Dancing in the Connective-Tissue Matrix

An Embryology Primer

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Structural integration (SI) is an art form that draws from the underpinnings of science. It is also a scientific inquiry into the human experience that employs the artistry of "seeing," "touching" and "communicating" to deliver the goods. Structural integration is a third-paradigm approach. First-paradigm work has to do with relaxation while second-paradigm work is a fix-it approach. Our work is certainly capable of eliciting the benefits of first- and second-paradigm results. However, the nexus that is structural integration has to do with the third-paradigm approach, which is holistic.[1] This article will facilitate the practitioner's ability to work from this third-paradigm perspective through an examination of embryology[2] and the connective tissues.

Most practitioners of structural integration likely have some understanding of the field of embryology. This article will systematically delve into embryological development to reveal a new understanding of the connective-tissue matrix. The reader will understand how the connective-tissue matrix comes into being, and this information will assist the practitioner to work with clients in a new and profound way. In the early years of the Rolf Institute®, the training began with a week of anatomy during which an introduction to embryology was included. Peter Melchior and Louis Schultz gave me my first glimpses into the importance of embryology and its relationship to our work: Peter during my basic training, and Louis with an inspirational presentation at an annual meeting of the Rolf Institute back in the mid 1980s.

In recent years Erich Blechschmidt's work has rekindled some practitioners' interest in the field of embryology. My own interests in this area over the past few years have deepened my understanding of the map of the human body provided by the connective-tissue matrix and the fascial layers in particular. This quest to better appreciate the fascial layers has led me enthusiastically into the realm of embryology. Jan Sultan introduced a conceptual model, The Five Structural Elements, to assist students in their ability to "see" and to strategize. These structural elements are the pelvic girdle, the shoulder girdle, the core, the sleeve, and the axial complex. This conceptual model sheds light on some of the "spirit thread" weaving through the Ten-Series recipe.[3]

Sultan's model defines the core space as the viscera and the path from the oral pharynx to the respiratory and digestive systems. The core space is profoundly related to the intent of the fourth, fifth, and seventh sessions. Conversely, the axial complex in Sultan's model is defined as the structures associated with the spinal column and cranial vault (the neurocranium). This complex is related to the intent of the sixth and seventh sessions. The seventh session is the time we contemplate the meeting of the neurocranium with the viscerocranium; it relates a deeper understanding of Ida Rolf's axiom that "The goal of the Seventh Hour is to get the head on." As we will see, an understanding of embryological development sheds further light on this conceptual model. It also provides our "seeing," "touching," and "communicating" with a newfound regard for the whole that is the human organism.

Three Germ Layers and Four Tissue Types

The embryonic period occurs from conception through the eighth week. During the third week of embryonic life the three germ layers differentiate. The three layers are known as the ectoderm, mesoderm, and endoderm. Each of these germ layers gives rise to specific tissue types. There are four types of tissue, which will eventually give rise to all the organs of the body. These four tissue types are nerve, connective, muscle, and epithelial tissues.

Epithelial tissue is composed of sheets of attached cells. Its function is the protection of underlying tissues. Epithelial tissue creates a boundary between "outside" and "inside," controlling what is capable of being transported across this boundary. Epithelial tissue is also capable of secreting enzymes and hormones. It is derived from all three germ layers. The epithelial tissue derived from the ectoderm layer becomes the most superficial layer of the skin, the epidermis. Epithelial tissues derived from the mesoderm form the linings of the urogenital organs and the cardiovascular system. The endoderm germ layer is comprised completely of epithelial tissue and contributes to the linings of the gastrointestinal tract, respiratory system, the liver and pancreas. The endoderm does not give rise to any muscle, nerve or connective tissues.

Muscle tissue is composed of elongated cells that have the unique ability to contract. No other tissue in the body has this ability. There are three types of muscle tissue: skeletal, smooth, and cardiac, and all are derived from the mesoderm germ layer. No muscle tissue arises from the ectoderm or endoderm germ layers.

