# Digital Image Processing

## Image Enhancement
## (Histogram Processing)

# 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]

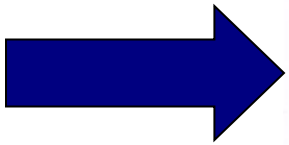
# What Is Image Enhancement?

Image enhancement is the process of making images more useful

The reasons for doing this include:

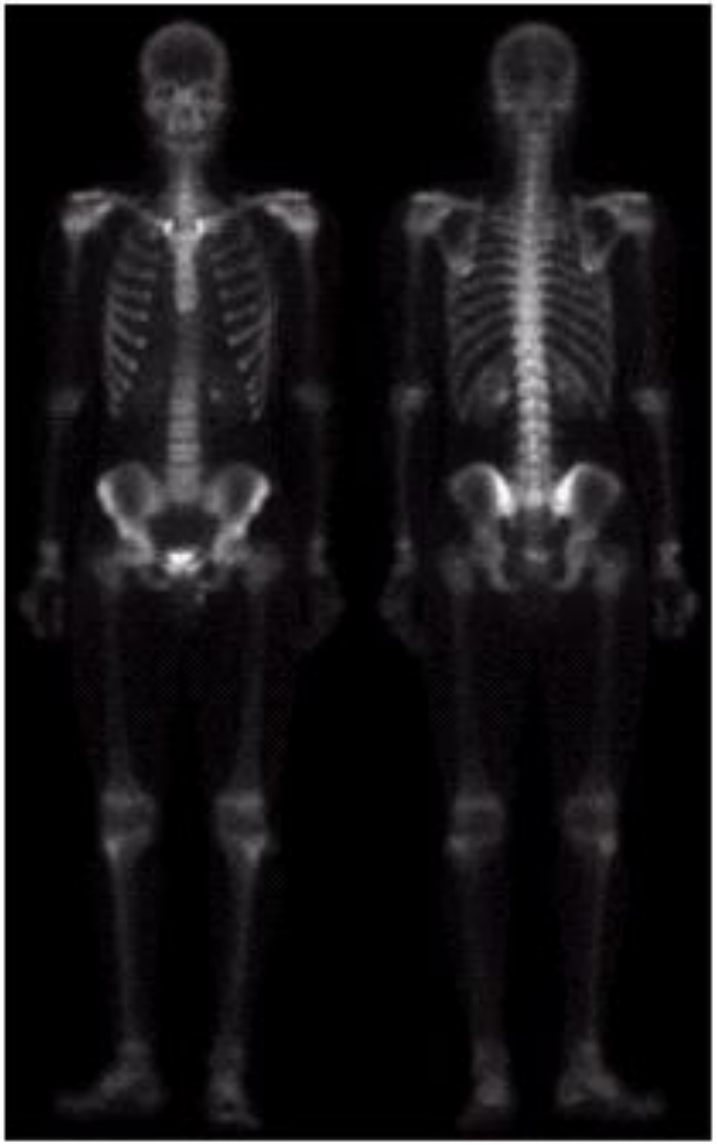
- Highlighting interesting detail in images
- Removing noise from images
- Making images more visually appealing

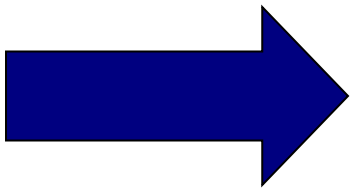
# Image Enhancement Examples



Images taken from Gonzalez & Woods, Digital Image Processing (2002)

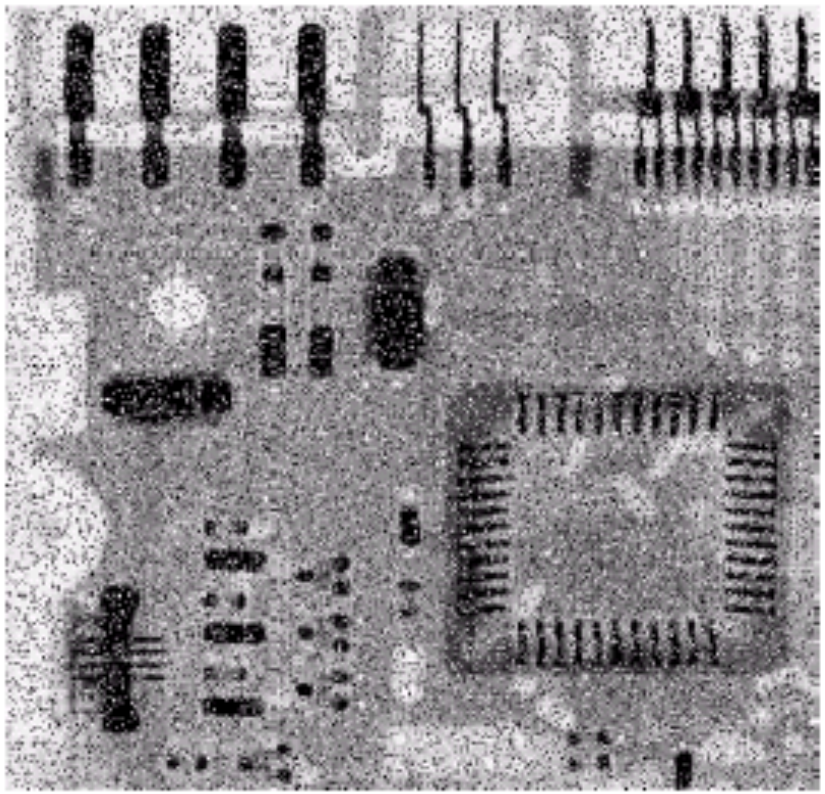
# Image Enhancement Examples (cont…)

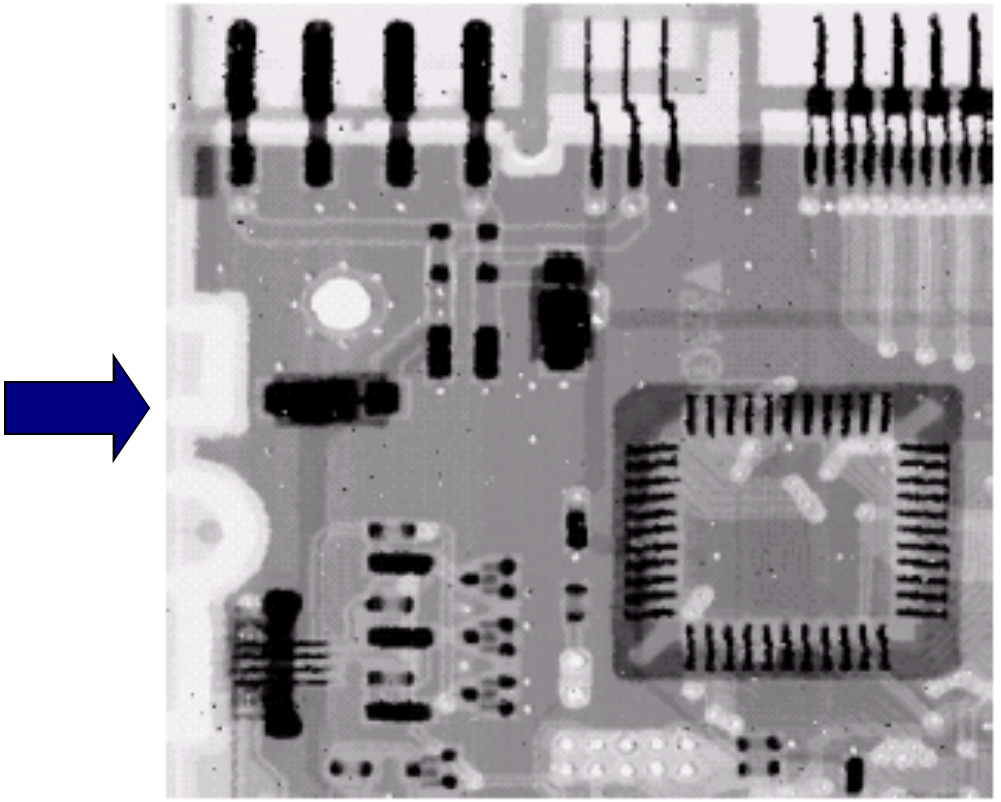




Images taken from Gonzalez & Woods, Digital Image Processing (2002)

# Image Enhancement Examples (cont…)





# Image Enhancement Examples (cont…)

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

# 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

# Histogram of an Image

Histogram: the distribution of gray intensity over all pixels in the images

*r* presents the gray level of a pixel

n presents the number of pixels with intensity *r*

*L* presents the highest gray level

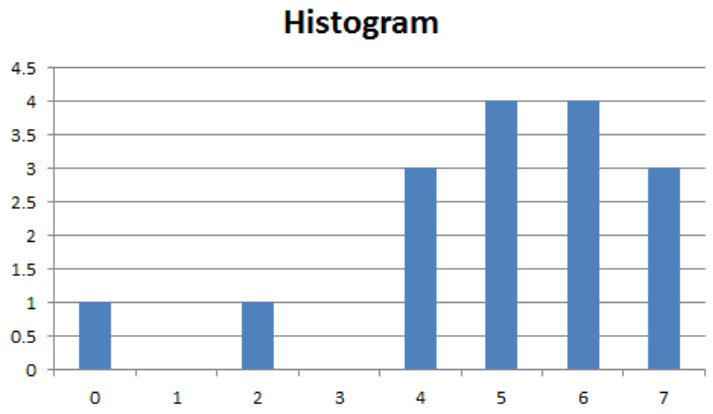
Normalized histogram: Divide its value to total number of pixels

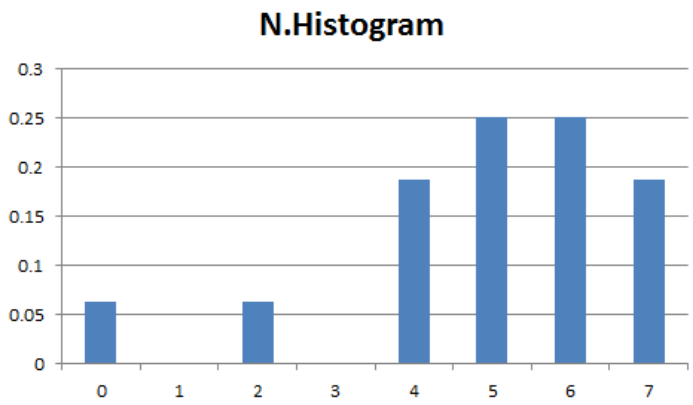
*N* presents total number of pixels in the image

# Histogram Example

| | | | |
|---|---|---|---|
| 2 | 5 | 7 | 6 |
| 4 | 5 | 4 | 7 |
| 6 | 5 | 6 | 4 |
| 0 | 7 | 5 | 6 |

| Intensity | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Histogram | 1 | 0 | 1 | 0 | 3 | 4 | 4 | 3 |
| N.Histogram | 0.0625 | 0 | 0.0625 | 0 | 0.1875 | 0.25 | 0.25 | 0.1875 |



