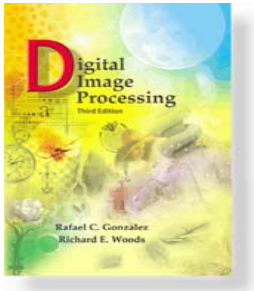

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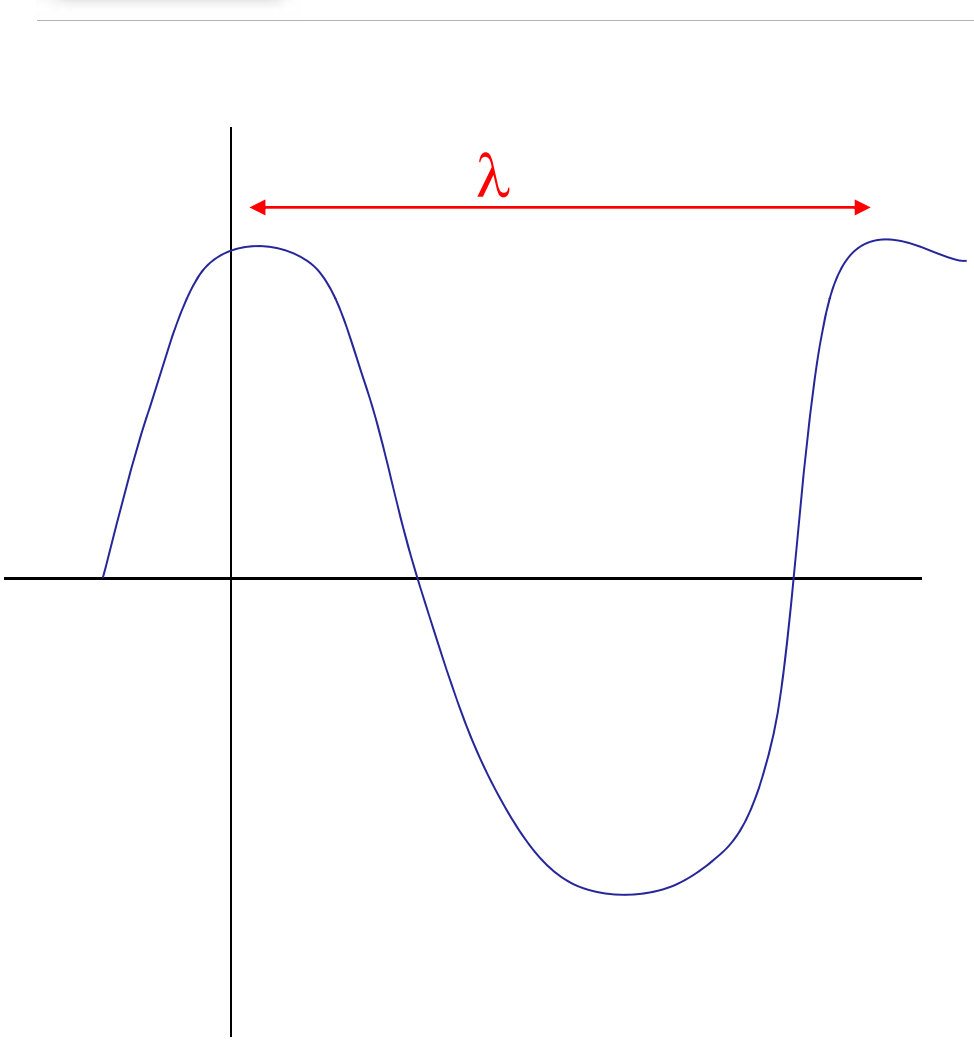
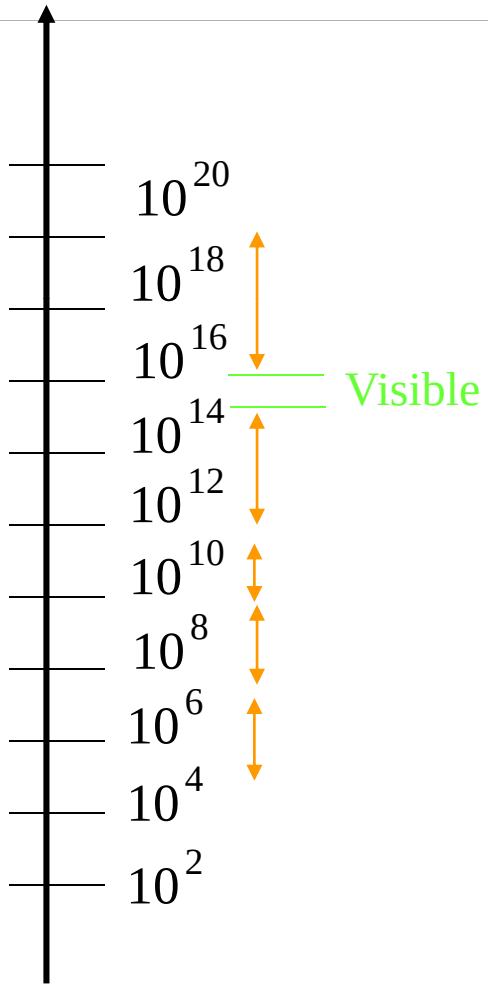
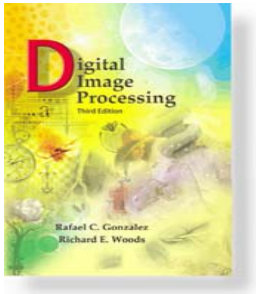






Colorimetric

Color Perception involve Hue, Saturation, and Lightness

Hue :distinguish among colors such as red, green, and purple.

Saturation :refer to how color far from gray.

Lightness: the perceived intensity of a reflecting object.

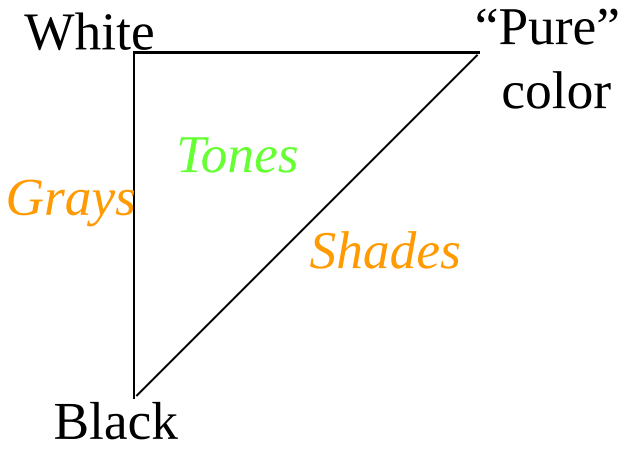
Brightness :refer to the perceived intensity of self-luminous.

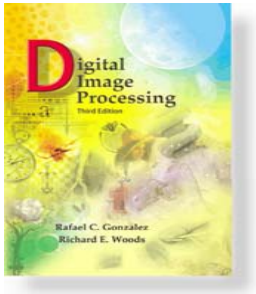
Artists Terms

Tint: results of adding white pigments pure pigments

Shade: comes from adding black pigments to pure pigments

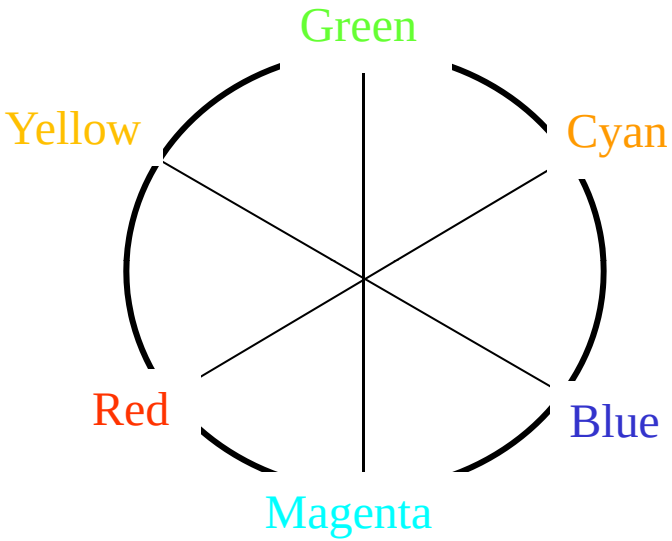
*Tone:*results of adding both black and white pigments to pure pigments



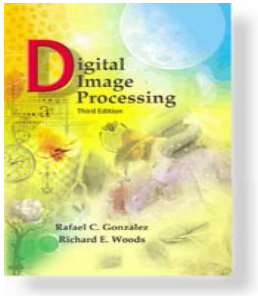


Color Models:

The Newton Color Circle



- The Newton color circle provides a convenient way to perceive the additive mixing properties of colors.
- The R,G,B and their complementary colors C,M,Y are placed on the circle in the order of the wavelengths of the corresponding spectral colors.



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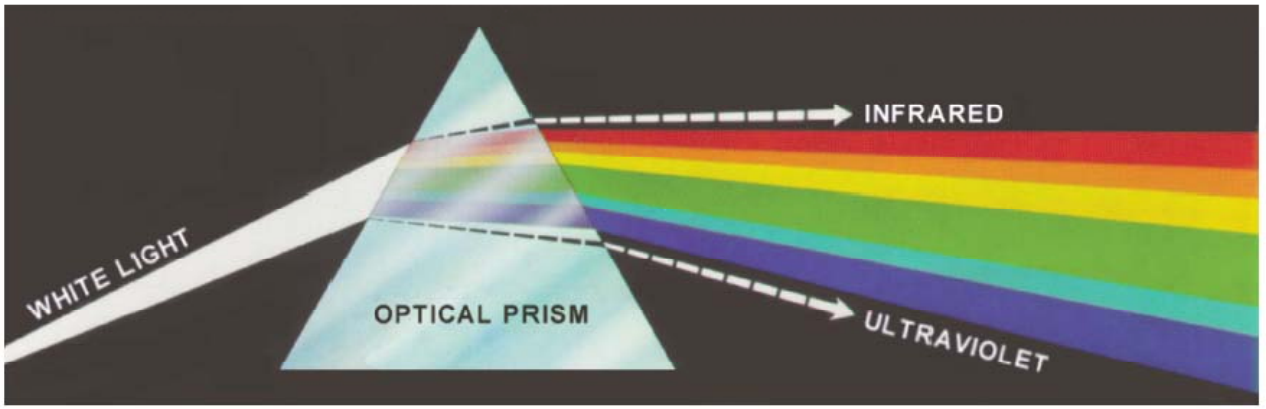
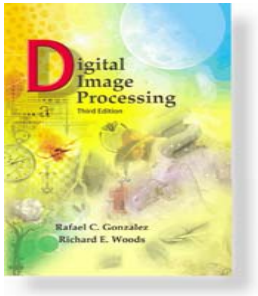


- The separation of colors by a prism expose a continuous range of spectral colors



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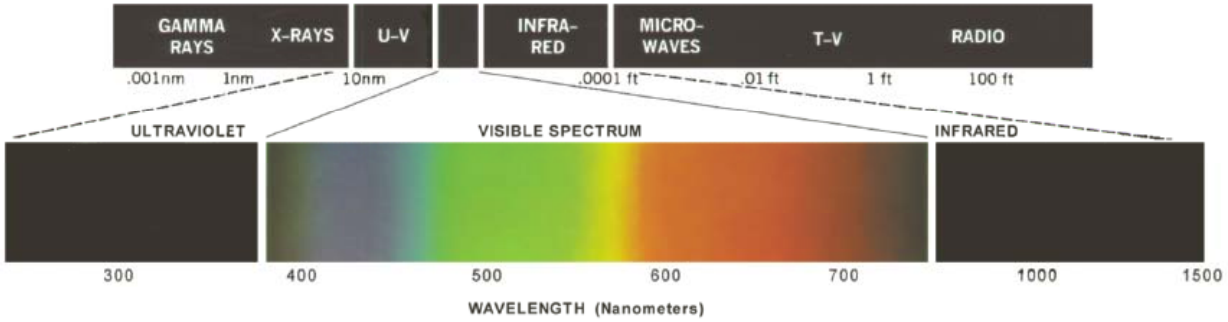
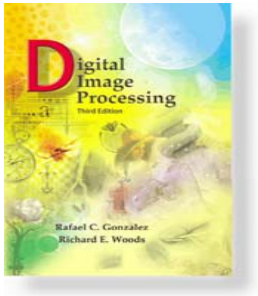


- A spectral color is composed of a single wavelength
- The helium-neon laser monochromatic light is red (632 nm).
- Most colored objects give off a range of wavelengths and the characterization of color is much more than the statement of wavelength.



