Chapter 10
Auditory Content

# The Design and Implementation of Multimedia Software

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Jones and Bartlett Publishers

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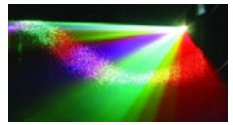
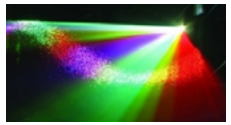


# About this Chapter

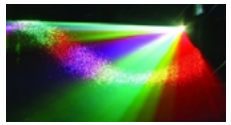
- The physics of sound.
- The biology of hearing.
- The psychology of auditory perception.
- Auditory output devices, and how they can be used to present auditory content.



# A Definition

## Definition

*Sound* is a series of vibrations moving as waves through air or other gases, liquids, or solids.



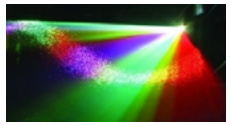
# Sound Waves in Air

- Compressions/Condensations:

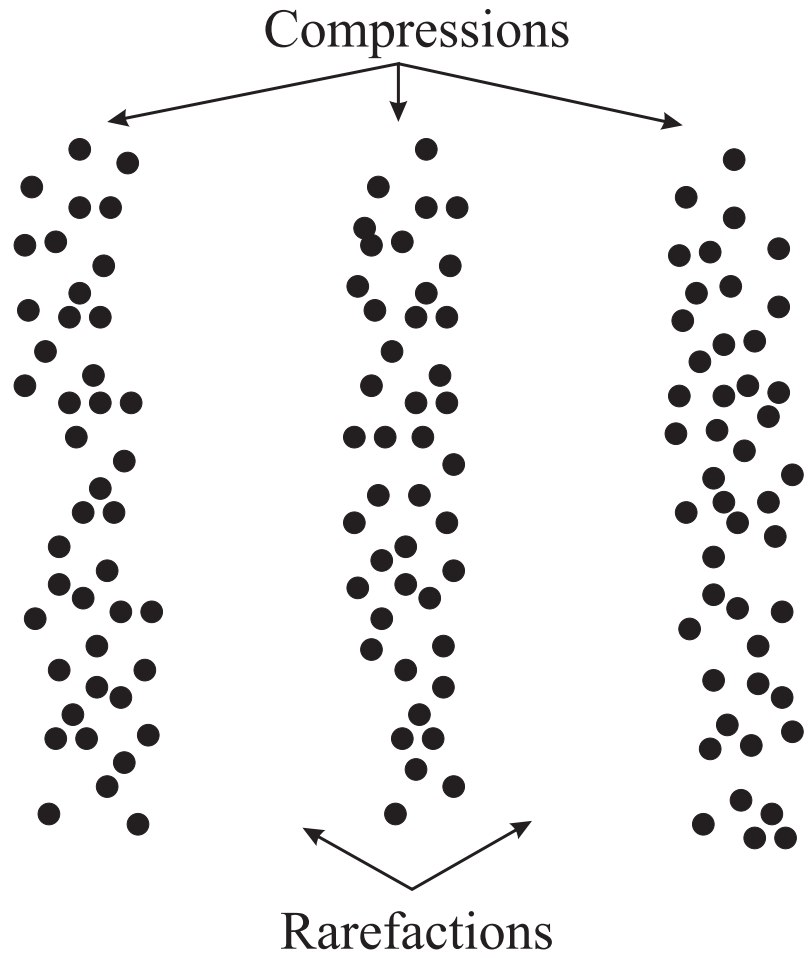
  Air molecules are pushed closer together and, hence, the air pressure is higher.

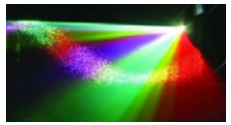
- Rarefactions:

  Air molecules are pulled farther apart and the air pressure is lower.



# Sound Waves in Air (cont.)



# Properties of Sound Waves in Air

- Transverse:

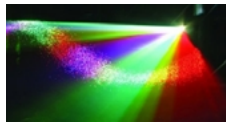
  The wave is in the direction of travel.

- Traveling:

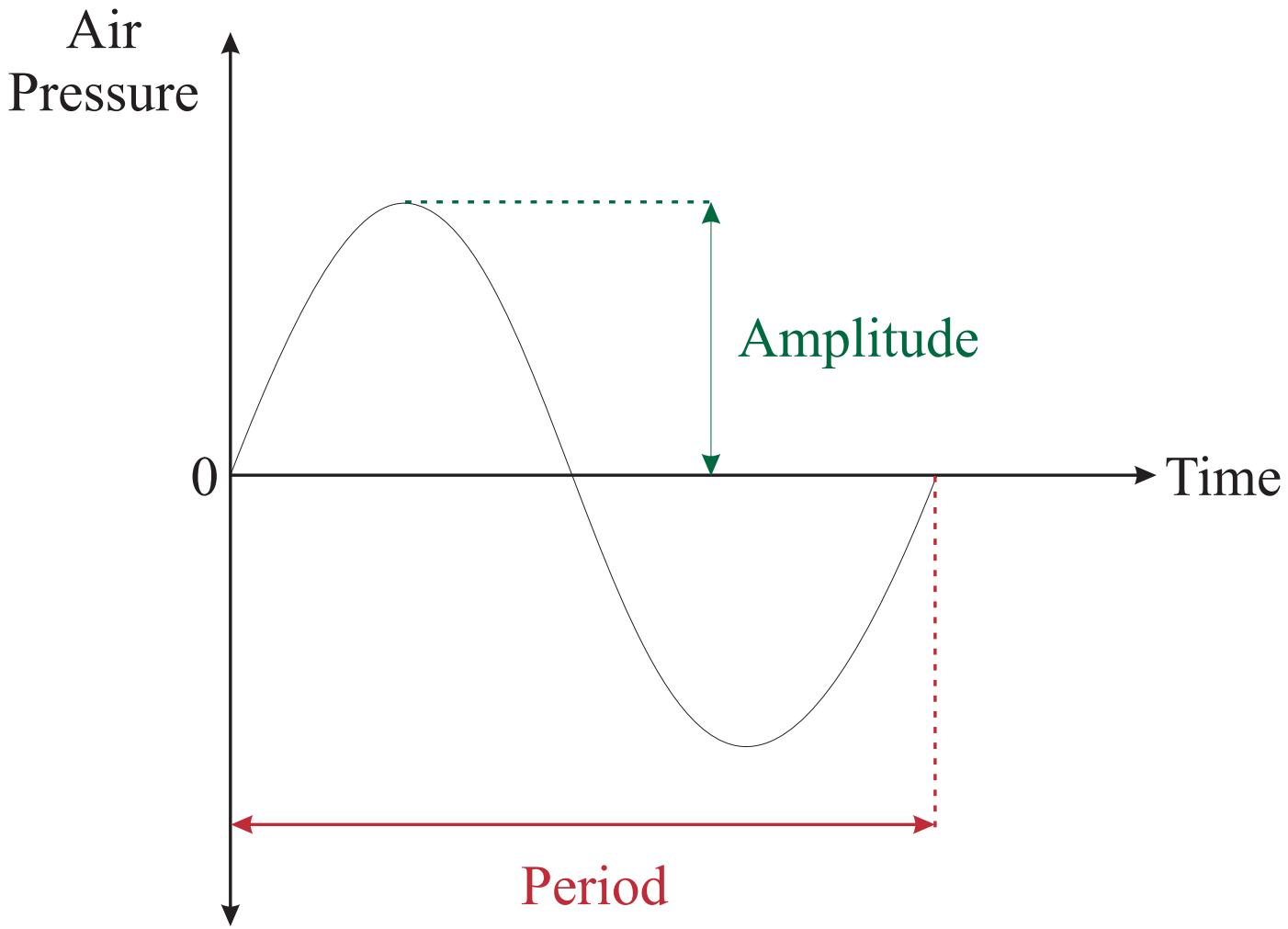
  Air molecules disturb neighboring molecules, transferring their energy to them.

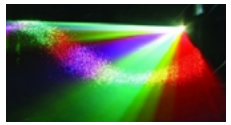
- Omnidirectional:

  The waves radiate spherically from the source), while others direct sounds in particular directions.



# A Periodic Pressure Wave

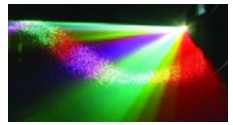


# Reflection and Absorbtion

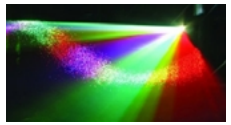
## Definition

A *free field* is an environment in which there are no reflections.

