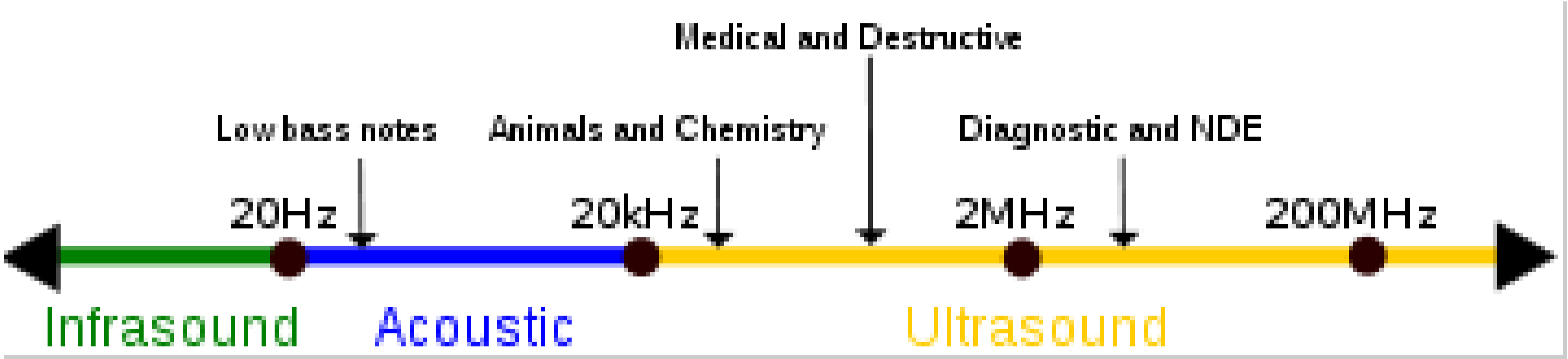
# BASIC PRINCIPLES OF ULTRASOUND IN REGIONAL ANAESTHESIA

Mafeitzeral Mamat

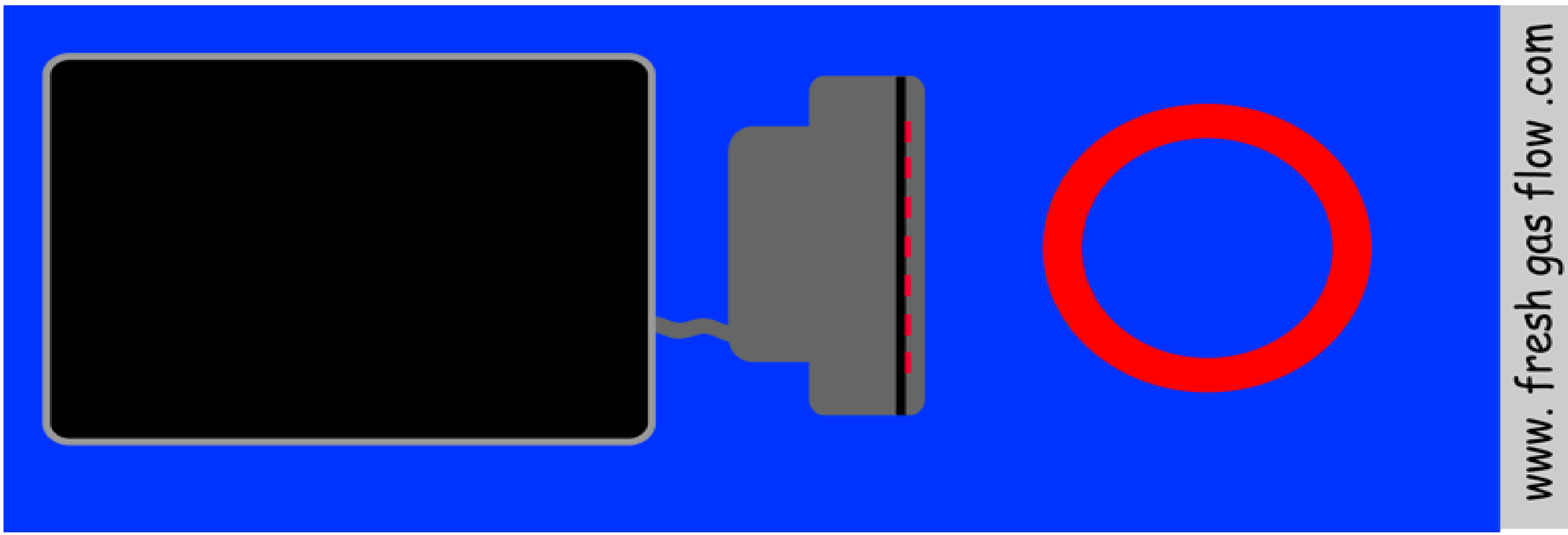
# Ultrasound

- Sound with frequency greater than the upper limit of human hearing



# Medical ultrasound

- Use of ultrasound to visualize muscles, tendons, nerves and many internal organs, to capture their size, structure and any pathological lesions with real time tomographic images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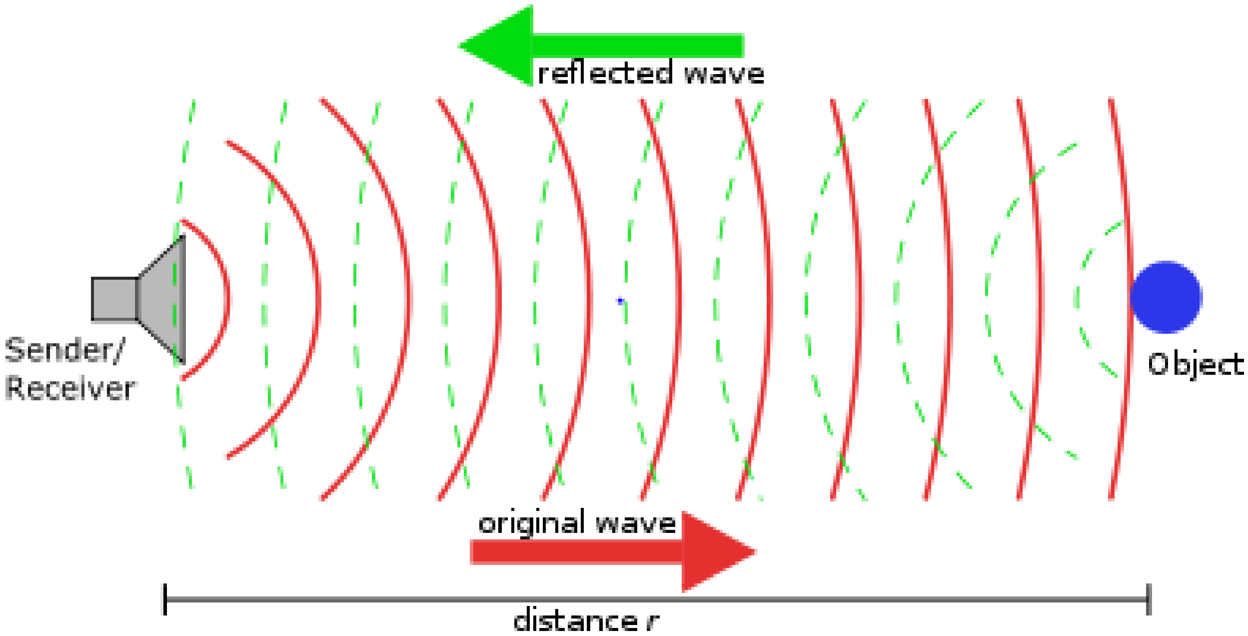
# Ultrasound safety

- Involves no radiation
- Induces inflammation
- Heats soft tissue
  - Cavitation – microscopic pockets of air
  - Thermal effect
  - Post natal mechanical effect
- ALARA
  - As low as reasonably achievable

# Ultrasonic range finder

- SONAR – sound navigation & ranging
- Range finding by measuring the difference in time between the pulse being transmitted and the echo being received

