

Kiminori Sato

# Functional Histoanatomy of the Human Larynx

---

# Functional Histoanatomy of the Human Larynx

---

Kiminori Sato

# Functional Histoanatomy of the Human Larynx

 Springer

Kiminori Sato  
Department of Otolaryngology-Head and  
Neck Surgery  
Kurume University School of Medicine  
Kurume-shi  
Fukuoka  
Japan

ISBN 978-981-10-5585-0      ISBN 978-981-10-5586-7 (eBook)  
<https://doi.org/10.1007/978-981-10-5586-7>

Library of Congress Control Number: 2017964266

© Springer Nature Singapore Pte Ltd. 2018

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Printed on acid-free paper

This Springer imprint is published by Springer Nature

The registered company is Springer Nature Singapore Pte Ltd.

The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore



*Dr. Hirano and Dr. Sato (left to right)*

*This book is dedicated to my teacher, mentor and outstanding role model, Emeritus Professor Minoru Hirano, the consummate academic surgeon. He has had the greatest impact not only on my medical knowledge but also on my approach to learning, teaching and academic life as a physician. He continues to serve as a source of inspiration to me.*

*Sincerely and with the deepest gratitude I dedicated this book to him.*

*Kiminori Sato, M.D., Ph.D.*

*Kurume-shi, Fukuoka*

*May 2017*

---

## Preface

The basic functions of the human larynx are to act as a protective sphincter, to act as a passageway for air, and to produce sound. The human larynx has a complex structural organization with a framework characterized by an external cartilaginous skeleton and internal connective tissues in a variety of arrangements in the different regions of the larynx. This framework composed of cartilage, ligaments and muscles contributes to the physiologic functions of the human larynx.

Histology and histoanatomy reflect the organ's functions very well. Functional histoanatomy (physiological histoanatomy, morphophysiology) is a histoanatomy studied in its relation to functions.

Among mammals, only humans can speak and only the human adult vocal fold has a vocal ligament, Reinke's space, and a layered structure. Why do only human adults have such a characteristic vocal fold structure? Why and how does the newborn vocal fold mucosa grow, develop and mature? What are the factors for initiating and continuing the growth and development of the human vocal fold mucosa? Why does the voice change with age?

Vocal folds are comparable to the strings of a musical instrument. The strings must be changed from time to time, because they become old and do not vibrate well. However, human vocal folds maintain their viscoelasticity and produce good vibration for many decades. The renewal of extracellular matrices in the vocal folds is believed to occur continuously to maintain viscoelasticity.

Recent advances in molecular biology shed light on the metabolism of extracellular matrices that are essential for the viscoelastic properties of the human vocal fold mucosa. The manipulation, not only of cells but also their microenvironment, is one of the strategies in regenerative medicine. Artificial manipulation of these cells could lead to advanced development in vocal fold regeneration. Understanding the mechanisms responsible for microenvironmental regulation of the cells in the maculae flavae of the human vocal fold will provide the tools needed to manipulate cells through their microenvironment for the development of therapeutic approaches to diseases and tissue injuries of the human vocal fold. Translational medicine focused on how to regulate cells and extracellular matrices (microenvironments) contained in the maculae flavae of the human vocal folds will contribute to our ability to restore and regenerate human vocal fold tissue.

Phonosurgery is a surgery performed on the human larynx to treat phonatory functions and to improve quality of voice. It is very important to be able to visualize the internal laryngeal structures by looking at the laryngeal cartilage when performing phonosurgery via an extralaryngeal approach. It is also important to be able to visualize the internal laryngeal structures including histoanatomy by observing the mucosa of the lumen when performing phonosurgery via an intralaryngeal approach. Knowledge of the three-dimensional structure, histology and histoanatomy of the larynx is indispensable to performing phonosurgery.

This book provides essential "functional histoanatomy of the human larynx" information of which the laryngeal surgeon must have mastery. I feel strongly that a true surgeon is not only a physician but also a scientist who always approaches each patient with a deep understanding

of the basic medicine, such as essential histoanatomy and pathophysiology of voice disorders. Understanding of the histologic structures related to laryngeal functions and the histopathology of the vocal fold and larynx are vital for understanding the concepts behind phonosurgery.

