

Contents

<i>Clinical Cases and Applications</i>	<i>xv</i>
<i>Preface</i>	<i>xix</i>
<i>Acknowledgments</i>	<i>xxii</i>
<i>About the Illustrator</i>	<i>xxiii</i>
<i>About the Contributor</i>	<i>xxv</i>

1	Introduction	1
1.1	The Clinical Usefulness of Speech and Voice Science	2
	Scenario 1	2
	Scenario 2	2
	Scenario 3	3
1.2	Defining Speech Science	3
1.3	Advice for Students on Effective Study Techniques	5
	Study as Though You Are Having a Test Every Week	6
	Study With a Partner or Group	6
	Reach Beyond Memorization to Understand the Material	7
	Administer Self-Exams	7
	Stay Mindfully Present in Class	7
	Don't Focus Only on the Slides!	8
	Read Assignments Before <i>and</i> After Class	8
	Use the Study Aids	8
	Understand the Reason Why Facts Are Important	9
	Create Diagrams and Charts	9
	Do Not Rely on Index Cards	9
	Talk It Out!	9
	Look Over Your Tests and Quizzes for a Pattern of Errors	9
	Work It Out!	9
	Ask the Instructor	9
	Make Sure That Your Study Time Is Focused Without Distractions	10
	Don't Wait Until the End of the Semester to Ask Your Professor for Help!	10
	Advice for Synchronous or Asynchronous Online Classes	10
2	Describing and Explaining Motion	11
2.1	Systems of Measurement	12
2.2	Describing Motion: Speed, Velocity, Acceleration, and Deceleration	13
2.3	Newton's Laws Explain Motion	14
	The First Law of Motion	14
	The Second Law of Motion	14
	The Third Law of Motion	14
2.4	Momentum and Energy	15

Momentum	15
Energy	16
<i>Energy, Work, and Power</i>	16
<i>Kinetic and Potential Energy</i>	17
2.5 Three States of Matter	18
Density	20
Elasticity and Stiffness	21
Pressure	23
<i>Units of Measurement of Pressure</i>	24
References	25
3 Sound Waves	27
3.1 Vibration	28
3.2 The Nature of Waves	28
Pulse Waves	30
Longitudinal Pressure Waves	30
3.3 Transfer of Energy in Waves	32
3.4 Visualizing a Sound Wave	35
3.5 Properties of Sound Waves	35
Frequency	35
Period	39
Intensity	40
Wavelength	44
<i>Speed of Sound</i>	45
3.6 The Perception of Sound Waves	46
Perception of Intensity	47
Perception of Frequency	48
3.7 Pure and Complex Tones	49
Power Spectra	52
Noise	55
3.8 Behavior of Sound Waves	56
Interference	56
Boundaries	58
<i>Reflection</i>	59
3.9 Resonance	59
Natural Resonant Frequency	60
Standing Wave Patterns	62
<i>Rules Governing Standing Waves</i>	63
Forced Vibration	65
Acoustic Resonators	68
Recommended Internet Sites for Further Learning	69
References	69
4 Breathing	71
Clinical Case 1: Breath-Holding Speech	72
4.1 Introduction	73
4.2 Respiration	76
4.3 Balloons or Boyle's Law?	76

4.4 Anatomy of the Lower Airway	78
The Work of Muscles	82
<i>Agonist-Antagonist Pairs</i>	82
<i>Muscles and Levers</i>	83
The Muscles of Breathing	84
4.5 The Biomechanics of Breathing	87
The Biomechanics of Tidal Breathing	87
Lung Volumes and Capacities	91
The Biomechanics of Forced Inhalation and Exhalation	93
4.6 The Biomechanics of Speech Breathing	95
Relaxation Curve and Phonation	96
Running Speech	98
<i>Phrase Breath Groups</i>	99
Adaptation of Speech Breathing to Variable Internal and External Demands	101
<i>Body Type</i>	102
<i>Cognitive-Linguistic Variables</i>	102
<i>Speech Breathing Personality</i>	103
<i>Respiratory Demands</i>	104
4.7 The Work of Breathing	106
Airway Resistance	106
Laminar and Turbulent Airflow	108
Elastic Resistance	108
Viscosity	109
4.8 Instrumentation for Measuring Breathing Kinematics	110
Electromyography (EMG)	110
Respiratory Inductance Plethysmography	112
4.9 Clinical Application: Disorders Related to Breathing	112
Etiologies	112
Symptoms and Characteristics	113
Diagnostic Strategies	114
Therapeutic Approaches	114
Recommended Internet Sites for Further Learning	115
References	115