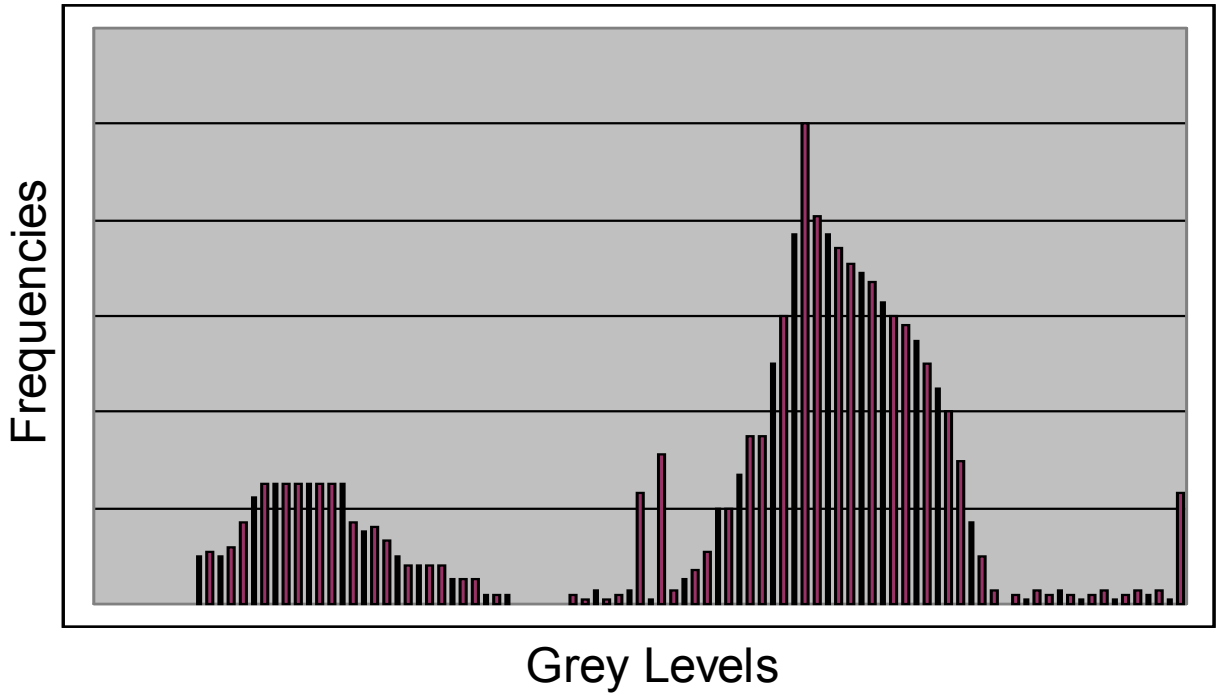
| | | | |
|---|---|---|---|
| 0 | 2 | 1 | 7 |
| 3 | 2 | 5 | 2 |
| 1 | 1 | 7 | 6 |
| 5 | 0 | 0 | 3 |

| | | |
|---|---|---|
| 3 | 3 | 2 |
| 1 | 1 | 0 |
| 2 | 2 | 2 |

# Image Histograms

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

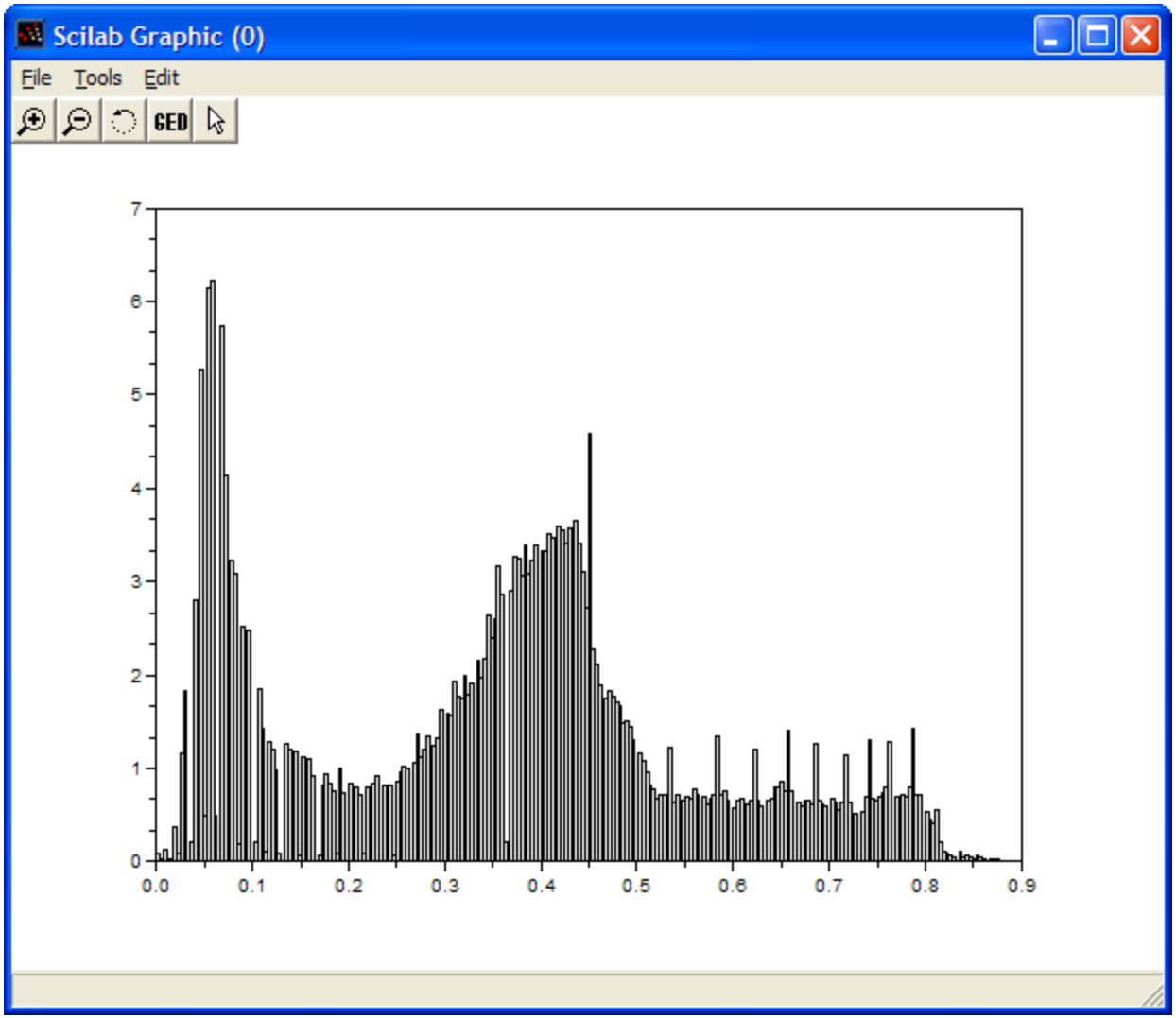
Massively useful in image processing, especially in segmentation



# Histogram Examples

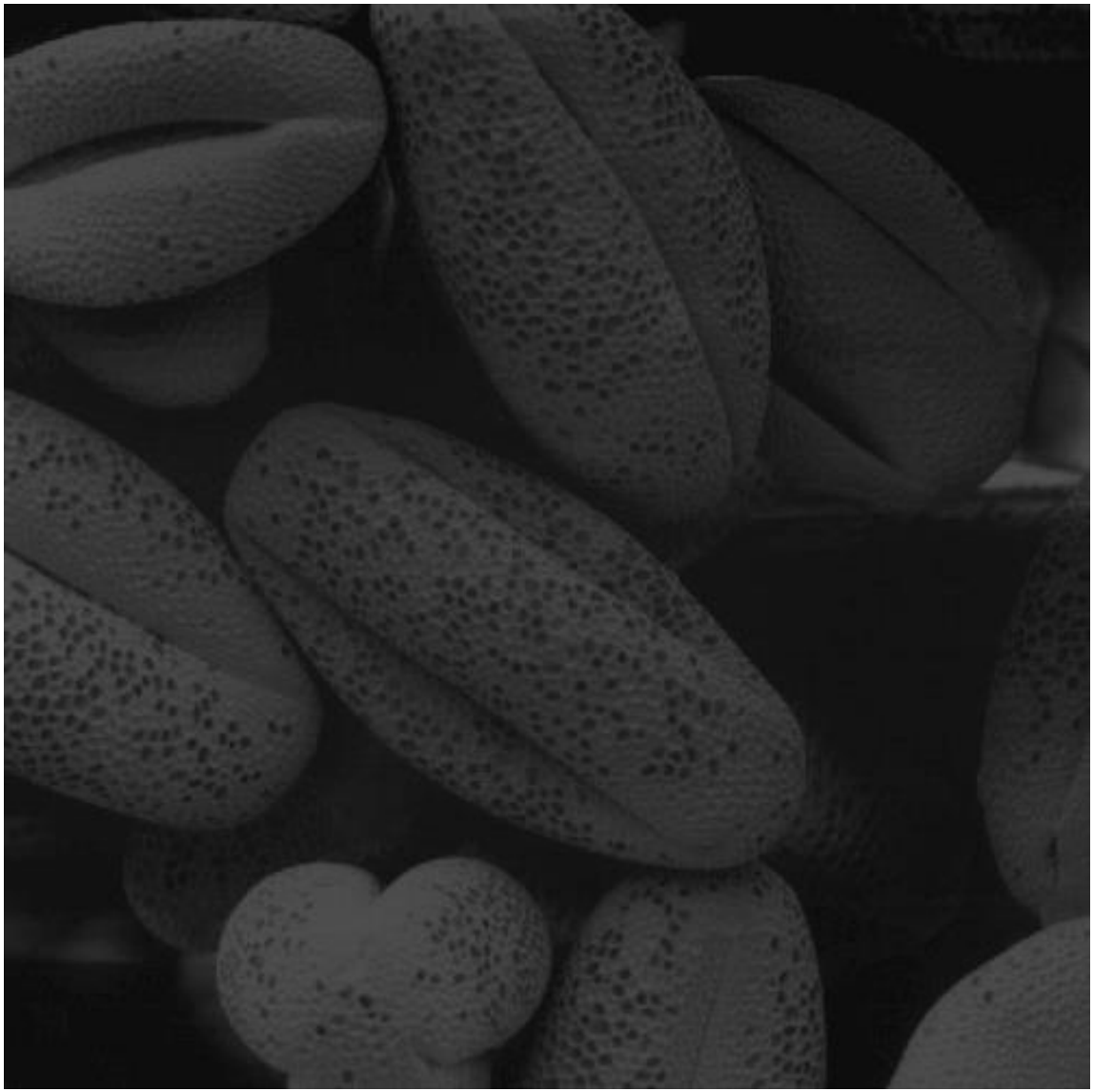
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

