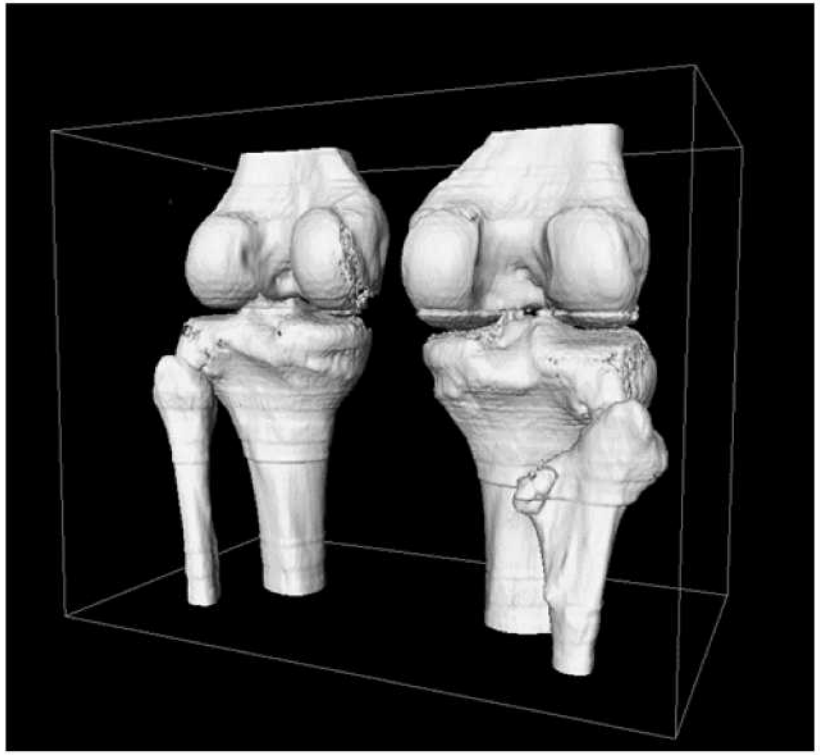
Illustrate how biological signals are processed

- o Generation
- o Pick up
- o Filtration
- o Amplification
- o Interpretation
- o Display



13.1.3 Illustrate how biological signals are processed

Unit B 13.2 Measuring Biological Signals

Module 279 18 B Medical Instrumentation I

Signal Processing

In the previous lectures we have seen how the body generates signals, or – stated differently – that the functioning of a body leaves traces in the world, both inside and outside the body. Those traces we can pick up with transducers that convert them into (mainly) electrical signals.

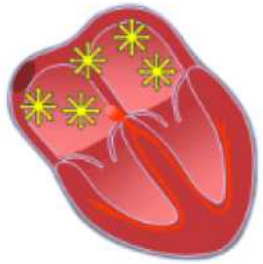
This enables us to apply our full arsenal of electronics, hardware and software to make these signals useful for human interpretation by:

- Transmission
- Amplification
- Filtering and Selection
- Reconstruction
- Interpretation and Display

All this can be captured by the term
Signal Processing

Signal Processing

Patient



Signal

Transducer
Receiver
Pick-up

Pre-amplification
Transmission
Amplification

Signal Processing
Image Processing
Reconstruction

Display

Medical
Doctor
Computer
algorithm

'You have the flu'

Diagnosis

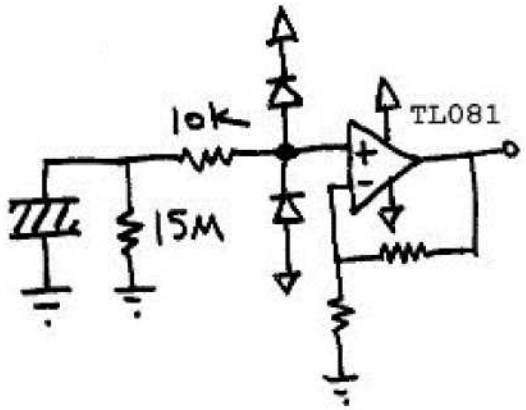
Therapy

Signal Pick up

Signal Pick-up: receive, bring it under your control

this is the function of the transducer/receiver/detector/sensor, pre-amplifier, transmission and amplifier

Pre-amplification: first electronic amplifier stage near the transducer.
This step is necessary in case of very small signals, to avoid that the electric noise that is picked up during transmission is spoiling the signal. Pre-amplifiers are sometimes integrated with the transducer, such as in ultrasound probes.

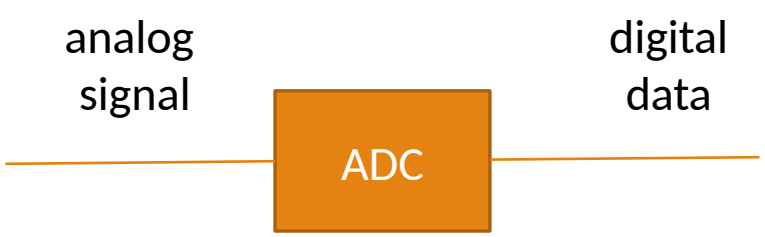


Transmission: the 'raw' (pre-amplified) signal from the transducer is transported (up to 10 meters or so) to the further amplification and processing unit (box/cabinet). It is important not to pick up too much noise (shielded cables, grounding, etc.)

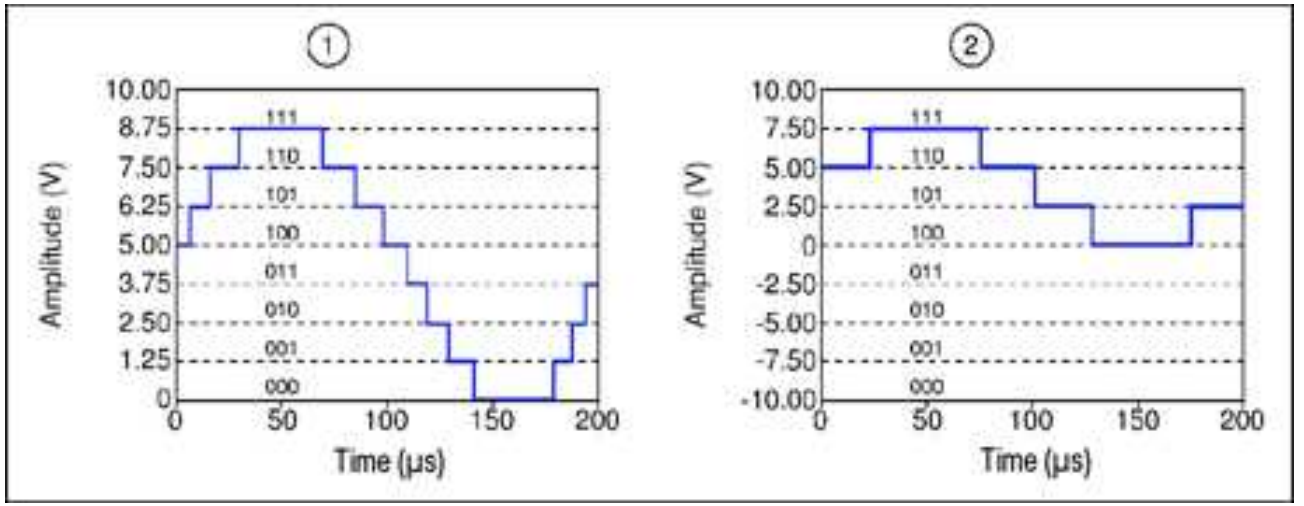
Signal Amplification: adjust to next processing phase

Amplification: further amplification may be necessary, to match the dynamic range of the signal to

- the dynamic range of the display or
- the dynamic range of the A to D converter, to make optimal use of the digital resolution of the system.



an A-to-D Converter converts (analog) Input voltage to digital numbers.
If the ADC is specified between 0 and 10V, we need to amplify the input signal to cover this range.