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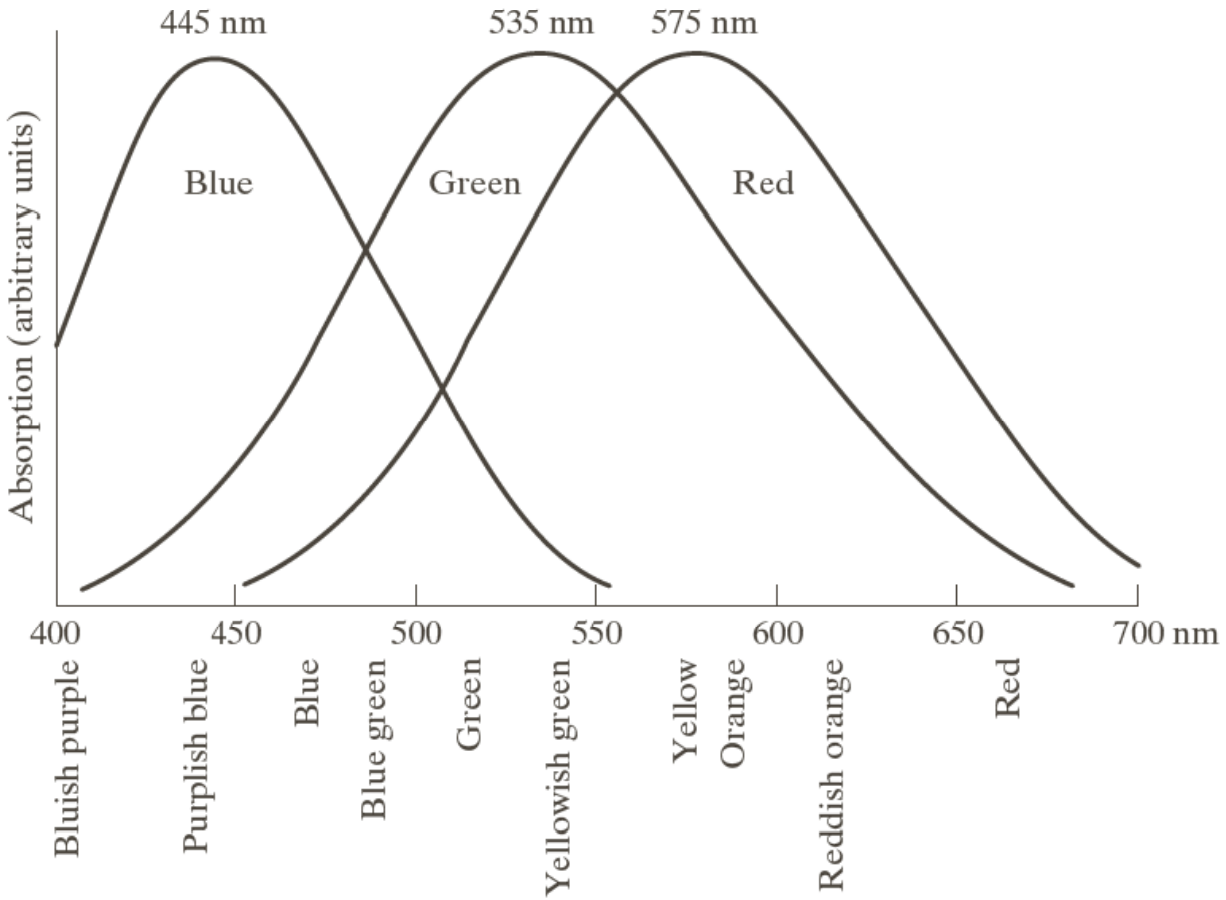

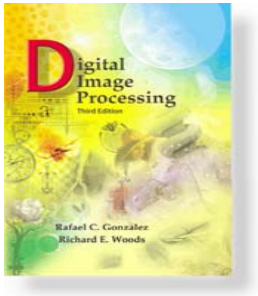

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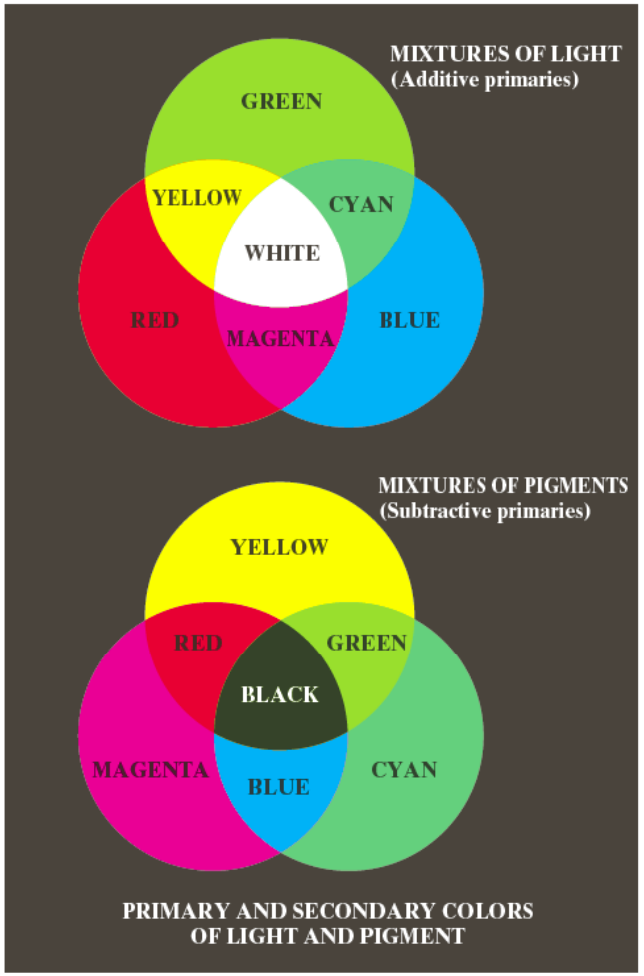
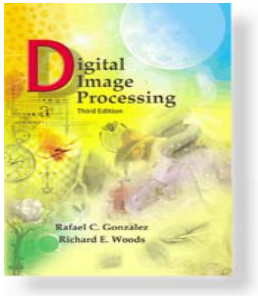
Primary and Secondary colors





Standard Color Model

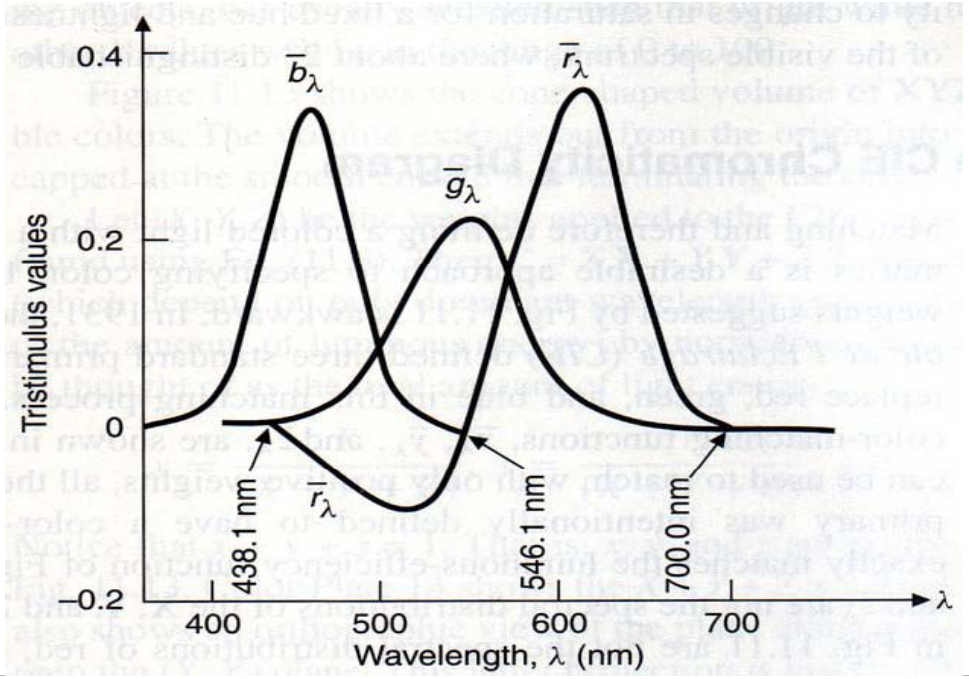
Commission Intenationale de l'Eclairage (CIE), 1931 defined three standard primaries, called X,Y,Z to replace Red, Green, Blue.

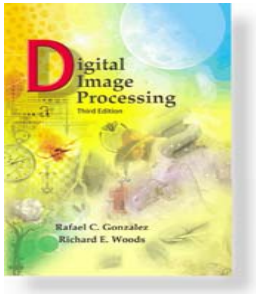
The primaries are used to match color by using three corresponding color-matching functions

$$X = k\int P(\lambda)\, x\, d\lambda$$

$$Y = k\int P(\lambda)\, y\, d\lambda$$

$$Z = k\int P(\lambda)\, z\, d\lambda$$





CIE Chromatic Diagram

Chromatic values depend on dominant wavelength and saturation and independent of luminous energy.

Consider a color C, the we can Write

$C = X\boldsymbol{X} + Y\boldsymbol{Y} + Z\boldsymbol{Z}$

Normalize Against X+Y+Z

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

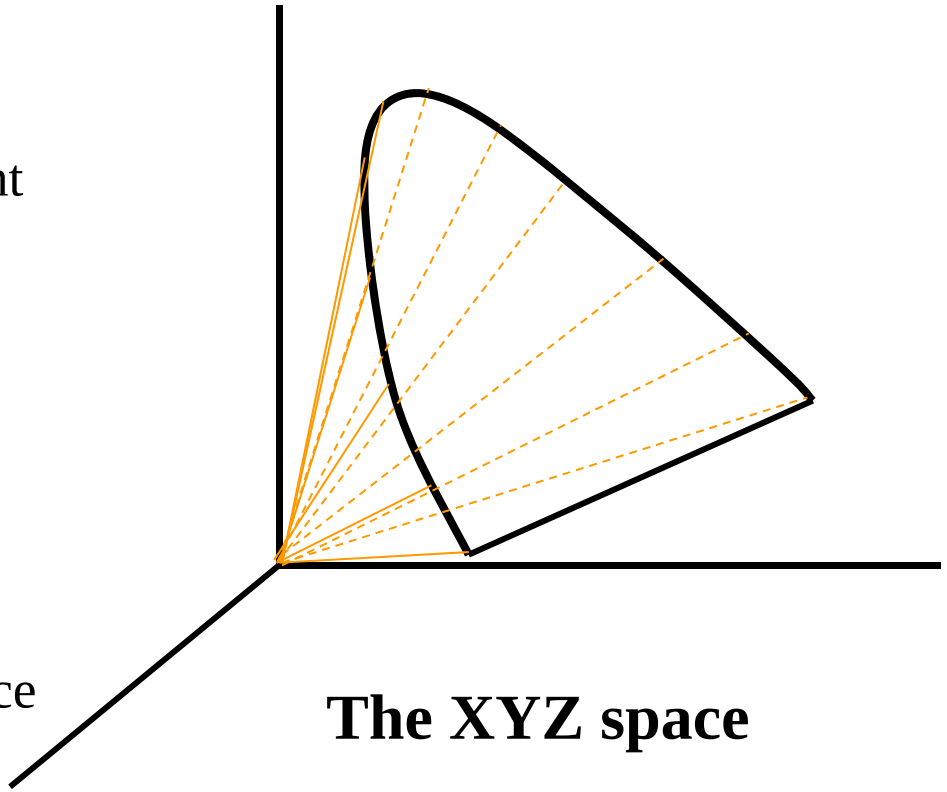
$y = Y/(X+Y+Z)$

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

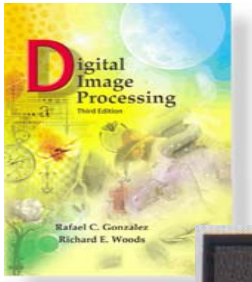
We know that $x+y+z = 1$, and the luminance information usually in Y (***Y*** cef.), thus we can recover X,Y,Z

$X = Y\,(x/y)$; $Y = Y$; $Z = Y(1-x-y)/y$

Plotting these parameters



The XYZ space



XYZ Color Space

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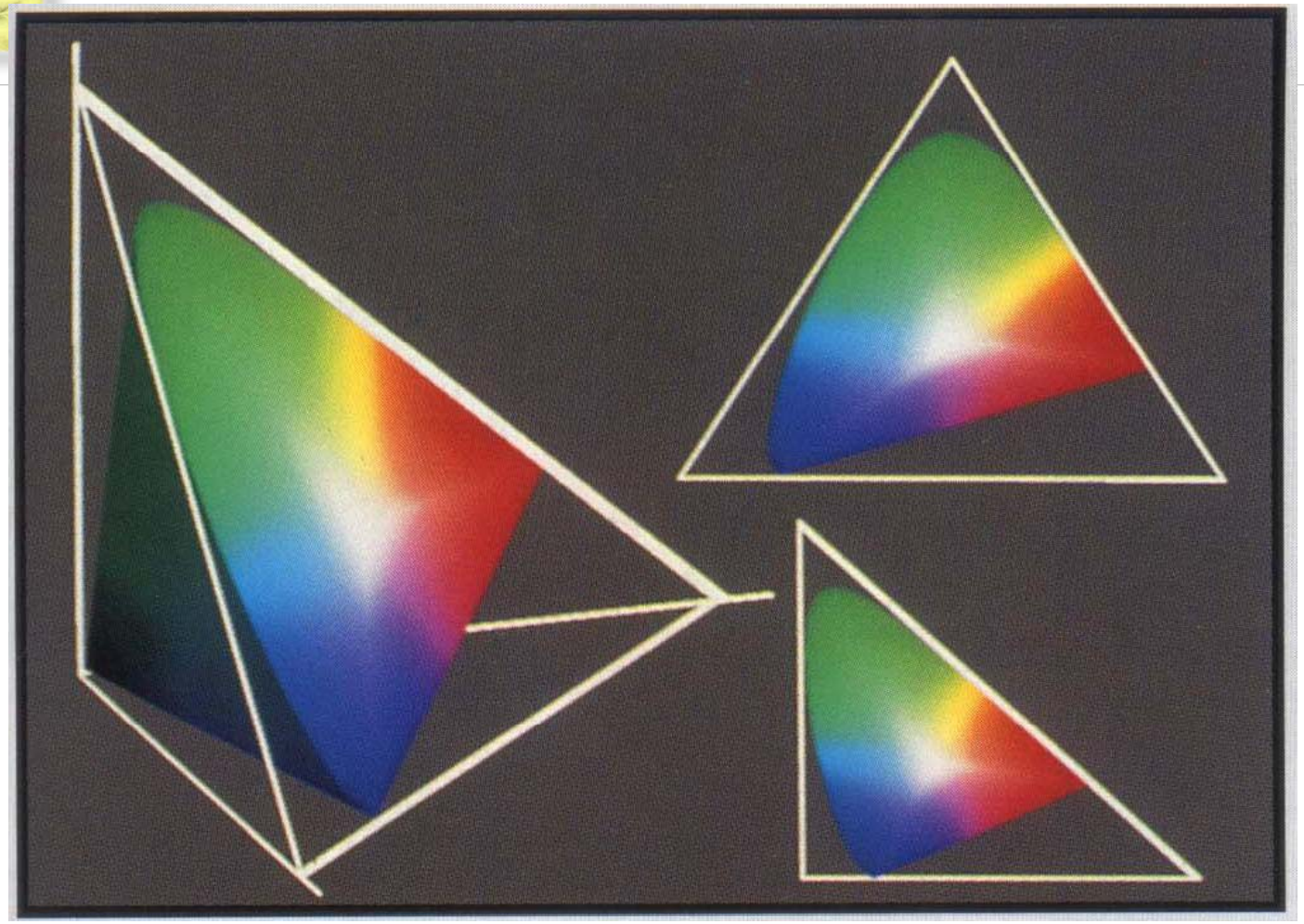

