



Master on Integrative Synthetic Biology

Engineering Molecular and Cellular Systems

1st Edition. 2021-2023

Semester 1 (10/2021 – 02/2022)

M1. FUNDAMENTALS (25 ECTS)

M1a. Basic principles & research topics (15 ECTS): ASSEMBLY, SYNTHESIS, BIOFACTORIES

M1b. TOOLS (10 ECTS)

- 3 days of classes per week (Tues, Wed, Thu): up to 3 classes / 1 h (morning; 10:00, 11:15, 12:30) + afternoon sessions (optional)
- Mon and Fri reserved for tutorials, journal clubs, **FRONTIERS** activities of the semester

M2. FRONTIERS I (2-3 seminars & 1-2 workshops)

FUNDAMENTALS 1 (04-08/10/2021)

INTRODUCTORY SESSIONS: Essentials of SynBio and related disciplines

Coordination: MISB team

FUNDAMENTALS 2 (13/10/2021 – 15/11/2021)

Engineering molecular systems (bottom-up approaches)

ASSEMBLY & SYNTHESIS (I) + TOOLS (I)

Coordination: ASSEMBLY & SYNTHESIS (I) – R Pérez, S Martín-Santamaría & G Rivas (CIB). TOOLS (I): B Monterroso, S Zorrilla & G Rivas (CIB)

FUNDAMENTALS 3 (16/11/2021 – 10/12/2021)

Engineering cellular systems (top-down approaches)

ASSEMBLY & SYNTHESIS (II) + TOOLS (II)

Coordination: R Giraldo & J Nogales (CNB); J Buceta & J Peretó (I₂SysBio)

EXAMS 1 (12/2021)

FUNDAMENTALS 4 (10/01/2022 – 18/02/2022):

BIOFACTORIES + TOOLS (III)

Coordination: BIOFACTORIES - J Barriuso (CIB) & J Nogales (CNB). TOOLS (III) J Nogales (CNB); I Otero & J Buceta (I₂SysBio)

EXAMS 2 (second half 02/2022)

Semester 2 (03/2022 – 06/2022)

M2. FRONTIERS I (5-6 seminars & 2-3 workshops) – engineering synthetic and natural systems

M3. EXTENSION I

M4 LAB ROTATIONS I

04-08/10/2021 FUNDAMENTALS 1 - Welcoming and Introductory Lectures		
Day	Lectures / Activities	Teachers
04/10	10:00 – 11:30: Welcoming (*) 12:00 – 13:00: KEYNOTE SEMINAR: Synthetic Biology from scratch in a new organism (*) <i>(*) on-line</i>	G Rivas & MISB team L Serrano (CRG)
05/10	10:00 – 12:00: Introduction to the MISB + practical aspects / questions (*)	G Rivas & MISB team
06/10	10:00 – 11:15: Bottom up and top-down Synthetic Biology approaches – introductory remarks (*) 11:30 – 12:30: Synthetic Biology –story of a yearning (*)	R Giraldo (CNB) J Peretó (I2SysBio)
07/10	10:00 – 11:00: The chemical origins of life (*) 11:30 – 12:30: Proto-cell: what is in a name? (*) 16:00: OPENING LECTURE – The origin of cellular life (**) Prof. Jack Szostak (Nobel Prize Medicine 2009)	J Peretó (I2SysBio) K Ruiz-Mirazo (Biofisika-UPV) J Szostak (U. Harvard) Chairs: J Peretó & K Ruiz-Mirazo
08/10	11:00 - 13:30: SPECIAL EVENT – 25 YEARS OF THE DISCOVERY OF THE MOLECULAR BASIS OF ALKAPTONURIA (*)	MA Peñalva (CIB) coord.

