
# Operations in color space

**Andrea Torsello**
**DAIS**
**Università Ca' Foscari**
**via Torino 155,**
**30172 Mestre (VE)**


I(x,y) Image

We are looking at transformations f that discard spatial inforamtion

I->f(I)  f(I)(x,y)=f(I(x,y))

f uses color information only and maps colors to colors independently of the spatial context

# Tresholding

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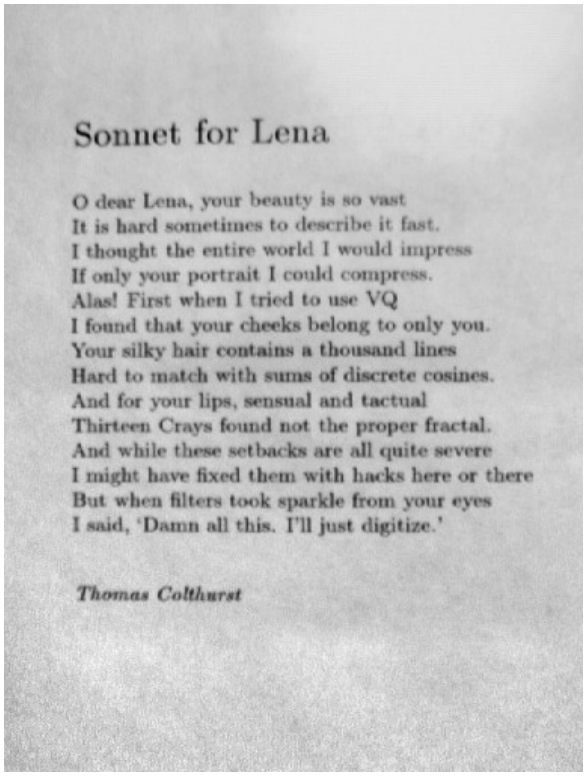
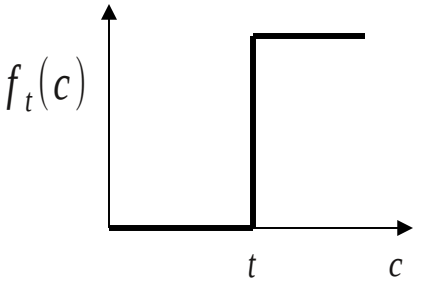
$$f_t(c) = \begin{cases} 0 & \text{se } c < t \\ 1 & \text{altrimenti} \end{cases}$$

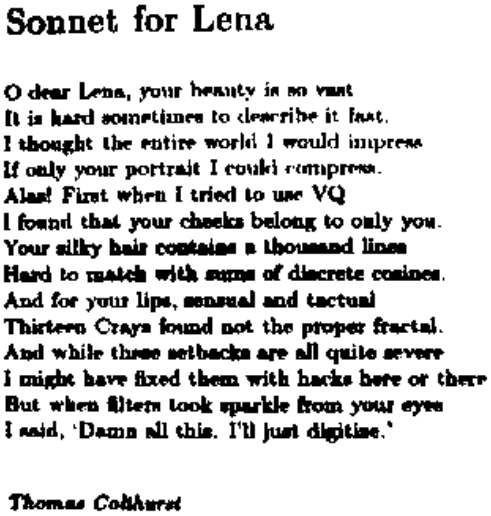


Sonnet for Lena

O dear Lena, your beauty is so vast
It is hard sometimes to describe it fast.
I thought the entire world I would impress
If only your portrait I could compress.
Alas! First when I tried to use VQ
I found that your cheeks belong to only you.
Your silky hair contains a thousand lines
Hard to match with sums of discrete cosines.
And for your lips, sensual and tactual
Thirteen Crays found not the proper fractal.
And while these setbacks are all quite severe
I might have fixed them with hacks here or there
But when filters took sparkle from your eyes
I said, 'Damn all this. I'll just digitize.'

*Thomas Colthurst*



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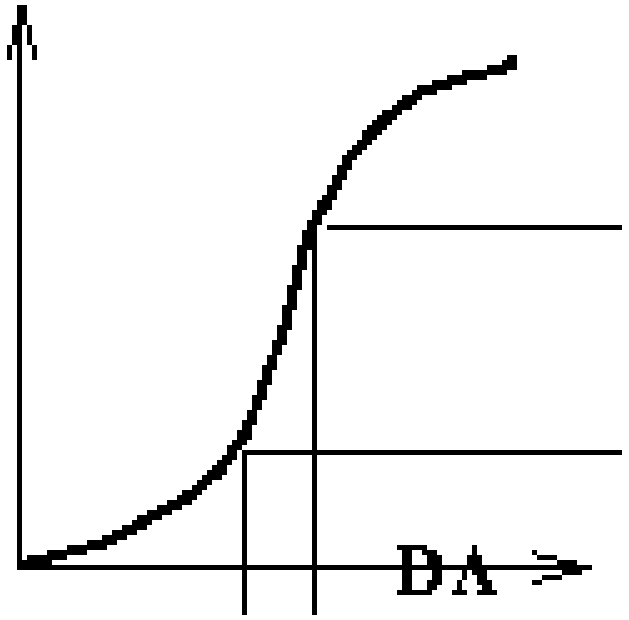
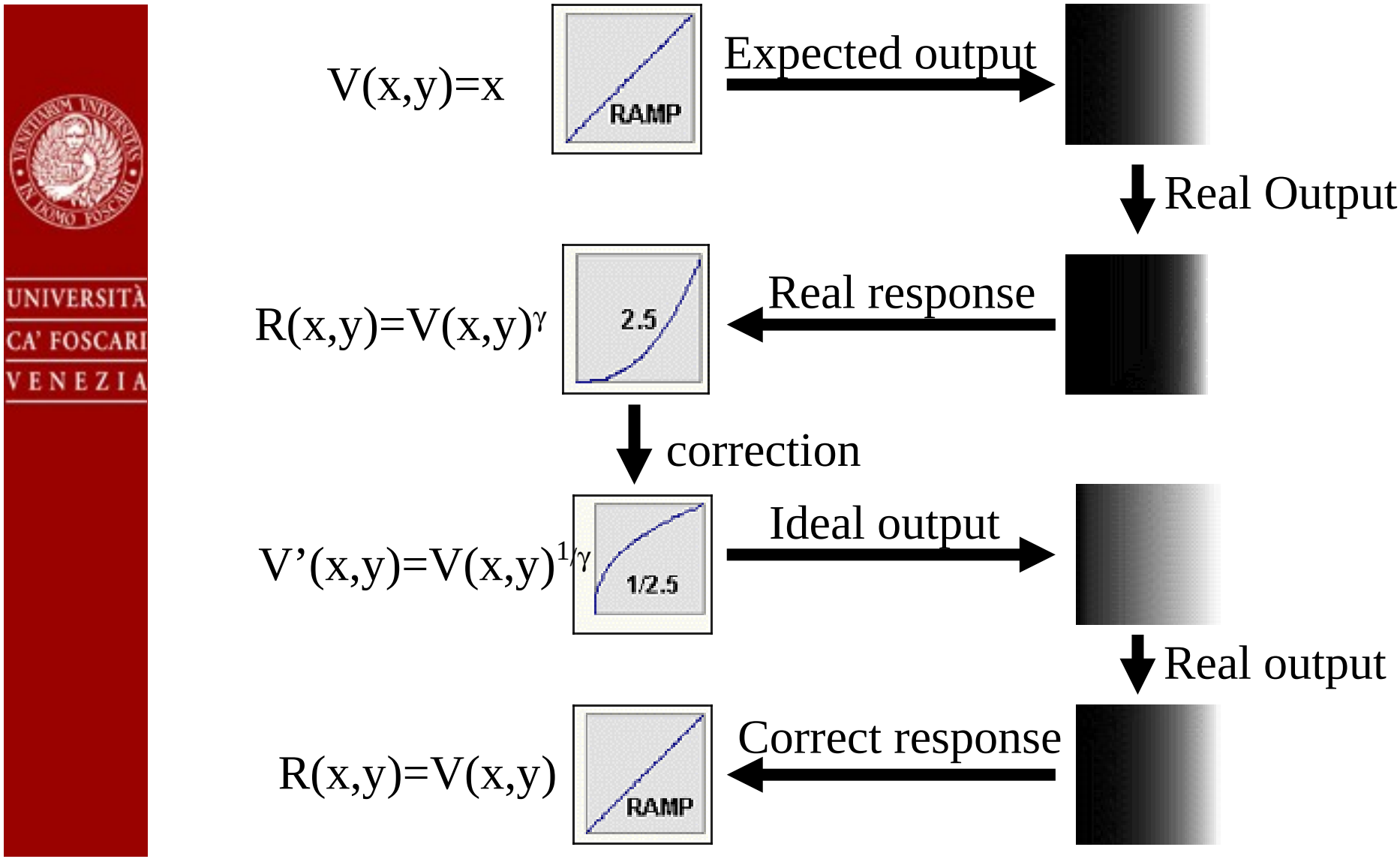
# What happens in general?


