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Integration of Movement/Posture:  
A Dynamic Adaptive Process Model

by

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### Abstract

Structural Integration (SI) is a process of manual therapy and sensorimotor education that aims to facilitate sustainable improvement in whole-body biomechanical functioning and a sense of ease and coherence in normal movement/posture. Traditional and currently widespread explanations for the physiological mechanisms underlying SI theory and practice have focused on notions of fascial tissue change and postural alignment, while recent challenges to these explanations advocate a shift away from these interests toward a neurocentric model that emphasizes movement, pain, and biopsychosocial factors. SI seeks to professionalize and become an auxiliary to healthcare, so it must embrace scientific standards while maintaining its nature as a whole-body somatic education practice. Since the phenomena with which SI is concerned are complex and multifactorial, any explanatory model that focuses on a single physiological mechanism or system is insufficient. This paper attempts to define key terms and proposes an explanatory model that portrays the integration of movement/posture as a dynamic adaptive process consisting of complex interactions between various physiological systems at multiple levels of scale, and each aspect of the model is examined in terms of scientific evidence.

## Integration of Movement/Posture:

### A Dynamic Adaptive Process Model

“It has been the object of myself and also of my teachers to direct and be guided by the compass that points to nothing but demonstrative truth. ... Give me anything but a theory that you cannot demonstrate” (Still, 1908/2000).

## **Introduction**

Structural Integration is a systematic and principle-based process of manual therapy and sensorimotor education. Its aim is to facilitate sustainable improvement in whole-body biomechanical functioning and a sense of ease and coherence in normal movement/posture (Bishop, 2002; Flury, 1989; Jacobson, 2011; Maitland & Sultan, 1992; Rolf, 1977/1989).

Traditional and currently widespread explanations for the physiological mechanisms underlying SI’s clinical outcomes have focused on notions of fascial tissue change and postural alignment (International Association of Structural Integrators, n.d.; Rolf, 1977/1989), while recent challenges to this explanation advocate a shift away from concerns about soft tissue and posture, and toward a neurocentric model that emphasizes movement, pain, and biopsychosocial factors (Hargrove, 2014). As SI seeks to professionalize and integrate with healthcare (International Association of Structural Integrators, 2015), more scientific standards must be adopted while maintaining its distinct nature as a somatic education practice rather than a therapeutic modality (Akins, 2016). This paper seeks to address the question: How might the SI profession’s explanation of structure and its integration be revised to more explicitly account for complex factors, and to what degree might such a model be scientifically verifiable?

## **Historical Background**

SI was originated by Ida P. Rolf, Ph.D., a biochemist who developed an interest in a variety of unorthodox body therapies. Rolf was a dedicated yoga practitioner and studied manual manipulation with several osteopaths. Her influences included the movement awareness practices of F. M. Alexander and Moshe Feldenkrais, and the somatic psychology of Wilhelm Reich. Equally-important intellectual influences included Alfred Korzybski's General Semantics, which explored limitations of human perception, and Buckminster Fuller's "tensegrity" concept, in which the balanced tension among parts of a structure are recognized as influencing the integrity of the whole. Rolf started practicing manual therapy sometime around 1940, and began teaching her method toward the end of that decade. The preceding historical background was summarized from Jacobson (2011).

SI enjoyed a surge of popularity throughout the 1970s, during which it came to be known by the nickname "Rolfing." In the wake of Rolf's passing in 1979, underlying rifts surfaced that led to the splintering off of various SI schools. A major departure occurred in 1988, when some of the Rolf Institute's senior faculty (including some of Dr. Rolf's first generation of instructors) and staff left to form the Guild for Structural Integration (Sise, 2005). The Guild sought to preserve a traditional approach to the work and teaching of SI, while the Rolf Institute was more progressive.

In 2002, the International Association of Structural Integrators (IASI) was formed to promote common professional standards and interests. The IASI currently has fourteen member schools, and "Rolfing" is now a trademarked term to be used only by graduates of the Rolf Institute. Many of the other SI schools have adopted their own exclusive terms including Hellerwork, Soma Neuromuscular Integration, and Kinesis Myofascial Integration, even though

the various SI approaches are more similar than different (Myers, 2004a; Myers, 2004b). While the basic strategies taught at the entry level differ somewhat between schools, the underlying goals and principles are mostly consistent (Maitland & Sultan, 1992; Myers, 2004a; Myers, 2004b).

### **Current Challenges**

**Internal calls for professionalization and healthcare integration.** Calls for cohesion between the different schools have come from within the SI profession, expressed as the desire for a standardized curriculum, protocol, and narrative that would allow for SI to align with social institutions, including established healthcare professions (Myers, 2013). The IASI (2015) has articulated a vision to move toward these goals and distinguish SI as a profession.