Nerve tissue is composed of large, irregularly shaped cells. Nerve cells, or neurons, can be very long, spanning up to over a meter in length. The function of a neuron is to receive, generate and transmit signals to target tissues. It is derived entirely from the ectoderm layer.

Connective tissue, simply put, connects tissues together. Connective tissue further differentiates into a wide spectrum of derivatives categorized as "general" and "special" connective tissues. General connective tissues include fascia, tendons, ligaments, and joint capsules. Special connective tissues include cartilage, bone, and blood cells. The fibroblast is the major cell type of connective tissue. These cells secrete the extracellular matrix. Connective tissue is derived primarily from the mesoderm layer; however, there is also a small contribution of the body's connective tissue from the ectoderm layer (more on this later).

Table 1: Germ layers and related tissues

Germ Layer	Tissues Differentiated from Germ Layer
Ectoderm	Nerve Tissue (all) Connective Tissue (a small amount – related to the cranium) Epithelial Tissue
Mesoderm	Muscle Tissue (all – skeletal muscle, smooth muscle and cardiac) Connective Tissue (all except the small amount derived from ectoderm) Epithelial Tissue
Endoderm	Epithelial Tissue

See Table 1 for a summary of the three germ layers and the tissues that are derived from each layer.

When an embryo differentiates into the three germ layers, the resulting structure becomes the embryonic disc. This embryonic disc has the mesoderm layer in the middle with the ectoderm and endoderm layers on either side of it when viewed in a horizontal cross-section (see Figure 1).

The arrows depicted in each of the three germ layers in Figure 1 represent growth vectors occurring in the horizontal plane. As this growth occurs, body folding begins to affect each of these three layers. Bear in mind that this folding and growth in the developing embryo occurs not just in the horizontal plane, but in the sagittal plane (cranial/caudal dimension) as well. To simplify the task of understanding the embryological process, we will consider each germ layer independently.

Development of the Ectoderm Layer: The Neural Tube, Neural Crest and Skin

The ectoderm gives rise to two different tissues: nerve tissue and epithelial tissue. The midline region of the ectoderm is the first region of the developing embryo to commit to differentiation into a specific tissue. This region undergoes what is referred to as "induction." Induction occurs by the interaction between the ectoderm and the underlying mesoderm, specifically a region of the underlying mesoderm known as the neuroectoderm or the primitive streak. The lateral ends of the developing ectoderm will develop into the epithelial ectoderm. This will eventually become the outermost layer of the skin, the epidermis of the adult body.

Around the third week after fertilization, the embryo begins the process of body folding. The ectoderm layer folds so that

