EE663
Image Processing
Histogram Equalization I

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Contents

Over the next few lectures we will look at image enhancement techniques working in the spatial domain:

- What is image enhancement?
- Different kinds of image enhancement
- Histogram processing
- Point processing
- Neighbourhood operations

A Note About Grey Levels

So far when we have spoken about image grey level values we have said they are in the range [0, 255]

- Where 0 is black and 255 is white

There is no reason why we have to use this range

- The range [0,255] stems from display technologes

For many of the image processing operations in this lecture grey levels are assumed to be given in the range [0.0, 1.0]

What Is Image Enhancement?

Image enhancement is the process of making images more useful

The reasons for doing this include:

- Highlighting interesting detail in images
- Removing noise from images
- Making images more visually appealing

Image Enhancement Examples

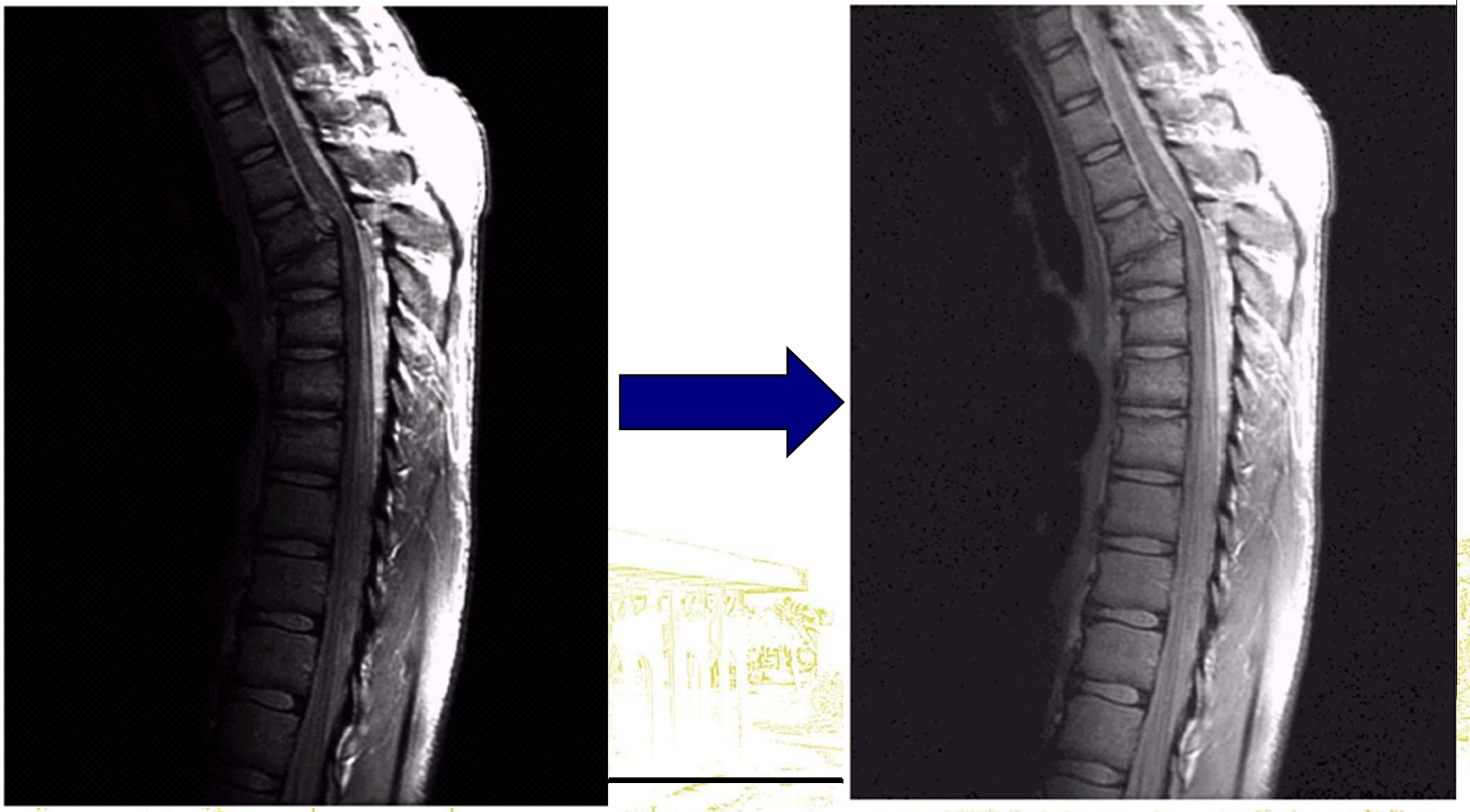


Image Enhancement Examples (cont…)

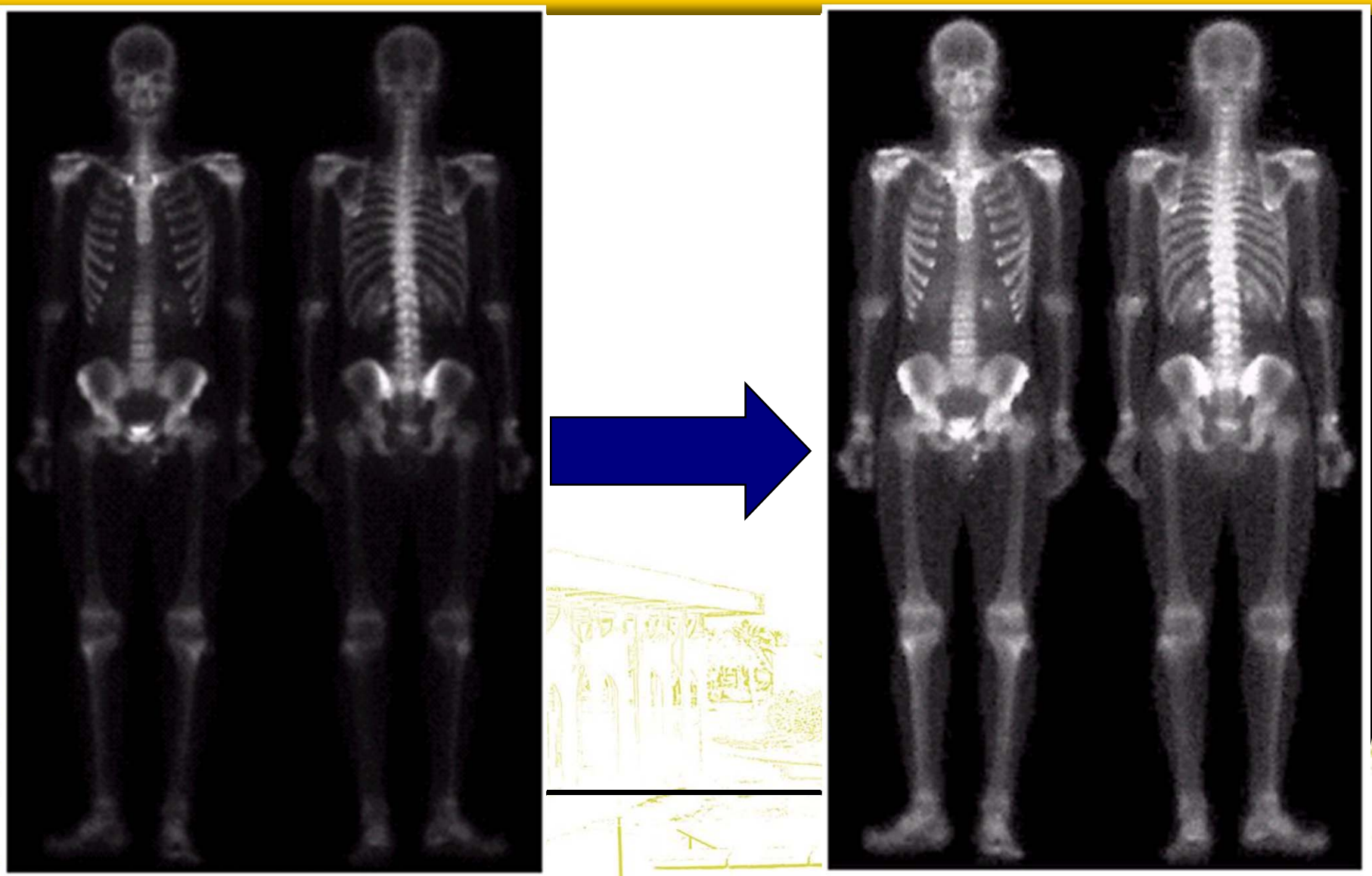


Image Enhancement Examples (cont…)

