Colour Balancing and Mapping

Rene Magritte, “The Empire of Lights”

CSC320: Introduction to Visual Computing

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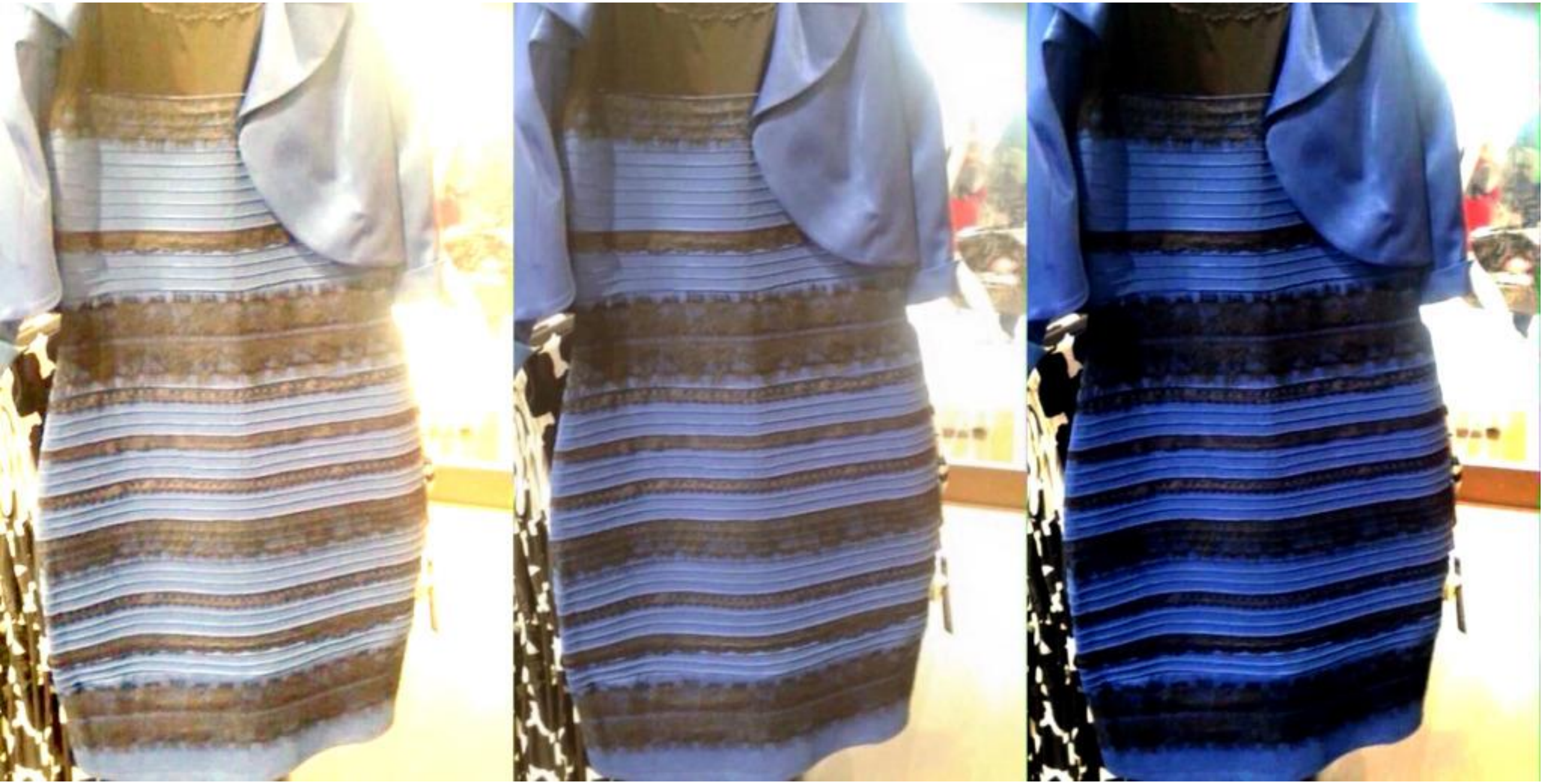
Slides from Derek Hoiem, Robert Collins

Colour balancing

- Make objects have the colour in the photo that they have in the world (with neutral illumination)

Photos: http://www.kenrockwell.com/tech/whitebalance.htm



The original is in the middle. At left, white-balanced as if the dress is white-gold. At right, white-balanced to blue-black

•www.wired.com/2015/02/science-one-agrees-color-**dress**/

Important ideas

- Typical images are gray on average; this can be used to detect distortions
- Larger differences are more visible, so using the full intensity range improves visibility
- It's often easier to work in a non-RGB color space