Making full use of digitizing range (left)

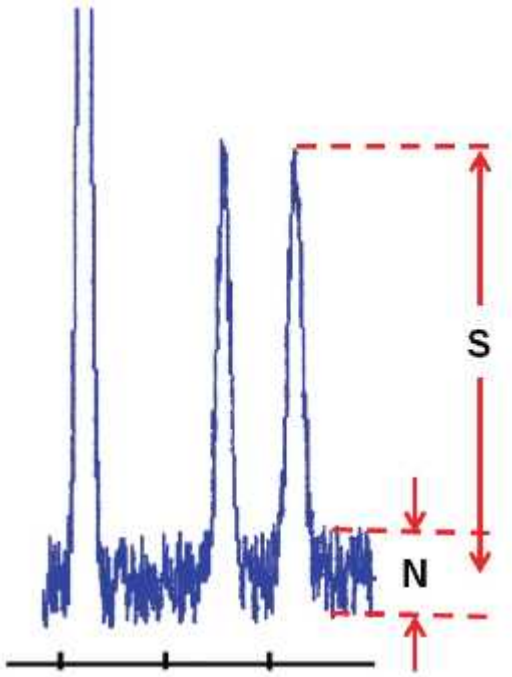
Signal to Noise ratio

Noise

Noise is the part of a signal that one is not interested in. It can be signal that is picked up from the environment (e.g. '50 Hz' signal)

Signal-to-Noise ratio

Sometimes, the body signals are 'clear' and it is 'easy' with normal electronics to extract useful information.
Sometimes, the body signals have a low signal/noise ratio: the signals almost 'drown' in the noise.



S = signal

N = noise

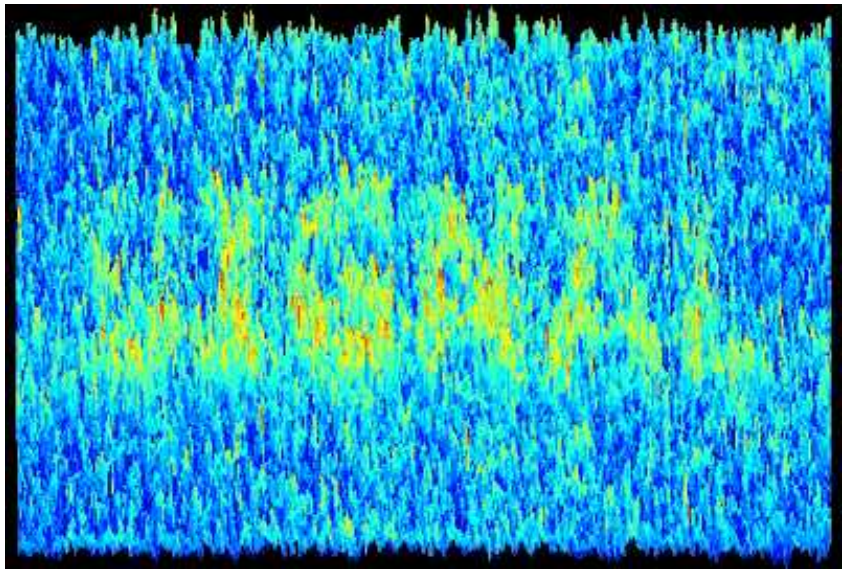
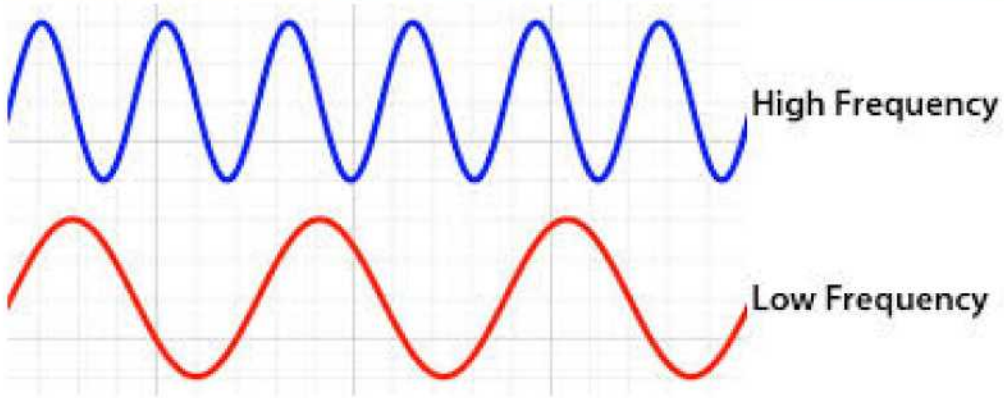


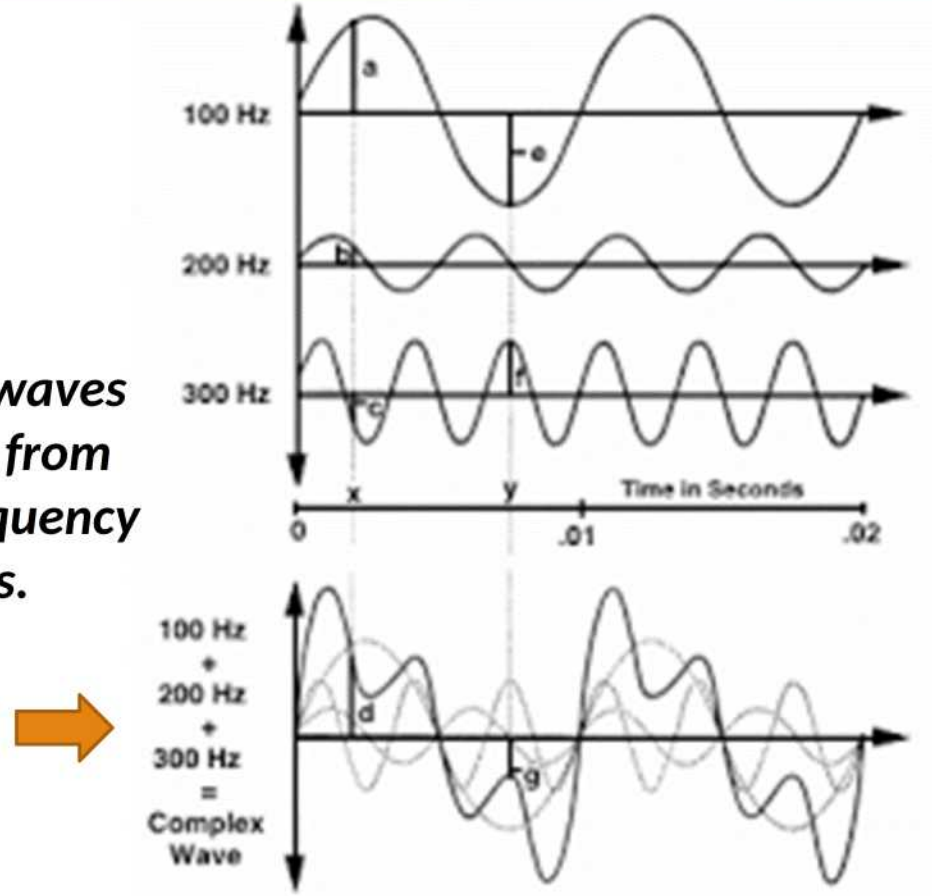
Image with low signal-to-noise ratio !

Signal Frequencies and Filters



In the same way that sound (e.g. music) contains different tones (high tones, low tones) all complex signals are composed of different wave frequencies.

