ADVANCING ECO-Friendly Photonic Nanostructures

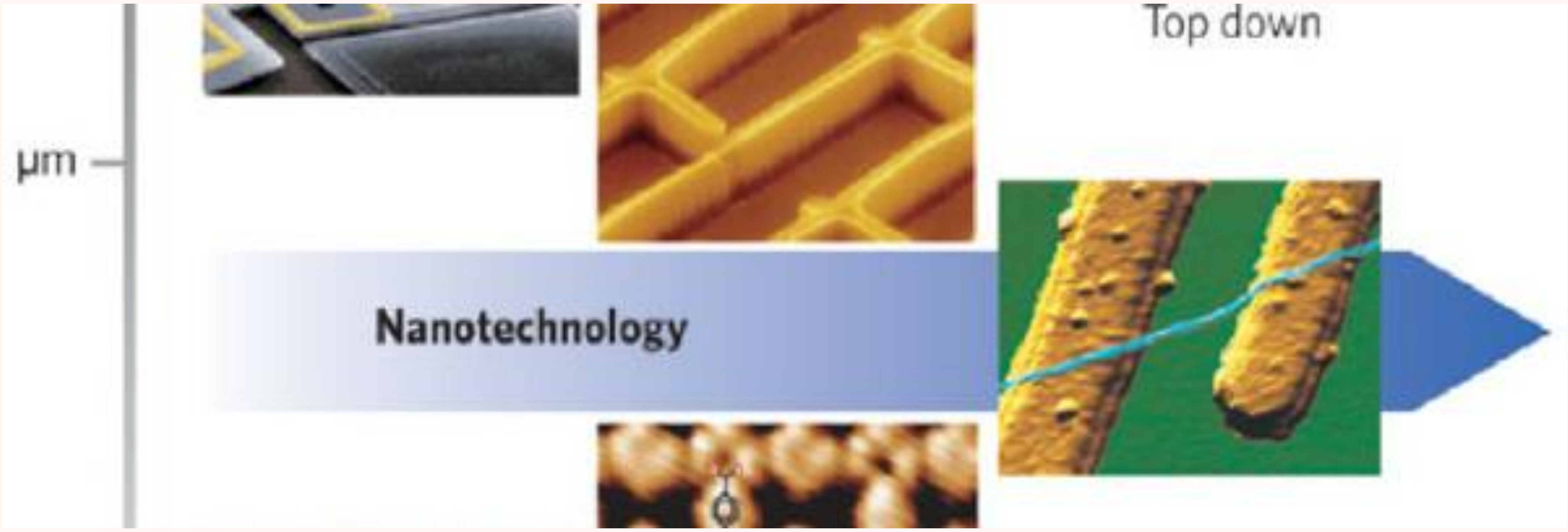
Where physics meets synthetic biology

NANOPHOTONICS

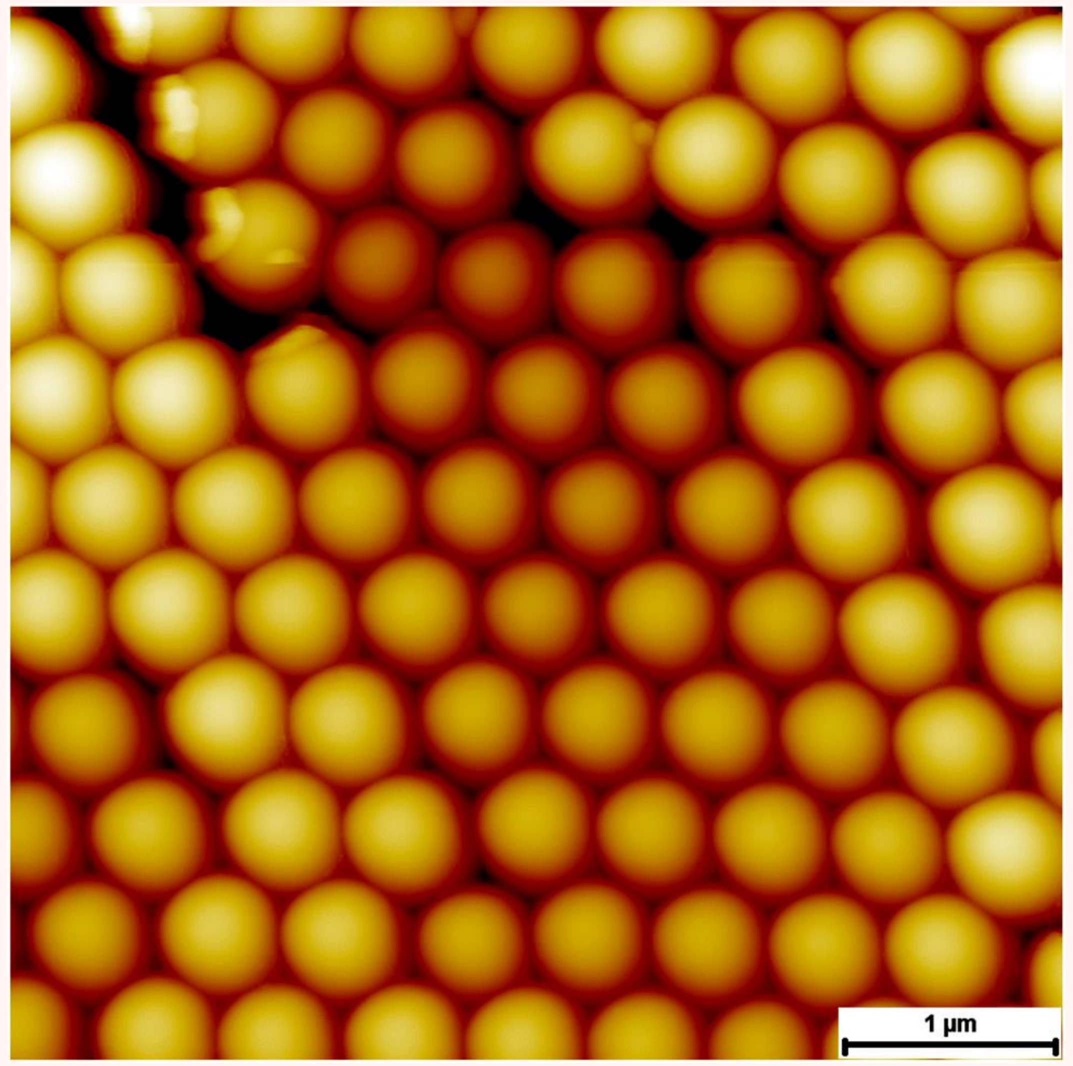
Branko Kolaric, RMA, 15.102024

BRUSSELS

CURRENT LIMITATIONS

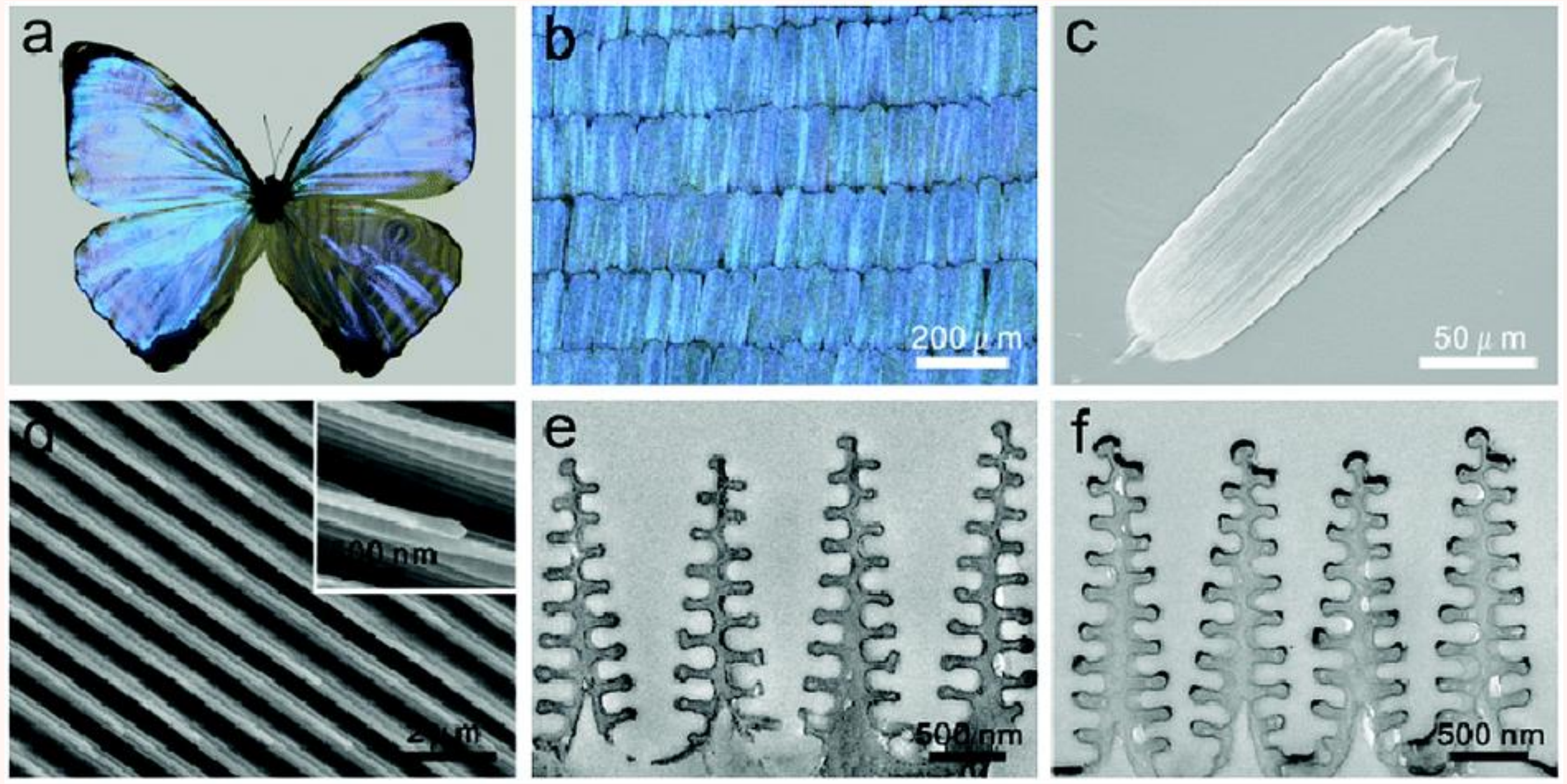


TOP DOWN



BOTTOM UP

How we can overcome current limitations



MORPHO PHOTONICS STRUCTURES

MOYA

THE NEW KEY WORD IS SYNTHETIC BIOLOGY

Harnessing the power of NATURE exploiting synthetic biology

CURRENT STATE

- Lack of understanding of developmental control in natural systems;
- Unknown genetic and regulatory mechanisms;
- Non environmentally friendly fabrication methods;
- High cost of manufacturing;
- Low tolerance to imperfections and defects;

