Module

Tutors	Philippe Guégan (Professor), Nicolas Illy (Associate Professor), Georgios Kyzas (Professor), Christina Nannou (Assistant Professor), Kalliopi Ladomenou (Assistant Professor)

- **GENERAL**

Title of Module	**Sustainable polymers for the benefit of the society**	
Autonomous Teaching Activities *in case credits are awarded separately for distinct parts e.g. Lectures, Lab Exercises, etc. Specify the total teaching hours and credits.*	**Total Teaching Hours**	**Credits Units**
	28.0 hours	2.9
Language of Tutoring and Examination:	English	

- **EDUCATIONAL OBJECTIVES**

Educational Objectives

The Educational objectives of the thematic unit/course describe the specific knowledge, skills, and abilities of an appropriate level that learners will acquire upon successful completion of the course.

The aim of the course is to enable the student to have an overview of the various strategies to use polymers for drug delivery applications. The drug selection corves small organic/natural molecules to large polynucleotides and proteins. The polymer synthesis is shortly reminded to allows the student to be able to access to the design of the drug delivery strategy. Physico-chemical properties and biological results are illustrating the way the vectors function. At the end of this course, students should be able to identify the most suitable strategies for developing vectors for drug delivery applications, and understand the originality of the suggested vectors. Scale-up issues will be discussed to get closer to industrial developments. The objective of this course is to enable students to better understand the reasons behind the widespread use of plastic materials and the resulting environmental issues (land and marine pollution, non-renewable resources, end-of-life challenges, and toxicity). Subsequently, the various end-of-life management options (mechanical or chemical recycling, energy recovery, landfill) will be discussed and reviewed. At the end of this course, students should be able to identify the most suitable strategies for developing sustainable materials based on the specific application. Upon successful completion of this lecture, students/trainees will acquire the following **knowledge, skills, and abilities**:

Upon successful completion of this lecture, students/trainees will acquire the following knowledge, skills, and abilities:

1. Knowledge Objectives
    - Fundamentals of Magnetic Nanocomposites and Molecularly Imprinted Polymers (MIPs)
        - Definition, composition, and synthesis methods
        - Key physicochemical properties influencing environmental applications
    - Mechanisms of Environmental Pollutant Removal
        - Adsorption, degradation, and catalytic properties of MNPs and MIPs
        - Selectivity and specificity in pollutant targeting
    - Current and Emerging Applications
        - Water and wastewater treatment
        - Air purification and soil remediation
        - Detection and sensing of environmental contaminants
    - Challenges and Future Trends
        - Scalability, reusability, and environmental safety considerations
        - Innovations in hybrid materials and smart nanocomposites
2. Skill Objectives
    - Analytical and Critical Thinking

- Evaluate the advantages and limitations of MNPs and MIPs in environmental applications
- Compare different synthesis and functionalization techniques

- Problem-Solving and Application
  - Identify appropriate nanocomposite and polymer technologies for specific environmental problems
  - Propose potential improvements in design and efficiency

3. Abilities Objectives

- Scientific Communication and interdisciplinary Integration
  - Interpret and discuss research findings related to MNPs and MIPs
  - Connect principles from chemistry, materials science, and environmental engineering
  - Assess the role of nanotechnology in sustainable environmental management

By the end of the lecture, learners will have a solid foundational understanding of how magnetic nanocomposites and molecularly imprinted polymers contribute to environmental sustainability, equipping them with the ability to analyze, evaluate, and apply these materials in real-world scenarios.

Upon successful completion of this lecture, students/trainees will be able to:

