Au delà des bilames?

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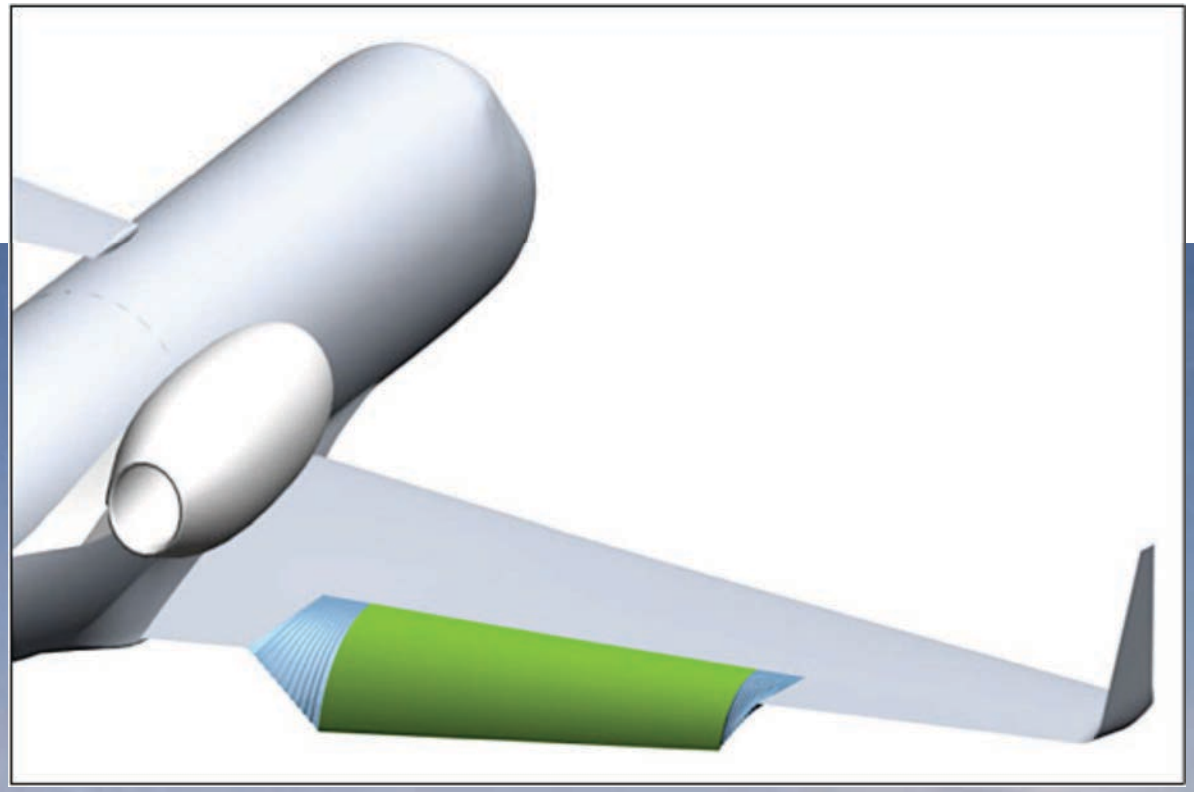
Shape Morphing

2001

« An artist's rendering shows advanced concepts NASA envisions for an aircraft of the future. »



2015 Adaptive Compliant Trailing Edge (ACTE)

how do we induce shape changes?

morphing surfaces : lessons from botany

Two strategies to achieve surface morphing in biology

blooming

blooming

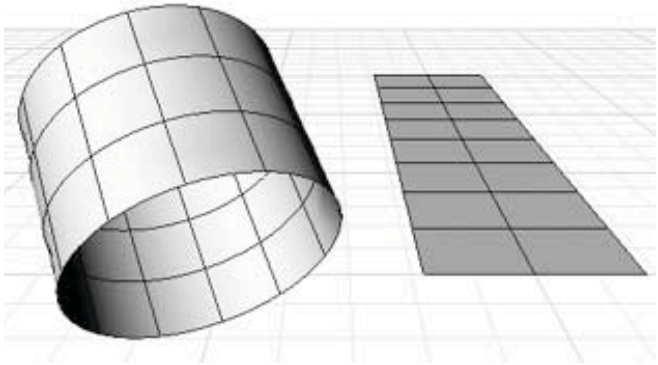
Gauss curvature

(1777-1855)

