Tensegrity

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Cell Models

•Continum models: cell is viewed as a soft material inside an elastic membrane (a ballon filled with jelly) with a single isotropic elastic and viscous modulus. Cell interactions are purely based on reaction and diffusion. The model assumes that the cell's microstructure is insignificant . The only structural element is the cell membrane.

•Foam or sponge model: the cell has an internal stuctrural element (actin) which resists compression.

•Tensegrity model: cell is viewed as a composite structure composed of discrete stress beraing elements.

Mechanotransduction: How do organisms sense mechanical signals and tranlsate them into biological responses?

We know that mechanical forces play a role in growth and morphogenesis. Eg, bones grow strong in the opresence of gravity. Furthermore, all cell functions growth, differentiation, motion, gene expression are shown to be sensitive to forces in-vitro.

Durotaxis, endothelial cells in response to flow,...
If cells were viscous blobs, they would not respond to forces. They would not become more rigid when stressed. They would not pull on soft surfaces.

Note: No-one has directly found a receptor mechanical transducer yet- but evidence points to integrins and CAMS.

Tensegrity

“tensegrity is islands of compression inside an ocean of tension”
Buckminster Fuller
TENSIONAL INTEGRITY

Characteristics:
Discrete compression elements
Continuous tension
Stable form and volume
Prestressed
The system naturally assumes a form which minimises the internal elastic energy.

Think of a tent: the higher the prestress (rods compressed, material pulled), the stiffer the tent.

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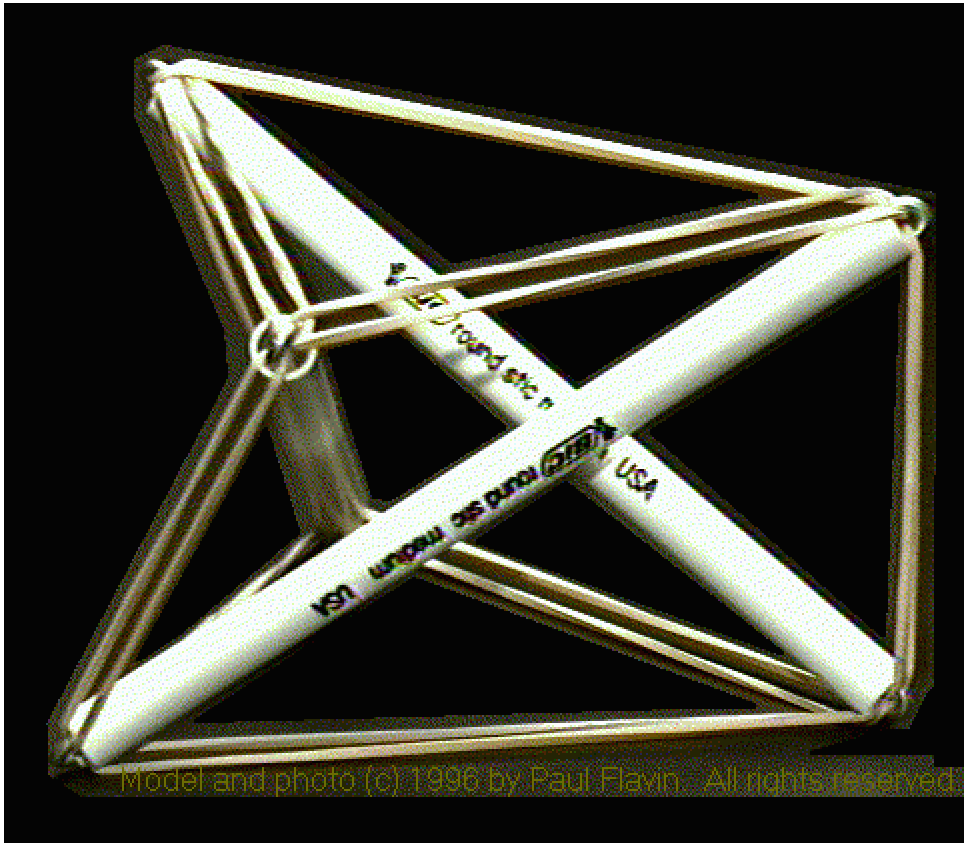


The triangle is the basic element.

