4D-printed motion mechanisms inspired by Dioscorea bulbifera

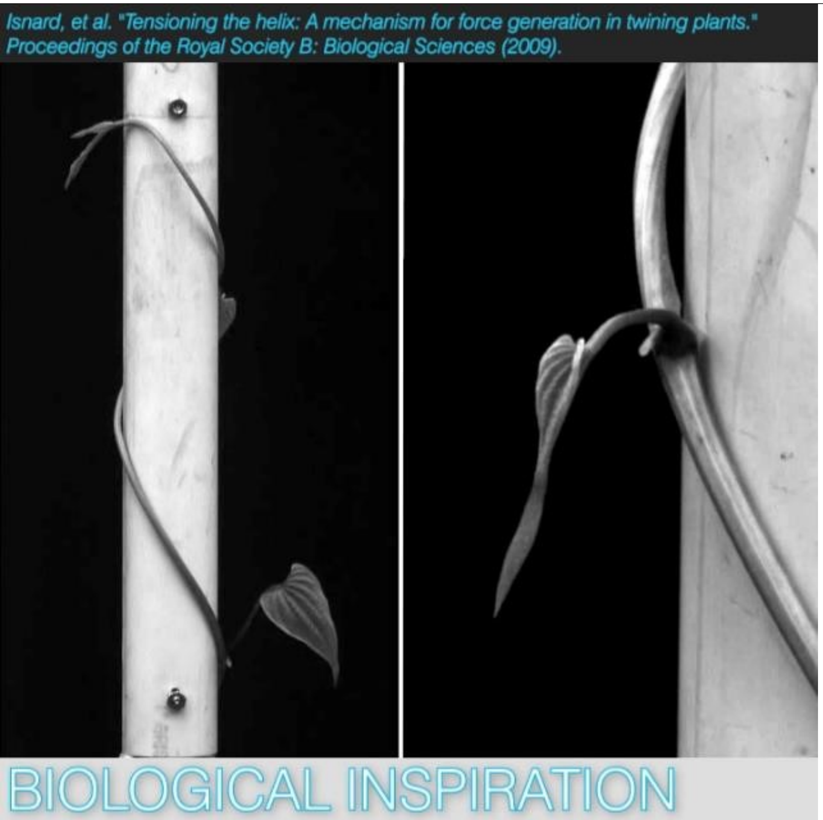
Tiffany Cheng
Material Programming, Institute for Computational Design and Construction (ICD), University of Stuttgart

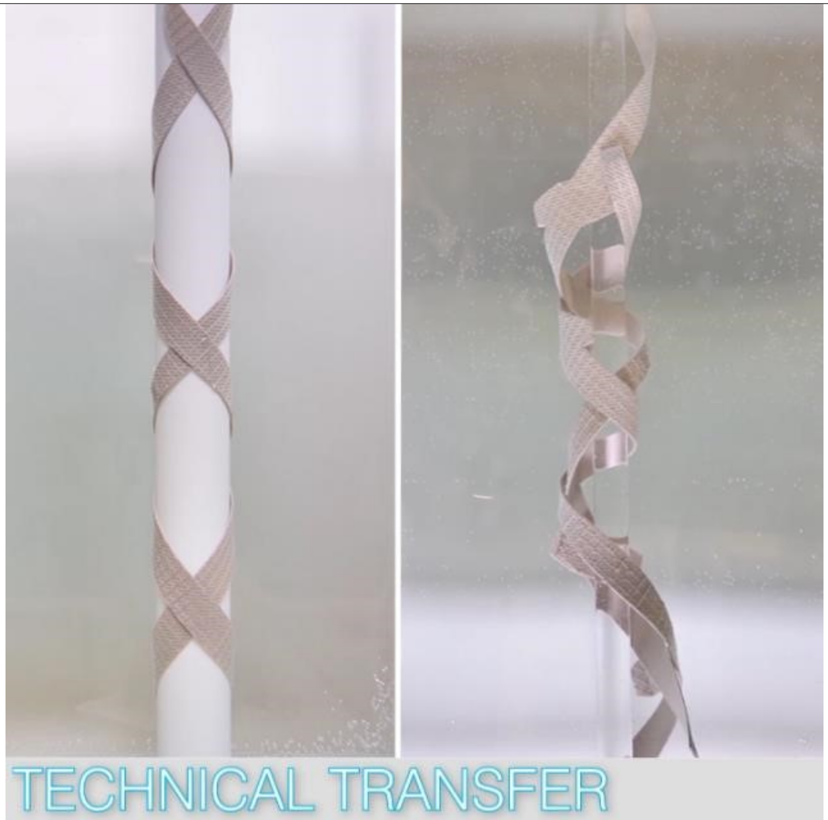
2021 June 22 | MéPhy Seminar: From Computational Fabrication to Material Design

University of Stuttgart

ICD Institute for Computational Design and Construction

4D-printed motion mechanisms inspired by Dioscorea bulbifera





4DmultiMATS:

Personalised 3D- and 4D-Printing of programmable, self-adjusting and multifunctional Material Systems for Sports and Medical Applications

Collaborators:

Institute of Macro Molecular Chemistry (Prof. R. Mülhaupt)

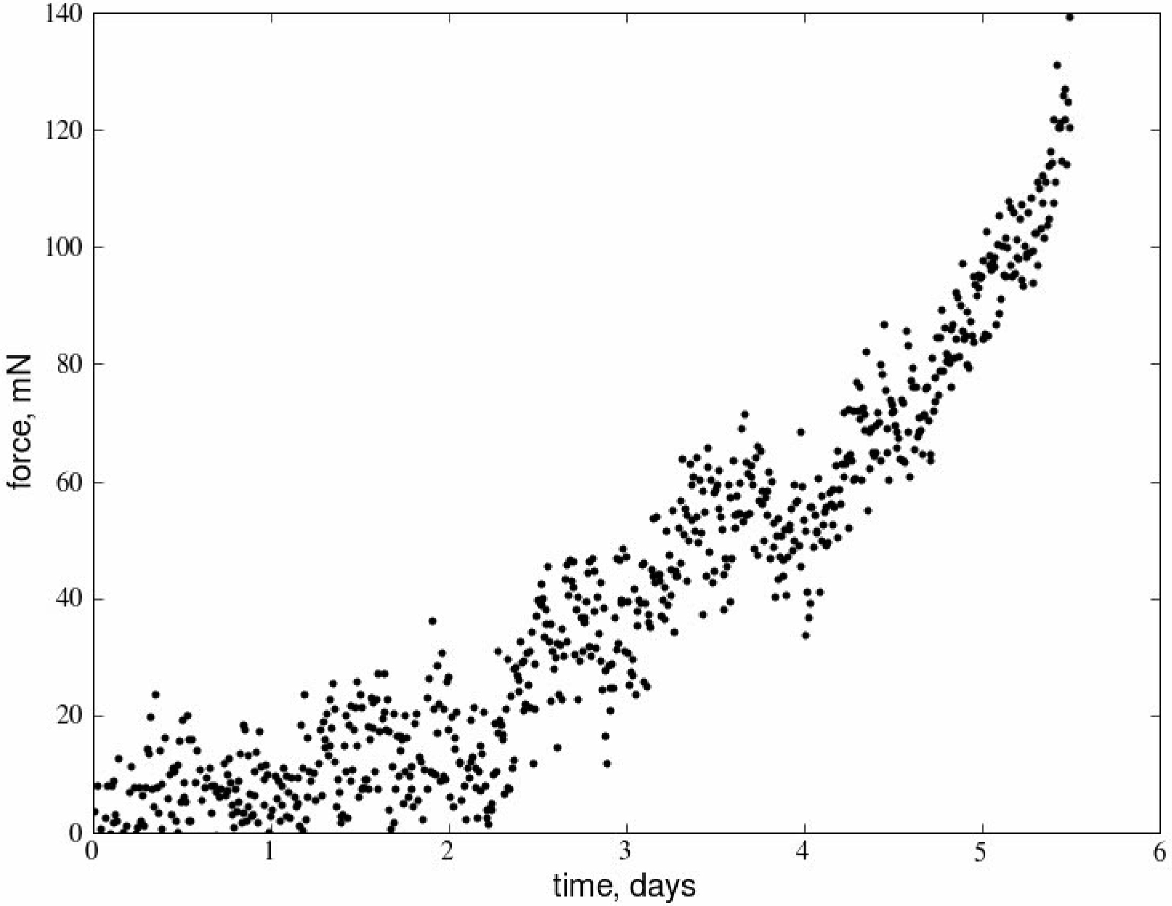
Plant Biomechanics Group Freiburg (Prof. T. Speck)

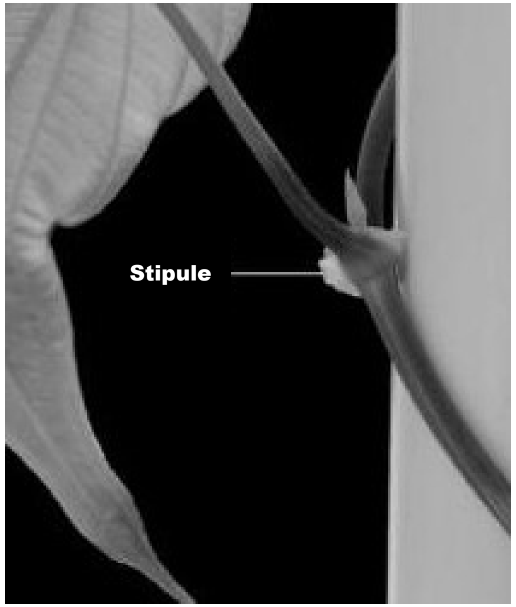
Oral Biotechnology, University Hospital Freiburg (Prof. T. Steinberg)

IntCDC CLUSTER OF EXCELLENCE   livMatS   Baden-Württemberg Stiftung

T Cheng, M Thielen, S Poppinga, Y Tahouni, D Wood, T Steinberg, A Menges, T Speck: 2021, ***Bio-Inspired Motion Mechanisms: Computational Design and Material Programming of Self-Adjusting 4D-Printed Wearable Systems****. Advanced Science.*

