ISEL

INSTITUTO SUPERIOR
DE ENGENHARIA DE LISBOA

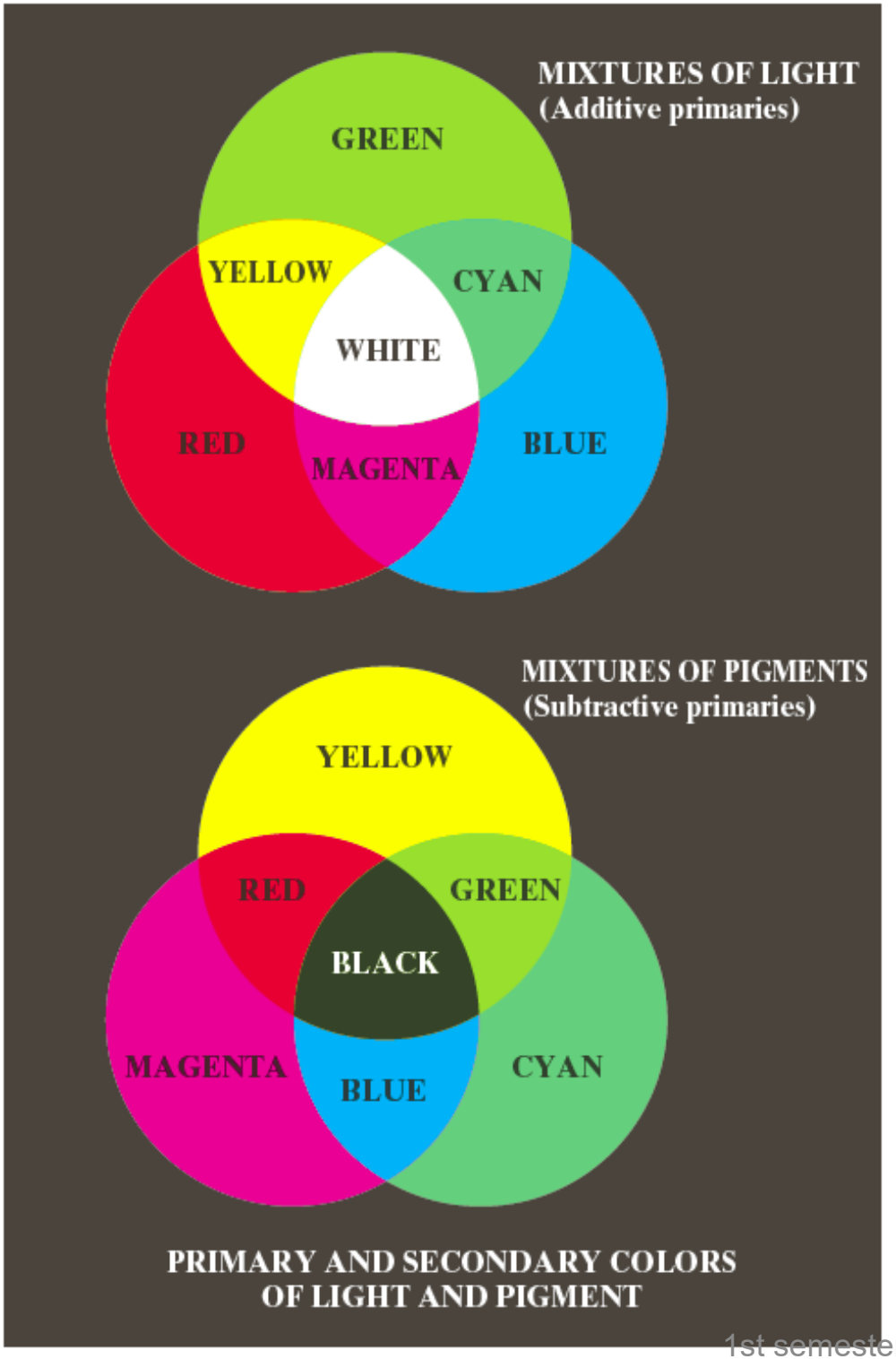
PROCESSAMENTO DE IMAGEM E BIOMETRIA

IMAGE PROCESSING AND BIOMETRICS

7. **COLOR IMAGE PROCESSING (part 2)**

Summary (part 2)

- Colors
- Web safe colors
- Color spaces
- Full color image processing
- MATLAB functions
- Bibliography



a
b

FIGURE 6.4
Primary and secondary colors of light and pigments. (Courtesy of the General Electric Co., Lamp Business Division.)

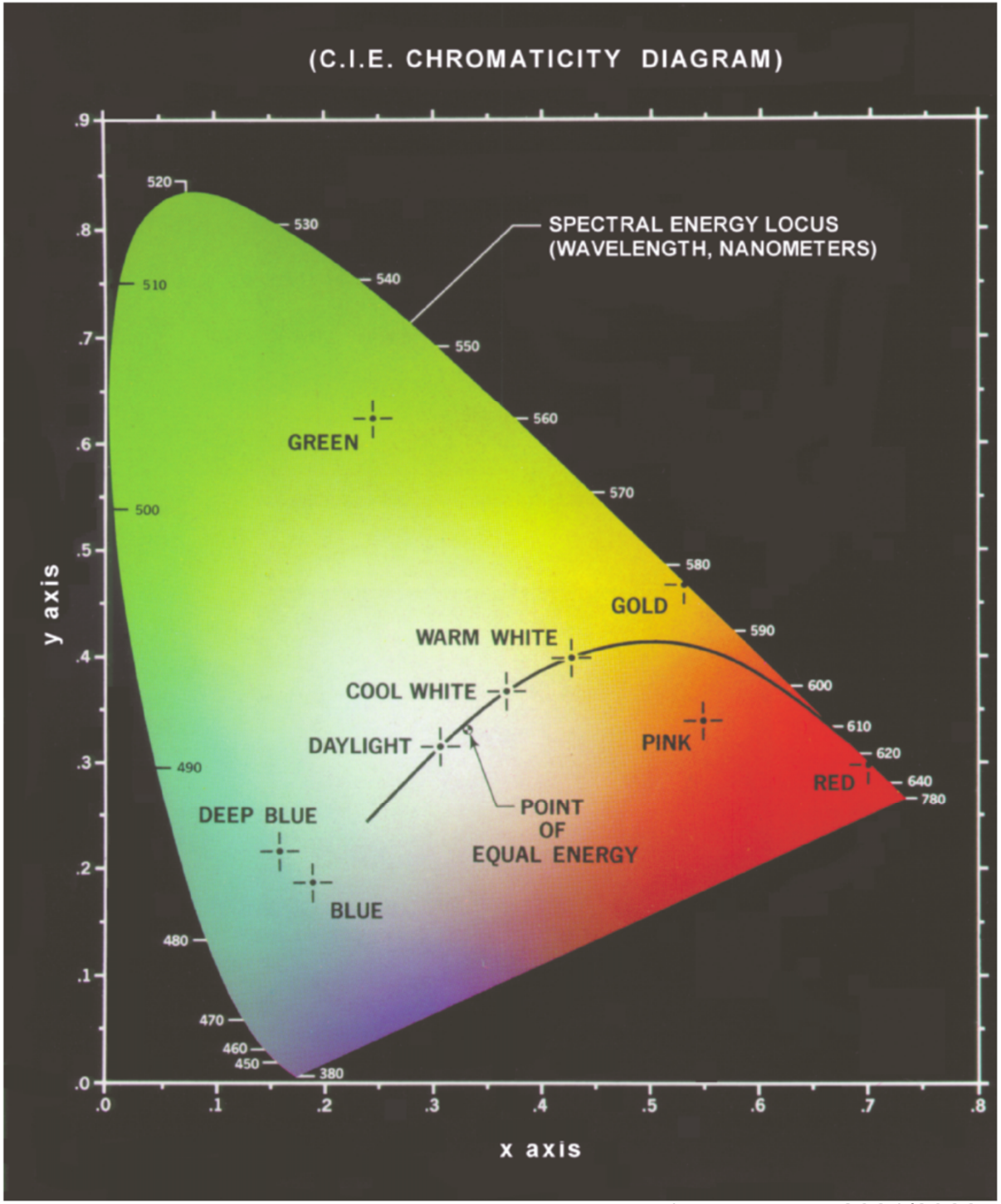


FIGURE 6.5
Chromaticity diagram. (Courtesy of the General Electric Co., Lamp Business Division.)

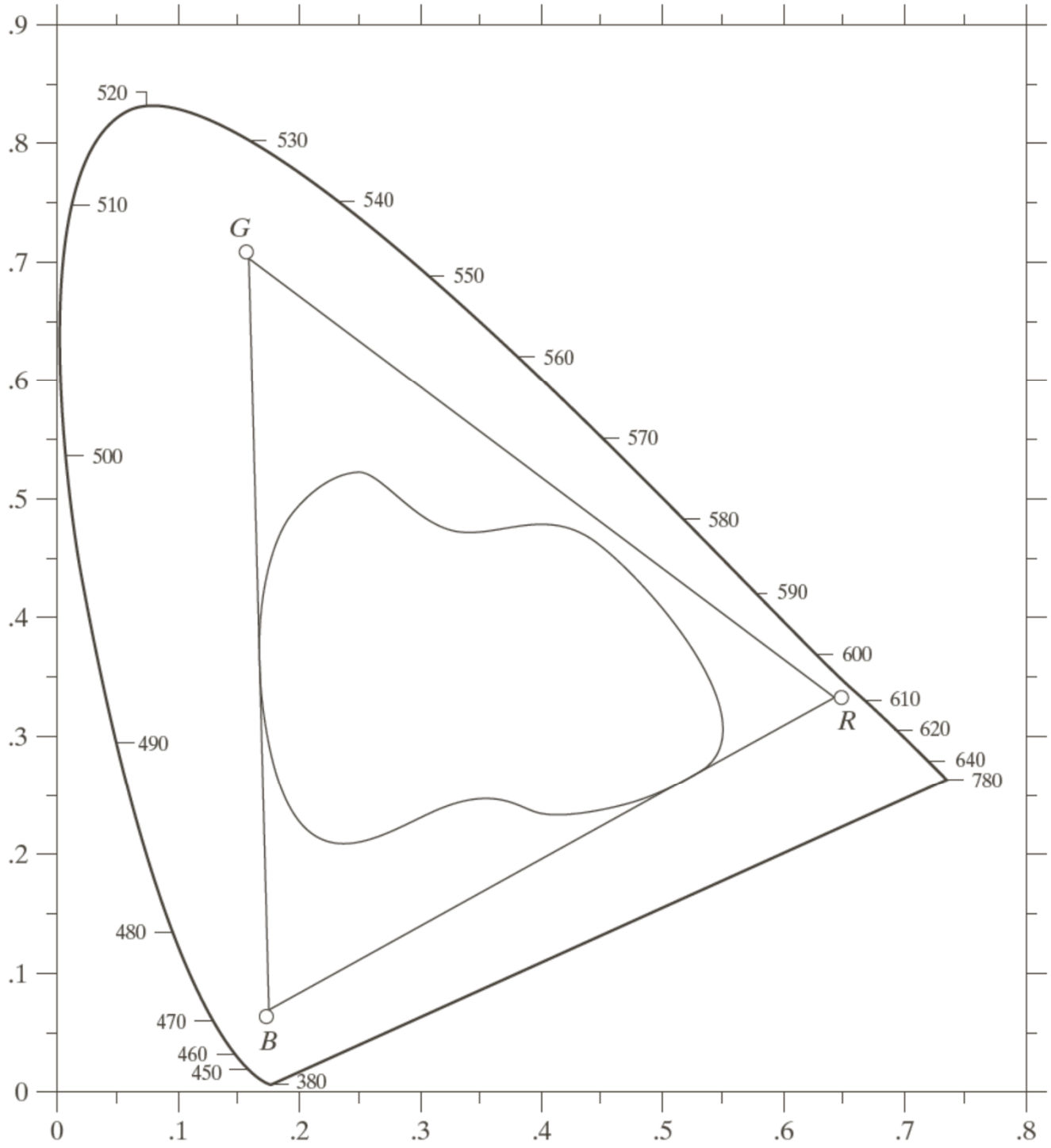


FIGURE 6.6
Typical color gamut of color monitors (triangle) and color printing devices (irregular region).