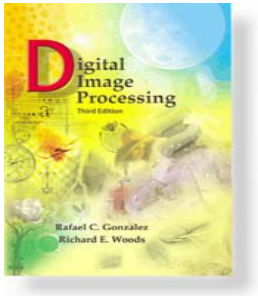

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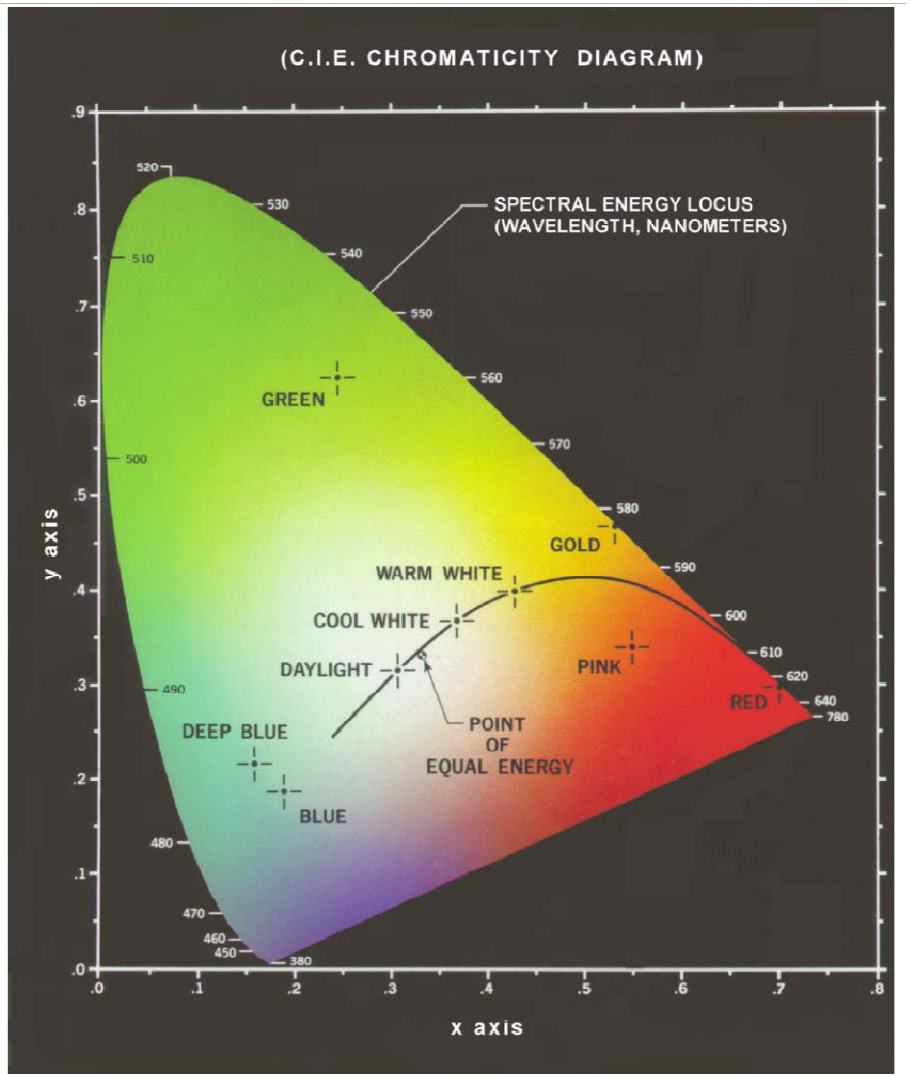
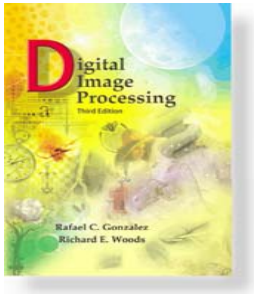
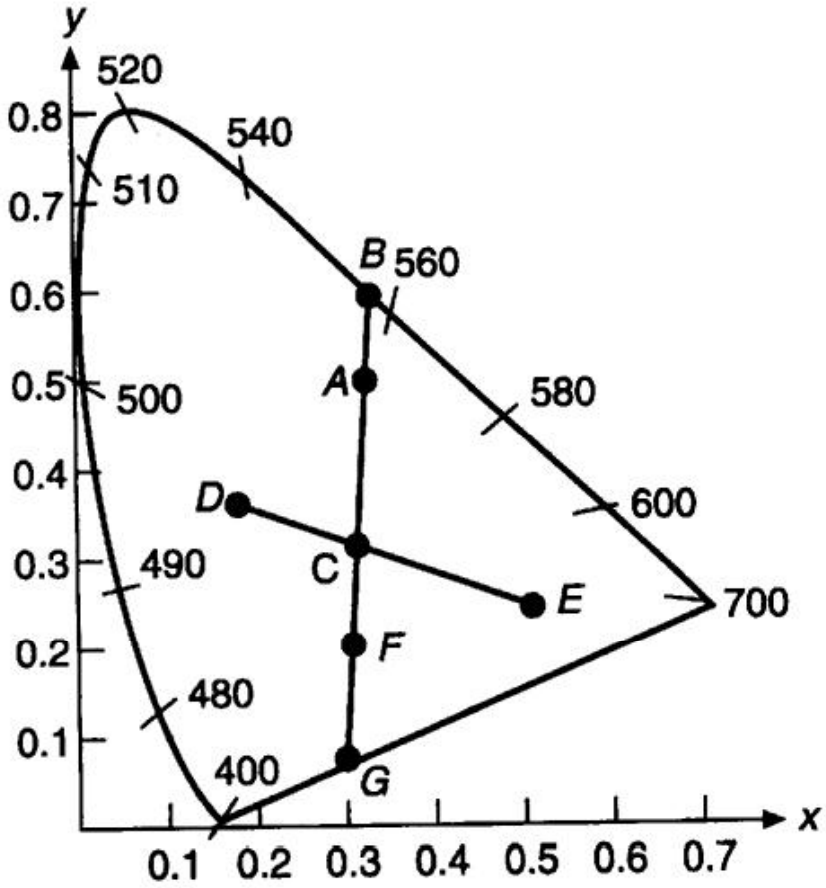
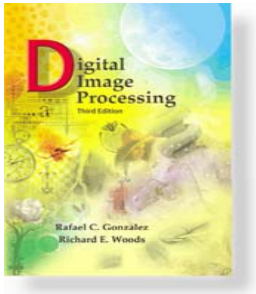






When two color A and B are added together new color C lies on the line connects both colors.
In the side Figure, B defines the dominant wavelength, and the ratio AC to BC expressed as a percent of the excitation purity of A.
The closer A to C the more light A includes.

Complementary colors are those that can be mixed to produce white light. D and E on the side Figure are complementary colors.
Nonspectral color are those that can not be defined by dominant wavelength such as F.
Color gamuts or color ranges is the effect of adding colors together



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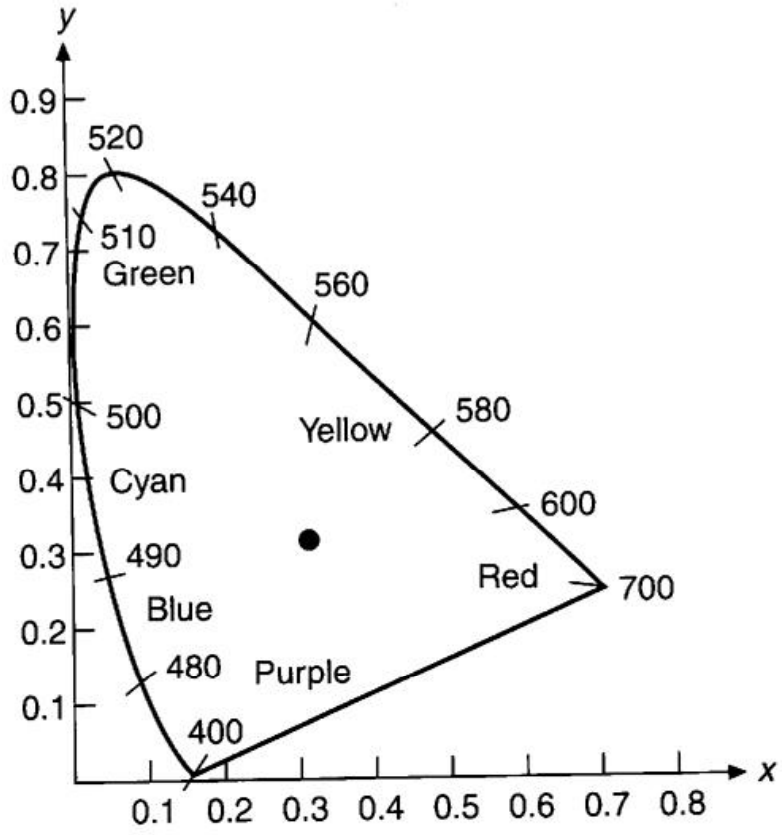

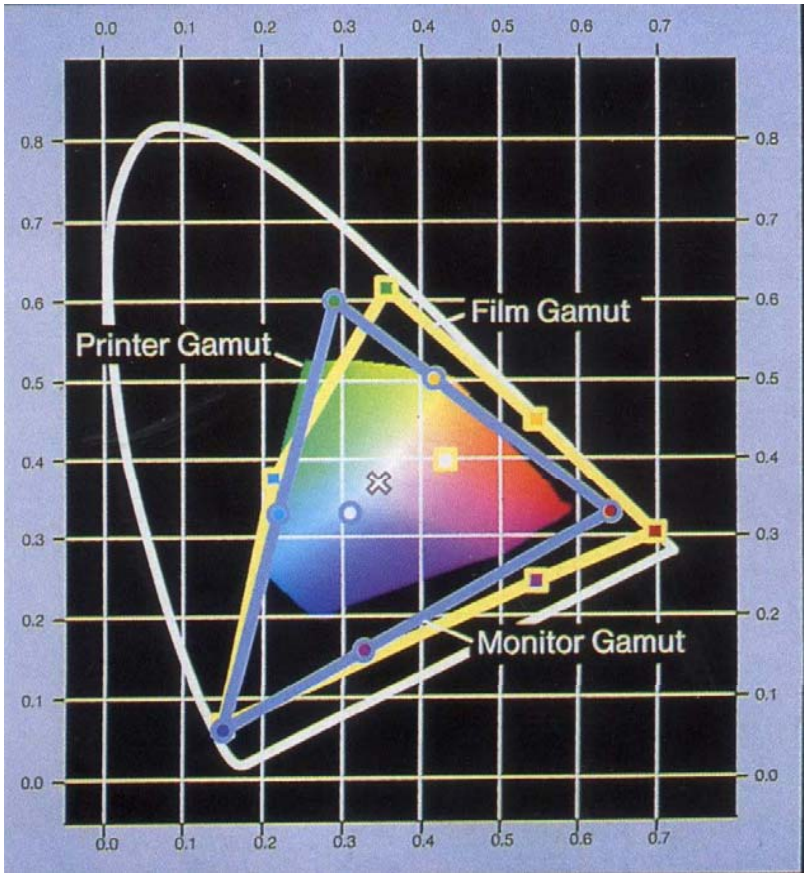

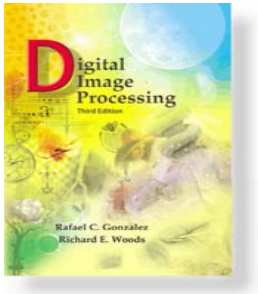

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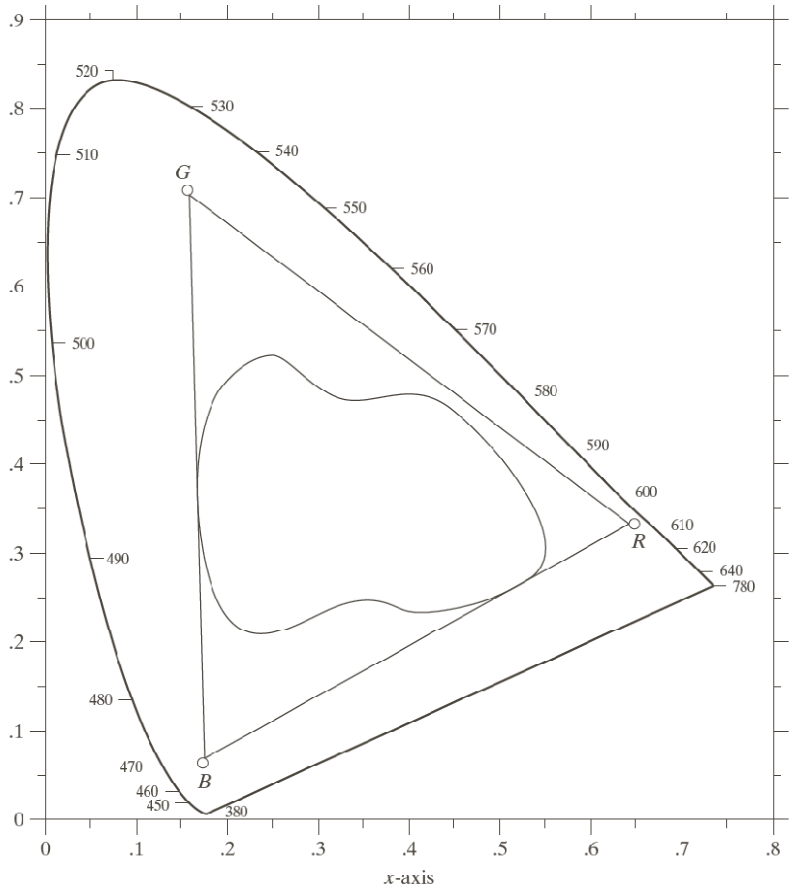
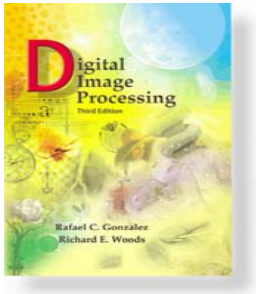


FIGURE 6.6
Typical color gamut of color monitors (triangle) and color printing devices (irregular region).