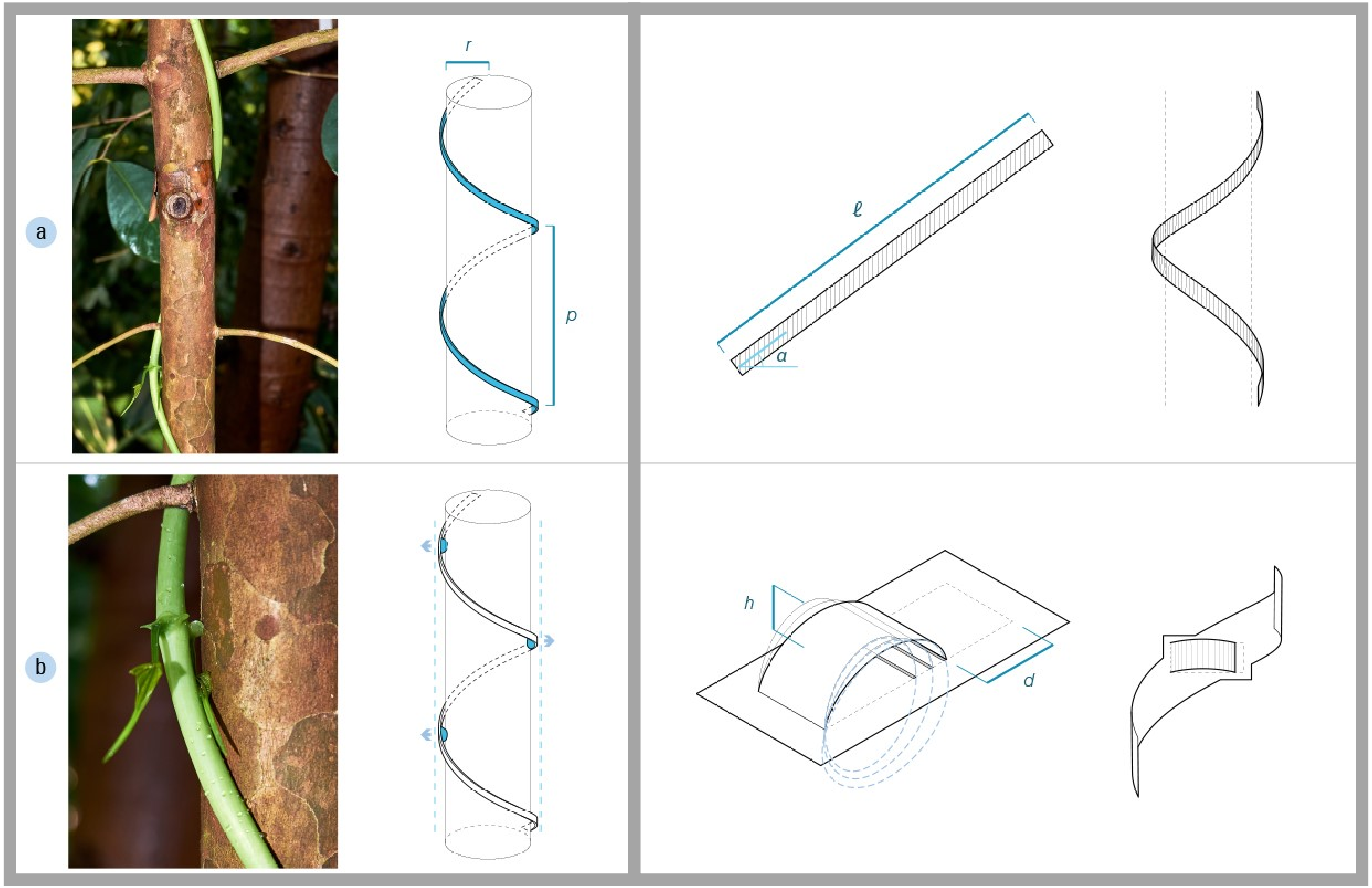
BIOLOGICAL INSPIRATION: FORCE GENERATION OF DIOSCOREA BULBIFERA





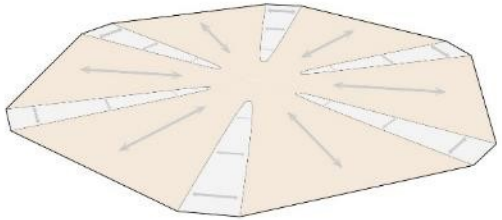
S Isnard, AR Cobb, NM Holbrook, M Zwieniecki, J Dumais: 2009, ***Tensioning the helix: A mechanism for force generation in twining plants****.*
Proceedings of the Royal Society B: Biological Sciences.

Functional principle

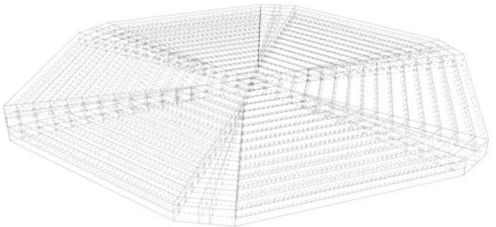


Abstraction & technical interpretation

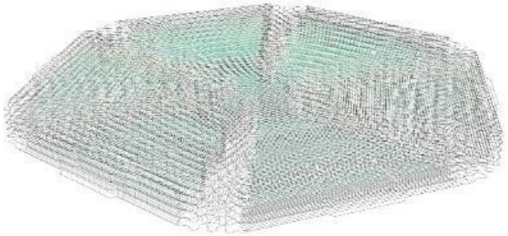
*T Cheng, Y Tahouni, D Wood, B Stolz, R Mülhaupt, A Menges: 2020, **Multifunctional Mesostructures: Design and Material Programming for 4D-printing**. Symposium on Computational Fabrication (SCF '20).*



Geometric Modelling



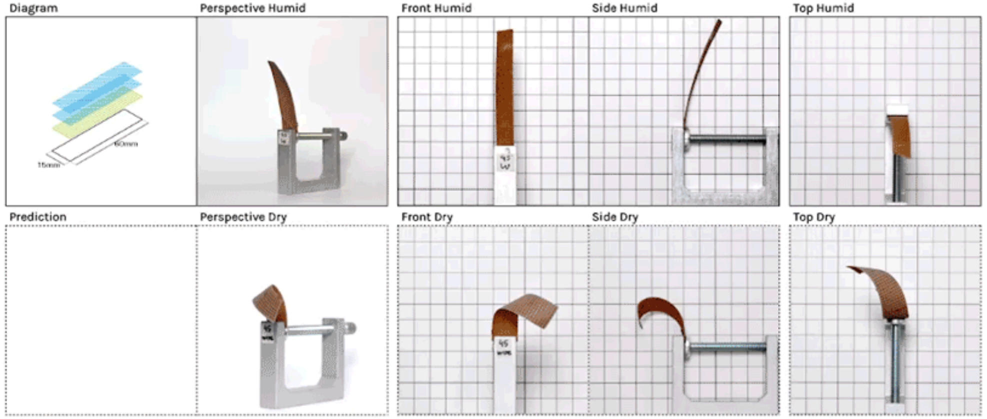
Shape prediction



Fabrication data

T Cheng, Y Tahouni, D Wood, B Stolz, R Mülhaupt, A Menges: 2020, ***Multifunctional Mesostructures: Design and Material Programming for 4D-printing****. Symposium on Computational Fabrication (SCF ’20).*

STwist_15x60_A.45deg.2layers_R.grid_01 (S"Serie's name"_R"restrictive layer info"_A"active layer info"_Other info_Number 2 digits)



PRINTING SETUP

Printer Model	Filament Type	Temps	Rates
Felix 3.0	Laywood-D3 1.75mm	195°C Nozzle 50°C Bed	700 Feed 0.033 Flow

LOW RH MEASUREMENTS (average)

Weight (g)	Width (mm)	Length (mm)	Height (mm)
0.4	#DIV/0!	#DIV/0!	#DIV/0!

HIGH RH MEASUREMENTS (average)

Weight (g)	Width (mm)	Length (mm)	Height (mm)
0.4025	12.885	58.98	0.71

ACTUATION CONDITIONS

Humidity (%)	Temp (°C)	Duration (hr)
25	19	5

SPECIMEN INFO

Restrict	Active
Grid	Line
0°, 90°	45°
1.4mm	0.5mm
1 layer	2 layer

SAMPLE 1

PRINTING ENVIRONMENT

Date	Time	Temperature	Humidity
2018.03.16	11:00	18°C	27%

LOW RH MEASUREMENTS

Weight (g)	Width (mm)	Length (mm)	Height (mm)

HIGH RH MEASUREMENTS

Weight (g)	Width (mm)	Length (mm)	Height (mm)
0.316	10.4	57.72	0.76

SAMPLE 2

PRINTING ENVIRONMENT

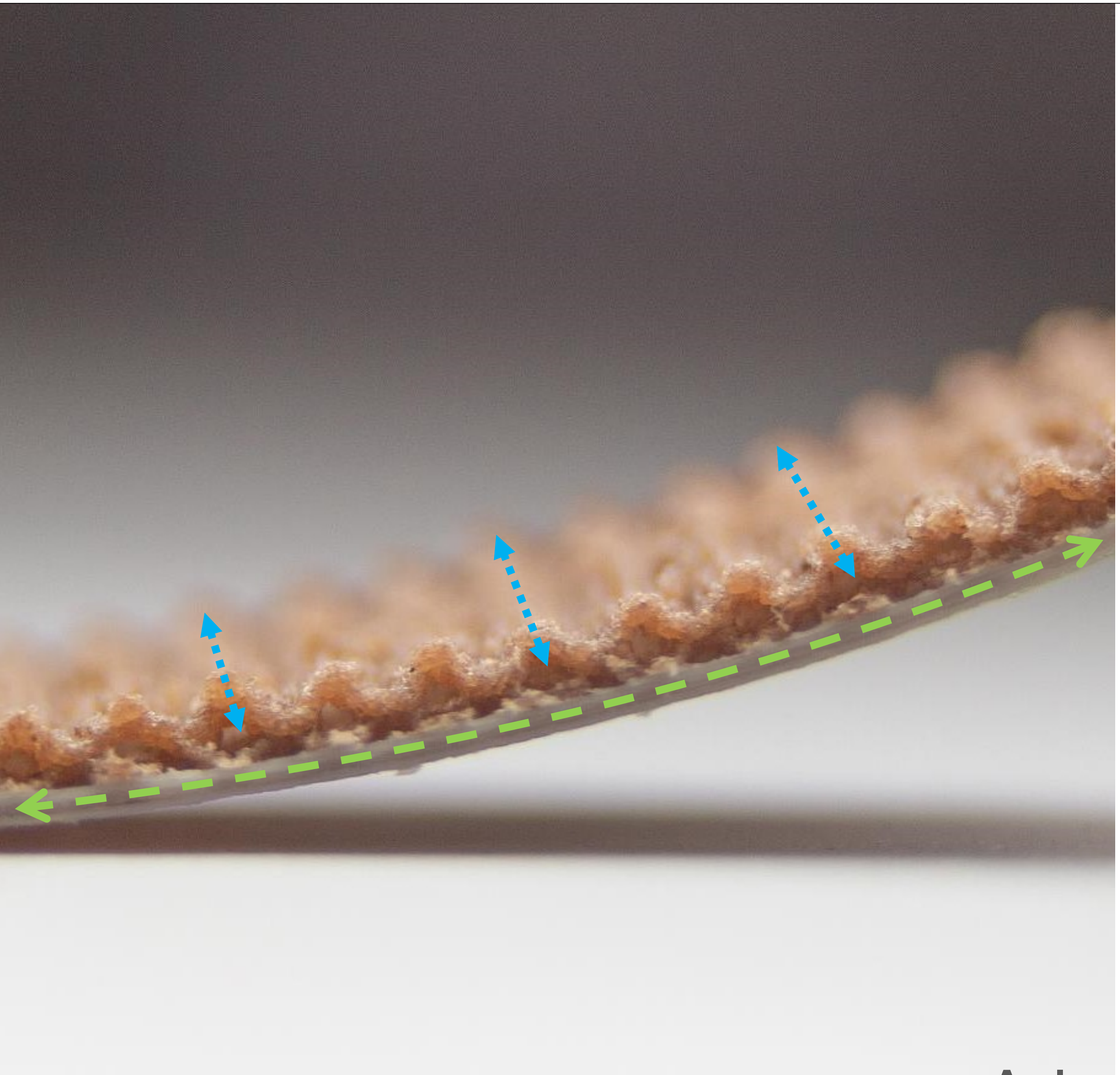
Date	Time	Temperature	Humidity
2018.04.02	11:00	21°C	30%

