Fundamentals of Multimedia

Lecture 3
Color in Image & Video

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Outcomes of Lecture 2

- *Black & white imags*
  - 1 bit images, 8-bit gray-level images
  - Image histogram
- *Dithering*
  - Printing (ordered dithering)
- *Color imags*
  - 24-bit color images
  - Quantization and compression (8-bit color images)
    - *Color Tables*
- *Popular File Formats*
  - GIF , JPEG , PDF, BMP

Outline

- *Physical and perceptual aspects of color*
  - Human Vision
- *Color models in image*
  - RGB
  - CMYK
  - HSB
- *Gamma Correction*
- *Color models in video*
  - YUV
  - YCbCr

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- ***Physical and perceptual aspects of color***
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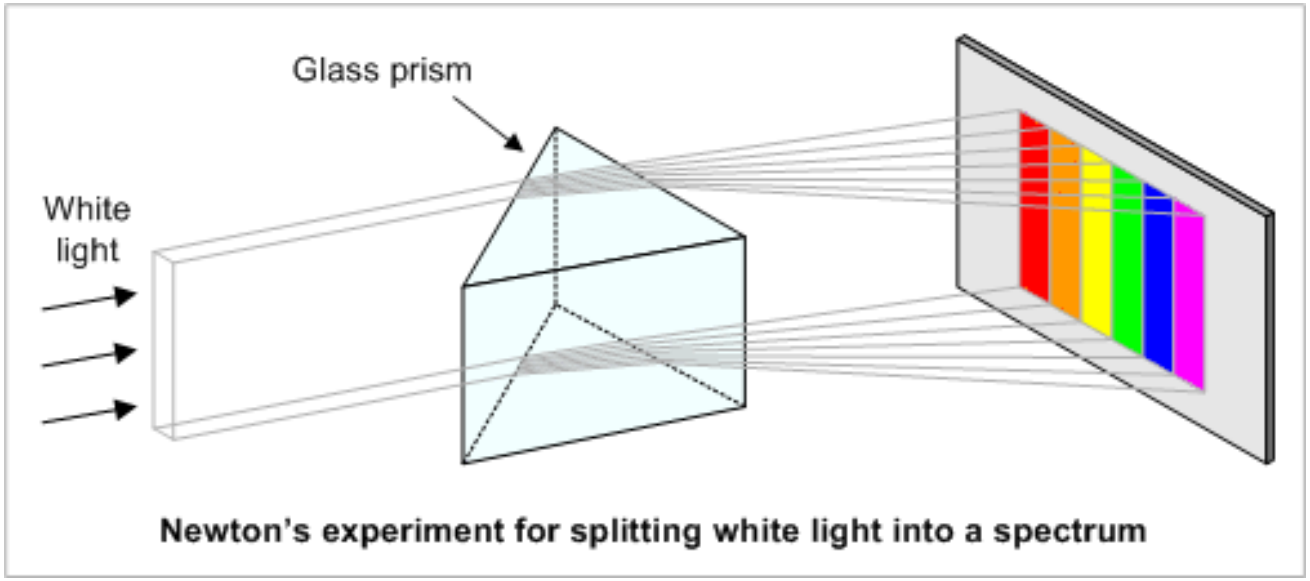
The Physics of Color

