Breathing In The Gravity Field
Part I

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This is the first of a three-part series.

PREFACE

Breathing is a familiar phenomenon to us all. Each one of us has a unique experience of breathing; in fact, we don't have any experience of life without breath. Nonetheless, if I were to ask you "what is the function of breathing?" chances are you would answer something like "CO2-O2 exchange." You would answer something learned, and not from your actual experience at all.

The group of thinkers that called themselves phenomenologists tried to take experience as the starting point for their investigations of human issues. Starting from experience implies at least two fundamental changes in the way we usually pursue knowledge. For one, experience implies an experiencer. From this point of view, to divide experience into subject and object is exactly what we don't want. The role of actual experience and perception is considered the key to understanding any phenomenon.

Another aspect that changes is that experience always and only takes place in a context. It is never independent of the situation. From this point of view, there is no way to study an object independent of its environment. The context is always part of the experience.

Today, the phenomenological point of view, while less popular in the academic circles of philosophy and psychology, has been followed up by scientists looking at issues of development and rehabilitation[1]. It is not surprising that it would be in seeking to *apply* the insights of physiology and biomechanics that the influence of the context and the experience of the subject would take on more importance.

This paper seeks to apply the knowledge of physiology and biomechanics to working with the breath. It is an attempt to look at breath keeping the phenomenological considerations in mind. To really make sense of breathing we need to look at the physiology and mechanics of breath in the context in which they take place. For human beings, the most ubiquitous context is the field of gravity. This is the force, the environment, that is always with us. We also need to consider the role perception plays in the dynamics of breathing. In fact, what this paper reveals is that the physiology and mechanics only really make sense when these factors are given their primary place.

The first part of the paper will take a look at the basic physiology of breathing, and see how it can be applied to working with breath. In the second part will expand our understanding of the anatomy and biomechanics that underlie the breath, which will lead to Part 3, an indepth look at the interactions between the body's way of organizing itself in gravity and the organization of the breath. We will find that perception plays a fundamental and inevitable role in the organization of the human breath and being.

INTRODUCTION

Breath is the basic movement of life. Gravity is the most basic force. No matter what else we are doing, we are also breathing and with each breath our body subtly adjusts to keep us upright in relation to gravity's field. These two primary functions are intimately connected.

A careful study of basic respiratory physiology, and the anatomy and mechanics that underlie the breath, reveals that breathing is an involuntary, automatic process. The ease and adaptability of the movement of breathing depends on the body/muscles being free to respond to the nerve signals coming from the lower brain centers. A natural breath also depends on the ability of the muscles of inspiration to operate freely and minimal interference from unnecessary muscles.

An individual's particular posture inevitably comes into play here. Posture depends on the gravity system: the brain, nerve, muscle connections whose continuous resistance to stretch, what is known as tonic activity, forms the basis of our ability to adjust our uprightness to constantly changing circumstances. When this system is not operating properly, muscles will be inappropriately coopted to maintain upright stance, which will interfere with the normal ease of breathing.

Furthermore, appropriate tonic postural activity depends on sensation and perception. Every single breath we take involves the coordination of all these aspects; breakdown in any one of them will immediately affect the breath. They will be important considerations in assessing the function of respiration (because what looks like a breathing problem may originate elsewhere), and in strategizing interventions with integrative results.

