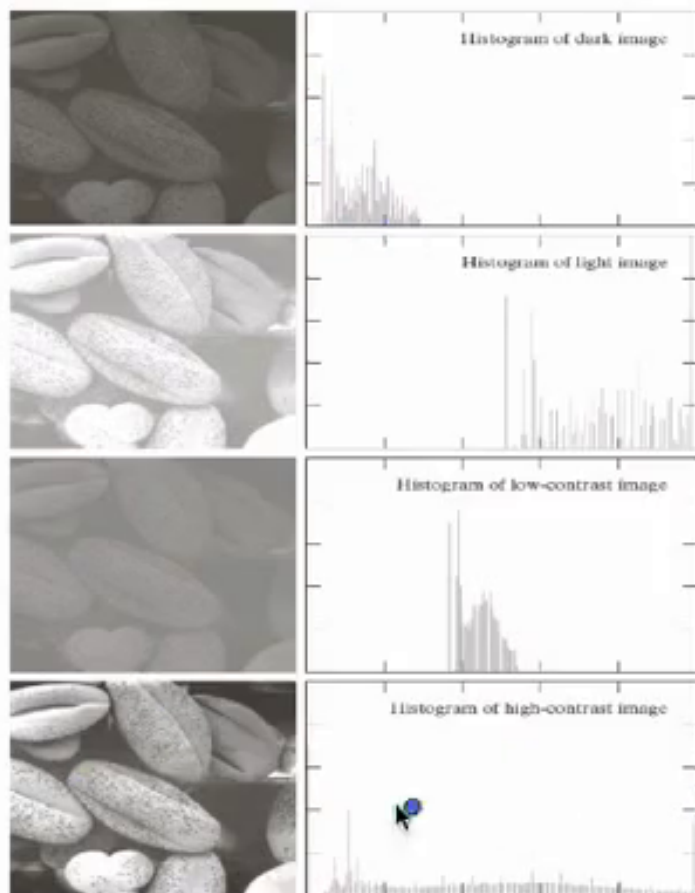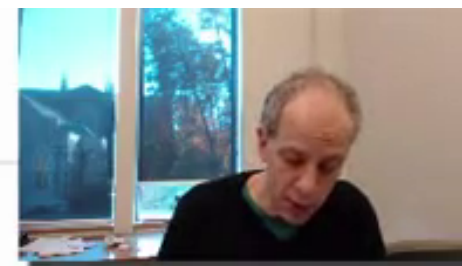**FIGURE 3.16** Four basic image types: dark, light, low contrast, high contrast, and their corresponding histograms.
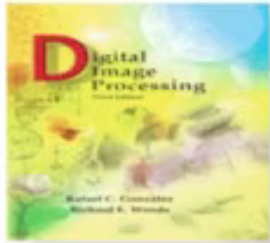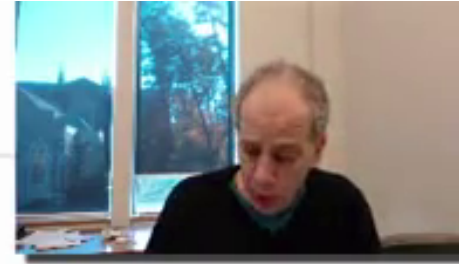
Histogram Equalization

