JSS Academy of Higher Education & Research

Department of Microbiology

MSC IN SYNTHETIC BIOLOGY

SYLLABUS

2023

MSC IN SYNTHETIC BIOLOGY- LOCF SYLLABUS

Semester I	Semester II	Semester III	Semester IV
Core Papers DSC 01 Molecular Biology & Genetic Engineering DSC 02 Introduction to Synthetic Biology DSC 03 Genome Editing Technologies Practical 01 Practical 02	**Core Papers** DSC 04 Computational Synthetic Biology DSC 05 Genome/Nucleic acid and Protein Engineering DSC 06 Metabolic Engineering Practical 03 Practical 04	**Core Papers** DSC 07 Bioengineering/ Stem cells & Tissue Engineering DSC 08 Vaccine Platforms & Biosimilars DSC 09 Industrial & Agricultural Synthetic Biology Practical 05 Practical 06	Dissertation
AECC Principles of Statistics SEC 01 Research Methodology I	**Electives** DSE 1A Nucleic acid sequencing techniques or DSE 1B Bioinformatics DSE 2A Proteomics Or DSE 2B Synthetic RNA Biology & Transcriptomics SEC 02 Research Methodology II	**Electives** DSE 3A Engineered Cell based therapeutics & Synthetic Organs DSE 3B Synthetic Biology Research & Entrepreneurship SEC 03 Advanced Instrumentation & Analytical techniques Internship/ Summer report	

SEMESTER I

DSC 01- MOLECULAR BIOLOGY & GENETIC ENGINEERING

UNIT - I FUNDAMENTALS OF MOLECULAR BIOLOGY

DNA structure and Replication: DNA as Genetic material, Chemistry of DNA, Modes of DNA Replication, Enzymes and molecular mechanism of DNA replication, Differences in prokaryotic and eukaryotic DNA replication. DNA Damage and Recombination: Types of DNA damage - deamination, oxidative damage, alkylation and pyrimidine dimers; DNA repair – mismatch, short patch repair, nucleotide/base excision repair, recombination repair and SOS repair. Molecular basis of mutation.

UNIT-II GENE EXPRESSION AND PROTEIN SYNTHESIS

Structure of RNA- Classes of RNA, Chemistry of RNA. Transcription in prokaryotes and eukaryotes, Eukaryotic transcription factors. RNA processing, Ribozymes, Antisense RNA, Inhibitors of transcription and their mechanism of action. Translation: Role of ribosome and different types on RNA in protein synthesis, basic feature of genetic code, mechanism of initiation, elongation and termination, Translational control and post-translational events.

UNIT - III FUNDAMENTALS AND TOOLS OF GENETIC ENGINEERING

Definition, concepts and scope of genetic engineering. Historical perspectives and milestones in Recombinant DNA Technology. Tools in Genetic Engineering: Enzymes in genetic engineering. Cloning vectors: Ti Plasmid, pBR322, pUC –series. Phage vectors-M13 phage vectors, Cosmids-Types, Phasmids or Phagemids, Shuttle vectors. YAC and BAC vectors, Adenoviruses, Retroviruses, Synthetic construction of vectors, Ti cloning vector

UNIT - IV TECHNIQUES IN GENETIC ENGINEERING

Preparation, Manipulation and Insertion of desired DNA into vector. Introduction of DNA into host cells – Transformation, Transduction, Transfection, Microinjection, Biolistics, Electroporation, Liposome fusion. Shotgun cloning. Genomic and c-DNA Libraries. Cloning and expression in bacteria, yeasts, Identification and Selection of recombinants. Applications of gene cloning in Biotechnology, Medicine, Agriculture, Forensic Science, Antisense technology; Restriction and regulation for the release of GMOs into Environment. Ethical, Legal, Social and Environmental Issues related to rDNA technology.

DSC 02 - INTRODUCTION TO SYNTHETIC BIOLOGY

UNIT - I FUNDAMENTAL CONCEPTS IN SYNTHETIC BIOLOGY

Definition and historical development of synthetic biology, Overview of the key components: DNA, RNA, proteins, and cells; Synthetic biology approaches and applications. Parts, devices, systems, modules, chassis, orthogonality, retroactivity. Genetic circuits, logic gates and logic networks. DNA reading and DNA assembly, Assembly standards. Gene expression flow and its synthetic variants. Alternative genetic codes.

UNIT - II TOOLS USED IN SYNTHETIC BIOLOGY

DNA manipulation techniques: PCR, cloning, and gene synthesis; Genetic circuits and genetic parts; Introduction to genome editing techniques: CRISPR-Cas9; Standard biological parts and devices, Modularity and abstraction in genetic engineering, Computational tools for designing genetic circuits; Cell signaling and communication, Metabolic engineering and pathway design, Synthetic microbial communities.

UNIT - III APPLICATIONS OF SYNTHETIC BIOLOGY

Gene therapies. Metabolic engineering – products, CAD of new pathways and multi-objective optimization. Bioproduction of chemicals, fuels, and pharmaceuticals; Biosensors and bioactuators & Microbiome engineering: Therapeutic strains & Probiotics. Leveraging intracellular architecture. Scaling-up and biomanufacturing.

UNIT - IV BIOSAFETY, BIOSECURITY & IP

Socio-economic ramifications. SynBio and SDGs. Biomaterials and Engineered living materials (ELM). Genetic firewalls, containment. Barcoding & watermarking genomes. Global SynBio-based environmental interventions. Programming HGT. Biosecurity and biocontainment, Ethical, Legal, and Social Implications of Synthetic Biology - Public perception and acceptance of synthetic biology, Regulatory frameworks and ethical considerations & Intellectual property and patent issues.