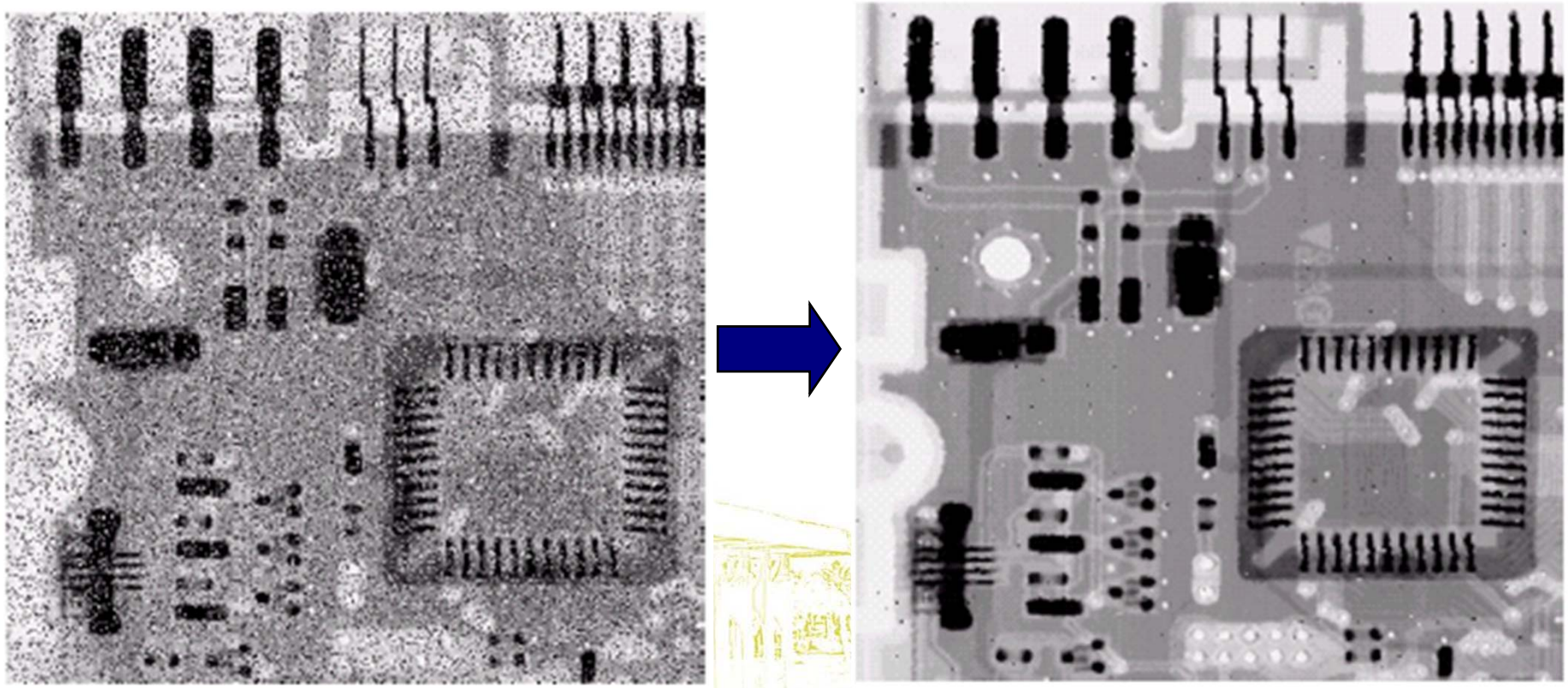


Image Enhancement Examples (cont…)

Spatial & Frequency Domains

There are two broad categories of image enhancement techniques

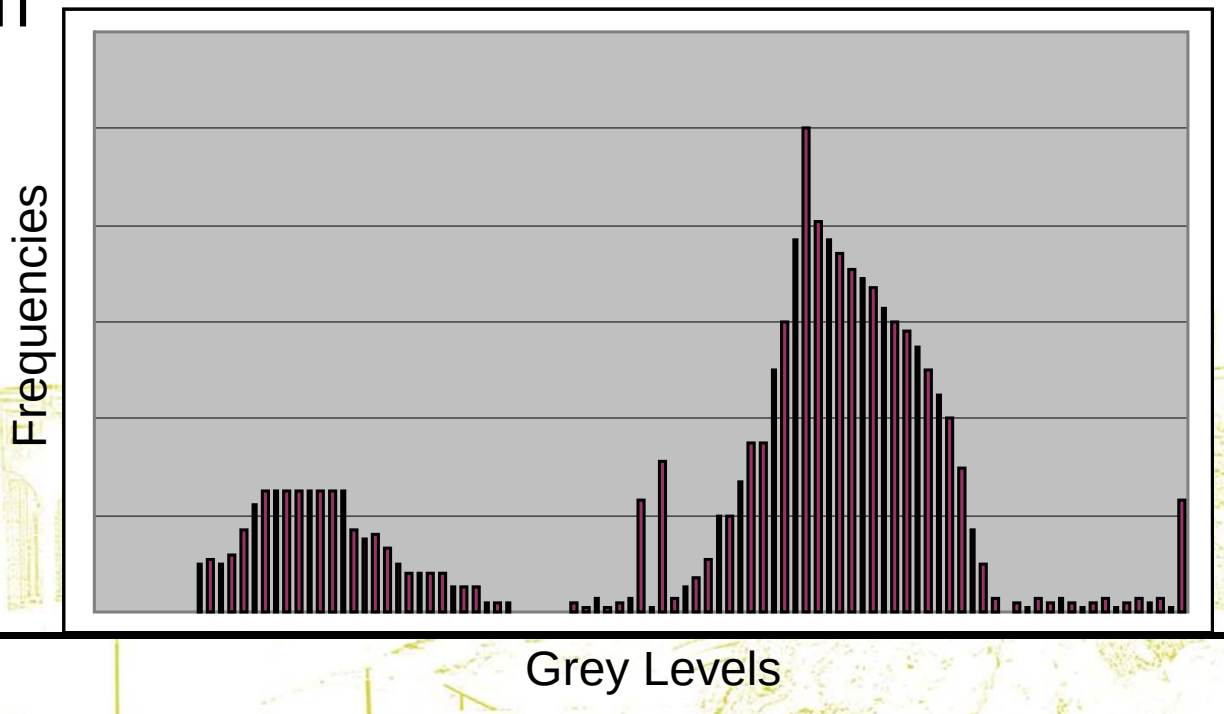
- Spatial domain techniques
  - Direct manipulation of image pixels
- Frequency domain techniques
  - Manipulation of Fourier transform or wavelet transform of an image

For the moment we will concentrate on techniques that operate in the spatial domain

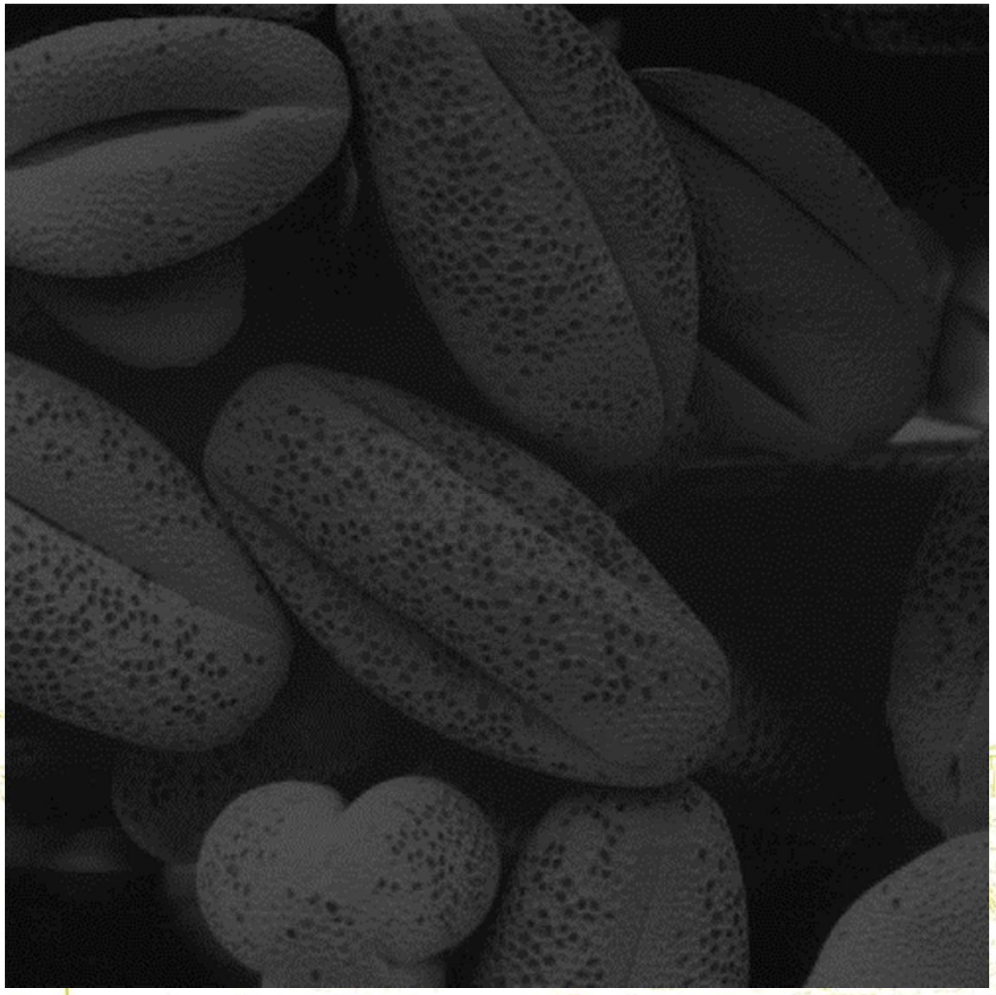
Image Histograms

The histogram of an image shows us the distribution of grey levels in the image

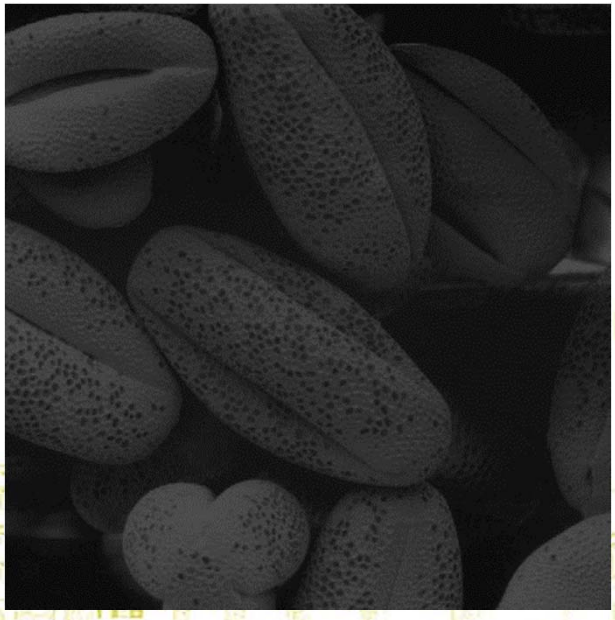
Massively useful in image processing, especially in segmentation

