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FASCIA SCIENCE AND CLINICAL APPLICATIONS: NOMENCLATURE REVIEW

What is 'fascia'? A review of different nomenclatures

Robert Schleip*, Heike Jäger, Werner Klingler

Fascia Research Group, Division of Neurophysiology, Ulm University, Albert-Einstein-Allee 11, 89081 Ulm, Germany

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Summary There are many different definitions of fascia. Here the three most common nomenclatures are compared, including that of the Federative International Committee on Anatomical Terminology (1998), the definition included in the latest British edition of Gray's Anatomy (2008) and the newer and more comprehensive terminology suggested at the last international Fascia Research Congress (2012). This review covers which tissues are included and excluded in each of these nomenclatures. The advantages and disadvantages of each terminology system are suggested and related to different fields of application, ranging from histology, tissue repair, to muscular force transmission and proprioception. Interdisciplinary communication involving professionals of different fields is also discussed.

As pointed out repeatedly by other authors, fascia has been extensively overlooked in mainstream medicine over the last few decades, and its contribution to many areas of biomechanics and physiology has been underestimated. However in recent years this 'Cinderella tissue' has attracted increasing attention among academic researchers (Benjamin, 2009; Findley, 2012). While this drastic shift is hardly coincidental, there are two major reasons for it.

The first reason is the development of new assessment methods. While bones have long been objectively explored via x-rays and muscles via electromyography, changes in fascial tissues have been difficult to measure with any precision in vivo. Nevertheless, recent developments in tissue imaging and other advanced assessment technologies have allowed for increased acuity in the study of differences in fascial behaviour, for example differentiating between behavioural differences in pathological and healthy fascia. The use of high-resolution ultrasound by Tozzi et al. (2011) in assessing the efficacy of an osteopathic manipulation is a good example of this. Other promising technologies for in vivo measurement of fascial behaviour are bioelectrical impedance (Kim et al., 1997) and myometry (Gavronski et al., 2007).

The second reason for the long neglect of fascial tissues is the preferred method in Western anatomy: dissecting (Greek 'anatemnein') a connected tissue entity with a scalpel into several fragmented pieces that can be counted and named. You can reasonably estimate the number of bones or muscles; any attempt to count the number of fasciae in the body will be futile. The fascial

* Corresponding author. Tel.: +49 89 398574; fax: +49 731 501223257.
E-mail address: robert.schleip@uni-ulm.de (R. Schleip).

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body seems to be one large networking organ, with many bags and hundreds of rope-like local densifications, and thousands of pockets within pockets, all interconnected by sturdy septa as well as by looser connective tissue layers (Findley, 2012). While the three dimensional description of such a network had been a very difficult challenge in the past, modern methods of systems analysis as well as digital modelling have advanced; they are becoming more and more up to the task.

A question of category boundaries

Both reasons are important to understand, when attempting to follow the rapid developments in this field. A meaningful example related to the second reason — the reliance on dissection — is the current divergence in the use of the term 'fascia'. No area of anatomical science is characterised by such divergent terminology, as is the case in fascia-related connective tissues. For some authors, only dense sheet-like connective tissues are included, and only if they express more than one dominant fibre direction. Such fibre arrangement is then often called 'irregular', a term which more often than not is incorrect, particularly when the fibres are in a lattice-like arrangement and cross each other at very specific angles (Benetazzo et al., 2011.). In contrast, other authors include very soft and transparent layers such as within the hypodermis or as is found in the envelopes around tiny vessels.

Many authors restrict the term fascia to muscular connective tissues. Visceral connective tissues — no matter whether they are of loose composition like the major omentum or more ligamentous like the mediastinum — are then excluded. In contrast, more clinically oriented books have put great emphasis on the visceral fasciae (Paoletti, 2006; Schwind, 2006). Similarly there has been confusion about the question as to which of the three hierarchical muscular tissue bags — epimysium, perimysium and endomysium — could be included as fascia. While most authors would agree to consider muscular septi and the perimysium (which is often quite dense, particularly in tonic muscles) to be fascial tissues, there is less consensus on the endomysial envelopes around single muscle fibres due to their lesser density and the higher quantity of collagen types III and IV.

The resultant confusion in language makes for difficulty in communication between researchers as well as clinicians. While it might seem that authors can arbitrarily include whatever they like in their own 'fascia' definitions, it helps to understand the background for the most prominent terminologies in the field.

Federative Committee on Anatomical Terminology

The International Anatomical Nomenclature Committee (1983) confirmed the usage of previous nomenclature committees and used the term "fascia superficialis" for the whole loose layer of subcutaneous tissue lying superficial to the denser layer of "fascia profunda". While most medical authors in English speaking countries followed that terminology, authors in other countries did not congruently adopt it. For example many Italian authors excluded the panniculus adiposus situated within this tissue layer, and French authors have continued to exclude both the panniculus adiposus and the textus connectivus laxus beneath the stratum membranosum.

The subsequent international nomenclature, proposed by the Federative Committee on Anatomical Terminology (1998), therefore attempted to lead towards a more uniform international language (Wendell-Smith, 1997). It defined fascia as "*...sheaths, sheets or other dissectible connective tissue aggregations*". This includes "*investments of viscera and dissectible structures related to them...*" This group suggested that authors should no longer use the term fascia for loose connective tissue layers and should apply it only to denser connective tissue aggregations. They therefore recommended no longer making use of the old term "superficial fascia" as such (and to substitute 'tela subcutanea' or 'subcutaneous tissue').

Congruently, this most recent international 'Teminologia Anatomica' even suggested excluding some of the most frequently used 'fasciae' names in anatomy from their proposed definition. For example it proposed that the commonly used terms "Camper's fascia" and "Scarpa's fascia" — for two respective tissue layers in the abdominal wall — should be abandoned and be replaced by the terms "panniculus adiposus abdominis" and "stratum membranosum abdominis".

This attempt for the most part failed (Huijing and Langevin, 2009). Most English textbook authorities continued to use the term "superficial fascia" to describe subcutaneous loose connective tissues (Platzer, 2008; Standring, 2008; Netter, 2011; Tank, 2012). In addition an increasing number of non-English authors — following the British-American-trend in international medicine — started to adopt the same terminology as their American or British colleagues. Not surprisingly, most international anatomy books have continued to use the terms 'Camper's fascia' and 'Scarpa's fascia' in their description of the abdominal wall.

Gray's Anatomy

In the light of these difficulties, many contemporary authors instead refer to the latest British edition of Gray's Anatomy (Standring, 2008) when describing fascial tissues (Benjamin, 2009; Willard et al., 2012; Schuenke et al., 2012). This highly respected textbook of anatomy defines fascia as "*...masses of connective tissue large enough to be visible to the unaided eye*". In contrast to aponeuroses, fasciae are described as tissues with an 'interwoven' fibre arrangement.

Since this textbook is strongly oriented toward the British tradition, it is not surprising that it explicitly includes "loose areolar connective tissue" such as the membranous and fatty layers of the hypodermal "superficial fascia". Also included under the term 'fascia' are the envelopes around peripheral nerves, blood and lymph vessels. Among the muscular bags, epimysium, perimysium and endomysium are described as 'connective tissue of muscle', however among these interconnected layers only the epimysium is considered to be a fascial tissue.

While the Terminologia Anatomica does not mention any kind of geometrical fibre arrangement (such as 'regular' or 'interwoven') to specify fascial tissues, the definition of Gray's Anatomy attempts to make a clear demarcation between fasciae and aponeuroses. Such distinction is easily possible in areas such as the human lower back, where the latissimus aponeurosis expresses very different properties from the underlying posterior layer of the lumbar fascia (Benjamin, 2009; Willard et al., 2012). However other areas of the body show large transitional areas between aponeuroses and fascial tissues with a multidirectional texture. In fact, as shown by the work of van der Wal (2009), tendons and aponeuroses often do not insert directly into the skeleton; instead they tend to blend and connect with capsular and ligamentous tissues close to their attachments.

Fig. 1 illustrates a description of the iliotibial band in which the authors — quoting Gray's Anatomy multiple times in the respective article — attempted to apply proper terminology and to use the term 'aponeurosis' — as distinguished from other dense connective tissue bands and sheets — for structures which can be seen as direct extensions of skeletal muscle fibres (Benjamin et al., 2008). Based on this terminology, the authors excluded one of the sturdiest pieces in their otherwise exemplary analysis of the iliotibial band since it did not fit their nomenclature. However, in clinical practice, particularly in the field of sports medicine, the ligamentous tissue piece excluded by the authors often constitutes one of the toughest and densest tissue bands in the whole of the body. The stable strength of this band-like structure is also expressed by the common thickening of the iliac crest at the origin of this band. It seems likely that any subsequent analysis of the function of the iliotibial tract will tend to be misleading. In fact, it seems that while using their scalpel in perfect adherence to Gray's Anatomy, the authors threw the baby out with the bath water, i.e. they discarded one of the most important force transmitting elements from this structure.

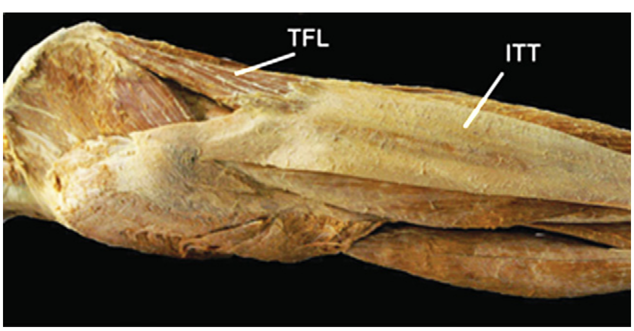

Figure 1 Example of a fascia dissection based on medically 'correct' terminology. This dissection image was used in an otherwise excellent treatise on the iliotibial tract (ITT). Following the proposal of Gray's Anatomy (Standring, 2008) to distinguish between aponeuroses and fasciae, the authors chose to describe this tissue as an aponeurosis. Considering the function of the tensor fasciae latae, this choice seems logical, if not unavoidable. Congruently with this decision, their dissection and illustration therefore excluded all tissue portions with a non aponeurotic character. Unfortunately his included one of the most dense and most important portions of the iliotibial tract: the connection to the lateral iliac crest, posterior of the anterior superior iliac spine. Notice the common thickening of the iliac crest at the former attachment of this ligamentous portion (located at a straight force transmission line from the knee over the greater trochanter), reflecting the very strong pull of this tissue portion on the pelvis. (TFL: tensor fascia lata). Illustration taken with permission from Benjamin et al. (2008).

Tensegrity: seeing fascia as a body-wide interconnected tensional network

Recent descriptions of the fascial net have frequently been influenced by a fascination with the biomechanical properties of tensegrity structures (Myers, 1999; Chaitow, 2011; Levin and Martin, 2012). Such structures are composed of compressional elements (struts) and tensional elements (bands). On closer analysis, compression and tension always co-exist inside each single element. However, the effect of compression clearly dominates in the overall behaviour of the struts and tensional deformation dominates in the bands (Fig. 2). In tensegrity structures, the struts are not continuous with each other (they don't transmit compression directly to each other), while the bands are all arranged in a continuous arrangement and directly distribute their tension load to all other tensional members (Fuller, 1961). Similarities in healthy biological systems, such as cells or whole animal bodies have been pointed out (Ingber, 2008; Levin and Martin, 2012). In particular it has been suggested that healthy human bodies — particularly when engaged in well-orchestrated or elegant movements — tend to express a higher degree of tensegrity-like properties than dysfunctional ones (Levin and Martin, 2012).

If so, it can then be asked what constitutes the compressional-resistant struts in the human body, and what makes up the continuous network of elastic bands? While other materials and tissue properties certainly play important biomechanical roles too, it seems obvious that the bones may be seen as 'struts' and the body wide system of fascial tissues as our elastic net. However such a perspective would need to include ligaments and joints capsules as well as aponeuroses as parts of this tensional network.

While all connective tissues originate from the embryological layer of the mesenchyme, their loading history influences whether a given tissue specialises to resist local compression (and then becomes cartilage or bone) or whether it specialises for tensional loading (by formation of collagen fibres embedded in a semi-fluid ground substance). The specific loading history of the tensionally loaded tissues then influences whether they express as thick and strong bands, as loose areolar tissues or as planar sheets with multidirectional fibre arrangements, or as another fibre arrangement in between (Blechschmidt and Gasser, 2012).

For example, due to the challenges of human biped locomotion, the iliotibial band — a unique structure only found in homo sapiens — usually turns into one of the strongest bands in the whole body. However in wheelchair patients the lateral thigh fascia often feels, upon palpation, as thin and soft as the neighbouring tissue on the anterior or

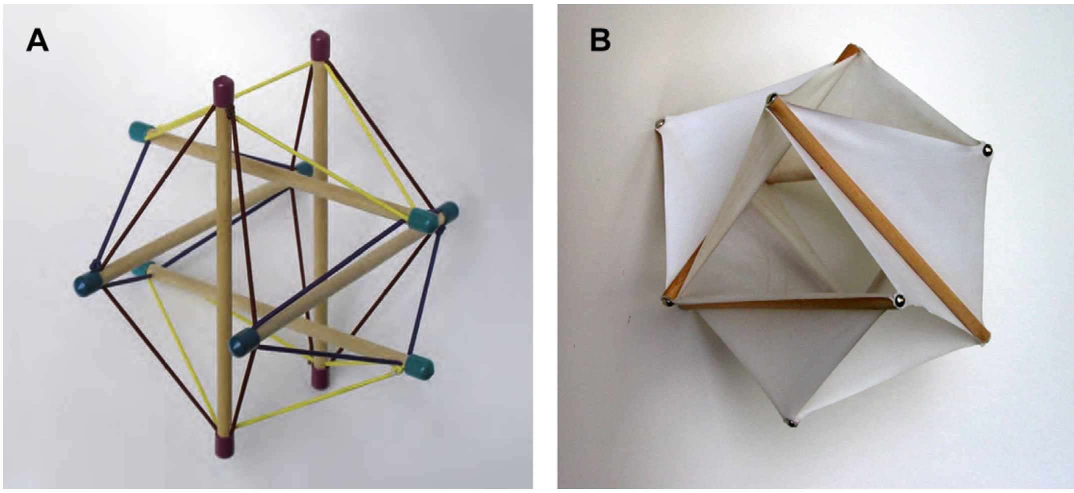

Figure 2 Examples of tensegrity structures. A: Icosahedron. B: With elastic membranes instead of elastic bands. Both images copyright Flemons 2010 (intensiondesign.com) with friendly permission.

posterior side of the thigh. Professional horseback riders on the other hand, who often spend more time straddling a horse than walking, often show severe collagen densifications — up to expression of the so called 'rider's bone' — along the medial side of their thigh (el-Labban et al., 1993).

The perspective arising from these considerations is therefore that there is a body-wide network of mesenchymal-derived connective tissues. In a healthy body — which expresses a high degree of elastic mobility and tensegrity-like biomechanics — the load bearing elements will tend to become isolated spacers (rather than brick-like building blocks) while the tensional members will tend to interconnect with each other in order to better transmit their loading demands. The appeal of this concept among holistic health oriented movement teachers and bodywork practitioners served as an important motivator for them to look for an anatomical language that allows them to better describe and analyse the continuity of such a whole-body tensional force transmission system.

Fascia Research Congresses (FRC)

Based on this background, a more encompassing definition of the term fascia was proposed as a basis for the first Fascia Research Congress (Findley and Schleip, 2007) and was further developed (Huijing and Langevin, 2009) for the following two congresses. The term fascia here describes the 'soft tissue component of the connective tissue system that permeates the human body'. One could also describe them as fibrous collagenous tissues that are part of a body wide tensional force transmission system. The complete fascial net then includes not only dense planar tissue sheets (like septa, muscle envelopes, joint capsules, organ capsules and retinacula), which might also be called "proper fascia", but it also encompasses local densifications of this network in the form of ligaments and tendons. Additionally it includes softer collagenous connective tissues like the superficial fascia or the innermost intramuscular layer of the endomysium. The cutis, a derivative of the ectoderm, as well as cartilage and bones are not included as parts of the fascial tensional network. However, the term fascia now includes the dura mater, the periosteum, perineurium, the fibrous capsular layer of vertebral discs, organ capsules as well as bronchial connective tissue and the mesentery of the abdomen (Fig. 2).

This more encompassing terminology offers many important advantages for the field. Rather than having to draw often-arbitrary demarcation lines between joint capsules and their intimately involved ligaments and tendons (as well as interconnected aponeuroses, retinacula and intramuscular fasciae), fascial tissues are seen as one interconnected tensional network that adapts its fibre arrangement and density according to local tensional demands. This terminology fits nicely to the Latin root of the term "fascia" (bundle, strap, bandage, binding together). It is also synonymous with the layman's understanding of the term "connective tissue" (Schleip et al., 2012).

Calling the investigation of this body-wide tensional network 'connective tissue research' — as had been suggested prior to the first fascia congress — would not be suitable as it would then equally include bones, cartilage, and even blood and lymph, all of which are derivatives of the mesenchyme. In addition, the well-established contemporary field of 'connective tissue research' has shifted its primary focus from the macroscopic considerations of several decades ago to tiny molecular dynamics. The newly forming field of fascia research on the other hand addresses microscopic as well as macroscopic tissue aspects and always attempts to relate findings to the dynamics the body as a whole.

To extend this more comprehensive terminology, Huijing and Langevin (2009) proposed including twelve additional specifying terms wherever possible into the description of a fascial tissue at the second fascia congress (see Table 1). This direction was subsequently further elaborated on in the new textbook of fascia which was co-edited/authored by most of the leading figures behind the fascia congresses (Schleip et al., 2012). Fig. 3, taken from that book, illustrates how different tissues can be seen as local adaptations within a body-wide tissue network. Some local tissue — such as most areas of the latissimus aponeuroses — can be clearly defined by one of the twelve specifying tissue terms suggested by Huiijng & Langevin. However, many important areas of the body are characterised by gradual transitions between such morphological categories, and a more geometrical description of local collagen architecture (in terms of dominant fibre directions, tissue thickness and density) might then be more useful in understanding specific tissue properties.

Moving forward to a common understanding of language and perspective

While the originators of this newly proposed definition of the 'fascial net' pointed out several advantages in their more comprehensive definition of fascial tissues, they clearly acknowledged that more traditionally oriented authors will continue to follow either the Terminologia Anatomica or the nomenclature proposed by Gray's Anatomy, or they will apply specific mixtures between the two. In fact, as long as the Federative Committee on Anatomical Terminology does not come up with a new connective tissue nomenclature (which is acceptable to the editors of Gray's Anatomy and other leading international anatomy text books), the field of fascia-related terms will continue to express a similar degree of diversity and complexity as is seen in the fascial web itself.

Rather than using a sharp scalpel to distinguish between right and wrong, exercising the capacity to understand the descriptions expressed in different nomenclatures is recommended (Table 2). Each approach brings with it major advantages which make it superior when applying the related terminology within a specific context (Table 3). For example the nomenclature of Gray's Anatomy usually works best when communicating with medical and academic professionals whose semantic understanding is primarily rooted in conventional British/-American terminology. On the other hand, application of the FCAT nomenclature has

Table 1 Specifying terms for the description of fascial tissues.

1.	Dense connective tissues
2.	Non-dense or areolar tissues
3.	Superficial fascia
4.	Deep fascia
5.	Intermuscular septa
6.	Interosseal membrane
7.	Periost
8.	Neurovascular tract
9.	Epimysium
10.	Intramuscular and extramuscular aponeurosis
11.	Perimysium
12.	Endomysium.

Terms suggested by Huijing and Langevin (2009) to more clearly describe different elements of the fascial web when operating within the terminology used at the international fascia congresses.

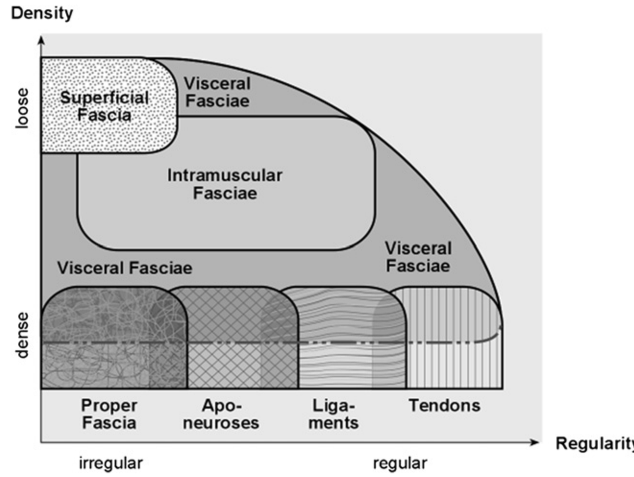

Figure 3 Different connective tissue considered as 'fascial tissues' within the terminology of the international Fascia Research Congresses. These tissues differ in terms of their density and directional alignment of collagen fibres. For example, superficial fascia is characterized by a loose density and a mostly multidirectional or irregular fibre alignment; whereas in the denser tendons or ligaments the fibres are mostly unidirectional. Note that the intramuscular fasciae — septi, perimysium and endomysium — may express varying degrees of directionality and density. The same is true — although to a much larger degree — for the visceral fasciae (including soft tissues like the omentum majus and tougher sheets like the pericardium). Depending on local loading history, proper fasciae can express a two-directional or multidirectional arrangement. Not shown here are retinaculae and joint capsules, whose local properties may vary between those of ligaments, aponeuroses and proper fasciae. Illustration from Schleip et al. (2012).

the advantage of having improved predictive accuracy in terms of histological analysis. Putting loose areolar connective tissues into a different linguistic container than denser joint capsules is indeed helpful when analysing these tissues through a microscope.

On the other hand, when looking at the role of connective tissues in organ repair and other aspects of wound healing, it is helpful to include both loose as well as denser connective tissues types in a common analysis based on their shared functional properties (Hinz et al., 2012). The same applies to proprioception and nociception for which a high density of nerve endings has recently been reported from the hypodermal loose connective tissues (Willard et al., 2012). The more comprehensive terminology of the fascia congresses seems more advantageous when looking at force transmission across several joints (and to avoid analytical pitfalls as described in Fig. 1). It also appears that this terminology may be more useful in discussing or describing areas around major joints, where an arbitrary division of local tissues into capsules, ligaments, tendons, fascia and aponeuroses seems more then cumbersome and would tend to ignore the local tissue continuity present in these areas.

The choice of nomenclature may also depend on the focus of the intended description. If an analysis of detailed structural anatomical elements is intended, then the most

Table 2 Comparison of different fascia related nomenclatures related to the term 'fascia'. The table shows which tissue types are included in the respective definition of 'fascia' and which are excluded. The first column represents the terminology proposed by the Federative Committee on Anatomical Terminology (FCAT). This is compared with the most recent edition of Gray's Anatomy (British edition) as well as with the new nomenclature used at the latest international Fascia Research Congress (FRC) and accompanying text books.

	FCAT 1998	Gray's 2008	FRC 2012
'Fascia' defined as…	"*…sheaths, sheets or other dissectible connective tissue aggregations*". Includes "*investments of viscera and dissectible structures related to them*". It is recommended to no longer use the previous term "*superficial fascia*" as such (and to substitute it with '*tela subcutanea*' or '*subcutaneous tissue*')	"*…masses of connective tissue large enough to be visible to the unaided eye*", "*…fibres in fascia tend to be interwoven…*". Includes "*loose areolar connective tissue*" such as the subcutaneous "*superficial fascia*"	"*…fibrous collagenous tissues which are part of a body wide tensional force transmission system*"
Multidirectional dense planar multidirectional c.t. (Example: proximal portion of fascia lata)	✓	✓	✓ Referred to as '*proper fascia*'
Aponeuroses (Example: distal portion of fascia lata)	✓ ?	No	✓
Loose planar c.t. (Example: membranous layer within subcut. c.t.)	No	✓	✓
Other loose c.t. (Example: fatty layers within subcutaneous c.t.	No	✓	✓
Joint capsules (Example: knee joint capsule	✓	✓	✓
Organ capsules	✓	✓	✓
Muscular septi	✓	✓	✓
Retinaculi	✓	✓ ?	✓
Tendons & ligaments	No	No	✓
Epimysium (muscle envelope)	✓	✓	✓
Perimysium	?	No	✓
Endomysium	No	No	✓
Epineurium, dura mater	✓ ?	✓	✓
Periosteum	✓	✓	✓
Mediastinum	✓	✓	✓
Mesentery	✓ ?	✓	✓
Intracellular fibres (Example: microtubili inside of fibroblasts)	No	No	No
Spinal discs	?	No ?	Nucleus pulp.: No Annulus fibr.: ✓
Cartilage	No	No	No
Intraosseal collagen fibres	No	No	No
Intramuscular titin fibres	No	No	No

c.t.: connective tissue.
'?' is used if the respective categorisation of a given tissue within this nomenclature is not clear.

narrow fascia definition makes sense (here the FCAT). However, if one intends to properly describe more functional aspects - like force transmission or proprioception - as seen through a more macroscopic lens, then the more encompassing 'fascia' definitions (of Gray's Anatomy or the even wider definition of the fascia congresses) will be more suitable.

Unproductive semantic disputes can often be avoided by referring to specialised dense connective tissues (such as capsules or ligaments) as being part of the 'fascial web', rather than insisting that they are 'just fascia', whereas the term 'proper fascia' often serves well to acknowledge that such tissues most clearly express the features described as fascia in conventional text books such as in Gray's Anatomy

Table 3 Comparison of specific advantages of the three different terminologies.

	FCAT 1998	Gray's 2008	FRC 2012
Histology	++	+	−
Force transmission	−	−	++
Tissue repair	−	+	++
Proprioception & nociception	−	+	++
Communication with medical professionals familiar with conventional anatomy	+	++	−
Communication with embodiment oriented movement instructors (yoga, stretching, Pilates, dance, ...)	−	+	++

or the Terminologia Anatomica. Using one of the twelve specifying terms for the descriptions of local fascial tissue architecture from Huijing and Langevin (2009) is also recommended, at least whenever this is possible, as this approach allows one to respect important distinctions while still recognising their being part of a wider tensional network.

The diversity of existing terminologies is reflective not only of the architecture of the fascial web itself, it also reflects the rich diversity of professionals from different fields which have started to share an interest in this intriguingly complex tissue. Traditional researchers can profit from looking at the living human body from the perspective of their fellow clinicians by learning to see the larger continuities within the fascial web. Likewise, professionals in complementary medicine can profit at least as much by learning to recognise important tissue distinctions described by their respected scientific colleagues.

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