SNS COLLEGE OF ALLIED HEALTH SCIENCE

Affiliated to The Tamil Nadu Dr MGR Medical University, Chennai

DEPARTMENT OF CARDIAC TECHNOLOGY

COURSE NAME : Echocardiography

UNIT : Principles & Techniques of Echocardiography

TOPIC : Physics of Ultrasound and Doppler

FACULTY NAME : Kavipriya S

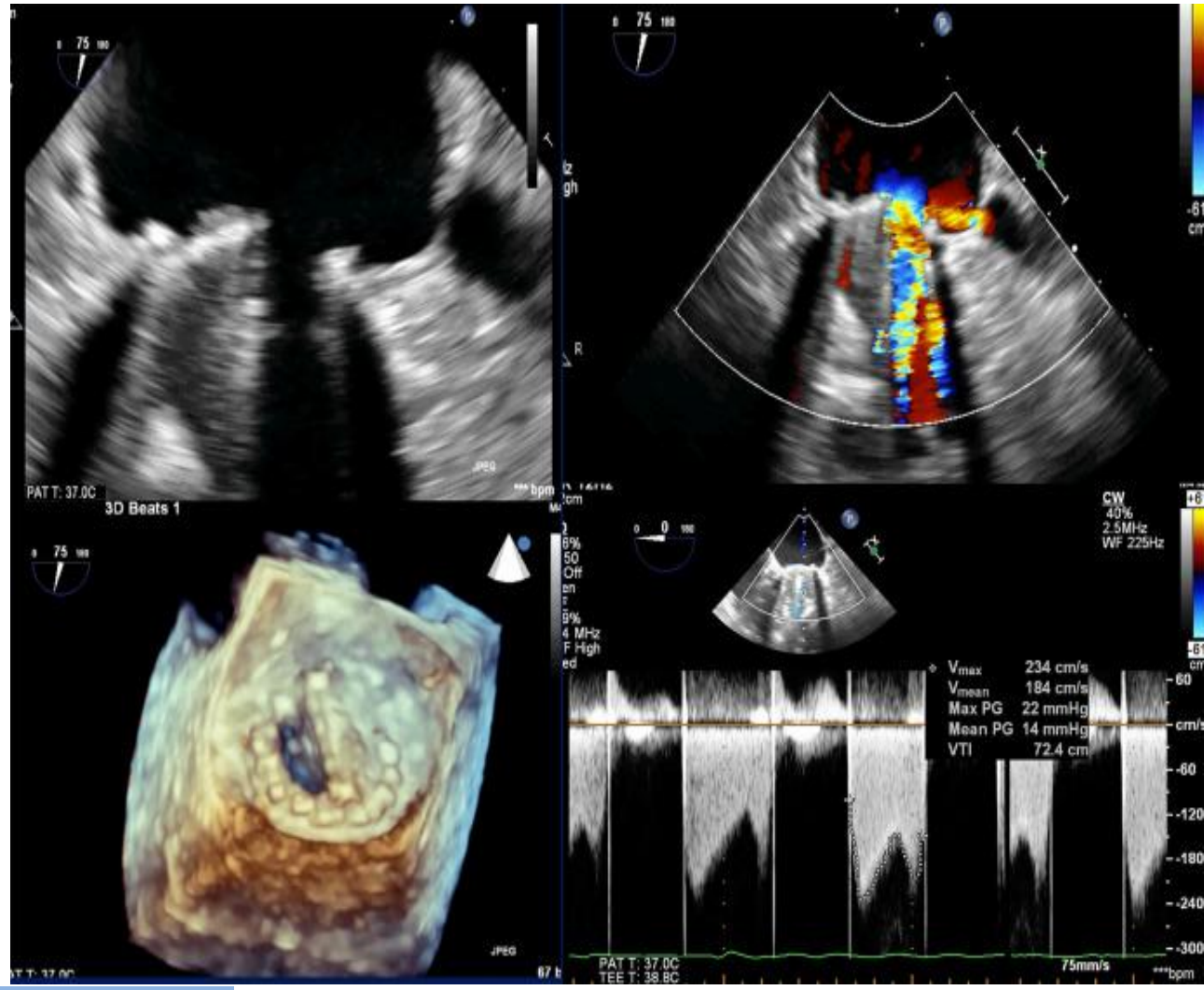
1. Empathize – Understanding the Need

Goal:

To understand how sound waves help visualize the heart and assess blood flow non-invasively.

Clinical Need:

- Echocardiography uses **ultrasound** to produce images of cardiac structures.
- **Doppler ultrasound** evaluates the **direction and velocity of blood flow** — crucial for diagnosing valve diseases, shunts, stenosis, and regurgitation.



🎯 Define – Identifying the Core Concepts

Concept	Description
Ultrasound	Sound waves with frequencies >20,000 Hz used for imaging. In echocardiography, typical frequencies range from **2–10 MHz**.
Acoustic Impedance (Z)	Property of tissue = ρ × c (density × speed of sound). Determines reflection and transmission of sound at tissue interfaces.
Reflection	Occurs when sound hits a boundary between tissues of different impedances — basis for image formation.
Attenuation	Reduction in sound intensity due to absorption, reflection, and scattering.
Refraction & Scattering	Change in wave direction or dispersion; affects image clarity.
Pulse-Echo Principle	The transducer sends a pulse and receives echoes from tissue interfaces. Time delay determines depth.
Doppler Effect	Apparent change in frequency due to motion of reflector (RBCs). Used to measure blood flow velocity and direction.

💡 DEFINE — Ideate – Concept Development

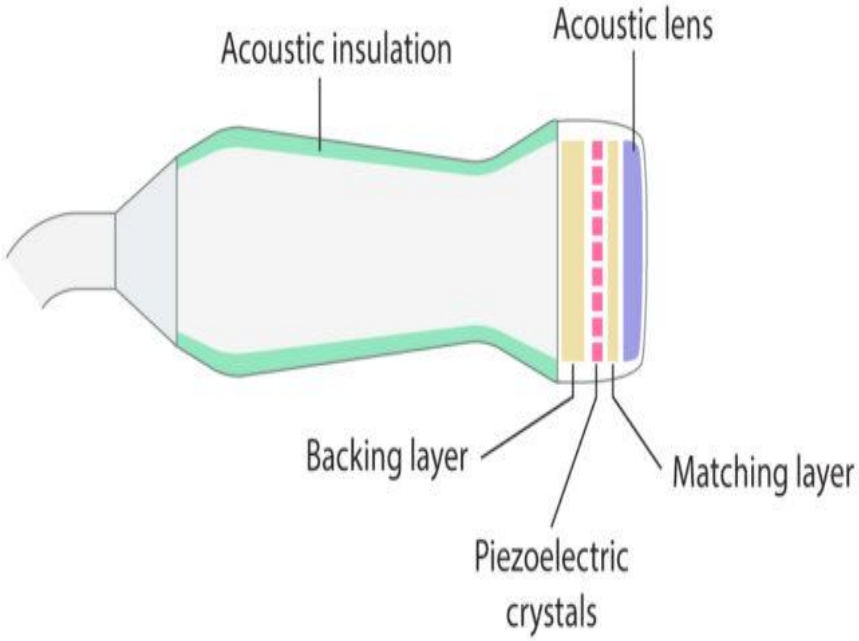
Generation of Ultrasound:

Based on **piezoelectric effect**:

- **Piezoelectric crystals** convert electrical energy → mechanical vibrations → ultrasound waves.
- In reception mode: convert returning echoes → electrical signals.

The ultrasound transducer

The ultrasound transducer from the side and front.