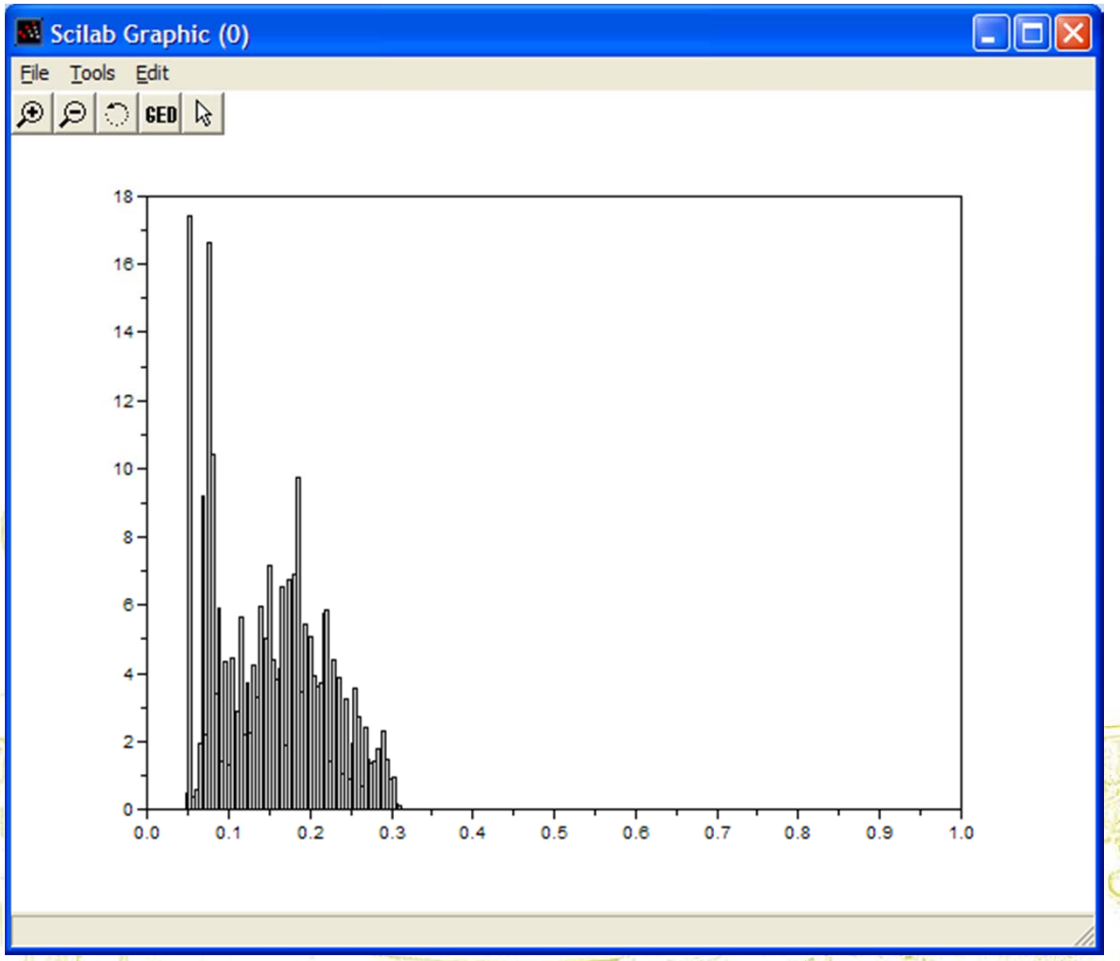


Histogram Examples (cont…)

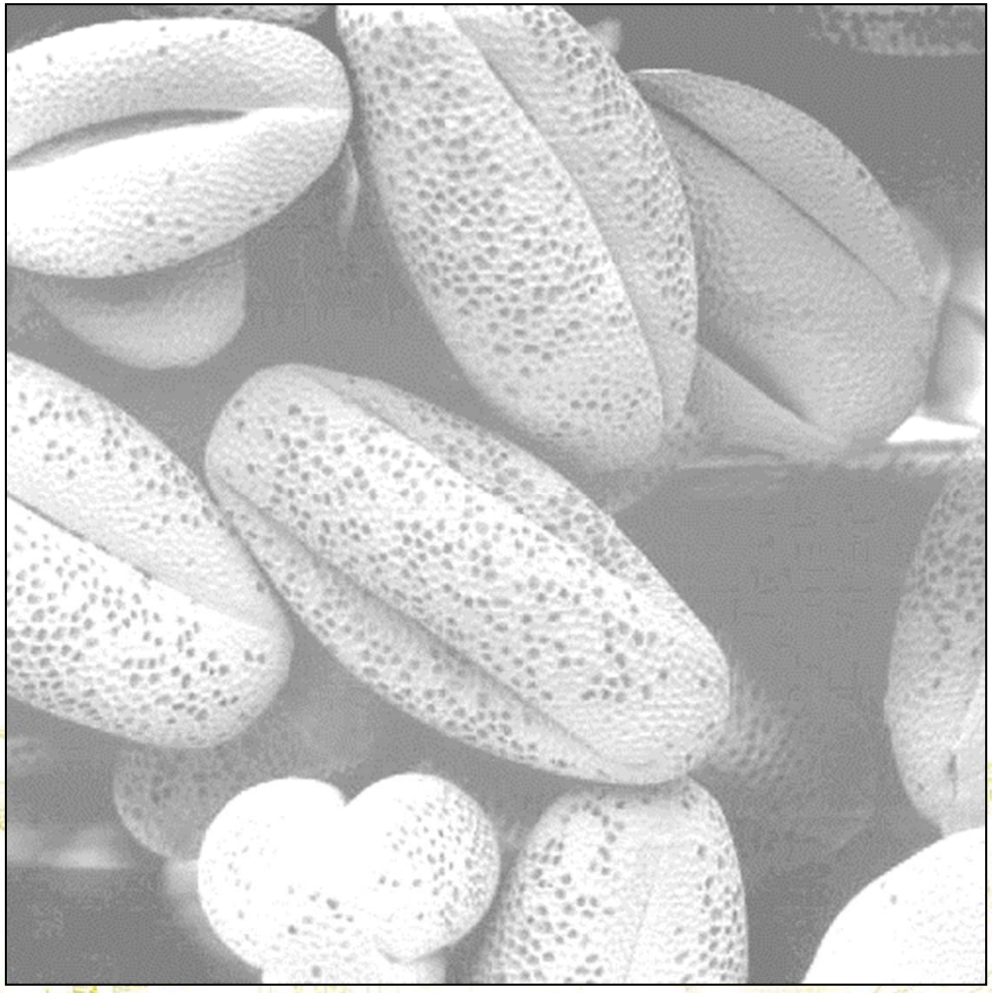


Histogram Examples (cont…)