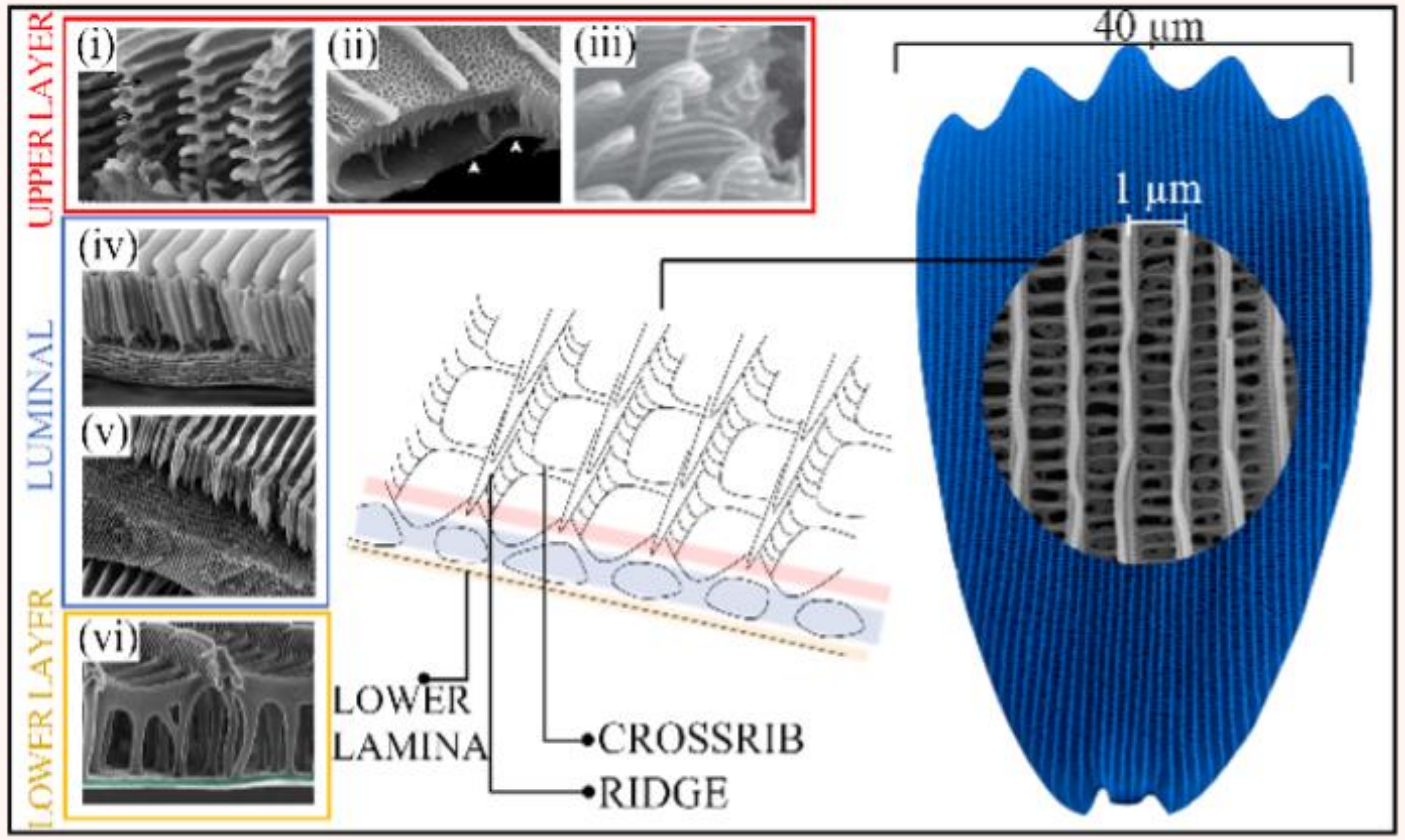
GAP

ACTION PLAN

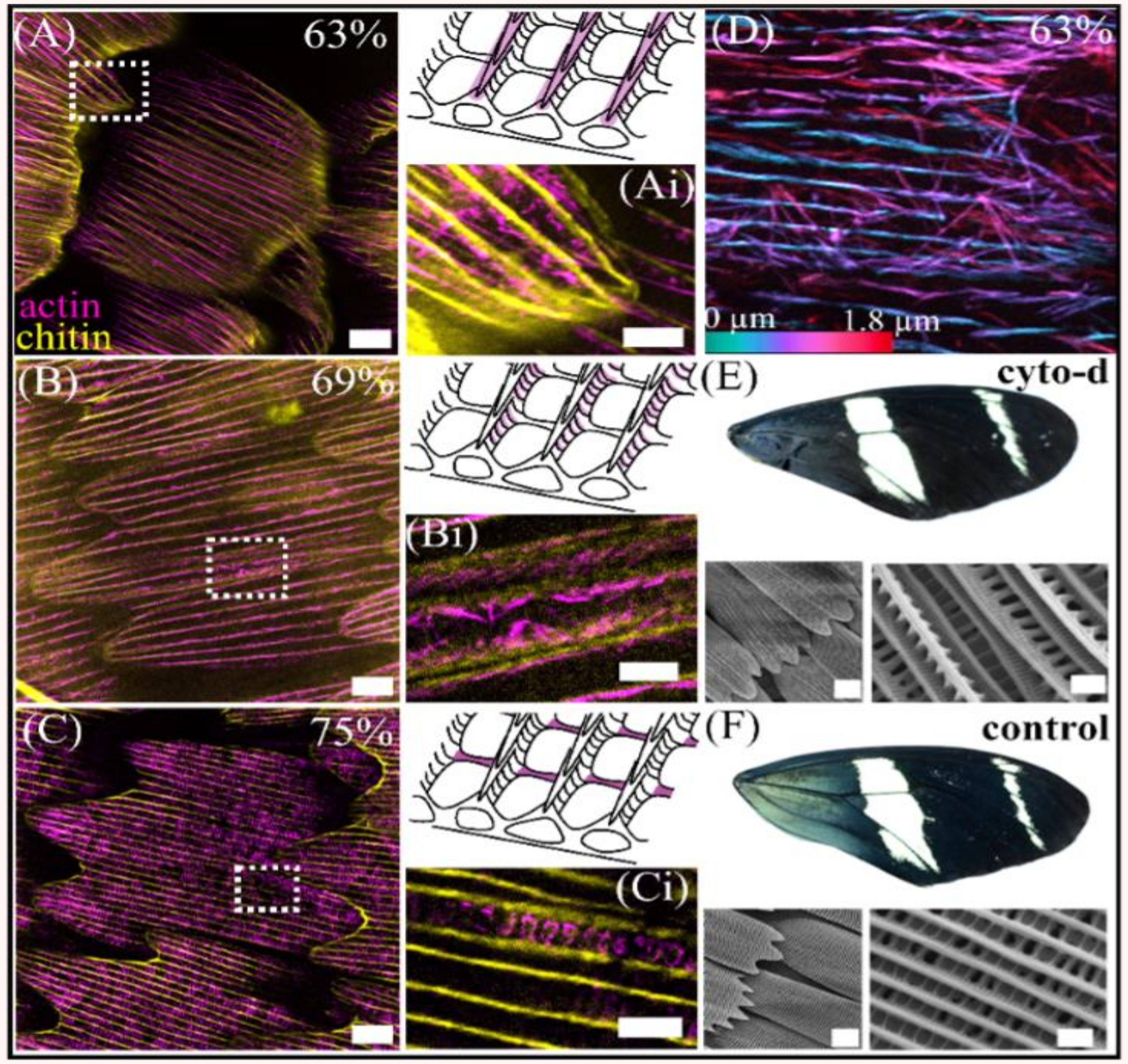
- Fundamental synergetic research in physics, genetics, and synthetic biology;
- Exploiting biology to design and shape photonic structures;
- Exploiting advanced physical methods (NLO, Fluorescence spectroscopy and microscopy SEM) to reveal morphogenesis at the nanoscale using natural photonic structures to tailor nanoscale plasmonic architecture on command and shape their properties;

TARGETED STATE

- ✓ Understanding of developmental control in natural systems;
- ✓ Identified genetic and regulatory mechanisms;
- ✓ Fabrication of photonic nanostructures by genetically controlled organisms;
- ✓ Green technology;
- ✓ Low cost;
- ✓ Fault tolerance;



Nanostructures in butterfly scales. SEM image of a *Heliconius* sp. butterfly scale (**right**). Enlarged section shows the parallel cuticle ridges as well as the cross ribs, perpendicular to the ridges. These structures form part of a basic scale 'ground plan' (**centre**). Morphologically diverse nanostructures in butterflies (**i – vi**) have evolved through modification of the basic scale ground plan. From Lloyd and Nadeau, Curr. Opin. Genet. Dev., 2021, 69, 28



The actin cytoskeleton controls the development of butterfly scale structures. Scale bars A-C, 5 µm; Ai-Ci, 2 µm; E, F, scales, 15 µm, ridges 1 µm.