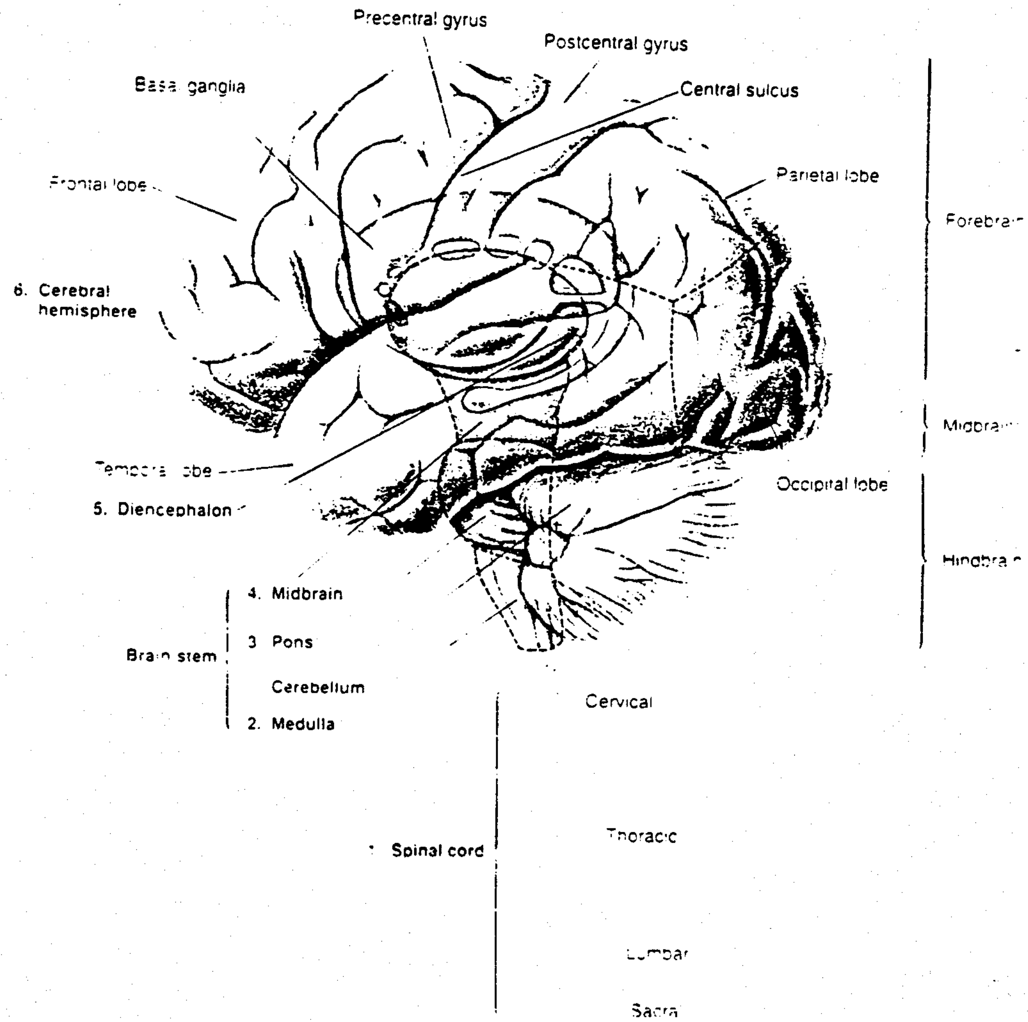


Figure 1: Divisions of the central nervous system [2]

1 -Thelen, Esther and Smith, Linda, A Dynamic Approach to the Development of Cognition and Action, MIT Press, Cambridge, MA 1995

-Reed, Edward, An Outline of a Theory of Action Systems

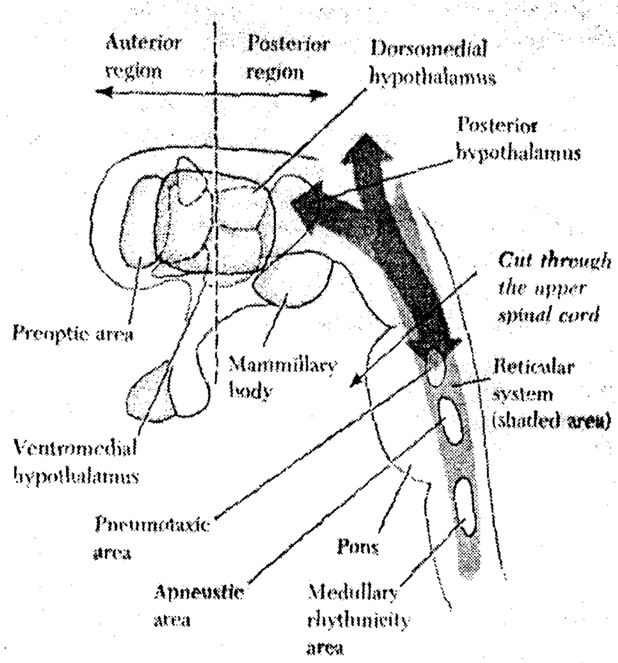
BREATHING BASICS

"TAKE A DEEP BREATH"

How often have you heard this suggestion? Usually it is meant as a way to calm yourself, to pull yourself together. Have you ever heard or said, "I know I don't breathe right; I catch myself holding my breath," or "I'm not breathing?"