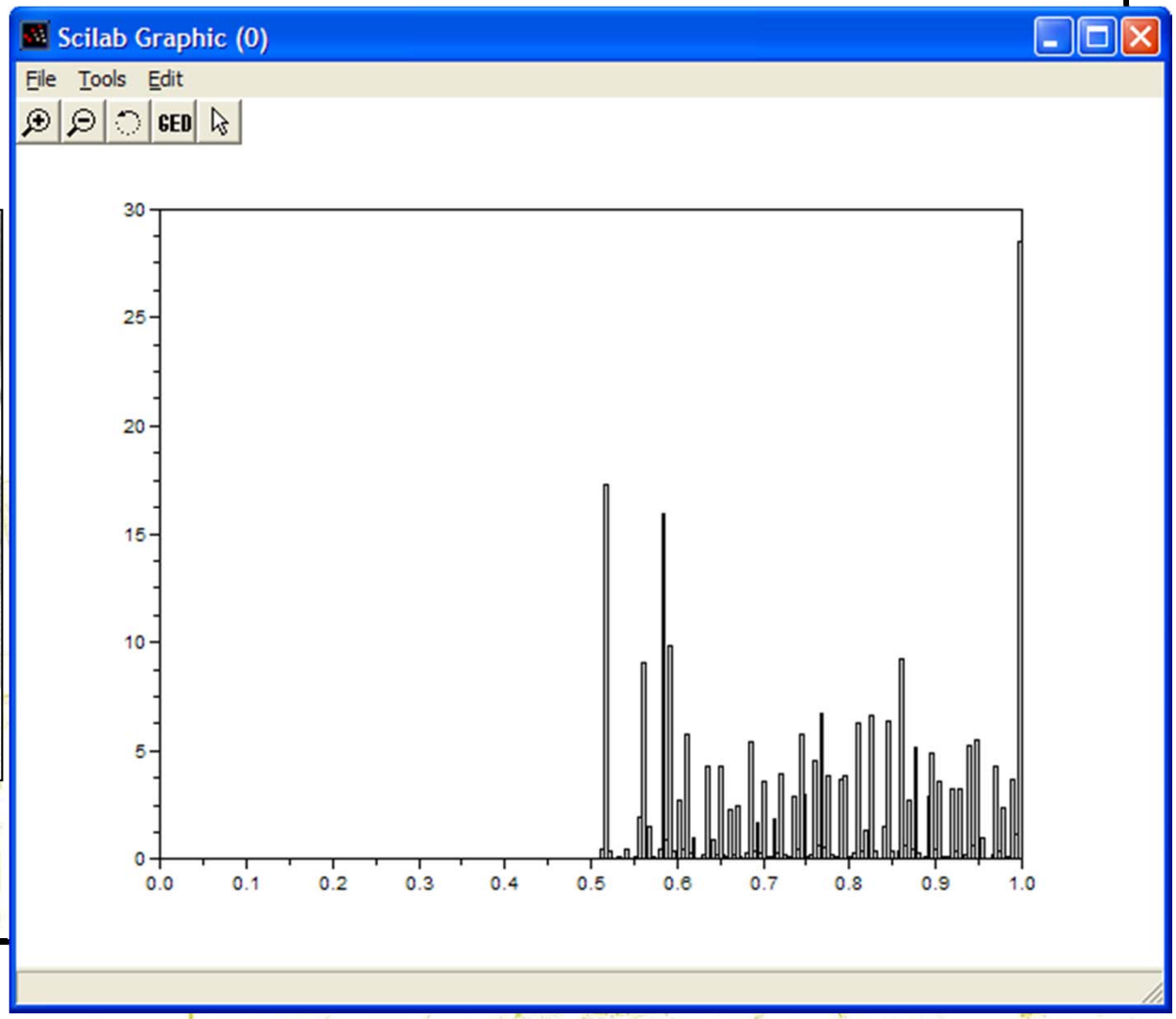




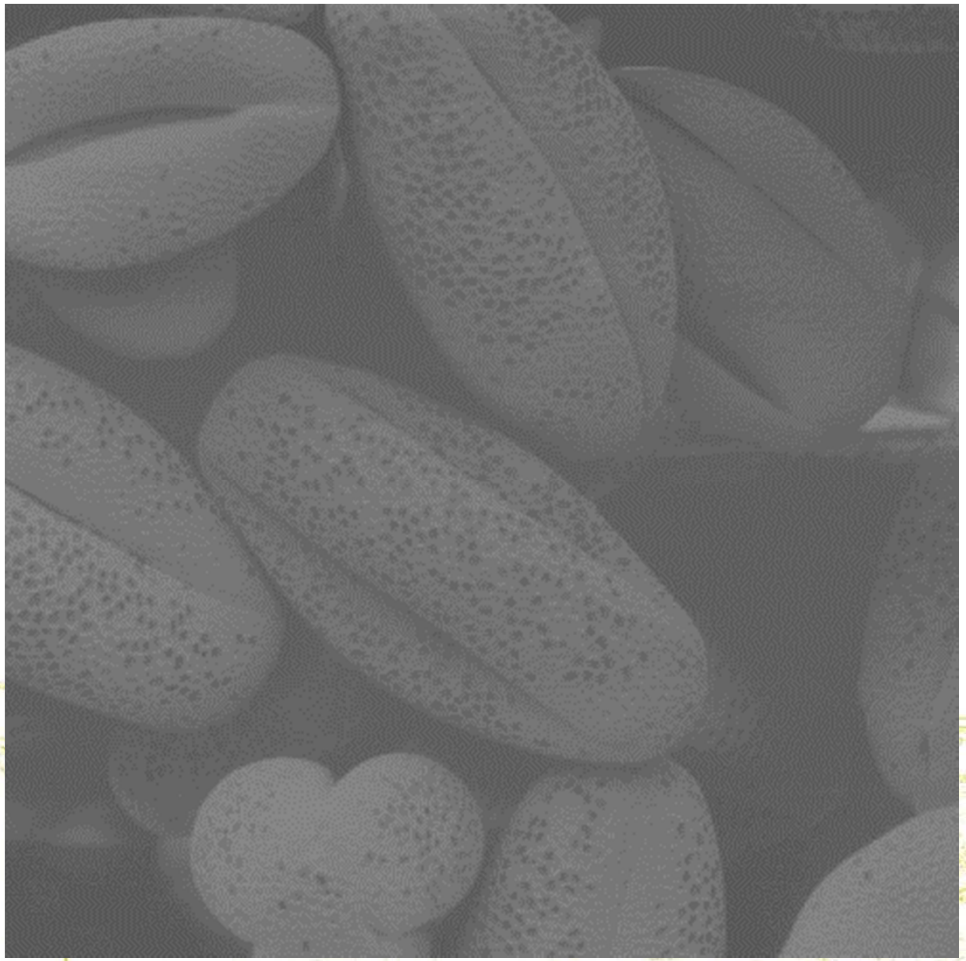
Histogram Examples (cont…)



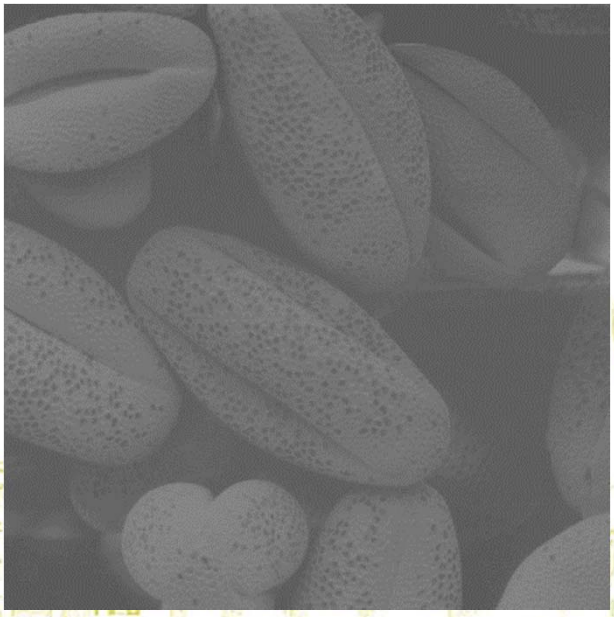
Histogram Examples (cont…)

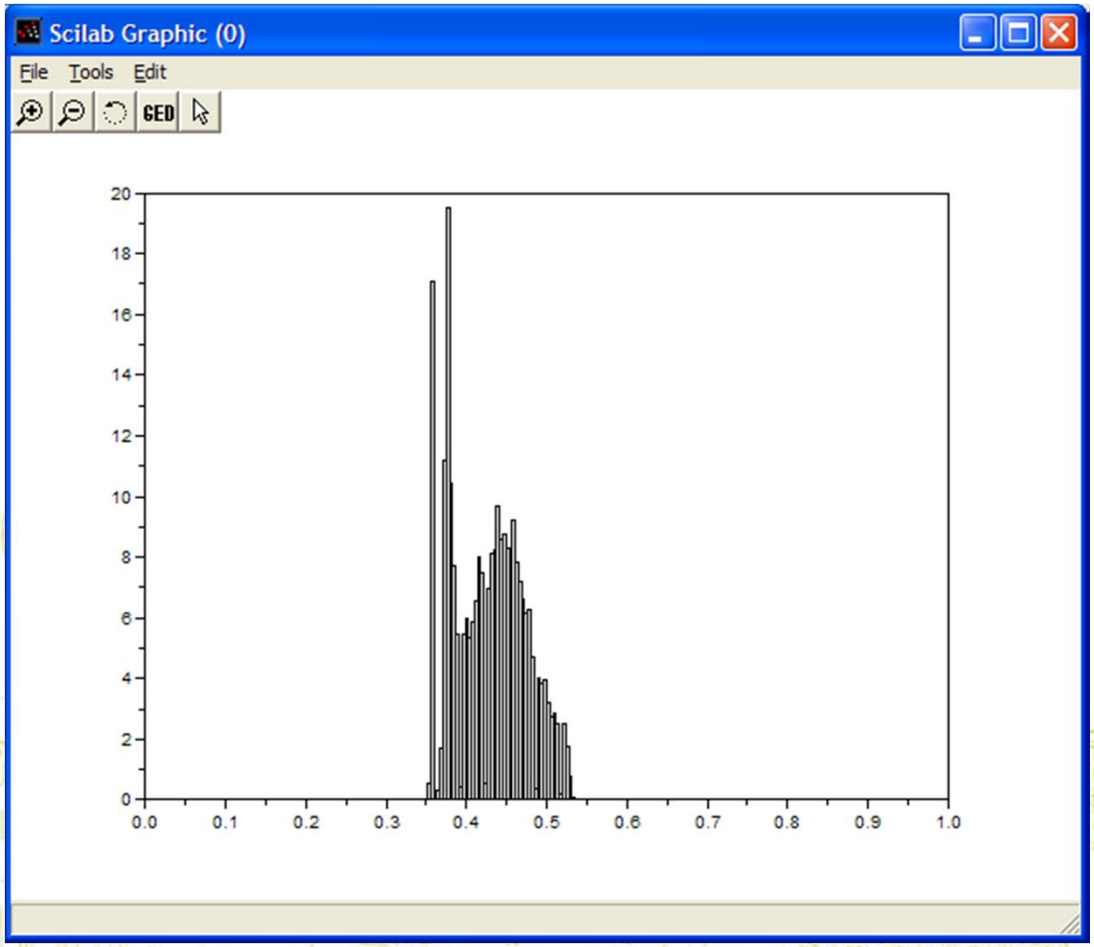


Histogram Examples (cont…)



Histogram Examples (cont…)





Histogram Examples (cont…)

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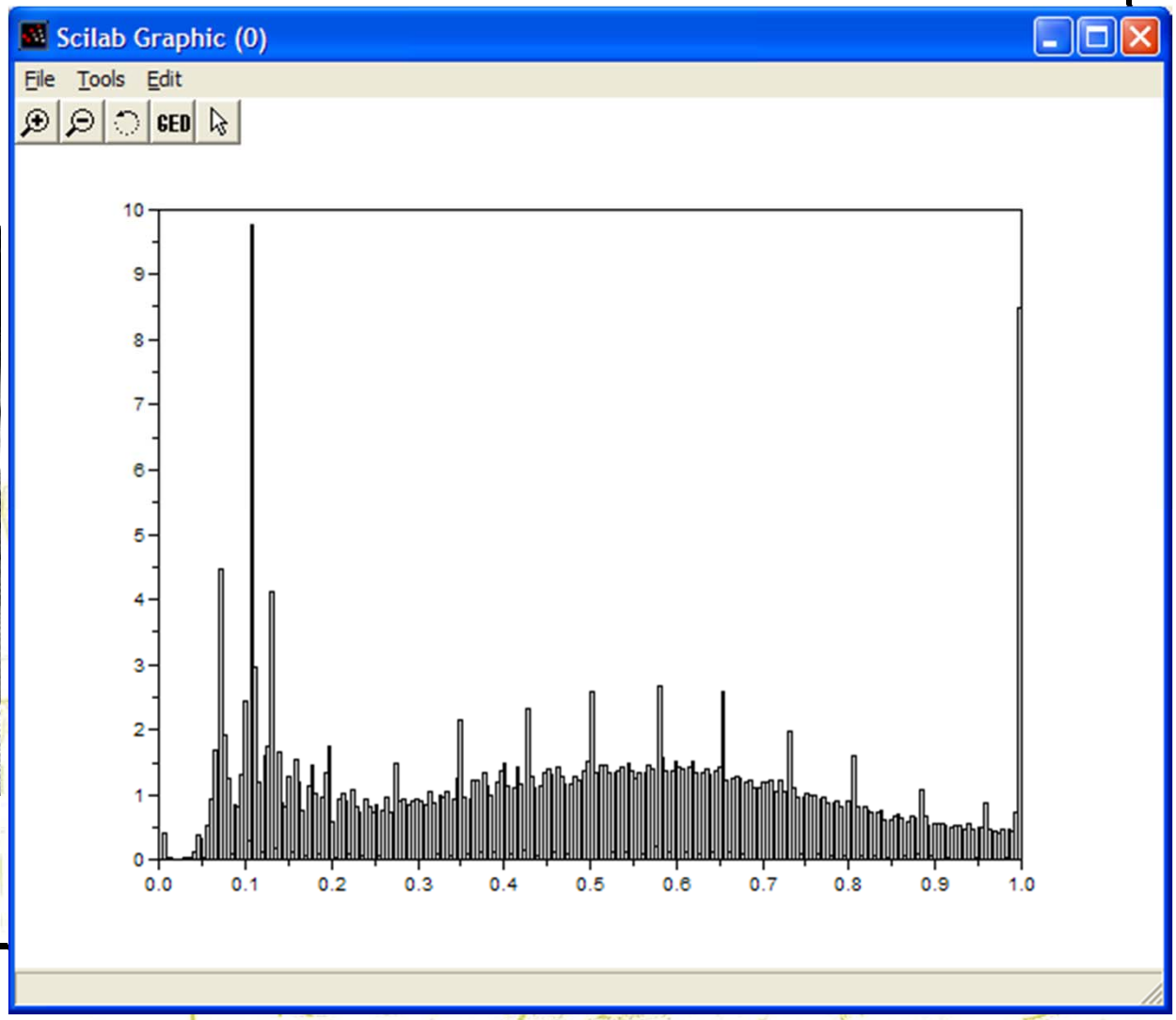
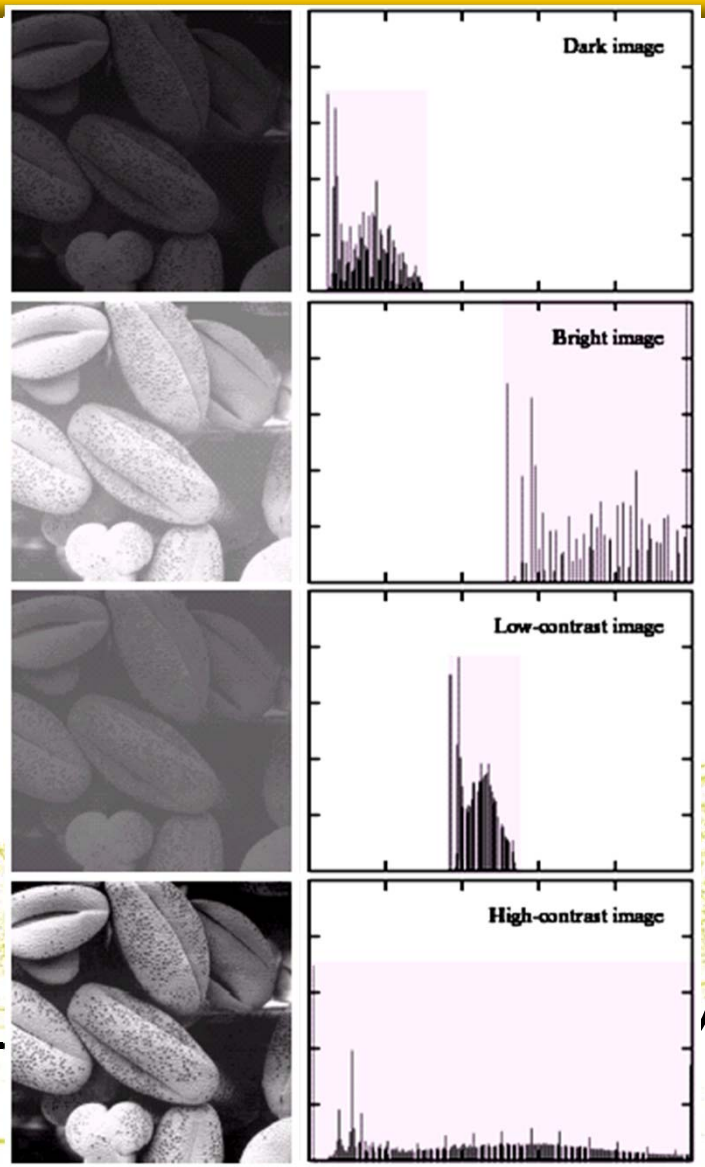


Histogram Examples (cont…)

A selection of images and their histograms

Notice the relationships between the images and their histograms

Note that the high contrast image has the most evenly spaced histogram



Histogram Equalisation

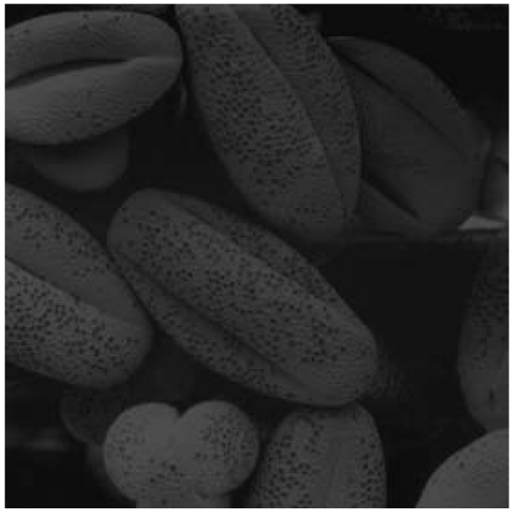
Spreading out the frequencies in an image (or equalising the image) is a simple way to improve dark or washed out images

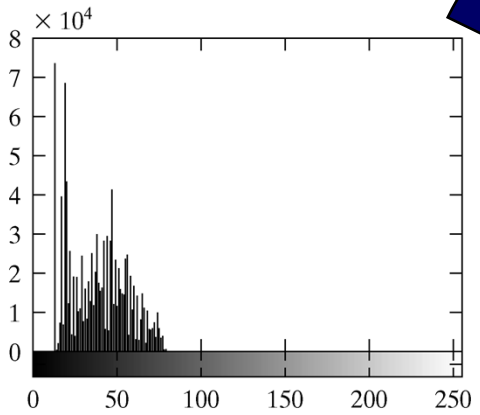
The formula for histogram equalisation is given where

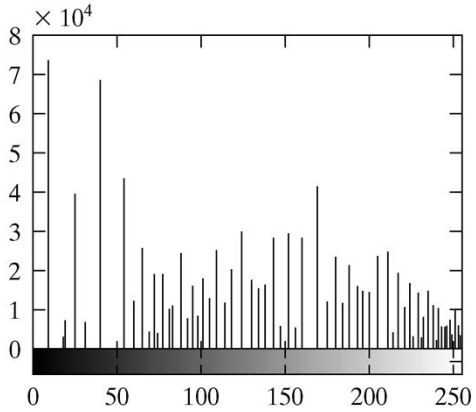
- r_k: input intensity
- s_k: processed intensity
- k: the intensity range (e.g 0.0 – 1.0)
- n_j: the frequency of intensity j
- n: the sum of all frequencies

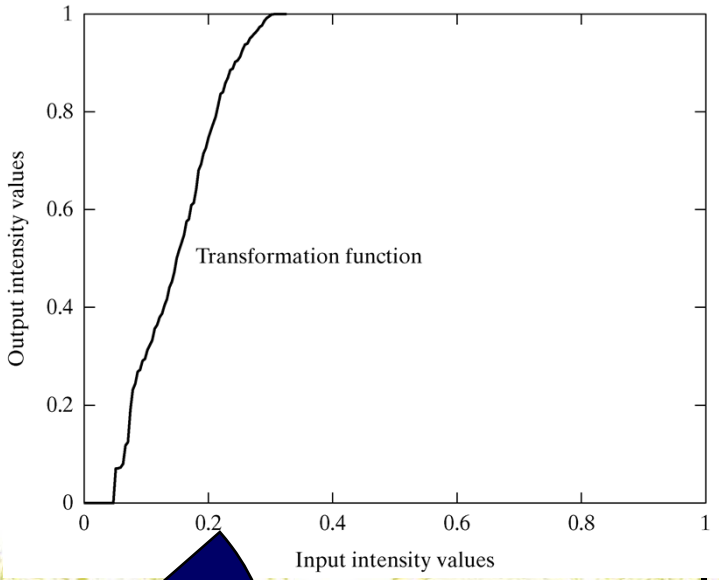
$$s_k = T(r_k)$$
$$= \sum_{j=1}^{k} p_r(r_j)$$
$$= \sum_{j=1}^{k} \frac{n_j}{n}$$

Equalisation Transformation Function

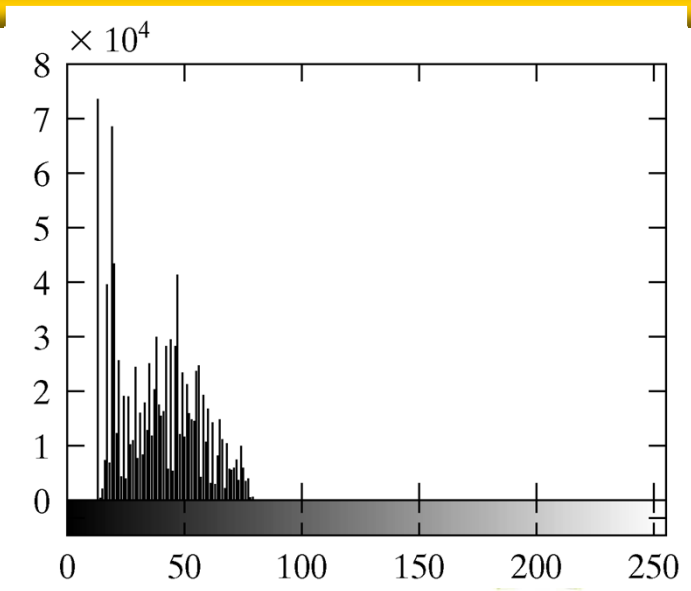


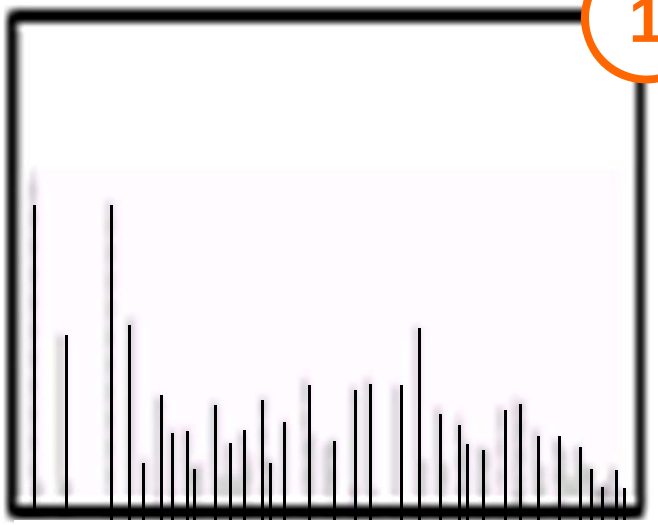


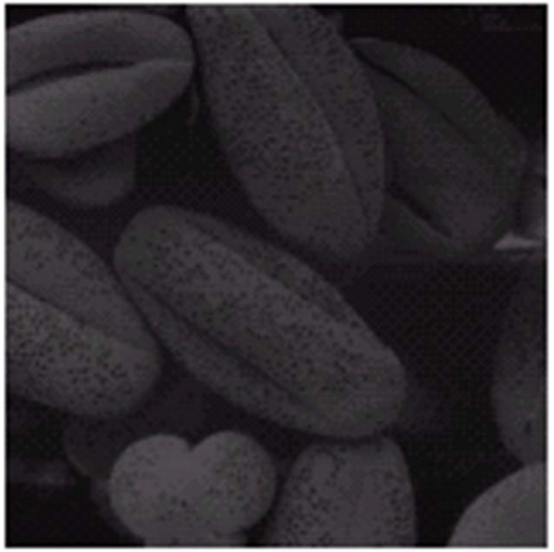




Equalisation Examples

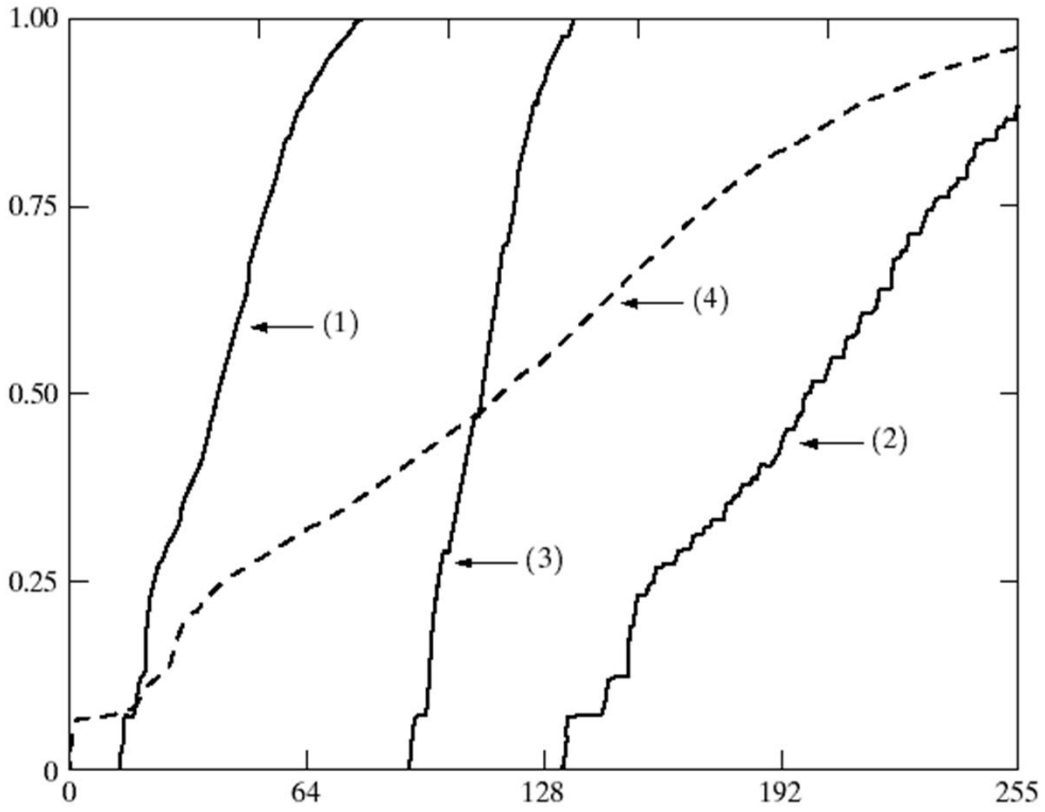




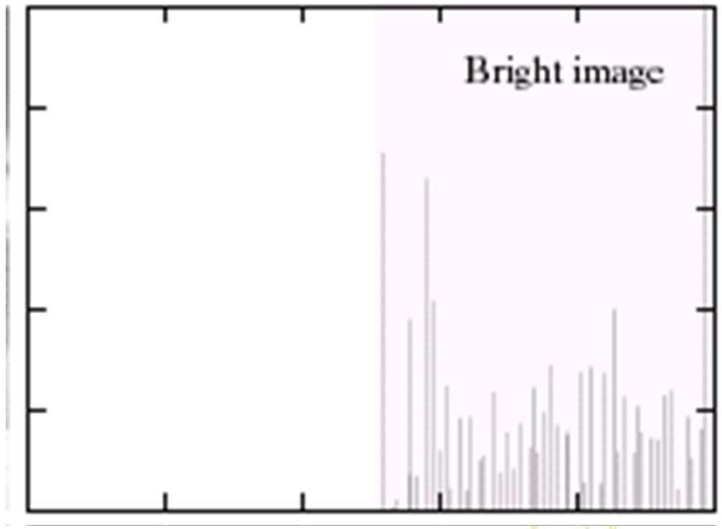


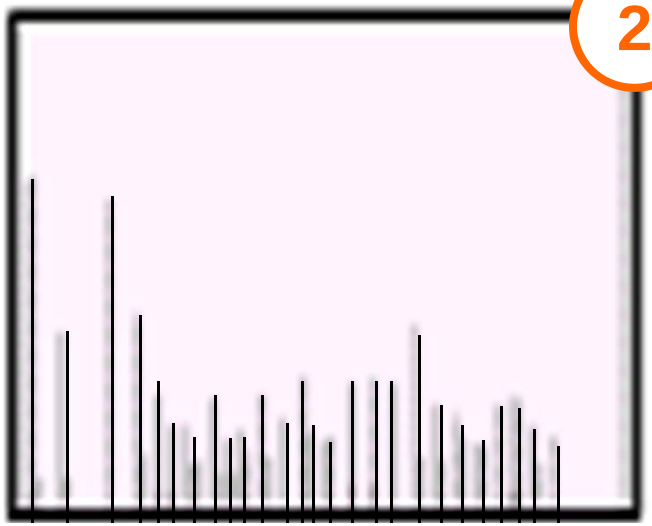
Equalisation Transformation Functions

