Voice Disorders

FOURTH EDITION

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Contents

Foreword

Christine Sapienza and Bari Hoffman offer an up-to-date, highly revised edition of *Voice Disorders, Fourth Edition*. The authors share their extensive clinical and research experiences, combined with an array of current findings from the world voice community, with clinicians, scientists, and others who study voice and voice disorders. Drs. Sapienza and Hoffman are highly successful educators and have expanded this edition to the current needs of those who study and work in the areas of laryngeal and respiratory physiology and who treat a wide variety of voice disorders. This fourth edition updates Chapters 1 and 2 with brilliant illustrations of the respiratory and laryngeal anatomy and physiology, providing a gold box of guidance to the student and teacher.

The authors have again chosen to begin their text with a chapter on respiration. That unique feature has been amplified with color illustrations and makes this book quite distinctive from many other books on voice. This chapter provides an in-depth study of the respiratory system and its unique relationship with phonation. Respiratory structures, from the lungs to the subglottis, and their anatomy, physiology, and contribution to phonation are explained with detailed drawings and graphs. The chapter is written with great detail, yet is easy enough to understand, thanks to the well-written text that accompanies the illustrations. The addition of clear illustrations and tables in Chapters 1 and 2 highlight this edition.

This book extends the study of respiratory anatomy and physiology specifically as it relates to breathing for phonation. Chapters 1 and 2 serve as a basis for the remainder of the book, as the respiratory system serves as the foundation for the larynx and vocal fold vibration.

The latest research on laryngeal biomechanical modeling is presented for ease in discussion with patients and caregivers. In this edition, the authors demonstrate a breadth of knowledge in their research and clinical histories and practicality in their teachings. The authors strive to educate students how to synthesize complex material and present it to patients and other clinicians.

This fourth edition of *Voice Disorders* builds on the earlier editions and offers the student and clinician a comprehensive combined study of the respiratory, laryngeal, and neurological subsystems that make up voice production. The authors blend voice science with voice treatments ranging from traditional interventions to recent advances in cellular therapies, muscle strength training, and treatments for special populations such as singers and actors and those with complex medical conditions. Cases highlight various intervention strategies. With this fourth edition, the study of voice disorders comes out of its infancy and into the modern era of comprehensive care for the voice.

It is the unique mix of basic science and treatment strategies that Sapienza and Hoffman are known for, and which they successfully brought into their first edition of *Voice Disorders* in 2009. That edition was highly successful with a large readership and brought compliments from instructors and students. The second and third editions of *Voice Disorders* built on that framework with their detailed descriptions of the anatomy, physiology, and clinical presentations of voice disorders. The fourth edition brings the study of voice disorders up to date with additional chapters on laryngeal reflexes, immunology, and the effects of medications on the voice, and expands on the key clinical entities of the previous editions. In addition, a completely revised chapter related to gender-affirming voice has been included. The authors have kept abreast of the latest developments in the medical, behavioral, and patient-oriented aspects of this rapidly changing discipline.

In the current management of voice disorders, the clinician now needs medical, surgical, and behavioral knowledge of the vocal mechanism and of the structures and systems that contribute to voice production. The authors discuss the importance of understanding office-based surgical treatments, medical intervention, and psychological management as part of the treatment protocols. The authors update the unique role of the speech-language pathologist and his or her relationship with the other members of the voice care team: research scientist, psychologist, surgeon, singing specialist, vocal coach, and so forth. Each of those individuals has varying roles in the care of patients with voice disorders, but it is often the speech-language pathologist who provides the leadership of the team.

There are other added features in the fourth edition, as well. New images of laryngeal pathology and a variety of cases are incorporated throughout the text. The cases are presented to elucidate the importance of proper assessment and management. Hoffman and Sapienza update the reader on new medications and their effects on the voice and on the treatment of voice disorders. The student will learn the classes of medications and their effects on the voice.

The fourth edition expands the approaches to voice therapy and better defines clinical decision making with information about humanistic communication strategies, adherence, and the multitude of variables that influence patient outcomes. The authors have chosen to categorize therapy approaches by type, such as symptomatic, combined modality, and hygienic. For each approach, they describe specific treatment methods, case examples, and expected outcomes.

It is not surprising that the management of singers has its own chapter. Both Hoffman and Sapienza are well known to the performing arts community. Their partnership in the study and treatment of performers has extended over 25 years. In the chapter on vocal performance, they describe the relationship of the voice pathologist to the singer, performer, and other professionals who care for singers. This may be the only book used by the voice rehabilitation team in which descriptions of the Alexander technique and the Feldenkrais method are found in one place. Special sections like this make this book a textbook for today's speech-language pathologist who wants to be up-to-date in treating voice disorders.

The authors have substantially updated the chapter on head and neck cancer, with new case study presentations and statistics on the disease, information on safety for the laryngectomy patient, and more images to guide the reader in understanding the various modes of communication after laryngectomy. The authors also introduce robotic surgery and include images from the operating room and video footage of several surgical procedures.

