

History and basic physics

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History of US/MSUS

I. Where are we (US) coming from?

II. Where are we (US) now?

1. Echo

- nymph
- Zeus
- Hera made her only able to speak the last few words spoken to her
- Echo fell in love with Narcissus
- Narcissus died “oh marvellous boy, I loved you in vain, **farewell**”



Waterhouse 1903, Art Gallery, Liverpool

Ovid, Metamorphoses

- “Today all that remains of Echo is the sound of her voice”

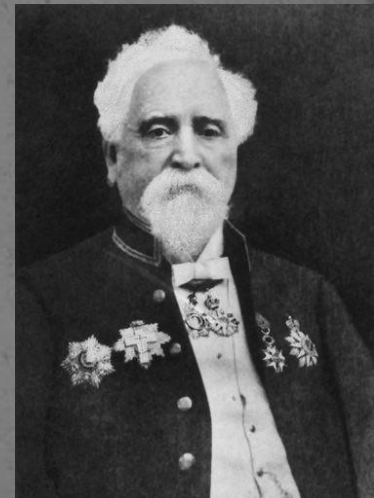


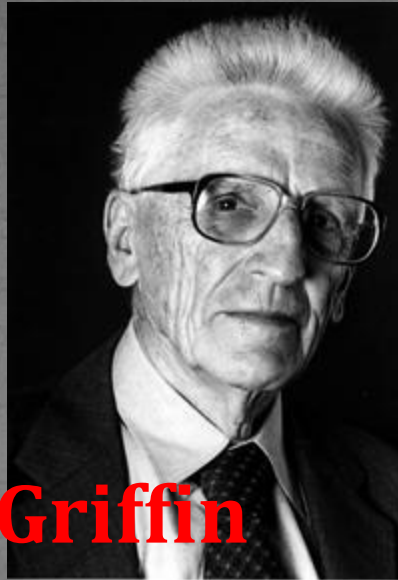
Alexandre Cabanel's *Echo*

2. From animals

Bats

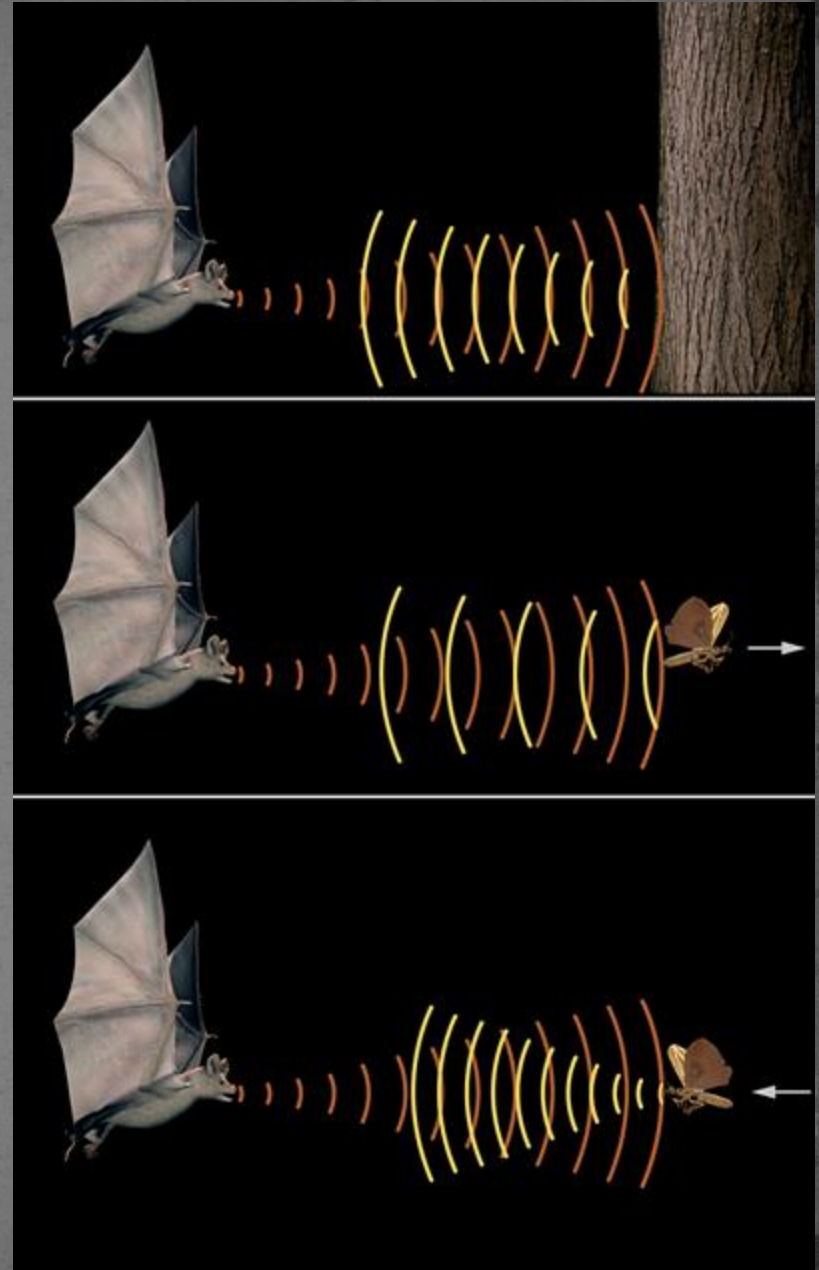
- **Lazzaro Spallanzani** (1729-1799): bats use sound and their ears for navigation in total darkness
- **Sir Hiram Maxim** 1912: bats used sound below the human auditory range to avoid obstacles





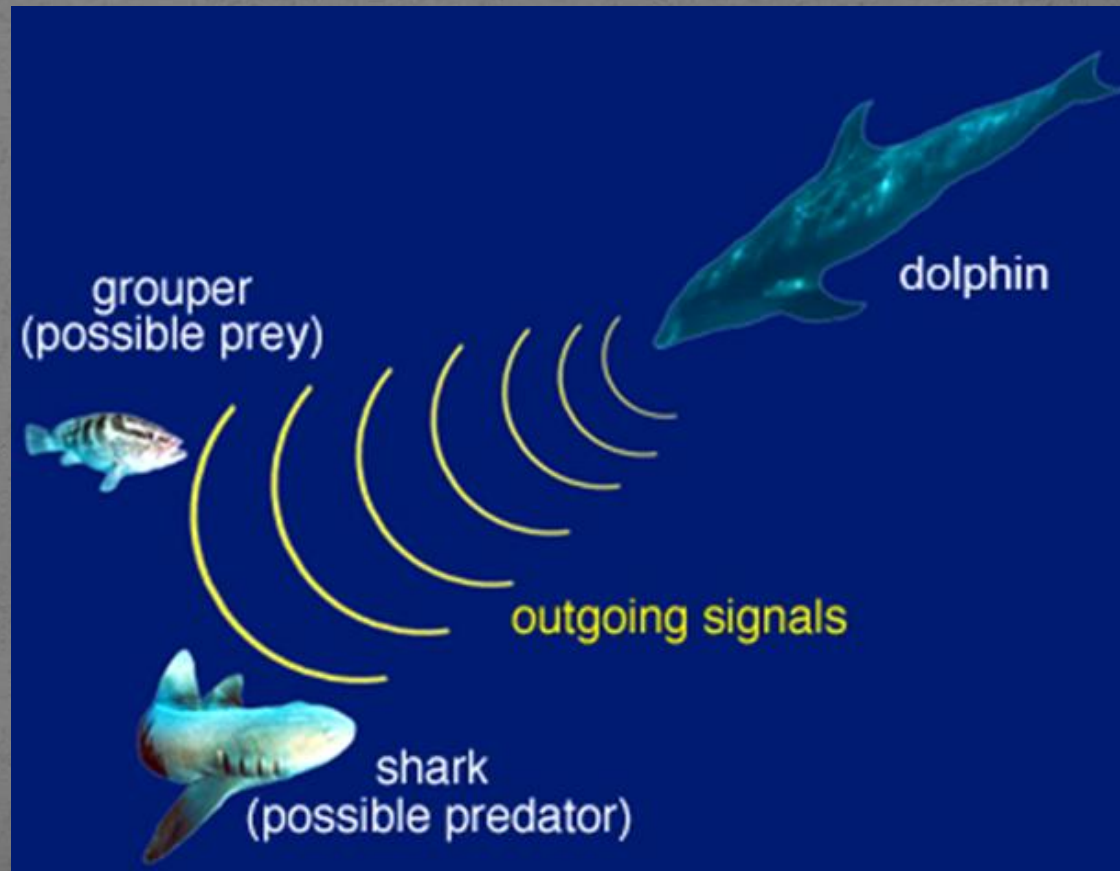
1938 **Donald Griffin**
studied the navigational
method of bats