## f alters the color distribution

- Where f’ is large close colors are mapped to distant colors
- Where f' is small dissimilar colors are mapped to similar ones



# Gamma correction



# Power and exp transformations

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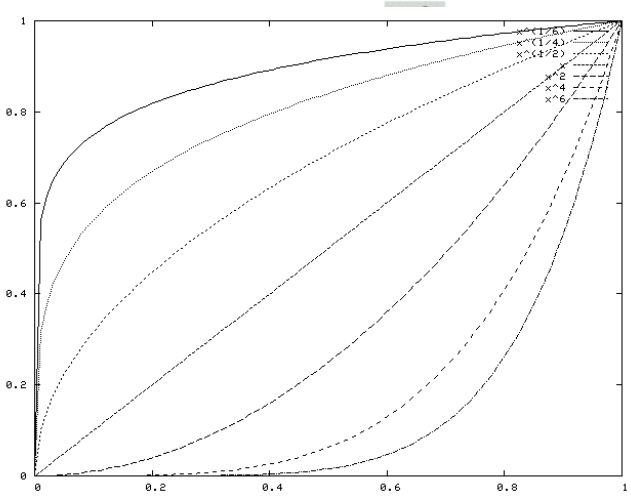


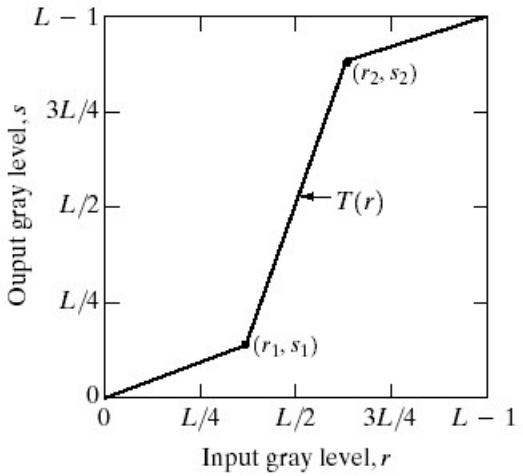

$\gamma$=1, 3, 4, 5

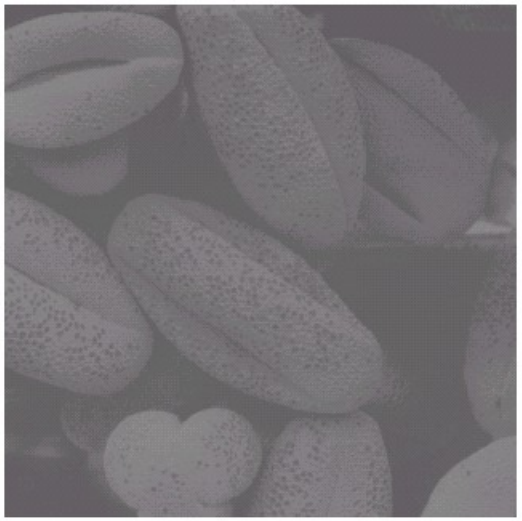
$f(c) = c^{\gamma}$

$f(c) = \alpha^{c}$

# Contrast Enhancement





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.)

# Histogram


- Without spatial information we can assimilate the image to a random color emitter (random variable)

Let X be a uniform random variable in $R^2$

I(X) is a random variable in the space of colors

The color histogrm is the empirical distribution of colors

- for each color it records how many times it is present in the image

# Histogram

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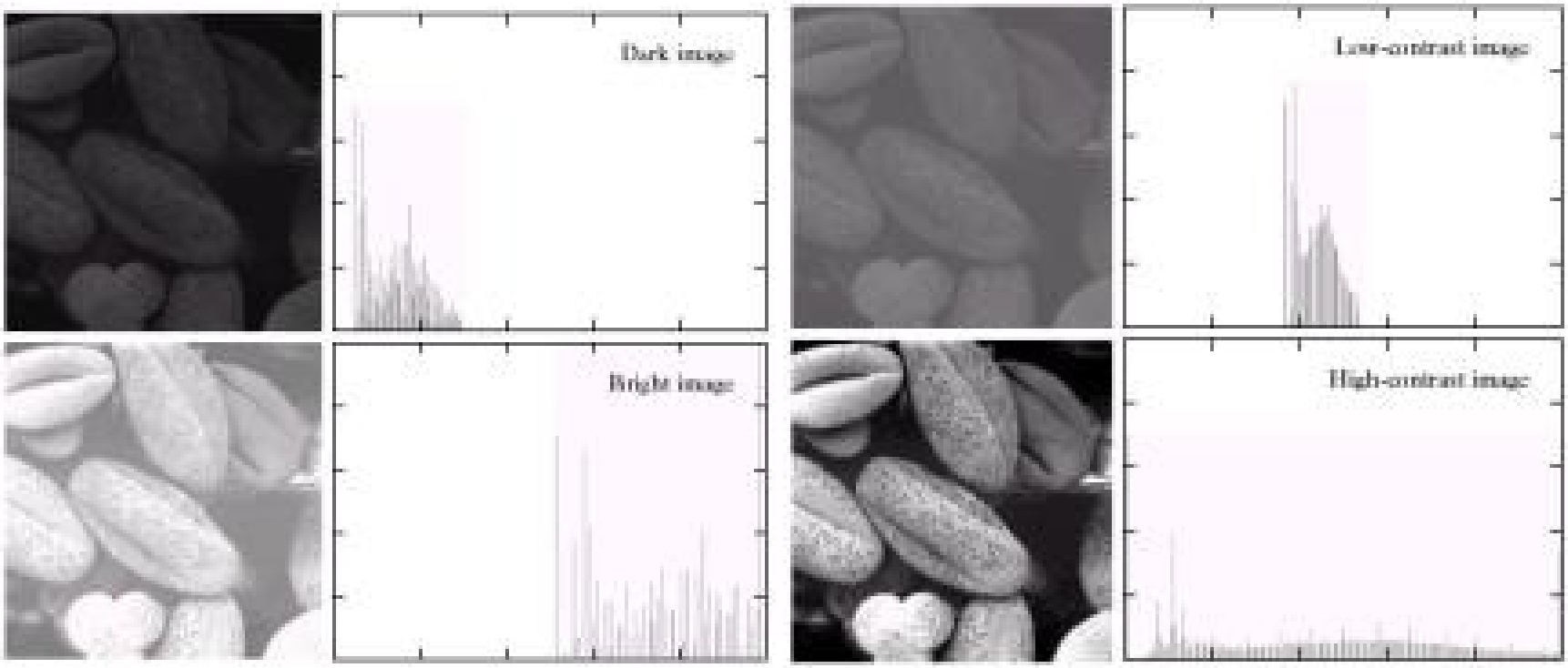
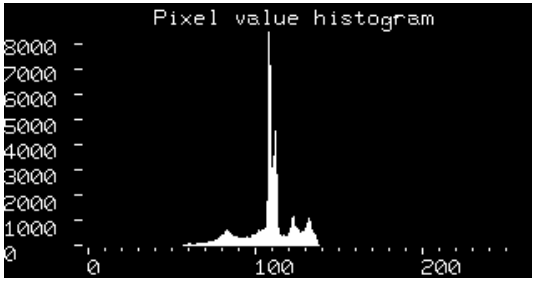
- The histograms allows us to analyze problems in the color distribution of an image

