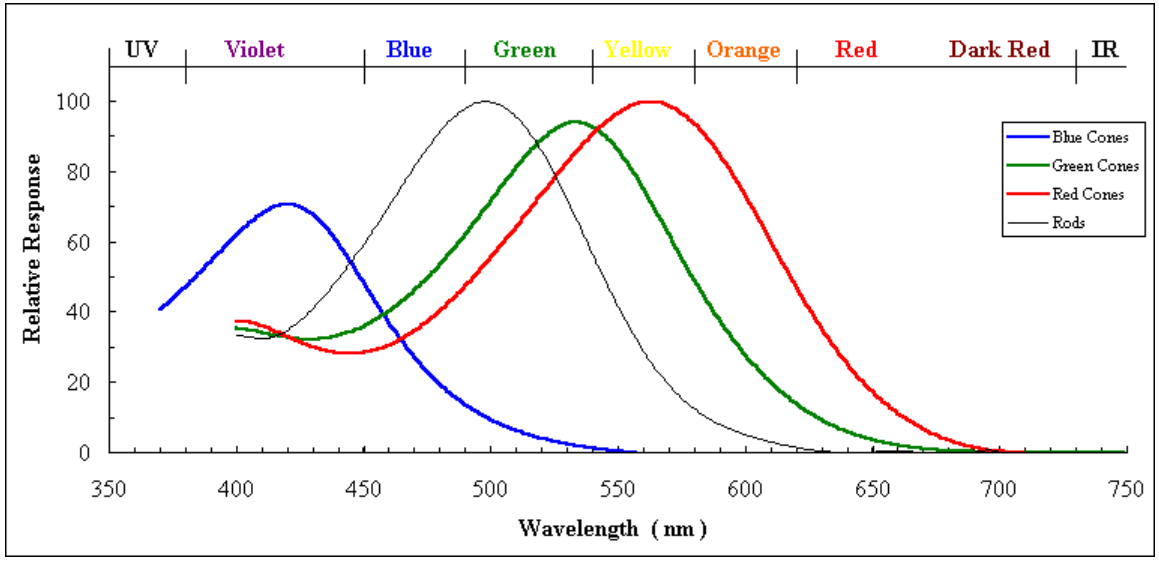
Digital Image Processing

Chapter 6
Color Space

Ming-Han Tsai
Department of Information Engineering and Computer Science,
Feng Chia University

What is Color?

- Recall：Different cones sense different wavelength light



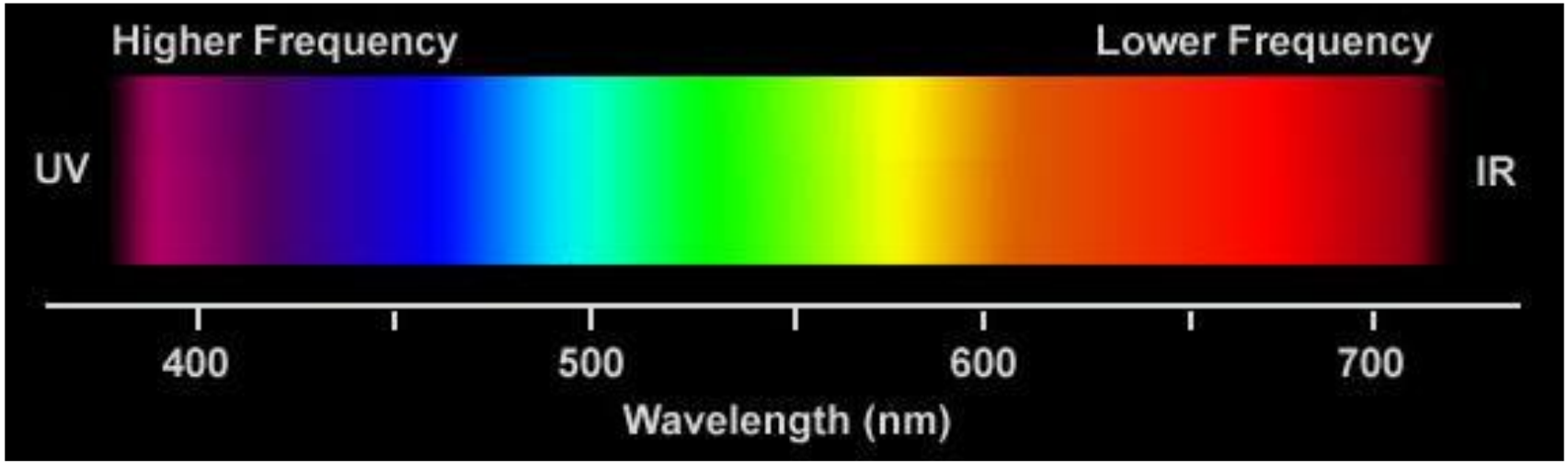
- Different wavelength -> different light color

What is Color?

- Light is produced in different amounts at different wavelengths by each light source.
- Light is differentially reflected at each wavelength, which gives objects their natural colors.
- The sensation of color is determined by the human visual system, based on the product of light and reflectance (or transmission).

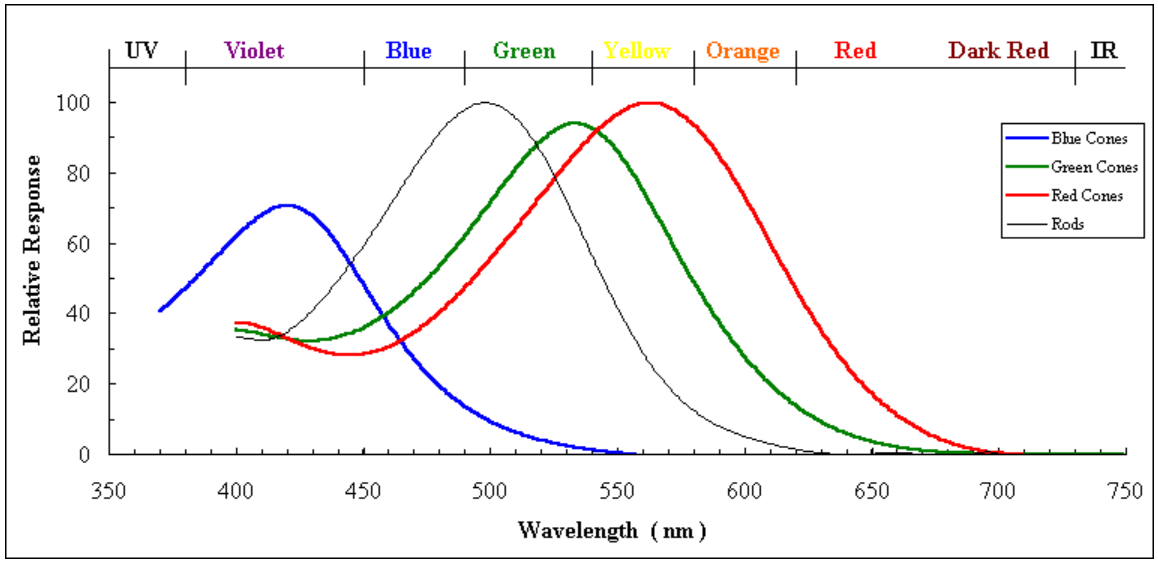
Light wavelength spectrum

- 400nm ~ 700nm
- Continuous in color changing



Color perception via cones

- 3 types: blue, green, "red" (really yellow) (or S, M, L cones)
  - each sensitive to different bands of spectrum
  - ratio of neural activity of the 3 -> color
    - other colors are perceived by combining stimulation

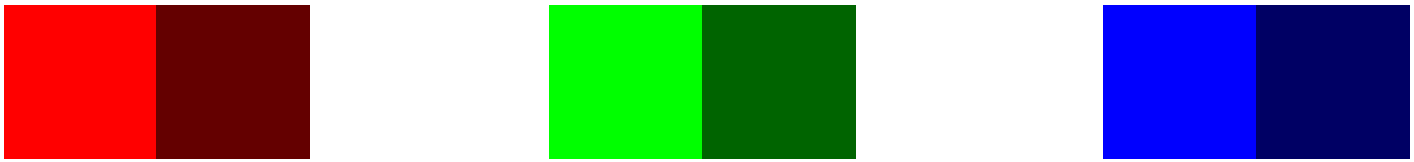


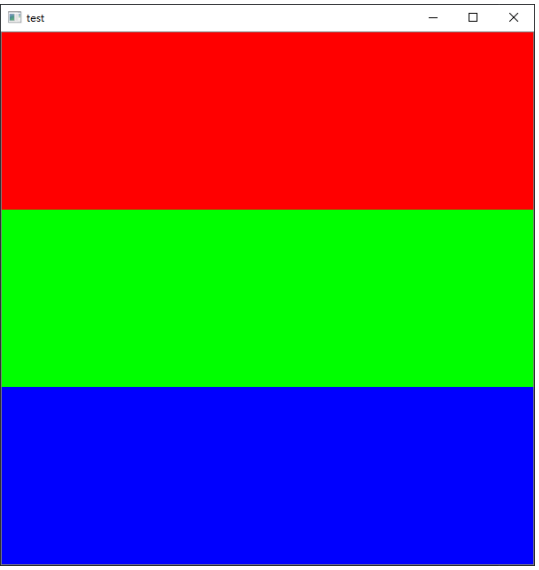
Distribution of Photopigments

- Not distributed evenly
  - mainly reds (64%) & very few blues (4%)
    - insensitivity to short wavelengths

