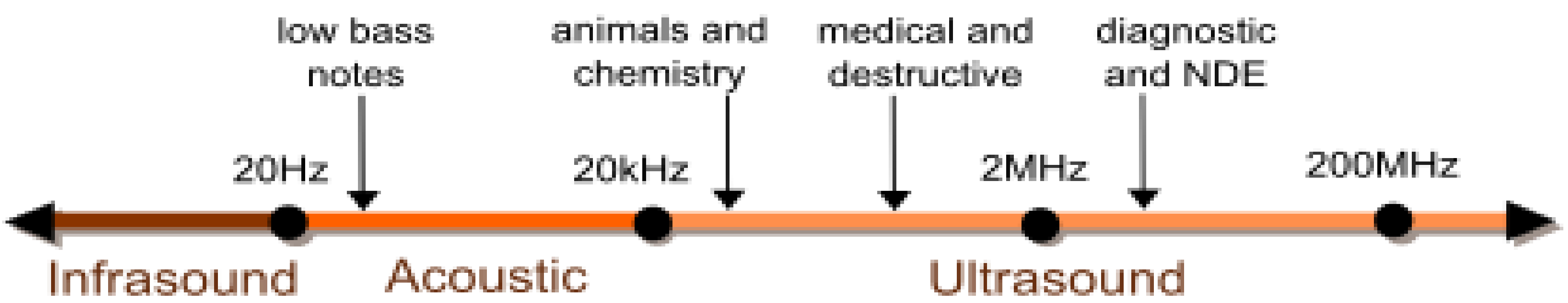
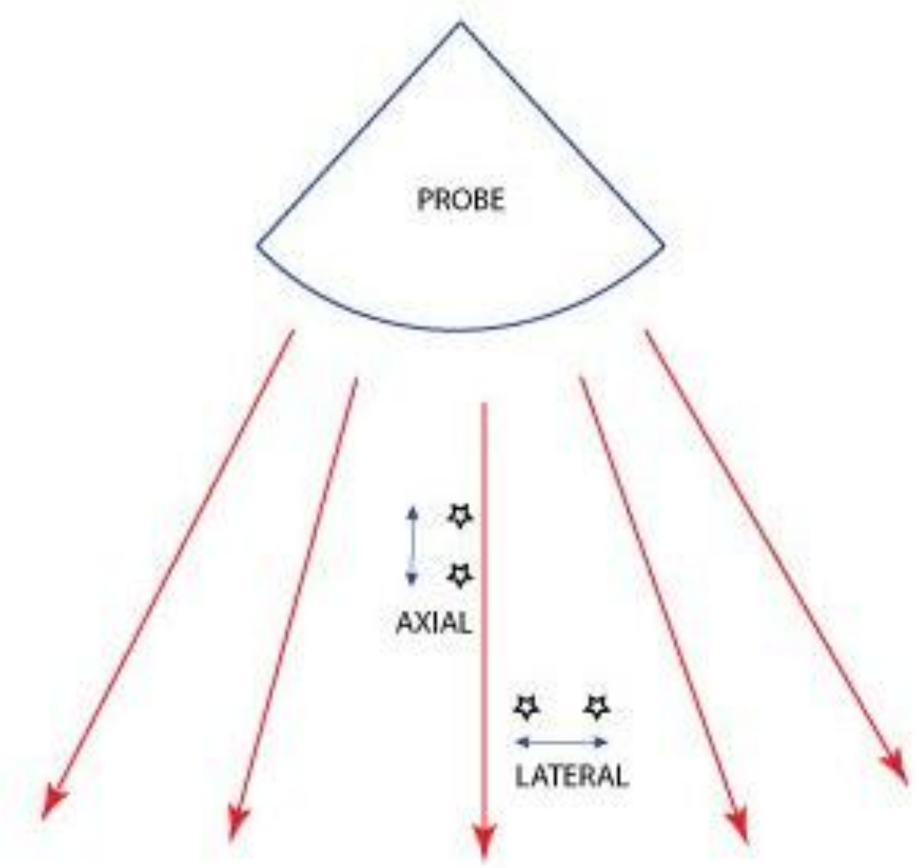
ULTRASOUND: BASIC DEFINITION

- Ultrasound is acoustic(sound) energy in the form of waves having a frequency above the human hearing range(i.e. 20KHz)
- Ultrasound is a way of using sound waves to look inside the human body.

