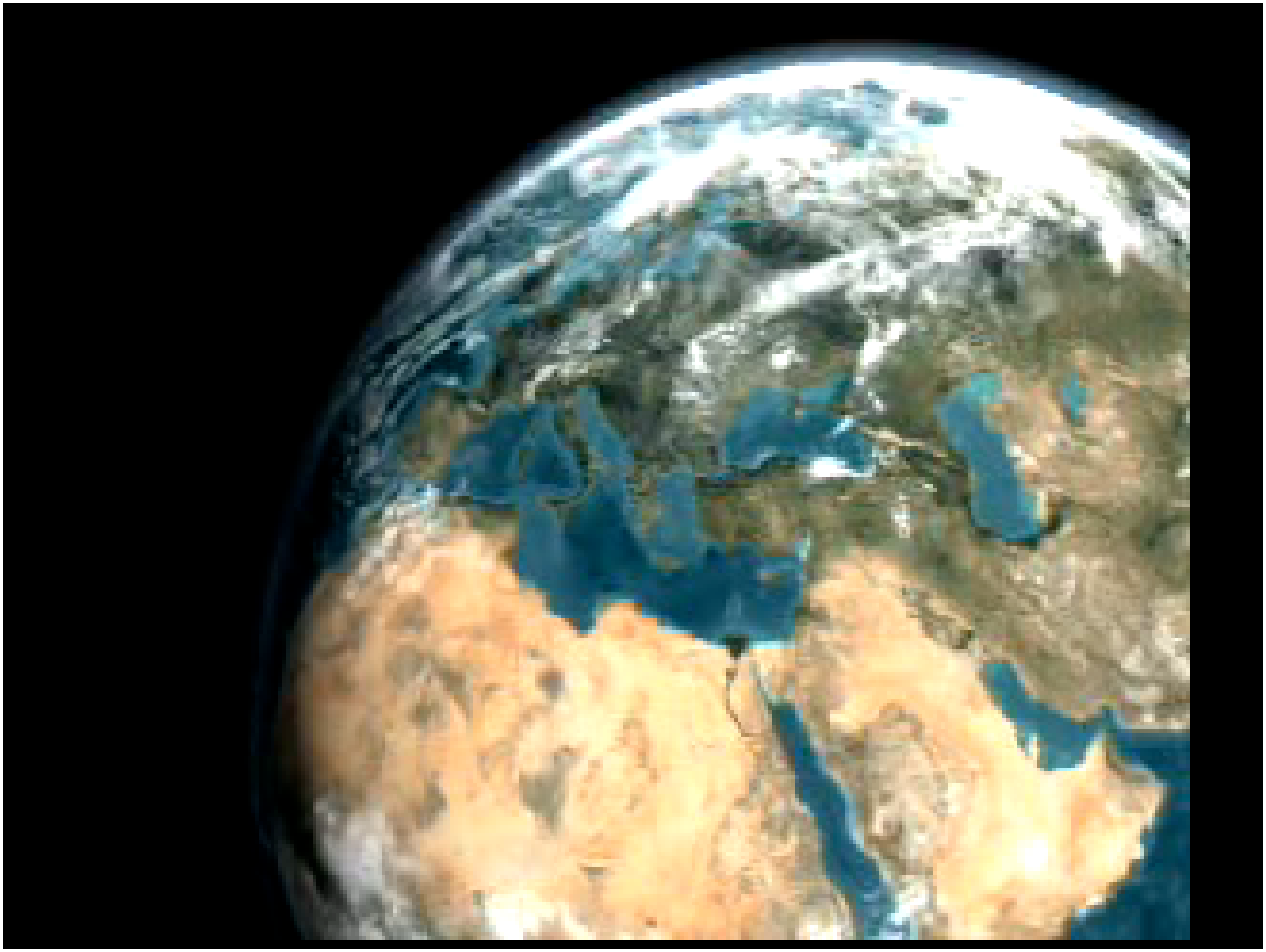
- Homework posted tonight (for real:)
- During sections
- Homework grading

About homework 2

- Data visualization
- 2d and 3d plotting
- Colormaps/false color representation
- Filtering
- Basic analysis techniques (Thursday)

Color theory and visualization

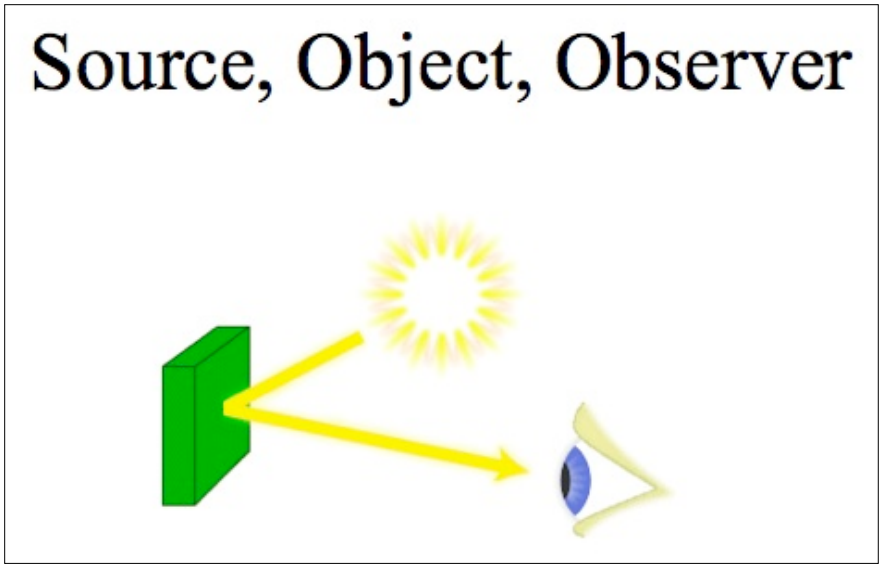
- Why be aware of color theory for modeling and data analysis?
  - Communication
  - Good presentation
    - Examples
  - information encoding/representation
  - Simulation

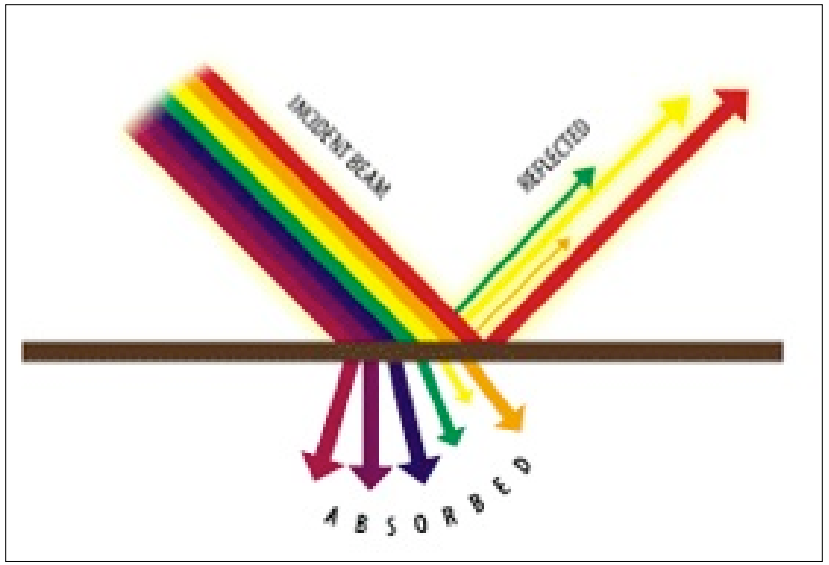


Visualization

- Can communicate information without words, by encoding motion as part of the information
- http://svs.gsfc.nasa.gov/

