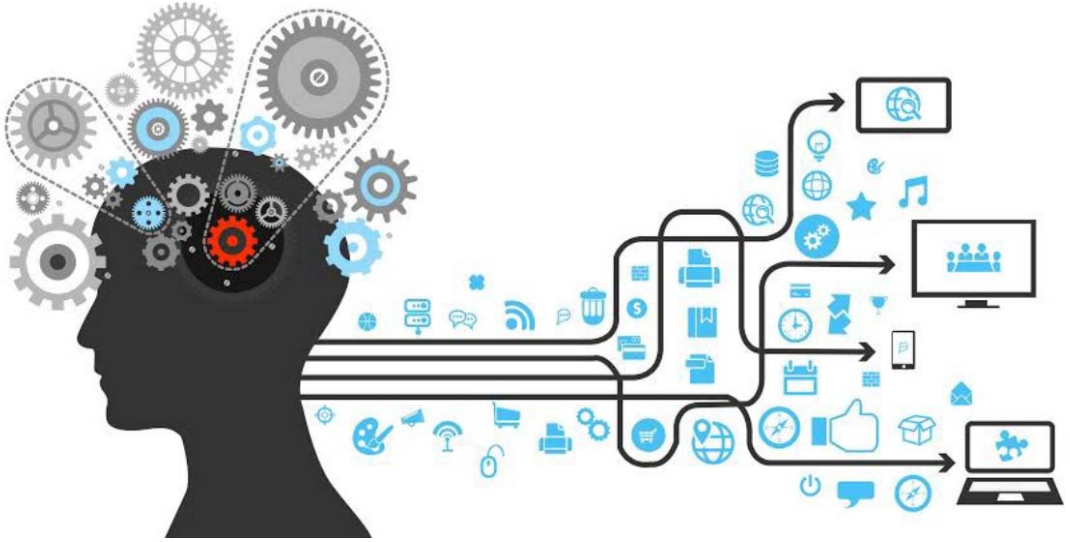
Computer Vision

Image formation



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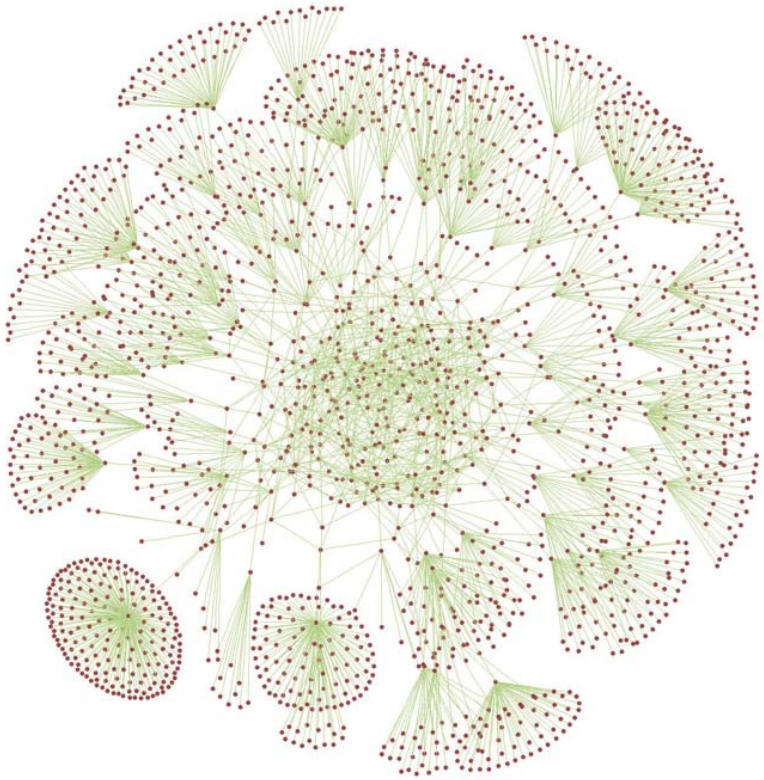
Medical Image Processing



Color

What is color?

- A perceptual attribute of objects constructed by the visual system
- A quantity related to the wavelength of light in the visible spectrum
- A significant industry with conferences, standards, bodies, etc.

