Ultrasound

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Ultrasound

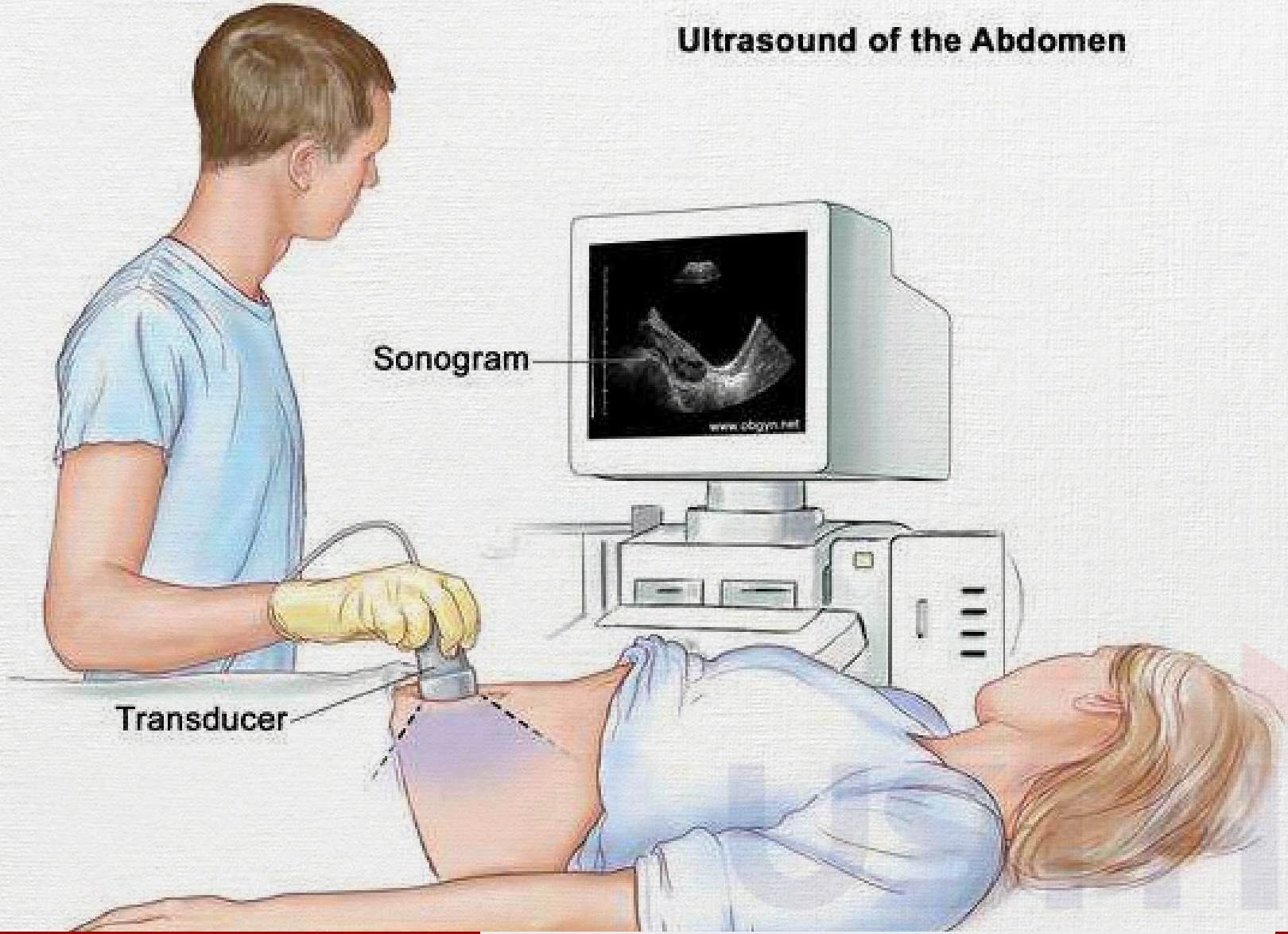
Medical Imaging

- Radiological technologies
  - X-ray (projection)
  - computed tomography (CT)
  - mammography
- Magnetic resonance imaging (MRI)
- Nuclear medicine imaging
  - single photon computed tomography (SPECT)
  - positron emission tomography (PET)
- **Ultrasound (US)**
- Other imaging techniques

Introduction

- Ultrasound
  - energy source for image formation
  - use sound waves to interact with tissues
  - the tissue responses to sound waves