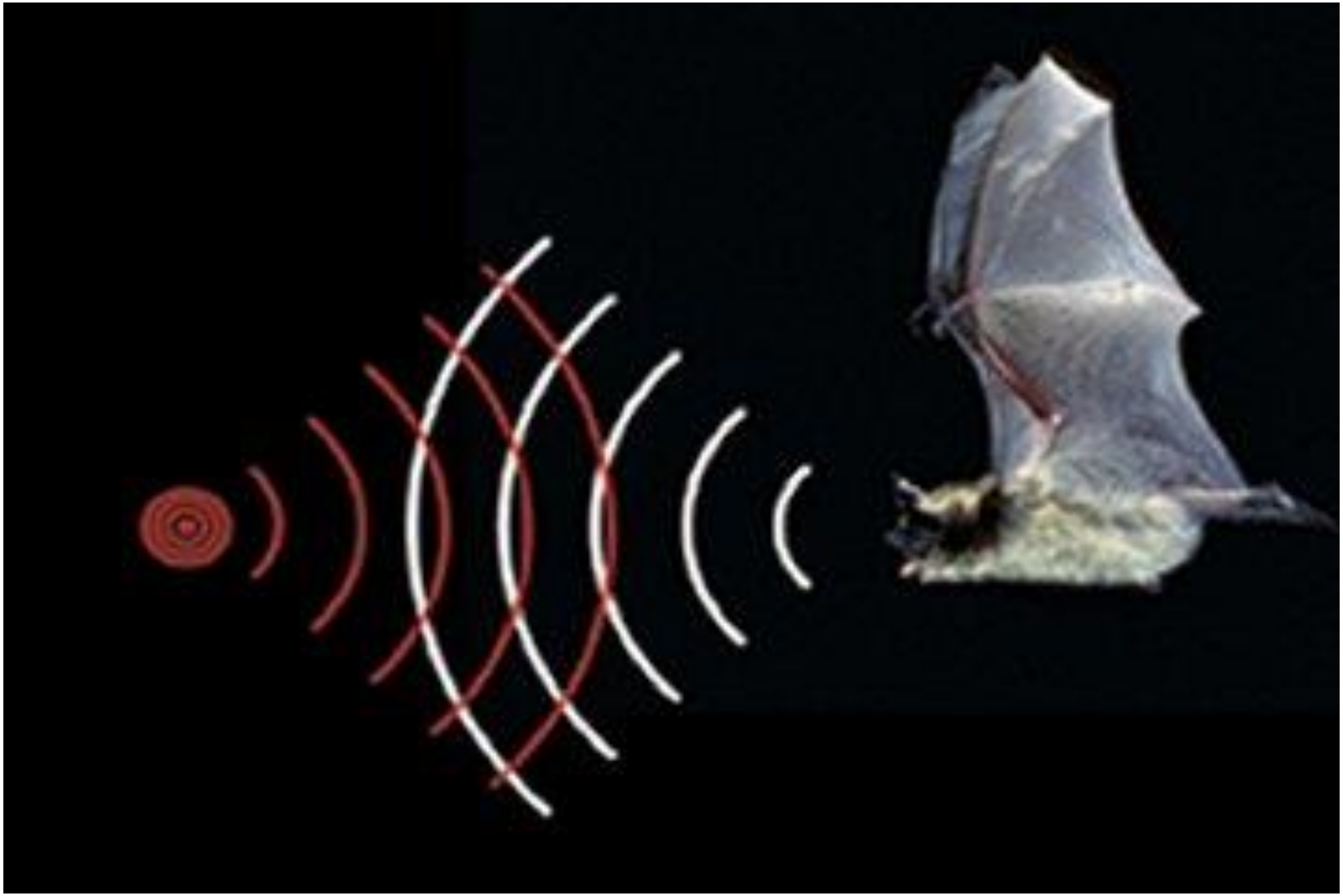


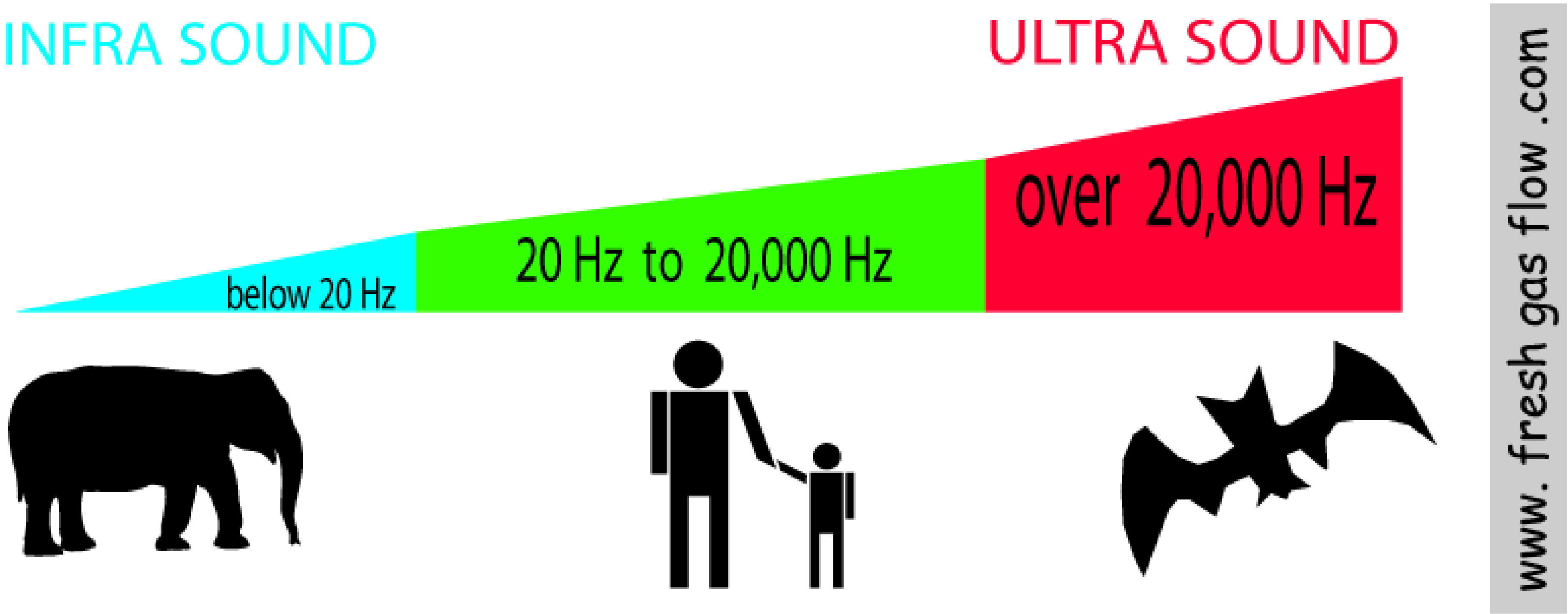
# $V = f \times \lambda$

- **Velocity** - the speed at which sound waves travel through a particular medium. Velocity is equal to the frequency x wavelength.

| Material | Speed of Propagation |
| --- | --- |
| bone | 4080 m/s |
| blood | 1570 m/s |
| tissue | 1540 m/s |
| fat | 1450 m/s |
| air | 330 m/s |

# Bats did it first, & do it better





INFRA SOUND
ULTRA SOUND
over 20,000 Hz
20 Hz to 20,000 Hz
below 20 Hz
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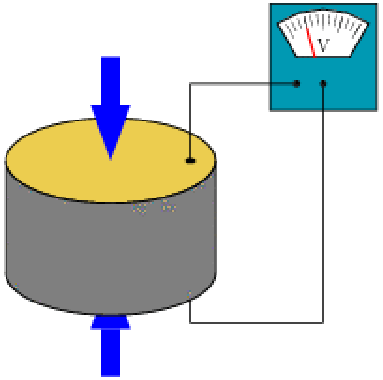
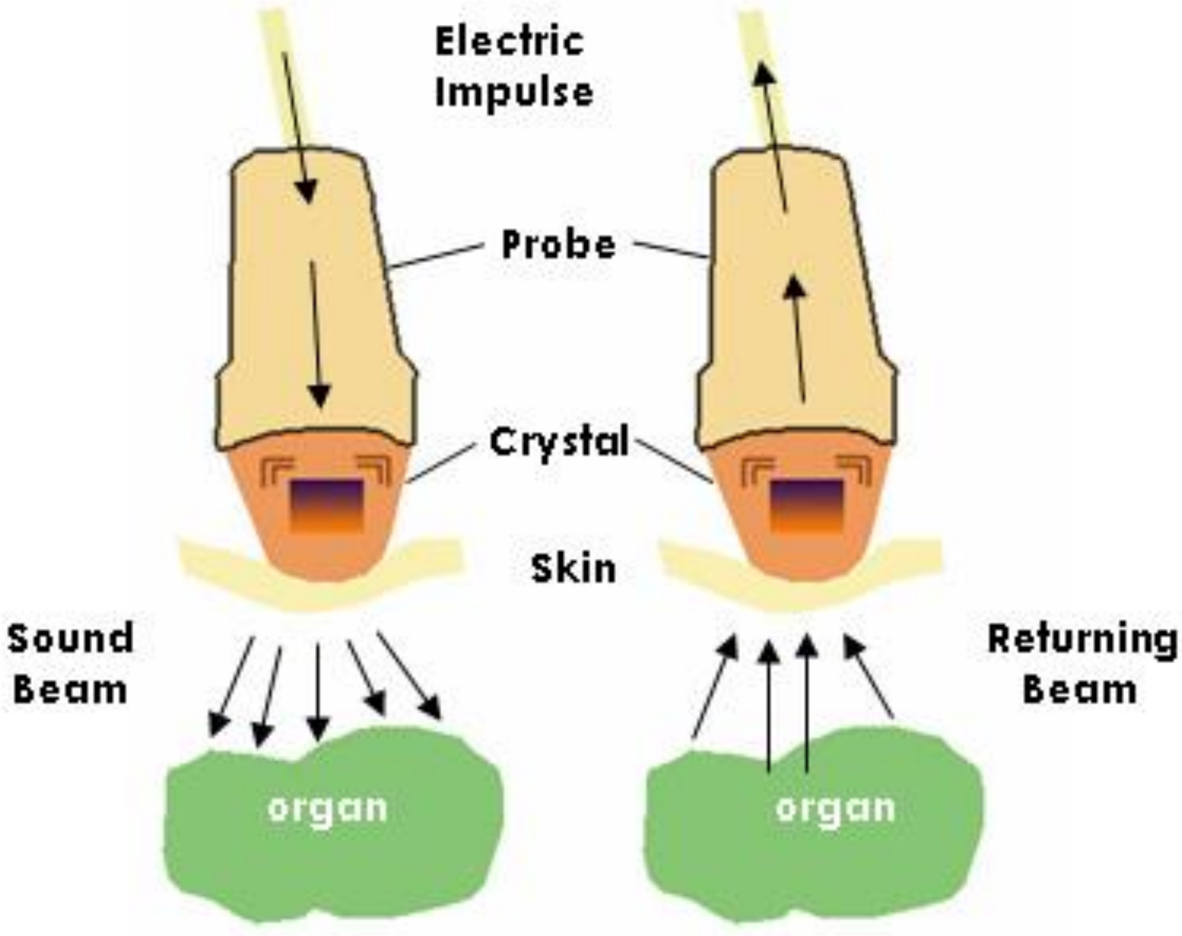
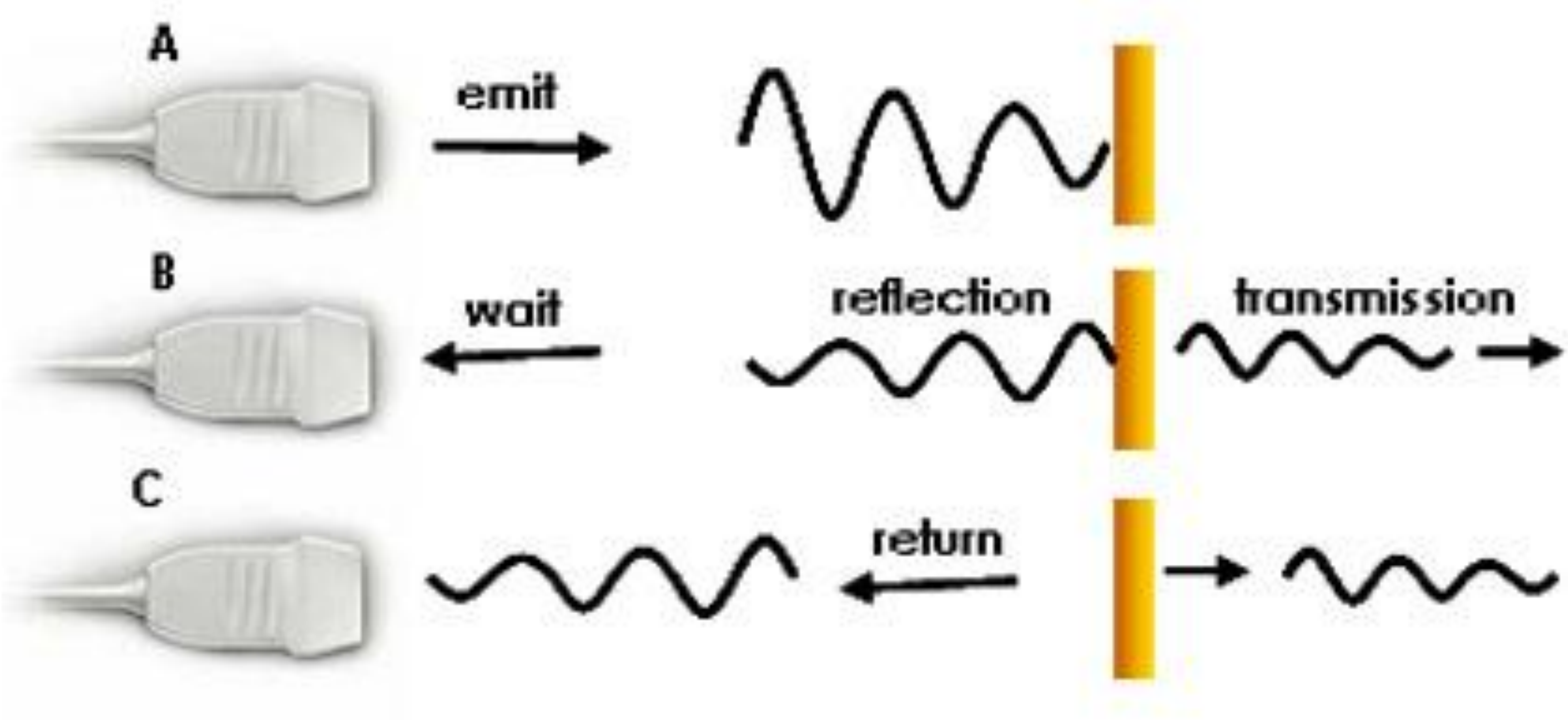
# Sender/receiver

- Piezoelectric transducer are made of ceramics
- Sends out ultrasound signal of a certain frequency
- ‘Listens’ to the echo received
- Phased array arrangement enables changes in direction & depth of focus



