Digital Image Processing

Chapter 2:

Image Representation

Spectrum of White Light

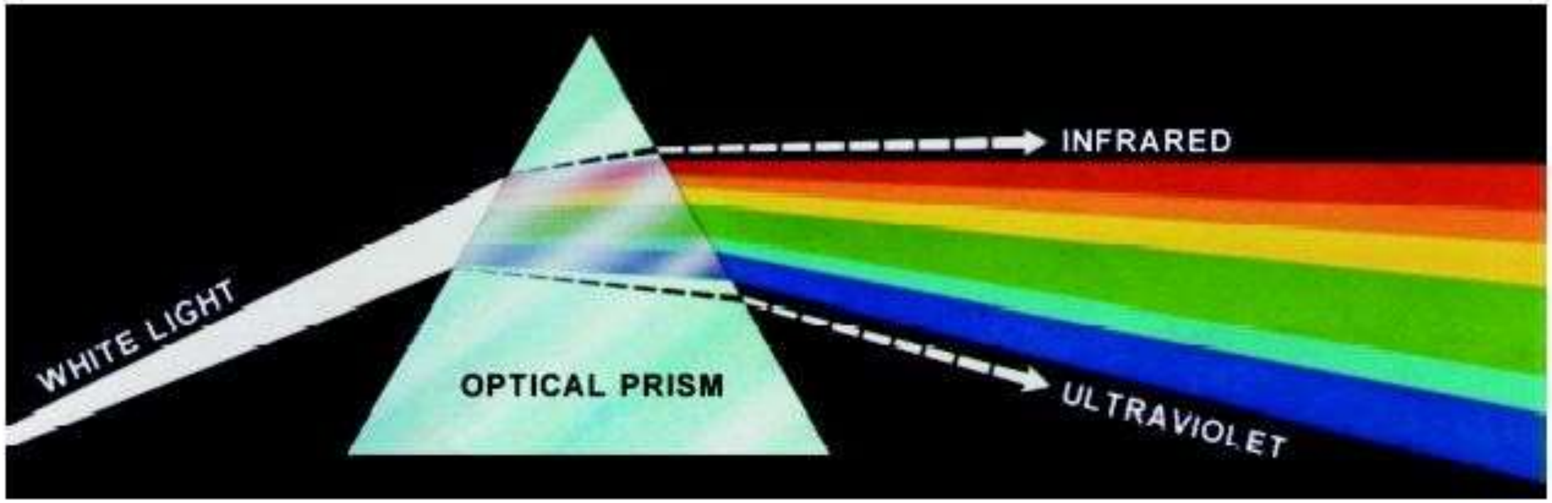
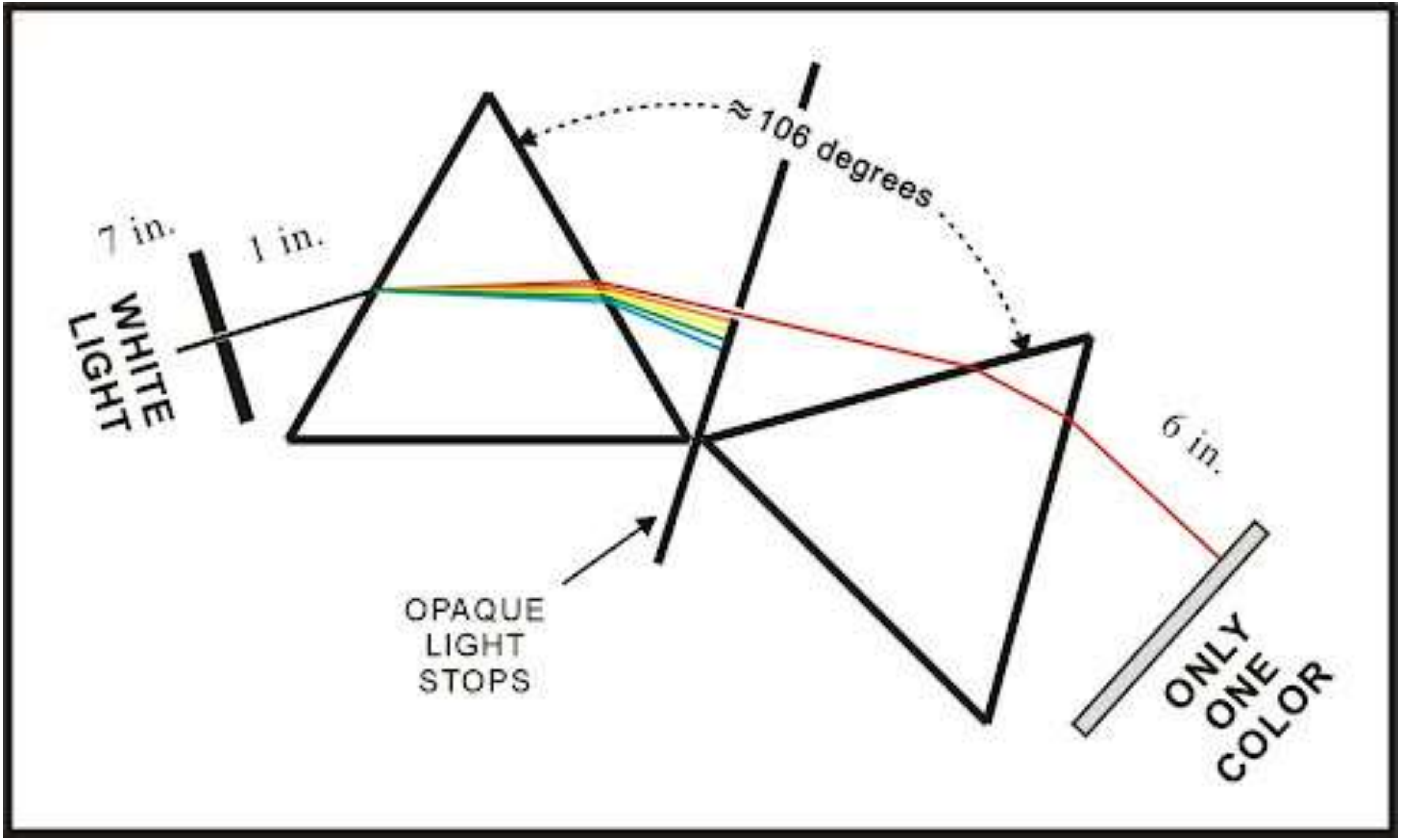


