# Supporting Information

## Liang and Mahadevan 10.1073/pnas.1007808108

### SI Discussion

**The Relative Role of Edge Actuation.** Having demonstrated that the midrib is unnecessary for the actuation of the blooming response (Fig. 2, main text), we focused on the role of edge actuation on blooming by considering the morphology of the petal/sepal (without midribs) both before and after the edges have been surgically removed. In Fig. S1, we show the results of these experiments. We can see that sepal/petal whose edge is cut opens out and exhibits a smaller curvature compared to those with intact edges, as viewed from two perspectives. In Fig. S1, the average radius of curvature of the intact petal is approximately 2 cm whereas that of the one with edges removed is approximately 5 cm. We see that there is a variation of the curvature as a function of location along the longitudinal axis of the petal; in particular removing the edges causes the petal to spring back near the apex much more than near the base. This is because edge actuation is far more dominant where the petal-midrib composite is thinner (and less stiff); i.e., near the apex.

Thus, we see that the dominant mechanism underlying the blooming of a lily is that of edge actuation of a thin lamina. Of course there are quantitative corrections to this due to the presence of a midrib of thickness that varies along the longitudinal axis and a hinge -like actuation at the base itself. However, the qualitative feature of curvature change induced by lateral growth persists, as clearly evidenced in our surgical and mechanical measurements.

**The Relative Contribution of the Leafy and Woody Parts of the Petal to its Stiffness.** In cross-section, a petal can be seen to be made of a woody midrib and a leafy tissue that forms the petal itself, as shown in Fig. S2. The leafy region has a thickness $t = 0.5$ mm and a midrib of diameter $d = 2$ mm, and the cross-section of a petal may be geometrically approximated by a half circle at the onset of opening, with a radius $r = 10$ mm. To assess the contributions of the two materials to the stiffness of the whole petal, we measured the Young's modulus of the leafy part $E_l$ and woody parts of the midrib $E_m$ using a microtensile tester (CMT80202 dual column electromechanical universal testing machine, MTS Systems Co.), after these regions were surgically separated from the leaf. We find that $E_l = 5$ MPa and $E_m = 20$ MPa. Similar measurement on herbaceous plants shows that the Young's modulus of parenchyma (leafy) and the sclerfied (woody) tissues are around $10^2$ MPa and $10^3 \sim 10^4$ MPa (1). The neutral axis of the composite is given by the expression

$$\bar{y} = \frac{\int_0^{\pi} r^2 t \sin\theta d\theta + A_m r}{\pi r t + A_m} = 8.0 \text{ mm}, \quad \textbf{[S1]}$$

where the effective area of midrib is $A_m = (E_m/E_l)\pi d^2/4 = 12.6$ mm$^2$. The bending stiffness of leafy part is

$$B_l = E_l \int_0^{\pi} (r\sin\theta - \bar{y})^2 trd\theta = 948.7 \text{ N mm}^2. \quad \textbf{[S2]}$$

The bending stiffness of midrib is

$$B_m = E_m\left[\frac{\pi d^4}{64} + A_m(r-\bar{y})^2\right] = 271.7 \text{ N mm}^2. \quad \textbf{[S3]}$$

Therefore, the contributions of leafy part and midrib to the total bending stiffness are 78% and 22% respectively, so that to a first approximation, we may neglect the effect of the midrib in determining the stiffness of the petal.

1. Moulia B, Fournier M (1997) Mechanics of the maize leaf: A composite beam model of the midrib. *J Mater Sci* 32:2771–2780.


**Fig. S1.** The shape of petals with and without its lateral edges. Midribs of both petals have been removed. (*A*) and (*C*) show the same petal with edge intact from two different perspectives, whereas (*B*) and (*D*) show the same petal with the edge removed from the same two perspectives. We see that near the apex, the curvature of the petal with intact edges is much larger than that of the petal with its edges removed. Near the base, the curvature of the petal with and without its lateral edges is similar because the thickness of the leafy and woody parts and thus the stiffness of the petal is so large that edge actuation alone is not enough.

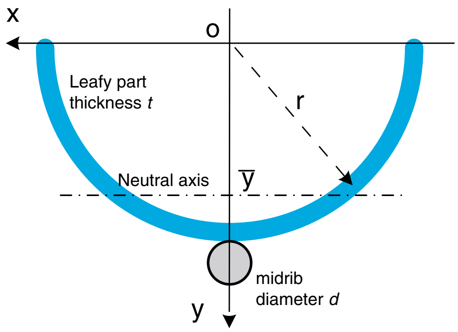


**Fig. S2.** The geometry of petal/sepal. The leafy part is well approximated by a semicircle of radius $r$ over much of its length, and the midrib is well approximated by a circle of diameter $d$.

**Movie S1** Blooming of a bud of the common Lily *Lilium casablanca*. We place it with its stem immersed in water and in an environment of uniform humidity, temperature and under continuous fluorescent lighting and then film it with time lapse video to record the blooming process, with the camera programmed to take a photograph every minute. The blooming process takes four and a half days until the lily opens fully—shown here using time lapse video.
Movie S1 (MOV)

**Movie S2** To understand how edge growth leads to the reversal of petal curvature and blooming, we use a simple numerical simulation of a single petal modeled as a convex doubly curved elastic shell that grows along its edge quasistatically (see text for details). As it grows, it everts and wrinkles along its edges, as can be seen in this movie.
Movie S2 (MOV)