In the U.S., state governments usually determine the bodies which issue healthcare licensure. Structural integrators currently practice under various professional licenses, even though the goals and intentions of SI are distinct from the professions under whose licenses they practice. The most common license held by structural integrators is massage therapy, though some practice under physical therapy, occupational therapy, chiropractic, or other licenses. At the time of this writing, only one state in the U.S. specifically licenses structural integrators (Keeling, 2013), but does so under a broad title of “bodyworker” that is shared with the dissimilar practices of reflexology and “Asian bodywork therapy” (New Hampshire Department of Health and Human Services, n.d.). SI seeks to professionalize, distinguishing itself from these professions while positioning itself as a complementary adjunct (International Association of Structural Integrators, 2015; Jacobson et al., 2015). However, bitter disagreements have ensued both within the SI community and in interactions with other professions based on

misunderstandings around practice scope and intentions. The content of these disagreements will be described in the following sections.

To realize its goals and better align with healthcare, the SI profession must embrace standards of accountability common to healthcare professions, including a grounding in evidence and science, while remaining true to its nature as a method of whole-body somatic education distinct from therapy (Akins, 2016). One challenge in achieving these goals is that clinical research methodology is better-suited to evaluate the specific therapeutic outcomes sought by the rehabilitation professions, such as physical therapy and occupational therapy. Another challenge is that long-standing hypotheses regarding the underlying physiological mechanisms responsible for clinical outcomes are being confronted with newer research.

**Disagreement regarding explanatory models.** Traditionally, SI has considered itself a method of fascial manipulation and somatic education that often results in a more vertically-oriented postural alignment (Rolf, 1977/1989), a view which persists as the dominant explanatory model (IASI, n.d.). Some practitioners suggest abandoning these long-standing interests in fascia, posture, structure, and biomechanics in favor of a neurocentric model emphasizing movement, pain science, and biopsychosocial factors (Hargrove, 2014). Concerns exist within the SI community that the two approaches are not mutually exclusive, and a widespread shift toward neurocentrism and pain treatment risks abandoning the work's essence as a whole-body somatic education practice and ignoring a recent surge in fascia research that could offer useful insights.

**External criticism of posture/structure/biomechanics.** Meanwhile, clinical consideration of human structure is under attack from those who dismiss so-called postural/structural/biomechanical (PSB) models wholesale. One oft-cited critic (Lederman,

2010) declares the “death” of an apparent PSB model in manual in physical therapies, citing over one-hundred clinical studies to demonstrate that PSB factors do not correlate with low back pain, surmising that PSB factors would also fail to correlate with other pain conditions. Some have taken arguments such as this to mean that clinicians should rarely or never concern themselves with PSB factors.

It should be noted, however, that many of these criticisms come from outside the SI community, often from practitioners who are primarily concerned with rehabilitation and pain treatment. Though there may be some overlap with rehabilitative approaches, SI has distinguished itself as a whole-body somatic education process since its inception (Rolf, 1977/1989). Since chronic pain is a common complaint of SI clients with many anecdotes of successful outcomes, it would behoove the SI profession to heed these critics to some extent by including modern pain science as part of a standard entry-level curriculum. Critics also sometimes assume that all practitioners who concern themselves with PSB seek to impose “utopian” postural ideals on their clients by striving for perfect alignment (Lederman, 2015). Though outliers may exist, Ida Rolf herself discouraged such notions, recognizing the impossibility of perfection due to the inherent asymmetry of the human form (1977/1989, p. 148).

**Culminating isolation of SI.** The rifts described between various factions within the SI community and between the SI profession and critics outside the profession, along with a failure to clearly articulate the work in a relatable, scientific manner have contributed to a disconnect of the SI community from established healthcare professions and the public. As a profession, SI remains relatively obscure.



### **Meeting the challenges**

To meet the aforementioned challenges, the SI community must define its terms, justify its value, and account for its interventions in as clear and scientific a manner as possible.

Definition of terms and development of an inclusive explanatory model that, instead of focusing on a single physiological system, better accounts for complex interactions between systems, is the intention of this paper. Clinical interventions will not be addressed here, but should be investigated at a later time.

### **Methods**

This project will consist of several steps:

1. Define terms and articulate theory. There have been attempts to define terms and articulate theory from within the SI community (Bishop, 2002; Flury, 1989; Maitland & Sultan, 1992; Rolf, 1977/1989). However, these efforts do not examine their hypotheses in terms of science, presenting a challenge in communicating their concepts beyond SI circles. Flury (1989) accused practitioners of too often using the terms “structure” and “integration” as impressive-sounding buzzwords to obscure a shallow grasp of its underlying concepts. A definition of terms that integrates considerations from these various attempts is needed.
2. Develop an inclusive model. Flury (1989) offered a model that can be developed by a more explicit treatment of neurological factors and scientific analysis of its hypothesized mechanisms. In his book *The Science and Practice of Manual Therapy* (2<sup>nd</sup> ed., 2005), Lederman synthesized numerous mechanistic studies to illustrate how manual therapy might affect change in the neurological, tissue, and psychosocial dimensions. These will be considered as foundational sources for the current project.

