Some Basic Intensity Transformation Functions

- Image Negatives

  $s = L - 1 - r$

  - S is the output intensity value
  - L is the highest intensity levels
  - r is the input intensity value
  - Particularly suited for enhancing white or gray detail embedded in dark regions of an image, especially when the black areas are dominant in size

Some Basic Intensity Transformation Functions

- Image Negatives

Some Basic Intensity Transformation Functions

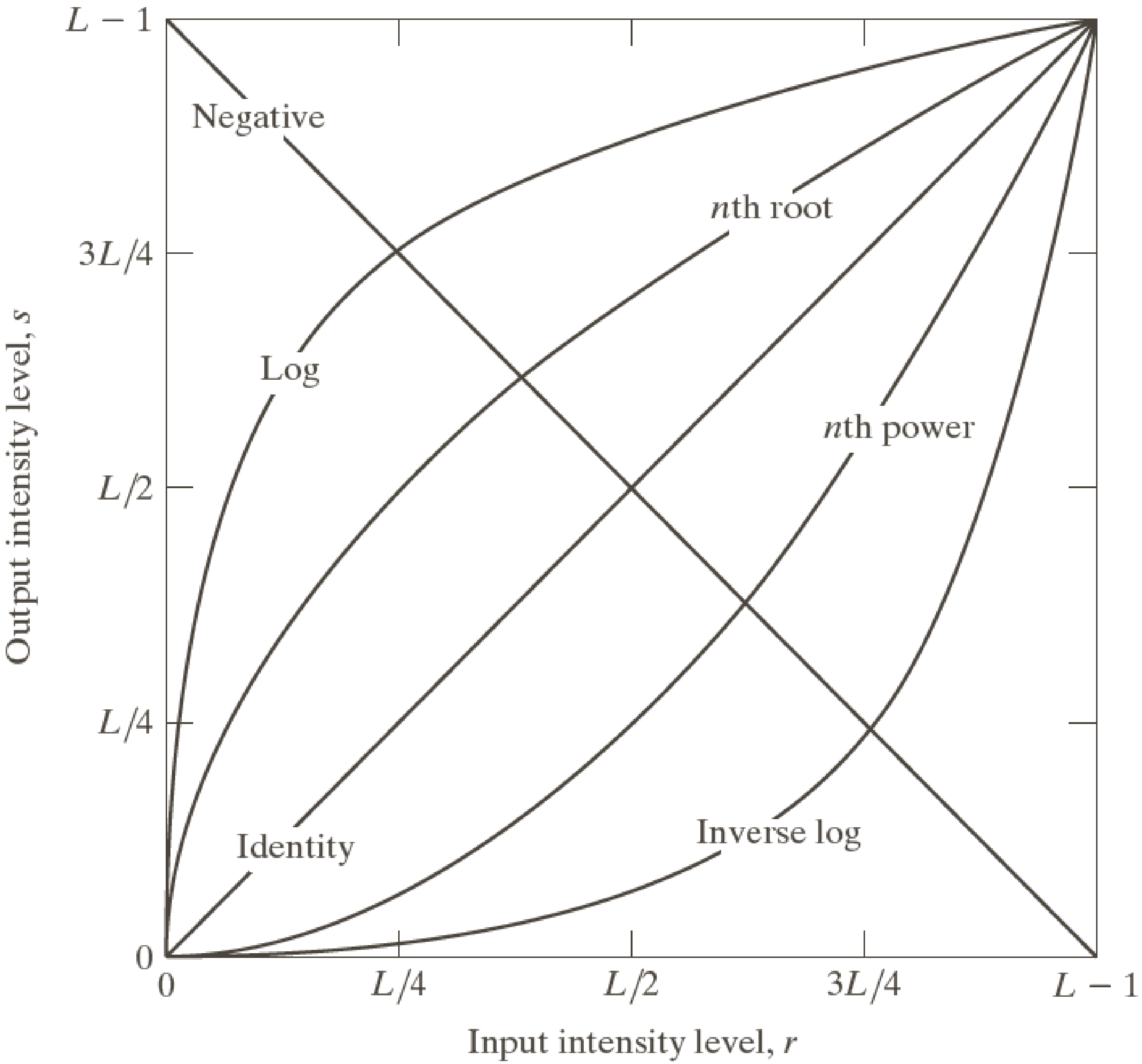


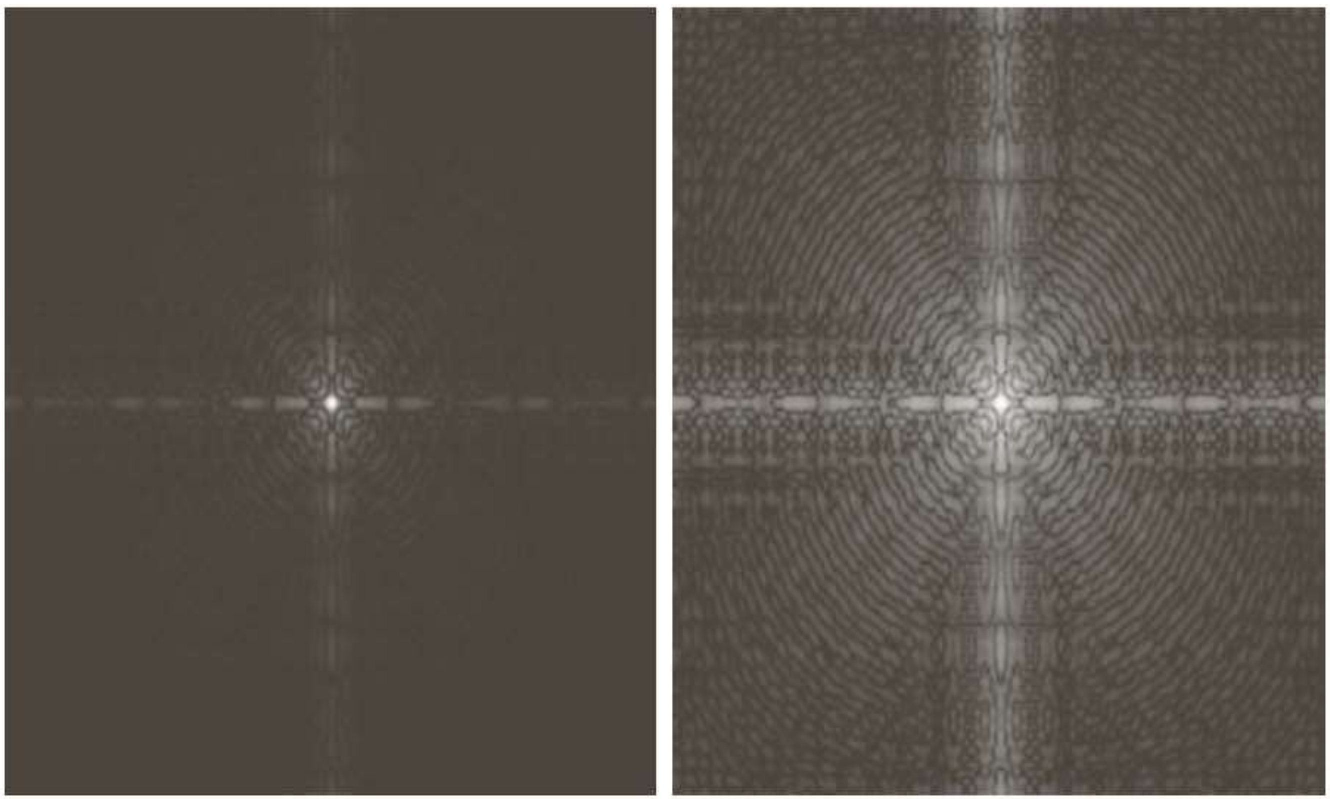
FIGURE 3.3 Some basic intensity transformation functions. All curves were scaled to fit in the range shown.

