Introduction Emergency to Ultrasound

Emergency Ultrasound

- Environment:
  - Hurried, varied, pressured, crowded
  - Unstable, critical patients
  - Lack of information
- Ultrasound:
  - Compact
  - Easy to use
  - Provides information in seconds

Ultrasound is the perfect data-gathering tool in this environment

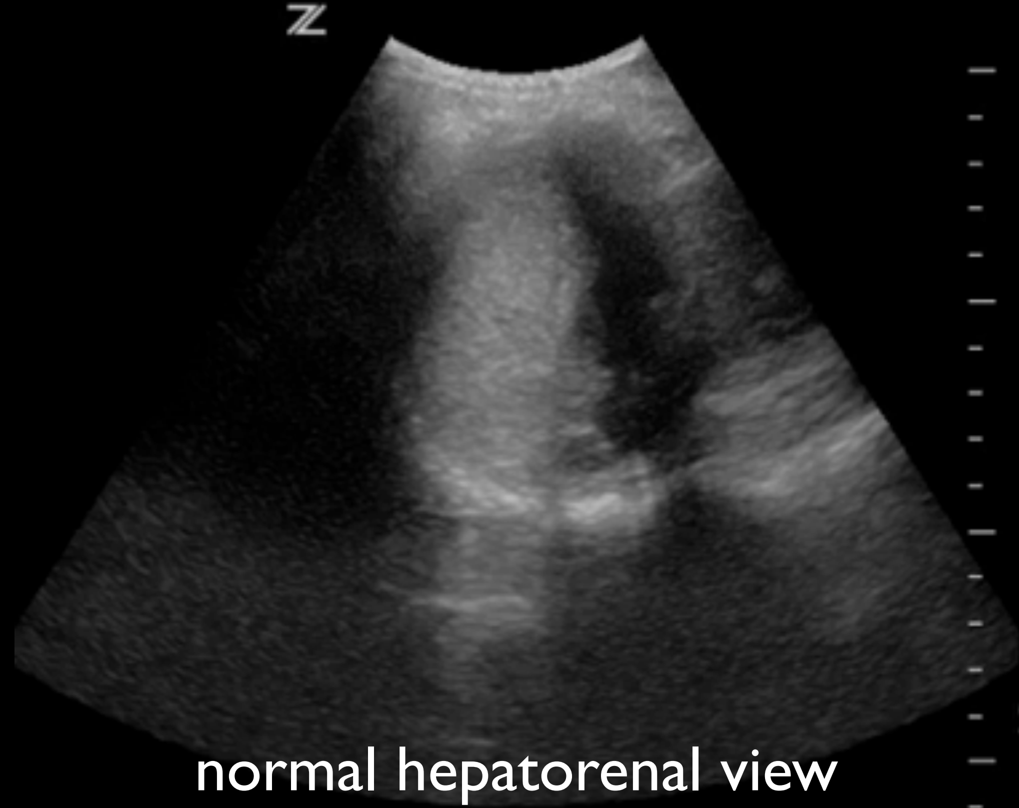
Case

- 35 y/o African-american male, self-inflicted stab wound to epigastrium about 20 min prior to arrival
- Confused, agitated, tachycardic
- P 120 BP 105/70 O2 95%
- Pt exposed, single 2cm stab wound epigastrium

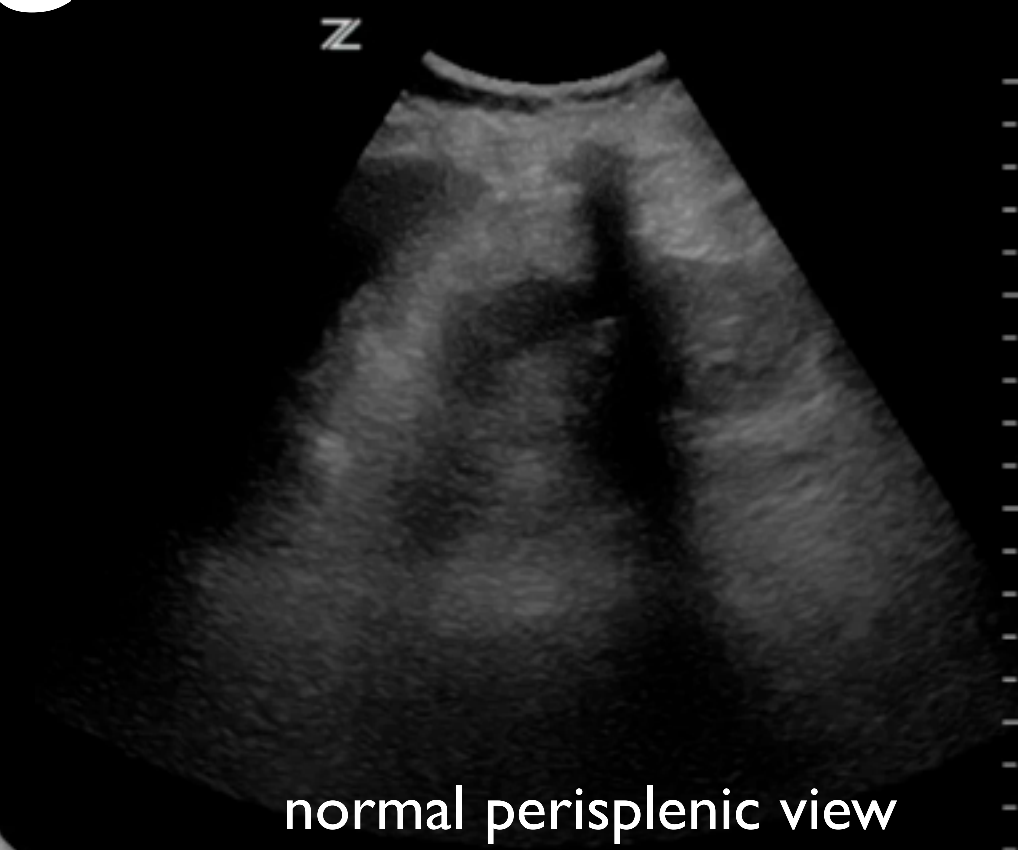
Case

- Screaming, combative. Abdomen soft, equal breath sounds, trachea midline, rapid thready pulses
- Bilateral IV's established, fluid boluses
- Rapid sequence intubation for agitation

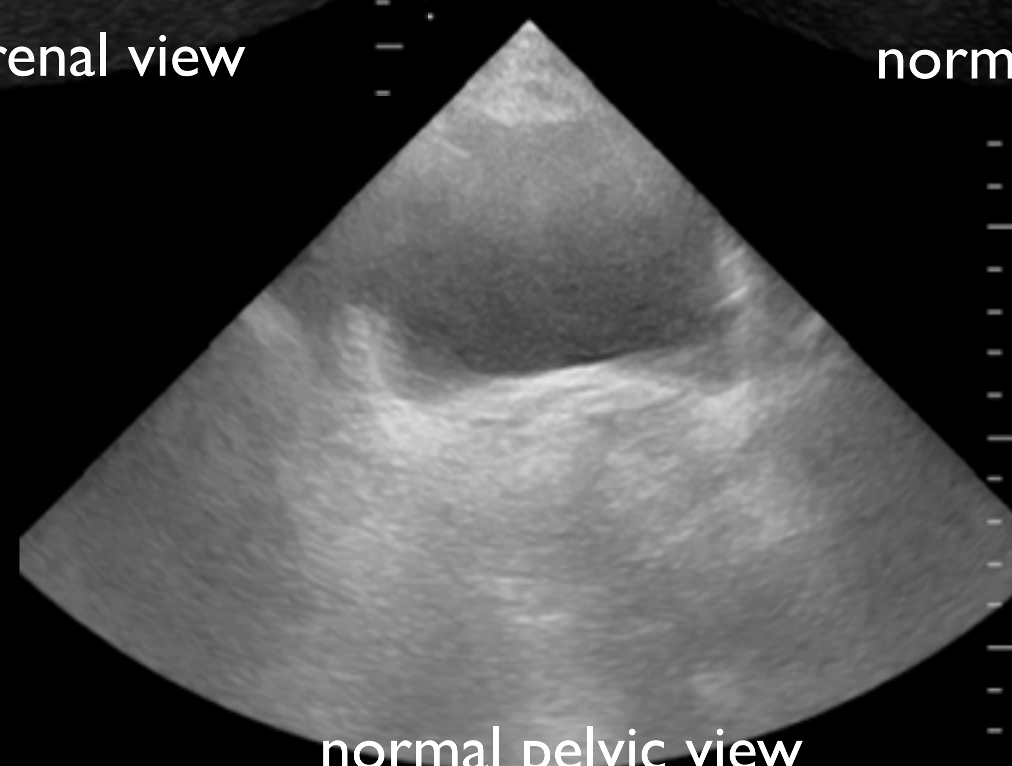
Case



normal hepatorenal view



normal perisplenic view

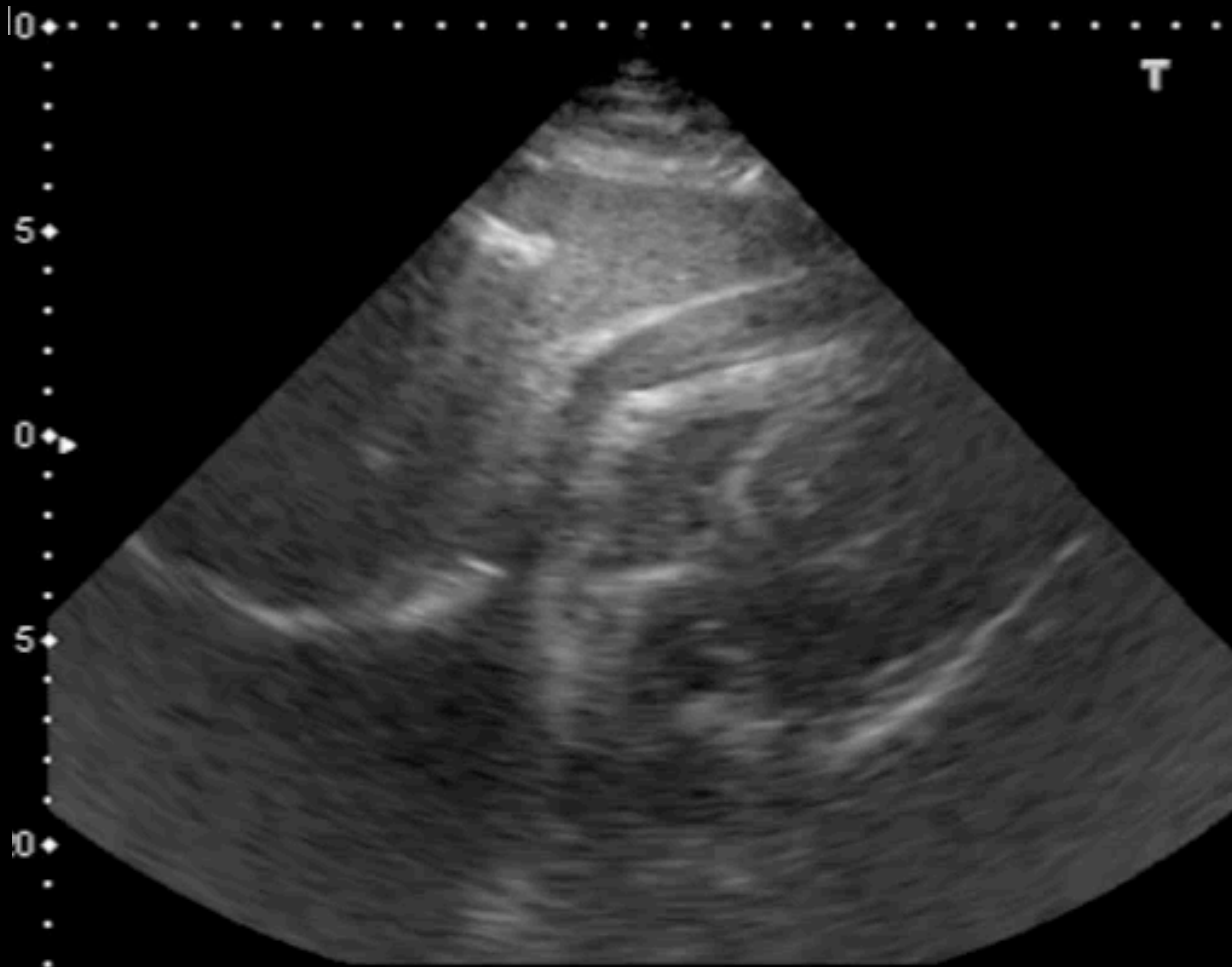

normal pelvic view

No major intra-abdominal hemorrhage

Case

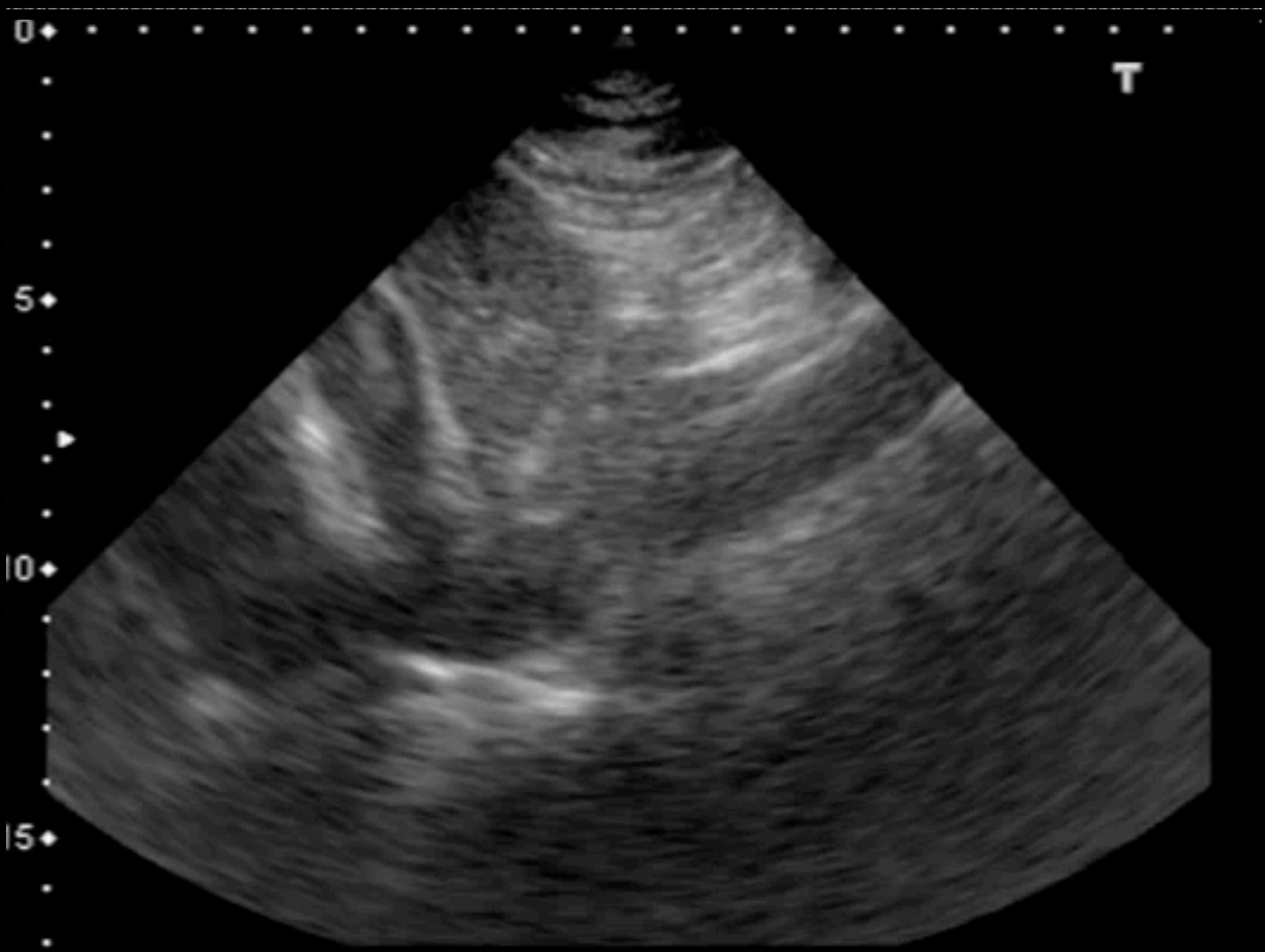
No pneumothorax bilaterally

Case



Hemopericardium with impending tamponade

Case



Distended IVC: CVP elevated from obstruction

Case

Several minutes later, vitals are not obtainable.

Case

- Imagine the case without ultrasound: patient becomes a "black box"
  - Is patient dying from intra-abdominal hemorrhage?
  - Is patient dying from tension pneumothorax?
  - Is patient dying from cardiac laceration?
- Physical exam often unreliable or unobtainable
- Ultrasound provides quick information and may direct care

Comparison to Other Imaging

- Very large infrastructure requirements
  - Expensive equipment
  - Large space requirement
  - Specially trained personnel
  - Large data loop

Comparison to Other Imaging




- Ultrasound:
  - Relatively small infrastructure
    - Limited equipment needs
    - Small space requirements
    - Minimal training required
    - Small data loop

Comparison to Other Imaging

- Why has ultrasound become a common tool for clinicians?

Small Infrastructure

Comparison to Other Imaging

Introduction

Comparison to Other Imaging

Comparison to Other Imaging

- Processor is major component of ultrasound
  - As processors get smaller, so does ultrasound machine
- Imaging hardware stays the same size
  - X-ray/CT tubes and detectors, MRI magnets
  - Ultrasound crystals

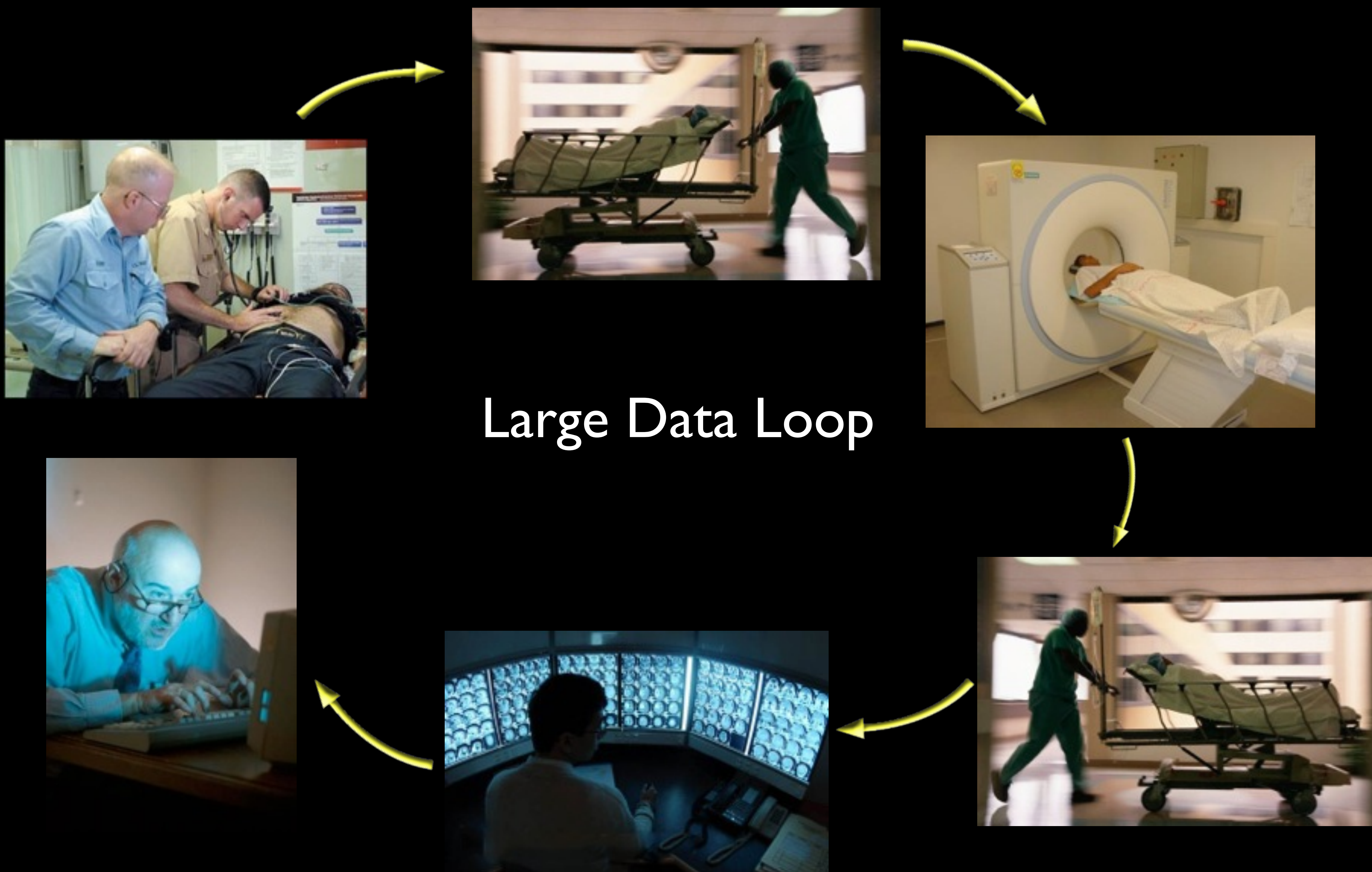
Comparison to Other Imaging

- Why has ultrasound become a common tool for clinicians?