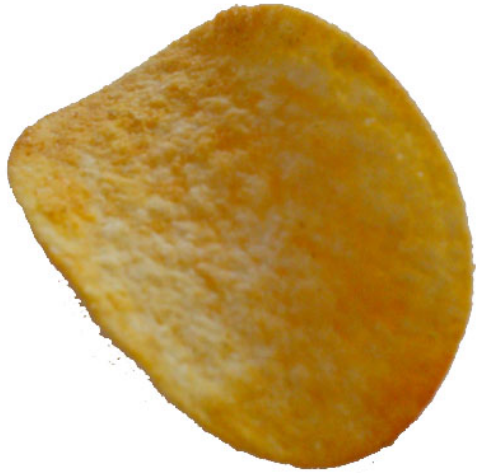
$G > 0$

$G = 0$

développable surfaces



$G < 0$

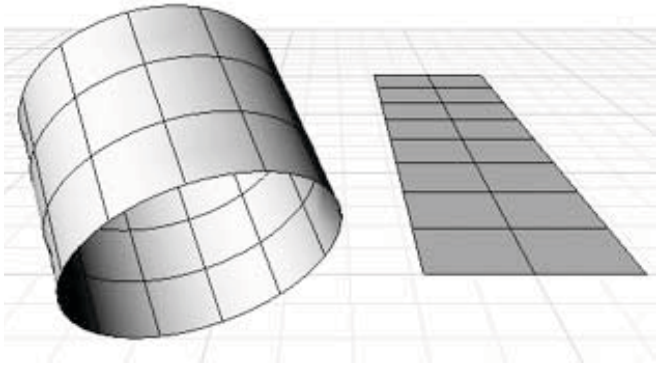


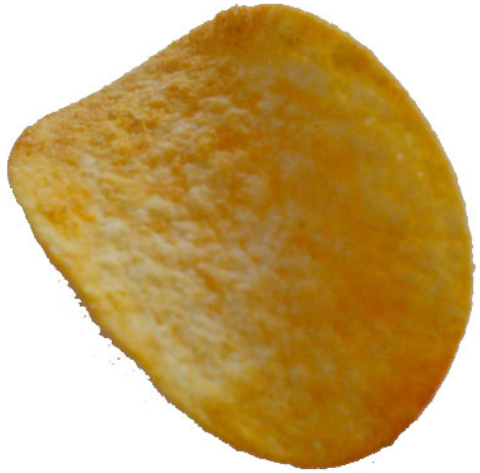
Gauss curvature

(1777-1855)

$G > 0$ $G = 0$ $G < 0$

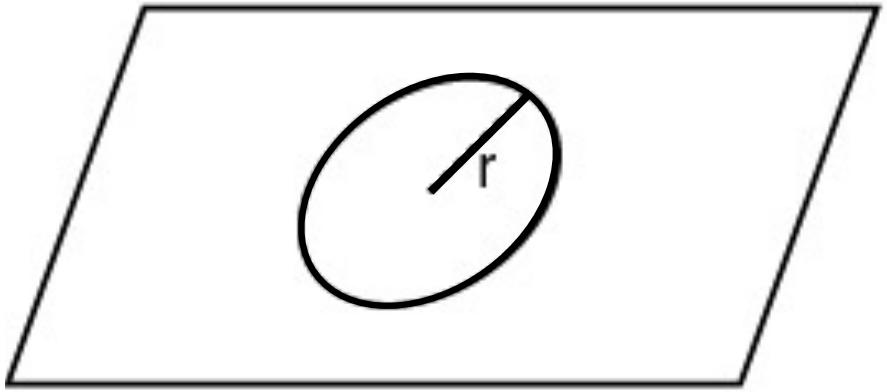
développable
surfaces

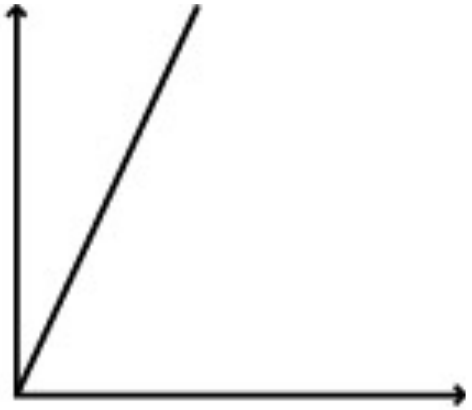




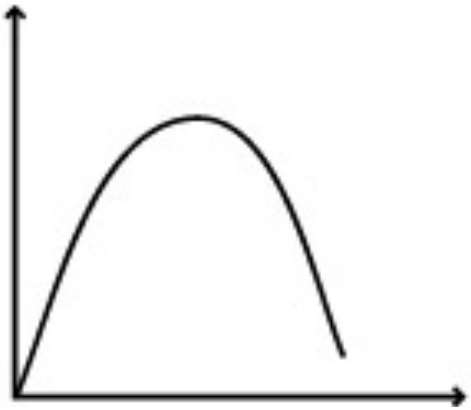
Theorema egregium

Some Geo-metry





$$L = 2\pi r$$



$$L = 2\pi R \sin(r/R)$$

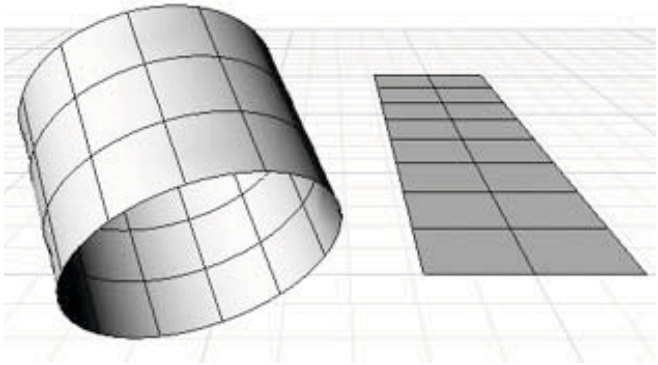
Gauss curvature

(1777-1855)