Electric
Impulse
Probe
Crystal
Skin
Sound
Beam
Returning
Beam
organ
organ

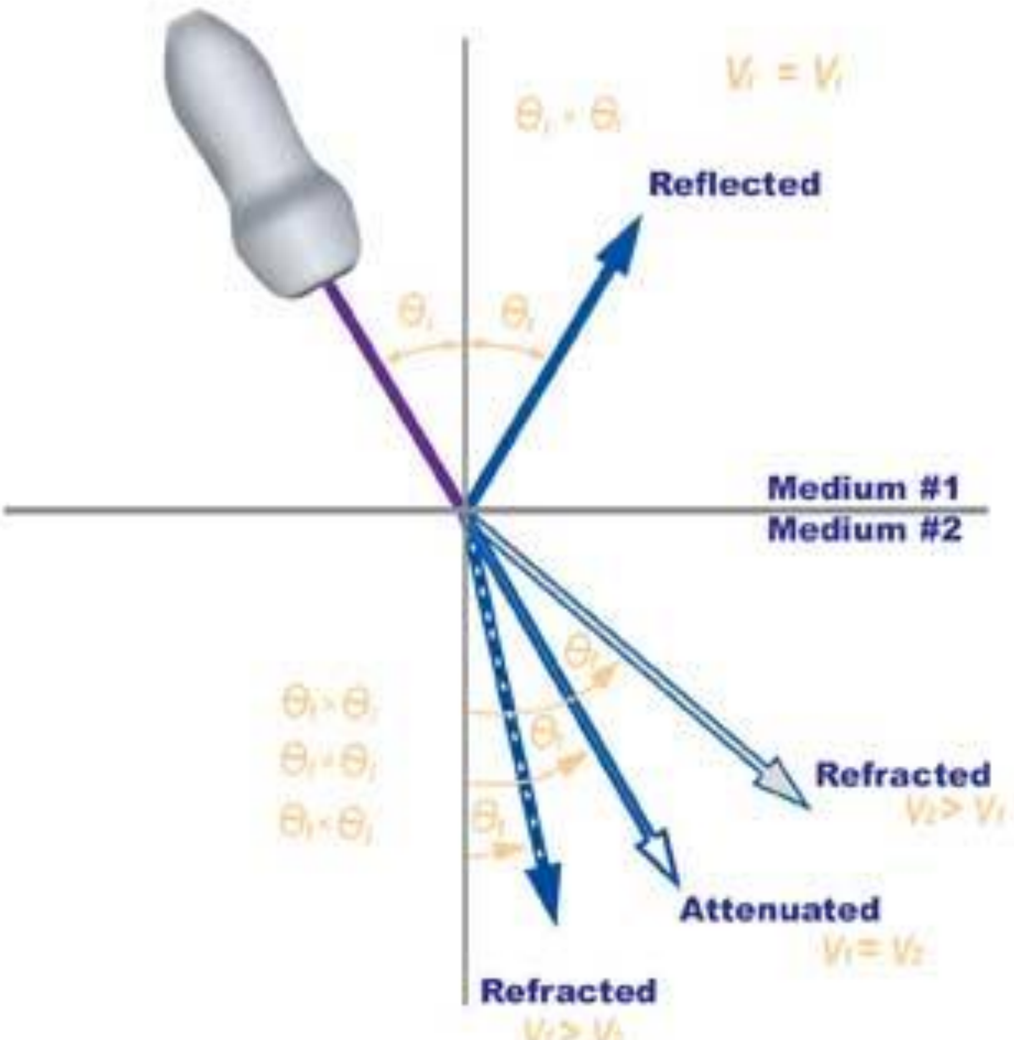

A
emit
B
wait
reflection
transmission
C
return

# Image formation

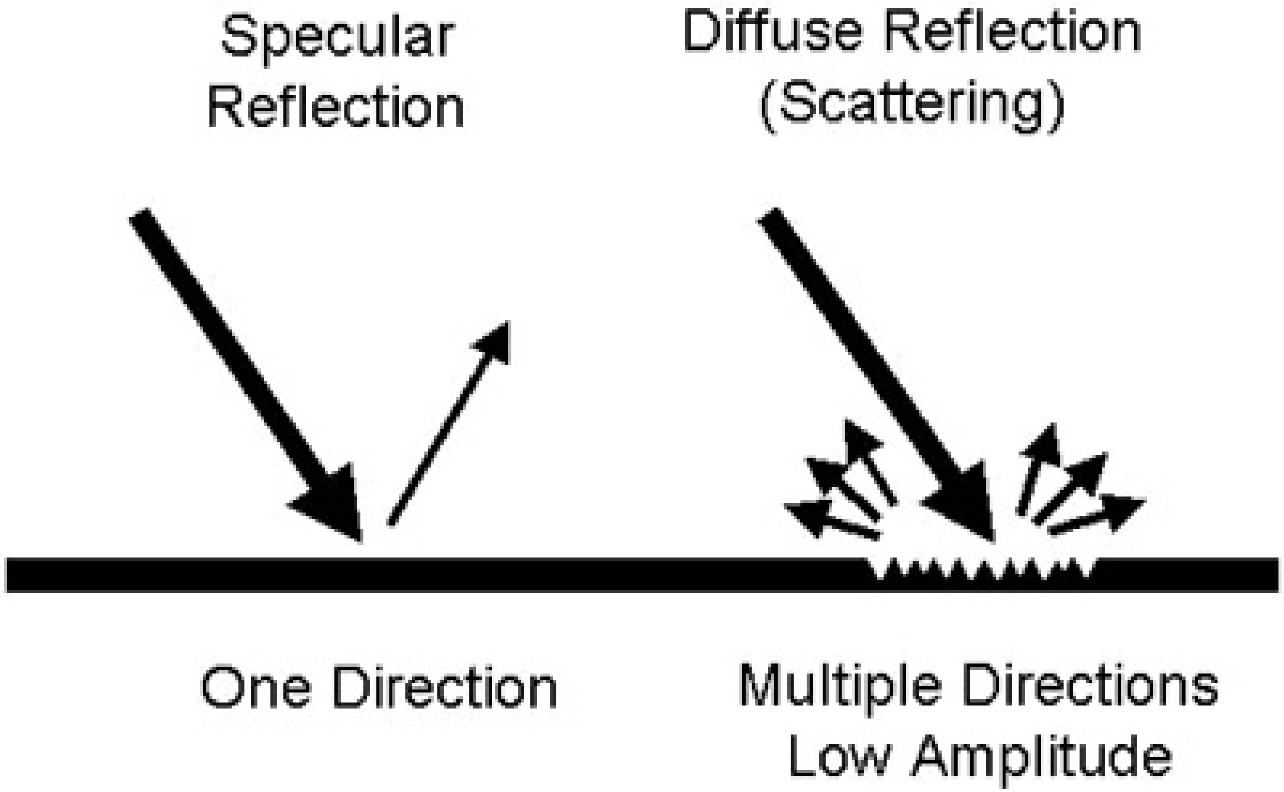
- By processing information such as
  - Time for echo to be received (distance)
  - Loudness of echo (amplitude/brightness)
  - Focal length of phased array
- The processor can display a 2D image on screen
- Post processing of the image can be done to tweak the image

# Principles of ultrasound

- Reflection
  - the portion of a sound that is returned from the boundary of a medium (echo)
  - Bone, metal, etc
- Refraction
  - the change of sound direction on passing from one medium to another
  - Fat, muscle, fluid
- Attenuation
  - the decrease in amplitude and intensity as a sound wave travels through a medium
  - Air/gas – sound converted into heat


Reflected
Medium #1
Medium #2
Refracted
Attenuated
Refracted

# Scattering

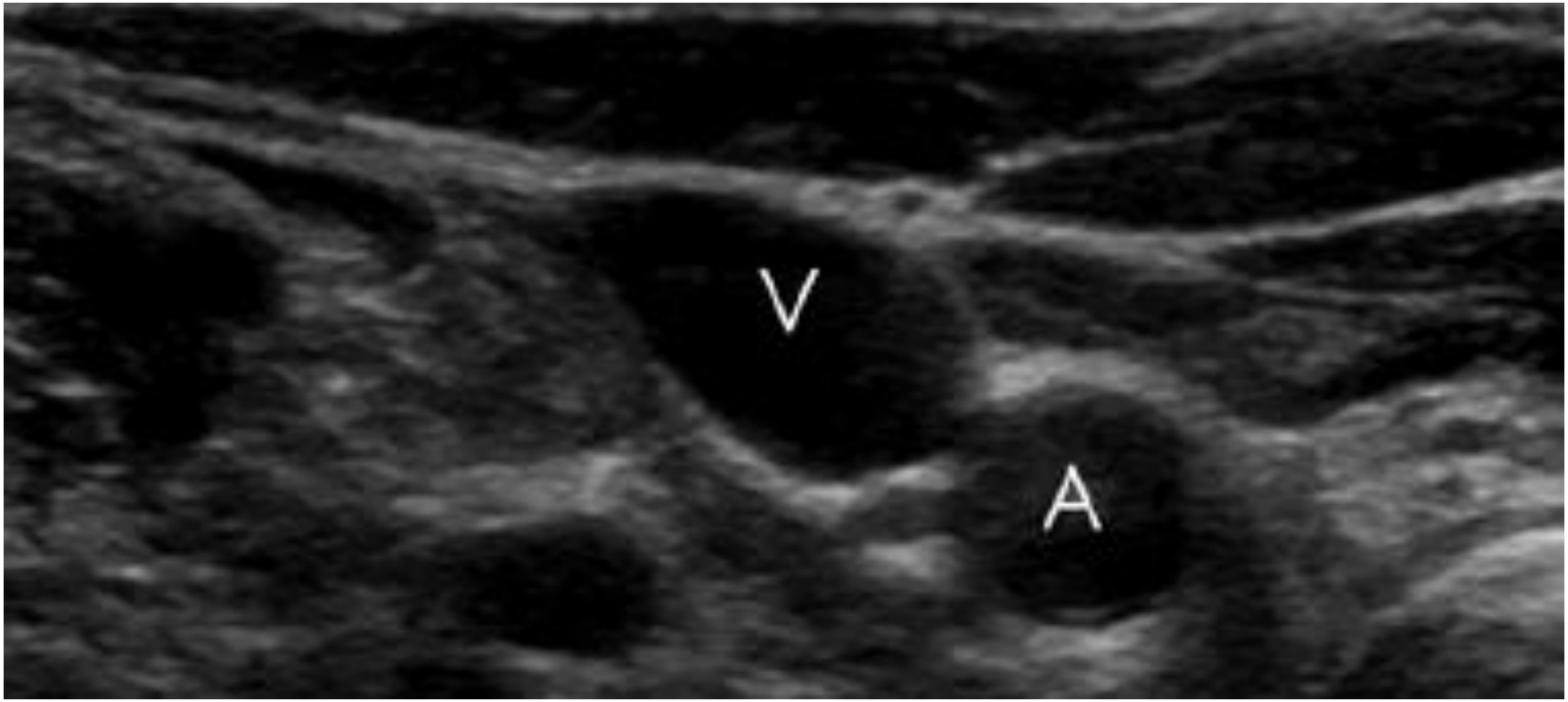

Specular
Reflection
Diffuse Reflection
(Scattering)
One Direction
Multiple Directions
Low Amplitude