The helix can also be a basic element

TENSEGRITY is a structural system that maintains stability by distributing mechanical forces through components that interact in just one of two different ways - attraction (tension) or repulsion (compression). Such simplicity is due to some basic laws of physics, and because it is energetically efficient is likely to have developed throughout evolution to produce biological organisms of great complexity. Tensegrity systems eliminate the need for bulky elements, and are lightweight structures with a high resiliency that depends on the integration of every part. It seems to be pervasive in biology and is described in the human body through molecules, cells, the extra-cellular matrix, vascular system and entire musculo-skeletal-fascial system.

There are many examples in nature. Carbon atom, spider web, water molecule, proteins,
Think of a tensegrity stucture as one which allows continuous adapation to external forces without breaking. Even when elements are broken, the system maintains form (and function!!)

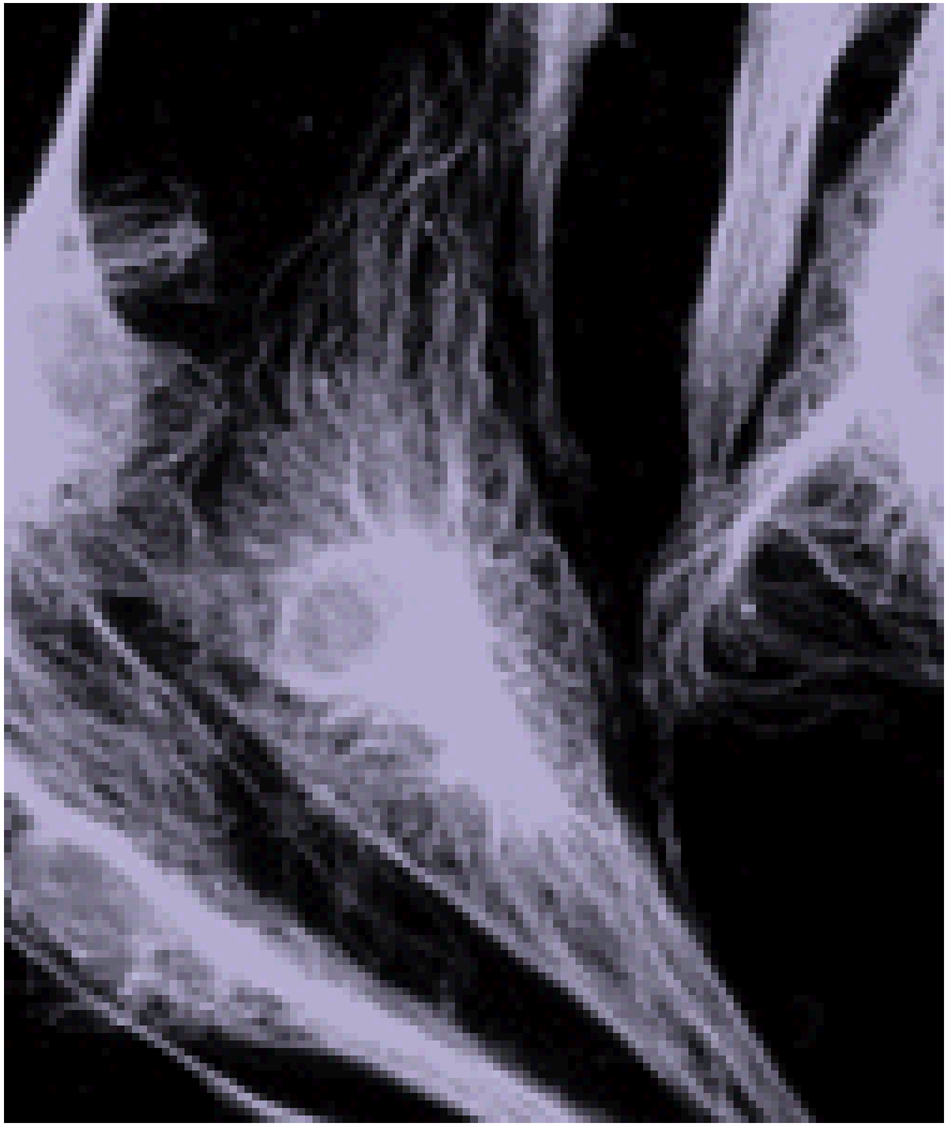
Moreover, the whole structure responds to stress (local signal produces a global response).