FIGURE 6.1 Color spectrum seen by passing white light through a prism. (Courtesy of the General Electric Co., Lamp Business Division.)

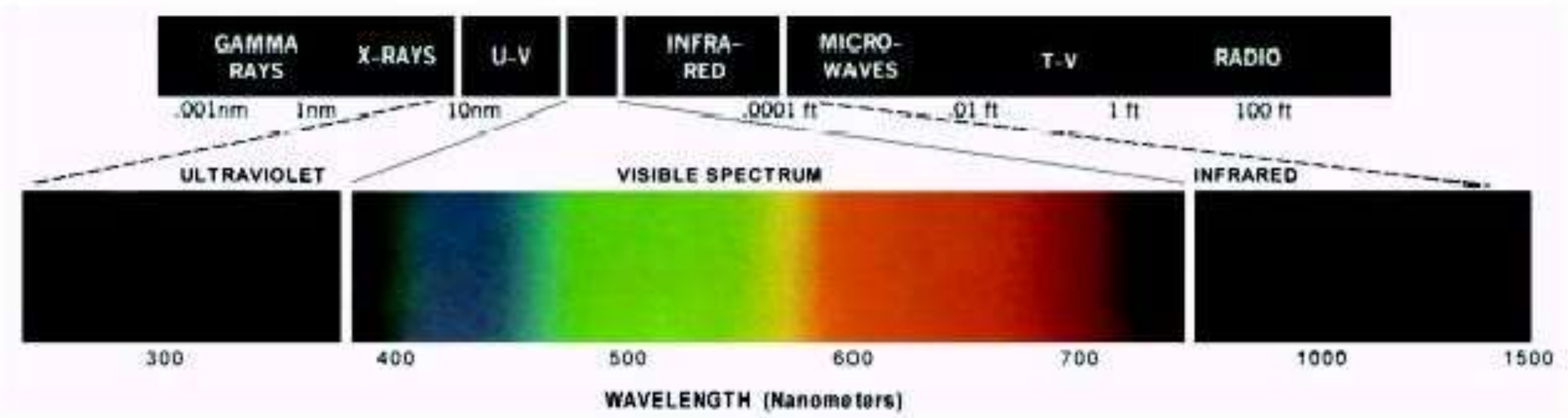
1666 Sir Isaac Newton, 24 year old, discovered white light spectrum.

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Is Other Color Pure?



