

# Lecture 5 – Image Color

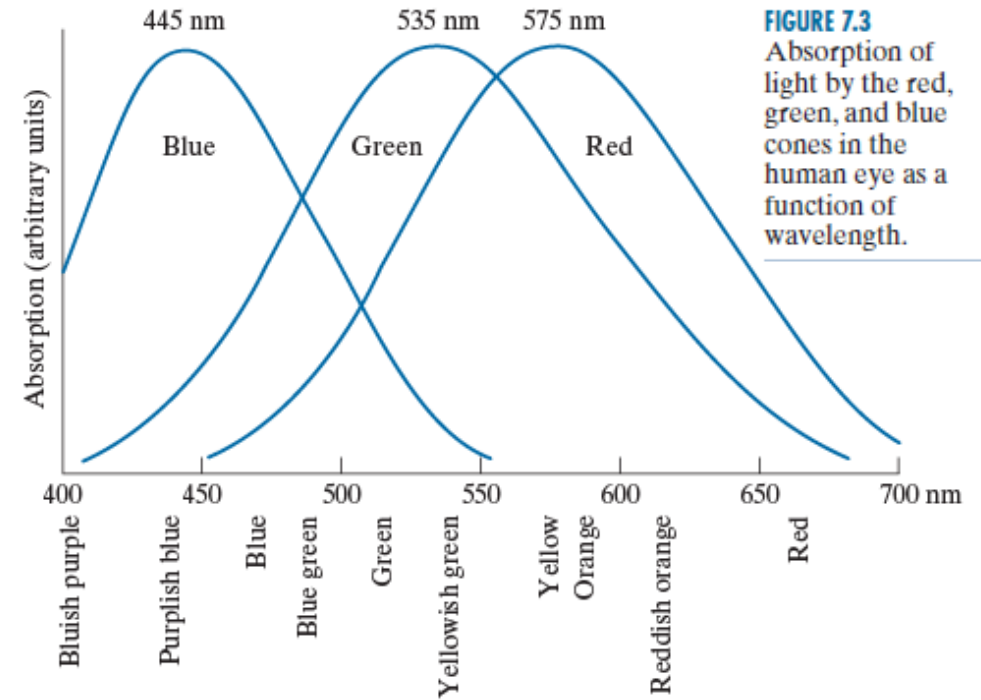
This lecture will cover:

- **Color fundamentals**
  - Primary colors
  - Secondary colors
- **Color models**
  - RGB model
  - CMY and CMYK model
  - HSI model
- **Color transformation**

# Primary colors (原色)

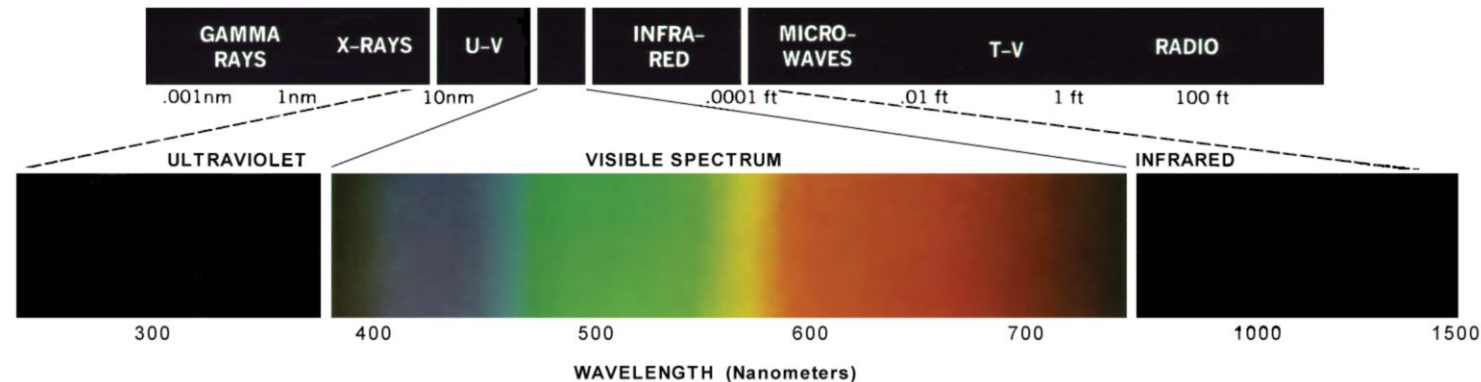
## ➤ Three basic quantities to describe the quality of chromatic light source:

- Radiance (辐射): the total amount of energy from the light source, in watt
- Luminance (光强): the amount of energy perceived by an observer, in lumen
- Brightness (亮度): achromatic notion of intensity, subjective descriptor, key factor in describing color sensation.



