REVIEW OF THE EAR AND ITS FUNCTIONS

Reg.No.M9019

AN INDEPENDENT PROJECT WORK SUBMITTED IN PART FULFILMENT FOR FIRST YEAR MASTER OF SCIENCE (SPEECH AND HEARING), UNIVERSITY OP MYSORE

ALL INDIA INSTITUTE OF SPEECH AND HEARING: MYSORE 570006
1991

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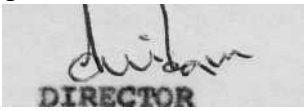

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Mysore
1991

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DECLARATION

I hereby declare that this Independent Project Entitled: Review of the Ear and its Functions is the result of my own study under the guidance of Dr.(Miss) S.Nikam, Prof, and Head of the Department of Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier to any University for any other Diploma or Degree.

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- A Help rendered in Hour of Need
- Though small is Greater than the world
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CHAPTER 1
INTRODUCTION

WEALTH OF WEALTHS IS LISTENING'S WEALTH

IT IS THE BEST OF WEALTHS OR EARTH.

Saint Valluvar* in this Holy Kural brings out the significance of listening through the above couplet.

EAR – being one of the well developed sense organs, provides the individual with a variety of information in one's environment. In man, it forms an important channel of language learning. The ear is believed to have undergone evolution independently atleast a dozen times and a large number of different hearing organs are found in vertebrates and animals.

The encoding and decoding of acoustic stimulis takes place through a transduction - a series of process involving, the conversion of Acoustic to Mechanical to Electrical information thereby enabling speech perception.

This Holy Kural a masterprice for all, for all times, authored by Saint Valluvar comprises of 133 chapters with 1330 couplets. LISTENING the 42nd Chapter has ten couplets. This universal holy Tamil work is being translated into English by eminent scholars like G.U.POPE, K.M.BALASUBRAMANIAM, ROBINSON, YOGI SHUDDHANANDA BHARATI et al.

Moreover in the present trend, the ear is being viewed as a bidirectional transducer since ear can even emit sounds. In addition ear also helps us maintain the state of equilibrium. A detailed understanding of these auditory events can be achieved with a therough knowledge of the various structures of the ear and their function.

In this review, an attempt has been made towards collecting recent information on the functions of the ear with ancillary details towards its anatomy and it is a modification of Suma (1984) Independent Project work "Questions and answers to the Ear and functions."

This work proceeds through a series of chapters by following sound energy on its journey through the ear. A unique array of graphics and visuals has been used in presenting the materials with the aim of holding the reader's interest. This project also serves a purpose of "Self-Check" Inventory. Also, it can be used as a Supplemental text. Thus, there is no doubt that the felicitous expressive output of applicability will help us prove our cognitive complexities as well as aid in the growth of Hearing Science .

CHAPTER - 2

In this chapter, general topics about the ear and hearing such as identification, of parts, types of ear, types of threshold, synonyms, animals for ear research, the role of listening and various researches(in the form of WHO IS FOR WHAT) have been dealt here.

1. Identify the parts of the ear with the help of initial better depicted below.

   (a) External ear : P, A, H, T, C, D, A, T, S, L, H, E.
   (b) Middle ear : M, I, S, TM, S, TT, ET, CT, M.
   (c) Inner ear : BL, ML, V, SSC, LSC, PSC, C, OW, DE, A, C, M, H, SV, ST, SM, U, S, RM, BM, TM, HC, SC, RM.

2. TYPES OF EAR

   Given below are the descriptions of types of ear. Coin the term.

   (a) A device using a microphone in a cavity for the measurement of the acoustic output of an earphone. The cavity (6cc in volume) is designed to present an acoustic impedance to the earphone equal to the impedance of the average human ear.

   (b) Hearing loss resultiag from noise exposure. It is typified by the high frequency loss of saaay workers who have spent years repairing or assembling boilers.

   (e) A congenitally deformed ear ia which the upper border is not rolled-over to form the helix but extends flatly upward.

   (d) Pain resulting from unequal balance of pressure between the middle ear and outer ear. Also known as

Aerootitis or Bacotrauma.

(e) Unequal appearance in size and shape of external ear.

(f) An outer ear with no lobe. Also known as catgot's ear.

(g) An ear thickened and malformed by injury.

(h) An external ear which protects directly outward from the head.

(i) An outer ear in which the rim appears to be rolled forward and inward.

3. TYPES OF THERSHOLD

With the ears we listen to various sounds. The ability of the stimulus varies with the ears. Attempt to explain the following:

(a) Threshold
(b) Absolute threshold
(e) Thershold, adaptation
(d) Threshold of audibility
(e) Threshold, auditory
(f) Bone conduction threshold
(g) Threshold of detectibility
(h) Threshold of discomfort
(i) Threshold of feeling
(j) Threshold of intelligibility

(k) Lowered threshold

(l) Threshold of pain, tickle or discomfort

(m) Threshold of perceptibility

(n) Raised threshold

(o) Threshold of sensitivity

(p) Threshold shift

(g) Terminal Threshold

4. Give synonyms for the following: (Tips, are given in brackers).

(a) Outer ear (Two)

(b) Middle ear (Two)

(c) Inner ear (one)

5. Name the animals used in ear research. (Tip: Their names begin with the encircled letter).

A (B) (c) (D) E (F) (G) (H) I J K L (M) N 0 P Q (R) S T U V W X Y Z .

6. THE ROLE OF LISRENING

(a) what iS listening?

(B) what is hearing?

(C) what iS the gain ia hearing measurment through listening?

7. WHO IS FoR WHAT

Given are some names and parts of th ear. Match them appropriately.

NAMES: Eustachi, Empedocles, Hippocrates, Rufus of Ephesus, Galen, Vesalis, Sicilian Hippocrates, Politzer, Tabulae, Linnaeus, Rosenthal, Reissner, Kolliker, Corti.

PARTS: Sensory epithlium resting on Basilar Membrane, Tectorial Membrane, Stria Vascularis, the spiral gatglion, etc; Vestibular Membrane, first user of the term organ of corti, canal of modiolus, coined the terms endolymph, perilymph, Helicotrema, Otolit, Otoconia; Chorda tympani nerve, Tensor tympani, stapes, Malleus and Incus, Labyrinth, given several trems, pinna, concha, lobe, helix etc; Tympanic membrane Cochlea, Eustachian tube.

CHAPTER-2

KEYS

1. (a) External Ear : Pinna, Antihelix, Helix, Tragus, Concha, Darwin's Tubercle, Anti-tragus, Triangular Fossa, Scaphoid Fossa, Lobule, Hairs, External Auditory Meatus.

   (b) Middle Ear : Malleus, Incas, Stapes, Tympanic Membrane, Stapedius, Tensor Tympani, Eustachian Tube, Chorda Tympani, Mastoid.

   (c) Inner ear : Bony Labyrinth, Membranous Labyrinth, Vestibule, Superior Semicircular Canal, Lateral semi-Circular Canal, Posterior Semicircular Canal, Cochiea, Oval window, Ductus Endolymphatius, Ampulla, Cristae, Modiolous, Hamulus, Scala Vestibuli, Scala Tympani, Scala Media, Utricle, Saccule, Reissner's Membrane, Basilar Membrane, Tectorial Membrane, Hair Cells, Supporting Cells, Raticular Membrane.

2. TYPES OF EAR (Delk,J.H.(1975) in Comprehensive Dictionary of Audiology)

   (a) Artificial Ear (b) Ear, boilermaker's

   (e) Darwanian Ear (d)}Aviator's Bar

   (e) Blainville's Ear (f) Aztec's Ear

   (g) Cauliflower Ear (h) Lop Ear

   (i) Ear Scroll

3. TYPES OF THRESHOLD (Delk, J.H. (1975) in Comprehensive Dictionary of Audiology).

(a) Threshold : The point at which a listener can determine that a sound is becoming audible.

(b) Absolute threshold : The minimum level of intensity at which a sound can just be determined to be present.

(c) Threshold, adaptation : Another term for tone decay or fast adaptation.

(d) Threshold of audibility : The point on a SPL scale at which fifty percent of the stimuli presented to the ear are heard.
Synonym: Threshold of detectibility, auditory threshold of sensitivity.

(e) Threshold, auditory : The SPL of the minimum acoustic signal that causes an auditory sensation for a specified percentage of the number of times the signal is presented to the ear. The Auditory threshold for spondees, for example, is defined as the minimum sound pressure level at which a subject can repeat correctly 50% of the spondaic words presented to him. Auditory thresholds vary with different stimuli and the particular stimulus must be specified.

(f) Bone Conduction threshold : Level of intensity at a pure tone can be recognized through a bone oscillator

pressed against the skull.

(g) Thsreshold of detectibility : The threshold of sensitivity, that is the point at which 50% of the presantations of a pure tone can be heard. Differential threshold: Some times called just noticeable difference or difference limen (DL) Aud: The smallest Change in frequaney which can be recognized.

(h) Threshold of discomfort : The minimum level of intensity which will produce a sensation of discomfort. Considered to be about 120dB.

(i) Threshold of feeling: The minimum intensity level at which sound pressure produces a sensation of feeling which is distinct from the sensation of hearing. The minimum level of intensity at which sound pressure will produce the sensation of hearing.

(j) Threshold of intelligibility: Obsolete term for speech reception threshold - the intensity level at which 50% of the words presented can be repeated.

(k) Lowered threshold: A better threshold of sensitivity; that is, one reflecting lower numbers on an audiogram.

(l) Threshold of pain, tickle or discomforts: The minimum level of intensity at which sound pressure will produce sensation of pain, tickle or discomfort.

(m) Threshold of perceptibility: A seldom used term for the level of intensity at which sound begin to be perceived as words. It is between the threshold of detectibility and threshold of intelligibility.

(a) Raised threshold: An indication of lessened hearing sensitivity - the intensity of sound must be raised to be heard.

(o) Threshold of sensitivity; The faintest sound that can be heard at 53% of presentations. Formerly referred to as threshold of acuity.

(p) Threshold shift: & change in hearing sensitivity such as may be caused by exposure to noise. It may be either TTS or PTS. Permanent threshold shift: As in reversible loss of hearing sensitivity. The term usually relates to noise induced hearing loss.

(q) Terminal threshold: The lowest intensity of sound pressure which when increased will cause no further increase in the sensation of loudness. Also known as terminal limen and tolerance limit.

4. (a) Auris Externa, Exeternal Ear

(b) Auris Media, Tympanic Cavity

(e) Auris Interna

5. B-Bat; C-Cat, Chinchilla; D-Dolphin; F-Fish, Frog; G-Gerbil, Guinea Pig; H-Human, Hamsters; M-Monkey, Mice; R-Rabbit, Rat.

6. THE ROLE OF LISTENING
   a) Listening is an active voluntary process of attention focused on particular sounds. Scharf(1988).

   b) Hearing is an involuntary and passive process of reception of sounds without selection. Scharf(1988).

   c) Listening can lower the threshold of the individual by 3-6 dB. Scharf(1988).

7. WHO IS FOR WHAT

Eustachi	-	Eustachian tube
Empedocles	-	Cochlea
Hippocrates	-	Tympanic membrane
Rufus of Ephesus	-	Given several terms: pinna, concha, lobe, helix etc.
Galen	-	Labyrinth
Vesalins	-	Malleus and Incus
Sicilian Hippocrates	-	Stapes
Politzer	-	Tensor Tympani
Tabulae	-	Chorda Tympani nerve
Linnaeus	-	Coined the terms endolymph, Perilymph, helicotrema, Otolit, Otoconia.

Rosenthal	+	Canal of Modiolus
Reissner	+	Vestibular membrane
Kolliker	-	First user of the term Organ of Corti
Corti	-	Sensory epithelium resting on Basilar membrane, the tectorial membrane, the stria vascularis, the spiral ganglion etc.

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CHAPTER – 3

DEVELOPMENT, EAR AND HEARING

It is well known that “Ontogeny recapitulates phylogeny”. Information on forerunners of Hearing and Developmental aspects of ear are dealt in two parts:

3.1 - PHYLOGENY

3.2 - ONTOGENY

PHYLOGENY

SAY ‘TRUE’ OR ‘FALSE’ FOR THE FOLLWING:

1. Statocysts are the first evolved organ of hearing in Jelly fish and many other lower forms of animals.

2. Statocysts are organs of equilibrium.

3. The lateral line is possessed by fishes and amphibians.

4. Lateral line helps in hearing in African clawed frog.

5. The lateral line helps in detecting movement in the water.

6. Weberian Ossicles are present in some fishes.

7. Airbladder in fishes help in creating sounds.

8. Lungs act as resonators for tadpole.

9. Ear drum is absent in frog after metamorphosis.

10. Cochlea is absent in frogs where as it is present in birds.

11. Butterflies and moths have their ears sometimes in the base of their wings.

12. Thorax or Abdomen or knees also function as ears in some insects.

13. Jawbones of amphibians and reptiles has migrated to the middle ear in mammals.

14. Middle ear is very essential for aquatic animals.

15. Pinna is present only in terrestrial animals evolved after aves.

16. Katydid an insect has its ears below its knees.

17. Grasshoppers have ears on their thorax.

18. Hearing especially in animals is helpful for recognition, for warning, for mating, for knowing their path and obstacles present.

ONTOGENY

a) Math the following:

Clues on origin: First Branchial arch, Second Branchial arch and first pharyngeal pouch.

Clues on parts developed:

External Ear: External Auditory Meatus, Pinna, Tympanic ring, Tragus, and Cuticular portion of tympanic membrane.

Middle Ear: Tympanic Cavity, Auditory tube, Manubrium of the malleus, long process of incus and superstructure of stapes, stapedius, Head of malleus, body of incus and Tensor tympani.

b) Group the following:

Germinal Layers: Ectoderm, Endoderm, Mesoderm.

Parts of the Ear: Ossicular chain, Middle fibrous layer of the tympanic membrane, Middle ear muscles, Bony labyrinth (Otic capsule), External Acoustic Meatus, Outer epithelial layer of tympanic membrane, Inner ear and Statoacoustic ganglion, Eustachian tube and Tympanic cavity, Mucosal layer of the tympanic membrane.

CHAPTER – 3
KEYS

3.1 PHYLOGENY

TRUE: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15

FALSE: 4, 9, 14

3.2 ONTOGENY

1) Origins and Parts developed from VISCERAL ARCHES AND CLEFTS.

Origin Parts Developed	First Branchial Arch	Second Branchial Arch	Fist Pharyngea Pouch
External Ear	Tragus Cuticular portion of Tympanic membrane.	Pinna Tympanic ring	External Audi Meatus.
Middle Ear	Head of Malleus, Body of incus. Tensor tympani	Manubrium of Malleus Long process of incus and super structure of stages. Stapedius	Tympanic cavi Auditory tube

3.2 (b) GERMINAL LAYERS AND EAR DEVELOMPENT.

Ectoderm	Mesoderm	Endoderm
External acoustic meatus.	Ossicular chain	Eustachian tube and tympanic cavity.
Outer epithelial layer of tympanic membrane.	Middle fibrous layer of tympanic membrane.	Mucosal layer of the Tympanic membrane.
Inner Ear (Membranous labyrinth)	Middle ear muscles.	
Stato-acoustic ganglion.	Bony labyrinth (Otic capsule)	

CHAPTER – 4

OUTER EAR

This chapter deals with the various anatomical aspects of the outer ear such as labeling the parts, dimension, microanatomy (in Section-A); Nerve supply, Blood supply and lymphatic supply (in Section-B).

Various physiological aspects of the outer ear viz pinna (in Section-C)and External Auditory Meatus (in Section-D) are also included.

The classified parts of this chapter are:

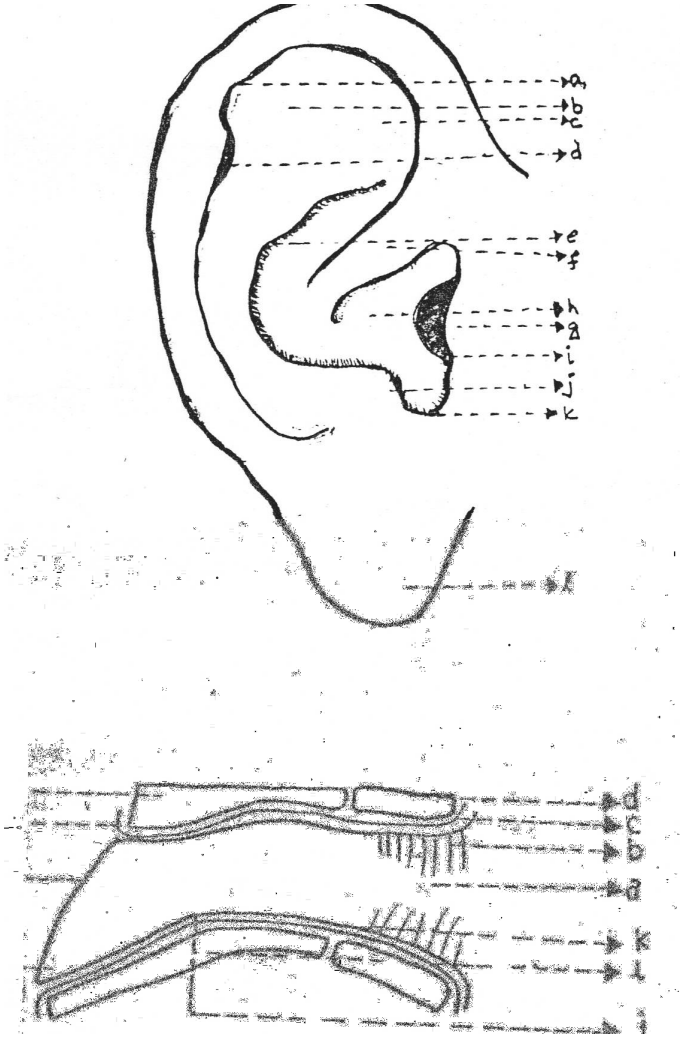
4.1 - Anatomy, Outer Ear.

4.2 - Physiology, Outer Ear.