Electromagnetic Spectrum



Visible light wavelength: from around 400 to 700 nm

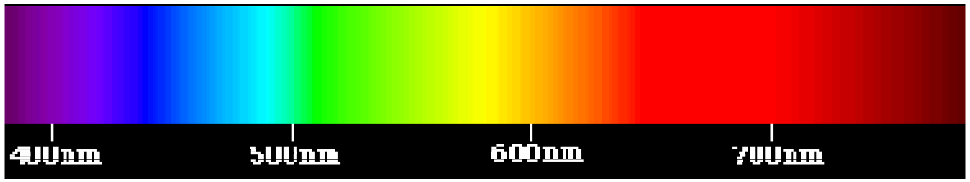
1. For an achromatic (monochrome) light source,
there is only 1 attribute to describe the quality: intensity

2.For a chromatic light source, there are 3 attributes to describe the quality:
  Radiance = total amount of energy flow from a light source (Watts)
  Luminance = amount of energy received by an observer (lumens)
  Brightness = intensity

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Color of Light

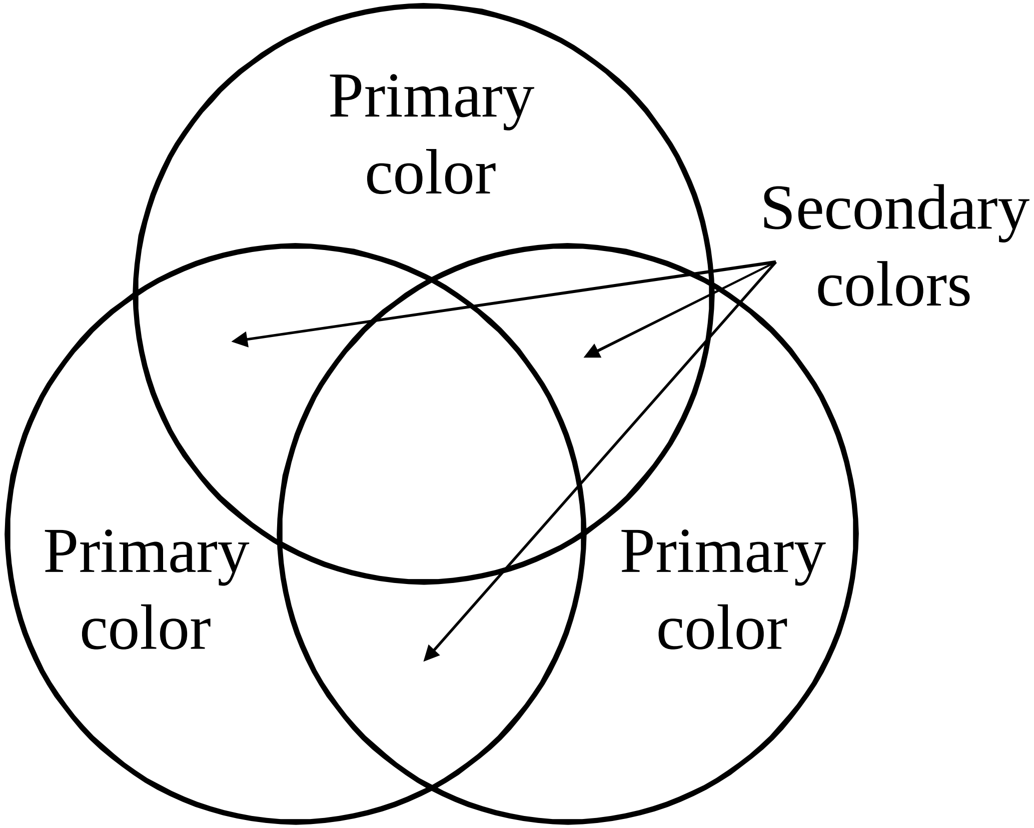
- Perceived color depends on spectral content (wavelength composition)
  - e.g., 700nm ~ red.
  - "spectral color"
    - A light with very narrow bandwidth