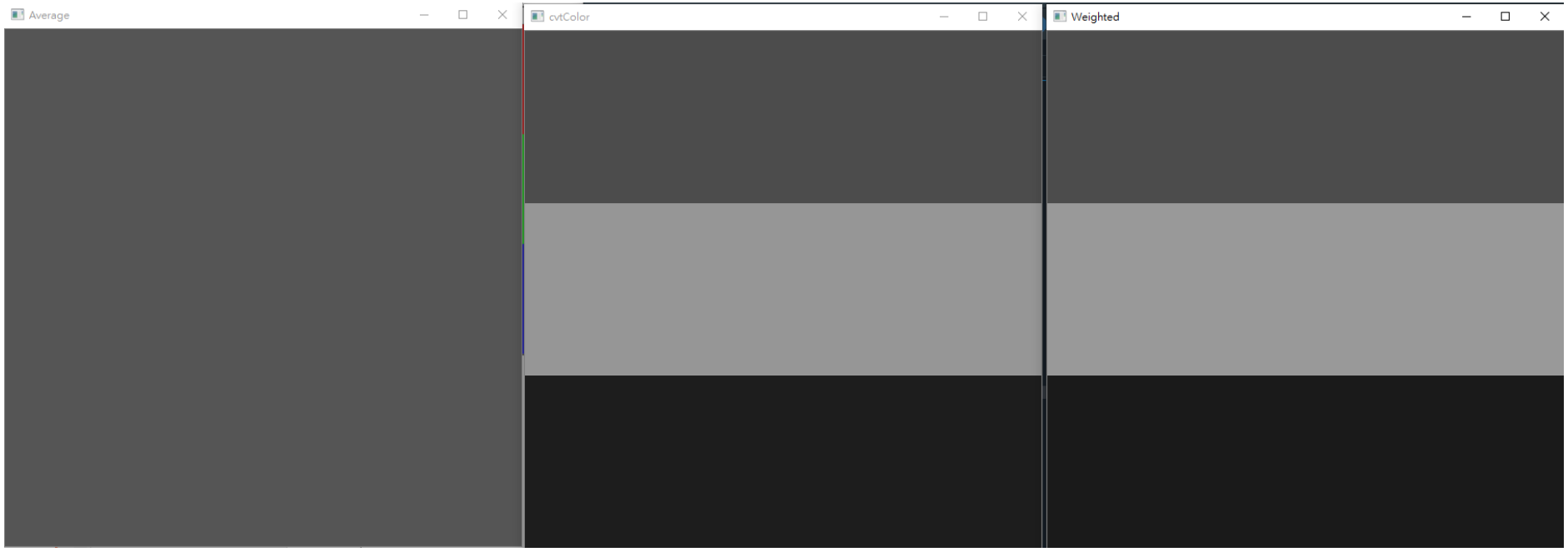
Yellow/150

- Center of retina (high acuity) has no blue cones
  - disappearance of small blue objects you fixate on
  - Boundary using different color and brightness

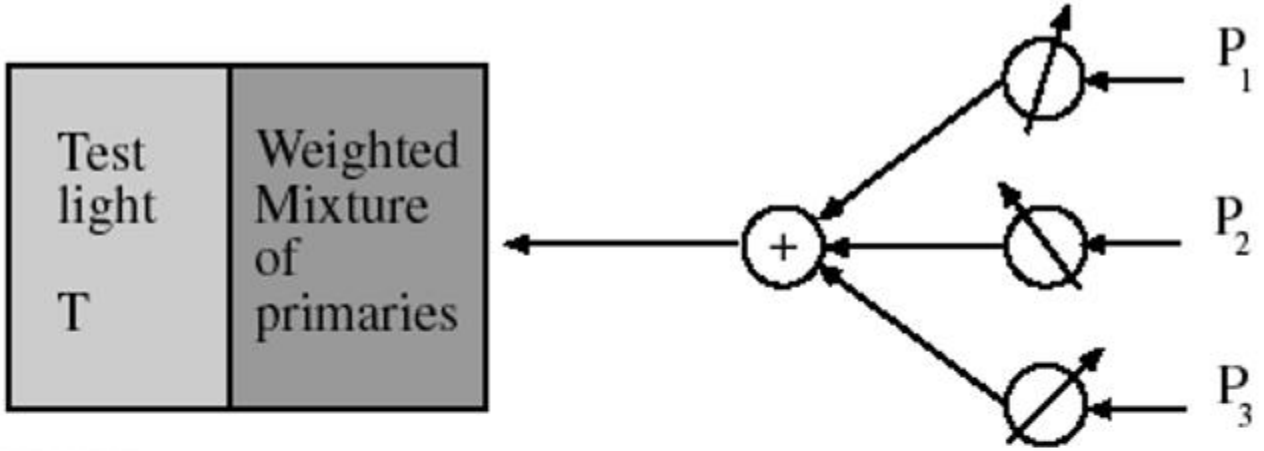


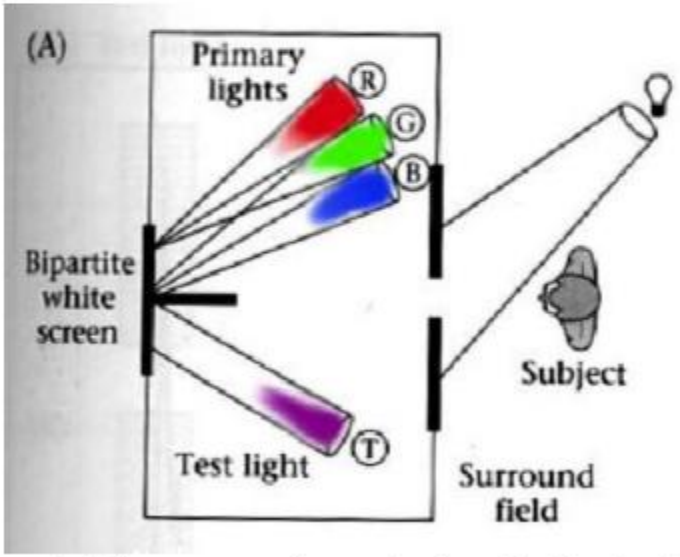


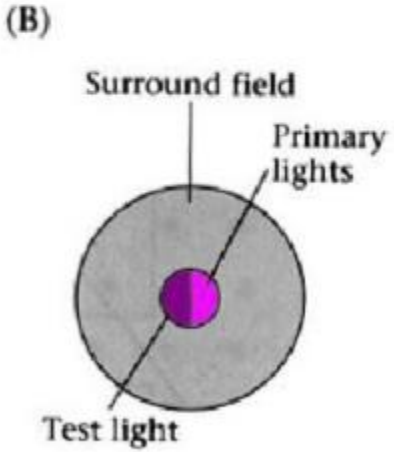

```
img1 = 1/3 *(img[:,:,0]+img[:,:,1]+img[:,:,2] )
img2 = cv2.cvtColor(img,cv2.COLOR_BGR2GRAY)
img3 = img[:,:,0]*0.1 + img[:,:,1]*0.6 + img[:,:,2]*0.3
```