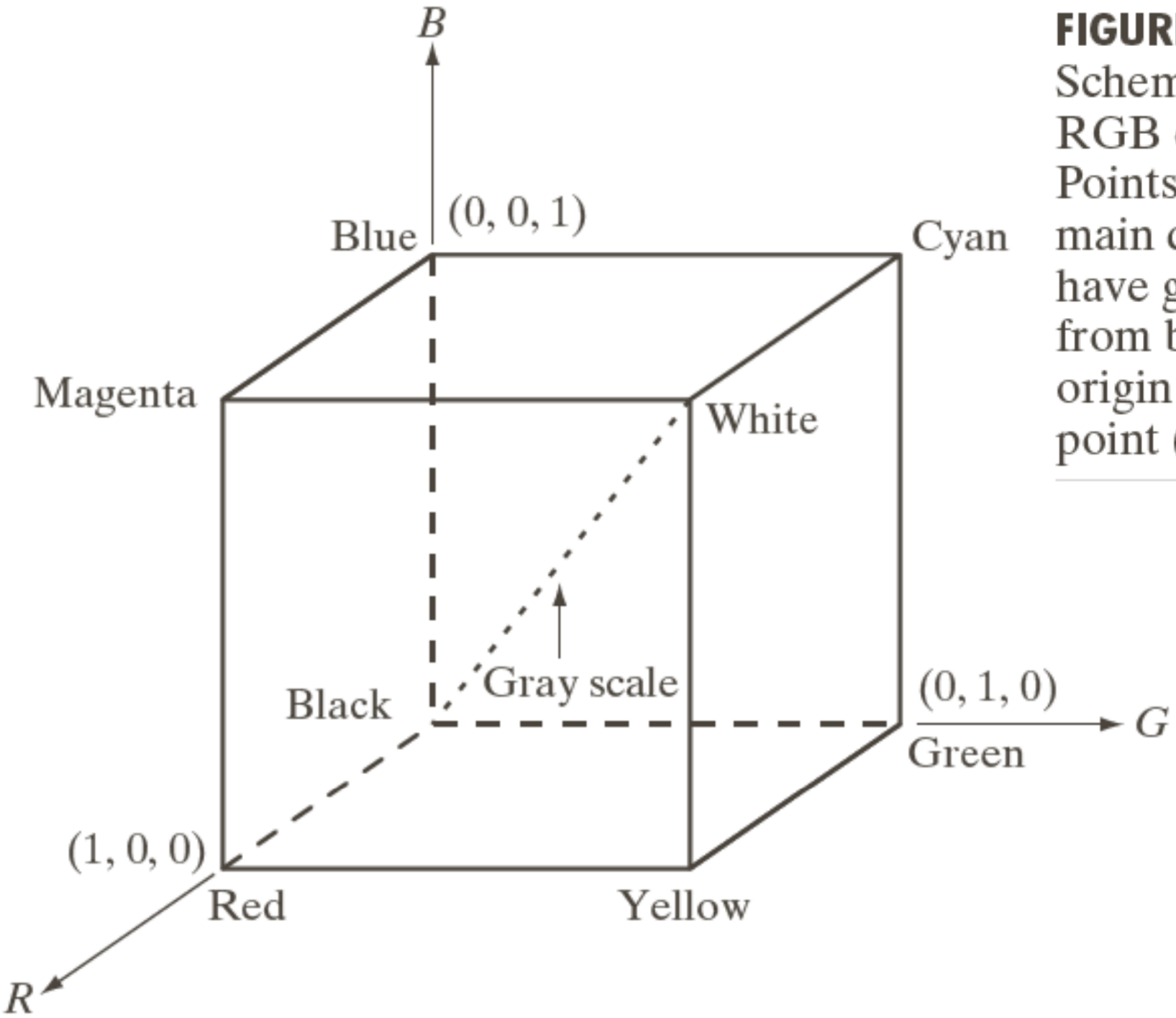
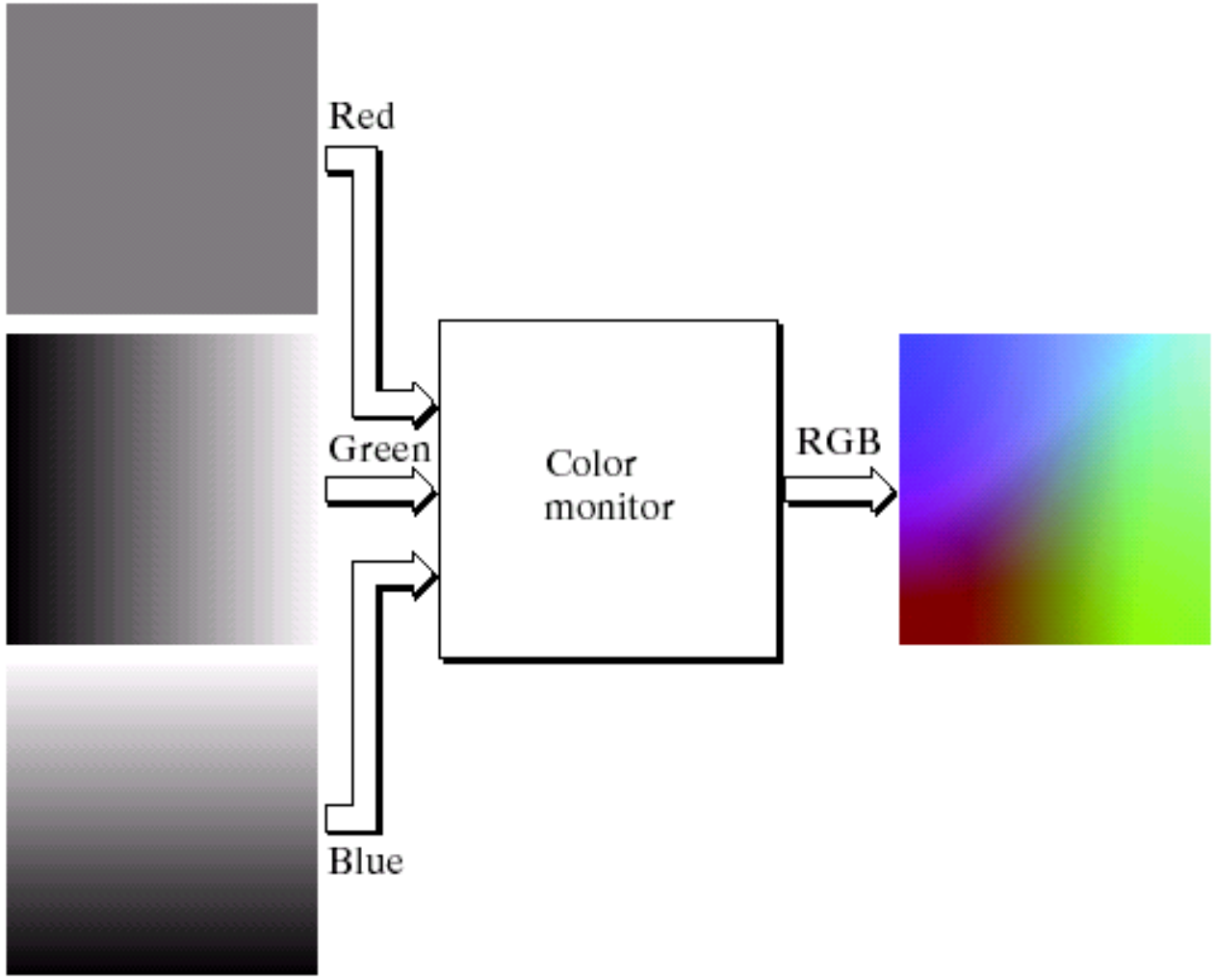


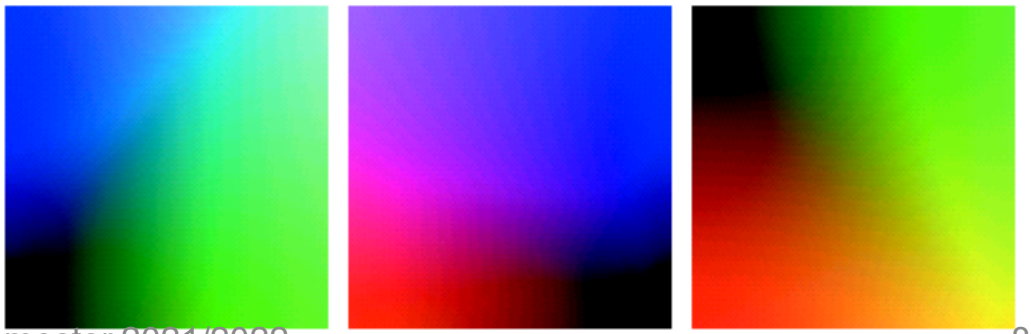
FIGURE 6.7
Schematic of the RGB color cube. Points along the main diagonal have gray values, from black at the origin to white at point (1, 1, 1).

FIGURE 6.8 RGB 24-bit color cube.

a
b

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.

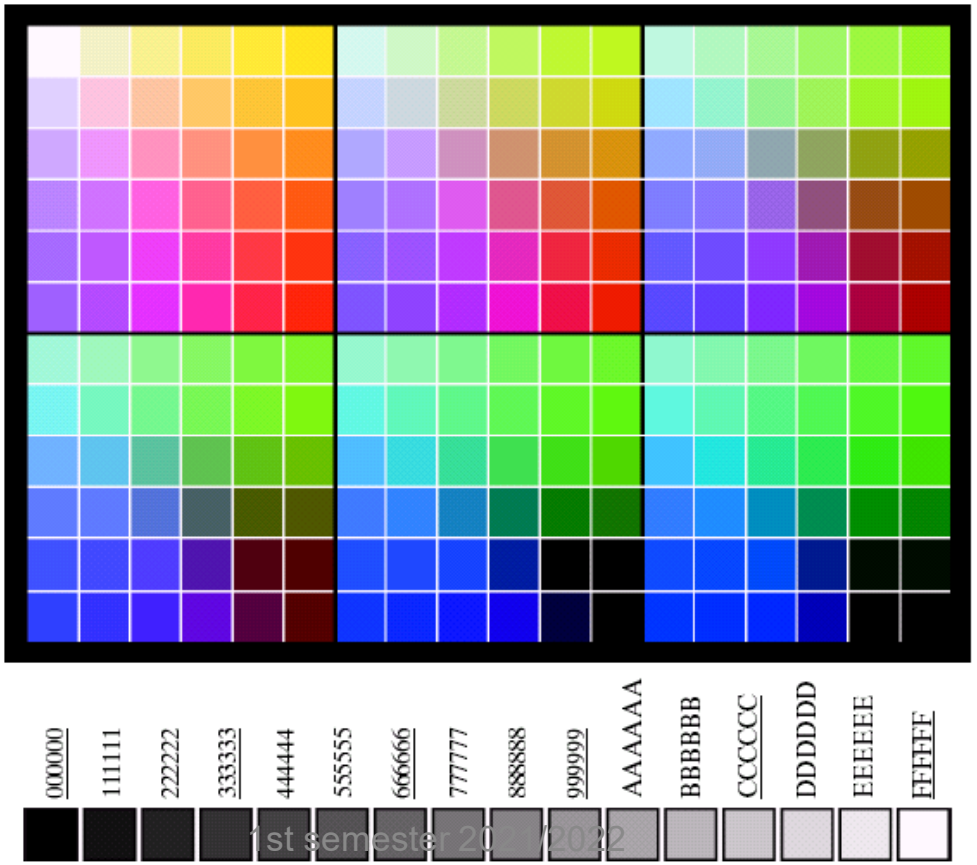




WEB safe colors (1)

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

TABLE 6.1
Valid values of each RGB component in a safe color.



a
b

FIGURE 6.10
(a) The 216 safe RGB colors. (b) All the grays in the 256-color RGB system (grays that are part of the safe color group are shown underlined).