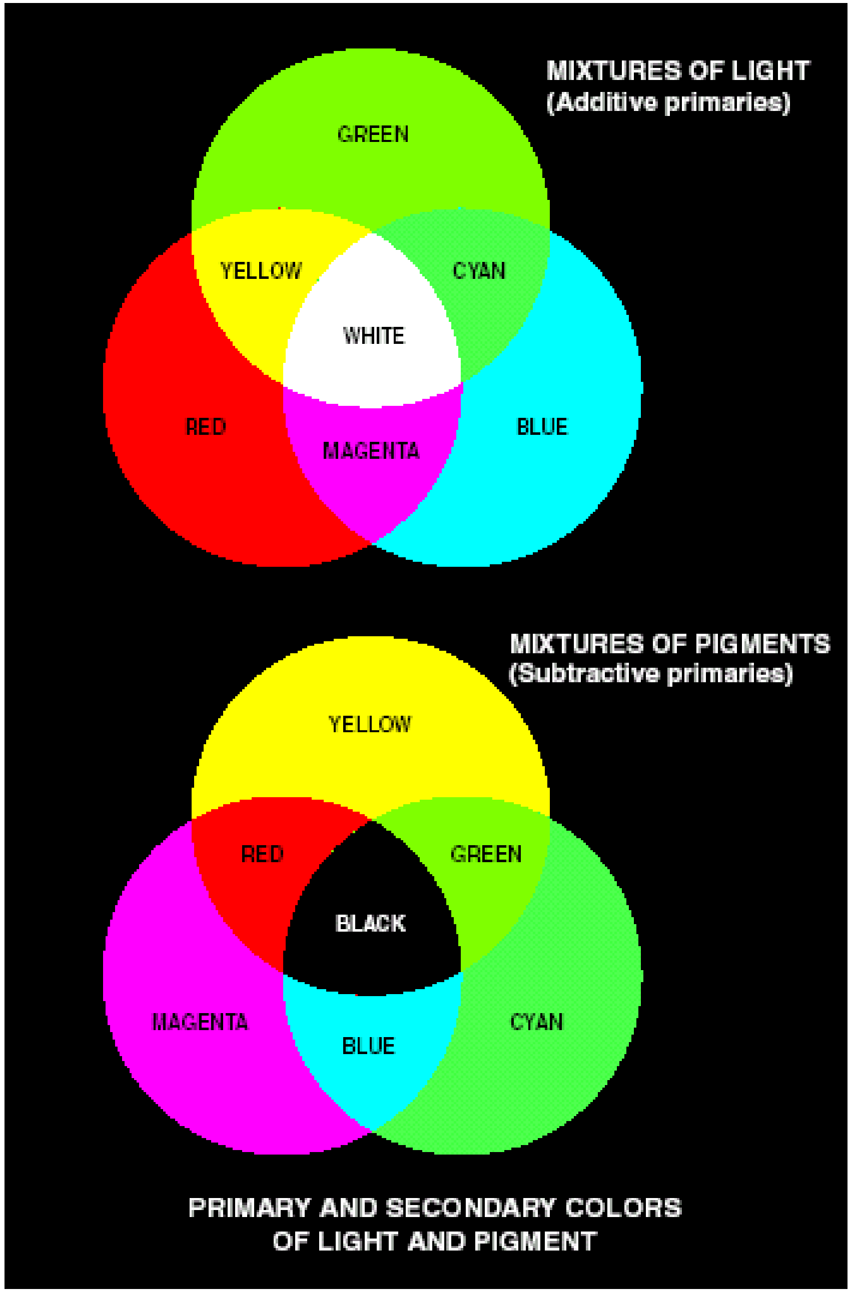
"Spectrum" from http://www.physics.sfasu.edu/astro/color.html

- A light with equal energy in all visible bands appears white

Primary and Secondary Colors



Primary and Secondary Colors (cont.)



Additive primary colors: RGB use in the case of light sources such as color monitors

RGB add together to get white

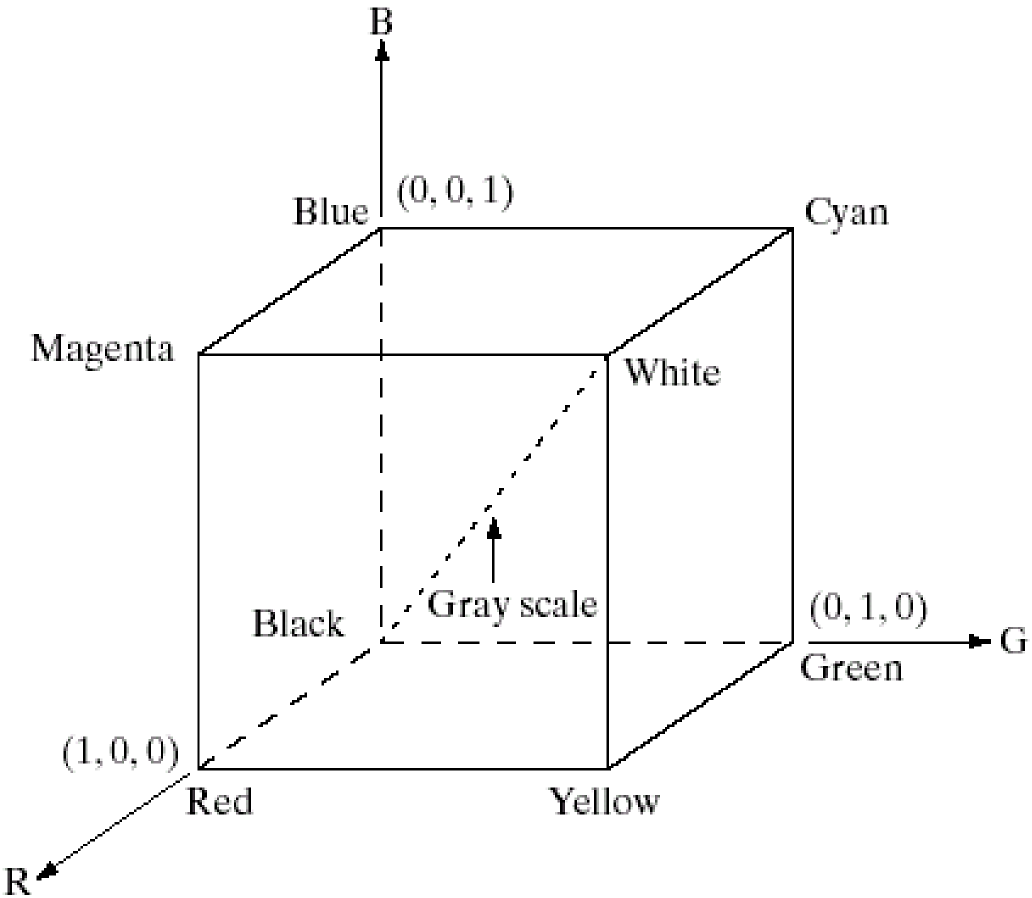
Subtractive primary colors: CMY use in the case of pigments in printing devices