(*) <https://rediris.zoom.us/j/84611619482>

ID: 846 1161 9482

Access code: 808179

(**) Broadcast live on CSIC's YouTube channel

13/10/2021 – 15/11/2021:

FUNDAMENTALS 2 (engineering molecular systems – bottom-up approaches)

ASSEMBLY & SYNTHESIS (I) + **TOOLS (I)** + **FRONTIERS**

Day	Lectures / Activities	Teachers
	Lectures ASSEMBLY & SYNTHESIS I (in black) Lectures TOOLS 1 (in blue)	
	L1 (10:00-11:00) L2 (11:15-12:15) L3 (12:30-13:30) L4 (afternoon sessions - OPTIONAL) MOST F2 LECTURES WILL BE AT CIB (EXCEPT THOSE AT IQFR, AS SHOWN IN THE CALENDAR) (*) Online	
11/10/21	NON LECTIVE	
12/10/21	HOLIDAY	
13/10/21	10:00 – 10:30: Introduction to FUNDAMENTALS 2 MOLECULES OF LIFE AND THEIR INTERACTIONS 10:45 – 11:45: Macromolecules and small molecules. Molecular recognition. 12:00 – 13:00: Non-covalent interactions. 15:00 – 16:00: Basis of the Chemical Biology	G Rivas (CIB) S Martín-Santamaría / R Pérez (CIB)
14/10/21	10:00 – 11:30: Nucleic acids (natural and synthetic) 12:00 – 13:30: Lipids – essential concepts & assembly (membranes) 15:00 – 16:00: Carbohydrates – molecular recognition	C González (IQFR) I López Montero (UCM) FJ Cañada (CIB)
15/10/21	10:00 – 11:30: Molecular interactions in the test tube and the living cell: implications for synthetic biology research 12:00 – 13:30: Bottom-up biology: a biophysical approach	G Rivas (CIB) I López - Montero (UCM)

Day	Lectures / Activities	Teachers
18/10/21	Session on minimal cells (*) 16:00 – 16:45: J Pelletier's talk - <i>Genetic requirements for cell division in a genomically minimal cell</i> (*) 16:45-17:30: Round-table (*)	J Pelletier (UCM) C Danelon (TU Delft) R Gil (I2SysBio-UVA)
19/10/21	ESSENTIAL CELLULAR PROCESSES 10:00-11:00: Information processing - replication 11:15-12:15: Information processing – transcription 12:30-13:30: Information processing - translation (*)	R Bermejo (CIB) CF Tornero (CIB) M Valle (BioGune)
20/10/21	10:00 – 12:00: Protein folding and assembly 12:30 – 13:30: Protein modifications	D Laurents (IQFR) D Pérez-Sala (CIB)
21/10/21	10:00 - 11:00: Organization – cytoskeleton / cell division 11:30 – 13:00: Organization – cytoskeleton / intracellular traffic 15:00 – 16:00: Organization – signaling and cell adhesion	G Rivas (CIB) MA Peñalva (CIB) D Lietha (CIB)
22/10/21	10:00 – 11:00: JOURNAL CLUB 0	

Day	Lectures / Activities	Teachers
25/10/21	INTEGRATED STRUCTURAL BIOLOGY (1) 10:00 – 11:00: Introductory remarks (*)	CF Tornero (CIB)
26/10/21	INTEGRATED STRUCTURAL BIOLOGY (2) <u>Sessions at IQFR Main Hall</u> 10:00-10.45: Fundamentals of X-ray Crystallography: from molecules to crystals and beyond” Short application notes (20 min + 10 min for discussion) 11:00-11:30: Membrane Maintenance at Contact Sites 12:00 12:30 Glyco-Synthetic Biology 12:30 13:00 Conformational Versatility in Protein Complexes (*) 14:30-16:30 Practical session: Crystallization, data collection and structure solution	JA Hermoso (IQFR) A Albert (IQFR) J Sanz (IQFR) C Vega (CIB) L Infantes et al(IQFR)
27/10/21	INTEGRATED STRUCTURAL BIOLOGY (3) <u>Morning sessions at IQFR Main Hall</u> 10:00 - 11:00: NMR – fundamentals 11:15 - 12:15: NMR - Nucleic acids 12:30 - 13:30: NMR - Proteins 15:30 - 16:30: NMR – practical session <u>Afternoon session at CIB-Margarita Salas</u>	F Blanco (CIB) C González (IQFR) J Oroz (IQFR) FJ Cañada (CIB)
28/10/21	INTEGRATED STRUCTURAL BIOLOGY (4) 10:00 - 11:00: EM – fundamentals 11:15 – 12:15: EM – reconstructing cellular machines (1) 12:30 - 13:30: EM – reconstructing cellular machines (2) (*) 15:00 - 16:30: EM – practical workshop	E Arias (CIB) CF Tornero (CIB) JM Valpuesta (CNB) F Escolar & R Núñez
29/10/21	MOLECULAR INTERACTIONS: <u>Computational approaches</u> 10:00-11:00: Fundamentals 11:15-12:15: Applications 12:30-13:30: Practical cases	S Martín-Santamaría (CIB)

