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Bone is Fascia

Stephen M. Levin

Schleip et al's (2012) *What is 'fascia'? A review of different nomenclatures,* as a starting point and with subsequent posts (Adstrum et al 2016, Stecco et al, 2018), it is clear that nothing is clear: fascia nomenclature is in a state of flux. The definition of fascia keeps expanding and what is now considered fascia includes all the muscles except the cells encased within epimysium and perimysium, the nerve devoid of its neural component, the gut devoid of its digestive cells, and the organs (kidney, heart, liver, etc.) devoid of their specialized organ cells. In fact, anything that encapsulates or connects anything to anything else in the body with the exception of skin, bone, cartilage, the inside of cells, and anything that takes a compression load, is considered fascia. (It is obscure to me just what the basis is for excluding the body's firmer structures). More simply defined, fascia seems to be that which is not parenchyma (the functional tissue of an organ as distinguished from the connective and supportive tissue).

Since there is a range of opinions in the medical and scientific community as to how the term "fascia" should be defined, those of us in the field need to make up our own minds as our understanding of how tissues in the body functionally interact continues to emerge. From my perspective as an orthopedic surgeon, manual therapist, and structural theorist, we might think of the body as a multi-purpose building with supporting walls and structure and multiple partitions with some of them load-bearing, and others non-load-bearing. Many of the rooms are crowded with manufacturing processes and some have dual use. The walls (fascia) give form and continuity to the totality of it all and resists the external entropic forces pulling it apart. The various apartments and rooms may be filled with stuff (parenchyma) but without the internal and external fascia walls, there is no structure, no organ, no function, just a soupy slurry of cells enclosed in a formless leather flask. All organs are fascial structures that contain and support the specialized cells within them. Kidney cells are specialized cells within the kidney fascia, neurons are specialized cells within the neural fascia, etc. It is the fusion of parenchyma and its fascia that define a tissue, organ, and organ system. These fascial apartments with their occupants fill the space within the building. Then there is fascia, the building, in which a whole host of activities and events are transpiring within its many apartments and rooms and that often is the organizing structure that facilitates the parenchyma's functionality.

The role of the fascia

It is possible to sub-categorize the fascia into internal systems that primarily concern themselves with internal functioning of their sub-system and the fascial sub-system that is mainly concerned with handling the external forces affecting the body and interacting with the ground.

In the first category, we can place the genitourinary fascia sub-system that encapsulates the kidneys, ureters, bladder, etc., and joins them into a functional unit. A similar fascial network exists for the gastrointestinal system, the respiratory system, and so on. In these systems, although the parenchymal cells may be the soul of the unit, they only function as they do because of their fascial organization. The fascia is there to support the parenchyma. In these tissues and organs, the parenchyma are events within the fascia building and are not intimately involved with the body's response to external forces. In fact, the body seems very good at shielding these events from external forces. Breathing, bladder, and bowel

functions continue to the extent that they can because they are partially shielded from these forces, even under extraordinary stressful conditions.

Then there is the part of the fascial system that deals with external forces head-on. This is the fascial network that, with its enclosed parenchyma, interacts with the external world, be it in utero, sea, land, air or space. As examples, we can include the strong fascias such as the thoracolumbar fascia, the fascia lata, the tendons and ligaments, and also the less dense peri-muscular fascias and assorted connective tissues. In these, the parenchyma exists to support the fascia. Most think of this part of the network as the only fascia system, but, as indicated above, there are others that are integrated with it. They are all connected but usually have their own specific roles to play, each sub-system of fascia both independent and interdependent within the entire fascia system.

What about the bone?

Is the bone part of the building's structural support or just an event within it? To argue that bone (and cartilage and discs as well) is a specialized organ with its parenchyma as its primary role, an event separate from the function of the fascia so it should not be included as a fascia structure, belies the embryologic development of bone and its existence as part of the fascia network, i.e. its functional role. It is not the case that first osteoblasts exist and then the fascia room is built around them, but rather that the room is in the process of construction and the osteoblasts are brought in to plaster the walls. The walls then become part of the load-bearing structure of the fascia building. Bone is ossified fascia that incorporates various parenchyma cells within its interstices. Osteoblasts exist within the interstices of fascia just as muscle cells exist within the interstices of fascia and their very functional existence is dependent on this fascia structural continuum. Osteoblasts and other parenchymal cells reside within the walls of this boney apartment but their residence is not its sole purpose: the walls are there to help hold up the building. Osteoblasts are there to support fascia; fascia is not there to support the parenchyma (the way fascia is used in the kidney or liver). If the room is no longer needed, the osteoblasts are evicted, the plaster is peeled from the walls, and the now non-weight-bearing walls remain as part of the fascial support network but are used in other ways. Other functions such as hemopoiesis may take up temporary residence in the apartment and share some space, but those cells may be structural freeloaders, contributing very little to the building's structural maintenance.

The continuity

Functional anatomy now describes integrated systems, when in the past we only thought in terms of independent structures, and the various fascias of the body are now recognized as part of a "fascial system". As we move away from thinking of muscles as isolated structures, we must recognize that muscles are useless unless they pull against something. A functional support and motor system must include the compression elements such as bones. In a musculoskeletal system, where does a muscle end and the bone begin? Unless the muscle cell pulls on fascia, and fascia pulls on bone, nothing much can happen. As Guimberteau and Delage, (2012), Huijing and Baan (2001), and van der Wal (2009), have shown, boundaries in the body are artificial, arbitrary, descriptive conveniences. Tissues in the body are not contiguous, just sharing borders, but continuous, transmuting into one another. The body is an open-office plan, a union of organs united under one roof. The distinction between the muscle parenchyma and its various -mysiums is a subjective one that is inconsistent with its function. Where endo-/peri-/epimysium ends and tendon, ligament or periosteum begins is arbitrary. Like a doorway connecting rooms in an apartment, the periosteum is continuous with both the fascia of the muscle and the matrix of bone.

If fascia is considered a continuum, and tendons and ligaments are fascia, then to what do they continue when they transition to bone? The tendon at one end of a muscle is a

continuum of the fascia components of the muscle and continuous with the tendon on the other end of the muscle. If tendons and ligaments are continuations of the muscle fascia, then the periosteum (fascia by everyone's definition) is a continuation (not an attachment but a continuation) of the tendons, the Sharpey's fibers are a continuation of the periosteum and the fibrous matrix of the bone is a continuation of Sharpey's fibers and out the other side. The bone's fascia interpenetrates the bone as the muscle's fascia interpenetrates muscle. Bone is not a crystalline column of calcium, it is a stiffly starched shirt very much dependent on the structure of its fabric for both form and function. The underlying structure of the bone is the same soft collagenous connective tissue network that composes the rest of the fascial organ. The calcium crystals manufactured by the bone's parenchyma do not become part of the bone's parenchyma (its inner workings), or a product to be excreted or used elsewhere in the body; they become part of the fascia support system of the bone organ. However, the calcium crystals do not dictate the layout of the boney apartment, they are stiffeners that strengthen the collagenous weight-bearing walls.

Do we define "muscle" as only the parenchyma or do we also include its structural support system? Remove the parenchyma from a muscle and you have a ligament. It would remain as part of the fascia continuum that supports the body's role in contending with external forces (the thoracolumbar fascia comes close to that description). The role of the muscle parenchymal cells is to stiffen and tension its fascia; it is the fascia that is the soul of the parenchyma/fascia interaction. If the interstices and structural functioning of muscle, the endo-/peri-/epimysium, are to be considered fascia, then why exclude the interstices of bone from being considered fascia, as the cells within it are specialized for their function as much as the muscle cells are specialized for theirs?

It is not about stiffness

A distinction by Schleip et al (2012) seems to be that anything that is stiff and resisting compression is not fascia. This would be at odds with the findings of Davis (1867), Wolff and Wessinghage (1892), and then Stopak and Harris (1982), who showed that fascia is transmutable and can manifest as cartilage or bone when under compression and can revert to its compliant state when the compression is removed. As noted above, the parenchyma of bone, cartilage, discs, etc. come after the room is built and only when there is a 'demand' for the product. As the manufacturing process of the stiffer matter begins, the structure comes before the contents. Some make the assumption that fascia only pulls. There cannot be pulling without pushing and isolated areas of fascia may at times stiffen. Skeletal muscles are hardened and stiffened by their parenchyma interacting with their fascia. And think of all the soft-bodied creatures and the "muscular hydrostats", (worms, tongues, elephants' trunks, tentacles, most penises), where that fascia stiffens without bones. Biological tissues often have properties that are consistent with "soft matter" (Gonzales-Rodriquez et al 2012, Gatt et al 2015) rather than the hard matter physical responses we usually expect of them. For example, many fascial components and some parenchymal matter may undergo phase changes, often in less than the blink of an eye. Ice changing to water energy-wise is a big deal, but flowing or stiffening of biologic matter is a body temperature event that may depend on such things as rate or force of loading. (For example, see the slow-mo of a boxer being punched, https://www.youtube.com/watch?v=l9OH5PWOjd4&frags=pl%2Cwn). Ossification is only one way that fascia stiffens, so stiffness should have nothing to do with defining fascia. Stiff or compliant, the structure remains part of the fascial continuum whose role is to contend with external forces acting on the body.

What's in a name?

It is expedient to give different names to regions of the fascia that have different functions; calling mesentery "mesentery" does not diminish its role as fascia. It is not necessary to take a hard stand as to what is or is not fascia as the science in the field keeps evolving. As

Schleip et al (2012) and subsequent associated researchers (Adstrum et al 2016, Stecco et al, 2018) are essentially saying, fascia is what we define it to be. Muscle has muscle cells within its fascial encasement, bone has osteoblasts and osteoclasts within its fascial encasement, cartilage has cartilage cells within its fascial encasement, just as pericardium has heart cells within its fascial encasement, mesentery has digestive cells within its fascial encasement, the meninges have neural cells within their fascial encasement, and pleura has lung cells within its fascial encasement. How we define "fascia" is governed by its role in connecting, encapsulating, and supporting parenchyma, not by its parenchyma's functions.

What I am suggesting is that the locomotor system, the structure of the body that has most to do with managing external forces, is a fascial continuum with specialized cells within certain of its parts and it is the building that encapsulates and physically supports the other functional components of a body. These specialized cells may be separated into fascial apartments, but they are linked by the closed kinematic chain network (Levin et al 2017) of hallways and stairways that unite them into a single structure. This unified structure resists the external forces that would crush it or tear it apart. The major role of the parenchymal cells within this fascial complex is to support the fascia in its struggle to resist external forces. In a kidney or liver, it is the parenchyma that is primal and the fascia facilitates the space while the parenchyma provides the function. If we are concerning ourselves with the fascia of the locomotor and structural support system, what holds the body up and gets it moving, then surely the bone is within that definition: it is just stiffened fascia. Ossified fascia (bone) is not a non-weight bearing wall in an apartment where there is an event (as fascia would be in the kidney or liver), but a load-bearing support integral to the structure of the building. If we are defining a fascial continuum which encapsulates and structurally supports the cellular components, then the ossified fascia must be included in that definition. The bone is an organ with its parenchyma having internal obligations but it is simultaneously an integral component of the fascia support system that is adept at dealing with external forces. Its dual use does not exclude it from its role as an essential component of the fascia locomotor and support system.

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