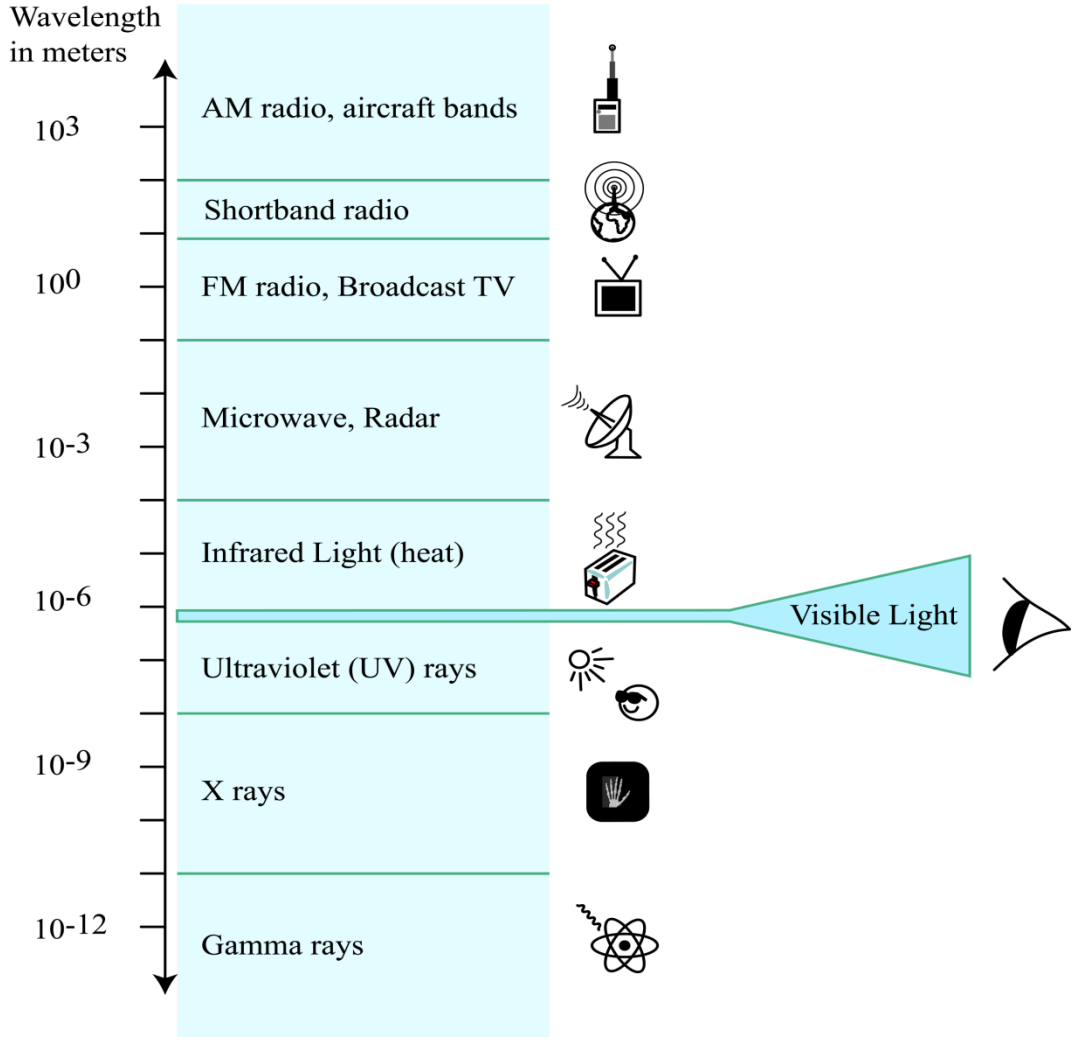
- *Light is an electromagnetic wave*
- *White light contains all the colors of a rainbow*



