ANNEXE

Maquette Pédagogique Détaillée

MASTER **M**icroalgae **B**ioprocess **E**ngineering « **MBE** »

Polytech Nantes

Etablissements :	**Université de Nantes & Ecole des Mines Nantes**
Composante :	**Ecole Polytechnique de l'Université de Nantes**
Responsabilité et portage du projet :	**Polytech-Nantes Département GPB / Laboratoire GEPEA-CNRS**
Contact :	**El-Khider SI-AHMED, Université de Nantes, Polytech**

Program structure (MBE)

2nd year – Semester 1

UV ST9 – Biology of microalgae	**4 ECTS**
UV ST10 – Industrial valorization of microalgae	**2 ECTS**
UV ST11 – Biochemical and Metabolic Engineering	**5 ECTS**
UV ST12 – Microalgae culture and photobioreactor engineering	**4 ECTS**
UV ST13 – Harvesting and Biorefinery of microalgae	**5 ECTS**
UV ST14 – Process integration and operation of microalgae exploitation facilities	***5 ECTS***
UV PR3 – Project	**3 ECTS**
UV LV3 – Language	**2 ECTS**
2nd year – Semester 2	
FEM – Master Thesis	**30 ECTS**

Note : M1 PME program structure

1st Year-

Semester 1 *"Basic Sciences*	
UV ST1 Transfer Phenomena	**4 ECTS**
UV ST2 Introduction to Energy and Environmental Issues	**3 ECTS**
UV MIG 1 Foundations in Mathematics	**4 ECTS**
UV MIG 2 Foundations in Economics	**3 ECTS**
UV MIG 3 Putting Innovation Into Practice	**3 ECTS**
UV SSG1 Management 1: Foundations	**4 ECTS**
UV SSG2 Organization Science	**3 ECTS**
UV PR1 Project 1	**4 ECTS**
UV LV1 Language 1	**2 ECTS**

Semester 2 *"Eco Technologies and Environment Process Engineering"*	
UV ST3 Environment and Process Engineering	**3 ECTS**
UV ST4 Incineration and Waste Minimization	**3 ECTS**
UV ST5 Air & Soil Remediation	**3 ECTS**
UV ST6 Water Treatment Processes	**4 ECTS**
UV ST7 Water Strategies and Innovation	**3 ECTS**
UV ST8 Process Modeling, Simulation and Control	**4 ECTS**
UV SSG3 Management 2 : Risk Analysis and Environment Management	**4 ECTS**
UV PR2 Project 2	**4 ECTS**
UV LV2 Language 2	**2 ECTS**

Spécialité : MBE	Parcours :	Semestre : 3

Teaching Unit	Lectures	Tutorials	Lab	Project	Personnal Work	ECTS	Lecturers
UV ST9 – Biology of microalgae	44	6	16	0	30	**4**	In charge of UV Dominique Grizeau
Overview of microalgal taxonomy and identification	*6*		*6*		*6*		Vona Meleder
Physiology and metabolism of microalgae	*24*		*4*		*6*		Benoit Schoefs
Genetic engineering of microalgae	*8*				*6*		Justine Marchand
Kinetics of photoadaptation		*6*	*6*		*6*		Jean-Luc Mouget
Microalgae lipids	*6*				*6*		Yonghua Li-Beisson

Prerequisites:

Teaching Assessments		
	Quizzes	4
	Mid-term exam	
	Final Exam	1

Objectives: Providing students basics for photosynthetic microorganisms (microalgae and cyanobacteria) physiology. This UV gives the core knowledge in biology for microalgae culture and valorization. All necessary aspects will be covered, from taxonomy-identification of strains to microalgae metabolism and photosynthesis.

Content: Overview of microalgal taxonomy, strain conservation, identification. Primary and secondary metabolisms, and microalgae pigments/lipids. Photosynthetic reactions and physiological responses to environmental stresses. Genetic engineering of microalgae.

Teaching Unit	Lectures	Tutorials	Lab	Project	Personnal Work	ECTS	Lecturers
UV ST10 – Industrial valorization of microalgae	28	0	0	0	7	**2**	**in charge of the UV:** Pascal Jaouen
Industrial interest of microalgae and cyanobacteria	*8*				*2*		*J.Legrand*
Current and future markets	*4*				*1*		*Olivier Lépine*
Industrial exploitation units and current valorizations	*10*				*2*		*Industrial partners AlgoSource, etc..*
Regulation rules	*6*				*2*		
Prerequisites:							
Teaching Assessments	Quizzes	4					
	Mid-term exam						
	Final Exam						
Objectives: Providing students examples and constraints of industrial valorization of microalgae. Current and future markets will be covered, from raw biomass use to high-value products commercialization, with a special attention on regulation rules related to the introduction of new biomass/products on markets. Examples of current industrial exploitation units will also be given, along with their operating/building constraints.							
Content: Industrial interest of microalgae and cyanobacteria, Current and future markets, Regulation rules, Industrial exploitation units, Examples of current valorizations. This course is mainly covered by industrialist of microalgae field (AlgoSource ; MicroPhyt ; Roquette Frères,)							