Some Basic Intensity Transformation Functions

- Log Transformations
  - $s = c \log(1 + r)$
    - c is constant
  - It maps a narrow range of low intensity values in the input into a wide range of output levels
  - The opposite is true of higher values of input levels
  - It expands the values of dark pixels in an image while compressing the higher level values
  - It compresses the dynamic range of images with large variations in pixel values

Some Basic Intensity Transformation Functions

- Log Transformations



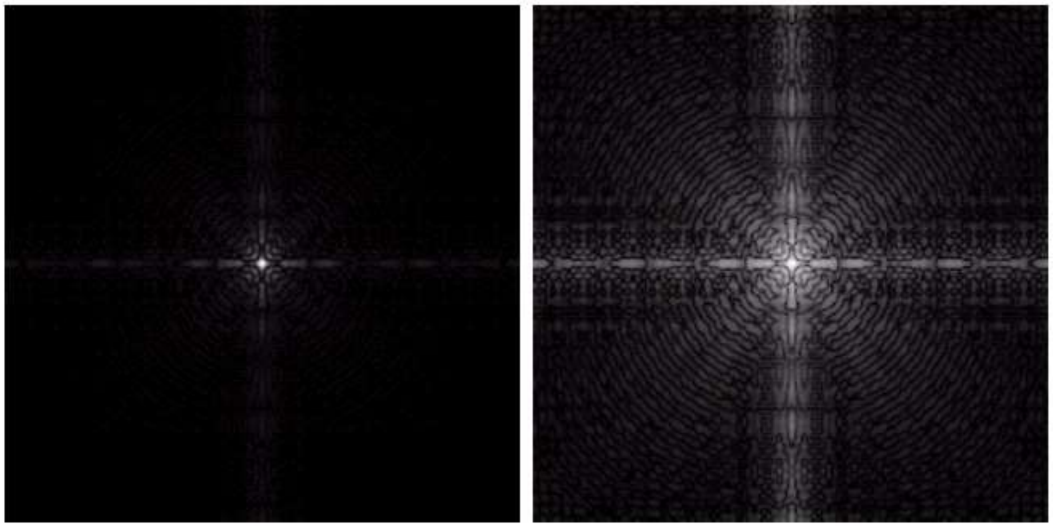
a b

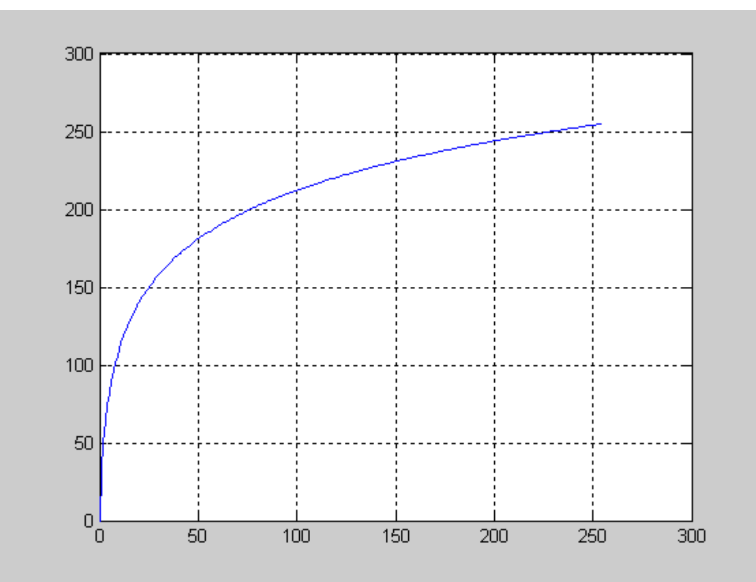
FIGURE 3.5 (a) Fourier spectrum. (b) Result of applying the log transformation in Eq. (3.2-2) with $c = 1$.

Log Transform

a b

FIGURE 3.5
(a) Fourier spectrum.
(b) Result of applying the log transformation given in Eq. (3.2-2) with $c = 1$.





$$T(r) = c\log(1+r)$$

Some Basic Intensity Transformation Functions

- Power Law (Gamma) Transformations
  - $s = c\,r^{\gamma}$
    - c and γ are both positive constants
  - With fractional values($0<\gamma<1$) of gamma map a narrow range of dark input values into a wider range of output values, with the opposite being true for higher values ($\gamma>1$)of input levels.
  - C=gamma=1 means it is an identity transformations.
  - Variety of devices used for image capture , printing, and display respond according to a power law.
  - Process used to correct these power law response phenomena is called *gamma correction.*

Some Basic Intensity Transformation Functions

- Power Law (Gamma) Transformations

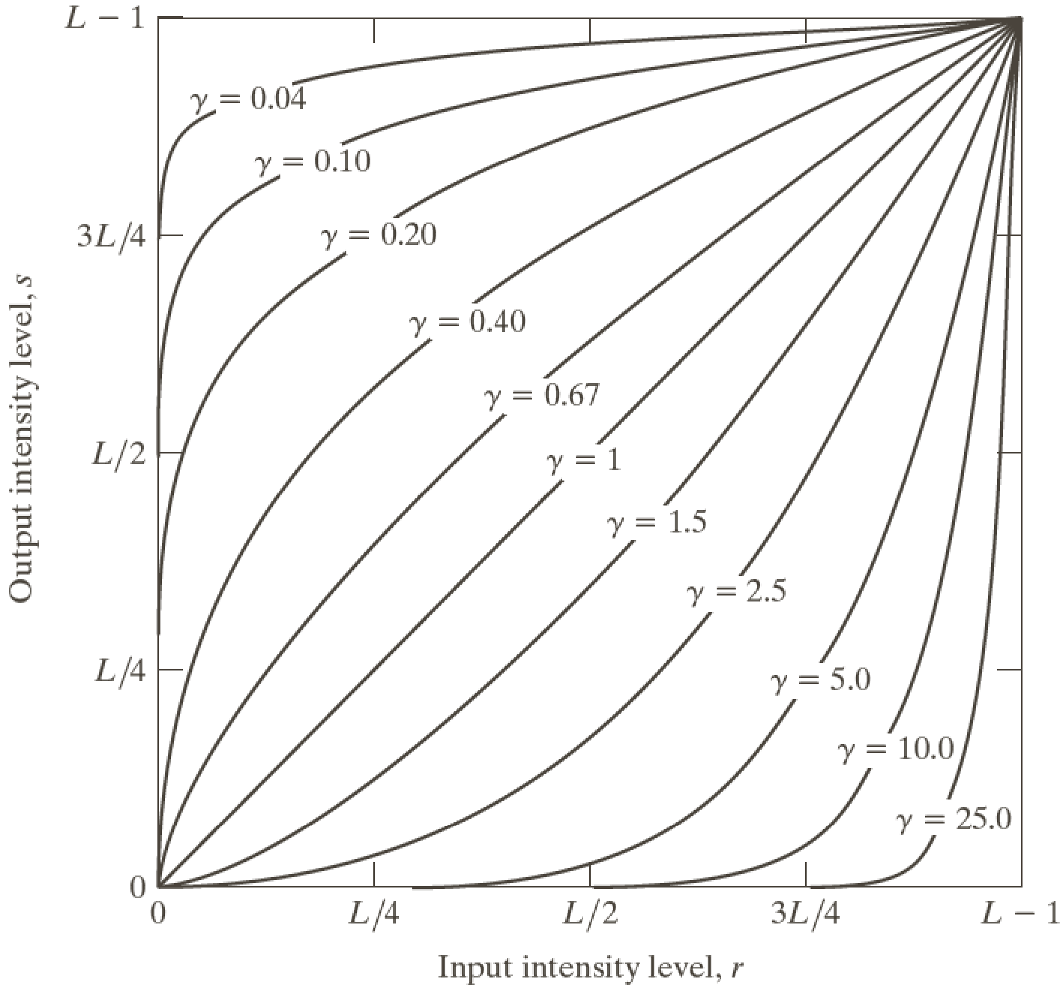
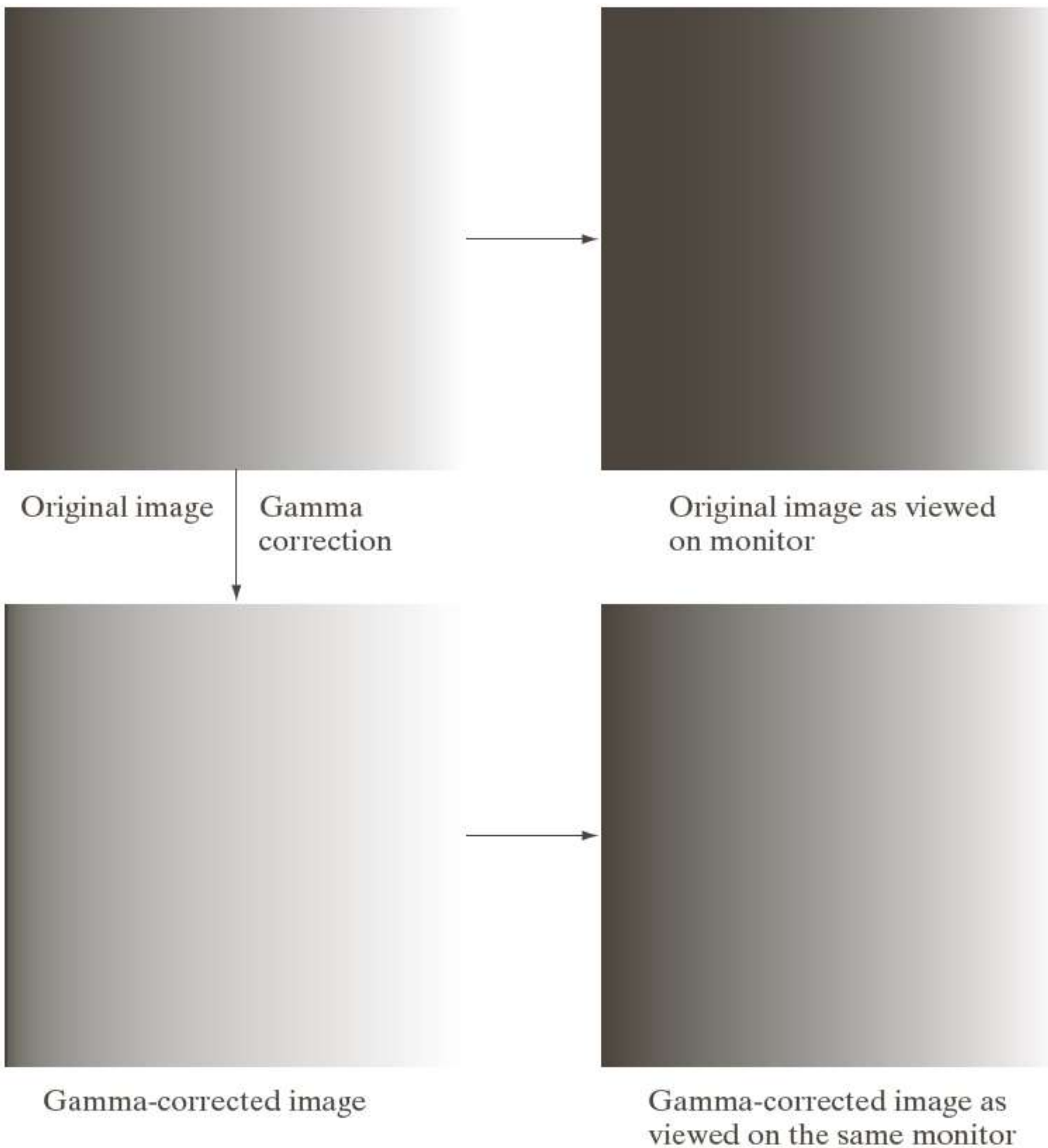