Day	Lectures / Activities	Teachers
01/11/21	HOLIDAY	
02/11/21	MOLECULAR INTERACTIONS: Biophysical approaches 10:00-11:00: AUC, light scattering 11:15-12:15: Fluorescence spectroscopy 12:30 – 13:30: Calorimetry (ITC), circular dichroism 15:00 – 16:30: Molecular interactions - practical workshop	JR Luque (CIB) S Zorrilla (CIB) B Monterroso (CIB) JR Luque et al
03/11/21	CHEMICAL BIOLOGY 10:00 – 12:00: Chemical biology tools – chemical systems and probes 12:30 – 13:30: Protein Engineering: making α -helices (*)	R. Pérez (CIB) M. Eugenio Vázquez (CiQUS – USC)
04/11/21	IMAGING (1) 10:00-12:00: Confocal and multi-D microscopy	MA Peñalva (CIB)
05/11/21	10:00 – 12:00: JOURNAL CLUB 1	

Day	Lectures / Activities	Teachers
08/11/21		
09/11/21	HOLIDAY	
10/11/21	PROTEIN PRODUCTION SESSION (*) 10:00-10:45: Fundamentals of protein production tools (*) 11:00-11:45: Membrane protein production (*) 11:45-12:30: Antibody production in cell-free systems (*) <i>Lunch break</i> 15:00-15:45: In vitro reconstitution of cell-mimicking systems (*) 15:45-16:30: Protein structural domains: evolutionary significance and biotechnological applications (*)	C Vega & A Albert C Vega (CIB) D Lietha (CIB) FJ Fernández (Abvance) C Fernández (I2SysBio) Julio Polaina (IATA-CSIC)
11/11/21	MICROFLUIDICS in Synthetic Biology 10:00 – 11:00: Fundamentals in microfluidics design (*) 11:15 – 12:15: Microdroplets in microfluidics 12:30-13:30: Microfluidics – Practical session	J Buceta (I2SysBio) B Monterroso (CIB) B Monterroso / S Zorrilla (CIB)
12/11/21	BOTTOM-UP BIOLOGY 10:00 – 11:00: Assembling a minimal cell (C Danelon) (*) 11:00 – 11:30: Colloquium of Danelon with the students (*) 12:00 – 13:00: Synthetic cells – the novo assembly with DNA technology (K Göpfrich) (*) 13:00 – 13:30: Colloquium of Göpfrich with the students (*)	Coord.: G Rivas C Danelon (TU-Delft) K Göpfrich (MPI-Heidelberg)
15/11/21	IMAGING (2) 10:00 – 12:00: Single-molecule and super-resolution tools (*)	M Nollmann (CBS-Montpellier)

16/11/2021 – 10/12/2021		
FUNDAMENTALS 3: Engineering cellular systems (top-down approaches)		
ASSEMBLY & SYNTHESIS (II) + TOOLS (II) + FRONTIERS		
Day	Lectures / Activities	Teachers
	Lectures ASSEMBLY & SYNTHESIS II (in black) Lectures TOOLS II (in blue)	
	L1 (10:00-11:00) L2 (11:15-12:15) L3 (12:30-13:30) L4 (afternoon sessions – OPTIONAL) F3 LECTURES WILL BE AT CNB (c/Darwin, 3 - Campus UAM-CSIC Cantoblanco) (*) Online	
16/11/21 Room B Hall CNB	10:00-11:00: Therapeutic bacteria: from probiotics to synthetic biology 11:15-12:15: Bacteria and immune system interface 12:30-13:30: Synbio of bacterial membrane	LA Fernández (CNB) E Veiga (CNB) D López (CNB)
17/11/21 Room B Hall CNB	10:00-11:00: Amyloids as constructive parts in SynBio 11:15-12:15: Optogenetics 12:30-13:30: Assembling structured microbial ecosystems	R Giraldo (CNB) R Giraldo (CNB) E Martínez (CNB)
18/11/21	10:00-11:00: An introduction to Biomolecular Networks in Synbio (I): from gene-regulatory networks to metabolic pathways. Introduction to Biocircuits (*) 11:15-12:15: Revisiting basic calculus tools: Introduction to ODEs (*) 12:30-13:30: An introduction to Biomolecular Networks in Synbio (II): from the reaction graph to dynamics (*)	I Otero-Muras (I2SysBio) J Buceta (I2SysBio) J Buceta (I2SysBio)
19/11/21		

