ECE 468: Digital Image Processing

Lecture 25

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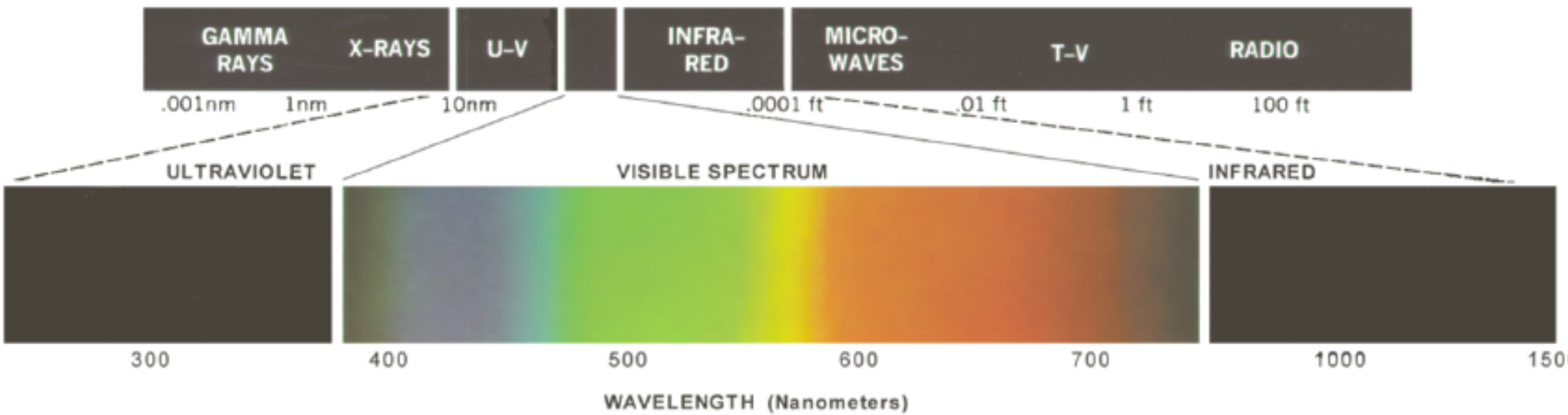
Outline

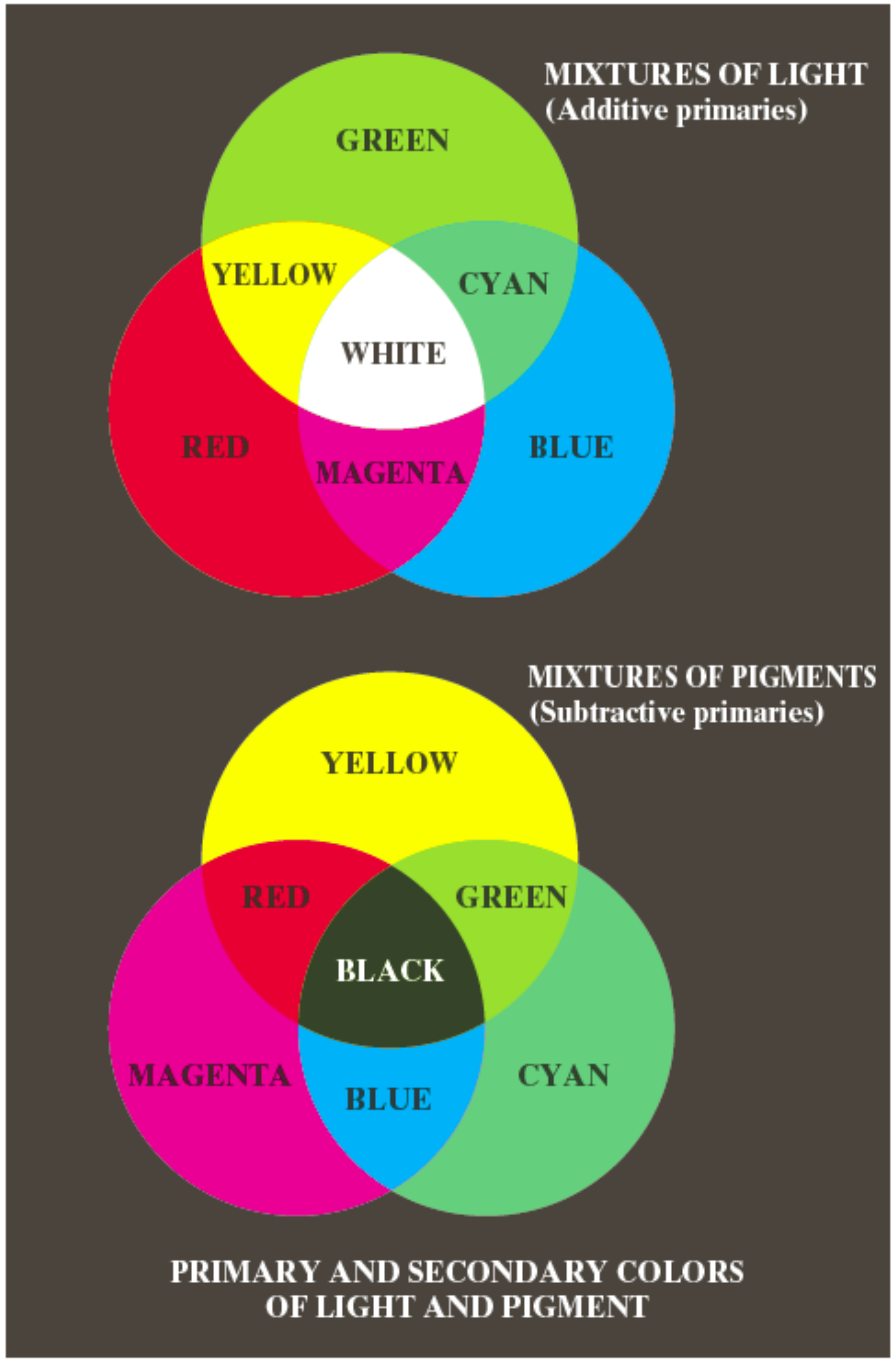
- Color models (Textbook 6.2)
- Color transformations (Textbook 6.5)

Visible Spectrum of EM



Based on Psychophysical Studies

- Cones in the human eye
  - red (R) 65%
  - green (G) 33%
  - blue (B) 2%



- R = 700nm
- G = 546.1nm
- B = 435.8nm

- Color = combination of primary colors R, G, B

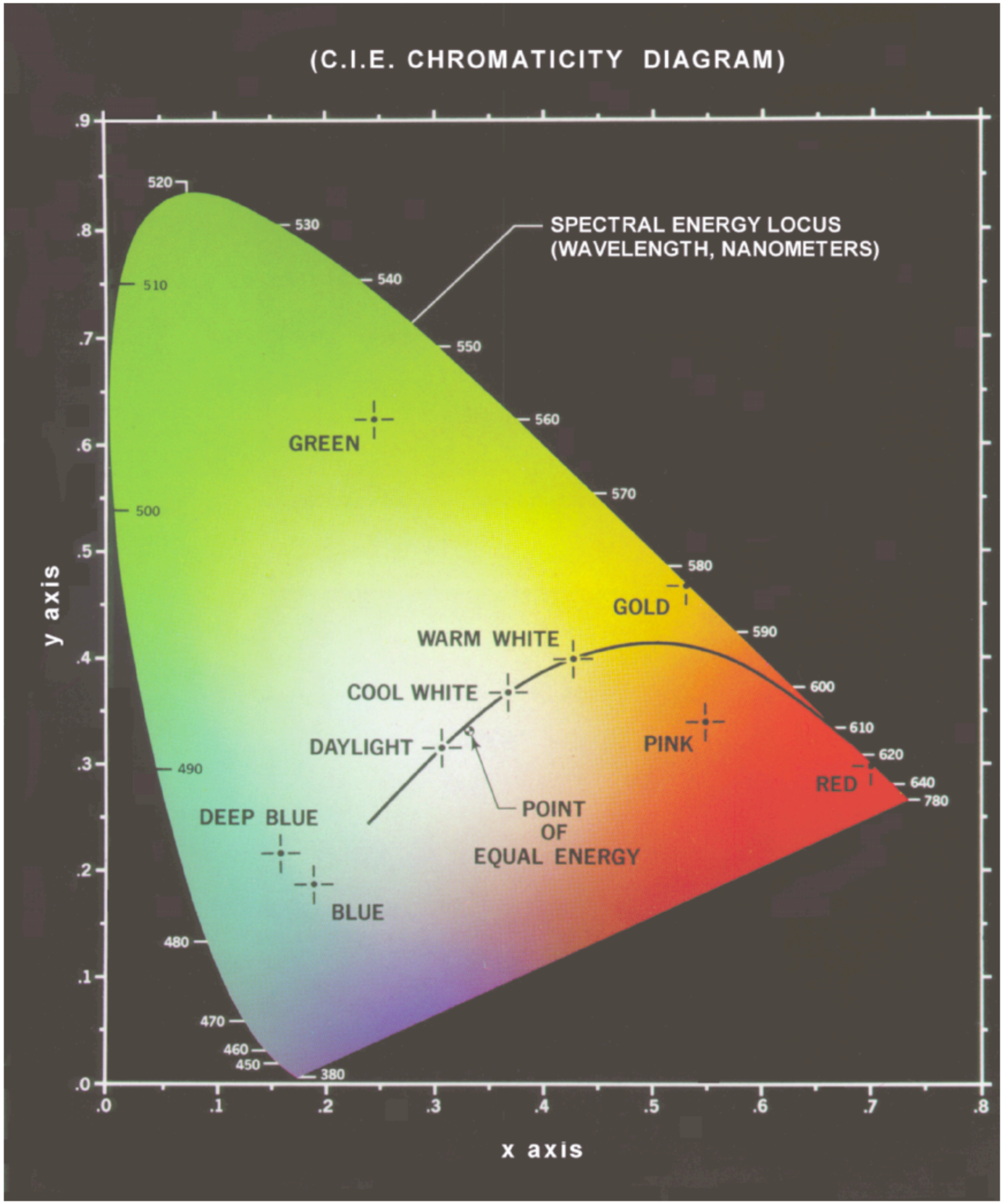
CRT vs. LCD

- Cathode ray tube (CRT):
  - Triads of red, green, blue electron-sensitive phosphor dots
  - “Adding” of electron-gun rays, 30 frames/sec
- Liquid crystal dislpays (LCD), Active matrix technology (AMT), Plasma
  - 3 red, green, blue subpixels forming a pixel
  - LCD - polarized light
  - AMT - thin film transistors
  - Plasma - tiny gas cells coated with phosphor