Colour balancing via linear adjustment

- Simple idea: multiply R, G, and B values by separate constants

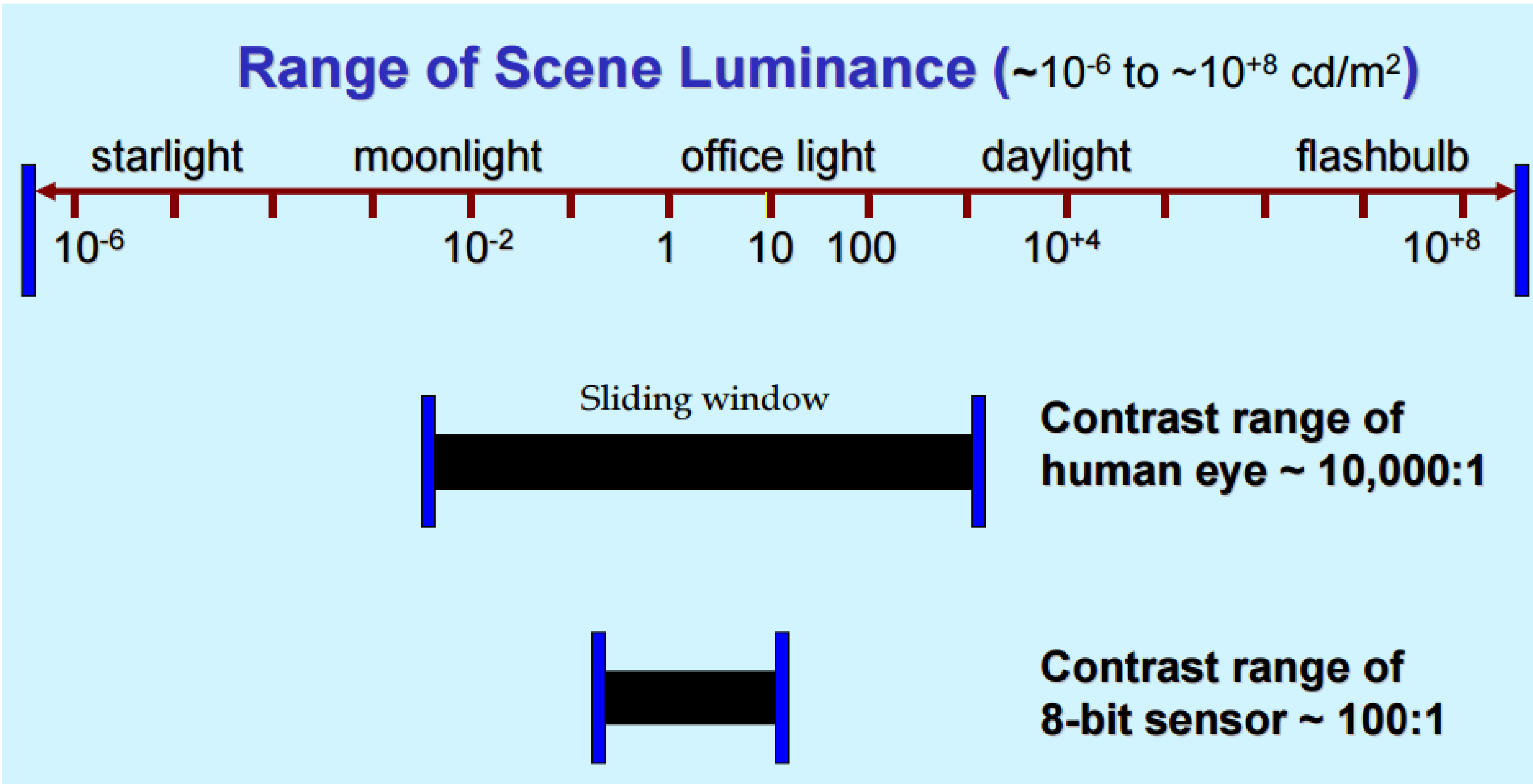
$$\begin{bmatrix} \tilde{r} \\ \tilde{g} \\ \tilde{b} \end{bmatrix} = \begin{bmatrix} \alpha_r & 0 & 0 \\ 0 & \alpha_g & 0 \\ 0 & 0 & \alpha_b \end{bmatrix} \begin{bmatrix} r \\ g \\ b \end{bmatrix}$$

- How to choose the constants?
  - "Gray world" assumption: average value should be gray
  - White balancing: choose a reference as the white or gray color
  - Better to balance in camera's RGB (linear) than display RGB (non-linear)

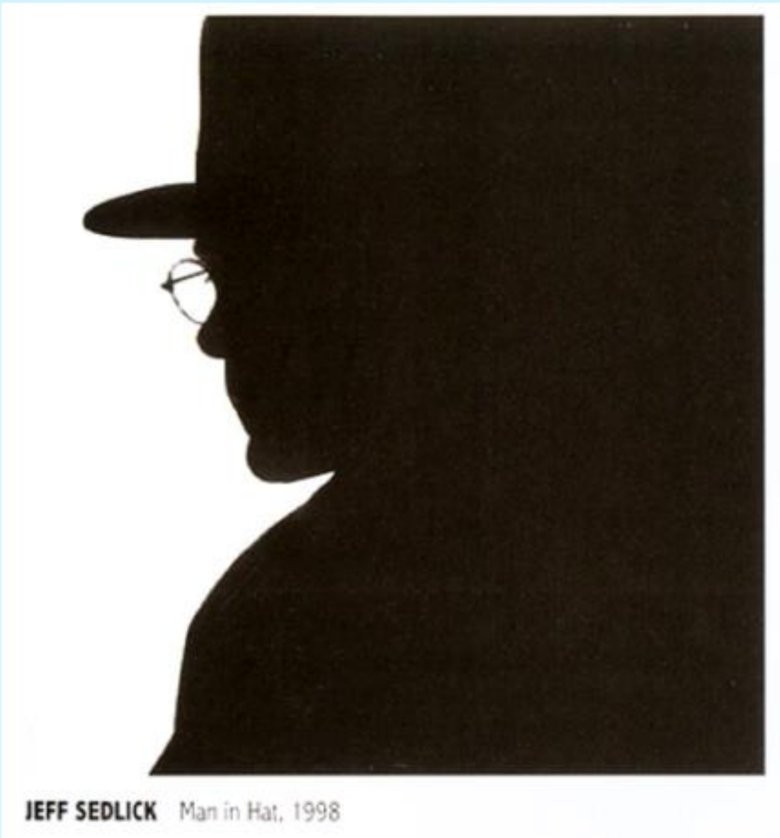
Tone Mapping

- Typical problem: compress values from a high range to a smaller range
  - E.g., camera captures 12-bit linear intensity and needs to compress to 8 bits

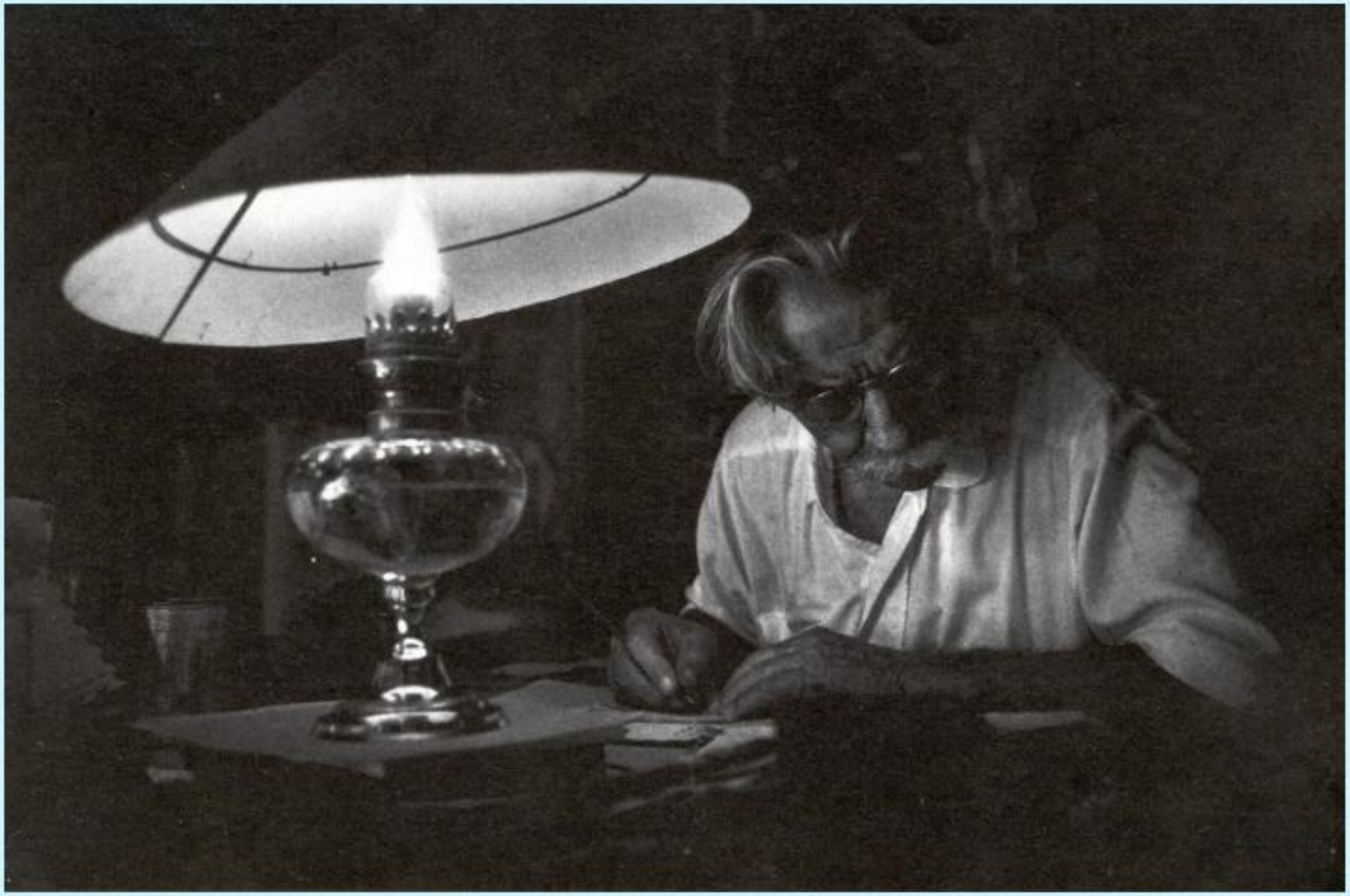
Limited Dynamic Range



Limited Dynamic Range Can be Good

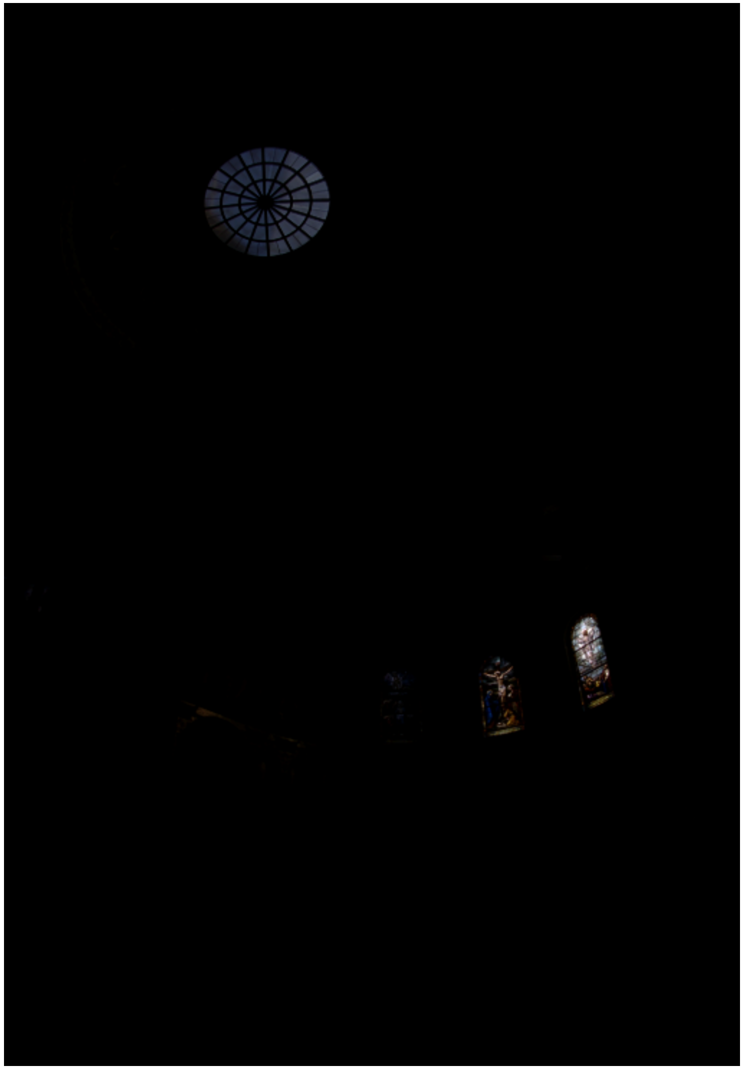


Artistic Use of Low Dynamic Range

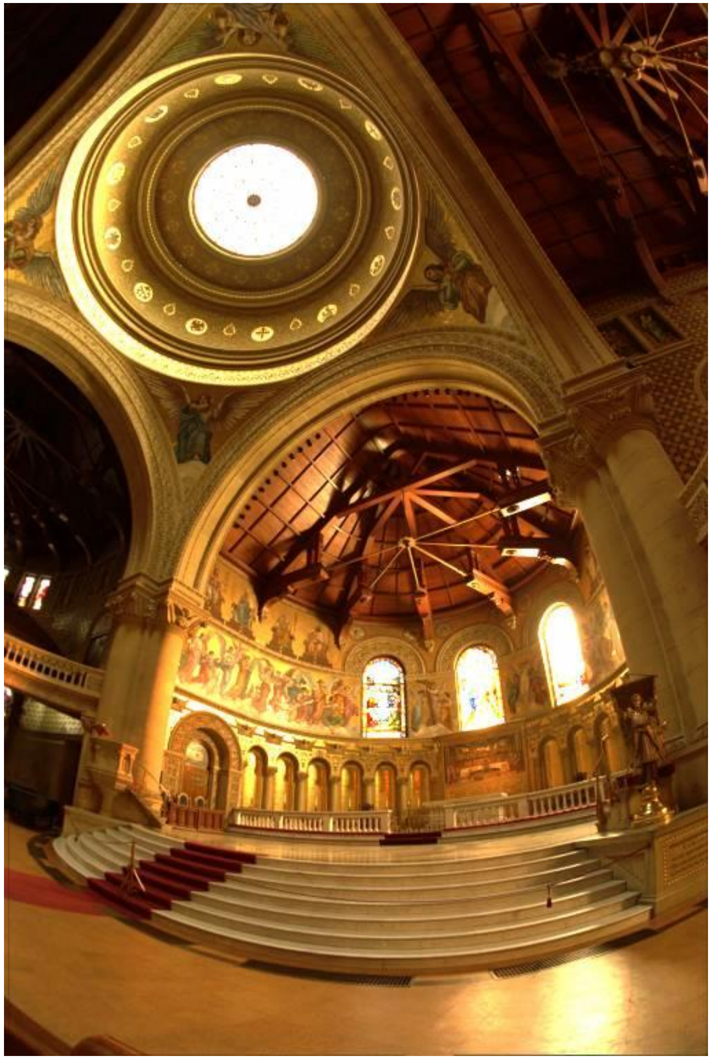


W. Eugene Smith photo of Albert Schweitzer

Example: Linear display of HDR (high dynamic range)