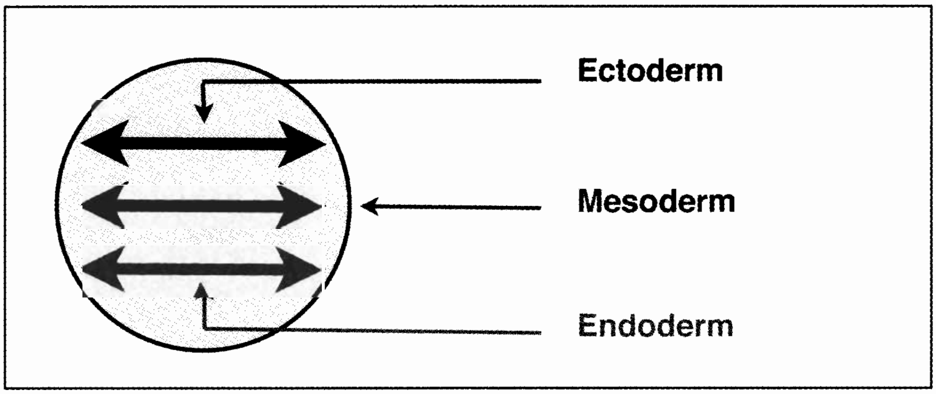


Figure 1: Horizontal cross-section of the embryo depicting the three germ layers

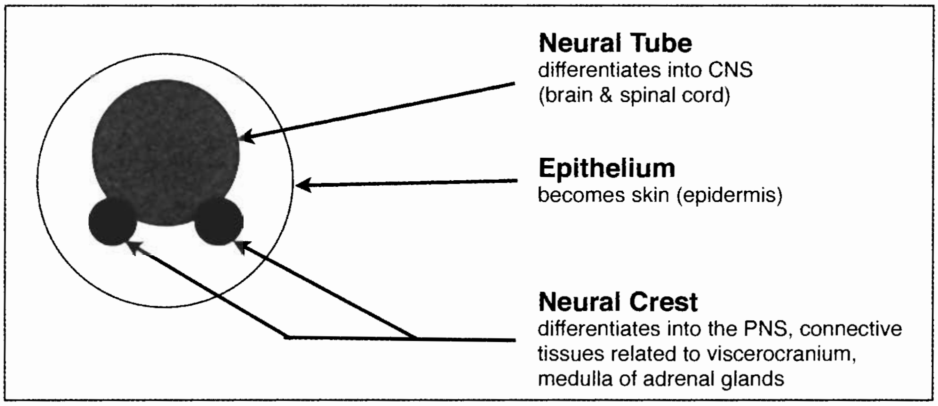


Figure 2: Horizontal cross-section of the embryo depicting the ectoderm layer

the midline ectoderm creates a structure that looks like a tube with two bumps on it. This tube is known to embryologists as the neural tube and the bumps as the neural crest (see Figure 2). Once again, this region of the ectoderm gives rise to all of the nerve tissue of the adult body. Specifically, the tissue forming the neural tube will give rise to the entire central nervous system (CNS), the spinal cord, and brain.

The tissue forming the neural crest gives rise to what are referred to as "typical" and "atypical" tissues. The typical tissues derived from the neural crest are nerve tissues, specifically those of the peripheral nervous system (PNS) and the sensory and autonomic motor ganglia. The atypical tissues derived from the neural crest are connective tissues associated with the cranium, the medulla of the adrenal glands, Schwann's cells, melanocytes, and the most cranial portions of the arachnoid mater and pia mater. To complete our picture of the developmental fate of the ectoderm layer, look again at Figure 2 and notice the outer layer of the embryo/body formed from the ectodermal epithelium – the epidermis or outermost layer of skin.

Development of the Mesoderm Layer: The Axial and Paraxial Mesoderm

The mesoderm gives rise to muscle, connective, and epithelial tissues. All muscle tissue is derived from the mesoderm layer. However, as we shall see, specific regions of the developing mesoderm will give rise to the specific *types* of muscle tissue: skeletal, smooth and cardiac. Most connective tissues found in the adult body are generated from the mesodermal layer. The only exceptions to this are the connective tissue contributions to the cranium derived from the ectoderm layer. The epithelial tissue contributions to the adult body from the developing mesoderm layer are the epithelial linings of the cardiovascular system and most parts of the epithelial linings of the reproductive and urinary systems.

We will illuminate the mesodermal developmental process in the same manner that we observed the development of the ectoderm layer – from a horizontal-plane view. Recall the image from Figure 1. It depicts the three germ layers: mesoderm flanked by ectoderm and endoderm. We have already seen how the ectoderm layer evolves to create the outermost layer of the embryo/adult body, the skin, as well as a tube referred to as the neural tube. The mesoderm layer, as it grows in the horizontal plane, will eventually grow to surround the neural tube as well as the endoderm tube (see Figure 3).

This growth of the mesoderm layer in the horizontal plane occurs from the midline out bilaterally. The growth of the mesodermal tissue eventually wraps around the neural tube, which has been formed by the ectoderm and the endoderm tube (formation of the endoderm tube to be discussed later in this article). The midline region of the developing mesoderm is termed the axial mesoderm and the region just lateral to this is termed the paraxial mesoderm. The only remnant of the axial mesoderm in the adult body is the nucleus pulposus, a form of connective tissue making up the center of the intervertebral discs.

