Meeting Educational Needs with “Course” Correction
Remodelled Biotechnology Curricula
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MESSAGE

Department of Biotechnology initiated Integrated Human Resource Development Programme way back in 1985-86 to cater to the requirement of quality manpower for R&D, teaching and manufacturing activities. I am very proud that India is one of the first countries in the world to initiate postgraduate teaching programme in Biotechnology. M.Sc./M.Tech. programme was initiated in 5 universities and has been expanded to over 70 universities/IITs in the country to cover general, medical, agricultural, veterinary, environmental, industrial, marine, food, pharmaceutical biotech.

Students for these programmes are selected on the basis of an All India entrance test and all selected students are paid studentships. I am very happy to know that the Department has initiated major curriculum revision exercise for specialisations offered under DBT supported teaching programme. The exercise has been coordinated by Biotech Consortium India Limited. The Department invited feedback from researchers, academic community, biotech industries and past as well as present students. Feedback has been considered by the Expert groups and areas with recent developments have been included and identified gap areas which need inclusion and updation have been taken care of. I compliment the Department for taking up this major exercise for the benefit of student community and congratulate the group for bringing out this publication.

(Dr. Harsh Vardhan)
MESSAGE

Andy Hargreaves a renowned educational expert has once remarked “Capacity building originally meant helping people to help themselves. Now it means required trainee to deliver imposed policies”. In the Indian context, Integrated Human Resource Development Programme of Department of Biotechnology is a flagship and dynamic programme which has done exceedingly well to meet the requirements of capacity building. The central idea should be to take enough care in selection of quality students and provide hands-on practical training to students.

I am extremely happy to note that Department is revising curriculum for various PG programmes in Biotechnology at regular intervals to incorporate latest developments in the field. While doing so, I am told that Biotech Consortium India Limited has obtained necessary feedback from different stakeholders viz., researchers, academia, industries and students regarding the proposed changes in curriculum. Feedback was analysed and considered by the Expert Groups vis-a-vis with curricula followed by best international universities. I am assured that the proposed curricula have incorporated papers on research methodology, scientific communication, prevailing regulations in the country etc.

I am confident that this curriculum revision exercise would be very beneficial for faculty and students of not only DBT supported programmes but also other universities involved in biotechnology teaching. I compliment the Department for undertaking this valuable exercise.

(Shri Y. S. Chowdary)
Message

K. VijayRaghavan
Secretary
Department of Biotechnology

MESSAGE

Integrated Human Resource Development Programme in biotechnology is a unique, innovative initiative taken by Department of Biotechnology way back in 1985-86. Human Resource Development programmes of the Department are highly dynamic and have evolved continuously based on need, regional aspirations and feedback from different stakeholders.

Emphasis is laid on selection of institutions based on existing expertise, infrastructure, nearby institutions engaged in research in relevant areas and students are provided hands on practical training. These programmes are continuously mentored and monitored by Advisory Committee, Expert Task Force and Course Coordinators meeting. An attempt is made to conduct curriculum revision exercise at frequent intervals to incorporate feedback from stakeholders as well as inclusion of latest developments. I am confident that revised curriculum has been framed after intense deliberations and would serve as a valuable resource to experts and student community.

I thank the Biotech Consortium India Limited for assisting DBT in this important exercise and compliment my colleague Dr. Suman Govil, Adviser, DBT for bringing out this publication.

(K. VijayRaghavan)
The biotechnology sector in India is extremely innovative and on the rise. Next few years are bound to see exponential growth in this sector. India is among the top 12 biotechnology destinations in the world and ranks third in the Asia-Pacific region. It is regarded as one of the most significant sectors in enhancing India's global economic profile. India has been blessed with highly talented pool of students in biotechnology.

The National Biotechnology Development Strategy (2015 – 2020) and National Education Policy (2016) envisions a quality education system to produce graduates equipped with the knowledge, skills, attitudes and values that are required to lead a productive life and participate in the country’s development process. Improving employability in this sector is heavily dependent on the overall curriculum of the educational programs. Since last national course curriculum revision exercise was undertaken in 2008, it is necessary to update the current curriculum.

In view of the scientific advancements taking place globally in the field of biotechnology, it was highly desirable to update the current course accordingly and modify it based on the needs of both research and industry. The Department of Biotechnology, Ministry of Science and Technology, Government of India through Biotech Consortium India Limited (BCIL), took the mandate to update the curriculum to keep abreast with the latest developments and to meet the needs of skilled manpower in rapidly advancing field of biotechnology. After continuous deliberations, discussions and several brainstorming sessions, the Core Committee and Subject-specific Committees comprising of experts in various fields of biotechnology arrived at revised and updated course curricula for 13 post-graduate programmes in biotechnology. Each course curriculum has about 90 – 100 credits comprising of core subjects, technology-based subjects, practicals and electives. These course curricula shall serve as model guidelines for academicians across the country for design and development of course curriculum in their institutions.

It is envisaged that the course curriculum revision exercise shall promote outcome-based education to meet not just the local and national manpower requirements, but also provide personal satisfaction and career potential for professionals with supporting pathways for their development.

In concluding this important task for human resource development, I thank my Co-chair Prof. K.K.Rao, fellow members of the Core Committee and Subject-Specific Committees for contributing towards this exercise. I would like to congratulate DBT for taking up this exercise and also BCIL for successfully coordinating it. I am confident that the present guidelines shall be extremely useful to the educators for imparting quality education for biotechnology in the country.

(Prof. Rakesh Bhatnagar)
Preface

Background

Promotion of Indian Biotechnology sector is high on policy agenda of Government of India. Biotechnology has also been recognized as one of the key priority sectors under ‘Make in India,’ ‘Skill India’ and ‘Startup India’ initiatives of Government of India, as it is one of sectors expected to contribute towards enterprise creation, innovation and economic growth. Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India has immensely contributed to this dynamism through various policies and initiatives, establishment of innovation clusters, academia-industry partnerships, increasing capabilities for technology development, etc. The National Biotechnology Development Strategy (2015 – 2020) released by DBT provides a strategic roadmap for India’s emergence as a global biotechnology innovation and manufacturing hub. It has also highlighted importance of human resource development and need for nurturing tailor-made human capital for advanced scientific research and entrepreneurship.

DBT has taken a number of initiatives aimed at integrated human resource development to evolve an ecosystem where scientists, innovators and future entrepreneurs can be nurtured. Keeping in mind requirement for trained manpower in various areas of Biotechnology, DBT initiated Post-Graduate Teaching Programme way back in 1985 with 5 universities which has expanded to 74 universities imparting M.Sc./M.Tech./M.V.Sc. degrees in general, agricultural, animal, food, environmental, industrial marine, medical, neuroscience and pharmaceutical biotechnology. 10 programmes are being phased out. These universities and institutes are provided liberal financial support towards strengthening of laboratory facilities, equipment, consumables, fellowships to students, dissertation grant per student etc. Post-Graduate Teaching Programme selects best students and trains them to join research or industry workforce contributing significantly to biotechnology workforce.

About the Course Curriculum Revision Exercise

Taking into cognizance the changing needs of the economy and to keep abreast with latest developments in the field of biotechnology, DBT proactively initiated revision of course curricula of Post-Graduate Programmes in biotechnology. The present exercise has been undertaken by Biotech Consortium India Limited (BCIL), New Delhi. Earlier exercise was carried out in 2008. The Course Curriculum Revision Exercise has been carried out for 13 Post-Graduate programmes in Biotechnology supported by DBT.

The revision of the course curricula aims to address mismatch between ‘knowledge’ gained by students and appropriate skill set required for technology development and implementation including present contemporary needs of economy.

Methodology

A meticulous and structured approach has been adopted to accomplish the Course Curriculum Revision exercise.

BCIL had initiated the exercise with a review of literature of relevant national and international documents on curriculum design and planning for biotechnology programmes of premier national as well as international universities, guidelines by University Grants Commission, recent curricular guidelines released by Indian Council of Agricultural Research, Ministry of Health and Family Welfare and Indian Institute of Science Education & Research and other relevant research papers on curriculum development in peer-reviewed journals.
The findings of the literature review were adopted to design questionnaires for eliciting feedback from stakeholders of Biotechnology community i.e. academicians, scientists, industry representatives and students. Feedback was received from 165 experts and 20 students belonging to academic institutions, research organizations and industry regarding addition of advanced topics, deletion of elementary, redundant and overlapping topics, updation of laboratory practicals, re-adjustment of credit load, incorporating 'technology' component in the curriculum, among others. It was also suggested that re-orientation of curricula should be done keeping in view the needs of the industry.

### Strategic Approach

A Core Committee along with 9 subject specific subcommittees comprising of 63 academicians, scientists and industry representatives were constituted to revise and update the curricula. The constitution of Core Committee and subject specific subcommittees is given below:

#### Core Committee of M.Sc. Biotechnology

**Chairperson**
1. Dr. Rakesh Bhatnagar, Professor, School of Biotechnology, Jawaharlal Nehru University, New Delhi

**Co-chairperson**
2. Dr. K. K. Rao, Professor, Department of Biosciences and Bioengineering, Indian Institute of Technology, Bombay

**Members**
3. Dr. Suman Govil, Advisor, Department of Biotechnology, Ministry of Science and Technology, Government of India
4. Dr. B. J. Rao, Senior Professor, Department of Biological Sciences, Tata Institute of Fundamental Research, Mumbai
5. Dr. Chandrababu, Professor, Centre for Plant Molecular Biology and Biotechnology, Tamil Nadu Agricultural University, Coimbatore
6. Dr. Probodh Borah, Professor, Department of Animal Biotechnology, Assam Agricultural University, Guwahati
7. Dr. Deepak Kaul, Professor, Department of Experimental Medicine and Biotechnology, Postgraduate Institute of Medical Education and Research, Chandigarh
8. Dr. Rajesh Gokhale, Staff Scientist VII, National Institute of Immunology, N. Delhi
9. Dr. Indira Ghosh, Professor, School of Computational and Integrative Sciences Jawaharlal Nehru University, New Delhi
10. Dr. Amitabh Bandopadhyay, Associate Professor, Department of Biological Sciences and Bioengineering, Indian Institute of Technology, Kanpur
11. Dr. Jitender Verma, CEO, M/s. Lifecare Innovations, New Delhi

**Member Secretary**
12. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi

#### Subject Specific Subcommittee of M.Sc. Agricultural Biotechnology

**Chairperson**
1. Dr. R. Chandra Babu, Professor, Director and Coordinator, Centre for Plant Molecular Biology and Biotechnology, Tamil Nadu Agricultural University, Coimbatore

**Members**
2. Dr. Anil Kumar, Professor and Head, Department of Biotechnology, GB Pant University, Pantnagar
3. Dr. Ramanjini Gowda, Professor, Department of Plant Biotechnology, University of Agricultural Sciences, Bangalore
4. Dr. Sabhyata Bhatia, Staff Scientist VI, National Institute of Plant Genome
Subject Specific Subcommittee of M.Sc. Bioresource Biotechnology

**Chairperson**
1. Dr. Saroj Barik, Director, National Botanical Research Institute, Lucknow

**Members**
2. Dr. Paramvir Singh Ahuja, Former Director General, Council of Scientific and Industrial Research, New Delhi and Former Director, Institute of Himalayan Bioresource Technology, Palampur
3. Dr. A. K. Koul, Dean, Academic Affairs, Baba Ghulam Shah Badshah University, Rajouri
4. Dr. Manmohan Singh Chauhan, Director, Central Institute for Research on Goats, Mathura

**Member Secretary**
5. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi

Subject Specific Subcommittee of M.Sc. Environmental & Marine Biotechnology

**Chairperson**
1. Dr. Shyam Asolekar, Professor, Centre for Environmental Science and Engineering, Indian Institute of Technology, Bombay

**Members**
2. Dr. S. Felix, Professor and Dean, Fisheries College and Research Institute, Tamil Nadu Fisheries University, Chennai
3. Dr. S. P. Govindwar, Professor, Department of Biochemistry, Shivaji University, Kolhapur
4. Dr. Hemant Purohit, Chief Scientist, National Environmental Engineering Research Institute, Nagpur
5. Dr. Sanjeev C. Ghadi, Professor, Department of Biotechnology, Goa University, Goa
6. Dr. Dilip R. Ranade, Consultant, Microbial Culture Collection, National Centre for Cell Science, Pune
7. Dr. Lidita Khandeparker, Senior Scientist, National Institute of Oceanography, Goa

**Member Secretary**
8. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi

Subject Specific Subcommittee of M.Sc. Industrial Biotechnology

**Chairperson**
1. Dr. K. J. Mukherjee, Professor, School of Biotechnology, Jawaharlal Nehru University, New Delhi

**Members**
2. Dr. Saroj Mishra, Professor, Department of Biochemical Engineering, Indian Institute of Technology, New Delhi
3. Dr. Datta Madamwar, Professor, School of BRD Biosciences, Sardar Patel University, Vallabh Vidyanagar
4. Dr. Gautam Ghosh, Sr. Vice President, Panacea Biotec Ltd., New Delhi
5. Dr. Gaurav Pandey, Associate Director, Product Development at Malaria Vaccine Development Program, New Delhi

**Member Secretary**
6. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi
### Subject Specific Subcommittee of M.Sc. Medical Biotechnology and Molecular & Human Genetics

**Chairperson**
1. Dr. B. J. Rao, Senior Professor, Tata Institute of Fundamental Research, Mumbai

**Members**
2. Dr. Jaya Tyagi, Professor, Department of Biotechnology, All India Institute of Medical Sciences, New Delhi
3. Dr. Pramod Mehta, Professor, Centre for Biotechnology, Maharshi Dayanand University, Rohtak
4. Dr. Alok Ray, Consultant Professor, School of International Biodesign and Former Head of Biomedical Engineering, Indian Institute of Technology, New Delhi
5. Dr. Madhumita Roy Chowdhury, Senior Scientist, Department of Pediatrics, Division of Genetics, All India Institute of Medical Sciences, New Delhi
6. Dr. Mousumi Mutsuddi, Assistant Professor, Department of Molecular and Human Genetics, Banaras Hindu University, Varanasi
7. Dr. Surajit Sarkar, Assistant Professor, Department of Genetics, University of Delhi
8. Dr. Arjun Surya, Chief Scientific Officer, Curadev Pharma, New Delhi
9. Dr. Vibhu Kanchan, Senior Scientist, MSD Wellcome Trust Hilleman Labs Pvt. Ltd., New Delhi

**Member Secretary**
10. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi

### Subject Specific Subcommittee of M.Sc. Neuroscience

**Chairperson**
1. Dr. Ishan Patro, Professor and Coordinator, School of Studies in Neuroscience, Jiwaji University, Gwalior

**Members**
2. Dr. S. Ganesh, Dean, Research & Development and Professor, Department of Biological Sciences and Bioengineering, Indian Institute of Technology, Kanpur
3. Dr. Nihar Ranjan Jana, Professor and Scientist-VI, National Brain Research Centre, Manesar
4. Dr. Aurnab Ghose, Associate Professor, Department of Biology, Indian Institute of Science Education and Research, Pune
5. Dr. Amal Mondal, Associate Professor, School of Life Sciences, Jawaharlal Nehru University, New Delhi

**Member Secretary**
6. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi

### Subject Specific Subcommittee of M.V.Sc. Animal Biotechnology

**Chairperson**
1. Dr. Probodh Borah, Professor and Head of Department, Department of Animal Biotechnology, Assam Agricultural University, Guwahati

**Members**
2. Dr. Satish Kumar, Scientist and Group Leader, Centre for Cellular and Molecular Biology, Hyderabad
3. Dr. Riaz Shah, Professor and Head, Division of Biotechnology, Sher-e-Kashmir University, Srinagar
4. Dr. Minakshi Prasad, Sr. Scientist and Head, Department of Animal Biotechnology, Lala Lajpat Rai University, Hisar
5. Dr. Ramneek Verma, Professor and Director, School of Animal Biotechnology, Guru Angad Dev University, Ludhiana

**Member Secretary**
6. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi
The salient recommendations identified from stakeholder survey were presented to the Committees. Several brainstorming discussion sessions were held for achieving the desired balance between the foundation courses, recent developments in biotechnology and updation needs identified during the stakeholder survey. Core Committee finalized broad contours for revising all the course curricula. The guidelines set by the Core Committee were taken up by the subject specific subcommittees for updating the curricula. The subject specific subcommittees incorporated latest advancements in domain areas of Biotechnology in their respective curricula. Separate meetings were held to discuss and deliberate the updations to be made in the curricula. The revised curricula were vetted and finalized by the Core Committee.

The members of Committees agreed that revised course curriculum should provide skill and outcome based education and help the students to gain domain knowledge, ability to design and interpret research experiments and acquire effective communication skills. The course curricula have been re-designed accordingly to promote skill-based and outcome-based education.

The revised course curricula totals to about 90 – 100 credits comprising of theory, practical, technology-based topics, electives and dissertation. Each course includes learning objectives, student learning outcomes, course plan (number of lectures/unit) and reference textbooks/resources. Theory and practical courses include relevant examples, case scenarios and tutorials for inculcating critical thinking against rote
learning. Several new courses have been included and content for existing courses has also been updated. In addition, emphasis has been laid onto problem-solving and application-based approach by including Review of Research Papers, Seminars, Research Methodology and Communication Skills. Also, Bioentrepreneurship, Bioinformatics, Intellectual Property Rights, Biosafety and Bioethics have been included in view to provide holistic education, enhance research and communication skills along with industry-oriented knowledge. With importance of students being able to execute research projects independently, separate credits have been allotted for proposal preparation and presentation before initiating dissertation and also credits for dissertation have been increased accordingly.

We hope that model course curricula shall serve as guidelines for academicians and researchers from different parts of the country for adoption in their institutions with modifications as per availability of expertise, infrastructure and specific needs.

We wish to put on record our sincere appreciation for constant guidance and encouragement received from Dr. K. VijayRaghavan, Secretary, DBT for bringing out this publication. We wish to acknowledge whole-hearted support of Core Committee and subject specific subcommittees members. Sincere thanks are due to Dr. Manoj Singh Rohilla, Scientist- D, DBT, Ms. Shweta for creative design, Mrs. Rita Bhatla, DBT and Shri. Dilip Joy, BCIL.
Milestones

Important Milestones Achieved

1982
National Biotechnology Board (NBTB) set up

1985-86
DBT supported M.Sc.(Biotechnology) Teaching Programme initiated in 5 Universities. Expanded to 74 programmes from 1985-86 to 2016-17

1986
NBTB upgraded to Department of Biotechnology (DBT)

1993-94
Biotechnology Industrial Training Programme (BITP) initiated to provide Industrial exposure to Biotech students

2001
DBT - Post Doctoral Fellowship (PDF), Later renamed as Research Associateship (RA) Programme initiated to provide fellowships for Post Doctoral Research

2004
DBT- JRF (Junior Research Fellowship) Programme initiated to provide fellowships for doctoral research

2008
Model Course curricula for M.Sc./M.Tech Biotech in 10 specialisation framed

2009
DBT decision not to support any more general biotechnology PG courses

2010
Revision of fellowship for JRF-SRF (Senior Research Fellowship) and RA

2011
Revision of studentship for M.Sc./M.Tech. students in DBT supported programmes

2011-12
Karnataka Biotechnology Finishing School programme supported

2012
Online feedback by students for PG teaching programmes launched

2014
Revision of fellowship for JRF/SRF and RA
Independent Evaluation exercise for DBT HRD programmes assigned to BCIL & ASCI

2016
Independent evaluation exercise recommendations implemented
10 programmes phased out

2017
Curriculum revised
M.Sc. Biotechnology
Introduction

Background

Promotion of Indian Biotechnology sector is high on policy agenda of Government of India. Biotechnology has also been recognized as one of the key priority sectors under ‘Make in India,’ ‘Skill India’ and ‘Startup India’ initiatives of Government of India, as it is one of sectors expected to contribute towards enterprise creation, innovation and economic growth. Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India has immensely contributed to this dynamism through various policies and initiatives, establishment of innovation clusters, academia-industry partnerships, increasing capabilities for technology development, etc. The National Biotechnology Development Strategy (2015 – 2020) released by DBT provides a strategic roadmap for India’s emergence as a global biotechnology innovation and manufacturing hub. It has also highlighted importance of human resource development and need for nurturing tailor-made human capital for advanced scientific research and entrepreneurship.

DBT has taken a number of initiatives aimed at integrated human resource development to evolve an ecosystem where scientists, innovators and future entrepreneurs can be nurtured. Keeping in mind requirement for trained manpower in various areas of Biotechnology, DBT initiated Post-Graduate Teaching Programme way back in 1985 with 5 universities which has expanded to 74 universities imparting M.Sc./M.Tech./M.V.Sc. degrees in general, agricultural, animal, food, environmental, industrial marine, medical, neuroscience and pharmaceutical biotechnology. 10 programmes are being phased out. These universities and institutes are provided liberal financial support towards strengthening of laboratory facilities, equipment, consumables, fellowships to students, dissertation grant per student etc. Post-Graduate Teaching Programme selects best students and trains them to join research or industry workforce contributing significantly to biotechnology workforce.

Taking into cognizance the changing needs of the economy and to keep abreast with latest developments in the field of biotechnology, DBT proactively initiated revision of course curricula of Post-Graduate Programmes in biotechnology. The present exercise has been undertaken by Biotech Consortium India Limited (BCIL), New Delhi. Earlier exercise was carried out in 2008. The Course Curriculum Revision Exercise has been carried out for 13 Post-Graduate programmes in Biotechnology supported by DBT.

The revision of course curriculum of M.Sc. Biotechnology aims to address mismatch between ‘knowledge' gained by students and appropriate skill set required for technology development and implementation including present contemporary needs of economy.

Methodology

A meticulous and structured approach has been adopted to accomplish the Course Curriculum Revision exercise.

BCIL had initiated the exercise with a review of literature of relevant national and international documents on curriculum design and planning for biotechnology programmes of premier national as well as international universities, guidelines by University Grants Commission, recent curricular guidelines released by Indian Council of Agricultural Research, Ministry of Health and Family Welfare and Indian Institute of Science Education & Research and other relevant research papers on curriculum development in peer-reviewed journals.
The findings of the literature review were adopted to design questionnaires for eliciting feedback from stakeholders of Biotechnology community i.e. academicians, scientists, industry representatives and students. Feedback was received from 165 experts and 20 students belonging to academic institutions, research organizations and industry regarding addition of advanced topics, deletion of elementary, redundant and overlapping topics, updation of laboratory practicals, re-adjustment of credit load, incorporating ‘technology’ component in the curriculum, among others. It was also suggested that re-orientation of curricula should be done keeping in view the needs of the industry.

**Strategic Approach**

A Core Committee along with 9 subject specific subcommittees comprising of 63 academicians, scientists and industry representatives were constituted to revise and update the curricula. The constitution of Core Committee is given at Annexure-1.

The salient recommendations identified from stakeholder survey were presented to the Committee. Several brainstorming discussion sessions were held for achieving the desired balance between the foundation courses, recent developments in biotechnology and updation needs identified during the stakeholder survey. Core Committee finalized broad contours for revising all the course curricula including M.Sc. Biotechnology. The guidelines set by the Core Committee were taken up by the subject specific committees for updating the respective curricula. The revised curriculum was vetted and finalized by the Core Committee.

**Course Curriculum Revision**

The members of Committee agreed that revised course curriculum should provide skill and outcome based education and help the students to gain domain knowledge, ability to design and interpret research experiments and acquire effective communication skills. The course curriculum has been re-designed accordingly to promote skill-based and outcome-based education. The revised course curriculum totals to 94 credits comprising of theory, practical, technology-based topics, electives and dissertation. Each course includes learning objectives, student learning outcomes, course plan (number of lectures/unit) and reference textbooks/resources. Theory and practical courses include relevant examples, case scenarios and tutorials for inculcating critical thinking against rote learning. Bridging courses in Chemistry, Physics, Mathematics and Statistics have been introduced. Content for Foundation courses Biochemistry, Cell and Molecular Biology, Genetics, Microbiology, Immunology and Genetic Engineering has been updated. Courses such as Critical Analysis of Classical Papers and Emerging Technologies have to develop problem-solving approach. New courses such as Bioentrepreneurship, Intellectual Property Rights, Biosafety and Bioethics, Bioinformatics, Research Methodology, Scientific Communication Skills, etc. with a view to provide holistic education. With importance of students being able to execute research projects independently, separate credits have been allotted for proposal preparation and presentation before initiating dissertation and also credits for dissertation have been increased accordingly.

We hope that model course curriculum shall serve as guidelines for academicians and researchers from different parts of the country for adoption in their institutions with modifications as per availability of expertise, infrastructure and specific needs.

We wish to put on record our sincere appreciation for constant guidance and encouragement received from Dr. K. VijayRaghavan, Secretary, DBT for bringing out this publication. We wish to acknowledge whole-hearted support of Core Committee and subject specific subcommittees members. Sincere thanks are due to Dr. Manoj Singh Rohilla, Scientist- D, DBT, Ms. Shweta for creative design, Mrs. Rita Bhatla, DBT and Shri. Dilip Joy, BCIL.
Biotechnology in India has been a rapidly growing industry and has captured the essence of life beautifully. It is estimated that this industry will soon become a $100 billion entity. Universities are the platform of intellectual growth and course curriculum helps the students reach their goals which can be either research or industry. Thus, it is mandatory to keep updating the course curriculum regularly so that the students are able to take the most informed route to reach their goals.

The Department of Biotechnology, Ministry of Science and Technology, Government of India has been actively making numerous efforts to raise the biotechnology sector in India. Looking at this rapidly growing sector and the ever increasing gap of knowledge between university graduates and industry recruits led to the need for an updated course curricula. The responsibility for this task was entrusted to the Biotech Consortium India Limited, New Delhi to arrive at the best possible methods to update the current curricula keeping in mind the needs of students and industries. This exercise was previously undertaken in 2008 and hence this exercise was long overdue. The current updation exercise not only brings the course curricula at par with the current development in biotechnology, but also seeks to create a manpower and human resource capable of high order thinking and skills. Several inclusions like bioentrepreneurship and IPR will help the graduates to explore the $100 billion market, while other inclusions like Critical Analysis of Classical Papers and Project proposal and Presentation would help them augment the market to $200 billion.

This booklet is a result of several deliberations between the esteemed Core committee and the numerous subject specific committees. After several rounds of personal interactions and numerous discussions, we have tried to come up with the best possible course curricula for the universities to implement. In conclusion, I would like to thank and congratulate the Department of Biotechnology, Ministry of Science and Technology, Government of India for extending its support; BCIL for conducting this exercise efficiently; the core committee and all the experts in different committees for lending their valuable time and expertise to this noble cause. I hope this guideline curricula will enable the educators to impart best possible knowledge and learning experience to students.