DSC 03 - GENOME EDITING TECHNOLOGIES

UNIT - I PRINCIPLES OF GENOME EDITING TECHNIQUES

Principles and applications of Clustered regularly interspaced short palindromic repeats (CRISPR)-CRISPR-associated protein 9 (Cas9), transcription activator-like effector nucleases (TALENs), and zinc-finger nucleases (ZFNs). Artificial transcription factors.

UNIT - II TOOLS FOR MODULATING GENE EXPRESSION

Restriction endonucleases, Riboswitches - ribosome-dependent ribo-regulator (LRR). Regulation of Gene expression: Regulation of gene expression in prokaryotes and Eukaryotes. Regulation of gene expression in bacteriophages, gene silencing – gene regulation after transcription.

UNIT - III GENOME EDITING APPLICATION

Engineering Cell Lines and Organisms, Agriculture and Food Production: Enhance crop traits, improving yield, disease resistance, and nutritional content. Livestock and Animal Husbandry: Enhance livestock traits - disease resistance, growth rates, and meat quality. Industrial Biotechnology: Microbe based biofuel production, waste remediation, and enzyme production. Environmental Conservation. Engineer fibers with improved properties for the textile industry. Renewable Energy - biomass conversion and increase biofuel yield.

UNIT - IV THERAPEUTIC GENOME EDITING

Pharmaceutical and Biotechnology: drug discovery, development, and production. Disease models for research, validate drug targets, and engineer cell lines and transgenic organisms for the production of therapeutic proteins. Genome editing in personalized medicine. Gene therapy/ immunotherapy for cancer research, cardiovascular and Metabolic diseases, neurodegenerative diseases, inherited diseases. Challenges in therapeutic targeting. Ethical issues.

AECC - PRINCIPLES OF STATISTICS

UNIT - I DESCRIPTIVE STATISTICS

Importance and Scope of Statistics, Data Types, Variables, Frequency Distribution, Graphical Representation Methods (Histogram, Bar Charts, Pie Charts), Measures of Center Tendency (Mean, Median, Mode,) and Dispersion (Standard Deviation, Variance) Advantages and Disadvantages.

UNIT - II PROBABILITY

Basic Terminology: Trial, Events, Sample Space and Sample Points, Basic Laws of Probability, Types of Probability, Normal probability curve, Standard Normal Distribution, Bayes theorem - simple problems.

UNIT - III SAMPLING METHODS

Concept of Population, Sample, Sampling, Sample Size, Sampling Error, Advantages and Disadvantages of Sampling Method, Types of Random Sampling Methods – SRS, Stratified Random Sampling, Systematic Random Sampling and Cluster Sampling.

UNIT - IV TESTING OF HYPOTHESES

Statistical Hypotheses-Null and Alternative, Level of Significance, Type I and Type II Error, P Value, Degrees of Freedom, Chi-Square Test, Student's t Test: One Sample t Test and Paired and unpaired t Test, Analysis of Variance. Correlation-Karl Pearson's and Spearman's rank correlation. Regression Analysis.

SEC 01- RESEARCH METHODOLOGY I

UNIT - I RESEARCH TYPES

Motivation and objectives – Research methods vs. Methodology. Types of research – Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical, concept of applied and basic research process, criteria of good research.

UNIT - II FORMULATING RESEARCH PROBLEMS

Defining and formulating the research problem, selecting the problem, necessity of defining the problem, importance of literature review in defining a problem, literature review- primary and secondary sources, reviews, monograph, patents, research databases, web as a source, searching the web, critical literature review, identifying gap areas from literature and research database, development of working hypothesis.

UNIT - III RESEARCH DESIGN

Meaning, Need, Features of Good Design, Concepts, Types. Basic principles of Experimental Design, various methods of Research. Survey, Philosophical, Historical, Experimental, Causal Comparative, Genetic, Case Studies.

UNIT - IV TOOLS FOR DATA COLLECTION

Collections of Primary Data, Collection of Data through questionnaire and Schedules, other Observation Interview Methods, Collection of Secondary Data, Selection of appropriate method for data collection, Case Study, Focus Group Discussion, Techniques of developing research tools, viz. Questionnaire and rating scales etc. Reliability and validity of Research tools.

PRACTICAL 01: MOLECULAR BIOLOGY AND GENETIC ENGINEERING

1. Polymerase Chain Reaction (PCR) - Amplify a specific DNA fragment using PCR, Design primers and optimize PCR conditions, Analyze the PCR products using agarose gel electrophoresis.
2. 2. Restriction Digestion and Plasmid Mapping - Perform restriction enzyme digestion of a plasmid DNA, Analyze the digested fragments using agarose gel electrophoresis, Predict and draw the plasmid map based on the restriction pattern.
3. Transformation and Recombinant Protein Expression - Transform *E. coli* cells with a recombinant plasmid containing a reporter gene (e.g., GFP), Induce protein expression and visualize the fluorescent protein, Confirm successful transformation by plating on selective media.
4. DNA Cloning and Plasmid Construction - Clone a DNA fragment into a plasmid vector, Perform ligation reaction and transform competent cells, Verify successful cloning by colony PCR and DNA sequencing.
5. RNA Extraction and Reverse Transcription - Extract RNA from cells or tissues, Perform reverse transcription to synthesize cDNA, Analyze gene expression by quantitative PCR (qPCR) or RT-PCR.
6. Gene Expression Analysis by Western Blotting - Extract proteins from cells or tissues, Separate proteins by SDS-PAGE, Transfer proteins to a membrane and detect target proteins using specific antibodies.