3. Scientifically evaluate the component relationships. Hypothetical relationships portrayed in the model will be reviewed in light of scientific literature.

It is my hope that a science-based model consistent with the goals of SI will help organize the internal debate, help unite the factions, help facilitate engagement with other professions, and help support the ongoing development of SI as a science-based profession while reaffirming its somatic roots.

## **Definitions & Theory**

### **Defining Structure**

Flury (1989) offered the most thorough attempt to define foundational terms that I was able to locate in the SI literature. He offered two definitions of structure: a broad definition, and a narrow one. Flury broadly defined structure as a mental construct accounting for the spatial interrelationship of the body's parts in the context of mechanical forces imposed by (a) gravity, (b) the soft tissues, and (c) neuromuscular tension. He recognized that neuromuscular tension is not part of the "flesh and bone" structure per se, but it is rather a functional element imposed on the muscles by the nervous system.

This leaves us with a second, narrower definition of structure as the soft tissue "structural body" which the force of gravity acts upon. Flury (1989) loosely defined fascia as "all collagenous fibrous dense elements which are of mechanical relevance," and used the term "fascial network" to specifically refer to fascia in terms of its whole-body continuity and organizational function. As such, the fascial network may be considered the structural body's primary component, that which lends the structural body its wholeness. Flury (1989) also considered bone, loose connective tissue, fat, the internal organs, and muscle as part of the

structure, soft tissue “islands” within the fascial network. Besides gravity and neutrally-mediated influences, he noted that the structure is affected by injury, disease, and nutrition.

### **Defining Integration**

In Flury’s exploration of the term “integration” (1989), he noted that a system becomes whole when order predominates in that system, and as the human body organizes around a vertical line in relation to gravity, then that axis may be considered an organizing principle for the structural body. Flury considered that the parts and segments of the body’s structure organize within the structural body, which itself organizes in relationship with a particular environmental element: the gravitational field.

Bishop (2002) exposed another aspect of integration: the “emerging sense of order” that typically arises in the client’s felt sense of their body throughout the course of SI work. The client may feel vaguely “better,” he notes, but if they don’t demonstrate an enhanced sense of order in their bodies, such as improved ability to discern between free and restricted joints, then he questions whether integration has truly taken place. According to Bishop, a well-integrated client should be able to articulate, in their own language, a sense of internal coherence he terms “embodiment.” This is clearly not a precise endeavor. To help the client internalize this sense of embodiment, the SI practitioner (a) fully engages the client in the process, (b) encourages them to describe their experience in their own words, and (c) empowers them through education on how to apply their refined somatic awareness to common uses like breathing, sitting, and walking, as well as activities enjoyed by the individual. Embodiment involves processes mediated through the nervous system.

**Defining Structural Integration**

Rolf (1989) described SI as “a system that induces change toward an ordered pattern.” Joining this with the concepts of Flury (1989) and Bishop (2002), structural integration involves the emergence of order in the human soft tissue and sensorimotor systems. Order reveals itself externally through the visible orientation of the body along a vertical axis in the gravitational field, and through articulation of internal perceptions of (a) spatial orientation to that axis, and (b) a sense of coherence in this experience. This lived experience manifests in the soft tissues of the body, as mediated through the human nervous system, in the movement/posture qualities of the individual. Psychosocial factors mediated through the nervous system include “emotional and affective state at the moment, the degree of vigilance, the conscious or not conscious intention of what a person wants to communicate or withhold from being communicated, [and] volition” (Flury, 1989).

**Importance of Integration**

If more integration is better, and integration involves orienting to a vertical axis, then this might imply that a perfect alignment with that axis should be pursued. Yet, Rolf herself thought otherwise:

Bodies are not perfect; the precise symmetrical planes of theory are not actualized in nature. Differences of habitual muscular use (right- or left-handedness) as well as visceral structure (liver complex on the right side compared to heart and stomach on left) preclude literal symmetry. Nevertheless, to ensure reasonable physiological health, weight-bearing must approach a practical balance. (1977/1989, p. 148)

Rolf suggested that a practical balance – not a perfect one – be pursued. While practical sufficiency may represent a base level of integration, Rolf also referred to a “joyous radiance of health” and vitality (1989, p. 16), expanding the domain of integration beyond mere practicality.

Practicality implies the functional range and efficiency to meet one’s needs. An integrated body allows for a wider range of movement, and therefore more options for functional adaptation (Flury, 1989). Adaptive needs are idiosyncratic: as Flury observes, the order of a ballet dancer is typically similar to that of other ballet dancers, while being very different from the order common to body builders.

Adaptability implies an energetic economy that is, at least, sufficient to meet demands. To this end, Rolf (1990, p. 40) characterized SI as a process of learning to use one’s body more efficiently, with less unnecessary tension, in which the structural integrator plays the role of educator. Though symptomatic relief may occur, this is not the goal of the process Rolf distinguished from relief and restoration of a pre-symptomatic state, which she considered the realm of therapy.