Basic Color Characteristics

- Brightness = achromatic intensity
- Hue = dominant wavelength as perceived by an observer
- Saturation = relative purity of hue vs. white light

Chromaticity Diagram



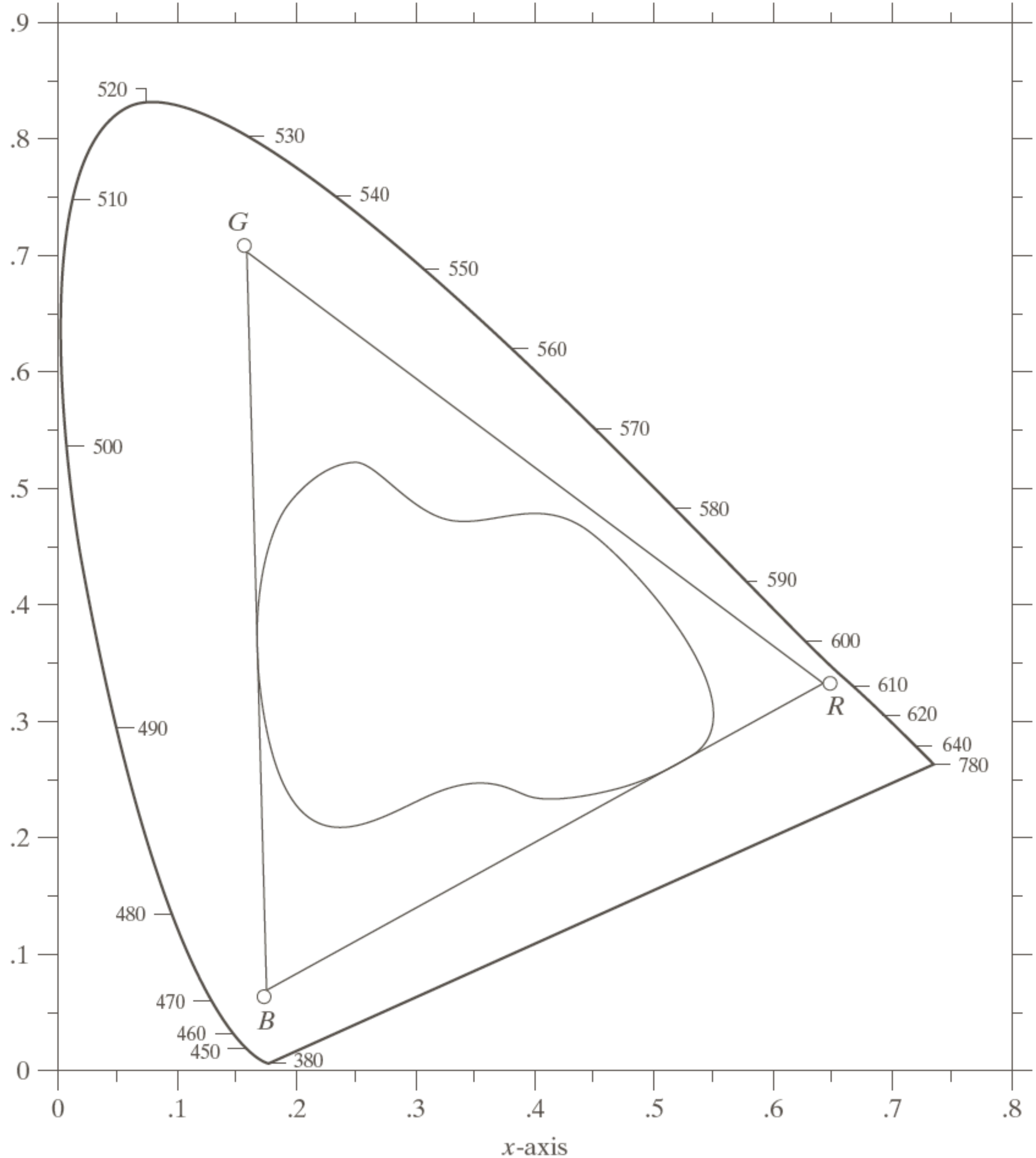
Color composition as a function of

x = red

y = green

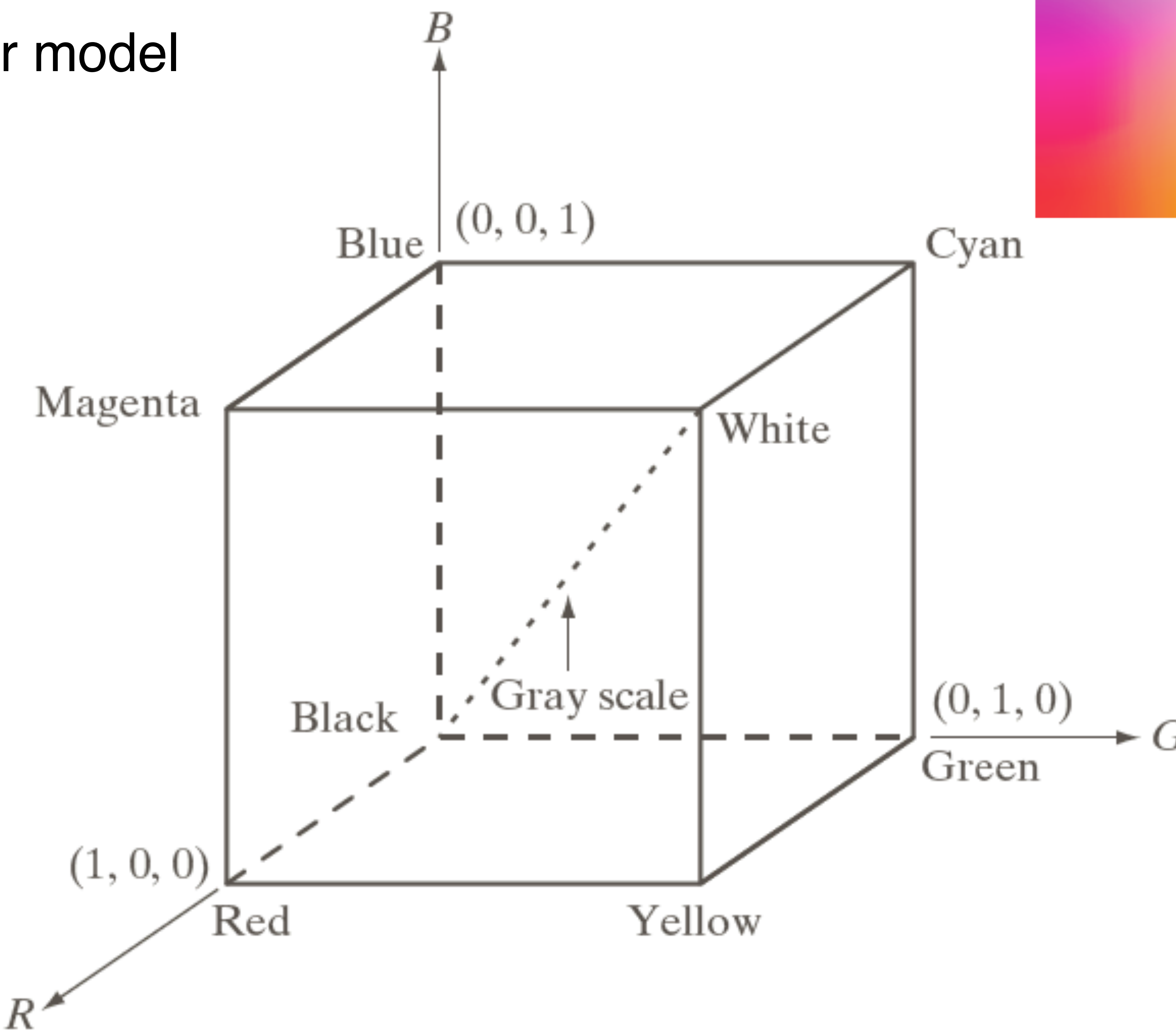
z = 1 - x - y

Gamut = Range of Colors