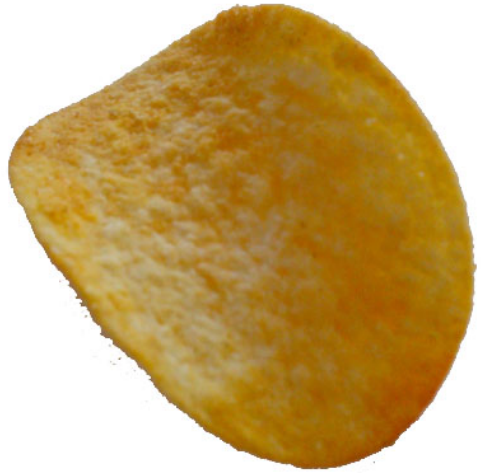
$G > 0$

$G = 0$

développable surfaces



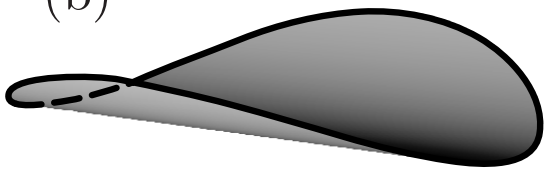
$G < 0$



« short » perimeters

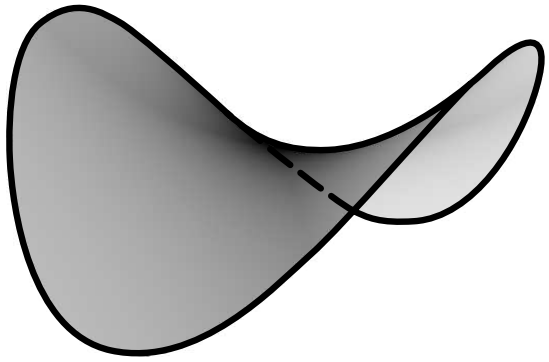
(a)

(b)



« long » perimeters

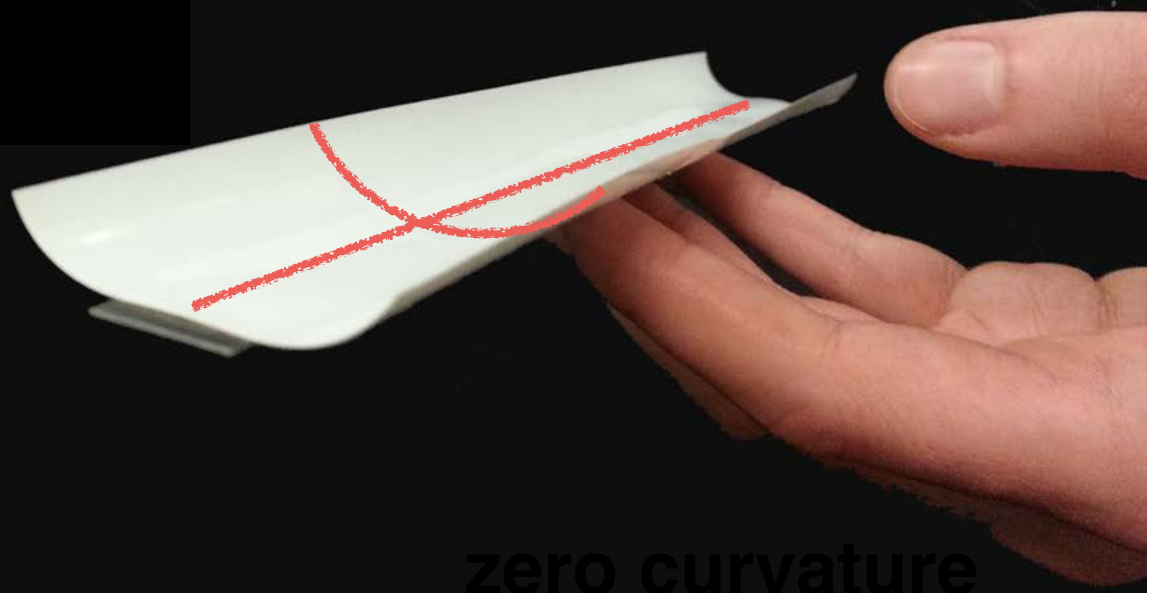
(c)



blooming

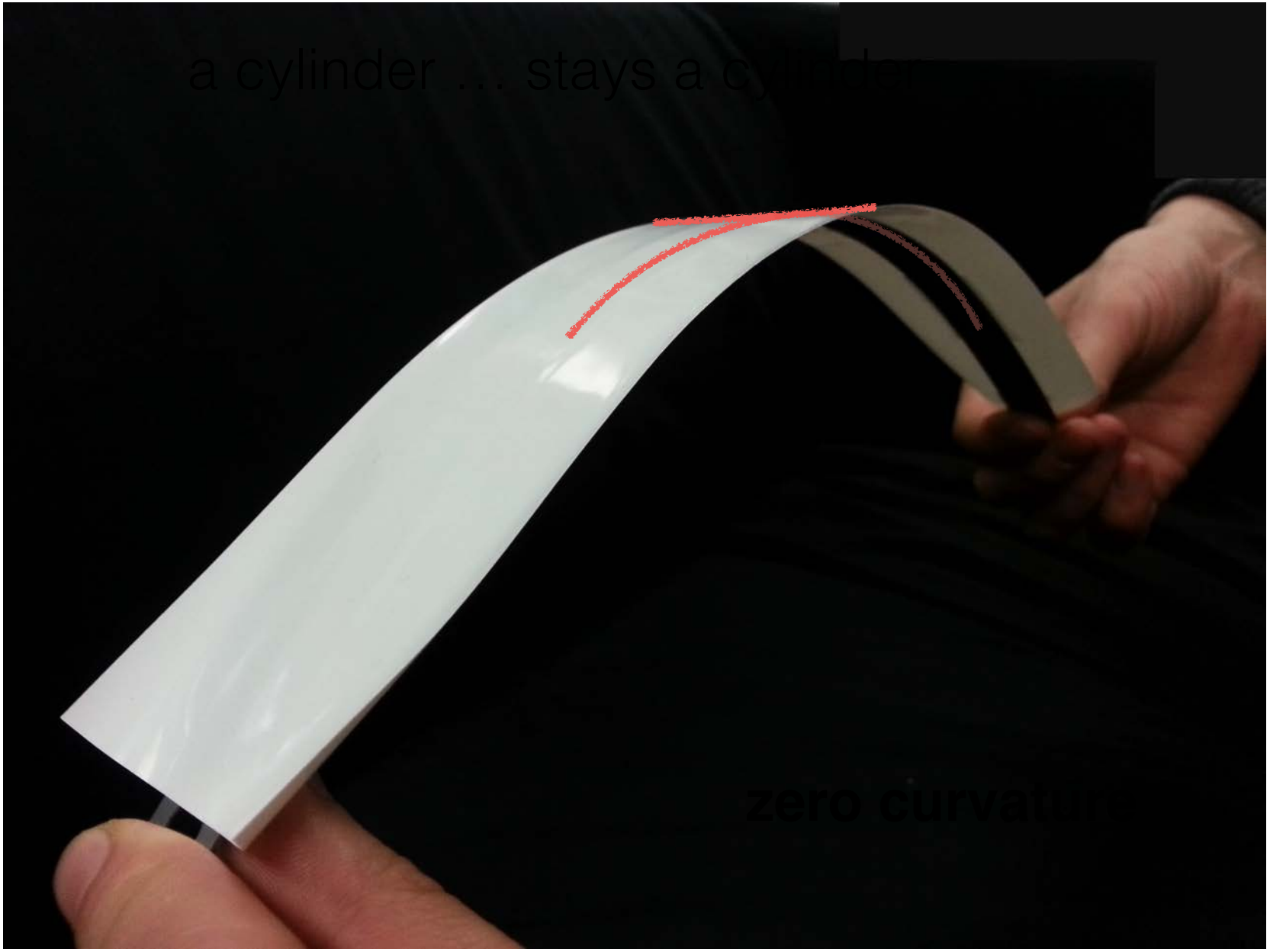
curvature G modified : distances have changed !

