Multiscale characterization of the hierarchical structure of *Dynastes hercules* elytra

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Introduction:

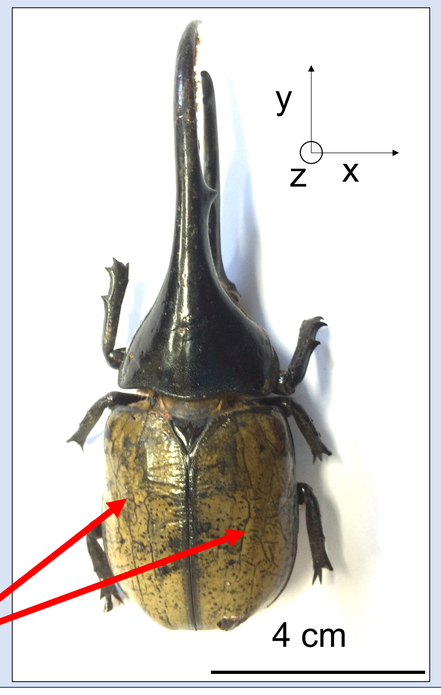
Beetle elytra are the hard thickened forewings that protect the fragile hindwings. Thanks to millions years of natural selection, elytra are optimal composite of proteins, lipids and chitin.

Objective:

The objective of the study is to characterize the structure of the elytron of *Dynastes hercules*.

Elytra

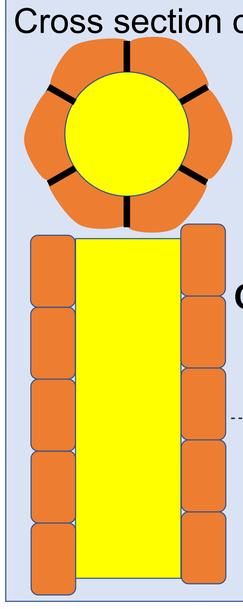
***Dynastes hercules* :**



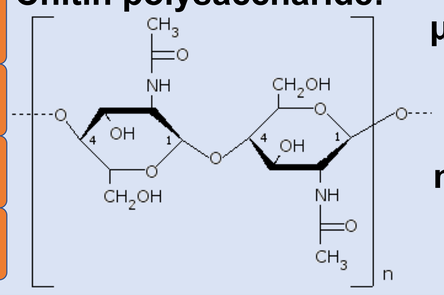
Materials & Methods:

The core component of endocuticle is chitin microfibres.

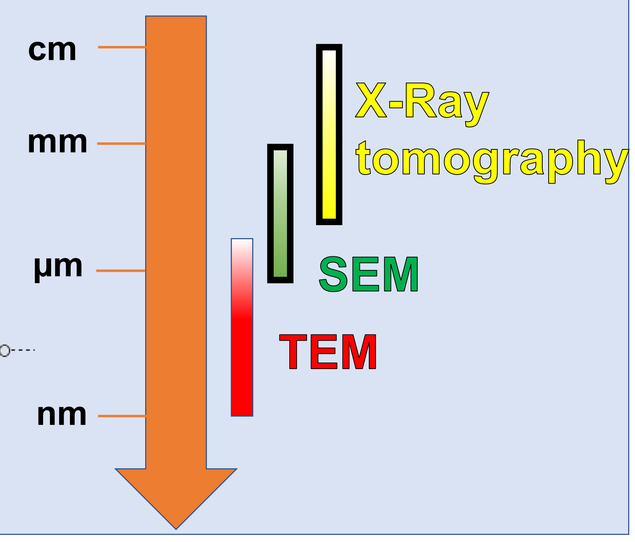
Cross section of a chitin microfibre :



Chitin polysaccharide:

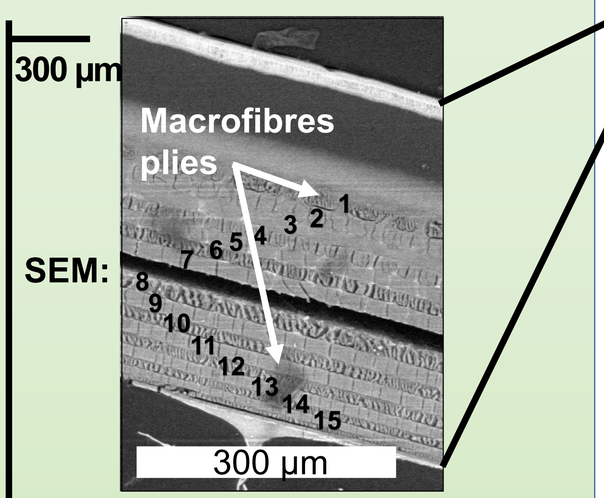


The chitinous part of the cuticle is characterized from the centimetre down to the scale of chitin microfibres; the nanometre. Size range used for each characterization method of the article:

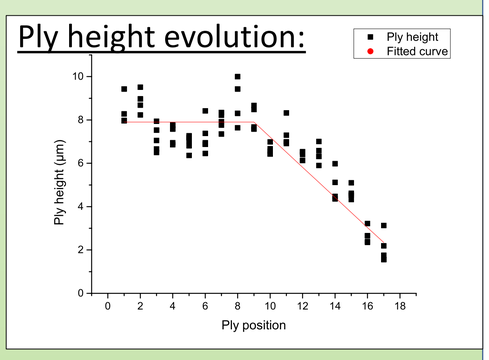


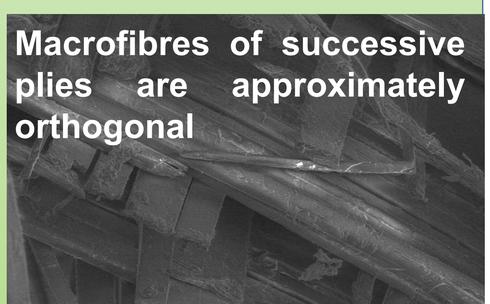
Results of the multi-scale characterization :

Dorsal cuticle:



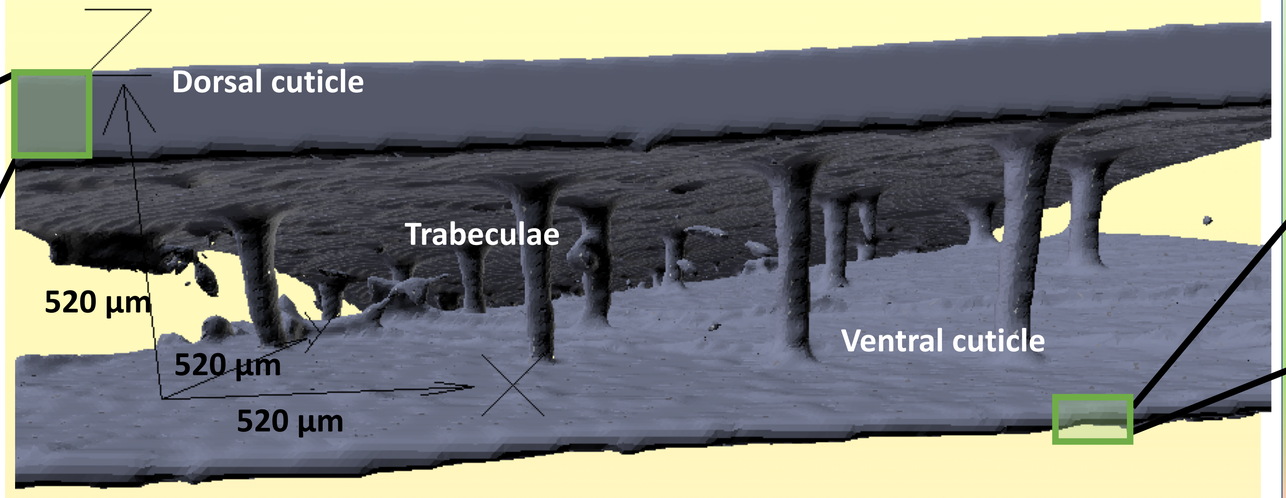
Ply height evolution:





Laminate structure of approximately orthogonal macrofibres.

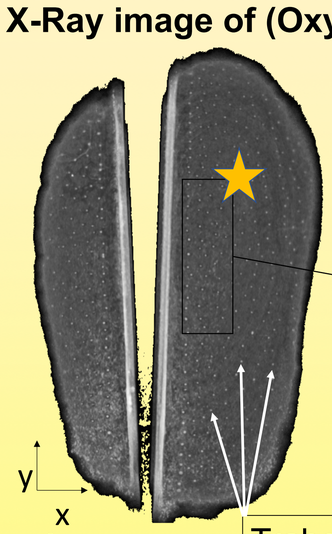
3D structure of the whole elytron:



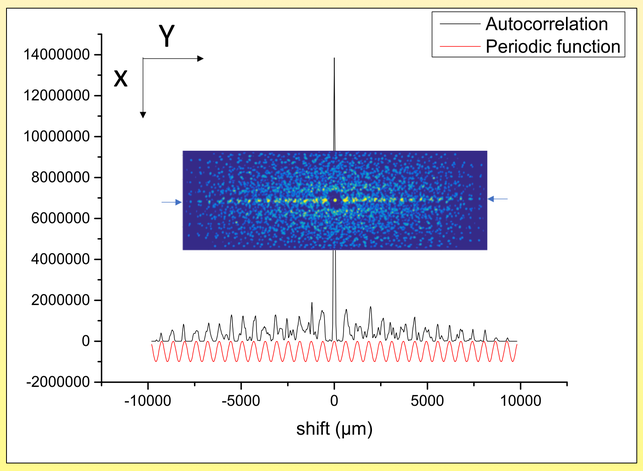
X-Ray tomography of the 3D structure of the elytron. Trabeculae connect the two cuticles.

