Digital Image Processing: Digital Imaging Fundamentals

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Contents

This lecture will cover:

- The human visual system
- Light and the electromagnetic spectrum
- Image representation
- Image sensing and acquisition
- Sampling, quantisation and resolution

Human Visual System

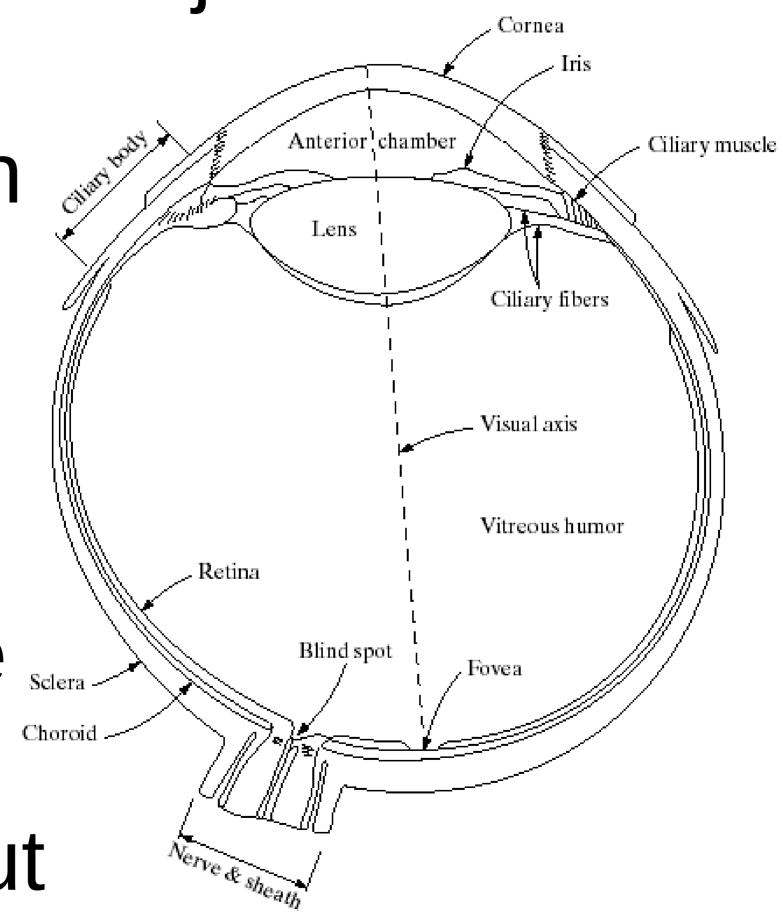
The best vision model we have!

Knowledge of how images form in the eye can help us with processing digital images

We will take just a whirlwind tour of the human visual system

Structure Of The Human Eye

The lens focuses light from objects onto the retina



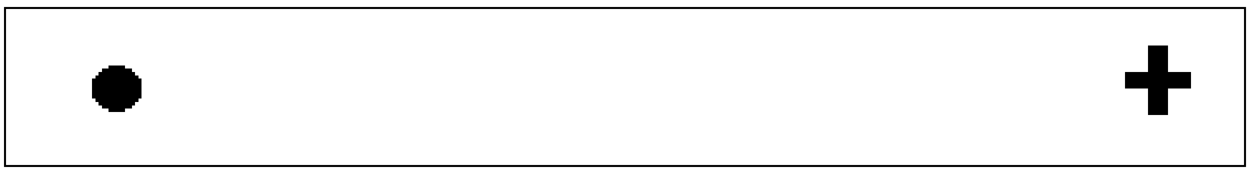
The retina is covered with light receptors called *cones* (6-7 million) and *rods* (75-150 million)

Cones are concentrated around the fovea and are very sensitive to colour

Rods are more spread out and are sensitive to low levels of illumination

Blind-Spot Experiment

Draw an image similar to that below on a piece of paper (the dot and cross are about 6 inches apart)



Close your right eye and focus on the cross with your left eye

Hold the image about 20 inches away from your face and move it slowly towards you

The dot should disappear!

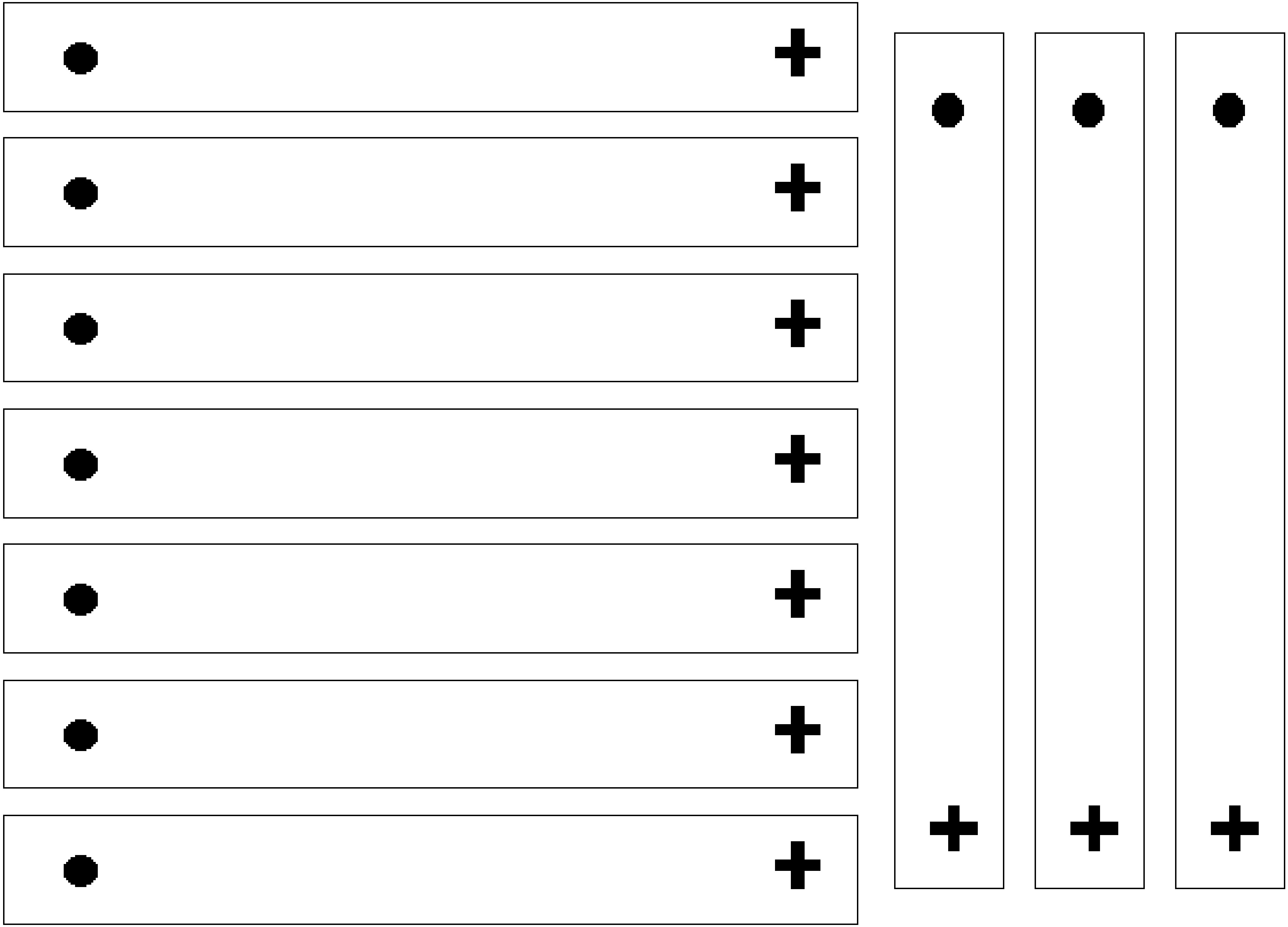
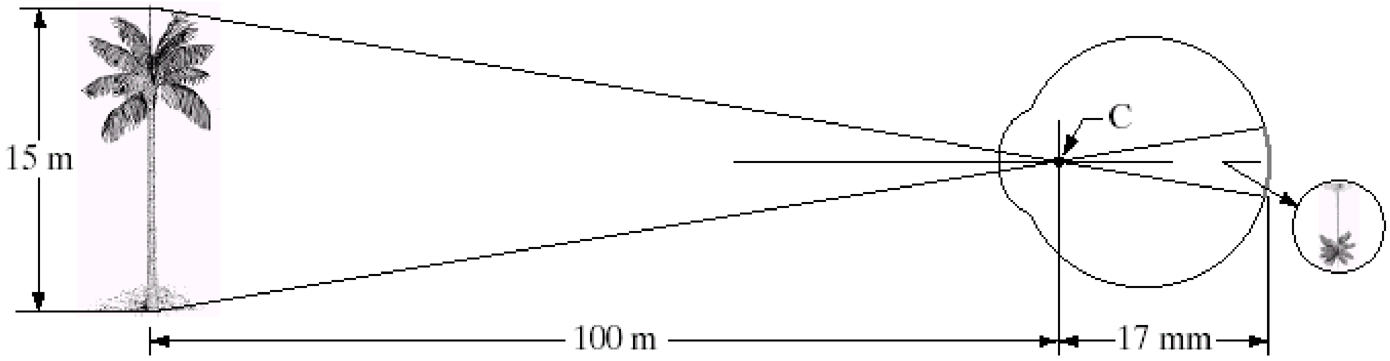


Image Formation In The Eye

Muscles within the eye can be used to change the shape of the lens allowing us focus on objects that are near or far away

An image is focused onto the retina causing rods and cones to become excited which ultimately send signals to the brain



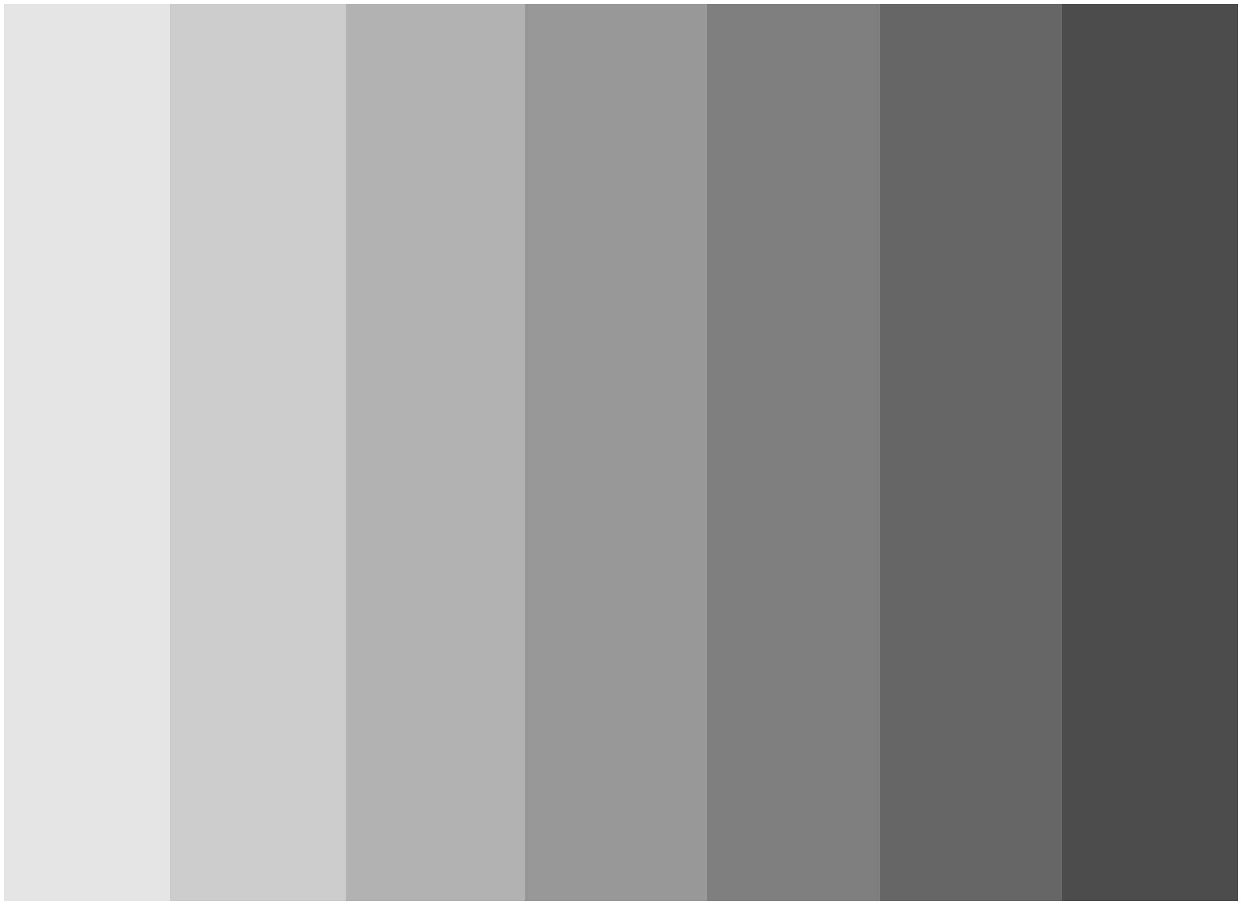
Brightness Adaptation & Discrimination

The human visual system can perceive approximately 10^{10} different light intensity levels