The paraxial mesoderm differentiates into three distinct regions. These regions are termed the sclerotome, myotome, and dermatome. Each region will develop into distinct elements in the adult body (see Figure 4). The sclerotome will differentiate into the connective tissue related to the axial skeleton: bones, tendons, ligaments, and myofascial elements. Embryologically, this axial skeleton includes the vertebrae, ribs, and some parts of the base of the cranium. The myotome will differentiate into *all skeletal muscle* in the adult body. The dermatome will differentiate into yet another form of connective tissue – the dermis, the layer of skin directly beneath the epidermis, which formed from the ectoderm layer.

As the embryo continues to grow, development of the mesoderm layer includes further divisions called the intermediate mesoderm and the lateral plate mesoderm (see Figure 5). The intermediate mesoderm differentiates into the connective tissues, smooth muscle tissue and epithelial tissue related to the urogenital area. The lateral plate mesoderm differentiates to form all the tissues of the cardiovascular system (connective, smooth muscle, and epithelial tissues) as well as most of the tissues contributing to the limbs, cranium, and body wall.

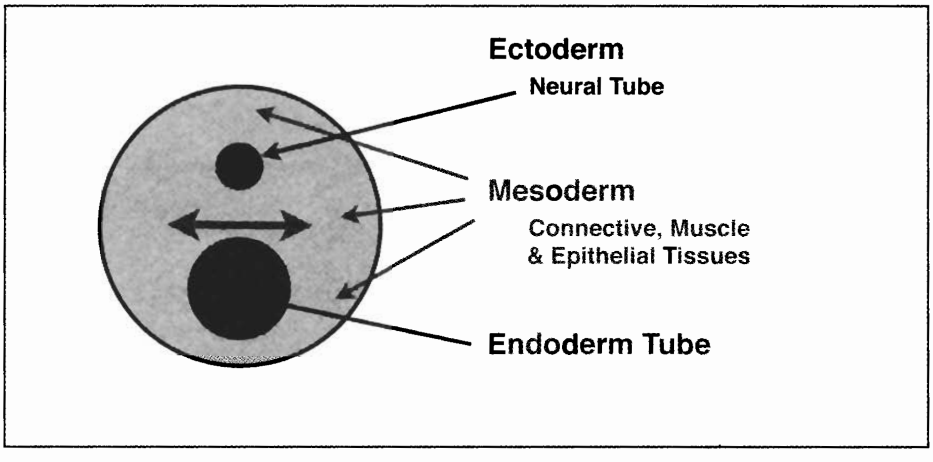
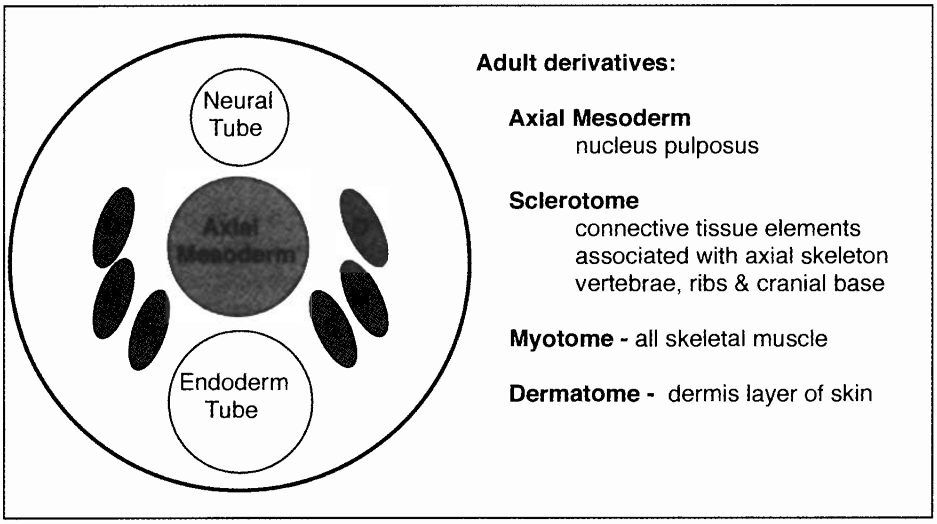