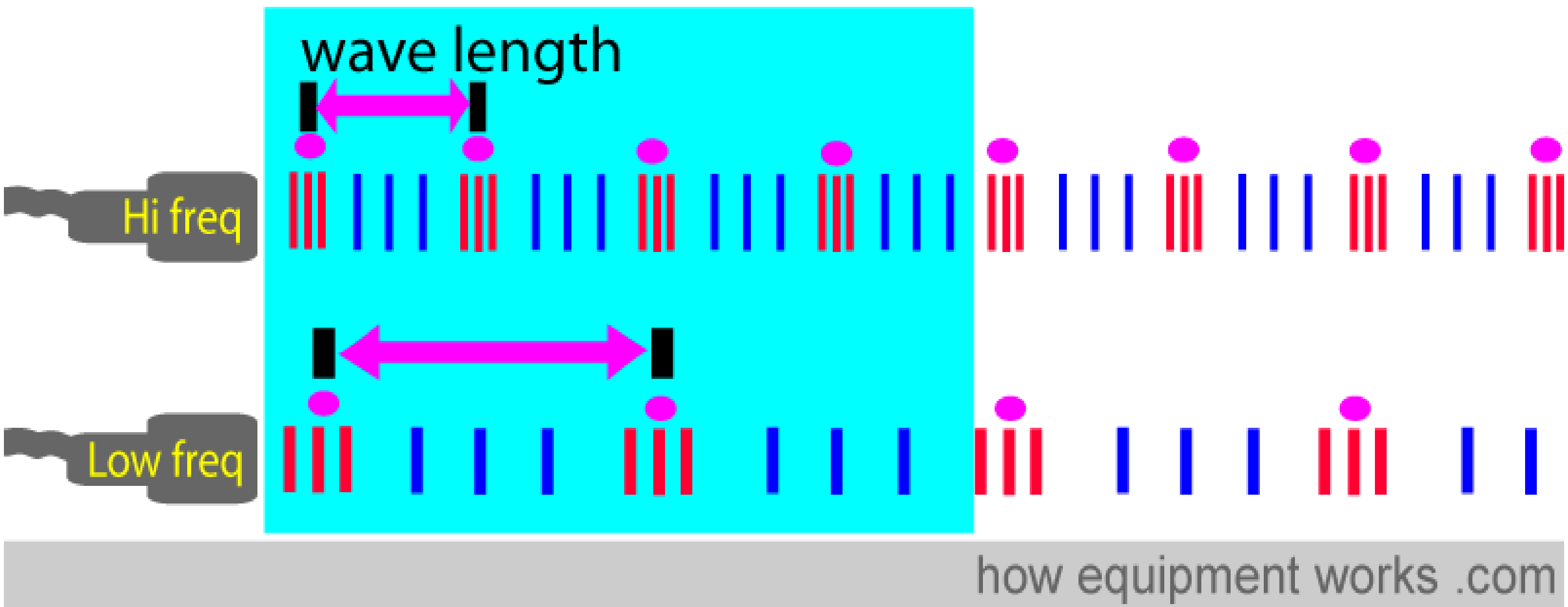



PROBE
AXIAL
LATERAL

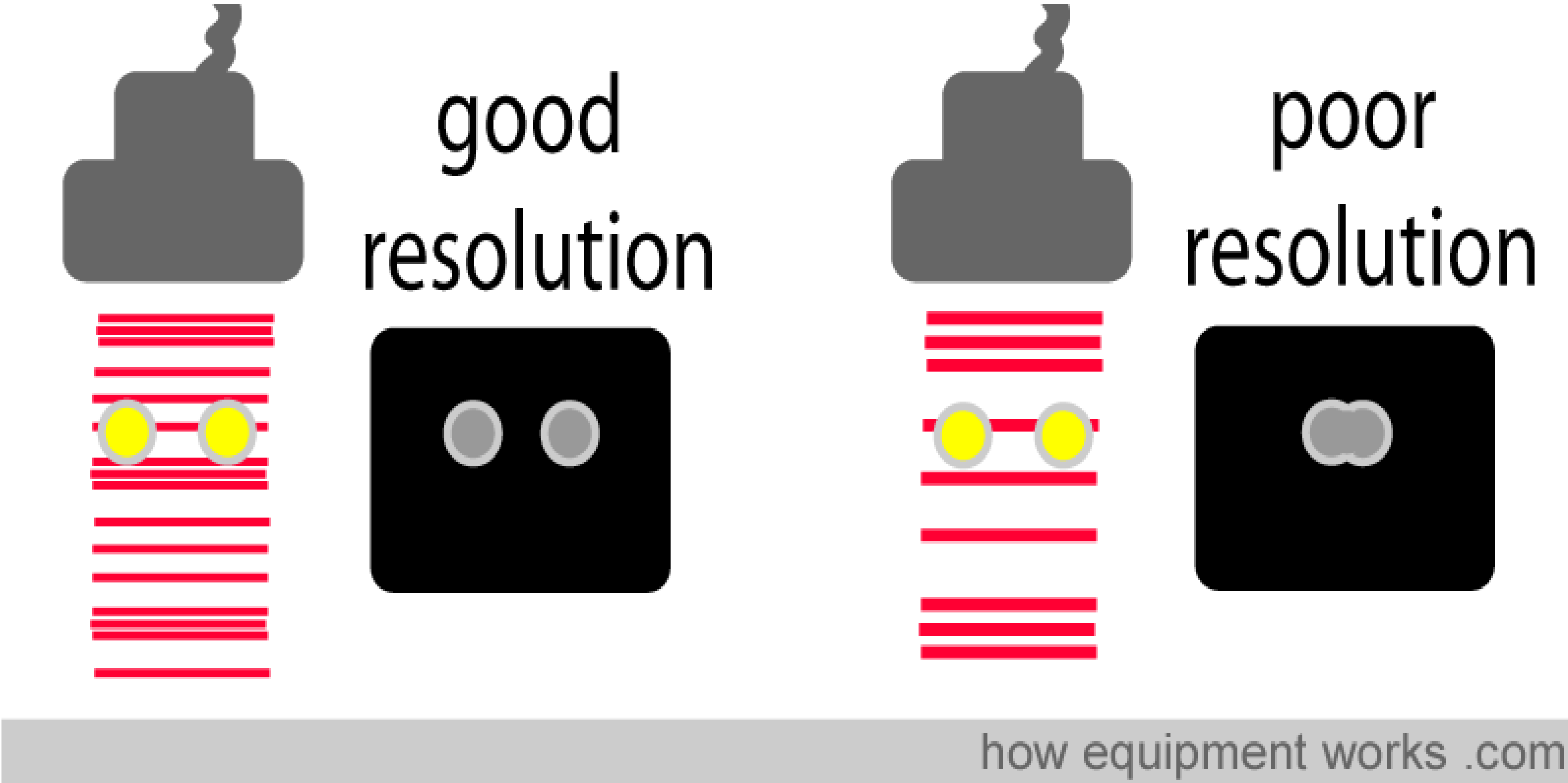
High frequency has short wave length

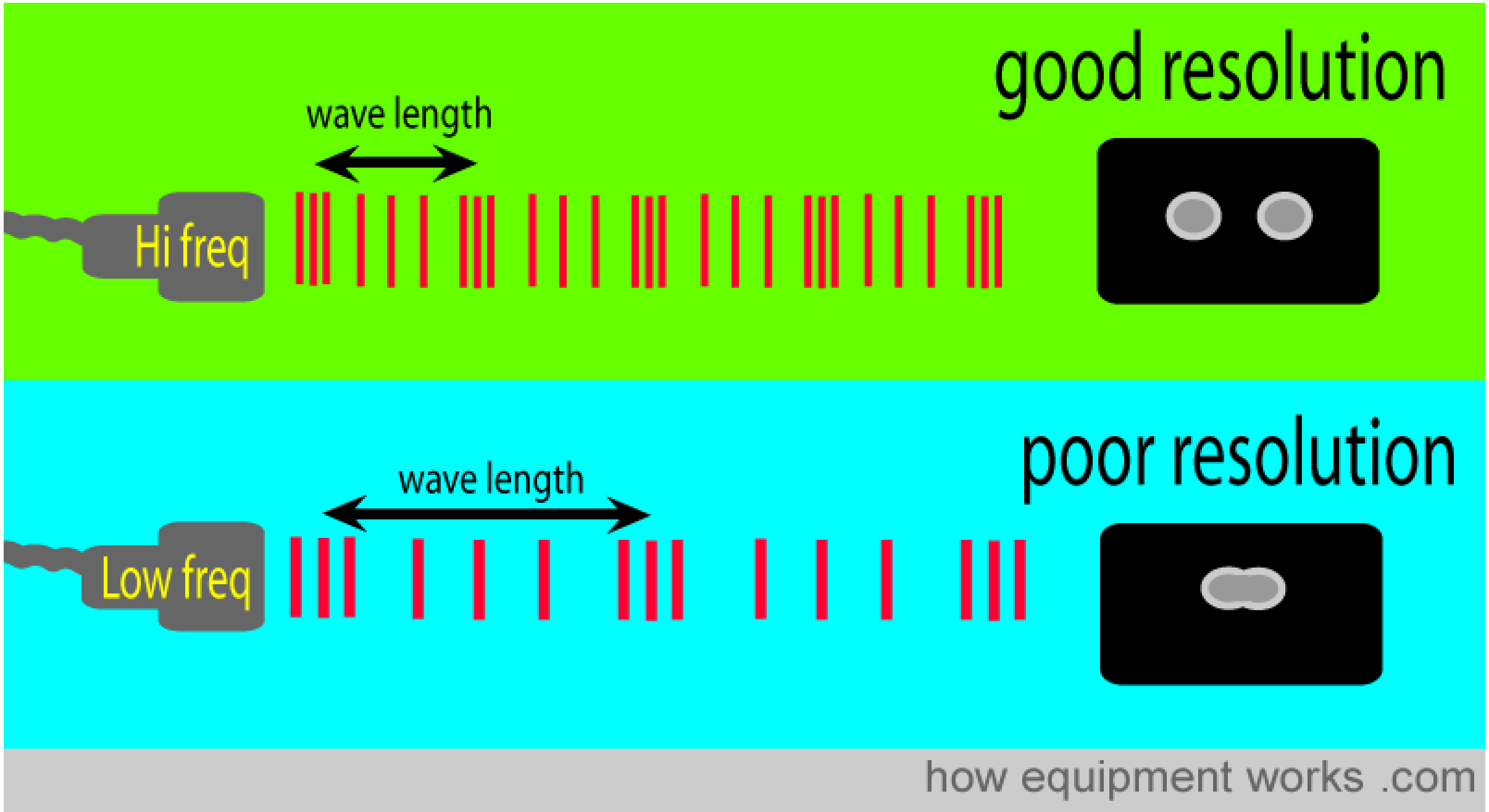
Low frequency has Long wave length

$$\text{wave length} \propto \frac{1}{\text{frequency}}$$



Resolution




good resolution
wave length
Hi freq
poor resolution
wave length
Low freq
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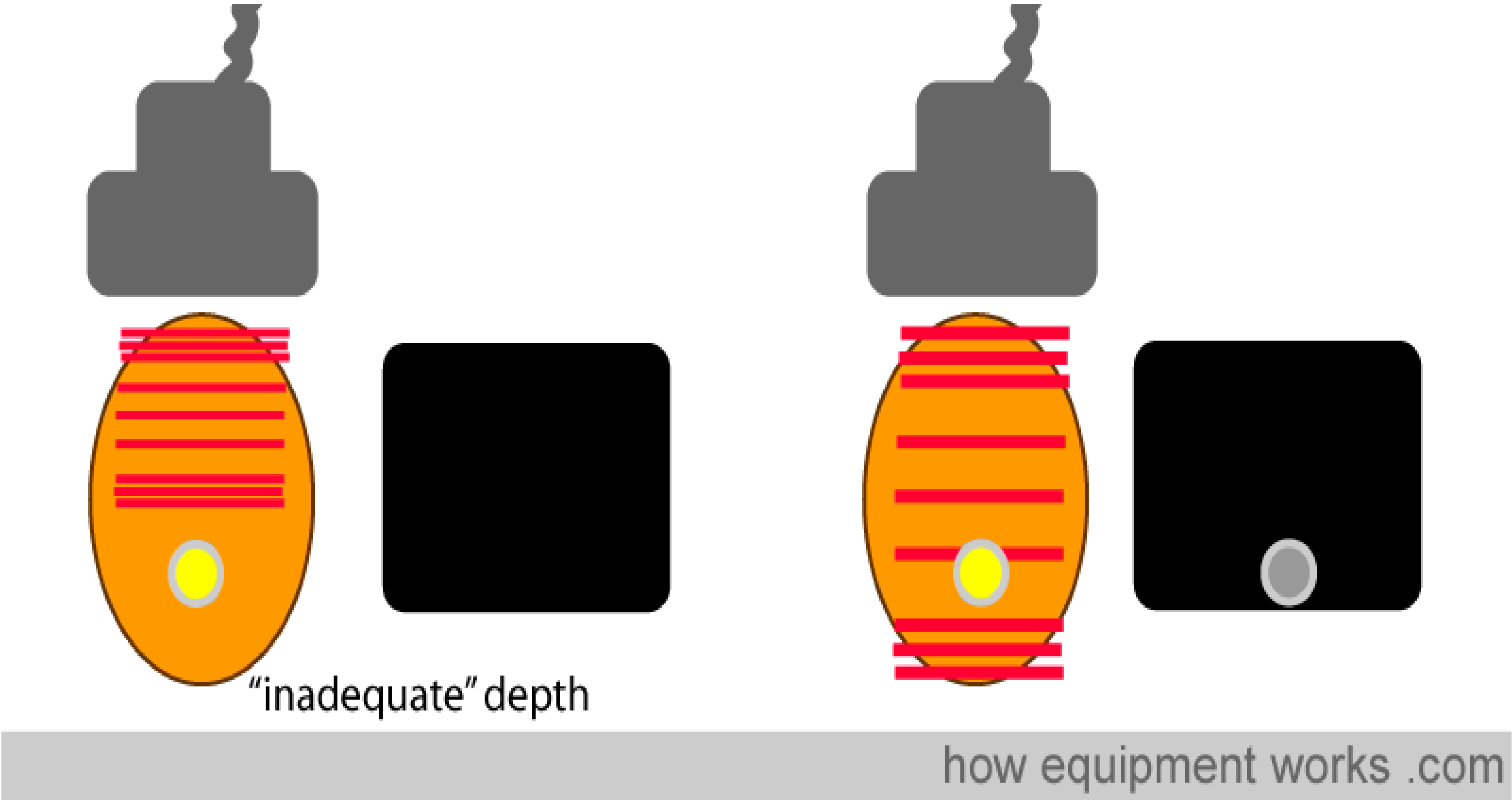
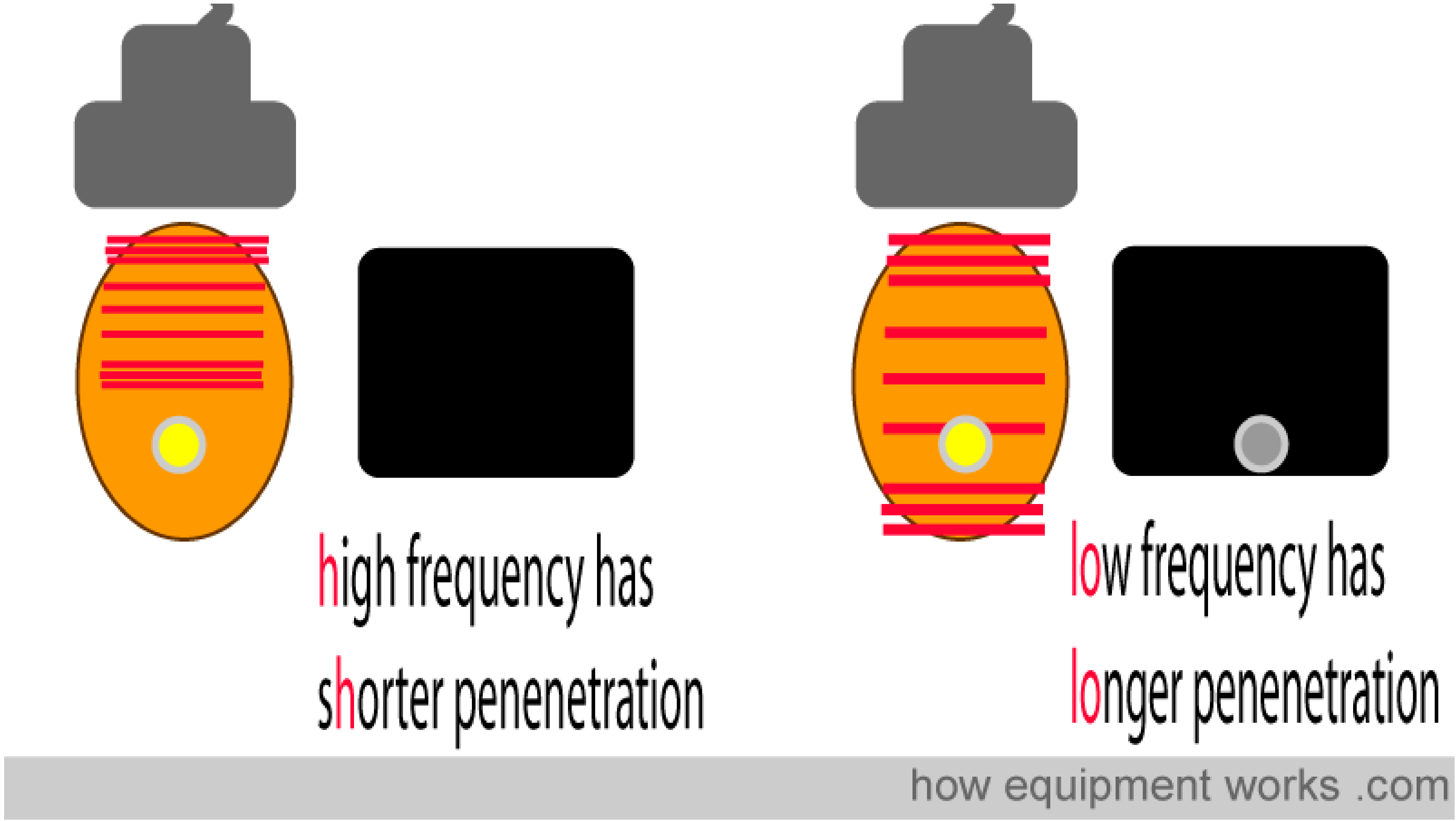
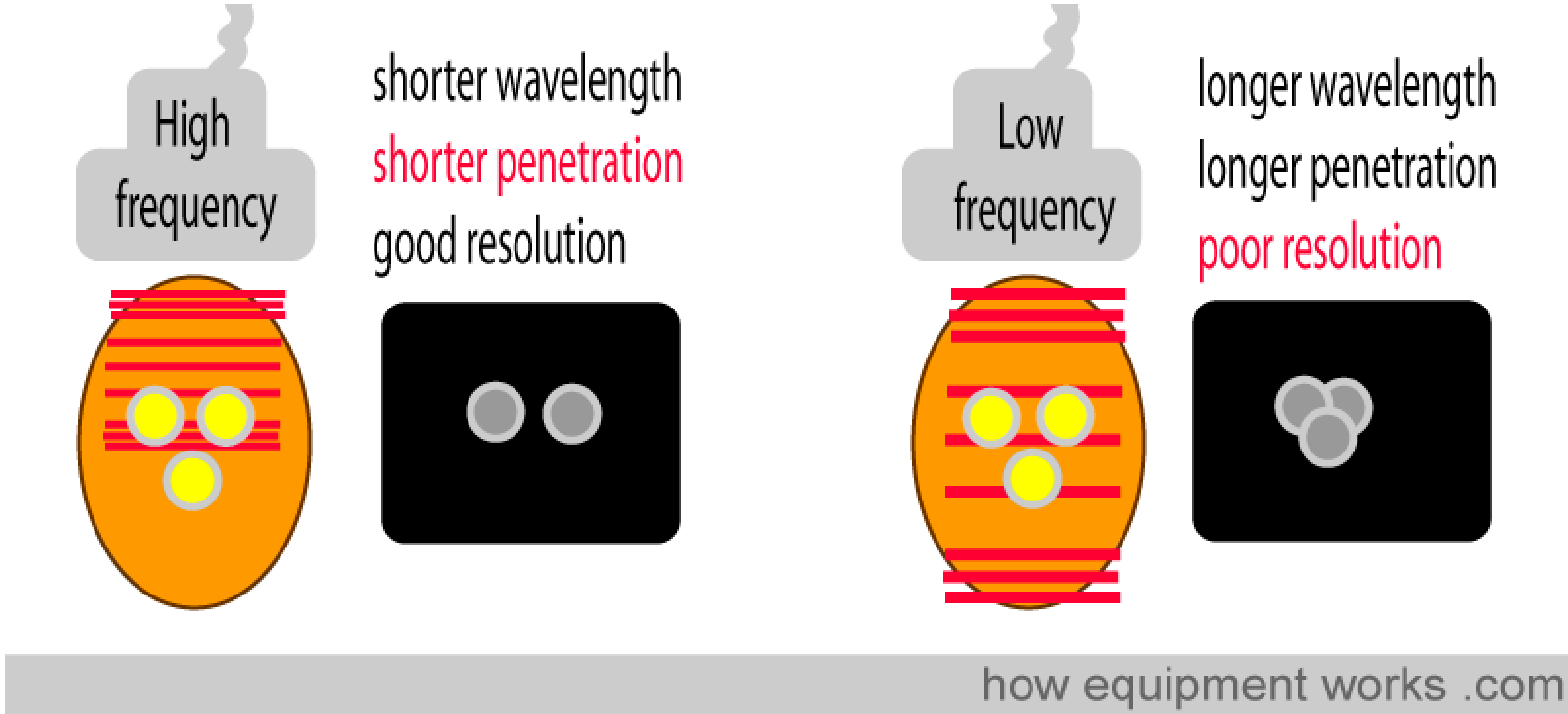
Depth




high frequency has
shorter penenetration
low frequency has
longer penenetration
how equipment works .com



High
frequency
shorter wavelength
shorter penetration
good resolution
Low
frequency
longer wavelength
longer penetration
poor resolution
how equipment works .com

Depth Vs Resolution

Low frequency	High frequency
Low resolution	High resolution
Longer depth	Shorter depth

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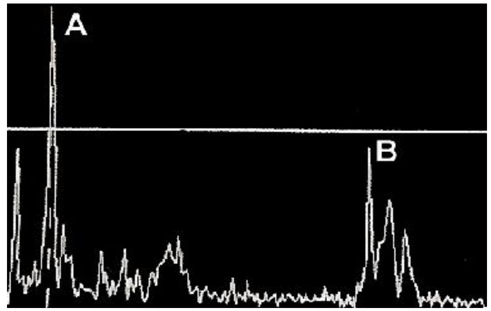
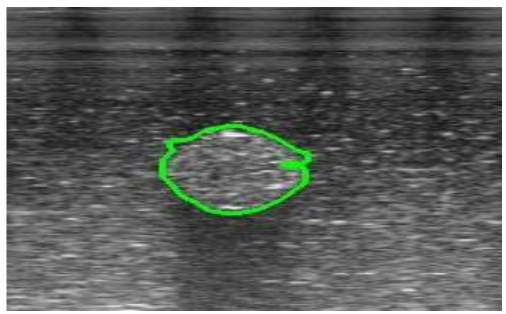
Ultrasound Modes

- A Mode



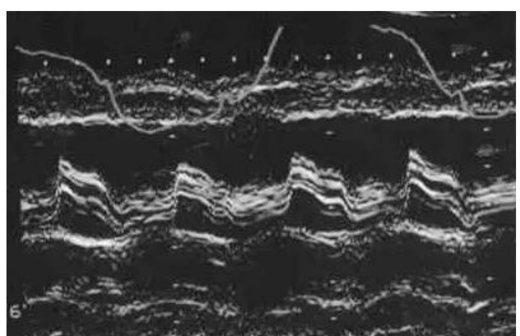
Amplitude Modulation, is the display of amplitude spikes of different heights. It is used for opthamalolgy studies to detect finding in the optic nerve.

- B Mode



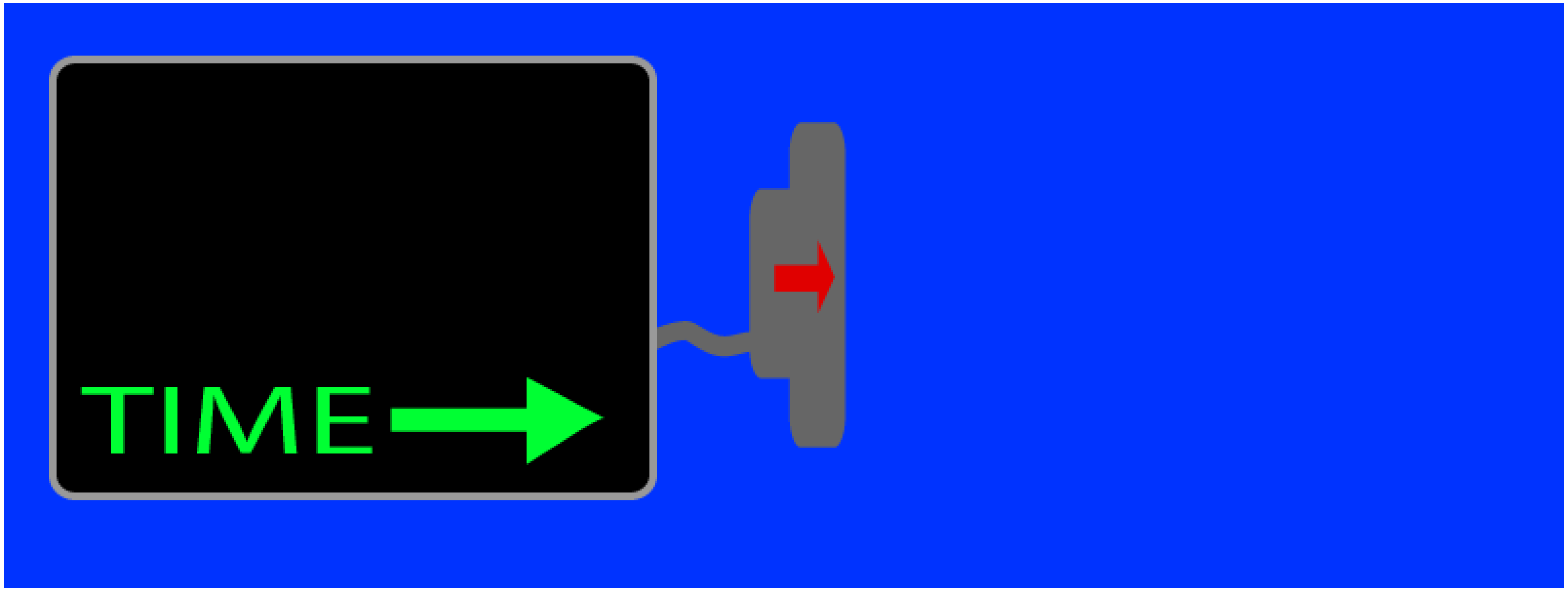
Brightness Modulation, will display an image of large and small dots, which represent strong and weak echoes, respectively

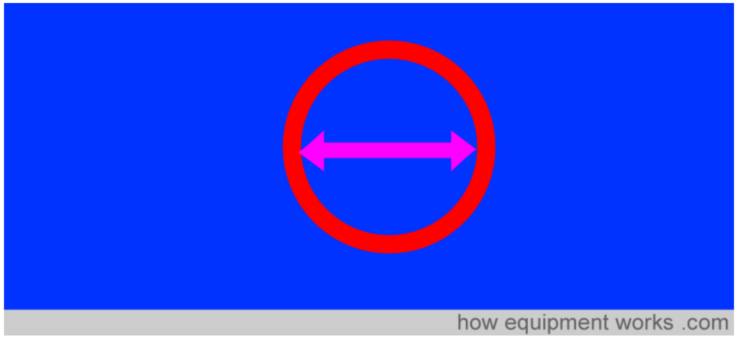
- M Mode



Motion Mode, is the display of a one-dimensional image that is used for analyzing moving body parts commonly in cardiac and fetal cardiac imaging

