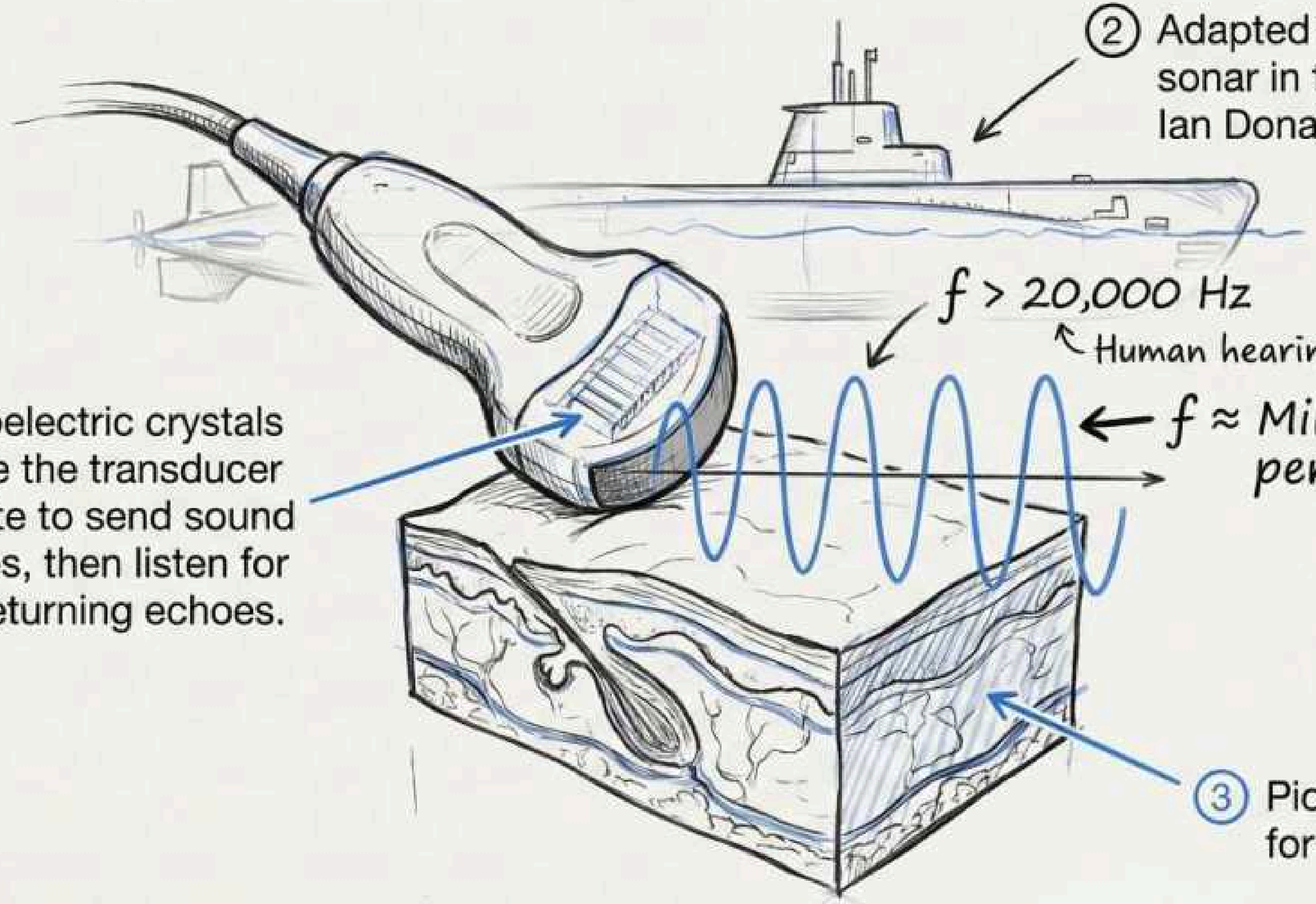
The Physics of Ultrasound

¶ 3.1



② Adapted from military sonar in the 1950s by Ian Donald (Glasgow).