Teaching Unit:	Lectures	Tutorials	Lab	Project	Personnal Work	ECTS	Lecturers
UV ST11 – Biochemical and Metabolic Engineering	**30**	**20**	**20**	**0**	**40**	**5**	**in charge of the UV:** Guillaume Cogne / Olivier Gonçalves
computational approaches in metabolic engineering	*15*	*10*	*10*		20		*G. Cogne*
omics technologies	*15*	*10*	*10*		20		*O. Gonçalves*
Prerequisites:							
Teaching Assessments	Quizzes	1					
	Mid-term exam						
	Final Exam	1					
Objectives: Providing students basics for quantitative physiology depicting the flow, or flux, of mass through the metabolic network of living systems with the purpose of redirecting the (carbon) flux towards desired metabolic products. These objectives will be achieved by both a deep understanding of fundamental biology (genomics, proteomics, metabolomics and fluxomics) and the efficient treatment of large sets of data by a range of mathematical tools (linear algebra, numerical and statistical methods, group theory, topology and graph theory, etc.).							
Content: Metabolite balancing and metabolic flux analysis (MFA), computational approaches, linear programming, thermodynamic analysis of biochemical reaction networks, omics technologies							

Teaching Unit	*Lectures*	*Tutorials*	*Lab*	*Project*	*Personnal Work*	*ECTS*	*Lecturers*
UV ST12 – Microalgae culture and photobioreactor engineering	**30**	**6**	**20**	**0**	**27**	**4**	**in charge of the UV**: Jeremy Pruvost
Microalgae culture, PBR engineering	15	6	20		20		*J.Pruvost*
Hydrodynamics and gas-liquid mass transfer	10				5		*C.Gentric*
Culture monitoring	5				2		*B. Le Gouic*
Prerequisites:							
Teaching Assessments	Quizzes	2					
	Mid-term exam	1					
	Final Exam						
Objectives: To learn the knowledge for the setting and optimization of microalgae cultivation systems (open systems and photobioreactors technologies).							
Content: Existing cultivation technologies (open and closed systems), cultivation procedures, theoretical and practical aspects related to microalgae cultivation systems engineering and operation (engineering/design/scaling tools, optimization of biomass and metabolites production, practical operation and supervision of cultivation units).							

Teaching Unit	Lectures	Tutorials	Lab	Project	Personnal Work	ECTS	Lecturers
UV ST13 – Harvesting and biorefinery of microalgae	**20**	**15**	**16**	**4**	**28**	**5**	**in charge of the UV:** Luc Marchal
Cell disruption, solvent extraction	*8*	*6*	*4*	4	*10*		*L Marchal*
Harvesting	*4*	*3*	*4*		*6*		*M Frappart*
(membrane	*4*	*3*	*4*		*6*		*E Couallier*
membrane	*4*	*3*	*4*		*6*		*A Massé*
Prerequisites:							
Teaching Assessments	Quizzes	4					
	Mid-term exam						
	Final Exam	1					
Objectives: To know the available techniques, to understand their main engineering aspects and to be able to propose a process scheme for a microalgae metabolite valorization.							
Content: Fundamentals of main unit operations encountered in microalgae harvesting, cell disruption and metabolites extraction will be presented. This comprises centrifugation, membrane concentration or fractionation, high pressure or bead milling cell disruption and solvent extraction. Students will have to manage in small groups a biorefinery practical case from the photobioreactor to the fraction of interest.							

Teaching Unit	Lectures	Tutorials	Lab	Project	Personnal Work	ECTS	Lecturers
UV ST14 – Process integration and operation of microalgae exploitation facilities	**21,5**	**11**	**25**	**15**	**41**	**5**	**in charge of the UV:** Patrick Legentilhomme & Walid Blel
System modelling: Dynamic control of cultivation units	7,5	11		15	*20*		*M.Titica*
System modelling :process design and plan efficiency improvement	*4*		*9*		*6*		*W. BLEL and P. Legentilhomme*
System modelling: process integration and project economic evaluation	*10*		*16*		*15*		*S. RIOS and T. Rinaldi*

Prerequisites:

Teaching Assessments	Quizzes	3
	Mid-term exam	
	Final Exam	

Objectives: To learn the knowledge for the use and the development of optimization models embedded in a more general software tool to help the plant managers in their daily decision-making in the different operation units of microalgae from the cultivation to the exploitation. Process modelling and optimization include unit operations in addition to the reduction of the environmental impact and the energy consumption of microalgae cultivation and exploitation.

Content:

System modelling (process integration and project economic evaluation)

SuperPro Designer facilitates modeling: evaluation and optimization of integrated processes from the cultivation to the production of commodity biochemicals, such as biofuels. This explains why it is so important for a new engineer to master the skills of preliminary process design and cost estimation.

