UNIVERSITAT POLITÈCNICA
DE CATALUNYA
BARCELONATECH

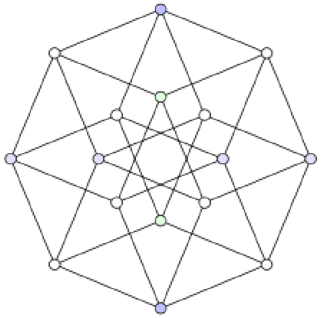
CIMNE

MASTER ON NUMERICAL
METHODS IN ENGINEERING
OFFICIAL MASTER of UPC Barcelona Tech

Learning from the nature: Bionic & Lightweight design

Jorge Alvarez
2017

Learning from the nature
Bionics & Lightweight design!



Bioexoskeleton

Research

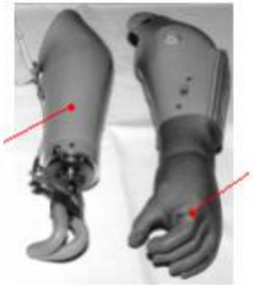
Innovation

Development

Co-working

Social impact

1a. A passive prosthesis made at the Northern General Hospital, Sheffield.



1b. A body-powered prosthesis

1c. *A* myoelectric prosthesis

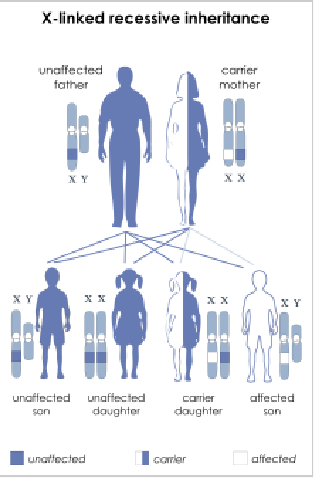
Disease … the extreme paradigm…!!!

Paralysis of Duchenne (DMD)

- Neuromuscular disease
- X chromosome

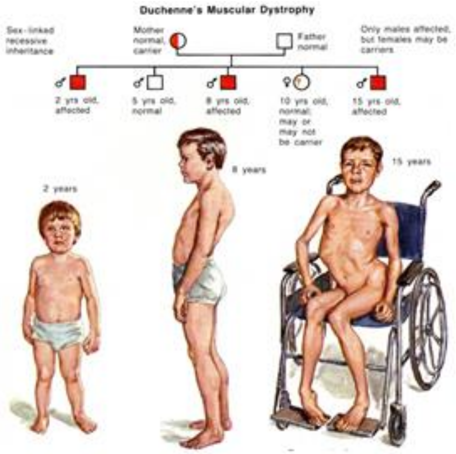
FEM Simulation

- Mechanical Modelling
- Structure Optimizing

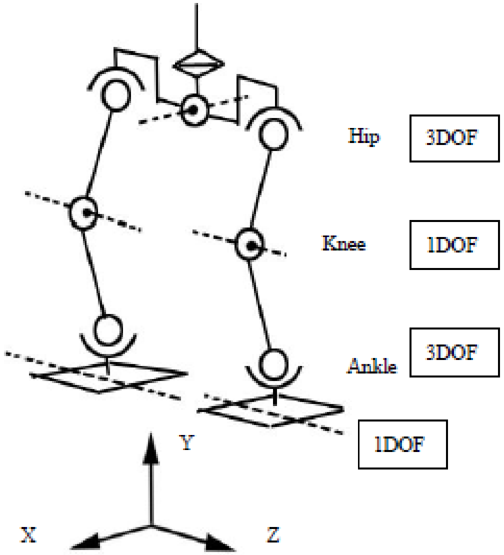


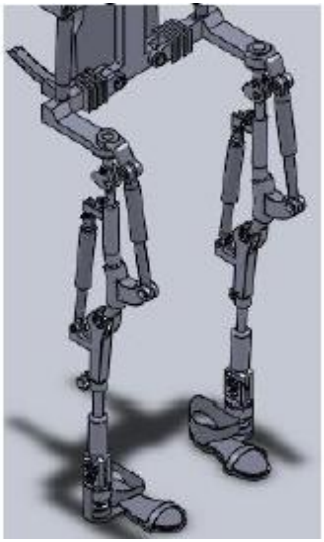
DMD is inherited in a X-linked recessive manner