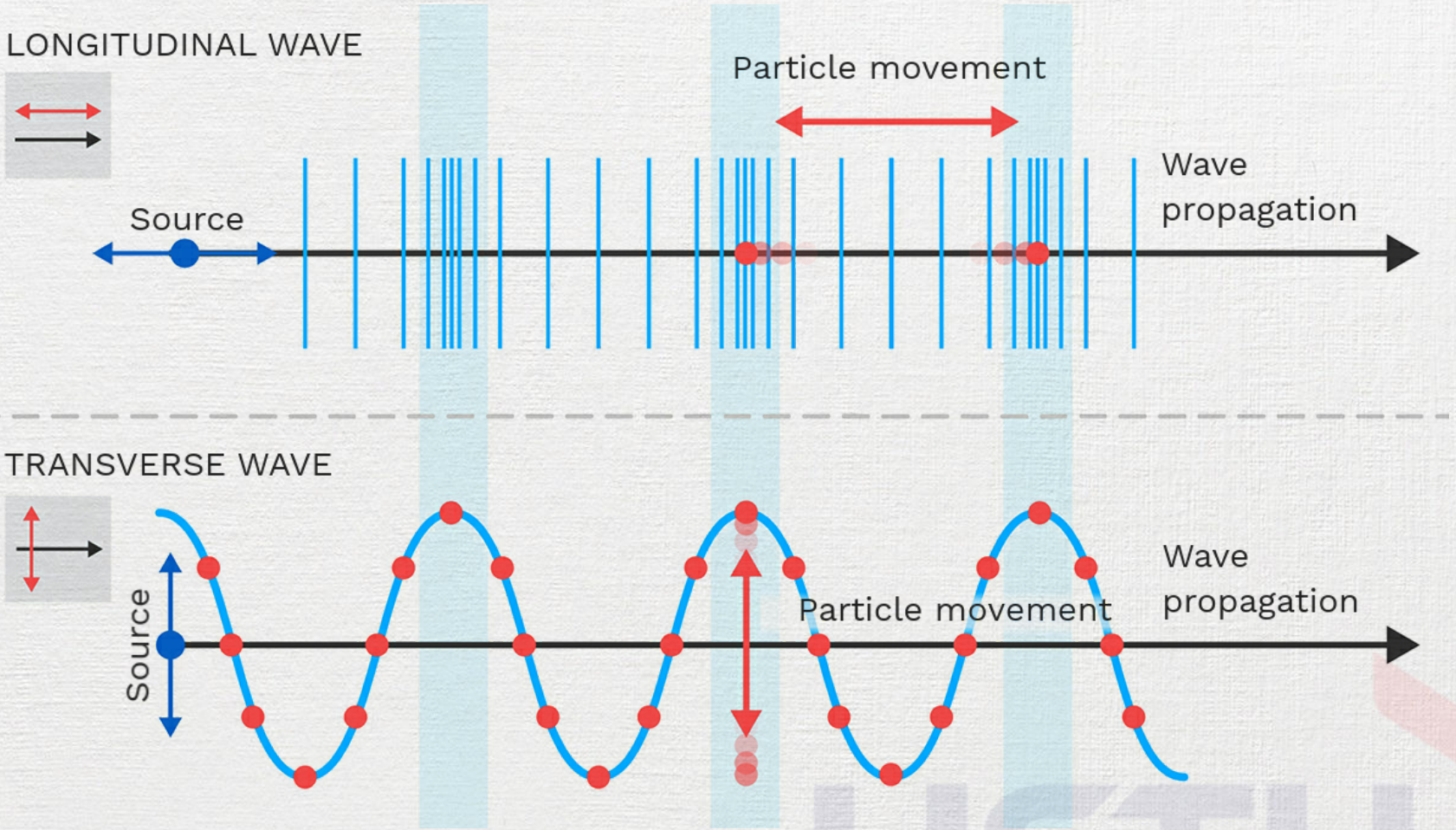
Introduction



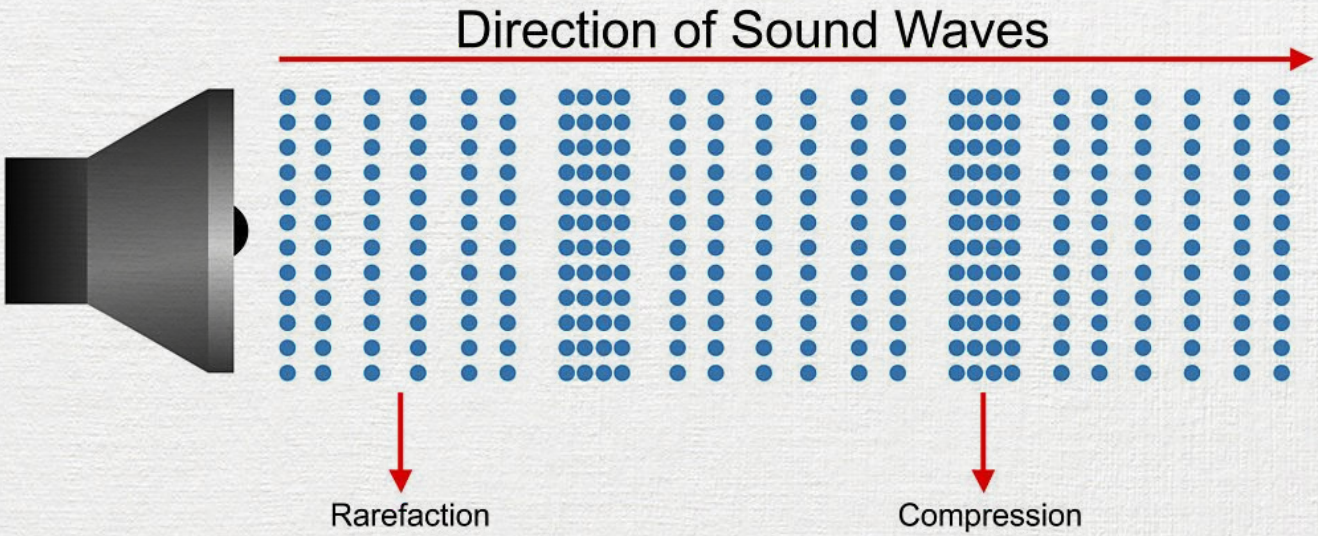
Introduction

- Sound waves are mechanical, longitudinal waves
- Longitudinal waves:
  - Motion of the mechanism that forms the wave is parallel to the direction of wave propagation