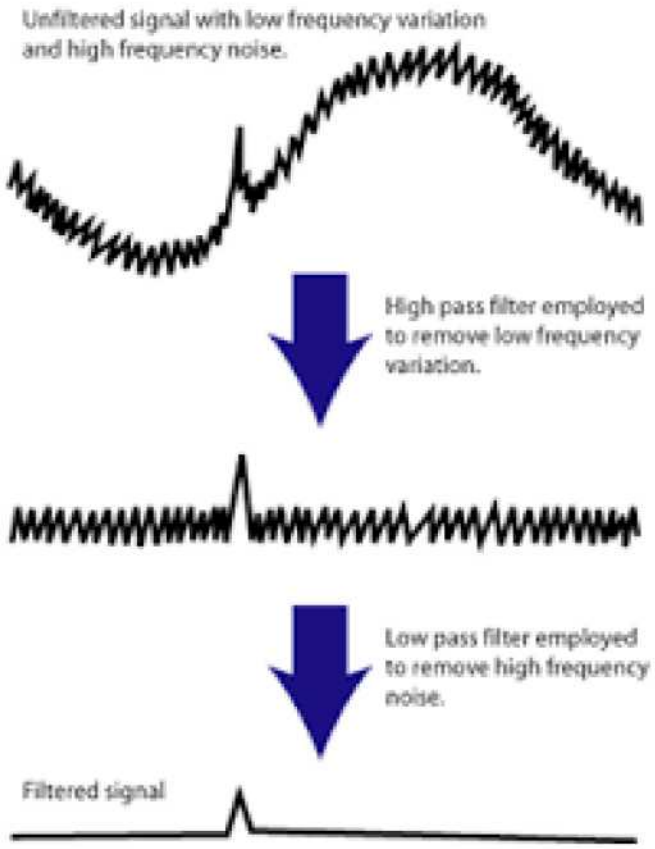
complex waves are built from single frequency waves.

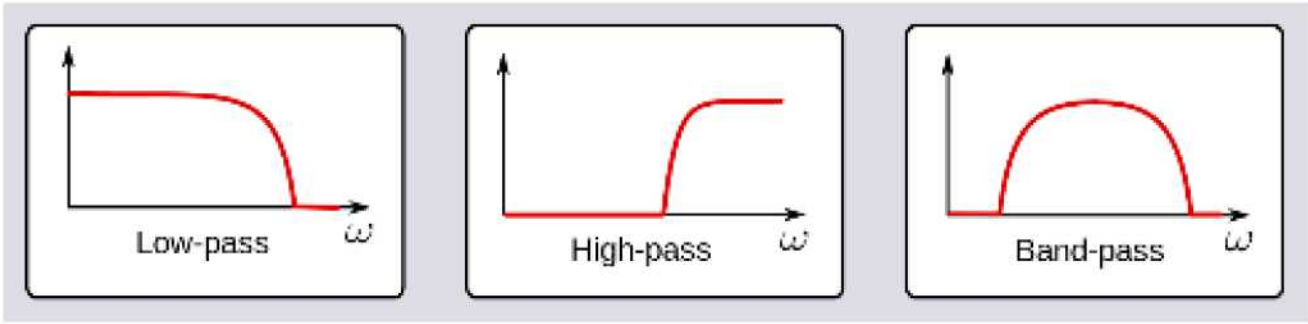


With a filter some (unwanted) frequencies can be removed to 'clean up' the signal.

Signal Filtering: 1-dimensional

A **filter** removes from a signal some unwanted component or feature, often to reduce noise.

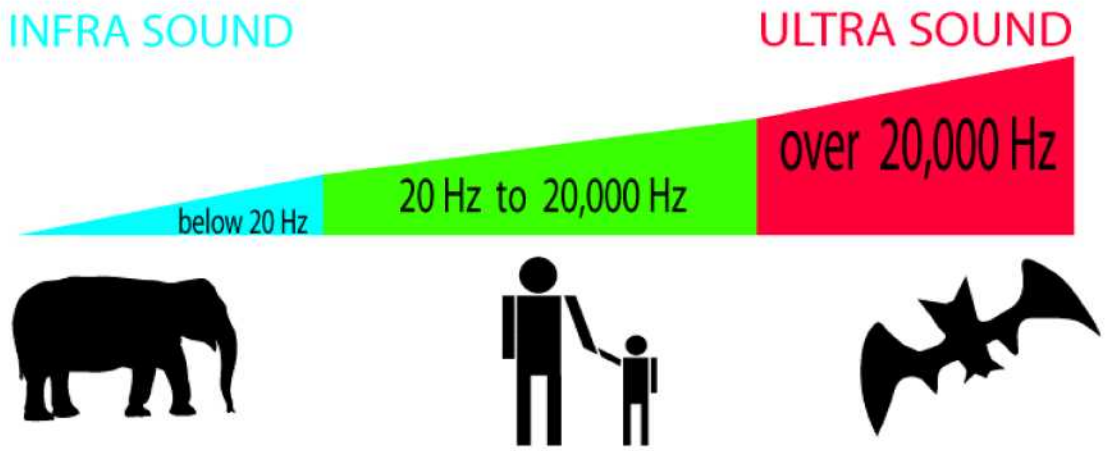




Different types of filters remove different frequencies from the signal

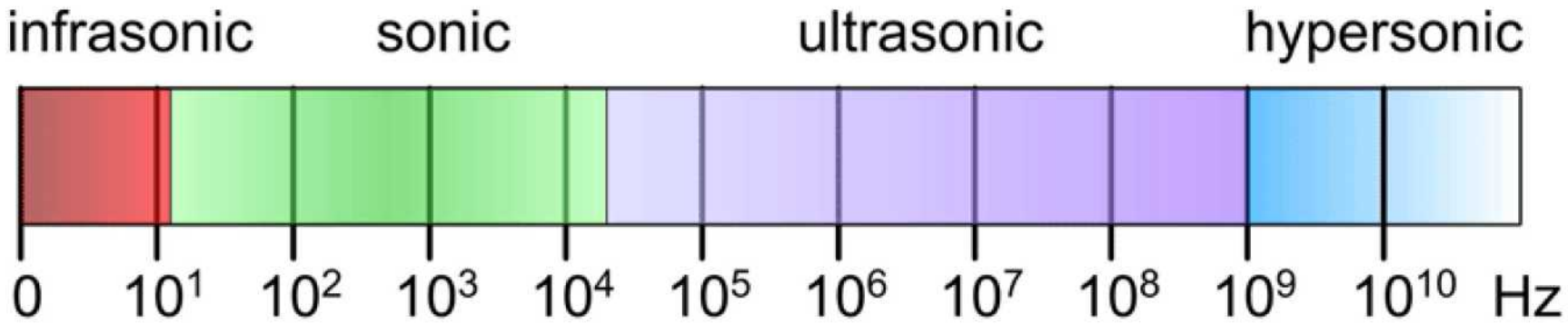
An amplifier can have different amplification for different frequencies.