a b

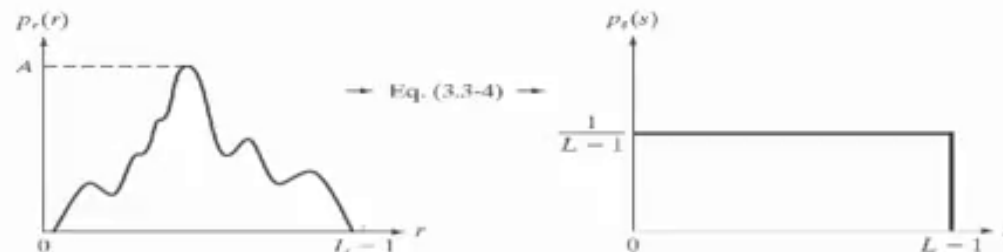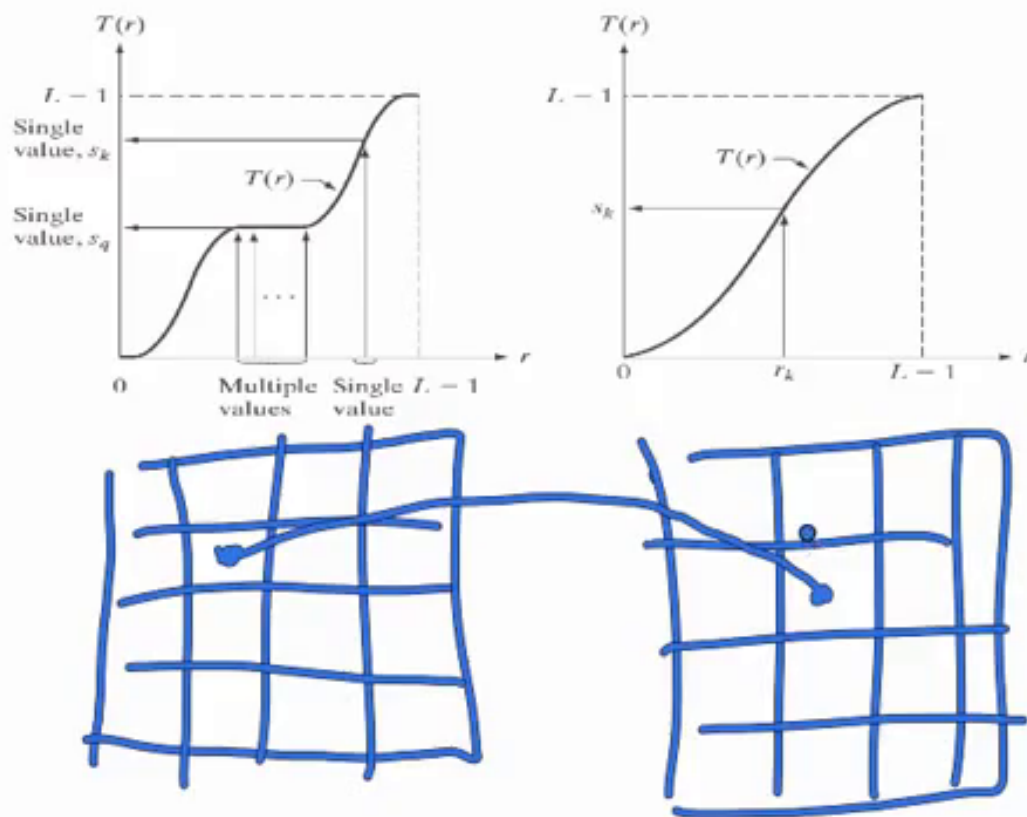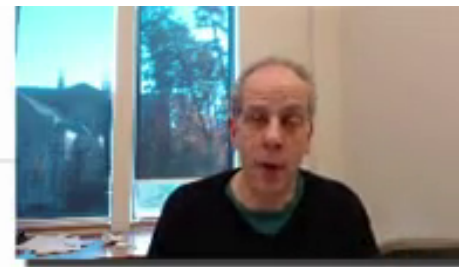**FIGURE 3.18** (a) An arbitrary PDF. (b) Result of applying the transformation in Eq. (3.3-4) to all intensity levels, r. The resulting intensities, s, have a uniform PDF, independently of the form of the PDF of the r's.
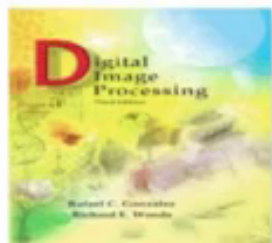
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a b

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.
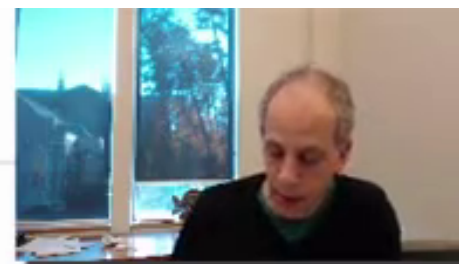
$$S = T(r) \qquad P_s(s) = P_r(r) \left| \frac{dr}{ds} \right|$$

$$S = T(r) = (L-1) \int P_r(\omega) d\omega$$

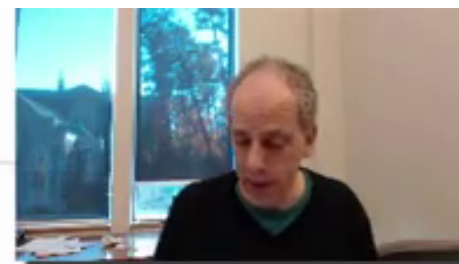$$\frac{dS}{dr} = \frac{dT(r)}{dr} = \frac{d(L-1) \int_0^r P_r(\omega) d\omega}{dr}$$
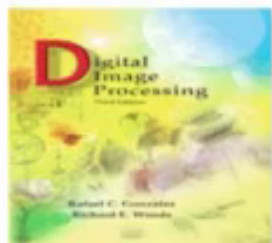
$$P_s(s) = P_r(r) \left| \frac{dr}{ds} \right| =$$

