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OPTIMIZING LOTUS FLOWERS

"PAPER"

Tibor Tarnai

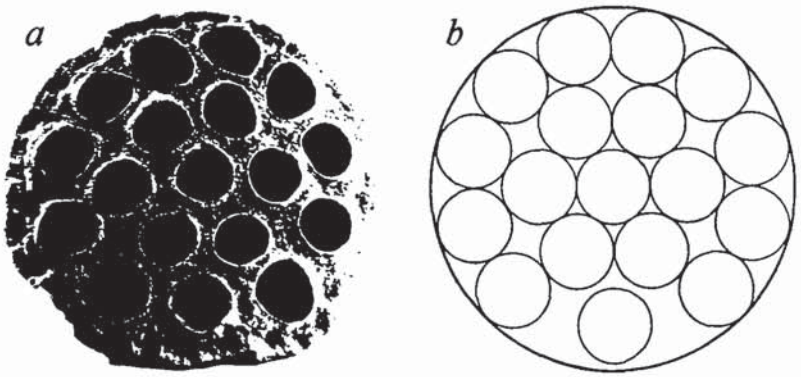
Technical University of Budapest, Department of Structural Mechanics,

Budapest, Műegyetem rkp. 3., H-1521, Hungary;

E-mail: tarnai@botond.me.bme.hu

In this paper we would like to call attention to a surprising property of sacred lotus (*Nelumbo nucifera*) flowers, which is related to morphology and, to our knowledge, has not been studied before.

Nelumbo flowers have a conical receptacle with a circular even upper surface. In that circular face there are several small dimples, each of which contains one carpel. At first sight it seems that the carpels are arranged spirally. At close inspection, however, we have found that the arrangement of carpels, and later the arrangement of fruits, in the receptacle is in accordance with the solution to the following mathematical close packing problem: How must N equal discs be packed in a given circle without overlapping so that the diameter



a, Arrangement of 18 fruits in a lotus receptacle. *b*, Closest packing of 18 equal discs in a circle.

of the discs will be as large as possible? The solution provides the most economical configuration of discs because the area of the given circle covered by the discs is a maximum. So, *Nelumbo* optimizes the fruit arrangement in the receptacle. Since in living objects there are always imperfections and mutations, this is not a rigid law but only a prevalent tendency.

For $N \leq 65$ the proven and conjectured solutions of the above packing problem are known (Graham *et al.*, 1997). Comparing actual fruit arrangements with these results, the agreement was surprising (see figure), disagreement was found mainly in those cases where the upper surface of the receptacle was distorted and/or the fruits were not equal. This is in accordance with the fact that the solutions of mathematical packing problems are sensitive for changes in data.

Some of the fruit arrangements had high order of symmetry, but many of them showed low order of symmetry or were even unsymmetrical.

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REFERENCE

Graham, R.L., Lubachevsky, B.D., Nurmela, K.J. & Östergard, P.R.J. (1997), Dense packings of congruent circles in a circle, *Discrete Math.* (submit)