# Tissue echogenicity

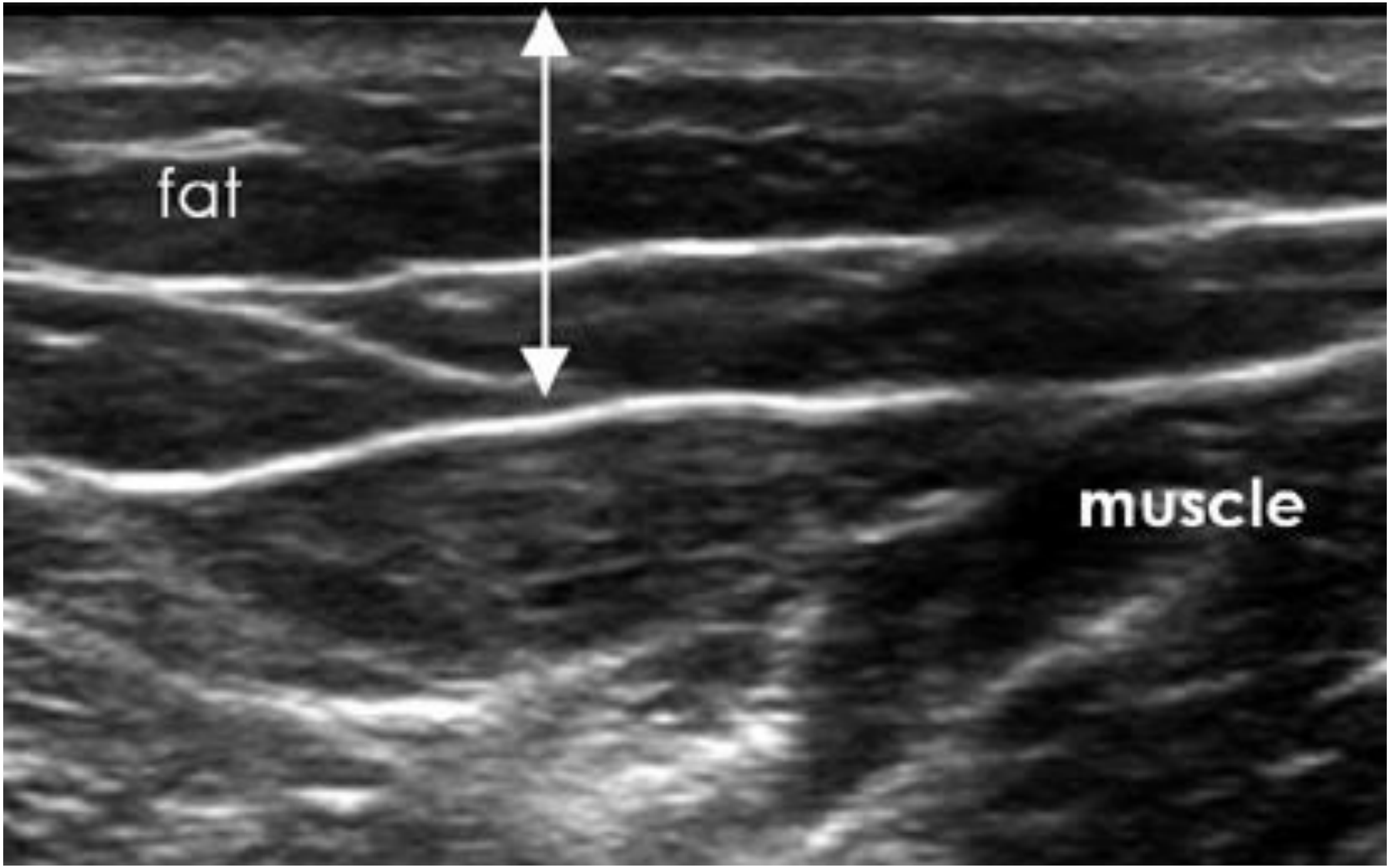
- When an echo returns to the transducer, its amplitude is represented by the degree of brightness (i.e. echogenicity) of a dot on the display.
- Combination of all the dots forms the final image.
- Strong specular reflections give rise to bright dots **(hyperechoic)** e.g., diaphragm, gallstone, bone, pericardium.
- Weaker diffuse reflections produce grey dots **(hypoechoic)** e.g., solid organs.
- No reflection produces dark dots **(anechoic)** e.g., fluid and blood filled structures because the beam passes easily through these structures without significant reflection.
- Also, deep structures often appear **hypoechoic** because attenuation limits beam transmission to reach the structures, resulting in a weak returning echo.

| TISSUE | ULTRASOUND IMAGE FOR REGIONAL ANESTHESIA |
|---|---|
| Veins | anechoic (compressible) |
| Arteries | anechoic (pulsatile) |
| Fat | hypoechoic with irregular hyperechoic lines |
| Muscles | heterogeneous (mixture of hyperechoic lines within a hypoechoic tissue background) |
| Tendons | predominantly hyperechoic technical artifact (hypoechoic) |
| Bone | ++ hyperechoic lines with a hypoechoic shadow |
| Nerves | hyperechoic / hypoechoic technical artifact (hypoechoic) |