I have had the privilege of reviewing previous editions of *Voice Disorders* and share a rich professional and personal relationship with the authors. They both reflect the title of teacher–scientist–clinician and this edition punctuates that title perfectly. Since they are both teachers, they understand students' needs and have developed educational approaches to nourish those needs in the classroom as well as in the research lab and in clinical practice.

Both authors put a high level of energy into their work and this book offers a prime example. They have transformed their keen levels of observation, testing, and analysis into a book rich with their experience and knowledge.

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Preface

The human ability to produce voice, shape it into meaningful tones and sounds, and use it for so many varied purposes is truly special. Those who have the opportunity to study voice will experience teachings from many disciplines and observe outcomes both clinically and from the literature that exemplify a truly emerging relationship between knowledge and practice.

With enhancements in medical technologies and medical care, treatment plans are reaching an efficiency that optimizes vocal recovery in a favorable and timely manner. Continual education is critical to stay contemporary and abreast of new techniques and technologies and respond to the ever-changing clinical environment. You will find an increasing responsibility to collaborate and communicate with all members of the patient's health care team and a need to familiarize yourself with the ever-changing medical models. You must continue to educate yourself to keep up with the advances in technology. This need may not be due solely to a rapidity of change in your discipline, but also to the swiftness of change in other disciplines (e.g., imaging, molecular biology, surgery).

The physical, social, and spiritual issues surrounding your patients will require more skills and fluid knowledge in human anatomy and physiology, neuroanatomy and physiology, instrumentation, computer applications, and multitudes of topics surrounding medical management issues, including phonosurgical options and drug treatments. Learning how to communicate with your patient, and understanding marriage and family systems and the dynamics of variables such as race, gender identity, and religion, will be some of the more intricate complexities surrounding your patient's care. Sometimes, the changes to which we, as clinicians, must adapt to are sweeping and sometimes they occur slowly over time.

In writing this textbook we wanted you, the student, to have access to contemporary information that could be easily read. We took pride in developing the original anatomical figures for the text so they would portray the structures precisely. Additionally, we wanted to give you the opportunity to have laryngeal examinations of vocal pathology for your reference, including the opportunity to view phonosurgical procedures and outcomes. In short, we wrote the book in a manner that would enable you and your instructor to have the best resources in one source.

This fourth edition of *Voice Disorders* is written so that you, the student, can comprehend complex material by using sidebars for complex terms, providing a comprehensive glossary of terms and case examples throughout the chapters, such as those found in the vocal pathologies and voice therapy chapter, the chapter on singer's voice, and the comprehensive chapter on head and neck cancer. With updated statistics on the demographics of voice users, this new edition now helps you learn the clinical pathways that lead to the most efficient, cost-effective outcomes. The pathophysiology of disease is thoroughly explained, helping to guide you on choices for best treatment outcomes. By clearly documenting the important anatomical and physiological properties of voice, you can determine the best course of treatment action, and the case examples, with accompanying audio samples, will help you identify and practice your assessment skills. Two newly distinct chapters are now included on laryngeal reflexive behavior and the immune system. And, while these chapters contain high-level information, the material is a treasure of knowledge synthesized for your level of learning. Finally, we have updated our information for web sources and all additional resources.

Cherish your time to learn. The care of the voice has already evolved from a traditionally behaviorally oriented discipline to one that has responsibilities within the medical domain. For example, the role of the voice pathologist has broadened and includes vocal imaging specialist, researcher, therapist guiding recovery and restoration of healthy voice, trainer guiding effective voice use, counselor, and more. Our field has developed ad hoc position statements, such as *The Role of the Speech-Language Pathologist and Teacher of Singing in the Remediation of Singers With Voice Disorders* (1992). We have guidelines for training in endoscopy and laryngostroboscopy and guidelines for the role of the speech-language pathologist (2001), with respect to the evaluation and treatment of tracheoesophageal fistualization/puncture and prosthesis (2004). These position statements indicate that a certain level of skill must be obtained prior to administering particular assessment and treatment techniques.

Specific to the assessment and treatment of voice, we find ourselves challenged with cases involving syndromic complexities and are asked to delve into histories involving multiple disease processes or polypharmacies. Also, the reorganization of the health care industry has created an extensive array of changes in the organization, ownership, and regulation of health care providers and in the delivery of services. Cost concerns, increasing competition, influence of investor priorities, technological advances, changing social attitudes, and an aging and increasingly diverse population are factors that sustain this dynamic condition.

There is a requirement to objectively document the outcomes of specific treatments to provide hard evidence that can be analyzed, based on data, studied, and modeled. Not all aspects of physiology can be seen. And, while technology is racing forward in the field of laryngeal imaging, subsystem processes that create, for example, the air pressure and airflow for voice are often equally important to examine. At the same time, overcollection of data is not a wise way to spend time with a patient. Most of you have probably heard the saying "if it walks like a duck, quacks like a duck—it's a duck." The bottom line is: If the collection of more data is not going to alter the treatment plan, then do not subject the patient to unnecessary procedures.