FIGURE 3.6 Plots of the equation $s = cr^{\gamma}$ for various values of γ ($c = 1$ in all cases). All curves were scaled to fit in the range shown.

Some Basic Intensity Transformation Functions



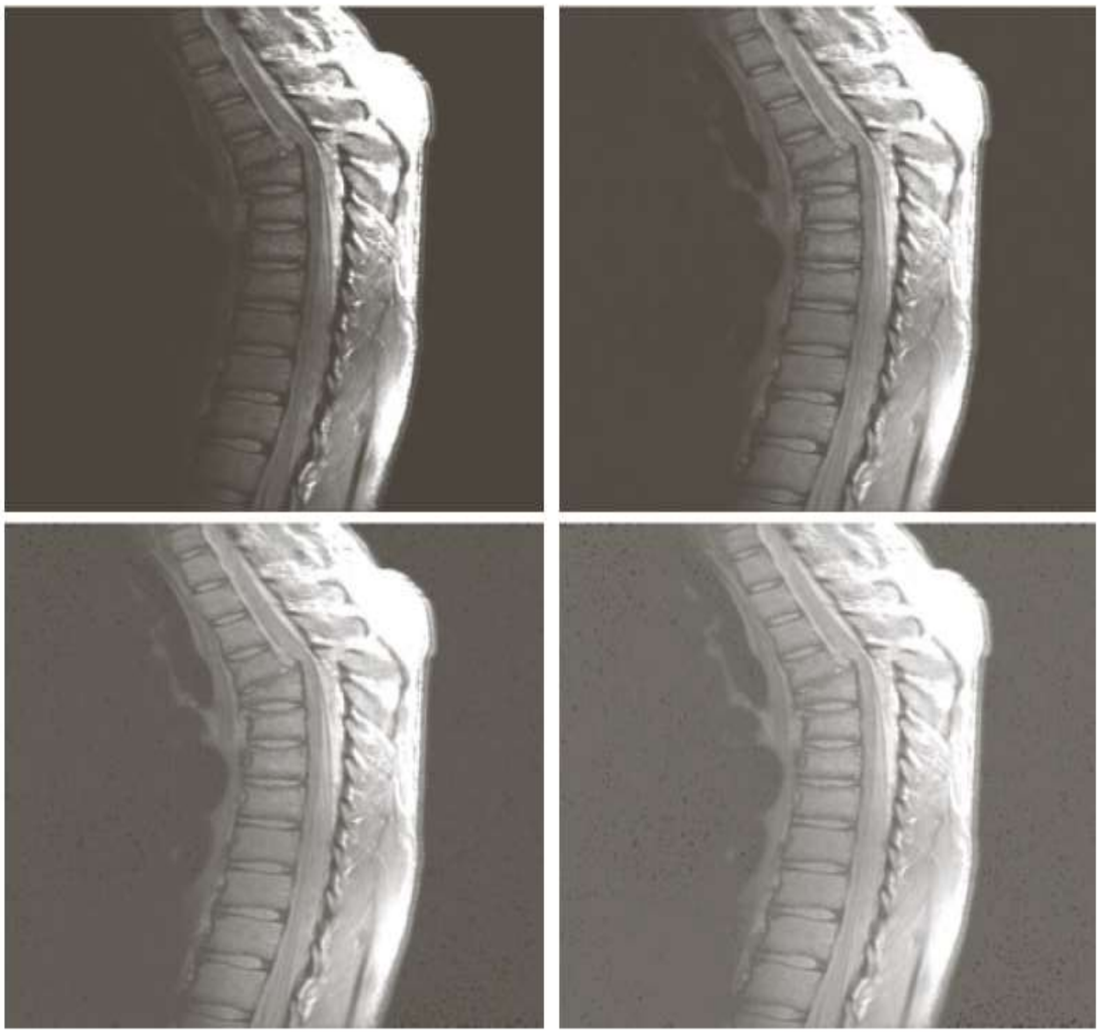
a	b
c	d

FIGURE 3.7 (a) Intensity ramp image. (b) Image as viewed on a simulated monitor with a gamma of 2.5. (c) Gamma-corrected image. (d) Corrected image as viewed on the same monitor. Compare (d) and (a).

Some Basic Intensity Transformation Functions

- Power Law (Gamma) Transformations
  - Images that are not corrected properly look either bleached out or too dark.
  - Varying gamma changes not only intensity, but also the ratio of red to green to blue in a color images.
  - Gamma correction has become increasingly important, as the use of the digital images over internet.
  - Useful for general purpose contrast manipulation.
  - Apply gamma correction on CRT (Television, monitor), printers, scanners etc.
  - Gamma value depends on device.

Some Basic Intensity Transformation Functions



a b
c d

FIGURE 3.8 (a) Magnetic resonance image (MRI) of a fractured human spine. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 0.6, 0.4$, and 0.3, respectively. (Original image courtesy of Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