Newton's experiment for splitting white light into a spectrum

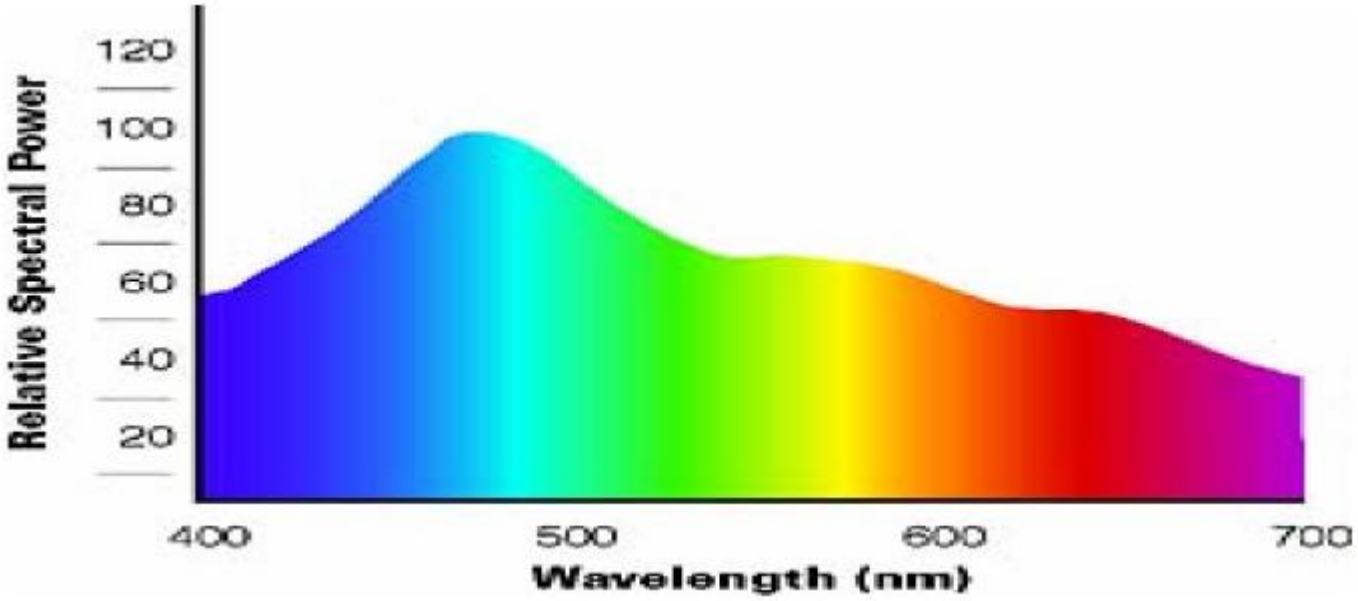
Visible Light

- *The electromagnetic spectrum, of which visible light is a very thin band*



The spectrum of visible light

- *The Spectral Power Distribution (SPD) of day light shows the relative amount of light energy.*
- *The color of the light is characterized by the wavelength of the light*
  - Short wavelengths produce a blue sensation, long wavelengths produce a red one

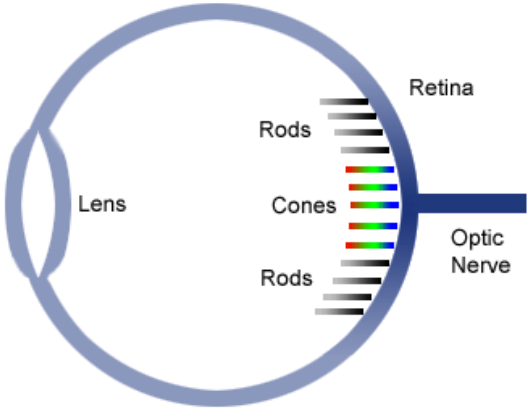


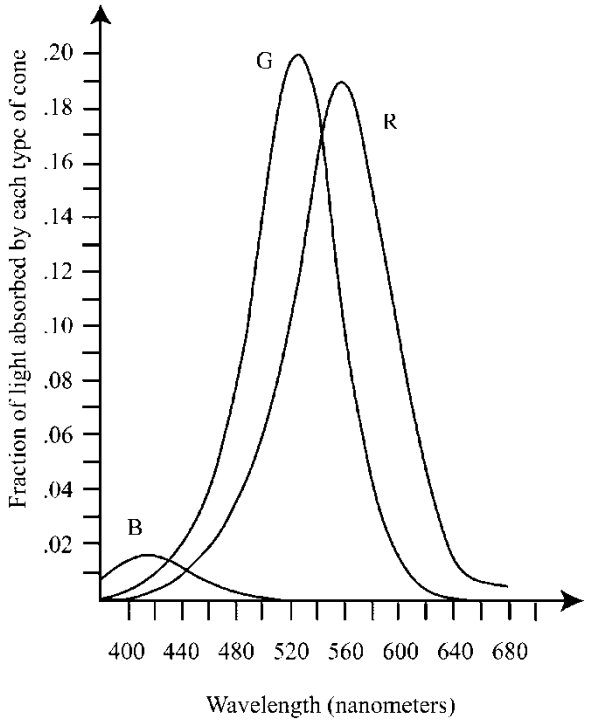
Human Vision

- ***Sensor:*** *Eye*
  - Most sensitive to red (R), green (G), and blue (B)
- ***Processor:*** *Brain*
  - R, G, B
  - R-G, G-B, B-R

Human response to color

- *Human retina consists of an array of rods and three kinds of cones*
- *Rods*
  - Detect gray-level information
- *Cones*
  - Three kids of cones are used to detect R,G, B
  - The proportions of R, G, B cones are 40:20:1
- *The eye is most sensitive to light in the middle of the visible spectrum*