The functions used to equalise the images in the previous example



Equalisation Examples





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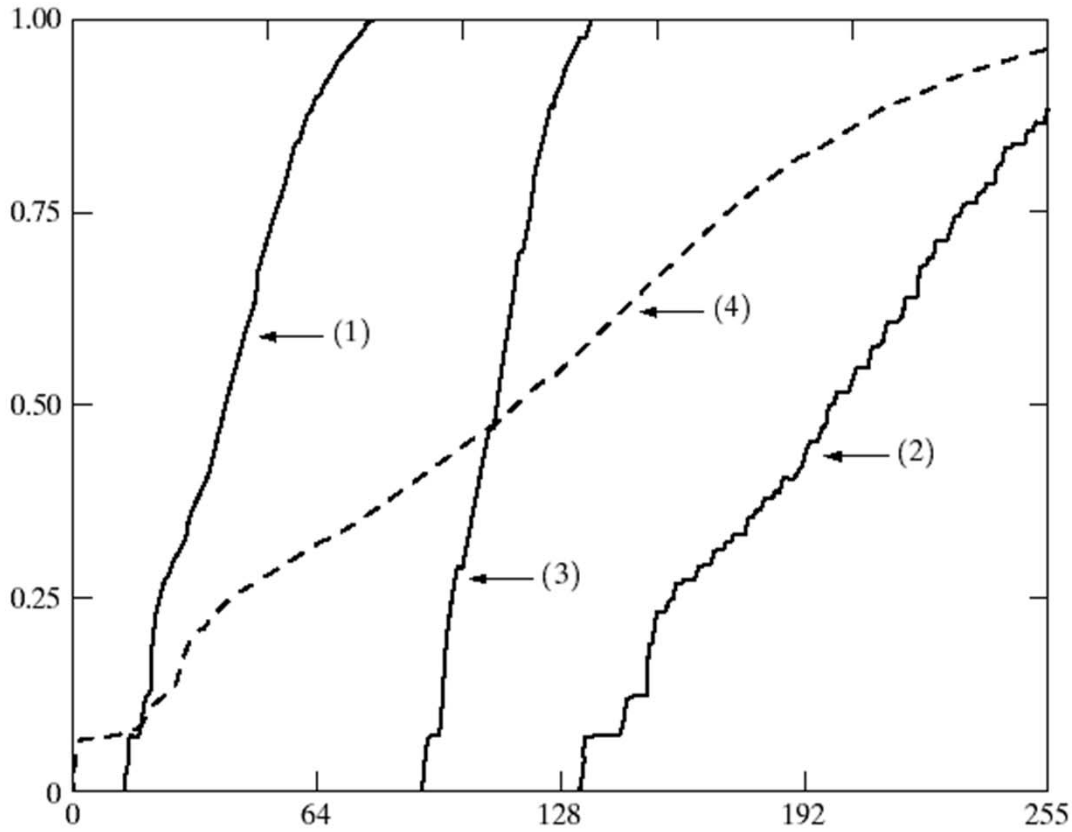
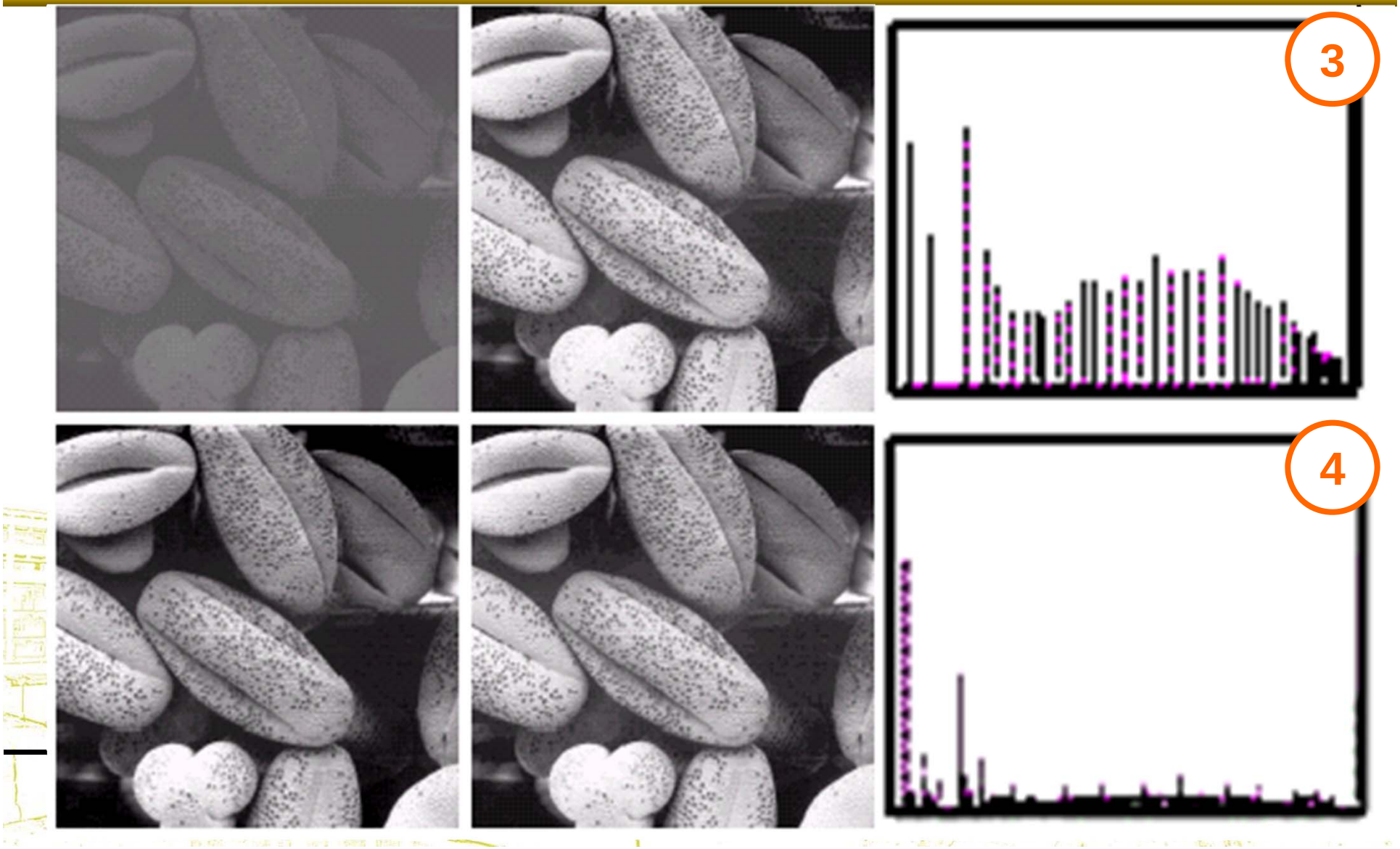
Equalisation Transformation Functions

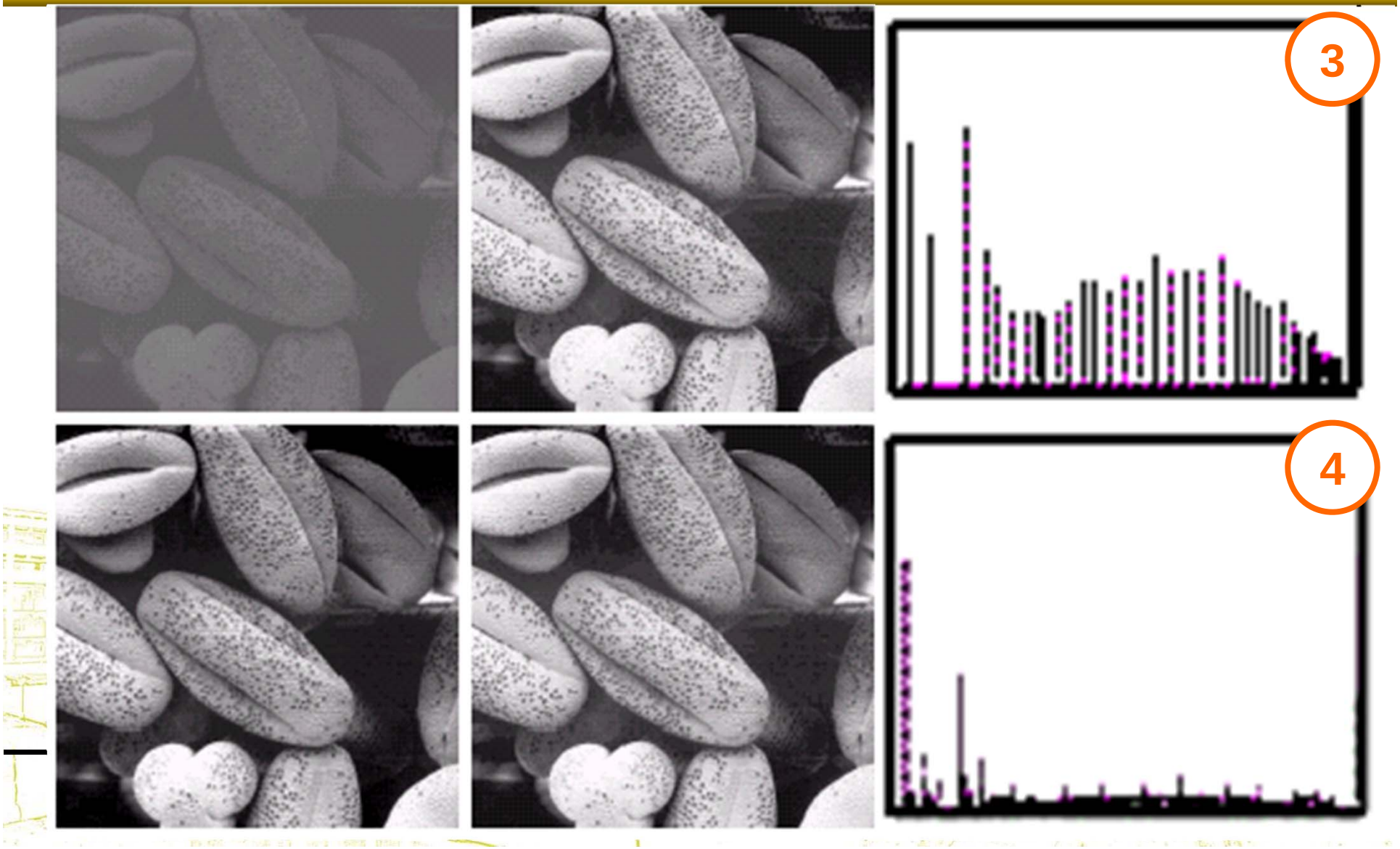
The functions used to equalise the images in the previous example