Kurume-shi, Japan

Kiminori Sato, M.D., Ph.D.

---

## Acknowledgements

I would like to thank Emeritus Professor Tadashi Nakashima and my colleagues in the Department of Otolaryngology-Head and Neck Surgery, Kurume University School of Medicine.

I would also like to express my deepest appreciation to Ms. Ikuko Tsuda, a technician in our laryngeal research laboratory. Her efforts and dedications over the three decades ultimately have resulted in the highest quality histological and histopathological specimens of the human larynx to date.

I also wish to express thanks to Mr. Edward Martin Kellerman III for his English advise in the making of this book.

The careful review of the articles by the tireless staff at Springer publishing company is much appreciated. Without their support, this book would not have been published. Thank you very much again.

Finally, to my wife, Kaori, to my sons, Kiminobu and Fumihiko and to my daughter, Riko, thank you for your forbearance over the years of work-related absences.

Kiminori Sato, M.D., Ph.D.



---

# Contents

## Part I Whole-Organ Serial Sections of the Human Larynx

<b>1</b>	<b>Whole-Organ Midsagittal Section of the Human Adult Larynx</b> . . . . .	<b>3</b>
<b>2</b>	<b>Whole-Organ Serial Transverse Sections of the Human Adult Larynx</b> . . . . .	<b>5</b>
<b>3</b>	<b>Whole-Organ Serial Coronal Sections of the Human Adult Larynx</b> . . . . .	<b>23</b>
<b>4</b>	<b>Whole-Organ Midsagittal Section of the Human Newborn Larynx</b> . . . . .	<b>35</b>
<b>5</b>	<b>Whole-Organ Serial Transverse Sections of the Human Newborn Larynx</b> . . . . .	<b>37</b>
<b>6</b>	<b>Whole-Organ Serial Coronal Sections of the Human Newborn Larynx</b> . . . . .	<b>49</b>

## Part II Functional Histoanatomy of the Human Larynx

<b>7</b>	<b>Clinical Anatomy of the Human Larynx</b> . . . . .	<b>61</b>
7.1	Introduction . . . . .	61
7.2	Clinical Anatomy of the Human Larynx for an Extralaryngeal Approach . . . . .	61
7.3	Clinical Anatomy of the Human Larynx for an Intralaryngeal Approach . . . . .	63
7.3.1	Endoscopic Surgery . . . . .	63
7.3.2	Endolaryngeal Microsurgery . . . . .	63
	References. . . . .	67
<b>8</b>	<b>Compartment of the Human Larynx</b> . . . . .	<b>69</b>
8.1	Introduction . . . . .	69
8.2	Anterior Commissure Tendon . . . . .	69
8.3	Physiological and Clinical Significance of the Anterior Commissure Tendon . . . . .	72
8.3.1	Laryngeal Functions. . . . .	72
8.3.2	Anterior Commissure Carcinoma . . . . .	72
8.3.3	Midline Lateralization Thyroplasty (Type II Thyroplasty) . . . . .	73
8.4	Cricothyroid Ligament. . . . .	73
8.5	Physiological and Clinical Significance of Cricothyroid Ligament . . . . .	74
8.6	Vocal Ligament and Conus Elasticus (Crico-vocal Membrane) . . . . .	75
8.7	Physiological and Clinical Significance of the Vocal Ligament and Conus Elasticus. . . . .	75
8.8	Reinke's Space. . . . .	75
8.9	Physiological and Clinical Significance of Reinke's Space. . . . .	78
8.10	Thyroglossal Ligament. . . . .	78
8.11	Physiological and Clinical Significance of the Thyroglossal Ligament. . . . .	80
8.12	Quadrangular Membrane and Ventricular Ligament . . . . .	80
8.13	Physiological and Clinical Significance of the Quadrangular Membrane and Ventricular Ligament. . . . .	82

