

THE  
TEMPORAL  
BONE  
AND THE  
EAR

BAST  
and  
ANSON

THOMAS

# The Temporal Bone and The Ear

---

By

THEODORE H. BAST, A.B., PH.D.

*Professor of Anatomy  
University of Wisconsin  
Madison, Wisconsin*

and

BARRY J. ANSON, M.A., PH.D.

*Professor of Anatomy  
Northwestern University Medical School  
Chicago, Illinois*



---

CHARLES C THOMAS • PUBLISHER  
*Springfield • Illinois • U.S.A.*

CHARLES C THOMAS • PUBLISHER  
BANNERSTONE HOUSE  
301-327 EAST LAWRENCE AVENUE, SPRINGFIELD, ILLINOIS

*Published simultaneously in The British Commonwealth of Nations by*  
BLACKWELL SCIENTIFIC PUBLICATIONS, LTD., OXFORD, ENGLAND

*Published simultaneously in Canada by*  
THE RYERSON PRESS, TORONTO

This book is protected by copyright. No part of it may be reproduced in any manner  
without written permission from the publisher.

*Copyright, 1949, by* CHARLES C THOMAS • PUBLISHER

FIRST EDITION

*Printed in the United States of America*

## Preface

**D**URING the progress of initial studies upon the development and the adult anatomy of the ear and the temporal bone in man, it became increasingly evident that no matter what course the investigation happened, momentarily, to take, new morphological features were established or features regularly described in the standard textbooks were found to be erroneously presented. It was equally clear that intelligible interpretations of structure could be made only when the developmental history of the particular part was understood — that is, after it had been followed from its genesis to adulthood. Fresh realization of this generally accepted fact led the authors to depend upon embryonic and fetal material to progressively greater degree as the investigation advanced.

This volume has, therefore, been organized on a developmental basis. The otic labyrinth, which is the only part of the internal ear present in early fetal stages, is described first. The account of the periotic labyrinth follows, that being succeeded by the description of the otic capsule. Although all portions of the ear are discussed, emphasis is placed on those structures which have been neglected in the past. Consequently, the textual material and the pictorial records are not distributed equally over the anatomical divisions of the organ of hearing; rather, preponderant attention is given to features concerning which information has been sparse, erroneous or misleading. Concerning the pathology of the ear, only such information is given as is related to development. A more extensive study of otic pathology is now in progress. The closing chapter in the monograph is devoted to an historical account of various concepts of hearing and equilibrium.

For the several divisions of the otological investigation herein reported more than 550 series of sections were studied; in many instances the same series was employed for examination of several different anatomical features. In the Wisconsin Collection, approximately 200 series were examined; in the Harvard Embryological Collection, 200 series; in the Carnegie Collection, 30; in the Northwestern Collection, 125. At Wisconsin the collection is a graded series of human ears, ranging from the embryo of 7 mm. (CR length) to the child of 6 years; in this



set are included 30 series from infants and children; frequently both right and left sides are available for comparison. The Harvard Collection covers representative mammalian orders, usually with specimens in the interval between 5 mm. and 30 mm. At Northwestern almost all of the human series are from postnatal specimens, and are preponderantly adult (to the age of 85 years). In the Carnegie Collection the series cover mainly the early human stages. For the privilege of studying the series in the Harvard and in the Carnegie Collections the authors are indebted to Drs. Frederic T. Lewis, J. Lewis Bremer, George L. Streeter and George W. Corner.

The illustrations are either photomicrographs, drawings of reconstructions, or drawings made from projection tracings of actual sections. In preparing drawings of the last-named sort, an Edinger projection apparatus was used; in this way an accurate outline of histological areas was obtained. The same apparatus was also used in preparing the serially arranged tracings for the reconstructions. The tracings were made on thin paper for transference to plates composed of wax mixed with paraffin, or directly to cardboard. Some of the smaller structures or areas of complex anatomy were traced at a magnification of 125 diameters, others of less detailed morphology at lower magnification (50 or 20 times natural size). The reconstructions, or "models," represent either space (for example; of endolymphatic duct, or air cells, or a fissular tract across bone) or solid (for example; of ossicles, walls of air cells and otic capsule, or nodule of pathological bone). In either case, the individual pieces were piled in the succession in which the parent sections occur in the original histological series, using as guides, in superimposing the plates, sectioned structures whose conformation was already known. In this way microscopic features are converted into three-dimensional, large-scale, models. Since all cutting is done with vertical edges, the piled plates for any structure which itself departs from vertical plane produces a reconstruction whose edge is irregularly stepped; normal contours were, in some instances, approximated by smoothing the inequalities between contiguous plates. At Wisconsin, the special otological material was prepared by Mr. Robert Hoelz, at Northwestern by Miss Helen Banks. For drawings we are indebted to Miss Lucille Cassell, Mrs. Mary Dixon Elder, Miss Rosamond Howland, Miss Marion J. Fredericks, Miss H. J. Wakeman, Mr. J. F. Didusch, and Mr. Lawrence E. Blair; for photographic illustrations to Miss Madge Walsh and