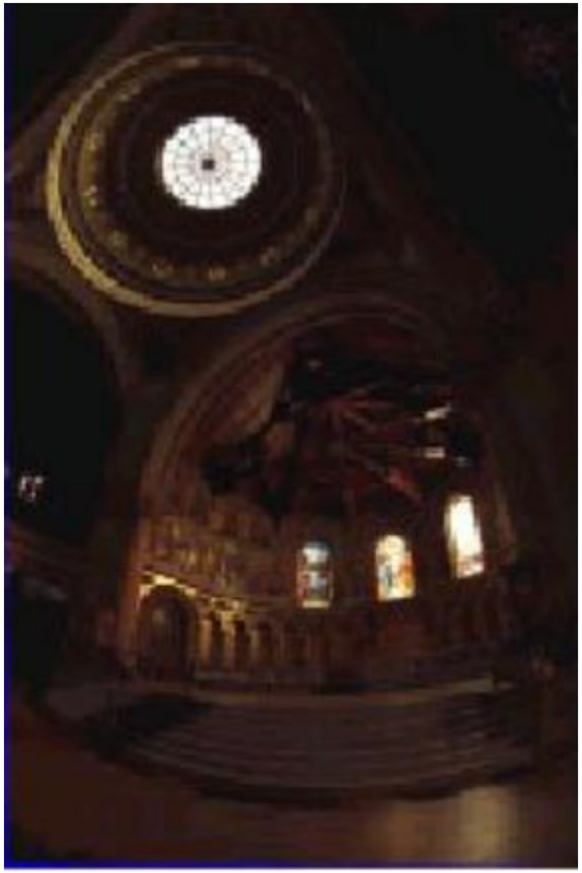


Scaled for brightest pixels

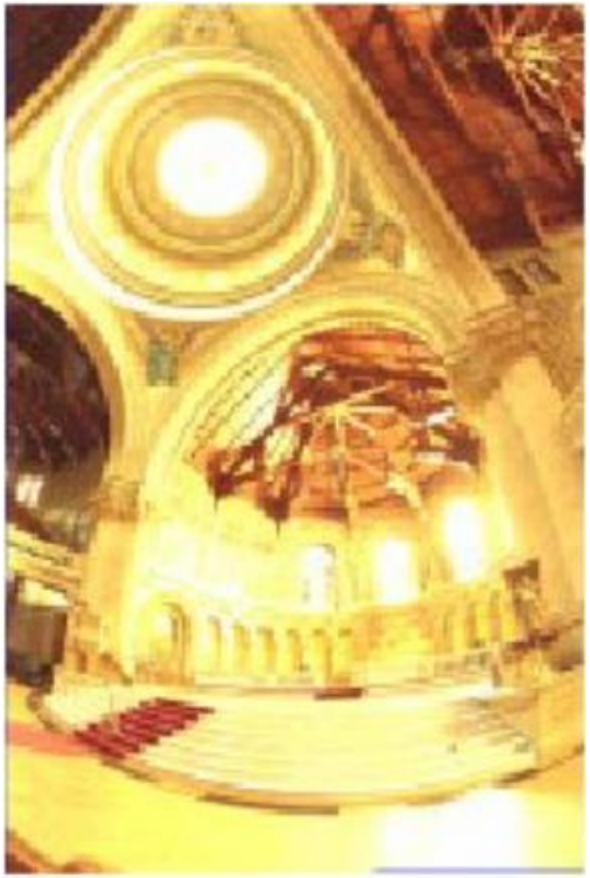


Scaled for darkest 0.1% intensities

Less “Strawmannish” Version



Underexposed (shutter too fast)