Color match experiments

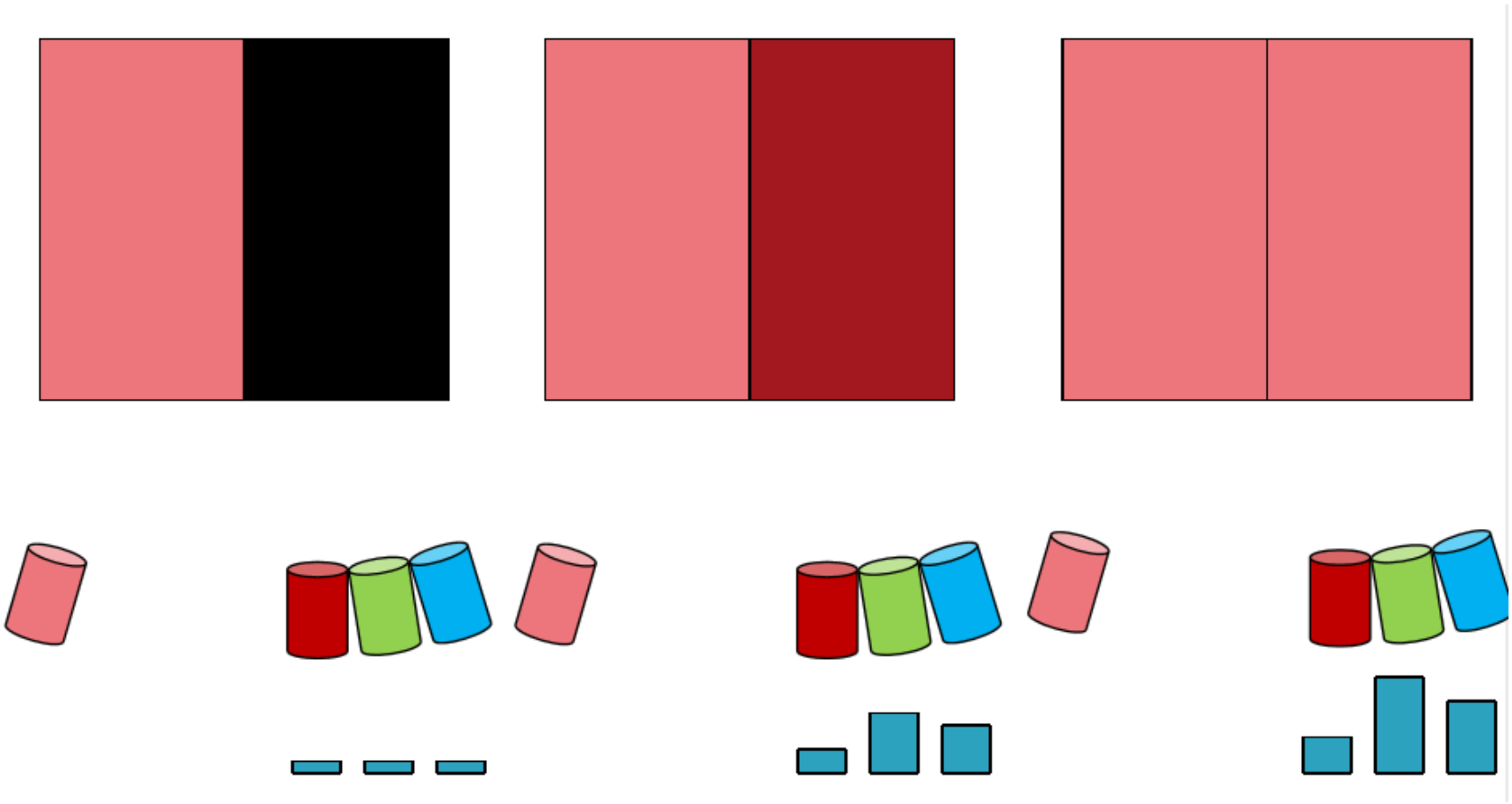






Color matching experiments imply that 3 primaries are enough for most people.

Color match experiments

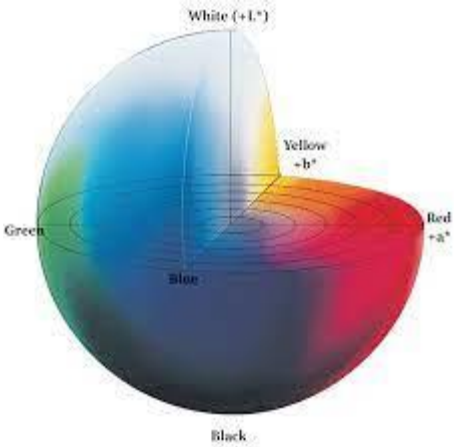


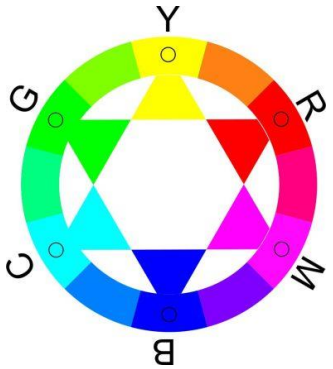
三色視覺(Trichromacy)

- Experimental facts:
  - Three primaries will work for most people if we allow subtractive matching
  - Exceptional people can match with two or only one .
  - Some elderly people may choose weights that differ from the norm.
  - Most people make the same matches.
- Color matching experiments imply that three good primaries are sufficient.

Color Space

- Use color matching functions to define a coordinate system for color.
- RGB, LAB, HSV
  - CMYK: Complementary color space of RGB
- LAB：L: intensity，AB: color
- HSV：Hue, Saturation, Value





https://irishmodernism.com/2018/04/14/ryb-rgb-cmy-wtf/

RGB color space

- R: 645.2nm, G: 526.3nm and B: 444.4nm
- visible light wavelength

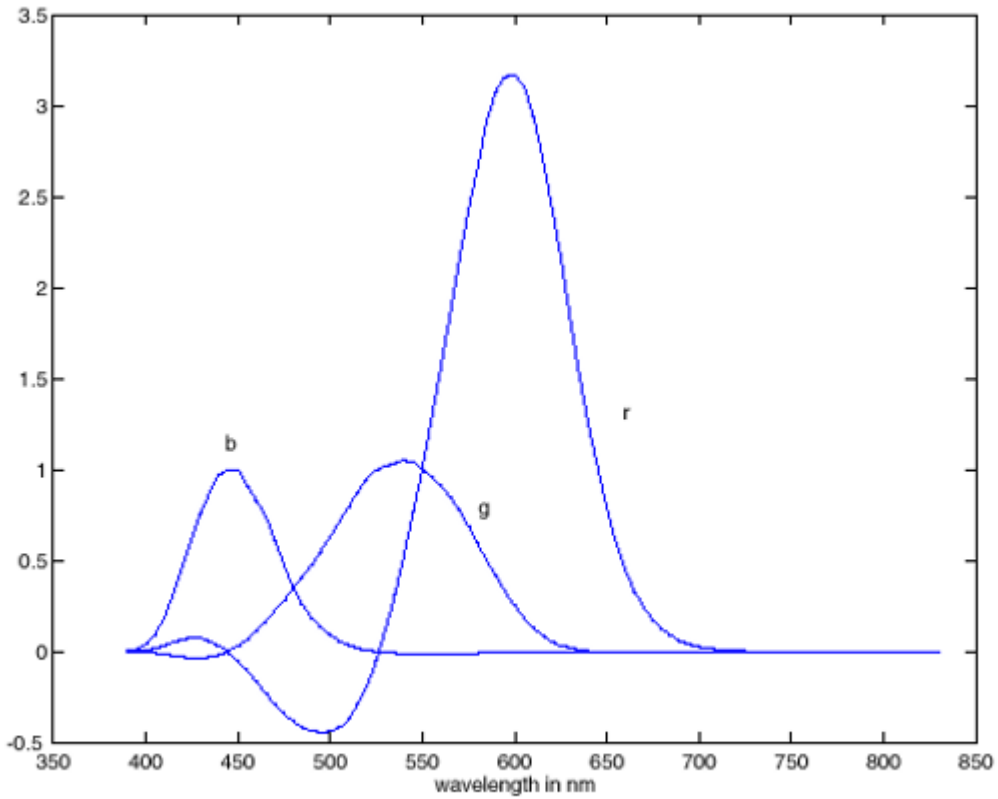
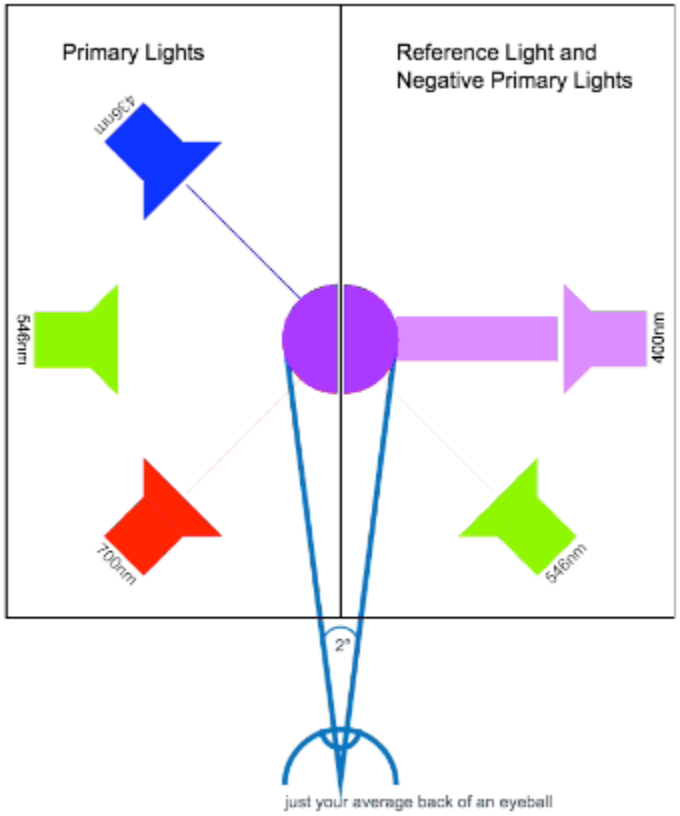
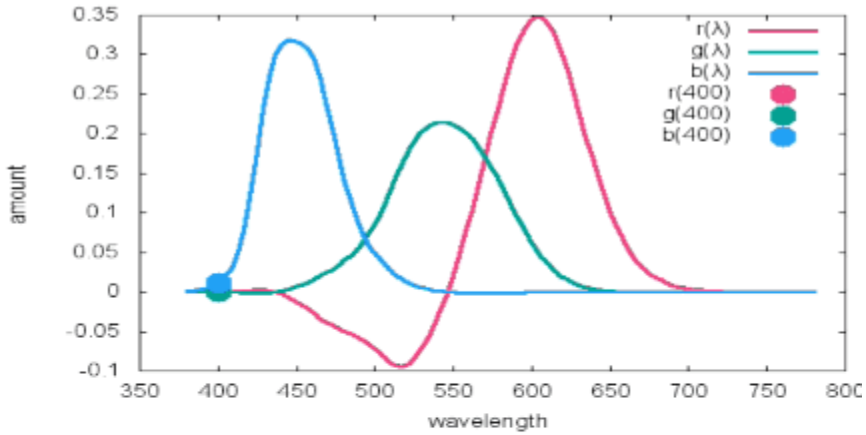


