

FOUNDATIONS OF SPEECH AND HEARING ANATOMY AND PHYSIOLOGY

THIRD EDITION

Jeannette D. Hoit
Gary Weismer
Brad H. Story
Rosemary A. Lester-Smith





9177 Aero Drive, Suite B
San Diego, CA 92123

email: information@pluralpublishing.com
website: <https://www.pluralpublishing.com>

Copyright © 2027 by Plural Publishing, Inc.

Typeset in 11/13 Minion Pro by Flanagan's Publishing Services, Inc.
Printed in Printed in Canada by Friesens.

All rights, including that of translation, reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, recording, or otherwise, including photocopying, recording, taping, web distribution, or information storage and retrieval systems without the prior written consent of the publisher.

For permission to use material from this text, contact us by
Telephone: (866) 758-7251
Fax: (888) 758-7255
email: permissions@pluralpublishing.com

Every attempt has been made to contact the copyright holders for material originally printed in another source. If any have been inadvertently overlooked, the publisher will gladly make the necessary arrangements at the first opportunity.

Library of Congress Cataloging-in-Publication Data:

Names: Hoit, Jeannette D. (Jeannette Dee), 1954- author | Weismer, Gary author | Story, Brad author | Lester-Smith, Rosemary A. author
Title: Foundations of speech and hearing : anatomy and physiology / Jeannette D. Hoit, Gary Weismer, Brad Story, Rosemary A. Lester-Smith.
Description: Third edition. | San Diego, CA : Plural Publishing, Inc, [2027] | Includes bibliographical references and index.
Identifiers: LCCN 2025032149 (print) | LCCN 2025032150 (ebook) | ISBN 9781635508710 hardcover | ISBN 1635508711 hardcover | ISBN 9781635505191 ebook
Subjects: LCSH: Speech--Physiological aspects | Speech perception | Speech disorders | Respiratory organs--Anatomy | Hearing--Physiological aspects
Classification: LCC QP306 .H65 2027 (print) | LCC QP306 (ebook)
LC record available at <https://lcn.loc.gov/2025032149>
LC ebook record available at <https://lcn.loc.gov/2025032150>

Contents

<i>Preface</i>	<i>xv</i>
<i>Acknowledgments</i>	<i>xvii</i>
<i>About the Authors</i>	<i>xix</i>
<i>About the Illustrator</i>	<i>xxi</i>

CHAPTER 1. INTRODUCTION TO BASIC CONCEPTS	1
Introduction	1
Stages of Spoken Communication	1
Subsystems	3
Speech Subsystems	3
Hearing Subsystems	5
Directions and Planes	5
Directions	6
Anterior/Posterior (Ventral/Dorsal)	7
Superior/Inferior (Rostral/Caudal)	7
Medial/Lateral	7
Proximal/Distal	7
External/Internal (Superficial/Deep)	7
Ipsilateral/Contralateral	7
Planes	7
Sagittal Plane	8
Coronal Plane	8
Horizontal Plane	8
Tissue Types	8
Neural Tissue	8
Muscle Tissue	10
Connective Tissue	10
Epithelial Tissue	10
Movements and Forces	10
Review	12

CHAPTER 2. NEURAL STRUCTURES AND FUNCTIONS FOR SPEAKING, HEARING, AND SWALLOWING	13
Introduction	13
Organizing Concepts	13
Central Versus Peripheral Nervous System	13
Anatomical Planes and Directions	14
Gray Matter and Nuclei	17

White Matter and Fiber Tracts	17
Ganglia	17
Efferent and Afferent	17
Lateralization, Specialization, and Somatotopic Organization	18
Motor and Sensory Integration	19
Cerebral Hemispheres	19
Frontal Lobe	19
Primary Motor Cortex	21
Broca's Area	22
Premotor and Supplementary Motor Area	22
Prefrontal Cortex	22
Parietal Lobe	23
Temporal Lobe	23
Occipital Lobe	25
Insula	25
Limbic System (Limbic Lobe)	26
Cerebral White Matter	26
Association Tracts	26
Striatal Tracts	27
Commissural Tracts	28
Descending Projection Tracts	28
Ascending Projection Tracts	31
Subcortical Nuclei and Cerebellum	32
Basal Ganglia	32
Thalamus	33
Cerebellum	33
Brainstem	34
Surface Features of the Brainstem: Ventral View	36
Ventral Surface of Midbrain	36
Ventral Surface of Pons	37
Ventral Surface of Medulla	37
Surface Features of the Brainstem: Dorsal View	37
Dorsal Surface of Midbrain	38
Dorsal Surface of Pons	38
Dorsal Surface of Medulla	39
Cranial Nerves and Associated Brainstem Nuclei	39
Cranial Nerve V (Trigeminal)	41
Cranial Nerve VII (Facial)	41
Cranial Nerve VIII (Vestibulocochlear)	43
Cranial Nerve IX (Glossopharyngeal)	43
Cranial Nerve X (Vagus)	44
Cranial Nerve XI (Spinal Accessory Nerve)	44
Cranial Nerve XII (Hypoglossal)	45
Spinal Cord	45
Spinal Nerves	46
Cortical Motor Innervation Patterns	47
Nervous System Cells	48
Glial Cells	49
Neurons	49
Cell Body (Soma)	50