• *echolocation*



Dolphins

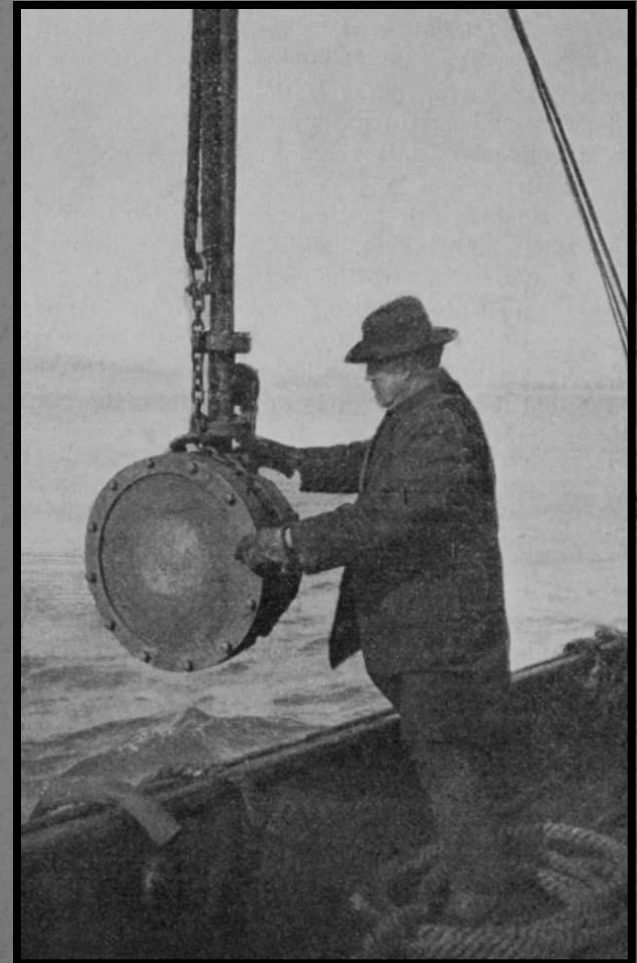
- “they see with sounds”



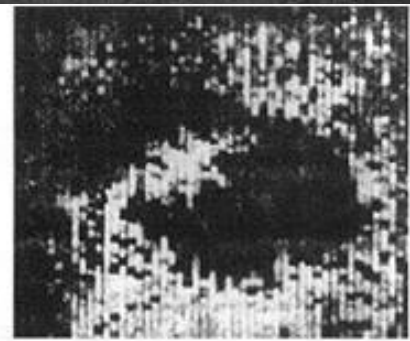
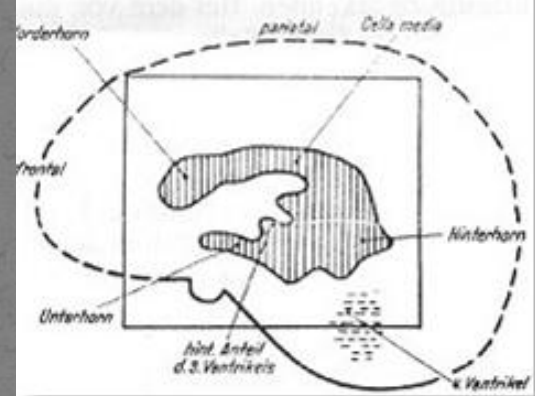
3.From Titanic

- **Reginald A. Fessenden**, 1912

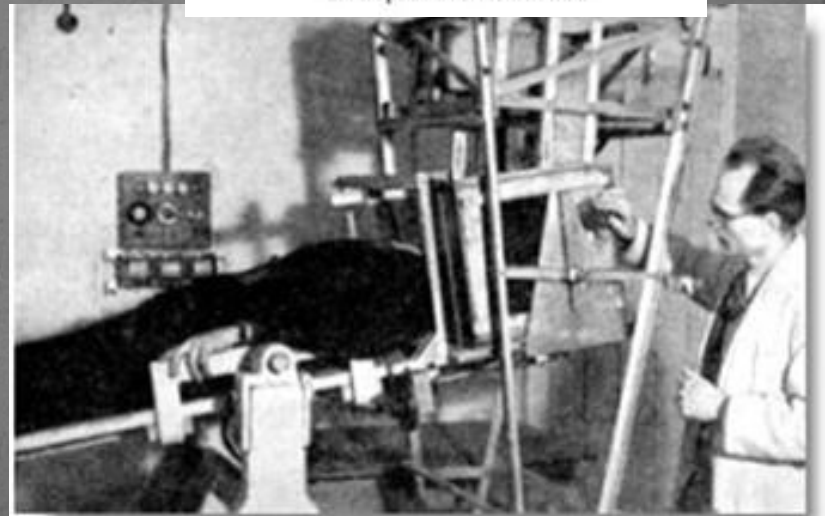
- first sonar: **Fessenden oscillator** detecting an iceberg at two miles (3 km) range



Karl Dussik, neurologist 1942
the first physician to apply
ultrasound as a diagnostic method
in human subjects
“hyperphonography”



The hyperphonogram was thought
to depict the ventricles

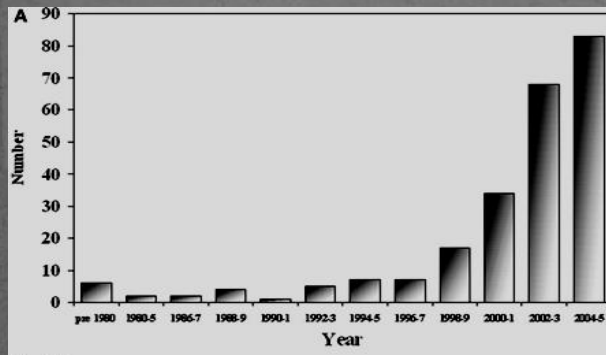


Dussik and his ultrasonic apparatus in 1946

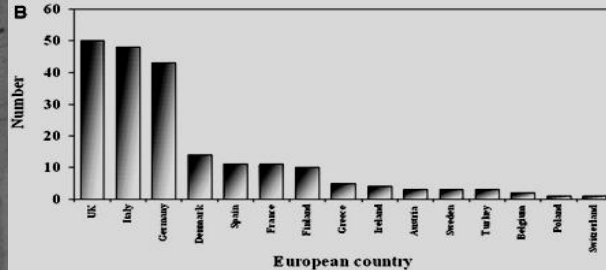
- 1958: "Measurement of articular tissue with ultrasound" American Journal of Physical Medicine
- described the ultrasonic artifact "**acoustic fibre anisotropy**"

- 1955: 6000 published papers about ultrasound and their applications

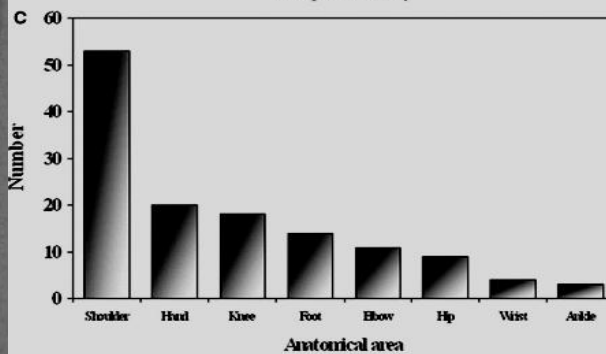
II. Where are we now?



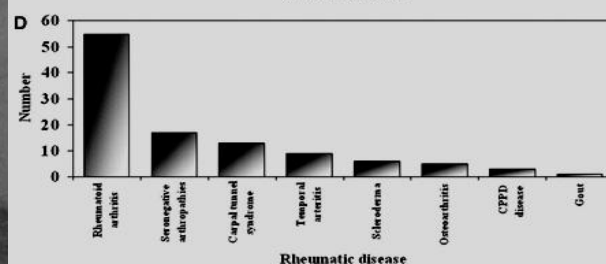
Number of MSUS publications



Nationality of authorship



Anatomical area investigated



Rheumatic disease evaluated

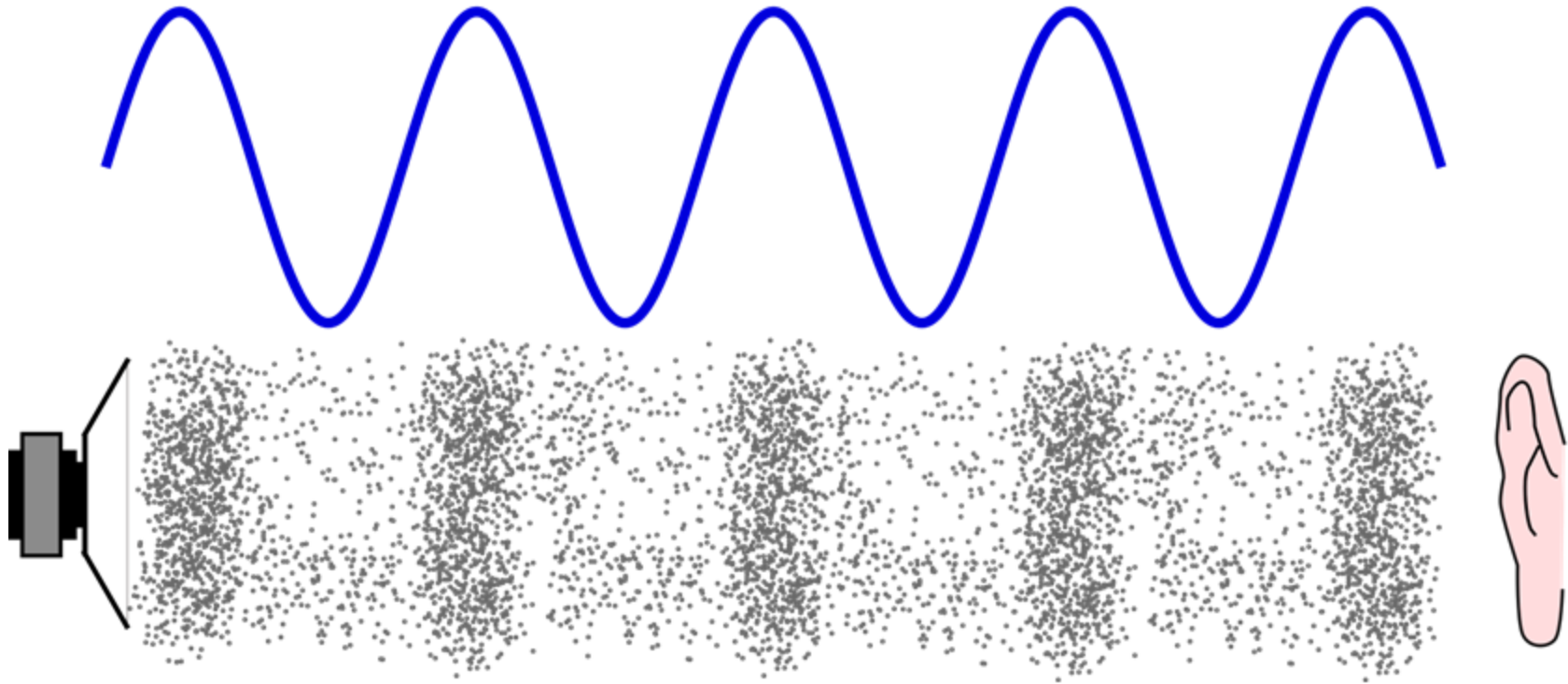
Meenagh G et al. Rheumatology 2007;46:3-5

Ultrasound physics

Lecture Objectives

- Review basic physics vocabulary
- Explain the principles of sound waves
- Use ultrasound physics to explain how images are produced
- Teach how to use these principles in daily ultrasonographic examination

What is sound wave?



Sound is a mechanical wave (sine wave) that travel in straight line

1 cycle

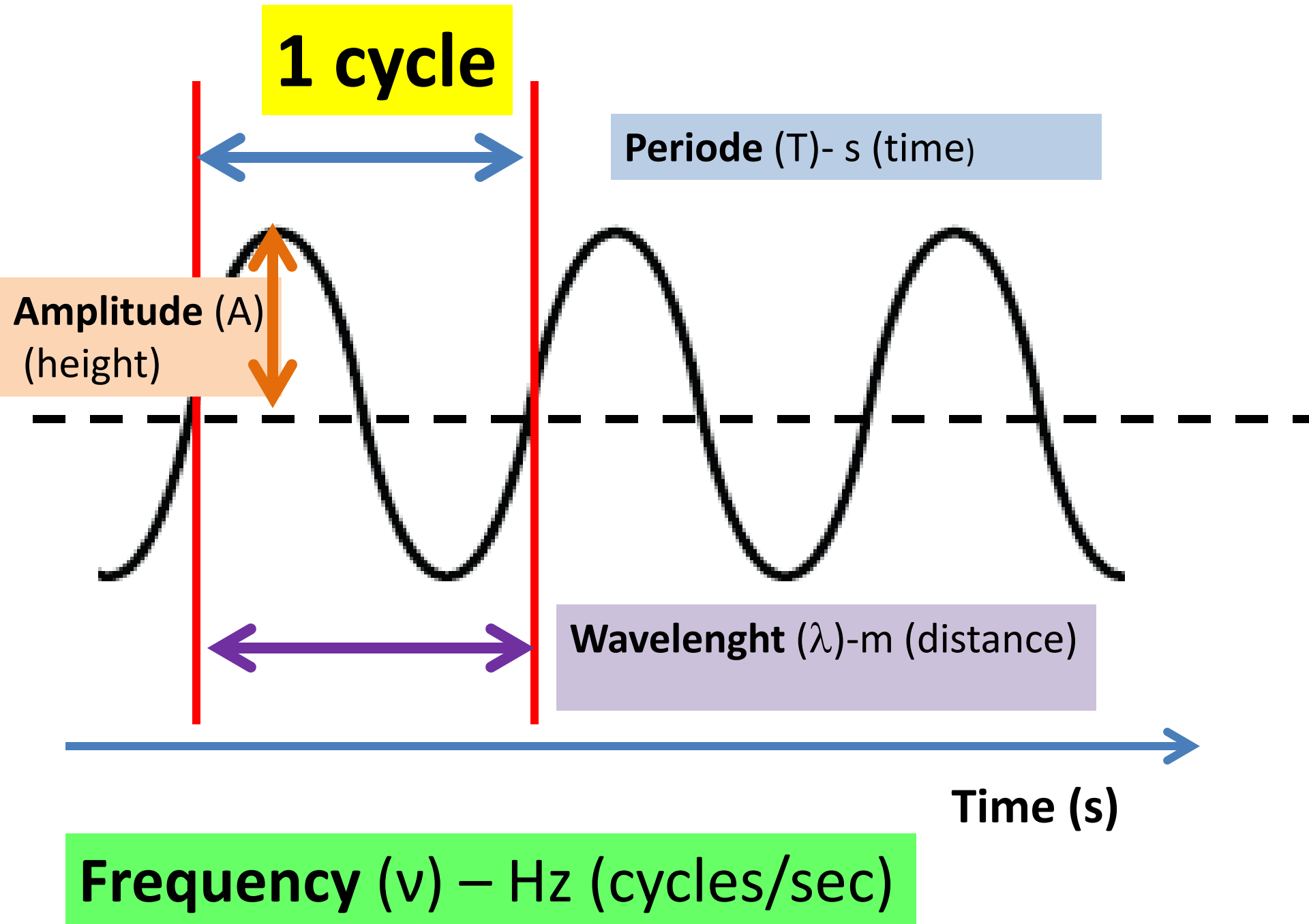
Periode (T)- s (time)