8.14	Thyrohyoid Membrane . . . . .	82
8.15	Physiological and Clinical Significance of the Thyrohyoid Membrane . . . . .	83
8.16	Spaces of the Larynx . . . . .	83
8.17	Physiological and Clinical Significance of the Spaces of the Larynx . . . . .	83
8.18	The Laryngeal Cartilages . . . . .	83
8.19	Physiological and Clinical Significance of the Laryngeal Cartilages . . . . .	84
8.20	Compartments and Laryngeal Inflammatory Diseases . . . . .	85
8.20.1	Acute Epiglottitis . . . . .	85
8.20.2	Subglottic Laryngitis (Croup) . . . . .	87
	References . . . . .	88
<b>9</b>	<b>Histoanatomy of the Human Glottis . . . . .</b>	<b>89</b>
9.1	Introduction . . . . .	89
9.2	The Structures Around the Human Adult Glottis. . . . .	92
9.3	The Dimensions and Morphological Characteristics of the Human Adult Glottis . . . . .	92
9.4	The Dimensions and Morphological Characteristics of the Human Newborn Glottis . . . . .	93
9.5	The Functions of the Human Newborn Glottis . . . . .	94
9.6	The Clinical Significance of the Dimensions of the Human Glottis . . . . .	96
9.7	Prolonged Endotracheal Intubation in Infants and Adults . . . . .	97
9.7.1	Histopathologic Changes in the Laryngeal Mucosa of Low-Birth-Weight Infants After Endotracheal Intubation . . . . .	97
9.7.2	Histopathologic Changes of Infant Larynges After Intubation . . . . .	98
9.7.3	Correlation Between Duration of Intubation, Degree of Laryngeal Injury, and Weight at Birth. . . . .	102
9.8	Histoanatomy of the Arytenoid Cartilage . . . . .	103
9.8.1	Distribution of Elastic and Hyaline Cartilages in the Arytenoid Cartilage of Adult Larynges . . . . .	103
9.8.2	Distribution of Elastic and Hyaline Cartilages in the Arytenoid Cartilage of Newborn Larynges . . . . .	105
9.8.3	Behavior of the Elastic Cartilage Portion of the Arytenoid Cartilage During Abduction and Adduction . . . . .	105
9.9	Distribution of Elastic Cartilage in the Arytenoid Cartilage and Its Physiologic Significance . . . . .	108
9.10	Ultrastructure of the Vocal Process of the Arytenoid Cartilage . . . . .	110
9.10.1	Chondrocytes of the Vocal Process . . . . .	110
9.10.2	Collagen Fibers of the Vocal Process. . . . .	111
9.10.3	Elastic Fibers of the Vocal Process . . . . .	111
9.11	Microstructure of the Vocal Process of the Arytenoid Cartilage and Its Physiologic Significance . . . . .	113
9.11.1	Tip of the Vocal Process. . . . .	113
9.11.2	Posterior Portion of the Vocal Process. . . . .	115
9.11.3	Biomechanical Properties of the Human Vocal Process . . . . .	116
9.12	Histoanatomy of the Posterior Glottis . . . . .	116
9.12.1	Neutral Condition. . . . .	116
9.12.2	Vocal Fold Abduction. . . . .	116
9.12.3	Vocal Fold Adduction. . . . .	117
9.13	The Posterior Glottis and Its Physiologic Significance . . . . .	118
9.14	Cricothyroid Joint (Articulation) . . . . .	118
9.15	Geriatric Changes of the Cricothyroid Joint (Articulation) . . . . .	119
9.16	Age-Related Changes of the Cricothyroid Joint (Articulation) and Their Biomechanical Properties . . . . .	119
	References . . . . .	123