5 Phonation I: Basic Voice Science **119**

Clinical Case 2: Running Out of Breath	120
5.1 Overview	121
5.2 Anatomy of the Larynx	122
Structural Framework	122
Laryngeal Membranes and Cavities	124
Three Functions of the Larynx	127
Laryngeal Muscles	128
<i>Intrinsic Muscles</i>	130
<i>Extrinsic Muscles</i>	133
The Vocal Folds	135
<i>Structural Overview</i>	135
<i>Lamina Propria</i>	136
Mechanical Layers	137

Cricothyroid Joints	139
Cricoarytenoid Joints	140
Blood Supply to the Larynx and Lymphatic Drainage	141
5.3 Neural Control of Phonation	142
Central Motor Control	142
Peripheral Motor Neural Control and Brainstem Nuclei	142
Peripheral Sensory Control and Brainstem Nuclei	145
5.4 Theories of Voice Production	145
The Bernoulli Effect	147
The Myoelastic-Aerodynamic Theory	150
5.5 Biomechanics of Vocal Fold Vibration	150
Viscoelastic Component	154
Vertical Phase Difference: The Mucosal Wave	154
The Importance of Vocal Fold Closure	156
Glottal Volume Velocity	156
Laryngeal Airway Resistance	157
Phonation Threshold Pressure	158
Phonation Onset	158
5.6 Biomechanical Stress-Strain Properties of Vocal Fold Tissues	160
5.7 Physiology of Phonatory Control	162
Fundamental Frequency (f_0)	162
<i>Natural Resonance of the Vocal Folds</i>	163
<i>Cover-Dominant Vibration</i>	164
<i>Body Plus Cover Vibration</i>	166
<i>Lung Pressure in the Regulation of f_0</i>	166
<i>Differential Control of f_0: Evidence From EMG Data</i>	167
Control of Intensity	168
<i>Auditory Feedback of Control of f_0 and Intensity</i>	172
Biomechanical Forces During Phonation	173
5.8 Voice Quality	174
5.9 Clinical Application: Disorders Related to Voice Production	175
Etiologies	176
Symptoms and Characteristics	176
Diagnostic Strategies	177
Therapeutic Approaches	178
Recommended Internet Sites for Further Learning	179
References	179
6 Phonation II: Measurement and Instrumentation	185
Clinical Case 3: Camp Voice	186
6.1 Measurement of f_0 and Intensity	187
f_0 Measures	187
Intensity Measures	189
Voice Range Profile (VRP)	190
6.2 Measurement of Phonatory Aerodynamics	193
Airflow and Lung Pressure	193
<i>Vocal Efficiency</i>	195
<i>S/Z Ratio</i>	197

<i>Maximum Phonation Time</i>	198
<i>Phonation Quotient</i>	198
6.3 Instrumentation for Exploring the Dynamics of the Vocal Folds	199
Stroboscopy	200
High-Speed Laryngeal Imaging	203
Videokymography (VKG)	203
Photoglottography (PGG)	203
Electroglottography (EGG)	206
Open Quotient (OQ), Speed Quotient (SQ), and Contact Quotient (CQ)	208
6.4 Vocal Registers	210
Modal Register	211
Vocal Fry	211
Falsetto	213
Clinical Case 4: Persistent Mutational Falsetto	214
Recommended Internet Sites for Further Learning	215
References	215