Mr. Robert Hoelz. The authors gratefully acknowledge the substantial aid Dr. Harold A. Davenport, Dr. Weston D. Gardner and Mrs. Maxine Adam rendered in their critical reading of portions of the manuscript.

The authors are deeply indebted to the following editors of journals, presidents of otolaryngological societies, and directors of laboratories for granting permission to reproduce illustrations and to adapt text material from their journals and published transactions: Edmond J. Farris, Ph.D., Executive Director of the Wistar Institute of Anatomy and Biology, and Edward A. Boyden, Ph.D., Editor, *Anatomical Record*; Arthur W. Proetz, M.D., Editor, *Annals of Otology, Rhinology and Laryngology*; George M. Coates, M.D., Editor, *Archives of Otolaryngology*; George W. Corner, M.D., Director, Laboratory of Embryology of the Carnegie Institution; Theodore E. Walsh, M.D., Editor, *Laryngoscope*; Barry J. Anson, Ph.D., Editor, *Quarterly Bulletin of Northwestern University Medical School*; Harry W. Lyman, M.D., President, American Laryngological, Rhinological and Otological Society; William E. Grove, M.D., President, American Otological Society.

To the staff of Charles C Thomas, Publisher, we express our gratitude for painstaking attention to detail, for general counsel in all matters covering text and illustrations and for the appreciation of the special problems which confront authors in the preparation of books of a research nature.

All phases of this project were carried out under the auspices of the Central Bureau of Research of the American Otological Society. Through the encouragement of the Bureau's members, the writers began, two years ago, to lay plans for the preparation of the present monograph. During that period certain hiatuses in the research program were filled in by closer collaboration between the two contributing laboratories, at the University of Wisconsin and at Northwestern University Medical School. As plans for this volume matured, it was realized that the cost of publishing a profusely illustrated volume would lift the purchase price to such level as to curtail its distribution. In order to insure wider reference use of the monograph, the Central Bureau of Research provided a generous sum as a subvention toward publishing cost. For this material assistance and for all prior aid, the authors wish to express their sincere thanks to the Board of Trustees of the Research Fund, consisting of the following members: Wesley C. Bowers, M.D.; Starling W. Childs; Edmund P. Fowler, M.D.; Stacy R. Guild, Ph.D.; Marvin F.

Jones, M.D.; John F. Page, M.D.; D. Harold Walker, M.D.; J. Gordon Wilson, M.D.

In all relations with the Board, Dr. Edmund P. Fowler, Secretary, has been consistently and patiently helpful; to him the authors are deeply indebted. In every step in the advancement of our program of research Dr. J. Gordon Wilson has been either a collaborator, or an enthusiastic guide and mentor. Now, despite retirement from the position of Chairman of the Department of Otolaryngology at Northwestern University Medical School, Dr. Wilson's interest in scientific studies continues undiminished. The writers sincerely hope that the completion of this volume will afford Dr. Wilson at least a modicum of the satisfaction which his friendly guidance and interest so abundantly deserve.

THEODORE H. BAST, Ph.D.

BARRY J. ANSON, Ph.D.

## Source of the Illustrations

The publications, by the authors, from which illustrations and text were employed in the present volume, are listed below:

*Anatomical Record*: vol. 46, 1930, pp. 333-347; vol. 48, 1931, pp. 141-151; vol. 57, 1933, pp. 53-58; vol. 58, 1934, pp. 127-137; vol. 59, 1934, pp. 15-25; vol. 65, 1936, pp. 485-498; vol. 68, 1937, pp. 75-97; vol. 90, 1944, pp. 139-148; vol. 99, 1947, pp. 55-74.