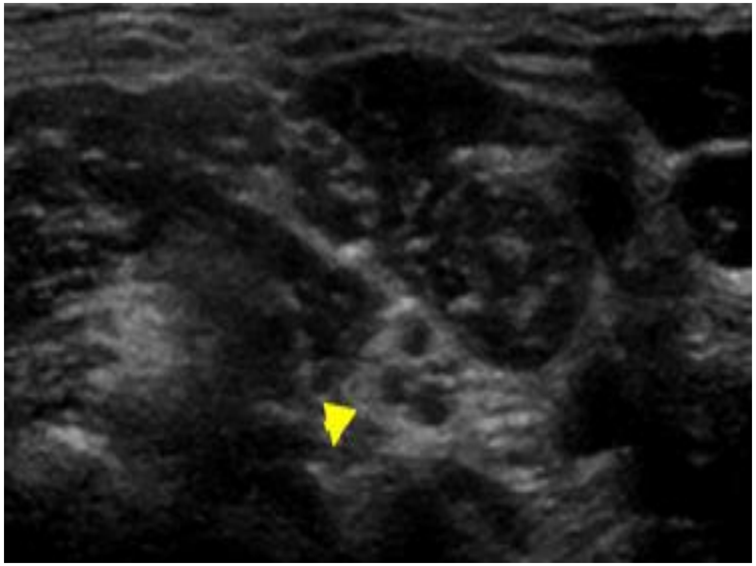
# Vessels

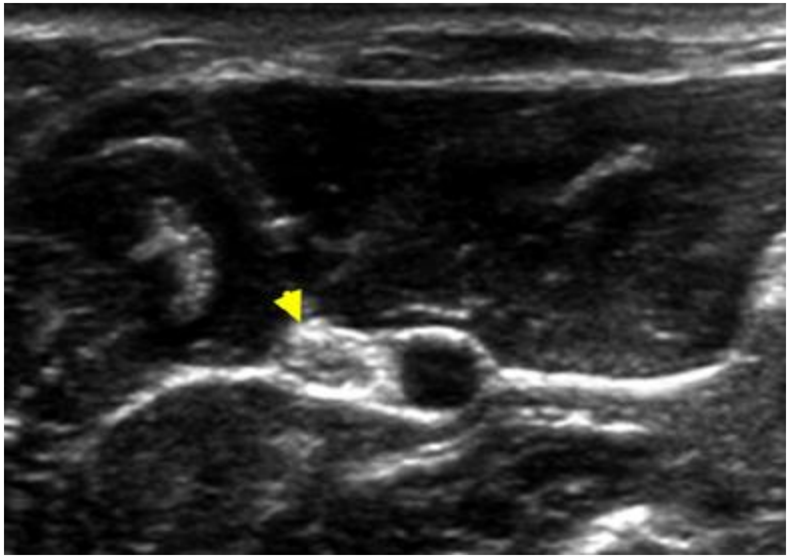


# Fat & Muscles



# Nerves

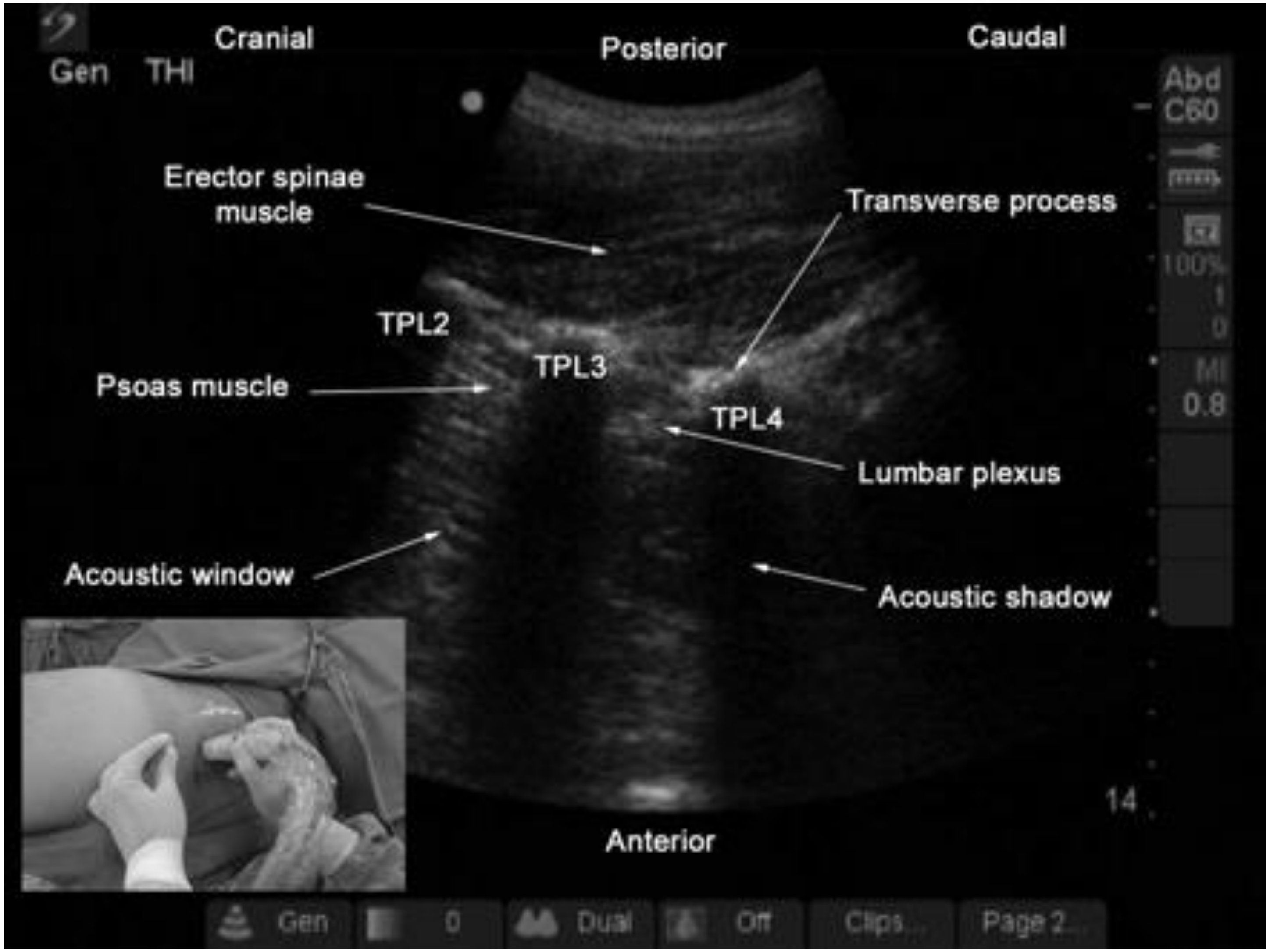




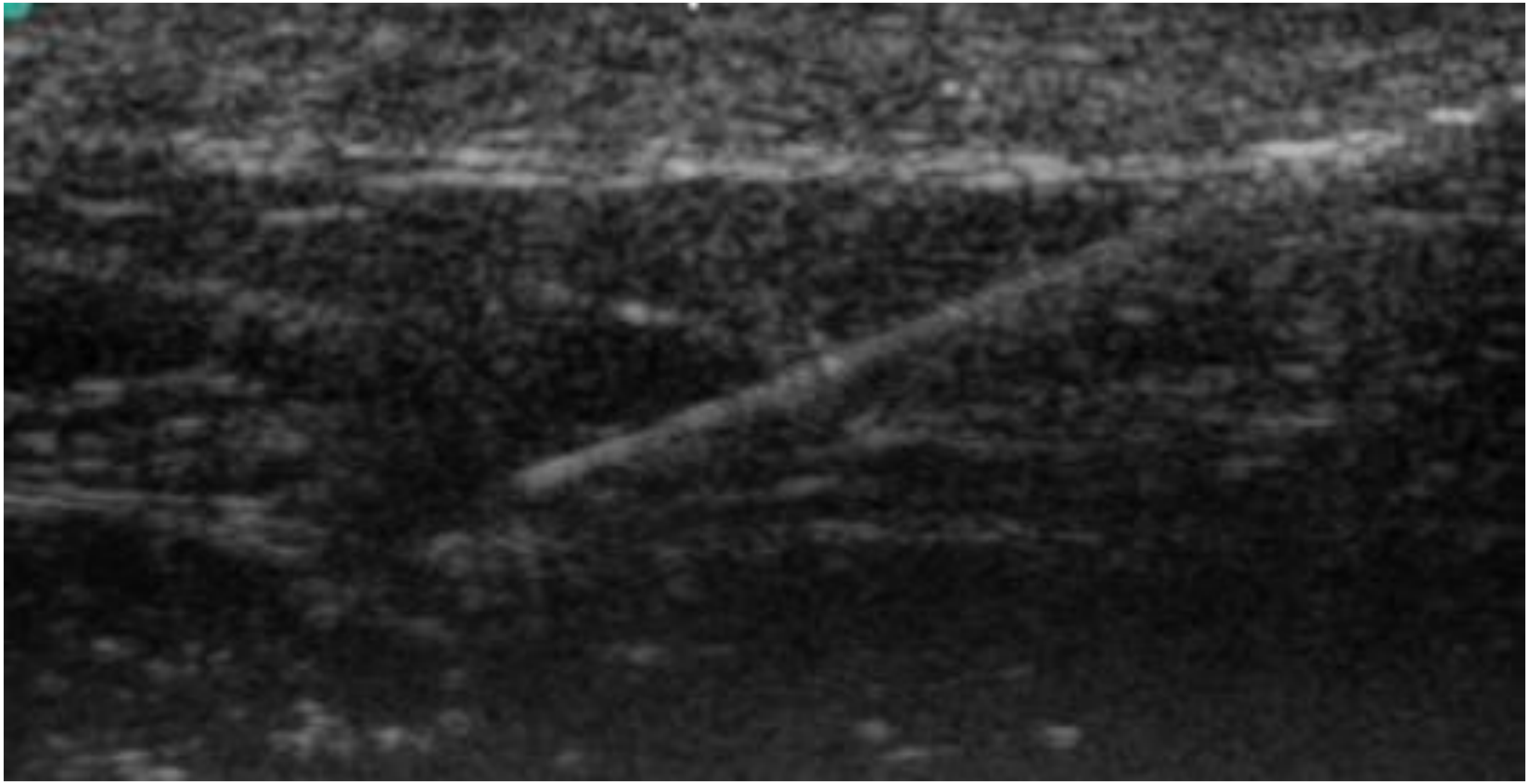
Nerve roots

Peripheral nerves

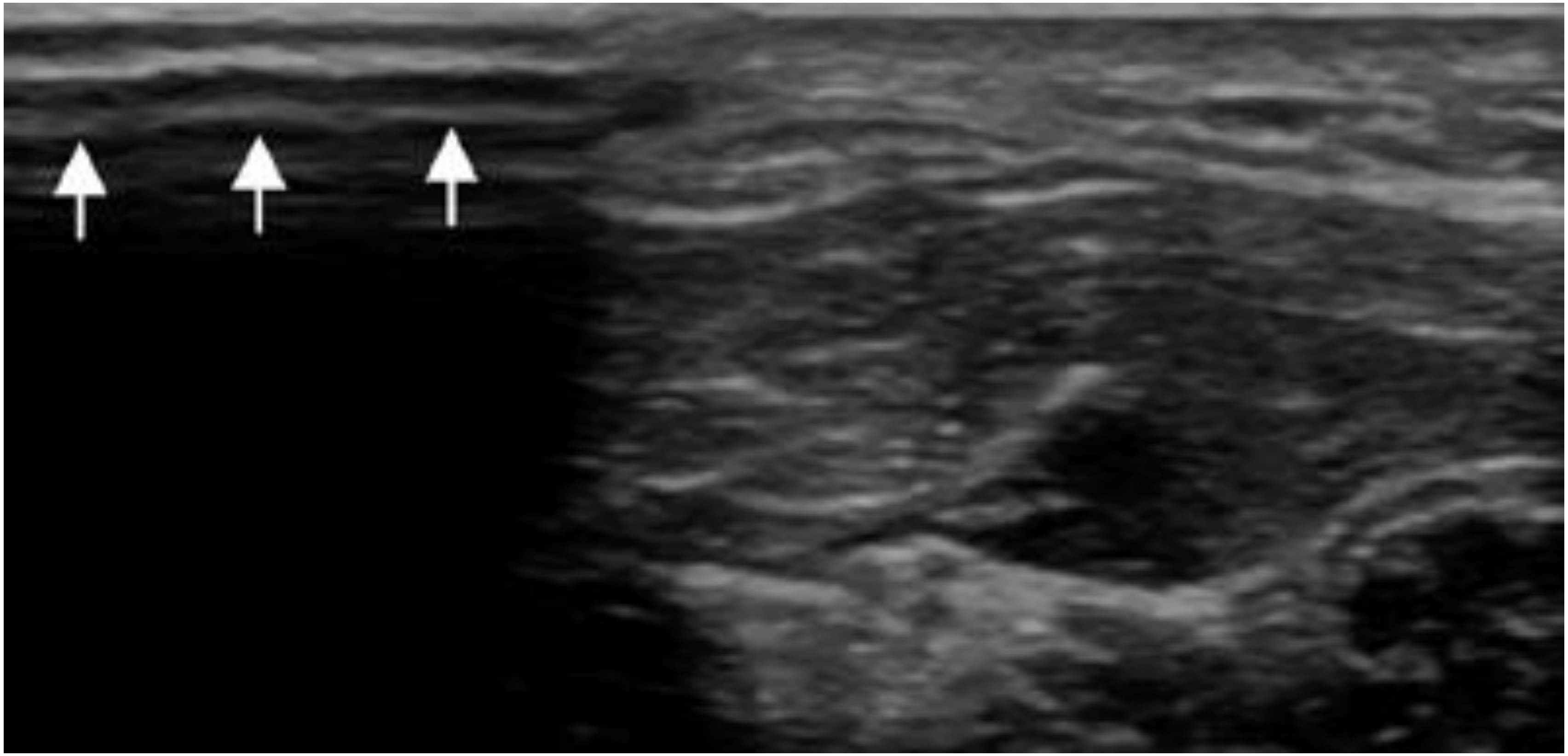
# Bone & Acoustic shadow



# Needles

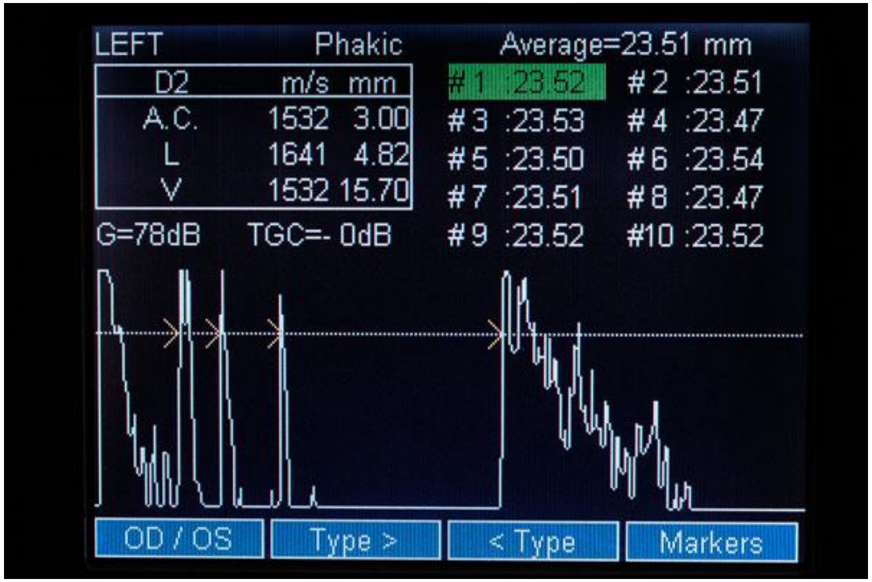


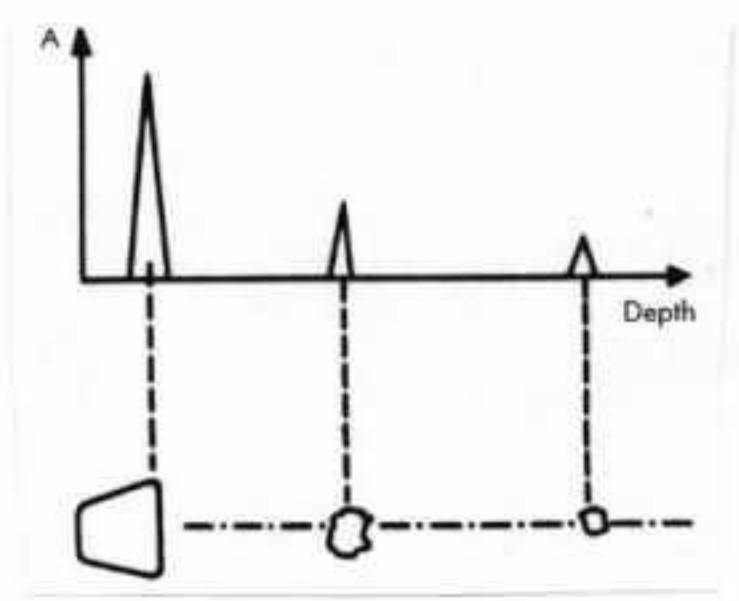
# Air



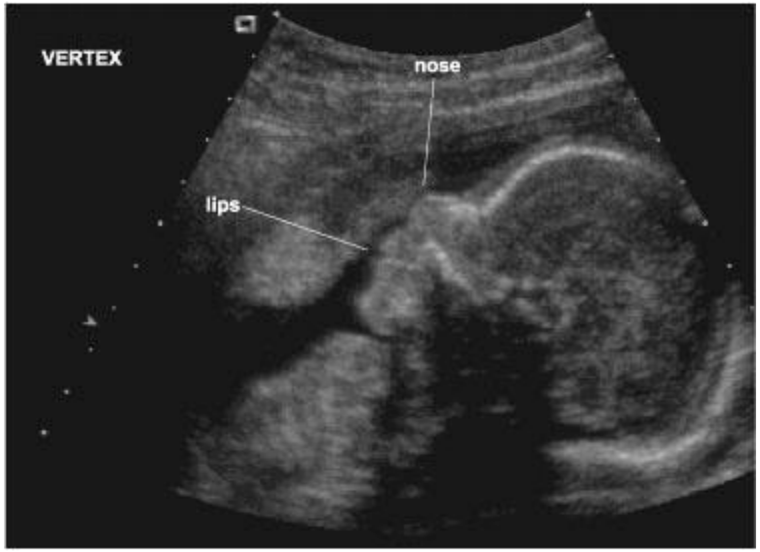
# Scanning modes

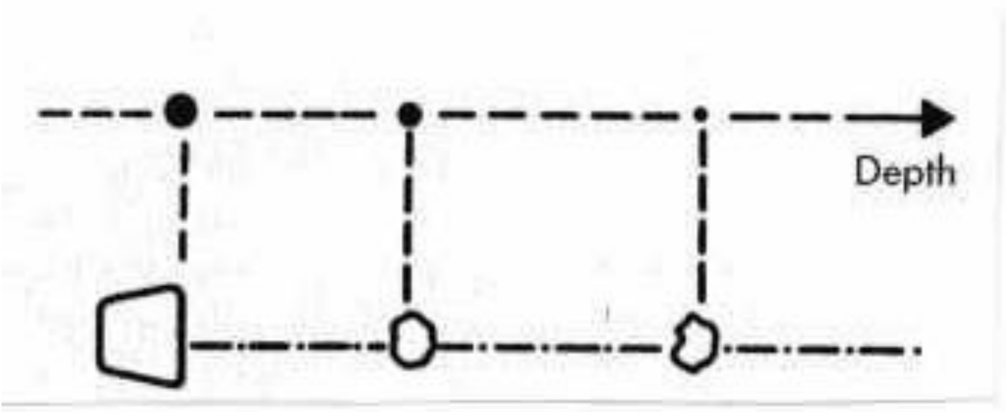
- A mode (amplitude)
  - Where the signals are displayed as spikes that are dependent on the amplitude of the returning sound energy.