A Mode Scanning

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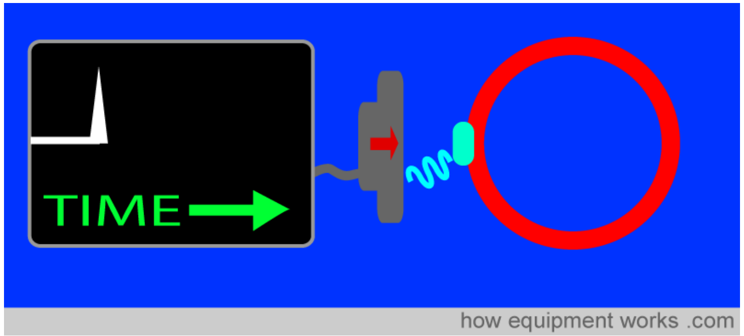
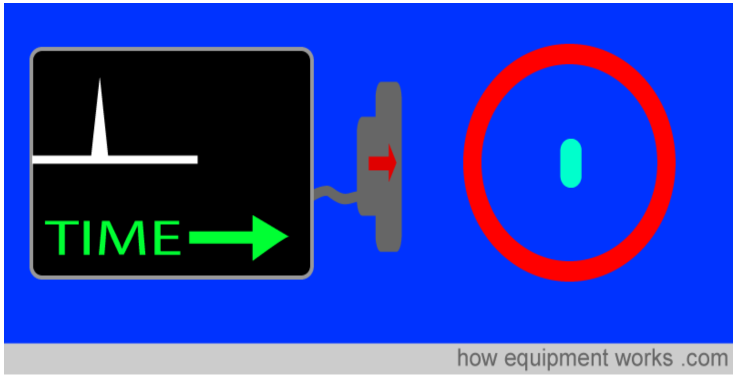
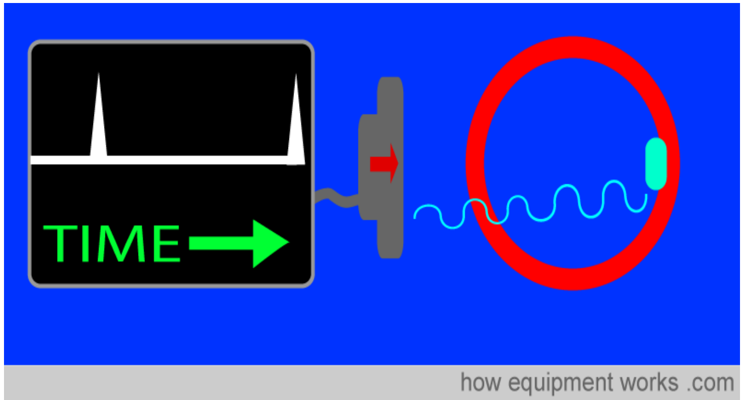
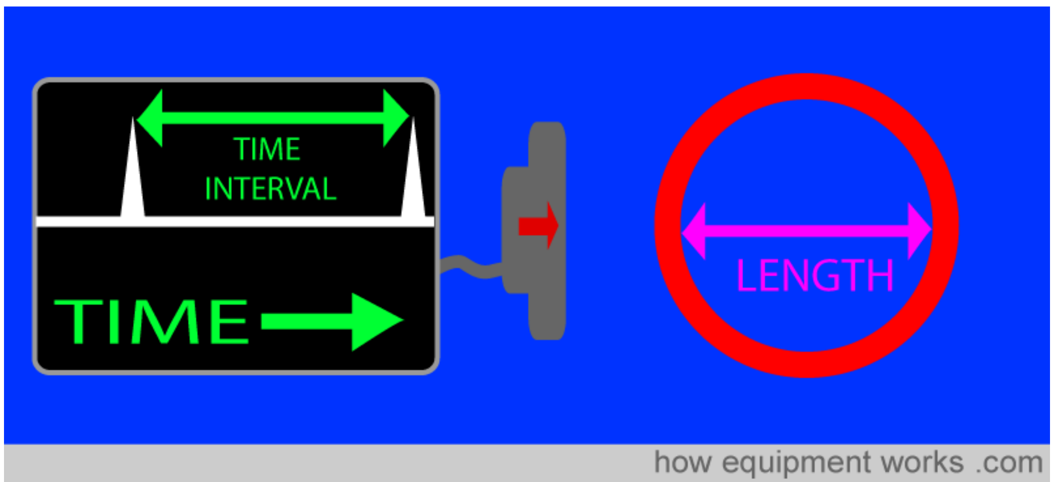
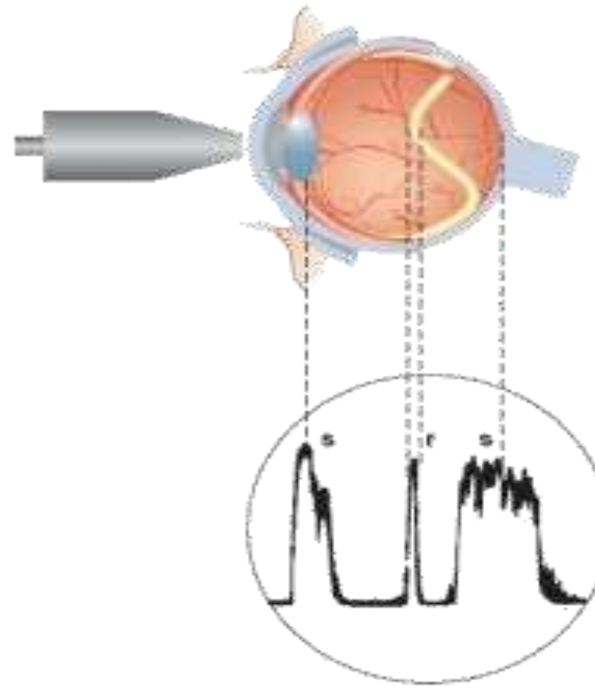