Day	Lectures / Activities	Teachers
22/11/21		
23/11/21 Room 36 3 rd Floor CNB-annex	10:00-11:00: Analysis of Nonlinear ODEs (and implications in biological function): phase space analysis and bifurcations (I) (*) 11:15-12:15: Analysis of Nonlinear ODEs (and implications in biological function): phase space analysis and bifurcations (II) (*) 12:30-13:30: Analysis of biological networks: a complex-network approach (*)	J Buceta (I2SysBio) J Buceta (I2SysBio) F. Pazos (CNB)
24/11/21 Room 36 3 rd Floor CNB-annex	10:00-11:30: Making Biological Switches (*) (with on-site connection from CNB) 12:00-13:30: Clocks and rulers in life in the context of Synthetic Biology	I Otero (I2SysBio) S Ares (CNB)
25/11/21 Room 36 3 rd Floor CNB-annex	10:00-11:00: Introduction to Metabolic Network Analysis (*) (with on-site connection from CNB) 11:15-12:15: The SEVA project as a standardization approach 12:30-13:30: High-throughput pathway assembly and optimization	P Carbonell (I2SysBio) E. Martínez (CNB) Blas Blázquez (CNB)
26/11/21 Auditorium CIB-MS	12:00 - SEMINAR - Sebastian Maerkl (EPFL). Cell-free synthetic biology: bottom-up construction of complex molecular systems	S Maerkl (EPFL)

Day	Lectures / Activities	Teachers
29/11/21		
30/11/21 Room 36 3 rd Floor CNB-annex	10:00-11:00: Large-scale and high-throughput genome editing 11:15-12:15: Sequence-based assignment of protein functional sites 12:30-13:30: Genome-scale metabolic modeling	Tomás Aparicio (CNB) F. Pazos (CNB) J Nogales (CNB)
01/12/21 Room B hall CNB	10:00-11:30: Bottom up assembly of microbial ecosystem from metagenome data 12:00-13:30: Standards in synthetic biology (*) (with on-site connection from CNB)	J Tamames (CNB) M Porcar (I2SysBio)
02/12/21	Activities to be announced (Journal Club or FRONTIERS-SEMINAR)	
03/12/21		

Day	Lectures / Activities	Teachers
06/12/21	NON LECTIVE	
07/12/21	NON LECTIVE	
08/12/21	NON LECTIVE	
09/12/21	Activities to be announced (FRONTIERS-SEMINAR or Journal Club)	
10/12/21		
	EXAM WEEK (DATE TO BE DEFINED)	
13/12/21		
14/12/21		
15/12/21		
16/12/21		
17/12/21		



Master on Integrative Synthetic Biology

Engineering Molecular and Cellular Systems

1st Edition. 2021-2023

Semester 1 (10/2021 – 02/2022)

M1. FUNDAMENTALS (25 ECTS)

M1a. Basic principles & research topics (15 ECTS): ASSEMBLY, SYNTHESIS, BIOFACTORIES

M1b. TOOLS (10 ECTS)

FUNDAMENTALS 4 (10/01/2022 – 11/02/2022):

BIOFACTORIES + **TOOLS (III)**

Coordination: *BIOFACTORIES* - J Barriuso (CIB) & J Nogales (CNB). *TOOLS (III)* J Nogales (CNB); I Otero & J Buceta (I₂SysBio)

BIOFACTORIES *Synthetic biology for green solutions and global health. Industrial biotechnology: biocatalyst engineering, bioremediation, biodegradation, directed evolution of enzymes. Metabolic engineering. SynBio to combat diseases: bacterial infections, protein-related pathologies. Drug delivery systems*