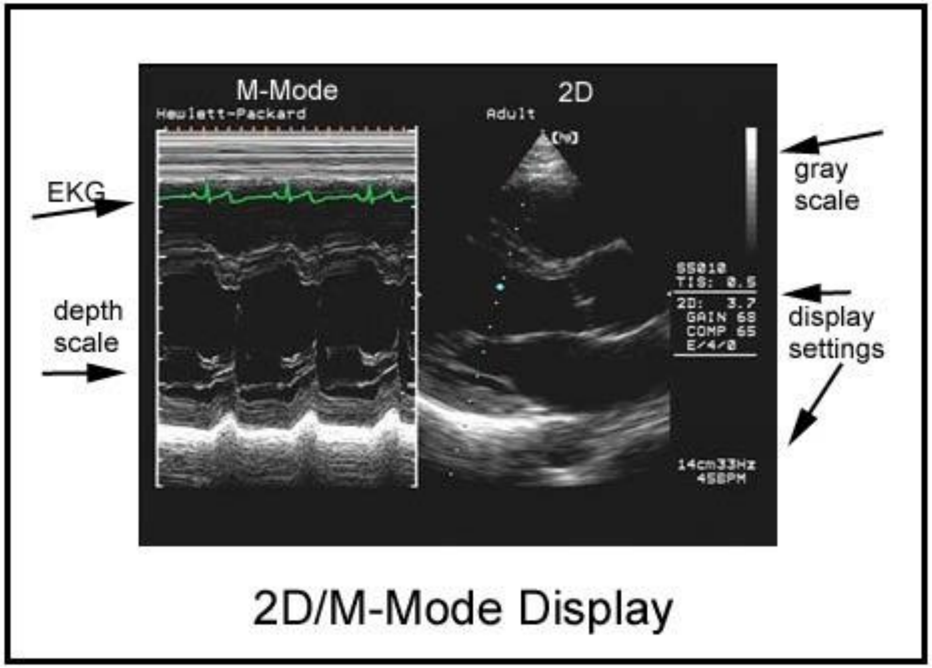



- B mode (Brightness)
  - a linear array of transducers simultaneously scans a plane through the body that can be viewed as a two-dimensional image on screen



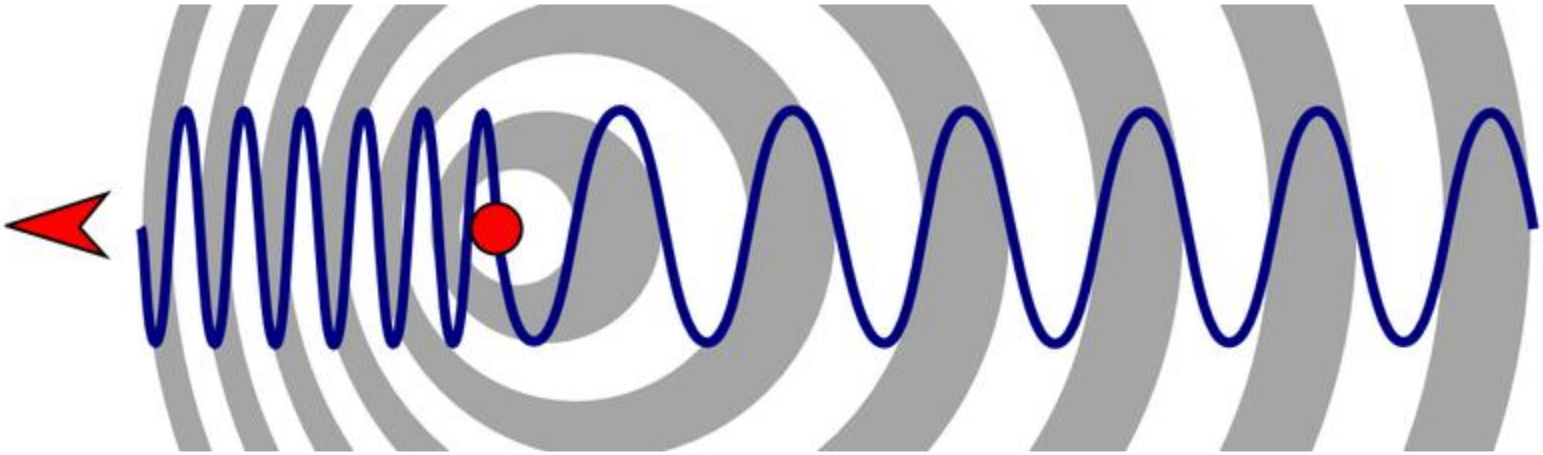



- M mode (Motion)
  - The application of B-mode and a strip chart recorder allows visualization of the structures as a function of depth and time.

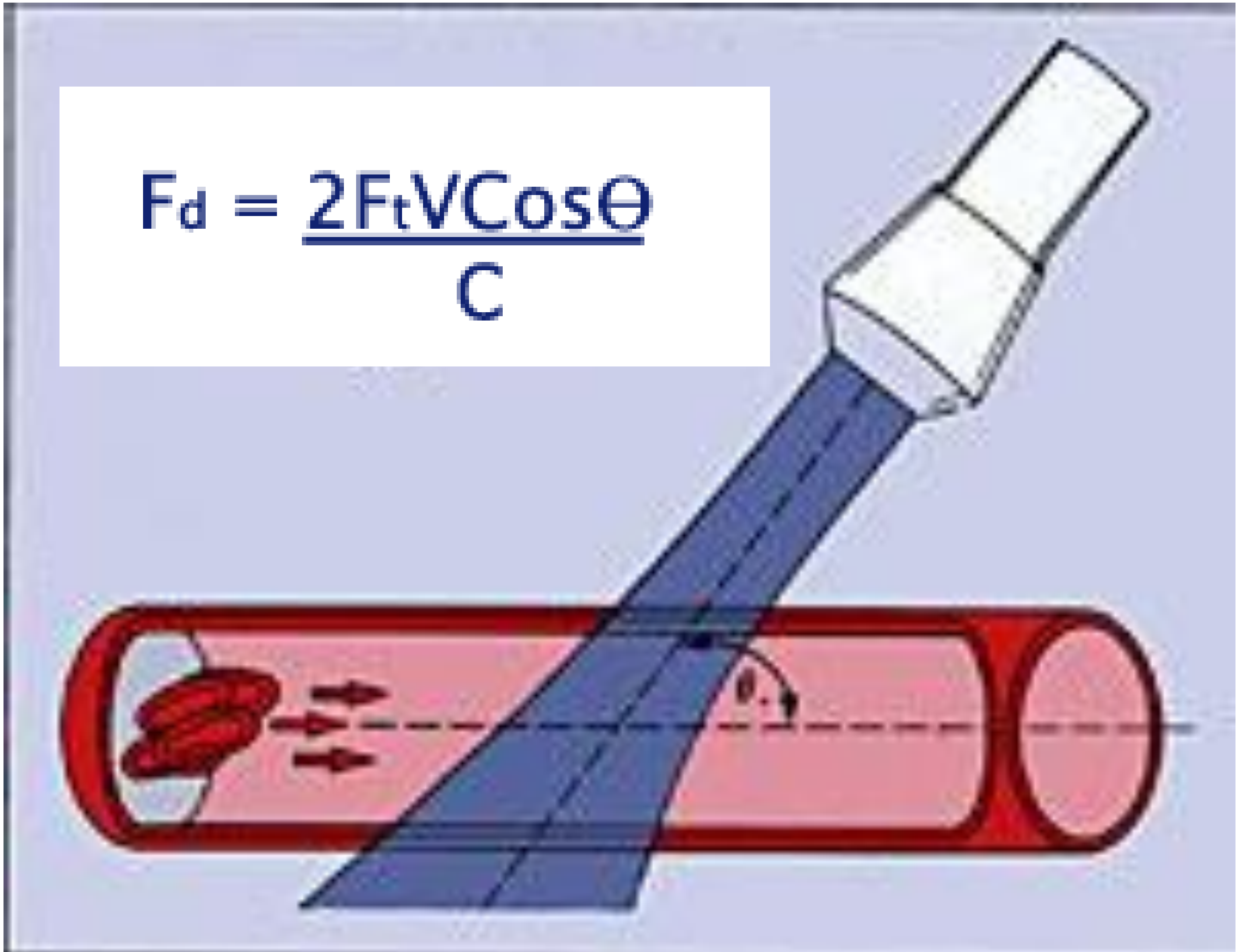


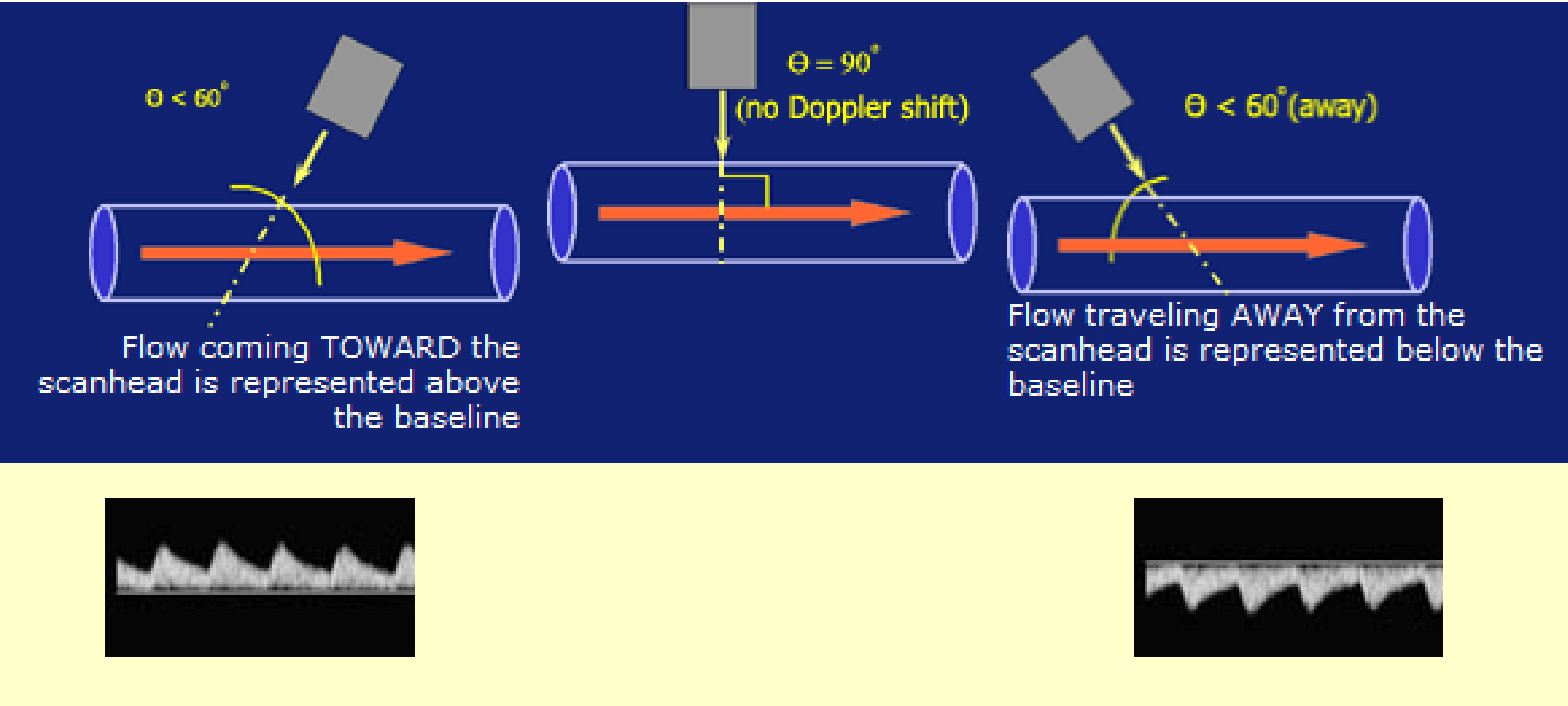
# Doppler mode

- Doppler effect - change in frequency of a wave for an observer moving relative to the source of the wave



