

BIO-INSPIRED MATERIALS & TECHNOLOGIES:

A pathway towards sustainability

10-14 November 2025, 9:00-11:00, aula MS1 DICAr



Aim of the course: Equip students with the ability to analyze, model, and design systems and technologies inspired by biological structures and processes, with a focus on sustainable innovation.

Course structure: The course will be divided in two phases: 1) 4 hours of frontal lectures and 6 hours of lab/group activities. At the end, there will be a return phase (exam) in which the students will present their projects. The date of this return phase will be decided together with the students.

Frontal lectures (4 hours):

1. *Bio-Inspired Design and its Practices: Making Innovation Sustainable (1 hr QA included)*
This introductory lecture will cover the fundamental principles of bio-inspired design: why we learn from nature, and how to approach biological systems without falling into common misconceptions. We will explore best practices, frequent pitfalls, and conclude with an overview of key biological materials such as silk, nacre, bone, collagen, and wood.
2. *Bio-inspired Adhesion Phenomena (1 hr QA included)*
This lecture will begin by introducing the fundamental concepts of adhesion, with a focus on the key challenges faced in designing effective adhesives: the development of reversible adhesives and those capable of functioning in wet environments. It will then examine how nature has addressed these challenges, exploring examples such as the adhesion mechanisms of octopus suckers and gecko-inspired systems. Finally, the lecture will present real-world devices that have been developed based on these natural adhesion strategies.
3. *Bio-inspired Textiles and fibrous materials (1 hr QA included)*
This lecture addresses the global challenge of developing high-performance fibers through environmentally sustainable approaches. Silk will be presented as a prime example, offering a viable and renewable alternative to synthetic, petroleum-based materials. The lecture will then review the current state-of-the-art systems and protocols for spinning artificial silk fibers, highlighting the key challenges that remain to be overcome.
4. *Structural hydrophobicity and wettability (1 hr QA included)*
This lecture will explore the challenge of engineering surfaces with tunable wettability. Superhydrophobic surfaces are essential, e.g., for applications such as anti-freezing and self-cleaning, while super hydrophilic surfaces are critical, e.g., in fields like biomedicine, where enhanced biocompatibility is required. Nature offers elegant solutions to both extremes: the lotus leaf exemplifies super hydrophobicity, while carnivorous plants of the genus *Nepenthes* have evolved super hydrophilic surfaces. The lecture will conclude by examining real-world applications and bioinspired surfaces developed based on these natural models.

Lab activities (6 hours):

The lab activities will begin with an introduction to the department's facilities, including available equipment and computational resources.

Students will then be invited to independently select a specific technological challenge that could be addressed by drawing inspiration from a natural process or material. Based on their chosen problem, they will develop a mini-project aimed at proposing an evidence-based solution.

This evidence may be obtained through experimental, numerical, or analytical work conducted using the department's laboratory infrastructure. For experimental activities, students may be organized into small groups as needed.

Modality of exam:

Each student will develop and present a case study of their choice: a bio-inspired prototype or material concept, integrating principles learned during the course. To support this activity, if needed, the student will be granted access to the lab and supervised.

Student duty:

Students are expected to attend the lectures and develop their own project idea. It is recommended that they identify a potential technological challenge in advance and explore possible bio-inspired solutions. During the practical sessions, the course organizer will assist students in refining their ideas and arguments. When applicable, students are also encouraged to choose a challenge that aligns with their own research interests.

Independent study and/or experimental work may be required to support their project.

Target audience: PhD students of any scientific or technological area.

Max participants: 20.

Program:**10th November Room MS1 DICAr**

9:00 - 10:00: *Bio-Inspired Design and its Practices: Making Innovation Sustainable*

10:00 - 11:00: *Bio-inspired Textiles and fibrous materials*

11th November Room MS1 DICAr

9:00 - 10:00: *Bio-inspired Adhesion Phenomena*

10:00 - 11:00: *Lab activities on student projects*

12th November Room MS1 DICAr

9:00 - 10:00: *Structural hydrophobicity and wettability*

10:00 - 11:00: *Lab activities on student projects*

13th November Room MS1 DICAr

9:00 - 11:00: *Lab activities on student projects*

14th November Room MS1 DICAr

9:00 - 11:00: *Lab activities on student projects*

Date to be decided: Return phase (students presentations)

Course organizer:



Gabriele Greco received his bachelor and master degree in physics from the University of Ferrara and his Ph.D. in mechanical engineering from the University of Trento. He is currently a post-doctoral researcher at the University of Pavia and his research interests focus on the mechanics of biological materials such as pericardium, spider silk, and artificial silk structures. His passion for spiders led him to co-found the Italian Society of Arachnology - Aracnofilia, in which he serves as vice president.

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