Arrangement of piezoelectric crystals

💡 DEFINE — Ideate – Concept Development

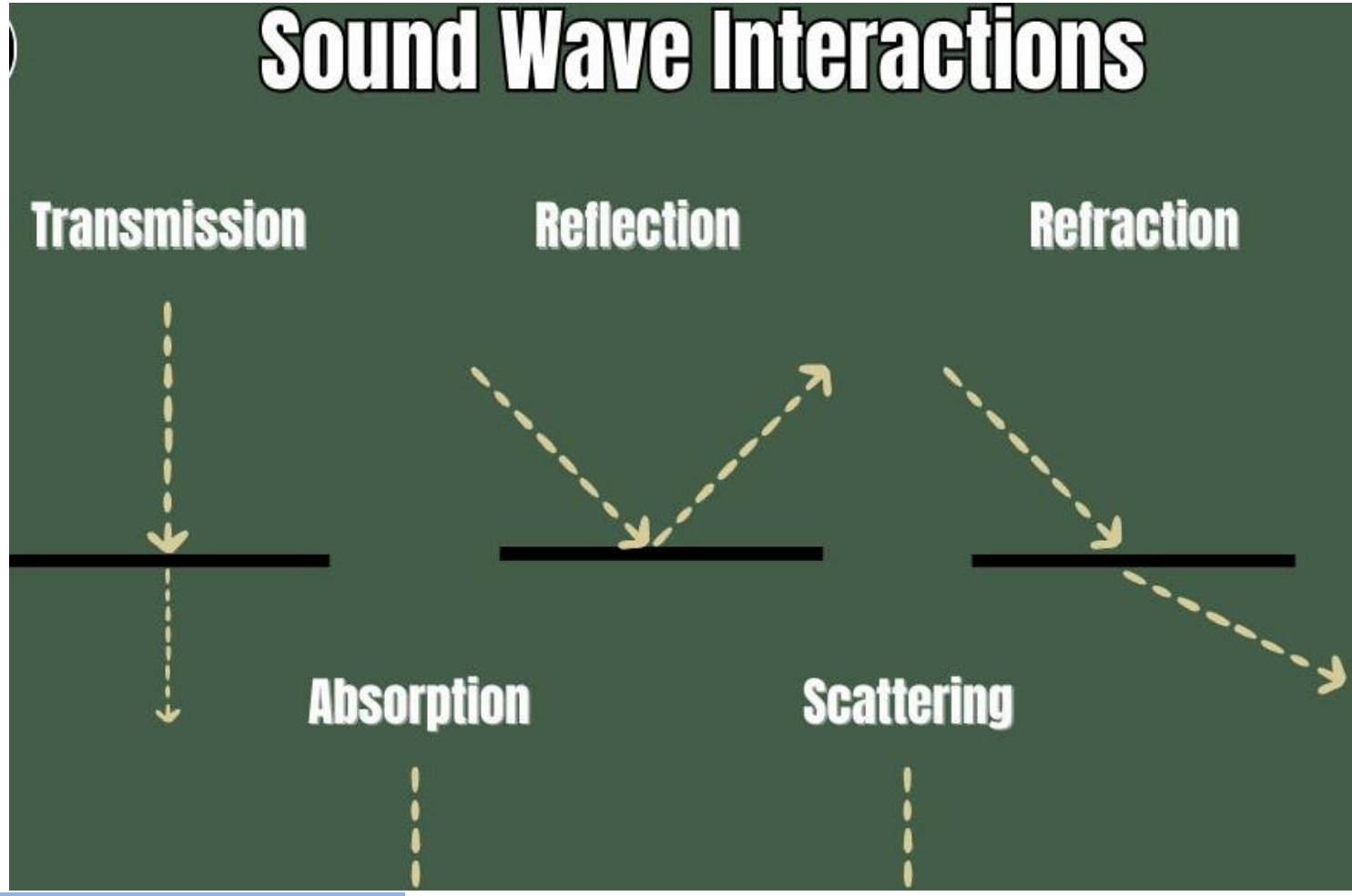
Interaction of Ultrasound with Tissues

1.Reflection – from tissue boundaries.

2.Refraction – bending at interfaces.

3.Scattering – from small structures (cells).

4.Absorption – conversion of sound to heat.



💡 DEFINE — Ideate – Concept Development

Doppler Ultrasound Principles

Formula:

$$f_D = \frac{2 f_0 v \cos\theta}{c}$$

where

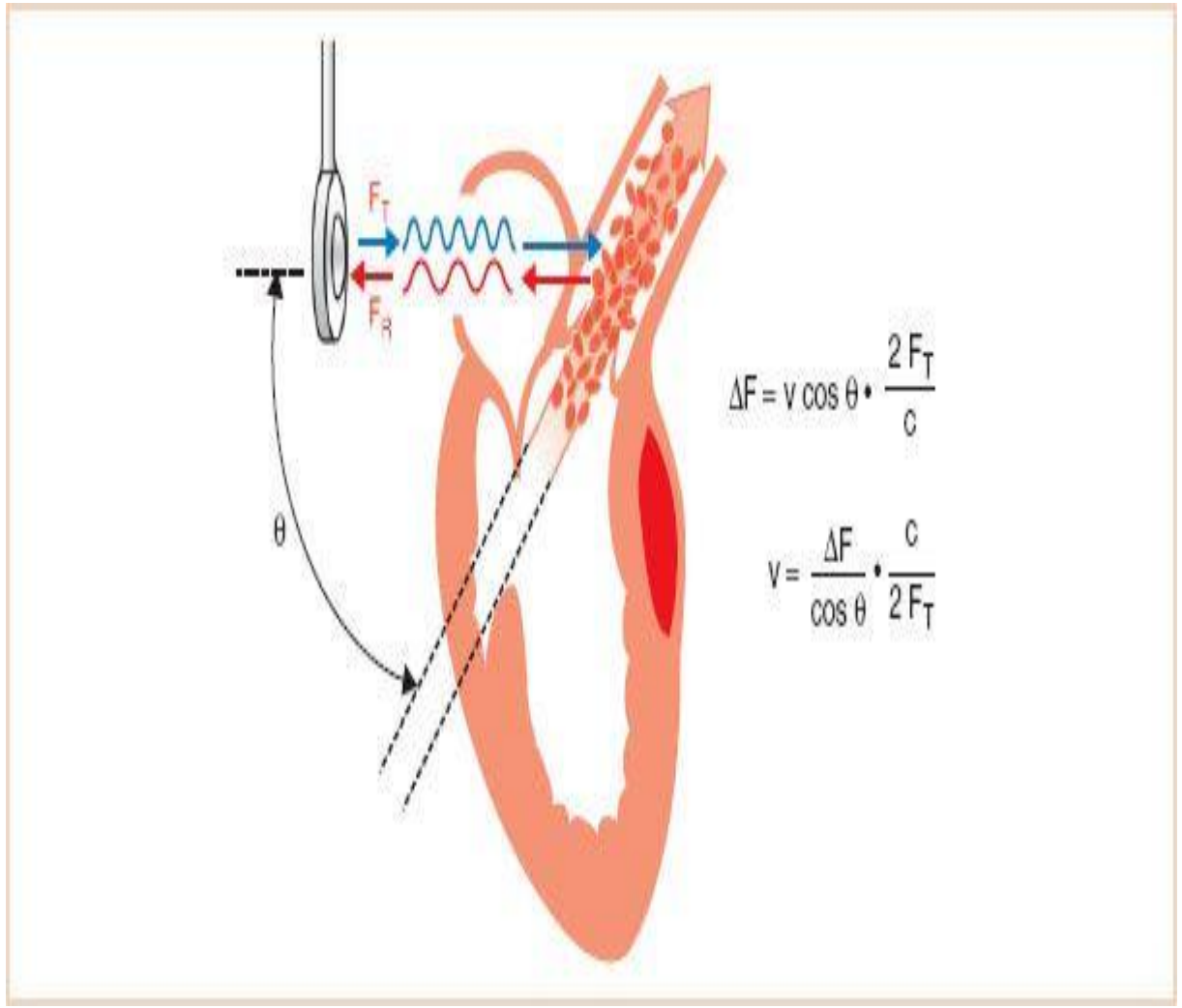
f_D =Doppler shift,

f_0 =transmitted frequency,

v= velocity of blood,

θ= angle between ultrasound beam and flow direction,

c= velocity of sound in tissue (~1540 m/s).