LOW RH MEASUREMENTS

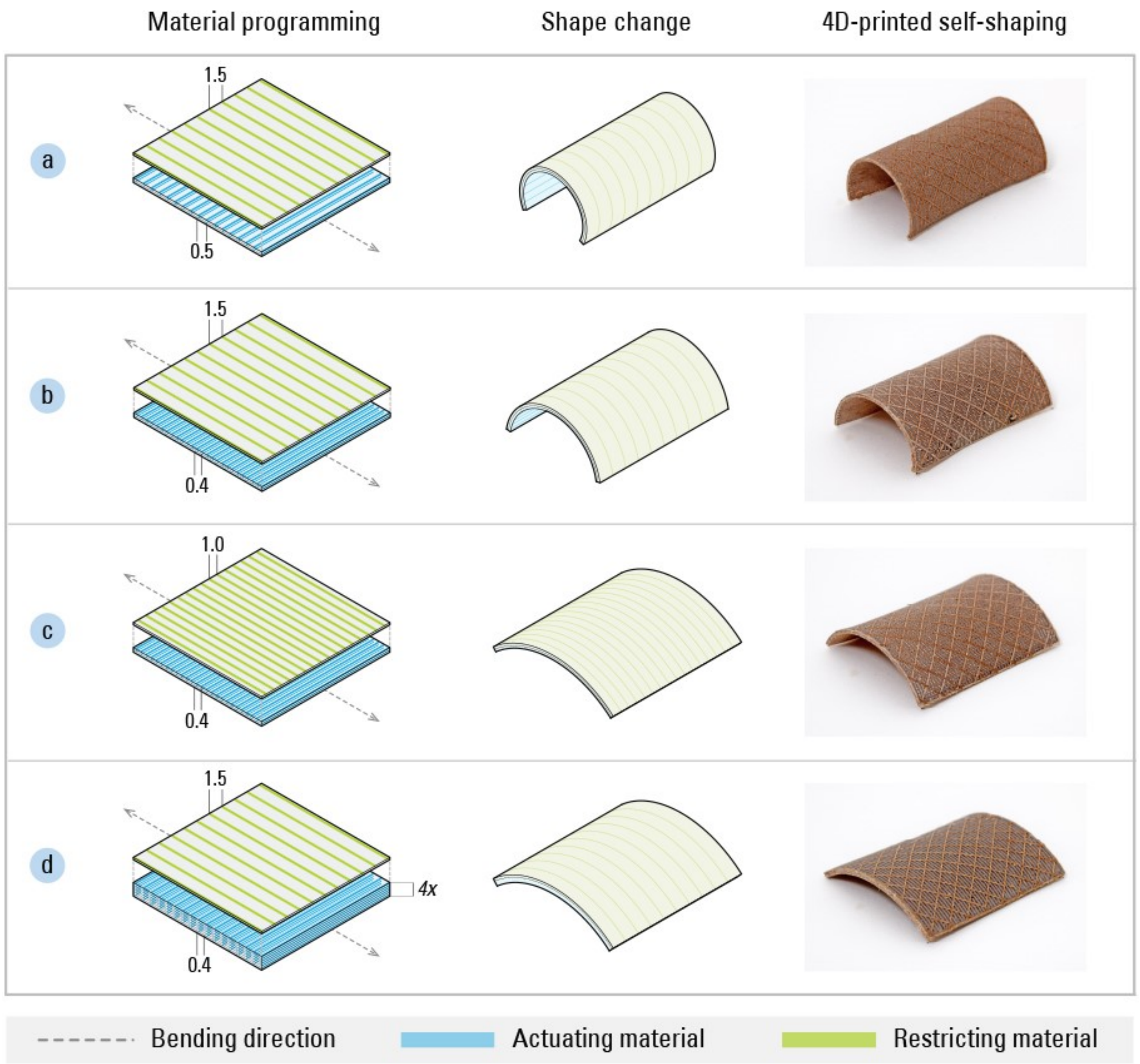
Weight (g)	Width (mm)	Length (mm)	Height (mm)
0.4			

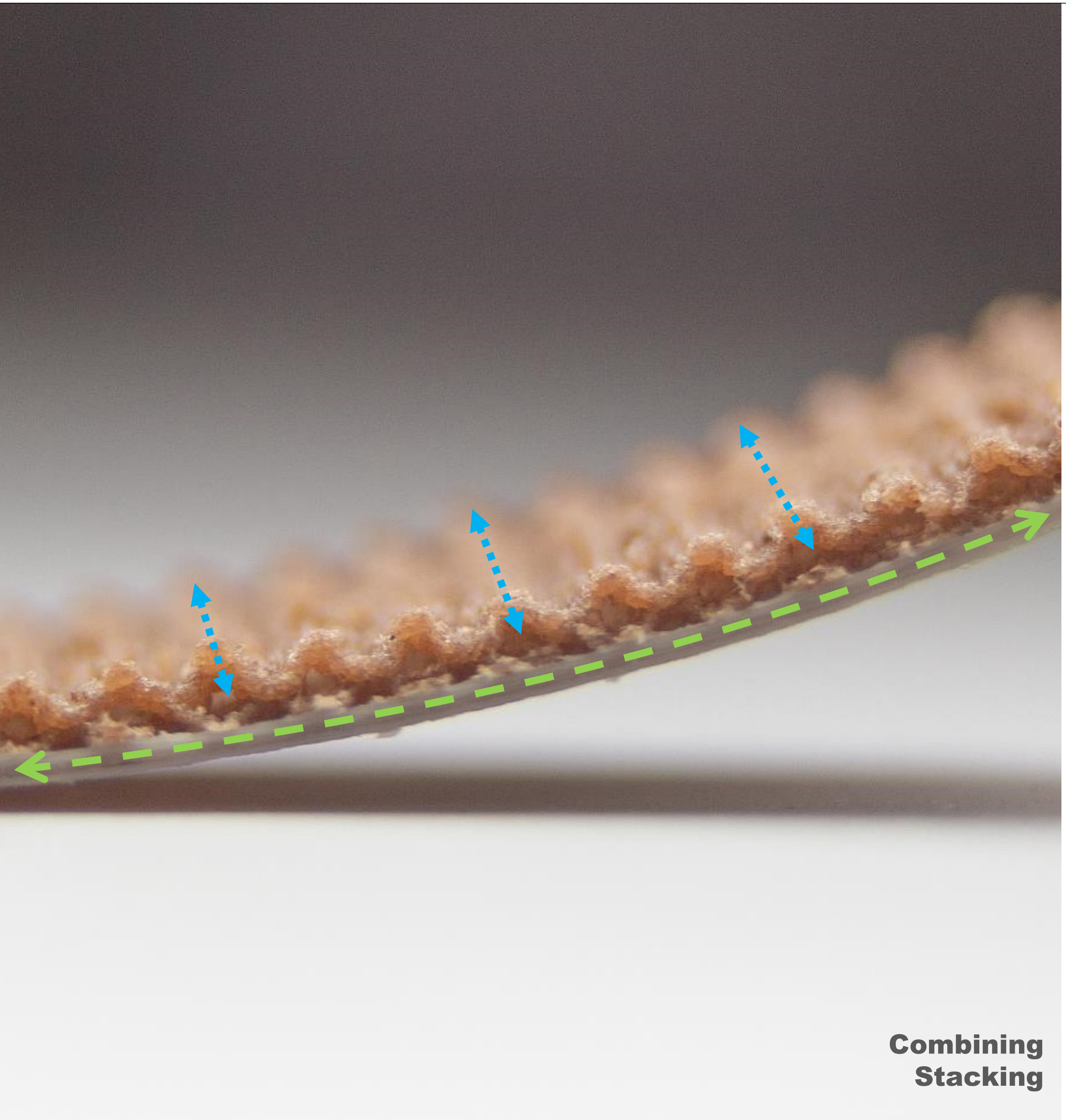
HIGH RH MEASUREMENTS

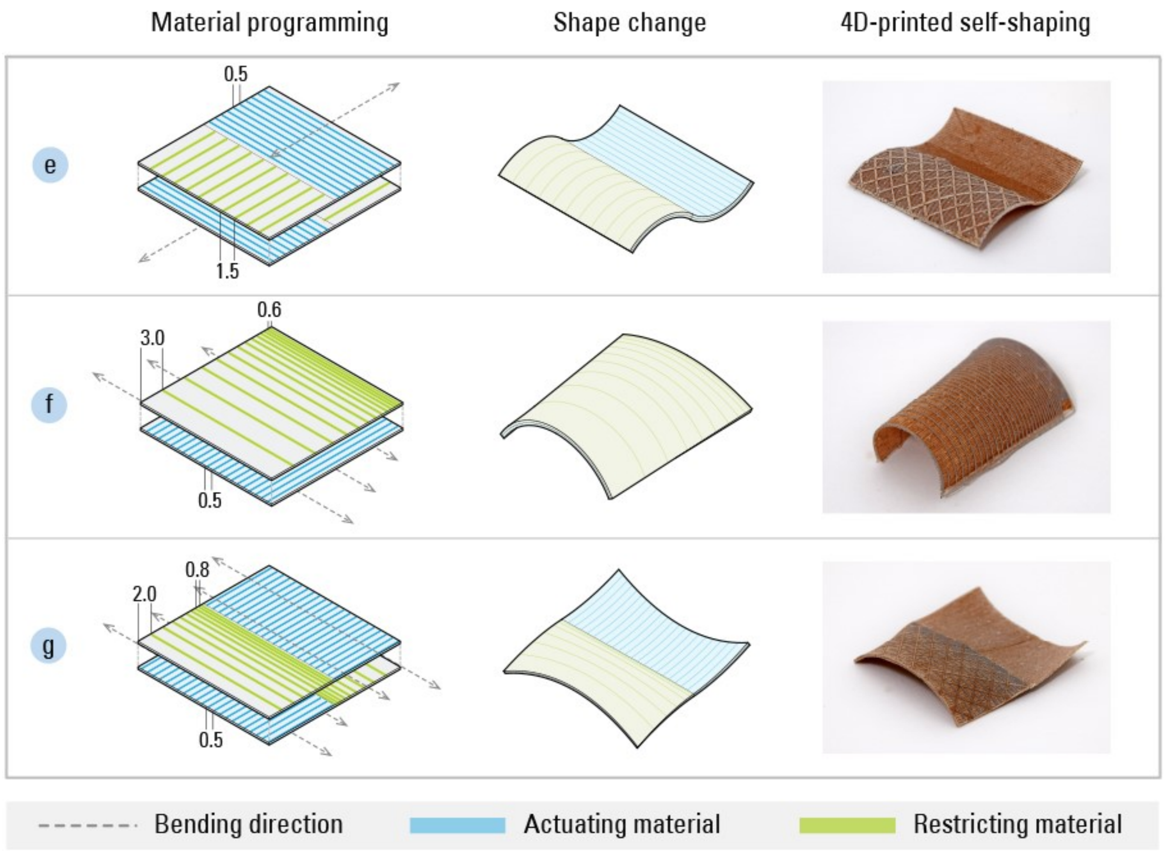
Weight (g)	Width (mm)	Length (mm)	Height (mm)
0.489	15.37	60.24	0.66

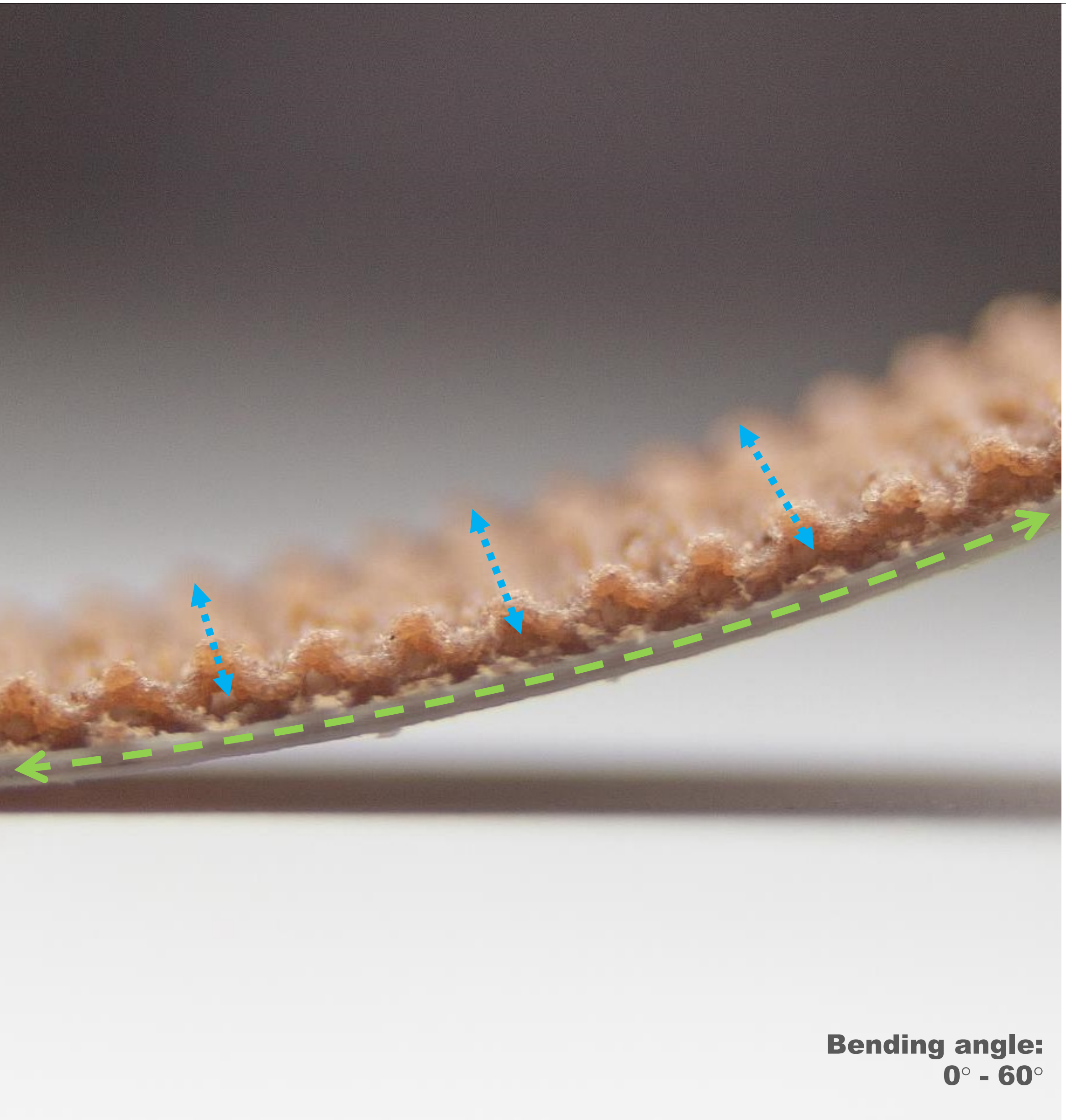


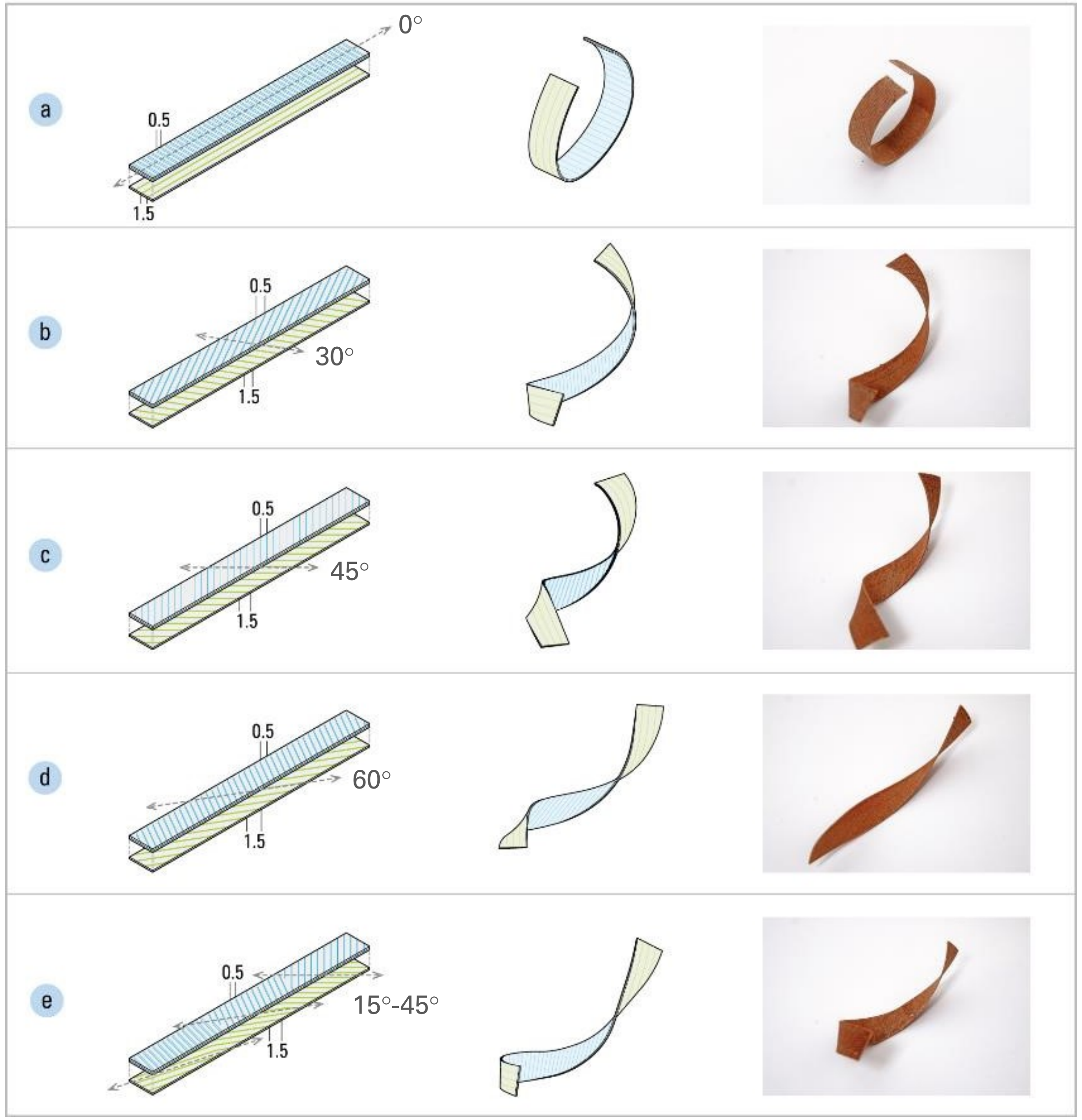
- **Angle**
- **Offset**
- **Height**

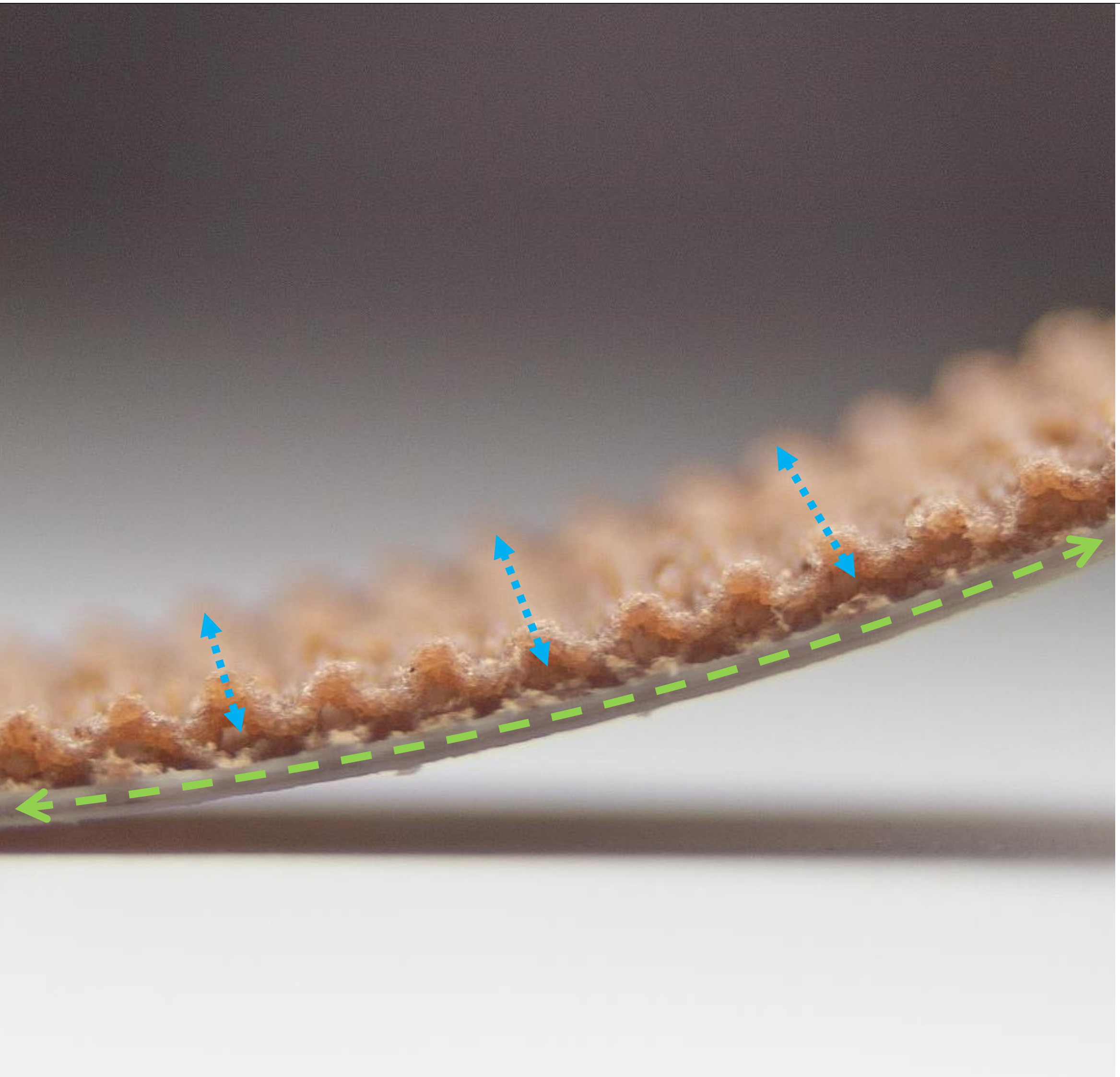



Combining
Stacking

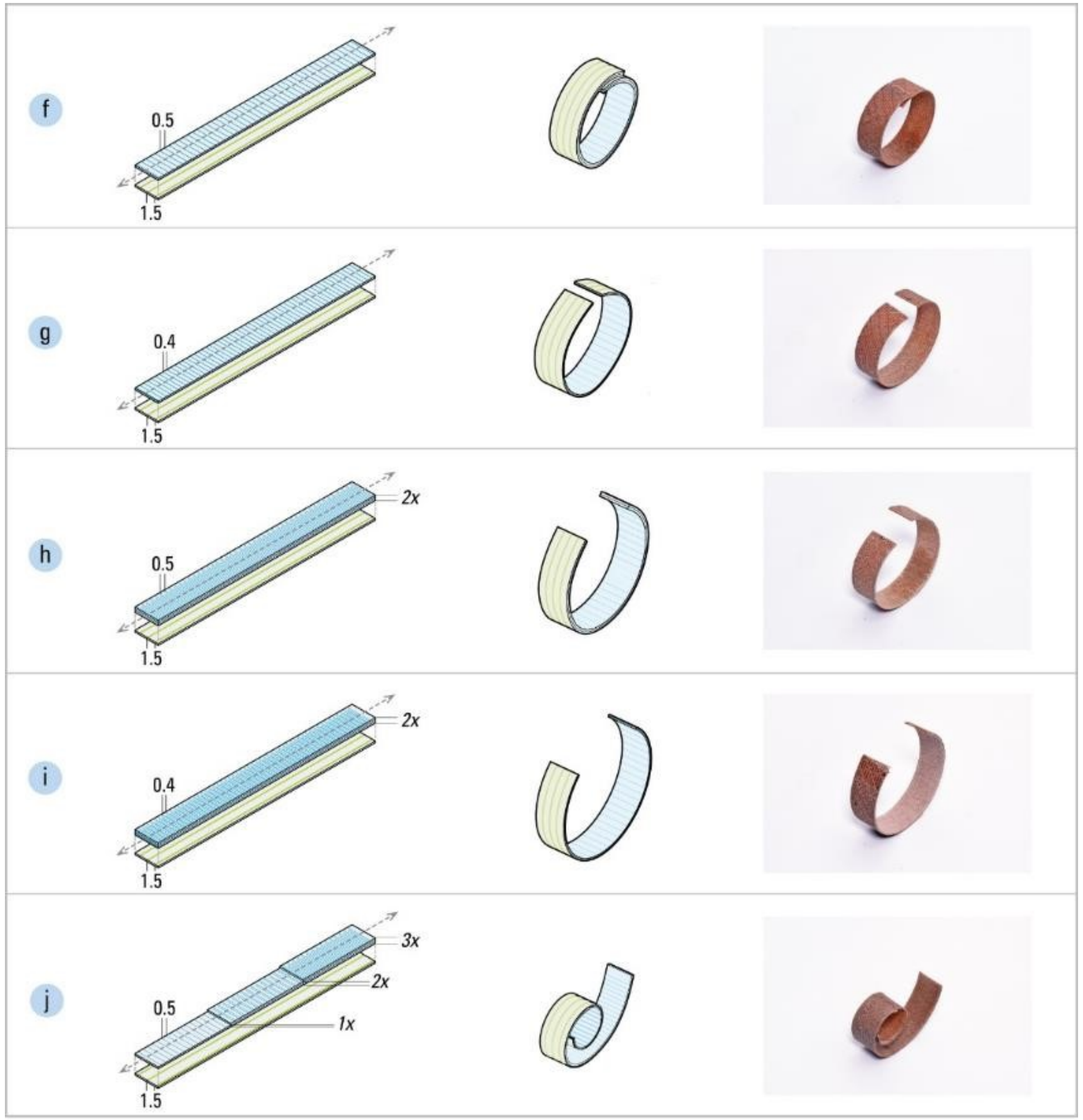

Material programming
Shape change
4D-printed self-shaping
e
0.5
1.5
f
0.6
3.0
0.5
g
0.8
2.0
0.5
Bending direction
Actuating material
Restricting material