Introduction



Introduction



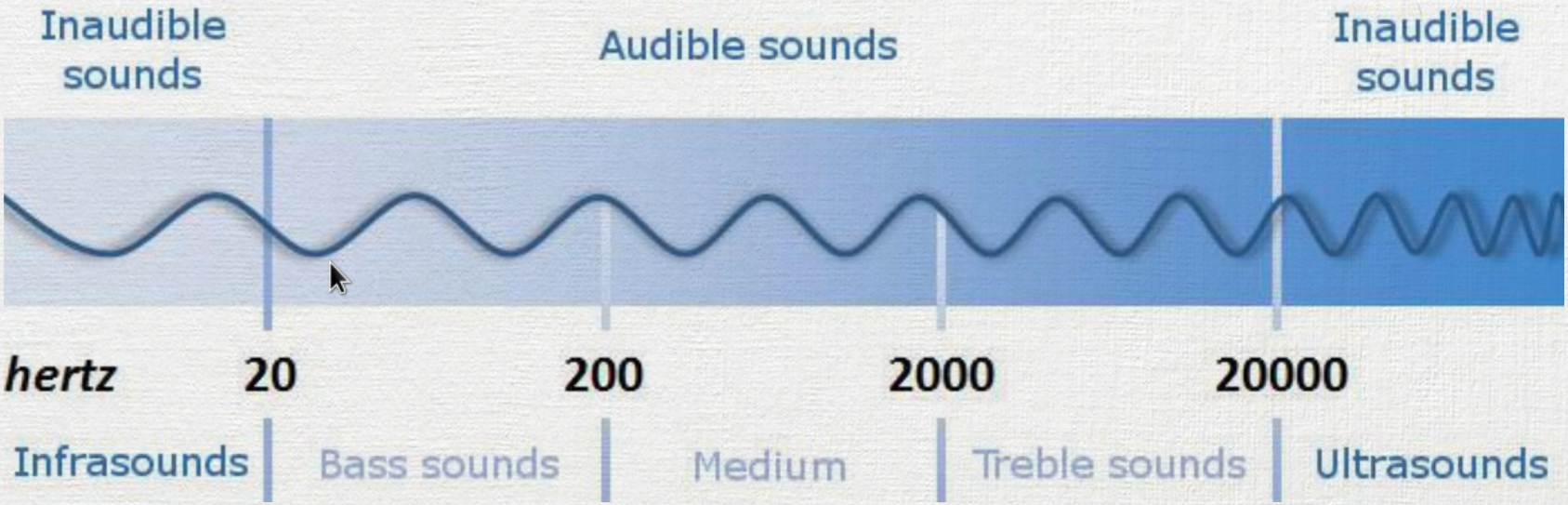
Characteristics

- **Very** different to electromagnetic waves (e.g., light, x-ray, and radio waves)
- Cannot travel in a vacuum
- Energy is propagated by the motion of the particles in the medium
- Ultrasound waves are represented by pressure waves; compression and expansion form