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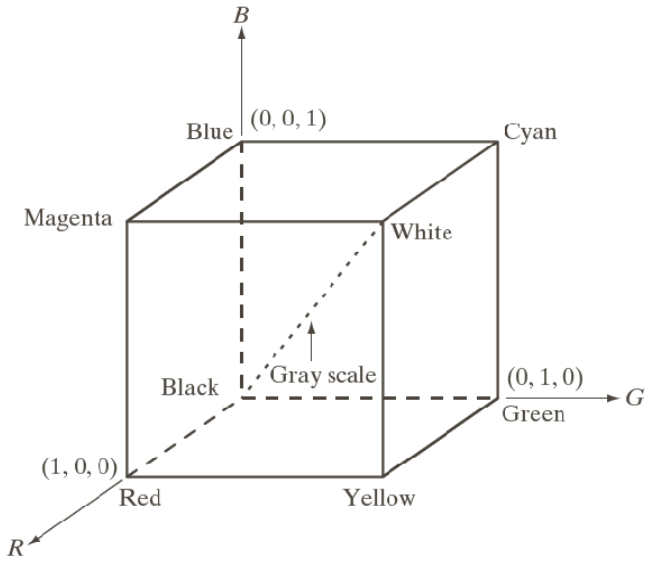
RGB Color Model

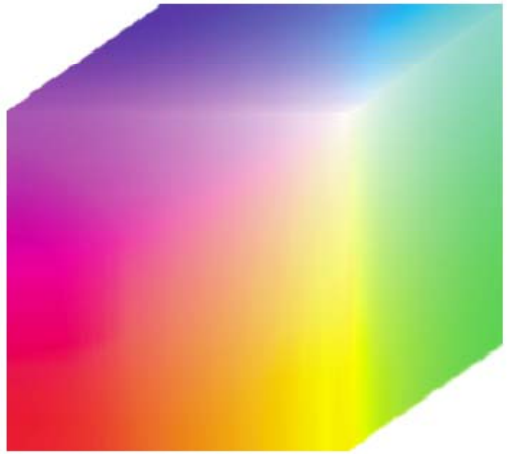
The color range (gamut) RGB model is defined by the CRT's phosphor.

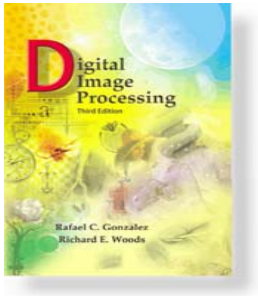
$$C = R\boldsymbol{R} + G\boldsymbol{G} + B\boldsymbol{B}$$

Let us look at these colors in XYZ space

RGB	NTSC	CIE	Monitor
R	**(0.67, 0.33)**	**(0.73, 0.26)**	(0.62, 0.34)
G	**(0.21, 0.71)**	**(0.27, 0.71)**	(0.26, 0.59)
B	**(0.14, 0.08)**	**(0.16, 0.01)**	(0.15, 0.07)







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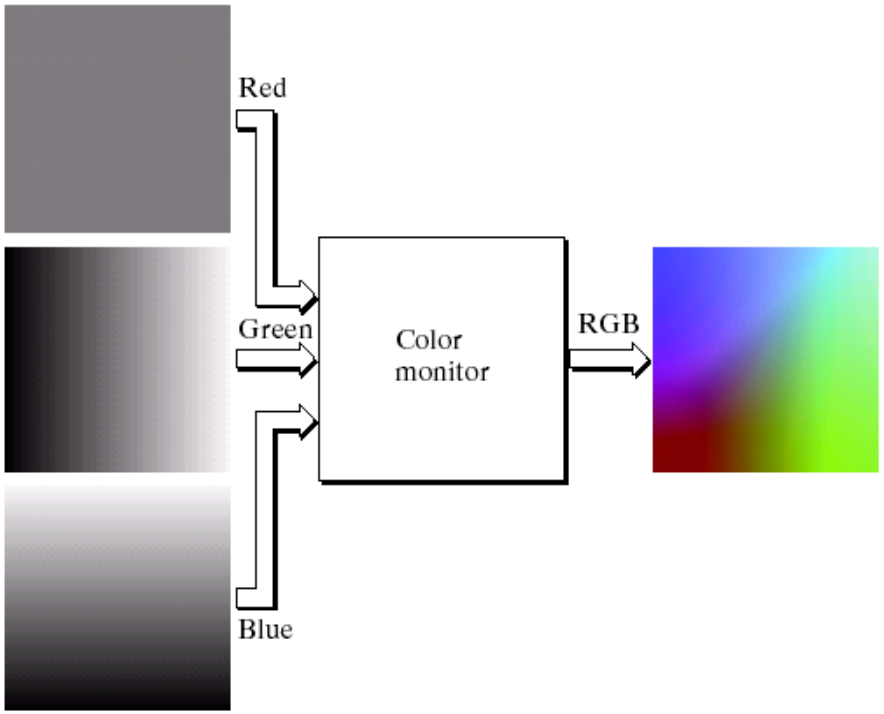

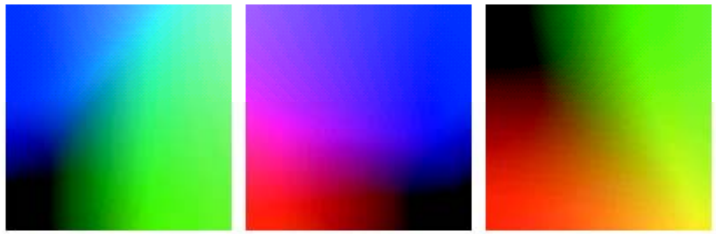

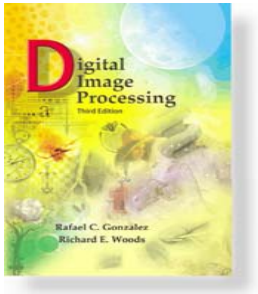

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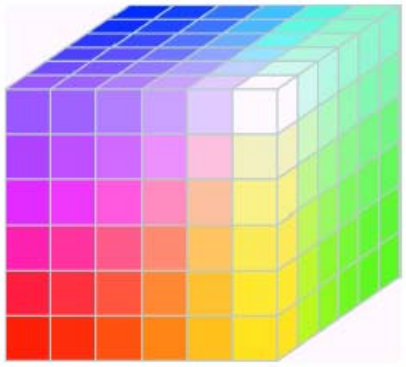
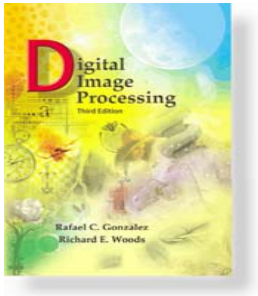


FIGURE 6.11 The RGB safe-color cube.



CMY Color Model

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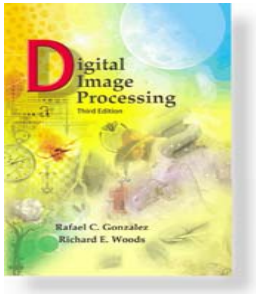
Cyan, magenta, and blue are the complements of red, green, blue. CMY is important when dealing with hardcopy that deposit color pigments onto paper.

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

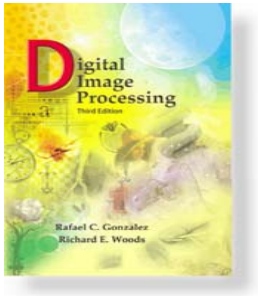
$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} + \begin{bmatrix} C \\ M \\ Y \end{bmatrix}$$



YIQ Color Model

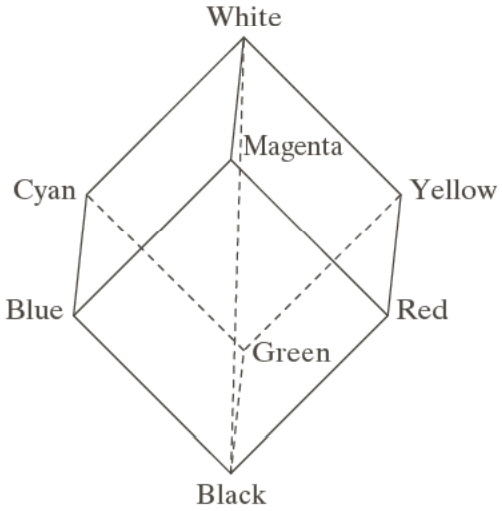
- YIQ model exploits two properties of the visual system
  - More sensitive to changes luminance than to change hue or saturation
  - Object that cover an extremely small part of our field of view, produce a limit color sensation.
- Y is the luminance (the same Y in XYZ space).
- The chromaticity is encoded encoded in I and Q
- Only Y component will show black/White TV
- More bits are used for Y, and either I or Q has less bits than the other.

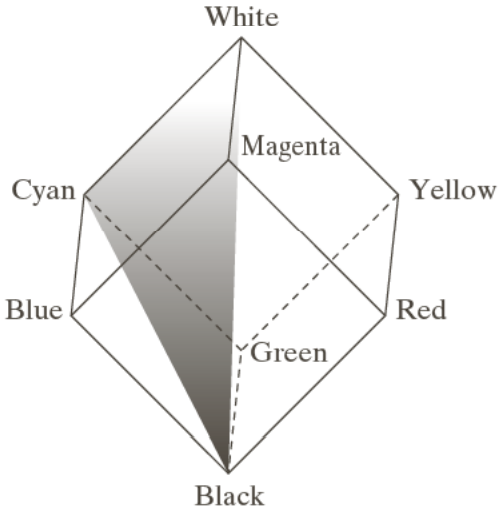
$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.596 & -0.275 & -0.321 \\ 0.212 & -0.528 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$



HSI Model

The relationship between RGB and HSI





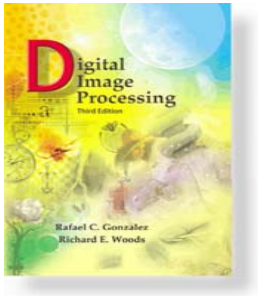
RGB to HSI

$$H = \begin{cases} \theta & B \le G \\ 360 - \theta & B > G \end{cases}$$

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

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

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



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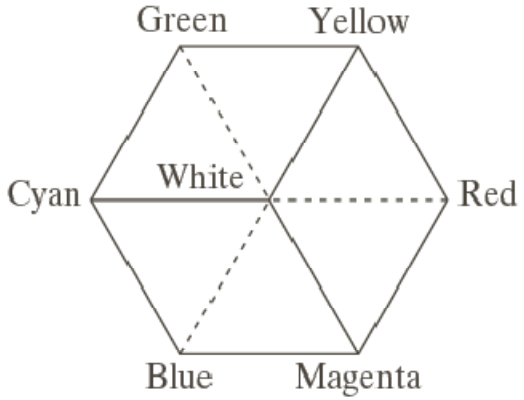
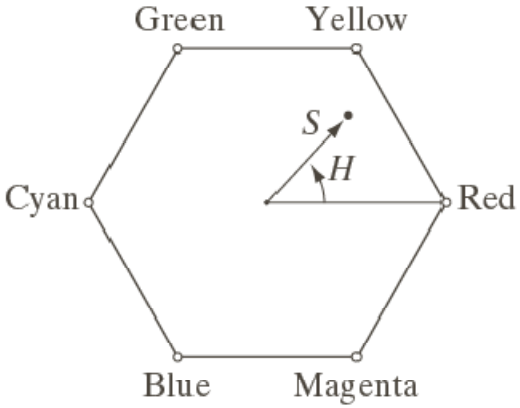
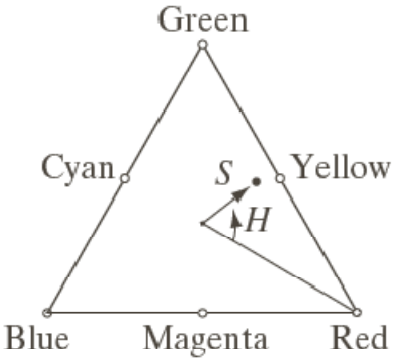
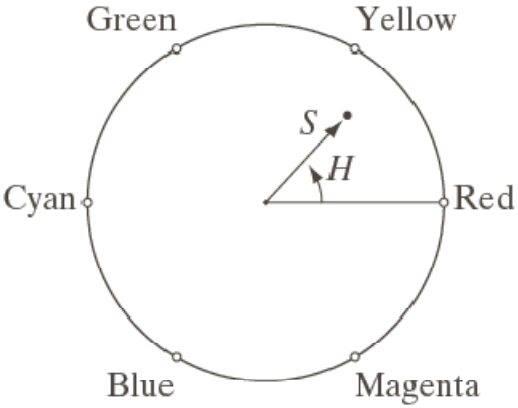
Hue and saturation in the HSI color model.

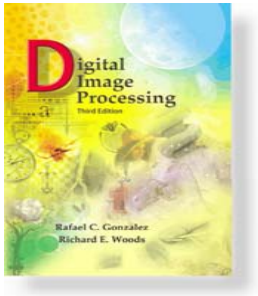
- The angle from the red axis gives the hue
- The length of the vector is the saturation.











