Interior Architectures.

Hello,

This movie is the fruit of many years of surgical experience, of hours and hours of endoscopy, video-screenings , trying to understand how flexibility , sliding between organs and water distribution can be explained . While looking for an explanation, I was confronted with the main problem: how is living matter organized ? Step by step, I will try to explain our conclusions, and show how the concept of a multifibrillar structural organisation has emerged. Thanks to completely new images in High Definition you will be able to better appreciate the beauty and the behavior of our Interior Architectures.
Have a nice trip !

Watch the hand of a pianist perform a Chopin Ballade, flexing extending, and removing its fingers, with astounding speed seems quite banal.

And yet… who doubts that when we bend our fingers, within the palm of the hand, the tendons move about 2 cm without any transmission of this movement to the surface of the skin.

When we massage, stretch, or lift the skin, we feel a little resistance to traction but the skin does not tear, and when we let go as if by memory, it returns to its initial position.

This ability to store body shape, maintain our integrity does not get much of our attention. Why indeed explain a daily miracle?

Physicians have long solved this phenomenon semantically with the terms elasticity, plasticity and flexibility.

In the twentieth century, anatomical studies have even tried to explain it from a strongly mechanistic point of view by alluding to notions of virtual space and stratification of tissue, with the sliding to and fro of fibrils of decreasing diameters, called "connective tissue".
Descriptive anatomy stopped there, when came era of the microscope using optic, electronic, slot, scanning, and transmission techniques that explored living matter, but at a very different level, that of the cell.
The cell then became the central focus of research.
Now, thanks to new technology, we can learn more from this connective tissue which has been neglected for so long. Thanks to the endoscopy mainlywe will try to find out if connective tissue is simplythta connects organs, or is it the constitutive tissue in which the organs are developped. This could be a significant paradigm shift.

The introduction of endoscopic surgery changes this perception and we are confronted with new situations, of colours, of life in motion.

It allows us to discover an arachnoid world of extreme morphological diversity and forces us to address an unexpected structural biological organization, opening up avenues of deep introspection.

Endoscopy is performed during surgery under tourniquet, with the written consent of patients.

This technology requires a high definition camera, known as "full HD", with a tube wrapped in fibreglass, a lens and a cold light source.
The diameters of the lenses are either 4 mm or 2.5 mm with excellent focus but an extremely limited depth of field.
With this new technology, it is possible to obtain levels of detail never achieved.

Consider, for example, what happens under the skin, around the flexor tendons in the palm of our pianist's hand.
Observe two things. First, the wide variety of vessels around the tendons and then the fact that, during movement of the tendon, there is no influence on surrounding tissues, which remain stable.
There is therefore obviously some kind of force absorption system.

By looking at a Y – shaped vessel, we were able to approach the problem more simply. We came across a Y-shaped vertical structure with two branches, 1 and 2 with connections at the bottom at point A, and at the extremities B & C.

But let's analyse the movement more closely.
We observe that during flexion, the two large vessels, 1 and 2, are indeed moving apart. However, compared to a smaller vessel, number 3, not only do they move faster, but the two branches move at different speeds, as the distance between B & C has doubled.

So, several forms of speed and progression seem to exist in homogeneous living matter.
How can this be explained?

Due to the influence of reductionist linear thinking, the only rational explanation used to be that vascular structures were reinforced by several coaxial layers of connective tissue, sliding between them, harnessing the vascular structures, with degressive diameters.

However, this view of annular layers sliding together needed the existence of a hierarchical distribution.
In vivo observation made the notion unacceptable.
There are no distinct laminated layers with stratified strips wisely stored next to each other.

This meant that we needed a new way of thinking– something posing the problem in terms of global dynamics, and continuous matter – a theory involving the concept of a tissue continuum, in total contradiction with the traditional view of sliding structures.
In the body everything is connected.

However, another fact also leaves us puzzled when we watch the hand of the pianist extending his fingers, the extensor tendon moves a few inches transversely and longitudinally on the dorsum of the hand, but the subcutaneous veins, here in blue, just above, move much less and the skin even less.
How can we explain this ability to absorb movement between structures so close together and in such a short space of time?

Because if everything is connected, if everything moves at the same time but in different ways, we must be able to explain how all the components connect and adapt to each other during movement.
Yes, we must emphasise this fact. All the fibers are connected and all the structures are in continuity, but working in different ways and different speeds. How is this possible ?

To attempt to address these fundamental issues, which have been totally disregarded, let us first examine the skin of the artist.

The skin surface is woven into a framework by these polyhedral drawings… irregular, fundamental, simple and yet rarely described in anatomical literature while all its cellular constituents are fully examined. And yet each of us can observe these so-called "polyhedral shapes on our own body. Therefore, questions must be asked:
Why is the skin surface made of polyhedron shapes?
Why isn't the cutaneous surface perfectly smooth?

Questions which might seem ridiculous but are in fact fundamental, yet remain unanswered.

Let us look at the surface of the skin under the microscope.

The epidermis, our most superficial limit, is a surface printed with theses small changing polyhedrons, all of them irregular and different, limited to 3, 4, or 5 sides, each side measuring about 500 µm*, with lines approximately 50 µm wide between the polyhedrons.
No one polyhedron looks like its neighbour, and their distribution is totally irregular.

When the skin stretches and creases during everyday activities, these small polyhedrons move, their shape and appearance change, and when the forces are removed, they return to their initial state.

Yet, on closer observation, we do see those lines of force which change from vertical to horizontal, then blur out to appear again according to the strength of the pressure exerted.
These lines of force have an undeniable physical reality, and the filter of polarized light enables us to imagine how complex this constitutive network is.

First, let's see the movement magnified 10 times.
Polyhedrons are directed to the right.
Let's press on the left. They all move rapidly, apparently in a disordered manner; their forms change and the lines of force move to the left.

The response to the constraint, to physical force applied, is obvious. The gymnastic agility of the polyhedrons, the apparent mechanical ability to change forms and orientation needs further investigation.

The next sequence will clarify these movements, by drawing the microscope closer with 25 times magnifying power.
At rest, let's examine a polyhedron A, B, C, D.
Let's pull downwards lightly on the framework without changing the depth of field of the camera.
The elements B, C and D are moving downwards. The separation lines are only stretched.
But A remains rather static.
Then, as the traction exerted becomes stronger, new lines of force, E, F & H, emerge, oriented in the direction of constraint, passing through existing structures. Then, as the traction becomes stronger, new lines appear coloured in pink even slightly modifying the initial structural lines. Increasing constraint creates new lines here in green. The distance from A to C has increased by 15%.

So, we see stretching in the direction of the applied force with successive appearance of new lines of force added to the original ones, which look different and change the general shape.

Moreover, inside each polyhedron, we can observe other subunits with varied dimensions and forms, which remain inactive until the tension overwhelms the fibres, and produces their final shape.

We get the impression that there is a dynamic environment, with structural latent solutions. It is certainly a fractalisation that makes the dispersion of the force easier.

These dynamic comportments based on fractal organization are extremely fascinating phenomena, and can be easily observed in heavily exposed skin, like skin of the palm, where wrinkles are particularly visible.

Inside these polyhedrons, measuring 500µ on each side, we can observe sub-polyhedrons of 50 µ. These substructures are perfectly distinct, both morphologically and mechanically, because each small polyhedron adjusts to its neighbour inside the bigger one.

The cutaneous architecture is not inert; it is living, and under constraint, as it always returns to its original position, with perfect tissue memory.
Furthermore, from observation of modifications at the skin surface, it seems that the shape of the polyhedral epidermis is certainly shaped by the underlying structures.

However, what is their nature?

The section of the epidermis and part of the dermis will strengthen our assumptions.

Firstly, when we cut the skin, we observe the separation of skin edges. The tissue tension is obvious.

Then we find the fibrils from the hypodermis and subcutaneous tissue, penetrating into the dermis, intertwining.
The dynamic cut of the dermis will confirm this by highlighting clear fibrillar lines passing through the dermis and upwards towards the furrows, thus defining the polyhedrons at the surface.
Unquestionably, these micro fibrils with their specific biomechanical behaviour, infiltrate the dermis, penetrate and demonstrate fibrillar continuity - and therefore identifie the physical link between the surface of the skin and the deeper structures - while allowing the flexibility of the skin, without any rigidity. The epidermis is not only a simple carpet of cells

So we are facing an evidence. The organisation of the cutaneous surface is polyhedral and fractal, and has physical links with the subcutaneous world. Therefore, the question is : What kind of link is it ? Where does it come from ?

With the aid of a video endoscope, we'll continue to stroll around under the skin to try to understand this apparently simple world of sliding, mobility and smooth slippery surfaces. We wanted to find out how it could accomplish both fast, sometimes violent movements and gentle minute ones, without the slightest jerkiness.

When you look closer, you can see that just below the dermis and hypodermis, there's a highly mobile network of tissue filling every available space.
The show is total with pseudogeometrically shaped fibrillar structures encompassing the muscles, skin and fat.

