

Sound waves

Longitudinal waves - compression zones alternate with rarefaction zones

speed = frequency x wavelength

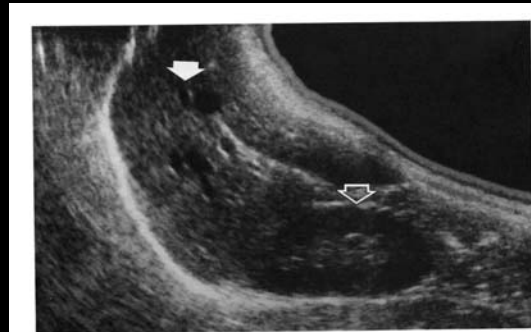
Velocity of sound in tissue = 1540 m/s

## Sound waves

At tissue interfaces, some sound travels through (and is bent) the rest is reflected

The greater the mismatch between two tissues the greater amount of sound is reflected

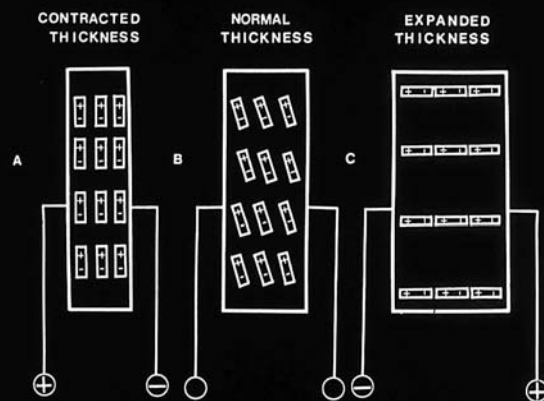
Intensity of image (measured ultrasound signal) is proportional to mismatch



## Sound waves

Reflection mismatch at air-tissue interface is enormous resulting in total loss of transmission into patient - use gel

Gel couples transducer to gel and gel to tissue



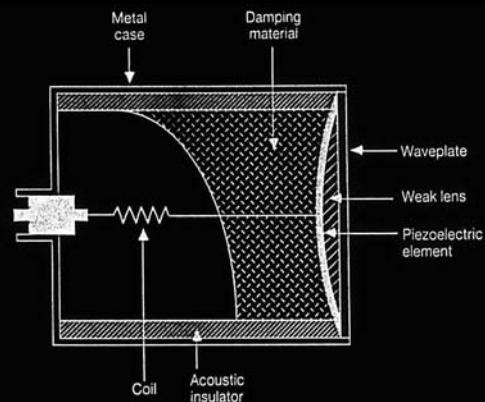
Transducer made of PZT (lead zirconate titanate)

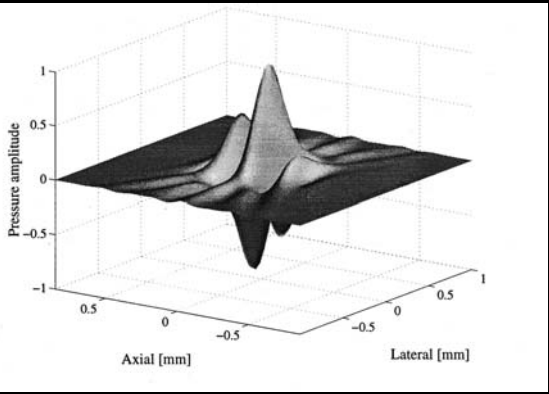
Extremely thin < 1 mm

Brittle - do not autoclave!

After striking it rings and then damped (high Q, Low Q)