Small Infrastructure

Small Data Loop

Comparison to Other Imaging



Comparison to Other Imaging

Comparison to Other Imaging

- Not meant to replace formal ultrasound studies
- Clinician-based ultrasound
  - A *limited* exam that answers a *binary* question
    - Is there a pericardial effusion?
    - Is there intra-abdominal hemorrhage?
  - Goal-oriented, focused
  - Performed quickly without need for transport

Comparison to Other Imaging

- Why has ultrasound become a common tool for clinicians?

Small Infrastructure

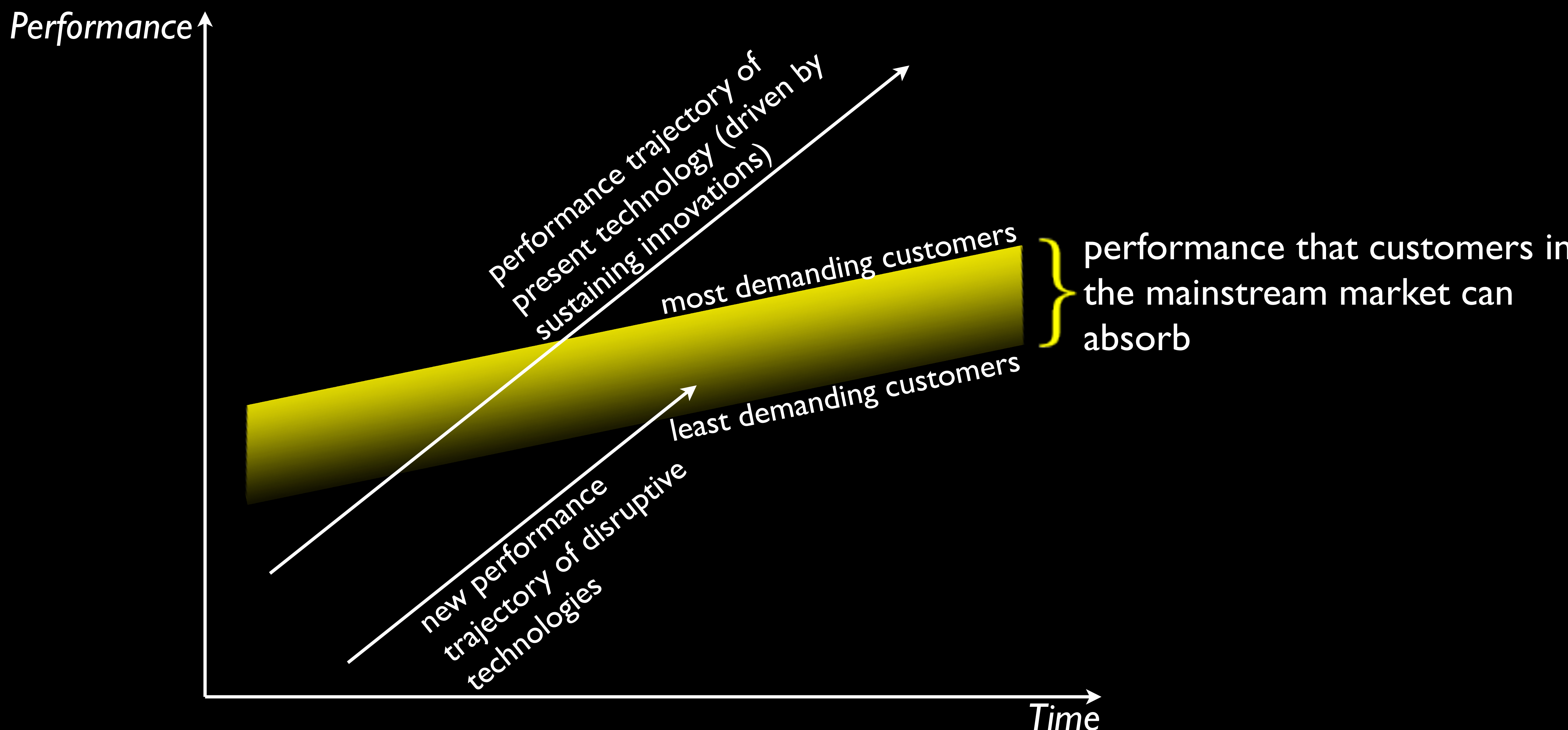
Small Data Loop

Disruptive Innovation

Comparison to Other Imaging

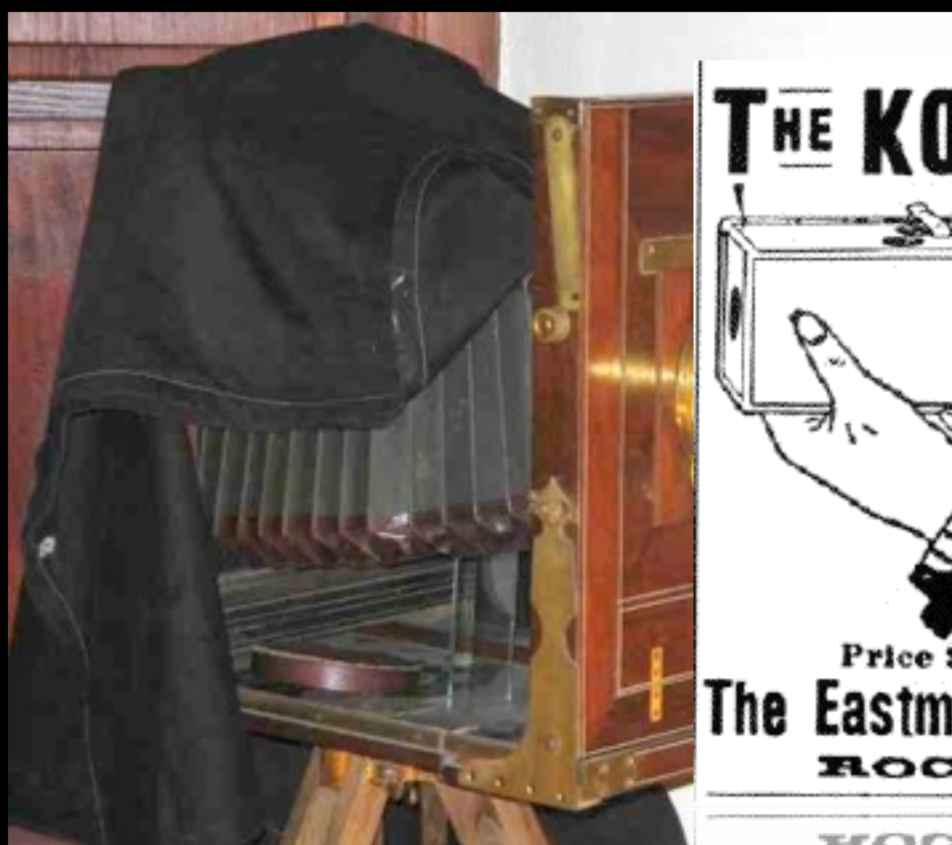
- How disruptive innovations work:
  - A simpler form of an existing complex technology that can be used by the masses
  - Enables a task to be done by a larger population of less skilled people
  - Done in a more convenient, less expensive setting

Comparison to Other Imaging



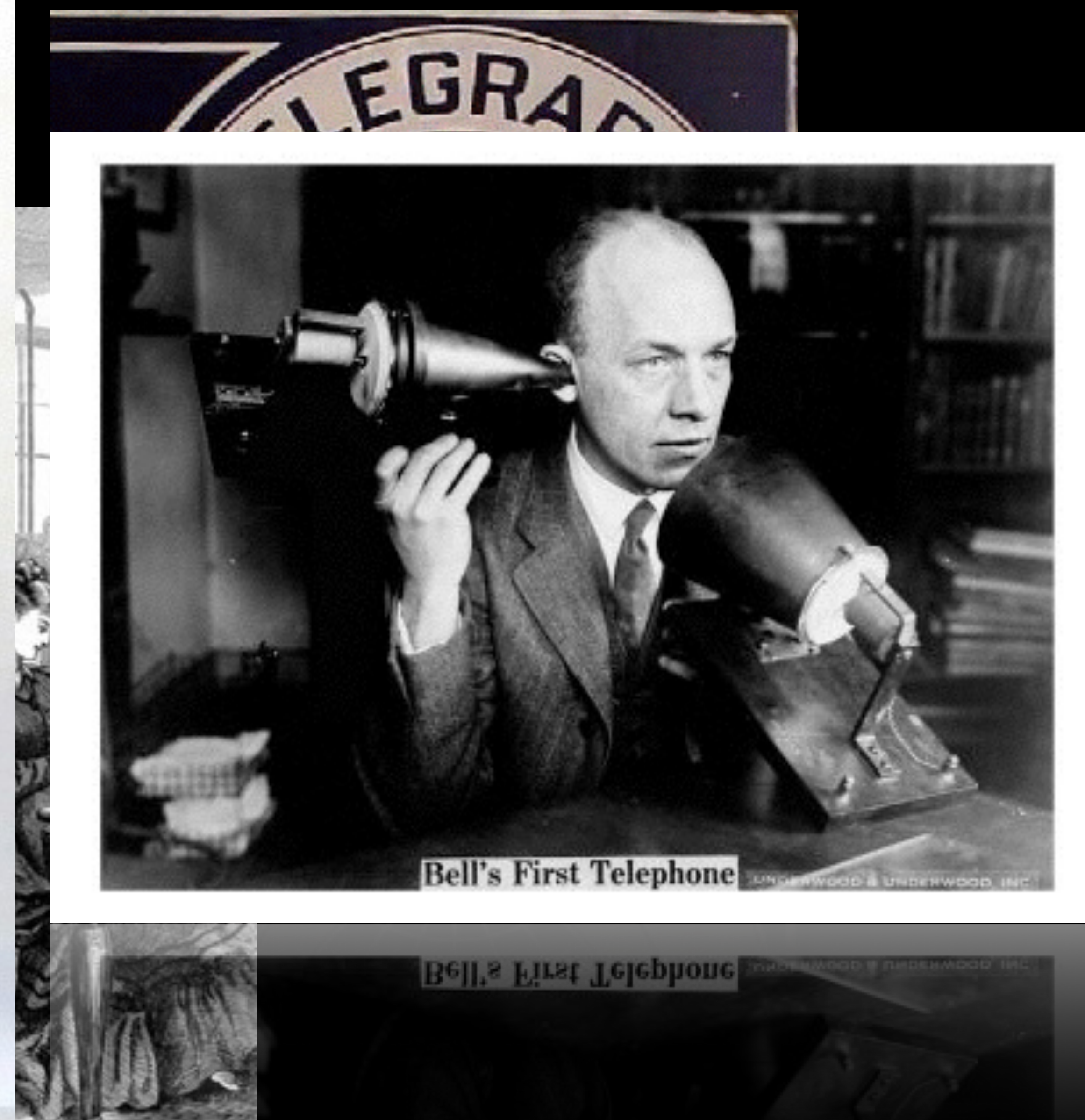
Disruptive Technologies

Comparison to Other Imaging



Disruptive Technologies

Comparison to Other Imaging



Disruptive Technologies

Comparison to Other Imaging

Disruptive Technologies

Comparison to Other Imaging

Disruptive Technologies

Comparison to Other Imaging

- Disruptive innovation
  - In these cases, disruption left consumers far better off than before.
- Benefits:
  - greater convenience
  - more access
  - lower cost

Comparison to Other Imaging

- Clinician-based ultrasound now overtaking traditional ultrasound in sales
- Ultrasound vendors moving aggressively into this market
  - Sonosite (1999), Ultrasonix (2004), Zonare (2005), General Electric (2005)

Ultrasound in Medicine

- General surgery and trauma
- Emergency medicine
- Anesthesia
- Critical care
- Orthopedics
- EMS, military, NASA

Program Goals

Objectives

- Technique (anatomy, physics, knobs)
- Indications and limitations of ultrasound
- Clinical decision making in the critically ill patient

Course Overview

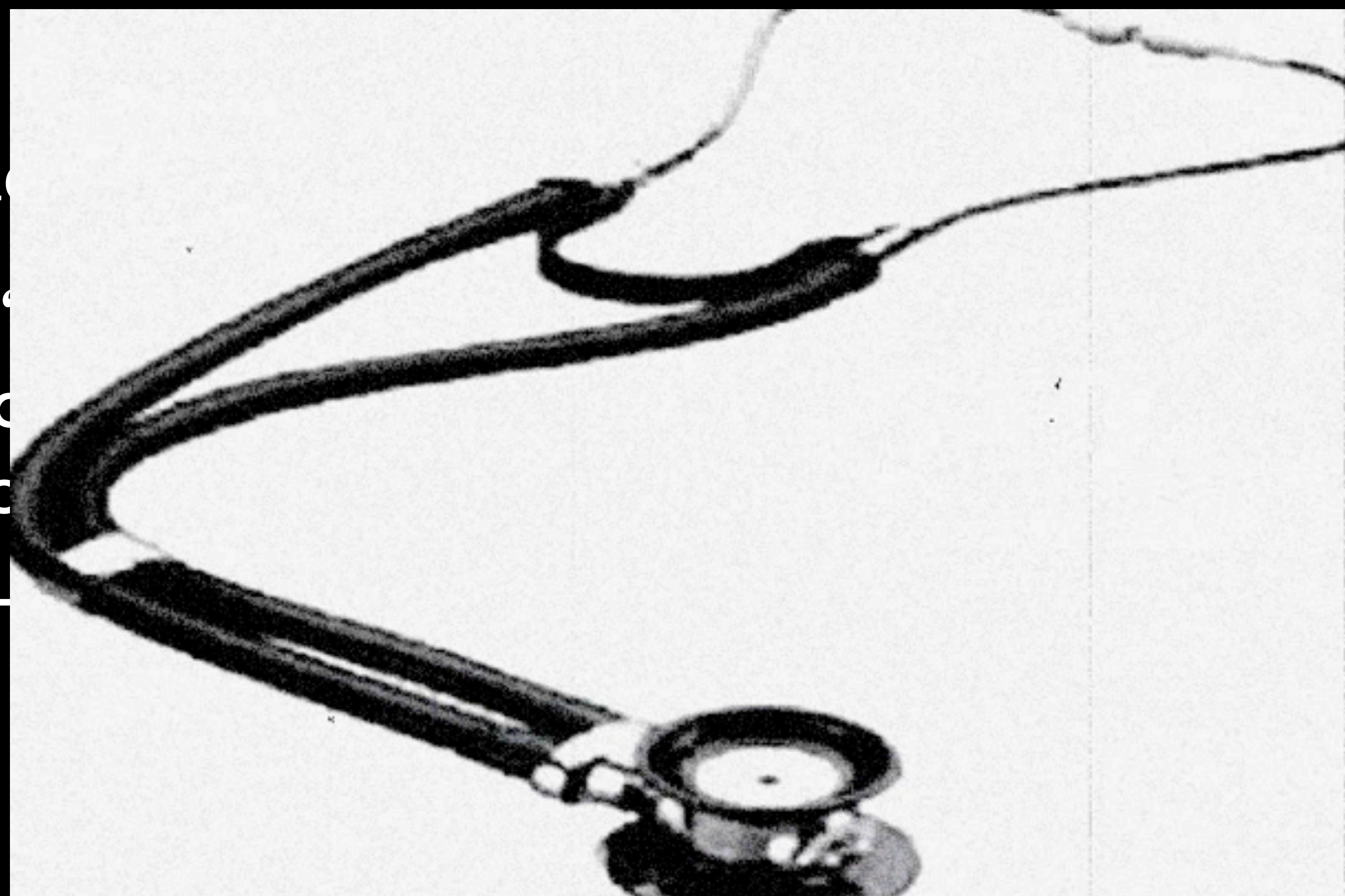
- Physics/instrumentation
  - Important for obtaining quality images and differentiating artifacts
- The E-FAST exam
  - Intrathoracic/intra-abdominal hemorrhage
- Retroperitoneal ultrasound
  - Aortic aneurysm and hydronephrosis
- Biliary ultrasound
  - Gallstones and cholecystitis

Course Overview

- Basic echocardiography
  - Pericardial effusion, LV function, pulmonary embolus, ascending aortic dissection
- Thoracic ultrasound
  - Pneumothorax, pulmonary edema, pleural effusion, pneumonia
- Pelvic sonography
  - 1st trimester pregnancy, ectopic pregnancy
- Central and peripheral vascular access

Ultrasound Proficiency

- Prac



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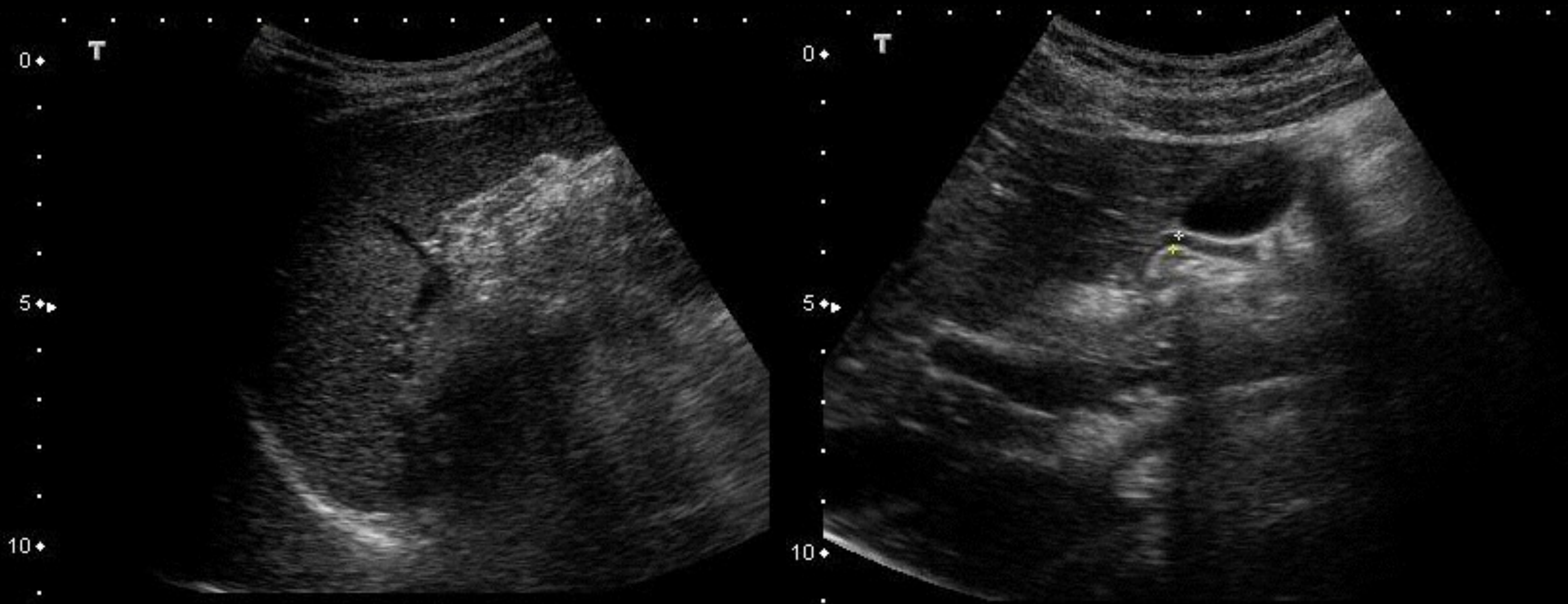
Basic Ultrasound Physics

Physics of Ultrasound



- Anatomic structure or artifact?