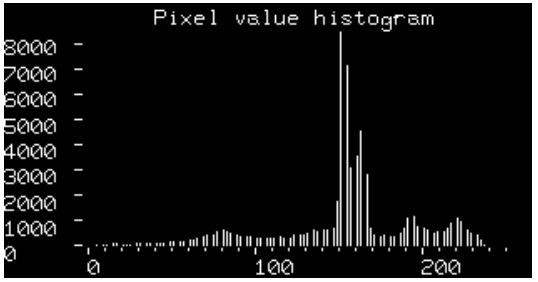


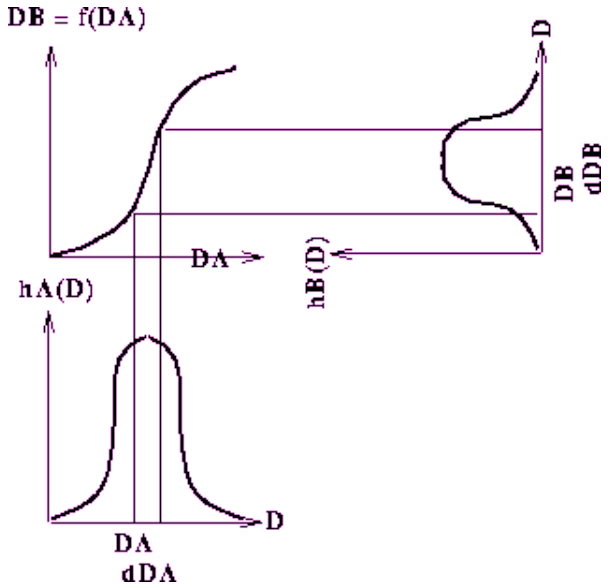
# Effects of a color-space operation


f transforms the I(X) into the new variabile f(I(X))

The histogram is transformed accordingly (following the rules of random valriable transformations)

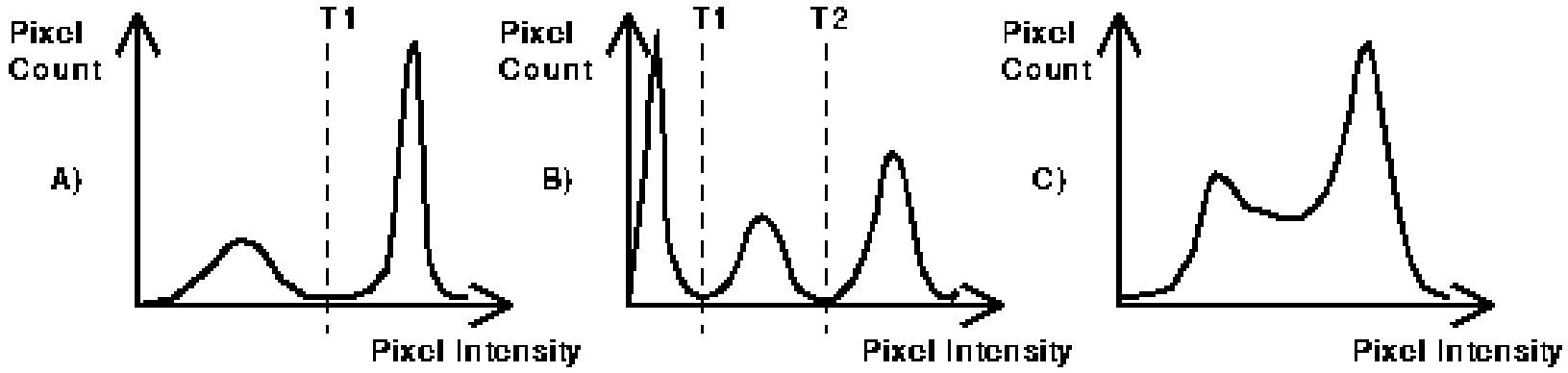


# Thresholding 2


- If an image is separable through thresholding there will be a range of colors with 0 (low) probability



# Contrast Enhancement

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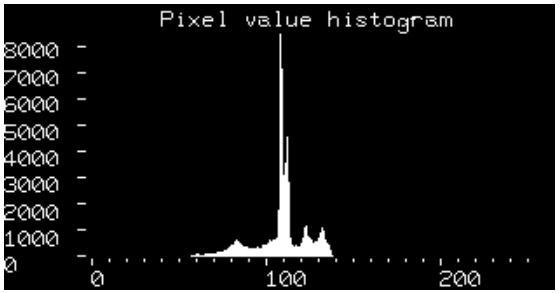
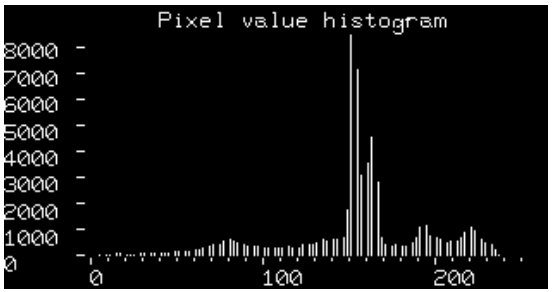
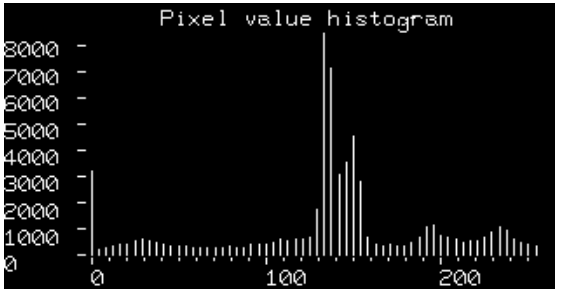
- Contrast enhancement requires human intervention for teh choice of the parameters
  - **Where does the histogram begin?**
  - **Where does it end?**
- It does not redistribute the tones (peaks still present)