TIME
how equipment works .com

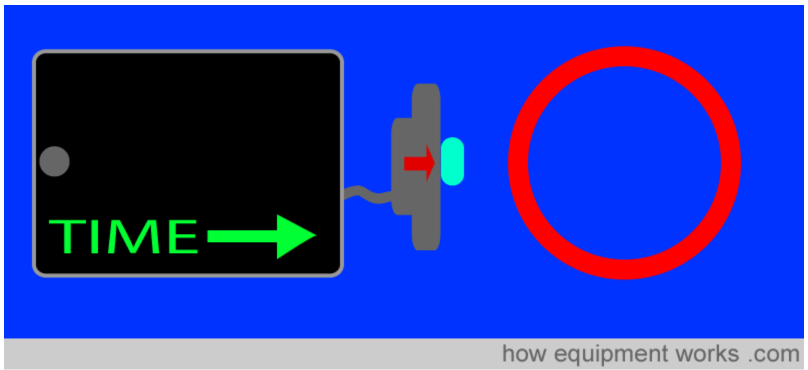

TIME
how equipment works .com

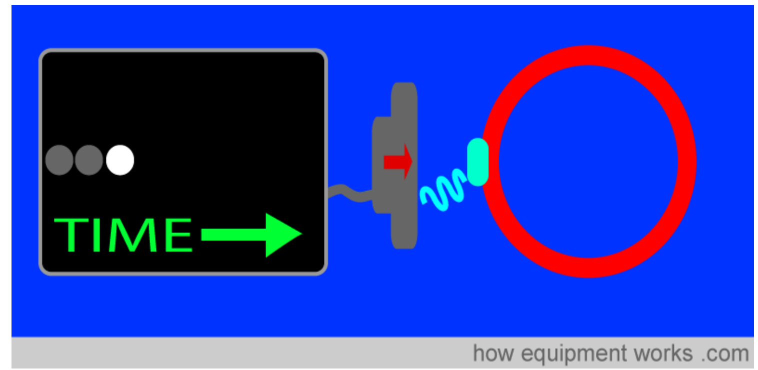

TIME
how equipment works .com

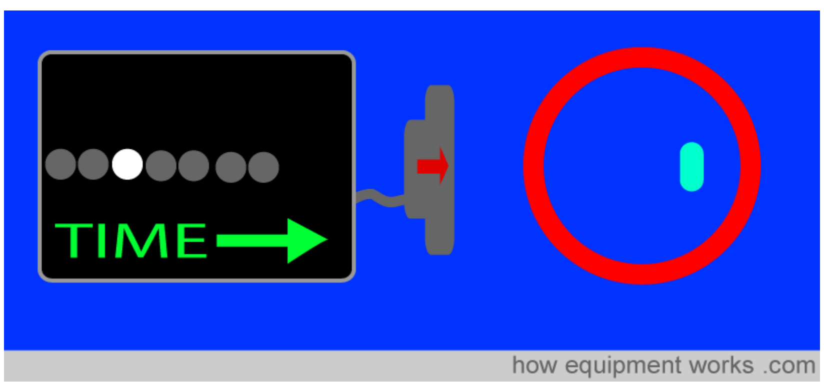

TIME
INTERVAL
TIME
LENGTH
how equipment works .com

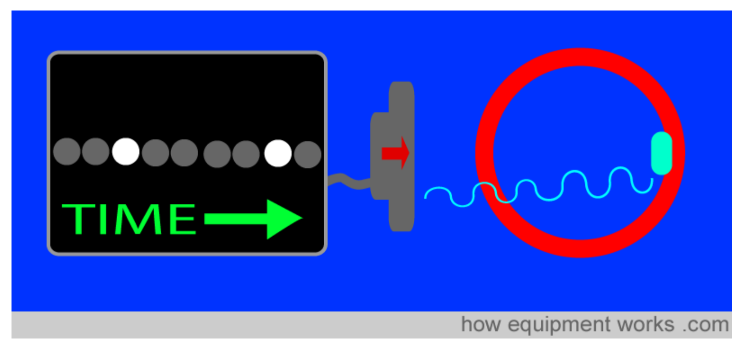


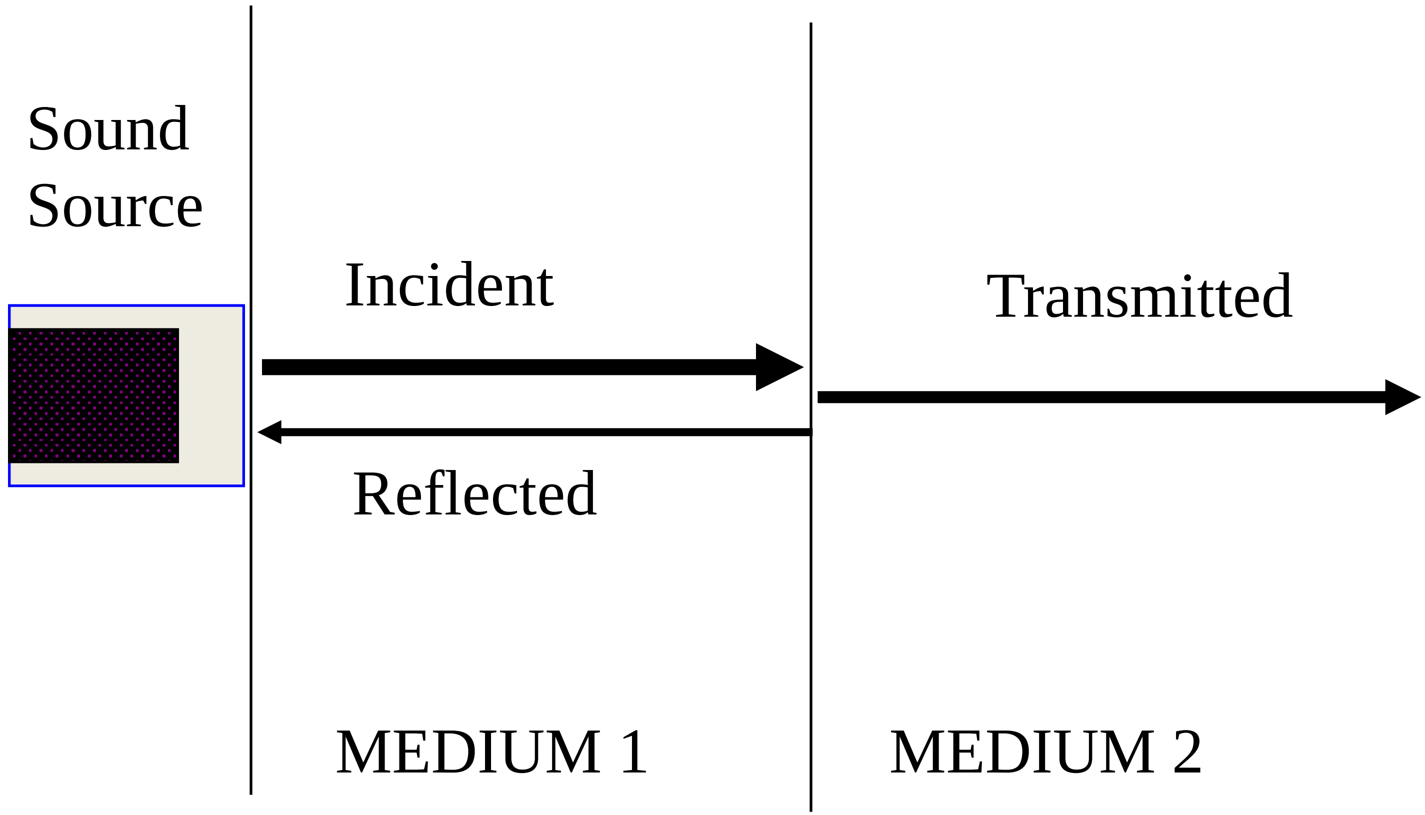
B Scan


TIME
how equipment works .com


TIME
how equipment works .com

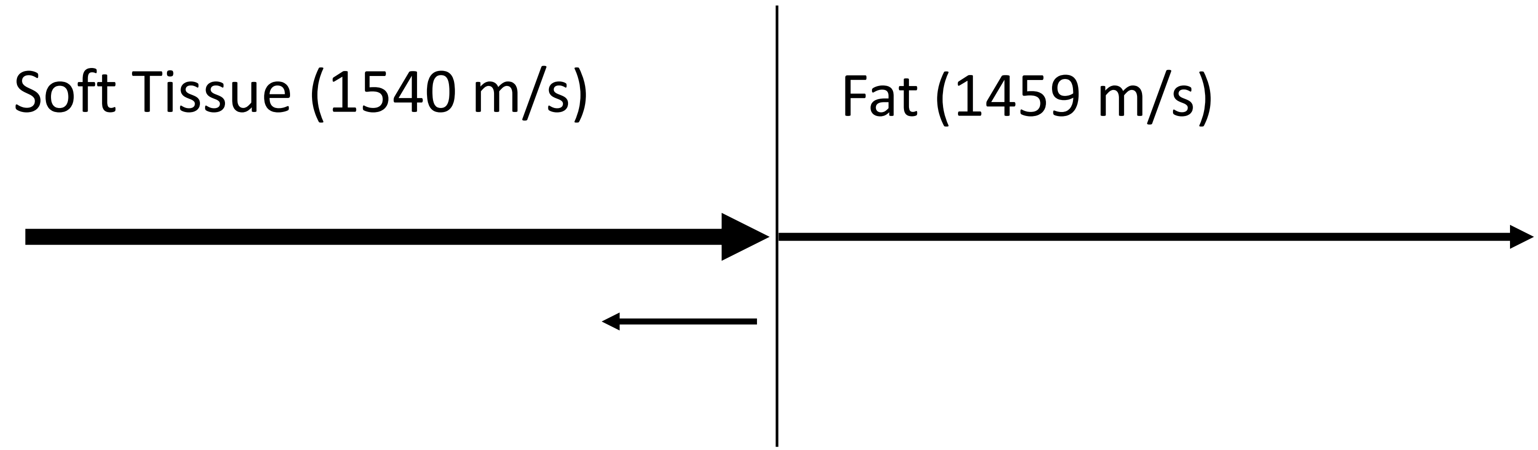

TIME
how equipment works .com


TIME
how equipment works .com

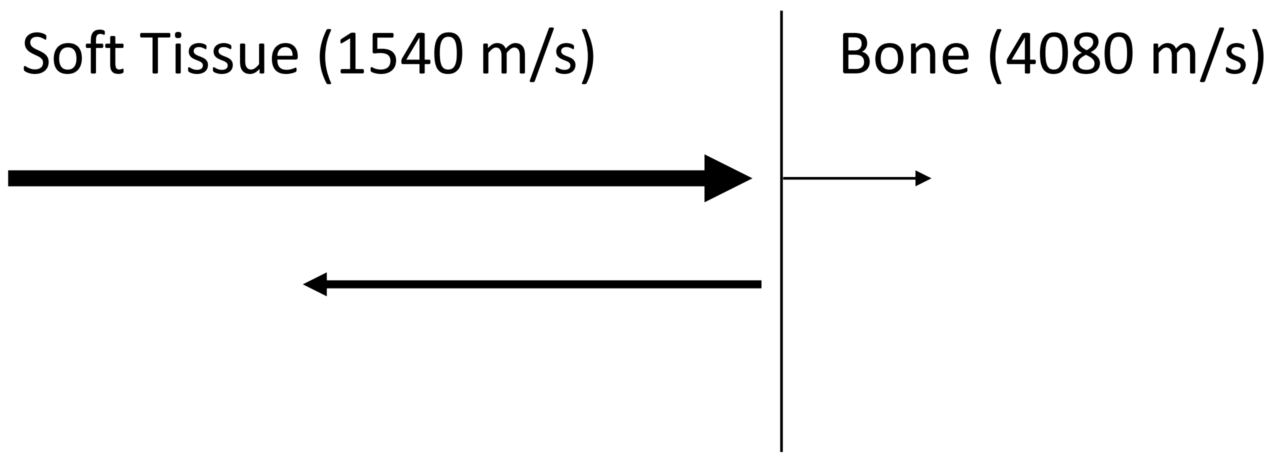


Acoustic Interface

Reflection

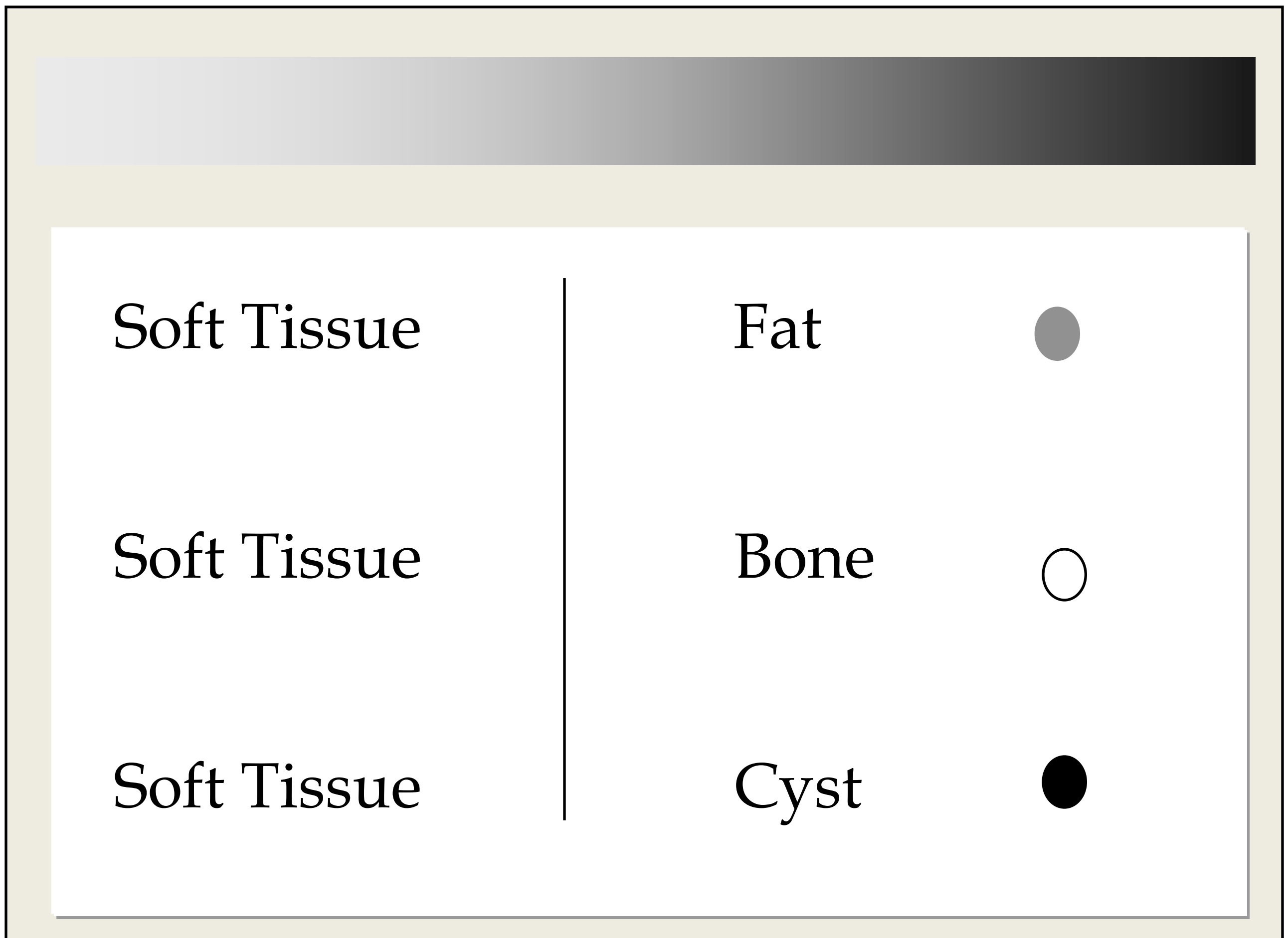


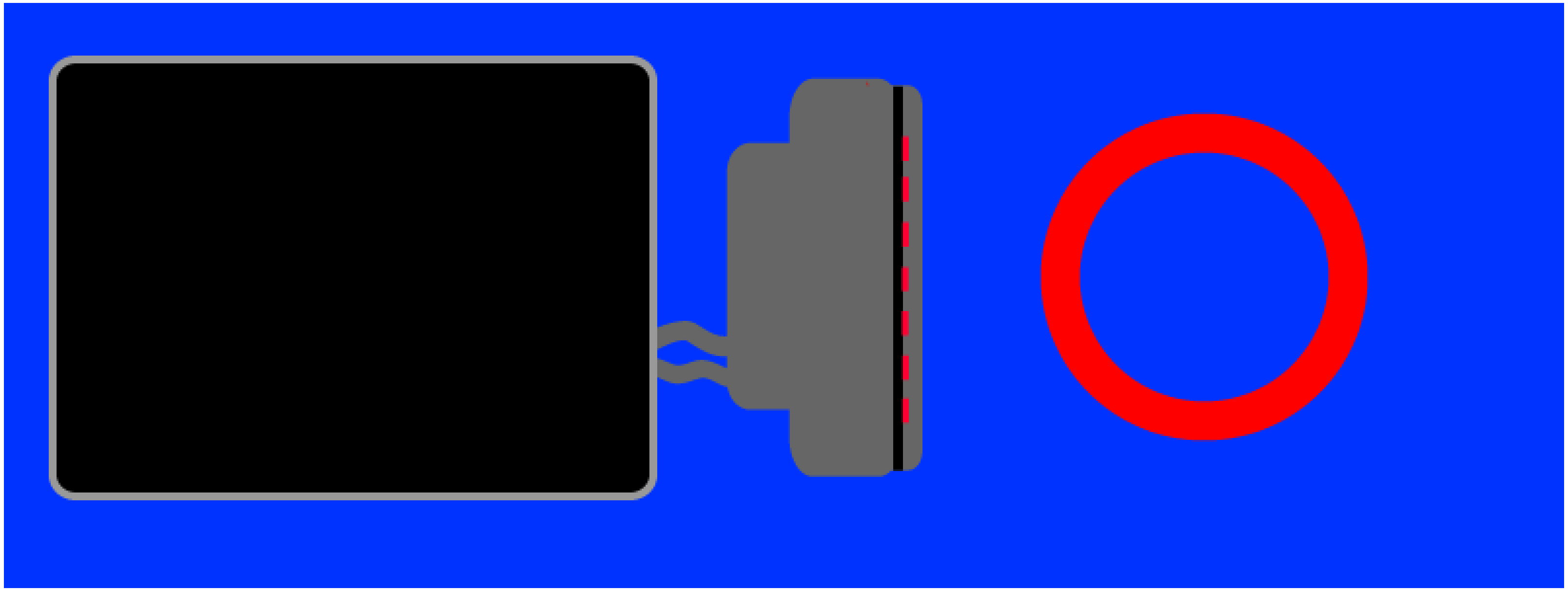
Acoustic interface / Acoustic Mismatch

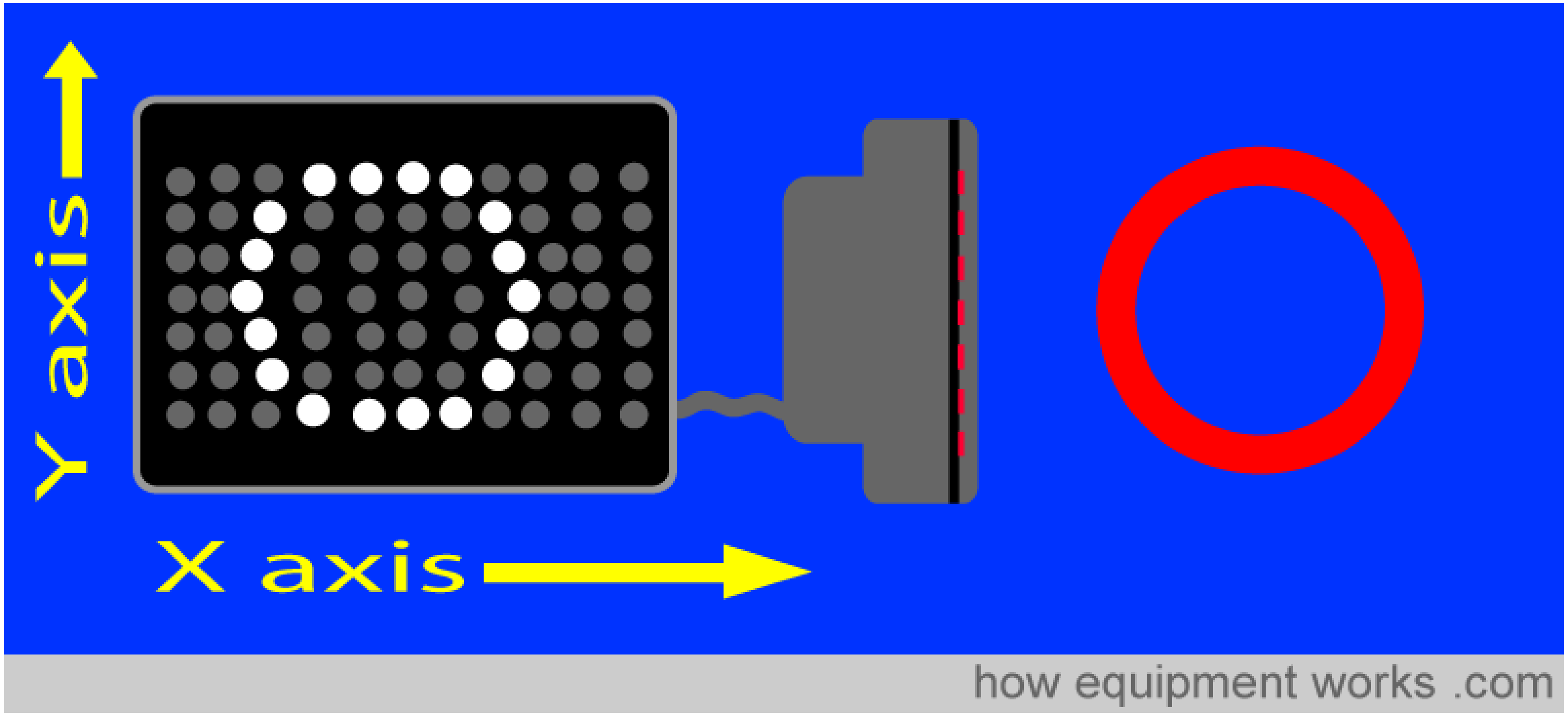


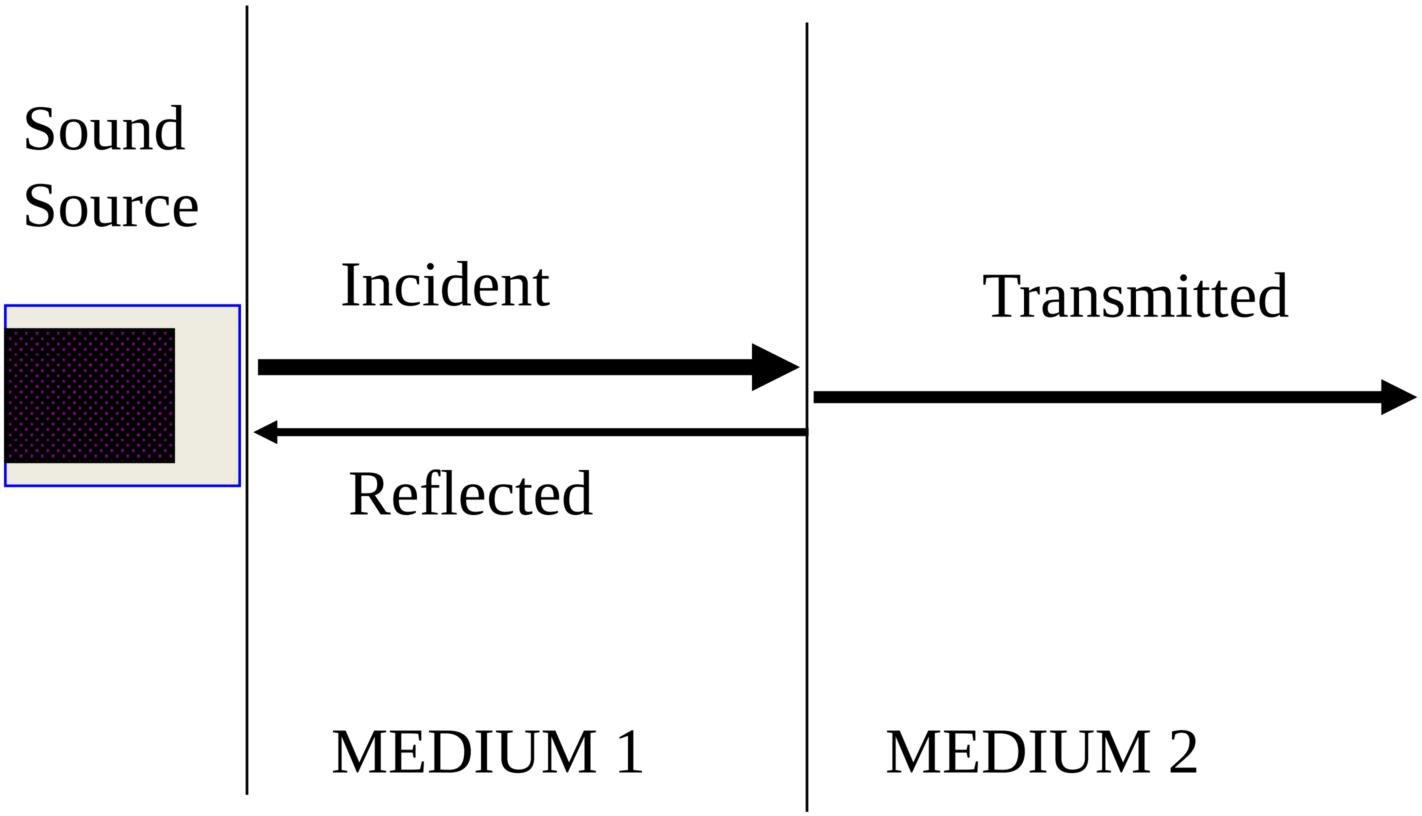
Gray Scale

B-Mode Ultrasound



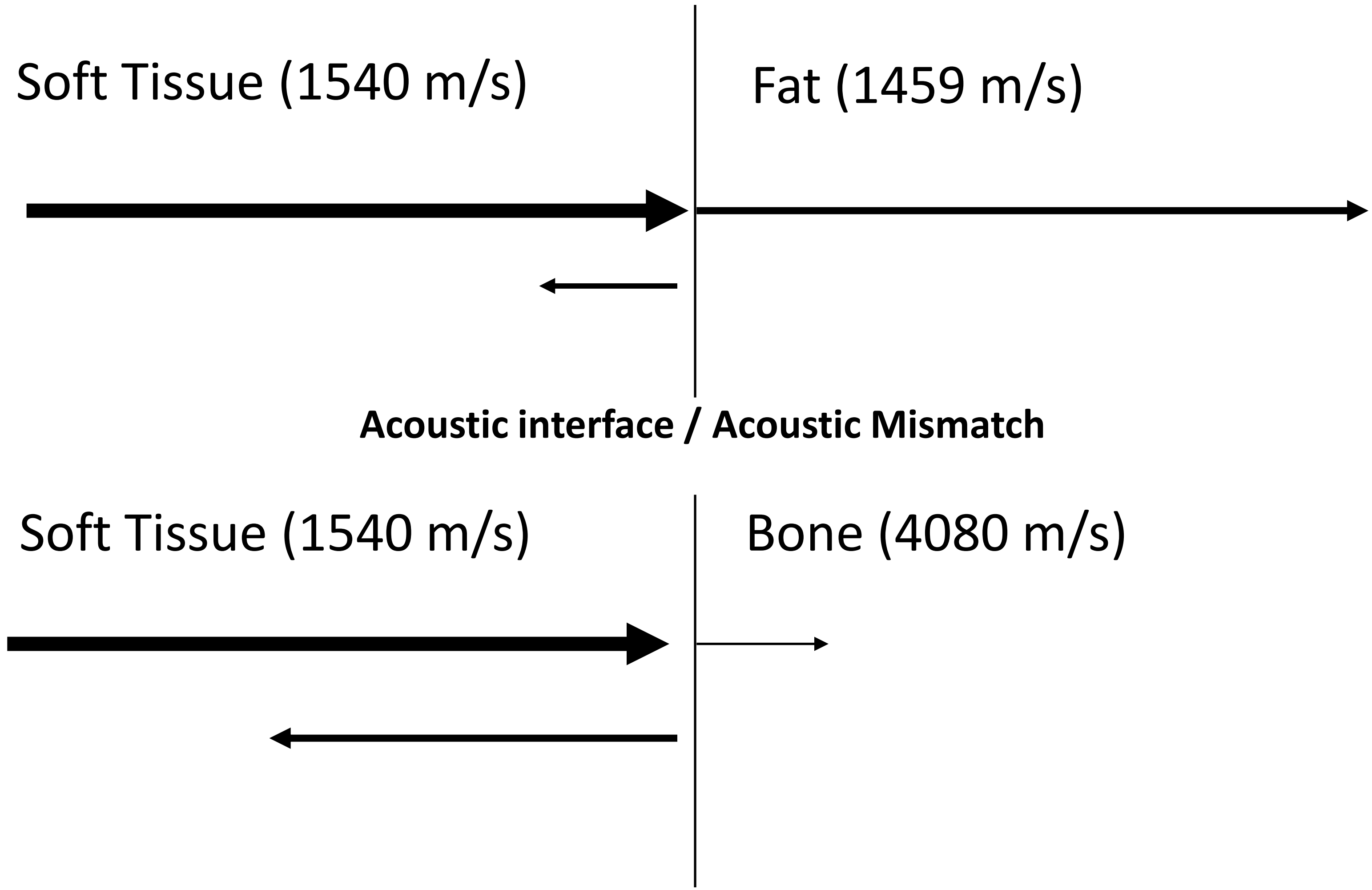



Y axis
X axis
how equipment works .com



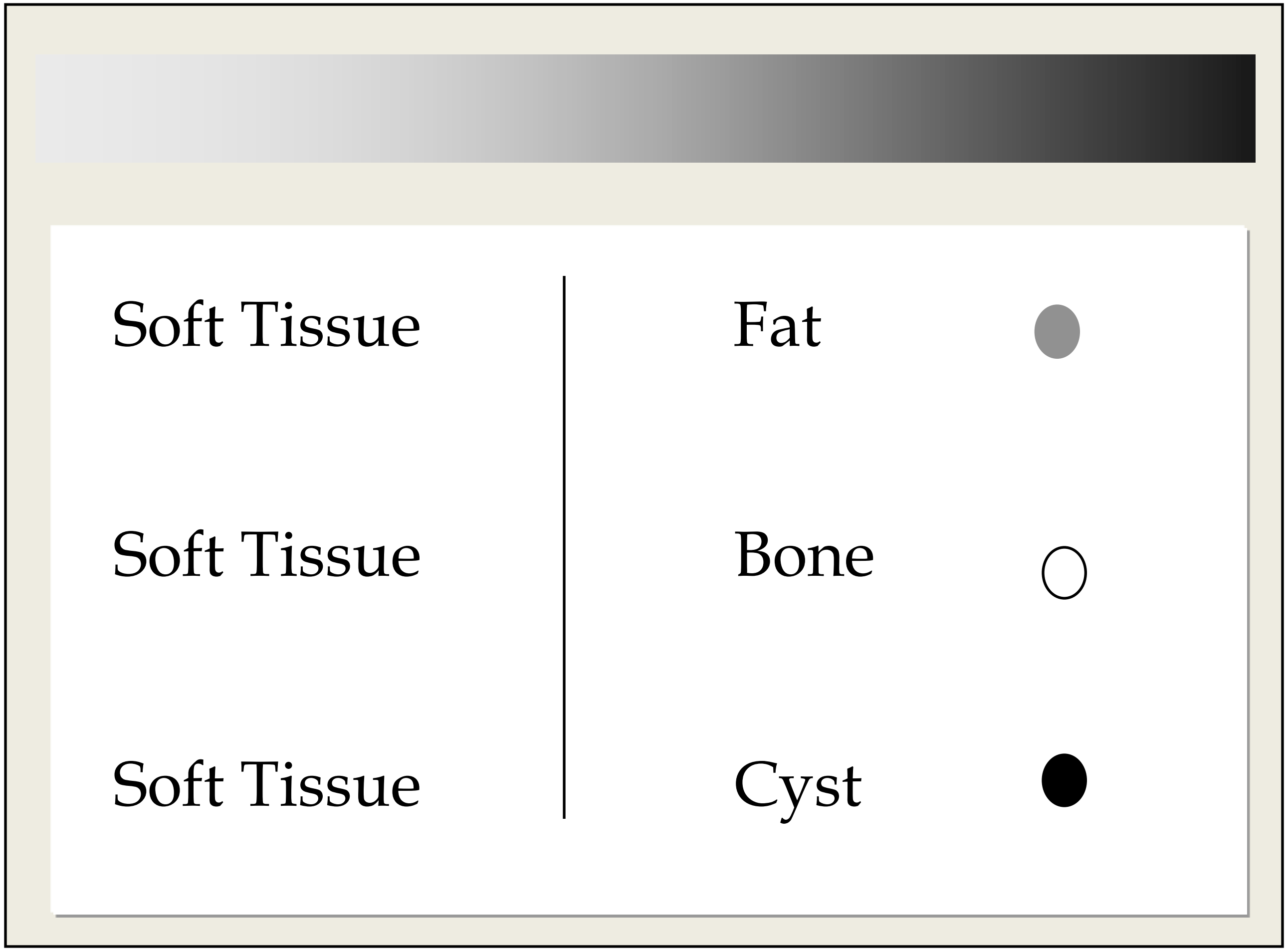
Acoustic Interface

Reflection


Soft Tissue (1540 m/s)
Fat (1459 m/s)
Acoustic interface / Acoustic Mismatch
Soft Tissue (1540 m/s)
Bone (4080 m/s)

Gray Scale

B-Mode Ultrasound



B MODE

- B stands for Brightness
- B scans give two dimensional information about the cross- section.
- Generally used to measure cardiac chambers dimensions, assess valvular structure and function.

1970

1980

2D

2D FETAL PROFILE

1990

3D

3D FETAL PROFILE

1995

4D

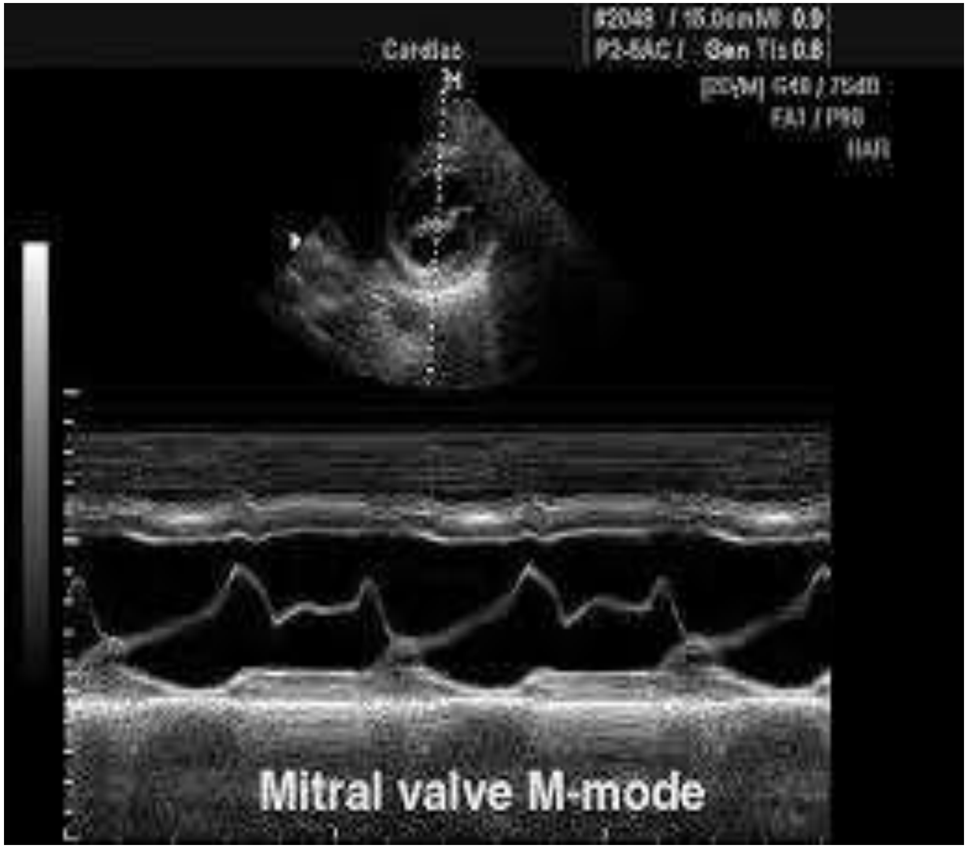
4D FETAL PROFILE

2002

Development of the B-mode Ultrasound image quality

M MODE

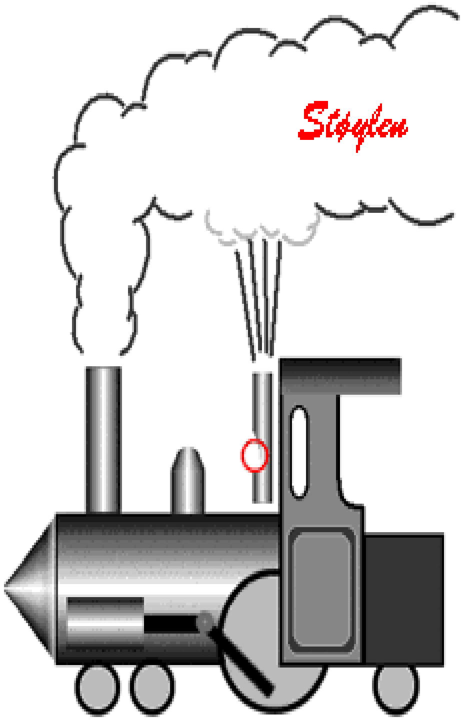
- M stands for motion
- This represents movements of structures over time.
- M Mode is commonly used for measuring chamber dimensions.