Relative Frequencies

Human hearing

20-20K Hz

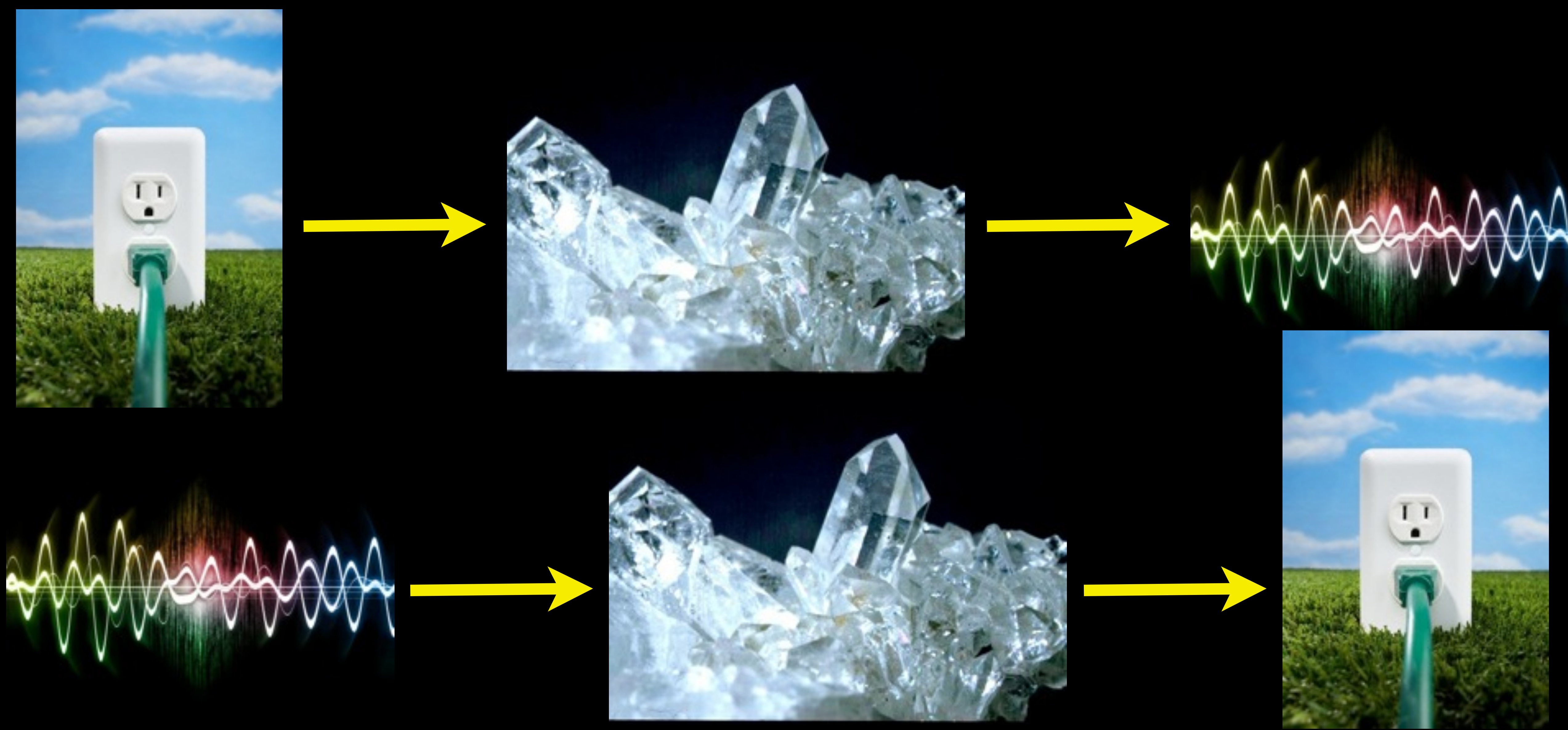
Ultrasound

Greater than 20K Hz

Diagnostic Ultrasound

Greater than 1 MHz

Diagnostic Ultrasound

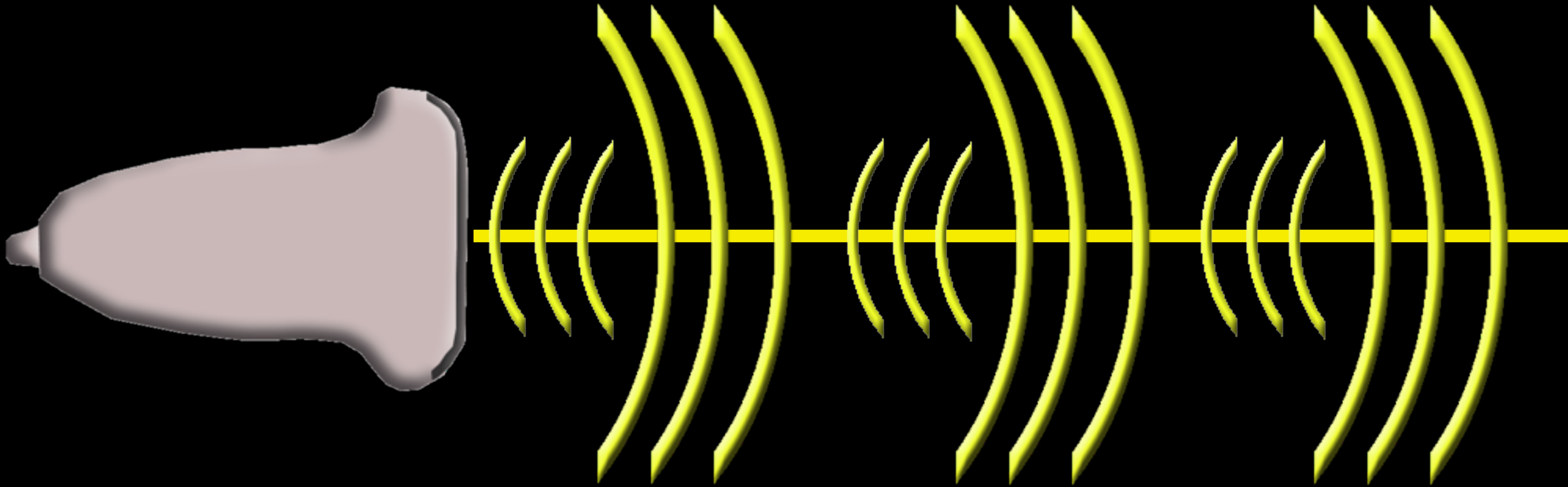


- *Piezoelectric effect:* the charge which builds up in certain solids in response to applied mechanical strain

Transducers

- Transmit
- Receive

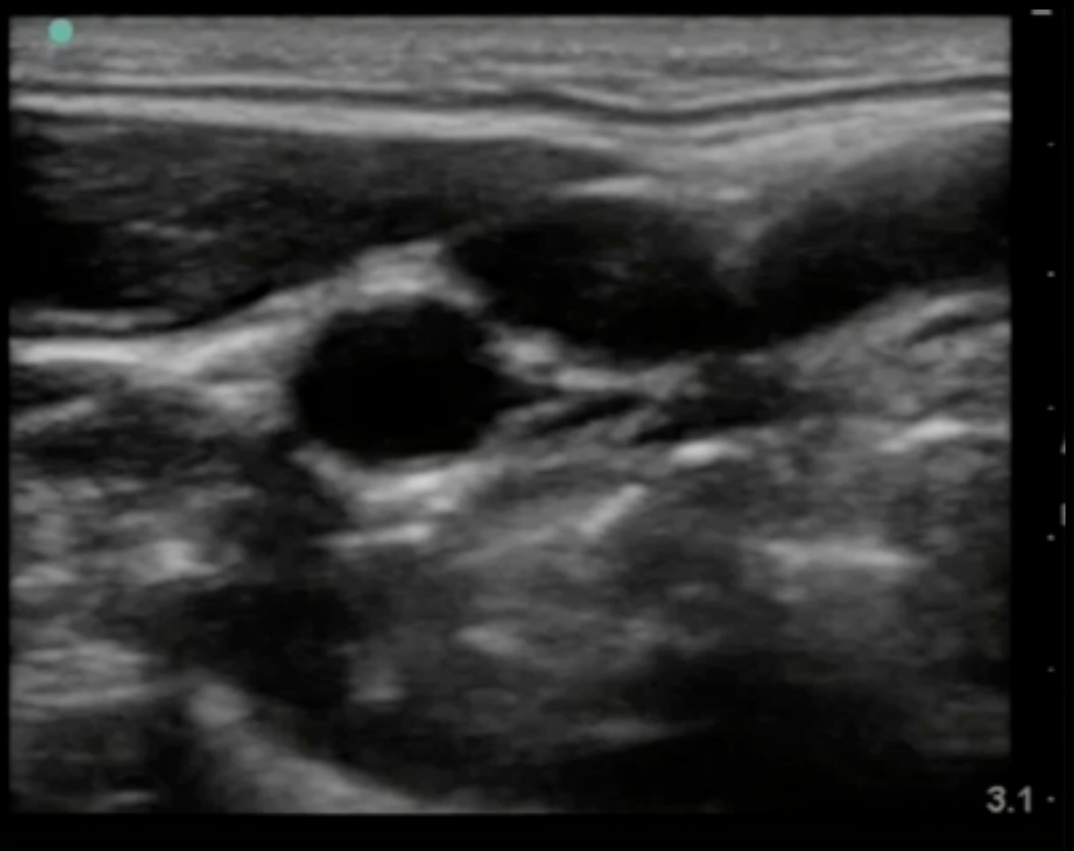
Transducers



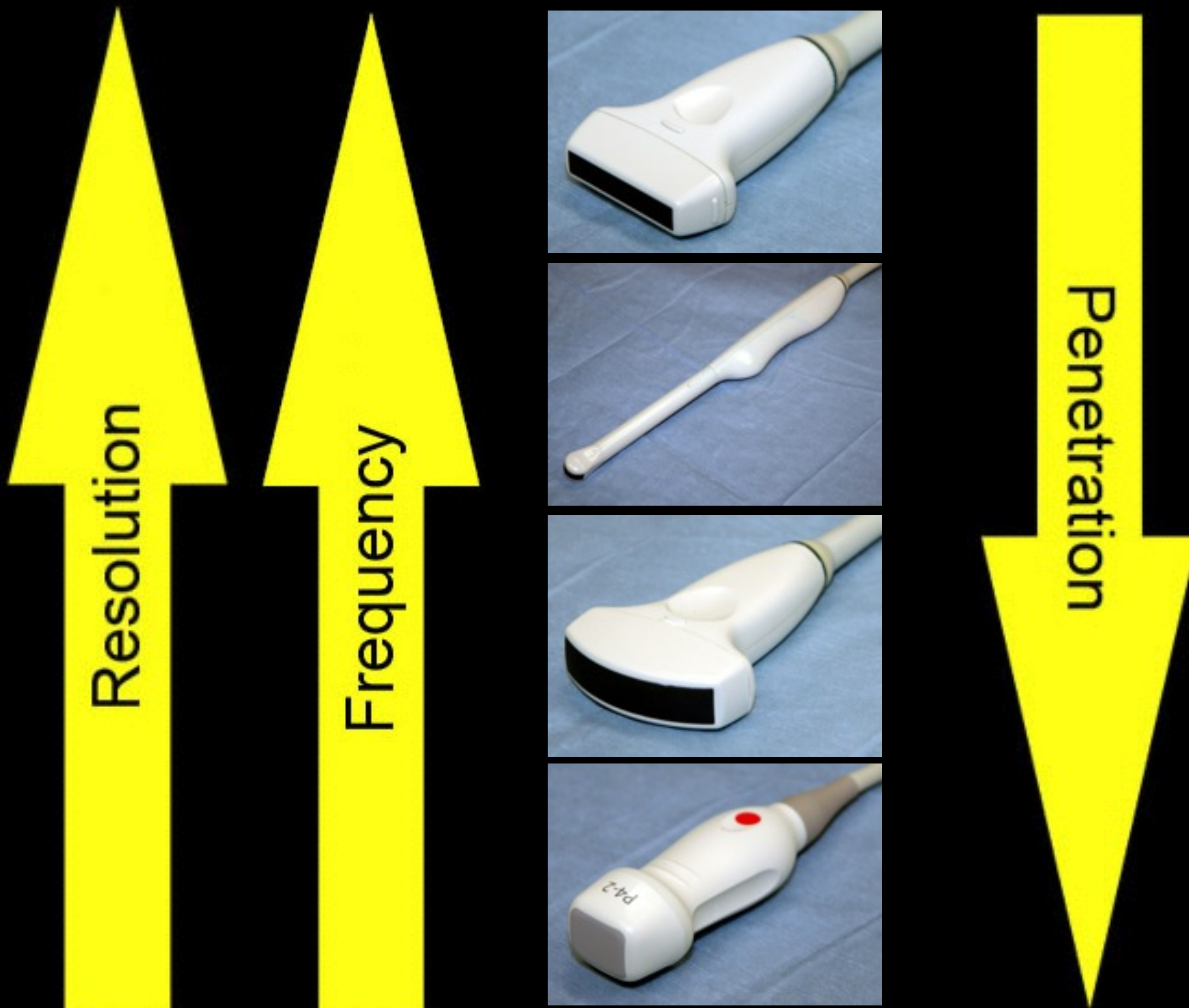
- Transducer sends out ultrasound waves 99% of the time
- Transducer listens for ultrasound waves 1% of the time

Image Display

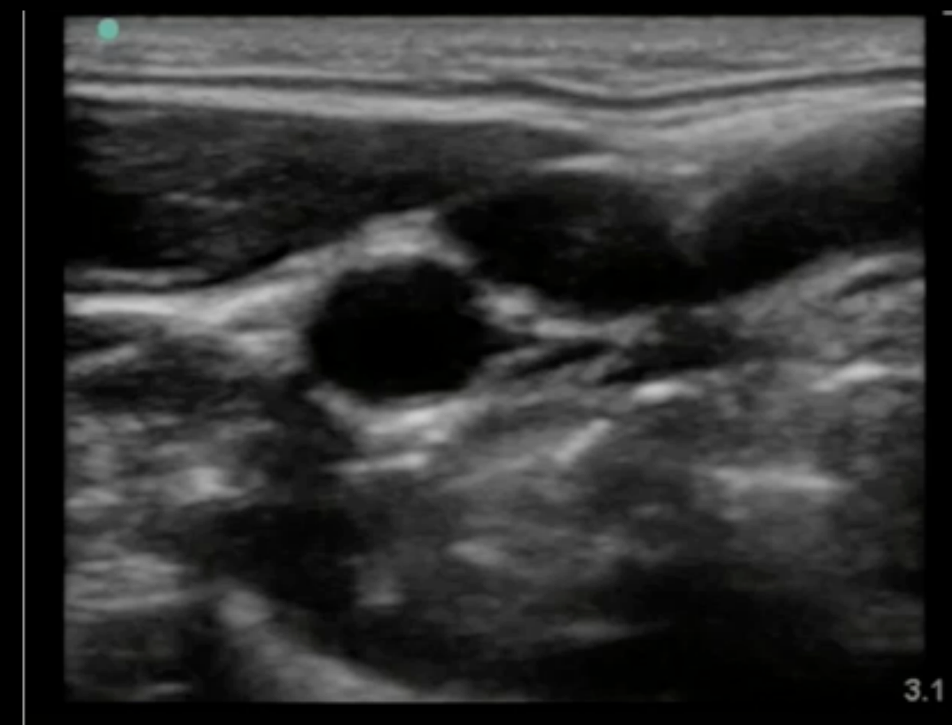
- Return signal used to create real time, grayscale, B-mode
- Reflected sound waves are assigned a position and amplitude to create a 2D image
- Based on time for signal return and strength