4.1 ANATOMY, OUTER EAR

SECTION-A

1. Label the parts of the External ear in the diagrams given below:

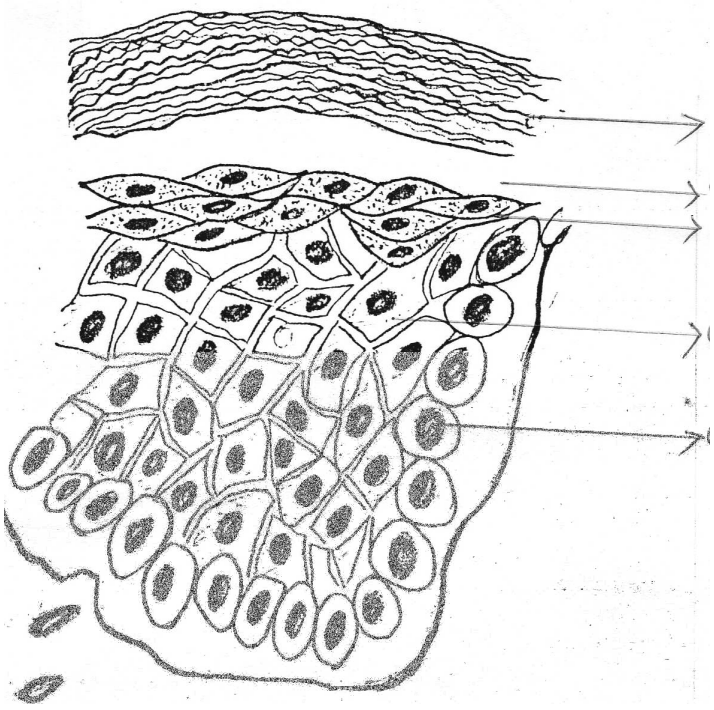


2. Fill up the ‘O’s in the table and get the anatomical details.

Structures	Pinna	Concha	Earcanal
Length	0		0
Diameter		0	0
Angle	0		
Area			0
Volume		0	0
Resonant Frequency		0	0
Shape based on the English alphabet	0	0	0

3. Name the muscles of Pinna.

4. Mark the layers of the earcanal in this diagram, with their zones.



SECTION - B
NERVE SUPPLY, BLOOD SUPPLY AND LYMPHATIC SUPPLY

Fill in the blanks:

1. The a _ _ _ _ _ _ _ _ t _ _ _ _ _ _ _ _ nerve supplies the upper two third of the lateral surface of the auricle and anterior wall of the external auditory Meatus.

2. The g _ _ _ _ a _ _ _ _ _ _ _ _ _ nerve supplies the lower third of the lateral surface of the auricle and the lower two thirds of te4h medial surface of the auricle.

3. The 1 _ _ _ _ _ o _ _ _ _ _ _ _ _ _ nerve supplies the upper third of the medial surface of the auricle.

4. The posterior wall of the meatus is supplied by A _ _ _ _ _ _ _ _ _ branch of v _ _ _ _ nerve.

5. The lateral surface of the auricle and the anterior wall is supplied by s _ _ _ _ _ _ _ _ _ _ t _ _ _ _ _ _ _ artery.

6. The cranial surface of the auricle and the posterior wall of the meatus are supplied by P _ _ _ _ _ _ _ _ a _ _ _ _ _ _ _ _ artery.

7. The m _ _ _ _ _ _ _ _ artery supplies the inner part of the meatus.

8. The posterior part of the meatus as well as the auricle is supplied by the P _ _ _ _ _ _ _ _ a _ _ _ _ _ _ _ _ vein.

9. The venous drainage of the anterior part of the meatus is by r _ _ _ _ m _ _ _ _ _ _ _ _ _ vein.

10. The lateral surface of the auricle and the anterior wall are supplied by p _ _ a _ _ _ _ _ _ _ _ lymph nodes.

11. The cranial surface and the posterior wall of the meatus are supplied by m _ _ _ _ _ _ _ _ _ lymph nodes.

4.2 PHYSIOLOGY, OUTER EAR

SECTION -C

PINNA

1. Match the nonauditory functions of pinna.

1. Cartilaginous Portion	(a) Head cushion
2. Lobe	(b)Gives shape and some rigidity
3. Helix	(c) Decorative Purpose.

2. Point out three auditory functions of Pinna.

EXTERNAL AUDITORY MEATUS

SECTION D

3. Unscramble the jumbles to obtain the functions of the earcanal.

   a) PTIROENTO – of the eardrum and other intraaural structures thereby the entry of foreign bodies such as insects can be prevented.

   b) SRNOETIEC – of wax.

   c) MIORATNIG – Eg. Grommet extrusion.

4. unscramble the jumbles and find out the structures helpful for nonauditory functions.

   a) HSRAI – for obstruction of foreign body entry.

   b) GDLANS – for secretion.

   c) LERAYS – of earcanal for migration.

5. Encircle the correct answer(s)and gain the general information on Hairs and Wax.

   a) Hairs are located in

   i. Cartilaginous portion only

   ii. Osseous portion of the canal only

   iii. Outer cartilaginous and posterosuperior part of the osseous canal.

   b) The medial hairs are short and lie obliquely where as the lateral hairs are more upright and this arrangement is termed:

   i. trap like arrangement

   ii. Honeycomb like arrangement

   iii. both

   iv. none of the above

   c) Wax is to be removed mainly because

   i. it causes hearing loss

   ii. to visualize the eardrum

   iii. to facilitate the normal physiological cleansing mechanisims.

6. Say TRUE or FALSE

a) The wax is secreted by sebaceous and ceruminous glands of the earcanal.

b) Local pressure on the skin, clenching of the teeth, adrenergic stimuli helps in the secretion of wax.

c) The fresh wax has more lipid content than the stale wax.

d) The fresh wax has more lipid content than the stale wax.

e) Cerumen is milky at first but changes into a brown waxy material soon exposure to air.

7. Give the Characteristics of Dry Wax and Wet Wax in the table given below:

Sl. No.	Characteristics	Wet wax	Dry Wax
1.	Other name		
2.	Color		
3.	Odour		
4.	Texture		
5.	Trait		
6.	Chemical composition		
7.	Breast cancer		

8. Explain the phenomenon of migration.

9. (a) Name any two auditory functions of the earcanal.
   (b) Match the structures with their respective gain.

Sl. No.	Structures	Gain
1.	Pinna	(A) 10dB at 4-5 KHz
2.	Concha	(B) 3dB at 4 KHz
3.	Earcanal	(C) 20dB
4.	Concha + Earcanal + Tympanic membrane	(D) At 2.6 KHz

CHAPTER-4
KEYS

4.1 ANATOMY, OUTER EAR
SECTION-A

1. Label the parts:

i. a) Helix
b) Scaphoid fossa
c) Triangular fossa
d) Darwin’s tubercle
e) Antihelix
f) Crus of helix
g) Tragus
h) Concha
i) External Auditory Meatus
j) Antitragus
k) Intertragal incisures
l) Lobule

ii. a) External Auditory Meatus
b) Hairs
c) Perichondrium
d) Outer cartilaginous part
e) Inner bony part
f) Periostium
g) Outer thin skin layer of tympanic membrane
h) Anterior recess

i) Inner bony part formed by tympanic part of temporal bone.
j) Narrowest part
k) Isthmus

2.

Structures	Pinna	Concha	Earcanal
Length	60-75mm		2.5cm
Diameter		1-2cm	0.7cm
Angle	15^0-45^0		
Area			0.3 – 0.5 Cm^2
Volume		2.5Cm^3	1Cm^3
Resonant Frequency		4-5 KHz	2.6 KHz
Shape based on the English alphabet	C	O	S

3. Muscles of Pinna :- Auricularis anterior, Auricularis superior and Auricularis posterior muscles.

4. Micro Anatomy :

a) Stratum corneum

b) Stratum lucidum Zona Cornea

c) Stratum granulosum

d) Stratum spinosum

Zona Germinative

e) Stratum basale

SECTION-B

NERVE SUPPLY, BLOOD SUPPLY, AND LYMPHATIC SUPPLY

(1) Auriculotemporal (2) Great auricular (3) Lesser occipital (4) Auricular, vagas (5) Superficial temporal (6) Posterior auricular (7) maxillary (8) Posterior auricular (9) Retromandibular (10) Preauricular (11) Mandibular

4.2 PHYSIOLOGY, OUTER EAR

SECTION-C

PINNA

1-b, 2-c, 3-a

2. Sound collection; sound source localization; sound transmission.

SECTION-D

EXTERNAL AUDITORY MEATUS

1. (a) Protection (b) Secretion (c) Migration

2. (a) Hairs (b) Glands (c) Leyers

3. (a) (iii); (b) (i), (c) (i), (ii) & (iii) (d) to (h) – TRUE Statements.

i) Characteristics of dry wax and wet wax.

Sl. No.	Characteristics	Wet Wax	Dry wax
1.	Other name	Honey wax	Ricebran wax
2.	Color	Golden Brown	Light gray or Brownish
3.	Odour	Axillary odour	Odourless
4.	Texture	Moist & Sticky	Dry and flaky
5.	Trair	Dominant	Recessive
6.	Chemical Composition	Lesser protein content, Lysozyme and igG	More protein content, Lysozyme and igG
7.	Breast cancer	High incidence	Low incidence

4. **MIGRATION** an active process occurring in the deep layers of stratum granulosum, stratum spinosum, and stratum basale of the external auditory canal. Stratum corneum moves laterally and desquamates. It wrinkles up in an accordion like fashion.

Migration is one of the factors responsible for grommet extrusion. The disturbance of migration is found in outer and middle ear pathological conditions in which there is accumulation of debris.

5. AUDITORY FUNCTIONS

a) To facilitate sound transmission; to delay sound propagation.

b) 1-B; 2-A; 3-D; 4-C

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CHAPTER – 5

MIDDLE EAR

This chapter comprises of two parts:

5.1 - Anatomy, middle ear
5.2 - Physiology, middle ear

The first comprises of sections A to G dealing with the tympanic cavity, tympanic membrane, ossicles, ligaments, muscles, Eustachian tube, nerve supply and vascular supply to the middle ear.

In the second part, various physiological aspects, both non-auditory as well auditory functions including sound transmission to the cochlea is being dealt in three sections H, I and J.

5.1 ANATOMY, MIDDLE EAR

SECTION-A

TYMPANIC CAVITY

1. Draw a schematic diagram of walls of the tympanic cavity and label the parts.

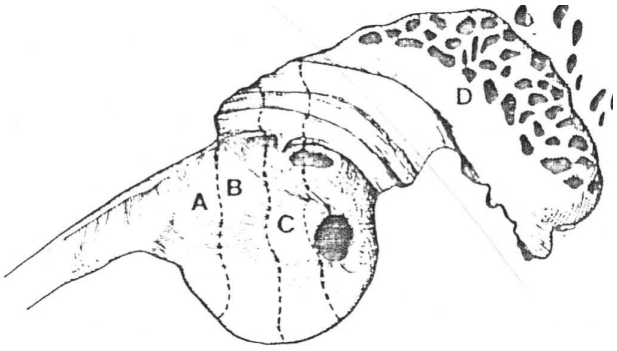
2. Tabulate the values of the tympanic cavity in terms of volume, width and vertical dimension.

3. Match the walls of the tympanic cavity, along with their common terms and landmarks.

Wall (a)	Common term (b)	Landmark (c)
a1) Lateral wall	b1) Membranous wall	c1) Tympanic membrane and squamous portion of the temporal bone.
a2) Medial wall	b2) Mastoid wall	c2) Tympanic aditus and pyramidal eminence.
a3) Posterior wall	b3) Carotid wall	c3) Tegmen tympani
c4)Roof	c4) Labyrinthine wall	c4) Tensor tympani & auditory tube.

Wall (a)	Common term (b)	Landmark (c)
a5) Anterior wall	b5) Tegmental wall	c5) Oval window, Round window, promontory prominence of the facial nerve canal.
a6) Floor	b6)Bony wall	c6)Tympanic plate of temporal bone and jugular bulb.

4. A schematic representation of the middle earcleft showing the potential route by which the mucociliary system transports mucus from the anterior or superior portion of the middle and the anterior or inferior portion of the middle ear toward the Eustachian tube is given below:



Say whether ciliated epithelium and goblet cells are present in these areas – A, B, C, D. If so, to what extent they are present?

5. Name the five types of cells present in the normal middle ear.

6. Name the types of mastoid process.

SECTION-B

TYMPANIC MEMBRANE

I. (1) Draw neatly the diagram of tympanic membrane.
(2) Use the clues to get the landmarks:

(a) On otoscopy, the major hallmark of a healthy eardrum seen is _____

(b) The Maximum depression caused at tympanic membrane by the manubrium is _____

(c) Left or Right, manubrium at 11 O'clock position _____

(d) Left or Right, manubrium at 1 O'clock position-_____

(e) Fibrocartilaginous ring _____

(f) Seat of the tympanic annulus is _____

(g) Deficient portion of the tympanic sulcus is _____

(h) Lax area _____

(i) Tense area _____

(3) Fill up the quadrants with their respective structures.

II. Give anatomical details of tympanic membrane on the following:

(1) Thickness (2) Diameter: vertical, horizontal (3) Angle: to the floor of the meatus, to the upper wall (4) Mass (5) Area (6) Effective movable area (7) Mean braking strength (8)Reflectance.

III. (1) Name the layers of tympanic membrane.

(2) Tabulate the divisions of outer epithelial layer on the basis of : (a) number of layers (b) cellular/acellular nature (c) cell contents.

(3) Explain the middle fibrous layer and inner mucosal layers.

SECTION-C

OSSICLES

1. Draw the diagram of normal middle ear ossicles.

2. Give other names:
   (a) Malleus (b) Incus (c) Stapes (d) Incudo Malleal joint (e) Incudo stapedial joint (f) The triangular space enclosed by the crura and the foot plate.

3. Give the dimensions of Malleus, Incus, and Stapes for ‘O’s filled in Table.

Structure Dimension	Malleus	Incus	Stapes
Length	0	0	
Weight	0	0	0
Height			0

SECTION-D

LIGAMENTS

Ligaments are highly responsible for the suspension of Ossicular chain within the tympanic cavity. This helps the ossicles balanced with very small inertia. Some of the principal ligaments are given below. Match them with their connection:

LIGAMENT	CONNECTION
1. Superior malleolar ligament	a. From foot plate to fenestra vestibule
2. Lateral malleolar ligament	b. Connects
3. Anterior malleolar ligament	c. Anterior process to anterior wall of the middle ear
4. Ligament supporting incus	d. Connects malleus to tegmen tympani
5. Annular ligament	e. From short process to fossa incudis

SECTION-E

TYMPANIC MUSCLES

The tympanic muscles are called the pennate muscles and they have been shown to contribute to the strength of the Ossicular chain.

Fill in the blanks with the cues given in brackets.
(NOTE: Only limited cues are available)

(Tensor tympani, Stapedius, Stapes, Anterior, Lateral, Medial, Acoustic reflex, Unilateral, Bilateral)

1. The smallest muscle of the body is the _____. Where as the largest muscle of the middle ear is _____ .

2. The middle ear muscle which responds to acoustic stimuli is _____ . Whereas the muscle to nonauditory stimuli is _____ .

3. At 80 or 90 dBSL, the stimulation of the middle ear results in _____ acoustic reflex.

4. Tensor tympani orginates from the _____ part of auditory tube and it pulls the tympanic membrane _____ and _____ .

5. The Stapedius tendon attaches to the _____ of the stapes and draws the same. _____ .

6. The length of tensor tympani and stapedius muscle are _____ and _____ respectively.

SECTION-F

EUSTACHIAN TUBE

I. Classify the auditory tube into (1) two parts, (2) three portions (3) four portions.

II. Tabulate the values of ‘O’ s and get anatomical details of the auditory tube.

Length	Bony	0
	Cartilaginous	0
Diameter		0
Angle made with horizontal plane	Bony	0
	Cartilaginous	0

III. Mark ‘+’ if present; ‘-‘ if absent; and ± if not always present, for the following:

1. The bony portion is always wide open where as the cartilaginous portion of the auditory tube has a valve like mechanism.

2. The bony portion is lined with pseudostratified ciliated epithelium whereas the cartilaginous portion is lined with respiratory ciliated columnar epithelium.

3. There are abundant submucosal glands in the bony portion.

4. The Eustachian tube can be opened both in passive and active ways, and the opening pressure varies from

individual to individual, ear to ear, and from time to time.

5. There are four clinical types: Type-A, Type-B, Type-C, and Type-D based on the open condition of the auditory tube and thus this helps in diagnosing middle ear effusions.

6. The positive pressure with reference to middle ear leads to Alternobaric Vertigo whereas the negative pressure leads to Barotrauma and locking.

7. Politzer and Bezold’s theory deals with the diffusion of the gas, exchange of fluid and tubal passages with reference to auditory tube.

8. The muscle which helps in Eustachian tube dilation is Levator veli Palatini.

9. There is simultaneous contraction of the palatoglossus and superior pharyngeal contrictor muscles of the Eustachain tube during the act of swallowing and yawning.

10. The opening pressure of the tube is 400mm H2O pressure or 4 Kpa and on swallowing, the auditory tube open for a duration of 0.3 to 0.5 seconds only.

SECTION-G

NERVE SUPPLY AND VASCULAR SUPPLY TO THE MIDDLE EAR

1. Match:

Nerve supply	Nerve
1. Sensory	a. Facial nerve
2. Motor	b. Glossopharyngeal nerve
i. Tensor tympani	c. Trigeminal nerve
ii. Stapedius	

2. Match:

Vessel supplying	Portion supplied
1. A branch of mastoid branch of stylomastoid artery derived from auricular artery.	a. Superior portion
2. A branch of internal maxillary artery and Ramus tympanici (a branch of ICA)	b. Inferior portion
3. A branch of the ascending pharyngeal artery	c. Anterior portion
4. Superior petrosal, superior tympanic and ramus nutrica incudomallei (branches of the middle meningeal artery)	d. Posterior portion

5.2 PHYSIOLOGY, MIDDLE EAR

SECTION-H

Answer the following:

1. Is the middle ear a pressure receptor? If so, give reason.

2. Is the middle ear a gas pocket? If so, give reason.

3. What are the various types of gases present in the middle ear cavity? State their percentage.

4. Name the structures that are helpful in regulating middle ear pressure.

5. Explain the classification given by Jacob Sade, Michal Luntz and kfar Saba on the assessment of middle ear based on the amount of air.

6. Which layer gives tensile strength to the tympanic membrane?

7. What is reflectance? State their values at various frequencies?

8. Who measured the displacement of the tympanic membrane first? What was his finding?

9. How is the vibration of the tympanic membrane measured in a three dimensional manner? Who measured it? What is their finding?

10. Explain the mechanism of Ossicular movement when there are no sound. Waves striking the tympanic membrane.

11. Explain the role of Ossicular mechanism when the static air pressure is varied in the external auditory canal.

12. How do the middle ear muscles act on the ossicles for acoustic transmission?

13. What are the various ways of middle ear modification on sound transmission?

14. What will be the gain when there is blockage of the aditus-ad-antrum?

15. How does the aditus-ad-antrum affect the sound transmission through the middle ear?

16. How does the resection of the tensor tympani muscle affect the sound transmission?

17. State three functions of the middle ear acoustic reflex.

18. State the functions of the auditory tube as per modern theory.

SECTION-I

I. Match the formulae:

Given below are a few formulae. Match those and state the formula for impedance transformer action of the middle ear.