- Understand the Fundamentals of Photodynamic cancer Therapy (PDT)
  - Explain the principles of PDT, including the role of light, oxygen, and photosensitizers.
  - Describe the mechanism of ROS generation and its biological effects in cancer therapy.
- Explore the Chemistry of Porphyrins
  - Understand the structure, properties, and synthesis of porphyrins.
  - Explain how porphyrins can be chemically modified for enhanced PDT efficacy.
- Analyze the Mechanism of Action in Cancer Treatment
  - Describe how porphyrins interact with light and oxygen to induce cell death.
  - Evaluate the factors affecting the effectiveness of PDT, including photosensitizer localization and illumination conditions.
- Examine Clinical Applications and Research Developments
  - Identify current and emerging applications of PDT in cancer therapy and other medical conditions.
  - Discuss historical advancements and Nobel Prize-winning research related to PDT and porphyrins.
- Develop Practical Skills in PDT Porphyrin Synthesis
  - Synthesize a porphyrin-based photosensitizer in a laboratory setting.
  - Assess the properties of synthesized porphyrins and their potential for PDT applications.
- Critically Evaluate Advances and Future Directions in PDT
  - Analyze recent research trends and breakthroughs in photodynamic therapy.
  - Identify current challenges and propose potential solutions for improving PDT efficiency.

This course will equip students with both theoretical knowledge and practical skills, preparing them for research or professional applications in the field of photodynamic cancer therapy.

Assess the role of biomass in sustainable environmental management. Recommended level: Graduate students in chemistry or chemistry + biology

General Skills

Research, analysis, and synthesis of data and information, using the necessary technologies
Adaptation to new situations
Decision making
Working in an international environment
Working in an interdisciplinary environment
Generating new research ideas
Project planning and management
Respect for the natural environment
Exercise of critical and self-critical thinking
Promotion of free, creative, and inductive thinking
Analytical and Critical Thinking Skills

Problem-Solving Skills
Research and Data Interpretation Skills
Scientific Communication and Collaboration Skills
Working in an international environment
Awareness of Environmental Sustainability and Ethical Considerations
Respect for the natural environment
Analytical and Critical Thinking Skills
Problem-Solving Skills
Research and Data Interpretation Skills
Scientific Communication and Collaboration Skills
Working in an international environment
Awareness of Environmental Sustainability and Ethical Considerations
Respect for the natural environment
Analytical and Critical Thinking Skills
Problem-Solving Skills
Research and Data Interpretation Skills
Teamwork
Scientific Communication and Collaboration Skills
Working in an international environment
Exercise of critical and self-critical thinking

- **MODULE CONTENT**

  - General Issues

    First part of the module is recalling the biological constrains to design new vectors. Questions of size of the vectors, toxicities, elimination/accumulation and their sustainability is addressed and is included in the journey of a vector as a function of its administration mode.

  - Vectors design

    In the second part, the vectors design is addressed in order to take in account the accordance between the vector design and the drug properties that need to be delivered. The course is organize as a function of the size of the drug, starting from small organic/natural molecules up to larger drugs (proteins, polynucleotides), and follow the following plan:

    3. Small molar masses vectors

    3.1. Cyclodextrin vectors

    3.2. Dendrimers

    3.3. Peg-based Excipient

    4. Polymer-based systems for drug delivery

    4.1 Polymer-drugs conjugates

    4.2 Self-assembled copolymers for drug delivery

    4.3 Nanogels

  - Environmental issues related to polymer industry

The first part of this course will focus on the plastics industry, including both (petro)chemical industry and plastics engineering. The polymers of major economic

importance ("Big six": polyethylene, polypropylene, polystyrene, poly(vinyl chloride), and poly(ethylene terephthalate)) will be presented.

Their main application fields, such as packaging, building and construction or transportation, will be discussed.

In the second part of the course, the focus will be put on environmental issues related to the manufacture, the use and end-of-life of plastics. The rapid increase of the global plastic production will be presented together with the depletion of oil resources. The necessity to develop bio-based alternatives to petro-based plastics will be discussed. Then, the pollution and health scandals caused by plastics materials will be analyzed: toxicity of additives, microplastics, marine plastic pollution, soil contaminations by non-biodegradable materials... In particular, the various end-of-life management options (mechanical or chemical recycling, energy recovery, landfill) will be discussed.

- Bio-based Polymers

Bio-based polymers are defined as materials for which at least a portion of the polymer consists of material produced from renewable resources, such as *algae*, bacteria, microorganisms, plants, etc.).