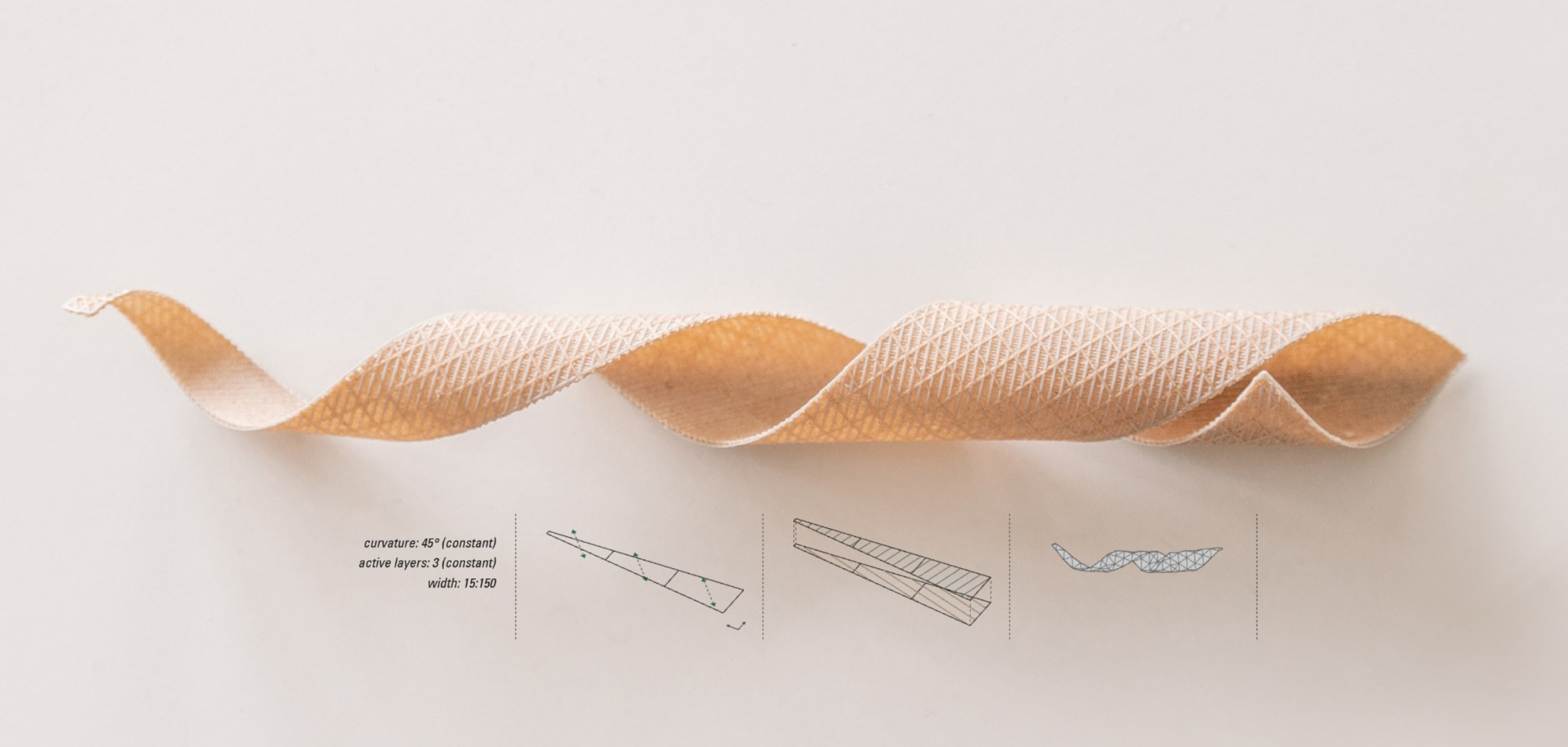

Bending angle:
0° - 60°


a
0.5
1.5
0°
b
0.5
1.5
30°
c
0.5
1.5
45°
d
0.5
1.5
60°
e
0.5
1.5
15°-45°

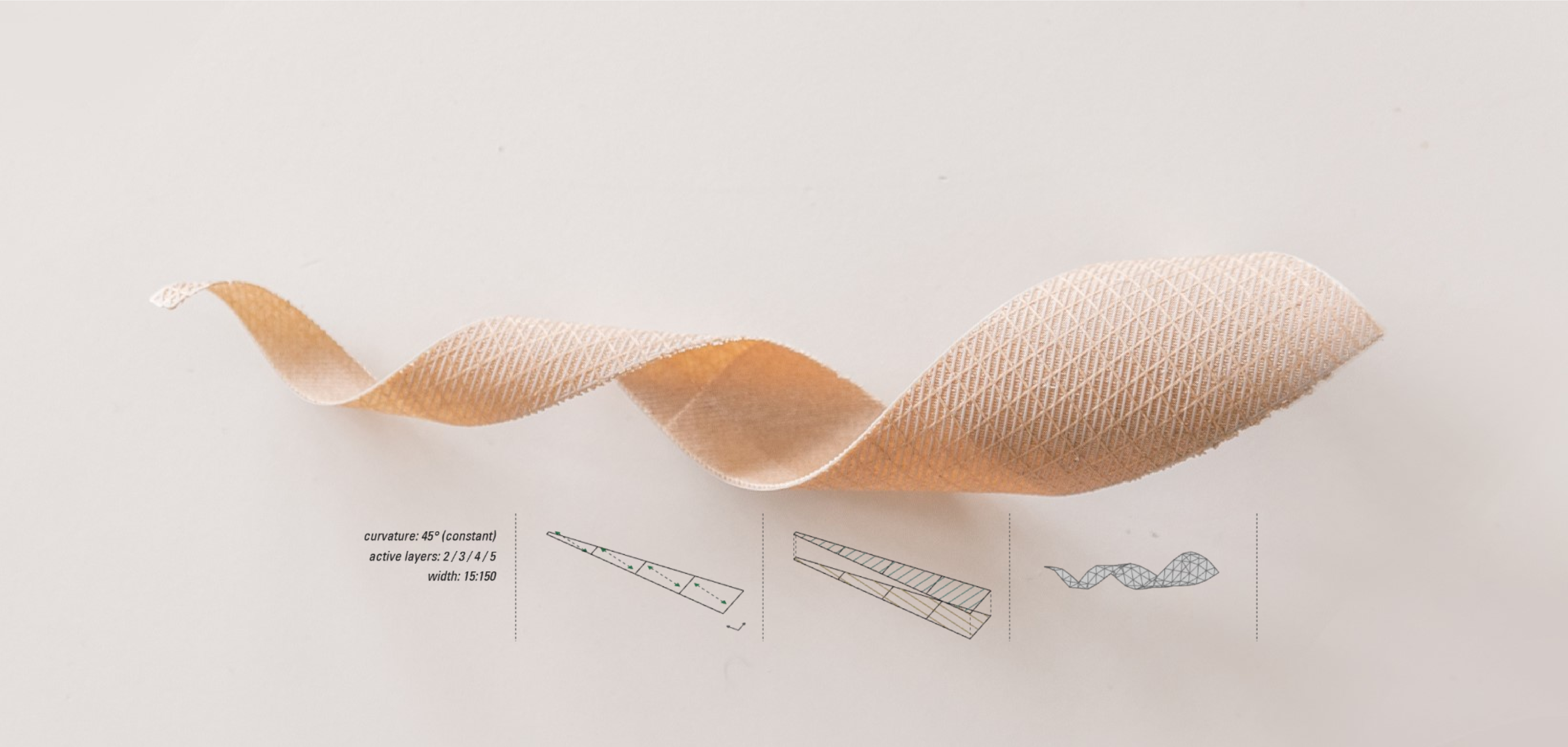


**Bending radius:
15mm – 60mm**

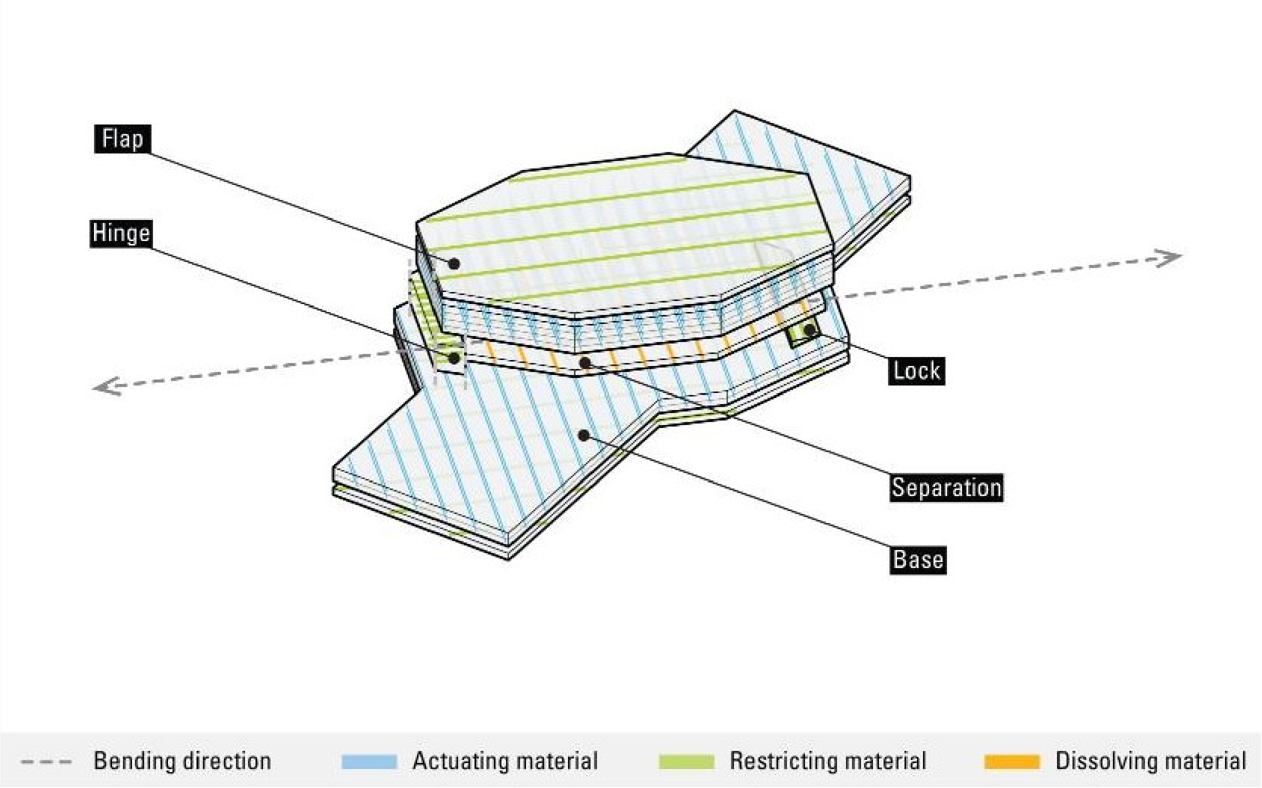


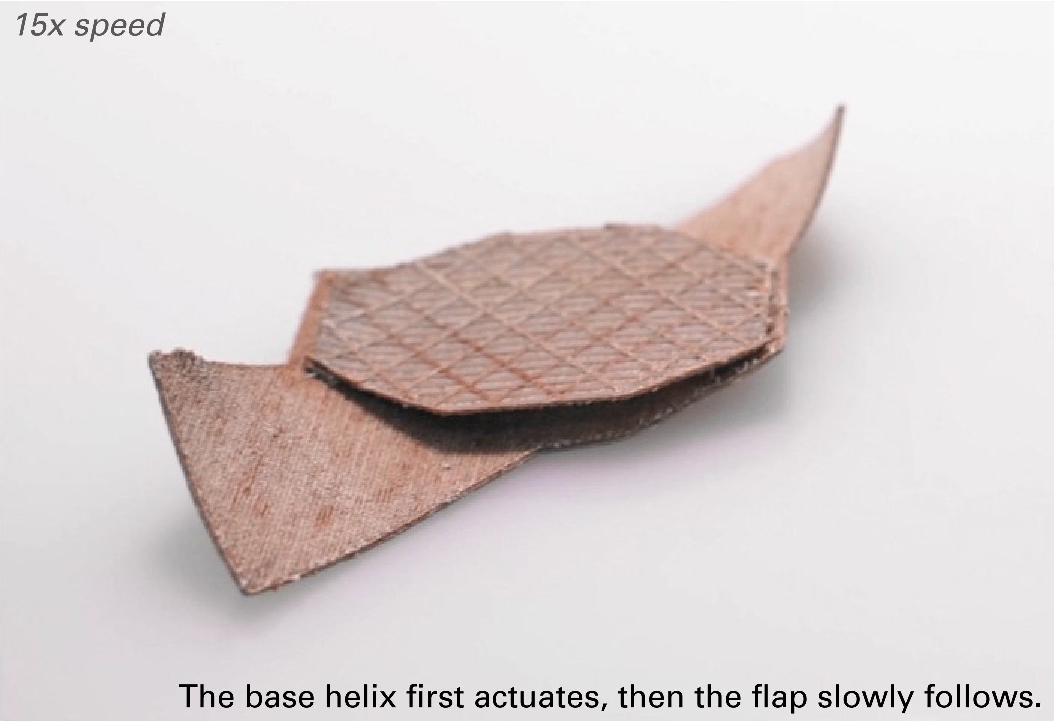