Amount of ringing affects resolution



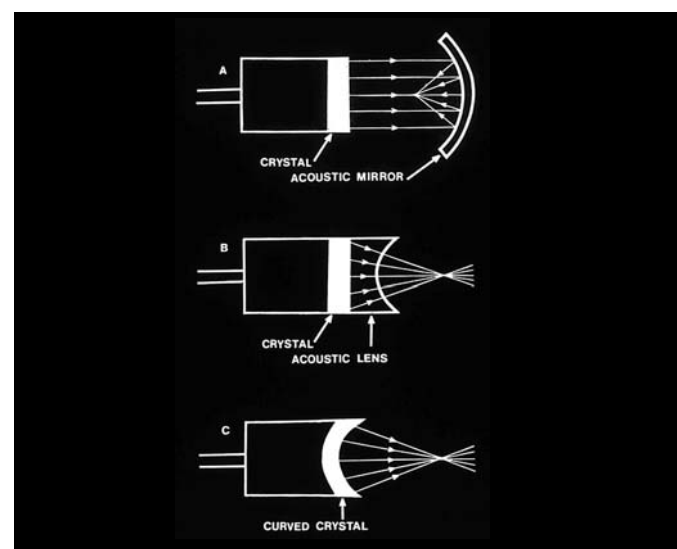
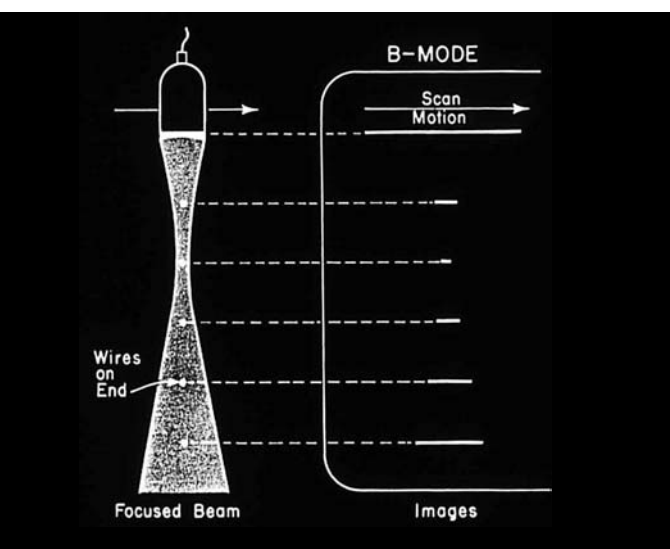
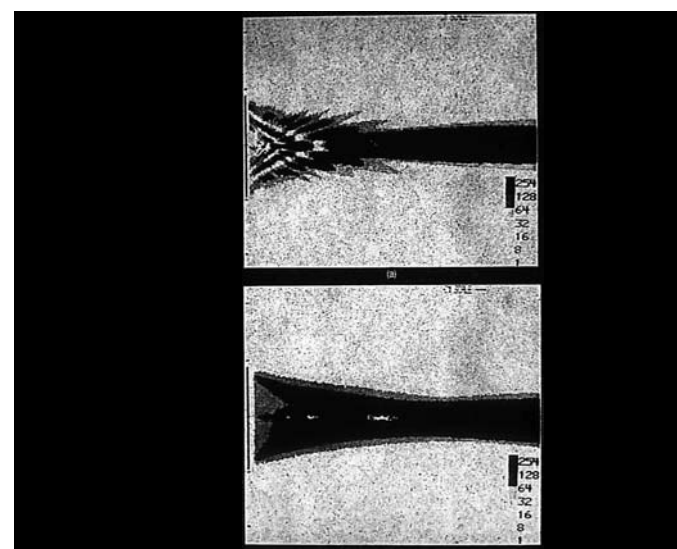
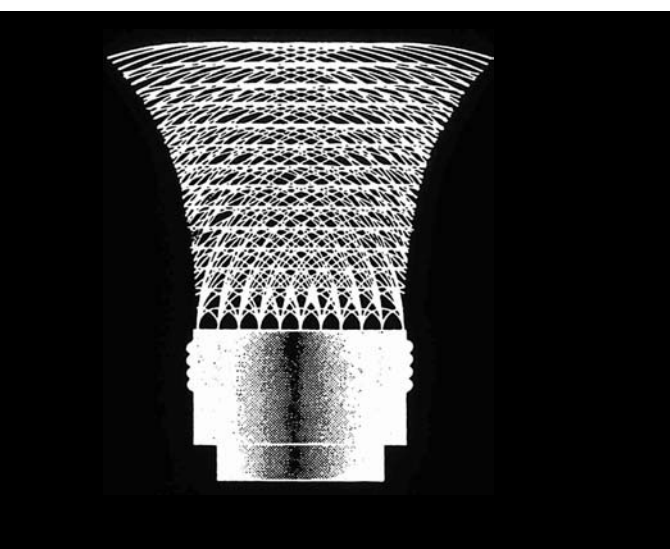