WEB safe colors (2)

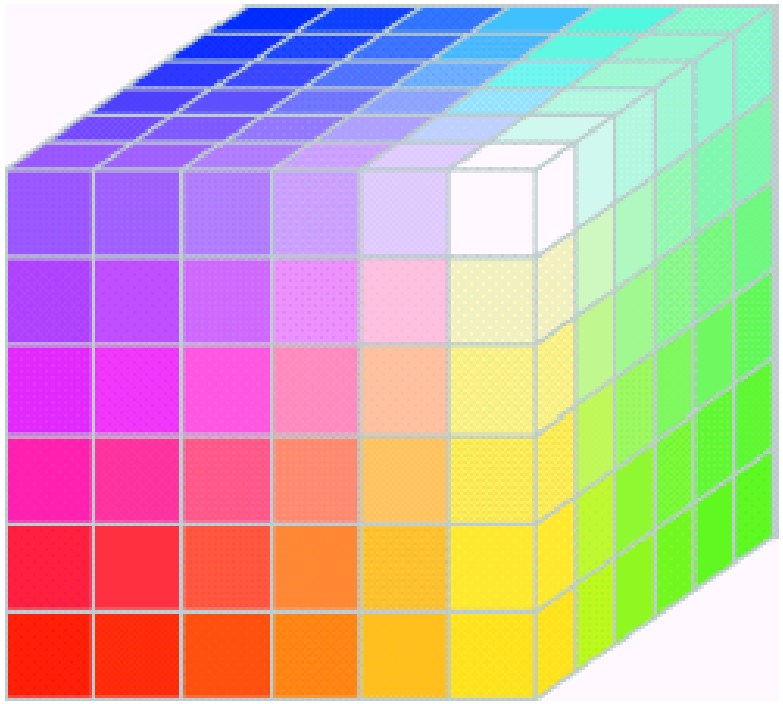
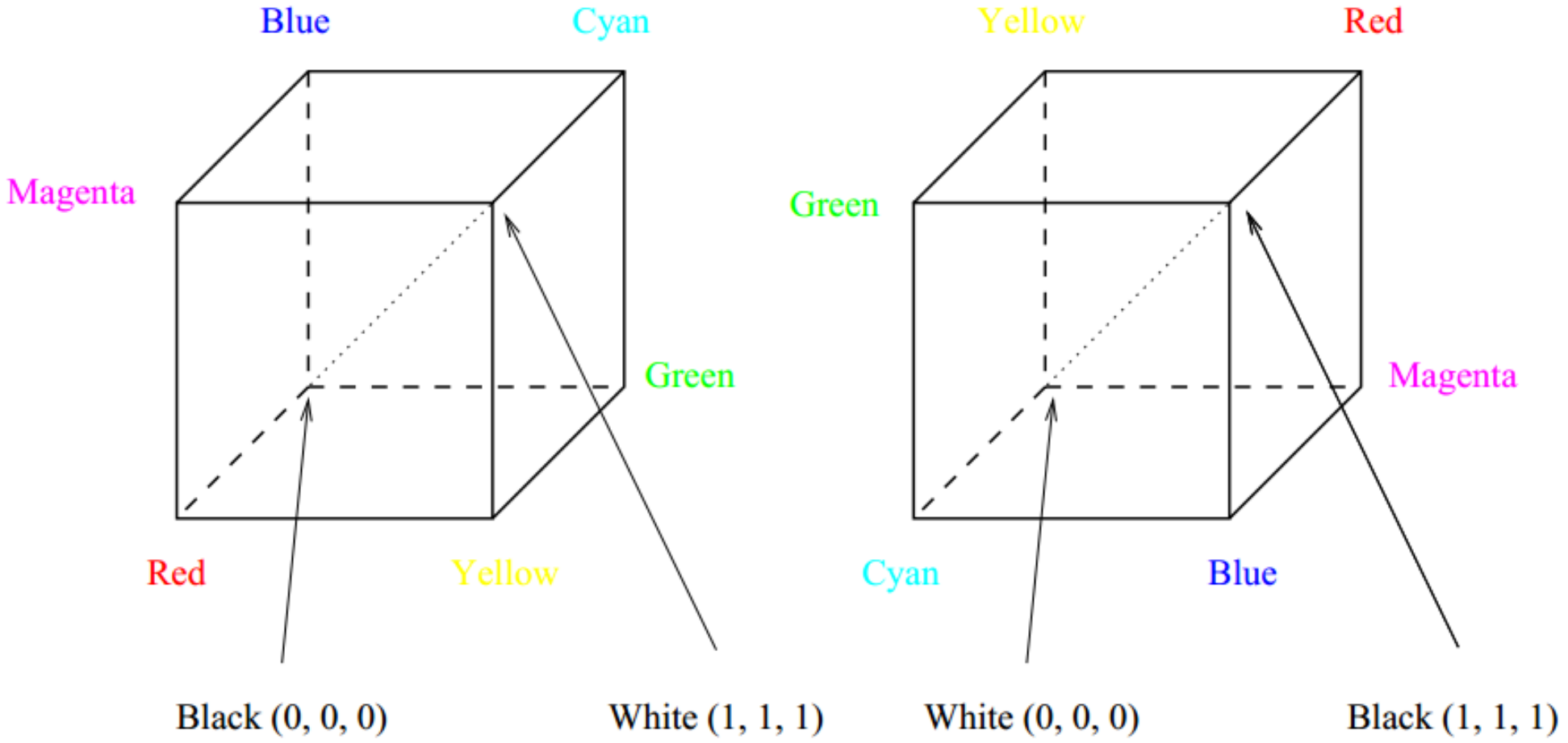


FIGURE 6.11 The RGB safe-color cube.

Color Space (1)

- A color space is a mathematical representation of color
- The color is represented as a vector (with 3 components)
- Some color spaces:
  - RGB, sRGB (acquisition and display)
  - CMY, CMYK (printing devices)
  - HSI, HSV, and HSL (image analysis)
  - YUV, YIQ, YCbCr (image and video coding)

Color Space (2)

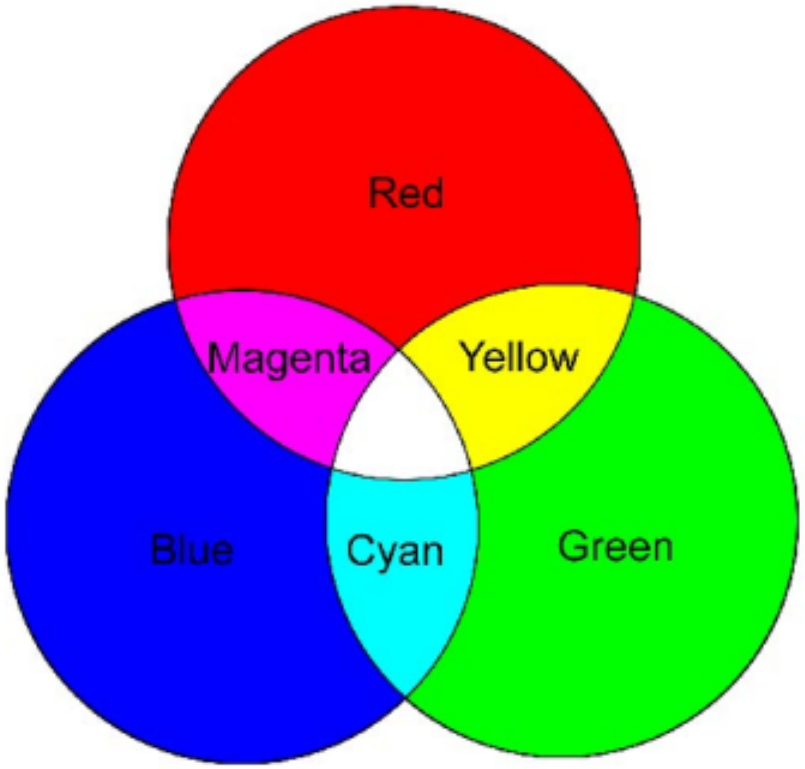


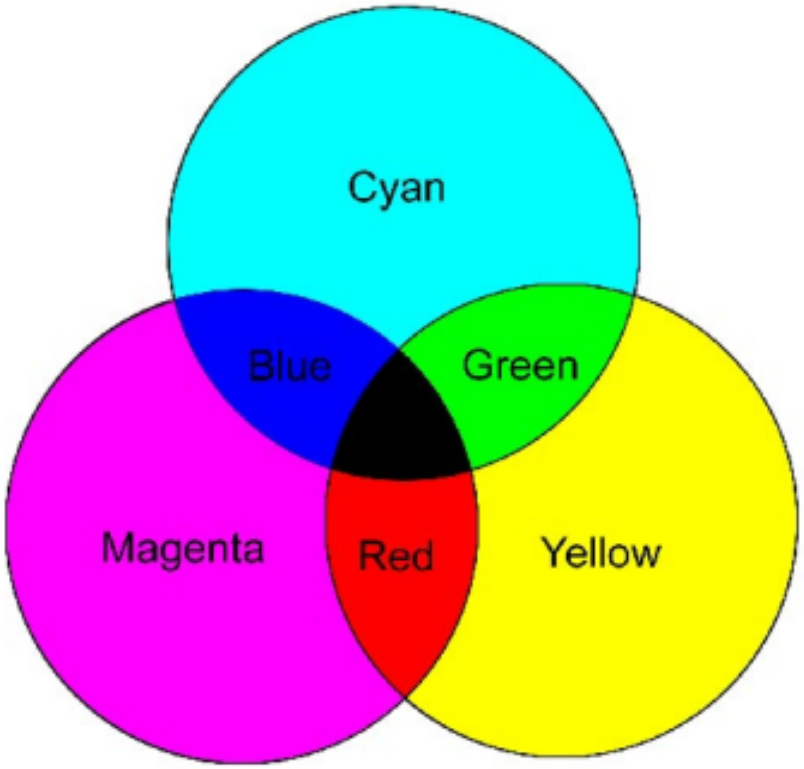
The RGB Cube

The CMY Cube

Color Space (3)

- RGB and CMY





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

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

Color Space (4)

- CMY and CMYK

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

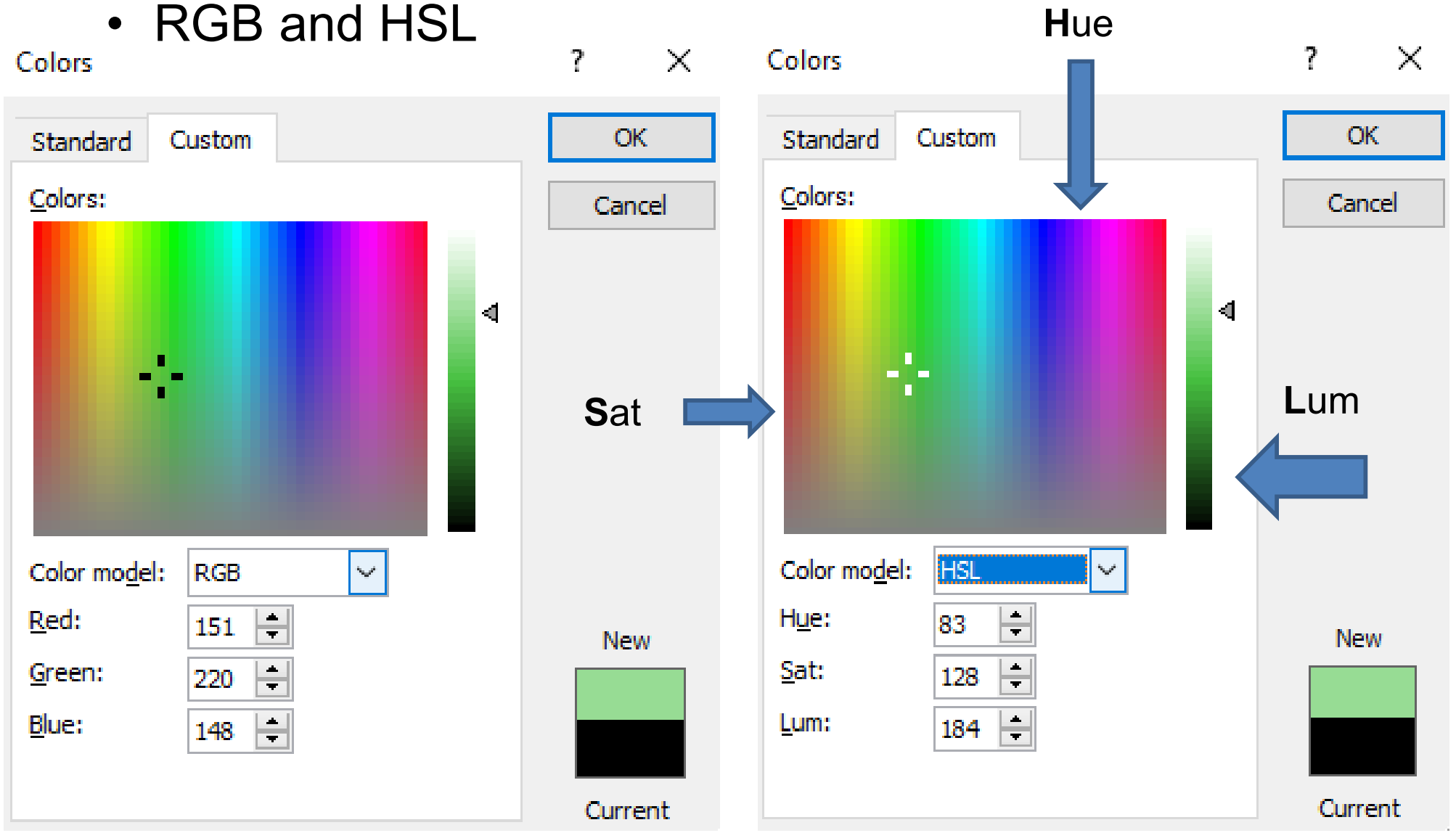
- **Undercolor removal**:. Sharper and cheaper printer colors: calculate that part of the CMY mix that would be black, remove it from the color proportions, and add it back as real black.