Color Model = Color System = Color Space

- Purpose: To facilitate specification of colors
- RGB color model



24-bit RGB image

$$(2^8)^3 = 16777216$$

Generating the RGB Image

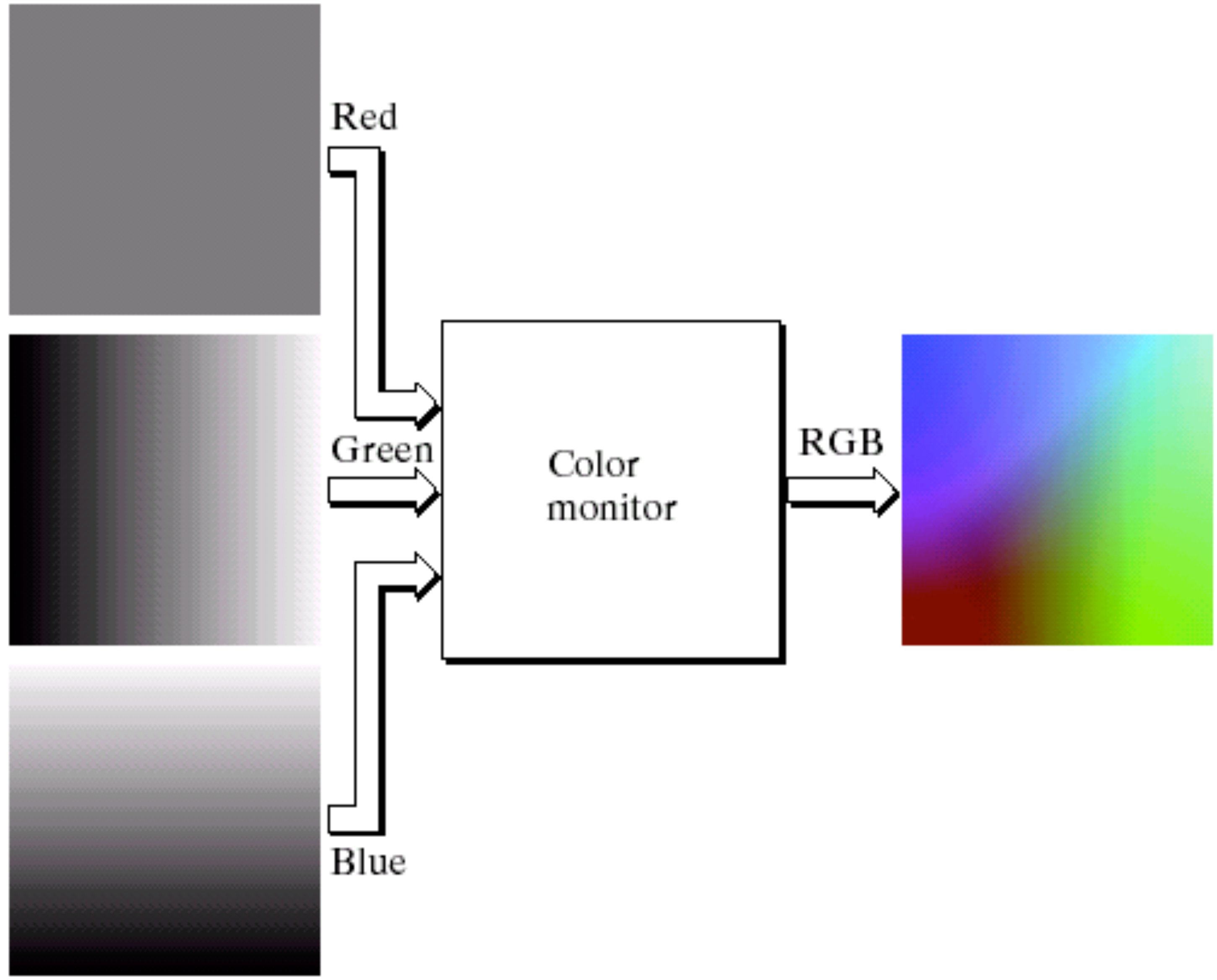
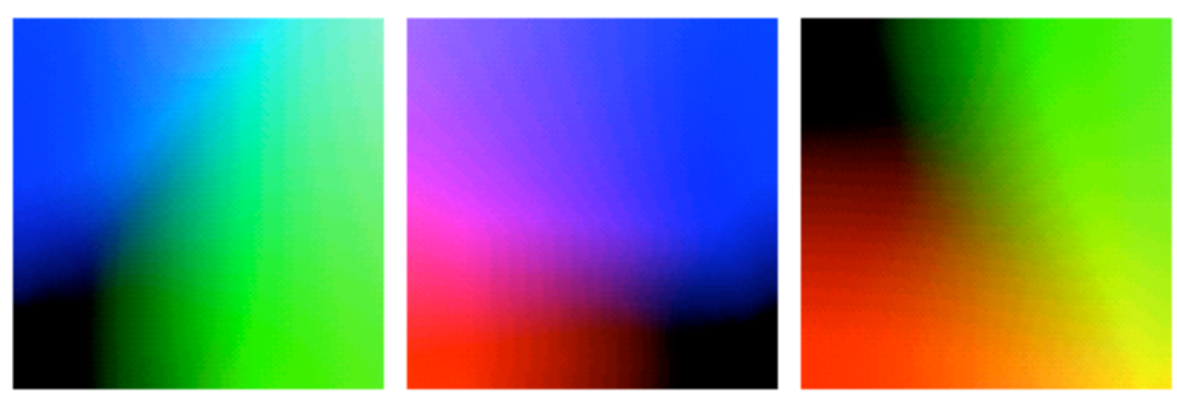


FIGURE 6.9
(a) Generating the RGB image of the cross-sectional color plane $(127, G, B)$.
(b) The three hidden surface planes in the color cube of Fig. 6.8.