$f > 20{,}000$ Hz

↖ Human hearing limit

$f \approx$ Millions of cycles per second (MHz)

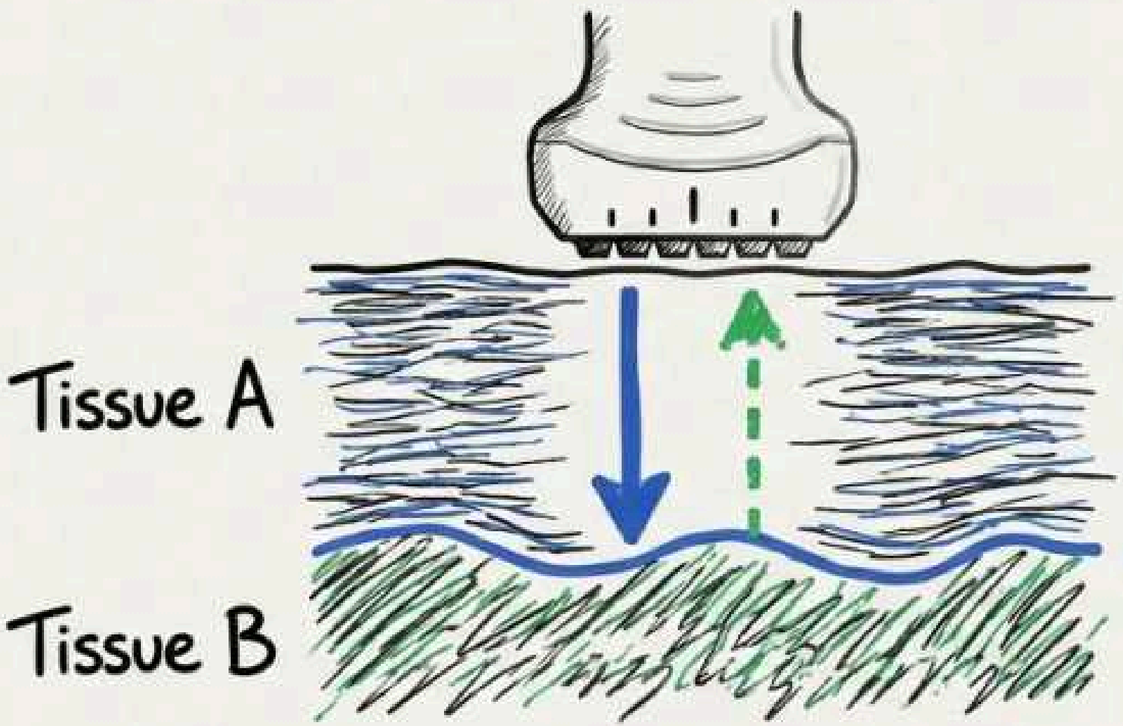
① Piezoelectric crystals inside the transducer vibrate to send sound pulses, then listen for the returning echoes.

③ Pioneered specifically for obstetric medicine.

Gemini Notebook

Echoes & Acoustic Impedance

¶ 3.2



Acoustic Impedance:

$Z = \rho c$ (Density × Speed of Sound)

Depth calculation:

$d = \frac{ct}{2}$ (Return time dictates the depth of the structure)

- Echoes arise wherever sound passes between tissues with differing acoustic impedance (how strongly they resist sound).
- Scanner measures return time → reveals exact depth.
- Scanner measures signal strength → reveals tissue type.
- Building up thousands of these echo lines produces a real-time moving picture.

Gemini Notebook

The Echogenicity Spectrum

¶ 3.3



Black (Anechoic):
Fluid.
Transmits sound perfectly, producing no echoes.

Grey (Echogenic):
Solid organs.
Produces speckled grey return patterns.

White (Hyperechoic):
Bone, gallstones, and gas.
Very strong reflectors.

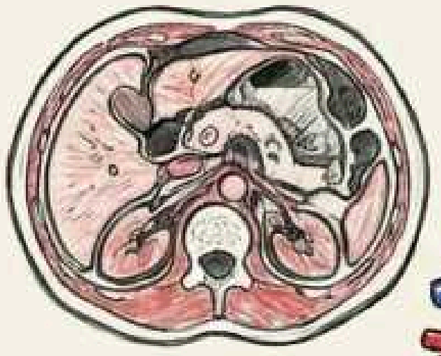
Key Limitation: Ultrasound cannot see through bone, air-filled lungs, or bowel.