<b>10</b>	<b>Cells and Extracellular Matrices in the Human Adult Vocal Fold Mucosa</b> . . . . .	125
10.1	Introduction . . . . .	126
10.2	Layered Structure of the Human Vocal Fold . . . . .	126
10.3	Epithelium of the Human Vocal Fold. . . . .	127
10.4	Microstructure of the Epithelium of the Human Vocal Fold and Its Physiologic Significance . . . . .	127
10.5	Basal Lamina (Basement Membrane) of the Human Vocal Fold. . . . .	128
10.6	Microstructure of the Basal Lamina (Basement Membrane) of the Human Vocal Fold and Its Physiologic Significance. . . . .	128
10.7	Langerhans Cells of the Human Vocal Fold. . . . .	130
10.8	Langerhans Cells of the Human Larynx and Their Physiologic Significance . . . . .	130
10.9	Extracellular Matrices in the Human Vocal Fold Mucosa . . . . .	132
10.9.1	Extracellular Matrices in the Superficial Layer of the Lamina Propria (Reinke's Space) of the Human Vocal Fold Mucosa. . . . .	135
10.9.2	Extracellular Matrices in the Intermediate and Deep Layers of the Lamina Propria of the Human Vocal Fold Mucosa. . . . .	144
10.10	Interstitial Cells in Reinke's Space of the Human Vocal Fold Mucosa . . . . .	144
10.10.1	Fibroblasts. . . . .	144
10.10.2	Myofibroblasts . . . . .	144
	References. . . . .	145
<b>11</b>	<b>Macula Flava and Vocal Fold Stellate Cells of the Human Adult Vocal Fold</b> . . . . .	147
11.1	Introduction . . . . .	147
11.2	Maculae Flavae in the Human Adult Vocal Fold . . . . .	148
11.3	Morphological Characteristics of the Human Adult Vocal Fold Stellate Cells . . . . .	154
11.4	Synthesis of Extracellular Matrices by the Vocal Fold Stellate Cells . . . . .	155
11.4.1	Collagen Fibers. . . . .	156
11.4.2	Elastic Fibers. . . . .	156
11.4.3	Glycosaminoglycan. . . . .	156
11.5	Vitamin A-Storing Stellate Cells in the Human Maculae Flavae. . . . .	158
11.6	Vocal Fold Stellate Cells as a Diffuse Stellate Cell System. . . . .	159
11.7	Irradiated Macula Flava in the Human Vocal Fold Mucosa. . . . .	160
11.7.1	Morphological Changes of Irradiated Macula Flava in the Human Vocal Fold Mucosa. . . . .	160
11.7.2	Functional Morphology of the Irradiated Vocal Fold Stellate Cells. . . . .	162
	References. . . . .	163
<b>12</b>	<b>Tissue Stem Cells and the Stem Cell Niche of the Human Vocal Fold Mucosa</b> . . . . .	165
12.1	Introduction . . . . .	166
12.2	Intermediate Filaments of the Cells in the Human Adult Maculae Flavae . . . . .	166
12.3	Radiosensitivity of the Cells in the Human Adult Maculae Flavae . . . . .	168
12.4	Telomerase of the Cells in the Human Adult Maculae Flavae. . . . .	168
12.5	Cell Cycle of the Cells in the Human Adult Maculae Flavae . . . . .	168
12.6	Transition Area Between the Human Adult Maculae Flavae and Surrounding Tissue . . . . .	169

