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Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

DESK Developing Shared Knowledge

SIMHA

Smart Innovative Materials for Health Applications

International Training School
25–26 May 2026 • BARI

SMART LIPOSOMES & NANOVACCINES

BIO-BASED & LIVING MATERIALS

CARBON DOTS FOR BIOMEDICINE

SYNTHETIC CELLS & PROTOTISSUES

LIGHT-RESPONSIVE DRUG DELIVERY

BIOMEDICAL APPLICATIONS

PROTON ACCELERATOR

Villa La Rocca,
Via Celso Ulpiani 27, Bari

SIGILLUM UNIVERSITATIS BARENSIS MCMXXV

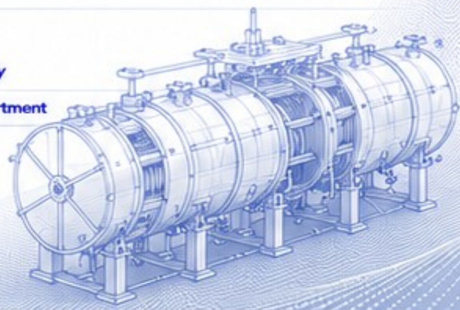
PROGRAMME

DAY 1 Monday, 25 May 2026

09:00 – 09:30	Welcome coffee and registration
09:30 – 10:30	Materials from living organisms and living organisms as materials: possibilities and challenges in biomedicine *Gianluca Maria Farinola, University of Bari, Italy*
10:30 – 11:00	Coffee break
11:00 – 12:00	Engineering Bioactive Multifunctional Hydrogels for Cell Therapy Applications. *Ângela Maria Moraes, University of Campina, Brazil*
12:00 – 13:00	Flexible Sensing: Leveraging Natural Polymer Eutectogels for Motion Monitoring *Guillermo J. Copello, University of Buenos Aires, Argentina*
13:00 – 14:30	Light lunch
14:30 – 15:30	Tailoring Immunity: "SMART" Liposomes as NanoVaccines for Precision Disease Prevention *Michele Fiore, University of Lyon 1, France*
15:30 – 16:30	Novel peptide-based nanomaterials applied for vaccines, antivenom and diagnostic kits development *Silvia Andrea Camperi, University of Buenos Aires, Argentina*
16:30 – 17:00	Coffee break
17:00 – 18:00	Light-responsive synthetic cells as smart drug delivery platform *Paola Albanese, University of Siena, Italy*
18:00 – 18:30	General discussion

DAY 2 Tuesday, 26 May 2026

09:00 – 09:30	Welcome and introduction to Day 2
09:30 – 10:30	Engineering Smart Carbon Dots for Advanced Biomedical Applications *Nicolò Mauro, University of Palermo, Italy*
10:30 – 11:00	Coffee break
11:00 – 12:00	Functional Colloidal Nanoparticles for Emerging Health and Biomedical Applications *Elisabetta Fanizza, University of Bari, Italy*
12:00 – 13:00	Plasma Technology for Surface Modification Processes on Biomedical Materials *Pietro Favia, University of Bari, Italy*
13:00 – 14:15	Light lunch
14:15 – 15:00	Transfer to Ruvo di Puglia
15:00 – 15:30	Welcome and institutional greetings by the ITEL Group
15:30 – 16:15	Visit to LinearBeam – Proton Therapy Department. Introduction to the ERHA project – Enhanced Radiotherapy with Hadrons and to the proton linear accelerator
16:15 – 16:30	Coffee Break
16:30 – 17:00	Radiopharmaceuticals for Diagnosis and Therapy: Current Applications and Future Perspectives *Anna Tolomeo, Itelpharma S.r.l., Ruvo di Puglia, Italy*
17:00 – 18:00	Visit to Radiopharmaceuticals and Microbiology Department
18:00 – 18:30	Final discussion and closing remarks



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International Training School funded by the DESK project

Smart Innovative Materials for Health Applications

SIMHA

25-26 May 2026 – University of Bari Aldo Moro
Villa La Rocca, Via Celso Ulpiani 27, Bari Italy

Book of Abstract

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Introduction

The International Training School "Smart Innovative Materials for Health Applications" (SIMHA), funded by the DESK project, will bring together researchers, lecturers and early-career scientists working at the interface of chemistry, materials science, nanotechnology, bioengineering and biomedicine. The school will provide an interdisciplinary overview of how smart materials can be designed, functionalized and translated into health-related applications.