curvature: 45° (constant)
active layers: 3 (constant)
width: 15:150

MATERIAL PROGRAMMING: HELIX MECHANISM



MATERIAL PROGRAMMING: POCKET MECHANISM

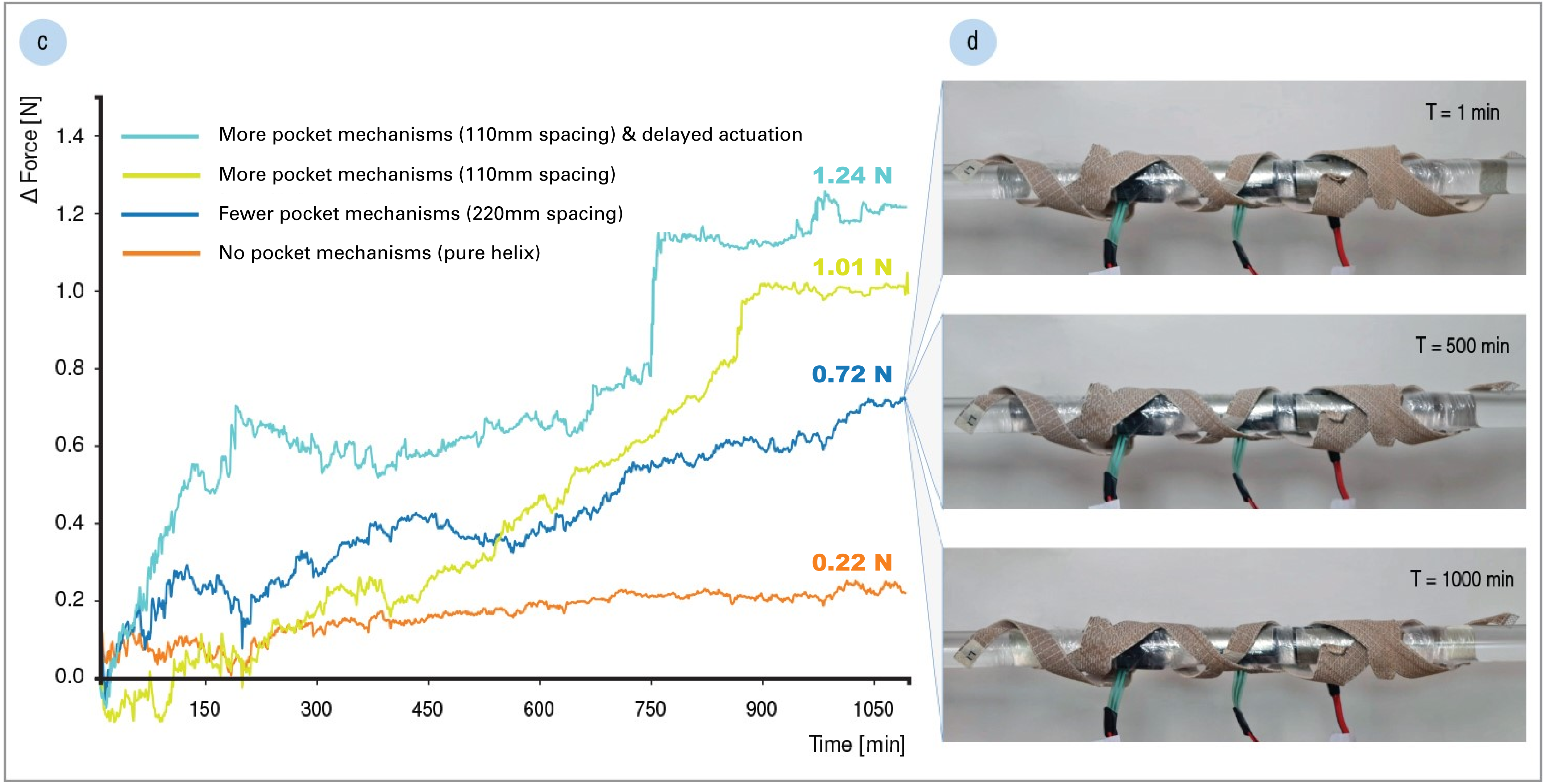


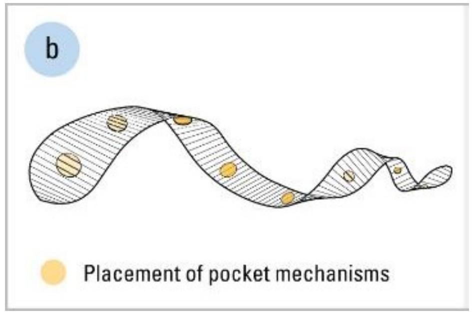


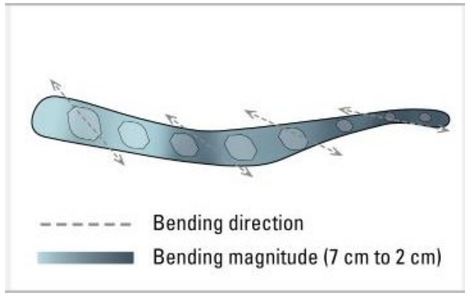

15x speed