White subtracted by CMY to get Black

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

RGB Color Model

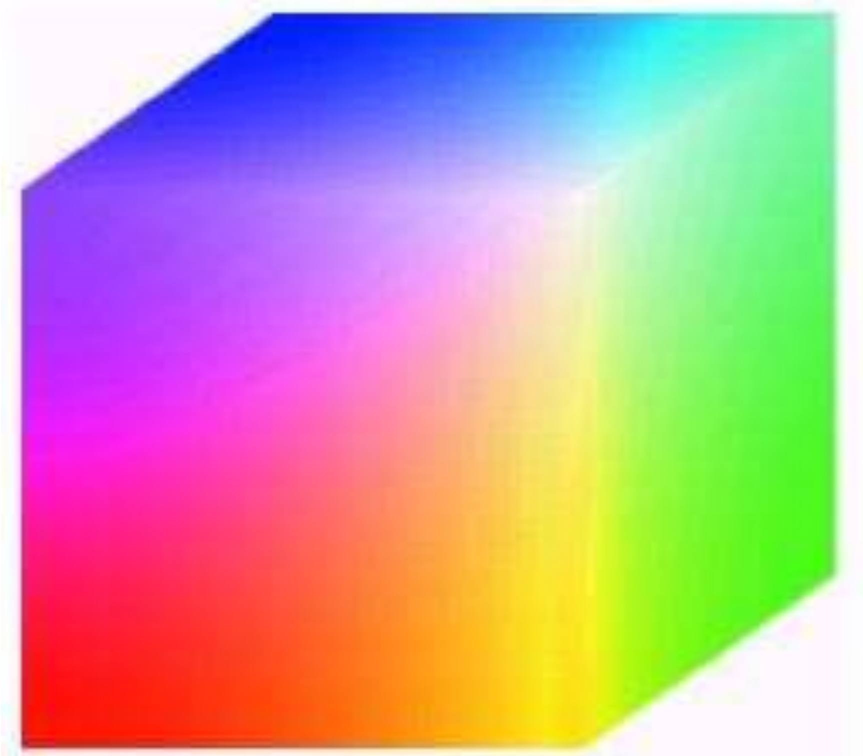
Purpose of color models: to facilitate the specification of colors in some standard