Frequency



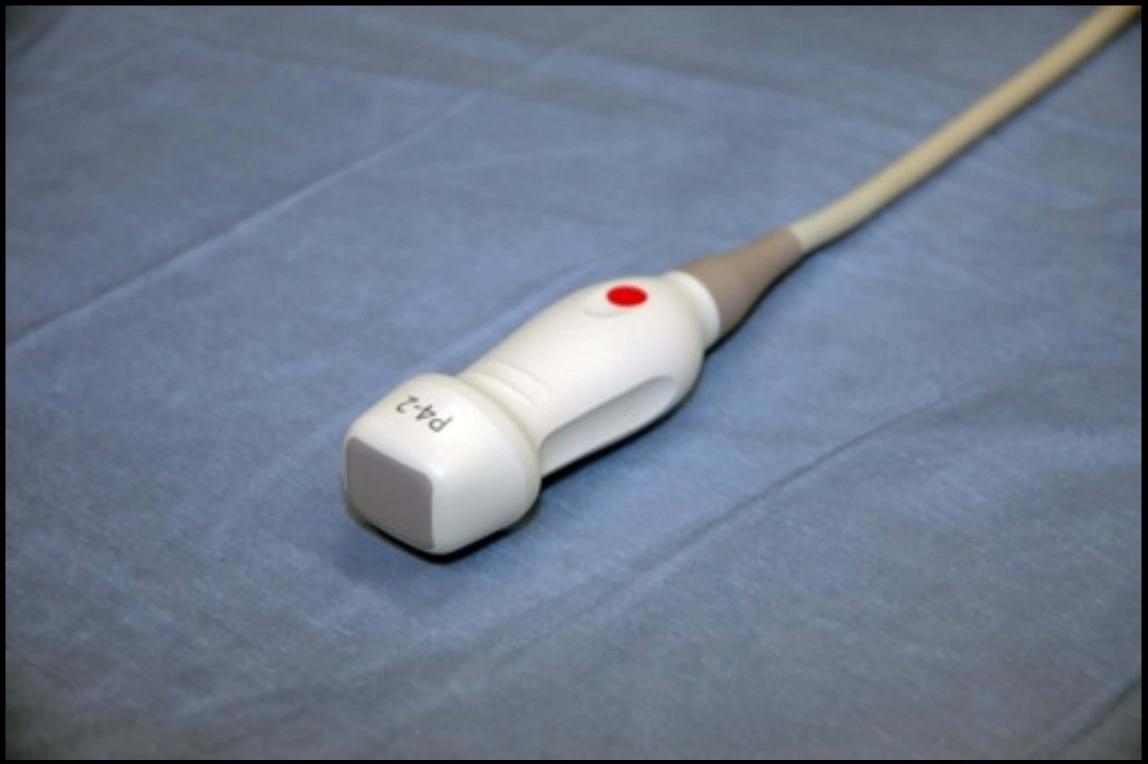
Resolution / Penetration



Transducer Footprint

footprint

Transducer Footprints



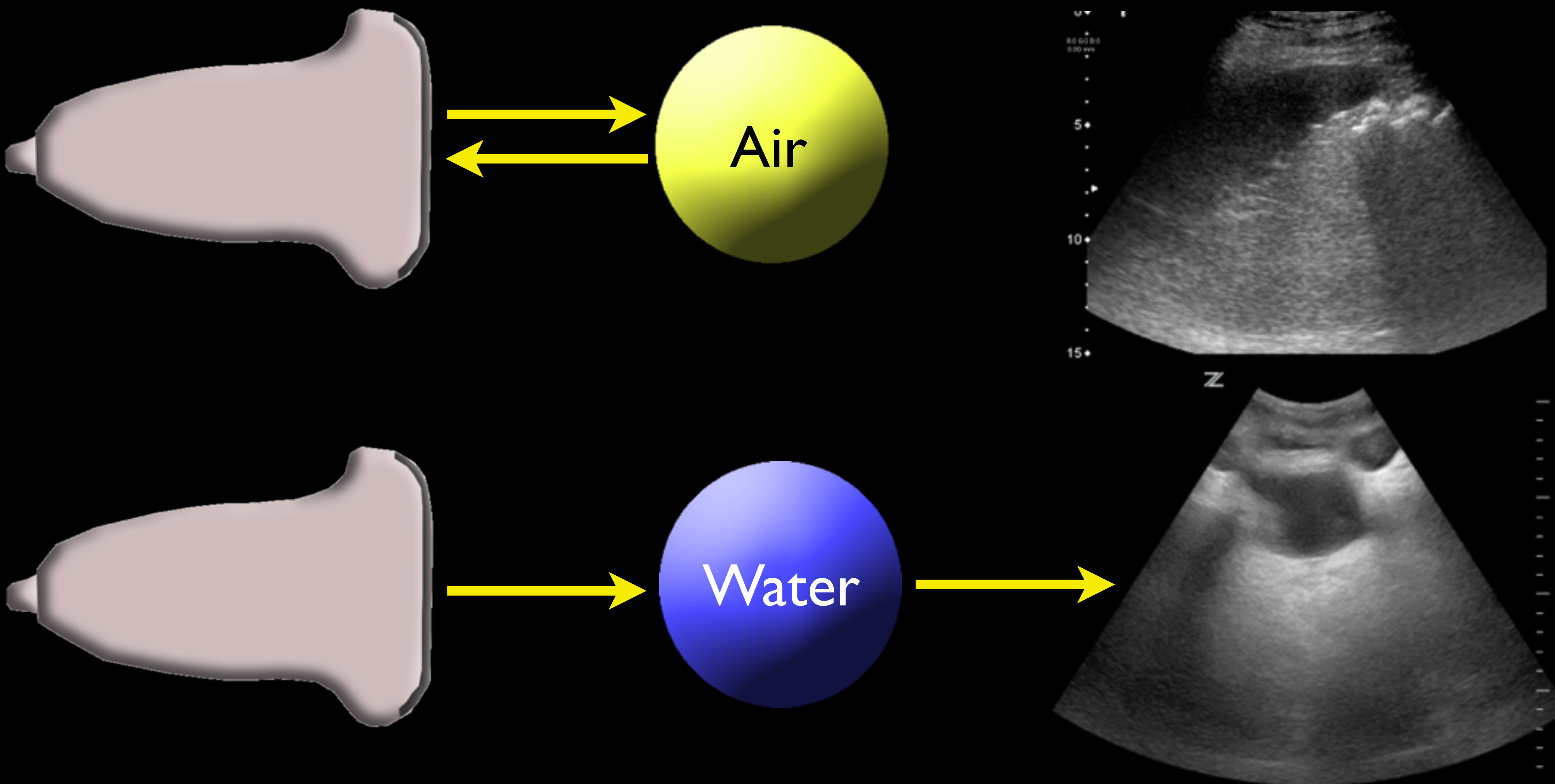
Sound transmission

- Factors that influence sound transmission in tissues:
  - Density
  - Flexibility (“stiffness”)

Density

- High density (liver, spleen, water)
  - Good transmission of sound
- Low density (air)
  - Poor transmission of sound

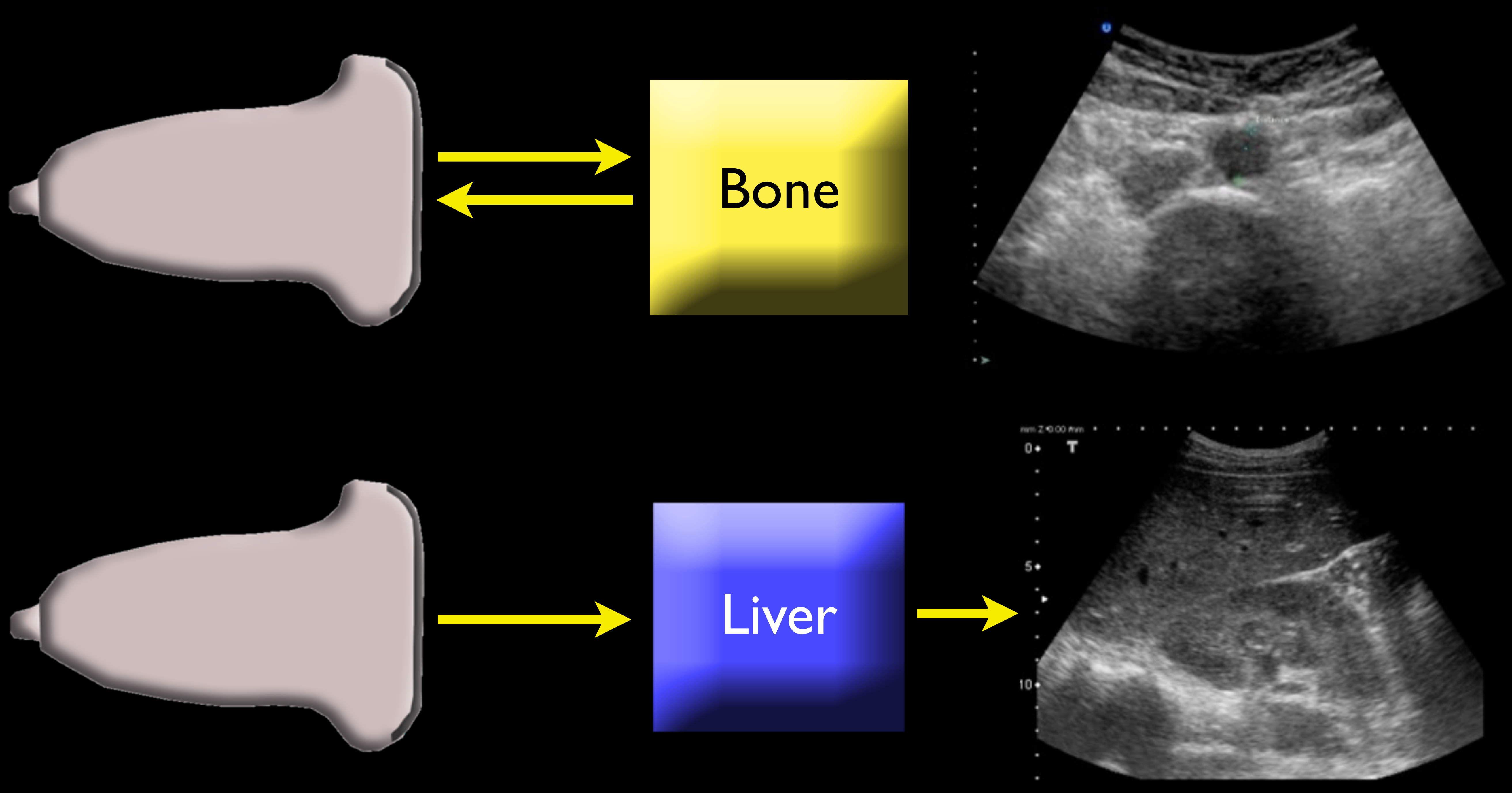
Density



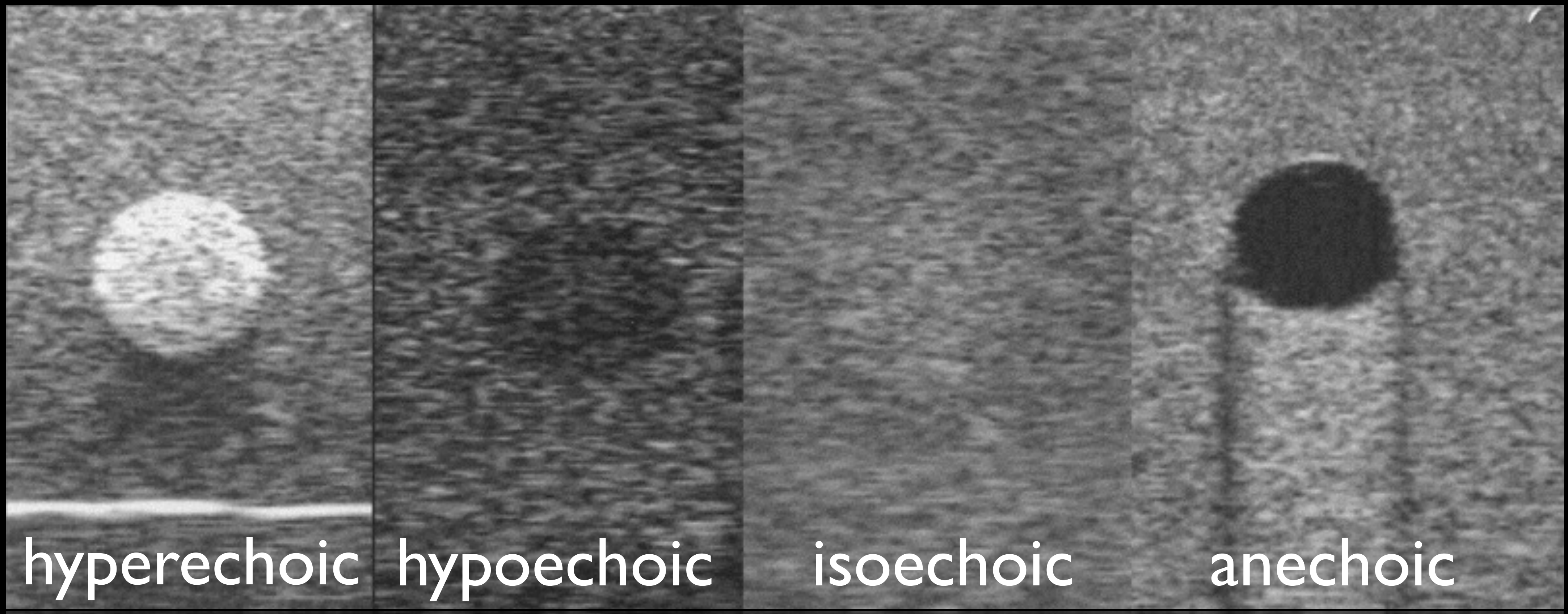
Flexibility ("stiffness")

- "Flexible" substances transmit sound well (liver, spleen)
- "Stiff" substances reflect sound (bone)

Flexibility ("Stiffness")



Terminology



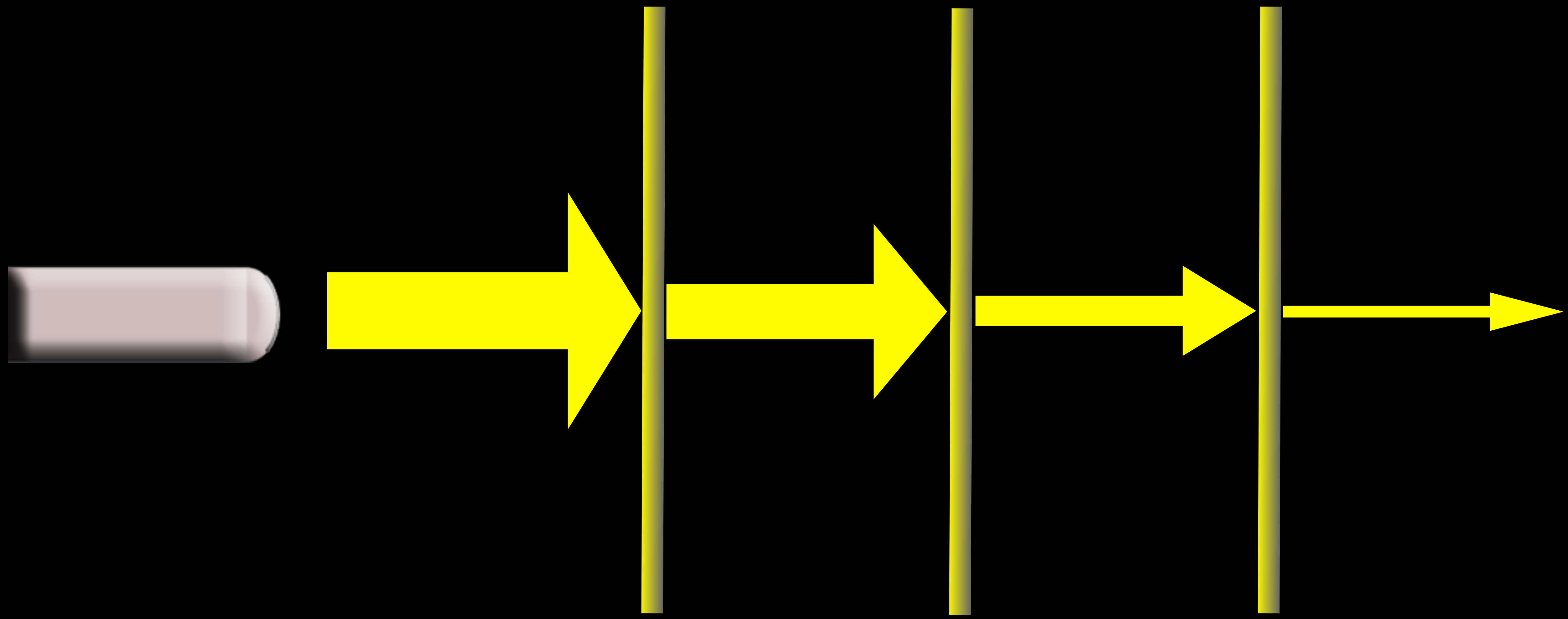
- Hyperechoic = more echogenic than surrounding structures
- Hypoechoic = less echogenic than surrounding structures
- Isoechoic = same echogenicity as surrounding structures
- Anechoic = no internal echoes

Artifact or Pathology?

Sound & Tissue Interaction

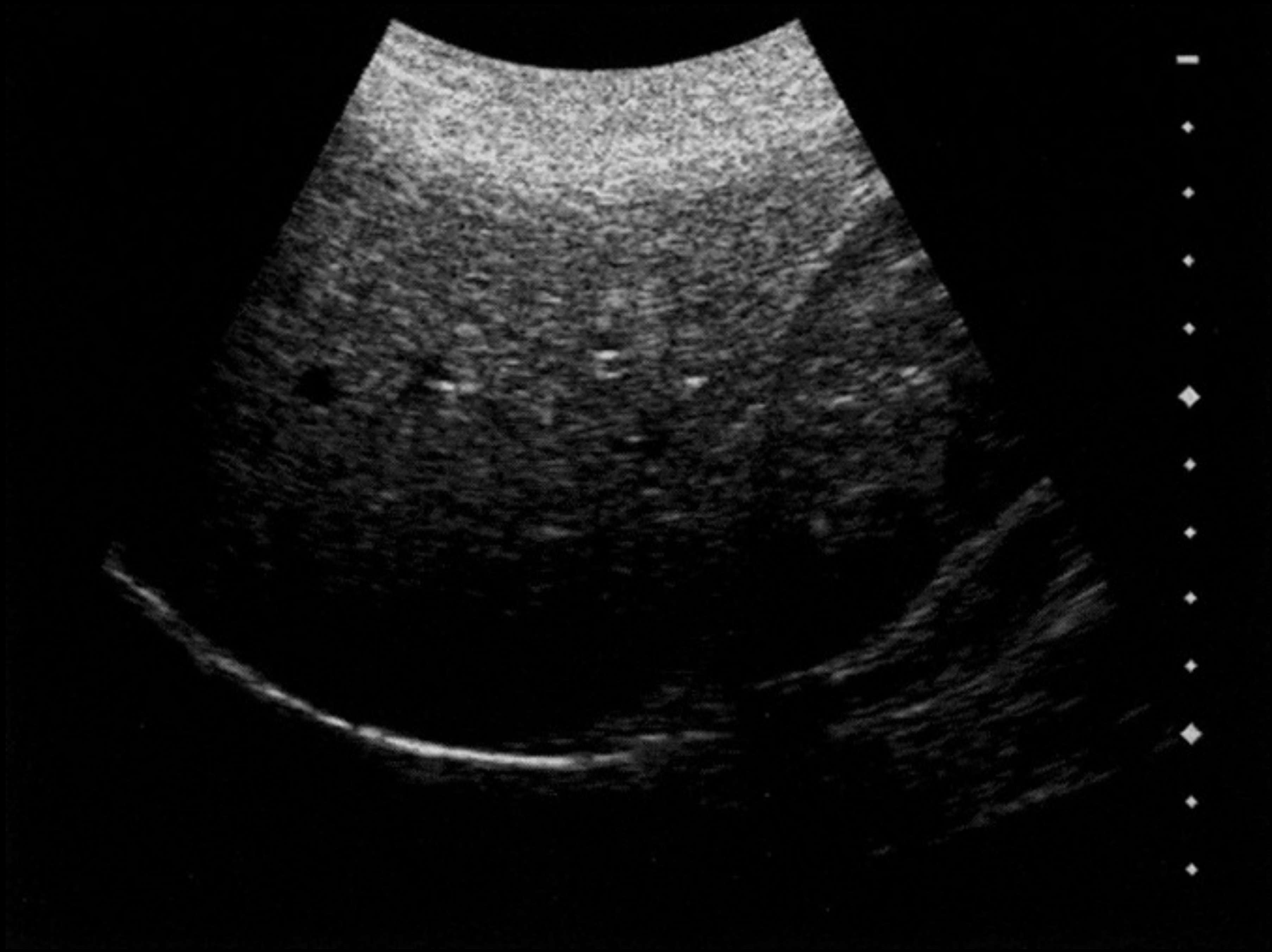
- As sound waves strike tissues, it changes
  - Attenuation
  - Reflection
  - Scatter
  - Refraction
  - Absorption