Of course, this could not be true exactly—since our lives depend upon our breath, so long as we are alive, we must be breathing—but it does illustrate a unique aspect of breathing: it is a function that is mostly involuntary, out of our control, like our heart beat and the electric impulses of our nervous system; but at the same time, unlike our heartbeat (except for rare instances) we can voluntarily affect our breathing rate and rhythms; there is the possibility of conscious override.

This may lead us to the unconscious assumption that breathing is a voluntary activity which requires our conscious attention, but a careful look at the physiology underlying breathing makes it abundantly clear that this is not the case. Breathing happens, but you do not have to do it, any more than you have to beat your heart or remember to trigger the release of enzymes in your stomach after you have eaten. The real work of breathing is an automatic mechanism that simply does not need our voluntary attention or interference. Not only that, but even the involuntary muscular work necessary is minimal: in quiet respiration[1], both



UPPER SPINAL CORD

Medulla: contains the medullary rhythmicity area: contains the inspiratory and expiratory neurons responsible for the basic rhythmicity of respiration.

Pons: contains the apneustic area and the pneumotaxic area; provides an inspiratory drive to respiration (when stimulated, inspiration is stronger and more prolonged), whereas the pneumotaxic area accelerates breathing and provides an expiratory drive.

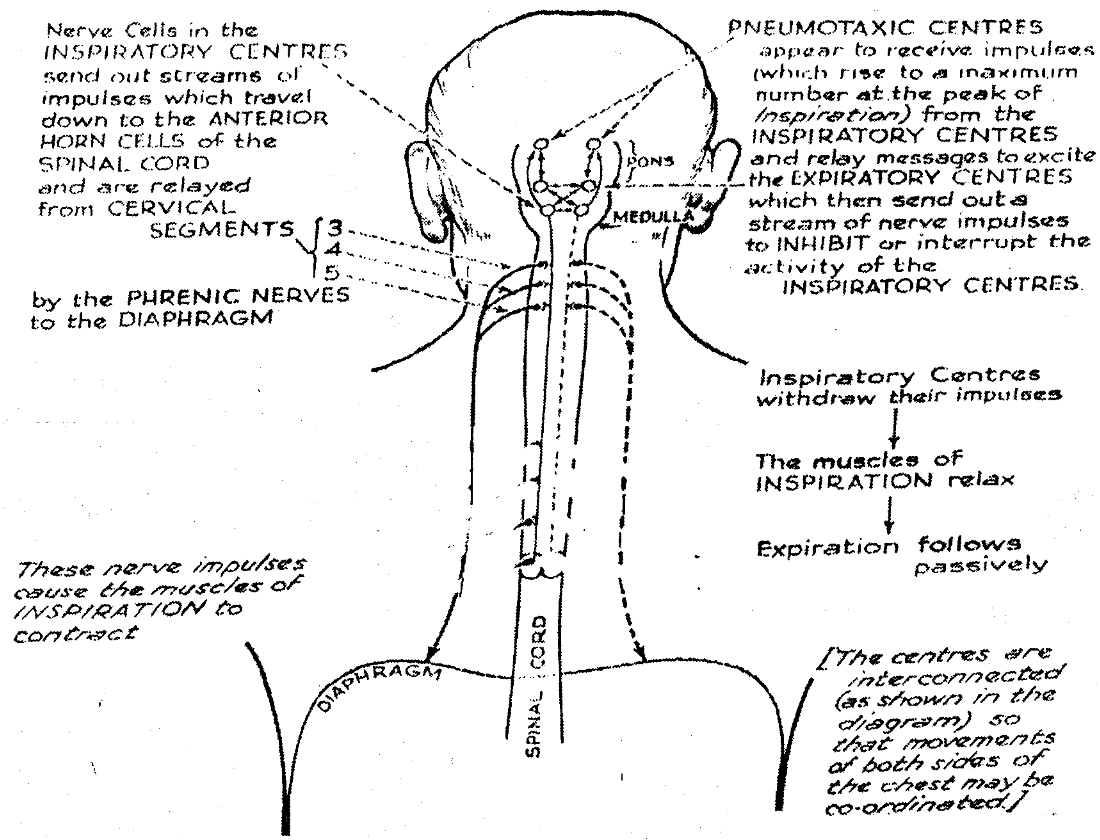
HYPOTHALAMUS

Preoptic area: involved in temperature regulation. When body temperature rises, cells in this area increase the rate of respiration (panting).

Posterior region: includes the posterior hypothalamus, mammillary body, dorsomedial hypothalamus, and ventromedial hypothalamus; when stimulated, increases the rate of breathing. The posterior region is involved in many arousal mechanisms.

Figure 2: Many areas of the brainstem have specific functions in respiration. (Bloch p. 64)

Figure 3
The following chart outlines the neurological events that control inhalation and exhalation.*



* Adapted from McNaught, A. and Callendar, R. Illustrated Physiology. Churchill Livingstone, London. 1975. p.130

inhalation and exhalation happen as a result of pressure differences inside and outside the ribcage. Natural breathing is almost effortless.