Trabeculae:

X-Ray image of (Oxy) plane:

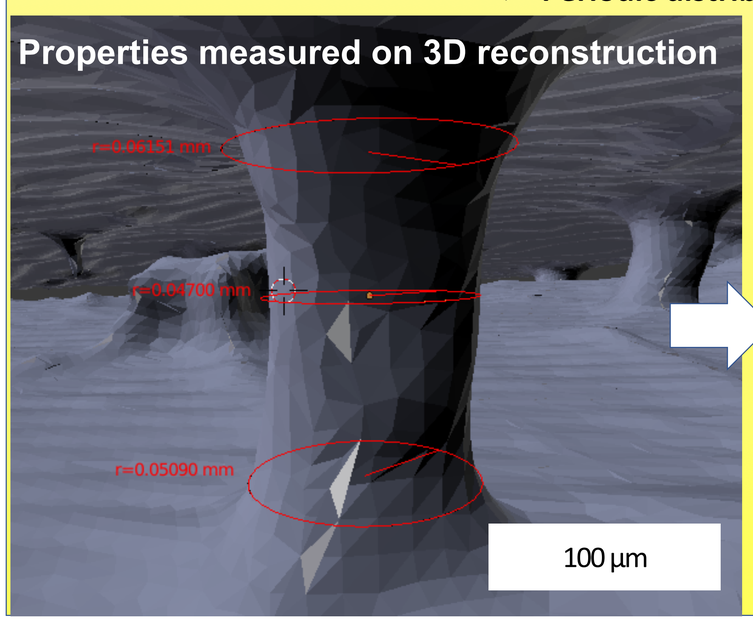


Autocorrelation function and map calculated over the rectangle ★ :



➢ **Periodic distribution of trabeculae in Y direction**

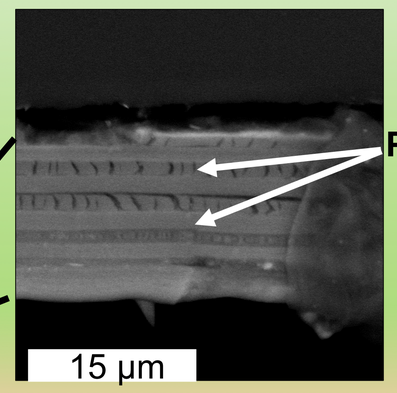
Properties measured on 3D reconstruction

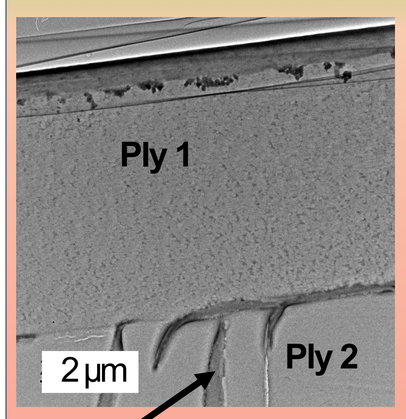


Trabeculae properties:

Radius	91±33 µm
Height	305±41 µm
Y periodicity	618 µm
Density	10,5 µm^{-2}

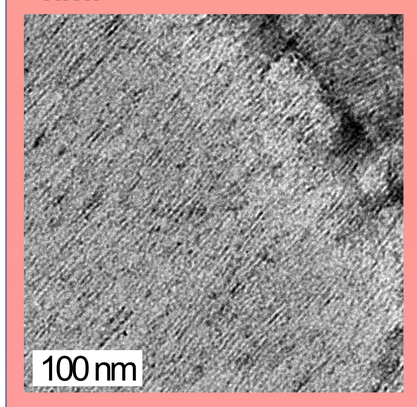
Ventral cuticle:





Pore canals visible when chitin microfibres parallel to observation plane.

In each ply, chitin microfibres are parallel. Chitin core have a width of 2.3±0.4 nm:



Laminate structure of approximately orthogonal microfibres.

Conclusion:

- For the first time: non-destructive confirmation of the known 3D structure of beetle elytra by X-ray tomography.
- Beetle elytra are sandwich structures of two laminates linked by trabeculae → trabeculae are distributed periodically in Y direction.
- *Dynastes hercules* elytra are rich structures with two types of laminates. The ventral cuticle is a laminate built from continuous plies of aligned microfibres. In the dorsal cuticle, plies are subdivided in paralleling macrofibres built from microfibres.

Bibliography:

Roux-Pertus, C., Oliviero, E., Richard, V., Fernandez, F., Maillot, F., Ferry, O., Fleutot, S., Mano, J.F., Cleymand, F., n.d. Multiscale characterization of the hierarchical structure of Dynastes hercules elytra. Micron. doi:10.1016/j.micron.2017.05.001

Aknowledgements:

FC and JFM would like to thank Region Lorraine, FEDER and Mines Nancy for financial support. CR acknowledges the DGA for financial support through PhD grant.