The story of this film began about 20 years ago. We were transferring vascularised turkey tendons in our University research lab. and were struck by the intricacy of the vascular network. Thereafter, the Chinese school of plastic surgery discovered the notion of the retrograde flap and we began to develop a technique for transferring vascularised retrograde tendon flexor transfers onto the cubital pedicle to get round the problem of reconstructing flexor tendons.

Little by little, this new vision of anatomy began to throw light on the relationships between the tendons, the sliding sheaths and the vessels, and to challenge the very foundations of the classical school of thought.

During the revascularisation following the release of a garrot, we observed that not only the tendinous extremities bled, with an apparently circular longitudinal and peripheral vascularisation, in contradiction with the avascular theory that held sway at that time, but that there seemed to be a real continuity between the sheaths and the tendons, which was not interrupted despite the distension occurring during sliding. It was also clear from observing the behaviour of the vessels of the common carpal sheath during flexion and extension that rather simplistic mechanistic explanations could no longer account for these phenomena, and that this apparent disorder and irregularity of shapes was in fact the basis of some other form of complexity that we still knew hardly anything about.
In our attempts to find an explanation, we began detailed in vivo microscopic analysis of the distribution and mobility of the vessels using 25-fold video magnification.

By looking at a vessel as a petrol pump, we were able to approach the problem more simply. There was this vertical structure looking like the main part of the pump, then the pipe, and finally the adjoining vessel, just like a car filling up at the gas station. The pipe seemed to move away as the car moved off, and to fold up as it approached. Look at this sequence. A large vessel, vessel three, is gradually moving behind vessel two and the pump during flexion, then goes past it while approaching vessel one, which in fact is the car-vessel, whose pump is slowly receding as the pipe extends to its maximum. Finally, vessel three has overtaken vessel two and has closed on vessel one, which itself has receded from vessel two.

So several forms of speed and progression seem to exist in homogeneous living matter. 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, the closest to the tendon moving the fastest and the furthest away moving the slowest.

However, that view of annular layers sliding together needed the existence of a hierarchical histological distribution to stand up to scrutiny. Yet in vivo observation made the notion unacceptable. This meant that we needed a new way of thinking– something posing the problem in terms of global dynamics, continuous matter – a theory involving the concept of a tissue continuum, in total contradiction with the traditional view of sliding structures. Briefly, the notion of stratification and virtual space.

In vivo observation or with electron microscopy after dehydration showed that this collagen network in fact formed continuous matter composed of billions of tiny disorganised vacuoles apparently arranged in a fractal manner. It was pseudopolygonal but with a very special dynamic forming a volume of glycolycan, whose surrounding was composed of type 1, 3, 4 or 6 collagen fibres of considerably different sizes, according to their anatomical location and the role they had to perform. In this chaotic haphazard world, there was absolutely no geometric regularity, no linearity. Just fractal chaos.

This system is customarily known as the connective or areolar tissue. But we called it the Multimicrovacuolar Collagenic Absorbing System.

To our minds, it was a rubbery elastic system because its role is to avoid reaching a threshold of resistance at which the collagen might shear. It has to allow the tendon to move freely without transferring the movement to the surrounding structures.

It also struck us that the biomechanical behaviour of this shock-absorbing system could be accounted for by the theory of drawers: as the tendon moves, the first vacuole might undergo traction to a point where it triggers the adjoining vacuole into action. Then the third is triggered, and the fourth, to such an extent that the final vacuole remains almost inactive. Our second hypothesis was that the same process was involved, but that the pressure was distributed equally among the vacuoles. However, this meant we were still only in two dimensions and that our only explanation was based on linear processes.

Yet we were sure of something: the tissue continuum, the existence of basic vacuolar-type structures and the presence of a shock-absorbing system allowing the organs to act independently.

We had to move to three dimensions to really understand what was happening. And it was around that time that computer synthesized images came on line. They made it possible to visualise structures as a system in perpetual motion, with two rigid boundaries: a fixed external one and a fully mobile internal one.

What we did was to introduce a cross-linking mesh-type architecture which included the microvacuoles on the armature. We then looked for the fractal distribution. The scientific approach and the graphic model pointed to the same apparent reality: there really was a sliding system with brilliant liquid lying between the vacuoles and an armature of collagen fibres. This confirmed what we had initially thought about the pulling and tugging going on between the vacuoles. Moreover, thanks to this discovery, we were able to confirm that not only the tendons were able to move independently from each other: entire organs could do likewise, so the system was common to the whole organism. It was then that we realised what we had discovered: this Multimicrovacuolar Collagenic Absorbing System was to be found everywhere in the body.

