New Conceptions of Breathing Anatomy and Biomechanics

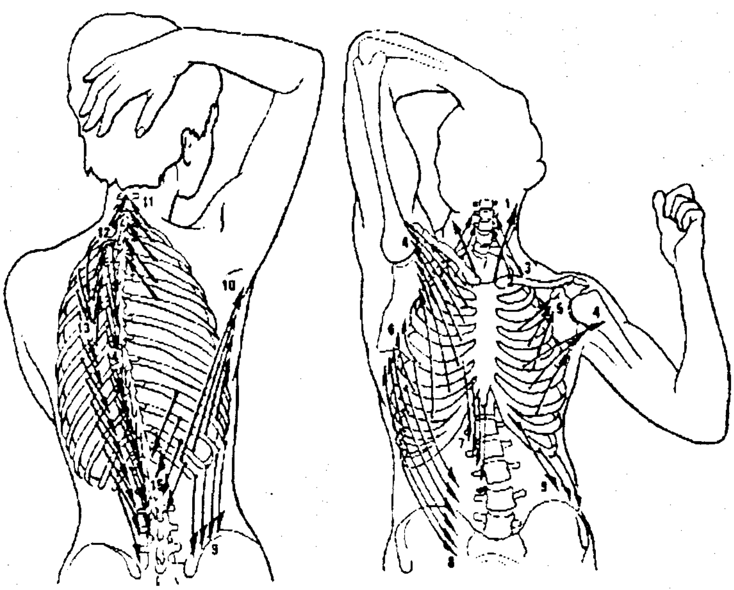
Part Two

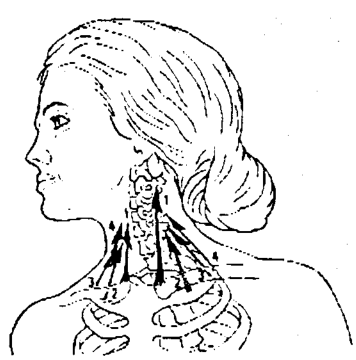
By Aline Newton

This paper is an attempt to synthesize in written form the perspective of breathing, perception and biomechanics I have heard Hubert Godard articulate on many occasions. I am grateful for his patience and assistance and also for his many references.

To understand the role of posture in the breath, we are going to start by looking at the biomechanics of the breath itself. Again, we will be primarily concerned with normal, quiet breathing and focusing therefore on the muscles involved in inhalation.

All the muscles in Table One are said to be involved in inspiration in some way. Obviously though, some must be more important than others. Which muscles should be considered primary? Among anatomists, this is not a simple matter. There is continued debate about which muscles are involved in which aspects of breathing. The diaphragm is the one muscle everyone agrees is primary in breathing—but here the opportunity for argument is provided by the complexity of the biomechanics. In this section we will consider some of the differing views and their impact on our understanding of the relationship





COSTAL
intercostals
diaphragm

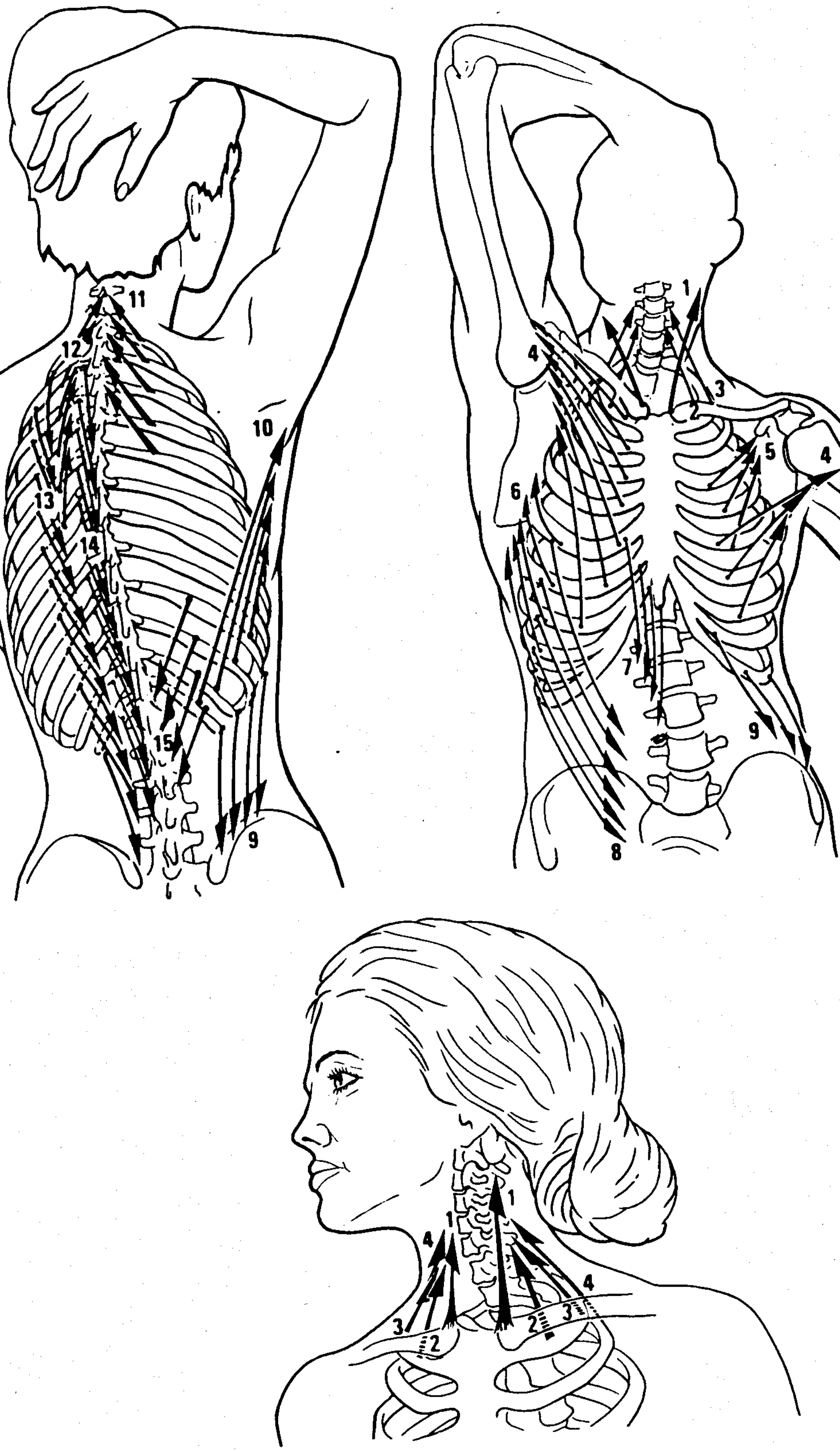
NUCHAL
sternocleidomastoid-1
scalenes 2-3-4
superior trapezius
subclavius

