Using textbook pg 111-118, identify the terms and concepts & answer the questions associated with the auditory sensations.

- **Sound**: A repeated fluctuation, a rising and falling, in the pressure of air, water, or some other substance called a medium.
- **Waveform**: Representation of sound in two dimensions (although sound moves in all directions).

### Physical Dimensions of Sound (pg 111-113)

<table>
<thead>
<tr>
<th>Define:</th>
<th>Wavelength</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference b/w the peak &amp; baseline of a wave form.</td>
<td>The distance from one peak to the next in a wave form.</td>
<td>The number of complete waveforms, or cycles, that pass by a given point in space every second.</td>
</tr>
</tbody>
</table>

### Psychological Dimensions of Sound (pg 111-113)

<table>
<thead>
<tr>
<th>Define:</th>
<th>Pitch</th>
<th>Timbre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determined by the amplitude of a sound wave.</td>
<td>How high or low a tone sounds. Determined by: Frequency</td>
<td>Mixture of frequencies &amp; amplitudes that make up the quality of sound.</td>
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</table>

1. **Work of the Accessory Structures**: (pinna, tympanic membrane, malleus, incus, stapes, oval window)
   - Sound waves are collected in the outer ear beginning with the pinna.
   - The **pinna** funnels sound down through the ear canal.
   - Sound waves reach the middle ear where they strike the **eardrum** or tympanic membrane. The sound waves set vibrations here.
   - The vibrations of the tympanic membrane are passed on by a chain of 3 tiny **ossicle bones**: the **malleus** (or hammer); the **incus** (or anvil); and the **stapes** (or stirrup). These bones amplify the changes in pressure produced by the sound wave: focuses the vibrations of the **tympanic membrane** onto a smaller membrane known as the **oval window**.

2. **Transduction**: (cochlea, basilar membrane, hair cells, organ of corti)
   - After sound vibrations pass through the oval window, they reach the **cochlea** at the inner ear. This is the structure responsible for auditory transduction. Unwrapped, the cochlea contains a fluid filled tube.
   - At the bottom of the fluid filled tube in the cochlea is the **basilar membrane**. When sound waves pass through the basilar membrane it bends hair cells of the **organ of Corti** (a group of cells that rest on the membrane). The hair cells connect with fibers from the **auditory nerve** (a bundle of axons that go to the brain).
   - When the hair cells bend, they stimulate the neurons in the auditory nerve to fire a pattern that sends the brain a coded message about the amplitude and frequency of the sound waves. This information is sensed as loudness & pitch.

3. **The Role of the Primary Auditory Cortex**:
   - The auditory nerve that connects to structures in the brainstem, and to the thalamus. After preliminary processing, the sound information is relayed to the primary auditory cortex (which lies in the temporal lobe). Here the information about sound is subjected to complex analysis. **The auditory cortex is also activated by imagining sound (hearing a song in your head or during auditory hallucinations that accompanies certain mental disorders).**
   - Each part of the cortex processes certain types of sound. For example, one area is specialized in responding to human voices, while others are responsive to sounds made by musical instruments, etc.
   - The primary auditory cortex also receives information from other senses as well. It is activated when you watch someone say words.
4. **Sensing Pitch**: (116)
   1. Why is sensing pitch difficult for humans?
      Sounds are made up of a mixture of frequencies.
   2. How does culture play a role in how humans sense pitch?
      *It is not exactly clear, but ambiguous scales are viewed as progressing in one culture and the opposite in another culture.*

5. **Locating Sound**: (116)
   1. How does the brain analyze location of sound?
      *It is based on the very slight difference in the time at which a sound arrives at each of the ears. The intensity will allow a human to recognize how close the sound is even if the source can’t be seen.*

**Auditory Coding**: (116-118)
- How does the auditory system generally code intensity of sound?
  *The more intense the sound the more rapid the firing of a given neuron.*