## ➤ CIE RGB Standard

- Blue = 435.8 nm
- Green = 546.1 nm
- Red = 700 nm



# Secondary colors (二次色)

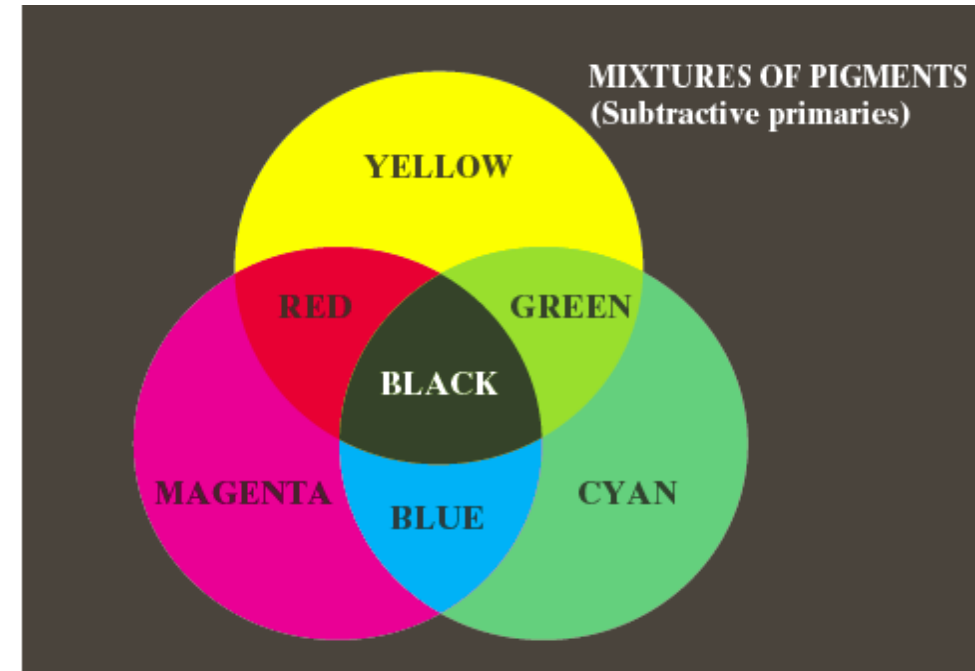
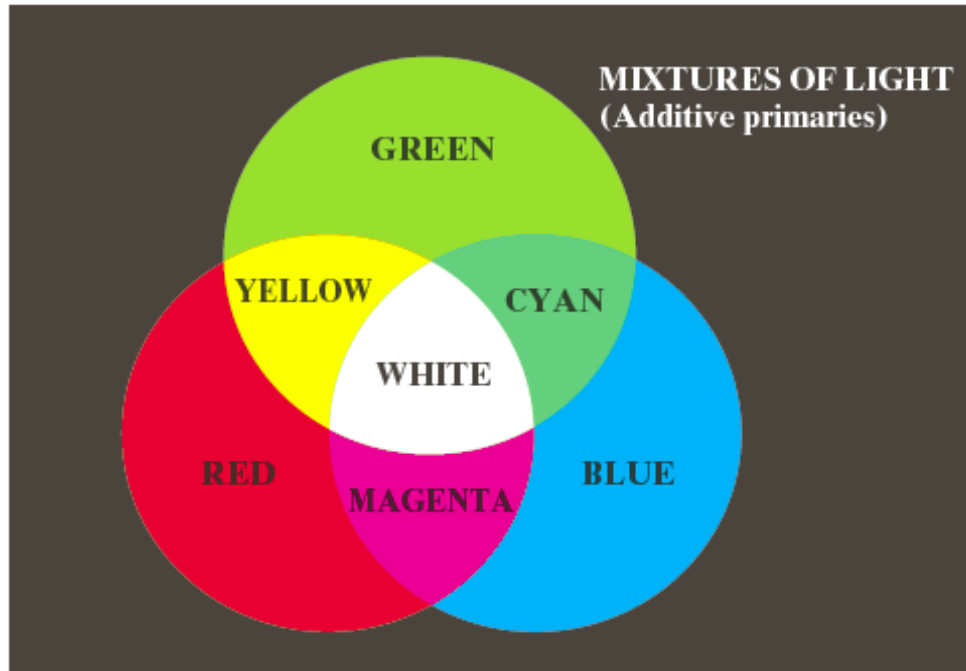
## CMY and CMYK color