SCAPULAR
pectoralis minor-5
pectoralis major-4
Medial trepezius
levator scapula
rhomboids
serratus anterior
latissimus-10

SPINAL
longissimus-14
iliocostalis
lumborum-12
spinalis

TABLE ONE/FIGURE 1[1]: INSPIRATORY MUSCLES

Figure 1
Inspiratory Muscles
From Kapandji



between posture and breathing. Increasing clarity in our images of anatomy and biomechanics may lead to a different understanding of function and to new ideas for working with the breath in practice.

As we begin to consider the biomechanics of the breath, the notion of "fixed point" becomes an important theme: Anatomists often talk of muscle attachments in terms of origins and insertions. From a functional point of view this can be misleading: it implies that the muscle's pull is always in the same direction; that the insertion moves towards the origin. In reality, the result of the pull of a muscle depends on which end is fixed. The term "fixed point" is a little misleading: it would be more descriptive if it could include the sense that the point is dynamic, active but stabilizing, in contrast to the other end, which is active and moving. Which end of a muscle acts as the fixed point is the consequence of a combination of the demands of the moment, the individual's postural habits, neurological organization and relationship with the surrounding space[2], and the coordinated action of many muscles that act as stabilizers. The variability of the location of the fixed point will be an important aspect of the dynamics of breathing.

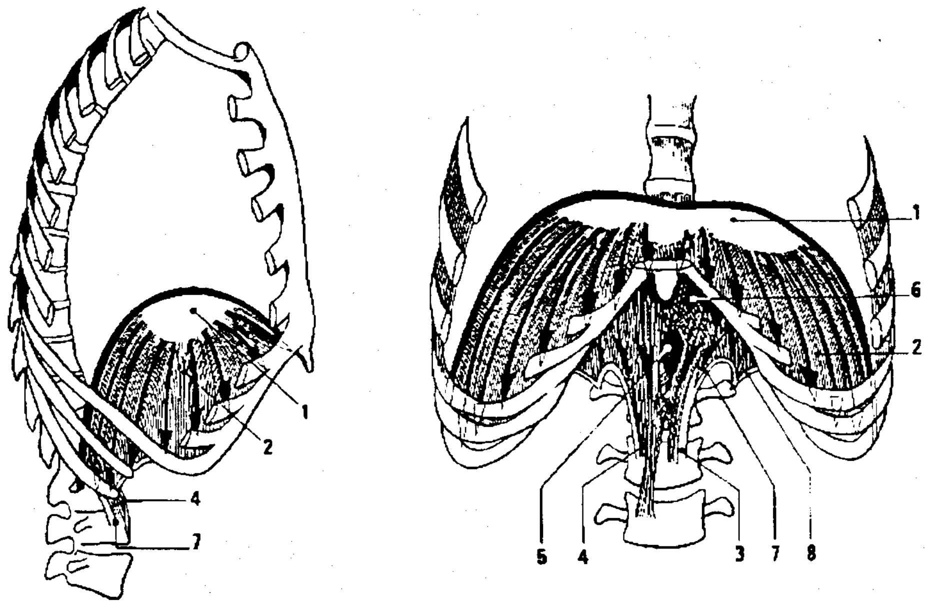


FIGURE 2: DIAPHRAGM AND CRURA CAN BE CONSIDERED AS SEPARATE MUSCLES

I. THE DIAPHRAGM

One thing all the authoritative anatomy texts agree on: the diaphragm is the most important muscle for respiration. But even this is not so simple. In an article published in Science in 1981, research showed that the diaphragm consists of two muscles that act differently on the ribcage—at least in the dogs that were the subjects of the study.[5]

Traditionally, the diaphragm is composed of three main parts: the costal diaphragm (2) which attaches to the border of the ribs and to the central tendon (1); the crural diaphragm (3-4) going from the vertebral column to the central tendon; and the central tendon itself. When the costal diaphragm's fibers contract, they pull on the central tendon. The resulting change in volume causes a fall in the pressure inside the thorax which leads to inflation of the lungs. Stimulation of the crural fibers will also result in a change in pressure inside the thorax but without displacing the ribcage at all. Other experiments show that the embryological development and the segmental spinal innervation of the two parts are also different. The costal diaphragm and the crura have different anatomic origins, different embryological development, different segmental innervation and different actions. They can thus be considered two separate muscles.[5]

IN PRACTICE:

The central tendon, the ribs and the spinal attachment of the crura can each act as a fixed point, leading to a different movement of breathing. The underlying biomechanics will be developed further in following sections.

a- The lower ribs can be stabilized by posture and by the abdominal muscles, in which case the diaphragm muscles will pull on the central tendon. Although the sensation of inhaling in this case can feel very big, the actual excursion of the central tendon of the diaphragm is only one or two centimeters. We don't feel the diaphragm's movement directly, but only the consequences of it on the ribs and viscera.

b- With proper abdominal tone, as the central tendon descends, the mass of the viscera will provide a supporting point so that the central tendon can act as a fixed point. The contraction of the diaphragm's fibers will then lead to elevation of the lower ribs. In this case, the abdominal muscles, normally considered muscles of forced exhalation, actually become accessory to inspiration.

c- If the lumbars act as the fixed point, contraction of the crura will pull down on the back of the diaphragm. The fact that the crura may be considered a separate muscle may help to explain certain respiratory patterns which result in a breath in spite of minimal diaphragm involvement or movement of the ribcage.

