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Melissa A. Carroll
DeSales University

Alison McKenzie
Chapman University, amckenzi@chapman.edu

Mary Tracy-Bee
University of Detroit Mercy

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DR. MELISSA A CARROLL (Orcid ID : 0000-0003-0701-8572)

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Movement System Theory and Anatomical Competence: Threshold Concepts for Physical Therapist Anatomy Education

Melissa A. Carroll[1], Alison McKenzie[2,3], Mary Tracy-Bee[4,5]

[1]Division of Healthcare Professions, Doctor of Physical Therapy Program, DeSales University, Center Valley, Pennsylvania
[2]Department of Physical Therapy, Chapman University, Irvine, California
[3]Department of Neurology, University of California, Irvine, California
[4]Department of Biology, University of Detroit Mercy, Detroit, Michigan
[5]Department of Movement Science, Physical Therapy Program, Oakland University, Rochester, Michigan

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Correspondence to: Dr. Melissa A. Carroll, Division of Healthcare Professions, Doctor of Physical Therapy Program, DeSales University, 2755 Station Avenue, Center Valley, PA 18034-9568, USA. E-mail: macarroll@gwu.edu

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ABSTRACT
This viewpoint proposes eight anatomy threshold concepts related to physical therapist education, considering both movement system theory and anatomical competence. Movement system theory provides classifications and terminology that succinctly identifies and describes physical therapy practice from a theoretical and philosophical framework. The cardiovascular, pulmonary, endocrine, integumentary, nervous, and musculoskeletal systems are all included within this schema as the movement system theory encompasses all body systems interacting to create movement across the lifespan. Implementing movement system theory requires an ability to use human anatomy in physical therapist education and practice. Understanding the human body is a mandatory prerequisite for effective diagnosis, assessment, treatment, and patient evaluation. Anatomical competence refers to the ability to apply anatomic knowledge within the appropriate professional and clinical contexts. Exploring the required anatomical concepts for competent entry-level physical therapist education and clinical practice is warranted. The recommended threshold concepts (fluency, dimensionality, adaptability, connectivity, complexity, stability or homeostasis, progression or development, and humanity) could serve as an integral and long-awaited tool for guiding anatomy educators in physical therapy education.

Keywords: Gross anatomy education, physical therapist education, movement system theory, health professions education, threshold concepts, anatomical competence, curriculum recommendations.

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INTRODUCTION

A need exists to develop threshold concepts that outline and recommend anatomic content in physical therapist education (PTE). Threshold concepts challenge and transform a learner's thought pattern as they progress to professional use and mastery of the educational material (Meyer and Land 2003; Jensen, 2011; Land and Meyer 2011; Land et al., 2016; Barradell, 2017; Barradell and Peseta, 2017, 2018). Anatomy educators in PTE programs should strive to examine, review, and reach consensus concerning relevant, foundational anatomic content. To do so, one must first consider how physical therapists integrate anatomy into practice and how the profession defines its role in healthcare. As the movement system defines the identity of physical therapy practice (APTA, 2015), the movement system theory must be part of the foundation for anatomy threshold concepts. This viewpoint discusses anatomic content for effective physical therapy practice, first within the movement system theory framework and second within achieving anatomical competence.

Movement System Theory

In 2013, the House of Delegates of the American Physical Therapy Association (APTA) adopted the movement system as an integral part of a physical therapist's professional identity (Hunter et al., 2015; Saladin and Voight, 2017; APTA, 2019; Sebelski et al., 2020). Defined as a group of body systems, namely the cardiovascular, pulmonary, endocrine, integumentary, nervous, and musculoskeletal, the movement system is foundational for PTE, research, and practice (APTA, 2015; Hunter et al., 2015; Sahrmann, 2017; Saladin and Voight, 2017). Movement system theory (MST) stems from the Tenth Mary McMillan Lecture in 1975. Helen Hislop, former Chair of the Division of Biokinesiology and Physical Therapy at the University of Southern California, stated that *"physical therapy [had] a soft belly because its science [was] in disarray"* and recommended that "pathokinesiology" was the most important scientific identity for the physical therapist (Hislop, 1975; Sahrmann, 1998; Van Sant, 2017). Evolving from this concept of pathokinesiology, MST succinctly identifies and describes the theoretical and philosophical framework of physical therapy

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practice – incorporating a holistic view of the human body with movement as it pertains to wellness and indications of disease (Cott et al., 1995; Ludewig et al., 2013; Sebelski et al., 2020).