$$K \equiv min\{C, M, Y\}$$

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} \Rightarrow \begin{bmatrix} C-K \\ M-K \\ Y-K \end{bmatrix}$$

Color Space (5)

- RGB and HSL

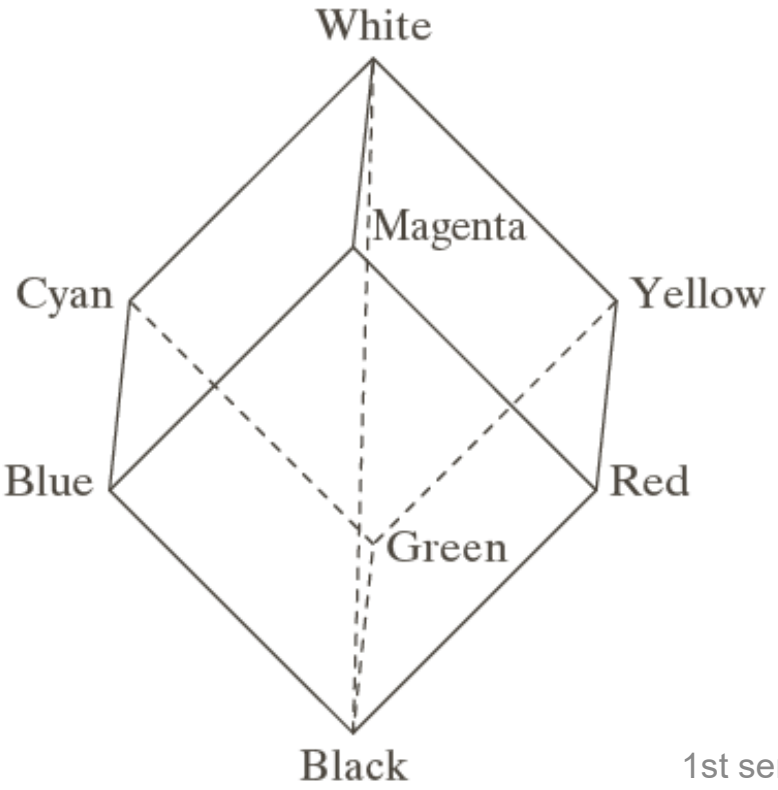


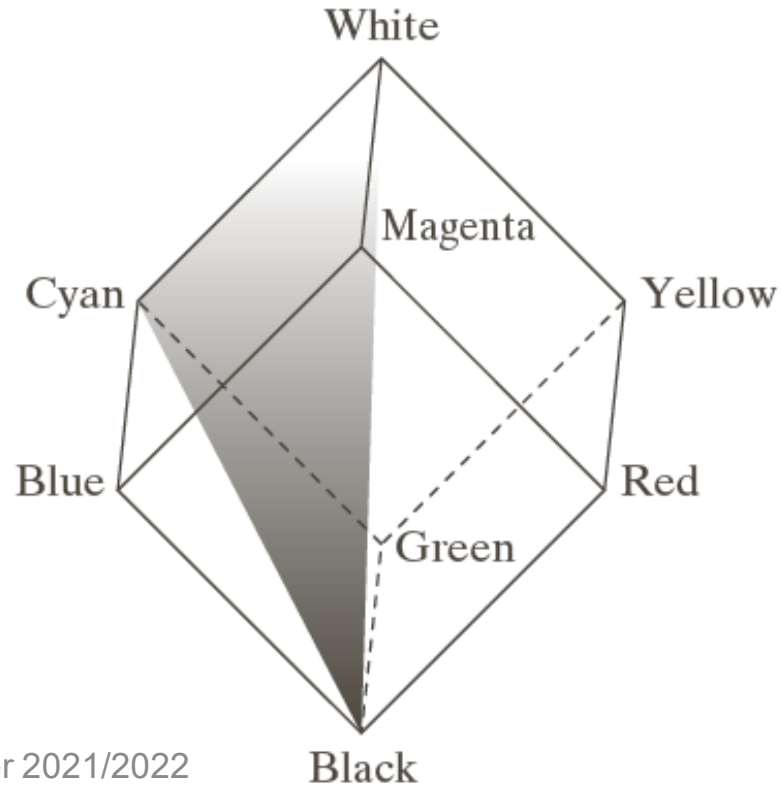
Color Space (6)

- RGB and HSI

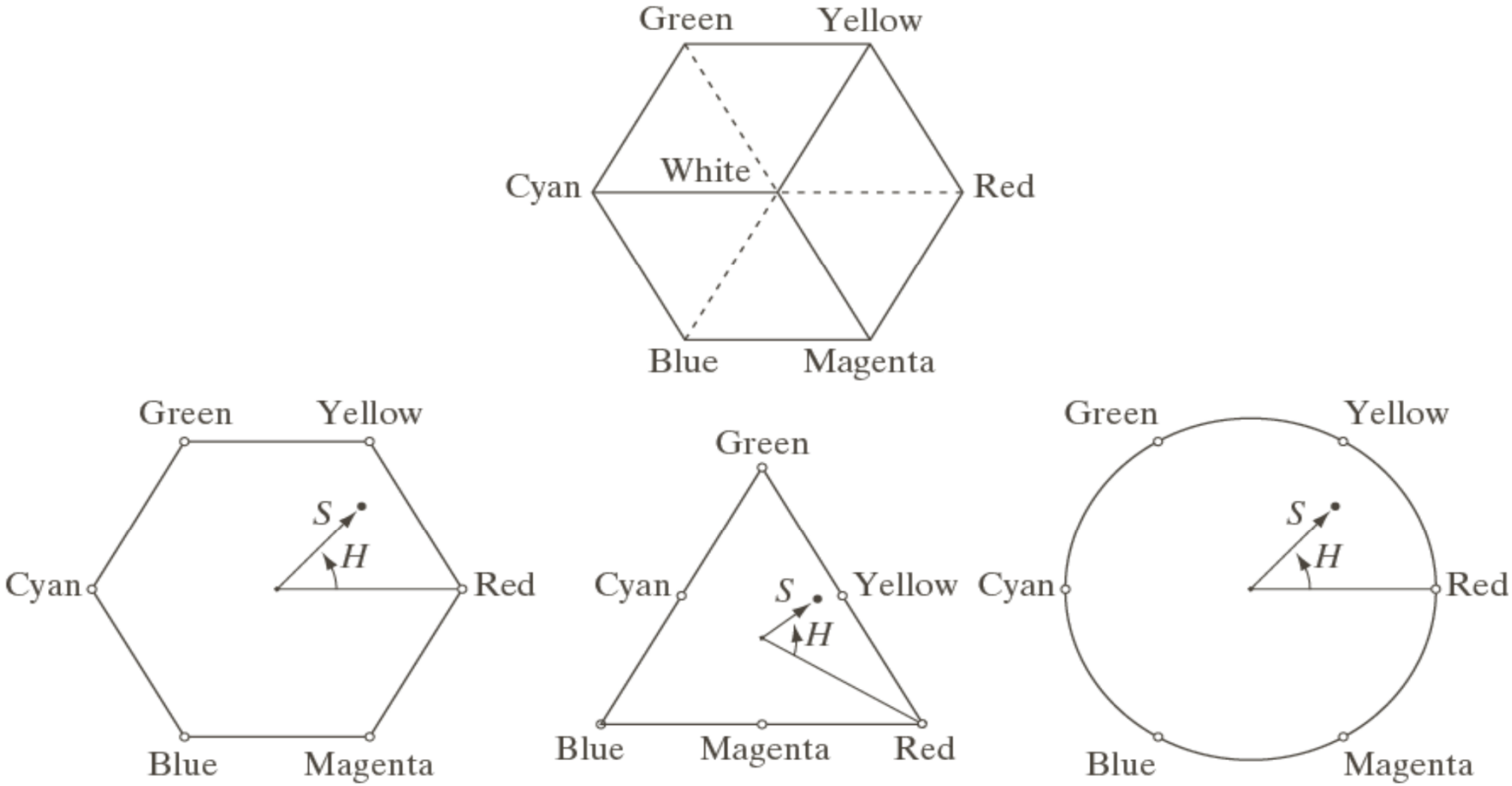
a b

FIGURE 6.12 Conceptual relationships between the RGB and HSI color models.





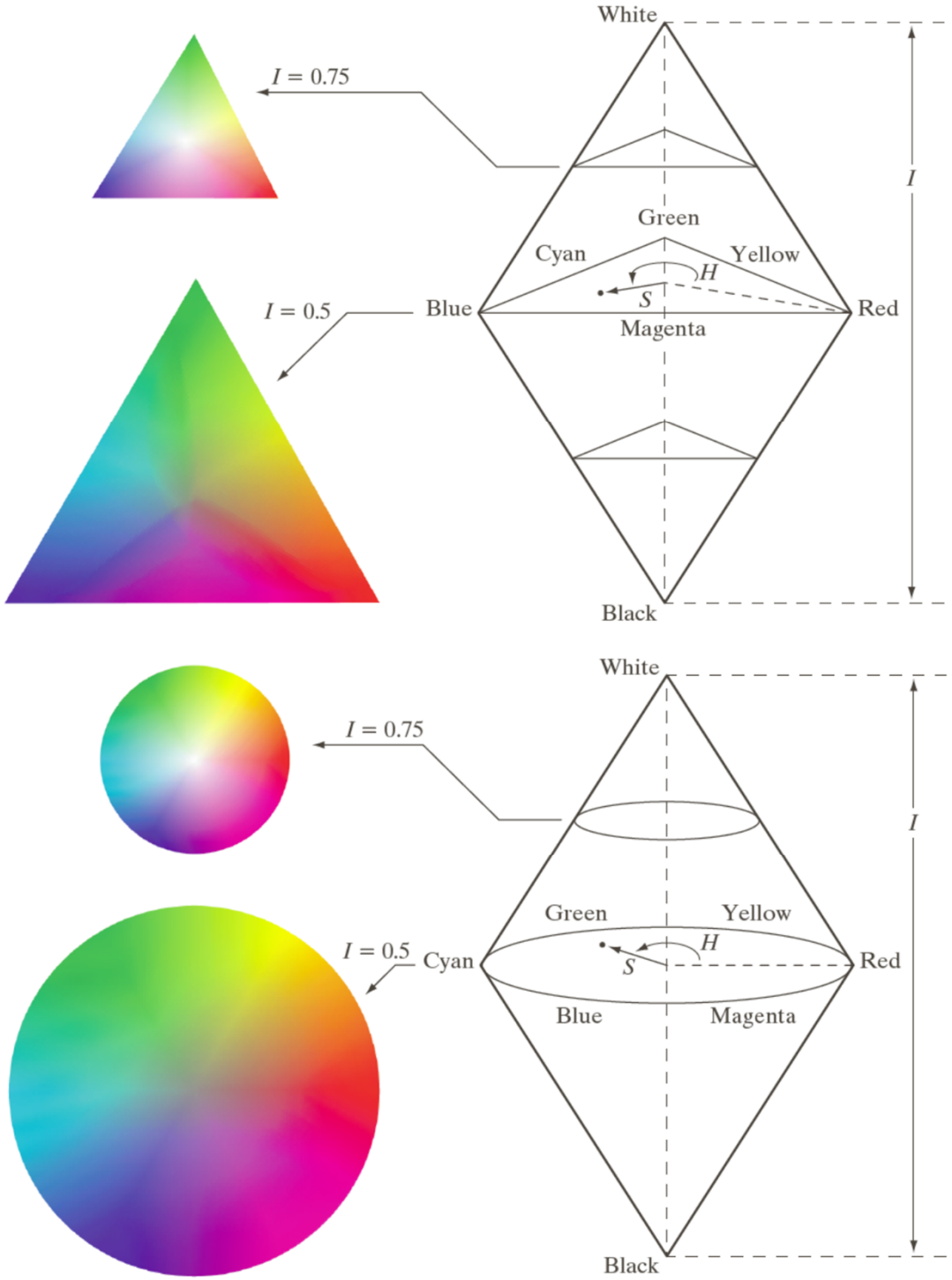
Color Space (7)



a
b c d

FIGURE 6.13 Hue and saturation in the HSI color model. The dot is an arbitrary color point. The angle from the red axis gives the hue, and the length of the vector is the saturation. The intensity of all colors in any of these planes is given by the position of the plane on the vertical intensity axis.