*Annals of Otology, Rhinology and Laryngology*: vol. 44, 1935, pp. 736-838; vol. 51, 1942, pp. 343-357; vol. 51, 1942, pp. 891-904; vol. 52, 1943, pp. 281-329; vol. 53, 1944, pp. 42-53; vol. 55, 1946, pp. 278-298; vol. 55, 1946, pp. 467-494.

*Archives of Otolaryngology*: vol. 10, 1929, pp. 459-471; vol. 12, 1930, pp. 686-695; vol. 16, 1932, pp. 19-38; vol. 18, 1933, pp. 1-20; vol. 18, 1933, pp. 291-297; vol. 19, 1934, pp. 537-550; vol. 21, 1935, pp. 303-323; vol. 23, 1936, pp. 57-77; vol. 23, 1936, pp. 509-525; vol. 24, 1936, pp. 127-140; vol. 25, 1937, pp. 560-580; vol. 27, 1938, pp. 402-412; vol. 27, 1938, pp. 588-605; vol. 28, 1938, pp. 676-697; vol. 29, 1939, pp. 939-973; vol. 30, 1939, pp. 183-205; vol. 32, 1940, pp. 771-782; vol. 36, 1942, pp. 816-826; vol. 36, 1942, pp. 891-925; vol. 37, 1943, pp. 650-671.

*Contributions to Embryology* (Carnegie Institution of Washington): publ. No. 407, 1930, pp. 53-82.

*Laryngoscope*: vol. 47, 1937, pp. 461-479; vol. 56, 1946, pp. 561-569.

*Quarterly Bulletin of Northwestern University Medical School*: vol. 14, 1940, pp. 250-257 and pp. 258-268; vol. 15, 1941, pp. 263-269; vol. 18, 1944, pp. 33-40.

*Transactions of the American Laryngological, Rhinological and Otolological Society*: vol. 48, 1936, pp. 325-343.

*Transactions of the American Otological Society*: vol. 25, 1935, pp. 99-112.



# CONTENTS

Preface .....	vii
Source of the Illustrations.....	xi

## CHAPTER I

### The Temporal Bone and the Ear

The Temporal Bone ( <i>OS Temporale</i> ).....	3
A. Squamous Portion .....	3
B. Mastoid Portion.....	5
C. Petrous Portion .....	5
D. Tympanic Portion .....	9
E. Styloid Process .....	9
F. Ossification .....	9
Parts of the Ear .....	11
A. External Ear.....	12
1. Auricle	
2. External acoustic meatus	
3. Tympanic membrane	
B. Tympanic Cavity and Antrum, Epitympanic Recess, and Auditory Tube .....	16
1. Tympanic cavity	
2. Tympanic antrum	
3. Tympanic mucous membrane	
4. Auditory ossicles	
5. Ligaments of the ossicles	
6. Tympanic muscles	
7. Nerves of the tympanic cavity	
8. Auditory tube	
9. Intrapetrous portion of the facial nerve	
10. Acoustic nerve	
C. Internal Ear .....	25
Terminology .....	27

## CHAPTER II

### The Otic Labyrinth

Introduction .....	30
A. Epithelium of Otic Labyrinth.....	31
Early Relation of the Otic Vesicle to the Ectoderm in Human Embryos .....	31
Differentiation of the Various Parts of the Otic Labyrinth .....	37
Otic (Endolymphatic) Duct System.....	43
A. Introduction.....	43

B. Otic Duct and Sac.....	47
1. Course of the endolymphatic duct in the fetus and adult	
2. Sinus and isthmus of the endolymphatic duct	
3. Endolymphatic sac	
4. Rugose portion of the endolymphatic sac	
5. Endolymphatic sac proper	
6. Distal projection of the endolymphatic sac in embryos	
C. Saccular Duct.....	62
D. Utricular Duct.....	64
E. Utriculo-endolymphatic Valve or Fold.....	64
1. Structure	
2. Relation of the utricular duct and valve to the rest of the duct system	
3. Function of the utriculo-endolymphatic valve	
Utriculus and Sacculus.....	72
A. Maculae of the Utriculus and Sacculus.....	72
Otic Semicircular Ducts.....	75
A. Introduction.....	75
B. Development of the Otic Semicircular Duct.....	75
C. Cristae Ampullares.....	76
Maculae and Cristae.....	76
A. Form and Position.....	76
Ductus Reuniens.....	84
Cochlear Duct (Scala Media).....	84
A. Introduction.....	84
B. Histogenesis.....	87
C. Position of the Parts of the Organ of Corti.....	92
D. Relation of the Inner Pillar Cells to the Tip of the Bony Spiral Lamina.....	92
Blood Vessels of the Otic Labyrinth.....	95
Neural Mechanism of the Otic Labyrinth.....	97
A. Cochlear Mechanism.....	97
1. First neurons	
2. Second neurons	
3. Third neurons	
B. Vestibular Mechanism.....	100
1. First neurons	
2. Second neurons	

