

## FASCIA, FABRICA OR FABRIC – On the Origin of Fascia

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### Abstract

In this essay the author will also have to address the matter of How to Define Fascia. He will approach the issue from the two domains of science he stands for: anatomy and embryology. And he will do so applying the phenomenological approach which he has been able to learn during his decennia long experience as a teacher in dynamic morphology and embryology.

As an anatomist, he participated in a groundbreaking project conducted in the 1980s at the Maastricht University in The Netherlands on the organization of muscle and connective tissue in the so-called Posture and Locomotion System (PLS)<sup>1</sup>. The outcome of this research challenged the usual anatomical thinking in discrete and thus decomposable structures such as muscles, bones and ligaments. It opened the view of a functional architecture of muscle and connective tissue in the PLS. Architectural thinking appears to be an important necessary correction of the usual image of the so-called 'muscle person' (or better: addition to it). It is this image that still plays a dominant role in our modern minds as far as the functional anatomy of the so-called musculo-skeletal system is at stake. Moreover, it will be shown that an architectural consideration of fascia and connective tissue fits better with the modern concept of biotensegrity in the body and in the PLS in particular than the classical anatomical notion of muscles, ligaments and other PLS-elements as discrete structures.

As embryologist who became acquainted with the ideas of osteopathy about fascia during his teaching activities, he also logically put the question Where does the fascia come from? It will be defended here that the mesenchyme of the so-called 'mesoderm' can be revalued as the primary manifestation of fascia as a system or 'organ'. It will be shown that the 'mesoderm' is not just one of the three so-called germ layers, but actually the morphological substrate of what will later be our psychosomatic interior and innerness. Fascia can be appreciated as the matrix substrate of our body or as 'the fabric' (the texture) "in which all organs are embroidered" (*Levin, 2018*).

As said before the line of thought followed in this article will be to a large extent a phenomenological approach. Trying to understand What fascia is and What it could mean, is considered here as more important than to explain the functional properties and possibilities of the fascial system (if anything like that exists).

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<sup>1</sup> Here the notion PLS (Posture and Locomotion System) is preferred for reasons that will be cleared in the text. 'System' instead of 'Apparatus' because the anatomical 'Locomotion Apparatus' (consisting of bones, joints, ligaments and muscles and so) is a too narrowminded concept: at least the nervous system should be partly incorporated in order to function as PLS system. Posture **and** Locomotion because 'locomotion' is too poor a notion: in humans standing in equilibrium (posture) is typical and essential, keeping one's upright position is an integral part of our bipedal locomotion. The notion 'musculo-skeletal system' will be shown in this text to be a too poor and reductionistic concept that should be abandoned.



## Foreword and accountability

From 2009 to 2020 I have been able to contribute to the discussions on the theme of *Fascia, what it is and why it matters*. It started in 2009 with the presentation of my 'rediscovered' research from the 90s of the last century (!) concerning the organization of muscle and connective tissue in the so-called musculoskeletal system that I performed at the time with colleagues Van Mameren and Drukker of the Maastricht University.

During a presentation as a keynote speaker at the second International Fascia Research Congress in Amsterdam (2009), I presented the concept of architecture of muscle and connective tissue instead of, or in addition to, the usual anatomical thinking in discrete units of muscle, connective and bone tissue. I also brought there the idea of 'dynaments' as the architectural units of connection and force transmission in the so-called Posture and Locomotion System. At the time, this concept was enthusiastically received and continued by many. In this context I mention names such as Thomas Myers, Tom Findley and Robert Schleip. In the years that followed I was active in lectures and seminars at conferences on fascia and also by participating in committees looking for the most comprehensive, exact definition of the term 'fascia'. In those years I also increasingly found an association between embryo and fascia by applying my phenomenological approach as developed in human embryology to fascia.

Looking back on that decade of active contribution to fascia research, I realize that I tried to pass on two major concepts to the 'fascia community'. First, that current analytical-spatial anatomical thinking completely hinders a correct understanding of what a 'system' like fascia could mean. In fact, our totally anatomized<sup>2</sup> view of the human body is an artifact ("Anatomy destroys more than you like" was my slogan). In this context, I became acquainted with the concept of biotensegrity. So I started to try to make people clear that the architectural concept of the so-called musculo-skeletal system that I advocate, fits much better with this functional (biotensegrity) concept of the organization of the human body in general and of the Posture and Locomotion System in particular. The second major concept that I have tried to highlight is that the current attempts to define fascia as a kind of spatial connective tissue system represent an overly reductionist view of fascia. That this definition in the narrower sense should be extended with a definition of fascia in a broader sense, starting from the idea that the embryonic mesenchyme ('mesoderm') can be considered as the fabric of our inner self, the matrix in which all organs are woven.

In the present article, both concepts and related ideas are brought together in a line of thought that runs from 'fabrica thinking' of Andreas Vesalius in 1543 (*De Fabrica Humani Corporis*) to 'fabric' (or weaving) thinking in the context of the biotensegrity concept as expressed by Stephen Levin: "Fascia is the fabric of the body; not the vestments covering the corpus, but the warp and weft of the material" (2012).

I am aware that the content of the article may come across for some people as 'little scientific' or 'too general'. Throughout my life I have remained the generalist (anatomist / embryologist) and as a phenomenologist I search for sense and meaning and put less emphasis on explanations.

Jaap van der Wal, May 2020

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<sup>2</sup> I could rightly use the term 'atomized' here. The 'anatomical view', that is to say the view that 'wholes' assemblies are composed of parts and particles, has become dominant in all possible domains of science and culture: atomic theories, individualization of communities, molecular chemistry, etc. etc.. The scientific obscurity of terms such as 'holism' also point to this trend..

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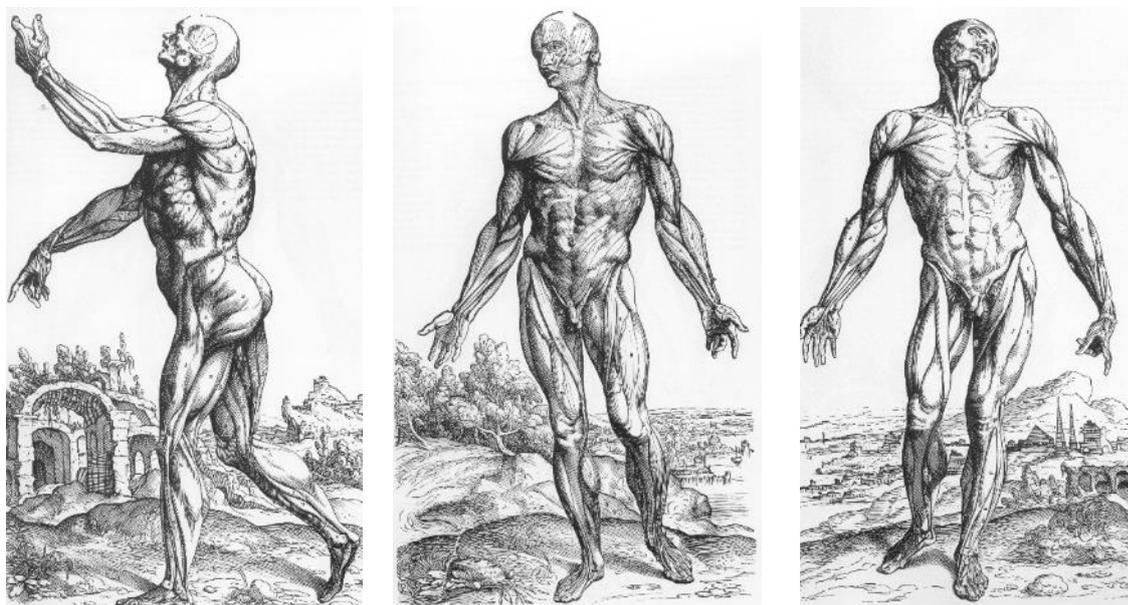
## FASCIA, FABRICA OR FABRIC – On the Origin of Fascia

Fascia is the fabric of the body; not the vestments covering the corpus, but the warp and weft of the material (Stephen M. Levin, 2012)

Anatomy destroys more than you like (Jaap van der Wal)

It was five centuries ago that Andreas Vesalius opened the eyes of the Western world to the analytical and scientific way in which we, as modern people, nowadays view ourselves and the world. His publication, *De Humani Corporis Fabrica Libri Septem*, represents nothing less than the birth of anatomy as a basic science, and as a basic attitude of modern medicine. The word 'fabrica' has several meanings: "factory" (building, construction); "fabric" (textile, weaving); and "structure" (organization, construction). There is little doubt that when choosing *Fabrica* for the title Vesalius did not think in terms of textiles or materials, but as the metaphor of the building (Garrison 2016). He made that abundantly clear when he titled his *De Humani Corporis Fabrica*. And thus, he ushered in the age of modern anatomy.

The anatomical mindset of today is still heavily influenced by the work of Vesalius. That mindset considers the human body to be something built from discrete parts. However, in my view, that concept is sorely in need of an update. It is imperative that we come to embrace a new more holistic view of the human organism in order to truly and fully understand the 'anatomy of fascia'. The notion 'anatomy of fascia', as I might explain, could be considered to be a *contradictio in terminis*. We must move beyond the mere 'building blocks' concept to a deeper understanding of the architecture - the structure - of the body. In so doing, we can examine and therefore more fully appreciate the relationships between the so-called parts and elements of the body and their interest. Such updated view may lead to a shift in thinking of *Fabrica* into the sense in which orthopedic surgeon S.M. Levin (a founding father of biotensegrity) meant it when he described fascia as "the fabric of the body" (Levin 2018).



Three of the 'muscle men' as they are presented in the *De Humani Corporis Fabrica libri septem* (*Seven books of the Structure of the Humane body*) by Andreas Vesalius, Basel, 1543. Three of fourteen anatomical drawings made by Johan Stefan van Kalkar. The 14 plates next to each other show a panoramic drawing in the background of a region just outside Padua, Italy.

## What is in a name?

Before moving on, let me be perfectly clear, this suggested shift in thinking in no way diminishes my admiration for the scientific genius of Vesalius as the ‘founding father’ of modern anatomy (*Van der Wal 2006*).

Centuries of dissection have now shown the anatomical plates of Vesalius to be somewhat outdated. Anatomy as a scientific discipline however also presented and proclaimed the near paradigm, that the parts that are found by means of dissection are considered ‘building blocks’ by which the body is constituted. The paradigm that our bodies are made up of the organs and the parts that the anatomists describe, is still alive and kicking - as are the images of Vesalius burned on the retina of modern man and almost indelibly planted in our brains (see the figures above). For example, anyone who thinks of the so-called musculoskeletal system ‘sees’ the Vesalius muscle man/person. But in fact, this image is an artifact. The fundamental method of the anatomist after all is dissection - a process that disassembles the ‘whole’ into ‘parts’.

This perhaps explains why the connective tissue, the fascia, has become the stepchild of medical anatomy. Even in the 2005 edition of Gray’s Anatomy, fasciae are still identified as “masses of connective tissue units large enough to be visible to the naked eye”. It continues: “In general, the collagen fibers in fasciae tend to be interwoven and seldom show the compact, parallel orientation seen in tendons and aponeuroses” (*Standring 2005*). It is the anatomist who has discriminated and assigned parts (fasciae) to the connective tissue continuity that others call a fascial system (*Schleip et al. 2012, Stecco 2018*). In doing so, the anatomists ‘created’ fasciae as anatomical structures related to body walls or regions (e.g. fascia colli media), to organs (e.g. fascia renalis) or to body parts (e.g. fascia cruris or fascia lata). Thus, the names of fasciae are almost always related to either anatomical units or organs. So, that is in the name: it says nothing about functionality, it is purely based upon non-functional categories of topography.

But are fasciae in the body really discrete anatomical elements or are we dealing here with a continuity that qualitatively is not and cannot be known by the anatomist? A growing body of evidence supports to move away from thinking about fasciae as discrete anatomical elements towards the definition of fascia as a system of continuity and connectivity (*Stecco et al, 2016, Adstrum 2017*). Schleip puts it as follows: “Fascia is the dense irregular connective tissue that surrounds and connects every muscle, even the last myofibril, and every single organ or the body, thus forming continuity throughout the body” (*Schleip 2012b*). Later in this excerpt more about definition.

In his book *Fascia, what it is and why it matters*, David Lesondak (2018) exclaims: “While I agree that embalmed cadaver fascia can appear as interesting as wet insulation, I do wonder if the very act of so very casually disregarding the connective tissue sets up an unconscious bias towards minimizing its importance?”. His rhetorical conclusion is “Does dissective exploration lead to dissective thinking?”. I can only endorse it. Following this line of thought, is something such as the traditional ‘muscle man (person)’ merely then an artifact - something we made with our scalpels and our minds? Is it logically consistent to first divide the body into parts, tissues, and organs and then look for another tissue or organ that holds the body together as a whole? Or, in more philosophical terms, do Whole and Parts even belong to similar categories?

In functional anatomy, however, the ‘musculoskeletal system’ is still often thought of as a complex construct of discrete elements (bones) connected by (hinged or non-hinged) ‘joints’ that are moved by muscles that attach to the bones and in turn are moved by a central nervous system. In the field of functional anatomy the engineering approach in which the structural analysis is the main tool, is dominating: discrete *structural members* (anatomical

bones) are the sources of stability and *structural joints* are the sources of potential flexibility (i.e. instability via displacements) and are *pre-assigned* and *pre-formed* in a given particular construction or mechanism. In terms of tensegrity (see later) there is no *fixed assignment or order* between members and joints necessary at all, which leads to the fundamental disappearance (and unnecessary) of static or kinematic determinacy (Blyum 2020). The classical anatomical construct of a 'musculoskeletal system' can also be questioned on both functional and physiological grounds. In physiology for example, the functional unit for 'muscle' is the motor unit. The central nervous system orchestrates motor units. The brain knows nothing about the muscles: for decades it has been clear that the brain is not organized in muscles but in movements and targeted actions.. Of course, muscles are morphological units (vascular for example: think of isolated muscle cramps), but whether the musculoskeletal system in the narrower sense is indeed an anatomical construct of bones, ligaments and muscles (and possibly nerves) can be questioned on such functional and physiological grounds. Moreover, would an anatomical concept such as 'musculoskeletal system' also survive a deeper re-evaluation of the principles of anatomy?

### **Anatomy and Architecture – contrary of complementary**

Simulation experiments in the 1980s at the Maastricht University in The Netherlands questioned the existence of ligaments in the elbow joint - at least in the way they are usually described, namely as regular dense collagenous connective tissue structures that run from bone to bone (van Mameren 1983). A connective tissue-saving dissection was made starting in the region of the elbow joint. This time the connective tissue and the fascial structures were no longer considered to be 'excess' tissue that had to be removed to make structures 'clean', the old-fashioned approach in a way. The collagenous dense connective tissue that exists in this region as fasciae, as inter- and intramuscular septa, as aponeuroses and tendons and so on, was visible made by means of this 'sparing' dissection in its context and its continuity with muscle and bone tissue.

Evidence showed that many of these 'traditional' connective tissue structures do not exist as discrete elements (Van Mameren and Drukker, 1984, van der Wal 1988, 2009). As an example, the fascia antebrachii could be dissected as a separate anatomical structure, but such a discrete unit does not actually exist. In order to create it, one must break the continuity with hundreds of muscle fibers that attach proximally in the forearm to this so-called 'envelop' of epimysium (or fascia). In this area, the epimysium is not an enveloping membrane at all, but an aponeurosis of regular dense collagenous connective tissue along which the muscle fibers reach the humerus. The fascia here also is continuous with intramuscular septa between the various forearm muscles. However, distally in the forearm, the fascia antebrachii is of a completely different nature. Here the fascia does look like and thus functions as a sort of enveloping sheath. The loose-meshed, fibrillary connective tissue beneath this distal part of the antebrachial fascia creates a space between the fascial layer and underlying muscle and tendons where movement and gliding are possible. Similar remarks can also be made, for example, with regard to the fascia cruris.

Later in this article it will be argued a primary aspect of fascia that it may *connect* as well as *separate* (i.e. creating space, making movement possible). The fascial connective tissue creates mechanical relationships between (in this case) muscles and the fascial epimysium but also between units of muscle tissue and periosteum. Fascia makes movement possible by creating spaces and fissures, for one example in the case of tendon and muscle sheaths. On the other hand, fascia also creates mechanical relationships between adjacent muscles. These relationships both govern and guide tensile forces that occurs during movement throughout the body.

It should be noted that 'connective tissue-saving' dissections may create a different kind of artifacts namely when in this way discrete fascial 'elements' are created. All the fascial 'parts'

and the complex connective tissue devices that can be found ('dissected') in this way e.g. in the forearm, can only be understood if the (mechanical) **relationship** of these connective tissue septa and layers with adjacent muscle tissue is known. It may come as no surprise that these relationships can only be seen and determined during the dissection procedure itself! This mechanical relationship is not a matter of spatial location (so anatomy) but a matter of functional relationship (connecting, governing and passing on forces, separating, making movement possible, etc.). In other words: one must know the architecture of the fascial system or connective tissue device. Architecture is different from, or rather, is the complement of anatomy. Anatomy informs us about the '**Where**', architecture tells about the '**How**' (the mechanical relationships of the connective tissue with its environment are).

**How** matters! Anatomical representation alone is insufficient. In anatomical atlases the 'muscle man' (person) still often is presented as a collection of discrete muscle units. Likewise, a representation of the 'fascia person' as a construct of discrete layers, septa, aponeuroses, etc. could have the same shortcoming. Relationships between the two would be missing in such representations. The anatomy of 'parts' must be supplemented with an architecture of force-controlled relationships between different anatomical elements.

This principle is now also recognized in *Gray's Anatomy*: "*From a morphological point of view, most anatomy books have described the skeletal muscles of the human body as being discrete activators with clear origins and insertions (van der Wal, 2009). Recent analyzes of published anatomical cadaveric studies have challenged this assumption revealing that the active components of the locomotor system are directly linked by fibrous connective tissue (Wilke et al. 2016)*" (Standing 2015).

### Not 'in parallel' but 'in series'

There is another argument for considering the anatomical approach to fascia as insufficiently informative about the function of that same fascia. The traditional dissective approach of the anatomist has led to the idea that around a synovial articular joint there exists a connective tissue construct of so-called ligaments reinforcing the joint capsule that preserves the integrity of the joint. In this model the ligaments function as passive collagenous connective tissue elements whose fibers are supposed to run from bone to bone and therefore to provide movement stability only in those positions of the joint when the given ligament resists further displacement because it is maximally tensed. In all other positions of the joint, when the insertions of the ligament are closer together, the ligament is considered 'flaccid' and is not considered to contribute to the stability of the joint. Anatomists usually think from 'outside to inside' - from 'superficial to deep'. On the outside (in the anatomical arrangement) there are, above and parallel to those ligaments, the muscles. They function as joint-stabilizing units in a more 'dynamic' way. This concerns the so-called 'shunt action' of the muscle. This means that the muscle is in continuous tonus and can tension itself (by so-called 'contraction') in all positions of the joint. In this way the muscle dynamically transmits tensile forces around the joint and dynamically maintains joint integrity and stability. But is this really the case, is this anatomical model of the situation correct?

When connective tissue-saving dissection protocols are followed, it appears all too often that the so-called 'ligaments' do not *really* exist in 'objective' architectural reality but rather emerge as an artifact of the dissection process itself. This is explained by the example of the supinator muscle in figure 1. Figure 1A shows the "classical" situation: the joint capsule (blue) is reinforced by ligaments (yellow). In this example the latter are the so-called collateral ligaments as well as the ligamentum annulare, which as a kind of connective tissue ring, would stabilize the head of the radial bone relatively to the ulna and the humeral capitulum. At first, such a decision to figure a strong anatomical designation-labeled 'ligaments' doesn't appear to be too harmful to the functional interpretation. However, upon

closer inspection, it does create confusion and completely misleads functional anatomists and kinesiologists.

Once the ligaments are dissected away from the muscles and their connections severed, however, there seems to appear an organization of a kind of the **geometrical parallelism**. The muscles form a longer, superficial layer in respect to the joint, and the ligaments form a more deeply situated shorter, inner layer. The muscles provide a dynamic positional control throughout the whole range of motion of the joint while constantly adapting and maintaining their tension or tonus (in what usually is referred to as 'eccentric' and 'static' contraction but maybe better could be interpreted as 'stiffening'). Meanwhile the inner ligament layer only passively controls joint stability, most of the time (only) efficient at certain extremes of the range of motion when the ligament is tightened. This is illustrated in figure 2A <sup>3</sup>.

Such interpretation raises obvious doubts. First, it is not energy efficient. Using an active function of a muscle for a positional control of a joint costs a lot more metabolic energy than utilizing to the maximum the cost-free passive stiffness of connective tissue. However, it is again inefficient that the effectiveness can only be used for part of the joint's range of motion (exceptions, see footnote 5). Secondly, the periarticular connective tissue usually contains tension- /stretch-receptors (Paciform) Lamellated corpuscles (LC), Ruffini like Corpuscles (RC), which seemingly contradicts the slacking of a ligament during concentric movement as is assumed in the classical concept of an in parallel geometry of ligaments and muscles (fig. 2A). Thirdly, it seems logical in the current model that receptors located in iuxta-articular structures, which are thus located closer to the so-called pivot, have to travel a smaller arc distance in order to 'detect' a certain angular displacement of the joint compared to similar receptors in more periarticular structures such as muscles and tendons. This would be a drawback for muscles to function as dynamic pivot stabilizers (given the higher threshold of their receptors for detecting angular displacement) with even the risk of counterproductivity. While the anatomical distinction between the elements that are labeled as 'ligaments' and other surrounding periarticular connective tissue related to periarticular muscle tissue is so blurred that therefor often a distinction is made artificially by sharp cutting, the classical concept as to joint stability and integrity perhaps is based on outdated assumptions and might appear to be false, at least in the case of the lateral elbow region.

Figure 2B describes the situation as it becomes visible with the connective tissue-saving dissection. As a result, muscle fibers of the so-called superficial muscles appear are no longer in geometric parallelism to the connective tissue attachments as capsule, and ligaments across the joint. Muscle tissue is often geometrically **consecutive / serial** with the periarticular connective tissue. 'Sparing dissection' reveals a complex system of regular dense collagenous connective tissue layers and cases that (in the example of the elbow joint) converge to the epicondyle to which on their turn all muscle fibers of the superficial muscles insert (in order to reach in this way 'their insertion' to the skeletal element). No single collagenous connective tissue fiber appears to run here from bone to bone. As to the elbow joint it means that the muscle fibers attach to the epicondyle of the humerus via a system of 'fascial, epimysial and intermuscular' layers of collagenous connective tissue. In the case of the supinator muscle, for example, the ligamentum annulare also does not exist at all as an isolated discrete structure but appears to be organized serially (in serial geometry) with the muscle fibers of the supinator muscle. Figure 2B shows that in the current construction the connective tissue of the joint is brought to tension in ALL joint positions and

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<sup>3</sup> Of course, there are exceptions to this model. Collagen connective fiber fibers completely resist stretch. Therefore, the distance between the two insertions of a so-called ligament to the bones of the joint must remain the same in each joint position (may become shorter at most, as a result of which the ligament 'relaxes'). In the human knee joint, both so-called cruciate ligaments are so complexly spiral-shaped that in almost every position of the knee joint (part of) the collagen fibers are (is) tightened.

is capable of transmitting forces and signaling in the sense of mechanoreceptor triggering (Van der Wal, 2009).

Let us examine the differences between Figures 1A and 1B as well as 2A and 2B. Change of dissection changed the geometry. But the change of geometry causes a change of functional mechanics interpretation as well. Instead of two separate elements i.e. muscle and ligament, the system integrates muscle and ligament into a single kinematic mechanism, where they work simultaneously together in a geometrically 'in series' or consecutive (serial) organization. The difference between the situations in figures 1 and 2 describing the tensile forces transfer and joint stability (i.e. the connective tissue in more 'static' or 'passive' and muscle tissue more in a 'dynamic' or 'active' sense) is essential. In situation A discrete/separate connective tissue and muscle elements lay parallel to each other geometrically, situation B represents a much more logical situation in which the same muscle tissue and connective tissue are geometrically serial (consecutive) to each other. The latter situation allows them to form a morphological '**dynamant**' providing a different 'mix' of passive (periarticular connective tissues) and dynamic (muscle fibers) stiffness depending on the situational needs. Such a '**dynamant**' can put the periarticular connective tissue under tension in all positions of the joint, therefore is functionally force-transmitting and joint-stabilizing. Taken into account the three connotations made year above as to the 'classical' organization-model of the periarticular connective tissue, it may be concluded that introducing a '**dynamant**' interpretation of the connective/muscle fibers organization addresses those 'problems' by energy efficiency (a), explaining proprioceptive richness in iuxta- as well peri-articular connective tissue (b) and ability to detect angular displacement at the so-called pivot via the shortest arc length (c).

For years I have struggled with the dated idea that muscles are 'contractile organs. From physiology as from embryology there are good arguments to understand muscle tissue in principle as a (connective) tissue that can stretch **and** shorten, that can be stretched **and** shortened (Blechs Schmidt 2011). The muscle as a more dynamic form of connective tissue. (Levin 2015). I here propose designating the '**dynamant**' as a 'new' element in the construction of the Posture and Locomotion System (PLS<sup>4</sup>). Not as a morphological nor anatomical nor (neuro) physiological unit but as a hypothetical architectural unit. The '**dynamant**' consists of a zone of muscle tissue that is organized in series on both sides with 'connective tissue structures', if one prefers, fascial 'units'. See figure 3A en 3B.

On the one hand for example in the distal forearm, the latter can then appear as intramuscular tendons. The organization of the connective tissue is here anatomically determined. On the other hand (in the proximal forearm region), the 'connective tissue element' can manifest itself as an intermuscular septum or a 'muscle-covering' epimysial or fascial element. Here the connective tissue is more *trans*-muscularly organized (see below and Fig 3C). In the example of elbow and forearm used here, the force-transmitting architecture is organized proximally TRANS-muscular and distally INTRA-muscular (in separate muscles). The architectural *How*-relationships are in this case like warp and weft to the anatomical *Where*-relationships.

### **Biotensegrity – it is about two: pulling together and pushing apart.**

The tissue mix inside the dynamant enables it to provide different proportions of passive and active stiffening and tensile force transfer, depending on the functional context related to posture and locomotion. It may therefore be seen as the force-transmitting, flexible cable element of what is now called a *biotensegrity* system. In the traditional biomechanical model of the musculoskeletal system (or PLS), the bones are joined by connective tissue structures, (e.g. capsules and ligaments) usually creating joints that can be moved and positioned by

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<sup>4</sup> See footnote 1

active muscles. The standard biomechanics interprets and explains the anatomy of the organisms by implying the leading role of the compression elements (bones). Those transfer the main loads, assisted by the tensional elements that actively work in inherently unstable lever systems. This approach favors the active force generation by contractile muscles and reduces the collateral force transfer elements (ligaments etc.) to a secondary support and limiting function.

Biotensegrity approach offers the mechanical model that emphasizes the leading role of force transfers through the entire system that spread via the tensional elements. Compression elements in biotensegrity are ‘tension multipliers’ that enhance the stability throughout the integrated tensed framework. The biotensegrity approach thus prioritizes a global architecture of force transfer with variable morphology (dynamics) over an anatomy of individual force generators (muscles). Tensegrity offers a general solution to the issue of the stability / flexibility of structures at the level of *edges* and *vertices* and, as a system of inequalities, it encloses the most abstract concepts of struts / cables / bars. That is an important difference from engineering where the *members / elements* and *joints* are *pre-assigned and preformed* and captured in a particular construction or mechanism. Organisms of ‘soft’ matter have frictionless connections, lack rivets, screws or glues, have variable thicknesses, show constant changes in shape, etc. So, there is no fixed order between parts and joints, which fundamentally excludes kinematic determination (*Blyum 2020*).

In the classical architectural tensegrity model, the rigid elements (struts) are suspended in a network of continuous, more-or-less flexible, cables. Respectively, a biotensegrity system integrates both tension and compression - *pulling together and pushing apart*. The entire PLS can be considered a biotensegrity system with the skeletal elements pushing outwardly (‘expansion’/struts), and the force-transmitting elements fascial elements doing the pulling inwardly actions (‘compression’/cables). One could also characterize the tensional members as being responsible for the ‘togetherness’ of the organism, whilst the compression members provide the ‘apartness’ within the unity of the organism. In other words, the “sea of tension in which the rigid elements are suspended” (*Myers 2015*) or “islands of compression in an ocean of tension” (*Buckminster Fuller, 1975*) ensure the stability of the whole. Biotensegrity perspective takes architectural tensegrities as a base reference but goes further by emphasizing the leading role of architecture in the whole organism, where the specific morphological embodiments reflect the balance of the invisible forces working in the background.

Biotensegrity systems are always about the *relationship* between anatomical elements. A **dynamic** biotensegrity model is thus created if we replace ‘cables’ with ‘dynaments’. In the biotensegrity model the spatial relationships between the constituent elements can constantly be adjusted. On a gross anatomy level, in such a system tension and compression (pull and push) are transmitted by the dynaments and the skeletal elements respectively. As stated above the tensional members in biotensegrity approach are responsible for the ‘togetherness’ of the organism, whilst the compression members are the one that provide the ‘apartness’ / ‘separation’ within this unity. However, even these roles are not fixed between the anatomical elements. For example, even the larger skeletal elements could either perform as struts (separation at the joints), or as cables (tensional connections at the level of periosteum). In fact, the roles could switch and be reassigned with variable recruitment of fibers, gels, etc. depending on the situation, whatever assignment of such roles favors architectural stabilization for the organism with minimal energy. In such minimal energy-optimized tensed frameworks integrated by internal pre-stress/ self-stress, fascia and maybe the entire ‘meso’ (see later) turn from anatomical appendix to an architectural organizing principle, because it has the capacity to form infinite transient combinations of edges and vertices (*Blyum, 2020*). Introducing the ‘dynaments’ as dynamically adjustable ‘cable-elements’ creates in my view the ideal Posture and Locomotion System. Then locomotion is not conceived as a movement of body parts but as a continuous positioning in

space of the body as a whole. A lightning-fast change and adaptation of the spatial planning across the entire body. 'Gestaltung' (German) or 'performance' (English) are clarifying terms here.

If we consider the 'dynamet' as a fundamental architectural unit, then all possible anatomical units of the PLS are conceivable or imaginable by providing a different 'mix' of passive (periarticular connective tissues) and dynamic (muscle fibers). The template 'dynamet' is shown schematically in Figure 3A. The red striped zone is the central muscle tissue element ('unit') with on both sides (yellow) 'connective tissue structures' (in series to the muscular tissue) attached to a skeletal element (black circle). In terms of organization, the dynamet resembles a unipennate muscle (Fig. 2B). From this basic model of the dynamet, therefore, all possible anatomical units can be conceived and represented where two skeletal elements are connected in such a way that, in each position of the joint, the relevant 'dynamet' can give stability and transmit force without a wasteful slack (dynamic shunt operation). Figure 4 shows the options.

Whether the so-called Posture and Locomotor apparatus (or PLS) is viewed as a biomechanical construct with fixed anatomical roles, or as the architecture-based biotensegrity system with variable functional anatomy also determines how the organization of proprioception is interpreted. It has been shown that the spatial organization of the morphological substrate of proprioception in the narrower sense (i.e. the mechanoreceptors in the muscle and connective tissue of the PLS) does not follow the anatomical relationships of bones, muscles, ligaments, joints but is organized according to architectural force relationships (*van der Wal 2009*). Perhaps, in this respect the brain is not very interested in muscles and joints per se, but in force transmission and movement relationships. In this context it also makes sense to notice that all the main mechanoreceptors in proprioception (Muscle Spindles, Golgi Tendon Organs, Ruffini and Pacini Corpuscles etc.) represent the spectrum for detecting the variable role that the same anatomical element of connective tissue can play depending on the functional context (tension, compression etc.). Van der Wal (2009) shows clearly that also the spatial organization of the morphological substrate of proprioception is not related to the topography anatomy of discrete structures but that in essence it is the architecture of connective tissue that is instrumental in proprioception. So it is 'again' not only the 'Where' of the receptors that determines what triggers them, but also a question of 'How' they are organized in the functional context of the force architecture (pressing, pulling, sliding, sliding). Perhaps the traditional dichotomy of joint receptors versus muscle receptors should be replaced by a 'trans-anatomical' spatial arrangement in which the architecture of the muscle and connective tissue is instrumental for proprioception (instead of the anatomy of discrete anatomical elements of the muscle person) (*van der Wal 2009*).

There are authors who argue that muscles and bones can also be considered specializations of fascia (*Levin 2015, Sharkey 2019*). Would this mean that we have to distinguish a fascia 'in the narrower sense' and a fascia 'in the broader sense'? With the former being a complex of layers and structures that form a continuity with each other (*Schleip 2012a and 2012b*) and the latter then a kind of matrix-connective tissue-fluid continuum that forms the morphological substrate of our proprioceptive inner or the embryonic mesenchyme? The duality of pressure and tension (physiological) that can also manifest itself in shortening and lengthening (of the dynamet), but also morphologically in compacting (bone tissue) and connecting (connective and muscle tissue), is characteristic of the 'fascia in a narrower sense (biotensegrity). Could it be that this duality can be traced back to the duality of separating a connecting that is the basic principle of the fascia in a broader sense', the mesenchyme? This is what the second part of this article is about: What is the fascia derived from in the embryo? What is the origin of fascia?

## On the origin of fascia

We have seen that the traditional anatomical approach of dissection did not provide a basis for describing the functional architecture of the fascia (continuity and connectivity). Perhaps we might find more answers to the questions like What fascia is and why it matters? by exploring where and how the fascia, the fascial system, the connective tissue arises in embryonic development. Perhaps from *fabrica* to ‘fabric’?

“Each being can only be understood from its becoming” is the way the German biologist Ernst Haeckel summarized the importance of the embryological approach. Knowing how a certain organ or structure came about, simply tells more about what it is (*Lesondak, 2018*). From the phenomenological stance the functional meaning of forms is more important than their causal explanation. So, here the question of the origin of fascia will be: Where does fascia come from? How is fascial body matrix shaped and what, if anything, does that tell us about its function?

In embryology the question Where it comes from, usually leads to the so-called germ layers<sup>5</sup> (*Sadler, 2012*). In human development the three germ layers appear during the so-called *gastrulation* approximately in the third week after conception (*Moore, 2019*). In common embryology germ layers are regarded as *morphological organ-forming* units from which the various tissues and organs develop, resulting in a functional organism. In most textbooks the three primary germ layers are referred to as ectoderm, mesoderm and endoderm, sometimes mentioned as ectoblast (or epiblast), mesoblast and endoblast (or hypoblast). Embryology textbooks usually summarize which germ layer gives rise to which organs and which tissue types. Nowadays however it is no longer that simple to trace every organ or tissue to one given germ layer - almost every organ is at least a ‘mixture’ of several germ layer derivatives. With some nuances, the germinal layers are generally regarded as constituting elements of the body, supporting the idea that the body is ‘built up’ from these three components and that the various organs and tissues on their turn are derived from them. Like cells and organs, germ layers are considered a kind of ‘building blocks. Under this model, we start as a fertilized egg that undergoes the process of cell multiplication and growth which constitutes the parts and the organs and which at the end results into the body.

In a phenomenological or organicistic view on development however we look at this in a different way. We do not start as a cell but as a zygote. A zygote is the first manifestation of the human body. The zygote is not a cell but a (unicellular) organism that from that moment on constantly (sub)organizes itself in cells, and via those cells is differentiating into organs and tissues. The embryo itself demonstrates this by the phenomenon of so-called ‘*morphogenetic fields*’. In developmental biology of the twentieth century, a *morphogenetic field* has been considered a group of cells able to respond to given localized and biochemical signals leading to the development of specific morphological structures or organs. (This specific definition should not be confused with the more far-fetched interpretation of this hypothesis as propagated by Rupert Sheldrake). Blechschmidt (*2011*) refers to ‘morphogenetic fields’ as “kinetic metabolic fields”. Meaning that within the embryo there are constantly emerging metabolic fields, in which the cells, controlled by and in response to the changing environment, differentiate into new types of cells. In this view of the body, the organism is not the product of the parts but is a self-organizing, self-assembling organism (entity) maintaining its unity throughout all those different fields and differentiations as a life-long process. The morphological body is seen as a ‘performance’, as a process in time.

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<sup>5</sup> Here the notion ‘layer’ is preferred over the term ‘leaf’.

## Where does fascia and fascial tissue, come from?

If one looks for the 'primeval fascia' (or the 'primary fascia'), one almost inevitably ends up with the 'mesoderm'. The primary appearance of the 'mesoderm' is mesenchyme (Blechschtmidt, 2012). In the third week of human development the bilaminar germinal disc is transformed by the so-called *gastrulation* process in a trilaminar disc. It is at this point that 'mesoderm' emerges: the body now consists of ectoderm, mesoderm and endoderm. This tripartite or threefold organization is a biological necessity or must-be-condition for the development of every animal or human body. Human beings that only consist of two germ layers do not exist, a 'mesoderm' is an absolutely necessary condition and domain.

Applying the epitheton '-derm' ('derm' means skin) to the name of all three components suggest (perhaps wrongly) that we deal with three more or less equivalent constituent elements of the human body and creates ambiguity: how to imagine a 'middle skin' ('mesoderm')? Histologically however 'trilaminar' is not an accurate notion. Gray's Anatomy (Stendring 2016) indicates that it is not correct to consider the trilaminar disc as being constituted by three **epithelial** leaves or layers. The ectoderm and endoderm clearly have the character of an epithelium. However, the 'mesoderm' manifests itself as a connective tissue - the *mesenchyme*. The German embryologist Erich Blechschtmidt (Blechschtmidt 2004) is emphatic that it is not about three equivalent 'building blocks' or elements but that at this point of embryonic development the primordial organization of a human body is already emerging.

In other words, this means that we now deal with a body and a bodily organization, not wither building blocks! A body characterized by two boundary layers (*limiting tissue*) and an intermediate 'layer' of tissue that can be referred to as an *inner tissue* (Blechschtmidt 2004). One could say the trilaminar disc is about an animal organization plan: the adult animal (as well as the human being) is characterized by an existence in an anatomical and psychosomatic 'inner space' between two body walls. Broadly spoken, the outer (parietal) body wall (from which later limbs and head also develop) and an inner (visceral) body wall (from which later in broad outlines the gut and its derivatives develop). Hence the terms ectoderm and entoderm can be maintained as indeed accurate. They are the substrate or primordium of the later skins or body walls or boundaries. However, in this frame of thought, the term 'mesoderm' no longer makes sense because mesenchyme is quite a different quality of tissue than the epithelium of ecto- and ento- altogether: connective tissue. Here one can or should speak of 'inner tissue' (in German: *Innegewebe*). Therefore, the term 'meso' (middle, in between) is applied here to emphasize that it is not a matter of three layers but of a three-part or 'triune' body with an inner dimension. 'Meso' as the quality and mesenchyme as the tissue of Innerness (the Middle) <sup>6</sup>.

Thus, we arrive at a completely different perspective which can also provide a new and special dimension to our understanding of fascia. In Blechschtmidt's view, all cells are always kinetic or metabolically linked to each other through the transport of substances: *"There are cells that absorb nutrients from the environment or from neighboring cells and mutually attract each other through this physical absorption of substances. On the other hand, cells also exert mutual rejection by producing and shedding metabolic by-products. This constant interaction between uptake and excretion, between attraction and repulsion is a condition for cells to organize themselves in relation to each other and thereby to bring about certain forms. 'Limiting tissue' forms the boundary between fluid on the one hand and the inner*

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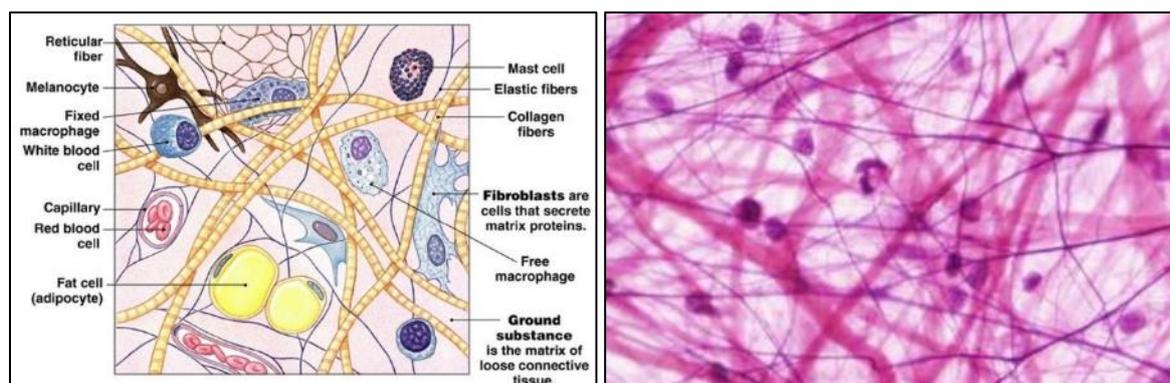
<sup>6</sup> Worth mentioning is that mesenchyme later in human development again might come up everywhere where an 'Inner' is to be constituted. For example, the mesenchyme of the head originates from a second 'wave' of mesenchymal formation that appears to emerge from the neural crest.

tissue on the other. While the inner tissues are surrounded on all sides by boundary tissues and therefore are permanently 'on the inside' - that is: *IN* the body. Inner tissue can therefore also be described as undifferentiated connective tissue (mesenchyme)" (Blechsmidt, 2012).

This model applied to the human body may give us a different view of the 'inner' dimension. The organs that are usually described as viscera can therefore be considered as a body wall that limits us to the outside world and enables mainly metabolic and material interaction with that outer environment. The designation 'inside' is therefore meant in this context literally and anatomically, it is an 'inside' body wall. The 'outside' body wall forms our parietal boundary to the world. This body wall also relates us to the outside world and allows a different kind of interaction with it: perception and action for example. One could argue that our 'anatomical' (but also our psychological) interior is the space created by the original mesenchymal connective tissue, or meso. In this 'inner', all organs, including the ectodermal and endodermal derivatives and those that can be understood as derivatives of the meso, are thus embedded. The mesenchyme, the original primal connective tissue, is the matrix tissue of the body; the larger "fabric in which the organs are embroidered" (Levin, 2019).

Broadly speaking, it therefore is not 1, 2, 3 times 'the same' (in other words three 'blasts' or three 'derms'), but it is (1 + 1) two limits (epithelia) with a third dimension in between them. While epithelia are characterized by the fact that intercellular space is virtually absent, the absolute characteristic of mesenchyme or inner tissue is the existence of (interstitial) space between the cells, the Extra-Cellular Matrix (ECM). The ECM or *interstitium* can be 'filled' or formed by all kinds of substances (from interstitial organic 'bound water', to cartilage substance or calcified bone matrix) and also always contains a third dimension namely *fibers* of all possible nature and quality. In this way, concepts such as fascia, connective tissue, matrix, inner space, are aligned and all congruent, if not essentially the same. It is thus very well possible to conceive that meso and thus fascia represents the matrix, the 'fabric' of our body organization.

### Mesenchyme: connecting and shaping space or 'pull and push' (biotensegrity)



Schematic representation (left) and a histological image of loose areolar connective tissue, representing the primeval fascial tissue. In the right image the three components of fascia (cells, fibers and interstitium) together with capillaries are represented.

In the previous quote from Blechsmidt, reference is made to uptake and excretion, attraction and rejection as principles of interaction between cells. These principles of relationship can also be attributed to fascia, mesenchyme and connective tissue. Mechanically, histologically, embryologically one can think of two different types of interactions in the mesenchyme, namely **connecting and forming space (separation)**. Remember in this context the notions of 'pushing apart' and 'pulling together', the keywords

of the biotensegrity system (composed by compression struts and tension cables). These two dimensions have all kinds of histologic and physiologic appearances.

If for example the cell component of the mesenchyme becomes dominant, the cells (and thereby the mesenchyme) condense largely into cellular agglomerations. This is the case for example in fat or muscle tissue. The cells form a parenchyma embedded in a fibrous matrix. Stephen Levin: "Think away (remove) the parenchyma of muscle cells from the muscle tissue and you get a band or ligament" (*Levin 2015*). The opposite, shedding cells (in Blechschmidt's jargon) could then be recognized in the ability of the mesenchyme to create so-called 'body cavities'. Consider the so-called pleural cavities or peritoneal cavity lined up with a so-called serous membrane. Such membranes are often histologically described as a so-called 'mesothelium'. This is an epithelium formed by mesenchyme (connective tissue). The essential difference is that the mesothelium defines an interstitial space (in fact actively creates it) and that an epithelium usually defines an outside wall or a lumen of a tube. Mesothelia also tend to accrete if the (sliding) movement that is enabled here, is no longer practiced. In a so-called body cavity such as the oral cavity, covered with epithelium, that tendency will not be as pronounced. Perhaps, instead of naming these spaces 'cavities', we should rather think of them as 'joint fissures' where two organs, or a body wall and organs, encounter each other (adhere) but can still move against each other (contiguity). One could rightly call this the principle of creating space that makes moving possible. The mesenchyme in this case can almost be considered 'cell and fiber empty'. This is how joint fissures and body cavities become movement organs. Not simply mechanical hinges, but biological activities, creating space to enable mobility. For example, it is obvious that in the case of the peritoneal cavity, the membranes will adhere and accrete to each other when immobility occurs for longer period. "Use it or lose it" is the principle for such 'cavities'.

Apply the concept of connecting and creating space to the 'fascia in a broader sense'. The 'fascia in a broader sense' is that often-discussed network or system that is present everywhere in the body and that forms the 'tensional network' (*Schleip 2012a*) of our body in which all organs and structures are interwoven and embedded. In short: the mature representation of our 'mesodermal' innerness and of the primary mesenchymal framework of the body with possibly a regulatory role on multiple function levels (*Stecco, 2018*). In a narrower sense, fascia is then the subcutaneous collection of anatomically recognizable connective tissue structures that connect, support and enclose muscles, bones, nerves and blood vessels and other internal organs in the form of layers, membranes, fasciae, and envelopes (*Schleip 2012b, Stecco, 2018*).<sup>7</sup>

Given these two characteristics of fascia, a picture emerges that meso(mesenchyme) can both densify, connect, and contract. It can also decentralize, stretch, and create space. Again, there is a theme of push and pull, connection and separation. These polar tendencies in the connective tissue can also be seen in the different qualities of interstitial substances, and in different relationships between fibers, cells, and interstitium. Hence, most anatomy textbooks speak about supportive *and* connective tissue.

Consequently, there are good arguments to also consider body cavities and joint clefts as functions of fascia. The subcutaneous connective tissue e.g. is a loose areolar connective tissue with a lot of interstitial space between the fibers. The functional principle here is focused on separating, creating space and enabling motion (*Guimberteau, 2008*) similar to tendon and muscle sheaths and bursae (in bursae the fibers even are absent: a kind of 'body

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<sup>7</sup> In some definitions of fascia, it is stated that the connective tissue not only covers and envelopes organs and structures but also is 'penetrating' those. According to the concept presented here the notion 'penetrating' seems to be false: the parenchyma of some organs of references like muscles is 'embedded' in the connective tissue. In other nearly pure parenchymatous organs (like liver) such an 'endo-skeleton' of connective tissue is absent.

cavity' is formed). Intermuscular septa, the 'classical' fasciae such as epimysia, fascia antebrachii, fascia lata, thoracolumbar fascia and many more are meant to mechanically connect and to govern tensile forces. In these cases, the appearance of 'fascia' is quite different. The fibers now are dense, tight and dominant, so that there is hardly any room for interstitium or cells (the so-called regular dense collagenous connective tissue RDCCT). This is the fascia we typically see in the PLS as described by *Schleip (2012)*, *Van der Wal (2009)* and *Stecco (2018)*.

It may also be the interstitial substance of mesenchyme or fascia that forms the mechanically connecting (or separating!) dimension. Consider in this context cartilage with cartilaginous substance or bone tissue with its calcified matrix. In intervertebral discs and symphyses, the cartilage type includes the tough, chondrocyte-laden fibrous cartilage that connects skeletal elements. The other types of cartilage are elastin rich elastic cartilage (comprising much of your ear) and the collagen type II-rich, glass-like hyaline cartilage in synovial joints. Cartilage therefore can also serve motility by the space-creating principle, as is the case in the fissures of the synovial joints and sometimes in symphyses and intervertebral discs.

The interstitium is the third dimension of fascia and mesenchyme! It forms in principle a hugely extensive space that can be found everywhere between organs, structures and tissue elements. It therefore can be regarded as one large continuous inter-anatomical body 'cavity' along which communication, coordination and organization by means of substances are possible (*Theise 2018*, *Oschman 2015*). The extracellular matrix ECM as a transportation system (*Friedel 2020*). From embryology we know that signaling proteins, important conditions for creating fields, are organized and distributed via the mesenchyme. During human embryonic development the 'meso' provides the metabolic conditions for the development of the ectodermal structures and plays a role in their differentiation (*Blechsmidt and Gasser, 2012*). It is conceivable and demonstrated that even gradients of so-called epigenetic control molecules could also be established via diffusion through the interstitial space.

No 'meso' without blood. Mesenchyme is associated in the embryo with the formation of blood and blood vessels. Contrary to popular belief, blood is a tissue, not a fluid. Blood is categorized in many histology textbooks as supportive or connective tissue. The primary manifestation of blood is mesenchyme in which (via the formation of blood islands and blood strands) a network of capillary vessels is formed. The capillaries transport 'liquid tissue' i.e. blood cells. The vast network of capillaries (estimates vary from 60.000 to 90,000 km!) likewise performs what is typical for connective tissue, that is connecting and creating space in a dynamic physiological way. Organs are connected by means of blood, but during evolution in animals the (perhaps also psychological) inner space for the organism can become larger and more complicated as blood allows it. Blood therefore is also a dimension of 'innerness'. The widespread presence of capillaries throughout the body also makes it possible to visualize the image of the 'fascia in a broader sense' as the matrix tissue in which all organs are woven and embedded. Blood and fascia 'take the shape of the body', one might say, and literally create the web in which everything is embedded.

### **Fascia – the 'organ of innerness'?**

All this is a logical consequence of the idea that fascia (in broader sense) coincides with the 'meso' or mesenchyme. Mechanically one can think of two forces in the fascial connective tissue system: push and pull, connection and separation. The entire Posture and Locomotion System can therefore in a certain sense be considered a biotensegrity system with compacted elements (skeletal elements) on the one hand and pull transmitting elements (ligaments, fasciae, muscles and 'dynaments') on the other. To understand a tensegrity system, one needs the tension (the cable elements) as well as the compression (the stiff elements). So, all the 'apparatus' components like muscles, ligaments, fasciae, bones and so

on, can also be interpreted as fascia specializations. Bone is fascia (*Sharkey, 2019*), muscle is fascia (*Levin, 2012*), dynaments are fascia (*Van der Wal, 2009*). Fascia as well as biotensegrity is about **architecture** and therefore **relationships** between the anatomical elements not about anatomy. The fascia 'in broader sense' forms the fabric of our body and in this fabric all organs are somehow woven or embroidered' (*Levin 2012*). Fascia as 'organ of innerness'.

The 'theme' for fascia (and connective tissue) is connecting and separating, connecting and creating space, compaction and expansion, and so on. Fascia is the mediating, the 'middle and also 'innerness'. Therefore, I think that the concept of mesenchyme as inner tissue may lend credence to the 'non-scientific' concept, first espoused by Dr. Andrew Taylor Still that the fascia (in a broader sense) may constitute the 'space of the soul'. "*The soul of man, with all the streams of pure living water, seems to dwell in the fascia of his body*" (A.T, still quoted in *Lee, 2005*). The further elaboration of this possible psychosomatic body-concept is beyond the scope of this article. Here an attempt has been made to show that fascia in a broader sense may be the literal representation of our inner being ('Innerness').

May 2020  
Jaap van der Wal MD PhD

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### **Acknowledgment**

I want to thank David Lesondak and his wife Coletta Perry who on an earlier occasion succeeded to translate my 'Dutch' English into more scientific English. I gratefully accepted many of their proposals and corrections. Moreover, I owe a lot of thanks to Leonid Blyum, who streamlined my text where it concerned terminology and concepts in the domain of biotensegrity in relation to the concept of architecture.

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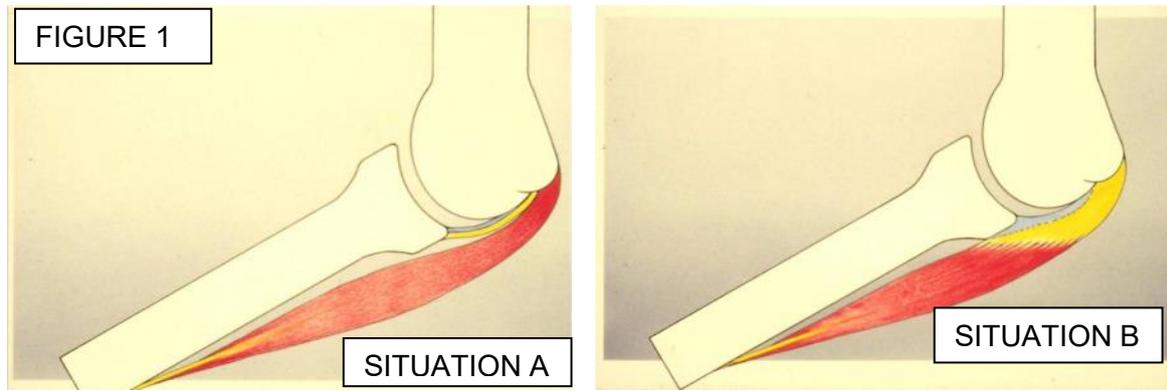
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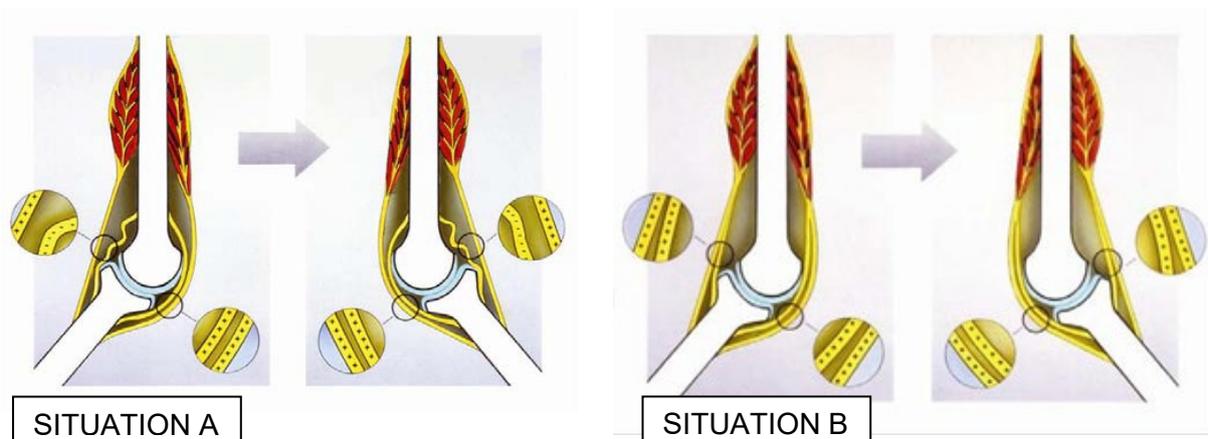
APPENDIX Figures

FIGURE 1



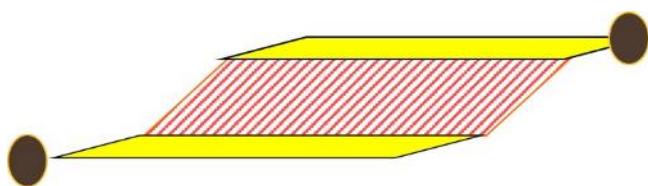
<p>Situation 1A Capsule (blue) with ligaments (yellow) organized <i>in parallel</i> to the superficially situated muscle tissue</p>	<p>Situation 1B Capsule (blue) with periarticular connective tissue (yellow) organized <i>in series</i> with the muscle tissue</p>
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FIGURE 2



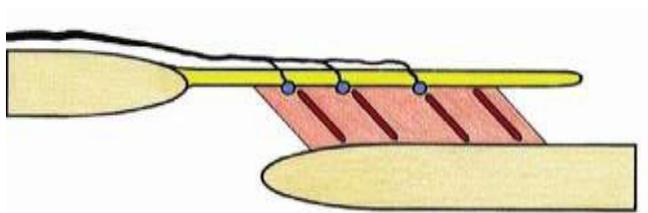
<p>Situation 2A The “classical” organization principle of iuxta-articular connective tissue running from bone to bone, organized in parallel to the muscular component (tendons). Only in a particular joint position can the connective tissue transmit forces or signal in the sense of mechanoreceptor triggering (++++ versus ---). NB Articular cartilage here represented in blue.</p>	<p>Situation 2B The alternative organization of iuxta-articular connective tissue organized in series to the muscular component. In all joint positions the connective tissue of the joint is brought to tension and is capable of transmitting forces and signaling in the sense of mechanoreceptor triggering (++++ and +++++). NB Articular cartilage here represented in blue.</p>
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FIGURE 3A



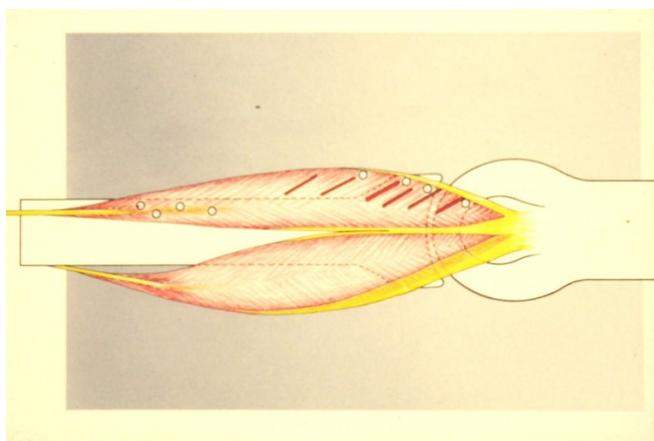
Schedule of a so-called dynament

FIGURE 3B



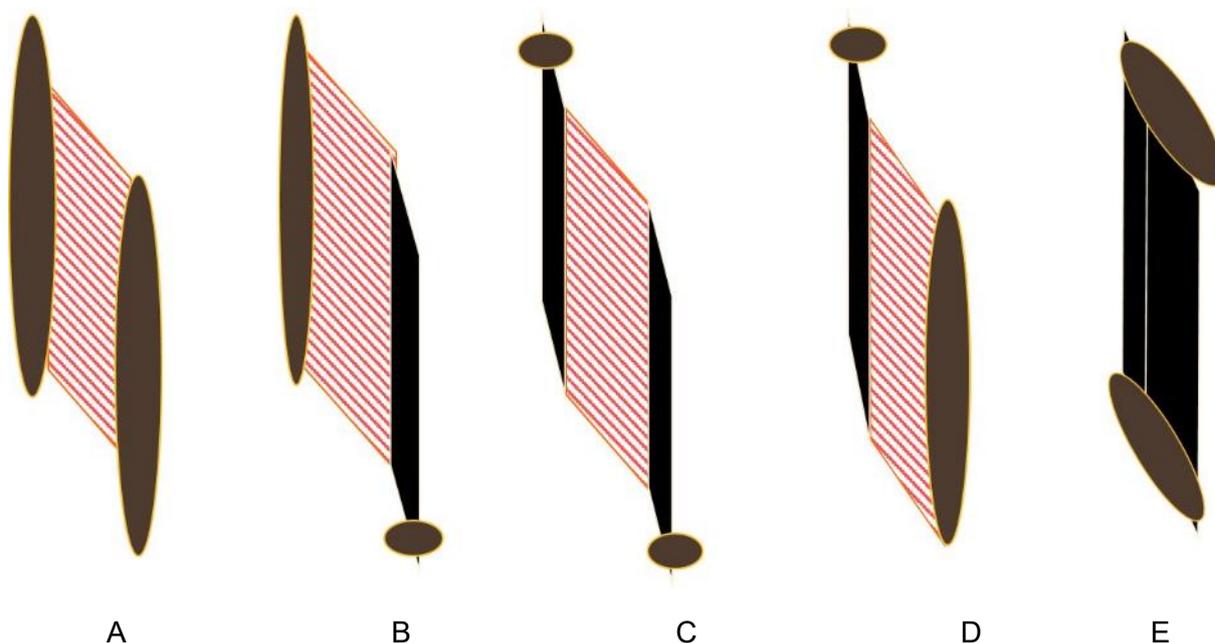
Schedule of a unipennate muscle alias dynament

FIGURE 3C



The 'warp and weft' organization of the distal (intramuscular) versus the proximal (transmuscular) organization of the connective tissue structures that connect the muscle tissue with the periosteum.

FIGURE 4



**4C** represents the more or less 'ideal or template dynamite': one connective tissue structure / layer (e.g. fascia, aponeurosis, septum, tendon) adheres to one ('proximal') bone (top), another connective tissue structure / layer (tendon or aponeurosis) adheres to the other ('distal') bone (down). In between two RDCCT structures an intermediate zone of muscle tissue (muscle fibers). See figure 4A.

*RCDDT: regular dense collagenous Connective Tissue*

**4A** represents the one extreme situation in which no separate connective tissue structures are "needed" and the muscle fibers in question immediately insert to the periosteum of both bones involved.

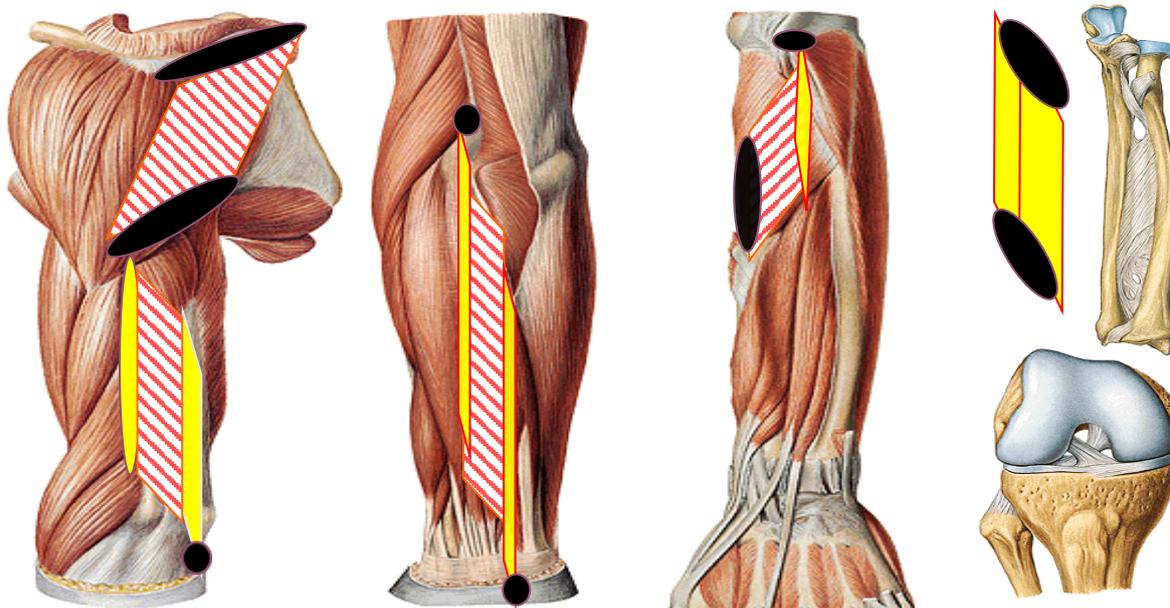
**4B** represents an intermediate situation where muscle fibers adhere on the one hand directly to the periosteum of a bone while on the opposite side through a connective tissue structure (tendon, aponeurosis, septum or fascia layer).

**4C** represents the 'ideal' or 'template' dynamite

**4D** represents the other intermediate situation where muscle fibers adhere on the one hand by means of a connective tissue structure (tendon, aponeurosis, septum or fascia layer) while on the opposite side muscle fibers adhere directly to the periosteum of a bone.

**4E** represents the other extreme situation of a dynamite i.e. without intermediating muscle tissue between the connective tissue layers or structures. In this case a dynamite acts as a static tensile forces transmitting structure, in other words as a 'classical' ligament.

FIGURE 5



Deltoid and Triceps  
Dynament A and B

Dorsal extensor forearm  
Dynament C ('ideal')

Supinator muscle  
Dynament D

Interosseous Mem.  
Cruciate ligaments  
Dynament E