All diagnostic areas of physical therapy practice can be described as a movement system dysfunction, from a macroscopic congenital or acquired dysfunction to a cellular level of abnormal blood flow. Movement dysfunction can occur as a result of metabolic dysfunction and dysregulation of the cardiopulmonary circuits, myopathy due to endocrine disorders, atypical neurodevelopment or neurological pathologies, musculoskeletal diseases, scarring and tissue deformation, in addition to a myriad of interrelated systemic changes (Hislop, 1975; Cott et al., 1995; Peel, 1996; Shields, 2017). The movement system provides a comparison for any abnormal structural variations or dysfunction through understanding foundational sciences such as anatomy, kinesiology, biomechanics, physiology, histology, neurology, and other related biological sciences (Hislop, 1975; Rose, 1986; Sahrmann, 1998, 2014, 2017; Sahrmann et al., 2017; Van Sant, 2017). Knowledge of these biological sciences help to distinguish between "normal" human structure and function, structural variation, including congenital or developmental anomalies, and acquired dysfunction, adaptations, or pathologic structural changes. Using MST in physical therapy practice should provide clinicians with a comprehensive approach that integrates all factors related to movement dysfunction into the International Classification of Disability and Function (ICF) domains of impairments and limitations in body structure or function, activities, and participation (Cott et al., 1995; Hendricks et al., 2000; WHO, 2001; Wade and Halligan, 2003; Ludewig et al., 2013; APTA, 2015; Ludewig 2017). There are, however, some competing ideologies to the MST, mainly because the body is more than just a biological entity; social and cultural contexts influence perceptions of the body as well (Cott et al., 1995; Hendriks et al., 2000; Nicholls and Gibson, 2010; Barradell, 2017). Some stakeholders have concerns that the movement system downplays the complex continuum of movement, which includes psychosocial constructs of movement dysfunction (such as fear of movement), environmental factors, and societal norms (Cott et al., 1995; Allen 2007a;

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Cott and Finch, 2007). Additional concerns center around standardizing a pedagogical approach for integrating MST into clinical reasoning and practice (Perry, 1981; Sebelski et al., 2020).

However, for more than half a century, the APTA has been trying to institute some version of pathokinesiology or MST into the standard educational curriculum. The primary underpinning was to identify the human body as a complex and intricate unit of movement due to unique characteristics that delineate the healthcare role that physical therapists fulfil in comparison to that of other healthcare providers (Gotten and Campbell 1933; Hermann 1937; Miller 1942; Hislop, 1975; Devine, 1984; Pinkston, 1986; Van Sant, 2017). Nevertheless, integrating the MST, or a similarly unique identity, into PTE programs has been challenging due to: (1) inconsistencies in diagnostic exemplars and movement system terminology, (2) resistance from and variability within programs, and (3) independent and siloed teaching versus integration of the body systems as a whole (Behneman, 1934; Snyder and Duvall, 1950; Callahan et al., 1961; Cott and Finch, 2007; Hoogenboom and Sulavik, 2017; Sahrmann, 2017; Sebelski et al., 2020). Recognizing that the MST incorporates and acknowledges the influence of cells, the basic building blocks of the human body, in addition to tissues, organs, and the body as a whole (Hislop 1975; Cott et al., 1995; Sahrmann, 2014) requires an in-depth examination of PTE signature pedagogies and the ability to integrate these concepts through anatomical education.

The signature learning instrument recognized in PTE is the human body, because of a distinctly unique pedagogical approach for teaching students to think, problem-solve, apply anatomic knowledge, and perform complex psychomotor skills (Jensen et al., 2017; Sebelski et al., 2020). During the physical examination, entry-level physical therapists can use anatomic knowledge to reason through structural involvement in movement dysfunction (van der Sijde et al., 1987; Gilliland, 2017; Sahrmann, 2017; Sahrmann et al., 2017; Berg-Carramusa, 2019). Understanding and incorporating MST in PTE and practice means approaching the human body holistically, which requires a deep understanding of human

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anatomy (Broberg et al., 2003). Therefore, learning human anatomy develops knowledge of the human body, specifically comprehension of normal structure and function, to provide rationale for appraising and analyzing dysfunction. However, the requisite anatomic knowledge, skills, and abilities necessary for understanding movement system diagnoses are yet to be determined; confounded by the continued development and validation of standard movement system diagnoses (Allen, 2007b; Ludewig et al., 2013; Hoogenboom and Sulavik, 2017). Therefore, a discussion of the required anatomical concepts for competent entry-level PTE and clinical practice is warranted.

Physical Therapy and Anatomy Education

The practice of physical therapy began as a supplement to medical doctoring. "Reconstruction aides" (early physical and occupational therapists) were vital during World War I and the early polio epidemic to perform and conduct the technical directives originally ordered by physicians (Decker, 1974; Plack and Wong, 2002; APTA, 2011; Carroll and Lawson, 2014). As the medical profession and healthcare system evolved, so did the role of the physical therapist; from solely a technician following physician's orders to a diagnostician with an increased ability to evaluate, assess, and treat movement dysfunction (Johnson, 1974; James and Stuart ,1975; Overman et al., 1988; Plack and Wong, 2002; APTA, 2011; Moffat, 2012). This division of labor and skills allowed the profession of physical therapy to transition to clinical collaborators within the healthcare field. Formal curricular training of "physiotherapy technicians" and "physical therapy aides" (both terms used for early physical therapists) included anatomy and other basic sciences since its inception, and its importance evolved through the major curricular reform of the 20th century (Cutter, 1931; Hagelthorn, 1932; Callahan et al., 1961; Decker, 1974; Plack and Wong, 2002).