Figure 3: Horizontal cross-section depicting mesoderm layer

Specifically, these tissues include *all the connective tissues of the limbs* (bones, tendons, ligaments, and associated myofascia) and many of the connective tissues of the cranium. Additional contributions to the connective tissues of the limbs come from the neural crest of the ectoderm layer previously mentioned.

Development of the Endoderm Layer: The Endoderm Tube

The endoderm gives rise to only one tissue type – epithelial tissue. The endoderm layer is also affected by the body folding that occurs in the third week after fertilization. In the horizontal plane this results in the creation of the endoderm tube, which we have already included in Figures 3-5. This tube grows along with the developing embryo in the cranial/caudal dimension. This epithelial lining of the endoderm tube gives rise to the gastrointestinal tract and to the epithelial lining of several organs "budding" from the endodermal tube. These buds grow out into the surrounding mesoderm. As the embryo continues its development, some of these buds will eventually separate from the gastrointestinal tube.



Adult derivatives:

Axial Mesoderm
nucleus pulposus

Sclerotome
connective tissue elements associated with axial skeleton vertebrae, ribs & cranial base

Myotome - all skeletal muscle

Dermatome - dermis layer of skin

Figure 4: Horizontal cross-section of developing mesoderm depicting the axial mesoderm and the three subdivisions of the paraxial mesoderm (S = sclerotome, M = myotome, D = dermatome)

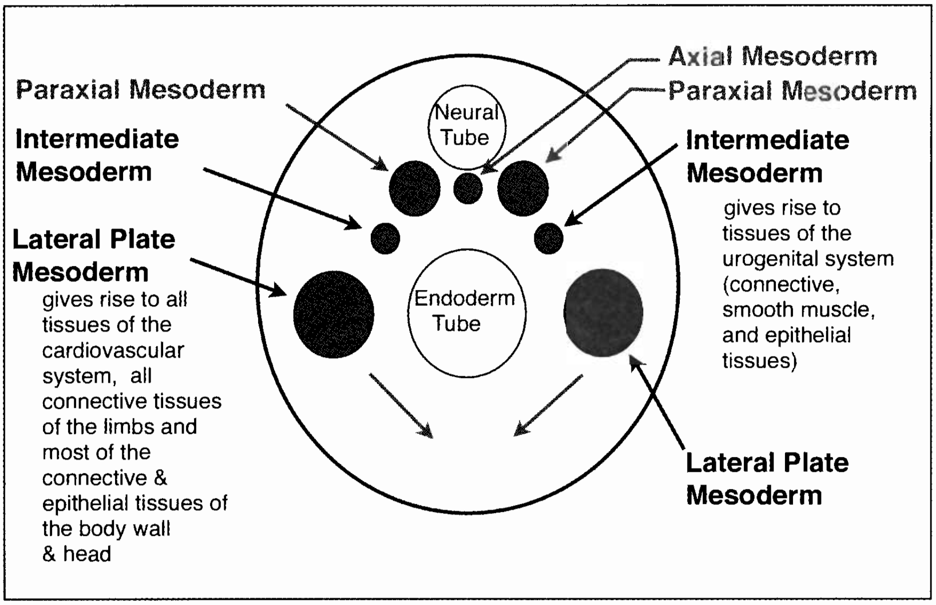


Figure 5: Horizontal cross-section depicting the development of the mesoderm into the intermediate mesoderm and lateral plate mesoderm.