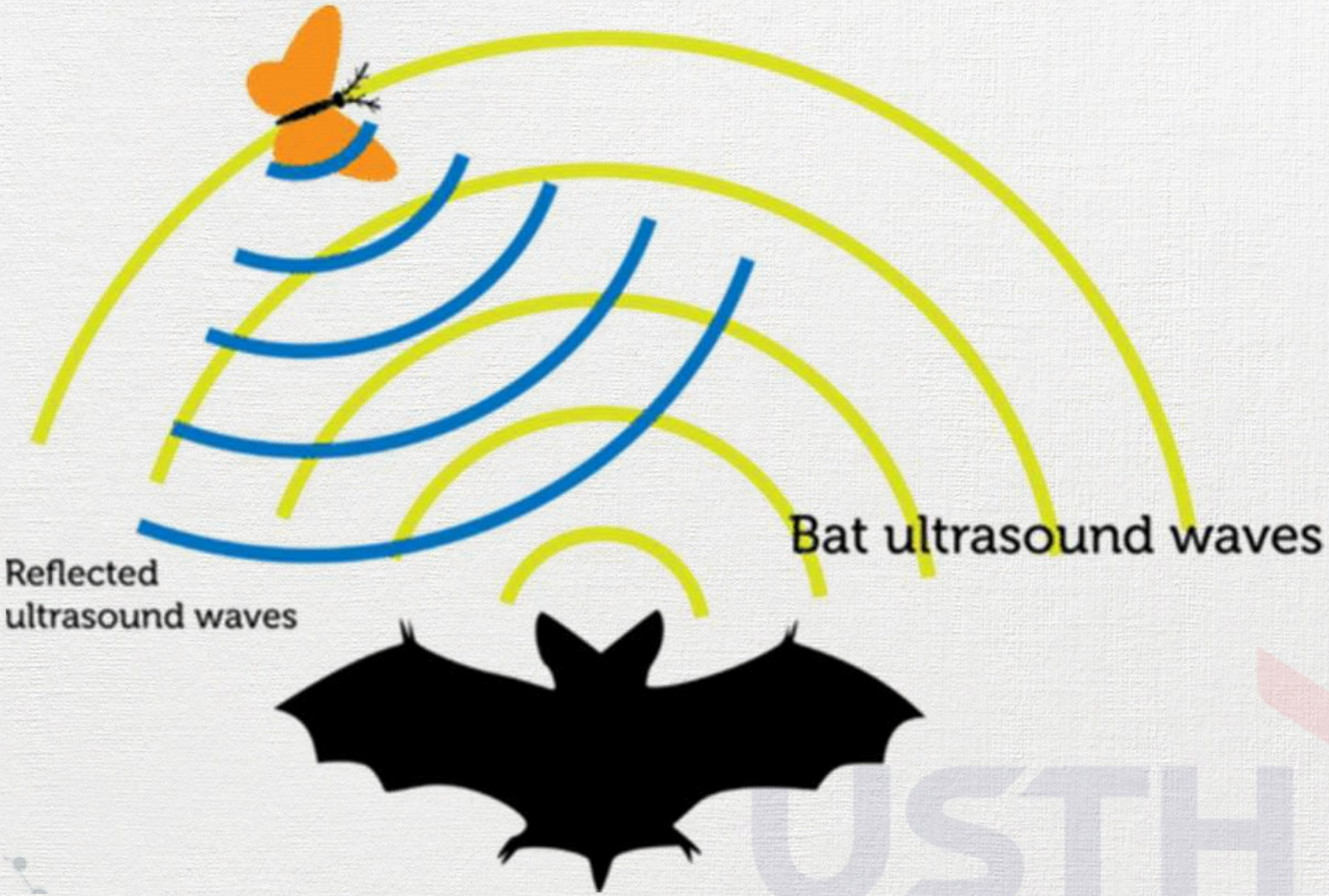
Sound Frequency

- Frequency of the waves: Hz
- Human ear: 20Hz - 20000 Hz
  - $<$ 20 Hz: Infrasound
  - $>$ 20000 Hz: Ultrasound
- Diagnostic ultrasound: 1-100 MHz

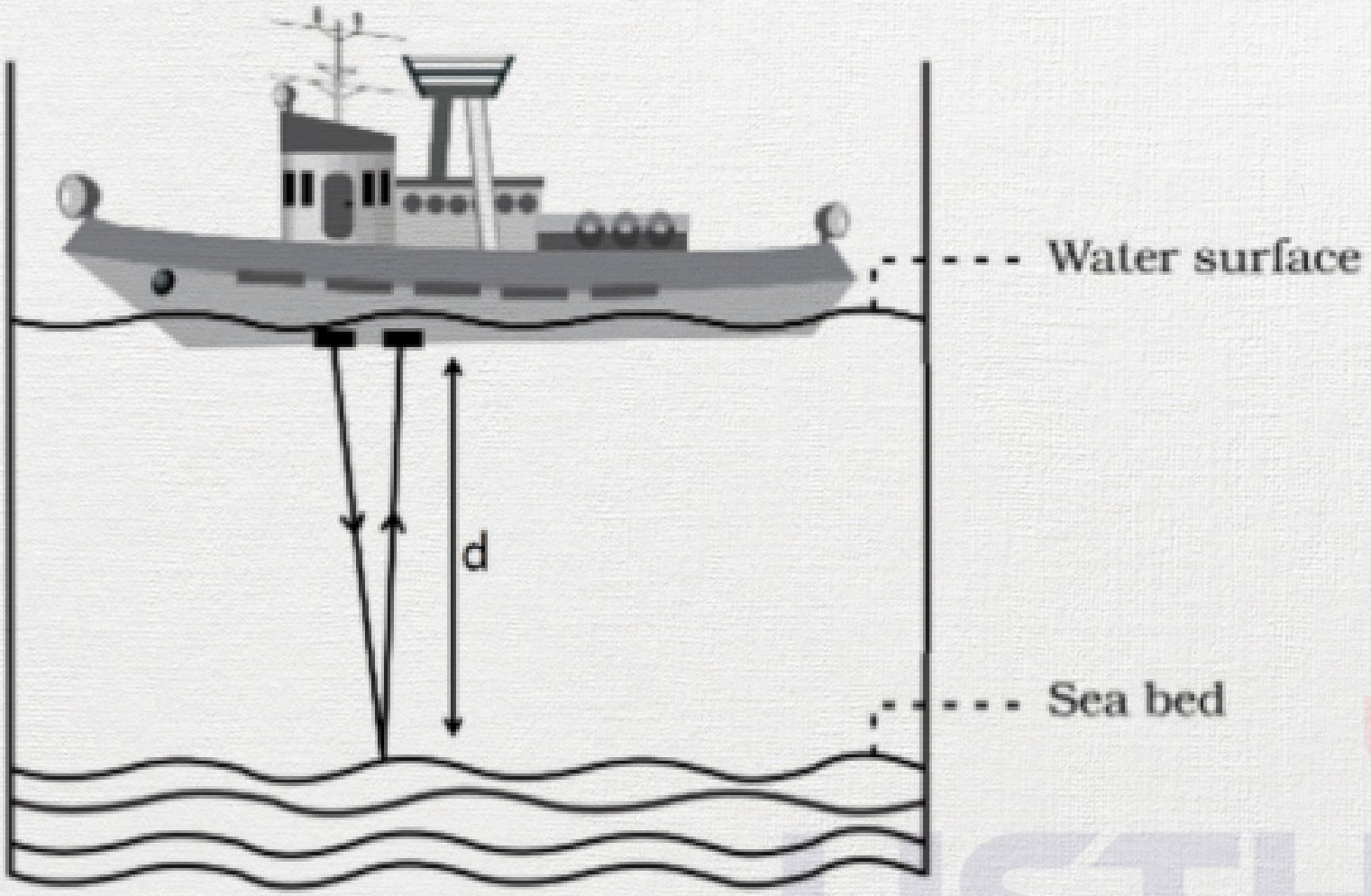
Sound Frequency



Ultrasound



Ultrasound



Ultrasound Imaging

- Also called sonography
  - Exposing part of the body to high-frequency sound waves
  - Produce pictures
  - No ionizing radiation (as X-rays)
  - Realtime
- Show the structure and movement of the body's internal organs

Why Ultrasound?