Source: www.lgmpharma.com



Source: able BIONICS *and* Rick Hansen Foundation





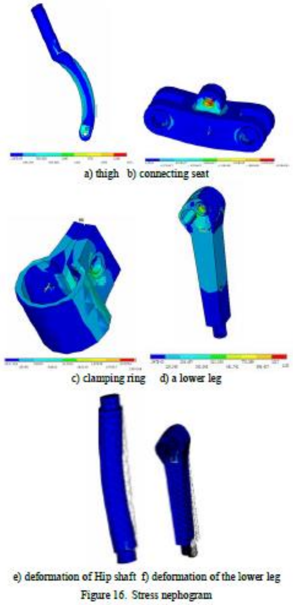


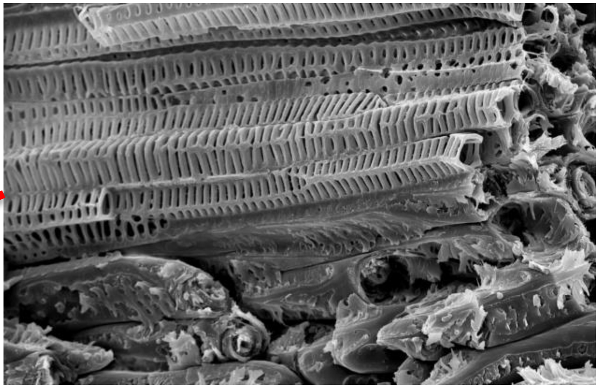
Figure 16. Stress nephogram

Source: Zhao Yanjun, et al., 2013, Finite Element Simulation of Soldier Lower Extremity Exoskeleton, doi:10.4304/jmm.8.6.705-712

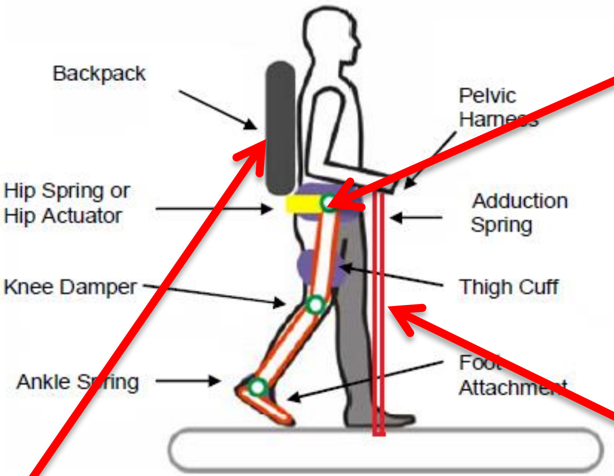
Bioskeleton

- Bionics lightweight structure
- Innovation on biocomposite

Coconuts shell

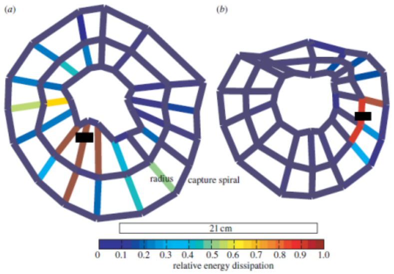


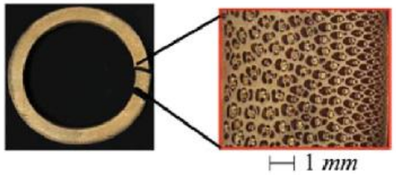
Source: Freiburg University, Biomechanic Group



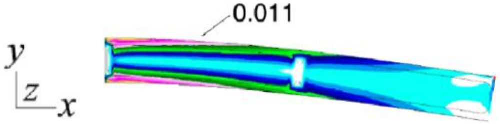
Source: able BIONICS *and* Rick Hansen Foundation