💡 DEFINE — Ideate – Concept Development

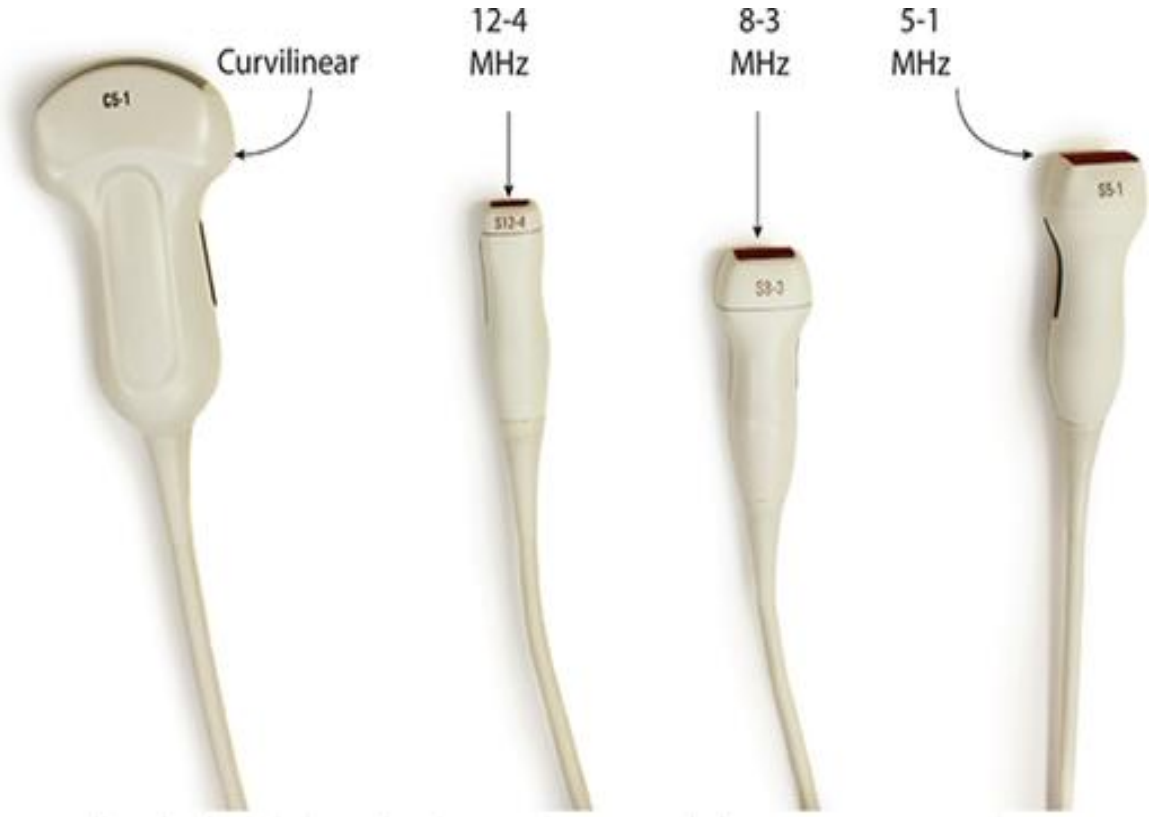
Type	Description	Clinical Use
Continuous Wave (CW)	Two crystals: one transmits, one receives continuously.	High velocity flows, e.g., aortic stenosis.
Pulsed Wave (PW)	Single crystal alternates transmit/receive; samples at specific depth.	Localized flow (but limited by aliasing).
Color Doppler	Superimposes color-coded velocity map on 2D image.	Visualizes flow direction and turbulence.
Power Doppler	Displays signal strength (amplitude) rather than velocity.	Sensitive for low-velocity or weak flows.

💡 DEFINE — Ideate – Concept Development

Transducer frequency: Higher for superficial imaging (children), lower for deeper (adults).

Gain & Depth settings: Optimize image quality.

Angle correction: Ideally ≤20° between beam and flow direction.



🧠 Test – Evaluate, Analyze, and Reflect

Diagnostic Interpretation:

Normal flow: Uniform color, laminar flow pattern.