- Relatively inexpensive
- Speed
- High resolution images (e.g. vs. X-ray)
- Provides soft tissue information
- Low-tech :)

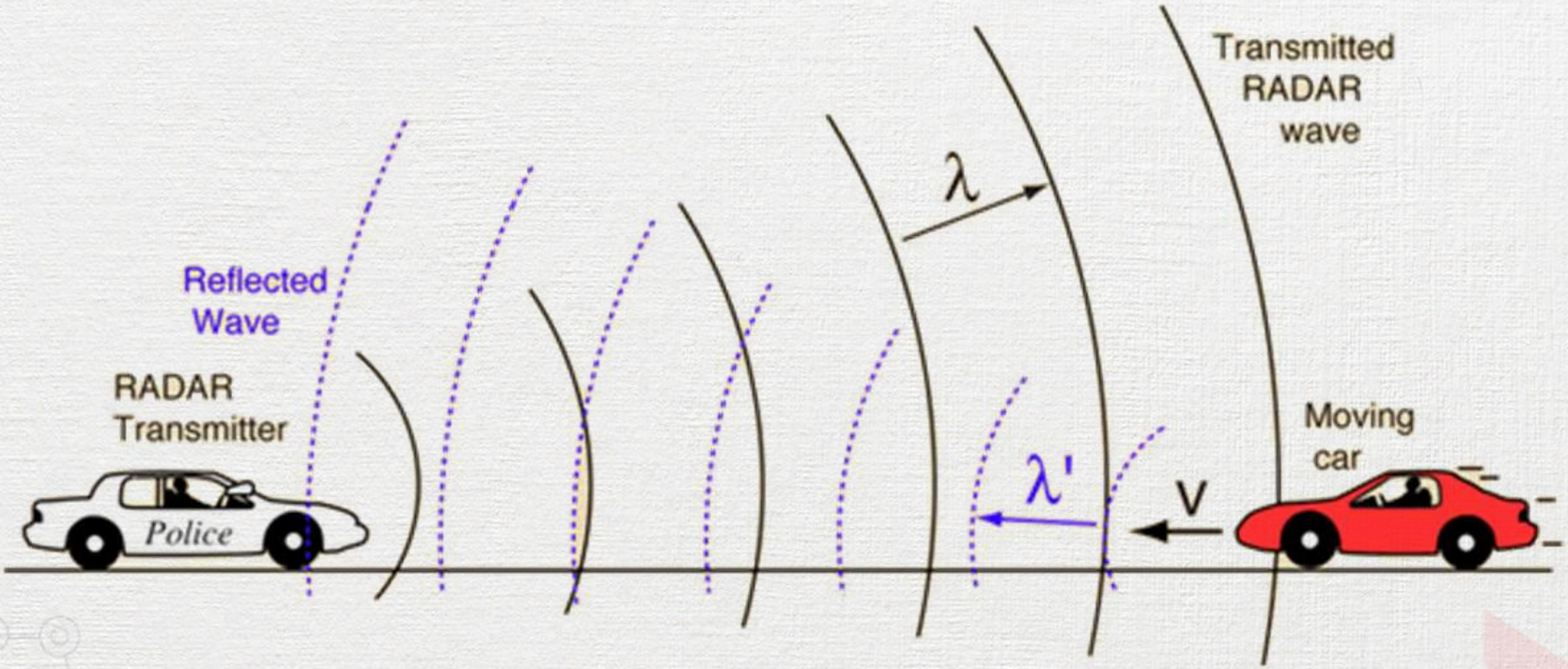
Mechanism

Frequency

- How many times per second a pattern repeats itself

$$f = \frac{1}{T}$$

Doppler Effect

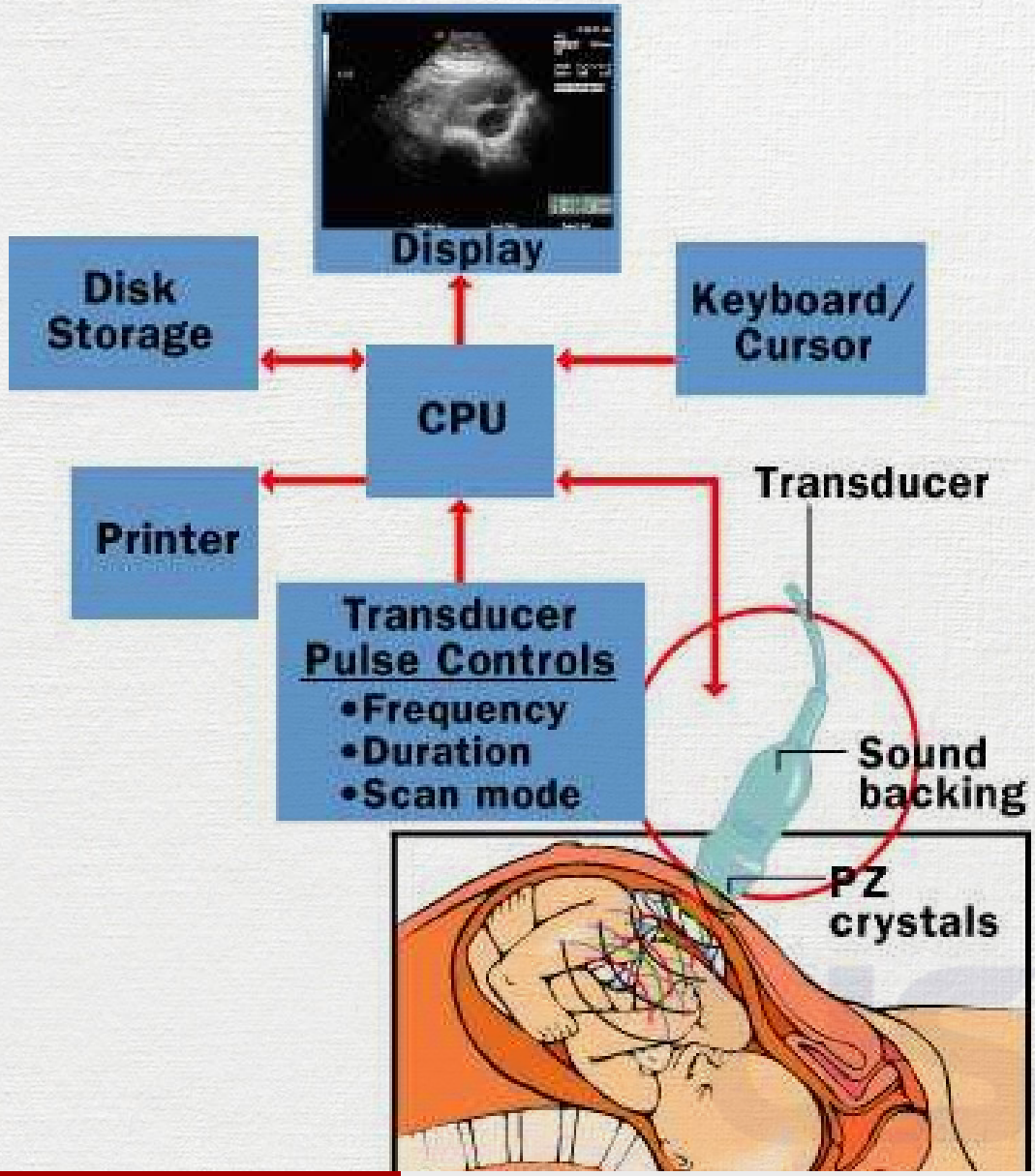


Doppler Effect