(K. Krishnamurthy Rao)
# M.Sc. Biotechnology

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<td>Bioprocess Engineering and Technology</td>
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<td>Emerging Technologies</td>
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<td>Critical Analysis of Classical Papers</td>
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<td>Bioentrepreneurship</td>
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<td>Intellectual Property Rights, Biosafety and Bioethics</td>
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<td>Project Proposal Preparation and Presentation</td>
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<td>8</td>
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<td>Laboratory VII: Bioinformatics</td>
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**Recommended Electives:**
# Semester One

## Biochemistry

<table>
<thead>
<tr>
<th>Unit I</th>
<th>Chemical basis of life and proteins</th>
<th>7 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Chemical basis of life: Miller-Urey experiment, abiotic formation of amino acid oligomers, composition of living matter; Water – properties of water, essential role of water for life on earth pH, buffer, maintenance of blood pH and pH of gastric juice, pH optima of different enzymes (pepsin, trypsin and alkaline phosphatase), ionization and hydrophobicity, emergent properties of biomolecules in water, biomolecular hierarchy, macromolecules, molecular assemblies.</td>
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<thead>
<tr>
<th>Unit II</th>
<th>Protein structure</th>
<th>4 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Structure-function relationships: amino acids – structure and functional group properties, peptides and covalent structure of proteins, elucidation of primary and higher order structures, Ramachandran plot, evolution of protein structure, protein degradation and introduction to molecular pathways controlling protein degradation, structure-function relationships in model proteins like ribonuclease A, myoglobin, hemoglobin, chymotrypsin etc.; basic principles of protein purification; tools to characterize expressed proteins; Protein folding: Anfinsen's Dogma, Levinthal paradox, cooperativity in protein folding, free energy landscape of protein folding and pathways of protein folding, molten globule state, chaperons, diseases associated with protein folding, introduction to molecular dynamic simulation.</td>
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<tr>
<th>Unit III</th>
<th>Enzyme kinetics</th>
<th>5 lectures</th>
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<tr>
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<td>Enzyme catalysis – general principles of catalysis; quantitation of enzyme activity and efficiency; enzyme characterization and Michaelis-Menten kinetics; relevance of enzymes in metabolic regulation, activation, inhibition and covalent modification; single substrate enzymes; concept of catalytic antibodies; catalytic strategies with specific examples of proteases, carbonic anhydrases, restriction enzymes and nucleoside monophosphate kinase; regulatory strategies with specific example of hemoglobin; isozymes; role of covalent modification in enzymatic activity; zymogens.</td>
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<tr>
<th>Unit IV</th>
<th>Glycobiology</th>
<th>2 lectures</th>
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<td>Sugars - mono, di, and polysaccharides with specific reference to glycogen, amylase and cellulose, glycosylation of other biomolecules - glycoproteins and glycolipids; lipids - structure and properties of important members of storage and membrane lipids; lipoproteins.</td>
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<tr>
<th>Unit V</th>
<th>Structure and functions of DNA &amp; RNA</th>
<th>3 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Self-assembly of lipids, micelle, biomembrane organization - sidedness and function; membrane bound proteins - structure, properties and function; transport phenomena; nucleosides, nucleotides, nucleic acids - structure, a historical perspective leading up to the proposition of DNA double helical structure; difference in RNA and DNA structure and their importance in evolution of DNA as the genetic material.</td>
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<tr>
<th>Unit VI</th>
<th>Lipids, DNA &amp; RNA</th>
<th>8 lectures</th>
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<td>Bioenergetics-basic principles; equilibria and concept of free energy; coupled interconnecting reactions in metabolism; oxidation of carbon fuels; recurring motifs in metabolism; Introduction to GPCR, Inositol/DAG//PKC and Ca++ signaling pathways;</td>
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glycolysis and gluconeogenesis; reciprocal regulations and non-carbohydrate sources of glucose; Citric acid cycle, entry to citric acid cycle, citric acid cycle as a source of biosynthetic precursors; Oxidative phosphorylation; importance of electron transfer in oxidative phosphorylation; F1-F0 ATP Synthase; shuttles across mitochondria; regulation of oxidative phosphorylation; Photosynthesis – chloroplasts and two photosystems; proton gradient across thylakoid membrane; Calvin cycle and pentose phosphate pathway; glycogen metabolism, reciprocal control of glycogen synthesis and breakdown, roles of epinephrine and glucagon and insulin in glycogen metabolism; Fatty acid metabolism; protein turnover and amino acid catabolism; nucleotide biosynthesis; biosynthesis of membrane lipids and sterols with specific emphasis on cholesterol metabolism and mevalonate pathway; elucidation of metabolic pathways; logic and integration of central metabolism; entry/exit of various biomolecules from central pathways; principles of metabolic regulation; steps for regulation.

Calvin cycle and pentose phosphate pathway; glycogen metabolism, reciprocal control of glycogen synthesis and breakdown, roles of epinephrine and glucagon and insulin in glycogen metabolism; Fatty acid metabolism; protein turnover and amino acid catabolism; nucleotide biosynthesis; biosynthesis of membrane lipids and sterols with specific emphasis on cholesterol metabolism and mevalonate pathway; elucidation of metabolic pathways; logic and integration of central metabolism; entry/exit of various biomolecules from central pathways; principles of metabolic regulation; steps for regulation; target of rapamycin (TOR) & Autophagy regulation in relation to C & N metabolism, starvation responses and insulin signaling.

Recommended Textbooks and References:

Cell and Molecular Biology

Credits 3

Unit I
Dynamic organization of cell
6 lectures

Universal features of cells; cell chemistry and biosynthesis: chemical organization of cells; internal organization of the cell - cell membranes: structure of cell membranes and concepts related to compartmentalization in eukaryotic cells; intracellular organelles: endoplasmic reticulum and Golgi apparatus, lysosomes and peroxisomes, ribosomes, cellular cytoskeleton, mitochondria, chloroplasts and cell energetics; nuclear compartment: nucleus, nucleolus and chromosomes.

Unit VII
Role of vitamins & cofactors in metabolism
12 lectures

Course Objectives
The objectives of this course are to sensitize the students to the fact that as we go down the scale of magnitude from cells to organelles to molecules, the understanding of various biological processes becomes deeper and inclusive.

Student Learning Outcomes
Student should be equipped to understand three fundamental aspects in biological phenomenon: a) what to seek; b) how to seek; c) why to seek?
Chromatin organization - histone and DNA interactome: structure and assembly of eukaryotic and prokaryotic DNA polymerases, DNA-replication, repair and recombination; chromatin control: gene transcription and silencing by chromatin-Writers, -Readers and -Erasers; Transcriptional control: Structure and assembly of eukaryotic and prokaryotic RNA Polymerases, promoters and enhancers, transcription factors as activators and repressors, transcriptional initiation, elongation and termination; post-transcriptional control: splicing and addition of cap and tail, mRNA flow through nuclear envelope into cytoplasm, breakdown of selective and specific mRNAs through interference by small non-coding RNAs (miRNAs and siRNAs), protein translation machinery, ribosomes-composition and assembly; universal genetic codes, degeneracy of codons, Wobble hypothesis; Iso-accepting tRNA; mechanism of initiation, elongation and termination; co- and post-translational modifications, mitochondrial genetic code translation product cleavage, modification and activation.

Molecular mechanisms of membrane transport, nuclear transport, transport across mitochondria and chloroplasts; intracellular vesicular trafficking from endoplasmic reticulum through Golgi apparatus to lysosomes/cell exterior.

Cell cycle and its regulation; cell division: mitosis, meiosis and cytokinesis; cell differentiation: stem cells, their differentiation into different cell types and organization into specialized tissues; cell-ECM and cell-cell interactions; cell receptors and trans-membrane signalling; cell motility and migration; cell death: different modes of cell death and their regulation.

Isolation of cells and basics of cell culture; observing cells under a microscope, different types of microscopy; analyzing and manipulating DNA, RNA and proteins.

Mutations, proto-oncogenes, oncogenes and tumour suppressor genes, physical, chemical and biological mutagens; types of mutations; intra-genic and inter-genic suppression; transpositions- transposable genetic elements in prokaryotes and eukaryotes, role of transposons in genome; viral and cellular oncogenes; tumor suppressor genes; structure, function and mechanism of action; activation and suppression of tumor suppressor genes; oncogenes as transcriptional activators.

Recommended Textbooks and References:

## Course Objectives

The objectives of this course are to introduce students to the principles, practices and application of animal biotechnology, plant tissue culture, plant and animal genomics, genetic transformation and molecular breeding of plants and animals.

## Student Learning Outcomes

Students should be able to gain fundamental knowledge in animal and plant biotechnology and their applications.

### Unit I

**Plant tissue culture and animal cell culture**

- Plant tissue culture: historical perspective; totipotency; organogenesis; Somatic embryogenesis; establishment of cultures – callus culture, cell suspension culture, media preparation – nutrients and plant hormones; sterilization techniques; applications of tissue culture - micropropagation; somaclonal variation; androgenesis and its applications in genetics and plant breeding; germplasm conservation and cryopreservation; synthetic seed production; protoplast culture and somatic hybridization - protoplast isolation; culture and usage; somatic hybridization - methods and applications; cybrids and somatic cell genetics; plant cell cultures for secondary metabolite production.
- Animal cell culture: brief history of animal cell culture; cell culture media and reagents; culture of mammalian cells, tissues and organs; primary culture, secondary culture, continuous cell lines, suspension cultures; application of animal cell culture for virus isolation and in vitro testing of drugs, testing of toxicity of environmental pollutants in cell culture, application of cell culture technology in production of human and animal viral vaccines and pharmaceutical proteins.

### Unit II

**Plant genetic manipulation**

- Genetic engineering: Agrobacterium -plant interaction; virulence; Ti and Ri plasmids; opines and their significance; T-DNA transfer; disarmed Ti plasmid; Genetic transformation - Agrobacterium-mediated gene delivery; cointegrate and binary vectors and their utility; direct gene transfer - PEG-mediated, electroporation, particle bombardment and alternative methods; screenable and selectable markers; characterization of transgenics; chloroplast transformation; marker-free methodologies; advanced methodologies - cisgenesis, intragenesis and genome editing; molecular pharming - concept of plants as biofactories, production of industrial enzymes and pharmaceutically important compounds.

### Unit III

**Animal reproductive biotechnology and vaccinology**

- Animal reproductive biotechnology: structure of sperms and ovum; cryopreservation of sperms and ova of livestock; artificial insemination; super ovulation, embryo recovery and in vitro fertilization; culture of embryos; cryopreservation of embryos; embryo transfer technology; transgenic manipulation of animal embryos; applications of transgenic animal technology; animal cloning - basic concept, cloning for conservation for conservation endangered species; Vaccinology: history of development of vaccines, introduction to the concept of vaccines, conventional methods of animal vaccine production, recombinant approaches to vaccine production, modern vaccines.

### Unit IV

**Plant and animal genomics**

- Overview of genomics – definition, complexity and classification; need for genomics level analysis; methods of analyzing genome at various levels – DNA, RNA, protein, metabolites and phenotype; genome projects and bioinformatics resources for genome research – databases; overview of forward and reverse genetics for assigning function for genes.
Molecular markers - hybridization and PCR based markers RFLP, RAPD, STS, SSR, AFLP, SNP markers; DNA fingerprinting-principles and applications; introduction to mapping of genes/QTLs; marker-assisted selection - strategies for introducing genes of biotic and abiotic stress resistance in plants; genetic basis for disease resistance in animals; molecular diagnostics of pathogens in plants and animals; detection of meat adulteration using DNA based methods.

Recommended Textbooks and References:

Microbiology

Course Objectives
The objectives of this course are to introduce field of microbiology with special emphasis on microbial diversity, morphology, physiology and nutrition; methods for control of microbes and host-microbe interactions.

Student Learning Outcomes
Students should be able to:
- Identify major categories of microorganisms and analyze their classification, diversity, and ubiquity;
- Identify and demonstrate structural, physiological, genetic similarities and differences of major categories of microorganisms;
- Identify and demonstrate how to control microbial growth;
- Demonstrate and evaluate interactions between microbes, hosts and environment.

Unit I
Microbial characteristics
6 lectures

Introduction to microbiology and microbes, history & scope of microbiology, morphology, structure, growth and nutrition of bacteria, bacterial growth curve, bacterial culture methods; bacterial genetics: mutation and recombination in bacteria, plasmids, transformation, transduction and conjugation; antimicrobial resistance.

Unit II
Microbial diversity
9 lectures

Microbial taxonomy and evolution of diversity, classification of microorganisms, criteria for classification; classification of bacteria; Cyanobacteria, acetic acid bacteria, Pseudomonads, lactic and propionic acid bacteria, endospore forming bacteria,
Mycobacteria and Mycoplasma. Archaea: Halophiles, Methanogens, Hyperthermophilic archae, Thermoplasm; eukarya: algae, fungi, slime molds and protozoa; extremophiles and unculturable microbes.

Unit III
Control of microorganisms
3 lectures
Sterilization, disinfection and antisepsis: physical and chemical methods for control of microorganisms, antibiotics, antiviral and antifungal drugs, biological control of microorganisms.

Unit IV
Virology
5 lectures
Virus and bacteriophages, general properties of viruses, viral structure, taxonomy of virus, viral replication, cultivation and identification of viruses; sub-viral particles – viroids and prions.

Unit V
Host-microbes interaction
5 lectures
Host-pathogen interaction, ecological impact of microbes; symbiosis (Nitrogen fixation and ruminant symbiosis); microbes and nutrient cycles; microbial communication system; bacterial quorum sensing; microbial fuel cells; prebiotics and probiotics.

Recommended Textbooks and References:

Course Objectives
The objectives of this course are to take students through basics of genetics and classical genetics covering prokaryotic/ phage genetics to yeast and higher eukaryotic domains. On covering all classical concepts of Mendelian genetics across these life-forms, students will be exposed to concepts of population genetics, quantitative genetics encompassing complex traits, clinical genetics and genetics of evolution.

Student Learning Outcomes
On successful completion of this course, student will be able:
- Describe fundamental molecular principles of genetics;
- Understand relationship between phenotype and genotype in human genetic traits;
- Describe the basics of genetic mapping;
- Understand how gene expression is regulated.

Unit I
Genetics of bacteria and bacteriophages
10 lectures
Concept of a gene in pre-DNA era; mapping of genes in bacterial and phage chromosomes by classical genetic crosses; fine structure analysis of a gene; genetic complementation and other genetic crosses using phenotypic markers; phenotype to genotype connectivity prior to DNA-based understanding of gene.

Unit II
Yeast genetics
6 lectures
Meiotic crosses, tetrad analyses, non-Mendelian and Mendelian ratios, gene conversion, models of genetic recombination, yeast mating type switch; dominant and recessive genes/mutations, suppressor or modifier screens, complementation groups, transposon mutagenesis, synthetic lethality, genetic epistasis.
Unit III  
**Drosophila genetics as a model of higher eukaryotes**  
4 lectures

- Monohybrid & dihybrid crosses, back-crosses, test-crosses, analyses of autosomal and sex linkages, screening of mutations based on phenotypes and mapping the same, hypomorphy, genetic mosaics, genetic epistasis in context of developmental mechanism.

Unit IV  
**Population genetics and genetics of evolution**  
4 lectures

- Introduction to the elements of population genetics: genetic variation, genetic drift, neutral evolution; mutation selection, balancing selection, Fishers theorem, Hardy-Weinberg equilibrium, linkage disequilibrium; in-breeding depression & mating systems; population bottlenecks, migrations, Bayesian statistics; adaptive landscape, spatial variation & genetic fitness.

Unit V  
**Quantitative genetics of complex traits (QTLs)**  
2 lectures

- Complex traits, mapping QTLs, yeast genomics to understand biology of QTLs.

Unit VI  
**Plant genetics**  
2 lectures

- Laws of segregation in plant crosses, inbreeding, selfing, heterosis, maintenance of genetic purity, gene pyramiding.

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**Recommended Textbooks and References:**


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**Course Objectives**

The objective of this course is to give conceptual exposure of essential contents of mathematics and statistics to students.

**Student Learning Outcomes**

- On completion of this course, students should be able to:
  - Gain broad understanding in mathematics and statistics;
  - Recognize importance and value of mathematical and statistical thinking, training, and approach to problem solving, on a diverse variety of disciplines.

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**Basics of Mathematics and Statistics**

**Credits**

2

Unit I  
**Algebra**  
6 lectures

- Linear equations, functions: slopes-intercepts, forms of two-variable linear equations; constructing linear models in biological systems; quadratic equations (solving, graphing, features of, interpreting quadratic models etc.), introduction to polynomials, graphs of binomials and polynomials; Symmetry of polynomial functions, basics of trigonometric functions, Pythagorean theory, graphing and constructing sinusoidal functions, imaginary numbers, complex numbers, adding-subtracting-multiplying complex numbers, basics of vectors, introduction to matrices.

Unit II  
**Calculus**  
4 lectures

- Differential calculus (limits, derivatives), integral calculus (integrals, sequences and series etc.).
Population dynamics; oscillations, circadian rhythms, developmental patterns, symmetry in biological systems, fractal geometries, size-limits & scaling in biology, modeling chemical reaction networks and metabolic networks.

Probability: counting, conditional probability, discrete and continuous random variables; Error propagation; Populations and samples, expectation, parametric tests of statistical significance, nonparametric hypothesis tests, linear regression, correlation & causality, analysis of variance, factorial experiment design.

Recommended Textbooks and References:
12 lectures:
10 hours teaching +
2 hours tutorials
ions; chemical reactions, reaction stoichiometry, rates of reaction, rate constants,
order of reactions, Arrhenious equation, Maxwell Boltzmann distributions, rate-
determining steps, catalysis, free-energy, entropy and enthalpy changes during
reactions; kinetic versus thermodynamic controls of a reaction, reaction equilibrium
(equilibrium constant); light and matter interactions (optical spectroscopy, fluorescence,
boluminescence, paramagnetism and diamagnetism, photoelectron spectroscopy;
chemical bonds (ionic, covalent, Van der Walls forces); electronegativity, polarity;
VSEPR theory and molecular geometry, dipole moment, orbital hybridizations; states
of matter - vapor pressure, phase diagrams, surface tension, boiling and melting points,
solubility, capillary action, suspensions, colloids and solutions; acids, bases and pH -
Arrhenious theory, pH, ionic product of water, weak acids and bases, conjugate acid-base
pairs, buffers and buffering action etc; chemical thermodynamics - internal energy, heat
and temperature, enthalpy (bond enthalpy and reaction enthalpy), entropy, Gibbs free
energy of ATP driven reactions, spontaneity versus driven reactions in biology; redox
reactions and electrochemistry - oxidation-reduction reactions, standard cell potentials,
Nernst equation, resting membrane potentials, electron transport chains (ETC) in
biology, coupling of oxidative phosphorylations to ETC; theories of ATP production and
dissipation across biological membranes; bond rotations and molecular conformations -
Newman projections, conformational analysis of alkanes, alkenes and alkynes; functional
groups, optically asymmetric carbon centers, amino acids, proteins, rotational freedoms
in polypeptide backbone (Ramachandran plot).

Recommended Textbooks and References:
   of Singapore.
   New York: Macmillan Company.
   New York: Wiley.
   Mifflin.
   San Francisco: Benjamin Cummings.
   W.H. Freeman.

Course Objectives
The objective of this laboratory course is to introduce students to experiments in
biochemistry. The course is designed to teach students the utility of set of
experimental methods in biochemistry in a problem oriented manner.

Student Learning Outcomes
On completion of this course, students should be able to:
• To elaborate concepts of biochemistry with easy to run experiments;
• To familiarize with basic laboratory instruments and understand the
  principle of measurements using those instruments with experiments in
  biochemistry.

Syllabus
1. Preparing various stock solutions and working solutions that will be needed
   for the course.
To prepare an Acetic-Na Acetate Buffer and validate the Henderson-Hasselbach equation.

To determine an unknown protein concentration by plotting a standard graph of BSA using UV-Vis Spectrophotometer and validating the Beer-Lambert's Law.

Titration of Amino Acids and separation of aliphatic, aromatic and polar amino acids by thin layer chromatography.

Purification and characterization of an enzyme from a recombinant source (such as Alkaline Phosphatase or Lactate Dehydrogenase or any enzyme of the institution’s choice).

a) Preparation of cell-free lysates
b) Ammonium Sulfate precipitation
c) Ion-exchange Chromatography
d) Gel Filtration
e) Affinity Chromatography
f) Dialysis of the purified protein solution against 60% glycerol as a demonstration of storage method
g) Generating a Purification Table (protein concentration, amount of total protein; Computing specific activity of the enzyme preparation at each stage of purification)
h) Assessing purity of samples from each step of purification by SDS-PAGE Gel Electrophoresis
i) Enzyme Kinetic Parameters: Km, Vmax and Kcat.

Experimental verification that absorption at OD_{260} is more for denatured DNA as compared to native double stranded DNA, reversal of the same following DNA renaturation. Kinetics of DNA renaturation as a function of DNA size.

Identification of an unknown sample as DNA, RNA or protein using available laboratory tools. (Optional Experiments)

Biophysical methods (Circular Dichroism Spectroscopy, Fluorescence Spectroscopy).

Determination of mass of small molecules and fragmentation patterns by Mass Spectrometry.

**Laboratory II: Microbiology**

The objective of this laboratory course is to provide practical skills on basic microbiological techniques.

**Course Objectives**

Students should be able to:

- Isolate, characterize and identify common bacterial organisms;
- Determine bacterial load of different samples;
- Perform antimicrobial sensitivity tests;
- Preserve bacterial cultures.

**Student Learning Outcomes**

1. Sterilization, disinfection and safety in microbiological laboratory.
2. Preparation of media for cultivation of bacteria.
3. Isolation of bacteria in pure culture by streak plate method.
4. Study of colony and growth characteristics of some common bacteria: Bacillus, E. coli, Staphylococcus, Streptococcus, etc.
5. Preparation of bacterial smear and Gram's staining.
7. Antimicrobial sensitivity test and demonstration of drug resistance.
8. Maintenance of stock cultures: slants, stabs and glycerol stock cultures
9. Determination of phenol co-efficient of antimicrobial agents.
10. Determination of Minimum Inhibitory Concentration (MIC)
11. Isolation and identification of bacteria from soil/water samples.

**Recommended Textbooks and References:**

3. Tille, P. M., & Forbes, B. A. *Bailey & Scott's Diagnostic Microbiology*.

**Course Objectives**

The objectives of this course are to provide hands-on training in basic experiments of plant and animal biotechnology.

**Student Learning Outcomes**

On completion of course, students should be able to gain basic skills in plant and animal biotechnology.

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**Syllabus**

**Plant Biotechnology**

1. Prepare culture media with various supplements for plant tissue culture.
2. Prepare explants of Valleriana wallichii for inoculation under aseptic conditions.
3. Attempt *in vitro* andro and gynogenesis in plants (*Datura stramonium*).
4. Isolate plant protoplast by enzymatic and mechanical methods and attempt fusion by PEG (available material).
5. Culture *Agrobacterium tumefaciens* and attempt transformation of any dicot species.
6. Generate an RAPD and ISSR profile of *Eremurus persicus* and *Valleriana wallichii*.
7. Prepare karyotypes and study the morphology of somatic chromosomes of *Allium cepa*, *A. sativum*, *A. tuberosum* and compare them on the basis of karyotypes.
8. Pollen mother cell meiosis and recombination index of select species (one achiasmate, and the other chiasmate) and correlate with generation of variation.
9. Undertake plant genomic DNA isolation by CTAB method and its quantitation by visual as well as spectrophotometric methods.
10. Perform PCR amplification of ‘n’ number of genotypes of a species for studying the genetic variation among the individuals of a species using random primers.
11. Study genetic fingerprinting profiles of plants and calculate polymorphic information content.

**Animal Biotechnology**

1. Count cells of an animal tissue and check their viability.
2. Prepare culture media with various supplements for plant and animal tissue culture.
3. Prepare single cell suspension from spleen and thymus.
5. Chromosome preparations from cultured animal cells.
6. Isolate DNA from animal tissue by SDS method.
7. Attempt animal cell fusion using PEG.
### Course Objectives

The objectives of this course are to teach students with various approaches to conducting genetic engineering and their applications in biological research as well as in biotechnology industries. Genetic engineering is a technology that has been developed based on our fundamental understanding of the principles of molecular biology and this is reflected in the contents of this course.

### Student Learning Outcomes

Given the impact of genetic engineering in modern society, the students should be endowed with strong theoretical knowledge of this technology. In conjunction with the practicals in molecular biology & genetic engineering, the students should be able to take up biological research as well as placement in the relevant biotech industry.

### Unit I

**Introduction and tools for genetic engineering**

- Impact of genetic engineering in modern society; general requirements for performing a genetic engineering experiment; restriction endonucleases and methylases; DNA ligase, Klenow enzyme, T4 DNA polymerase, polynucleotide kinase, alkaline phosphatase; cohesive and blunt end ligation; linkers; adaptors; homopolymeric tailing; labelling of DNA: nick translation, random priming, radioactive and non-radioactive probes, hybridization techniques: northern, southern, south-western and far-western and colony hybridization, fluorescence *in situ* hybridization.

### Unit II

**Different types of vectors**

- Plasmids; Bacteriophages; M13 mp vectors; PUC19 and Bluescript vectors, hagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Principles for maximizing gene expression expression vectors; pMal; GST; pET-based vectors; Protein purification; His-tag; GST-tag; MBP-tag etc.; Intein-based vectors; Inclusion bodies; methodologies to reduce formation of inclusion bodies; mammalian expression and replicating vectors; Baculovirus and *Pichia* vectors system, plant based vectors, Ti and Ri as vectors, yeast vectors, shuttle vectors.

### Unit III

**Different types of PCR techniques**

- Principles of PCR: primer design; fidelity of thermostable enzymes; DNA polymerases; types of PCR – multiplex, nested; reverse-transcription PCR, real time PCR, touchdown PCR, hot start PCR, colony PCR, asymmetric PCR, cloning of PCR products; T-vectors; proof reading enzymes; PCR based site specific mutagenesis; PCR in molecular diagnostics; viral and bacterial detection; sequencing methods; enzymatic DNA sequencing; chemical sequencing of DNA; automated DNA sequencing; RNA sequencing; chemical synthesis of oligonucleotides; mutation detection: SSCP, DGGE, RFLP.

### Unit IV

**Gene manipulation and protein-DNA interaction**

- Insertion of foreign DNA into host cells; transformation, electroporation, transfection; construction of libraries; isolation of mRNA and total RNA; reverse transcriptase and cDNA synthesis; cDNA and genomic libraries; construction of microarrays – genomic arrays, cDNA arrays and oligo arrays; study of protein-DNA interactions: electrophoretic mobility shift assay; DNase footprinting; methyl interference assay, chromatin immunoprecipitation; protein-protein interactions using yeast two-hybrid system; phage display.

### Unit V

**Gene silencing and genome editing technologies**

- Gene silencing techniques; introduction to siRNA; siRNA technology; Micro RNA; construction of siRNA vectors; principle and application of gene silencing; gene knockouts and gene therapy; creation of transgenic plants; debate over GM crops; introduction to methods of genetic manipulation in different model systems e.g. fruit flies.
(Drosophila), worms (C. elegans), frogs (Xenopus), fish (zebra fish) and chick; Transgenics - gene replacement; gene targeting; creation of transgenic and knock-out mice; disease model; introduction to genome editing by CRISPR-CAS with specific emphasis on Chinese and American clinical trials.

### Recommended Textbooks and References:

4. Selected papers from scientific journals, particularly Nature & Science.
5. Technical Literature from Stratagene, Promega, Novagen, New England Biolab etc.

### Course Objectives

The objectives of this course are to learn about structural features of components of immune system as well as their function. The major emphasis of this course will be on development of immune system and mechanisms by which our body elicits immune response. This will be imperative for students as it will help them to predict about nature of immune response that develops against bacterial, viral or parasitic infection, and prove it by designing new experiments.

### Student Learning Outcomes

On completion of this course, students should be able to:

- Evaluate usefulness of immunology in different pharmaceutical companies;
- Identify proper research lab working in area of their own interests;
- Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out kind of immune responses in the setting of infection (viral or bacterial).