Attenuation

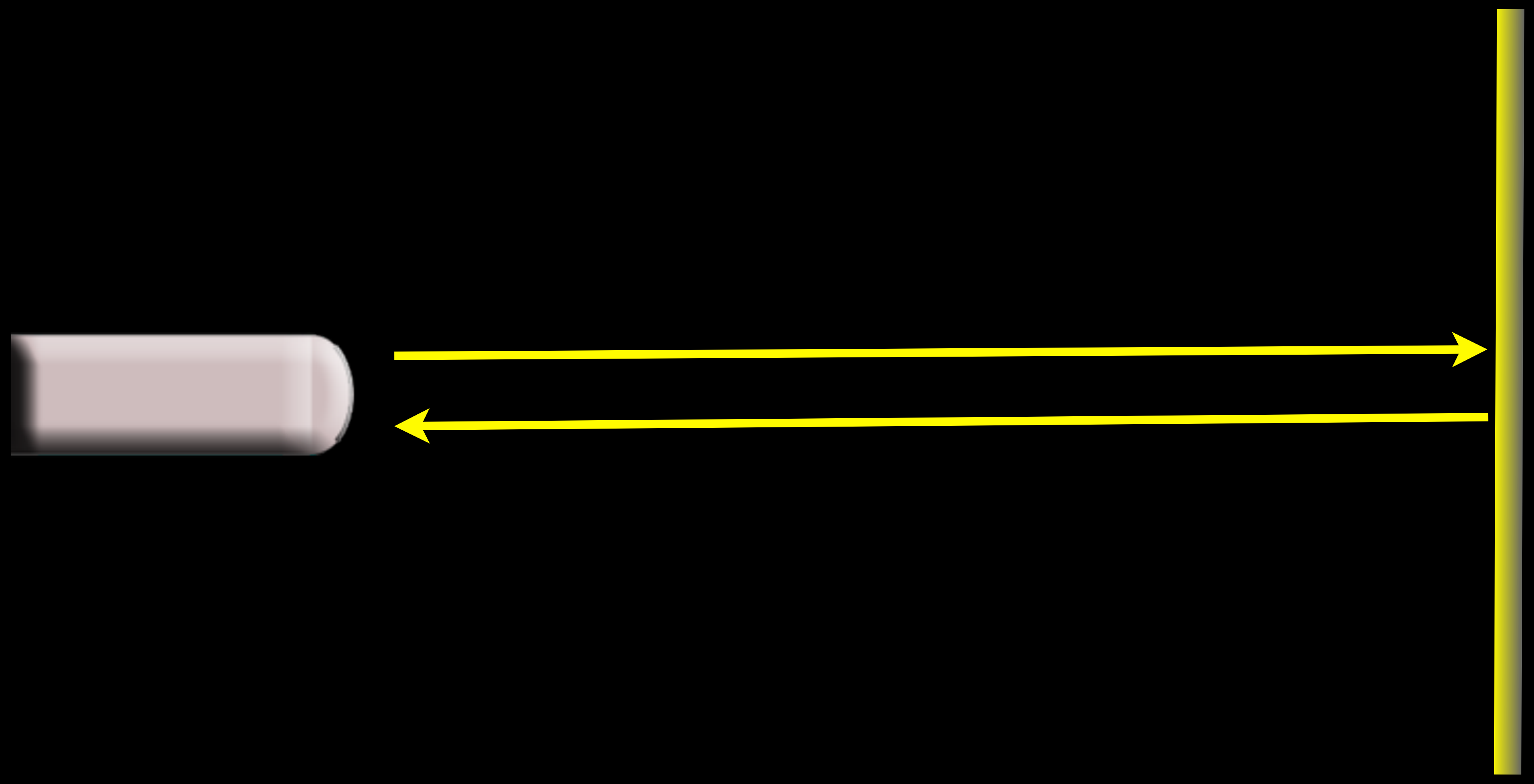


Sound loses strength with each successive tissue plane

Attenuation

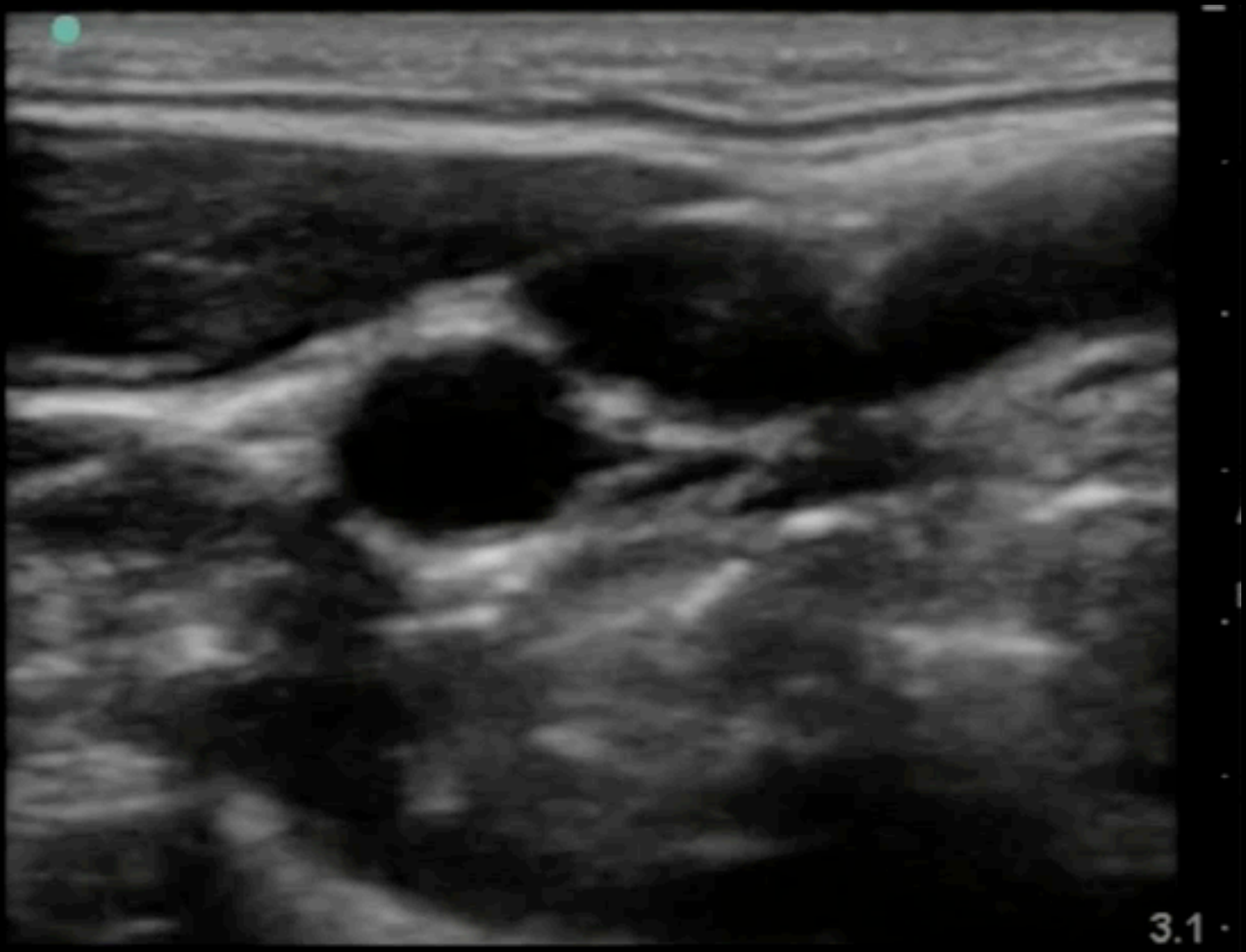


Reflection



Sound is reflected back to the transducer

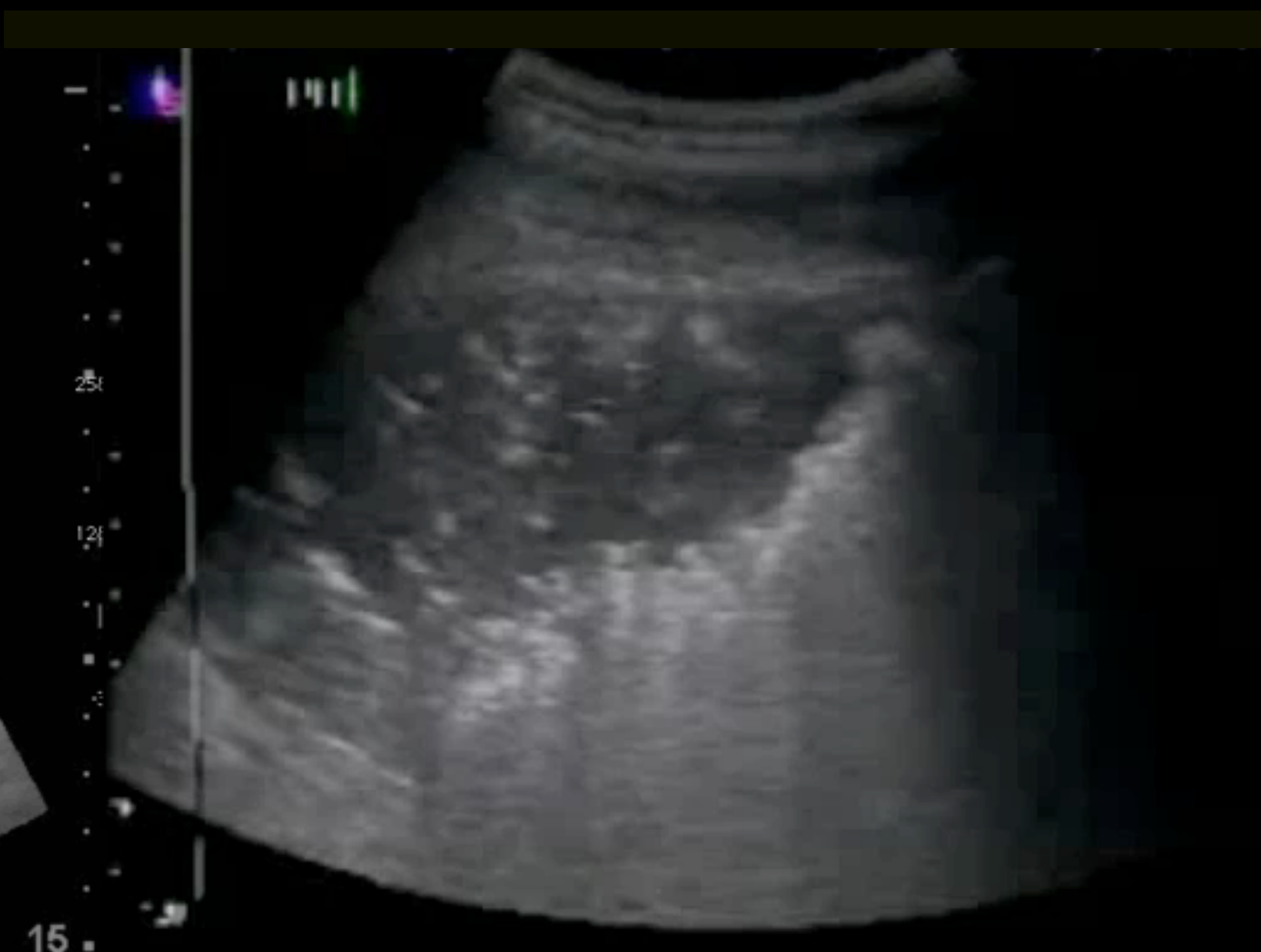
Reflection



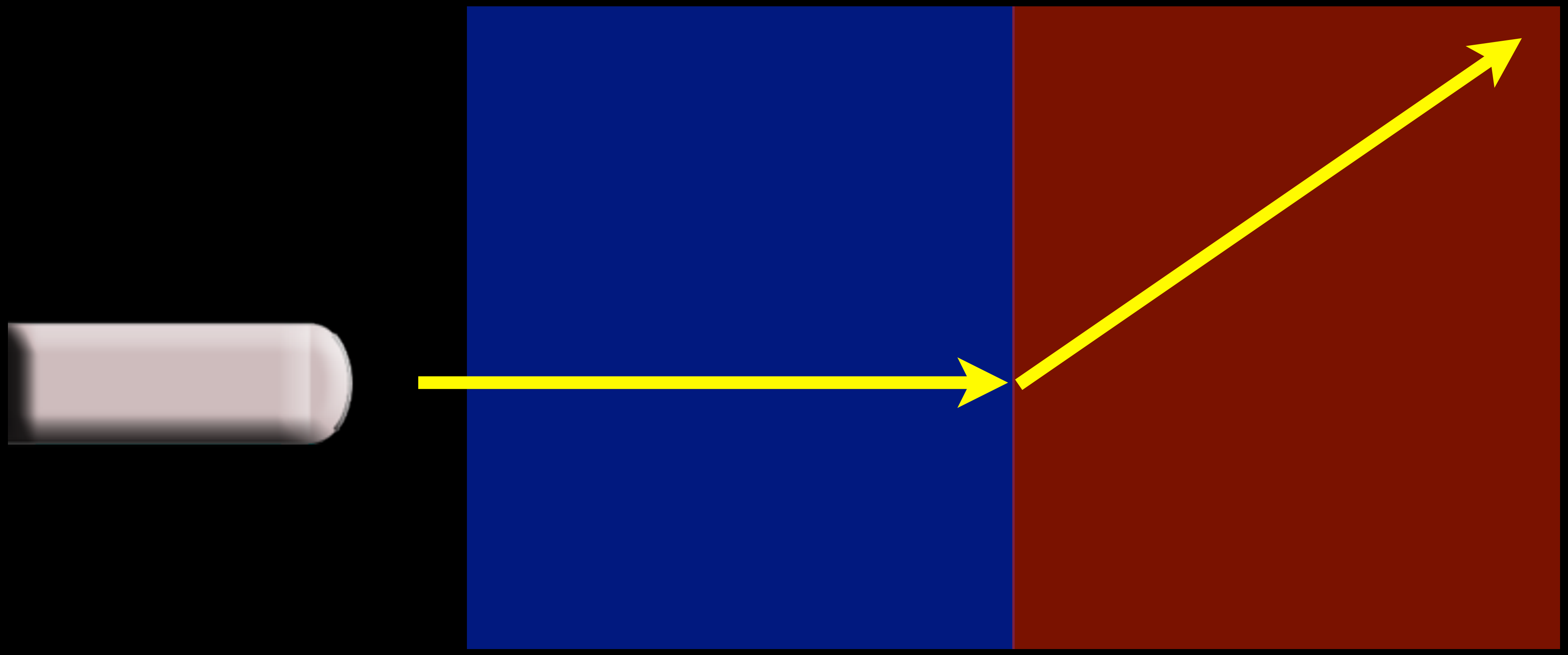
Scatter

Sound is reflected in multiple directions

Scatter

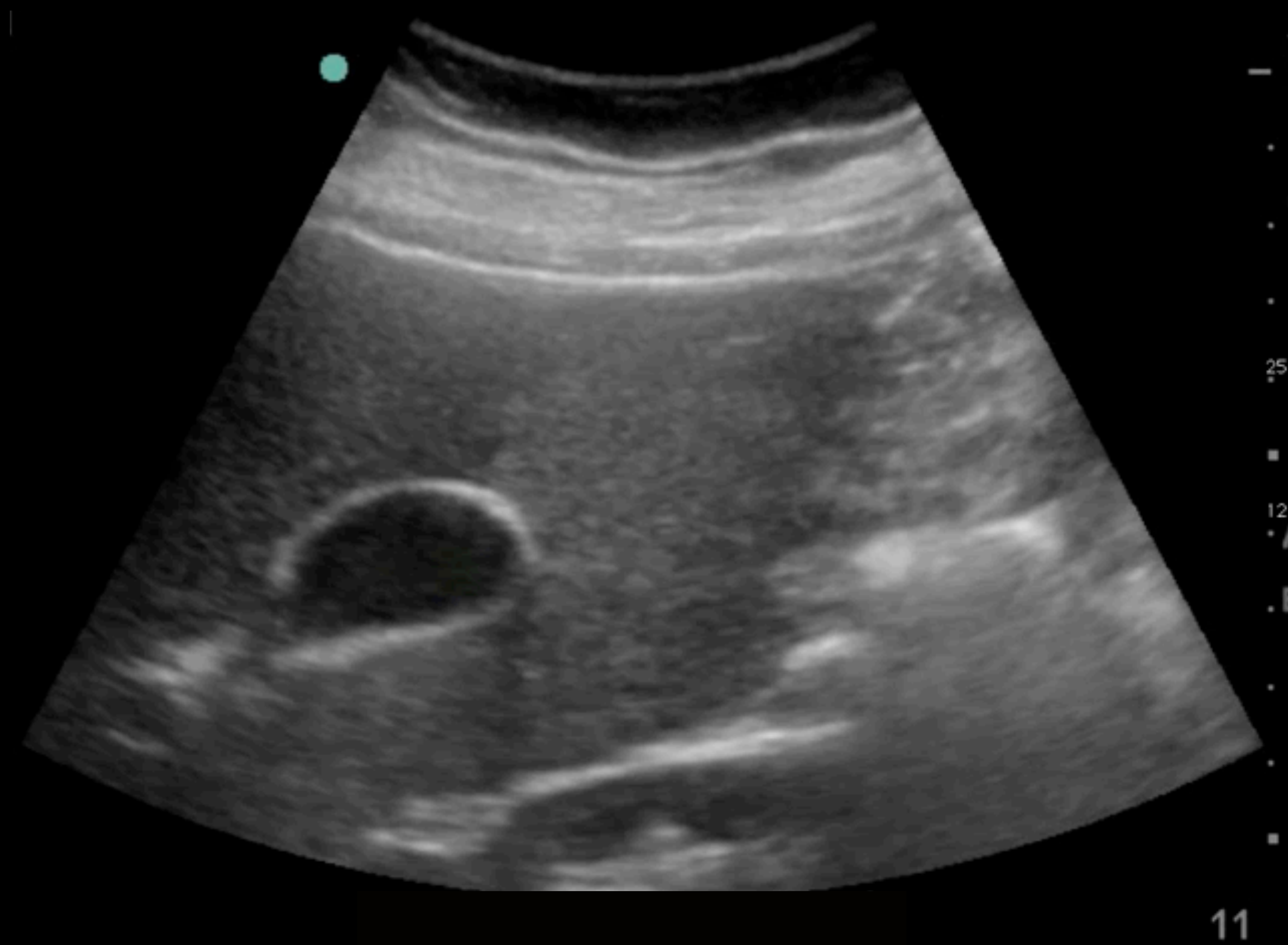


Refraction



Direction of sound is changed at interface between different media

Refraction



Absorption

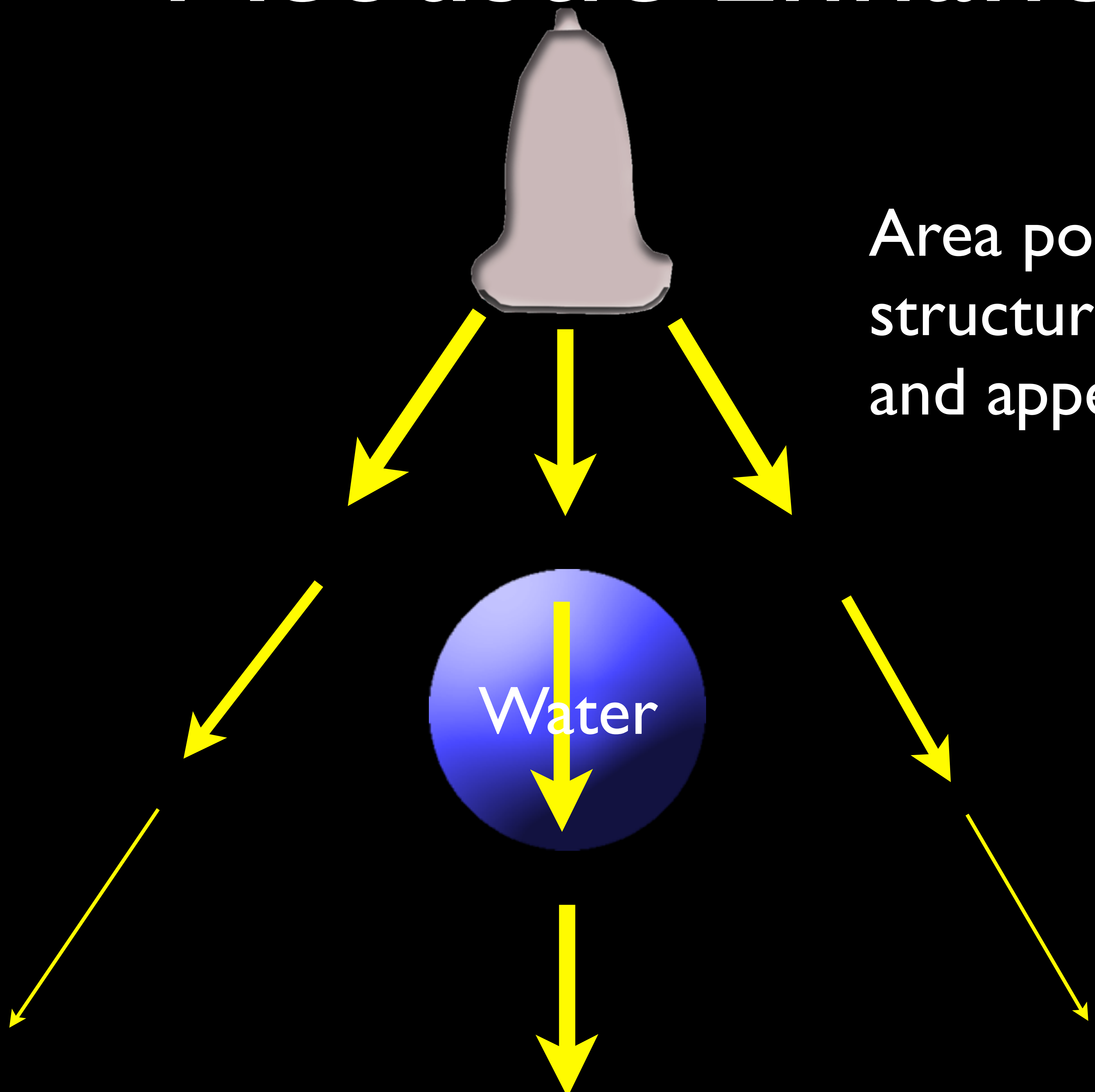
Sound is absorbed and changed to heat

Ultrasound Artifacts

Artifact Types

- Enhancement – bladder, gallbladder, vessel
- Shadowing – stones, bones, or gas
- Mirroring - lung
- Refraction – gallbladder, urinary bladder
- Side Lobe - gallbladder
- Reverberation - urinary bladder
  - Ringdown - lung