However, at any one time we can only discriminate between a much smaller number – *brightness adaptation*

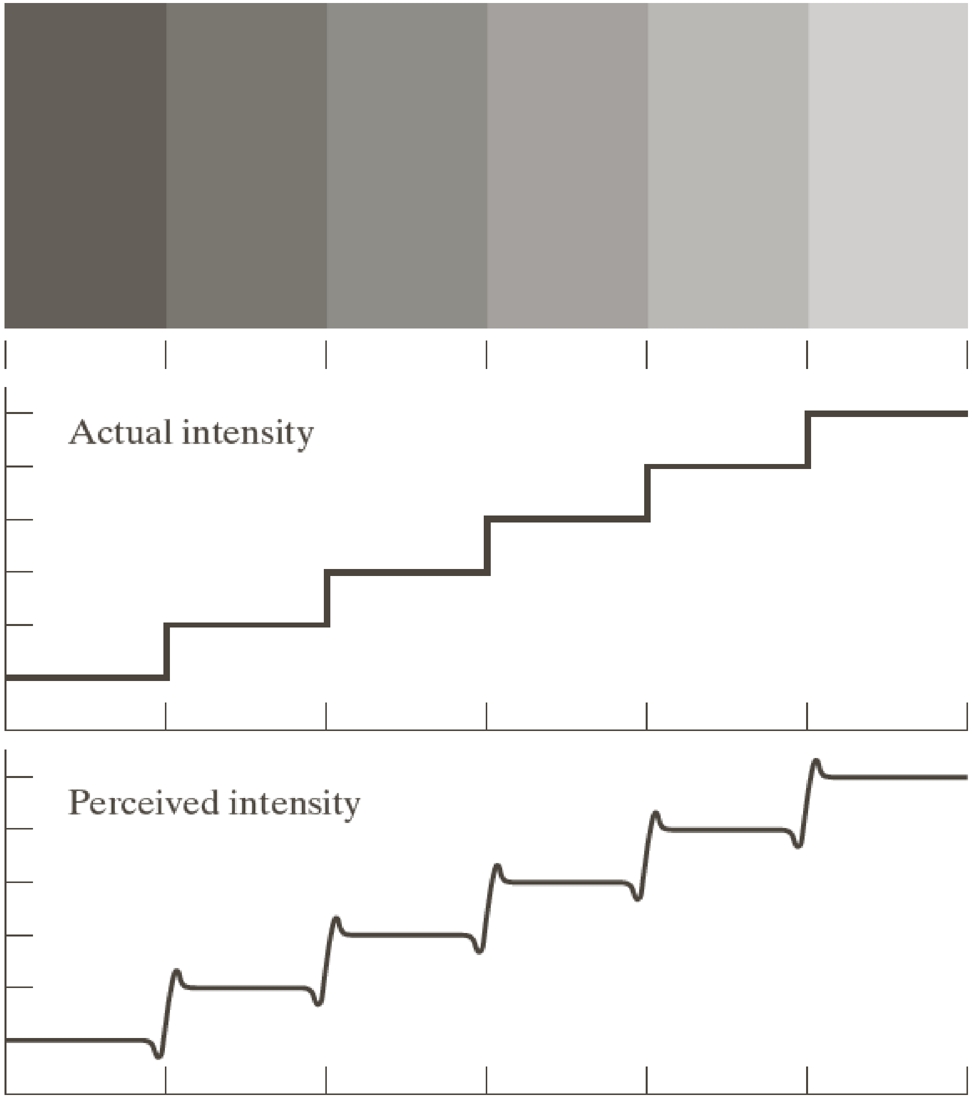
Similarly, the *perceived intensity* of a region is related to the light intensities of the regions surrounding it

Brightness Adaptation & Discrimination (cont…)

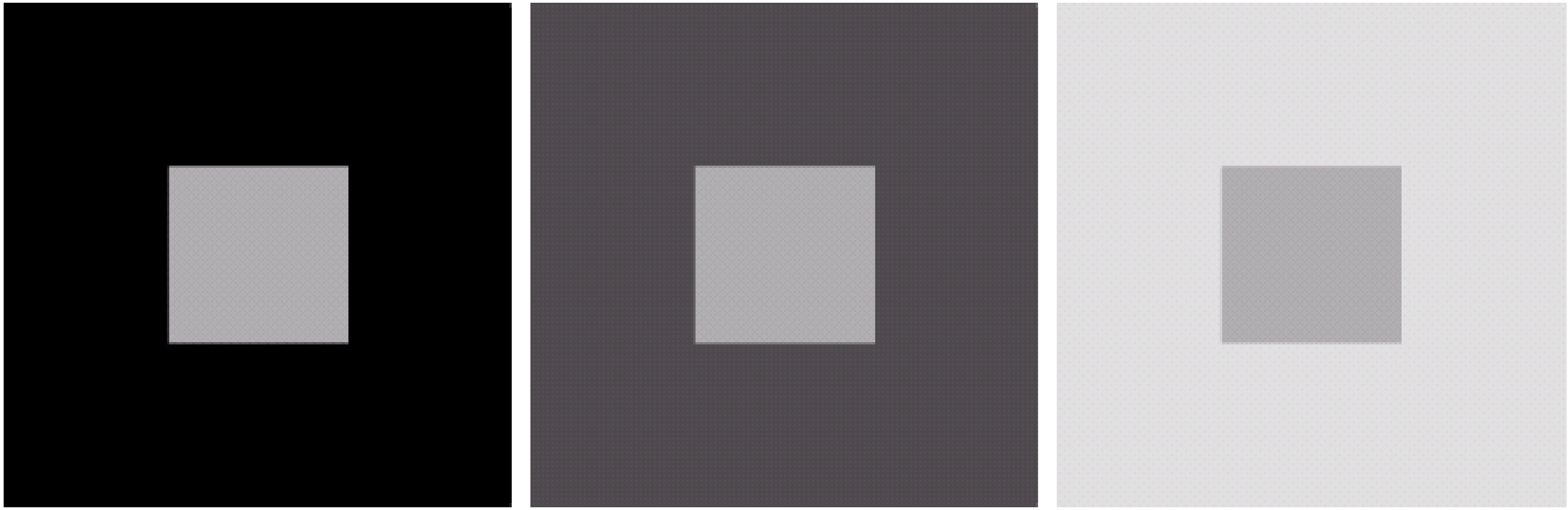


An example of Mach bands

Brightness Adaptation & Discrimination (cont…)

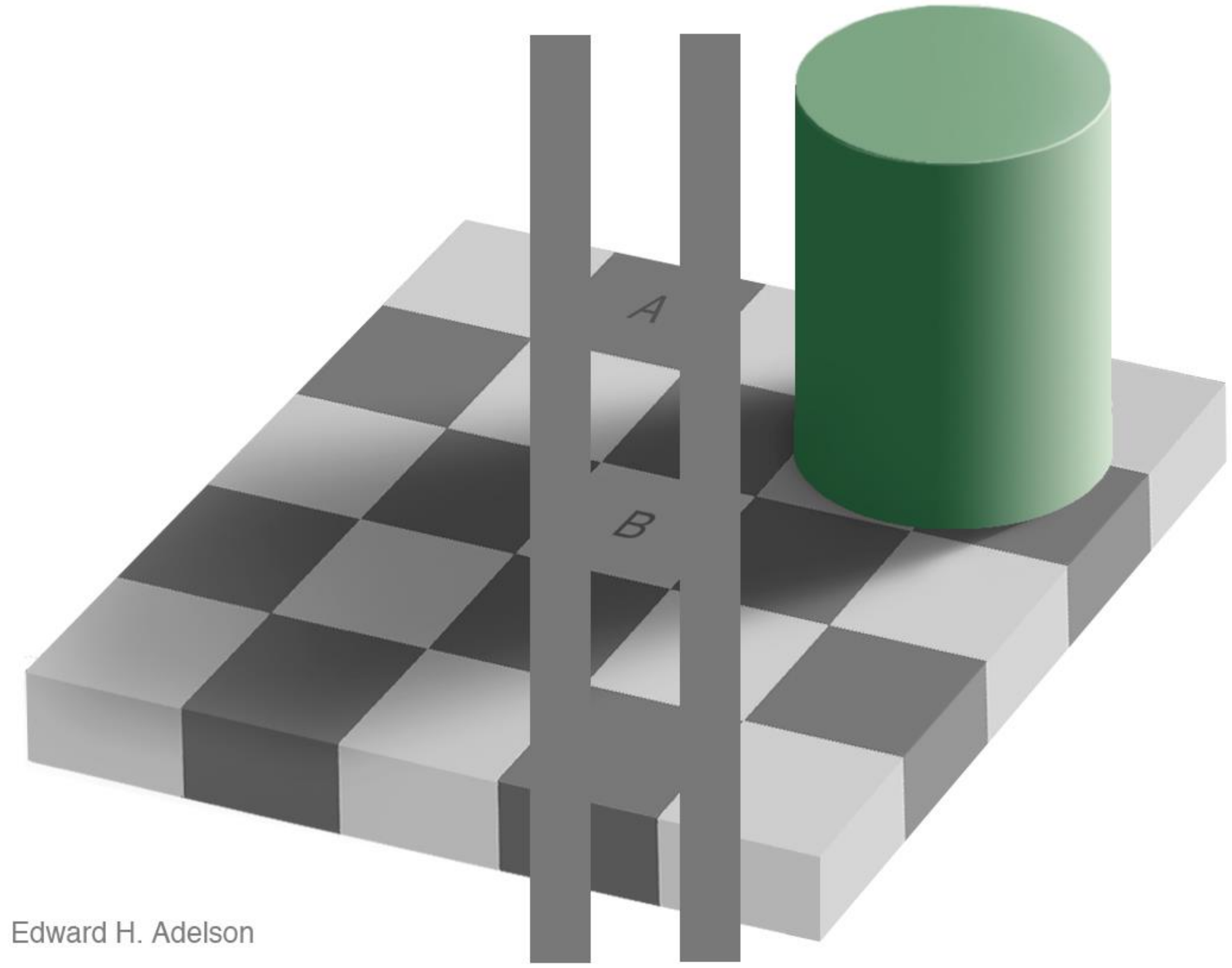


Brightness Adaptation & Discrimination (cont…)