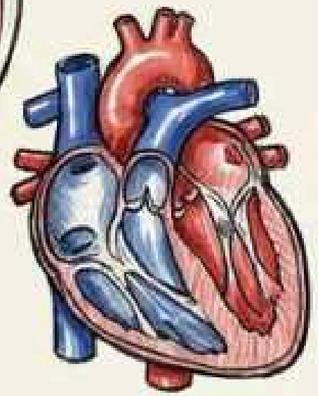
Gemini Notebook

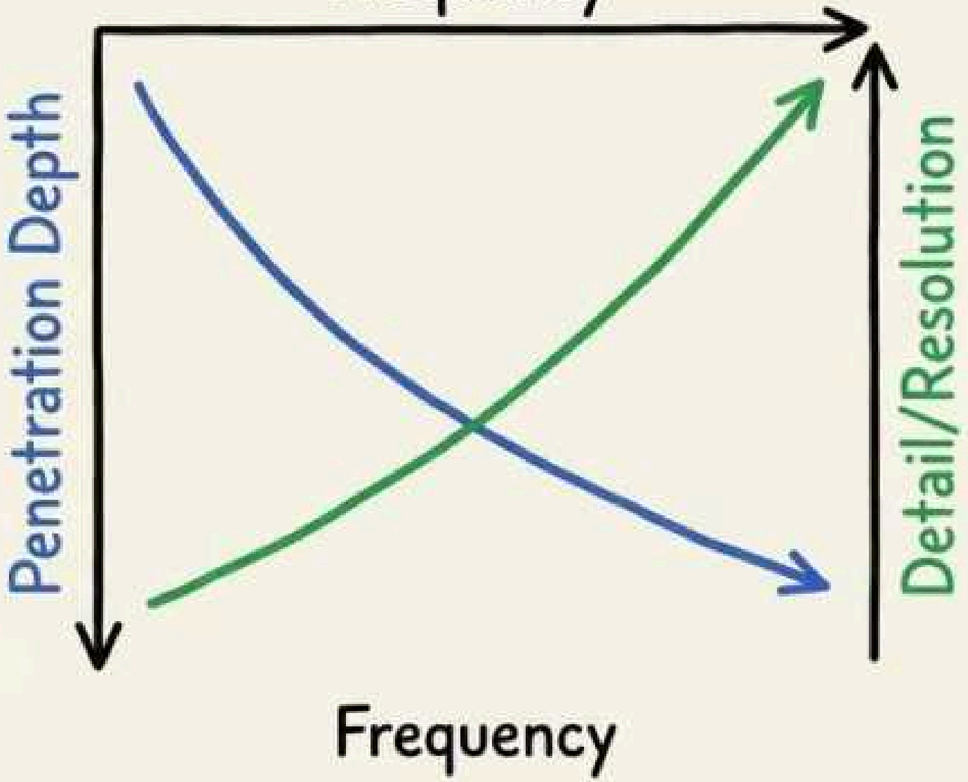
Frequency Trade-offs & Application

¶ 3.4

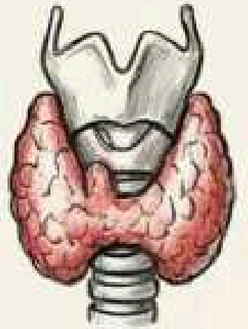
Deep penetration, lower detail.

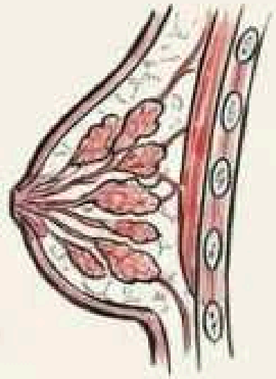


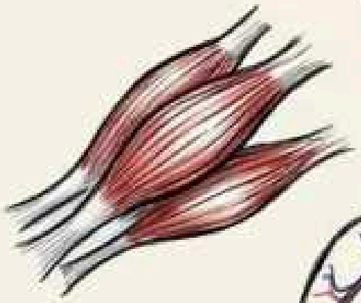


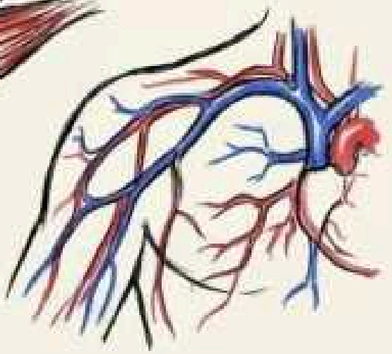


Shallow depth, highly fine detail.