Since 1998, there have been significant advances in the following areas of medicine, all of which have impact on the care of the voice:

- pharmacogenomics
- brain damage and spinal cord injury
- cancer therapy and viruses
- antibiotics and resistant infections
- autoimmune disease
- slowing of the aging process

Within our discipline, technological advances include functional magnetic resonance imaging, high-speed video image analysis, computer-assisted biofeedback techniques, advanced animal modeling techniques, enhanced surgical procedures, and many others. It wasn't long ago that we witnessed the first laryngeal transplant performed at the Cleveland Clinic in 1999 by Dr. Marshall Strome and his team of physicians.

To appreciate such groundbreaking events, we need to acknowledge the fact that advances in the core science of our discipline are being made nationally and internationally at facilities dedicated to the advancement of science and medical practice. Recall one area of voice research that began in Groningen, Netherlands, at the Institute of Physiology of the Faculty of Medicine by Van den Berg in the late 1940s. His fundamental article on the myoelastic-aerodynamic theory of voice production in 1958 forever shaped our perceptions on the function of the vocal folds. The contributors referenced in this book, as well as all of our contemporary colleagues dedicated to the study of voice, are included in historical lists of contributors to voice, voice care, and voice science.

We hope this book serves you well in your graduate coursework in voice disorder. We believe it provides the core information needed for your training. For those practicing in the area of voice and its disorders, we currently expect the following academic preparation: understanding of the normal and physiologic process of voice production; understanding of the etiological bases of voice disorders; the ability to examine and interpret laryngeal structure and function; understanding of the instrumentation used to examine laryngeal structure and function; understanding of the principles of diagnosis; understanding of the structural and functional differences across the life span; the ability to assist in differentially diagnosing the disorder and classifying it as structural, functional, idiopathic or neurological; the ability to develop a treatment plan that considers the patient's functional outcome goals; and others. Included on the PluralPlus companion website is a comprehensive workbook that should allow you to reflect on the reading and help you practice your knowledge and skills through test questions and problem-solving assignments.

Additional courses we recommend include: issues surrounding continuum of care; interdisciplinary approaches; pharmacology; medical terminology; patient advocacy; and accreditations. This is not an inclusive list but one that suggests that our literature, as well as academic coursework, must accommodate our needs more fully.

CHAPTER 1

Respiratory Anatomy and Physiology

This chapter describes intricacies of the human anatomy of the respiratory system and explains how it functions to produce voice. Anatomy is the study of structures and physiology is the study of how structures function to produce a particular action. In the case of voice production, respiratory structures play a very important role by providing the necessary driving force to initiate and sustain vocal fold vibration.

Breathing appears to be a relatively simple process—seemingly automatic and unconscious. Yet, it is highly controlled and complex. And, breathing for voice production is a unique process—different from the act of ventilation or circulation for the life purpose of exchanging O_2 and CO_2. Anatomically, the most basic elements of the respiratory system are the lungs, rib cage, and diaphragm and abdominal unit.

After reading this chapter, you will:

- Understand the basic components of respiratory anatomy
- Understand the passive and active forces involved in breathing
- Understand the role of the respiratory system for producing voice
- Understand how disordered respiratory function may affect voice production

> *Ventilation* means bringing oxygen into the lungs. *Circulation* is the transportation of oxygen all over the body, to where it is needed.

The Lungs

The lungs are elastic tissue that inflate and deflate and, as a result of the inflation and deflation, move air. Anatomically, there are three lobes on the right lung and two lobes on the left lung. The right lung is larger than the left lung to make room for the heart (Figure 1–1).

Inspiration is the act of taking air into the lungs and *expiration* is the act of expelling air out of the lungs. By bringing air into the lungs during inspiration, oxygen can be circulated into the bloodstream to the cells in the body. Expiration allows for the release of CO_2.

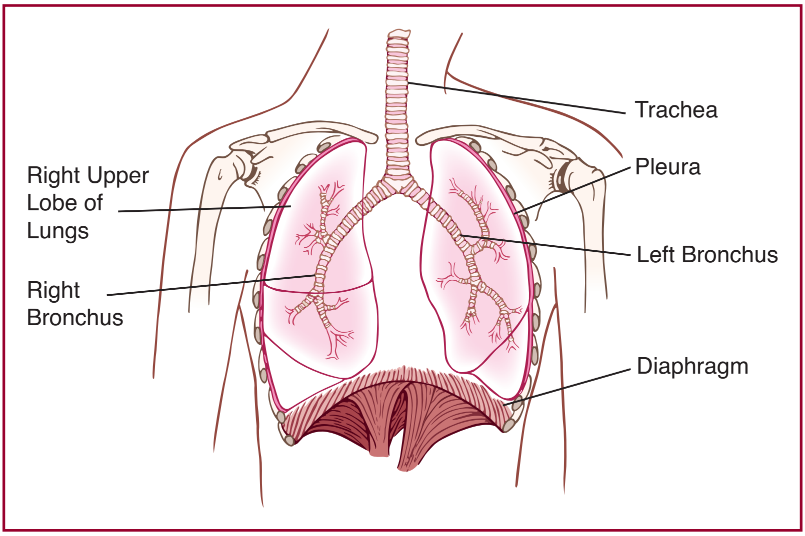

Figure 1–1. Lower airway and right and left lungs.

For airflow to increase, a greater pressure differential must be created.