12.7	Cell Division of Cells in the Human Maculae Flavae . . . . .	169
12.8	Hierarchy of Tissue Stem Cells in the Human Maculae Flavae. . . . .	171
12.9	Microenvironment of Maculae Flavae as a Stem Cell Niche in the Human Vocal Fold . . . . .	171
12.9.1	Hyaluronan-Rich Matrix. . . . .	171
12.9.2	A Proper Microenvironment in the Maculae Flavae as a Stem Cell Niche. . . . .	173
12.10	Origin of Cells in the Human Maculae Flavae. . . . .	174
12.11	Side Population Cells in the Vocal Fold Mucosa . . . . .	176
12.12	Vocal Fold Stem Cells and Their Niche in the Human Newborn Vocal Fold Mucosa . . . . .	176
	References. . . . .	176
<b>13</b>	<b>Cells and Extracellular Matrices in the Human</b>	
	<b>Newborn Vocal Fold Mucosa . . . . .</b>	<b>179</b>
13.1	Introduction . . . . .	179
13.2	Epithelium of the Newborn Vocal Fold . . . . .	179
13.3	Basal Lamina (Basement Membrane) of the Newborn Vocal Fold Mucosa. . . . .	180
13.4	Lamina Propria of the Newborn Vocal Fold Mucosa. . . . .	180
13.4.1	Fibroblasts. . . . .	181
13.4.2	Collagen Fibers . . . . .	182
13.4.3	Reticular Fibers. . . . .	182
13.4.4	Elastic Fibers. . . . .	182
13.4.5	Ground Substances . . . . .	183
13.4.6	Blood Vessels . . . . .	183
13.5	Epithelium and Basal Lamina of the Newborn Vocal Fold Mucosa as a Vibrating Tissue . . . . .	183
13.6	Lamina Propria of the Newborn Vocal Fold Mucosa as a Vibrating Tissue . . . . .	184
	References. . . . .	184
<b>14</b>	<b>Macula Flava of the Human Newborn Vocal Fold. . . . .</b>	<b>185</b>
14.1	Introduction . . . . .	185
14.2	Macula Flava in the Human Newborn Vocal Fold Mucosa . . . . .	186
14.3	Cells in the Macula Flava of the Human Newborn Vocal Fold Mucosa . . . . .	186
14.4	Morphological Comparison of Newborn and Adult Cells Including Vocal Fold Stellate Cells in the Maculae Flavae. . . . .	191
14.5	Morphological Comparison Between Cells Including Vocal Fold Stellate Cells in the Maculae Flavae and Fibroblasts in the Lamina Propria of the Human Newborn Vocal Fold Mucosa . . . . .	191
14.6	Cell Origin in the Macula Flava of the Human Newborn Vocal Fold Mucosa. . . . .	191
14.6.1	Intermediate Filaments of the Cells in the Newborn Macula Flava. . . . .	192
14.6.2	Telomerase of the Cells in the Newborn Macula Flava . . . . .	193
14.6.3	The Relationship between Bone Marrow-Derived Cells and Cells in the Human Newborn Macula Flava. . . . .	193
14.6.4	Pluripotency of the Cells in the Newborn Maculae Flavae. . . . .	194

14.7	Cells Including Vocal Fold Stellate Cells in the Newborn Maculae Flavae. . . . .	195
14.8	Extracellular Matrices in the Macula Flava of the Human Newborn Vocal Fold Mucosa . . . . .	195
14.8.1	Collagen and Reticular Fibers. . . . .	195
14.8.2	Elastic Fibers. . . . .	195
14.8.3	Glycosaminoglycan. . . . .	196
14.9	Microenvironment in the Macula Flava of the Newborn Vocal Fold Mucosa. . . . .	197
	References. . . . .	197
<b>15</b>	<b>Growth and Development of the Human Vocal Fold Mucosa. . . . .</b>	<b>199</b>
15.1	Introduction . . . . .	199
15.2	Cells and Extracellular Matrices in the Human Infant Vocal Fold Mucosa. . . . .	200
15.3	Maculae Flavae of the Human Infant Vocal Fold. . . . .	203
15.4	Growth Initiation of the Human Vocal Fold Mucosa in Infancy . . . . .	205
15.5	Cells and Extracellular Matrices in the Human Child Vocal Fold Mucosa. . . . .	206
15.6	Maculae Flavae of the Human Child Vocal Fold . . . . .	207
15.7	Morphological Characteristics of the Human Child Vocal Fold Stellate Cells . . . . .	208
15.8	Growth and Development of the Human Vocal Fold Mucosa and Vocal Fold Vibration . . . . .	210
15.9	Growth and Development of the Human Vocal Fold Mucosa . . . . .	211
	References. . . . .	211
<b>16</b>	<b>Mechanical Regulation (Cellular Mechanotransduction) of the Human Vocal Fold Mucosa . . . . .</b>	<b>213</b>
16.1	Introduction . . . . .	213
16.2	Human Adult Vocal Fold Unphonated Since Birth . . . . .	214
16.2.1	Macroscopic Findings of the Human Adult Vocal Fold Unphonated Since Birth . . . . .	214
16.2.2	Light and Electron Microscopic Findings of the Lamina Propria of the Human Adult Vocal Fold Mucosa Unphonated Since Birth . . . . .	214
16.2.3	Light and Electron Microscopic Findings of the Maculae Flavae of the Human Adult Vocal Fold Mucosa Unphonated Since Birth . . . . .	216
16.3	Human Child Vocal Fold Unphonated Since Birth . . . . .	219
16.3.1	Macroscopic Findings of the Human Child Vocal Fold Unphonated Since Birth . . . . .	219
16.3.2	Light and Electron Microscopic Findings of the Lamina Propria of the Human Child Vocal Fold Mucosa Unphonated Since Birth . . . . .	219
16.3.3	Light and Electron Microscopic Findings of the Maculae Flavae of the Human Child Vocal Fold Mucosa Unphonated Since Birth . . . . .	220
16.4	Human Adult Vocal Fold Unphonated for Over a Decade. . . . .	224
16.4.1	Macroscopic Findings of the Human Adult Vocal Fold Unphonated for Over a Decade . . . . .	224
16.4.2	Light and Electron Microscopic Findings of the Lamina Propria of a Human Adult Vocal Fold Mucosa Unphonated for Over a Decade. . . . .	224