- This is analogous to recording a video in ultrasound.

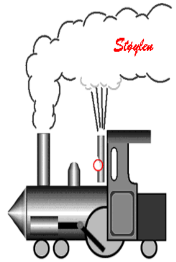


M-mode — When is it used?

- Aorta/left atrium (measurements, opening of aortic valve)
- Mitral/Prosthetic valve (type of valve)
- Tricuspid annular plane systolic excursion (TAPSE) for RV function
- Left/right ventricle (measurements, LV function)
- Endocarditis (motion of suspected vegetation)
- Mitral valve (Mitral stenosis)

Other types of M-mode	Characteristics	Application
Anatomical M-mode	Freedom of axis	Myocardial function
Color Doppler M-mode	Display time motion of color	Timing of flow (i.e. flow propagation)
Tissue Doppler M-mode	Time motion display of functional information	Deformation and myocardial velocity analysis
Curved M-mode	Color-coded segmental myocardial display format that provides information about myocardial function in various segments over time	Display of myocardial velocities and deformation parameters to obtain functional information


Støylen



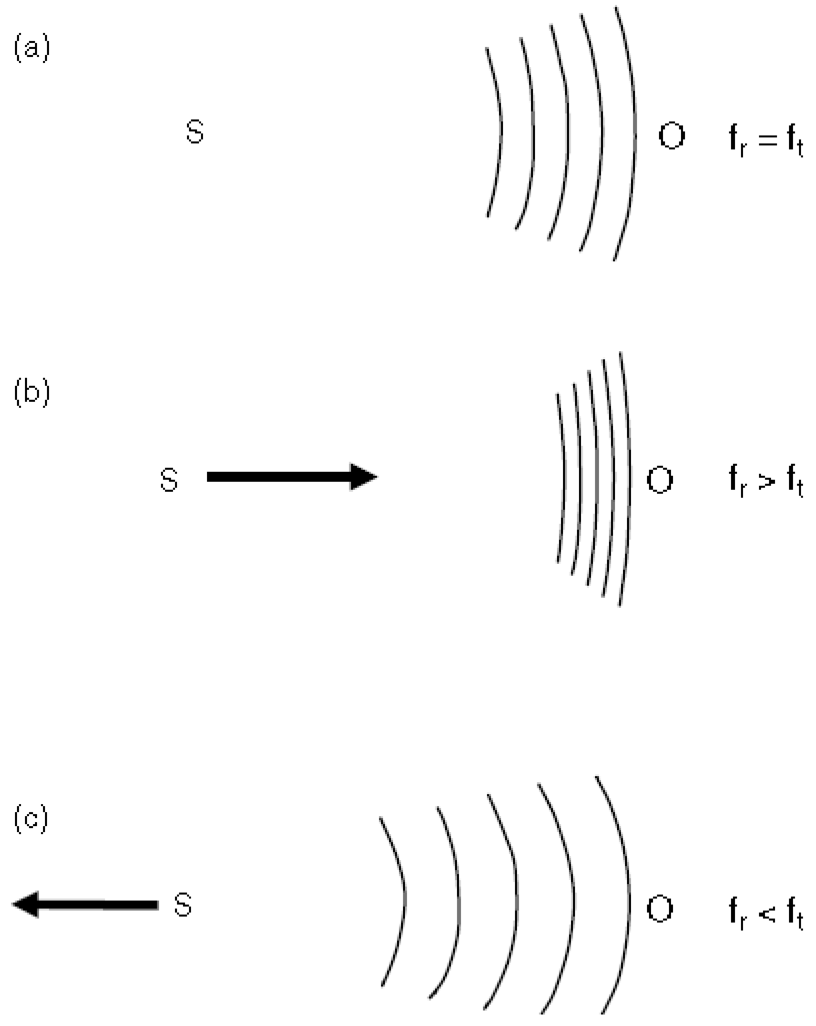
The Doppler effect

- The distance between the wave crests is decreased in the direction of the motion, and increased in the opposite direction.

- As the distance between the wave crests is equal to the wavelength, wavelength decreases (i.e. sound frequency increases) in front of the engine, and increases (sound frequency decreases) behind it.

- This effect can be heard, as the pitch of the train whistle is higher coming towards a listener than moving away, changing as it passes

Principles of Doppler ultrasound



Principles of Doppler ultrasound

- The Doppler effect enables ultrasound to be used to detect the motion of blood and tissue.