BIOMECHANICS OF THE "BELLY BREATH"

The movement of diaphragm and crura may seem to have a piston-like effect on the abdominal contents. Were this so, the force of the diaphragm would press the viscera down into the pelvis with each breath. Some approaches to working with the breath do encourage this downward movement. Other sources point out the vulnerability of the pelvic viscera, emphasizing the detrimental effect repeated pressure would have.

In his book, *Les chaines musculaires*, Leopold Busquet[6] describes what he considers the body's ingenious solution to this problem: The viscera are contained in two different pouches. The organs contained within the peritoneum benefit from the variation of pressure caused by the movement of the diaphragm and lumbar spine, whereas the organs in the other pouch, the rectum, uterus, prostate and bladder, need to be protected from the same pressure. The biomechanics allow just this difference: When the diaphragm contracts, the sum of the force of contraction pushes forward and downward just below the navel, an area which is reinforced by the transversus abdominis muscle. The pressure does not go directly down into the pelvis. The iliac bones, by their very shape, orient the downward force of the diaphragm's pressure in a forward direction, above the pubes. The organs in the pelvis are thus protected from the changing pressure caused by the diaphragm's action. **(Figure 3)** The obturator membrane is yet another mechanism which serves the same purpose: to protect the pelvic organs by regulating the pressure in the pelvic basin. The natural lordotic curve of the lumbars also helps direct the pressure towards the sub-umbilical area. Good tonus in this area is essential to sustain the forces that come to bear here. If the lumbar lordosis is lost or the pelvis is held too posteriorly, the protection of the pelvic organs will be compromised.

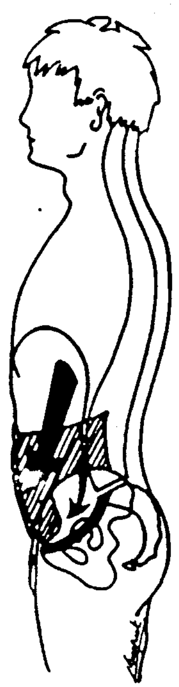
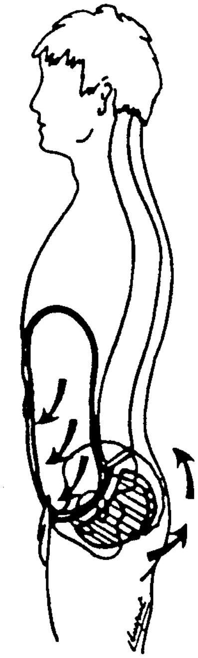


FIGURE 3

SUM OF DIAPHRAGM'S PRESSURE



THE PELVIC ORGANS ARE PROTECTED FROM THE ABDOMINAL PRESSURES

IN PRACTICE

a- Exercises that encourage breathing into the pelvic floor can be very useful from a proprioceptive point of view: The movement of the breath can stimulate sensory awareness of the pelvic floor. It is important, however, to differentiate a movement for proprioceptive education from movements of normal respiration.

b- Belly breathing. The movement of the ribcage in response to the breath we will call upper respiration and the movement of the breath down toward the subumbilical area we will call lower respiration. The chain of sympathetic nerve ganglia, that relates to the fight or flight response, runs along side the spine the length of the ribcage. Upper respiration stimulates sympathetic capacity: it increases overall tone and energizes. Lower respiration stimulates the parasympathetic part of the autonomic nervous system, bringing rest and relaxation. Breathing with the belly alone can thus be a positive exercise. But misapplied, it can also depress sympathetic capacity. In the case of someone who is depressed or lacks energy, a focus on belly breathing may actually reinforce the presenting problem. For someone with a collapsed ribcage, or for a person with depression, encouraging movement of the ribcage and chest during breathing can be constructive.

SUSPENSORY SYSTEM OF THE DIAPHRAGM

In the book, *Fascias et Pompages*[7], Marcel Bienfait describes a fascial chain that he says could be named the "chain of the 3 diaphragms." It begins at the base of the skull and continues in the neck as the prevertebral fascia and in the thorax as the fascial sheaths around the heart to the diaphragm. Below the diaphragm, the fascial sheet continues via the crura and the psoas fascia, thus connecting to the lumbar spine, and divides into two fascial chains for the lower limbs.[8] As a whole, this long span of fascia is known appropriately as the deep cervico-thoraco-abdomino-pelvic fascial chain.

The diaphragm is in some sense suspended by a sling of connective tissue from the base of the cranium. The mass of aponeuroses, fascia and ligaments that form the upper part of the chain creates a fascial webbing that acts as a suspensory system for the diaphragm. Bienfait calls it the anterior mediastinal ligament, (also known as the phreno-pericardiac ligament). Souchard describes it as a virtual tendon, which looks as if designed for repeated big effort. **(Figure 5[10])**

Instead of the usual image of the diaphragm as a central tendon with muscles all around, Bienfait describes the diaphragm as a musculo-tendinous complex made up of 8 digastric muscles. The central tendon adapts to the movements of the trunk and ribcage and at the same time serves as the fixed point for the movement of the ribs in breathing. Suspended from above by the anterior mediastinal ligament and pulled from below by the crura, the movement of the central tendon is extremely limited. **(Figure 6[11])** Both the abdominal viscera and the tendon of the diaphragm act as brakes on the diaphragm's movement.[12] Thus, as we mentioned earlier, if the abdominal muscles are properly toned, when the muscular fibers of the diaphragm contract, they pull on the ribs below which lift and and allow lateral expansion of the ribcage.