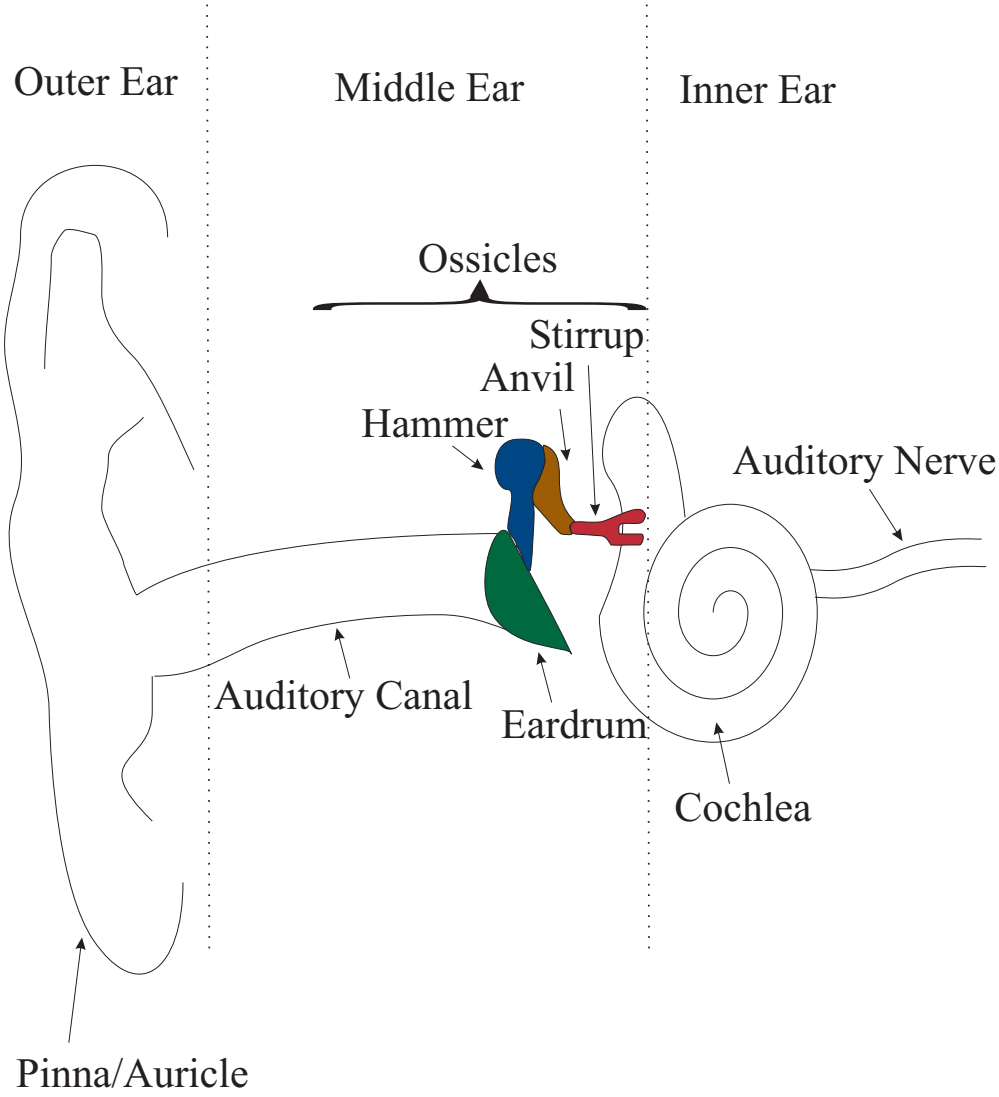


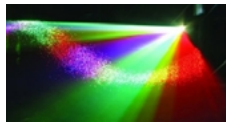
# Organs Involved

- We sense sound using organs called ears.
- We interpret the sensation using the brain.



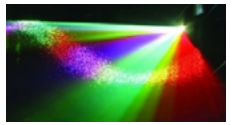
# The Human Ear



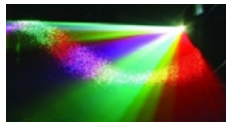
# The Sensing Process

- Sound waves are collected by the *auricle/pinna*.
- They travel through the auditory canal to the *eardrum*.
- The compressions and rarefactions result in a change in pressure on the two sides of the eardrum.
- The difference in pressure causes the eardrum to vibrate.



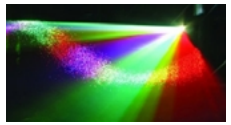
# The Sensing Process (cont.)

- The vibrations of the eardrum are transmitted through the *ossicles*.
- The stirrup pushes a membrane and the movement of the membrane is transferred to the *endolymph fluid* in the *cochlea*.
- This causes the *basilar membrane* to move. (Each point on the basilar membrane is 'tuned' to a small range of frequencies.)
- This causes the *stereocilia* to vibrate, causing a voltage difference, that leads to the release of a neurotransmitter which initiates the transmission of impulses along the *auditory nerve*.



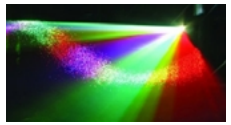
# Processing in the Brain

- Most of the output of the auditory nerve is processed in the auditory cortex (in the temporal lobe).
- Some processing is also done in the frontal lobe and the parietal lobe.



# Volume – A Simplified Approach

- Sound pressure levels are measured in decibels (dB), which is a logarithmic unit.
- Humans normally perceive differences in amplitude as differences in *volume*.
- 0dB is loosely defined to be the softest sound that is audible to humans.
- 120dB sounds are painful.

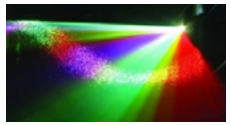


# Thresholds

**Definition**

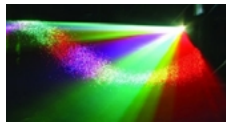
The *threshold* of a neuron is the lowest level of sound that causes a measurable change in response.

- The threshold varies inversely with its spontaneous firing rate.
- Continued exposure to auditory stimuli leads to *adaptation* (an apparent decrease in volume).
- Continued exposure to auditory stimuli also leads to *fatigue* (an increase in the threshold for subsequent stimuli)



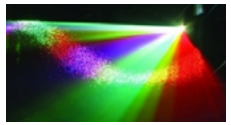
# Pitch and Frequency

- The greater the frequency, the higher the pitch.
- Humans can hear sounds from about 15Hz (i.e., 15 cycles per second) to 18kHz (i.e., 18,000Hz).

