Mechanical properties of poorly connected soft solids

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Self-assembly and aggregation of soft condensed matter like proteins, colloids or polymers into poorly connected and weakly elastic solids is very common and ubiquitous in nature. Phase separation, spinodal decomposition as well as externally driven self-assembly or aggregation often lead to gels, which display diverse structures and solid-like mechanical features. The structural complexity of soft gels entails a versatile mechanical response that allows for large deformations, controlled elastic recovery and toughness in the same material. A limit to exploiting the potential of such materials is the insufficient fundamental understanding of the microstructural origin of the bulk mechanical properties. Investigating how the mechanical response depend on the material microstructure will provide a new rationale, which would ultimately lead to several applications, ranging from improving the performance of batteries (colloidal gels), designing smart composites that can prevent the cascade of catastrophic events and can be used in anti-seismic buildings, and many with important biological function, such as new scaffolds for tissue engineering.
In the first part of my talk, using numerical simulations of a minimal model, I will present the link between the topology of the network and the non-linear rheological response: our analysis elucidates how the network connectivity alone could be used to modify the gel mechanics at large strains, from strain-softening to hardening and even to a brittle response. Then I will show the relevance of our model to understand the mechanics of F-actin cytoskeleton. Our study helps to clarify, the mechanism by which mutations cause podocyte dysfunction and progressive kidney disease in humans.

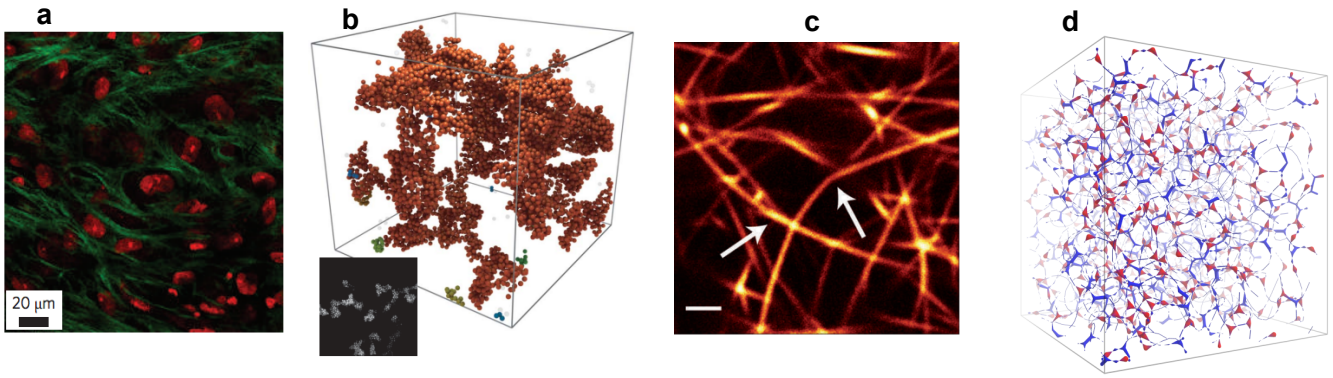

Figure 1: **Examples of soft solids :** a) Alginate scaffolds containing short motifs of extra cellular matrix adhesion proteins such encouraged mesenchymal stem cells to spread and attach to the matrix [Dvir et al Nature nanotechnology 2010]. b) Reconstruction and confocal image of a colloid-polymer system gel [Lu et al Nature 2008]. c) Confocal image of a fluorescently labelled actin/fascin bundle network [Lieleg et al. Nature Materials. 2011] d) A snapshot of our particle network simulation forming at number density $\rho = 0.14$, showing the parts of the network under tension (red) and under compression (blue) [Nature Comm. Bouzid et al 2017].