ENZYMES ENGINEERING FOR BIOTRANSFORMATIONS

1. Enzyme biocatalysis for green chemistry: biotransformations mediated by microbial hydrolases (Ali Prieto CIB) M18 Enero 10:00h
2. Genome mining and rational design of new biocatalysts for lignocellulose biorefineries (FJ Ruiz- Dueñas CIB) M18 Enero 11:15h
3. Design of tailor-made biocatalysts by enzyme directed evolution (S Camarero CIB) X19 Enero 10:00h
4. The revolution of directed evolution (M Alcalde ICP) X19 Enero 11:15h

INDUSTRIAL BIOTECHNOLOGY

5. Metabolic engineering of food-producing yeasts (A Aranda I₂SysBio) M25 Enero 12:30h
6. Carbon dioxide and hydrogen as feedstock for bacteria (G Durante CIB) X26 Enero 12:30h
7. Bioproduction of metallic nanoparticles in bacteria (M Carmona CIB) J27 Enero 12:30
8. Synthetic genomes and their evolution (E García ICP) J3 Feb 12:30h

POLYMERS BIOTECHNOLOGY

9. Domesticating bacteria for tailored bioplastic production (Auxi Prieto CIB-SUSPLAST) M8 10:00h
10. Systems metabolic engineering for bacterial biodegradation/bioconversion of aromatic compounds (E Díaz CIB) M8 Feb 11:15h
11. Engineering microbial cell factories by adaptive laboratory evolution (Isabel Pardo CIB-SUSPLAST) J10 Feb 10:00h
12. Nanotechnological tools: Dendrimeric and magnetic nanoparticles (J Sanz CIB) J10 Enero 11:15h

SYNTHETIC DISTRIBUTED BIOCATALYSIS

13. Biofactories based on synthetic bacterial compartmentalization (D López CNB) M15 Feb 10:00h
14. Synthetic communities-based biofactories (J Nogales CNB) M15 Feb 11:15h
15. Microbial cell to cell communication in biotechnology (J Barriuso CIB) X16 Feb 10:00h

BIOCIRCUITS & FUNCTIONAL MOTIFS

1. Introduction parts, systems and devices (I. Otero)
2. Feedforwards (J Buceta)

BIOCIRCUITS OPTIMIZATION

3. Synthetic Biocircuit Design (I. Otero)
4. Biocircuit Optimizacion (I. Otero)
5. Biocircuit Control (I. Otero)
6. Practical session: Genetic switches (I. Otero)

CHALLENGES IN SYN BIO DESIGN

7. Modeling of intracellular processes. Resource allocation (I. Otero)
8. The role of molecular noise (J. Buceta)

MACROMOLECULAR DYNAMICS

9. Queueing: proteases and degradation as a tool in synthetic biology (Arantxa Urchuegia)
10. Multicellular dynamics and tissue biomechanics (J. Buceta)

RNA-BASED SYN BIO TOOLS

11. Examples of de novo RNA sequences with targeted function (A. Jaramillo)
12. Computational and experimental design of de novo RNA sequences with targeted function (A. Jaramillo)
13. De novo virus design. (A Jaramillo)