Due to the training in anatomy, physiology, kinesiology, and exercise, physical education or nursing degrees were a standard prerequisite for early physical therapists (Peck, 1930; Behneman, 1934; Beard, 1961; Decker, 1974; Plack and Wong 2002). Emergency training courses were designed to enhance the knowledge of physical therapy practice based on the

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foundation of the theoretical sciences (including anatomy) to meet the war's medical needs (Hagelthorn, 1932; Beard, 1961; Decker, 1974). However, it was not until ten years after World War I ended and seven after the APTA formation, the first educational standards for physical therapy and a list of accredited physical therapy schools were published (AMA, 1936a, b; Hazenhyer, 1939; AMA, 1941; Hazenhyer, 1946; Decker, 1974). Of note, 25% of the early PTE curriculum was devoted to anatomy content and coursework (Cutter 1931; Decker, 1974). Furthermore, anatomy and kinesiology were the majority (54-67%) of all foundational training in basic science hours in PTE programs from 1918-1955 (Decker, 1974).

Anatomy knowledge has always been considered essential to physical therapy practice (Milacek and Pederson, 1967); it is part of the explicit curriculum and a theoretical foundation to clinical practice – even though the time allotted to teach anatomy has decreased (Hagelthorn, 1932; Hazenhyer, 1939; Hogue, 1974; Plack, 2000; McKenzie and Gutierrez, 2007; Gabard et al., 2012; Shead et al., 2018). Since introduced in PTE programs, anatomy training included cadaveric dissection (Beard, 1961), yet like many other healthcare programs, the time, availability, cost, and stakeholders influenced the inclusion of this modality (Mattingly and Barnes, 1994; Berube et al., 1999; Plack, 2000; Gabard et al., 2012; Simons et al., 2020). Even with these influences, the majority (71-98.2%) of PTE programs surveyed in the 1990s used cadaveric materials (Mattingly and Barnes, 1994; Berube et al., 1999). Furthermore, 90-92.6% of the PTE programs surveyed in 2010s still used cadaveric dissection as their primary teaching modality (Reimer et al., 2013; Cope et al., 2017). This timeframe is significant because it corresponds with the transition to a clinical doctorate as the primary entry-level degree (Plack and Wong, 2002; CAPTE, 2019).

Entry-level PTE in the U.S. has spanned the gamut from certificate, baccalaureate, post-baccalaureate, master's degree to doctoral education (Worthingham, 1968; APTA, 2020; Moffat, 2003; Swisher and Page, 2005). For years, some or all of those program types existed concurrently. The same accreditation standards were applied to all programs,

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regardless of the type of degree granted. Since 2016, all accredited U.S. programs have been required to award the Doctor of Physical Therapy (DPT) degree, yet the specific amount or type of anatomic content has never been established by the accrediting body (Worthingham, 1968; APTA, 2020). For example, current accreditation requirements mention in very general terms that anatomic content "necessary for entry-level practice" must be included in the curriculum. However, within the U.S., the range of credit units devoted to anatomy instruction can vary widely (McKenzie and Gutierrez, 2007; Myers et al., 2013; Youdas et al., 2013, 2015). Likewise, although minimal required skills for entry-level physical therapists have been described (APTA, 2009), the anatomic content required to meet those skills is not defined. Further, no uniform international standard for entry-level PTE exists concerning the degree required, while the program types and lengths vary widely (WCPT, 2011; Moffat, 2012; Adam et al., 2013; FAP, 2016; Barradell, 2017; Shead et al., 2018). As a result, despite the long-standing history of including anatomy education within PTE, no consensus exists regarding how much is needed, what specific content should be included, or how anatomy should be taught (McKenzie and Gutierrez, 2007; Youdas et al., 2015; Shead et al., 2016, 2018; Blum et al., 2020; Simons et al, 2020).

Post-graduate and residency-like training in physical therapy also developed to allow further specialization for movement dysfunction across the lifespan. Board-certified Physical Therapists demonstrate an increased need and understanding of anatomical concepts compared to physical therapy generalists (Brooks, 1996; Mulligan et al., 2014; Rapport et al., 2014; Bartlo et al., 2015; Johanson et al., 2016; Simons, 2019). Less clear are the relationships between therapists' areas of specialty and the anatomical knowledge specific to each area of expertise, in part, because the anatomy content assessed can vary from 4-20% across board certification specialty examinations (Johanson et al., 2016; Simons, 2019).