# Equalization


- An automated tool is needed
- Make the color distribution as close as possible to a uniform distribution
  - **Reduce peaks and valleys in the distribution**

- F(c) cumulative distribution function (cdf) of I(X)
- What is the cdf of F(I(X))?

$$P\{F(I(X))<t\}=P\{I(X)<F^{-1}(t)\}=F(F^{-1}(t))=t$$

- F(I(X)) is a uniform cdf!
- When using the empirical cdf, F(I(X)) will only be approximately uniform

# Equalization


- Empirical cumulative distribution function

$$s(k) = \sum_{j=0}^{k} p(c_j)$$

- Equalization

$$c_i \leftarrow c_{\max} s\left(\frac{c_i}{c_{\max}}\right)$$

# Equalization

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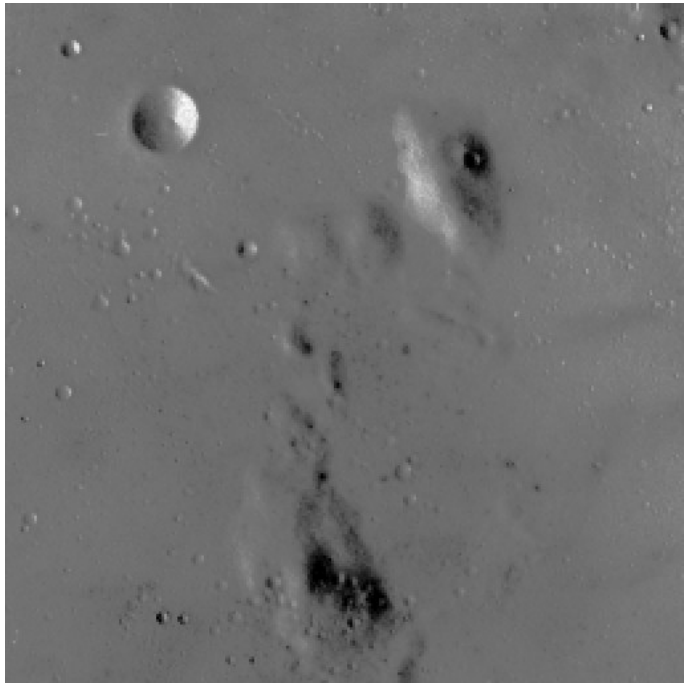

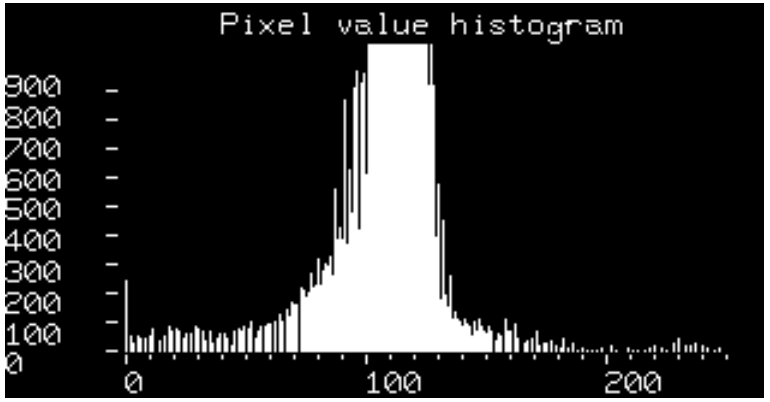


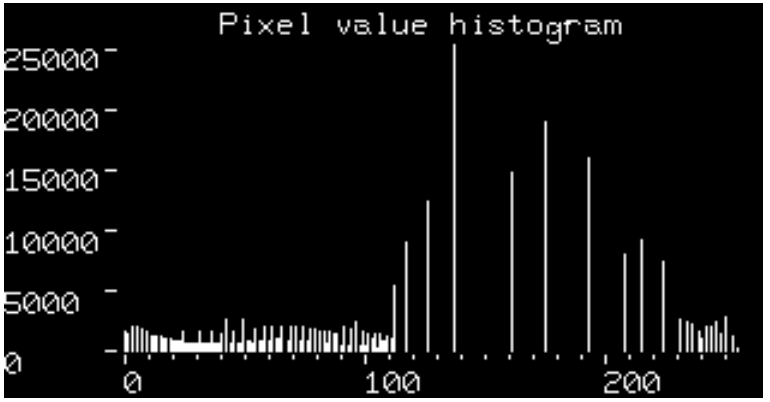

# Equalization VS Contrast Enhancement

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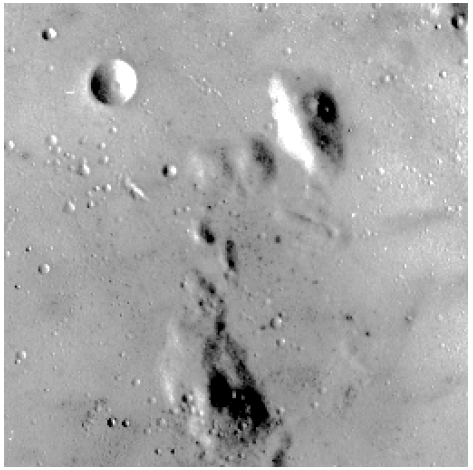
- Is uniform distribution really what we want?



# Limits of equalization

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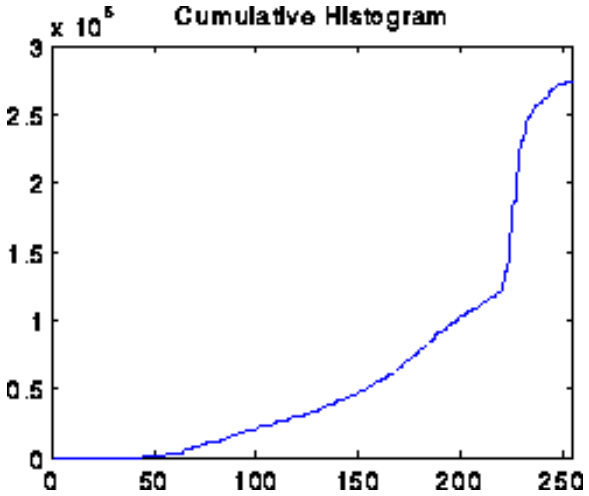