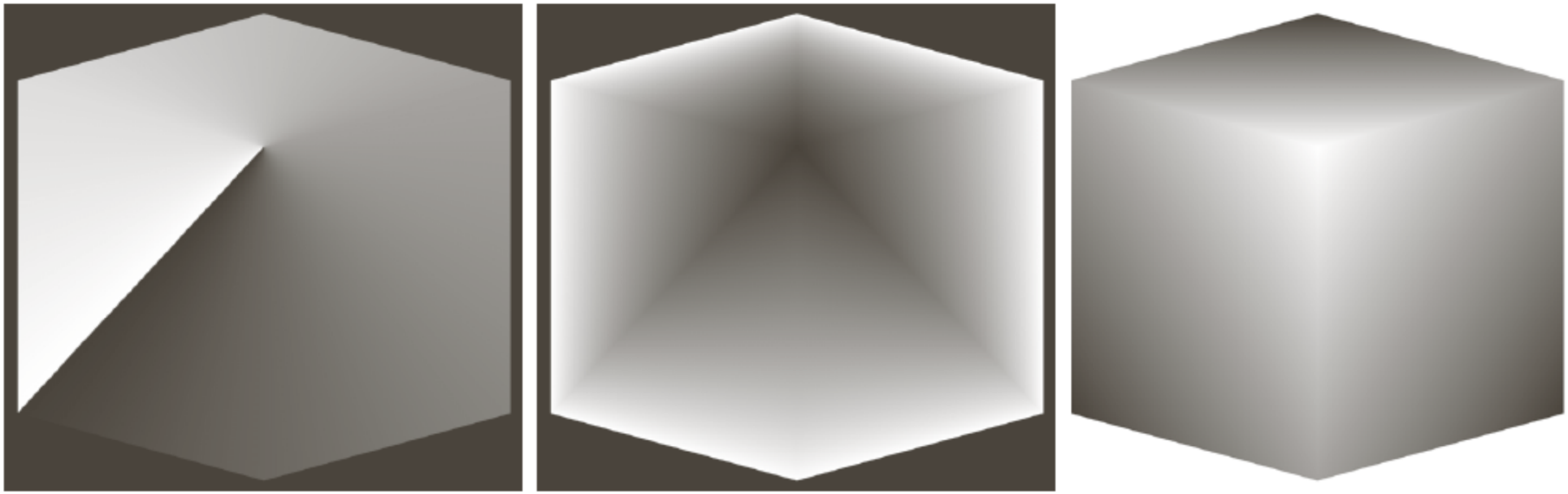
Color Space (8)



a
b

FIGURE 6.14 The HSI color model based on (a) triangular and (b) circular color planes. The triangles and circles are perpendicular to the vertical intensity axis.

Color Space (9)

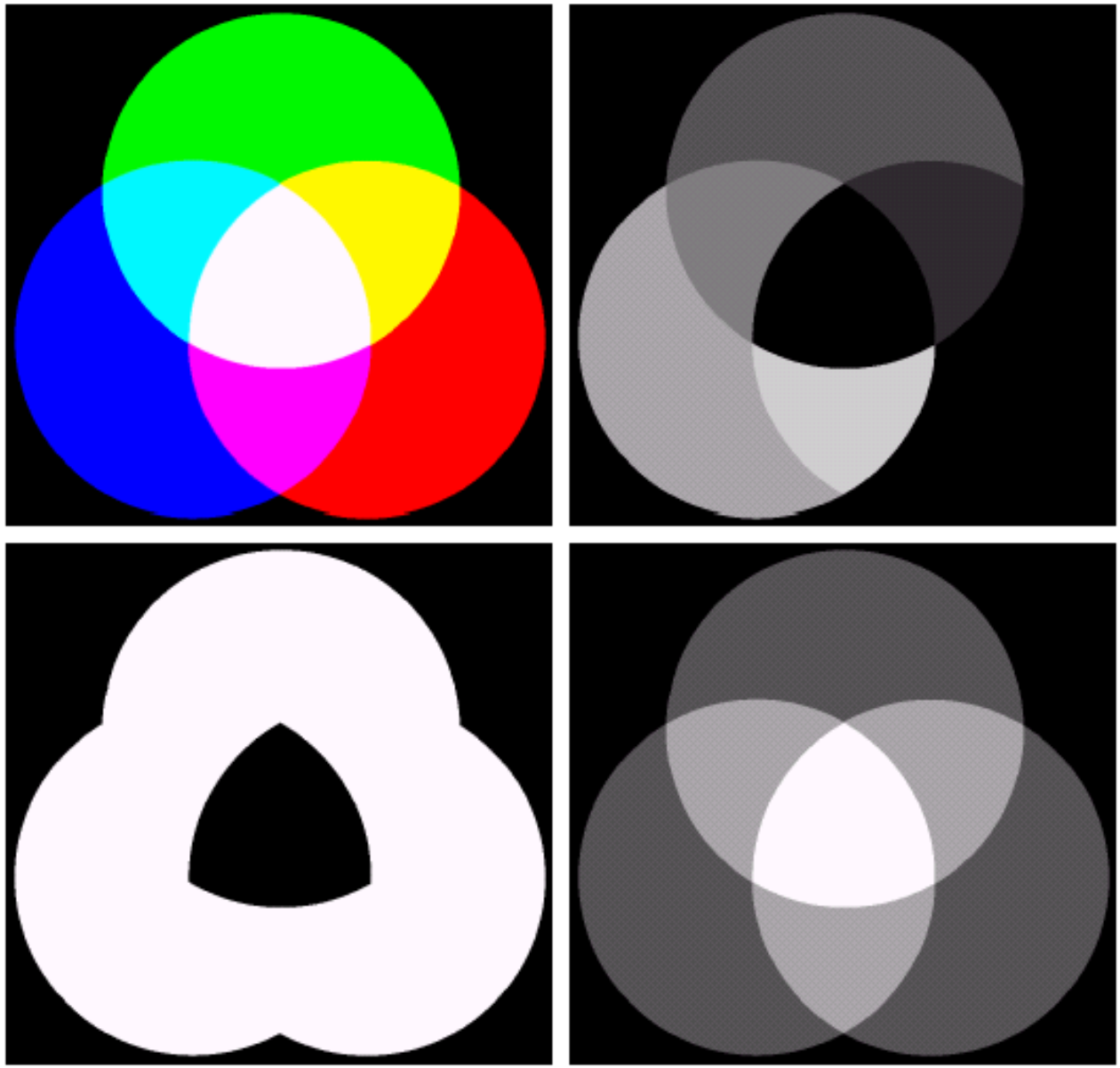


a b c

FIGURE 6.15 HSI components of the image in Fig. 6.8. (a) Hue, (b) saturation, and (c) intensity images.

Color Space (10)

- RGB and HSI

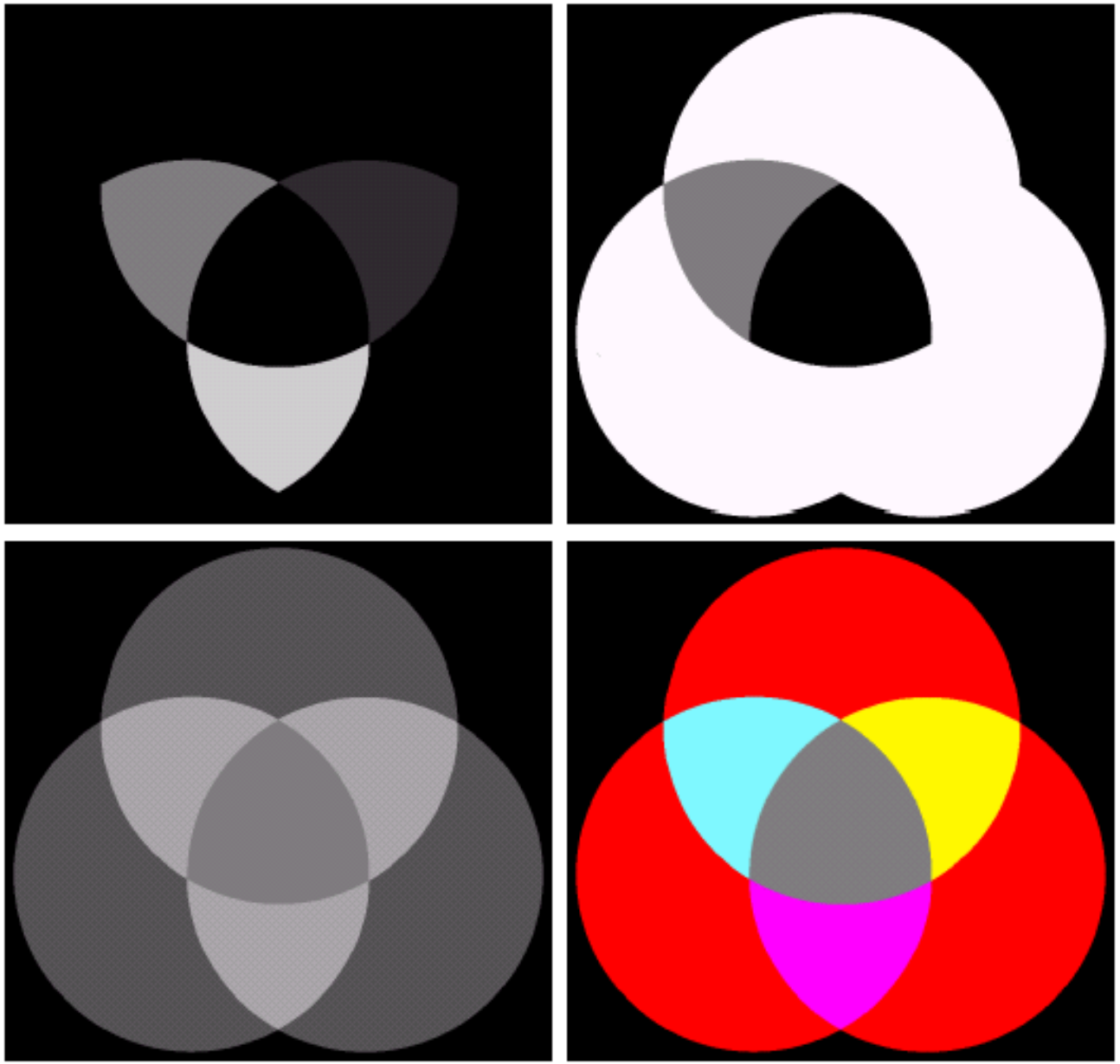


a b
c d

FIGURE 6.16 (a) RGB image and the components of its corresponding HSI image: (b) hue, (c) saturation, and (d) intensity.

Color Space (11)

- Modify image in HSI
- Get resulting RGB image



a b
c d

FIGURE 6.17 (a)–(c) Modified HSI component images. (d) Resulting RGB image. (See Fig. 6.16 for the original HSI images.)