a cylinder … reste un cylindre



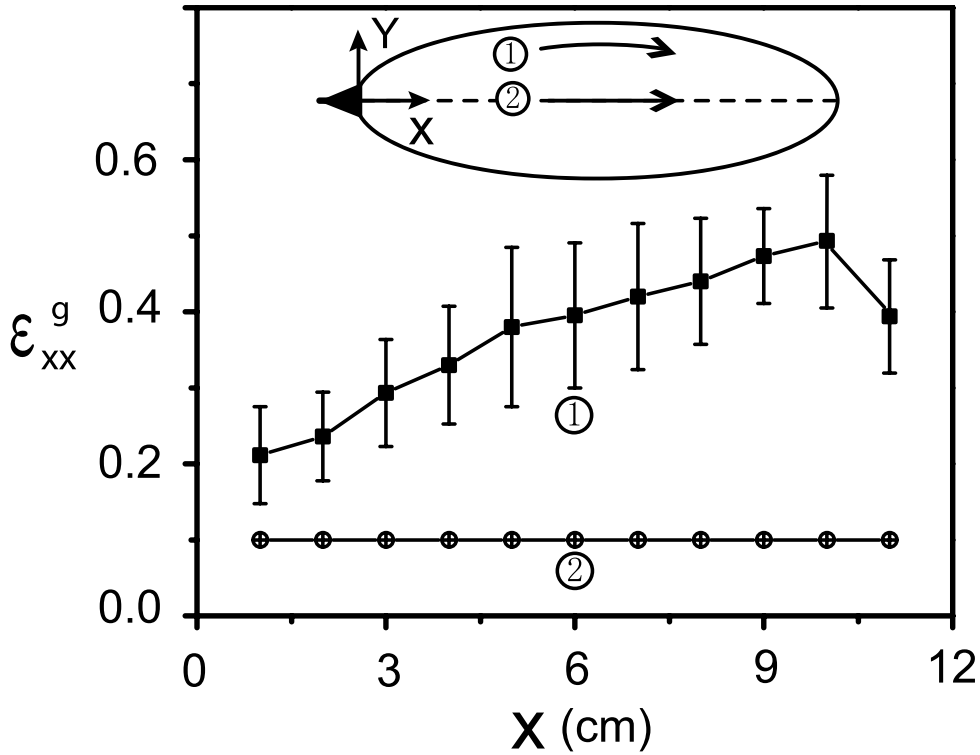
zero curvature

artificial petal conserving distances :



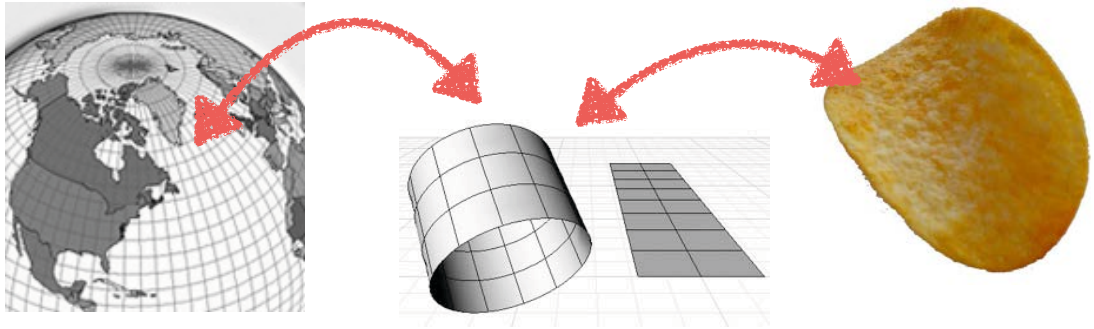
artificial petal conserving distances :

blooming : growth is more active on the edges of petal



lily blooming strategy :

in-plane growth differences will change distances



everything is possible

How to use this stragegy?