Spider web





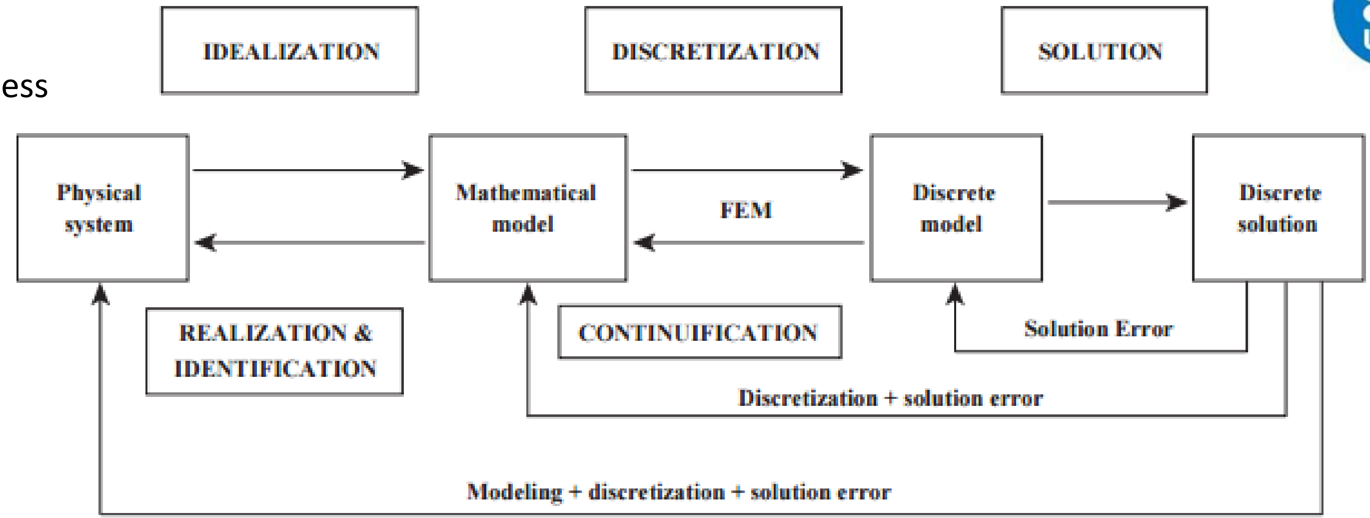
Bamboo



Source: Emilio Nelli, et al., 2008, **Modeling Bamboo as a Functionally Graded Material**

Bamboo

A simplified view of the physical simulation process



Anisotrop, axial load

$$\mathbf{u}^{\varepsilon} = \left\{ u_r^{\varepsilon} \quad u_z^{\varepsilon} \right\}^{T} = \mathbf{u}_0(\mathrm{x}) + \varepsilon \mathbf{u}_1(\mathrm{x}, \mathrm{y})$$

Displacement

$$\mathbf{u}_1 = \chi(x,y)\,\varepsilon\left(\mathbf{u}_0(x)\right) \text{ and } \partial_y \mathbf{u}_1(x,y) = \partial_y \chi(x,y)\,\partial_x\left(\mathbf{u}_0(x)\right)$$

Displacement inside the unit cell

$$\frac{1}{|Y|}\int_Y \left[\left(\mathbf{I} + \partial_y \chi(x,y)\right) : \mathbf{E}(x,y) : \partial_y \delta \mathbf{u}_1(x,y)\right] dY = 0, \quad \forall \delta u_1 \in H_{per}\left(Y, R^3\right)$$

unit-cell (microscopic) equations

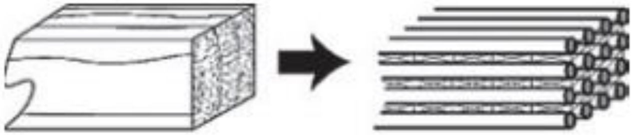
$$E^H = \frac{1}{|Y|}\int_Y \left[\left(\mathbf{I} + \partial_y \chi(x,y)\right) : \mathbf{E}(x,y) : \left(I + \partial_y \chi(x,y)\right)\right] dY,$$