### **Quantifying Integration**

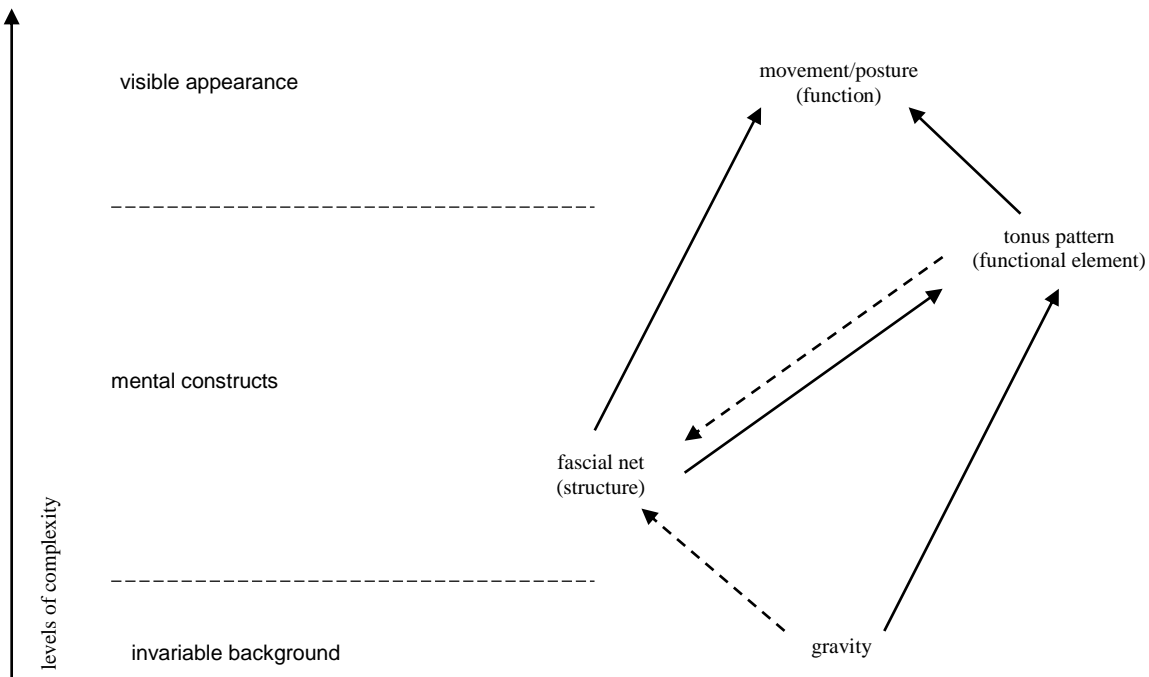
At what point does a body transition from being random to being integrated, and how does an SI practitioner assess when and to what degree an integrated state has been achieved? Flury (1989) argues that structure is not observable from spatial relationships depicted in static images, as the dynamic functional pattern imposed on the structure via the nervous system is constantly changing. He describes the ideal neuromuscular tonus pattern to be that which requires the least amount of tension, its minimal energetic demand maximizing ease. This exemplifies structural integrity, and Flury imagines its ideal as a point at which any less neuromuscular tension would cause collapse, and any more would require greater energetic

demands than necessary. This basic level of tension at this point has qualities of (a) spatial distribution and (b) amount, or rate, of energy consumption. Even though base tension is a moving target even in apparent stillness, any movement away from this point would demand tension elsewhere in the body to restore its structural integrity. Muscles shorten as they contract, compressing the body and increasing pressure in the joints, restricting movement.

As simplicity is exemplified through order, integrated bodies appear more similar in that they orient more closely to a simple vertical axis, while random structures are more varied, complex, and less ordered. Flury (1989) notes that Rolf equated “integrated” with “normal,” but claims that she didn’t mean normal in the sense of “average” or even “natural.” She considered normalcy a “Platonic idea” (Rolf, 1989, p. 16) that could be approximated at best, with SI bringing the client closer toward the ideal. Flury (1989) considered Rolf’s ideas that a well-integrated body does not resist its own functional efforts (Rolf, 1990, p. 158), and that the turning point toward integration can be noticed when clients seem to have progressed, rather than lost some of the gain from the previous session. Flury (1989) offers an example of a cheaply-made bookshelf that is unstable until books are placed on it, at which point it either stabilizes under the weight, or collapses. The exact point at which minute differences between the stabilizing and collapsing structures make for either result is impossible to determine beforehand.

### Flury's Attempt to Illustrate SI Concepts

Besides the definitions described above, Hans Flury (1989) attempted to illustrate some core SI concepts. Flury's work will be summarized here, as it serves as a foundation for the current project. The diagram below combines two of his diagrams for conciseness.