1.	Acoustic impedance	A. $\frac{??}{??}$
2.	Area ratio	B. $\frac{?_?}{?_?} = \frac{??_??_?}{??_?\,?\,?_?\,?^?}$
3.	Lever ratio	c. $\frac{?_?}{?_?} = \frac{?_?}{?_?}$
4.	Volume velocity	D. $\frac{?_?}{?_?}$

5. Therefore, the impedance transformer action of the middle ear is given by the formula: ?

II. Match the following sets of formulae.

1.	Complex impedance magnitude	A) ϕ = arc tan ? ? ?
2.	Complex impedance phase angle	B) z = $?\overline{??^?\,?\,?^?}$
3.	Admittance magnitude	C) Y=$?\overline{\frac{?}{?^?\,?\,??S??\;?\frac{?}{?S?\,?}?}}$
4.	Admittance phase angle	D) ϕ=arc tan $?\frac{?\frac{?}{????}?\,????\,?}{?^?}?$
5.	Resonant frequency	E) $\frac{?}{?}\,\frac{?}{?}$
6.	Band width	F) $\frac{?}{?}\,?\overline{\frac{?}{?\,?}}$

III. Match the following with their numerals:

1.	Acoustic impedance of air, Acoustic impedance of water	A) 60-80%
2.	Expected loss of sound pressure due to reflection at the tympanic membrane	B) 2Db
3.	Real loss of sound pressure due to reflection at the tympanic membrane	C) 15dB
4.	Effect area of the tympanic membrane	D) 1: 3470

SECTION-J

TRANSMISSION OF SOUND BY MIDDLE EAR TO COCHLEA

Fill in the blanks with the clues given in bracket.

1. For perfect transmission of sound into the middle ear system, the Impedance of the middle ear must be _____ to the impedance of the air in the earcanal. (equal/more/less)

2. Impedance is a _____ quantity as it has both magnitude and direction and it is strongly dependent on frequency. (Scalar/Vector)

3. Impedance is the _____ of reactance, an imaginary part and resistance, the real part. (Square/Sum/Inverse).

4. Admittance is the _____ of impedance. (Sum/square/reciprocal).

5. Admittance of the middle ear is _____ than that of air. (equal/more/less)

6. Admittance is _____ at the resonant frequency. (maximum/minimum).

7. At high frequencies, the admittance magnitude is proportional to the _____ of frequency. (Sum/inverse/square)

8. Admittance increases leading to a _____ volume velocity. (greater/lesser/equal)

9. Transfer function is _____ to the input admittance (proportional/equal)

10. At the resonant frequency, the transfer function is _____ and in other frequencies it is _____ . (one/two/less than one)

11. Admittance is the _____ of the following components namely the conductance, the real part and susceptance, the imaginary part. (square/power/sum)

12. The effect of mass is important at _____ frequencies. (low/mid/high)

13. Compliance is the _____ of stiffness.

14. Compliance is important at _____ frequencies. (low/mid/high)

15. In normal human ears, the compliance of the tympanic membrane is _____ than the compliance of the middle ear space and therefore the compliance of the tympanic membrane tends to dominate the total compliance. (equal/larger/smaller)

CHAPTER-5

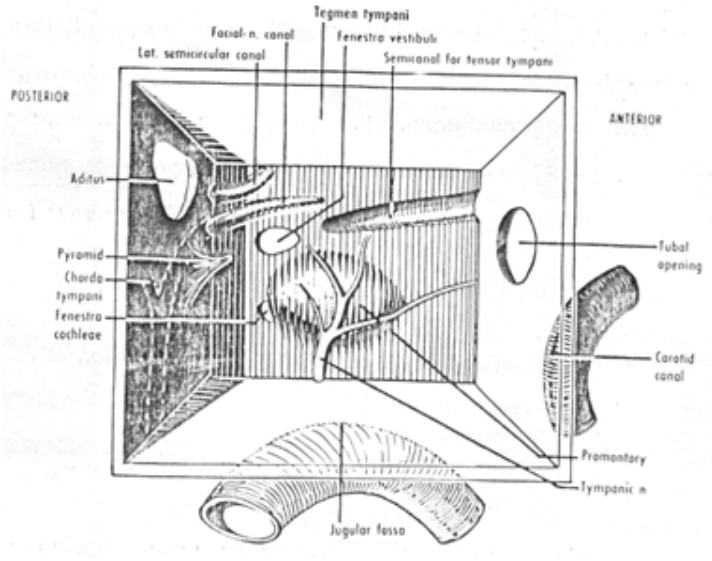
KEYS

5.1 ANATOMY, MIDDLE EAR

SECTION-A

TYMPANIC CAVITY

1. Schematic representation of the middle ear.



2. Values, Tympanic cavity:

Volume	:	2cc
Width	:	2-4mm
Vertical Dimension	:	15mm

3. Match.

Wall (a)	Common term (b)	Landmark (c)
a1	b1	c1
a2	b4	c5
a3	b2	c2
a4	b5	c3
a5	b3	c4
a6	b6	c6

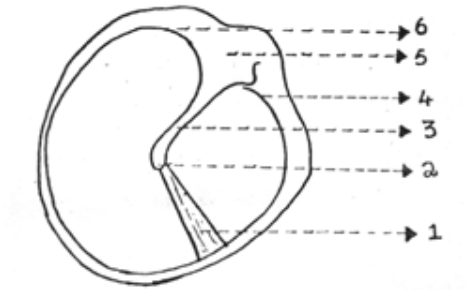
4. Middle Ear Mucosa:
   A-always present; B-usually present; C-Rarely present; D-never present.

5. Types of cells in the middle ear:
   (a) Non ciliated cells with secretory granules
   (b) Ciliated cells with secretory granules
   (c) Ciliated cells without secretory granules
   (d) Intermediate cells
   (e) Basal cells
   (Reference: Hentzer, 1970).

6. There are three types of definite mastoid process:
   (a) Cellular, where air cells are large and numerous.
   (b) Diploic, where cells are small and less numerous. Marrow spaces are present.
   (c) Sclerotic(or ’ivory’) where cells and marrow spaces are absent.

SECTION-B
TYMPANIC MEMBRANE

I. (1) Tympanic membrane



1. Cone of light 2. Umbo 3. Handle of malleus surmounted by shoot process 4. Anterior horizontal fold 5. Attic 6. Posterior horizontal fold.

2. Landmarks:
   (a) Cone of light (b) Umbo (c) Left (d) Right (e) Annulus (f) Tympanic sulcus (g) Notch of Rivinus (h) Pars flaccida (i) Pars tensa

3. Quadrants and their structures:

(a) Postero-superior quadrant	-	Oval window (lies opposite)
(b) Postero-inferior quadrant	-	Round window (lies opposite)

(C) Antero-superior quadrant - Opening of Eustachian Tube (lies anteriorly)

(d) Antero-inferior quadrant - Swelling formed by internal carotid artery. (lies anteriorly)

II. Antomical details :
(1) 0.1mm (2) 9-10mm, 8-9mm (3) 40^{o}, 140^{o} (4) 14mg (5) 0.5 – 0.9 cm^2 (6)55mm^2 (7) 1.6 x 10^6 dynes/cm^2 (8) 0.3 to 0.8

III. (1) Layers of tympanic membrane:
- Outer epithelial layer (Epidermis)
- Middle fibrous layer (Lamina propria)
- Inner mucous layer

2. The divisions of the epidermis of the tympanic membrane are: Stratum corneum, Stratum granulosum, Stratum spinosum, and Stratum basale.

Divisions	No. of layers	Cellular OR Accelular nature	Cell contents
Stratum Corneum	1-6	Accelular	Desmosomes ++ Organelles -- Other cell -- Contents

Divisions	No. of layers	Cellular OR Accelular nature	Cell contents
Stratum Granulosum	1-3	Cellular	Keratohyaline granules ++ Lamellar granules ++ Cytoplasm characteristics. tonofilaments occasionally ++
Stratum spinosum	2-3	Cellular	Bundles of tonofilaments ++ Mitochondria ++ Ribosomes ++
Stratum basale	1	Cellular	Polyhedral cells or elongated cells ++ Basement membrane ++

P.S. : ++ : Present -- : Absent

3) Middle fibrous layer and inner mucosal layer.

The predominant feature of the middle fibrous layer (Lamina propria), in both the Pars tensa and Pars flaccida is the presence of collagen fibrils. In the pars tensa,

the fibrils closest to the epithelial layer are usually in direct contact with the basement membrane of the epidermal layer, although in places a thin layer of connective tissue intervenes. These lateral fibres are radial in orientation, while the deeper ones are circlular, parabolic and transverse.

In The Pars flaccid, lamina propria is less marked, but it still contains collagen fibres although they appear to lie in an almost random orientation.

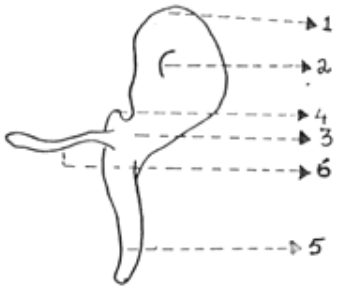
A loose connective tissue layer containing fibroblasts, macrophages, nerve fibres (mainly unmyelinated) and many capillaries, lies between the deep layers of the lamina propria and the inner mucosal layer. Neither the capillaries nor the nerves appear to penetrate the basement membrane or enter the mucosal layer.

The mucosal layer of the pars tensa varies in height from a low simple squamous or cuboidal type to a pseudostratified columnar epithelium. In the Pars flaccid, the taller ciliated cells are not found.

SECTION-C

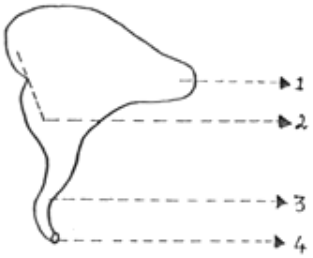
OSSICLES

MALLEUS



1. HEAD
2. ARTICULAR FACET
3. NECK
4. LATERAL PROCESS
5. MANUBRIUM
6. ANTERIOR PROCESS

INCUS



1. SHORT PROCESS
2. ARTICULAR FACET
3. LONG PROCESS
4. LENTICULAR PROCESS.

STAPES

1. HEAD
2. NECK
3. POSTERIOR CRUS
4. BASE
5. ANTERIOR CRUS

2. Other names:

(a) Hammer (b) Anvil (c) Stirrup (d) Double saddle joint (e) Enarthrodial joint (f)Obturator foramen.

3. Dimensions:

Structure Dimension	Malleus	Incus	Stapes
Length	9mm	7mm	
Weight	23-27mg	25-32mg	2.05 to 4.34 mg
Height			6mm

SECTION-D

LIGAMENT

1-b; 2-c; 3-d; 4-e; 5-a

SECTION-E

TYMPANIC MUSCLES

1. Stapedius, Tensor tympani; 2. Stapedius, Tensor tympani; 3. Bilateral 4. Cartilaginous, medially, anterior 5. Head, posteriorly 6. 25mm, 6mm

I. SECTION-F

EUSTACHIAN TUBE

I. Auditory tube can be classified into: (1) Bony and Cartilaginous parts (2) Bony, Cartilaginous, and membranous portions (3) Bony, Cartilaginous, membranous and isthmus.

II. Anatomical details:

Length	ony	12mm
	Cartilaginous	18-24mm
Diameter		3-6mm
Angle made with horizontal plane	Bony	25^{o}
	Cartilaginous	40^{o}

III. 1(+); 2(-); 3(-); 4(+); 5(+); 6(+); 7(-); 8(=); 9(-); 10(+)

SECTION-G

NERVE SUPPLY AND VASCULAR SUPPLY TO THE MIDDLE EAR

I. 1-b; 2(i)-c; 2(ii)-a
II. 1-d; 2-c; 3-b; 4-a

****

5.2 PHYSIOLOGY, MIDDLE EAR
SECTION-H

1. The middleear acts as a pressure receptor, reacts not only to acoustic vibrations but also to charges of static air pressure i.e. gushes of wind, sneezing, blowing one's nose, diving flying as well as tympanometry and pneumatic otoscopy.

   Supplement: The pressures surpassing 100cm H_2O are nearly always tolerated by the ear without damage, as there is an efficient protective mechanism in the joints of the Ossicular chain incudo malleal and incudo stapedial joints.

2. A Physiologic middle ear is a gas pocket balanced by diffusion of gases into and from the tissues as well as by ventilation through and out of the Eustachian tube.
3.

Gases	Percentage
Carbondioxide	52 mm Hg
Nitrogen	605 mm Hg
Oxygen	54 mm Hg

4. Structures that are helpful in regulating middle ear pressure are Eustachian tube and Middle ear capillaries.

5. The authors Jacob Sade. Michael Luntz and Kfar Saba in July 1990 has given the following classification on the assessment of middle ear based on the amount of air in

the middle ear.

Grade O :- Air was present behind the entire tympanic membrane as well as in the attic or even beyond it.

Grade 1 :- Air was present behind the entire tympanic membrane upto the horizontal part of the facial nerve and the facial ridge, yet the attic and mastoid were devoid of air.

Grade 2 :- Air was present behind the tympanic membrane except for its posterior, superior quadrant.

Grade 3 :- Atleast half of the tympanic membrane including the regions of the oval window and round window, was found to be reclined or adherent to the promontory. The anterior half was filled with air.

Grade 4 :- Three quarter of the tympanic membrane was found reclined or adherent to the promontory, yet an anterior inferior aircrescent was present behind the tympanic membrane.

Grande 5 :- Anteriorly a cushion or airbubble was seen. The rest of the drum was atelectasis.

Grade 6 :- The tympanic membrane as a whole was collapsed, with no trace of air found behind it.

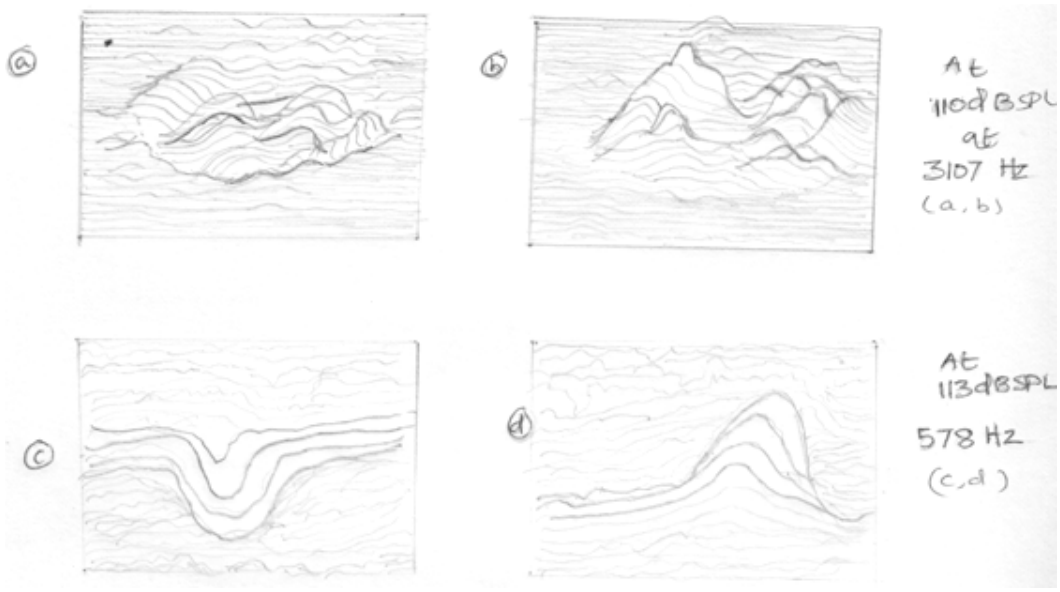
6. The middle fibrous layer withstands tensile force and provides tensile strength to the tympanic membrane.

7. Reflectance is the acoustic energy reflection co-eficient measured at the eardrum. Here standing waves are analyzed by using probe microphone. It is denoted by ‘R’

Frequency	‘R’ Value
Upto 4 KHz	0.3
4 KHz to 8 KHz	0.8
8 KHz to 13 KHz	0.5 to 0.8

8. G.Von Bekesy (1941) measured the displacement of the tympanic membrane first. He concluded that the tympanic membrane vibrated like a stiff plate hinged superiorly around the Ossicular axis of rotation.

9. The vibration of the tympanic membrane in a three dimensional manner was measured by Nils Gunnar Toremalm (1988) by using Laser Doppler Scanning. Experiments have been done on human temporal specimens within 48 hours after death. The authors used a constant intensity of 113 dBSPL. The vibration pattern at 578 Hz and 3113 Hz respectively were compared at two antagonistic phases.



9.The tympanic membrane acts as a transformer so that at a given SPL, the anterior and posterior parts of the drum shows a larger displacement than the central part which is connected to the malleus.

10.In the regular middle ear there is no sound actually. Therefore there is gliding movement of the incudo malleal joint which leads to the gliding movement of the incudo stapedial joint. Therefore the stapes and inner ear are decoupled from the excessive displacement of the drum membrane and malleus.

11. Variation of static airpressure in the external earcanal ranging from 0 to $\pm$ 400 mm H_2O induces an inward and outward movement of the malleus. The average umbo displacement between +400 to -400 mm H_2o was 620 Um.

The average ratio of malleus:incus:stapes (m:i:s) inward outward movement ration was determained to be 21: 1.8 : 1. This implies that the stapes is displaced inwardly and outwardly 21 times less than the malleus handle. Thus pressures surpassing 100 Cm H_2O are nearly always tolerated by the ear without damage, as there is an efficient protective mechanism in the joints of the Ossicular chain, incudo malleal and incudo stapedial joints.

12. The middle ear muscles keep the ossicles in an optimal vibrating position for acoustic transmission. The concept of middle ear muscles being anatomical antagonists is genereally accepted. However regarding the directions of the rotational and the motional axis of the ossicles, it appears that instead of being exerted in a true antagonistic manner, the fractions are direction at right angles to each other.

At loud sounds, tympanic muscles cannot protect the ossicles from being torn out by the negative pressure in the earcanal. Instead this is accomplished by the ligamentous fixation of the malleus handle at the cochleariform

process. (Thus the sheath of the tendon of the tensor tympani muscle is exceptionally strong. It might even therefore be called the malleo cochleoriform ligament)

13. Middle ear sound transmission can be changed by modifications such as blocking the auditus-ad-antrum, enlarging the auditus and mastoid cavity, changing the volume of the tympanic cavity and sectioning the middle ear muscles.