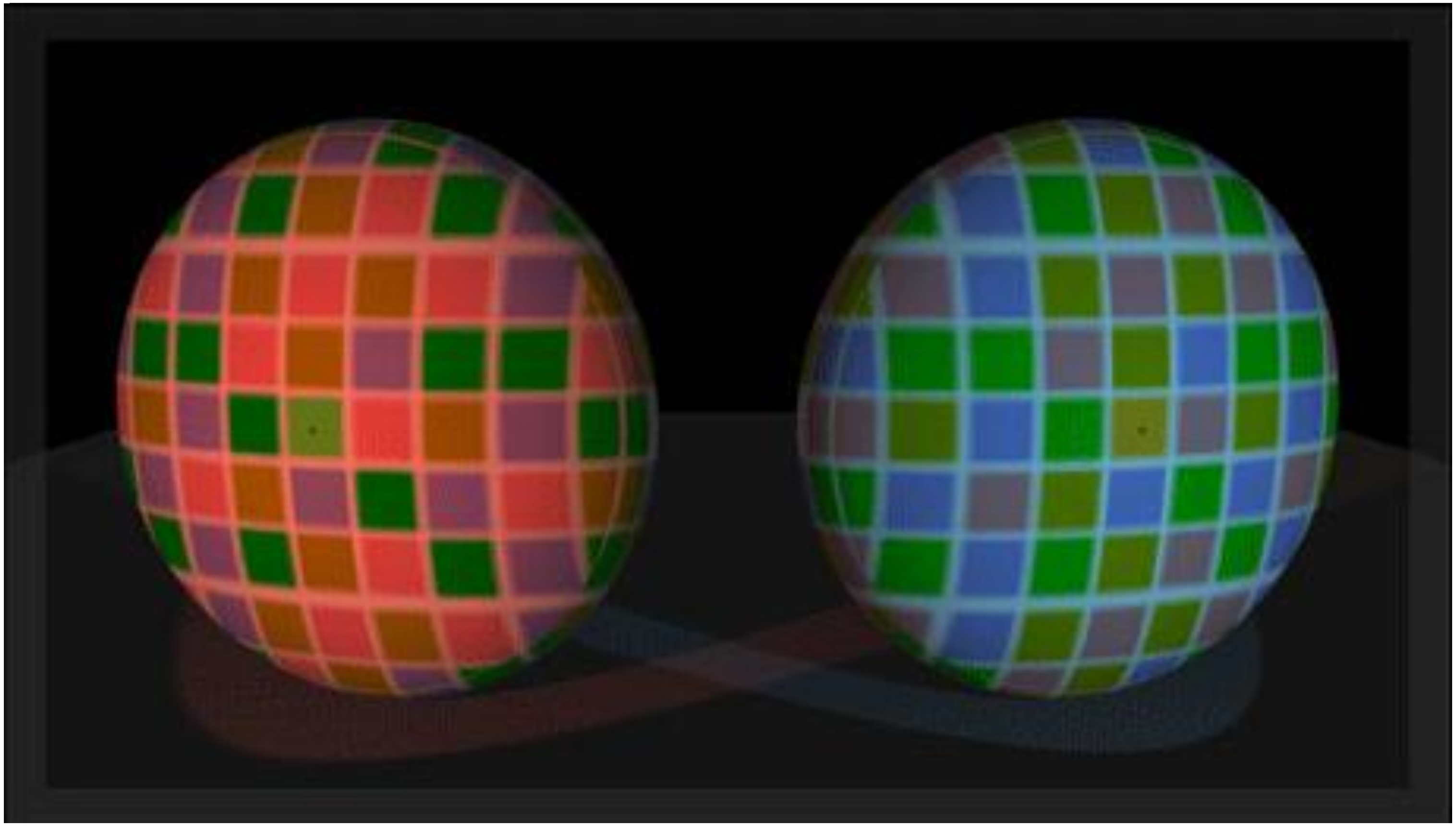


An example of *simultaneous contrast*

Brightness Adaptation & Discrimination (cont…)



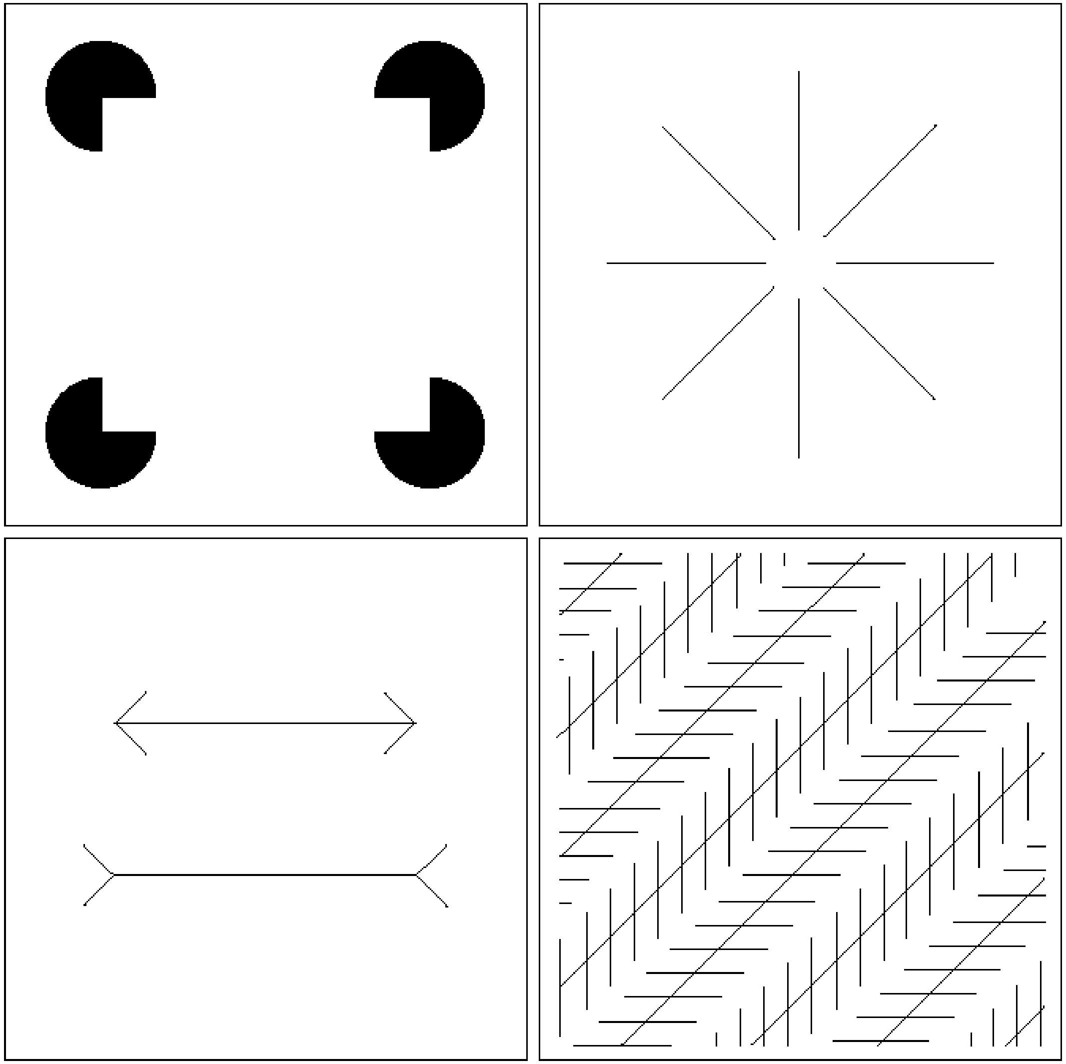
For more great illusion examples take a look at: http://web.mit.edu/persci/gaz/



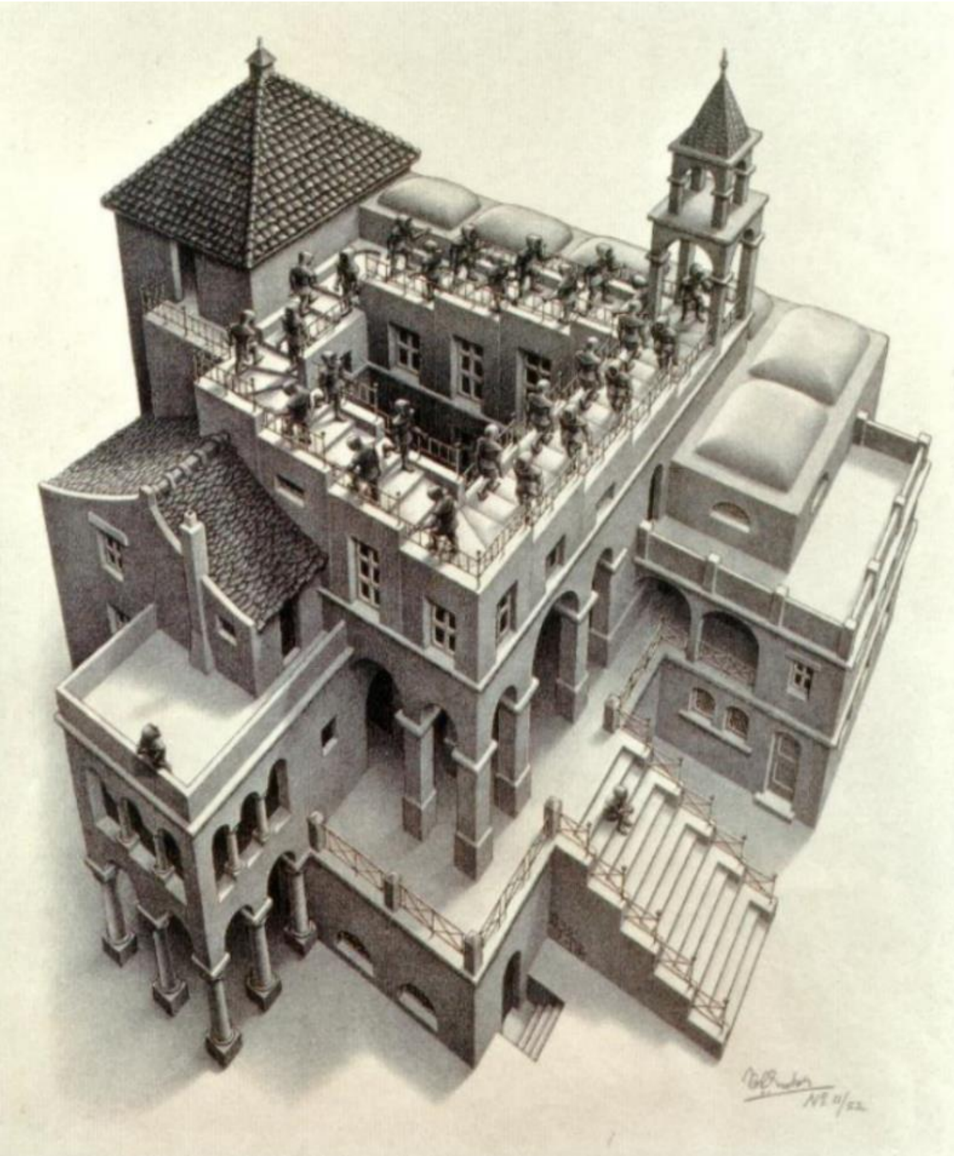
Available here: http://www.lottolab.org/Visual%20Demos/Demo%2015.html