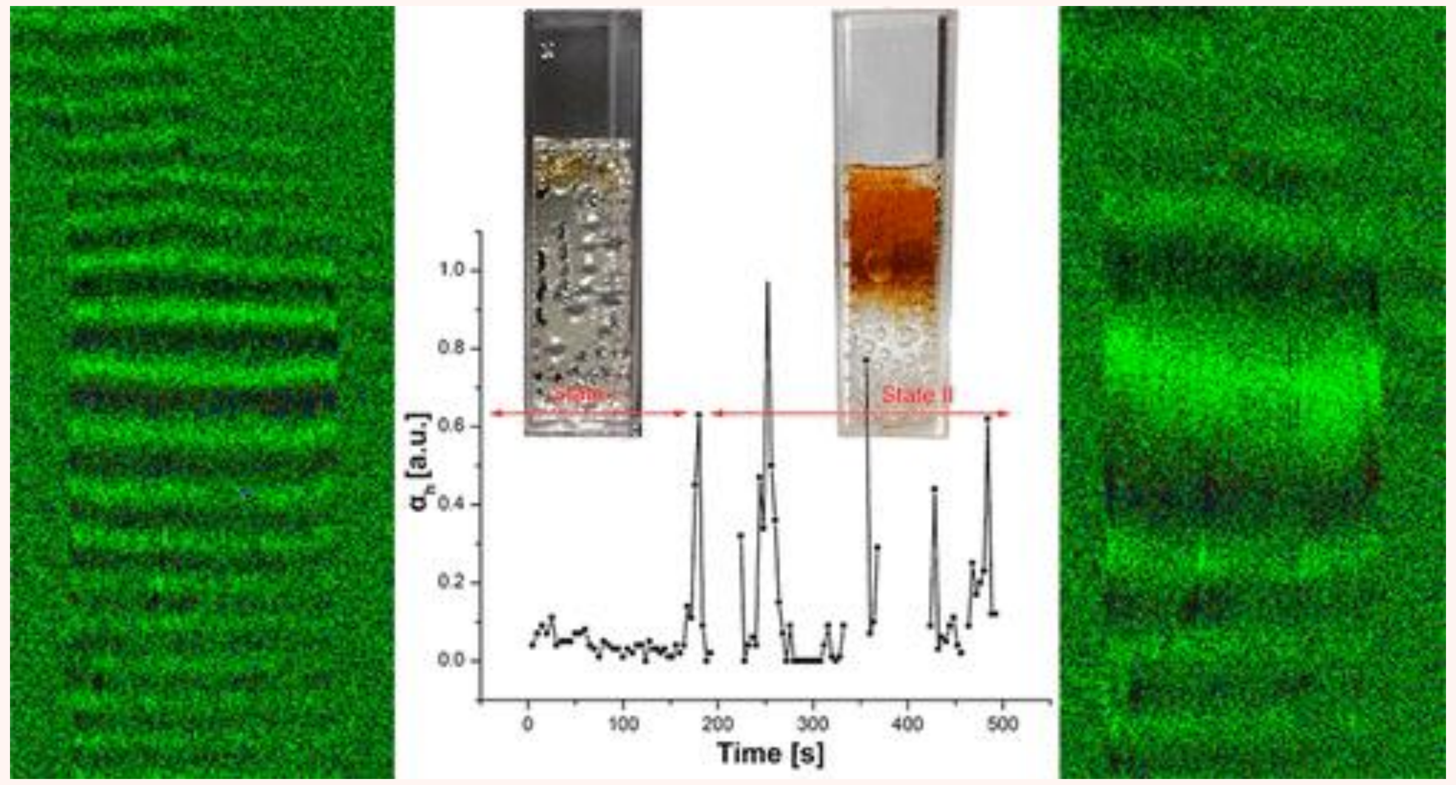
HOW TO REACH NATURE COMPLEXITY?

- **Improved** artificial enzymes can be obtained (enzyme engineering) to produce chemical compounds in a sustainable way or replace existing commercially applied enzymes with better performing ones.

- **Shaping metabolic engineering** as a cornerstone of synthetic biology, involving the manipulation of cellular metabolic pathways to enhance the production of desired compounds. As an illustration, yeast can be engineered to produce biofuels, vitamins, or even drugs by redirecting their metabolic processes.