There are many opinions about what is the natural breath, and what the best way is to work with it. Different schools describe different rhythms, (whether there is a pause, whether it comes before or after exhalation), and different movements (breathing into the belly, chest or pelvis) that underlie what each considers the best breath. Some favor special breathing techniques, a "right way" to breathe. Whatever point of view we hold, the breath itself depends on basic physiological mechanisms.

In this chapter we will take a careful look at the neural, chemical and mechanical processes that underlie a natural breath.

I. NEURAL CONTROL OF RESPIRATION

Normal breathing occurs without conscious control through complex neurological and chemical feedback systems.

1. NEURAL CONTROL AT THE REPTILIAN BRAIN LEVEL

Deep within the old, reptilian part of the brain, the brainstem, lie special nerve cells, the respiratory centers, that are in control of the rhythm of breath at the most basic level. Activity in these neurons triggers a signal which travels through the spinal cord to the muscles of inhalation, causing them to contract, expanding the ribcage and thus initiating the process of inhaling. The normal movements of respiration are involuntary: They are carried out automatically through the rhythmic discharge of these nerve impulses. Neural mechanisms within the brain stem and reflex signals from stretch receptors in the lungs themselves influence the switch-off point of the respiratory neurons. When the respiratory centers stop discharging, the muscles relax and inspiration ceases. Exhalation follows from the elastic recoil of the lungs and ribcage: muscle contraction is not necessary[3].

2. NEURAL CONTRAL AT THE VOLUNTARY-CORTICAL LEVEL

Breathing can certainly be affected by intention. We can override the reptilian system: Using descending nerve pathways from the cerebral cortex to the motor neurons of the respiratory muscles, we can voluntarily regulate the rhythm of the breath, and we do, for example, whenever we talk or sing. However, this voluntary control cannot be maintained when involuntary stimuli, such as high levels of carbon dioxide,become intense. Ultimately, the autonomic system is stronger. For example, if you tried to hold your breath underwater, even though an intake of breath would mean drowning, eventually you would breathe in. The will would not be able to prevent the body's breathing, even though it means death. In a demanding action, a sudden or effortful movement such as jumping or dancing, it will not be possible to control the breath. The attempt to control, or the habit, may even interfere with the spontaneous adjustment of the breath to the situation, and impede the movement we are making.