Figure courtesy of D. Forsyth

RGB color space – negative parts





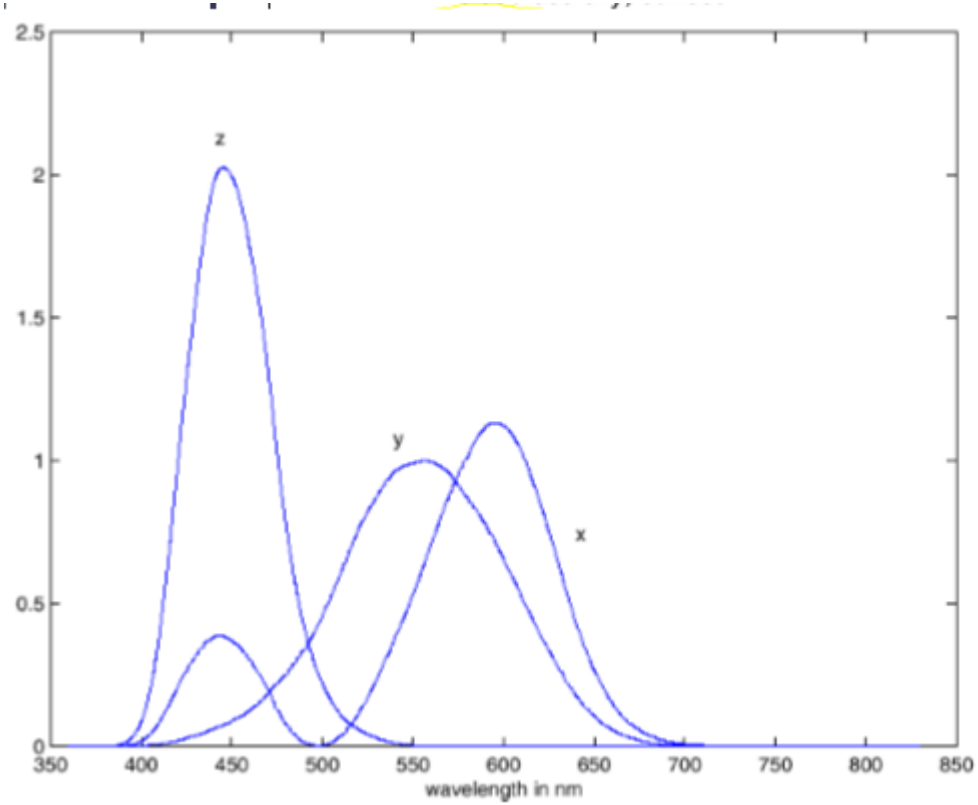
https://medium.com/hipster-color-science/a-beginners-guide-to-colorimetry-401f1830b65a

CIE XYZ color space

- CIE XYZ: define in mathematical relationships
- 3 original colors(X,Y,Z) are imaginary numbers
- Usually draw x, y, as

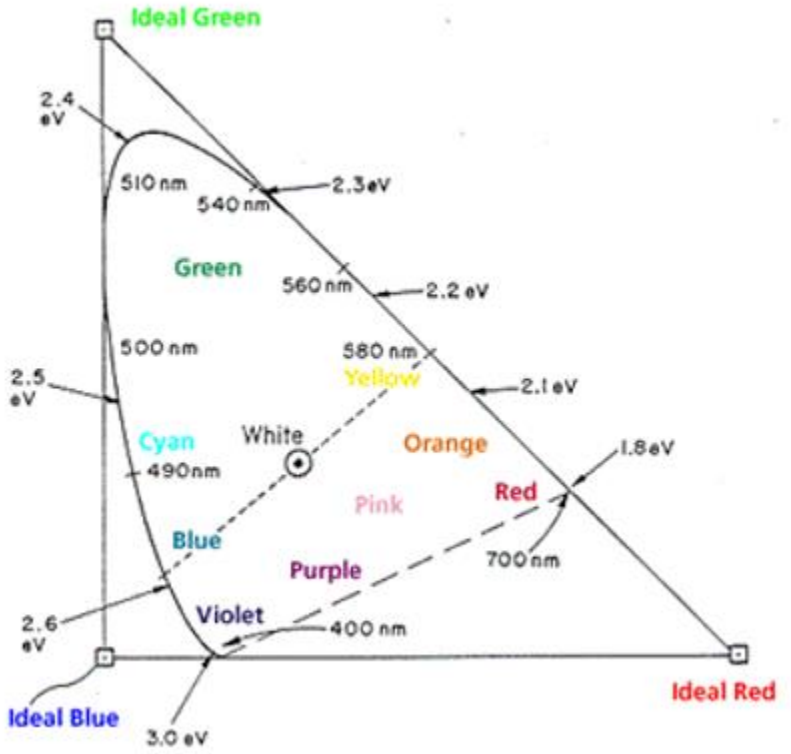
  $x = X/(X+Y+Z)$

  $y = Y/(X+Y+Z)$

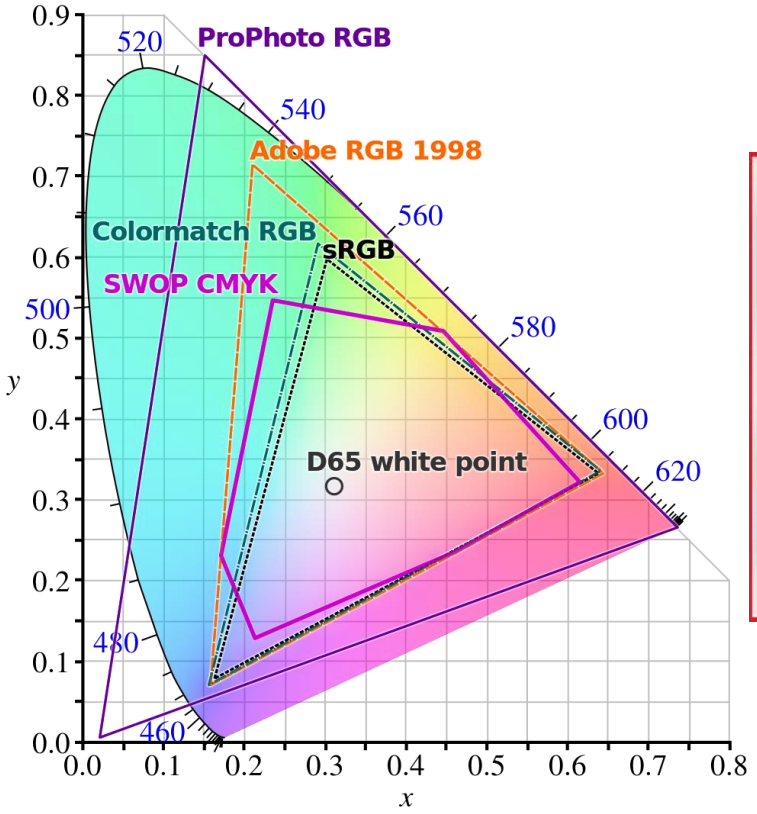


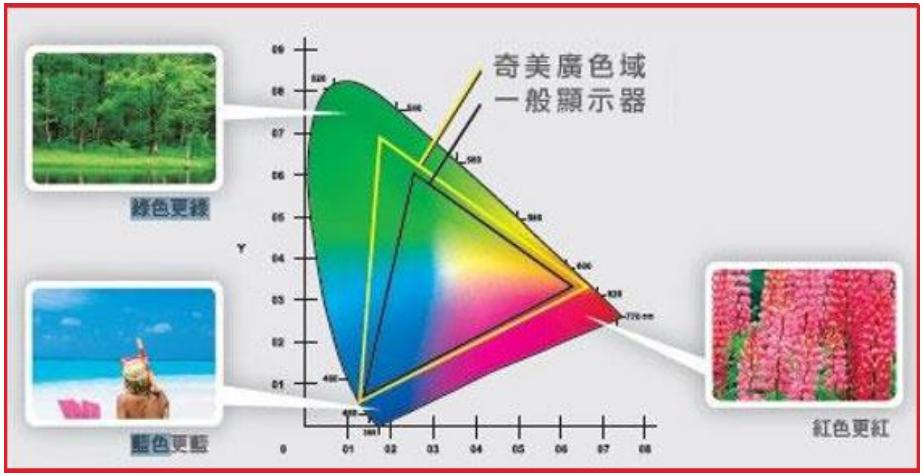
CIE xy Color space

- White is in the center
- The combination of two color is located along the line (Linear)
- Some regions cannot map to “real” color