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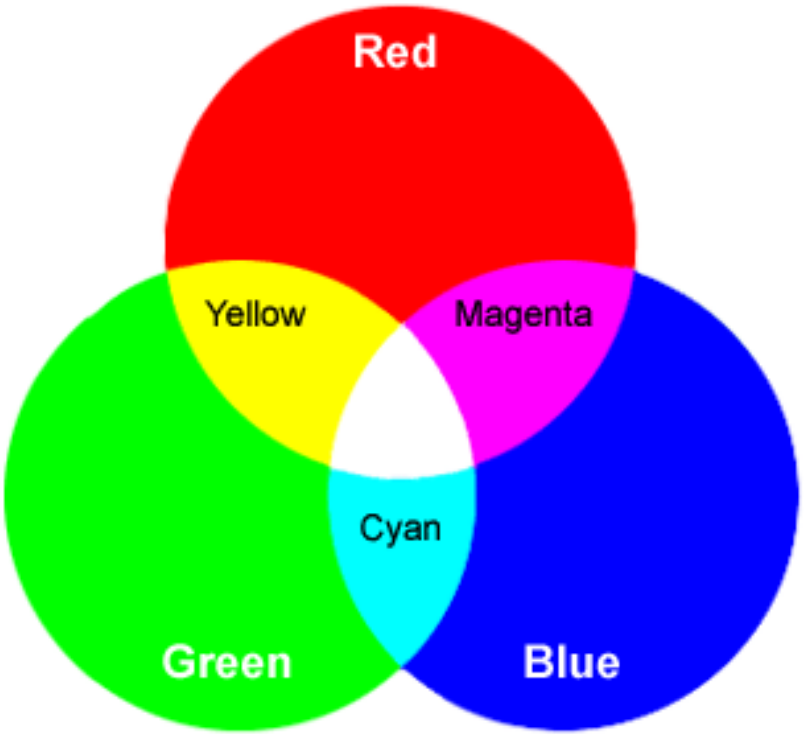
Color Models

- *Additive color: red, green, blue (RGB)*
- *Subtractive color: cyan, magenta, yellow, and black (CMYK)*
- *Hue, saturation, and brightness (HSB)*

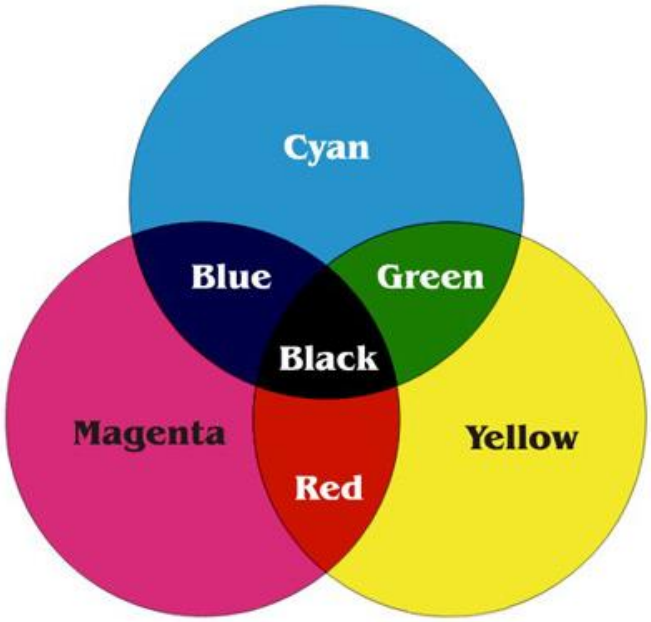
RGB Color Model

- *Additive color: things that emit light, especially monitors*



CMY Color Model

- *Subtractive color: things that reflect (and selectively absorb) light*



- *CMY ←→ RGB transformation is invertible*

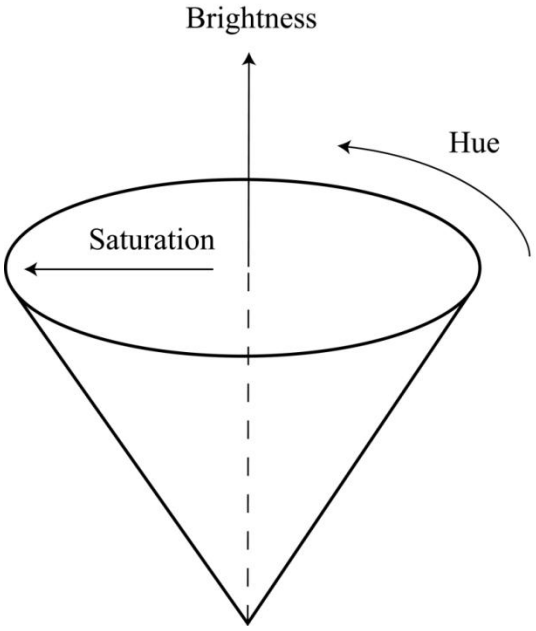
$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