Dendrites	51
Axon and Terminal Segment	51
Synapse	51
Presynaptic Membrane	51
Postsynaptic Membrane	51
Synaptic Cleft	51
Electrochemical Transmission	52
Resting Potential	52
Action Potential	54
Synaptic Transmission and Neurotransmitters	56
Neuromuscular Junction	57
Meninges, Ventricles, and Blood Supply	57
Meninges	57
Ventricles and CSF	60
Blood Supply of Brain	60
Anterior Circulation	62
Posterior Circulation	63
Circle of Willis	63
Review	65
References	66
CHAPTER 3. RESPIRATORY STRUCTURE AND FUNCTION	67
Introduction	67
Respiratory Anatomy	68
Skeletal Framework	68
Respiratory System Subdivisions	69
Pulmonary Apparatus	69
Chest Wall	71
Pulmonary Apparatus–Chest Wall Unit	72
Forces of the Respiratory System	73
Passive Force	73
Active Force	73
Muscles of the Rib Cage Wall	73
Muscle of the Diaphragm	77
Muscles of the Abdominal Wall	78
Summary of Passive and Active Forces	79
Realization of Passive and Active Forces	79
Movements of the Respiratory System	81
Movements of the Rib Cage Wall	81
Movements of the Diaphragm	82
Movements of the Abdominal Wall	82
Relative Movements of the Rib Cage Wall and Diaphragm-Abdominal Wall	82
Forces Underlying Movements	84
Respiratory Control Variables	85
Lung Volume	85
Alveolar Pressure	86
Chest Wall Shape	89
Neural Control of Breathing	90
Control of Tidal Breathing	92
Control of Special Acts of Breathing	93

Peripheral Nerves of Breathing	94
Ventilation and Gas Exchange During Tidal Breathing	95
Speech Breathing	97
Extended Steady Utterances	98
Connected Speech Activities	100
Variables That Influence Respiratory Structure and Function	103
Body Position	103
Body Type	107
Age	107
Sex	109
Ventilation and Drive to Breathe	109
Cognitive-Linguistic and Social Variables	110
Clinical Measurements of Respiratory Function	110
Spirometry	111
Manometry	112
Plethysmography	112
Pulse Oximetry	112
Clinical Case: Spinal Cord Injury	115
Review	117
References	119
Answers to Clinical Case Questions	121

CHAPTER 4. LARYNGEAL STRUCTURE AND FUNCTION **123**

Introduction	123
Laryngeal Anatomy	123
Skeletal Framework	124
Thyroid Cartilage	124
Cricoid Cartilage	125
Arytenoid and Corniculate Cartilages	126
Epiglottis	126
Hyoid Bone	127
Laryngeal Joints	127
Cricothyroid Joints	129
Cricoarytenoid Joints	130
Internal Topography	130
Laryngeal Cavity	131
Vocal Folds	132
Ventricular Folds	136
Laryngeal Ventricles	136
Ligaments and Membranes	136
Forces of the Larynx	138
Intrinsic Laryngeal Muscles	139
Extrinsic Laryngeal Muscles	143
Supplementary Muscles	144
Infrahyoid Muscles	144
Suprahyoid Muscles	146
Summary of the Laryngeal Muscles	147
Movements of the Larynx	147
Movements of the Vocal Folds	147
Vocal Fold Abduction	147

Vocal Fold Adduction	148
Vocal Fold Length Change	149
Movements of the Ventricular Folds	152
Movements of the Epiglottis	153
Movements of the Laryngeal Housing	153
Laryngeal Control Variables	155
Laryngeal Opposing Pressure	155
Laryngeal Airway Resistance	155
Glottal Size and Configuration	156
Stiffness of the Vocal Folds	157
Effective Mass of the Vocal Folds	157
Neural Control of the Larynx	158
Laryngeal Function and Speech Production	161
Transient Noise Production	163
Sustained Noise Production	163
Sustained Voice Production	164
Vocal Fold Vibration	165
Fundamental Frequency	169
Sound Pressure Level	170
Fundamental Frequency-Sound Pressure Level Profiles	171
Spectrum	172
Voice Registers	174
Connected Speech Activities	174
Fundamental Frequency	174
Sound Pressure Level	176
Spectrum	177
Articulation	178
Variables That Influence Laryngeal Structure and Function	178
Age	178
Sex	180
Clinical Measurements of Laryngeal Function	182
Endoscopy	182
Electroglottography	182
Aeromechanical Observations	185
Clinical Case: Vocal Fold Paralysis	187
Review	188
References	190
Answers to Clinical Case Questions	195

CHAPTER 5. VELOPHARYNGEAL-NASAL STRUCTURE AND FUNCTION 197

Introduction	197
Velopharyngeal-Nasal Anatomy	198
Skeletal Framework	198
Pharynx	198
Velum	202
Nasal Cavities	203
Outer Nose	204
Forces of the Velopharyngeal-Nasal Mechanism	206
Muscles of the Pharynx	207

Muscles of the Velum	210
Muscles of the Outer Nose	213
Movements of the Velopharyngeal-Nasal Mechanism	214
Movements of the Pharynx	214
Movements of the Velum	215
Movements of the Outer Nose	216
Movements That Change the Size of the Velopharyngeal Port	216
Velopharyngeal-Nasal Control Variables	216
Velopharyngeal-Nasal Airway Resistance	217
Velopharyngeal Sphincter Compression	218
Velopharyngeal-Nasal Acoustic Impedance	218
Neural Control of the Velopharyngeal-Nasal Mechanism	220
Velopharyngeal-Nasal Function and Ventilation	221
Velopharyngeal Function and Speech Production	222
Sustained Utterances	222
Connected Speech Activities	223
Variables That Influence Velopharyngeal-Nasal Structure and Function	225
Body Position	225
Age	226
Sex	228
Clinical Measurements of Velopharyngeal-Nasal Function	229
Nasendoscopy	229
Aeromechanical Observations	229
Nasometry	231
Clinical Case: Cleft Lip and Palate	232
Review	234
References	235
Answers to Clinical Case Questions	239

CHAPTER 6. PHARYNGEAL-ORAL STRUCTURE AND FUNCTION 241

Introduction	241
Pharyngeal-Oral Anatomy	241
Skeletal Framework	241
Maxilla	242
Mandible	243
Temporomandibular Joints	244
Internal Topography	247
Pharyngeal Cavity	247
Oral Cavity	247
Buccal Cavity	248
Mucous Lining	248
Forces of the Pharyngeal-Oral Mechanism	248
Muscles of the Pharynx	249
Muscles of the Mandible	250
Muscles of the Tongue	252
Muscles of the Lips	256
Movements of the Pharyngeal-Oral Mechanism	259
Movements of the Pharynx	260
Movements of the Mandible	260