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HSI to RGB

$$for(0^\circ \le H < 120^\circ)$$

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

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

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

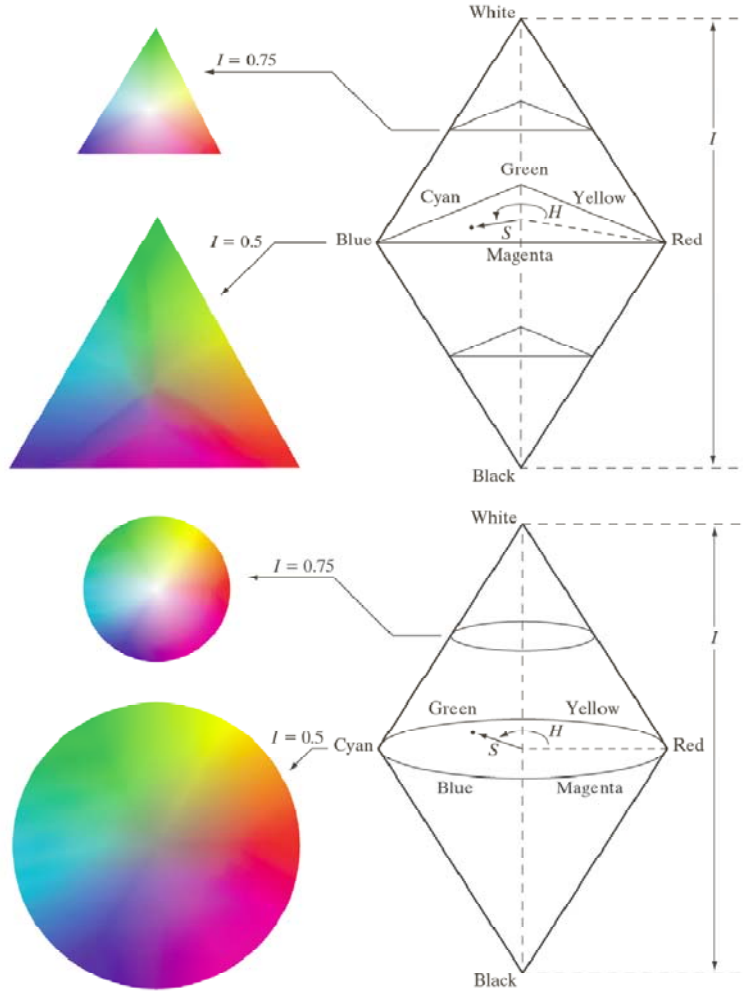
$$120^\circ \le H < 240^\circ \Rightarrow H = H - 120^\circ$$

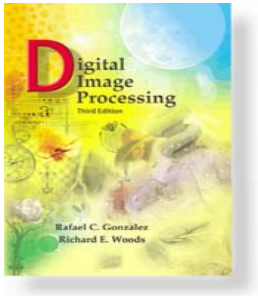
$$240^\circ \le H < 360^\circ \Rightarrow H = H - 240^\circ$$

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

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

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





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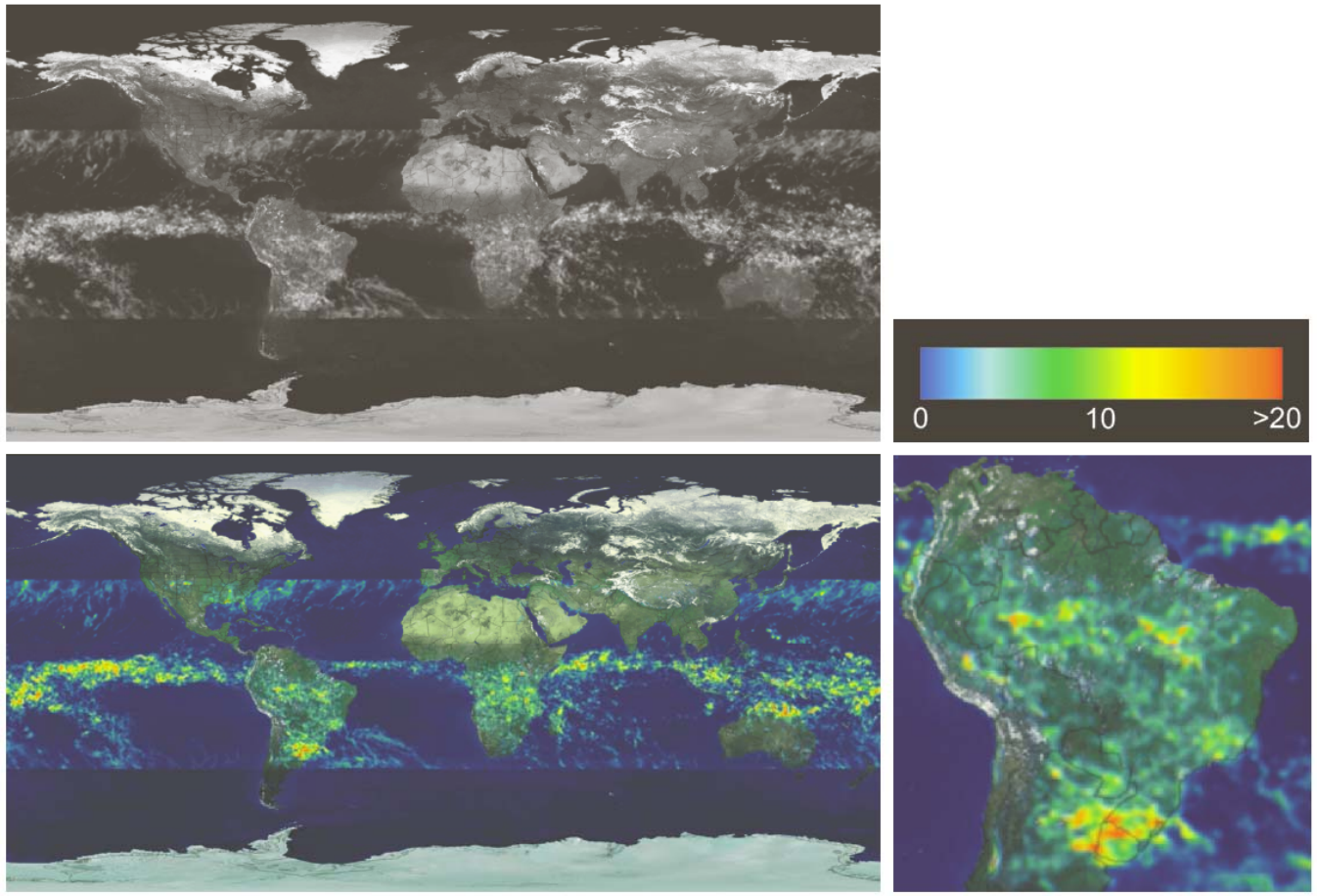

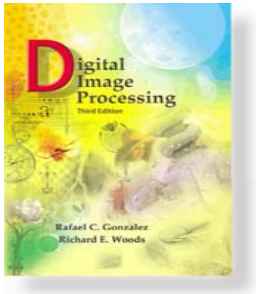

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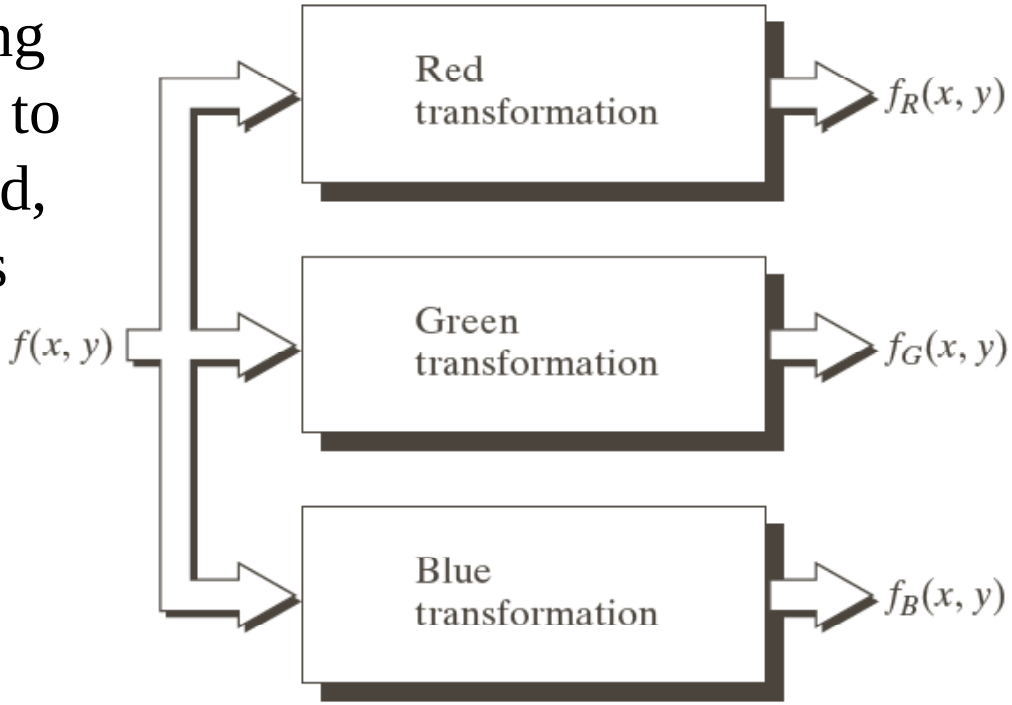
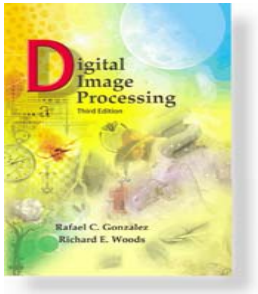
In various color processing applications it is possible to use the corresponding Red, Green, and Blue channels





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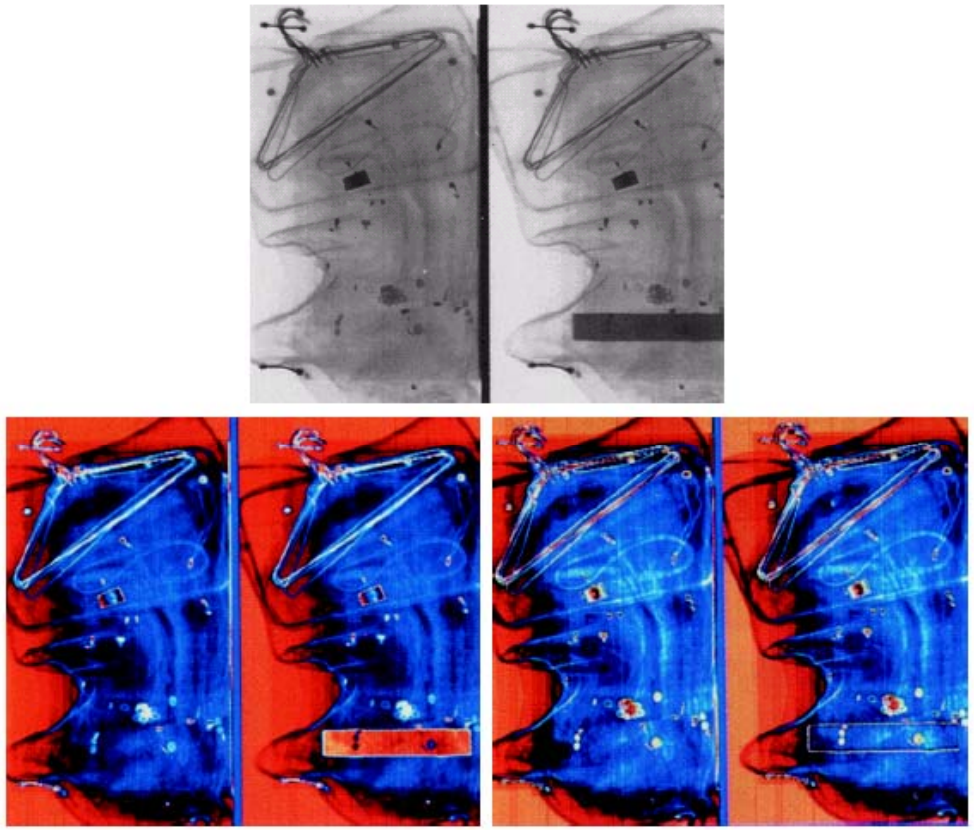
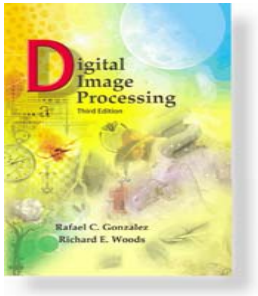


a
b c

FIGURE 6.24 Pseudocolor enhancement by using the gray-level to color transformations in Fig. 6.25. (Original image courtesy of Dr. Mike Hurwitz, Westinghouse.)



