Learning outcomes

After finishing this chapter, You should be able to

- Define the “sound” (physically) and how it can be measured,
- Describe the mechanism of hearing,
- Explain the main anatomical structure of the ear and the functions of each one,
- Define “noise” and its effects on people,
- Measure the noise using different tools,
- Protect Your hearing from noise,
- Minimize the negative effects of noise exposure,
- Explain the process of being deaf and the different types of hearing loss,
Sound is created by vibrations from a source and is transmitted through a media (such as the atmosphere) to the ear.

**Sound has two main attributes:**

1. Frequency of Sound Waves
2. and Sound intensity
1. Frequency of sound waves

- When sound is generated, it causes vibration and makes the air molecules to be moved back and forth. This alternation creates corresponding increase and decreases in the air pressure.

- The vibration forms sinusoidal (sine) waves. The height of the wave above and below the midline represents the amount of above-normal and below-normal air pressure respectively.

- The waveform above the midline is the image of the waveform below the midline in a sine wave. The waveform repeats itself again and again in a sine wave.

1. Frequency of Sound Waves (cont.)

- The number of cycles per second is called the frequency of the sound. Frequency is expressed in hertz (Hz) and is equivalent to cycles per second.

The human ear is sensitive to frequencies in the range of 20 to 20,000 Hz (highest sensitivity between 1000 to 3000 Hz), but it is not equally sensitive to all frequencies. In addition, people differ in their relative sensitivities to various frequencies.
2. Sound intensity & Complex sounds

It is defined in terms of power per unit area. The Bel (B) is the basic unit for measuring sound. The most convenient measure is the decibel (dB), 1 dB=0.1B.

Very few sounds are pure. Most complex sounds are non-harmonic.

Auditory Displays

There are four types of human functions involved in the reception of auditory signals:

1. Detection
2. Relative discrimination (differentiating between two or more signals presented together)
3. Absolute identification (only one signal is present)
4. Localization (knowing the direction that the signal is coming from)
Summary: How sound travels through the ear?

*Acoustic energy*, in the form of sound waves, is channeled into the ear canal by the pinna.

Sound waves hit the tympanic membrane and cause it to vibrate, like a drum, changing it into *mechanical energy*.

The malleus, which is attached to the tympanic membrane, starts the ossicles into motion.

The stapes moves in and out of the oval window of the cochlea creating a fluid motion, or *hydraulic energy*.

The fluid movement causes membranes in the Organ of Corti to shear against the hair cells.

This creates an *electrical signal* which is sent up the Auditory Nerve to the brain. The brain interprets it as sound!

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**Main Components of the Hearing Mechanism**

- Outer Ear
- Middle Ear
- Inner Ear
- Central Auditory Nervous System
The Outer Ear

- The Pinna - cartilaginous, highly variable in appearance, some landmarks.
- External Auditory Canal (or external auditory meatus) - 2.5 cm tube.

Structures of the Outer Ear

- Pinna
  - Collects sound
  - Helps in sound localization
  - Most efficient in directing high frequency sounds to the eardrum
The functions of the Outer Ear

- Amplification / Filtering
- Protection
- Localization

The Middle Ear: A cleft within the temporal bone

- Lining is mucous membrane
- Tympanic Membrane separates it from external auditory canal (EAC)
- Eustachian tube connects it to nasopharynx
- Also Connected to Mastoid Air Cells
Middle Ear Structures

1- Malleus
2- Incus
3- Stapes
4- Tympanic Membrane (Eardrum)
5- Round Window
6- Eustachian Tube

External Auditory Canal

- Approximately 1¼ inch in length
- “S” shaped
- Lined with cerumen glands
- Outer 1/3rd cartilage; inner 2/3rds mastoid bone
- Increases sound pressure at the tympanic membrane by as much as 5-6 dB (due to acoustic resonance)
Structures of the Inner Ear

- **Cochlea** - Snail-shaped organ with a series of fluid-filled tunnels; converts mechanical energy into electrical energy

- **Oval Window** – located at the footplate of the stapes; when the footplate vibrates, the cochlear fluid is set into motion

- **Round Window** – functions as the pressure relief port for the fluid set into motion initially by the movement of the stapes in the oval window
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Cochlea Functions

- **Transduction**: Converting acoustical-mechanical energy into electro-chemical energy.

- **Frequency Analysis**: Breaking sound up into its component frequencies
  - Bekesy's Traveling Wave (For his studies of the traveling wave, Georg von Bekesy received the Nobel Prize in 1961. His incredible delicate and elegant experiments had traced sound to the very threshold of sensation."