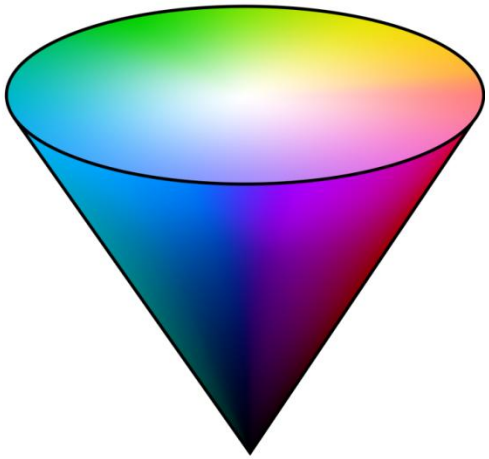
CMYK Color Model

- *C, M, Y not mix to real black: Muddy brown.*
  - Sharper printers
- *Black ink is in fact cheaper than mixing colored inks.*

HSB Color Model

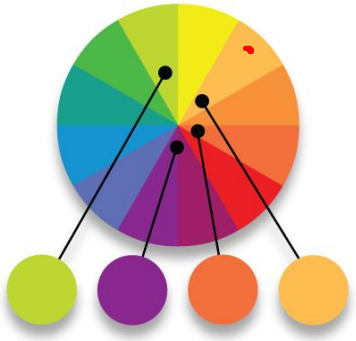
- *Hue: Position in the color spectrum*
  - where a color lies around a color wheel: red, green, yellow, blue-green, etc.
- *Saturation: the intensity ("purity") of a color*
  - a fully-saturated color has no white mixed with it, in paint terms of painting
- *Brightness: light, dark, or in between?*