The different synthesis strategies to obtain bio-sourced polymers will be presented. Natural polymers, such as polysaccharides, are known and extensively used for centuries. Several artificial polymers, which are obtained by the chemical modification of natural polymers, have been developed in the 19th century. Few polymers are formed directly as polymers in bio-organisms, such as bacteria. More recently, a substantial amount of research has been performed on the preparation of bio-based monomers allowing to obtain after polymerization structures similar to pre-existing petroleum-based polymers or fully original macromolecular structures. In particular, several biomass-derived platform chemicals have been developed and are very promising in the field of polymer synthesis. Particular emphasis will be placed on the few industrially-produced and commercially-available bio-sourced polymers, such as poly(lactic acid), polyamide 11, polyhydroxyalkanoate, bio-based polyethylene or polybutylene adipate terephthalate (PBAT). If the bio-based polymers are sources of hope and are seen as potential middle-term replacement to petroleum based polymers, they still represent only 1% of the global plastic production. In addition, the generalization of bio-sourcing faces several major challenges, such as the availability of the resource, the cost of the new materials, the competition with food supply, or the pollution generated by the crops (fertilizers, herbicides...).

- Biodegradable polymers / Polymer recycling

Plastic materials end of life is also a crucial issue. Different situations have to be considered. If polymers end up in the environment, as for example polymers found in cosmetics and detergents, or microplastics coming from paints, coating, tires and washing of textiles. For these applications, no waste collect is possible, and the polymers end up in wastewater and in waterways. The question of their accumulation in the environment has therefore become crucial and the use of biodegradable polymers is a priority. In this course, the question of the definition of biodegradability and its evaluation will first be addressed. Then the focus will be put on the biodegradable plastics, which are currently on the market and on their

main applications. Finally, this course plans to provide an overview of the most promising current research.

If it is possible to collect the waste, plastics are currently recovered energetically, recycled mechanically or landfilled. In many countries, energy recovery is the main outlet for waste. Nevertheless, this recovery generates atmospheric pollution and the production of so-called ultimate waste. The physical (mechanical) recycling of polymers is strongly promoted by public authorities. However, it also suffers from several important disadvantages such as the inevitable loss of quality of the recycled materials due to the degradation of the polymer chains and to the contamination by the accumulation of additives. In addition, the degradation of biodegradable polymers in landfills or directly in ecosystems leads to a loss of valuable materials and is therefore not the most interesting strategy from an economic point of view. Moreover, the accumulation of degradation products in the environment could eventually have harmful consequences. A growing number of studies are interested in the development of **chemically recyclable plastics** that would allow us to move towards a virtuous circular economy. The second part of this course will present the two main strategies that have been developed: *repurposing* and *depolymerization processes*.

Repurposing consists of breaking down polymer chains by adjusting the pH or in the presence of a chemical reagent in order to convert them into new "building blocks" that can be used to synthesize new virgin materials with high added value.

Depolymerization processes put forward a cycle of polymerization-depolymerization allowing to regenerate the original pure monomer and thus to re-synthesize a virgin polymer having its native properties.

1. Introduction to Wastewater treatment management
2. Adsorption definitions
3. Adsorption equilibria
4. Adsorption isotherms (Langmuir, Freundlich models)
5. Adsorption interactions
6. Adsorption experimental design
7. Experiment/Practical work
8. Use of bioinspired materials - Synthesis
9. Use of bioinspired materials – Characterization
10. Use of bioinspired materials – Adsorption evaluation

1. Introduction to Nanotechnology in Environmental Science
    - Overview of nanomaterials in environmental applications
    - Key advantages of magnetic nanocomposites and molecularly imprinted polymers
2. Fundamentals of Magnetic Nanocomposites
    - Composition and synthesis methods
    - Magnetic properties and their role in pollutant removal
    - Applications in wastewater treatment, air purification, and soil remediation
3. Fundamentals of Molecularly Imprinted Polymers (MIPs)
    - Concept of molecular imprinting and selective adsorption
    - Synthesis techniques and functionalization

- Applications in environmental monitoring and sensing

4. Mechanisms of Pollutant Removal

- Adsorption, catalytic degradation, and filtration mechanisms
- Case studies on heavy metal removal, pesticide adsorption, and organic pollutant degradation

5. Challenges and Future Perspectives

- Material stability, scalability, and environmental impact
- Innovations in hybrid materials and smart nanocomposites