14. The auditus blockage case a mean increase of 5.4dB with a peakage at 2.8n KHz and a mean decrease of 3.4 dB below 1.6 KHz. (In this study human temporal bones were used as specimen and the middle ear characteristics between 1KHz to 4 KHz range were studied by Kiyofumi Gyo, M.G., Richard, L.Goode, M.D., Craig Miller, D.C. 1986).

15. The air volume in the middle ear cavity acts as a compliance in series with the tympanic membrane and O ossicles. As the large mastoid is connected to the tympanic cavity through the auditus-ad-antrum, the acoustic characteristics are explained as follows: At low frequencies, the compliance of the cavities acting on the tympanic membrane is corresponding to the total volume of two cavities. Whereas at high frequencies, the aditus closes acoustically and the compliance is that of the tympanic cavity alone. Blocking the aditus improved the sound transmission in the 1KHz to 3KHz range

by 5Db to 10Db whereas below 1KHz, it decreased the transmission by 5Db Compared with normal ear. (Onchi,1961)

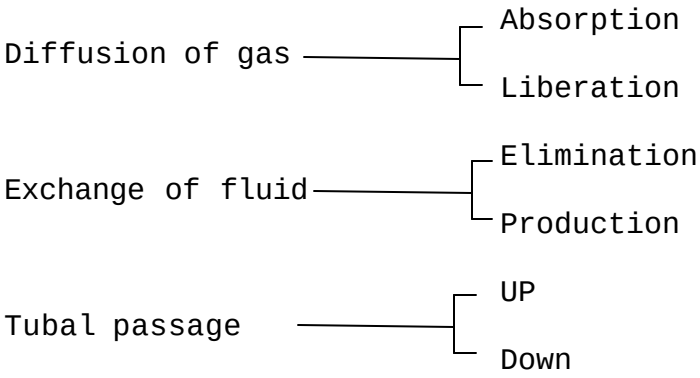
16. Clubb(1965) reported improvement in speech discrimination after tensor tympani section and peumomassage in humans with SN hearing loss but no change in puretone thresholds.

In the study by Kiyofumi Gyo, et al. (1986) resection of the tendon of tensor tympani muscle produces minimal changes in umbo vibration, and a slight improvement of 1.7Db at 1.8KHz.

17. Extention of the dynamic range of the auditory system with reference to intensity:

- decrease masking of low frequency sounds on high are enhanced.

18. Functions of the auditory tube as per modern theory.



SECTION-I

I. Match.

1-B; 2-D; 3-A; 4-C

Impedance transformer action of the middle ear is

$\frac{?_?}{?_?} = ?\frac{?_?}{?_?}?^{?} \; ?\frac{?_?}{?_?}?^{?}$

II. Match.

1-B; 2-A; 3-C; 4-D; 5-F; 6-E.

III. Match.

1-D; 2-C; 3-B; 4-A.

SECTION-J

TRANSMISSION OF SOUND BY MIDDLE EAR TO COCHLEA

1.equal 2. vector 3. sum 4. reciprocal 5. less 6. maximum 7. inverse 8. greater 9. proportional 10. one, less than one 11. sum 12. high 13. inverse 14. low 15. smaller

******

CHAPTER – 6

INNER EAR

This chapter comprises of two parts namely :

6.1 : Anatomy, Inner Ear

6.2 : Physiology, Inner Ear

6.1: deals predominantly with various anatomical aspects of the inner ear such as parts of the inner ear, their anatomical dimensions, cochlear membranes, hair cells, supporting cells, stria vascularis, spiral ligament, endolymphatic duct and sac, cochlear fluids, vestibular apparatus and vascular supply in sections A to I.

6.2: deals with various physiological aspects of the inner ear such as cochlear fluids, hair cells, potentials, and cochlear models including Otoacoustic emissions in sections J to N.

6.1 : ANATOMY, INNER EAR

SECTION A

I. Give me a name (Clue: Greek (G) or Latin(L)term is being provided here).

1. I am “hard and stony” (L). I enclose the bony labyrinth. I am portion of the temporal bone.

2. I am like a snail shell (L).

3. I am a dilation of the semicircular canals. I am called as a jug (L).

4. I am the pillar. I am the core. The “Snail shell” go round on me. I am called the hub (L).

5. I am the top of the “snail shell”. All call me a little tub (L).

6. I am not an actual “staircase” (L). I am a spiral shaped duct.

7. ‘Coil’ and a ‘hole’ makes my name in Greek.

II. Name the parts which occur in twos/ threes.

1. Cavity systems of the inner ear.

2. Labyrinthine systems of the inner ear.

3. Parts of the otic capsule.

4. Perforations/openings of the vestibule.
5. Semicircular canals.
6. Cochlea.
7. Ducts of the bony cochlea.
8. Openings of the bony cochlea.
9. Labyrinthine fluids.
10. Membranous labyrinth, parts.
11. Membrane boundaries of scala media.
12. Spiral laminar lips.
13. Spiral lamina, layer of bones.
14. Zones of Basilar membrane.
15. Cells of ‘Spiral Organ’.
16. Pillars of corti.
17. Tunnels of corti.
18. Hair cells.
19. Phalangeal cells.
20. Zones of tectorial membrane.
21. Fibrils of tectorial membrane.

III. WINDOWS OF THE INNER EAR

Unscramble the following :

1. The shape of the oval window – DIKYEN

2. The oval window opens into – ELUBITSEV

3. During life the oval window is occupied by the POOLFETTA of the PASTES.

4. Round window is thicker at SEDEG and thinner towards the RECTEN.

5. It has an outer THEPIELUMI facing middle ear, a core of IVCONCNETE tissue and an inner THEPIELUMI layer bounding the inner ear, thus there are ETERH layers.

SECTION B

Anatomical dimensions and their values:

1. State the value :

   a. Length of the vestibule

   b. Length of the cochlea.

   c. Length of the scala media.

   d. Length of the Basilar membrane

   e. Number of outer rods of corti.

   f. Number of inner rods of corti.

   g. Number of inner hair cells.

h. Number of outer hair cells.

i. Width of the Basilar membrane

j. Number of fibres of the Basilar membrane.

k. Diameter of the filaments of parts tecta.

l. Diameter of the type A fibrils of the Tectorial membrane.

m. Diameter of the type B fibrils of the tectorial membrane.

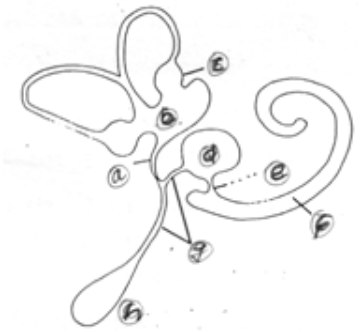
n. Area of the round window

Horizontal Vertical

o. Angle between the plane of the tympanic sulcus and plane of the vertical part of the round window.

p. The inches of oval window and round window are -

2. Label the parts of the membranous labyrinth :



3. Draw the diagram of cochlear scalae and label the parts neatly.

4. Neatly draw the diagram of spiral organ and label the parts.

SECTION C

COCHLEAR MEMBRANE :

1. List the membranes present in cochlea (clue-5).

2. Compare and contrast the basilar membrane, the tectorial membrane and the Reissner's membrane based on their.

   (a) Structure (b) Attachment or extention (c) Zones. (d) Cellular components (e) Other important structures seen (f) Role.

3. Draw the ultrastructure of Basilar membrane, Reissners membrane and Tectorial membrane and label their parts.

SECTION D

HAIR CELSS

1. Draw the diagram of outer and inner hair cells and label their parts.

2. Pointout the differences existing between inner and outer hair cells with respect to the following :
   (a) Arrangement (b) Size and shape (c) Cell contents
   (d) Stereocilia (e) Nerve innervation (f) Responses.
   (g) Function (h) Resting potential (i) Kinetics

(j) Metabolism (k) Cochlear transduction process. (l) Tuning curves (m) Tight junction (n)Postmortem changes.

SECTION E

SUPPORTING CELLS

1. Name the supporting cells. There is information given on its cytology and function :

   a. Epithelial cells – secretory in function :

      A _ _ _ _ _ _ _ T _ _ _ _

   b. large flat polygonal cells

      I _ _ _ _ S _ _ _ _ _ C _ _ _ _

   c. Flat cells with numerous microvilli – supporting Inner Hair cells.
      B _ _ _ _ _ C _ _ _ _ OF _ _ _ D.

   d. Cells having a body and a “finger like” process.

      P _ _ _ _ _ _ _ _ _ C _ _ _ S.

   e. “ Rods of Corti” – most conspicuously seen structure.
      P _ _ L _ _ C _ _ _ _ .

   f. Cell body proper ; slender phalangeal process cup shaped- Accommodate the outer hair cells basalend ; Form the reticular lamina.
      D _ _ T _ _ ‘ _ C _ _ _ _ .

g. Columnar cells forming the outer tunnel of corti.
H _ _ S _ _ ‘S C _ _ _ S.

h. Cuboidal cells – secretory or transportation function.
B _ T T _ _ _ _ _ C _ _ _ _ .

i. Polygonal cells – appears to provide a paracellular barrier between the endolymphatic space and the cells of Bottchers and External sulcus.
C _ _ U _ _ _ _ C _ _ _ _ .

j. A paracellular barrier to the aforenamed polygonal cells.
E _ _ _ R _ _ _ S _ _ _ _ _ C _ _ _ _ .

k. Epithelial cells – Dark cells – secretion ; Light cells- Absorption.
_ O T C _ _ _ _ .

2. NUMBER GAME : (Mention the units appropriately)

a. The nucleus of the outer pillar cell is _____ in diameter.

b. In the Deiter’s cells, Tight junctions are extensive with _____ to _____ sealing filaments.

c. Hensen’s cells consist of _____ to ____ rows of columnar cells.

d. The tight junctions of Hensen’s cells consist of _____ sealing filaments.

e. Bottcher’s cells have a diameter of _____

f. The clandius cells which are polygonal are _____
thick and _____ wide with a diameter of _____.

I STRIA VASCULARIS

Fill in the blanks and complete the paragraph :

The stria vascularis is a (1) _____ cell layer (2) _____ epithelium (enriched blood supply) that is not bounded by a basal lamina. The stria vascularis is separated from the spiral prominence and Reissner’s membrane by spindle shaped (3) _____ cells.

Stria vascularis has (4) _____ and (5) _____ cells.

The marginal cells have a lobulated (6) _____ . dark staing (7) _____ and containing more (8) _____. There also (9) _____ is their axial cytoplasm and (10) _____ .

Function : Active in transport.
Active enzyme transport.

Intermediate cells have (11) _____ nucleus and (12) _____ strained cytoplasm. Their plasma

membranes exhibit interdigitating processes and their cytoplasm is filled with clear vesides. Intermediate cells also contain (13) _____ and (14) _____ pigments.

The basal surface of the stria vascularis is sealed against paracellular transport from the underlying spiral ligament by several layers of fusiform (15) _____ cells.

II SPIRAL LIGAMENT :

Say true or false :

1. Spiral ligament is a connective tissue vascular structure that forms the most lateral wall of the scala media.

2. The matrix consists of fibroblast like cells, abundance of extracellular filaments.

3. Bekesy differentiated the cells into type I fibroblast and type II fibroblast like cells.

4. Takahashi and Kimura (1970) gave the aforementioned classification.

5. Type I Fibroblasts are most numerous and has few cytoplasmic organelles including lipid inclusions.

6. Type II fibroblast shows numerous cytoplasmic organelles and mitochondria.

7. The cells function in fluid transport and carbonic anhydrase activity.

III. ENDOLYMPHATIC DUCT AND SAC

Mark the correct answer(s) with a (/)

1. Endolymphatic sac and duct were first described by:

   (a) Bekesy

   (b) Linnaeus

   (c) Corti

   (d) Bottcher

2. The endolymphatic duct courses

   (a) through the cochlear duct.

   (b) through the vestibular duct to end in a blind pouch located near the dura mater.

   (c) None of the above.

3. Endolymphatic duct and sac function in

   (a) Fluid and ion exchange.

   (b) Phagocytosis of waste product.

   (c) Pressure regulation of endolymphatic compartment.

   (d) Majorsite of antigen processing.

SECTION G

COCHLEAR FLUIDS

I. Match the cochlear fluids with their scala.

Fluid	Scala
1. Perilymph	a. Scala media
2. Endolymph	b. Scala tympani
3. Cortilymph or	c. Organ of Corti
Perilymph like fluid	d. Scala vestibuli

The values of components of Perilymph and endolymph are given below choose the components given in brackets. (Electrical potentials, Ca^{2+}, Mg^{2+}, Cl^{-}, HCO^{-}_{3}, K^{+}, Na^{+}, P^{h}, Osmolarity).

	Scala Tympani Perilymph	Endolymph	Scala Vestibuli Perilymph
1. ?	147	1	141
2. ?	3.4	158	6.7
3. ?	0.68	0.023	0.64
4. ?		0.011	
5. ?	7.28	7.37	7.26
6. ?	129	136	130
7. ?	19	21	18
8. ?	293	304	294
9. ?	0	90	5

SECTION H

VESTIBULOLOGY

I. 1. What are the structures seen in the receptol organs in the vestibular apparatus.

2. Which part of the inner ear is responsible for (a) linear motion and (b) angular motion.

3. What is cupula ?

4. How is the vestibule different from the cochlear membranous labyrinth.

II. 1. The angles of cristae in humans are given below find their deviation from right angle :

	Cristae	Angles
1.	Anterior to Poseerior cristae	100.4^{o}
2.	Posterior and Lateral cristae	94.8^{o}
3.	Lateral and anterior cristae	108^{o}

2. The angle between semicircular canals (scc) and cristae are given, below find their deviations from right angle

	Semicircular canals and cristae	Angles
a.	Anterior Semicircular canals to long axis of cristae	62.9^{o}
B.	Lateral Semicircular canals to long axis of cristae	65^{o}
c.	Poterior Semioircular canals and its cristae	59.6^{o}

3. The angles between Semicircular canals are given find their deviation.

	Semicircular canals (SCC)	Angles
a.	Anterior Semicircular Canals to posterior Semicircular canals	108.2^{o}
b.	Lateral Semicircular canals to Anterior Semicircular canals	101.8^{o}
c.	Posterior Semicircular canals and lateral semicircular canals	101.3^{o}

4. What do you infer from these data.

III. Say true or false :

1. The small sphereical saccule is located posterior to the utricle.

2. A short and narrow canal, the Ductus reunions emanates from the lower part of the saccule and connects it with membranous cochlea.

3. The Utricle and saccule are connected by the utriculo saccular duct.

4. The endolymphatic sac terminates in the pia mater of the posterior surface of the temporal bone.

5. Type I and type II cells differ primarily in their pattern of vibration.

SECTION I

VASCULAR SUPPLY

Choose the arterial or venous blood supply from the abbreviations * and choices given below: (* These abbreviations are not universal).

1.	S M A	(a) Spiral modiolar artery (chochlear branch) (b) Scala media artery.
2.	C C A	(a) Central ceribellar artery (b) Common cochlear artery.
3.	V C A	(a) Ventral cochlear artery (b) Vestibulo cochlear artery.

4.	L A	(a) Labyrinthine artery (b) Lamellar artery.
5.	A V A	(a) Anteroventral vestibular artery (b) Anterior vestibular artery.
6.	V C A	(a) Vein of the cochlear aqueduct (b) Vein of the cerebellar anastomose
7.	V S V & V S T	(a) Vein of the scala vestibuli and vein of the scala tympani (b) Vein of the scala tympani and vein of the scala vestibuli.

Choose the correct answer(s)

8. The other veins present in the cochlea are

a) Common, modiolar vein.

b) Vestibulo cochlear vein.

c) Posterior vestibular vein.

d) Anterior vestibular vein.

e) Vein of the round window.

f) All the above.

6.2 : PHYSIOLOGY, INNER EAR

SECTION J

COCHLEAR FLUIDS

I. Read the passage given below and follow further instructions :

Traditionally, the inner ear is described in terms of bony labyrinth, an intricate series of fluid filled tubes running through the temporal bone, with which is suspended the membranous labyrinth. The membranous labyrinth contains a fluid of unique ionic composition, the endolymph, which is separated by cellulal structures from the Perilymph, a fluid of typical extracellular ionic composition. In the cochlea, these structures devide the structure into three chambers :- scala tympani (S.T.), scala media (S.M.), and scala vestibule (S.V.). In humans three chambers, form a spiral of approximately ?$\frac{?}{?}$ turns. S.T. and S V form the outer chambers, which contain Perilymph. Both of these scala have fenestrae to the middle ear cavity that are closed by the round window membrane and footplate of the stapes, respectively S T and S V are connected at the cochlear open by an opening called the helicotrema. In addition, both compartments are connected to other fluid filled spaces.

S T Perilymph of the basal turn is connected to the cerebrospinal fluid (C S F) of the subarachnoid space by the cochlear aqueduct S V Perilymph o the basal turn has wide communication with the Perilymph of the vestibuli. S M, Containing endolymph, is completely bounded by tissues to that there is no direct fluid connection between endolymph and Perilymph. The cells surrounding the endolymphatic compartment constitute an endolymph/Perilymph barrier, characterized by specialized tight intercellular junctions (zonulae occludentes) to limit paracellular solute movement. In the basal turn, cochlear endolymph is connected to saccular endolymph by ductus reunions. Thus all three cochlear scale have ducts allowing communication with other fluid-filled spaces.

State whether the following are “True” or “False”.

1. The cochlea is devided into three chambers.
2. S T and S V form the outer chambers.
3. Both S T and S V are closed by the round window and the footplate of the stapes.
4. S T and S V contains Perilymph.
5. S T Perilymph of the basal turn is connected to the C S F and S V with Perilymph of the vestibuli.

6. Both endolymph and Perilymph contains same ionic composition.

7. S M forms the outer chamber.

8. There is direct fluid connection between endolymph and Perilymph.

9. Zonulae occludentes limit paracellular solute movement.

10. In the basal turn, cochlear Perilymph is connected to saccular endolymph by ductus reunions.

II. a. What are the functions of cochlear fluids ?

b. What are all the technical difficulties faced in the study of cochlear fluids ?

SECTION K

OUTER HAIR CELL

Given here is a special section on outer hair cell. Encircle the right choice :

1.	O H C can be maintained for	a. two days b. four days
2.	A healthy O H C behaves like an	a. elastic rod b. turgid rod

3. Turgidity is related to
   a. positive hydrostatic pressure
   b. Negative hydrostatic pressure

4. Insults to the cytoplsmic membrane causes often the ejaculation of nucleus
   a. yes
   b. no

5. Electrical stimulation of O H Cs generates

   O H C is
   a. shortening of the cells
   b. elongation of the cells.