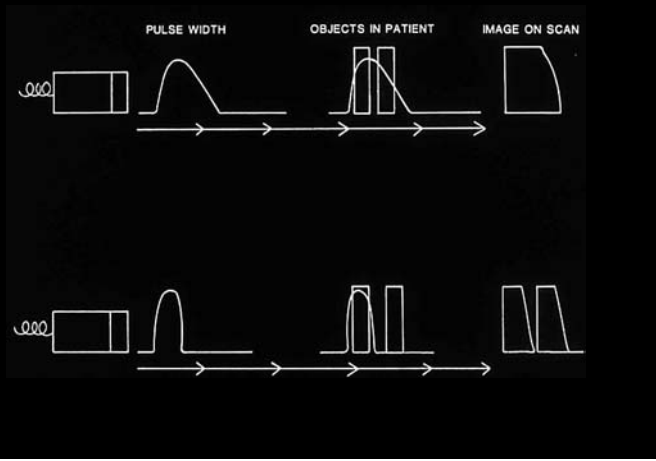
### Transducers

Continuous wave - sets up standing wave patterns

Pulsed - ring down generates spread of frequencies and washes out standing waves

Both types have "near field" and "far field" - region of focus





## Transducers

Can be used at different frequencies

Higher frequencies have shorter wavelengths and therefore better resolution

Higher frequencies have greater absorption and therefore lower penetration

## Phased array transducers

Multiple elements - can be fired in succession

Can steer

Can focus

Can sweep

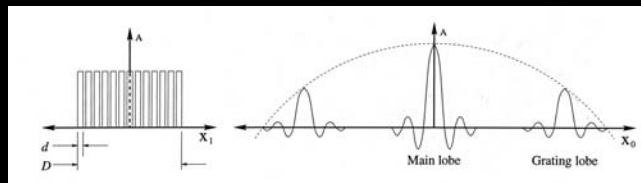
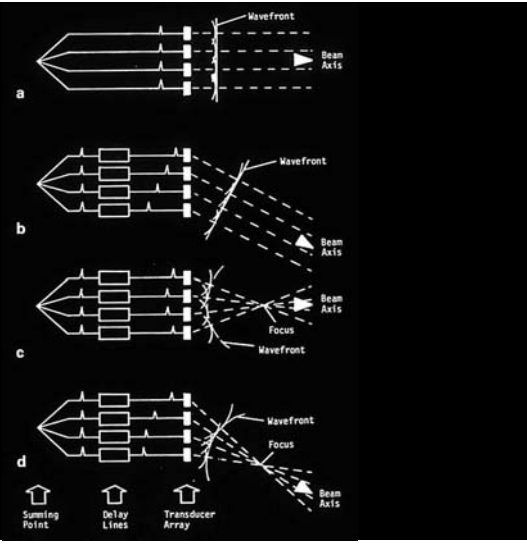
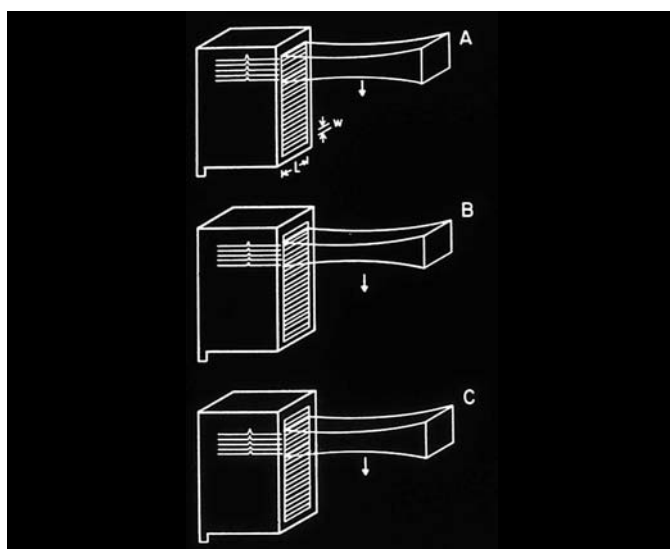


Figure 2.11: (Left) An aperture of size  $D$  composed of elements of size  $d$  is modeled as  $\Pi(D) [\Pi(d) \Pi(x/d)]$ . The Fourier transform of this pattern (right) is  $\text{sinc}(u/d) [\text{sinc}(u/D) * \Pi(du)]$ . The subdivision of the array into elements produces grating lobes.