In a clinical report you may see the term, *hypercapnia*, which is when excessive carbon dioxide in the bloodstream occurs, typically caused by inadequate respiration.

The Trachea

The trachea is a cartilaginous structure that allows air to pass from the nose and mouth into the lungs. It is made up of 16 cartilaginous rings. The larynx sits on top of the uppermost tracheal ring. Damage to the trachea is potentially life threatening. In the event the trachea is damaged, a tube is placed into the airway to allow air to flow into the lungs. This is called *intubation*. Intubation may be necessary due to injury or illness, or during a surgical procedure where the muscles of respiration are paralyzed and ventilation requires support.

The Bronchi

There are two main bronchi that branch off the trachea, one going to each lung. Smaller branches from the bronchi continue to divide, known as *secondary bronchi*. There are three secondary bronchi supplying the right lung and two secondary bronchi supplying the left lung. *Bronchioles* are the smallest branches stemming from the secondary bronchi and lead to the alveoli, where gas exchange occurs, allowing air to enter into the blood. The cartilage and mucous membrane of the primary bronchi are similar to that in the trachea. The amount of hyaline cartilage in the bronchial walls decreases as the branching continues throughout the bronchial tree. Hyaline cartilage is absent in the smallest bronchioles (Figure 1–2).

Hyaline cartilage forms most of the fetal skeleton and is found in the trachea, larynx (see Chapter 2), and joint surfaces of the adult.

The Thorax

The thorax is the chest cavity that surrounds and protects the lungs, as well as the heart and other respiratory structures, such as the bronchial tree. Made up of the ribs and muscles, the most inferior aspect of the thorax is the diaphragm.

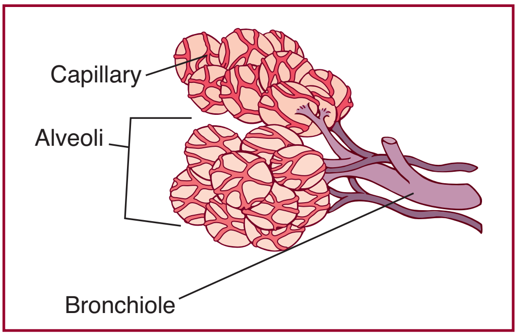

Figure 1–2. Final branches of the respiratory tree where primary gas exchange occurs.

The Ribs

There are 12 pairs of ribs. Ribs 1 to 7 are called the *true ribs* and ribs 8 to 10 are called the *false ribs*. Ribs 11 and 12 are called *floating ribs* because they do not attach to the sternum like ribs 1 to 10.

The Diaphragm

The diaphragm anatomically separates the chest from the abdomen. It is the major muscle of inspiration (Figures 1–3 and 1–4). At rest, the diaphragm sits in a dome-shaped position, and when it contracts during inspiration, it

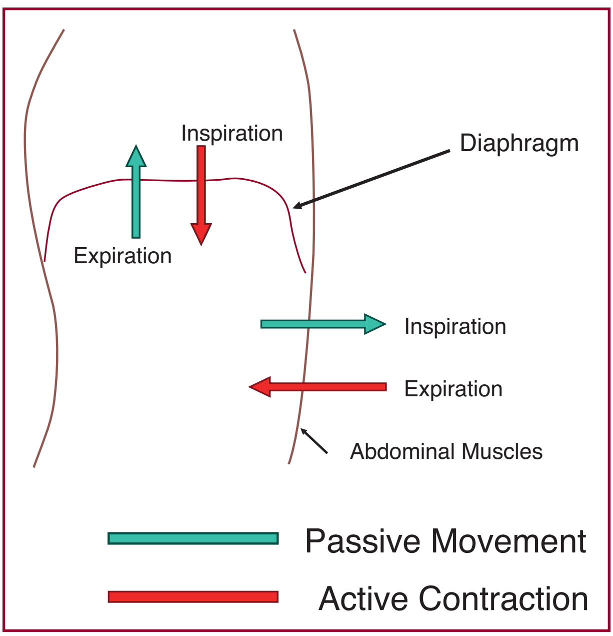

Figure 1–3. Direction of thoracic cavity movement with inspiration and expiration.