Sound waves can contain different sound frequencies

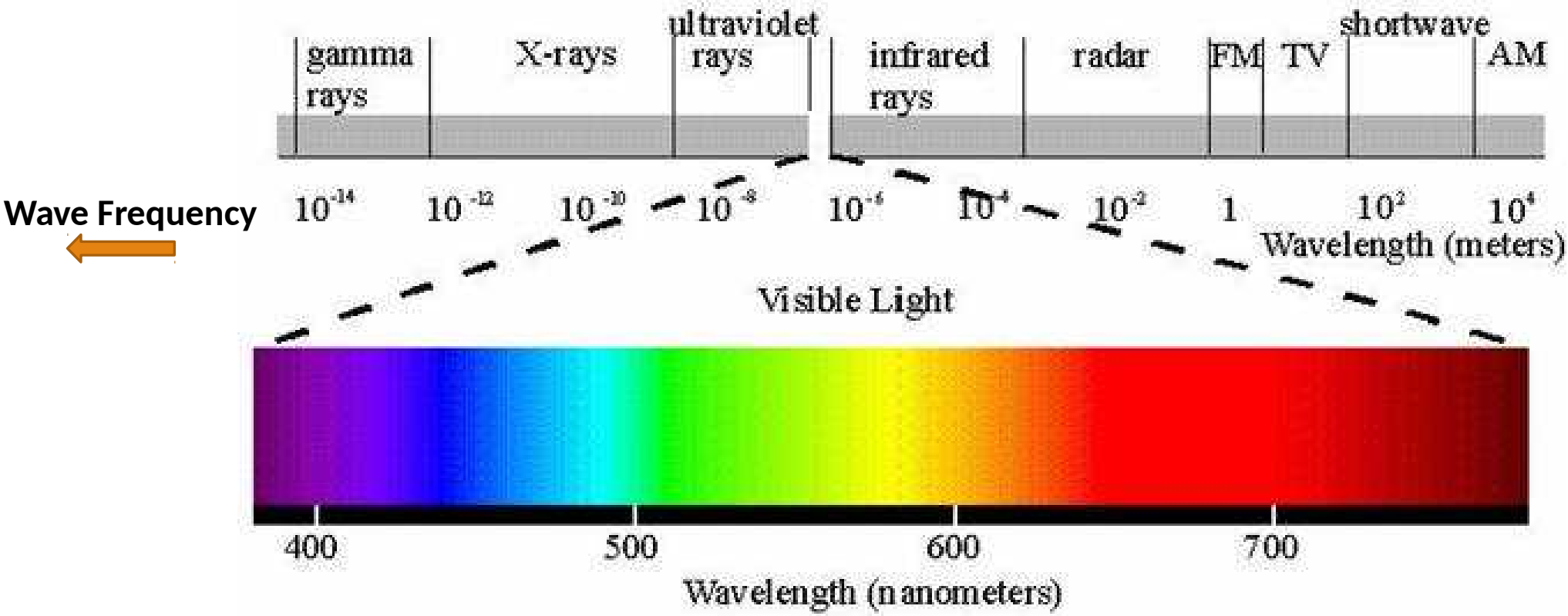


An single tone (that you hear) corresponds to a single sound frequency

Most ‘natural sounds’ consist of many tones: they contain many sound frequencies, including e.g. high tones and low tones.



Electro-magnetic waves also can have different frequencies



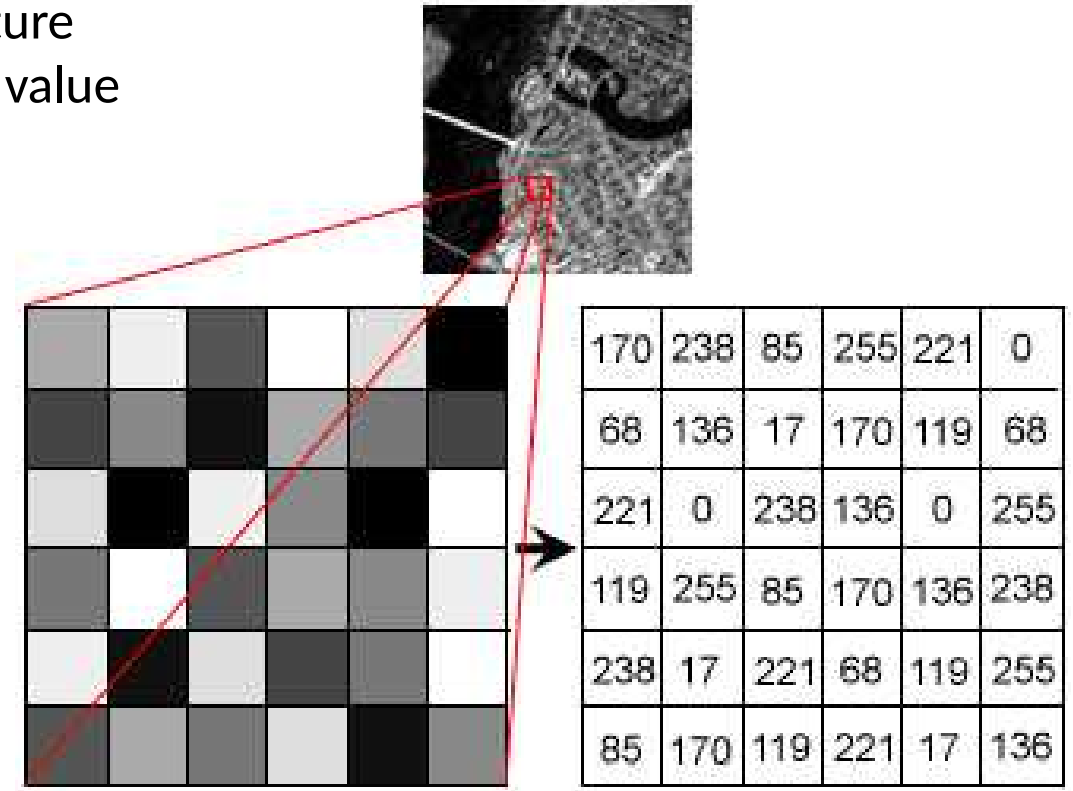
Most 'natural images' consist of many light frequencies, i.e. they include different colors.

2-Dimensional Signals: Images

An image consists of pixels: **pic**ture **el**ements: each pixel contains a value (number).

1	1	1	1	1	1	1	1	1	1
1	0	0	0	1	1	0	0	0	1
1	1	0	1	1	1	1	0	1	1
1	1	0	1	1	1	1	0	1	1
1	1	0	1	1	1	1	0	1	1
1	1	0	0	0	0	0	0	1	1
1	1	0	1	1	1	1	0	1	1
1	1	0	1	1	1	1	0	1	1
1	1	0	1	1	1	1	0	1	1
1	0	0	0	1	1	0	0	0	1
1	1	1	1	1	1	1	1	1	1

an image with 1 bit pixels:
each pixel has value 0 or 1



170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

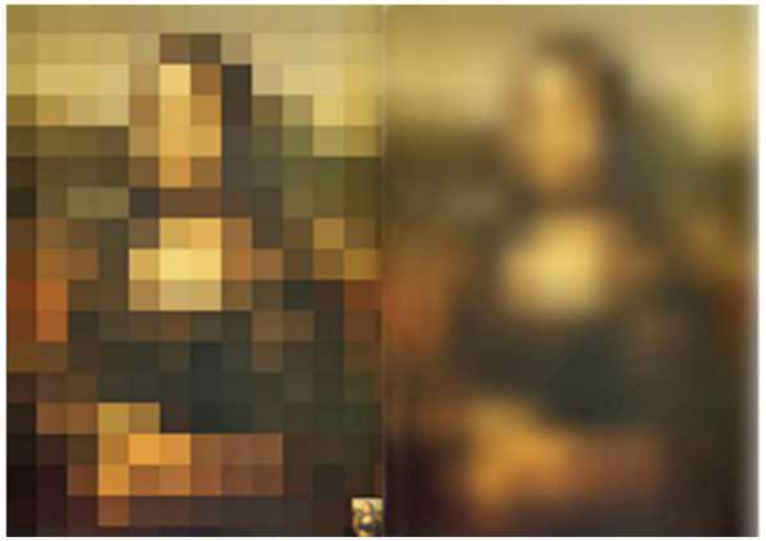
an image with 8 bit pixels:
each pixel has value between 0 and 255: grey scales

R 255 G 0 B 0	R 102 G 102 B 255	R 51 G 204 B 153
R 255 G 255 B 102	R 255 G 0 B 204	R 51 G 204 B 255
R 51 G 51 B 0	R 51 G 51 B 153	R 255 G 153 B 153

color images:
3 values per pixel

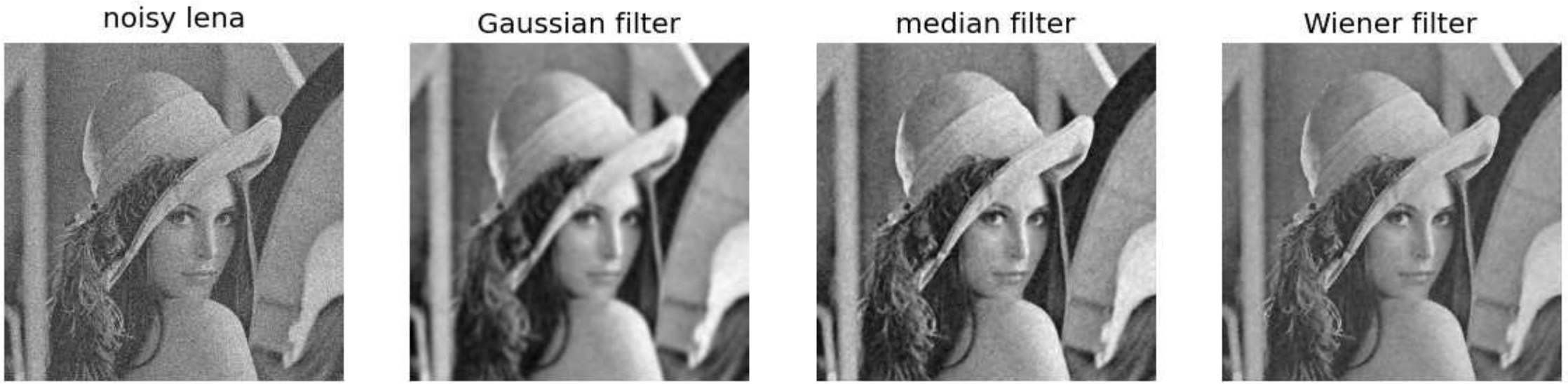
Images consist of pixels: picture elements





