

Adaptive Psychomotor Learning and the Young Child

Tara Fenamore

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Abstract

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This dissertation aimed to spotlight a prevalent issue in lifespan development and learning that is under-appreciated in educational research and practice. Many children in the United States and abroad learn to coordinate fundamental motor actions with maladaptive postural deviations that impose excessive stress and strain on musculoskeletal structures. The stabilization of maladaptive movement patterns during a critical period of psychomotor development produces non-structural sagittal misalignments of the spine, including Forward Head Posture (FHP) and Postural Thoracic Hyperkyphosis. Moreover, the reproduction of maladaptive movement patterns may be associated with the development of musculoskeletal disorders and associated chronic pain conditions that impact the global public.

The researcher employed philosophical synthesis to describe and explain the adverse effects of maladaptive postural coordination on lifespan human development while amplifying its origins in early childhood. Principles from the traditions of Pragmatism and Dynamical Systems Theory are applied to develop a positive model of adaptive psychomotor learning and development that is seamlessly integrated into Early Childhood Education curriculum and learning formats. To this end, Early Childhood Education should structure learning experiences to guide the discovery and stabilization of adaptive movement patterns that (1) accomplish fundamental action goals in the here-and-now and (2) support the health of the changing neuromuscular-skeletal system across its lifetime. Therefore, the researcher proposes a model of early learning in which the study of the body-self is seamlessly woven into all aspects of the general ECE curriculum.

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Dedication

Dedicated to the Memory of Ted and Themis Dimon

Introduction

“Sit up straight.” “Don’t slouch.” “Put your shoulders back.” “Pretend you’re squeezing a dime between your shoulder blades.” “Hold a broomstick above your head, pull the broomstick behind your back, lower your arms as much as you can, and hold it there for several minutes—every day.” Social directives as these littered my childhood and adolescence like the trails of breadcrumbs heedlessly strewn across a forest floor in fairy tales. They flitted in my stream of thought like little birds alighting to the ground in quick, tentative bursts to consume the discarded crumbs. A school nurse diagnosed me with Postural Kyphosis when I was in third grade after a routine screening. I remember her cold hands palpating my spine as she administered the Adam’s Forward Bend Test (Fine & Stokes, 2018). She conveyed the instructions with the monotonous tone of someone who had palpated hundreds of developing vertebral columns, the central axis of children’s restless motor systems: “Stand up as straight as you can, keep your feet together, now bend over, don’t bend your knees, yes, keep them straight, and let your arms hang at your sides, yes, good. Now, slowly come back up, wait, let your head come up last, good.”

It was a mild case, and I don’t recall being referred to a specialist for any kind of medical or therapeutic intervention. Instead, the nurse put me on a watch list of children whose musculoskeletal development would be more regularly assessed, and in my case, to evaluate whether the Postural Kyphosis would develop into a more insidious Scoliosis of the spine over time. It was understood that Postural Kyphosis, which presents as an increase in the curvature of the thoracic spine, is not a congenital structural misalignment of the vertebral column (Zećirović et al., 2021). Rather, it was impressed upon me that Kyphosis is an acquired or learned postural deformity caused by misaligned motor patterns. In my case, it was 100% preventable if only I would “stand up straight, stop slumping, roll my shoulders down and back—and keep them

there, stretch my pectoral muscles by resting my forearms on either side of a doorframe and leaning forward for 30 seconds—every day.”

The chronic musculoskeletal pain set in when I was 11 years old. I remember the constant backdrop of pain, a diffused ache, that radiated through my neck and trunk as I dutifully performed the role of attentive student in the classroom. By this stage of my education, I was painfully aware that maintaining an upright posture, or “sitting up straight,” was a measure of respectful attentiveness in the worldview of authoritative adults. As an adolescent, I was desperate to align myself with the worldview of others, so I was equally determined to appropriate the roles others ascribed to me with calculated skill. The role of upstanding student was one such role, and it was contingent upon my ability to “sit up straight” for the duration of a 45-minute class period without remission.

To this end, I learned to increase the arch in my lumbar curve by anteriorly rotating my pelvis so that my “sit bones” rocked forward on the surface of the chair. Increasing the lordosis of the lumbar curve had the effect of elevating my thorax (rib cage and sternum), which tended to induce the posterior tilt of my shoulder girdle relative to the thoracic cage. In this position, I externally rotated my scapulae and forced my shoulders back into submission. In his book *Neurodynamics*, Theodore Dimon (2015) described this as a compensatory motor pattern, which gives rise to harmful states of musculoskeletal imbalance:

If, for instance, we habitually slump, the back muscles will stop working properly and, when we need to sit up, we will be forced to compensate by tightening the muscles of the lower back, which will become chronically contracted. Specific muscle groups are often forced to overwork in this way because of an imbalance in the overall system so that, even when we try to relax them, they are constantly receiving messages to contract. (pp. 70-71)

It cannot be overstated that the coordination and stabilization of this motor pattern to achieve a socially constructed aesthetic was an action goal in and of itself. Moreover, it was the action goal

undergirding all other action goals performed in the public sphere. However, my neuromuscular-skeletal system invariably self-organized into a collapsed state when I felt unencumbered by the social other's critical gaze.

An action goal is a task for which the motor system deploys a specific pattern of motion from the totality of body segments and joints (Magill & Anderson, 2017). The designation of "action goal" is typically reserved for voluntary actions like sitting in a chair, throwing a baseball, and lifting a mug to drink coffee. Moreover, action goals are learned behaviors acquired through periods of intentional and sustained experimentation at some stage of the developmental process. Postural control seems like an automatic and mostly involuntary physiological process for most healthy adults in predictable environmental conditions. For this reason, the status of postural control as a voluntary action is not an intuitive classification. However, observe the weeks of trial-and-error experiences actively sought by a typically developing 14-month-old infant striving to walk independently. At this early stage of human development, the regulation of postural control to support the dynamics of bipedal locomotion is an unequivocal action goal.

Adolph et al. (2012) reported the average novice walker "takes 2,368 steps, travels 701 m—the length of 7 American football fields—and falls 17 times per hour" (p. 1393). Moreover, Adolph et al. concluded that independent walking emerges and stabilizes over days, weeks, even months of time—distributed, variable practice throughout infancy and early childhood. To emphasize the protractive development of walking, the characteristics of the stride cycle, including gait velocity, step length, cadence, and step width, continue to change and stabilize throughout the preschool and early childhood years (Hadders-Algra, 2010). Thus, the development and refinement of postural control underlies the emergence and stabilization of

independent walking. Infants must learn to maintain upright postural orientation and equilibrium as the basis for bipedal locomotion. Moreover, infants are active participants in the learning process and exhibit an intrinsic motivation to achieve bipedalism as their primary mode of posture and locomotion.

Admittedly, some might argue persuasively that upright postural control and locomotion are not action goals in infancy. Instead, they may identify the action goal as a desired interaction with an out-of-range object or caregiver, requiring self-propulsion across the translational distance. Thus, upright postural control and bipedal locomotion are the means whereby the action goal is achieved. However, novice walkers may revert to a more stable quadrupedal posture when they perceive it to be a more efficient motor solution for a particular action goal, thus weakening this interpretation (Adolph & Tamis-LeMonda, 2014). Novice walkers are certainly not limited to bipedal locomotion and can choose from an arsenal of formerly acquired self-propulsive strategies, i.e., creeping, crawling, scooting. Yet, novice walkers are persistent in their exploration of upright postural control and bipedal locomotion, despite the increased instability and fall rates compared to quadrupedal locomotion.

According to Hoch et al. (2020), bipedal locomotion exploration in novice walkers is not always motivated by the goal of reaching a predetermined destination. They reported that only about 30% of novice walkers' locomotor bouts are target-driven (p. 1016). Rather, a large percentage of infant locomotor bouts include stationary stepping in front of a person, object, or destination that is already visible and within reach. Based on these findings, the authors hypothesized that "locomotion in the absence of a destination or goal may simply be pleasurable—a means unto itself" (p. 1018). Thus, novice walkers may be motivated by the intrinsic perceptual-motor rewards of learning to coordinate upright bipedal locomotion. Thus, as

in non-fundamental psychomotor skills like using scissors or riding a bike, the fundamental skills of upright postural control and locomotion are action goals unto themselves during the early stages of the learning process (Newell, 2020). The coordination pattern stabilizes and is automated by the nervous system in the service of higher-order action goals after some period of time-distributed and variable practice (Dimon, 2015).

However, in my case, upright postural control re-emerged as an action goal in response to social pressures in my childhood and adolescence. By the time I entered high school, I was hyper aware that my presentation of an upright postural aesthetic yielded social rewards like praise and admiration. I remember one prideful occasion when a peer in my seventh-grade science class, who, incidentally, had teased me relentlessly in elementary school, said, “Your posture is so good. I wish I could sit up as straight as you.” Social interactions such as this one reinforced my commitment to hoisting my rib cage up and my shoulders back like I was wearing an invisible corset. My muscle nociceptors screamed in protest, but I assumed musculoskeletal pain was an unavoidable existential condition—even for a 12-year-old.

Meanwhile, the social pressures of my home environment were less compelling and, therefore, I was less inclined to bear the pain of a maladaptive but socially reinforced musculoskeletal coordination at home. My arrival home from school and other wider social contexts invariably coincided with the return of my visibly misaligned postural state. Parental reminders to “sit up straight” and “put your shoulders back” often elicited immediate compliance, which just-as-quickly dissolved into the variation of musculoskeletal collapse, so-called “slouching” or “slumping.” The directives “sit up straight” or “stop slouching” are well-known to many children and are probably the best indicator that postural control persists as a socially regulated action goal well beyond infancy.

As an early childhood educator, I have consistently observed parents and teachers employ directives to regulate the postural behavior of young children. Intriguingly, I have also observed a relationship between parent- and/or teacher-directed activities and the presentation of postural deviations in preschool children. The increased rates of postural misalignment in the context of adult-managed activities may be associated with the increased demands on children's cognitive and self-regulatory processes. Adult-managed activities are extrinsically motivated and often depend upon a form of behavioral regulation called adherence (Kostelnik et al., 2018). Adherence describes the regulation of behavior by external controls such as physical guidance, rewards, and negative consequences (Kostelnik et al., 2018). Moreover, adult-initiated activities tend to be more sedentary and passive than child-initiated, choice-based activities (Essa & Burnham, 2019).

The prescribed goal behavior of sitting still and passively attending to an adult-moderated activity is challenging for most young children. Direct instruction in the preschool classroom is commonly structured into the daily routine as large- or small-group activities. The large-group activity setting is popularly called 'circle time,' 'story time,' 'meeting,' or other variations on these themes (Essa & Burnham, 2019). These terms generally refer to a routine time block when students and teachers gather together to engage in a shared activity moderated by one or more teachers (Essa & Burnham, 2019). During large-group activities, teachers constantly remind children to "sit up," "sit still," and "pay attention" to regulate the children's adherence to the task constraints (Essa & Burnham, 2019).

Group-based instruction is recognized as developmentally appropriate for a limited duration of time based on the chronological age and abilities of the children. The National Association for the Education of Young Children (NAEYC) recommended shorter durations of

group-based direct instruction with preschool children (Friedman et al., 2021). Similarly, Essa and Burnham (2019) recommended limiting teacher-initiated group instruction to 10 minutes with 3-year-olds and 15-20 minutes with 4- and 5-year-olds (p. 363). Sustained periods of teacher-initiated group activity are developmentally inappropriate because they overtax the children's developing self-regulatory processes.

Self-regulation is defined as “the ability to control emotional states, cognitive processes and behavior when faced with external pressures or impulses in order to accomplish a desired state or goal” (Timmons et al., 2016). Self-regulation is an umbrella concept that encompasses other “reactive” (lower-order) and “effortful” (higher-order) constructs (Blair, 2016; Gagne et al., 2021). The regulation of emotion, attention, and the stress response are more automatic processes, thus falling somewhere along the reactive end of the self-regulation spectrum. The executive functions, including inhibitory control, working memory, and cognitive flexibility, are self-regulatory processes that occupy the effortful end of the spectrum (Blair, 2016; Friedman et al., 2021). Self-regulation develops across the lifespan, but the first 5 years of life are recognized as a critical period for self-regulation development (Timmons et al., 2016). For this reason, early learning environments like childcare, preschool, and kindergarten implement curriculum to support the development of self-regulatory skills (Kostelnik et al., 2018; Rimm-Kaufman et al., 2009; Timmons et al., 2016).

As a recommended practice, early childhood settings sequence child-initiated activities and structured teacher-directed activities intentionally, ensuring the flow of the day is responsive to the children's emergent interests and abilities (Essa & Burnham, 2019; Friedman et al., 2021). Research has suggested that activity type is associated with task-based constraints that influence the cognitions, emotional response, and overt behavior of preschool children (Zaghlawan &

Ostrosky, 2011). Thus, the three primary learning formats utilized in early childhood classrooms (self-directed free play, teacher-directed small-group activity, and teacher-directed large-group activity) implement unique affordances for action and reaction that constrain learning and development.

Concerning the development of self-regulatory skills, child-directed free play is associated with gains in executive functioning, particularly inhibitory control (Goble & Pianta, 2017; Timmons et al., 2016). On the other hand, structured teacher-directed group activities are known to support the development of language and literacy skills (Goble & Pianta, 2017; Timmons et al., 2016). However, the task-based constraints of teacher-directed activities may also give rise to disruptive and challenging behavior in preschool children. Temper tantrums, noncompliance, and inappropriate social initiations (i.e., repeatedly touching or poking another child) are maladaptive psychosocial behaviors that emerge more frequently during structured, teacher-directed activities (Essa & Burnham, 2019; Zaghawan & Ostrosky, 2011).

The development of children's social-emotional behavior and its expression in the early childhood classroom is well-researched in the field of Early Childhood Education (ECE) (Cohen, 2001; Rademacher & Koglin, 2019; Rakap et al., 2018). However, the interactions between learning formats in ECE and children's psychomotor behaviors have been less extensively studied. To clarify, the association between preschool learning formats and the occurrence of maladaptive psychomotor behavior is not well addressed in the research literature. The central question addressed in this dissertation is whether ECE's recommended practices recognize and reliably support adaptive psychomotor learning and development.

To delimit the scope of study, adaptive psychomotor learning is simply defined as the discovery and stabilization of movement patterns that (1) accomplish action goals in the here-

and-now, and (2) support the health of the changing neuromuscular-skeletal system across its lifetime. The second criterion of adaptive psychomotor learning is often unaddressed in the proficiency-driven field of Education. Instead, the successful achievement of the task outcome is privileged over the dynamics of the underlying neuromuscular-skeletal coordination. For example, teachers are inclined to assess the child's ability to sit in relative stillness during a structured teacher-led activity as an adaptive response to the implicit task constraints. They do not typically consider postural alignment as a developmental variable within the gross-motor domain when evaluating adaptive learning and behavior across the various classroom contexts.

Admittedly, the stated criteria do not describe the movement characteristics that adaptively support lifespan neuromuscular-skeletal health. The chapters of this dissertation build toward a more descriptive operational definition that addresses the movement characteristics that are the outcome of adaptive psychomotor learning. To this end, adaptive psychomotor learning is the discovery and stabilization of movement patterns that efficiently and flexibly partner with gravity and other environmental constraints to achieve action goals. Conversely, maladaptive psychomotor learning is the discovery and stabilization of movement patterns that inefficiently and inflexibly partner with gravity and other environmental constraints to achieve action goals. As a consequence of their inefficiency and inflexibility, maladaptive movement patterns may induce excessive stress and strain on the body's musculoskeletal structures over time. As a result, these structures may undergo morphological changes that facilitate the progressive deformation and functional impairment of the whole system.

Postural Kyphosis was the morphological change that represented the consequences of maladaptive psychomotor learning on my developing musculoskeletal system. The excessive curvature of my thoracic spine was a local symptom of a more global disorder of the

neuromuscular-skeletal system's coordination of actions. My reproduction of maladaptively coordinated actions facilitated progressive deformation, functional impairment, and a chronic pain condition by the time I was 14 years old. My attentive and concerned parents consulted medical specialists, therapists, and interventionists to treat my neuromuscular-skeletal disorder, including orthopedic doctors, osteopaths, chiropractors, physical therapists, massage therapists, yoga teachers, dance teachers, and an Alexander Technique teacher.

Incidentally, my family's use of Complementary and Alternative Medicine (CAM) like manipulation and movement therapies is consistent with the popularity of CAM therapies in the treatment of pediatric musculoskeletal disorders (Cohen et al., 2017). Cohen et al. (2017) reported that children with musculoskeletal conditions are three times more likely to use CAM therapies than children without musculoskeletal conditions. I was one of those children.

Unfortunately, the medical specialists and various CAM therapies did not address the source of my progressive disorder. They did not stop me from reproducing the maladaptive movement patterns I had learned to coordinate to achieve the most fundamental of action goals, nor did they guide the re-discovery and stabilization of new coordination patterns in adaptive partnership with gravity and other environmental constraints to achieve action goals.

The heartfelt purpose of this dissertation is to spotlight a prevalent issue in lifespan development and learning that is under-appreciated in educational research and practice. To this end, I aim to spotlight the adverse effects of maladaptive postural coordination on lifespan human development while amplifying its origins in early childhood. Many children in the United States and abroad learn to coordinate fundamental psychomotor actions with maladaptive postural deviations that impose excessive stress and strain on musculoskeletal structures. The stabilization of maladaptive movement patterns over time supports the development of non-

structural sagittal misalignments of the spine, including Forward Head Posture (FHP) and Postural Thoracic Hyperkyphosis (Kyphosis) (Czaprowski et al., 2018; Wilczyński et al., 2020). Moreover, the reproduction of maladaptive movement patterns is likely associated with the development of musculoskeletal disorders and associated chronic pain conditions that impact the global public (Anderson, 2020; Clarke et al., 2016; Cohen et al., 2017; Global Burden of Disease [GBD] Collaborative Network, 2021). Finally, I argue in this dissertation that, in the absence of a congenital structural disorder and/or acute injury, maladaptive neuromuscular-skeletal movement patterns are learned due to critical gaps in children's processes of psychomotor learning.

Through this dissertation, I advocate for a centralized Psychophysical Education framework that underpins the self-directed and guided dimensions of the ECE curriculum. Psychomotor learning should be intentionally scaffolded to promote the coordination of adaptive movement patterns in task-dependent contexts. In other words, the ECE curriculum should frame the child's ability to adaptively coordinate her body-self to perform fundamental motor acts like standing, sitting, and walking as task-dependent learning goals. For example, children should learn how to coordinate and regulate an aligned sitting posture as the basis for their adaptive participation in more demanding teacher-managed group activities. To this end, Psychophysical Education, and the intentional development of kinesthetic fluency, should be leveraged as an aqueduct-like central structure that constrains other learning goals and content areas towards adaptive developmental outcomes.

Another argument within this dissertation is that a fundamental goal of ECE should be structuring learning experiences to guide the discovery and stabilization of adaptive movement patterns that (1) accomplish fundamental action goals in the here-and-now, and (2) support the health of the changing neuromuscular-skeletal system across its lifetime. The assimilation of

Psychophysical Education and its associated diagnostic frameworks into educational theory and practice would constitute a paradigm shift in the field of ECE. This dissertation provides an explanation for why psychomotor learning and development should be re-centered within the ECE curriculum to scaffold learning and development appropriately across domains and content areas.

Chapter 1: Literature Review

Early childhood is a critical period for sensorimotor development wherein the parameters that define one's sense of embodiment are discovered, explored, and refined. The experience and condition of being an embodied organism—"a moveable self"—is foundational to the question of adaptive psychomotor learning in the early childhood classroom (Gibson & Pick, 2000, p. 103). The embodiment construct was popularized as an expression of the mind's groundedness in the body's sensorimotor functions by 20th century social scientists (Pink, 2011). The gradual assimilation of "embodiment" into scholarly and colloquial discourse represented a shift in the seat of knowledge from the formerly insubstantial mind to the minded body and its dynamic, goal-directed states. The concept of embodiment displaced the rational mind and elevated the sensing-and-moving body as the vehicle for learning through its interaction with environmental affordances (Pink, 2011). Thus, "embodiment" represents the empiricist commitment that "...knowledge was not simply something of the mind, but (...) 'knowing' is embedded in embodied practices and cannot necessarily be expressed in spoken words" (p. 84).

The epistemological shift in favor of embodiment coincided with the globally coordinated effort to define child development and education as substantive fields of research, scholarship, and applied practice. Moreover, the fortification of the empirical worldview allowed psychologists and pedagogues to hypothesize that preverbal infants and young language learners are capable and active meaning-makers, acquiring knowledge by forming dynamic relationships with their environments (Cantor et al., 2021). Thus, contrary to the rationalist tradition, language is not antecedent to knowledge, nor is language the sole medium for the construction of knowledge. Instead, consistent with the empirical tradition, knowledge is embedded in the symbiotic relationship between the embodied organism and its environment. Therefore,

knowledge is constructed through perceptuomotor processes that correspond to the environment's dynamic contexts and affordances.

The development of language, numeracy, logical thinking, and other species-expectant cognitive functions are likewise embedded in and dependent upon environmental affordances. The multimodal sense receptors of the body must be sensitive and responsive to select stimuli and, at critical periods of development, to support the emergence and stabilization of these higher-level faculties. Therefore, relative to top-down comparisons afforded by complex cognition, the physically and culturally emplaced sensing-and-moving body is the central medium and agent that propel the developmental process and its varied outcomes. The concept of “emplacement” in the social sciences posits the body as a biological and material subject-object that is continuous with its environment insofar as the body reciprocally shapes and is shaped by the places it occupies (Pink, 2011).

Emplacement is conceptually related to the ecological approach to perception pioneered by E. J. Gibson and J. J. Gibson in the field of Psychology (E. J. Gibson, 1988, 1994, 1997; J. J. Gibson, 1979; Gibson & Pick, 2000). The ecological approach views the organism as a perception-action system comprised of subsystems that holistically regulate function by interacting across levels of complexity. For instance, the body's molecular substrate is nested within specialized cells, which, in turn, are nested in a continuous network of diverse tissues and organ systems. Moreover, and central to the ecological approach, the body's integral subsystems are nested within external physical and sociocultural ecological levels of the system (Cantor et al., 2021). Thus, the coaction of multiple system levels gives rise to developmental processes that support a range of behavioral adaptations across the organism's lifespan (Cantor et al., 2021). Newell (1986) expanded on this idea by conceptualizing the coaction of environmental, task, and

organismic constraints to parameterize the “optimal pattern” of psychomotor coordination and control (p. 348). Newell expanded on this idea by conceptualizing the coaction of environmental, task, and organismic constraints to parameterize the “optimal pattern” of psychomotor coordination and control (p. 348).

For example, the development of bipedal locomotion in typical human infants is afforded or constrained by features of the physical and sociocultural environments. Walking will not develop in isolation of physical conditions that dynamically (1) act on the physiological properties of the human body to capacitate its functional organization and (2) are acted upon by the human body to exploit its (the environment’s) resources (environmental constraint), actualize a dispositional property of the body-self (organismic constraint), and achieve its ends (task constraint). Thus, the field of external forces (gravitational, inertial, ground reaction, etc.) helps constrain the development and stabilization of walking in partnership with the organismic constraints of the typical human body plan (Gibson & Pick, 2000, p. 110; Newell, 1986). With respect to the social-cultural systems level, the onset of walking is motivated by the modeling, social-emotional encouragement, and even physical support of caregivers in the infant’s social environment (Adolph & Tamis-LeMonda, 2014). Moreover, the transition from crawling to walking expands the infant’s sphere of action and supplies new opportunities for social engagement, including increased proximity and access to language (Schneider & Iverson, 2022).

The environment provides the external conditions whereby the developing organism’s sensing-and-moving parts will assume structural forms that afford for meaningful and adaptive action. Thus, experience is necessarily embodied and emplaced in an ecological superstructure that influences the developmental trajectory of the organism across its lifespan. It follows that learning, a product of experience and a critical mediator of the developmental process, is

necessarily embodied and embedded in specific environmental contexts (Adolph & Hoch, 2019). Moreover, the inflow of sensory-perceptual information and its translation into increasingly skilled motor outputs has a transformational effect on the developing organism over time (Cantor et al., 2021).

Thus, learning and development are interdependent processes grounded in the condition of being an emplaced body-self. In other words, the human being is an organism emplaced in its physical and social-cultural environments through a highly specialized network of sensory receptors that guide self-movement. Consequently, children must learn to extract contextually relevant perceptual information that guides their coordination of adaptive movement patterns as the basis for their emplaced psychomotor behaviors and activities. Thus, a central question raised in this dissertation is whether perceptual learning is adequately scaffolded in the early childhood classroom to facilitate adaptive psychomotor coordination patterns in children.

In support of the functional interdependence of perception and cognition, E. J. Gibson (1994) cited the *Random House Dictionary*, which defined cognition as “the act or process of knowing: perception” (p. 493). In similar fashion, J. J. Gibson (2015) articulated the functional interdependence of the motor and perceptual systems, stating: “We must perceive in order to move, but we must also move in order to perceive” (p. 213). The independent and collaborative research efforts of both Gibsons contended that motor, perceptual, and cognitive processes are not discrete and independent, as popularly conceived. Alternatively, these are functionally interdependent subsystems that cohere in complex organisms—specifically, learning that develops a range of self-sustainable activities in response to a landscape of affordances. The learned behavioral patterns reciprocally modify the whole organism-environment system over time (Read & Szokolszky, 2018).

In the ensuing decades, Ecological Psychology has developed as a non-reductive experimental science that studies the perceiving-and-acting organism as a complex whole (Heras-Escribano, 2019). Moreover, its principles and methods have been applied to other related disciplines, including Embodied Psychology, Developmental Ecological Psychology, Dynamical Systems Theory, and Education (Phillips & Finn, 2022; Read & Szokolszky, 2018; Robinson & Thomas, 2021). In particular, the ecological principle of affordances has been readily assimilated into developmental and educational theories (Phillips & Finn, 2022). For instance, the ecological approach is highly compatible with the education field's consideration of the child's home, school, and community environments as formative influences on learning outcomes and developmental trajectories (National Academies of Sciences, Engineering, and Medicine, 2018; Wells & Claxton, 2022).

However, the ecological approach has not been fully assimilated wholesale into educational theory and practice. Education is still beholden to cognitivism's representational schemas and, thus, entrenched in the traditional psychological dichotomies of perception/action and mind/body (Lobo et al., 2018). Consequently, the field of education still primarily conceptualizes and addresses content areas and skills as differentiated neurophysiological functions and processes. The primary skills associated with academic achievement, including language, literacy, logical reasoning, mathematical fluency, and scientific inquiry, are traditionally classified as complex cognitive functions. Consequently, educational research, policy, and practice have historically focused on the cognitive domain because of its status as the gold standard of life-span learning, development, and achievement (Cantor & Osher, 2021). Additionally, social-emotional functioning has recently earned greater recognition as a "correlate of learning" and development in educational research and policy (p. 160). However, the large-

scale reconstruction of the PreK-12 curricula to integrate cognitive and social-emotional learning seamlessly is still in the early stages of implementation with ECE at the experimental forefront (Cantor & Osher, 2021). Finally, psychomotor development, which concerns sensorimotor learning and the stabilization of perceptually guided action, is typically elevated in ECE and increasingly displaced over maturational time.

Within the field of Human Development, the enduring legacy of the Swiss psychologist Jean Piaget (1896-1980) helped centralize motor learning and development in the early childhood years. Famously, Piaget asserted the primacy of the sensorimotor domain in infancy and early childhood when he articulated the four stages of cognitive development. His developmental framework consists of the sensorimotor, preoperational, concrete operational, and formal operational stages of development (Piaget et al., 1973). Notably, these four stages are stacked to build the foundation for the higher-level cognitive functions and skills across many academic disciplines.

According to this framework, sensorimotor intelligence is the most phylogenetically primitive expression of cognitive development. The sensorimotor phase of cognitive development spans the gestational period through the second year of life. Piaget theorized that the sensing-and-moving organism assimilates sensorimotor schemas through interaction with its environment during the first 2 years of life (Piaget, 1997). Moreover, sensorimotor schemas are the building blocks for the representational thought operations constructed throughout the later stages of cognitive development. Thus, Piaget recognized sensorimotor exploration, learning, and development as critical and indispensable steps toward mental representation and symbolic thinking abilities (Bremner, 2014). In addition, his theory framed psychomotor action as the primordial source of the human primate's prized arsenal of cognitive abilities and skills.

However, Piaget's hierarchical model also helped entrench the view that psychomotor action is "a lower form of cognition being progressively liberated from its bodily roots by a process of abstraction" (Smitsman & Corbetta, 2010, p. 170). Moreover, its age-dependent taxonomy implies that a qualitatively different form of intelligence supplants sensorimotor intelligence after the second year of life.

Arguably, Piaget's model reduces sensorimotor intelligence to a discrete and finite developmental phase. Additionally, the emergent forms of operational intelligence are perceived to be increasingly alienated from their sensorimotor origins over developmental time. Ultimately, this perspective does not conceptualize sensorimotor processing and kinesthetic fluency as an integral dimension of holistic learning and adaptive neuromuscular-skeletal function across the lifespan. Instead, Piaget's legacy has perhaps inadvertently helped reduce sensorimotor intelligence to a means to the phylogenetic end of cognitive development.

In relative alignment with Piaget's theories, Western education systems are primarily structured to decouple psychomotor action and cognitive processing as a function of maturational time (Cantor et al., 2021). For example, the primary learning formats in secondary school are sedentary activities as the basis for demonstrating proficiency in higher-level mathematical, scientific, and literacy skills (Cantor et al., 2021). Admittedly, psychomotor development and sensory-motor learning are centralized in traditionally non-academic content areas like physical education, athletic performance, the movement arts (i.e., dance and yoga), and, to some extent, the visual arts as well (Aartun et al., 2022). However, the academic disciplines mostly dismiss psychomotor development and sensorimotor learning as separate from and subordinate to the increasingly privileged cognitive and, more recently, the social-emotional dimensions of human development (Cantor et al., 2021). Consequently, and as a central argument in this dissertation,

the moving-and-sensing body-self becomes increasingly displaced from the core of learning and academic achievement. As is argued in this dissertation, the educational displacement of psychomotor learning in the pursuit of cognitive proficiencies may adversely impact the structural and functional integrity of the student's developing neuromuscular-skeletal system (Alexander & Fischer, 1996; Dimon, 2015, 2021).

ECE is the most closely aligned with ecological and embodied views of development relative to the broader field of education. Moreover, as discussed, the early childhood years also loosely correspond to Piaget's construct of sensorimotor intelligence. Therefore, ECE addresses motor development as a fundamental domain of early childhood, alongside cognitive, social-emotional, and language development (Friedman et al., 2021). Moreover, ECE views the four developmental domains as functionally integrated processes in the developing child such that "each domain both supports and is supported by the others" (Friedman et al., 2021, p. 26). In fact, the National Association for the Education of Young Children (NAEYC) identified the equal importance of all four developmental domains as one of their Nine Principles of Child Development and Learning (Friedman et al., 2021). This principle is supported by scientific and medical research describing how the highly coordinated activity of body systems mobilizes whole human-environment adaptation: "All biological systems in the body interact with each other and adapt to the contexts in which a child is developing—for better or for worse—and adaptations in one system can influence adaptations in others" (National Scientific Council on the Developing Child, 2020, p. 2). According to this principle, the developing child should be viewed as a whole organism-environment system. As such, the structure and function of any specific part of the emplaced body is determined by the "context, field, or whole" of which it is a part (Cantor et al., 2021).

The conceptual distinctions of physical/motor, cognitive, social-emotional, and language development are meant to articulate the four domains of child development within a holistic theoretical framework. However, these conceptual distinctions often inadvertently disintegrate the domains, particularly through their application to ECE curriculum and teaching practices. Additionally, each developmental domain can be broken down into subsidiary constructs and processes, which further contributes to the disunion of the developing child. For example, the physical/motor domain is subdivided into gross- and fine-motor development.

Gross-motor development refers to generalized coordination and control of the whole neuromuscular-skeletal system to perform fundamental skills like walking and more complex skills like dribbling a basketball (Cameron, 2018; Essa & Burnham, 2019; Newell, 2020). Fine-motor skills refer to the coordinated movement of the wrist, hand, and fingers to perform prehensile tasks with precision and agility (Cameron, 2018; Essa & Burnham, 2019). ECE curriculum intentionally structures activities that support the development of gross- and fine-motor competencies throughout the daily routine. Although these conceptual dimensions of motor coordination and control are functionally interdependent, fine- and gross-motor skills are often addressed separately in the ECE curriculum.

The ECE learning formats commonly used to structure gross-motor learning and development include self-directed outdoor play and teacher-guided large-group activities. These formats facilitate the organization of physical space to encourage the exploration of dynamic balance, plyometric, and ballistic motor skills. Thus, ECE classroom practices that support gross-motor development typically involve play-based contexts for children to coordinate explosive movement patterns that fulfill embedded action goals. The physical and social dimensions of the

playscape give rise to meaningful contexts for the acquisition of motor skills like running, jumping, climbing, kicking, and throwing. The New York State Early Learning Guidelines (2012) listed the ability to coordinate a range of contextualized motor skills as indicators of typical gross-motor development in preschool-aged children (Figure 1.1). Notably, the learning guidelines do not describe the qualitative properties of the movement patterns that define the adaptive performance of these motor skills. The absence of these criteria in the learning guidelines indicates the classroom practice of using action goal achievement as an outcome-based evaluation of gross-motor competency. Furthermore, process-based evaluations of the movement patterns coordinated by the typical child to achieve fundamental motor skills are generally beyond the scope of developmental assessment in ECE (Newell, 2020).

Many of the gross-motor skills listed in the Learning Guidelines are discouraged outside of the designated learning formats due to the constraint of physical space and other classroom management contingencies. Therefore, activities that invite gross-motor exploration offer a critical respite from the forms of adherence that delimit the child's range of physical self-expression in the classroom. For this reason, the NAEYC recommended using movement activities to break up large-group activities and reduce the demand on children's self-regulatory functions (Friedman et al., 2021). Embedded gross motor activities also reinvigorate children's active participation in large group instruction. The invitation to get up and move helps to dispel passivity and restlessness promoted by the more didactic elements of the large-group learning format (Kostelnik et al., 2018). Thus, in this context, gross-motor activity is primarily viewed as supportive of but separate from early academic learning traditionally associated with the cognitive functions and their development.

Table 1.1

New York State Early Learning Guidelines: Indicators for Gross-Motor Development in Children, 30-60 Months

NYS Early Learning Guidelines: Indicators for gross-motor development in preschool children (30-60 months)
1. Walks and runs and navigates obstacles and corners
2. Crawls through a play tunnel or under tables
3. Climbs on play equipment
4. Throws ball overhead with some accuracy
5. Catches large balls with two hands
6. Kicks ball forward
7. Hops forward on one foot without losing balance
8. Jumps on two feet and over small objects with balance and control
9. Gallops with skill
10. Pedals consistently when riding tricycle and navigates obstacles and corners
11. Walks up and down stairs, using alternating feet, without support
12. Walks backwards and runs with enough control for sudden stops

Source: New York State Early Learning Guidelines, 2012, p. 26

The NAEYC's recommendation to structure movement activities into the large-group learning format is further evidence that its more sedentary activity sequences are not categorically motor activities by ECE standards (Friedman et al., 2021). However, motor learning and development are neurophysiological processes that operate continuously as the developing child interacts with its dynamic ecological contexts. Thus, the child's neurophysiological processes do not conform to the discrete categories that the ECE field ascribes to particular learning experiences and activities. Instead, perceptual-motor learning and development proceed apace, whether they are the curricular focus of a specific learning format or activity. Moreover, viewed through an ecological lens, perceptual-motor learning and development are the foundation for all learning formats and activities.

Karen Adolph, a contemporary researcher in the ecological psychology field, poignantly amplified this point by describing motor learning as "learning to learn" (Rieser et al., 2005). Accordingly, learning is the outcome of continuous neurophysiological processes, which optimally encompass a complex of interdependent variables: the direction of attention to (1) extract contextually relevant perceptual information from an array of stimuli, to (2) perceive the veridical correspondence between body-self and environment that instantiates affordances for action, to (3) assemble movement coordination patterns that adaptively and selectively leverage biodynamic force and pressure variables at the interface of body-self and environment, to (4) coordinate task-dependent and context-sensitive movement patterns that holistically achieve embedded action goals sustainably and efficiently, thereby supporting healthy lifespan learning and development.

However, the inversion of these four variables guides processes of maladaptive learning that support the development of deviated and unhealthy movement coordination patterns. The

primary difference is that maladaptive learning is the outcome of the misdirection of attention to variables that do not support the perception of a veridical correspondence between the body-self and its environment. Consequently, the learner does not assemble movement coordination patterns that adaptively and selectively leverage biodynamic force and pressure variables that optimize the organism-environment partnership. As a result, the learner coordinates movement patterns that are mechanically and metabolically inefficient to achieve embedded action goals. The reproduction of these inefficient patterns over developmental time causes progressive degeneration of the global system's form and function. Therefore, if sustainability and efficiency of learned neuromuscular-skeletal patterns are brought into pedagogical focus, we can begin to envision ECE curricula that support adaptive learning and development across all stages of development.

Thus, the coordination dynamics of postural control, or the organization of gravity-driven musculoskeletal parts as the structural basis for action, are the expression and representation of emplaced perceptual-learning processes. It follows that states of postural alignment (or misalignment) undergirding a child's goal-directed embodiment in the context of ECE classroom activities are the expression and/or representation of perceptual-motor learning processes occurring in the here-and-now. Consequently, the perceptual-motor learning processes that underlie the discovery and stabilization of goal-directed embodied states should be a curricular focus across the ECE domains and the learning activities that holistically guide their development. The omission of intentionally scaffolded perceptual-motor learning in the ECE curriculum results in the young learner coordinating task-dependent and context-sensitive movement patterns that inefficiently achieve embedded action goals in the here-and-now. The periodicity of these patterns yields mechanical and metabolic costs to the system dynamics,

which are unsustainable over the lifespan. Therefore, the ECE curriculum should intentionally scaffold perceptual-motor learning to support the adaptive coordination of fundamental motor skills like sitting, standing, walking, and reaching in naturalistic task-relevant contexts.

Implicit in the preschool curriculum is the expectation that typically developing 3- and 4-year-old children learn to coordinate the most basic psychomotor skills adaptively in infancy (Newell, 2020). It is further assumed that the underlying movement patterns have since stabilized as a prototypical motor skill on which the preschool curriculum can assemble higher-level cognitive, linguistic, social-emotional, and self-regulatory skills. The Indicators for Gross-Motor Development chart produced by the New York State Early Learning Guidelines (2012) reflects the assumptions implicit in a developmental framework based solely on outcome-based competencies (Figure 1.2). According to the chart, the fundamental motor skills related to posture, locomotion, and object-interaction emerge and stabilize during the first 18 months of life (Newell, 2020). These basic motor competencies are considered the building blocks for acquiring more complex functions and skills across late infancy and early childhood (Newell, 2020).