Color Space (12)

- Conversion of RGB to HSI

- $T = \arccos(\ 0.5*[(R-G) + (R-B)] / [(R-G)^2 + (R-B)(G-B)]^{0.5})$
- if B <= G

  H = T

  else

  H = 360 – T

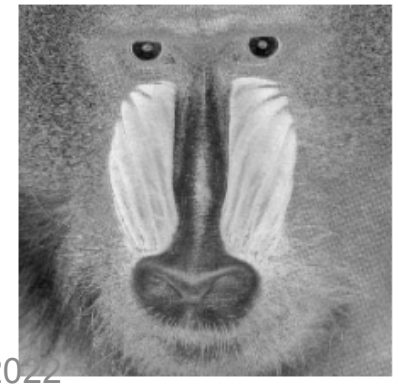
- $S = 1 – (3 / (R+G+B)) * \min([R, G, B])$

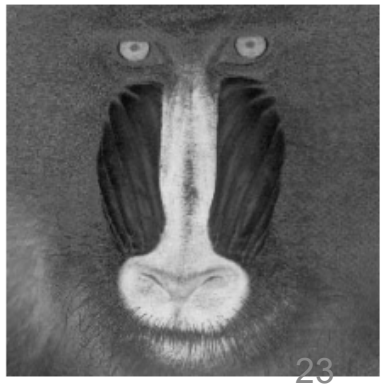
- $I = (1/3) * (R + G + B)$

Color Space (13)

- YUV (1 luminance + 2 chrominances)

$$\begin{bmatrix} Y' \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ -0.299 & -0.587 & 0.886 \\ 0.701 & -0.587 & -0.114 \end{bmatrix} \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix}$$



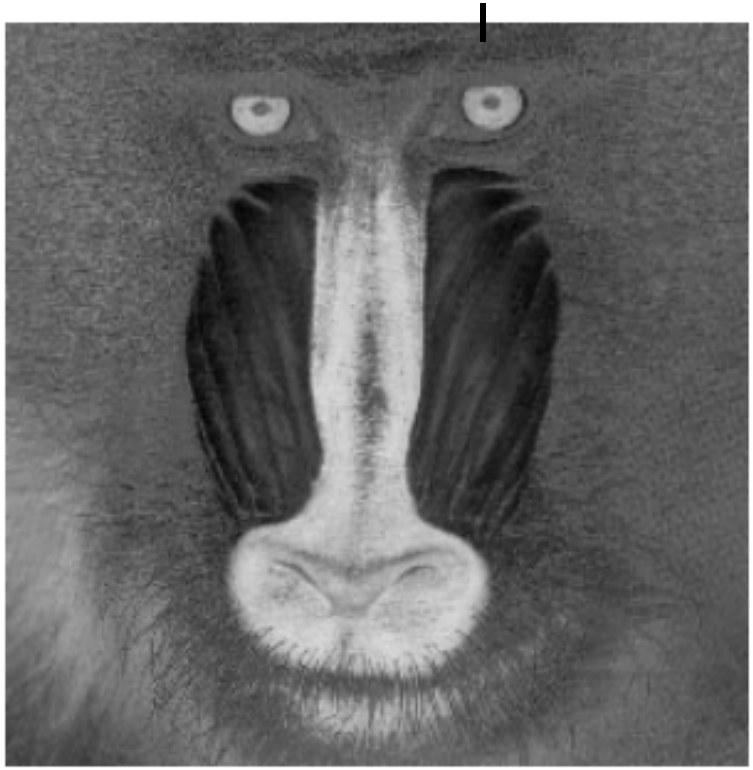


Color Space (14)

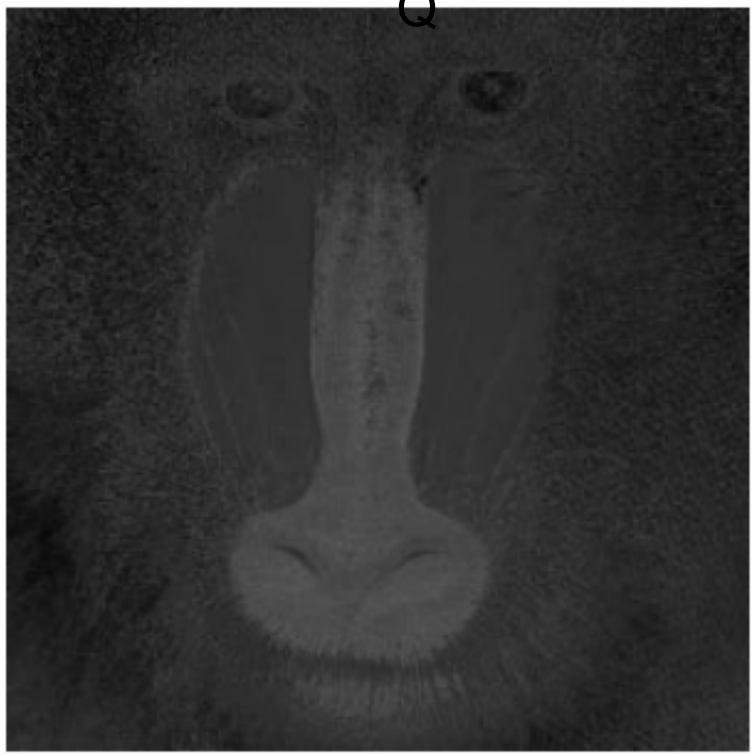
- YIQ (1 luminance + 2 chrominances)

$$\begin{bmatrix} Y' \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ 0.595879 & -0.274133 & -0.321746 \\ 0.211205 & -0.523083 & 0.311878 \end{bmatrix} \times \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix}$$

I



Q



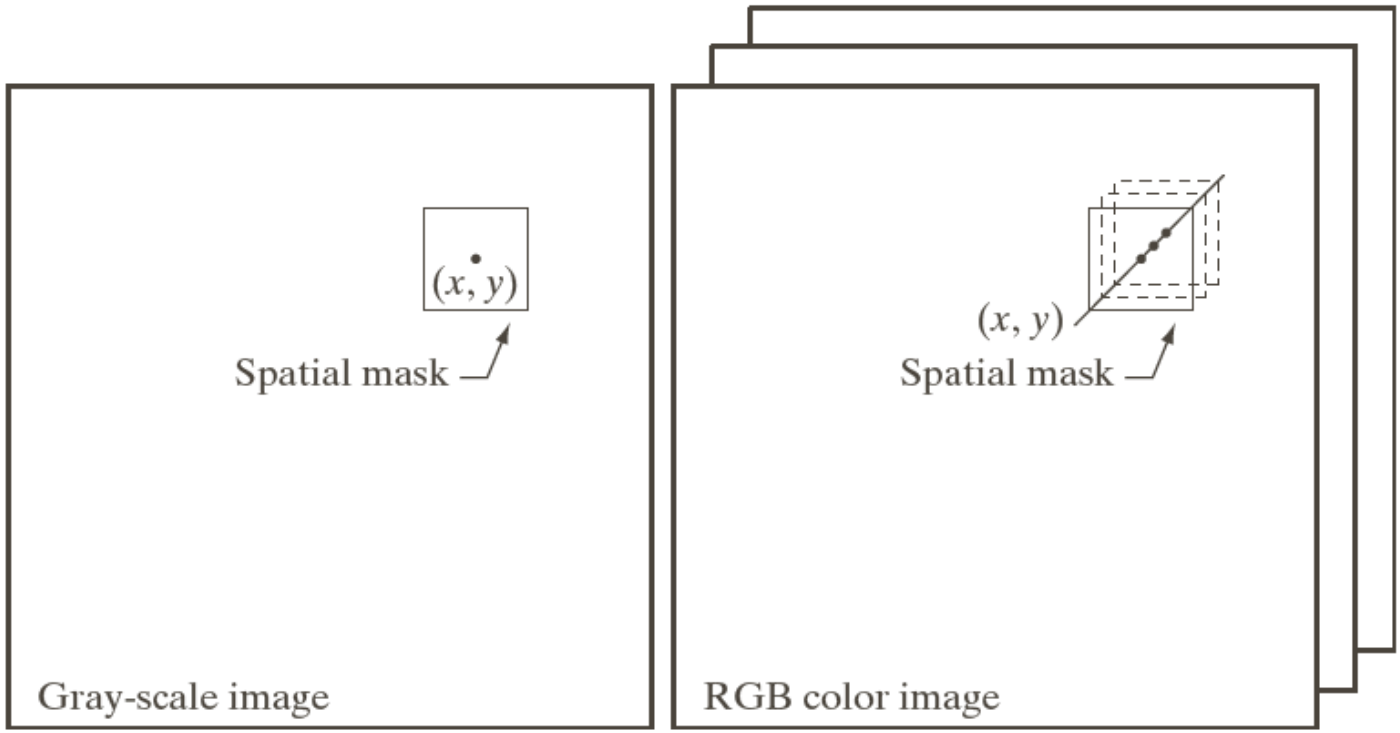
Color Space (15)

- YCbCr (1 luminance + 2 chrominances)

$$\begin{bmatrix} Y' \\ C_b \\ C_r \end{bmatrix} = \begin{bmatrix} 65.481 & 128.553 & 24.966 \\ -37.797 & -74.203 & 112 \\ 112 & -93.786 & -18.214 \end{bmatrix} \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix}$$

- RGB to gray scale: Y = 0.2989R + 0.5870G + 0.1140B
- MATLAB rgb2gray.m
  https://www.mathworks.com/help/matlab/ref/rgb2gray.html

Full Color Image Processing (1)

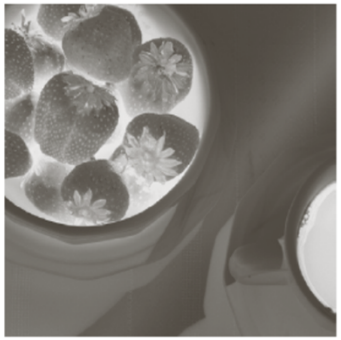


a b

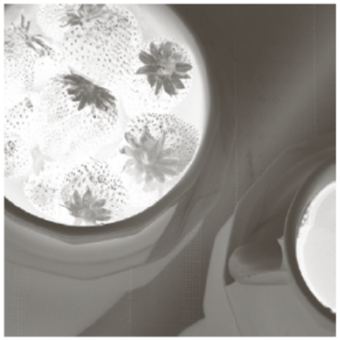
FIGURE 6.29 Spatial masks for gray-scale and RGB color images.

Full Color Image Processing (2)