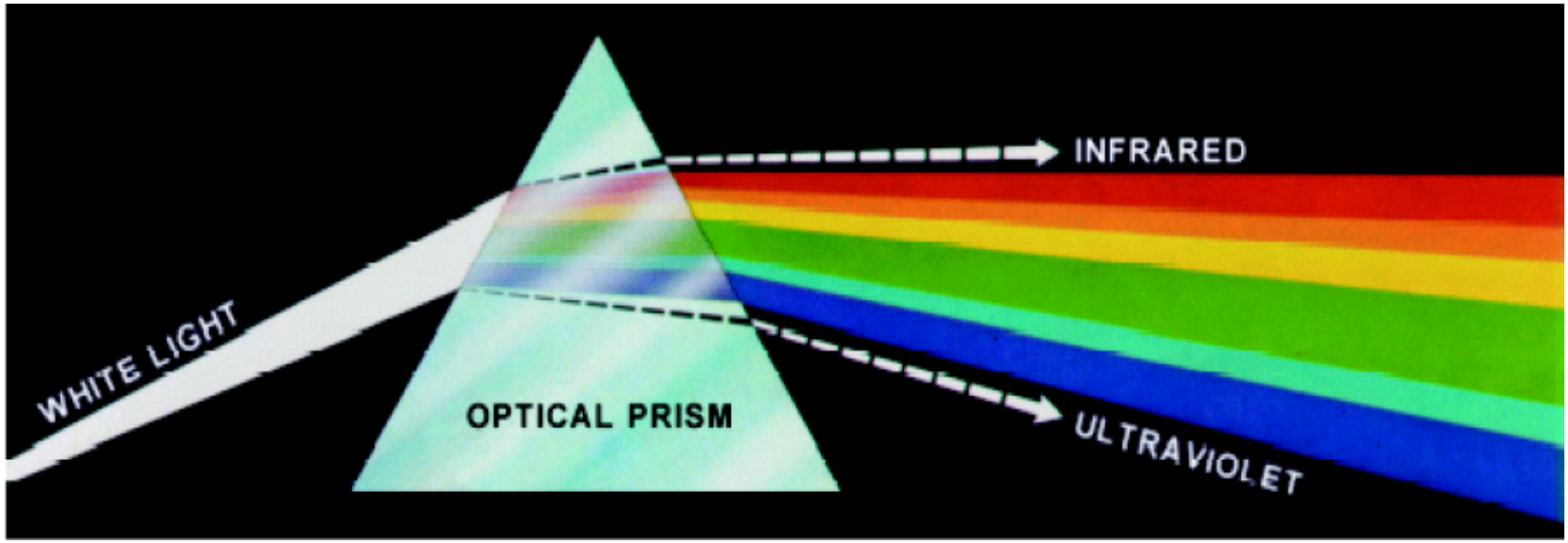
Why is color important?

- In animal vision
  - Distinguish food from non-food
  - Help identify predators and prey
  - Check health, fitness, etc. of other individuals

- In computer vision
  - Find a person's skin
  - Segment pixel regions belonging to the same object

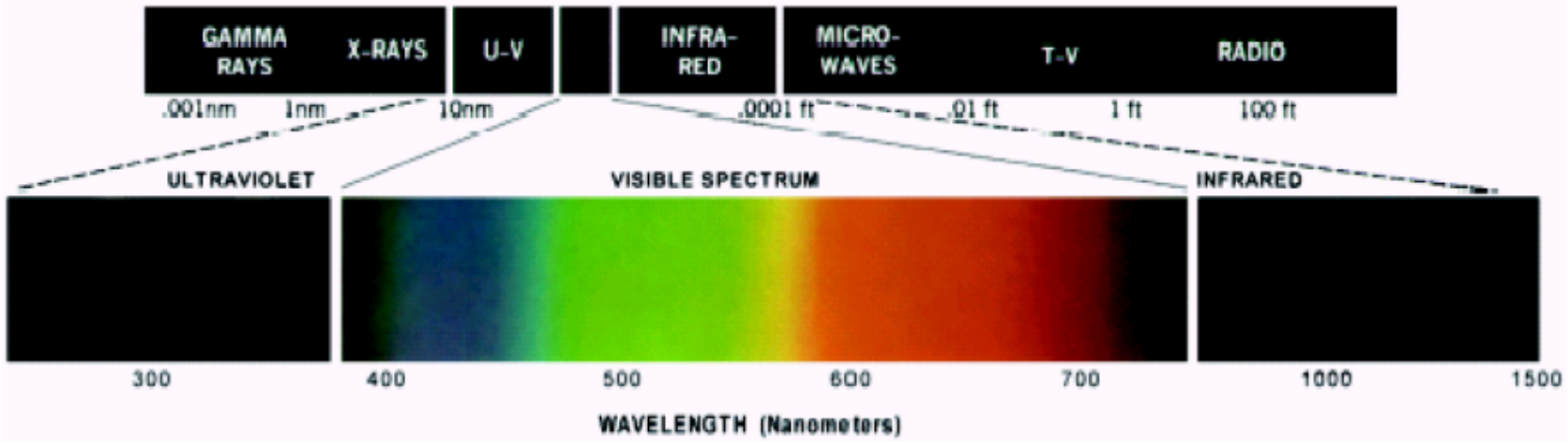
Color fundamentals

- A beam of sunlight
  - Not white
  - Consists of a continuous spectrum of colors