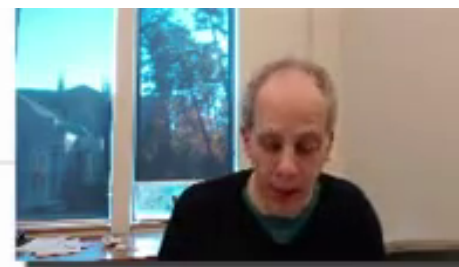$$= P_r(r) \left| \frac{1}{(L-1) P_r(r)} \right| = \frac{1}{L-1}$$

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

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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
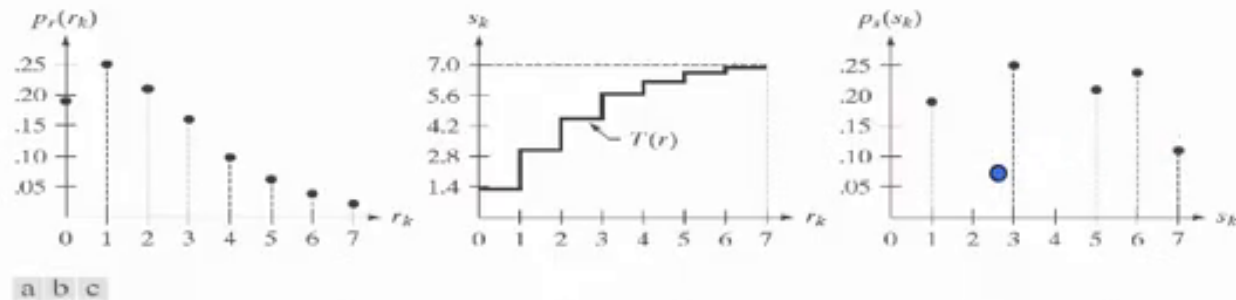Intensity distribution and histogram values for a 3-bit, 64×64 digital image.
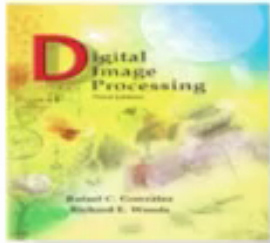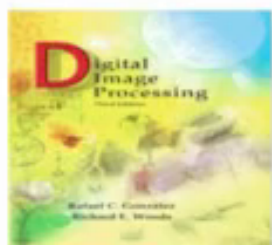
FIGURE 3.19 Illustration of histogram equalization of a 3-bit (8 intensity levels) image. (a) Original histogram. (b) Transformation function. (c) Equalized histogram.

$$\int_0^r p_r(\omega)\,d\omega$$

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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.
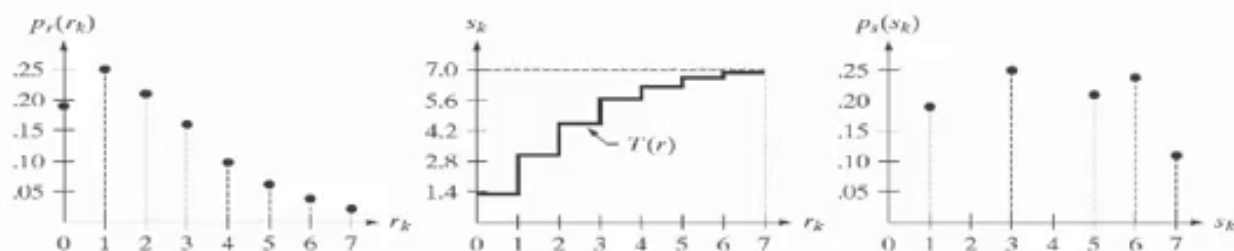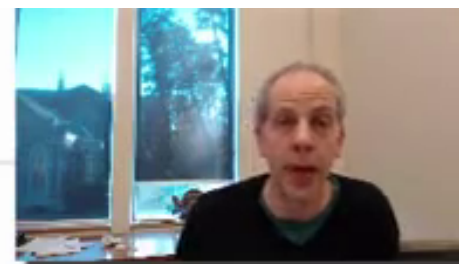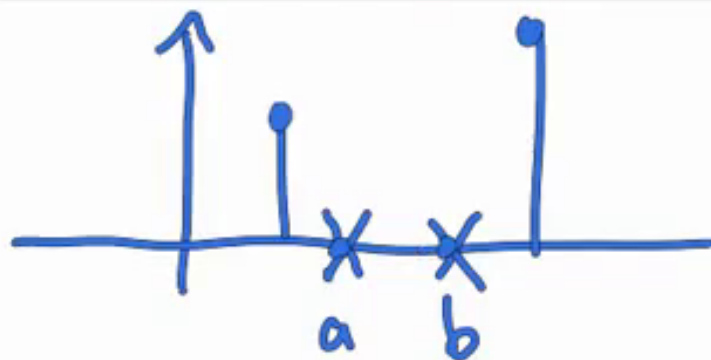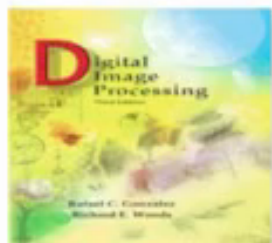
$$T(a) \overset{?}{\underset{\leq}{=}} T(b)$$