Movements of the Tongue	261
Movements of the Lips	262
Pharyngeal-Oral Control Variables	263
Pharyngeal-Oral Lumen Size and Configuration	263
Pharyngeal-Oral Structural Contact Pressure	265
Pharyngeal-Oral Airway Resistance	265
Pharyngeal-Oral Acoustic Resonances	266
Neural Control of the Pharyngeal-Oral Mechanism	268
Speech Production: Sound Generation and Filtering	269
Speech Production: Articulatory Descriptions	272
Vowels	272
Place of Major Constriction	272
Degree of Major Constriction	274
Lip Rounding	274
Real-Life Vowels	274
Diphthongs	275
Consonants	275
Manner of Production	276
Place of Production	276
Voicing	277
Real-Life Consonants	277
Speech Production: Articulatory Processes	278
Coarticulation	278
Articulatory Phonology or Gesture Theory	281
Variables That Influence Pharyngeal-Oral Structure and Function	282
Age	282
Sex	285
Clinical Measurements of Pharyngeal-Oral Structure and Function	285
Structural and Functional Imaging	286
Articulatory Tracking	287
Acoustic Observations and Measurement	288
Clinical Case: Glossectomy	291
Review	293
References	295
Answers to Clinical Case Questions	298
CHAPTER 7. SWALLOWING STRUCTURE AND FUNCTION	301
Introduction	301
Anatomy	301
Esophagus	301
Stomach	304
Salivary Glands	304
Forces and Movements of Swallowing	305
Oral Preparatory Phase	307
Oral Transport Phase	309
Pharyngeal Phase	309
Esophageal Phase	310
Overlap of Phases	311
Breathing and Swallowing	311

Neural Control of Swallowing	314
Role of the Peripheral Nervous System	314
Role of the Central Nervous System	315
Variables That Influence Swallowing	316
Bolus Characteristics	316
Consistency and Texture	316
Volume	317
Taste	317
Swallowing Mode	318
Single Versus Sequential Swallows	318
Cued Versus Uncued Swallows	319
Body Position	319
Age	320
Sex	321
Clinical Measurements of Swallowing	322
Videofluoroscopy	322
Endoscopy	323
Ultrasonography	323
Manometry	324
Clinical Case: Parkinson's Disease	326
Review	328
References	329
Answers to Clinical Case Questions	335

CHAPTER 8. AUDITORY SYSTEM STRUCTURE AND FUNCTION 337

Introduction	337
Skeletal Framework	337
Peripheral Anatomy of the Ear	339
Outer Ear (Conductive Mechanism)	339
Pinna	341
External Auditory Meatus	342
Tympanic Membrane	343
Middle Ear (Conductive Mechanism)	344
Ossicles and Associated Structures	344
Ligaments and Muscles of the Middle Ear	346
Eustachian Tube	347
Summary of Middle Ear Structures	348
Inner Ear (Sensorineural Mechanism)	349
Semicircular Canals	350
Vestibule	350
Cochlea	351
Cochlear Nerve	354
Transformation of Sound by the Ear	355
Transformation of Sound by the Conductive Mechanism	355
Transformation of Sound by the Sensorineural Mechanism	358
Central Auditory Pathways	360
Clinical Measurements of Hearing	361
Pure-Tone Audiometry	362
Auditory Brainstem Response	363
Otoacoustic Emissions	364

Clinical Case: Unilateral Hearing Loss	364
Review	366
References	367
Answers to Clinical Case Questions	368
<i>Index</i>	371

About the Authors

Jeannette D. Hoit, PhD, CCC-SLP (Retired), is Professor Emerita in the Department of Speech, Language, and Hearing Sciences and former director of Postdoctoral Affairs at the University of Arizona. Dr. Hoit received her BA in anthropology from the University of California at Los Angeles, her MA in communication disorders from San Diego State University, and her PhD in speech and hearing sciences from the University of Arizona and pursued postdoctoral study at the Harvard School of Public Health Respiratory Biology Program and Massachusetts Institute of Technology Speech Research Laboratory. Dr. Hoit's research focused on speech physiology with an emphasis on normal aging and development, neuromotor speech disorders, and respiratory function and dysfunction. Dr. Hoit is past editor of the *American Journal of Speech-Language Pathology*, a fellow of the American Speech-Language-Hearing Association, and University of Arizona College of Science Galileo Fellow. She has received a Distinguished Alumnus Award from San Diego State University and several teaching and mentoring awards from the University of Arizona.

Gary Weismer, PhD, is Oros-Bascom Professor Emeritus in the Department of Communication Sciences & Disorders, University of Wisconsin-Madison. He received his bachelor's and master's degrees from the Pennsylvania State University and his doctorate from University of Wisconsin-Madison in 1975. Dr. Weismer's research publications concern speech production in healthy talkers, as well as speech production and speech intelligibility in persons with motor speech disorders. Dr. Weismer served twice as Associate Editor for the *Journal of Speech, Language, and Hearing Research* (formerly the *Journal of Speech and Hearing Research*), as Associate Editor at *Folia Phoniatica et Logopaedica* (FPL) from 2004 to 2011, and as Editor-in-Chief at FPL from 2011 to 2016. During his 35 years at University of Wisconsin-Madison, Dr. Weismer won several teaching awards, including for mentoring efforts in the University of Wisconsin-Madison Honors program. Dr. Weismer mentored 16 doctoral students during his career, many of whom are currently scientific leaders and university administrators. He is a past member of the Executive Board of the International Association of Logopedics and Phoniatrics (IALP), an Honored Member of IALP, a Fellow of the Acoustical Society of America, and past chair of his department. He has edited, authored, and coauthored five textbooks.