Color fundamentals

- Spectrum
  - The different colors in spectrum do not end abruptly
  - Each color blends smoothly into the next



Numeric color

- Importance of ***numeric color***
  - Accurate color reproduction is commercially valuable
    - Many products are identified by color
  - Few color names are widely recognized by Korean speakers
    - Other languages have fewer or more
    - It’s common to disagree on appropriate color names
  - Color reproduction problems increased by prevalence of digital imaging

Color spaces

- Purpose of a color space
  - Facilitate the specification of color in some standard fashion

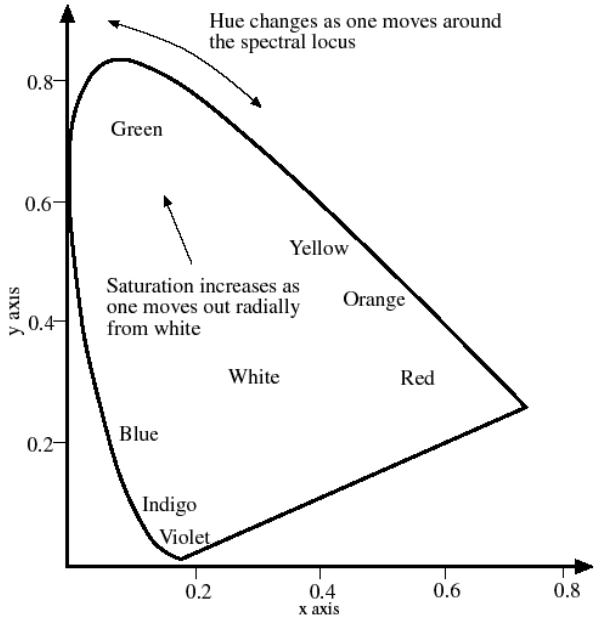
- Color space: ***3D coordinate system***
  - Use color matching functions to define a coordinate system for color
  - Each color is assigned to a triple of coordinates with respect to color spaces
  - Choice of primaries is equivalent to choice of color space

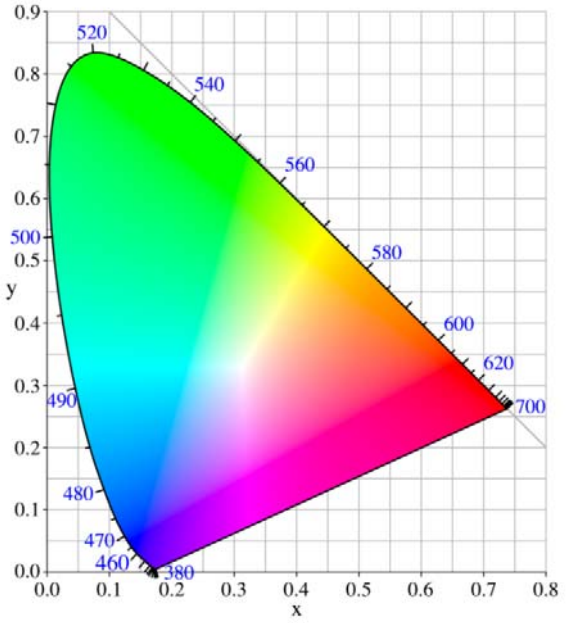
CIE color spaces

- Color is specified by its three trichromatic coefficients

$$x = \frac{X}{X+Y+Z}, \qquad \mathrm{y} = \frac{\mathrm{Y}}{X+Y+Z}, \qquad z = \frac{Z}{X+Y+Z}$$

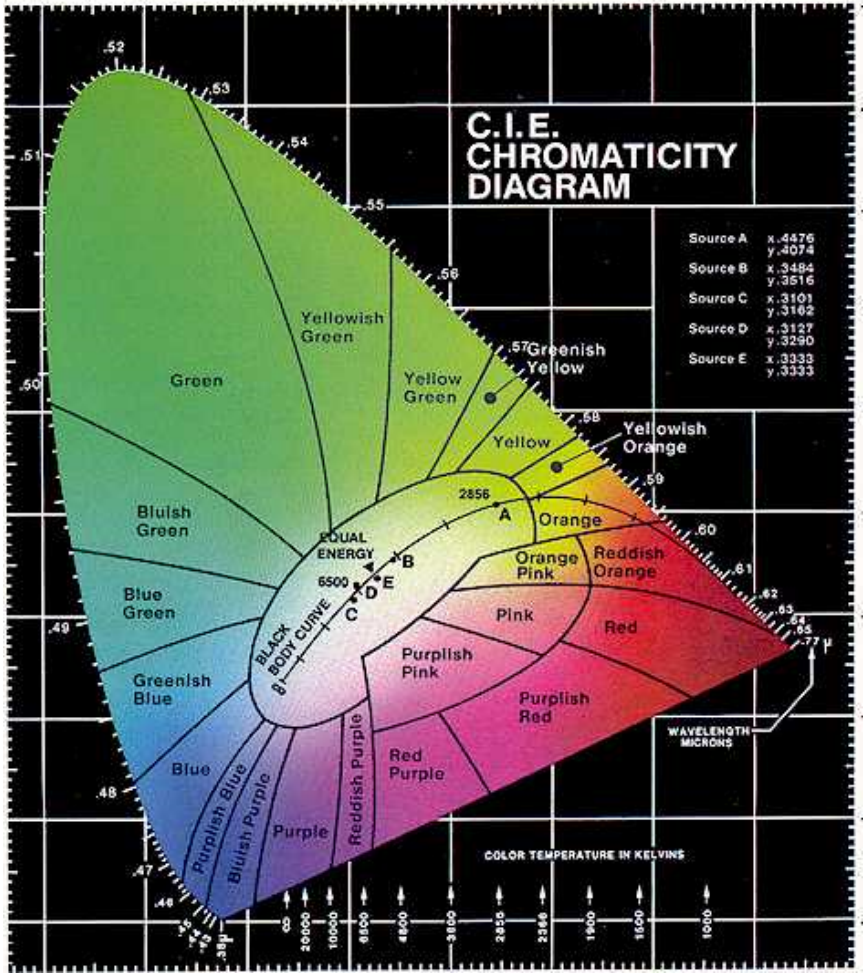
- $x + y + z = 1$ (i.e., $z = 1 - (x + y)$)





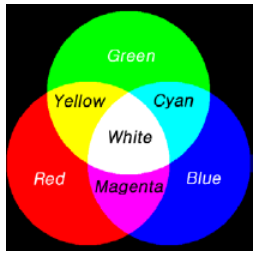
CIE color spaces

- CIE chromaticity diagram
  - Curved outer edge consists of single wavelength colors (completely saturated or “pure” colors)
  - Points inside this region represent some mixture of the pure colors
  - The point of equal energy corresponds to zero saturation

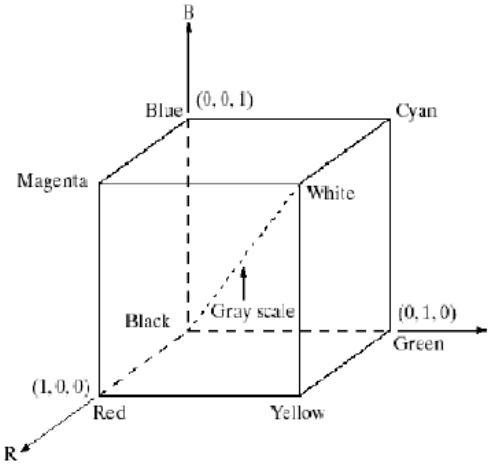


RGB color spaces

- Primaries are monochromatic energies with
  - Red (R: 645.2 nm), Green (G: 526.3 nm), Blue (B: 444.4 nm)

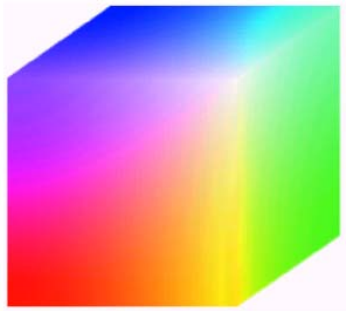


- Used mainly in color monitor and video camera



- Grayscale is represented by the diagonal joining black to white

- Additive color system
  - Colors are creased by adding components to black (0, 0, 0)

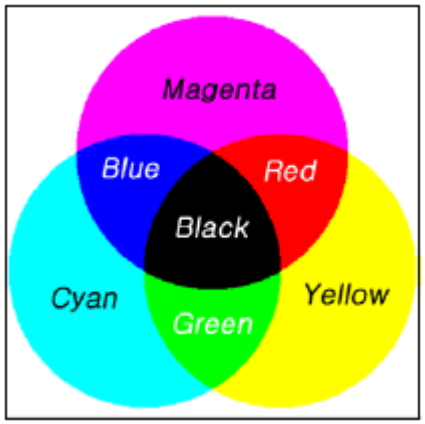


CMY color spaces

- Each color is represented by the 3 secondary color of light
  - Cyan (C), magenta (M), and yellow (Y)

- Mainly used in color printing devices that deposit color pigments

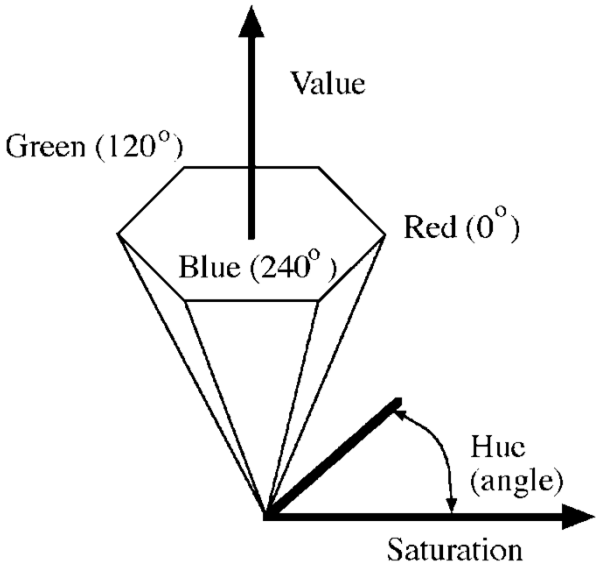
- Subtractive color system
  - It models printing on white paper and subtracts from white rather than adds to black as the RGB system does

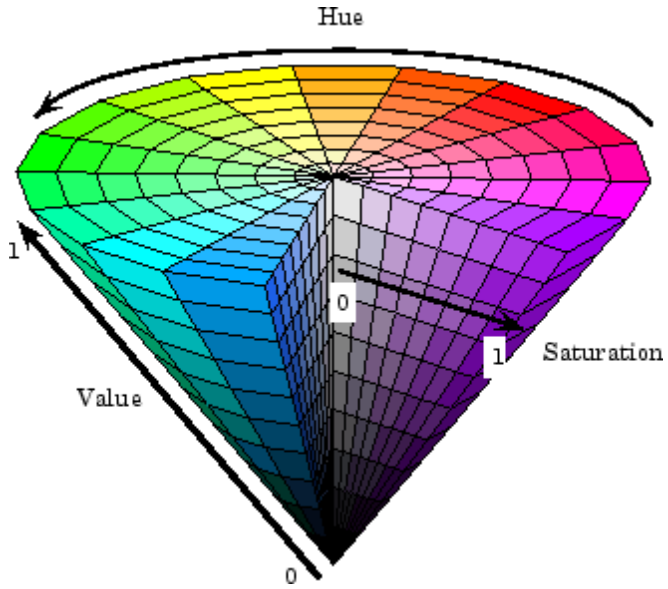


- It is related to the RGB color space: $\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$

HSV/HSI color spaces

- Each color is specified using
  - Hue (H), saturation (S), and value (V) or intensity (I)
  - Hue: Color attributes (an angle relative to the red-axis)
  - Saturation: The purity of the color or hue
  - Value or intensity: Embody achromatic notion of brightness