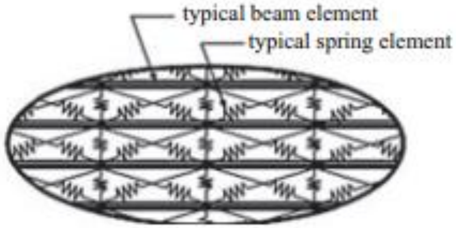
Specimen (macroscopic) equations

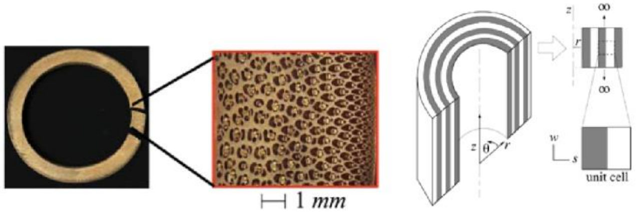
Source: Emilio Nelli, et al. , 2008, **Modeling Bamboo as a Functionally Graded Material**

FEM of the Bamboo: Functionally Graded Material (FGM)

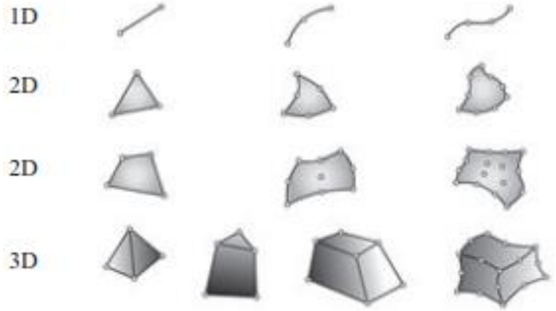
A simplified view of the FEM simulation

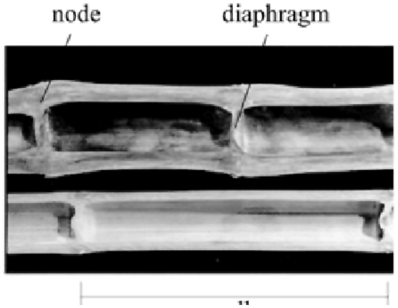


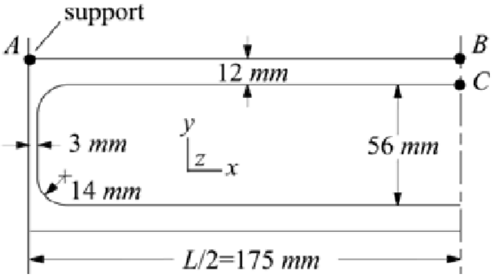




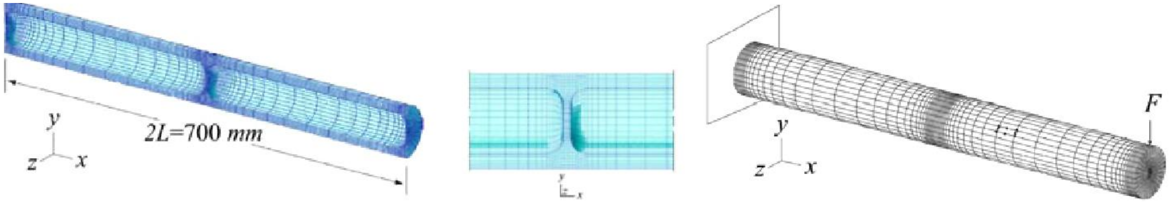
Source: Tankut et al., 2014, Finite Element Analysis of Wood Materials, *doi:10.5552/drind.2014.1254*