IN PRACTICE

A breath can be taken, using a voluntary action that employs the cortical pathways, or it can be allowed, ie, the lower brain processes can be left to breathe free from inhibition. The specific words we choose when working with someone's breath pattern will influence which pathway is triggered: For example, directing a client to "Take a deep breath," or commanding a client, "Breathe!," will evoke different neural responses than suggesting, "Allow the air to fill your lungs." The practitioner always has the choice to use either direct intervention approaches (such as controlled breathing, or pranayama), which may trigger a cortical, voluntary action in the client, or indirect approaches (working with sensory perception, exploring without changing), which may lead to more lower brain influence.

II. CHEMICAL CONTROL OF RESPIRATION

The rate of breathing is closely tied to the levels of oxygen and carbon dioxide in our blood, as well as body pH. Sensitive chemoreceptors in the respiratory centers themselves register the level of CO_2 in the blood that supplies them. Peripheral chemoreceptors located in the neck and thorax are also involved. An increase in the amount of CO_2 serves as a trigger that causes the respiratory neurons—both inspiratory and

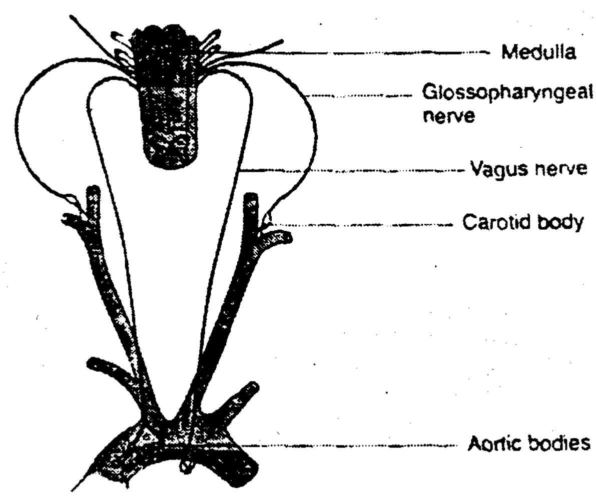


Figure 4: The carotid and aortic bodies located in the neck and thorax are important peripheral chemoreceptors[5].