The education field generally accepts that the stereotyped sequence of typical psychomotor learning and development in infancy automatically produces healthy movement coordination patterns. It further assumes that children learn to scale these fundamental skills to perform increasingly demanding tasks with minimal instruction or guidance. These presuppositions may be the persistent legacy of neuro-maturational theories of motor development produced by Arnold Gesell (1880-1961) and Myrtle B. McGraw (1899-1988) (Gesell & Thompson, 1938; McGraw, 1943). The neuro-maturational account attributes development's phase-like sequence to time-locked genetic changes to the central nervous system

Table 1.2

New York State Early Learning Guidelines: Indicators for Gross-Motor Development in Children

Birth to 18 months	18 to 36 months	36 to 60 months
Some Indicators for Children:	Some Indicators for Children:	Some Indicators for Children:
<ol style="list-style-type: none"> 1. Lifts head and chest while on tummy 2. Supports upper body with arms while lying on tummy 3. Gains control of arm and leg movements 4. Rolls over (front to back, back to front) 5. Pounds on things with hands and kicks legs 6. Sits with support 7. Rocks back and forth on hands and knees and, later, crawls 8. Sits without support 9. Pulls self up to stand, holding onto something or someone 10. Stands independently 11. Walks holding onto furniture 12. Walks 13. Stoops or squats to explore things on the ground 14. Tries to climb stairs, with assistance 	<ol style="list-style-type: none"> 1. Carries toys or objects while walking 2. Walks and runs with skill, changing both speed and direction 3. Walks backwards 4. Climbs both in and out of bed or onto a steady adult chair 5. Pounds object with intent and precision (e.g., hammers peg with accuracy) 6. Jumps in place 7. Has a basic ability to kick and throw a ball 8. Balances on one foot briefly 9. Bends over easily without falling 10. Walks in a straight line 11. Walks downstairs placing both feet on each step; walks upstairs alternating feet with support/holding handrail 12. Uses feet to push forward and backwards while riding a toy 13. Runs fairly well and negotiate stairs with alternating feet 14. Pedals appropriate sized tricycle 	<ol style="list-style-type: none"> 1. Walks and runs and navigates obstacles and corners 2. Crawls through a play tunnel or under tables 3. Climbs on play equipment 4. Throws ball overhand with some accuracy 5. Catches large balls with two hands 6. Kicks ball forward 7. Hops forward on one foot without losing balance 8. Jumps on two feet and over small objects with balance and control 9. Gallops with skill 10. Pedals consistently when riding tricycle and navigates obstacles and corners 11. Walks up and down stairs, using alternating feet, without support 12. Walks backwards and runs with enough control for sudden stops
Sample Strategies to Promote Development and Learning:	Sample Strategies to Promote Development and Learning:	Sample Strategies to Promote Development and Learning:
<ul style="list-style-type: none"> • Provide opportunities for child to move freely during waking hours, including time on tummy. • Provide a variety of objects to be pulled, pushed, and held. • Play interactive games and sing songs from child's cultural background that involve child's hands and feet. 	<ul style="list-style-type: none"> • Provide opportunities for child to run, throw, jump, and climb. • Provide physical activities that promote balance (e.g., rocking, swinging, rolling, spinning). • Modify activities to ensure participation of child with special needs (e.g., provide ramps or low steps to ensure access to climbing equipment). 	<ul style="list-style-type: none"> • Provide safe equipment and environments that vary in skill levels (e.g., tricycles, tires, hoops, balls, balance beam, climbing equipment). • Teach child new skills (e.g., skip, throw overhand, jump rope, hula hoop, swim). • Provide opportunities for dance and other movement activities that use both sides of the body (e.g., bending, twisting, stretching, balancing).

Note. This chart was produced by the NYS Early Learning Guidelines to present the continuum of gross-motor developmental indicators from birth through 60 months old (New York State Early Learning Guidelines, 2012, p. 26).

(Gesell & Thompson, 1938; McGraw, 1943). Their observations and interpretative frameworks were accepted as gospel by their successors, which disincentivized further study of motor development for the next three decades (Thelen, 1995, pp. 79-80).

Developmental psychologist Esther Thelen (1941-2001) and her colleagues reversed the hypnotic spell of the neural-maturational theory that had been cast over the academic community. She boldly claimed that the maturational paradigm failed to sufficiently predict and explain significant variations in developmental data that were unveiled through quantitative research (Thelen & Smith, 1994). Additionally, her experiments consistently demonstrated that the phasal sequence of motor development could be influenced by the selective manipulation of biodynamic and environmental conditions (Thelen, 1986; Thelen & Ulrich, 1991; Thelen et al., 1982; Thelen et al., 1984). Thelen dared to ask the pressing question: If development is a genome-driven, stereotyped phasal sequence determined by our phylogenetic inheritance, then why is there significant intersubject variation across ontogenetic process, and why is phasal sequencing responsive to biodynamic and environmental perturbations? Unable to resolve this discrepancy using existing models, Thelen and her colleagues determined to assemble a new paradigm that could exert the explanatory power needed to interpret the research findings. Thelen's efforts materialized into a principled theory of cognitive-motor development.

Dynamical Systems Theory (DST) argues that, contrary to neuro-maturational assumptions, the instantiation of behavior is not determined by a linear sequence of biogenetic activation. Behavior that appears linear and uniform is revealed to be multidimensional, unstable, and unpredictable when analyzed mathematically (Thelen et al., 1993). Influenced by Ecological Theories, DST concludes that organized behavior emerges at the stochastic intersection of organism, environment, and task (Thelen & Smith, 1994, p. xxi). Common solutions to action

problems result from typicalities across the participating constraints (Adolph, 1997, 2000; Adolph & Avolio, 2000; Adolph & Berger, 2006; Adolph et al., 2012; Hadders-Algra, 2018; Smitsman & Corbetta, 2010; Thelen & Smith, 1994). Thus, motor development across infancy and early childhood is a process of learning to exert voluntary control over the neuromotor system through active experimentation. The developing human learns how to use the embodied body-self (its “self”) as the principal means to its ends (Thelen et al., 1993).

DST applies the principles of Chaos Theory to produce a compelling explanation of psychomotor developmental processes. Chaos Theory is a mathematical model that was appropriated by physicists to describe the forms and processes of nature. It describes the behavior of complex systems that defy the reductive laws of classical Newtonian physics (Gleick, 1987; Prigogine & Stengers, 1984). Accordingly, DST conceptualizes the human body as a complex system, or a system of interacting parts, that synergistically compel its behavioral forms. A defining criterion of complex systems is numerosity, meaning that they consist of simpler elements or subsystems that operate at different hierarchical levels. For example, the constitutive elements of the human body are distributed across hierarchical levels: highly differentiated cells, tissue, organs, and organ systems. Each level carries out local functions that contribute to the maintenance of the complex whole.

In this respect, DST also builds on the biophysical framework of the famed Soviet neurophysiologist Nikolai Bernstein (1896-1966). Bernstein (1967, 1996) theorized that motor control and skill acquisition is a process whereby the hierarchical system learns to harness its many degrees of freedom. The degrees of freedom are the independent parameters of the system that produce variable coordinative synergies. The degrees of freedom inherent in the body’s global network of joints is an intuitive example of how the system obtains patterns of articulation

to coordinate and control movement (Newell & Liu, 2021). Accordingly, the human body is a hierarchical system with many interacting parts arranged in a *specific order* to obtain degrees of freedom. DST applies principles of Chaos Theory to Bernstein's framework, theorizing that the sum of local interactions between the sited elements gives rise to collective behavior, a phenomenon known as *emergence* (Bar-Yam, 1997; Thelen & Smith, 1994; Thelen et al., 1993).

The global system is purposive. The dynamics of the system, generated by the coordinated activity of many parts, seem to be shaped by a teleological force. There is a sense the system has been engineered to produce a definable function inherent in its functional design (Bar-Yam, 1997, p. xi; Prigogine & Stengers, 1984, p. 154). However, another criterion of complex systems is nonlinearity. In other words, the function of the whole is an emergent property that cannot be reduced to the sum of systemic parts. Although the behavior of the system may be somewhat predictable, the dynamics that regulate the behavior are unstable. Recall the argument of DST is that what appears to be a stable and predictable sequence of motor development emerges at the intersection of unstable variables, intrinsically and extrinsically sourced. Instability is advantageous because it allows the system to self-organize flexibly into dynamic structures that partner with environmental variables to coordinate self-sustaining actions.

Finally, complex systems are open systems, meaning that they transfer energy, matter, and information with other systems. Transference can alter the dynamics of the system, inducing entropic or dissipative states that spontaneously shift the system into new behavioral modes. Therefore, complex systems are also called dissipative structures because their interaction with environmental conditions can catalyze entropic states, activating transformative processes that engender new structural and behavioral forms (Prigogine & Stengers, 1984). Such structures are

softly assembled to amplify their responsiveness to perturbative events, which shift the system into new behavioral patterns (Thelen, 1995; Thelen & Smith, 1994).

According to DST, “soft assembly” is an adaptive design feature of complex systems (Thelen, 1995; Thelen & Smith, 1994). It facilitates the assembly of behavior “from multiple interacting components that can be freely combined from moment to moment based on the context, task, and developmental history of the organism” (Spencer et al., 2011, p. 3). There is more give to softly assembled systems, making them more responsive to external perturbations that may destabilize the system dynamics. Phase-shifts are observable events that catalyze the reorganization of the system’s component elements to support the “emergence of a new qualitative form” (Thelen et al., 1993, p. 1060). In other words, phase-shifts yield new patterns of self-organization occasioned by functional capacities not formerly realized by the system.

Recall the third criterion of adaptive psychomotor learning is to assemble movement coordination patterns that adaptively and selectively leverage biodynamic force and pressure variables at the interface of body-self and environment. The Earth’s gravitational field is an environmental constant that applies forces to the body-self while it coordinates its learned arsenal of skilled action. Adaptive psychomotor learning should guide the development of movement coordination patterns that organize the parts of the musculoskeletal system to metabolize most efficiently the energy demands of action in the applied gravitational loads on the body-self in each goal-directed configuration. To this end, the particular organization of the parts would partner collectively with the gravitational medium to reduce the energetic cost to the whole system. In this way, the complex system would interact with gravitational forces and activate transformative processes that engender healthy, efficient, and sustainable behavioral forms.

A much-anticipated event in the second trimester of pregnancy is when a mother begins to feel the fetus move or ‘quicken’ (Piontelli, 2010). During this time, the mother’s interoceptive senses register the ebb and flow of her gestating infant’s maturation and sensorimotor development over the next 6 months. By the end of the third trimester, the infant is able to coordinate goal-directed movements and exercises limited motor control over its limbs (Fagard et al., 2018; Rachwani et al., 2020). In addition to self-exploratory behaviors like rubbing the eyelids and sucking the thumb, the fetus uses manual action and forceful kicks to interact with the uterine walls (Rachwani et al., 2020). This exploration of goal-directed movements *in utero* is motivated by their sensory consequences with the fetus exhibiting a preference for richly innervated body parts like the face, hands, and feet (Fagard et al., 2018). Thus, the cumulative process of sensorimotor learning begins in the buoyant, near-weightless womb and continues apace when the infant is born into the dynamic, gravity-laden world.

The intrauterine environment can be considered a microgravity chamber for the first 22 weeks of gestation (Reid, 2006; Vinogradova et al., 2021). As such, the phasic nature of prenatal development scaffolds the fetus’s adaptation to the Earth’s gravitational field. The fetus floats in a state of near-weightlessness throughout this phase, suspended in a nourishing sea of amniotic fluid. However, the buoyancy of the aquatic environment reduces in proportion to the relative mass-density of the developing fetus (Reid, 2006). As a result, the intrauterine environment shifts and changes as the fetus grows and consumes nutrients and water in the amniotic fluid. Stanojevic (2022) claimed that microgravity *in utero* increasingly approaches but never quite reaches 1G, the standard gravitational force on earth. Therefore, the dynamic interdependence between the fetus and its intrauterine environment plays a critical role in facilitating the fetus’s gradated adaptation to gravity’s effects.

Gravity-induced mechanical stress on the biological tissues is an indispensable influence on the healthy development of the fetal organ systems (Sekulić et al., 2005). Insufficient exposure to gravitational loading in the third trimester is associated with fetal and infant pathophysiological conditions of the musculoskeletal, nervous, cardiovascular, and respiratory systems (Reid, 2006; Sekulić et al., 2005). Similar detrimental effects on human physiology are well-documented in astronauts exposed to microgravity during space flight (Hariom et al., 2021). However, these effects tend to be impermanent and can be reversed upon reentry into the Earth's gravitational field (Hariom et al., 2021). Gravity deprivation of the developing fetus is more likely to have irreversible pathophysiological effects detrimental to morphological development (Reid, 2006; Sekulić et al., 2005).

Without the critical input of gravity, the fetus may develop pathophysiological fetal hypokinesia, which is characterized by low frequency and variation in fetal motor activity (Reid, 2006; Sekulić et al., 2005). In this scenario, the uterus may function as a sensory deprivation chamber during a gestational phase that requires the dynamic flow of sensory input and motor output to sustain typical development. For example, gravity deprivation coupled with reduced fetal motor activity affects bone loading, which adversely impacts musculoskeletal morphogenesis (Reid, 2006). The musculoskeletal structures directly involved in respiration like the tongue, diaphragm, and thorax will also be affected. For example, reduced tongue movement *in utero* is associated with abnormal jaw and palate morphogenesis; and low frequency of diaphragmatic and intercostal muscle movement correlates with decreased lung growth (Reid, 2006). These relationships suggest that sensorimotor behavior in a gravitational continuum is a critical mediator of morphogenesis and the developmental process. Moreover, the

interdependency of the motor and respiratory systems bespeaks the irreducibility of the whole organism.

In further support of this idea, it has been demonstrated that gravity is an indispensable partner that interacts with the integrative physiology of biological organisms to regulate their behavior, development, and morphology across the lifespan (Hariom et al., 2021; Vinogradova et al., 2021). As such, the experience and condition of being an embodied organism—“a moveable self”—are predicated on the inheritance of a body with built-in adaptations to Earth’s gravitational field (Gibson & Pick, 2000, p. 103). In fact, adaptation to gravity is prerequisite for the survival of all viable organisms, so the stated predication applies, regardless of our highly socialized “ability” and “disability” designations. Vinogradova et al. (2021) described gravity’s formative role in mammalian phylogeny, particularly the evolution of the motor system:

Encountering various environmental factors, a living organism fights them, overcomes their resistance, or adapts to take advantage of the useful environmental elements. Gravity was a factor that played a leading role in evolution of the mammalian motor system. The role was so important that evolution of the motor system may be defined as evolution of the fight against gravity. As a result, mammals acquired a strong skeleton, a powerful muscular system, a sensory system, and a system that controls movements. (...) Evolution of the weight bearing/support function manifests itself in the complication of the geometry of the skeleton and the shape of muscular structures in terrestrial animals. (p. 718)

Perhaps no mammal has overcome the “evolution of the fight against gravity” more formidably than the Homo sapien. Our species evolved a complex geometrical structure that supports upright posture and our distinctive bipedal stance, freeing the arms for manual action (Dimon, 2011).

The human neuromuscular-skeletal system is an integrative network of biological tissues that cooperatively oppose the force of gravity. The sensorineural and musculoskeletal subsystems generate muscle activation forces to resist gravitational forces and maintain the body’s center of mass (CoM) within its limited base of support (Buscemi et al., 2021). Thus,

posture is the manner in which musculoskeletal parts are arranged to produce individual force through dynamic interactions with the Earth's surface and the enveloping field of external forces. Put another way, the neuromuscular-skeletal systems of all vertebrates produce forces of structural support, which facilitate the coordination of self-preserving actions. These intrinsic forces are the summative effect of the synergism between the organism and its 1G environment. In the particular case of the human vertebrate, the biomechanical relationships implicit in the body's geometry constrain its neuromuscular-skeletal activations to produce vectors that support upright postural control and bipedalism (Dimon, 2021; Dimon & Brown, 2018).

The ubiquitous force of gravity played a formative role in the evolution of the integrative geometries, shapes, and forms that define the neuromuscular-skeletal systems of land vertebrates. To this end, the process of evolution is like a locksmith that inscribes specific geometrical patterns into diverse biomaterials with complex functions. These patterns are like the notches and slots in keys corresponding to the obstructions or wards in a specialized lock. Finally, rounding out this analogy, the lock is like the local environment, and its wards impart evolutionary pressures that constrain nature's pattern-making processes. Thus, the motor systems of complex organisms tend to obtain geometries and shapes that directly correlate and correspond to the environmental constraints present. Moreover, gravity is an environmental constant, which assimilates the particulars of local constraints and affordances into an all-encompassing macro-constraint. Thus, the correspondence between the organism's physical form and its 1G environment unlocks the potential for postural control and translational movement, skilled task-dependent action, maturation, and development.

It is helpful to consider gravity's force as an energy sink, i.e., source of energy, that biological structures can draw from and leverage. In other words, complex biological systems

obtain forms that purposively derive potential energy from gravity's pull, which they then convert into translational motion to facilitate self-sustaining action. It may be helpful to think of land vertebrates as structural systems capable of turbine-like power generation. To clarify, the actual physical form and function, or morphology, of the brain and body contain *a priori* design elements that are intended to extract energy from gravity and convert it into kinetic energy, i.e., movement. Thus, within the upright human design, there is a highly cooperative relationship between structures of mechanical force generation, the specific geometric patterns or arrangements inherent in these structures, and the applied forces of gravity.

According to Buscemi et al. (2021), posture is an expression of the balance between neuromuscular-skeletal forces and the applied force of gravity. Moreover, Buscemi et al. described posture as “an indicator of the adaptive capacity of an individual against the force of gravity” (p. 2). In this context, adaptive capacity is a measure of an organism's overall effectiveness and efficiency while coordinating, regulating, and modifying the force-generating relationship that exists between its motor system and Earth's gravity. The fetus's exposure to gravitational forces in the womb also supports its adaptation to the demands and affordances of extrauterine life (Stanojevic, 2022). However, infancy and early childhood are critical periods for developing this adaptive capacity by learning how to partner with gravity to exercise motor coordination and control. Thus, the adaptive capacity of each organism is not entirely inherited and must be acquired through the ontogenetic process. In alignment with Ecological Theory and Dynamical Systems Theory, the adaptive capacity must be learned through active experimentation and problem solving.

In this dissertation, I question whether the generally unstructured processes of psychomotor learning in early childhood reliably cultivate this adaptive capacity. The global rise

of musculoskeletal disorders in the public suggests the ontogenetic process might benefit from structured learning processes that intentionally support adaptive outcomes. Anderson (2020) characterized musculoskeletal disorders as a longstanding pandemic approximating the scale of COVID-19 and systemic racism in its global impact. To put the scale of this public health crisis into perspective, the 2012 National Health Interview Survey (NHIS) reported that 54% of American adults (n = 125 million) had a musculoskeletal pain disorder in 2012 (Clarke et al., 2016; U. S. Department of Health and Human Services, Centers for Disease Control and Prevention, & National Center for Health Statistics 2016). After analyzing data from the 2012 NHIS's Household, Family, Person, Adult, and Child Core surveys, Cohen et al. (2017) reported that 15.5% of American children aged 4-17 (n = 4,227,562) had a musculoskeletal pain disorder

Meanwhile, the GBD Collaborative Network (2021), jointly developed by the World Health Organization (WHO) and the Institute for Health Measurement and Evaluation (IHME, 2018), supported the characterization of musculoskeletal disorders as a global pandemic. The study identified musculoskeletal disorders as the leading cause of Years Lived with Disability (YLD) in the United States and globally, independent of sex and age characteristics (<http://ihmeuw.org/5qe6>). Moreover, the GBD's top ranking of musculoskeletal disorders has also remained stable from 1990 until 2019 (<http://ihmeuw.org/5qe6>). Additionally, and of particular importance to this dissertation, the GBD results highlighted the fact that, contrary to common belief, musculoskeletal disorders like low back pain and neck pain emerge in 5-9 year olds and 10-14 year olds, respectively (<http://ihmeuw.org/5qh3>).

ECE does not address psychomotor learning as the foundation of cognitive, social-emotional, linguistic, and even traditionally conceived gross- and fine-motor development in a meaningful and practical way. As a result, many classroom activities are not appropriately

scaffolded to support adaptive psychomotor learning and associated outcomes as the basis for more challenging academic content and learning experiences. ECE's curricular discontinuity with respect to perceptual-motor learning and development creates critical gaps in children's holistic learning processes, which inadvertently support psychomotor maladaptation. At least in part, psychomotor maladaptation can be attributed to (1) the underdevelopment of curriculum designed to intentionally scaffold the learning of fundamental motor skills, and (2) the scarcity of instructional support to guide their generalization to increasingly complex skills and behaviors—both inside and outside of the classroom.

The call to refocus our pedagogical efforts to encompass the learning, stabilization, and adaptive generalization of fundamental motor skills is not unique to this dissertation. Newell (2020) stated, “There is a need for fresh experimental approaches on instructional strategies for learning the fundamental motor skills and the early stages of their integration and adaptation into other motor skills” (p. 305). Early childhood educators should be at the helm of innovating ‘fresh experimental approaches’ to structure curriculum that supports the development of fundamental skills that optimize the adaptive capacities of each learner. Educators’ inherent creativity and proximity to young learners place them in an optimal position to rethink, reinvigorate, and restructure ECE curriculum to support psychomotor learning and development. Teachers trained to implement Psychophysical Education in their teaching practice can catalyze a paradigm shift that re-centers psychomotor learning in early childhood classroom practice. The standardization of Psychophysical Education may help change how the public views and evaluates adaptive learning and behavior across the lifespan.

Chapter 2: Methodology

In this research, I applied philosophical synthesis to scaffold a theoretical overview of the phenomenon of interest: namely, maladaptive psychomotor learning and development. To this end, the synthesis discusses research studies within a broader theoretical framework. Dynamical Systems Theory (DST) in Developmental Psychology and the Motor Sciences and the Pragmatist School of Philosophy constitute the principal modes of theoretical inquiry. The principles of DST and its major players were introduced in the literature review. The practice-focused theories of F. M. Alexander (1869-1955) and Theodore Dimon constitute the primary modes of inquiry within the pragmatist tradition. The particulars of these theories are explicated in Chapters 3 through 6. A general explanation of Pragmatism and its relevance to the research question is undertaken in the following section.

Pragmatism was conceived at the end of the 19th century by Charles Sanders Peirce (1839-1914). William James (1842-1910) and John Dewey (1859-1952) further developed and popularized pragmatism as a philosophical method. James, Dewey, and Dewey's friend Jane Addams (1860-1935), the eminent reformer and founder of social work, applied its principles to accord meaning to the practices associated with religion, politics, education, and, ultimately, the humanistic telos of social improvement. William James (1975) described pragmatism as an "attitude of orientation" in the pursuit of truth: "*The attitude of looking away from first things, principles, 'categories', supposed necessities; and of looking towards last things, fruits, consequences, facts*" (p. 32). Pragmatism builds upon the empirical precept that truth is a function of experience as acquired through emplaced action. The objects of our conception, the beliefs and ideas that are assimilated through perceptual experience, are the impetus of action and conduct. Pragmatism contends that the practical efficacy of beliefs and ideas, their "sensible

results”, is the substance of their value and veracity (Peirce et al., 1992, p. 131) Thus, the objects of our conception are accorded meaning and value based on their practical consequences, or the ends they produce.

The study of human movement is an inherently pragmatic endeavor because it is the study of ends, the practical consequences of “our objects of conception.” According to James (1975), the term *pragmatism* is derived from the Greek word, *πραγμα*, meaning “action” (p. 28). Recall that the word “action” denotes coordinated movement that is directed towards a conceptualized goal in the field of Motor Learning. Here, I question whether our “objects of conception” reliably culminate in goal-directed motor acts that are (1) a coordinated psychomotor reaction to environmental stimuli to accomplish goals in the here-and-now, and (2) supportive of the musculoskeletal health of the changing system across its lifetime. The pragmatic method is a robust philosophical lens through which to interpret the phenomenon of human psychomotor behavior and consider the problem of maladaptation.

There is also a compelling historical precedent for the inclusion of Pragmatism in a dissertation that addresses Psychophysical Education. The esteemed pragmatist John Dewey’s support of F. M. Alexander’s work is touched on in Chapter 4. Moreover, Psychophysical Education’s epistemological commitment to the unity of theory and practice is also consistent with the Pragmatist tradition. Incidentally, the Greek word, *πραγμα*, from which the term *pragmatism* is derived, is also the etymological root of the English words “practical” and “practice” (James, 1975, p. 28). Thus, the theory and practice of F. M. Alexander are subsumed in the historical tradition of Pragmatism, and Psychophysical Education is a distinctly pragmatic endeavor. Psychophysical Education involves the study of our “objects of conception” and their association with learned patterns of practical action.

This dissertation interweaves the compatible discourses of Pragmatism and Postpositivism to frame the problem of maladaptive psychomotor learning. Consistent with these traditions, the dissertation frames an empirical research study to supplement the theoretical discussion. This pilot study was developed in Fall 2020, and the subsequent impact of the COVID-19 global pandemic precluded its implementation. The proposed research methods are explicated herein to demonstrate how maladaptive psychomotor learning in young children can be qualitatively measured by evaluating the occurrence of postural deviations in a naturalistic setting. I hope to have the opportunity to implement this proposed research study in the near future.

The purpose of the pilot study was to evaluate the occurrence of a maladaptive postural deviation in early childhood. The proposed research study is titled “Do Maturation and Cognitive Demand Influence the Occurrence of *Forward Head Posture* in Early Childhood?” The study employs qualitative methodology to address the question: Do maturation and cognitive demand influence the presentation of forward head posture in children performing a graphomotor task? I hypothesized that the occurrence of FHP will correlate positively with maturation and cognitive demand in typically developing subjects performing a graphomotor task.

In the context of this study, age is not asserted as an explanatory variable for the occurrence of *forward head posture*. Instead, age is a marker for maturation, as well as the differentiated experiences that are typically acquired across maturational time. The study adopts the Dynamical Systems framework with its emphasis on the synergistic coupling of the genome and emplaced experience to produce behavior. According to DST, age is not an exhaustive predictor of behavior in isolation of other variables. The emergent capacities across development are learned through experiences afforded by the properties of the individual system, its emplaced

environmental contexts, and task constraints. The contributing variables are numerous, layered, and dynamic, undergoing continuous change across developmental time (Adolph, 2019). Their coordination into functional patterns is occasioned by the emergence of highly complex behavior.

Identifying the onset of a postural deviation in early childhood offers a significant contribution to existing research in the motor sciences. Much of the literature has addressed the health implications of postural deviations in adult populations (Ariëns et al., 2000; Ariëns et al., 2001; Jull et al., 1999; Kang et al., 2012; Kapreli et al., 2009; Quek et al., 2013; Silva et al., 2009; Vasavada et al., 2015; Visscher et al., 2000; Watson & Trott, 1993; Weon et al., 2010; 1993; Yip et al., 2008). Postural deviations like forward head posture have been associated with chronic pain conditions and reduced mobility in adult subjects (Quek et al., 2013; Silva et al., 2009; Visscher et al., 2000).

However, an increasing number of research studies have examined the prevalence of back and neck pain in children and adolescents (Huguet et al., 2016; Michaleff et al., 2014). These studies were motivated by the recognition that idiopathic spinal pain in childhood and adolescence is an important predictor of chronic spinal pain in adulthood (Brattberg, 1994, 2004; Jeffries et al., 2007). The literature consistently expressed concern that the prevalence of back, neck, and generalized musculoskeletal pain is on the rise in child populations (Huang et al., 2019; Kjar et al., 2011; MacDonald et al., 2017). Tracking the occurrence of forward head posture in a child population may help isolate a critical period of musculoskeletal vulnerability to postural deviation.

The identification of a critical period is admittedly reliant on the use of chronological age as a standard measure. It must be reiterated that age is not asserted as an explanatory variable in

the occurrence of forward head posture. This study uses age as a reference for the continuum of experiences that typically accompany maturational processes in Western cultures. For instance, educational programming is typically designed to encourage developmental outcomes that comply with standardized measures across domains. The goal of Westernized educational institutions is to reliably produce age-appropriate experiences that support the acquisition of knowledge across disciplines and the learning of practical skills. In pragmatic terms, the desired practical consequence of the educational process is the assimilation of knowledge that compels the selection of adaptive behaviors. Here, the word ‘adaptive’ is used in the broadest sense, and I do not reference the operational definition developed for this dissertation.

The study uses graphomotor tasks to assess the relationship between cognitive demand and FHP in young children. Graphomotor skill acquisition exemplifies the synergism of maturational process and cultural-educational experience in the emergence of skilled behavior. The ability to grasp and control a writing tool is a practical skill that most children are in the process of learning throughout early childhood. Graphomotor skills are regarded as a highly complex perceptual-motor task that requires the integration of motor and cognitive processing (Dinehart, 2015; Smits-Engelsman et al., 2001). Children typically begin experimenting with graphomotor competencies at the age of 2 years (Dinehart, 2015). Crayons, markers, and colored pencils are commonly used by preschool children in the context of visual art-making. Prewriting tasks create opportunities for learning and practice, thereby supporting the development of component skills like fine-motor control, visuomotor coordination, and visuo-spatial integration (Huffman & Fortenberry, 2011; Ziviani & Wallen, 2006).

Children transition into more targeted educational programming in handwriting by kindergarten and first grade (Marr et al., 2003). Children spend 31% to 60% of each school day

performing handwriting and other fine-motor tasks (Cutler & Graham, 2008; Feder & Majnemer, 2007; McHale & Cermak, 1992). They must learn to scale the coordinative patterns of their prewriting skills to the refined task demands of forming letters, words, and even short phrases. This study questions whether the psychomotor transition from prewriting to writing, guided by cultural and educational practices and supported by maturational change, influences the occurrence of a maladaptive postural deviation.

To use Dynamical Systems terminology, this research study may help identify some of the contributing variables that shift the musculoskeletal system into a maladaptive coordination pattern (Thelen & Smith, 1994). This knowledge could be applied practically to the development of targeted educational programming. A preventative intervention would aim to optimize neuromuscular-skeletal structure and function as the basis for skill acquisition across development. The demand for clinical and therapeutic interventions later in life might be reduced by preventative educational measures in early childhood. The study may also yield information that will make us reconsider existing cultural and educational practices, particularly those associated with graphomotor skill acquisition.

This proposed research study was inspired by Baer et al.'s (2019) examination of postural alignment of the head and neck across three target-directed gait initiation tasks in adult subjects (p. 110). The researchers were particularly interested in whether motor preparation was associated with changes in head-neck-thoracic alignment. The researchers hypothesized that (1) postural deviation would be greater when preparing to move than during baseline standing, (2) postural deviation would be greater when preparing to complete a task that required more complex movements relative to tasks that required less complex movements; and (3) postural deviation would be greater before movements with lower target heights relative to neutral target

heights. The results of the study supported the three hypotheses, suggesting that motor preparation, as influenced by the perceived complexity of the task, correlates positively with the occurrence of a maladaptive FHP.

The proposed study uses qualitative methods to track the occurrence of FHP during three graphomotor tasks; 2x3 within-subjects factorial design is used to examine the effects of age and cognitive demand on head-neck-thoracic alignment. There are two groups of 7 subjects (n = 14), each representing a chronological age: **Group 1:** 3-4 years; **Group 2:** 6-7 years (Table 2.1). The parents and guardians of participants will submit written informed consent before their child’s participation in the study.

Table 2.1

Groups of Subjects

Group	Age	N = 14
Group 1	3-4 years	7
Group 2	6-7 years	7

Participants

The three experimental conditions will be assigned to all participants in a blocked, counterbalanced order: (1) Low cognitive demand, (2) High cognitive demand (Level 1), (3) High cognitive demand (Level 2). All participants will perform two trials of each condition (see Table 2.2). Across conditions, the graphomotor tasks will be performed in a fully upright, standing position. A height-adjustable children’s easel will provide a vertical surface for the graphomotor tasks across trials. The low cognitive demand condition will consist of a self-directed drawing task.

The high cognitive demand (Level 1) condition will consist of a tracing task, which is used as a standard assessment for visuomotor coordination. The high cognitive demand (Level 2) condition will consist of a copying task, which is used as a standard assessment of visuospatial integration. Drawing, tracing, and copying are tasks that are commonly used as prewriting tasks to develop writing readiness in preschool and kindergarten classrooms. The tasks used in this study might be encountered in home, preschool, kindergarten, and primary school settings. The purpose is to use familiar, naturalistic tasks that would permit the observation of habitual psychomotor behaviors. The procedure for each task is outlined in

Table 2.3.

Table 2.2

Conditions and Tasks

	Group 1	Group 2
Condition 1	Low Cognitive Demand <i>self-directed drawing task</i>	Low Cognitive Demand <i>self-directed drawing task</i>
Condition 2	High Cognitive Demand <i>Constrained drawing task</i>	High Cognitive Demand <i>Constrained drawing task</i>
Condition 3	High Cognitive Demand <i>Copying task</i>	High Cognitive Demand <i>Copying task</i>

Note. The proposed study will use a 2x3 within-subjects factorial design. The three conditions would be assigned to all participants in a blocked, counterbalanced order.

Table 2.3*Procedure for Each Task*

<p>Task 1 Low Cognitive Demand <i>Self-directed drawing task (2 trials)</i></p>	<p>The participant will be invited to draw a picture using a colored marker. The participant will be invited to select a color to use. The participant will be asked to stand in front of the easel, which will be preset with a white drawing paper (24" x 19"). The drawing paper will be blank except for a circle (D = 1 inch; C = 6.3 inches) The researcher will hand the participant the marker and gently guide the participant's hand (from the elbow and wrist) to the center of the circle at the sound of a "moo" cue. The researcher will release the participant's elbow and wrist at the sound of a "meow" cue played 3 seconds after the tip of the marker has contacted the paper. The researcher will release the participant's elbow and wrist, and the participant will draw independently until they are "finished" with the drawing or for 30 seconds.</p>
<p>Task 2 Level 1: High cognitive demand <i>Constrained drawing task (2 trials)</i></p>	<p>The participant will be asked to stand in front of the easel, which will be pre-set with a drawing of a large "lazy 8" that is covered with tracing paper. The point of intersection of the "lazy 8" will be the center of a light grey circle (D = .5 inch; C = 3.14 inch). The participant will be invited to trace the outline of the black "lazy 8" outline using a marker. First, the researcher will hand the participant the marker and guide the participant's hand (from the elbow and wrist) to the center of the circle at the sound of a "moo" cue. The researcher will release the participant's elbow and wrist at the sound of a "meow" cue played 3 seconds after the tip of the marker has contacted the paper. The participant will begin tracing the "lazy 8." The participant will trace the "lazy 8" for two full cycles or until 45 seconds have elapsed.</p>
<p>Task 3 Level 2: High cognitive demand <i>Copying task (2 trials)</i></p>	<p>The participant will be asked to stand in front of the easel, which will be pre-set with a drawing of a shape that is covered with white paper. The participant will be invited to select the marker that they would like to use for this task. The white paper will be removed from the easel at a "quack" cue. The child will be given 7 seconds to study the shape. A second "quack" cue will signal the end of the 7 seconds, and the picture will be removed. Five seconds later, the researcher will hand the participant the marker at a "moo" cue. Three seconds later, a "meow" cue will signal that the participant can begin drawing the shape from memory. The participant will draw until he/she is finished or for 60 seconds.</p>

Note. Description of task procedures for Task 1 (Low Cognitive Demand), Task 2 (Level 1: High Cognitive Demand), and Task 3 (Level 2: High Cognitive Demand).

Methodology

Two digital video cameras will be used to collect data in the sagittal and frontal planes. One camera will be positioned to the side of the participant and capture the sagittal plane view. The other camera will be positioned behind the participant to capture the frontal plane view. Each camera will be positioned at shoulder height relative to the participant and 2.0 m away. The video data will be uploaded onto a hard drive and analyzed by a primary coder. Two secondary coders will be assigned 30% of the sampled participants. All coders will use a Postural Deviation Rating Scale (PDRS) that was developed for this study (Table 2.4).

Table 2.4

Postural Deviation Rating Scale (PDRS)

Postural Deviation Rating Scale
<p>0: None The absence of <i>forward head posture</i> is characterized by cervical-thoracic alignment. The skull is balanced at the atlanto-occipital joint, and the weight of the front of the skull acts as a cantilever to lengthen the muscles of the neck and back.</p>
<p>1: Mild The mild presentation of <i>forward head posture</i> is characterized by the anterior position of the head and cervical spine in relation to the thoracic spine. The nose and facial structures tilt upwards as the head tilts backward relative to the neck. There will be a decrease in the angle formed by the occipital ridge and C7. There is an increase in muscle tone, which may present as neck and back muscle tension. The increased muscle tone corresponds to an increase in muscular shortening activity to compensate for the mechanical imbalance of the cervical-thoracic structures.</p>
<p>2: Extreme The extreme presentation of <i>forward head posture</i> is characterized by the exaggeration of the criteria listed under the mild presentation.</p>

Note. The values correspond to the magnitude of Forward Head Posture (FHP) observed by visual examination.

Interrater reliability will be measured to assess the validity of the rating scale as a measure of the dependent variable. The scale is based upon descriptions of FHP in studies that measured cervical-thoracic kinematics in adult populations (Baer et al., 2019; Silva et al., 2009). Photographs will also be provided to supplement the rating scale as a more concrete reference (Figure 2.1).



Data will be analyzed using descriptive statistics and a one-way ANOVA to compare differences in group means across conditions and groups. Significant effects will be analyzed using the post-hoc test, Tukey's Honestly Significant Difference.

A design limitation that will not be revised is the small sample size, which decreases the power of the study. However, this is a pilot study, and there may be an opportunity to replicate the experiment with a larger sample size in the future. The use of a non-standardized observational rating scale is another design limitation. The use of standardized assessment tools that are validated for the study of visuomotor coordination and visuospatial integration may help to counteract this limitation. The NEPSY-II subtests for Visuomotor Precision and Design Copying would standardize the procedures for the constrained drawing and design copying tasks (Korkman et al., 2007). Additionally, they would provide an evaluative marker of subject performance on these two tasks relative to age-mate peers (Davis & Matthews, 2010). Subject scores can then be tested using statistical methods to assess for significant group differences with respect to maturation, cognitive demand, within group task performance, and forward head posture.