- **Coding Theories**
  1. **Place Theory**: says we hear pitch based on WHERE on the basilar membrane the hair cells vibrate.
     a. What type of sensory coding does place theory describe?
        *Spatial (place-related) code for frequency.*
     b. Using this theory, how can a person lose their ability to hear sounds of a particular frequency?
        *Extended exposure to a very loud sound of a particular frequency can destroy hair cells at one spot on the basilar membrane, making it impossible to hear sounds of that frequency.*
  2. **Frequency-Matching Theory**: we hear pitch based on HOW FAST the hair cells vibrate.
     a. What type of sensory coding does frequency matching theory describe?
        *Temporal (time-related) code for frequency.*
     b. Explain how the Volley Effect allows for frequency matching code be created above 1000 Hz?
        *The volley effect, where some neurons in the group might fire, for example, at every other peak, and others at every fifth peak.*
  3. Which theory—Place or Frequency-Matching, is better for detecting:
     a. High Pitch? **PLACE THEORY**
     b. Low Pitch? **FREQUENCY-MATCHING**
     c. Intermediate Range of pitch? Some combination of both
Deafness
Read the following information about auditory malfunction and answer the response questions that follow.

✓ Deafness occurs in two major forms: conduction deafness and nerve deafness. These have different causes and can be measured by doctors in different ways. The following discussion focuses on their differences.

Background
The normal anatomy of the auditory system is designed to receive and transmit vibrations from the air to the fluid of the cochlea. Thus, vibrations of air molecules vibrate against the eardrum, or tympanic membrane. The tympanic membrane is attached to three tiny middle ear bones, so these bones vibrate when the tympanic membrane does. Because of the angles at which the bones vibrate, the parts of the bones furthest from the tympanic membrane vibrate more strongly than the parts of the bones closest to the tympanic membrane. As a result, the middle ear bones amplify sound vibrations. The last middle ear bone connects to the oval window of the fluid-filled cochlea, inside of which vibrations of fluids are transduced into neural signals going to the brain. That sensory-neural transduction occurs along neurons laid out on the cochlea’s basilar membrane, which is organized so that sounds of different pitch preferentially vibrate specific basilar membrane regions, and, thus, preferentially set up sensory-neural transduction at those regions.

1. Explain how the location of the middle ear bones influence vibration.

2. Define conduction deafness.

3. List at least three causes of conduction deafness.

4. Explain how hearing aids can help in conduction deafness.

In conduction deafness, vibrations from sound do not properly conduct through the system leading into the cochlea. Anything that disrupts any part of the system before the cochlea can cause conduction deafness. A common cause of such deafness is a build-up of fluid. In a middle ear infection, the fluid dampens the ability of the bones to vibrate. Old age can impair the flexibility between the middle ear bones and worsen conduction through the middle ear as well. Other causes of conduction deafness include a perforated tympanic membrane or an obstruction in the external ear canal leading into the tympanic membrane (e.g., from a foreign object or an unusually large amount of ear wax). Note, then, that many causes of conduction deafness are temporary and reversible. Note, too, that in conduction deafness, the cochlea is still just as good as it always was in transducing the signals it receives, changing physical vibrations into neural signals that the brain can understand. The problem is not in the sensory-neural transduction, it is in the weaker signal that enters the cochlea in the first place. Thus, hearing aids that simply send a stronger signal in the system can sometimes help.

6. Explain the characteristics of nerve deafness.

In nerve deafness, the neural part of the auditory system is damaged. Usually, part of the cochlea’s basilar membrane is damaged. As a result, the person has trouble hearing certain sounds—sounds of pitches that preferentially activated the now damaged regions of the basilar membrane. In an extreme example, someone can develop “notch deafness,” in which a narrow, sharply defined “notch” of basilar membrane is destroyed by very loud sounds of a particular pitch. As a result, the person is deaf to all sounds of that pitch. This can be a problem for people who work near jet airplane engines without wearing ear protection—such people can eventually develop deafness for sounds at the same pitch at which the loud jet engines whine. Note that since neurons do not regenerate, damaged basilar membrane neurons in nerve deafness are not replaced, so the hearing losses that occur are permanent. Note too that in this type of deafness, the problem is not with the signal that goes into the cochlea. The problem centers on what happens to the signal once it reaches the cochlea, where there is no longer a capacity to convert certain sound vibrations into neural signals. Consequently, conventional hearing aids do not help much because feeding a stronger signal into the cochlea does not help absent neurons perform sensory-neural transduction.