16.4.3	Light and Electron Microscopic Findings of the Macula Flava of a Human Adult Vocal Fold Mucosa Unphonated for Over a Decade. . . . .	225
16.5	Cytoskeletons (Mechanoreceptor of Cells) of the Cells in the Human Macula Flava Unphonated since Birth. . . . .	227
16.6	Comparison Between Vocal Fold Mucosae Phonated and Unphonated (Non-Vibrated) Since Birth or Unphonated for Over a Decade . . . . .	228
16.7	Expression and Distribution of Hyaluronic Acid and CD44 in Unphonated Human Vocal Fold Mucosa . . . . .	230
16.8	Mechanotransduction in the Human Vocal Fold Mucosa . . . . .	231
16.9	The Role of Intermediate Filaments in the Vocal Fold Stellate Cells . . . . .	231
16.10	Mechanical Regulation of Human Vocal Fold Stellate Cells. . . . .	232
	References. . . . .	232
<b>17</b>	<b>Geriatric Changes of Cells and Extracellular Matrices in the Human Vocal Fold Mucosa . . . . .</b>	<b>235</b>
17.1	Introduction . . . . .	235
17.2	Reticular and Collagen Fibers in the Superficial Layer of the Lamina Propria (Reinke's Space) of the Human Vocal Fold Mucosa . . . . .	235
17.3	Age-Related Changes of Reticular and Collagen Fibers in the Superficial Layer of the Lamina Propria (Reinke's Space) of the Human Vocal Fold Mucosa . . . . .	236
17.4	Age-Related Changes of Collagen Fibers in the Intermediate and Deep Layers of the Lamina Propria (Vocal Ligament) of the Human Vocal Fold Mucosa . . . . .	237
17.5	Age-Related Changes of Reticular and Collagen Fibers in the Lamina Propria of the Human Vocal Fold Mucosa and their Biomechanical Properties . . . . .	238
17.5.1	Superficial Layer of the Lamina Propria (Reinke's Space) of the Aged Vocal Fold Mucosa . . . . .	238
17.5.2	Intermediate and Deep Layer of the Lamina Propria (Vocal Ligament) of the Aged Vocal Fold Mucosa . . . . .	240
17.5.3	Destruction of the Layered Structure in the Aged Adult Vocal Fold Mucosa . . . . .	240
17.6	Age-Related Changes of Elastic Fibers in the Superficial Layer of the Lamina Propria (Reinke's Space) of the Human Vocal Fold Mucosa. . . . .	241
17.7	Age-Related Changes of Elastic Fibers in the Intermediate and Deep Layers of the Lamina Propria (Vocal Ligament) of the Human Vocal Fold Mucosa . . . . .	243
17.8	Age-Related Changes of Elastic Fibers in the Lamina Propria of the Human Vocal Fold Mucosa and their Biomechanical Properties. . . . .	243
17.9	Age-Related Changes of Ground Substances in the Superficial Layer of the Lamina Propria (Reinke's Space) of the Human Vocal Fold Mucosa . . . . .	244
17.10	Bowing of the Aged Vocal Folds . . . . .	245
17.11	Age-Related Changes of Epithelium of the Human Vocal Fold Mucosa. . . . .	245
17.12	Age-Related Changes of Epithelium of the Human Vocal Fold Mucosa and their Biomechanical Properties. . . . .	247
17.13	Age-Related Changes of Extracellular Matrices and Aging Voice . . . . .	248
17.14	Age-Related Changes of Interstitial Cells in Reinke's Space of the Human Vocal Fold Mucosa . . . . .	249