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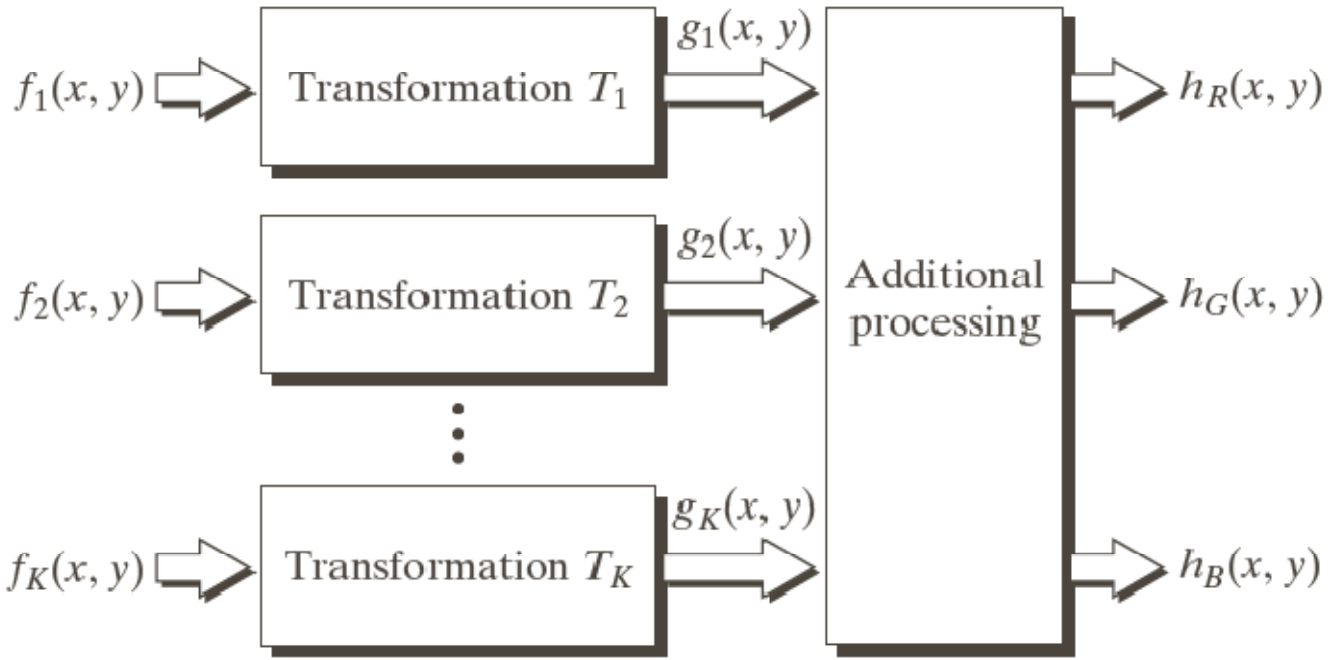
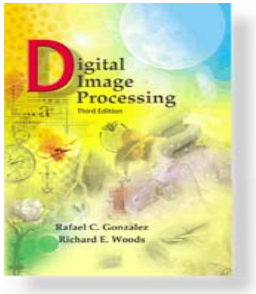
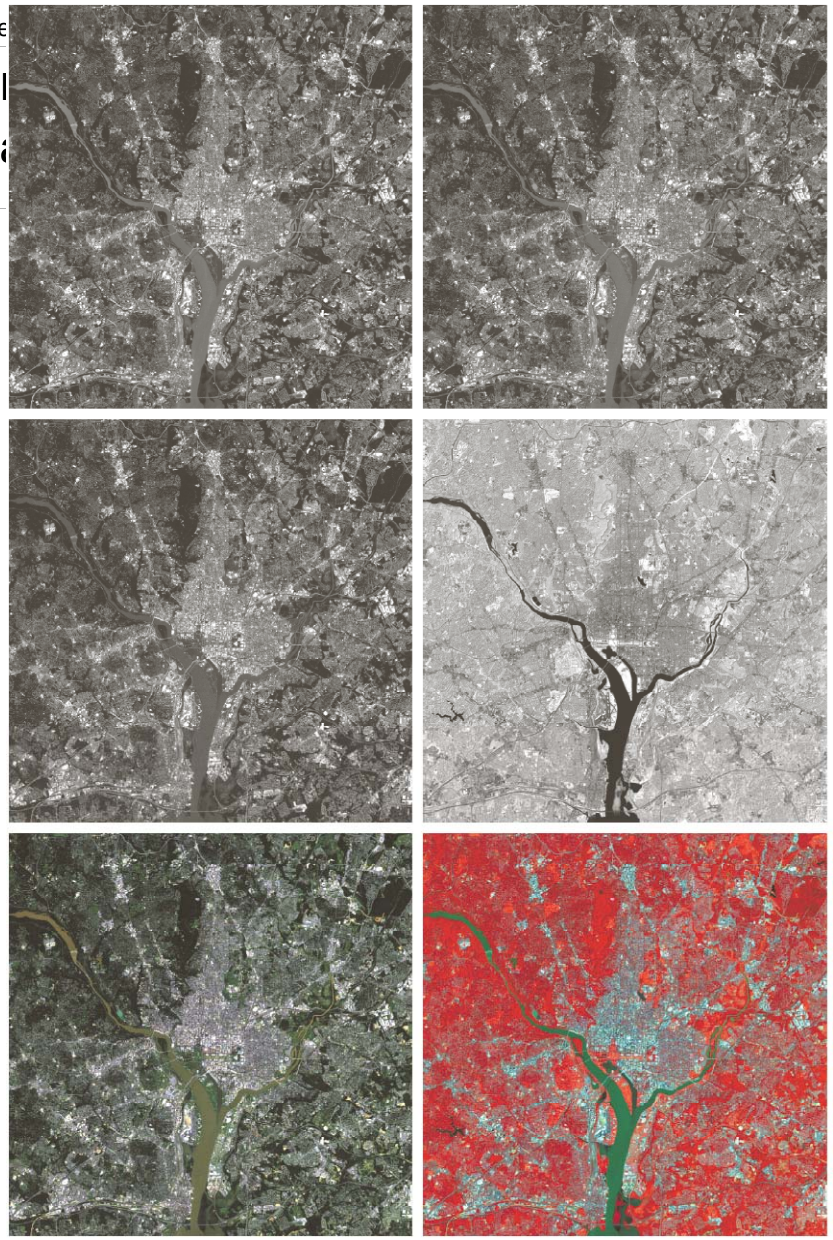
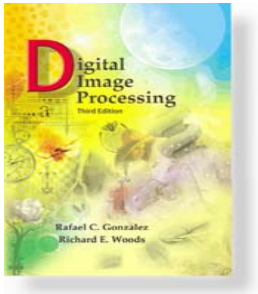




Color Coding for visualization





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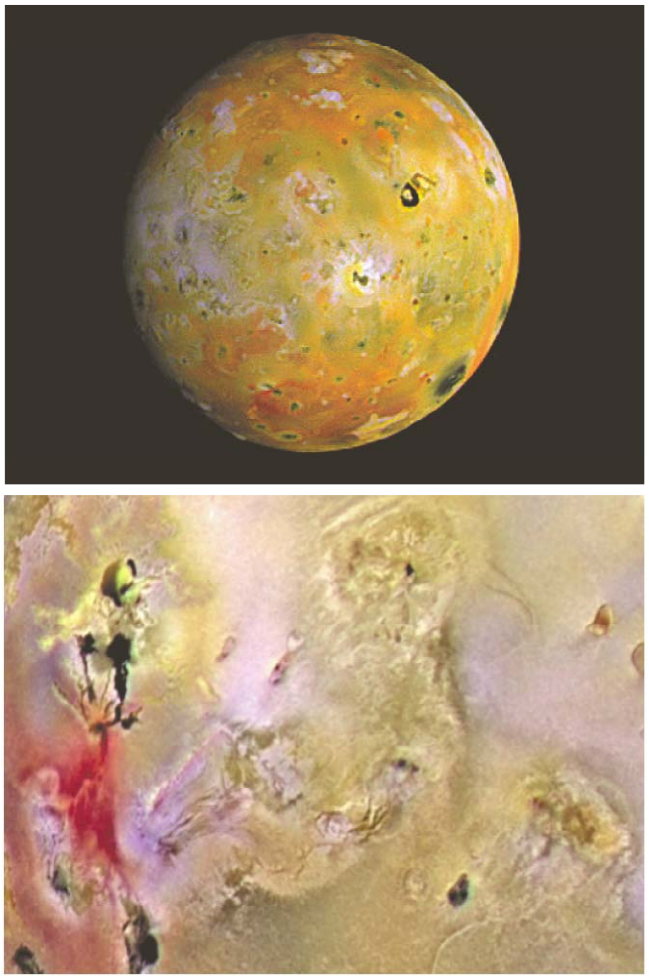
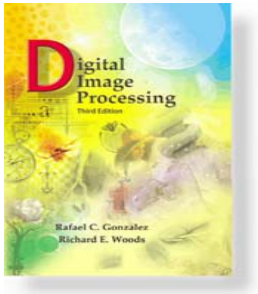


a
b

FIGURE 6.28
(a) Pseudocolor rendition of Jupiter Moon Io. (b) A close-up. (Courtesy of NASA.)



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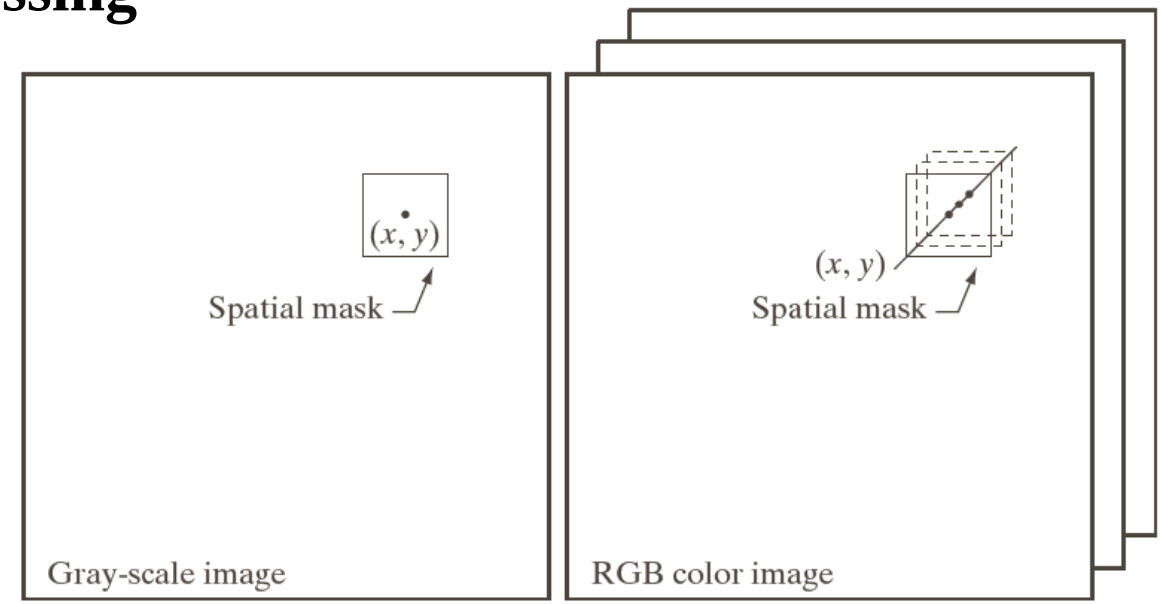

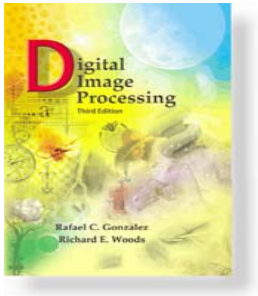

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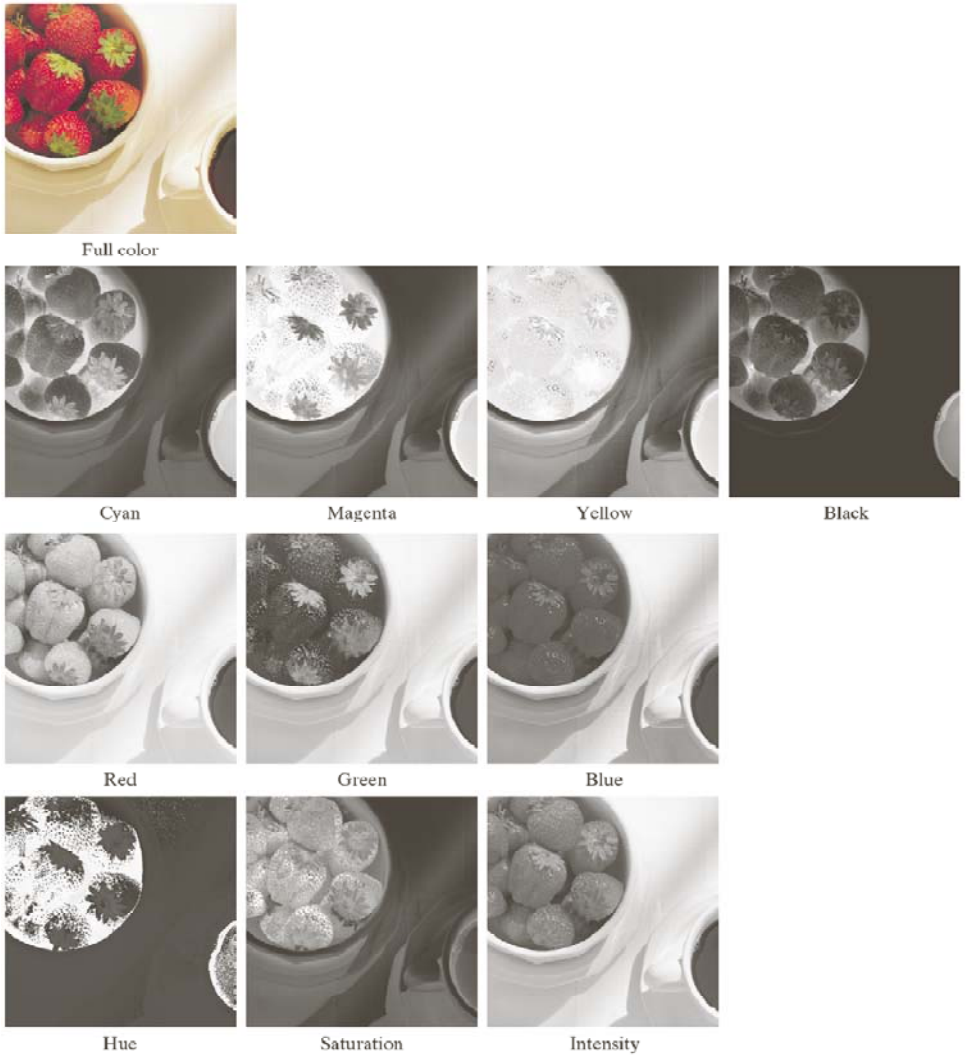
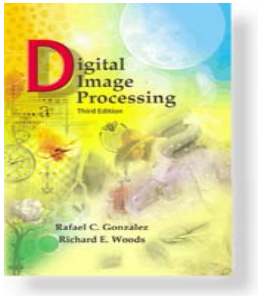
Color Transformation





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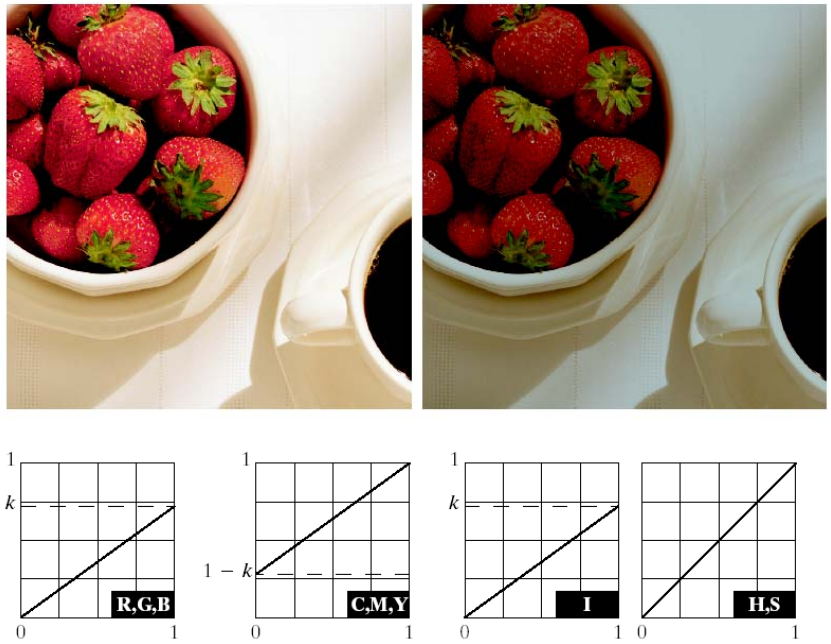
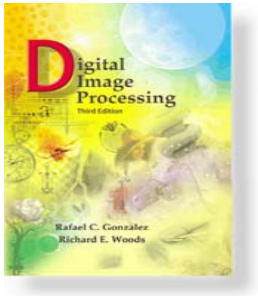
a b
c d e

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.)