$$f' = f * \frac{v+v_0}{v-v_s}$$

- f': observed frequency
- f: emitted frequency
- v: sound velocity
- v_s: source velocity
- v_o: observer velocity

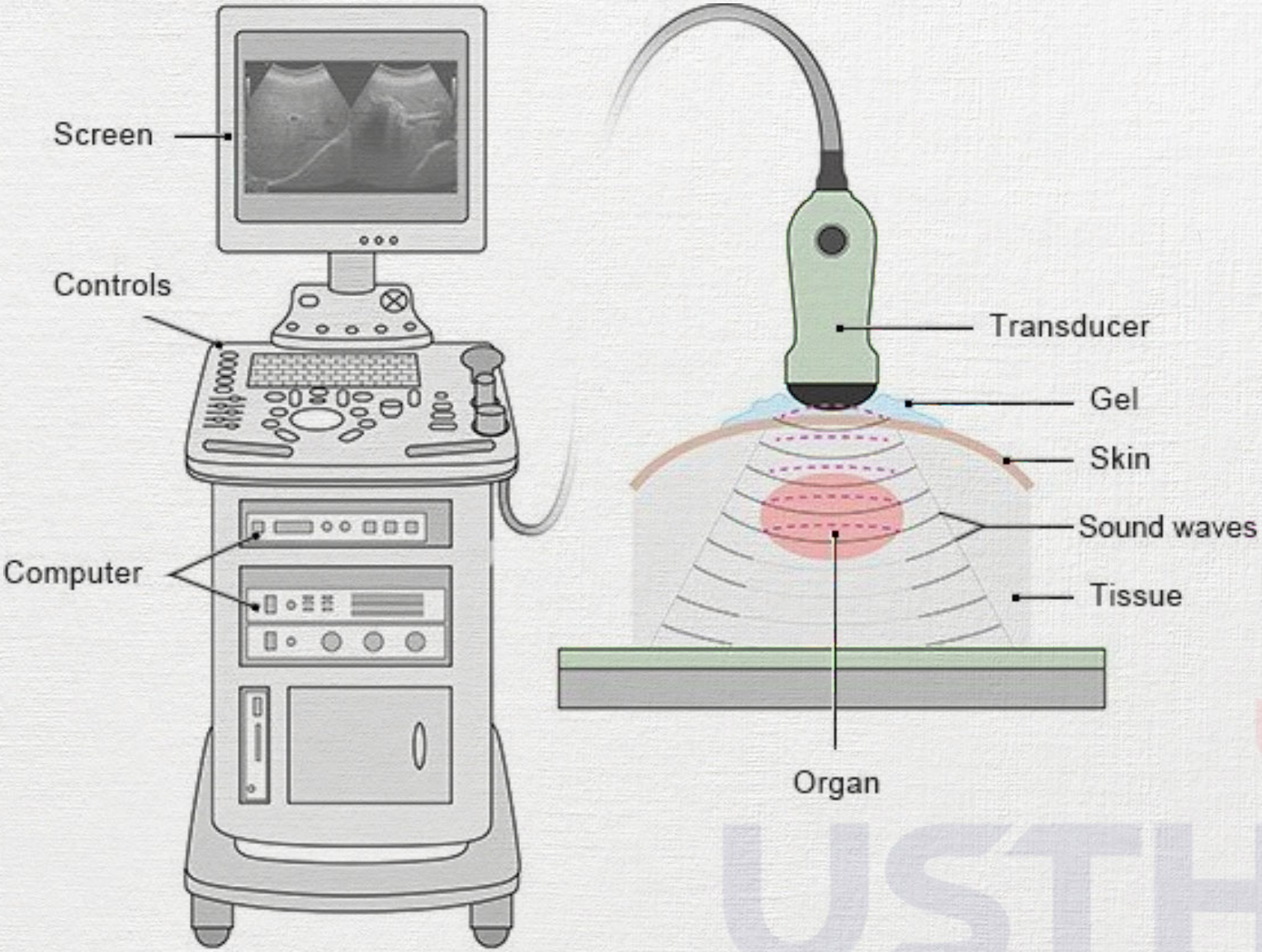
Mechanism


Display
Disk Storage
Keyboard/ Cursor
CPU
Printer
Transducer
Transducer Pulse Controls
•Frequency
•Duration
•Scan mode
Sound backing
PZ crystals