**Amplitude (A)
(height)**

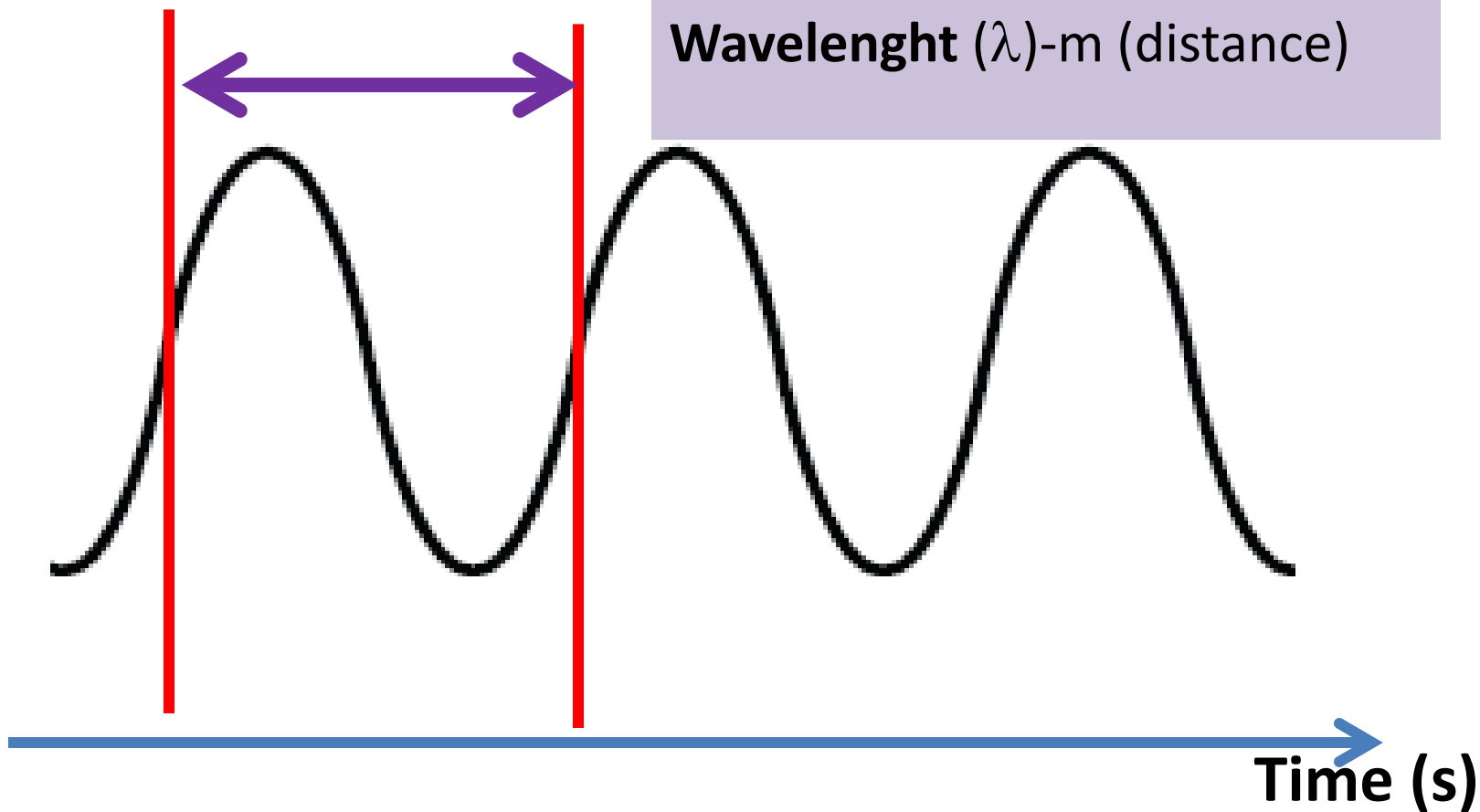
Wavelength (λ)-m (distance)

Time (s)

Frequency (ν) – Hz (cycles/sec)



Wavelength (λ)-m (distance)



frequency



wavelength



Speed of sound

Speed (c)-m/s

$$c = v \times \lambda$$

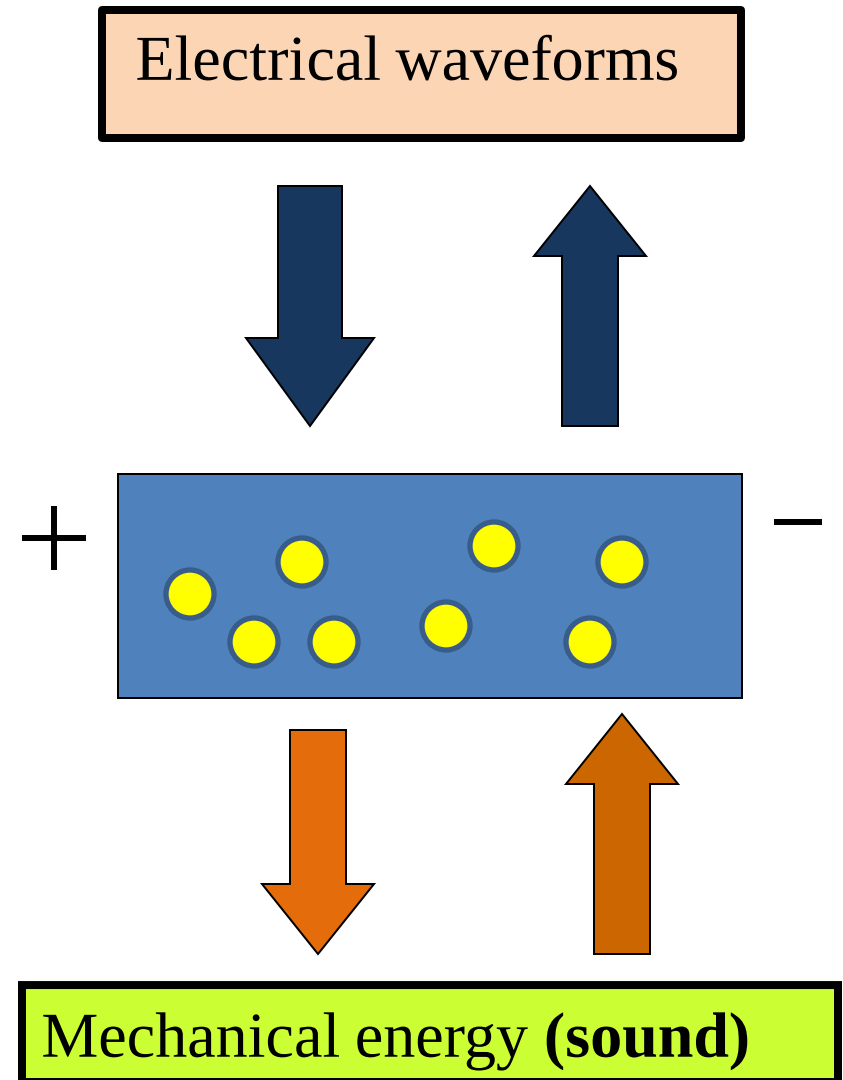
Medium	Speed (m/s)
Air	330
Fat	1450
Water	1480
Average soft tissue	1540
Liver	1560
Blood	1560
Muscle	1600
Tendon	1700
Bone	3500
Metal	2000–7000