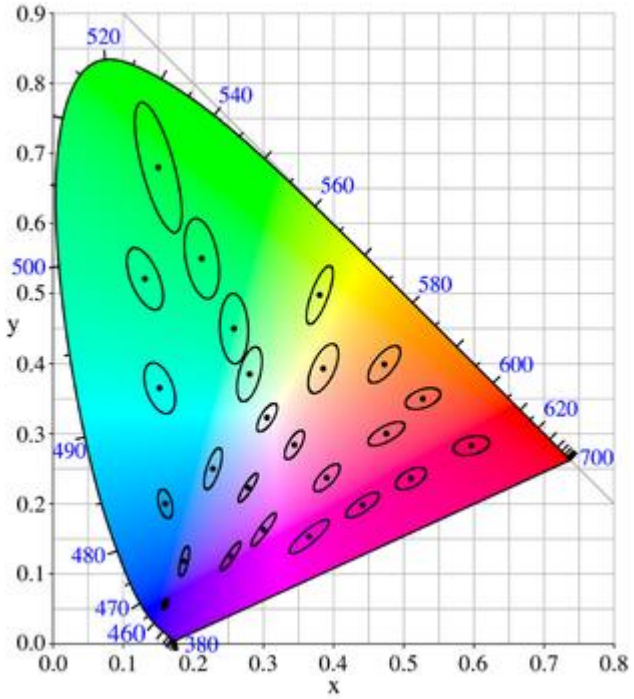
Color display



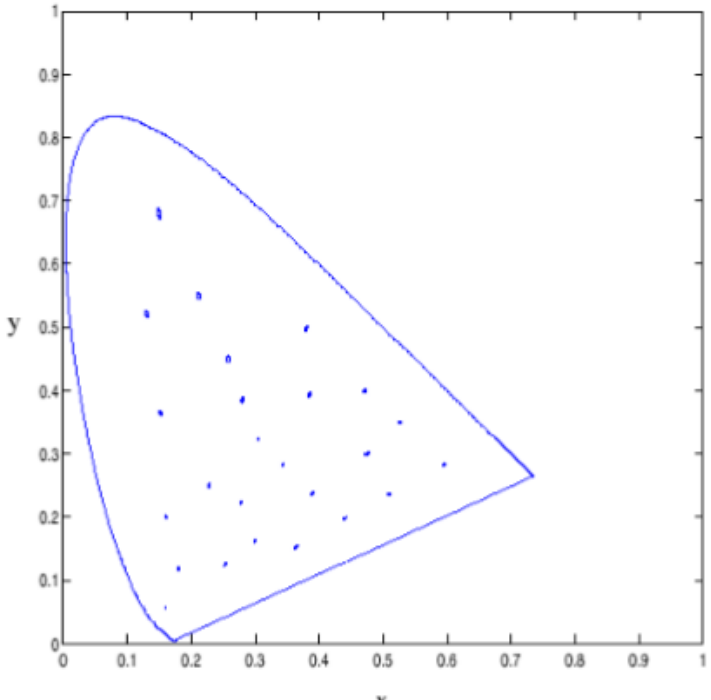


Uniform color spaces

- McAdam ellipses demonstrate that differences in x,y coordinates are a poor guide to differences in color
-



10 times of the actual size



Actual size

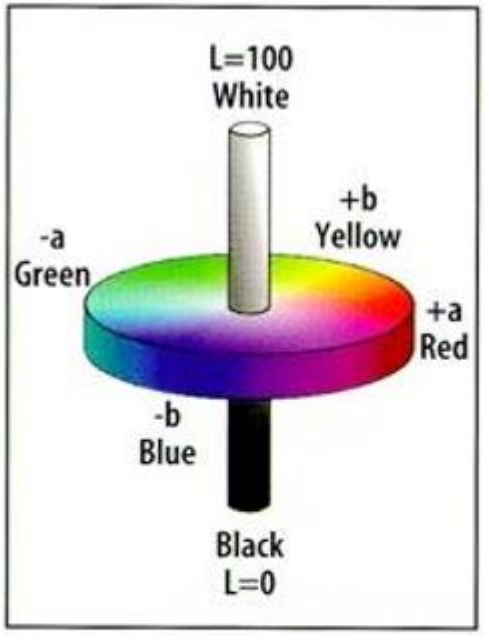
LAB color space

- CIE LAB is the most popular uniform color space

$$L^* = 116\left(\frac{Y}{Y_n}\right)^{1/3} - 16$$

$$a^* = 500\left[\left(\frac{X}{X_n}\right)^{1/3} - \left(\frac{Y}{Y_n}\right)^{1/3}\right]$$

$$b^* = 200\left[\left(\frac{Y}{Y_n}\right)^{1/3} - \left(\frac{Z}{Z_n}\right)^{1/3}\right]$$



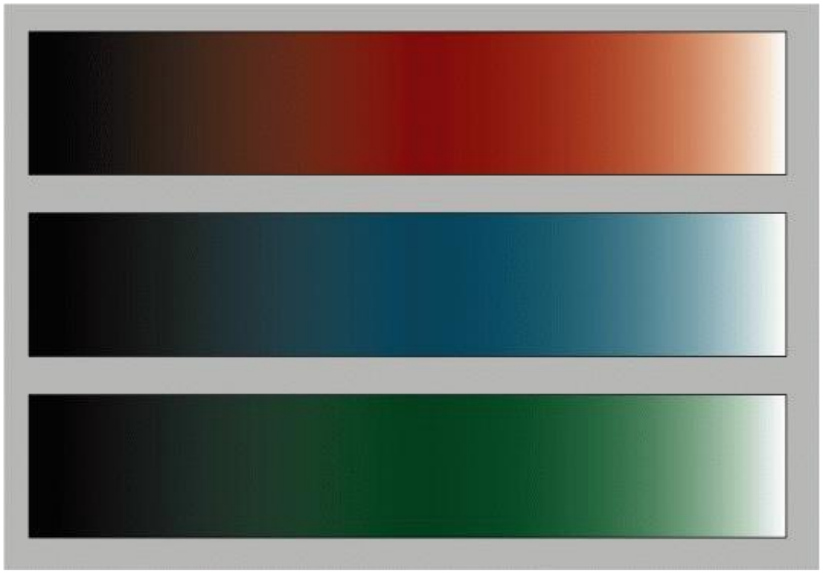
Lab model

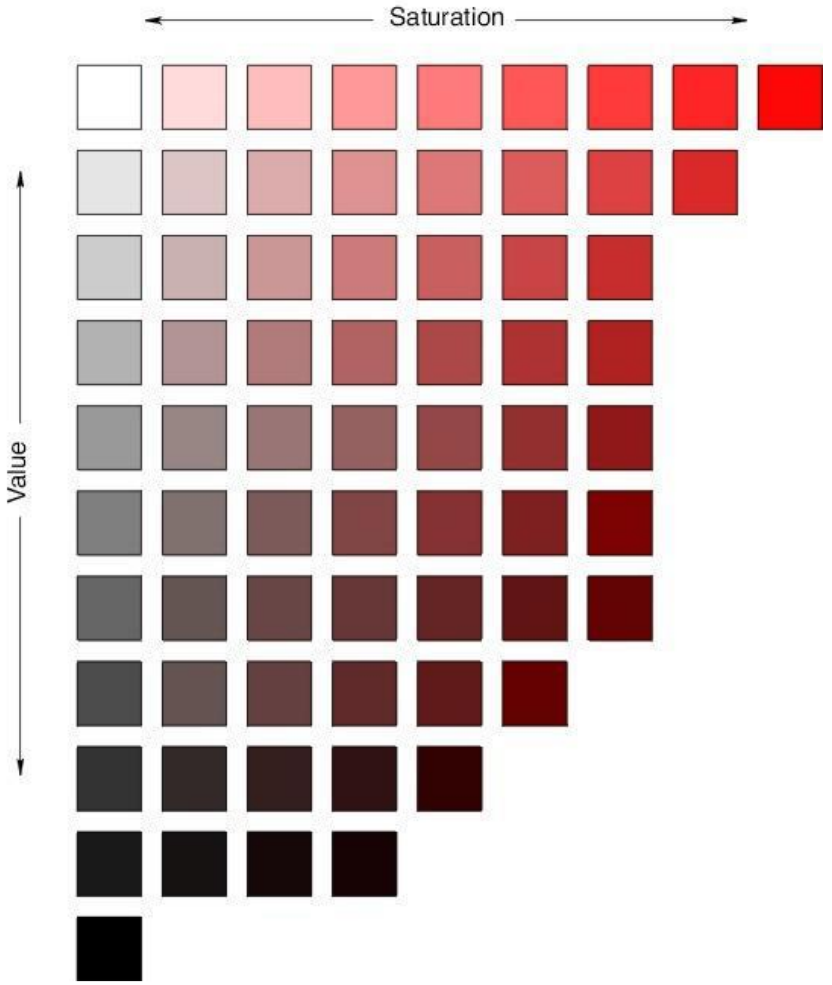
http://www.cs.sfu.ca/CC/365/mark/material/notes/Chap3/Chap3.3/Chap3.3.html