Equalisation Examples (cont…)

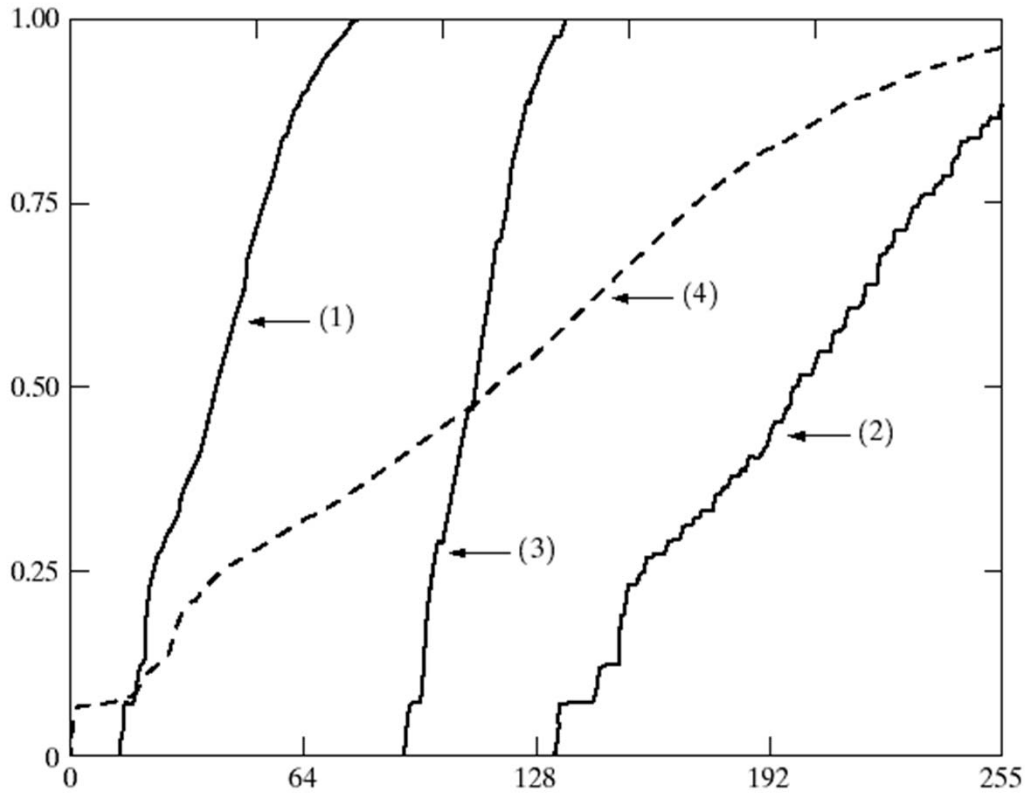


Equalisation Examples (cont…)



Equalisation Transformation Functions

The functions used to equalise the images in the previous examples



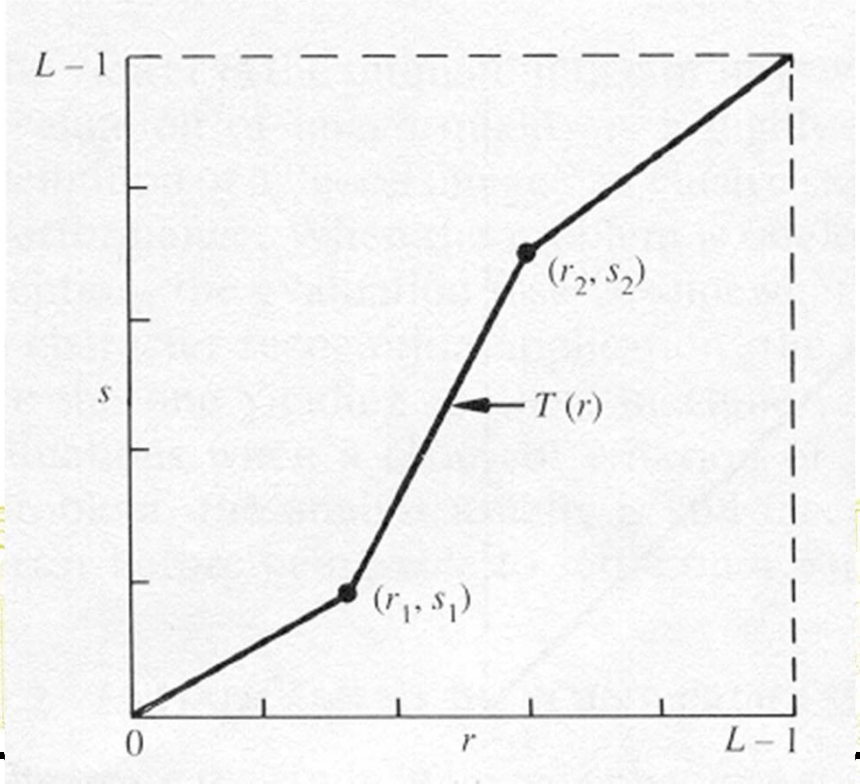
Contrast Stretching

We can fix images that have poor contrast by applying a pretty simple contrast specification

The interesting part is how do we decide on this transformation function?

Contrast Stretching

- To increase the dynamic range of the gray levels in the image being processed.



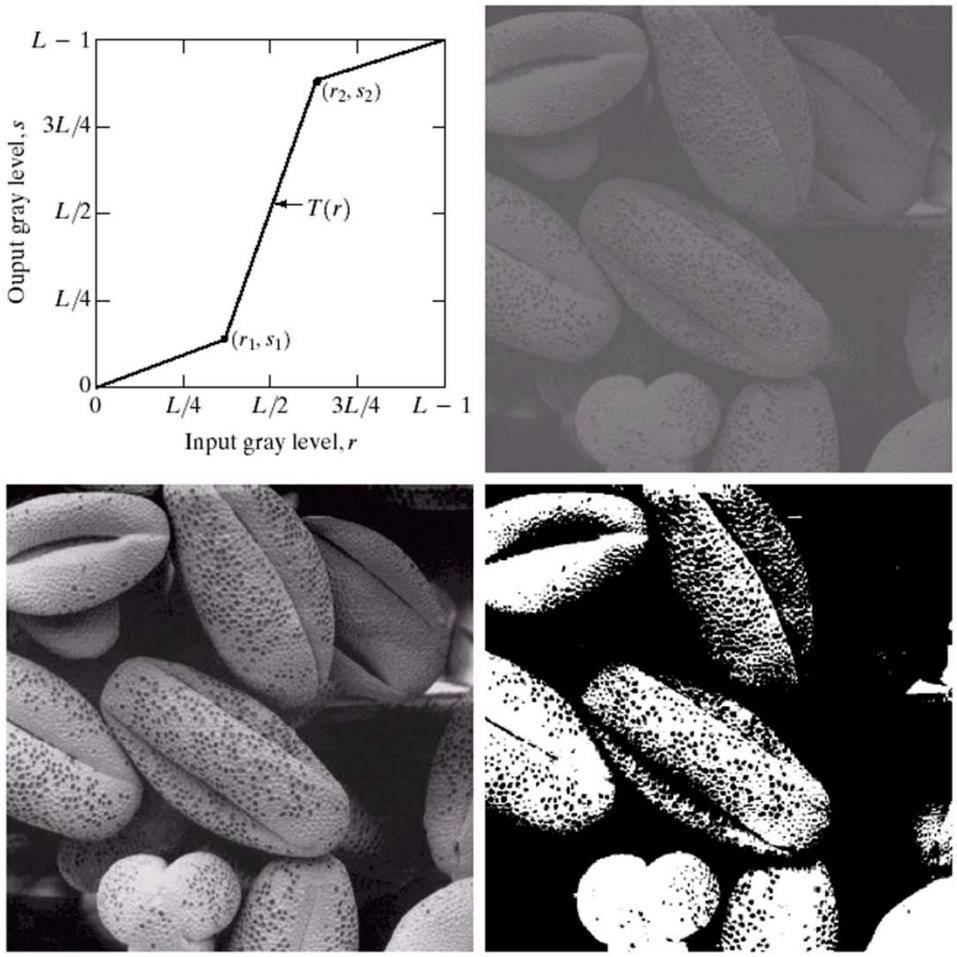
Contrast Stretching

- The locations of (r_1,s_1) and (r_2,s_2) control the shape of the transformation function.
  - If $r_1 = s_1$ and $r_2 = s_2$ the transformation is a linear function and produces no changes.
  - If $r_1=r_2$, $s_1=0$ and $s_2=L-1$, the transformation becomes a thresholding function that creates a binary image.

Contrast Stretching

- More on function shapes:
  - Intermediate values of (r_1,s_1) and (r_2,s_2) produce various degrees of spread in the gray levels of the output image, thus affecting its contrast.
  - Generally, $r_1 \leq r_2$ and $s_1 \leq s_2$ is assumed.

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.)

Summary

We have looked at:

- Different kinds of image enhancement
- Histograms
- Histogram equalisation

Next time we will start to look at point processing and some neighbourhood operations