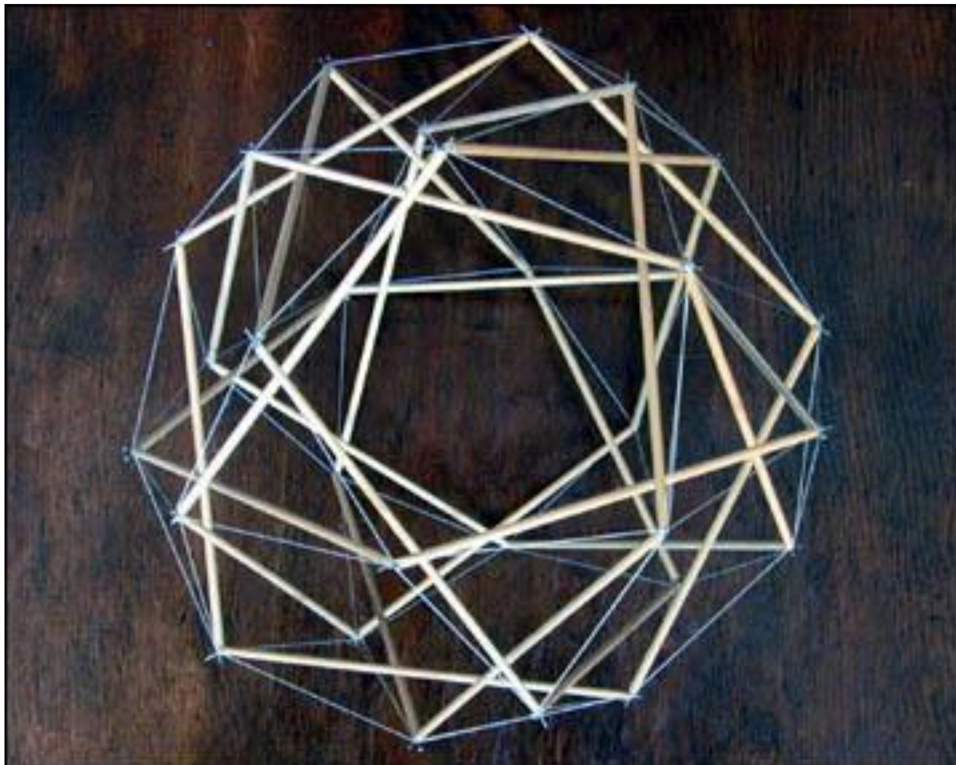
A man made building is NOT a tensegrity structure.

Cellular tensegrity

Ingber showed how the cytoskeleton behaves as a multi-functional tensegrity structure that influences cell shape and activates multiple intra-cellular signalling cascades. Within the cell, **microtubules under compression** are balanced by **microfilaments of actin under tension** with bundles of actin and spectrin fibres playing similar respective roles in the cell cortex. Intermediate filaments link them all together from the nucleus to the cell membrane so that any change in force at one part of the structure causes the entire cytoskeleton to alter cell shape. Tension is generated through the action of actomyosin motors and polymerization of microtubules.

The cell stress can be transferred externally through integrins.





The cell tensegrity model suggests that cell spreading is due to the transfer of stress in the CSK to the substrate.

The cytoskeleton connects to the extracellular matrix (ECM) and other cells through adhesion molecules such as integrins and cadherins, respectively. These transmembrane proteins create a mechanical coupling that transfers tension generated within the cytoskeleton to the ECM and adjacent cells. Because a prestressed state of tension exists between them, so a change in ECM tension also causes a realignment of structures within the cytoplasm and a change in cell function; this process is known as mechanotransduction.

The cellular tensegrity model does describe several aspects of cell behaviour, particularly the non linear stiffening in response to mechanical stress and the fact that high presstress (CSK more rigid due to actin and microtubule polymerization) is indicative of higher elastic modulus.

Question: Define cellular tensegrity in your own words after building and playing with a tensegrity model