Cyan = White – Red

Magenta = White – Green

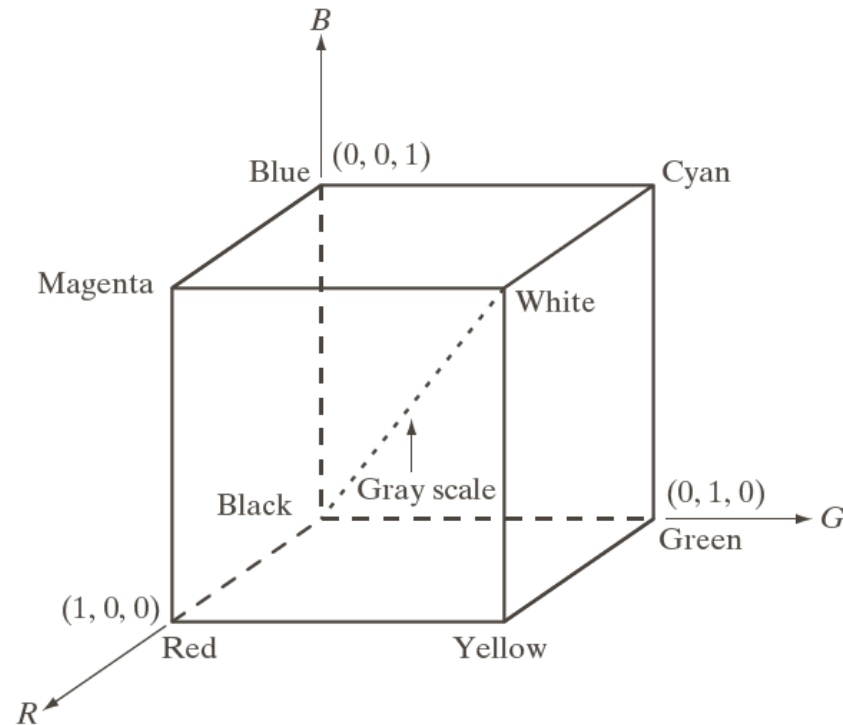
Yellow = White – Blue

Black = White – Red – Green – Blue



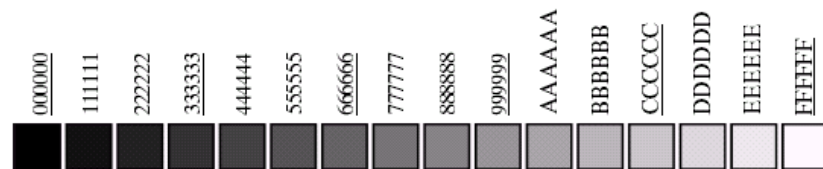
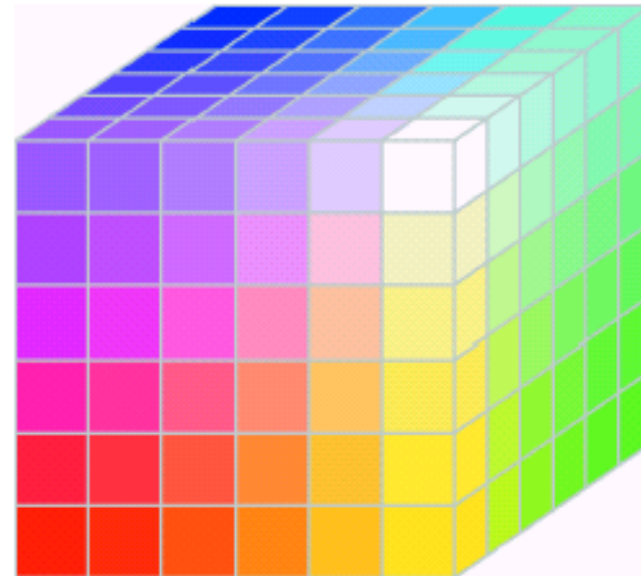
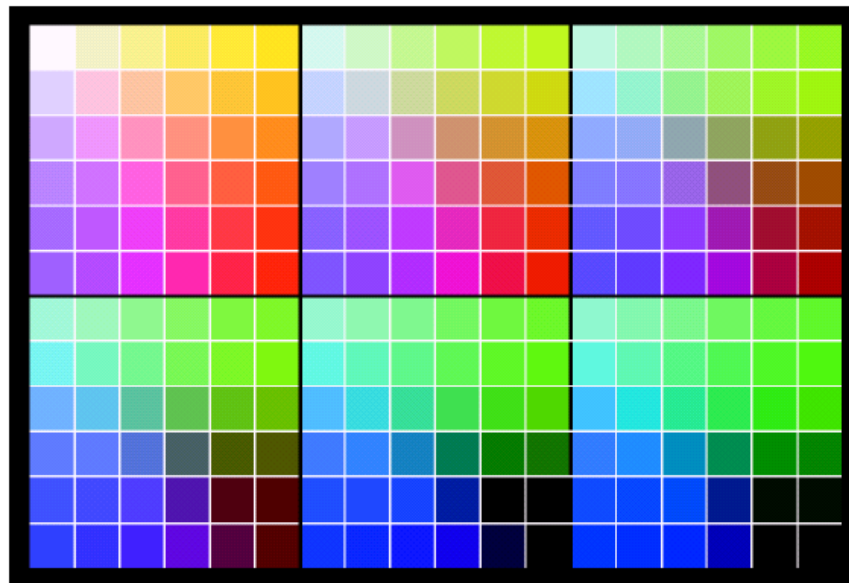
# RGB Color Model

- Towards hardware: color monitor, color video camera;
- Primary spectral components of red, green and blue;
- Based on Cartesian coordinate system;