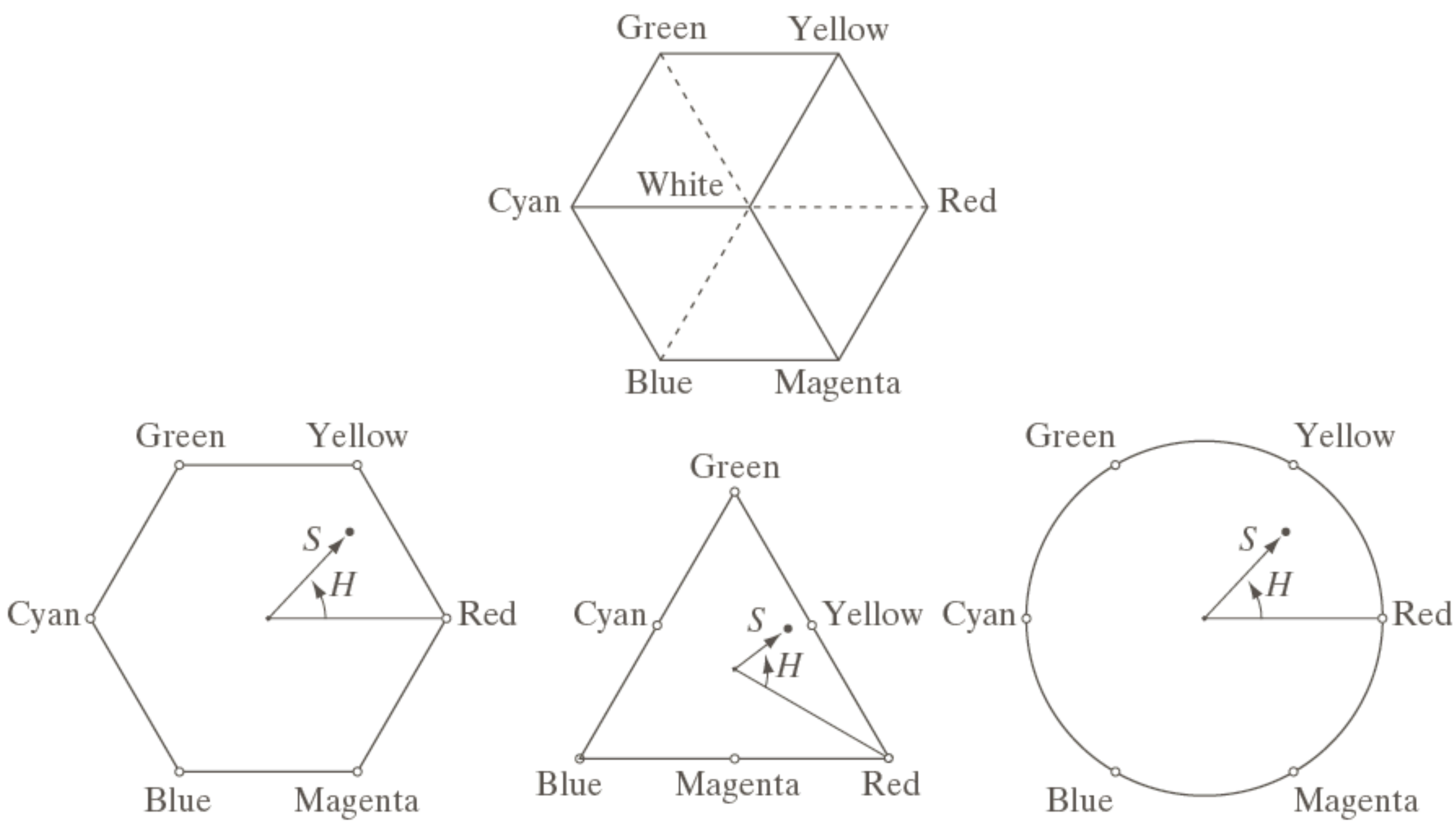


CMY System

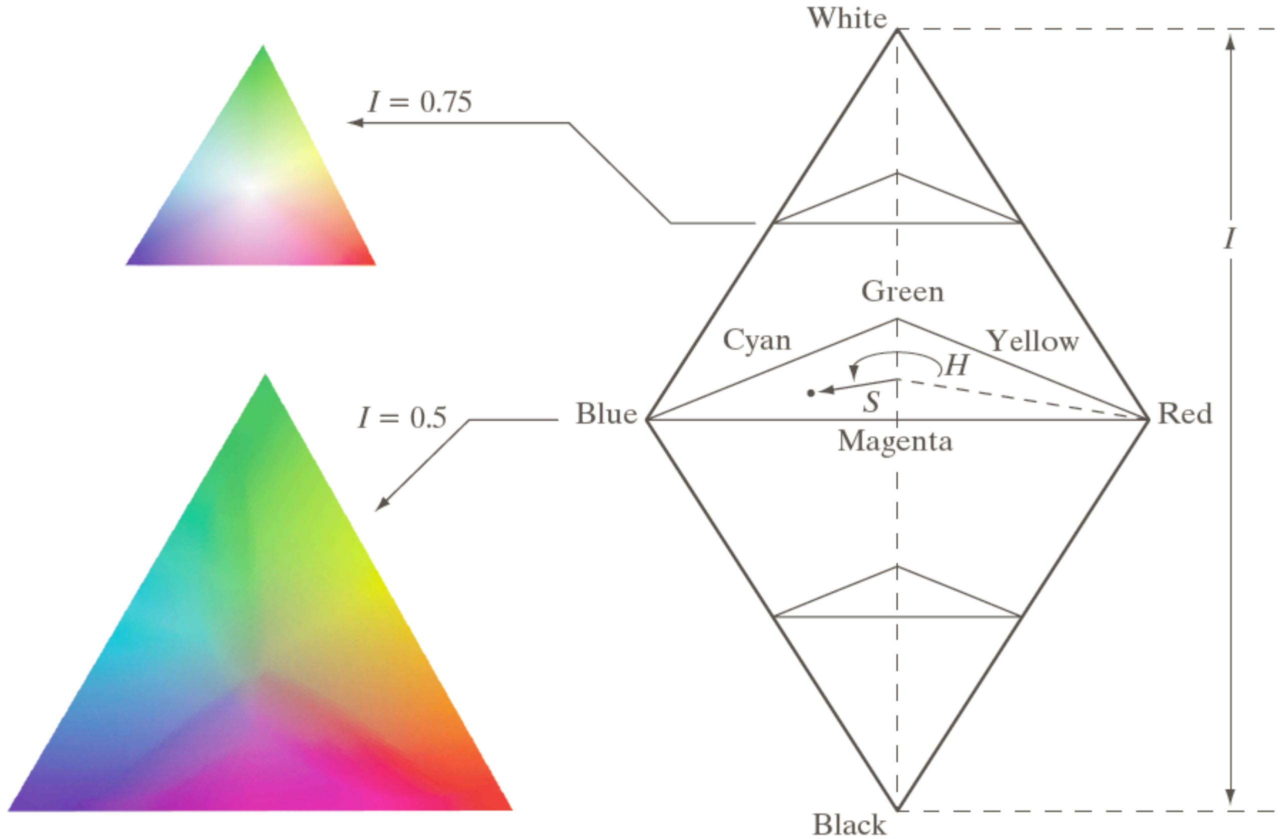
$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

HSI System

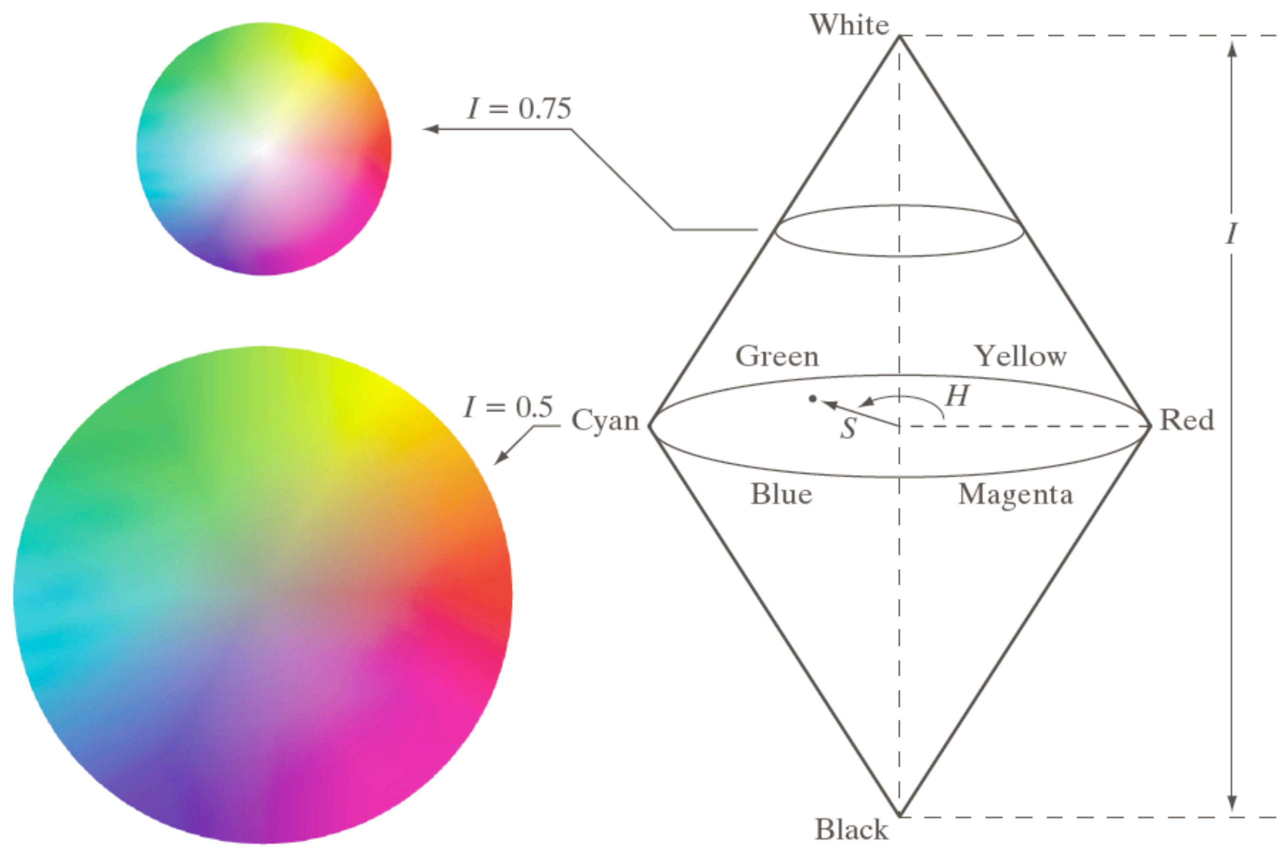
- RGB or CMY systems not convenient for describing how humans perceive color
- Inconvenient to represent intuitive notions of hue, saturation, and brightness
- Does not capture human intuitions that hues form a circle



HSI System



White
I = 0.75
I
Green
Cyan
Yellow
H
I = 0.5
Blue
S
Red
Magenta
Black



White
I = 0.75
I
Green
Yellow
H
I = 0.5
Cyan
S
Red
Blue
Magenta
Black

RGB to HSI Conversion

$$H = \begin{cases} \theta & , \quad \text{if } B \leq G \\ 360 - \theta & , \quad \text{if } B > G \end{cases}$$

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

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

$$I = \frac{1}{3}(R+G+B)$$

HSI to RGB Conversion

Sector: $0 \leq H \leq 120$

$$B = I(1 - S)$$

$$R = I\left[1 + \frac{S\cos H}{\cos(60 - H)}\right]$$

$$G = 3I - (R + B)$$

HSI to RGB Conversion

Sector: $120 \leq H \leq 240$

$$H = H - 120$$

$$R = I(1 - S)$$

$$G = I\left[1 + \frac{S\cos H}{\cos(60 - H)}\right]$$

$$B = 3I - (R + G)$$

HSI to RGB Conversion

Sector: $240 \leq H \leq 360$

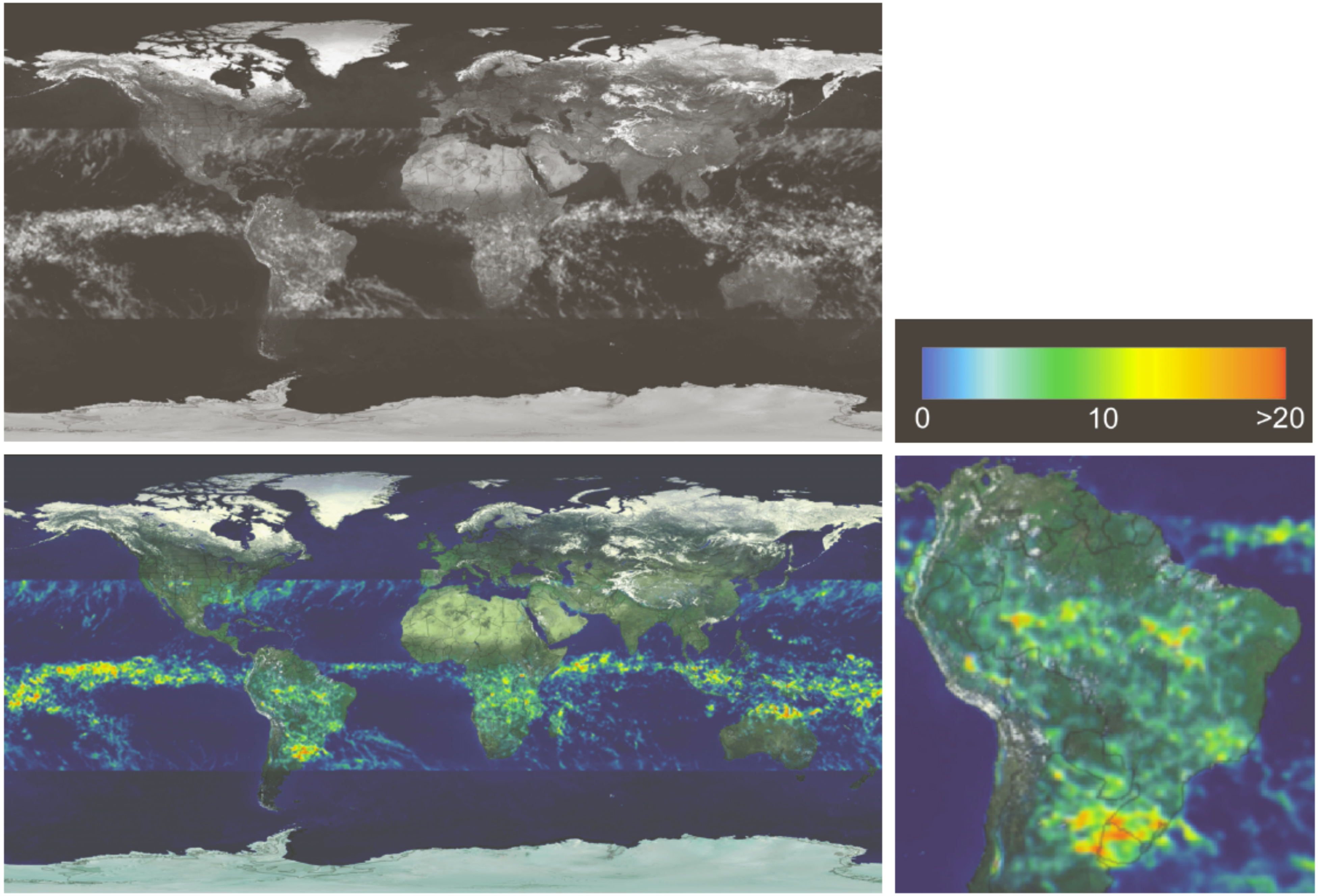
$$H = H - 240$$

$$G = I(1 - S)$$

$$B = I\left[1 + \frac{S\cos H}{\cos(60 - H)}\right]$$

$$R = 3I - (B + G)$$

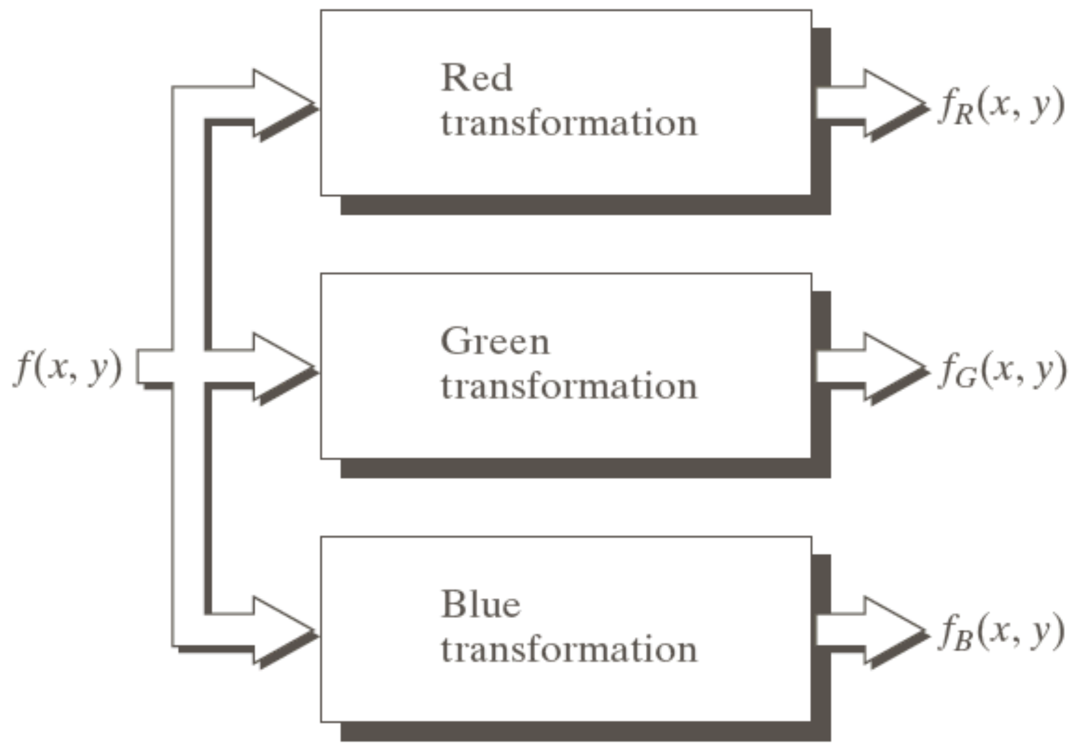
Intensity to Color Transformations

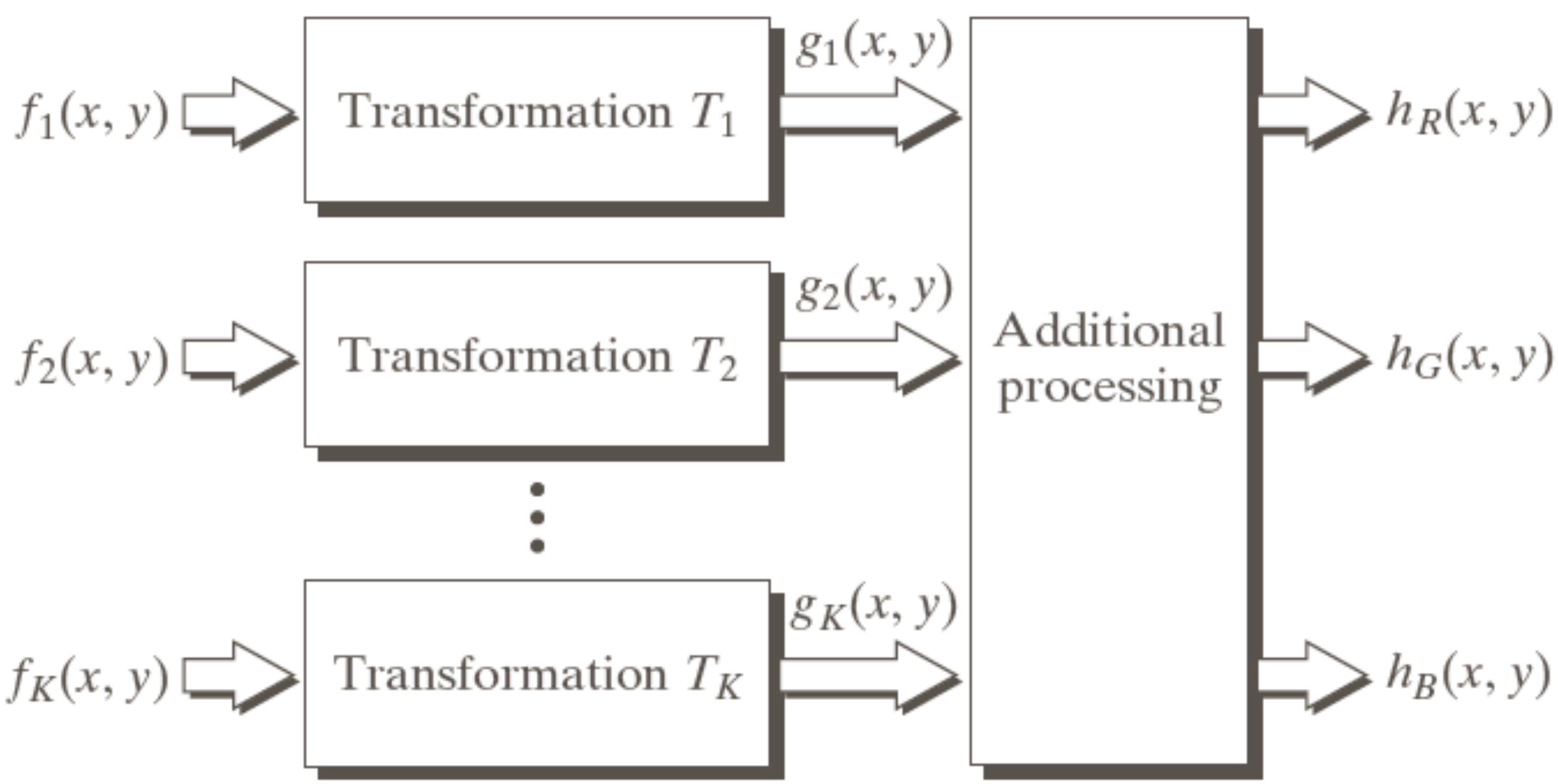


a b
c d

FIGURE 6.22 (a) Gray-scale image in which intensity (in the lighter 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 to Color Transformations