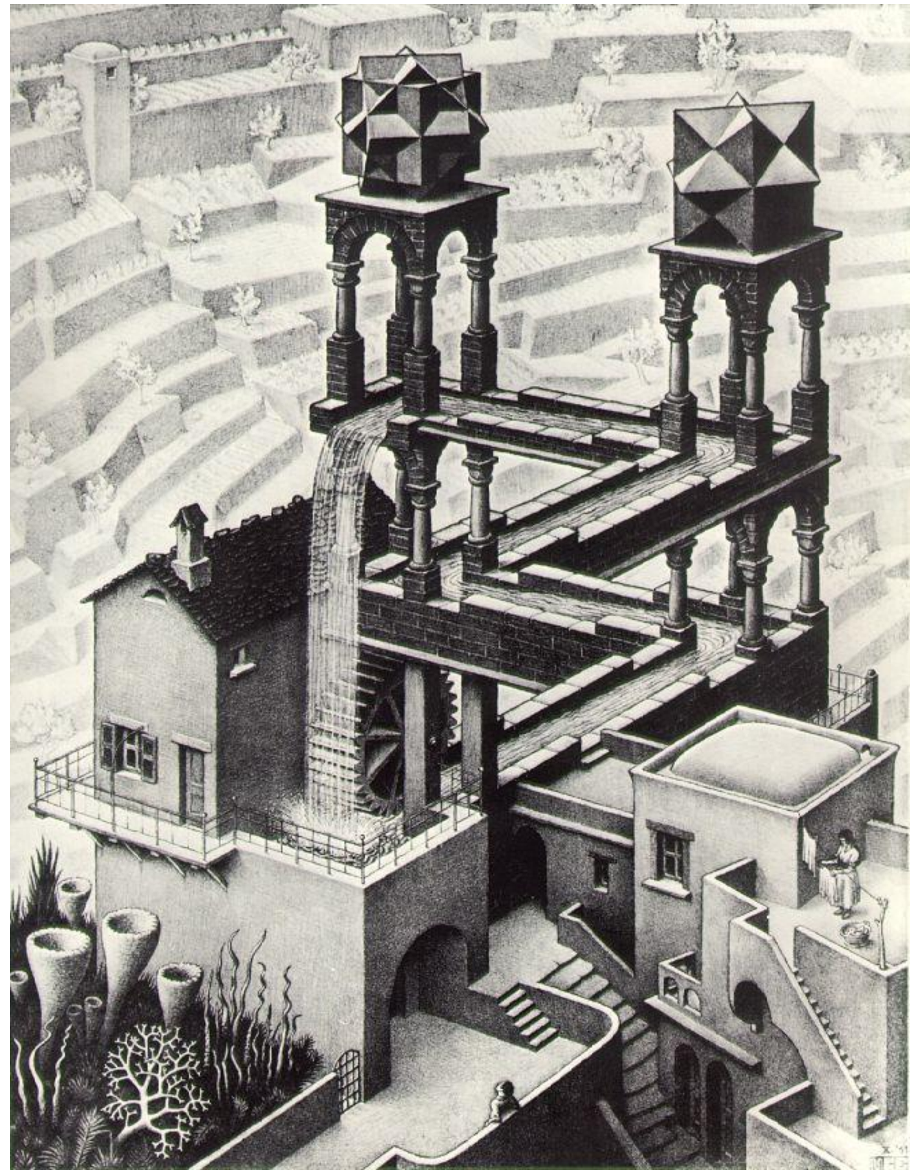
Optical Illusions

Our visual systems play lots of interesting tricks on us

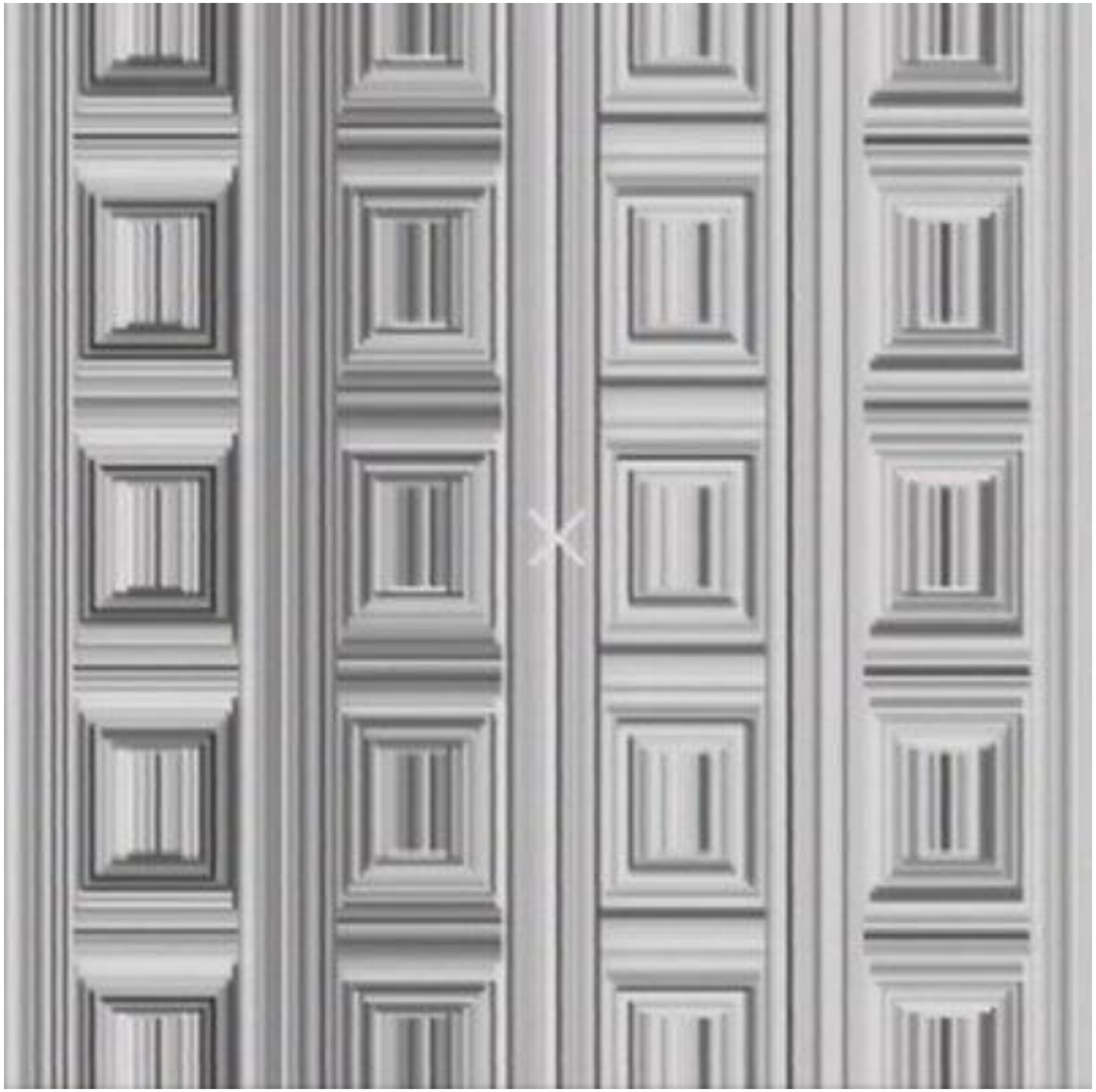


Optical Illusions (cont…)





Optical Illusions (cont…)



Stare at the cross in the middle of the image and think circles

Mind Map Exercise: Mind Mapping For Note Taking

TED Ideas worth spreading

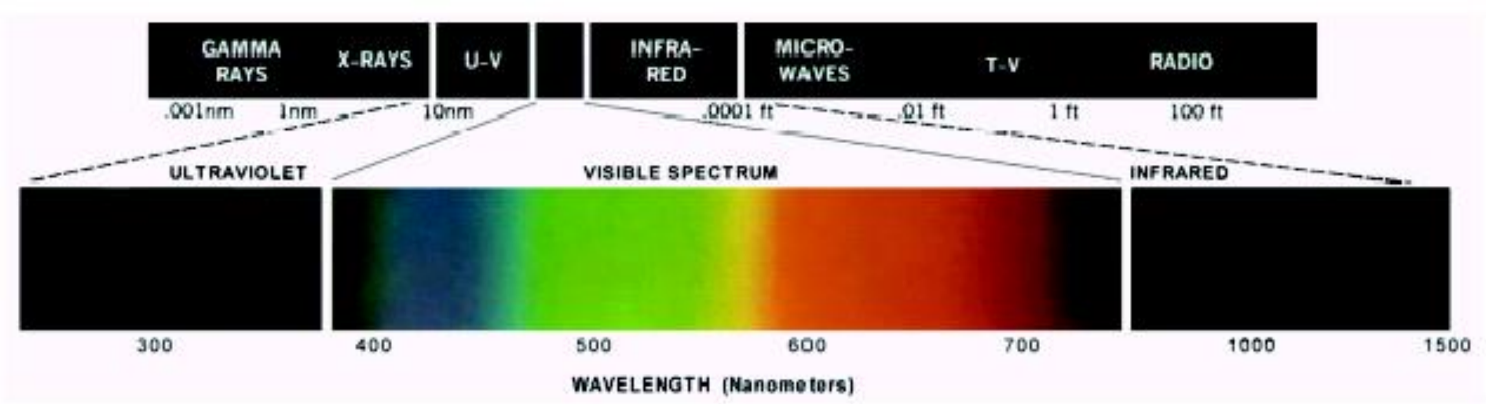
Beau Lotto: Optical Illusions Show How We See

http://www.ted.com/talks/lang/eng/beau_lotto_optical_illusions_show_how_we_see.html

Light And The Electromagnetic Spectrum

Light is just a particular part of the electromagnetic spectrum that can be sensed by the human eye

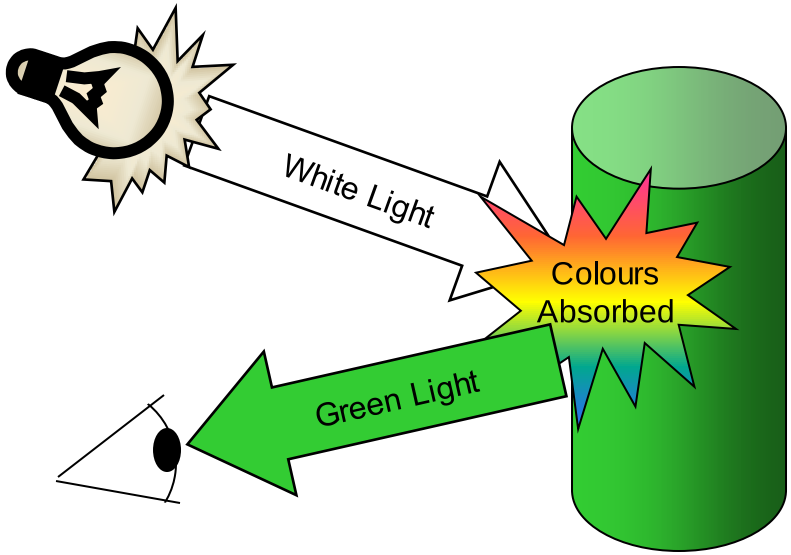
The electromagnetic spectrum is split up according to the wavelengths of different forms of energy



Reflected Light

The colours that we perceive are determined by the nature of the light reflected from an object

For example, if white light is shone onto a green object most wavelengths are absorbed, while green light is reflected from the object



Sampling, Quantisation And Resolution

In the following slides we will consider what is involved in capturing a digital image of a real-world scene

- Image sensing and representation
- Sampling and quantisation
- Resolution

Image Representation

Before we discuss image acquisition recall that a digital image is composed of M rows and N columns of pixels each storing a value

Pixel values are most often grey levels in the range 0-255(black-white)

We will see later on that images can easily be represented as matrices

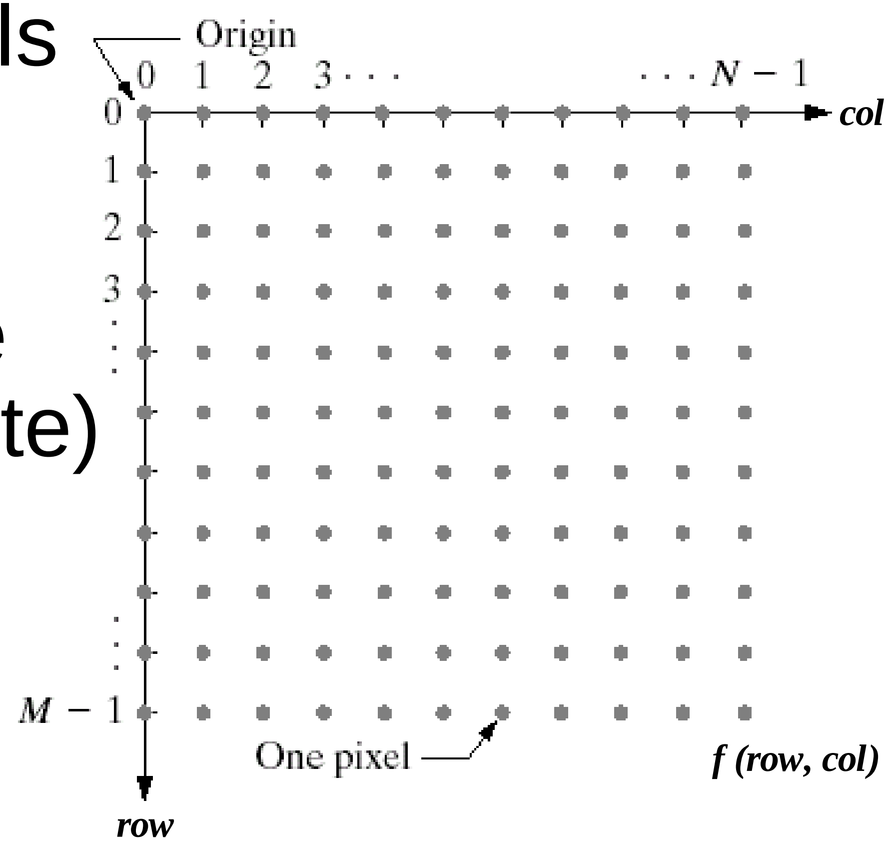
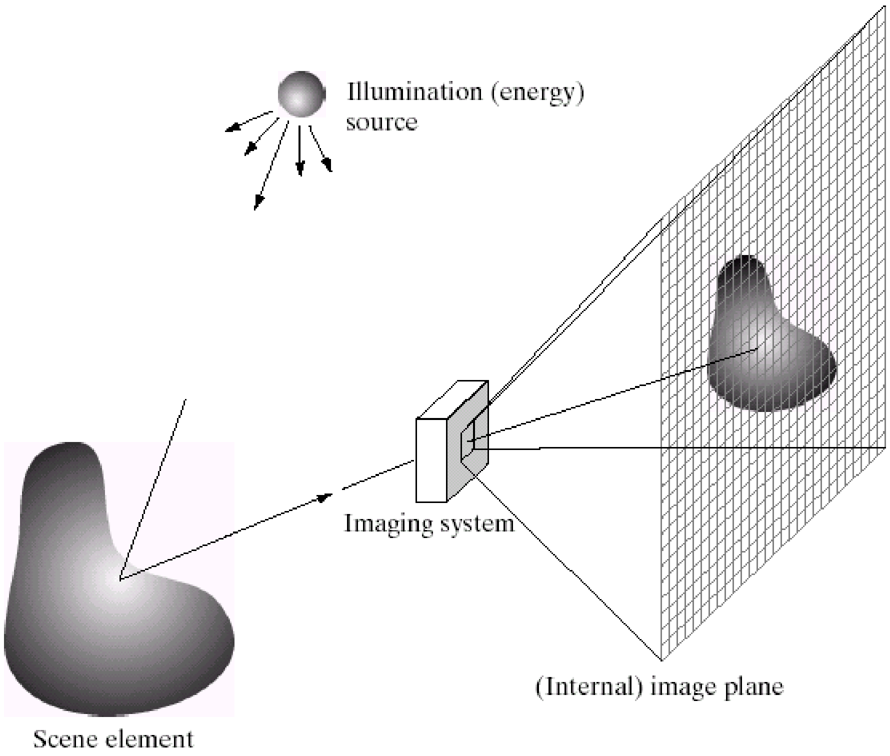