# Safe RGB Color (稳定色)

Number System		Color Equivalents					
Hex		00	33	66	99	CC	FF
Decimal		0	51	102	153	204	255



# CMY Color Model

- RGB to CMY conversion

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

- CMYK: In order to produce true black in printing, a fourth color, black, is added into the CMYK color model:

## CMY to CMYK:

- when  $K=1$ ,  $C=M=Y=0$
- Otherwise:  $K=\min(C,M,Y)$     $C=(C-K)/(1-K)$     $M=(M-K)/(1-K)$     $Y=(Y-K)/(1-K)$

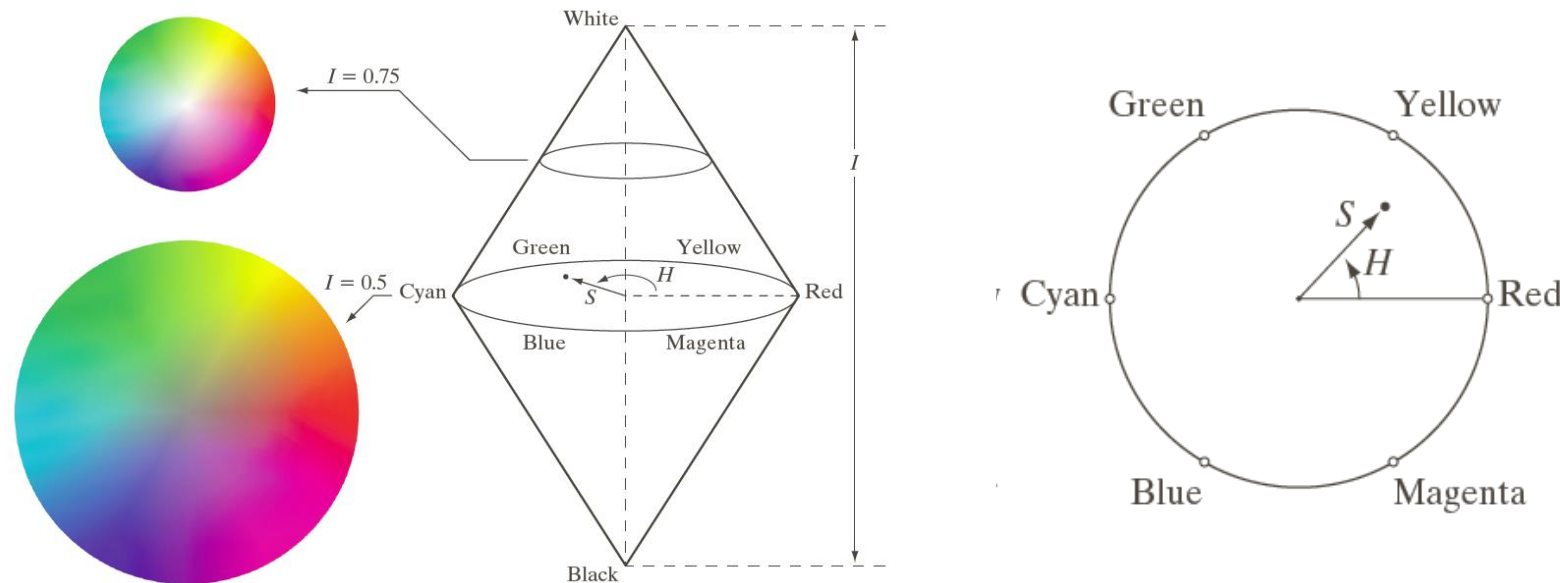
## CMYK to CMY:

$$C = C*(1-K) + K \quad M = M*(1-K) + K \quad Y = Y*(1-K) + K$$

# HSI Color Model

## ➤ HSI Color Model:

- Hue: Dominant color associated with wavelength
- Saturation: relative purity, the amount of white light mixed with a hue
- Intensity: brightness (V: value, L: lightness)



# RGB to HSI

$$\theta = \arccos \left\{ \frac{\frac{1}{2}[(R - G) + (R - B)]}{[(R - G)^2 + (R - G)(G - B)]^{\frac{1}{2}}} \right\}$$