Intensity to Color Transformations

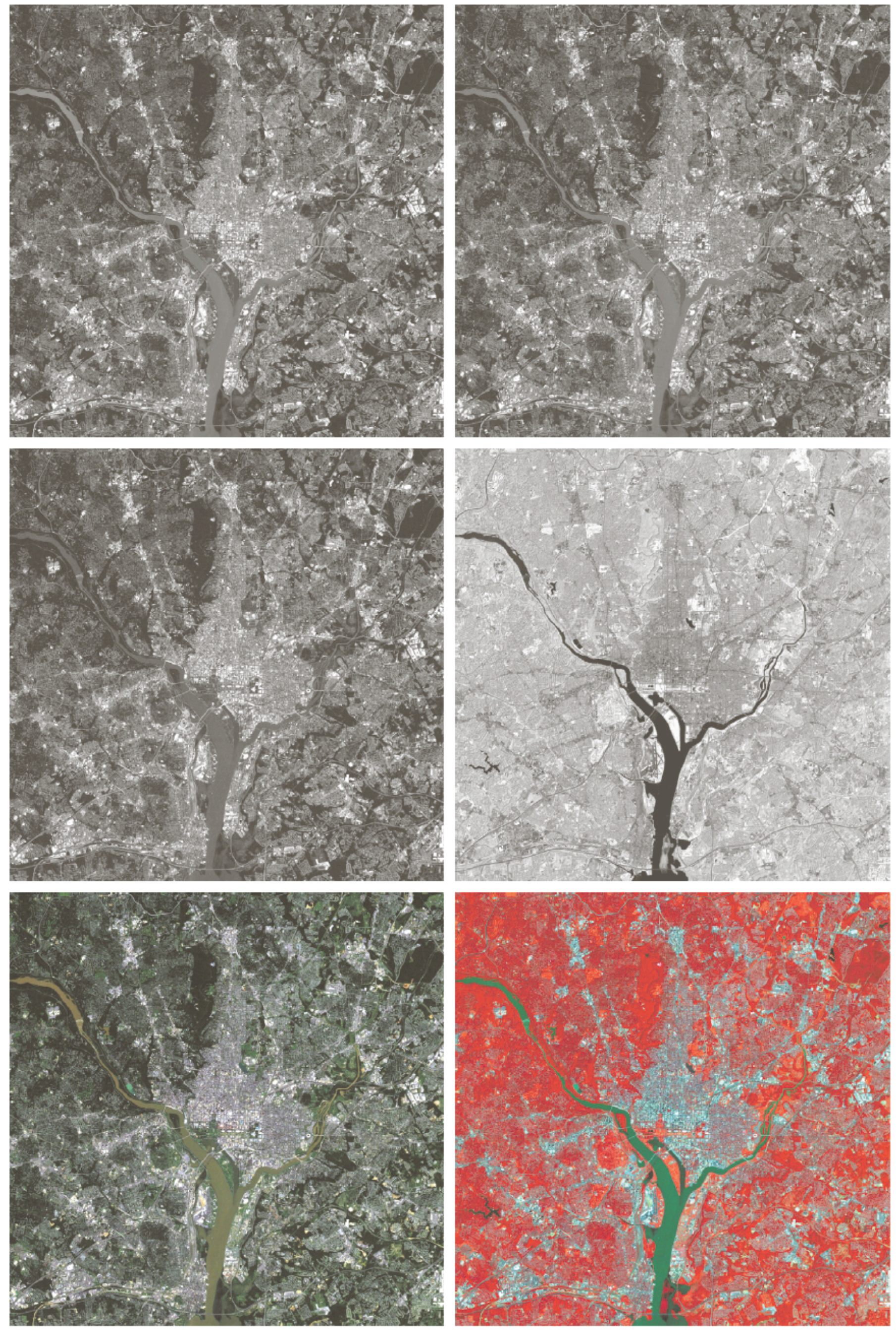


FIGURE 6.27 (a)–(d) Images in bands 1–4 in Fig. 1.10 (see Table 1.1). (e) Color composite image obtained by treating (a), (b), and (c) as the red, green, blue components of an RGB image. (f) Image obtained in the same manner, but using in the red channel the near-infrared image in (d). (Original multispectral images courtesy of NASA.)

a	b
c	d
e	f

Color Image Processing

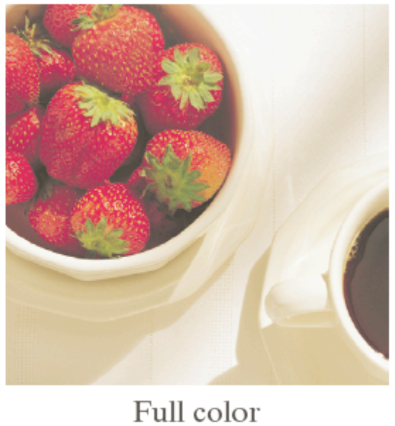
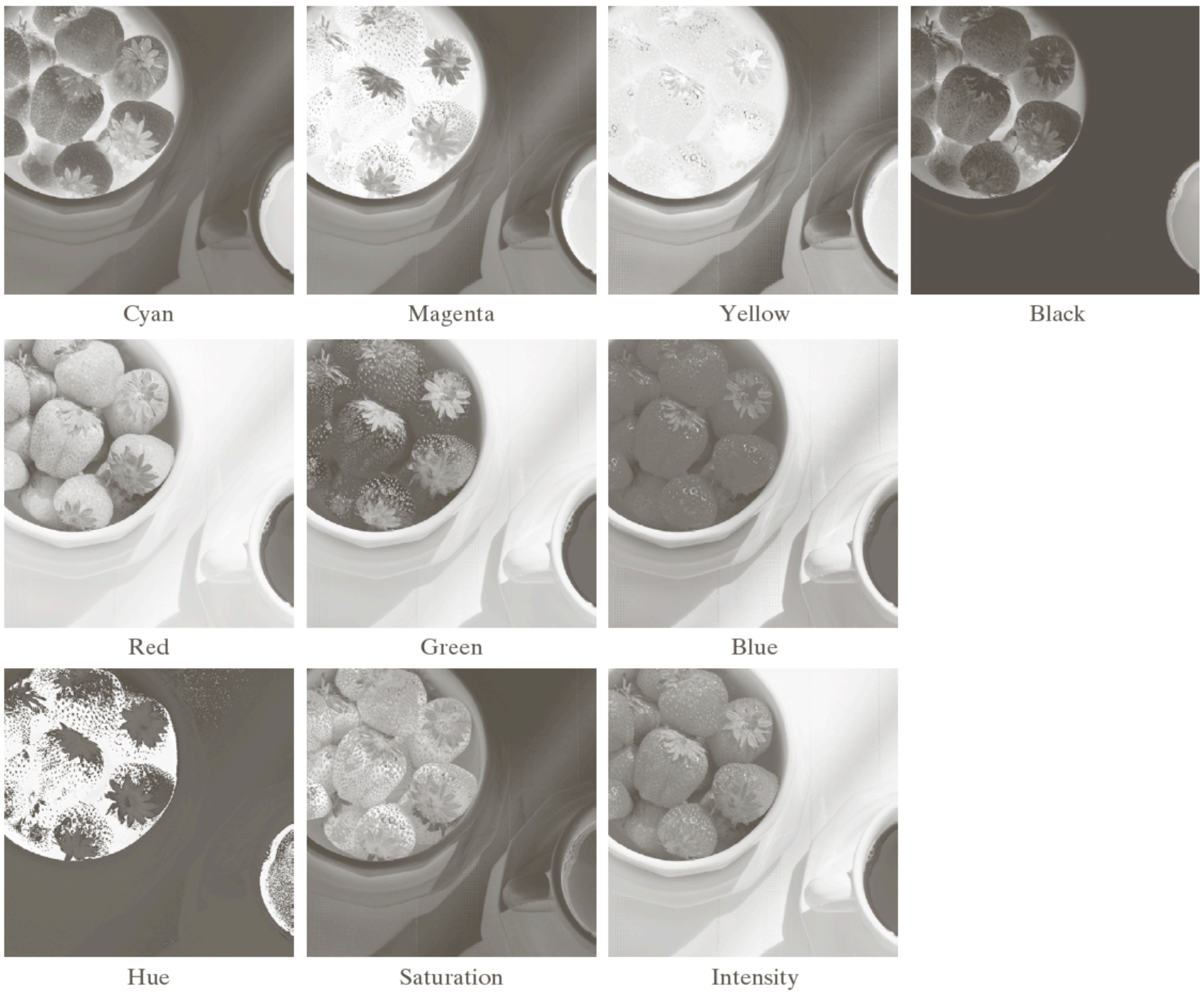
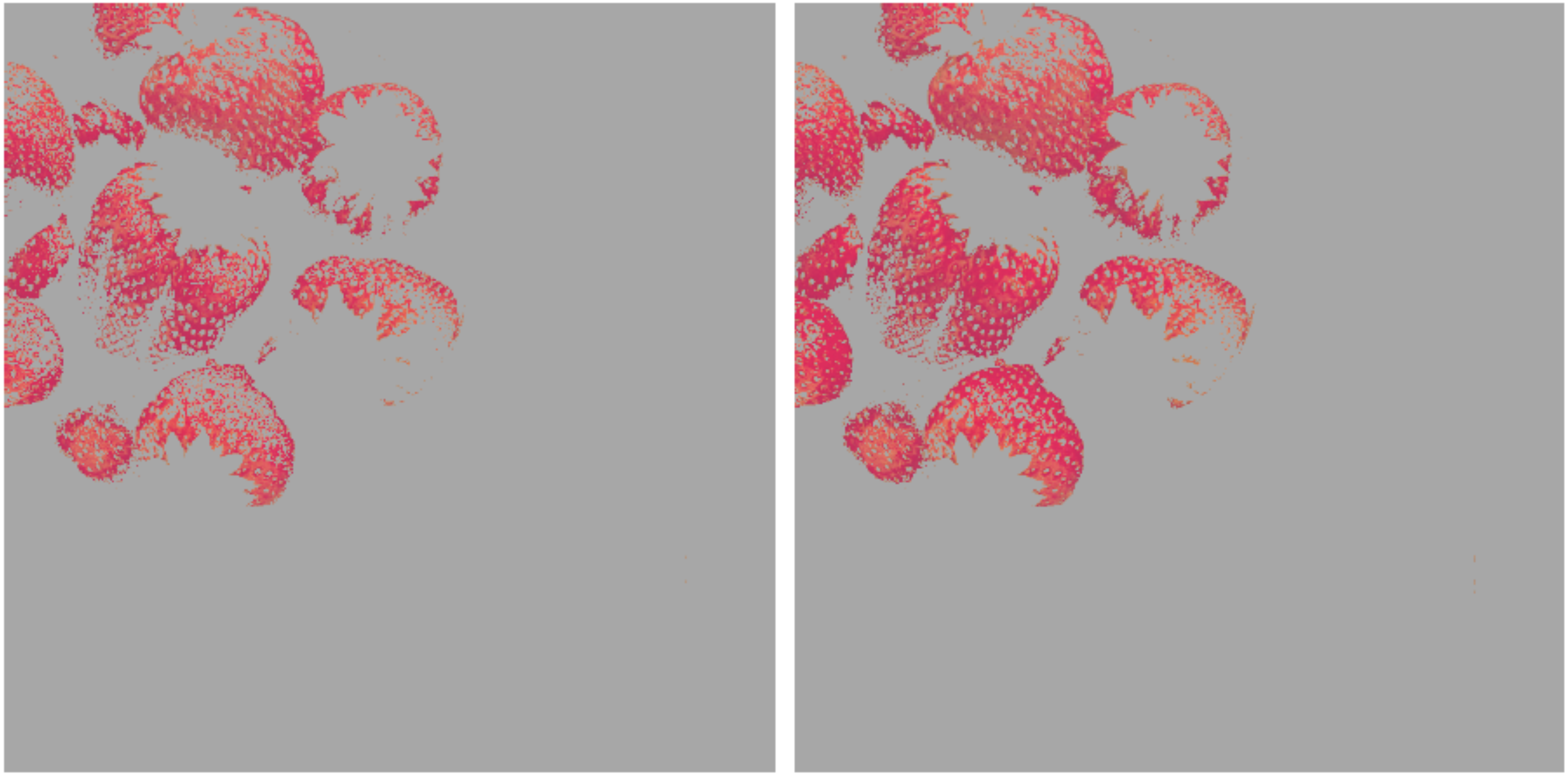


