Flat leaves—a curly problem

David Catchpoole

Flat leaves are ubiquitous, but why should this be? Because the flat shape allows maximal area for a given amount of material, so the leaf can capture the most sunlight energy. This sunlight is essential for photosynthesis to produce carbohydrates (starch and sugars) necessary for growth.

Flatness seems so obvious, but under close examination, it is a puzzle to explain. Plant physiologists point out that 'it is more difficult to make a flat leaf than to make a curved one because growth of central regions of the leaf must be coordinated with growth at the leaf edges'.[1] In fact, flat leaves are the result of very carefully controlled growth processes, which researchers recently discovered are regulated by genes.[2]

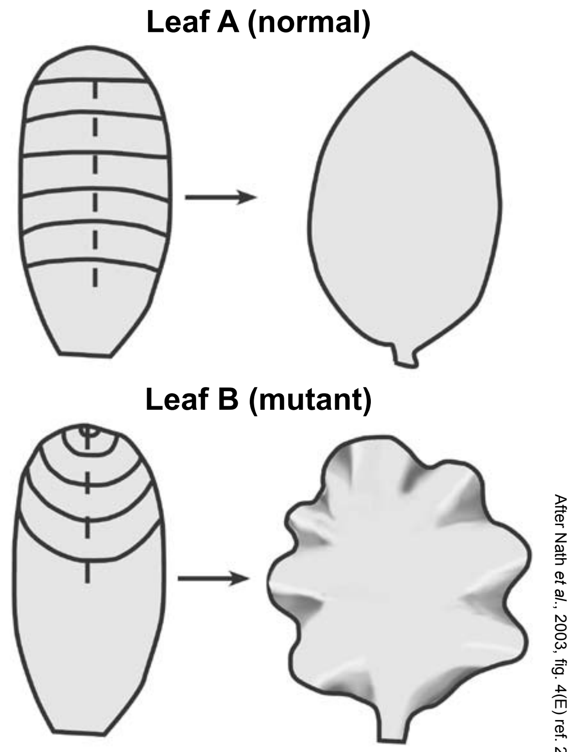
So what happens if leaf growth is not coordinated properly, e.g. in plants with a genetic mutation? Such plants do not have flat leaves, but are curved—far from the ideal 'zero curvature' (flatness). For example, when cells near the leaf edge grow more slowly than those in the centre, the leaf will finish up being cup-shaped, i.e. with 'positive Gaussian curvature'. Conversely, when cells near the leaf margin grow more quickly than those in the central region, the leaf will buckle to form a shape with a wavy edge, similar to a horse-riding saddle, which has 'negative Gaussian curvature'.

The zero curvature of leaves is indeed quite remarkable, given the much higher likelihood of negative or positive curvature, as the researchers point out:

> 'Although such flatness is often taken for granted, the probability of this happening by chance is low because there are many more ways for a structure to adopt negative or positive curvature than zero curvature.'[2]

A closer look at leaf growth in the snapdragon plant reveals the precise control necessary to make flat leaves. As new leaves appear, they expand by cell division—i.e. each cell divides to form two new cells, each of which then divides to form two new cells, and so on. In normal (i.e. flat) leaves, cells at the tip of the leaf stop dividing and become mature (differentiate) before cells at the base of the leaf.

Now researchers have shown that, in essence, a 'wave' or 'arrest front' passes along the snapdragon leaf from tip to base, causing cells to stop dividing and to differentiate into mature leaf cells. But the timing and shape of this wave is absolutely critical for both the shape and curvature of the leaf. In normal leaves, the arrest front is convex, such that at a given distance from the leaf tip, cells at the edges cease dividing before cells in the centre of the leaf, resulting in an ellipse-shaped leaf with zero curvature (see diagram, Leaf 'A').



When the arrest front progressing down the developing leaf is weakly convex (Leaf A), an elliptical final leaf shape results with zero Gaussian curvature. But in mutants, a concave arrest front (Leaf B) produces greater growth at the leaf margins, resulting in a broader leaf with negative curvature.

But in snapdragon plants with a certain genetic mutation, the arrest front is concave and progresses more slowly than in normal leaves. Consequently, in snapdragon mutants, cells in the centre of the leaf stop dividing before cells near the leaf margins, giving greater growth in edge regions, resulting in a broader leaf with negative curvature (Leaf 'B' in diagram).

The same problem applies to the membranous wings of insects. Evidently, there is much control of the growth rate here, too. This is shown by mutations that result in crinkly wings, just as mutations can result in crinkly leaves. But with insects, flatness is even more critical, because it is essential for the aerodynamics of flight.

Considering all that's involved in producing a flat leaf, if 'the probability of this happening by chance is low',[2] then where did flat leaves come from? Neo-Darwinians would invoke small mutations and natural selection. However, flatness requires *highly coordinated changes* in growth rates, so it's impossible to explain simply by cumulative selection of one continuous variable in Dawkinsian fashion. But if not by chance or cumulative selection, then logic dictates that the only remaining alternative is Design, just as Romans 1:18–32 suggests.

References

1. McConnell, J.R. and Barton, M.K., Leaf development takes shape, *Science* **299**(5611):1328–1329, 2003.
2. Nath, U., Crawford, B.C.W., Carpenter, R. and Coen, E., Genetic control of surface curvature, *Science* **299**(5611):1404–1407, 2003.