Full color

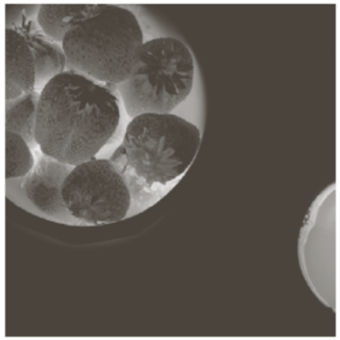


Cyan



Magenta

Yellow

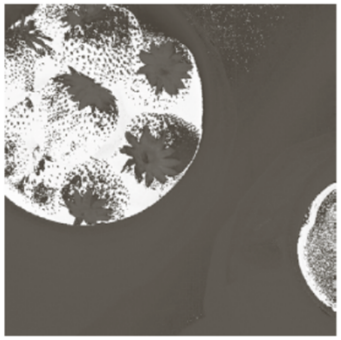


Black

Red

Green

Blue



Hue

Saturation

Intensity

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

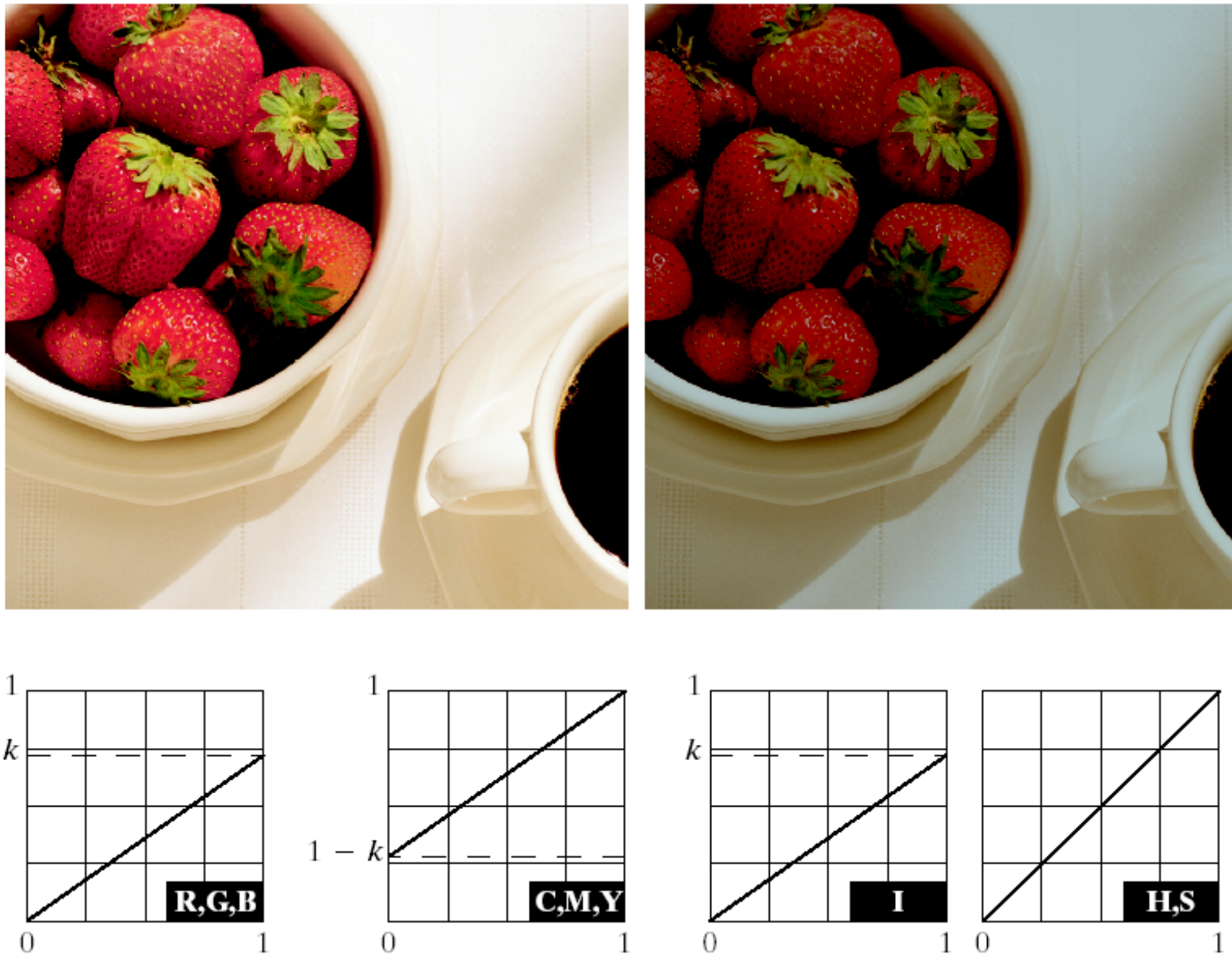
Full Color Image Processing (3)

- Some common full-color image operations:
  - Intensity Transformations
    - Increase/decrease brigthness/contrast
    - Negative version
  - Color complements
  - Color slicing
    - Isolate regions with a given color
    - Separate the background from the foreground
  - Tonal and color correction
  - Color balancing

Full Color Image Processing (4)

a b
c d e

FIGURE 6.31 Adjusting the intensity of an image using color transformations. (a) Original image. (b) Result of decreasing its intensity by 30% (i.e., letting $k = 0.7$). (c)–(e) The required RGB, CMY, and HSI transformation functions. (Original image courtesy of MedData Interactive.)



Full Color Image Processing (5)

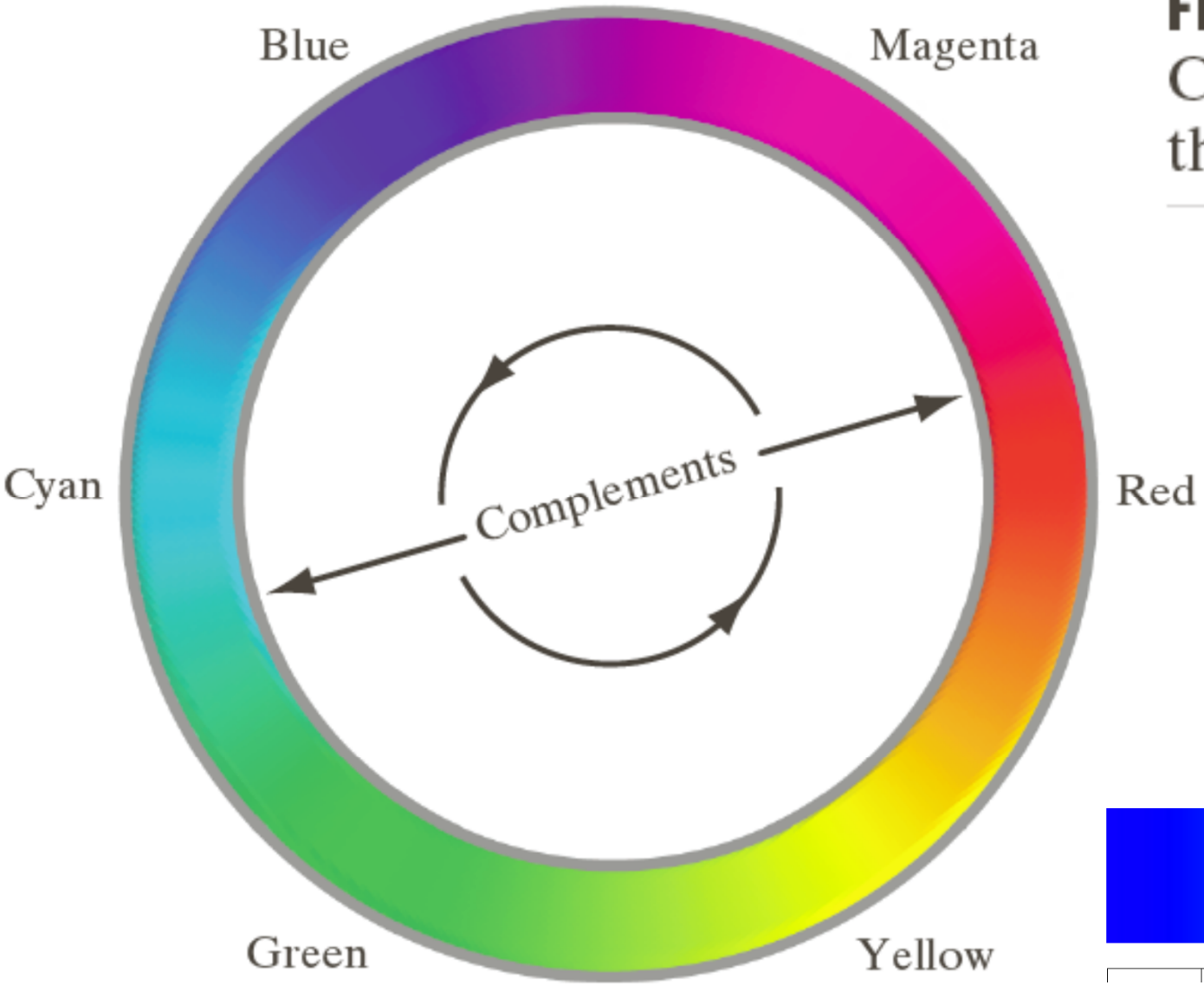
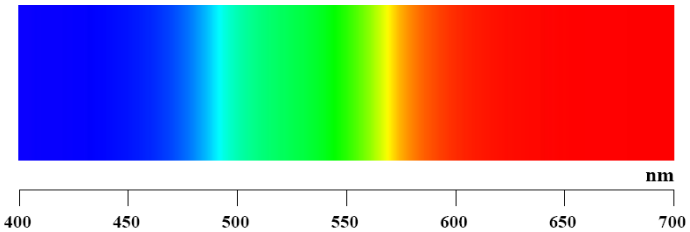
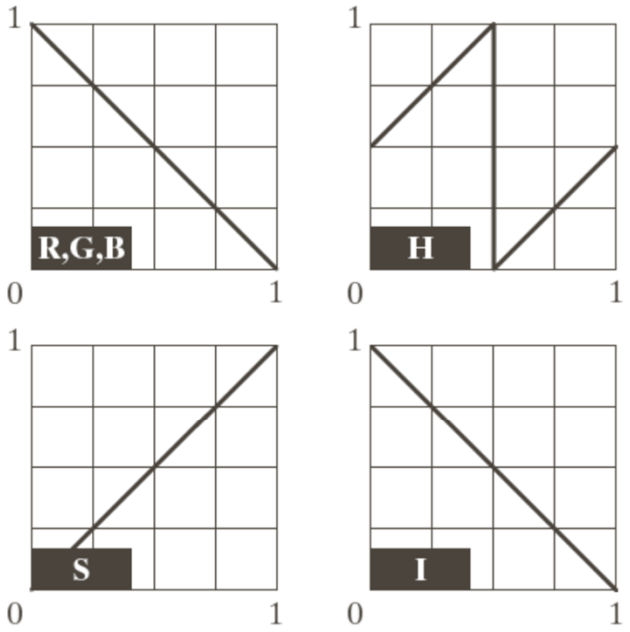
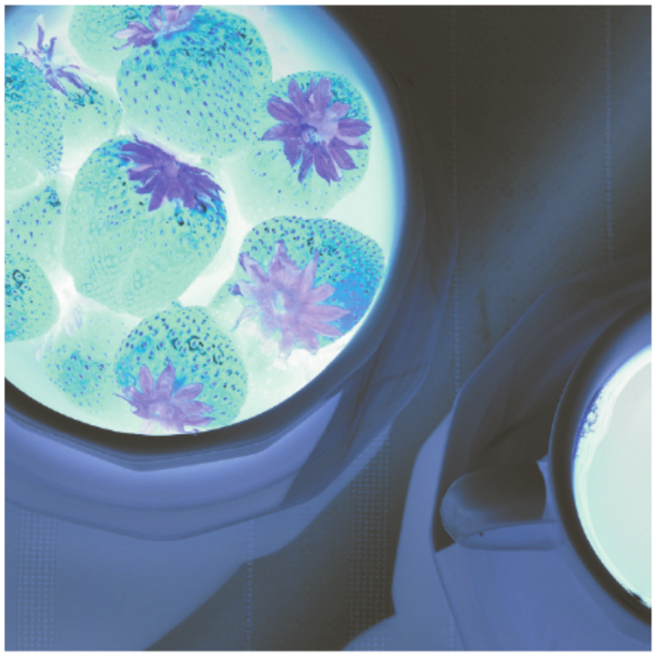


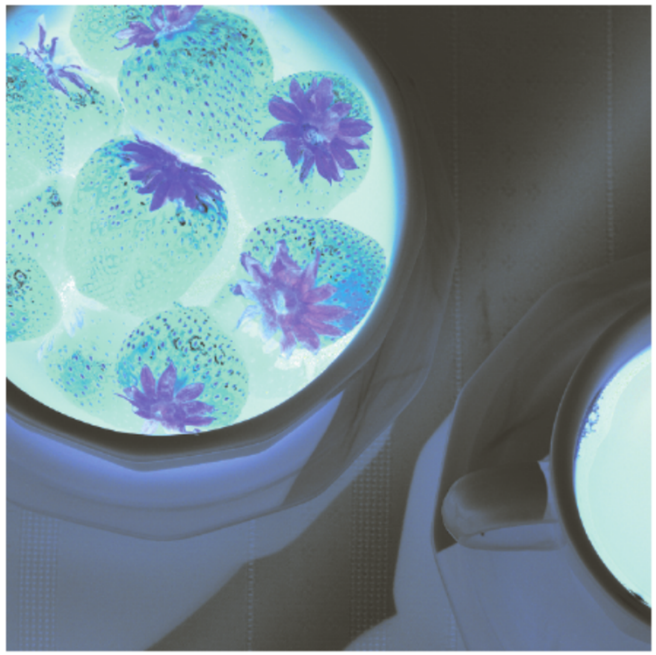
FIGURE 6.32
Complements on the color circle.