HSV Color Space

- Hue(色相)
  - The property according to the wavelength aka. color
- Lightness (or value)(明度)
  - How brightness is the color
- Saturation(飽和度)
  - How pure is the color
    - pure red, pure blue > pink, orange > white
    - Color is the mixture result of pure color and **black/white**

HSV Color Space



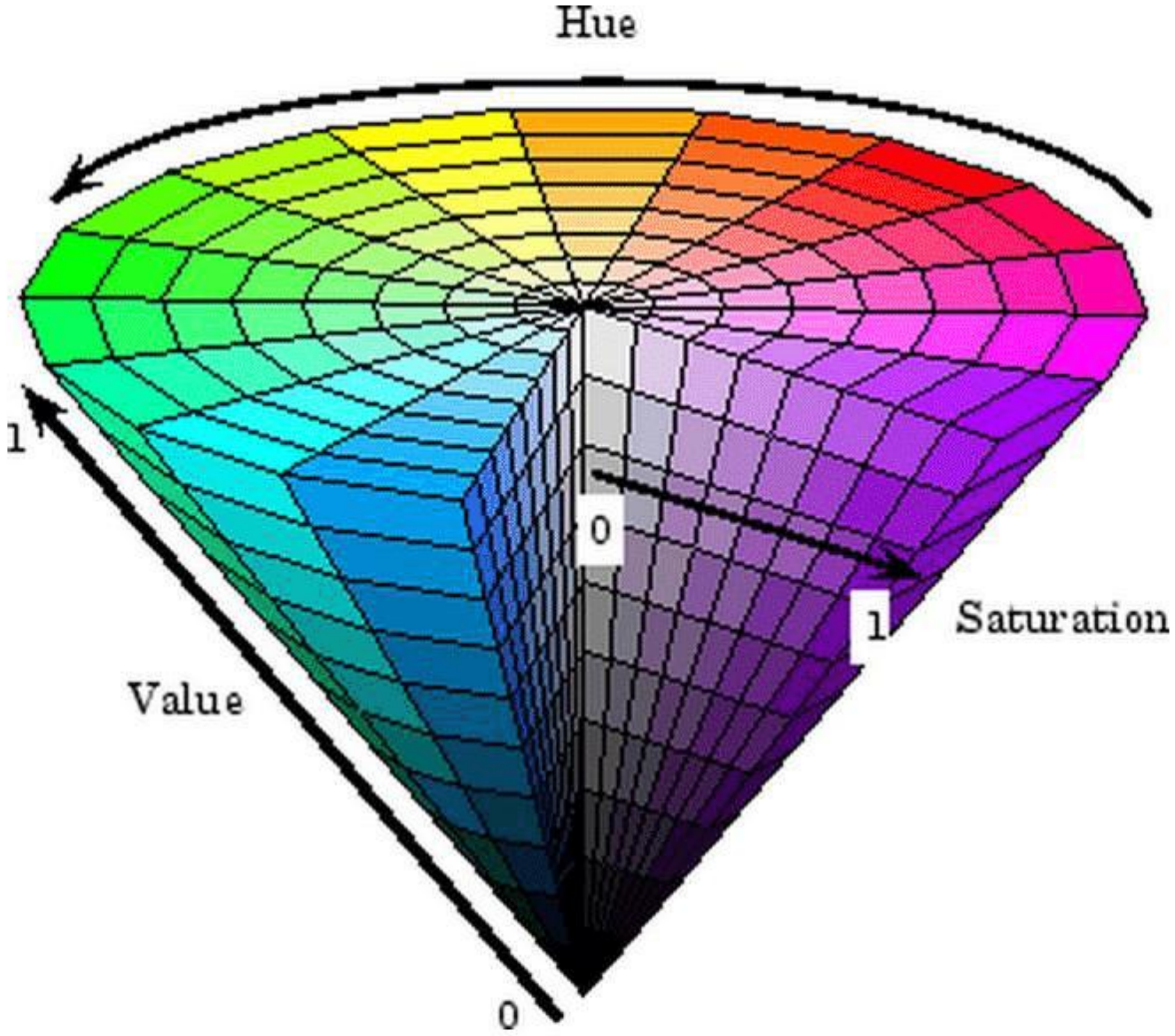


Value = Lightness

Saturation

http://www2.ncsu.edu/scivis/lessons/colormodels/color_models2.html#saturation.

HSV Color Space



HSV color space

$H \in [0 .. 360]$; $S, V, R, G, B \in [0, 1]$

$MAX = \max(R, G, B)$; $MIN = \min(R, G, B)$

$$H = \begin{cases} \text{undefined}, & \text{if } MAX = MIN \\ 60 \times \frac{G-B}{MAX-MIN} + 0, & \text{if } MAX = R \text{ and } G \geq B \\ 60 \times \frac{G-B}{MAX-MIN} + 360, & \text{if } MAX = R \text{ and } G < B \\ 60 \times \frac{B-R}{MAX-MIN} + 120, & \text{if } MAX = G \\ 60 \times \frac{R-G}{MAX-MIN} + 240, & \text{if } MAX = B \end{cases}$$

$$S = \begin{cases} 0, & \text{if } MAX = 0 \\ 1 - \frac{MIN}{MAX}, & \text{otherwise} \end{cases}$$