PRACTICAL 02 - GENOME EDITING TECHNOLOGIES

1. Gene Knockout by CRISPR/Cas9 - Design guide RNAs (gRNAs) for targeted gene knockout using CRISPR/Cas9, Transfect cells with gRNA and Cas9 expression vectors, Verify gene knockout by PCR, DNA sequencing, or protein analysis.
2. CRISPR/Cas9-Mediated Gene Knock-in - Design gRNAs and a donor DNA template for precise gene insertion, Co-transfect cells with gRNAs, Cas9, and donor DNA, Confirm successful gene insertion by PCR, DNA sequencing, or fluorescence-based assays.
3. ZFN- or TALEN-Mediated Gene Editing - Design zinc finger nucleases (ZFNs) or transcription activator-like effector nucleases (TALENs) targeting a specific gene, Transfect cells with ZFN or TALEN expression vectors, Verify gene modification by PCR, DNA sequencing, or protein analysis.
4. Base Editing or Prime Editing - Design base editors or prime editors targeting a specific nucleotide change. Transfect cells with the respective editor system. Confirm the desired nucleotide change by PCR, DNA sequencing, or restriction digest analysis.
5. BioBrick Assembly - Design and order BioBrick parts (standardized DNA sequences) for a simple genetic circuit, Perform DNA assembly using BioBrick restriction enzymes and ligase, Transform the assembled construct into a bacterial host and analyze gene expression.
6. RNA Aptamer Development - Select a target molecule of interest (e.g., small molecule or protein), Use in vitro selection techniques (SELEX) to isolate RNA aptamers that bind to the target, Validate binding affinity and specificity of the selected aptamers.
7. Cell-Free Protein Expression - Extract cell lysate from *E. coli* or other cell sources, Set up an in vitro transcription-translation system using the cell lysate, Express and analyze the protein of interest in a cell-free environment.
8. Biosensor Design and Characterization - Design a biosensor using a promoter, reporter gene, and a specific inducer molecule, Clone the biosensor construct into a suitable vector, Characterize the biosensor response by measuring reporter gene expression in the presence of the inducer.

SEMESTER II

DSC 04 - COMPUTATIONAL SYNTHETIC BIOLOGY

UNIT - I INTRODUCTION TO SYNTHETIC BIOLOGY AND COMPUTATIONAL MODELING

Overview of synthetic biology and its applications, Introduction to computational modeling in synthetic biology, Mathematical modeling techniques: differential equations, Boolean networks, stochastic models, Simulation tools and software for synthetic biology modeling

UNIT - II DESIGN AND ANALYSIS OF GENETIC CIRCUITS

Principles of genetic circuit design, Genetic circuit components: promoters, transcription factors, riboregulators, Logic gates and their implementation in genetic circuits, Model-driven design and optimization of genetic circuits, Case studies of engineered genetic circuits

UNIT - III GENOME-SCALE ENGINEERING AND DESIGN

Introduction to genome-scale engineering and design, Computational tools for genome-scale modeling and design, Metabolic network modeling and analysis, Pathway engineering and optimization, Synthetic genome design and assembly

UNIT - IV MACHINE LEARNING AND DATA ANALYSIS IN SYNTHETIC BIOLOGY

Introduction to machine learning in synthetic biology, Predictive modeling and pattern recognition, Data analysis techniques for high-throughput experiments, Designing genetic circuits using machine learning, Applications of machine learning in synthetic biology.

DSC 05- GENOME AND PROTEIN ENGINEERING

UNIT - I INTRODUCTION TO NUCLEIC ACID

Basic nucleic acid chemistry (structure and thermodynamics), DNA structure: double helix, base pairing, and major/minor grooves; RNA structure: secondary structure, folding motifs, and non-canonical base pairing Nucleic Acid Thermodynamics - DNA stability: melting temperature, GC content, and effect of sequence; RNA folding and stability: free energy landscapes and folding kinetics Chemical and biological synthesis of nucleic acids, Analysis of nucleic acids

UNIT - II NUCLEIC ACID ENGINEERING

Nucleic Acid Modifications - Methylation, acetylation, and phosphorylation, Epigenetic modifications and gene expression regulation, Nucleic acid engineering with aptamers, ribozymes, DNA nanotechnology, DNA computation, DNA data storage, DNA materials, Genome reprogramming and gene therapy

UNIT - III PROTEIN STRUCTURE, CHEMISTRY AND FUNCTION

Directed evolution, rational design, and de novo design for protein engineering, An ontology-based search engine for protein-protein interactions, Protein engineering for pathway design and metabolic engineering, Engineered Proteins: Redox Properties and Their Applications, Deep sequencing methods for protein engineering and design.