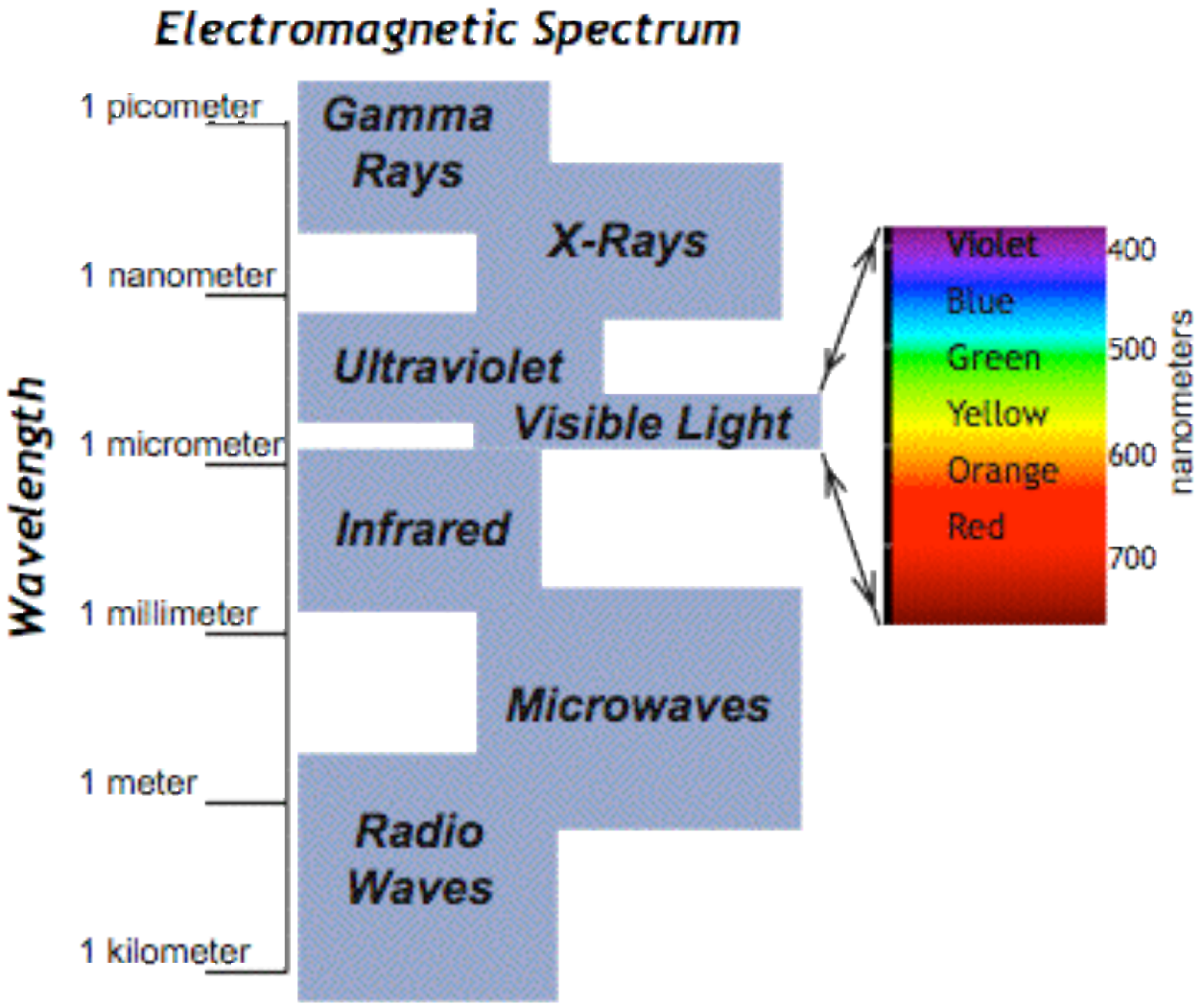
What is color?



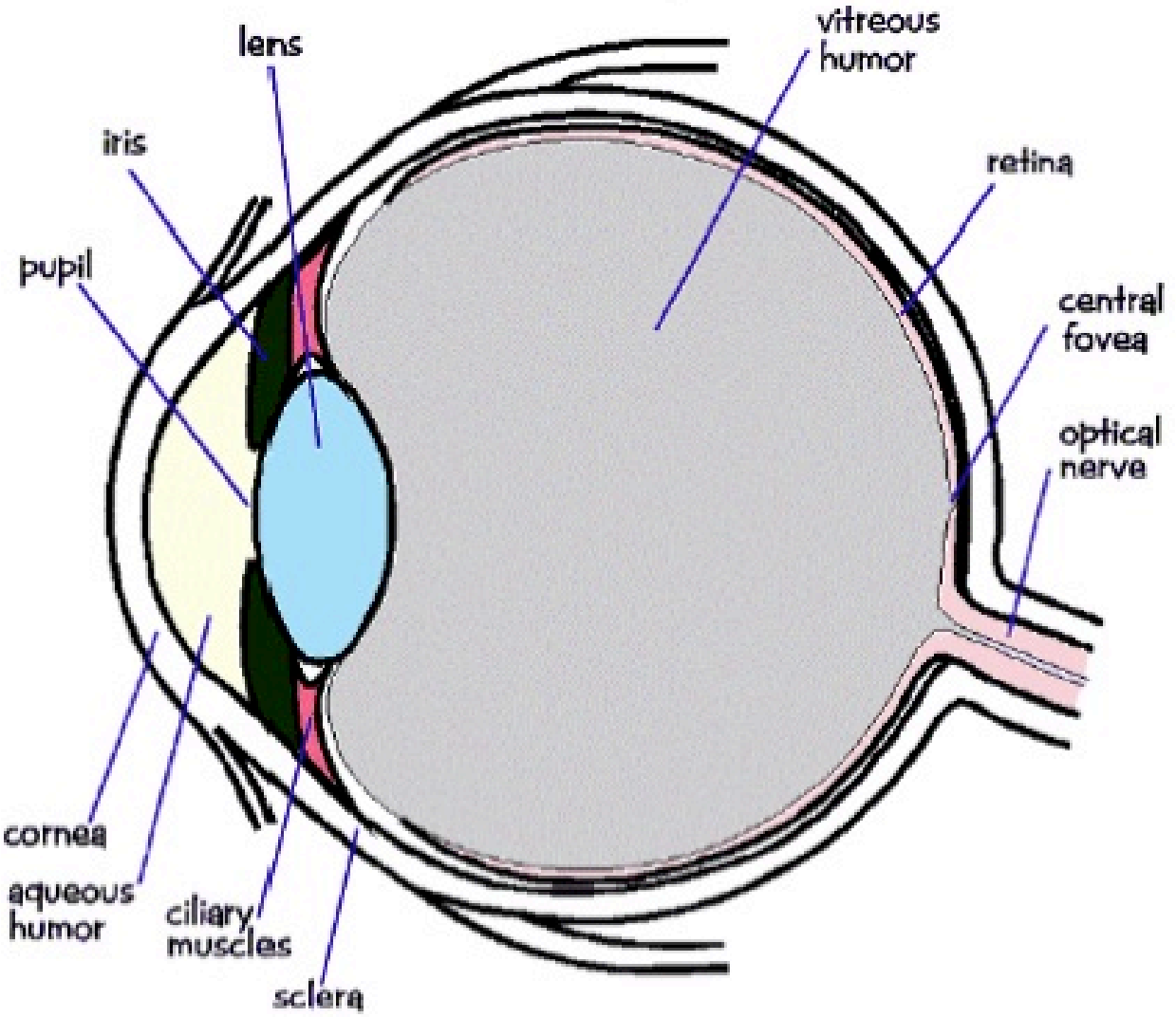


- Reflected light = color of object
- Color is the set of wavelengths of light reflected from an object
- A light source can be a light bulb, the sun, etc or another object

Electromagnetic Spectrum



The Eye

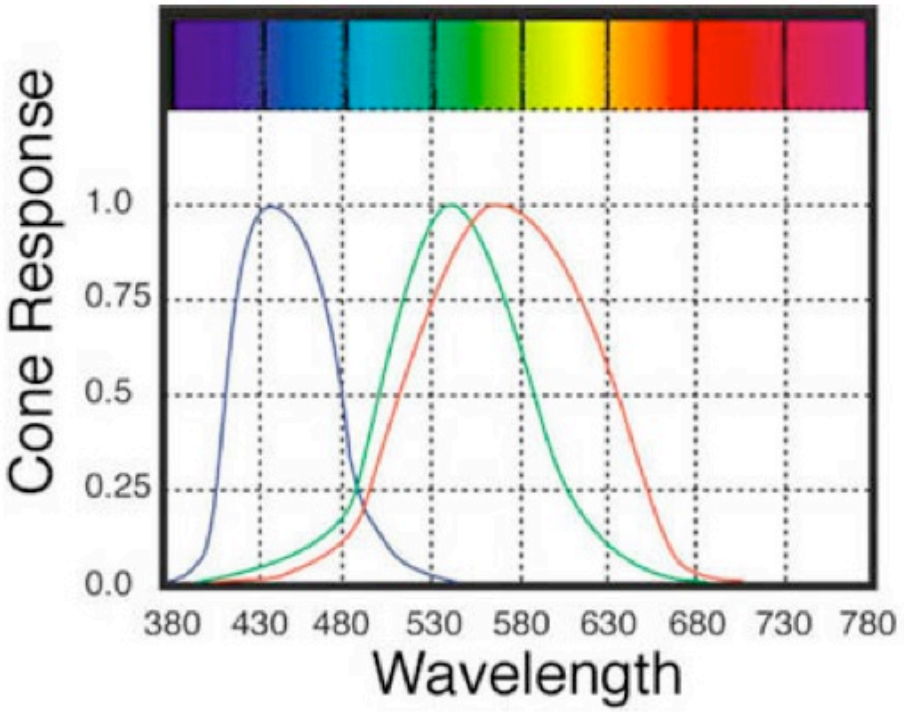

lens
vitreous humor
iris
retina
pupil
central fovea
optical nerve
cornea
aqueous humor
ciliary muscles
sclera

Human perception of color

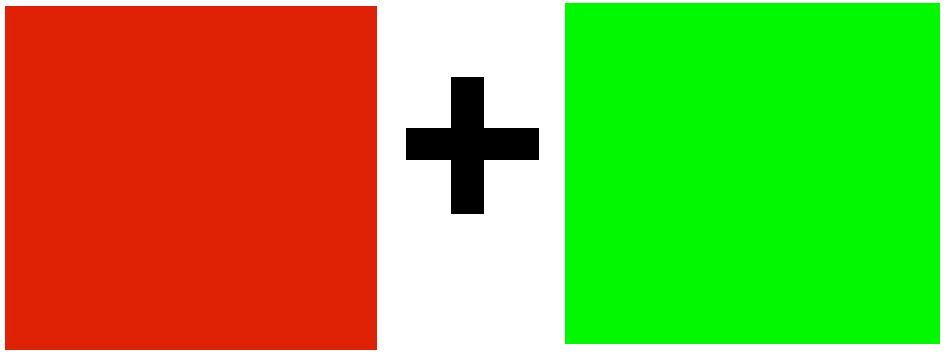
- Color constancy - our visual perception is constantly adjusting to compensate for changing surroundings
- Human color perception is context dependent
  - Ever try to perceive the difference between two colors of clothing in low light?
  - Movie example - Abyss Yellow/green light source, “Cut the blue wire with the white stripe, NOT the black wire with the yellow strip”
    - Side note- how to fix this as the designer of the device? Use one wire with dashes instead of a stripe - “Cut the wire with the dashes.” Person cutting: “Easy. It’s done!”

Rods and Cones

- **Rods** - sensitive to intensity (black and white sensitivity in low light conditions)
- **Cones** - three types, S, M and L corresponding to short, medium and long wavelength light sensitivities

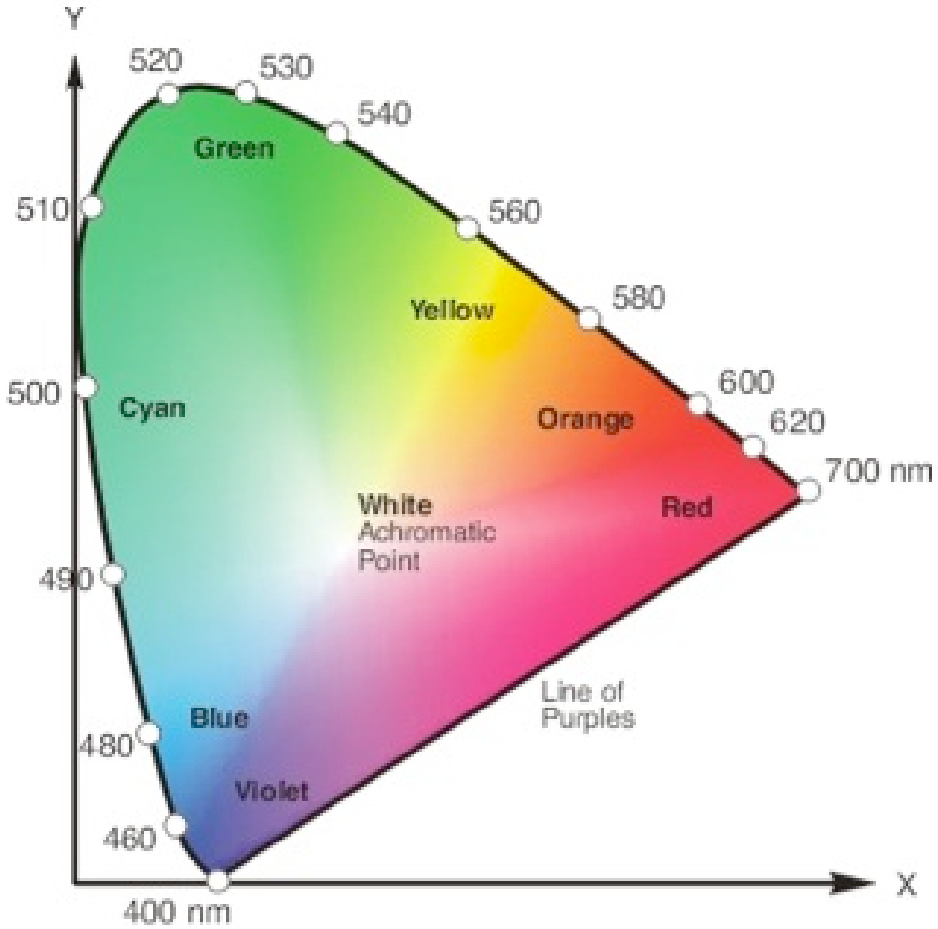


Perceptual example: Afterimages



Perceptual example : Afterimages

CIE Color chromaticity chart

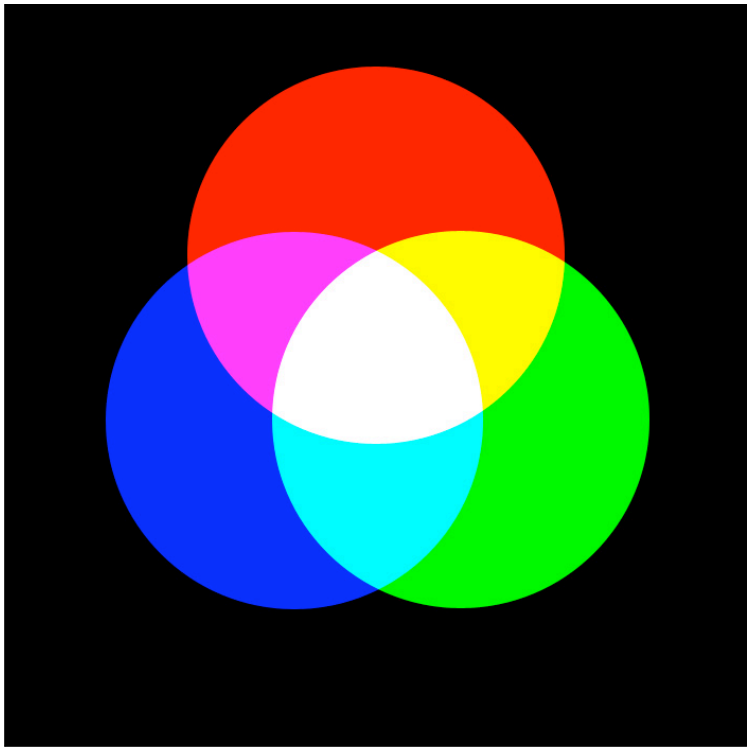


Color spaces

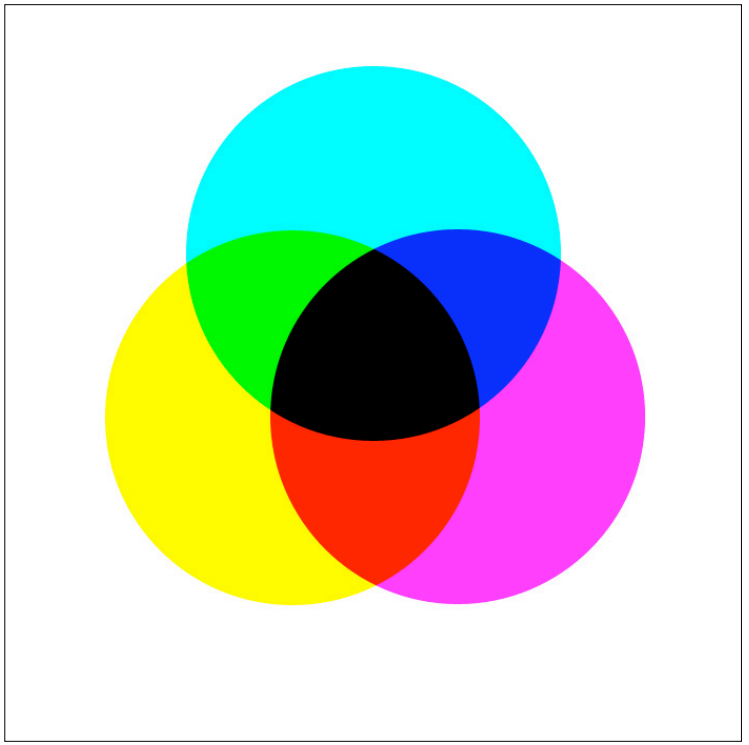
- Now that we have a sense of how we perceive light and color, we can define several *MODELS* of color
- Each color is assigned a coordinate which has three components relative to some color *space model (*ie RGB)
- Some of these color spaces are additive, some are subtractive

Additive vs. subtractive color

Additive (RGB)



Subtractive (CMY)



$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1-R \\ 1-G \\ 1-B \end{bmatrix}$$

Color models

- RGB
  - red-green-blue
  - Additive scheme
- CMY
  - Cyan-magenta-yellow
  - Subtractive scheme
  - Black (CMYK) is typically added to inkjet printers
    - Difficult to make exact black by mixing CMY, requires precision
    - Typically one uses black the most so it makes sense to have a separate ink cartridge for black
- HSV
  - Hue-saturation-value
  - Many feel this is a more natural way to describe color for humans

Example: Bad color matching

- Eeeghh!
- The red and blue are on opposite ends of the visual color spectrum, so we have trouble focusing on both colors simultaneously
- I could have made this worse by adding all equations, but last time too many people passed out!
- AVOID REDS ON BLUES OR BLUES ON REDS

Example: Good color matching

- Ahhh…
- This is much more comfortable for the eyes.
- Choose colors which are based on luminance differences
- generally avoid two fully saturated colors as foreground and background
- Increase contrast by reducing the perceived intensity of either the foreground or background

Bad Contrast

- The most important thing you need to know to get the most out of your education is that you should value the learning and try to make it your own
- The most important thing in this paper is that we did not really find anything important

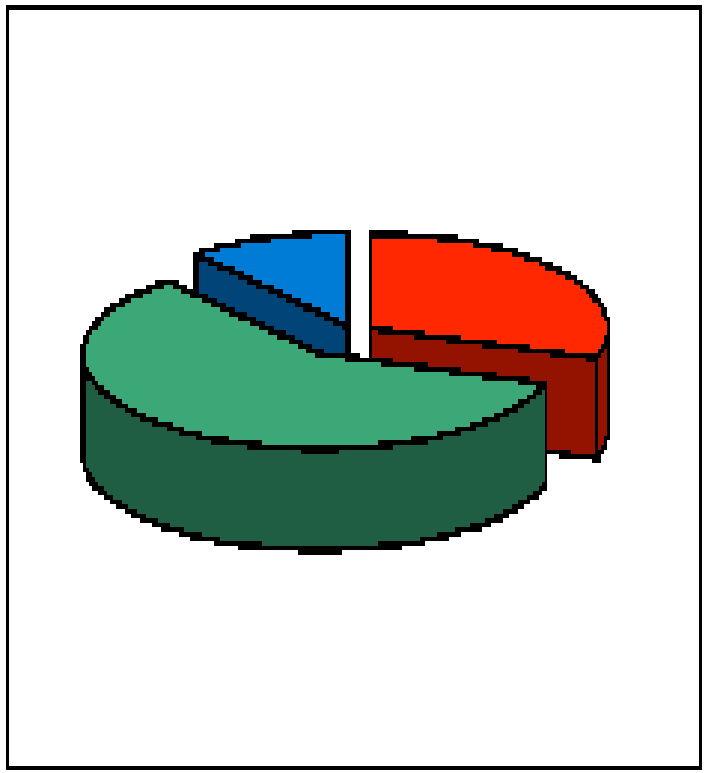
Good Contrast

- Use the luminance equation (or an intuitive understanding of it) to suggest good contrast combinations, also can use the precomputed luminance and contrast tables

Luminance equation

$$Y = .30*Red + .59*Green + .11*Blue$$

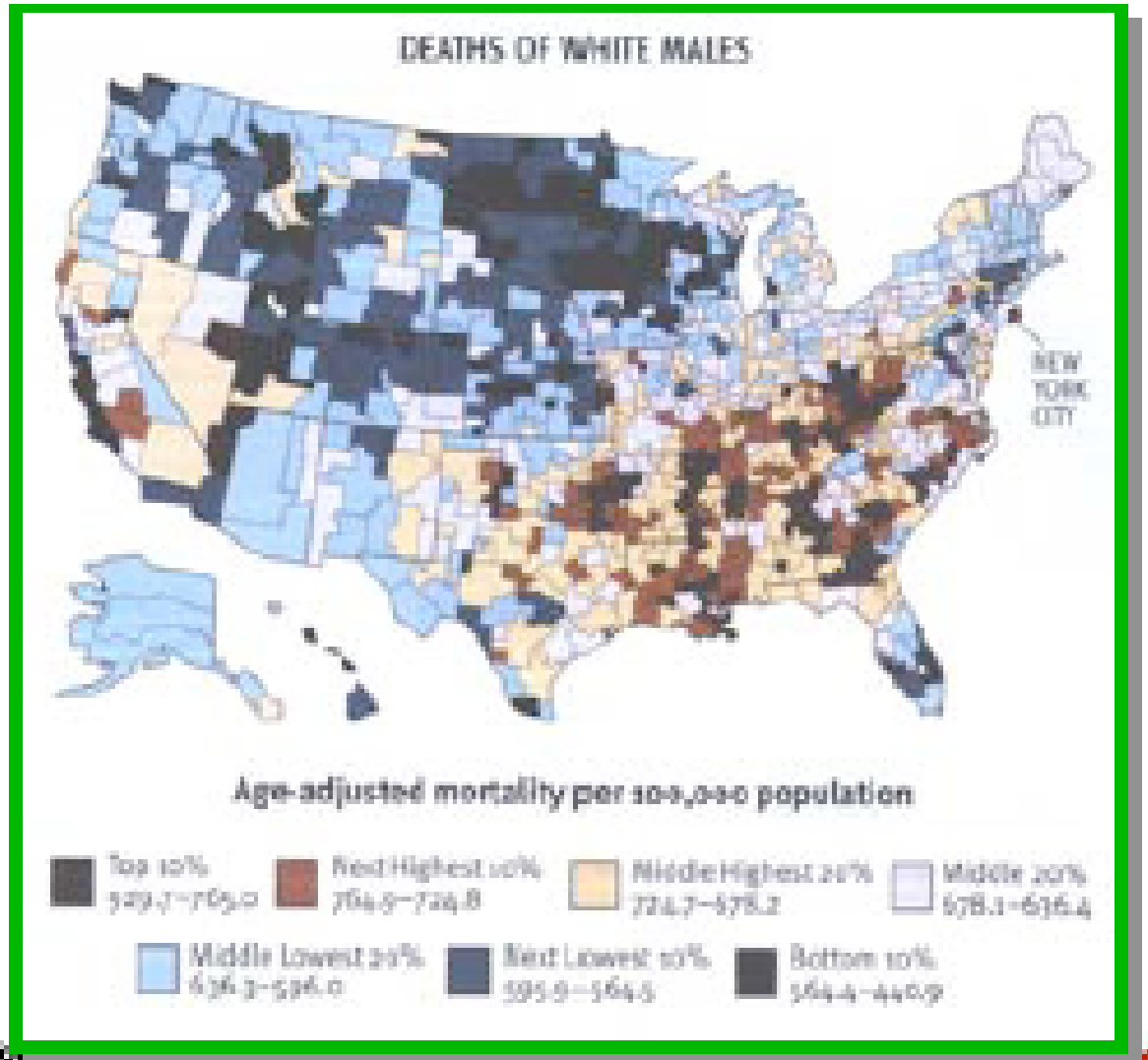
- Perceived intensity due to a color
  - Different contributions of red/green/blue components
  - Empirically determined



≈ Contrast Table

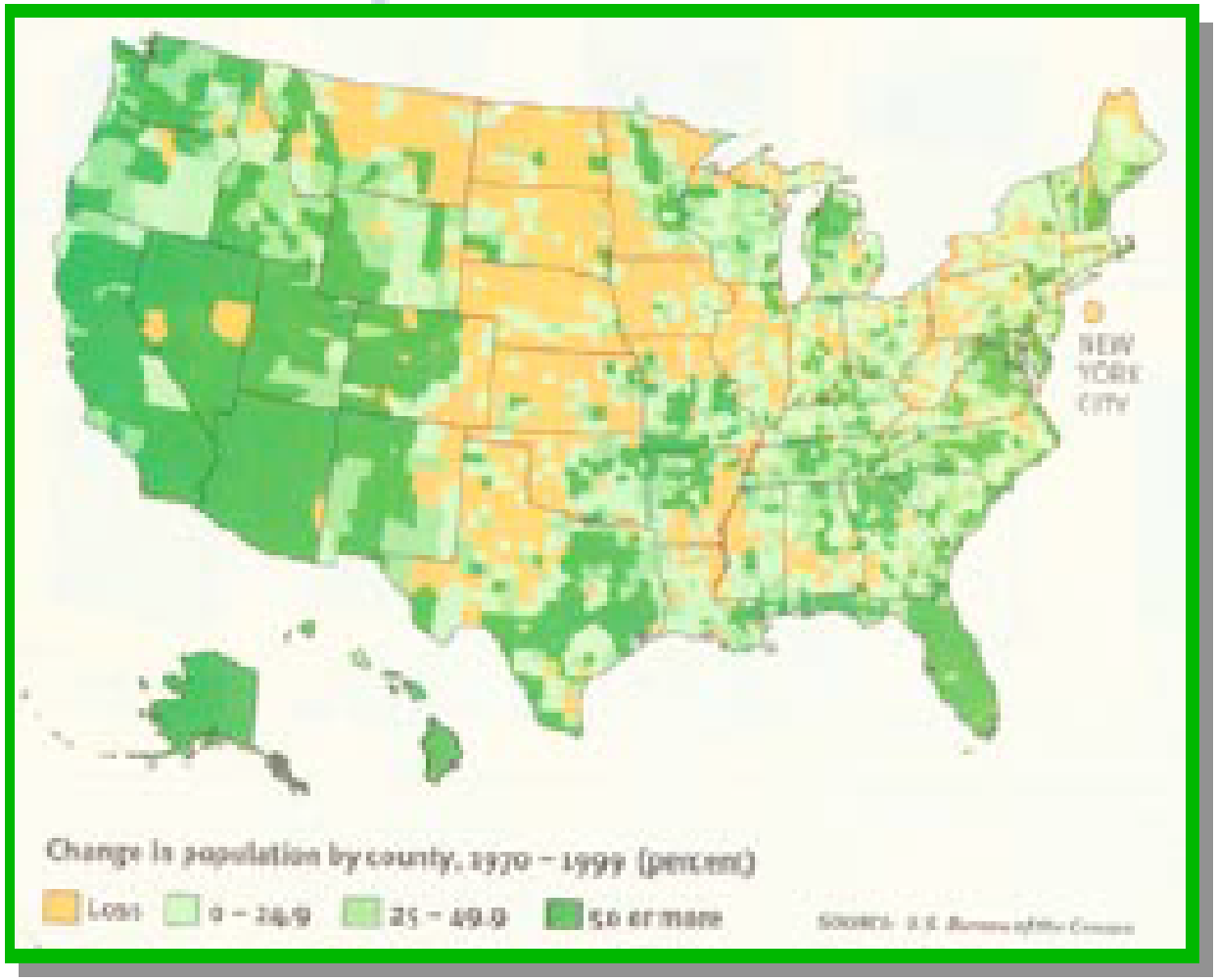
	Black	White	Red	Green	Blue	Cyan	Magenta	Orange	Yellow
Black	0.00	1.00	0.30	0.59	0.11	0.70	0.41	0.60	0.89
White	1.00	0.00	0.70	0.41	0.89	0.30	0.59	0.41	0.11
Red	0.30	0.70	0.00	0.29	0.19	0.40	0.11	0.30	0.59
Green	0.59	0.41	0.29	0.00	0.48	0.11	0.18	0.01	0.30
Blue	0.11	0.89	0.19	0.48	0.00	0.59	0.30	0.49	0.78
Cyan	0.70	0.30	0.40	0.11	0.59	0.00	0.29	0.11	0.19
Magenta	0.41	0.59	0.11	0.18	0.30	0.29	0.00	0.19	0.48
Orange	0.60	0.41	0.30	0.01	0.49	0.11	0.19	0.00	0.30
Yellow	0.89	0.11	0.59	0.30	0.78	0.19	0.48	0.30	0.00

What's Wrong with this Picture?



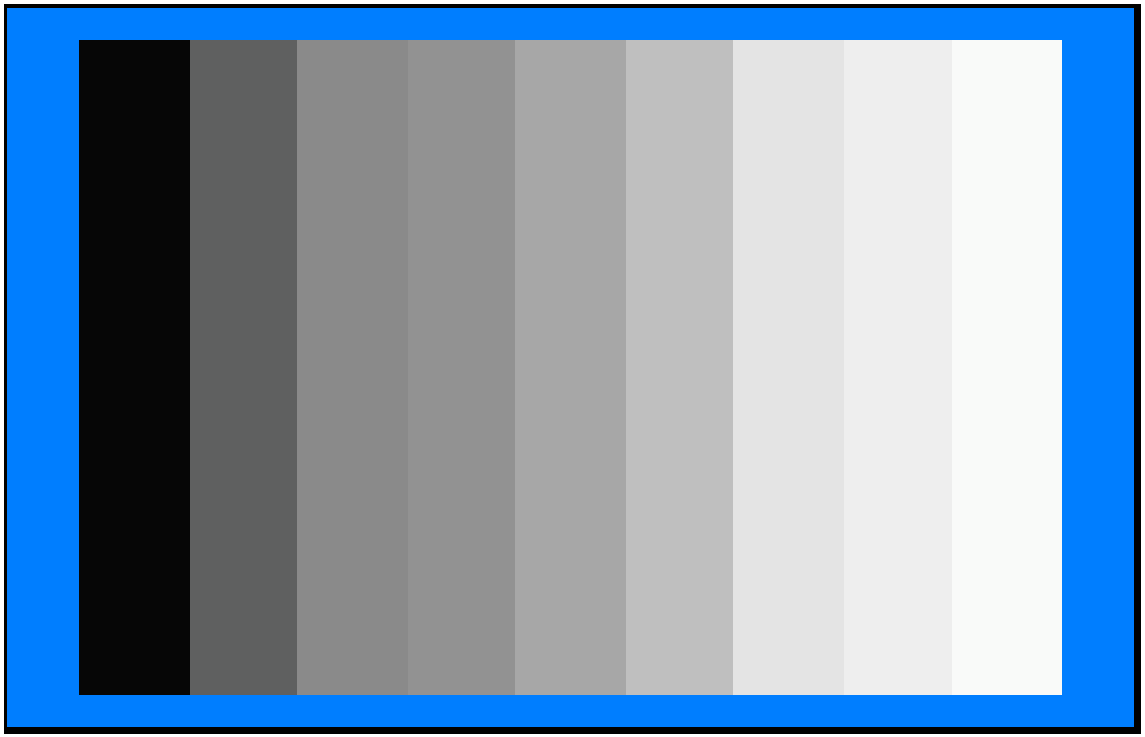
Source:
Scientific American,
June 2000

What's Right with this Picture?

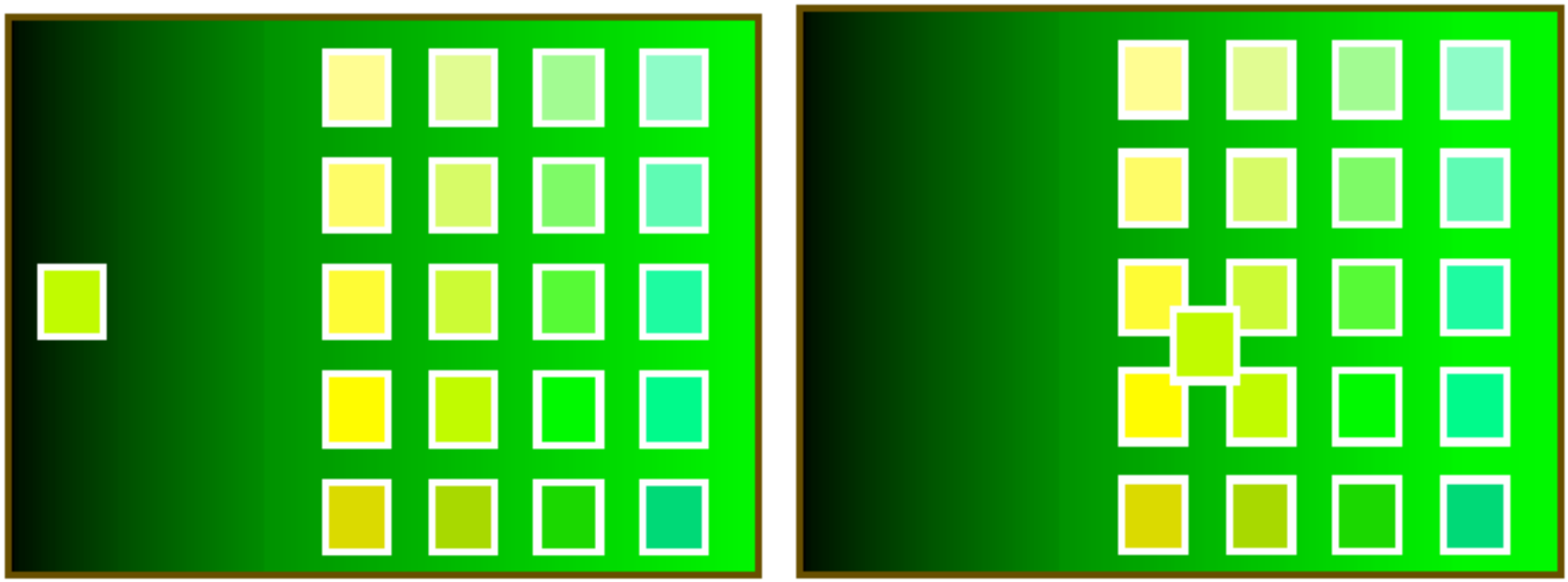


Source:
Scientific American,
August 2000

Beware of Mach Banding

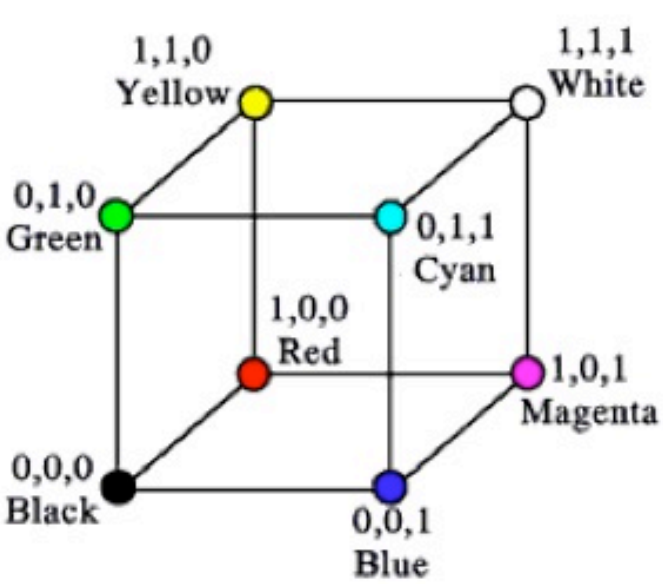


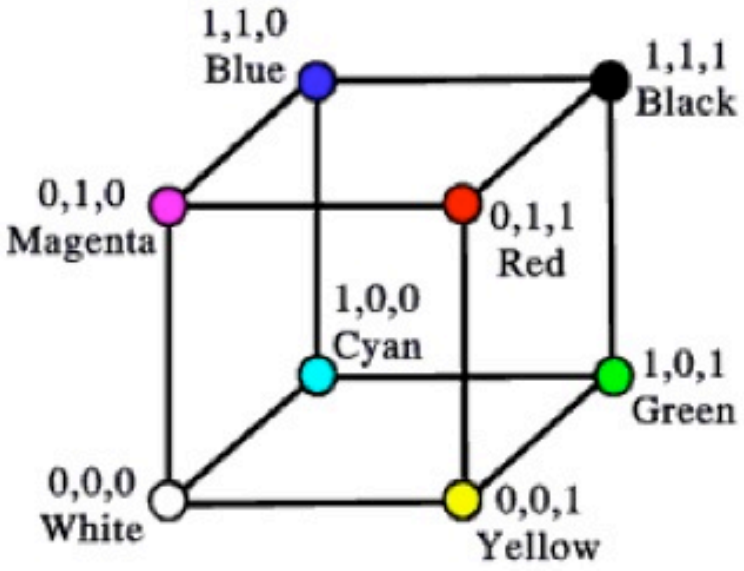
Recall that perceived color intensity is also context-dependent



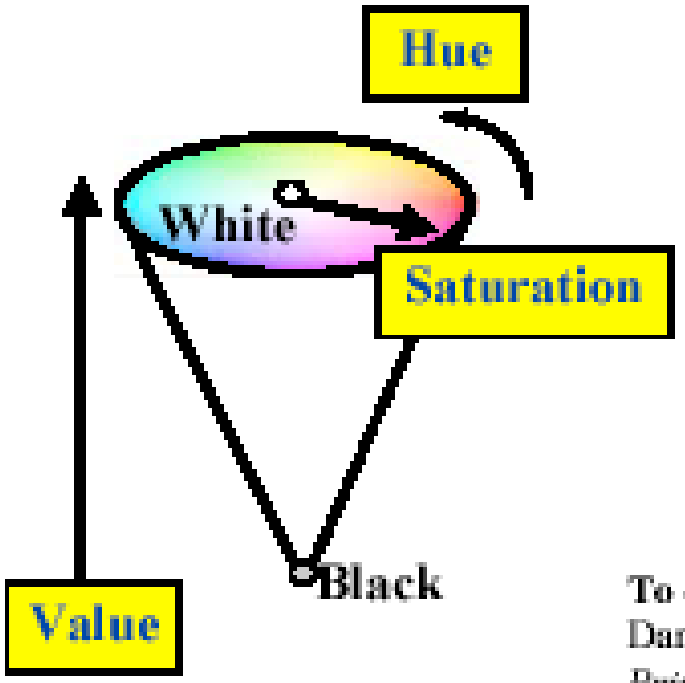
RGB and CMY color cubes

- Map (r,g,b)->(x,y,z) or (c,m,y)->(x,y,z)





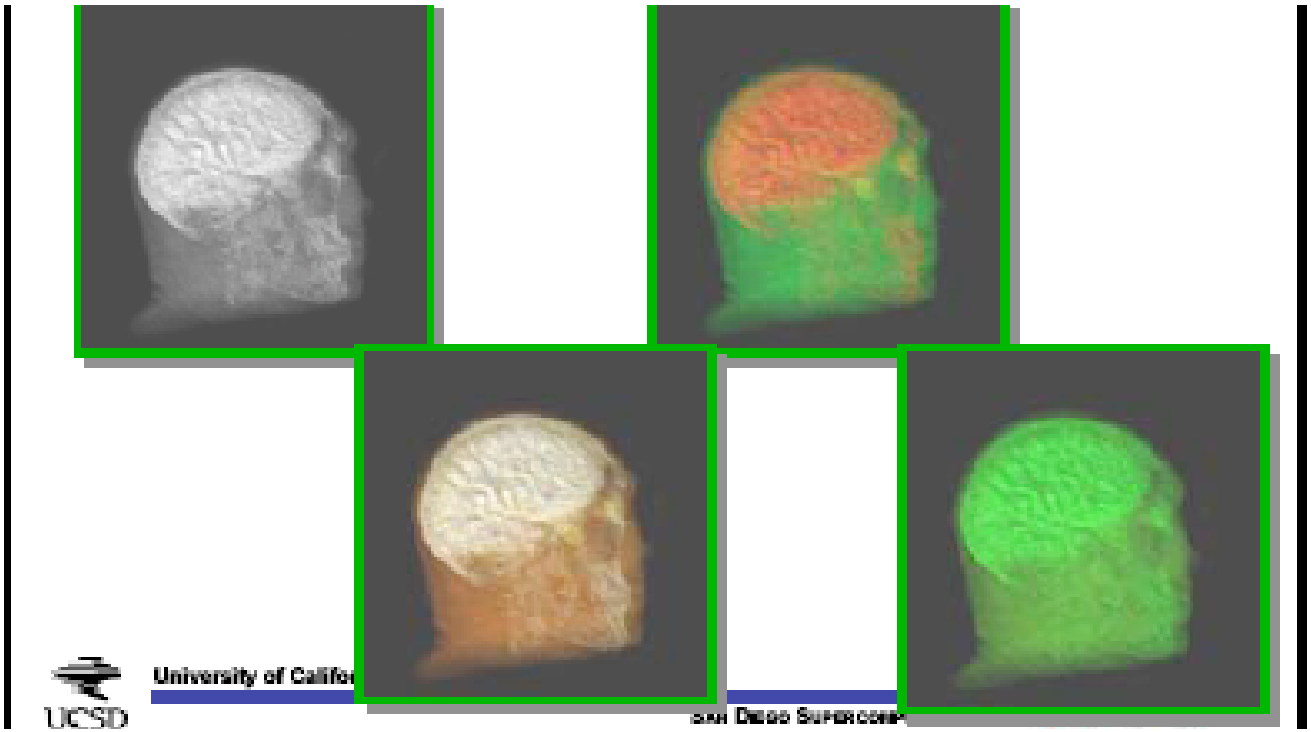
HSV color cone



To convert from HSV to RGB, see: Foley, Van Dam, Feiner, and Hughes, *Computer Graphics: Principles and Practices*, Addison-Wesley, 1990.