This sliding tissue is to be found in every nook and cranny of our organism: in other tendons like the extensors, 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. Indeed, it would seem that this tissue serves to anchor 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 fibre, but with differences in their arrangement and size.

This mesoscopic framework of living matter required a more holistic view to be fully understood. So we began to look at the cutaneous and sub-cutaneous structures, which we thought we would find to be more stable in this mobile tissular environment.

By its structure and its role of enclosing the other sensory organs, the skin is more than just an organ: it's a set of organs which is anatomically, physiologically, culturally and psychically complex.

Of all the senses, touch is the most fundamental: you can survive without smelling, seeing or tasting, but not without touching.

The skin permanently relays information. It never shuts down, blocks up or sleeps. It has an odour, a texture, it perspires, secretes, eliminates. It exchanges signals with the outside world. Thanks to the skin, the body's surface is as much a machine for communication as a protective barrier. It can change colour, texture and shape, and retains the vestiges of aggression such as sunburn, scars and disease. At birth, it is taught, ready for life: then, little by little, it ages, gets wrinkled, folded, and sags.

Whether in newborn babies, adolescents or adults, the skin is never totally flat and smooth. Through the hairs on its surface, you can see pseudogeometric structures separated by strength lines allowing movement in all dimensions of space. These triangular, pyramidal structures move in relation with each other.

With any movement, they immediately align themselves with the traction. Their former position disappears and a new shape is adopted. Then, as if by memory, they return to their initial position. With every single daily gesture, be it a caress or a fall, the skin undergoes this form of translation, traction and stretching. Yet with the exception of open wounds, it returns to its initial position. Of course, this movement has been known since time immemorial: it's called elasticity. But the question is: how is this elasticity linked to the sub-cutaneous structures?

With the aid of a video endoscope, we began to stroll around under the skin to try to understand this apparently simple word 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.

Dissect with a surgical blade and what do you see? Just a wealth of tissue connections, a histological continuum, without any clear separations between the skin, the dermis, the hypodermis, the vessels, the aponeurosis and the muscles. How is it then that this can all move so smoothly? And how can sliding come about?

When you look closer, you can see that just below the dermis and hypodermis, there's a highly mobile tissue encompassing everything else and penetrating what is known as the undermined plane. When this tissue is tracted upward, you get a surprise. Curious movements occur due to the bursting of vacuoles at atmospheric pressure, demonstrating the existence of hydraulic systems under different levels of pressure. The show is total with pseudogeometrically shaped fibrillar structures encompassing the muscles, skin and fat. Yet what are these shapes? What do they do and why are they there? Is this what we have traditionally termed the connective tissue?

Let's now delve into this world of fibrils. Intial scrutiny reveals basically two types of structure. Some are quite wide, with edges like knives and diaphanous surfaces. These surfaces are made of glycoproteinous derivatives. Others resemble longitudinal fibrils which may be fine, long or short, swollen or cylindrical. At first sight, they look alike. But look closer and you can see tremendous diversity.

Bird's plumage. Reed stems. Bundles of rushes. Ears of wheat whose resistance to traction is considerable. Ropes, rigging, harnesses, with rings that reinforce the solidity like an articulated bamboo stem, transparent sails, dewdrops. Travel along these pearly structures and you notice the same fractal arrangement everywhere: large fibrils endlessly punctuated by other smaller ones. The tissue continuum is total, the marriage homogeneous and the arrangement completely fractal.

A world of fibrillar chaos. The human body would seem to be one and the same tissue that has differentiated over time but whose basic organisation is stereotyped.

Yet this organisational framework supporting life must have its inherent rules of behaviour. How are these structures organised? How do they resorb and move and what role do they play?

To use the jargon of physical mechanics, the arrangement can be termed a complex one, completely stable and in search of equilibrium: a system with tremendous capacity to resist and adapt to change. For physicists and doctors alike, there is no other such entity with so much cacophonous movement on the microscopic and macroscopic level: movements involving the muscles, fluids, fibrils and cells. Here we are at the very heart of complexity. A Capernaum of collagen bathed in glycolican with reservoirs of fatty microglobules storing energy, information and matter. A communications network for exchanging energy, matter and information between the component parts of the system and the various reservoirs by way of a torrent of blood rushing between the nerves, veins, arteries and cells. Some mechanisms are still poorly understood such as the fluctuations in pressure visible in these images of the movement of drops within a filament that is clearly hollow.

And there's even more to the story. Within this global network encompassed by the skin, you also have valves able to increase or decrease the flow of information in terms of intensity and speed. Storage times play a leading role here in amplifying or inhibiting other mechanisms, with a direct consequence on fat and lymph reserves.

This multimicrovacuolar system, which at first sight seemed chaotic and complex, is therefore a set of elements with a large number of non-linear interconnections and arranged with a universal aim in mind: to promote life, to subdivide, to multiply according to pre-ordained criteria such as the level of oxygen, the temperature of the body and the composition of the plasma. This internal state of equilibrium must be maintained at all cost.

Yet this internal equilibrium comprises another essential aspect: the maintenance of the structural equilibrium in terms of mechanical stability and not in terms of flows or transmitters. In order to transmit, the structure must be able to resist, to adapt to basic environmental requirements and to maintain its architecture.

Most sequences demonstrate the existence of pseudogeometric shapes with a polygonal distribution. This visual impression is the most simply expressed in its basic element: the microvacuole. We have already seen this with regard to the peritendinous system. It is composed differently according to the dynamic role it is called upon to play. The greater the longitudinal travel, the finer and more repetitive the form of vacuolar organisation. However, the basic composition of a polyhedric fibrillar network filled with jelly remains the same.

The bottom line is that the network must ensure its own total movement without disturbing anything else around it. The dynamic has to be absolute and the shock absorption immaculate. These two apparently conflicting roles must also be accompanied by the spring-back memory function, while saving on energy and heat expenditure. The rheologic equation -- that is, the local relationship between stress and deformation -- could be thought of in terms of rubber-like elastic behaviour, as suggested by the collagen fibres, which cannot stretch indefinitely.

Another school of thought has it that there could be a mechanism based on fluctuating ion concentrations. The issue is still open but we believe that the key lies in the notion of combined transmitted stress: each fibrous element might be connected to its neighbour by a form of pre-stress. When stress is applied, the adjoining element might undergo a slightly lesser stress until it attains the required deformation.

However, these sequences of interlacing, intertwining fibrillar structures created by the repetition of movements within other movements cannot be accounted for by standard reasoning. What's needed is physical rules calling upon non-linear mathematics.

To approach these mechanical phenomena, we looked at the theories of chaos, fractal distributions and their relationships with traditional science. There were many avenues to explore and their purely theoretical aspects and metaphysical conclusions were to be treated with caution. Since that time, several scientific articles have discussed the notion of tensegrity.

This concept of tensegrity undoubtedly threw light on our understanding of how organs slide together. The Americans Buckminster Fuller, an architect and Kenneth Nelson, a sculptor, both worked on macroscopic structures and designed buildings and sculptures with common characteristics. The basic concept is that the forces applied are transmitted to all the elements of a structure composed of long articulated girders linked by pre-stressed elastic cables already under tension.

The principle is an architectural system in which the structures are stabilised by an equilibrium between the opposing forces of compression and tension, thereby allowing shape, solidity, multidirectional movement and independence from gravity to be conserved. Structures established by tensegrity are not stabilised by the resistance of each component part like a column resisting gravity but by a distribution and equilibrium between the mechanical stresses throughout the whole network. Such structures are therefore multidirectional, stable in all directions and independent of gravity. These forces stabilise the structure through their equilibrium. But most importantly, all the forces are subjected to all the structural elements, with the result that the slightest increase in tension on any one of the elements is transmitted to all the others, even those the furthest away.

In real applications, the resulting shapes are often geometric, triangular, quadrangular or somewhat icosahedral. It is essential to grasp that in order to fill space, living structures obey the forces that make them take on various shapes. It would seem that the icosahedron is the optimal shape for occupying space with the most minimal arrangement. In fact, nature frequently applies rules of self-assembly when creating natural triangular, polygonal or spiral motifs.