These buds are referred to as the pharyngeal, lung, liver and pancreatic buds (see Figure 6), and each evolves to create different structures. The pharyngeal buds separate from the endoderm tube and create the palatine tonsils and the thymus, thyroid and parathyroid glands. The lung bud forms the epithelial lining of the entire respiratory system. The liver bud gives rise to the epithelial linings of the liver and gallbladder while the pancreatic bud performs the same function for the pancreas. Finally, the caudal end of the developing endoderm tube is termed the cloaca. It gives rise to the epithelial tissues associated with the urogenital area.

Implications of Embryology for SI Practitioners

An appreciation and understanding of the embryological origins of the tissues of the human body can assist a practitioner of structural integration in a variety of ways. We acquire a refined vision of the connective-tissue matrix and fascial planes as well as developing a new way of conceptualizing muscles and their associated myofascia. In this way we refine our understanding of the vision of Ida Rolf's Ten Series.

Finally, we begin to see the whole, known as the human organism, and in so doing begin working from the third-paradigm perspective of holism. We can now conceive of the connective-tissue matrix being derived from two separate germ layers, the mesoderm and the ectoderm. The connective-tissue contribution derived from the mesoderm layer gives rise to most of the bones, tendons, ligaments, and fascial layers of the body. Specifically, as we have seen, the paraxial mesoderm gives rise to all of the connective tissues responsible for creation of the axial skeleton (vertebrae, ribs, and some bones of the base of the cranium). The lateral plate mesoderm gives rise to the connective tissues of the extremities and some connective tissues related to the cranium.

In the case of the lower extremity, some of these connective tissues will give rise to the innominate bones, femurs, tibiae, fibulae, tarsals, and metatarsals. In the more cranial region of the developing embryo, the lateral plate mesoderm gives rise to the connective tissues that will eventually evolve into the clavicles, scapulae, radii, ulnae, carpals, and metacarpals.

Recall that *all skeletal muscle* is derived from the paraxial mesoderm. This understanding allows us to conceive of three categories of skeletal muscle. One category is the group of muscles that connect axial skeleton to axial skeleton. This group of muscles migrates into the connective-tissue matrix of the sclerotome (a subregion of the paraxial mesoderm), which will further differentiate into the "origin" and "insertion" of this first order of skeletal muscle. Examples of this first order of skeletal muscle are the multifidi, diaphragm, and scalenes. These muscles have their origin and insertions on osseous structures derived from the paraxial mesoderm – specifically the sclerotome.

A second category of skeletal muscle connects axial skeleton to appendicular skeleton. Examples of this category include the psoas, quadratus lumborum, and serratus anterior. Like all skeletal muscles, these originate in the myotome subregion of the paraxial mesoderm. However, in this case the muscle migrates into the sclerotome *and* into the lateral plate where it "finds" its eventual osseous attachments. The psoas illustrates this category of skeletal muscle perfectly. The psoas muscle is "created" in the myotome region of the paraxial mesoderm. As it develops, one end will migrate into the sclerotome region that will eventually become the lumbar vertebral bodies. The other end will migrate out to the lateral plate connective tissues and wait for the emergence of the lesser trochanter from this region of the mesoderm.

Finally, consider a third category of skeletal muscle that connects appendicular skeleton to appendicular skeleton. Examples of this category include the intrinsic muscles of the hand and foot. Once again, we have the intrinsic muscle originating in the myotome region of the paraxial mesoderm. However, in this case it migrates out to the lateral plate to "look for" the connective tissue fated to become the osseous attachments of these structures.

As practitioners, our desire is to affect the whole while touching a specific region. While contacting the myofascial element of the diaphragm we can now conceive of holding the connective-tissue matrix associated with the sclerotome: the entire spine, the ribs and the base of cranium. While contacting the myofascial element of the psoas, we can, in our mind's eye, reach *up* into the sclerotome (axial skeleton) and *down* into the lateral plate associated with the lower extremity (appendicular skeleton). While contacting the myofascial element of the intrinsics of the hand, we can visualize the connective-tissue matrix of the lateral plate associated with the upper extremity.