The scientific program will address a broad continuum of topics: bio-based and living materials obtained from organisms and microorganisms; bioactive hydrogels, bioinks and cell-laden constructs for regenerative medicine; natural-polymer eutectogels for flexible sensing and motion monitoring; supramolecular liposomes and glycan-centered nanovaccines; peptide-based nanomaterials for vaccines, antivenoms and diagnostic kits; light-responsive synthetic cells for controlled drug delivery; carbon dots and colloidal nanoparticles for imaging, theranostics and precision medicine; and plasma technologies for surface modification of biomedical materials.

A distinctive feature of the school will be the visit planned on the afternoon of the second day to the ITEL facilities in Ruvo di Puglia. The visit will include the LinearBeam Proton Therapy Department, an introduction to the ERHA project – Enhanced Radiotherapy with Hadrons and to the proton linear accelerator, as well as a lecture and technical visit focused on radiopharmaceuticals and the Itelpharma radiopharmaceutical and microbiology facilities.

The acronym SIMHA, drawn from Smart Innovative Materials for Health Applications, also recalls the Sanskrit word *siṃha*, meaning *lion*, a symbol of strength, courage and leadership. This image reflects the ambition of the school to foster an international community of researchers able to address health challenges through innovative materials and interdisciplinary approaches.

Materials from living organisms and living organisms as materials: possibilities and challenges in biomedicine

Gianluca Maria Farinola

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Several living organisms can be seen as a plentiful source of micro/nanostructures, polymers, and molecules suitable for use as materials for biomedical applications. In many cases, the organisms themselves can be engineered or exploited as functional materials for specific technological and therapeutic purposes.
In contrast to traditional industrial processes, biosynthetic routes operate under mild conditions, often in water and at room temperature, and typically have a much lower environmental footprint. This strategy therefore offers a promising pathway toward sustainable, large-scale production of advanced nanomaterials for use in biomedicine and related fields. However, several challenges still need to be addressed to improve their biocompatibility, therapeutic safety, and long-term stability when this is necessary.
In the lecture, I will present emblematic examples such as biosilica, cellulose, lignin, polydopamine, and silk fibroin, and I will discuss how microalgae and other photosynthetic microorganisms can be harnessed as renewable sources of functional materials for a broad range of biomedical applications.
Finally, the lecture will explore both the opportunities and current limitations of this bio-based approach, outlining key challenges, technological needs, and possible future directions.

Engineering bioactive multifunctional hydrogels for cell therapy applications

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In this lecture, the selection, combination, and modification of biopolymers for the development of hydrogel scaffolds using different strategies for stem cells and differentiated cells will be discussed, with the aim of expanding therapeutic alternatives in regenerative medicine.

The fundamental reasons underlying the successful use of polysaccharides and proteins for these applications will be addressed, together with formulations and techniques commonly employed in the fabrication of cylindrical biomaterials, dense and porous films, injectable thermosensitive hydrogels, and bioinks for 3D bioprinting. Particular emphasis will be placed on alginate, chitosan, carboxymethyl chitosan, xanthan gum, hyaluronic acid, methylcellulose, cellulose nanocrystals, collagen and gelatin. Techniques for scaffold production based on molding, crosslinking, lyophilization, and additive manufacturing, among others, will also be highlighted, together with strategies for the incorporation of bioactive agents aimed at simultaneous drug delivery. Finally representative advances in the development of cell-laden constructs for applications in the treatment of skin, periosteal, vascular, and cartilaginous tissue lesions will be presented.