How to use this stragegy?

numerical simulation (Floraform)

https://n-e-r-v-o-u-s.com/

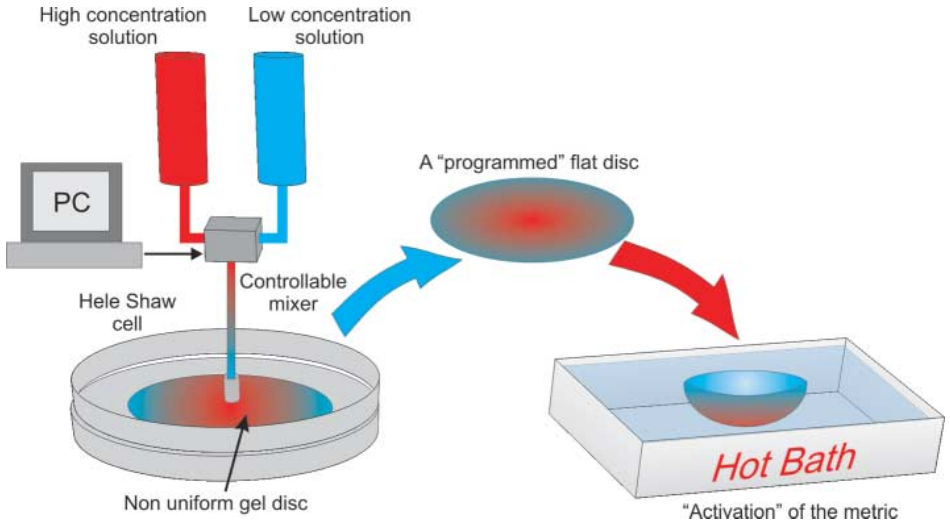
How to use this stragegy?

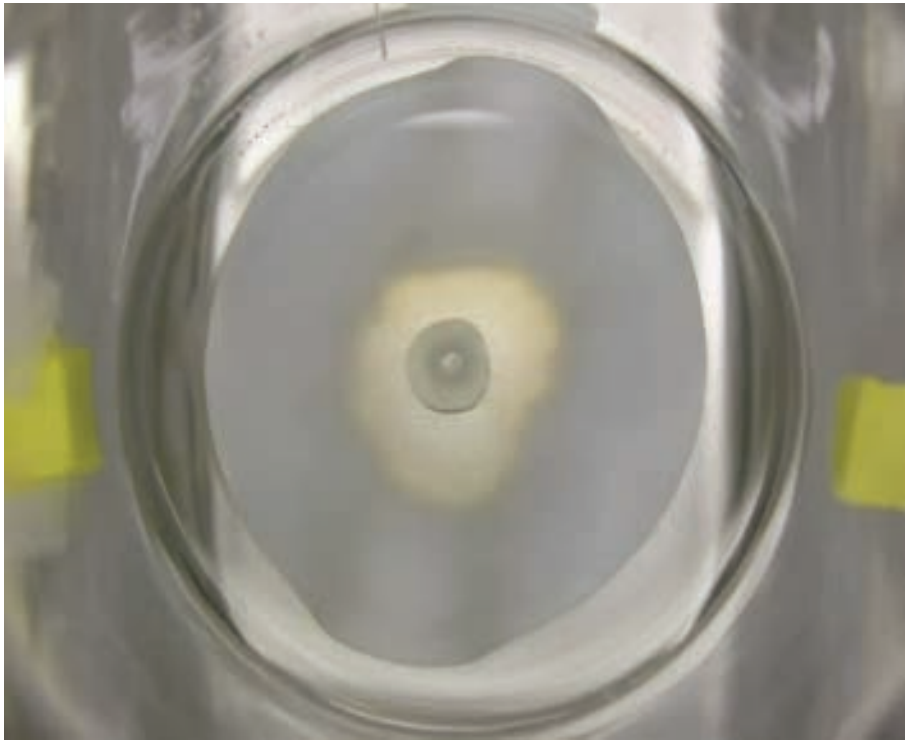
Sharon et al, Nature 2002

How to use this stragegy?

plastic bag tearing.

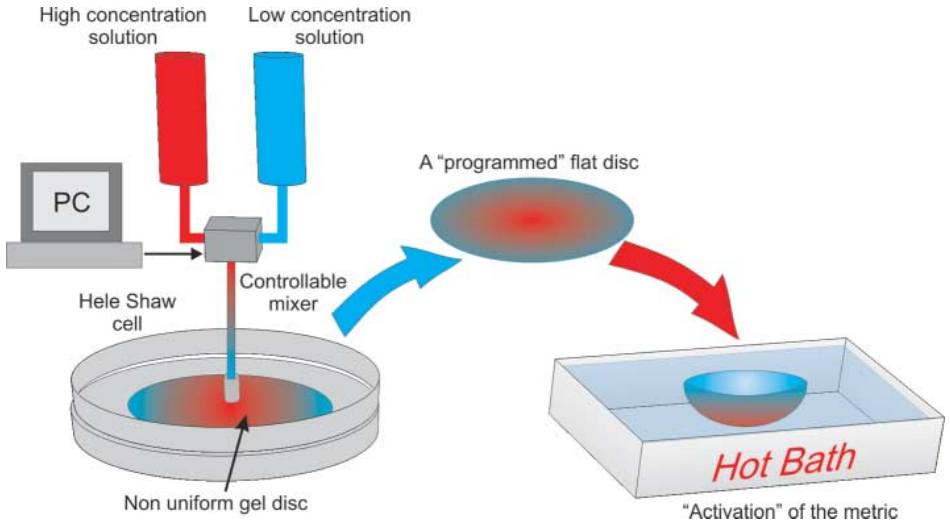
can we mimic « differential growth » at will ?



