Supplementary Materials and Methods

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**Pitcher geometry facilitates extrinsically powered 'springboard trapping' in carnivorous *Nepenthes gracilis* pitcher plants**

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***Plant material***

*Nepenthes gracilis* and *N. rafflesiana* plants were grown in a climate-controlled growth chamber (Reftech B.V., Netherlands) mimicking the natural climate in the tropical lowland habitat (12 h days; 30°C/60% rel. hum. at day; 25°C/80% rel. hum. at night). As both species naturally grow in waterlogged soils, pots were placed in water filled trays with expanded Hydroleca clay pebbles. This ensured that pitchers were optimally hydrated for all experiments.

***Computerized micro-tomography imaging***

Scans were conducted at the XTM Facility, Palaeobiology Research Group, University of Bristol, using a Nikon XT H 225 ST (Nikon Metrology Inc., Brighton, U.S.) µ-CT scanner at 70kV, with an exposure time of 354ms and 3141 projections. The voxel size (30µm for *N. gracilis* and one *N. rafflesiana*; 38µm for the remaining *N. rafflesiana*) was determined by pitcher size. Each scan took approximately 20 minutes. Together with the high humidity in the enclosed container, this ensured that the tissue remained fully hydrated and the measurement conditions were consistent across scans. Successful scans confirmed the constant conditions, as any movement of the specimen during the scanning process corrupts the scan.

The time scale of natural lid impact responses (in the ms regime) is much shorter than that of a CT scan (20 min). Living plant tissues are complex composite materials with viscoelastic properties [R1] and are therefore susceptible to fatigue under continued loading. Preliminary results from material tests in our lab indicate that the deformation of the *N. gracilis* pitcher is affected by material fatigue during continued downward lid displacement, but not in the case of upward displacement. This fatigue takes place on a time scale of seconds. Therefore, CT scans under downward lid will underestimate the *amount* of deformation, because they show deformation after tissue relaxation has taken place. However, the locations and general mode of deformation remain unaffected by this issue.

***Analysis of pitcher deformation visualized in serial µ-CT scans***

Image stacks from the three scans with different lid positions were imported into 3D Slicer 4.11.20210226 (https://www.slicer.org/; [R2]) and aligned to the same 3D coordinates, using a least square fit over five identical features in the lowest cross-sectional slice. The scans were segmented using a threshold grey value of 15000, and the resulting 3D pitcher models were superimposed to visualize deformation. Longitudinal sections through 3D reconstructions of *N. gracilis* pitchers were overlaid in GIMP 2.10.30 (https://www.gimp.org; [R3]) to determine local changes in curvature of the dorsal pitcher ‘spine’ between neutral, upward-displaced, and downward-displaced lid position. To this end, initially 100 equidistant points were fitted along the dorsal pitcher spine for each lid position. The curvature *κ* in each point was calculated as

(1)

where y and z are coordinates of each point along the spine. First and second derivatives of y and z were calculated using the function numpy.gradient in Python 3 / NumPy 1.19.5 [R4]. This function takes second order accurate central differences between each coordinate and its immediate neighbours to estimate the gradient numerically. Simply speaking, this process returns a local gradient in each point, based on its relative position to the immediate neighbouring points. Inherent in this method is a trade-off where increasing spatial resolution also increases noise, as the calculation of local gradients is based on increasingly shorter spine sections. As the spine sections get shorter, the analysis increasingly reveals microscopic surface topology instead of macroscopic curvature.

Calculating curvatures in all 100 points resulted in exactly this high noise which concealed deformation ‘hotspots’ along the spine. A convergence study (see supplementary figure S1) was therefore performed on one *N. gracilis* pitcher to determine the optimal number of points that minimized noise while maximizing spatial resolution. For 100 and 50 points, the noise levels were too high to reveal macroscopic curvature changes. For 10 and 20 points, the resolution was too low, and the main sites of deformation could not be reliably located. In the convergence study, 30 points were determined as optimal spacing, and this was applied to all pitchers. For all pitchers, the 0-index was defined at the transition point between the pitcher body and lid (indicated by a dorsal spur which is homologous to the leaf tip). This allowed direct comparisons between pitchers with different relative lid and body sizes. The wooden skewer used to manipulate the lid position deformed the lid in its immediate vicinity in a non-natural way. Therefore, points at or beyond the attachment point of the skewer were discarded. The remaining five points in the lid were assigned positive indices. Depending on the pitcher height and the depth of embedding for the CT scans, between seven and 26 negatively indexed points remained along the spine of the pitcher body. Due to their tubular cross-section, *N. gracilis* pitchers had to be embedded less deeply than funnel-shaped *N. rafflesiana* pitchers. Therefore, there were on average more points along the pitcher body in *N. gracilis* (average of 18 points in body) than in *N. rafflesiana* (average of 9 points on body).

For each point, the local spine curvature was calculated according to equation 1. Differences in curvature were then calculated between neutral and extreme upward, and neutral and extreme downward lid position, respectively. For data analysis and visualisation Python 3 and Matplotlib were used [R5]. Image processing and measurements from images were made using GIMP 2.10.30 (https://www.gimp.org; [R3]) and ImageJ 1.53 (https://imagej.nih.gov/ij/; [R6]

***References***

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