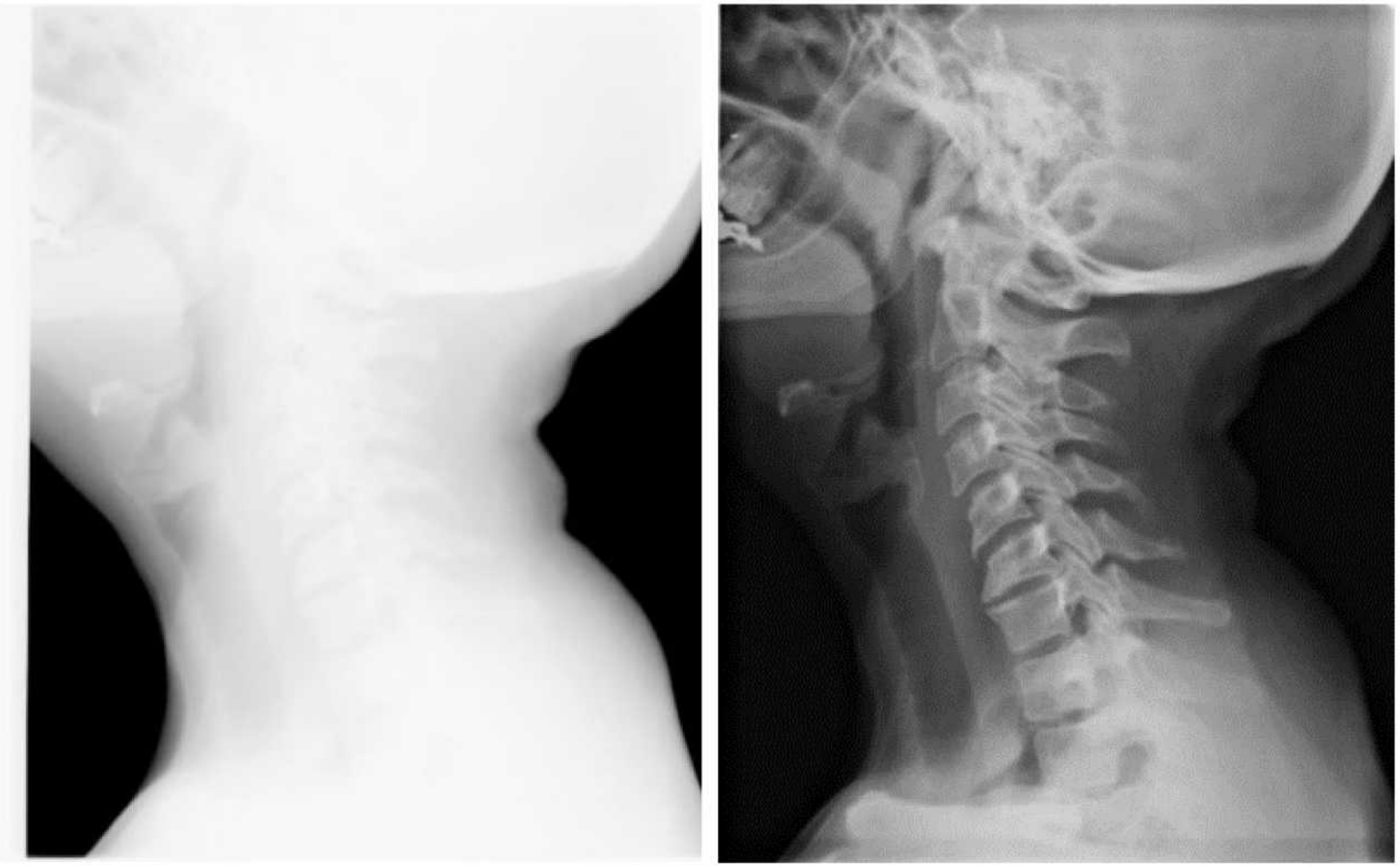
And the human brain is very good at making sense out of these…

Signal Filtration: 2 dimensional



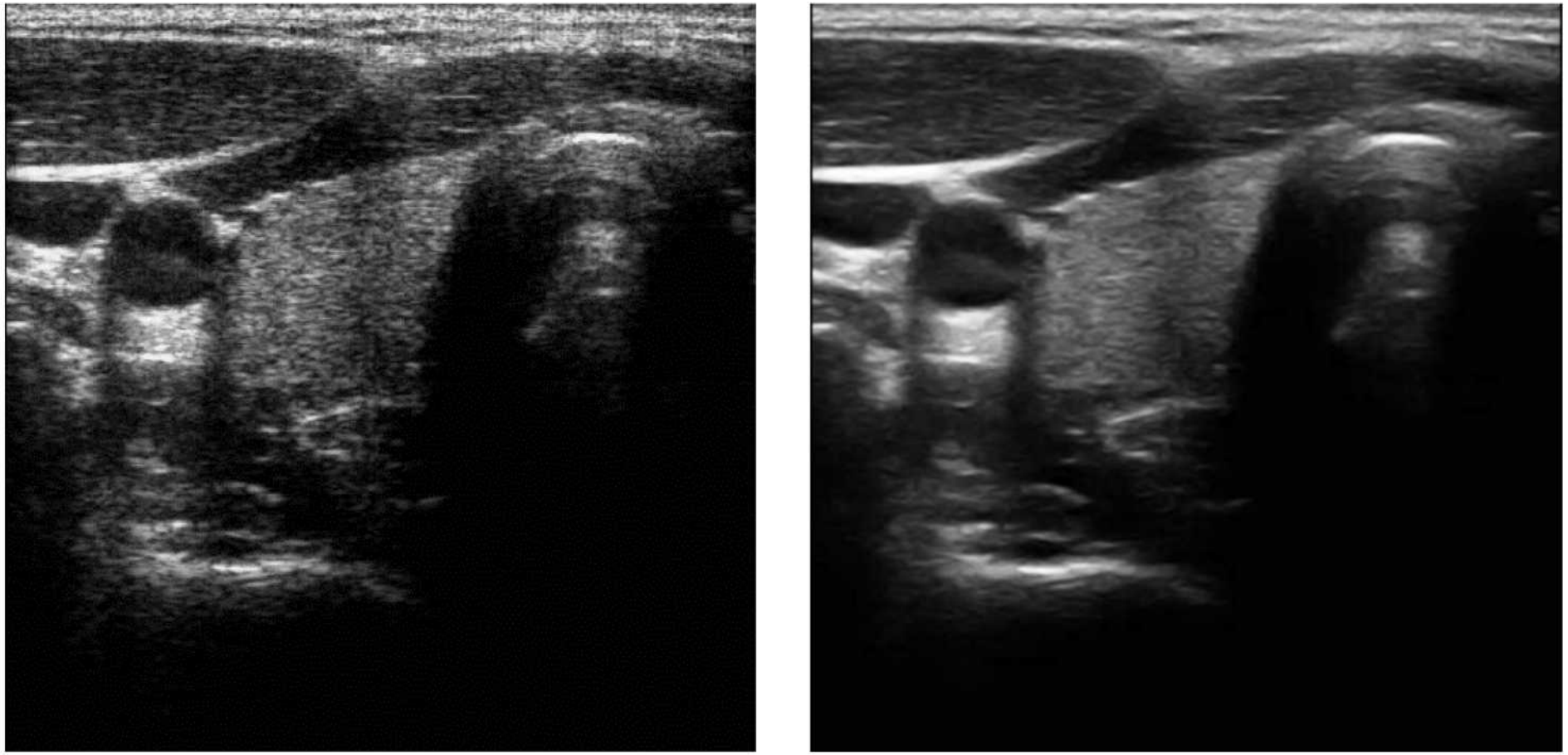
Many image processing filters are available in computer software libraries and can be applied to (medical) images to enhance certain features of clinical interest