Anatomical Competence

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Competence requires having the knowledge and skills needed to practice the discipline (Epstein and Hundert, 2002; Chesbro et al., 2018). For physical therapy, this includes the cognitive abilities that encompass clinical rationale and judgment, the affective abilities to display the correct attitudes and values, the psychomotor abilities to perform therapeutic techniques manually, and the ability to reason through problems that emerge during practice (Jensen et al., 2000; Brosky and Scott, 2007; Chesbro et al., 2018; Simons, 2019). To function with "excellence" in professional competence, Gordon (2011) advocates that physical therapists must also be prepared to practice in a direct access setting, where a physician referral is not required by state law. While multiple resources refer to the term professional competence, inconsistent definitions create difficulty in assessing and adequately demonstrating achievement (Brosky and Scott, 2007; Regan de Bere and Mattick, 2010; Fernandez et al., 2012; Chesbro et al., 2018). However, the level of required professional competence is always changing depending on the clinical setting and learning environment, suggesting a competence continuum as a novice transitions to an expert (Jensen et al., 2000; Brosky and Scott, 2007; Barradell, 2017; Chesbro et al., 2018).

Measuring the continuum of professional competence in healthcare fields has been reframed with several identifying terms. Educational milestones are used to assess this developmental phenomenon in medical residency and fellowship education programs, defined in 2013 by the Accreditation Council for Graduate Medical Education (ACGME) (Teherani and Chen, 2014; Williams et al., 2015; Edgar et al., 2018). Meanwhile, observable practice activities (OPAs) and entrustable professional activities (EPAs) have been used to describe the smaller behavior units that are attainable and measurable components of clinical practice and specialist training programs (ten Cate, 2005; Teherani and Chen, 2014; Warm et al., 2014; Chesbro et al., 2018). Milestones, OPAs, and EPAs are fundamental components of competency-based curricular designs, yet they all depend on the acquisition of clinical and didactic knowledge, the skills for clinical performance, and the ability to discuss clinical progress and processes. Therefore, performance and clinical readiness are not predicted by isolated domains of competence, but through characteristics

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that display or express the professional behaviors of several areas of competence within the desired discipline (Rapport et al., 2014; Chesbro et al., 2018; Timmerberg et al., 2019). One such area for the entry-level physical therapist to demonstrate clinical readiness is in anatomical competence (ACAPT, 2017; Timmerberg et al., 2019).

Anatomical competence was conceived to identify the anatomy knowledge, skills, and abilities necessary and relevant for adequate clinical practice (Regan de Bere and Mattick, 2010; Schoeman and Chandratilake, 2012; Fillmore et al., 2016). Similar to educational milestones, OPAs, and EPAs, measuring anatomical competence can capture the transition of a novice learner to a reflective and proficient student ready for clinical practice (Shepard and Jensen, 1990; Fillmore et al., 2016; Chesbro et al., 2018; Timmerberg et al., 2019). Although pure, rote-memorized, basic science is not considered relevant for clinical practice, the experience of identifying major concepts and synthesizing the use of anatomical concepts is part of each implicit or hidden curriculum (Sahrmann, 1998; Jensen, 2011; Bandiera et al., 2013; Barradell, 2017). Curricular overcrowding and the increase in anatomic details combined with the decrease in time related to teach them, enhances the need to teach threshold concepts (Morris, 2015; Shead et al., 2016; Barradell, 2017; Hoang and Lau, 2018).

Competency-based education is often defined as a set of standard "deliverables" that should be achieved by the end of each healthcare education program to demonstrate a graduate's competence for entry-level practice (Fernandez et al., 2012; Adam et al., 2013; Hoang and Lau, 2018). The profession and other stakeholders regulate the quality and preparedness of education programs to produce competent practitioners through the accreditation process (Brosky and Scott, 2007; Fernandez et al., 2012; Adam et al., 2013; Barradell, 2017; Timmerberg et al., 2018), requiring physical therapist educators to "prove" or document student progression and achievement towards competence. The Commission on Accreditation in Physical Therapy Education (CAPTE) was created and is used to verify that each PTE program is upholding the minimum standards for entry-level practice (Brosky and

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Scott, 2007). The National Physical Therapy Examination (NPTE®), administered through the Federation of State Boards of Physical Therapy (FSBPT) is another metric used to assess clinician readiness (Caramagno et al., 2017; Wolden et al., 2020). Neither, however, clearly delineates the specific anatomical competence required for physical therapist practice (Bartlo et al., 2015; Caramagno et al., 2017).

The development of entry-level anatomical competence, and therefore professional competence, should be slow and deliberate because it is defined by critical stakeholders, cultural experiences, and from the needs of the healthcare society (Higgs et al., 1999; Brosky and Scott, 2007; Gregory et al., 2009; Gordon, 2011; Fernandez et al., 2012; Bandiera et al., 2013; Warm et al., 2014). The required levels of anatomical competence may vary, for example, at graduation from professional-training programs compared to specialist training in residency programs, or for board certification and expert practice (Brooks, 1996; Regan de Bere and Mattick, 2010; Bartlo et al., 2015; Fillmore et al., 2016; Johanson et al., 2016; Simons, 2019). Therefore, physical therapist educators need to be able to assess progression towards professional and anatomical competence so that they can analyze achievement compared to a national standard or terminal outcome (Regan de Bere and Mattick, 2010; Fernandez et al., 2012).