*Figure 1.* Flury's representation of some SI concepts (1989).

In Flury's own words, "the arrows indicate strong influences but not exclusive determination. Dotted arrows are for long-term influences which are not relevant for short-term considerations."

**Gravity.** According to Flury, gravity is the "invariable background" affecting different parts of the body differently according to their configuration in space at a particular time. He claims that gravitational force affects the body's structure over the long-term, and the body's nervous system more immediately.

**Fascial net (structure).** Flury's definitions of "structure" was outlined in the previous section, "defining structure." He emphasizes the fascial network, which he defines as "all collagenous fibrous dense elements which are of mechanical relevance," for its whole-body connective properties. Flury also includes bone, loose connective tissue, fat, muscle, and internal organs as part of the soft-tissue structure. Structure is influenced by gravity, and is affected by the neural tonus pattern over both the short and long term such that the shape of structure may be altered. Structure is also influenced by factors such as nutrition, disease, and injury.

**Tonus pattern (functional element).** This is Flury's term for neuromuscular tension, which he describes as an energy-consuming factor that is both constant and dynamic. It is a functional influence that imposes a constantly-changing pattern of contraction on the structure. The tonus pattern of a given moment is influenced by non-structural factors such as emotional state, autonomic stimulation, body language, and volition.

**Relationship between structure & function.** The arrows between the structure and the functional element in Flury's diagram illustrate their interrelationship. The structure, via the tensional properties of the fascial net that continuously permeates the entire body, affects the tonus pattern by allowing/disallowing mobility, thereby determining the degree of muscular tension required for posture/movement. The less muscular tension required to achieve a given movement/posture, the greater the integrity of the structure. A certain degree of muscular tension is required to counteract gravity's influence on the structure. Too little muscular tension and gravity pulls the structure into collapse, while an inefficiently organized structure will require more tension than would otherwise be necessary.



**Movement/posture (function).** From all of the previously described elements emerges the function of movement/posture. The tonus pattern of movement changes quickly, while that of posture is maintained so long as a posture is held, according to Flury.

**Criticism.** Flury's attempt to illustrate these core SI concepts appears to have been based on his own conversations with SI colleagues and readings of SI literature, as no sources were cited. At the time of its writing in 1989, this may have been sufficient in that it offered a philosophical exploration of key terms and concepts. Each relationship between elements of the diagram represents a hypothesis, and examination of these hypotheses in light of scientific research is long overdue.

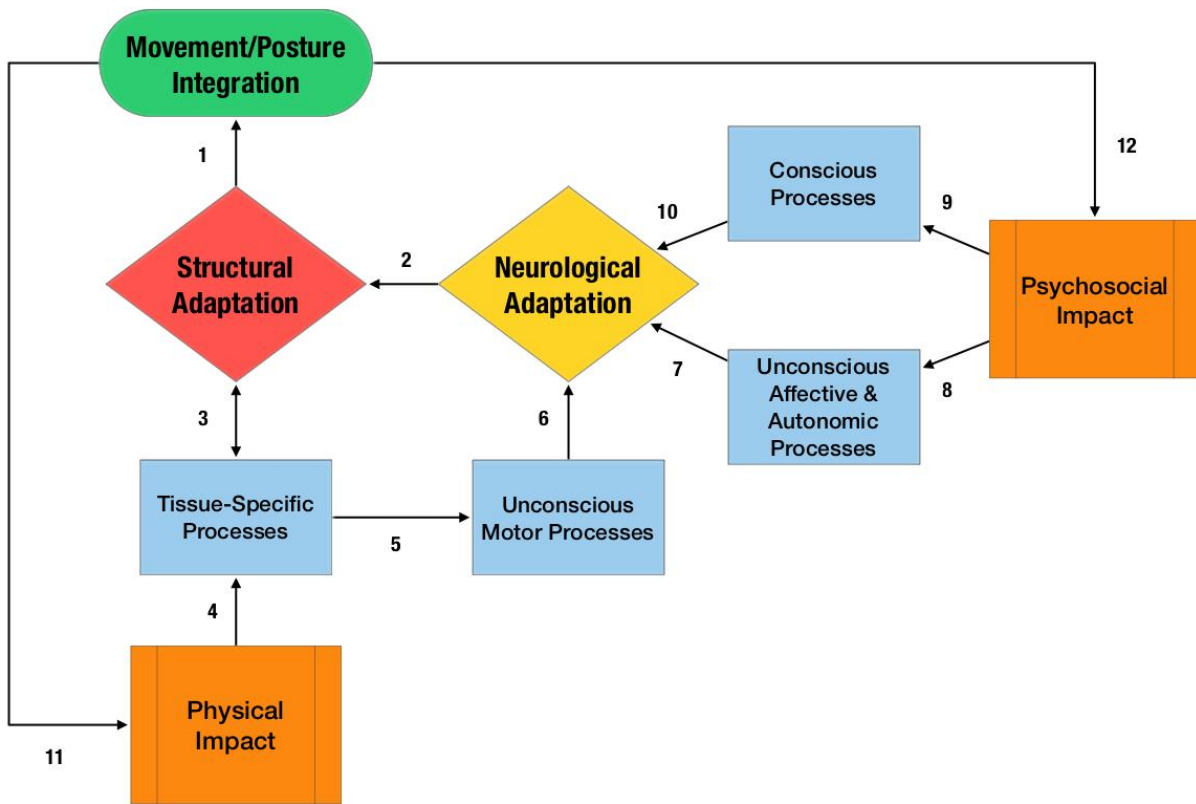
Some modern critics accuse SI of traditionally ignoring the nervous system. However, Flury's model did account for neural influences, though his account was more implied than explicit. "Tonus pattern" is just another way of describing the neural tension exerted upon the musculature which animates the body's structure, resulting in movement/posture. Flury also listed emotional state, autonomic stimulation, body language, and volition as factors contributing toward the tonus pattern – all functions of the nervous system. It should be noted that Flury was only attempting to organize established assumptions within the SI community, and these included nervous system functions. Flury places emphasis on the musculature, but in a revised model, neural influences should be more explicit.