Future research directions in sustainable nanotechnology

1: Introduction to Photodynamic Therapy (PDT)
- Definition and principles of PDT
- Historical background and key discoveries (Nobel Prize-winning research)
- Components of PDT: Light, photosensitizer, and oxygen
- Mechanism of PDT: Energy transfer and ROS generation
- Applications of PDT in oncology and non-cancerous diseases

2: Chemistry and Structure of Porphyrins
- Basic structure of porphyrins: Tetrapyrrole core and methylene bridges
- Natural and synthetic porphyrins
- Porphyrin coordination chemistry and metal complexation
- Structural modifications and functionalization for PDT applications

3: Synthesis and Modification of Porphyrins for PDT
- Synthetic routes for porphyrins and derivatives
- Strategies for enhancing porphyrin-based photosensitizers
- Substituent effects at meso- and β-positions
- Stability and solubility improvements

4: Photophysical and Photochemical Properties of Porphyrins
- Absorption and emission spectra of porphyrins
- Excited-state dynamics and intersystem crossing
- Mechanism of singlet oxygen ($^1O_2$) generation and ROS production
- Factors influencing phototoxicity and therapeutic efficacy

5: Mechanism of Action in Cancer Therapy
- Cellular uptake and localization of porphyrin photosensitizers
- PDT-induced cytotoxicity and apoptosis pathways
- Selectivity and tumor-targeting strategies
- Effects of illumination conditions and oxygen availability

6: Clinical Applications of Porphyrin-Based PDT
- Approved porphyrin-based PDT agents (e.g., Photofrin)
- PDT for skin, esophageal, and lung cancers
- Emerging applications in non-neoplastic diseases
- Limitations and side effects of PDT

7: Advances and Future Perspectives in PDT
- Recent research and technological developments
- Nanoparticle-based porphyrin delivery systems
- Combination therapies (PDT with immunotherapy, chemotherapy, or radiotherapy)
- Challenges and opportunities in clinical translation

8: Laboratory Synthesis and Characterization of a PDT Porphyrin
- Hands-on synthesis of free base tetraphenyl porphyrin
- Spectroscopic characterization techniques (UV-Vis, fluorescence, NMR, mass spectrometry)
- Photophysical analysis and ROS detection

Evaluation of cytotoxicity in model systems

- **TEACHING and LEARNING METHODS - ASSESSMENT**

Training Method *Physical presence/on-line /blended.*	Physical presence
Use Of Information And Communication Technologies (Ict) *Use of ICT in Teaching, in Laboratory Education, in Communication with Trainees*	Integrating Information and Communication Technologies (ICT) into the lecture on *Practical work (lab course) on adsorption processes* enhances learning, engagement, and assessment. Digital Presentation Tools such as PowerPoint will be used to deliver visually appealing lecture slides with diagrams, animations, and infographics explaining bioinspired adsorbent materials structures and mechanisms. On-line quizzes, such as Kahoot will be used for real-time knowledge check session. Finally, QR Code-Based submissions will enable trainees to scan a QR code to submit quiz and feedback digitally, making the evaluation process seamless and paperless
Evaluation Of Trainees *Description of the evaluation process* *Evaluation Language, Evaluation Methods, Formative or Summative, Multiple Choice Test, Short Answer Questions, Essay Questions, Problem Solving, Written Assignment, Report, Oral Examination, Public Presentation, Laboratory Work, Clinical Patient Examination, Artistic Interpretation, Other* *Explicitly specified evaluation criteria are mentioned and if and where they are accessible to the trainees.*	Short answer questions during course Multiple Choice Test at the end of the course