"Flexible Sensing: Leveraging Natural Polymer Eutectogels for Motion Monitoring"

Guillermo J. Copello

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Our working group seeks the development of materials for the partial or total replacement of petroleum-derived materials using new materials derived from renewable sources. As our primary objective, we study the use of waste from the fishing, livestock, and agricultural industries to obtain materials based on natural polymers such as chitosan, chitin, keratin, pectin, and okara, among others. Given the relevance of Argentina's agro-livestock industry, the resulting waste represents interesting sources of biopolymeric material. Various chemical treatments applied to these biopolymers lead to the production of materials with interesting properties, such as flexibility and enhancement of electrical response.
Taking advantage of these properties, we have developed strain sensors for wearable technologies, obtaining materials capable of withstanding multiple deformation cycles typical of the body region being monitored, skin compatibility, and durability. At the same time, harmless voltages are used that must exhibit measurable resistance changes in response to deformation and ideally be proportional to it.

Tailoring Immunity: "SMART" Liposomes as NanoVaccines for Precision Disease Prevention

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Mucins such as MUC1, MUC4, MUC5, and MUC16 form a highly glycosylated protective interface that regulates cell adhesion and shields tissues from pathogens and environmental stress. In contrast, epithelial cancers (breast, lung, pancreas, and colon) exhibit profound dysregulation of mucin expression and glycosylation. This leads to truncated glycan structures and the pathological exposure of tumor-associated carbohydrate antigens (TACAs), which actively contribute to tumor progression, invasion, and metastatic dissemination. Early experimental vaccines using glycosylated mucin peptides have already demonstrated superior immunogenicity and specificity compared with their non-glycosylated counterparts, highlighting the transformative potential of glycan-centered immunotherapy. Although clinical adoption remains limited, emerging trials continue to confirm the promise of this approach.
An innovative supramolecular potential vaccine platform that integrates tumor-associated carbohydrate antigens and complementary T-cell epitopes in a controlled manner is a challenging result of a combination of chemistry and immunology obtained in NanOMed lab. This approach relies on assembling programmable liposomes capable of simultaneously presenting B-cell, $CD4^+$, and $CD8^+$ epitopes and adjuvants while ensuring their coordinated delivery to the immune system. The objective is to generate a synergistic humoral and cellular response that surpasses the limitations of conventional vaccination strategies.

References

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C. Chieffo, A. Comte, P. Strazewski and **M. Fiore**, *Eur. J. Org. Chem*, DOI:10.1002/ejoc.202300820
S. Mebarek, K. Jacob, C. I. Pierro, D. Romanini and M. **Fiore**, *ChemistryOpen*, DOI:10.1002/open.202500530.

Novel peptide-based nanomaterials applied for vaccines, antivenom and diagnostic kits development

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In the last years, peptide application has made a great progress thank to the optimization of their synthesis which allows obtaining purity peptides at high speed and low cost. To facilitate their pharmacological or industrial applications, peptides are formulated in nanometric structures to increase their stability, affinity, and bioactivity. In the lecture, we will talk about the design of novel peptide-based nanomaterials applied to the development of diagnostic kits, vaccines and antivenoms. We will explore how to design more economical and safer immunogens and immunoassays based on nanomaterials containing the peptides that constitute the epitopes of a target antigen. Epitope identification is facilitated by bioinformatics tools, and the resulting peptide sequences are synthesized at low cost, with high purity and yield, using solid-phase synthesis. Specifically, we will discuss the design and synthesis of immunogenic nanostructured peptides to produce antivenoms used to treat arachnid envenomation and to produce vaccines for cancer treatments. We will also discuss how to design peptide-based immunoassays as diagnostic reagents for autoimmune diseases such as coeliac disease.