Image Acquisition

Images are typically generated by *illuminating* a *scene* and absorbing the energy reflected by the objects in that scene



– Typical notions of illumination and scene can be way off:
  - X-rays of a skeleton
  - Ultrasound of an unborn baby
  - Electro-microscopic images of molecules

Image Sampling And Quantisation

A digital sensor can only measure a limited number of **samples** at a **discrete** set of energy levels

Quantisation is the process of converting a continuous **analogue** signal into a digital representation of this signal

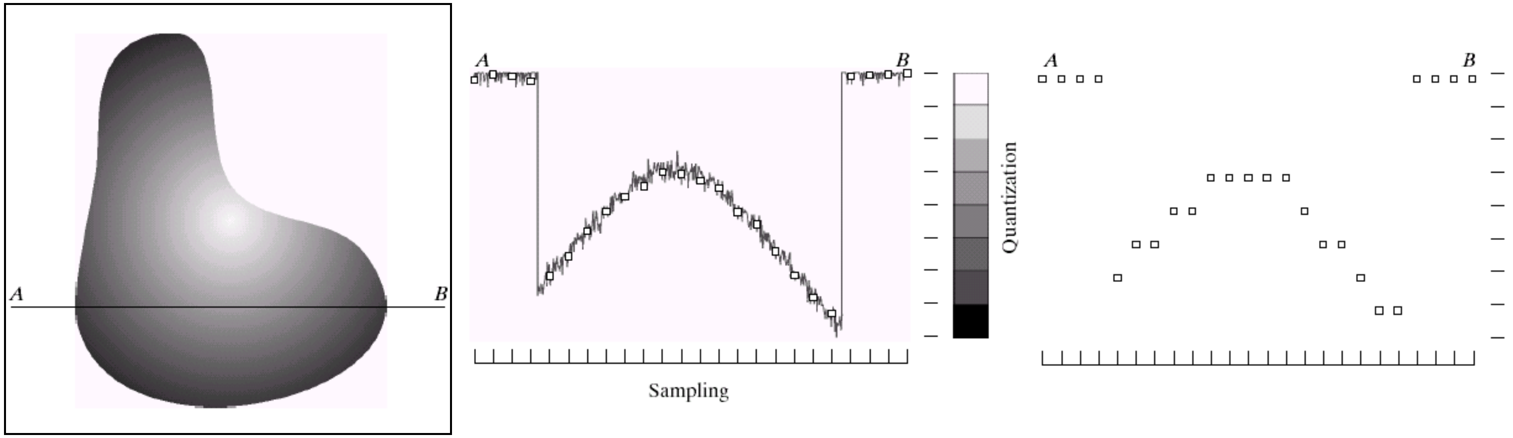


Image Sampling And Quantisation

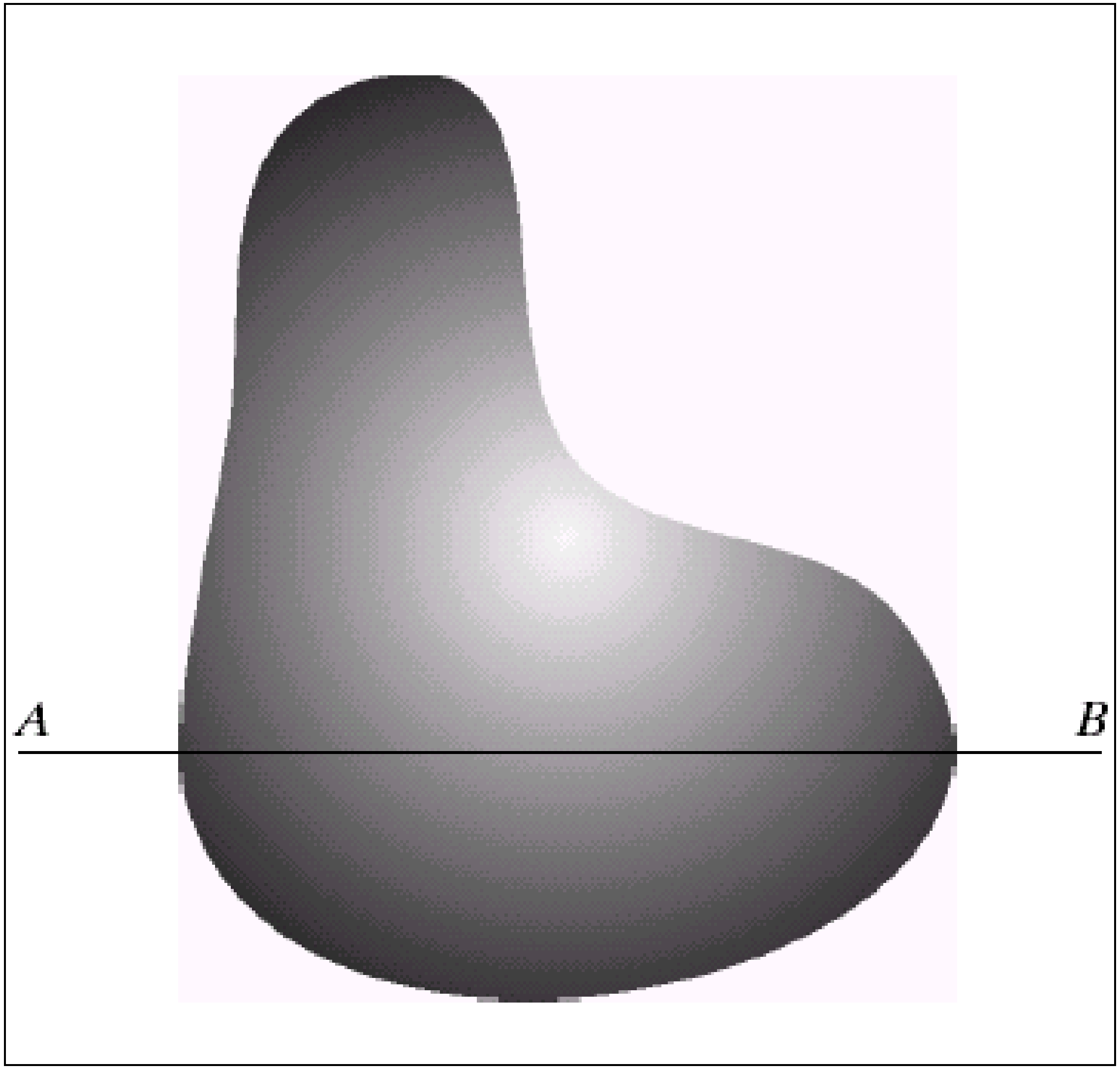
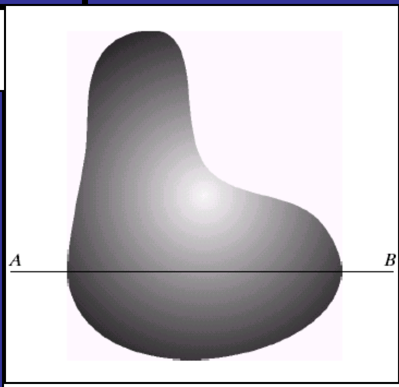


Image Sampling And Quantisation



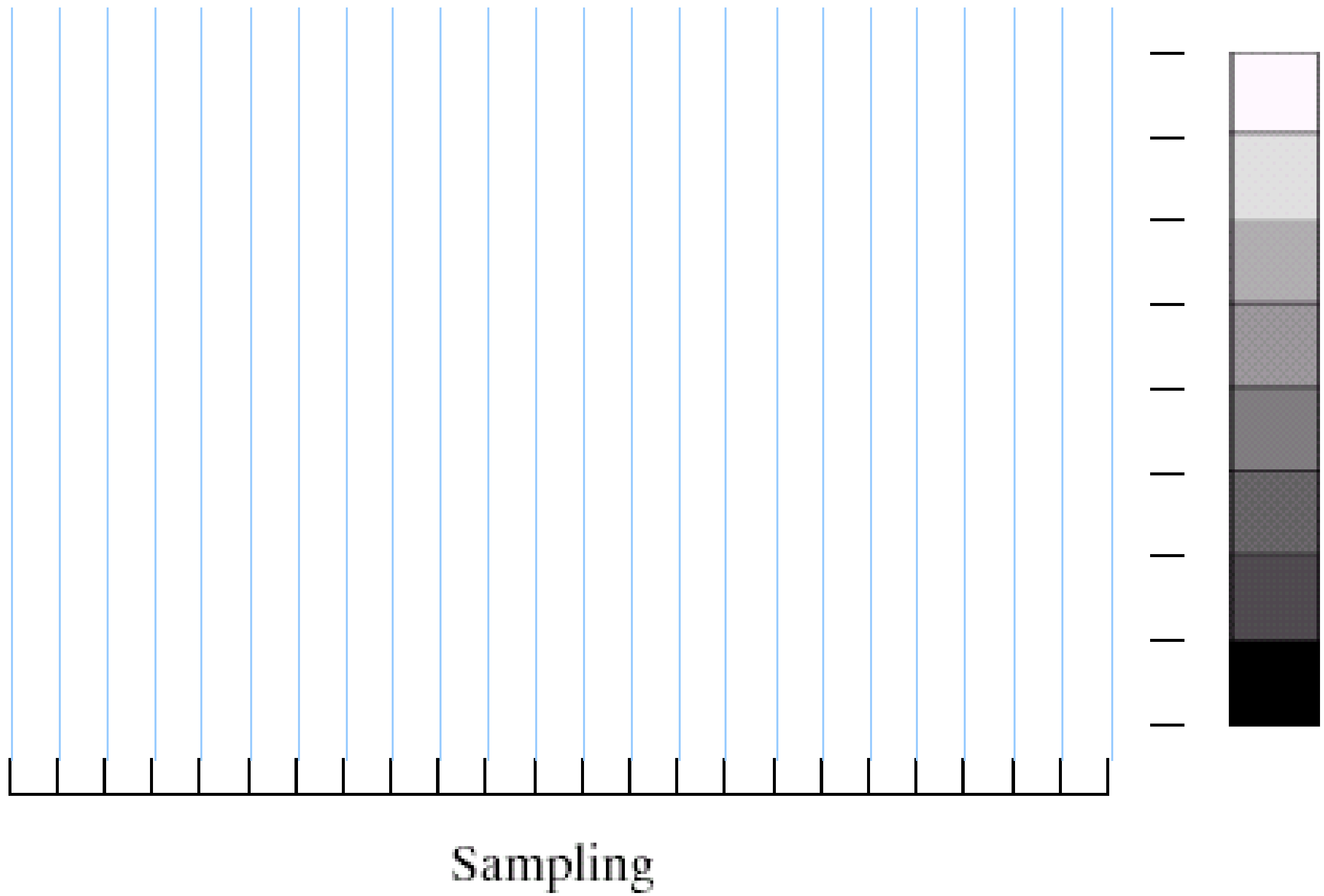


Image Sampling And Quantisation (cont…)