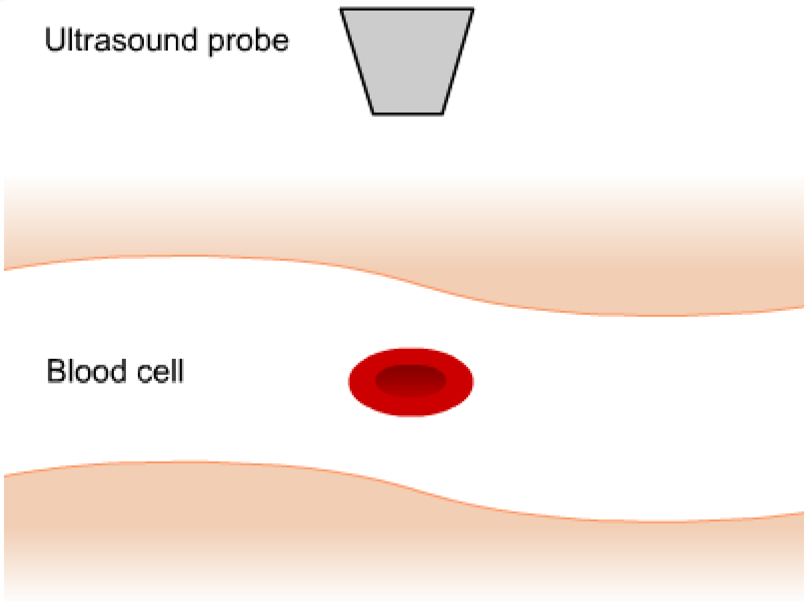
- The Doppler effect is the change in the observed frequency of the sound wave (*f r) compared to the emitted frequency (f t) which* occurs due to the relative motion between the observer and the source.

- Doppler shift frequency is proportional to the relative velocity between the source and the observer.

- It does not matter whether the source or the observer is moving. If either one is moving away from the other, the observer will witness a lower frequency than that emitted.

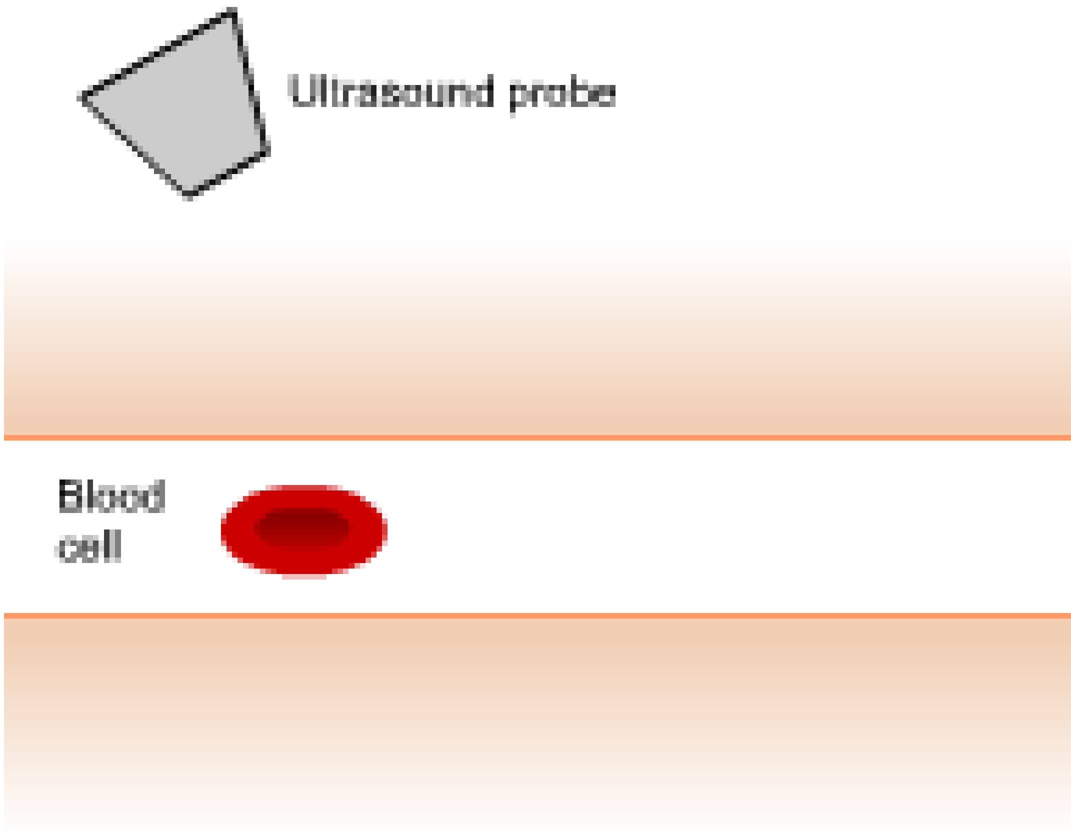
Doppler effect: change in wavelength with speed

- Ultrasound, like normal sound, is a wave.
- If a source of sound moves towards the listener, the waves begin to catch up with each other. The wavelength gets shorter and so the frequency gets higher – the sound has a higher pitch.
- We use this principle to work out how fast blood cells move. Ultrasound reflects off the blood cells and causes a Doppler shift

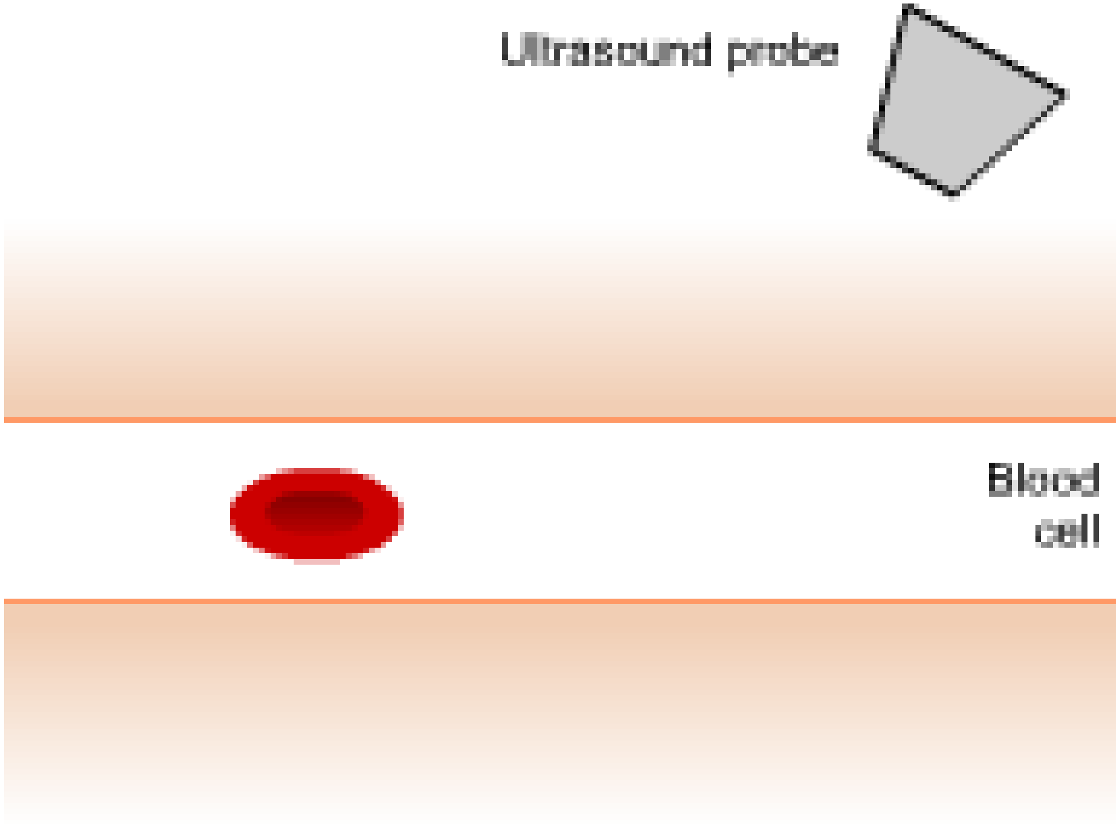


- The ultrasound probe emits an ultrasound wave
- A stationary blood cell reflects the incoming wave with the same wavelength: there is no Doppler shift

- The ultrasound probe emits an ultrasound wave
- A blood cell moving away from the probe reflects the incoming wave with a longer wavelength
- In reality, there is actually two Doppler shifts. The first one occurs between the probe and the moving blood cell (not shown here) and the second one occurs as the red blood cell reflects the ultrasound.



- Now, the blood cell moves towards the probe. It reflects the incoming wave with a shorter wavelength



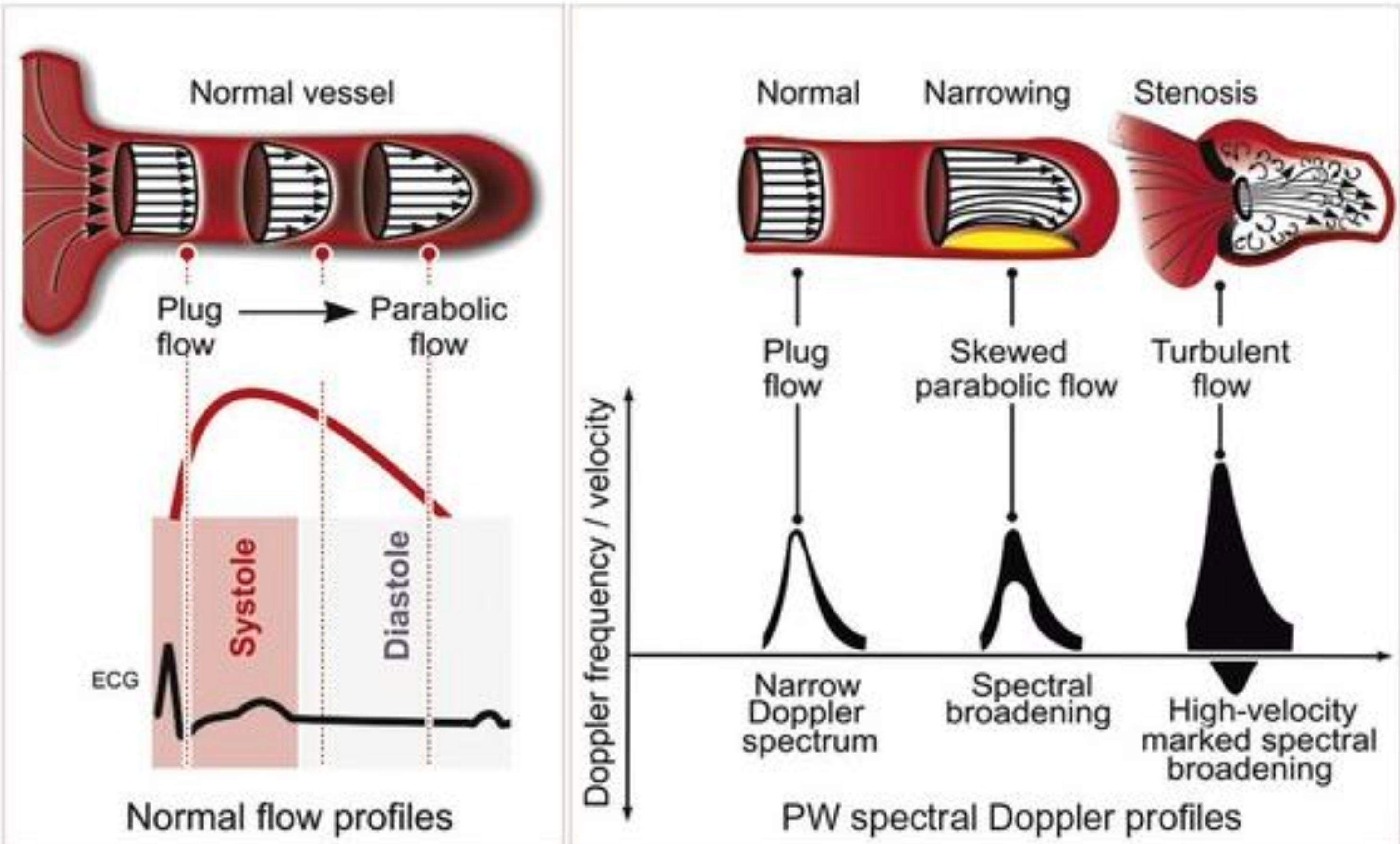
- The detected Doppler shift frequency (*f d) is the difference* between the transmitted frequency (*f t) and the* received frequency (*f r).*

- *The Doppler shift frequency f d depends on the frequency of the transmitted ultrasound,* the speed of the ultrasound as it passes through the tissue (*c) and the velocity of the blood (v)*

- The is relationship can be expressed by the Doppler equation:

$$f_d = f_r - f_t = \frac{2 f_t v \cos\theta}{c}$$

Blood Flow Profiles and Doppler Signals



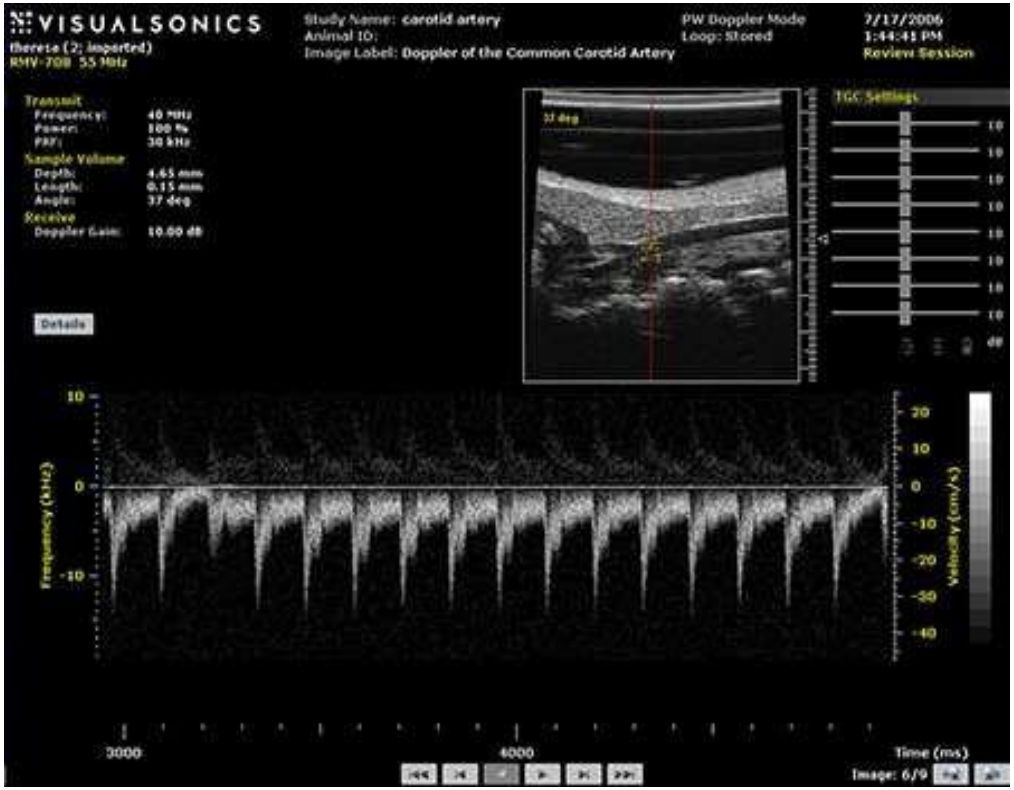
TYPES OF DOPPLER ULTRASOUND

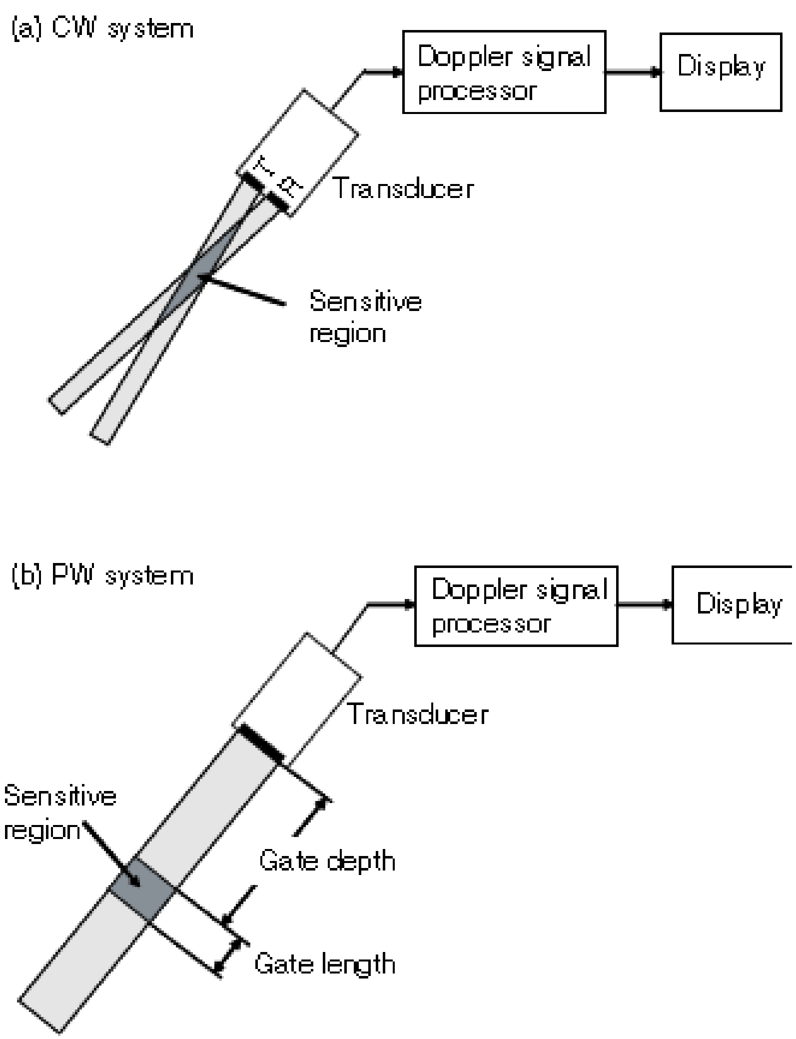
1. CONTINUOUS WAVE DOPPLER (CW)

- Uses **different** crystals to send and receive the signal
- One crystal constantly sends a sound wave of a single frequency, the other constantly receives the reflected signal

2. PULSED WAVE DOPPLER

- Produces short bursts/pulses of sound
- Uses **the same** crystals to send and receive the signal
- This follows the same pulse-echo technique used in 2D image formation.