Let's dive into this world of fibrils.
If one grasps and pulls the tissue with tweezers, we immediately find this multi fibrillar multi vascular organization, surprising because there is a lack of any apparent harmony. Sharp traction causes curious movements to occur due to the bursting of vacuoles at atmospheric pressure, demonstrating the existence of hydraulic systems under different levels of pressure.
These micro fibrils may have quite large diaphanous surfaces, reflecting sharp edges but they can also be, narrow, long or short, swollen or cylindrical.

Diversity is everywhere and there is endless variety.
Ropes, rigging, harnesses, with rings that reinforce the solidity like an articulated bamboo stem, transparent sails, dewdrops.
Tissue continuity is total, the blend is homogeneous and the organization completely irregular, disordered, and fractal. Smaller fibrils are found between major ones of a similar nature, and so on…
Beneath the skin, at first sight, there is no conceivable order. Instead, there is a completely disorganised network of collagen fibers with a diversity of shapes and a combination of fractal and chaotic patterns, similar to the diversity at the surface of the skin.

And this fibrillar chaos is found throughout the body. In every nook and cranny, at the level of other extensor tendons, but also in the abdominal wall near the rectus abdominis muscle, in contact with the thorax near the latissimus dorsi muscle, in the retro-conjunctival groove of the eye, and so on. It would seem that this tissue serves to frame the muscles and tendons, and could even be their primary constituent material.

Even structures not called upon to move as such nerves and the periosteum are composed of this tissue fibres, but with differences in their organization.
So, this fibrillar chaos, which could be defined as the unpredictable behavior of non linear systems, is everywhere and varies depending on its functional role. But important questions remain.

How can this fibrillar continuity, this tissue cohesion, ensure simultaneous movement and sliding in the fingers, and hands of the pianist, or legs and shoulders of the gymnast, while having no effect on surrounding tissues, and ensuring their return to their resting position, while at the same time modulating the input of nervous or vascular energy and constantly maintaining the pre-ordained shape of our bodies?

For, the essential imperatives of any attempt to explain the morphological dynamics of life should be in accordance with the principles we have just stated.

To really understand this we must think in three dimensions and to think of our bodies, our fingers, our backs, our legs, in terms of volumes.
Most sequences demonstrate the existence of pseudogeometric shapes, resulting from the intertwining of fibrils. This visual impression of the accumulation of polyhedrons, that is reminiscent of the surface of the skin, finds its elementary definition in the concept of the micro vacuole and intra fibrillar micro volume, which is the basic element consisting of a polyhedral fibrillar frame enclosing multiple micro vacuolar spaces of varying size, between 10 µm and 100 µm, with a glycosaminoglycan gel inside.

The notion of the microvacuole is the first obvious information we received at the begining of our endoscopic tours. It's a physical reality. Don't forget that the microvacuole is an interfibrillar microvolume .

These micro-fibrils have a diameter of about ten to twenty microns and are made up predominantly of collagen type I and III.

By intertwining in an irregular, fractal manner, they determine the volume of the micro-vacuole, which is filled with a glycosaminoglycan gel.

By accumulation and superposition, these multi micro-vacuolar polyhedral patterns build elaborate forms.
The cell fits into this structure perfectly and has similar dimensions ranging from 10 to 60 µm.

So now we understand better what is already happening in the pianist's hands or the legs of the gymnast. It's a real firework display of movements of fibrils, intersecting, overlapping and substituting. There is, however, an apparent underlying logic - the orientation of the fibres in the direction of the imposed force. Thus, thanks to this fractally organised network, constraints are distributed around to ensure the achievement of mobility in 3 dimensions.

However, how can this observe chaos result in a coherent motion of surprising force and accuracy?
How can this multi-micro-vacuolar ensemble, ensure the overall increase of the mobile structures, with no surrounding movement, and while preserving the shape of the structures? That is to say, an absolute dynamic role and total absorption. In other words, two dynamically opposed roles combined with a memory of return to the original form.

How do these fibres ensure tissue cohesion, preserve volume, and adaptable mobility?

The answer is perhaps this:
Look at this fibril. In an instant, three movements are performed: sliding, division, and stretching.
This sequence is fundamental because it shows the morphodynamic capacity of the fibrils, and when you imagine that it is performed by billions of fibrils, in three dimensions, in an instant, one gets an impression of extreme complexity and even infinity.
To be achieved, these three types of movements involve the intrinsic properties of the fibrils.

It would seem that the fibres intrinsically possess the ability to distend or retract due to their molecular structure.

Closer scrutiny reveals that ringed superpositions between the fibres become distended just before the overall movement ensues. This could be the first stage, a form of preparation before the request to move is dealt with.