Light-responsive synthetic cells as smart drug delivery platform

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Light-responsive synthetic cells are emerging as powerful platforms for the controlled delivery of therapeutic agents, enabling precise spatiotemporal regulation through external optical inputs. Here, we engineer synthetic cells based on giant unilamellar vesicles (GUVs) incorporating photoswitchable membrane components to dynamically regulate membrane permeability and stability [1-3]. Light responsiveness is introduced by doping the lipid bilayer, composed of POPC and cholesterol, with azobenzene-containing amphiphiles. These molecules undergo reversible E (trans, linear) to Z (cis, bent) isomerization under UV irradiation, returning to the E state upon exposure to white light or thermal relaxation.

Isomerization within the membrane perturbs lipid packing and bilayer organization, leading to marked changes in vesicle morphology and transport property. At the vesicle level, this translates into tunable permeability, spanning from transient pore formation and enhanced leakage to complete vesicle disruption and cargo release. By modulating membrane composition and irradiation conditions, this behavior can be precisely controlled, enabling on-demand release with high spatiotemporal resolution [1]. Collectively, these features establish a versatile platform for light-triggered drug delivery, applicable across both micrometric GUVs [1] and nanoscale [2] liposomes.

Recently, we demonstrated the biological relevance of this approach by interfacing light-responsive synthetic cells with human mammalian cells [3]. Using adenosine triphosphate (ATP) and histamine as model signaling molecules, we showed that light activation induces rapid and tunable cargo release, which in turn elicits a measurable response in mammalian cells via calcium-mediated signaling pathways. Importantly, the synthetic cells remain functionally inert in the absence of stimulation, providing a stealth-like behavior that minimizes premature release. This approach establishes a versatile framework for the development of smart drug delivery systems capable of interfacing with living cells, with potential applications in targeted therapies, immunomodulation, and the design of adaptive bio-hybrid systems.

References

[1] P. Albanese et al. Photomodulation of vesicle dynamics using fluorescent photoswitchable amphiphiles. *Journal of Materials Chemistry B* 14 (2026) 3093.

[2] P. Albanese et al. Light-Switchable Membrane Permeability in Giant Unilamellar Vesicles. *Pharmaceutics* 14 (2022) 2777.

[3] Barbaro R., Albanese P., et al. Light-Triggered Communication Between Synthetic and Living Cells via Photoswitchable Membranes. Under submisison for *ChemBioChem* (2026).

Engineering Smart Carbon Dots for Advanced Biomedical Applications

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Advances in cancer theranostics are reshaping precision oncology by integrating diagnostic and therapeutic functionalities within single nanoscale platforms. Among emerging nanomaterials, optically active carbon nanodots (CDs) have attracted growing interest owing to their tunable photoluminescence, efficient photothermal conversion, high biocompatibility, chemical stability, and ease of surface functionalization [1]. These features make CDs versatile candidates for both the diagnosis and targeted treatment of solid tumors. In particular, the near-infrared (NIR) emission of CDs enables deep-tissue fluorescence imaging, supporting real-time tumor visualization, enhanced detection sensitivity, and improved intraoperative guidance. Recent advances in heteroatom doping and hybrid nanostructure engineering have further expanded their functionality, allowing their integration into multimodal imaging platforms, including magnetic resonance imaging (MRI), thereby improving diagnostic accuracy and spatial resolution [2]. Beyond imaging, CDs exhibit remarkable potential in light-activated therapies. Their ability to convert light into heat under irradiation enables effective photothermal therapy (PTT), while their capacity to generate reactive oxygen species (ROS) under appropriate excitation supports photodynamic therapy (PDT) [3]. These minimally invasive approaches allow selective tumor ablation with reduced systemic toxicity. Moreover, surface functionalization with targeting ligands enhances selective accumulation at tumor sites, increasing therapeutic specificity and minimizing off-target effects. CDs can also be incorporated into fluorescent nanocomposite biomaterials, enabling the development of multifunctional and traceable systems. Such nanocomposites allow non-invasive monitoring of material distribution, degradation, and interaction with biological tissues in real time, opening new opportunities in drug delivery, tissue engineering, and implantable theranostic platforms. A key advantage of CDs lies in their adaptability to precision medicine strategies. By engineering responsiveness to tumor microenvironmental cues, such as pH, redox gradients, or enzymatic activity, CDs can be tailored for selective activation and controlled therapeutic delivery. This capability supports patient stratification and enables real-time monitoring of therapeutic responses. Overall, optically active carbon nanodots represent a promising class of nanomaterials with significant potential to advance both cancer diagnosis and treatment, while also enabling the design of next-generation fluorescent, trackable biomaterials for personalized and minimally invasive biomedical applications.