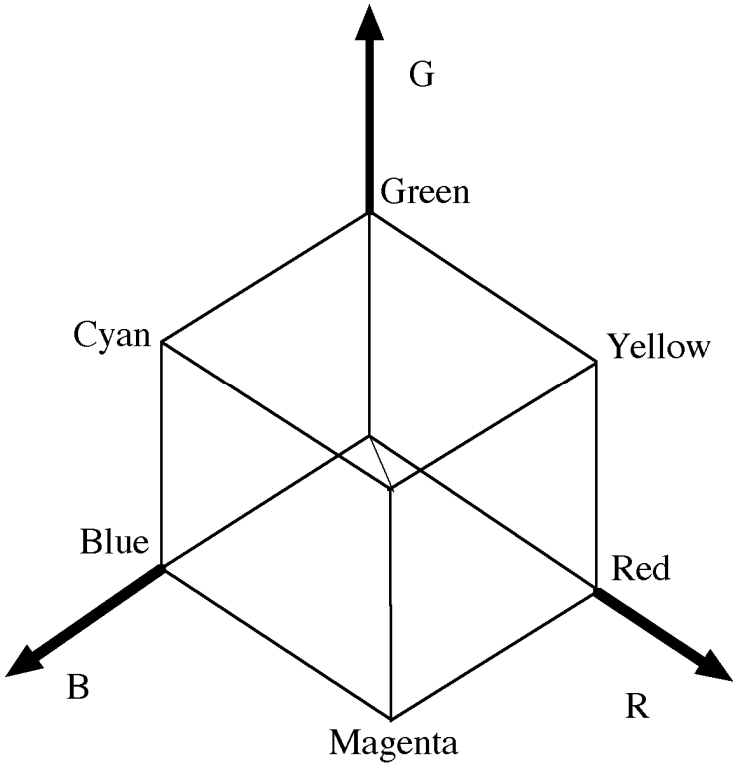
HSV/HSI color spaces

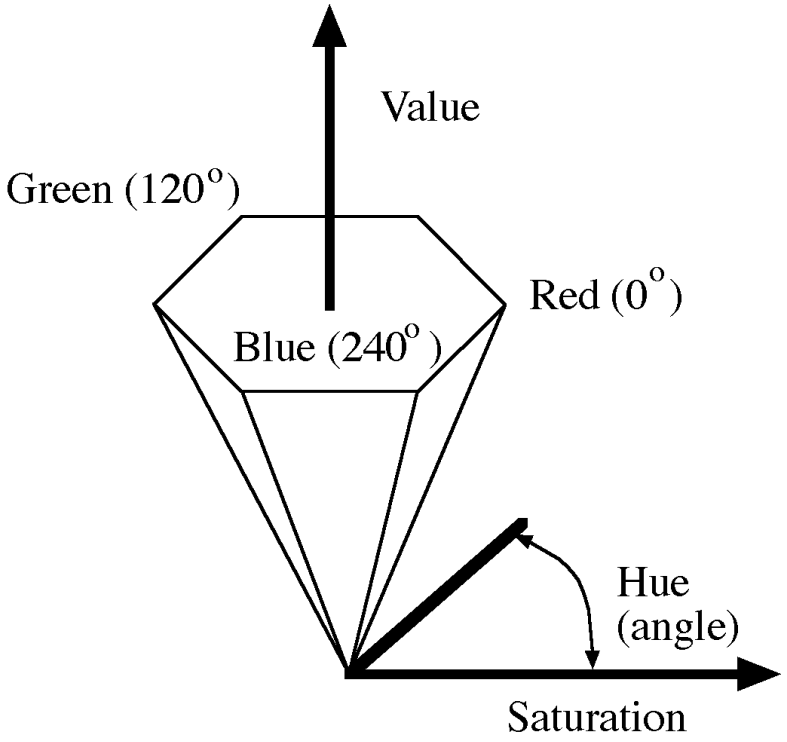
- Advantages
  - Chrominance (H, S) and luminance components are decoupled (separate color and grayscale information)
  - Hue and saturation is intimately related to the way the human visual system perceives color

- RGB & HSV
  - RGB model is suited for image color generation
  - HSV model is suited for image color perception