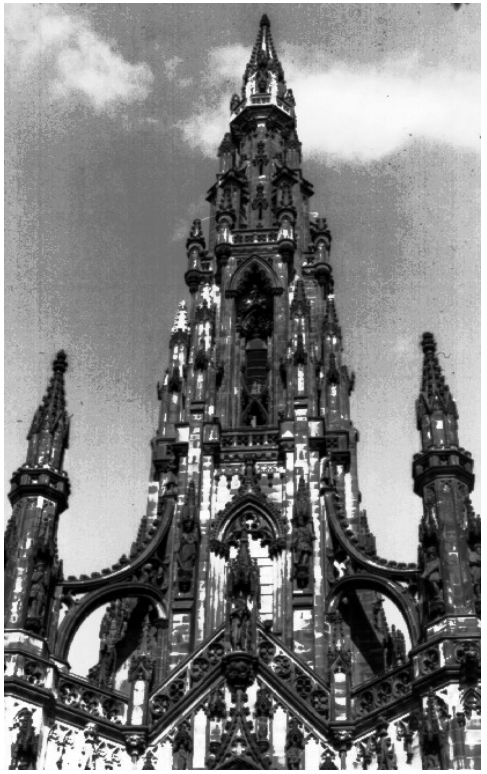

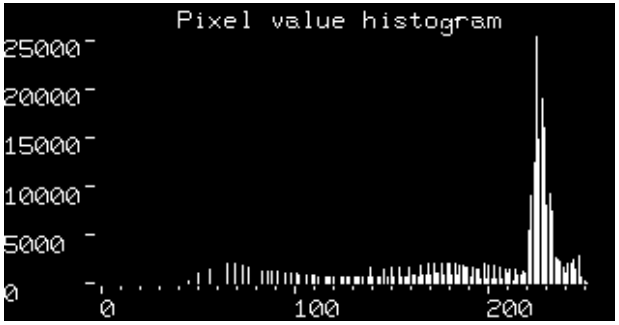

# Center metering

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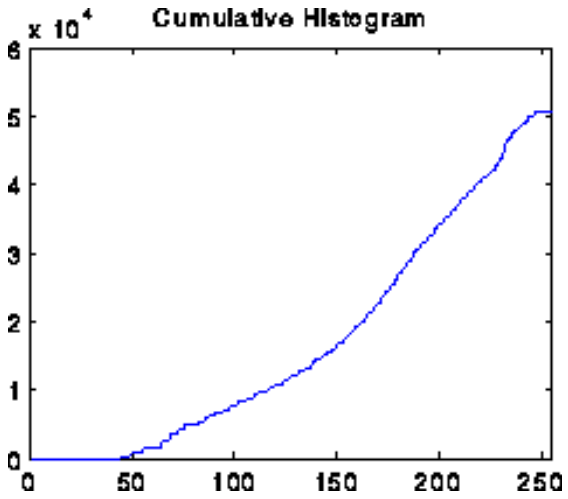
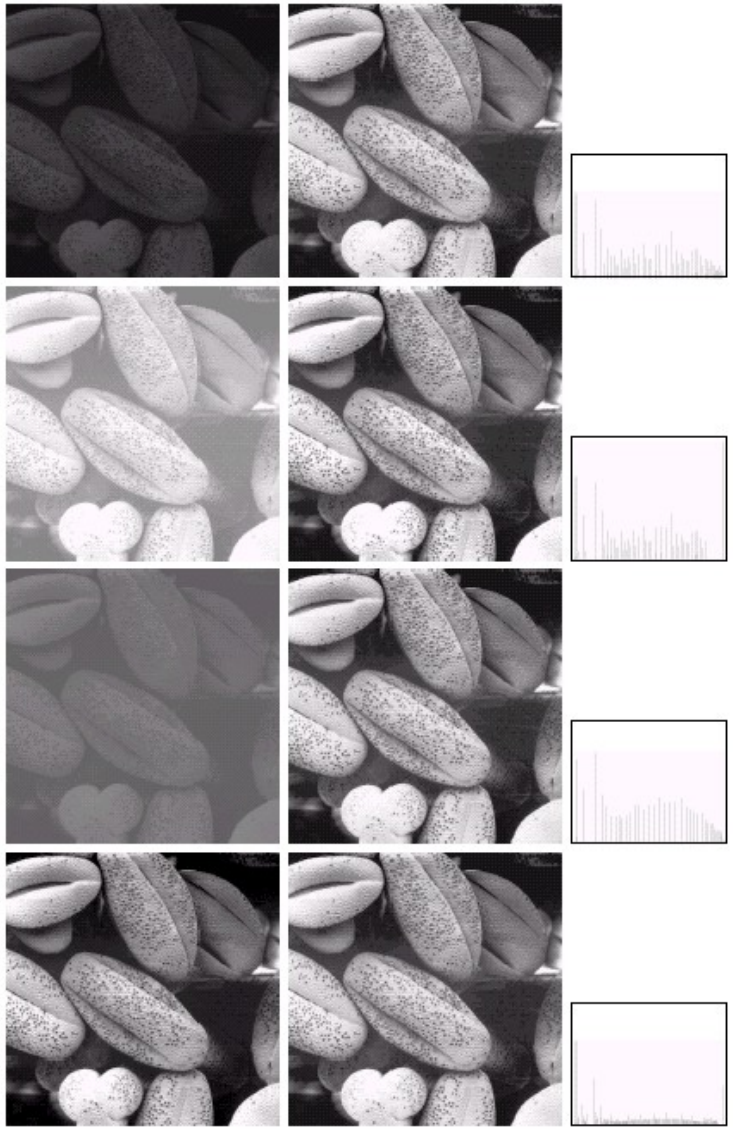
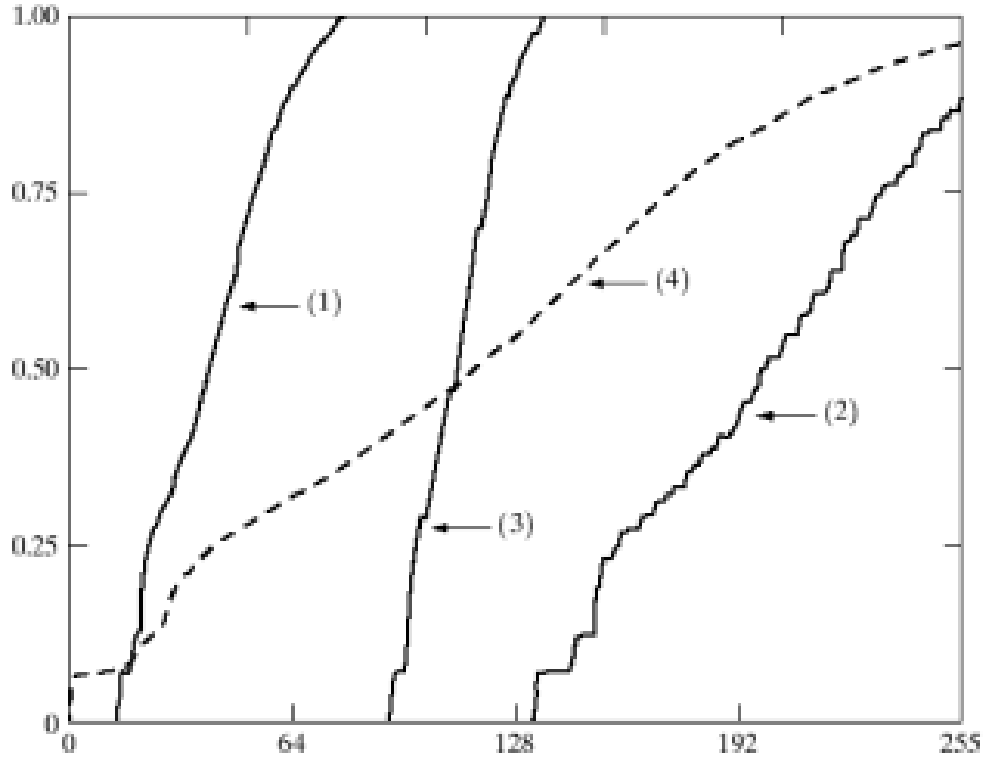