To respond to the direction of the stress, the biomechanics of the microvacuoles are assisted by the added capacity of the fibres to migrate around a nodal point, along another fibre as a kind of living hinge.

Finally, fibres also seem to be able to dissociate into several parts, just like the hydra-headed monster of mythology, to shear off and reform.
And when you imagine that these myriads of seemingly random micro motions are performed instantly on millions of fibres, then you understand that this ability of matter and its spatial organization, offers an infinite potential of movements.
Highly effective, pre-stressed, flexible fibrillar structures are undoubtedly advantageous due to their ability to take various forms, being more stable, more adapted to sliding in between themselves, and allowing for better metabolism, thus prolonging their life span.

However, not all these fibres are mobile. Form has to be maintained. Some are fixed, with stable crossing points.
The building architecture can be mobile while keeping a given and maintained shape.
This shape, however, is subject to the mother of all forces, the force of gravity.
How does this multifibrillar architecture resist gravity ?
How can it avoid crashing?

Bio tensegrity and mechanical transduction are a partial answer, or at least an attempt to explain this, and so deserve close attention.
Bio tensegrity explains the distribution and transmission of the force of gravity on all system components. It is suitable for the architectural and fractal composition of life as we observe it in vivo or in vitro.

It introduces the concept of a state of tissue pretension that seems obvious to those who handle living human matter. One only needs to make an incision on the skin to see the separation of the edges as the skin is cut to confirm this.

Finally, the geometry of the polyhedral type components is reminiscent of the micro vacuole concept, whose semantics should definitely be changed, but imposes the concept of a micro volume formed by a myriad of structuring, interlacing fibrils.

It is also necessary to consider additional factors ignored by the biotensegrity concept. These are the mobility of the structuring materials and the concept of pressure and volume between the structuring materials. The concept of an adaptable micro vacuole at constant volume, but variable pressure, can explain the distribution of water within the body.

Because if water is everywhere, comprising 85% of the body's weight, which is appreciable at the least incision, and is present in all tissues, cellular and especially extra cellular, how it is distributed in the body?
The problem of the distribution of water in the body is a basic question with no satisfactory answers. The Microvacuole, a microvolume filled with water and glycoaminoglycans, subject to the laws of minimal arrangement, is able to explain this by it's capacity to accumulate and to establish the form and shape of a body.

The microvacuole volume containing hydrophilic glycosaminoglycans maintains an optimal volume generating pressure. A phenomenon that one can enjoy seeing in the multitude of tiny bubbles hatching in the open air.
The destruction of this structure causes the occurrence of droplets along the fibrils and so explains this phenomenon observed regularly as droplets of dew.

Flexibility, agility, mobility and strength can be better explained, and therefore the motion of flexion of the fingers on the piano keys may find an explanation through this lively perception of the isolated flexion of one or more fingers, and the prowess of stretching skin during a movement of the shoulder.
These fibrillar architectures and their micro vacuolar spaces lubricated with glycosaminoglycans, are indeed major players in the choreography of this ballet.

From now on, we can account for the anatomical structures differently.
From the skin to the muscle, from the tendon to the periosteum, the body is one and has the same multi-fibrillar architecture possessing constant intra and inter-fibrillar movements with different cellular and morphological specifications.

The cell belongs to this system, it is this system, it is in this system, from the DNA helix to the cytoskeleton including the links to the integrins and neighbouring cells. Everything is in continuity, everything is connected, everything moves to fit, everything moves and always comes back to its previous position, everything moves within the tissue continuity.

The body seems to be an ideal mesh, made of fibres, fibrils and micro-fibrils, and micro-vacuolar spaces with a structural rationalism allowing us to associate molecular physicochemical biodynamics with quantum physics.
Therefore, living form can be described and interpreted.
A real structural ontology can be worked out through a basic functional unit, which is the micro-vacuole, the micro-volume responsible for the form and the dynamics.

Now, while we stitch the skin and close the suture, let's keep in mind that, from now on, nothing can be accounted for without considering this fractally organised and chaotic tissue architecture, vector of that most beautiful of efficiencies life

So, as we have seen, connective tissue is not only a tissue for connexion between different organs, it is actually the constitutive tissue, the tissue that makes the frame and gives organised and structural existence to the body. Form is maintained and preserved thanks to this interior fibrillar architecture, in which different cellular specificities are embedded.
Thanks to this concept which embraces fractal organisation and non linearity , we enter the realms of disordered systems , self organisation and the science of complexity . Through our work, we believe that we are participating in the search for a rational explanation of nature.