UNIT - IV PROTEIN ENGINEERING AND PRODUCTS

Commercialized Protein Engineered Products, Artificially engineered protein polymers, Protein engineering approaches to chemical biotechnology, Protein engineering and its applications in food industry, Natural and Genetically Engineered Proteins for Tissue Engineering

DSC 06 - METABOLIC ENGINEERING

UNIT - I METABOLIC PATHWAYS AND REGULATORY NETWORK

Metabolic and regulatory network pathway in prokaryotes and eukaryotes, enzymatic, transport, and regulatory functions of the cell, directed modulation of metabolic pathways for metabolite over production or the improvement of cellular properties, native pathway engineering and synthesis of heterologous pathways for converting microorganisms into microbial cell factories

UNIT - II STRATEGIES USED FOR METABOLIC ENGINEERING

Overexpressing the gene encoding the rate-limiting enzyme of the biosynthetic pathway, blocking the competing metabolic pathways, heterologous gene expression, and enzyme engineering; Experimental, computational, and modelling approaches for the elucidation of metabolic pathways and their manipulation by genetic, media; Efficient probing of metabolic pathways, modeling and data analysis techniques from engineering

UNIT - III METABOLIC ENGINEERING BIOSYSTEMS

In vitro metabolic engineering biosystems (ivMEB), Systems metabolic engineering for cell factories construction, CRISPRi-library and genetically encoded biosensor as metabolic engineering tools, “design-build-test” cycle of metabolic engineering.

UNIT - IV APPLICATIONS OF METABOLIC ENGINEERING

Sustainable Agricultural Improvements: nutritional content of crops, resistance to pests and diseases, or increase their tolerance to environmental stress. Bioenergy Production: advanced biofuels and bioenergy technologies. Pharmaceutical Production: complex pharmaceutical compounds from microbial fermentation. Environmental Remediation and ecosystem restoration. Waste Conversion into valuable products including bioplastics.

DSE 1A- NUCLEIC ACID SEQUENCING TECHNIQUES

UNIT - I NUCLEIC ACID AMPLIFICATION AND SEQUENCING

DNA amplification using PCR and its variants, Introduction to DNA Sequencing, The Universal Primers and the Shotgun DNA Sequencing Method, M13 Sequencing, Primer Design and Primer-Directed Sequencing

UNIT - II TYPES OF DNA SEQUENCING

Whole genome sequencing (WGS), Targeted sequencing, Whole exome Sequencing, Targeted Panels, Hybridization capture, Amplicon sequencing, Molecular inversion probes (MIPs), Comparative Genomics and Evolutionary Analysis - Comparative analysis of genomes & Phylogenetic analysis and evolutionary relationships

UNIT - III TYPES OF RNA SEQUENCING

Whole transcriptome sequencing (WTS), Targeted gene expression with RNA-Sequencing, Ribosomal RNA depletion, Epigenomics **(**ChIP-Sequencing & Methyl-seq). Single-Cell Sequencing - Principles and applications of single-cell sequencing, Single-cell RNA sequencing (scRNA-seq) and other modalities, Emerging Sequencing Technologies and Future Directions - Long-read sequencing technologies (e.g., Oxford Nanopore), Single-molecule sequencing, Advances in sequencing throughput and accuracy

UNIT - IV NGS AND ITS APPLICATIONS

Automated DNA sequencers, capillary DNA sequencers, heterozygote mutation detection, web-based sequencing databases and genome sequencing sites, and the human genome project. Next-Generation Sequencing (NGS) Chemistry: library preparation, cluster generation, sequencing, and alignment and data analysis. NGS platforms (e.g., Illumina, Ion Torrent, Pacific Biosciences), Applications of nucleic acid sequencing and NGS

DSE 1B – BIOINFORMATICS

UNIT – I INTRODUCTION TO BIOINFORMATICS

Biological databases and data retrieval - Nucleotide databases (Genbank, EMBL, DDBJ), Sequence submission Methods and tools (Sequin, Sakura, Bankit), Sequence retrieval systems (Entrez & SRS), Sequence File Formats and Conversion tools, Protein (Swiss-Prot, TrEMBL, PIR_PSD, Expasy), Genome (NCBI, EBI, TIGR, SANGER), Derived Databases (Prosite, PRODOM, Pfam, PRINTS), Metabolic Pathway DB (KEGG, EMP, EcoCyc, BioCyc and MetaCyc).

UNIT – II BIOLOGICAL DATABASE

Introduction to data types and Source. Population and sample, Classification and Presentation of Data. Quality of data, private and public data sources. Biological Databases: General introduction of databases, Nucleic acid databases (NCBI, DDBJ, and EMBL). Protein databases (Primary, Composite, and Secondary). Specialized Genome databases: (SGD, TIGR, and ACeDB). Structure databases (CATH, SCOP, and PDBsum)

UNIT – III DATA ANALYSIS TOOLS

Data storage and retrieval and Interoperability Flat files, relational, object-oriented databases and controlled vocabularies. File Format (GenBank, DDBJ, FASTA, PDB, SwissProt). Structural databases: Protein Data Bank (PDB), Nucleic Acid Data Bank (NDB), Molecular Modelling Data Bank (MMDB).

UNIT – IV SEQUENCE ALIGNMENTS AND VISUALIZATION

Introduction to Sequences, alignments, and Dynamic Programming; Local alignment and Global alignment (algorithm and example), Pairwise alignment (BLAST and FASTA Algorithm) and multiple sequence alignment (Clustal W algorithm). Methods for presenting large quantities of biological data: sequence viewers (Artemis, SeqVISTA), 3D structure viewers (Rasmol, SPDBv, Chime, Cn3D, PyMol), Anatomical visualization.