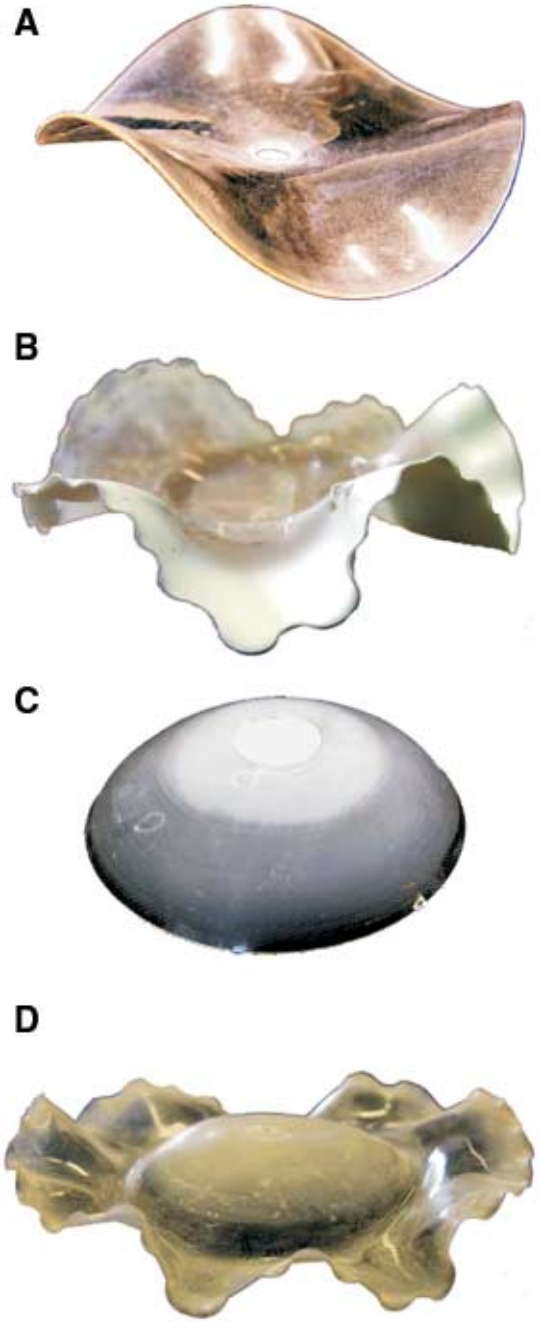


Klein et al , Science 2007

a gel swelling with water (triggered by temperature)