$$V = MAX$$

原始影像

R 通道

G 通道

B 通道

圖 8-4　RGB 色彩模型

原始影像

H 通道

S 通道

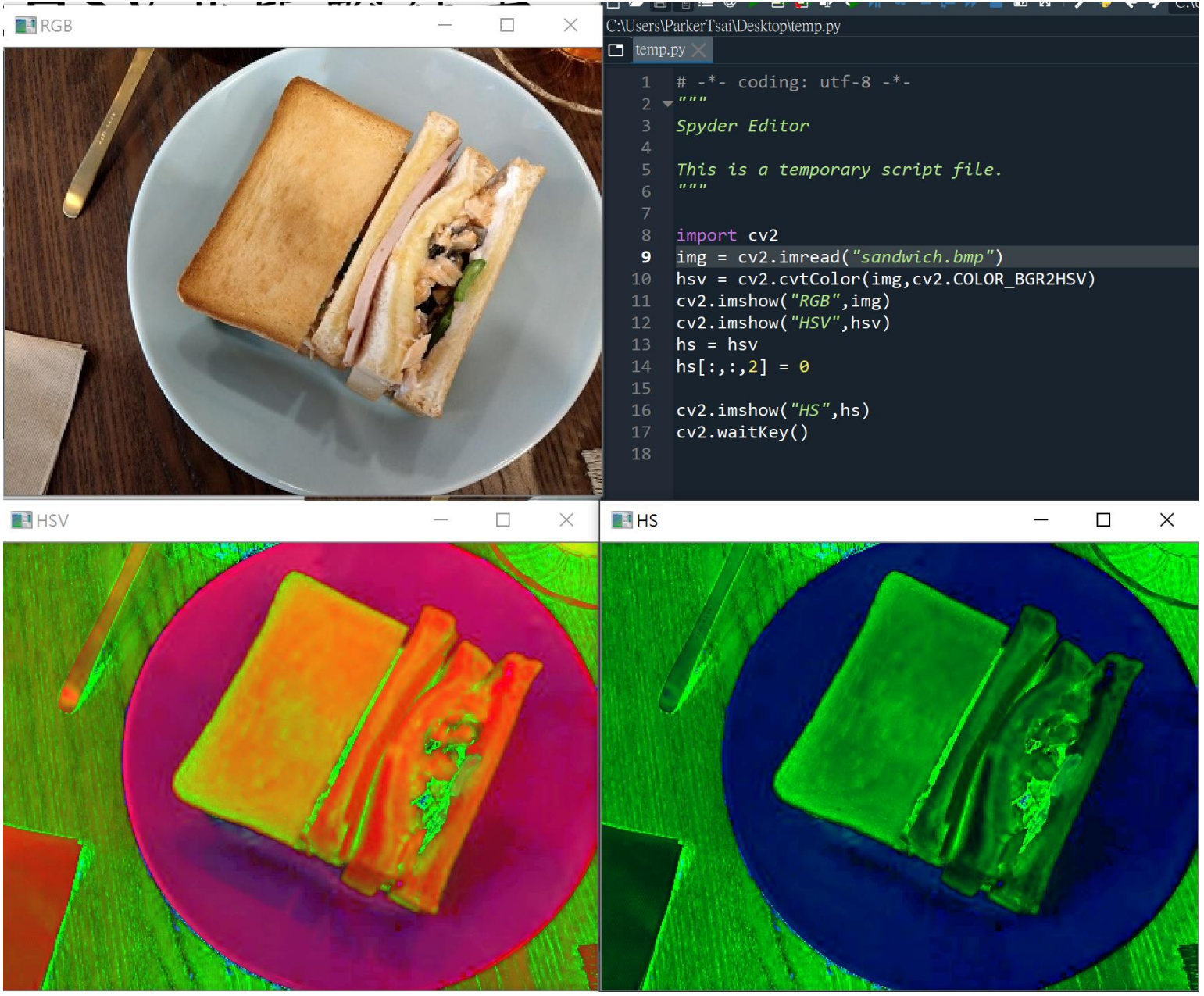
V 通道

圖 8-9　HSV 色彩模型

8-6 HSV 色彩分割

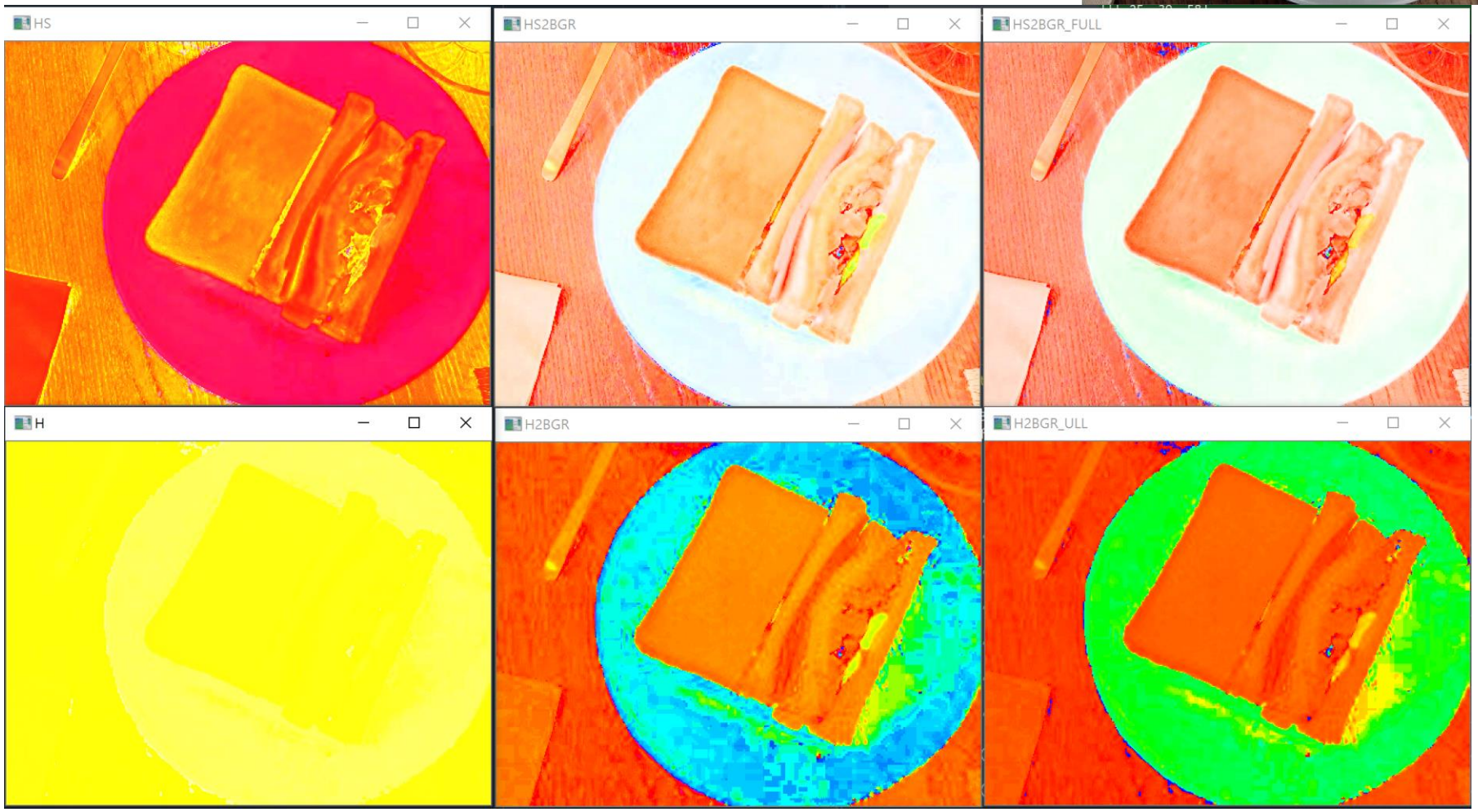
原始影像　　色彩分割 (黃色)

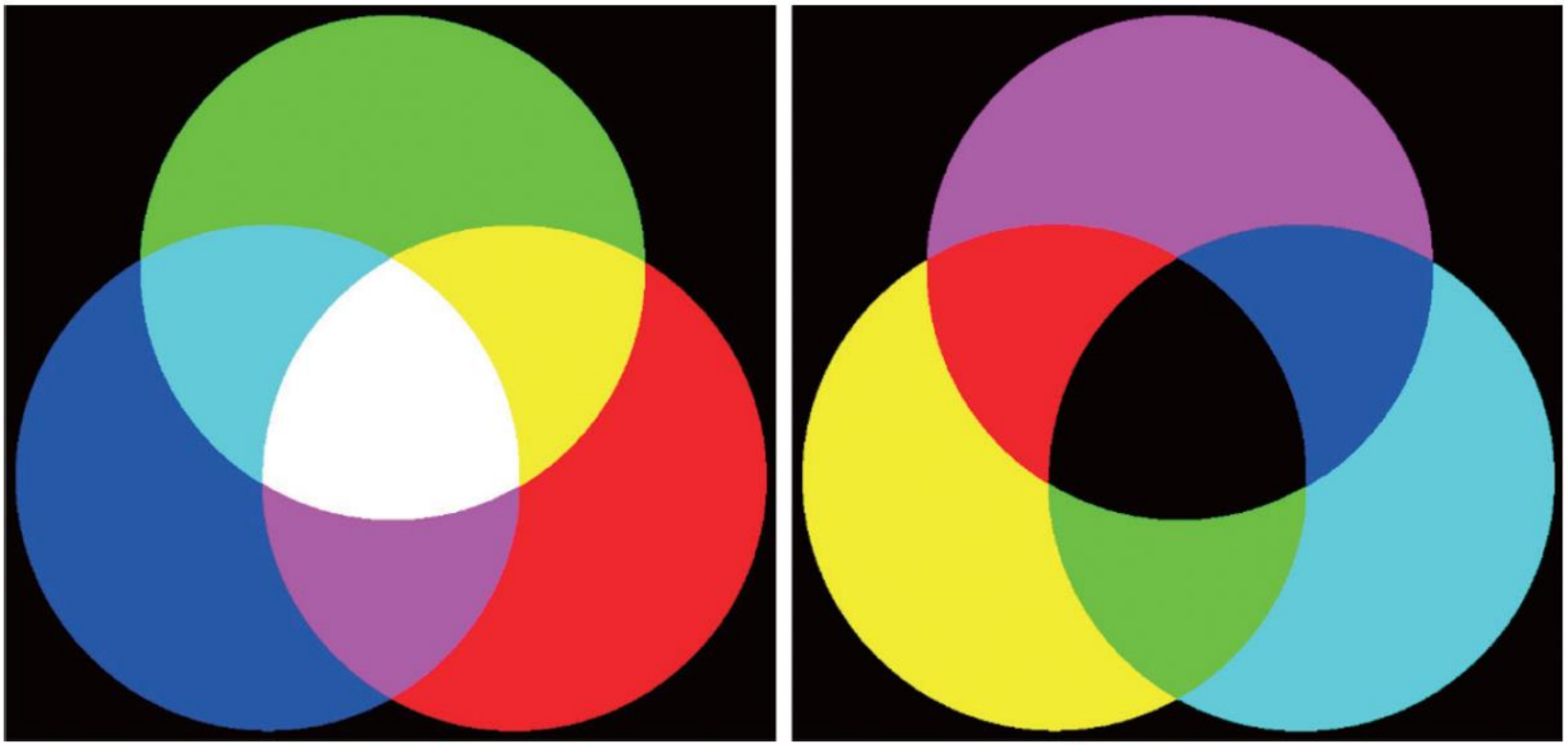
圖 8-18　HSV 色彩分割



For equation:
https://docs.opencv.org/3.2.0/de/d25/imgproc_color_conversions.html