DSE 2A – PROTEOMICS

UNIT - I INTRODUCTION TO PROTEOMICS

Overview of proteomics and its importance in biological research, Historical development and evolution of proteomics, Introduction to mass spectrometry and its applications in proteomics, Protein separation techniques: gel electrophoresis, liquid chromatography, Protein quantification methods: label-based and label-free approaches

UNIT- II PROTEIN IDENTIFICATION

Protein databases: sequence databases (UniProt, NCBI) and structural databases (PDB), Protein sequence analysis: sequence alignment, motif identification, Introduction to peptide mass fingerprinting (PMF) and tandem mass spectrometry (MS/MS), Database searching algorithms for protein identification: SEQUEST, Mascot, X!Tandem Post-translational modifications (PTMs) and their analysis

UNIT - III PROTEOME PROFILING AND QUANTIFICATION

Overview of quantitative proteomics approaches: stable isotope labeling (SILAC, iTRAQ, TMT), label-free quantification, Experimental design considerations for proteome profiling, Data-dependent and data-independent acquisition methods in mass spectrometry, Proteomics data analysis: protein inference, statistical analysis, data visualization, Applications of proteomics in biomarker discovery and drug target identification

UNIT – IV SYSTEMS BIOLOGY AND FUNCTIONAL PROTEOMICS

Protein-protein interactions: methods for identifying and characterizing protein interactions (yeast two-hybrid, co-immunoprecipitation, affinity purification), Protein localization and subcellular proteomics, Structural proteomics: protein structure prediction, X-ray crystallography, cryo-electron microscopy, Functional proteomics: protein function prediction, protein-protein interaction networks, Applications of proteomics in systems biology and understanding cellular pathways.

DSE 2B - SYNTHETIC RNA BIOLOGY & TRANSCRIPTOMICS

UNIT - I INTRODUCTION TO SYNTHETIC RNA BIOLOGY

Overview of synthetic RNA biology and its significance in molecular biology, Historical development and milestones in synthetic RNA research, RNA structure and function, RNA-based gene regulation and signaling, RNA interference (RNAi) and small interfering RNAs (siRNAs), RNA-based gene expression control, RNA-based sensors and regulators

UNIT - II RNA ENGINEERING AND DESIGN

RNA synthesis and modification techniques, RNA aptamers and riboswitches, Designing RNA-based genetic circuits, RNA nanotechnology and RNA-based materials. RNA editing techniques: base editing, RNA-guided editing systems, Chemical modification of RNA: nucleoside analogs, modified backbones, RNA splicing and alternative splicing, RNA modification and its impact on RNA function and stability

UNIT - III RNA EDITING AND MODIFICATION AND TRANSCRIPTOMICS

Transcriptomics for Functional annotation of the genome, transcriptional structure of the genes, Deciphering transcriptional start site, Elucidating splicing, posttranslational modifications and Cataloguing all types of transcripts (mRNA, tRNA, rRNA, siRNA, noncoding RNAs, etc.), Transcriptome profiling techniques, quantitative real-time PCR (qRT-PCR), RNA-seq (whole-transcriptome shotgun sequencing), RNA microarrays

UNIT - IV APPLICATIONS OF SYNTHETIC RNA BIOLOGY

RNA-based therapeutics: Synthetic RNA circuits and networks, RNA vaccines, RNA interference (RNAi), antisense oligonucleotides, RNA imaging and tracking techniques, RNA-based biosensors and diagnostics, Synthetic RNA in cellular engineering and synthetic biology, RNA origami applications in Synthetic biology.

SEC 02- RESEARCH METHODOLOGY II

UNIT - I ETHICAL ISSUES IN RESEARCH

Introduction, overview and research misconduct, rules and regulations in India, data management, mentoring, mentor - mentee responsibilities, authorship guidelines, publication and peer review, intellectual property, plagiarism, patents, collaboration, reporting and representation research, representing images. Bias, conflicts of interest, ethical use of animal subjects, protection of human subjects, stem cell ethics,

UNIT - II BIOSAFETY

Eco sourcing code of practice, radioactive, chemical and biohazard safety, waste management and disposal, social responsibility. Introduction to Biological Safety Cabinets; Primary Containment for Biohazards. Biosafety Levels; Biosafety Levels of Specific Microorganisms; Biosafety guidelines - Government of India; Definition of GMOs; LMOs; Roles of Institutional Biosafety Committee, RCGM, GEAC etc. for GMO pplications in food and agriculture. Environmental release of GMOs; Risk Analysis; Risk Assessment; Risk Management and communication; Biosafety in relation to transgenic research and applications.

UNIT - III PATENT, FILING AND INFRINGEMENT

Types of patents, Patent application- types (Provisional and complete specifications), forms and guidelines, fee structure, time frames; Precautions before patenting- disclosure/non- disclosure, Databases- Country-wise patent searches [USPTO, esp@cenet (EPO), PATENT Scope (WIPO), IPO, etc.].

UNIT - IV SCIENTIFIC WRITING

Meaning of Interpretation, Technique of Interpretation, Precaution in Interpretation. Significance of Report Writing, Different Steps in Writing Report, Layout of the Research Report, Types of Reports, Oral Presentation, Mechanics of Writing a Research Report, Precautions for Writing Research Reports, Conclusions.