- **RECOMMENDED BIBLIOGRAPHY**

- Recycling of Plastics, Edited by Norbert Niessner, Hanser Publications, 2022.
- Environmental Impact of Polymers, Thierry Hamaide (Editor), Rémi Deterre (Editor), Jean-François Feller (Editor), Wiley, 2014, ISBN: 978-1-848-21621-1
- Nanogel—an advanced drug delivery tool: Current and future
  Ankita Sharma, Tarun Garg, Amrinder Aman, Kushan Panchal, Rajiv Sharma, Sahil Kumar & Pages 165-177 doi.org/10.3109/21691401.2014.930745.
- Polymer–drug conjugate therapeutics: advances, insights and prospects
  Iriny Ekladious, Yolonda L. Colson and Mark W. Grinstaff NATuRe RevIews volume 18 | APRIl 2019 | 273
- Principles of Adsorption and Adsorption Processes – Edited by Douglas M. Ruthven (1984)
- Adsorption Technology & Design – Edited by John Thomas and Barry Crittenden (1998)
- Principles of Chemical Separations with Environmental Applications - Richard D. Noble and Patricia A. Terry (2009)
- Nanocomposite Materials for Environmental Applications – Edited by R. Praveen Kumar, K. K. Pant, and P. Ghosh (2020)
- Magnetic Nanomaterials in Analytical Chemistry – Edited by I. F. Gorbatchuk (2022)
- Nanotechnology in Environmental Science – Edited by A. Sharma & R. Sanghi (2019)
- Magnetic Nanocomposites for Environmental Applications: A Review" – Journal of Hazardous Materials (2021)
- Molecularly Imprinted Polymers: A Versatile Tool for Environmental Applications" – Chemical Society Reviews (2020)
- Recent Advances in Magnetic Nanocomposites for Water Purification" – Environmental Science & Technology (2022)
- Molecularly Imprinted Polymers in Environmental Analysis: A Critical Review" – Trends in

Analytical Chemistry (2019)

- Photodynamic therapy based on porphyrin-based metal–organic frameworks - Journal of Materials Chemistry B, 2023, 11, 5976.
- Recent advances of multi-dimensional porphyrin-based functional materials in photodynamic therapy, Coordination Chemistry Reviews, 2020, 420, 213410.
- Porphyrins as Theranostic Agents from Prehistoric to Modern Times, Theranostics, 2012, 2 (9), 905.
- Handbook of Photodynamic Therapy: Updates on Recent Applications of Porphyrin-Based Compounds, World Scientific Publishing Company, 2016.
- Handbook of Photodynamic Therapy: Updates on Recent Applications of Porphyrin-Based Compounds, Edited by: Ravindra K Pandey (Roswell Park Cancer Institute, USA), David Kessel (Wayne State University, USA), and Thomas J Dougherty (Roswell Park Cancer Institute, USA), World Scientific.
- Fundamentals of Porphyrin Chemistry: A 21st Century Approach, Penelope J. Brothers, Mathias O. Senge, 2022, John Wiley & Sons, Ltd.
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Module

Tutors	SALMAIN MICHELE (Professor), Candice BOTUHA (Associate Professor), Dr. Benoît Bertrand, Tsoupras Alexandros (Assistant Professor)

- **GENERAL**

Title of Module	**Hybrid nanomaterials for biomedical and environmental applications**	
Autonomous Teaching Activities *in case credits are awarded separately for distinct parts e.g. Lectures, Lab Exercises, etc. Specify the total teaching hours and credits.*	**Total Teaching Hours**	**Credits Units**
	18 hours	1.8
Language of Tutoring and Examination:	English	

- **EDUCATIONAL OBJECTIVES**

Educational Objectives
The Educational objectives of the thematic unit/course describe the specific knowledge, skills, and abilities of an appropriate level that learners will acquire upon successful completion of the course.

The course intends to give a broad overview of the emerging therapeutic modalities currently under development or recently approved to treat some life-threatening pathologies, with a special emphasis put on various forms of cancer. Focus will be put on therapeutic strategies involving (bio)macromolecules and metal-based drugs.

The course intends to give a broad overview of the emerging methodologies to investigate and decipher the mechanisms of action of metal-based drugs. This will include discussion of method for the characterization of the reactivity of the complexes in model environments for biological systems, studies of cellular uptake and excretion, studies of intracellular speciation and localization and target identifications.