Some Basic Intensity Transformation Functions

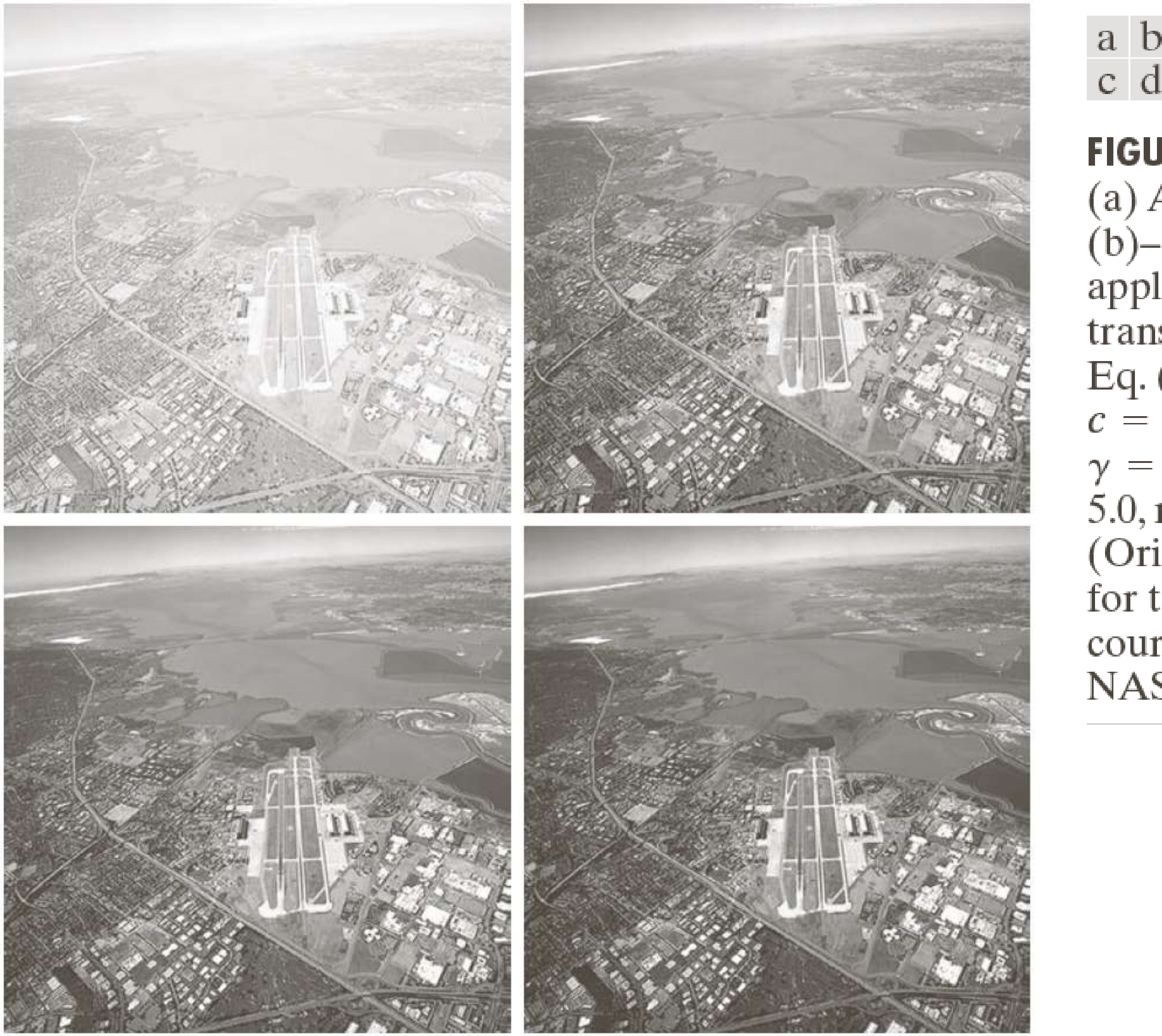


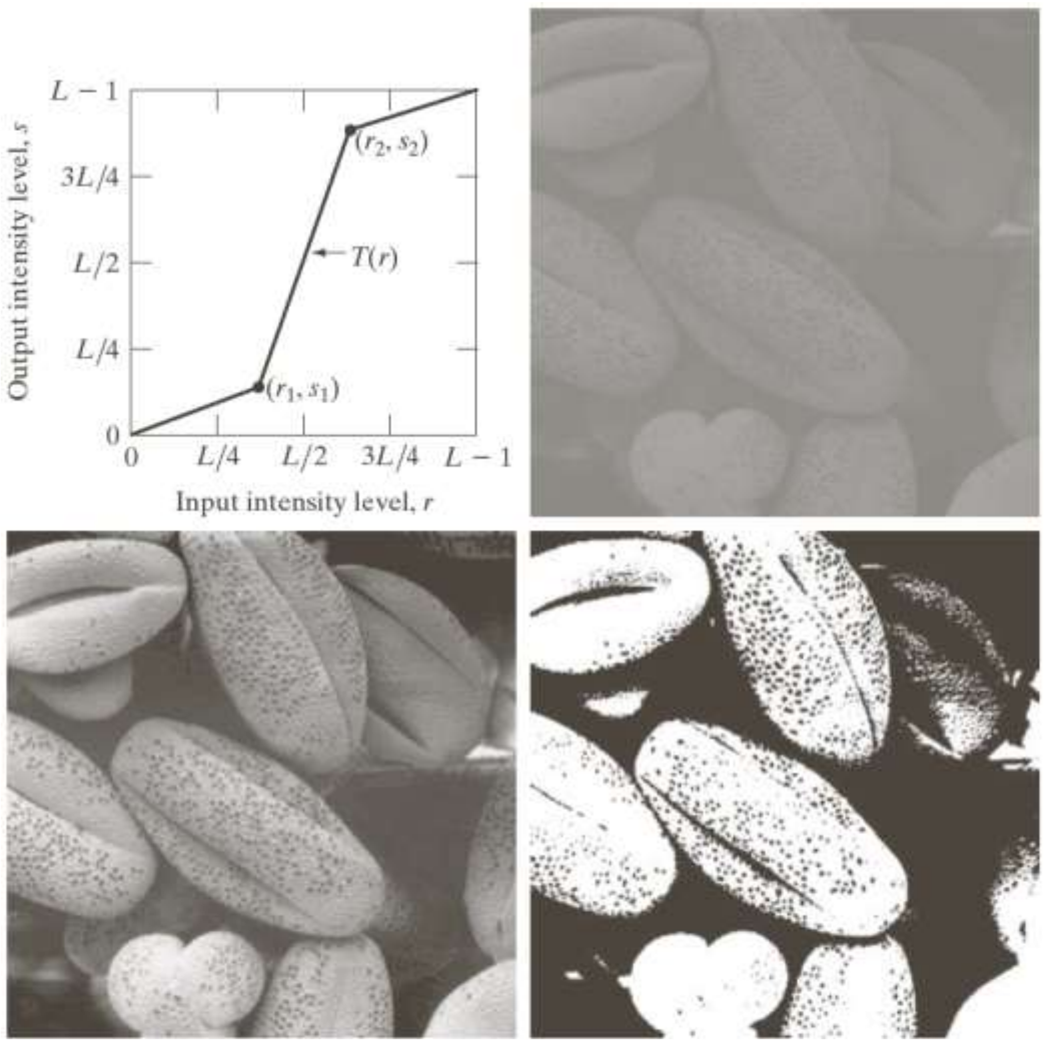
FIGURE 3.9 (a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 3.0, 4.0$, and 5.0, respectively. (Original image for this example courtesy of NASA.)

Piecewise-Linear Transformation Functions

- Contrast Stretching
  - Low contrast images can result from poor illuminations.
  - Lack of dynamic range in the imaging sensor, or even the wrong setting of a lens aperture during image acquisition.
  - It expands the range of intensity levels in an image so that it spans the full intensity range of display devices.
  - Contrast stretching is obtained by setting

    $(r1,s1) = (r_{min}, 0)$ and $(r2,s2) = (r_{max}, L-1)$

Piecewise-Linear Transformation Functions



a b
c d

FIGURE 3.10 Contrast stretching. (a) Form of transformation function. (b) A low-contrast image. (c) Result of contrast stretching. (d) Result of thresholding. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

Piecewise-Linear Transformation Functions

- Intensity Level Slicing
  - Highlighting specific range of intensities in an image.
  - Enhances features such as masses of water in satellite imagery and enhancing flaws in X-ray images.
  - It can be Implemented two ways:
  - 1) To display only one value (say, white) in the range of interest and rests are black which produces binary image.
  - 2) brightens (or darkens) the desired range of intensities but leaves all other intensity levels in the image unchanged.