Finally, Flury's diagram may contain more information than necessary for purposes of describing the phenomenon of integrated structure in a scientific manner. Denoting levels of complexity is not necessary for this purpose, nor is signifying short-term and long-term influences, or distinguishing visible appearance, mental constructs, and invariable background from each other. A revised diagram should focus on categorizing the physiological phenomena

relevant to the integration of human structure narrowly enough to make accurate and clinically-appropriate distinctions, but broadly enough to maintain a practical simplicity without omitting any key elements.

**A Modern Attempt to Visually Describe the Integration of Movement/Posture**

Figure 2 shows a causal diagram which builds upon Flury’s work.



*Figure 2: Integration of Movement/Posture: A Dynamic Adaptive Process*

Rather than describing the general phenomenon of movement/posture, the emphasis is placed on the emergent quality of integrated movement/posture at the level of the organism, represented by the green oval. Adaptive functions at the organ system level are illustrated by the two diamonds. The red diamond encompasses Flury’s narrow definition of structure, and it is through its adaptive function that movement/posture is directly expressed. That expression, of

course, is influenced by neurological adaptive function, represented by the yellow diamond. The blue boxes represent organ and tissue-level physiological processes which culminate in adaptive functions. The orange boxes represent environmental interfaces which directly impact our physiology at the molecular and cellular level.

Each numbered link between items in the diagram represents a relationship. The following section will briefly explore scientific research concerning each.

### **Physiological Component Relationships of Movement/Posture Integration**

#### **Link 1: Movement/Posture Integration represents a quality of Structural Adaptation.**

Integration is defined here as a quality of movement/posture that embodies ease, fluidity, presence, wholeness, and efficiency (Bishop, 2002; Flury, 1989). This quality is often considered to appear well-organized and aesthetically pleasing. Highly-integrated movement is commonly observed in elite athletes, dancers, and musicians, though it is possible that anyone can develop this quality to some extent. Structural Adaptation (SA) is defined here as the result of systemic functions contributing toward movement/posture directly via the soft tissue of the body, using Flury's (1989) narrow definition of structure: primarily muscle and fascia, but also bone, loose connective tissue, fat, and internal organs, all residing within the continuous whole-body fascial network, in response to muscular contraction stimulated by the nervous system.

Integration may be considered as a macro-level expression emerging from smaller scale tensegrity functions within the body's structure, most directly from the myofascial and skeletal systems. Tensegrity systems are characterized by continuous tensional forces interacting with discontinuous compressional forces, resulting in stability (Swanson, 2013). As applied to living systems, we will use the term "biotensegrity." Though few experimental studies have examined biotensegrity at the level of the organism (Kassolik et al., 2009), the principle of biotensegrity

has helped explain how complex hierarchical organisms can function as integrated mechanical systems and has been used to explain a broad range of phenomena across various systems and species (Ingber, 2003).

Swanson (2013) summarizes the theory of biotensegrity at the level of the organism, the bones acting as discontinuous struts or spacers resisting compression, while tensional forces are provided by the muscles, tendons, and ligaments. The fascial network can function in both ways, resisting compression and generating tension. The compressional and tensional elements interface at points of focal adhesion, prestressing the biotensegrity system. Movement occurs when a muscle increases the amount of tension within a local area of the prestressed system.

Besides movement, stability is another property of prestressed biotensegrity systems. Chen and Ingber (1999) use the spine as an example. If the spine were to function only as a column of support, they argue, it would have to be much wider and heavier in order to bear the increased compressive forces. Instead, the spine is comprised of numerous vertebrae of varying sizes being prestressed by an even greater number of muscles and ligaments pulling in all directions. This design allows the spine to be both dynamic and stable, a key feature of well-integrated movement.