Mechanism

- Transducer probe: sends and receives the sound waves
- CPU: performs all of the calculations
- Transducer pulse controls: changes the amplitude, frequency and duration
- Display: image from the ultrasound data processed by the CPU
- Keyboard/cursor: data and takes measurements from the display
- Disk storage device: stores the acquired images
- Printer: prints the image from the displayed data

Mechanism


Screen
Controls
Computer
Transducer
Gel
Skin
Sound waves
Tissue
Organ

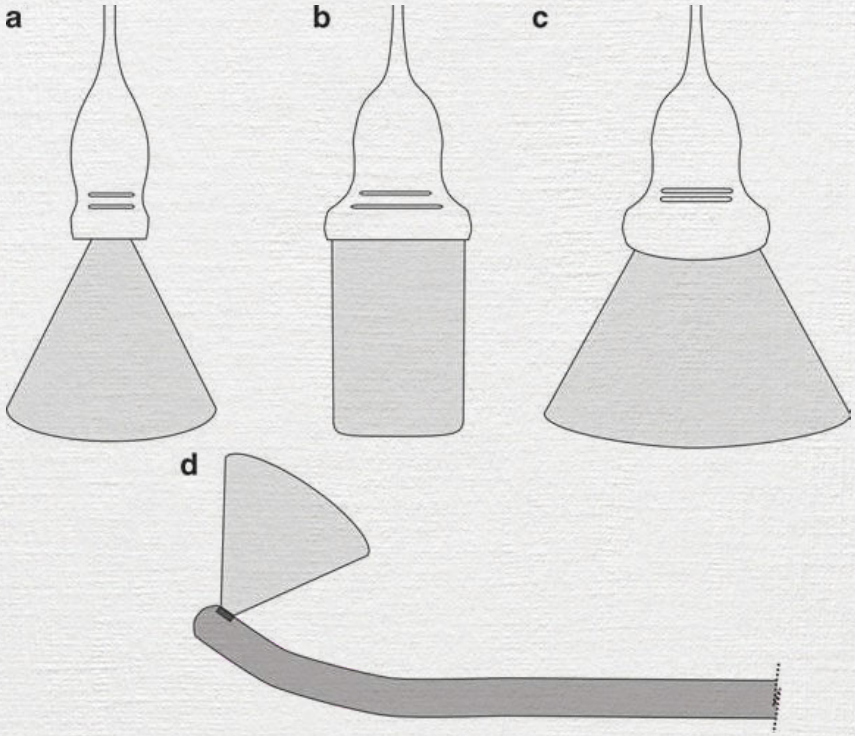
Mechanism

- Transducer sends out a beam of sound waves into the body
- The sound waves are reflected back to the transducer by boundaries between tissues in the path of the beam
  - the boundary between fluid and soft tissue or tissue and bone.
- When these echoes hit the transducer, they generate electrical signals that are sent to the ultrasound scanner

Mechanism

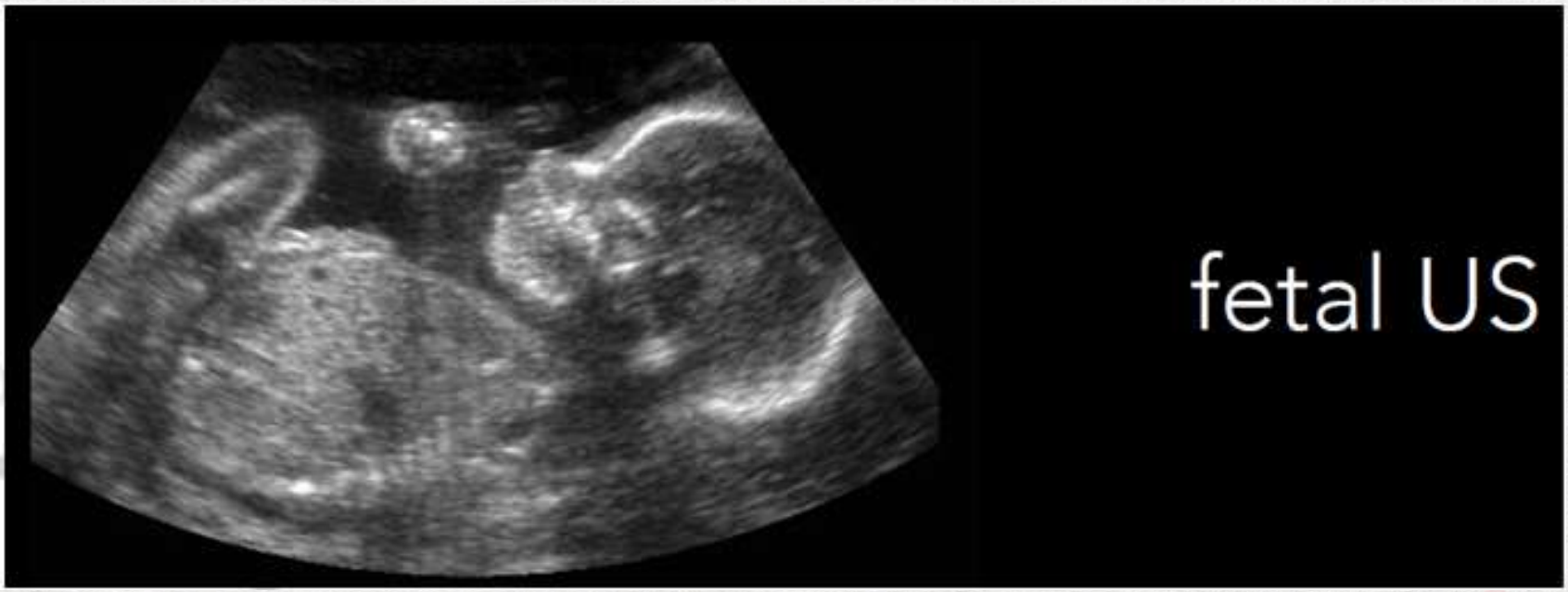
- Scanner calculates the distance to tissue boundary using
  - the speed of sound
  - the time of each echo's return
- These distances are then used to generate 2D-images of tissues and organs.