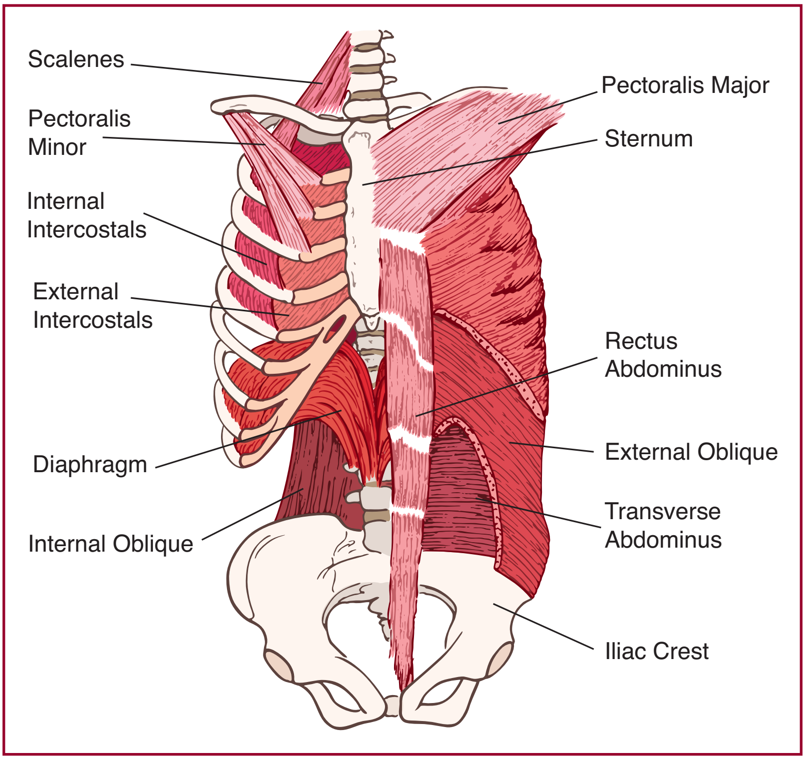

Figure 1–4. The diaphragm muscle and the supporting abdominal muscle structures.

moves downward and flattens, enlarging the chest cavity. As the diaphragm moves downward, the force is transferred to the lower ribs, moving them outward. As the diaphragm contracts, it is opposed by the passive properties of the abdominal wall, the tone of its muscles, and the inertia of the abdominal contents. When this occurs, the intra-abdominal pressure rises and the lower rib cage expands (Goldman, Rose, Morgan, & Denison, 1986). This, in turn, enlarges the thoracic dimension, creating an inspiratory maneuver.

> When the diaphragm contracts during normal breathing, it moves down about 1 to 2 cm and, interestingly, can move as much as 10 cm during deep inspiration.

The Abdominal Wall

The abdominal wall is a layered structure with external, internal, and innermost regions. Made up of central and lateral muscles that arise from the ribs and the pelvic girdle, the abdominal wall has passive and active properties that are described in more detail below. During passive expiration, the abdominal wall draws in, and during effortful tasks such as coughing, sneezing, and certain voicing tasks, the abdominal muscles contract to compress the abdominal contents. This, in turn, increases the intra-abdominal pressures. This compression is also important for other functions such as defecation and childbirth. The next section describes other important anatomical structures to the respiratory system.

Sternum

The sternum has three processes that serve as attachments for respiratory muscles such as the diaphragm and intercostal muscles. The three processes include the manubrium, body, and xiphoid process.

The first seven ribs are attached to the sternum. The manubrium appears as a handle and serves as an attachment for ribs 1 and 2; the corpus is the body of the sternum and serves as the attachment for ribs 2 to 7; and the xiphoid process is the smallest of the three parts and serves as a partial attachment for many muscles, including some of the abdominal wall muscles.

When giving CPR, pressure on the xiphoid process should be avoided as it can cause a piece of the xiphoid process to break off, creating potential damage to the heart lining and muscle and/or resulting in punctures or lacerations of the diaphragm.

Clavicle

The clavicle is known as the *collarbone*, and the two bones of the clavicle extend from the manubrium. The clavicle serves for attachment of certain respiratory muscles such as the trapezius, pectoralis major, and sternocleidomastoid.

Driving Forces of the Respiratory System

The process of moving air requires a driving force. The force comes from a pressure gradient or difference between the alveolar pressure and the atmospheric pressure (Figures 1–5 and 1–6). *Alveolar pressure* is the pressure within the alveoli.

Alveolar pressure is the smallest gas exchange unit of the lung and is about 105 mm Hg or 142.8 cm H_2O.

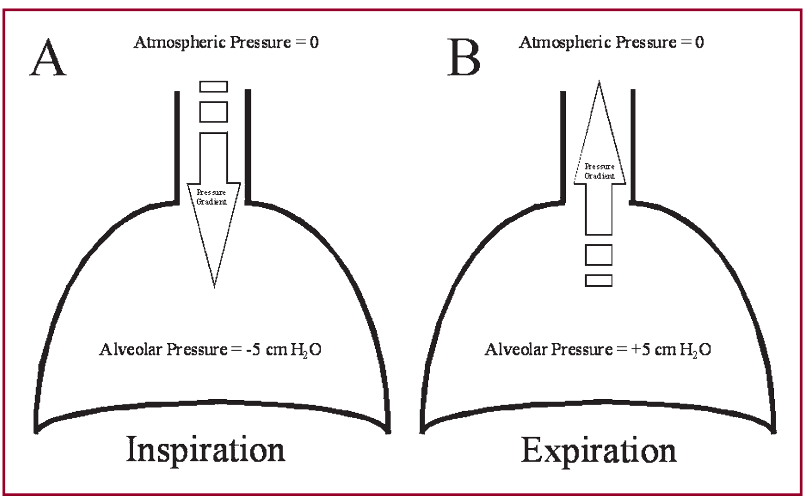

Figure 1–5. Schematic depicting pressure relationships for inspiration and expiration. The arrow indicates the direction of the driving force.

