# Origami in seed capsules

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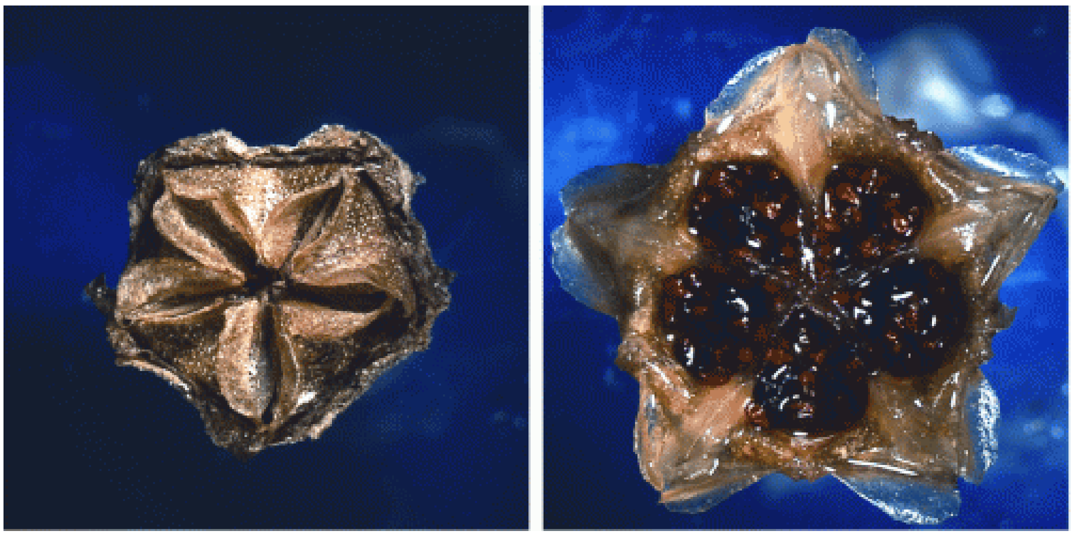


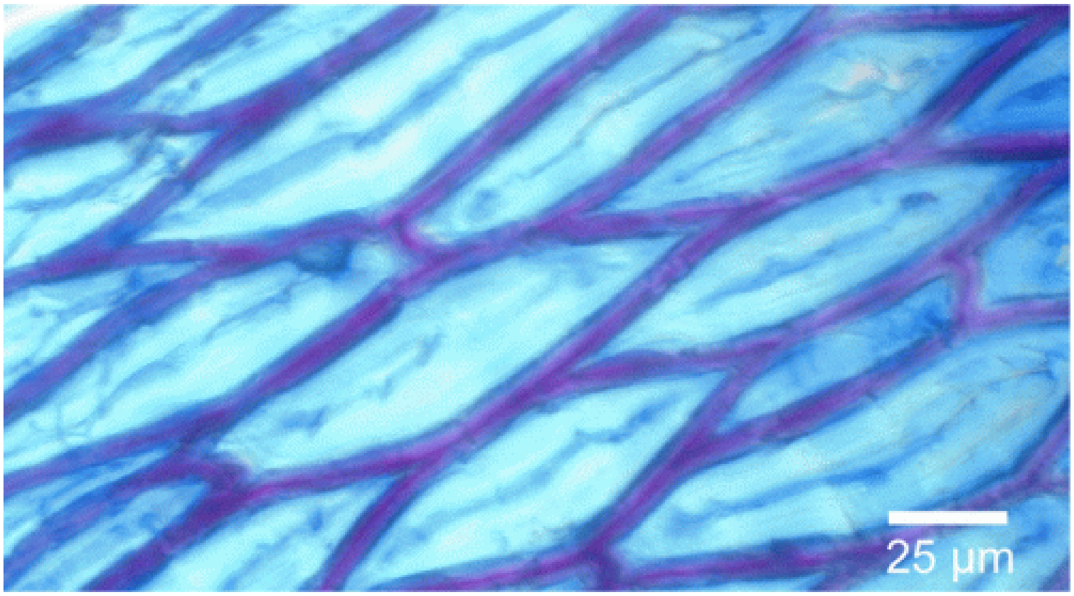
The seed capsule of the ice plant D. nakurense opens at the right moment. When conditions are dry, five lids seal the capsule (left). When it rains, the five lids of the capsule open (right). Pressure is applied to them by a swellable tissue that becomes saturated with water.The seed capsule of the ice plant D. nakurense opens at the right moment. When conditions are dry, five lids seal the capsule (left). When it rains, the five lids of the capsule open (right). Pressure is applied to them by a swellable tissue that becomes saturated with water. © Matt Harrington / MPI of Colloids and Interfaces

(PhysOrg.com) -- A number of plants disperse their seeds in a rather artistic way: the seed capsules of the ice plant Delosperma nakurense, for instance, unfold lids over the seed compartments in the manner of a movable origami when they are moistened by rain. This is the finding of researchers at the Max Planck Institute of Colloids and Interfaces in

Potsdam and the Technische Universität Dresden in a precise investigation of the opening mechanism. The lids open up because cells on the inside of them absorb water and change their structure. The plant, which grows in very arid regions, thereby ensures that its seeds have a good chance of opening. The researchers are keen to use this model to develop materials that move when they become wet or when their temperature changes.

Some plants do not need living cells that promote movement with their metabolism in order to react. Awns bend when they are wet; cones open when they dry in air. "In the seed compartments of Delosperma nakurense, we have observed a highly complex movement of plant material that is no longer living", says Ingo Burgert. The scientist heads a research group in Peter Fratzl's Biomaterials Department at the Max Planck Institute of Colloids and Interfaces, and along with Christoph Neinhuis of the TU Dresden had the idea of researching the opening mechanism of the seed capsules of D. nakurense.

The research team has discovered that the lids of the seed capsules unfold on a kind of hinge when they are wet; conversely, they close again once they dry. This also changes the curvature of the lids so that the valves tightly seal the seed compartments in dry conditions. The curvature also prevents a seal opening accidentally. "This is in fact a coordinated folding mechanism in two directions, which we know from movable origami", explains Matthew Harrington who, together with his colleagues, has analysed this movement in detail. The five lids of the seed capsule therefore become deformed because of their refined structure and a clever combination of the properties of various biological materials.




The honeycomb structure that has become saturated with water and preferably expands in one direction. The researchers have stained the swellable cellulose blue. The lignin in the cell walls is stained red. © Matt Harrington/ MPI of Colloids and Interfaces

The lids have a triangular shape, so that the seed capsule, in its opened state, is reminiscent of a five-pointed star. They have a highly swellable tissue on the side which, in the closed state, points downwards, and in the open state, upwards. The tissue is divided into two halves and runs on the open lids – thus when the capsule is wet – from inside to outside. The two halves then close to a narrow ridge. In dry conditions, a split separates the two halves of the tissue. In these splits are, in the dry state, the partition walls of the five seed compartments, so that the compartments are tightly sealed.

When the lid opens, it deforms particularly where it is attached to the capsule. "This section acts like a hinge", explains Matthew Harrington. How the seal opens, however, only became apparent to the researchers when they looked very closely at the structure of the swellable tissue.

This consists namely of upward-opening, more or less hexagonal cells that form a honeycomb structure.

The opening mechanism only functions, however, because the cells are constructed of two different materials, as the researchers discovered in spectroscopic investigations. The cell walls consist essentially of cellulose and lignin, a major component of wood. Lignin absorbs little water, but inside the cell there is cellulose without lignin; this soaks up a lot of water and thus swells considerably. The machine is then complete, folding an origami virtually by water power. "When the cellulose expands, the hexagonal cells extend predominantly in the longitudinal direction of the lid", explains Matthew Harrington. The honeycomb structure expands in this direction and thus presses on the lid. Conversely, the valve closes again when the cellulose dries and the honeycomb structure contracts.

"The mechanism is interesting for technical applications because the energy for the directed movement is already stored in the material", says Peter Fratzl. As part of the focus program "Biomimetic Materials Research: Functionality by Hierarchical Structuring of Materials" funded by the DFG 1420, the scientists are now keen to transfer this concept to a technology that could be used for example in biomedicine or architecture. The principle can also be transferred to materials that expand or contract in very different ways when the temperature changes: for example, an awning unfolding by itself over the patio when the sun becomes uncomfortably hot.

**More information:** Matthew J. Harrington, Khashayar Razghandi, Friedrich Ditsch, Lorenzo Guiducci, Markus Rueggeberg, John W.C. Dunlop, Peter Fratzl, Christoph Neinhuis & Ingo Burgert, Origami-like unfolding of hydro-actuated ice plant seed capsules, *Nature Communications*, 7 June 2011; DOI: 10.1038/ncomms1336

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