6. The source of energy for the electromotility of

   O H C is
   a. voltage dependent
   b. calcium independent
   c. both.

7. In the intact cochlea, O H C maintain
   a. low resting potential
   b. high resting potential.

8. “O H Cs can move at rate no muscle is capable of”
   a. yes
   b. no

9. Hyperpolarization causes the O H C to
   a. elongate
   b. shorten
   c. both.

10. Depolarization causes the O H C to

a. elongate
b. shorten
c. both.

11. O H C is firmly anchored in the reticular lamina

a. yes
b. no

12. O H C nucleus is eccentrically placed

a. yes
b. no

13. In the stereocilia and Cuticular plate, long chained compounds are :

a. present.

b. present but loosely packed

c. present but densely packed

d. not at all present.

14. O H C has

a. tension resisting element

b. compression resisting element

c. no such elements present distinctly.

d. both present.

15. The compression component is the volumous component and it is :

a. the cytoplasm

b. the Nucleus
c. the Plasma membrane.

16. The tension resisting element is

a. sub plasma lamina
b. laminated cisternal network
c. cytoplasm
d. all the three.

17. The low ionic strength sugar solutions

a. depolarize the cell
b. hyperpolarize the cell
c. depolarize or hyperpolarize based on the concentration of the sugar solution.

18. The increase in hydrostatic pressure of the O H C leads to

a. increase in volume
b. decrease in volume
c. change I sunpredictable.

19. Sustained depolarization leads to

a. decrease in volume due to loss of fluid
b. increase in volume
c. change in volume is unpredictable.

20. O H C undergoes changes in the shape

a. unidimensionally
b. two dimensionally
c. three dimensionally.

21. morphometric analysis reveals that both the sugar and potassium manipulation lead to

a. increased all volume.
b. decreased all volume
c. increased all volume with no change in surface area.
d. decreased all volume with change in surface area.

22. Turgidity of the O H C is affected by

a. extracellular application of salicylates
b. intracellular application of salicylates
c. either of the above
d. none of the above.

23. Aspirin

a. blocks the electromotility of O H C
b. improves the electromotility of O H C
c. none of the above
d. blocks for a certain and then improves the electromotility.

24. The substance which inhibits the response of the O H C are

    a. cytochalasin B and Inorganic Bisphosphate
    b. Trifluoroperezine and Antiactin
    c. none of the above
    d. all the above.

25. Though the cochlear cells vary from individual to individual, there is an agerelated decline in the number of hair cells per mm.

    a. True
    b. True but not always
    c. False.

SECTION L

COCHLEAR POTENTIALS

Encircle the correct answer(s)

1. Potentials which occur without acoustic stimulation are

    a. Action Potentials
    b. Resting Potentials
    c. Cochlear Microphonics.

2. Potentials prevailing at rest can be classified into

    a. Intracellular Potentials
    b. Summating Potentials
    c. Endocochlear Potentials.

3. The bioelectric potential prevailing within a cell is

   a. Cochlear Mircorphonics
   b. Intracellular Potential
   c. Endocochlear Potential

4. The Resting Potential of inner hair cell is

   a. + 45 mV
   b. – 45 mV
   c. - 70 mV
   d. + 70 mV

5. The Resting Potential of Outer hair cell is

   a. – 45 mV
   b. + 45 mV
   c. – 70 mV
   d. + 70 mV

6. The Resting Potential of the supporting cell is

   a. – 45 to + 70 mV
   b. – 70 to – 100 mV
   c. + 45 to – 100 mV
   d. + 70 to – 190 mV

7. The intracellular potential is caused

   a. due to the presence of fluids more specifically

b. due to the presence of ions more specifically
c. both ‘a’ and ‘b’
d. due to the properties of the plasma membrane and the concentration of various ions on either side of the membrane

8. The plasma membrane has a phospholipid layer which

a. acts as a resistor
b. acts as a capacitor
c. both ‘a’ and ‘b’
d. acts as ‘a’ or ‘b’

9. In a cell at rest

a. the net current across the membrane is zero
b. voltage across the membrane is zero
c. net current is 500 mV
d. the voltage across it is the resting potential

10. The potential difference across a semipermeable membrane at which electrochemical forces are in

balance and there is no net flux of ions across the membrane is termed

a. Equation Potential
b. Action Potential
c. Permeability
d. Equilibrium Potential

11. The potential difference across the membrane can be quantified by this equation

$$Vm = 2.3 \frac{??}{?} \log \frac{?_{?}? \; ??_{?}? \; ?_{?}? \; ?_{?}? \; ?_{?}? \; ?_{?}? \; ?_{?}? \; ?_{?}? \; ?_{?}? \; ?_{?}?}{?_{?}? \; ??_{?}? \; ?_{?}? \; ?_{?}? \; ?_{?}? \; ?_{?}? \; ?_{?}? \; ?_{?}? \; ?_{?}? \; ?_{?}?}$$

a. Nernst equation
b. Goldman's equation
c. Ohm's law
d. Muller's principle

12. The equilibrium potential of sodium ion is

a. E_{Na} – 86 mV
b. E_{Na} + 85 mV
c. E_{Na} – 65 mV

13. The equilibrium potential of potassium is

a. E_K = - 86 mV
b. $E_{K\,=}$ + 85 mV
c. E_K = - 65 mV

14. The equilibrium potential of chlorine ion I given by

    a. E_{Cl} = - 86 mV
    b. E_{Cl} = + 85 mV
    c. E_{Cl} = - 65 mV

15. The plasma membrane of hair cell is

    a. polarized apically
    b. depolarized basolaterally
    c. polarized into an apical portion and basolateral portion
    d. none of the above

16. Tight junctions are

    a. those which are present inside the cytoplasm
    b. special membrane structures tightly joining the apical circumference of the hair cells to adjacent supporting cells
    c. special “karyon” of hair cells
    d. ‘a’ and ‘c’

17. The following channels are present in the basolateral membrane

a. calcium ion channels and potassium ion channels
b. calcium activated potassium channels and chlorine channels
c. all the above
d. none of the above

18. The transduction channels

a. not at all conduct at resting potential
b. in a low conducting state at resting potential
c. in a high conduction state at resting potential
d. ‘b’ and ‘c’

19. The theory commonly used in explaining the electrophysiological properties of hair cells is

a. place theory
b. the membrane theory
c. frequency theory
d. Bekesy’s travelling wave theory

20. The endocochlear Potential (EP) also bears the other name

    a. Cochlear microphonics
    b. Endolymphatic potential
    c. Reissner’s potential

21. The source of EP is

    a. Reissner’s membrane
    b. Basilar membrane
    c. Stria vascularis

22. Though the value of EP reduces slightly at higher turns, the approximate value

    a. – 80 mV
    b. + 80 mV
    c. – 100 mV
    d. + 100 mV

23. EP is

    a. Oxygen dependent
    b. Oxygen independent
    c. independent of hair cells
    d. ‘a’ and ‘c’

24. The role of EP

    a. helps is prevention of necrosis of hair cells

b. helps in providing an electrical driving force for the movement of positively charged ions through transduction channels
c. ‘a’ and ‘b’

25. DC fall is the phenomenon in which

a. EP decreases as long as the sound is present
b. the elicitation of cochlear microphonics through a special technique
c. base line potential

26. The stimulus realted potentials are

a. cochlear microphonics
b. summating potentials
c. action potentials
d. intracellular potential

27. Stimulus related potentials are

a. Electrical responses to acoustic stimulation
b. Acoustical response to acoustic stimulation

c. Electroacoustic response to acoustic stimulation
d. all the above

28. The AC response and the DC response to any acoustic stimulation are

a. intracellular and summation potentials
b. cochlear microphonics and summation potentials
c. cochlear microphonics and endocochlear potentials
d. all the above

29. Encircle the following CM statements, if found true

a. There is no/real threshold for CM
b. There is no frequency limits
c. CM varies from turn to turn
d. CM is not affected by adaptation and fatigue

30. CM disappears when

a. there is damage of the inner hair cell

b. there is damage of the outer hair cell
c. there is damage of stria vascularis
d. never disappears

31. Encircle the correct statement(s)

a. Upto 80 dB SPL, the magnitude of CM is proportional to the stimulus signal
b. Upto 105 dB SPL, the amplitude of CM is proportional to the stimulus signal
c. Upto 105 dB SPL, there is nonlinearity in signal to amplitude ratio
d. The magnitude of the response will vary depending on the frequency of the acoustic stimulation.

32. Cochlar frequency maps are

a. ultra high frequency response of CM

b. Tomotopographical mapping tone from 60 Hz to 7500 Hz
c. largest response produced at the apical end
d. largest response produced for a high frequency stimulus.

33. The characteristic frequency is

a. the best frequency which produces the largest response
b. the best frequency which produces the largest response at the basal end of the cochlea.
c. the best frequency which produces the largest response for a low frequency stimulus

34. The types of cochlear microphonics can be abbreviated as follows:

a. CM_1 and CM_3
b. CM_1 and CM_2
c. CM_1 and CM_3

35. Encircle the correct statement(s) realted to CM

a. CM is dependent on the blood supply to the ear
b. CM is independent of the blood supply to the ear
c. CM is oxygen dependent
d. CM is oxygen independent.

36. The CM helps in understanding

a. The functional integrity of the inner ear
b. The abnormal conditions of the inner ear
c. The mechanical events of the Basilar Membrane.

37. Summating potentials(SP) is the dc response arising as a composite, made of a number of bioelectric components. It is being recorded

a. in the scala media
b. in the scala vestibuli
c. differentially between the scala vestibuli and tympani
d. ‘a’ and ‘c’

38. At the best frequency, SP is

    a. always positive
    b. always negative
    c. always zero
    d. varies from + value to – value

39. At low to moderate intensity at frequencies below the best, SP is

    a. always positive
    b. always negative
    c. always zero
    d. varies

40. SP helps in

    a. understanding the frequency tuning along the cochlear partition, but to a lesser extent than CM
    b. to compare hair cells
    c. understanding the frequency tuning along the cochlear partition but to a greater extent than CM

41. On acoustic stimulation, stereocilia

a. bend toward the kinocilia
b. bend away from the kinocilia
c. swinging action of the stereocilia
d. thickens and breaks off

42. Depolarization occurs when

a. the stereocilia bends towards the kinocilia
b. the stereocilia bends away from the kinocilia
c. both ‘a’ and ‘b’
d. no such movement of stereocilia c occurs.

43. Hyper polarization occurs when

a. the stereocilia bends toward the kinocilia
b. the stereocilia bends away from the kinocilia
c. both ‘a’ and ‘b’
d. no such movement of stereocilia occurs.

44. On depolarization

a. outward flow of K^+
b. outward flow of Na^+
c. both ‘a’ and ‘b’
d. outward flow of all ions.

45. During depolarization, the fusion of intracellular membranous vesicles is promoted by

a. all the ions
b. the intracellular increase of Ca^{2+}
c. outward flow of Na^+

46. The fusion of vesicles result in the release of neurotransmitter into the extracellular space between the hair cell and nerve transmitter. The neurotransmitter bind to receptors located on the postsynaptic membrane of the nerve fibre and alter the ionic conductance of this membrane. Thus this results in

a. hyperpolarization
b. depolarization
c. action potential
d. both ‘a’ and ‘c’

47. The action potential comprises of

a. large negative potential N_1 occuring due to the synchronous discharge of a large number of neurons.
b. large positive potential N_1 Occuring due to the synchronous discharge of a large number of neurons
c. the initial negative potential followed by a second lesser potential N_2
d. ‘a’ and ‘c’.

48. Action potentials can be measured by

a. Electrocochleography
b. placing an electrode on the wall of the External Auditory Meatus directly on the drum membrane or annular ligament
c. Electroencephalography
d. ‘a’ and/or ‘B’

49. “Tuning curve” for the fibre is defined

a. as the frequency and intensity combination of stimulus

that increase the mean firing rate above spontaneous level of discharge
b. the frequency to which the fibre
c. temporal coding phenomenon of the fibre

50. The tuning curve is also termed

a. Frequency Threshold Curve (FTC)
b. Spectral Curve
c. Curve of linearity
d. Cochlear Frequency Maps.

51. The phenomenon in which the discharge rate of cochlear nerve fibre is maximal at first and afterwards there is a reduction in an exponentialfashion is termed

a. Phase locking
b. Tuning curve
c. Cochlear frequency mapping
d. Adaptation effect

52. “Phase-locking”

a. The phenomenon which occurs in temporal coding

b. Phase relationship between the spike and the stimulus waveform
c. Maximal response at the characteristic frequency
d. ‘a’ and ‘b’

53. Reduction in firing rate occurs due to

a. Phase locking
b. Two tone suppression
c. Adaptation
d. ‘b’ and/or ‘c’.

54. Speech sounds are coded in terms of their

a. intensity
b. phase
c. characteristic frequency

55. The speech stimuli is understood by

a. spectral codings
b. temporal coding
c. ‘a’ and ‘b’
d. adaptation.

SECTION M

COCHLEAR MODELS

I. Cochlear models help us to understand cochlear functions. The designers usually express then morphological, electrochemical, mechanical, acoustical, biophysical viewpoints through their models. Explain these key words: (1) Macromechanics (2) Micromechanics (3) Transduction (PS: These three are the classification on pedagogical purpose of cochlea)

II. MACROMECHANICS

a) Match the Macromechanical models to their respective researchers.

RESEARCHER	MODEL
1. Helmholtz model	a. Hydrodynamic model
2. Zwislocki model	b. Rectangular box model
3. Lesser and Berkley	c. Transmission line model
4 Ranke’s model	d. Resonance model

b) Fill in the blanks:

1. Helmholtz model views cochlea as a _____ and it failed because of the omission of _____

2. Ranke’s model studies the _____ in the cochlea.

3. Transmission line model is a simplified version of the _____ model.

4. Transmission line model considers the _____ of the cochlea, _____ and _____ the Basilar membrane.

5. The transmission line model considers the _____ portion of the cochlea and cochlea is viewed as a _____ filter.

III. MICROMECHANICS

a. Name four micromechanical models of the cochlea.

b. Fill in the blanks:

1. In Zwislocki and Kletsky’s model I, the resonant reed is _____ the other name of this model is _____

2. The resonant system is meant to represent the mass and the _____ stiffness.

3. In Zwislocki and Kletsky’s model II, there are a parallel bank of resonating reeds tuned to slightly different frequencies and these reeds are connected along the _____ axis with a nonlinear elastic medium that mechanically couples them.

4. Both the Zwislocki’s models are _____ models.

5. In the ter Kuile’s model, sensing the motion of the Basilar membrane is studied by the transformation of the _____ of the Basilar membrane into a radial _____ which is required to drive the inner hair cell cilia.

6. The ter Kuile’s model is equivalent to a _____ that linearly converts the vertical Basilar Membrane motion into radial shearing motion appropriate for the excitation of hair cells.

7. _____ model is an extension of the ter Kuile’s model in which is given a new degree of freedom to _____ to vibrate in a _____ direction.

IV. NEURAL TRANSDUCTION

Fill in the blanks:

1. _____ model is also termed the negative resistance model as it calls on the concept of _____ damping or resistance in the Basilar Membrane.

2. This model assumes that the _____ response and _____ response are identical.

3. The negative resistance model along with the resonant tectorial membrane model of Allen best fits the tuning curve between the frequency range of _____

4. The use of negative resistance is supported by cochlear _____

5. Zwicker’s model is a hardware cochlear _____preprocessing model with _____ feedback.

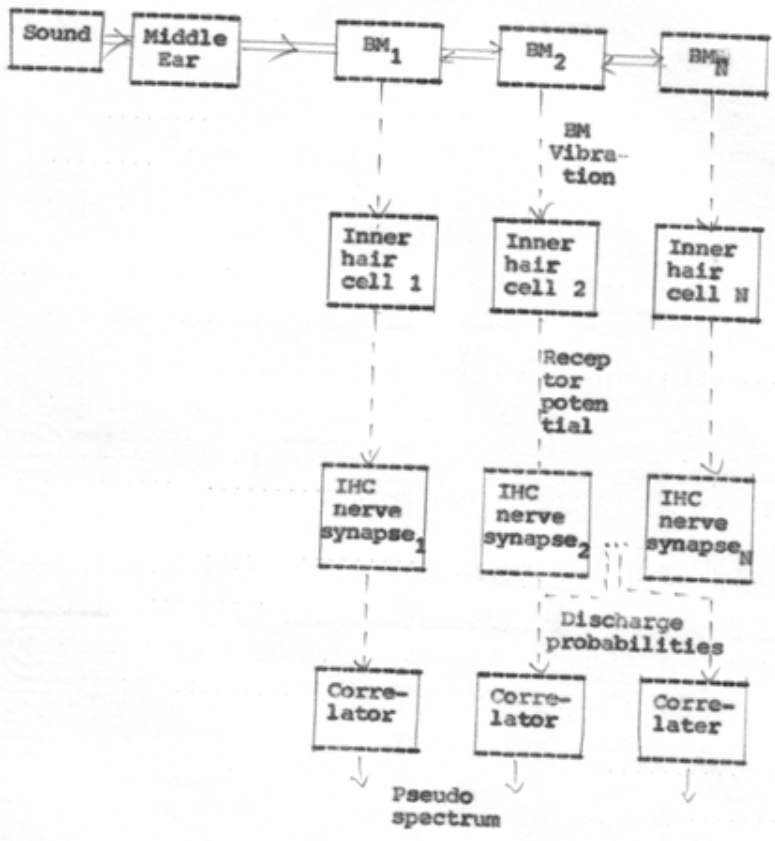
6. The components of Zwicker’s model consists of a combination of _____ and ones along with _____ loops.

7. In Zwicker’s model the inner ear was divided into _____ section and the frequency range considered was _____

8. The Zwicker’s model assumes that the _____ cells act as a saturating nonlinear mechanical amplifiers which feedback to the vibration of the _____ membrane and while only the _____ cells.

9. This model explains the otoacoustic _____

GUESS WHO FOR WHAT



A composite inner ear model containing the middle ear, Basilar Membrane (BM), Inner Hair Cell (IHC), Nerve fibre synapses is presented in the flow chart depicted above. Guess who proposed the model

- Ray Meddis
- Pickles
- Bekesy
- LiDeng and C. Daniel Geisler

SECTION N

OTOACOUSTIC EMISSIONS (OAE)

Choose the correct answer(s) :

1. The presence of OAE indicate

   a. The response of middle ear mechanism to the sound.
   b. the response of preneural cochlear receptor mechanism
   c. the matchness of the auditory brain stem pathway
   d. cortical response.