Brad H. Story, PhD, is Professor in the Department of Speech, Language, and Hearing Sciences and Associate Dean of Faculty Affairs in the College of Science at the University of Arizona. Dr. Story received his BS in Applied Physics from the University of Northern Iowa in 1987 and his PhD in Speech and Hearing Sciences from the University of Iowa in 1995. From 1987-1991, he was employed in industry as an engineer where he developed computational models and instrumentation systems for designing and measuring the performance of mufflers. Dr. Story's research publications concern the mechanics,

aerodynamics, and acoustics of speech production, as well as the perception of speech sounds. Dr. Story is a past Associate Editor for the *Journal of the Acoustical Society of America*, a fellow of the Acoustical Society of America (ASA), and recipient of the ASA's Rossing Prize in Acoustics Education in 2016. Dr. Story was recognized by the American Speech Language and Hearing Association in 2013 with the Willard R. Zemlin Lecture Award, and by the University of Iowa in 2018 with a Distinguished Alum Award. His research has been supported by the National Institutes of Health and the National Science Foundation.

Rosemary A. Lester-Smith, PhD, CCC-SLP, is an Associate Professor of Speech, Language, and Hearing Sciences at The University of Texas at Austin. She received a BA in speech and hearing sciences from the University of New Mexico, an MA in speech and hearing sciences from Indiana University, an MS in clinical investigation from Northwestern University, and a PhD in speech, language, and hearing sciences with a minor in neuroscience from the University of Arizona. She completed postdoctoral training at Mayo Clinic, Boston University, Northwestern University, and Shirley Ryan AbilityLab (formerly Rehabilitation Institute of Chicago). Dr. Lester-Smith's research focuses on voice production in speakers with neurological disorders, healthy speakers, and singers with the goal of understanding factors that impair or improve vocal control. Her research is supported by the National Institutes of Health. Dr. Lester-Smith is also a certified speech-language pathologist and has worked in a variety of clinical settings, primarily evaluating and treating adults with voice and swallowing disorders.

About the Illustrator

Maury Aaseng began illustrating as a freelancer for young-adult nonfiction publications in San Diego, California. While he was there, his work expanded into the realm of medical and anatomical art. He collaborated with authors and experts to create digitally rendered illustrations for publications that illuminate concepts in the health sciences, the body, and nature. Besides medical illustration, his range includes cartooning, watercolor, logos, line art, ink, and digital art. Clients include various publishing companies, podcasts, botanical gardens, lawyers, public works utilities, an opera company, and a creative studio in Melbourne, Australia.

His work first won recognition in the juried exhibition Upstream People Gallery in 2008. In 2016, a collection of his watercolor work was displayed at the Great Lakes Aquarium gallery. He has taught classes covering scientific illustration and nature-inspired watercolor and recently has “drawn on” his experience to create books that demonstrate techniques to other budding artists.

Maury resides with his wife, Charlene, a graphic designer, and their two children in Duluth, Minnesota, near the shores of Lake Superior. They enjoy spending time outdoors as much as possible in the surrounding woods and lakes.



Introduction to Basic Concepts

Introduction

This book is about the **anatomy** (the study of the structure of organisms and the relations of their parts) and **physiology** (the study of functions of living organisms or their parts) of the speech and hearing mechanisms. In this first chapter, we provide an overview of certain overarching and basic concepts that will make the reading of later chapters much easier. It begins with a simple description of the *stages of spoken communication*, a general framework meant to guide the reader through the material in the remaining chapters. Following this is a general description of the speech and hearing *subsystems*, *anatomic directions and planes*, and *tissue types*. The final section focuses on *movements and forces*, phenomena that are critical to understanding speech production and certain aspects of hearing.

Stages of Spoken Communication

Spoken communication can be thought of as the process of conveying ideas from one person's brain to the brain(s) of one or more other people by using our speaking and hearing mechanisms. It is convenient to

describe spoken communication as a linear set of stages, such as those depicted in Figure 1–1 and described below. Nevertheless, this depiction is overly simplistic, and in fact, there are significant interactions among the processes involved at all these stages. Some of these interactions are explored in more detail in subsequent chapters.

The **neural** stage of spoken communication is carried out by the brain, spinal cord, and the peripheral nerves that serve the speech mechanism. This stage of spoken communication involves the neural processes that participate in conceptualization of the message, the planning and execution of the speech movements, and the processing of the sensory information that influences the ongoing control of speech production. Some neural processes are voluntary, and some are automatic; some require awareness, and some do not.

The nervous system communicates with muscles to initiate the **muscular** stage of spoken communication. Muscles are effectors that respond to signals from the nervous system to produce forces and movements. In the speech mechanism, it is often difficult to determine individual muscle contributions to forces and movements because they are usually accomplished by groups of muscles working together.

