PhD in Chemical Sciences
Department of Chemistry “Ugo Schiff” University of Florence

PhD course: PROTEIN AND PEPTIDE-BASED BIOMATERIALS

SYLLABUS

1. Lecturer information

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2. Title of the course

Protein and peptide-based (bio)materials

3. Course program

Nature showcases its elegant functional design through marvelous materials made up of proteins. In fact, these protein-based materials and formulations are useful in a range of biomedical applications. An ideal biomaterial should be biocompatible, biodegradable, and easily processable into various scaffold formats, preferably under situations similar to physiological conditions. This course briefly covers protein-based biomaterials for various biomedical applications such as drug delivery, wound healing, tissue engineering, and regenerative medicine. A number of lectures cover reductionistic approaches of employing natural amino acids, peptides, and their designer mimics to produce (bio)materials with a range of properties and functions. The course also introduces a novel research theme and an umbrella concept “molecular architectonics” to develop molecular and nanoarchitectures with novel properties and applications. This concept of designing noncovalent systems enables us to focus on distinct functional aspects of designer molecules for biological and non-biological applications, which also strengthens our efforts in understanding the art of controlled molecular assemblies. In this context, biomolecules with in-built information for molecular recognition can guide the scheme of molecular architectonics. The tailorability of molecular assemblies can be accomplished by employing biomolecules like amino acids and peptides as auxiliaries with functional cores. Molecular architectonics of modular functional building blocks, and the derived molecular and material architectures that are developed led to understanding homochirality, protein folding, organic (bio)electronics, high-mechanical

strength (bio)organic materials, self-cleaning, (bio)sensors, and tissue engineering applications among others.

4. Course content detailed per lesson of two hours (possibly with dates and room, real and virtual)

Tentative outline (in person/real):

Lesson 1: Introduction to amino acids, peptides, and proteins; structure and function. Introduction to biomaterials, biocompatibility, and other related aspects
Lesson 2: Noncovalent interactions, self-assembly, molecular and material architectures
Lesson 3: Protein-based biomaterials (eg. collagen, elastin, silk)
Lesson 4: Amino acid based (bio)materials
Lesson 5-7: Peptide-based (bio)materials
Natural peptides, protein-derived peptides, cyclic dipeptides, designer peptides, peptoid, metallo-peptides, amyloids
Lesson 8-9: Amino acid and peptide-guided molecular architectonics
Amino acid, peptide and their mimetics as auxiliaries
Lesson 10: Upcycling of cyclic dipeptides

(All lectures deal with design, structure, properties, function, and applications)

5. Suggested reading

1) L. P. Datta, S Manchineella and T Govindaraju, Biomolecules-derived biomaterials, *Biomaterials* **2020**, *230*, 119633.
2) Protein-Based Biological Materials: Molecular Design and Artificial Production, A. Miserez, J. Yu and P. Mohammadi, *Chem. Rev*. **2023**, *123*, 2049-2111.
3) S.M. Choi, P. Chaudhry, S.M. Zo and S.S. Han, Advances in protein-based materials: from origin to novel biomaterials, in cutting-edge enabling technologies for regenerative medicine. *Advances in experimental medicine and biology*, H. Chun, C. Park, I. Kwon and G. Khang, (eds), vol 1078. Springer, Singapore, 2018.
4) Peptide-based Biomaterials in Soft Matter Series, The Royal Society of Chemistry, London, M. O. Guler (Ed.), 2021.
5) B. Roy and T. Govindaraju, Amino acids and peptides as functional components in arylenediimide-based molecular architectonics, *Bull. Chem. Soc. Jpn*., **2019**, *92*, 1883-1901.
6) Molecular Architectonics and Nanoarchitectonics In the series of Nanostructure Science and Technology, Springer Nature, Singapore, T. Govindaraju and Katsuhiko Ariga (Eds.), 2021.
7) C. Balachandra, D. Padhi, and T. Govindaraju, Cyclic dipeptide: a privileged molecular scaffold to derive structural diversity and functional utility, *ChemMedChem* **2021**, *16*, 2558-2587.
8) S. Manchineella and T. Govindaraju, Molecular self-assembly of cyclic dipeptide derivatives and their applications, *ChemPlusChem* **2017**, *82*, 88-106.

(Note: A number of other references will be covered in lectures)

6. Learning Objectives

- Protein based biomaterials and their structure and function.
- Reductionistic strategies to biomaterials: Amino acids, peptides, and their mimics-based materials.

- Molecular architectonics: amino acids, peptides, and mimics as auxiliaries to guide the controlled molecular assembly of functional molecules.
- Design, structure, function, and applications in each category.
- Applications: Health, Energy and Environment

7. Knowledge and Skills to be acquired

General knowledge: Engineering

- protein-based biomaterials
- amino acid-based biomaterials
- peptide-based biomaterials
- molecular architectonics: design of functional biomaterials
- design, structure, function, and applications of novel biomaterials

Specific skills:

- Design and controlled organization of peptides to produce materials and gels
- Spectroscopy and microscopy characterization of peptide-based materials
- Biophysical and biological studies
- Custom-design of biomaterials specific applications
- In vitro and in vivo evaluation

8. Prerequisites

Basic Knowledge of

- amino acids, peptides, and proteins (structure & function)
- organic chemistry, bioconjugate chemistry and peptide synthesis
- various spectroscopy and microscopy techniques and analysis
- biophysical techniques and bioassays

9. Teaching Methods

O MODE 1 – Pre-recorded lessons uploaded on the moodle platform (a meeting must be organized with PhD students in order to clarify eventual doubts)
x MODE 2 (preferred) – Lecture delivered in-person and in remote with simultaneous recording by the WEBEX platform

10. Further Information

N.A.

11. Type of Assessment

The final evaluations will have to be validated maximum 1 month after the end of the course. Evaluation sheets will be handed out directly after the course.

12. Period

August 2024 - 12 h including final exam