Piecewise-Linear Transformation Functions

- Intensity Level Slicing

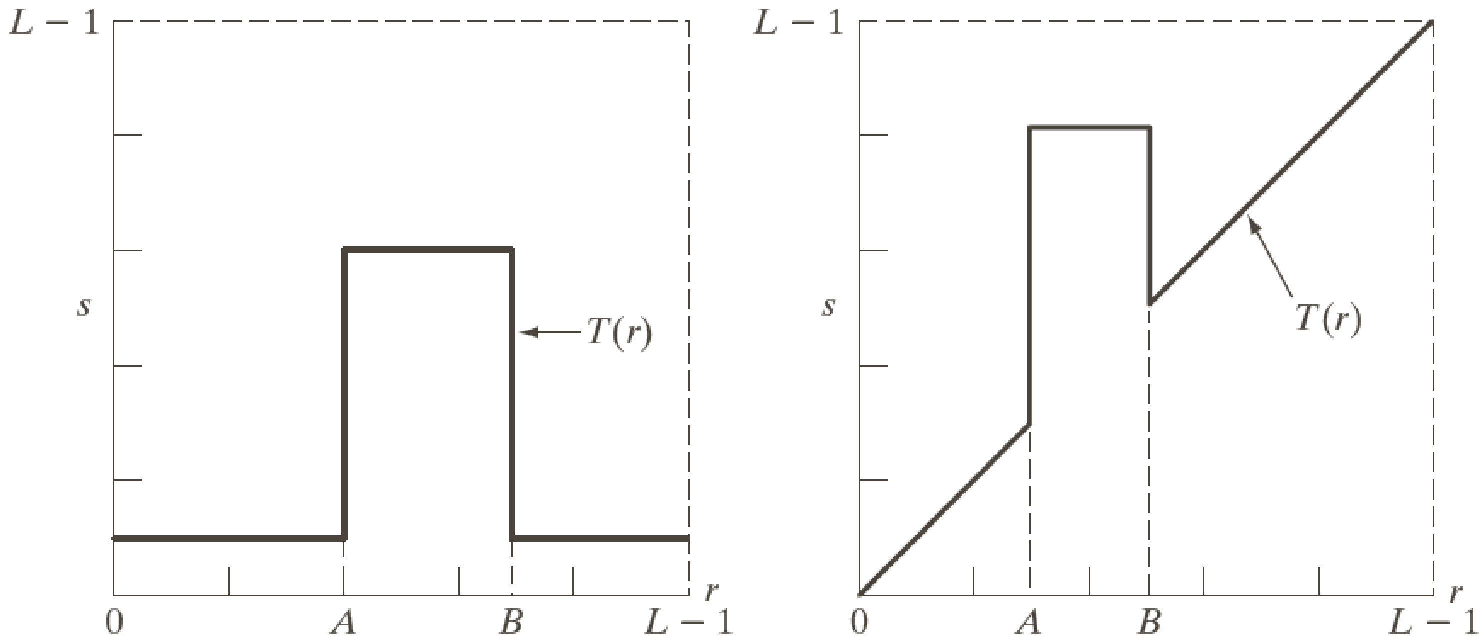
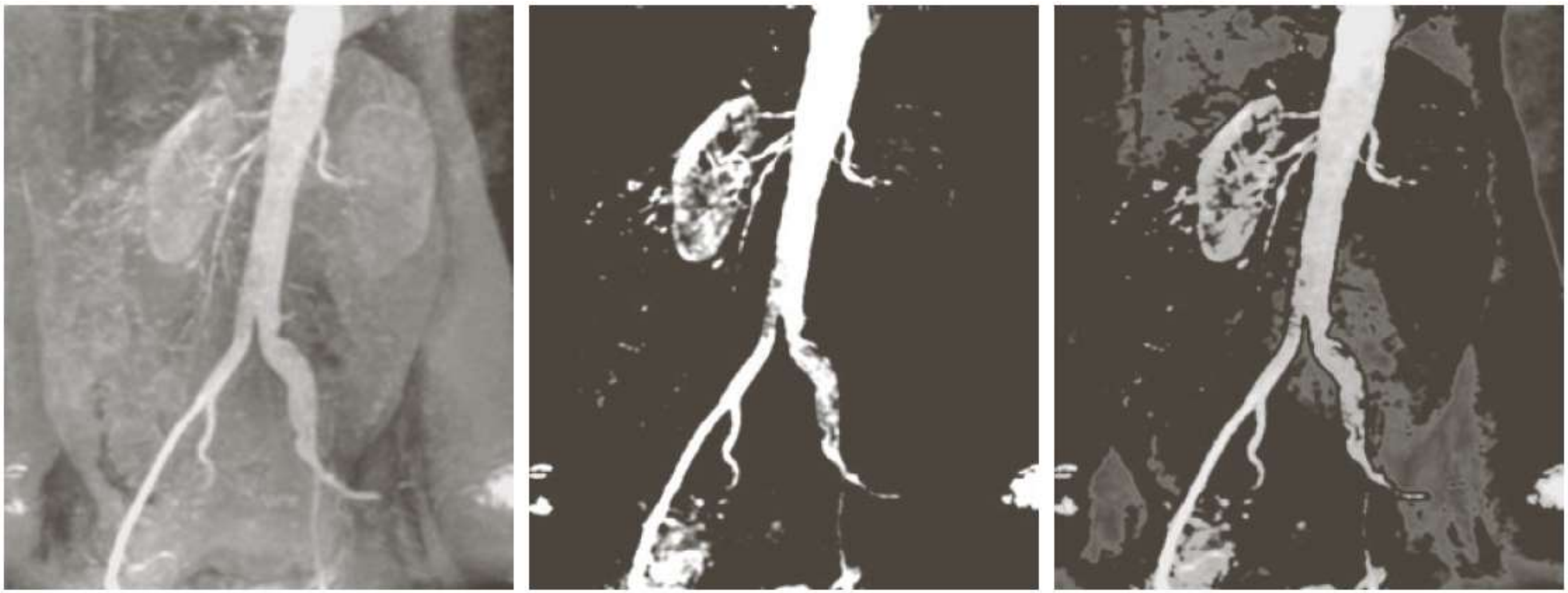


FIGURE 3.11 (a) This transformation highlights intensity range $[A, B]$ and reduces all other intensities to a lower level. (b) This transformation highlights range $[A, B]$ and preserves all other intensity levels.

Piecewise-Linear Transformation Functions

- Intensity Level Slicing



a b c

FIGURE 3.12 (a) Aortic angiogram. (b) Result of using a slicing transformation of the type illustrated in Fig. 3.11(a), with the range of intensities of interest selected in the upper end of the gray scale. (c) Result of using the transformation in Fig. 3.11(b), with the selected area set to black, so that grays in the area of the blood vessels and kidneys were preserved. (Original image courtesy of Dr. Thomas R. Gest, University of Michigan Medical School.)

Piecewise-Linear Transformation Functions

- Intensity Level Slicing

Piecewise-Linear Transformation Functions

- Bit Plane Slicing
  - Pixels are digital numbers composed of bits.
  - 256 gray scale image is composed of 8 bits.
  - Instead of highlighting intensity level ranges, we could highlight the contribution made to total image appearance by specific bits.
  - 8-bit image may be considered as being composed of eight 1-bit planes, with plane 1 containing the lowest-order bit of all pixels in the image and plane 8 all the highest-order bits.

Piecewise-Linear Transformation Functions

- Bit Plane Slicing

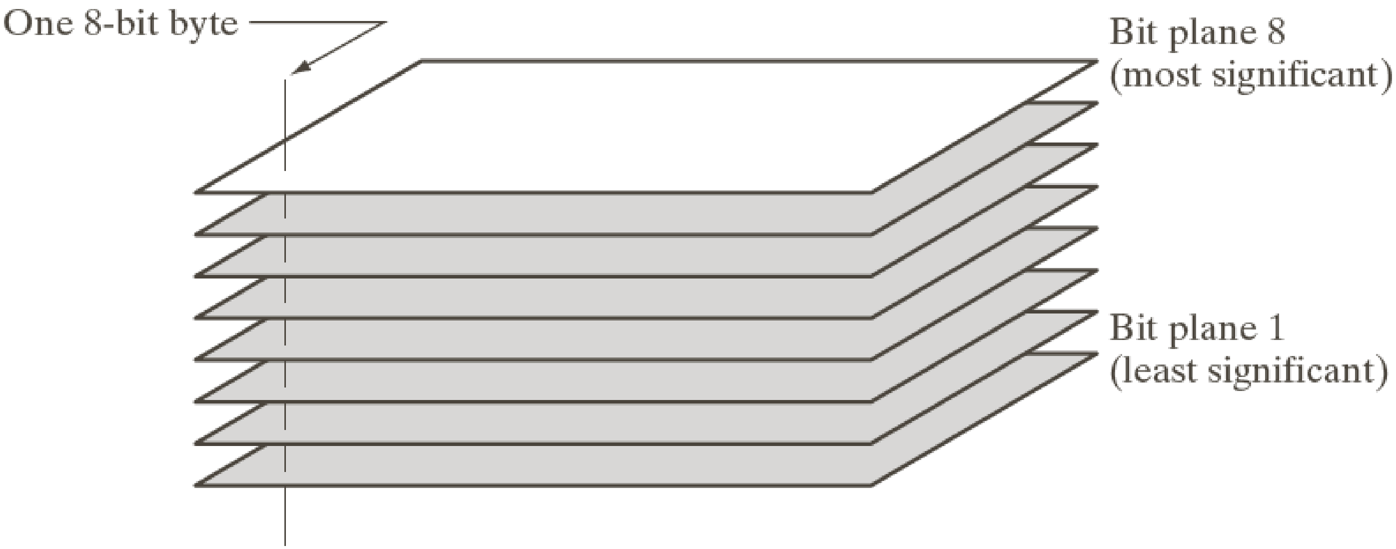


FIGURE 3.13 Bit-plane representation of an 8-bit image.

Piecewise-Linear Transformation Functions

- Bit Plane Slicing

a	b	c
d	e	f
g	h	i

FIGURE 3.14 (a) An 8-bit gray-scale image of size 500 $\times$ 1192 pixels. (b) through (i) Bit planes 1 through 8, with bit plane 1 corresponding to the least significant bit. Each bit plane is a binary image.

Piecewise-Linear Transformation Functions

- Bit Plane Slicing

a b c

FIGURE 3.15 Images reconstructed using (a) bit planes 8 and 7; (b) bit planes 8, 7, and 6; and (c) bit planes 8, 7, 6, and 5. Compare (c) with Fig. 3.14(a).