PRACTICAL 03: COMPUTATIONAL SYNTHETIC BIOLOGY

1. Sequence Analysis and Annotation - Retrieve a DNA or protein sequence from a database, Perform sequence alignment using bioinformatics tools (e.g., BLAST), Predict and annotate functional elements in the sequence (e.g., coding regions, regulatory motifs).
2. Gene Expression Analysis - Analyze gene expression data from a public repository (e.g., RNA-seq or microarray data), Normalize and process the data using bioinformatics software (e.g., R or Python), Perform differential gene expression analysis to identify differentially expressed genes.
3. Gene Regulatory Network Inference - Collect gene expression data from multiple conditions or time points. Apply network inference algorithms (e.g., Bayesian networks or Boolean networks) to infer gene regulatory interactions. Visualize and analyze the inferred gene regulatory network.
4. Metabolic Pathway Modeling and Flux Analysis - Construct a metabolic network model of a specific organism or pathway. Use software tools (e.g., COBRApy or MATLAB) to perform flux balance analysis or metabolic flux modeling. Predict and analyze metabolic flux distributions under different conditions or genetic modifications.
5. Protein Structure Prediction and Docking - Retrieve a protein sequence from a database. Use computational tools (e.g., homology modeling, ab initio modeling) to predict the protein's 3D structure. Perform protein-protein docking to predict interactions between the protein of interest and its partners.
6. Synthetic Circuit Design and Simulation - Design a synthetic genetic circuit using a modeling software (e.g., iBioSim or SynBioSS). Simulate the behavior of the circuit under different conditions and parameter settings. Analyze the circuit dynamics and predict its output response.

PRACTICAL 04: GENOME PROTEIN & METABOLIC ENGINEERING

1. Site-Directed Mutagenesis - Choose a target protein and identify a specific amino acid residue to mutate. Perform site-directed mutagenesis using PCR-based methods or commercial kits. Express and purify the mutant protein and compare its properties to the wild-type protein.
2. Enzyme Kinetics Analysis - Select an enzyme of interest and design a kinetic assay (e.g., measuring substrate conversion over time). Determine kinetic parameters such as Michaelis-Menten constant (Km) and maximum reaction velocity (Vmax). Compare the kinetic properties of the wild-type enzyme to variants with mutations or modifications.
3. Directed Evolution of Enzymes - Design a library of mutant enzymes using error-prone PCR or DNA shuffling techniques. Screen the library for variants with improved or altered enzymatic activity. Characterize the selected variants using enzyme assays and compare them to the wild-type enzyme.
4. Metabolic Pathway Knockout - Identify a metabolic pathway in a host organism (e.g., *E. coli*) and choose a target gene to knockout. Use CRISPR/Cas9 or other genetic techniques to disrupt the target gene. Analyze the impact of the knockout on the metabolic flux and product formation.
5. Metabolite Overproduction - Identify a metabolite of interest for overproduction (e.g., a valuable compound or a precursor). Design and engineer a metabolic pathway in a host organism to enhance metabolite production. Analyze the metabolite production levels and optimize the pathway for higher yields.
6. Flux Balance Analysis (FBA) - Build a genome-scale metabolic model of a microorganism. Use FBA software (e.g., COBRApy or MATLAB) to perform flux balance analysis. Predict and optimize metabolic flux distributions for specific objectives (e.g., maximizing biomass production).

SEMESTER III

DSC 07- BIOENGINEERING/ STEM CELLS & TISSUE ENGINEERING

UNIT - I STEM CELLS AND THEIR MANIPULATION

Properties and types of stem cells: embryonic, adult, and induced pluripotent stem cells, significance of stem cells in development, tissue repair, and regenerative medicine. Stem cell differentiation and reprogramming, Techniques for stem cell isolation, expansion, and characterization, Genetic modification of stem cells using synthetic biology tools

UNIT - II SYNTHETIC GENE CIRCUITS FOR STEM CELL CONTROL

Introduction to genetic circuits, Design and construction of synthetic gene circuits for stem cell behavior control, Inducible gene expression systems and regulatory elements, Signal processing and feedback control in stem cells. Stem cells in drug discovery and toxicology testing. Clinical applications and translational challenges. Bioprocess Engineering: Basics of bioreactors and their types, cell culture techniques and cultivation parameters, downstream processing and purification of biomolecules.

UNIT - III TISSUE ENGINEERING AND BIOFABRICATION

Basics of tissue engineering and regenerative medicine, Scaffold design and fabrication techniques: biomaterials for tissue engineering scaffolds & 3D printing, electrospinning, and self-assembly., Cell-material interactions and biomaterial selection, Biofabrication methods for creating complex tissue systems, Applications of Tissue Engineering: Tissue engineering for specific organs and tissues (e.g., bone, cartilage, skin), organoid and mini-organ development.

UNIT - IV APPLICATIONS & ETHICAL AND SOCIETAL CONSIDERATIONS

Stem cell-based therapies for regenerative medicine. Organ-on-a-chip and body-on-a-chip technologies. Biofabrication and 4D printing. Ethical implications of synthetic biology in stem cell research and tissue engineering, Responsible conduct of research and biosecurity considerations, Public perception, policy, and regulation of synthetic biology applications

DSC 08 -VACCINE PLATFORMS & BIOSIMILARS

UNIT - I SYNTHETIC BIOLOGY IN VACCINE DESIGN AND BIOSIMILARS

Overview of synthetic biology and its applications in vaccine design and biosimilar development, Introduction to key concepts in synthetic biology, including genetic engineering and gene synthesis, Role of synthetic biology in improving vaccine efficacy and developing biosimilars, Ethical considerations and safety aspects in synthetic biology research for vaccines and biosimilars

UNIT - II PRINCIPLES OF GENETIC ENGINEERING AND ITS APPLICATION IN VACCINE DEVELOPMENT

Design and construction of synthetic genes and genetic circuits for vaccine design. Techniques for gene expression, protein production, and purification in biosimilar development. Molecular cloning techniques for the assembly of genetic constructs. Genome editing technologies and their applications in vaccine design and biosimilar development