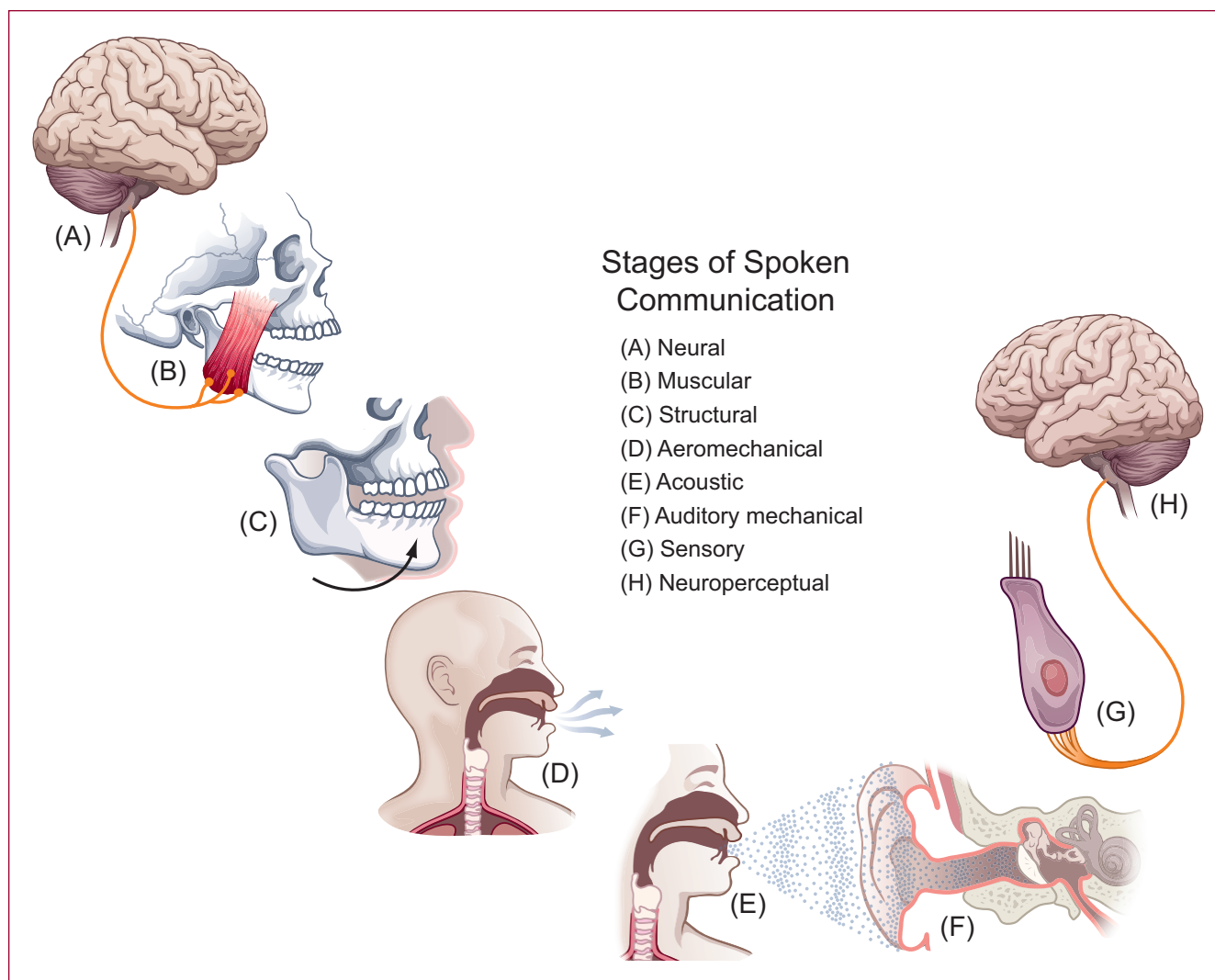


Figure 1-1. The stages of spoken communication are (A) neural, (B) muscular, (C) structural, (D) aeromechanical, (E) acoustic, (F) auditory mechanical, (G) sensory, and (H) neuropsychological.

The **structural** stage of the speech communication process is the stage in which speech production becomes visible. Some movements of speech production, such as the movements of the vocal folds, are visible only with the aid of special viewing instruments, whereas other movements, such as the movements of the lips, are visible to the naked eye. Speech reading (lip reading) has its roots in the structural stage of speaking.

Movements of speech structures give rise to the **aeromechanical** (air motion) stage of the spoken communication process. Structural movements raise and lower the air pressure in different parts of the speech mechanism and cause the air to flow from one region to another. These air pressures and airflows are usually invisible, except in those who speak and smoke

at the same time or in those who speak in subfreezing temperatures.

Next is the **acoustic** stage, the stage of the process in which speech is produced. Speech is the sound wave—the acoustic product—which results from the act of speaking. It is made up of sonorous, buzzing, hissing, and popping sounds caused by the speaker valving the airstream in different ways and at different locations. The sound that is speech is the rapid alternations of compressions (increase in density) and rarefactions (decrease in density) of air molecules that constitute pressure waves. These pressure waves radiate from the mouth, nose, and skin surfaces. It is this acoustic stage that makes it possible to communicate around corners, through obstacles, in the dark, and over long distances.

Air Travel

Students often find it hard to separate the aeromechanical from the acoustic stage of speech production, probably because they both involve air travel. An example may help clear things up. Try talking while holding your hand up to your mouth—you should feel air flowing into your hand. Now do that while talking to someone at least 6 feet away from you. That person can hear you just fine, but they can't feel the air flowing from your mouth (hopefully). That's because the air flows from your mouth slowly

and that flow only travels a short distance from your mouth. In contrast, the compressions and rarefactions created by air molecules bumping into each other (while remaining more or less in place) move rapidly *through* the air and over long distances as waves of energy. So think of the aeromechanical stage as transporting air molecules themselves from one place to another, whereas in the acoustic stage, the air molecules assist in moving energy from one place to another.

These acoustic pressure waves reach the ears of the listener and initiate the next stage of the spoken communication process: the **auditory mechanical** stage. It is during this stage that the acoustic pressure waves hit structures of the ear and cause them to move ever so slightly. These movements are transmitted from one structure to the next through various regions of the ear until they reach the auditory sensors that serve as the interface between sound and the nervous system.

The auditory sensors, which look like small hairs (and are, in fact, called hair cells), bend when a hydraulic pressure wave hits them. This is the **sensory** stage of the spoken communication process. The bending of these hair-like sensors causes an electrical signal to be generated, and that signal is sent through the nervous system. In this way, the sensors transduce their movement into neural activity.

The final stage of the spoken communication process is the **neuroperceptual** stage. This stage relies on the nervous system of the listener (although it is also true that the speaker's nervous system is simultaneously processing the acoustic speech signal). The signals generated in the ears' sensory cells are sent through peripheral nerves and routed to different parts of the brain, where they are eventually perceived, thereby completing the spoken communication process. The message that began in the speaker's brain completes its journey in the listener's brain.

Subsystems

Spoken communication is carried out via the *speech* mechanism and *hearing* mechanism, each of which can be divided into *subsystems*. Although the speech and

hearing mechanisms cannot be divided up without sacrificing their functional integrity, it is convenient to discuss their separate parts as a way to make the information easier to understand and remember.

Speech Subsystems

Most textbooks divide the speech mechanism into three or four subsystems. The first two, respiratory and laryngeal, are also used in this book. Where this book diverges from the others is in the treatment of the region above the larynx. Some textbooks present this region as a single subdivision of the speech mechanism, often called the *articulatory subsystem* and encompassing the pharyngeal, oral, and nasal cavities and associated structures. Other textbooks present this region as two subdivisions, using terms such as *articulatory* (in this context meaning the oral region) and *resonatory* (usually meaning the velopharyngeal region and sometimes including the nasal region). The term *articulatory* is problematic when used in this context because it is not the only speech subsystem that contains an articulator (defined as a movable structure that contributes to the production of speech sounds); the larynx also acts as an articulator (see Chapters 4 and 6), as does the velopharynx (see Chapter 5). Similarly, the term *resonatory* is problematic because the resonators (defined as parts of an acoustic system that emphasize certain sound frequencies and reject others) are not found exclusively in the velopharyngeal and nasal regions; the lower pharynx and the oral cavities also serve as acoustic resonators. Also, it is important to acknowledge that these anatomical regions are not used exclusively for articulating or resonating but also serve other functions,

such as swallowing (covered in Chapter 7). For all these reasons, we have adopted an anatomical approach to naming the speech subsystems.

In this book, we divide the speech system into four subsystems, as depicted in Figure 1–2: *respiratory*, *laryngeal*, *velopharyngeal-nasal*, and *pharyngeal-oral*. The *respiratory subsystem* consists of the pulmonary apparatus (lungs and lower airways) and the chest wall that surrounds it (rib cage, diaphragm, abdomen and its contents). The *laryngeal subsystem* includes the vocal folds and other structures that are located at the exit of the respiratory subsystem. The *velopharyngeal-nasal subsystem* includes both the velopharynx and the nasal airways and associated structures. The nasal portion is

included because it is critical to understanding the aero-mechanical and acoustic functions of this part of the speech system. The *pharyngeal-oral subsystem* includes the middle and lower pharynx and the oral cavity and associated structures. Inclusion of the pharyngeal part of the apparatus reflects the fact that during speech production, this part of the pharynx acts as an articulator and resonator along with its oral counterparts. Although we refer to these as speech subsystems, all four subsystems also participate in swallowing.

The pharyngeal-oral and velopharyngeal-nasal subsystems form what is called the upper airway. In this book, the term *upper airway* is used in the context of the anatomy and physiology of this region to be consistent

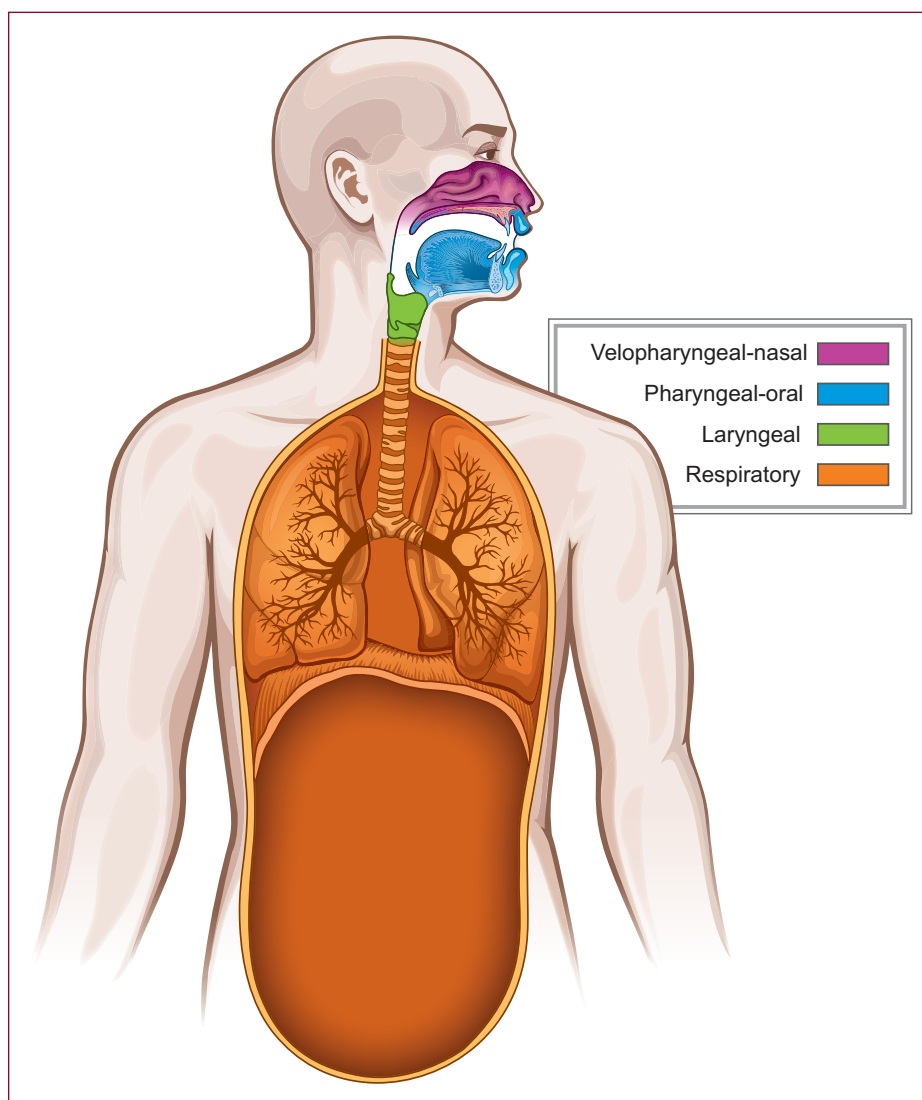


Figure 1–2. The four speech subsystems are respiratory (brown), laryngeal (in green), velopharyngeal-nasal (purple), and pharyngeal-oral (blue).

with terms such as *lower airways*, *laryngeal airway*, *velopharyngeal-nasal airway*, and *oral airway*. The term *vocal tract* also refers to the pharyngeal-oral regions but is used primarily when referring to their acoustic (sound) properties. Similarly, the term *nasal tract* is often used when discussing the acoustic properties of the nasal air spaces.

Anatomical details of each of these speech subsystems will be presented in the upcoming chapters. To gain an appreciation for what these structures look like in a human cadaver, we recommend that the reader watch **Video 1-1** (Anatomy).



inner ear, shown in Figure 1-3 with color-coding. It is important to recognize that the inner ear contains both auditory (hearing) structures and vestibular (balance) structures. The major hearing structure of the inner ear is the part that looks like a snail's shell (called the cochlea), and the vestibular portion looks like a trio of loops (called semicircular canals). Figure 1-3 should give the reader an appreciation of the location of the auditory-vestibular system within the head as well as how small it is relative to most of the other structures discussed in this book. More details are provided in Chapter 8.

Hearing Subsystems

The hearing mechanism, like the speech mechanism, acts as an integrated system but is often divided into parts. The most conventional way to divide the hearing system, and the one that is adopted in this book, is into regions simply called the *outer ear*, *middle ear*, and

Directions and Planes

A special vocabulary is used when describing locations and orientations of anatomical structures. This vocabulary pertains to *directions* and *planes* and is generally discussed in the context of what is called the *anatomical position* of the body. This position is described as the

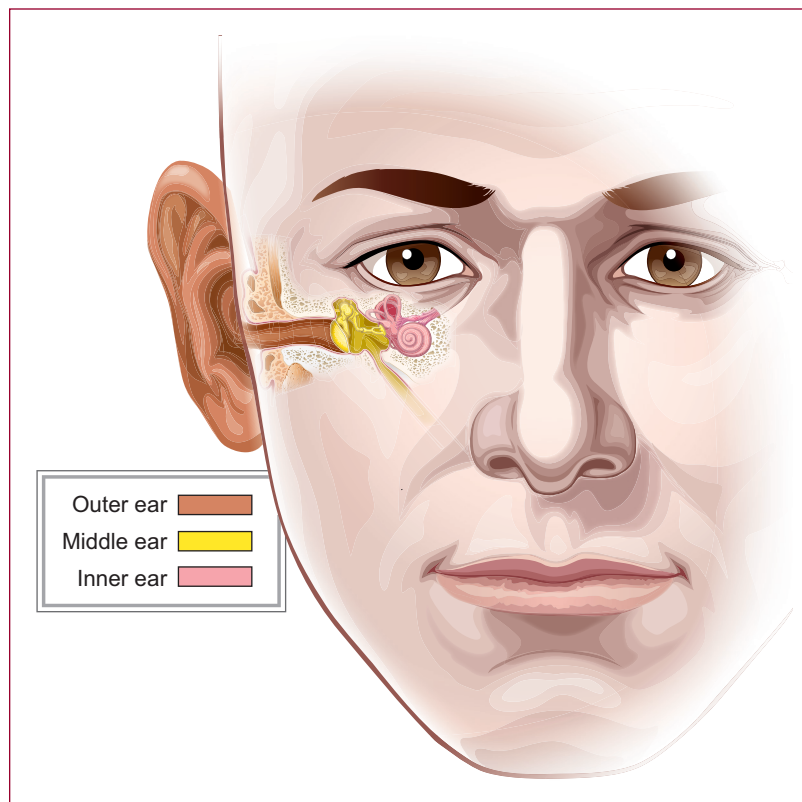


Figure 1-3. The three hearing subsystems are outer ear (brown), middle ear (yellow), and inner ear (pink). Note that the inner ear also contains vestibular (balance) structures.

body standing erect with the arms at the sides and the palms facing forward, as shown in Figure 1–4.

Directions

Several directional terms are used in this book to describe anatomical locations and orientations within the speech and hearing mechanisms. These terms are

anterior/posterior (ventral/dorsal), superior/inferior (rostral/caudal), medial/lateral, proximal/distal, external/internal (superficial/deep), and ipsilateral/contralateral, the first three sets of which are depicted in Figure 1–4. Although these terms are technically the most accurate and precise, to maintain readability throughout the textbook, we will sometimes use colloquial words for anatomical directions (such as front/back, above/below) and assume that the person is in an upright position.