Remember that a digital image is always only an **approximation** of a real world scene

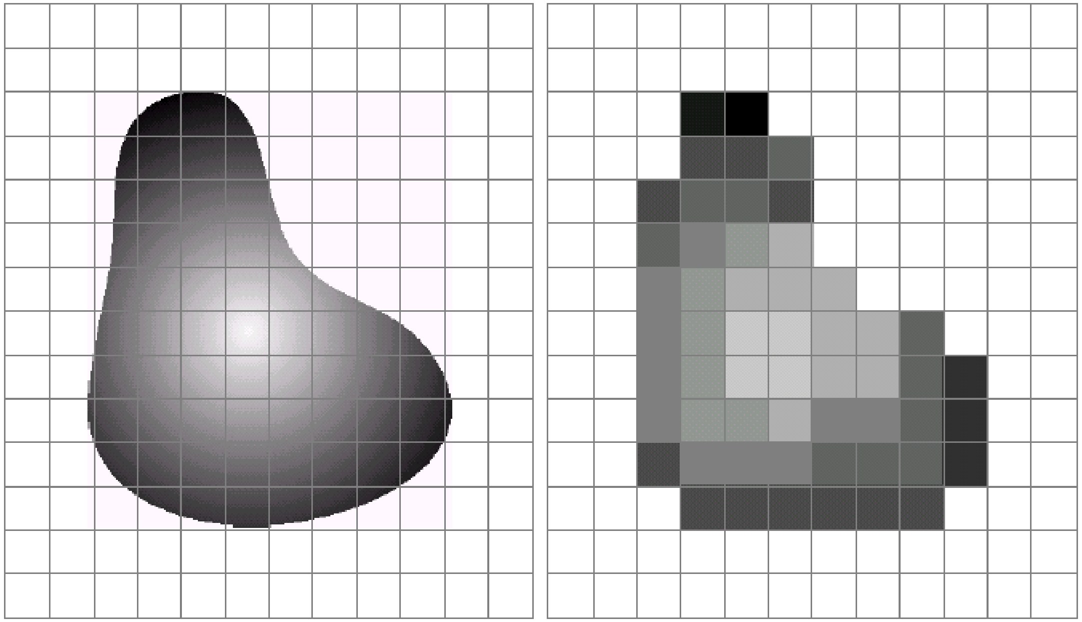
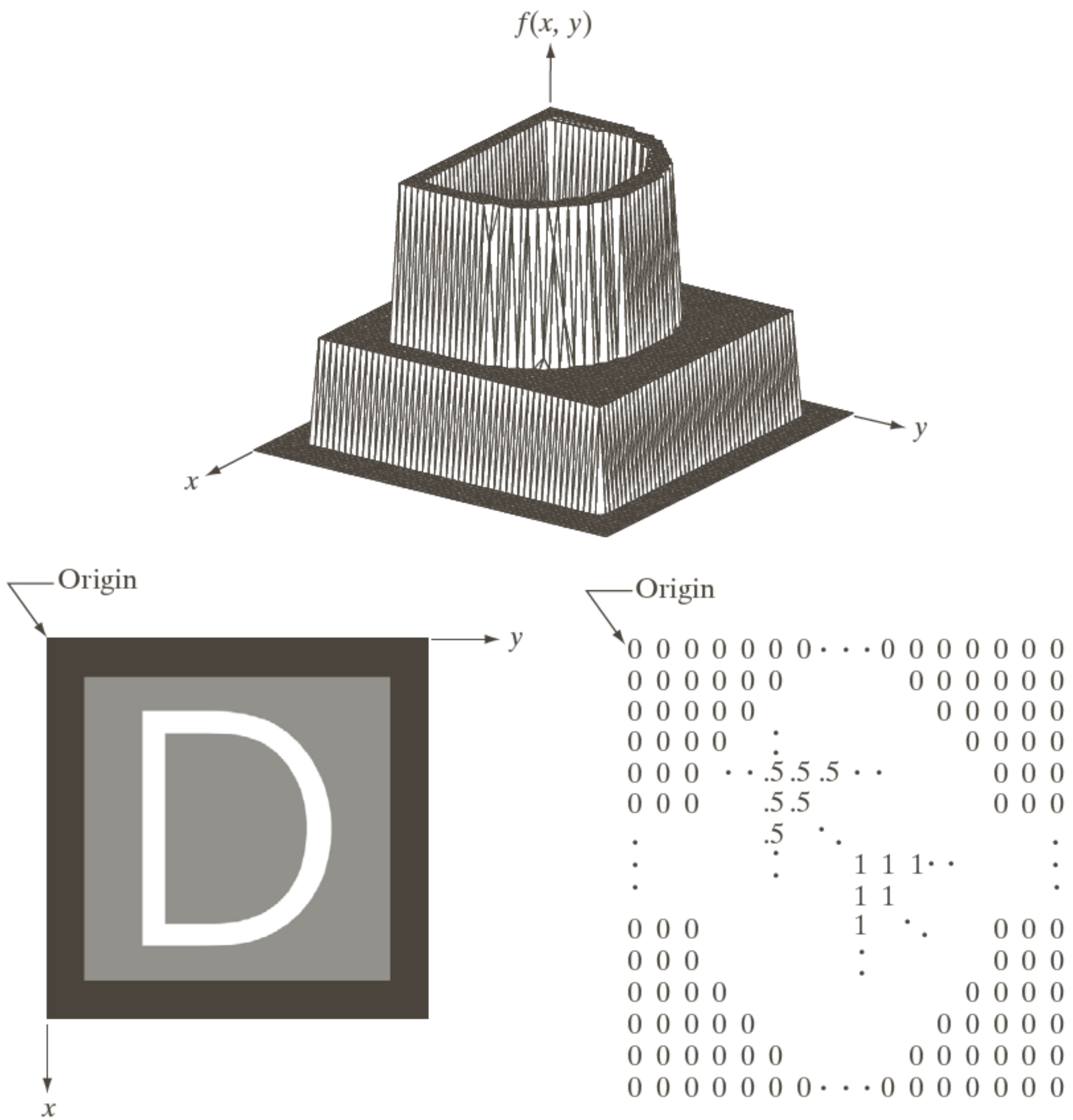