# Histogram matching

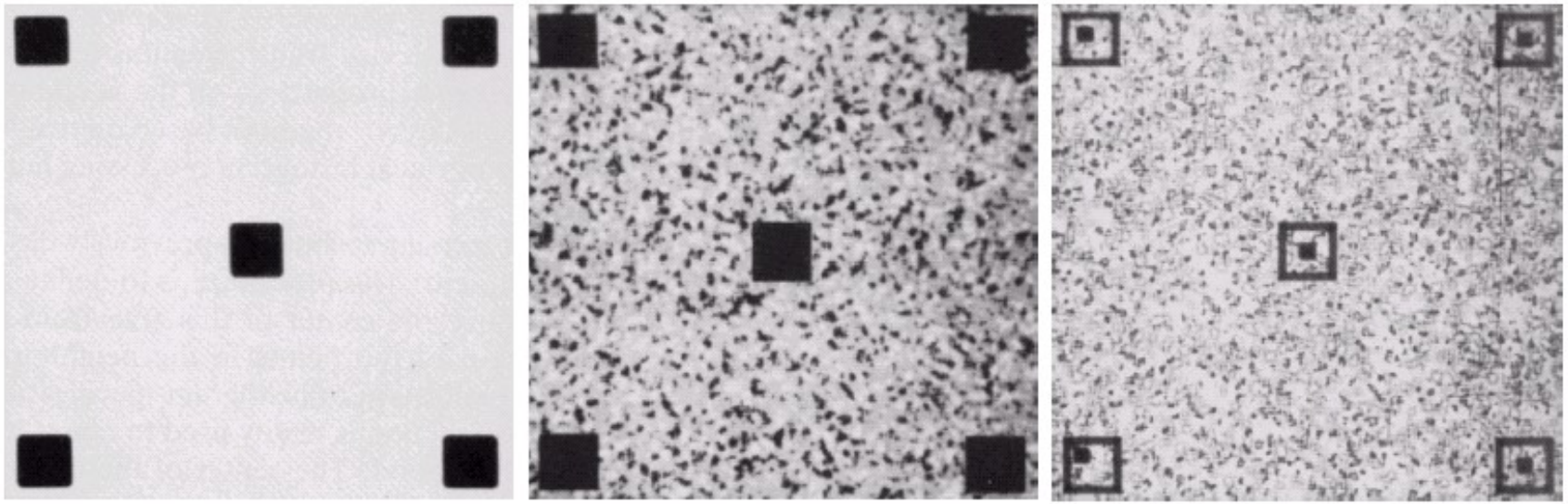

- Let I and  be two images with cdfs F and Q.
- F(I) = uniform distribution = Q(J)
- $Q^{-1}(F(I))$ has the same histogram of J.

# Histogram matching





# Local equalization



a b c

**FIGURE 3.23** (a) Original image. (b) Result of global histogram equalization. (c) Result of local histogram equalization using a $7 \times 7$ neighborhood about each pixel.

# Local transformations

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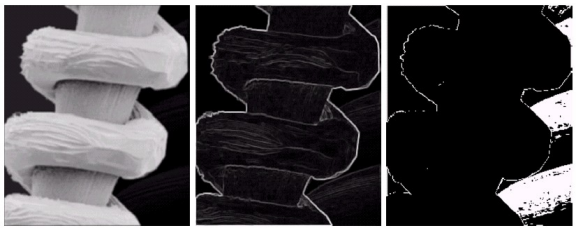
$$m_{xy} = \sum_{s,t \in S_{xy}} c_{s,t}\, p(c_{s,t}) \qquad \sigma^2_{xy} = \sum_{s,t \in S_{xy}} (c_{s,t} - m_{xy})^2\, p(c_{s,t})$$

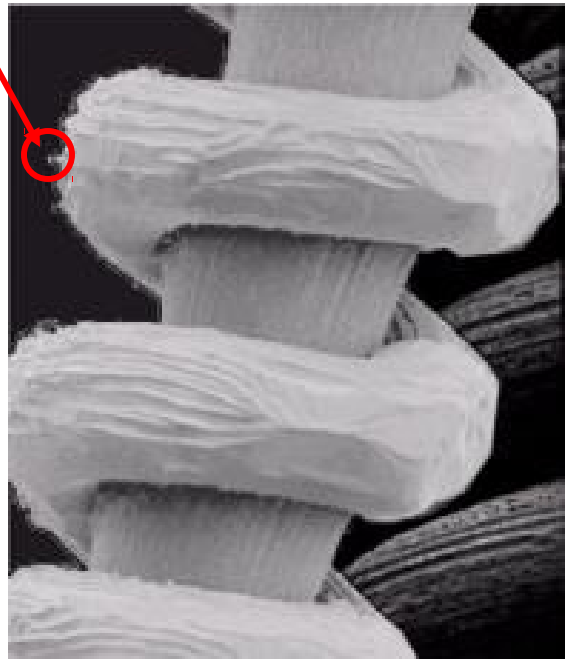
$$f(I(x,y)) = \begin{cases} E \cdot I(x,y) & \text{if } m_{xy} \le k_0 M \text{ and } k_1 D \le \sigma_{xy} \le k_2 D \\ I(x,y) & \text{otherwise} \end{cases}$$



a b c

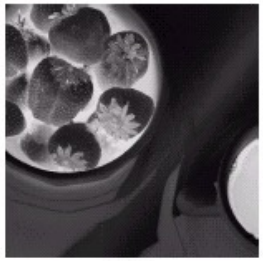
**FIGURE 3.25** (a) Image formed from all local means obtained from Fig. 3.24 using Eq. (3.3-21). (b) Image formed from all local standard deviations obtained from Fig. 3.24 using Eq. (3.3-22). (c) Image formed from all multiplication constants used to produce the enhanced image shown in Fig. 3.26.