THE SCALENES

In most anatomy texts, the scalenes are considered only as accessory muscles of inhalation, while the external intercostals are thought to do the primary work of changing the shape of the ribcage during inhalation (Kendall, Kapandji). But according to Platzer, (1986 p. 82) electromyographical studies by Fick show that the intercostals are active only in forced inhalation. Platzer states that the scalenes are the most important muscles for quiet inspiration. By lifting the top ribs and the upper part of the thorax, they are

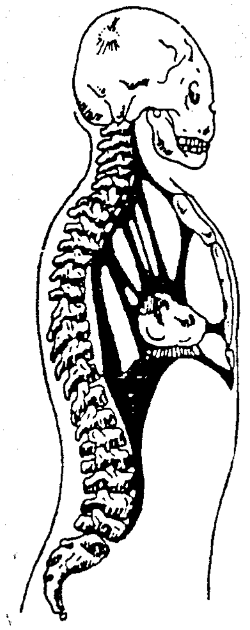


FIGURE 4: THE WEB OF CONNECTIVE TISSUE THAT SUSPENDS THE DIAPHRAGM WRAPS AROUND THE HEART, CONNECTS TO THE LUMBAR SPINE.[9]

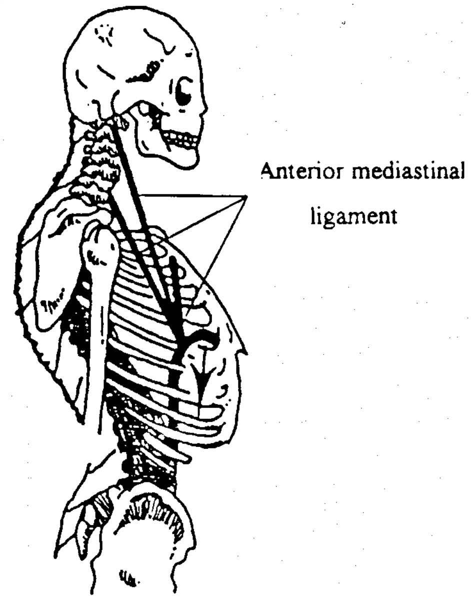


FIGURE 5

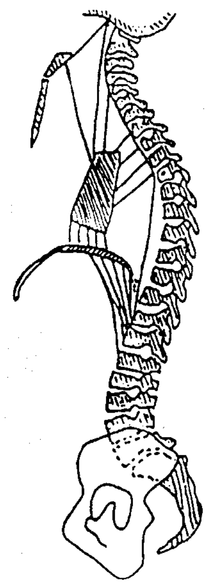


FIGURE 6

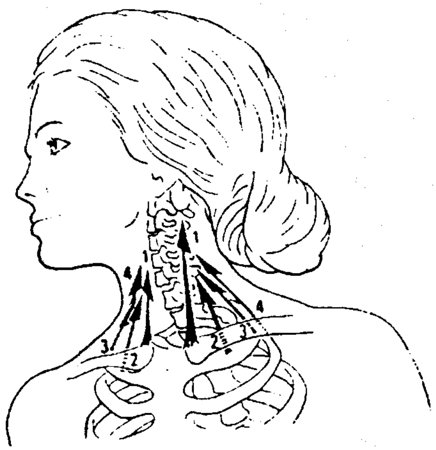


FIGURE 7: THE SCALENES[13]

crucial to the expansion of the ribcage which allows the mechanics of inspiration to operate with minimum effort. Perhaps the role of the scalenes is so controversial because it depends on many factors, including overall posture and what is acting as the fixed point.

Souchard calls the scalenes "static suspensory muscles of the upper thorax." They attach to the vertebrae very far laterally and parallel to the spinal column. If the head and neck are correctly placed, when the scalenes contract symmetrically they will be able to lift the first and second rib without causing rotation or forward bending of the cervical vertebrae.

Kapandji points out that the scalenes' action will only be effective when they act on a cervical column stabilized by other muscles, in other words, when the neck or head act as a fixed point. If there was no upper fixed point, the action of the scalenes would pull on the cervicals, compromising the head's stability in gravity. Contraction of the scalenes would pull the head down and forward. The upper fixed point will be important for both inhalation and exhalation: when the scalenes' contraction ceases after inhalation, the upper point of support will ensure their ability to release as the weight of the ribs exerts its pull.

PRIMARY RESPIRATORY MECHANISM

If the diaphragm/crura and the scalenes alone are considered the primary muscles of inspiration, we arrive at an odd situation: Without stabilization of the lumbar spine, the action of the crura pulls the lumbars forward; without stabilization of the cervical spine, the action of the scalenes pulls the neck forward and down. What is required is something to create a fixed point that will stabilize the lumbars, neck and head. From a functional point of view, spinal stabilizers are exactly suited for this role. They should therefore also be considered essential players in the basic biomechanics of breathing.[14]

THE SPINAL MUSCLES

The spinal stabilizers are a complex of muscle groups that blanket the back from the sacrum to the occiput. The individual muscles do not extend directly from lumbars to occiput: there is an interweaving of muscle fibers. The multifidus continues to the occiput in the form of semispinalis capitis, and longissimus as longus capitis. Spinalis stops at T1 and iliocostalis lumborum at C3.