2. The OAE are usually elicited in the normal ears

   a. at 30 dB HL
   b. at 44.5 dB HL
   c. at 72.5 dB SL
   d. at 0 dB SPL

3. The latency of human OAE at 5 KHz and 500 Hz are

   a. 4 msec. and 20 msec. respectively.

b. 25 msec. approximately
c. 15 msec. and 45 msec. respectively
d. none of the above.

4. The unstimulated OAE are

a. the spontaneous nature
b. puretones
c. narrowband noise
d. ‘a’ and ‘b’

5. The spontaneous OAE is

a. elicited in 100% of the ears
b. requires no stimuli to elicit
c. requires two tones as stimuli
d. elicited in 40-60% of the normal ears.

6. Evoked otoacoustic emissions are

a. Transiently evoked OAE (TEOAE)
b. Unstimulated OAE

c. Stimulus Frequency OAE (SFOAE)
d. Distortion Product OAE (DPOAE)

7. Clicks are used in eliciting

a. short TEOAE
b. DPOAE
c. SFOAE
d. Long TEOAE

8. The low level puretone stimulus elicits

a. Short TEOAE
b. SFOAE
c. DPOAE
d. Long TEOAE

9. Two tones stimulus elicits

a. SOAE
b. SFOAE
c. DPOAE
d. Long TEOAE

10. The incidence of TEOAE and DPOAE are

a. approximately 50%
b. 55 - 70%
c. 85 - 94%
d. approximately 100%

11. The incidence of SFOAE is found to be

    a. approximately 50%
    b. 55 -70%
    c. 85-94%
    d. approximately 100%

12. The characteristic frequency range of OAEs

    a. SOAE 0.5 – 6 KHz
    b. TEOAE 0.5 – 4 KHz
    c. DPOAE 0.5 – 8 KHz
    d. all the ‘a’ ‘b’ ‘c’ statements are false as there is no such frequency specificity found in eliciting OAEs

13. Neonates

    a. do not emit OAE
    b. emit uniformly from 1 to 5 KHz
    c. ‘b’ but without deep notches
    d. ‘b’ with deep notches often

14. Adult responses have

    a. missing frequency bands
    b. nonlinear response
    c. slow growth

15. Neonatal emissions

    a. have deep notches frequently
    b. have fast growth of response to the stimulus
    c. have deep notches very rarely
    d. no emissions prevail.

CHAPTER-6

KEYS

6.1 : ANATOMY, INNER EAR

SECTION A

I. Give me a name

(1) Petrous (2) Cochlea (3) Ampulla (4) Modiolus (5) Cupola (6) Scala (7) Helicotrema

II. Name the parts

1. Cavity systems – one which houses the organs of equilibrium and the other which houses the organ of hearing.

2. Membranous and bony labyrinthine systems

3. Vestibule, semicircular canals and cochlea.

4. Oval window, vestibular aqueduct and ductus endolymphaticus

5. Lateral, superior and posterior.

6. Bony and membranous

7. Scala vestibuli and scala tympani

8. Round window, helicotrema and cochlear aqueduct

9. Perilymph and endolymph

10. Membranous semicircular canals, utricle and saccule and cochlear duct (Scala media)

11. Basilar membrane and Reissner’s membrane

12. Vestibular lip, tympanic lip

13. spiral limbus and habenula perforata

14. Iona arcuata and zona pectinata

15. supportive cells and receptor cells

16. Outer pillar, and inner pillar

17. Outer tunnel and inner tunnel

18. Outer and inner

19. Outer and inner

20. Limbal, middle and marginal zones

21. Type A and Type B fibrils.

III. Windows:

1. KIDNEY 2. VESTIBULE 3. FOOT PLATE, STAPES 4. EDGES, CENTER 5. EPITHELIUM, CONNECTIVE, EPITHELIUM,

THREE.

SECTION B

1. Anatomical dimensions

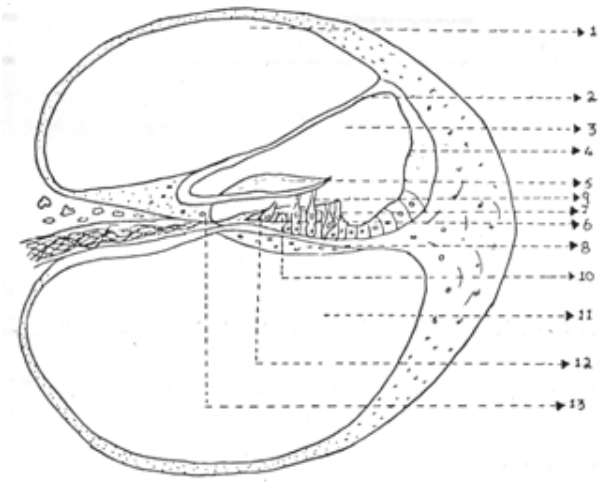
a) 8 mm b) 35 mm c) 34mm d) 31.5 mm e) 4000 f) 60000 g) 3500

h) 20,000 i) 150-450 /nm j) 24,000 k) 20 nm l) 10nm m) 15-20 nm n) 1.01 $mm^{2,}$ 1.28 mm^2 o) 73^o p) 3 mm

2. Parts, membranous labyrinth:

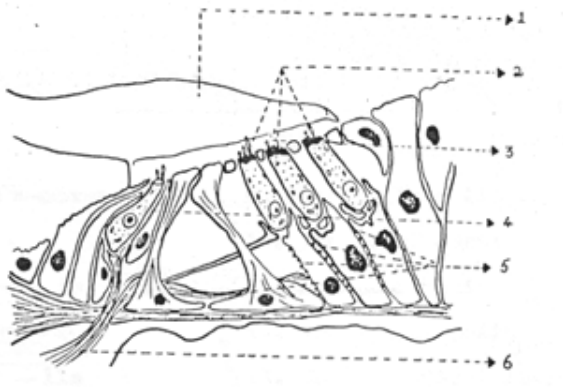
a) Ductus endolymphaticus
b) Utricle
c) Ampulla
d) Saccule
e) Canalis reuniens (of Hensen)
f) Cochlear duct
g) Ductus utriculo sacularis
h) Endolymphatic sac.

3. Cochlear sealae



1. Scala vestibuli
2. Reissner’s membrane
3. Scala media
4. Stria vascularis
5. Tectorial membrane
6. Supporting cells
7. Rods of corti
8. Basilar membrane
9. Outer hair cells
10. Tunnel of corti
11. Scala tympani
12. Inner hair cells
13. Osseous spiral lamina

4. Spiral organ



1. tectorial membrane 2. Outer hair cells

3. Hairs 4. inner hair cells 5. Afferent nerve fibres

6. cochlear nerve fibres.

SECTION C

COCHLEAR MEMBRANES

1. The membranes of cochlear are Basilar membrane, Tectorial membrane, Reissner’s membrane, Reticular membrane, and Hardesty’s membrane.

2.

Basilar membrane (BM)	Tectorial membrane (TM)	Reissner’s membrane (RM)
Acellular, connective tissve structure	a. Structure Acellular semitransparent, fibrous gelatinous structure	Two cell layer membrane.
	b. Attachment or extension	
BM is attached medially to the spiral lamina and laterally, to the spiral ligament thus forming the floor or the scala media	Attached to the spiral limbus	Extends from the medial edge of the spiral limbus to the upper (vestibular edge of the stria vascularis thus forming the roof of the cochlear duct

BM	TM	RM
	c. Zones	
Medial zone (parstecta)	1. Limbal zone	
	2. Middle zone	
Lateral zone (parspectinata)	3. Marginal zone	
	d. Cellular componenets	
Mestothelial cells (at the tympanic surface) and ground substance along with unidentified	Fibres and fibrils	Squamous or low cuboidal cells and microvilli
	e. Other important structures	
Vas-spirale	Hardesty’s membrane	Microvilli
Hearing	f.Role Purely mechanical	Secretion of endolymph

3.

FIG. (1) A radial section through Reissner's membrane showing the two cell types separated by a basal lamina (BL). The cell facing the endolymph exhibits apical microvilli (MV) and tight cell junctions (arrows). Bar = 5 μm.

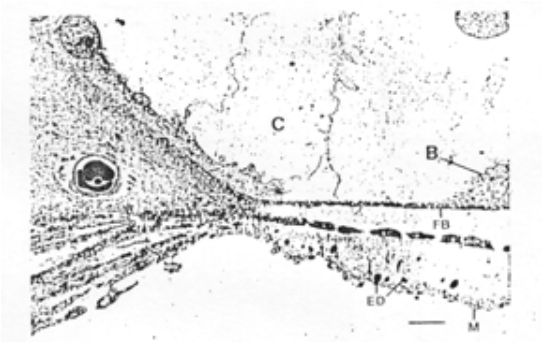


FIG. (2) A transmission electron micrograph showing a portion of the pars pectinata of the basilar membrane and the wedge-shaped basilar crest. Note: Claudius' cells (C), Böttcher's cells (B), two fiber bundles of the basilar membrane (FB), electron-dense deposits (ED), and the mesothelial cells (M). Bar = 0.5 μm.

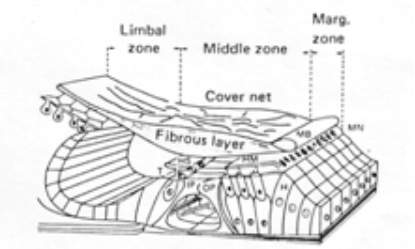
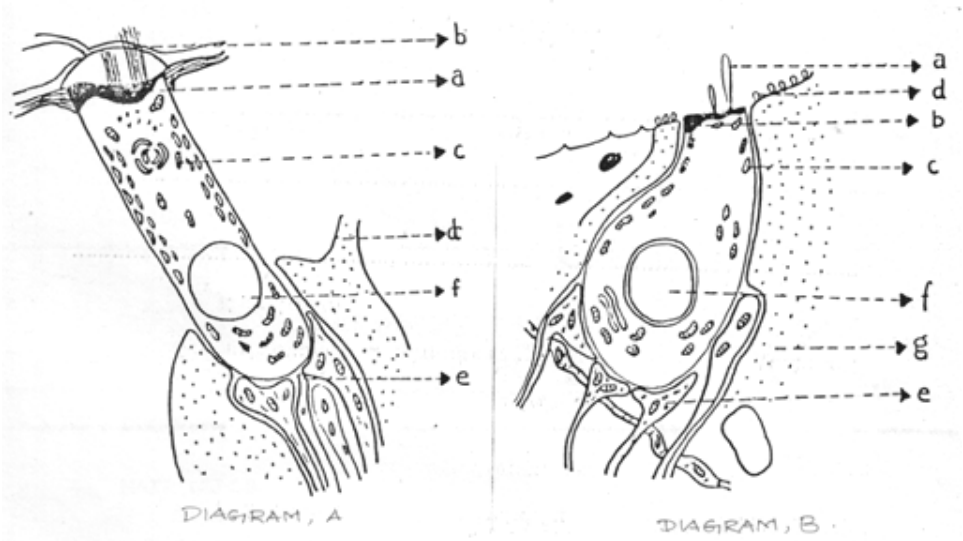


Figure (3) A schematic of the substrata of the tectorial membrane, illustrating the cover net, fibrous main body, and homogenous basal layer (of Hardesty).

SECTION D

HAIR CELLS



A. Outer hair cells parts:

a. Basal body b. Stereo cilia c. Mitochondria d. deiter’s cell e. Nerve endings f. Nucleus

B. Inner hair cells parts:

a. Stereocilia b. Basal body c. Mitochondria d. Microvilli e. Nerve endings f. Nucleus g. Supporting cells

2. Differences existing between outer hair cells (OHC) and inner hair cells (IHC)

	OHC		IHC
	a. Arrangement		
1.	Arranged in 3-5 rows	1.	Arranged in a single row
2.	They are about 20,000 cells in number	2.	About 3000-4000 cells in numbers
3.	Cell is obliquely placed	3.	Not obliquely placed
4.	Cells are arranged such that there is intercellular space	4.	No intercellular space
5.	Towards spiral ligement	5.	Towards modiolus
6.	Supported by outer phalangeal cells	6.	Supported by inner phalangeal cells
7.	Bordered by Hensen and Claudius cells.	7.	Bordered by cells of Held
	b. Size and shape		
1.	Less bulky	1.	Bulkier
2.	Cylindrical	2.	Flask shaped
3.	25 /um in length	3.	35/um in length
4.	Cell surface or cuticle is flat	4.	Cell surface or cuticle is oval or round.

	OHC		IHC
5.	Kidney shaped at the base, oval in apex; Rounded nucleated base like miniature test tube.	5.	Wide at nucleated base.
6.	6 – 7 /u m wide, thickness of cuticle is same	6.	10 /um wide cuticle.
	c. Cell contents		
1.	Nucleus is oval/round	1.	Nucleus is round
2.	Nucleus is situated at the end of the cell	2.	Situated centrally.
3.	Nucleus is smaller in size	3.	Bigger than that of OHC
4.	Lamellated body in the supranuclear region seen	4.	Not seen.
5.	Infranuclear portion contains large number of mitochondria and endoplasmic reticulum	5.	Supranuclear portion contains large number of mitochondria and endoplasmic reticulum.

	OHC		IHC
6.	Has two to three layers of discontinuous membrane	6.	Has only one layer of discontinuous membrane.
7.	Plasma membrane is smooth.	7.	Not so smooth as OHC
8.	The central portion is free of cytoplasm but contains glycogen	8.	Rich in cytoplasm
9.	In all OHCs, cisternae are present which participate in the production of CM and give protection.	9.	Not in all
	d. Stereocilia		
1.	100-200 stereocilia on the Cuticular plate	1.	60 stereocilia
2.	V and W stereocilia	2.	Stereocilia arranged parallel to each other
3.	Cilia is short and thick	3.	Cilia is long and thick
4.	Stereocilia decrease from apex to base	4.	Stereocilia decrease from base to apex.
	First X Second X 100 to 90 row x		77 to 65
	Third row 80 to 18		

	OHC	IHC
5.	Lesser diameter (0.20 /um)	5. Greater diameter (0.45 /um)
6.	Length: 55 /um to 0.5 /um first row X increases X 35 to X 55 /um to from third X 55 /um X row X	6. Decreases from base to apex 45 /um to 20 /um
7.	Rootlets are tube like	7. Rootlets are thinner and pointed.
8.	Long extensions of the rootlets from the Cuticular plate into the cytoplasm of the cell is seen.	8. Not seen.
	e. Nerve Innervation	
1.	Afferent fibres inner vate in the longitudinal direction.	1. Afferent fibres innervate radially
2.	Type II nervous give afferent innervation	2. Type I nervous give afferent innervation to radial fibres, leading to IHC. These radial fibres are susceptible to hypoxia.

	OHC		IHC
3.	Following transaction of VIII nerve, only Type II Cells remain	3.	Following transaction, Type I cells die and degenerate
4.	A single fibre innervates many hair cells (1:many)	4.	Many fibres to single one hair cells (Many:1)
5.	Efferent fibres innervates the hair cells radially	5.	Efferent fibres innervation is in the longitudinal direction.
6.	No axoaxonic connections of nerves	6.	Axoaxonic connection present.
7.	The dendrites of outer spiral fibres are in the range of 0.5 /u	7.	The dendrites of afferent fibre to IHC are largest with an average diameter of 1 /u.
8.	The region of neural contact is limited to the lower end (afferent)	8.	The afferent fibre contact the lower end of the cell or at the side and occasionally high up along the sensory cells (plasma membrane of the sensory cell).

	OHC		IHC
9.	OHC possibly monitors the receptor organ electrically or mechanically	9.	IHC rather participate in direct neural information transmission to Central nervous system.
	f. Responses		
1.	OHC respond to displacement magnitude	1.	IHC respond to the velocity of Basilar membrane displacement
2.	OHC respond to radial shearing force.	2.	IHC respond to longitudinal shearing force.
	g. Function		
1.	Associated with spatial summation	1.	Associated with fine discrimination of frequency.
	h. Resting potential		
1.	The membrane potential of OHC is -70 mV (similar to that of the supporting cells)	1.	Membrane potential is – 45 mV

OHC	IHC
i. Kinetics	
OHC are capable of fast and slow motile responses based on the polarity of the electrical stimulation. Depolarization shortens the cell Hyperpolarization elongates the cell.	Neither IHC nor supporting cells display motile response
j. Metabolism	
1. Lesser than that of IHC Same level inuptake of glucose during acoustic stimulation.	1. More than that of OHC higher uptake of 3H-2-DG during noise exposure.
2. The OHC could rely upon amino acids or stored glycogen (alternate sources)	2. Glucose metabolism is similar to that of stria vascularis
k. Cochlear transuction process	
1. OHC is considered modulator of the IE mechanics capable of fine tuning of the cochlear receptive functioning.	1. IHC is considered the receptor of the IE mechanics.

	OHC		IHC
	1. Tuning curves		
1.	OHC damage increases the threshold and change the shape of the tuning curves.	1.	IHC damage increase the threshold but not changes the shape of the tuning significantly.
	m. Tight junctions		
1.	OHC are coupled to supporting cells by tight junctions which are more extensive then those occurring on the IHC with a minimum of 10-15 sealing filaments.	1.	IHC are coupled to the supporting cells by tight junctions with 5-15 sealing filaments.
2.	These sealing filaments arranged mainly in a parallel fashion but certain rounded areas devoid of filaments also occur with the junctions.	2.	The sealing filaments are arranged in a more or less parallel fashion. Polygonal arrangements may also be seen with the junction.

OHC	IHC
n. Postmortem changes	
1. Human – 15 minutes post mortem	
Outer hair cell bundles look well preserved but protrusions of cell surfaces are common OHC showing good preservation and retention of some tip links	Stereocilia of IHC shows incipient disintegration of surface membrane.

SECTION E

SUPPORTING CELLS

1. Name the supporting cells.

a. A U D I T O R Y T E E T H

b. I N N E R S U L C U S C E L L S

c. B O R D E R C E L L S O F H E L D

d. P H A L A N G E A L C E L L S

e. P I L L A R C E L L S

f. D E I T ER' S C E L L S

g. H E N S E N ' S C E L L S

h. B O T T C H E R ' S C E L L S

i. C L A U D I U S C E L L S

j. E X T E R N A L S U L C U S C E L L S

k. R O O T C E L L S

2. Number Game:

a) 6 /um b) 5 to 15 c) 5 to 6 d) 3 e) 6/um f) 13, 25, and 6 /um.

SECTION F

I. STRIA VASCULARIS

1) Three 2) Vascularized 3) Border cells 4) Marginal 5) Intermadiate 6) nucleus 7) cytoplasm 8) mitochondria 9) Microtubules 10) Cell processes 11) Spherical 12) Lightly stained 13) Lipofuscin 14) Melanin 15) Basal.