<table>
<thead>
<tr>
<th>Unit I</th>
<th>Immunology: fundamental concepts and overview of the immune system</th>
<th>5 lectures</th>
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<td></td>
<td>Components of innate and acquired immunity; phagocytosis; complement and inflammatory responses; pathogen recognition receptors (PRR) and pathogen associated molecular pattern (PAMP); innate immune response; mucosal immunity; antigens: immunogens, haptons; Major Histocompatibility Complex: MHC genes, MHC and immune responsiveness and disease susceptibility, Organs of immune system, primary and secondary lymphoid organs.</td>
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<th>Unit II</th>
<th>Immune responses generated by B and T lymphocytes</th>
<th>8 lectures</th>
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<td>Immunoglobulins - basic structure, classes &amp; subclasses of immunoglobulins, antigenic determinants; multigene organization of immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; principles of cell signaling; basis of self &amp; non-self discrimination; kinetics of immune response, memory; B cell maturation, activation and differentiation; generation of antibody diversity; T-cell maturation, activation and differentiation and T-cell receptors; functional T Cell subsets; cell-mediated immune responses, ADCC; cytokines: properties, receptors and therapeutic uses; antigen processing and presentation- endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens; cell-cell co-operation, Hapten-carrier system.</td>
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<table>
<thead>
<tr>
<th>Unit III</th>
<th>Antigen-antibody interactions</th>
<th>6 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Precipitation, agglutination and complement mediated immune reactions; advanced immunological techniques: RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence microscopy, flow cytometry and immuno electron microscopy; surface plasmon resonance, biosensor assays for assessing ligand –receptor interaction; CMI techniques: lymphoproliferation assay, mixed lymphocyte reaction, cell cytotoxicity assays, apoptosis, microarrays, transgenic mice, gene knock outs.</td>
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</tbody>
</table>
Active and passive immunization; live, killed, attenuated, subunit vaccines; vaccine technology: role and properties of adjuvants, recombinant DNA and protein based vaccines, plant-based vaccines, reverse vaccinology; peptide vaccines, conjugate vaccines; antibody genes and antibody engineering: chimeric, generation of monoclonal antibodies, hybrid monoclonal antibodies; catalytic antibodies and generation of immunoglobulin gene libraries, idiotypic vaccines and marker vaccines, viral-like particles (VLPs), dendritic cell based vaccines, vaccine against cancer, T cell based vaccine, edible vaccine and therapeutic vaccine.

Immunity to infection: bacteria, viral, fungal and parasitic infections (with examples from each group); hypersensitivity: Type I-IV; autoimmunity; types of autoimmune diseases; mechanism and role of CD4+ T cells; MHC and TCR in autoimmunity; treatment of autoimmune diseases; transplantation: immunological basis of graft rejection; clinical transplantation and immunosuppressive therapy; tumor immunology: tumor antigens; immune response to tumors and tumor evasion of the immune system, cancer immunotherapy; immunodeficiency: primary immunodeficiencies, acquired or secondary immunodeficiencies, autoimmune disorder, anaphylactic shock, immunosenescence, immune exhaustion in chronic viral infection, immune tolerance, NK cells in chronic viral infection and malignancy.

Major histocompatibility complex genes and their role in autoimmune and infectious diseases, HLA typing, human major histocompatibility complex (MHC), Complement genes of the human major histocompatibility complex: implication for linkage disequilibrium and disease associations, genetic studies of rheumatoid arthritis, systemic lupus erythematosus and multiple sclerosis, genetics of human immunoglobulin, immunogenetics of spontaneous control of HIV, KIR complex.

Recommended Textbooks and References:

Course Objectives

The objectives of this course are to provide theory and practical experience of the use of common computational tools and databases which facilitate investigation of molecular biology and evolution-related concepts.

Student Learning Outcomes

Student should be able to:
- Develop an understanding of basic theory of these computational tools;
- Gain working knowledge of these computational tools and methods;
- Appreciate their relevance for investigating specific contemporary biological questions;
- Critically analyse and interpret results of their study.
Unit I
**Bioinformatics basics**
5 lectures

- Bioinformatics basics: Computers in biology and medicine; Introduction to Unix and Linux systems and basic commands; Database concepts; Protein and nucleic acid databases; Structural databases; Biological XML DTD's; pattern matching algorithm basics; databases and search tools: biological background for sequence analysis; Identification of protein sequence from DNA sequence; searching of databases similar sequence; NCBI; publicly available tools; resources at EBI; resources on web; database mining tools.

Unit II
**DNA sequence analysis**
5 lectures

- DNA sequence analysis: gene bank sequence database; submitting DNA sequences to databases and database searching; sequence alignment; pairwise alignment techniques; motif discovery and gene prediction; local structural variants of DNA, their relevance in molecular level processes, and their identification; assembly of data from genome sequencing.

Unit III
**Multiple sequence analysis**
5 lectures

- Multiple sequence analysis; multiple sequence alignment; flexible sequence similarity searching with the FASTA3 program package; use of CLUSTALW and CLUSTALX for multiple sequence alignment; submitting DNA protein sequence to databases: where and how to submit, SEQUIN, genome centres; submitting aligned sets of sequences, updating submitted sequences, methods of phylogenetic analysis.

Unit IV
**Protein modelling**
5 lectures

- Protein modelling: introduction; force field methods; energy, buried and exposed residues; side chains and neighbours; fixed regions; hydrogen bonds; mapping properties onto surfaces; fitting monomers; RMS fit of conformers; assigning secondary structures; sequence alignment- methods, evaluation, scoring; protein completion: backbone construction and side chain addition; small peptide methodology; software accessibility; building peptides; protein displays; substructure manipulations, annealing.

Unit V
**Protein structure prediction and virtual library**
6 lectures

- Protein structure prediction: protein folding and model generation; secondary structure prediction; analyzing secondary structures; protein loop searching; loop generating methods; homology modelling: potential applications, description, methodology, homologous sequence identification; align structures, align model sequence; construction of variable and conserved regions; threading techniques; topology fingerprint approach for prediction; evaluation of alternate models; structure prediction on a mystery sequence; structure aided sequence techniques of structure prediction; structural profiles, alignment algorithms, mutation tables, prediction, validation, sequence based methods of structure prediction, prediction using inverse folding, fold prediction; significance analysis, scoring techniques, sequence-sequence scoring; protein function prediction; elements of in silico drug design; Virtual library: Searching PubMed, current content, science citation index and current awareness services, electronic journals, grants and funding information.

### Recommended Textbooks and References:

# Genomics and Proteomics

## Course Objectives
The objectives of this course is to provide introductory knowledge concerning genomics, proteomics and their applications.

## Student Learning Outcomes
Students should be able to acquire knowledge and understanding of fundamentals of genomics and proteomics, transcriptomics and metabolomics and their applications in various applied areas of biology.

### Unit I
**Basics of genomics and proteomics**
3 lectures

Brief overview of prokaryotic and eukaryotic genome organization; extra-chromosomal DNA: bacterial plasmids, mitochondria and chloroplast.

### Unit II
**Genome mapping**
4 lectures

Genetic and physical maps; markers for genetic mapping; methods and techniques used for gene mapping, physical mapping, linkage analysis, cytogenetic techniques, FISH technique in gene mapping, somatic cell hybridization, radiation hybrid maps, *in situ* hybridization, comparative gene mapping.

### Unit III
**Genome sequencing projects**
3 lectures

Human Genome Project, genome sequencing projects for microbes, plants and animals, accessing and retrieving genome project information from the web.

### Unit IV
**Comparative genomics**
5 lectures

Identification and classification of organisms using molecular markers- 16S rRNA typing/sequencing, SNPs; use of genomes to understand evolution of eukaryotes, track emerging diseases and design new drugs; determining gene location in genome sequence.

### Unit V
**Proteomics**
5 lectures

Aims, strategies and challenges in proteomics; proteomics technologies: 2D-PAGE, isoelectric focusing, mass spectrometry, MALDI-TOF, yeast 2-hybrid system, proteome databases.

### Unit VI
**Functional genomics and proteomics**
8 lectures

Transcriptome analysis for identification and functional annotation of gene, Contig assembly, chromosome walking and characterization of chromosomes, mining functional genes in genome, gene function- forward and reverse genetics, gene ethics; protein-protein and protein-DNA interactions; protein chips and functional proteomics; clinical and biomedical applications of proteomics; introduction to metabolomics, lipidomics, metagenomics and systems biology.

## Recommended Textbooks and References:
Molecular Diagnostics

Course Objectives
The objectives of this course are to sensitize students about recent advances in molecular biology and various facets of molecular medicine which has potential to profoundly alter many aspects of modern medicine including pre- or post-natal analysis of genetic diseases and identification of individuals predisposed to disease ranging from common cold to cancer.

Student Learning Outcomes
Students should be able to understand various facets of molecular procedures and basics of genomics, proteomics and metabolomics that could be employed in early diagnosis and prognosis of human diseases.

Unit I
DNA, RNA, Protein: An overview; chromosomal structure & mutations; DNA polymorphism: human identity; clinical variability and genetically determined adverse reactions to drugs.

Unit II
PCR: Real-time; ARMS; Multiplex; ISH; FISH; ISA; RFLP; DHPLC; DGGE; CSCE; SSCP; Nucleic acid sequencing: new generations of automated sequencers; Microarray chips; EST; SAGE; microarray data normalization & analysis; molecular markers: 16s rRNA typing; Diagnostic proteomics: SELDI-TOF-MS; Bioinformatics data acquisition & analysis.

Unit III
Metabolite profile for biomarker detection the body fluids/tissues in various metabolic disorders by making using LCMS & NMR technological platforms.

Unit IV
Direct detection and identification of pathogenic-organisms that are slow growing or currently lacking a system of in vitro cultivation as well as genotypic markers of microbial resistance to specific antibiotics.

Unit V
Exemplified by two inherited diseases for which molecular diagnosis has provided a dramatic improvement of quality of medical care: Fragile X Syndrome: Paradigm of new mutational mechanism of unstable triplet repeats, von-Hippel Lindau disease: recent acquisition in growing number of familial cancer syndromes.

Unit VI
Detection of recognized genetic aberrations in clinical samples from cancer patients; types of cancer-causing alterations revealed by next-generation sequencing of clinical isolates; predictive biomarkers for personalized onco-therapy of human diseases such as chronic myeloid leukemia, colon, breast, lung cancer and melanoma as well as matching targeted therapies with patients and preventing toxicity of standard systemic therapies.

Unit VII
Quality oversight; regulations and approved testing.

Recommended Textbooks and References:
# Research Methodology and Scientific Communication Skills

## Course Objectives

The objectives of this course are to give background on history of science, emphasizing methodologies used to do research, use framework of these methodologies for understanding effective lab practices and scientific communication and appreciate scientific ethics.

## Student Learning Outcomes

Students should be able to:

- Understand history and methodologies of scientific research, applying these to recent published papers;
- Understand and practice scientific reading, writing and presentations;
- Appreciate scientific ethics through case studies.

## Credits

2

## Unit I

### History of science and science methodologies

8 lectures

Empirical science; scientific method; manipulative experiments and controls; deductive and inductive reasoning; descriptive science; reductionist vs holistic biology.

## Unit II

### Preparation for research

2 lectures

Choosing a mentor, lab and research question; maintaining a lab notebook.

## Unit III

### Process of communication

5 lectures

Concept of effective communication - setting clear goals for communication; determining outcomes and results; initiating communication; avoiding breakdowns while communicating; creating value in conversation; barriers to effective communication; non-verbal communication-interpreting non-verbal cues; importance of body language, power of effective listening; recognizing cultural differences; Presentation skills - formal presentation skills; preparing and presenting using overhead projector, PowerPoint; defending interrogation; scientific poster preparation & presentation; participating in group discussions; Computing skills for scientific research - web browsing for information search; search engines and their mechanism of searching; hidden Web and its importance in scientific research; internet as a medium of interaction between scientists; effective email strategy using the right tone and conciseness.

## Unit IV

### Scientific communication

9 lectures

Technical writing skills - types of reports; layout of a formal report; scientific writing skills - importance of communicating science; problems while writing a scientific document; plagiarism, software for plagiarism; scientific publication writing: elements of a scientific paper including abstract, introduction, materials & methods, results, discussion, references; drafting titles and framing abstracts; publishing scientific papers - peer review process and problems, recent developments such as open access and non-blind review; plagiarism; characteristics of effective technical communication; scientific presentations; ethical issues; scientific misconduct.
Recommended Textbooks and References:

Course Objectives
The objectives of this course are to provide students with experimental knowledge of molecular biology and genetic engineering.

Student Learning Outcomes
Students should be able to gain hands-on experience in gene cloning, protein expression and purification. This experience would enable them to begin a career in industry that engages in genetic engineering as well as in research laboratories conducting fundamental research.

Laboratory IV: Molecular Biology and Genetic Engineering

Credits
4

Syllabus
1. Concept of lac-operon:
   a) Lactose induction of B-galactosidase.
   b) Glucose Repression.
   c) Diauxic growth curve of E.coli
2. UV mutagenesis to isolate amino acid auxotroph
3. Phage titre with epsilon phage/M13
4. Genetic Transfer-Conjugation, gene mapping
5. Plasmid DNA isolation and DNA quantitation
6. Restriction Enzyme digestion of plasmid DNA
7. Agarose gel electrophoresis
8. Polymerase Chain Reaction and analysis by agarose gel electrophoresis
9. Vector and Insert Ligation
10. Preparation of competent cells
11. Transformation of E.coli with standard plasmids, Calculation of transformation efficiency
12. Confirmation of the insert by Colony PCR and Restriction mapping
13. Expression of recombinant protein, concept of soluble proteins and inclusion body formation in E.coli, SDS-PAGE analysis
14. Purification of His-Tagged protein on Ni-NTA columns
   a) Random Primer labeling
   b) Southern hybridization.

Syllabus

Recommended Textbooks and References:
Laboratory V: Immunology

Course Objectives
The objectives of this laboratory course are to develop an understanding about practical aspects of components of immune system as well as their function. Basic as well as advanced methods will be taught to detect different antigen and antibody interactions, isolation of different lymphocyte cells and how they can be used in respective research work.

Student Learning Outcomes
Students should be able to:
• Evaluate usefulness of immunology in different pharmaceutical companies;
• Identify proper research lab working in area of their own interests;
• Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out kind of immune responses in setting of infection (viral or bacterial) by looking at cytokine profile.

Syllabus
1. Selection of animals, preparation of antigens, immunization and methods of blood collection, serum separation and storage.
2. Antibody titre by ELISA method.
5. Isolation and purification of IgG from serum or IgY from chicken egg.
6. SDS-PAGE, Immunoblotting, Dot blot assays.
8. Separation of leucocytes by dextran method.
9. Demonstration of Phagocytosis of latex beads and their cryopreservation.
10. Separation of mononuclear cells by Ficoll-Hypaque and their cryopreservation.
11. Demonstration of ELISPOT.
12. Demonstration of FACS.

Semester Three

Bioprocess Engineering & Technology

Course Objectives
The objectives of this course are to educate students about the fundamental concepts of bioprocess technology and its related applications, thus preparing them to meet the challenges of the new and emerging areas of biotechnology industry.

Student Learning Outcomes
Students should be able to:
• Appreciate relevance of microorganisms from industrial context;
• Carry out stoichiometric calculations and specify models of their growth;
• Give an account of design and operations of various fermenters;
• Present unit operations together with the fundamental principles for basic methods in production technique for bio-based products;
• Calculate yield and production rates in a biological production process, and also interpret data;
• Calculate the need for oxygen and oxygen transfer;
• Critically analyze any bioprocess from market point of view;
• Give an account of important microbial/enzymatic industrial processes in food and fuel industry.
<table>
<thead>
<tr>
<th>Unit I</th>
<th>Basic principles of biochemical engineering</th>
<th>4 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Isolation, screening and maintenance of industrially important microbes; microbial growth and death kinetics (an example from each group, particularly with reference to industrially useful microorganisms); strain improvement for increased yield and other desirable characteristics.</td>
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<tr>
<td>Unit II</td>
<td>Stoichiometry and models of microbial growth</td>
<td>4 lectures</td>
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<td></td>
<td>Elemental balance equations; metabolic coupling – ATP and NAD+; yield coefficients; unstructured models of microbial growth; structured models of microbial growth.</td>
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<tr>
<td>Unit III</td>
<td>Bioreactor design and analysis</td>
<td>8 lectures</td>
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<td></td>
<td>Batch and continuous fermenters; modifying batch and continuous reactors: chemostat with recycle, multistage chemostat systems, fed-batch operations; conventional fermentation v/s biotransformation; immobilized cell systems; large scale animal and plant cell cultivation; fermentation economics; upstream processing: media formulation and optimization; sterilization; aeration, agitation and heat transfer in bioprocess; scale up and scale down; measurement and control of bioprocess parameters.</td>
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<tr>
<td>Unit IV</td>
<td>Downstream processing and product recovery</td>
<td>8 lectures</td>
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<td></td>
<td>Separation of insoluble products - filtration, centrifugation, sedimentation, flocculation; Cell disruption; separation of soluble products: liquid-liquid extraction, precipiation, chromatographic techniques, reverse osmosis, ultra and micro filtration, electrophoresis; final purification: drying; crystallization; storage and packaging.</td>
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<tr>
<td>Unit V</td>
<td>Fermentation economics</td>
<td>4 lectures</td>
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<tr>
<td></td>
<td>Isolation of micro-organisms of potential industrial interest; strain improvement; market analysis; equipment and plant costs; media; sterilization, heating and cooling; aeration and agitation; bath-process cycle times and continuous cultures; recovery costs; water usage and recycling; effluent treatment and disposal.</td>
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<tr>
<td>Unit VI</td>
<td>Applications of enzyme technology in food processing</td>
<td>4 lectures</td>
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<tr>
<td></td>
<td>Mechanism of enzyme function and reactions in process techniques; enzymatic bioconversions e.g. starch and sugar conversion processes; high-fructose corn syrup; interesterified fat; hydrolyzed protein etc. and their downstream processing; baking by amylases, deoxygenation and desugaring by glucose oxidase, beer mashing and chill proofing; cheese making by proteases and various other enzyme catalytic actions in food processing.</td>
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<tr>
<td>Unit VII</td>
<td>Applications of microbial technology in food process operations and production, biofuels and biorefinery</td>
<td>4 lectures</td>
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<td>Fermented foods and beverages; food ingredients and additives prepared by fermentation and their purification; fermentation as a method of preparing and preserving foods; microbes and their use in pickling, producing colours and flavours, alcoholic beverages and other products; process wastes-whey, molasses, starch substrates and other food wastes for bioconversion to useful products; bacteriocins from lactic acid bacteria – production and applications in food preservation; biofuels and biorefinery</td>
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**Recommended Textbooks and References:**

Emerging Technologies

Course Objectives
This course is broad-based in nature encompassing several new technologies that current experimental researchers are employing to probe complex system biology questions in life-sciences. The objectives of this course are to teach basics of the new principles to students so as to appreciate current-day research tool-kit better.

Student Learning Outcomes
Students should be to learn history, theoretical basis and basic understanding of latest technologies in area of biotechnology. They should also be able to learn about various applications of these technologies. The students may also learn one application in depth through an assignment and/or seminar.

Unit I
Optical microscopy methods
8 lectures

Basic Microscopy: Light Microscopy: lenses and microscopes, resolution: Rayleigh’s Approach, Darkfield; Phase Contrast; Differential Interference Contrast; fluorescence and fluorescence microscopy: what is fluorescence, what makes a molecule fluorescent, fluorescence microscope; optical arrangement, light source; filter sets: excitation filter, dichroic mirror, and barrier, optical layout for image capture; CCD cameras; back illumination, binning; recording color; three CCD elements with dichroic beamsplitters, boosting the signal.

Advanced Microscopy: Confocal microscope: scanning optical microscope, confocal principle, resolution and point spread function, light source: gas lasers & solid-state, primary beamsplitter; beam scanning, pinhole and signal channel configurations, detectors; pixels and voxels; contrast, spatial sampling: temporal sampling: signal-to-noise ratio, multichannel images. nonlinear microscopy: multiphoton microscopy; principles of two-photon fluorescence, advantages of two-photon excitation, tandem scanning (spinning disk) microscopes, deconvolving confocal images; image processing, three-dimensional reconstruction; advanced fluorescence techniques: FLIM, FRET, and FCS, Fluorescence Lifetime, Fluorescence Resonant Energy Transfer (FRET), Fluorescence Correlation Spectroscopy (FCS), Evanescent Wave Microscopy; Near-Field and Evanescent Waves, Total Internal Reflection Microscopy; Near-Field Microscopy; Beyond the Diffraction Limit: Stimulated Emission Depletion (STED), Super-Resolution Summary, Super-Resolution Imaging with Stochastic Optical Reconstruction Microscopy (STORM) and Photoactivated Localization Microscopy (PALM).

Unit II
Mass spectroscopy
4 lectures

Ionization techniques; mass analyzers/overview MS; FT-ICR and Orbitrap, fragmentation of peptides; proteomics, nano LC-MS; Phospho proteomics; interaction proteomics, mass spectroscopy in structural biology; imaging mass spectrometry.

Unit III
Systems biology
3 lectures

High throughput screens in cellular systems, target identification, validation of experimental methods to generate the omics data, bioinformatics analyses, mathematical modeling and designing testable predictions.

Unit IV
Structural biology
3 lectures


Unit V
CRISPR-CAS
6 lectures

History of its discovery, elucidation of the mechanism including introduction to all the molecular players, development of applications for in vivo genome engineering for genetic studies, promise of the technology as a next generation therapeutic method.
Introduction to nanobodies, combining nanobody with phage-display method for development of antibody against native proteins, nanobody as a tool for protein structure-function studies, use of nanobodies for molecular imaging, catabolic antibodies using nanobodies.

Recommended Textbooks and References:
Critical Analysis of Classical Papers

Course Objectives
The objectives of this course are to familiarize students with classic literature to make them appreciate how ground-breaking discoveries were made without, necessarily, use of high-end technologies.

Student Learning Outcomes
Students should be able to train in the exercise of hypothesis building and methods of addressing the hypothesis with readily available technology.

How does the Course Module work? Students may be divided in groups and each group may be responsible for one classical paper. Each week there may be a 1.5 hour presentation cum discussion for each of the papers. At the end of the semester each student will be asked to write a mini-review (2-3 pages long) on any one classical paper, other than the one he/she presented/discussed.

A list of sixteen classic papers and some suggested reference materials:

Syllabus

Molecular Biology

   Note: This paper demonstrates that DNA is the transforming Principle originally described by Fredrick Griffith.

   Note: This paper demonstrates that DNA, and not protein, component of phages enter bacterial cells.

3. Molecular structure of nucleic acids; a structure for deoxyribose nucleic acid Watson JD and Crick FH; Nature. 1953 Apr 25;171(4356):737-8
   Note: In this one page paper Watson and Crick first described the structure of DNA double helix
   Study help - Watson_Crick_Nature_1953_annotated

4. Transposable mating type genes in Saccharomyces cerevisiae James Hicks, Jeffrey N. Strathern & Amar J.S. Klar; Nature 282, 478-483,1979
   Note: This paper provided evidence for ‘cassette hypothesis’ of yeast mating type switches i.e. interconversion of mating types in yeast (S. cerevisiae) occurs by DNA rearrangement.

   Note: The experiment demonstrating semi-conservative mode of DNA replication is referred to as “the most beautiful experiment in biology”

   Note: This paper demonstrates that the telomerase contains the template for telomere synthesis

Syllabus

Cell Biology

1. A proteinconducting channel in the endoplasmic reticulum Simon SM AND Blobel G.; Cell. 1991 May 3;65(3):371-80
   Note: This paper demonstrates the existence of a protein conducting channel
   Study help - A brief history of Signal Hypothesis
2. Identification of 23 complementation groups required for post-translational events in the yeast secretory pathway
Note: In this groundbreaking paper Randy Schekman’s group used a mutagenesis screen for fast sedimenting yeast mutants to identify genes involved in cell secretion

3. A yeast mutant defective at an early stage in import of secretory protein precursors into the endoplasmic reticulum
Note: Using another yeast mutation screen Schekman lab identifies Sec61, a component of ER protein Conducting Channel (PCC)
Suggested reference paper - A biochemical assay for identification of PCC.

4. Reconstitution of the Transport of Protein between Successive Compartments of the Golgi
Balch WE, Dunphy WG, Braell WA, Rothman JE.; Cell. 1984 Dec;39(2 Pt 1):405-16
Note: This paper describes setting up of an in vitro reconstituted system for transport between golgi stacks which eventually paved the way for identification of most of the molecular players involved in these steps including NSF, SNAP etc.

5. A complete immunoglobulin gene is created by somatic recombination
Note: This study demonstrates DNA level molecular details of somatic rearrangement of immunoglobulin gene sequences leading to the generation of functionally competent antibody generating gene following recombination.

6. A novel multigene family may encode odorant receptors: a molecular basis for odor recognition
Buck L and Axel R; Cell. 1991 Apr 5;65(1):175-87
Note: This paper suggests that different chemical odorants associate with different cell-specific expression of a transmembrane receptor in Drosophila olfactory epithelium where a large family of odorat receptors is expressed.

7. Kinesin walks hand-over-hand
Yildiz A, Tomishige M, Vale RD, Selvin PR.; Science. 2004 Jan 30;303(5658):676-8
Note: This paper shows that kinesin motor works as a two-headed dimeric motor walking hand-over-hand rather than like an inchworm on microtubule tract using the energy of ATP hydrolysis.

1. Mutations affecting segment number and polarity in Drosophila
Note: This single mutagenesis screen identified majority of the developmentally important genes not only in flies but in other metazoans as well.

2. Information for the dorsal--ventral pattern of the Drosophila embryo is stored as maternal mRNA
Anderson KV and Nüsslein-Volhard C; Nature. 1984 Sep 20-26;311(5983):223-7
Note: This landmark paper demonstrated that early dorsal-ventral pattern information is stored as maternal mRNA in flies and devised the method of identifying genes encoding such genes

3. Hedgehog signalling in the mouse requires intracellular transport proteins
Note: One of the architects of original fly mutagenesis screens conducted a mouse mutagenes screen which identified a gene Kif5a as a major component of hedgehog signaling pathway. Eventually this discovery revolutionizes our understanding of mechanisms of action of signaling pathways by demonstrating central role of cilia in it.
Suggested Reference paper - Design and execution of an embryonic lethal mutation screen in mouse.

Syllabus

Developmental Biology/ Genetics
**Bioentrepreneurship**

**Credits**

<table>
<thead>
<tr>
<th>Unit I</th>
<th>Innovation and entrepreneurship in bio-business</th>
<th>8 lectures</th>
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<tbody>
<tr>
<td>Unit II</td>
<td>Bio markets - business strategy and marketing</td>
<td>8 lectures</td>
</tr>
<tr>
<td>Unit III</td>
<td>Finance and accounting</td>
<td>8 lectures</td>
</tr>
<tr>
<td>Unit IV</td>
<td>Technology management</td>
<td>8 lectures</td>
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</table>

**Course Objectives**

Research and business belong together and both are needed. In a rapidly developing life science industry, there is an urgent need for people who combine business knowledge with the understanding of science & technology. Bio-entrepreneurship, an interdisciplinary course, revolves around the central theme of how to manage and develop life science companies and projects. The objectives of this course are to teach students about concepts of entrepreneurship including identifying a winning business opportunity, gathering funding and launching a business, growing and nurturing the organization and harvesting the rewards.

**Student Learning Outcomes**

Students should be able to gain entrepreneurial skills, understand the various operations involved in venture creation, identify scope for entrepreneurship in biosciences and utilize the schemes promoted through knowledge centres and various agencies. The knowledge pertaining to management should also help students to be able to build up a strong network within the industry.