UNIT - III SYNTHETIC BIOLOGY APPROACHES FOR ENHANCED VACCINE EFFICACY

Rational design and optimization of antigen expression systems, Introduction to novel vaccine platforms, such as viral vectors and RNA-based vaccines, Incorporation of adjuvants and immune modulators using synthetic biology tools, Designing multi-epitope vaccines and synthetic peptides for improved immune response, Synthetic biology approaches for developing vaccines against emerging infectious diseases

UNIT - IV SYNTHETIC BIOLOGY IN BIOSIMILARS DEVELOPMENT

Engineering biosimilar production systems using synthetic biology approaches, Designing synthetic pathways for the production of biosimilar proteins, Optimization of protein expression, folding, and post-translational modifications, Analytical techniques for biosimilar characterization and comparability assessment

DSC 09- INDUSTRIAL, FOOD & AGRICULTURAL SYNTHETIC BIOLOGY

UNIT - I INDUSTRIAL SYNTHETIC BIOLOGY

Synthetic biology to engineer biosensors and Whole cell biosensors, synthetic speciation, microbial metabolic engineering, mammalian multiplexed CRISPR, novel anti microbials, Biosynthesis of High Value Plant Metabolites in Microorganisms, Yeast 2.0 Projects. Metabolic engineering for the synthesis of valuable chemicals, metabolites, enzymes and pharmaceuticals

UNIT - II FOOD SYNTHETIC BIOLOGY

Synthetic biology for sustainable food ingredients production; Microbes as sources of biosynthetic food to ensure food and nutrition security; Production of macronutrients in food by synthetic biology; Future food generated by engineered microbes; Synthetic biology for alternative feedstocks and biomaterials, Production of micronutrients in food by synthmodular G-protein coupled receptor (GPCR) system developed using chimeric BRET-biosensors (Bioluminescence Resonance Energy Transfer) to detect food spoilage

UNIT - III PLANT SYNTHETIC BIOLOGY & AGRICULTURE

Synthetic biology for crop improvement and novel bioproduction in plants, Smart Plant with molecular circuitry, plant sentinel biosensor to respond to environmental pollutants, nutrients, abiotic stresses, pests, pathogens and other environmental factors; Reverse engineering of traits such as halotolerance; Plant microbiome engineering to improve nitrogen fixation & improve photosynthetic efficiency. Metabolic rewiring in plants to improve nutritional value; Genome minimization, Genetic recoding, Bioconfinement; Regulatory framework and IPRs.

UNIT - IV ENVIRONMENTAL APPLICATIONS

Engineered microbial cell factories to identify pollutants and toxins; bioremediation of heavy metal contamination, degradation of toxic aromatic compounds, and biomass based sugars using engineered microbes; engineering new cultivars suitable for non-conventional environments; nuclease-based gene drives to eradicate pest species

DSE 3A- ENGINEERED CELL BASED THERAPEUTICS & SYNTHETIC ORGANS

UNIT - I INTRODUCTION TO ENGINEERED CELL-BASED THERAPEUTICS

Overview of cell-based therapies and their potential applications, Historical context and evolution of engineered cell-based therapeutics, Introduction to the concept of genetic engineering in cell therapies, Regulatory considerations and ethical issues in cell-based therapeutics, Tools and Techniques for Cell Engineering, Genome-scale engineering approaches for cell engineering

UNIT - II DESIGNING CELL-BASED THERAPIES

Cell types used in therapeutic applications: stem cells, immune cells, etc., Engineering cells for disease modeling and drug discovery, Cell programming and reprogramming for specific functions, Modulating cell behavior: signal transduction, gene regulation, and epigenetics, Cell-based immunotherapies: CAR-T cells, TCR-T cells, NK cells, Clinical Applications and Challenges

UNIT - III INTRODUCTION TO SYNTHETIC ORGANS

Overview of synthetic organs and their significance in medicine, Historical development and milestones in synthetic organ research, Comparison of synthetic organs with natural organs, Ethical considerations and societal implications of synthetic organs

UNIT - IV TISSUE ENGINEERING AND ORGANOGENESIS

Cellular sources for synthetic organ generation, Bioreactors and perfusion systems for organogenesis, Vascularization strategies for synthetic organs, Approaches for generating specific organ types, Transplantation and Clinical Applications, Immunological considerations, Evaluation and monitoring of synthetic organ functionality, Case studies of successful synthetic organ transplants, Challenges and future directions in synthetic organ research

DSE 3B - SYNTHETIC BIOLOGY RESEARCH & ENTREPRENEURSHIP

UNIT - I INTRODUCTION TO SYNTHETIC BIOLOGY AND ENTREPRENEURSHIP

Overview of synthetic biology and its applications, Introduction to entrepreneurship in the field of synthetic biology, Exploration of successful synthetic biology startups and case studies, Identifying opportunities for entrepreneurship in synthetic biology, Introduction to business models and intellectual property considerations

UNIT - II DESIGN AND ENGINEERING IN SYNTHETIC BIOLOGY

Synthetic biology toolkits and standardization, Laboratory techniques for genetic engineering and prototyping Synthetic Biology products - Engineering bacteria for insulin production, Biosynthesis of artificial flavors and fragrances, Genetic modification of crops for enhanced nutrition and Development of biosensors for environmental monitoring

UNIT - III ENTREPRENEURIAL STRATEGIES IN SYNTHETIC BIOLOGY

Market analysis and identifying target markets for synthetic biology products, Business plan development and pitching skills, Funding opportunities and strategies for synthetic biology startups, Regulatory landscape and ethical considerations in synthetic biology entrepreneurship, Intellectual property protection and technology transfer