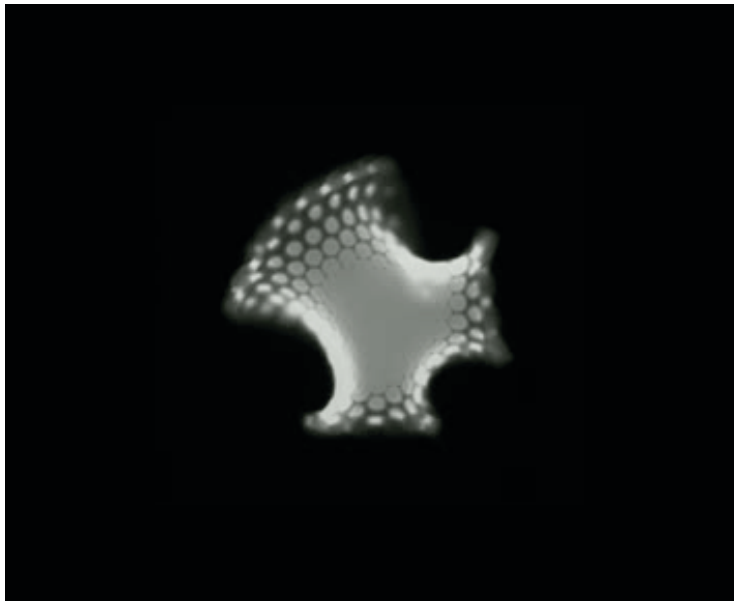


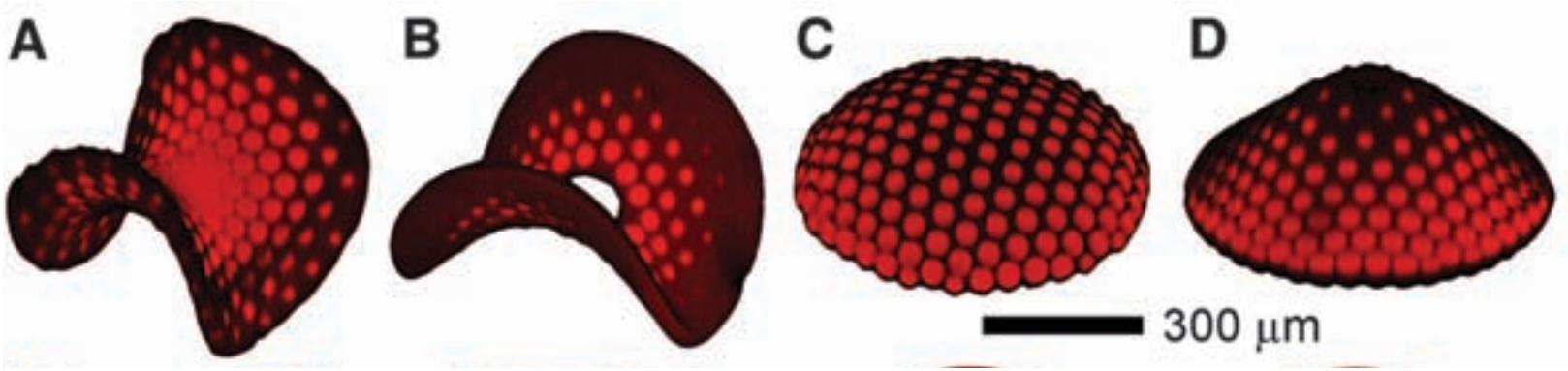
Klein et al , Science 2007



a gel swelling with water (triggered by temperature)

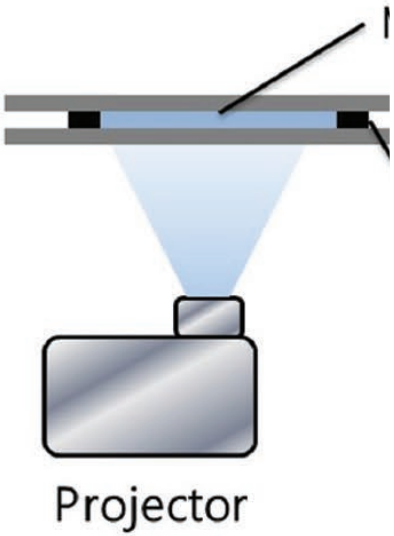
Kim et al , Science 2012

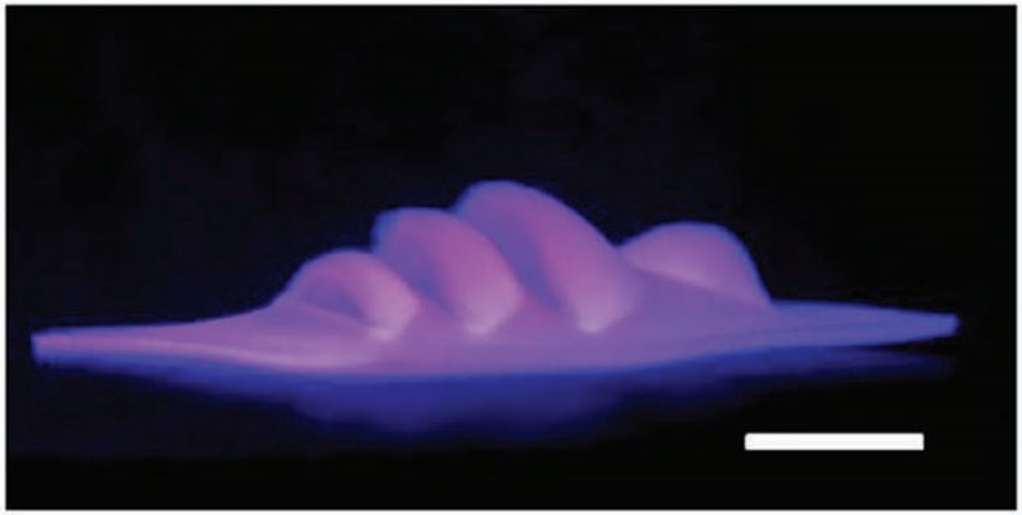




a gel swelling with water (triggered by temperature)