SYNTHETIC DISTRIBUTED BIOCATALYSIS

14. Computational Protein Design (P Carbonell)
15. Metabolic Pathway Design (P Carbonell)

10/01/2022 – 18/02/2022: FUNDAMENTALS 4 (BIOFACTORIES + in silico SynBio)	
BIOFACTORIES: Synthetic biology for green solutions and global health. Industrial biotechnology: biocatalyst engineering, bioremediation, biodegradation, directed evolution of enzymes. Metabolic engineering. SynBio to combat diseases: bacterial infections, protein-related pathologies. Drug delivery systems	
TOOLS III: In silico SynBio: model-based circuit design; simulation, optimization and control; cell modelling	
FRONTIERS:	
	Lectures / Activities
	Lectures BIOFACTORIES / Lectures TOOLS III
17/01/22	
18/01/22	L1 (10:00-11:00): Enzyme biocatalysis for green chemistry: biotransformations mediated by microbial hydrolases (A Prieto CIB) L2 (11:15-12:15): Genome mining and rational design of new biocatalysts for lignocellulose biorefineries (FJ Ruiz-Dueñas CIB) L3 (12:30-13:30):
19/01/22	L1 (10:00-11:00): Design of tailor-made biocatalysts by enzyme directed evolution (S Camarero CIB) L2 (11:15-12:15): The revolution of directed evolution (M Alcalde ICP) L3 (12:30-13:30):
20/01/22	
21/01/22	
24/01/22	SEMINAR Yuval ELANI (ICL)
25/01/22	L1 (10:00-11:00): Introduction parts, systems and devices (I. Otero, I2SysBio) L2 (11:15-12:15): Introduction to Feedforwards Loops (J Buceta, I2SysBio) L3 (12:30-13:30): Metabolic engineering of food-producing yeasts (A Aranda I2SysBio)
26/01/22	L1 (10:00-11:00): Synthetic Biocircuit Design (I. Otero) L2 (11:15-12:15): Biocircuit Optimizacion (I. Otero) L3 (12:30-13:30): Carbon dioxide and hydrogen as feedstock for bacteria (G Durante CIB)
27/01/22	L1 (10:00-11:00): Biocircuit Control (I. Otero) L2 (11:15-12:15): Practical session: Genetic switches (I. Otero) L3 (12:30-13:30): Bioproduction of metallic nanoparticles in bacteria (M Carmona CIB)
28/01/22	
31/01/22	SEMINARIO: Challenges in synbio design (III) Resource allocation (Thomas Gorochowskil)
01/02/22	L1 (10:00-11:00): Modeling of intracellular processes. Resource allocation (I. Otero) L2 (11:15-12:15): The role of molecular noise (J. Buceta) L3 (12:30-13:30):
02/02/22	L1 (10:00-11:00): Queueing: proteases and degradation as a tool in synthetic biology (A. Urchuegia, I2SysBio) L2 (11:15-12:15): Multicellular dynamics and tissue biomechanics (J. Buceta) L3 (12:30-13:30): Examples of de novo RNA sequences with targeted function (A. Jaramillo, UV)
03/02/22	L1 (10:00-11:00): Computational and experimental design of de novo RNA sequences with targeted function (A. Jaramillo) L2 (11:15-12:15): De novo virus design. (A Jaramillo) L3 (12:30-13:30): Synthetic genomes and their evolution (E García ICP)
04/02/22	

07/02/22	SEMINAR – Tobias ERB (MP)
08/02/22	L1 (10:00-11:00): Domesticating bacteria for tailored bioplastic production (Auxi Prieto CIB-SUSPLAST) L2 (11:15-12:15): Systems metabolic engineering for bacterial biodegradation/bioconversion of aromatic compounds (E Díaz CIB) L3 (12:30-13:30):
09/02/22	L1 (10:00-11:00): Computational Protein Design (P Carbonell, UV) L2 (11:15-12:15): Metabolic Pathway Design (P Carbonell) L3 (12:30-13:30):
10/02/22	L1 (10:00-11:00): Engineering microbial cell factories by adaptive laboratory evolution (Isabel Pardo CIB-SUSPLAST) L2 (11:15-12:15): Nanotechnological tools: Dendrimeric and magnetic nanoparticles (J Sanz CIB) L3 (12:30-13:30): L4 (15:00-16:00): Seminario: Synthetic gene regulatory networks to study pattern formation and evolution (Yolanda Schaerli)
11/02/22	Seminario: Synthetic gene regulatory networks to study pattern formation and evolution (Y Schaerli)
14/02/22	
15/02/22	L1 (10:00-11:00): Biofactories based on synthetic bacterial compartmentalization (D López CNB) L2 (11:15-12:15): Synthetic communities-based biofactories (J Nogales CNB) L3 (12:30-13:30):
16/02/22	L1 (10:00-11:00): Microbial cell to cell communication in biotechnology (J Barriuso CIB) L2 (11:15-12:15): L3 (12:30-13:30):
17/02/22	L1 (10:00-11:00): L2 (11:15-12:15): L3 (12:30-13:30):
18/02/22	

21-23/02/2022: EXAMS 2 (FUNDAMENTALS 4)	
Day	Lectures / Activities
21/02/22	
22/02/22	
23/02/22	
24/02/22	NON LECTIVE
25/02/22	NON LECTIVE
28/02/22: DEADLINE EVAL FUNDAMENTALS	