Course title: Artificial Intelligence and Machine Learning for Biotechnology			
Course code: BBP 124	**No. of credits:** 3	**L-T-P:** 28-17-0	**Learning hours:** 45
Pre-requisite course code and title (if any): None			
Department: Department of Biotechnology			
Course coordinator:		**Course instructor:**	
Contact details:			
Course type: DSE		**Course offered in:** Semester 1/Semester 3 of 1-/2-year M.Sc. Biotechnology programs respectively.	

Course description:

This course introduces postgraduate biotechnology students to the principles, applications, and emerging frontiers of Artificial Intelligence (AI) and Machine Learning (ML) in life sciences. It provides a conceptual and application-oriented understanding of how AI technologies are transforming genomics, proteomics, drug discovery, precision medicine, and bioprocess engineering. The course covers foundational ML concepts such as supervised and unsupervised learning, model evaluation, and data workflows, followed by advanced applications including biomarker discovery, protein structure prediction, generative AI in drug design, and digital twins in biotechnology. Students will also explore AI-driven innovations in synthetic biology, medical imaging, and personalized healthcare.

Special emphasis is placed on explainable AI, ethical considerations, bias in healthcare algorithms, and regulatory challenges to ensure responsible application of AI in biomedical research. Through case studies and research paper discussions, students will develop the ability to critically analyze AI-based scientific literature and interpret model outputs in biological contexts. Designed for MSc-level learners without requiring extensive coding or advanced mathematics, this course prepares students for research careers, doctoral studies, and emerging AI-enabled roles in biotechnology and healthcare industries.

Course objectives:

- To develop conceptual and analytical understanding of AI/ML in life sciences.
- To explore advanced and emerging AI applications in genomics, drug discovery, and bioprocessing.
- To critically evaluate AI-based research literature.
- To prepare students for research, PhD pathways, and AI-enabled biotech careers.

Course contents

S. No.	Topic	L	T	P
Module 1	**Foundations of AI & Machine Learning in Life Sciences**	**6**	**2**	

1	**Introduction to AI -** Evolution of AI**,** AI vs ML vs Deep Learning**,** AI ecosystem in biotechnology	1		
2	**Machine Learning Basics -** Supervised and unsupervised learning, Classification & regression, Clustering, Dimensionality reduction	2		
3	**ML Workflow -** Data collection**,** Training vs testing data**,** Model building**,** Validation**,** Deployment	2	1	
4	**Model Evaluation Metrics –** Accuracy**,** Precision**,** Recall**,** F1 Score**,** ROC Curve, *Conceptual understanding only (no heavy mathematics).	1	1	
Module 2	**AI in Genomics, Proteomics & Biomedical Research**	**6**	**3**	
1	**AI in Genomics -** Gene expression data analysis**,** High-dimensional biological datasets**,** Biomarker identification**,** Disease subtype clustering, introductory multi-omics integration, single-cell RNA sequencing (scRNA-seq), and spatial transcriptomics (conceptual overview).	3	1	
2	**AI in Sequence Analysis & Structural Biology -** Pattern recognition in DNA sequences**,** Mutation impact prediction**,** AI-based protein structure prediction using AlphaFold	2	1	
3	**AI in Clinical & Precision Medicine -** Genotype–phenotype mapping**,** Risk prediction models**,** Stratified medicine**,** AI in electronic health records	1	1	
3	**AI in Drug Discovery & Bioprocessing**	**6**	**4**	
1	**AI in Drug Discovery -** Virtual screening**,** Target identification**,** Drug repurposing**,** AI-driven molecular modeling	1	2	
2	**Generative AI in Drug Design -** Concept of generative models, AI-designed molecules, generative AI in drug discovery, protein design, molecular optimization, biological foundation models and large language models (LLMs) in life sciences. and AI-assisted vaccine development.	2	1	
3	**Introduction to Digital Twins in Biotechnology -** Concept of digital twin**,** Difference between simulation & digital twin**,** Digital twin in: Fermentation monitoring**,** Bioprocess optimization**,** Virtual patient modeling, imaging and monitoring environment, industrial biomanufacturing applications, Role in personalized medicine	2	1	
Module 4	**Frontier & Responsible AI in Biotechnology**	**7**	**3**	
1	**AI in Synthetic Biology** - Gene circuit prediction, CRISPR off-target prediction, Pathway optimization using AI	1	1	
2	**AI in Imaging & Diagnostics -** Neural networks, CNN for histopathology, AI in cancer detection, CT imaging workflows, digital pathology concepts, POCUS/ultrasound workflows, scan interpretation, triage support, and AI-assisted clinical decision systems.	2	1	

3	**Explainable AI (XAI) -** Importance in healthcare, Model interpretability, Bias detection	2	1	
4	**AI Ethics & Regulatory Landscape -** Data privacy in healthcare, Bias in biomedical AI, Regulatory challenges, Responsible AI principles	2		
Module 5	**Research Paper Analysis & Case Studies -** Critical reading of AI-biotech research articles, Identifying research gaps, Evaluating methodology, Understanding limitations, Student presentations	**3**	**5**	
	Total	**28**	**17**	**0**

Evaluation criteria:

- Mid-semester exam: 30%
- End-semester exam: 40%
- Case study presentation: 30%

Learning outcomes:

Upon successful completion of this postgraduate course, students will be able to:

1. Describe the fundamental concepts of AI and ML as they apply to biotechnology research. (End-semester exam)

2. Evaluate how AI is utilized across various domains of biotechnology

3. Understand, interpret and critically evaluate the results generated by AI-based biological models (Mid-semester examination)

4. Analyze contemporary AI-driven research articles, identifying research gaps, and assessing methodologies and limitations. (Case study presentation)

5. Understand the ethical, bias-related, and regulatory implications of deploying AI in healthcare and biomedical research. (End-semester exam)

Pedagogical Approach:

- Interactive lectures
- Biological analogies
- Case studies and examples from original research articles
- Short videos and animations

Skill Set:

This course equips undergraduate biotechnology students with interdisciplinary data literacy, analytical thinking, and ethical awareness, enhancing their employability in AI-enabled biotechnology, healthcare, and pharmaceutical sectors.

- Conceptual understanding of Artificial Intelligence and Machine Learning principles relevant to biotechnology
- Ability to interpret AI-based outputs in genomics, proteomics, diagnostics, and drug discovery
- Foundational data literacy for biological datasets, including sequence, expression, imaging, and clinical data
- Analytical and critical thinking skills through AI-based biological case studies
- Awareness of ethical, legal, and societal issues related to AI applications in life sciences
- Interdisciplinary communication skills bridging biology and data-driven technologies

Employability:

This course is designed to prepare students for various emerging roles in the AI-enabled biotech and healthcare sectors:

- **Academic Research:** Preparation for PhD pathways in Computational Biology and Bioinformatics research.
- **Industrial R&D:** Roles in AI-driven drug discovery laboratories and biotechnology startups.
- **Healthcare Analytics:** Positions in clinical data analytics and precision medicine projects.
- **Bioprocess Engineering:** Applying digital twin technology and AI for fermentation monitoring and bioprocess optimization.

Materials:

Suggested Readings

1. "AI in Biology: A Beginner's Guide" by K.N. Jha (2023)
2. "Deep Learning for the Life Sciences" by Bharath Ramsundar et al.
3. The AlphaFold Breakthrough: Jumper, J., et al. (2021). *"Highly accurate protein structure prediction with AlphaFold."* Nature. (Focus on the *Results* and *Biological Significance* sections).
4. AI in Diagnostics: Esteva, A., et al. (2017). *"Dermatologist-level classification of skin cancer with deep neural networks."* Nature.
5. Bera, K., et al. (2019). "Artificial intelligence in digital pathology — new tools for

diagnosis and precision oncology." Nature Reviews Clinical Oncology.
6. Litjens, G., et al. (2017). "A survey on deep learning in medical image analysis." Medical Image Analysis.
7. Implementing generative artificial intelligence in precision oncology: safety, governance, and significance." Journal of Hematology & Oncology.
8. Academic journals and regulatory guidelines focusing on data privacy in healthcare, explainable AI, and bias in biomedical algorithms.
9. Online resources: Nature AI collections, NIH and EMBL-EBI AI resources, and other online academic content.

Industry case materials and technical resources

- NVIDIA Healthcare AI – AI infrastructure, medical imaging, and accelerated healthcare computing
- Isomorphic Labs – AI-driven drug discovery and protein structure research
- Tempus AI – Precision medicine and clinical AI applications
- Illumina – Genomics and sequencing analytics workflows
- GRAIL – Multi-cancer early detection and AI-enabled diagnostics
- Paige – AI-assisted digital pathology and cancer diagnostics
- PathAI – Digital pathology and AI-assisted pathology analysis
- Aidoc – AI-supported radiology workflows and clinical decision support
- Siemens Healthineers – AI-enabled medical imaging and healthcare workflow systems
- GE HealthCare – AI-assisted imaging and clinical workflow tools

Additional information (if any): This course has been jointly designed and developed by Dr. Ankit Kumar and Dr. Priya Bhatnagar (both of EYM Life Sciences) at the request of Dr. Ramakrishnan Sitaraman. Dr. Mahesh S. Dhar, Director, Haryaksh Scientific Pvt. Ltd. provided invaluable inputs that ensured alignment with current industry standards of student employability.

Student responsibilities:

- Class attendance.
- Active participation in case study discussions.
- Self-study of provided reading materials.
- Submission of case study presentation.

Course reviewers:

1. Dr. Pawan K Dhar, Executive Director, CVJ Centre for Synthetic Biology and Biomanufacturing, CUSAT Technology Business Incubator, 3rd Floor, CUSAT-Students Amenity Centre, Cochin University of Science and Technology, Kalamassery, Kochi 682 022 (Formerly Professor, School of Biotechnology, Jawaharlal Nehru University, New Delhi)

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