Figure 2.1

PDRS Reference Photographs

Rating	
0: None	 A young girl with dark hair in a ponytail, wearing a blue apron over a white shirt, is focused on painting on a large wooden easel. She is holding a purple paintbrush and applying paint to a canvas that already has some green and blue paint on it. In the background, another child is partially visible, also painting. The setting appears to be a classroom or art room with wooden walls and floors. There are several paint containers on a table in front of the easel.

Rating	Sagittal Plane
1: Mild	
Rating	Sagittal Plane
2: Extreme	

Note. Figure 2.1 presents examples of each Forward Head Posture (FHP) score on the PDRS. These photographs were taken of 3-year-old children in a preschool setting engaged in a prewriting task during a free play period.

Tracking the emergence of a postural deviation in early childhood will help to elucidate some of the conditions under which a maladaptive coordination pattern is more likely to be assembled and reproduced. This knowledge can contribute to the innovation of a lifespan developmental model of psychomotor health. The practical application of such a model to educational practice will change the way we view and scaffold psychomotor learning in the classroom. Actualizing a positive model of psychomotor health in early childhood can prevent the stabilization of postural deviations associated with adverse health outcomes in adulthood. The first step in actualizing a positive model of psychomotor health is providing resources so that clinicians and educators can identify postural deviation.

To this end, future directions include implementing the Postural Deviation Rating Scale (PDRS) in educational settings to support the identification of maladaptive psychomotor behavior in young children. The advantage of a qualitative rating scale is its accessibility, making it a realistic assessment tool for early childhood educators to apply in classroom settings. Qualitative measures of psychomotor behavior are not as reliable as quantitative methods developed for use in the Motor Sciences. However, the application of quantitative methods to evaluate psychomotor behavior in young children would be inaccessible, unrealistic, and disruptive to learning in ECE settings. The reliability of the PDRS could be improved by the implementation of a follow-up study comparing PDRS scores with kinematic data using three-dimensional motion capture technology, as used in Baer et al. (2019). This quantitative study would help assess whether the PDRS is validated for use in clinical and educational settings as a diagnostic tool. The collected data could also be used to guide the refinement of the tool and increase its reliability.

To reiterate, the proposed research methods have not been implemented due to the impact of COVID-19. At the onset of the pandemic, I pivoted to develop a theoretical paper that thoroughly defines the problem of maladaptive learning in early childhood. To this end, I have taken a multidisciplinary approach to analyze the problem from multiple angles. As stated previously, this dissertation primarily drew from the philosophical tradition of Pragmatism and the Postpositivist tradition of DST to examine psychomotor maladaptation as an educational problem. In essence, the endeavor I have undertaken is to synthesize literature from disparate sources to afford readers a different perspective of adaptive learning and development.

To this end, the next chapter begins with a vignette that offers readers a view of the problem as it arises in the early childhood classroom. Vignettes are commonly used in educational research to present in narrative form the problems, events, and experiences that arise through classroom practice. Jeffries and Madder (2004) defined vignettes as “incomplete short stories written to reflect, in a less complex way, real-life situations in order to encourage discussions and potential solutions to problems where multiple solutions are possible” (p. 20). Accordingly, the purpose of the vignettes developed for this dissertation is to present a real-life situation that encourages discussion and potential solutions to the educational problem of maladaptive psychomotor learning. Vignettes, in the form of “learning stories,” are also used by early childhood educators as a reflective practice tool and an assessment tool to document and track student learning and development (Escamilla et al., 2021). These vignettes and the accompanying photographs emerged organically from my classroom practice as an early childhood educator. They are based on real-life events that I documented in vignette form to track student development as I considered the problem framed in this dissertation.

Chapter 3: Through the Looking Glass

The Discovery of an Educational Problem

Vignette 3.1

It is 8:45 a.m. Children are dispersed throughout the classroom. They play animatedly with a variety of materials that were thoughtfully curated and installed by the teachers earlier that morning. Alert and energized, they move fluidly across the classroom in pursuit of new encounters with these familiar and sometimes unfamiliar materials. A small group of children explore the construction possibilities of tree stumps and large sticks within an area demarcated by a large and inviting oval carpet. The children collaborate to build bridges by stabilizing the lateral ends of the sticks on tree stumps. The rug area erupts with joyous cries of laughter as the children take turns balancing on the narrow sticks to cross the bridges. In this activity, the children's gross-motor activity is broadly characterized by neutral spinal alignment as they practice stabilizing and coordinating walking on the narrow, unstable surface.

Children are also busy at work in the Art Area, painting with pastel tempera paints and paintbrushes at the upright easels or creating three-dimensional winter scenes using black construction paper, wet chalk, cotton balls, and glue at the tables. In the adjacent Table Area, a group of children is engaged with construction materials, small manipulatives, and table puzzles. The classroom emanates with the continuous "buzz" of movement, activity, thought, laughter, and dialogue as the children concretize their thinking and learning through these various media.

A 3-year-old child, Meredith, quietly studies a complex structure that a teacher built with bamboo blocks earlier that morning. After a moment, she deconstructs the structure one piece at a time with systematic precision. She stands thoughtfully considering the strewn parts for some moments before reassembling the structure by returning the parts to their original positions with

exacting care. Satisfied with her reconstruction, Meredith begins adding new elements to make the structure more complex. She places three small pillars within the building, intuitively making them symmetrical to each other and the surrounding structure.

Meredith demonstrates well-developed visuomotor coordination as she balances the bamboo slab and roof structures on the columns and places the small columns within the formed building without upsetting its larger structure. Throughout this process, Meredith mostly maintains neutral spinal alignment as she reaches over the table, grasps the construction materials, and exercises fine-motor control to manipulate them and form functional structures. Meredith explains to a teacher that she has built a house for the duck figurines. Following her explanation, Meredith's satisfaction becomes even more apparent as she devises pretend play situations for the ducks living in the home that she built for them (see Figure 3.1). Her exploration of the emergent possibilities at the dynamic intersection of body-self and environment is supported by the organismic backdrop of poised musculoskeletal coordination.

Vignette 3.2

It is 9:00 a.m. The vibrant sound of a handbell suddenly breaks through the resonant buzzing of children busy at play. "Come, dear children, come..." the teachers sing in unison, summoning the children to the rug for Meeting Time. The children gradually make their way to the rug and sit down at their designated "special spots" on the floor around its periphery. They face the front of the classroom and direct their attention to the teacher leading the meeting. The teacher addresses the children and begins with "roll call," an interactive activity that consists of the teacher leading a song in which each child is greeted in turn. Within a few minutes of teacher-directed activity, the behavior of the children changes in a way that is usually

Figure 3.1

Preschool Child Exhibits Musculoskeletal Alignment During Free Play



Note. Photograph used with permission from Hollingworth Preschool, NYC (2020).

undetectable to the untrained eye: the neutral spinal alignment that was observed in the context of child-directed play now deviates in a remarkable way. With very few exceptions, the children present with mild to severe exaggerations of the spinal curves as they sit and participate in Meeting Time. Meredith, who minutes before maintained a neutral spine in the context of self-directed fine-motor activity, is now in a state of neuromuscular-skeletal collapse (see Figure 3.2).

Figure 3.2

Preschool Children Exhibiting Various Types and Magnitudes of Maladaptive Postural Deviations During a Teacher-Directed Activity



Note. Forward head posture and Thoracic Hyperkyphosis are postural deviations that can be observed in this photograph. Photograph used with permission from Hollingworth Preschool, NYC (2020).

The absence of an educational theory of adaptive psychomotor learning in early childhood education has created a critical gap in young children’s learning processes. Children do not learn how to perform fundamental psychomotor skills adaptively in school settings. This systemic oversight curtails the development of kinesthetic sensitivity as a perceptual-motor competency (Anderson, 2020, p. 5) and inadvertently supports maladaptive psychomotor outcomes. As discussed, psychomotor maladaptation refers to the reproduction of learned motor coordinations, which may adversely impact the changing system’s musculoskeletal health across its lifetime. Framing psychomotor maladaptation as an educational problem may partially explain the prevalence of musculoskeletal problems and associated chronic pain conditions

(Anderson, 2020, p. 4). The sheer scale of the global musculoskeletal health crisis suggests that psychomotor maladaptation is a stable, albeit unintended, learning outcome of the educational process.

Maladaptive postural deviations can become the musculoskeletal basis for higher-level skills when they are not recognized or prevented in educational settings. Currently, ECE teacher training programs do not address the learning and assessment of fundamental motor skills, like sitting, standing, and walking (Newell, 2020). The performance of these basic motor skills is not regarded as a substantive content area to be addressed by ECE curricula. As a result, educators are generally inattentive to children's coordination of fundamental motor skills in the classroom due to lack of training and awareness. Educators thereby miss the opportunity to redirect maladaptive psychomotor behaviors that may accumulate in higher-level skill acquisition. Furthermore, educators do not appropriately scaffold educational activities to support adaptive psychomotor learning and associated outcomes.

Maladaptive psychomotor behavior is the central problem addressed by the re-educational theory and practice of F. M. Alexander (1869-1955). F. M. Alexander was a 19th century actor who developed a method of self-study that yielded: (1) the identification of the problem, (2) a causal explanation for its occurrence, and (3) a solution delivered through re-educational intervention. To this end, Alexander discovered biomechanical laws that mediate the qualitative dynamics of the organism-environment partnership. Throughout the process of discovery, he innovated a replicable method of "learning how to learn" to evoke Karen Adolph's (2005) description of motor learning. Therefore, Alexander's method encompassed the four interdependent variables of adaptive learning explicated in the literature review:

1. the continuous direction of attention to the self-environment interface to extract contextually relevant perceptual information from an array of competing stimuli, to
2. perceive the veridical correspondence between body-self and environment that instantiates affordances for action, to
3. assemble movement coordination patterns that adaptively and selectively leverage biodynamic force and pressure variables that emerge at and from the interface and relationship between the emplaced body-self and its environment, to
4. coordinate task-dependent and context-sensitive movement patterns that holistically achieve embedded action goals sustainably and efficiently, thereby supporting healthy lifespan learning and development.

I was first introduced to F. M. Alexander in the context of The Alexander Technique as an adolescent with Thoracic Hyperkyphosis and a chronic musculoskeletal pain condition. At the time, my weekly Alexander Technique lessons were just one more Complementary and Alternative Medicine (CAM) method that failed to address my musculoskeletal disorder. The teaching methods associated with The Alexander Technique did not generate a process of “learning how to learn.” I cannot emphasize enough that the following analysis does not describe The Alexander Technique as it is marketed and practiced today. Instead, it describes the heuristic procedures innovated by F. M. Alexander to discover and address the problem of maladaptive learning and its adverse impact on lifespan development. The pedagogical differences between The Alexander Technique and Alexander’s method of self-study that facilitated his original discovery are beyond the scope of this dissertation. The latter analysis supports the goal of explicating the problem of maladaptive learning and envisioning the potential for adaptive learning in ECE and beyond.

The titles of the chapters that discuss Alexander's discovery are laced with references to the literary works of Lewis Carroll (1832-1898). Carroll was a contemporary of F. M. Alexander insofar as both men lived, worked, and wrote in the social-cultural milieu of the English Victorian Era. Alexander's lifespan crossed into the Edwardian Era. However, he made the discovery that shaped his writing and vocation towards the end of the Victorian Era in the 1890s. It was a discovery that evoked the phenomenological experience of childhood as expressed in the works of Lewis Carroll. Carroll's iconic works, *Alice in Wonderland* (1865) and *Through the Looking Glass, And What Alice Found There* (1871), explored the dynamism of childhood as mediated by dramatic sequences of maturational change. The rate of maturation and the evolution of morphological change afford continuously changing perceptual experiences in reciprocity with the environment and task constraints. Moreover, the child's existential and social identities are inherently unstable because they fluctuate in concert with the mercurial shapes and forms of the developing body-self. Carroll (2015) captured the phenomenology of childhood in his characterization of Alice striving to establish a stable partnership with the absurdly unpredictable environment of Wonderland.

It was so long since she had been anything near the right size, that it felt quite strange at first; but she got used to it in a few minutes, and began talking to herself, as usual, 'Come, there's half my plan done now! How puzzling all these changes are! I'm never sure what I'm going to be, from one minute to another!' (p. 47)

F. M. Alexander's method, which he called Psychophysical Re-Education, has the effect of destabilizing the organism-environment partnership in order to induce behavioral and morphological change (Alexander, 1910, 1923). The resultant instability allows the adult learner to self-direct the reorganization of neuromuscular-skeletal parts in adaptive and flexible response to veridically perceived environmental conditions. Realigning the environment-organism system by relearning to coordinate actions can be a disorienting and overwhelming experience. The

re-educational process ushers in a phenomenological experience that approximates the phenomenology of childhood expressed through Alice's adventures in Wonderland. Moreover, the adult learner is likely to discover that her existential and social identities are rooted in the backdrop of sensory-perceptual feedback from the body's mechanoreceptors. In other words, the sense of self is intimately connected with the feeling of self-movement while performing motor actions and skills: "I feel, therefore I am," to evoke the famous syntax of Descartes. The process of dismantling excessively stable movement coordination patterns invites new kinesthetic-proprioceptive experiences that destabilize the sense of self. Thus, Alexander's holistic method of "learning to learn" teaches the learner to exercise true agency in the construction and care of herself.

The most comprehensive description of Alexander's (1932, reprinted in 1969) method of self-study can be found in the iconic account of its formation, *Evolution of a Technique*. This seminal work was composed approximately 44 years after the chronicled events. Research in cognitive science has concluded that memory is an unreliable source for an authoritative historical record of events (Roediger, 1996). However, Alexander standardized the methodology described in the account into a formal teaching practice. Alexander reproduced his method hundreds of times in the intervening years to guide students to (1) the identification of the problem of psychomotor maladaptation, (2) an understanding of its causes, and (3) an educational solution. The methodological procedure developed in the 1890s had become fossilized in his teaching practice's procedural method by 1932. Therefore, his historical account was based on procedural knowledge of his methodological process that bridged the discontinuity of time.

The problem discovered and articulated by Alexander is referred to as the ‘problem of maladaptive psychomotor behavior.’ The reader should infer that the problem of psychomotor maladaptation essentially originated with and is sustained by processes of maladaptive psychomotor learning. Recall the dynamical systems and ecological view that most human behavior is learned through experiences afforded by organismic, environmental, and task constraints (Gibson & Pick, 2000; Kelso, 1995; Newell, 1986; Thelen & Smith, 1994). It so follows that the developmental origin of maladaptive psychomotor behavior in processes of learning and motor skill acquisition is implicated in the problem of maladaptive psychomotor behavior. The method of self-study that framed Alexander’s descriptive account of the problem will further reinforce the causal relationship between maladaptive psychomotor learning and behavior.

Alexander’s theory and practice, called Psychophysical Education, earned the recognition and support of one of the 19th century’s most influential American philosophers, John Dewey (1859-1942). Regarding the informal but principled method Alexander employed in the process of discovery, which he later formalized for teaching purposes, Dewey wrote:

...in order to justify a claim to be scientific, it must provide a method for making evident and observable what the consequences are; and this method must be such as to afford a guarantee that the observed consequences actually flow from the principle. And I unhesitatingly assert that, when judged by this standard—that is, of a principle at work in effecting definite and verifiable consequences—Mr. Alexander’s teaching is scientific in the strictest sense of the word. It meets both of these requirements. In other words, the plan of Mr. Alexander satisfies the most exacting demands of scientific method. (Dewey 1923, in Alexander, 1923, pp. xxvii-xxviii, reprinted in 2004)

Dewey staked his reputation on the validity of Alexander’s method and its critical contribution to the project of education.

The Dutch biologist and Nobel laureate Nicolaas Tinbergen (1907-1988) also expressed appreciation for the work of F. M. Alexander. In his 1973 Nobel Prize Lecture, Tinbergen

recognized Alexander's procedures as an innovative application of observational research methods (p. 122). The lecture discussed Alexander's discovery and presented his method as an example of the "usefulness of an ethological approach to medicine" (p. 122). Tinbergen credited Alexander with anticipating the methods of modern Ethology decades before their acceptance by the scientific community. The science of Ethology is the study of animal behavior and primarily employs observational methods in naturalistic settings.

Alexander's method may have met Dewey's and Tinbergen's scientific standards, but it was the emergent product of personal circumstance and not formalized design. Alexander was not a trained scientist reporting his study results for peer-review when he developed his method. His purpose was not to construct a replicable study and submit a verifiable report of its findings. Instead, the development of each phase of his "applied research" design (Wiersma & Jurs, 2005) was motivated by the larger purpose of restoring his vocal apparatus's function. Alexander was an inquisitive man afflicted with a chronic health problem, and his quest for a cure raised a succession of perplexing questions. Alexander intuitively applied the basic tenets of the scientific method to address each phase of questioning. A replicable method of self-study materialized throughout his process of experimentation.

Alexander's methodology led to the conclusion that his original vocal infirmity was a localized symptom of a more integrative health condition, and the health condition was causally associated with instances of maladaptive psychomotor behavior. The events that compelled the discovery of psychomotor maladaptation form a structure that coherently illustrates three elements of discovery: (1) the problem, (2) its causes, and (3) an educational solution. A thorough treatment of these three elements establishes a solid foundation to support the claim

that Alexander's discovery has critical implications for the assessment and guidance of adaptive psychomotor learning and development across the lifespan.

The following analysis of Alexander's method of self-study helps contextualize the proposal that learning in the early childhood classroom should be evaluated within a framework of psychomotor adaptation. To restate my thesis, I define adaptive psychomotor learning as the discovery and stabilization of movement patterns that (1) accomplish action goals in the here-and-now, and (2) support the health of the changing neuromuscular-skeletal system across its lifetime. I further propose the development of a curriculum that structures adaptive psychomotor learning in the classroom as the basis for higher-level skill acquisition. This interdisciplinary curriculum would support the development of kinesthetic fluency as a core competency in ECE. As part of this process, the curriculum would scaffold classroom activities to guide the discovery and stabilization of adaptive psychomotor outcomes in childhood, thereby supporting neuromuscular-skeletal health across lifespan development.

The Problem

F. M. Alexander did what most of us would do when confronted with a chronic malady. He sought the diagnosis and treatment protocols of medical professionals and specialists. His malady was debilitating vocal hoarseness that ensued from the use of his voice in theatrical performance. The clinical diagnosis was "irritation of the mucous membrane of the throat and nose, and inflammation of the vocal cords which were said to be unduly relaxed" (Alexander, 1969, p. 139). Alexander did not describe the treatment protocols prescribed by the professionals he consulted. The only identifiable feature of these prescribed protocols is that they were ineffectual. Invariably, his symptoms intensified despite his commitment to the treatment

regimen. Alexander was “dismayed” by this lack of progress (p. 139) because his vocal instrument’s chronic infirmity threatened his professional acting career.

Alexander consulted his doctor once more when he was offered an engagement that could make or break his career. The doctor instructed him to abstain from reciting and vocal use in the days anticipating his performance. Alexander eagerly accepted this prescription, reassured by the doctor’s promise that his compliance would condition his voice for the demands of recitation. He accepted the engagement with the expectation that his voice would be functioning optimally in time for his performance. Alexander was encouraged by the abatement of vocal hoarseness in the days before the recital. The doctor’s advice seemed to be working! As promised, his voice was functioning optimally in time for the recital, and there was no sign of hoarseness. He started the program with confidence, but his vocal function deteriorated halfway through the evening. The hoarseness returned and progressed to the point that Alexander nearly lost his voice by the end of the night.

Alexander returned to his doctor the next day to report the disappointing results of the treatment. Predictably, the doctor insisted that the only course of action was to continue with the treatment and await more satisfying results (Alexander, 1969, p. 140). Alexander’s response to the inefficacy of this round of medical treatment marks a profound and historical deviation from what most of us would do. He rejected the idea that the solution to his problem was a therapeutic regimen that had proven ineffectual. In Alexander’s (1932, reprinted in 1969) own words:

‘We must go on with the treatment,’ he said. I told him I could not do that, and when he asked me why, I pointed out to him that although I had faithfully carried out his instruction not to use my voice in public during his treatment, the old condition of hoarseness had returned within an hour after I started to use my voice again on the night of the recital. ‘Is it not fair, then,’ I asked him, ‘to conclude that it was *something I was doing that evening in using my voice that was the cause of the trouble?*’ He thought a moment and said, ‘Yes, that must be so.’ ‘Can you tell me, then,’ I asked him, ‘*what it*

was that I did that caused the trouble?’ He frankly admitted that he could not. ‘Very well,’ I replied, ‘if that is so, I must try and find out for myself.’ (pp. 140-141)

Thus, Alexander hypothesized that the cause of his symptoms was something he was doing to perform the speech act in recitation. Moreover, he resolved to test this hypothesis using a heuristic method of self-observation.

Alexander did not explicitly state his research question in his 1932 account. However, the substantive question framing his problem and guiding his methodology was implicated in the informal narrative: *What am I doing when I recite that causes the debilitation of the vocal organs such that my voice becomes hoarse?* Alexander postulated there must be qualitative differences in the behavioral characteristics of ordinary speech and recitation. Those qualitative differences would account for the more functional vocal outcomes in ordinary speech and the increased tendency for vocal dysfunction in recitation. In other words, there must be behavioral events present in recitation and absent in ordinary speech, and the identification of those events would help define the cause of his vocal dysfunction. To this end, Alexander reframed his hypothesis as a measurable research question: *Are there observable differences in my motor behavior during ordinary speaking and formal recitation?*

Alexander contrived a methodological procedure to address this question using two experimental conditions: (1) ordinary speaking and (2) recitation. Alexander observed his motor behavior in a mirror under both conditions. He started with the first condition, ordinary speaking, to establish a behavioral baseline to compare his behavior during recitation. Trials under the second condition yielded the discovery of three behaviors that invariably coincided with the act of formal reciting and were imperceptible during the baseline trials. The three behavioral events identified by Alexander in his 1932 (reprinted in 1969) account were (1) “pulling back the head,”

- (2) “sucking in the breath through the mouth and producing a gasping sound,” and
- (3) “depressing the larynx” (p. 141).

These findings affirmed observable differences in his motor behavior during ordinary speaking and recitation. Moreover, Alexander identified three behavioral events that could help define the cause of his vocal dysfunction. His next step was to isolate these behavioral events during the ordinary speaking and recitation tasks to assess differences in frequency and magnitude between the two conditions. To this end, he questioned whether the three events observed in the context of recitation (Condition 2) were at all appreciable during ordinary speaking (Condition 1). Were the three behaviors completely absent in ordinary speech, or did they manifest imperceptibly? Alexander performed another block of trials under the first condition to address this question. After careful observation of himself in the mirror, Alexander concluded that the three events did occur under the condition of ordinary speaking. Although these behaviors were present during ordinary speaking, Alexander observed that they intensified during the act of recitation. Thus, he concluded that the isolated behaviors intensified as the psychomotor demands of the speech act increased.

Alexander believed that his findings warranted further investigation into the validity of his original hypothesis: *The symptoms of vocal hoarseness are caused by something I am doing to perform the speech act in recitation.* To this end, he hypothesized a positive correlation between the onset of vocal hoarseness and the following events: (1) “pulling back the head,” (2) “sucking in the breath through the mouth and producing a gasping sound,” and (3) “depressing the larynx” (Alexander, 1969, p. 141). To test this hypothesis, Alexander narrowed his next phase of study to examine the three observed events. Alexander’s hypothesis and emergent research methods rested on the assumption that these events were not constitutive

elements of the whole act of vocal production. Instead, they represented the systemic “misuse” of the parts implicated, ushering in his respiratory and vocal mechanisms’ malfunction (p. 142). In his own words, the observed events must “constitute a misuse of the parts concerned. I now believed that I had found the root of the trouble, for I argued that if my hoarseness arose from the way I used parts of my organism, I should get no further unless I could prevent or change this misuse” (p. 142).

Alexander (1932, reprinted in 1969) hypothesized that the three aberrant motor events were particular instances of the misuse of musculoskeletal parts (p. 142). A brief discussion of Alexander’s concept of “misuse” begins to sketch the physiological dynamics that underlie maladaptive psychomotor behavior. Throughout his works, Alexander consistently referred to psychophysical “misuse” (pp. 142, 144, 166; Alexander, 1996, pp. 10, 124; Alexander, 2004, pp. 7, 8, 197) or one of its variants, which includes such phrases as “wrong habitual use” (Alexander, 1932, pp. 147, 156, 159, 160; Alexander, 2004, p. 74) or “incorrect or bad manner of use” (Alexander, 1932, p. 163). Alexander adopted this language to describe the problem of psychomotor maladaptation. As a basis for analyzing Alexander’s concept of psychophysical “misuse,” the discussion employs modern theoretical principles from the *Strength of Materials* engineering field.

Strength of Materials studies the physical properties of modified or stressed materials when exposed to mechanical, thermal, or chemical forces. The purpose of the field is to design structural systems that withstand forces applied to their constitutive elements during use (Mott & Untener, 2017). Engineers design structures like buildings, bridges, and cranes to ensure their physical dependability in response to conditions of “any foreseeable use or misuse” (p. 135). As described in Mott and Untener (2017), a condition of misuse is one where the “accidental

overload on any part” of the structural system is possible or appreciable (p. 135). The physical properties of materials describe the mechanics that govern how a physical system enables functionally sustainable behavior. They also describe and predict the physical conditions that tend to instigate states of systemic dysfunction. As a result, these physical properties are examined extensively in scientific fields that study the behavior of biomaterials and the living organisms they form.

For example, the field of Biomechanics was defined by Humphrey and DeLange (2013) as “the study of the motions experienced by living things in response to applied loads” and is predicated on “the development, extension, and application of mechanics for the purposes of understanding better the influences of mechanical loads on the structure, properties, and function of living things” (p. 3). Unlike the buildings, bridges, and cranes studied in *Strength of Materials*, the human body has a remarkable ability to make efficient and effective adaptations in pursuit of survival through use. In other words, the human body is a physical system that uses itself to become better at a given task over time, whereas buildings, bridges, and cranes purely expend themselves to sustain or retain original form and function. Despite these functional differences, the human body is still subject to the same mechanical principles of stress and strain that govern the use of a physical system. As a natural consequence, the human body, like a building, bridge, or a crane, is vulnerable to misuse.

The concept of misuse implies the incorrect use of an object with respect to its form or function. For instance, an object can be misappropriated for a purpose that is not implicit in or supported by its structural design. Tools are often used to accomplish tasks that are not suited to their intended purpose. For example, a large wooden spoon could be used to hammer a nail into a wooden frame in the absence of a proper hammer. However, repetition of this action would

degrade the spoon's structural integrity—a consequence that might impair the performance of its intended purpose. Alternatively, an object can be appropriated for the proper task, but the manner of its use can be excessive or encumbering. In this scenario, a tool is used for its intended purpose, but the magnitude or frequency of use is beyond the tool's physical tolerance limit. For example, a pair of all-purpose scissors may be used to cut thousands of thick cardstock pieces daily. The scissors are designed to cut cardstock, but the task's demands and frequency would accelerate the rate of structural deterioration. It would not be long before the scissors needed to be sharpened or replaced with a new pair. Thus, misuse, regardless of the type, eventually results in excessive wear-and-tear that modifies or deforms the task-enabling structure inherent in a tool.

The examples used to describe the two types of misuse referred to simple objects: a wooden spoon and scissors. However, the same principles apply to more complex physical systems like a car engine or the human body. Under conditions of misuse, the task demands may result in sustained energetic loads that significantly increase the magnitude of mechanical stress experienced by a physical system and its elements. Under increased load, the physical system's critical components may be unable to retain their shape or form, which can result in “excessive deformation” of the physical system's overall structure (Mott & Untener, 2017). With respect to excessive loads, the field of *Strength of Materials* has demonstrated that a physical system may fail in response to “accidental overload on any of its parts,” which, as previously stated, occurs in conditions of “misuse” (Knudson, 2003, p. 71; Mott & Untener, 2017, p. 135).

Strength of Materials uses the term “failure” to denote “excessive deformation or fracture” that occurs when a structure yields to applied loads beyond a critical “elastic limit” (Knudson, 2003, p. 71; Mott & Untener, 2017; pp. 132-133). The term “failure” is also used in the field of Biomechanics to describe the point at which biomaterials, including skeletal muscle,

connective tissues, and bone, experience excessive deformation or fracture in response to mechanical loads (Humphrey & DeLange, 2013, pp. 45-46; Knudson, 2003, p. 72).

As a result of structural collapse, mechanical failure results in the partial or complete loss of the physical system's functional properties (Mott & Untender, 2017). Notably, the excessive deformation and loss of function that results from mechanical failure may or may not be permanent (Humphrey & DeLange, 2013, p. 46). Under certain circumstances, a physical system's functional shape can be restored by reducing the amount of stress and strain on the overloaded parts or through reconstruction. As stated by Humphrey and DeLange (2013), "if a body is in equilibrium, then each of its parts are likewise in equilibrium" (p. 104). Thus, mechanical equilibrium can be reinstated in physical systems by selectively balancing the distribution of applied forces throughout the entire structure. Consequently, it must be possible that the adaptive and resilient neuromuscular-skeletal system inherent in the human body is also capable of being partially or wholly restored after experiencing conditions of physical misuse.

Alexander continued to develop his self-study to understand this phenomenon. His innovative application of ethological research methods led him to observe the consequences of the musculoskeletal system's structural collapse and the concomitant loss of functional properties. Harkening back to John Dewey's edifying words, these consequences "flow from the principle" of misuse (Dewey, 1923, in Alexander, 1923, p. xxviii, reprinted in 2004). Guided by these observations, Alexander devised a re-educational method to induce a mechanical equilibrium that restores the musculoskeletal system's form and function. Alexander predicated his educational method on contingent hypotheses: *(1) the dysfunction of my vocal apparatus is caused by the misuse of parts of my organism, and (2) this type of musculoskeletal dysfunction is both preventable and reversible.* The discussion resumes the description of Alexander's

scientific and re-educational methods in the next section of this chapter, which outlines the causes of maladaptive psychomotor behavior. This section concludes with a thorough treatment of the physical dynamics that underlie both the condition of *psychophysical misuse* and the possibility of its reversal.

In part, musculoskeletal dysfunction is reversible because the human body is a biodynamic system that responds to changes in internally and externally applied forces with remarkable resilience. The neuromuscular system has specialized receptors called mechanoreceptors, which register changes in tensile and compressive forces that act upon musculoskeletal biomaterials (Knudson, 2003, pp. 98-99). The system responds to these changes by recruiting muscle units to redistribute mechanical forces across the parts of the musculoskeletal structure. This response is characterized by the neuromuscular system's electrochemical signaling and the biochemical process of mechanotransduction in multicellular tissues of bone, skeletal muscle, connective tissues, and even fascial layers (Burkholder, 2007; Kim et al., 2010).

Mechanotransduction is a process whereby cells sense and respond to mechanical perturbations, like tensile and compressive forces, by eliciting cellular and genetic modifications (Ingber et al., 2014; Jacobs et al., 2013; Lim et al., 2010). As a result of mechanical forces inducing conformational changes to cells, intracellular signaling pathways are activated, leading to altered cellular function (Ingber et al., 2014; Jacobs et al., 2013; Lim et al., 2010). For example, cartilage is a skeletal tissue that plays various roles in musculoskeletal function and the maintenance of systemic health. When cartilage is mechanically compressed, changes to the chondrocyte cells' shape and volume, the cells that constitute cartilaginous structures, are observed (Jacobs et al., 2013). In the absence of effective force distribution throughout the

musculoskeletal system, a significant localized strain can induce cell-mediated structural changes that can contribute to musculoskeletal degeneration (Fearing et al., 2018). Indeed, some changes in the mechanics of cells, and the multicellular tissues that they form, have been associated with pathophysiological outcomes (Lim et al., 2010, p. S292).

Mechanisms across different levels of structural organization (cellular, tissues, organs, organ systems, and organism) purposively regulate biomechanical forces to maintain the varied functions of the complex biodynamic system. However, Alexander discovered that the automatic redistribution of forces across the musculoskeletal system may result in mechanical imbalance. Further, he theorized that mechanical imbalance will necessarily increase the magnitude of mechanical stress within local structures. Alexander postulated that, in his case, over time, localized increase in mechanical strain caused musculoskeletal components of the vocal system to experience morphological changes that impaired his vocal performance. In the fields of Strength of Materials and Biomechanics, this process of degradation is described as “fatigue failure.” As defined in Humphrey and DeLange (2013), “fatigue failure” is a type of mechanical failure that is onset by a “loss of strength in material due to repeated loading” (p. 244). Fatigue failure is associated with a progressive rate of deformation over periodic cycles of applied stress. Over time, the component’s loss of structural integrity may compromise or incapacitate the performance of its intended function.

The fatigue failure of any component will invariably create structural and functional disturbances throughout the entire biodynamic system. Alexander (1932, reprinted in 1969) reminded us that “the use of a specific part in any activity is closely associated with the use of other parts of the organism, and that the influence exerted by the various parts one upon another is continuously changing in accordance with the manner of use of these parts” (p. 149).

Therefore, the mechanical overload of a structural element will impact the coordination of the other parts. To retain global functions, these other parts will modify their local output to compensate for the mechanical failure of the overloaded element. In other words, the components mutually compensate for each other to preserve the functional outcomes of the coordinative structures they form. Thus, some parts of the musculoskeletal system will be altered in their functional and structural aspects as they compensate for the functional loss of other parts to preserve global functions.

The principle of redundancy in the motor sciences describes the compensatory functions of complex systems with many degrees of freedom (Newell & Liu, 2021). A reported advantage of such systems is their ability to leverage different utilizations of functional units to preserve their macroscopic functional architecture (Huys et al., 2014; Newell & Liu, 2021). Less discussed in the literature is the potential for these compensatory modes to give rise to progressive states of mechanical stress and strain that deform the system's functional architecture. Instead, neuromuscular-skeletal dysfunction is broadly attributed to the natural course of aging, disease, and acute or chronic injury. The idea that, in some cases, structured educational intervention can prevent the degeneration of neuromuscular-skeletal structure and function is currently undeveloped.

Alexander's narrative described his observation that automatic neuromuscular responses to changes in applied force may misappropriate musculoskeletal parts for purposes that are not implicit in or supported by their structural design. Alternatively, the musculoskeletal parts may be used for the appropriate task, but the manner of their use in terms of intensity or duration may be unsustainable. Either way, the parts are misused as the system works to restore mechanical equilibrium in the context of ever-increasing mechanical dysfunction. Thus, the viscoelastic

properties of living tissues afford compensatory responses to mechanical imbalance that may preserve global functions but potentially at a cost. As previously described, the progressive deformation of overloaded tissues may result in mechanical failure, leading to pathophysiological outcomes. Therefore, Alexander's concept of *psychophysical misuse* describes the misapplication of body structures for a purpose that is not *adaptively* supported by their structural design.

The somatic educator, Mabel E. Todd (1880-1956), presented a thorough analysis of how the human body is designed to distribute loads and support mechanical equilibrium in her seminal work, *The Thinking Body: A Study of the Balancing Forces of Man* (1937, reprinted in 2008). She also described the possibility of functional disturbances associated with mechanical imbalance and localized strain. Mabel E. Todd was a faculty member in the Physical Education Department at Teachers College, Columbia University. Her work is a valuable resource that helps to illustrate the structural deformations that may result from *psychophysical misuse*. Here, she offered a succinct description of mechanical strain on musculoskeletal structures using a simple anatomical example:

In the body, balance cannot be effected by opposing weight for weight, as it can in artificial structures by such means as putting an equal weight opposite and at an equal distance from the center, or a smaller weight farther away. The essential supporting mechanism is a compact, flexible column, whose integrity depends upon the closeness of the various compression members to a central axis and to each other. If, therefore, weights are held out of balance, this must be done by throwing extra work on the small muscles and ligaments about the individual vertebrae in order to accent, or even distort, the normal compensatory curves; or by tightening suspension muscles or tensile members, as in the neck, causing them to bear more weight than is their proper task. (Todd, 2008, p. 97)

Todd (2008) described the increased complexity of the bipedal vertebrate physical system as compared to human-made systems, which, as previously stated, are also reliant on the balanced distribution of mechanical forces to maintain stability and function. She referred to the spinal

column as the “essential supporting mechanism” of the human structure, and she explained what happens when the tissues of the spine are stressed due to mechanical imbalance (p. 97). The disruption of mechanical equilibrium compels the soft tissues that hold the vertebral column together (ligaments) and facilitate their movement (muscles and tendons) to compensate by changing their behavior. The magnitude of mechanical stress is increased in these tissues and the bony spinal column to which they are attached and exert pulls. As a result, the spinal column may yield to the resultant applied loads and sustain excessive deformation to its structure.

Todd (2008) did not explicate a concept of misuse, but it is implicit in her reasoning about mechanical imbalance and its effect on musculoskeletal structures. Recall the two types of misuse that were described earlier in this section: (1) an object can be misappropriated for a purpose that is not implicit in or supported by its structural design; and (2) an object can be appropriated for the proper task, but the manner of its use can be excessive or encumbering. In Todd’s example, the spinal column, “the essential supporting mechanism” in the human body, experiences mechanical failure due to the second type of misuse (p. 97).

The ligaments and deep muscles of the back that coordinate the spine’s stabilization and extension are appropriated for the proper task. They are working to stabilize and move the vertebrae, facilitating the spinal column’s extension and the maintenance of upright posture (Dimon, 2008). However, their manner of use is excessive and encumbering in response to conditions of mechanical imbalance. The ligaments are strained by the increased demands of maintaining the “closeness” of the vertebrae “to a central axis and to each other” (Todd, 2008, p. 97), and the deep postural muscles are chronically contracted as they strain to support the increased mechanical loads. Under these conditions, the muscles will exert pulls that further strain the ligaments and vertebral column. As a result, the spinal column may yield to the applied

forces and suffer the collapse of its curves, which are mechanically advantageous to upright posture. Todd's description of the collapse of the spinal column indicates fatigue failure as a result of progressive misuse.

Todd (2008) also suggested that, in correspondence with the first type of misuse, the other musculoskeletal structures must alter their behavior to compensate for the collapsed spinal column (p. 97). The mechanical failure of the "essential supporting mechanism" will demand that other parts of the musculoskeletal system pick up the slack to preserve global functions (p. 97). Todd referred to the neck muscles as one such part, which may "bear more weight than is their proper task" in the context of mechanical imbalance and failure (p. 97). The neck's musculoskeletal structures include the hyoid bone, laryngeal cartilages, intrinsic laryngeal muscles, suspensory laryngeal muscles, and the pharyngeal muscles of the throat (Dimon & Brown, 2018). Compellingly, Alexander's vocal problem was directly associated with this intricate system's dysfunction, which is positioned anteriorly to the cervical spine (Dimon & Brown, 2018; O'Brien, 2015).