Recommended level: Graduate students in chemistry or chemistry + biology

General Skills
Note the general skills that the trainee acquires. Which of these does the course aim at?
Research, analysis, and synthesis of data and information, using the necessary technologies
Adaptation to new situations
Decision making
Independent work
Teamwork
Working in an international environment
Working in an interdisciplinary environment
Generating new research ideas
Project planning and management
Respect for diversity and multiculturalism
Respect for the natural environment
Demonstrating social, professional, and ethical responsibility and sensitivity to gender issues
Exercise of critical and self-critical thinking
Promotion of free, creative, and inductive thinking

The course aims at:

- Working in an international environment
- Analysis and synthesis of data and information
- Exercise of critical thinking
- Acquire up-to-date knowledge beyond his / her own discipline
- The students will develop skills in critical thinking, problem-solving, scientific communication, and working effectively in interdisciplinary environments. These abilities will prepare them to contribute to multidisciplinary research teams and drive innovation in the field of medicinal chemistry.

- **MODULE CONTENT**

- Biomacromolecules for therapy : gene therapy, (radio)immunotherapy; in vivo drug activation strategies
- Metal-based drugs: classification according to the mechanism of action
- Introduction to Bioinspired Molecules
- Drug Design and Interaction with Biological Targets , Case Study 1.
- Fluorescent Probes for Detecting Biological Processes, Case Study 2
- Perspectives with Emerging trends in bioinspired medicinal chemistry
- Behavior of the complex in solvent and culture medium
- Internalization of the complex
- Intracellular localization
- Intracellular speciation
- Identification of the targets
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- **TEACHING and LEARNING METHODS - ASSESSMENT**

Training Method *Physical presence/on-line /blended.*	Physical presence
Use Of Information And Communication Technologies (Ict) *Use of ICT in Teaching, in Laboratory Education, in Communication with Trainees*	NO
Evaluation Of Trainees *Description of the evaluation process* *Evaluation Language, Evaluation Methods, Formative or Summative, Multiple Choice Test, Short Answer Questions, Essay Questions, Problem Solving, Written Assignment, Report, Oral Examination, Public Presentation, Laboratory Work, Clinical Patient Examination, Artistic Interpretation, Other* *Explicitly specified evaluation criteria are mentioned and if and where they are accessible to the trainees.*	Short answer questions during course Multiple Choice Test at the end of the course

- **RECOMMENDED BIBLIOGRAPHY**

- Gene therapy : principles, challenges and use in clinical practice. C. Ay, A. Reinisch, Wien. Klin. Wochenschr. 2024
- Classification of metal-based drugs according to their mechanisms of action. E. Boros, P.J. Dyson, G. Gasser, Chem 2020, 6, 41-60

- Monoclonal Antibodies in Cancer Therapy, D. Zahavi, L. Weiner. Antibodies 2020, 9, 34
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- Synthetic prodrug design enables biocatalytic activation in mice to elicit tumor growth suppression. I. Nasibullin et al. Nature Comm. 2022, 13, 39
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- Nina-Diogo A, Hyzewicz J, Hamon MP, Forté J, Thorimbert S, Friguet B, Botuha C. Synthesis of New Bodipy Hydrazide Fluorescent Probes for the Detection of Carbonylated Proteins Generated by Oxidative Stress. Chembiochem. **2024** Oct 1;25(19):e202400093. doi: 10.1002/cbic.202400093
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- I.-S. Song, N. Savaraj, Z. H. Siddik, P. Liu, Y. Wei, C. Ji. Wu, M.T. Kuo, Neurotoxicology 2008, 29, 444-452
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- C. Schmidt, M. Zollo, R. Bonsignore, A. Casini, S. M. Hacker, Chem. Commun., 2022, 58, 5526-5529

Module

Tutors	NEBEWIA GRIFFETE (Associate Professor), Sebastien Abramson (Associate Professor), Dr. Alexandros Tsoupras (Assistant Professor), Georgios Kyzas (Professor)

- **GENERAL**

Title of Module	**Molecular chemistry for biomedical applications**	
Autonomous Teaching Activities *in case credits are awarded separately for distinct parts e.g. Lectures, Lab Exercises, etc. Specify the total teaching hours and credits.*	**Total Teaching Hours**	**Credits Units**
	22 hours	2.3
Language of Tutoring and Examination:	English	

- **EDUCATIONAL OBJECTIVES**

Educational Objectives

The Educational objectives of the thematic unit/course describe the specific knowledge, skills, and abilities of an appropriate level that learners will acquire upon successful completion of the course.