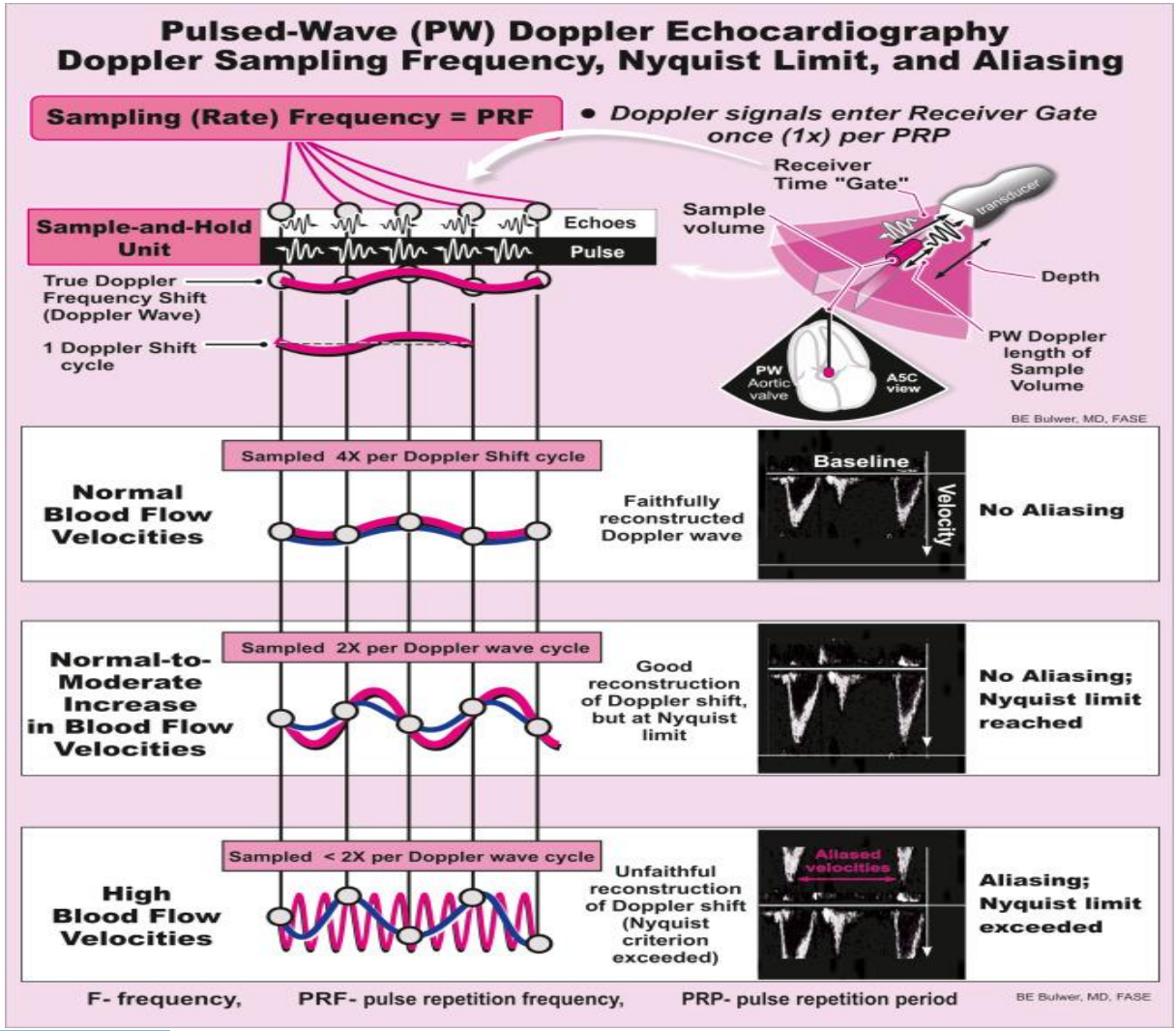
Abnormal flow: Turbulence, aliasing, or reversed flow indicates pathology (e.g., stenosis, regurgitation).

Artifacts and Errors:

Aliasing: Occurs in pulsed Doppler when frequency shift exceeds Nyquist limit.

