Since I've started writing powerpoint lectures, it seems that writing detailed *additional* lecture notes (like I did for Chapter 1) may be superfluous. Here, just a brief summary and comments about the lecture on Chapter 2. (The powerpoints of individual lectures should serve as my lecture notes in the future!) But at least for this week, I'll continue with Key Chapter 2 points I want to emphasize:

Chapter 2 zooms in on period and frequency. These refer to any periodic signal, something which repeats itself with a well defined period (time). The signal can be smooth and simple (a "perfect sine wave", like you see in Fig 2.12a) or a more complex but repetitive signal (like the ones in Fig 2.4 and 2.5 of the text) We already talked about these in the last chapter:

Period is the time to get back to where you started, the time for a "cycle".
Frequency is 1/Period, it's the inverse, the number of cycles in a second.
(Frequency is measured in Hz, 1 Hz = 1 cycle/sec)

Humans can hear periodic pressure waves from roughly 20 Hz to 20 kHz (kiloHz => 20,000 Hz) This depends, of course, on your age, the loudness, etc.

The text goes on to write down one of the most important relationships in any study of waves, one which we will get to towards the *end* of covering Ch. 1 and 2, rather than the beginning. (Although I discussed wavelength in Ch. 1 notes, I've put it off in lecture to the end of the second week, that's why we won't see this formula until probably the end of week 2)
It's the statement that wavelength * frequency = speed (for any wave)
Or, in symbols, $\lambda f = v$

It's important to understand WHY this formula is true. Try to picture a wave (a water wave might make the most direct visual image?)... You can think of it in various ways. E.g., you could zoom in on one point, where you will see the water bob up and down at the frequency f. Or, you can take a more holistic view, and watch the waves traveling along in front of you. (Focus on a "peak" or crest - it will move along in space, traveling outwards.) Or, you could take a snapshot - which does not pick one point in space, it picks one TIME. You will see a "wave" pattern, with peaks and troughs. The distance between one peak and the next is λ, the wavelengh. Now let the snapshot "run" like a movie - you will see the wave move, the crest will slide along...

How long does it take for one crest to "slide over" one wavelength, λ? Think about it - it's exactly one period of the wave! (Watch the "destination spot" carefully, the place where the peak is heading to, the "next peak over". This spot starts high, but of course if you're focusing on ONE SPOT, it then goes low, and then gets high again... in exactly one period. That's how long it takes the wave to move a crest over to the next crest!)
So the peak has moved a distance λ in one period. The speed it travels is
Distance/time = λ/Period = $\lambda * f$.
Again, $v = \lambda f$...

This formula is generally true for any wave. They travel with a speed given by wavelength (distance from peak to peak) divided by period (TIME from peak to peak) For sound, v = 344 m/s at 20 C, and we discover that wavelength and frequency of sounds are *related*. If you wiggle something faster (higher frequency), the wave that you produce will have a smaller wavelength. Plug in numbers - for "typical, human" kind of frequencies (a few hundred Hz), the wavelength is on the order of meters, a "typical, human" kind of distance! (Coincidence? Maybe not, as we'll see when we think about how sounds are produced)

You can look at more complex waves, that aren't beautiful "sin" waves, and still they have a definite period, and they have a definite wavelength (the distance from peak to peak, or from any "equivalent point in the shape" to the next one...) And again, you'll find λ f = speed!

Oscilloscopes are great tools for studying sound, because it's easy to build a microphone (a little flexible membrane that wiggles as the air pressure on the outside wiggles, and an electric sensor to measure that flex.) The pressure wave is thus converted to an electrical wiggle, and the scope shows the electric signal as a function of time. So you can "see" visually what the pressure is doing as time goes by. This image is called a "**waveform**". These are very characteristic - you can (with practice) recognize the waveform of a violin, an oboe, etc. We won't do that, although we will analyze waveforms more carefully to see what they tell us about the *character* of the sound. Generally, more complicated (but periodic) waveforms sound "richer" to our ears. (But not always, it's subtle! We'll come back to it)

Vibrations generally have a period, they arise from a repetitive motion. Sometimes people call repetitive motion "harmonic motion" (a lovely name, which makes me think of music). The simplest kind of harmonic motion is the "sin wave" shown in Fig 2.12, this is called, naturally, "simple harmonic motion" (I'll abbreviate that SHM). The cool thing is that MANY OBJECTS which can vibrate tend to vibrate in this simple way! The smaller the vibration, the more closely most motion resembles SHM. It's a remarkable fact of nature, one which you can make sense of with a little more physics and calculus than I want to get into... but it's plausible. Look at vibrating objects: a whacked ruler, a swinging pendulum, a vibrating guitar string. They go back and forth smoothly and steadily, "position vs time" looks like Fig 2.12a!

