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All trumpet players know the importance of maintaining an effective air stream in order to produce and sustain notes. Much has been written about tongue placement, embouchure development, proper placement of the mouthpiece, and similar topics.[1] However, there does not appear to be much information within the trumpet literature about the anatomic and physiological factors that are instrumental in initiating and maintaining an effective air stream while playing a wind instrument. It is important for trumpet players to understand these factors in clear, understandable terms, as well as some of the changes in lung mechanics that are the inevitable consequences of aging.

As we breathe in (inspiration) during rest, the lungs expand in two ways. Primarily, the diaphragm contracts, moving downward, to lengthen the chest cavity. Secondarily, the external intercostal muscles contract to elevate the ribs, thereby increasing the front-to-back (anteroposterior) diameter of the chest cavity. Inspiration is almost completely controlled by displacement of the diaphragm during normal relaxed breathing. Breathing out (exhalation, or expiration) reverses this process, and exhalation during relaxed breathing is basically a passive event that is dependent upon elasticity of the lungs, chest wall, and abdominal structures that compress the lungs through the diaphragm.[2]

A model of breathing is illustrated in Figure 1, in which a bell-shaped jar represents the chest cavity, a thin rubber sheet the diaphragm, a balloon the lungs, and a tube the trachea (wind pipe). Inspiration is simulated in parts A and B, where the rubber sheet is being pulled downward to simulate contraction of the diaphragm. This action inflates the balloon (lungs). This simplistic example does not illustrate the roles of the chest wall muscles as previously mentioned, however. In this model, exhalation is presented in parts C and D, when tension on the rubber sheet is released to simulate the relaxation of the diaphragm.

As all trumpet players well know, relaxed, or eupneic, breathing will not produce the effective air stream that is required for playing the trumpet. Therefore, other factors must be called into play. Prior to discussing these factors, it is necessary to define and understand a few terms as classically defined.[3]

A. *Compliance:* The measure of the ease with which the lungs may be inflated.

B. *Tidal volume* or "breath": The volume of air breathed in and out during a normal breath, approximately 500 cc in a normal adult male.

C. *Inspiratory reserve volume:* The *extra* volume of air that can be breathed in over and beyond a normal breath (*i.e.,* "tidal volume"), approximately 3,000 cc in an adult.

D. *Expiratory reserve volume:* The *extra* amount of air that can be breathed out by forceful expiration after the end of a normal expiration, approximately 1,100 cc.

E. *Inspiratory capacity:* The amount of air that can be breathed in after a normal expiration distending the lungs to their maximum capacities. This is the sum of B + C and is equal to approximately 3,500 cc.