II. SPIRAL LIGAMENT

True – 1, 2, 4, 5, 6, 7

False – 3,

III. ENDOLYMPHATIC DUCT AND SAC

1 (d); 2 (b); 3(a,b,c,d)

SECTION G

COCHLEAR FLUIDS

I. Match:

1 – b and d; 2 – a; 3.- c

II. 1 Na^{+} ; 2. K^{+} ; 3. Ca^{2+} ; 4. Mg^{2+} ; 5. p^{H} ; 6. cl^{-} ; 7. HCo_3^{-} ; 8. Osmolarity 9. Electrical potentials.

SECTION H

VESTIBULOLOGY

I.1. Supporting cells, sensory cells, cirstate, masculae nerves, otolithic membranes, and cupulae.

2. The two maculae are stimulated by linear acceleration and the effect of gravity. The three cristae ampullares register angular accelereation in the same plane as the semicircular duct is irritated.

3. Cupula is a gelatinous membrane similar to that of the otolithic membrane.

4. The vestibular sensory areas are localized in five specific regions. The two maculae and three cirstae.

Each of the receptor organs is composed of sensory and supporting cells but they are arranged in a compact mass. (They are more like the auditory papillae of reptiles and birds than the mammalian organ of corti).

Thus the vestibule is different from cochlear membranous labyrinth in two respects, as mentioned above.

II. 1. 4.8^{o} to 18^{o}

2. 25^{o} to 30.4^{o}

3. 11.3^{o} to 18.2^{o}

4. The angle (i) between the semicircular canals (ii) between two cristae (iii) between the semicircular canal and its cristae do not lie at right angles.

III. True – 2, 3, 5

False – 1, 4

SECTION I

VASCULAR SUPPLY

1. (a); 2(b); 3(b); 4(a); 5(b); 6(a); 7(a); 8(f).

6.2 : PHYSIOLOGY, INNER EAR

SECTION J

COCHLEAR FLUIDS

I. True – 1, 2, 3, 4, 5, 9

False – 6, 7, 8, 10

II. a. Functions of cochlear fluids – Metabolism, Elimination of waste products, Cochlear transduction.

b. Technical difficulties faced in the studyof cochlear fluids- Total volume of the cochlear fluids is relatively small; Specialized procedures of sample withdrawal, handling and analysis are required to get uncontaminated pure samples; There is a practical difficulty of gaining access to the cochlear fluids without excessive disruption of the normal state leading to variation in results.

SECTION K

OUTER HAIR CELL

Encircle:

1 (b); 2(b); 3(a); 4(a); 5(a); 6(c); 7(b); 8(a); 9(a); 10(b); 11 (a); 12(a); 13(d); 14(d); 15(a); 16(a b); 17(b); 18(a); 19(a); 20(c); 21(c); 22(c); 23(a); 24(d); 24(a)

SECTION L

COCHLEAR POTENTIALS

Encircle:

1(b); 2(a and c); 3(b); 4(b); 5(c); 6(b); 7(d); 8(c); 9(a and d); 10(d); 11(b); 12(b); 13(a); 14(c); 15(c); 16(b); 17(c); 18(b); 19(b); 20(b); 21(c); 22(b); 23(a); 24(b); 25(a); 26(a); 26(a,b, and c); 27(a); 28(b); 29(a,b,c, and d); 30(b); 31(b and d); 32(b); 33(a); 34(b); 35(a, c, and d); 36(a,b, and c); 37(d); 38(b); 39(a); 40(c); 41(a); 42(a); 43(b); 44(a0: 45(b); 46(c); 47(d); 48(d); 49(a); 50(a); 51(d); 52(d); 53(d); 54(c); 55(c).

SECTION M

COCHLEAR MODELS

I. Key words:

1. Macromechanics – Study of fluid motions of scalae; assumes for analysis – mass, stiff-ness and damping.

2. Micromechanics – Here motions of organ of corti, inner hair cells, outer hair cells, tectorial membrane, pillar cells, motions of fluid in the space between the reticular lamina and tectorial membrane are concerned.

3. Transduction - Here the electrochemical response of the inner hair cell to basilar membrane motions are studied.

II. Macromechanics:

a) 1-d; 2-c; 3-b; 4-a.

b) 1. Piano cochlear fluids; 2. fluid effect; 3. Ranke’s 4. mass, stiffness, mass per unit; 5. longitudinal, band pass.

III. Micromechanics:

a. 1. Swislocki’s model

2. Zwislocki and Kletsky’s tectorial membrane model

3. ter Kuile’s model on Basilar membrane displacement

4. Allen’s Tectorial membrane model.

b. 1) mass loaded, sharpening

2) tectorial membrane, stereocilia 3)longitudinal

4) non-linear; 5) displacement; shearing;

6) lever 7) Allen’s; tectorial membrane, radial

IV. Neural transuction:

1. Neely and Kim’s; negative. 2) Neural, Basilar membrane; 3) 100 Hz to 30 KHz; 4) Emissions; 5) non-linear, active; 6) linear, non-linear, feedback; 7) 90, 900 Hz to 8000 Hz; 8) Outer hair, Basilar, Inner hair; 9) Emission.

V. Guess who for what:

Li Deng and C. Daniel Geisler

SECTION N

OTOACOUSTIC EMISSIONS(OAE)

Choose:

1. (a and b); 2. (a); 3. (a); 4.(d); 5(b and d); 6. (a, c, and d); 7. (a and d); 8(b); 9.(c); 10(d); 11 (c); 12. (a,b, and c); 13(c); 14(a, b, and c); 15. (b and c).

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CHAPTER 7

CENTRAL AUDITORY NERVOUS SYSTEM

This chapter contains two parts:

7.1 : Anatomy, Central Auditory Nervous System

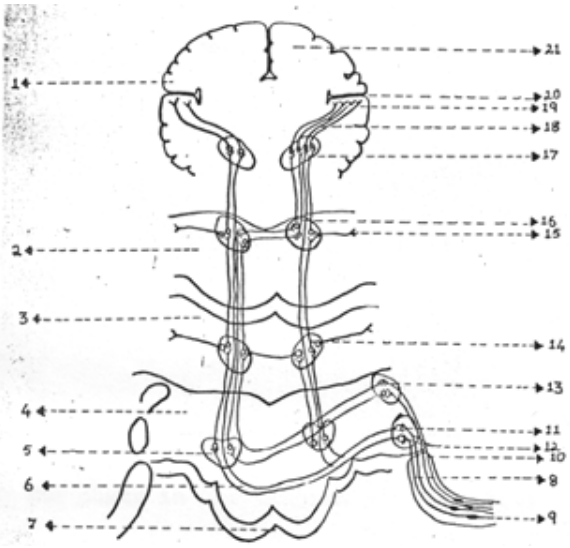
7.2 : Physiology, Central Auditory Nervous System The Sections A and B of :

7.1 : deals with various anatomical aspects within and outside the cochlea, towards the cortex. Section C deals with the efferent auditory pathway.

The Sections D, E and F: of:

7.2 : deals with the physiological aspects involving Neurons, Neurotransmitters and tonotopicity.

I. Label the parts in the diagram given below:



II. Fill in the blanks:

1. The _____ nerve supplies the cochlea and its other names are _____ nerve and _____ nerve.

2. The three innervation components of the acoustic nerve are _____ , _____ , and _____ .

3. Every afferent nerve has a _____ axonal extension and a _____ dendrite extention.

4. Afferent nerve supply forms the spiral ganglion which lies in the _____ has the other name _____

5. The dendritic extension terminates at the _____ and forms the _____ (150 A^{o})

6. The _____ and _____ are the presynaptic characteristic structures seen

7. _____ denotes the number of nerve fibres per unit length of the organ of corti.

8. _____ base nerve fibres enter through each channel of the habenula perforeta out of which _____ percentage form _____ fibres and innervates _____ hair cells

9. Outer hair cells are supplied only by _____ of nerve fibres.

10. Inner hair cells are innervated in the ratio of _____ nerves to _____ hair cell whereas the outer hair cells in ratio of _____ to _____

11. Outer hair cells supplied by _____ neurons and inner hair cells by _____

12._____ neurons are bipolar and _____ neurons are pseudo monopolar.

13.Type I neurons are affected by _____ deficiency.

14.Type II neurons follow the _____ _____ pattern (nerve)

15.Efferent nerve supply is also termed as _____

16.Efferent nerve fibres are classified into _____ and _____ fibres and further they can be classified into _____ and _____ fibres.

17.Inner hair cells are supplied by _____ fibres by _____ percentage.

18.The efferent pathway produces _____ effect.

19.The autonomic innervation is assumed to be originating from _____ ganglion and _____ ganglion.

20.The function of autonomic pathway is _____

SECTION B

I. 1. Name the auditory structures present in the brainstem.

2. Match the structures with their location

Structures	Location
1. Cochlear nuclei	a. Pons
2. Superior olive	b.
3. Lateral leminiscus	c. Pontomedullary junction
4. Inferior collicular	d. Thalamus
5. Redial geniculate body	

3. What are all the divisions of cochlear nuclei?

4. What are all the types of cells seen in the cochlear nuclei?

5. Find the common site in VCN for the following cells: 1) Bushy cell 2) Octopus 3) Multipolar cells.

6. Given the striae of cochlear nuclei – Trace their origin and projection. (Cues: Dorsal stria, intermedial stria, Ventral stria, DCN, AVCN,PVCN, SOC, LL, IC, contralateral ipsilateral).

7. What are all the divisions of SOC?

8. How does LSO and MSO receive their input?

9. State any two functions of SOC.

10. What are all the branches of LL?

11. Where does LL get its input from?

12. What are all the divisions of IC?

13. What does the divisions of IC comprise of?

14. Name the division of MGB? What type of cells they comprise of?

II. Fill in the blanks:

1. The auditory areas encompass the

   S _ _ _ _ _ _ _ temporal lobe, I – F _ _ o parietal lobe and the I N _ _ _ _ _ _ parietal lobe.

2. H _ _ _ _ _ _ _ gyrus is called the primary auditory area.

3. S _ _ _ _ _ N fissure contains primary auditory area.

4. I _ _ _ _ A is also an aera, or a patch of cortex that lies medial to the middle segment of the superior temporal gyrus, which is acoustically responsive in the cortex.

5. C L _ _ _ _ _ _ M is another narrow strip of grey mater which seem to be highly responsive to acoustic stimulation.

6. The first major pathway to the cortex originates from the V _ _ _ _ _ _ L MGB and is essentially all auditory fibres.

7. The second pathway from MGB to auditory cortex consists of A _ _ _ _ _ _ Y, S _ _ _ _ _ C and possibly V _ _ _ _ L fibres.

8. The primary auditory area has both I _ _ _ _ and I _ _ _ _ hemispheric connections.

9. The auditory cortical areas as well as most of the temporal lobe, have connection to the F _ _ _ T _ _ lobe.

10. A _ _ UA _ _ F _ _ CI _ _ L _ _ fibre tract connects wernickes to Broca’s area.

11. In primates as well in humans, in the Heschl’s gyrus. The high frequencies are represented C A U D O _ _ _ _ _ _ _ _ and the low frequencies R O S T R O _ _ _ _ _ _ _ _ _.

12. In the cortex the cells of the primary auditory area aer sharply tuned to frequency and _ S _ _ _ E _ _ E _ _ Y strips (contours) can be found.

13. There is a S _ _ T _ _ _ component to frequency representation in the auditory cortex.

14. The main artery that provides the blood supply to the auditory cortex is the _ _ D D _ _ _ _ R E _ _ A L artery.

15. The first major branch that supplies an auditory region is the _ _ O _ _ _ opercular artery.

SECTION C

EFFERENT AUDITORY PATHWAY

1. What are the other names of efferent auditory pathway?

2. Where does the efferent auditory pathway originate?

3. What are the divisions of efferent pathway? Where do they end?

4. What are the functions of the efferent auditory pathway?

7.2 : PHYSIOLOGY, CENTRAL AUDITORY NERVOUS SYSTEM

SECTION D

NEURONS

I. a. Neurons are the basic structural and functional units of the nervous system. It is well known that a neuron comprises of axons and dendrites. Given here is information on nerve axon. Match them to their exact numbers.

	Nerve axon		Number
1.	Human nerve axon	a.	2,00,000
2.	Cat	b.	16,000
3.	Marine animals	c.	30,000
4.	Kangaroorat	d.	50,000

b. Information on phenomena, statistical technique, nerve response etc. are given as cues. Match the following.

A	B
1. Nerve	a. Natural decline of discharge.
2. Noise stimuli investigation	b. Phase locking
3. Adaptation	c. C.F.
4. Temporal coding	d. Reverse correlation
	e. Tuning curve.

II. Fill in the blanks:

1. _____ and _____ are the two forms of discharge or firing rate of auditory cortical neurons as a function of intensity.

2. Many of the neurons in the auditory cortex are sharply _____

3. _____ plays a critical role in localization abilities of the auditory cortex.

4. _____ tones are more effective stimuli for cortical cells than steady state tones. (Whitfield and Evans, 1965).

5. Abeles and Goldstein (1972) showed four kinds of responses of cortical neurons to a 100 msec. tone.
   a) Neurons sustained a response for the duration of the stimulus.

   b) _____ Neurons responded only to the onset.

   c) _____ neurons responded after the tone was terminated.

   d) This type responded both to onset and offset of the tone but _____ sustain a response during the tone.

6. At resting the average firing rate of neurons in the guinea pig cochlear afferent nerve is _____ spikes/sec on an average.

7. Liberman classified the spontaneous rate of discharge into three groups as _____, _____ and _____ .

SECTION D

NEURO TRANSMITERS

Neurotransmitters released on the primary afferent neurons at the base of the inner hair cell and outer hair cell are called Afferent Neurotransmitters.

Neurotransmitters released on the hair cells by the motor neurons are called Efferent Neurotransmitters. Neurotransmitters which are slow in action are termed as Neuromodulators.

I. Name the criterion.

1. The transmitter candidate when applied to the synapse, should elicit a postsynaptic response that mimics the response produced by natural stimulation of the presynaptic element.

2. Substance that influence the natural postsynaptic response should also have the same influence on the response elicited by the transmitter candidate.

3. Stimulation of the presynaptic element should result in the release of the transmitter candidate and the release should be dependent on extracellular calcium ions.

4. The transmitter candidate must be shown to exist presynaptically associated with structures capable of its release.

5. Enzymes responsible for the biosynthesis of the transmitted candidate must be present in the presynaptic element of the synapse.

6. A mechanism must be demonstrated that can either remove the transmitter candidate from the synaptic cleft or inactivate its physiological influence on the postsynaptic receptors.

II. Group – the afferent transmitters; efferent transmitters and the modulators: Adenosine, Glue, Ach, Asp, Atropine, KA, Taurine, Curare, GABA, QA, KyN, Methionine encephalin.

III. Fill in the blanks:

1. GABA receptors are of two types, They are _____ and _____ .

2. _____ receptor is sensitive to Bicuculline and is not affected by _____

3. _____ receptor is sensitive to Baclofen and is not affected by _____

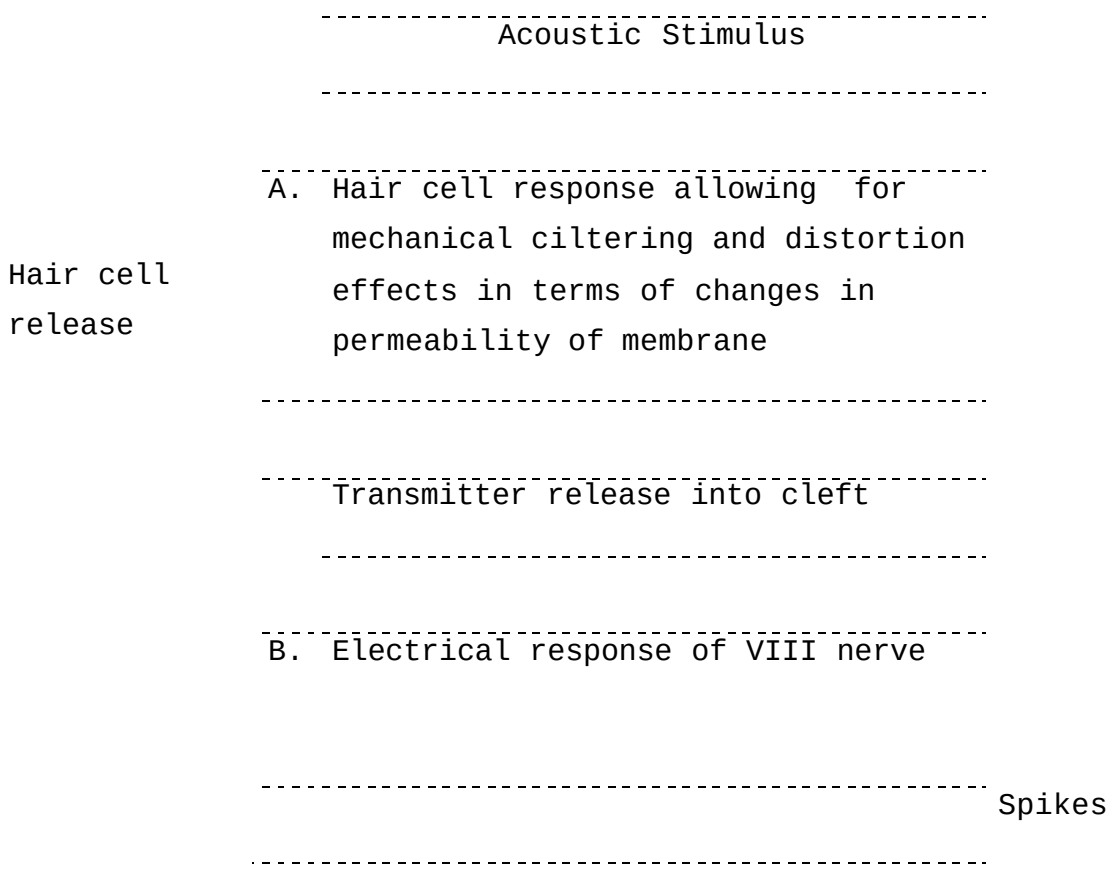
4. Baclofen is a GABA _____ where as picrotoxin is a GABA _____

5. The neurotransmitters usually influence the potentials such as _____ and _____

6. _____ has been proved an important Neurotransmitter and neuromodulator serving not only as an excitatory transmitter of the first afferent synapse of pain pathways but as a valuable neuromodulator in the primary cortical areas of senso sensorial integration in _____

IV. Guess who for what.

The nerve cell transduction model is given below This helps in understanding action potential. Guess who proposed this model: (1) Ray Meddis, (2) Gelfand, (3) Moore, (4) LiDeng and C. Daniel Geisler.