**Recommended Textbooks and References:**

### Course Objectives

The objectives of this course are:

- To provide basic knowledge on intellectual property rights and their implications in biological research and product development;
- To become familiar with India’s IPR Policy;
- To learn biosafety and risk assessment of products derived from biotechnology and regulation of such products;
- To become familiar with ethical issues in biological research. This course will focus on consequences of biomedical research technologies such as cloning of whole organisms, genetic modifications, DNA testing.

### Unit I

**Introduction to IPR**

5 lectures

Introduction to intellectual property; types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of ‘prior art’; invention in context of “prior art”; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation.

### Unit II

**Patenting**

5 lectures

Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure - patent application- forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting-requirement, procedures and costs; financial assistance for patenting-introduction to existing schemes; publication of patents-gazette of India, status in Europe and US; patent infringement- meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing – outright sale, licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives.

### Student Learning Outcomes

On completion of this course, students should be able to:

- Understand the rationale for and against IPR and especially patents;
- Understand why India has adopted an IPR Policy and be familiar with broad outline of patent regulations;
- Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents;
- Gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research and environmental release of genetically modified organisms, national and international regulations;
- Understand ethical aspects related to biological, biomedical, health care and biotechnology research.
Biosafety and Biosecurity - introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants – sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk – environmental risk assessment and food and feed safety assessment; problem formulation – protection goals, compilation of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops vs cisgenic plants or products derived from RNAi, genome editing tools.

International regulations – Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations – EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – biosafety levels and category of rDNA experiments; field trails – biosafety research trials – standard operating procedures - guidelines of state governments; GM labeling – Food Safety and Standards Authority of India (FSSAI).


Recommended Textbooks and References:
2. National IPR Policy, Department of Industrial Policy & Promotion, Ministry of Commerce, GoI
5. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/
Course Objectives
The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.

Student Learning Outcomes
Students should be able to demonstrate the following abilities:
- Formulate a scientific question;
- Present scientific approach to solve the problem;
- Interpret, discuss and communicate scientific results in written form;
- Gain experience in writing a scientific proposal;
- Learn how to present and explain their research findings to the audience effectively.

Syllabus
Project Proposal Preparation
Selection of research lab and research topic: Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them select a topic for their project. The topic of the research should be hypothesis driven.

Review of literature: Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources.

Writing Research Proposal: With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc. Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.

Syllabus
Poster Presentation
Students will have to present the topic of their project proposal after few months of their selection of the topic. They should be able to explain the novelty and importance of their research topic.

Syllabus
Oral Presentation
At the end of their project, presentation will have to be given by the students to explain work done by them in detail. Along with summarizing their findings they should also be able to discuss the future expected outcome of their work.
Course Objectives
The objectives of this laboratory course are to provide hands-on training to students in upstream and downstream unit operations.

Student Learning Outcomes
Students should be able to:
• Investigate, design and conduct experiments, analyze and interpret data, and apply the laboratory skills to solve complex bioprocess engineering problems;
• Apply skills and knowledge gained will be useful in solving problems typical of bio industries and research.

Syllabus

1. Basic Microbiology techniques
   a) Scale up from frozen vial to agar plate to shake flask culture.
   b) Instrumentation: Microplate reader, spectrophotometer, microscopy.
   c) Isolation of microorganisms from soil samples.

2. Experimental set-up
   a) Assembly of bioreactor and sterilization.
   b) Growth kinetics.
   c) Substrate and product inhibitions.
   d) Measurement of residual substrates.

3. Data Analysis
   a) Introduction to Metabolic Flux Analysis (MFA).

4. Fermentation
   a) Batch.
   b) Fed-batch.
   c) Continuous.

5. Unit operations
   a) Microfiltrations: Separation of cells from broth.
   b) Bioseparations: Various chromatographic techniques and extractions.

6. Bioanalytics
   a) Analytical techniques like HPLC, FPLC, GC, GC-MS etc. for measurement of amounts of products/substrates.

Recommended Textbooks and References:
Laboratory VII: Bioinformatics

Course Objectives
The aim of this course is to provide practical training in bioinformatic methods including accessing major public sequence databases, use of different computational tools to find sequences, analysis of protein and nucleic acid sequences by various software packages.

Student Learning Outcomes
On completion of this course, students should be able to:

- Describe contents and properties of most important bioinformatics databases;
- Perform text- and sequence-based searches and analyze and discuss results in light of molecular biological knowledge;
- Explain major steps in pairwise and multiple sequence alignment, explain principle and execute pairwise sequence alignment by dynamic programming;
- Predict secondary and tertiary structures of protein sequences.

Syllabus

1. Using NCBI and Uniprot web resources.
2. Introduction and use of various genome databases.
4. Similarity searches using tools like BLAST and interpretation of results.
5. Multiple sequence alignment using ClustalW.
7. Use of gene prediction methods (GRAIL, Genscan, Glimmer).
8. Using RNA structure prediction tools.
9. Use of various primer designing and restriction site prediction tools.
10. Use of different protein structure prediction databases (PDB, SCOP, CATH).
11. Construction and study of protein structures using Deepview/PyMol.
13. Use of tools for mutation and analysis of the energy minimization of protein structures.
14. Use of miRNA prediction, designing and target prediction tools.

Semester Four

Course Objectives
The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.

Student Learning Outcomes
Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:

- In-depth knowledge of the chosen area of research.
- Capability to critically and systematically integrate knowledge to identify issues that must be addressed within framework of specific thesis.
- Competence in research design.
Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.

Course Objectives
The objectives of this course are to provide complete overview of state-of-art live-cell imaging techniques using microscopes currently available in literature. Live-cell imaging techniques allow real-time examination of almost every aspect of cellular function under normal and experimental conditions. With live-cell imaging experiments, main challenges are to keep cells alive and healthy over a period of time. The growing number of live-cell imaging techniques means one can obtain greater amounts of information without stressing out cells.

Student Learning Outcomes
On completion of this course, students shall be able to gain a complete overview of super-resolution field from fundamentals to state-of-art methods and applications in biomedical research. The students shall learn the comparative advantages and disadvantages of each technique, covers all key techniques in field of biomedical science. The students shall also learn how to use new tools to increase resolution in sub-nanometer-scale images of living cells and tissue, which leads to new information about molecules, pathways and dynamics and state-of-the-art examples of applications using microscopes.

One of the most basic techniques for live-cell imaging is widefield fluorescent microscopy. Standard inverted research grade microscopes can yield valuable results if you are imaging adherent cells, large regions of interest (such as organelles) or very thin tissue sections (less than 5 micrometer). In widefield, a CCD camera is usually used to
capture images and the epi-fluorescence illumination source can be a mercury lamp, xenon lamp, LED's, etc. Each of these light sources require carefully matched interference filters for specific excitation and emission wavelengths of your fluorophore of interest. With widefield microscopy, your specimen is only exposed to excitation light for relatively short time periods as the full aperture of emission light is collected by the objectives. Widefield fluorescence microscopy can be used in combination with other common contrast techniques such as phase contrast and differential interference contrast (DIC) microscopy. This combination is useful when performing live-cell imaging to examine general cell morphology or viability while also imaging regions of interest within cells.

**Unit II**

**Confocal laser scanning microscopy (CLSM)**

CLSM has the ability to eliminate out-of-focus light and information. It is also possible to obtain optical serial sections from thicker specimens. A conjugate pinhole in the optical path of confocal microscopy prevents fluorescence from outside of the focal plane from being collected by photomultiplier detector or imaged by camera. In CLSM, a single pinhole (and single focused laser spot) is scanned across the specimen by scanning system. This spot forms a reflected epi-fluorescence image back on the original pinhole. When the specimen is in focus, fluorescent light from it passes through the pinhole to detector. Any out-of-focus light is defocused at the pinhole and very little of this signal passes through to the detector meaning that background fluorescence is greatly reduced. The pinhole acts as a spatial filter for emission light from the specimen.

**Unit III**

**Spinning disc confocal microscopy (SDCM)**

This method utilizes a 'Nipkow Disc' which is a mechanical opaque disc which has a series of thousands of drilled or etched pinholes arranged in a spiral pattern. Each illuminated pinhole on disc is imaged by microscope objective to a diffraction-limited spot on the region of interest on the specimen. The emission from fluorophores passes back through Nipkow disc pinholes and can be observed and captured by a CCD camera. The effect of spinning disc is that many thousands of points on the specimen are simultaneously illuminated. Using SDCM to examine a specimen means that real-time imaging (30-frames-per-second or faster) can be achieved, which is extremely useful if you are looking at dynamic changes within living cells over a wide spectrum of time-scales.

**Unit IV**

**Light-sheet fluorescence microscopy (LSFM, or SPIM)**

This method enables one to perform live-cell imaging on whole embryos, tissues and cell spheroids in vivo in a gentle manner with high temporal resolution and in three dimensions. One is able to track cell movement over extended periods of time and follow development of organs and tissues on a cellular level. The next evolution of light-sheet fluorescence microscopy, termed lattice light-sheet microscopy as developed by Eric Betzig (Nobel Prize Laureate 2014 for PALM super-resolution microscopy) will even allow live-cell imaging with super-resolved in vivo cellular localization capabilities.

**Unit V**

**Super-resolved fluorescence microscopy**


**Unit VI**

**Re-scan confocal microscopy**

Structured Illumination Microscopy; Correlative Nanoscopy: AFM Super-Resolution (STED/STORM) ; Stochastic Optical Fluctuation Imaging.
Course Objectives
The objective of this course is to provide students with theory and practical experience of essentials to aid for genomic, proteomic and metabolomics courses and drug design program.

Student Learning Outcomes
On completion of this course, the students are expected to:

• Develop an understanding of the basic theory of these computational tools;
• Develop required database extraction, integration, coding for computational tools and methods necessary for all Omics;
• Create hypothesis for investigating specific contemporary biological questions, provide help to experiment with or develop appropriate tools;
• Critically analyze and interpret results of their study with respect to whole systems.

Unit I
Introduction to computational biology basics and biological databases
4 lectures

Computers in biology and medicine; Overview of biological databases, nucleic acid & protein databases, primary, secondary, functional, composite, structural classification database, Sequence formats & storage. Access databases, Extract and create sub databases, limitations of existing databases.

Unit II
Pairwise and multiple sequence alignments
5 lectures


Unit III
Genome analysis
6 lectures

Polymorphisms in DNA sequence, Introduction to Next Generation Sequencing technologies, Whole Genome Assembly and challenges, Sequencing and analysis of large genomes, Gene prediction, Functional annotation, Comparative genomics, Probabilistic functional gene networks, Human genome project, Genomics and crop improvement. Study available GWAS, ENCODE, HUGO projects, extract and build sub databases; Visualization tools including Artemis and Vista for genome comparison; Functional genomics case studies.

Unit IV
Structure visualization
3 lectures

Retrieving and drawing structures, Macromolecule viewing platforms, Structure validation and correction, Structure optimization, Analysis of ligand-protein interactions; Tools such as PyMol or VMD.
Unit V
Molecular modelling
6 lectures

Significance and need, force field methods, energy, buried and exposed residues; side chains and neighbours; fixed regions; hydrogen bonds; mapping properties onto surfaces; RMS fit of conformers and protein chains, assigning secondary structures; sequence alignment: methods, evaluation, scoring; protein curation: backbone construction and side chain addition; different types of protein chain modelling: ab initio, homology, hybrid, loop; Template recognition and alignments; Modelling parameters and considerations; Model analysis and validation; Model optimization; Substructure manipulations, annealing, protein folding and model generation; loop generating methods; loop analysis; Analysis of active sites using different methods in studying protein–protein interactions.

Unit VI
Structure-based drug development
6 lectures

Molecular docking: Types and principles, Semi-flexible docking, Flexible docking; Ligand and protein preparation, Macromolecule and ligand optimization, Ligand conformations, Clustering, Analysis of docking results and validation with known information. Extra-precision docking platforms, Use of Small-molecule libraries, Natural compound libraries for virtual high throughput screenings.

Unit VII
Ligand-based drug development
6 lectures

Quantitative structure activity relationships; Introduction to chemical descriptors like 2D, 3D and Group-based; Radar plots and contribution plots and Activity predictions, Pharmacophore modeling, Pharmacophore-based screenings of compound library, analysis and experimental validation.

Recommended Textbooks and References:

Course Objectives
This course will give a broad overview of research and development carried out in industrial setup towards drug discovery.

Student Learning Outcomes
On completion of this course, students should be able to understand basics of R&D in drug discovery and should be able to apply knowledge gained in respective fields of pharmaceutical industry.
structures and physicochemical properties of drugs and receptors; Modelling drug/receptor interactions with the emphasis on molecular mechanisms, molecular dynamics simulations and homology modelling; Conformational sampling, macromolecular folding, structural bioinformatics, receptor-based and ligand-based design and docking methods, in silico screening of libraries, semi-empirical and ab-initio methods, QSAR methods, molecular diversity, design of combinatorial libraries of drug-like molecules, macromolecular and chemical databases.

**Unit II**

**Lead optimization**

5 lectures

Identification of relevant groups on a molecule that interact with a receptor and are responsible for biological activity; Understanding structure activity relationship; Structure modification to increase potency and therapeutic index; Concept of quantitative drug design using Quantitative structure–activity relationship models (QSAR models) based on the fact that the biological properties of a compound are a function of its physicochemical parameters such as solubility, lipophilicity, electronic effects, ionization, stereochemistry, etc.; Bioanalytical assay development in support of *in vitro* and *in vivo* studies (LC/MS/MS, GC/MS and ELISA).

**Unit III**

**Preclinical development**

5 lectures

Principles of drug absorption, drug metabolism and distribution - intestinal absorption, metabolic stability, drug-drug interactions, plasma protein binding assays, metabolite profile studies, Principles of toxicology, Experimental design for preclinical and clinical PK/PD/TK studies, Selection of animal model; Regulatory guidelines for preclinical PK/PD/TK studies; Scope of GLP, SOP for conduct of clinical & non clinical testing, control on animal house, report preparation and documentation Integration of non-clinical and preclinical data to aid design of clinical studies.

**Unit IV**

**Drug manufacturing**

4 lectures

Requirements of GMP implementation, Documentation of GMP practices, CoA, Regulatory certification of GMP, Quality control and Quality assurance, concept and philosophy of TQM, ICH and ISO 9000; ICH guidelines for Manufacturing, Understanding Impurity Qualification Data, Stability Studies.

**Unit V**

**Clinical trial design**

4 lectures

Objectives of Phase I, II, III and IV clinical studies, Clinical study design, enrollment, sites and documentation, Clinical safety studies: Adverse events and adverse drug reactions, Clinical PK, pharmacology, drug-drug interaction studies, Statistical analysis and documentation.

**Unit VI**

**Fundamentals of regulatory affairs and bioethics**

4 lectures

Global Regulatory Affairs and different steps involved, Regulatory Objectives, Regulatory Agencies; FDA guidelines on IND and NDA submissions, Studies required for IND and NDA submissions for oncology, HIV, cardiovascular indications, On-label vs. off-label drug use GCP and Requirements of GCP Compliance, Ethical issues and Compliance to current ethical guidelines, Ethical Committees and their set up, Animal Ethical issues and compliance.

**Recommended Textbooks and References:**

Environmental Biotechnology

Course Objectives
This course aims to introduce fundamentals of Environmental Biotechnology. The course will introduce major groups of microorganisms-tools in biotechnology and their most important environmental applications. The environmental applications of biotechnology will be presented in detail and will be supported by examples from the national and international literature.

Student Learning Outcomes
On completion of course, students will be able to understand use of basic microbiological, molecular and analytical methods, which are extensively used in environmental biotechnology.

Unit I
Introduction to environment
6 lectures
Introduction to environment; pollution and its control; pollution indicators; waste management: domestic, industrial, solid and hazardous wastes; strain improvement; Biodiversity and its conservation; Role of microorganisms in geochemical cycles; microbial energy metabolism, microbial growth kinetics and elementary chemostat theory, relevant microbiological processes, microbial ecology.

Unit II
Bioremediation
6 lectures
Bioremediation: Fundamentals, methods and strategies of application (biostimulation, bioaugmentation) – examples, bioremediation of metals (Cr, As, Se, Hg), radionuclides (U, Te), organic pollutants (PAHs, PCBs, Pesticides, TNT etc.), technological aspects of bioremediation (in situ, ex situ).

Unit III
Role of microorganisms in bioremediation
6 lectures
Application of bacteria and fungi in bioremediation: White rot fungi vs specialized degrading bacteria: examples, uses and advantages vs disadvantages; Phytoremediation: Fundamentals and description of major methods of application (phytoaccumulation, phytovolatilization, rhizofiltration phytostabilization).

Unit IV
Biotechnology and agriculture
11 lectures
Bioinsecticides: Bacillus thuringiensis, Baculoviruses, uses, genetic modifications and aspects of safety in their use; Biofungicides: Description of mode of actions and mechanisms (e.g. Trichoderma, Pseudomonas fluorescens); Biofertilizers: Symbiotic systems between plants – microorganisms (nitrogen fixing symbiosis, mycorrhiza fungi symbiosis), Plant growth promoting rhizobacteria (PGPR) – uses, practical aspects and problems in application.

Unit V
Biofuels
11 lectures
Environmental Biotechnology and biofuels: biogas; bioethanol; biodiesel; biohydrogen; Description of the industrial processes involved, microorganisms and biotechnological interventions for optimization of production; Microbiologically enhanced oil recovery (MEOR); Bioleaching of metals; Production of bioplastics; Production of biosurfactants: bioemulsifiers; Paper production: use of xylanases and white rot fungi.

Recommended Textbooks and References:
Microbial Technology

Course Objectives
The objectives of this course are to introduce students to developments/advances made in field of microbial technology for use in human welfare and solving problems of the society.

Student Learning Outcomes
On completion of this course, students would develop deeper understanding of the microbial technology and its applications.

Unit I
Introduction to microbial technology
8 lectures
Microbial technology in human welfare; Isolation and screening of microbes important for industry – advances in methodology and its application; Advanced genome and epigenome editing tools (e.g., engineered zinc finger proteins, TALEs/TALENs, and the CRISPR/Cas9 system as nucleases for genome editing, transcription factors for epigenome editing, and other emerging tools) for manipulation of useful microbes/strains and their applications; Strain improvement to increase yield of selected molecules, e.g., antibiotics, enzymes, biofuels.

Unit II
Environmental applications of microbial technology
6 lectures
Environmental application of microbes; Ore leaching; Biodegradation - biomass recycle and removal; Bioremediation - toxic waste removal and soil remediation; Global Biogeochemical cycles; Environment sensing (sensor organisms/biological sensors); International and National guidelines regarding use of genetically modified organisms in environment, food and pharmaceuticals.

Unit III
Pharmaceutical applications of microbial technology
8 lectures
Recombinant protein and pharmaceuticals production in microbes – common bottlenecks and issues (technical/operational, commercial and ethical); Attributes required in industrial microbes (Streptomyces sp., Yeast) to be used as efficient cloning and expression hosts (biologicals production); Generating diversity and introduction of desirable properties in industrially important microbes (Streptomyces/Yeast); Microbial cell factories; Downstream processing approaches used in industrial production process (Streptomyces sp., Yeast).

Unit IV
Food applications of microbial technology
7 lectures
Application of microbes and microbial processes in food and healthcare industries - food processing and food preservation, antibiotics and enzymes production, microbes in targeted delivery application – drugs and vaccines (bacterial and viral vectors); Non-recombinant ways of introducing desirable properties in Generally recognized as safe (GRAS) microbes to be used in food (e.g., Yeast) - exploiting the existing natural diversity or the artificially introduced diversity through conventional acceptable techniques (mutagenesis, protoplast fusion, breeding, genome shuffling, directed evolution etc.).

Unit V
Advances in microbial technology
8 lectures
Microbial genomics for discovery of novel enzymes, drugs/antibiotics; Limits of microbial genomics with respect to use in human welfare; Metagenomics and metatranscriptomics – their potential, methods to study and applications/use (animal and plant health, environmental clean-up, global nutrient cycles & global sustainability, understanding evolution), Global metagenomics initiative - surveys/projects and outcome, metagenomic library construction and functional screening in suitable hosts – tools and techniques for discovery/identification of novel enzymes, drugs (e.g., protease, antibiotic) etc.
Course Objectives

The aim of this course is to introduce methods and strategies commonly used in protein engineering.

Student Learning Outcomes

On completion of this course, students should be able to:

• Analyse structure and construction of proteins by computer-based methods;
• Describe structure and classification of proteins;
• Analyse purity and stability of proteins and explain how to store them in best way;
• Explain how proteins can be used for different industrial and academic purposes such as structure determination, organic synthesis and drug design.

Unit I
Introduction to protein engineering
5 lectures

Protein engineering – definition, applications; Features or characteristics of proteins that can be engineered (definition and methods of study) – affinity and specificity; Spectroscopic properties; Stability to changes in parameters as pH, temperature and amino acid sequence, aggregation propensities, etc. Protein engineering with unnatural amino acids and its applications.

Unit II
Stability of protein structure
5 lectures

Methods of measuring stability of a protein; Spectroscopic methods to study physicochemical properties of proteins: far-UV and near-UV CD; Fluorescence; UV absorbance; ORD; Hydrodynamic properties–viscosity, hydrogen-deuterium exchange; Brief introduction to NMR spectroscopy – emphasis on parameters that can be measured/obtained from NMR and their interpretation.

Unit III
Applications
5 lectures

Forces stabilizing proteins – Van der waals, electrostatic, hydrogen bonding and weakly polar interactions, hydrophobic effects; Entropy – enthalpy compensation; Experimental methods of protein engineering: directed evolution like gene site saturation mutagenesis; Module shuffling; Guided protein recombination, etc., Optimization and high throughput screening methodologies like GigaMetrix, High throughput microplate screens etc., Application to devices with bacteriorhodopsin as an example; Engineering antibody affinity by yeast surface display; Applications to vaccines, Peptidomimetics and its use in drug discovery.
### Nano-biotechnology

**Course Objectives**
The course aims at providing a general and broad introduction to multi-disciplinary field of nanotechnology. It will familiarize students with the combination of the top-down approach of microelectronics and micromechanics with the bottom-up approach of chemistry/biochemistry; a development that is creating new and exciting cross-disciplinary research fields and technologies. The course will also give an insight into complete systems where nanotechnology can be used to improve our everyday life.

**Student Learning Outcomes**
On successful completion of this course, students should be able to describe basic science behind the properties of materials at nanometre scale, and the principles behind advanced experimental and computational techniques for studying nanomaterials.

### Unit I

**Introduction to nanobiotechnology**

<table>
<thead>
<tr>
<th>5 lectures</th>
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<tbody>
<tr>
<td>Introduction to Nanobiotechnology; Concepts, historical perspective; Different formats of nanomaterials and applications with example for specific cases; Cellular Nanostructures; Nanopores; Biomolecular motors; Bio-inspired Nanostructures, Synthesis and characterization of different nanomaterials.</td>
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### Unit II

**Nano – films**

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<th>5 lectures</th>
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<tr>
<td>Thin films; Colloidal nanostructures; Self Assembly, Nanovesicles; Nanospheres; Nanocapsules and their characterisation.</td>
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### Unit III

**Nano – particles**

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<th>5 lectures</th>
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<td>Nanoparticles for drug delivery, concepts, optimization of nanoparticle properties for suitability of administration through various routes of delivery, advantages, strategies for cellular internalization and long circulation, strategies for enhanced permeation through various anatomical barriers.</td>
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</table>

### Unit IV

**Applications of nano – particles**

<table>
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<th>5 lectures</th>
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<tr>
<td>Nanoparticles for diagnostics and imaging (theranostics); concepts of smart stimuli responsive nanoparticles, implications in cancer therapy, nanodevices for biosensor development.</td>
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</tbody>
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**Recommended Textbooks and References:**

Unit V  
**Nano – materials**  
5 lectures  
Nanomaterials for catalysis, development and characterization of nanobiocatalysts, application of nanoscaffolds in sythesis, applications of nanobiocatalysis in the production of drugs and drug intermediates.

Unit VI  
**Nano – toxicity**  
5 lectures  
Introduction to Safety of nanomaterials, Basics of nanotoxicity, Models and assays for Nanotoxicity assessment; Fate of nanomaterials in different stratas of environment; Ecotoxicity models and assays; Life Cycle Assessment, containment.

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**Recommended Textbooks and References:**

5. Recent review papers in the area of Nanomedicine.

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**Unit I**  
**Fundamentals of immune system**  
6 lectures  
Overview of Immune system; Human Immune system: Effectors of immune system; Innate & Adaptive Immunity; Activation of the Innate Immunity; Adaptive Immunity; T and B cells in adaptive immunity; Immune response in infection; Correlates of protection.

**Unit II**  
**Immune response to infection**  
9 lectures  
Protective immune response in bacterial; viral and parasitic infections; Primary and Secondary immune responses during infection; Antigen presentation and Role of Antigen presenting cells: Dendritic cells in immune response; Innate immune response; Humoral (antibody mediated) responses; Cell mediated responses: role of CD4+ and CD8+ T cells; Memory responses: Memory and effector T and B cells, Generation and Maintenance of memory T and B cells.

**Unit III**  
**Immune response to vaccination**  
8 lectures  
Vaccination and immune response; Adjuvants in Vaccination; Modulation of immune responses: Induction of Th1 and Th2 responses by using appropriate adjuvants and antigen delivery systems - Microbial adjuvants, Liposomal and Microparticles as delivery systems; Chemokines and cytokines; Role of soluble mediators in vaccination; Oral immunization and Mucosal Immunity.

**Unit IV**  
**Vaccine types & design**  
3 lectures  
History of vaccines, Conventional vaccines; Bacterial vaccines; Viral Vaccines; Vaccines based on routes of administration: parenteral, oral, mucosal; Live attenuated and inactivated vaccine; Subunit Vaccines and Toxoids; Peptide Vaccine.
New Vaccine Technologies; Rationally designed Vaccines; DNA Vaccination; Mucosal vaccination; New approaches for vaccine delivery; Engineering virus vectors for vaccination; Vaccines for targeted delivery (Vaccine Delivery systems); Disease specific vaccine design: Tuberculosis Vaccine; Malaria Vaccine; HIV/AIDS vaccine; New emerging diseases and vaccine needs (Ebola, Zika).