Starting the Discussion for Threshold Concepts in Anatomy

To facilitate the discussion, the following threshold concepts are suggested as a starting point (TABLE 1), with recognition that these suggestions may not accurately capture the needs of all physical therapist educators worldwide due to variation in practice acts and legal rights of the profession (WCPT, 2011; Moffat, 2012; FAP, 2016; Barradell, 2017). However, knowing the unique nature of physical therapy practice allows for anatomy threshold concepts that are bounded in MST to be developed as a shared resource to anatomy educators. It is the authors' sentiment that building a modular platform of educational thresholds provides a foundation on which the anatomy training for clinical specialties and future needs for the profession could root themselves and grow.

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To be useful and informative to new and established anatomy educators, the proposed threshold concepts provide sample areas for mastery, integration, and transformation towards anatomical competence (Meyer and Land, 2003; Barradell, 2017; Barradell and Peseta, 2017). Several iterations and permutations of these initial suggestions may be required until the process ultimately refines the anatomy threshold concepts that capture the level of anatomical competence, bounded by the MST, and needed for entry-level physical therapy practice.

Fluency:

Demonstrate anatomic comprehension and signification through the use of appropriate terminology with the goal of efficient communication within the healthcare system, including health literacy and effective patient communication (Sahrmann, 1998; Morris, 2015; Youdas et al., 2013; Sytsma et al., 2015; Green et al., 2017; Sahrmann et al., 2017).

Dimensionality:

Explain, synthesize, integrate, analyze, and assess the human structure in consideration of dimensionality, axes of movement, and the anatomic and functional relationships of the "movement system" (integumentary, musculoskeletal, endocrine, cardiopulmonary, and neuromuscular systems), including the microanatomy as related to tissue healing, biomechanics, posture, and movement (Hislop 1975; Rose 1986; Peel, 1996; Sahrmann, 1998; Regan de Bere and Mattick, 2010; Morris, 2015; Sahrmann et al., 2017).

Adaptability:

Construct and deconstruct the structures involved in normal human movement, including the assessment of muscle architecture, attachments, and functions; the neurovascular supply; and joint components (e.g., joint surfaces, ligamentous support, capsular complexes, cartilage, synovial fluid, fascial elements, neurovascular supply, etc.) of the limbs, head,

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neck, and trunk (Hislop, 1975; Peel, 1996; Sahrmann, 1998; Krause et al., 2011; Morris, 2015; Meyer et al., 2017; Sahrmann et al., 2017)

Connectivity:

Describe, integrate, analyze, and interpret the relationships and functions of the structures of the nervous system with respect to the motor, sensory, and autonomic innervation of the body's structures and in consideration of the bony protections and areas of potential compression or impingement, including a structural understanding of pain generators by tissue type and location and including differentiating potential areas of damage (e.g., nerve root vs. peripheral nerve) (Sahrmann, 1998; Regan de Bere and Mattick, 2010; Moffat, 2012; Morris, 2015; Sahrmann et al., 2017). Neuroanatomy or neuroscience coursework should address the extensive content regarding the nervous system in totality (structure, function) and pain science which is likely beyond the typical gross anatomy coursework of most PTE programs (Scudds et al., 2009; Myers et al., 2013; Bement and Sluka, 2015; Louw et al., 2017).

Complexity:

Relate and integrate the normal structure and basic functions of the visceral organs (including their normal location, anatomic variations, three-dimensional relationships, and neurovascular supply), to visceral referred pain patterns, common pathologies, clinical correlates, and health considerations (e.g., nutrition, deglutition, digestion, drug delivery and absorption, cardiopulmonary, and urogenital function) (Sahrmann, 1998; Regan de Bere and Mattick, 2010; Spitznagle and Sahrmann, 2011; Moffat, 2012; Morris, 2015; Kurz and Borello-France, 2017).

Stability or Homeostasis:

Explain and integrate the three-dimensional structure, function, and relationships of the human "cavities" (thoracic and abdominopelvic) pertaining to cardiopulmonary, gastrointestinal, endocrine, and urogenital systems, and the autonomic control of their

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physiologic or metabolic processes (e.g., ventilation, respiration, circulation, – including perfusion – digestion, elimination, –including micturition and defecation – biological sex organs, and reproduction) (Peel, 1996; Sahrmann, 1998; Regan de Bere and Mattick, 2010; Moffat, 2012; Morris, 2015; Sahrmann et al., 2017; Shields, 2017).

Progression or Development:
Identify and examine some of the anatomic and functional changes across the lifespan, including genetic or metabolic influences that may affect the human movement system from embryology to childhood and adolescence through the aging and dying process (Sahrmann, 1998; Moffat, 2012; Morris, 2015; Sahrmann et al., 2017; Shields, 2017).