# Histogram Examples (cont…)

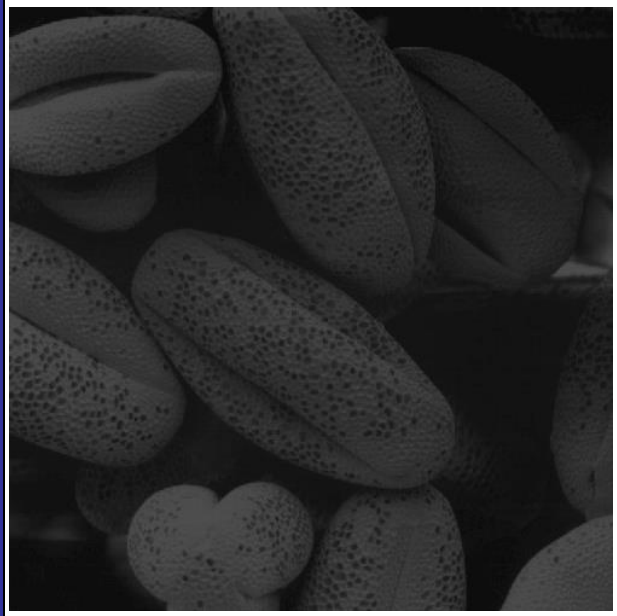


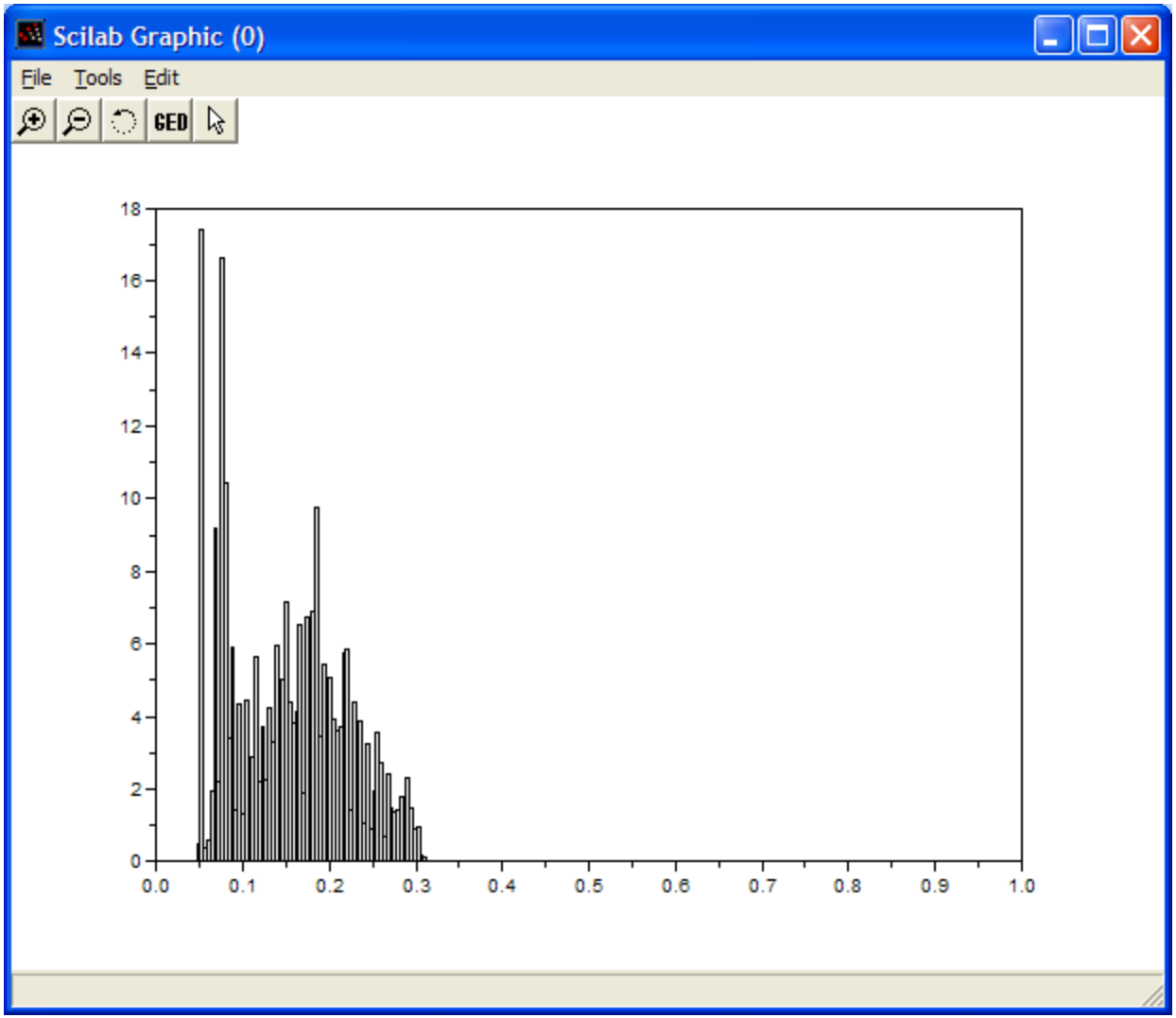

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

# Histogram Examples (cont…)



# Histogram Examples (cont…)

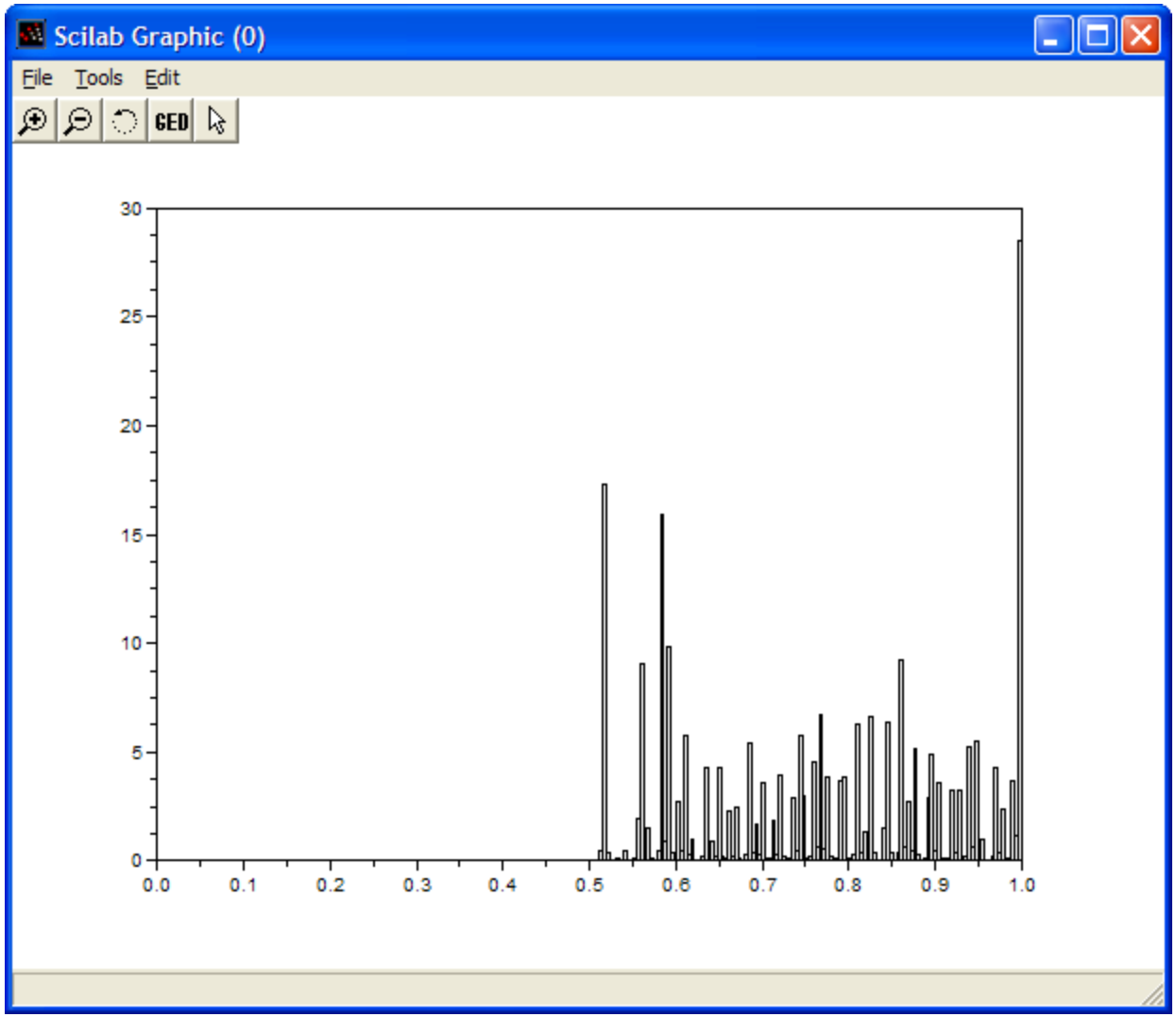





Images taken from Gonzalez & Woods, Digital Image Processing (2002)

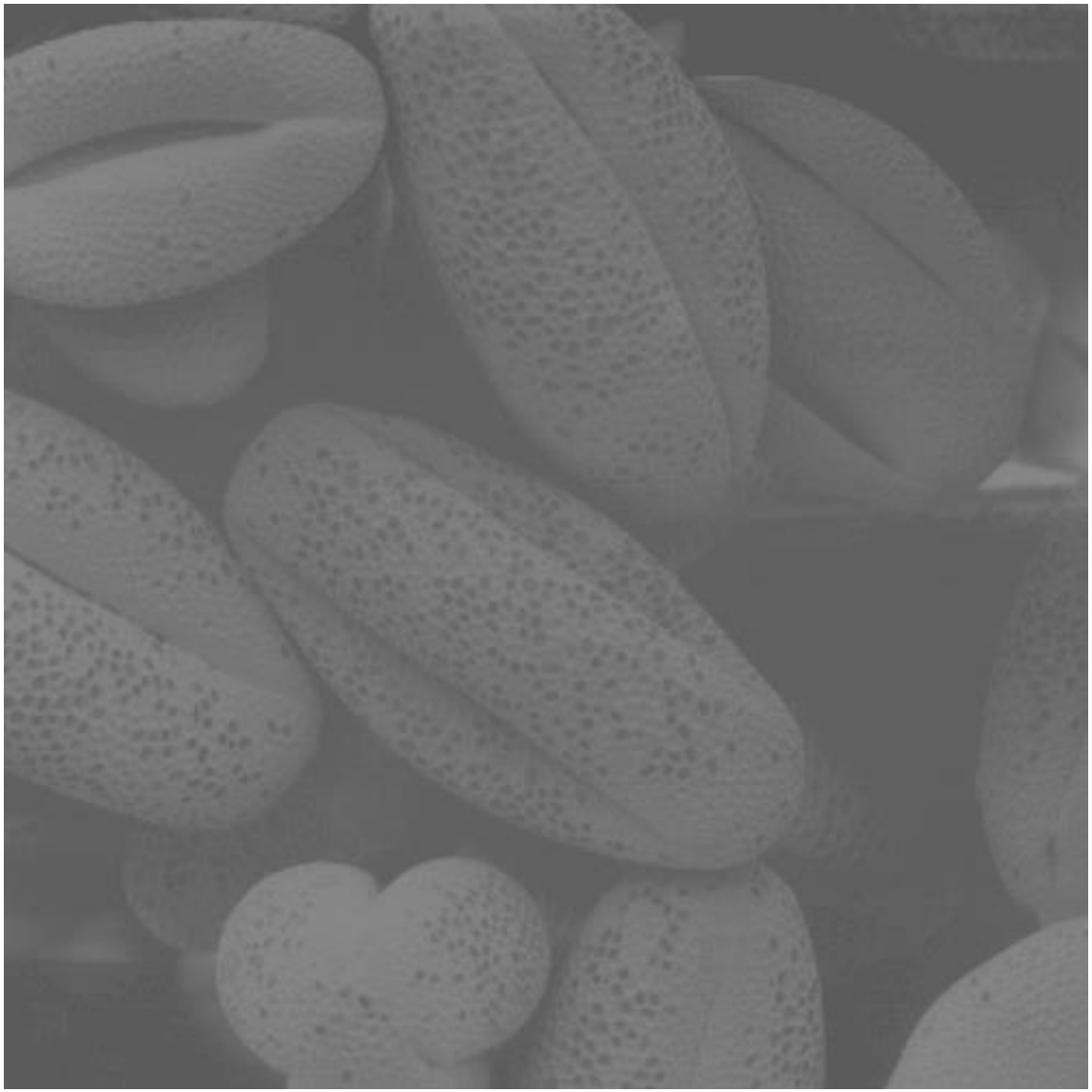
# Histogram Examples (cont…)

# Histogram Examples (cont…)

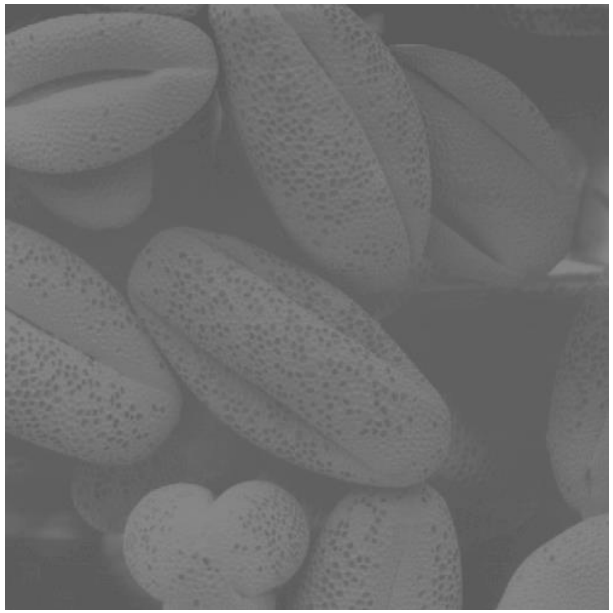


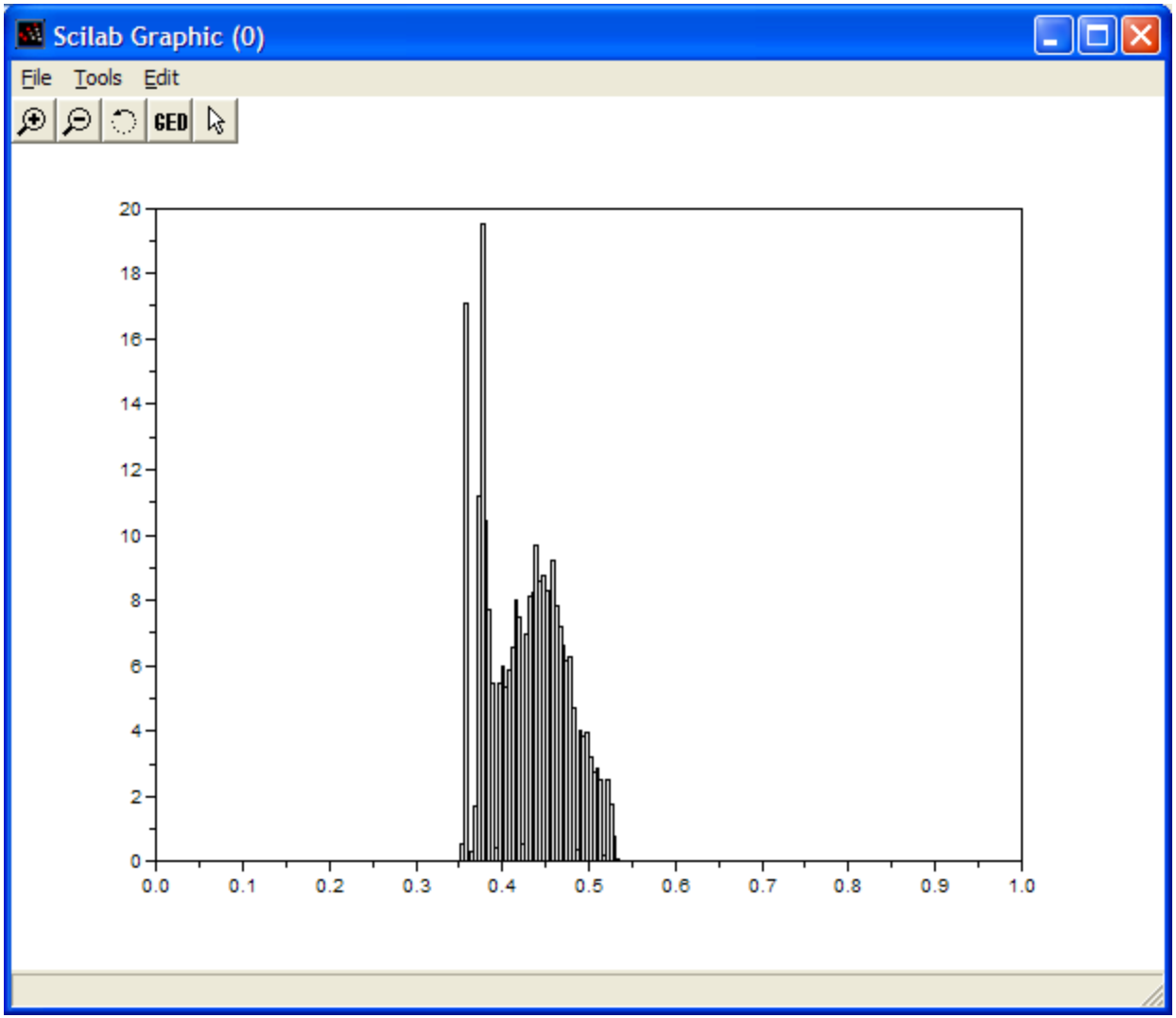

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

# Histogram Examples (cont…)



# Histogram Examples (cont…)

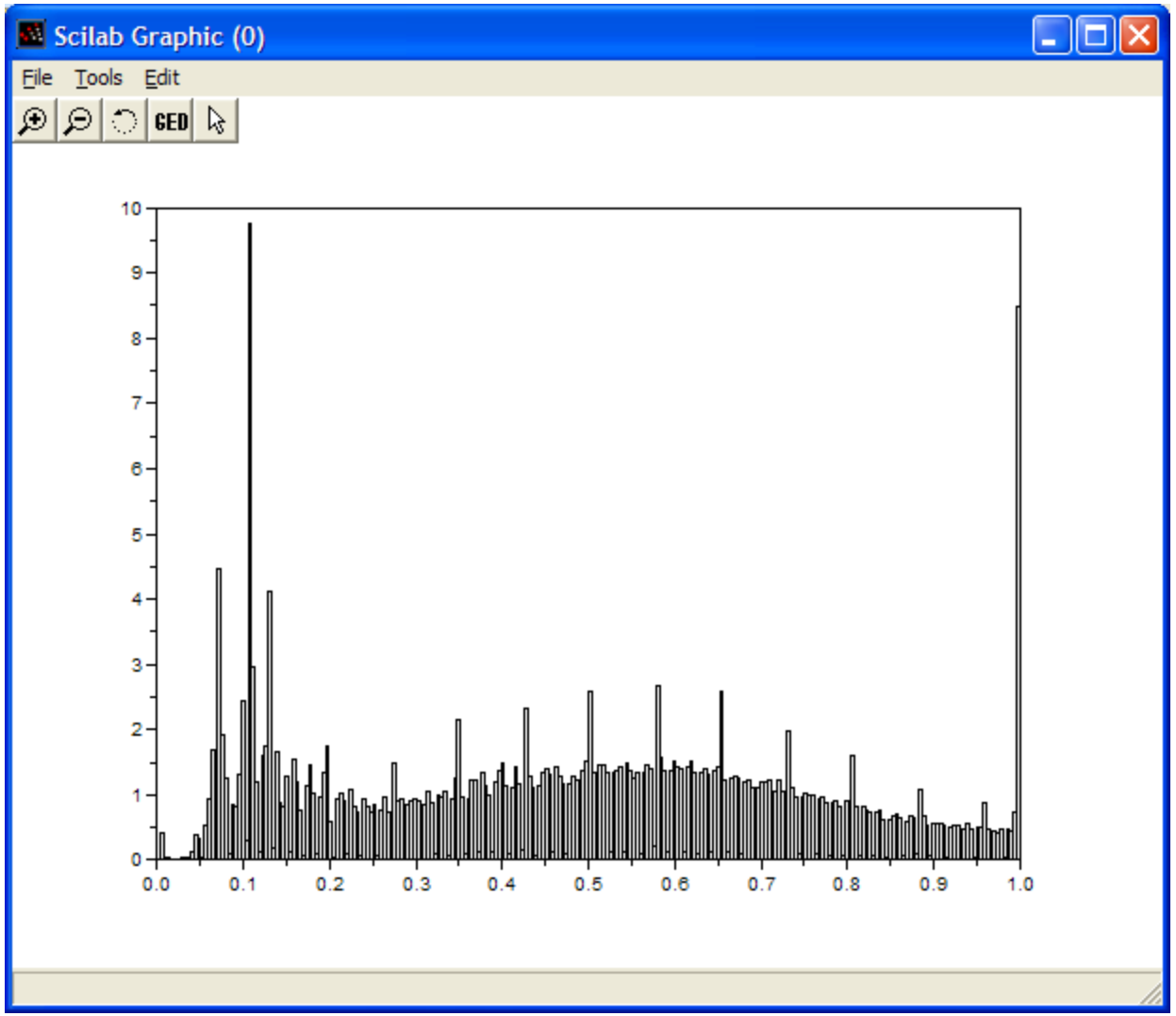





Images taken from Gonzalez & Woods, Digital Image Processing (2002)

# Histogram Examples (cont…)

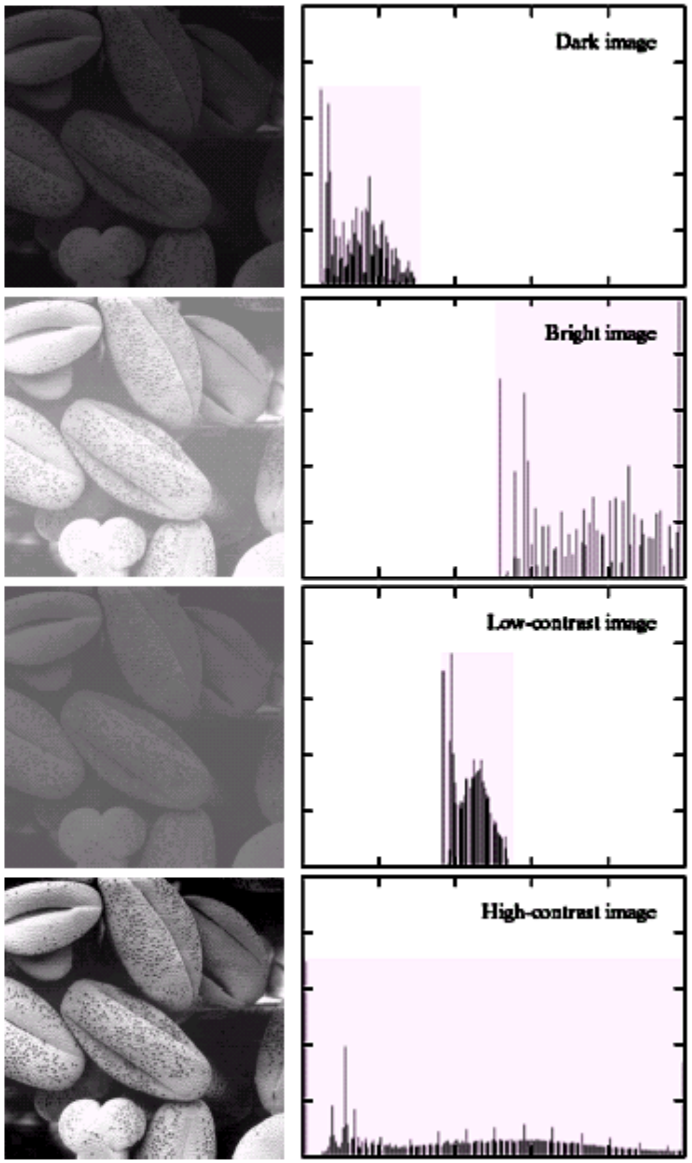
# Histogram Examples (cont…)




Images taken from Gonzalez & Woods, Digital Image Processing (2002)

# 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

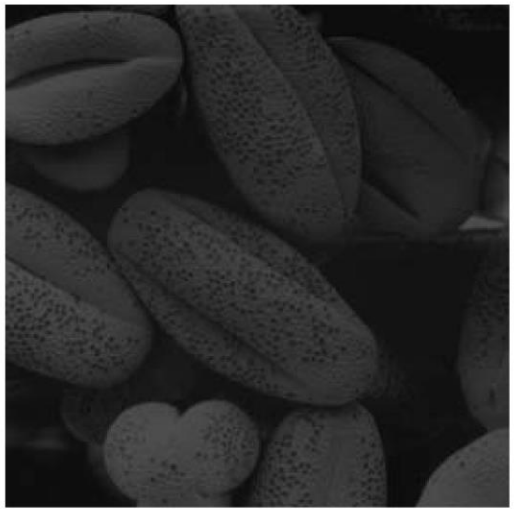


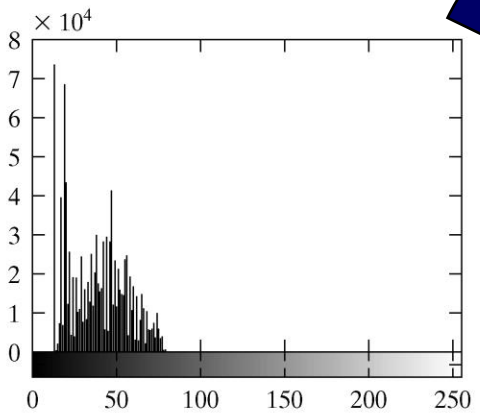
# Contrast Stretching

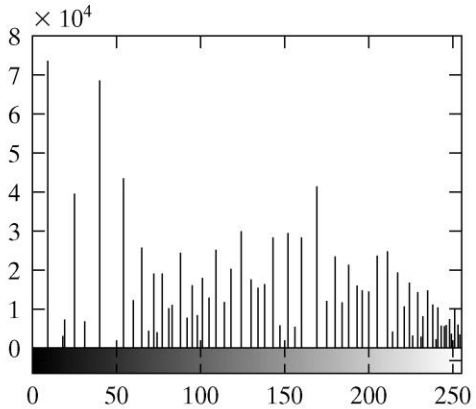
We can fix images that have poor contrast by applying a pretty simple contrast specification

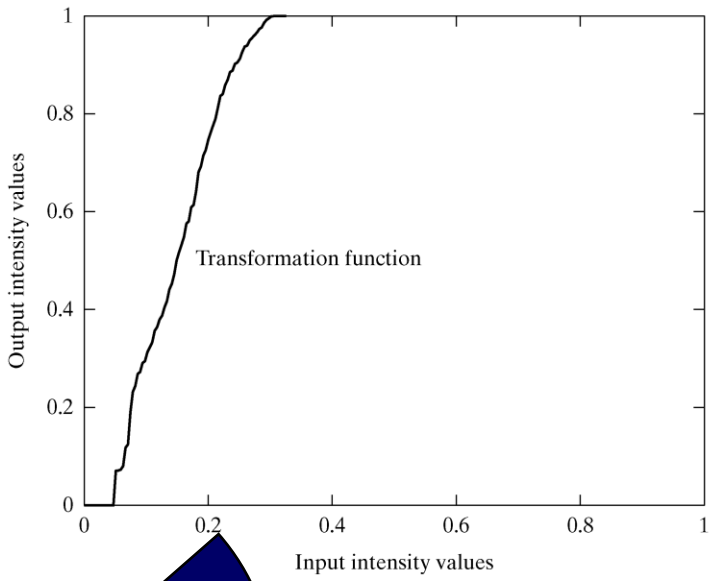
The interesting part is how do we decide on this transformation function?

# Equalisation Transformation Function



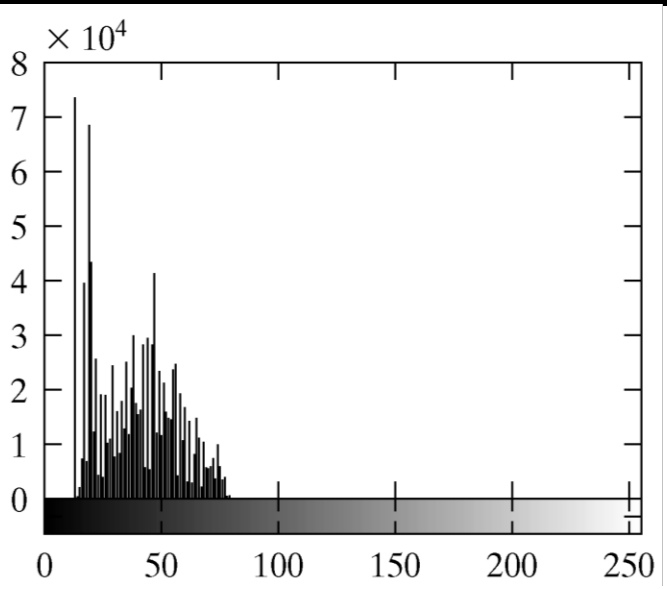


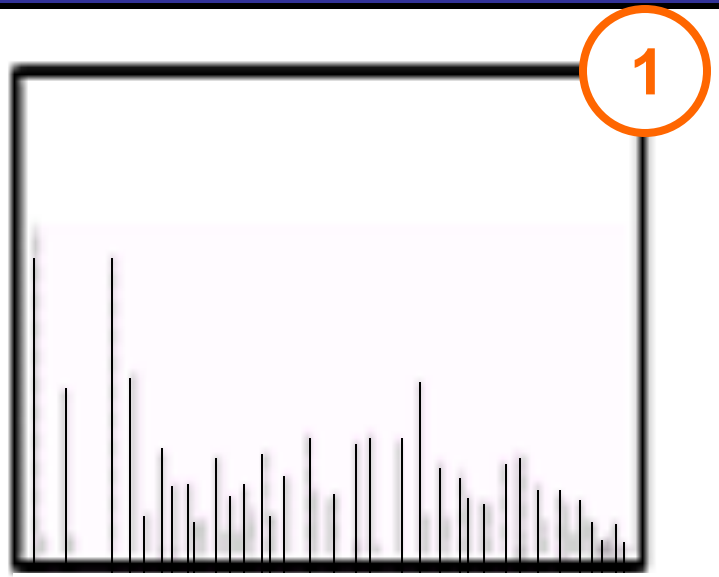



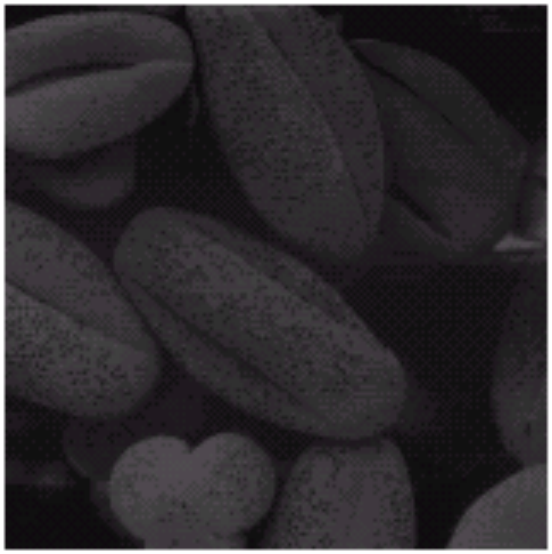




Images taken from Gonzalez & Woods, Digital Image Processing (2002)

# Equalisation Examples

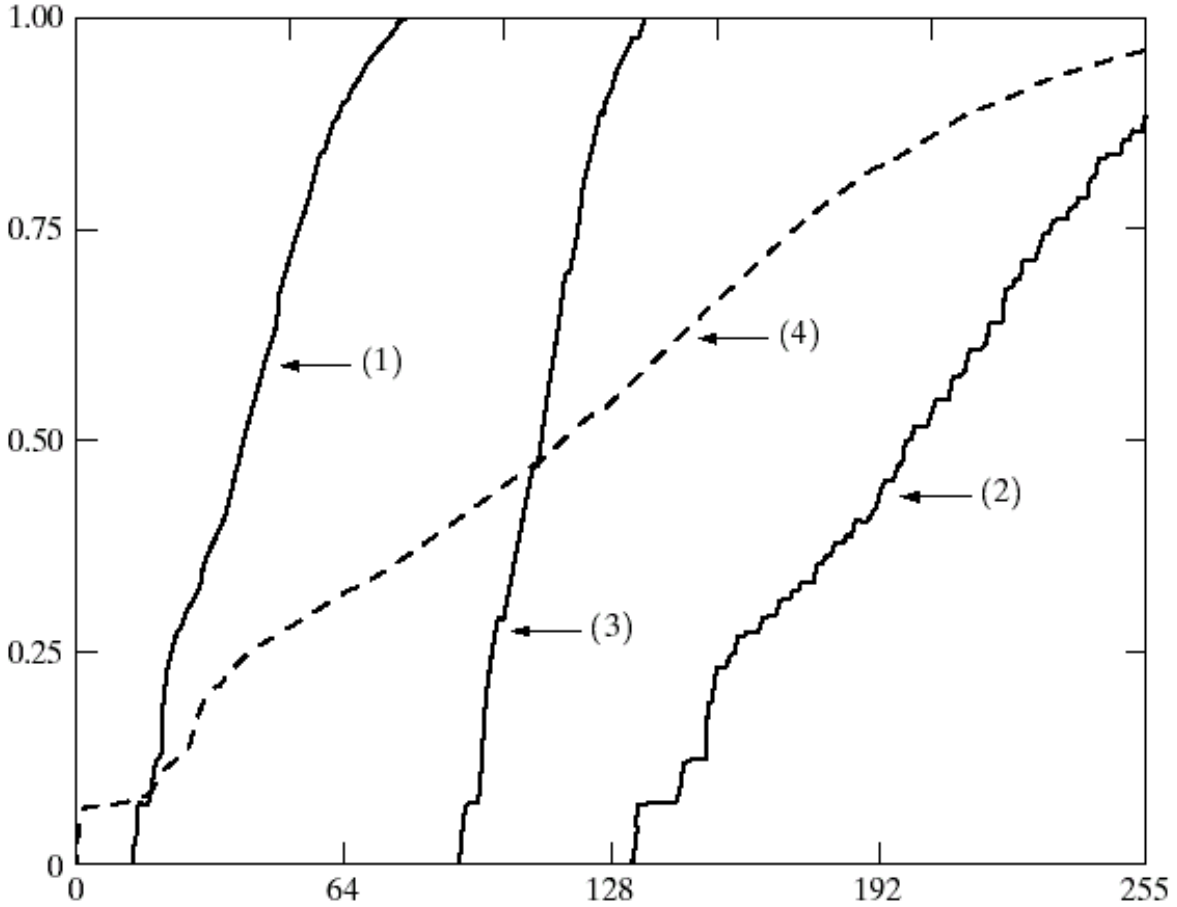


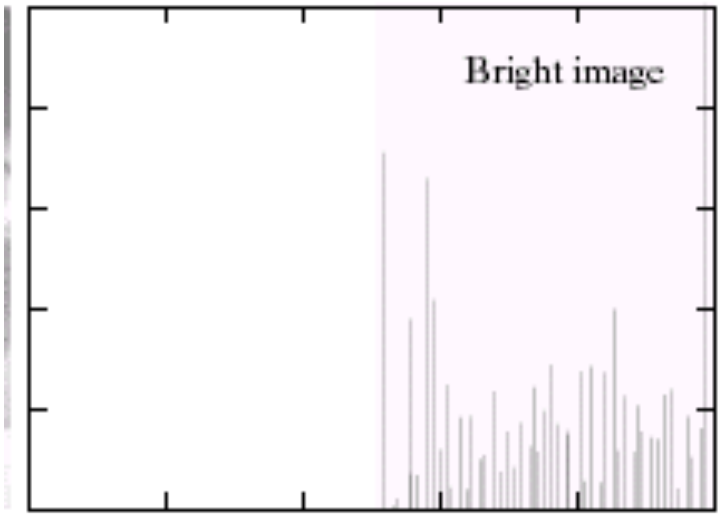



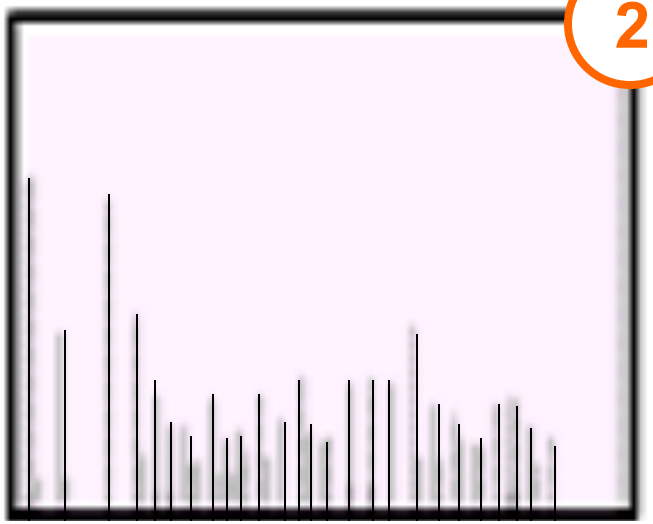
# Equalisation Transformation Functions

The functions used to equalise the images in the previous example



# Equalisation Examples

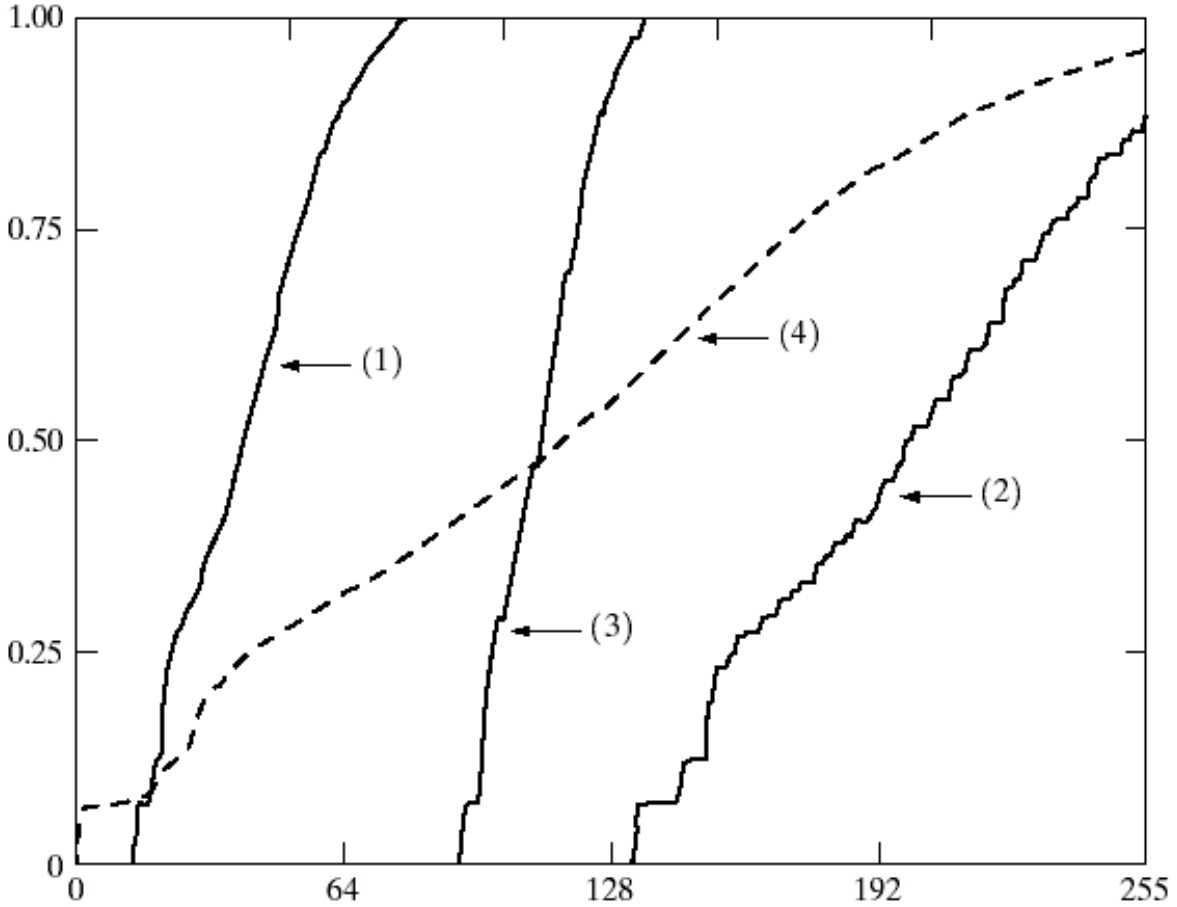


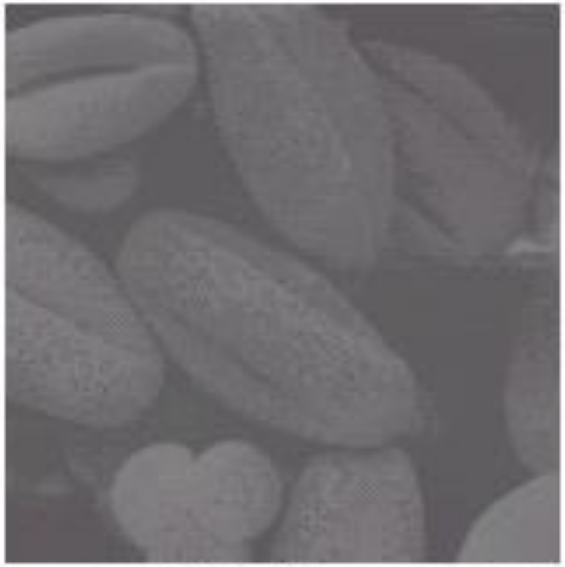

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

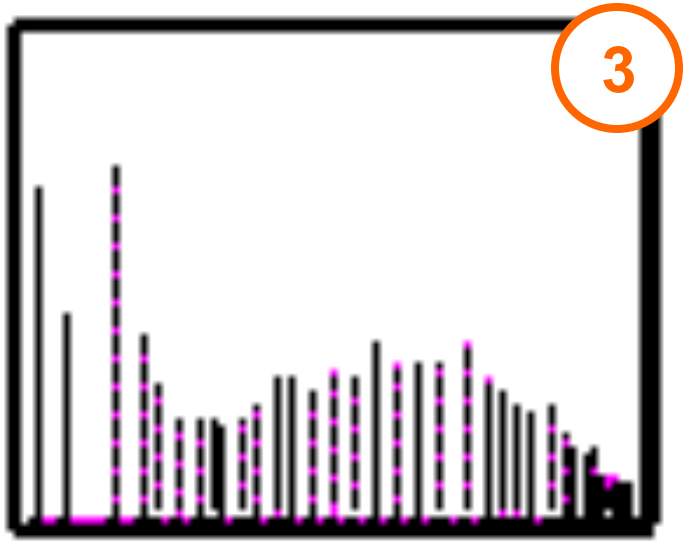
# Equalisation Transformation Functions

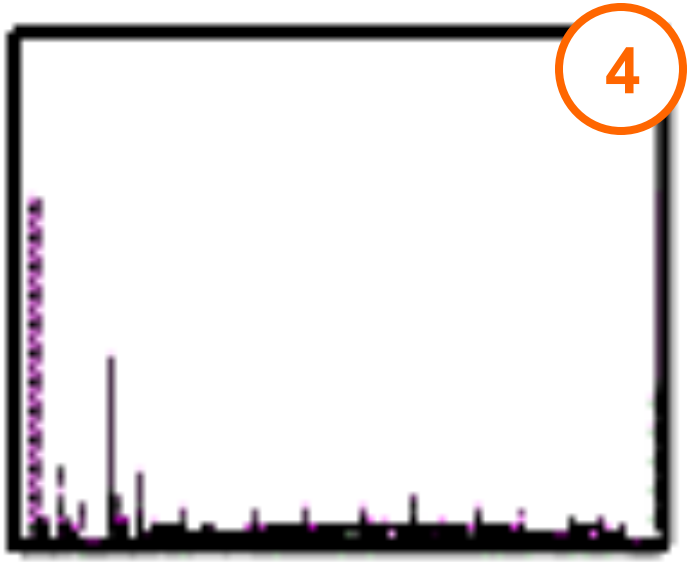
The functions used to equalise the images in the previous example



# Equalisation Examples (cont…)

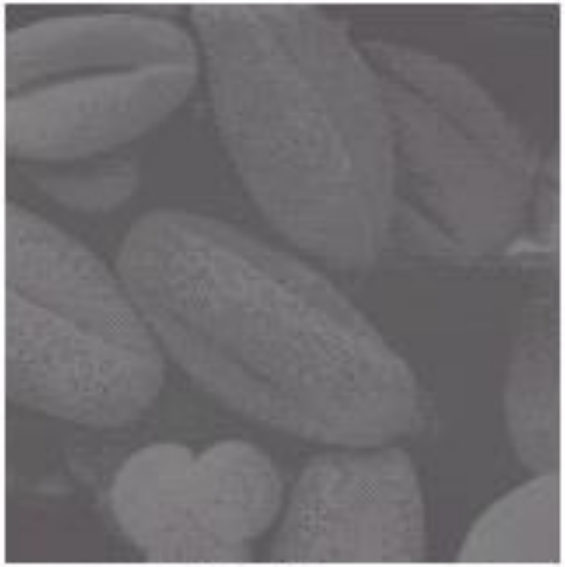


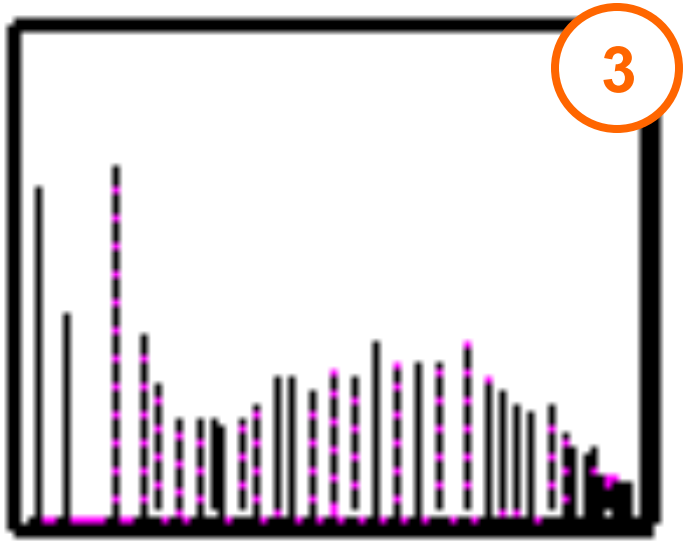


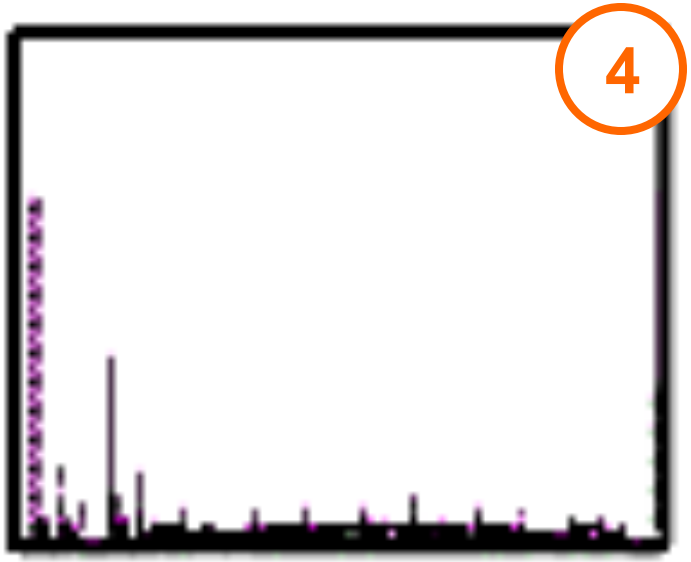




Images taken from Gonzalez & Woods, Digital Image Processing (2002)