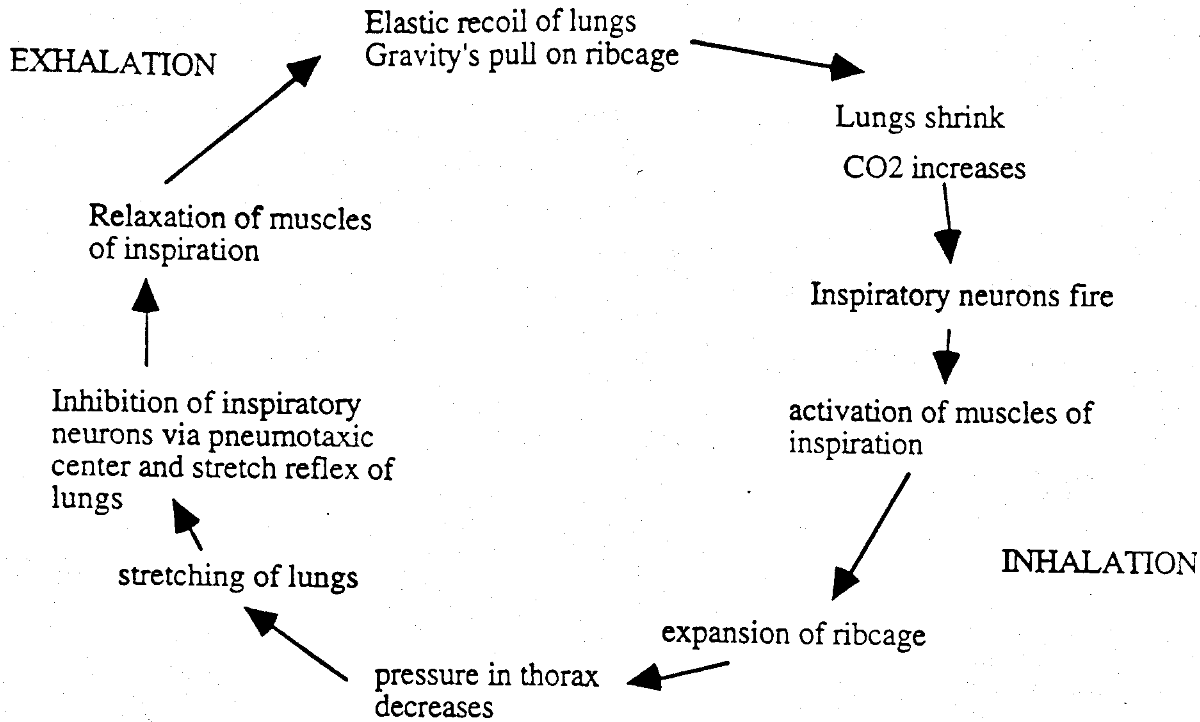


Figure 5

expiratory—to increase their activity.

IN PRACTICE

Understanding the chemical regulation of breathing may provide an explanation of one point of view: that the natural rhythm of breathing is inhalation, exhalation, followed by a pause. After exhalation, there is still oxygen in the alveoli. The pause after the exhalation allows the time for the CO_2 level to mount in the alveoli. When the appropriate level is reached, the various receptors trigger a signal to the respiratory centers in the brainstem, which automatically trigger a new inhalation. Like the breath of a newborn, there is no sense of effort in the breath. The autonomic response allows the breath to be bigger and easier. If you inhale again immediately after exhaling, the natural rhythm cannot occur. You will have to involve a cortical pathway, a voluntary override to the natural rhythm of breath.

OTHER CHEMICAL INFLUENCES ON THE RATE OF BREATHING

The respiratory neurons will also be activated by a fall in blood oxygen levels or a decrease in body pH (reflected by an increase in $H+$ ions). Thus, at each moment, the neurological regulation of the breath is directly tied in with the chemical makeup of the blood.

IN PRACTICE

The mechanisms that control breathing are complex and highly organized. None of them depend on voluntary behavior or conscious experience, but all can be affected in a critical way by conscious behaviors. Breathing exercises requiring conscious direction could run the risk of interfering with the automatic mechanisms[6]. For example, rapid breathing elevates body pH, reducing the amount of free ionized calcium in the blood. This makes nerve and muscle much more excitable, increasing their level of tension.

III. THE MECHANISM OF BREATHING

The neural and chemical processes lead to inspiration by stimulating muscles that act on the ribcage to expand its volume. This in turn changes the volume of the lungs, which then determines the intake of air. From a mechanical point of view, normal exhalation is entirely passive; no muscular action is required at all. In both normal or forceful breathing, the muscles only work indirectly on the breath, to change the shape of the container. That is what changes the flow of air. Our muscles don't pull air into the lungs nor push it out, in spite of how we may model (or perceive) it.

INHALATION

In inspiration, action potentials from the reptilian brain's respiratory centers trigger the muscles of inhalation (primarily diaphragm and scalenes in normal inhalation). The muscles contract, increasing the diameter of the ribcage, and thereby

Normal, Quiet Breathing

INSPIRATION:

SCALENES muscles actively contract.
-upper ribs move upward
sternum moves upwards and forwards

DIAPHRAGM contracts
-descends
-depth of chest increases

Capacity of thorax is increased

Pressure between pleural surfaces (already negative) is reduced from -2 to -6mmHg (i.e. an increased suction pull is exerted on lung tissue)

Elastic tissue of lungs is stretched

Lungs expand to fill thoracic cavity

Air pressure within alveoli is now less than atmospheric pressure
Air is sucked into alveoli from atmosphere

EXPIRATION:

SCALENES relax

-ribs move downwards

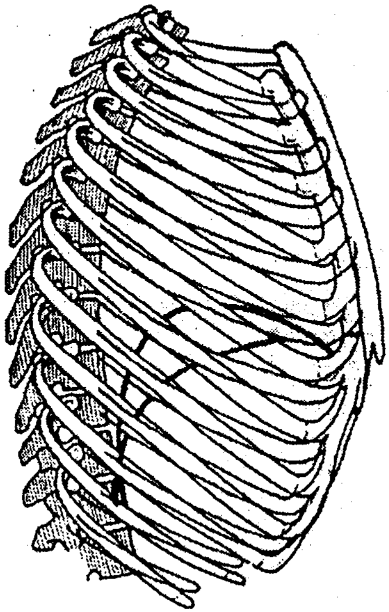
DIAPHRAGM relaxes
-ascends
-depth of chest diminishes