The two most important spinal muscles for respiration are longissimus and iliocostalis lumborum. Both these muscles have attachments on the ribcage itself. These muscles influence respiration in several ways:

a) On the spine itself: When the muscles on both sides of the spine contract simultaneously, with the lumbars as the fixed point, the spinal column will extend (backbending),

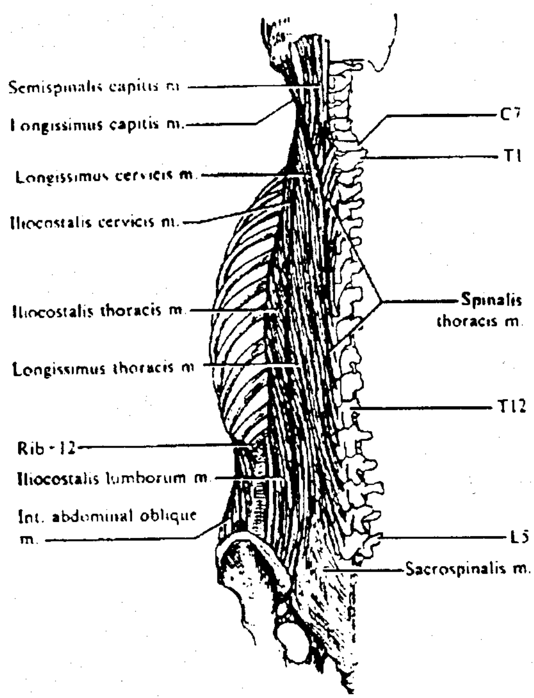


FIGURE 8: SPINAL MUSCLES[15]

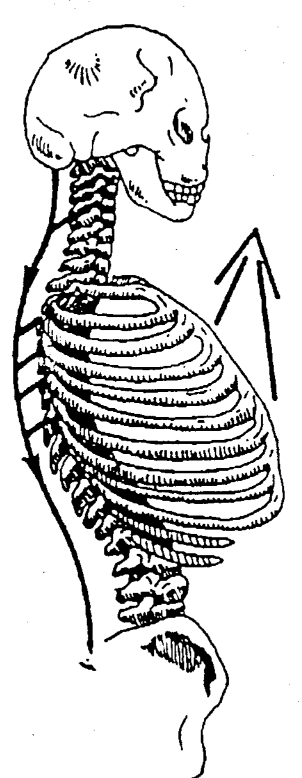


FIGURE 9A

which elevates and opens the ribcage. (**Figure 9a,** from Souchard, p.57)

b) On the ribs: Longissimus and iliocostalis lumborum can also act from below, pulling down on the small arm of the rib (inside the costal angle). The 90 degree angle of the long arm relative to the short one transforms the rotation into elevation of the long arm of the rib. From one fixed costal point to the next, longissimus and iliocostalis lumborum pull on the ribs like the cord of a venetian blind. With inspiration, each rib rotates just like the slats of the blind. (**Figure 9b**)

c) As a stabilizer: The attachments via the upper insertion of iliocostalis lumborum and via semi-spinalis can act to stabilize the neck and head, providing the support necessary for effective scalenes action. This also allows the cervical muscles that are accessory to inspiration to be active. The influence of the spinal muscles can reach as far up as the first rib and the first thoracic vertebra, stabilizing the thoracic spine which allows the accessory muscles of inspiration attached to the scapulae to come into play.[17]

The basic mechanism of inspiration includes the diaphragm, the erector spinae, and the scalenes muscles. The diaphragm remains the basic element, but added to its contraction is the action of the spinal muscles which give the lumbar and cervical spine the necessary support to bring the muscles into play. This stabilization also enables the action of the scapular, cervical and thoracic accessory muscles of inspiration.

IN PRACTICE: PATTERNS OF COMPENSATION

The dual role of the spinal muscles is one important element in the interconnection between posture and respiration. Through them, breathing patterns influence posture, and posture influences the breath. In both cases, the patterns can end up interfering with the basic physiology of breath (—that it's an automatic movement, that you don't have to do it, but just not prevent it—) described in Part 1.

When the primary respiratory mechanism is not working—if the spinal extensors don't come in to play, if the head is not stabilized, if somewhere the extension is not available—the movement of the breath will be concentric: With each breath the action of the scalenes will pull the head down and voluntary muscles will become involved and increasingly contracted.

BREATH INFLUENCES POSTURE

There are many factors influencing the movement of the diaphragm. Muscular restrictions, blood chemistry, as well as the impact of the autonomic nervous system can all affect the basic respiratory pattern. When the diaphragm's movement is blocked, you have to use the other muscles to make room for the air. One such compensation involves the