HSB Color Model

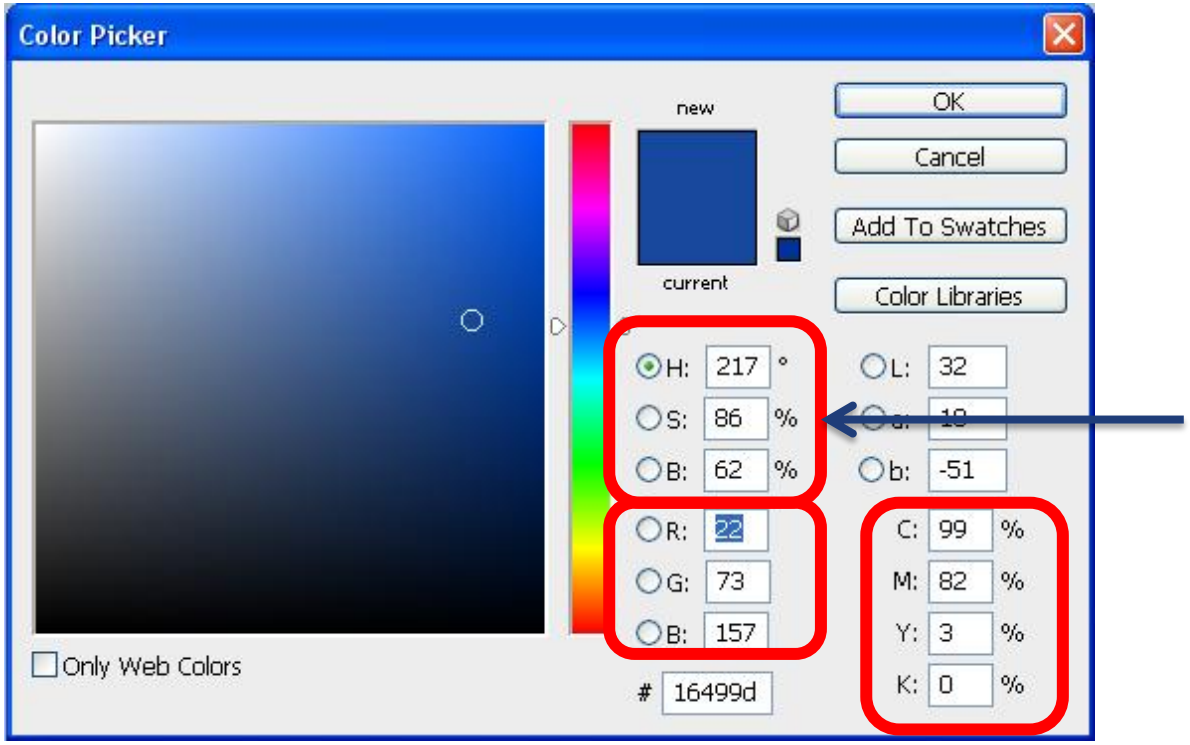
- *Hue:* a specific tone of color



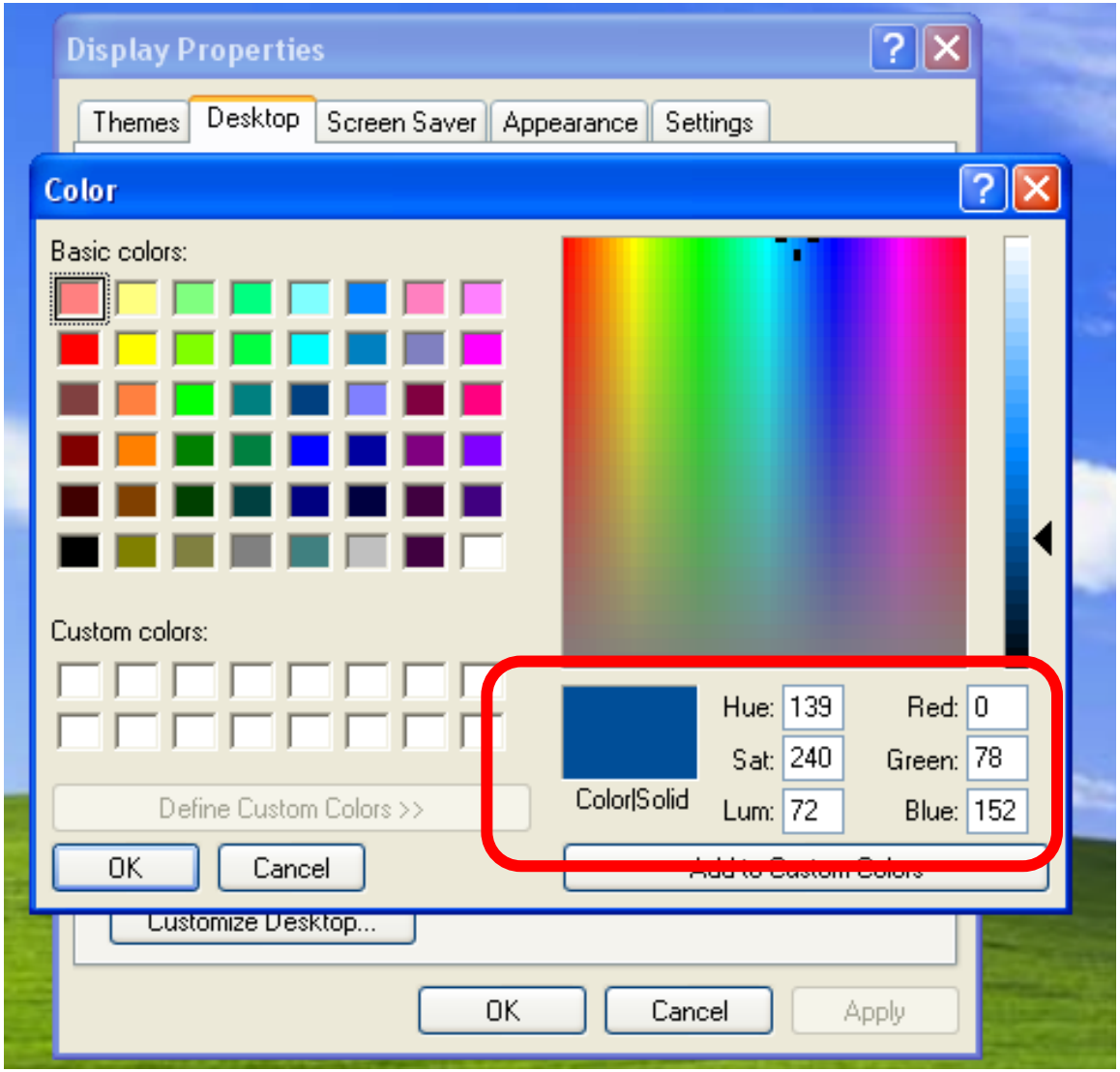
- *Saturation: It is the intensity of a hue from grey. At maximum saturation a color would contain no grey at all. At minimum saturation, a color would contain mostly grey.*

- Brightness refers to how much white, or black, is contained within a color.