**Recommended Textbooks and References:**


4. Journal Articles (relevant issues) from: Annual Review of Immunology, Annual Review of Microbiology, Current Opinion in Immunology, Nature Immunology, Expert review of vaccines.
## DBT Supported Teaching Programmes

<table>
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<tr>
<th>S.No.</th>
<th>Name of University</th>
<th>Contact Details of Course Coordinator</th>
</tr>
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</table>
| 1.    | Aligath Muslim University, Aligarh          | Dr. Rizwan Hasan Khan  
Inter-disciplinary Biotechnology Unit  
0571-2720388, 2720165, 09997778669  
Rizwankhan1@yahoo.com Rizwankhan1@gmail.com |
| 2.    | University of Allahabad, Allahabad          | Dr. Shanthy Sundaram,  
Centre for Biotechnology  
0532-2545021 (O); 09874614795, 09335158759  
shanthy.cbt@gmail.com |
| 3.    | Banaras Hindu University, Varanasi          | Prof. Arvind Kumar  
School of Biotechnology  
0542-6701584 (Lab) 1590(office) 09473875706(O)  
arvindkumararvind8@gmail.com |
| 4.    | Banasthali Vidyapeeth, Banasthali           | Prof. Vinay Sharma  
Deptt. of Biosciences & Biotechnology  
01438-228302, 228456 (O), 228341/280, 01438 -228365  
vinaysharma30@yahoo.co.uk |
| 5.    | University of Calicut, Calicut              | Dr. P.R. Manish  
Deptt. of Biotechnology  
0494-2407404 (O), 09447760771  
manishramakrishnan123@gmail.com |
| 6.    | Devi Ahilya Viswavidalaya, Indore           | Prof. Anil Kumar  
School of Biotechnology  
0731-240372, 2470373, 2446802 (R)  
ak_sbt@yahoo.com |
| 7.    | Gulbarga University, Gulbarga               | Prof. Ramesh Londonkar  
Deptt. of Biotechnology  
08472-263291,245633, 245337, 09880416391  
londonkarramesh53@rediffmail.com |
| 8.    | Guru Jambheshwar University of Science & Technology, Hisar | Dr. Namita Singh  
Deptt. of Bio and Nanotechnology  
0662-263312, 263165  
namitasingh71@gmail.com |
| 9.    | Guru Nanak Dev University, Amritsar         | Sh. P.K. Verma  
Deptt. of Biotechnology  
0183-2258431, 2258802, 09878366009  
bioechgndu@yahoo.com |
| 10.   | Himachal Pradesh University, Shimla          | Prof. Reena Gupta  
Deptt. of Biotechnology  
0177-2832154  
reenagupta_2001@yahoo.com |
| 11.   | HNB Garhwal University, Garhwal             | Prof. J. P. Bhatt  
Deptt. of Zoology & Biotechnology  
01370-267322 (O)  
hodzoobiotech@gmail.com; profjpbhhatt@gmail.com |
| 12.   | University of Hyderabad, Hyderabad          | Dr. Anand Kondapi  
Deptt. of Biotechnology, School of Life Sciences  
040-23134731, 23134730  
head.dobb@uohyd.ac.in, akksl@uohyd.ernet.in |
| 13.   | Indian Institute of Technology, Mumbai      | Dr. Rinti Banerjee  
Deptt. of Biosciences & Bioengineering  
022-2576 7771, 25767770  
head.bio@iitb.ac.in |
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<tr>
<th>S.No.</th>
<th>Name of University</th>
<th>Contact Details of Course Coordinator</th>
</tr>
</thead>
</table>
| 14.   | Indian Institute of Technology, Roorkee | Dr. Partha Roy  
Dept. of Biotechnology  
0332-285686  
paroylbs@iitr.ac.in, partharoy1970@gmail.com |
| 15.   | University of Jammu, Jammu          | Dr. Jyoti Vakhlu  
Dept. of Biotechnology  
0191-2456534 (O), 09419117624  
jyotivakhlu@gmail.com, jyotivakhlu@jammuuniversity.in |
| 16.   | Jawaharlal Nehru University, New Delhi | Dr. Uttam K. Pati  
Centre for Biotechnology  
011-26704087, 26704089  
dean_sbt@mail.jnu.ac.in, uttam@mail.jnu.ac.in, uttamkpati@yahoo.co.in |
| 17.   | University of Kashmir, Srinagar     | Prof. Raies Ahmad Qadri  
Dept. of Biotechnology  
09419001315  
raies.qadri@gmail.com |
| 18.   | Kumaun University, Nainital         | Dr. Veena Pande  
Dept. of Biotechnology  
05942-248185  
veena_kumaun@yahoo.co.in |
| 19.   | University of Lucknow, Lucknow      | Prof. U.N. Dwivedi  
Dept. of Biochemistry  
0522-2740132, 2740148 (O), 09415022445 (M)  
upendradwivedi@hotmail.com |
| 20.   | MS University of Baroda, Baroda     | Dr. Mrinalini Nair  
Dept. of Microbiology and Biotechnology  
0265-2794396/32  
mnair_in@yahoo.com |
| 21.   | University of Mysore, Mysore        | Prof. H.S. Prakash  
Dept. of Applied Botany & Biotechnology  
0821-2414450 ,0821-2411467, 09845488400 (M)  
hsp@appbot.uni-mysore.ac.in |
| 22.   | University of North Bengal, Siliguri | Dr. Shilpi Ghosh  
Dept. of Biotechnology  
07602974964, 0353- 2776354  
ghoshshilpi@gmail.com |
| 23.   | North Eastern Hill University, Shillong | Prof. A. Chatterjee  
Dept. of Biotechnology & Bioinformatics  
0364-2722403 (O), 09402131929  
chatterjeeanupam@hotmail.com, anupamchatterjee@nehu.ac.in |
| 24.   | Pondicherry University, Puducherry | Dr. V. Arul  
Dept. of Biotechnology, School of Life Sciences  
0413-2654429, 9444753179  
head.dbt@pondiuni.edu.in |
| 25.   | Savitribai Phule Pune University, Pune | Dr. Ameeta RaviKumar  
Dept. of Biotechnology  
020-25691331/4952/1821  
hodbiotech@unipune.ac.in; directoribb@unipune.ac.in |
| 26.   | Tezpur University, Tezpur            | Dr. S. K. Ray  
Dept. of Molecular Biology & Biotechnology  
03712-26708/9 (O), 09957184351  
suven@tezu.ernet.in, suvendra1973@gmail.com |
| 27.   | Utkal University, Bhubaneswar        | Prof. Jagneshwar Dandapat  
PG Deptt. of Biotechnology  
0674 (O) 2587389, 09437466087  
jdandapat.nou@gmail.com, j.dandapat@rediffmail.com |
## Annexure I

### Core Committee of M.Sc. Biotechnology

<table>
<thead>
<tr>
<th>No.</th>
<th>Institution/Address</th>
<th>Contact Person</th>
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<td>28</td>
<td>Visva Bharati University, Shantiniketan</td>
<td>Dr. Amit Roy&lt;br&gt;Centre for Biotechnology&lt;br&gt;0346-3261101, 0830014393 (M)&lt;br&gt;<a href="mailto:hod.biotech@visva-bharati.ac.in">hod.biotech@visva-bharati.ac.in</a></td>
</tr>
<tr>
<td>29</td>
<td>Sri Padmavati Mahila Visvavidyalayam, Tirupati</td>
<td>Dr. R. Usha&lt;br&gt;Deptt. of Biotechnology&lt;br&gt;0877-2284529, 2100027, 0970470464&lt;br&gt;<a href="mailto:dbtspmvv@gmail.com">dbtspmvv@gmail.com</a></td>
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**Chairperson**
1. Dr. Rakesh Bhatnagar, Professor, School of Biotechnology, Jawaharlal Nehru University, New Delhi

**Co-chairperson**
2. Dr. K. K. Rao, Professor, Department of Biosciences and Bioengineering, Indian Institute of Technology, Bombay

**Members**
3. Dr. Suman Govil, Advisor, Department of Biotechnology, Ministry of Science and Technology, Government of India
4. Dr. B. J. Rao, Senior Professor, Department of Biological Sciences, Tata Institute of Fundamental Research, Mumbai
5. Dr. Chandrababu, Professor, Centre for Plant Molecular Biology and Biotechnology, Tamil Nadu Agricultural University, Coimbatore
6. Dr. Probodh Borah, Professor, Department of Animal Biotechnology, Assam Agricultural University, Guwahati
7. Dr. Deepak Kaul, Professor, Department of Experimental Medicine and Biotechnology, Postgraduate Institute of Medical Education and Research, Chandigarh
8. Dr. Rajesh Gokhale, Staff Scientist VII, National Institute of Immunology, N. Delhi
9. Dr. Indira Ghosh, Professor, School of Computational and Integrative Sciences Jawaharlal Nehru University, New Delhi
10. Dr. Amitabh Bandopadhyay, Associate Professor, Department of Biological Sciences and Bioengineering, Indian Institute of Technology, Kanpur
11. Dr. Jitender Verma, CEO, M/s. Lifecare Innovations, New Delhi

**Member Secretary**
12. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi
M.Sc. Agricultural Biotechnology
Introduction

Background

Promotion of Indian Biotechnology sector is high on policy agenda of Government of India. Biotechnology has also been recognized as one of the key priority sectors under ‘Make in India,’ ‘Skill India’ and ‘Startup India’ initiatives of Government of India, as it is one of sectors expected to contribute towards enterprise creation, innovation and economic growth. Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India has immensely contributed to this dynamism through various policies and initiatives, establishment of innovation clusters, academia-industry partnerships, increasing capabilities for technology development, etc. The National Biotechnology Development Strategy (2015 – 2020) released by DBT provides a strategic roadmap for India’s emergence as a global biotechnology innovation and manufacturing hub. It has also highlighted importance of human resource development and need for nurturing tailor-made human capital for advanced scientific research and entrepreneurship.

DBT has taken a number of initiatives aimed at integrated human resource development to evolve an ecosystem where scientists, innovators and future entrepreneurs can be nurtured. Keeping in mind requirement for trained manpower in various areas of Biotechnology, DBT initiated Post-Graduate Teaching Programme way back in 1985 with 5 universities which has expanded to 74 universities imparting M.Sc./M.Tech./M.V.Sc. degrees in general, agricultural, animal, food, environmental, industrial marine, medical, neuroscience and pharmaceutical biotechnology. 10 programmes are being phased out. These universities and institutes are provided liberal financial support towards strengthening of laboratory facilities, equipment, consumables, fellowships to students, dissertation grant per student etc. Post-Graduate Teaching Programme selects best students and trains them to join research or industry workforce contributing significantly to biotechnology workforce.

About the Course Curriculum Revision Exercise

Taking into cognizance the changing needs of the economy and to keep abreast with latest developments in the field of biotechnology, DBT proactively initiated revision of course curricula of Post-Graduate Programmes in biotechnology. The present exercise has been undertaken by Biotech Consortium India Limited (BCIL), New Delhi. Earlier exercise was carried out in 2008. The Course Curriculum Revision Exercise has been carried out for 13 Post-Graduate programmes in Biotechnology supported by DBT.

The revision of course curriculum of M.Sc. Agricultural Biotechnology aims to address mismatch between ‘knowledge’ gained by students and appropriate skill set required for technology development and implementation including present contemporary needs of economy.

Methodology

A meticulous and structured approach has been adopted to accomplish the Course Curriculum Revision exercise.

BCIL had initiated the exercise with a review of literature of relevant national and international documents on curriculum design and planning for biotechnology programmes of premier national as well as international universities, guidelines by University Grants Commission, recent curricular guidelines released by Indian Council of Agricultural Research, Ministry of Health and Family Welfare and Indian Institute of Science Education & Research and other relevant research papers on curriculum development in peer-reviewed journals.
The findings of the literature review were adopted to design questionnaires for eliciting feedback from stakeholders of Biotechnology community i.e. academicians, scientists, industry representatives and students. Feedback was received from 165 experts and 20 students belonging to academic institutions, research organizations and industry regarding addition of advanced topics, deletion of elementary, redundant and overlapping topics, updation of laboratory practicals, re-adjustment of credit load, incorporating ‘technology’ component in the curriculum, among others. It was also suggested that re-orientation of curricula should be done keeping in view the needs of the industry.

Strategic Approach

A Core Committee along with 9 subject specific subcommittees comprising of 63 academicians, scientists and industry representatives were constituted to revise and update the curricula. The constitution of subject specific subcommittee for Agricultural Biotechnology is given at Annexure-1.

The salient recommendations identified from stakeholder survey were presented to the Committee. Several brainstorming discussion sessions were held for achieving the desired balance between the foundation courses, recent developments in biotechnology and updation needs identified during the stakeholder survey. Core Committee finalized broad contours for revising all the course curricula. The guidelines set by the Core Committee were taken up by the subject specific subcommittee of Agricultural Biotechnology for updating the curriculum. The subject specific subcommittee incorporated latest advancements in areas of Agricultural Biotechnology in the curriculum. Separate meeting was held to discuss and deliberate the updations to be made in the curriculum. The revised curriculum was vetted and finalized by the Core Committee.

Course Curriculum Revision

The members of Committee agreed that revised course curriculum should provide skill and outcome based education and help the students to gain domain knowledge, ability to design and interpret research experiments and acquire effective communication skills. The course curriculum has been re-designed accordingly to promote skill-based and outcome-based education. The revised course curriculum totals to 94 credits comprising of theory, practical, technology-based topics, electives and dissertation. Each course includes learning objectives, student learning outcomes, course plan (number of lectures/unit) and reference textbooks/resources. Theory and practical courses include relevant examples, case scenarios and tutorials for inculcating critical thinking against rote learning. Several new courses have been included and content for existing courses has also been updated. Focus has been given in areas such as Plant Growth and Development with Response to Stress, Genetics and Principles of Plant Breeding, Concepts of Research, Designing Experiments and Statistical Data Analysis, etc. With importance of students being able to execute research projects independently, separate credits have been allotted for proposal preparation and presentation before initiating dissertation and also credits for dissertation have been increased accordingly.

We hope that model course curriculum shall serve as guidelines for academicians and researchers from different parts of the country for adoption in their institutions with modifications as per availability of expertise, infrastructure and specific needs.

We wish to put on record our sincere appreciation for constant guidance and encouragement received from Dr. K. VijayRaghavan, Secretary, DBT for bringing out this publication. We wish to acknowledge whole-hearted support of Core Committee and subject specific subcommittees members. Sincere thanks are due to Dr. Manoj Singh Rohilla, Scientist- D, DBT, Ms. Shweta for creative design, Mrs. Rita Bhatla, DBT and Shri. Dilip Joy, BCIL.
Dr. R. Chandra Babu
Professor
Centre for Plant Molecular Biology and Biotechnology

MESSAGE

Agriculture, as a source of livelihood, remains the largest sector of Indian economy. This necessitates continued improvement of our agricultural production and its value addition. However, this increase in agricultural production has to overcome challenges such as yield plateau, decreasing land, water and labour and the effects of climate change. Biotechnology is a promising tool to overcome the above constraints and achieving “Second Green Revolution”. The contribution of Biotechnology is significant in areas such as healthcare, agriculture, food, industrial and environmental sectors. Indian biotech industry ranks 3rd in the Asia-Pacific and ranks 2nd among countries harbouring economically important plants. Indian biotech industry witnessed a phenomenal growth of 57.14 per cent in FY16 valued at Rs.71, 400 crores. It is aimed to achieve an ambitious growth rate of around 30 per cent for taking this industry to a value of Rs.5, 50, 000 crores by 2025 for India to attain the status of one among top three global players in biotechnology. One of the defined goals to achieve this target, stated in National Biotechnology Development Strategy (NBDS) 2015 - 2020 formulated by DBT, is development of skilled human resources. The National Education Policy - 2016 also envisons a quality education system to produce graduates equipped with the knowledge, skills, attitudes and values that are required to lead a productive life and participate in the country’s development process. NBDS has identified Agricultural Biotechnology as one of the focus areas to implement the “Make in India” concept in the biotechnology sector.

Enhancing skills among students for employability and entrepreneurship rely heavily on the overall curriculum of the education programs. It determines the attainment of knowledge by the students and the ability to relate acquired knowledge to real-life situations. Since the last syllabus revision, significant advancements have been made in the field of biotechnology and there was a strong need for revising the existing curriculum and introducing new courses on cutting edge science and emerging frontier areas. Thus the curriculum was revised based on the feed-back from faculty, students, industry and other stakeholders. The revised curriculum aims at developing knowledgeable, skilled and high calibre quality human resource in Agricultural Biotechnology to meet the needs of the industry, academia and the nation.

(R. Chandra Babu)
# M.Sc. Agricultural Biotechnology

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**Recommended Electives:**
1. Environmental Biotechnology  
2. Food Biotechnology  
3. Nanobiotechnology  
4. Systems & Synthetic Biology  
5. Molecular Basis of Host-Pathogen Interactions
Semester One

Biochemistry

Credits

3

Course Objectives
The objectives of this course are to build upon undergraduate level knowledge of biochemical principles. The course shall make the students aware of biochemical and molecular basis of various plant processes and plant growth regulatory substances.

Student Learning Outcomes
On completion of this course, students should be able to gain fundamental knowledge in biochemistry and understand molecular basis of various plant processes.

Unit I
Biosynthesis of biomolecules
7 lectures

Scope and importance of biochemistry in Agriculture; Biosynthesis of structural carbohydrates, sucrose-starch interconversion; storage proteins and lipids; Assembly of lipids, biomembrane organization, membrane bound proteins, glycoproteins, lipoproteins.

Unit II
Enzymes
8 lectures

Isolation of enzymes - purification methods; Enzyme classification, Mechanism of action; Enzyme kinetics - MM equation, LB plot; Enzyme assay methods; Enzyme inhibition; Enzyme regulation; Isozymes, Abzymes, Ribozymes, Synzymes, Immobilized enzymes.

Unit III
Biochemistry of nitrogen and sulphur metabolism
6 lectures

Biochemistry of nitrogen fixation and nitrate assimilation, sulphate reduction and incorporation of sulphur into amino acids; Biochemistry of seed germination and development; Biochemistry of fruit ripening.

Unit IV
Stress biochemistry and plant defence
9 lectures

Abiotic stresses, ROS; Enzymic and non-enzymic antioxidants; Biosynthesis & mechanism of action of osmoprotectants – glycine betaine, proline; polyamines; heat shock proteins; Plant defense system-organization; PR proteins, phytoalexins, cinnamic acid, salicylic acid, jasmonic acid, toxic amino acids - mode of action; Signal transduction- role of G proteins, protein kinases, cyclic nucleotides and calcium; Anti-nutritional factors in pulses, cereals, oil seeds, fruits & vegetables; Importance of Lectins and Bt toxins in insect pest management.

Unit V
Phytohormones and secondary metabolites
9 lectures

Phytohormones – synthesis and mode of action. Role of auxin, gibberellins, ethylene, cytokinins, ABA and brassinosteroids; Secondary metabolites - introduction, types and role of secondary metabolites in plant system; Shikimate pathway, Acetate-mevalonate pathway, Alkaloids biosynthesis; Biochemistry and significance of cyanogenic glycosides, glucosinolates.

Recommended Textbooks and References:
Fundamentals of Molecular Biology

Credits

3

Course Objectives
The objectives of this course are to make students understand how molecular machines are constructed and regulated so that they can accurately copy, repair, and interpret genomic information in prokaryotes and eukaryotic cells. Further, to appreciate the subject of molecular biology as a dynamic and ever-changing experimental science.

Student Learning Outcomes
Students should be able to acquire basic knowledge on molecular architecture of prokaryotic and eukaryotic genomes and learn various molecular events that lead to duplication of DNA, recombination of genes, gene expressed into transcripts and translated into proteins following a central dogma. Also, the mechanisms by which DNA could be damaged and repaired will be also discussed. Further, the course helps to understand molecular mechanisms behind different modes of gene regulation in bacteria and eukaryotes at both pre- and post-transcriptional levels and methods to study DNA and protein interactions.

Unit I
Structure of nucleic acids and genome organization
6 lectures

Historical developments of molecular biology - Nucleic acids as genetic material – Discovery of DNA; Chemistry of nucleic acids-composition of DNA and RNA; Purines, pyrimidines and minor bases; Nomenclature of nucleic acids; Forms of DNA-A,B, Z and triplex DNA; Structure of DNA and RNA- primary structure; secondary structure – Base pairing and Base stacking; Tertiary and Quaternary structure; Properties and functions of nucleic acids; Genome organization in prokaryotes and eukaryotes; Chromosomal structure- composition and structure of chromatin; Genome packaging- role of Histones; Nucleosome, chromosome - 30 nm chromatin fibre–Solenoid structure; Nuclear matrix in chromosome organization and function; Heterochromatin and Euchromatin; C value and C-value paradox; DNA re-association kinetics (Cot curve analysis)- DNA melting and buoyant density-Tm value; Analysis of repetitive sequences – Highly repetitive-satellite DNA, moderately repetitive –Tandem repeats and Interspersed transposons.

Unit II
Molecular events in DNA replication, DNA repair and recombination
8 lectures

Central dogma of Molecular Biology; DNA replication- Classical experiments in DNA replication; Models of DNA replication; Origin of replication; Steps in DNA replication-initiation, elongation and termination; DNA replication in bacteria, phages and eukaryotes; Enzymes and accessory proteins and its mechanisms; fidelity; Replication of chromosomal ends; Assembly of new DNA into nucleosomes; Replication of single stranded circular DNA and link with cell cycle; DNA damaging agents - Physical, chemical and biological mutagens; Types of DNA damages; mutations- Nonsense, missense, silent, point mutations and frame shift mutations; DNA repair mechanisms-direct reversal, photoreactivation, base excision repair, nucleotide excision repair, mismatch repair, double strand break repair, SOS repair; Recombination: Chi sequences in prokaryotes; Homologous, non-homologous and site specific recombination.

Structure and function of prokaryotic mRNA, tRNA, rRNA and ribosomal proteins; Prokaryotic Transcription - RNA polymerase and sigma factors, Transcription unit, Promoters and consensus, Promoter recognition - Initiation - promoter clearance, Elongation and Termination (intrinsic, Rho and Mfd dependent). Post transcriptional processing of mRNA, rRNA and tRNA transcripts; Structure and function of eukaryotic mRNA, tRNA and rRNA and ribosomal proteins. Eukaryotic transcription - RNA polymerase I, II and III mediated transcription: RNA polymerase enzymes, eukaryotic promoters and enhancers, General Transcription factors; TATA binding proteins (TBP) and TBP associated factors (TAF); assembly of pre-initiation complex for nuclear enzymes, interaction of transcription factors; Promoter melting and open complex formation; Abortive initiation; Elongation – Pausing, poising and backtracking events; Termination of transcription; Post transcriptional processing - Processing of hnRNA, tRNA, rRNA; 5' - Cap formation; 3' - end processing of RNAs and polyadenylation; Splicing of tRNA and hnRNA; snRNPs and snoRNPs in RNA processing; Exon skipping and alternative splicing. Nuclear export of mRNA - mRNA stability and degradation; RNA editing - insertion, deletion - Guide RNA and base substitution; Catalytic RNA: Group I and Group II introns splicing.

Ribosomes – structure, composition and assembly; Genetic code - universal genetic code and modified genetic code; Genetic code in mitochondria; Codon degeneracy - codon bias; Start and termination codons; Wobble hypothesis; Isoaccepting tRNA; Translational machinery; Mechanism of Translation in prokaryotes and Eukaryotes. Initiation complex formation - 30S and 70S in prokaryotes and 40S and 80S initiation complex in eukaryotes; Cap dependent and Cap independent initiation in eukaryotes, Elongation - translocation – transpeptidation and termination of translation; Co- and Post-translational modifications of proteins; Translational control; Protein stability - Protein turnover and degradation.

Gene regulation – regulation of gene expression in prokaryotes; Repressors, activators, positive and negative regulation, Constitutive and Inducible, small molecule regulators; Operon concept: lac, trp, his operons, attenuation, anti-termination, stringent control, translational control, DNA re-arrangement, Small RNAs - regulatory RNA – riboswitch, tmRNA, antisense RNA; Small RNA mediated gene regulation; Transcriptional control in lambda phage; Gene regulation in eukaryotes - regulatory RNA and RNA interference mechanisms, miRNA, non coding RNA; Silencers and insulators, enhancers, mechanism of silencing and activation; Families of DNA binding transcription factors: Helix-turn-helix, helix-loop-helix, homeodomain; zinc fingers, basic DNA binding domains, nuclear receptors; Interaction of regulatory transcription factors with DNA: properties and mechanism of activation and repression - Ligand-mediated transcription regulation by nuclear receptors; Histone modifications and chromatin remodeling; Methods for studying DNA - protein interactions: Electrophoretic mobility shift assay (EMSA), DNase I footprinting, methylation interference assay and chromatin immunoprecipitation.

Recommended Textbooks and References:
Genetic Engineering

Credits 3

Course Objectives
The objectives of this course are to teach various approaches to conducting genetic engineering and its applications in biological research as well as in biotechnology industries.

Student Learning Outcomes
Given the impact of genetic engineering in modern society, students should be endowed with strong theoretical knowledge of this technology. In conjunction with the practicals in molecular biology & genetic engineering, the students should be able to take up biological research as well as placement in the relevant biotech industry.

Unit I
Introduction and tools for genetic engineering
6 lectures

Impact of genetic engineering in modern society; general requirements for performing a genetic engineering experiment; restriction endonucleases and methyIases; DNA ligase, Klenow enzyme, T4 DNA polymerase, polynucleotide kinase, alkaline phosphatase; cohesive and blunt end ligation; linkers; adaptors; homopolymer tailing; labelling of DNA: nick translation, random priming, radioactive and non-radioacrive probes, hybridization techniques: northern, southern, south-western and far-western and colony hybridization, fluorescence in situ hybridization.

Unit II
Different types of vectors
7 lectures

Plasmids; Bacteriophages; M13mp vectors; pUC19 and pBluescript vectors, phagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Principles for maximizing gene expression vectors; pMal; GST; pET-based vectors; Protein purification; His-tag; GST-tag; MBP-tag etc.; Intein-based vectors; Inclusion bodies; methodologies to reduce formation of inclusion bodies; mammalian expression and replicating vectors; Baculovirus and pichia vectors system, plant based vectors, Ti and Ri as vectors, yeast vectors, shuttle vectors.

Unit III
Different types of PCR techniques
7 lectures

Principles of PCR: primer design; fidelity of thermostable enzymes; DNA polymerases; types of PCR – multiplex, nested; real time PCR, touchdown PCR, hot start PCR, colony PCR, cloning of PCR products; T - vectors; proof reading enzymes; PCR based site specific mutagenesis; PCR in molecular diagnostics; viral and bacterial detection; sequencing methods; enzymatic DNA sequencing; chemical sequencing of DNA; automated DNA sequencing; RNA sequencing; chemical synthesis of oligonucleotides; mutation detection: SSCP, DGGE, RFLP.

Unit IV
cDNA analysis
7 lectures

Insertion of foreign DNA into host cells; transformation, electroporation, transfection; construction of libraries; isolation of mRNA and total RNA; reverse transcriptase and cDNA synthesis; cDNA and genomic libraries; construction of microarrays –
Unit V
Gene silencing and genome editing technologies
13 lectures

Gene silencing techniques; introduction to siRNA; siRNA technology; Micro RNA; construction of siRNA vectors; principle and application of gene silencing; gene knockouts and gene therapy; creation of transgenic plants; debate over GM crops; introduction to methods of genetic manipulation in different model systems e.g. fruit flies (Drosophila), worms (C. elegans), frogs (Xenopus), fish (zebra fish) and chick; Transgenics - gene replacement; gene targeting; creation of transgenic and knock-out mice; disease model; introduction to genome editing by CRISPR-CAS with specific emphasis on Chinese and American clinical trials; Cloning genomic targets into CRISPR/Cas9 plasmids; electroporation of Cas9 plasmids into cells; purification of DNA from Cas9 treated cells and evaluation of Cas9 gene editing; in vitro synthesis of single guide RNA (sgRNA); using Cas9/sgRNA complexes to test for activity on DNA substrates; evaluate Cas9 activity by T7E1 assays and DNA sequence analysis; Applications of CRISPR/cas9 technology.

Recommended Textbooks and References:
7. Technical Literature from Stratagene, Promega, Novagen, New England Biolab etc.,

Course Objectives
The objectives of this course are to understand basic principles of important physiological processes in plants including stress adaptation and to study functions of nutrients and plant growth regulators in crop production.

Student Learning Outcomes
On completion of this course, students should be able to acquire knowledge on important physiological processes in plants and role of nutrients and growth regulators in growth and development besides the crop's response to various abiotic stresses.
Introduction and role of Physiology in Agriculture – structure, properties and role of water in plants; soil and cell water terminologies; field capacity and PWP (Permanent Wilting Point); mechanism of water absorption; ascent of sap – theories; transpiration; stomatal structure – mechanism of stomatal movement; anti-transpirants.