The objective of this course is to have an overview on the different existing diagnostic and therapies used for cancer. A focus on nanomaterials and hybrid nanomaterials, composed of both inorganic (silica, gold, magnetic) and organic (polymer) components and how they have recently been examined as promising platforms for biomedical applications will be done. Molecularly Imprinted Polymer nanoparticles will be discussed as a promising theranostic platform for cancer. The objective of this course is to give an overview on the use of magnetic nanoparticles and nanocomposites in environmental applications. Notably, magnetically-assisted separation in water treatment will be covered. After a general introduction on the challenges associated with drinking water and wastewaters treatment processes, specific examples, including magnetically-assisted coagulation-flocculation-sedimentation processes, adsorption and heterogenous catalytic advanced oxidation processes with magnetic materials, will be described. Other environmental applications will also be outlined, such as magnetically activated water-treatment processes, magnetic separation for soil and air treatment, along with sensing and other analytical processes. These lectures aim to introduce the trainee in the field of isolation, and chemical and structural characterization of natural bioactive organic compounds and metabolites present in sustainable sources, as well as on their appropriate valorization as bio-functional ingredients in several innovative products, such as functional foods, food supplements, nutraceuticals, nutricosmetics, cosmeceuticals, cosmetics and pharmaceuticals-drugs.

Moreover, the trainee will be able to understand and evaluate the need for utilizing “Green” methodologies and Omics-based ultra-modern analyses, using appropriate bioassay tools, evaluating structure activity relationships and when needed employing chemical modification of natural bioactives and nanoencapsulation techniques to increase bioavailability, as well as to deepen their knowledge into personalized administration, bio-efficacy, health claims and safety issues related to the use of such “natural” products. Upon successful completion of this lecture, students/trainees will acquire the following knowledge, skills, and abilities:

1. Knowledge Objectives
   - Fundamentals of adsorption process

- Definition, composition, and synthesis methods
- Key physicochemical properties influencing adsorption

- Mechanism of adsorption processes
  - Electrostatic forces, van der Waals, pi-pi stacking, H-bonding
- Current and Emerging Applications
  - Water and wastewater treatment

2. Skill Objectives

- Analytical and Critical Thinking
  - Evaluate the advantages and limitations of adsorption process
  - Compare different synthesis and functionalization techniques
- Problem-Solving and Application
  - Identify appropriate technologies for specific environmental problems
  - Propose potential improvements in design and efficiency

3. Abilities Objectives

- Scientific Communication and interdisciplinary Integration
  - Interpret and discuss research findings related to bioinspired adsorbent materials
  - Connect principles from chemistry, materials science, and environmental engineering

Assess the role of biomass in sustainable environmental management Recommended level: Graduate students in chemistry or chemistry + biology.

General Skills

Note the general skills that the trainee acquires. Which of these does the course aim at?
Research, analysis, and synthesis of data and information, using the necessary technologies
Adaptation to new situations
Decision making
Independent work
Teamwork
Working in an international environment
Working in an interdisciplinary environment
Generating new research ideas
Project planning and management
Respect for diversity and multiculturalism
Respect for the natural environment
Demonstrating social, professional, and ethical responsibility and sensitivity to gender issues
Exercise of critical and self-critical thinking
Promotion of free, creative, and inductive thinking

The course aims at:

- Working in an international environment
- Working in an interdisciplinary environment
- Analysis and synthesis of data and information
- Exercise of critical thinking
- Acquire up-to-date knowledge beyond his / her own discipline
- Promotion of free, creative; and inductive thinking
- Working in an interdisciplinary environment
- Analysis and synthesis of data and information
- Exercise of critical thinking
- Acquire up-to-date knowledge beyond his / her own discipline
- At the end of this course the student will have further developed the following skills (generic competencies):
- Ability to demonstrate knowledge and understanding of essential data, concepts, theories and applications related to Food Biochemistry.
- Ability to apply this knowledge and understanding to the solution of problems of an unfamiliar nature.