  - Active Tuning from Outer Hair Cells (OHCs)
Physiology of the Cochlea

Healthy Cochlea

The cilia (sensory hairs) appear normal.
Hair Cells

- Frequency-specific
  - High pitch sounds = base of cochlea
  - Low pitch sounds = apex of cochlea
- When the basilar membrane moves, a shearing action between the tectorial membrane and the organ of Corti causes hair cells to bend
Central Auditory System

- 8th Cranial Nerve or “Auditory Nerve” carries signals from cochlea to brain
- Fibers of the auditory nerve are present in the hair cells of the inner ear
- Auditory Cortex: Temporal lobe of the brain where sound is perceived and analyzed

Noise

- Noise is referred to as unwanted sound.
- In the context of information theory, noise is defined as “that auditory stimulus of stimuli bearing no informational relationship to the presence or completion of the immediate task”.
- How loud is it?
- Loudness depends on intensity and frequency.
- A low frequency tone will not sound as loud as a high frequency sound of the same intensity.
Noise is any annoying, disturbing or unwanted sound.

**Noise effects on people:**
- Irritate people; Interfere with verbal communication;
- Reduce working efficiency; Disturb sleep; Excessive noise can result in hearing loss
- Damage hearing.

**The effects of noise:**
The main effect of noise is the development of deafness, especially when you are exposed to high levels of continuous noise. This may result in 'noise-induced occupational deafness'.

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Hearing can be affected by a noise level of 85dBA over an 8 hour exposure, this usually affects the ability to hear higher frequency sounds

- One of the most important effects of noise is hearing loss.
- Temporary loss, permanent loss.
- Occupational hearing loss.
- Continuous noise or non-continuous noise.
- Physiological effects of noise.
**Noise and Loudness**

<table>
<thead>
<tr>
<th>Specific environment</th>
<th>Health effects</th>
<th>Target level (dB(A))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor living area</td>
<td>Various annoyance, daytime and evening</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Moderate annoyance, daytime and evening</td>
<td>50</td>
</tr>
<tr>
<td>Indoor living area</td>
<td>Speech intelligibility and moderate annoyance, daytime and evening</td>
<td>55</td>
</tr>
<tr>
<td>Inside bedrooms or hospital ward rooms</td>
<td>Sleep disturbance, night time</td>
<td>30</td>
</tr>
<tr>
<td>Outside bedrooms</td>
<td>Sleep disturbance (window open)</td>
<td>45</td>
</tr>
<tr>
<td>School classrooms</td>
<td>Speech intelligibility, disturbance of information extraction, message communication</td>
<td>55</td>
</tr>
<tr>
<td>Hospital treatment rooms</td>
<td>Interference with rest and recovery</td>
<td>As low as possible</td>
</tr>
<tr>
<td>Industrial, commercial, shopping and traffic areas</td>
<td>Hearing impairment</td>
<td>79</td>
</tr>
<tr>
<td>Ceremonies, festivals and entertainment events</td>
<td>Hearing impairment</td>
<td>100</td>
</tr>
<tr>
<td>Public address</td>
<td>Hearing impairment</td>
<td>05</td>
</tr>
<tr>
<td>Music through headphones</td>
<td>Hearing impairment</td>
<td>05</td>
</tr>
</tbody>
</table>

**Hearing Protection – when is it required?**

- There are regulations that state when hearing protection is mandatory; however, a good rule of thumb is that hearing protection should be used if you have to shout at someone standing 3 feet away from you to be heard over the noise.

- The two most frequent problems for Labor & Industry (L&I) are that people are not wearing the hearing protection when it is required or not wearing it correctly.
Masking

- Masking: It is the condition when one component of the sound environment reduces the sensitivity of the ear to another component.

- Masking Effect: when two sounds are present at the same time
  - One signal may mask or cover up the other
  - This can result in false threshold for hearing during audiometric testing

- Masking typically occurs when the interfering noise is low in frequency

- White Noise

Effects of Noise Exposure

Hearing Loss From Noise Exposure

- Hearing loss from noise exposure is usually not noticed because it is so gradual.

- Usually a person loses the ability to hear higher pitches first.

- Often the first noticeable effect is difficulty in hearing speech.
Effects of Noise Exposure (cont.)

- The damage from exposure to noise occurs in the inner ear.
- There are tiny hair cells in this part of the ear that are flattened out when exposed to noise.
- If the exposure is short, the hair cells raise back up. If the exposure is long or extremely loud, the hair cells don’t recover and hearing ability is reduced.
- When all the hair cells are damaged, complete deafness occurs.
- “People who say they are ‘used to the noise’ often have already lost some of their hearing.”

Types of Hearing Protection

- The Washington Industrial Safety and Health Act (WISHA) noise regulations require that we have at least 2 types of hearing protection to choose from.
- There are three types of hearing protection – ear muffs, earplugs and ear caps.
- Ear muffs and earplugs provide about equal protection, ear caps somewhat less.
Hearing Protection

Types of Hearing Protectors:

- All hearing protectors are designed to reduce the intensity (loudness) of noise to the inner ear.
- They work much better than wads of cotton or bits of cloth stuffed in the ear.
- All three types have advantages and disadvantages and people vary on which they prefer to use.

Ear Plugs

- Earplugs are made of foam, rubber or plastic and are either one-size-fits-all or in sizes small, medium and large.
- Some are disposable, some are reusable.
- They are lightweight, and require no maintenance.
- They are inserted into the ear canal.