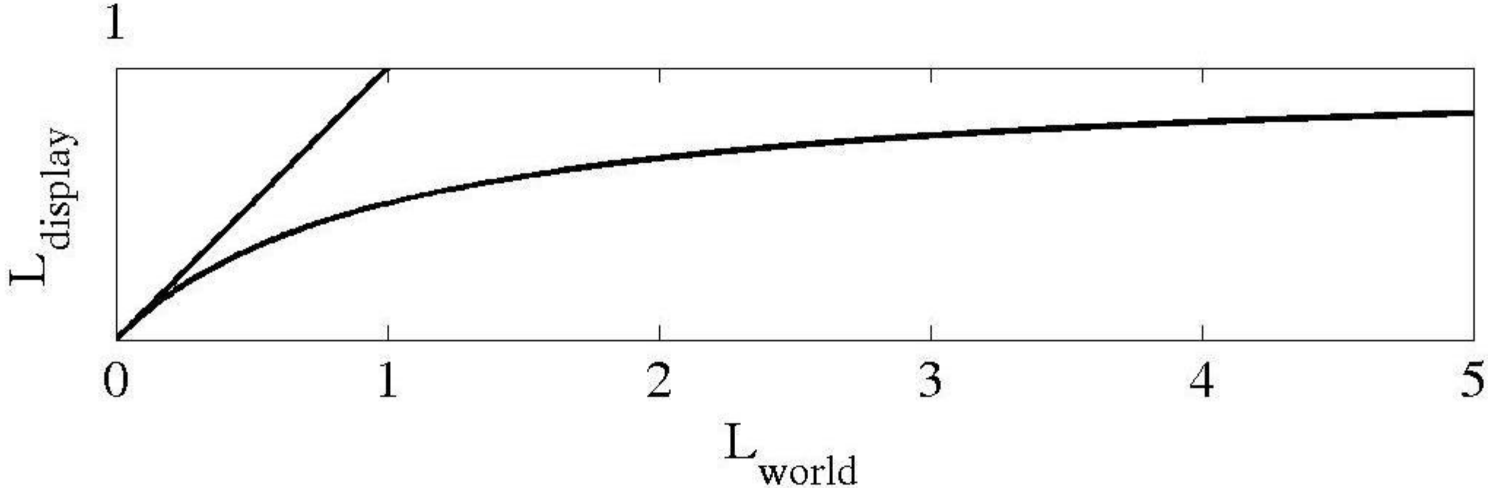


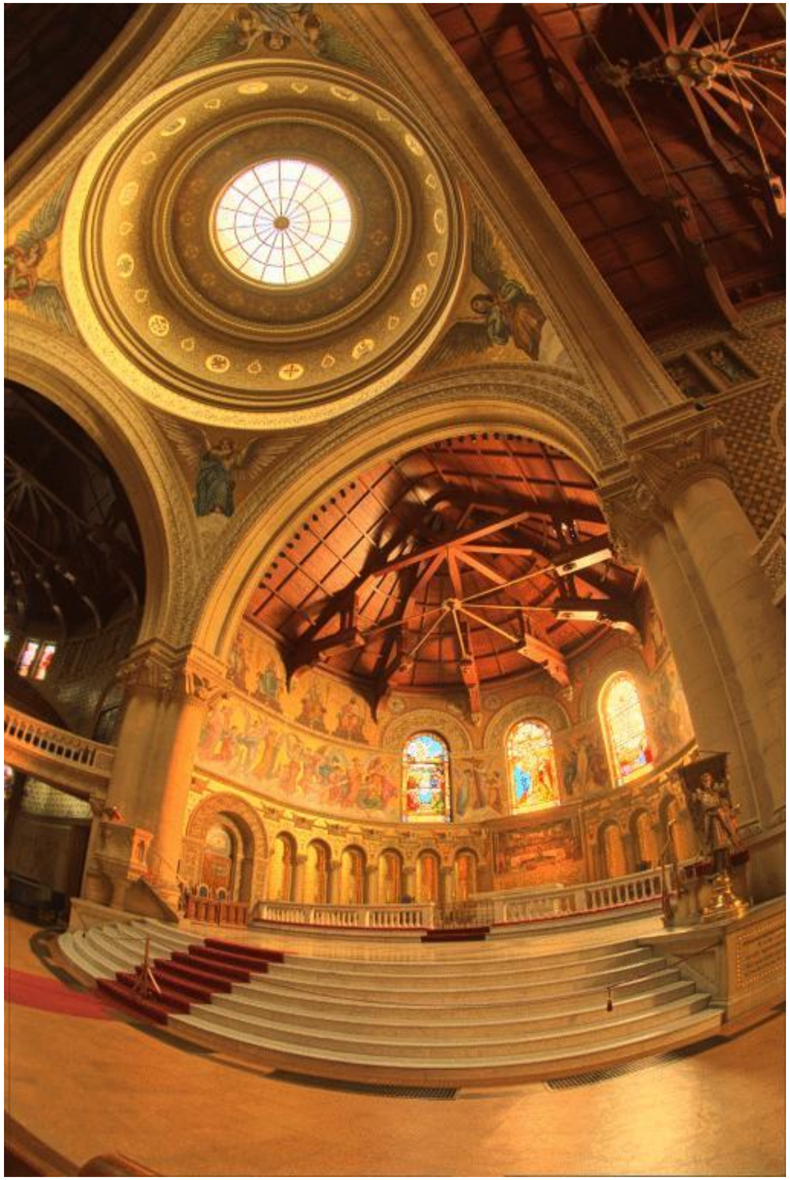
Oversaturated (shutter too slow)

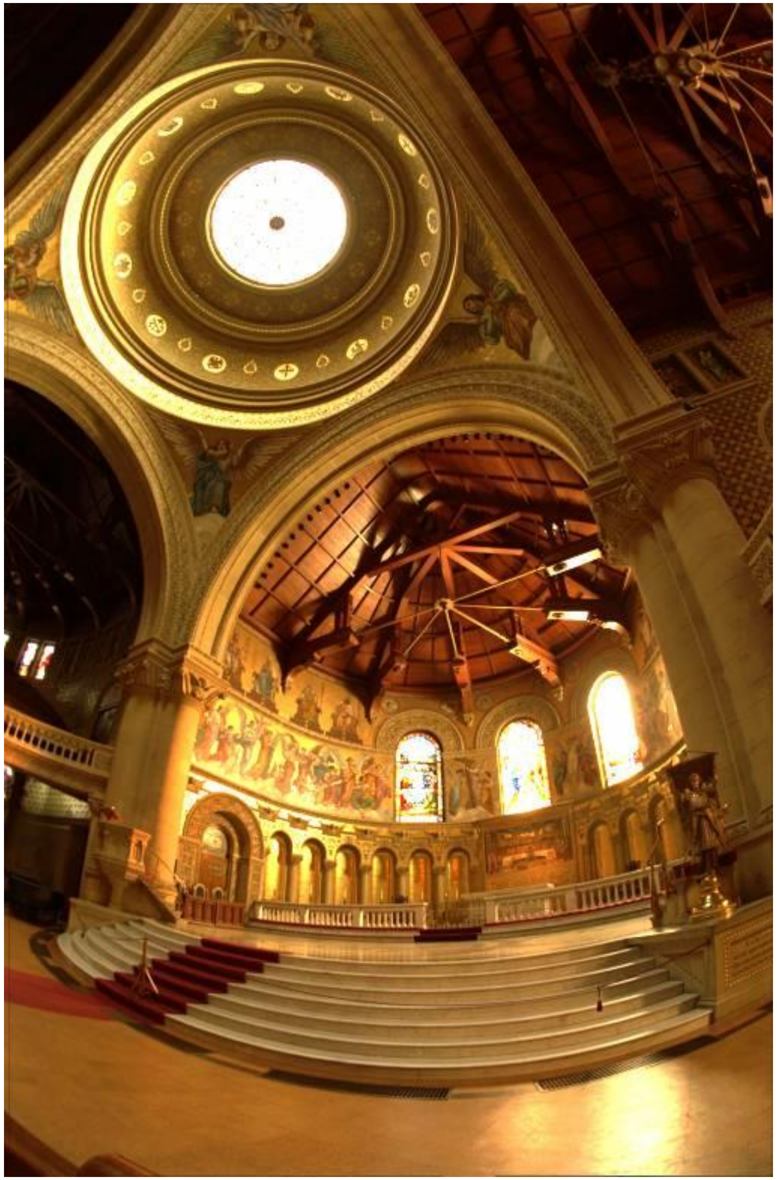
Global operator (Reinhard et al.)