RGB color models:
- based on cartesian coordinate system

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

RGB Color Cube



R = 8 bits
G = 8 bits
B = 8 bits

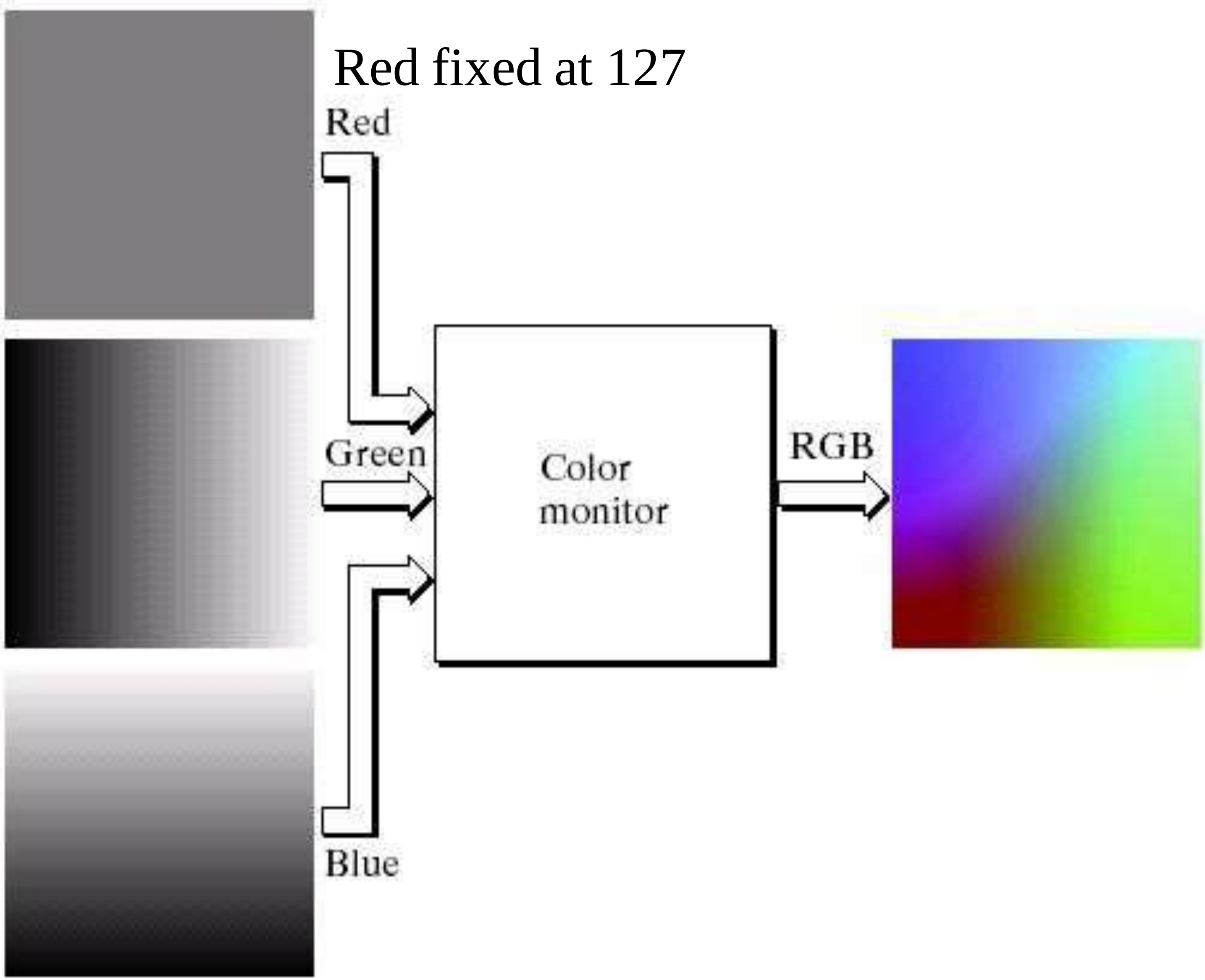
Color depth 24 bits
= 16777216 colors

(R = 0) (G = 0) (B = 0)

Hidden faces
of the cube

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

RGB Color Model (cont.)