Some earplugs have little “handles” for use in dirty environments.
Foam type earplugs are one-size-fits-all and must be inserted properly into the ear. Roll earplug into small cylinder first, then insert in ear.

The technique for inserting earplugs is to first, roll the earplug into a small cylinder, pull the ear up and back, this opens the ear canal. Push the earplug into the ear canal and hold there for a few seconds until it expands and fills the ear canal. This will provide the tightest fit and greatest protection.

The left picture shows plugs only partially inserted into the ear canal – a common mistake.
Islamic University of Gaza - Palestine

**Facts About Ear caps**

- Do not have same noise reduction as earplugs or ear muffs because they do not penetrate the ear canal and the seal is not as tight as earplugs.
- More expensive than earplugs and disposable tips are not as readily available.
- People tend to use when dirty like the ones in the photo.
- Not the best choice for a logging environment.

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**Attached Earmuffs**

- Some muffs are attached to hardhats or goggles and are somewhat less protective than stand alone earmuffs.
- Some high-tech muffs can filter out certain frequencies or have radios inside for communication in high noise areas.
- Earplugs can be worn under earmuffs for really loud noise levels.
Employer’s Responsibility

What the WISHA Rules Require?

Hearing Protection—The employer must provide hearing protection for all employees that have an eight hour time weighted exposure of 85 dBA or above, who have any continuous exposure at or above 115 dBA, or who have an exposure to any impulse noise levels above 140 dB.

Effects of Noise Exposure

Daily Allowable Exposure Times to Noise

The table below shows noise levels and how long a person can be exposed without hearing protection before there is damage to the ear.

<table>
<thead>
<tr>
<th>Noise Level</th>
<th>Allowable Exposure Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>85 decibels</td>
<td>8 hours</td>
</tr>
<tr>
<td>90 decibels</td>
<td>4 hours</td>
</tr>
<tr>
<td>100 decibels</td>
<td>1 hour</td>
</tr>
<tr>
<td>105 decibels</td>
<td>30 minutes</td>
</tr>
<tr>
<td>110 decibels</td>
<td>15 minutes</td>
</tr>
<tr>
<td>115 decibels</td>
<td>0 minutes</td>
</tr>
</tbody>
</table>
Noise and performance

- Noise causes fatigue and loss of concentration and efficiency, resulting in a decrease in work output and an increase in the number of mistakes made.
- The World Health Organization (WHO) provides some guidance on acceptable levels of noise in the community.

Noise Exposure Can Be Reduced By

- Substitute with a quieter process or equipments
- Separate employees from noisy equipment
- Change the direction of the noise
- Absorb the noise with sound damper
- Use white noise
Two Types of Hearing Loss

- Conductive
- Sensory

Conductive Hearing Loss

- Caused by damage to or a malfunction of the outer and middle ear
- Some causes
  - excessive ear wax
  - fluid in the ear
  - a torn eardrum
  - Colds
- Usually hearing is restored once the cause is diagnosed and treated
Sensory Hearing Loss

- Caused by damage to or a malfunction of the inner ear, auditory nerve, or the brain
- Causes of sensory hearing loss
  - Aging, Damage to fetus, Hereditary, Noise, Disease, Injury, Drugs

Damaged Cochlea

Loss of cilia as a result of Noise
Noise Hazard Evaluation

• Purpose
  – To identify noise hazardous areas
  – To document the magnitude of the noise hazard
  – To aid in the implementation of a hearing conservation program
  – To protect personnel from developing a noise-induced hearing loss
  – To implement engineering controls

Noise Measuring Equipment

Sound Level Meters (SLM)
Continuous on-mobile sources

Noise Dosimeters
Mobile/variable noise sources
### Sound Level Meters

Calibrated noise measuring device which meets the criteria of American national Standard Institute (ANSI) Standard S1.4-1971 (R 1983)

- Microphone (transducer)
- Amplifier
- Weighting network
- Slow/fast averager
- Display meter  
  - Analog
  - Digital

### Type I Precision SLM

- Tolerance of + or –1 dB accuracy
- Individual octave band measurements
- Required for booth certification
- Cost: $2,000.00
Type II SLM

- Used routinely for surveys in the field
- Has individual weightings networks:
  - A weighing
  - B weighing
  - C weighing
- Cost: $400.00 to $600.00

Source of Error

- Reading (averaging) errors
- Wrong scale setting
- Wrong microphone position
Distance from Source

- Inverse square law applies:
  - Each time the distance from a source is doubled, in a free field, the sound pressure level drops by 6dB
  - This principal is used to define the noise hazard radius

Care of SLM things to Avoid

- Excessive heat
- High humidity (>90%)
- Hard blows or shocks
- Handling of microphone
- Excessive dust
- Strong electromagnetic fields
- Pegging the needle
Sound Levels and Hearing Conservation

- Noise measurements are essential
- Health Care Plan (HCP) enrollment base on:
  - Noise survey, data-sound level surveys or dosimetry
  - Job/task factors-length of exposure, level of noise/vibration
  - Patient specific factors-pre-existing hearing loss or ear disease

END