295122 - 2951332 - Biofunctional Materials

Coordinating unit: 295 - EEBE - Barcelona East School of Engineering
Teaching unit: 702 - CMEM - Department of Materials Science and Metallurgy
713 - EQ - Department of Chemical Engineering

Academic year: 2019
Degree: MASTER'S DEGREE IN MATERIALS SCIENCE AND ADVANCED MATERIALS ENGINEERING (Syllabus 2019). (Teaching unit Optional)
MASTER'S DEGREE IN INTERDISCIPLINARY AND INNOVATIVE ENGINEERING (Syllabus 2019). (Teaching unit Optional)

ECTS credits: 6
Teaching languages: English

Teaching staff
Coordinator: Rodríguez Rius, Daniel
Others: Rodríguez Rius, Daniel
Ginebra Molins, Maria Pau
Pegueroles Neyra, Marta
Mas Moruno, Carlos
Canal Barnils, Cristina
Guillem Marti, Jordi
Aleman Llansó, Carlos Enrique

Prior skills
Knowledge of Materials science.
Knowledge of Chemistry (both organic and inorganic).

Degree competences to which the subject contributes

Specific:
CEMUEII-19. Develop translational applications with the aim of achieving a better understanding of physiological phenomena of clinical relevance and for the design of new applications in areas that have an impact on the health care of people. (Specific competence of the Healthcare and Biomedical Applications specialty)

General:
CGMUEII-01. Participate in technological innovation projects in multidisciplinary problems, applying mathematical, analytical, scientific, instrumental, technological and management knowledge.
CGMUEII-05. To communicate hypotheses, procedures and results to specialized and non-specialized audiences in a clear and unambiguous way, both orally and through reports and diagrams, in the context of the development of technical solutions for problems of an interdisciplinary nature.

Transversal:
05 TEQ. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
06 URI. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
03 TLG. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
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Teaching methodology

The subject is divided as follows:
- 15% lectures
- 5% seminars and problem sessions
- 15% laboratory sessions
- 65% self-directed learning

Learning objectives of the subject

- Understand the biological mechanisms of cell-material interactions and their signaling cascades.
- Decide which type of cell is required for each biomaterial depending on the tissue/site of implantation.
- Discriminate between different in vitro and in vivo assays and select the appropriate method for a specific approach.
- Adjust biomaterial-tissue interactions at macro, micro and nano scale.
- Evaluate the best characterization techniques to analyze a biomaterial-tissue surface interaction.
- Design methods of surface functionalization to control cell and bacterial behavior on biomaterials.
- Analyze strategies to mimic biologically complex scenarios on artificial scaffolds.
- Engineer self-assembling processes to obtain supramolecular structures with diverse biological functions.
- Analyze strategies to design drug delivery systems; awareness of interactions biomaterial-drug.
- Select the most suitable drug delivery analysis techniques and methods.
- Design methods for the generation of smart hydrogels with specific responses to different external stimuli.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 150h</th>
<th>Hours large group:</th>
<th>22h</th>
<th>14.67%</th>
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<tbody>
<tr>
<td></td>
<td>Hours medium group:</td>
<td>0h</td>
<td>0.00%</td>
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<tr>
<td></td>
<td>Hours small group:</td>
<td>22h</td>
<td>14.67%</td>
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<tr>
<td></td>
<td>Guided activities:</td>
<td>4h</td>
<td>2.67%</td>
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<tr>
<td></td>
<td>Self study:</td>
<td>102h</td>
<td>68.00%</td>
</tr>
</tbody>
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The subject is divided as follows:
- 15% lectures
- 5% seminars and problem sessions
- 15% laboratory sessions
- 65% self-directed learning
## Content

### Unit 1: Cell/biomaterial interaction

<table>
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<th>Description:</th>
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| - The extracellular matrix (ECM): composition and structure; functions; synthesis and remodeling; Fibronectin and other adhesive glycoproteins; collagens and collagen associated proteins; proteoglycans.  
- Cell surface receptors: Integrins; syndecans; growth factor receptors; intracellular signaling pathways  
- Extracellular control of cell behavior: cell division and mitogens; cell growth and growth factors; apoptosis and survival factors.  
- Stem cells: origin and types; cloning; clinical applications.  
- Host response to biomaterials: biomaterial-host interaction; inflammation; healing; foreign body response; biocompatibility; host response to naturally derived biomaterials.  
- Biomaterials associated infection: bacteria and biofilms; host reaction to infection. |

| Learning time: 34h |
| Theory classes: 5h |
| Laboratory classes: 4h |
| Guided activities: 1h |
| Self study : 24h |

### Related activities:
- Debates on papers and scientific news; Oral presentations; Tests.

### Specific objectives:
- Understand the biological mechanisms of cell-material interactions and their signaling cascades.  
- Decide which type of cell is required for each biomaterial depending on the tissue were will be implanted.  
- Discriminate between the different in vitro and in vivo assays and select the appropriate for a specific approach.
**Unit 2: Topography**