上：V=255　下：S=V=255



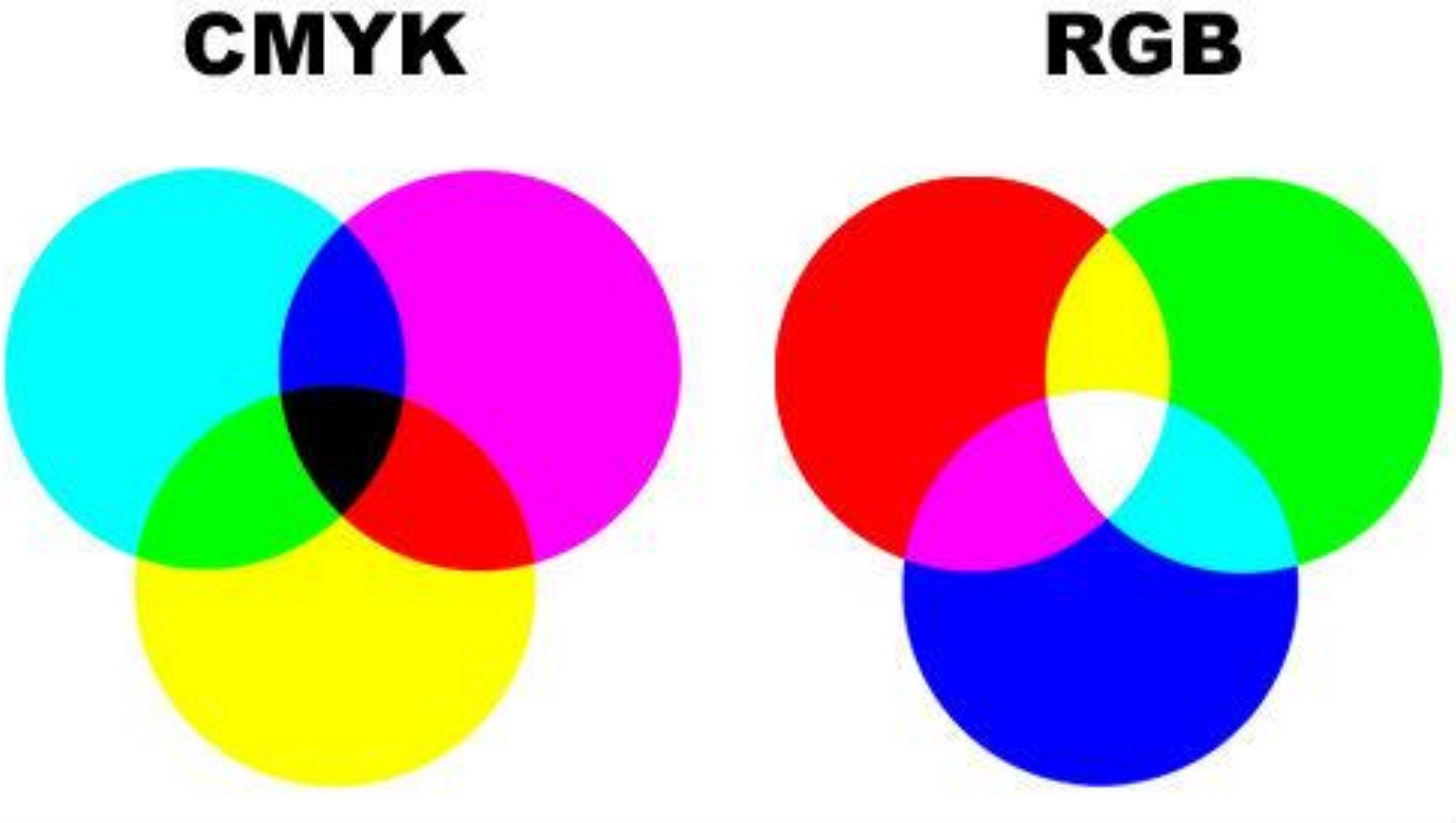


光的混合　　顏料的混合

圖 8-2　光或顏料的混合

RGB(Additive)vs. CMYK(Subtractive)

- Cyan(青色), Magenta(洋紅), Yellow(黃), Key(Black)



色調與色彩之修正

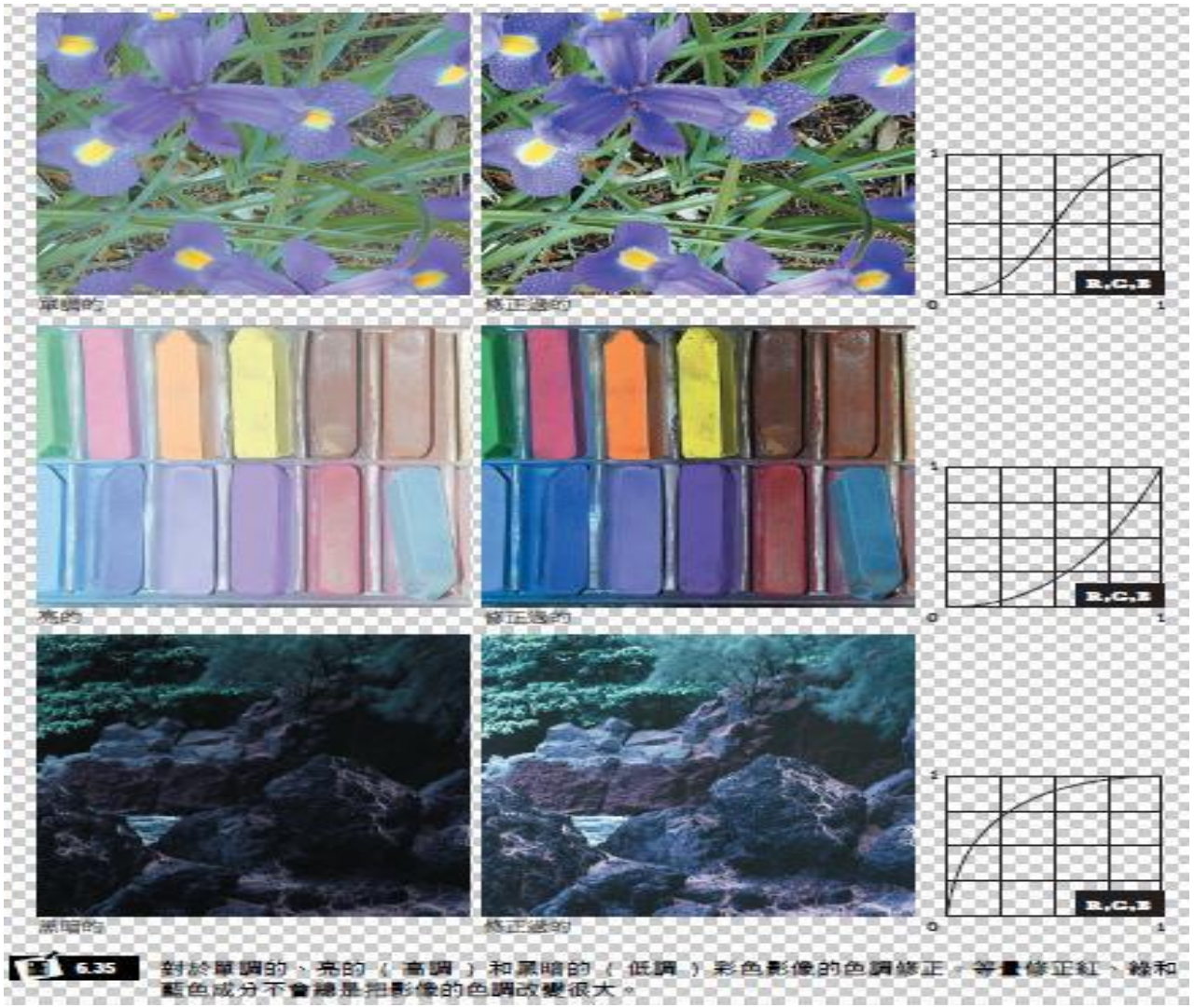


圖 6.35 對於單調的、亮的（高調）和黑暗的（低調）彩色影像的色調修正。等量修正紅、綠和藍色成分不會總是把影像的色調改變很大。