Average speed of ultrasound in the body: 1,540 m/sec

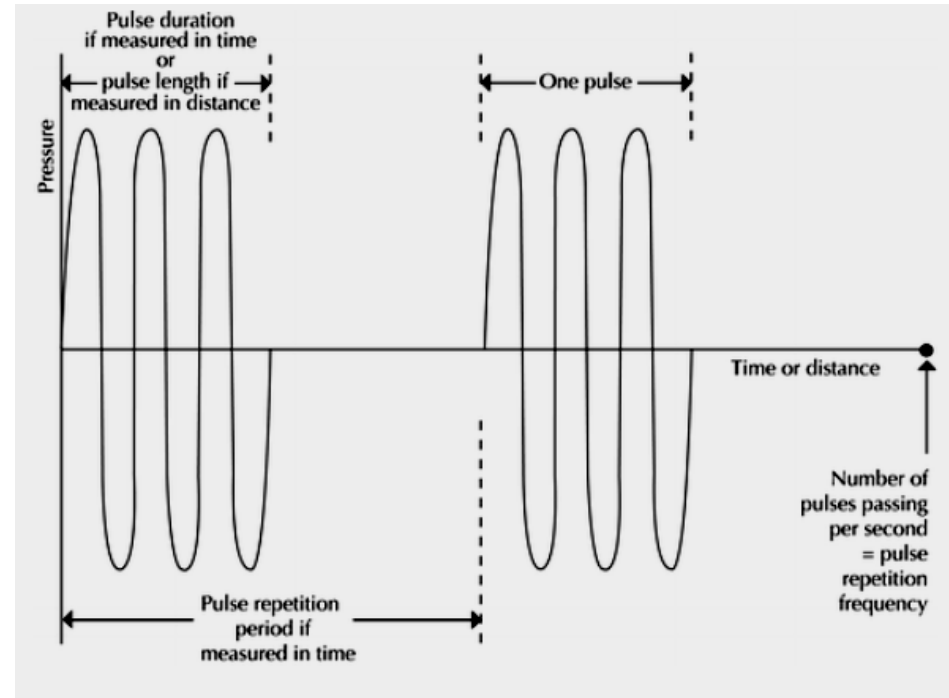
PRODUCTION OF SOUND

Transducer

- allow back and forth conversion of ultrasound energy and electric energy



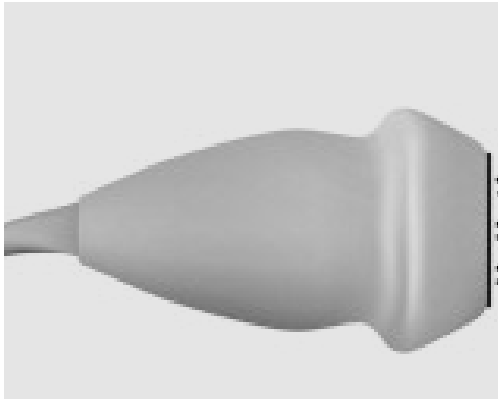
- Short pulses of sound 2-4 cycles long.
- between pulses, the machine “listens” for echoes to return.
- Ultrasound machine spends
 - 1% of the time producing sound
 - 99% of the time listening for echoes to return



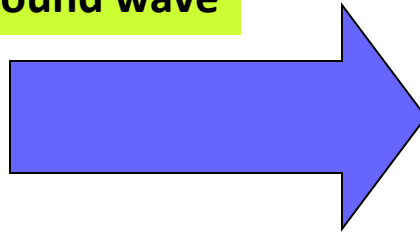
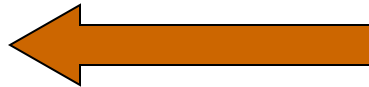
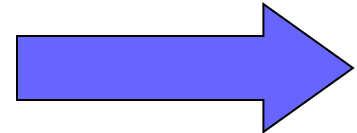
INTERACTION SOUND-TISSUE

1. Reflection

Transducer (**emitter**)