Acoustic Enhancement

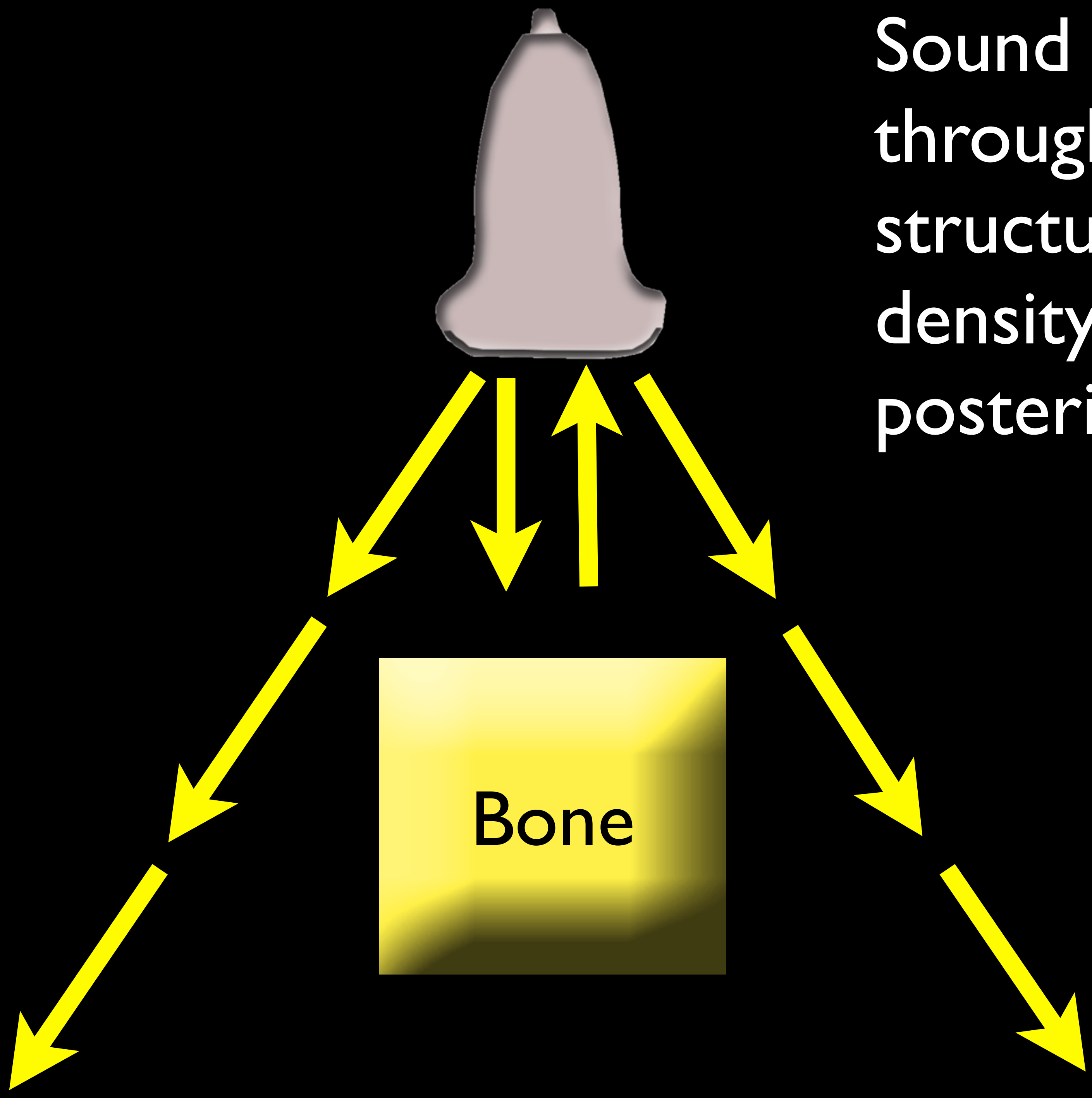


Area posterior to cystic structures is less attenuated and appears brighter

Acoustic Enhancement

bladder
gallbladder
vessels

Shadowing

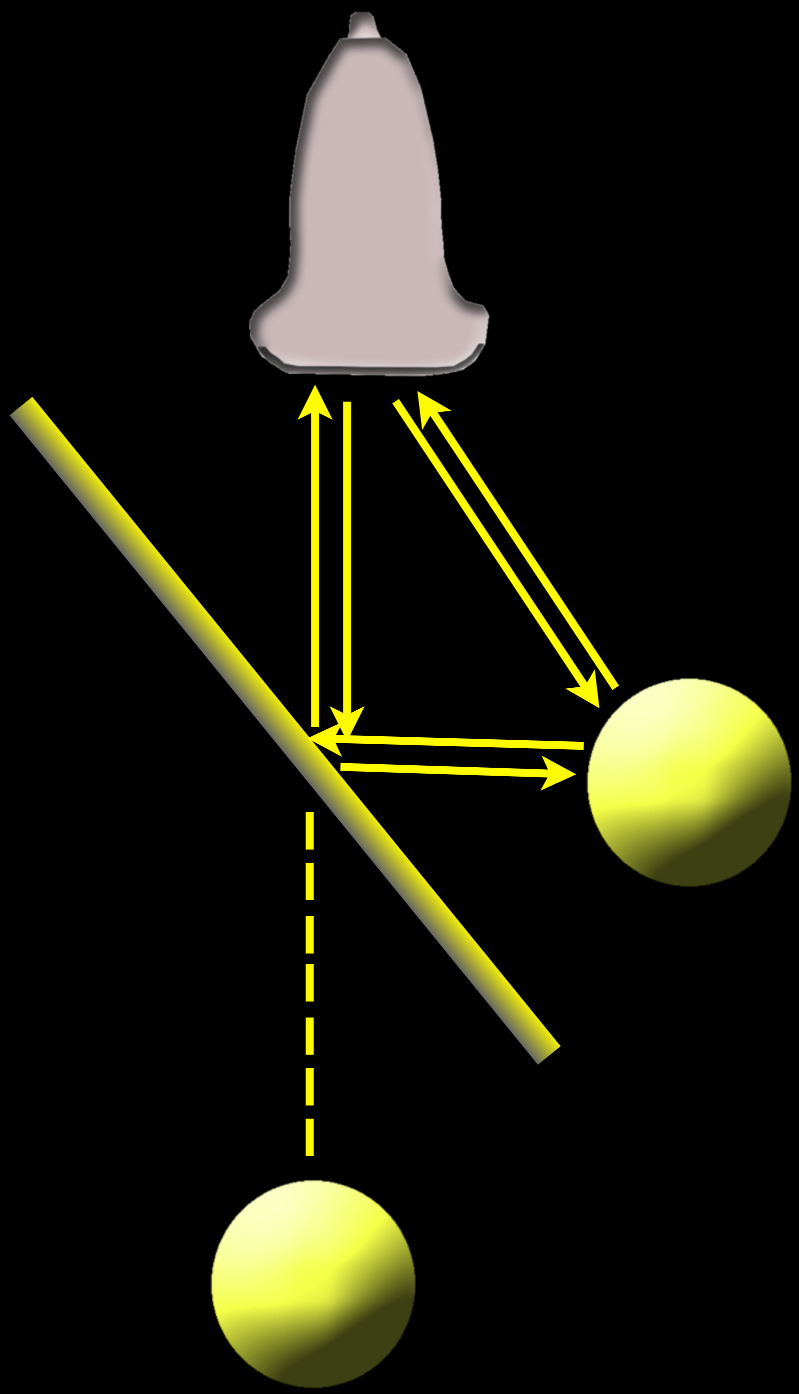


Sound waves cannot pass through stiff structures(bone) or low density structures (air), so posterior area appears dark

Shadowing

stones
bones
gas

Mirror Artifact

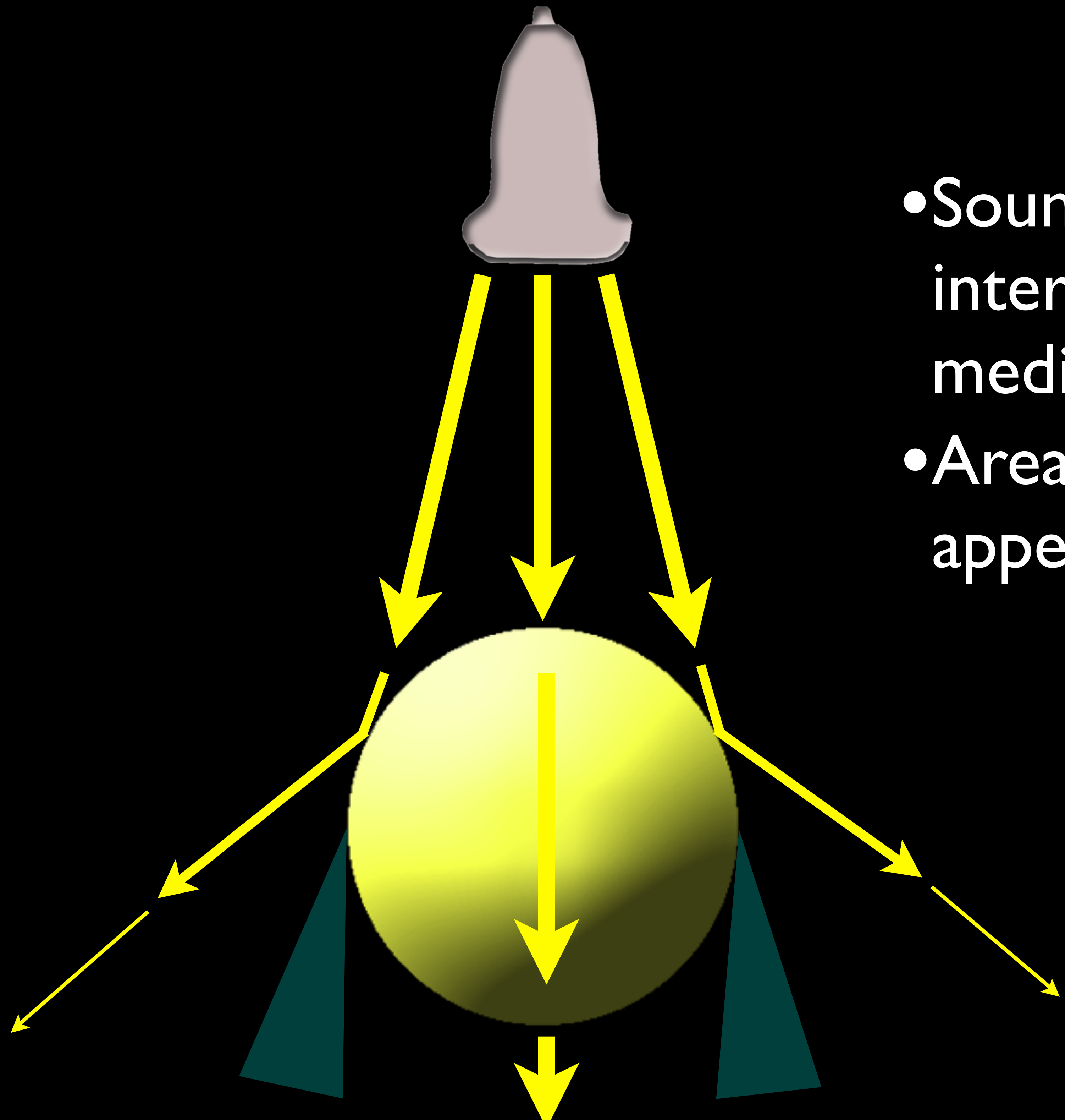


- Sound waves are bounced off a structure normally
- Sound waves are also bounced off a reflector and then to the structure and back
- Ultrasound machine “sees” two structures on either side of reflector

Mirror Artifact

Mirror Artifact

Edge Artifact

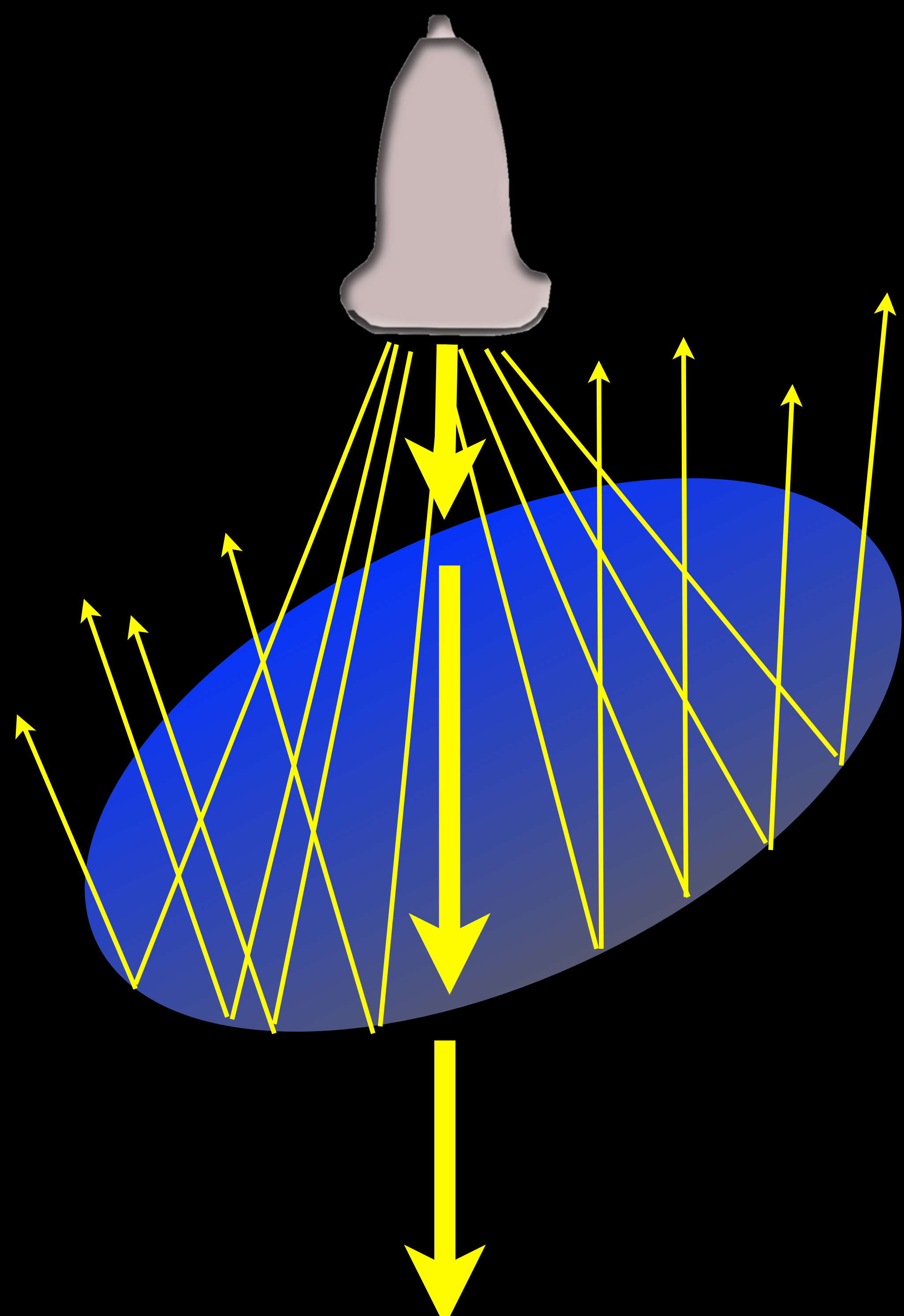


- Sound is bent at the interface between two media (refracted)
- Area behind refraction appears dark