17.15	Age-Related Changes of Cells including Vocal Fold Stellate Cells in Maculae Flavae of the Human Vocal Fold Mucosa . . . . .	249
	References. . . . .	249
<b>18</b>	<b>Geriatric Changes of the Macula Flava of the Human Vocal Fold. . . . .</b>	<b>251</b>
18.1	Introduction . . . . .	251
18.2	Maculae Flavae in the Human Aged Vocal Fold . . . . .	252
18.3	Morphological Characteristics of the Human Aged Vocal Fold Stellate Cells . . . . .	255
18.4	Synthesis of Extracellular Matrices by the Aged Vocal Fold Stellate Cells . . . . .	258
	18.4.1 Collagen Fibers . . . . .	258
	18.4.2 Elastic Fibers. . . . .	258
	18.4.3 Ground Substance . . . . .	259
18.5	The Microenvironment of the Maculae Flavae in the Aged Human Vocal Fold . . . . .	259
18.6	Age-Related Changes of the Cells Including Vocal Fold Stellate Cells in the Maculae Flavae and Aging of the Voice. . . . .	259
	References. . . . .	262
<b>19</b>	<b>Comparative Histoanatomy of the Vocal Fold Mucosa . . . . .</b>	<b>263</b>
19.1	Introduction . . . . .	263
19.2	Canine Vocal Fold: Lamina Propria of the Vocal Fold Mucosa. . . . .	264
19.3	Canine Vocal Fold: Macula Flava of the Vocal Fold Mucosa . . . . .	265
	19.3.1 Interstitial Cells. . . . .	266
	19.3.2 Collagen Fibers . . . . .	266
	19.3.3 Elastic Fibers. . . . .	266
	19.3.4 Ground Substance . . . . .	266
19.4	Rat Vocal Fold: Lamina Propria of the Vocal Fold Mucosa. . . . .	268
19.5	Rat Vocal Fold: Macula Flava of the Vocal Fold Mucosa . . . . .	268
	19.5.1 Interstitial Cells . . . . .	268
	19.5.2 Collagen Fibers . . . . .	270
	19.5.3 Elastic Fibers. . . . .	270
	19.5.4 Ground Substance . . . . .	270
19.6	Lamina Propria of the Animal Vocal Fold Mucosa . . . . .	270
19.7	Maculae Flavae of the Animal Vocal Fold Mucosa . . . . .	270
19.8	Unique Structure of the Human Vocal Fold Mucosa . . . . .	271
	References. . . . .	271
<b>20</b>	<b>Spaces of the Larynx. . . . .</b>	<b>273</b>
20.1	Introduction . . . . .	273
20.2	Distribution of the Preepiglottic Space (PES) . . . . .	273
20.3	Three-Dimensional Reconstruction of the Preepiglottic Space (PES) . . . . .	276
20.4	Physiological and Clinical Significance of the Preepiglottic Space (PES) . . . . .	276
20.5	Distribution of the Paraglottic Space (PGS) . . . . .	278
20.6	Three-Dimensional Reconstruction of the Paraglottic Space (PGS) . . . . .	278
20.7	Physiological and Clinical Significance of the Paraglottic Space (PGS). . . . .	279
20.8	Distribution of the Cricoid Area (CA) . . . . .	279
20.9	Three-Dimensional Reconstruction of the Cricoid Area (CA) . . . . .	282
20.10	Physiological and Clinical Significance of the Cricoid Area (CA) . . . . .	283
	References. . . . .	285
<b>21</b>	<b>Blood Vessels of the Larynx and Vocal Fold . . . . .</b>	<b>287</b>
21.1	Introduction . . . . .	287
21.2	Blood Supply of the Larynx. . . . .	287