$$H = \begin{cases} \theta, & G \geq B \\ 360 - \theta, & G < B \end{cases}$$

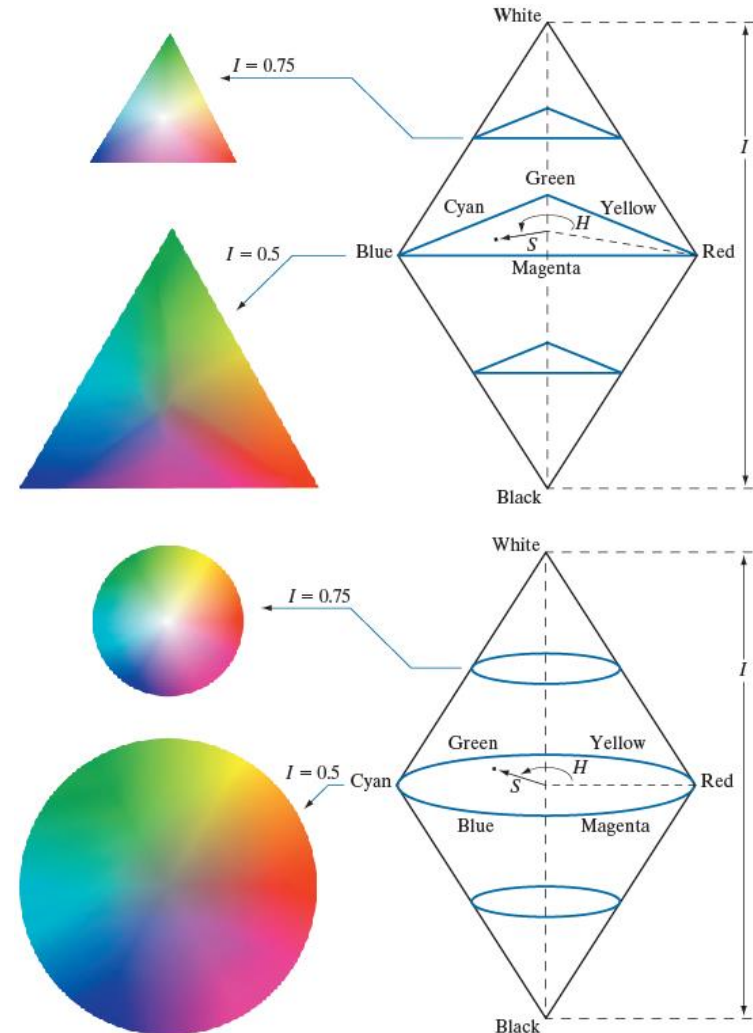
$$S = 1 - \frac{3}{R + G + B} [\min(R, G, B)]$$

$$I = \frac{R + G + B}{3}$$

Two special cases:

$$S = 0 \rightarrow H = 0$$

$$I = 0 \rightarrow S = 0, H = 0$$



**a**  
**b**  
**FIGURE 7.12**  
The HSI color model based on (a) triangular, and (b) circular color planes. The triangles and circles are perpendicular to the vertical intensity axis.



# HSI to RGB

➤  $0^\circ \leq H < 120^\circ$

$$B = I(1 - S), \quad R = I \left[ 1 + \frac{S \cos(H)}{\cos(60^\circ - H)} \right], \quad G = 3I - (R + B)$$

➤  $120^\circ \leq H < 240^\circ$

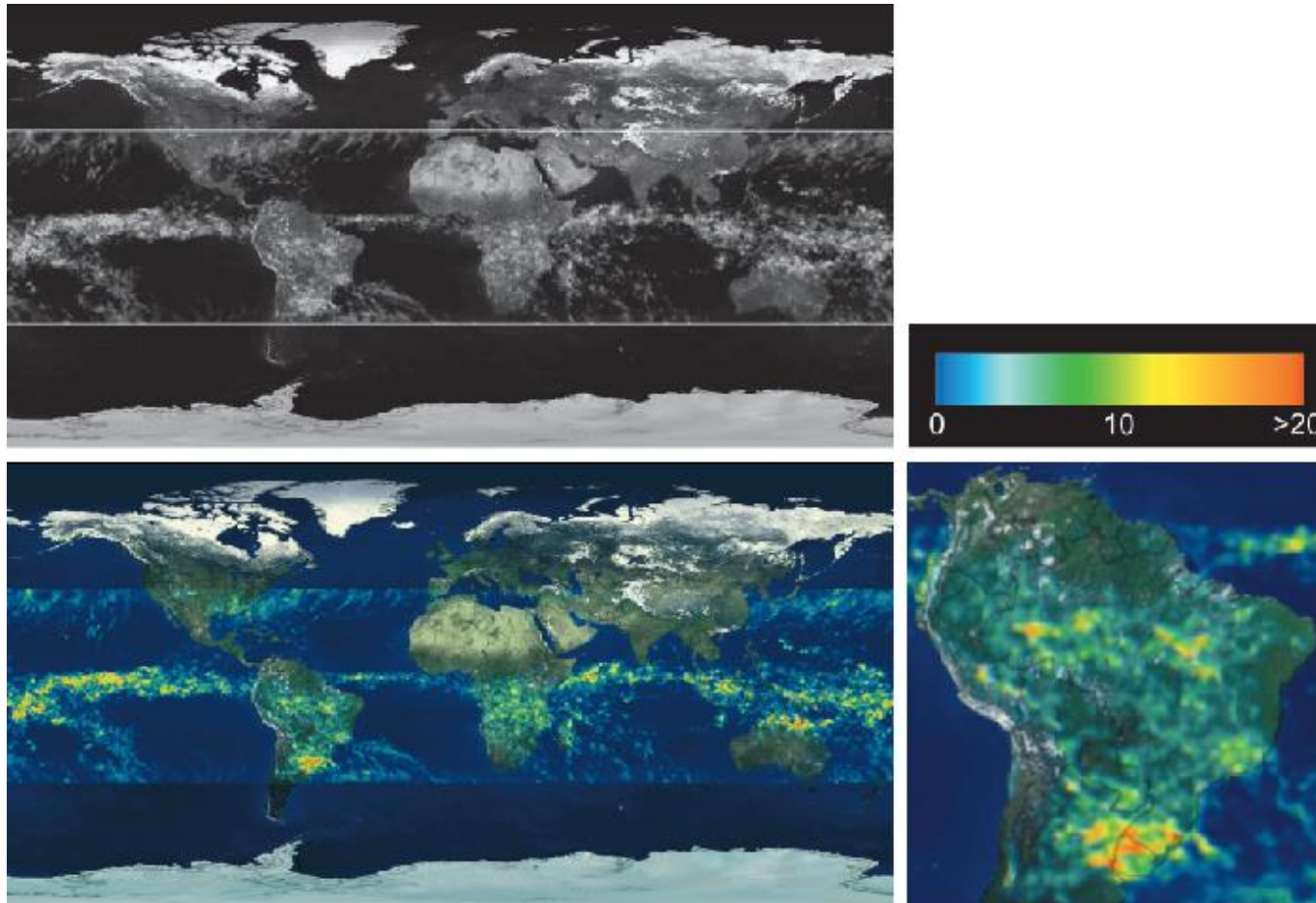
$$R = I(1 - S), \quad G = I \left[ 1 + \frac{S \cos(H - 120^\circ)}{\cos(180^\circ - H)} \right], \quad B = 3I - (R + G)$$