# Equalisation Examples (cont…)



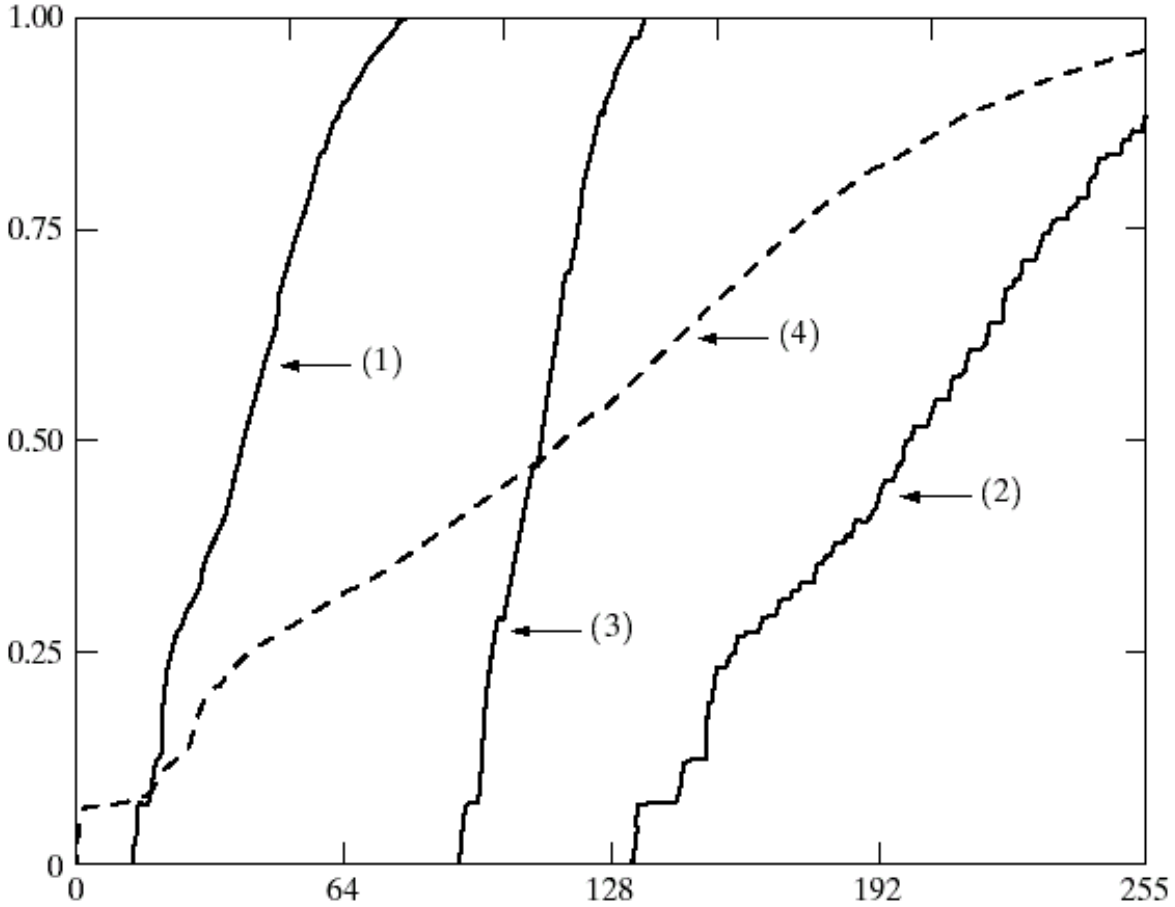


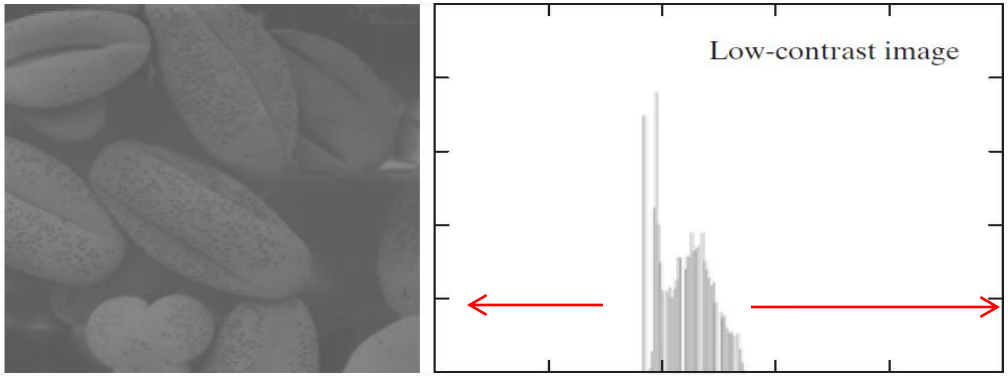

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

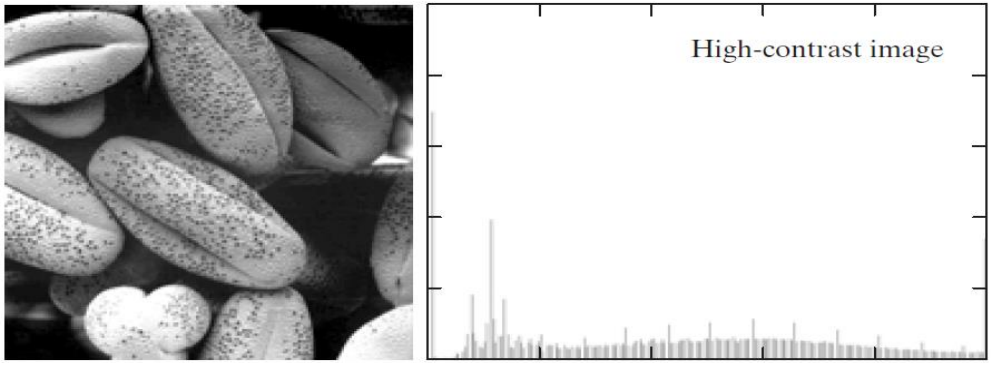
# Equalisation Transformation Functions

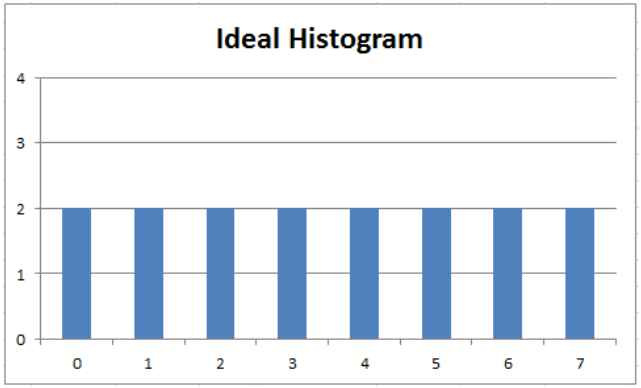
The functions used to equalise the images in the previous examples



# Histogram equalization



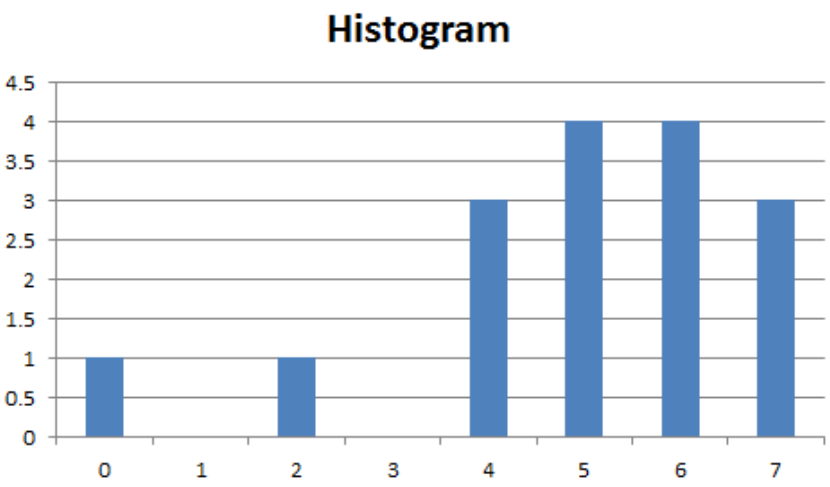
- Cumulative Distribution Function: $cdf(r)$ the total number of pixels with intensity up to *r*

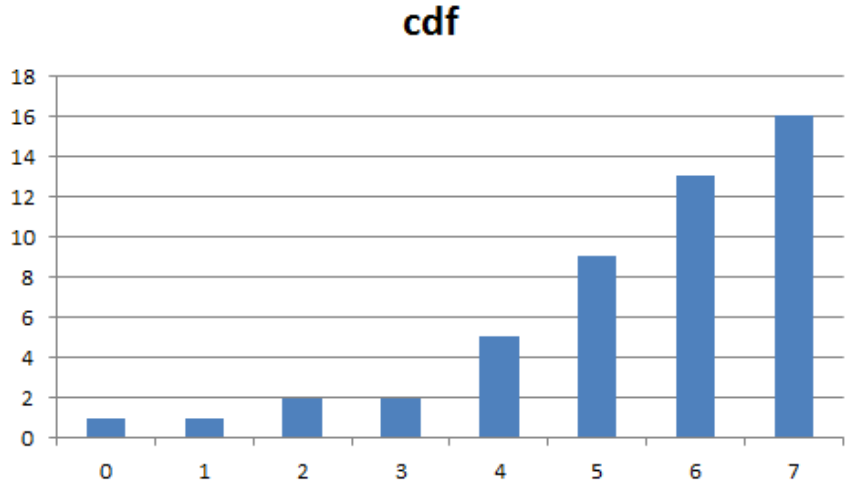
$$cdf(r) = \sum_{i=0}^{r} h(i)$$

- Histogram $h(r)$ the number of pixels with intensity *r*

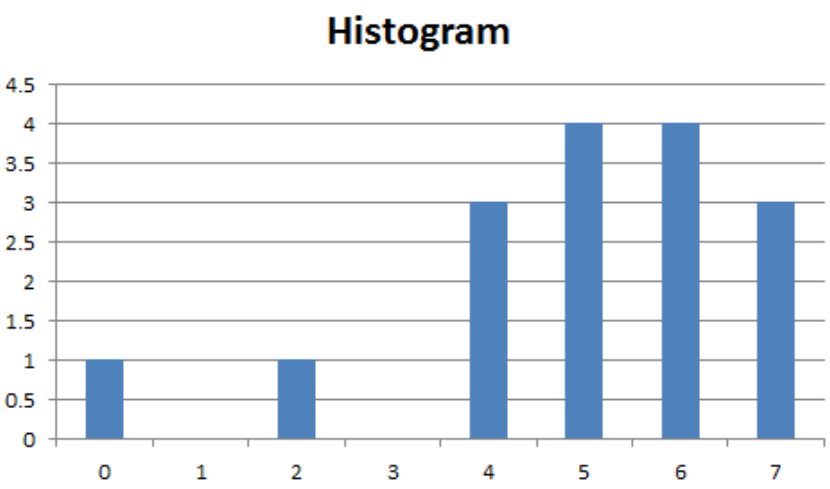
| Intensity | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Histogram | 1 | 0 | 1 | 0 | 3 | 4 | 4 | 3 |
| N.Histogram | 0.0625 | 0 | 0.0625 | 0 | 0.1875 | 0.25 | 0.1875 | 0. 25 |
| cdf | 1 | 1 | 2 | 2 | 5 | 9 | 13 | 16 |