Edge Artifact

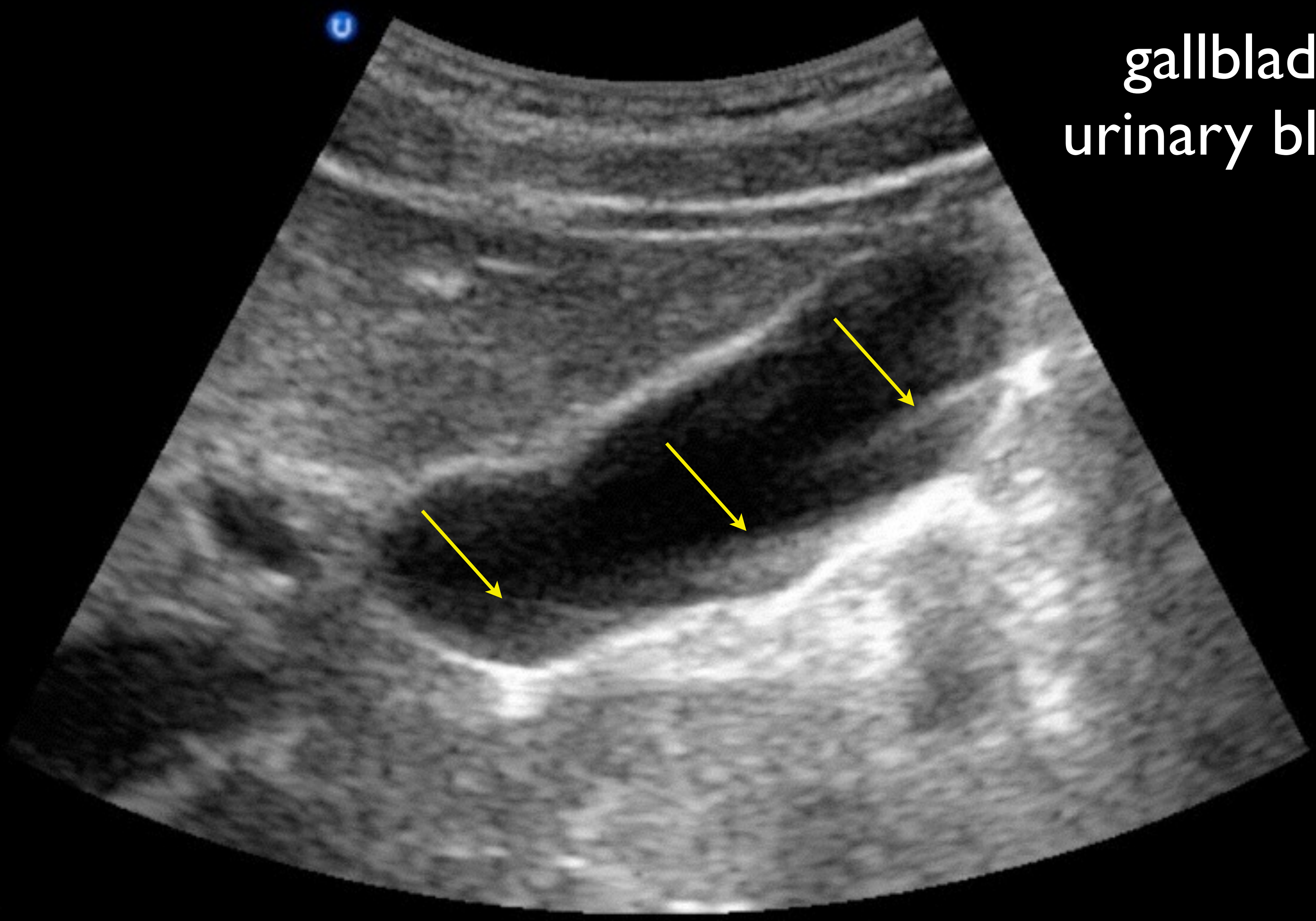
gallbladder
urinary bladder
cystic structures

Side Lobe



- Sound passes normally through a cystic structure
- Beams at other angles may be reflected off the posterior wall

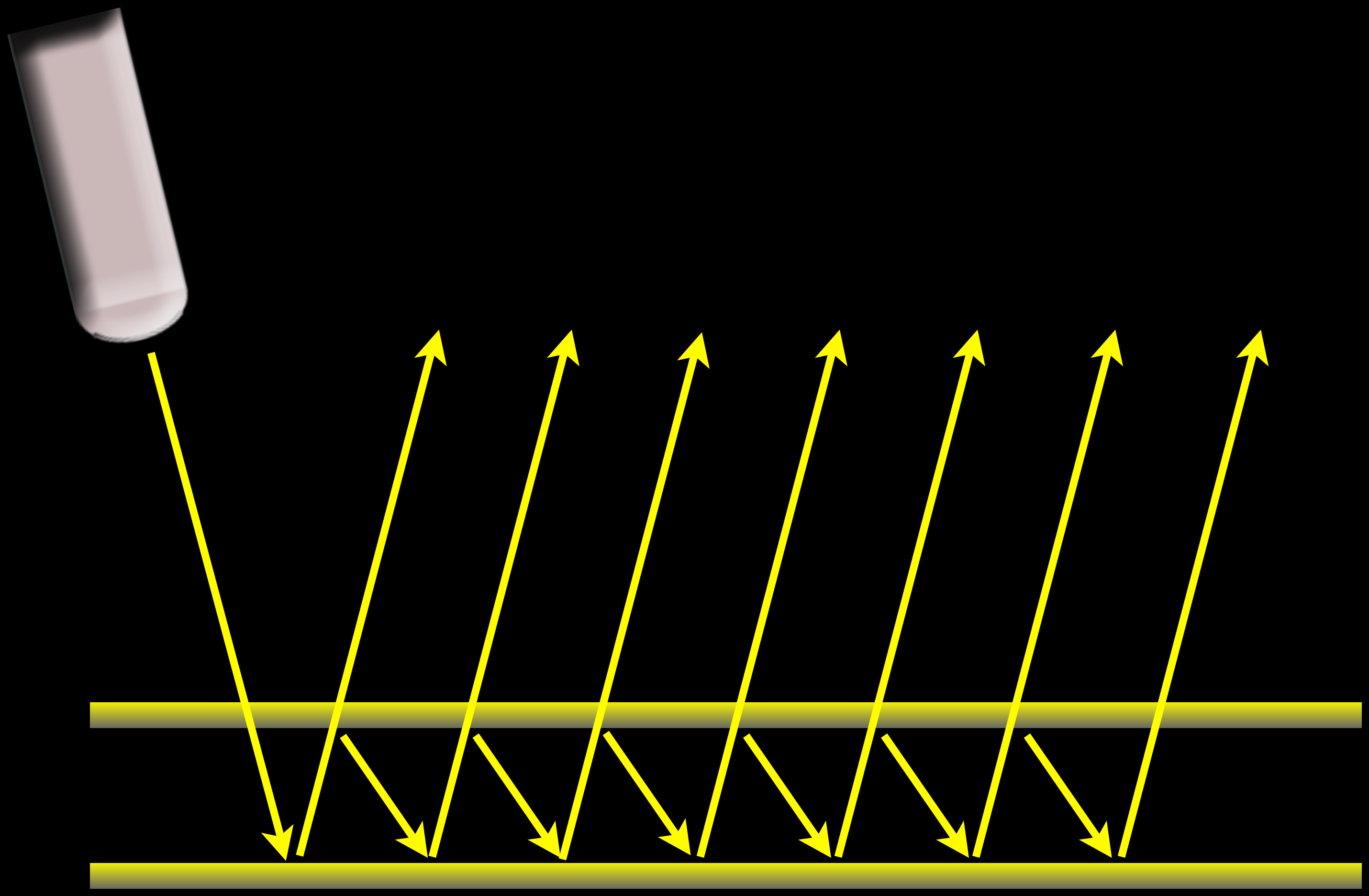
Side Lobe



gallbladder
urinary bladder

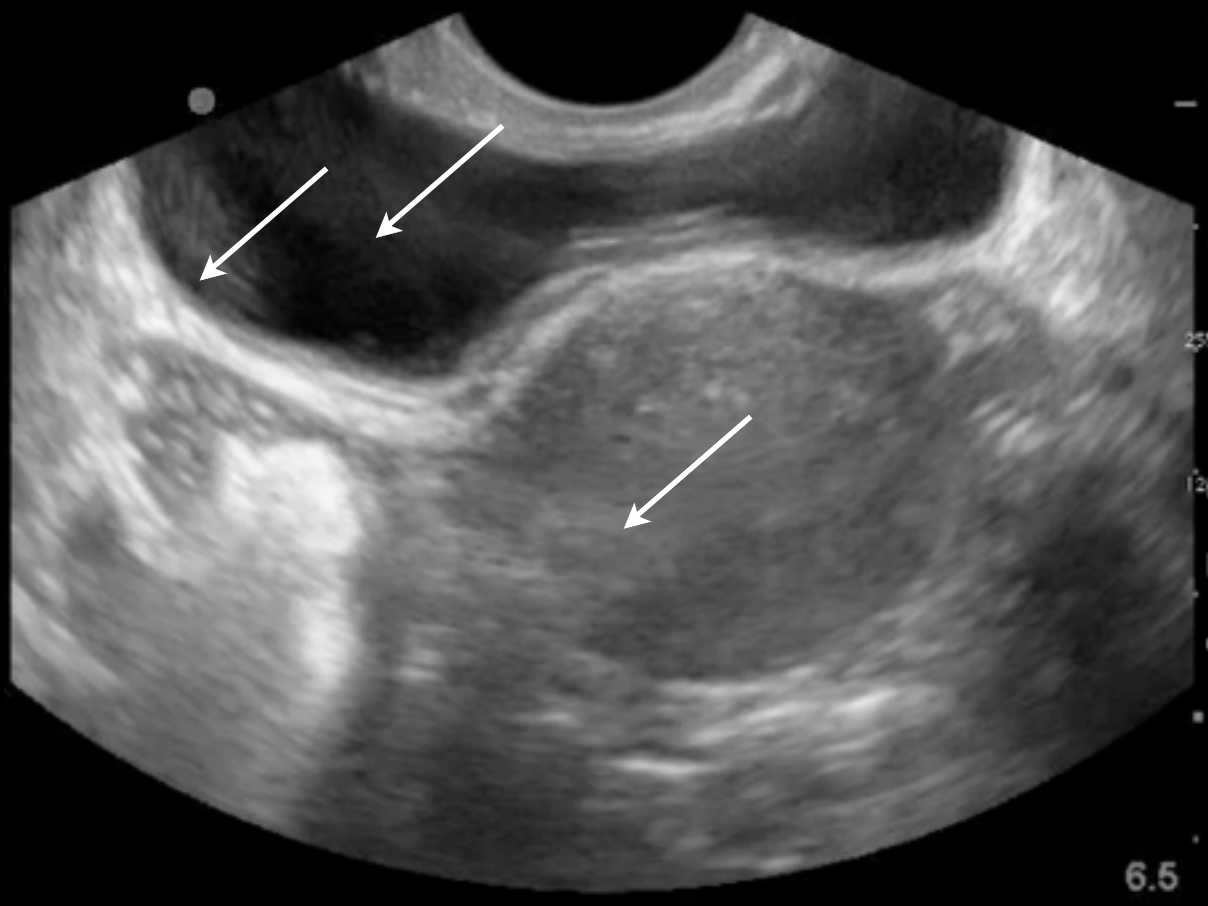
Side Lobe

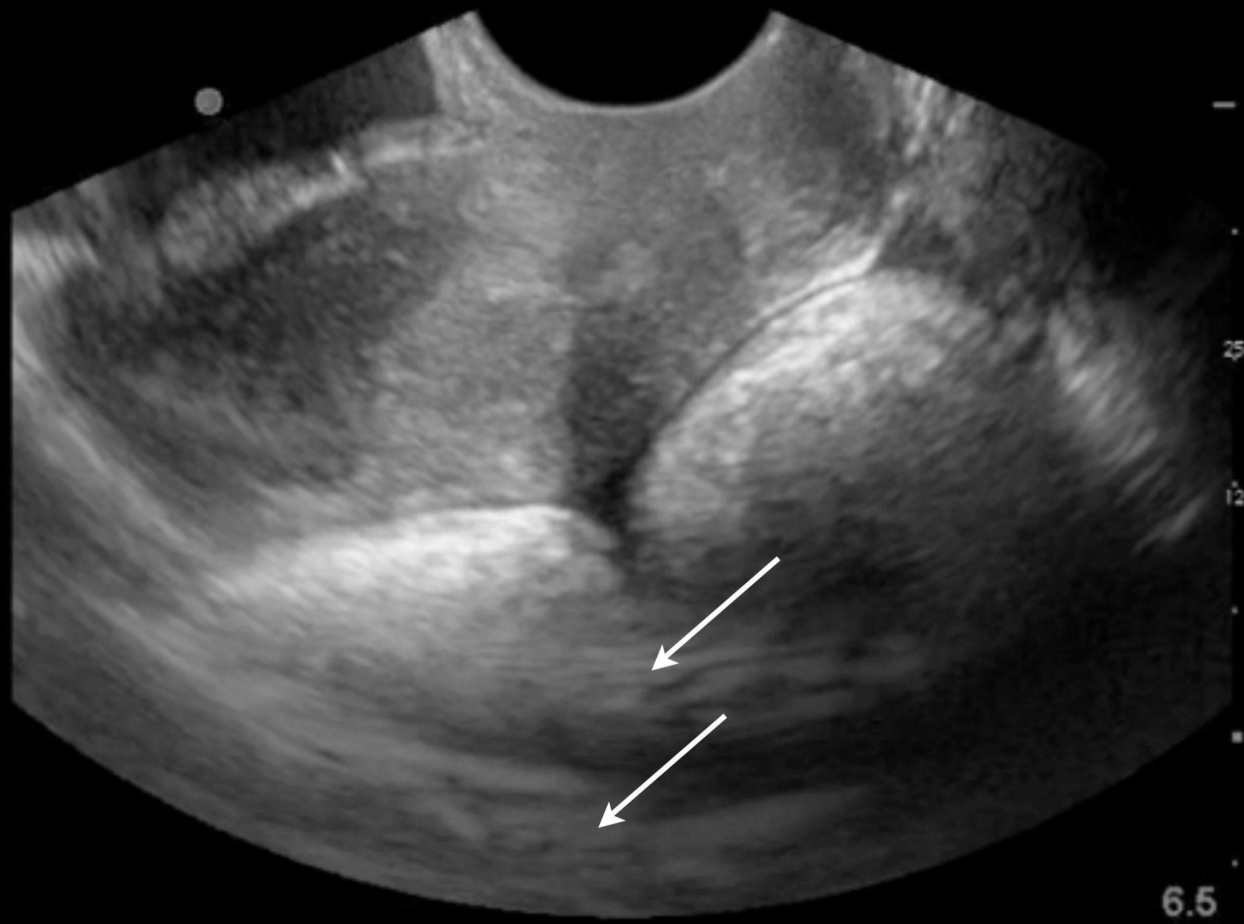
Reverberation



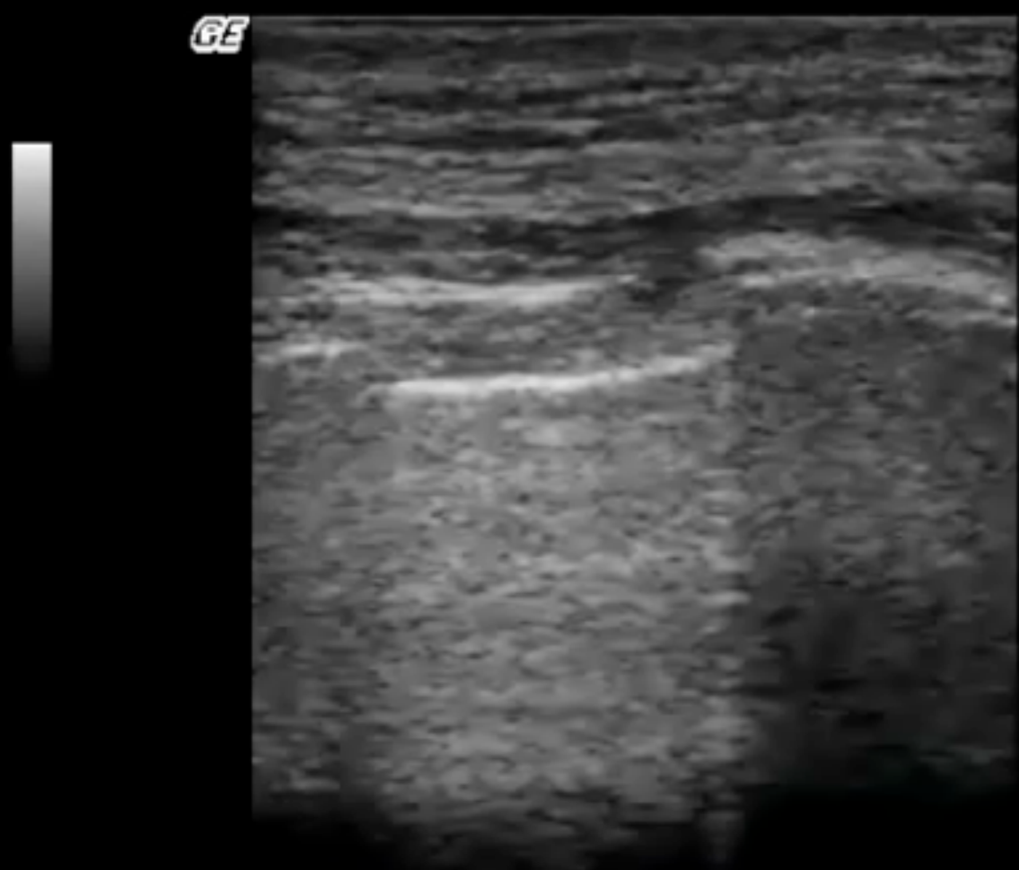
- This artifact involves two reflective surfaces
- Sound bounces off the reflective surface
- Is also reflected internally many times before returning to transducer

Reverberation





Reverberation



"Ringdown" artifact: a type of reverberation artifact seen in the lungs

Artifact or Pathology?

Instrumentation

Common Elements

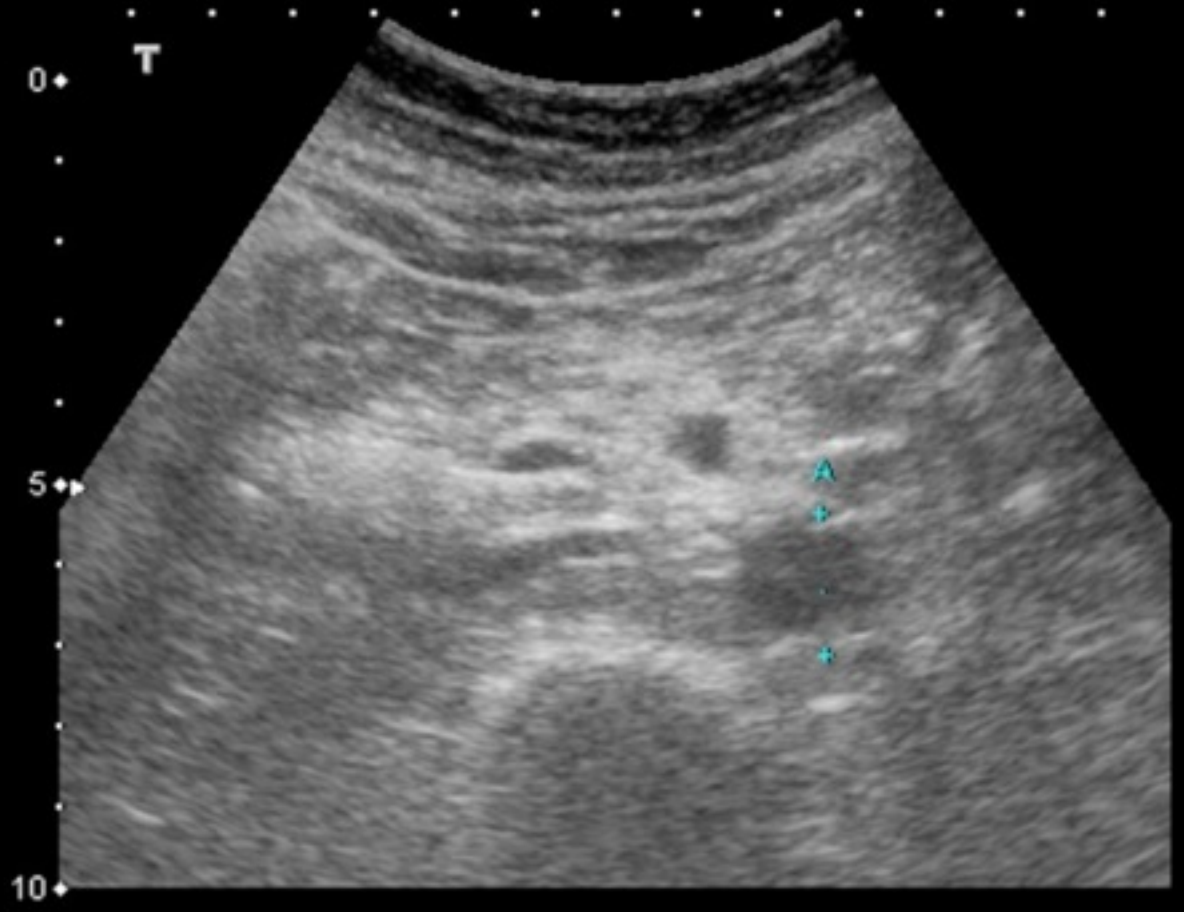
- Though ultrasound machines may look very different from each other, they all share important common elements:
  - Probe indicators
  - Methods to record still images and clips
  - Gain adjustment
  - Time Gain Compensation (TGC)
  - Depth adjustment
  - Color