Capacity of thorax is decreased

Pressure between Pleural surfaces is Increased from -6 to -2mm Hg (i.e. less pull is exerted on Lung Tissue)

Elastic Tissue of Lungs Recoils

Air pressure within alveoli is now greater than atmospheric pressure
Air is forced out of alveoli to atmosphere



Forced Breathing

Muscles of Nostrils and around glottis may contract to aid entrance of air to lungs
external intercostals may contract
-extensors of vertebral column may aid inspirations

-Internal intercostals may contract
-move ribs downwards more actively.
-Abdominal muscles contract--actively aid ascent of diaphragm

Figure 6
Adapted from McNaught and Callendar

decreasing the pressure in the thoracic cavity and lungs. Air flows into the lungs until the pressures inside and outside equalize. The muscular effort is not to pull air into the body: The work performed by the muscles acts on the ribcage to increase its volume, but the flow of air into the lungs is the result of the pressure gradient—an entirely passive process.

EXHALATION

Normal exhalation is simply what happens when the inspiratory centers cease firing: The inhalation muscles then cease contracting, the effect of gravity on the ribcage in turn lessens its dimensions, lessening the pull on the lung tissue itself. The elastic recoil of the lungs then promotes exhalation without the need of any muscular contraction. From a muscular point of view, exhalation is a passive process. The weight of the ribcage responding to gravity lengthens the muscles of inspiration; muscles considered muscles of exhalation, primarily the abdominals, are only necessary for forced exhalation.

IN PRACTICE

When working with the breath, to get a free and easy exhalation, are the muscles of inspiration free to release? Rather than imposing voluntary, cortical control on the breath, we can work from the point of view of the container—working with the freedom of the ribcage to expand and the freedom of the muscles of inhalation to release.

CONCLUSION

Physiology, chemistry and mechanics all underline the same point: breathing at a basic level is involuntary. You don't have to work to breathe. Normal breathing is triggered automatically by the brainstem. The physical properties of the lungs and the atmosphere, and gravity take care of the rest. Breathing is not designed to involve intention nor much muscular effort, voluntary or involuntary. Breath can respond to direct approaches through the cortical pathways. Breath also responds to indirect work, with the freedom of the ribcage, with the sensations of the skin[7], with increased sensory, immediate experience. The work is not to bring about the breath, but to act in such a way that does not prevent it.

The simplicity and efficiency of the process upon which breath depends relies on the freedom and coordination of the muscles involved. The muscles of inhalation (primarily diaphragm and scalenes) must be free to contract to change the volume of the ribcage so that the air can flow into the lungs—that means no unnecessary antagonist activity. Normal exhalation is primarily a passive process, that should not require muscular action. For this, it is important that the muscles of inhalation be free to release so that muscles that can contribute to exhalation not be called upon unnecessarily. Given this, we can begin to anticipate the role posture will play in the dynamics of breathing. We will explore this at length in the next sections. ❏

FOOTNOTES

1. The mechanisms for forced or high amplitude inhalation or exhalation will often involve muscle contraction. In this paper we are primarily considering quiet, normal breathing.

2. Kandel, E.,Schwartz, J., Principles of Neural Science. Appleton&Lange, CT, 1991. p. 8

3. Again, we are considering normal breath. In forced exhalation, abdominal muscles will be called into play.

4. Adapted from McNaught, A.and Callendar, R. Illustrated Physiology. Churchill Livingstone, London.1975. p.130

5. Guyton, A., Human Physiology and Mechanisms of Disease. Harcourt, Brace, Janovich, Philadelphia. 1992. p. 309

6. Bloch, George, Body and Self. William Kaufmann, Inc. Los Altos, CA, 1985. p.70

7. Bloch, George, Body and Self. William Kaufmann, Inc. Los Altos, CA. 1985. p.59