➤  $240^\circ \leq H < 360^\circ$

$$G = I(1 - S), \quad B = I \left[ 1 + \frac{S \cos(H - 240^\circ)}{\cos(300^\circ - H)} \right], \quad R = 3I - (G + B)$$

# Pseudocolor image

- **Pseudocolor(伪彩色)**: assigning colors to gray values based on specified criterion

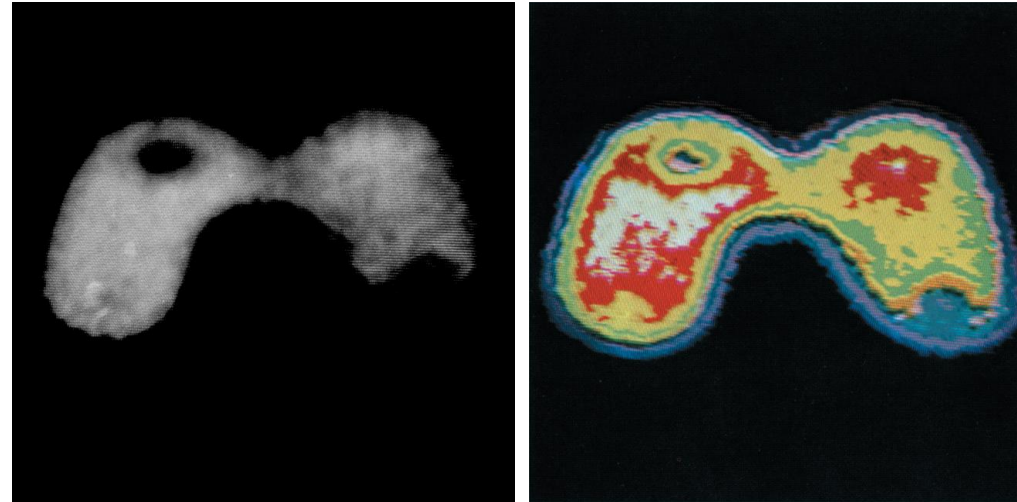
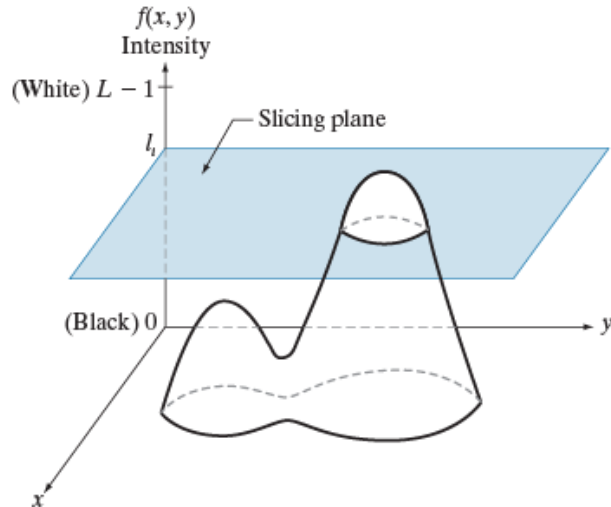


**FIGURE 7.20** (a) Grayscale image in which intensity (in the horizontal band shown) corresponds to average monthly rainfall. (b) Colors assigned to intensity values. (c) Color-coded image. (d) Zoom of the South American region.(Courtesy of NASA.)