Image Representation



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

Image Representation

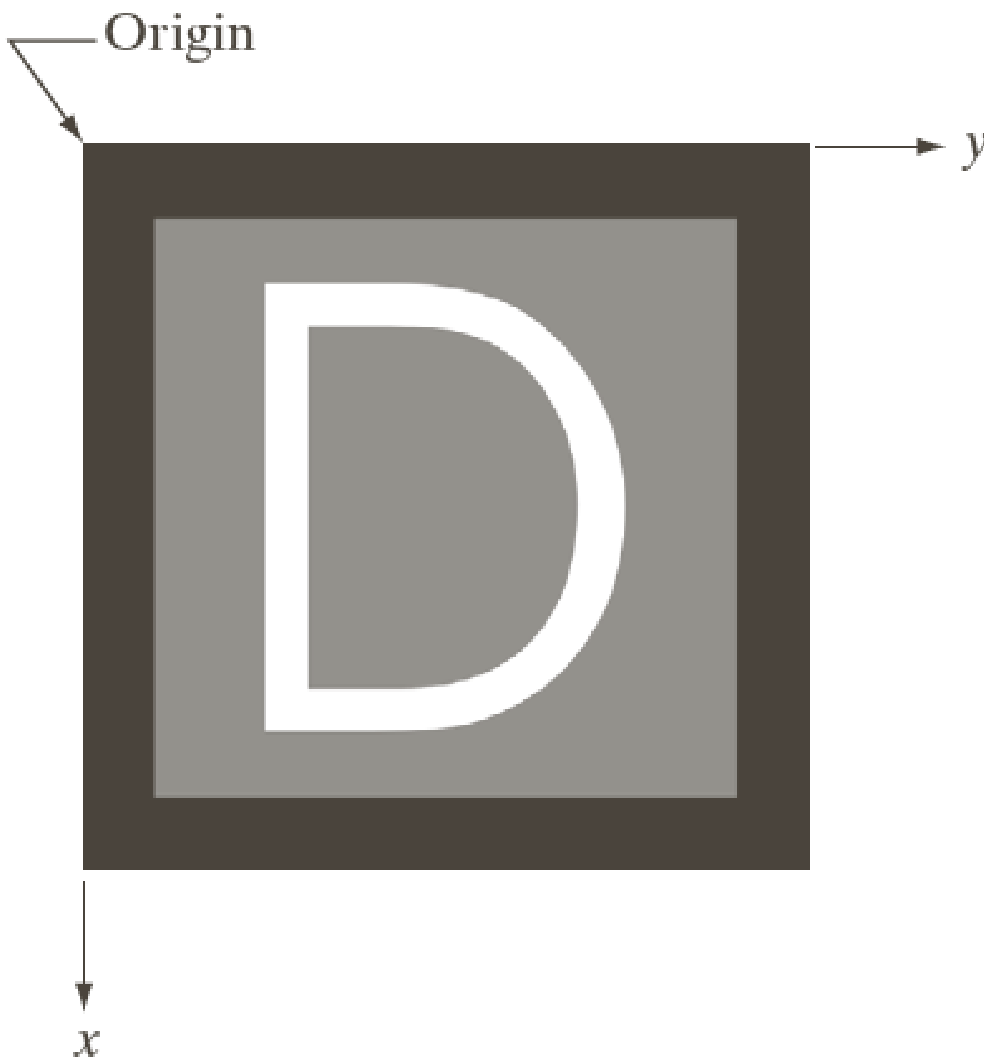


Image Representation

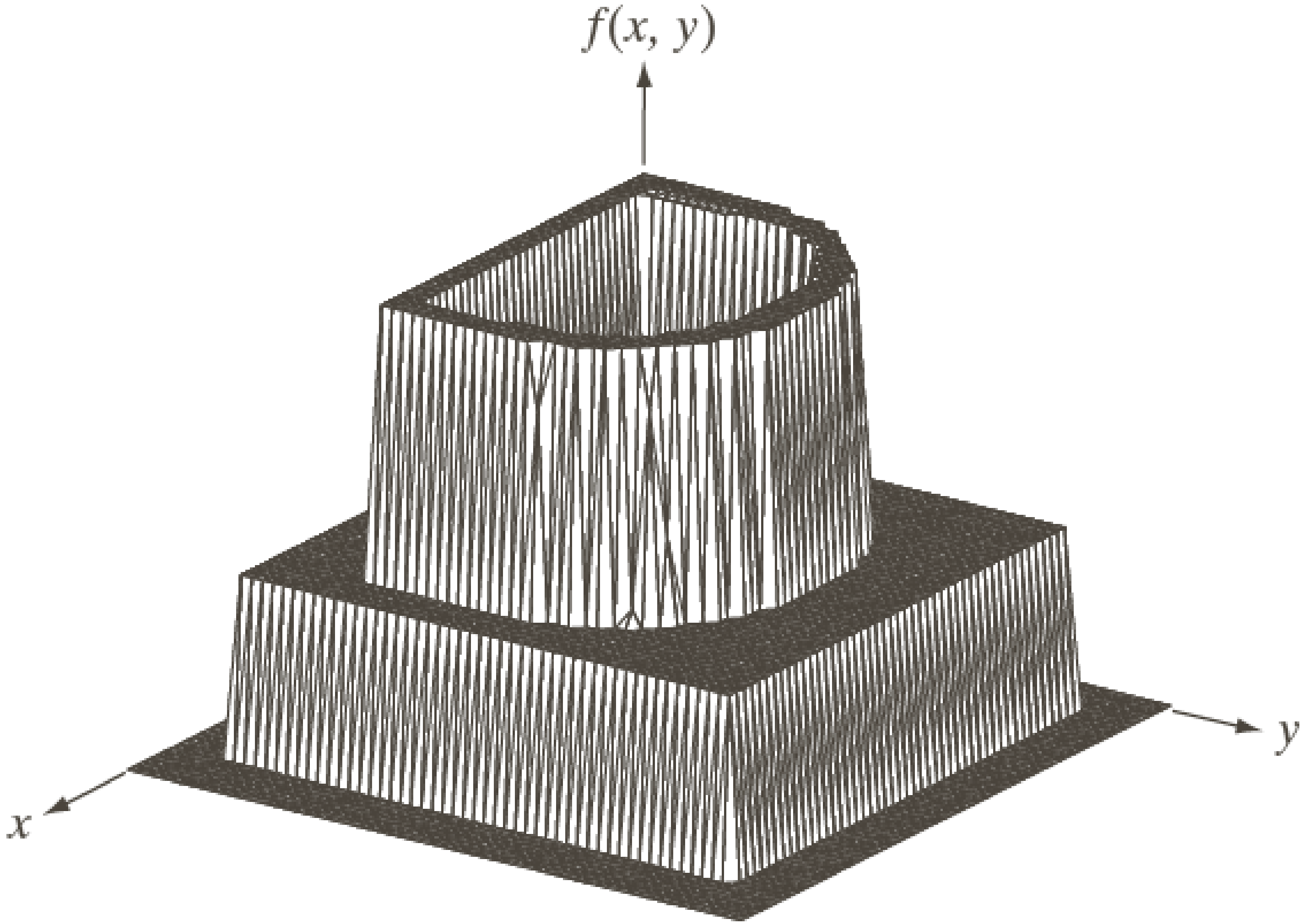
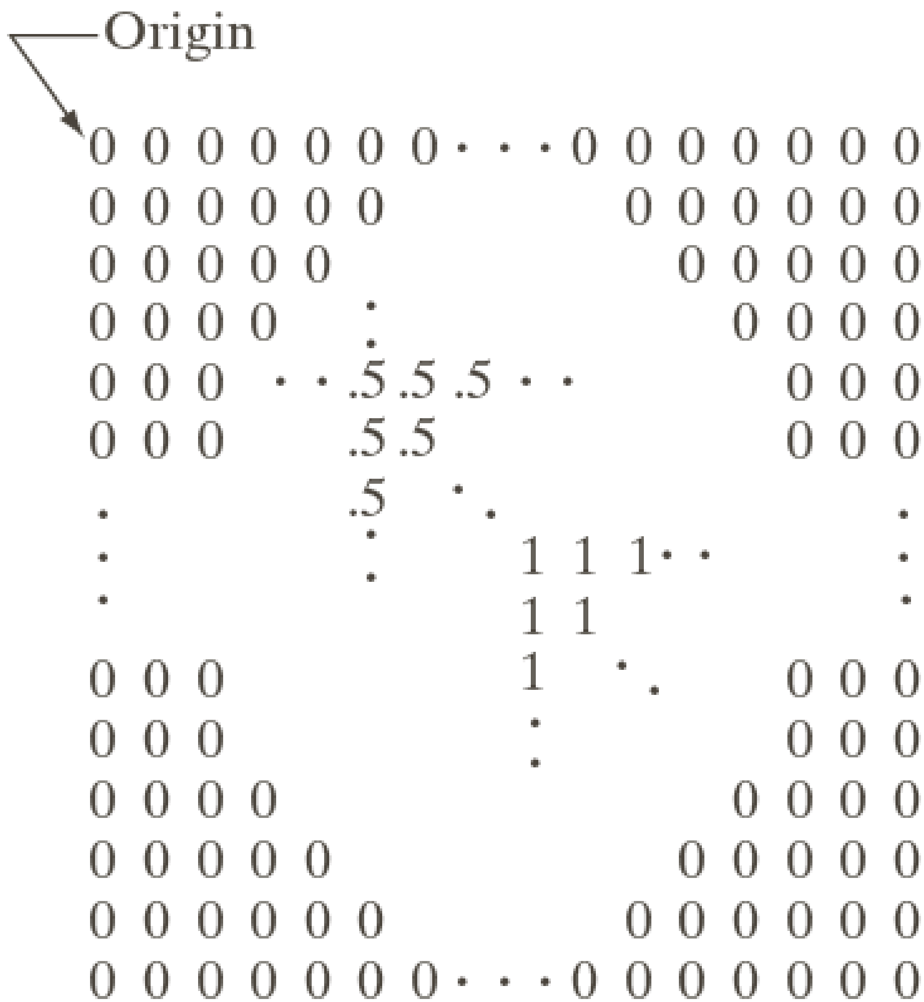


Image Representation



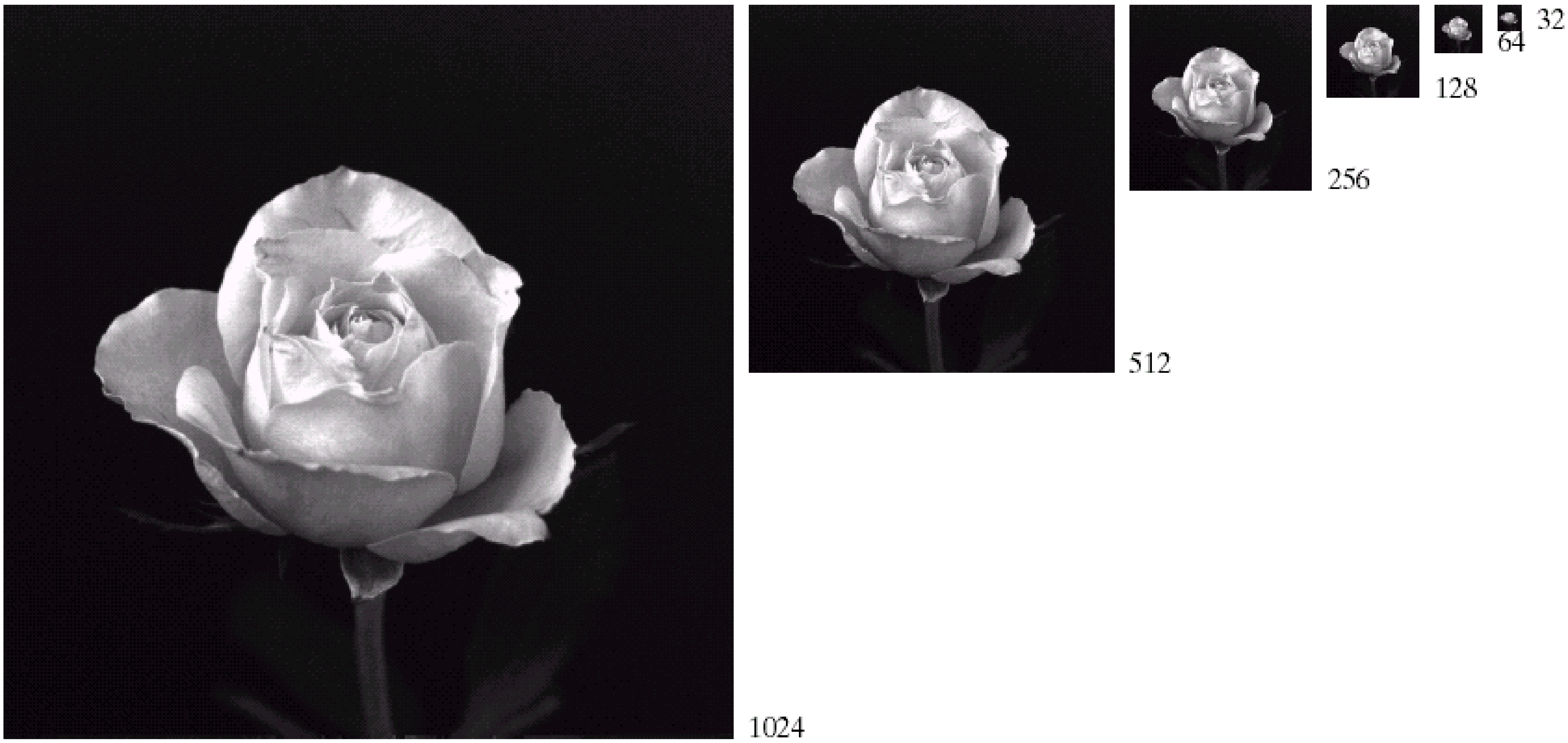
Spatial Resolution

The spatial resolution of an image is determined by how sampling was carried out

Spatial resolution simply refers to the smallest discernable detail in an image

- Vision specialists will often talk about pixel size
- Graphic designers will talk about *dots per inch* (DPI)

Spatial Resolution (cont…)



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

Spatial Resolution (cont…)

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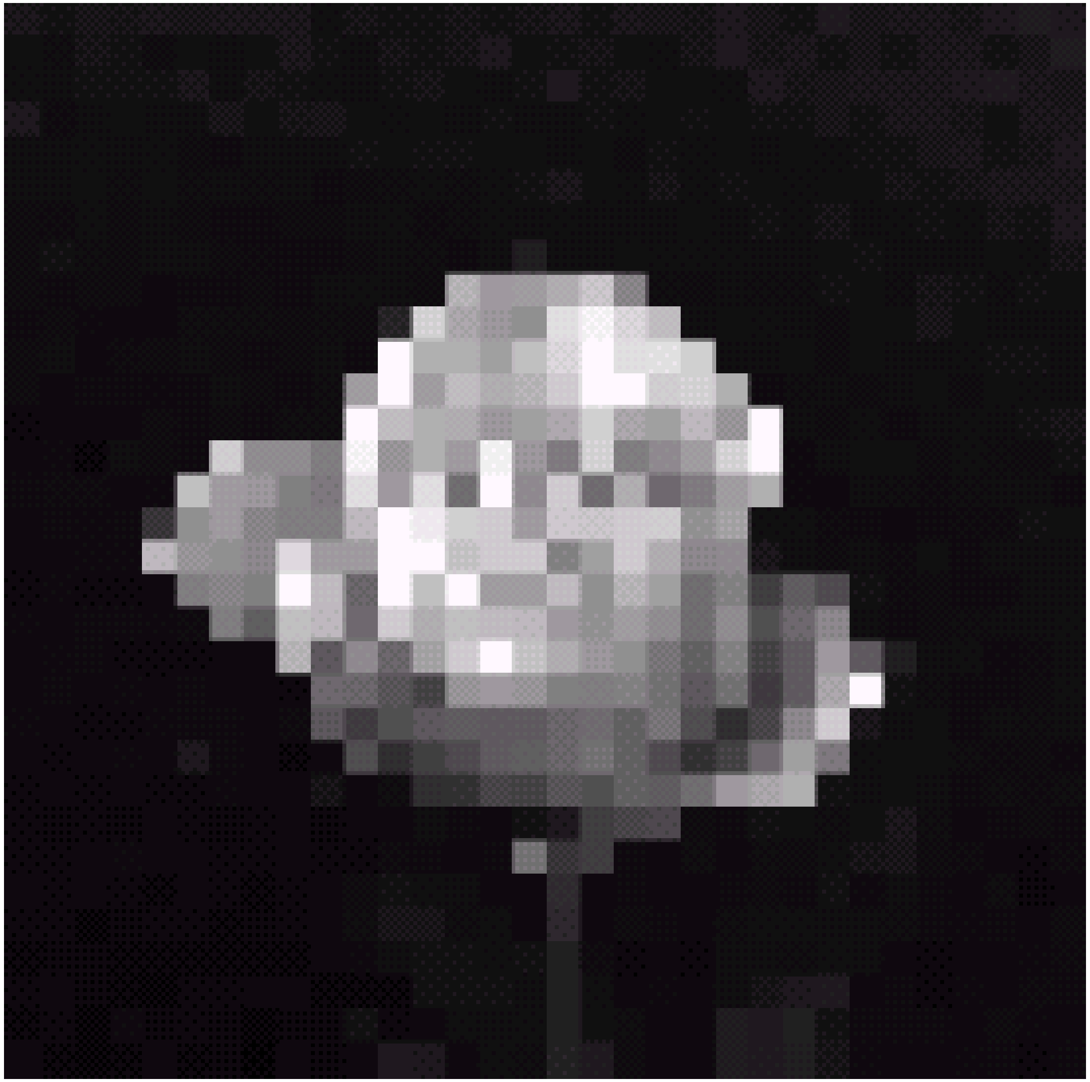