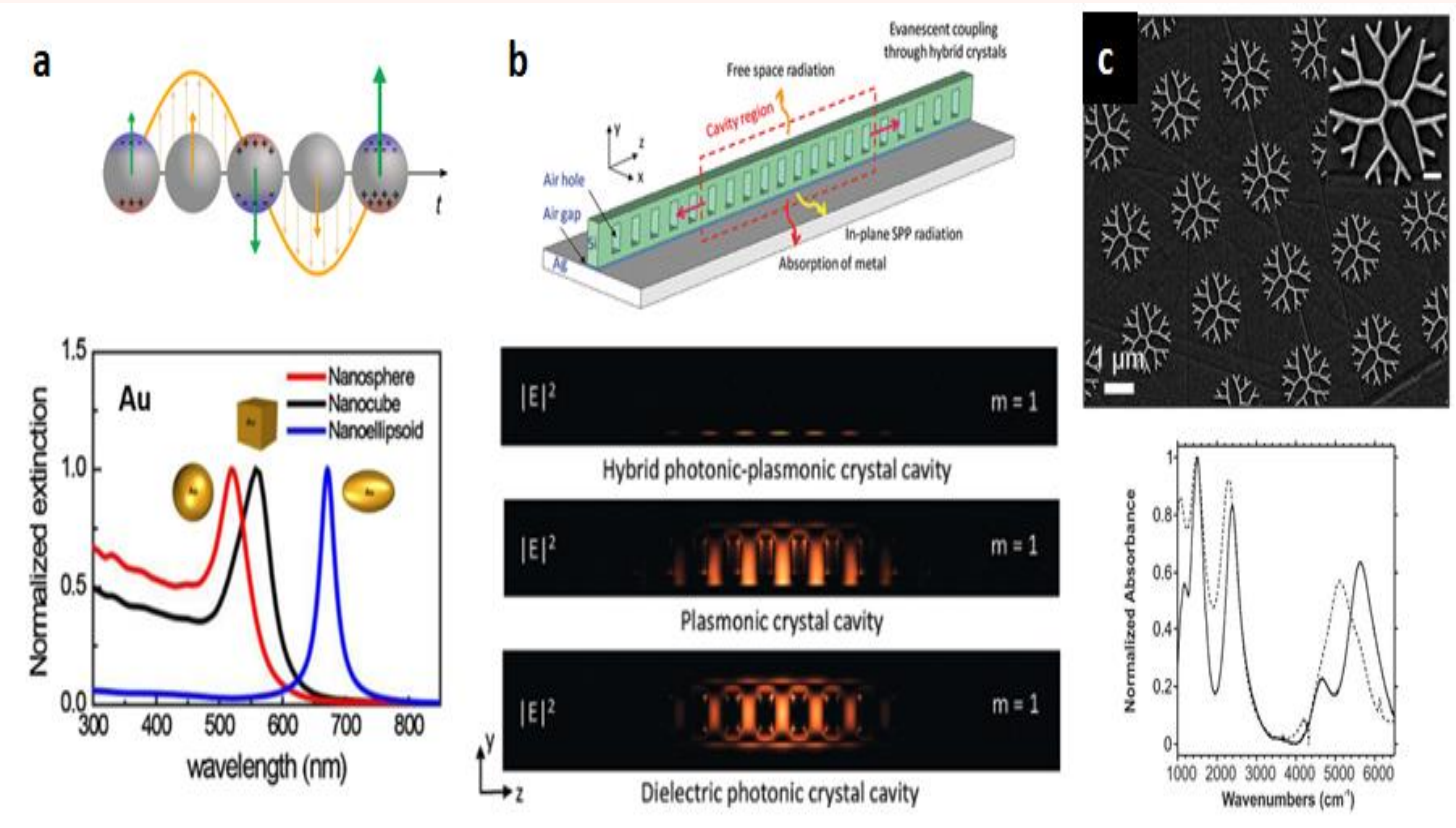
- **Synthetic gene circuits** will be designed to mimic electronic circuits, allowing for the control of gene expression in a programmable and predictable manner. This can be applied to create biological devices with specific functions. An example is the development of biosensors that respond to environmental cues, applied in environmental monitoring and healthcare diagnostics.

- Following these processes, exploiting power of
  - **Nonlinear optics**
  - **Fluorescence (linear and nonlinear)**
  - **Holography**



BEYOND NATURE COMPLEXITY

- Designing **metamaterials** combining complex natural patent with plasmonics.