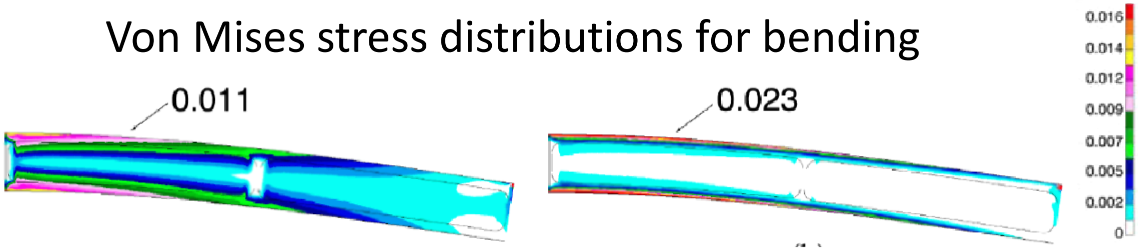


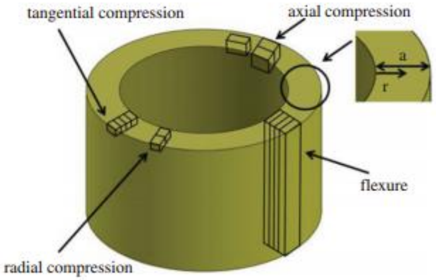


Higher order element-nodes



Von Mises stress distributions for bending





Geometry of mechanical test specimens

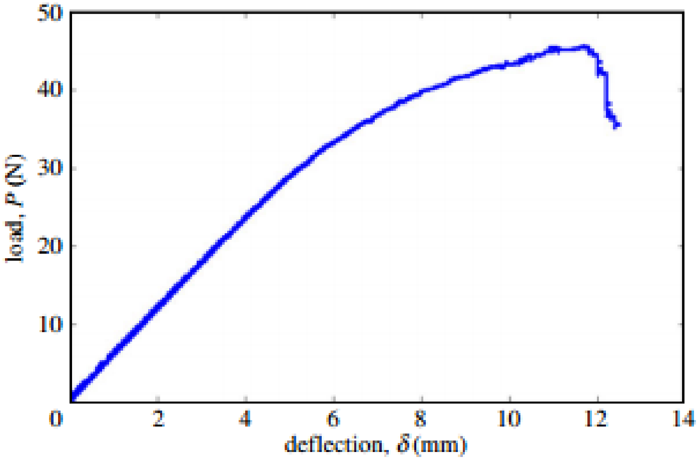
Source: http://dx.doi.org/10.1098/rsif.2014.0321

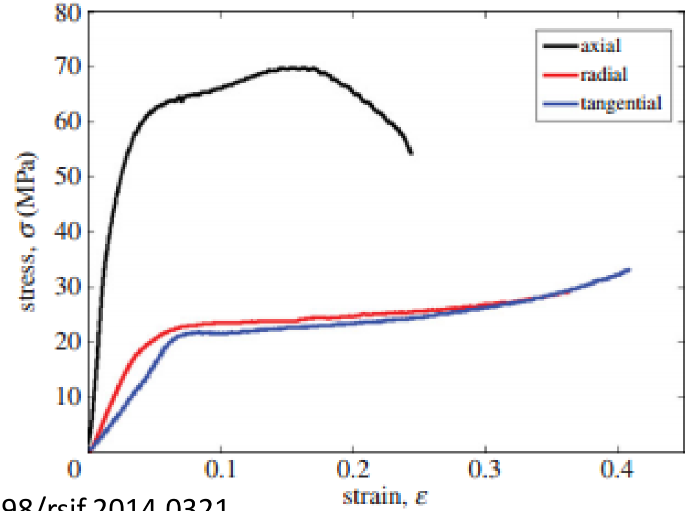
Source: Zhao Yanjun, et al., 2013, Finite Element Simulation of Soldier Lower Extremity Exoskeleton, doi:10.4304/jmm.8.6.705-712

Bamboo Properties

Comparisons of Moso bamboo and North American wood properties

material	density (kg m^{-3})	axial compressive strength (MPa)	Young's modulus (GPa)	modulus of rupture (MPa)
Moso bamboo	630	69.1	10.56	130.0
eastern white pine	350	33.1	8.50	59.0
Douglas fir, coast	480	49.9	13.40	85.0
white spruce	360	35.7	9.60	65.0
northern red oak	630	46.6	12.50	99.0