- Simple solution: map to a non-linear range of values

$$L_{display} = \frac{L_{world}}{1 + L_{world}}$$







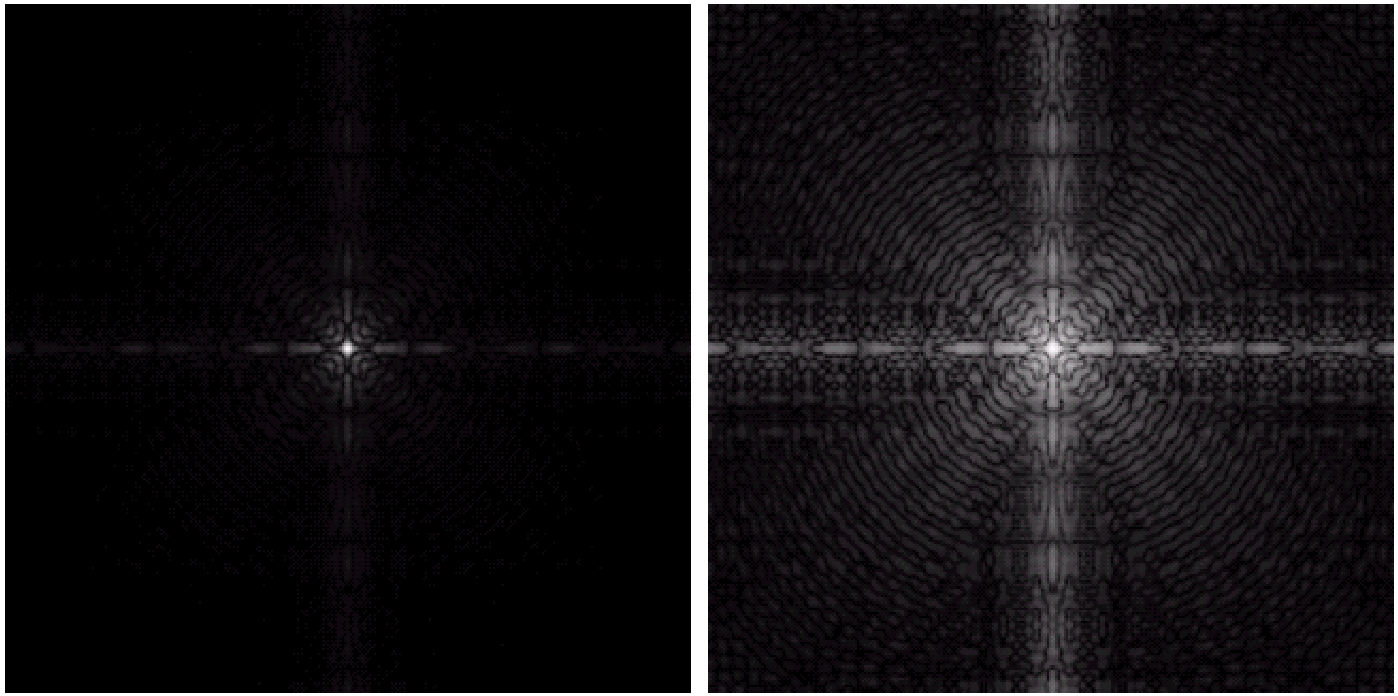
Reinhart Operator

Darkest 0.1% scaled to display device

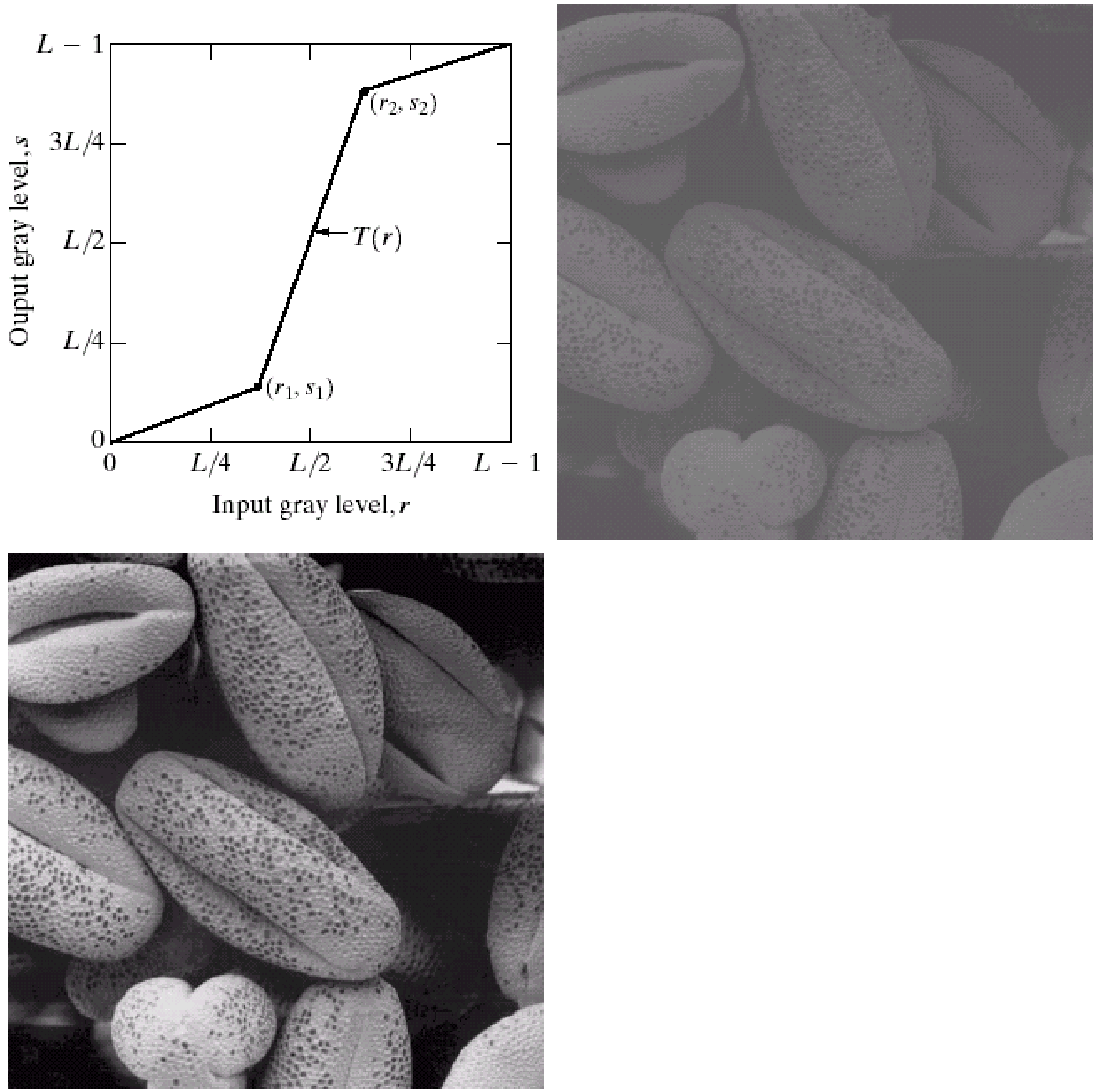
Log transformations help with displaying Fourier Transforms