This highly specialized system is a complex framework of musculoskeletal structures designed to coordinate the essential functions of breathing, swallowing, and, perhaps incidentally, phonation (Dimon & Brown, 2018). The larynx is suspended from the skull and hyoid bone by four suspensory muscles (p. 48). Their size and location make them particularly well-suited to stabilize and move the larynx in support of its various functions (Dimon & Brown, 2018). This delicate network of muscles was not intended as an auxiliary system to support upright posture in opposition to gravitational forces. However, these muscles may be conscripted to support loads discharged by the collapsed spine.

Thus, the biodynamic system resiliently conserves postural control by misappropriating the neck musculature for a purpose that is not implicit in or supported by their structural design. These conditions of misuse will result in the strain, deformation, and dysfunction of the whole laryngeal apparatus, which, in turn, will adversely impact the muscles of the throat. The progressive rate of deformation of these structures over periodic cycles of applied stress will result in “fatigue failure” (Humphrey & DeLange, 2013, p. 244). It is becoming clear how the chronic misuse of musculoskeletal structures could lead to chronic vocal dysfunction, as experienced by Alexander.

Alexander’s concept of *psychophysical misuse* describes the neuromuscular-skeletal biodynamics that underlie maladaptive psychomotor behavior. Further, it explains the associated degeneration of musculoskeletal health over time. As previously defined, maladaptive psychomotor behavior fails to satisfy the explicated standards of adaptive motor behavior: (1) a coordinated psychomotor response that accomplishes action goals in the here-and-now, and (2) supports the health of the changing neuromuscular-skeletal system across its lifetime. Maladaptive psychomotor behavior is assembled from the imbalanced and strained conditions that are associated with musculoskeletal misuse. The causal association between the two concepts signifies that they both refer to aspects of the same phenomenon. Psychomotor maladaptation signifies what the problem is, and *psychophysical misuse* explains why the problem occurs.

If Alexander’s hypothesis was correct, then the psychomotor system’s maladaptively coordinated performance of the speech act was an ineffective reaction to stimuli that compelled the act. Admittedly, it was effective across some percentage of *here-and-nows* when functional vocal production capacitated his willed speech act. However, the biodynamics of the systems

that support sound and speech production were unreliable over time. The misuse of the system applied forces that strained its constitutive parts and compromised their functional output, resulting in systemic health deterioration over time. Sustained periods of vocalizing would cause the recurrence of symptoms and the incapacitation of vocal production. Consequently, Alexander often encountered *here-and-nows* when his will to speak was thwarted by vocal dysfunction.

The chronic loss of his voice during vocal performance is an example of psychomotor maladaptation that violates the first criterion, which states that adaptive psychomotor behavior is a coordinated psychomotor reaction to environmental stimuli that accomplishes goals in the *here-and-now*. Alexander was consistently unable to coordinate a psychomotor response to environmental and vocational demands that accomplished his action goals of speech and recitation. The maladaptive psychomotor coordination associated with the speech act yielded systemic malfunction over time, which resulted in chronic episodes of incapacitation across *here-and-nows*. Therefore, the second criterion's violation may be causally associated with the violation of the first criterion. Thus, maladaptive psychomotor behaviors often come into violation of both criteria across developmental time.

The reciprocity between the two criteria is why both should be considered critical to our evaluation of psychomotor learning processes in early childhood settings. Assessment and teaching practices that only consider the efficacy of psychomotor behavior in the *here-and-now* is insufficient. Educators must not accept deviated postural coordination associated with chronic disorder and incapacitation over time as effective or adaptive motor solutions. Nevertheless, every day, in early childhood educational settings across the world, maladaptive psychomotor behaviors are often misclassified as both effective and adaptive despite the eventual presentation of chronic disorder.

Alexander's principal claim was that the developing human could learn to *misuse* the emplaced body-self in the performance of goal-directed action. He observed that over time the repetitive performance of maladaptive movement coordination patterns issued systemic malfunction occasioned by local symptoms of disorder. Applying a Biomechanics model, the systemic malfunction was caused by periodic cycles of applied mechanical stress that culminated in neuromuscular-skeletal fatigue failure. This potentially debilitating impact of maladaptive psychomotor learning remains under-recognized and underdeveloped in the interdependent fields of Education, Healthcare, and Medicine.

Chapter 4: Down the Rabbit Hole:

The Four Causes of Psychomotor Maladaptation

F. M. Alexander's investment in weeks of self-study compelled the refinement of his original theory. The results of his self-observation in the mirror supported the hypothesized causal association between his coordination of the speech act, particularly during recitation, and vocal dysfunction. In other words, something he was doing to perform the speech act in recitation was causing his vocal hoarseness. Alexander identified three prominent behavioral events that coincided with the speech act during ordinary speaking *and* recitation: pulling back the head, depressing the larynx, and sucking in the breath through the mouth (Alexander, 1932, reprinted in 1969). Moreover, he hypothesized that these behaviors were superfluous to the speech act and represented instances of musculoskeletal misuse. He concluded that he was misusing parts of his musculoskeletal system whenever he willed the speech act irrespective of context, and this pattern of misuse was causally associated with his vocal dysfunction. At this time, Alexander believed that the pattern of musculoskeletal misuse was limited to the structures of his head, neck, and larynx.

As previously discussed, the principle of misuse provides a mechanical explanation for the condition of psychomotor maladaptation. In Alexander's lexicon, *misuse* refers to the misappropriation of musculoskeletal parts in the coordination of voluntary actions. Under conditions of misuse, the parts may be used for purposes not implicit in or supported by their structural design. For example, the neck muscles may "bear more weight than is their proper task" in the context of mechanical imbalance and failure (Todd, 2008, p. 97). Alternatively, the parts may be appropriated for the proper task, but the manner of use is excessive or encumbering. For example, a state of mechanical imbalance will strain the spine's ligaments and the deep

postural muscles. The increased demands on these biomaterials in their proper tasks will have a debilitating effect on their structure and function over time. Regardless of type, the *misuse* of body parts imposes excessive stress and strain on the body's composite structures. As a result, the form and behavior of those structures and their constituent elements are progressively altered as they coordinate in service of the biodynamic whole. Thus, the principle of *misuse* explains the changes to the musculoskeletal form that result from the maladaptive performance of actions, and it accounts for the impairment of functions that are correlated with these structural changes.

The Greek philosopher, Aristotle (385 BC-322 BC), developed a four-causal explanation of objects, natural substances like organisms, and the natural changes that objects and substances undergo (Aristotle & Barnes, 1984a; Reece, 2019, p. 214). As described in Reece (2019), an action is a natural change that occurs in the substratum of a self-moving body: "Human action is a species of animal self-movement, and animal self-movement is a species of natural change" (p. 213). As an extension of this logic, maladaptive actions are a species of human action. Thus, maladaptive action is also a natural change that occurs in a self-moving body—a natural change predicated on the *misuse* of the body's parts. As discussed, such changes tend to impose excessive mechanical stress and strain on musculoskeletal structures. As a result, these structures undergo morphological changes that facilitate progressive deformation and functional impairment.

Aristotle's causal framework helps construct a coherent picture of the multidimensional causes of psychomotor maladaptation. As a species of natural change, psychomotor maladaptation can be explained in terms of Aristotle's four causes: *the material, the formal, the efficient, and the final* (Aristotle & Barnes, 1984a). Each of these four causes is considered in turn and their explanatory powers applied to psychomotor maladaptation.

The Material Cause

In one way, then, that out of which a thing comes to be and which persists, is called a cause, e.g. the bronze of the statue, the silver of the bowl, and the genera of which the bronze and the silver are species. (Aristotle & Barnes, 1984a, p. 332)

Here, Aristotle identified the material cause of a natural change as the substratum of an object that undergoes the change (Aristotle & Barnes, 1984a; Reece, 2019). The substratum of a natural object is “that immediate constituent of it which taken by itself is without arrangement” (Aristotle & Barnes, 1984a, p. 329). Following this principle, Aristotle argued that bronze is the material cause of a bronze statue, and wood is the material cause of a bed (Aristotle & Barnes, 1984a). Bronze and wood are species of matter beholden to physical laws constraining the kinds of changes they undergo. For example, bronze is an alloy that melts at 2,200°F and hardens into a solid when cooled. These properties support physical changes that make it amenable to casting and metalwork. Bronze can function as the substratum of a statue because of its physical properties. Therefore, bronze is the material cause of a statue that has bronze as its “immediate constituent” (Aristotle & Barnes, 1984a, p. 329).

Human action is a species of natural change that can source its cause to a material substratum. Reece (2019) argued that the material cause of human action is the body “because it is a substratum that undergoes a change that action is” (p. 216). It follows that the material cause of maladaptively performed actions is also the body. In particular, the diverse biomaterials that are the body’s “immediate constituents are taken by themselves without arrangement” (Aristotle & Barnes, 1984a, p. 329). The material cause operates at the microscopic and mesoscopic levels of biophysical organization. More granularly, the histology of musculoskeletal tissues and their resultant physical properties are the material cause of psychomotor maladaptation. For instance, the musculoskeletal system is composed of skeletal muscle, bones, cartilage, connective tissue,

and fascial networks. The physical properties of these multicellular tissues are influenced by the structure and behavior of their constitutive cell types. Cellular and multicellular dynamics actuate the physical properties that determine how tissues change in response to applied forces and support “a change that action is” (Reece, 2019, p. 216).

For example, skeletal muscle cells are composed of interdigitating molecular chains that form an intracellular contractile mechanism (Dimon, 2015). The resultant contractile property of skeletal muscle tissue causes its fibers to contract (shorten) or release (lengthen) in response to applied forces as mediated by the continuous interplay of neuromotor activity. The contractile property of skeletal muscle is the primary force-producing mechanism that facilitates movement at joints, enabling the performance of involuntary and voluntary actions. It is also one of the mechanisms implicated in the excessive deformation and dysfunction of musculoskeletal structures under conditions of misuse. These mechanisms are discussed in more detail when Theodore Dimon’s theory-practice of Movement Awareness is introduced in Chapter 6: The Physiology of Kinesthetic Fluency (Dimon, 2015, 2021).

Another example of a material cause is the articular cartilage that covers the joint surface of bones to facilitate the transition of loads. Articular cartilage is a specific type of cartilage called hyaline cartilage (Martin et al., 2015). This specialized tissue provides a smooth and lubricated surface for joint articulation, reducing friction that would otherwise damage bone (Sophia Fox et al., 2009). Hyaline cartilage is comprised of a dense extracellular matrix (ECM) that is uniquely equipped to retain water and withstand loads because of its molecular components: water, collagen, proteoglycans, and other non-collagenous proteins and glycoproteins (Sophia Fox et al., 2009). Embedded within the ECM are a limited number of highly specialized chondrocyte cells that respond to growth factors, mechanical loads,

piezoelectric forces, and hydrostatic pressures (p. 463). The viscoelastic properties of the ECM protect the less resilient chondrocyte cells from the impact of mechanical loads. However, as stated in the previous section, the chondrocyte cells are modified with respect to their shape and volume when cartilage is mechanically compressed (Jacobs et al., 2013, p. 317). The deformation of chondrocytes due to overloading alters the structure and function of hyaline cartilage. For instance, the pathophysiological condition of osteoarthritis is caused by changes in physical loading that alter the mechanical signaling of chondrocytes (p. 4).

The material cause of psychomotor maladaptation is closely related to the *Strength of Materials'* principles discussed in the last section. The types of biomaterials that constitute the musculoskeletal system and their specialized responses to mechanical stress are the material cause. The human body mechanically leverages the dynamic interplay of organismic and environmental forces to coordinate self-movement in the fulfillment of action goals. For example, the intracellular contractile mechanism of muscle cells is a design feature that generates forces with the support of elastic intracellular and extracellular connective tissues (Ethier & Simmons, 2007). The forces generated by muscular contraction act on the bony levers of the skeleton to produce movement at joints. The muscular forces are thereby transferred into the environment through bone. Reciprocally, the environment transmits reactionary forces that cooperatively support goal-directed self-movement (Ethier & Simmons, 2007).

This dynamic transference of forces is also predicated on the particular arrangement of the body's biomaterials into an organized functional system. However, Aristotle's material cause is limited to the species of matter that underlies an object or self-moving body. The material cause addresses the potential for emplaced action given the physical properties of discrete biomaterials, but it cannot fully explain its actualization. For example, the bronze is potentially a

statue, and the wood is potentially a bed (Aristotle & Barnes, 1984a). It follows that the diversity of biomaterials are potentially a functional self-moving body. The statue is actualized when bronze receives the form of a statue, and the bed is actualized when wood receives the form of a bed (Aristotle & Barnes, 1984a). Thus, the self-moving body is actualized when the biomaterials are organized to form a self-moving body. Aristotle's formal cause addresses the actualization of emplaced action given the biomaterials' natural tendency to occupy a determinate structure. It also addresses the holistic design principles that support both adaptively and maladaptively coordinated action.

The Formal Cause

In another way, the form or the archetype, i.e. the definition of the essence, and its genera, are called causes (i.e. of the octave the relation 2:1, and generally number), and the parts in the definition. (Aristotle & Barnes, 1984a, p. 332).

All members develop themselves according to eternal laws,
And the rarest form mysteriously preserves the primitive type.
Form therefore determines the animal's way of life,
And in turn the way of life powerfully reacts upon all form,
Thus the orderly growth of form is seen to hold
Whilst yielding to change from externally acting causes.

(Johann Wolfgang von Goethe, *The Metamorphosis of Animals*,
from Haeckel & Lankester, 2009)

Aristotle's formal cause is the paradigmatic shape that a particular object or natural substance tends to obtain. Reece (2019) described the formal cause as that which "makes something a determinate and unified thing rather than a mere accidental aggregate" (p. 218). Aristotle invoked the structure of a musical octave to exemplify a formal cause (Aristotle & Barnes, 1984a). He explained that the 2:1 relationship between two frequencies is the formal cause of an octave. In other words, the emission of one musical pitch and another with double its frequency is the formal cause of the particular interval called an octave. The octave's formal cause builds on its material cause, which is mechanical waves that travel through air and register

as audio frequencies to the ear's sensory receptors (Wikimedia Foundation, 2020). Thus, an octave's determinate structure is the 2:1 relationship between two pitches, which are materially caused by mechanical waves.

Aristotle assigned formal causes to the natural changes that objects and substances undergo (Aristotle & Barnes, 1984a; Reece, 2019). For example, he used the formal cause as a teleological explanation for natural changes such as animal generation [GA], respiration [De res.], and sleep [De somn.] (Aristotle & Barnes, 1984a, 1984b; Reece, 2019). As discussed, human action is a species of natural change that is materially caused by the coordinated activity of specialized tissues of the body. The formal cause of human action is how these multicellular tissues are organized on certain principles to form a complex functional design. Thus, the formal cause operates at the macroscopic level of biophysical organization. Stated simply, the formal cause of human action is associated with the morphology of the human body. As such, the Musculo-skeletal structure is formed by the arrangement of its constitutive tissues in accordance with a coherent body plan. Therefore, skeletal muscle tissue, bones, cartilage, connective tissue, and fascial networks are arranged teleologically to establish biomechanical relationships that facilitate emplaced action. Importantly, the system's macroscopic organizational properties emerge from the synergistic material properties operating at the microscopic and mesoscopic levels (Newell & Liu, 2021).

For example, hyaline cartilage is strategically located at synovial joints to form a relationship with bone that supports the transition of loads in the dynamic context of joint articulation. Joints refer to a biomechanical relationship between two bones. The distal ends of bony levers form an articular cavity that is shaped to circumscribe their range of motion. Skeletal muscle forms tendinous attachments to bone at origin and insertion points, which typically cross

over one or more joints (Blottner, 2013). The location (specific origin & insertion points), shape, and size of muscle are variables that influence their relationships to both local skeletal structures and the functional maintenance of the complex whole (Blottner, 2013). The interdependent relationships between skeletal muscle, connective tissues, and bony levers are a formal cause of movement in vertebrates. It follows that the formal cause of psychomotor maladaptation is the disruption of these integral relationships throughout the complex neuromuscular-skeletal system.

As discussed in the literature review, Dynamical Systems Theory (DST) comprehensively describes the formal cause of human development and action. As introduced in the literature review, DST is derived from Chaos Theory and is closely related to Complex Systems Theory (CST). These theories share the world view that nature tends to produce complex systems, which are often driven by irreversible and probabilistic processes (Bar-Yam, 1992; Prigogine & Stengers, 1984). The behavior of these systems emerges from interactions among their highly differentiated elements or subsystems (Bar-Yam, 1992; Prigogine & Stengers, 1984). A universal property of complex systems is “emergent complexity,” which describes the collective behavior that arises from the local behavior of interdependent parts (Bar-Yam, 1997, p. 5). Further, the nonlinear processes that support emergent complexity are adaptively responsive to environmental feedback. The exchange of energy, matter, and information between the complex system and its environment catalyzes the organization of the system’s ordered parts into a coordinated whole (Prigogine & Stengers, 1984). Thus, the precise arrangement of constitutive elements enables the system’s function as a unified whole with global emergent properties.

Recall that DST views the human neuromuscular-skeletal system as a complex system, which manifests global emergent properties in response to environmental conditions (Teulier

et al., 2015; Thelen, 1995; Thelen & Ulrich, 1991; Thelen et al., 1993; Ulrich et al., 1998).

Voluntary behavior is considered one such global emergent property caused by the interaction of the unified system's interdependent elements with critical input from environmental fields.

Further, DST claims the developing human learns to assemble patterns of interaction voluntarily to achieve self-directed action goals (Teulier et al., 2015; Thelen, 1995; Thelen & Ulrich, 1991; Thelen et al., 1993; Ulrich et al., 1998). These voluntary patterns stabilize as attractor states across developmental time, enabling the system to self-organize into relational configurations that afford for meaningful action in specific contexts. The stable attractors are paradigmatic modes of behavior, which emerge from interactions among the neuromuscular-skeletal system's manifold and interdependent parts. These paradigmatic modes, predicated on the organizational properties of the system architecture, are the formal cause of human action and psychomotor maladaptation.

As a basis for explaining psychomotor maladaptation's formal cause, the discussion interprets the next phases of F. M. Alexander's self-study through a Dynamical Systems lens. Alexander studied the self-organization of his respiratory and neuromuscular-skeletal systems into the stable speech attractor. In particular, he observed periodic changes to the relational configuration of neuromuscular-skeletal parts during the phase shift between *not-speaking* to *speaking*. Accordingly, he identified three changes that occurred at the critical moment his system self-organized into the speech attractor: pulling back the head, sucking in the breath through the mouth and producing a gasping sound, and depressing the larynx. As previously discussed, Alexander suspected these changes were superfluous to the speech act and represented instances of musculoskeletal misuse. Therefore, he believed they could be prevented and extracted from the paradigmatic mode assembled whenever he willed the speech act. He

hypothesized that their prevention and extraction would elicit the proper function of his respiratory and vocal mechanisms, preventing the onset of hoarseness, a local symptom associated with systemic misuse. *Therefore, Alexander hypothesized that the prevention of these three periodic changes would correlate negatively with vocal hoarseness.*

Alexander's description of his methodology at this stage of study is less developed than his account of the first experimental phase. The reader of his 1932 account can infer Alexander observed his physical behaviors in a mirror under the condition of recitation. He may have isolated this condition because it had previously afforded the most measurable observation of the three changes. Alexander interpreted these observed changes as behavioral events that coincided with the speech act. With regard to the relationship between changes and events, Demonte and McNally (2012) described events as a "*change* from one state to another, explicitly defined, state" (p. 2). For Alexander, the observed neuromuscular-skeletal changes were associated with goal-directed transitions between coordinative states. For example, the "pulling back the head" event involved a neuromuscular-skeletal change from a relatively aligned state to a comparatively deviated state (Alexander, 1932). Alexander assigned himself the experimental task of preventing the occurrence of the three behavioral events when he performed the speech act. The duration of this phase of experimentation was an unspecified number of months.

Alexander discovered that he could not directly prevent the events, (2) "sucking in the breath through the mouth and producing a gasping sound," and (3) "depressing the larynx." However, he could exert some control over behavior, (1) "pulling back the head" (Alexander, 1932, reprinted in 1969). Fortuitously, he discovered a correlation between the direct prevention of event (1) and the indirect cessation of events (2) and (3). Pulling back the head was most accessible to behavioral modification and appeared to be associated with events that implicated

the respiratory and vocal apparatus more directly. Over months, the prevention of event (1) indirectly inhibited the occurrence of events (2) and (3), which prevented the onset of vocal hoarseness. These anecdotal results supported Alexander's hypothesis that his chronic hoarseness was caused by something he was doing to perform the speech act. He was "pulling his head back," and this maladaptive behavior was associated with the chronic dysfunction of his respiratory and vocal systems (Alexander, 1969, p. 143).

The pivotal musculoskeletal event that Alexander described as *pulling back the head* corresponds to a postural deviation that many contemporary researchers and medical professionals have classified as "forward head posture" (FHP) (Alexander, 1932, p. 143; Baer et al., 2019; Fiebert et al., 1999; Hanten et al., 1991; Haughie et al., 1995; Lau et al., 2010; Sheikhhoseini et al., 2018; Silva et al., 2009; Yip et al., 2008). FHP refers to the movement of the head and neck forward relative to the thoracic spine (Baer et al., 2019). The association may seem counterintuitive because pulling back the head and forward head posture seem to denote oppositional directions. How can the act of *pulling back the head* be related to the clinical presentation of a *forward head* posture? Considering the biomechanics of FHP reveals a more complex process than suggested by its clinical presentation. Further, FHP is an example of qualitative changes to the formal relationships between musculoskeletal parts, which may lead to systemic malfunction over time. As a result, these postural deviations represent mechanically disadvantageous changes to the relationships formed by musculoskeletal parts. FHP is a collective state that leads to more harmful or ineffective use of the musculoskeletal system in the context of voluntary action.

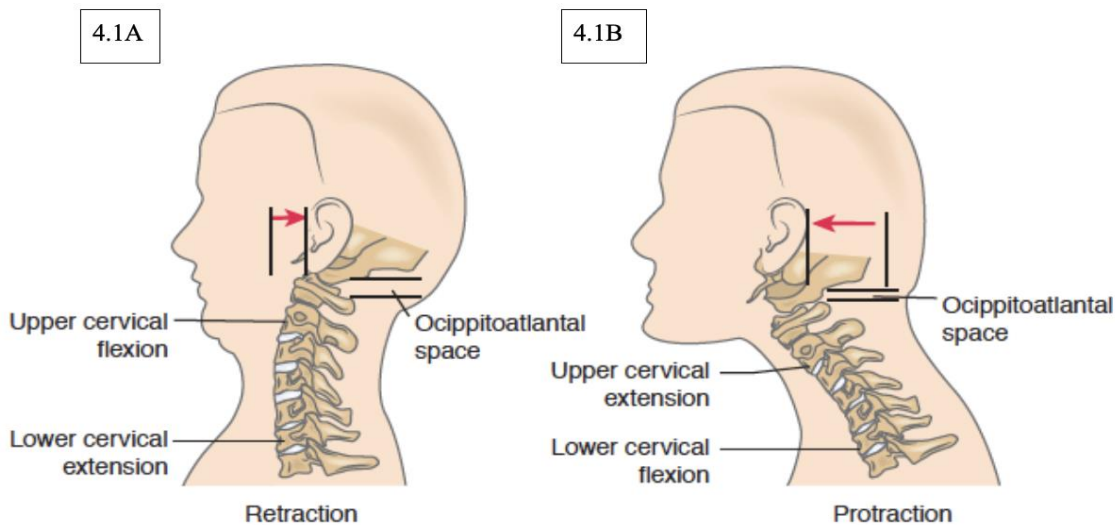
Forward Head Posture (FHP) is caused by the flexion of the lower cervical vertebrae (C3-C7) "in a forward glide" (Fiebert et al., 1999) and the extension of the upper cervical

vertebrae (occiput, C1-C2) (Hanten et al., 1991; Haughie et al., 1995; Mahmoud et al., 2019).

The kinematics of FHP is illustrated in Figure 4.1B labeled 'Protraction,' which describes the protracted or forward placement of the head. The lower cervical vertebrae's flexion causes the neck to move forward relative to the thoracic spine, and the extension of the upper cervical vertebrae causes the head to tilt backward relative to the neck and torso. These two movements of the head-neck commonly co-occur in the clinical manifestation of FHP. However, in Biomechanics research, they are often decoupled and assessed using two standard kinematic measures: the "craniovertebral angle" and the "gaze angle" (Mahmoud et al., 2019). Both of these measures enable quantitative analysis of the head-neck relationship by calculating the values of angles formed by cephalic anatomical landmarks and joints.

Figure 4.1

Postural Deviations of the Head and Neck



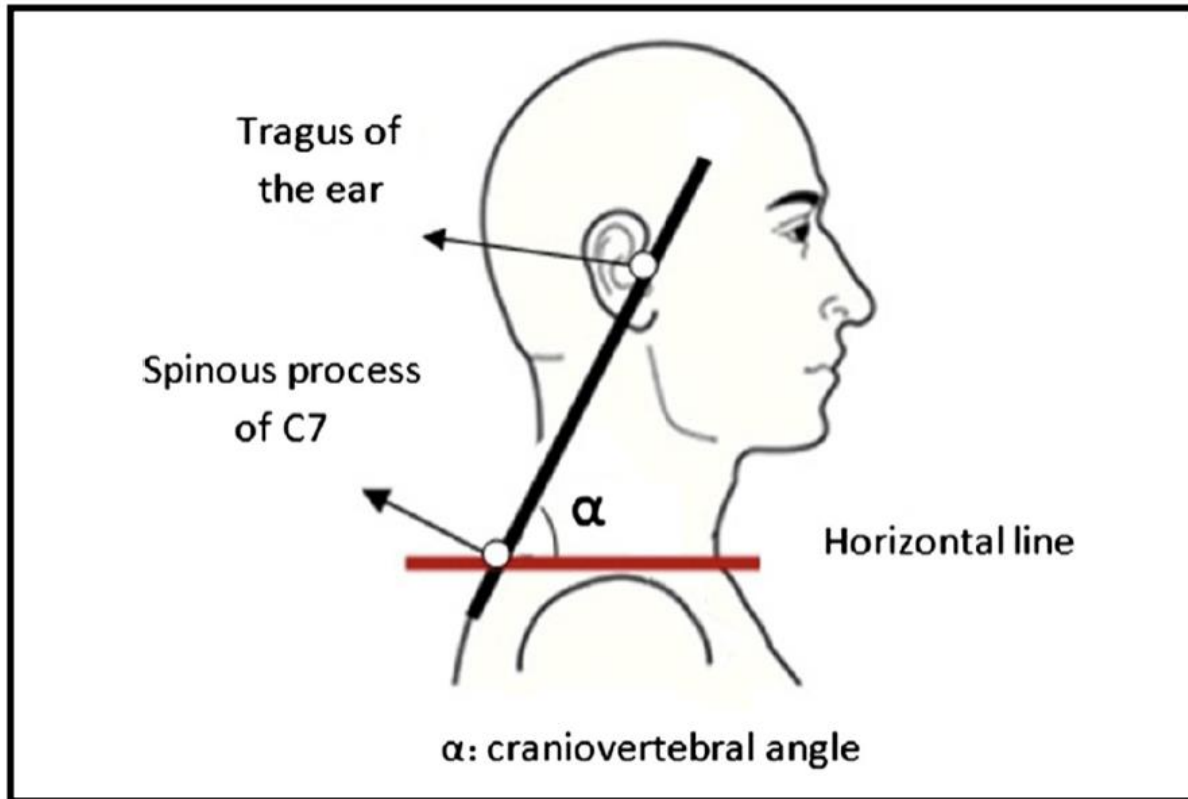
Note. The image labeled 'Retraction' depicts a postural deviation of the head and neck characterized by flexion of the upper cervical vertebrae (occiput, C1-C3) and extension of the lower cervical vertebrae (C3-C7). The image labeled 'Protraction' depicts the kinematic characteristics of Forward Head Posture (FHP). FHP is caused by the extension of the upper cervical vertebrae (occiput, C1-C3) and the flexion of the lower cervical vertebrae (C3-C7). From C. H. Wise (2015), *Orthopedic manual physical therapy: From art to evidence*, F. A. Davis Company. fadavispt.mhmedical.com/content.aspx?aid=1156872591

As depicted in Figure 4.2, the craniovertebral angle is formed by the intersection of a horizontal plane and a line that passes through the tragus of the ear and the spinous process of the 7th cervical vertebrae. The angle decreases as flexion of the lower cervical vertebrae increases, and the head-neck deviates farther away from supporting vertebrae in a “forward glide” (Fiebert et al., 1999). It follows that lower values of craniovertebral angle measures indicate more severe presentations of FHP (Lau et al., 2010; Silva et al., 2009; Yip et al., 2008). The severe presentation of FHP, as measured by the craniovertebral angle, is a consequence of increased flexion of the lower cervical vertebrae, which causes the neck to deviate anteriorly relative to the thoracic spine. However, the craniovertebral angle is not an exhaustive measure of FHP, and many research studies have elected to supplement this traditional assessment with measurement of the gaze angle (Figure 4.3).

As shown in Figure 4.3, the gaze angle is formed by a horizontal plane that intersects with a line passing through the eye and tragus of the ear. The gaze angle increases as the upper cervical vertebrae’s extension increases, and the head tilts backward relative to the neck and torso. It follows that higher gaze angle values indicate more severe presentations of FHP (Sheikhoseini et al., 2018; Silva et al., 2009; Mahmoud et al., 2019). The severe presentation of FHP, as measured by gaze angle, is a consequence of the increased extension of the upper cervical vertebrae. As a result of this increased extension, the head tilts backward relative to the neck and torso. Thus, Baer et al. (2019) explained, “If one puts one’s head forward of one’s body while continuing to look straight ahead, the head will be tilted backward relative to the neck (as commonly seen in FHP)” (p. 109). The inclusion of both the craniovertebral and gaze angles in biomechanics research affords more comprehensive measures of FHP.

Figure 4.2

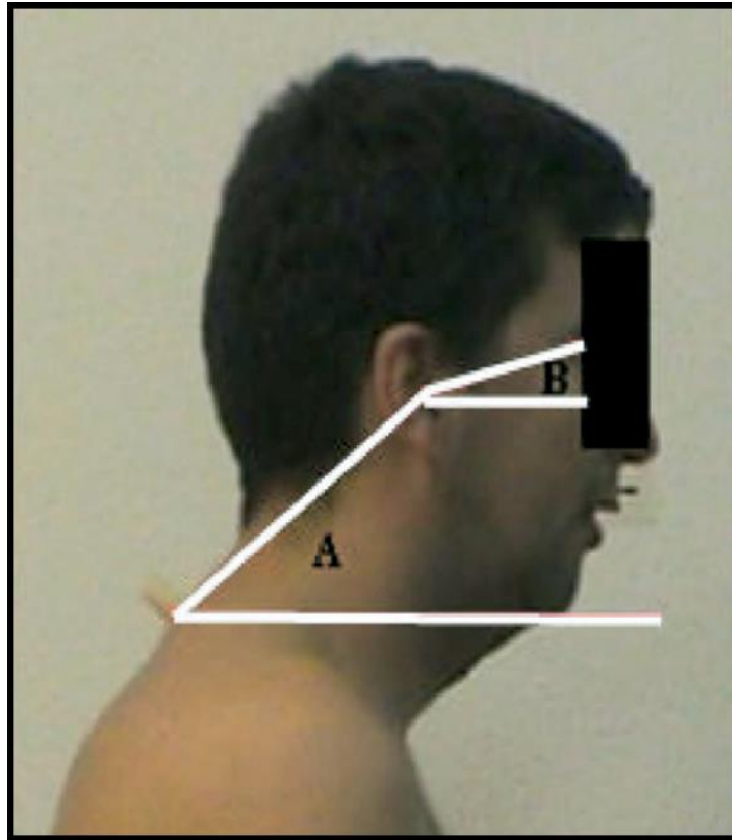
Craniovertebral Angle Measurement



Note. From B. Shaghayeghfard et al. (2016), Evaluation of forward head posture in sitting and standing positions, *European Spine Journal*, 25(11), 3577–3582. <https://doi.org/10.1007/s00586-015-4254-x>

Figure 4.3

Gaze Angle and Craniovertebral Angle Measurements



Note. The gaze angle and craniovertebral angles are both shown in this image. The gaze angle is labeled B and the craniovertebral angle is labeled A. The photographed research subject is an example of Forward Head Posture measured by both the craniovertebral and gaze angles. From A. G. Silva (2009), Head posture and neck pain of chronic nontraumatic origin: A comparison between patients and pain-free persons, *Archives of Physical Medicine and Rehabilitation*, 90(4), 669–674. <https://doi.org/10.1016/j.apmr.2008.10.018>.

Forward head posture is a complex musculoskeletal event that functionally splits the cervical spine into upper and lower halves that apply oppositional forces to craniocervical structures. The integral relationship between the skull and spinal column is disrupted, which results in mechanical imbalance and dysfunction. Moreover, the moment arm between the head and the base of the neck increases as the skull deviates further from its axis atop the cervical spine (Baer et al., 2019, p. 109). As a consequence, the gravitational load on the spine increases as the weighted skull moves forward from the supporting vertebrae and tilts backward (Baer et al., 2019). Muscular moments are compounded by increased gravitational forces that result from the elongated moment arm (Baer et al., 2019; Nevins et al., 2014). These physical dynamics reinforce the neck's anterior positioning relative to the thoracic spine and the head's posterior position relative to the neck and torso.

In summary, FHP is a maladaptive psychomotor behavior formally caused by the displacement of craniocervical structures and the consequent disruption of an integral formal relationship. Thus, forward head posture is associated with a state of mechanical imbalance that results in localized stress and strain on the tissues of the skull and spine. The biomechanical events of FHP are indicative of the spinal column yielding to the resultant applied loads. Alexander's (1932) description of pulling back the head refers to these mechanics, particularly the observable backward tilt of the head caused by the upper cervical vertebrae's extension (p. 143). The spinal column may sustain excessive deformation to its overall structure as FHP is reproduced as a stable attractor over time.

Recall Alexander's (1932, reprinted in 1969) discovery that preventing FHP had an inhibitory effect on the concomitant behaviors of "sucking in the breath through the mouth and producing a gasping sound" and "depressing the larynx" (p. 141). Anecdotal evidence suggested

that assembling the speech act without the three events yielded improved vocal function as measured by the self-reported cessation of his symptoms. Alexander claimed further that his throat was examined by “medical friends” whose appraisal provided objective support for his experience of recovery: “What is more, when, after these experiences, my throat was again examined by medical friends, a considerable improvement was found in the general condition of my larynx and vocal cords” (p. 143). *Thus, Alexander claimed to have identified a positive correlation between the prevention of the three isolated events and the absence of vocal hoarseness.*

These results supported his hypothesis that the three events were not integral to the whole act of recitation. They could be extracted from the speech attractor, and the functional product, vocal production, was unimpaired. In fact, the cessation of symptoms suggested that the events represented the systemic misuse of the parts implicated and that their prevention elicited an *improvement* in function. Thus, Alexander (1932, reprinted in 1969) identified an association between the excessive deformation of the spinal column observed in FHP and the chronic dysfunction of his vocal apparatus. Alexander inferred that the exercise in preventing FHP affected “changes in *use*” that introduced qualitative changes into the system’s functional output (p. 143). Alexander wrote, “This conclusion, I now see, marked a second important stage in my investigations, for my practical experience in this instance brought me to realize for the first time the close connection that exists between use and functioning” (p. 143).

The previous phase of experimentation affirmed that the prevention of the backward tilt of the head was associated with improved function of his respiratory and vocal apparatus. Based on these results, Alexander hypothesized that positioning the head further forward without pulling the head back would yield additional functional improvement. The methods that

Alexander used to test this hypothesis are difficult to decipher from his account. It seems that reporting and interpreting the results of his self-study was prioritized over methodological description as his account progressed. At this stage, Alexander did not state whether he observed himself in the mirror as he practiced adjusting the forward positioning of the head. It is also unclear how he was moving his craniocervical structures to study the forward placement of the head and its influence on functional outcomes.

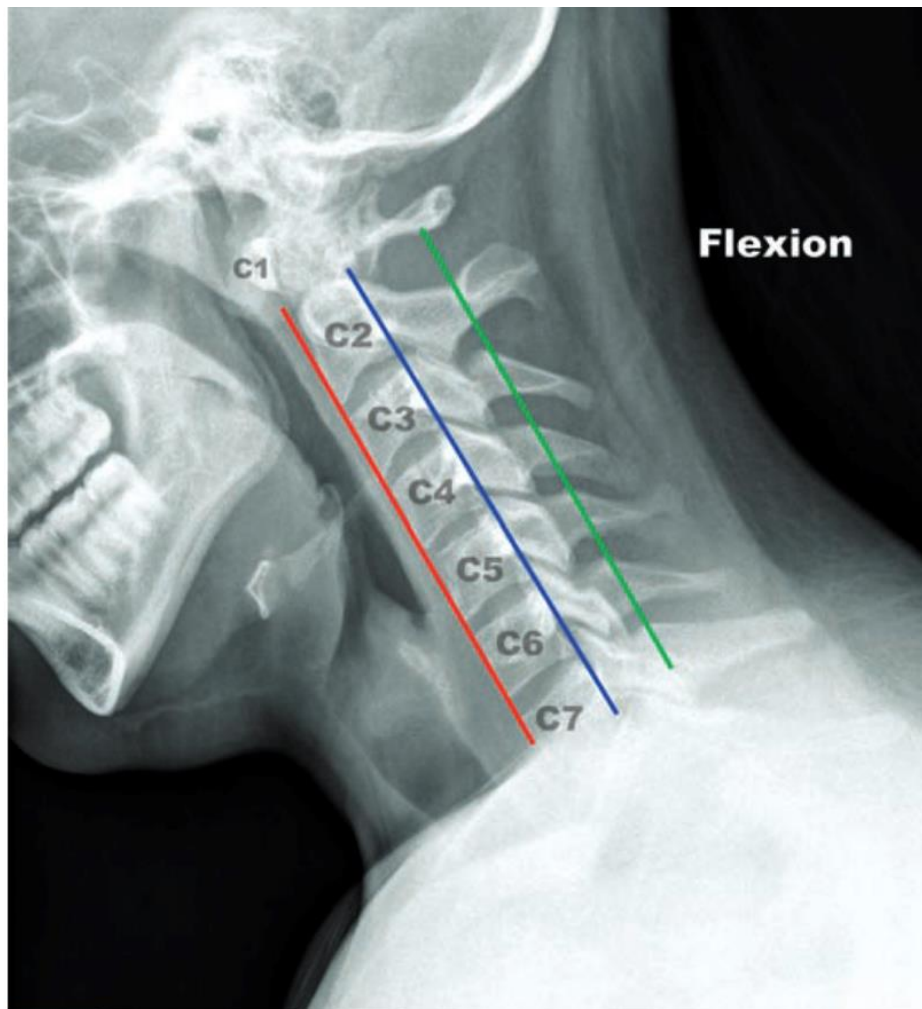
Alexander may have been increasing the amount of flexion in the lower cervical vertebrae while preventing the often-synchronous extension in the upper vertebrae. Increased flexion in the lower cervical vertebrae causes the anteriorization of the head and neck relative to the thoracic spine. He may also have been tilting the head forward at the atlanto-occipital joint. Perhaps he maintained neutral alignment of the lower cervical vertebrae as he explored flexion of the upper cervical vertebrae. Yet, it is more likely that his exploration caused the flexion and compression of the whole cervical column as his head position applied muscular moments that exceeded the degrees of flexion available at the atlanto-occipital joint (7.2 ± 2.5), the craniocervical unit (C1 & C2: 12.3 ± 2.0), and the root vertebrae (C2 & C3: 3.5 ± 1.3) (Galbusera et al., 2018; Punjabi et al., 2001).