FIGURE 6.30 A full-color image and its various color-space components. Interactive.)



Color Slicing



a b

FIGURE 6.34 Color-slicing transformations that detect (a) reds within an RGB cube of width $W = 0.2549$ centered at $(0.6863, 0.1608, 0.1922)$, and (b) reds within an RGB sphere of radius 0.1765 centered at the same point. Pixels outside the cube and sphere were replaced by color $(0.5, 0.5, 0.5)$.

Color Slicing

$$s_i = \begin{cases} 0.5 & , \quad \text{if } |r_j - a_j| \geq W, \quad 1 \leq j \leq n \\ r_i & , \quad \text{o.w} \end{cases}$$

Color Correction

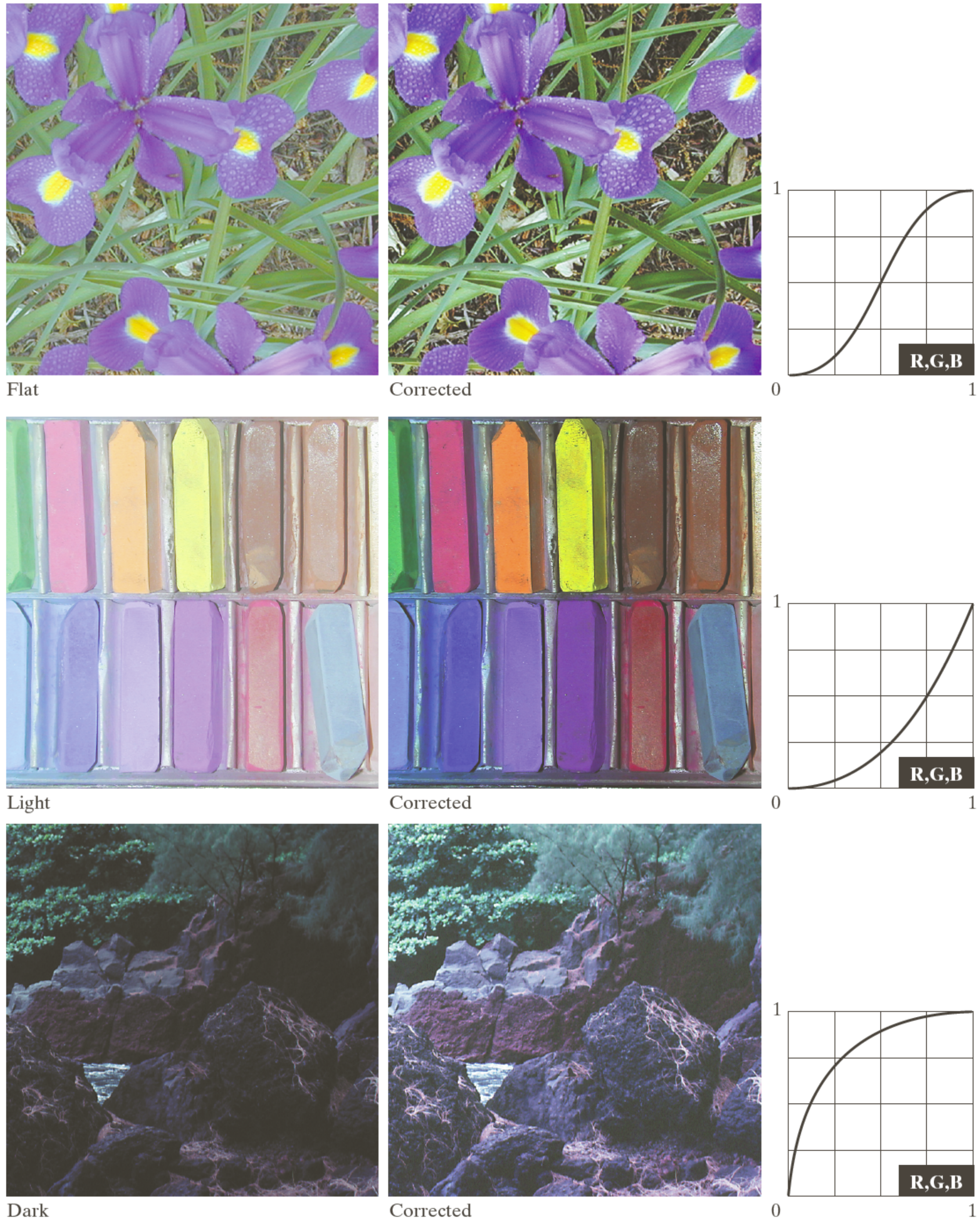
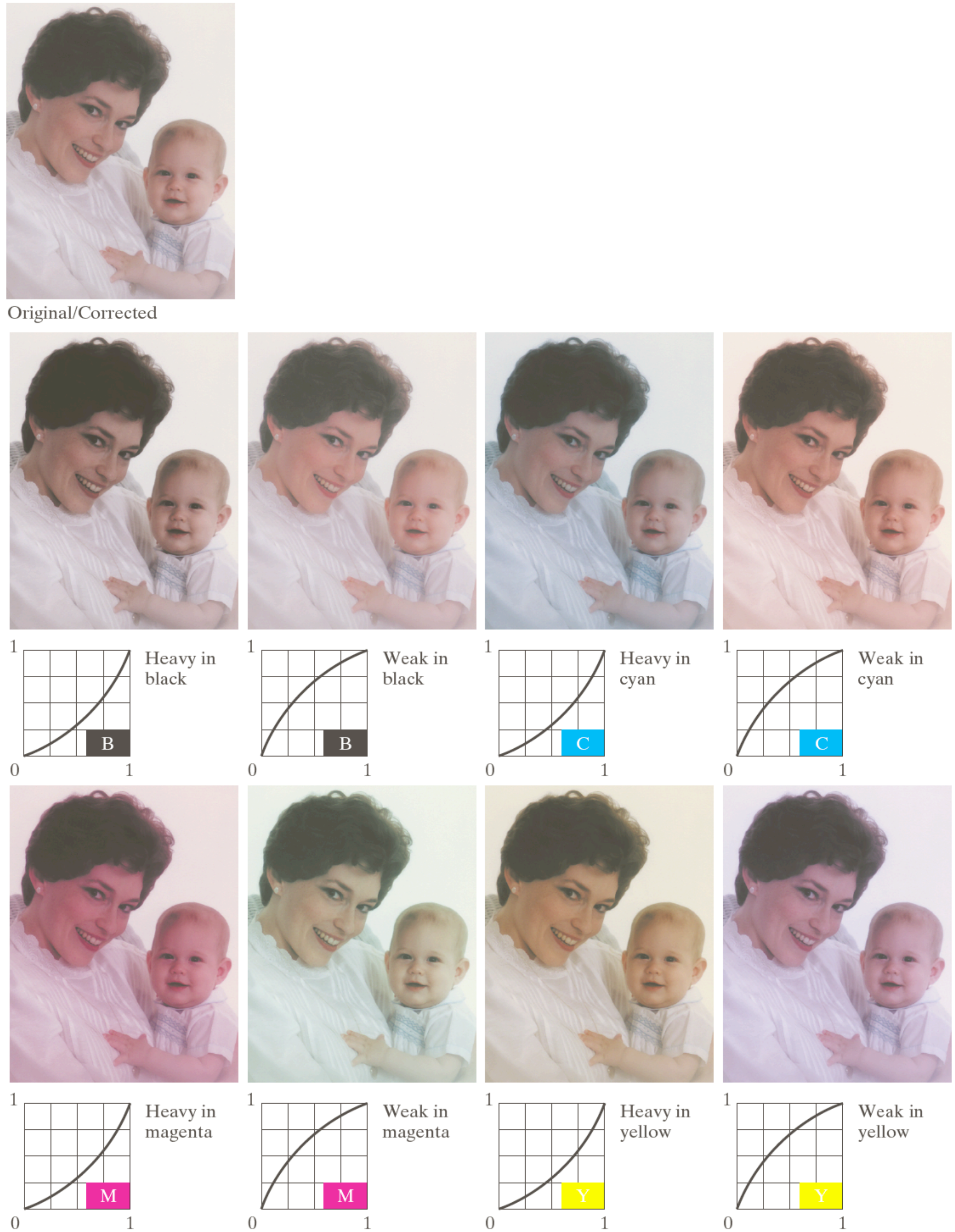
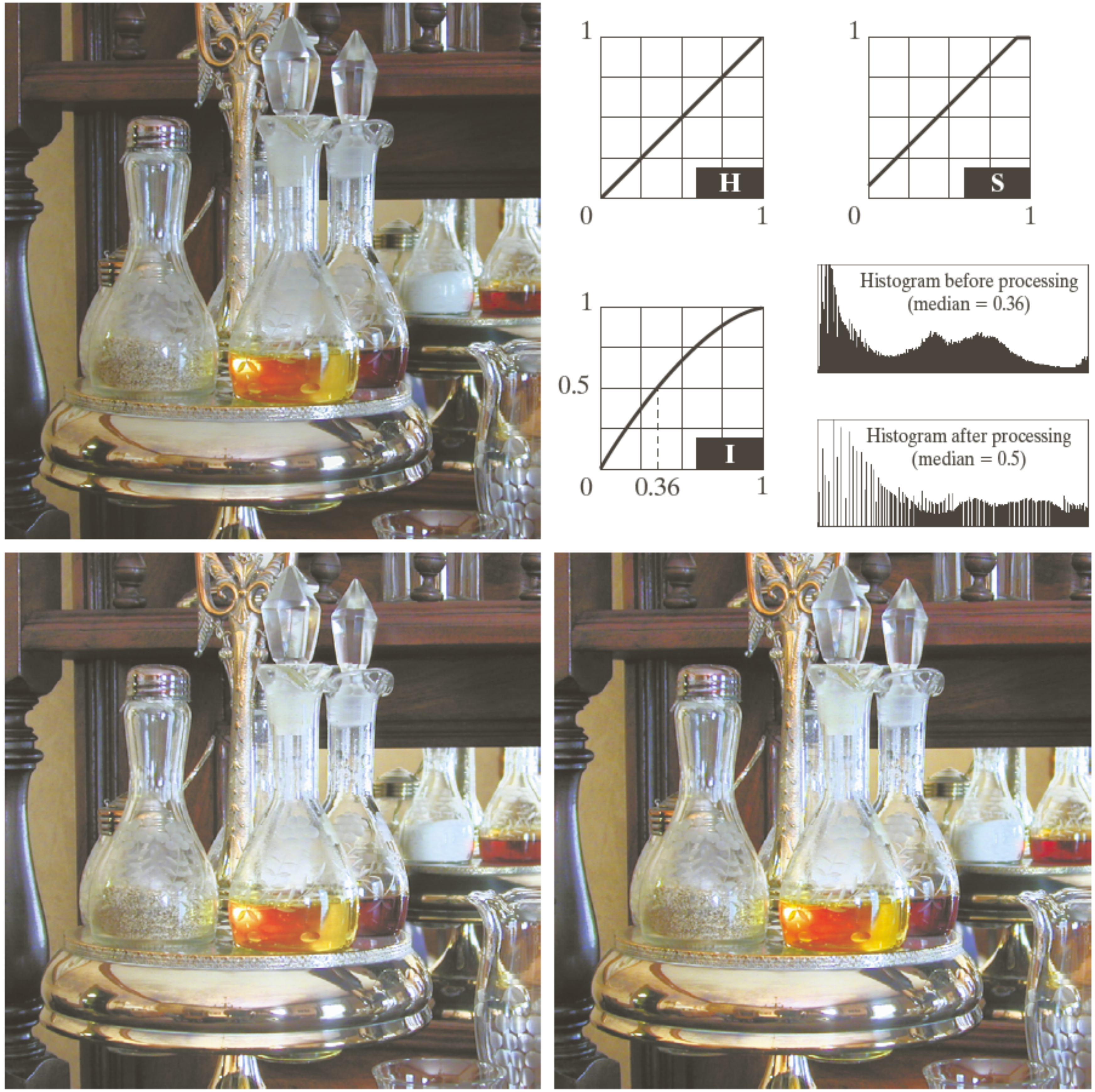