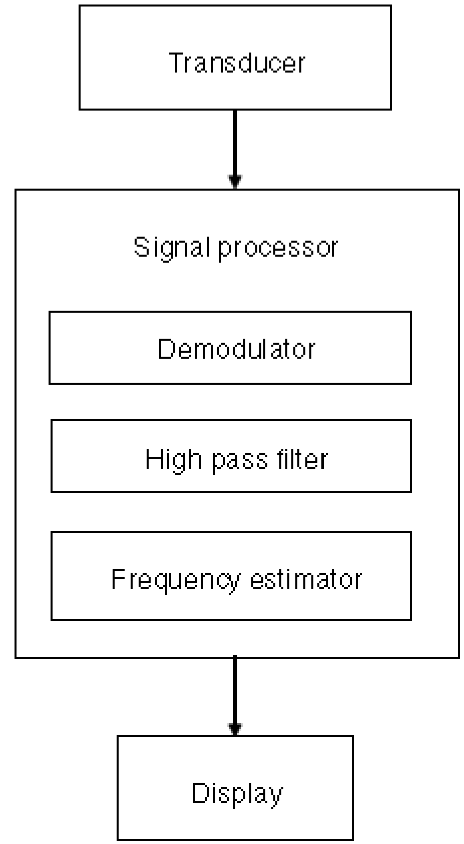
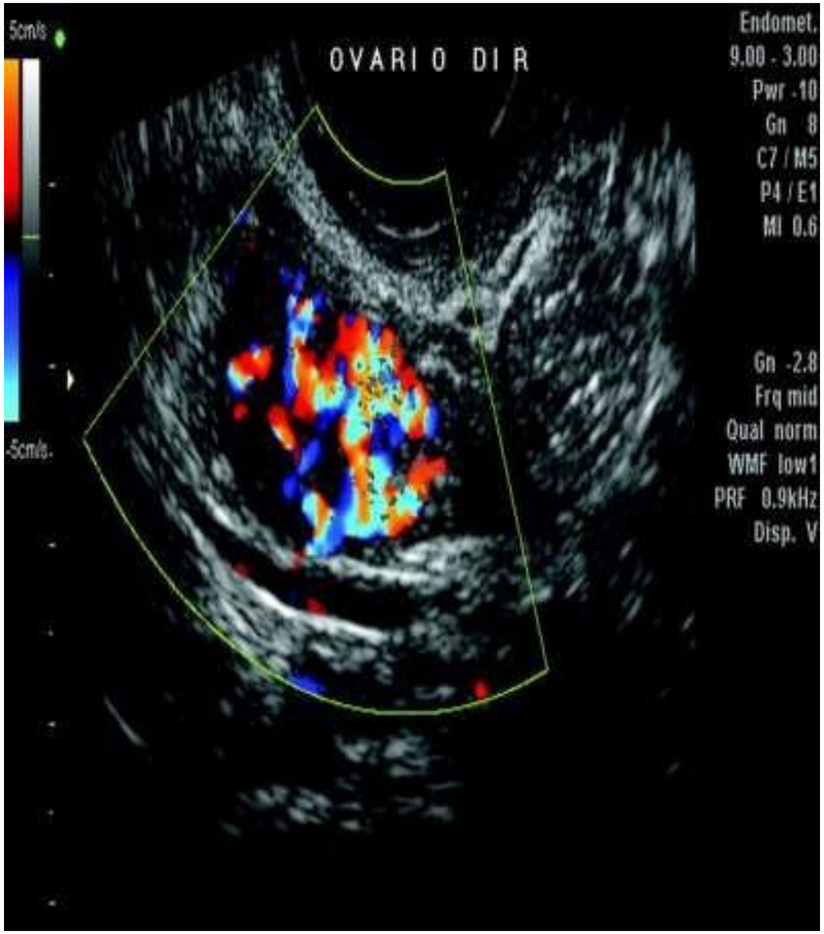


Fig. 7.8 The Doppler signal processor can be considered to be made of three parts; the demodulator, the high-pass filter and the frequency estimator.

3. COLOR DOPPLER

- Utilizes pulse-echo Doppler flow principles to generate a color image.
- Image is superimposed on the 2D image.
- The red and blue display provides information regarding DIRECTION and VELOCITY of flow.
- Used for general assessment of flow in the region of interest
- Gives only descriptive or semi quantitative information on blood flow.



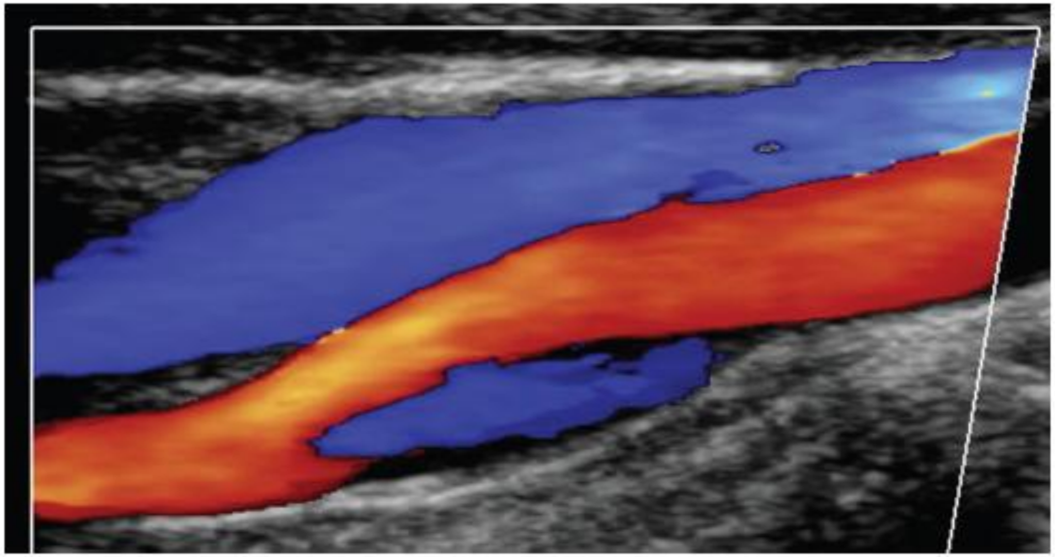
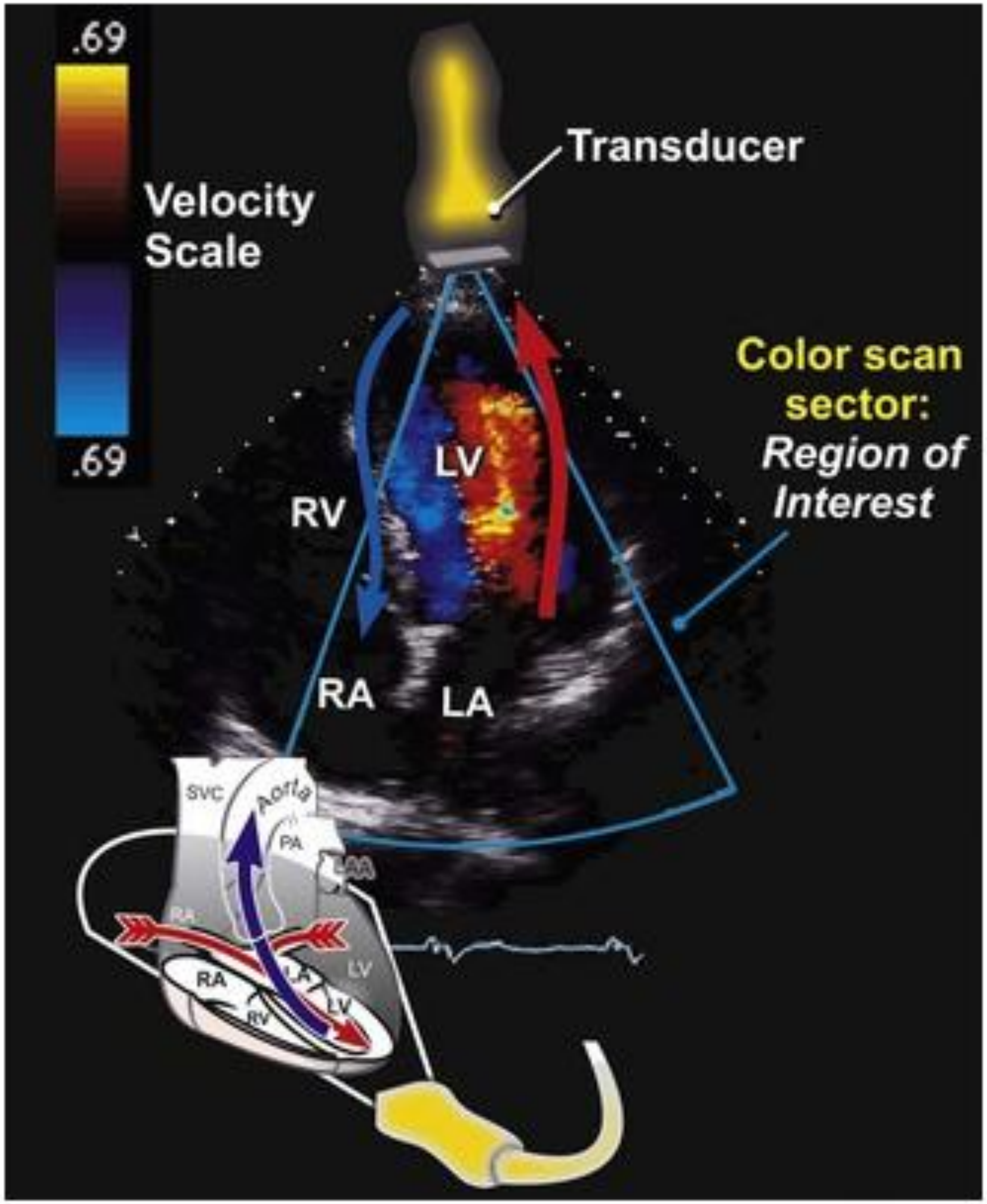
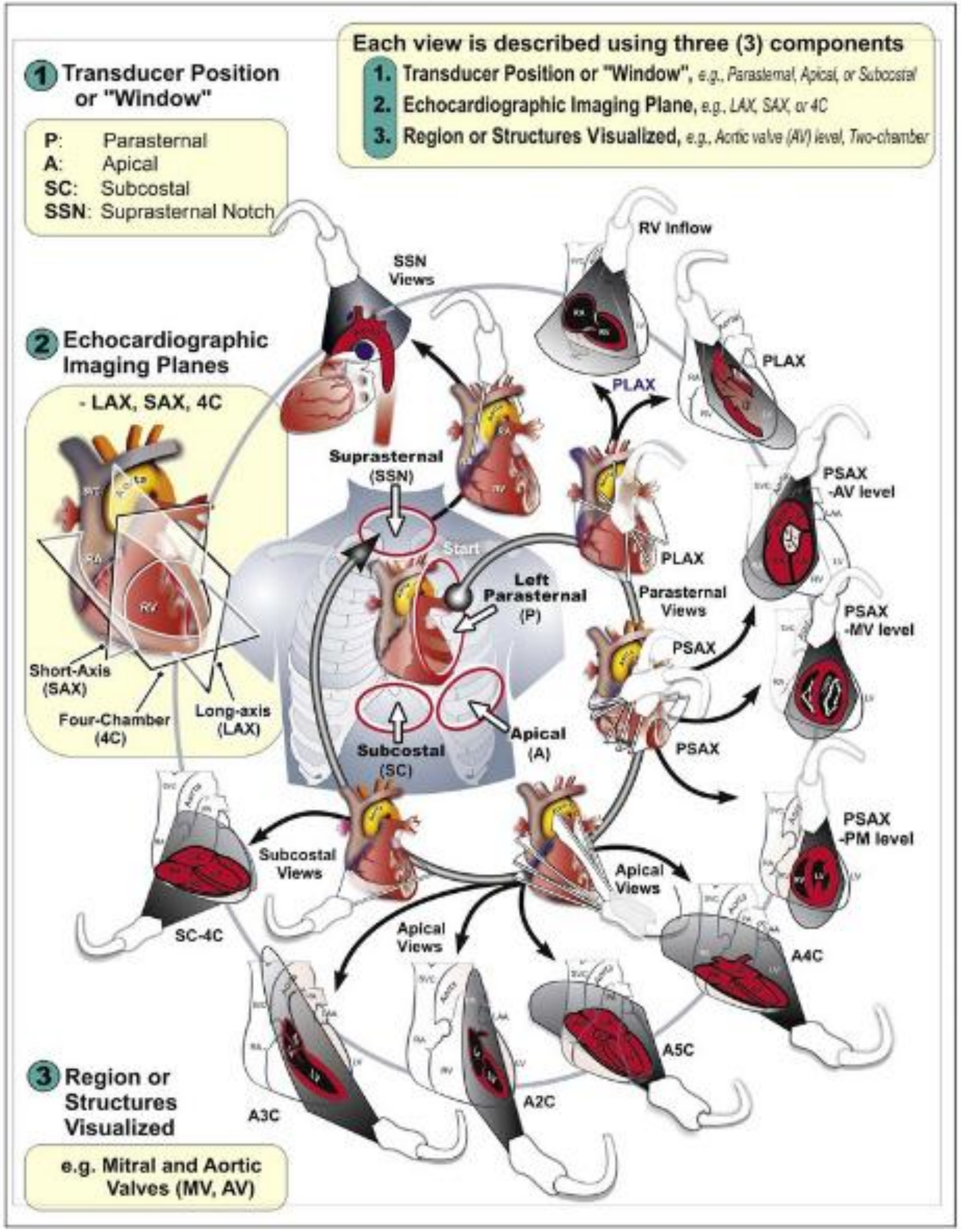