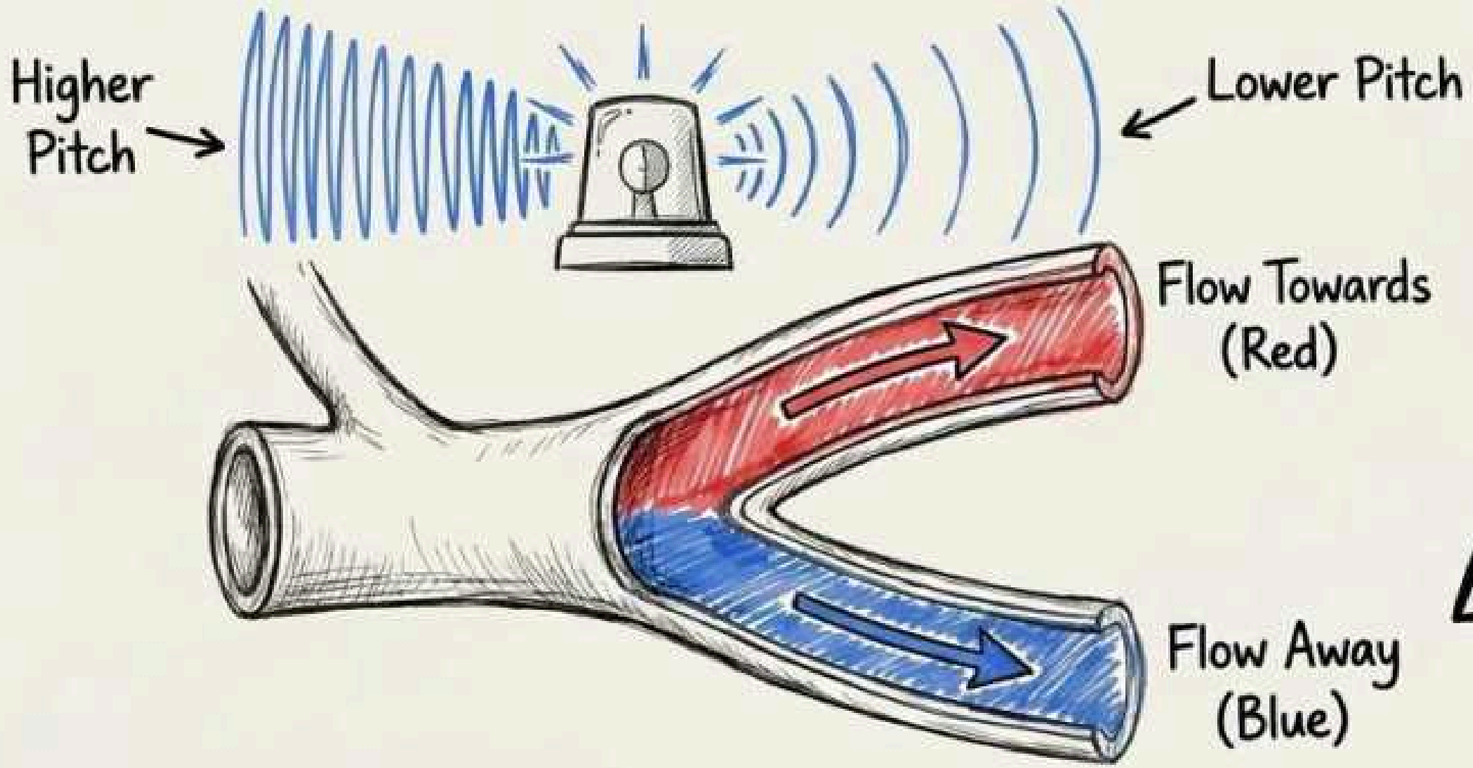


Gel is applied between the probe and skin to remove air, which would otherwise completely block the sound.

Gemini Notebook

Doppler Ultrasound & Blood Flow

¶ 3.5



Doppler Equation

$$\Delta f = \frac{2 f_o v \cos(\theta)}{c}$$

- Utilizes the **Doppler effect**: a change in pitch of sound reflected from a moving object.