# Intensity slicing

- **Intensity slicing (灰度分层):** the gray level was assigned to a different color;

**FIGURE 7.16**  
Graphical interpretation of the intensity-slicing technique.

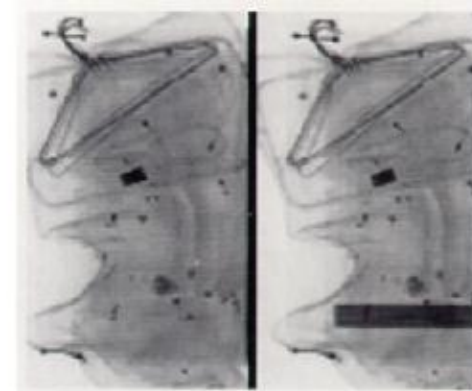
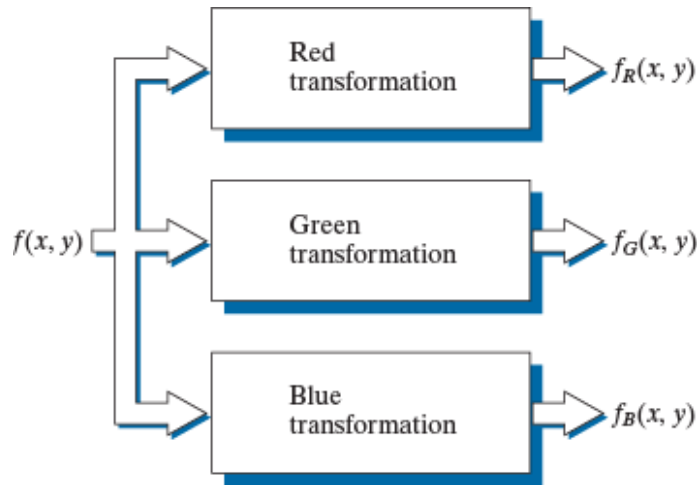


**a b**  
**FIGURE 7.18**  
(a) Grayscale image of the Picker Thyroid Phantom.  
(b) Result of intensity slicing using eight colors. (Courtesy of Dr. J. L. Blankenship, Oak Ridge National Laboratory.)

# Intensity to color transformation

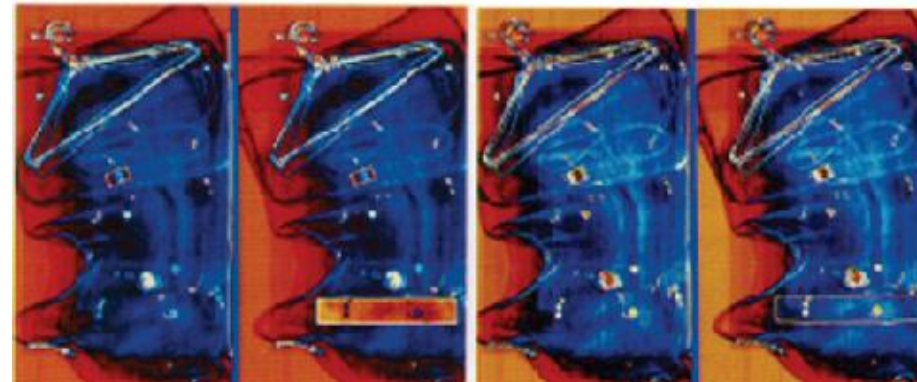
- Three independent transformations on the intensity of any pixel for red, green and blue channels

**FIGURE 7.21**  
Functional block diagram for pseudocolor image processing. Images  $f_R$ ,  $f_G$ , and  $f_B$  are fed into the corresponding red, green, and blue inputs of an RGB color monitor.