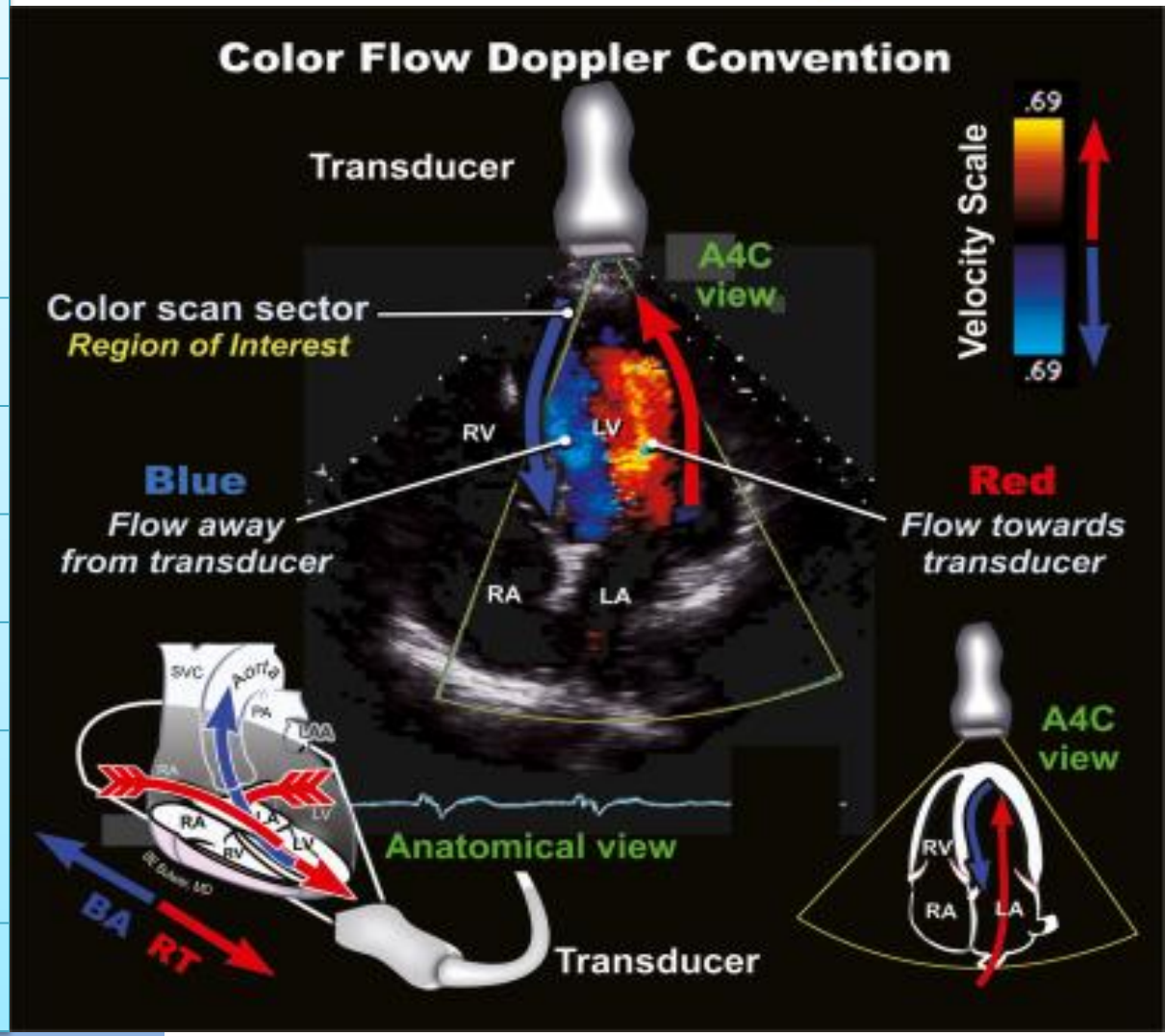
Mirror image, reverberation, side lobes: Caused by reflection/refraction errors.

Angle error: Underestimates velocity if beam not parallel to flow.



Summary

Concept	Key Point
Ultrasound frequency	2–10 MHz (higher = better resolution, less penetration)
Speed of sound in tissue	1540 m/s
Doppler angle	< 20° preferred
Aliasing	Limitation in PW Doppler
CW Doppler	Detects high velocities
Color Doppler	Direction & velocity encoded by color
Power Doppler	Sensitive to weak or slow flow



REFERENCE BOOKS

Echocardiography & Doppler Imaging

- **Otto, Catherine M.**

  Textbook of Clinical Echocardiography (6th Edition)

  Elsevier, 2021.

  → Comprehensive coverage of ultrasound physics, Doppler principles, and echocardiographic interpretation.

- **Feigenbaum, Harvey.**

  Feigenbaum's Echocardiography (8th Edition)

  Wolters Kluwer/Lippincott Williams & Wilkins, 2019.

  → Classic reference text explaining M-mode, 2D, and Doppler echocardiography with detailed diagrams.

- **Kerstin L. Thornbury, Myrle L. Miller.**

  Principles and Practice of Echocardiography.

  → Includes clinical correlations, transducer technology, and Doppler artifacts.