**Learning time:** 28h
- Theory classes: 4h
- Laboratory classes: 4h
- Guided activities: 2h
- Self study: 18h

**Description:**
- **Introduction:**
  - Roughness. Basic roughness parameters.
  - Porosity. Role of porosity in the biological interactions of materials.
  - Multiscale topography and porosity, at the macro, micro and nano scale.
  - Main characterization techniques (SEM, profilometry, wettability, interferometry, AFM, MIP, Gas adsorption, microCT)

**Related activities:**
- Laboratory session on roughness; Invited speakers, discussion of scientific publications, debates and oral / poster presentations.

**Specific objectives:**
- apply the knowledge about topography and porosity to adjust biomaterial-tissue interactions at macro, micro and nano scale
- evaluate the best characterization techniques to analyze a biomaterial-tissue surface interaction
### Unit 3: Surface biofunctionalization

**Learning time:** 34h

- Theory classes: 5h
- Laboratory classes: 4h
- Guided activities: 1h
- Self study: 24h

**Description:**
- Introduction: current limitations of biomaterials; bioinertness vs. bioactivity; classical methods of functionalization (plasma spraying, chemical etching, electrochemical methods, sand blasting, etc.).
- Physical methods: plasma-based strategies to functionalize biomaterials; plasma-assisted polymerization.
- Chemical methods (I) - Inorganic coatings: hydroxyapatite coatings by plasma spray and electrodeposition; thermochemical treatments (Kokubo method); apatite formation in vivo.
- Chemical methods (II) - Organic coatings: SAMs; polymers and recombinamers; proteins; peptides; peptidomimetics; dendrimers and hierarchical structures; nanoparticles; multifunctional systems.
- Antibacterial coatings: the “race for the surface”; biofilms and antibiotics; anti-fouling coatings; bactericidal coatings (release-based); bactericidal coatings (immobilized).
- Characterization techniques: QCM-D, XPS.

**Related activities:**
- Invited speakers, discussion of scientific publications, debates and oral/poster presentations.

**Specific objectives:**
- Design methods of surface functionalization to control cell behavior on biomaterials.
- Design methods of surface functionalization to inhibit bacterial adhesion on biomaterials.
- Analyze strategies to mimic biologically complex scenarios on artificial scaffolds.
Unit 4: Peptide-based materials

Learning time: 27h
- Theory classes: 4h
- Laboratory classes: 4h
- Guided activities: 1h
- Self study: 18h

Description:
- Fundamentals of chemistry and physics of peptide materials: 3D peptide structures; optical properties; quantum confinement and thermal phase transitions.
- Peptronics: Electron transfer through peptide materials in solution; supported peptide materials and their interactions; electron transfer through supported peptide materials; applications.
- Peptide nanostructures: molecular architectures with peptide assembling for nanomaterials; building blocks; shape driven nanostructures; function of peptide assemblies; peptide-based spherical and dendritic structures; applications.
- Peptide conjugates and hybrid peptide-based materials: peptide-polymer conjugates; block copolymers; peptide-based carbon nanotubes; hyperbranched polymers and dendrimers; applications.
- Characterization techniques: TEM, CD.

Related activities:
- Invited speakers, discussion of scientific publications, debates and oral / poster presentations.

Specific objectives:
- Analyze strategies to mimic biologically complex scenarios on artificial scaffolds.
- Engineer self-assembling processes to obtain supramolecular structures with diverse biological functions.
Unit 5: Drug delivery

Learning time: 27h
- Theory classes: 4h
- Laboratory classes: 4h
- Guided activities: 1h
- Self study: 18h

Description:
- Introduction: basic concepts in drug delivery; conventional drug delivery formulations; systemic vs. local drug delivery, vectoring; Kinds of drugs & kinds of carriers; Formulation; Stability.
- Strategies for drug delivery from different materials / implants:
  - Dendrimers; colloidal systems - emulsions, micelles; CNTs; etc.
  - Strategies for incorporating drugs to implants & modulating drug release, examples: Polymers (Films; fiber-based systems (textiles, stents); etc.); Bioinstructive / smart hydrogels - controlled by external stimuli, different examples + drug delivery; Bioceramics.

Related activities:
Online tests, discussion of scientific publications, debates, oral / poster presentations.

Specific objectives:
- Analyze strategies to design drug delivery systems; awareness off interactions biomaterial-drug
- Selection of the most suitable drug delivery analysis techniques and methods

Qualification system
Partial tests: 30%
Final test: 30%
Workgroup and seminars: 40%

Regulations for carrying out activities
The use of any electronic equipment with wireless communication capabilities is strictly forbidden in the evaluations.

Bibliography
Basic:

Complementary: