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***COMMENTARY***

# Our Internal Universe

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> The universe is a continuous web. Touch it at any point and the whole web quivers.
>
> – Stanley Kunitz

Our internal universe, our body, perceives its internal workings of its soma and how it moves, its sense of its immediate surroundings, and what it physically connects to, through its internal web, the haptic perceptual system. Touch any part of it and the whole system responds, and does so much faster than the slow, complicated and cumbersome neurologic system can accommodate. Turvey and Fonseca (2014) propose that the internal communication and adaptive system in the body is mediated primarily through the mesodermal descendants, the muscular, connective tissue, skeletal interconnections—their MCS system—rather than relying solely on the ectodermal descendants via the neuroderm. Their medium for the haptic perceptual system is the biotensegrity model of the MCS, based on the tensegrity icosahedron as defined by Buckminster Fuller (Fuller & Applewhite, 1975). In the biotensegrity model as initially proposed, the tensegrity icosahedron is the model for the framework of all viable structures from viruses to vertebrates, their systems and subsystems (Levin, 1981, 1986). Turvey and Fonseca (2014) conclude that the physical structure of the neurologic network is also based on the tensegrity icosahedron and the two networks are but one, integrated and nested, what they term multifractal tensegrity (MFT). I fully agree with their use of the biotensegrity model to explain the haptic system. If I have disagreement, it is with the understanding of the technical workings of tensegrities. Deformation of tissue is the key to understanding the haptic system. In Turvey and Fonseca's (2014) model, information is mechanically generated by a shear in the extracellular matrix (ECM) that is transferred to the cell through its integrin adhesions to the ECM and, in turn, the cell is sheared, generating a chain reaction of shearing through the organism's mesodermal interconnections.

Because Turvey and Fonseca (2014) use the tensegrity icosahedron model as the basis of the haptic system, then adherence to the mechanics of that model is necessary. The tensegrity icosahedron has a nonlinear stress–strain curve (S/S) and is unlike the linear, Hookean materials and structures that make up our usual building blocks. The tensegrity icosahedron does not shear (Earnhardt, 2006; Fuller & Applewhite, 1975), but symmetrically contracts and expands, getting stiffer and stronger as it is compressed, and it is this behavior that give rise to the nonlinear S/S and the thixotropic characteristic that Turvey and Fonseca describe as integral to their model. If they were to shear, then the structure would have a linear S/S curve and lose the characteristics that make it unique. In biologic systems structured as MFTs, shear does not exist as each of the nested tensegrities is shear free. Cells may connect to a slide with integrin holdfasts, and monkeys may swing from trees, but the mechanics of the integrated internal biologic universe is through the nested tensegrity structures within that are expanding and contracting and not dependent on the external support structure. A single cell, attached to an outside substrate and tested in isolation, may appear to shear, but its internal organization would remain as a contracting and expanding MFT; an outer attachment does not generate inner shear. Within the organism, the ECM is also part of the MFT and nest within it. A contraction of any structure in the system, cell, or organism will send nonlinear waves distributing throughout the weblike network with instantaneous signaling to all that is connected. The tensegrity icosahedrons are also oscillators and interact with other oscillators to pass on information as part of small world networks.

Turvey and Fonseca (2014) see the cellular tensegrity as an open system, fastened to its substrate and supported by guy-ropes and external rods, a pup tent model, based on Kenneth Snelson's first model, the X-Piece. It was Buckminster Fuller who conceived the idea of separating tension and compression components of a structure, what Fuller termed continuous tension, discontinuous compression (Fuller & Applewhite, 1975). Kenneth Snelson, following Fuller's lead, constructed the first tensegrity model recognized as a distinctly different design principle. His first sculpture, the X-Piece, came close, but both Snelson and Fuller realized that it was not a true tensegrity because it needed external support guy-wires to stabilize it and could not exist on its own. Their true tensegrities were universes unto themselves, whole closed systems that existed without external support. That each tensegrity is a closed system immediately became recognized as an essential component of tensegrities (Flemons, 2007; Wang, 1998). These structures are quite unlike anything we are use to outside of nature. Others, such as Motro (2003), followed Fuller's and Snelson's lead, but others have modified the model for their own purposes. Architects and engineers are free to take what they like from a model and use it as they see fit, but, to call it a true tensegrity we should define it as the originators did. During my exploration of the subject over the last 40 years, I have continually found that, for biologic structures, only the definition that includes the closed system concept of Snelson and Fuller succeeds.

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Fish gotta swim and birds gotta fly, and man and animal must move or they die. Tethering to the ground with tent guy-ropes and supporting with tent poles, is not a functional design for animated constructs, be they single cells or whole organisms. Certainly, we interact with our surroundings, but we do not depend on the outside world, external forces, to structurally maintain our internal universe. Even sea creatures with holdfasts, or plants and trees, do not depend on the outer world to maintain the structure of their inner world. Within the tensegrity construct there are hierarchical, nested tensegrities, with each tensegrity functioning both independently and interdependently, such as soap bubbles in a foam. Each bubble in a foam is dependent on its neighbors for its existence, often sharing a wall, but the bubble also has an independent existence and functional wholeness. Their structural organization is at the mesokinetic level, as it is for living organisms.

Turvey and Fonseca (2014) have made an important contribution to the understanding of intraorganism communication. While doing so, they have also reinforced the importance of the recognition of the wholeness of the organism and its structural integration. Organisms are universes to themselves and their internal communication systems are self-contained and independent of outside forces. While I may take issue with some of the mechanics Turvey and Fonseca (2014) propose, I am completely supportive of their underlying thesis. We may differ on the technicalities of the mechanics, but the premise is solidly grounded. A tensegrity MCS as a medium for the haptic perceptual system makes perfect sense.

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