Histogram Processing

- Histogram of a digital image with intensity levels in the range [0,L-1] is a discrete function $h(r_k) = n_k$, where r_k is the kth intensity value and n_k is the number of pixels in the image with intensity r_k
- Normalized histogram $p(r_k)=n_k/MN$, for k = 0,1,2……. L-1.
- Histogram manipulation can be used for image enhancement.
- Information inherent in histogram also is quite useful in other image processing applications, such as image compression and segmentation.

Histogram Equalization

- Intensity mapping form

$$s = T(r),\ 0 \le r \le L-1$$

Conditions:

a) T(r) is a monotonically increasing function in the interval [0, L-1] and

b) $0 \le T(r) \le L-1 \, for 0 \le r \le L-1$

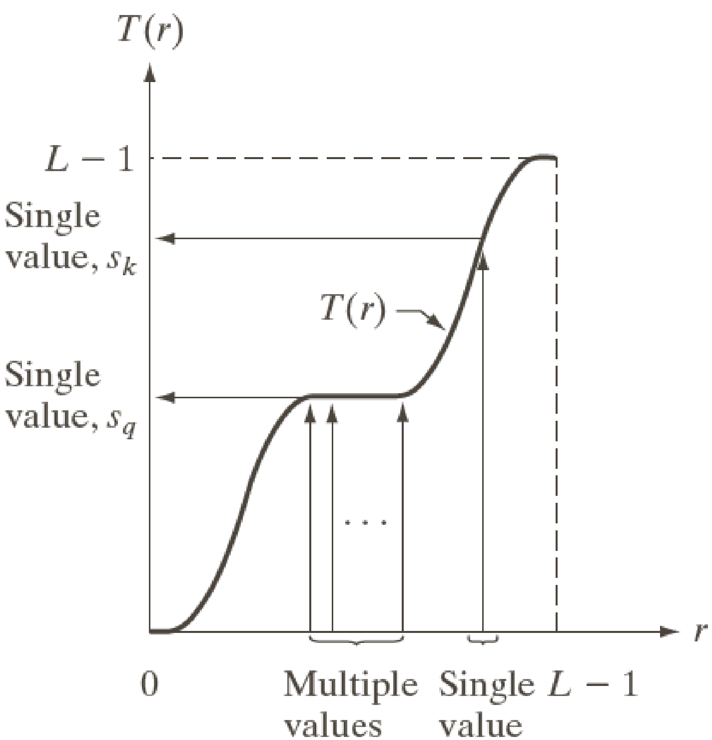
In some formulations, we use the inverse in which case

$$r = T^{-1}(s),\ 0 \le s \le 1$$

(a) change to

a’) T(r) is a strictly monotonically increasing function in the interval [0, L-1]

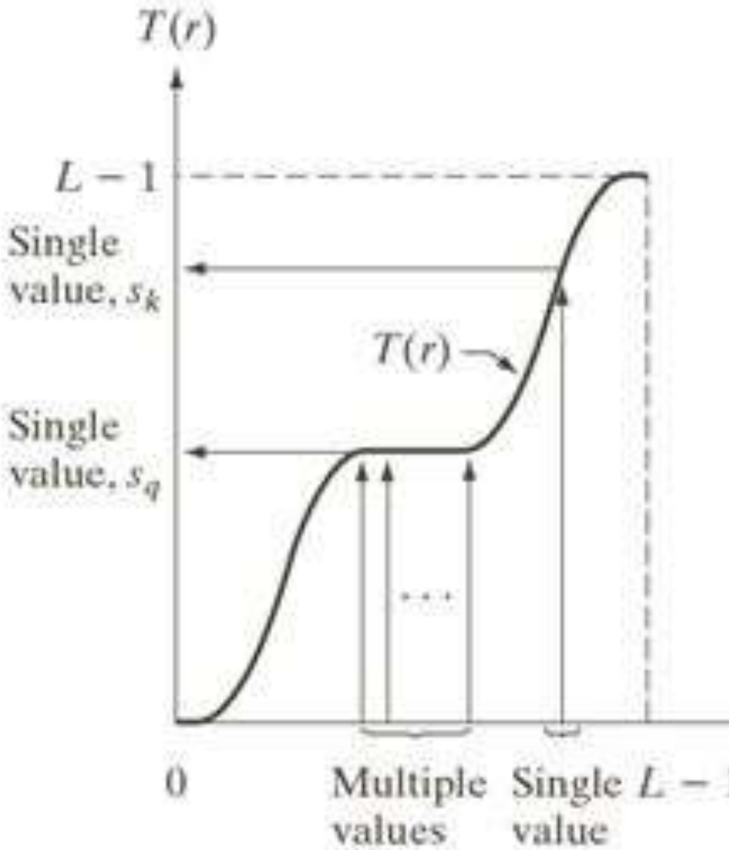
Histogram Processing

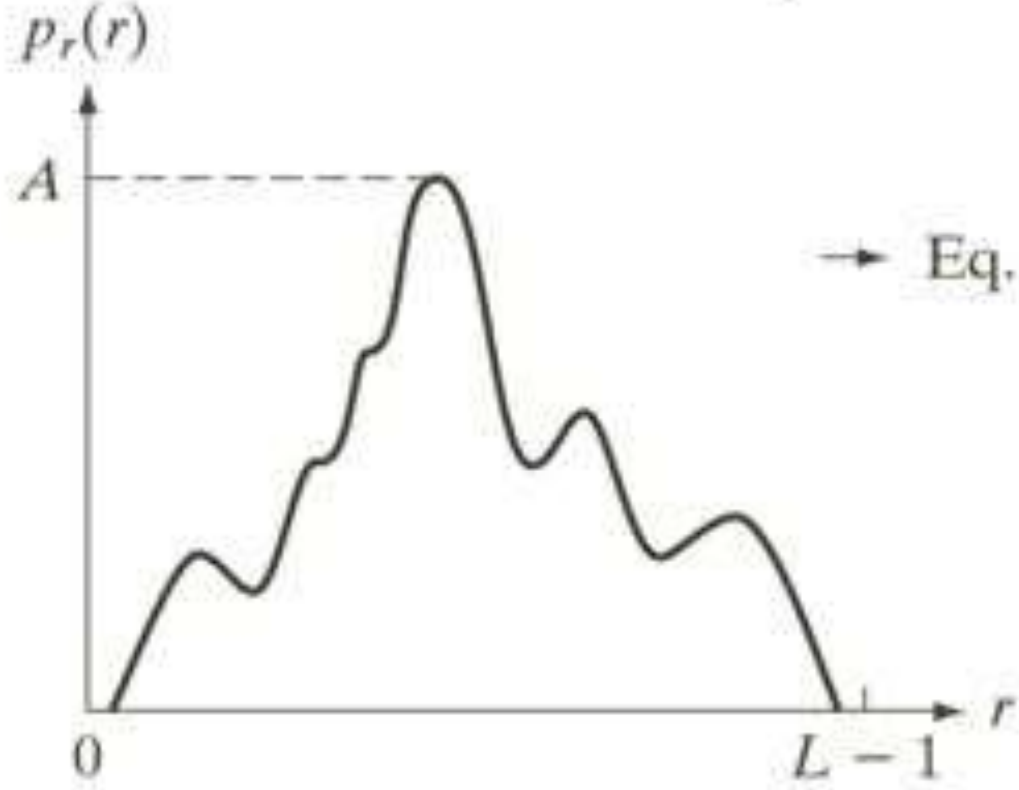


a b

FIGURE 3.17 (a) Monotonically increasing function, showing how multiple values can map to a single value. (b) Strictly monotonically increasing function. This is a one-to-one mapping, both ways.