HSV/HSI color spaces

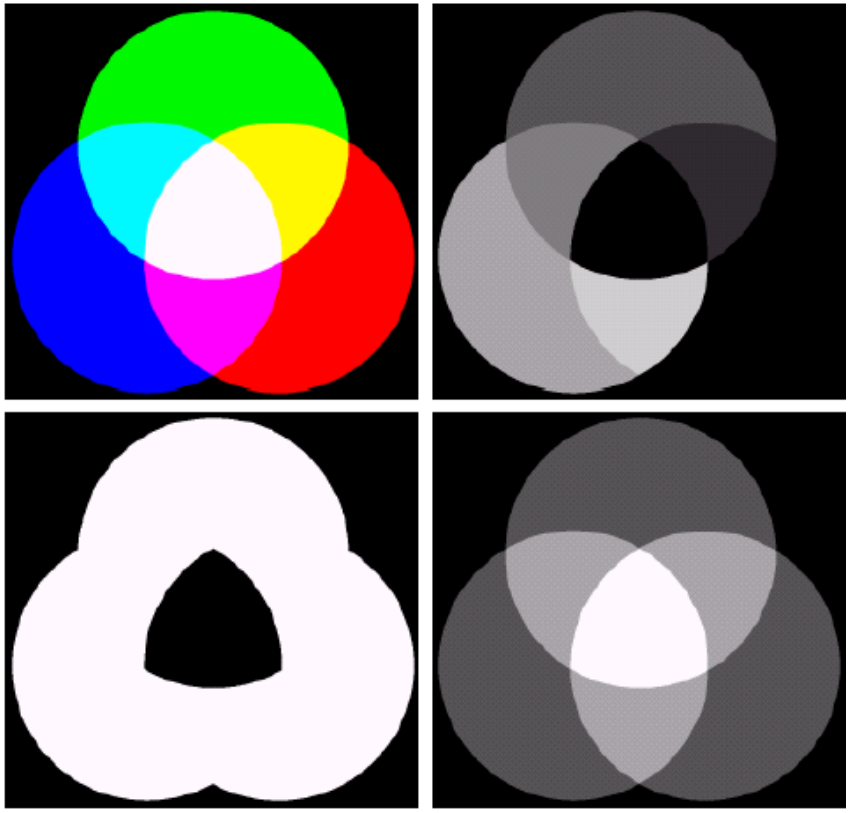
- HSV hexacone





HSV/HSI color spaces

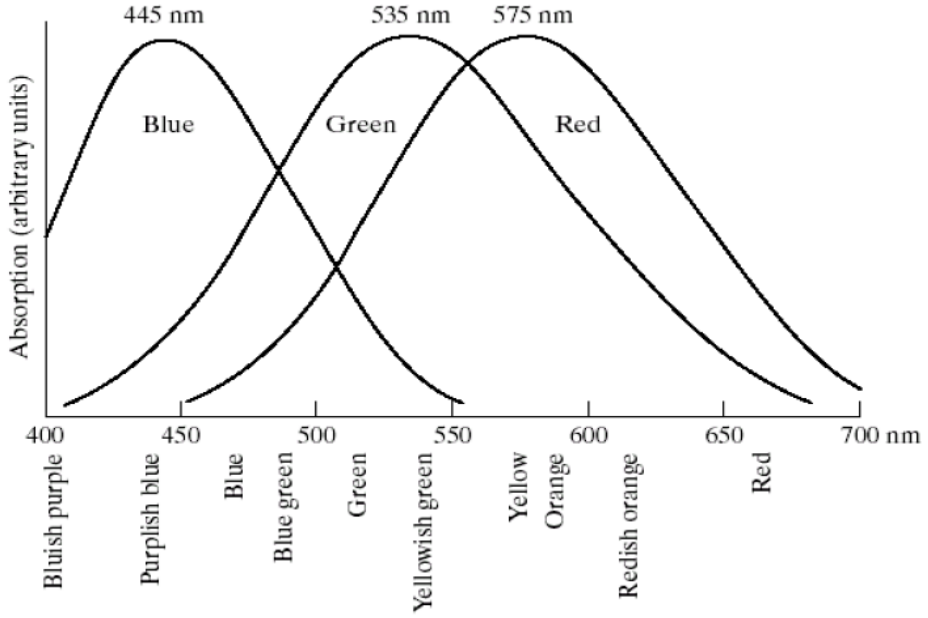
- RGB image and the components of its corresponding HSV image



Human color perception: Photoreceptors

- Visible range of human eye: 350 nm < wavelength < 780 nm

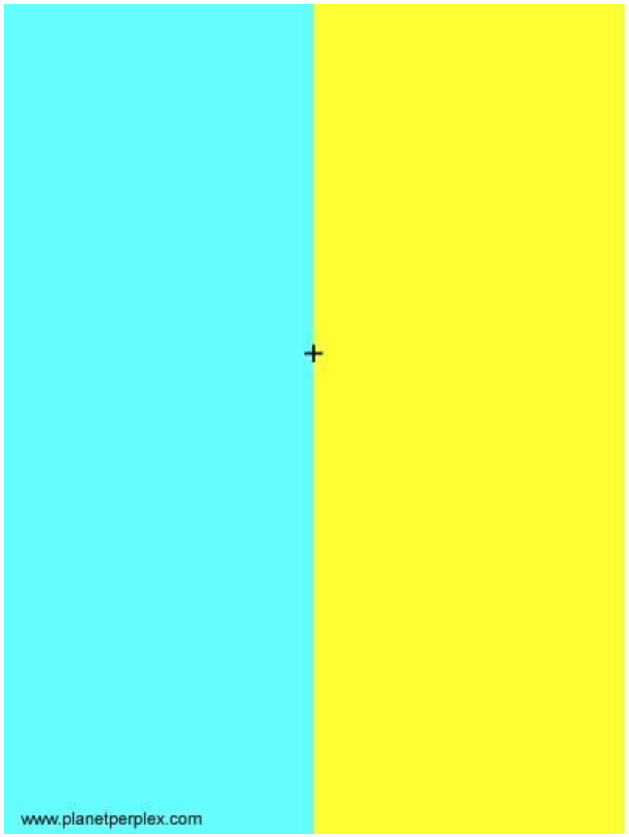
- Photoreceptors
  - Rods: 250 ~ 100 millions (luminance)
  - Cones: 6~7 millions (color vision)
    - Red sensitive cones: 65 %
    - Green sensitive cones: 33 %
    - Blue sensitive cones: 2 %



Absorption of light by the red, green, and blue cones in the human eye as a function of wavelength