### **Link 2: Structural Adaptation is influenced by Neurological Adaption.**

Neurological Adaptation (NA) is defined here as the result of any systemic neurological process that influences the human structural system, thereby affecting the organism's Structural Adaptation. According to Selye's theory of general and local adaptation syndromes, adaptive functions result from physiological processes in response to physical and psychosocial stressors in effort to restore homeostasis within the organism (Chaitow, 2013; Straub, 2014). While short-term stressors can have positive effects, long-term stress may result in an overwhelming of the

adaptive capacity, and eventually pathology. The most obvious and relevant instance of SA being influenced by NA is the phenomenon of contraction and relaxation in skeletal muscle, which Flury (1989) described as the neuromuscular “tonus pattern,” the functional element imposed upon the structure.

**Pathway 3-4: Structural Adaptation is also influenced by Tissue-Specific Processes, and Tissue-Specific Processes are influenced by Structural Adaptation. Tissue-Specific Processes are influenced by Physical Impact.**

SA is also influenced by Tissue-Specific Processes (TSPs) occurring at the tissue level. TSPs are distinguished as mechanically-stimulated biochemical processes which function independent from direct neural influence. Neural influence does occur indirectly, via SA. It is possible that TSPs may be influenced directly by neural processes, though I am unaware of any such processes, and if they exist they may or may not pertain directly to the integrative qualities with which this diagram is concerned.

*Mechanotransduction* describes the process of physical forces being translated by cells into biochemical responses (Chaitow, 2013; Paluch et al., 2015). Burkholder (2007) offers two common examples of mechanotransduction: strengthening of skeletal muscle in response to increased mechanical load, and increased flexibility in response to stretch. Even though numerous biochemical effectors have been identified, the complex interrelationships between mechanical signals with electrical, metabolic, and hormonal signals make it difficult to isolate exactly which responses occur directly in response to mechanical stimulation (Burkholder, 2007).

Lederman (2005) identifies stiffness and restricted range of motion as common clinical presentations that partially result from tissue-specific processes. Non-traumatic, long-term

adaptive tissue changes may contribute to these complaints. For example, using a muscle repetitively within a reduced range of motion has been shown to result in the muscle shortening due to a reduction in the number of serial sarcomeres, along with an accumulation of connective tissue within the muscle (Baker & Matsumoto, 1988; Williams, Catanese, Lucey, & Goldspink, 1988). This shortening can be likened to removing links from a chain, while movement and stretching stimulate mechanotransduction, which increases synthesis of muscle and connective tissue, allowing for adaptive elongation of the chain (Lederman, 2005).

SA may also feed information back to TSPs. Chen (2008) notes several studies in which mechanotransduction has been shown to take place in the absence of externally-applied forces, in response to endogenous mechanical forces within the cytoskeleton.

**Pathway 4-5-6: Physical Impact influences Tissue-Specific Processes, which influence Unconscious Motor Processes affecting Neurological Adaptation.**

The impact of physical force is not directly sensed; rather, it registers as “changes in length, shape, strain, position, or the lifetime of biomolecular interactions” (Katta, Krieg, & Goodman, 2015). As such, this path of the diagram begins with Physical Impact influencing TSPs, which stimulate neurological processes and their resulting adaptations.

The cerebellum is well-known for its role in the refinement and coordination of movement/posture. It affects adaptation by coordinating elemental movements into more complex, synergistic movements (Thach, Goodkin, & Keating, 1992) through the mapping, analysis, and prediction of motion trajectory (Baumann et al., 2015). It does this in response to proprioceptive input transduced by receptors in the various soft tissues of the body (Gandevia, 2014), expressed in link 5 of Figure 2. Other inputs include optic flow processed through the visual system, sound waves processed through the auditory system, and acceleration sensed

through the vestibular organs, all of which are combined into a coherent representation through neural processes of sensorimotor fusion (St. George & Fitzpatrick, 2011).

**Pathway 7-8: Neurological Adaptation is influenced by Unconscious Affective and Autonomic Processes in response to Psychosocial Impact.**

This pathway suggests that psychological and social events can stimulate affective and autonomic physiological processes which result in neurological adaptations that influence the body's structure. The limbic system is where psychoemotional and physiological processes are integrated in the brain, with psychoemotional experience resulting in somatic expression through physiological responses carried out by the autonomic, neuroendocrine, and motor systems concurrently (Lederman, 2005). Emotional, flight-or-flight reactions are automatically stimulated by projections from the limbic hypothalamus to the brainstem where, along with the spinal cord, sensorimotor integration allows for unconscious refinements to variables such as postural muscle tone and limb movement rhythm which overlay the basic movement patterns determined by neural networks in the spine known as central pattern generators (Takakusaki, 2013). The central pattern generators are represented by link 6 in the diagram, while the refinements added by the limbic hypothalamus are represented by link 7.