Color Models in Computer



Color Models in Computer



HSL

Hue

Saturation

Luminance

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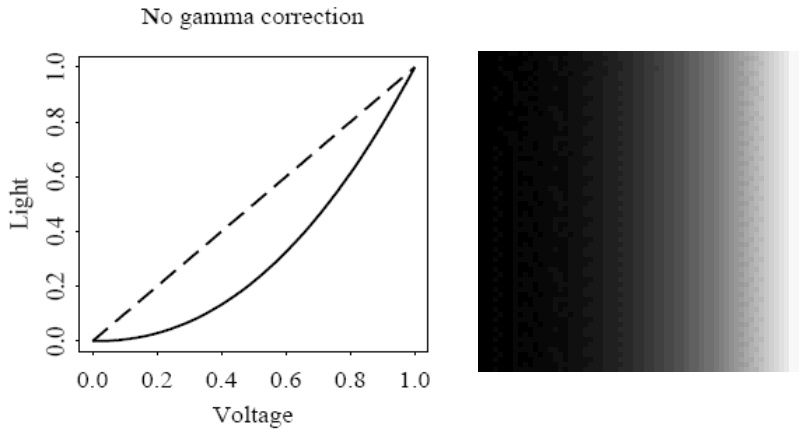
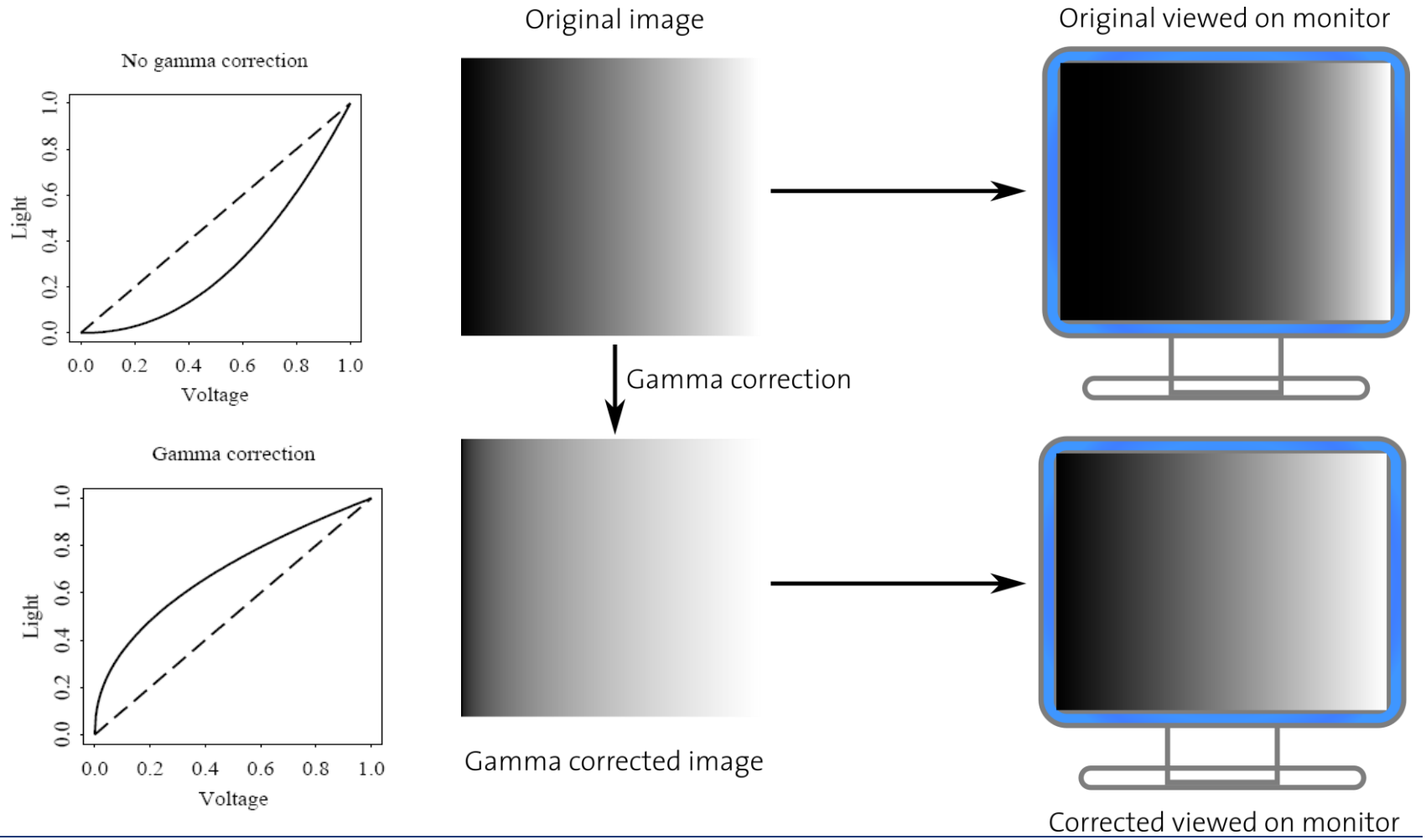
Gamma Correction