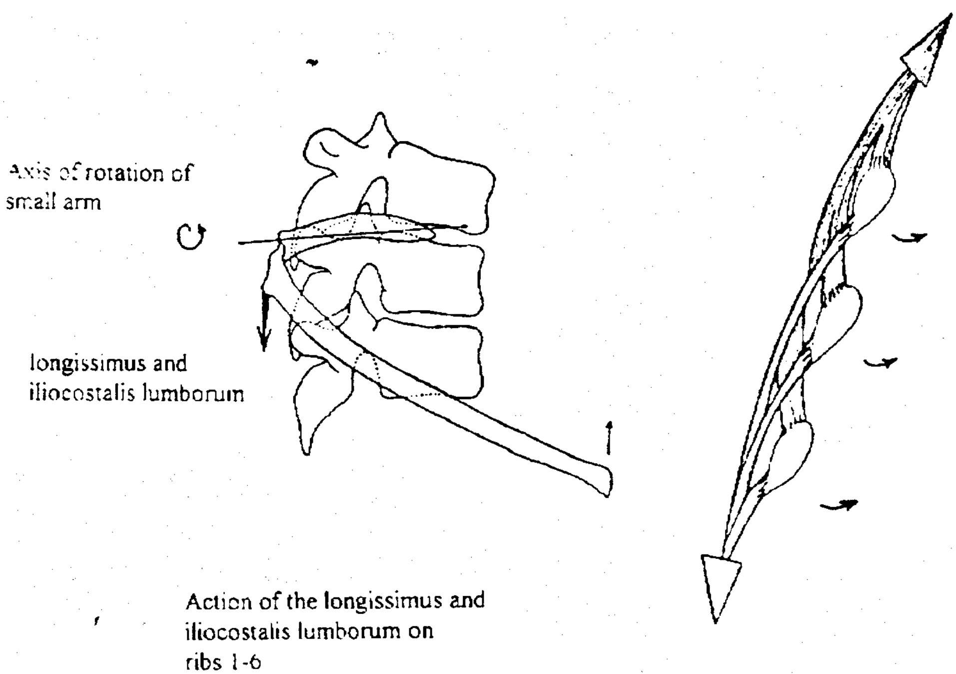


FIGURE 9B

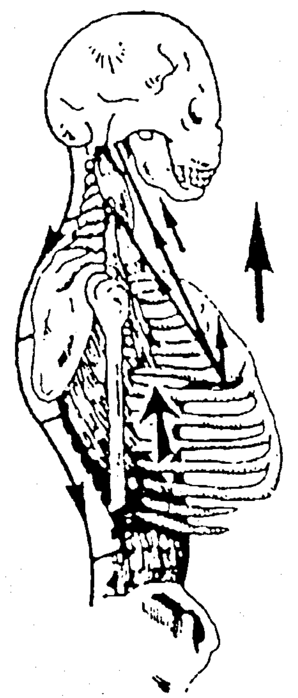


FIGURE 10: PRIMARY RESPIRATORY MECHANISM

crura and scalenes acting together. It results in a breath but also in chronic contraction of the spinal extensors. If these muscles become contracted because of involvement in the breath, then when the person tries to move the muscles are not free to release. When the spinal muscles act in their role as antagonists to another group of muscles, they will no longer easily or properly lengthen. The agonists will have to work much harder, requiring more energy, more contraction, and ultimately leading to a loss of length and freedom of movement in the body as a whole.

BREATH AND POSTURE INFLUENCE EACH OTHER

In the deep fascial chain that runs from the cervicals to the diaphragm, Bienfait distinguishes the mediastinal ligament and the prevertebral fascia.(**Figure 11a**[18]). Posteriorly, the spine and its long muscles and anteriorly, the mediastinal ligament, prevertebral fascia and diaphragm affect each other.

The mediastinal ligament and spinal muscles are like a bow and its string. The spinal muscles control the tension of the bow in the back, and the mediastinal ligament and crura control the tension of the string in the front. (**Figure 11b**[19]) If the spinal muscles are hypertoned, this can lead to shortening of the ligament in front. Conversely, shortening of the ligament in front will lead to hypertonicity of the spinal muscles. In turn, shortness in the prevertebral fascia is implicated in spinal problems such as scoliosis and Scheuermann's disease. (Bienfait, 1995, p.79)

IN PRACTICE

One way to work with this deep fascia is to ask for an inhalation, and a paradoxal exhalation, ie exhaling while pushing out the belly wall. As the client exhales, traction of the cervicals will have the effect of stretching the fascial chain in two directions.

LORDOSIS AND BREATH

- We can distinguish two kinds of hyperlordosis: one could be called "diaphragmatic," and affects the spine at T11,12, and L1,2.[20] It is the result of restricted or overused crura. The other hyperlordosis occurs primarily as a result of psoas contraction and affects the 3rd, 4th and 5th lumbars.

- Normally, the lumbar lordosis has to act in two capacities in breathing: it must be able to be stabilized in order to give the crura a stable point against which to pull; but it must also be free to aid in directing the down-

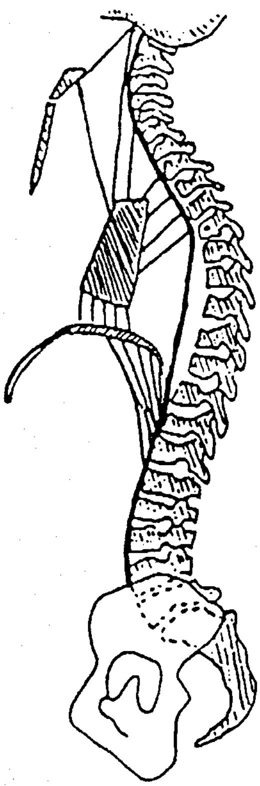


FIGURE 11A

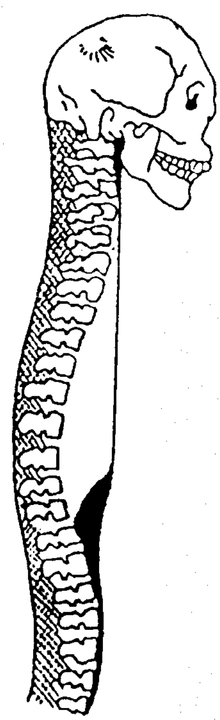


FIGURE 11B

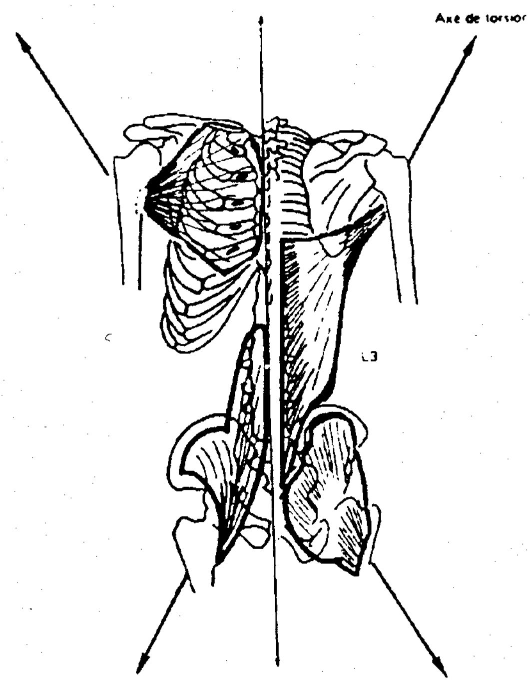


FIGURE 12

ward force of the diaphragm forward. The integrity of the lumbar lordosis—ie. the possibility of responsive movement—is one of the keys to the breath. We will consider lumbar stabilization from both a static and a dynamic point of view.

1. An increase in the proprioceptive sense of the body's weight activates the spinal muscles by activating the stretch reflex. The sense of weight will be further described in Part 3.