FIGURE 6.35 Tonal corrections for flat, light (high key), and dark (low key) color images. Adjusting the red, green, and blue components equally does not always alter the image hues significantly.

Color Correction



Color Histogram Balancing



Color Smoothing

a b
c d

FIGURE 6.38 (a) RGB image. (b) Red component image. (c) Green component. (d) Blue component.

a b c

FIGURE 6.39 HSI components of the RGB color image in Fig. 6.38(a). (a) Hue. (b) Saturation. (c) Intensity.

Color Smoothing

a b c

FIGURE 6.40 Image smoothing with a 5×5 averaging mask. (a) Result of processing each RGB component image. (b) Result of processing the intensity component of the HSI image and converting to RGB. (c) Difference between the two results.

$$R_{\text{out}} = \frac{1}{K} \sum_{S_K} R(x,y) \qquad G_{\text{out}} = \frac{1}{K} \sum_{S_K} G(x,y) \qquad B_{\text{out}} = \frac{1}{K} \sum_{S_K} B(x,y)$$

Color Sharpening

a b c

FIGURE 6.41 Image sharpening with the Laplacian. (a) Result of processing each RGB channel. (b) Result of processing the HSI intensity component and converting to RGB. (c) Difference between the two results.

$$R_{\text{out}} = R + \nabla^2 R$$

$$G_{\text{out}} = G + \nabla^2 G$$

$$B_{\text{out}} = B + \nabla^2 B$$

Edge Detection Based on Color

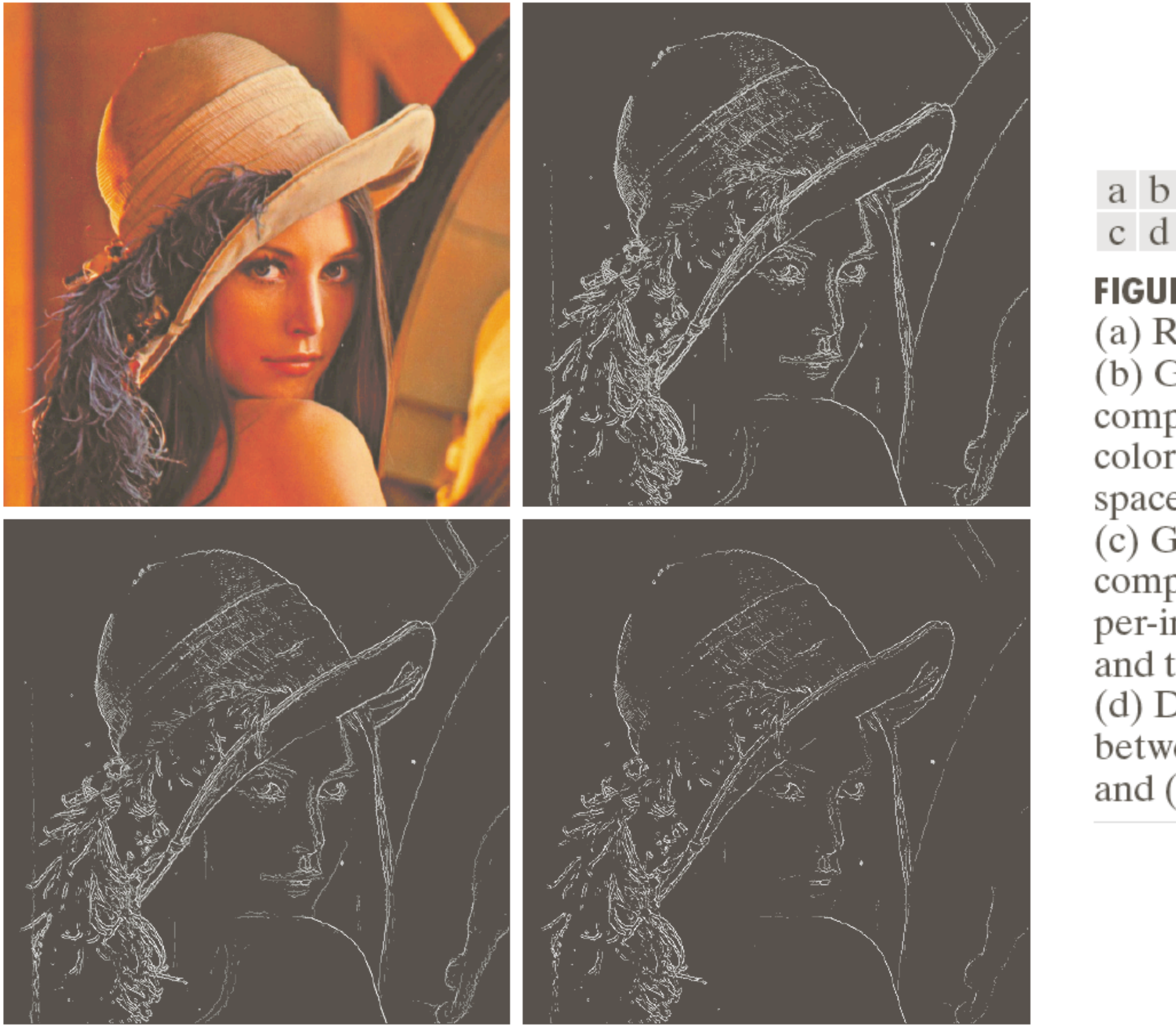


FIGURE 6.46
(a) RGB image.
(b) Gradient computed in RGB color vector space.
(c) Gradients computed on a per-image basis and then added.
(d) Difference between (b) and (c).

Issues with Using Color as Image Feature

- Color description systems do not provide smooth representations of
  - natural, intrinsic color variations of objects
  - extrinsic illumination, light saturation, etc., changes
- Color at one pixel location is not very informative
- Color is always used to characterize an image region
- Color constancy -- An example of human (subjective) perception