- Measures the speed and direction of blood flow, color-coded on the display.

- **Critical Diagnoses:** Finds blood clots in leg veins, narrowed neck arteries (which carry high stroke risk), and abnormal blood flow in the heart.

Gemini Notes

Standard of Care in Pregnancy

¶ 3.6



Uses **NO** ionizing radiation; no known harmful diagnostic effects.



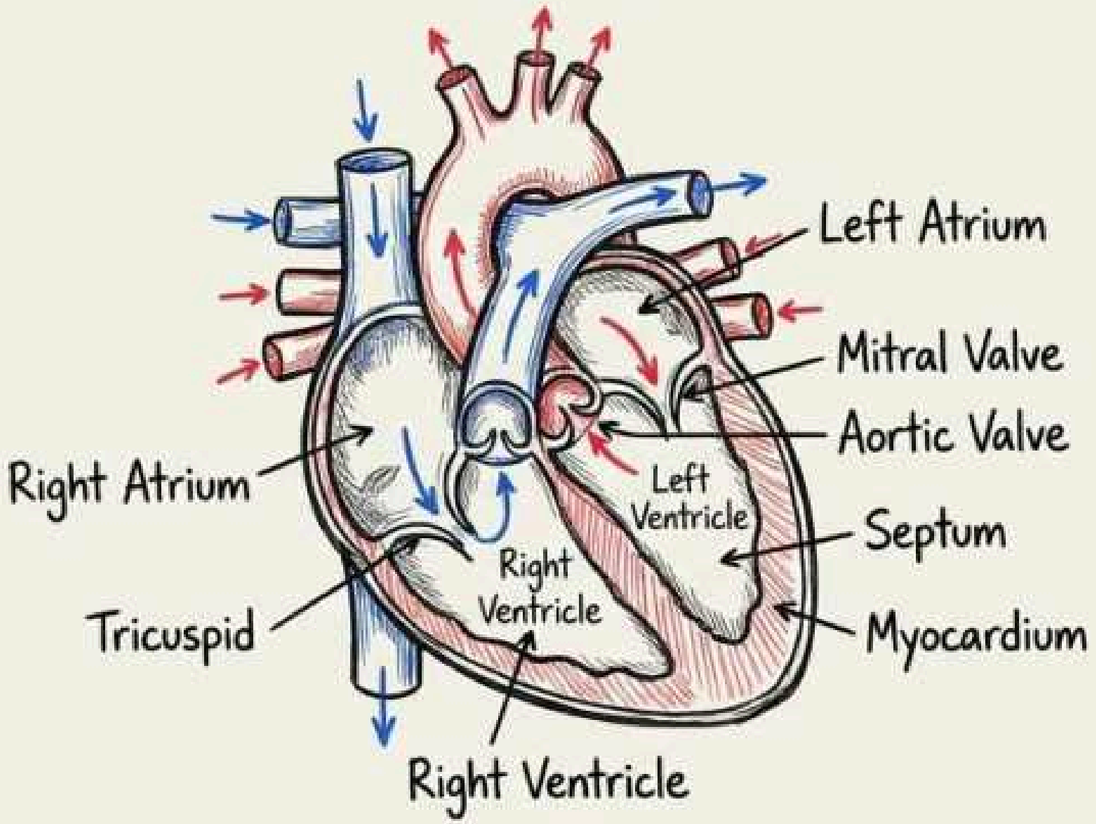
- ✓ Confirm viability & precisely date the pregnancy.
- ✓ Identify multiple gestations (e.g., twins).
- ✓ Check the baby's anatomical development.
- ✓ Monitor ongoing growth trajectories.
- ✓ Locate the placenta (As detailed in MED 532 B).