Histogram Processing





Histogram Equalization

- Intensity levels in an image may be viewed as random variables in the interval [0,L-1]
- Fundamental descriptor of a random variable is its probability density function (PDF)
- Let $p_r(r)$ and $p_s(s)$ denote the PDFs of r and s respectively

$$p_s(s) = p_r(r)\left|\frac{dr}{ds}\right|$$

$$s = T(r) = (L-1)\int_0^r p_r(w)dw$$

$$\frac{ds}{dr} = \frac{dT(r)}{dr} = (L-1)\frac{d}{dr}\left[\int_0^r p_r(w)dw\right] = (L-1)p_r(r)$$

Histogram Equalization

$$p_s(s) = \frac{1}{L-1}$$

$$s_k = T(r_k) = (L-1)\sum_{j=0}^{k} p_r(r_j) = (L-1)\sum_{j=0}^{k} \frac{n_j}{MN}, \quad k = 0,1,2,\ldots,L-1$$

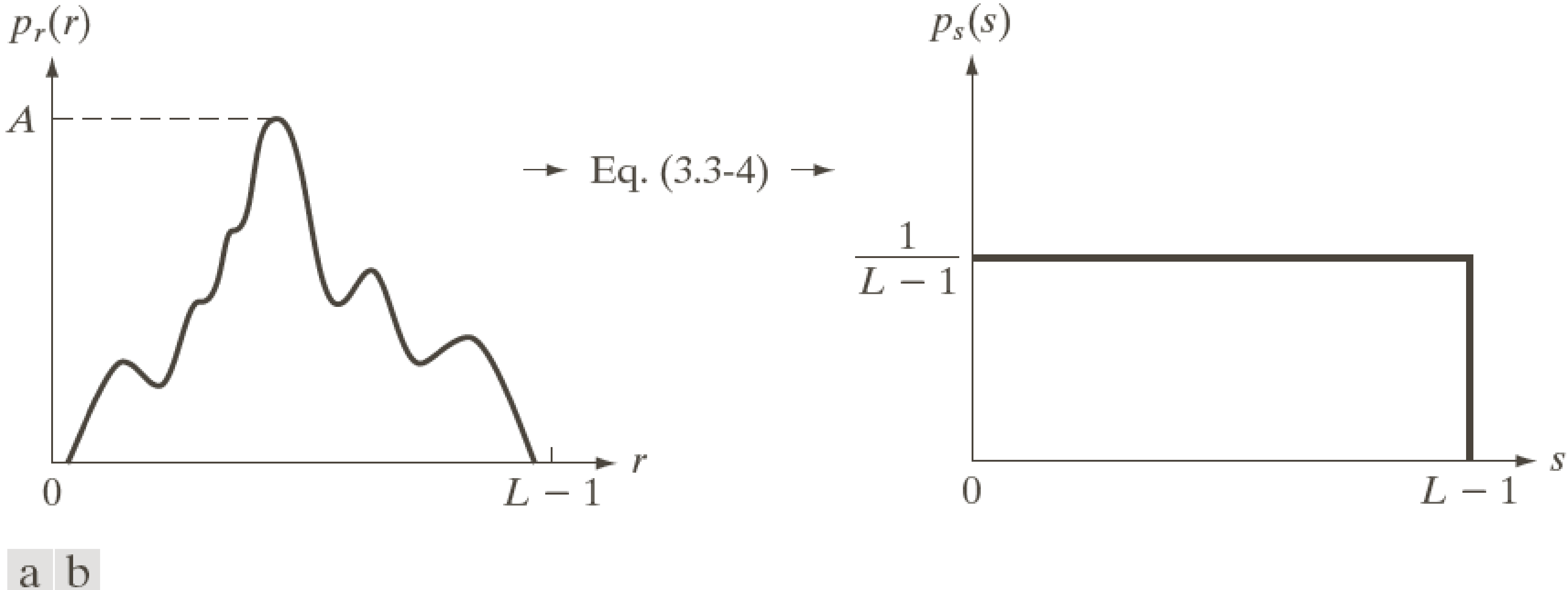
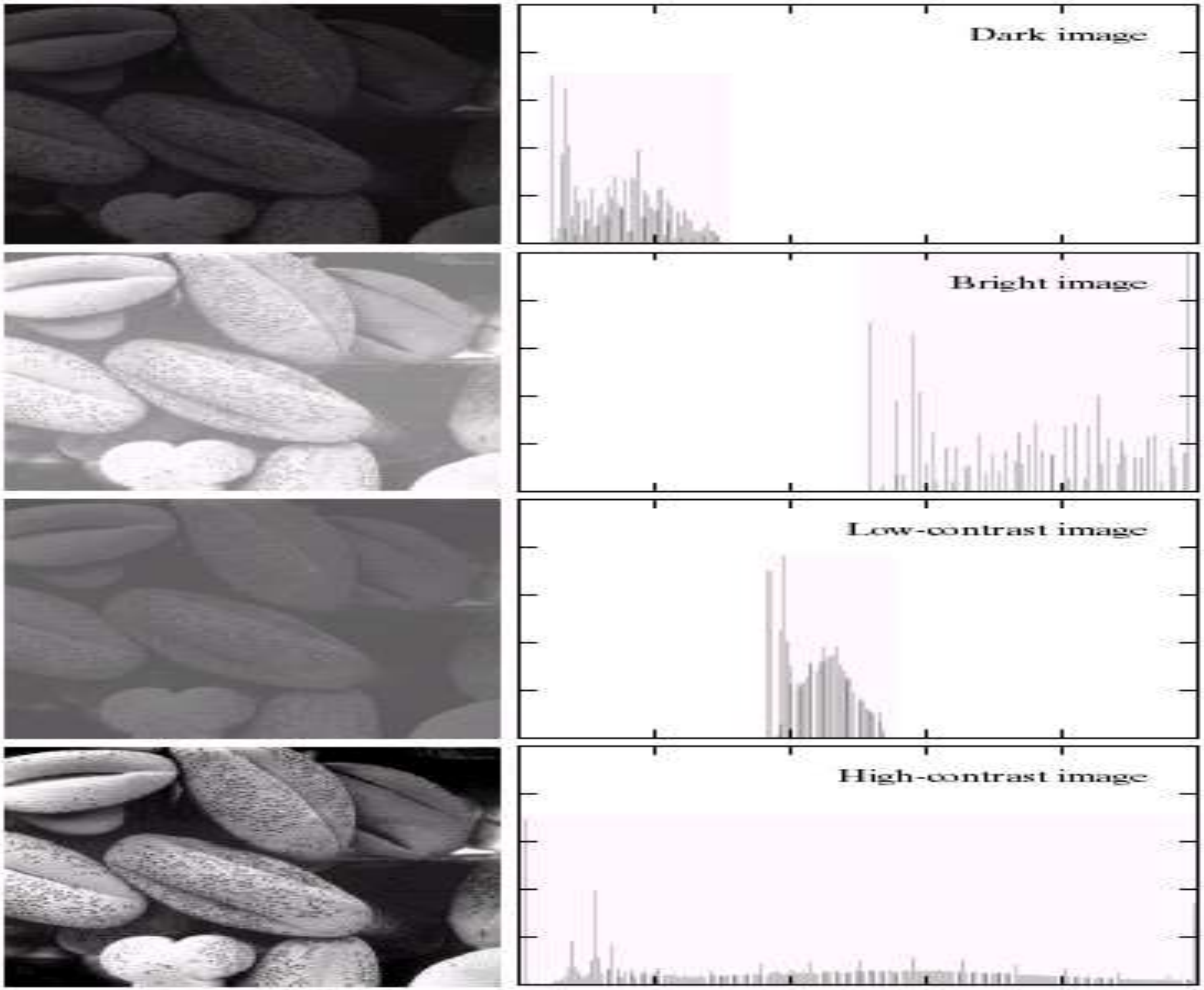


FIGURE 3.18 (a) An arbitrary PDF. (b) Result of applying the transformation in Eq. (3.3-4) to all intensity levels, r. The resulting intensities, s, have a uniform PDF, independently of the form of the PDF of the r's.

Histogram Processing

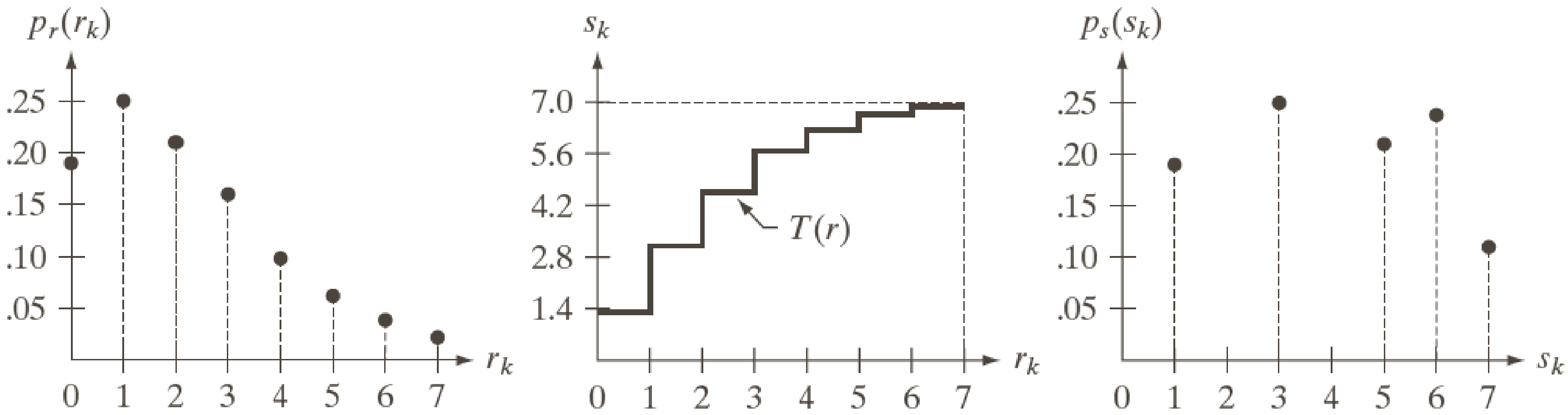


Histogram Equalization

r_k	n_k	$p_r(r_k) = n_k/MN$
$r_0 = 0$	790	0.19
$r_1 = 1$	1023	0.25
$r_2 = 2$	850	0.21
$r_3 = 3$	656	0.16
$r_4 = 4$	329	0.08
$r_5 = 5$	245	0.06
$r_6 = 6$	122	0.03
$r_7 = 7$	81	0.02

TABLE 3.1 Intensity distribution and histogram values for a 3-bit, 64×64 digital image.