SHM arises if there is a force pulling the object "back to equilibrium" (back to the middle.) The whacked ruler "wants" to be straight. If it's bent up, the force on it pulls it down. If it's bent down, the force on it pulls it up. The farther it's bent, the MORE force there is pulling it back. If this "restoring force" (the force pulling it back to the middle) grows linearly with displacement (i.e, if by moving it twice as far away from equilibrium, it feels a force twice as big pulling it back), then the object will undergo SHM (Easily provable with a little more math than we need here, but if you like this kind of stuff, I'll point you to the chapter in *any* intro physics book that works out the details!)

Here's an especially interesting, surprising, and important thing about SHM (simple harmonic motion). If you take such an object and whack it harder (so it starts off with MORE displacement away from the equilibrium, or "middle" point), what happens to the TIME it takes to get back to where it started? It has farther to go, but it will feel a bigger force.. So even though it has farther to go to get back to the middle, it feels a bigger force (which means it goes FASTER to get there). These two things "cancel" (*exactly,* surprise!) so that the amount of time it takes to get back to where you started is *always the same*.

Thus - any object which undergoes SHM (MOST objects!) will have one special, well-defined period: the time it takes to go through a vibration. That means there's one *natural frequency* for most objects. This is why instruments work so nicely! A string has a single natural frequency. Strum it soft or hard, fast or slow - you hear that one tone, that one frequency. To change the tone, you must change the *nature* of the object. If you make it "stiffer", it will vibrate faster, frequency goes up. If you make it "heavier" (more mass, inertia, sluggishness), it will vibrate more slowly. This is how you adjust your instrument to play different notes... you change the length of the string, or the mass, or the tension. Those things matter, but how LOUD you play does not! (Loudness, remember, is all about amplitude, and the whole point here is that the frequency does not depend on amplitude, that's the magic of the SHM)

Look back at Fig 2.12. These figures might represent MANY different physical things. Think, to be specific, of a mass bobbing up and down on a spring. Simple harmonic motion! The position of the mass (the "displacement from the middle", or "displacement from equilibrium") goes up, then back to zero, then down to a minimum, than back to zero. Over and over. That's graph 2.12a. The vertical axis ("y") shows where the mass is. It goes high, then low, always bobbing around the middle or "equilibrium" point. If there's not much friction, this can go on for a LONG time. The time it takes to go from one "peak" to the next (one "cycle") is, as always, called the "period". The distance you travel from the middle to the max is called the "amplitude". If the spring swings far up and down, it has a big amplitude motion. Note that the amplitude has NOTHING to do with the period! (We just argued this above, it's the "surprise" of SHM. If you pull the mass farther from equilibrium and let go, the amplitude is bigger, but the total time it takes to get through a cycle, the period, is the same as before!)

The next graph down is TOTALLY different (even though it looks the same). It's a shame that the author made it look *so* similar to the one above, because it doesn't need to, and shouldn't be. The horizontal axis is different, this is NOT a graph of "position vs time". In fact, this graph has nothing to do with graph a, it's a picture of a wave!! So why did he line them up like that? To remind you that SHM and waves are intimitely related, I guess!

The second graph is just a snapshot of a wave. Think of a water wave traveling through the water, and you get down near the water surface and take a picture. Some spots are high, some are low. This is a snapshot, time is FIXED in this picture. You can see the distance from one crest to the next, remember we call that λ (wavelength). That's the horizontal distance, how far do you go from side to side to get from one peak to the next. The VERTICAL distance (from equilibrium to the peak) is called the "amplitude". It tells you how tall, or "strong" the wave is. These two quantitites are unrelated. (Imagine stretching the curve vertically, by hitting the water harder. The peak height of the wave would go up, but there's no reason at all to expect the wavelength to change!)

The last figure is like a "time lapse" of the one above. Waves travel, the peak moves one λ in a time given by 1/f (the period, one over the frequency), where (remember!) λ f = speed. And now we get another connection between the graphs. If a wave travels by you, and you focus on ONE spot, one position ("x"), you'll see the water go up, and down, up and down. The height of the wave, at that one position, is just like figure a, it's simple harmonic motion, with the same amplitude and frequency as the wave has...

It might help you to go to
http://www.colorado.edu/physics/phet/simulations-base.html
and look for "wave on a string". There, you can play with a rope, watch a wave travel, change the tension (which changes the frequency, and speed! That's different about ropes and air - you CAN change the speed of a wave on a string, but you're stuck with 344 m/s in air)
Just play a little, figure 2.12 will probably make a ton more sense if you can see it in action! Watch the individual spots on the string (colored green). Notice that they go up and down (not sideways!) Their motion, if you just focus on one of them, is simple harmonic motion, up and down, with the same period and amplitude as the wave itself!