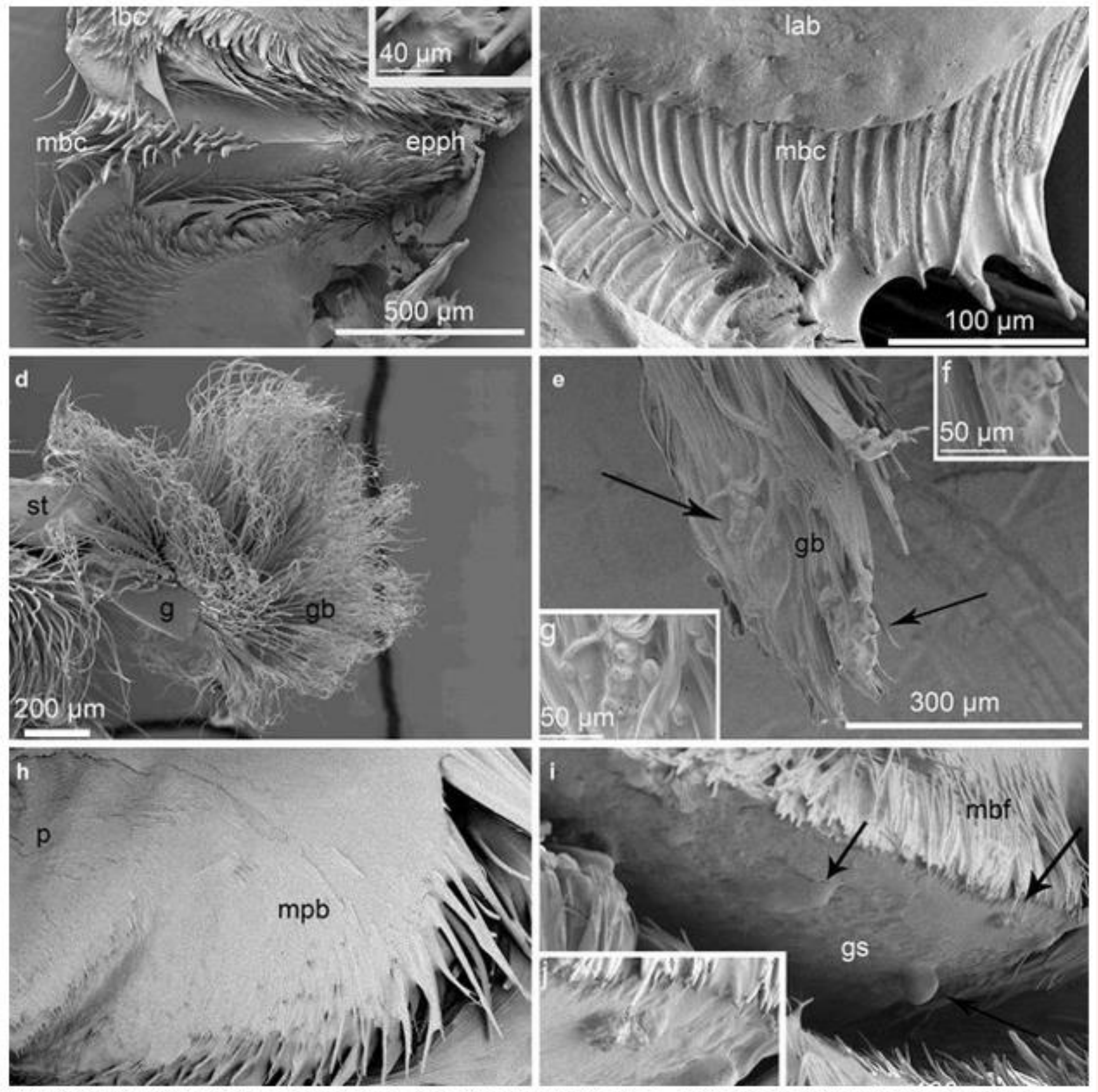
IMPORTANCE OF THE PROPOSED STUDY

- Controlling matter we shape physical response
  - By atomic structure
  - By **geometry** →
  - By **topology** →

Extreme case **NEGATIVE HEAT CAPACITY** (Cp)

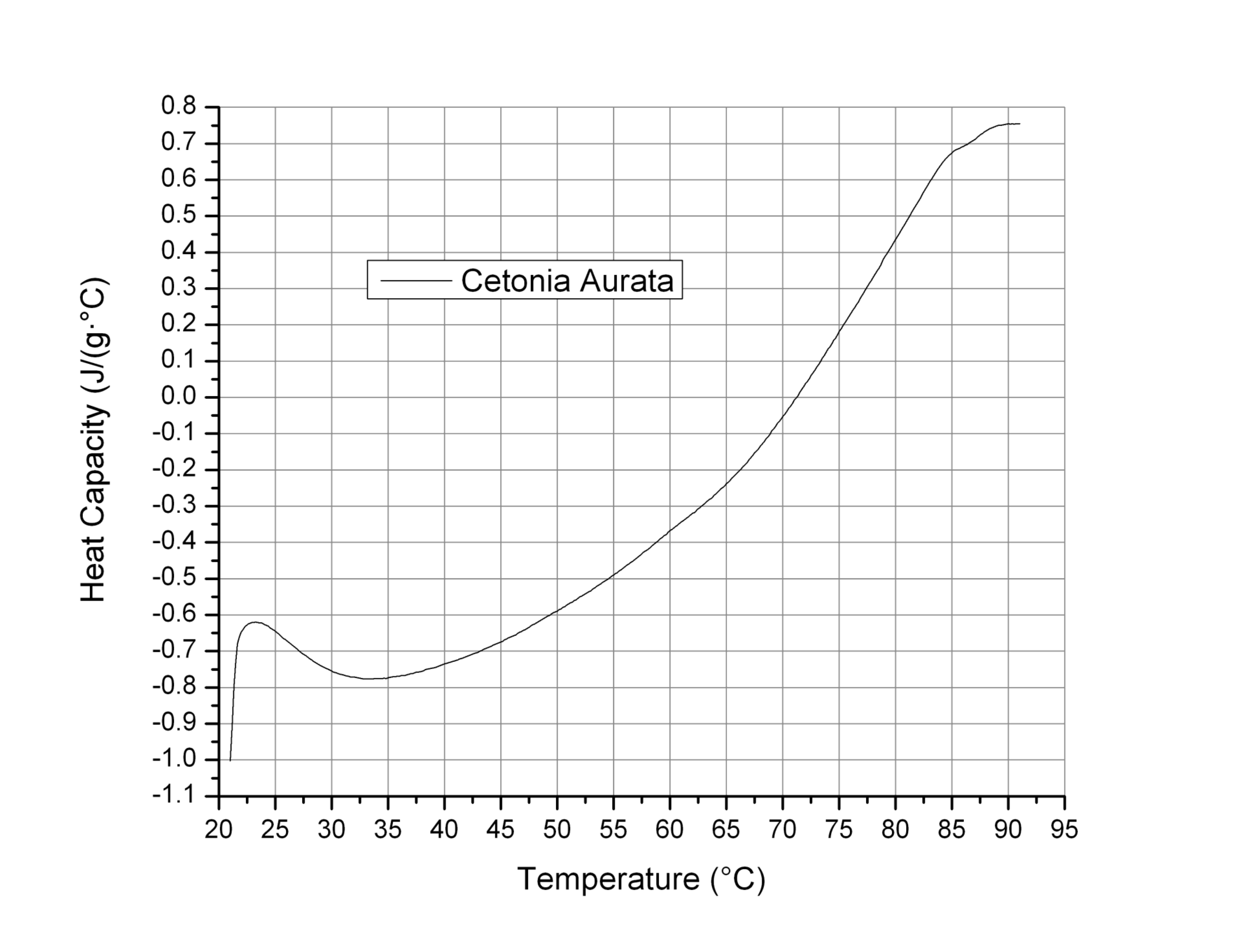
- Geometry connects **NANOPHYSICS** with **PHYSICS OF BLACK HOLES**