It is impossible to know the precise adjustments that Alexander (1932, reprinted in 1969) made to the position of his head across, presumably, many trials of placing the head “definitely forward, further forward, in fact, than I felt it was the right thing to do” (p. 144). Whatever the case, it can be inferred that Alexander was inhibiting the extension of the upper cervical vertebrae and exploring the possibilities of cervical flexion. Figure 4.1A depicted a retracted craniocervical deviation, which may approximate Alexander’s head and neck positions across

some of the trials. The alignment of the cervical vertebrae during flexion is also shown in Figure 4.4 on plain films with C1-C7 labeled.

Figure 4.4

Flexion of the Cervical Spine



Note. Anatomy of the cervical spine during flexion on plain films with C1-C7 labeled. The atlanto-occipital joint is formed by the skull's occiput and C1. The craniocervical unit refers to C1 and C2. The root vertebrae refer to C2 and C3. Reprinted from S. E. Forseen & N. M. Borden (2016), *Imaging anatomy of the human spine: A comprehensive atlas including adjacent structures* (p. 62), Demos Medical.

This phase of experimentation was motivated by the belief that the depression of the larynx was singularly associated with the act of pulling back the head. To his surprise, Alexander discovered a critical point at which the forward placement of his head coincided with the depression of the larynx. Therefore, the misuse of the cervical spine that resulted in vocal dysfunction was not limited to pulling the head back. The head could be placed forward such that the muscles of the head-neck asserted a downward pull on the structures to which they were attached, including the larynx. *Thus, Alexander's hypothesis that a more forward position of the head would yield additional functional improvement was false.* The intricate network of laryngeal muscles is subjected to strain by *any* deviation of the head from a neutrally aligned position. Thus, craniocervical protraction and retraction both had adverse effects on laryngeal function.

Alexander (1932, reprinted in 1969) claimed to have spent a substantial period of time studying the effect of head position on both larynx position and vocal function (p. 144). Across trials, Alexander collected observational data suggesting that the misuse of his organism was not limited to the head, cervical spine, and structures of the throat, as he previously believed. Alexander observed another change that coincided with any deviation of the head and neck associated with the depression of the larynx. Craniocervical deviation often coincided with lifting the chest and increased lordosis of the spinal curves, and these events had the total effect of shortening the stature. "Shortening in stature" is a phrase Alexander used to describe the observable reduction in the body's height and breadth (p. 145). "Shortening in stature" was associated with the occurrence of the original aberrant events as part of a global pattern-forming behavior (p. 145). Thus, the originally defined aberrant events were just the tip of the proverbial

iceberg. Alexander discovered that the whole musculoskeletal system was implicated in the maladaptive coordination of the speech act.

At this point, many months into his self-study, Alexander (1932, reprinted in 1969) began to conceptualize his problem as an integrative health condition associated with a maladaptive behavioral mode he called “shortening in stature” (p. 145). He ingeniously inferred there must also be a behavioral mode associated with lengthening in stature, which tended to increase the body’s height and breadth. Moreover, he hypothesized that he could induce the lengthened coordination pattern by preventing the events associated with shortening in stature, particularly any deviation of the head-neck, the elevation of the chest, and the exaggeration of the spinal curves. Thus, the question that guided Alexander’s next phase of experimentation was: *Will lengthening in stature as the musculoskeletal basis for speech correlate with an improvement in vocal function as measured by the absence of vocal hoarseness? ’*

Alexander (1932, reprinted in 1969) contrived a methodological procedure to address this question using two experimental tasks: *(1) prevent shortening in stature to induce lengthening more or less indirectly, and (2) actively lengthen in stature.* He alternated between these two conditions, evaluating the effect of each on the frequency and magnitude of vocal hoarseness across trials. Alexander did not specify the duration of this phase of study, referring only to “a long series of experiments” (p. 144). It is also unclear whether he used a mirror as an objective measure of his task performance.

Alexander (1932, reprinted in 1969) reported that “the best conditions” of his larynx and vocal mechanisms, as measured by the reduced frequency of hoarseness, were associated with “*lengthening in stature*” (p. 145). Alexander did not specify which of the two experimental tasks was most advantageous to lengthening in stature and the correlated effect of improved vocal

function. In this particular case, Alexander's research question, methods, and reported results are not entirely aligned. This discrepancy is no doubt related to Alexander's lack of formal scientific training, but it should not detract from the profundity of his findings.

Through his applied methodology, Alexander (1932, reprinted in 1969) defined a relational configuration of musculoskeletal parts associated with a lengthened coordination pattern. The basis for this explanation was a positive correlation between the shortening coordination pattern and the tendency to pull his head down as he "tried to put it forward in order to lengthen" (p. 145). After further experimentation, Alexander concluded that "the head should tend to go upwards, not downwards," when he put it forward to assemble and maintain the lengthened coordination pattern (p. 145). Thus, in particular, the positioning of the head "forward and up" facilitated neutral alignment of the cervical vertebrae and prevented the mechanical imbalances associated with craniocervical postural deviations.

The positioning of the head forward had the effect of nodding the head at the atlanto-occipital joint and prevented extension of the upper cervical vertebrae. The concerted positioning of the head "up" had the effect of preventing lower cervical flexion to support neutral alignment of the vertebrae. Significantly, Alexander (1932, reprinted in 1969) qualified that he had to put the head "forward and up in such a way that I prevented the lifting of the chest and simultaneously brought about a widening of the back" (p. 145). Thus, the misuse of his head, neck, and back constituted a global shortening pattern associated with the malfunction of the vocal apparatus. Based on this critical observation, Alexander claimed that the head-neck-trunk relationship was key to the self-organization of the whole neuromuscular-skeletal system. He called this biomechanical principle "the primary control of my use in all my activities" (p. 145).

In Dynamical Systems terms, the head-neck-trunk relationship is a control parameter that determines the qualitative dynamics of the neuromuscular-skeletal system's pattern of self-organization (Favela, 2020; Muchisky et al., 1996; Thelen & Smith, 1994). In other words, the head-neck-trunk relationship is a macroscopic variable that regulates the pattern-forming behavior of the whole complex system. As discussed, the coordination patterns identified as "shortening in stature" and "lengthening in stature" were paradigmatic modes of behavior (Alexander, 1932). These modes or movement coordination states emerged through the synergistic action of the neuromuscular-skeletal system's interdependent parts with critical input from environmental fields. Alexander's "primary control" refers to the moderating role of the head-neck-trunk relationship in the self-organization of the whole neuromuscular-skeletal system.

Alexander (1941, reprinted 2000) explained the primary control principle in his book, *The Universal Constant in Living*:

I found that in practice this use of the parts, beginning with the use of the head in relation to the neck, constituted a primary control of the mechanisms as a whole, involving control in process right through the organism, and that when I interfered with the employment of the primary control of my manner of use, this was always associated with a lowering of the standard of my general functioning. (p. 8)

The neutral alignment of the head-neck-trunk is a control parameter that shifts the whole neuromuscular-skeletal system into the lengthened attractor state associated with a higher standard of function. Any deviation from neutral head-neck-trunk alignment is a control parameter that shifts the system into the shortened attractor state associated with mechanical imbalance and functional impairment. Thus, the head-neck-trunk relationship acts as a physical and relational constraint on the macroscopic coordination of the systemic dynamics (Newell & Liu, 2021).

Alexander also reported an increased tendency to shorten in stature, despite his systematic effort to assemble and maintain the lengthened coordination pattern across conditions and trials. DST provides an explanation for the statistical probability that Alexander's system would occupy the shortened attractor state. As previously discussed, DST claims the developing human learns to coordinate the body's manifold parts to achieve self-directed action goals. The assembled patterns of interaction, coordinated under particular task, environmental, and social constraints, will stabilize as attractor states across developmental time to reliably produce goal-directed behavior (Teulier et al., 2015; Thelen, 1995; Thelen & Ulrich, 1991; Thelen et al., 1993; Ulrich et al., 1998). Thus, earlier in his development, Alexander had learned to assemble the shortening attractor as part of his coordinated response to the speech action goal. This attractor had stabilized as a preferred attractor state across time and became increasingly inflexible. As a result, decades later when Alexander was engaged in self-study, the exploration of other patterns to reassemble a lengthened attractor was curtailed by the excessive stability of the shortened movement coordination pattern.

The attractor landscape is a conceptual model developed to predict the behavioral probabilities of complex dynamical systems (Muchisky et al., 1996; Thelen & Smith, 1996). The attractor landscape is often depicted as a valley with wells of variable depths. Behavior is represented by a small ball that rolls across the landscape like a ball in a pinball machine. Alexander's shortened attractor state can be pictured as a ball at the bottom of a very deep well, as in Figure 4.5A. The ball's expulsion from the well would require a high magnitude of applied force to propel it over the top. Any perturbation under a minimum force threshold would predictably result in the ball falling back into the bottom of the well. For Alexander, shortening in stature was like the ball at the bottom of a deep well. A high magnitude of concentrated effort

was required to destabilize the shortened attractor to explore the possibility of a new coordination pattern.

Figure. 4.5

Conceptual Model of Stable and Unstable Attractors

4.5A



4.5B



Note. Figure 4.5A represents a very stable attractor because the well is deep, and the ball would require a high magnitude of applied force to expel it from the well. Most perturbations will result in the ball's return to the bottom of the well. Figure 4.5B depicts an unstable attractor because the well is shallow and smaller perturbations may propel the ball beyond its boundaries. The ball has a higher probability of settling into the deeper adjoining well than remaining for very long in the shallow well. Reprinted from E. Thelen & L. B. Smith (1996), *A dynamic systems approach to the development of cognition and action, Vol. 1*, Bradford Book (p. 60).

Meanwhile, the lengthened pattern was a very unstable attractor like the shallow well depicted in Figure 4.5B. Despite his best efforts, Alexander was resisting the statistical probability that his neuromuscular-skeletal system would automatically shift into the preferred shortened mode in response to the speech stimulus. It would take time and intentional self-study to destabilize the shortened attractor so he could more reliably assemble and sustain the lengthened attractor. Moreover, Alexander's ability to sustain the lengthening coordination pattern in the context of speech voluntarily required the discovery of the efficient and final causes of psychomotor maladaptation.

The young Alexander did not receive any guidance about how to perform actions adaptively from his early educational and social environments. Instead, he learned to coordinate voluntary actions without any form of principled guidance based on knowledge of the body's functional design. As a result, Alexander inadvertently assembled patterns of behavior that disrupted integral relationships between parts of the complex system. The harmful nature of these behaviors went undetected by his educators, and the coordination patterns were permitted to stabilize over time. Therefore, his neuromuscular-skeletal system spontaneously self-organized into maladaptive coordination patterns in response to environmental, social, and task constraints. The typical child would never be expected to acquire math skills without the requisite educational support. The results of Alexander's self-study suggested that the coordination of fundamental motor acts should be intentionally guided by educational processes to support adaptive psychomotor learning and developmental outcomes. The re-educational method developed by Alexander is further explicated through discussion of the efficient and final causes of psychomotor maladaptation.

In summary, the formal cause of psychomotor maladaptation is predicated on the precise arrangement of the body's constitutive parts and the shapes they independently and collectively obtain. The body's morphology is organized to form a complex network of interdependent relationships, which enable it to function as a unified whole with emergent behavioral dynamics (Newell & Liu, 2021; Thelen & Smith, 1994). The body's design principles are discussed further when Theodore Dimon's theory-practice of Movement Awareness is introduced in Chapter 6: The Physiology of Kinesthetic Fluency.

For now, it is sufficient to understand that the collective activity of the body's interdependent parts assembles task-relevant configurations. Furthermore, the task-dependent

coordination patterns stabilize over time into paradigmatic modes of behavior called attractor states (Newell & Liu, 2021). Thus, the formal cause of maladaptive psychomotor behavior is the assembly and stabilization of attractor states predicated on strained and deviated relationships among the complex system's interdependent parts.

The Efficient Cause

Again, the primary source of the change or rest; e.g. the man who deliberated is a cause, the father is the cause of a child, and generally what makes of what is made and what changes of what is changed. (Aristotle & Barnes, 1984a, p. 332)

Aristotle's four causes reduce a complex set of causal variables into identifiable agents of change. Each cause is distinct within the taxonomy, but their ontological interdependency builds structural and functional complexity. For instance, the material and formal causes are interdependent principles that underlie natural substances and the changes they undergo (Aristotle & Barnes, 1984a; Scharle, 2008). This synergism between the material and formal is further reinforced by the complexity of biophysical systems like the human body.

The material cause of human action, of which psychomotor maladaptation is a species, depends on formal principles of shape, structure, and design, which operate at the microscopic (i.e., molecular and cellular) and mesoscopic (i.e., multicellular and organs) levels of biophysical organization. For example, even in its most basic observable forms, biological matter still naturally and spontaneously obtains paradigmatic shapes and structures that interact with environmental conditions to support specialized functions. Molecular and cellular patterns are the microscopic substratum of natural materials, and they are also caused by teleologically directed formal principles. Reciprocally, the formal cause depends upon the substrate of matter to assemble structural forms across multiple levels of complexity: microscopic (i.e., molecular and cellular), mesoscopic (i.e., multicellular biomaterials and organs), and macroscopic (i.e.,

organism). Thus, the material and formal causes are interdependent and constitute simple and complex natural substances (Scharle, 2008).

For example, the interdigitating molecular structure of muscle cells is a formal principle that operates within the cell to support its specialized contractile function (Dimon, 2015). In this case, the molecules are the material cause, and their organization into a coherent pattern is the formal cause of skeletal muscle contraction. However, the activation of the contractile mechanism also requires an efficient cause in the form of a neural impulse to stimulate the interdigitating molecules into motion. Thus, the efficient cause is an emergent property that supports the functional cohesion of the material and formal natures.

Scharle (2008) argued that the efficient cause may emerge as a non-substantial principle “at work within” the inherently substantive material and formal compound (p. 36). Aristotle described the efficient cause as the “primary source” of natural change (Aristotle & Barnes, 1984, p. 332). Furthermore, he regarded the efficient cause as “the mover” or the “primary moving cause” of natural substances and the changes they undergo (Aristotle & Barnes, 1984a, p. 338). The most basic example of an efficient cause is the force transmitted from one moving object to a second resting object upon collision. The first object acts on the second object, thereby transmitting a force that shifts the resting object into a state of motion. The interaction of two billiard balls is often invoked as the classic example of an efficient cause. Returning to an earlier example, the sculptor is the efficient cause of the bronze sculpture when she applies her craft to change the form of bronze skillfully (Aristotle & Barnes, 1984a). Thus, the sculptor and her learned art are “what makes of what is made” when a sculpture is the thing made (Aristotle & Barnes, 1984a, p. 332).

The efficient cause may be an external agent of change as in the previous examples. However, it may also be a “source of change” intrinsic to the changing object (Scharle, 2008; Vella, 2008, p. 77). In this case, the source is an inner “principle of motion or change” operating within the formal structure of the changing object (Aristotle & Barnes, 1984a, p. 330). For example, the father is an efficient cause of a child when his genetic information is transmitted into a female ovum. The father’s genome, operating within the formal structure of his motile gamete cells, is an inner principle of motion and change. Thus, the father and his genome sequence are “what makes of what is made” and “what changes of what is changed” throughout the course of prenatal development (Aristotle & Barnes, 1984a, p. 330). Scharle (2008) suggested that all efficient causes are “*principles at work*” within natural substances (p. 36). Furthermore, she argued that these efficient *principles* emerge “from the teleologically directed formal causes” operating within the changing object (p. 35). Accordingly, the efficient cause of human action, of which psychomotor maladaptation is a species, is a “source of change,” an inner “principle of motion or change,” which operates within the formal structure of the neuromuscular-skeletal system to facilitate self-movement (Aristotle & Barnes, 1984a; Scharle, 2008).

The purpose of Alexander’s (1932, reprinted in 1969) next phase of self-study was to identify the nature of this inner principle, which he called “direction” (p. 149). At this point, Alexander pivoted from the strictly ethological methods employed in his earlier experiments so he could address the nature of *direction*. As previously described, ethological methods analyze and interpret animal behavior by systematically observing material bodily states in naturalistic settings. Ethology does not typically address the introspective observation of psychic states, nor does it analyze the relationship between material and mental states. Therefore, Alexander’s task

of correlating his phenomenological experience with observed physical conditions demanded a methodological shift into Psychophysics (Read, 2015).

Psychophysics is an experimental method developed in the 19th and 20th centuries to analyze sensory-perceptual processes (Read, 2015). The scientific field of Psychophysics evolved from Philosophy of Mind and the British empiricist tradition (Boring, 1965; Bruce et al., 2014). These philosophical traditions were paired with the natural sciences of physics and physiology to yield the “new experimental psychology” of Psychophysics (Boring, 1965, p. ix). Psychophysics was developed to establish an objectively mathematical foundation for the study of psychology. Thus, Psychophysics repurposes the methods of physics and physiology to analyze the quantitative relationship between bodily processes and psychic phenomena. However, the use of introspection and other qualitative methods of psychophysical research was also popular throughout the 19th century (Read, 2015).

F. M. Alexander inadvertently devised a qualitative psychophysical method to analyze the relationship between his objective bodily states and his subjective psychical experiences of those states. He was probably unfamiliar with the nascent field of Psychophysics, which was introduced some 30 years prior to Alexander’s self-study. Gustav Theodor Fechner (1801-1887), the German physicist, philosopher, and experimental psychologist, formally introduced Psychophysics as a quantitative method in his seminal work published in 1860, *Elements of Psychophysics* (Fechner, 1966). It is more likely that Alexander continued to develop his research methodologies intuitively to address questions as they emerged from his prior findings. Thus, Alexander was compelled by circumstance to devise a psychophysical experiment because he was confronted with a psychophysical problem.

Alexander's concept of *direction* incorporates the neural impulses that are continuously sent to and from the muscular system to coordinate movement. These neural impulses are the primary source of the physical changes to the musculoskeletal form that facilitate animal self-movement. They are "the movers" of the self-moving system, coordinating musculoskeletal function in response to specific task and environmental contexts. By extension, they are also the 'primary source' of deformational changes implicated in the material and formal causes of psychomotor maladaptation. As discussed, maladaptively coordinated action may result in excessive deformation and mechanical failure of the musculoskeletal system's coordinative structures over time. Alexander claimed that the "misdirection" of neural impulses is the "primary source" of these adverse morphological changes to the system's macrostructural form and its mesoscopic and microscopic material components (Alexander, 1969, p. 152; Aristotle & Barnes, 1984a, p. 332). A brief review of Alexander's findings will fortify the foundation on which a discussion of "misdirection" as the "primary source" of psychomotor maladaptation will be built (Alexander, 1969, p. 152; Aristotle & Barnes, 1984a, p. 332).

Recall that Alexander positively correlated the onset of vocal hoarseness with three physical changes that occurred at the critical moment of speech: (1) "pulling back the head," (2) "sucking in the breath through the mouth and producing a gasping sound," and (3) "depressing the larynx" (Alexander, 1932, reprinted in 1969). He, then, discovered that preventing his tendency to "pull back the head" indirectly inhibited the other two physical changes. Importantly, Alexander's verbiage, "pulling back the head," implicitly suggested that Forward Head Posture (FHP) is volitional and, therefore, preventable (pp. 142-143). Moreover, Alexander's (1932) concept of *misuse* reinforced the premise that voluntary actions may give rise to musculoskeletal patterns that misappropriate the system's coordinative structures. The

excessive stability of a maladaptive coordination pattern like FHP may be experienced subjectively and clinically as involuntary. However, central to Alexander's discovery is the recognition that FHP and other postural deviations are artifacts of learned voluntary behavior. In these cases, they are amenable to modification through re-educational processes whereby the deviated pattern is destabilized so a new coordination pattern can be assembled.

Recall that Alexander (1932, reprinted in 1969) also distinguished between two paradigmatic coordination patterns, which he called "shortening in stature" and "lengthening in stature" (p. 145). "Shortening in stature" was a global pattern-forming behavior that expressed the originally defined aberrant events in addition to the elevation of the chest and increased spinal curvature. Incidentally, the shortening coordination pattern correlated positively with the incidence of vocal hoarseness. "Lengthening in stature" was also a global pattern-forming behavior, which expressed the forward-up positioning of the head, the widening of the ribs and back, and the reduction of spinal curvature. These changes had the collective effect of a measurable increase in the height and breadth of the body. Therefore, the lengthening coordination pattern correlated negatively with instances of vocal hoarseness.

Alexander (1932, reprinted in 1969) reported that the head, neck, and trunk were a coordinative unit that constrained the macroscopic dynamics of the neuromuscular-skeletal system (p. 145). He called this biomechanical principle "the primary control" (p. 145). In Dynamical Systems terms, Alexander's findings suggested that the head-neck-trunk relationship is a control parameter. Thus, the head-neck-trunk forms a relational variable that determines the coordination dynamics of the global neuromuscular-skeletal system. In Alexander's case, the speech coordination pattern assembled a deviated head-neck-trunk relationship, which acted as a control parameter for a maladaptive coordination pattern. An account of the qualitative dynamics

of these relationships and a detailed explanation of their potentially debilitating impact on the neuromuscular-skeletal system is undertaken in Chapter 6.

For now, it is sufficient to understand that the coordination pattern that defined Alexander's (1932, reprinted in 1969) speech act was predicated on a maladaptive head-neck-trunk relationship, which he categorized as "shortening in stature" (p. 145). Furthermore, this "shortened" coordination pattern had come to define the intrinsic dynamics of Alexander's neuromuscular-skeletal system through decades of stabilization (p. 145). Thus, the excessive stability of the maladaptive speech pattern precluded the assembly of the lengthened coordination pattern. Therefore, Alexander was unable to establish an adaptive coordination pattern for speech. To be clear, Alexander's experimental task was not to scale the preexisting coordination pattern in response to changing environment-task parameters. Instead, his purpose was to learn a new movement pattern that selectively modified his neuromuscular-skeletal system's intrinsic dynamics to achieve the action goal of speech adaptively (Chow et al., 2009). However, Alexander was surprised to discover that he invariably reverted to the shortened coordination pattern after a short duration of speech.

Incidentally, the world inside the looking glass has a similar effect in the telling of Lewis Carroll. His heroine, Alice, wishes to view the gardens of the looking-glass house from a nearby hill, but she finds that all roads lead back to her point of departure:

'I should see the garden far better,' said Alice to herself, 'if I could get to the top of that hill: and here's a path that leads straight to it—at least, no, it doesn't do *that*—' (after going a few yards along the path, and turning several sharp corners), 'but I suppose it will at last. But how curiously it twists! It's more like a corkscrew than a path! Well, *this* turn goes to the hill, I suppose—no, it doesn't! This goes straight back to the house! Well then, I'll try it the other way.'

And so she did: wandering up and down, and trying turn after turn, but always coming back to the house, do what she would. Indeed, once, when she turned a corner rather more quickly than usual, she ran against it before she could stop herself. (Carroll, 2015, p. 133)

Alice makes many attempts to reach her destination, but she is inexplicably redirected to the looking-glass house each time. I invite the reader to re-read the excerpt replacing every mention of “house” with ‘maladaptively deviated coordination pattern’ and every mention of “hill” with ‘lengthened coordination pattern.’ Alice’s tantalizing pursuit of the hill expresses Alexander’s experience as he tried to maintain the lengthened coordination pattern during speech. “If anyone was at an impasse, it was I,” Alexander (1932, reprinted in 1969) wrote (p. 150). Alice, confounded by the unattainable hill, could just have easily spoken these words.

Alexander (1932, reprinted in 1969) believed he was at least preventing the shortened attractor while assembling and maintaining the lengthened attractor at the onset of speech. However, his inability to maintain the lengthened attractor as he proceeded to speak made him question the validity of his subjective experience in this regard: “I was suspicious that I was not doing what I thought I was doing” (p. 146). Alexander was compelled to recommence his experiment guided by the question: *Is my sensory-perceptual experience of maintaining the lengthened coordination pattern at the onset of speech valid?* To address this question, Alexander reemployed the mirror to observe his behavior as he practiced the dual task of preventing shortening and inducing lengthening as the basis for speech and recitation. Two additional mirrors were positioned on either side of the original to provide a more three-dimensional view of the frontal and sagittal planes. His methods assessed whether his sensory-perceptual experience was consistent with the objective physical conditions observed in the mirror.

Once more, Alexander observed that the shortened coordination was a more integrative pattern than he had appreciated. He now realized his legs, feet, and toes were also implicated in the global pattern-making behavior of shortening. Moreover, he perceived excessive contraction

of muscles in these peripheral structures that were incommensurate with the ecological demands of the task. Alexander (1932, reprinted in 1969) explicitly acknowledged the impact of formal miseducation on psychomotor learning and development processes at this point in the narrative. He described his concerted efforts to comply with a former teacher's instruction to improve his recitation skills by "taking hold of the floor with his feet" (p. 148). He interpreted this social directive as the need to increase the muscular effort in his pelvis, legs, feet, and toes to achieve the goal of "holding the floor with his feet" while reciting. Therefore, he cultivated the perceptual-motor behavior of gripping in the lower limbs and relying upon the feeling of increased muscular effort to guide the whole speech coordination pattern.

Alexander's account of his miseducative experience is evocative of my experience assimilating postural directives from teachers and other persons of purported knowledge. Miseducation is a concept explored by John Dewey (1938, reprinted 1997) in his treatise on *Experience and Education*:

Any experience is mis-educative when it precludes the possibility of future experience; restricts the field of action available to the human subject; arrests the plasticity of impulse and habit; inhibits the production of intelligent habit and self-concretizing actions, and tethers the individual to dead habit and deficient externalizations of self. (p. 16)

Alexander's experience as an acting student and my experience as a young learner share in common their miseducative impact. As a child and an adolescent, I learned to rely on the sense-perception of chronically contracted muscles to guide the socially regulated action goal of 'sitting up straight.' The social reinforcement of this perceptual-motor behavior entrenched the excessive contraction of skeletal muscle tissue as the basis for all voluntary action.

These miseducative experiences enlist the concerted efforts of the learner to dig a deep attractor basin in their developmental landscape. As a result, the learner is locked into a

circumscribed behavioral pattern and debarred from exploring the possibility of other more adaptive and flexible psychomotor responses. The possibility of change is the *sine qua non* of learning; when the possibility of change is precluded, then the process of learning is at an impasse. As in Alice's experience, the pathway to the hill's summit is lost, and the learner invariably finds herself back in the valley from whence she came.

Alexander (1932, reprinted in 1969) recognized the cultivated overexertion of his lower limbs as yet another variable in the global shortening pattern associated with speech. The stimulus to speak activated the coordination of the variables as a whole afferent-efferent neuromotor pattern. Thus, the overexertion of the lower limbs was functionally intertwined with the other variables implicated in the head-neck-trunk relationship. Therefore, the presence of one variable signaled the other variables as a total pattern of neuromuscular-skeletal shortening. In his own words:

The influence of this cultivated habitual use, therefore, acted as an almost irresistible stimulus to me to use myself in the wrong way I was accustomed to; this stimulus to general wrong use was far stronger than the stimulus of my desire to employ the new use of the head and neck, and I now saw that it was this influence which led me, as soon as I stood up to recite, to put my head in the opposite direction to that which I desired. I now had proof of one thing at least, that all my efforts up till now to improve the use of myself in reciting had been misdirected. (pp. 148-149)

Based on these findings, Alexander concluded that his sensory-perceptual experience of maintaining the lengthened coordination pattern at the onset of speech was invalid. The stimulus to speak and the maladaptive coordination pattern for speech were collapsed into one pattern-making instant. Therefore, his neuromuscular-skeletal system invariably shifted into the shortened coordination pattern at the critical moment he performed the speech act.

Up until now, Alexander designed his self-study method to observe and prevent the movement variables that were part and parcel of the shortened coordination pattern for speech.

However, his most recent findings raised the question: What is guiding the coordination of this particular pattern of variables at the critical moment of speech? In other words, Alexander needed to identify the “primary source” of natural change that occurred at the moment of speech. Alexander (1923, reprinted in 2004) concluded that the feeling of self-movement is the guiding principle of coordinated action, writing:

I had to admit that I had never thought out how I directed the use of myself, but that I used myself habitually in the way that *felt natural* to me. In other words, I, like everyone else, depended on ‘feeling’ for the direction of my use. Judging, however, from the results of my experiments, this method of direction had led me into error (as, for instance, when I put my head back when I intended to put it forward and up), proving that the ‘feeling’ associated with the direction of my use was untrustworthy. (pp. 149-150)

Alexander’s insightful deduction is consistent with contemporary theories of motor coordination and control. The role of guiding sensations in the coordination and scaling of movements is well-established in the motor sciences (Magill & Anderson, 2017).

Perception-action coupling is a concept arising from DST’s bold assertion that “movement must be considered as a perceptual category” (Thelen & Smith, 1994, p. 277). The prospective control of action depends on the organism’s ability to perceive and coordinate a response to environmental affordances (Magill & Anderson, 2017; Smitsman & Corbetta, 2010). Thus, the neuromotor system processes intermodal proprioceptive-visual information to regulate and constrain the coordination and control of movement variables. Recall James Gibson’s (2015) statement, “We must perceive in order to move, but we must also move in order to perceive” (p. 213).

The synchronicity of perception and action generates real-time feedback loops, enabling the self-mover to coordinate actions in reciprocity with changing environment-task parameters. Moreover, sequences of prior learning shape and inform the self-mover’s perceptual-motor faculties. Thus, the neuromotor system quickly reassembles motor strategies perceived by the

organism as successful under similar circumstances. For example, the neuromotor system will reassemble the coordination pattern for sitting-in-a-chair in response to perceived affordances that stimulate the voluntary act of sitting-in-a-chair. Moreover, the afferent neuromotor pathway is the ‘primary source’ of the coordination pattern’s instantaneous reassembly through efferent pathways.

Alexander learned that his neuromotor system reassembled the speech coordination pattern in response to perceived affordances that stimulated the voluntary act of speech. Moreover, he deduced that his coordination of the speech coordination pattern relied on the feeling of self-movement. Therefore, Alexander concluded that the afferent and efferent pathways of the neuromuscular system are functionally collapsed into one critical pattern-making instant of psychomotor coordination. The well-established theory of perception-action coupling supports Alexander’s observation and helps to explain the physiological dynamics of the neuromotor system’s pattern-making mechanism (Anderson & Magill, 2017; Smitsman & Corbetta, 2014).

However, Alexander also discovered an implication of perception-action coupling that is mostly unaddressed by the motor learning and control literature. He discovered that psychomotor coordination patterns can be the product of maladaptive learning. As such, these excessively stable coordination patterns achieve goals in the here-and-now in response to stimulating environment-task affordances. However, these movement patterns do not adaptively and efficiently meet the task-specific energy demands of the moving body-self under the applied force of gravity. Therefore, the underlying organization of musculoskeletal parts is mechanically inefficient and unsustainable over time. Moreover, the reproduction of these maladaptively coordinated states gives rise to progressive allostatic stress disorders and mechanical fatigue

failure of the whole musculoskeletal structure. The resultant morphological changes to the structural integrity of the global system further constrains the coordination of the neuromuscular-skeletal system. In other words, the progressive deformation of neuromuscular-skeletal structures is an organismic constraint that strengthens the system's preference for a paradigmatic movement pattern. The movement coordination patterns for all task-dependent coordination patterns will ultimately be constrained by the excessive stability of these deformational changes to the system architecture.

Applying DST concepts, Muchisky et al. (1996) explained that the "...the accumulated effect of the repeated real-time states themselves change their own parameters and system architecture—what we would conventionally call learning and development" (pp. 131-132). Thus, maladaptive learning changes the system architecture such that the organization of parts is out of sync with organism-environment force and pressure variables. As a result, the learner is locked into the paradigmatic movement pattern and debarred from exploring the possibility of other more adaptive and flexible psychomotor responses. In conclusion, Alexander's chronic vocal disorder was a local symptom of maladaptive learning processes that resulted in the progressive deformation of the whole psychomotor system, including the delicate structures of his vocal tract.

Alexander interchangeably used the terms "instinctive direction," "unreliable sensory appreciation," and "debauched kinesthesia" to describe the 'primary source' of maladaptively coordinated action (Alexander, 1969; Alexander & Fischer, 1995). Thus, the efficient cause of human action, including maladaptive psychomotor behavior, is the relay of intermodal proprioceptive-visual feedback that guides the self-mover's coordination and scaling of stable movement coordination patterns. The physiological source of the efficient cause are the afferent-

efferent neural pathways that innervate the body-self's musculoskeletal networks. Thus, the nervous system, encompassing its continuity with the coordinative structures of the psychomotor system, is the formal principle that operates within the body-self's material-formal structure to guide organized self-movement.

It is important to emphasize the nervous system's seamless integration into fascia, muscle, and bone such that the body-self operates as a pattern-forming whole. Therefore, the mass of the moving body-self in the gravitational field reciprocally acts as an organismic constraint on the patterns formed. In conclusion, the efficient cause of maladaptive psychomotor behavior is the emplaced self-mover's reliance on the feeling of self-movement to coordinate excessively stable musculoskeletal patterns stimulated by perceived environment-task affordances.

The Final Cause

Action for an end is present in things which come to be and are by nature. Further, where there is an end, all the preceding steps are for the sake of that. Now surely as in action, so in nature: and as in nature, so it is in each action, if nothing interferes. Now action is for the sake of an end; therefore the nature of things also is so. (Aristotle & Barnes, 1984a, p. 339)

The final cause of psychomotor maladaptation integrates the teleological strands of causality dispersed across Aristotle's four-causal framework. Aristotle was committed to the principle that nature "acts for the sake of something," and his final cause addresses this principle most directly (Aristotle & Barnes, 1984a, p. 339; Scharle, 2008). For instance, the *telos* or end of catching prey is the final cause of a spider's web-weaving behavior (Aristotle & Barnes, 1984a, p. 340). Aristotle's view of natural teleology was intimated in the formal causes of action and psychomotor maladaptation. The formal cause describes the ends implicit in the geometric shapes of the body's multiplex coordinative structures. The degrees of freedom afforded by the

complex organization of geometric shapes facilitates their interdependent articulation as a functional whole. As discussed, voluntary action is predicated upon movement coordination patterns (formal cause), which are stimulated by the stream of afferent-efferent impulses that innervate the emplaced musculoskeletal structure (efficient cause). Importantly, these innervated patterns are learned and automated by the neuromotor system in the service of action goals after they stabilize as a task-specific coordination pattern. Psychomotor maladaptation occurs when the paradigmatic neuromotor response coordinates excessively stable strained and deviated movement patterns as the basis for voluntary action.

The final cause of psychomotor maladaptation is the action goals formed at the dynamic interface of the organism-environment partnership. Action goals are the *telo*i or ends that constrain the neuromuscular-skeletal parts to obtain a particular coordination pattern. In other words, action goals are the ends for the sake of which the self-moving system assembles movement coordination patterns. For example, speech and recitation were the ends for the sake of which Alexander's neuromuscular-skeletal system assembled the strained and deviated coordination pattern. However, Alexander discovered that the ends for the sake of which his system assembled the shortened coordination pattern were not limited to recitation and speech. He achieved his fundamental motor competencies in the task categories of posture, locomotion, and object-interaction by assembling the shortened coordination pattern—without exception. The resultant periodic cycles of applied stress caused progressive deformation of Alexander's neuromuscular-skeletal structures, thereby modifying the geometric shapes that holistically obtained the form and function of his motor system. These modifications constrained the degrees of freedom available to his system's coordinative structures, effectively canalizing his system dynamics to occupy the excessively stable shortened coordination pattern.

Alexander reasoned that if the shortened coordination pattern was efficiently caused by his reliance on the feeling of self-movement to coordinate actions, then he must construct a different efficient cause to scaffold adaptively coordinated action. Therefore, he determined to cultivate a stream of kinesthetic-linguistic thoughts to override the automated guidance of afferent-efferent neural impulses. These thoughts were a layered polyphony of linguistically structured coordination parameters grounded in kinesthetic-proprioceptive referents: “Let my neck release, so that my head can go forward and up, so that my back can lengthen and widen, so that my knees can go away from my hips and my knees can go away from my feet.”

Alexander hypothesized that the stream of kinesthetic thinking would guide the reorganization of neuromuscular-skeletal parts in compliance with its semantic structure. First, the continuous and intentional conveyance of the kinesthetic thought pattern would help destabilize the shortened coordination pattern. Then, the restored flexibility and buoyancy of the system dynamics would support the reorganization of the head-neck-trunk control parameter. In other words, the kinesthetic thoughts would guide the alignment of the neck-head-trunk to shift the global system into the lengthened coordination pattern. Thus, Alexander was determined to develop the projection of kinesthetic thoughts as a fundamental psychomotor skill. To this end, he needed to learn how to leverage kinesthetic thought as a tool to optimize the organism-environment partnership. The learned kinesthetic fluency would then replace sensory-perceptual feedback as the ‘primary source’ of self-movement.

Alexander practiced coordinating kinesthetic thoughts to assemble and maintain the lengthened coordination pattern across innumerable trials. Despite his best efforts, his stream of kinesthetic thought was consistently overpowered by the paradigmatic afferent-efferent innervation pattern of the speech coordination pattern. The stimulus to perform the speech act

proceeded from his conception or idea of the goal stimulated by environment-task affordances in the here-and-now. Furthermore, his concept of the speech act was constructed from his historical sequences of learning to perceive environmental affordances. Thus, the stimulus to perform the speech act was a psychological construct grounded in afferent-efferent neural pathways that stimulated the task-relevant movement coordination pattern. Thus, the perceived environmental affordances triggered the discharge of misdirected afferent-efferent neural impulses (*efficient cause*) to assemble an excessively stable deviated movement pattern (*formal cause*), which imposed excessive mechanical stress and strain on the whole musculoskeletal structure and its constituent biomaterials (*formal and material cause*).