- *There is a nonlinear relationship between pixel value and displayed intensity that is typical for a colored monitor.*
  - The light emitted is in fact roughly proportional to the color voltage raised to a power; this power is called **gamma**, with symbol γ.
  - Thus, if the file value in the red channel is R, the screen emits light proportional to R^{γ}, most monitors have a gamma between 1.7 and 2.7
  - Images which are not properly corrected can look either lightened, or too dark.



Gamma Correction

- *It is customary to append a prime to signals that are gamma-corrected by raising to the power (1/γ) before transmission.*



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Color Models in Video

- *Largely derive from older analog methods of coding color for TV.*
  - ***Luminance is separated from color information**.*
- *For example, a matrix transform method called **YIQ** is used to transmit TV signals in North America and Japan.*
- *In Europe, a matrix transform called **YUV** is used.*
- *Finally, digital video mostly uses a matrix transform called **YCbCr** that is closely related to YUV.*

YUV Color Model

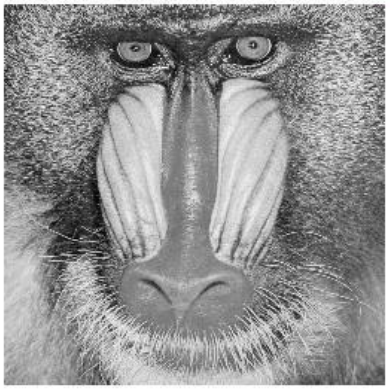
- *Be used in JPEG*
- *Y: luminance value*
  - Luma *Y'.* (gamma-corrected)
- *U and V: **Chrominance** components*
  - The difference between a color and a reference white at the same luminance.

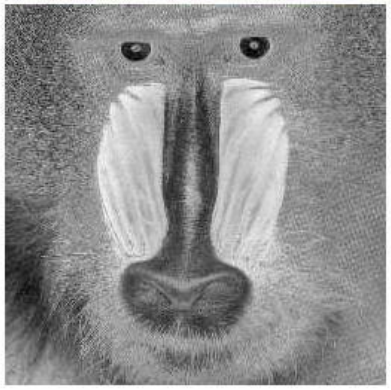
$$U = B' - Y';\ V = R' - Y'$$

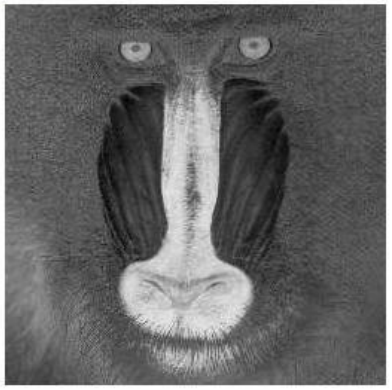
$$\begin{bmatrix} Y' \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ -0.299 & -0.587 & 0.886 \\ 0.701 & -0.587 & -0.114 \end{bmatrix} \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix}$$

R' , G' , B' : gamma correction applied

YUV Color Model







YCbCr Color Model

- *Closely related to the YUV (scaled and shifted)*
  - Be used in MPEG video compression

$$\begin{bmatrix} Y' \\ C_b \\ C_r \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ -0.168736 & -0.331264 & 0.5 \\ 0.5 & -0.418688 & -0.081312 \end{bmatrix} \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} + \begin{bmatrix} 0 \\ 0.5 \\ 0.5 \end{bmatrix}$$

Summary

- *Physical and perceptual aspects of color*
  - The spectrum of visible light
  - Human Vision
- *Color models in image*
  - RGB (Screen)
  - CMYK (Printing)
  - HSB (Screen)
- *Gamma Correction*
- *Color models in video*
  - YUV
  - YCbCr