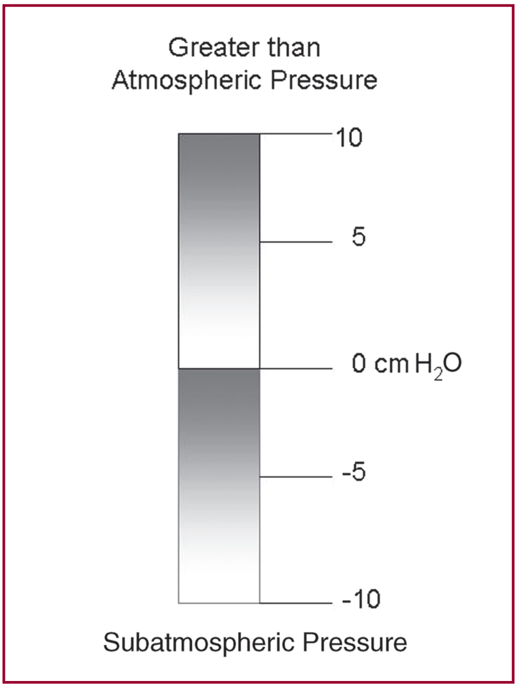

Figure 1–6. Schematic depicting positive pressure and negative pressure generation relative to atmospheric pressure (0 cm H_2O).

> Alveolar pressure is typically referenced with respect to atmospheric pressure, which is always set to zero. When alveolar pressure is above atmospheric pressure, it is positive; when alveolar pressure is below atmospheric pressure, it is negative.

For the lungs to inflate, the inward driving force must be an alveolar pressure less than atmospheric pressure. This creates a pressure gradient that causes air to flow into the lung (inspiration). On the other hand, for air to flow out of the lung (expiration), the driving force must be an alveolar pressure greater than atmospheric pressure. The pressure of a gas equals the perpendicular force exerted by the gas divided by the surface area on which the force is exerted.

To produce voice, air moves from the alveolar spaces through the conducting airways, including the trachea; through the glottis, or the space between the vocal folds; and vibrates the medial edges of the vocal folds. Sound from the vocal folds is then transferred to the pharynx and oral cavity, where it is shaped by the articulators into speech sounds. Discussion of how the voice is produced by vocal fold vibration is discussed in Chapter 2.

How Does the Human Body Generate These Respiratory Forces?

The alveolar pressure is changed by two forces. The first, a passive force, is due to the elastic properties of the respiratory system. The second force, an active force, is developed by the contraction of the respiratory muscles. One example that is often used to illustrate and explain the passive and active forces of the respiratory system is a balloon, as it helps explain the concepts of respiratory forces (Figure 1–7). Inflation of a balloon requires an active stretching of the balloon. This illustration shows how inspiratory muscles contract to expand the chest wall. It takes active muscle force to overcome the balloon stiffness and force air into the balloon. This increases the balloon's volume, just as the lungs increase in volume, creating a pressure gradient that allows air to flow into the balloon/lungs. With the balloon inflated and the opening to the balloon closed, the balloon retracts toward its rest position and produces a pressure inside the balloon causing the air inside the balloon to compress. This is an elastic force, which is an inherent property of the balloon, just like the lungs (see Figure 1–7). The strength of the elastic force is a passive property of the balloon/lungs and is directly proportional to the stretch of the balloon/lungs. The greater the balloon/lung volume (i.e., the greater the stretch of the balloon/lung wall), the greater the elastic recoil of the balloon/lung and the

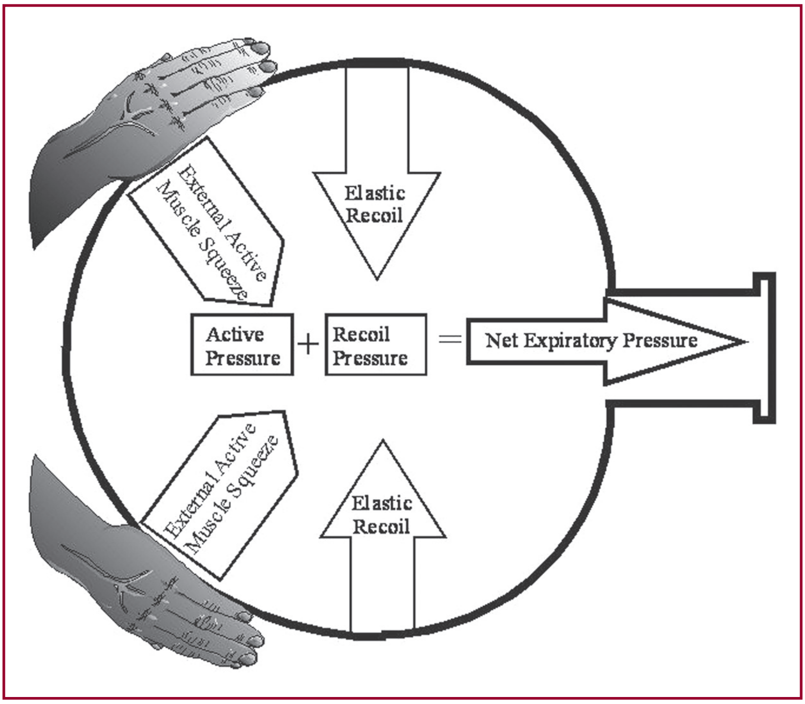

Figure 1–7. Schematic of a balloon depicting active and passive mechanisms during expiration. The hands squeezing the balloon illustrate the addition of an active expiratory force.

greater the pressure inside the balloon/lung. The pressure inside the balloon/lung can be further increased if the outside of the balloon/lung is squeezed (see Figure 1–7). This squeeze is the result of the active contraction of expiratory muscles and is referred to as an *active pressure*. The total pressure within the balloon/lung is then the sum of the passive elastic pressure and the active squeeze pressure.