Essential and beneficial nutrients – classification, functions and deficiency symptoms of primary, secondary and micro nutrients in plants; hidden hunger; mechanisms of nutrient absorption – chelates, foliar nutrition.

Photosynthesis – EMR and PAR; red drop and Emerson's enhancement effect; photochemical reactions; photolysis of water; Z scheme, photophosphorylation, reduction of CO$_2$, $i.e.$, carbon assimilation in C$_3$, C$_4$ and CAM pathways, difference between three pathways; photorespiration and its significance; phloem loading and unloading; munch hypothesis; source and sink strength – manipulations; respiration; glycolysis, TCA cycle, oxidative phosphorylation - differences between oxidative phosphorylation and photophosphorylation; energy budgeting in respiration - respiratory quotient.

Growth – growth curve; plant growth hormones/regulators (PGRs); physiological role and applications of auxins, gibberellins, cytokinin, ethylene and ABA; commercial uses of PGRs; senescence and abscission – classification; physiological and biochemical changes and its significance; photoperiodism; florigen theory of flowering; phytochrome; regulation of flowering in crops; vernalization; seed dormancy, breaking dormancy; seed germination, physiological basis of germination.

Physiology of abiotic stresses in plants – water, drought, submergence and flooding stress, temperature; cold, heat, global warming, green-house gases and salt; salinity, sodicity and alkalinity – effects and tolerance mechanisms; Nutrients; deficiency and excess-tolerance mechanisms and Nutrient use efficiency.

**Recommended Textbooks and References:**
Molecular Cell Biology

Course Objectives
The objective of this course is to familiarize the students with the cell biology at molecular level and to understand basic concepts of cell metabolism, cell growth and cell division.

Student Learning Outcomes
On completion of this course, students should be able to acquire basic knowledge on cell structure and function, transport in a cell, protein trafficking in the cell, cell communication, cell division, and cell death.

Unit I
Origin of life, evolution of cell and cell diversity
5 lectures

Origin of life, History of cell biology, Evolution of the cell: endosymbiotic theory, tree of life, General structure and differences between prokaryotic and eukaryotic cell; Similarities and distinction between plant and animal cells; different kinds of cells in plant and animal tissues.

Unit II
Structure and function of cell organelles
6 lectures

Cell wall, cell membrane, structure and composition of biomembranes, Structure and function of major organelles: Nucleus, Chloroplasts, Mitochondria, Ribosomes, Lysosomes, Peroxisomes, Endoplasmic reticulum, Microbodies, Golgi apparatus, Vacuoles, Cyto-skeletal elements.

Unit III
Internal organization of cell and cellular functions
7 lectures

Membrane transport; Transport of water, ion and biomolecules: Diffusion, osmosis, ion channels, active transport, ion pumps, mechanism of protein sorting and regulation of intracellular transport: gated, transmembrane and vesicular transport - endocytosis and exocytosis; General principles of cell communication: hormones and their receptors, cell surface receptor, signaling through G-protein coupled receptors, enzyme linked receptors; signal transduction mechanisms, second messengers, regulation of signaling pathways, Cell junctions, Cell adhesion, Cell movement; Extracellular matrix.

Unit IV
Cell division and cell cycle regulation
6 lectures

Cell division and regulation of cell cycle; Mechanisms of cell division, Molecular events at M phase, mitosis and cytokinesis, Ribosomes in relation to cell growth and division, Extracellular and intracellular Control of Cell Division; abnormal cell division: cancer - hall marks of cancer and role of oncogenes and tumour suppressor genes in cancer development - Programmed cell death (Apoptosis).

Unit V
Cell differentiation & tissue development
4 lectures

Morphogenetic movements and the shaping of the body plan, Cell diversification, cell memory, cell determination, and the concept of positional values; Differentiated cells and the maintenance of tissues and organ development; Stem cells: types and applications; Plant development.

Recommended Textbooks and References:
# Genetics and Plant Breeding

## Course Objectives
The objectives of this course are to:
- Provide a basic introduction to concepts of Genetics and Plant Breeding;
- Provide insight into the crop reproductive biology and strategies to breed self and cross pollinated varieties;
- Acquaint the students with the knowledge on cultivar development, plant variety protection etc.

## Student Learning Outcomes
On completion of the course, students should be able to:
- Have a deeper insight into the genetic basis supporting plant breeding, from the individual gene to the complete genome;
- Know the aim of the genome analysis projects of certain model plant species and the possibilities offered by their comparison with the genomes of other species of agronomic interest.

## Credits

### Unit I
**Basic genetics and plant breeding**
8 lectures

- History of Genetics and Plant Breeding (Pre and post Mendelian era), Mendelism, Centres of Origin-biodiversity and its significance, Chromosomal theory of inheritance; Multiple alleles, Sex-linkage, Linkage Detection, Linkage estimation by various methods, recombination and genetic mapping in eukaryotes.

### Unit II
**Systems and methods of breeding**
10 lectures

- Plant introduction and role of plant genetic resources in plant breeding. Modes of reproduction: Breeding methods for self-pollinated, cross-pollinated and asexually reproducing crops; Male sterility and incompatibility; Heterosis and hybrid development; Breeding methods for self-pollinated: Pure line theory; pure line selection and mass selection methods cross-pollinated and asexually reproducing crops, Apomixis.

### Unit III
**Chromosomal manipulations**
5 lectures

- Polyploidy: Structural and Numerical variations of chromosomes and their implications; Epigenetics Mutation; nature and classification of mutations: spontaneous mutations and induced mutations, Crop improvement through induced mutagenesis.

### Unit IV
**Heritability and gene action**
5 lectures

- Heritability and genetic advance, genotype-environment interaction, general and specific combining ability, types of gene actions and implications in plant breeding.

### Unit V
**Variety: synthesis, release and protection**
6 lectures

- Development - testing, release and notification of varieties / hybrids / transgenics / marker assisted backcross breeding lines, maintenance breeding, Participatory Plant breeding, Plant breeders' rights and regulations for plant variety protection and farmers rights, DUS testing, Quality seeds-types and production.

### Practical
experimental plots - nucleus and breeder seed production plots. Screening methods in laboratory and field for biotic and abiotic stresses.

**Recommended Textbooks and References:**


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**Biostatistics, Experimental Design and Data Analysis**

**Course Objectives**
To provide exposure about methods of statistical analysis, sampling techniques and designing agricultural experiments which are widely used in agricultural sciences. This course also provides usage of various statistical packages like MS Excel, SYSTAT/SPSS and SAS/IRRISTAT for the analysis of Agricultural Research Data.

**Student Learning Outcomes**
Students would be able to acquire knowledge on designing experiments, collection and analysis of biological research data.

**Credits**
2

**Unit I**
**Sampling theory and test of hypothesis**
6 lectures

Sampling theory – probability sampling and non-probability sampling methods – sampling distributions – standard error and its uses; Test of significance – Null and alternative hypothesis; Types of Errors, Level of significance – t-test – F-test and $x^2$-test.

**Unit II**
**Correlation and regression analysis**
5 lectures

Correlation, scatter diagram, properties and testing of correlation coefficient; Regression – simple linear regression – properties and testing of regression coefficient; Multiple linear regression – fitting and testing of multiple linear regression equation.

**Unit III**
**ANOVA, data transformation and mean comparisons**
6 lectures

Analysis of variance – CRD, RBD and LSD - Data transformation – logarithmic, angular and square root transformations – mean comparisons – critical difference (least significant difference) and Duncan’s Multiple Range Test (DMRT) – missing plot technique in RBD (data with one missing observation) – RBD with multi observations per cell.
Concept of factorial experiments – symmetrical and asymmetrical factorial experiments; 2n factorial experiments; analysis using regular method (RBD); Yates algorithm; asymmetrical factorial experiment (up to 3 factors); split-plot design, strip plot design.

Descriptive statistics, testing of hypothesis, correlation analysis and regression analysis using MS Excel – ANOVA, cross tabulation, non parametric tests and time series analysis using SYSTAT/SPSS – Completely Randomized Design (CRD), Randomized Block Design (RBD), factorial experiments, split plot design and data transformation using SAS/IRRISTAT.

Recommended Textbooks and References:
20. www.statsci.org/jourlist.html

Course Objectives
The objective of this laboratory course is to introduce students to experiments in biochemistry. The course is designed to teach utility of set of experimental methods in biochemistry in a problem oriented manner.

Student Learning Outcomes
On completion of this course, students should be able to:
- To elaborate concepts of biochemistry & physiology with easy to run experiments;
- To familiarize with basic laboratory instruments and understand the principle of measurements using those...
Syllabus

1. Preparation of Buffer and validation of the Henderson-Hasselbach equation.
2. Estimation of total sugars, starch by anthrone method, amylose.
3. Estimation of total free amino acids, protein by Lowry’s method / Bradford’s method.
4. Determination of fatty acid profile by GC.
5. Enzyme extraction and purification - assay of catalase, peroxidase, polyphenol oxidase - Determination of Km value.
7. Column chromatographic separation of chlorophyll, lycopene and carotene.
8. Determination of IAA.
10. Estimation of alkaloids, total phenols, tannins.
11. Plant water status by different methods – leaf water potential and relative water content.
12. Measurement of Leaf area, gas exchange parameters.
14. Diagnosis of nutritional disorders.
15. Assessment of drought tolerant capacity - Assay of nitrate reductase activity, chlorophyll stability index, proline content;
16. Growth analysis: Leaf area index (LAI), Leaf area duration (LAD), Specific leaf weight (SLW), Specific leaf area (SLA), Relative growth rate (RGR), Net assimilation rate (NAR), Crop growth rate (CGR) and Harvest index (HI).

Recommended Textbooks and References:

Course Objectives
The objectives of this course are to provide students with the experimental knowledge in molecular biology & genetic engineering.

Student Learning Outcomes
Students should be able to gain hands-on experience on gene cloning, protein expression and purification. This experience would enable them to begin a career in industry that engages in genetic engineering as well as in research laboratories conducting fundamental research.

Laboratory II: Techniques in Molecular Biology and Genetic Engineering

Credits

Syllabus

1. Isolation of total DNA from Bacillus subtilis.
2. PCR amplification of scoC gene and analysis by agarose gel electrophoresis
3. Preparation of plasmid, pET-28a from E.coli DH5α and gel analysis.
4. Restriction digestion of vector (gel analysis) and insert with NcoI and XhoI
5. Plasmid isolation restriction digestion, ligation, and transformation in E.coli DH5α, confirming recombinant by PCR and RE digestion.
6. Transformation of recombinant plasmid in E.coli BL21 (DE3) strain
7. Induction of ScoC protein with IPTG and analysis on SDS-PAGE
8. Purification of protein on Ni-NTA column and analysis of purification by SDS-PAGE
9. Random Primer labeling of scoC with Dig-11-dUTP
10. Southern hybridization of B. subtilis genome with probe and non-radioactive detection.
12. Growth curve, measure of bacterial population by turbidometry and studying the effect of temperature, pH, carbon and nitrogen.
13. Production of industrial compounds such as alcohol, beer citric acid, lactic acid and their recovery.

Recommended Textbooks and References:

Semester Two

Molecular Breeding

Course Objectives
This course introduces students to key principles of molecular breeding. In addition to this, genetic recombination as a tool for genetic map construction, theory and application of DNA markers for mapping and selection, including pros, cons and their special characteristics are discussed.

Student Learning Outcomes
After successful completion of this course, students are expected to:
• Understand advantages and limitations of plant breeding selection programmes;
• Understand role of mode of reproduction of plants on genetic composition of crops;
• Analyse genetic segregations in plants.

Unit I
Introduction to molecular markers
7 lectures

Genome organization and analysis – Nuclear and organellar genomes, genome size, sequence composition, C-Value paradox; Sequence complexity in genomes – Unique and Repeat sequences, Point mutations to polyploidy, transposable elements; Causes of sequence variations; Types of molecular markers – RFLP, AFLP, SCARs, CAPS, SSRs, STMS and SNPs; Development of marker resources.

Unit II
Assessment of genetic diversity and germplasm analysis
6 lectures

Introduction to geographical diversity, center of origin and diversity of plant species, gene pools (primary, secondary and tertiary); Germplasm characterization using morphological and molecular markers; Diversity analysis - Hierarchical and non-hierarchical cluster analysis, Phylogenetic analysis - maximum parsimony, distance methods, maximum likelihood; algorithms for forming clusters/ dendrograms, clustering softwares (MEGA, Phylik, NTSYS etc.); Molecular markers in Plant variety protection, IPR issues, hybrid purity testing, clonal fidelity testing and transgenic testing.

Unit III
Mapping populations for genome mapping
6 lectures

Introduction to genetic mapping; Construction of genetic linkage maps, Linkage mapping software packages and interfaces; Types of populations - F2 populations, RILs (recombinant inbred lines), Backcross lines, NILs (Near Isogenic Lines), HIF (Heterogeneous Inbred Families), AILs (Advanced Intercross Lines), Biparental mapping vs Multi-parent mapping, NAM (Nested Association mapping), MAGIC (Multi-parent advanced generation inter-cross).
Unit IV
Molecular mapping
7 lectures
Mapping simple and complex traits, QTL detection methods; Bulked Segregant Analysis; Fine mapping - Map based cloning/ positional cloning for gene discovery; Pseudo-test-cross mapping Association mapping – Principles and methods; GWAS (Genome Wide Association Studies); Navigating from genetic to physical map; Targeting Induced Local Lesions in Genomes (TILLING), ECOTILLING and its application in crop breeding, Allele mining, Comparative/Synteny mapping.

Unit V
Breeding by design
8 lectures
Strategies in molecular breeding - Marker Assisted Selection (MAS); Gene/QTL introgression; MABB (Marker Assisted Back cross breeding) - Foreground and back ground selection for introgression of QTL by SSR markers; Gene/QTL pyramiding strategies; MARS, Genomics assisted breeding – MAGIC, Genomic Selection.

Unit VI
High throughput genotyping platforms
5 lectures
Linked markers vs gene based markers; Development of gene based markers – SNPs, InDels; Advances in SSR genotyping – capillary system and chip based; DARTseq, SNP genotyping – Real Time PCR based methods, Illumina’s Golden Gate Technology, Fluidigm; GBS (genotyping by sequencing).

Recommended Textbooks and References:
2. Clark, D. P., (2005), Molecular Biology, Elsevier, USA.
Course Objectives
To impart theoretical knowledge on various techniques of plant tissue culture and plant genetic transformation and their application in crop improvement.

Student Learning Outcomes
Students should be able to acquire knowledge on basics of tissue culture and transgenic technology and their applications in modern agriculture.

Unit I
Concepts and techniques in plant tissue culture
7 lectures
- Totipotency; Tissue culture media; Plant hormones and morphogenesis; Direct and indirect organogenesis; Direct and indirect somatic embryogenesis; Applications of plant tissue culture – Micropropagation of field and ornamental crops; National certification and Quality management of TC plants; Virus elimination by meristem culture, meristem tip culture and micrografting; Virus indexing – PCR, ELISA; Nucleic acid hybridization and electron microscopy; Wide hybridization - embryo culture and embryo rescue techniques; Ovule, ovary culture and endosperm culture; Artificial seeds.

Unit II
In vitro culture methods and applications
8 lectures
- Androgenesis and gynogenesis - production of androgenic and gynogenic haploids - diploidization; Callus culture and in vitro screening for stress tolerance; Large-scale cell suspension culture - Production of alkaloids and other secondary metabolites - techniques to enhance secondary metabolite production; Protoplast culture - isolation and purification; Protoplast culture; Protoplast fusion; Somatic hybridization - Production of Somatic hybrids and Cybrids – Applications; Somaclonal and gametoclonal variations – causes and applications; In vitro germplasm storage and cryopreservation.

Unit III
DNA delivery methods
7 lectures
- Plant genetic engineering – DNA delivery methods: vector mediated method – Agrobacterium tumefaciens and direct DNA delivery methods. Agrobacterium mediated method - Agrobacterium biology; Ti plasmid-based transformation; crown gall and hairy root disease, Ti and Ri plasmids, T-DNA genes, borders, overdrive, chromosomal and Ti plasmid virulence genes and their functions, vir gene induction, mechanism of T-DNA transfer; Ti plasmid vectors, vir helper plasmid, super virulence and monocot transformation, binary vector; Floral dip transformation; Direct DNA delivery methods - protoplasts using PEG; electroporation; particle bombardment; Chloroplast transformation and transient expression by viral vectors.

Unit IV
Design of gene construct and advanced technologies
8 lectures
- Factors influencing transgene expression – designing gene constructs - Promoters and polyA signals; Protein targeting signals; Plant selectable markers; Reporter genes; Positive selection; Selectable marker elimination; Transgene silencing; Strategies to avoid transgene silencing; Analysis of transgenic plants – PCR, Southern blot hybridization analysis, northern blot analysis, reverse transcription PCR; Western blot and ELISA; Advanced technologies – cis genesis and intragenesis; RNAi technology, genome editing technology, CRISPR/Cas etc.

Unit V
Application of transgenic technology
10 lectures
- Applications of transgenic crop technology - Herbicide resistance; Pest resistance, Bt toxin, synthetic Bt toxin; Protease inhibitor; and other plant derived insecticidal genes; nematode resistance; Crop Engineering for disease resistance; genetic improvement of abiotic stress tolerance, Genetic engineering for male sterility - Barnase-Barstar;
Recommended Textbooks and References:


### Molecular Pathology and Molecular Diagnostics

#### Credits

2

#### Course Objectives

The objectives of this course are to make students learn about the structural features of the components of the immune system as well as their function. The major emphasis of this course will be on the development of the immune system and mechanisms by which our body elicit the immune response. It also provides the conceptual framework for the development of immuno- and molecular diagnostics and their applications in agricultural, biomedical and veterinary sciences.

#### Student Learning Outcomes

On completion of this course, students should be able to:

- Provide sequential and conceptual thinking and paradigms of cellular and molecular basis of immune system and their applications;
- Evaluate the usefulness of immunology in different pharmaceutical companies;
- Identify the proper research lab working in the area of their own interests;
- Apply their knowledge and design molecular diagnostic kits for detection of diseases.

#### Unit I

**Immune system, immunity and effector mechanism**

7 lectures

### Unit II
**Antigen, antibodies and vaccines**
6 lectures


### Unit III
**Tools for molecular diagnosis**
8 lectures

- Direct and Indirect Methods for detection of various diseases, PCR, RT-PCR, qRT-PCR, Loop mediated isothermal amplification (LAMP), FISH, DNA sequencing and genotyping. Next generation sequencing, Oligonucleotide-coupled fluorescent microsphere diagnostic assay, Nucleic acid hybridization based methods of detection – Southern, Northern and Western, Microarrays based detection, multiplexing etc., Immunodiffusion – double and single immune diffusion, ELISA and its types, Radio immuno assay, chemiluminescent immunoassay, Lateral flow immunoassay strips, Dot blot immuno assay, Western blotting, immunofluorescence, flow cytometry assays, Immunoelectron microscopy, Thermography, Fluorescence imaging, hyperspectral techniques, Biosensors – nanomaterials based, affinity based biosensors – antibody based, nucleic acid based, Enzymatic electrochemical based biosensors, bacteriophage based biosensor.

### Unit IV
**Molecular diagnostic applications in agriculture**
6 lectures

- Applications of DNA testing, detection of soil borne and seed borne infections, transgene detection in seed, planting material and processed food, molecular detection of impurities and seed admixtures in commercial consignments, use of molecular tools in detection of diseases in quarantine. Applications of immunological assays in plant science, Detection of viral, bacterial and fungal diseases and transgenic plants.

### Recommended Textbooks and References:

10. *Immunology by Kuby* - www.whfreeman.com/kuby/
15. http://www.mi.interhealth.info/
17. Lecture Notes, *Cellular and Molecular Immunology*, MIT - http://ocw.mit.edu/
Course Objectives
The overall aim of the course is to provide introductory knowledge concerning genomics and proteomics, and their applications.

Student Learning Outcomes
Through this course, the students should be able to acquire knowledge and understanding of the fundamentals of genomics and proteomics, transcriptomics and metabolomics and their applications in various applied areas of biology.

Genomics and Proteomics

Credits
2

Unit I
Genome organization
3 lectures

Unit II
Genome mapping
4 lectures
Genetic and physical maps; Methods and techniques used for gene mapping, physical mapping(BAC libraries etc), cytogentic techniques, FISH technique in gene mapping, somatic cell hybridization, radiation hybrid maps, in-situ hybridization, etc. Introduction to Molecular markers; linkage analysis.

Unit III
Genome sequencing
3 lectures
Importance of genome sequencing and benefits; Chromosome walking and characterization of chromosomes; Case studies on genome sequencing projects - human, microbes, plants and animals genomes. Accessing and retrieving genome project information from the web; Genome re-sequencing projects – rice 3K and Arabidopsis 1K genome projects; Mining SNPs; Metagenomics; 16S rRNA typing/sequencing.

Unit IV
Functional genomics
5 lectures
Forward and reverse genetics: Various genome wide transcriptome analysis methods for gene expression profiling (Microarrays, SSH libraries, MPSS, SAGE, RNA-Seq etc.) and functional annotation of genes (over-expression and knock out mutants); Mining functional genes in the genome, gene ethics; Introduction to Metabolomics and Lipidomics.

Unit V
Proteomics
5 lectures
Aims, strategies and challenges in proteomics; Proteomics technologies: 2D-PAGE, Isoelectric focusing, mass spectrometry, MALDI-TOF, yeast 2-hybrid system, Proteome databases. Protein-protein and protein-DNA interactions; Protein chips and functional proteomics; Clinical and biomedical applications of proteomics.

Recommended Textbooks and References:
2. TA Brown, Genomes 3, Garland Sciences.
6. Campbell AM & Heyer LJS, (2007), Discovering Genomics, Proteomics and
Microbial Biotechnology

Course Objectives
The objectives of this course are to introduce the students to the field of microbiology with special emphasis on microbial diversity, morphology, physiology and nutrition; methods for control of microbes and host-microbe interactions.

Unit I
Microbial diversity
6 lectures

Classical and modern methods and concepts; Domain and Kingdom concepts in classification of microorganisms; Criteria for classification; Classification of Bacteria according to Bergey's manual; use of DNA and RNA sequencing in classification. Molecular methods such as Denaturing Gradient Gel Electrophoresis (DGGE), Temperature Gradient Gel Electrophoresis (TGGE), Amplified rDNA Restriction Analysis and Terminal Restriction Fragment Length Polymorphism (T-RFLP) in assessing microbial diversity; 16S rDNA sequencing and Ribosomal Database Project; Unicellular Eukaryotes and the Extremophiles (with classical example from each group).

Unit II
Microbial growth kinetics and physiology
5 lectures

Ultrastructure of Archaea (Methanococcus); Eubacteria (E.coli); Unicellular Eukaryotes (Yeast) and viruses (Bacterial, Plant, Animal and Tumor viruses); Microbial growth: Batch, fed-batch, continuous kinetics, synchronous growth, yield constants, methods of growth estimation, stringent response, death of a bacterial cell. Microbial physiology: Physiological adoption and life style of Prokaryotes.

Unit III
Pathogenic microbes and host resistance
5 lectures

Host–Pathogen interactions; Microbes infecting humans, veterinary animals and plants; Pathogenicity islands and their role in bacterial virulence; Introduction, types of resistance, Genetics of resistance, pyramiding of R genes: Susceptible/resistance response, recognition/specificity of the pathogen by host, local and systematic biochemical defences; HR, cellular and molecular basis; Systemic acquired resistance and signal transduction; PR proteins in defenses, applications of biotechnological methods in plant disease diagnosis.

Credits

2

Student Learning Outcomes
On completion of this course, students should be able to:

- Identify the major categories of microorganisms and analyze their classification, diversity, and ubiquity;
- Identify and demonstrate the structural, physiological, and genetic similarities and differences of the major categories of microorganisms;
- Identify and demonstrate how to control microbial growth;
- Demonstrate and evaluate the interactions between microbes, hosts and environment.
Unit IV
Microbial ecology
4 lectures

Role of microorganisms in natural system and artificial system; Influence of Microbes on the Earth’s Environment and Inhabitants; Ecological impacts of microbes; Symbiosis (Nitrogen fixation and ruminant symbiosis); Microbes and Nutrient cycles; Microbial communication system; Quorum sensing.

Unit V
Bioprocess and bioproducts
10 lectures

Basic principles in bioprocess technology; Media Formulation; Sterilization; Thermal death kinetics; Batch and continuous sterilization systems; Primary and secondary metabolites; Extracellular enzymes; Biotechnologically important intracellular products; exopolymers; Bioprocess control and monitoring variables such as temperature, agitation, pressure, pH, Microbial enzymes various role in industrial process; Microbial processes-production, optimization, screening, strain improvement, factors affecting down-stream processing and recovery; Representative examples of ethanol, organic acids, antibiotics etc.; Enzyme Technology-production, recovery, stability and formulation of bacterial and fungal enzymes-amylase, protease, penicillin acylase, glucose isomerase; Immobilised Enzyme and Cell based bio transformations steroids, antibiotics, alkaloids, enzyme/cell electrodes; Use of genetically-engineered microorganisms in biotechnology; Bioinsecticides, biofertilizers; Microbial fuel cells; Prebiotics and Probiotics; Vaccines, Normal microflora of human body. Microbiologically produced food colours and flavours; Retting of flax. Microbial biofuels-Bioethanol, biohydrogen-fuel additives. Alternative biofuels-isopropanol and 1-butanol-Efflux pumps to improve biofuel production.

Recommended Textbooks and References:
8. Microbial Biotechnology: Genetic Engineering - http://nptel.ac.in/courses/102103013/33
10. Institute of Biomedical and Microbial Biotechnology - http://www.cput.ac.za/research/centres/ibmb
Course Objectives
The objective of this course is to develop a research orientation among the scholars and to acquaint them with fundamentals of research methods. Specifically, the course aims at introducing the students to the basic concepts used in research and methods of approach. It includes discussions on sampling techniques, research designs and techniques of analysis.

Student Learning Outcomes
On completion of this course, students should be able to:
• Develop understanding of the basic framework of research process;
• Develop understanding of various research designs and techniques;
• Identify various sources of information for literature review and data collection;
• Develop understanding of the ethical dimensions of conducting applied research;
• Appreciate the components of scholarly writing and evaluate its quality.

Unit I
Research objectives and formulation
7 lectures
Motivation and objectives – Research methods vs. Methodology; Types of research – Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical; Research Formulation – 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, treatise, monographs-patents – web as a source – searching the web; Critical literature review; Identifying gap areas from literature review – Research question - Development of working hypothesis.

Unit II
Research design and methods
6 lectures
Research design – Basic Principles, Need of research design, Features of good research design; Important concepts relating to research design – Observation and Facts, Laws and Theories, Prediction and explanation, Induction, Deduction, Development of Models; Developing a research plan - Exploration, Description, Diagnosis, Experimentation; determining experimental and sample designs.

Unit III
Data collection and analysis
5 lectures
Execution of the research - Observation and Collection of data; Methods of data collection – Sampling Methods- Data Processing and Analysis strategies; Data Analysis with Statistical Packages - Hypothesis-testing - Generalization and Interpretation; Maintaining a lab notebook with date-wise entry.

Unit IV
Reporting and thesis writing
7 lectures
Structure and components of scientific reports - Types of report – Technical reports and thesis – Significance – Different steps in the preparation – Layout, structure and Language of typical reports – Illustrations and tables - Bibliography, referencing and footnotes – software; Oral presentation – Planning – Preparation – Practice – Making presentation – Use of visual aids - Importance of effective communication - Concept of effective communication; Setting clear goals for communication; Determining outcomes and results; Initiating communication; Creating value in conversation; Barriers to effective communication; Non-verbal communication-Interpreting non-verbal cues; Importance of body language, Power of effective listening; recognizing cultural differences.