7 The Production and Perception of Vowels **223**

Clinical Case 5: Accent Management	224
7.1 Introduction	226
7.2 Acoustic Theory of Speech Production	227
Acoustic Characteristics of the Source	229
The Vocal Tract Transfer Function	231
Acoustic Characteristics of Lip Radiation	234
Resonance and Standing Waves	235
7.3 Vowels	237
Vocal Tract Constrictions and Formant Frequencies	237
<i>First Formant Frequency (F1)</i>	238
<i>Second Formant Frequency (F2)</i>	239
<i>Third Formant Frequency (F3)</i>	239
The Traditional Vowel Quadrilateral	239
Vowel Quality and Articulatory Posture	242
Acoustic Representation of Vowel Quality	243
Resonating Cavities of the Vocal Tract	245
Vowel Formant Normative Data	249
Tense-Lax Vowel Quality and Inherent Duration	249
Rhotacized Vowel Quality	251
Diphthongs	251
Intrinsic Pitch of Vowels	254
7.4 Language and Dialect Influences on Vowel Production	259
Accentedness—Everyone Has an Accent!	260
7.5 The Vocal Tract as a Regulator of Intensity	260
Harmonic Structure, Energy Loss, and Near-Periodicity	261
Revisiting the Voice Range Profile	261
<i>Singer's Formant and Formant Tuning</i>	264
<i>Speaker's Formant</i>	264
7.6 Acoustic Filters	265
7.7 Instrumentation for Measuring Vocal Tract Acoustics	268

Sound Spectrography	268
<i>Narrowband and Wideband Spectrograms</i>	269
<i>Exploring Spectrograms</i>	270
<i>Visualizing Language and Dialectical Vowel Differences</i>	274
<i>Nearly Periodic Voice Source</i>	275
<i>Voiceprints: Voice Science or Science Fiction?</i>	275
Quantitative Spectral Measures	275
<i>Long-Term Average Spectrum</i>	276
<i>Harmonics-to-Noise Ratio</i>	276
<i>Cepstral Measures</i>	277
Inverse Filtering	279
7.8 Vocal Tract Imaging: Current Research and Future Trends	279
Conventional Radiography (X-rays)	280
Computed Tomography (CT)	281
Magnetic Resonance Imaging (MRI)	282
Ultrasound	285
Clinical Case 6: Ataxic Dysarthria	287
Recommended Internet Sites for Further Learning	288
References	288

8 The Production and Perception of Consonants **293**

Clinical Case 7: Facial Nerve Trauma	294
8.1 Introduction	295
8.2 Three Sources of Speech Sounds	298
Coarticulation	299
8.3 Phonetic Description of Consonants	299
Place of Articulation	299
Manner of Articulation	300
8.4 Acoustic Representation of Consonants	301
Stops	301
<i>Stop Gap</i>	301
<i>Release Burst</i>	301
<i>Aspiration</i>	303
<i>Voice Onset Time</i>	304
<i>Formant Transitions</i>	308
<i>Released and Unreleased Stops</i>	312
<i>Glottal Stop</i>	312
Fricatives	314
Approximants	324
<i>Glides (Semivowels)</i>	325
<i>Liquids</i>	327
Nasals	333
<i>Vowel Nasalization</i>	336
Affricates	337
8.5 Clinical Application: Speech Sound Disorders	341
Etiologies	341
Symptoms and Characteristics	341
Diagnostic Strategies	341

Therapeutic Strategies	342
8.6 Language and Dialect Influences on Consonant Production	342
Accentedness	343
8.7 Instrumentation and Measurement of Vocal Tract Aerodynamics	344
Intraoral Air Pressure	345
Nasal Airflow and Acoustics	345
<i>Nasal Airflow</i>	346
<i>Nasalance</i>	346
8.8 Instrumentation for Measuring Articulation	347
X-ray Microbeam	348
Electromagnetic Midsagittal Articulography (EMMA)	349
Optoelectronic Tracking	350
Strain Gauges	351
Electropalatography	352
Clinical Case 8: Articulation Errors	353
Recommended Internet Sites for Further Learning	354
References	354
9 Prosody	361
Clinical Case 9: Parkinson's Disease	362
9.1 Introduction to Prosody	363
9.2 Basic Building Blocks of Prosody	363
Intonation (f_0 Contour)	364
Timing (Duration and Juncture)	366
Loudness (Intensity Contour)	369
9.3 Syllabic Stress and Prominence	370
9.4 Speech Rhythm	374
Temporal Measurement of Rhythm	375
9.5 Accentedness and Prosody	376
9.6 In Summary of Prosody	376
Clinical Case 10: Gender-Diverse Speech and Voice	377
References	378
10 Theories and Models of Speech Production	383
Clinical Case 11: Spastic Cerebral Palsy	385
10.1 Introduction	386
10.2 Theories and Models	388
10.3 Theoretical Issues for Consideration	390
Degrees of Freedom	390
<i>Motor Programs</i>	391
Output Targets	392
Serial Ordering and Sensory Feedback	394
Unit of Analysis	395
Coarticulation	401
10.4 Models of Speech Production	404
Directions Into Velocities of Articulators (DIVA)	404
Dynamical Systems	405
<i>Spatiotemporal Organization</i>	406

