The secret of resistance—shattering into a thousand pieces

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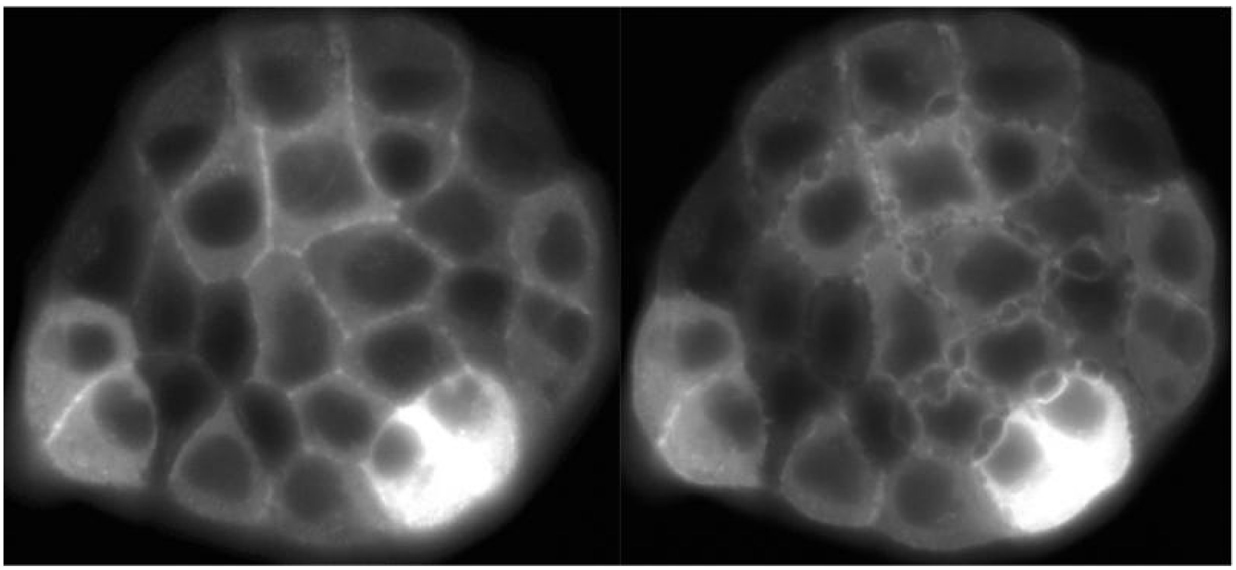

A single layer of epithelial cells stretched (left) and then released (right). On the right, cracks clearly visible along the cell junction lines. The cracks originated from the coupling of the epithelial tissue with the hydrogel substrate – Credits: L. Casares and X. Trepat, IBEC, Barcellona

Being all in one piece is not always a good strategy for resisting external strain. Biological tissues are well aware of it: they tend to crack simultaneously and gradually in several places, rather than catastrophically in one place only. This makes them particularly resistant. A group of SISSA researchers conducted a theoretical study that explains the mechanism underlying this phenomenon, which was experimentally observed in epithelial cell cultures. By doing so, they take their first steps towards creating artificial materials with features inspired by biomaterials. Materials of this kind may have a number of applications, for example in the medical field. The study has just been published in *Physical Review Letters*.

Biological tissues (blood vessel walls, skin, bones …) are incredibly resistant: continuously stretched, deformed and bashed about, but they do not tear. The secret lies in an apparently paradoxical property of theirs: these tissues tend to crack simultaneously in several places rather than in one (or a few) only. This is explained in a new study just published in *Physical Review Letters* and conducted by a group of researchers at the International School for Advanced Studies (SISSA) of Trieste in conjunction with scientists of the Polytechnic University of Catalonia.

"Strange as it sounds, a system capable of fracturing at several points is far more resistant than one that fractures in a localized fashion", explains Alessandro Lucantonio, SISSA researcher and first author of the study together with Giovanni Noselli, also from SISSA. The Italian team, led by SISSA professor Antonio DeSimone, carried out a theoretical analysis of the phenomenon, starting from the experimental data produced by the Spanish group (and previously published). The result of the study is a detailed description of the behaviour of these tissues when they are subjected to the action of external forces.

The computer simulation produced by DeSimone's team considered a single layer of epithelial cells coupled with a hydrogel substrate. The layer of cells was first stretched and then released. "Surprisingly, the cracks never appeared under stretch but only after release", explains Noselli. "We also observed – and this came quite as a surprise as well – that cracks appeared in many places, along the cell junction lines where one cell is in contact with another".

In the process, the authors explain, the hydrogel substrate – which represents the extracellular matrix in which biological tissues are normally immersed – is particularly important. We need to picture the hydrogel as a sort of sponge in which water is trapped. "It's the presence of this substrate that facilitates multiple cracking: when the system is compressed the fluid trapped in the hydrogel pores is forced inside the small cracks at the cell junctions in the epithelial cell layer, causing them to open" explains Lucantonio. By using computer simulations, the researchers determined which specific features of the hydrogel are responsible for promoting distributed cracking.

So here's how the scientist explains the paradoxical effect of multiple cracking: "having to force several fracture points, the overall energy required for system failure increases" says Noselli. "Systems that undergo distributed cracking are therefore more resistant than others where the fracture occurs in a localized manner".

Biomimetics

The work carried out by DeSimone and his group is not mere speculation: tissues having resistance similar to that of biological tissues are highly desirable for applications in a number of fields. "The possibility of regulating the permeability of a film by mechanical strain or the possibility of releasing drugs in a controlled manner through a membrane", explains DeSimone, "are of great interest for biomedical applications".

DeSimone and his team at SISSA are working on the project SAMBAbiomat, which deals precisely with "biomimetics", that is, the study of natural processes and materials with a view to engineering them for new technological applications. "Materials and mechanisms like those investigated in our latest paper may, for example, be applied in small 'devices' (microrobots) to be used in 'tasks' that are useful to humans."

Still in the field of biomimetics, De Simone and his colleagues conducted a series of studies on the motion of algae and micro-organisms, which may one day be used to design microscopic mobile devices.

More information: Alessandro Lucantonio et al. Hydraulic Fracture and Toughening of a Brittle Layer Bonded to a Hydrogel, *Physical Review Letters* (2015). DOI: 10.1103/PhysRevLett.115.188105

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