295122 - 2951332 - Biofunctional Materials

Coordinating unit: 295 - EEBE - Barcelona East School of Engineering
Teaching unit: 702 - CMEM - Department of Materials Science and Metallurgy
Academic year: 2018
Degree: ECTS credits: 6 Teaching languages: English

Teaching staff
Coordinator: Rodríguez Rius, Daniel
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Prior skills
Knowledge of Materials science.
Knowledge of Chemistry (both organic and inorganic).

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>
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<th>Hours large group:</th>
<th>Total Percentage</th>
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<tbody>
<tr>
<td><strong>Total learning time:</strong></td>
<td>150h</td>
<td>14.67%</td>
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<tr>
<td>Hours medium group:</td>
<td>22h</td>
<td>0.00%</td>
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<tr>
<td>Hours small group:</td>
<td>0h</td>
<td>14.67%</td>
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<tr>
<td>Guided activities:</td>
<td>22h</td>
<td>2.67%</td>
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<tr>
<td>Self study:</td>
<td>102h</td>
<td>68.00%</td>
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## Content

<table>
<thead>
<tr>
<th>Unit 1: Cell/biomaterial interaction</th>
<th>Learning time: 34h</th>
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<tbody>
<tr>
<td></td>
<td>Theory classes: 5h</td>
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<tr>
<td></td>
<td>Laboratory classes: 4h</td>
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<tr>
<td></td>
<td>Guided activities: 1h</td>
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<td>Self study: 24h</td>
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### Description:
- 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.

### 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 where it 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, perfilometry, 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

<table>
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<th>Learning time: 34h</th>
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<tbody>
<tr>
<td>Theory classes: 5h</td>
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<tr>
<td>Laboratory classes: 4h</td>
</tr>
<tr>
<td>Guided activities: 1h</td>
</tr>
<tr>
<td>Self study: 24h</td>
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</tbody>
</table>

**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:
- **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: