Flat Panel Display

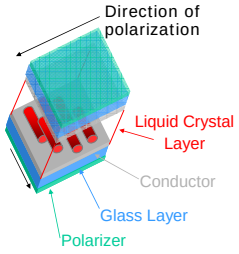
- 2 Types
  - Liquid Crystal Displays (LCDs)
  - Light-Emitting Diodes (LEDs)
- Applications
  - Laptop computers
  - Calculators
  - Hand-held organizers
  - Digital clocks
  - VCR/Stereo displays
  - And so on…

Liquid Crystal Display

- What is a liquid crystal?
  - Material that exists "between" liquid and solid phases
    - traits of both
  - Electric field changes optical properties of crystal
    - Causes light to pass through at varying brightness levels

Liquid Crystal Display

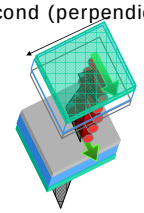
- *Liquid crystals* between two glass plates
  - Thin crystal layer
  - a few microns
- Transparent electrical *conductor* on inner sides of the glass
- Perpendicularly oriented *polarizers* placed over outer sides of each glass plate



Liquid Crystal Device

Liquid Crystal Display

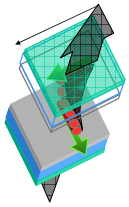
- When no voltage:
  - Liquid crystals are in “relaxed state” and aligned parallel to one another
  - Polarized light that has passed through the first polarizer is unaffected by aligned crystals and blocked by second (perpendicular) polarizer



No Light Transmitted

Liquid Crystal Display

- When voltage is on:
  - Electric field “twists” crystals
  - and direction of polarization
  - some light passes through 2nd polarizer



Light Transmitted

Liquid Crystal Display

- Voltage controls orientation of crystal and amount of twisting in each crystal:
  - *Maximum* amount of light is transmitted when first and last liquid crystals are *perpendicular*
  - *Minimum* amount of light is transmitted when first and last liquid crystals are *parallel*
  - Any intermediate amount of light is transmitted when the first and final crystals are oriented at other angles

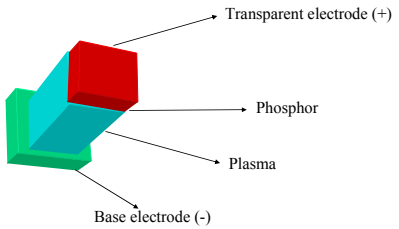
Liquid Crystal Display

- Individual liquid crystal device is a *cell*
- Two-dimensional matrix of cells is a screen
- Wires connected to cells to transfer voltages
  - Voltage to each cell controls light through each
  - Color filters placed over cells to make color screens
    - Color patterns and shapes change for different displays
- Back-lit
  - Initial light source must be bright enough to pass through LCD cells and detected by viewer

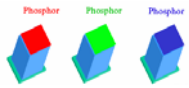
Plasma Display

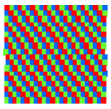
- An array of tiny CRTs or fluorescent light bulbs.
  - Each picture element (pixel) is a small "bottle" (cell) filled with Neon and/or Xenon gas.
  - Gas atoms ionize when excited by a high voltage across the cell ⇒ positive and negative charges created
    - electrons attracted to positive terminal ("anode")
    - protons attracted to negative terminal ("cathode")
  - Positive and negative charges collide with enough energy to release ultraviolet photons (with more energy than visible light)
  - UV photons are absorbed by the phosphor coating of each cell, some glow red, green, or blue

Plasma Picture Element



Plasma Picture Element





> 1,000,000 triads

> 3, 000, 000 elements

Imaging Chain Link #8: Perception

- How does the brain interpret the information?
- How does the human visual system use the information on the display?
- What components and characteristics of the visual system influence perception?
- How does that perception influence the design of imaging systems?

Limitations of Human Perception

- We know that the human visual system (HVS) cannot “see” everything and can make “mistakes”

HVS Limitations may be Beneficial:

- Merge still pictures in movies
- Create moving image from scanning “dot” in video
- Synthesize perceived colors from 3 primaries

HVS Limitations may be Detrimental

- Cannot see rapid changes in scene
- Different colors (as measured by a “spectrometer”) may appear identical
  - “metamerism”

What Color Is It?

What Color Is It?

Puce?
Pink?
Salmon?
Sunburn?
Flesh
Navaho Brick?
Magenta?
Bubble Gum
Baby Pink?
Sunset Smog?

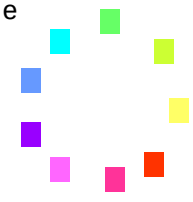
Need 3 "Descriptors" of Color

- RGB
- Hue, saturation, lightness
- CMY
- L-a-b
- YC_1C_2
- YIQ

- WHY?

"Hue"

- The "Name" of the Color
- All yellows differ in hue from all blues
- Specified by the dominant wavelength



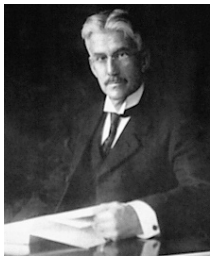
Hue

Wavelength (nm)	Appearance
370-470	
470-475	
475-480	
480-485	
485-495	
495-535	
535-555	
555-565	
565-575	
575-580	
580-585	
585-595	
595-730	

Lightness and Saturation

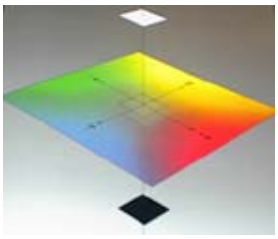
Brightness	Appearance	Saturation	Appearance
100%		100%	
90%		90%	
80%		80%	
70%		70%	
60%		60%	
50%		50%	
40%		40%	
30%		30%	
20%		20%	
10%		10%	
0%		0%	

Three Dimensions of Color
Hue, Lightness, Saturation

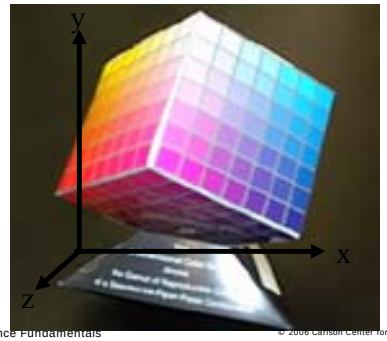


Albert H. Munsell

x,y,z space



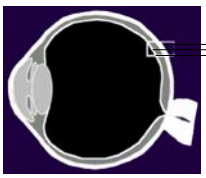
RIT Color Cube
A mathematical taxonomy for color

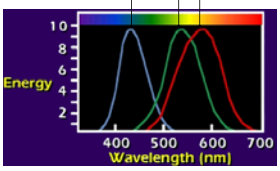


Why Three Dimensions?

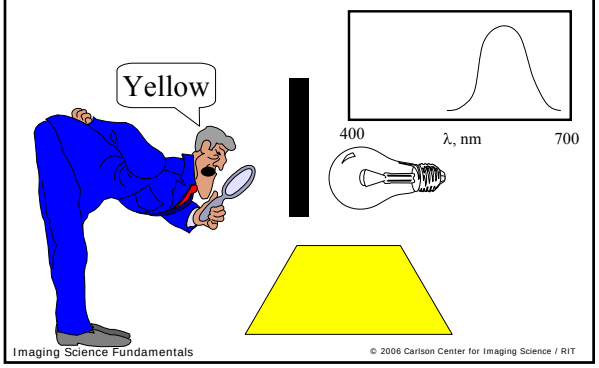
Why not 2?
Why not 4?

Because **Human** Eyes Have **Three**
Types of Color Sensors (cones)

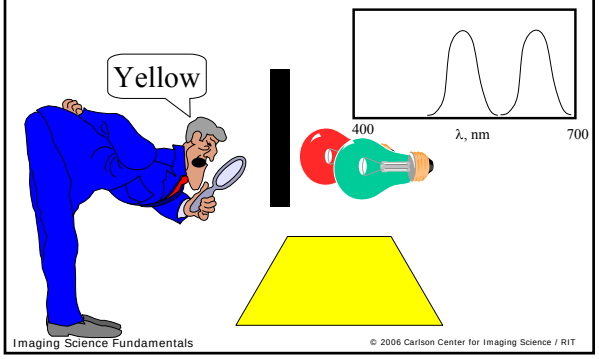




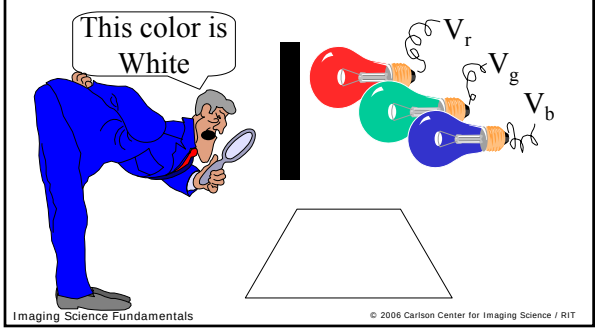
We are “Tri-chromatic
We do NOT really see the spectrum

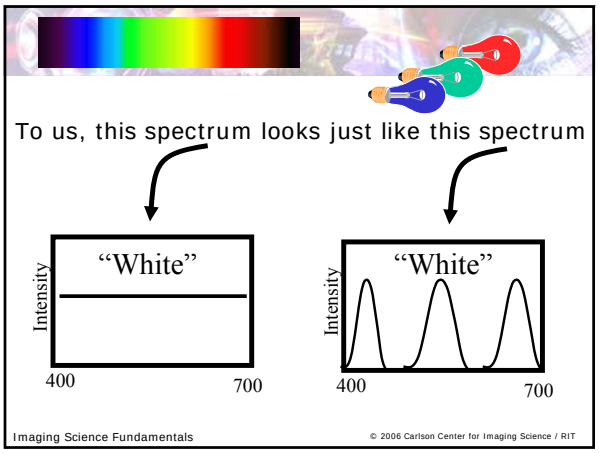


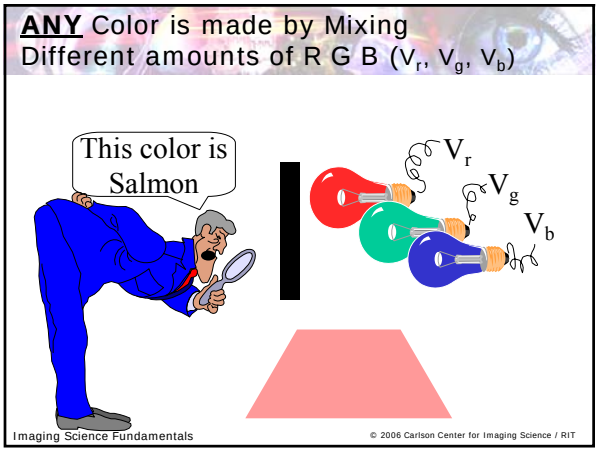
Yellow is formed by Mixing Red with Green Light



White by Mixing R G B lights




To us, this spectrum looks just like this spectrum
"White"
Intensity
400
700
"White"
Intensity
400
700
Imaging Science Fundamentals
© 2006 Carlson Center for Imaging Science / RIT