For imaging

Use pulsed ultrasound - velocity in tissue is  $c$

Emit pulse and listen for returning signal which is heard at  $t$  after pulse

Interface is present at a depth  
 $d = c \times t$

Pulsed ultrasound

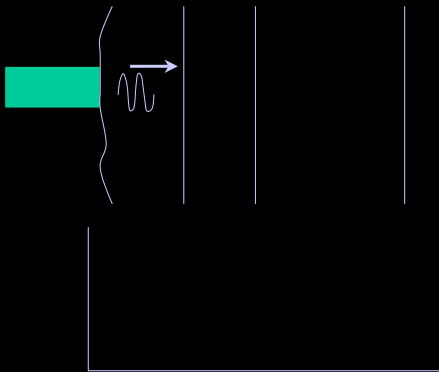
Pulse duration is about 1 micro sec

Pulse interval is about 0.1 ms

Can measure  
depth =  $1540/1000 \text{ m/ms} \times 0.1 \text{ ms}/2$   
= 8 cm

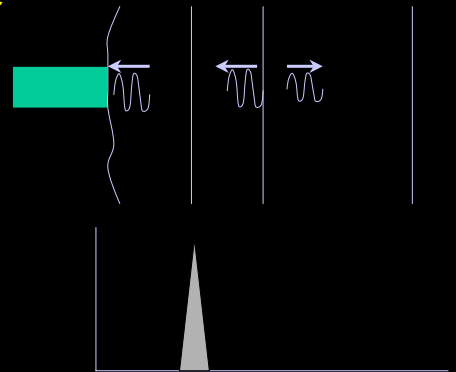
Ultrasound modes

A-mode



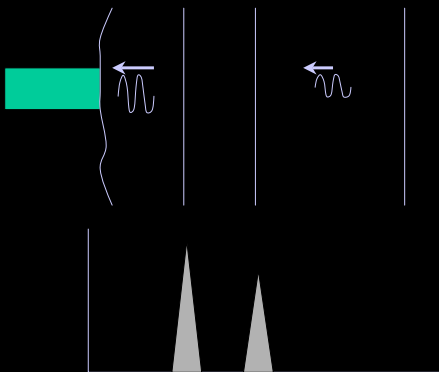
Ultrasound modes

A-mode



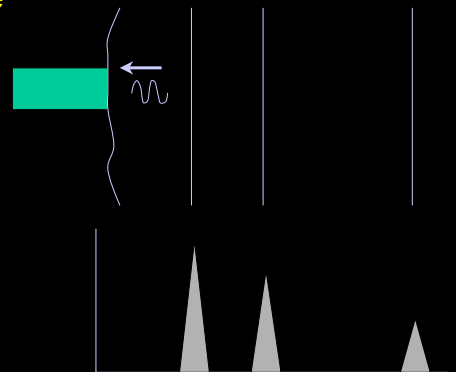
Ultrasound modes

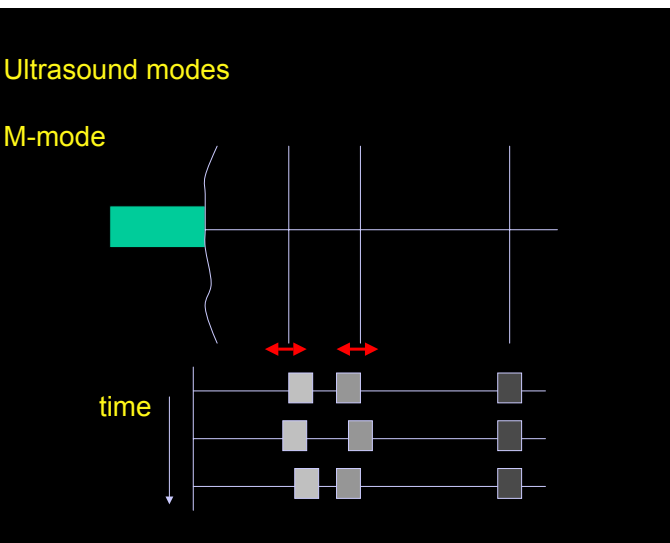
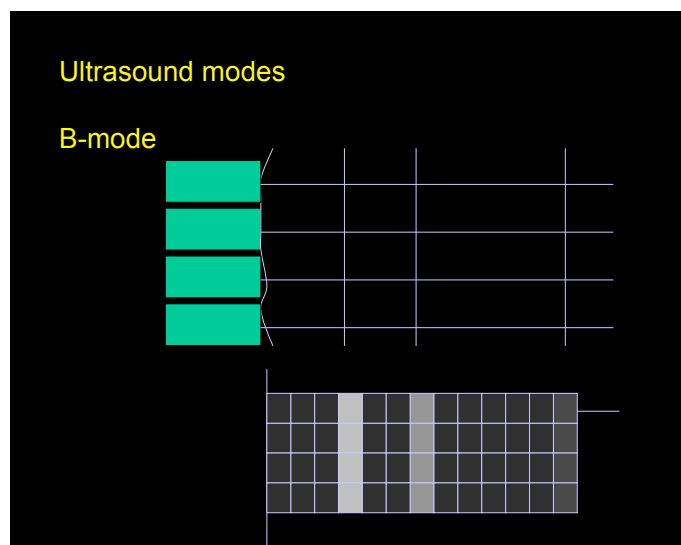
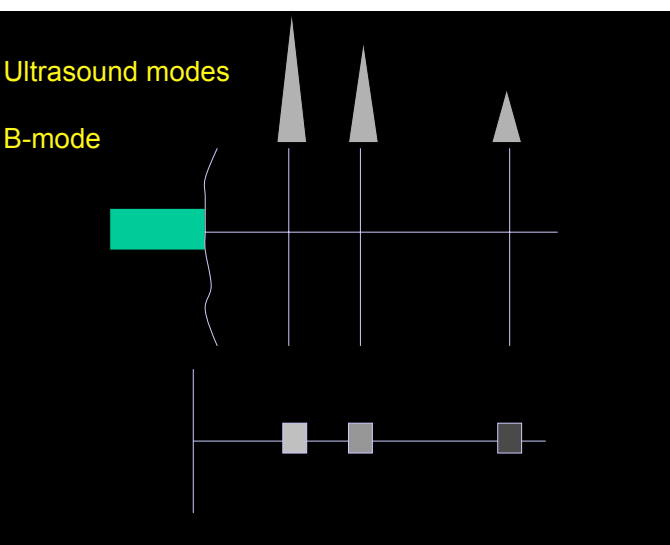
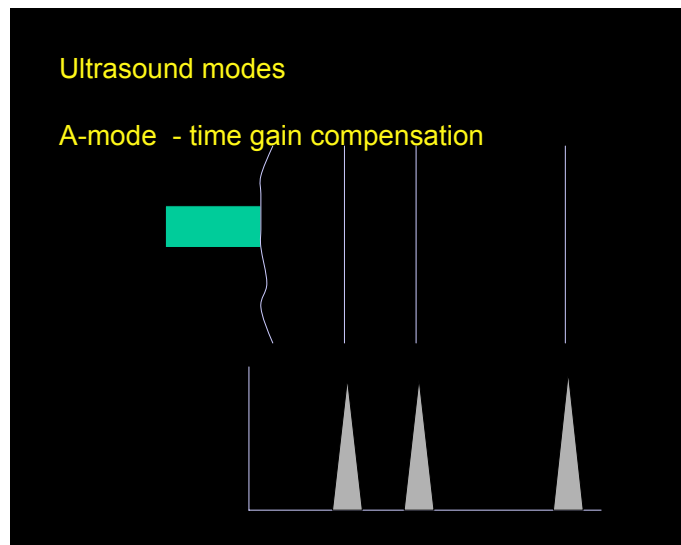
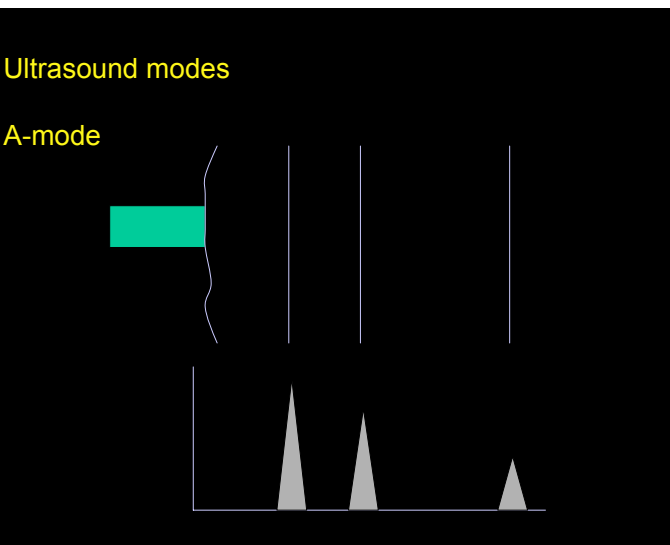
A-mode



Ultrasound modes

A-mode





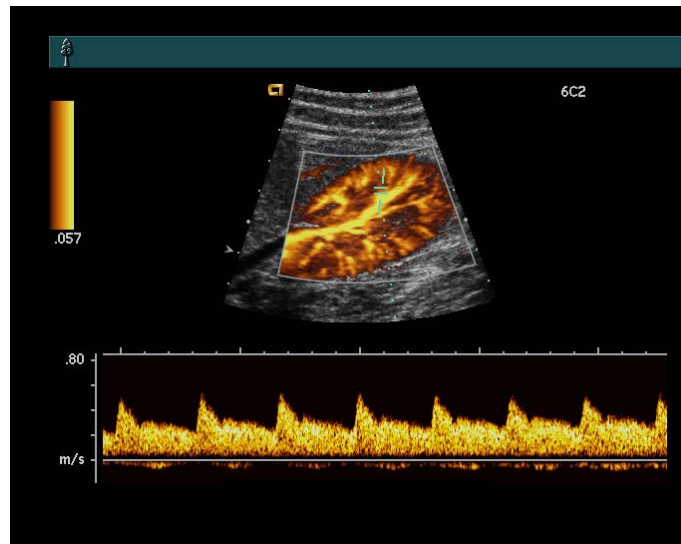
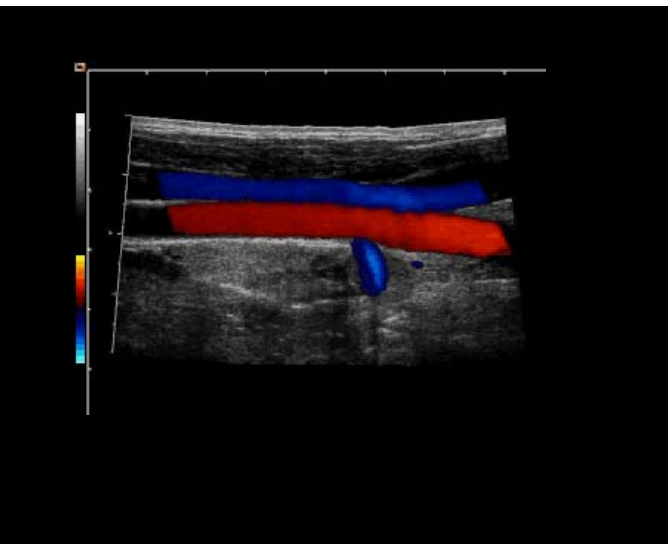
Ultrasound modes

Doppler Ultrasound-mode

frequency shift when sound strikes surface moving toward or away from transducer

Can color code frequency shift and overlay on image

Can use duplex - B-mode for imaging and Doppler for velocity



**Intensity in Diagnostic Ultrasound (mW/cm<sup>2</sup>)**

	I(SPTA)	I(SPTP)
B & M-Mode	0.01 - 20	0.6 - 200
Phased arrays	2.7 - 60	2 - 200
Pulsed Doppler (cardiac)	0.1 - 10	0.1 - 20
CW Doppler (periph vasc)	38 - 840	110 - 2500
PW Doppler (periph vasc)	87- 175	350 - 700
Fetal monitor		9 - 80

**Therapeutic Ultrasound**

Can heat tissue to a depth of 4-6cms without overheating superficial tissue

Typically 1 MHz or 3 MHz transducers

Relatively large transducer heads - spreads thermal energy

Output 0 - 2.0 Watts/cm<sup>2</sup>

Continuous wave used when heating is desired

**Therapeutic Ultrasound**

1 M Hz will heat tissue 2 - 5 cm deep

3 M Hz will heat tissue 1 - 2 cm deep

Applied for 5 mins

Spatially and temporal local regions of high energy deposition can occur

Move transducer head

**Therapeutic Ultrasound**

$W \text{ (mwatts)} = 230 \times \text{diam. (cms)} / \text{freq. (M Hz)}$

Amount of energy required to heat tissue by 1°C

Bone heats much more than soft tissue and may be more dangerous as it is enervated

## Ultrasound risk factors

Heating - 1 W/cm<sup>2</sup> considered safe for diagnostics

Mechanical - vibrations

Cavitation - gas bubbles oscillate and stream and can damage tissue

No genetic effects - or very murky

Risk versus benefit