2. As we have seen, when the abdominal muscles, especially transversus, keep a slight tension in inhalation, they help the central tendon act as a fixed point. They also support lumbar stability.

3. From a dynamic point of view, the lumbars are given an extra means of stabilization by the opposing tensions of the latissimus and its opposite psoas. In movement, as one arm moves forward, the resulting tension in the latissimus dorsi exerts a counterbalance to the pull of the opposite psoas. The normal rotational influence of the psoas on the lumbars is thus controlled resulting in a dynamic stabilization. (**Figure 12**[21])

INHALE OR EXHALE?

As we have already seen, anatomy is far from an exact science. There is an ongoing debate over which muscles are primary in respiration. Also, in several cases, there is disagreement over whether a particular muscle functions in inhalation or exhalation. In part the disagreement about function stems from a disregard of the influence of postural patterns on muscle function. Which muscles are most active in breathing will depend on the person you are looking at. For some muscles, whether they perform as a muscle of inhalation or exhalation depends on the particulars of the individual's posture and coordination. Habitual postural patterns affect the position of various muscles which in turn changes their effect. Habits of function, such as initiating a movement with a particular contraction, also changes the function of other muscles. For example, from one person to another, serratus anterior can serve as a muscle of inhalation or of exhalation, depending on what structures act as the fixed point: Serratus inserts on the ribs and on the scapula. If the scapula acts as the fixed point, a contraction of serratus pulls up on the ribs, and thus serratus is recruited to help with inhalation. However, in the case of a person who chronically contracts rectus abdominis first, where the fixed point is anterior, serratus can become a muscle of exhalation. In people with posterior pelvises and shortened recti, a contraction of serratus will help in exhalation. Thus in order to understand the function of a specific muscle in respiration, it behooves us to examine carefully the structural and movement patterns of each individual.

IN PRACTICE

When as practitioners we look at the breath, we can distinguish two basic patterns: one of inhalation and the other exhalation. If we look at the basic postural set, we can also distinguish two basic patterns based on the relationship of the upper center of gravity (G') and the head of the femurs: In one, G' is anterior of the line connecting the femoral heads, in the other, G' is posterior. (**Figure 13**) Breath and posture are intimately related: Breath is a movement between the two patterns, a shifting from one to the other, forward to

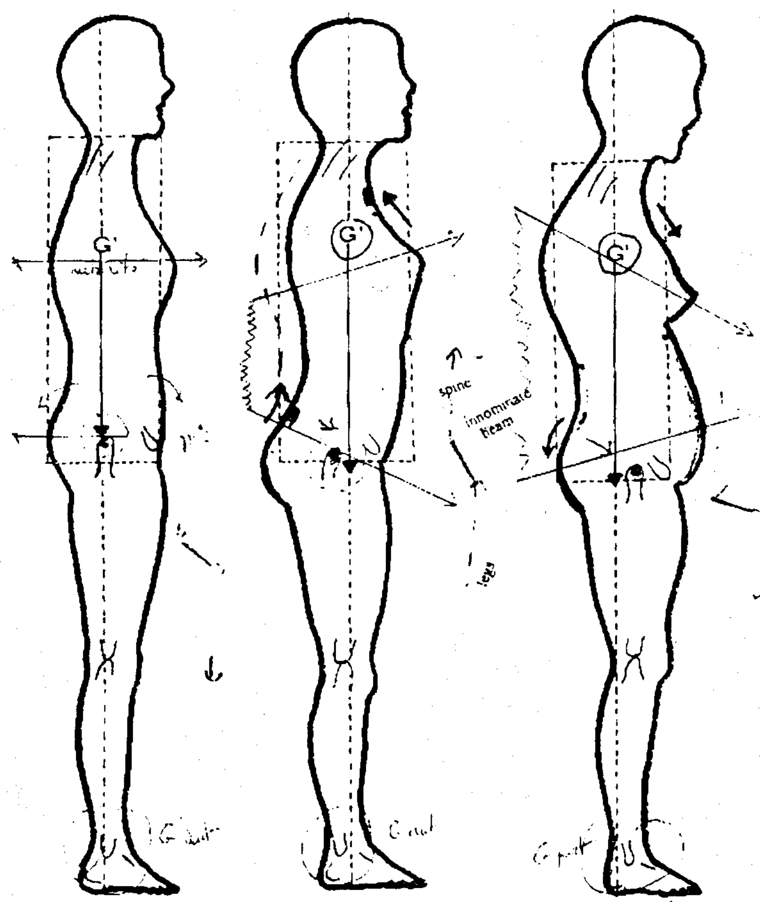
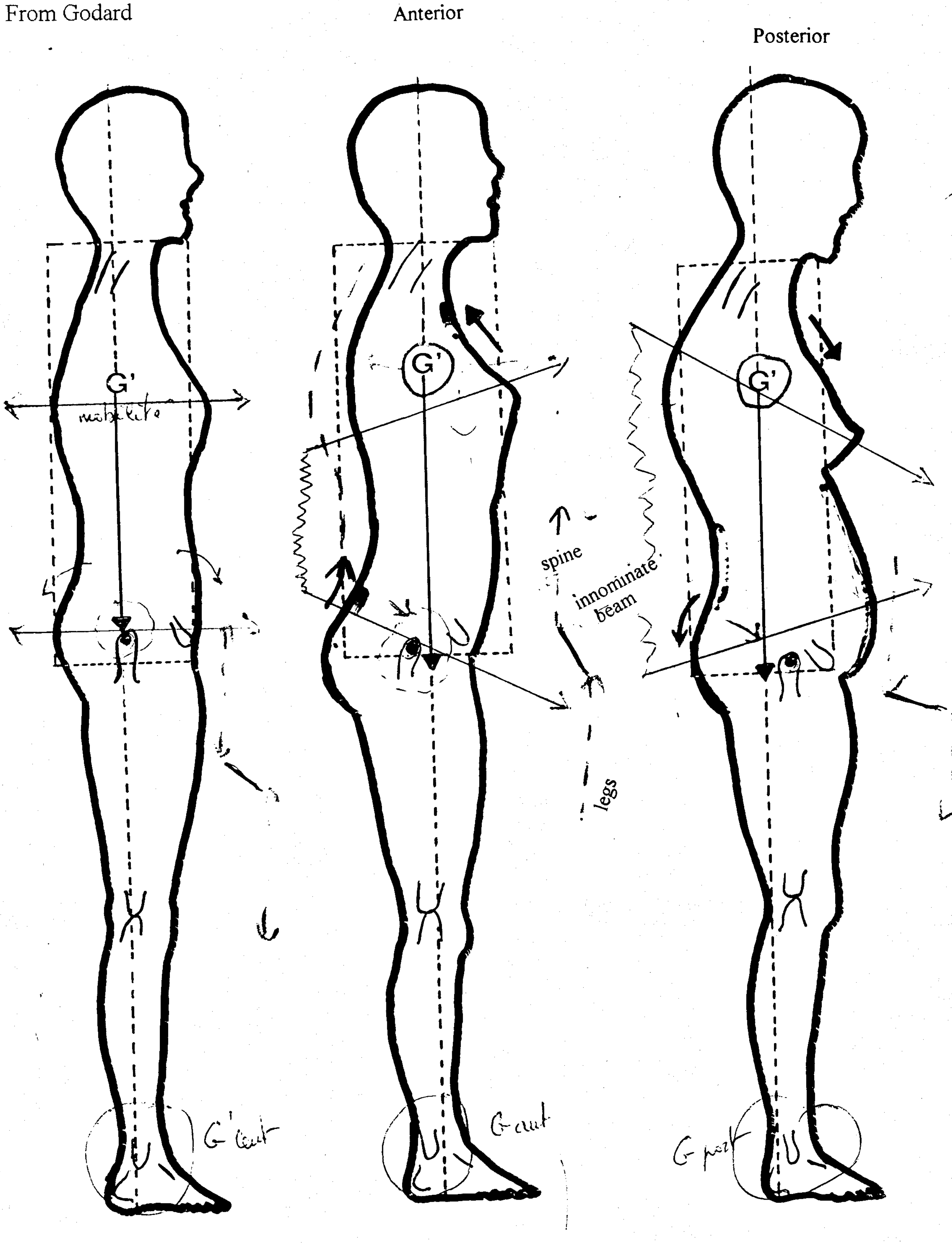