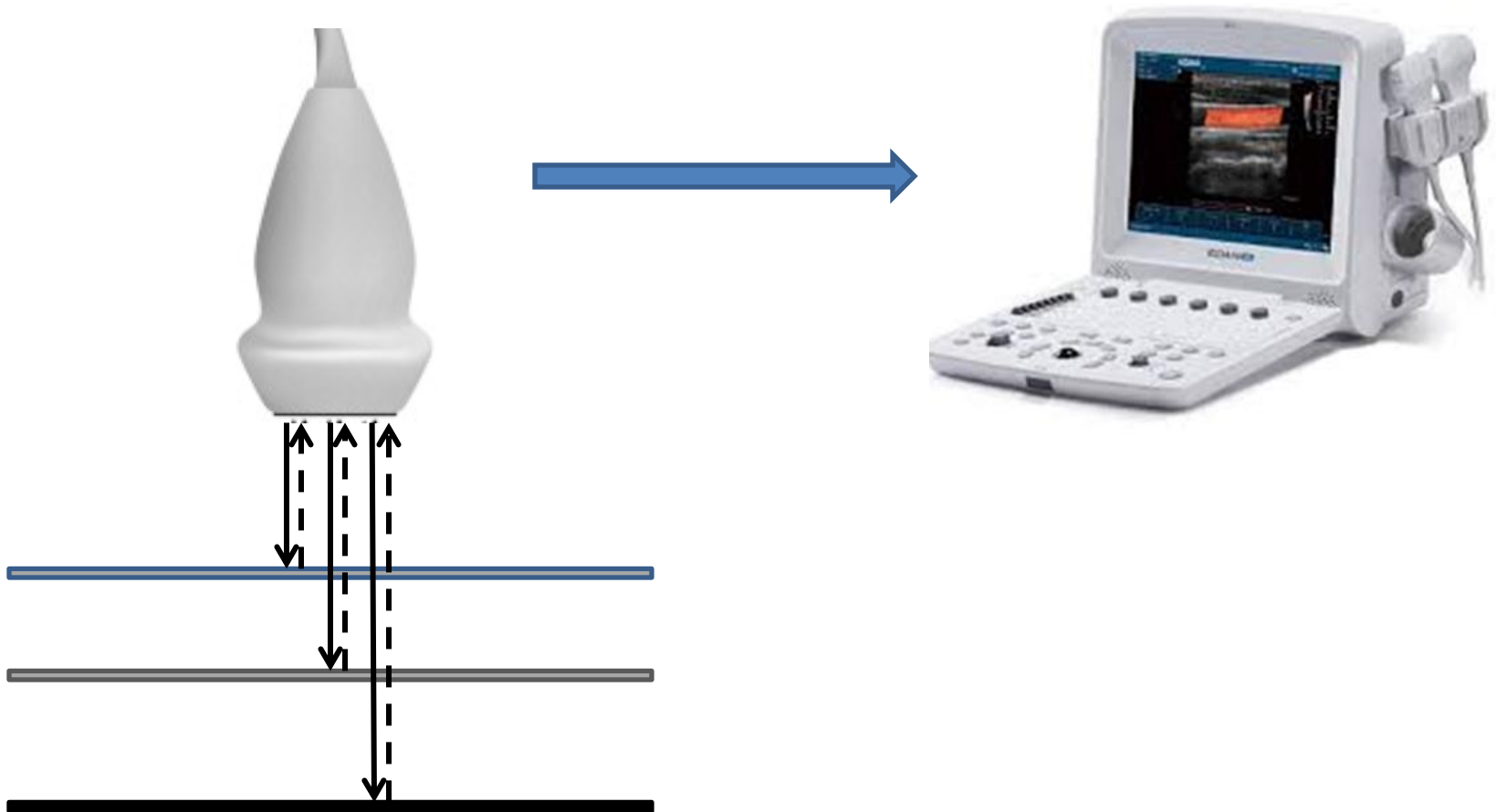
sound wave



Acoustic interface

change in the stiffness or density of adjacent tissues

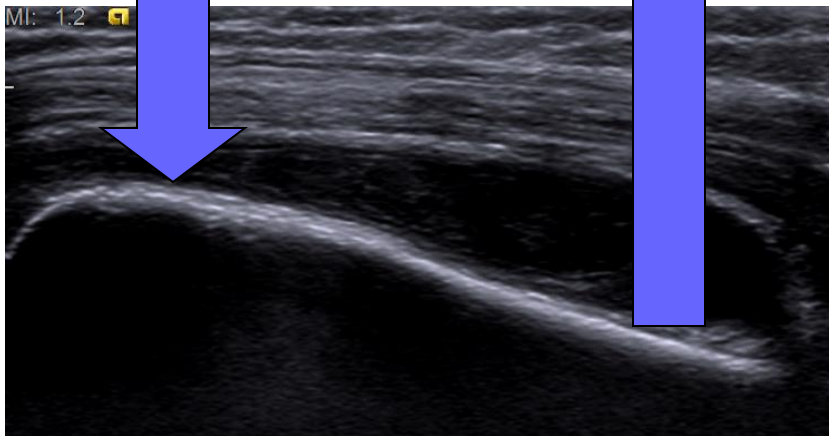
- The reflected waves are detected by the transducer (**receiver**)



Acoustic impedance

- Acoustic impedance (z) = density x propagation velocity

$$Z = \rho V$$

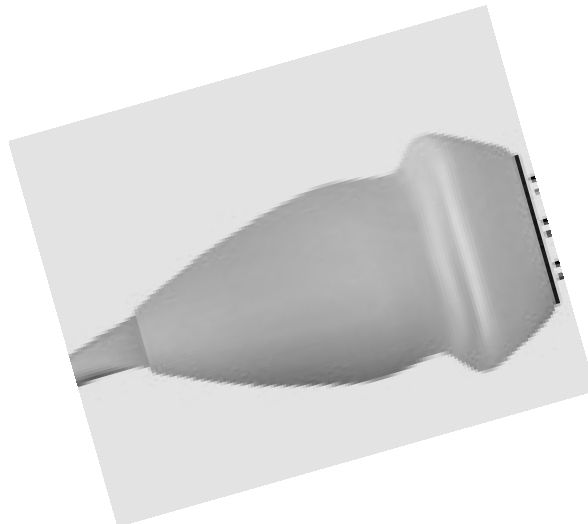
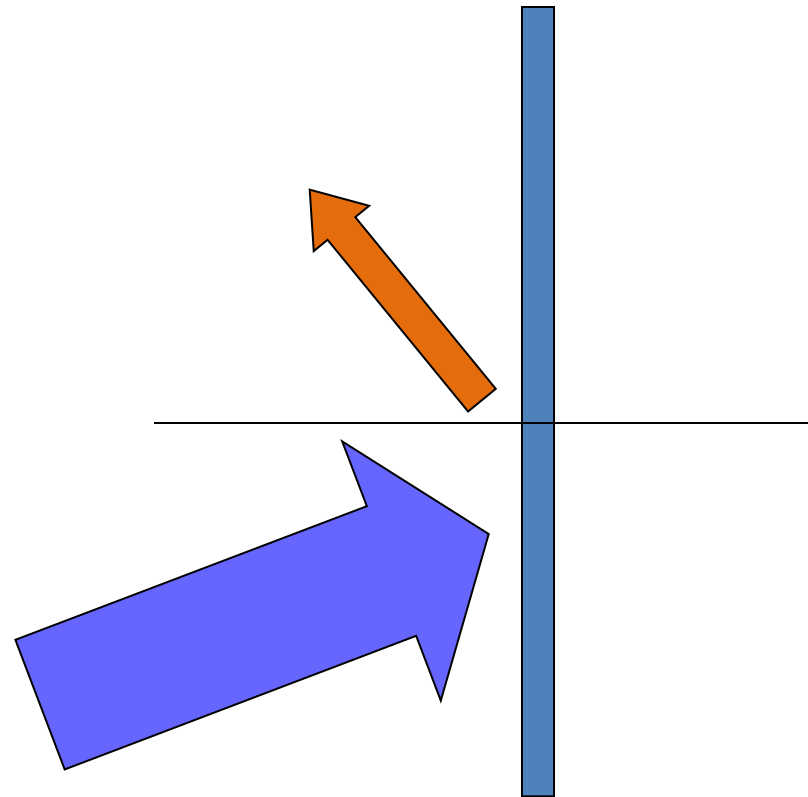


GEL

Medium	Acoustic impedance (rayl $\times 10^{-6}$)
air	0,0001
fat	1,38
water	1,50
blood	1,61
kidney	1,62
liver	1,65
muscle	1,70
bone	7,80