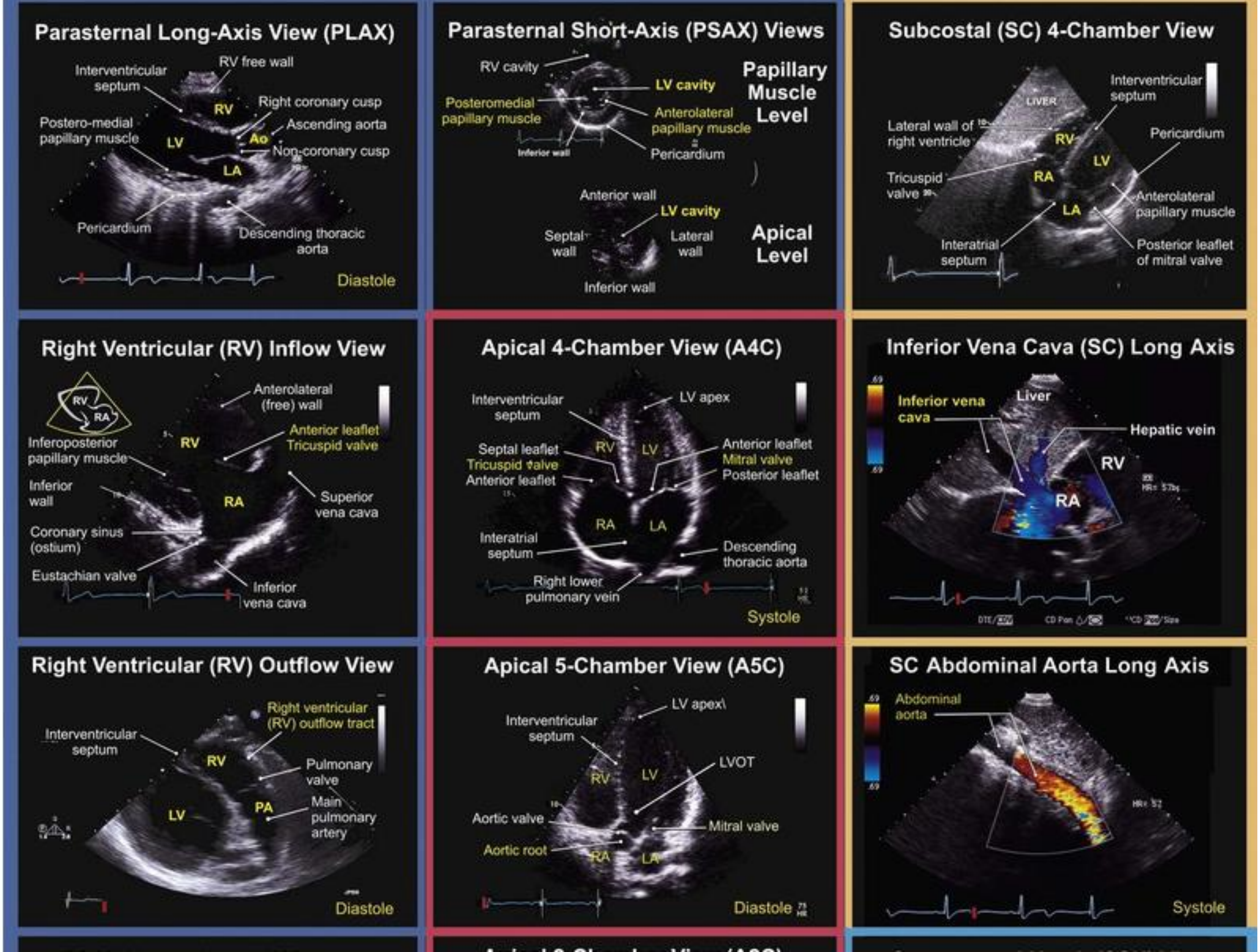
Fig. 8.3 Colour image showing flow reversal (blue in centre of image) in the carotid bulb of a normal internal carotid artery. The vein (blue at top of image) can be seen overlying the carotid artery.



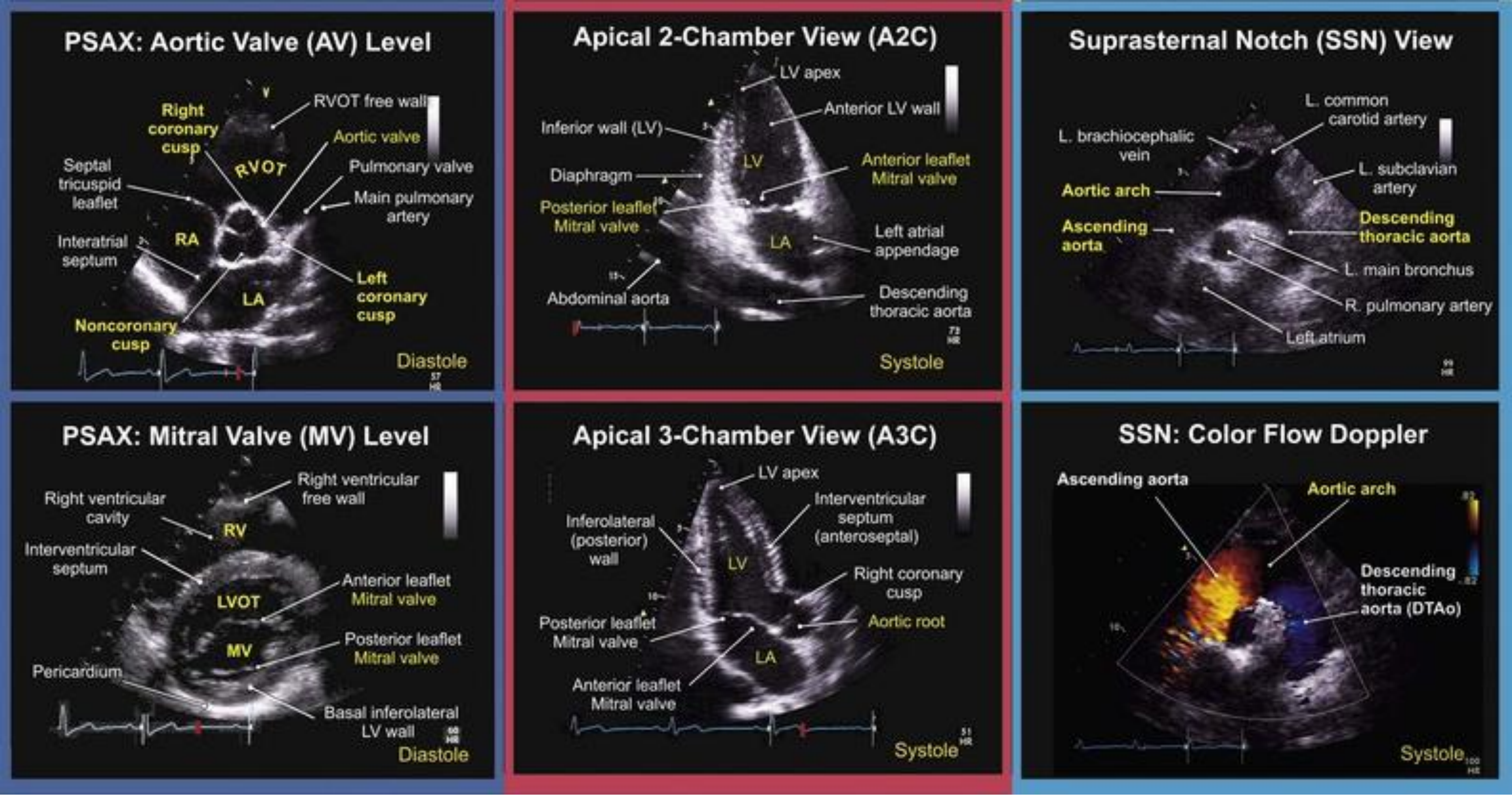
.69
Velocity
Scale
.69
Transducer
Color scan
sector:
Region of
Interest
LV
RV
RA
LA
SVC
Aorta
PA
LAA
RA
LV
RA
LA
RV
LV



Each view is described using three (3) components
1. Transducer Position or "Window", e.g., Parasternal, Apical, or Subcostal
2. Echocardiographic Imaging Plane, e.g., LAX, SAX, or 4C
3. Region or Structures Visualized, e.g., Aortic valve (AV) level, Two-chamber
1 Transducer Position or "Window"
P: Parasternal
A: Apical
SC: Subcostal
SSN: Suprasternal Notch
2 Echocardiographic Imaging Planes
- LAX, SAX, 4C
Short-Axis (SAX)
Four-Chamber (4C)
Long-axis (LAX)
3 Region or Structures Visualized
e.g. Mitral and Aortic Valves (MV, AV)
SSN Views
Suprasternal (SSN)
Start
Left Parasternal (P)
Subcostal (SC)
Apical (A)
RV Inflow
PLAX
PLAX
PLAX
Parasternal Views
PSAX
PSAX
PSAX -AV level
PSAX -MV level
PSAX -PM level
Apical Views
Apical Views
A4C
A5C
A2C
A3C
Subcostal Views
SC-4C



Parasternal Long-Axis View (PLAX)
Interventricular septum
RV free wall
RV
Right coronary cusp
Ascending aorta
Postero-medial papillary muscle
LV
Ao
Non-coronary cusp
LA
Pericardium
Descending thoracic aorta
Diastole
Parasternal Short-Axis (PSAX) Views
RV cavity
LV cavity
Posteromedial papillary muscle
Anterolateral papillary muscle
Inferior wall
Pericardium
Papillary Muscle Level
Anterior wall
LV cavity
Septal wall
Lateral wall
Inferior wall
Apical Level
Subcostal (SC) 4-Chamber View
LIVER
Interventricular septum
Lateral wall of right ventricle
RV
Pericardium
LV
Tricuspid valve
RA
LA
Anterolateral papillary muscle
Interatrial septum
Posterior leaflet of mitral valve
Right Ventricular (RV) Inflow View
RV
RA
Anterolateral (free) wall
Anterior leaflet Tricuspid valve
Inferoposterior papillary muscle
RV
Inferior wall
RA
Superior vena cava
Coronary sinus (ostium)
Eustachian valve
Inferior vena cava
Apical 4-Chamber View (A4C)
Interventricular septum
LV apex
Septal leaflet
Tricuspid valve
Anterior leaflet
RV
LV
Anterior leaflet
Mitral valve
Posterior leaflet
RA
LA
Interatrial septum
Descending thoracic aorta
Right lower pulmonary vein
Systole
Inferior Vena Cava (SC) Long Axis
Inferior vena cava
Liver
Hepatic vein
RV
RA
Right Ventricular (RV) Outflow View
Right ventricular (RV) outflow tract
Interventricular septum
RV
Pulmonary valve
LV
PA
Main pulmonary artery
Diastole
Apical 5-Chamber View (A5C)
LV apex\
Interventricular septum
LVOT
RV
LV
Aortic valve
Mitral valve
Aortic root
RA
LA
Diastole
SC Abdominal Aorta Long Axis
Abdominal aorta
Systole


PSAX: Aortic Valve (AV) Level
Right coronary cusp
RVOT free wall
Aortic valve
Pulmonary valve
Main pulmonary artery
Septal tricuspid leaflet
RVOT
RA
Interatrial septum
LA
Left coronary cusp
Noncoronary cusp
Diastole
Apical 2-Chamber View (A2C)
LV apex
Anterior LV wall
Inferior wall (LV)
LV
Diaphragm
Anterior leaflet Mitral valve
Posterior leaflet Mitral valve
LA
Left atrial appendage
Abdominal aorta
Descending thoracic aorta
Systole
Suprasternal Notch (SSN) View
L. common carotid artery
L. brachiocephalic vein
L. subclavian artery
Aortic arch
Ascending aorta
Descending thoracic aorta
L. main bronchus
R. pulmonary artery
Left atrium
PSAX: Mitral Valve (MV) Level
Right ventricular free wall
Right ventricular cavity
RV
Interventricular septum
LVOT
Anterior leaflet Mitral valve
MV
Posterior leaflet Mitral valve
Pericardium
Basal inferolateral LV wall
Diastole
Apical 3-Chamber View (A3C)
LV apex
Interventricular septum (anteroseptal)
Inferolateral (posterior) wall
LV
Right coronary cusp
Posterior leaflet Mitral valve
Aortic root
LA
Anterior leaflet Mitral valve
Systole
SSN: Color Flow Doppler
Ascending aorta
Aortic arch
Descending thoracic aorta (DTAo)
Systole

4. POWER DOPPLER

- 5 times more sensitive in detecting blood flow than color doppler.
- It can get those images that are impossible with color doppler.
- Used to evaluate blood flow through vessels within solid organs.

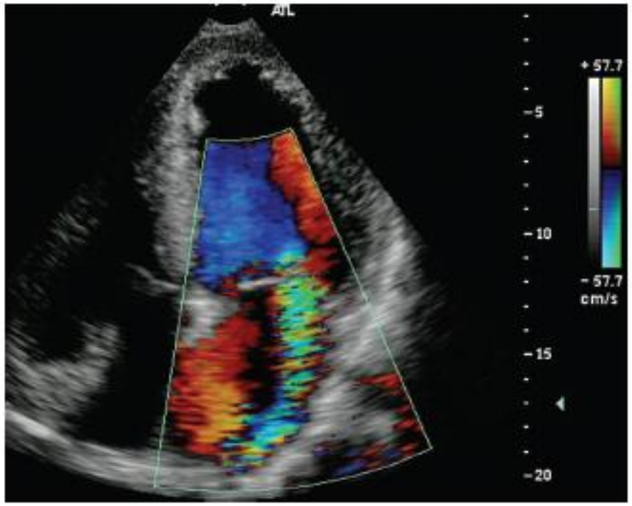


Fig. 10.10 Colour Doppler image of tricuspid regurgitation with variance admixed. Regions of green colouration associated with high variance are seen.

Fig. 10.11 Power Doppler image of arterio-venous fistulae, in which there is colour throughout the colour box.

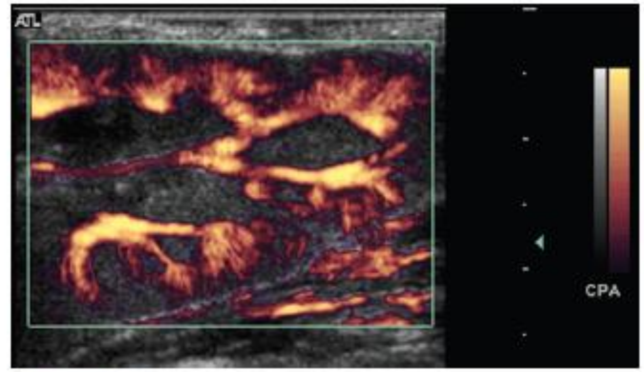


Fig. 10.12 Power Doppler image of the kidney taken intraoperatively consisting of colour superimposed on the B-mode image.

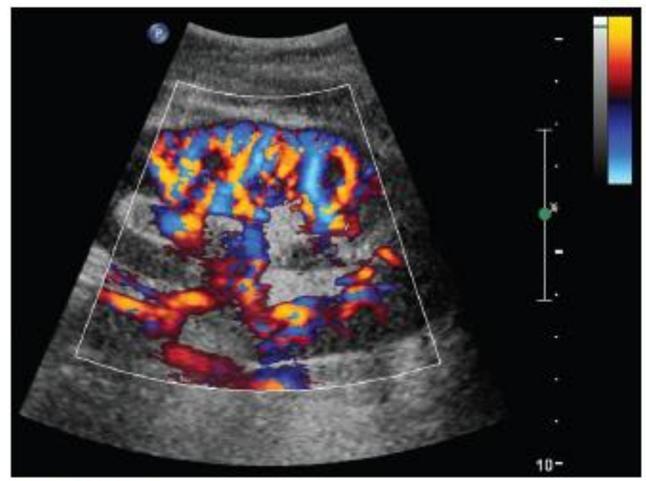


Fig. 10.13 Directional power Doppler from a transplanted kidney.

with low-signal levels. In order to make the best use of the increase in sensitivity, the first manufacturers

APPLICATIONS

- Obstetrics and Gynecology
  1. Measuring the size of the fetus
  2. Monitoring the baby for various procedures
- Cardiology
  1. Seeing the inside of the heart to identify abnormal functions
  2. Measuring blood flow through the heart and major blood vessels
- Urology
  1. Measuring blood flow through the kidney
  2. Locating kidney stones
  3. Detecting prostate cancer at early stage

RISKS

The two major risks involved with Ultrasound are:

- <u>Development of heat</u>:

  Tissues or water absorb the ultrasound energy which increases their temperature locally.

- <u>Formation of bubbles (cavitation):</u>

  When dissolved gases come out of solution due to local heat caused by Ultrasound.

BENEFITS

- Images muscle, soft tissues very well Renders “live images” where most desirable section is selected
- Shows structure of organs
- No long-term side-effects
- Widely available and comparatively flexible
- Highly portable
- Relatively inexpensive
- Spatial resolution is better in high frequency ultrasound scanners