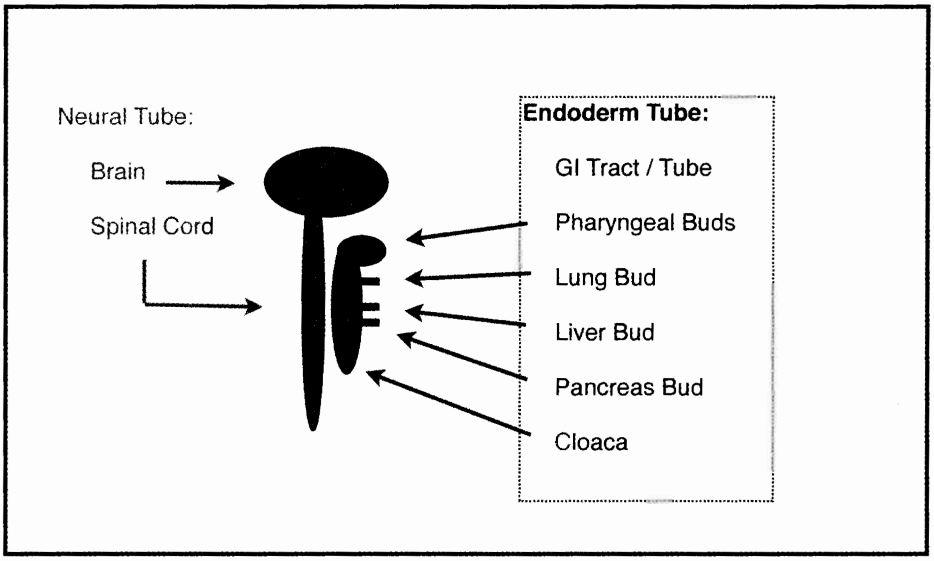


Figure 6: Sagittal cross-section depicting the neural tube and the endoderm tube

Next, consider the special case of the cranium, which receives connective-tissue contributions from both the mesoderm and the ectoderm. Recall that the neural crest ectoderm gives rise to a small but important contribution to the connective-tissue matrix. This is the *most* cranial portion of the developing embryo, and the neural crest contributes to a variety of connective tissues making up the cranium. Current evidence suggests that all bones related to the viscerocranium come from the neural crest. The bones of the neurocranium come from either the neural crest (frontal and parietal bones), the mesoderm (occipital bone), or from both germ layers (ethmoid, sphenoid, and temporal bones).

The viscerocranium is intimately related to the gastrointestinal tract (endoderm layer), while the neurocranium is intimately related to the neural tube (ectoderm layer). As mentioned above, the osseous structures associated with the viscerocranium are derived from the neural crest ectoderm. It is interesting to note that the muscles of mastication and of facial expression are related to bones originating from the neural crest. As practitioners we can conceive of our work with the face, jaw, and palate not only as the relationship of viscerocranium to neurocranium but also as relating viscerocranium to the guts via its association with the endoderm tube. Similarly, we can conceive of working with the galea aponeurotica (the connective tissue covering the top of the cranium) or the prevertebral fascial layer of the neck and relating this work to either the viscerocranium or the axial skeleton.

In conclusion, an appreciation of the embryological origins of tissues can assist the SI practitioner to "hold the whole" while working with a client. This intention of holding the whole is an important aspect of the presence a practitioner brings to each moment of each session. The vision of what is possible for the client is transformed. Quality of touch evolves. The science that is embryology informs the artistry that is structural integration.

Endnotes

1. For more information on the three paradigms see: Maitland, Jeffrey, "Das Boot." *Rolf Lines*, June 1993 (Volume XXI, No. 2), pp. 1-7.
2. For more information on embryology see: Sweeney, Laura J., Ph.D., *Basic Concepts in Embryology: A Student's Survival Guide.* New York: McGraw-Hill, 1998. This was the source for most of the embryology text in the article.
3. My initial SI teacher, Peter Melchior, used the term "spirit thread" to illustrate the connections between the sessions of the Ten Series.