Unit V
Application of results and ethics
5 lectures
Ethical issues, ethical committees; Commercialization; Intellectual property rights, patent law Copyright, royalty; Calculations of Impact factor of a journal, citation Index, ISBN & ISSN; Reproduction of published material; Plagiarism; Citation and acknowledgement - Reproducibility and accountability.
Recommended Textbooks and References:

Project Proposal Preparation & Presentation

Course Objectives
The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.

Student Learning Outcomes
Students should be able to demonstrate the following abilities:
- Formulate a scientific question;
- Present scientific approach to solve the problem;
- Interpret, discuss and communicate scientific results in written form;
- Gain experience in writing a scientific proposal;
- Learn how to present and explain their research findings to the audience effectively.

Syllabus

Project Proposal Preparation
Selection of research lab and research topic: Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them select a topic for their project. The topic of the research should be hypothesis driven. Review of literature: Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources. Writing Research Proposal: With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc. Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.

Poster Presentation
Students will have to present the topic of their project proposal after few months of their selection of the topic. They should be able to explain the novelty and importance of their research topic.

Oral Presentation
At the end of their project, presentation will have to be given by the students to explain work done by them in detail. Along with summarizing their findings they should also be able to discuss the future expected outcome of their work.
Course Objectives
The objective of this course is to impart hands-on-training to the students on recent advances in genomics and techniques/tools in molecular breeding, gene expression profiling and bioinformatics.

Student Learning Outcomes
Students should be able to acquire practical knowledge and skills in:
- Diversity analysis and population structure analysis using molecular markers;
- Genetic mapping procedures using bi- and multi-parental populations;
- Gene expression profiling using high-throughput transcriptomic, proteomics and metabolomics tools;
- Bioinformatics tools for genomics studies.

Syllabus
1. Principles and Methods involved in nucleic acid separation
2. Designing Primers - Gene specific primers – primers based on conserved regions – Degenerate primers
4. Molecular analysis of transgenic plants
5. RT-PCR – semi-quantitative and quantitative
6. Microarray – data analysis and interpretation
7. 2D PAGE – data analysis and interpretation
8. Metabolomics – GC-MS
9. Genome databases – rice; Retrieving marker information
10. Molecular markers - Germplasm characterization using molecular markers
11. Mapping populations - Linkage map construction - QTL mapping
12. Principle of Association mapping – GWAS

Recommended Textbooks and References:
**Laboratory IV: Plant Tissue Culture and Genetic Transformation**

**Course Objectives**
The objective of this course is to impart hands-on-training on various techniques of plant tissue culture and plant genetic transformation.

**Student Learning Outcomes**
On completion of this course, students should be able to acquire practical knowledge on the techniques involved in tissue culture and transgenic technology.

**Syllabus**

1. Preparation of stocks - macronutrients, micronutrients, vitamins and hormones, filter sterilization of hormones and antibiotics. Preparation of Murashige and Skoog medium
2. Micro-propagation of plants (rose, banana) by nodal culture and shoot tip culture
3. Embryo culture to overcome incompatibility and anther culture for haploid production
4. Callus induction in tobacco leaf discs, regeneration of shoots, root induction, role of hormones in morphogenesis
5. Acclimatization of tissue culture plants and establishment in greenhouse.
6. Isolation of plasmids, construction of transformation vector – restriction digestion, ligation and bacterial transformation
7. Preparation of micro-projectiles, transformation of rice using a particle gun, GUS staining
8. Mobilization of binary vector into *Agrobacterium tumafaciens* through triparental mating and confirmation of transconjugants
9. Tobacco leaf disc transformation using *Agrobacterium*, establishment of transgenic plants, and GUS staining or GFP viewing
10. DNA extraction from transgenic plants, DNA estimation, PCR analysis, Southern blot analysis to prove presence of foreign DNA sequences
11. RT-PCR to study transgene expression, western blotting to study the accumulation of transgene-encoded protein.

**Recommended Textbooks and References:**

Laboratory V: Techniques in Cell Biology, Immunotechnology and Molecular Diagnostics

Course Objectives
The objectives of this course are to provide the knowledge about the basic microbiological, cytological and immunological techniques.

Student Learning Outcomes
On completion of this course, students should be able to acquire basic hands-on skills of various microscopic, microbiological, cytological and immunological techniques.

Syllabus
1. Principles of microscopy and optics, Compound microscopy, Bright field microscopy, phase contrast microscopy, Fluorescence and confocal microscopy, Electron microscopy
2. Cell size determination by the use of an ocular and stage micrometer, Hanging drop technique for demonstrating motility of bacteria
3. Simple, Gram staining and Endospore staining of microorganisms
4. Observation of Mitosis and the Cell Cycle in Onion Root-Tip Cells
5. Histology – Hand-sectioning of stem and leaf, saffranin and fast green staining
6. Microtomy - fixing of tissues, dehydration, wax-embedding, sectioning and staining
7. Selection, Preparation of antigen, Immunization, methods of bleeding, serum preparation and storage
8. Detection and quantitation of antibodies by single radial immuno diffusion method (SRID), Double radial immunodiffusion (Ouchterlony’s method)
9. Isolation and purification of IgG from serum or IgY from chicken egg
10. Determination of Antibody titer by ELISA, Dot blot assay, Immunelectrophoresis
11. Western Blotting
12. PCR and ELISA based detection of plant diseases
13. PCR and ELISA based detection of transgenic plants

Recommended Textbooks and References:
Course Objectives
The objectives of this course are to familiarize the students about the major challenges faced by plants during their day-to-day struggle for survival and to understand the physiological and molecular strategies used by plants to deal with these challenges.

Student Learning Outcomes
On completion of this course, students should be able to understand the concepts of biotic and abiotic stress in plants.

Unit I
Stress conception in plants
4 lectures
General adaptation syndrome in plants; Plant cell as a sensor of environmental changes; role of cell membranes in signal perception; Ways of signal transduction in cells and whole plants as a response to external factors.

Unit II
Abiotic stress
13 lectures
Abiotic stresses affecting plant productivity – Drought, salinity, water logging, temperature stresses, light stress and nutrient stress; Drought stress – Effects on plant growth and development; Components of drought resistance; Physiological, biochemical and molecular basis of tolerance mechanisms; Strategies to manipulate drought tolerance – synthesis of proline, glycine betaine, poly amines and sugars; ROS and antioxidants; hormonal metabolism; signaling components; Salinity stress – effects, basis of cellular and whole plant level tolerance, tolerance mechanisms, utilizing glycophytes and halophytes in improving salinity tolerance; Water logging stress – effects on plant growth and metabolism; tolerance mechanisms; Temperature stresses – cold and high temperature stress; effects; cold tolerance mechanisms and improvement strategies; alleviating effects of high temperature stress; Light stress – low light, high light and UV light stress; effects and tolerance mechanisms; Heavy metal stress – Al and Cd stress in plants, biotech strategies to overcome heavy metal stress; Nutrient stress- effects on plant growth and genetic manipulation strategies.

Unit III
Biotic stress
16 lectures
Plant-pathogen interaction and disease development, changes in metabolism of cell wall composition and vascular transport in diseased plants, Reactive oxygen species, antioxidants, enzymes of defense system; Plant defense response, antimicrobial molecules, hypersensitive response and cell death, systemic and acquired resistance, pathogen derived resistance, antipathogenic principles; Plant viruses, host virus interactions, disease induction, virus movement and host range determination; viroids. R x Avr gene interaction, defense genes, Signaling pathway related to defense gene expression, R proteins and genes from pathogens and other sources, coat protein genes, detoxification genes, RNAi approach, transgenics and disease management, Transgenic plants for disease resistance. Plant-insect interactions a molecular view, biochemical and molecular basis of host plant resistance to insect pests, insects in relation to crop plants, biotypes and geographical variation- isolation and characterization of insect resistance genes, genes derived from microorganisms- Bacillus thuringiensis crystal protein genes, genes derived from plants, enzyme inhibitor and lectin genes, genes derived from animal sources. Marker Assisted Selection for pest management. Nematode resistance genes - local and systemic induced resistance to the nematode in crop plants, biochemical and molecular changes in plants, biotechnological approaches for nematode resistance, weeds, herbicide resistant transgenic crops, glyphosate resistance, phosphinotricin resistance – resistance to other herbicides.Impact of GM crops on non-target organisms; tritrophic interactions, molecular mechanisms of development of resistance to
Unit IV

Strategies for tolerance against stress
7 lectures

Bt proteins, resistance management strategies in transgenic crops, ecological impact of field release of transgenic crops.

Interactions between biotic and abiotic stresses; Molecular strategies for imparting tolerance against biotic and abiotic stresses for improvement of plants / crops by means of breeding and biotechnological approaches.

Recommended Textbooks and References:

Bioprocess Engineering & Technology

Course Objectives
The objectives of this course are to educate students about the fundamental concepts of bioprocess technology and its related applications, thus preparing them to meet the challenges of the new and emerging areas of biotechnology industry.

Student Learning Outcomes
Students should be able to:
- Appreciate relevance of microorganisms from industrial context;
- Carry out stoichiometric calculations and specify models of their growth;
- Give an account of design and operations of various fermenters;
- Present unit operations together with the fundamental principles for basic methods in production technique for bio-based products;
- Calculate yield and production rates in a biological production process, and also interpret data;
- Calculate the need for oxygen and oxygen transfer;
- Critically analyze any bioprocess from market point of view;
- Give an account of important microbial/ enzymatic industrial processes in food and fuel industry.
**Unit I**  
**Basic principles of biochemical engineering**  
4 lectures

- Isolation, screening and maintenance of industrially important microbes; microbial growth and death kinetics (an example from each group, particularly with reference to industrially useful microorganisms); strain improvement for increased yield and other desirable characteristics.

**Unit II**  
**Stoichiometry and models of microbial growth**  
4 lectures

- Elemental balance equations; metabolic coupling – ATP and NAD+; yield coefficients; unstructured models of microbial growth; structured models of microbial growth.

**Unit III**  
**Bioreactor design and analysis**  
8 lectures

- Batch and continuous fermenters; modifying batch and continuous reactors: chemostat with recycle, multistage chemostat systems, fed-batch operations; conventional fermentation v/s biotransformation; immobilized cell systems; large scale animal and plant cell cultivation; fermentation economics; upstream processing: media formulation and optimization; sterilization; aeration, agitation and heat transfer in bioprocess; scale up and scale down; measurement and control of bioprocess parameters.

**Unit IV**  
**Downstream processing and product recovery**  
8 lectures

- Separation of insoluble products - filtration, centrifugation, sedimentation, flocculation; Cell disruption; separation of soluble products: liquid-liquid extraction, precipitation, chromatographic techniques, reverse osmosis, ultra and micro filtration, electrophoresis; final purification: drying; crystallization; storage and packaging.

**Unit V**  
**Fermentation economics**  
4 lectures

- Isolation of micro-organisms of potential industrial interest; strain improvement; market analysis; equipment and plant costs; media; sterilization, heating and cooling; aeration and agitation; bath-process cycle times and continuous cultures; recovery costs; water usage and recycling; effluent treatment and disposal.

**Unit VI**  
**Applications of enzyme technology in food processing**  
4 lectures

- Mechanism of enzyme function and reactions in process techniques; enzymatic bioconversions e.g. starch and sugar conversion processes; high-fructose corn syrup; interesterified fat; hydrolyzed protein etc. and their downstream processing; baking by amylases, deoxygenation and desugaring by glucose oxidase, beer mashing and chill proofing; cheese making by proteases and various other enzyme catalytic actions in food processing.

**Unit VII**  
**Applications of microbial technology in food process operations and production, biofuels and biorefinery**  
4 lectures

- Fermented foods and beverages; food ingredients and additives prepared by fermentation and their purification; fermentation as a method of preparing and preserving foods; microbes and their use in pickling, producing colours and flavours, alcoholic beverages and other products; process wastes-whey, molasses, starch substrates and other food wastes for bioconversion to useful products; bacteriocins from lactic acid bacteria – production and applications in food preservation; biofuels and biorefinery.

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**Recommended Textbooks and References:**

Bioinformatics basics, scope and importance of bioinformatics, Importance of Unix and Linux systems and its basic commands, Biological databases for DNA and Protein sequences - PIR, SWISSPROT, genebank, DDBJ, secondary database, structural databases - PDB, Specialized genomic resources, Microarray database.

DNA sequence analysis, Sequence submission and retrieval system-SEQUIN, BANKit, SAKURA, Webin, Sequence alignment-, Global and local alignment, pair wise alignment techniques, multiple sequence alignment; Algorithms – Smith and Waterman, Needleman and Wunsch. Tools for Sequence alignment- BLAST –BLASTp, BLASTn, tBLASTn, BLASTx, tBLASTx, PHIBLAST, PSI BLAST, FASTA and its variants.


Structure Based Drug Design- Rationale for computer aided drug designing, Deriving 3D pharmacophore and its applications. Lipinski’s Rule, Quantitative Structure Activity Relationship - compound selection, deriving equation, interpretation, validation and prediction - Drug design-Types- Structure based, Virtual screening - ligand based, optimization methods.

Recommended Textbooks and References:
## Intellectual Property Rights, Biosafety and Bioethics

### Course Objectives

The objectives of this course are:

- To provide basic knowledge on intellectual property rights and their implications in biological research and product development;
- To become familiar with India’s IPR Policy;
- To learn biosafety and risk assessment of products derived from biotechnology and regulation of such products;
- To become familiar with ethical issues in biological research. This course will focus on consequences of biomedical research technologies such as cloning of whole organisms, genetic modifications, DNA testing.

### Student Learning Outcomes

On completion of this course, students should be able to:

- Understand the rationale for and against IPR and especially patents;
- Understand why India has adopted an IPR Policy and be familiar with broad outline of patent regulations;
- Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents;
- Gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research and environmental release of genetically modified organisms, national and international regulations;
- Understand ethical aspects related to biological, biomedical, health care and biotechnology research.

### Unit I

**Introduction to IPR**

6 lectures

Introduction to intellectual property; types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of ‘prior art’: invention in context of “prior art”; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation.

### Unit II

**Patenting**

6 lectures

Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure - patent application- forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting-requirement, procedures and costs; financial assistance for patenting-introduction to existing schemes; publication of patents-gazette of India, status in Europe and US; patent infringement- meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing – outright sale, licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives.
Biosafety and Biosecurity - introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants – sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk – environmental risk assessment and food and feed safety assessment; problem formulation – protection goals, compilation of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops vs cisgenic plants or products derived from RNAi, genome editing tools.

International regulations – Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations – EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – biosafety levels and category of rDNA experiments; field trails – biosafety research trials – standard operating procedures - guidelines of state governments; GM labeling – Food Safety and Standards Authority of India (FSSAI).


Recommended Textbooks and References:
2. National IPR Policy, Department of Industrial Policy & Promotion, Ministry of Commerce, GoI
5. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/


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**Bioentrepreneurship**

**Credits**

<table>
<thead>
<tr>
<th>Course Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>Basics of bioentrepreneurship</td>
<td>6</td>
</tr>
<tr>
<td>Accounting and finance</td>
<td>6</td>
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<tr>
<td>Business strategy</td>
<td>6</td>
</tr>
<tr>
<td>Marketing</td>
<td>5</td>
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<tr>
<td>Knowledge centre and R&amp;D</td>
<td>7</td>
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</table>

**Course Objectives**

The objectives of this course are to teach students about concepts of entrepreneurship including identifying a winning business opportunity, gathering funding and launching a business, growing and nurturing the organization and harvesting the rewards.

**Student Learning Outcomes**

Students should be able to gain entrepreneurial skills, understand the various operations involved in venture creation, identify scope for entrepreneurship in biosciences and utilize the schemes promoted through knowledge centres and various agencies.

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**Unit I Basics of bioentrepreneurship 6 lectures**

Importance of entrepreneurship; advantages of being entrepreneur - freedom to operate; introduction to bioentrepreneurship – biotechnology in a global scale; Scope in bioentrepreneurship; types of bio-industries – biopharma, bioagri, bioservices and bioindustrial; innovation – types, out of box thinking; skills for successful entrepreneur – creativity, leadership, managerial, team building, decision making; opportunities for bioentrepreneurship; entrepreneurship development programs of public and private agencies (MSME, DBT, BIRAC, Startup & Make in India); patent landscape, IP protection & commercialization strategies.

**Unit II Accounting and finance 6 lectures**

Business plan preparation; business feasibility analysis by SWOT; socio-economic costs benefit analysis; funds/support from Government agencies like MSME/banks and private agencies like venture capitalists/angel investors for bioentrepreneurship; business plan proposal for ‘virtual startup company’; statutory and legal requirements for starting a company/venture; basics in accounting practices: concepts of balance sheet, profit and loss statement, double entry bookkeeping; collaborations & partnerships; information technology for business administration and expansion.

**Unit III Business strategy 6 lectures**

Entry and exit strategy; pricing strategy; negotiations with financiers, bankers, government and law enforcement authorities; dispute resolution skills; external environment/ changes; avoiding/managing crisis; broader vision–global thinking; mergers & acquisitions.

**Unit IV Marketing 5 lectures**

Market conditions, segments, prediction of market changes; identifying needs of customers; Market linkages, branding issues; developing distribution channels - franchising; policies, promotion, advertising; branding and market linkages for ‘virtual startup company’.

**Unit V Knowledge centre and R&D 7 lectures**

Knowledge centres e.g., in universities, innovation centres, research institutions (public & private) and business incubators; R&D for technology development and upgradation; assessment of technology development; managing technology transfer; industry visits to successful bio-enterprises, regulations for transfer of foreign technologies; quality control; technology transfer agencies; Understanding of regulatory compliances and procedures (CDSCO, NBA, GLP, GCP, GMP).
Course Objectives
The objectives of this course are to familiarize the students with classical discoveries in life sciences to make them understand how ground-breaking discoveries were made without, necessarily, use of high-end technologies.

Student Learning Outcomes
Students should be able to comprehend the landmark discoveries in life sciences, especially biotechnology and their application in crop improvement.

Methodology for delivering the Course Module: Advances/milestones listed below will be grouped into major discussion areas. Students may be divided into groups and each group may be responsible for one major area.

A list of classical papers on landmark discoveries in life science/biotechnology/molecular biology is suggested for discussion:

Year 1950s
- Discoveries about the structure and function of biological macromolecules
- Identification of DNA as the carrier of genetic information.
- Directed synthesis of dinucleotide by Alexander Todd
- Phosphodiesters oligonucleotide synthesis by Har-Gobind Khorana and colleagues
- Central Dogma of Life - Francis Crick - RNA acts as an intermediary between DNA and protein.
- Mechanism of semiconservative DNA replication - Meselson and Stahl in 1958
- Discovery of DNA polymerase and production of DNA in vitro - Arthur Kornberg
- Confirmation of Central Dogma

Year 1960s
- Identification of genetic codon by Crick - In vitro protein translation by Marshall Nirenberg
- Development of phosphotriester oligonucleotide synthesis methods by Robert Letsinger and Colin Reese.
- First nucleic acid sequence (tRNA) and cracking of genetic code by Nirenberg, Holley, and Khorana, winning a 1968 Nobel Prize.
- Isolation of thermostable DNA polymerase from a hot spring bacterium in Yellowstone National Park by Thomas Brock

Year 1970s
- Recombinant DNA, cloning, and gene synthesis and sequencing.
- Discovery of restriction enzyme and sequence-specific DNA cutting
and production of recombinant DNA and transgenic organisms.

- Discovery of messenger RNA sequence rearrangement – alternate splicing Roberts and Sharp shared a 1993 Nobel Prize for this work.
- Edwin Southern – development of DNA blotting technique, which enabled researchers to identify, locate, and quantitate specific DNA sequences in a sample of genomic DNA
- Development of efficient DNA sequencing method by Frederick Sanger - first genome sequence of a DNA-based organism, bacteriophage \( \text{fX174} \)

**Year 1980s**

- Invention of PCR by Kary Mullis (1983) and subsequent wave of PCR-based innovations
- Discovery of Transpososns by Barbara McClintock as genetic tool
- Development of first recombinant chimeric monoclonal antibodies (1984) as modern therapeutics
- DNA fingerprinting as a forensic tool (1989)

**Year 1990s**

- Arrival of huge volumes of genomic and transcriptomic tools - automated sequencing and DNA microarray technologies
- Human Genome Project began in 1990
- Invention of DNA microarrays by Pat Brown and colleagues
- Development of bioinformatics
- Prediction of gene function from coding sequences, elucidation of noncoding DNA structures
- Cloning of Dolly the sheep

**Year after 2000**

- Acceleration of Genome sequencing projects – completion of *Drosophila*, *Arabidopsis* and human genomes.
- Invention of quantitative real-time PCR (qPCR) for the analysis of nucleic acids in applications such as forensics, food safety testing, and gene expression analysis.
- RNA interference: Biomedical researchers Andrew Fire and Craig Mello publish a study showing how small RNA molecules influence genetic pathways in *C. elegans* worms, opening up a new field of research into RNA interference. RNAi-based therapies could address a wide variety of illnesses, including AIDS, cancer, Huntington's and Alzheimer's disease.
- Development of NGS technologies – 3K rice and 1K Arabidopsis genome projects
- Genetic mapping – Classical work of Tanksley in Tomato; Case studies in rice and pulses - mapping and fine mapping of major traits
- GWAS and Association mapping – classical examples
- Advancements in genotyping – SSR/SNP genotyping methods; sequencing based genotyping
- Mapping using Multi-parental populations (MAGIC, NAM, GBS)
- Genetic engineering in crop plants – Golden rice, Bt crops, herbicide tolerance, improved quality in crops
- Genome Engineering – Conceptualization and advancements in crop plants

**Course Objectives**

The objectives of this course are to train the students to evaluate research papers, to assess quality of the papers and how the papers are refereed and published as well as learn how to get the papers published.

**Student Learning Outcomes**

Students should be able to:

- Critically analyse the research papers from different upcoming topics;
- Understand the weaknesses and strengths of the paper and what additional experiments could have been done to strengthen the
Each student will need to present one paper during the term. They should select research papers, which deal with upcoming or most recent scientific findings/breakthrough and technologies developed.

Every week, each student will be asked to write a short review and evaluations of the paper presented in the class and then indulge in discussion with flaws of the paper, important questions and impact of the overall paper. Recent technologies, can be discussed, where it can be applied.

**Course Objectives**
The objective of this course is to impart hands-on experience on the different areas underlying bioinformatics approaches which includes databases, tools and techniques to perform DNA, protein sequence and structure analysis. Also this course provides the usage of various statistical packages like MS Excel, SYSTAT/SPSS and SAS/IRRISTAT for the analysis of Agricultural Research Data.

**Student Learning Outcomes**
An intensive training on the sequence and structural analysis tools should inculcate the needed analytical skills towards deriving useful inferences from the analysis of protein and nucleotide sequences and structures. Further, students will be able to acquire hands on experience in designing experiments, collection and analysis of research data.

**Syllabus**
- Nucleic acid sequence databases: DDBJ, GenBank, NCBI
- Protein Sequence Databases: PIR, UNIPROT
- Protein Structure Database: PDB, MMDB
- Specialized genomic resources- ENTREZ – genome, gramene, SRA
- Sequence Alignment: BLAST variants and FASTA variants
- Gene prediction: PFAM, GENESCAN, FGENESH, GLIMMER
- Tools for primer designing – Primer3, Genefisher, FastPCR
- Multiple Sequence Alignment: Clustal X, Clustal W, MAFFT, MUSCLE
- Sequence submission and Retrieval System: BANKIT, SEQUIN
- Phylogenetic Analysis: PHYLIP, Tree finder, MEGA
- Function annotation – Prosite, ProDOM, Interpro, PRINTS, PFAM
- Protein Modelling- SWISS Model, Modeller, I TASSER
- Docking: Auto Dock, Swiss Docking
- Test of significance – t-test – F-test and2-test – correlation and regression analysis – ANOVA – data transformation
- Factorial experiments – split-plot design – strip plot design
- Statistical analysis using MS Excel, SYSTAT/SPSS, SAS/IRRISTAT.

**Recommended Textbooks and References:**
Course Objectives

The objective of this laboratory course is to introduce students to experiments pertaining to biotic and abiotic stresses in plants. The course is designed to teach students the different techniques involved in assaying the biotic and abiotic stresses in plants in a problem oriented manner.

Student Learning Outcomes

On completion of this course, students should be able to understand principles underlying biotic and abiotic stresses and detection and determination of cellular, molecular and biochemical changes in plants due to the stresses.

Syllabus

1. Meristem tip culture for generation of disease free plants
2. Isolation and Purification of toxins produced by plant pathogens
3. Bioassay of toxins
4. Tissue culture techniques to screen resistant cells/calli
5. Assay of PR proteins – Chitinase/gluconase
6. Detection of viral/bacterial/fungal diseases by PCR and ELISA
7. Isolation of Bt proteins from soil samples
8. Protein profiling of Bt proteins by SDS-PAGE analysis
9. Bioassay techniques: Leaf disc and Artificial diet based methods for epiptorperan insect pests
10. Study of biochemical changes in crop varieties for insect resistance
11. Impact of transgenic crops on non-target organisms
12. Assay of enzymes in resistant and susceptible tomato/potato genotypes to root knot/cyst nematodes
13. Evaluation for drought tolerance – screening using PEG; screening for root system traits;
14. Measurement of stomatal traits; gas exchange parameters and RWC;
15. Estimation of cell membrane stability
16. Evaluation for salinity tolerance – screening using NaCl; salt uptake pattern; osmotic tolerance
17. High temperature tolerance - temperature induction response test; screening for
Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

18. Estimation of ROS enzymes - Catalase, Peroxidase and Superoxide dismutase

Semester Four

Course Objectives
The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.

Student Learning Outcomes
Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:

- In-depth knowledge of the chosen area of research.
- Capability to critically and systematically integrate knowledge to identify issues that must be addressed within framework of specific thesis.
- Competence in research design and planning.
- Capability to create, analyse and critically evaluate different technical solutions.
- Ability to conduct research independently.
- Ability to perform analytical techniques/experimental methods.
- Project management skills.
- Report writing skills.
- Problem solving skills.
- Communication and interpersonal skills.

Syllabus

Planning & performing experiments
Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

Syllabus

Thesis writing
At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.

Recommended Mode of Assessment
Assessment may be done by thesis evaluation, viva voce and final presentation.
## Recommended Electives

### Environmental Biotechnology

**Course Objectives**
The course is designed to introduce students to scientific and technological aspects related to concept of ecosystem and its management, environmental degradation and its effect on living systems, bioremediation and waste management.

**Student Learning Outcomes**
Students should be able to understand use of basic microbiological, molecular and analytical methods, which are extensively used in environmental biotechnology.