When the respiratory system is at rest, the lung is partially inflated to approximately 40% of the total lung capacity (TLC). This is important to remember because the lungs are actually not deflated at rest but rather are partially inflated. This rest position is called the functional residual capacity or FRC (Figure 1–8). At FRC, neither the lung nor the thorax is really at its respective rest position. With age, the lungs may lose some of their elasticity.

The lungs are apposed (or connected) to the thorax by pleural linkage. In fact, three-quarters of the lung's surface contacts the thoracic wall by pleural linkage. With a pneumothorax, a lung immediately collapses, but the thorax expands. A pneumothorax occurs when the pleural space is disrupted.

> A pneumothorax can happen with a blast injury, as a result of a fractured rib, and sometimes with diseases such as cystic fibrosis and chronic obstructive pulmonary disease.

When a pneumothorax occurs, the lungs and thorax achieve a natural position, which is the natural preference if they were anatomically independent from one another.

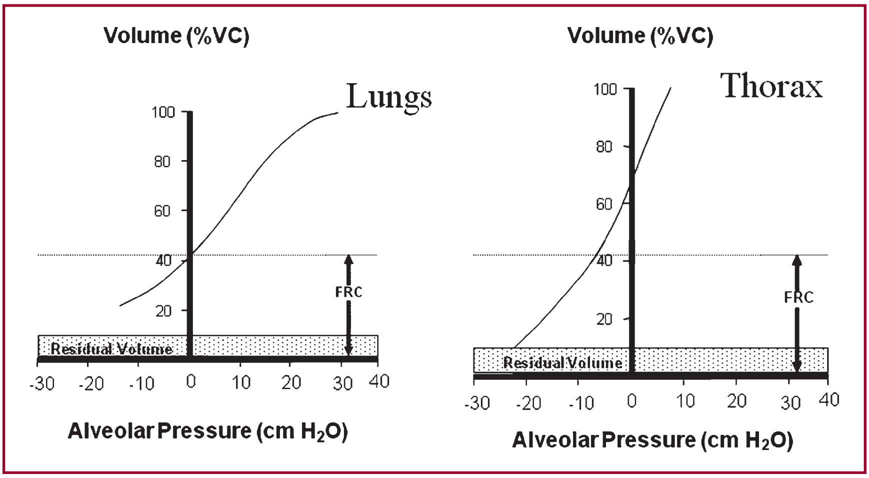

Figure 1–8. Pressure-volume curves for lungs and thorax.

The lungs' natural position is a volume much smaller than FRC. That is why the lungs have a natural tendency to collapse. The thorax's natural position is a volume much greater than FRC—approximately 70% of TLC—which means the thorax has a natural tendency to expand at FRC (see Figure 1–8).

When the lung is placed in the thorax, the outer surface of the lung is apposed to the inner surface of the thorax by the pleural linkage mentioned above. The pleural linkage is actually a hydrostatic force. A membrane called the *visceral pleura* covers the lung. A similar membrane called the *parietal pleura* covers the thorax. A small amount of fluid, the *pleural fluid*, separates these membranes. If you were to place two smooth surfaces against each other with fluid between them, like two microscope slides with water between them, you would see how easily they move back and forth but how very hard they are to pull apart. This is the hydrostatic force holding the two smooth surfaces together yet allowing free movement between the surfaces. In the respiratory system, the pleural fluid between the visceral and parietal pleurae holds the lung against the thoracic wall while allowing the lung to slide freely during volume changes. However, mechanically linking the lung and thorax means that the combined systems' elastic behavior is a result of the interaction of the lungs' and thoracic elastic forces. As stated above, this causes the lung to be at a volume that is above its elastic natural position, yielding a collapsing force. The thorax is at a volume smaller than its elastic natural position, yielding an expanding force. At FRC, the expanding elastic force of the thorax balances the collapsing elastic force of the lung.

Passive and Active Forces of the Respiratory System

Active inspiration is a muscle action that increases the dimensions of the chest wall. A portion of the inspiratory muscle energy used to expand the thorax is recaptured by the passive collapsing force of the elastic recoil pressure that is volume dependent. This is the passive property of expiration. Remember, the act of inspiration is always active. This means that for inspiration to occur, muscle contraction must happen. Mentioned briefly above, and of such importance to remember, is that the diaphragm is the main muscle of inspiration. The diaphragm is a large sheet of muscle and tendons. It attaches to the lumbar vertebrae of the spinal column, the lower ribs (ribs 7–12), and the xiphoid process of the sternum. The cervical nerves of the spinal cord called C3, C4, and C5, also known as the *phrenic nerves*, supply innervation to the diaphragm.