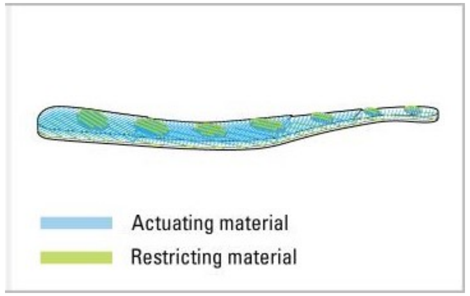

15x speed

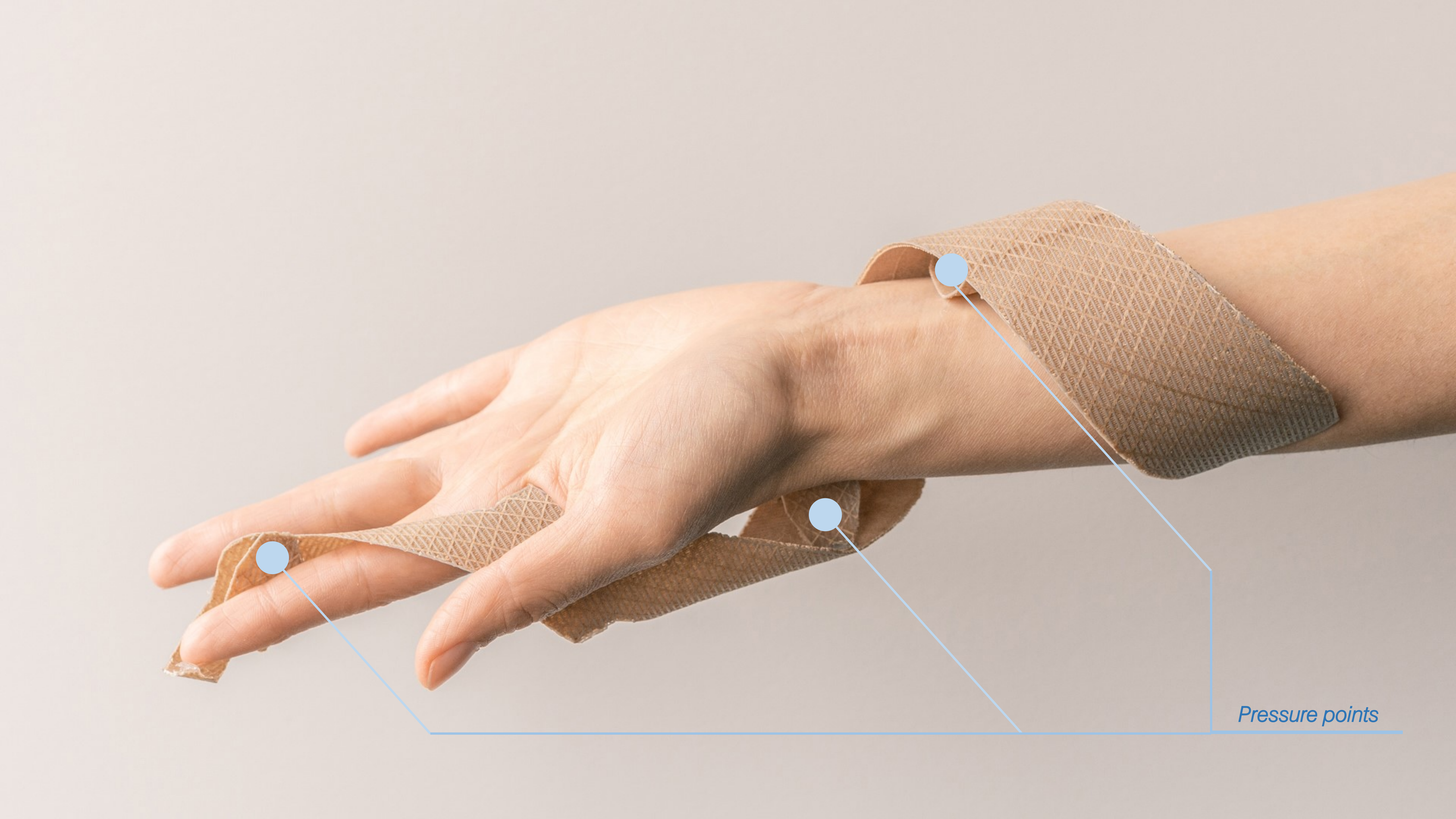
SQUEEZING FORCES OF THE 4D-PRINTED TENSIONING MECHANISM

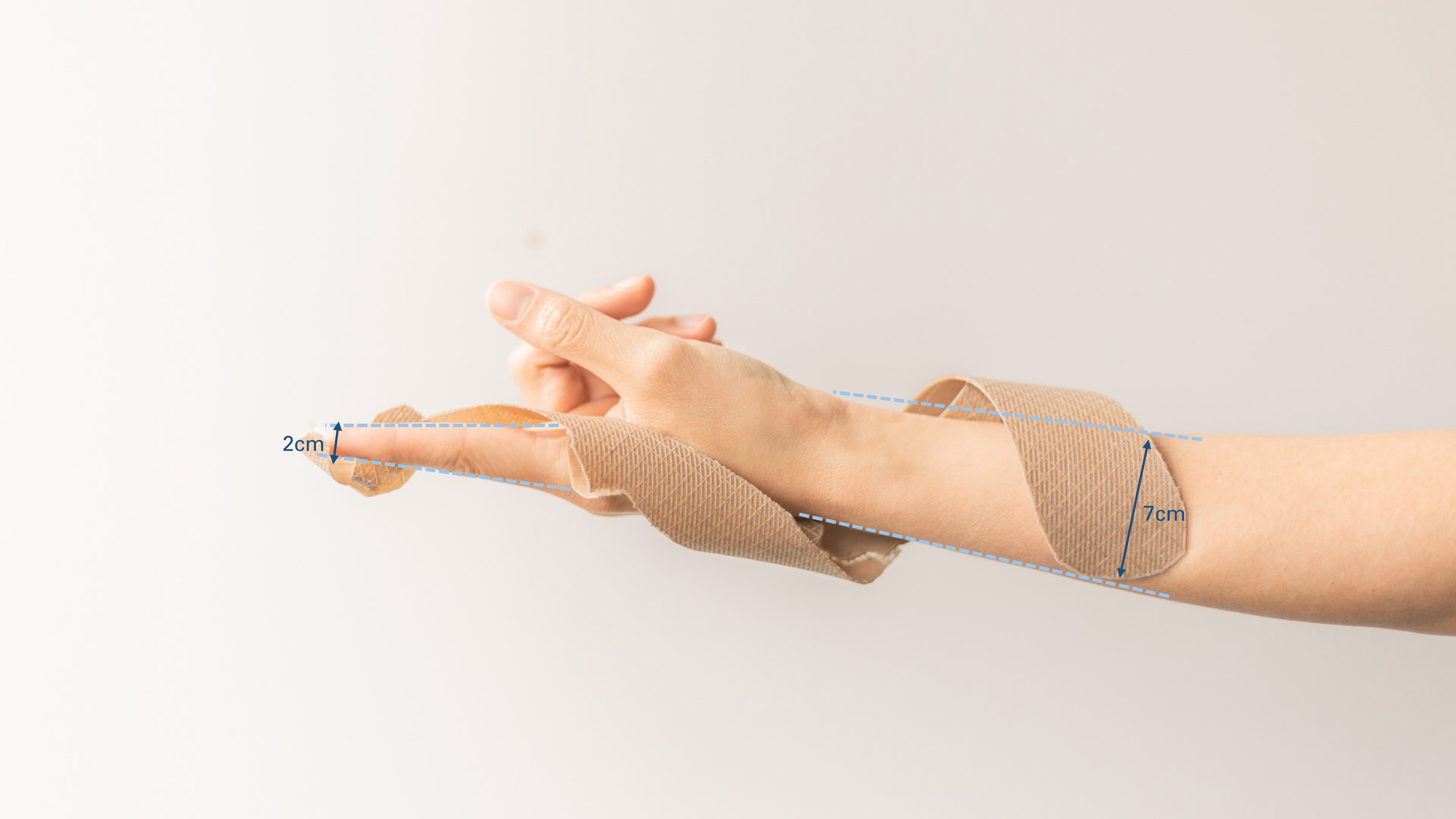


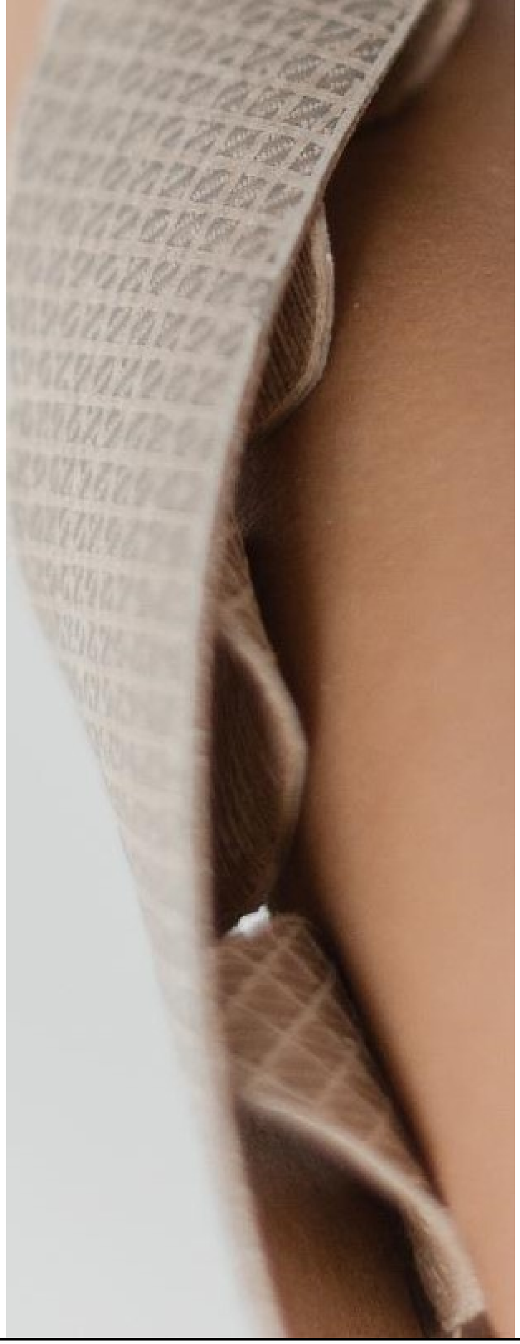

b
Placement of pocket mechanisms


Bending direction
Bending magnitude (7 cm to 2 cm)