False color representation and color maps

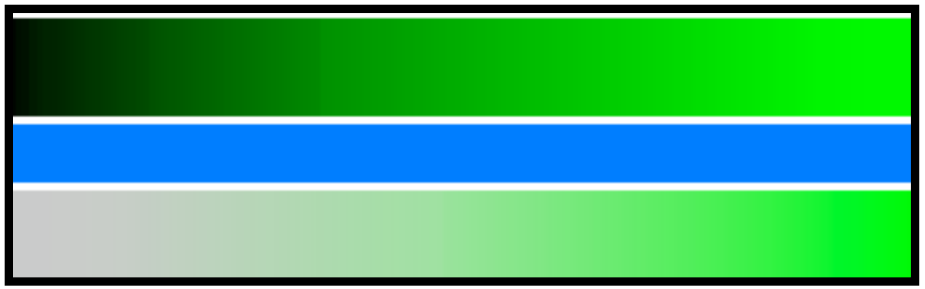
- Map values from any range to a map of colors
  - (ie a matrix of 0-1 range -> white-black)



Typical color maps

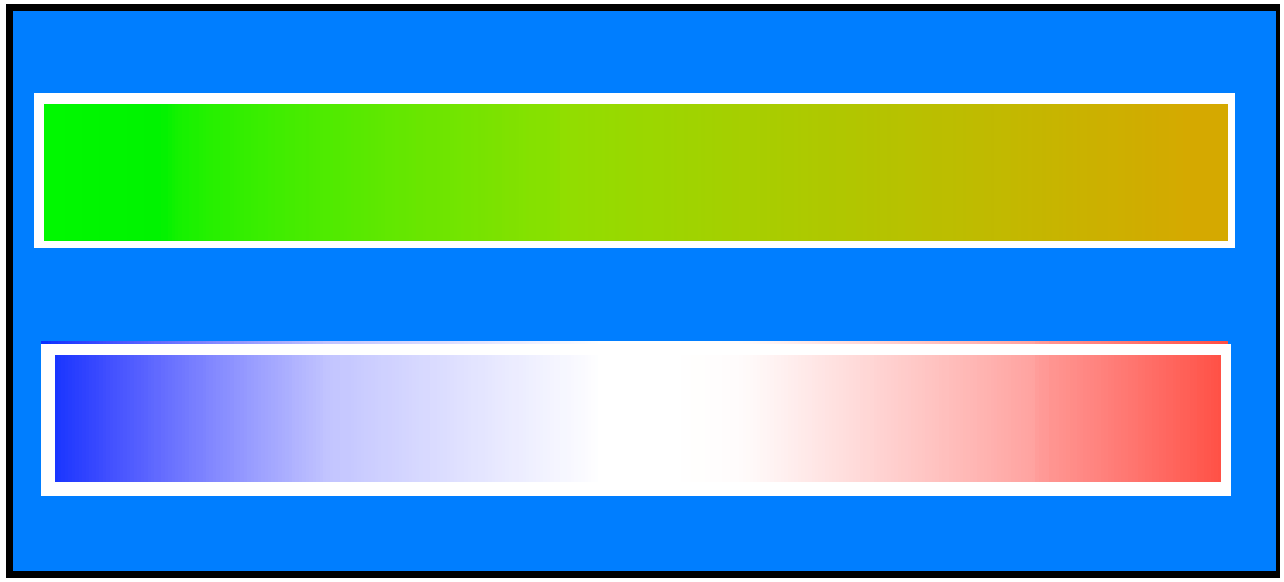
- **Gray scale** – get gray by setting all three color values to the same

- **Intensity and saturation color scales**- we often feel intuitively that black means nothing



More color maps

•**two color interpolation** – blue->red, interesting, bad visually, but strong meaning
•generally you put white in center, otherwise magenta in middle, means nothing



A few more color maps

- **Rainbow color scale** – magenta is not directly in the em spectrum

- **heated object color scale** – intensity increases left -> right

- **color scale contours**

Different display technologies have different limitations

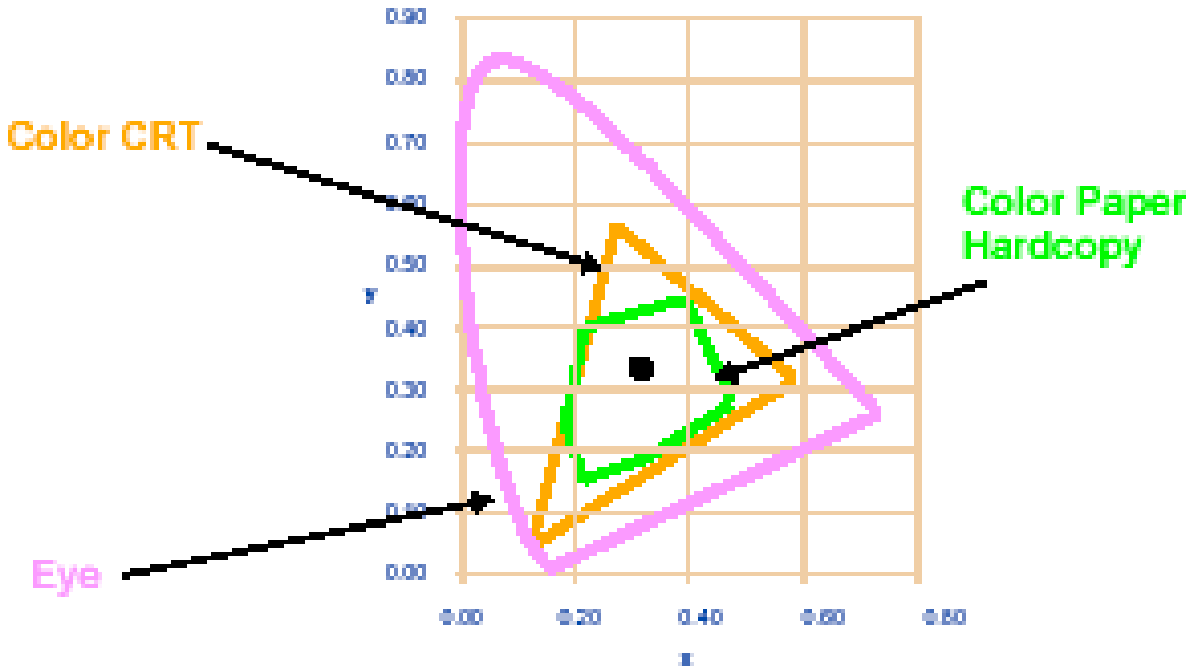
- CRT
  - Widest color gamut
  - Fast refresh for high performance VR applications
  - Still narrower gamut than human perception
  - Cheaper than LCDs
  - Multiple resolutions
- LCD
  - Slow response (‘refresh’)
  - Less colors than CRT typically, but improving
  - Tough
  - Not good for extreme temperatures
  - Multiple resolutions are interpolated, not true changes

More on different displays

- Color printer
  - Subtractive color
  - Narrow color gamut
  - Realize that you may have a $500 color printer with photorealistic detail IF you use the special paper, but others may not
- NTSC TV
  - Narrow color gamut, slow refresh, interlacing
- Film
  - Fairly wide color gamut
  - Good resolution typically

Comparison of typical color gamuts

- Try to stay away from the regions which cannot be printed when creating images for papers, or convert them beforehand



Output

- If you are creating visualizations for multiple contexts (video, computer monitors, printed papers, faxes, etc) be aware of device limitations
- Use redundant encoding of information if you don't know what the output is or who will be looking at it
  - Different fonts
  - Symbols
  - Fill pattern
  - Outline pattern
  - Outline thickness

Gratuitous Color Pollution

Just because you have 2^{24} different colors,

doesn't mean you must use them all •••