ANY Color is made by Mixing Different amounts of R G B (V_r, V_g, V_b)
This color is Salmon
V_r
V_g
V_b
Imaging Science Fundamentals
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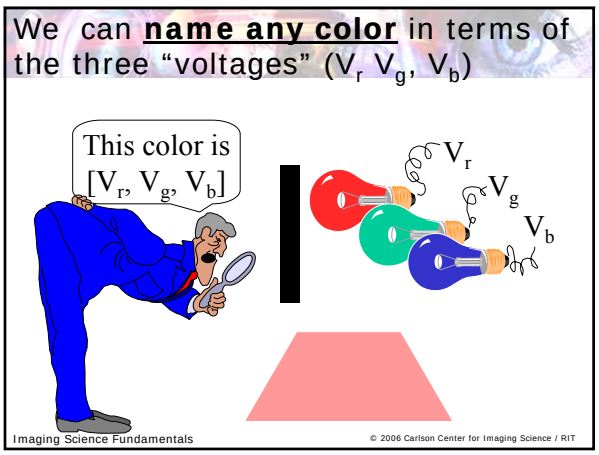
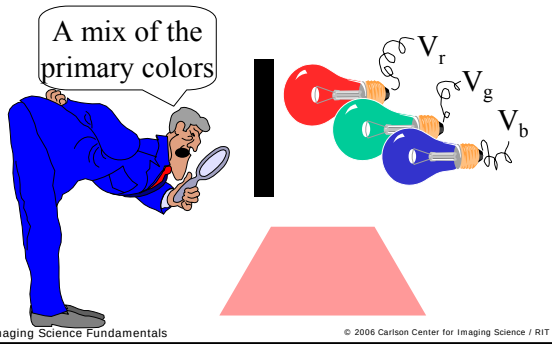
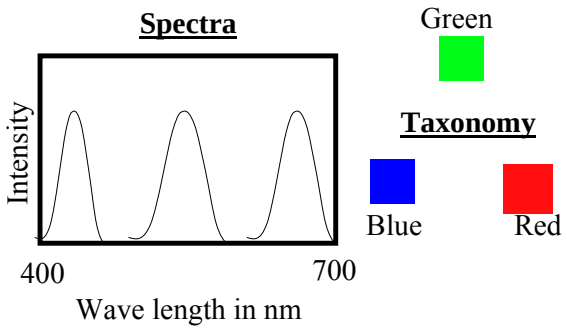

We can name any color in terms of the three "voltages" (V_r V_g, V_b)
This color is [V_r, V_g, V_b]
V_r
V_g
V_b
Imaging Science Fundamentals
© 2006 Carlson Center for Imaging Science / RIT

We call Red, Green, and Blue the "ADDITIVE PRIMARY COLORS"



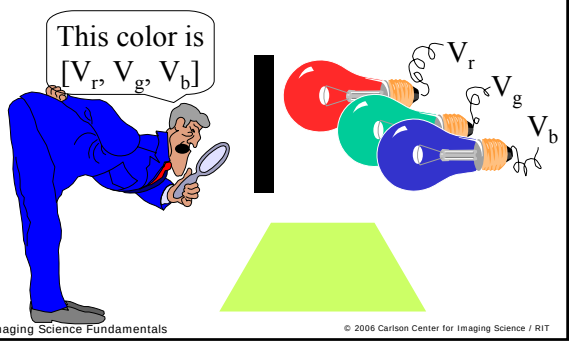
Imaging Science Taxonomy "The Additive Primary Colors"



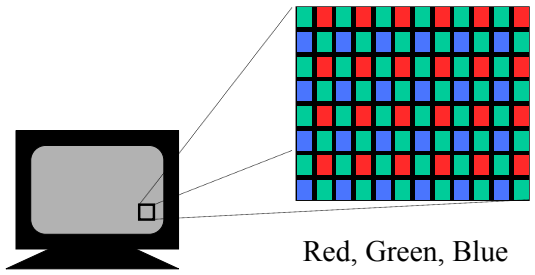
Two Ways to Mix Red, Green, and Blue Light

1. Additive Color Mixing
2. Subtractive Color Mixing

Additive Color Mixing



Examples of Additive Color Reproduction:
Television and Computer Monitor



Examples of Additive Color Reproduction:
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