Actuating material
Restricting material


Pressure points

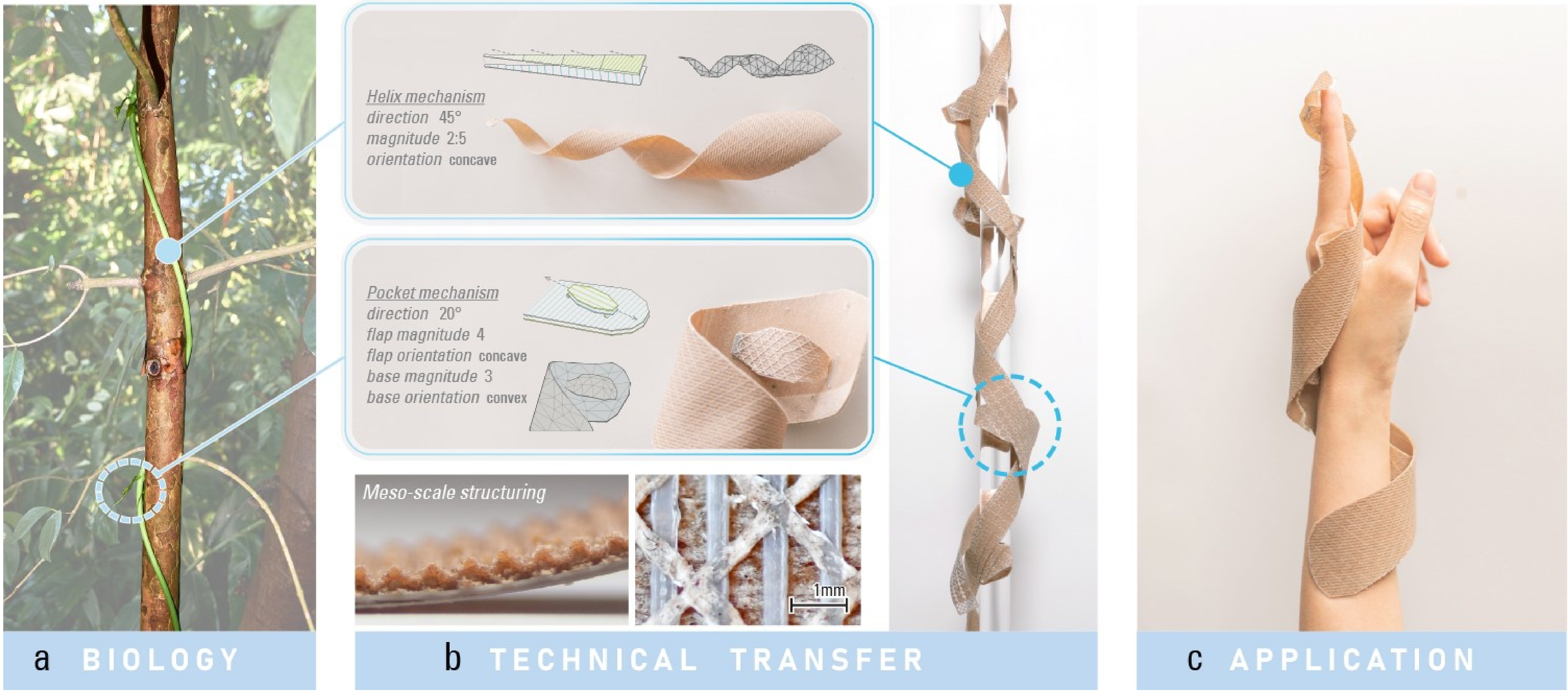

2cm
7cm



Customization
to unique body parts

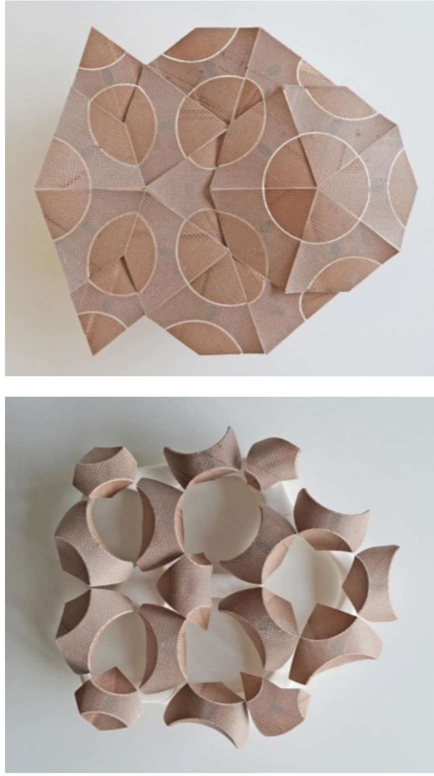
Adaptation
to changes over time

BIOMIMETIC PROCESS: BIOLOGY-PUSH APPROACH

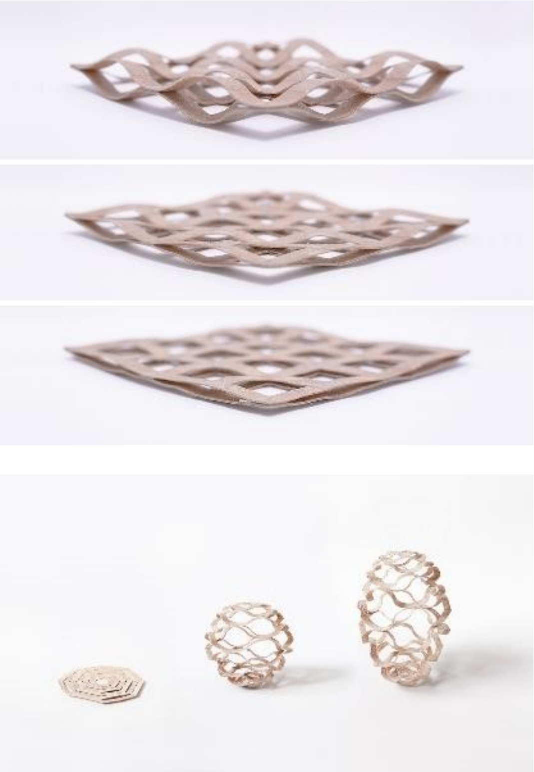


4D-PRINTING ACROSS SCALES AND MECHANISMS

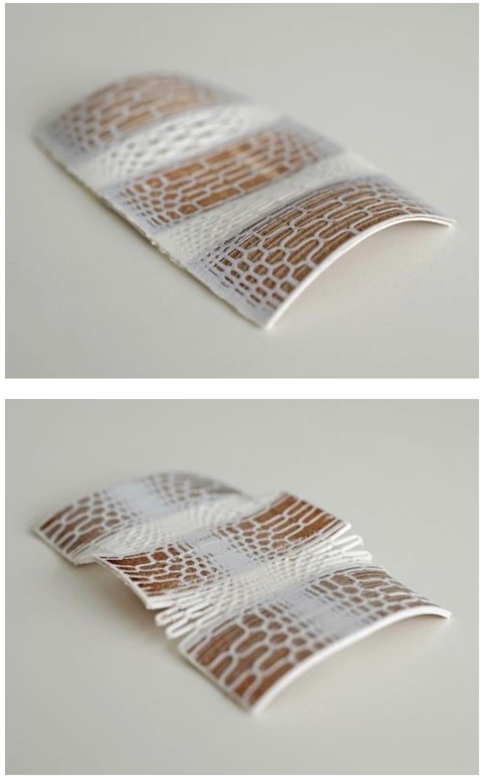
Bending



Folding

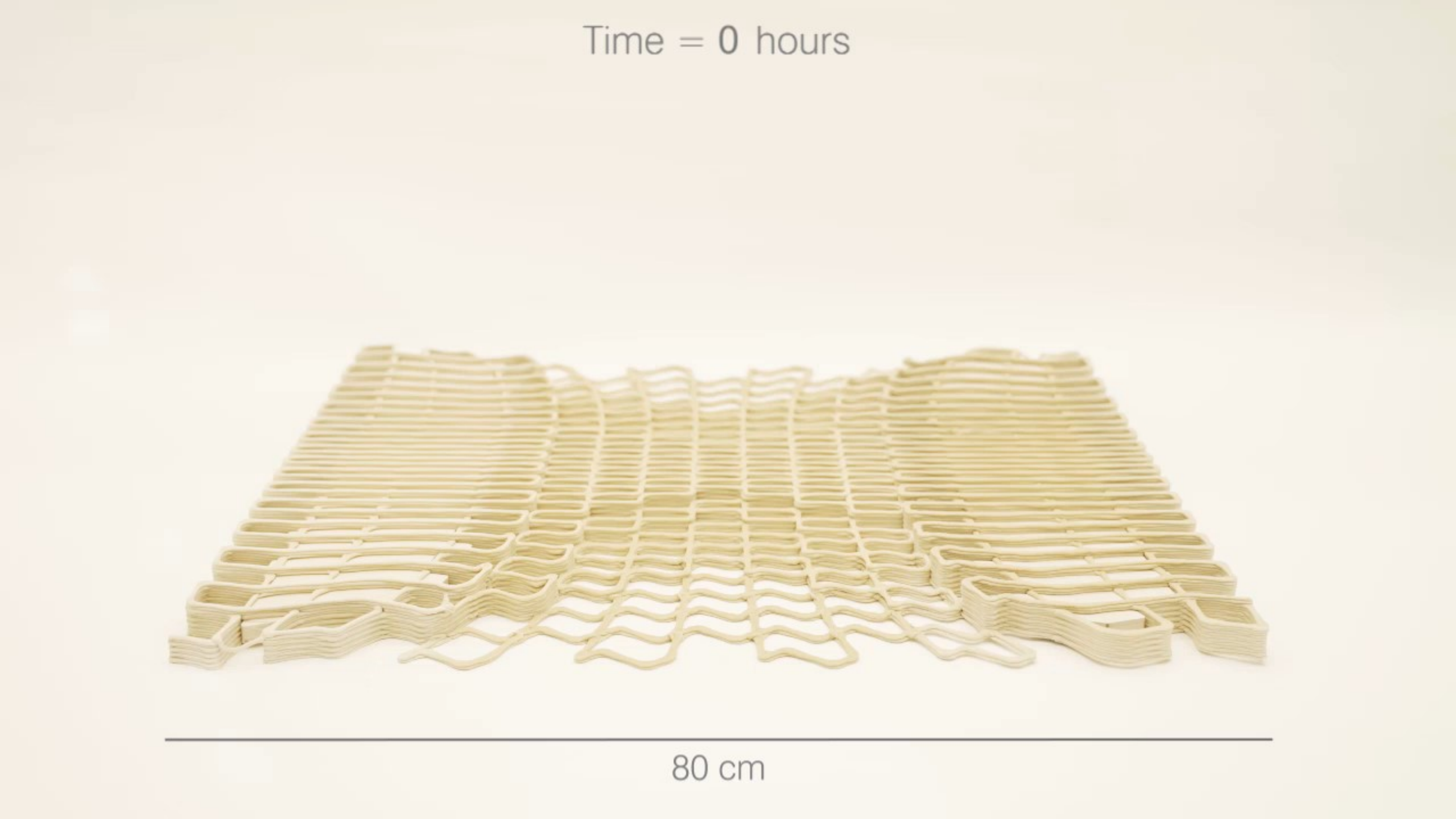


Stacking



Openings

TOWARDS SELF-TIGHTENING LARGE-SCALE STRUCTURES?



*T Cheng, D Wood, L Kiesewetter, E Ozdemir, K Antorveza, A Menges: 2021, **Programming Material Compliance and Actuation: Hybrid Additive Fabrication of Biocomposite Structures for Large-scale Self-shaping**. Bioinspiration & Biomimetics.*

4D-printed motion mechanisms inspired by Dioscorea bulbifera

Tiffany Cheng

Material Programming, Institute for Computational Design and Construction (ICD), University of Stuttgart

tiffany.cheng@icd.uni-stuttgart.de

University of Stuttgart

ICD Institute for Computational Design and Construction