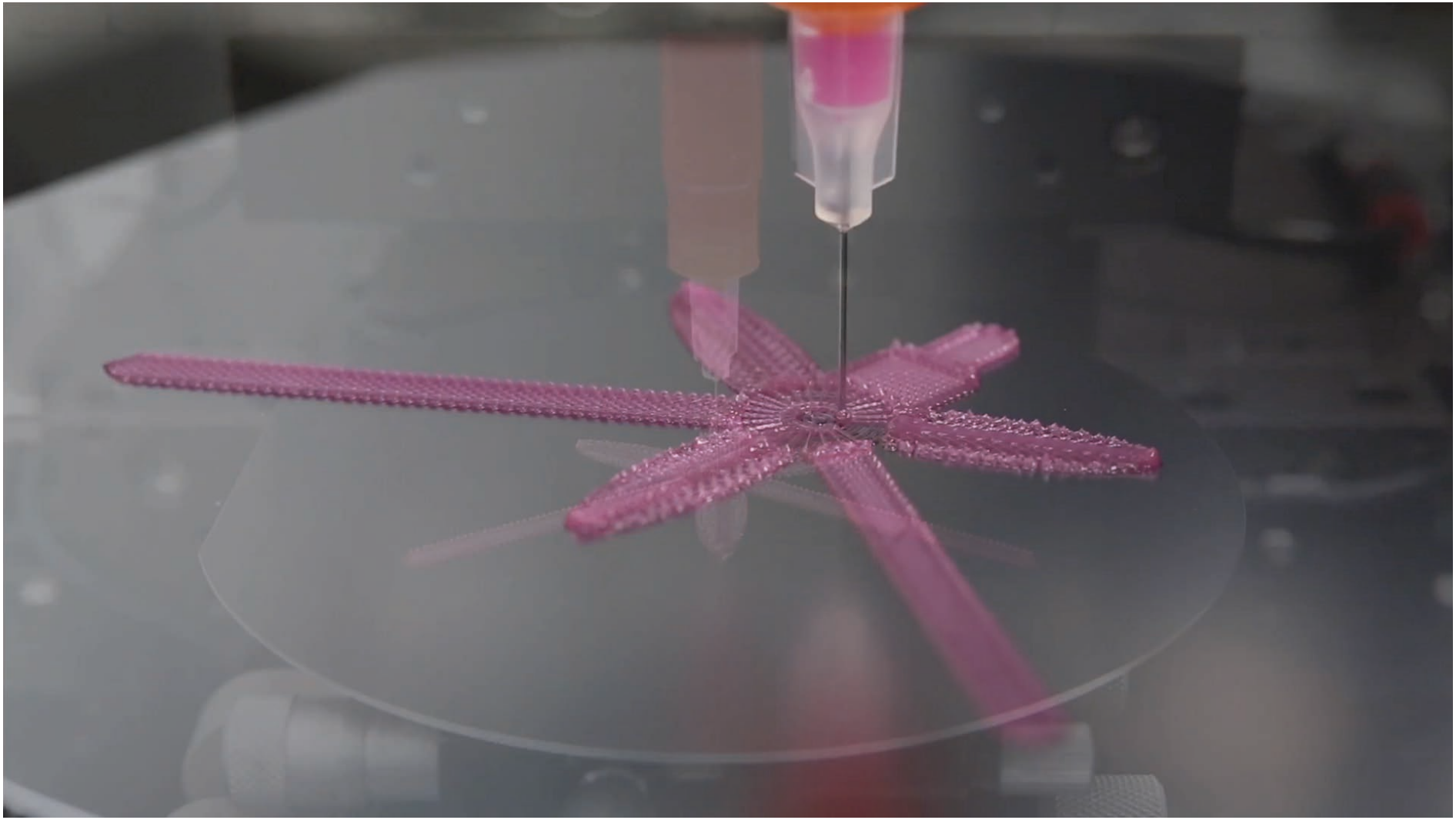
programmed swelling





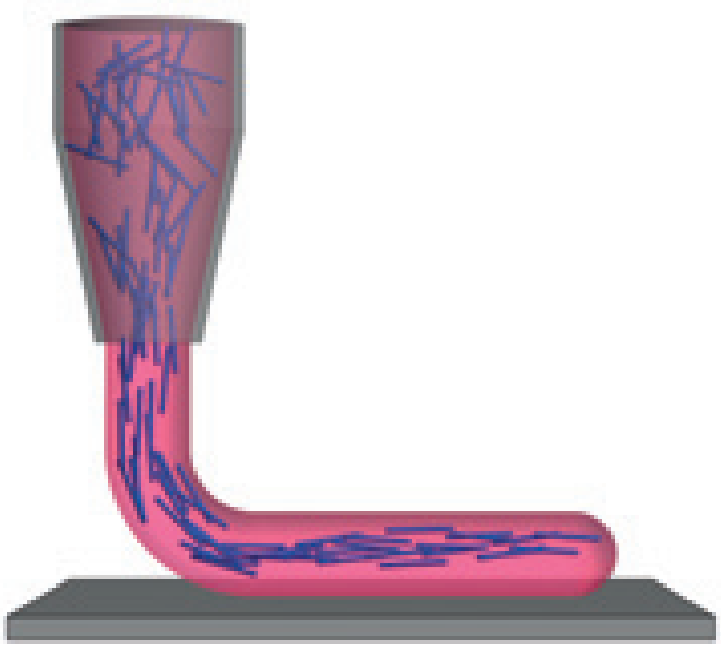
Huang 2017

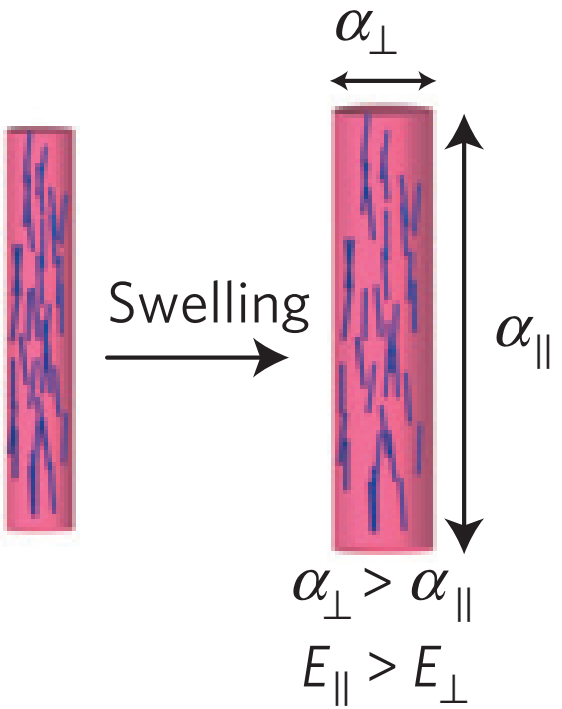
An exemple of 4D printing



Gladman et al, Nature Material 2016

controlled
non-uniform
(anisotropic) swelling





hydrogel + fibres

anisotropic swelling

Gladman et al, Nature Material 2016

Biomimetic 4D printing…

two strategies to achieve surface morphing
differential growth/swell

3D printing → **spatial programming**

bi-layer (through thickness)

spatial

limited shapes
(keep same curvature)

change distances:
no limitation !

well known/used

to be developed…

Biomimetic 4D printing…

two strategies to achieve surface morphing
differential growth/swell

3D printing → **spatial programming**

the same physical phenomenon for actuation :
swelling / pneumatic / electrostatic/ phase change… etc
(different spatial distribution)