Gemini Notes

Echocardiography & Abdominal Scans

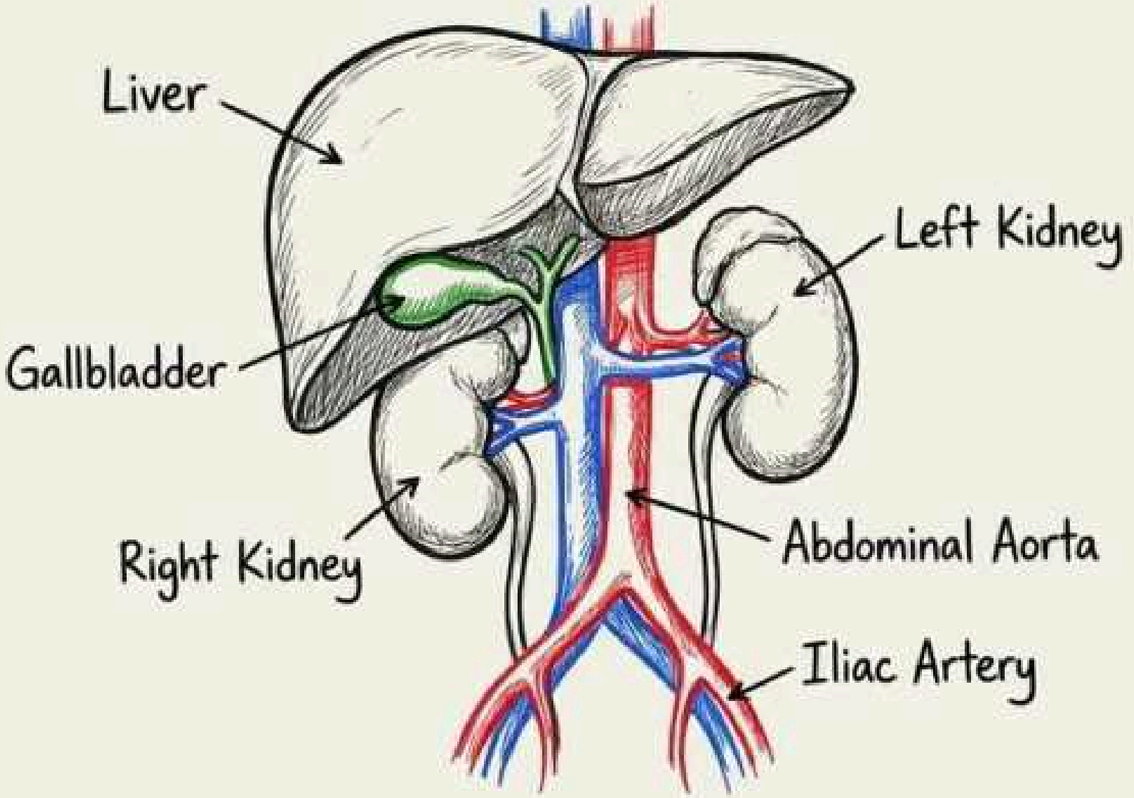
¶ 3.7

The Heart



Echocardiography: Essential for diagnosing heart failure and valve disease (As explained in MED 521 B).

The Abdomen



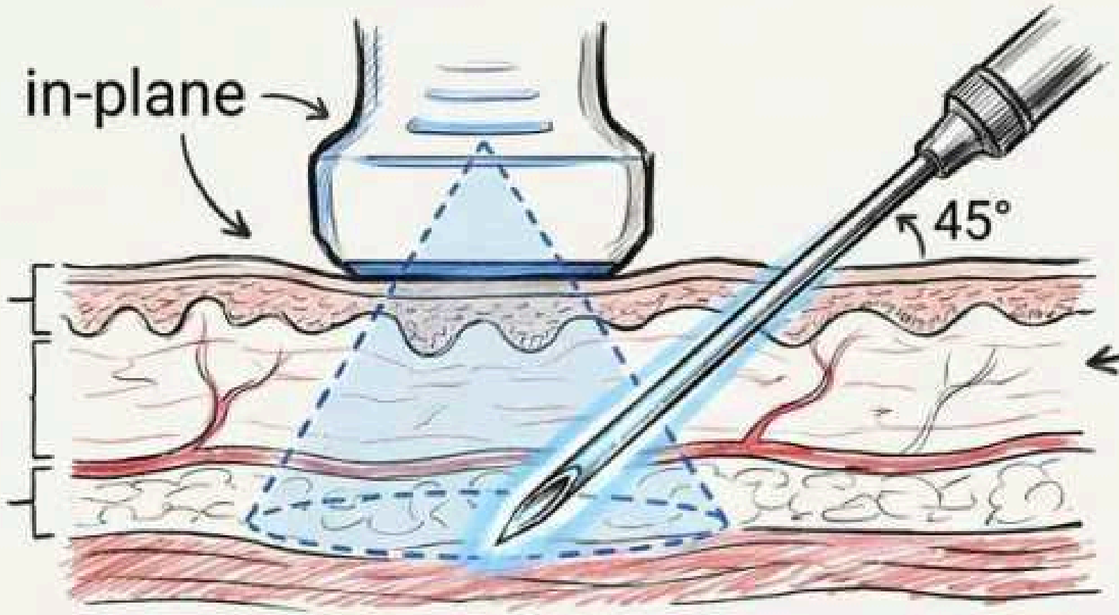
Abdominal Ultrasound: Detects gallstones, liver disease, and kidney swelling from blockages.