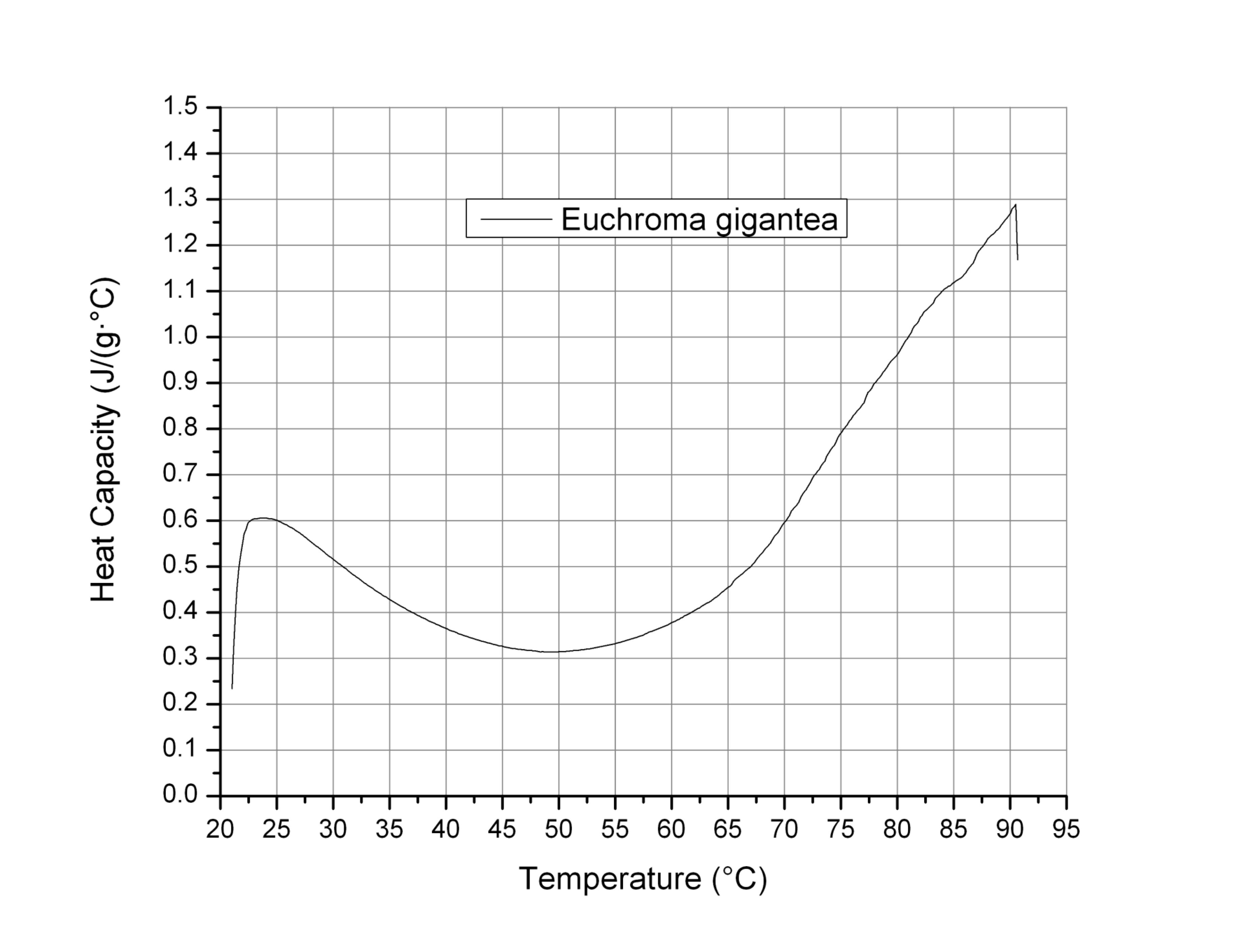
PRELIMINARY STUDY



Mouthparts of Cetonia aurata: Cryo-SEM micrographs (a-c, e-j) and SEM micrographs (d). a Ventral view of labrum with lateral bristle crests, median bristle crest and epipharynx. All bristles are covered with a fluid layer. b Detail of median bristle crest with pollen grains embedded in liquid layer (arrows). c Labium: dorsal view of moist median bristle crest covering the median depression. d Maxilla: wavy bristles of the galea forming a fan-like structure. e Galea tip, bristles forming a wet brush. Multiple pollen grains adhere to the liquid layer (arrows). f, g Pollen grains adhering to the moist galea

Pollen grains adhere to the moist mouthparts in the flower visiting beetle Cetonia aurata (Scarabaeidae, Coleoptera).March 2008 Arthropod-Plant Interactions 3(1):1-8
DOI:10.1007/s11829-008-9052-5





Applications: energy materials, batteries, passive cooling and much more…

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ARTEMIS