SECTION F

TONOTOPIC ORGANIZATION AND CHARACTERISTICS IN AUDITORY PATHWAY

Strike out whichever “Inapplicable”. (cues) Low Frequency – LF; High Frequency – HF; Lower, Higher).

1. The apex of the cochlea responds well to the LF / HF and base to LF / HF.
2. The core of the auditory nerve contains LF / HF fibres and in the periphery lies the LF / HF fibres.
3. In AVCN, the CF to which there is response will be lower / higher at the most anterior aspect of the dorsal segment.
4. The LSO has a unique tonotopic arrangement with LF / HF located medially.
5. MSO has mostly LF / HF representation when compared to LSO.
6. The dorsal nuclei and the ventral nuclei responds to LF / HF and LF / HF respectively.
7. In the IC, LF / HF are located medially and LF / HF progress in a ventrolateral direction.

8. In the Ventral segment of the MGB, LF / HF are located laterally and LF / HF are located medially.

9. In the primates as well in humans, the primary auditory area has LF / HF represented caudomedially and LF / HF represented rostrolaterally.

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KEYS

7.1 : Anatomy, Central Auditory Nervous System

I. Label the parts:

1. Auditory pathway:

(1) Cerebral Cortex; (2) Inferior Colliculus; (3) Lateral Leminiscus; (4) Medulla; (5) Superior olive (6) Decussating fibres; (7) Midline; (8) Auditory nerve, cochlear division; (9) Cell bodies; (10) Auditory nerve fibres; (11) Ventral cochlear nucleus; (12) Synapses (13) Dorsal Cochlear nucleus; (14) Nucleus of lateral laminiscus (15) Auditory reflex fibres; (16) Nucleus of the inferior colliculus; (17) Medial geneculate body of thalamus; (18) Auditory radiation; (19) Superior temporal convolution (gyrus); (2) Lateral sulcus; (21) Cerebrum.

II. Fill in the blanks:

1. Auditory, vestibule cochlear and 8^{th} cranial.

2. Afferent, Efferent and Autonomic nerve supply.

3. Central, peripheral.

4. Spiral ganglion, Canal of Rosenthal

5. Hair cells, Synaptic clefts.

6. Synaptic bars, synaptic vesicles.

7. Innervation density.

8. 30, 90%, inner hair cells.

9. 10%

10. Many, one, one, many.

11. Monopolar, bipolar.

12. Type-I, Type-II

13. Oxygen

14. Diffuse innervation

15. Centrifugal

16. Inner spiral, outer spiral, uncrossed, crossed.

17. Uncrossed, 90

18. Inhibiting

19. Superior cervical, stellate

20. Unknown.

SECTION B

I. 1. The auditory brain stem comprises of the cochlear nuclei, superior olivary complex, lateral leminscus, inferior colliculus, and medial geniculate body.

2. Match:

1 – c; 2-a; 3-a; 4-b; 5-d.

3. Cochlear nuclei is divided into: (i) Dorsal (DCN); (ii) Anteroventral (AVCN); (iii) posteroventral (PVCN)

4. Cell types of cochlear nuclei (a) Pyramidal; (b) Octopus; (c) Stellate cells; (d) Globular and (e) Spherical (bushy)

- Kiang (1975).

5.

	Cells	Common site in VCN
1.	Bushy cell	Rostral pole
2.	Octopus	Caudal pole
3.	Multipolar cells	Region of the nerve root.

6.

	Tract of fibres	Origin	Projection
1.	Dorsal stria	DCN	Contralaterally to SOC, LL and IC.
2.	Intermediate stria	PVCN	Contralaterally to LL and IC
3.	Ventral stria	AVCN	Contralaterally to SOC and other nuclei groups along the LL.

7. The division of SOC are medial superior olive (MSO); Lateral superior olive (LSO); Trapezoid body (TB); Lateral preolivary nuclei (LPO); and Medial preolivary nuclei (MPO).

8. Ipsilaterally, AVCN supplies LSO via the trapezoid body; contralaterally both AVCN and PVCN supplies LSO. Ipsilaterally and contralaterally AVCN supplies MSO.

9. Functions of SOC – (i) Binaural representation and interaction; (ii) sound localization.

10. Branches of lateral leminiscus – (i) Dorsal (ii) ventral.

11. SOC supplies ipsilaterally and contralaterally to LL.

12. Division of IC – (i) Central nucleus or core; (ii) Pericentral nucleus (or belt)

13. Central nucleus is composed of purely auditory fibres whereas the belt comprises of mostly somatosensory and auditory fibres.

14. Division of MGB – (1) Dorsal – Somatosensory and acoustic cells; (2) Ventral – Primarily acoustic responsive cells; (3) Medial – Somatosensory and acoustic cells.

II. Fill in the blanks:

1. SUPERIOR, INFERO, INFERIOR

2. HESCHEL'S 3. SYLVIAN 4. INSULA 5. CLAUSTRUM 6. VENTRAL

7. AUDITORY, SOMATIC, VISUAL 8. INTRA, INTER 9. FRONTAL
10. ARCUATE FASCICULUS 11. MEDIALLY, LATERALLY
12. ISOFREQUENCY 13. SPATIAL 14. MIDDLE CEREBRAL
15. FRONTO.

SECTION C

EFFERENT AUDITORY PATHWAY

1. Other names of efferent auditory pathway are centrifugal pathway or descending pathway.

2. Efferent auditory pathway originates at the auditory cortex.

3. Efferent auditory pathway ends at the MGB and the other branch of the pathway ends at the auditory nuclei in the brainstem and hair cells of the cochlea. Therefore there are two divisions of the efferent pathway.

4. The various inhibitory and excitatory influences of the efferent system on the ascending system may

result in the enhancement of essential neural signals and inhibition of unwanted neural signals ie noise (Noback, 1985).

7.2 : PHYSIOLOGY, CENTRAL AUDITORY NERVOUS SYSTEM

SECTION D

NEURONS

1. a:

   1 – c; 2 – d; 3 – a; 4 – b.

   b:

   1 – a/c and e; 2 – d; 3 – a; 4 – b.

II.Fill in the blanks:

1. Monotonic, non-monotonic; 2. non-monotonic; 3. Tuning; 4.Frequency modulated. 5(b) on; 5(c) off; 5(d) did not 6.60; 7. low, medium, high.

SECTION D

NEURO TRANSMITTERS

I. Name the criterion:

1. Identical action (2) Pharmacological identity
3. Stimulus induced release; (4) Presynaptic location
(5) Synthetic enzymes (6) Inactivation mechanism.

II. Group:

Afferent neurotransmitter	Efferent neurotransmitter	Neuro modulator
Glu	Ach	Adenosine
Asp	Curare	Methionineenc-ephalin
KA	Atropine	Taurine
QA	GABA	Asp
KyN		
GABA		

III. Fill in the blanks:

1. GABA – A receptor; GABA – B receptor

2. GABA – A; Baclofen; 3. GABA – B Bicuculline

4. Agonist; antagonist. 5. CAP, CM

6. Substance-P, humans.

IV. Guess who for what:

4. – LiDeng and C.Daniel Geisler

SECTION F

TONOTOPIC ORGANIZATION AND CHARACTERISTICS IN AUDITORY PATHWAY:

1. LF / F F / HF

2. LF / H F / HF

3. Lower / Higher

4. F/ HF

5. LF / F

6. LF / F F/HF

7. LF / F F/HF

8. LF / F F / HF

9. F / HF LF / F

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CHAPTER 8

MISCELLANEOUS FACTS

Miscellaneous facts are being organized in this format:

Outer ear

Middle ear

Inner ear

Auditory pathway

Developmental aspects

OUTER EAR

* The neonatal canal is more cartilaginous, shorter(20mm) more horizontal & more oval than the adult canal.

* The ear canal is usually wider at its outer end and has elliptical cross section.

* The velocity of sound at room temperature is 350 M/Sec.

* The effective acoustic length of ear canal is 30 mm ($\pm$) $\pm$ 2mm standard deviation)

* At high frequencies, it is essential to give importance to the variation of cross sectional area of the canal length and to the curvature of the canal axis.

* Noise in the enclosed ears is attributed to the “ Brownian Movement “ of the enclosed air molecules.

* Because of the Damping effect, external auditory meatus resonates fairly over a wide frequency range.

* The 4KHz notch is because of the earcanal resonance and this can be shifted by doubling the length of the ear canal.

* The acoustic proerties of the auricle & meatus augment the sound shadow effect and in addition heighten our sensitivity to sounds.

* The epidermis of the ear canal is the thinnest of the body & it has 15 Um thickness.

* Vibration applied to the Jaw creates an excess of sound in the ear canal, compared with vibration applied to the skull.

MIDDLE EAR

* Tympanic Cavity is divided into

  (1) Attic or EPitympanic Recess

  (2) Tympanic Cavity Proper

  Attic divided into

  (1) Tympanic aditus

  (2) Tympanic antrum

  (3) Head of the Malleus

  (4) Bulk of the Incus

Tympanic cavity proper consists of 6 walls.

* The relationship between the response to sound of the tympanic membrane and the response at the stapes is referred to as the transfer function of the middle ear and it is proportional to the input admittance.

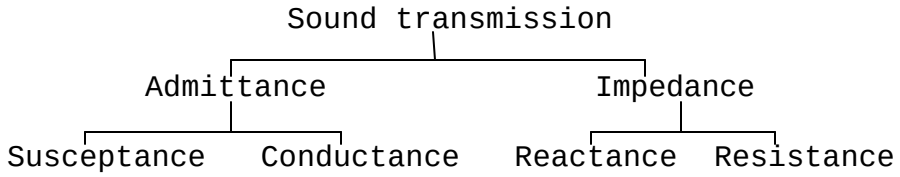
* The mass is equal to the weight devided by acceleration due to gravity; Greater the mass, greater the inertia.

The bulk of mass closer to the axis of rotation will have lesser inertia. The effect of mass is important at high frequencies.

* Compliance is the reciprocal of stiffness. Complience of the middle ear system is contributed mainly by the Tympanic membrane. Other contributors are the muscles, ligaments and Joints. Compliance is important at low frequencies.

* The band-width is a measure of the range of frequencies for which the magnitude function is close to its maximum value.

* A flow chart on sound transmission.



* Physical properties related to sound transmission are friction, mass and compliance.

INNER EAR

* **A FLOW CHART ON INNER EAR**

Inner ear

1) Osseous labyrinth

2) Membranous labyrinth

1) Osseous labyrinth

Otic Capsule

Vestibule	Semicircular canals	Cochlea
a) Oval window	a) Superior Semicircular Circular canals	a) Apex (cupola)
b) Vestibula-aqueduct	b) Lateral Semi circular canal	b) Base
c) Ductus - endolymphaticus	c) Posterior Semi-circular canal	c) Core

SCALA

a) Scala Vestibuli

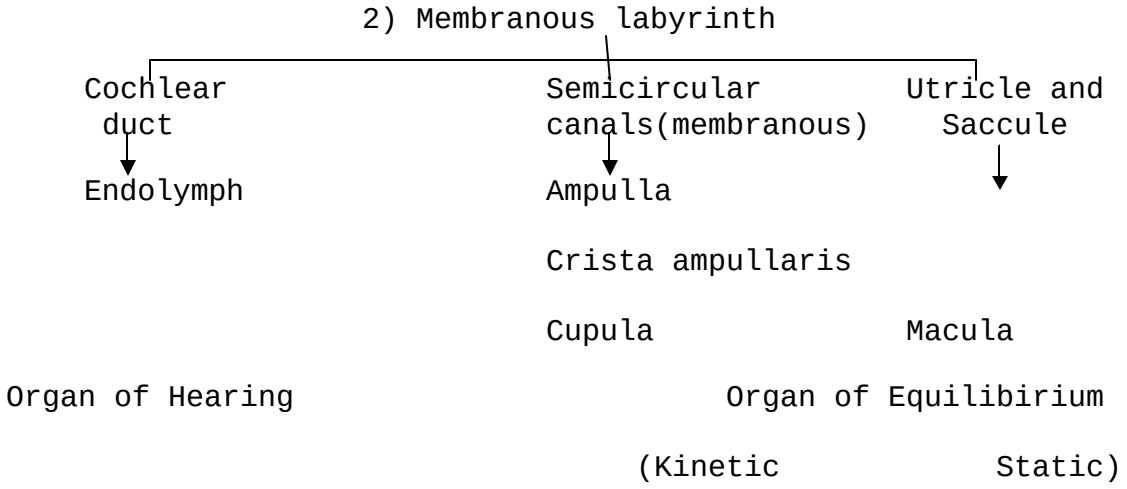
b) Scala Tympani

Openings

a) Helicotrema

b) Round window

c) Cochlear aqueduct



* Border cells of Held has numerous tall microvilli.

* Outer pillar cells have a broad base which consists of a cone shaped network of actin filaments.

* Deiter’s cells have abundant Endoplasmic Reticulum and a prominent strand of microtubules.

* Bottcher’s cell has cytoplasm containing cell organelles including microtubules; The cell membrane has microvillus structures and intracellular channels. These intracellular channels contain electron-dense materials.

* The cytoplasm of External Sulcus cells have a rich complement of organelles including Endoplasmic Reticulum, Mitochondria.

* In the human organ of Corti, investigation by freeze fracturing technique showed tight junction and gap junctions Hair cells were coupled extensively to the supporting cells by rather extensive tight junctions. The tight junction between the Deiter's cells were comparable to those of the hair cells while the tight junctions between the Hensen's cell are less extentive. Gap junctions are thought to act electronic couplers between cells.

* Gap junction can be visualized by Transmission Electron Microscopy (T.E.M)

AUDITORY PATHWAY

* Damage of Cochlear Nuclei leads to ipsilateral puretone deficits and at times may mimic auditory nerve dysfunction.

* Human Dorsal Cochlear Nuclei appears to be quite different from that in the Cat where as the Ventral Cochlear Nuclei of the Cats & Humans show similarities.

* The Lateral Leminiscus nerve fibres crosses onto the

other side via the pontine reticular formation.

* The reticular formation appears to play a major role in auditory alertness, reflexes & habituation.

* It requires about 2mm of cortex to encompass the frequency range of one octave.

* For high frequencies, less spatial area is needed for representation of one octave.

* Keidel etal (1933) demonstrated four main types of temporal response patterns which may relate to the four types of neurons observed by Benevents and Coleman (1970) The response patterns include

  1) On effects (response only to onset of stimulus)

  2) Sustained respone (discharge for the duration of the stimulus)

  3) Off effects (response after the stimulus) and

  4) Inhibition for the entire duration of the stimulus. These were obtained by using Post Stimulus Time Histograms (PSTH)

* These are three principal ways in which individual neurons of various brainstem nuclei respond to the intensity of the stimuli. One classification of intensity response is Monotonic which means as the intensity of the stimulus increases, the firing rate

of the neuron also increases proportionately. The second type of intensity function is one that is monotonic for low intensity but as the stimulus intensity increases the firing levels of the neuron levels off. In the third type of intensity function the neuronal firing rate reaches a plateau at a relatively low stimulus intensity. In certain cases, the firing rate actually decreases as the intensity of the stimulus increases resulting in a “Rollover phenomenon “.

* The acoustic & startle reflexes are mediated in the brain stem.

DEVELOPMENTAL ASPECTS

CHART ON GESTATIONAL PERIOD AND EAR DEVELOPMENT

Gestation period in weeks	External ear	Middle ear	Inner ear
0 – 4	-	3rd Week – formation of pharyngeal pouch	-
4 – 8	External Auditory Meatus (8 Weeks)	Tympanic ring (8weeks) Middle ear muscles are identified (8 weeks) Formation of ossicles.	Semicircular duct (7 weeks) Cochlear duct has coiled on itself on full revolution (7 weeks) Bony labyrinth (6 weeks) Formation of scala vestibuli and scala Tympani (8 weeks) Sensor cells Type I & II can be distinguished.
8 – 12			Cochlea coils two revolution by 10 weeks.

CONTD 2

Gestation period in weeks	External ear	Middle ear	Inner ear
12 – 16		Ossification of Ossicular chain starts in 16 weeks approximately & continues throughout the fetal development	Superficial appearance of macula is similar to that seen in adults (16 weeks)
		Middle ear muscles and tendons will be morphologically distinct (16 weeks)	The cartilaginous labyrinth undergoes ossification (16 weeks)
16 – 20	Walls of External Auditory Meatus are formed (16.5 weeks)	The mambrium of the malleus attaches itself to the fibrous stratum of the three layered tympanic membrane (16.5 weeks)	Scala vestibuli & Scala tympani impinge on Scala media of cochlea forcing it into a more triangular shape (16 weeks)
		Completion of ossification of tympanic ring (20 weeks)	The tunnel of Corti forms and hair cells appear at the basal end of the organ (16 weeks)

CONTD 3

CHART ON GESTATIONAL PERIOD AND EAR DEVELOPMENT

Gestation period in weeks	External ear	Middle ear	Inner ear
0 – 4	-	3rd Week – formation of pharyngeal pouch	-
4 – 8	External Auditory Meatus (8 Weeks)	Tympanic ring (8weeks) Middle ear muscles are identified (8 weeks) Formation of ossicles.	Semicircular duct (7 weeks) Cochlear duct has coiled on itself on full revolution (7 weeks) Bony labyrinth (6 weeks) Formation of scala vestibuli and scala Tympani (8 weeks) Sensor cells Type I & II can be distinguished.
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		Completion of ossification of tympanic ring (20 weeks)	The tunnel of Corti forms and hair cells appear at the basal end of the organ (16 weeks)

CONTD 3

Gestation period in weeks	External ear	Middle ear	Inner ear
20 – 24		Ossicular chain achieves adult size (20 weeks)	Cristae attain adult form by 23rd week Cochlea coils 2½ revolutions (25 weeks)
24 – 28	Auricle and tragus are fully formed (28 weeks) Medial extention of the lumen of primary External Auditory Meatus (28 weeks)		
28 – 32		Pneumatisation of Tympanic cavity (32 weeks)	
32 – 36		Tympanic ring achieves 9.5mm in diameter (35 weeks)	

* Last but not the least is a piecemeal taken from Oliver Clement’s report in the “ Indian Express “ regarding Bionics (The word comes from Bio-(life) and teachnique), the science which goes to the core of life to see how it works. Nature is millions of years ahead of us. The real inventor of the SONAR for instance is the bat. However, the butterfly invented ‘antiradar jamming’, particularly against the bat’s SONAR. By contracting its muscles a butterfly can operate a kind of mini ultrasound drum which is located near its third pair of legs. The chitin patch covering the drum starts to vibrate and emits ultrasounds on the same wavelength as the bat. The bat becomes disoriented and gives-up the chase. Thus Scientists have still a long way to go before they beat the wonders of nature!

CHAPTER 9

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