UNIT - IV COMMERCIALIZATION AND SCALING IN SYNTHETIC BIOLOGY

Technology transfer and licensing agreements, Manufacturing and scaling strategies for synthetic biology products, Quality control and regulatory compliance in commercial production, Marketing, sales, and distribution strategies for synthetic biology products, Case studies of successful synthetic biology startups and their growth strategies

SEC 03- ADVANCED INSTRUMENTATION & ANALYTICAL TECHNIQUES

UNIT - I INTRODUCTION TO ADVANCED INSTRUMENTATION AND ANALYTICAL TECHNIQUES

Overview of advanced instrumentation and analytical techniques used in synthetic biology, Principles and applications of techniques such as mass spectrometry, flow cytometry, next-generation sequencing, and high-throughput screening, Experimental design and optimization considerations for advanced instrumentation, Data analysis and interpretation methods for large-scale datasets

UNIT - II MASS SPECTROMETRY IN SYNTHETIC BIOLOGY

Introduction to mass spectrometry and its applications in synthetic biology, Different types of mass spectrometers and their operating principles, Sample preparation techniques for mass spectrometry analysis, Quantitative and qualitative analysis of proteins, metabolites, and lipids using mass spectrometry, Data analysis and interpretation of mass spectrometry data

UNIT - III FLOW CYTOMETRY AND HIGH-THROUGHPUT SCREENING

Introduction to flow cytometry and its applications in synthetic biology, Instrumentation and principles of flow cytometry, Cell sorting and analysis using flow cytometry, High-throughput screening techniques for genetic libraries and engineered strains, Data analysis and interpretation of flow cytometry and high-throughput screening data

UNIT - IV NEXT-GENERATION SEQUENCING AND BIOINFORMATICS

Introduction to next-generation sequencing technologies and their applications in synthetic biology, Library preparation techniques for next-generation sequencing, Analysis of DNA and RNA sequencing data for genome assembly, gene expression analysis, and variant calling, Bioinformatics tools and pipelines for data analysis and interpretation, Integration of next-generation sequencing data with other omics data

PRACTICAL 05: STEM CELLS AND TISSUE ENGINEERING

1. Stem Cell Isolation and Culture - Isolate stem cells from a suitable tissue source (e.g., bone marrow or adipose tissue). Culture the stem cells in vitro using appropriate growth factors and culture media. Characterize the stem cells by assessing their pluripotency or multipotency markers.

2. Stem Cell Differentiation - Induce the differentiation of stem cells into a specific lineage (e.g., osteogenic, adipogenic, or neural differentiation). Monitor the differentiation process through morphological changes, gene expression analysis, or specific staining methods. Confirm the successful differentiation by analyzing marker expression or functional assays.

3. Tissue Engineering - Scaffold Fabrication - Design and fabricate a scaffold using biocompatible materials (e.g., polymers or hydrogels). Characterize the scaffold's properties such as porosity, mechanical strength, and degradation rate. Assess the scaffold's biocompatibility by culturing cells on the scaffold and evaluating cell attachment and viability.

4. Cell Seeding and Tissue Formation - Seed cells onto a scaffold and culture them under appropriate conditions. Optimize cell seeding density and culture duration to promote tissue formation. Assess tissue formation by histological staining, immunofluorescence, or mechanical testing.

5. Tissue Engineering in Bioreactors - Culture tissue-engineered constructs in a bioreactor system to enhance nutrient supply and waste removal. Optimize bioreactor parameters such as flow rate, oxygenation, and mechanical stimulation. Evaluate the effects of bioreactor culture on tissue formation and functionality.

6. Tissue Integration and Implantation - Assess the integration of tissue-engineered constructs with host tissues. Implant tissue-engineered constructs in suitable animal models. Evaluate tissue integration, vascularization, and long-term viability of the implanted construct.

PRACTICAL 06: SYNTHETIC BIOLOGY APPLICATIONS IN VACCINE DESIGN, BIOSIMILARS, INDUSTRIAL AND AGRICULTURAL BIOLOGY

1. Antigen Identification and Expression - Identify a target antigen from a pathogen or disease of interest. Design and clone the antigen gene into an expression vector. Express the antigen in a suitable host system (e.g., bacterial or yeast cells) and purify it for further analysis.
2. Biosimilar Characterization - Select a marketed biologic drug as a reference. Clone and express the target protein in a suitable host system. Perform comparative analysis between the biosimilar and the reference drug using techniques such as SDS-PAGE, size-exclusion chromatography, and bioactivity assays.
3. Metabolic Engineering for Biochemical Production - Select a target compound of industrial interest (e.g., biofuels or chemicals). Engineer a microbial host (e.g., *E. coli* or yeast) to produce the target compound by introducing or modifying metabolic pathways. Analyze the production efficiency and yield of the target compound.
4. Bioprocess Optimization - Optimize culture conditions for maximum product yield and growth of the engineered microorganism. Assess the effects of parameters such as temperature, pH, and nutrient availability on the production process. Monitor the production kinetics, biomass growth, and product quality in bioreactor systems.
5. Genetic Modification of Plants - Choose a trait of interest (e.g., herbicide tolerance or insect resistance). Introduce a transgene into plants using Agrobacterium-mediated transformation or biolistic methods. Confirm the successful incorporation of the transgene and assess the phenotypic changes in the transformed plants.
6. Metabolic Engineering for Bioproduction - Identify a target compound of interest for bioproduction (e.g., a metabolite or enzyme). Design and introduce genetic modifications into a host organism to enhance production. Analyze the metabolic output and productivity of the engineered strain.

SEMESTER IV- DISSERTATION

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