Course title: Bioprocess Engineering and Environmental Biotechnology							
Course code: BBP 165		**No. of credits:** 3		**L-T-P:** 30-15-0		**Learning hours:** 45	
Pre-requisite course code and title (if any): Science graduate							
Department: Department of Biotechnology							
Course coordinator: Dr. Chaithanya Madhurantakam				**Course instructor** : Dr. Chaithanya Madhurantakam			
Contact details: chaithanya.madhurantakam@terisas.ac.in							
Course type: Elective				**Course offered in:** Semester 3			

Course description:

The course aims to provide students with methods employed in bioprocess engineering and environmental biotechnology. The course is structured to provide the students with fundamental concepts connected to systems metabolic engineering, bio separation, bioprospecting and bioprocessing, biofuels, and bioreactors. This course will offer the students a broad sense of understanding on emerging methods used in food and industrial biotechnology using different case studies.

Course objectives:

1. Acquainting students with concepts applied in the metabolic engineering and synthetic biology.
2. Familiarization students with ***upstream and downstream processing*** of molecules using bioreactors.
3. Providing information on new applications of biotechnology in the food industry.
4. Familiarizing the students with methods of microbial waste management and microbial treatment methods.

Course contents

Module	Topic	L	T	P
1	**Metabolic Engineering and Synthetic Biology**	6	3	0
	Rational genome modifications, strain analysis and characterization, DNA assembly technologies for libraries construction: Homology based (Gibson Assembly, Circular Polymerase Extension Cloning - CPEC, Yeast Transformation-associated recombination- TAR, seamless ligation cloning extract- SLiCE, Ligase Cycling Reaction- LCR), Restriction based (Biobricks, Golden Gate), Recombinase technologies (Gap-repair, Lambda-red, Multiplex Automated Genome Engineering -MAGE and CRISPR-Cas9)			
2	**Bioprocess Engineering**	8	4	0
	Bioreactor Engineering, Anaerobic and Aerobic Bioreactors; Design, Operation, monitoring and modeling of bioprocesses; Upstream versus Downstream processing; Biochemical and biological processes for conversion of biomass to biofuels (ethanol, biogas etc.) and value-added chemicals (biochemicals and biopolymers); Circular Bioeconomy versus Linear Bioeconomy, Basics of Life Cycle Analysis (LCA) and Techno-economic Analyses (TEA), Bioprocess scaleup and Technology Transfer			
3	**Industrial Biotechnology**			
	Enzymes and Microbial Cell Factories: Engineering enzymes, Approaches for improving the enzymes functionalities, Enzyme production, purification and immobilization, Enzymes stabilization and formulation preparations, Green industrial processes, Microbial cell factories, High value drugs and nutraceuticals, Bioprospecting and Bioprocessing: Cell Culture Technology, immobilized cell technology	4	2	0

	Food Nano-Biotechnology: Engineered nanomaterials for high value food production, edible nano-coatings for perishable fruits and vegetables, micro/nano encapsulation of active food ingredients, nanomaterials for food packaging, nano-sensors for food quality and security.	4	2	0
4	**Environmental Biotechnology**			
	Fundamentals of Environmental Biotechnology; Pollution abatement (wastewater, biomass waste-agrowaste, sludges, industrial waste): Bioremediation of xenobiotics, Organic waste management: Macrophyte Treatment Systems (MaTS), Algal Treatment Systems (ATS) for resource recovery from wastewater, Integrated resource recovery (IRR), Biological Treatment Methods: *in situ* techniques (biosparging, bioventing, injection, and recovery method), *ex situ* methods (land farming, soil banking and soil slurry method), Bioleaching and Biomining, microbial catalyzed electrochemical approaches, phytoremediation; Biomass based biorefineries; Environmental monitoring (Bioindicators –Biomarkers –Biosensors –Biomonitoring –Polluted environment – Short and long term monitoring of remediated sites)	8	4	0
	Total	**30**	**15**	**0**

Evaluation criteria:

1. Minor test 1 30%
2. Minor test 2 30%
3. Major test (end semester) 40%

Learning outcomes:

1. Able to acquire a detailed understanding of various tools and methods employed for metabolic engineering. (Minor test 1)
2. Able to gain deep insight into the design and functioning of bioreactors used for upscaling of microbes/products. (Minor test 2)
3. Conceptual understanding about enzymes and applications in industry (Minor test 2)
4. Develop understanding and production mechanism on various high value drugs and biobased molecules, and concepts of circular bioeconomy and life cycle analysis. (Minor test 2 and Major test)
5. Able to capture the concepts of bioremediation, waste management and integrated resource recovery methods. (Major test)

Pedagogical Approach:

1. Lectures and tutorials supported by critical appraisal of original research articles as case studies.
2. Peer-reviewed research articles to discuss on various modules in the course.