FIGURE 13

Figure 13
Basic Respiratory Patterns
From Godard



inhale, back to exhale. This gives us a dynamic definition of balance: the ability to move forward and back between the two gravity relationships—a different point of view from the one that equates balance with staying in the center. Any postural tension that prevents this forward and back movement will interfere with the breath. As well, a preference for inhalation or exhalation can be affected by working with the forward/back movement. To have this effect, we can start from a structural point of view by looking at the relationship of the body's masses: between the chest, head and pelvis; or from a functional view-point at the responsiveness of the spinal curves, cervical and lordotic.[22] In both cases, responsiveness of the spinal muscles will be one key.[23]

CONCLUSION

The biomechanics we have been exploring emphasize the inseparability of postural phenomena and breathing: The erector spinae, primary postural muscles, can also be considered primary breath muscles. The connective tissue sling that suspends the diaphragm can have a major effect on posture. Posture will also affect the work of specific muscles and the direction of the breath overall. Compensatory patterns provoke changes in breath and vice versa. For all these reasons, to understand an individual's breathing pattern it seems unavoidable to consider the postural patterns that interweave with it. But posture is not merely biomechanics. A person lives in constant relationship with an environment. Perception is a fundamental element in shaping that relationship. In the next section, we will look into this further. ❑

ENDNOTES

[1] Kapandji, I. *The Physiology of the Joints*, vol. 3. Churchill Livingstone, Edinburgh. 1974, p 149.

[2] The relationship of an individual's movement patterns and his/her perception of the surrounding space will be developed in Part 3.

[3] DeTroyer, A. Sampson, Michael, Sigrist, S. , Macklem, P., *The Diaphragm: Two Muscles, Science*, Vol. 213. 10 July 1981.

[4] Kapandji, 1974. p.147.

[5] Garlick, D. and Korner, P. (editors), The actions of the two muscles of the diaphragm, Frontiers in Physiological Research, Australian Academy of Science, p. 220-227.

[6] Busquet, Leopold, *Les chaines musculaires*, Tome II, Editions. Maloine. Paris, 1992 p 26.

[7] Bienfait, Marcel, *Fascias et Pompages*, SPEK. Paris 1995.

[8] Ibid.

[9] Souchard, Ph.E., *La respiration*. S.E.D. "Le Pousoæ" Saint-Mont, France.

[10] Ibid.

[11] Bienfait, 1995, p.79.

[12] Souchard, p.25.

[13] Kapandji, p.150.

[14] Souchard. Ph.E. Ibid.

[15] Pansky. B., *Review of Gross Anatomy*, Macmillan Publishing Co., NY 1979.

[16] Souchard, p.56: "The respiratory contraction of the erector spinae can reach as far as T1 and rib 1 via longissimus which goes to T1 and by iliocostalis lumborum whose two inferior heads (from the comonmass to the last 6 ribs and from the last six to the first ten) can contract independently of the superior head. This inspiratory fixation of the thoracic vertebral column allows the scapular inspiratory muscles to come into play." [translation mine]

[17] Souchard, Ibid.

[18] Bienfait, p.79.

[19] Souchard p.111.

[20] Souchard p.62.

[21] Busquet, L., p.73.

[22] The freedom of the knees, a virtual curve, will also be involved here.

[23] This is very much apparent in the traditional approach to the first session in Rolfing® structural integration. The goal is to affect the breath. The goal is accomplished by affecting the chest and pelvis relationship: by allowing them the freedom to move in relation to a changing gravity center.