# "Seeing" Inside the Body

*The Use of Ultrasound for Medical Diagnosis*

## 1. Ultrasound as a Diagnostic Tool…

a) Ultrasounds (high frequency sound waves) have been an important diagnostic tool in obstetrics and other areas of medicine since the 1940's. Why are waves useful for getting information about what is inside the human body, in a way that, say, using matter (an object with mass) as a probe to get that information is not?

*Note: Ultrasound can only work because sound waves reflect upon encountering an interface, which is an abrupt change in the medium carrying the sound wave. This encounter produces an echo, just as a person standing in front of a brick wall would hear an echo when he or she claps. The echo is the result of sound reflecting from the wall.*

b) Suppose you had a sensitive enough clock that you could measure the time between the sending and receiving of a sound wave. How then would you use ultrasound waves to determine the distance of a fetus from the surface of the body? What other piece(s) of information would you need to know?

## 2. All Body Parts Do Not "Sound" the Same…

*Ultrasound is a little trickier than clapping in front of a brick wall, because the body is made of bone and tissue and fat, etc. Sound travels at different speeds in each of these materials. For the brick wall to form an interface, sound must travel at different speeds in air and brick. Let's think about what it is about brick and air that are different and that therefore cause the sound to travel at different speeds in each.*

a) As you saw last week in recitation, the "springiness" of a material (its "tension") is one property that goes toward determining the speed at which waves travel through it. We also saw last week that the mass density of the material is important. In fluids or soft tissue the "springiness" of the material is described by the bulk modulus $B$, defined as $B = -\dfrac{\Delta P}{(\Delta V/V)}$, where $\Delta P$ is a change in pressure and $\Delta V/V$ is the corresponding proportional change in volume. Does a large bulk modulus correspond to more or less "springiness"?

b) The mass density in fluids or soft tissue is just the density $\rho = m/V$. Working by analogy from last week's result for the speed of a wave on a string, find the expression for the speed of sound in a fluid or soft medium, expressed in terms of

*B* and $\rho$? If you like, you can also find this expression using dimensional analysis!

The following table shows some densities and sound speeds through different parts of the human body:

| Tissue | v [m/s] | ρ [kg/m$^3$] |
|---|---|---|
| muscle (along fibers) | 1576 | $1.058 \times 10^3$ |
| muscle (across fibers) | 1592 | $1.058 \times 10^3$ |
| Liver | 1570 | $1.055 \times 10^3$ |
| Kidney | 1560 | $1.055 \times 10^3$ |
| Brain | 1520 | $1.032 \times 10^3$ |
| Fat | 1476 | $0.928 \times 10^3$ |
| Bone | 3360 | $2.32 \times 10^3$ |
| air | 343 | 1.205 |

Table 1. from *Diagnostic Ultrasound*, Matthew Hussey, Blackie & Son Limited (London, 1975).

c) When a pregnant woman undergoes an ultrasound procedure, a gel is often applied to the woman's abdomen prior to applying the ultrasound paddle device. Looking at the last row in the table above, why do you think that such a gel might be useful?

d) Now that we have a sense of the relevant factors involved in performing an ultrasound, let's put the pieces together. Combine the information in the table above with the time elapsed between the sending and receiving of ultrasound signals to explain how a 2-dimensional image of a fetus is formed. What other information, if any, might one want to have?

e) Pregnant women are often asked to drink a large amount of water prior to getting an ultrasound. Why do you think that is?

## 3. Low-tech Ultrasound…

You have probably had a physical at the doctor's office. One examination method used in a routine physical is "percussing". The doctor listens to the echoes to identify different density regions in the body. Give it a try if you like: Stand up. Place two fingers of one hand on the side of your abdomen, preferably where there is a cavity. Tap these fingers with two fingers from your other hand. (Physicians use one finger from each hand, but they are better at this procedure than most of us). Move your fingers to a higher position that is more filled. Is there a difference in what you hear?