### CHAPTER III

## The Periotic Labyrinth

Introduction.....	106
Precartilaginous Otic Capsule and the Formation of the Periotic Labyrinth.....	107
A. Development of Periotic Tissue from the Inner Zone.....	109
(Temporary Precartilage)	
B. Development of Periotic Spaces or Labyrinth.....	111
Main Divisions of the Periotic Labyrinth.....	115
A. Vestibule (Periotic Cistern).....	115
B. Periotic Semicircular Canals.....	115

C. Scala Vestibuli.....	115
D. Scala Tympani.....	117
<b>Appendages of the Periotic Labyrinth.....</b>	<b>117</b>
A. Periotic Space Surrounding the Endolymphatic (Otic) Duct.....	118
B. Periotic (Perilymphatic) Duct and the Arachnoid Spaces .....	118
1. Development of the periotic duct and aquaeductus cochleae	
2. Size and content of the periotic duct	
C. Fissula Ante Fenestram.....	130
1. Review of the literature	
2. Origin and development of the fissula	
3. Form of the fissula	
D. Fossula Post Fenestram .....	152
1. Review of the literature	
2. Origin and development of the fossula	
3. Blood supply of the fossula	
4. Types of fossula	

## CHAPTER IV

# The Otic Capsule

<b>General Review of Bone Development.....</b>	<b>163</b>
A. Development of Membrane Bone (Intramembranous Ossification).....	163
B. Development of Cartilage Bone.....	168
1. Formation of ossification centers	
2. Later histogenesis of perichondrial bone	
3. Rebuilding of the primary endochondral (replacement) bone	
<b>Development of the Otic Capsule.....</b>	<b>175</b>
A. Cartilaginous Model of the Otic Capsule and the Ossification Centers.....	176
1. Origin of the cartilaginous otic capsule	
B. Ossification Centers in the Otic Capsule.....	177
1. Historical	
2. Recent observations on ossification centers	
C. Histogenesis of the Otic Capsule.....	207
1. Historical	
2. Early ossification centers	
3. Structure, function and fate of the perichondrium with advent of ossification	
4. Formation of the external perichondrial bone	
5. Osteogenic buds and the transformation of the cartilaginous otic capsule into intrachondrial and endochondral bone	
6. Formation of the internal perichondrial bone	
7. Formation of endochondral (replacement) bone	
D. Types of Bone in the Otic Capsule.....	220
E. Regional Variations in the Development and Structure of the Otic Capsule.....	223
1. Cochlear portion of the otic capsule	
2. Development of the bony modiolus	
3. Development of the canal portion of otic capsule and its relation to the growth of the semicircular canals	
4. Otic capsule in the region of the fissula ante fenestram and oval window	
5. Otic capsule in the region of the round window and the cochlear aqueduct	
<b>Blood Supply of the Otic Capsule.....</b>	<b>249</b>
A. Arteries to the Otic Capsule .....	251
1. Inferior tympanic artery	

2. Posterior meningeal artery	
3. Recurrent mastoid artery	
4. Stylomastoid artery	
5. Accessory stylomastoid artery	
6. Subarcuate artery	
B. Drainage of the Endolymphatic Sac.....	257

## CHAPTER V

## Histological Variations and Pathological Processes

Historical.....	262
Fissular Region.....	264
A. Abnormal Cartilage Masses in the Fissular Area .....	267
1. Changes along the cochlear margin of the fissula	
2. Changes above the tympanic opening	
3. Changes at the vestibular opening	
4. Changes at the tympanic opening	
5. Changes between the tympanic opening and the stapedial joint	
6. Changes within the entire fissula	
B. Relation of Fetal Pathological Processes to Later Otosclerotic Bone.....	275
Fossular Region .....	280
A. Pathological Changes in the Fossula.....	280
Infracochlear Region .....	280
Styloid Region .....	281
Region of the Petrosquamous Suture .....	283
Canalicular Region .....	285
Region of the Cochlear (Round) Window.....	289