> A saying goes "C3, C4, C5, keeps you alive" . . . but there is now evidence that bilateral loss of the phrenic nerve might not necessarily result in death.

> Did you know that a hiccup is caused by a spasmodic, involuntary contraction of the diaphragm?

The external intercostal muscles are the other primary muscles of inspiration and are found between the ribs. The external intercostal muscles slant downward and outward, and their diagonal position allows them to do more work upon their contraction. Due to their hinged anatomical relationship at the spine and sternum, when they contract, they lift the ribs up and outward (Figure 1–9). Other secondary inspiratory muscles are listed in Table 1–1. Accessory muscles of inspiration are only most active with high ventilatory tasks (e.g., deep inspiration) and are not used during quiet inspiration.

Active expiratory pressure can be added to the passive, elastic expiratory driving force by generating muscle contraction that decreases the chest wall dimension. The decrease in chest wall dimension can happen by pulling

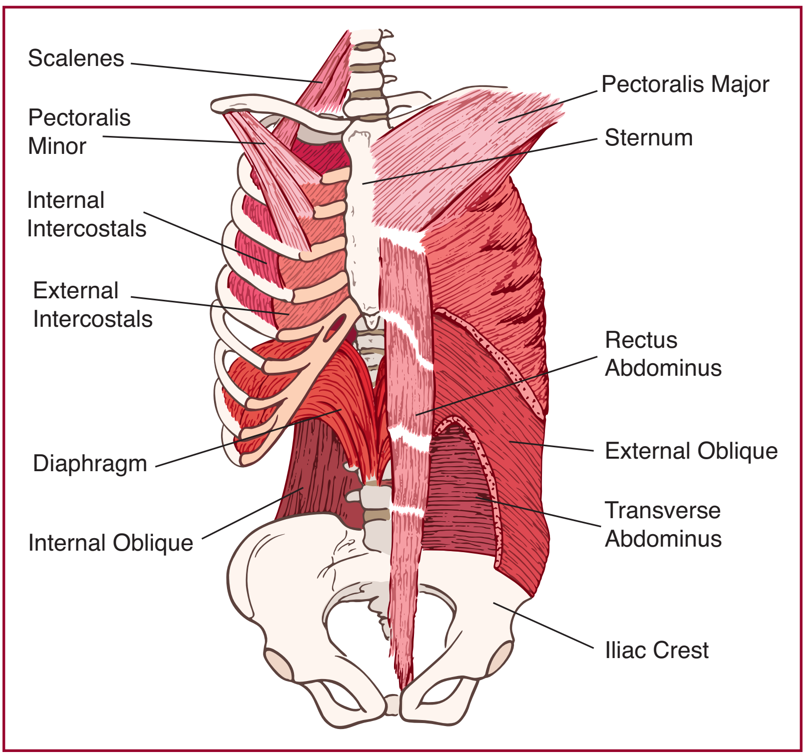

Figure 1–9. External and internal intercostal muscles, and abdominal wall muscles.

Table 1–1. Accessory Inspiratory Muscles and Their Origins and Insertions and Major Expiratory Muscles and Their Origins and Insertions

Muscle	Function	Origin	Insertion
Levatores costarum	Accessory Inspiratory	Transverse processes of C7 to T12 vertebrae	Superior surfaces of the ribs immediately inferior to the preceding vertebrae
Serratus posterior superior	Accessory Inspiratory	The spinous processes of C7 through T3	The upper borders of the 2nd through 5th ribs
Sternocleido-mastoid	Accessory Inspiratory	Manubrium and medial portion of the clavicle	Mastoid process of the temporal bone
Scalenus	Accessory Inspiratory	C2–C7 vertebrae	The first and second ribs
Trapezius	Accessory Inspiratory	The spinous processes of the vertebrae C7–T12	At the shoulders, into the lateral third of the clavicle, and into the spine of the scapula
Pectoralis major	Accessory Inspiratory	The anterior surface of the clavicle; the anterior surface of the sternum, as low down as the attachment of the cartilage of the 6th or 7th rib	The crest of the greater tubercle of the humerus
Pectoralis minor	Accessory Inspiratory	3rd to 5th ribs, near their costal cartilages	The medial border and upper surface of the scapula
Serratus anterior	Accessory Inspiratory	The surface of the upper eight ribs	The entire anterior length of the medial border of the scapula
Subclavius	Accessory Inspiratory	Arises by a short, thick tendon from the first rib and its cartilage at their junction, in front of the costoclavicular ligament	The groove on the under surface of the clavicle
Levator scapulae	Accessory Inspiratory	Arises by tendinous slips from the transverse processes of the atlas and axis and from the posterior tubercles of the transverse processes of the 3rd and 4th cervical vertebrae	The vertebral border of the scapula
Rhomboideus major	Accessory Inspiratory	The spinous processes of T2 to T5	The medial border of the scapula
Rhomboideus minor	Accessory Inspiratory	The spinous processes of C7 and T1	The vertebral border near the point that it meets the spine of the scapula