a b

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



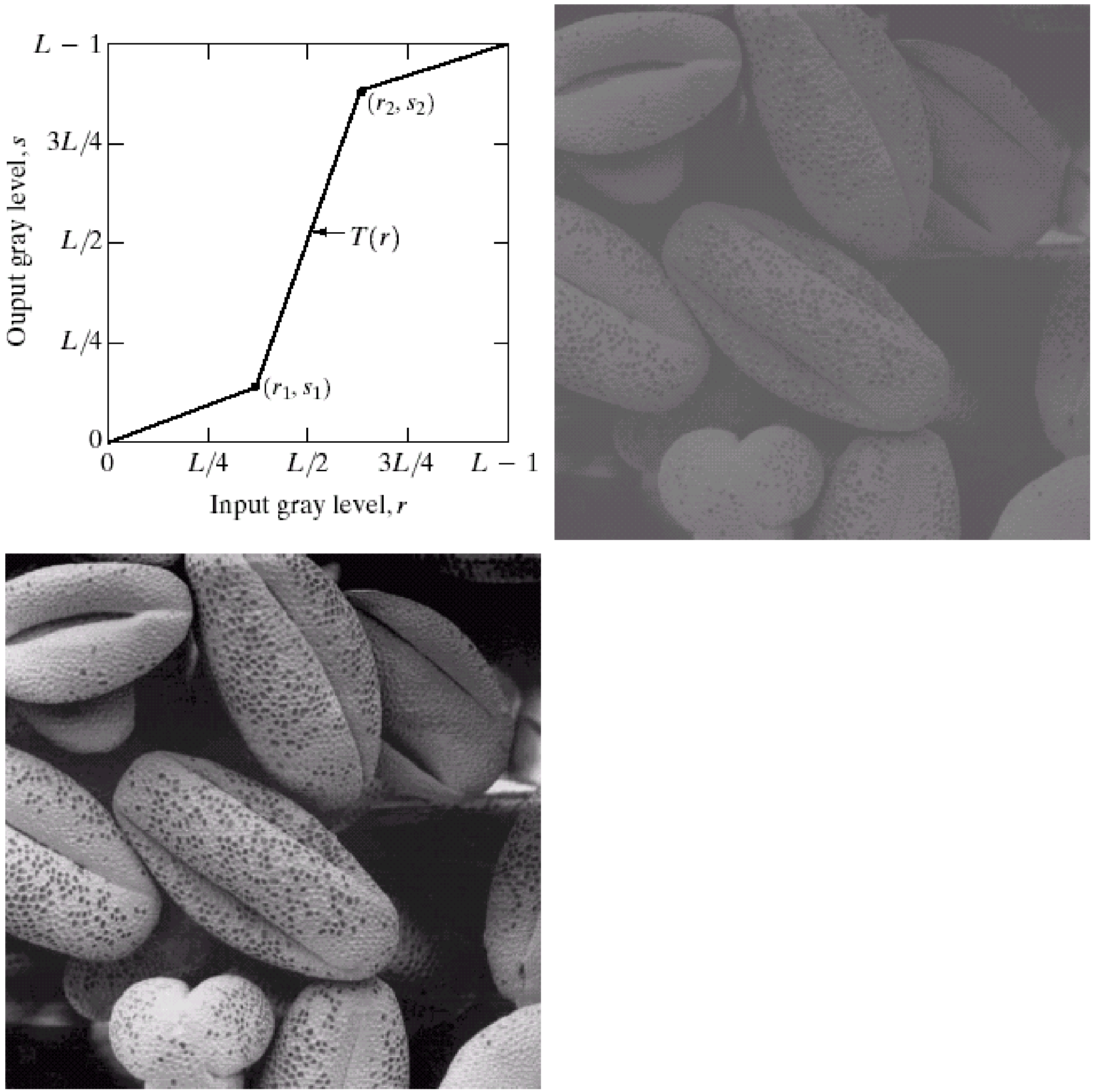
Contrast Stretching



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.)

Contrast Stretching



a b
c d

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Histogram equalization

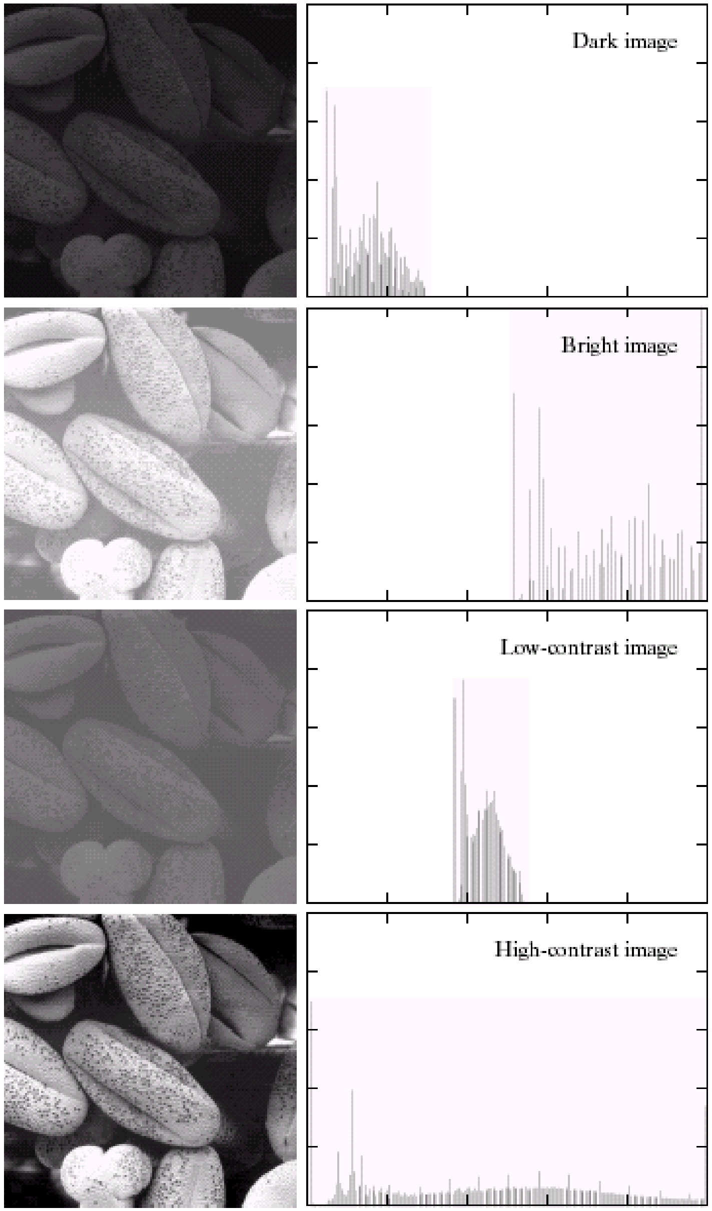
- Basic idea: reassign values so that the number of pixels with each value is more evenly distributed
- Histogram: a count of how many pixels have each value