Probe Orientation

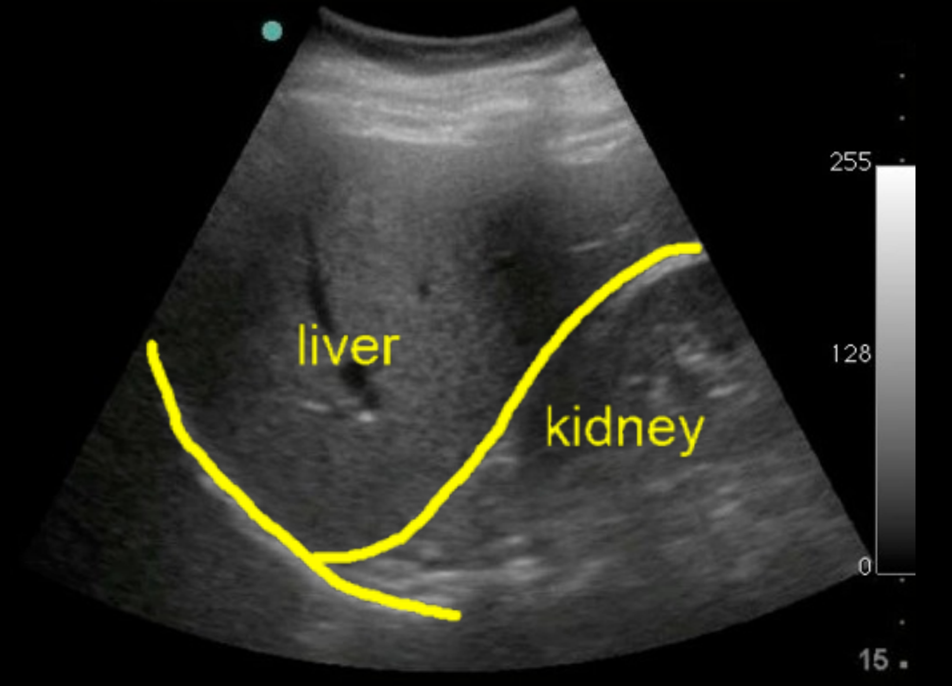
Probe indicator

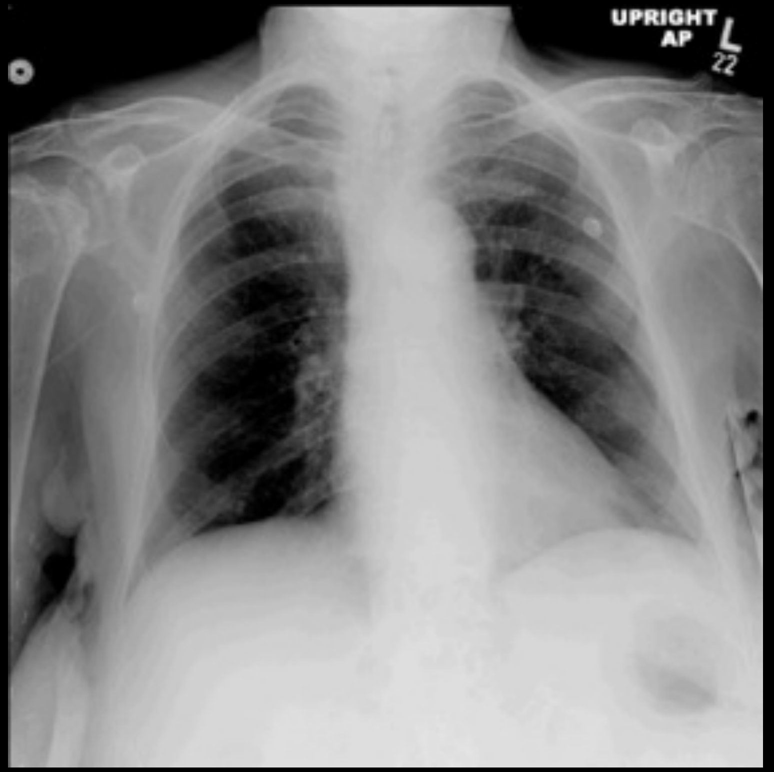
Probe Orientation

Probe Orientation

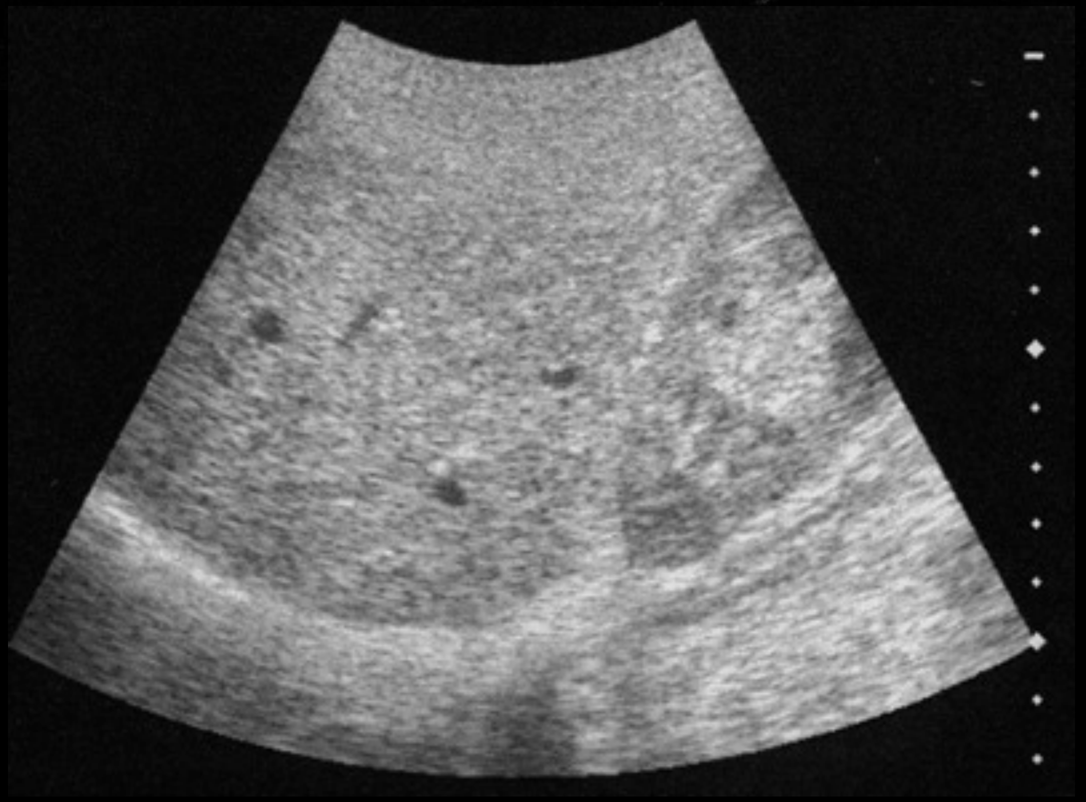


Probe Orientation

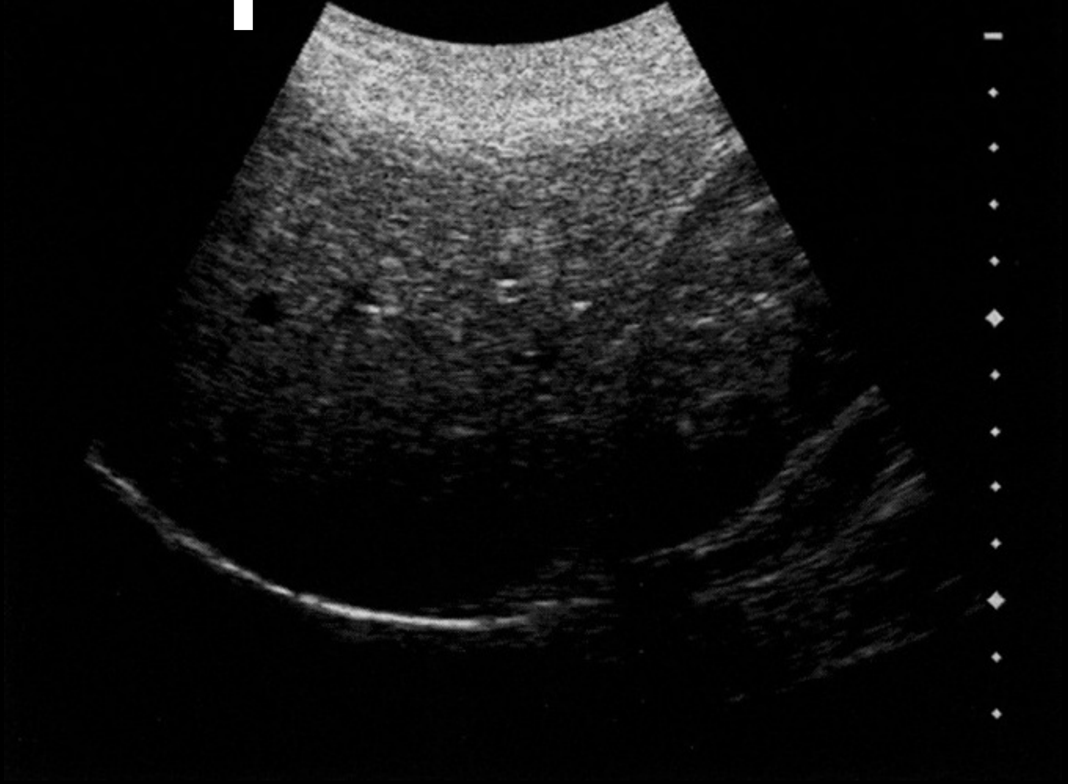


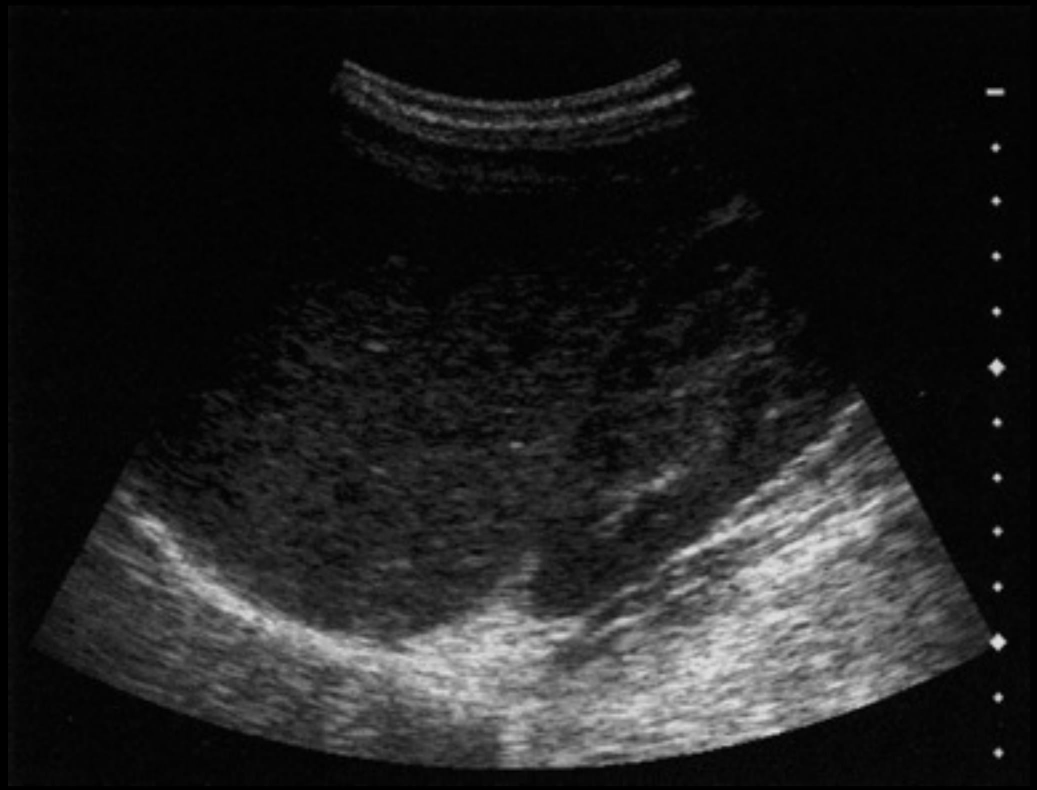


Gain



Time Gain Compensation





Depth


Depth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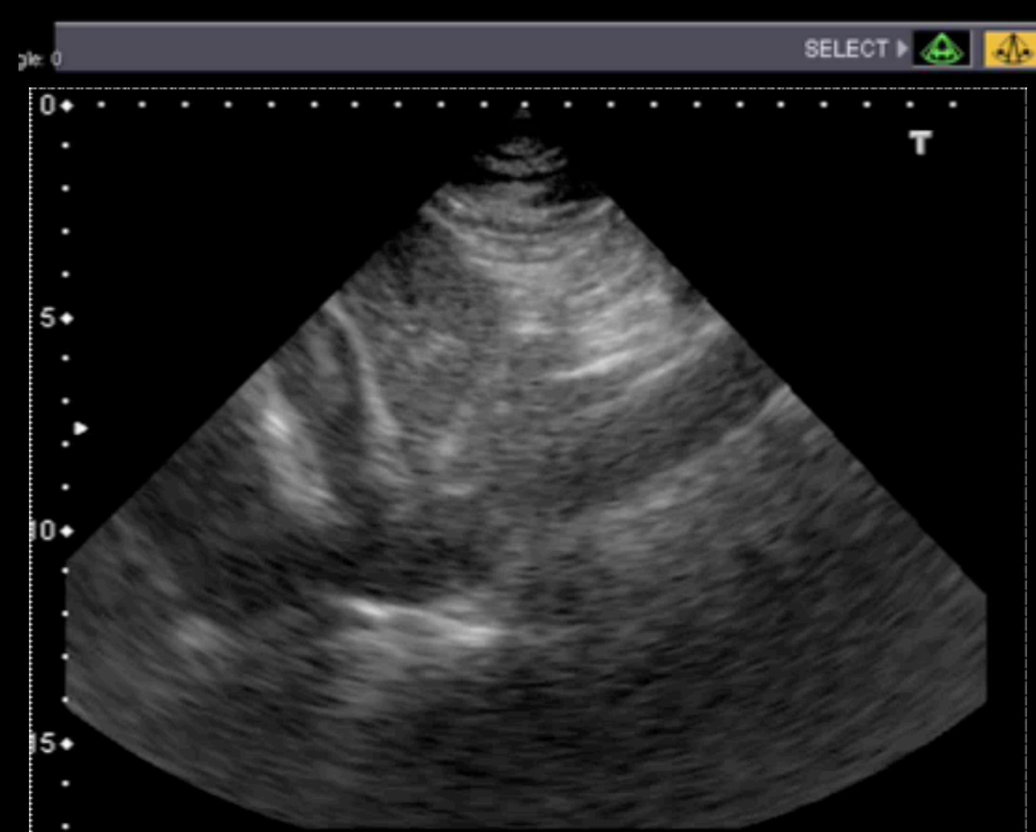
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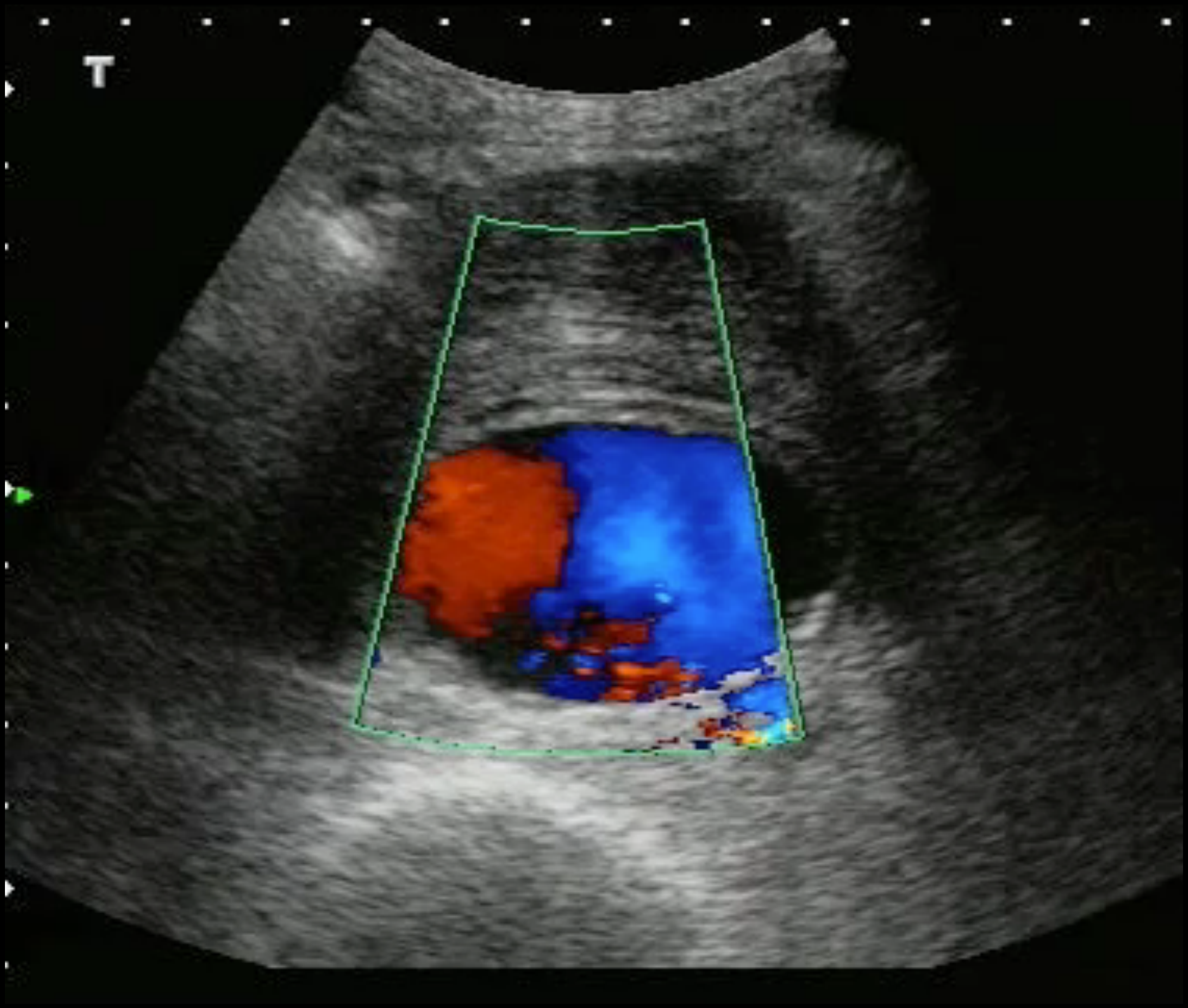
Color



Final Thoughts

- Clinician based ultrasound is a very powerful tool, especially in the emergency department
- Knowledge of ultrasound artifacts is key to image interpretation
- All ultrasound machines share important features
- Practice!