Signal Filtration: 2D examples



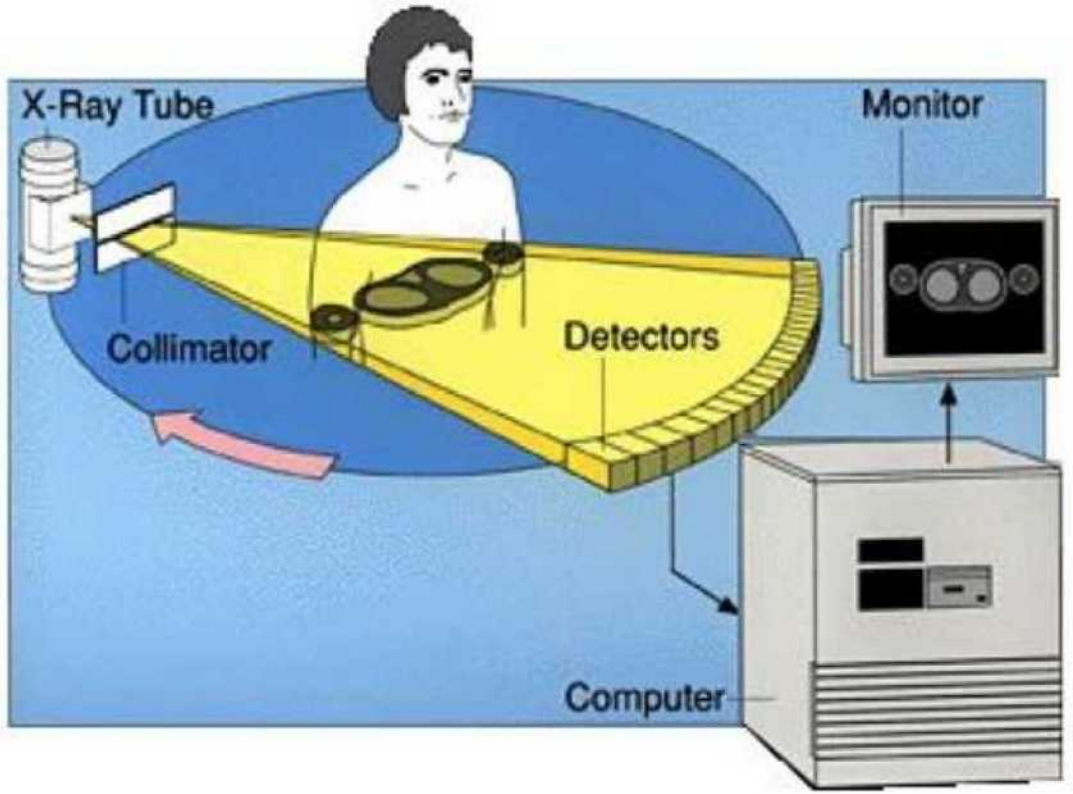
X-ray Projection Images:
filtering brings out
a lot of visible detail