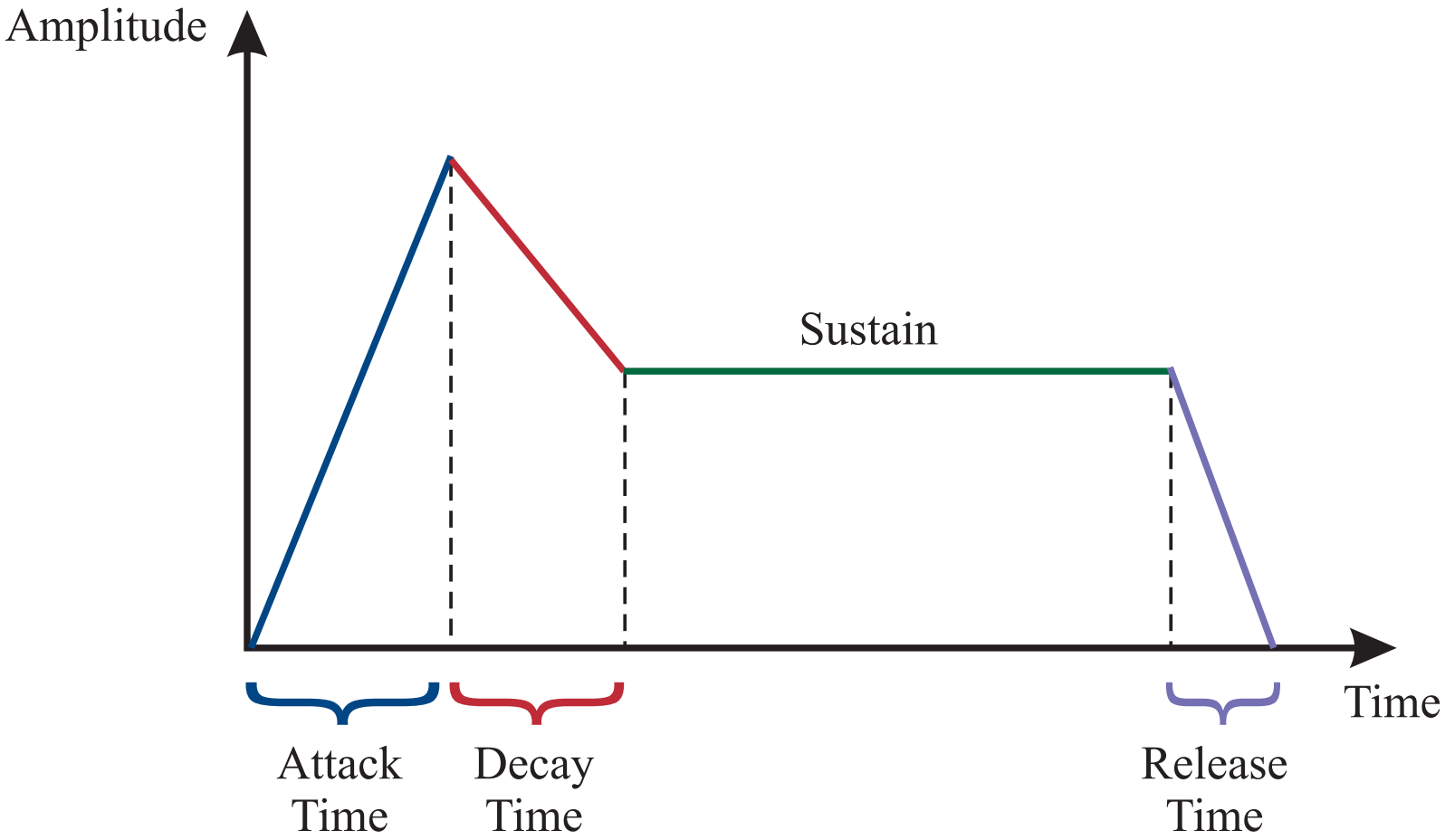


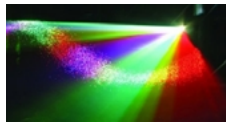
# Timbre – The Concept

- Two sound waves with the same pitch and volume, but produced by a piano and a trumpet, are perceived very differently.
- These differences, often referred to as *timbre*, are subjective.



# A Stylized Envelope



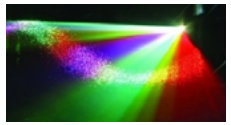
# Localization Mechanisms

- *Interaural time difference* – the difference in the time it takes for a sound to reach both ears.

  Most people can detect a difference of about 20 microseconds.

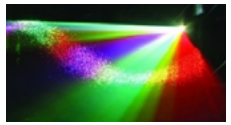
- *Interaural density difference* – the difference in amplitude caused by our head interfering with the sound wave.

- Frequency filtering performed by the outer ear.



# Common Uses of the Term 'Noise'

- In the context of noise pollution, it usually refers to amplitude.
- In the context of a restaurant, it usually refers to the fact that there are many sources (e.g., many different conversations, televisions, pots and pans) of auditory content.
- In the context of popular music, it usually refers to a anything your mother doesn't like.

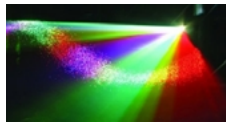


# Colors of Noise

## Definition

*Noise* is a signal that is generated by a random process.

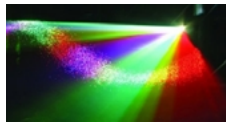
- *White noise* is a signal that has equal power in every band with the same width.
- *Red noise* is a signal that arises from a "random walk" (more formally, a signal that arises from Brownian motion).



# Reflections

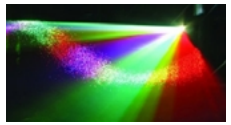
- Except in a free field, some sound waves reach the ear directly from the source and others reflect off of one or more surfaces before reaching the ear.

- When a reflected sound wave (with smaller amplitude because of the loss of energy) arrives at the ear after the original sound wave we perceive an echo or reverberation.



# Conventional Loudspeakers

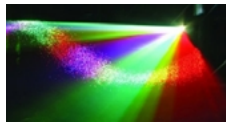
- Components:
  - Diaphragm
  - Electromagnet
  - Basket
- Classification:
  - Subwoofers
  - Woofers
  - Mid-range
  - Tweeeters



# Aural Rendering

## Definition

*Aural rendering* is the process of taking an internal representation of auditory content and presenting it using an auditory output device.

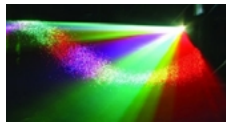


# Requirements

F10.1 Manage individual ‘pieces’ of auditory content.

F10.2 Manage ‘aggregate’ auditory content.

F10.3 Render/present auditory content.



# A Conceptual Model of an Auditory Content System