- Ability to adopt and apply methodology to the solution of unfamiliar problems.
- Study skills needed for continued professional development.
- Ability to interact with others in problems of an interdisciplinary nature.
- More generally, upon completion of this course the student will have further developed the following generic competencies:
- Search, analysis and synthesis of data and information, using the necessary technologies
- Adaptation to new situations.
- Decision-making.
- Autonomous work.
- Group work.
- Exercise of criticism and self-criticism.
- Respect for the natural environment.
- Promotion of free, creative and inductive thinking
- Analytical and Critical Thinking Skills
- Problem-Solving Skills
- Research and Data Interpretation Skills
- Scientific Communication and Collaboration Skills
- Working in an international environment
- Awareness of Environmental Sustainability and Ethical Considerations
- Respect for the natural environment

- **MODULE CONTENT**

  - Cancer diagnostic : MRI, PET SCAN, liquid biopsy
  - Cancer therapy: chemotherapy (targeted therapy, immunotherapy, hormone therapy…), surgery, radiation
  - Nanomaterials and hybrid nanomaterials for cancer therapy and diagnostic
  - Molecularly Imprinted Polymer in medicine
  - Challenges associated with water scarcity and water pollution
  - Wastewater and drinking water treatment methods
  - Synthesis, characterization, physicochemical properties and applications of magnetic nanoparticles and nanocomposites
  - Magnetically-assisted separation processes
  - Magnetically-assisted coagulation-flocculation-sedimentation processes
  - Use of magnetic materials in adsorption and heterogenous catalytic advanced oxidation processes
  - Other environmental applications of magnetic materials
  - Introduction to Wastewater treatment management
  - Adsorption definitions
  - Adsorption equilibria
  - Adsorption isotherms (Langmuir, Freundlich models)
  - Adsorption interactions
  - Adsorption experimental design
  - Experiment/Practical work
  - Use of bioinspired materials - Synthesis
  - Use of bioinspired materials – Characterization

- 10. Use of bioinspired materials – Adsorption evaluation

- **TEACHING and LEARNING METHODS - ASSESSMENT**

Training Method *Physical presence/on-line /blended.*	Physical presence
Use Of Information And Communication Technologies (Ict) *Use of ICT in Teaching, in Laboratory Education, in Communication with Trainees*	Integrating Information and Communication Technologies (ICT) into the lecture on Practical work (lab course) on adsorption processes enhances learning, engagement, and assessment. Digital Presentation Tools such as PowerPoint will be used to deliver visually appealing lecture slides with diagrams, animations, and infographics explaining bioinspired adsorbent materials structures and mechanisms. On-line quizzes, such as Kahoot will be used for real-time knowledge check session. Finally, QR Code-Based submissions will enable trainees to scan a QR code to submit quiz and feedback digitally, making the evaluation process seamless and paperless.
Evaluation Of Trainees *Description of the evaluation process* *Evaluation Language, Evaluation Methods, Formative or Summative, Multiple Choice Test, Short Answer Questions, Essay Questions, Problem Solving, Written Assignment, Report, Oral Examination, Public Presentation, Laboratory Work, Clinical Patient Examination, Artistic Interpretation, Other* *Explicitly specified evaluation criteria are mentioned and if and where they are accessible to the trainees.*	Short answer questions during course Multiple Choice Test at the end of the course

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- Relative Journals
- - Food Bioscience
- - The Journal of Nutritional Biochemistry
- - Journal of Food Biochemistry
- - Food Science and Human Wellness
- - Frontiers in Nutrition
- - Nutrients
- - Foods
- - Cosmetics
- - Pharmaceuticals
- - Food Research International
- - Journal of Functional Foods
- - Marine Drugs
- - Food Chemistry
- Biochemistry
- The Journal of Biochemistry
- The International Journal of Biochemistry & Cell Biology
- Trends in Biochemical Sciences
- Clinical Biochemistry
- Journal of Biological Chemistry
- Prostaglandins & Other Lipid Mediators
- International Journal of Molecular Sciences
- Frontiers in Biosciences Landmark
- Blood
- Blood Reviews
- Clinica Chimica Acta
- Mediators of Inflammation
- Life Sciences
- Journal of Inflammation
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