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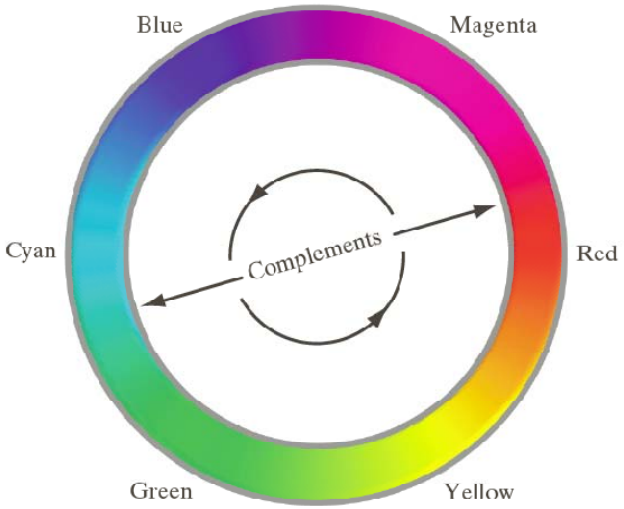
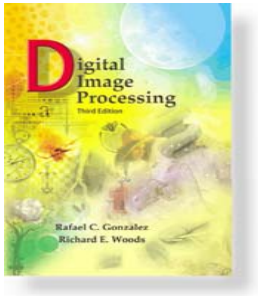


FIGURE 6.32 Complements on the color circle.



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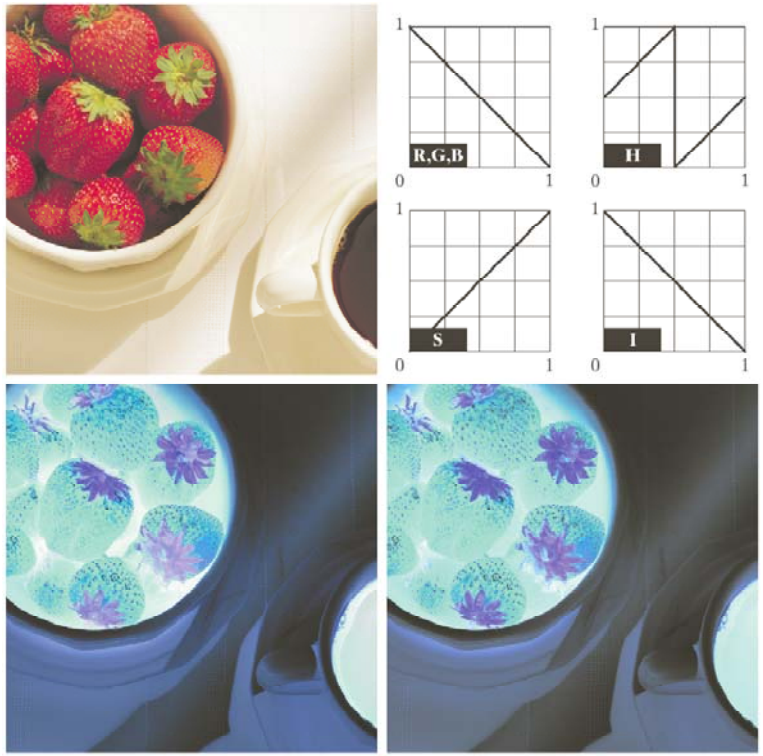
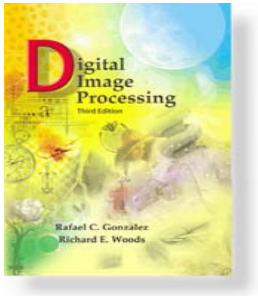


a b
c d

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.



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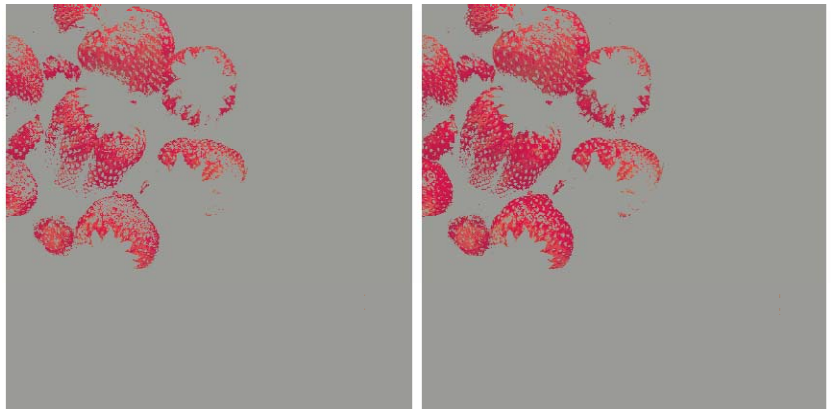
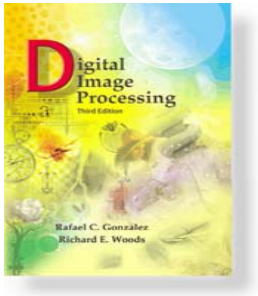


a b

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).



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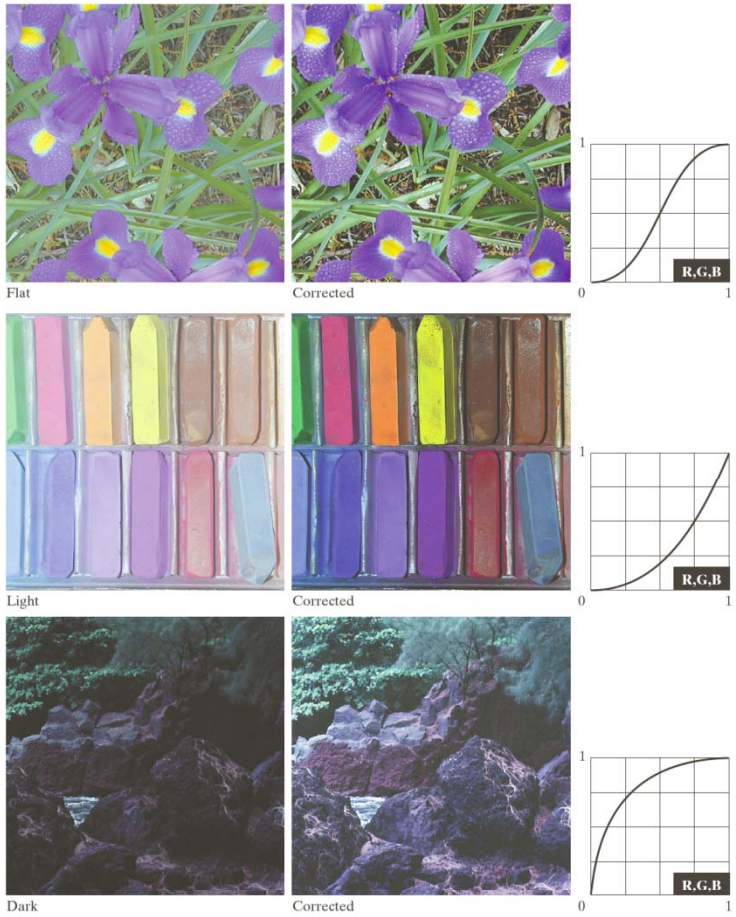
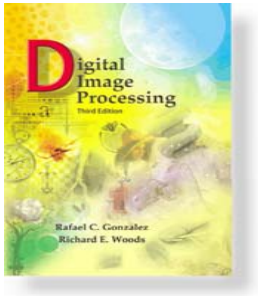


FIGURE 6.35 Tonal corrections for flat, light (high key), and dark (low key) color images. Adjusting the red, green, and blue components equally does not always alter the image hues significantly.



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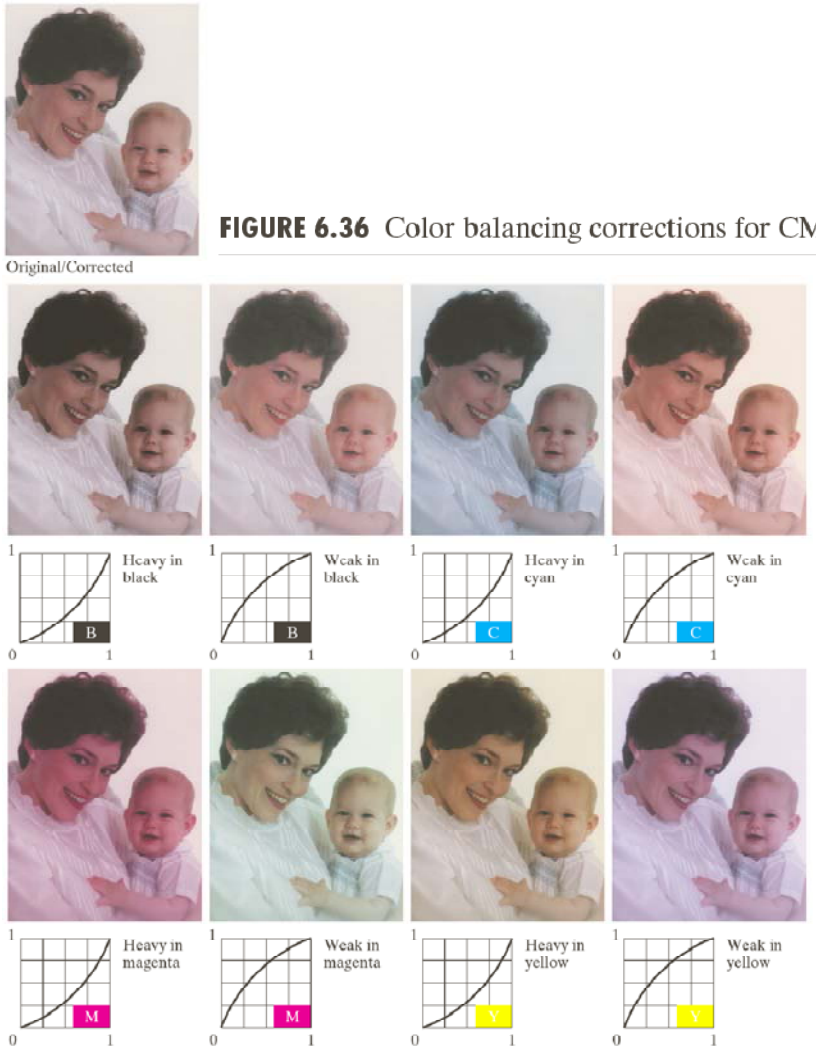
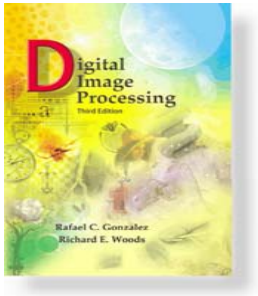


FIGURE 6.36 Color balancing corrections for CMYK color images.



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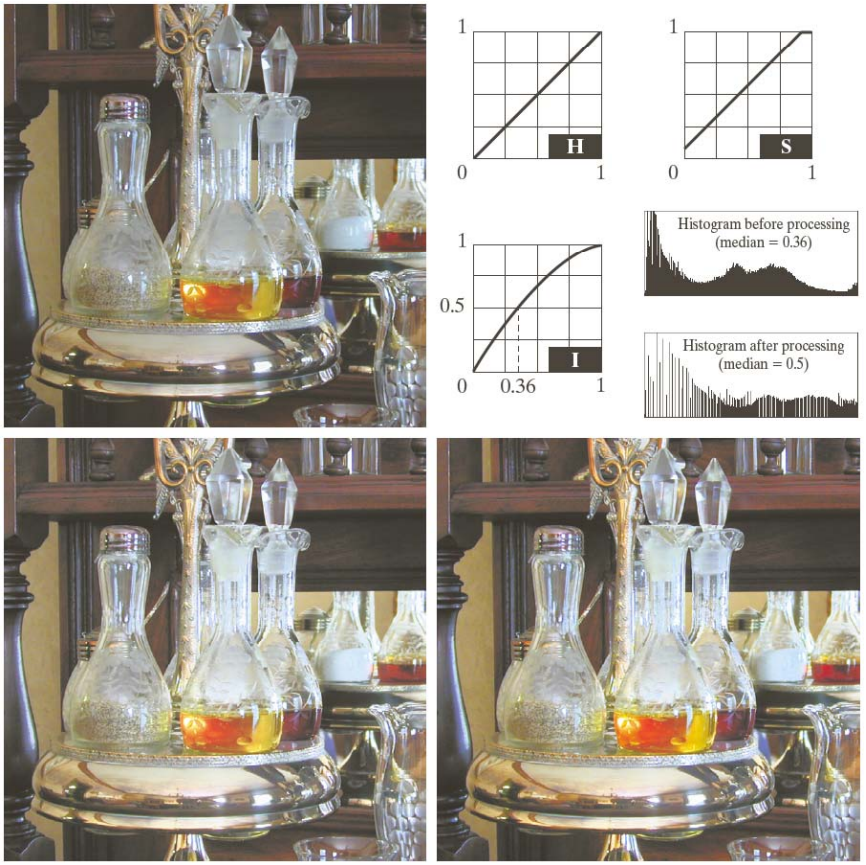
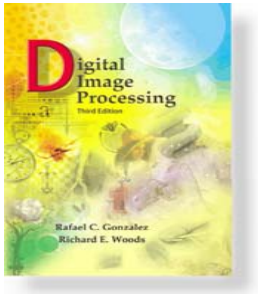


a b
c d

FIGURE 6.37 Histogram equalization (followed by saturation adjustment) in the HSI color space.



