I. The Middle ear
   
   A. Anatomy of the Middle Ear

**Figure 12.1** A schematic ‘coronal’-section of the human auditory periphery


| PINNA FLANGE | MEDIAL |
| CONCHA | POSTERIOR |
| CANAL | SUPERIOR |

5 mm

Courtesy of Acoustical Society of America. Used with permission.
Figure 12.3 Two Views of the Human Tympanic membrane (the eardrum)

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Figure 12.4 A Medial View of the Human Middle Ear

- TM
- ossicles
  Malleus with Umbo
  Incus
  Stapes with footplate
- middle-ear muscles
  Tensor Tympani
  Stapedius Muscle
- mastoid air spaces
- Tympanic cavity
- Eustachian Tube
- VII (Facial) Nerve


Figure 12.5 The Three Human Ossicles

Figure 12.6: A cast of the Human Inner ear: After Schuchnect 1974

Image removed due to copyright considerations.

Figure 12.7: A horizontal section through the human ear:  

B. There is a wide variation in the form and function of the ossicles and middle-ear air spaces.

Fig 12.8: (Source: Rosowski, J. J. *The Evolutionary Biology of Hearing*. New York: Springer-Verlag, 1992, pp. 625-631.)
The middle ears of mammals are different from those of other terrestrial vertebrates in that other vertebrates (bird’s reptiles and amphibians) have a single ossicle, a curved out tympanic membrane, one or no middle-ear muscle and a middle-ear cavity that is less well defined. (Source: Rosowski, J. J. "The middle and external ears of terrestrial vertebrates as mechanical and acoustic transducers." In Sensors and Sensing in Biology and Engineering. Edited by Barth, F. G., Humphrey J. A. C., and Secomb T. W. New York: Springer-Verlag, 2003, pp.59-69.)

Fig 12.10: Middle-Ear System Function: Stapes Velocity / Sound Pressure in Ear canal
C. There is also a wide variation in the hearing range of different animals
Figure 12.11:
Pure-Tone Audiograms (Threshold sound level vs frequency contours for the human (Sivian & White 1932) domestic cat (Heffner and Heffner 1985), bat (Long & Schnitzler 1975), pigeon (Heinz et al. 1985) and Bull Frog (Megela-Simmons 1987). The abscissa is tone frequency. The left ordinate is the threshold sound pressure in dB SPL. The right ordinate is the threshold in pascals. (Rosowski 2003)
D. The Effective Stimulus to the Inner Ear is a Difference in Sound Pressure at the Two Cochlear Windows

\[ P_{WD} = P_S + (P_{OW} - P_{RW}) \]

- **\( P_{WD} \)** is the Effective sound pressure difference at the cochlear windows
- **\( P_S \)** is the effective sound pressure produced by motion of the ossicular chain
- **\( P_{OW} \)** is the sound pressure in the middle-ear cavity outside of the oval window
- **\( P_{RW} \)** is the sound pressure in the middle ear cavity outside the round window

**In the Normal Middle Ear:**

\[ P_S \gg (P_{OW} - P_{RW}) = \Delta P \]

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**A Test of the pressure difference hypothesis (Voss et al 1995)**
**Ossicularly Coupled Sound in the Normal Ear**

\[ P_{WD} \approx P_S \]

and

**Acoustically Coupled Sound**

\[ (P_{OW} - P_{RW}) = \Delta P \]

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**In Cases of Severe Ossicular Disruption Acoustic Coupling Limits the hearing loss :** (Merchant & Rosowski 2002)

**A: Interrupt I-S Joint**

**B: Lost TM, malleus & incus**

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Image removed due to copyright considerations

Type IV Tympanoplasty:
Use of Acoustic Shielding to Manipulate Acoustic Coupling by Increasing the Window Pressure Difference: Merchant SN and Rosowski JJ. 2002

E. Another reconstructive surgery; the stapedectomy

Image removed due to copyright considerations.

Predicted Variations in Hearing Level with Different Prosthesis Cross-Sectional Areas

If we define the *Source Impedance* as the impedance on the Left (input side) of the transformer when the source is turned off, and the *Load Impedance* as the impedance loading the Right (output side) of the transformer, then the Maximum Available Power reaches the load when the transformer matches the two impedances. Matching occurs when the two impedances are complex conjugates.