SchedulePro: is a finite capacity scheduling (FCS) tool for batch and semi-continuous manufacturing processes. It handles resources such as equipment, working areas, labor, materials, utilities and inventory capacity. It allows for interruptions in the availability of resources to account for shift schedules, holidays, and planned maintenance.

System modelling (process design and plan efficiency improvement)

Prosim: this software allows chemical process simulation and consulting services to the energy, oil, gas, chemical, petroleum, pharmaceutical, food and beverage and other processing industries.

For microalgae application, sequential stages of esterification and then transesterification will be studied to convert the microalgae oil in biodiesel, glycerol, and water. The economic feasibility of biodiesel and bioethanol productions from microalgae can be discussed from the simulation of different production processes.

System modelling (Dynamic control of cultivation units)

In this module we consider process control in the context of the operability of an integrated bioprocess using microalgae for producing biomass with specified composition, and or as an effluent treatment step. Having covered the essential aspects of control theory, we will focus on model based control technics that will be designed and implemented in simulation for evaluating dynamic performances (operation during transitions and under fluctuating operating conditions).

At the end of this course, students will be able to propose and implement in simulation using Matlab and Simulink (or equivalent) for testing their performances before to be applied on a real process.

Teaching Unit	Lectures	Tutorials	Lab	Project	Personnal Work	ECTS	Lecturers
UV PR3 – Project	**0**	**0**	**0**	**20**	**30**	**3**	**Lecturers in charge of the UV:** Jeremy Pruvost (Luc Marchal Olivier Goncalves

Prerequisites:

Teaching Assessments	Quizzes	
	Mid-term exam	
	Final Exam	

Objectives: To be able to gather relevant information about a given subject, to be able to provide pedagogical materials, to be able to "teach" the audience

Content:

Case 1**:** A part of a course given by a regular lecturer is identified to become a subject for a group of 3 students (and removed from his/her course). The group have to work in strong link with the lecturer in order to prepare and present this part of the course to the rest of the class. As for the 1st semester, by following this path (moreover in case of a 4th semester done in a company), the Master done by the students will be similar to a *Master of Engineering*.

Case 2: As mentioned for the 1st semester, in link with the pedagogical team, it can be possible for a selected number of voluntary students to design this Project as a research activity. The subject must be in link with the research activity of the GEPEA laboratory in order to ensure a good supervision of the students. Added to a 4th semester done in a laboratory, these 3 research projects provide the master a research touch similar to the one provided in a *Master of Science*.

Teaching Unit	Lectures	Tutorials	Lab	Project	Personnal Work	ECTS	Lecturers
UV LV3 – Language	**10**	**10**	**18**		**10**	**2**	

Prerequisites:

Teaching Assessments	Quizzes	2
	Mid-term exam	
	Final Exam	

Objectives: To make the students able to communicate in French in current life, for job interviews and in professional situations (meeting and working reports). To support their social, cultural and professional integration by a better knowledge of French culture. At the end of the course, students will get a French diploma (TEF, Test d'Evaluation de Français), assessing their language proficiency.

For native French speakers, French course is replaced with English course.

Content: Intensive trainings are scheduled periodically along the 3 academic semesters of the Master course, as well as regular classes, once a week. Students are divided into small groups, depending on their French level. Oral participation is favored. Visits and social events are also organized to give the students the opportunity to meet French people, and discover some cultural aspects of Nantes and its region.

Teaching Unit	Lectures	Tutorials	Lab	Project	Personnal Work	ECTS	Lecturers
FEM – Master Thesis					**900**	**30**	

Prerequisites:

Thesis defense

Objectives: Crowning achievement of the studies, the professional project is the springboard towards professional activity. According to one's personal career objective, every student can choose to carry out either an industrial or research project for a period of 6 months. The internship gives the opportunity to get a consistent professional experience as an engineer in a company, an institution or a laboratory, having activities in the microalgae exploitation area. The mission assigned must answer a real industrial need, whilst the results obtained have to bring a real added value. Aside demonstration of the ability of the student to use technical and engineering knowledge, the exercise enables to evaluate in a professional situation the individual management skills, as well as the inter and intra personal qualities.

Content:

The subject must include:

- Technical, scientific achievements (conception, design, optimization, improvement of processes, industrial units, …)
- And/or implementation of new methodologies (control, procedure optimization, …)
- Analysis of the global context, by considering the economic, financial, social, human, cultural, geographical, policy and regulations aspects.

All along the duration of the project, the student is supervised by two tutors:

- One in the company or the laboratory, who defines the missions and guarantee an adequate environment for the development of the student's work
- Another one from the Polytech'Nantes Institute, who (as an academic referee), may advise or support the student during the project.

At the end of the project, a Master thesis is submitted by the student to both the tutors. This is followed with an oral defense in front of a jury. The global evaluation of the exercise is based on the partial assessments made by each tutor and the jury of the defense.