Critical for spotting Abdominal Aortic Aneurysms (AAA) — screening older men saves lives.

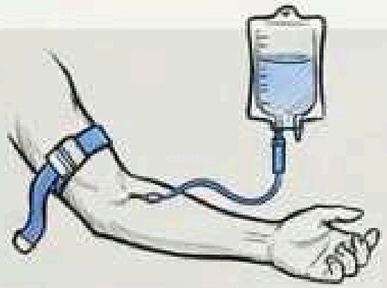
Gemini Notebook

Real-Time Procedural Guidance

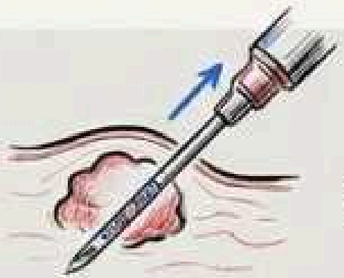
¶ 3.8



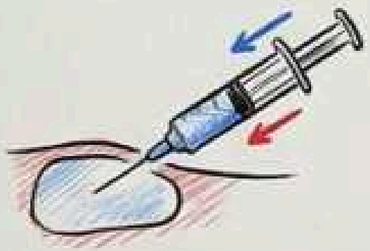
Watching the needle in real-time dramatically increases procedural accuracy and reduces complications.



1. Placing intravenous lines safely into veins.



2. Taking precise biopsy samples from suspicious lumps.



3. Draining abnormal fluid collections.



4. Injecting joints accurately.

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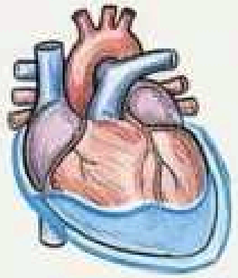
Point-of-Care Ultrasound (POCUS)

¶ 3.9

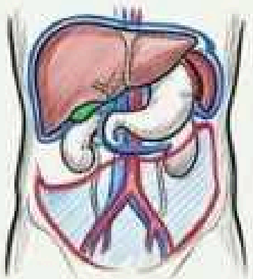
Doctors scanning at the bedside themselves to answer focused, highly urgent questions.



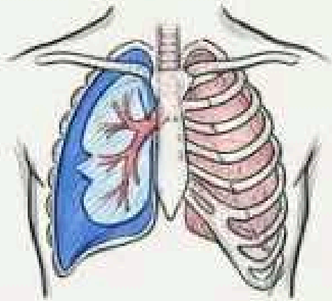
Triad of Urgent Questions



Heart: Is there fluid accumulating around the heart?



Abdomen: Is there free blood present after a trauma?