**Pathway 9-10: Neurological Adaptation is influenced by Conscious Processes in response to Psychosocial Impact.**

This pathway is concerned with goal-directed volitional processes that affect movement/posture. These processes are engaged through both guided and self-directed, "active" movement and exercise which systematic reviews have suggested are more effective for conditions such as acute and chronic neck pain (Lederman, 2005, p. 164). The cerebral cortex, particularly its premotor area and supplementary motor areas, issues the motor commands which

drive volitional processes. The premotor area responds to sensory input, primarily visual, while the supplementary motor area is thought to support refinement of the actions initiated by the premotor area (Takakusaki, 2013).

It is important to note that none of these pathways act alone. As Takakusaki (2013) points out, whether movement/posture is initiated by emotion (8-7-2-1 pathway) or volition (9-10-2-1 pathway), it is accompanied by automatic motor processes (4-5-6-2-1 pathway).

**Link 11: Movement/Posture Integration influences Physical Impact.**

This link suggests that well-integrated movement/posture enhances the body's resilience to physical forces, such as gravity. One way this resilience might show up is in the degree of efficiency in movement. In engineering, efficiency is defined as the ratio of the total amount of work performed to the energy expended to accomplish the work. Verdaasdonk, Koopman, and van der Helm (2009) note that the amount of work necessary to accomplish a task includes compensation for "damping losses" of energy. In walking, for example, this loss is due primarily to impact when the heel meets the ground. They found that the best way to enhance gait efficiency is by maximizing the sensory feedback which allows central pattern generators to adapt to environmental demands. Therefore, well-integrated movement is that which receives information about its environment in order to respond in such a way that its impact is minimized.

**Link 12: Movement/Posture Integration influences Psychosocial Impact.**

This link suggests that a sense of ease and coherence in one's body enhances somatic resilience to psychosocial stresses, such as state anxiety. Some research exists to support this relationship.

One method of cultivating bodily ease and coherence known as the Alexander Technique (AT) uses movement re-education and awareness of habitual body use patterns to release



unnecessary neuromuscular tension. A systematic review of studies that examined the effects of AT on the anxiety, posture, music performance, and respiratory function of musicians concluded that AT may improve performance anxiety in musicians, though results for the other effects were inconclusive (Klein, Bayard, & Wolf, 2014). Another study found that yoga, also a means of improving movement/posture integration, reduced performance anxiety in adolescent musicians (Khalsa, Butzer, Shorter, Reinhardt, & Cope, 2013), and meta-analyses have suggested that yoga may benefit anxiety and stress, among other conditions (Bussing, Michalsen, Khalsa, Telles, & Sherman, 2012; Li & Goldsmith, 2012). Studies of SI (Weinberg & Hunt, 1979) and the Feldenkrais Method (Kerr, Kotynia, & Kolt, 2002; Kolt & McConville, 2000) have shown promise for the effectiveness of their approaches in helping to relieve state anxiety. It is important to note that most of the studies cited in this section called for higher-quality research, with quantitative assessments, larger sample sizes, and better controls, before firm conclusions may be drawn.

### **Conclusion**

The diagram proposed in Figure 2 is not intended as a final word on what integrated movement/posture is, or how it emerges. Rather, it is intended as a foundation upon which a scientific description of the complex phenomenon of movement/posture integration might be developed. It offers a tool by which we might collect and organize scientific information, which is necessarily reductionist, that is relevant to somatic practice, which is necessarily holistic. It is simply a means of achieving more focused professional discussions about details without sacrificing our vision of the complex whole. The elements and their relationships can, and should, be thoroughly reviewed and modified, if necessary.

The descriptions of the links and pathways in this paper only offer brief introductions to some relevant research for each topic. A thorough review for each element and relationship was beyond the scope of the current project. This may be the subject of future papers, perhaps by other authors.

The diagram in Figure 2 is not specific to any particular clinical approach. It is most relevant to somatic practitioners of various forms, though it could also be used by rehabilitation professionals, dancers, or anyone interested in accounting for or describing the complex, multifactorial nature of what it is to experience the physical reality of life in human form. Though the idea of movement/posture integration is explained mostly from the perspective of a Structural Integrator, no attempt is made here to explain, account for, or justify any particular technique or intervention. The main concern here is a description of structure and its integration that lends itself toward an explanatory model that is sufficiently specific, yet holistic. Examination of strategies for movement/posture integration may offer opportunity for future studies.

A standard means of quantifying movement/posture integration is needed, if its study is to develop. While standing postural assessment may be useful in illustrating that change has occurred, functional assessments (such as standard range of motion assessments) may provide more clinically-useful information in that they are more quantifiable (in terms of degrees of range) and more relevant to the client's daily life experience, since one can go from efficient standing posture to inefficient movement patterns in an instant. Still, if functional economy is a main goal of somatic practices, then a more specific measure of effort expended is needed. This information could then be compared in relationship with different variables expressed in the Figure 2 diagram.

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