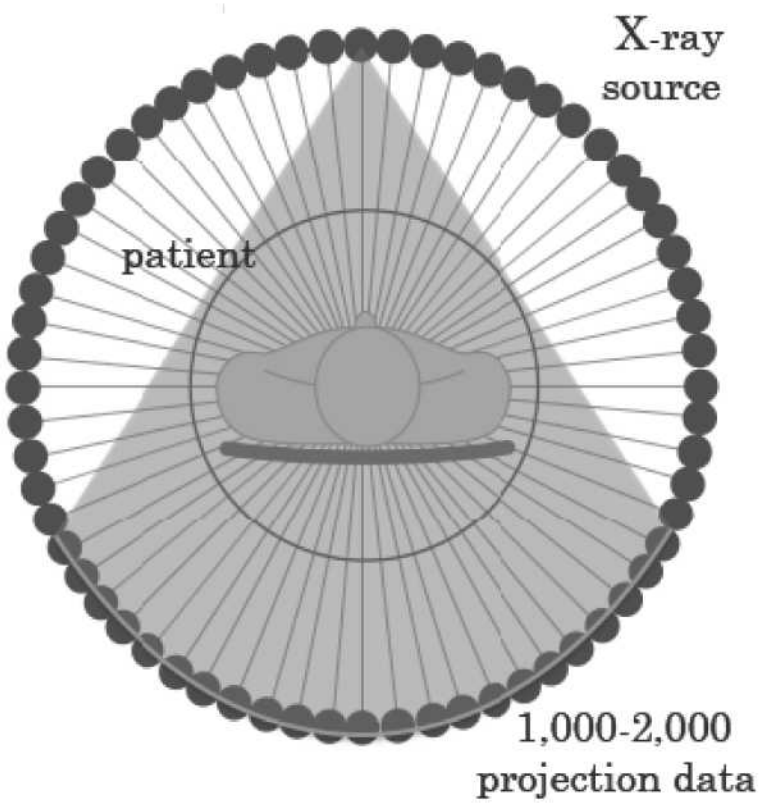
Signal Filtration: 2D examples



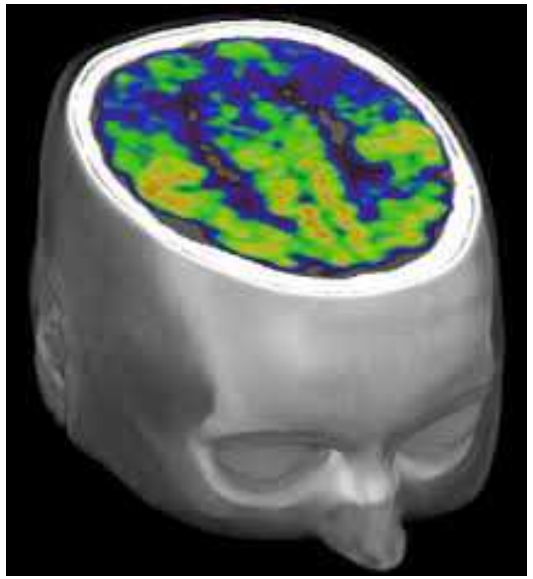
Ultrasound filter techniques

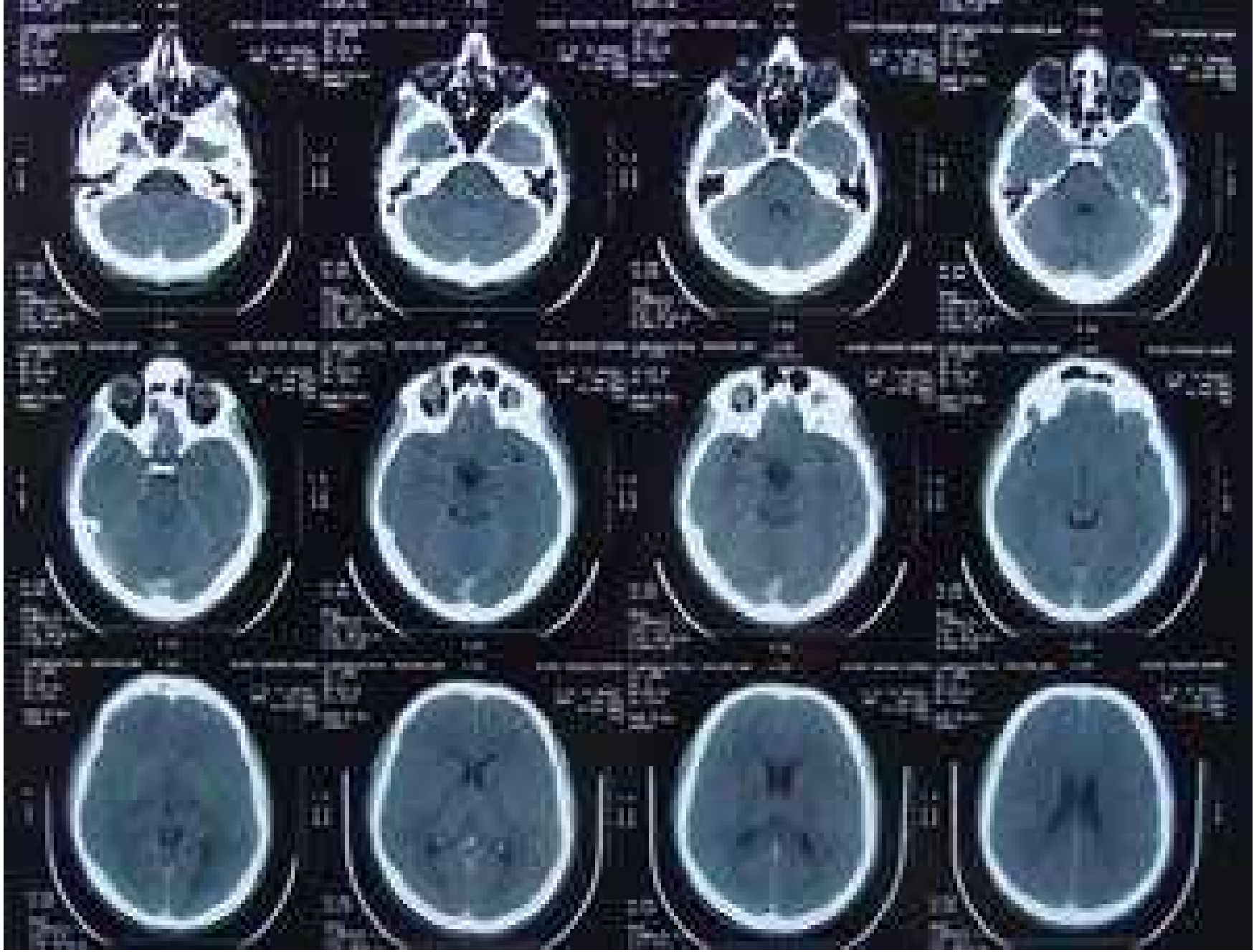
3D Reconstruction: Computerized Tomography