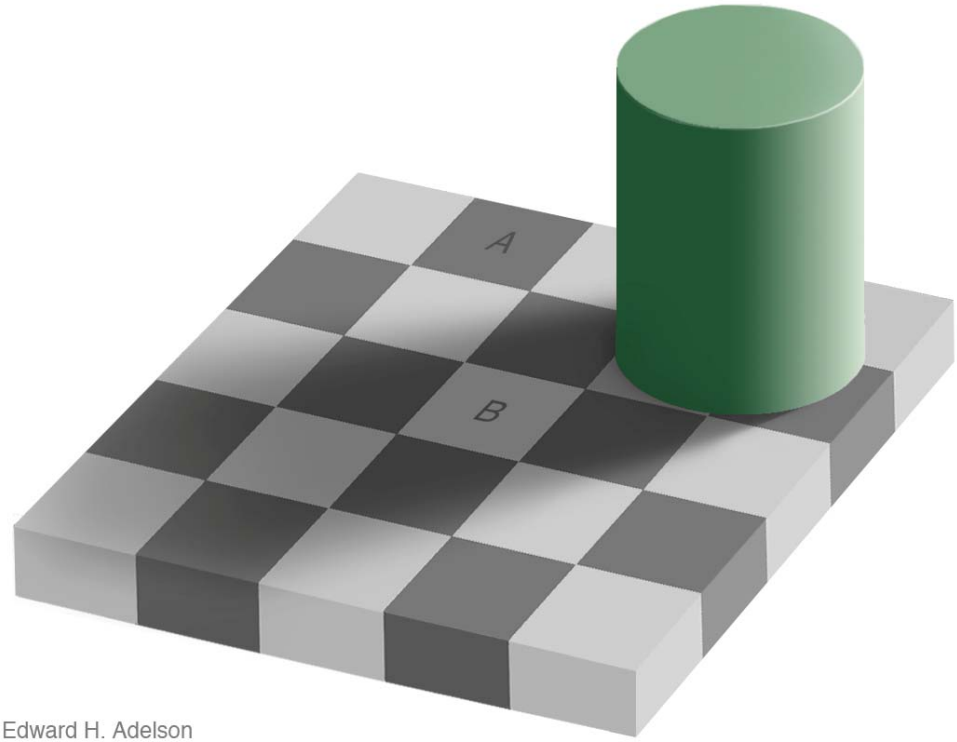
Color perception: Adaptation

- Chromatic adaptation
  - If the visual system is exposed to a certain illuminant for a while, color system starts to adapt and skew



Color perception: Adaptation

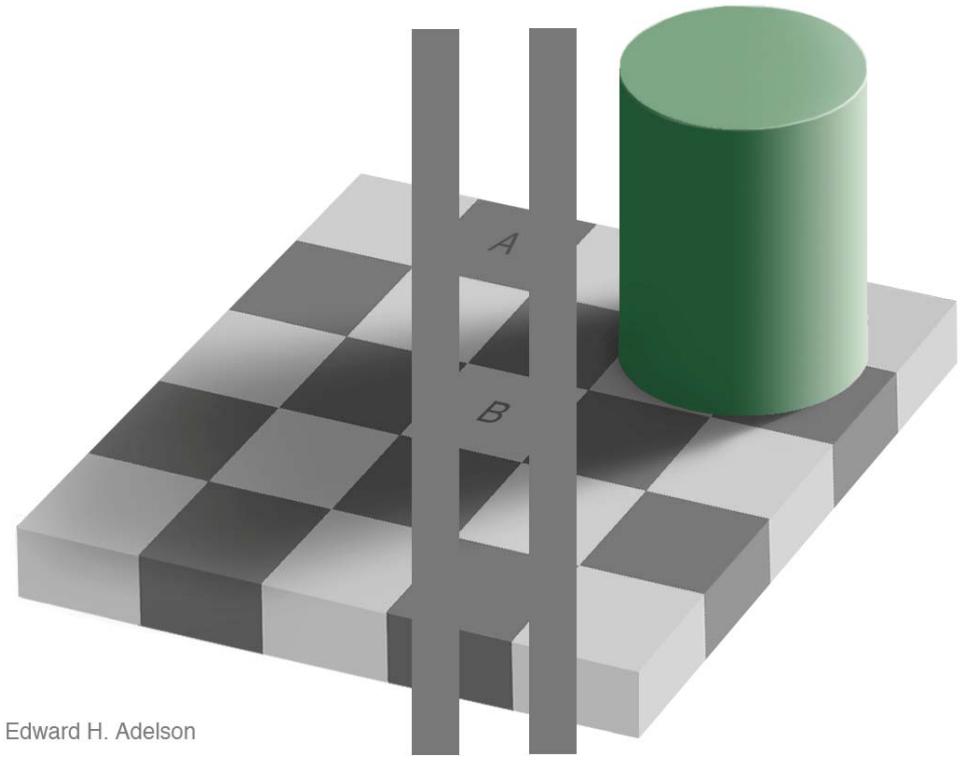
- Brightness perception



Edward H. Adelson

Color perception: Adaptation

- Brightness perception



A and B have the same color