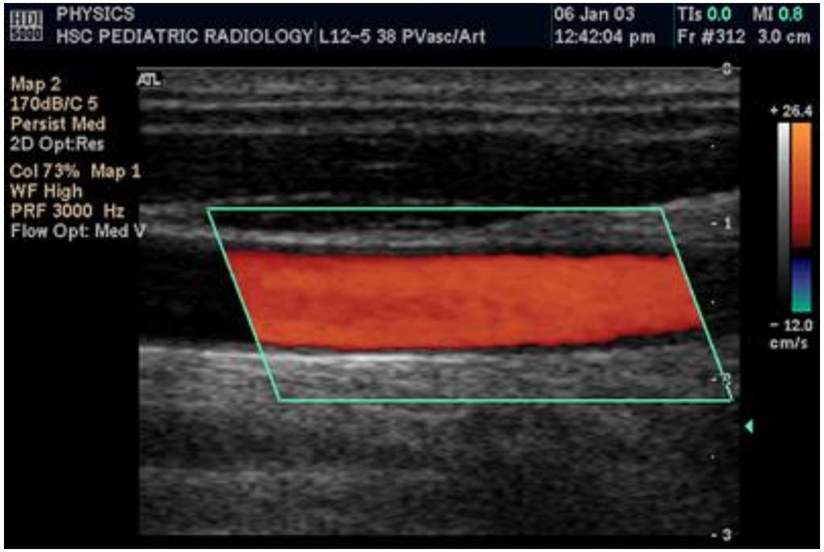
# Doppler equation

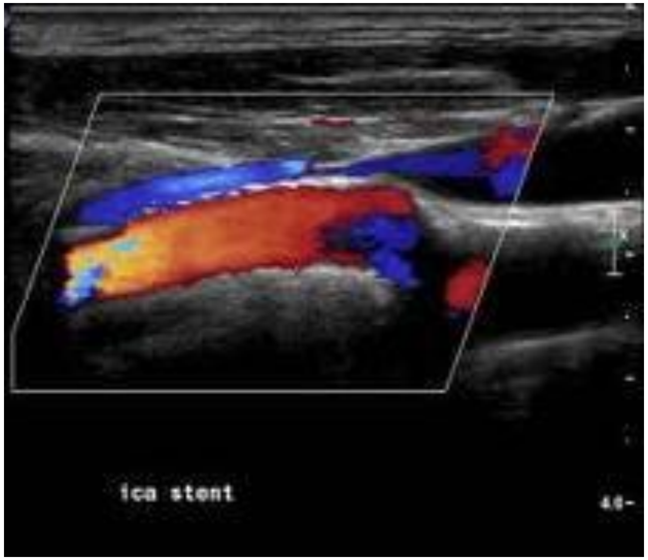



Θ < 60°
Θ = 90°
(no Doppler shift)
Θ < 60°(away)
Flow coming TOWARD the scanhead is represented above the baseline
Flow traveling AWAY from the scanhead is represented below the baseline

# Doppler

- **Doppler mode**: This mode makes use of the Doppler effect in measuring and visualizing blood flow **Color doppler**: Velocity information is presented as a color coded overlay on top of a B-mode image



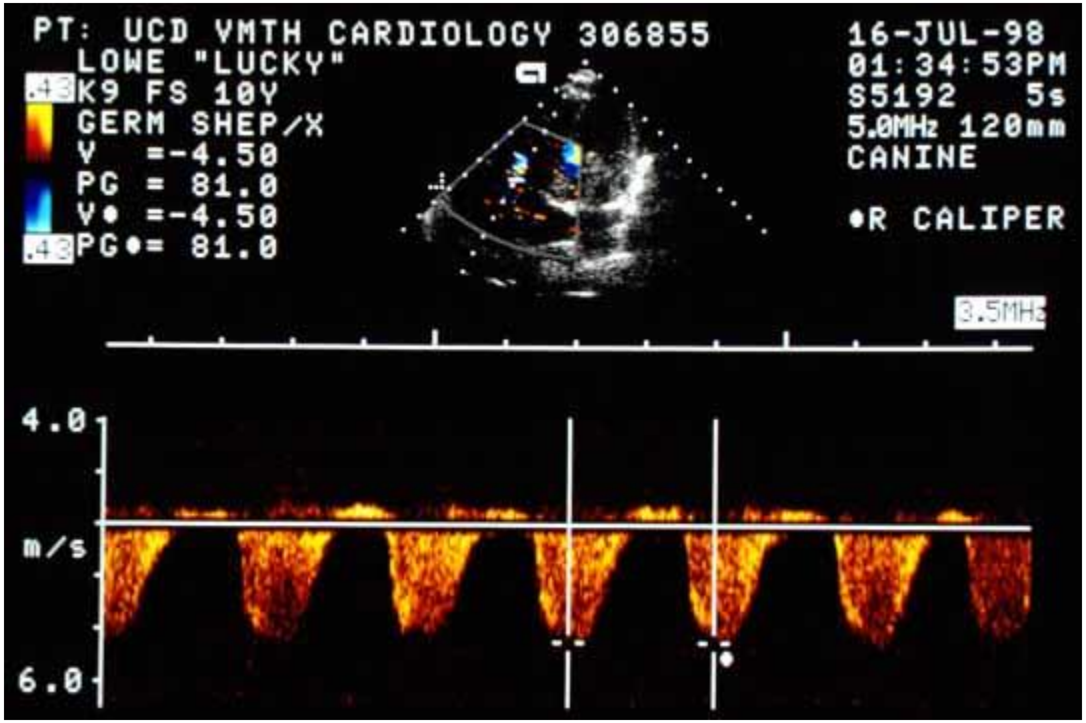



**Continuous doppler**: Doppler information is sampled along a line through the body, and all velocities detected at each time point is presented (on a time line)

**Pulsed wave (PW) doppler**: Doppler information is sampled from only a small sample volume (defined in 2D image), and presented on a timeline

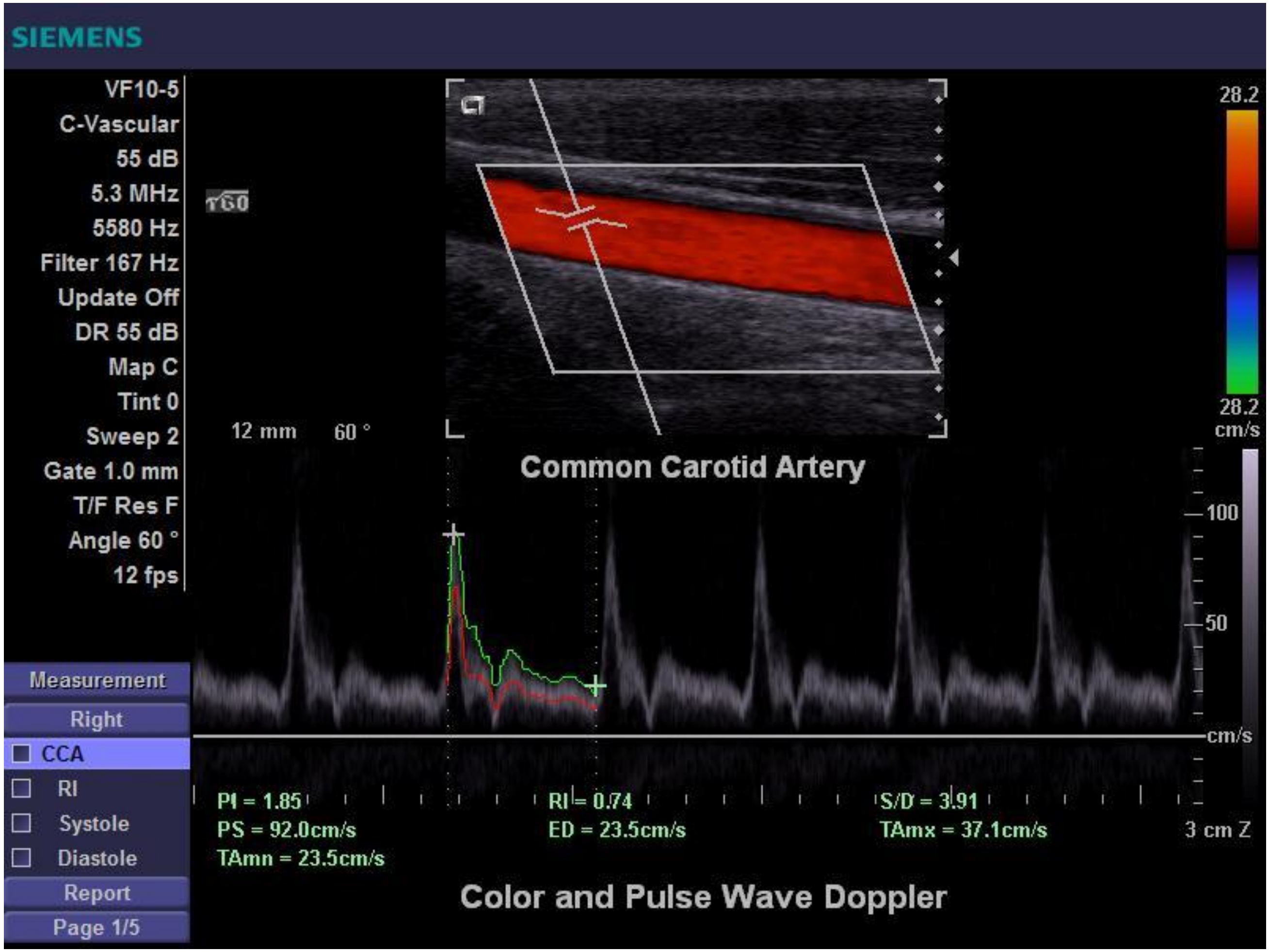
**Duplex**: a common name for the simultaneous presentation of 2D and (usually) PW doppler information. (Using modern ultrasound machines color doppler is almost always also used, hence the alternative name **Triplex**.)