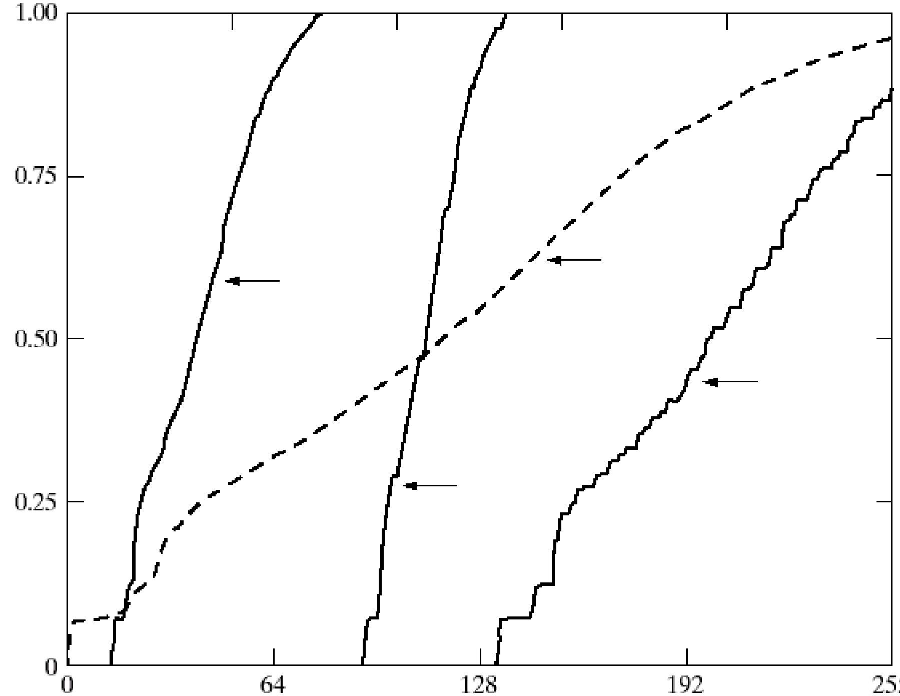
$$h_i = \sum_{j \in pixels} \mathbf{1}(p_j == i)$$

- Cumulative histogram: count of number of pixels less than or equal to each value

$$c_i = c_{i-1} + h_i$$

Image Histograms



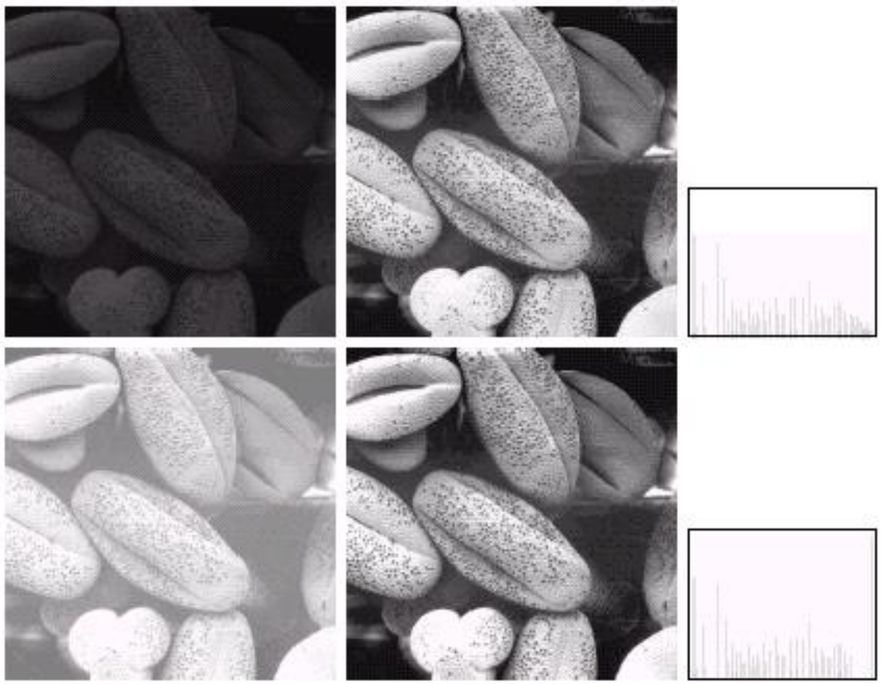


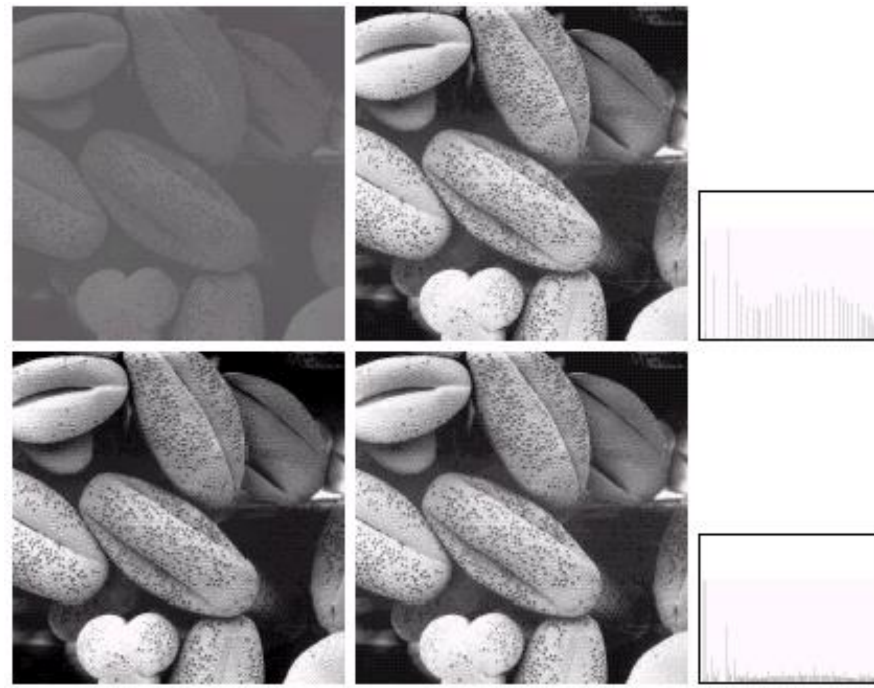
Cumulative Histograms

a b

FIGURE 3.15 Four basic image types: dark, light, low contrast, high contrast, and their corresponding histograms. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

Histogram Equalization





a b c

FIGURE 3.17 (a) Images from Fig. 3.15. (b) Results of histogram equalization. (c) Corresponding histograms.

Algorithm for global histogram equalization

Goal: Given image with pixel values $0 \leq p_j \leq 255,\ j = 0..N$ specify function $\mathrm{f}(i)$ that remaps pixel values, so that the new values are more broadly distributed

1. Compute cumulative histogram: $c(i), i = 0..255$

$$h(i) = \sum_{j \in pixels} \mathbf{1}(p_j == i),\ c(i) = c(i-1) + h(i)$$

2. $\mathrm{f}(i) = \alpha \cdot \frac{c(i)}{N} \cdot 255 + (1 - \alpha) \cdot i$
   – Blends between original image and image with uniform histogram

(Explanation on the blackboard)

- Explanation of histogram equalization