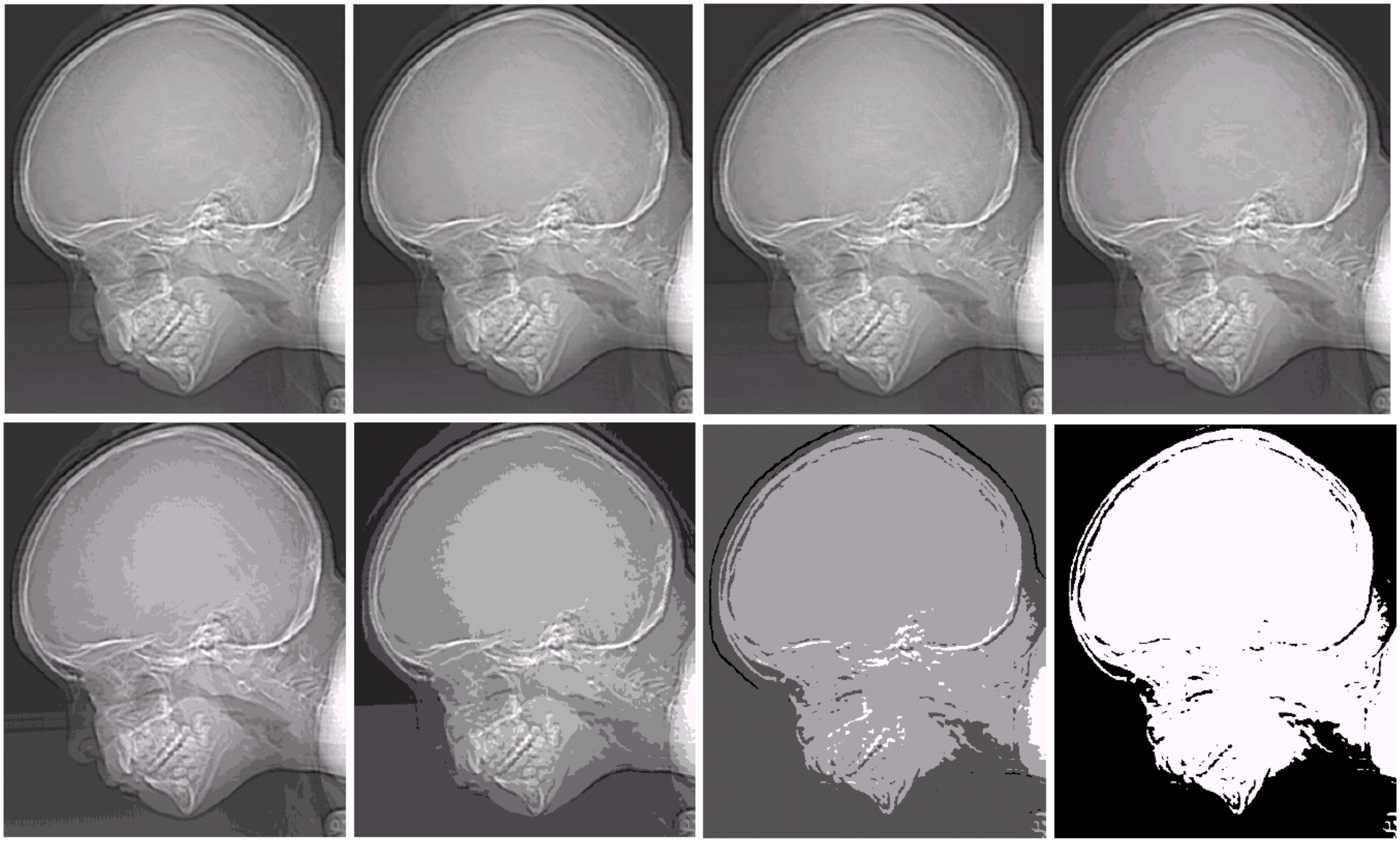
Intensity Level Resolution

Intensity level resolution refers to the number of intensity levels used to represent the image

- The more intensity levels used, the finer the level of detail discernable in an image
- Intensity level resolution is usually given in terms of the number of bits used to store each intensity level

Number of Bits	Number of Intensity Levels	Examples
1	2	0, 1
2	4	00, 01, 10, 11
4	16	0000, 0101, 1111
8	256	00110011, 01010101
16	65,536	1010101010101010

Intensity Level Resolution (cont…)



256 grey levels (8 bits per pixel) | 128 grey levels (7 bpp) | 64 grey levels (6 bpp) | 32 grey levels (5 bpp)

16 grey levels (4 bpp) | 8 grey levels (3 bpp) | 4 grey levels (2 bpp) | 2 grey levels (1 bpp)

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

Intensity Level Resolution (cont…)

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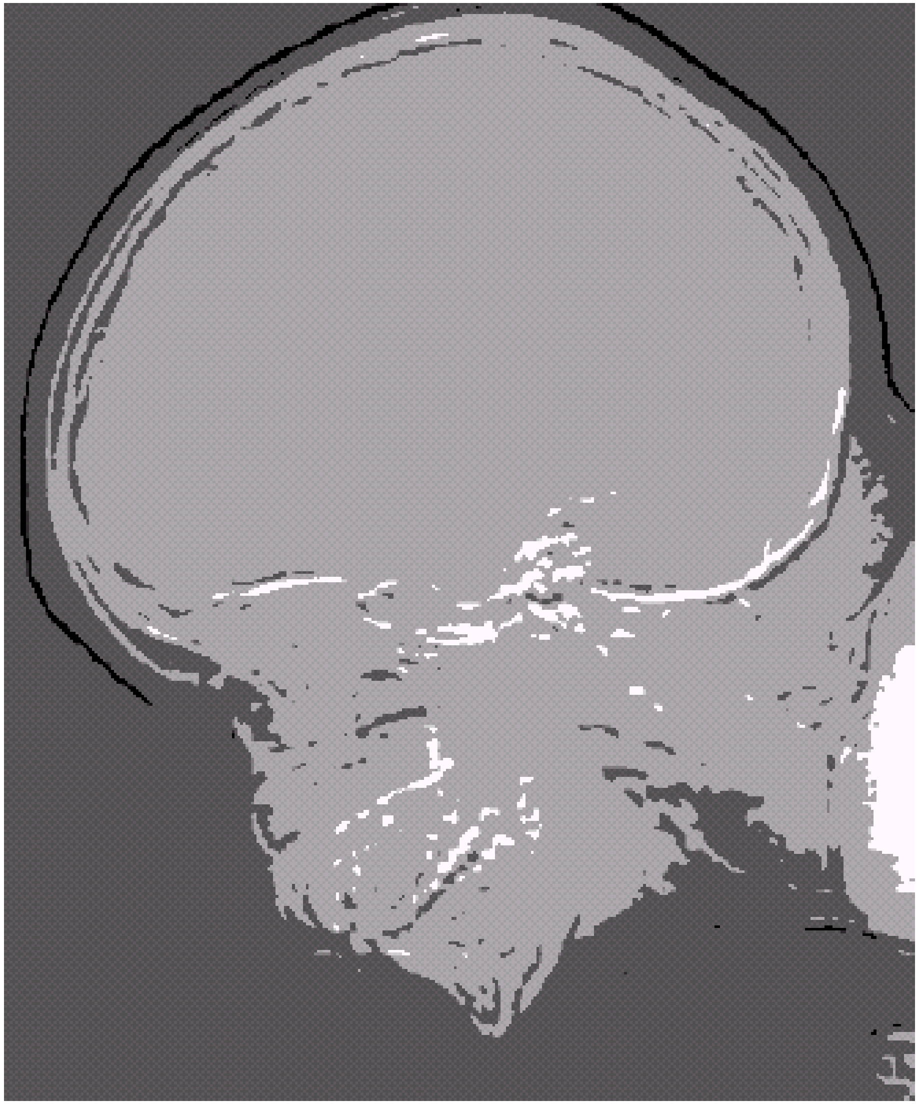
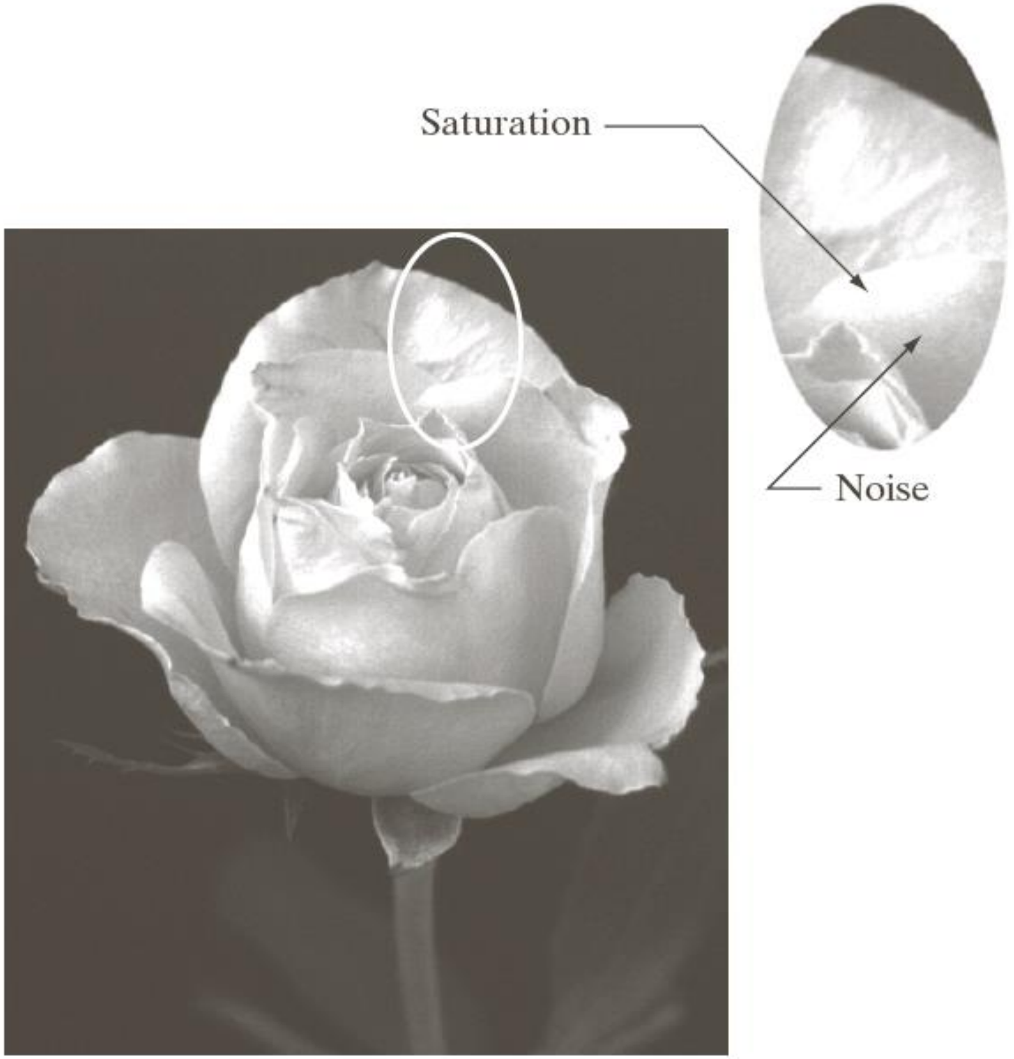


Intensity Level Resolution (cont…)

Saturation & Noise



Resolution: How Much Is Enough?

The big question with resolution is always *how much is enough*?

- This all depends on what is in the image and what you would like to do with it
- Key questions include
  - Does the image look aesthetically pleasing?
  - Can you see what you need to see within the image?

Resolution: How Much Is Enough? (cont…)

The picture on the right is fine for counting the number of cars, but not for reading the number plate

Intensity Level Resolution (cont…)

Low Detail

Medium Detail

High Detail

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

Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)

Summary

We have looked at:

- Human visual system
- Light and the electromagnetic spectrum
- Image representation
- Image sensing and acquisition
- Sampling, quantisation and resolution

Next time we start to look at techniques for image enhancement