a  
b c

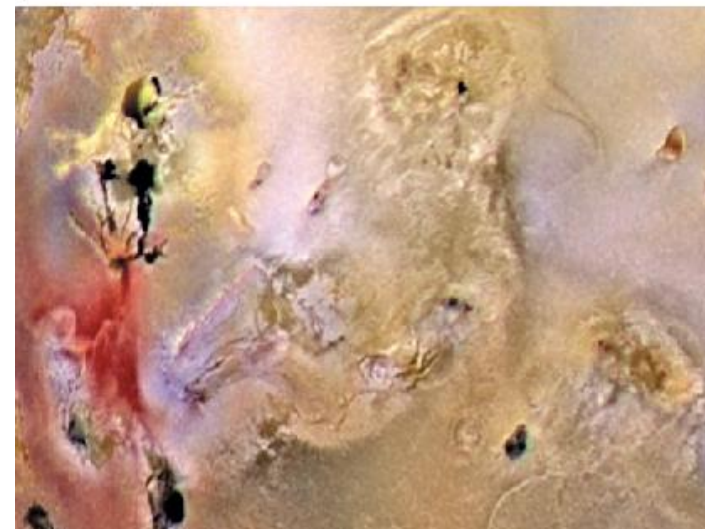
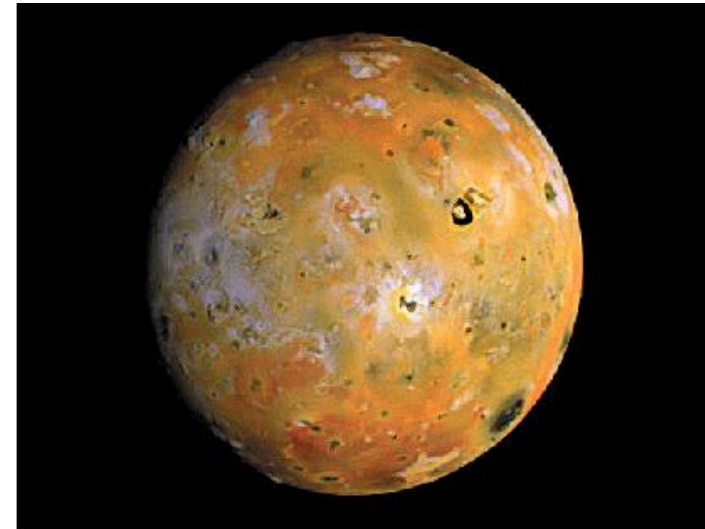
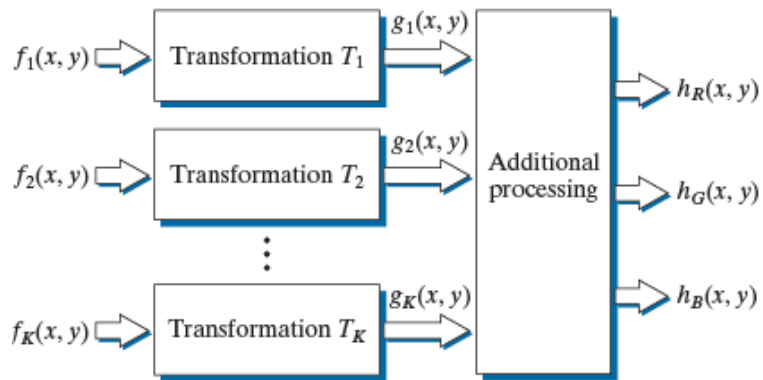
**FIGURE 7.22**  
Pseudocolor enhancement by using the gray level to color transformations in Fig. 7.23. (Original image courtesy of Dr. Mike Hurwitz, Westinghouse.)



# Intensity to color transformation

- **Color coding of multispectral images:** combine several monochrome images into a single color composite;

**FIGURE 7.24**  
A pseudocolor coding approach using multiple grayscale images. The inputs are grayscale images. The outputs are the three components of an RGB composite image.



a  
b

**FIGURE 7.26**  
(a) Pseudocolor rendition of Jupiter Moon Io. (b) A close-up. (Courtesy of NASA.)

# RGB to Gray scale

- Maximum value:

$$g_R(x, y) = g_G(x, y) = g_B(x, y) = \max[f_R(x, y), f_G(x, y), f_B(x, y)]$$

- Average value

$$g_R(x, y) = g_G(x, y) = g_B(x, y) = [f_R(x, y) + f_G(x, y) + f_B(x, y)]/3$$

- Weighted value

$$g_R(x, y) = g_G(x, y) = g_B(x, y) = 0.299f_R(x, y) + 0.587f_G(x, y) + 0.114f_B(x, y)$$



# Color Balance (彩色平衡)

## ➤ White balance:

$$I(x, y) = 0.299f_R(x, y) + 0.587f_G(x, y) + 0.114f_B(x, y)$$

$$k_R = \frac{\bar{I}}{\bar{R}} \quad k_G = \frac{\bar{I}}{\bar{G}} \quad k_B = \frac{\bar{I}}{\bar{B}}$$

$$\begin{bmatrix} g_R(x, y) \\ g_G(x, y) \\ g_B(x, y) \end{bmatrix} = \begin{bmatrix} k_R & & \\ & k_G & \\ & & k_B \end{bmatrix} \begin{bmatrix} f_R(x, y) \\ f_G(x, y) \\ f_B(x, y) \end{bmatrix}$$



## ➤ Maximum value balance

$$S_{RGB} = \min[R_{max}, G_{max}, B_{max}]$$

$$k_R = \frac{S_{RGB}}{T_R} \quad k_G = \frac{S_{RGB}}{T_G} \quad k_B = \frac{S_{RGB}}{T_B}$$

$$\begin{bmatrix} g_R(x, y) \\ g_G(x, y) \\ g_B(x, y) \end{bmatrix} = \begin{bmatrix} k_R & & \\ & k_G & \\ & & k_B \end{bmatrix} \begin{bmatrix} f_R(x, y) \\ f_G(x, y) \\ f_B(x, y) \end{bmatrix}$$