At the molecular level as in the collagen molecule, recent research has demonstrated that long-chain amino acids fold into a helix, become stable thanks to the equilibrium between the attractive forces of hydrogen bonds and other forces allowing proteins to resist compression. This sets up sequences which behave like flexible joints. At the cellular level, Dr Ingber discovered the intracellular armature, an internal mesh composed of fibrillar elements arranged haphazardly but ensuring the fundamental role of restoring the original shape once the pressure is released. This

pseudopolygonal tendency indeed raises fundamental questions since it is present at all levels of living matter, be it animal or vegetal. Through the importance of physical forces such as osmotic and electromagnetic pressure, it would seem to be the preferential system of construction that Nature has developed during evolution.

We should pay homage to D'Arcy Thompson, a humanistic Scottish biologist of the nineteenth century. He thought that the adaptational teleology of Darwin needed to be added to by including physical and mechanical causality. Convinced that neither chance nor destiny could account for the stupefying diversity of biological shapes, the unquestionable unity of organisms and the limited number of living forms, he incorporated physical forces into a theory accounting for the multiplicity of natural shapes. Intuitively, he hit on the idea that the forces that shape life resemble each other. It was his wish that biology should not leave aside physical aspects; that it should incorporate physical mechanisms so as to account for both shape and growth; and that it should not focus entirely on teleology. Indeed, neither Darwinism nor neo-Darwinism is able to explain the original morphogenesis.

We began to wonder whether all these triangular, rectangular and polyhedral shapes that we were filming might not be part and parcel of the icosahedron, the basis of tensegrity, which so closely resembles a three-dimensional vacuole.

These highly efficient flexible pre-stressed fibrillar architectural shapes associating great mechanical resistance and optimal sparing of matter are no doubt helped by their capacity to take on various shapes that are more stable and adapted to sliding between each other. This presumably enhances their metabolism and thus prolongs life. Surgeons feel this notion of pre-stressing every time they incise skin since the margins recede spontaneously. And at the end of an intervention, you can also feel it as you tug hard so as to bring the margins together when making sutures. It's as if the phenomenon were so common that we simply take it for granted.

Despite this apparent harmony that the theory of tensegrity offers, we are but beginning to perceive the vast complexity of the mechanism. Taking these sliding movements to be a simple adaptation of ropes and rigging according to an order pre-defined mathematically, even fractally, is rather insufficient an explanation.

Other factors should be taken into account. First, it would seem that the fibres intrinsically possess the ability to distend or retract thanks to their arrangement. 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, itself encompassing another fibre. The impression is one of a mobile hinge with angular distortion created by added shear forces.

Finally, collagen 4 and 6 seem to be able to shear off and reform as if nothing had happened. They also seem to be able to dissociate into several parts, just like the hydra-headed monster of mythology, meeting any and every request to morph mechanically in space. This ability of matter to organise itself spatially offers an infinite potential for movement. However, the collagen armature is only one player in this choreography. The permanent lubrication by glycoaminoglycans through these diaphanous veils, where the drops are reminiscent of morning dew, is omnipresent, as is the migration of liquid within the fibres, suggesting that hydraulic mechanisms must play a decisive role here. The appearance of bubbles and bursting whenever a structure meets the atmosphere or during traction signifies the existence of a pressure equilibrium. Moreover, one should not overlook the importance of these glycoaminoglycans, which are at different concentrations according to the location in the body. Whatever the final answer, the flexibility of these tissues relies on a mechanism of which one of the underlying modes of action could be tensegrity. Yet tensegrity cannot account for everything here.

This complex sliding system, which maintains the structures and keeps them mobile, is therefore modified according to the circumstances and is subjected to the natural laws of change. This occurs either as a result of overloading as in obesity, in which the vacuoles are dilated by adipocytes, or by wear as in tenosynovitis, in which the fibres break or fray. But this can also occur in the skin withering that accompanies slimming or skin aging.

This collapse of our collagen matrix takes place at a variable rate, but the process is inevitable as the forces of gravity progressively take their toll. Fibrillar tension, which keeps our tissues tonic, finally loses out to father time. Once again, entropy is the ultimate winner.

Whatever the final story, understanding the mechanical and biomolecular characteristics of this flexible tissue of communication will one day allow us to apprehend the full meaning of the healing process, to reconstruct living structures and perhaps – who knows? – to satisfy Man's eternal dream: to slow down the effects of Time.