Full Color Image Processing (6)



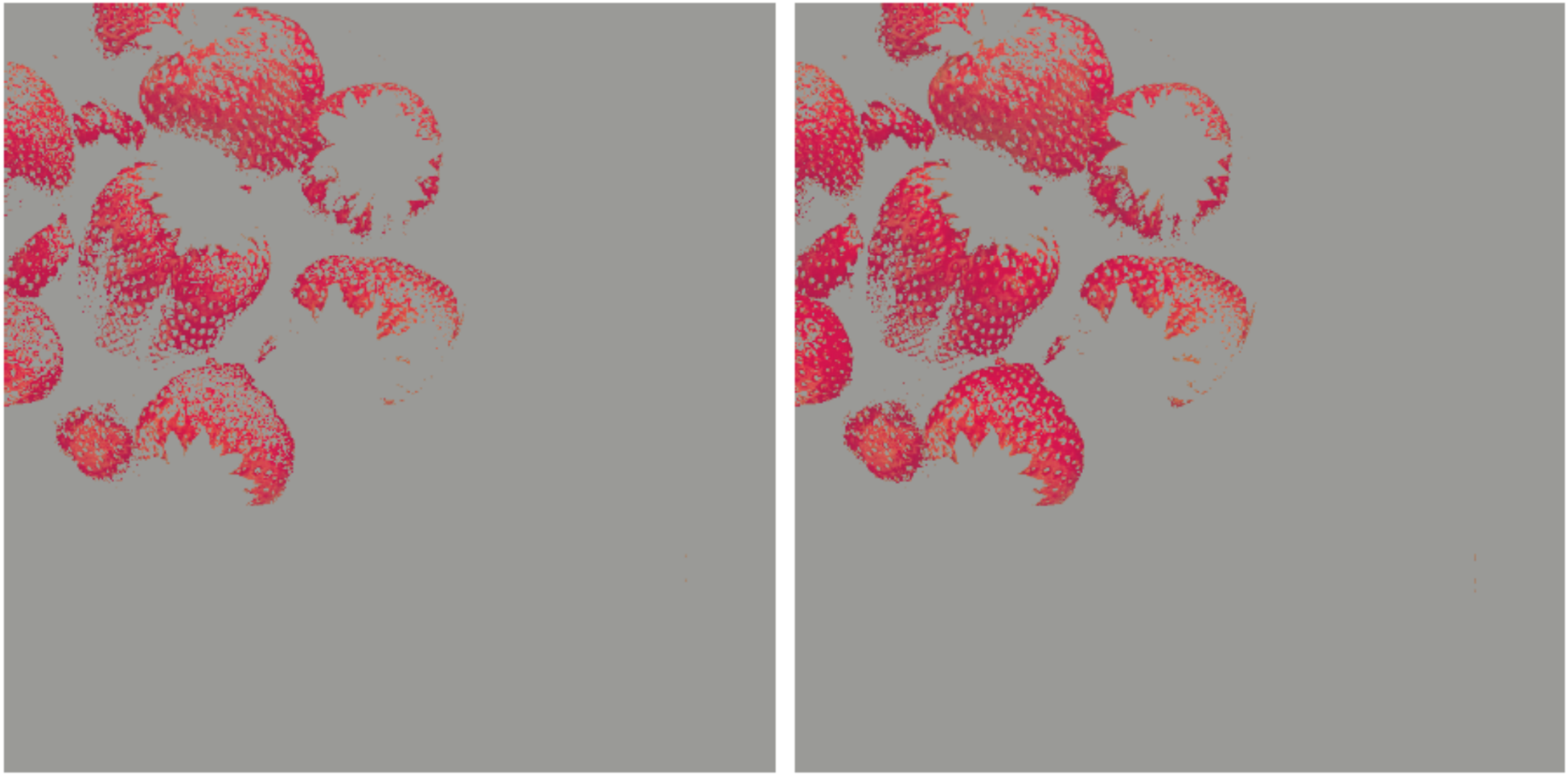




a b
c d

FIGURE 6.33 Color complement transformations. (a) Original image. (b) Complement transformation functions. (c) Complement of (a) based on the RGB mapping functions. (d) An approximation of the RGB complement using HSI transformations.

Full Color Image Processing (7)



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).

Full Color Image Processing (8)

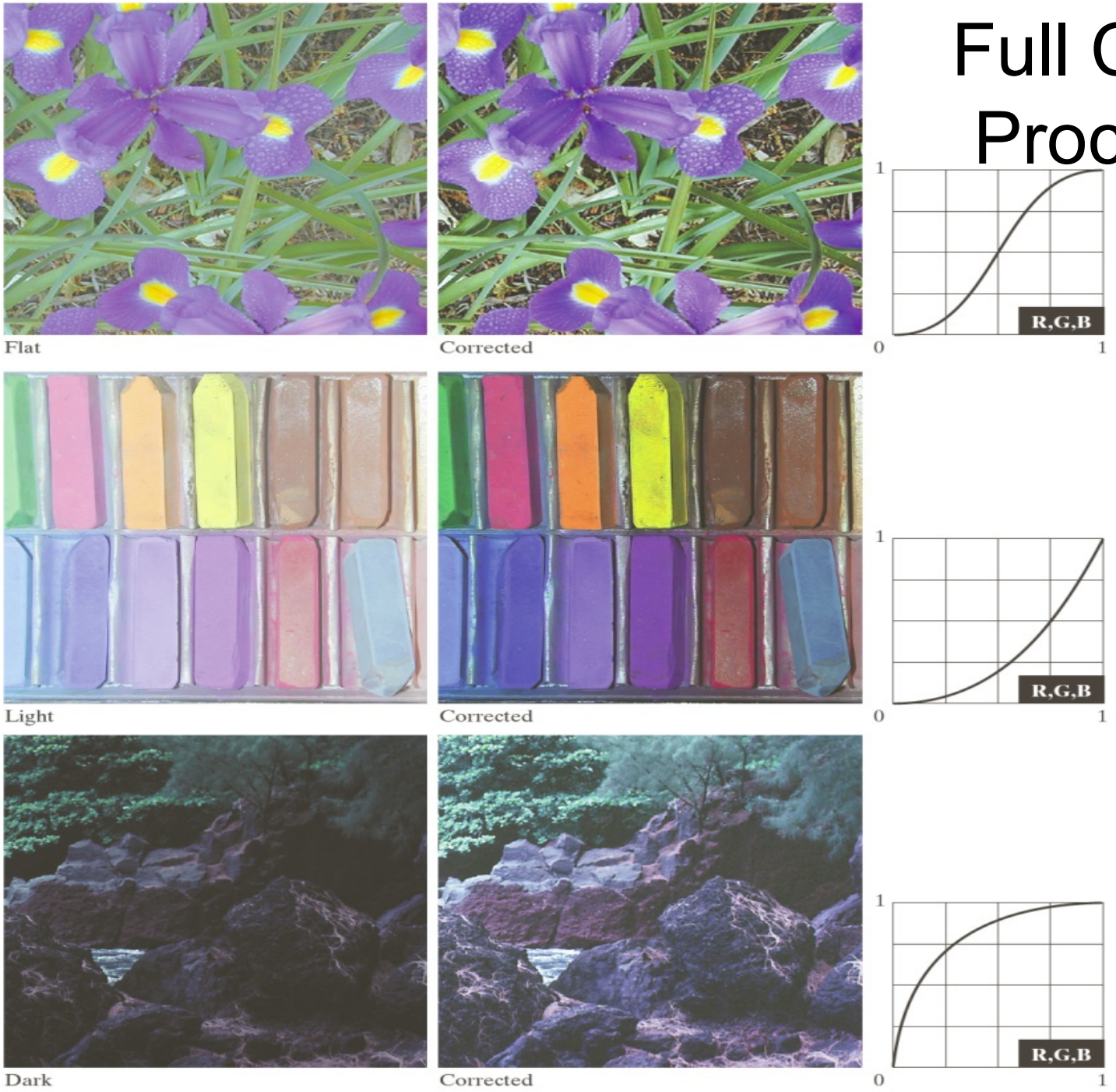
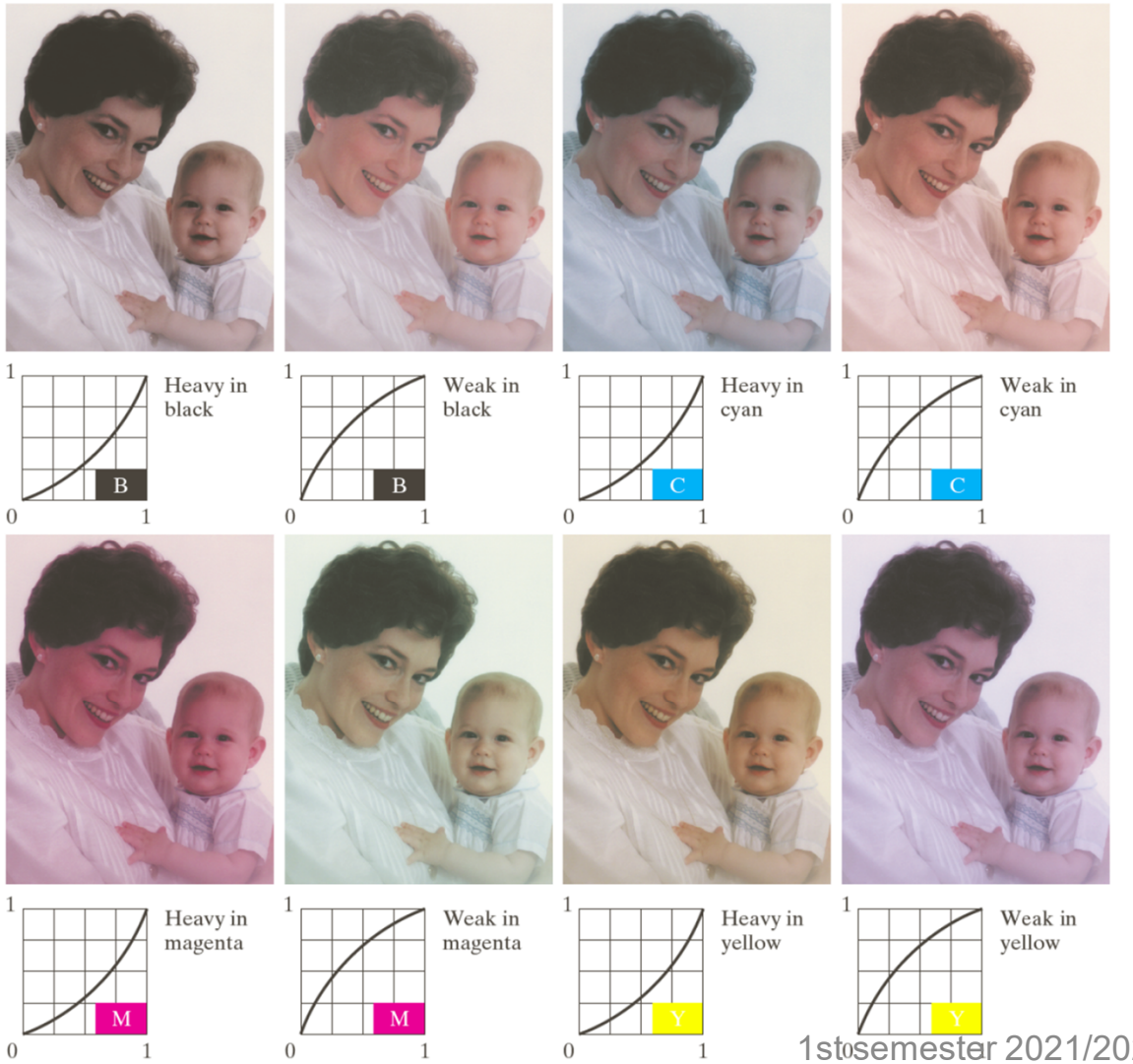


FIGURE 6.35 Tonal corrections for flat, light (high key), and dark (low key) color images. Adjusting the red, green, and blue components equally does not always affect the image hues significantly.

Full Color Image Processing (8)

Original/Corrected

FIGURE 6.36 Color balancing corrections for CMYK color images.



MATLAB functions

- rgb2gray.m, convert RGB image to grayscale version

https://www.mathworks.com/help/matlab/ref/rgb2gray.html

- rgb2hsv.m, convert RGB image to HSV color space

https://www.mathworks.com/help/matlab/ref/rgb2hsv.html

Bibliography

- The images displayed in these slides are from:
  - R. Gonzalez, R. Woods, *Digital Image Processing*, 4th edition, Prentice Hall, 2018, ISBN 0133356728
  - S. Smith, *The Scientist and Engineer's Guide to Digital Signal Processing*, Newnes, 2003, ISBN 0-750674-44-X [chapter 23]
  - O. Filho, H. Neto, Processamento Digital de Imagens, Rio de Janeiro: Brasport, 1999, ISBN 8574520098.
  - Wikipedia and Mathworks web pages