$$T(a) = T(b)$$

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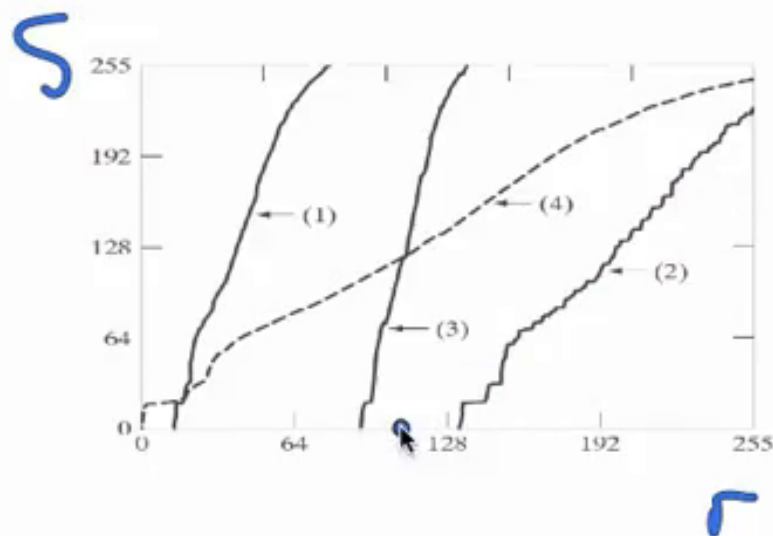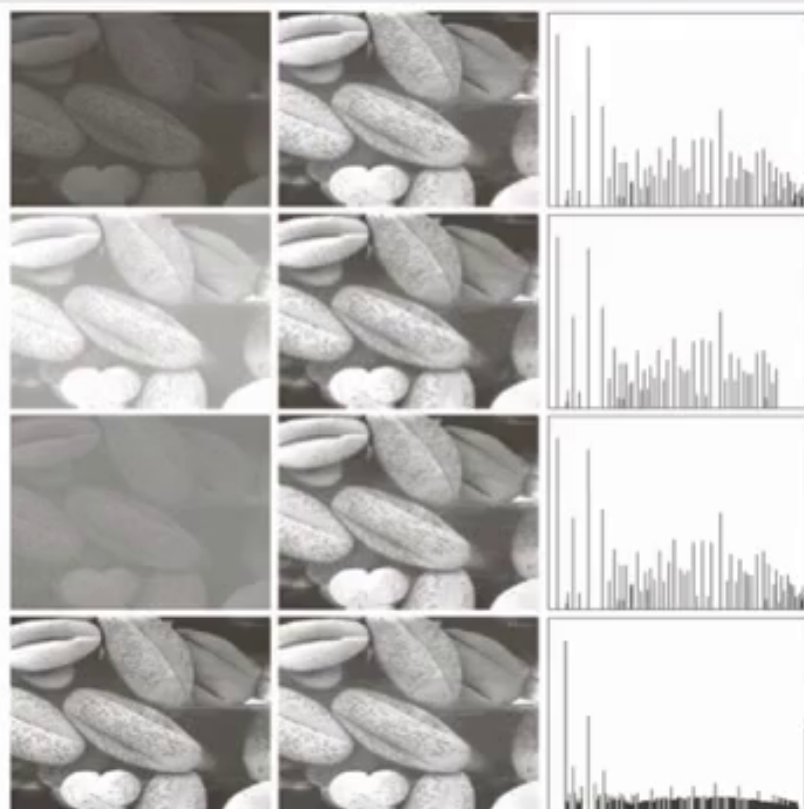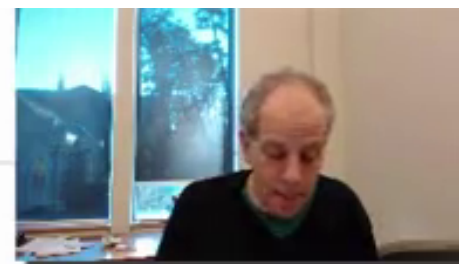## Intensity Transformations & Spatial Filtering

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.