In other words, the speech stimulus automatically discharged a cascade of afferent-efferent neural impulses that overcame his kinesthetic thinking like a tsunami wave overcomes the shoreline. As a practical consequence, his neuromuscular-skeletal system automatically self-organized into the shortened coordination pattern at the critical moment he responded to the perceived affordances of speech. In Alexander's (1932, reprinted in 1969) own words:

By careful experimentation I discovered that I gave my directions for the new use in their sequence right up to the point when I tried to gain my end and speak, but that, at the critical moment when persistence in giving the new directions would have brought success, I reverted instead to the misdirection associated with my old wrong habitual use. (pp. 156, 157)

Based on these experiences, Alexander believed he had finally identified the crux of the maladaptation problem. The emplaced perceptual-motor system's processing of action goals in the here-and-now is constrained by prior learning. Thus, the movement coordination pattern is automatically assembled by the perceived coherence of perceptual-motor variables, which the self-mover has learned to associate with the action goal over time. For example, the environmentally afforded stimulus to sit-in-a-chair will automatically discharge afferent-efferent

neural impulses to assemble the task-specific movement coordination pattern for sitting-in-a-chair. Thus, the action goals constructed through historical processes of maladaptive sensory-motor learning are the final cause of psychomotor maladaptation.

Alexander now concluded the action goal stimulated the efficient, formal, and material causes as a total pattern-forming mechanism. Thus, he determined that the solution to his vocal problem was most directly accessible by way of its final cause. Alexander hypothesized that disarming the final cause would defuse the efficient, formal, and material causes in turn. The only way to disarm the final cause was to circumvent the action goal stimulus entirely, but how? A vow of silence was not only foolishly impractical but in direct opposition to his vocational goals. Moreover, Alexander now understood the shortened coordination pattern was not limited to speech but was paradigmatic of all his voluntary actions. As discussed, the excessive stability of maladaptive coordination patterns yielded periodic cycles of stress and strain, which culminated in progressive deformation of his neuromuscular-skeletal system. These morphological changes to his system architecture further canalized his system dynamics to occupy the maladaptively deviated neuromuscular-skeletal patterns across tasks and contexts.

To address the problem, Alexander needed to achieve two learning objectives: (1) he needed to reverse the progressive deformation of neuromuscular-skeletal structures to reintroduce flexibility and buoyancy into the system dynamics, and (2) he needed to intentionally reconstruct his task-specific movement coordination patterns to prevent the periodic cycles of applied stress that had culminated in progressive deformation in the first place. To this end, Alexander needed to relearn how to perceive environmental affordances for actions and coordinate motor responses that optimally correspond to those affordances, but how?

The first step was to devise a method to bypass the maladaptively learned perceptual-motor parameters of the action goal that automated the associated afferent-efferent pathway. Then, he needed to develop the coordinative function of kinesthetic thinking to (1) regulate the continuous direction of attention to the self-environment interface so (2) he could intentionally define the perceptual-motor parameters of a new action goal. In other words, Alexander had to deconstruct the artifacts of maladaptive prior learning while simultaneously self-directing adaptive learning sequences. In this way, Alexander could finally learn to coordinate movement patterns to achieve embedded action goals sustainably and efficiently.

Thus, the final cause was the pathway to the source of Alexander's vocal problem. Recall Alice's compulsory desire to reach the hill in the *Looking Glass* world. Similarly, Alexander's compulsory desire to achieve a particular goal obscured his real-time perception of affordances at the dynamic intersection of body-self, environment, and task. Importantly, Alexander came to perceive a qualitative difference between the destination he perceived and the destination he sought. Meanwhile, Alice never learned to perceive the veridical correspondence between body-self, environment, and task to coordinate a pathway to the desired hill. Instead, Alice was distracted by a garden bed of talking flowers, and her intention to find the pathway evaded her. Resolutely committed to his intention, Alexander learned how to reconstruct the entire landscape to self-assemble the destination he sought.

Chapter 5: What Alexander Found There: The Development of Psychophysical Re-Education

In the first place, it is requisite that every man, considered merely as a man, and without reference to station or occupation, should know something of his own bodily structure and organization, of whose marvellous workmanship it is said, that it is fearfully and wonderfully made; *wonderfully*, because the infinite wisdom and skill, manifested in the adjustment and expansion of his frame, tend to inspire the mind with devotion and a religious awe; and *fearfully*, because its exquisite mechanism is so constantly exposed to peril and destruction from all the objects and elements around him, that precaution or fear is the hourly condition of his existence. (Horace Mann, *Report for 1839*, in Mann et al., 1867, p. 159)

Alexander had acquired knowledge of “his own bodily structure and organization” by using methods of ethological and psychophysical self-study (Mann et al., 1867, p. 159). On one hand, Alexander understood that the “exquisite mechanism” of the human form was vulnerable to “peril and destruction” from “objects and elements” sourced in its environment as beautifully expressed by Horace Mann (Mann et al., 1867, p. 159). On the other hand, Alexander also appreciated the potential injurious impact of periodic cycles of applied stress to the psychomotor system. He viewed maladaptively learned coordination pattern as an ever-present threat to the structural and functional integrity of the human body. However, Alexander welcomed this threat as an opportunity to adaptively ‘learn how to learn’ to coordinate movement patterns that optimize the organism-environment partnership.

Recall that maladaptive psychomotor learning refers to the unstructured discovery and stabilization of movement coordination patterns, which (1) may or may not reliably accomplish action goals in the here-and-now, and (2) do not flexibly support the health of the employed neuromuscular-skeletal system across its lifetime. The reproduction of these movement coordination patterns over time leads to the progressive deformation of the neuromuscular-

skeletal system. However, Alexander was able to appreciate the fitness value of a pattern-forming self-moving system fueled by former learning. The organism's ability to expedite functional matches between body-self, environment, and task is both phylogenetically and ontogenetically advantageous (Alexander, 1910, reprinted in 1996; Alexander, 1923, reprinted in 2004). Consider the inefficiency of an animal that must assemble a novel coordination pattern each time it performs a fundamental motor act, like sitting or crouching. This animal would not be able to accomplish much in the course of a day, let alone a lifetime. The spontaneous assembly of movement coordination patterns in response to perceived affordances is a broadly adaptive feature of the self-moving system. The pattern-forming mechanism expedites the coordination of self-sustaining actions that support survival and reproduction in a competitive ecosystem.

Contrary to the visionary aspirations of Horace Mann (1796-1859), the education system still does not prioritize learning about the structure and function of the body-self as the basis for learning and skill acquisition. In particular, the education field has not implemented the guiding frameworks to support adaptive psychomotor learning. The early childhood learning environment does not (1) intentionally scaffold the learning of the fundamental motor skills to regulate the stabilization of movement coordination patterns, (2) provide instructional support to guide their generalization to increasingly complex skills and behaviors, and (3) evaluate the qualitative dynamics of stable coordination patterns to assess their efficiency and sustainability in variable learning contexts. Thus, the educational process does not carefully cultivate, leverage, or scaffold the intrinsic neuromotor pattern-forming mechanism to support adaptive psychomotor learning. Instead, the coordinative patterns are formed through unstructured learning processes in socially and cognitively demanding environmental contexts. As a consequence, the pattern-

forming mechanism in the here-and-now is fueled by cumulative sequences of unstructured, maladaptive learning experiences.

The ultimate source of Alexander's vocal problem was the existential condition of being a self-moving system fueled by maladaptive psychomotor learning. Moreover, Alexander had discovered the problem of psychomotor maladaptation as an adult learner. As a consequence, his movement coordination patterns were excessively stable and resisted his efforts to self-direct new patterns of organization. Thus, Alexander's psychomotor behaviors were categorically maladaptive by *Dynamical Systems* standards:

It is a tenet of dynamic systems that they must lose stability to shift from one stable mode to another (attractor states). When patterns are very stable, there are no opportunities to explore and reassemble new solutions. Indeed, maladaptive behavior is usually the result of excessive stability. (Thelen, 2005, p. 264)

Recall that the possibility of change, or the ability to shift voluntarily from one behavioral mode to another, is also the *sine qua non* of learning. Maladaptive coordination patterns are distinctly miseducative because they curtail the possibility of change, thereby curtailing learning processes.

Alexander was determined to destabilize his maladaptive behavior by refueling his system with sequences of adaptive psychomotor learning. To this end, he used kinesthetic thinking as a self-generated fuel to guide adaptive psychomotor learning and coordination in the here-and-now. The kinesthetic thought stream can build a steady current that acts as a propulsive force to destabilize the preferred state and selectively guide the coordination of a new state. In other words, kinesthetic thinking can be intentionally leveraged as a control parameter to constrain the coordinative dynamics of the whole system.

In *The Principles of Psychology*, William James (1890, reprinted in 2016a) emphasized that “the great thing, in all of education, is to make our nervous system our ally instead of our enemy” (p. 122). Alexander was compelled to develop Psychophysical Re-education because his

education had effectively made his nervous system his enemy. He had learned to coordinate movement patterns that caused him physical harm and threatened to sabotage his vocational aspirations. He developed Psychophysical Re-Education to make his nervous system his ally in the achievement of his immediate and future goals. To this end, Psychophysical Re-education's twofold purpose was to (1) engineer a successful coup d'état that subjugated the maladaptive afferent-efferent pathways and (2) replace them with the coordinative function of kinesthetic thought as structured by biomechanical principles of the emplaced human body plan. In the simplest terms, Psychophysical Re-Education deconstructs the artifacts of maladaptive learning and replaces them with a continuous stream of adaptive psychomotor learning mediated by the coordinative function of kinesthetic thought.

Recall that Alexander identified the final cause as the most effective point of entry to disarm the maladaptively learned coordination pattern. The first step in the re-education process was to circumvent the speech stimulus by reconceptualizing the action goal. This step was required to inhibit the activation of the afferent-efferent pathway that automated the assembly of the excessively stable coordination pattern for speech. This first step was a precondition for the establishment of the second step: the intentional activation of kinesthetic thoughts to direct the reassembly of the neuromuscular-skeletal system's components into a new relational configuration. The kinesthetic thoughts scaffolded a coordination of the head-neck-trunk that activated the lengthening property of muscle tissue. Therefore, the lengthening property of skeletal muscle tissue was an organizing principle in the assembly of the new relational configuration (Dimon, 2015, 2021).

The generation of a propulsive stream of kinesthetic thinking to activate and sustain musculoskeletal length is a skill that must be cultivated through daily practice. Kinesthetic

thinking is the intentional generation of body-centered patterns of awareness to guide emplaced goal-directed movement. The stabilization of this skill was a precondition for the establishment of the third step: *the maintenance of musculoskeletal length through the phase shift into the speech attractor*. The momentum of the kinesthetic thoughts needed to generate an energetic perturbation strong enough to circumvent the preferred state and incite a phase shift into the new coordination pattern. Thus, Alexander developed this quality of thought as a *kinesthetic fluency* that optimized the qualitative dynamics of the organism-environment partnership.

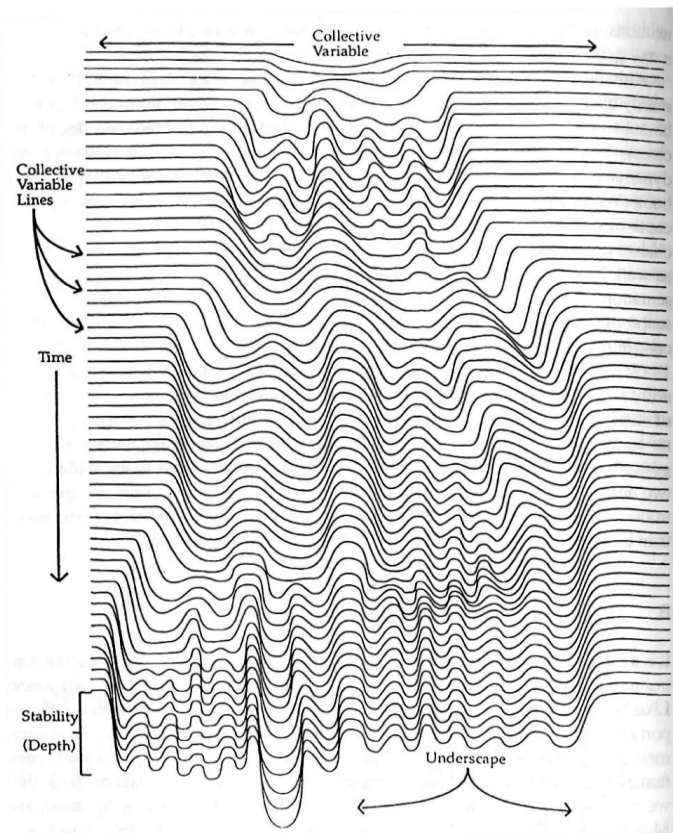
Recall the attractor landscape model with its wells of variable depths and the small ball that rolls across its valleys. Alexander's shortened coordination pattern was described as an attractor state represented by a ball at the bottom of a very deep well. It was said that the ball's expulsion from the well would require a high magnitude of applied force to propel it over the top. Thus, any perturbation under a minimum force threshold would result in the ball's return to the bottom of the well. Alexander discovered kinesthetic thinking can generate a perturbative force exceeding this minimum force threshold. Moreover, when developed as a higher-level skill, kinesthetic thinking was a tool that excavated a new attractor well to selectively direct the system's assembly of an adaptive lengthening pattern. Thus, Alexander was not just consciously directing the trajectory of the ball across a static attractor landscape. He was dynamically reengineering the topography of the attractor landscape to intelligently constrain the ball's course! Alexander's discovery that the developing human's attractor landscape can be selectively engineered and modified by a learned kinesthetic thinking skill is revolutionary.

Further analysis of the attractor landscape heuristic helps describe the effects of kinesthetic thinking on the modification and real-time guidance of psychomotor behavior. The illustration of an attractor landscape in Figure 5.1 is a qualitative representation of the Dynamical

Systems view of development (Muchisky et al., 1996; Spencer & Perone, 2008; Thelen, 1995). The landscape depicts a dynamic history of behavioral forms emerging as context-specific movement patterns. This picture of developmental change suggests that the dynamic constraints of individual, environment, and task cause behavior to emerge, disappear, and/or become increasingly stable across time (Newell, 1985). The landscape is oriented vertically in Figure 5.1, but it is helpful to conceptualize it as a horizontal surface with time advancing from the background to the foreground.

Figure 5.1

Attractor Landscape



Note. Figure 5.1 represents an attractor landscape for the development and stabilization of behavior. The three axes are labeled as the collective variable (state dynamics), time, and stability. The quantitative variable of time increases down the x-axis, and the attractor states that underlie the behavior are qualitatively represented along the y-axis. The depth of the attractor basins represents the probability that the system will self-organize into a particular attractor state at a specific point in time. Reprinted from M. Muchisky, L. Gershkoff-Stowe, E. Cole, & E. Thelen (1996), The epigenetic landscape revisited: A dynamic interpretation, in C. Rovee-Collier & L. R. Lipsitt (Eds.), *Advances in infancy research* (Vol. 10, p. 130), Ablex.

The attractor landscape is a conceptual model consisting of three levels of system dynamics, which collectively influence the changing topography of the landscape surface: (1) the state dynamics, (2) the parameter dynamics, and (3) the graph dynamics (Muchisky et al., 1996, p. 131). These three dimensions of system dynamics encompass multiple time scales, which codetermine the development of coordinated behavior. The state dynamics denote the system's expression of real-time behavior and is the shortest time scale operating within the multilayered system dynamics.

The horizontal lines in Figure 5.2 represent the state dynamics of the developing system at a given point across developmental time. The state dynamics are depicted as “collective variable lines” on the attractor landscape heuristic (Muchisky et al., 1996). Real-time behavior is regarded as “collective variables” in reference to hypothetical variables that determine the qualitative properties of the task-specific coordination pattern. The term “order parameter” is alternatively used to denote a coordination variable that defines the macroscopic organization of the system in task-specific contexts (Newell & Liu, 2021). In other words, “collective variables” and “order parameters” denote a measure that captures the global pattern emerging from coordinated interactions among the system's highly differentiated elements or subsystems.

These concepts originated in *physics* and traditionally expressed the degree of order in far from equilibrium thermodynamic systems (Newell & Liu, 2021). Scientists and theorists in the biological sciences apply these constructs to express the degree of order that characterizes the coordination dynamics of complex biological organisms (Fuchs & Kelso, 2018; Haken et al., 1985; Kelso, 1981, 1984; Turvey, 2004). In this context, the collective variable measures the “relational quantities that are created by the cooperation of the individual parts of the system” (Kelso, 2009; Newell & Liu, 2021). The attractor landscape is a metaphor, and, as such, it is not

based on measures of spatial or temporal quantities that reflect the macroscopic coordination dynamics. Instead, in this context, “collective variables” are a qualitative set of spatial and temporal properties that capture the task-dependent coordination pattern.

Thus, the state dynamics, represented by the horizontal lines in the landscape heuristic, are the real-time movement coordination patterns, which can be expressed in terms of collective variables. The state dynamics were modeled as individual wells when attractor states were introduced in Chapter 4. Viewed as a total landscape, the state dynamics are like the Earth’s surface with its diverse terrain and topographical features. Each of the collective variable lines forms deep and shallow wells representing the probability the system will occupy a specific attractor well. The attractor landscape was designed as a probability landscape to model the likelihood that the system will self-organize into a particular cooperative pattern at a specific point in time (Muchisky et al., 1996, p. 130).

The state dynamics loosely correspond to the final cause because they represent specific movement coordination patterns as defined by action goals. As discussed previously, the depth of the attractor well denotes the magnitude of the perturbation required to shift the system into a new behavioral form. Shallow wells represent states that are more sensitive to fluctuations in the system resulting from control parameter changes. Thus, there is a high probability that the system will shift into a new task-relevant coordination pattern. On the other hand, deep wells represent states that are very stable and resistant to fluctuations in the organism-environment system. Thus, there is a low probability that the system will shift into a new coordination pattern in response to a perturbative event. In this case, it is more likely that the system dynamics will remain firmly tethered to the preferred state. The state dynamics are the landscape of potential

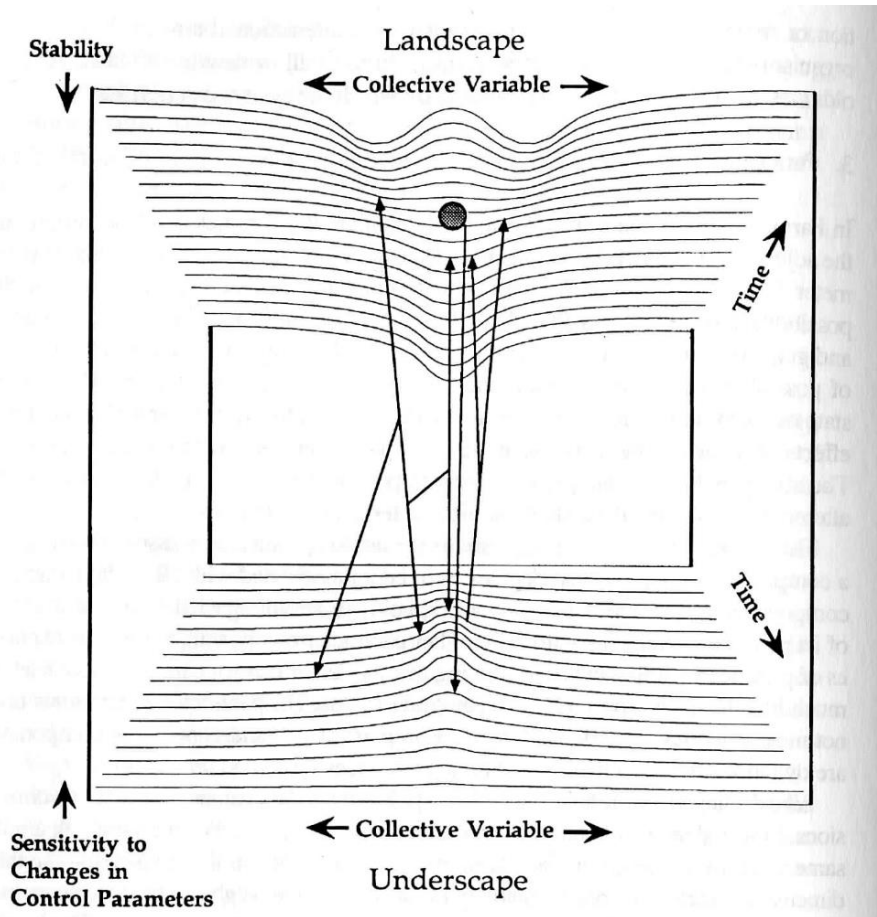
states that the system can occupy at a given point in time. Moreover, the system learns to prefer some states over others throughout its history as an emplaced learner.

The graph dynamics and parameter dynamics form the underscape, which is ambiguously referenced in Figure 5.1. The underscape is a framework of parameters that shape the collective variable lines, thereby constraining the system's real-time behavioral possibilities. If the state dynamics are like the Earth's surface, then the parameter dynamics and graph dynamics are like the subterranean plates whose continuous shifting changes the Earth's surface over longer time scales. Correspondingly, the underscape variables modify the landscape's topography from below its surface. Importantly, however, the state dynamics also exert their influence on the graph and parameter dynamics. The three levels are non-hierarchical and interdependent such that each level impacts directly on the other two. In other words, the state dynamics have a modifying influence on the parameter and graph dynamics. Thus, the landscape and underscape exert bi-directional influence across time scales to synergistically compel behavioral forms.

The parameter dynamics loosely correspond to the efficient cause due their sensitivity to sensory-perceptual variables in the coordination of outcomes. They are also likened to the time scale of learning (Muchisky et al., 1996). They broadly encompass the organismic, environmental, and task constraints that cooperatively regulate the real-time possibilities available to the system (p. 129). These parameter values are embedded in the history of the emplaced system: a continuum of psychomotor learning processes mediated by sensory-motor feedback cycles. Sensory-perceptual processing guides motor output in response to task-relevant information embedded in the organism-environment partnership. Thus, the parameter dynamics are task variables assimilated by the perceptual-motor system to coordinate a patterned response to real-time action goals.

Figure 5.2

The Underscape Consisting of the Parameter Dynamics and the Graph Dynamics



Note. Figure 5.2 depicts the underscape at a point in time the system is undergoing a phase shift into a novel behavioral form. The elevation of the landscape floor denotes an increase in sensitivity to a control parameter. The formation of wells on the attractor surface indicates the effects of changes in the system's sensitivity on real-time behavior. Reprinted from M. Muchisky, L. Gershkoff-Stowe, E. Cole, & E. Thelen (1996), *The epigenetic landscape revisited: A dynamic interpretation*, in C. Rovee-Collier & L. R. Lipsitt (Eds.), *Advances in infancy research* (Vol. 10, p. 136), Ablex.

Finally, the graph dynamics refer to the anatomical constraints inherent in the neuromuscular-skeletal system's architecture. The nature of the consortium between the constitution and configuration of the system's components define its behavioral possibilities. As a result, the system's functional abilities and limitations are determined by the material and formal constraints that permit and uphold the cooperation of the system's individual parts. Thus, the graph dynamics are closely aligned with the material and formal causes of behavior. They describe how these interdependent causal forces promote or inhibit behavioral expression at any point in time. Naturally, the anatomical constraints also dictate the energetic costs associated with the actions they enable. For example, the materials that constitute the human body (material cause) and the way they are arranged (formal cause) engenders bipedal walking as the energetic path of least resistance in the development of coordinated locomotion.

The emergence of the walking pattern in infancy is capacitated by changes in the graph dynamics such as significant gains in the musculoskeletal strength parameter (Muchisky et al., 1996). The species-typical anatomical structure is especially sensitive to control parameters that collectively shift the system into the preferred walking pattern. As discussed previously, upright bipedal walking is a species-expectant behavior because the system's inherent sensitivities make it predisposed to the discovery and selection of walking as its preferred locomotor pattern. Therefore, typically developing human infants learn to coordinate the walking pattern in the first few years of life as the supporting control parameters are actuated within the organism-environment system. Thus, the system's real-time behavior is moderated by its graph dynamics, which undergo continuous change throughout the lifespan of the system. Consequently, the morphological differences between a 2-year-old and a 35-year-old will create variance in the behavioral range and preferred states of each system.

The changing topography of the attractor landscape suggests the system is more flexible and responsive to perturbative events during earlier stages of development. Figure 5.1 illustrates the collective variable lines becoming increasingly differentiated and deep as time advances. The shallow collective variable lines indicate that the system is less stable and hypersensitive to perturbative events. In other words, the system has more freedom to shift into new organizational patterns at earlier stages of development. The variability of the state dynamics and the system's freedom to express new forms progressively diminishes as time advances. These temporal dynamics imply that early childhood is a critical period for the development and stabilization of movement coordination patterns. Thus, there is a developmental window for the learning and stabilization of coordination patterns that (1) accomplish action goals in the here-and-now, and (2) support the health of the changing neuromuscular-skeletal system across its lifetime. As in language development, psychomotor learning is optimized during a phase of plasticity in the system dynamics.

It is well-established that typically developing young infants are “universal perceivers” of phonological sounds (Hollich, 2010). This means that infants are born with universal sensitivities to the vowels, consonants, and phonemes of all languages (Burnham & Mattock, 2010; Hollich, 2010). However, infants develop selective sensitivity to the phonological structure of their native language during the first 6 months of postnatal life. Burnham and Mattock (2010) referred to this acquired preference as a “perceptual magnet effect” (p. 97). This “magnet effect” can also be conceptualized as the establishment and stabilization of a perceptual attractor state that prefers the internal structure of the native language. Burnham and Mattock referred to this process as a “general language-specific perceptual reorganization,” which also evokes the DST vernacular (p. 97). During the first year of postnatal life, infants lose the ability to perceive consonants,

vowels, and phonemes that are not used in their native language (Burnham & Mattock, 2010; Hollich, 2010). This is partially why acquiring a second language with native proficiency is increasingly challenging for older children and adults (Hollich, 2010).

However, increased neurocognitive plasticity in childhood typically supports relative ease in second language learning and the acquisition of native proficiency (Al-Harbi, 2019). Noam Chomsky argued that there is a language acquisition device (LAD) in the human brain that develops in coordination with the maturing body-self (Chomsky, 2006). The language acquisition device is a pattern-forming system that uses phonology, semantics, and grammar to extract meaning from a stream of sound (Hollich, 2010). The critical period hypothesis posits that this pattern-forming mechanism is primed for language learning between birth and puberty due to its heightened sensitivity to relevant environmental stimuli (Birdsong, 2018). However, the sensitivity period is a finite maturational span, and the desensitization that occurs post-puberty creates deficits in second language learning and acquisition (Birdsong, 2018). Age effects are well documented in linguistics research with decreased performance outcomes as a function of increased age (Birdsong, 2018; Hurford, 1991; Pinker, 1994). Thus, while it is possible to become fluent in a second language as an adult, it is significantly more challenging and requires disciplined study.

The development of coordination patterns for fundamental motor skills has a similar temporal trajectory to that observed in language acquisition. Early childhood seems to be a critical period for the learning of fundamental motor skills wherein the pattern-forming mechanism is highly sensitive to task-relevant stimuli. The learner's ability to perceive other possible solutions to fundamental action problems is progressively limited as the coordination patterns stabilize across maturational time. In this regard, the kinesthetic sense of self-movement

is a fluency that defines the behavioral range of the developing human in a manner comparable to language fluency. Thus, the dependency on feeling to guide movement coordination patterns is similar to the dependency on hearing to guide the phonological patterning of speech. As in language development, early childhood is a critical period for developing kinesthetic fluencies that guide healthy, efficient, and sustainable movement coordination patterns.

All motor competencies, including speech, are produced by a physical pattern-forming system with a complex functional architecture. Alexander discovered the system can learn to coordinate patterns that optimize or compromise its efficient and sustainable partnership with environmental constraints. He also discovered that the feeling of self-movement operated as an automated kinesthetic fluency that guided the coordination of task-relevant movement patterns. Finally, he discovered the coordinative function of thought and its application to sequencing adaptive psychomotor learning processes. These processes supported the intentional development of a kinesthetic fluency that supported embodied awareness of the embodied body-self in task-specific contexts.

Psychophysical Re-Education requires the learner to replace the maladaptively learned kinesthetic fluency with intentionally structured sequences of adaptive psychomotor learning. Through disciplined self-study, the adult learner could begin to harness kinesthetic thinking as an emergent fluency to guide the coordination of self-movement. However, as in language learning and acquisition, learning a new kinesthetic fluency as an adult is very challenging. The introduction of kinesthetic thinking in childhood helps establish it as the primary fluency and form of life that guides and nourishes lifespan human development (Hunter, 1968; Wittgenstein & Anscombe, 2000). Thus, Psychophysical Education aims to prevent the miseducative

experiences that culminate in the stabilization of inefficient, unsustainable, and unhealthy movement coordination patterns. In Alexander's words:

I wish to do away with such teachers as I am myself. My place in the present economy is due to a misunderstanding of the causes of our present physical disability, and when this disability is finally eliminated the specialized practitioner will have no place, no uses. This may be a dream of the future, but in its beginnings it is now capable of realization. (Alexander, 1996, pp. XXII, Original work published in 1910)

The next chapter introduces the work of Dr. Theodore Dimon, a philosopher and an educator who has built on the discovery of F. M. Alexander over the last four decades. An overview of Dimon's theory of neuromuscular-skeletal function helps explain the physiological underpinnings of kinesthetic fluency as a guiding principle in the coordination of human movement.

Chapter 6: The Physiology of Kinesthetic Fluency

Recall that Chapter 4 analyzed the problem of psychomotor maladaptation and introduced its four Aristotelian causes. A cursory explanation concluded that musculoskeletal biomaterials and their physical properties are the material cause of all species of human action, including psychomotor maladaptation. This chapter fleshes out the molecular mechanics that underlie the behavioral tendencies of musculoskeletal tissues in adaptive and maladaptive contexts. However, the study of how biomaterials behave requires us to hold multiple views of system dynamics simultaneously across microscopic (molecular and cellular); mesoscopic (multicellular structures, subsystems, or ‘parts’); and macroscopic levels (whole system) of complexity.

We begin this examination of Theodore Dimon’s holistic theory by fluidly interweaving the causes instead of treating them separately, as in Chapter 4. If, in the natural course of play, a child takes a ball of yellow playdough and a ball of blue playdough and mixes them together so they become fully integrated, then a larger ball of green playdough will emerge from the union. This is how we will treat the material and formal causes. We have taken each in turn, and now, the natural course of discussion (a kind of play) will have the effect of integrating them to produce a qualitatively different set of properties than when considered separately.

The theory presented in Dimon (2021) demonstrates that the system’s macroscopic dynamics act as an organismic constraint on the range of behaviors exhibited by its microscopic and mesoscopic subsystems. As explored in previous chapters, these macroscopic dynamics are neuromuscular-skeletal synergies that the self-moving system has learned to coordinate to achieve task-specific action goals. If the constraints imposed on a subsystem by the continuous flow of macroscopic dynamics delimit the range of behaviors available at the subsystem level,

then the loss of behavioral choices becomes a maladaptive consequence that impacts the whole complex system. A closer examination of how global neuromuscular-skeletal synergies act as a constraint on the behavior of skeletal muscle tissue, a subsystem, helps elucidate this highly theoretical claim.

This chapter begins with a description of the microscopic structures that underlie and contribute to the mesoscopic and macroscopic system dynamics. The discussion progresses towards the macroscopic level of coordination dynamics, which is the crux of Dimon's work. His theory of neuromuscular-skeletal function emphasizes that the vertebrate body is a complex, coordinated whole that works dynamically to organize goal-directed movement in a gravitational field (Dimon, 2021). Thus, Dimon (2021; Dimon & Brown, 2018) classified biomaterials and the subsystems they form with respect to the teloi or "ends" they produce as an integrated superstructure. Alternatively, the anatomized view of the human body breaks down the complex structures of the body into simpler and inert units, thereby abstracting them from the coordinated whole. Dimon's theory presents a method of studying the whole moving-and-perceiving body in the context of voluntary action without undercutting its complexity.

In this spirit, the following description of cellular biochemistry is undertaken for the purpose of examining the functional synergies that operate across the levels of system dynamics. This knowledge helps elucidate the cyclical relationship between the reproduction of maladaptive coordination patterns and the progressive degradation of musculoskeletal tissues, which further delimits the coordinative patterns available to the whole system. Moreover, the discussion explores the lengthening function of muscle tissue as the physiological basis for adaptive psychomotor learning and coordination. Muscular lengthening is an under-appreciated

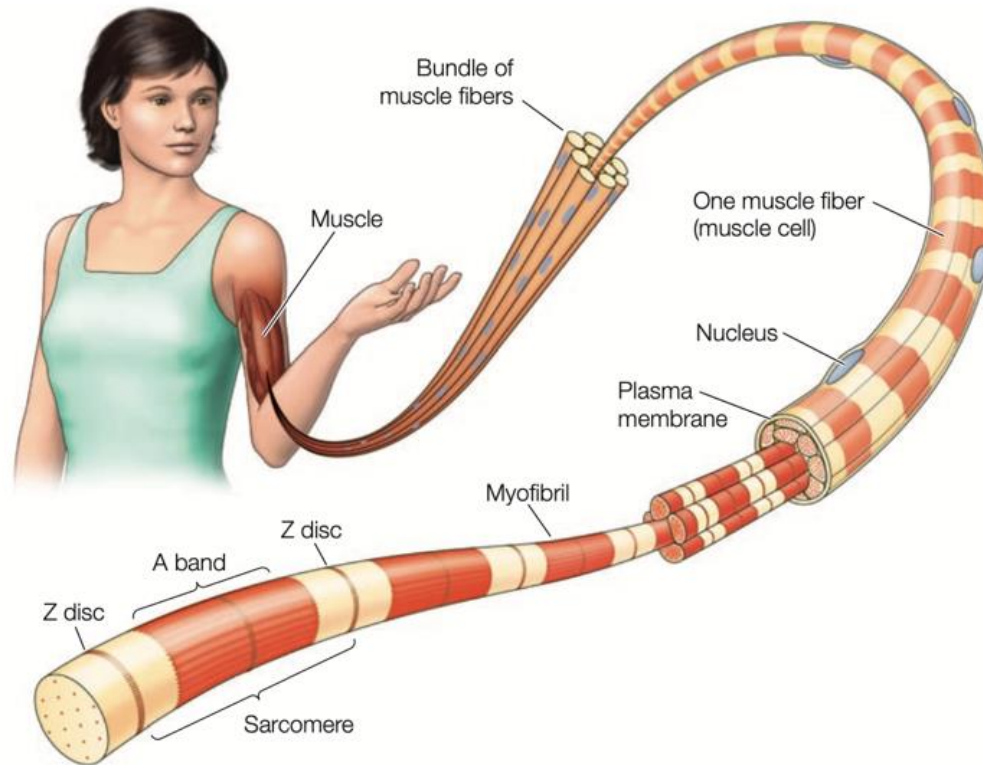
property of muscle tissue that cannot be understood in isolation of the body's macroscopic superstructure.

Animal muscle fibers are specialized eukaryotic cells, which incorporate and combine the functions of select metabolic machinery from their prokaryotic ancestors in the plant and germ kingdoms (Figure 6.1) (Cooper, 2019). As such, skeletal muscle cells contain organelles found in many other types of eukaryotic cells, including nuclei, endoplasmic reticulum, mitochondria, and the Golgi apparatus (Cooper, 2019). However, the skeletal muscle cell's organelles are specialized to support two classes of behavior, which correspond to two types of interaction with bones. The most familiar class of behavior is muscular contraction, which has been studied extensively by biochemists since the first half of the 20th century (Smith, 2018). In 1954, the Sliding Filament Hypothesis was introduced as a formal explanation of the contractile mechanism within striated muscle tissue (Huxley & Hanson, 1954; Huxley & Niedegerke, 1954; Smith, 2018).

Figure 6.1 illustrates the telescopic structure of skeletal muscle. Muscles like the human bicep are bundles of large cylindrical muscle cells, called fibers. Each muscle cell fiber contains many myofibrils, which are cylindrical bundles of two types of protein filaments, called actin and myosin. When categorized together, actin and myosin bundles are referred to as myofibrils. The actin and myosin filaments are organized into a chain of repeating units called sarcomeres, bordered by Z-discs. In considering the structure of muscle shown above, the Sliding Filament Hypothesis (SFH) theorizes that the interaction between actin and myosin generates the contractile forces that facilitate organismic movement (Cooper, 2019, p. 466).

Figure 6.1

The Structure of Skeletal Muscle Tissue



Note. Figure 6.1 illustrates the telescope structure of skeletal muscle tissue. Reproduced from G. M. Cooper (2019), *The cell: A molecular approach*, Sinauer Associates.

However, before delving into the details of the SFH, it is essential to emphasize that this theory was developed to explain the intracellular force-producing mechanisms whereby muscles pull on bones to facilitate movement at joints. The SFH assumes that muscle tissue is the dynamic component of musculoskeletal function, whereas bone is an inert tissue that passively responds to forces conveyed by the Central Nervous System by way of muscle. Thus, the SFH presents a hierarchical and top-down view of neuromuscular-skeletal coordination. Furthermore, it delimits the behavioral profile of skeletal muscle tissue to three types of contraction: concentric, eccentric, and isometric.