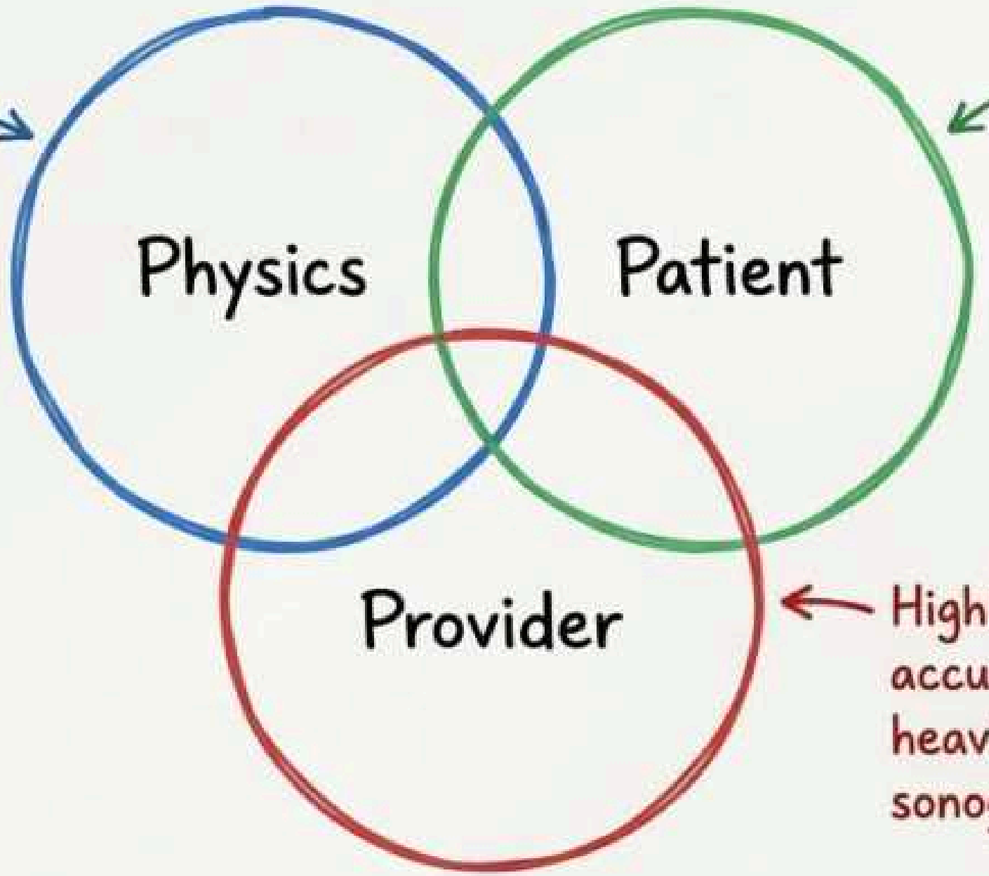
Lungs: Is there a collapsed lung (pneumothorax)?

Portability allows for advanced imaging anywhere, including environments without access to traditional imaging machines.

Gemini Notebook

Key Limitations of Ultrasound

¶ 3.10



Sound absolutely cannot pass through bone or gas.

Image resolution and overall quality fall significantly in people with higher amounts of body fat.

Highly operator dependent; the accuracy of the results relies heavily on the physical skill of the sonographer performing the scan.

Reviewability Constraint: Unlike CT or MRI, the static images captured by ultrasound are much harder for secondary clinicians to interpret after the scan is over.

Gemini Notebook

Summary Synthesis & Next Steps

¶ 3.11

Core Tech:

Builds real-time images purely from echoes.

Functionality:

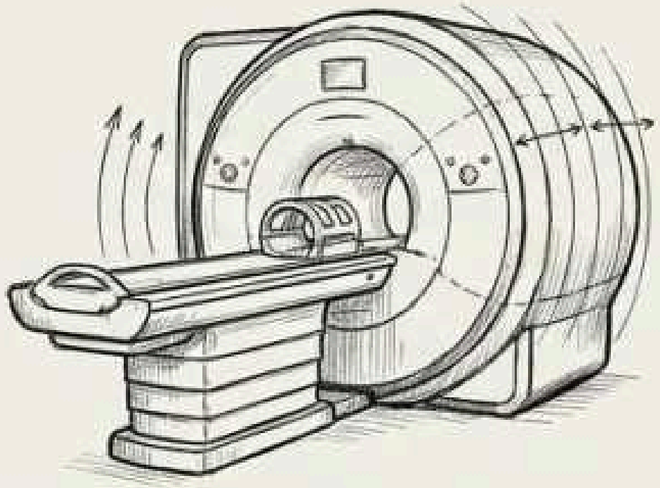
Doppler modalities reveal blood flow dynamics and direction.



Ultrasound Synthesis

Clinical Value:

Utterly safe (no radiation) and highly portable. Ideal for pregnancy, cardiac assessment, and urgent bedside (POCUS) diagnostics.



Next up: Magnetic Resonance Imaging (MRI).

Gemini Notebook