UAB
Universitat Autònoma de Barcelona

Nature-Inspired Functional Nanomaterials

Code: 45746
Credits: 3

2026/2027

Degree programme	Type	Course
Applied Nanoscience: From Materials to Devices	OP	1

Contact lecturer

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Teaching staff (external to UAB)

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Group languages

You can consult this information at the end of the document.

Prerequisites

Students should have knowledge in natural sciences, engineering, or related, including basic knowledge of chemistry and biology. Familiarity with fundamental concepts of materials science or nanotechnology is recommended but not essential. A working knowledge of scientific English sufficient for reading primary literature, attending lectures and preparing oral presentations is required.

Objectives

Nature has developed, over billions of years, highly efficient functional materials with properties that far exceed those achievable by conventional engineering approaches. This course aims to bridge the gap between biological inspiration and the rational design of advanced nanomaterials with optical, structural and biomedical functionalities, among others.

The course pursues the following objectives:

1. Introduce students to the principles of bioinspired and biomimetic material design, from hierarchical structural organisation to surface chemistry and optical response.
2. Provide a conceptual and practical framework for translating natural structural strategies into functional nanomaterials, coatings and scaffolds.
3. Develop the student's ability to critically assess the scientific literature and identify opportunities for innovation at the interface between biology and materials science.

4. Foster interdisciplinary thinking by connecting optical physics (photonic and plasmonic phenomena), surface chemistry (adhesive and functional coatings) and biomedical engineering (scaffold design and tissue regeneration).

Learning outcomes

- CA32 (Create photonic and plasmonic structures.) Create photonic and plasmonic structures.
- CA33 (Design new nanomaterial coatings by observing nature.) Design new nanomaterial coatings by observing nature.
- CA34 (Propose formulations of functional scaffolds compatible with the environment and sustainability.) Propose formulations of functional scaffolds compatible with the environment and sustainability.
- KA33 (Identify the different interactions that materials can have with light.) Identify the different interactions that materials can have with light.
- KA34 (List the different applications of biomedical scaffolding.) List the different applications of biomedical scaffolding.
- KA35 (Relate types of materials with different optical, biomedical and structural functionalities.) Relate types of materials with different optical, biomedical and structural functionalities.
- SA40 (Determine the components necessary for the preparation of biomedical scaffolds.) Determine the components necessary for the preparation of biomedical scaffolds.
- SA41 (Identify the characteristics that give a nanomaterial its ability to be used as an adhesive coating.) Identify the characteristics that give a nanomaterial its ability to be used as an adhesive coating.

Contents

Block 1 - Nature as a design principle

Introduction to bioinspiration and biomimicry. Hierarchical organisation in biological materials: from molecular to macroscopic scale. Key examples: nacre, bone, lotus leaf, spider silk, mussel adhesive proteins. Levels of structural complexity and their functional consequences. Design rules derived from nature: multifunctionality, self-assembly, ambient-condition fabrication.

Block 2 - Light-matter interactions and optical nanomaterials

Fundamentals of light-matter interaction: absorption, scattering, reflection, fluorescence and plasmon resonance. Structural colour in nature (Morpho butterfly, peacock feather, Pollia condensata): photonic crystals and interference phenomena. Plasmonic nanostructures: localised surface plasmon resonance, applications in sensing and imaging. Melanin-inspired materials: broadband absorption, free-radical scavenging, ionic-electronic conduction. Bioinspired photonic and plasmonic device design.

Block 3 - Bioinspired adhesive and functional coatings

Surface chemistry in nature: mussel adhesive proteins, DOPA and catechol chemistry. Polydopamine: synthesis, structure, post-functionalisation, universality of deposition. Wettability and anti-fouling: lotus effect, superhydrophobic and superhydrophilic surfaces. Bioinspired coatings and free-standing films for biomedical applications: antimicrobial, tissue regeneration, implant functionalisation.

Block 4 - Functional scaffolds for biomedical applications (and others)

Definition and requirements of biomedical scaffolds: biocompatibility, biodegradability, mechanical compliance, porosity, surface chemistry. Bioinspired scaffold materials: collagen-hydroxyapatite composites, silk fibroin, chitosan, etc. Fabrication strategies: electrospinning, freeze-drying, 3D bioprinting, self-assembly. Drug delivery and local release from scaffolds. Sustainability and green chemistry considerations on the desing. Regulatory and translational aspects: from laboratory to clinical application. Further applications in other areas (energy, materials science, etc.)