Connectionist Models	408
10.5 Investigational Considerations	408
Speaking Task	408
Perturbation Studies	409
Rate	411
10.6 Motor Learning Principles	413
10.7 Language and Speech	415
Clinical Case 12: Oral Motor Exercises	417
Recommended Internet Sites for Further Learning	418
References	418

11 Theories of Speech Perception **427**

Clinical Case 13: Visual Feedback	428
11.1 Introduction	428
11.2 Topics in Speech Perception	429
Lack of Invariance	429
Unit of Analysis Revisited	430
Lack of Segmentation	431
Perceptual Normalization	431
Specialized Perception of Speech	432
<i>Duplex Perception</i>	433
<i>The McGurk Effect</i>	433
Contextual Effect	434
11.3 Theories of Speech Perception	434
Updated Motor Theory of Speech Perception	435
<i>Mirror Neurons</i>	436
Acoustic Landmarks and Distinctive Features	437
11.4 What Babies Can Tell Us About Perception	438
Native Language Magnet Theory-Expanded	440
11.5 Perception of Speaker Identity	441
Indexical Properties	441
Sex, Gender, and Indexical Properties	441
Accentedness and Indexical Properties	442
Race and Ethnicity and Indexical Properties	442
Clinical Case 14: Auditory Feedback	443
Recommended Internet Sites for Further Learning	444
References	444

12 Instrumentation **451**

<i>Donald Finan</i>	
12.1 Introduction to Measurement	452
12.2 Basic Principles of Measurement	452
Error in Measurement	454
Transduction	455
It's Electric!	457
12.3 Sensors for Capturing Speech	457
12.4 Microphones	459
Microphone Designs	459

Microphone Transducer Types	460
Microphone Performance Characteristics	461
<i>Directionality</i>	461
<i>Frequency Response</i>	462
<i>Sensitivity and Dynamic Range</i>	463
<i>Adequate Microphone Performance for Speech Analysis</i>	464
12.5 Amplification	466
Amplifier Performance Characteristics	466
<i>Gain</i>	466
<i>Frequency Response</i>	467
<i>Dynamic Range</i>	467
Amplifier Compatibility	468
12.6 Making the Connection	469
12.7 Recording Environment	470
Ambient Acoustic Noise	471
Electromagnetic Interference	471
12.8 Data Acquisition: Let's Get Digital	472
Sampling: Time Representation	473
Quantization: Amplitude Representation	476
<i>Frequency-Based Error: Aliasing</i>	476
<i>Amplitude-Based Error: Quantization Noise and Peak Clipping</i>	477
12.9 Data Storage	478
12.10 Balancing Cost, Complexity, and Accuracy in Digital Data Acquisition	480
12.11 Best Practices for the Use of Instrumentation	483
Sensor Performance and Use	483
Preamplifier Performance and Use	485
Data Acquisition System Performance and Use	486
12.12 Let's Wrap This Thing Up!	486
References	487
<i>Appendix A. Measurement Conversions</i>	489
<i>Appendix B. Reading Passages</i>	491
<i>Appendix C. Frequencies of the Musical Scale ($A_4 = 440$ Hz)</i>	497
<i>Appendix D. The International Phonetic Alphabet</i>	499
<i>Index</i>	501