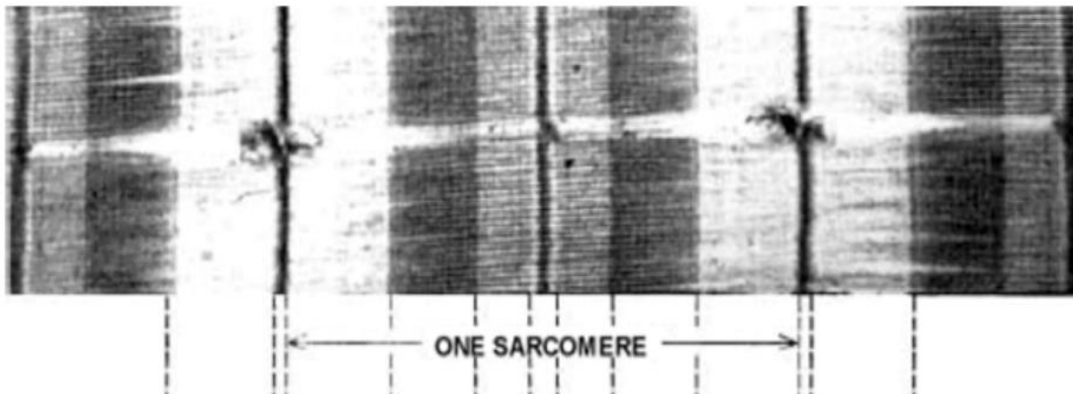
Moreover, the SFH does not directly explain the second class of skeletal muscle behavior introduced at the outset of this discussion. The developers of the SFH did not intend to explain the lengthening behavior of striated muscle tissue. They were not studying this behavior at all. Instead, the researchers were searching for an intracellular mechanism that could shorten muscle by drawing its distal ends, flanked by tendon and bone, closer together; and they found the object of their search. The still prevalent assumption that “muscle cells are highly specialized for a single task—contraction” guided their research into the mechanics of muscle function (Cooper, 2019, p. 466). This perspective demotes muscular length from a dynamic, functional property of muscle tissue to a passive, neutral state occupied by muscle during the cessation of contraction. Therefore, they were not seeking a mechanism of muscular length, and, even if they had been, they would not have found it within the sarcomere, the site of their targeted search for the source of contraction.

The sarcomere (Figure 6.1) is the contractile unit of striated muscle cells. It is a protein complex replicated in a chain- or polymer-like fashion within a muscle cell’s cytoplasm (Cooper,

2019). For reference or review, the muscle cell is a living entity that obtains the form of a cylindrical-shaped fiber like a single strand of hair. Each striated muscle cell is composed of many fine tubular organelles called myofibrils (Cooper, 2019; Dimon, 2021). A myofibril is a chain of serially connected sarcomeres, which shorten in a coordinated manner to facilitate contraction of the muscle cell. Sarcomeric shortening is facilitated by the relative sliding and convergence of two protein filaments. The filaments are part of the internal machinery of the sarcomere, and their cooperative mechanism is like the draw tube of a Galilean telescope. Moreover, the periodic sequencing of sarcomeres along the length of the thread-like myofibril gives muscle tissue its striated or striped appearance (see Figure 6.2).

Figure 6.2

Micrograph of a Frog Sartorius Muscle

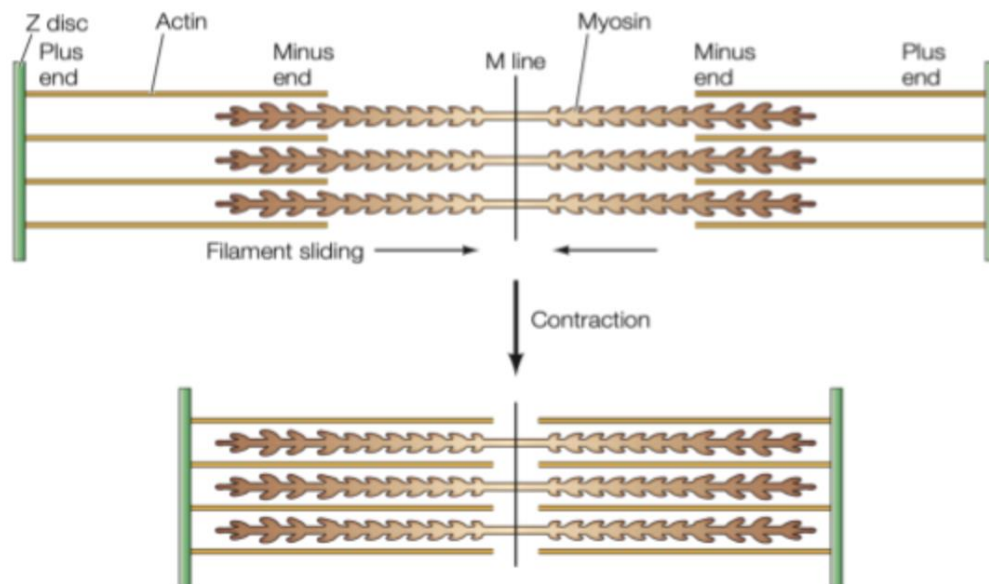


Note. Figure 6.2 is a micrograph of a frog’s sartorius muscle, an anterior thigh muscle. The micrograph shows the striated or striped pattern of skeletal muscle tissue formed by the sarcomere’s molecular structure. The arrows below the micrograph indicate the dimensions of one sarcomere or one contractile unit of the sartorius muscle, as demarcated by the bordering Z-discs. Thousands of sarcomeres are dispersed end-to-end across the length of a single myofibril to produce the striped patterning of skeletal muscle tissue (Huxley, 2004).

The Sliding Filament Hypothesis (SFH) foregrounds the sliding protein filaments as the key players in its description of striated muscle contraction. The protein filaments, called actin and myosin, are regarded as the primary components of the sarcomere's ultrastructure (Smith, 2018). As illustrated in Figure 6.3, the thin actin filaments are fastened at their terminal ends to the Z-discs, structural components that define a single sarcomere's borders. The thick myosin filaments are centrally anchored at the M-line and do not make contact with the Z-discs. The myosin filaments interdigitate with the actin filaments so they can slide past each other, thus changing the length of the sarcomere.

Figure 6.3

The Structure of the Sarcomere



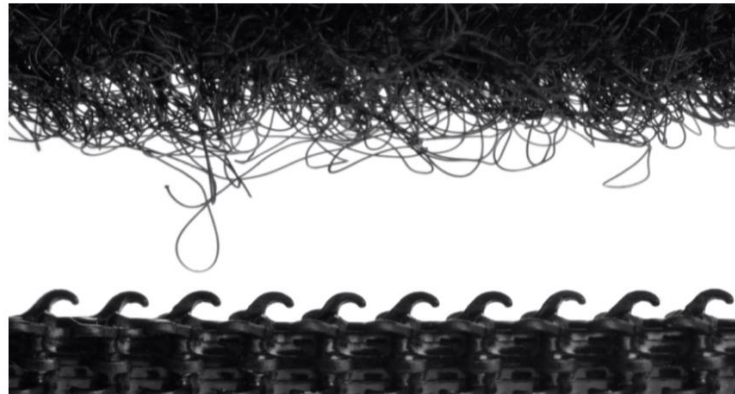
Note. Figure 6.3 illustrates the sarcomere, featuring the thick myosin filament nested in alternating layers of actin strands. The spherical appendages on the myosin filament represent the globular heads that bind to specialized sites on the actin strands. The Sliding Filament Hypothesis posits that the interaction between these two components is the mechanism of skeletal muscle contraction (Cooper, 2019, p. 467).

The SFH posits the sliding interaction between actin and myosin generates the contractile forces that facilitate organismic movement. However, the verb “sliding” used in the theory’s title may lead one to the erroneous conclusion that this interactive process is passive. In reality, the contractile interaction between actin and myosin requires large amounts of chemical energy in the form of ATP (Dimon, 2021). The myosin filaments are populated with globular heads that bind to specialized sites on the actin strands and pull them towards the M line (Dimon, 2021; Smith, 2019). The ratcheting action of the myosin filaments draws the Z-discs towards the midline and shortens the sarcomere.

It may be helpful to take a leaf from the field of Early Childhood Education (ECE) and ground this theoretical discussion of muscle function in phenomenal experiences. Therefore, let us pause and consider a familiar fastening device that operates according to similar structural principles as those found in the actin-myosin interaction. Velcro is a hook-and-loop fastener that is used in commercial and medical industries (Figure 6.4 and Figure 6.5). It has even been leveraged as a more accessible, developmentally appropriate fastening solution for children’s clothing, shoes, and toys. The components of Velcro are two opposing fabric strips specially designed to conjoin or temporarily bind to each other. One fabric strip is populated by small nylon hooks and the other consists of wooly polyester loops. The hooks interlace the loops when the two fabric strips are stacked, and a minimal amount of compressive force is applied. The two materials remain interconnected until they are pulled apart by the use of force (Hook and loop, n.d.).

Figure 6.4

Velcro Hook-and-Loop Fastener



Note. Figure 6.4 is a close-up photograph of a Velcro textile hook-and-loop fastener. The components of Velcro are two types of lineal fabric strips. One fabric strip is populated by small nylon hooks and the other consists of wooly polyester loops. The two components are specially designed to temporarily bind to each other until they are pulled apart by mechanical forces (The invention of Velcro, n.d.; Postiglione, 1993).

Figure 6.5

Magnification of the Hook-and-Loop Mechanism



Note. Figure 5 is a magnification of a Velcro hook fastening onto two Velcro loops. For reference, the above image is roughly 1 millimeter across when measured from left to right. The Velcro hooks are like the myosin heads that actively bind to the actin strands. The Velcro loops are like the actin filaments, which provide a specialized surface for the myosin heads to fasten onto and pull. The opposing Velcro strips are a useful analogy to describe how myosin and actin interact to form cross-bridges (Budde, 1995; The invention of Velcro, n.d.).

Like the components of Velcro, the opposing myosin and actin filaments are specially designed to temporarily bind to each other. Their opposing structures support an interaction called “cross-bridging” that activates a fastening mechanism, which is the basis of skeletal muscle contraction (Dimon, 2021). The globular heads of the myosin filament serve a similar function as the nylon hooks of the Velcro strip. The specialized sites on the actin strands are like the Velcro loops that ‘catch’ the hooks under compression. However, the hooked and looped fabric strips of Velcro are inert and respond passively to mechanical compression. As discussed, actin and myosin are dynamic molecular components of the sarcomere and actively participate in the processes that underlie skeletal muscle contraction.

The actin-myosin fastening mechanism is activated by complex biochemical processes that occur within the muscle cell. The structure and function of the muscle cell’s organelles are highly specialized to store and transport concentrations of Calcium ions (Ca^{2+}). In particular, the muscle cell’s sarcoplasmic reticulum (SR) is a specialized calcium storage organelle. To enumerate, when a muscle cell is stimulated by a motor nerve, the calcium ions (Ca^{2+}) stored in the SR are transported through the SR’s semi-permeable membrane into the myofibril space (Dimon, 2021). This flow of calcium ions into the myofibril space creates a potential energy gradient, which “turns on” the actin-myosin fastening mechanism, like a switch (Cooper & Hausman, 2007). Once activated, the myosin heads consume ATP to perform repeated cycles of binding, pulling, and detaching from the actin filament (Cooper, 2019; Dimon, 2021). The myosin filament is considered a molecular motor because it converts chemical energy (ATP) into mechanical energy to generate force and movement (Cooper, 2019; Sweeney & Hammers, 2018). The resultant ratcheting action of the myosin heads along the actin filament is called cross-bridge cycling (Sweeney & Hammers, 2018).

The advancement of the myosin heads along the actin filament is similar to the way a child advances along “monkey bars” in a playground. The child grasps a bar, swings to grasp another bar, and releases her grasp on the original bar in order to swing to the next bar. The child repeats the “grasp, swing, grasp, release, swing, grasp” cycle until she falls or reaches the end of the play structure. Similarly, the myosin heads repeat their cycle of “bind, pull, detach, bind” along the length of the actin filament. The cross-bridge cycling process continues until the reduction of calcium in the myofibril space “turns off” the actin-myosin fastening mechanism or the myosin reaches the Z-discs at the terminal ends of the actin filament.

The intrinsic mechanics of muscle tissue produces three types of muscle action, commonly called contraction: concentric, isometric, and eccentric. Concentric contraction refers to the muscle’s active production of greater forces than the applied force on a body segment (Floyd, 2021; Nishikawa & Huck, 2021). A crude example is the lift phase of a biceps curl wherein the biceps brachii muscle produces enough force to overcome the applied forces of gravity and the dumbbell on the forearm. Thus, the biceps brachii muscle produces tension and shortens to flex the elbow joint, raising the forearm in opposition to the applied environmental forces. At the molecular level, the cross-bridging processes are unencumbered by any tensile resistance to sarcomeric shortening from internal or environmental forces. Therefore, the myosin heads can walk along the actin filaments until the motor nerve ceases to stimulate the cell or the sarcomere is fully shortened. The sarcomeric shortening at the microscopic level corresponds to the shortening of the musculotendinous unit at the mesoscopic level. Thus, concentric contraction is also referred to as “shortening contraction” in muscle physiology literature (Nishikawa, Lindstedt et al., 2018).

Isometric contraction occurs when muscles produce a force that equals the applied forces on a body segment. The word “isometric” is a compound of the Greek prefixes *isos* (equal) and *metria* (measuring) because muscle length and joint angle remain constant during isometric contraction (Hines, 2018, p. 54). Thus, isometrically contracting muscles stabilize a body segment without changing length. For example, isometric contraction of the biceps brachii muscle stabilizes the forearm in relation to the upper arm and shoulder when the dumbbell is held in a stationary position in the middle of a biceps curl cycle. At the molecular level, the coupling between actin and myosin generates tension, but the myosin heads do not detach from the actin filament to reattach further along its length. Instead, the myosin heads remain anchored to a particular binding site on the actin filament, which stabilizes the sarcomeric length while generating tension. At the mesoscopic level, the musculotendinous unit produces a constant force equal to the applied forces on the body segment.

Eccentric contraction occurs when the applied force on the body segment exceeds the forces generated by the musculotendinous unit. During an eccentric contraction, the weight of the applied force exerts a stretch on the cross-bridges and the muscle resists the stretching load (Watkins, 2014). The cross-bridges ultimately respond to the applied stretch by detaching and reattaching at longer sarcomeric lengths, as the muscle lengthens. For example, eccentric action of the biceps brachii muscle controls the descending movement of the forearm during the lowering phase of the biceps curl. During the lowering phase of the biceps curl, the tension generated by the cross-bridges is less than the tensile stretch that is applied to the body segment by the resistance of gravity and the dumbbell.

As a result, the cross-bridges decouple in increments, which lengthens the muscle and facilitates the controlled descent of the forearm. The sarcomeric lengthening at the microscopic

level corresponds to the lengthening of the musculotendinous unit at the mesoscopic level. Thus, eccentric contraction is also referred to as “lengthening contraction” in muscle physiology literature (Nishikawa, Lindstedt et al., 2018; Tomalka et al., 2017). Additionally, it is increasingly common for contemporary Muscle Physiology and Kinesiology literature to refer to eccentric (or lengthening) contraction as lengthening “muscle action” (Floyd, 2021). This nomenclature shift is motivated by the enigmatic nature of lengthening muscle action, which seems to differentiate it from concentric and isometric contraction.

The behavioral properties of lengthening muscle action have puzzled researchers from the time the SFH was presented over 70 years ago. For example, lengthening muscle action produces increased energy efficiency and maximum muscle force relative to shortening contraction (Nishikawa, Lindstedt et al., 2018; Nishikawa, Monroy et al., 2018). The forces produced by the strain and incremental release of the actin-myosin cross-bridging under stretch do not fully account for the enhanced energy storage that supports greater force production (Nishikawa, Lindstedt, et al. 2018; Nishikawa, Monroy et al., 2018). In other words, the enhanced properties of lengthening muscle action cannot be singularly produced by an intracellular fastening mechanism when it is pulled apart like Velcro. Furthermore, conventional muscle models based on the SFH do not reliably predict in vivo muscle force (Dick et al., 2017; Lee et al., 2013).

Nishikawa (2020) speculated conventional models are misaligned with in vivo muscle dynamics because they cannot predict “muscle force enhancement and depression during dynamic changes in length” (p. 210) Thus, the idiosyncrasies of the perhaps aptly named “eccentric” action of skeletal muscle tissue have challenged the explanatory power of the SFH.

Furthermore, the unexplained properties of lengthening muscle action evoke more profound questions about muscle tissue structure and function in postural control and voluntary action.

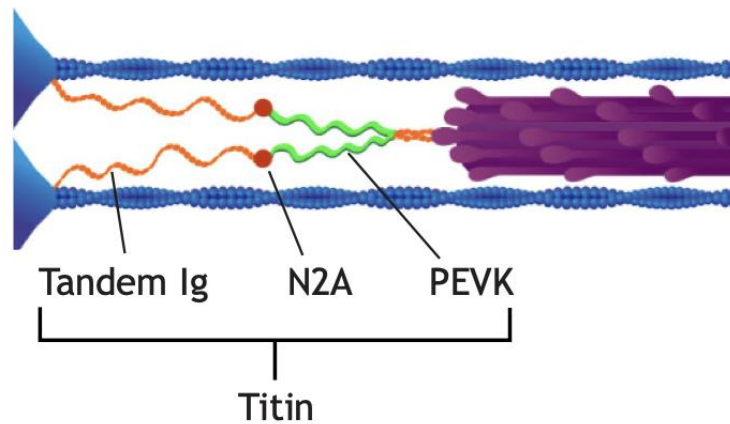
The limited ability of SFH-based models to predict *in vivo* muscle behavior suggests there must be other contributing players under-represented in the SFH. In the last decade, biologists have developed a compelling new hypothesis to address these limitations. The Winding Filament Hypothesis (WFH) is not intended to replace the SFH as the prevailing theory of muscle function. Instead, the WFH builds on the strong foundation of the SFH by re-examining the potential contributions of an underappreciated sarcomeric component, Titin (Nishikawa et al., 2012). Researchers discovered the sarcomeric protein, Titin, more than two decades after the SFH was developed (Maruyama, 1976; Nishikawa et al., 2012; Wang et al., 1979). The relative obscurity of Titin is ironic considering its status as the largest known protein and its current recognition as a “giant sarcomeric protein” in the muscle physiology literature (Nishikawa et al., 2012; Nishikawa, Lindstedt et al., 2018, p. 268).

Researchers initially theorized that Titin played a strictly supporting role in skeletal muscle activation (Nishikawa, Lindstedt et al., 2018). The Titin filament spans the entire length of a half-sarcomere, connecting into the Z-disc and the M-line at its distal ends (Figure 6.6). Titin is proximally bound to the actin and myosin filaments within the sarcomere (Nishikawa & Huck, 2021). Furthermore, the strands of Titin in adjacent sarcomeres overlap in the Z-discs, such that the Titin strands continuously interweave the entire length of each myofibril (Watkins, 2014). Thus, Titin has the appearance of a rigging system that maintains the structural integrity of each sarcomere unit and the whole series of sarcomeres that constitute a myofibril strand. Consequently, early research into Titin hypothesized that its function was to serve as a molecular scaffold, integrating the sarcomeric components into an operational whole (Nishikawa, Lindstedt

et al., 2018). However, contemporary research suggests that Titin may play a critical role in sarcomeric force production and the tonic activation of muscle tissue.

Figure 6.6

Illustration of Half Sarcomere with Titin Labeled



Note. The illustration depicts a half-sarcomere, spanning Z-disk to M-line. The Titin molecule is bound to the thin actin filaments (blue) and the thick myosin filament (purple). Between these anchor points are three distinct structural elements that function as viscoelastic springs: the more compliant IG domain, the stiffer PEVK domain, and the N2A segment (Nishikawa & Huck, 2021).

The Titin filament's elastic properties make it particularly well-suited to partner with actin and myosin cross-bridging to enhance muscle force production. Titin stores potential energy when stretched over distances like a viscoelastic spring (Dimon, 2021; Nishikawa, Lindstedt et al., 2018; Tomalka et al., 2017). The magnitude of the tensile forces produced by the Titin filament increases exponentially with the amount of stretch exerted on the filament (Nishikawa & Huck, 2021; Watkins 2014). Therefore, Titin generates more passive tension when the sarcomeres are lengthening and the Titin molecules are stretched across the whole, lengthening myofibril strand. Hessel et al. (2021) claimed that Titin is responsible for nearly all longitudinal force in unactivated, relaxed myofibrils. The passive contribution of Titin helps explain the increased efficiency of eccentric contraction or lengthening muscle action with

respect to energy storage and force production (Nishikawa, Lindstedt et al., 2018). It also begins to describe a length-dependent process that compels sarcomeres to behave like a series of interconnected microsprings (J. French, personal communication, January 2, 2022; Tamalka et al., 2017).

In addition to generating passive tension, Titin appears to function as a spring in activated muscle (Hessel et al., 2021). Like its partner filaments, actin and myosin, Titin is also activated by the flow of Calcium ions in the myofibril space (Columbini et al., 2016). However, Titin does not participate in the crossbridge cycling of actin-myosin, which shortens the sarcomere through a fastening mechanism. Instead, Titin stiffens in response to Calcium ions and resists stress-based deformation like a spring (Nishikawa & Huck, 2021). The passive and active contribution of Titin supports “the versatility and adaptability of muscle function” (Nishikawa, 2018, 2020).

However, science has not yet produced a conclusive model to describe and predict Titin’s functional interdependence with each sarcomeric unit’s adjacent structures and processes. Nor do existing theories comprehensively explain how Titin influences the functional elastic properties of a single myofibril cell and the muscle tissues of which it is a constitutive part. Yet, the evolution of compelling theories over the last few years suggests science may be acquiring more of the language and technologies needed to decipher the complex physiology of skeletal muscle tissue.

The next phase of inquiry is to consider how skeletal muscle tissue, operating as a composite elastic-contractile biomaterial, fits into an organismic view of adaptive human psychomotor action. It is important to remember that the molecular activity within muscle tissue is activated by motor nerves as a coordinated response to an action goal. Theodore Dimon (2015) presented a view of muscle tissue as tunable chords continuously integrated into the larger

network of body's fascia and connective tissues in a way that serves to regulate muscle tissue's force-generating capabilities. Thus, muscle tissue, connective tissue, and bone form continuous mesoscopic units that operate as a coordinated whole, synergistically impelling the macroscopic system dynamics. A fundamental principle in Dimon's view of the human neuromuscular-skeletal design is such that its diverse tissues are functionally indivisible; their continuity in form and function constraining their in vivo properties. Therefore, the post-positivist study of in vitro muscle action offers an overly reduced scope that is not directly transferable to the emplaced organism.

According to Dimon (2021), the interrelationship of muscle and bone is critical to the emergence of biological and mechanical synergies that support upright postural control. Furthermore, the quality of interaction between these biomaterials constrains their discrete and collective properties in dynamic contexts. The principle underpinning the following discussion is that diverse tissues seamlessly evolve into integrated functional units to achieve tasks of ever-increasing complexity. Similarly, these functional units self-assemble into an integrated biodynamic whole, supporting the emergence of macroscopic form and function (Dimon, 2021).

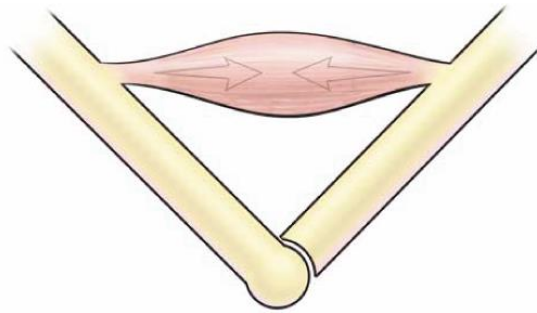
As inferred in the earlier discussion of the different types of muscle action, contracted muscle tissue pulls its bony distal ends closer together. Joint flexion is often the mesoscopic effect of this type of muscle action. Figure 6.7A and B illustrate how the reduction in muscle length as in concentric contraction reduces the angle formed by the articulating bone at the mesoscopic and microscopic levels, respectively. Importantly, the shortening of muscle tissue constitutes a deviation from a relative state of unactivated muscle length. Recall that eccentric contraction, or "lengthening muscle action," denotes the muscle's active production of force through the release of actin-myosin cross-bridges. This molecular process induced a deviation

from a shortened state to a relative state of muscle length. However, this change in state can also be facilitated by the deactivation of muscle tissue without activating force production, as in Figure 6.8A and B. In this case, the cross-bridges let go such that the filaments slide apart passively.

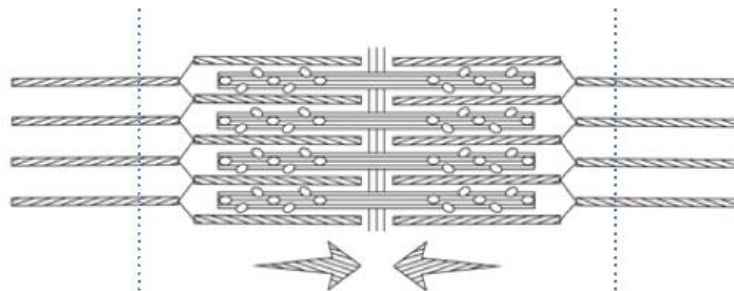
Figure 6.7

Mesosopic and Microscopic Levels of Concentric Contraction

6.7A



6.7B

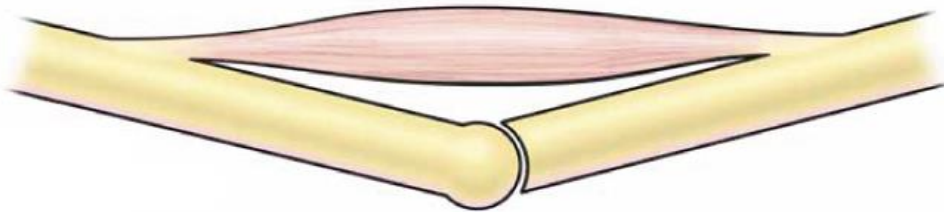


Note. Figures 6.7A and B depict concentric muscle contraction at the mesoscopic and microscopic levels, respectively. Figure 6.7A illustrates how the reduction in muscle length reduces the angle formed by the articulating bone. Figure 6.7B illustrates the ratcheting action of actin and myosin filaments that produce forces to draw the bony levers closer together. Reproduced with permission from T. Dimon (2021). *Anatomy in action: The dynamic muscular systems that create and sustain the moving body*, North Atlantic Books.

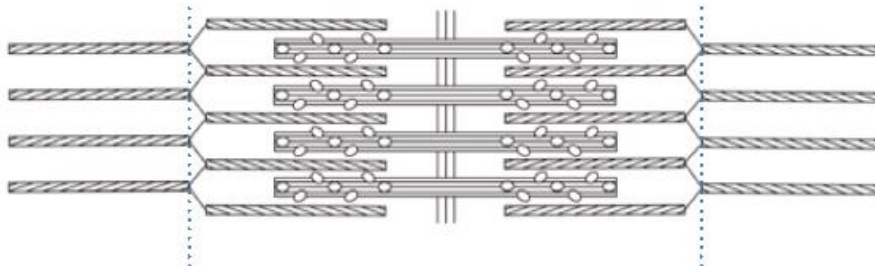
Figure 6.8

Mesoscopic and Microscopic Levels of Muscle Lengthening

6.8A



6.8B



Note. Figures 6.8A and B depict muscle lengthening at the mesoscopic and microscopic levels, respectively. Figure 6.8A illustrates how the deactivation of cross-bridging induces an increase in muscle length, increasing the angle formed by the articulating bone. Figure 6.8B illustrates the resting state of the deactivated actin-myosin filaments, which allows the bony levers to fall away from each other as driven by gravity. Reproduced with permission from T. Dimon (2021). *Anatomy in action: The dynamic muscular systems that create and sustain the moving body*, North Atlantic Books.

A simple analogy helps to illustrate the difference between the two molecular processes that facilitate muscle active and passive muscle lengthening. Eccentric contraction is like when the hooks and loops of Velcro are pulled apart to release the fastening mechanism forcibly. In contrast, passive lengthening is as if the mechanism were deactivated such that the hook and loop fasteners spontaneously disengage. The cessation of motor nerve impulses to the muscle cell facilitates this type of deactivation of the actin-myosin cross-bridges. The myosin and actin filaments disengage in a way that allows the muscle to return to its deactivated resting length. Muscle does not produce active force in this state, although Titin interactions may facilitate the generation of passive forces.

Recall that the magnitude of the tensile forces produced by the Titin filament increases exponentially with the amount of stretch exerted on the filament (Nishikawa & Huck, 2021; Watkins, 2014). The deactivation of muscle tissue and its resultant release into length stretches the Titin filaments, which causes them to stiffen. However, a dynamic operating at the level of the musculoskeletal unit may amplify the amount of stretch exerted on deactivated muscle tissue. Consider the interrelationship of muscle and bone depicted in Figure 6.7 and Figure 6.8. As stated previously, the musculoskeletal unit actively resists gravity in the context of contractile muscle action. Imagine, for instance, that the musculoskeletal unit in Figure 6.7A represents the human arm and the articulating joint is the elbow. In reality, of course, the architecture of the human arm is significantly more complex than the conceptual model. However, the figure sketches the basic dynamics of elbow flexion in response to the contractile action of muscles crossing the joint. The contractile action of the muscle would lift the lever of the forearm, wrist, and hand in opposition to gravity.

Similarly, Figure 6.8A shows the muscle passively lengthening, which lowers the lever of the forearm in coordination with gravitational forces. The elastic musculotendinous component is stretched between the gravity-driven bony levers as the angle increases. Thus, Figure 6.8A depicts the stretch exerted on muscle and tendon as their polar ends are pulled in opposite directions by the combined forces of bone mass and gravity. The emergence of musculoskeletal lengthening is supported by the suspension of weighted bone in a tensile web of muscle-fascia. The oppositional relationships formed by bony members in the gravitational medium supports the emergence of dynamic musculoskeletal lengthening. However, the muscle tissue must be receptive to the dynamic stretch applied by bone's geometric scaffolding. Muscle tissue that is excessively contracted will merely pull-on bone and will not release into the property of stretch. Reciprocally, the chronically shortened muscle tissue deactivates the oppositional relationships inherent in the skeleton's geometric structures.

Central to Ted Dimon's theory is that the oppositional relationships inherent in the musculoskeletal system's geometry are the basis for a biotensegrity structure (Dimon, 2015, 2021). Biotensegrity denotes the application of an architectural concept, tensegrity, to explain the complex forms and functions of biological organisms (Dimon, 2021; Levin, 2002). Tensegrity is an architectural concept wherein mechanical stability is achieved through the balance of tensile and compressive forces within a structure (Dimon, 2021; Edwards et al., 2012). Tensegrity structures are composed of members that are permanently under either tension or compression, thus balancing the intrinsic forces to optimize structural integrity with minimal resources (Dimon, 2021; Edwards et al., 2012).

Dimon (2015, 2021) argued that the biotensegral structure of the vertebrate body is an anti-gravity system, which evolved to operate efficiently and sustainably in the context of

musculoskeletal length. However, the contractile functions of muscle tissue tend to be overdeveloped by social and cultural influences on ontogenetic processes and the lengthening property is underdeveloped. Kinesthetic thinking operates as a self-organizing principle that facilitates musculoskeletal lengthening, a critical property of neuromuscular-skeletal function. The intentional circulation of kinesthetic thoughts in mechanically advantageous positions, or positions that optimize the organism-environment partnership, encourages muscles to release into length (Dimon, 2015). Thus, the intentional development of kinesthetic fluency helps regulate the dynamic interplay between elastic and compressive forces in the physical system in support of efficient and sustainable self-movement.

The purpose of Psychophysical Education is to intentionally guide the development of movement coordination patterns that maintain and leverage the oppositional relationships inherent in the biotensegral anti-gravity system. To this end, Psychophysical Education develops a kinesthetic fluency that continuously direct attention to the self-environment interface to enhance afferent-efferent perception of affordances for action. The semantic structure of the kinesthetic fluency guide movement coordination patterns that adaptively and selectively leverage biotensegral force and pressure variables that emerge from the organism-environment partnership. In this way, the child learns to assemble movement coordination patterns that flexibly achieve embedded action goals sustainably and efficiently. Thus, Psychophysical Education scaffolds adaptive psychomotor learning: The discovery and stabilization of movement patterns that (1) accomplish action goals in the here-and-now, and (2) support the health of the changing neuromuscular-skeletal system across its lifetime. The next chapter presents a sketch of how Psychophysical Education might be integrated into the ECE curriculum.

Chapter 7: Psychophysical Education:

Centering the Body in ECE

The decoupling of cognitive and regulatory processes from the moving-and-sensing body is a feature of our sociocultural milieu reinforced by curriculum and teaching practices at all educational levels. In the Fall of 2019, I had an experience that illustrated the effect of decentering the body-self from the perceptual, cognitive, and regulatory dimensions of behavior. At that time, I used public transportation to commute from my Washington Heights neighborhood in upper Manhattan to my ECE worksite in Morningside Heights. Incidentally, I shared my morning commute with many Washington Heights families en route to school and work. One family piqued my interest because I saw them daily, and the two children always read or completed worksheets during their commute. I do not know their exact ages, but I would estimate they were both in middle school or between 11-13 years old.

One morning, the younger of the two children sat “crisscross applesauce” on the bus seat. She used the school folder on her lap as a rigid surface to write in the boxes of a crossword puzzle. She confidently solved each word puzzle until she encountered a question that confounded her. Based on the ensuing conversation, I surmised that the word “shoe” would not fit into the allocated boxes when the word’s first letter was a known value, “f.” She turned to her father for support after staring quizzically at the word puzzle for several minutes: “It’s asking what is at the bottom of your leg that you stand on, but I can’t get ‘shoe’ to fit.”

“What is at the bottom of your leg?” he answered abruptly.

“Shoe,” the girl replied emphatically.

“No,” said her father, “think about it: What is at the *bottom of your leg?*”

She stared inquiringly at her leg for a few moments: “Socks?”

“No. What is at the bottom of your leg that you *stand* on?”

The child reflected her father’s impatience, adopting a frustrated tone: “My shoe!”

“No,” he said, softening his tone to avoid escalation. “When you take *off* your shoe, what is the *body part* at the bottom of your leg that you stand on?” The child stared at her shoe imploringly for several moments before exclaiming, My foot! My foot is at the bottom of my leg, and I stand on it!”

“Yes,” her father said, relieved. The child filled in the remaining letters and independently proceeded to the next question.

This parent-child interaction offers a clear example of how, for many of us, our kinesthetic sense of embodiment is decoupled from our conceptual and linguistic frameworks. Admittedly, the child’s ability to retrieve the word “foot” may have been impeded by the poor syntactical structure of the word puzzle and her father’s repetition of that syntax when framing guiding questions. However, she quickly retrieved the words for shoes and socks, footwear that clothe and protect the body’s structures but produce neither functional outcomes nor kinesthetic-tactile sensations in and of themselves. Moreover, the child’s tendency to look at her leg and shoe in response to her father’s questions suggests the underdevelopment of kinesthetic sensory awareness and over-reliance on the visual sense to extract information from the environment in the coordination of psychomotor responses.

In general, the perceptual learning afforded by our sociocultural and educational environments often directs attention to the voluntary regulation of our visual and auditory senses: “Pay attention, look at me. Are you listening to me?” However, we are rarely encouraged to sustain conscious attention to our kinesthetic-tactile sense to guide our behavior, self-regulation, and skilled performance of actions. As discussed in Chapter 1, the child’s developing self-

expression and self-perception of embodiment may be implicitly or explicitly discouraged by curriculum and learning formats. My observation of the child on the bus that morning evoked these questions: *What happens when our body-selves cease to be a moving-and-sensing object of our conception if, as Pragmatism contends, the objects of our conception are the source of action? What impact does this have on our ability to use—operate—the moving-and-sensing body-self to achieve our ends?*

Alexander's discovery suggests that the degradation of kinesthetic perceptual acuity has a reciprocal effect on neuromuscular-skeletal coordination. As discussed in Chapter 3, the stabilization of maladaptive neuromuscular-skeletal coordination patterns sourced from the objects of our conception can lead to progressive states of mechanical stress, strain, and failure. As argued throughout this dissertation, the unstructured learning processes that guide the stabilization of maladaptive coordination patterns may be a source of chronic pain conditions and progressive disability that impact the global population (Anderson, 2020; Clarke et al., 2016; IHME, 2018). In some cases, the emergence of idiopathic pain conditions in children may indicate an early stage of periodic stress and strain induced by maladaptive movement coordination patterns becoming increasingly stable.

Recall the Global Burden of Disease Study's (2021) suggestion that musculoskeletal disorders like low back pain and neck pain emerged in 5-9 year olds and 10-14 year olds, respectively (<http://ihmeuw.org/5qh3>). These findings aligned with other research studies reporting the prevalence of neuromuscular-skeletal pain and disorder in child populations (Huang et al., 2019; Huguet et al., 2016; Kjar et al., 2011; MacDonald et al., 2017; Michaleff et al., 2014). Moreover, the development of idiopathic spinal pain in childhood and adolescence is an important predictor of chronic spinal pain in adulthood (Brattberg, 1994, 2004; Jeffries et

al., 2007). Guided by these findings, this dissertation raises the question of whether developing kinesthetic fluency that guides adaptive psychomotor learning and behavior in early childhood will support improved neuromuscular-skeletal health outcomes in child and adult populations. I cannot answer this question at this early stage of research, but it is my purpose to address this question systematically throughout my career. To this end, I propose the development and implementation of a curricular model that fosters fluency between our kinesthetic-tactile sense of embodiment and the conceptual, linguistic frameworks that constrain our field of action.

This model, called Psychophysical Education, aligns curriculum with a fundamental law of nature as compulsory as Newton's Law of universal gravitation: The moving-and-sensing body is central to everything we do as emplaced organisms. The body is at the center of the cumulative processes of learning and adaptation that undergird lifespan human development. However, curricula at all educational levels have decentered the body in its efforts to support the acquisition of highly specialized cognitive, academic, technological, and communication skills. Therefore, curricular models are out of alignment with, and may even operate in opposition to, the physiological processes that underlie vertebrate behavior and conduct. Centering the body in Early Childhood Education (ECE) will respect the primacy of the neuromotor system in all that we do and leverage its untapped opportunities for human development.

Daily routines that engage the classroom community in teacher-directed songs, book and poem read-alouds, discussions, movement and music, and inquiry-based learning are common in ECE (Genishi & Dyson, 2015; Wohlwend, 2015). Commonly referred to as "circle time" or "meeting" in ECE curricula, these structured teacher-directed activities promote skill acquisition across developmental domains. Of note, these activities support the development of self-regulatory skills, executive functioning, cognitive-language skills, early literacy, numeracy, and

social-emotional skills (Bustamante et al., 2018; Canney & Byrne, 2006; Tominey & McClelland, 2011). Gross-motor games that invite the children to stand up and dance in the center of the circle or participate in popular movement-based songs like “Head, Shoulders, Knees, and Toes” or “Simon Says” are commonly integrated into the “meeting” structure. These are designated moments when motor development is highlighted as an obligatory domain, and the body-self is brought into the foreground of the children’s experience. In these moments, the early childhood classroom erupts in the excited cries and laughter of the children.

Perhaps the children’s energetic and joyful responses to these movement activities express a moment of self-recognition. They are reunited with the primary sensorimotor dimension of self, which affirms their sense of being a moving-and-sensing-and-feeling “me.” The social and physical environments they occupy tend to alienate them from their own sense of embodiment, but, at this moment, the “me” is invited to play. Then, after the conclusion of the planned movement activity, the children are cued to “sit down,” the next activity is introduced, and the body-self retreats into the background. The curricular “motor development” box is ticked for the day, and it is time to address the next developmental domain in its turn: The book is read aloud, the song is sung, the lesson is presented, and the children sit with “steady bodies.” Then, when they do not or cannot, they are given gentle reminders by teachers to “Sit up straight,” “Your bottom should be on the floor,” “Calm your body,” or, finally, “Do you need a steady chair?”