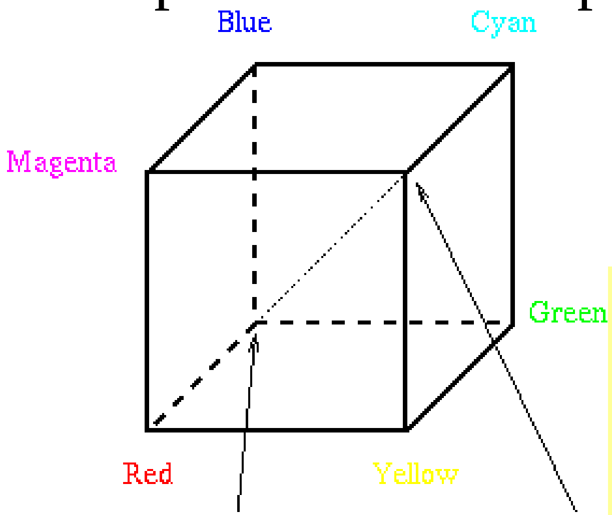


(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

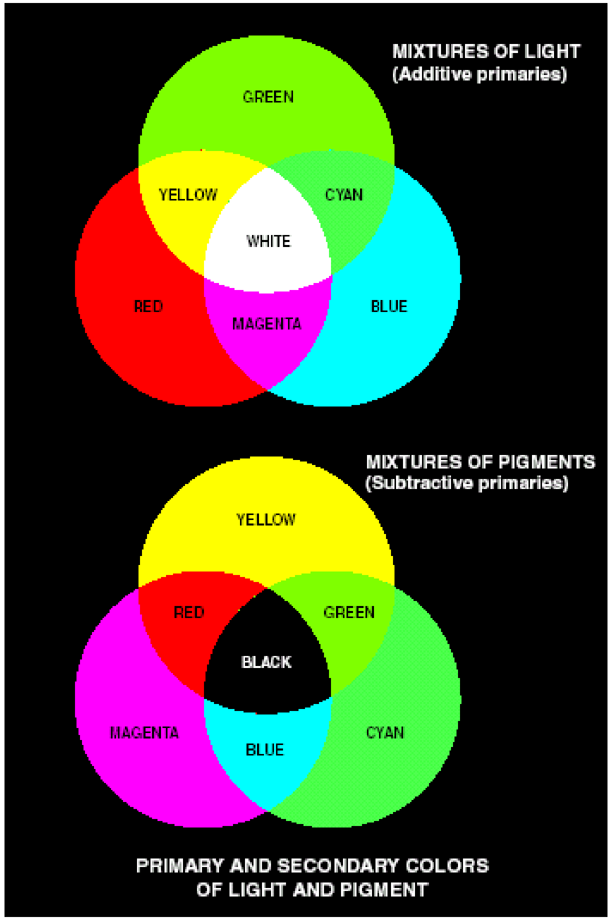
CMY and CMYK Color Models

C = Cyan
M = Magenta
Y = Yellow
K = Black

- Primary colors for pigment
  - Defined as one that subtracts/absorbs a primary color of light & reflects the other two
- CMY – Cyan, Magenta, Yellow
  - Complementary to RGB
  - Proper mix of them produces black

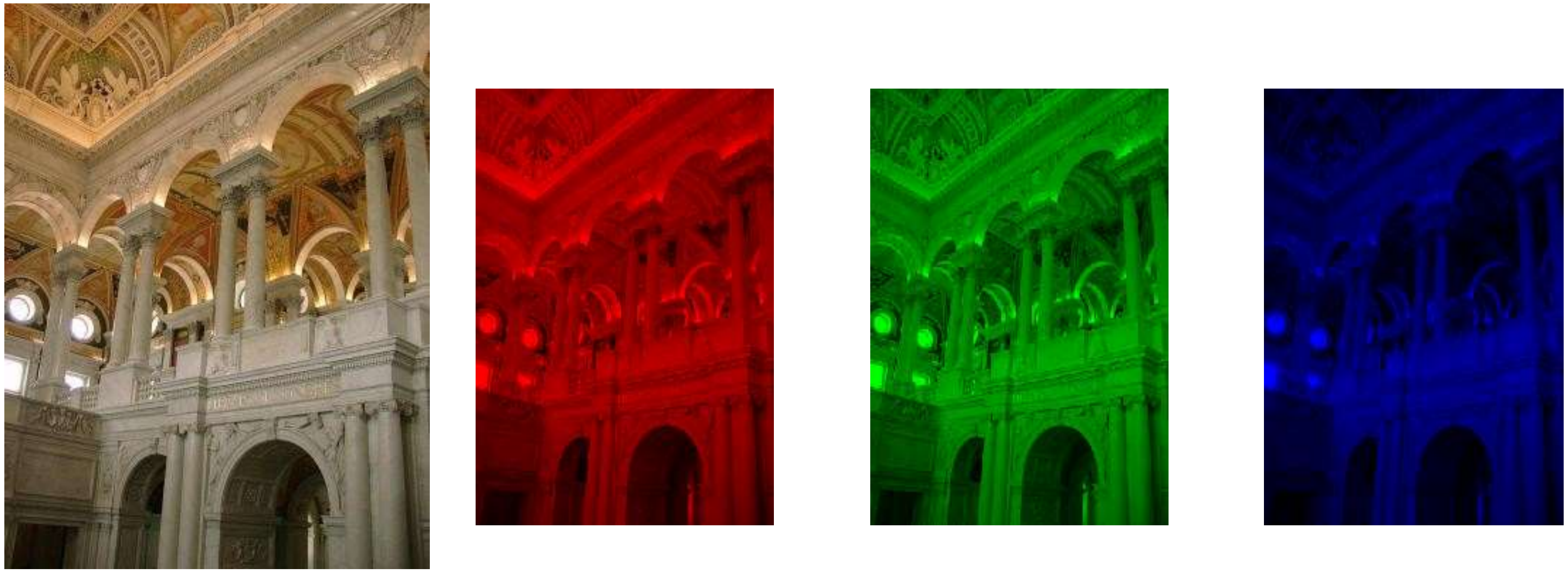


$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$



PRIMARY AND SECONDARY COLORS
OF LIGHT AND PIGMENT

Examples



RGB

Direct Coding

- Image representation is essentially the representation of pixel colors.
- Using **direct coding** we allocate a **certain amount of storage space** for each **pixel to code its color**.
- For example, we may **allocate 3 bits for each pixel**, with **one bit for each primary color.**
- This **3-bit representation** allows each primary to vary independently between two intensity levels:
    - **0 (off) or 1 (on).**

- Hence each pixel can take **on one of the eight colors** that correspond to the **corners of the RGB color cube.**

bit 1: *r*	bit 2: *g*	bit 3: *b*	color name
0	0	0	black
0	0	1	blue
0	1	0	green
0	1	1	cyan
1	0	0	red
1	0	1	magenta
1	1	0	yellow
1	1	1	white

Fig. 2-3 Direct coding of colors using 3 bits.