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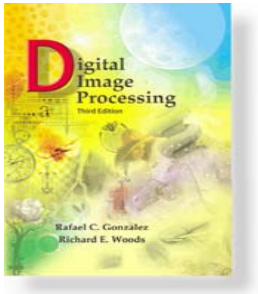
a b
c d

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



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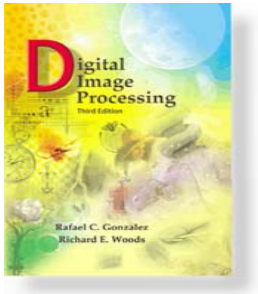
a b c

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



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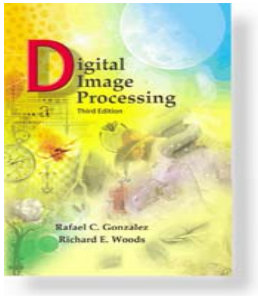
a b c

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.



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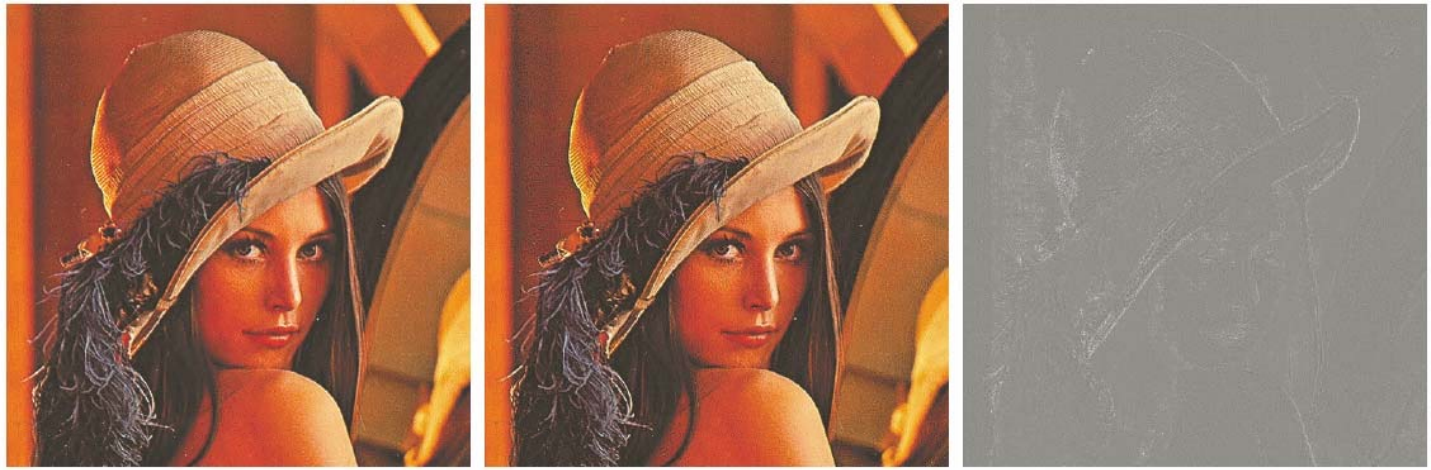
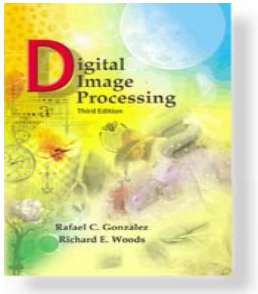


a b c

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.



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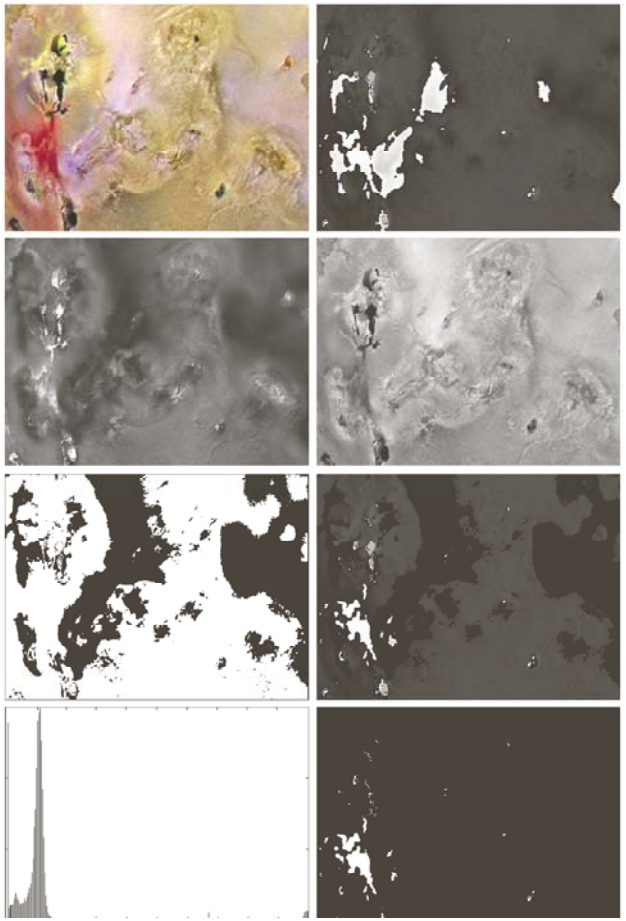
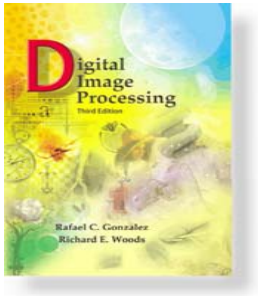


a b
c d
e f
g h

FIGURE 6.42 Image segmentation in HSI space. (a) Original. (b) Hue. (c) Saturation. (d) Intensity. (e) Binary saturation mask (black = 0). (f) Product of (b) and (e). (g) Histogram of (f). (h) Segmentation of red components in (a).



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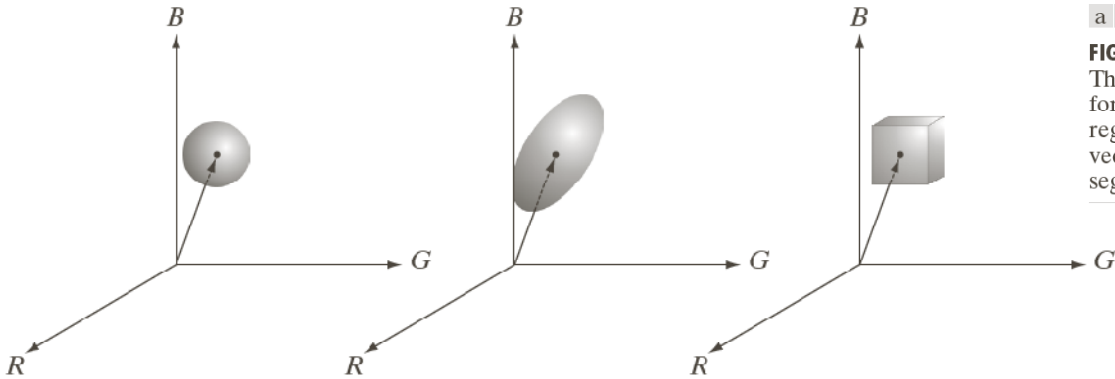
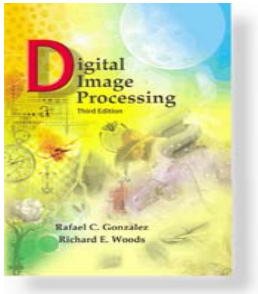


a b c

FIGURE 6.43 Three approaches for enclosing data regions for RGB vector segmentation.



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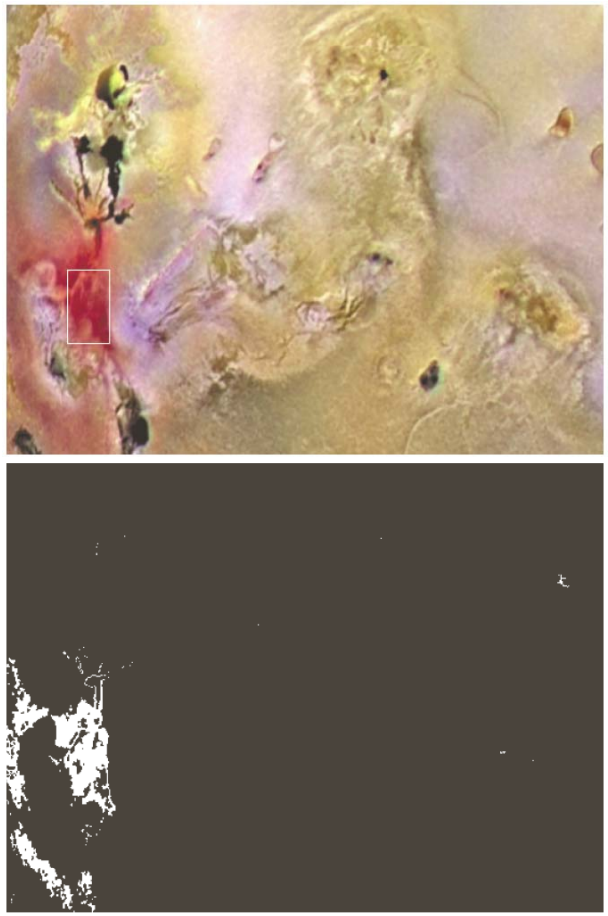
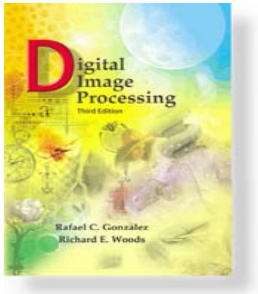


a
b

FIGURE 6.44
Segmentation in RGB space. (a) Original image with colors of interest shown enclosed by a rectangle. (b) Result of segmentation in RGB vector space. Compare with Fig. 6.42(h).



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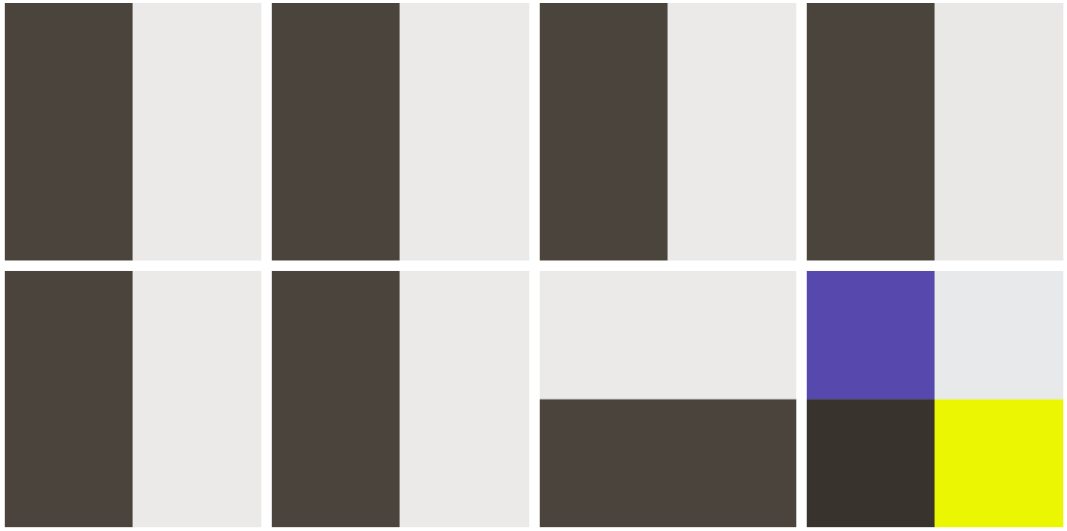
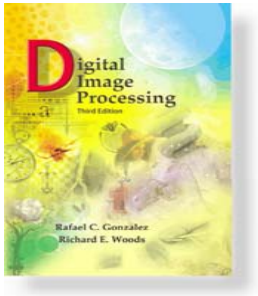


a b c d
e f g h

FIGURE 6.45 (a)–(c) *R*, *G*, and *B* component images and (d) resulting RGB color image. (e)–(g) *R*, *G*, and *B* component images and (h) resulting RGB color image.



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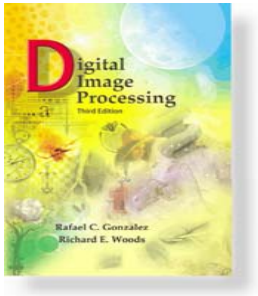
a b
c d

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).



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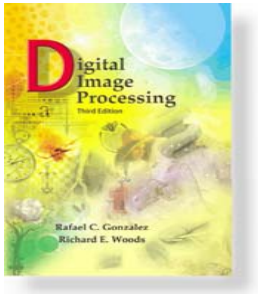
a b c

FIGURE 6.47 Component gradient images of the color image in Fig. 6.46. (a) Red component, (b) green component, and (c) blue component. These three images were added and scaled to produce the image in Fig. 6.46(c).



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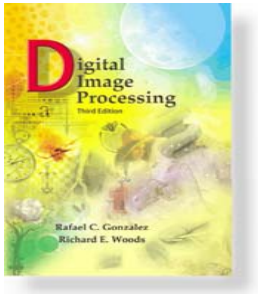
a b
c d

FIGURE 6.48
(a)–(c) Red, green, and blue component images corrupted by additive Gaussian noise of mean 0 and variance 800. (d) Resulting RGB image. [Compare (d) with Fig. 6.46(a).]



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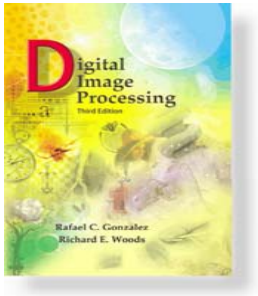
a b c

FIGURE 6.49 HSI components of the noisy color image in Fig. 6.48(d). (a) Hue. (b) Saturation. (c) Intensity.



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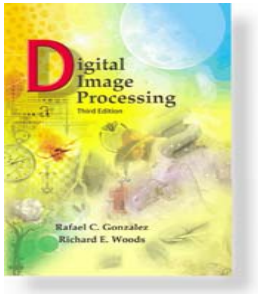
a b
c d

FIGURE 6.50 (a) RGB image with green plane corrupted by salt-and-pepper noise. (b) Hue component of HSI image. (c) Saturation component. (d) Intensity component.



Chapter 6
Color Image Processing

a
b

FIGURE 6.51
Color image compression. (a) Original RGB image. (b) Result of compressing and decompressing the image in (a).