Skill Set:

1. Knowledge of tools and techniques used in metabolic engineering and synthetic biology based on case studies provided.
2. Knowledge of biobased molecules, biofuels, and production mechanisms.
3. Knowledge of techniques employed in bioremediation, bioleaching and biomining.
4. Gain knowledge about nanotechnology and its interdisciplinary endeavours in food biotechnology sectors

Employability:

The course will provide skillsets and knowledge that may play key role to get employed in Universities, R & D industry, Medical centres/Colleges, Research Institutes and Diagnostic centres apart from specialized units like pharma, breweries, food, dairy and agri sectors.

Materials:
Suggested Readings

1. Stephanopoulos, G. (2012). Synthetic biology and metabolic engineering. *ACS Synth. Biol.* 1, 514–525. doi: 10.1021/sb300094q
2. Lee, S., Mattanovich, D. & Villaverde, A. Systems metabolic engineering, industrial biotechnology and microbial cell factories. Microb Cell Fact 11, 156 (2012). https://doi.org/10.1186/1475-2859-11-156.
3. Choi KR, Jang WD, Yang D, Cho JS, Park D, Lee SY. Systems Metabolic Engineering Strategies: Integrating Systems and Synthetic Biology with Metabolic Engineering. Trends Biotechnol. 2019 Aug;37(8):817-837. doi: 10.1016/j.tibtech.2019.01.003. Epub 2019 Feb 5. PMID: 30737009.
4. Wang, J. W., Wang, A., Li, K., Wang, B., Jin, S., Reiser, M., et al. (2015). CRISPR/Cas9 nuclease cleavage combined with Gibson assembly for seamless cloning. *BioTechniques* 58, 161–170. doi: 10.2144/000114261
5. Liu, R., Bassalo, M. C., Zeitoun, R. I., and Gill, R. T. (2015). Genome scale engineering techniques for metabolic engineering. Metab. Eng. 32, 143–154. doi: 10.1016/j.ymben.2015.09.013
6. Nathan Danielson, Sarah McKay, Paul Bloom, Jennifer Dunn, Neal Jakel, Timothy Bauer, John Hannon, Michael C. Jewett, and Brent Shanks.Industrial Biotechnology.Dec 2020.321-332.http://doi.org/10.1089/ind.2020.29230.nda
7. Brooks, R., Chambers, M., Nicks, L. and Robonson, B. (1998) Phytomining, Trends in Plant Science, 3:359–62.
8. M. A.V. Axelos and M. V. Voorde (2017), Nanotechnology in Agriculture and Food Science, Wiley-VCH Verlag GmbH.
9. Q. R. Huang (2012), Nanotechnology in the Food, Beverage and Nutraceutical Industries, Woodhead Publishing, Cambridge, UK
10. Bailey, J.E. and Ollis, D.F. Biochemical Engineering Fundamentals, 2nd Ed., McGraw-Hill, p163-172. 1986.
11. Ricky Lambert, Bioprocess Engineering, Kaufman Press, ISBN: 9781666888027, 2022.

Additional information (if any): The course framework and modules were designed by **Dr. Chaithanya Madhurantakam.**
Inputs and suggestions were received from following adjunct faculty (TERI)
1**. Dr. Amritpreet Kaur Minhas** (Associate Fellow, Centre for Excellence in Agrinanotechnology Sustainable Agriculture, TERI)
2**. Dr. Ruchi Agrawal** (Associate Fellow, Centre for Excellence in Agrinanotechnology Sustainable Agriculture, TERI)
3**. Dr. Shruti Shukla** (Fellow/ Senior Scientist, TERI)

Student responsibilities:
1. Study of course material as specified by the instructor.

Course Reviewers:

1. **Dr. Vinay Kumar Tyagi**, Scientist D, Environmental Hydrology Division, National Institute of Hydrology (NIH), Roorkee-247667, Uttarakhand, INDIA.
2. **Dr. Vivekanand V**, Ramalingaswami fellow, Biofuels Lab, Centre for Energy and Environment, Malaviya National Institute of Technology Jaipur JLN Marg Jaipur-302 017, Rajasthan, INDIA.
3. **Dr. Banwari Lal** (Senior Director, Environmental & Industrial Biotechnology, TERI).