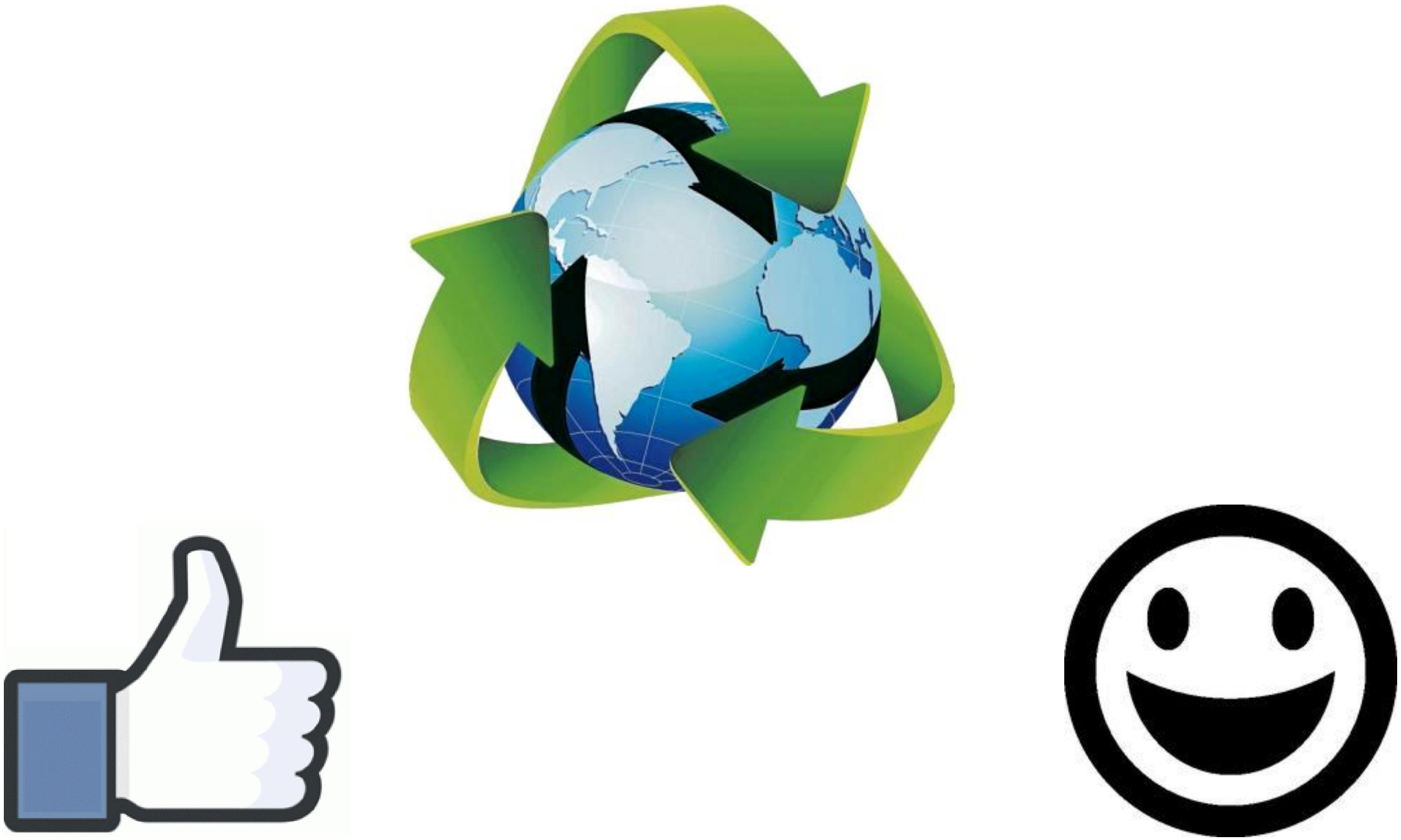
Source: http://dx.doi.org/10.1098/rsif.2014.0321

Bioexoskeleton

Benchmarking

Manufacturer	Exoskeleton model	Exoskeleton Materials	Cost [$]	Weight [kg]
Cyberdyne Inc.	HAL-5	Ni, Mo and duralumin	14.000-19.000	65-80
ReWalk Robotics	ReWalk Persona l 6.0	Duraluminium	70.000	~ 80
---	Bioexoskeleton	Biomaterials & Al	expected: 8.000	40

Source: Jorge Alvarez



do you want to know more or co-work with me?