Humanity:
Explore and reflect on personal attitudes of humanity, empathy, ambiguity, respect for people, and ethics in the study and clinical application of anatomy in culturally diverse populations. This includes consideration of perspectives on disability, dysfunction, societal expectations, and biases impacting the movement system (Higgs et al., 1999; Canby and Busy 2010; Regan de Bere and Mattick, 2010, Youdas et al., 2013; Hildebrant, 2016; Cope et al., 2017; Jensen et al., 2017).

DISCUSSION

Across a century of curricular changes, anatomy has served as the foundation to PTE and practice, yet the most relevant anatomy content remains ambiguous. Learning human anatomy, specifically the systems involved in human movement, will develop anatomical competence in physical therapy practice. The authors define anatomical competence as having the ability to apply anatomic knowledge within the appropriate professional and clinical contexts. This definition of anatomical competence includes the professional use and integration of anatomy threshold concepts and MST in clinical practice. Although integral to clinical reasoning and diagnostic skills, clear levels of anatomical competence within the MST framework are currently unknown (Caramagno et al., 2017). Anatomical competence

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should be linked to clinical performance and the ability to make sound judgments that ultimately contribute to clinical competence and the defined professional identity (Epstein and Hundert, 2002; Fernandez et al., 2012). Ultimately, anatomical competence in PTE, should produce a foundation of knowledge that prepares students for unknown and uncertain clinical diagnoses (Perry 1981; Barradell, 2017). Thus, important determinants of critical knowledge within PTE and practice are anatomy threshold concepts (Green et al., 2017).

The authors propose that threshold concepts for students enrolled in PTE programs must include the ability to demonstrate anatomic fluency by using appropriate terminology for efficient verbal and written communication within the healthcare system, including health literacy and effective patient communication. Where appropriate and applicable, anatomic content and descriptions should include terminology germane to MST and integration of movement systems (e.g., integumentary, musculoskeletal, metabolic and endocrine, cardiovascular and pulmonary, lymphatic, gastrointestinal, genitourinary, and neuromuscular and nervous systems). With the addition of direct access and the potential for an increase in imaging rights for practicing physical therapists (Gordon, 2011; Burley et al., 2020), conceptual emphasis should be placed on the complex and connected structures involved in normal human movement, such as muscle architecture, attachments, functions, neurovasculature, osteology, joint components, body cavities, viscera, and glandular tissue. Educators should also anticipate that anatomic content needs to be integrated with other basic sciences (related content such as physiology, biomechanics, neuroscience, histology, genetics, and pathology).

Clearly, threshold concepts demonstrate a need for more specific learning objectives to measure achievement and progression, in addition to serving as a resource to anatomy educators. Furthermore, support and development of competence occurs through the achievement of student learning objectives and assessable course outcomes in the domains of cognition (knowledge), psychomotor (skills) and affect (ethical attitudes of humanity,

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empathy) implemented in human anatomy education. Yet, oftentimes these objectives are created as exhaustive or prescriptive lists of anatomic content that may not always be germane to the target profession.

Creating a Framework

Twenty-five years ago, the essential anatomic content for PTE was examined (Mattingly and Barnes, 1994). Since that time, the number of papers published that are specific to anatomy coursework or content as it relates to PTE or practice is negligible (Donovan 1994; Armstrong and Rosser, 1996; Fiebert and Waggoner 1996; Latman and Lanier 2001; Reimer et al., 2013; Shead et al., 2016, 2018). Most often, the research studies survey anatomy educators in PTE programs or clinicians regarding faculty credentials, teaching modalities, student perceptions, or comparisons between other healthcare professions (Berube et al., 1999; Plack, 2000; Latman and Lanier 2001; Hamilton et al., 2008; Livingston et al., 2014; Simons et al., 2020). To date, no prospective investigation regarding the integrity of anatomical competence needed for physical therapy practice has been conducted. Retrospective survey data, collected from anatomy educators and clinicians, provided a simple consensus about essential anatomical regions or broad areas of anatomic content but nothing specific regarding the required anatomical competence for effective physical therapy practice nor the integration of the MST (Mattingly and Barnes, 1994; Latman and Lanier, 2001; Reimer et al., 2013).

In the wake of adopting the MST, the need to determine the required anatomical competence is clear. There is a definitive need for the integration of body movement and function within the scientific bases of PTE. Changing the view of the learner towards the use and application of anatomy in clinical practice is irreversible and transformative (Sahrmann, 1998; Meyer and Land, 2003; Jensen, 2011; Land and Meyer, 2011). Diagnostic reasoning is reliant on anatomical competence, especially to process through unfamiliar diagnoses and to transition from a novice to expert clinician (van der Sijde et al., 1987; Hendriks et al., 2000; Broberg et al., 2003; Banda, 2010; Gilliland 2017). As movement system specialists,

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physical therapists must have a thorough understanding of all body systems. Without clearly defining anatomy threshold concepts for entry-level anatomical competence, educators run the risk of confusing or negatively impacting students who may not be taught an adequate depth and breadth of anatomy.

Designing a framework that incorporates MST and anatomical competence is important to determine the threshold concepts for PTE. Described as integrative, liminal, transformational, irreversible, bounded, and troublesome, threshold concepts are disciplinary-based beliefs that must be accepted and mastered to progress towards the professional identity and complex behaviors of discipline-specific practice (Meyer and Land, 2003; Land and Meyer, 2011; Smith et al., 2014; Land et al., 2016; Barradell, 2017). Traditionally, threshold concepts have been referred to as portals or landing points that are difficult to learn but can never be undone once acquired (Meyer and Land, 2005; Jensen, 2011; Land and Meyer, 2011). The time needed to capture this knowledge can vary depending on the learner due to the cognitive and affective transformation that occurs as they develop their intended discipline's thought patterns.

Burgeoning physical therapists must change their thoughts and approach the human body as a movement entity. There needs to be an appreciation of the nature of movement and therefore the components or systems of movement to assess the human body as a whole. Threshold concepts for anatomical competence can contribute to this shift in thinking within the MST framework. Concepts in anatomy education that may be troublesome and challenging for students to grasp, but are transformative once attained, can be considered thresholds. While concurrently reducing teaching time, increasing anatomical facts prohibits an objective-based curriculum because it limits anatomic content to current knowledge, does not include future interpretations, and cannot explicitly isolate the acquisition of competence (Bandiera et al., 2013; Norman et al., 2014; Morris, 2015; Barradell, 2017; Hoang and Lau 2018). Anatomy educators in PTE must keep in mind that the intended goal is to contribute to professional competence in physical therapy practice and not create a future anatomist.

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However, the innate skills and cognitive approach to anatomic evaluation, integration, and conceptual synthesis may benefit the student physical therapist as they analyze movement.

The need to establish overarching anatomy threshold concepts may not be explicitly linked to prescriptive lists of learning objectives (Barradell, 2017; Barradell and Peseta, 2017, 2018). Inflexible recommendations for anatomy learning objectives may limit the uniqueness of physical therapy practice and prohibit educational autonomy. Conversely, anatomy threshold concepts can produce consistent student progression towards relevant anatomical competence. For that reason, decision makers must refrain from insisting upon prescriptive and rigid lists of student learning objectives, when identifying and adopting recommendations for anatomical competence, but strive for consensus on essential threshold concepts that adequately prepare students for integrating MST into physical therapy practice. While some programs may be incorporating MST terminology and diagnoses into their anatomy coursework, no evidence exists to suggest that such is the case. Furthermore, anatomical competence is just one contributing factor towards understanding the continuum of movement acquired and integrated during other didactic and clinical coursework (Caramagno et al., 2017). Since PTE programs have not yet reached consensus about how to define and integrate either MST or anatomical competence into their curricula, the time to do so is upon us.

Developing a competency-based model for anatomy in PTE will require future research that identifies the application of anatomy in PTE and practice. Any evidence that can contribute to understanding the minimum standards for practice can significantly contribute to educational thresholds and curricular planning for professional activities or assessments that can promote student competence (Perry, 1981; Adam et al., 2013). Researching threshold concepts for PTE and practice can capture the transformational and irreversible knowledge that students need for successful progression towards the APTA's definition of professional identity (Barradell, 2017).

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In recognition of this need, a subgroup of members of the Academy of Physical Therapist Education (APTE), a section of the APTA, began organizing themselves into a Special Interest Group in 2018 called the Anatomy Educators Special Interest Group (AESIG). The purpose of establishing the AESIG was, in part, to explore and define guidelines for anatomy education in PTE programs. However, this goal, which did not specifically include the incorporation of the MST, has not yet been achieved and efforts are currently on hold. The authors recommend that similar to the format in which the anatomical science competencies were created and vetted for the pre-clinical medical student (AAA, 2019), anatomy educators in PTE and clinicians work together to create task forces to ensure a relevant consensus. Once consensus is reached, the AESIG can work with the House of Delegates, Movement System Summit group, APTA Board of Directors, and CAPTE to effect change.

The international community of physical therapist educators is also researching relevant anatomical content and threshold concepts for PTE more broadly. Investigators in Australia are currently developing a core syllabus for anatomy education in physiotherapy, similar to a previous Delphi study for medical education (Webb, 2019). Concurrently, the International Federation of Associations of Anatomy, Federative International Program for Anatomy Education (FIPAE) committee is also organizing an effort to create a core syllabus for physiotherapy (IFAA, 2019).

To that end, reaching a consensus about foundational anatomic content for entry-level physical therapist practice, regardless of the educational degree granted or country involved, will help strengthen and standardize the professional education. By also integrating MST and anatomical competence into PTE, the profession can more clearly and effectively establish its specific role in healthcare. Doing so will facilitate greater consistency across the globe and help define physical therapist practice to those outside the profession.

Ensuring that the overall anatomy threshold concepts are achieved should be an essential step in meeting CAPTE requirements, along with standardizing the entry-level education

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received by a novice physical therapist. Therefore, developing and vetting threshold concepts with measurable learning objectives, that still allow for program flexibility and faculty autonomy, is a vital step in PTE with respect to teaching anatomy and fostering anatomical competence within the MST framework. Notwithstanding, healthcare policies and societal needs should also inform the anatomy threshold concepts. After meeting these goals for entry-level PTE, the profession can then progress towards determining the anatomical competence and threshold concepts required for implementing the MST in advanced specialization and practice.

CONCLUSIONS

The purpose of this viewpoint was to initiate the discussion regarding anatomy threshold concepts that encompass but consolidate a broad integration of MST and anatomical competence for PTE and practice. The proposed threshold concepts were created with the intent of starting a much-needed conversation in hopes that other anatomy educators would contribute. The discussion of anatomy threshold concepts in PTE could also help to develop evidence-based models for effective anatomy instruction.

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NOTES ON CONTRIBUTORS:

MELISSA A. CARROLL, Ph.D., M.S., is an associate professor in the Doctor of Physical Therapy Program at DeSales University, Center Valley, Pennsylvania. She teaches anatomy, neuroanatomy, evidence-based practice and research methods to physical therapy students. Her research interests are in anatomical education, variations, diversity, and effective assessments.

ALISON L. MCKENZIE, P.T., D.P.T., Ph.D., M.A., is a professor of physical therapy, Anatomy Team Leader, and Director of Anatomy Laboratory Operations at Chapman University, Irvine, California. She has taught anatomy, neuroanatomy, and embryology to physical therapist students for over thirty years. Her research interests include neuroplasticy, stroke, and anatomical education.

MARY TRACY-BEE, Ph.D., M.S., is a professor of anatomy at the University of Detroit Mercy, Detroit, Michigan. She teaches anatomy and neuroanatomy to graduate health professionals including physical therapy students at Oakland University in Rochester, Michigan. Her research interests include anatomical education, curricular development, and morphological variations in anatomical structures.

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Table 1: Proposed Threshold Concepts in for Physical Therapist Anatomy Education with Consideration of the Movement System Theory and Anatomical Competence

Threshold Concept	Brief Description	Domain(s) of Competence[a]	Link To APTA Minimum Required Entry-Level Physical Therapy Skills[b]
Fluency	• Appropriate terminology and comprehension, including health literacy and effective patient communication	• Communication • Knowledge for practice	• Examination/Reexamination • Evaluation • Plan of care • Consultation • Evidence-based practice Communication
Dimensionality	• Human structure in consideration of dimensionality, axes of movement, and the anatomic and functional relationships	• Knowledge for practice • Clinical reasoning • Systems-based practice	• Systems review screening • Examination/Reexamination • Diagnosis • Prognosis • Interventions • Plan of care
Adaptability	• Tissue healing, biomechanics, posture,	• Knowledge for practice	• Systems review screening

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	flexibility, and movement	• Clinical reasoning • Systems-based practice	• Examination/Reexamination • Diagnosis • Prognosis • Interventions • Plan of care
Connectivity	• Muscle architecture, attachments, and functions; the neurovascular supply; and joint components of the human extremities, head, neck, and trunk • Motor, sensory, and autonomic innervation and influence of the body's structures	• Knowledge for practice • Clinical reasoning • Systems-based practice	• Systems review screening • Examination/Reexamination • Diagnosis • Prognosis • Interventions • Plan of care
Complexity	• Bony protections and areas of potential compression or impingement, including a structural understanding of pain generators by tissue type and location • Typical location, anatomic variation, three-dimensional relationship, and neurovascular supply of the viscera	• Knowledge for practice • Clinical reasoning • Systems-based practice	• Systems review screening • Examination/Reexamination • Diagnosis • Prognosis • Interventions • Plan of care

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Stability and Homeostasis	• Structure, function, and relationships of the human "cavities" (thoracic and abdominopelvic) pertaining to their physiologic and metabolic processes • Maintenance of catabolic and anabolic responses to the external environment and internal set points through the autonomic nervous system	• Knowledge for practice • Clinical reasoning • Systems-based practice	• Systems review screening • Examination/Reexamination • Diagnosis • Prognosis • Interventions • Plan of care
Progression or Development	• Anatomic, pathologic, and functional changes across the lifespan, including genetic or metabolic influences that may affect the human movement system	• Knowledge for practice • Clinical reasoning • Systems-based practice	• Systems review screening • Examination/Reexamination • Diagnosis • Prognosis • Interventions • Plan of care • Promotion of health, wellness and prevention
Humanity	• Attitudes of humanity, empathy, ambiguity, respect for people and ethics in culturally diverse populations, and perspectives of disability, dysfunction and societal expectations and biases impact the	• Knowledge for practice • Clinical reasoning • Systems-based practice	• Plan of care • Education • Professionalism: Core Values • Communication

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	movement system		• Cultural competence • Promotion of health, wellness and prevention

[a]Domains of competence are based on Chesbro et al., (2018); [b]For the APTA Minimum Required Entry-Level Physical Therapy Skills see APTA (2009).

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