# CW Doppler

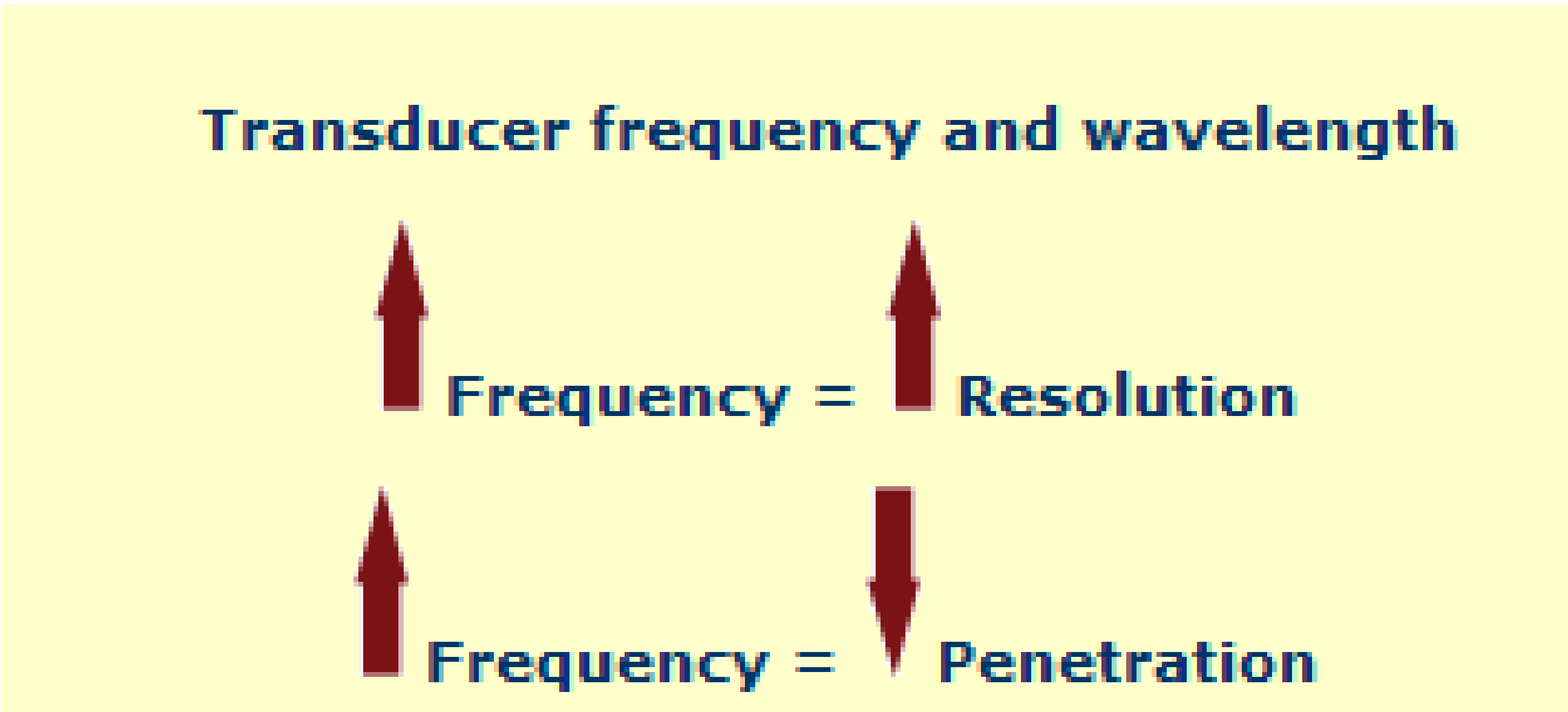


PT: UCD VMTH CARDIOLOGY 306855
LOWE "LUCKY"
K9 FS 10Y
GERM SHEP/X
V =-4.50
PG = 81.0
V• =-4.50
PG•= 81.0
16-JUL-98
01:34:53PM
S5192 5s
5.0MHz 120mm
CANINE
•R CALIPER
3.5MHz
4.0
m/s
6.0

# PW doppler

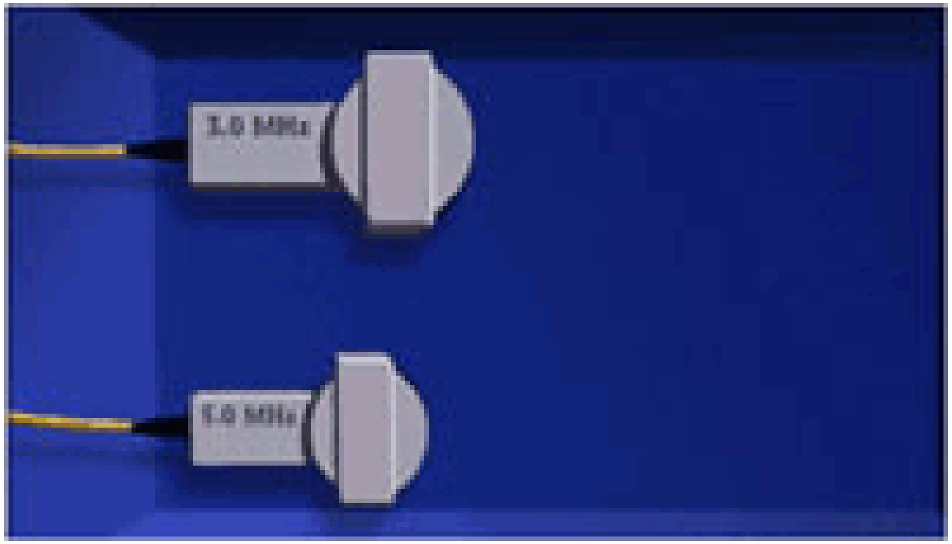

SIEMENS
VF10-5
C-Vascular
55 dB
5.3 MHz
5580 Hz
Filter 167 Hz
Update Off
DR 55 dB
Map C
Tint 0
Sweep 2
Gate 1.0 mm
T/F Res F
Angle 60 °
12 fps
12 mm
60 °
28.2
28.2
cm/s
Common Carotid Artery
100
50
cm/s
Measurement
Right
CCA
RI
Systole
Diastole
Report
Page 1/5
PI = 1.85
PS = 92.0cm/s
TAmn = 23.5cm/s
RI = 0.74
ED = 23.5cm/s
S/D = 3.91
TAmx = 37.1cm/s
3 cm Z
Color and Pulse Wave Doppler

# Frequency, resolution & penetration



# AM/FM analogy

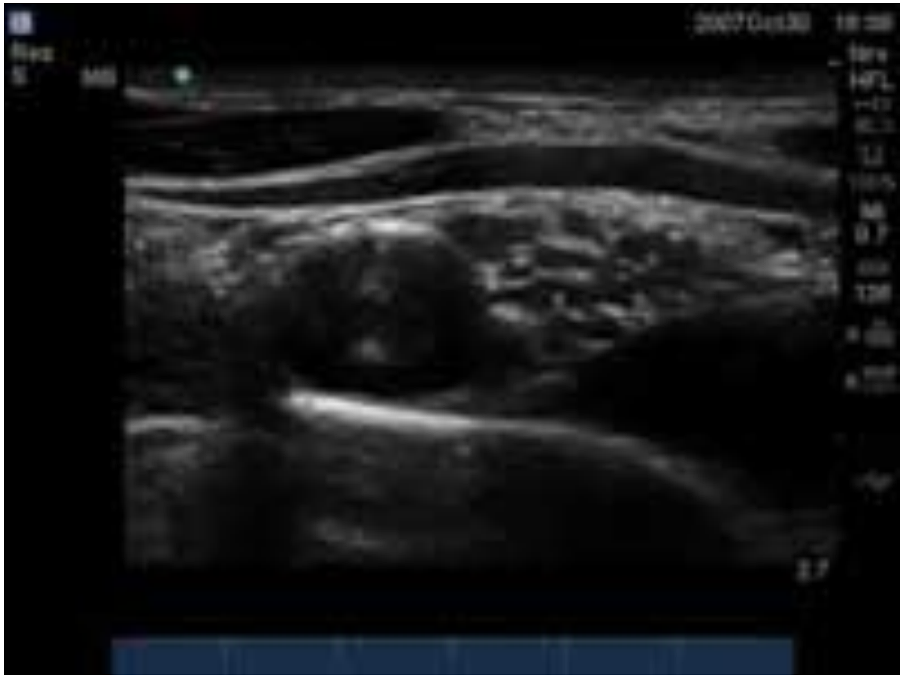
- A 12 MHz scanhead has very good resolution, but cannot penetrate very deep into the body
- A 3 MHz scanhead can penetrate deep into the body, but the resolution is not as good as the 12 MHz scanhead



# High-frequency linear probe

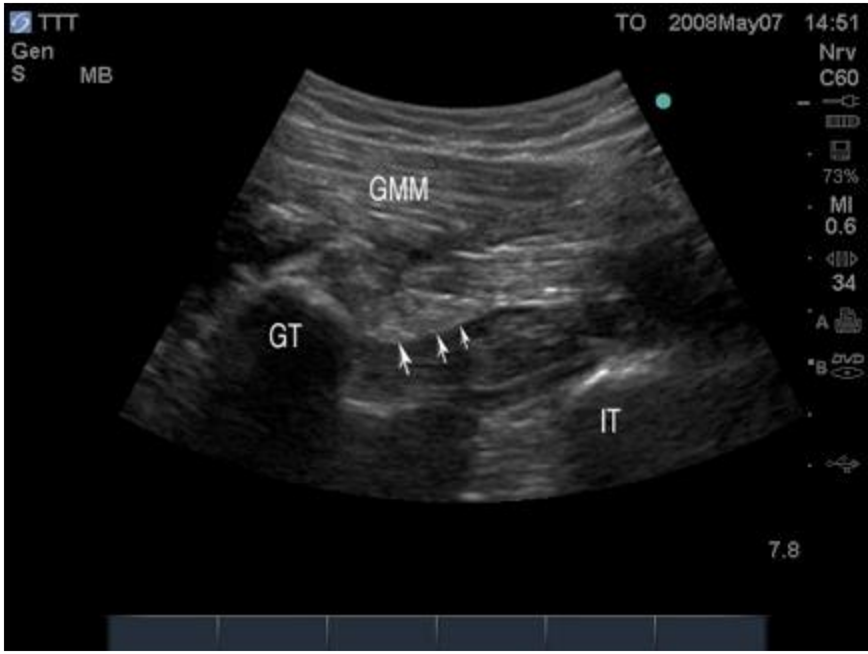
**Physical characteristics:**
Frequency: broadband 10-5 MHz
Maximum depth: 7 cm
Maximum field of view: 38 mm
Aperture: 38 mm

- **Clinical applications:**
Small parts imaging: thyroid, testicular and musculoskeletal,Breast, Vascular
Ultrasound-guided procedures



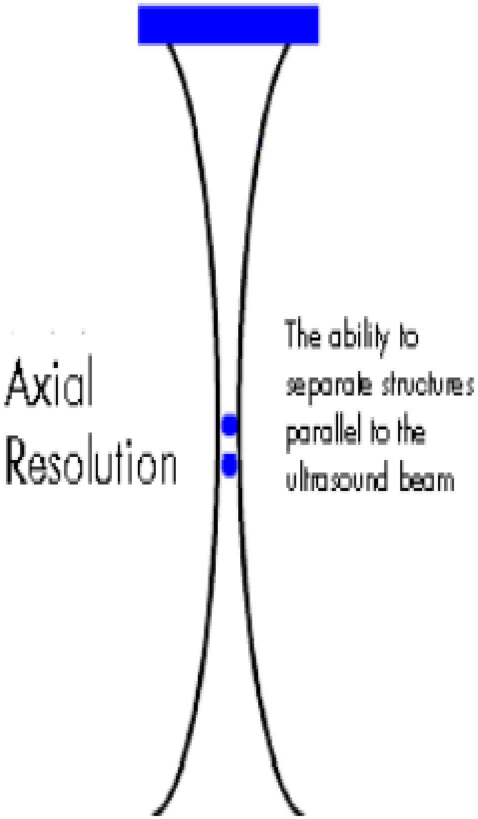
# Abdominal curved array probe

- **Physical characteristics:**
  Frequency: broadband 5-2 MHz
  Maximum depth: 22 cm
  Maximum field of view: 57º
- **Clinical applications:**
  General-purpose abdominal
  Obstetric
  Gynaecological



# Spatial Resolution (Clarity)

- ability of the ultrasound machine to distinguish two structures that are close together as separate
- **Axial resolution** refers to the ability to distinguish two structures that lie along the axis (i.e. parallel) of the ultrasound beam as separate and distinct. Axial resolution is determined by the **pulse length**. A high frequency wave with a short pulse length will yield better axial resolution than a low frequency wave.



- **Lateral resolution** refers to resolution of objects lying side by side (i.e., perpendicular to the beam axis). Lateral resolution is directly related to the transducer **beam width**, which in turn is inversely related to the ultrasound frequency.