Transducers

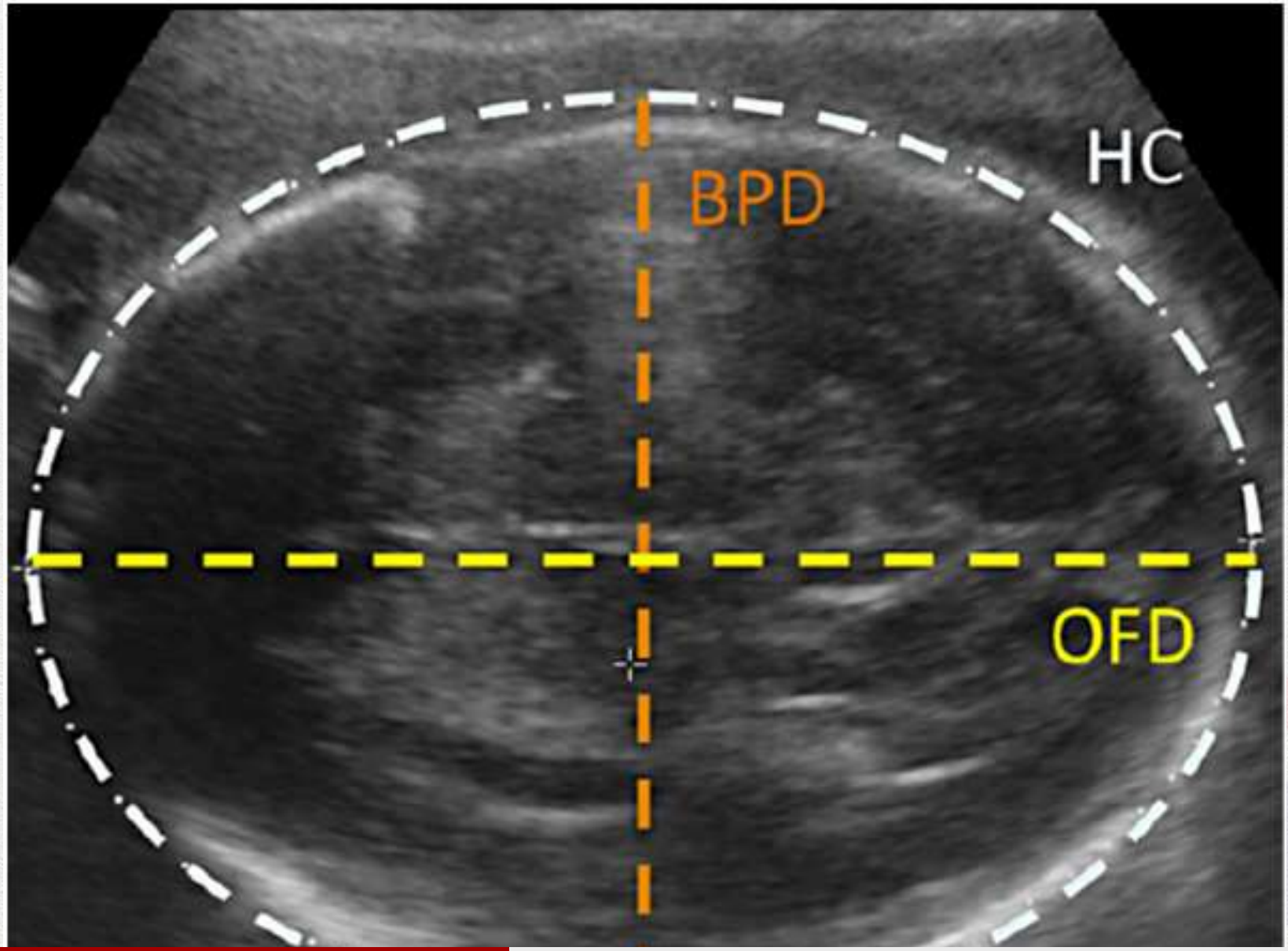


Applications

Applications



Applications



Practice!

Practical work 2

- Measurement of Fetal head circumference using Ultrasound
  - Download HC18 dataset
  - Explore the dataset
  - Build ONE machine learning/deep learning model to perform **regression**, with MAE metrics

Practical work 2

- Write a report (in LaTeX)
  - Name it « Report.2.tex »
  - Describe the dataset *in detail* that you have downloaded
  - Explain how you implement the model
  - Compare your results with the leaderboard
  - Try experimenting with different hyperparameter values
- Push the report and your code (Notebook and .py script) to your forked repository