Direct Coding

- A widely accepted industry standard uses **3 bytes, or 24 bits, per pixel, with one byte for each primary color.**
- This way we allow each primary color to have **256 different intensity levels**,
  - **corresponding to binary values from 00000000 to 11111111.**
- Thus a pixel can take on **a color from 256 x 256 x 256** or
  - **16.7 million possible choices.**
- The 24-bit format is commonly referred to as **the true color** representation, for the difference between two colors that **differ by one intensity level** in one or more of the primaries is virtually **undetectable** under normal viewing conditions.

Direct Coding

- A notable special case of direct coding is the representation of
  - **black-and-white (bilevel)** and
  - **gray-scale images**, where the **three primaries** have the same value and hence need not be coded separately.
- A **black-and-white** image requires only **one bit per pixel**, with bit value **0 representing black** and **1 representing white.**
- A **gray-scale image** is typically coded with **8 bits per pixel** to allow **a total 256 intensity** or **gray levels.**
- Although this direct coding method features simplicity and has supported a variety of applications, we can see a relatively high demand for storage space when it comes to the **24-bit standard**.
- For example, **a 1000 x 1000 true color image** would take up **three million bytes.**
- Furthermore, even if every pixel in that image had a different color, there would only be **one million colors** in the image.
- In many applications the number of colors that appear in any one particular image is much less.
- Therefore the **24-bit representation's ability** to have **16.7 million different colors** appear simultaneously in a single image seems to be somewhat overkill.

Lookup Table

- Image representation using a lookup table can be viewed as a compromise between our desire to have a lower storage requirement and our need to support a reasonably sufficient number of simultaneous colors.
- In this approach **pixel values** do not code colors directly.
- Instead, they are addresses or indices into a **table of color values.**
- The color of a particular pixel is determined by the color value in the table entry that the value of the pixel references.

- Figure shows a lookup table with **256 entries.**
- The entries have addresses **0 through 255.**
- Each entry contains a **24-bit RGB color value.**
- Pixel values are now **1-byte**, or **8-bit**, quantities.

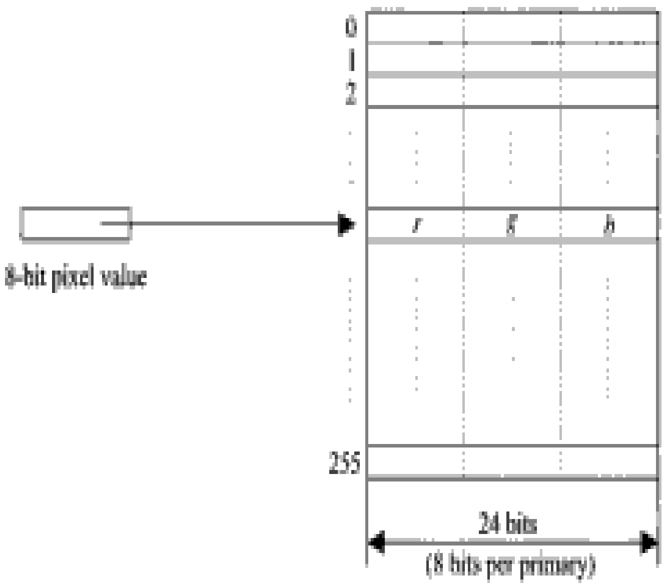


Fig. 2-4 A 24-bit 256-entry lookup table.

Lookup Table

- The color of a pixel whose value is i, where **0<=i<=255**, is determined by
  - the color value in the table entry whose address is i.
- This **24-bit 256-entry look up table** representation is often referred to as the **8-bit format**.
- It reduces the storage requirement of a **1000 x 1000 image** to one million bytes plus 768 bytes for the color values in the lookup table.
- It allows **256 simultaneous colors** that are chosen from 16.7 million possible colors.
- It is important to remember that,
  - using the lookup table representation,
  - an image is defined not only by its pixel values but also
  - by the color values in the corresponding lookup table.
- **Those color values *form* a color map for the image.**

Summary

- Monochrome human vision
  – visual properties: luminance vs. brightness, etc.
- Color
  – Color representations and three primary colors
  – Color coordinates
- Color Model
  - ❑ Direct Coding
  - ❑ Lookup Table

Questions of the day

- How will a printer print white color if it uses CMYK model?
- How will the lookup table be generated means how will it select which colors to be chosen to be indexed?