References

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[2] N. Mauro, et al., Gadolinium-Doped Carbon Nanodots as Potential Anticancer Tools for Multimodal Image-Guided Photothermal Therapy and Tumor Monitoring, ACS Appl Nano Mat., vol. 6, pp. 17206-17217, 2023.

[3] H. Wang, et al., Targeted multifunctional nano-engineered carbon dots with enhanced synergistic photothermal/photodynamic performance for precision tumor therapy, J. Coll. and Interf. Sci., vol. 700, pp. 138351, 2025.

Functional Colloidal Nanoparticles for Emerging Health and Biomedical Applications

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In recent years, extraordinary advances in nanomaterials science have offered great potential for healthcare and biomedical applications, thanks to the intriguing properties emerging from nanoscale materials.
In this lecture, we will briefly describe the colloidal approaches used for the synthesis of nanoscale materials and illustrate the unique physicochemical properties of various classes of nanomaterials, including metallic and non-metallic plasmonic nanoparticles, luminescent quantum dots, nanozymes, and superparamagnetic nanoparticles, which underpin their potential as innovative therapeutic or contrast agents. Furthermore, post-synthesis modifications through surface functionalizations or the ingenious fabrication of composite structures will be presented as a crucial approach for the development of advanced materials with improved and synergistic functions in the biomedical imaging, diagnosis and therapy.

Plasma Technology for Surface Modification Processes on Biomedical Materials

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Cold plasmas, i.e., neutral ionized gases in non-equilibrium conditions, are utilized since decades for developing relevant processes and products in strategic technological areas such as lights, ozone production, microelectronics, solar cells and many others, including biomaterials [1].
Etching, thin film deposition and grafting surface-modification plasma-processes can be applied on biomedical materials such as lab wares, biosensors, scaffolds for Tissue Engineering, drug release systems and prostheses to optimize their interactions with tissues, cells, blood, biomolecules and bacteria. Hydrophobic/philic character and cell adhesion/repulsion are among the many properties that can be adjusted with plasma processes in this context.
More recently, the research on the direct use of cold plasmas on biological living tissues started to be investigated in Medicine for wound healing and cancer treatments, and in the Agro-Food for decontamination and improved germination of seeds and food decontamination. [2, 3]
In this talk some examples will be given, from the research of the author, on plasma processes for surface modification of biomaterials.

References

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2. S Bekeschus et al., White Paper on Plasma for Medicine and Hygiene: Future in Plasma Health Sciences, Plasma Proc. Polym. 16, e1800033, 2019.
3. I Trizio et al., Plasma Processes for Life Sciences, In: Reedijk, J. (Ed.) Elsevier Reference Module in Chemistry, Molecular Sciences & Chemical Engineering. Waltham, MA: Elsevier doi:10.1016/B978-0-12-409547-2.12271-1, (2018).

Radiopharmaceuticals for Diagnosis and Therapy: Current Applications and Future Perspectives

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Radiopharmaceuticals play an increasingly important role in modern medicine, offering innovative approaches for both diagnosis and targeted therapy. Their applications range from medical imaging to the treatment of several diseases, particularly in oncology, with significant impact on precision and personalized medicine.

This lecture will provide a general overview of the current use of diagnostic and therapeutic radiopharmaceuticals, highlighting recent developments, main clinical applications, and emerging trends in the field. Different approaches and technologies will be discussed, together with the challenges and opportunities related to the development of new radiopharmaceutical systems.

The presentation will also explore future perspectives, including advances in molecular imaging, targeted therapies, and innovative materials that may contribute to the evolution of nuclear medicine and healthcare applications