Learning activities and methodology

Title	Hours	ECTS	Learning outcomes
Preparation of group presentation	22	0.88	CA32, CA33, CA34, SA40, SA41
Case-study seminars	5	0.2	CA32, CA33, CA34, SA40, SA41
Tutorials and group project follow-up	10	0.4	CA33, CA34, SA40, SA41
Study and literature review	18	0.72	KA33, KA34, KA35
Theoretical Lectures	14	0.56	CA32, CA33, CA34, KA33, KA34, KA35

The course combines structured lectures covering the theoretical and applied foundations of each content block with case-study seminars in which real scientific papers are discussed and critically evaluated.

A central component of the methodology is the group project activity: students, individually or in groups of 2-3, are assigned a concept or system drawn from nature. Starting from that biological reference, students must develop a presentation addressing: (i) why the natural system is of interest and which specific properties make it remarkable; (ii) how those properties can be translated into the design of a new functional nanomaterial and (iii) which specific biomedical, environmental or other applications could benefit from such a material. Assignments are presented orally to the whole group and are subject to questions from the instructor and peers.

Supervised hours include follow-up tutorials for the group project.

Annotation: within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continuous assessment activities

Title	Weight	Hours	ECTS	Learning outcomes
Oral defense of projects	30%	3	0.12	CA32, CA33, CA34, SA40, SA41
Individual written assignment	25%	1	0.04	KA33, KA34, KA35
Exam	45%	2	0.08	CA32, CA33, CA34, KA33, KA34, KA35, SA40, SA41

Individual written assignment (25%): Each student individually submits a short written proposal selecting a natural system or biological strategy, which may be related to, but distinct from, the group project topic, and outlining a preliminary strategy for translating it into a functional nanomaterial. The proposal must identify: the target property or function, the proposed translation strategy from biological principle to material design, and at least one plausible application. Evaluation criteria include clarity of the biological rationale, scientific soundness of the proposed translation strategy, and appropriate use and citation of the scientific literature. This assignment must be submitted individually, even for students working in groups for the oral defense.

Oral defense (30%): Each student or group presents their nature-inspired material design project. Evaluation criteria include: accuracy and depth of the biological analysis, quality and feasibility of the proposed material design, specificity and realism of the proposed applications, and ability to defend the work under questioning. Presentations must be delivered in English.

Exam (45%): A written exam covering the theoretical content of all four blocks. The exam consists of a multiple-choice section testing fundamental concepts and knowledge across all blocks, combined with one or two open-ended questions requiring the student to analyse a short scientific text or propose a bioinspired material strategy for a given functional target.

Bibliography

Basic:

- Wegst U.G.K., Bai H., Saiz E., Tomsia A.P., Ritchie R.O. Bioinspired structural materials. *Nature Materials* 14 (2015) 23-36.
- Lee H., Dellatore S.M., Miller W.M., Messersmith P.B. Mussel-inspired surface chemistry for multifunctional coatings. *Science* 318 (2007) 426-430.
- Aizenberg J., Fratzl P. Biological and biomimetic materials. *Advanced Materials* 21 (2009) 387-388.
- d'Ischia M. et al. Polydopamine and eumelanin: from structure-property relationships to a unified tailoring strategy. *Accounts of Chemical Research* 47 (2014) 3541-3550.
- Langer R., Vacanti J.P. Tissue Engineering. *Science* 260 (1993) 920-926.

Complementary:

- Bhushan B. (Ed.). *Biomimetics: Nature-Based Innovation*. CRC Press, 2012.
- Ratner B.D., Hoffman A.S., Schoen F.J., Lemons J.E. (Eds.). *Biomaterials Science: An Introduction to Materials in Medicine*. 3rd ed., Academic Press, 2012.
- Bolaños-Cardet J., Ruiz-Molina D., Yuste V.J., Suárez-García S. Bioinspired phenol-based coatings for medical fabrics against antimicrobial resistance. *Chemical Engineering Journal* 481 (2024) 148674.
- Maroli G., Rosati G., Suárez-García S. et al. Wearable, battery-free, wireless multiplexed printed sensors for heat-stroke prevention with mussel-inspired bio-adhesive membranes. *Biosensors and Bioelectronics* 260 (2024) 116421.
- Wong T.-S. et al. Bioinspired self-repairing slippery surfaces with pressure-stable omniphobicity. *Nature* 477 (2011) 443-447.

Software

No specific software is required. Students are expected to use standard office and presentation tools for the group project. Access to scientific literature databases (Web of Science, Scopus, PubMed) through the UAB library is essential.

Course groups and languages

The information provided is provisional until November 30. After this date, you will be able to consult the language of each group through this link. To access the information, you will need to enter the course

CODE

Type of teaching	Group	Language	Semester	Shift
(TEm) Theory (master)	1	English	first semester	afternoon