2. Refraction

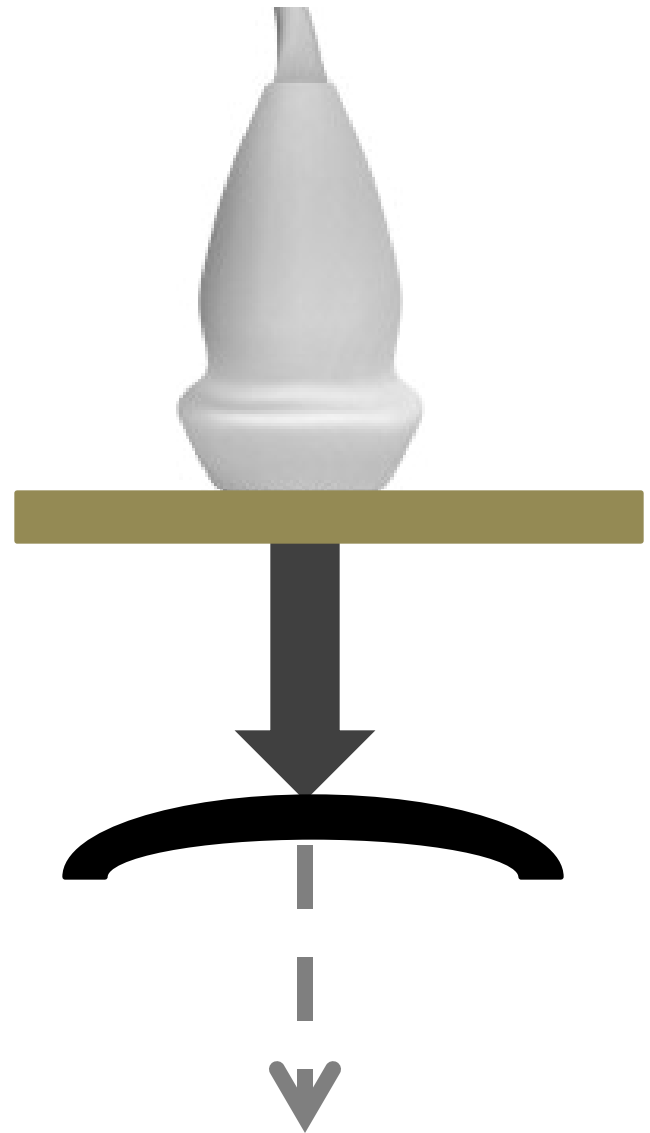
- angle of incidence of the interface is not 90° (perpendicular)



3. Attenuation

Sound energy is attenuated or weakened as it passes through tissue because parts of it are

- reflected
- scattered
- absorbed
- refracted
- diffracted



Signal Amplification

Time –gain compensation

Gain



Spatial resolution

Image quality is dependent on

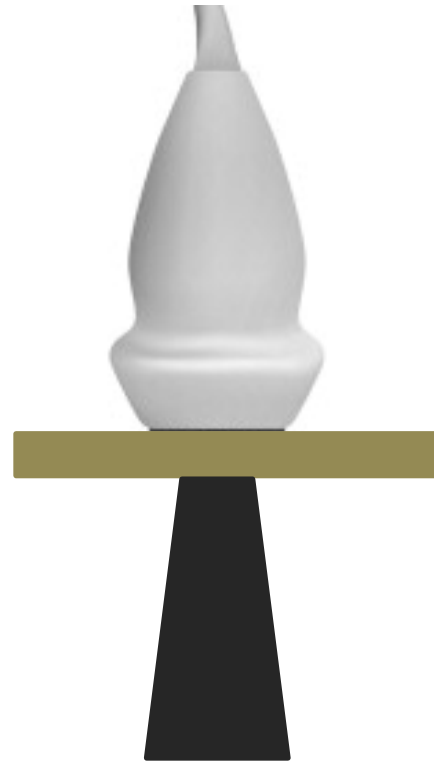
- Axial Resolution
- Lateral Resolution
- Focal Zone
- Probe Selection
- Frequency Selection
- Recognition of Artifacts

Axial Resolution

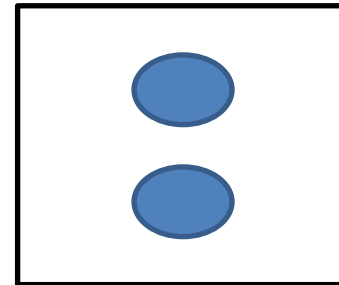
Ability to differentiate two objects along the long axis of the ultrasound beam

Determined by the pulse length

Higher frequencies produce better resolution (but lesser penetration)