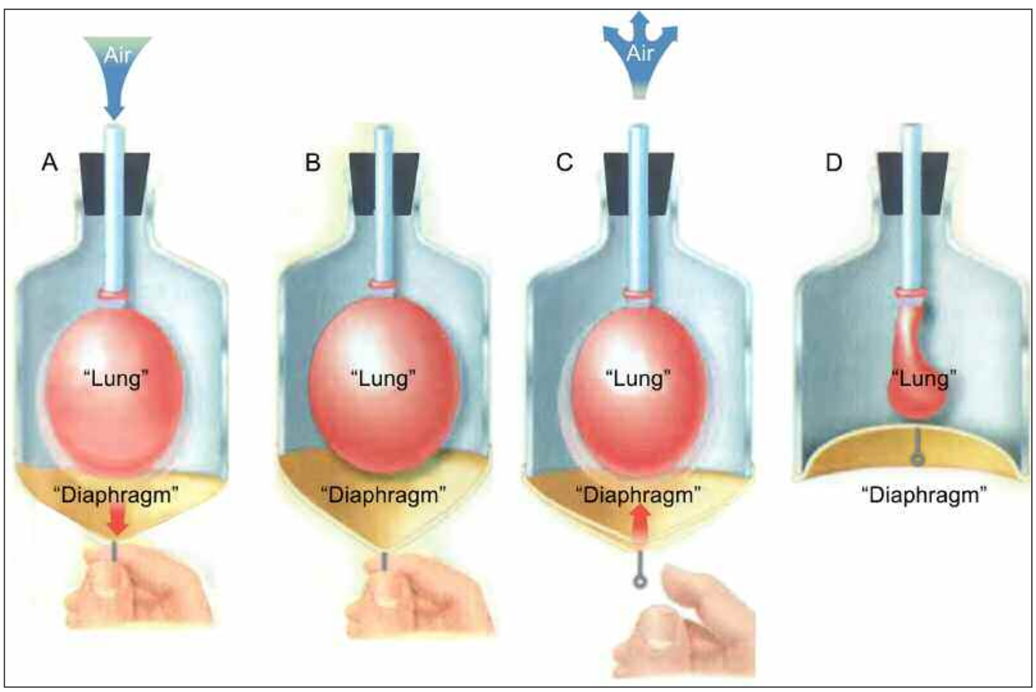

Figure 1. Balloon model of ventilation. A. Inspiration, caused by downward movement of the rubber sheet (diaphragm). B. End-inspiration (equilibrium point, no gas flow). C. Expiration. Caused by the elastic recoil of the diaphragm upward movement. D. End-expiration (equilibrium point, no gas flow). From Des Jardins, *Cardiopulmonary Anatomy & Physiology,* 6E, © 2013 Delmar Learning, a part of Cengage Learning, Inc. Reproduced by permission (http://www.cengage.com/permissions)

F. *Vital capacity:* The maximum amount of air that a person can exhale after first filling his or her lungs to their maximum capacities. It is the sum of B + C + D and is equal to about 4,600 cc.

The volumes and capacities described above are illustrated in Figure 2. These volumes are approximately 25 percent less in women than in men, and in large athletic individuals, the volumes are greater than the predicted norms.

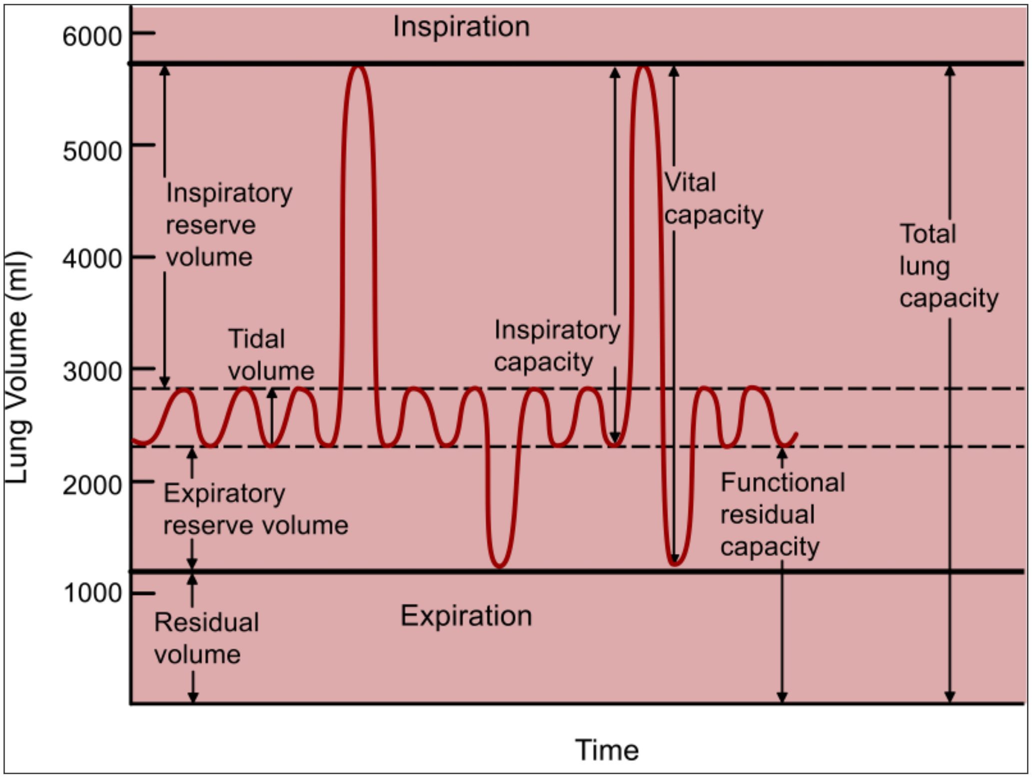

Figure 2. Diagram showing respiratory excursions during normal breathing and during maximal inspiration and maximal expiration. From *Textbook of Medical Physiology (8th ed.)*, p. 407, A.C. Guyton, W. B. Saunders Co., 1991. Reprinted by permission, Elsevier, Ltd. Permission /jbsubr/B9780721630878

There are no physical attachments of the lungs to the inside of the chest wall except at its hilum (the area where nerves and blood vessels enter and leave from the mediastinum, the median portion of the chest cavity). The lungs are elastic structures and would collapse if there were not a mechanism for them to be attached to the inside of the chest cavity. The lungs literally float in the chest cavity, surrounded by a very thin layer of fluid that lubricates the surface of the lungs and allows them to stick to the inside of the chest wall. Unlike glue, this fluid allows the lungs to slide freely as the chest expands when one breathes in and contracts as one breathes out.

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In considering the ability of the lungs to expand fully, it is important to realize that the chest wall itself has its own elastic and viscous characteristics. Thus, the ability to fill and empty the lungs is a combination of the elastic and viscous (sticky, adhesive) properties of both the lungs and the chest wall.

Bringing air into and out of the lungs (respiratory excursions) requires work. As mentioned previously, most of the energy expended during a respiratory cycle at rest is during inspiration. However, this is not necessarily true during heavy breathing associated with trying to attain inspiratory capacity, particularly over an extended period while playing a wind instrument.

The work of inspiration consists of trying to expand the lungs against their own innate elasticity, overcoming the viscosity of the lungs in combination with the chest wall and work required to overcome the resistance of airflow through the respiratory system.[4]

During heavy breathing, a group of muscles referred to as accessory muscles are recruited to assist the contraction of the diaphragm in filling the lungs. These muscles, their locations and functions are summarized in Table 1.[5] A player must work much harder with a contracted lung volume towards the end of a sustained note or phrase in order for the note to sound as full bodied as it did at the beginning of the phrase.[6]

Relaxation of the diaphragm alone is not enough to get a sufficient volume and velocity of air out of the lungs during heavy breathing, as in playing a trumpet. A group of muscles, referred to as "accessory muscles of expiration," come into play. These muscles, their respective locations, and their functions are presented in Table 2.[7] Work associated with attaining one's vital capacity consists of the work done by the accessory muscles of expiration, overcoming anatomic airway resistance,[8] and prevailing over the resistance imposed by the mouthpiece and musical instrument itself. The ability to maintain an adequate airflow (volume and velocity) while playing a wind instrument is dependent upon all of these factors.

For all practical purposes, anatomic airway resistance is negligible in healthy young individuals. It does, however, become an important consideration in persons who have been chronic smokers and in those with asthma, chronic obstructive lung disease, pulmonary fibrosis, and/or scarring of the lungs due to a prior infection or other pathological conditions that alter the compliance of the lungs. The importance of instructors insisting that their students refrain from smoking cannot be overemphasized. Any condition, such as multiple sclerosis, for example, that causes a weakening of the skeletal muscles will have a negative impact upon one's ability to obtain his/her vital capacity and associated adequate airflow.

It is only logical to ask if position (sitting, reclining, stooping, standing) has any impact upon pulmonary mechanics and

Table 1. Accessory Muscles of Inspiration

Muscle's name	Location	Function
External intercostal	Between the ribs	Pull the ribs upward & outward, thereby increasing both the lateral and front-to-back (anteroposterior) dimensions of the thoracic (chest) cavity
Scalenus	Connect vertebrae in the neck to the first and second ribs	Elevate the first and second ribs
Sternocleidomastoid	Connect the skull and sternum (breast bone)	Elevate the sternum, thus increasing the anteroposterior diameter of the chest
Pectoralis major	Each side of the upper chest	Elevate the chest, thereby increasing the anteroposterior diameter
Trapezius	Superficially in the upper back and back of the neck	Help to elevate the thoracic cage

Table 2. Accessory Muscles of Expiration

Muscle's name	Location	Function
Rectus abdominis	A pair of muscles that extend the entire length of the abdomen	Assist in compressing the abdominal contents, which in turn pushes the diaphragm upward
External abdominal oblique	Front sides of the abdomen	Assist in compressing the abdominal contents, which in turn pushes the diaphragm upward
Internal abdominal oblique	Underneath the external abdominal oblique muscles	Assist in compressing the abdominal contents, which in turn pushes the diaphragm upward
Transversus abdominis	Underneath the internal abdominal oblique muscles	Assist in compressing the abdominal contents, which in turn pushes the diaphragm upward
Internal intercostal	Between the ribs, beneath the external intercostal muscles	Pull the ribs downward and inward, decreasing both the lateral and anteroposterior diameter of the chest

the ability of an individual to play tongued and untongued *sforzando* notes. Price, Schartz, and Watson have done extensive work in this area and conducted a research study of the effects of posture on breathing in brass players. Their findings support standing as the most efficient position for a brass player, since abdominal muscle activity is always reduced when sitting on a flat or downward sloping seat. They report, however, that when greater respiratory effort is required, performance while seated on downward sloping seats may rise closer to that of standing.[9] Musicians who have a particular interest in this area are encouraged to refer to the extensive bibliography that accompanies that article.