Histogram Equalization



a b c

FIGURE 3.19 Illustration of histogram equalization of a 3-bit (8 intensity levels) image. (a) Original histogram. (b) Transformation function. (c) Equalized histogram.

Histogram Equalization

- Transformation functions

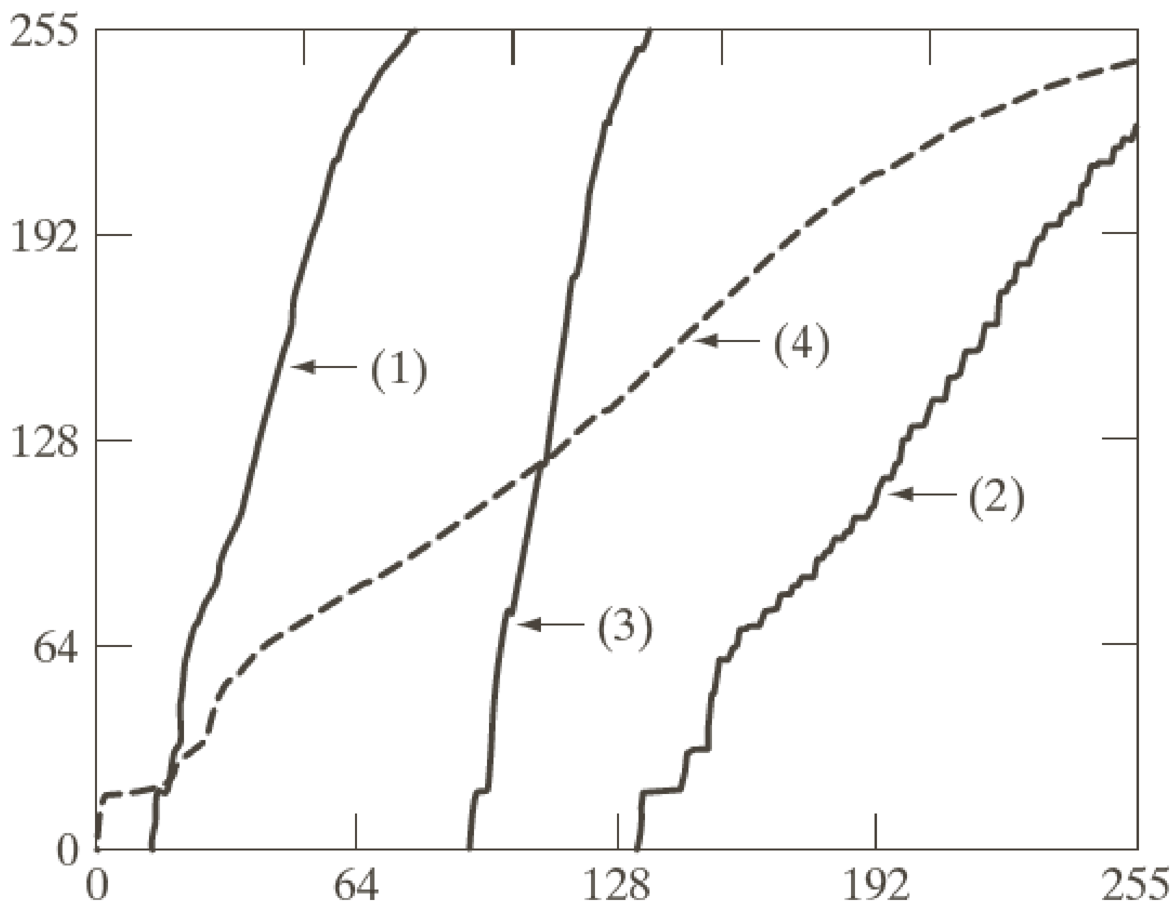


FIGURE 3.21 Transformation functions for histogram equalization. Transformations (1) through (4) were obtained from the histograms of the images (from top to bottom) in the left column of Fig. 3.20 using Eq. (3.3-8).

Histogram Equalization

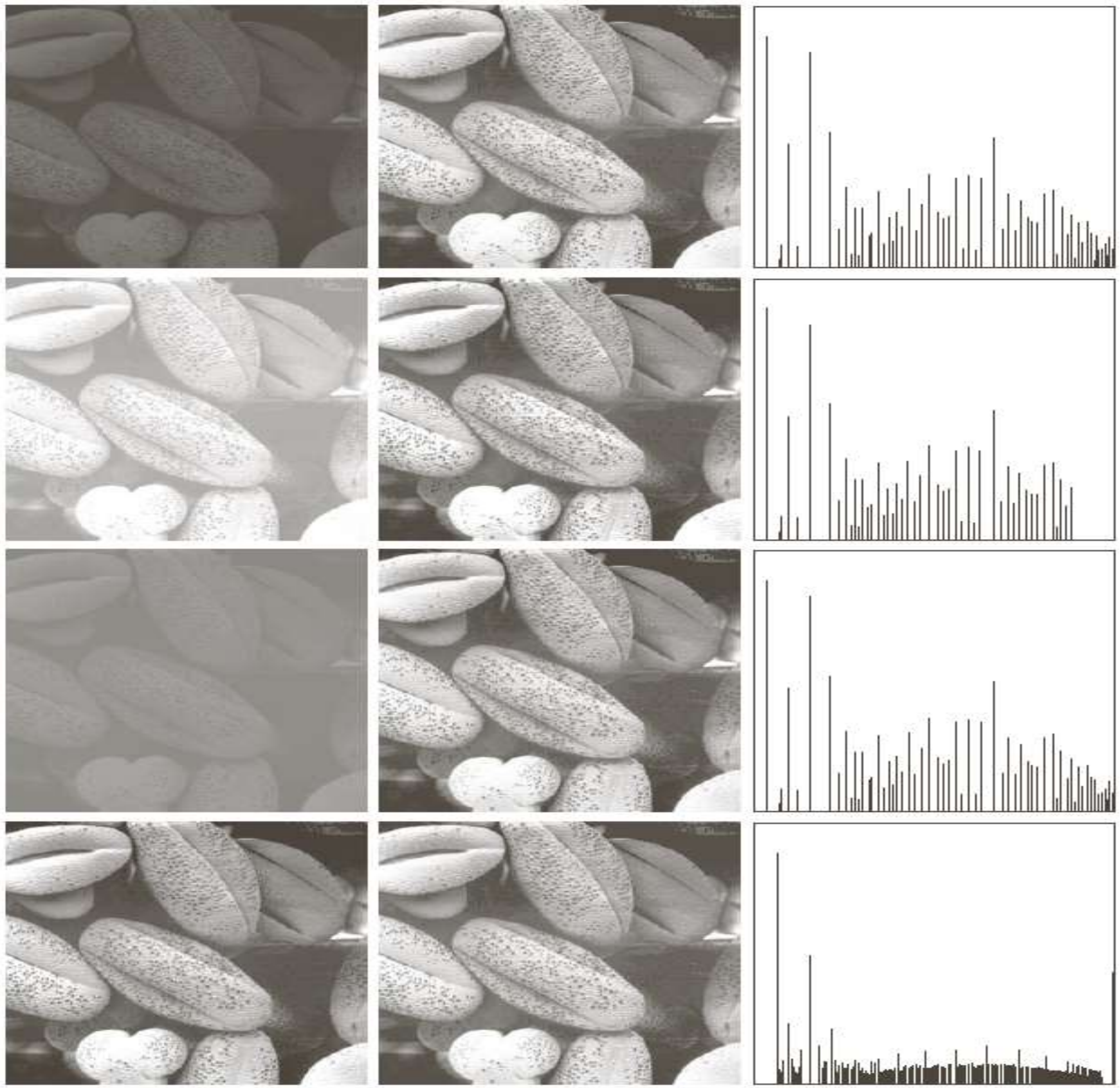


FIGURE 3.20 Left column: images from Fig. 3.16. Center column: corresponding histogram-equalized images. Right column: histograms of the images in the center column.