body



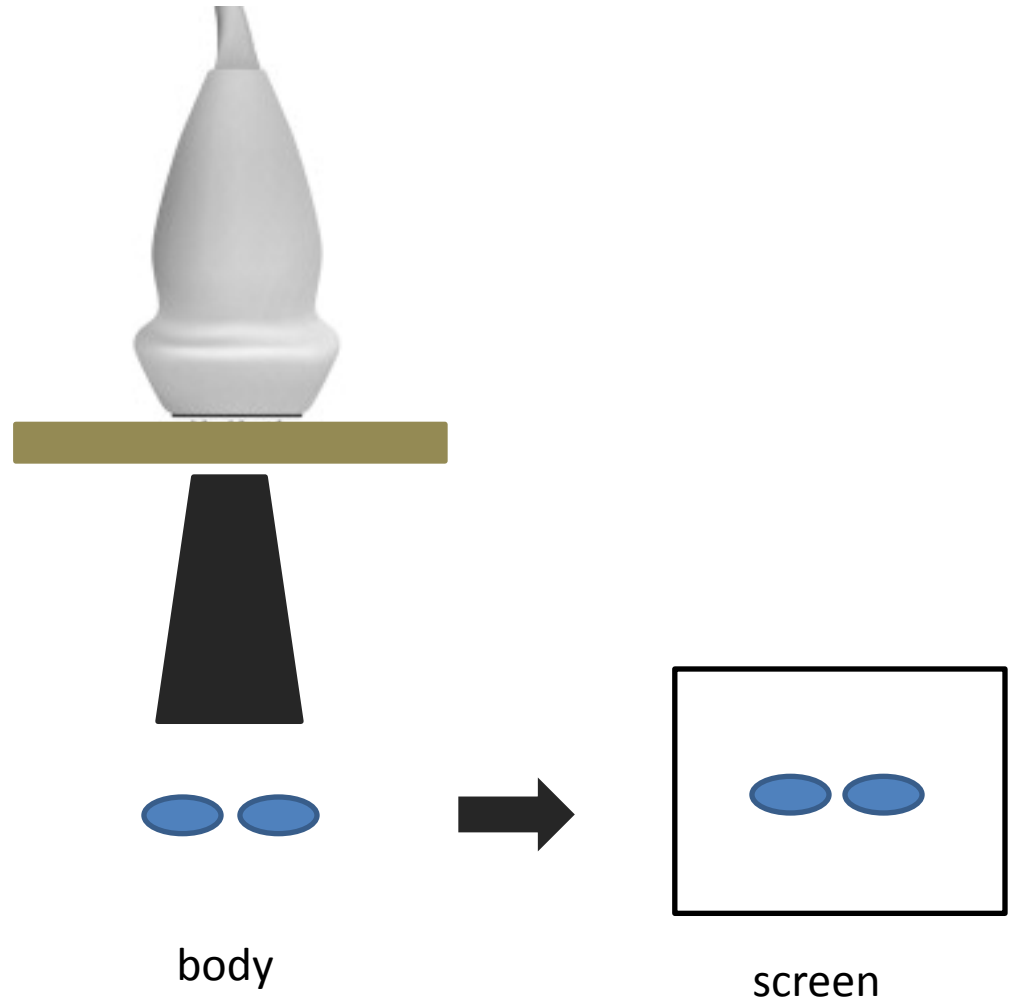
screen

- **5MHz- 1 mm**
- **10Mhz- 0.5 mm**

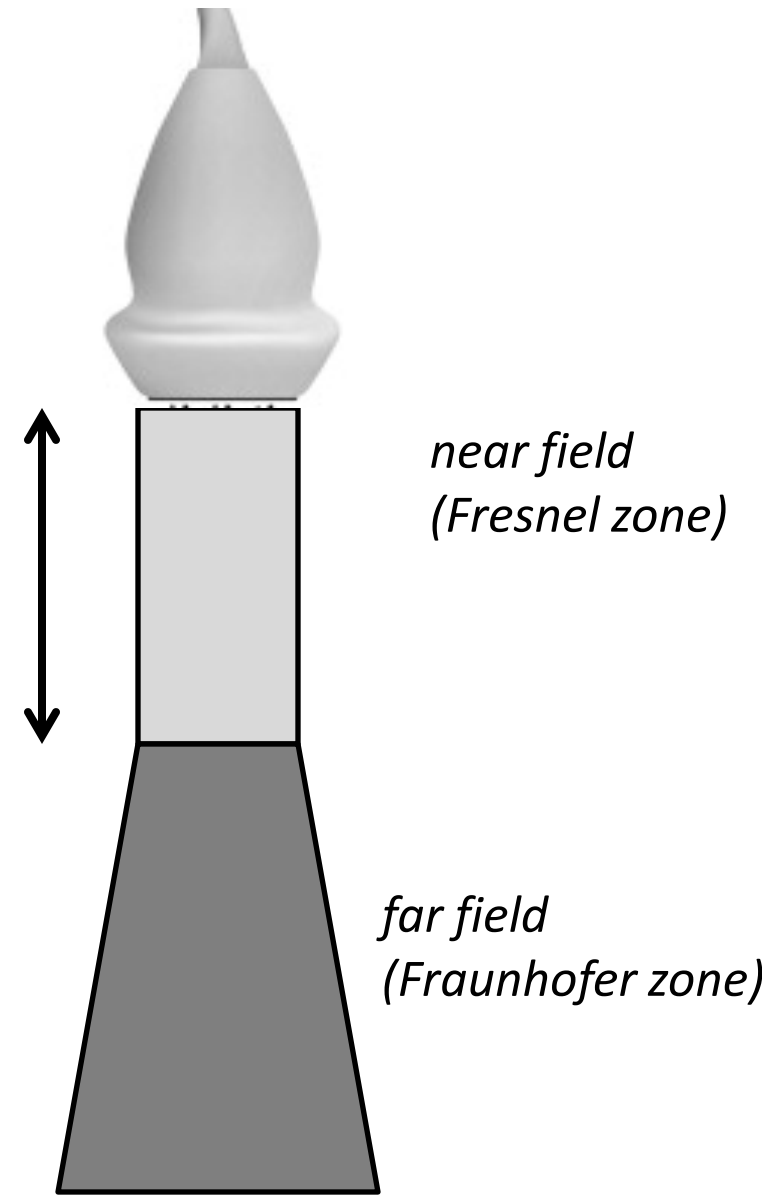
Lateral Resolution

Ability to differentiate
objects along an axis
perpendicular to the
ultrasound beam

Dependent on the width
of the ultrasound beam
(can be controlled by
focusing the beam)

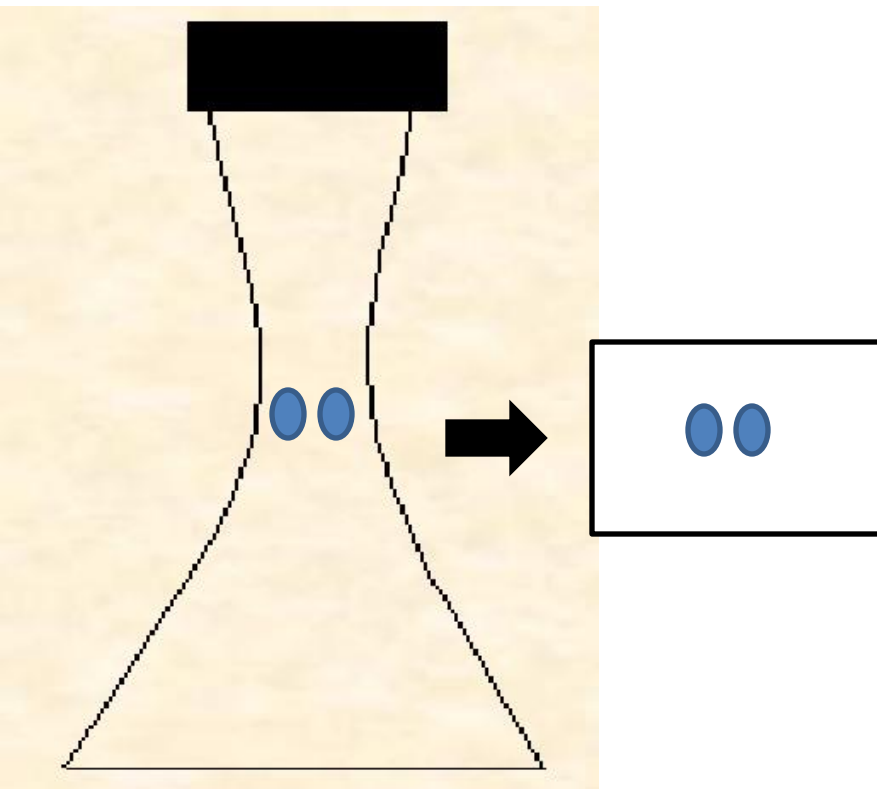


- Ultrasound beams have widths that vary with distance from the transducer
- The point of narrowest width occurs at the **focal distance**.

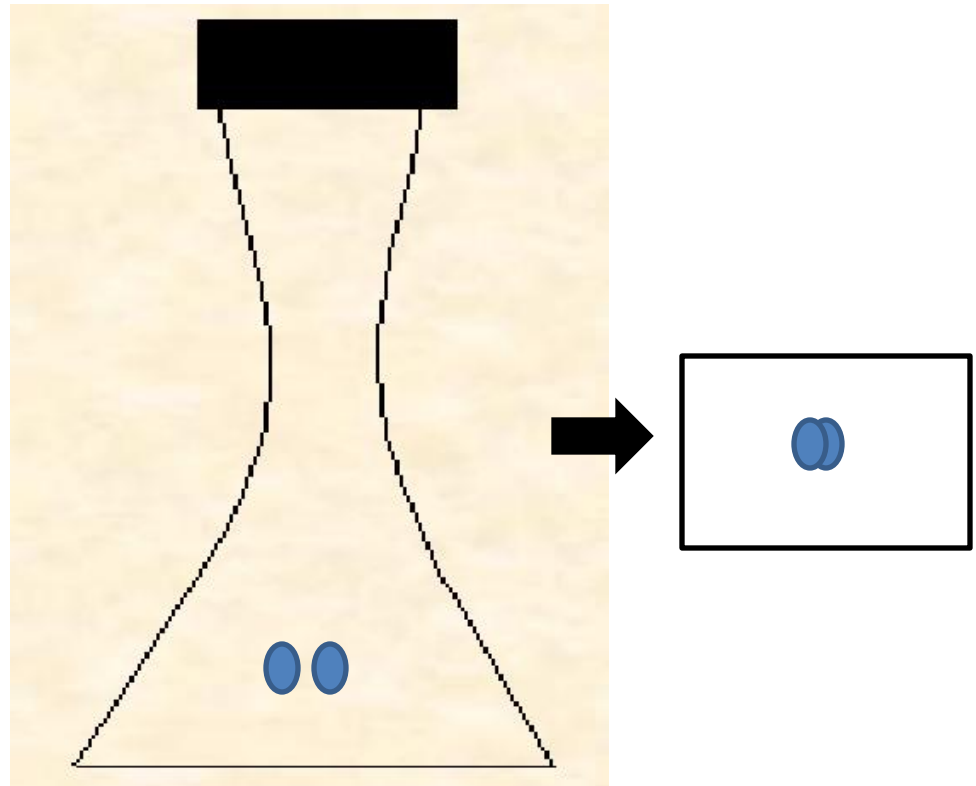


Focal Zone

Objects within the focal zone



Objects outside of focal zone



Take home message

- Ultrasonography uses sound waves reflected at interfaces to display the structures of the body

- To know how the ultrasound beam is working is essential for a good image