**Artifacts!**

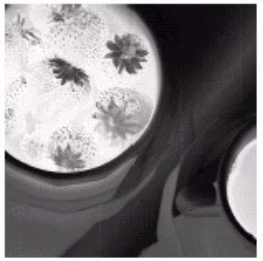


# Channel scomposition

Full color

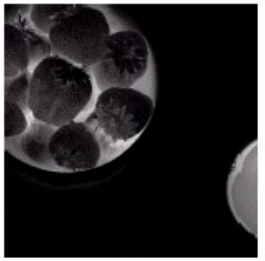


Cyan



Magenta

Yellow

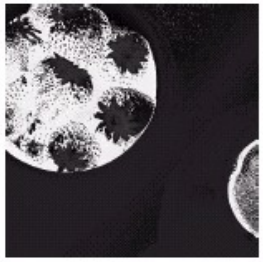


Black

Red

Green

Blue



Hue

Saturation

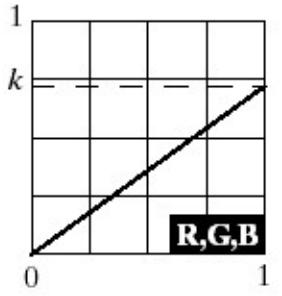
Intensity

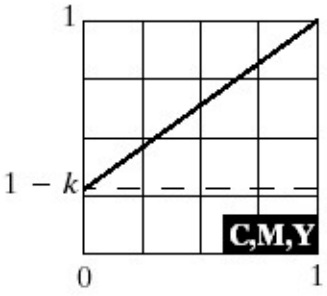
# Per-channel operation

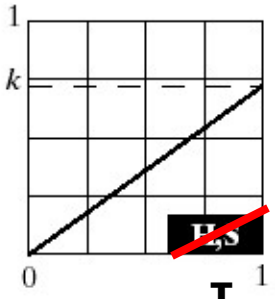


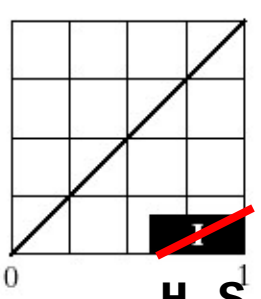
a b
c d e

**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.)

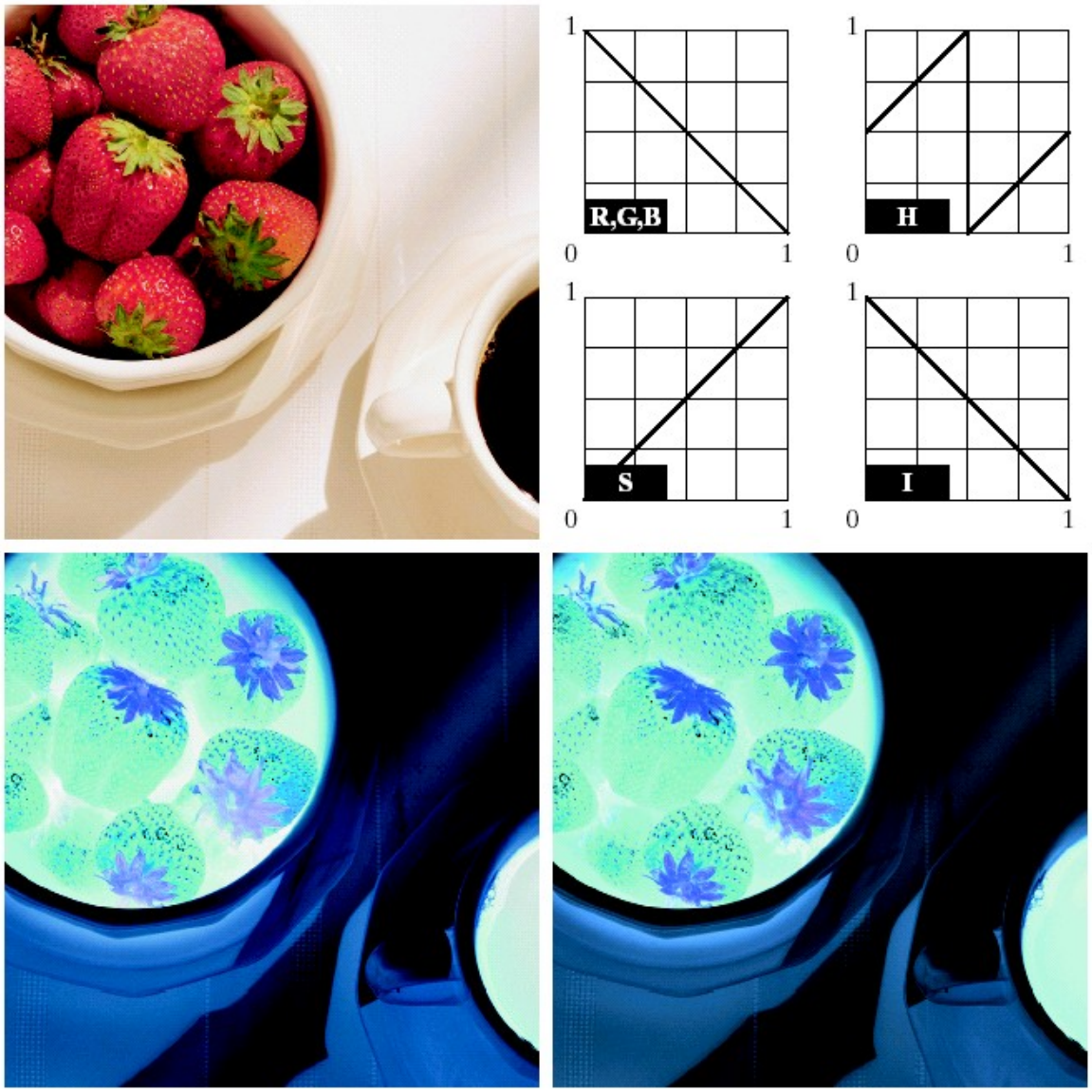


# Per-channel operation



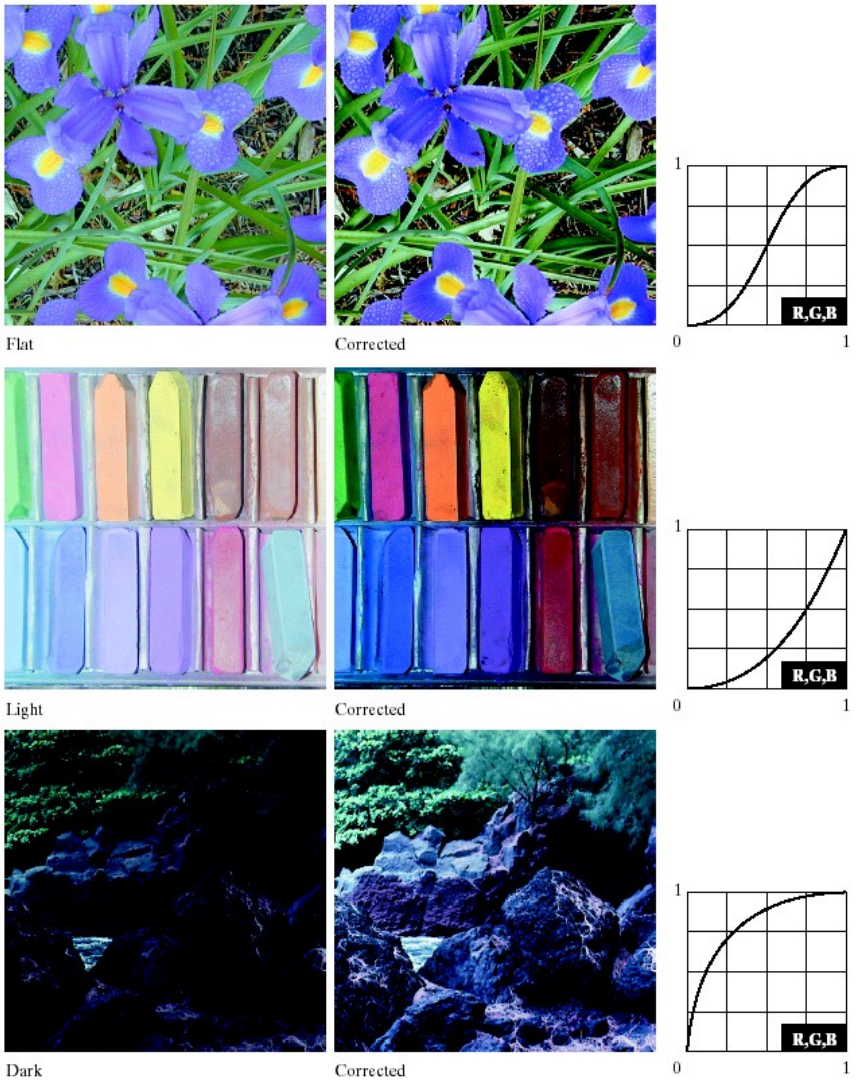

a b
c d

**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.

# Luminosity / Contrast



Acting equally on all the RGB componentsyou will not have tonal changes, but only changes in luminosity and/or contrast