7. Why are hearing aids not a beneficial treatment for nerve deafness?
Testing for Deafness
Doctors can test for both types of deafness in many ways. Two quick and simple tests—the Weber test and the Rinne test—can be used as a class demonstration, either before or after a discussion of deafness and the workings of the auditory system. Both tests require use of a simple tuning fork (512 Hz to 1,024 Hz), available for purchase at almost any medical supply store for around $10.

Weber Test
In the Weber test, hold the tuning fork by its handle only and tap one of the two teeth of the fork against a book or hard surface so that it produces a clearly audible note. Now, with the fork still vibrating, stand behind the person you are testing, and firmly but gently place the handle of the tuning fork on top of their head, on the skull bone, about equal in distance between the person’s two ears. Ask the person to say whether the sound appears to be louder in the left ear, in the right ear, or if the sound is about the same loudness in both ears.

Normally, a person should hear about the same intensity of sound from both ears. If one ear has nerve deafness, however, the sound will appear louder in the normal ear. So, in nerve deafness, sound lateralizes away from the “bad ear.” If one ear has conduction deafness, the sound will appear louder in that same ear. Thus, in conduction deafness, sound lateralizes toward the “bad ear.” This may seem counterintuitive. The reason it occurs is that the fork is vibrating the bone directly, thus bypassing at least some of the damaged conductive elements of the bad ear. Since sounds from the air are not affecting the damaged ear very much (the sounds cannot easily get the conduction system in this ear activated), the tuning fork’s vibrations stand out more clearly than in the normal ear, where room sounds from the air create a noisier “background.” You can simulate this effect by having your participant use a finger to plug one ear, creating a temporary conduction deficit in that ear. When doing so, the sound should lateralize toward the plugged ear in the Weber test. Then, by simply lifting the still vibrating tuning fork off the person’s head so that only air vibrations can activate either ear, the person should hear the sound better through the unplugged ear.

8. Explain how the Weber test works to detect both types of deafness.

Rinne Test
In the Rinne test, each ear is tested separately. Tap the tuning fork again, but more gently so that a more moderate intensity note is heard. Then, hold the handle of the tuning fork on the mastoid bone—the bone right behind the ear—and aim the vibrating teeth back and away from the person as you hold the base against the bone. Ask the person to tell you when he or she can no longer hear any sound. As soon as the person says he or she can no longer hear sound, quickly move the slightly vibrating fork to have its teeth very near, but not touching, the opening of their external ear canal, and ask the person if he or she can still hear the sound. Normally, the person should say “yes.” Repeat for the other ear.

The Rinne test is comparing bone conduction and air conduction of sound. Normally, a vibrating tuning fork can vibrate bone and thus directly activate the ear’s conducting system. However, in a normal ear, this indirect bone conduction is still much less efficient than air conduction. Consequently, as long as the conduction system is working well, bone conduction in the first part of the Rinne test does not last as long as air conduction in the second part of the Rinne test. If someone has conduction deafness, however, that person will hear the first part of the Rinne test longer since, at that time, vibrations get to bypass some of the damaged conductive elements. In nerve deafness, the relative differences between the first and the second parts of the Rinne test will not change. In that case, the problem is with what happens to the vibrations that get to the cochlea, but how the vibrations get there is still the same as in a normal ear. You can simulate these effects by again having your participant use a finger to plug one ear, creating a temporary conduction deficit in that ear. When doing so, the bone conduction in the first part of the Rinne should last longer than the air conduction in the second part of the Rinne.

9. Explain how the Rinne test works to detect deafness.