At these times, the body-self is treated as a liability that “gets in the way” of learning and productive participation in school activities. However, the body-self is not the problem that gets in the way of learning. The body-self is the primary source of learning that was gifted by nature to facilitate the perception-action cycles that are the basis of learning and adaptation. The

problem is that we have decentered the body in education. As a result, we have developed a system of education that systematically alienates the complex vertebrate's primary source of learning: the moving-and-sensing "me." Psychophysical Education re-centers the body-self by developing kinesthetic fluency to support adaptive learning experiences in the ECE classroom. Early learning experiences guided by kinesthetic fluency as a self-regulatory skill will support holistic and adaptive developmental processes. In this way, ECE can set the stage for establishing and sustaining psychomotor adaptation across the lifespan.

Psychophysical Education is the intentional sequencing of adaptive psychomotor learning into ECE curriculum and its learning formats. A premise of Psychophysical Education is that the child fundamentally acquires all skills, irrespective of developmental domain, through sensorimotor exploration, yielding increasingly stable psychomotor solutions. Therefore, the purpose of the curriculum is to structure learning experiences that carefully cultivate, leverage, and scaffold the learner's intrinsic neuromotor pattern-forming mechanism to support adaptive psychomotor learning and coordination. In other words, the curricular aim is to guide perceptual-cognitive development such that children's coordinated psychomotor responses adaptively and selectively leverage biodynamic force and pressure variables at the interface of body-self and environment. The learned ability to consciously self-regulate the elastic, biotensegral relationships inherent to the neuromuscular-skeletal structure will support efficient and sustainable self-movement.

Thus, Psychophysical Education will guide perceptual learning to support balanced sensory-perceptual regard for the self-environment interface. To this end, the curriculum's structured sequencing of kinesthetic learning and thinking will elevate kinesthetic-visual sense perception to a conscious level of awareness. The curriculum would help develop conscious

awareness, leveraging it like an aqueduct that siphons the sensory modalities (i.e., kinesthetic, tactile, visual, auditory, and vestibular) into a balanced perceptual whole. These perceptual learning processes will enhance the learner's perceptual acuity and reciprocally support mechanical balance in coordinating movement patterns. Moreover, the sequences of kinesthetic learning will be embedded in content knowledge that invites inquiry into the structure and function of the emplaced body-self. Thus, cognitive development and content knowledge would be firmly and intentionally tethered to kinesthetic learning and perceptual-motor skill acquisition.

Psychophysical Education is a model of early learning that seamlessly interweaves the study of the body-self into all aspects of the general ECE curriculum. To this end, structured inquiry of the body-self in action and the development of kinesthetic fluency would be the starting point of curricular explorations into early mathematics, science, language development, and early literacy (Figure 7.1). The overarching objective of the curriculum is to scaffold the development of a kinesthetic fluency that supports adaptive learning and development across all ECE domains. Therefore, Psychophysical Education positions the embodied self as the nexus of curricular exploration. The development of a kinesthetic fluency imbued with conceptual knowledge of the body-self is at the center of early learning and development.

It must be emphasized that Psychophysical Education is not a program or service embedded in the ECE curriculum. Nor is it a Complementary and Alternative Medicine (CAM) method or therapeutic treatment provided to children determined eligible by medical disability criteria. Instead, Psychophysical Education is an inclusive model that addresses the holistic development of *all* children regardless of ability or disability status. The Psychophysical Education method structures individualized perceptual-motor learning sequences that optimize the alignment of the environment-organism system. In other words, the curriculum aims to

develop children's "adaptive capacity" by optimizing their coordination and regulation of the force-generating relationships that cohere as neuromotor patterns of voluntary action (Buscemi et al., 2021). Thus, Psychophysical Education is a holistic method of "learning to learn" that teaches developing learners to exercise true agency in the construction and care of their *unique* body-selves. Moreover, Psychophysical Education can provide a common focus to integrate the developmental domains into classroom practice. For these reasons, Psychophysical Education is facilitated by classroom teachers rather than specialized health interventionists like occupational or physical therapists.

It must be admitted that the ideas presented in this dissertation are not altogether new; they have been considered at various times throughout the history of Education. For example, the Italian physician and educator, Maria Montessori (1870-1952), discussed the importance of directing the field of Education towards a more holistic conception of the developing child in *The Absorbent Mind* (1949):

There is a self-determination of the brain apart from movement and muscles. This is not independence; it is to break something that nature in her wisdom has put together. If mental development is spoken of, people say: "Movement! There is no need for movement; we are talking about mental growth!" When they think of mental improvement they imagine all are sitting down, moving nothing. But mental development must be connected with movement and is dependent on it. This is the new idea that must enter educational theory and practice. (...) Our new conception stresses the importance of movement as a help to the development of the brain, once it is placed in relation to the centre. Mental development and even spiritual development can and must be helped by movement. Without movement there is no progress and no health (mentally speaking). This is a fundamental fact which must be taken into consideration. (p. 203)

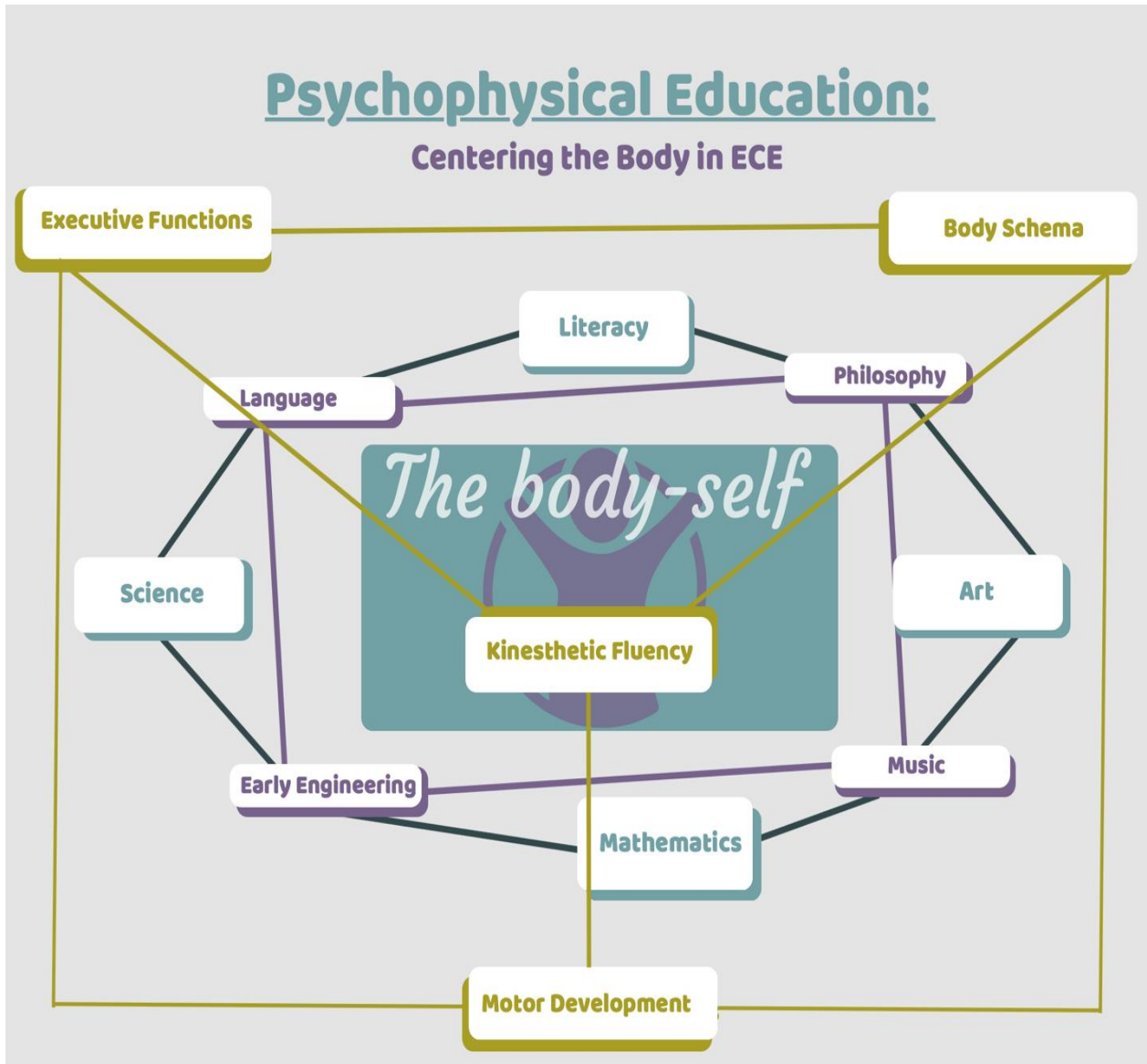
As Montessori poignantly articulated, the fundamental unity of perceptual-motor and cognitive functions implies their interdependence across developmental process. Thus, although not the focus of this dissertation, the project of centering the body-self in curriculum and learning may also promote aesthetic capacities that bestow social, creative, and ethical advantages on the

developing child. It is possible that the “adaptive capacity” of the complex self-moving organism is not limited to postural control, as suggested by Buscemi et al.’s (2021) definition of the term. Perhaps the organism’s “adaptive capacity” extends to behaviors and skills traditionally associated with the cognitive, psychosocial, and aesthetic domains. It may be that the ability to regulate the body-self consciously by means of a learned kinesthetic fluency is broadly associated with optimized learning and developmental outcomes.

The remainder of this chapter presents a sketch of the Psychophysical Education curriculum. I plan to develop this curriculum in collaboration with educators, children, and families throughout my career. Many of the preliminary ideas presented herein emerged through my teaching practice as an early childhood educator in New York City prior to the COVID-19 global pandemic. Although many of the curricular elements remain undeveloped, I aim to demonstrate how Psychophysical Education intentionally positions the perceiving-and-moving child at the center of learning and skill acquisition. Moreover, I hope to impress upon my reader the potential of Psychophysical Education to serve as a curricular infrastructure that undergirds and integrates the developmental domains (i.e., sensorimotor, cognitive, social-emotional, language) in ECE classroom practice. Consequently, Psychophysical Education provides a developmental infrastructure that helps integrate perceptual-motor and cognitive capacities in the young learner. Finally, this curricular outline will demonstrate how awareness of and care for the body-self can be the point of departure for conceptual learning and skill acquisition.

Figure 7.1

Psychophysical Education: Centering the Body in ECE



Note. Psychophysical Education positions the embodied self as the nexus of curricular exploration. The development of kinesthetic fluency to guide motor learning processes is at the center of early learning and development.

Curricular Outline

Psychophysical Education uses music and song to develop kinesthetic fluency in early childhood intentionally. Most young children have an affinity for music and song. The rhythmic, melodic, and linguistic structures capture their attention and imagination, offering a wellspring of stimuli to promote learning and development. Moreover, the song structure emulates the fluency and syntactical structure of thought and speech. Thus, songs externalize the rhythmic and syntactical properties of thought into a repeatable structure that encourages social engagement and play. For these reasons, music culture is a prominent feature of most early childhood classrooms, and songs are often used to promote early language, literacy, social-emotional, and conceptual learning. In my former ECE worksite, the teachers used song to orient children to the structure of the school day and support them through transitions. I always marveled at how the children immediately stopped their activity to listen and participate in the transitional songs. The songs called to them, and the children were instinctively receptive to their implicit invitation.

Psychophysical Education leverages children's musical instincts to generate a stream of kinesthetic awareness that supports self-regulatory and learning processes. Music is the language of kinesthetic fluency in early childhood and scaffolds its development. I created the "Check-In Song" to help the children in my classroom transition to "meeting time." Table 7.1 outlines the linguistic and action structure of the "Check-In Song." I routinely led the children through the "Check-In Song" structure at the beginning of every meeting I facilitated. I would sometimes lead the children in a brief reprise of the "Check-In Song" if I observed the concurrent signs of disengagement and musculoskeletal collapse as "meeting time" progressed. At other times, I might call the children back to their body-selves using verbal cues, "Let's check-in. Are your heads going up to the ceiling? Tap, tap, tap. Are your shoulders wide and going away from each

Table 7.1*Lyrics and Action of the “Check-In Song”*

Lyrics	Action
My head is going up	
Tap, Tap, Tap	Gently tap the head with palm of the open hand in tempo with the words.
Up to the ceiling	Point to the ceiling with pointer finger
Tap, Tap, Tap	Gently tap the head with palm of the hand in tempo with the words.
My shoulders are wide	Place the fingers of each hand on one of the shoulders (middle finger of each hand making contact with acromion process) with thumbs extended towards the back of the shoulder (proximal shaft of the humerus). The arms will be flexed at the elbows. The structure of the shoulders, arms, hands, and fingers will collectively create the form of a “chicken wing.”
Tap, Tap, Tap	Maintain general positioning of fingers and hands to tap the shoulders in tempo with the words.
They go away from each other	Point the thumb of each hand away from the shoulders while maintaining flexion of the in the “chicken wing” position.
Tap, Tap, Tap	Tap the shoulders in tempo with the words in the “chicken wing” position.
My bottom is on the floor Variation: My feet are on the floor	
Clap, Clap, Clap	Clap hands in tempo with the words. Over time: Encourage the children to see if they can clap their hands while still asking the shoulders to “go away from each other.”

Table 7.1 (continued)

Lyrics	Action
And my back is long and wide	<p>Bring the fingers of both hands together and pull them away from each other vertically on the word “long.”</p> <p>Bring the fingers of both hands together and pull them away from each other horizontally on the word “wide.”</p> <p>Over time: Encourage the children to see if they can perform these finger-hand-arm gestures while still asking the shoulders to go away from each other.</p>
<p>Because my... Head is going up [Repeat song]</p>	
<p>Second Verse Variation</p> <p>Depending on the context, the teacher may want to change the last phrase of the second verse (“and my back is long and wide”) to:</p> <p>And now I’m ready to listen and learn</p>	

other? Tap, tap, tap. Are your backs long and wide?” Most of the children would accept the invitation to reengage by observing their musculoskeletal coordination relative to the coordination parameters implicit in the lyrics. Many of them would allow the linguistically structured coordination parameters to guide behavioral change.

The children were enthusiastic about the “Check-In Song,” and it seemed to instill a sense of comfort and reassurance at a demanding moment of transition from free-play to teacher-directed learning. Even the children who were not inclined to engage in songs and activities during “meeting” eventually participated in the simple movements of the “Check-In Song.” Furthermore, children who tended to lie down on the rug or sit in an otherwise disengaged and collapsed manner would “sit with their bottoms on the floor and their heads going up the ceiling” for the duration of the song. I never had the opportunity to integrate the “Check-In Song” into the broader curriculum at my worksite. Additionally, I was the only teacher who sang the “Check-In Song,” so there was inconsistency in its use as a transitional tool for teacher-led meetings. I wonder if interweaving kinesthetic fluency more comprehensively would have led to more sustained behavioral changes in those children.

One child, Veronica, began using the “Check-In Song” to self-regulate during the meetings led by other teachers. She would mouth the words and perform the movements quietly (tapping her head and shoulders) at her “special spot” on the rug. She would do this for the approximate duration of one verse at various times throughout the “meeting.” This self-directed behavior demonstrated that Veronica internalized the “Check-In Song” and employed it as a self-regulation tool when experiencing the demands of sustained sitting during “meeting time.” Thus, the “Check-In Song” scaffolded a kinesthetic fluency that functioned as a vital self-regulation skill (Becker et al., 2014). Veronica could quietly perform the actions of the “Check-

In Song” from her seat before redirecting her attention to the teacher-directed instruction. The song empowered Veronica to practice self-care, potentially leading to increased classroom instruction engagement.

A physical artifact from my teaching practice further suggests that song structures support children to self-regulate and promote learning. Another child, Meredith, was asked by her mother to share something she appreciated about each teacher. Meredith responded, “Tara’s songs help me listen,” when asked to share something she appreciated about Teacher Tara. Meredith’s mother helped integrate her statement into a multimedia artwork, which Meredith presented to me as a holiday gift (Figure 7.2).

Figure 7.2

Teaching Artifact



I do not know if this statement was inspired by the “Check-In Song,” “The Body Thinking Song” (see Table 7.2), or my singing more generally. Nonetheless, I value this artifact as a child’s endorsement of music and song as a vehicle for learning and development.

The children’s receptiveness to the “Check-In Song” inspired me to develop the “Body Thinking Song” (Table 7.2). The “Body Thinking Song” song repurposes the melodic structure of the children’s classic “Open, Shut Them” to invite sustained attention to kinesthetic referents. The linguistic structure of the “Body Thinking Song” evokes the coordination parameters for an adaptively lengthened musculoskeletal configuration. However, the song presupposes knowledge of basic musculoskeletal anatomy. Therefore, the teachers should introduce children to the song’s conceptual language using the “Head, Shoulders, Knees, and Toes” song, age-appropriate human anatomy or body-focused children’s books, age-appropriate anatomy puzzles, anatomy-focused art investigations, and other learning activities. The children’s ability to construct meaning from the song’s anatomical references is a prerequisite for the song’s application to their sensing-and-moving body-self. Thus, the acquisition of kinesthetic fluency is connected to and dependent on conceptual knowledge of functional musculoskeletal anatomy.

Table 7.2

“The Body Thinking Song”

Verse 1	Verse 2
Feet and knees Knees and feet Muscles lengthen in between those points Knees and hips Hips and knees Muscles lengthen in between Hips and head Head and hips My bum drops and my head goes up Shoulder, shoulder, shoulder, shoulder My shoulders go away from each other	Knees and feet Feet and knees Muscles lengthen in between those points Hips and knees Knees and hips Muscles lengthen in between Head and hips Hips and head My bum drops and my head goes up Shoulder, shoulder, shoulder, shoulder My shoulders go away from each other

Note. The “Body Thinking Song” is appropriate for Pre-K through 3rd Grade. The tune is the classic children’s song “Open, Shut Them.” The older children would begin exploring the song using more demanding game structures.

The “Body Thinking Song” can be explored in different ways to vary the magnitude of cognitive demand. Very young children and older children in the early stages of learning the song should repeat two cycles of Verse 1. Teachers can introduce the second verse as the children become comfortable with the first verse. Altering the order of body parts across verses increases cognitive demand and prevents the song from becoming so repetitive as to become a meaningless litany. When adding the second verse, children (and teachers) need to remain attentive to the song structure to sing the correct words. Teachers should slow down the second verse and treat the inversion of body parts as a game that challenges memory, selective attention, and processing speed.

As the children become more skilled in singing one or both verses, teachers might explore layering other game structures onto the “Body Thinking Song.” The “Slow, Fast, Normal Game,” adapted from a children’s game developed by Viola Spolin (1986), invites the children to explore singing the song in a range of tempos, i.e., slow, fast, normal. Children will delight in exploring the range of tempos, becoming particularly excited by the fast tempos. Tempo rhythm is also a mathematical and musical concept that can be introduced in the context of this activity. Teachers might introduce a metronome (mechanical preferred over digital) to support the children’s experimentation with tempo and frame a focused discussion around the complementary concepts of time and rhythm. Children can also be invited to question how the kinesthetic sense of their body changes as they explore the song at different tempos. Teachers may want to introduce the game by isolating a short phrase of the first verse. Please note it would probably be far too demanding to play this game with the whole song (first and second verse) from start to finish.

The “Think the Song” game invites children to sing the first verse of the song out loud and then think the words of the second verse (or the second cycle of Verse 1). Teachers should scaffold this game by first asking the children to sing a phrase and think the subsequent phrase without singing. This game challenges children to internalize language and practice inhibitory control. Emphasis should be placed on “hearing” the song in one’s mind while thinking about the body parts referenced in the song. Teachers are also encouraged to play this game with the “Check-In Song.” In the case of the “Check-In Song,” children can be invited to sing and perform the accompanying actions for the first verse, and then only perform the actions without vocalization for the second verse. Children who find it challenging to stop singing the second verse can be encouraged to whisper or mouth the words without vocalizing. In general, teachers should be creative with scaffolding the games to support the participation of diverse learners in their classrooms.

The “Check-In Song” and the “Body Thinking Song” integrate the intentional development of kinesthetic fluency with literacy and language development. The coordination of spatial directives in the songs requires knowledge of basic spatial, mathematical, and anatomical concepts. Instead of teaching the spatial and relational concepts “up,” “down,” “away,” “wide,” and “lengthen” using external objects, these concepts can be learned using the body-self as the primary reference. As with the anatomical concepts, teachers should introduce children to the meaning of these spatial and relational concepts to support their active engagement with the song structures. The songs are an important curricular element that ground higher-order concepts and ideas in the child’s most immediate vehicle of being and becoming: their sensing-and-moving body-self.

Song structures such as the “Check-In Song” and the “Body Thinking Song” will fluidly interweave the Psychophysical Education curriculum. They will serve as reliable anchor points, grounding the interdisciplinary content knowledge in kinesthetic fluency and the corollary development of self-knowledge. As previously discussed, Psychophysical Education invites children to wonder and inquire about their unique body-selves. This guided wonder and inquiry is a launch pad for interdisciplinary curricular explorations in early mathematics, science, language development, and literacy.

This chapter concludes with two tables presenting the outlines for two curricular modules that exemplify the Psychophysical Education paradigm: Table 7.3, Early Mathematics and Engineering Module, and Table 7.4, Science. Each module is broken down into a Knowing Unit and a Practicing Unit, honoring Pragmatism’s commitment to integrating theoretical knowledge and practical experience. These units could be sequential or synchronous, depending on the ECE classroom routines, children’s capacities, and teacher preferences. The curricula can be adapted to different developmental stages and differentiated based on individual children’s emergent capacities. These modules have not yet been implemented, and they need to be fleshed out through curricular experimentation with children at various stages of development. Therefore, these tables are merely a skeletal framework, and I invite my readers to project their creativity and visions of the ECE classroom onto the as-yet meager scaffolding.

Table 7.3

Psychophysical Education: Early Mathematics and Engineering Module

<p>Early Mathematics and Engineering</p> <p><i>The curriculum can be adapted to address the abilities, skills, and interests of children from Pre-K through 3rd Grade.</i></p>	
Knowing Unit Title	From Bridges to Bodies: Early Engineering for Children
Knowing Unit Description	<p>The study of bridges and modes of transportation is popular throughout early childhood. Yet, surprisingly, this inquiry has overlooked the primary vehicle we use to traverse our environment: the upright vertebrate body. The curricular sequencing of <i>From Bridges to Bodies</i> will guide children from studying a local bridge used to facilitate transportation to studying their body-selves, or their most fundamental vehicle of transportation. <i>From Bridges to Bodies</i> explores foundational engineering concepts and principles by examining their applications to the designs of both human-made bridges and the biodynamic body-self. Children will explore connections between design principles of man-made structures like bridges and the natural structures of the vertebrate body.</p>
Practicing Unit Title	The Study of “Me”: Anatomy and Movement Awareness for Children
Practicing Unit Description	<p>In this unit, children will complete “body studies” to explore the integration of kinesthetic fluencies with their fundamental psychomotor skills. <i>The Study of “Me”</i> will build on the learning experiences and stores of knowledge acquired in <i>From Bridges to Bodies</i>. This unit will elevate the body-self, the moving-and-sensing structure the children conceptualize as “me,” as a primary source of curiosity and wonder. Children will apply early engineering principles and methods of analysis to investigate the anatomical structure and function of the body-self. Children will analyze how the parts are assembled to produce functional outcomes in environmental contexts. <i>The Study of “Me”</i> formally centers the body-self as a foundational object of study in ECE.</p>

Table 7.3 (continued)

Knowing Unit Title	From Bridges to Bodies: Early Engineering for Children
<p>Student Learning Outcomes for 2nd Grade (Knowing & Practicing)</p>	<ol style="list-style-type: none"> 1. Sings developmentally appropriate variations of the “Body Thinking Song” independently and in community with teachers, peers, and loved ones. 2. Identifies parts of the human body on a model skeleton, their own body, and the bodies of others (head, neck, back/trunk, hips, legs, knees, ankles, feet), and explains basic principles of their organization in the coordination of movement (i.e., “the head goes away from the hips, so the back gets longer”). 3. Describes the properties of musculoskeletal biomaterials, including muscles and bones, and describes how they work cooperatively to produce movement. 4. Applies knowledge of spatial prepositions, concepts of measurement, anatomical and basic biomechanical concepts to exploration and analysis of the body-self performing fundamental psychomotor tasks, including sitting, standing, walking, and grasping. 5. Uses developmentally appropriate language to describe how parts of the body are organized in the coordination of fundamental psychomotor tasks, including sitting, standing, walking, and grasping. 6. Identifies and describes the properties of geometric shapes and engineering that can be found as structural elements of the human body (i.e., sphere, semicircle, hemisphere, or arch, curved line, cylinder, triangle, rhombus, and other polygons). 7. Applies knowledge of shapes and anatomical structures to create visual representations of the body-self with increasing accuracy and detail.

Table 7.4

Psychophysical Education: Science Module

<i>Science</i>	
<i>The curriculum can be adapted to address the abilities, skills, and interests of children from Pre-K through 3rd Grade.</i>	
Knowing Unit Title	What Can a Body Do? A Comparative Study of Vertebrate Bodies
Knowing Unit Description	<p>Why do birds fly? Why do cats, dogs, and horses walk on four limbs instead of two? Why do most humans learn to stand upright and move on two limbs when walking from one place to another? This class invites children to wonder and think critically about the body designs of different animal species. Inquiry-based learning cycles will guide children to discover the integral relationship between form and function in biological organisms. On the path to discovery, children will learn to apply the scientific methods of Ethology! Teachers will structure a series of guided observations to examine how different species move and perform motor acts in their environments. Each of these observational studies will culminate in a teacher-guided, child-centered conversation and the development of a KWL (Know, Wonder, Learn) Chart. As a community of “ethologists,” the children will vote on three “research questions” from their KWL Chart, which will guide the curricular scope of the class.</p> <p>To address their questions, the “ethologists” will embark on a focused exploration of comparative musculoskeletal anatomy. Children will examine “body artifacts” through sensory and tactile exploration of musculoskeletal structures (model), bones (real, model, and/or 3D printed), feathers, and other relevant and age-appropriate materials. These explorations will facilitate individual and group investigations of the physical properties (shape, size, weight, texture, etc.) of materials in biology, called “biomaterials.” Moreover, this inquiry-based investigation of body parts will always be linked to a play-based exploration of how parts are integrated into a functional whole. Thus, child-directed early engineering activities will support practical exploration of how materials with different physical properties can be assembled to produce functional outcomes.</p> <p>The sequencing of activities and focused discussions will guide children to answer their research questions from the KWL Chart. Moreover, this course and its concurrent practice-based module, <i>A Sensorimotor Journey Through Vertebrate Evolution</i>, will guide children to the understanding that functional outcomes are built into the bodies of animals through evolutionary processes of adaptation.</p>

Table 7.4 (continued)

Knowing Unit Title	What Can a Body Do? A Comparative Study of Vertebrate Bodies
<p style="text-align: center;">Knowing Unit Student Learning Outcomes</p>	<p><i>The learning outcomes will be the same for children Pre-K through 3rd Grade with expected age-appropriate differences in the anatomical detail explored, as well as the vocabulary used to frame the anatomical exploration.</i></p> <ol style="list-style-type: none"> 1. Observes and communicates similarities and differences in the motor behavior and environmental contexts of different species. 2. Makes connections and recognizes some of the structural similarities between the composite structures and component parts of different vertebrate bodies with respect to the shape, size, volume (weight), spatial orientation, and/or numeracy (<i>e.g., Birds, dogs, humans, and whales can move because their bodies are all made of bone and muscle. Birds, dogs, humans, and whales all have spines (backbone), which are made of up of bones called vertebrae. The necks of humans, whales, and dogs are made up of seven vertebrae bones. The bodies of whales and dogs are horizontal.</i>). 3. Observes and recognizes some of the structural differences between the composite structures and component parts of different vertebrate bodies with respect to the shape, size, volume (weight), spatial orientation, and/or numeracy (<i>e.g., Human spines are vertical and dog spines are horizontal. Humans have smaller vertebrae than whales. Humans have seven vertebrae in their neck and owls have 14 vertebrae. Bird bones are lighter than human, dog, and whale bones because they are hollow.</i>). 4. Uses basic anatomical vocabulary words when communicating the observed similarities and differences of vertebrate bodies to peers and teachers 5. Asks questions, makes observations, and gathers information about the structure and function of vertebrate bodies; and develops hypotheses about how an animal's behavior is supported (and limited) by its anatomical structure (<i>e.g., Most birds can fly because their bones are hollow and light. Humans cannot fly because our bones are more solid and heavier than bird bones. Most humans can walk on two legs because their spines or backbones are vertical.</i>).

Table 7.4 (continued)

<p>Practicing Unit Title</p>	<p>A Sensorimotor Journey Through Vertebrate Evolution</p>
<p>Practicing Unit Description</p>	<p>Children will embark on a journey through vertebrate evolution using the book <i>Grandmother Fish: A Child’s First Book of Evolution</i> as a literary guide (Tweet & Lewis, 2016). Children will complete “body studies” for each vertebrate body plan addressed in <i>Grandmother Fish</i>: fish, reptile, quadruped mammal, ape, and human. Body studies will consist of more focused literary investigation and sensorimotor explorations of developmental postures associated with these body plans. Each “body study” unit will culminate in a sequence of structured, multimedia art activities. The art activities will invite children to create both a visual representation of the “animal body” they explored and a visual representation of their human body-self. The study of the human body-self will be the standard of reference through which children analyze and creatively explore other vertebrate body plans and their capacities for self-directed movement. A song-based kinesthetic thinking practice will serve as a routine “warm-up” that prepares children to “transform” into their “animal bodies” for the developmental movement sequence. Teachers will then apply the principles inherent to these songs to guide the developmental movement exploration. The joint development of kinesthetic fluencies and body schema will be the focus of this curriculum. The art activities will produce artifacts that may track the child’s development of body schema as they progress through each body study.</p>
<p>Practicing Unit Student Learning Outcomes</p>	<p><i>The learning outcomes will be the same for children Pre-K through 3rd Grade with expected age-appropriate differences in the anatomical detail explored, as well as the vocabulary used to frame the anatomical exploration.</i></p> <ol style="list-style-type: none"> 1. Identifies and communicates the characteristics of vertebrate animals and describes elements of vertebrate evolution in developmentally appropriate terms. 2. Sings developmentally appropriate variations of the “Body Thinking Song” independently and in community with teachers, peers, and loved ones. 3. Identifies parts of the human body (head, neck, back/trunk, hips, legs, knees, ankles, feet), and explains basic principles of their organization in the coordination of movement (i.e., “the head goes away from the hips, so the back gets longer”).

Table 7. (continued)

Practicing Unit Title	A Sensorimotor Journey Through Vertebrate Evolution
Practicing Unit Student Learning Outcomes	<ol style="list-style-type: none"> 4. Applies knowledge of spatial prepositions and concepts of measurement to the study of the body-self in different developmental postures. 5. Creates visual representations of the body-self and other vertebrate bodies, which reflect practical knowledge of vertebrate body plans, including the body-self.
Knowing & Practicing Culminating Project	<p>Children will apply their knowledge of vertebrate body plans to design a new vertebrate! First, children will identify the behavioral profile of their vertebrate by answering the following questions through written composition, drawing, collage, and/or speech-based interaction. This part of the assignment will be with the support of a teacher.</p> <ol style="list-style-type: none"> 1. Where does your vertebrate live? 2. How does your animal move from place to place? Does it have joints, muscles, bones, or does this system use different biomaterials to produce movement? 3. What does your animal eat, and how does it find food? 4. Can your animal see, hear, smell, feel through touch, and/or feel the body-self through joints and muscles? Does your animal have other types of sensory systems that help it perceive and act in its environment? <p>Then, children will identify the structural elements that will best support the adaptation of this animal to its habitat. They will create drawings of their vertebrates (or collages of pre-cut shapes/parts for younger children) and will explain how the different parts support adaptation or survival within the environment.</p>

Conclusion

In the final weeks of writing this dissertation, I was painfully aware of the progressive deformation of my neck-head-trunk relationship in response to the perceived demands and pressures of production. I know the neuromuscular-skeletal coordination pattern well: My neck muscles stiffen, becoming rigid and thick cables that elevate my shoulders and pull them forward into a protracted state. The thorax becomes inflexible as it is elevated and retracted with the costal arch splayed open. My breathing becomes more labored because the restricted mobility of the rib cage restrains the cyclic flow of air. My spinal curves become exaggerated, and all the joints of my body stiffen. This sequence of becoming is a developmental process that occurs over a short time scale to induce morphological transformation. I assume a deviated and mechanically strained physical form, which is a living artifact of maladaptive and miseducational learning processes. This coordination pattern defined my system's intrinsic dynamics for much of my childhood and adolescence. It is not long before the chronic pain sets in, which is a state of being that I had archived as a distant memory—until recently.

As an adult learner in Ted Dimon's school, The Dimon Institute, I was guided through structured sequences of adaptive psychomotor learning. The Dimon Institute afforded me 3 years to explore a developmental process guided by a new kinesthetic fluency that harnessed the coordinative function of thought. Regrettably, I have not had the time to commit to the disciplined practice required to address my psychomotor maladaptation as an adult learner. As discussed, the transition to adaptive psychomotor learning is formidably challenging after the pattern-making system has learned to metabolize the fuel of maladaptive learning. Environmental stress experienced by the adult learner inhibits the coordinative function of

kinesthetic thinking. As if perceiving an environmental threat, the neuromuscular-skeletal system shifts into its most stable coordination patterns to automate the generation of self-sustaining acts. The system reinstates the preferred afferent-efferent pathway to guide psychomotor function, which short-circuits the stream of self-directed kinesthetic thought.

Like learning a second language, Psychophysical Re-Education requires an immersive experience and disciplined daily practice. In many ways, Psychophysical Re-Education must be assimilated as a lived practice to achieve its two-tiered learning objectives: (B) The learner will reverse the progressive deformation of neuromuscular-skeletal structures to reintroduce flexibility and buoyancy into the system dynamics, and (A) The learner will intentionally reconstruct her task-specific coordination patterns to prevent the periodic cycles of applied stress that had culminated in progressive deformation in the first place. Dimon (2021) referred to these learning objectives as the “A Problem” and the “B Problem” of psychomotor maladaptation. The nonsequential listing of B and A in framing the learning objectives is a deliberate pedagogical tool.

In Dimon’s pedagogical framework, the *A Problem* of reconstructing task-specific coordination patterns is always the primary learning objective. As discussed in Chapter 4, Alexander identified the final cause as the most effective point of entry to disarm his maladaptively learned coordination pattern. Accordingly, the *A Problem*, or the restructuring of perceived action goals to facilitate sustainable behavioral change, is the gold standard of Psychophysical Re-Education. However, in Re-Educational contexts, the *B Problem* is required to destabilize maladaptively learned coordination patterns and reintroduce flexibility into the system dynamics. Thus, the *B Problem* arises from maladaptive learning processes that culminated in the excessive stability of deviated movement coordination patterns. In

Psychophysical Educational contexts, the *B Problem* is circumvented because the learning of fundamental motor skills is still in process during a critical period of psychomotor development.

As discussed, early childhood is a critical period for the assembly and stabilization of neuromotor patterns that will come to define the coordination dynamics of the developing system. The purpose of Psychophysical Education is to guide adaptive learning to support the stabilization of movement coordination patterns that (1) accomplish action goals in the here-and-now, and (2) support the health of the changing neuromuscular-skeletal system across its lifetime. The circulation of self-directed kinesthetic thoughts as the basis for goal-directed action helps to prevent the excessive stability of movement coordination patterns, regulating an adaptive state of flexibility in the system dynamics. The development of kinesthetic thinking as a self-regulatory skill constitutes a fluency that continuously orients the learner to action affordances in the here-and-now. In this way, the young learner assembles movement coordination patterns that maintain and leverage the geometric shapes and dynamic partnerships inherent in the biotensegral anti-gravity system.

The early childhood classroom is a site of novelty and wonder where children encounter new contexts to explore their developing repertoire of abilities and skills. They are constantly challenged to scale relatively stable coordination patterns to new environment and task constraints while adapting to the continuously shifting parameters of their maturing bodies (Adolph & Franchak, 2017; Adolph & Hoch, 2019; Bornstein & Lamb, 2015). Teachers and caregivers typically view the emergence and stability of new competencies as evidence of a child's adaptive learning and development. They rarely consider the qualitative properties of the task-relevant movement patterns the child uses to achieve the goal(s) of a given competency. In other words, the 4-year-old child's ability to write her name with a pencil is considered a

fine-motor and graphomotor milestone, but the child's postural alignment in the context of this task is not typically evaluated as a measure of proficiency. As a consequence, children may learn to coordinate actions with maladaptive postural deviations that promote musculoskeletal pathophysiology over time.

This dissertation introduced the problem of psychomotor adaptation to reform how motor learning and control are viewed and assessed in the early childhood classroom. I have argued that the absence of a robust model of adaptive psychomotor learning in ECE inadvertently supports the learning of deviated and mechanically disadvantageous movement coordination patterns. The establishment of a positive model of psychomotor health in early childhood can prevent the learning and stabilization of postural deviations associated with adverse health outcomes in adulthood. The implementation of this model would require the establishment of systems and practices to help educators evaluate the qualitative movement properties of fundamental motor skills as they arise in various classroom contexts. To this end, I hope to test the reliability of the Postural Deviation Rating Scale (PDRS) introduced in Chapter 2. The development of an accessible assessment tool to identify postural deviations would support the holistic evaluation of adaptive psychomotor learning in ECE settings.

Additionally, the ECE curriculum should be structured to centralize the body-self in learning activities across domains. The child's ability to coordinate mechanically balanced and posturally aligned movement patterns in response to environment and task constraints should be a fundamental learning outcome in ECE. To this end, next steps include implementation and further development of the curricular elements outlined in Chapter 7. The centering of the body in ECE can help prevent some of the chronic musculoskeletal pain conditions that plague learners like me. To evoke the words of F. M. Alexander: I wish to do away with *adult learners*

as I am myself. My place in the present economy is due to a misunderstanding *of the causes of chronic idiopathic neuromuscular-skeletal disorders*. Psychophysical Re-Education will have no place when maladaptation's four causes are dismantled through the standardization of adaptive learning processes in the early childhood classroom. "This may be a dream of the future, but in its beginnings it is now capable of realization" (Alexander, 1996, p. xxii).

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