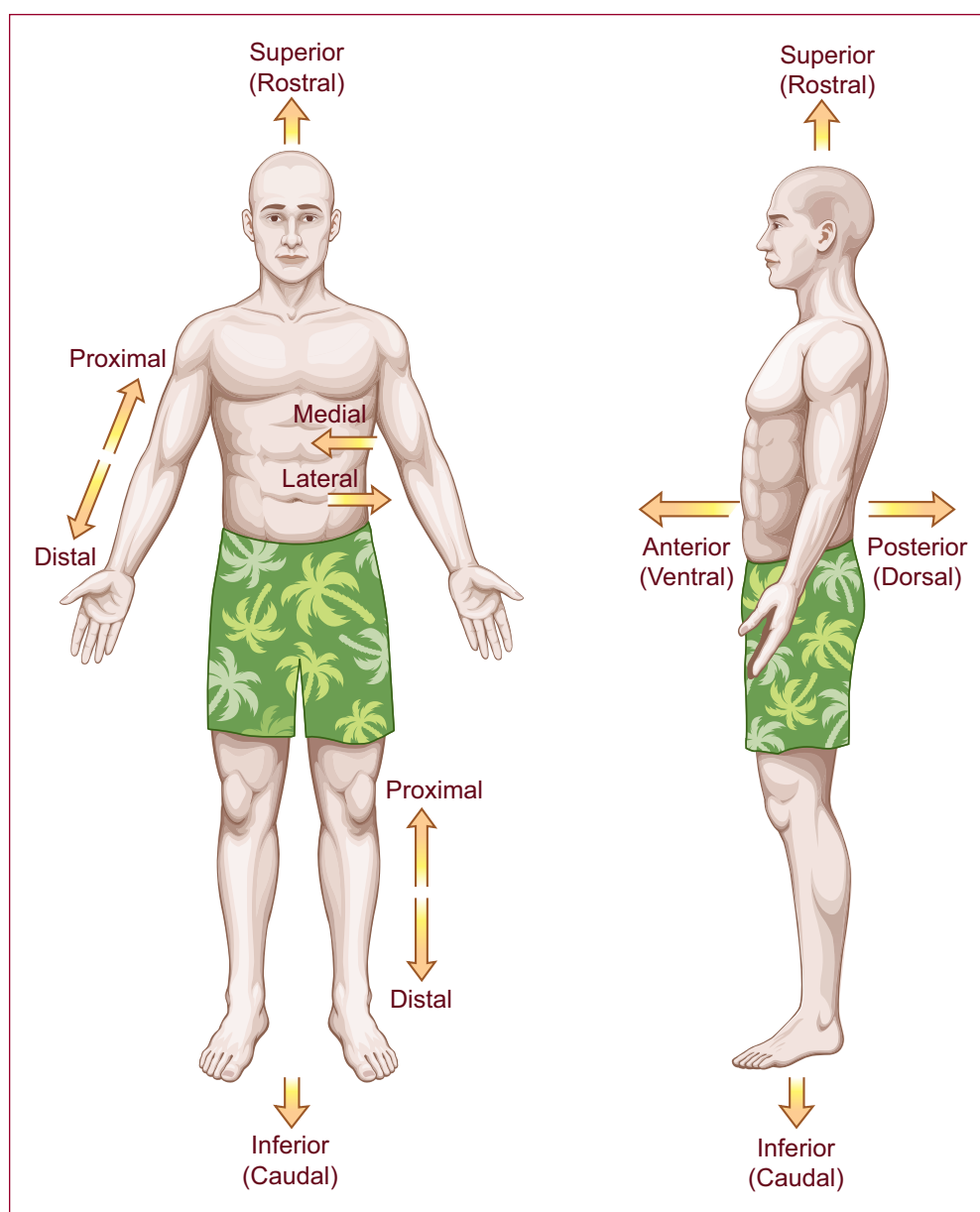


Figure 1–4. Four sets of anatomical directions are shown: superior (rostral) and inferior (caudal), medial and lateral, proximal and distal, and anterior (ventral) and posterior (dorsal). Note that the definitions of ventral and dorsal differ when applied to the upper part of the brain (see associated text and Chapter 2).

Anterior/Posterior (Ventral/Dorsal)

Anterior means toward the front of the body and *posterior* means toward the back of the body. Similarly, *ventral* means toward the front of the body (literally, toward the belly), and *dorsal* means toward the back of the body. Thus, in many contexts, *anterior* and *ventral* can be used interchangeably, as can *posterior* and *dorsal*. Nevertheless, it is best to use them in their designated pairs (e.g., *anterior* and *posterior*) rather than mix them (e.g., *anterior* and *dorsal*). An example of how these terms are used is: The umbilicus (belly button) is anterior (ventral) to the spine and the spine is posterior (dorsal) to the umbilicus.

There is an important exception to how the terms *ventral* and *dorsal* are used. When applied to the upper region of the brain comprising the cerebral hemispheres, *ventral* means toward the bottom and *dorsal* means toward the top of the cerebral hemispheres. This is explained and illustrated more fully in Chapter 2.

Superior/Inferior (Rostral/Caudal)

Superior and *rostral* mean toward the head. Sometimes the term *cranial* is also used to mean toward the head. The terms *inferior* and *caudal* mean toward the tail or, in the case of the human, away from the head. For example, the brain is *superior* (*rostral*) to the spinal cord and the spinal cord is *inferior* (*caudal*) to the brain.

Medial/Lateral

Medial means toward the midline. *Lateral* means away from the midline or toward the side. For example, the nose is *medial* to the ear and the ear is *lateral* to the nose.

Proximal/Distal

Proximal means toward the body and *distal* means away from the body. These terms are usually applied to the limbs (arms and legs). For example, the fingers are *distal* to the wrist and the wrist is *proximal* to the fingers.

External/Internal (Superficial/Deep)

When something is closer to the outer surface of the body than something else, it is said to be *external* (or *superficial*) to it. Conversely, when something is farther away from the outer surface of the body than something else, it is said to be *internal* (or *deep*) to it. These terms are often used interchangeably. An example of their usage is: The skin is *external* (or *superficial*) to the muscle and the muscle is *internal* (or *deep*) to the skin.

Ipsilateral/Contralateral

Ipsilateral means the same side of the body. *Contralateral* means the opposite side of the body. For example, the right ear is *ipsilateral* to the right arm and *contralateral* to the left arm.

Planes

Many structures of the speech and hearing mechanisms (and all structures of the nervous system) are inside the body and can only be viewed when exposed by slicing open the body. An example of this is Figure 1–2, which depicts the cranial portion of the speech mechanism (velopharyngeal-nasal and pharyngeal-oral subsystems) as viewed with that part of the body sliced in half.

Which Way Is Up?

Anatomy is hard enough to learn without having to learn that certain terms mean different things in different contexts. It's just not fair. Why doesn't *ventral* just mean "toward the front" and *dorsal* mean "toward the back"? Period. Why assign these terms different meanings when talking about the lower part of the brain versus the higher part? Believe it or not, it's simpler than you think. What may seem arbitrary at first glance is actually completely logical. Try this exercise: Ask your cat or dog or other

four-legged pet to stand quietly while you view it from the side. Now ask yourself these questions: "Which direction is ventral? Which direction is dorsal?" It should be immediately apparent that ventral is toward the lower part of the brain (cerebral hemispheres) and dorsal the opposite. Clear as a bell. The confusion comes when the animal stands on its two back legs. If we humans had only stayed on all fours, learning the anatomical directions would have been so much easier!