# Tonal correction


Acting separately on the different channes (CYMK in the example) you can correct global chromatic deviations (white balance)

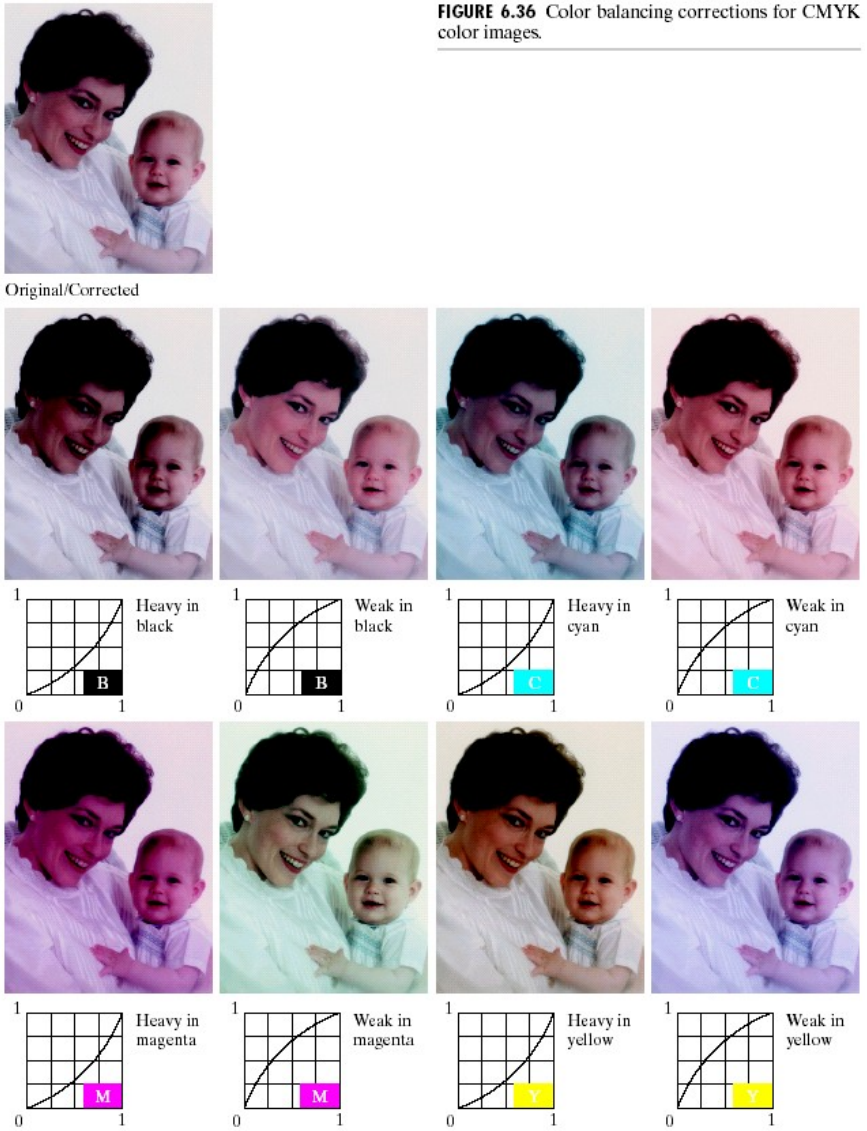
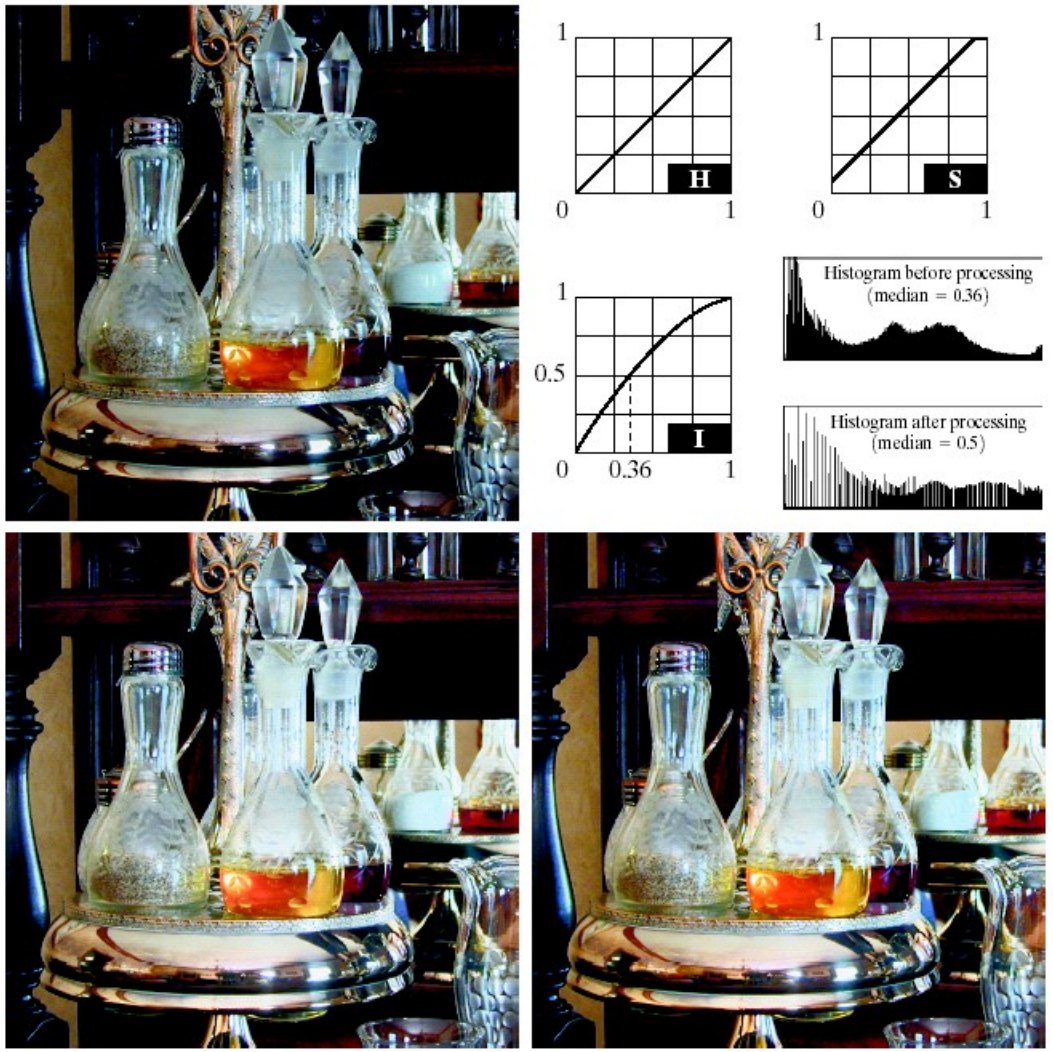



**FIGURE 6.36** Color balancing corrections for CMYK color images.

# Perceived Saturation


Intensity equalization alters the perception of saturation

Increasing the saturation restores the original perceptual quality




a b
c d

**FIGUR**
Histo
equal
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