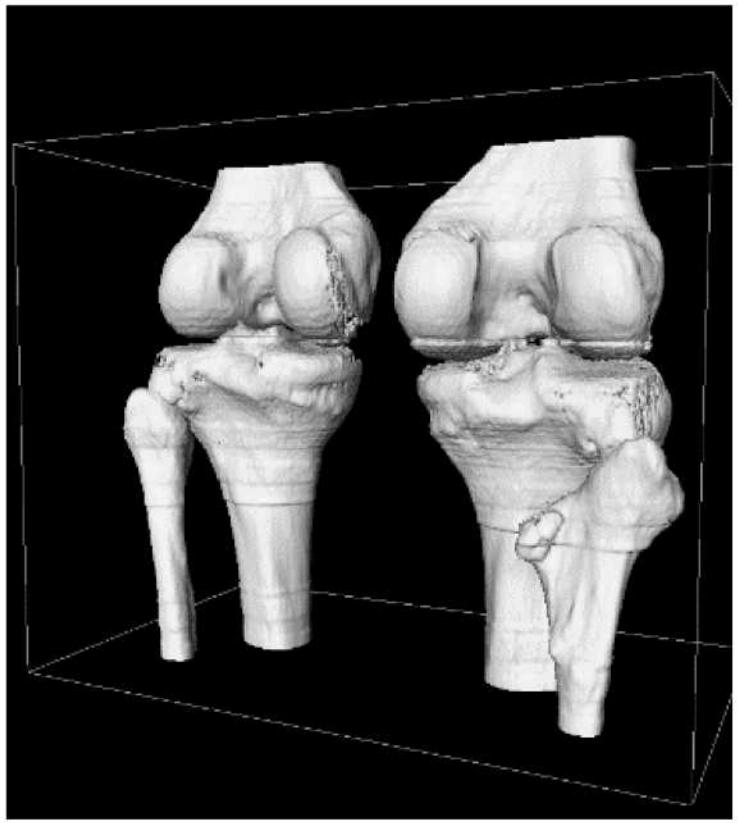


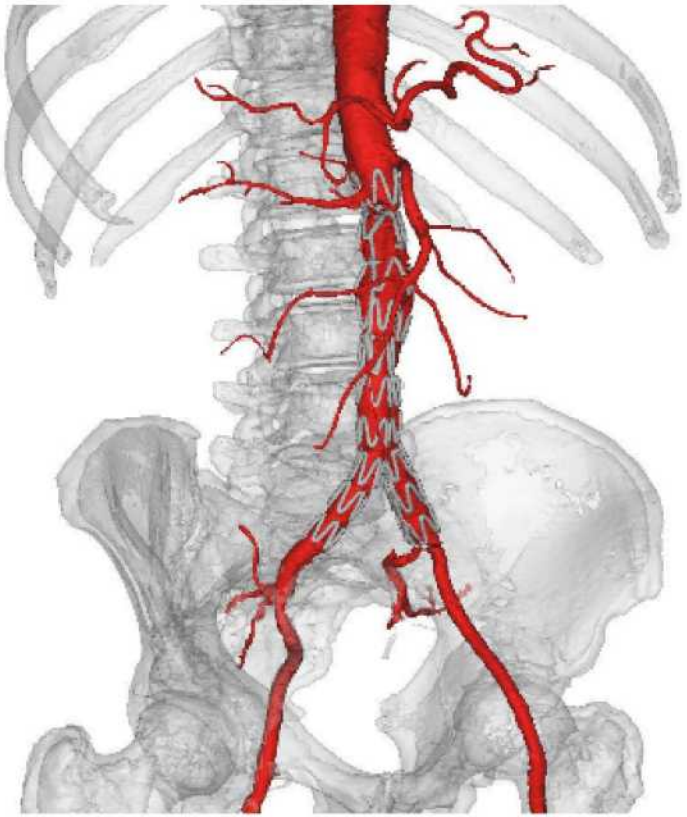
Computerized Tomography images





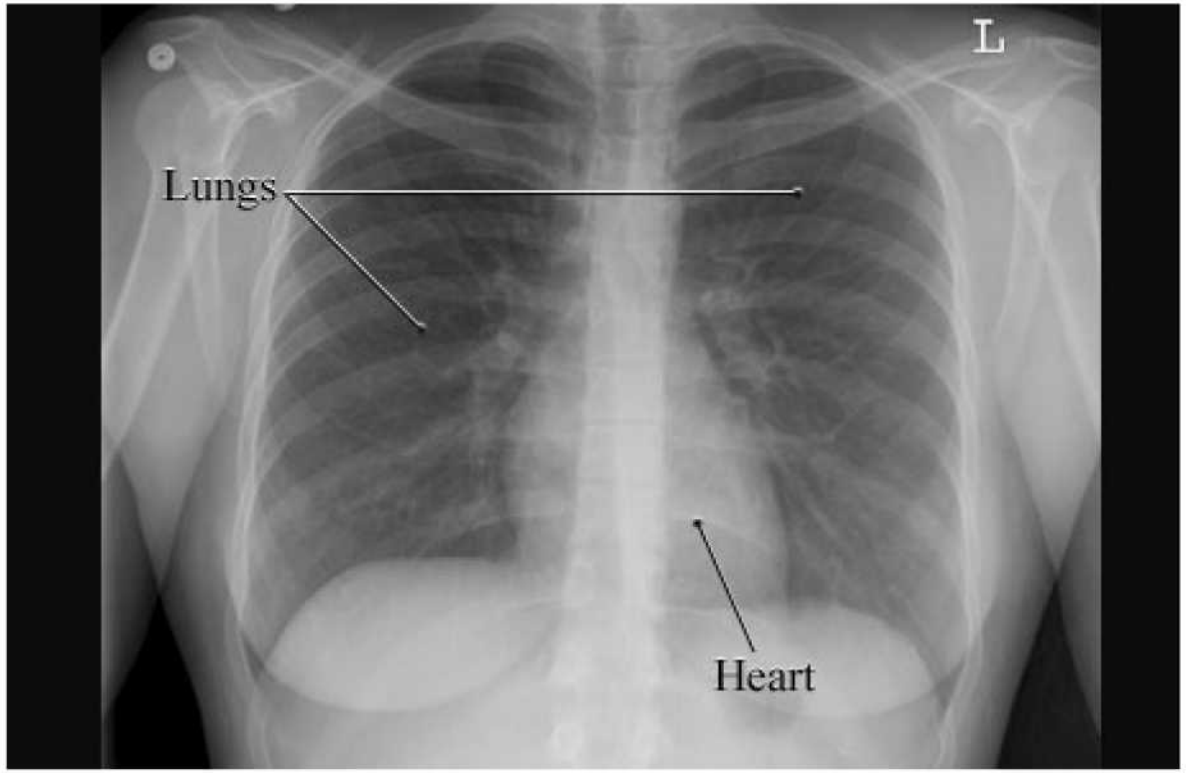
3D Reconstruction and display



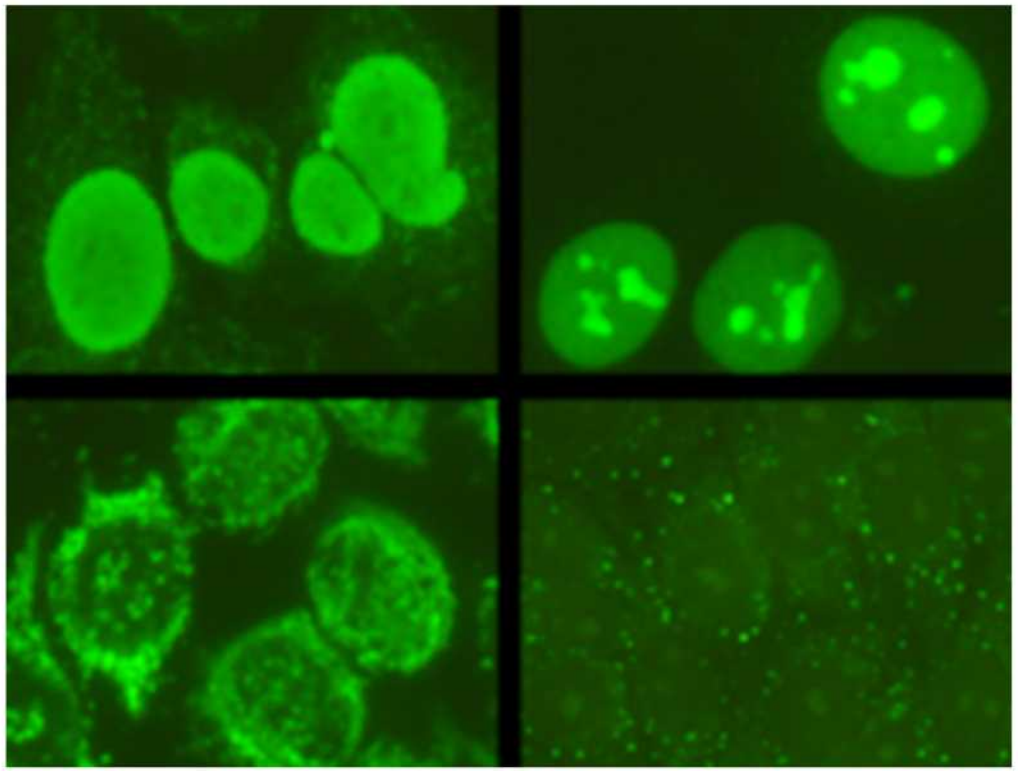


Imaging Methods like Magnetic Resonance (MR), Computerized Tomography (CT) and 3D ultrasound result in 3D data sets, which can be analysed by software programs and displayed to yield spectacular information which cannot be seen by a human observer from the original images.

Image Analysis / Pattern Recognition



Radiologists train many years to be able to recognize certain features in medical images



Starting with ‘simple’ images, computers are supporting image analysis and patient diagnosis

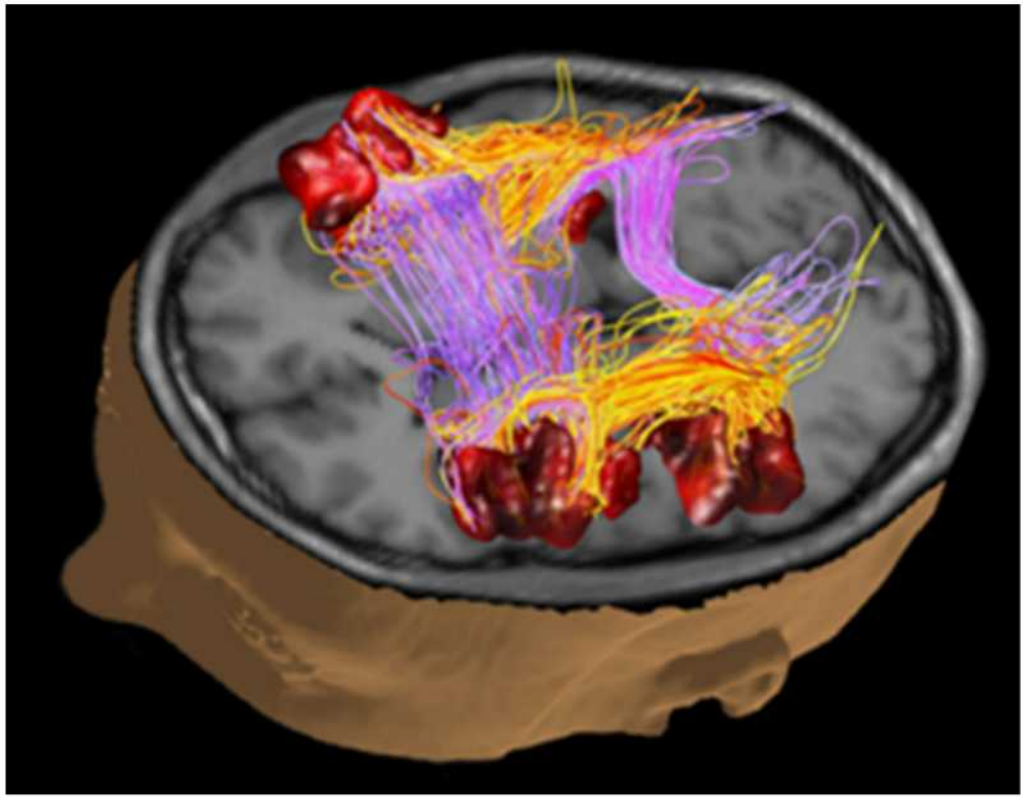
Signal Display: (Medical) Monitors and Hardcopies (Films)

6 MegaPixel Monitor for digital diagnosis
of high resolution X-ray images

Conventional (X-ray) Film
(for high contrast resolution it should be viewed on a light box)

Signal Display

colour is used to highlight ‘recognized patterns’



also modern graphic techniques can be used in medical imaging (nerve bundles in the brain’

END

The creation of this presentation was supported by a grant from THET:
see https://www.thet.org/