The dynamics involved in playing *forte* and *fortissimo* are different from those involved in playing *piano* and *pianissimo*. Relaxation is a key concept to playing loud. To play *forte* or *fortissimo,* the player must allow the aperture to relax as it becomes larger, while the airflow increases in both size (volume) and speed (velocity).[10] In 1977, Harry Berv stressed in his classic text *A Creative Approach to the French Horn* (no longer in print) the need for aperture control when playing at full volume. He states, "In very loud passages the aperture is large and air is blown through the lips with great intensity." The player must not be misled into believing that playing loudly requires a great deal of body tension. Rather, it requires a greater volume of air and an aperture that is relaxed and open enough to respond.[11]

The key to producing controlled soft dynamics is summarized in Farkas's concept of aperture.[12] In order to develop a fine *pianissimo,* the very small amount of air going through the lips makes the size of the lip opening of critical importance. If the opening is too large, the weak air stream gets through without the friction necessary to produce vibration. Conversely, if the opening is too small, the weak air stream will be occluded.[13] Berv concurs that when playing softly, the aperture is much smaller and the speed of the airstream slower. As brass players try to play softly, they often harden their lips making them less pliable. Greater *pianissimo* can be achieved by blowing less air without making the lips hard.[14] Hill cautions all brass players to listen to the pitch, as there is a tendency to play sharp at the end of *pianissimo* phrases.[15]

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As America's population ages and more seniors participate in community bands and orchestras, players and conductors alike should be aware that there are inevitable changes that take place in aging lungs. The lungs mature by ages 20 to 25, and thereafter, the respiratory system undergoes various anatomical, physiological, and immunological changes with age.[16] It has been reported that all components of the respiratory system are affected by aging, though at different rates.[17] Changes that have a deleterious impact upon one's ability to play the trumpet in the latter years of life include a decrease in chest wall compliance (*i.e.,* the chest wall becomes stiffer), thereby increasing the work associated with breathing;[18] a decrease in the strength of respiratory muscles including the diaphragm;[19] a decrease in the elastic recoil of the lungs;[20] a decrease in vital capacity;[21] and a compromised ability of the chest to expand and contract during breathing as the ribs become thinner and change shape.[22]

Unfortunately, there is no "magic bullet" to prevent or reverse the inevitable consequences of aging. According to the Mayo Clinic, regular aerobic exercises like walking and swimming increase the capacity of the lungs to deliver oxygen to the body's cells. Swimming is virtually impact free, and the method of breathing associated with swimming increases inspiratory capacity and oxygen uptake efficiency. Everyone is encouraged not to smoke, as smoking harms the lungs and accelerates aging of the lungs.[23] There is no evidence to suggest that playing a trumpet or any other wind instrument should be avoided as a healthy individual ages. On the contrary, regular practice associated with attaining maximal inspiration and

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expiration may well strengthen the muscles associated with respiratory excursions (the diaphragm and the muscles listed in Tables 1 and 2), much as directed regular physical exercise strengthens the other skeletal muscles of the body. There also is a commercially available device, the PowerLung, available online and at some retail stores, that allows the user to vary the resistance against which one inhales and, independently, to vary the resistance against which one exhales. According to the manufacturer, the user is not breathing through a restricted orifice (presumably a mouthpiece or tubing) in which the exhalation resistance can be reduced by changing the way the user breathes.

About the author: Dr. David Michie earned his PhD in physiology from the University of Texas (Medical Branch). He served as professor and chairman of the department of Physiology and Bioengineering at Eastern Virginia Medical (Norfolk) prior to establishing Clinical Physiology Associates, a multispecialty research group, in Ft. Myers, Florida. He is the author or co-author of 68 full-length scientific publications. Now retired, Dr. Michie is a community player within the trumpet section of Florida Southwestern State College's concert band and a member of the Bonita Springs Concert Band. He is a student of Cindy Scaruffi-Klispie.

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