## CHAPTER VI

## Bone Dystrophies

Paget's Disease .....	292
A. Historical .....	292
B. Observations .....	295

## CHAPTER VII

## The Origin and Development of the Middle Ear and Related Air Spaces

Early Embryology .....	306
Tympanum and Epitympanum .....	309



Antrum .....	311
Air Cells.....	315
A. Historical.....	315
B. Location of the Air Cells .....	317
1. Mastoid and antral air cells	
2. Petrous air cells	
C. Outlet of the Air Cells .....	329
D. Interrelation of Groups of Air Cells.....	332
E. Relation of the Air Cells to Bone Marrow.....	332
F. Percentage of Pneumatization of Petrous Bones.....	333

## CHAPTER VIII

## The Auditory Ossicles

Historical.....	337
Early Development .....	339
Later Fetal Development .....	344
Adult Form and Size of the Stapes .....	366
A. Base .....	367
B. Crura .....	370
C. Obturator Foramen .....	371
D. Neck .....	372
E. Muscular Process.....	373
F. Head .....	373
G. Stapes as a Whole; Dimensions and Weight.....	374
Adult Form of Malleus and Incus .....	374

## CHAPTER IX

A Historical Survey of the Structure and  
Function of the Internal Ear

Introduction .....	379
Entire Ear an Organ of Hearing.....	379
A. The Ear an Air-filled Space (550 B.C. to 1760 A.D.) .....	379
B. The Ear a Fluid-filled Space (1760 A.D. to 1824 A.D.) .....	385
Vestibular Portion of the Ear as the Organ of Equilibrium.....	389
Cochlea as the Organ of Hearing .....	402
A. The Resonance Theory (Helmholtz's Early Concept) .....	406
B. Hensen's Theory of Hearing .....	409
C. The Resonance or Harp Theory .....	410
D. Walter's Pressure-Pattern Theory.....	419
E. The Telephone Theory .....	421
F. Ewald's Sound-Pattern Theory .....	423

G. Emile ter Kuile's Theory.....	424
H. Max Meyer's Theory (The Traveling Bulge Theory).....	429
I. The Maximal Amplitude Theory of Gray.....	430
J. The Place of the Tectorial Membrane.....	434
K. Kishi's Theory.....	435
L. Shambaugh's Theory.....	435
M. Hardesty's Concept of the Tectorial Membrane.....	437
N. The Displacement Theory of Wrightson and Keith.....	438
O. The Space-Time Pattern of Fletcher.....	442
P. The Pressure Sense Theory of Wittmaack.....	442
Q. Newer Methods for Cochlear Study.....	443
1. Correlation of acuity of hearing with histopathology	
2. The Wever and Bray Method	
R. Cochlear Localization as Indicated by Cochlear Potentials.....	446
1. Partial localization	
2. Definite localization	
S. The Place Theory.....	447
T. The Resonance-Volley Theory.....	447
Index of Authors.....	455
Index of Subjects.....	460

THE  
TEMPORAL BONE  
AND  
THE EAR





## CHAPTER I

# The Temporal Bone and the Ear

---

The Temporal Bone ( <i>Os Temporale</i> ).....	3
A. Squamous Portion.....	3
B. Mastoid Portion.....	5
C. Petrous Portion .....	5
D. Tympanic Portion .....	9
E. Styloid Process.....	9
F. Ossification .....	9
Parts of the Ear.....	11
A. External Ear.....	12
1. Auricle	
2. External acoustic meatus	
3. Tympanic membrane	
B. Tympanic Cavity and Antrum, Epitympanic Recess, and Auditory Tube .....	16
1. Tympanic cavity	
2. Tympanic antrum	
3. Tympanic mucous membrane	
4. Auditory ossicles	
5. Ligaments of the ossicles	
6. Tympanic muscles	
7. Nerves of the tympanic cavity	
8. Auditory tube	
9. Intrapetrous portion of the facial nerve	
10. Acoustic nerve	
C. Internal Ear.....	25
Terminology .....	27

## The Temporal Bone (*Os Temporale*)

**T**HE TEMPORAL BONES are situated at the sides and base of the skull. Each consists of five parts, namely, the squamous, mastoid, the petrous, and tympanic parts, and the styloid process.

### A. Squamous Portion

The *squama temporalis* forms the anterior and upper part of the bone; it is scale-like and thin.