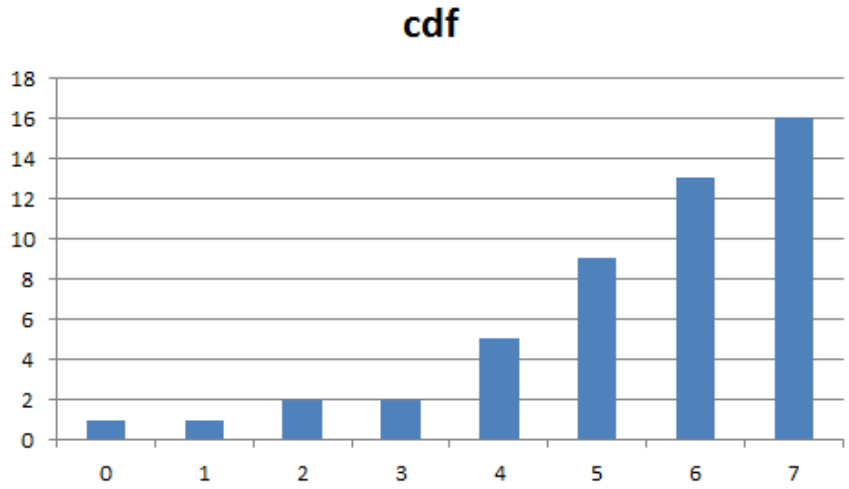
# Histogram and cumulative distribution function



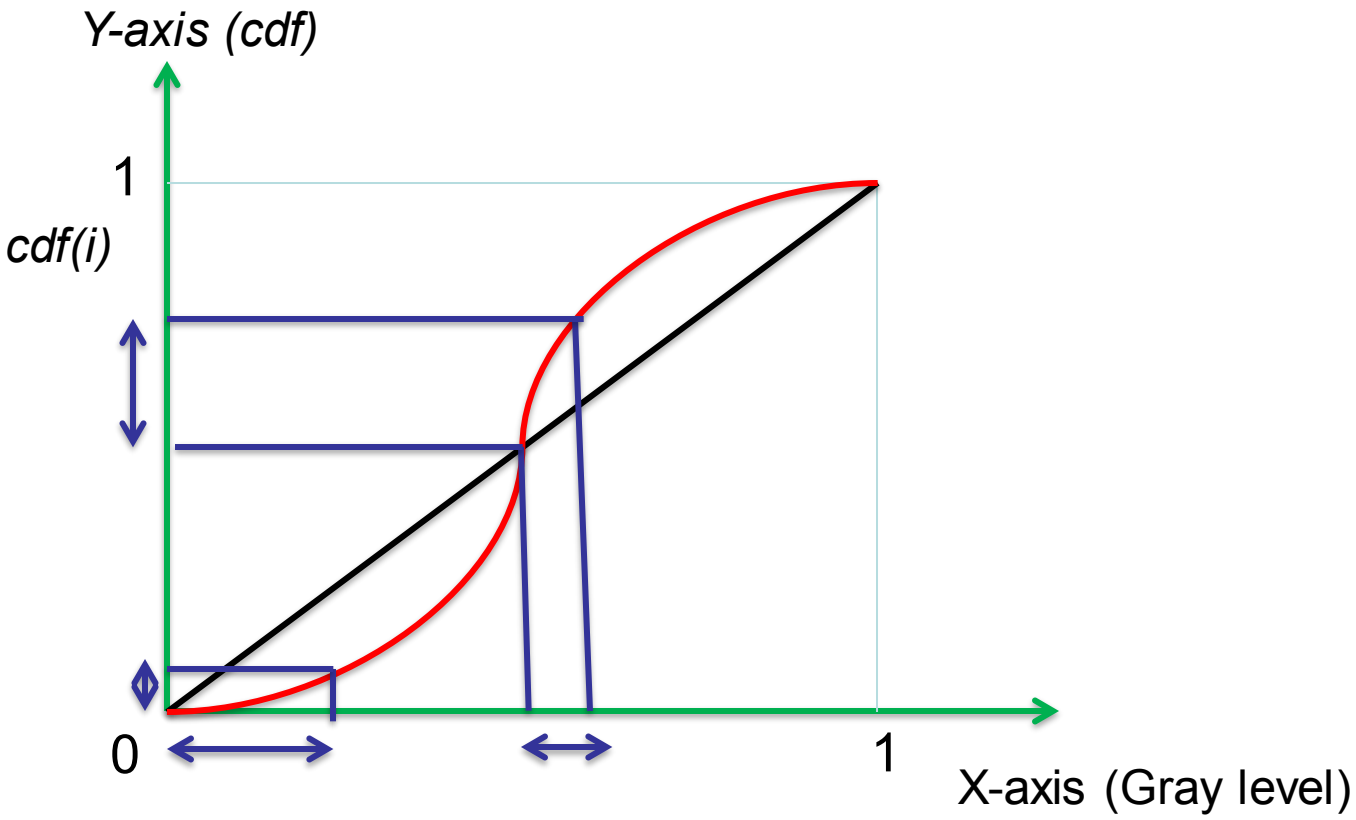
# Histogram and CDF are identical




Ideal histogram ⇔ Ideal CDF

# Histogram Equalization Technique



# Histogram Equalization Technique

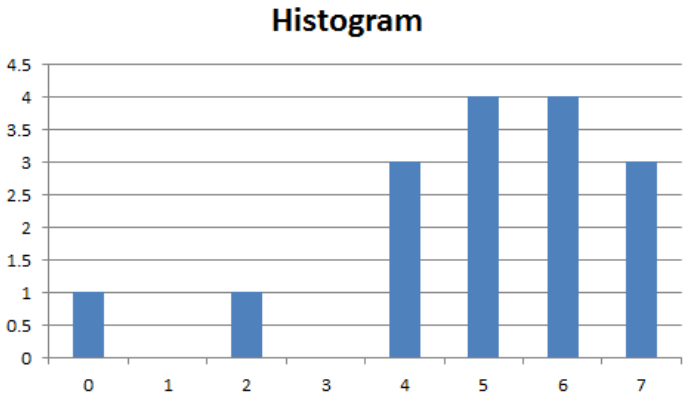
| | | | |
|---|---|---|---|
| **2** | **5** | **7** | **6** |
| **4** | **5** | **4** | **7** |
| **6** | **5** | **6** | **4** |
| **0** | **7** | **5** | **6** |

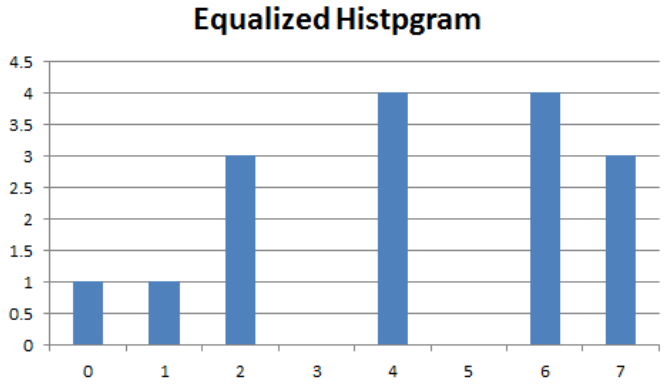
| Intensity | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Histogram | 1 | 0 | 1 | 0 | 3 | 4 | 4 | 3 |
| N.Histogram | 0.0625 | 0 | 0.0625 | 0 | 0.1875 | 0.25 | 0.1875 | 0. 25 |
| cdf | 1 | 1 | 2 | 2 | 5 | 9 | 13 | 16 |
| N.cdf | 0.0625 | 0.0625 | 0.125 | 0.125 | 0.3125 | 0.5625 | 0.8125 | 1 |
| N.cdf*L | 0.4375 | 0.4375 | 0.875 | 0.875 | 2.1875 | 3.9375 | 5.6875 | 7 |
| New Intensity | 0 | 0 | 1 | 1 | 2 | 4 | 6 | 7 |

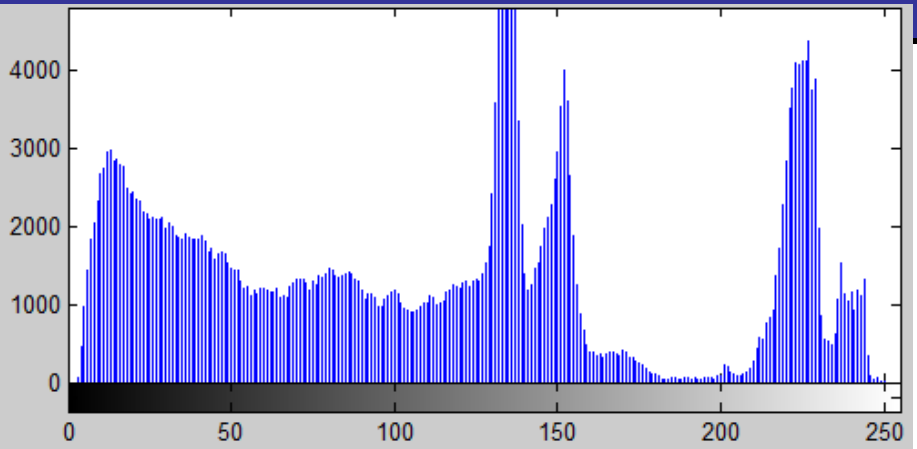
# Histogram Equalization Technique

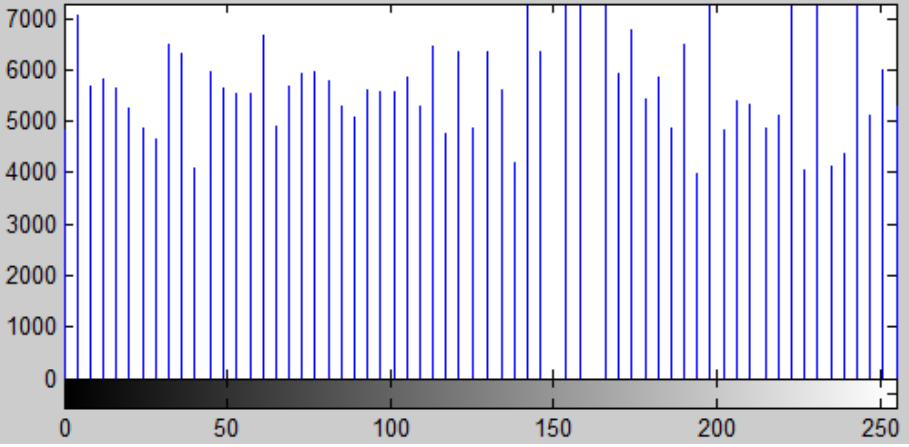
| | | | |
|---|---|---|---|
| 2 | 5 | 7 | 6 |
| 4 | 5 | 4 | 7 |
| 6 | 5 | 6 | 4 |
| 0 | 7 | 5 | 6 |

| | | | |
|---|---|---|---|
| 1 | 4 | 7 | 6 |
| 2 | 4 | 2 | 7 |
| 6 | 4 | 6 | 2 |
| 0 | 7 | 4 | 6 |




4000
3000
2000
1000
0
0
50
100
150
200
250


7000
6000
5000
4000
3000
2000
1000
0
0
50
100
150
200
250

Thank you for your attention !