<table>
<thead>
<tr>
<th>Unit I</th>
<th>Introduction to environment</th>
<th>5 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Concept of ecosystems and ecosystem management, Scope of environmental biotechnology, Response of microbes, plant and animals to environmental stresses; Environmental problems - ozone depletion, pesticides, greenhouse effect, water, air and soil pollution, radioactive pollution, land degradation. Biotechnological tools to monitor bio treatment efficiency.</td>
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<table>
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<tr>
<th>Unit II</th>
<th>Biotechnology for remediation of polluted habitats</th>
<th>7 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Role of environmental biotechnology in management of environmental problems, Bioremediation, advantages and disadvantages; In-situ and ex-situ bioremediation; slurry bioremediation; Bioremediation of contaminated ground water and phytoremediation of soil; microbiology of degradation of xenobiotics.</td>
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<table>
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<tr>
<th>Unit III</th>
<th>Biotechnology for waste water management</th>
<th>7 lectures</th>
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<td></td>
<td>Sewage and waste water treatment, solid waste management, chemical control of water pollution, role of microphyte and macrophytes in water treatment; recent approaches to biological waste water treatment, treatment for waste water from dairy, distillery, tannery, sugar and antibiotic industries.</td>
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<tr>
<th>Unit IV</th>
<th>Recent advances in environmental biotechnology</th>
<th>4 lectures</th>
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<td></td>
<td>Algal bioreactors, bioethanol, biohydrogen; use of biological techniques in controlling air pollution; Removal of chlorinated hydrocarbons from air. Applications –Nano biopolymers, bioplastics, biofilms, bioleaching and biosensors.</td>
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<tr>
<th>Unit V</th>
<th>Environmental laws and regulations</th>
<th>4 lectures</th>
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</table>

### Recommended Textbooks and References:

Course Objectives
The objectives of this course are to:
• Gain knowledge on the microbes associated with food spoilage, food borne illness and rapid detection of pathogens;
• Gain knowledge to differentiate food spoilage and fermentation, learn the process of fermentation to prepare value added food and microbial enzymes involved in food industry and bio-preservation;
• Learn regulatory aspects in food biotechnology.

Student Learning Outcomes
This course should be to help the students to:
• Obtain a good understanding of food biotechnology and become qualified for a food biotechnologist position in industry or in government;
• Determine microorganisms and their products in foods, understand causes of food spoilage and predict the microorganisms that can spoil a given food, when prepared, processed and stored under given conditions;
• Understand the causes of food-borne microbial diseases and predict pathogens that can grow in a given food, when prepared, processed and stored under given conditions;
• Predict the necessary measures to control the spoilage and pathogenic microorganisms in food;
• Learn milk processing and preparation of fermented dairy products.

Unit I
Introduction
5 lectures
History-Pre Pasteur Era and Post Pasteur Era; Modern Food Biotechnology; Application of biotechnology in food processing.

Unit II
Food fermentation
7 lectures
Types of fermented foods; Microbes involved in food fermentation; Beverages produced using microbes; Food Enzymes- microbial sources for organic acids, amino acids, microbial polysaccharides, applications; Microalgal Biotechnology.

Unit III
Food spoilage microbes
7 lectures
Food borne pathogens; Rapid detection of food borne pathogens using molecular and serological methods; Food preservation using anti-microbial peptides.

Unit IV
Dairy biotechnology
7 lectures
Fermented Dairy products; Probiotics and prebiotics; Microbes used as probiotics.

Unit V

Functional foods
6 lectures

Advances in Biotechnology for the production of functional foods; Regulatory aspects of food biotechnology; Future strategies for development of biotechnology-enhanced functional foods for human nutrition.

Recommended Textbooks and References:

7. http://www.bubl.ac.uk/link/foodscience.htm
8. https://www.who.int/food safety.html
10. https://www.library.ohio.edu/subjects/food.html

Course Objectives
The course aims at providing a general and broad introduction to multi-disciplinary field of nanotechnology. It will familiarize students with the combination of the top-down approach of microelectronics and micromechanics with the bottom-up approach of chemistry/biochemistry; a development that is creating new and exciting cross-disciplinary research fields and technologies. The course will also give an insight into complete systems where nanotechnology can be used to improve our everyday life.

Student Learning Outcomes
On successful completion of this course, students should be able to describe basic science behind the properties of materials at nanometre scale, and the principles behind advanced experimental and computational techniques for studying nanomaterials.

Unit I

Introduction to nanobiotechnology
5 lectures

Introduction to Nanobiotechnology; Concepts, historical perspective; Different formats of nanomaterials and applications with example for specific cases; Cellular Nanostructures; Nanopores; Biomolecular motors; Bio-inspired Nanostructures, Synthesis and characterization of different nanomaterials.

Unit II

Nano – films
5 lectures

Thin films; Colloidal nanostructures; Self Assembly, Nanovesicles; Nanospheres; Nanocapsules and their characterisation.

Unit III

Nano – particles
5 lectures

Nanoparticles for drug delivery, concepts, optimization of nanoparticle properties for suitability of administration through various routes of delivery, advantages, strategies for cellular internalization and long circulation, strategies for enhanced permeation through various anatomical barriers.
## Systems and Synthetic Biology

### Course Objectives
The objectives of this course are to provide fundamental understanding of basic cellular processes, design and implement new cellular behaviors by applying mathematical, analytical and engineering tools for studying biological systems.

### Student Learning Outcomes
Students should be able to acquire knowledge and improve quantitative understanding of natural phenomenon as well as foster an engineering discipline for obtaining new complex cell behaviors, also would enable them to perform research in interdisciplinary fields like systems biology and synthetic biology and know how to engineer live organisms to display novel functions using engineering practices such as modular assembly, characterization of parts and related policies and ethical issues.

### Credits
2

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### Unit I
**Electronic engineering- dynamic systems and control theory**
5 lectures


### Unit II
**Systems biology and synthetic biology: basics**
5 lectures


### Unit III
**Synthetic biology: foundation technologies and standards**

Key enabling technologies in synthetic biology. BioBricks - Definition of a BioBrick, black-box encapsulation, PoPs and RiPs. The Registry of Standard Biological Parts. Signal carrier, modularity, Abstraction hierarchy. Tools for Analyzing and Controlling Biological...
Unit IV
DNA re-writing, devices and circuits
5 lectures

Writing DNA: DNA synthesis, artificial genes, never born proteins, non-natural nucleic acids. Devices and circuits: Bacterial camera, Construction of toggle switches, logic gates, oscillators, pulse generators, time delayed circuits.

Unit V
Implications and applications of synthetic biology
5 lectures

Applications of synthetic biology - Bioplastics, Artemisinin, Opioids, DNA origami, RNA based designs, genome engineering, biofuel - microbial and minimal synthetic cell, Reconstructing viruses, 3D bioprinting. Directed evolution of chemical sensors.

Unit VI
Risks and ethical, legal and social issues
5 lectures


Recommended Textbooks and References:
8. Synthetic and Systems Biology for Microbial production of Commodity Chemicals - http://www.nature.com/articles/npsba20169

Course Objectives
To understand the concepts of molecular biology and biotechnology in relation to host-pest/pathogen interactions.

Student Learning Outcomes
By the end of this course, students should be able to:
• Formulate scientific questions about how plants and pathogens interact to result in disease or resistance;
• Evaluate experimental approaches for how to distinguish cause from effect;
• Interpret, evaluate, and discuss research papers on plant-microbe interactions;
• Describe the current hypotheses on how plants and microbes interact.


Genetics of disease resistance - Gene-for-gene theory, avirulence (avr) genes, characteristics of avrgene - coded proteins, hrgenes, protein-for-protein, Resistance (R) genes of plants, R-gene expression and transcription profiling, mapping and cloning of resistance genes, structure and classes of resistance genes, genomic organization of resistance genes.

Host defense mechanisms, morphological and anatomical resistance, phytoanticipins - phenolics, glucosinolates, cyanogenic glucosides, saponins, steroid alkaloids, dienes, induced structural and biochemical defences - cell wall modifications - papilla-callose deposition, HRGP accumulation - lignifications - suberization - phytoalexins, defense-related proteins, hypersensitive reaction and its mechanisms, reactive oxygen species.


Practical:
Isolation and purification of elicitor and toxin from fungal mycelium - Estimation of total phenols, PAL and PO activities - Estimation of lignin content - Assay of chitinase and β-1,3-glucanase activities - Western blot analysis of pathogenesis-related proteins - characterization of defense-related genes. Study of effect of plant derived genes on insects - bioassay of transgenic plants for insect damage - assay of PR proteins against nematodes-assay of enzymes in resistant and susceptible tomato genotypes to root knot nematode-assay of enzymes in resistant and susceptible potato genotypes to cyst nematode.

Recommended Textbooks and References:
13. Host-Pathogen Interactions: Genetics, Immunology, and Physiology - www.amazon.com/Host-Pathogen-Interactions/dp/1608762866
<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of University</th>
<th>Contact Details of Course Coordinator</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Assam Agricultural University, Jorhat</td>
<td>Prof. Mahendra Kumar Modi  Dept. of Agricultural Biotechnology 0376 – 2340095 (O) 9435091017(M) <a href="mailto:mkmodi@gmail.com">mkmodi@gmail.com</a>; <a href="mailto:mkmodi@aau.ac.in">mkmodi@aau.ac.in</a></td>
</tr>
<tr>
<td>2.</td>
<td>G.B. Pant University of Agriculture and Technology, Pantnagar</td>
<td>Prof. Anil Kumar Dept. of Biochemistry, Molecular Biology &amp; Genetic Engineering 05944- 233898, 2340101 (O) 09411195450 (M) <a href="mailto:ak_gupta2k@rediffmail.com">ak_gupta2k@rediffmail.com</a></td>
</tr>
<tr>
<td>3.</td>
<td>Indira Gandhi Agricultural University, Raipur</td>
<td>Prof. S.B. Verulkar Dept. of Plant Molecular Biology &amp; Biotechnology 0771–2442069, 09752152034 (M) <a href="mailto:satishverulkar@gmail.com">satishverulkar@gmail.com</a></td>
</tr>
<tr>
<td>4.</td>
<td>Kerala Agricultural University, Thrissur</td>
<td>Dr. M.R. Shylaja Centre for Plant Biotechnology and Molecular Biology 0487-2438577 09446364216 (M) <a href="mailto:shylaja_mr@kau.in">shylaja_mr@kau.in</a>; <a href="mailto:cpbmb@kau.in">cpbmb@kau.in</a></td>
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<tr>
<td>5.</td>
<td>Orissa University of Agriculture and Technology, Bhubaneswar</td>
<td>Prof. G.R. Rout Dept. of Agricultural Biotechnology 0674–2397755 (O) 09437308014 (M) <a href="mailto:headabt_bbsr@rediffmail.com">headabt_bbsr@rediffmail.com</a>; <a href="mailto:grrout@rediffmail.com">grrout@rediffmail.com</a>; <a href="mailto:abt.ouat@gmail.com">abt.ouat@gmail.com</a></td>
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<td>6.</td>
<td>Rajendra Agricultural University, Samastipur</td>
<td>Dr. Mithilesh Kumar Faculty of Basic Sciences and Humanities 06274-240272(0) 0943183070 <a href="mailto:deanfbshpusa@yahoo.co.in">deanfbshpusa@yahoo.co.in</a>; <a href="mailto:mithileshkumar.eecrau@gmail.com">mithileshkumar.eecrau@gmail.com</a></td>
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<td>7.</td>
<td>Tamil Nadu Agricultural University, Coimbatore</td>
<td>Prof. P. Chandrababu Centre for Plant Molecular Biology 0422 - 6611262(O) <a href="mailto:directorcpmb@tnau.ac.in">directorcpmb@tnau.ac.in</a></td>
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<td>8.</td>
<td>University of Agricultural Sciences, Bangalore</td>
<td>Dr. K. M. Harinikumar Dept. of Biotechnology 80-23330153/ 343 094488 32077 <a href="mailto:harinikm@rediffmail.com">harinikm@rediffmail.com</a></td>
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<tr>
<td>9.</td>
<td>University of Agricultural Sciences, Dharwad</td>
<td>Dr. Ishwarappa S. Katageri Dept. of Plant Biotechnology, College of Agriculture 09448822266 <a href="mailto:katageris@uasd.in">katageris@uasd.in</a></td>
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<tr>
<td>10.</td>
<td>Vasantrao Naik Marathwada Agricultural University, Latur</td>
<td>Dr. R. L. Chavhan Dept. of Plant Biotechnology, College of Agricultural Biotechnology 07588611027 <a href="mailto:coablatur@rediffmail.com">coablatur@rediffmail.com</a>; <a href="mailto:rlichavhan@gmail.com">rlichavhan@gmail.com</a></td>
</tr>
</tbody>
</table>
Annexure I

Subject Specific Subcommittee of M.Sc. Agricultural Biotechnology

Chairperson
1. Dr. R Chandra Babu, Professor, Director and Coordinator, Centre for Plant Molecular Biology and Biotechnology, Tamil Nadu Agricultural University, Coimbatore

Members
2. Dr. Anil Kumar, Professor and Head, Department of Biotechnology, GB Pant University, Pantnagar
3. Dr. Ramanjini Gowda, Professor, Department of Plant Biotechnology, University of Agricultural Sciences, Bangalore
4. Dr. Sabhyata Bhatia, Staff Scientist VI, National Institute of Plant Genome Research, New Delhi
5. Dr. Kishor Gaikwad, Principal Scientist, National Research Centre on Plant Biotechnology, New Delhi
6. Dr. Bharat Char, Lead, Biotechnology, Maharashtra Hybrid Seeds Company Private Limited, Jalna

Member Secretary
7. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi
M.Sc. Bioresource Biotechnology
Introduction

Background

Promotion of Indian Biotechnology sector is high on policy agenda of Government of India. Biotechnology has also been recognized as one of the key priority sectors under ‘Make in India,’ ‘Skill India’ and ‘Startup India’ initiatives of Government of India, as it is one of sectors expected to contribute towards enterprise creation, innovation and economic growth. Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India has immensely contributed to this dynamism through various policies and initiatives, establishment of innovation clusters, academia-industry partnerships, increasing capabilities for technology development, etc. The National Biotechnology Development Strategy (2015 – 2020) released by DBT provides a strategic roadmap for India’s emergence as a global biotechnology innovation and manufacturing hub. It has also highlighted importance of human resource development and need for nurturing tailor-made human capital for advanced scientific research and entrepreneurship.

DBT has taken a number of initiatives aimed at integrated human resource development to evolve an ecosystem where scientists, innovators and future entrepreneurs can be nurtured. Keeping in mind requirement for trained manpower in various areas of Biotechnology, DBT initiated Post-Graduate Teaching Programme way back in 1985 with 5 universities which has expanded to 74 universities imparting M.Sc./M.Tech./M.V.Sc. degrees in general, agricultural, animal, food, environmental, industrial marine, medical, neuroscience and pharmaceutical biotechnology. 10 programmes are being phased out. These universities and institutes are provided liberal financial support towards strengthening of laboratory facilities, equipment, consumables, fellowships to students, dissertation grant per student etc. Post-Graduate Teaching Programme selects best students and trains them to join research or industry workforce contributing significantly to biotechnology workforce.

About the Course Curriculum Revision Exercise

Taking into cognizance the changing needs of the economy and to keep abreast with latest developments in the field of biotechnology, DBT proactively initiated revision of course curricula of Post-Graduate Programmes in biotechnology. The present exercise has been undertaken by Biotech Consortium India Limited (BCIL), New Delhi. Earlier exercise was carried out in 2008. The Course Curriculum Revision Exercise has been carried out for 13 Post-Graduate programmes in Biotechnology supported by DBT.

The revision of course curriculum of M.Sc. Bioresource Biotechnology aims to address mismatch between ‘knowledge’ gained by students and appropriate skill set required for technology development and implementation including present contemporary needs of economy.

Methodology

A meticulous and structured approach has been adopted to accomplish the Course Curriculum Revision exercise.

BCIL had initiated the exercise with a review of literature of relevant national and international documents on curriculum design and planning for biotechnology programmes of premier national as well as international universities, guidelines by University Grants Commission, recent curricular guidelines released by Indian Council of Agricultural Research, Ministry of Health and Family Welfare and Indian Institute of Science Education & Research and other relevant research papers on curriculum development in peer-reviewed journals.
The findings of the literature review were adopted to design questionnaires for eliciting feedback from stakeholders of Biotechnology community i.e. academicians, scientists, industry representatives and students. Feedback was received from 165 experts and 20 students belonging to academic institutions, research organizations and industry regarding addition of advanced topics, deletion of elementary, redundant and overlapping topics, updation of laboratory practicals, re-adjustment of credit load, incorporating ‘technology’ component in the curriculum, among others. It was also suggested that re-orientation of curricula should be done keeping in view the needs of the industry.

A Core Committee along with 9 subject specific subcommittees comprising of 63 academicians, scientists and industry representatives were constituted to revise and update the curricula. The constitution of subject specific subcommittee for M.Sc. Bioresource Biotechnology is given at Annexure-1.

The salient recommendations identified from stakeholder survey were presented to the Committee. Several brainstorming discussion sessions were held for achieving the desired balance between the foundation courses, recent developments in biotechnology and updation needs identified during the stakeholder survey. Core Committee finalized broad contours for revising all the course curricula. The guidelines set by the Core Committee were taken up by the subject specific subcommittee of M.Sc. Bioresource Biotechnology for updating the curriculum. The subject specific subcommittee incorporated latest advancements in areas of Bioresource Biotechnology in the curriculum. Separate meeting was held to discuss and deliberate the updations to be made in the curriculum. The revised curriculum was vetted and finalized by the Core Committee.

The members of Committee agreed that revised course curriculum should provide skill and outcome based education and help the students to gain domain knowledge, ability to design and interpret research experiments and acquire effective communication skills. The course curriculum has been re-designed accordingly to promote skill-based and outcome-based education. The revised course curriculum totals to 96 credits comprising of theory, practical, technology-based topics, electives and dissertation. Each course includes learning objectives, student learning outcomes, course plan (number of lectures/unit) and reference textbooks/resources. Theory and practical courses include relevant examples, case scenarios and tutorials for inculcating critical thinking against rote learning. Several new courses have been included and content for existing courses has also been updated. Specialized courses such as Animal Bioresources, Plant Bioresources, Microbial Bioresources and Characterization & Conservation of Bioresources have been included to make the curriculum focussed. With importance of students being able to execute research projects independently, separate credits have been allotted for proposal preparation and presentation before initiating dissertation and also credits for dissertation have been increased accordingly.

We hope that model course curriculum shall serve as guidelines for academicians and researchers from different parts of the country for adoption in their institutions with modifications as per availability of expertise, infrastructure and specific needs.

We wish to put on record our sincere appreciation for constant guidance and encouragement received from Dr. K. VijayRaghavan, Secretary, DBT for bringing out this publication. We wish to acknowledge whole-hearted support of Core Committee and subject specific subcommittees members. Sincere thanks are due to Dr. Manoj Singh Rohilla, Scientist- D, DBT, Ms. Shweta for creative design, Mrs. Rita Bhatla, DBT and Shri. Dilip Joy, BCIL.
The M. Sc. syllabus on Bioresource Biotechnology aims at providing students the much-needed strong knowledge base on bioresources of the country as well as the exposure to the whole range of biotechnological tools and technologies those are available for utilization and value addition of our rich bioresources. In addition to the technologies required exclusively for specific bioresources, the course curriculum includes adequate hands-on practical training on the application of technologies related to industrial, food, agricultural, medical, and environmental biotechnology in the field of bioresource technology. Such applications include, bioprocesses, biomass, bioenergy, bio-transformations, and several conversion and production technologies. A dedicated semester for the project work would not only help the students in experimenting novel ideas and independently conceptualizing a problem but would also train them on strategies to solve it. The project work should also instill confidence in the students to design experiments, implement and interpret the results.

We do realize that there is ample scope for improvement of the syllabus and we welcome constructive suggestions for its improvement in future. I express my deep sense of gratitude to the efforts made by Late Dr. PS Ahuja, Prof. AK Kaul and other expert members for preparing the first draft of this syllabus. I also thank the Chairman and other expert members of the Core team on syllabus formulation for their valuable inputs.

(SK Barik)
# M.Sc. Bioresource Biotechnology

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<tr>
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<td>Cell and Molecular Biology</td>
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<td>Biostatistics</td>
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<td>Bioinformatics</td>
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<td>Bioresources: Characterization and Conservation</td>
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<td>Plant and Animal Biotechnology</td>
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<td>Intellectual Property Rights, Biosafety and Bioethics</td>
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<td>6</td>
<td>Project Proposal Preparation and Presentation</td>
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<td>Laboratory VII: Plant and Animal Biotechnology</td>
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**Recommended Electives:**
1. Climate Science
2. Nanobiotechnology
3. Synthetic Biology
Semester One

Biochemistry

Course Objectives
The objectives of this course are to build upon undergraduate level knowledge of biochemical principles with specific emphasis on different metabolic pathways. The course shall make the students aware of various disease pathologies within the context of each topic.

Student Learning Outcomes
Students should be able to:
- Gain fundamental knowledge in biochemistry;
- Understand the molecular basis of various pathological conditions from the perspective of biochemical reactions.

Unit I
Protein structure
5 lectures

Chemical basis of life: Miller-Urey experiment, abiotic formation of amino acid oligomers, composition of living matter; Water – properties of water, essential role of water for life on earth pH, buffer, maintenance of blood pH and pH of gastric juice, pH optima of different enzymes (pepsin, trypsin and alkaline phosphatase), ionization and hydrophobicity, emergent properties of biomolecules in water, biomolecular hierarchy, macromolecules, molecular assemblies; Structure-function relationships: amino acids – structure and functional group properties, peptides and covalent structure of proteins, elucidation of primary and higher order structures, Ramachandran plot, evolution of protein structure, protein degradation and introduction to molecular pathways controlling protein degradation, structure-function relationships in model proteins like ribonuclease A, myoglobin, hemoglobin, chymotrypsin etc.; basic principles of protein purification; tools to characterize expressed proteins; Protein folding: Anfinsen's Dogma, Levinthal paradox, cooperativity in protein folding, free energy landscape of protein folding and pathways of protein folding, molten globule state, chaperons, diseases associated with protein folding, introduction to molecular dynamic simulation.

Unit II
Enzyme kinetics
5 lectures

Enzyme catalysis – general principles of catalysis; quantitation of enzyme activity and efficiency; enzyme characterization and Michaelis-Menten kinetics; relevance of enzymes in metabolic regulation, activation, inhibition and covalent modification; single substrate enzymes; concept of catalytic antibodies; catalytic strategies with specific examples of proteases, carbonic anhydrases, restriction enzymes and nucleoside monophosphate kinase; regulatory strategies with specific example of hemoglobin; isozymes; role of covalent modification in enzymatic activity; zymogens.

Unit III
Glycobiology
2 lectures

Sugars - mono, di, and polysaccharides with specific reference to glycogen, amylase and cellulose, glycosylation of other biomolecules - glycoproteins and glycolipids; lipids - structure and properties of important members of storage and membrane lipids; lipoproteins.

Unit IV
Lipids, DNA and RNA
3 lectures

Self-assembly of lipids, micelle, biomembrane organization - sidedness and function; membrane bound proteins - structure, properties and function; transport phenomena; nucleosides, nucleotides, nucleic acids - structure, a historical perspective leading up to the proposition of DNA double helical structure; difference in RNA and DNA structure and their importance in evolution of DNA as the genetic material.

Unit V
Bio-energetics
8 lectures

Bioenergetics-basic principles; equilibria and concept of free energy; coupled interconnecting reactions in metabolism; oxidation of carbon fuels; recurring motifs in metabolism; Introduction to GPCR, Inositol/DAG//PKC and Ca++ signaling pathways; glycolysis and gluconeogenesis; reciprocal regulations and non-carbohydrate sources
Unit VI
Role of vitamins & cofactors in metabolism
12 lectures

Calvin cycle and pentose phosphate pathway; glycogen metabolism, reciprocal control of glycogen synthesis and breakdown, roles of epinephrine and glucagon and insulin in glycogen metabolism; Fatty acid metabolism; protein turnover and amino acid catabolism; nucleotide biosynthesis; biosynthesis of membrane lipids and steroids with specific emphasis on cholesterol metabolism and mevalonate pathway; elucidation of metabolic pathways; logic and integration of central metabolism; entry/exit of various biomolecules from central pathways; principles of metabolic regulation; steps for regulation; target of rapamycin (TOR) & Autophagy regulation in relation to C & N metabolism, starvation responses and insulin signaling.

Recommended Textbooks and References:
of codons, Wobble hypothesis; Iso-accepting tRNA; mechanism of initiation, elongation and termination; co- and post-translational modifications, mitochondrial genetic code.

**Unit III
Cellular signalling, transport and trafficking**
3 lectures

Molecular mechanisms of membrane transport, nuclear transport, transport across mitochondria and chloroplasts; intracellular vesicular trafficking from endoplasmic reticulum through Golgi apparatus to lysosomes/cell exterior.

**Unit IV
Cellular processes**
8 lectures

Cell cycle and its regulation; cell division: mitosis, meiosis and cytokinesis; cell differentiation: stem cells, their differentiation into different cell types and organization into specialized tissues; cell-ECM and cell-cell interactions; cell receptors and transmembrane signalling; cell motility and migration; cell death: different modes of cell death and their regulation.

**Unit V
Manipulating and studying cells**
3 lectures

Isolation of cells and basics of cell culture; observing cells under a microscope, different types of microscopy; analyzing and manipulating DNA, RNA and proteins.

**Unit VI
Genome instability and cell transformation**
8 lectures

Mutations, proto-oncogenes, oncogenes and tumour suppressor genes, physical, chemical and biological mutagens; types of mutations; intra-genic and inter-genic suppression; transpositions- transposable genetic elements in prokaryotes and eukaryotes, role of transposons in genome; viral and cellular oncogenes; tumor suppressor genes; structure, function and mechanism of action; activation and suppression of tumor suppressor genes; oncogenes as transcriptional activators.

**Recommended Textbooks and References:**

**Genetics
Credits**

2

**Course Objectives**
The objectives of this course are to take students through basics of genetics and classical genetics covering prokaryotic/phage genetics to yeast and higher eukaryotic domains. On covering all classical concepts of Mendelian genetics across these life-forms, students will be exposed to concepts of population genetics, quantitative genetics encompassing complex traits, clinical genetics and genetics of evolution.

**Student Learning Outcomes**
On successful completion of this course, student will be able :
- Describe fundamental molecular principles of genetics;
- Understand relationship between phenotype and genotype in human genetic traits;
- Describe basics of genetic mapping;
- Understand how gene expression is regulated.
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<tr>
<th>Unit I</th>
<th>Genetics of bacteria and bacteriophages</th>
<th>10 lectures</th>
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<tbody>
<tr>
<td>Concept of a gene in pre-DNA era; mapping of genes in bacterial and phage chromosomes by classical genetic crosses; fine structure analysis of a gene; genetic complementation and other genetic crosses using phenotypic markers; phenotype to genotype connectivity prior to DNA-based understanding of gene.</td>
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<th>Unit II</th>
<th>Yeast genetics</th>
<th>6 lectures</th>
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<tr>
<td>Meiotic crosses, tetrad analyses, non-Mendelian and Mendelian ratios, gene conversion, models of genetic recombination, yeast mating type switch; dominant and recessive genes/mutations, suppressor or modifier screens, complementation groups, transposon mutagenesis, synthetic lethality, genetic epistasis.</td>
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<th>Unit III</th>
<th>Drosophila genetics as a model of higher eukaryotes</th>
<th>4 lectures</th>
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<tr>
<td>Monohybrid &amp; dihybrid crosses, back-crosses, test-crosses, analyses of autosomal and sex linkages, screening of mutations based on phenotypes and mapping the same, hypomorphy, genetic mosaics, genetic epistasis in context of developmental mechanism.</td>
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<th>Unit IV</th>
<th>Population genetics and genetics of evolution</th>
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<tbody>
<tr>
<td>Introduction to the elements of population genetics: genetic variation, genetic drift, neutral evolution; mutation selection, balancing selection, Fishers theorem, Hardy-Weinberg equilibrium, linkage disequilibrium; in-breeding depression &amp; mating systems; population bottlenecks, migrations, Bayesian statistics; adaptive landscape, spatial variation &amp; genetic fitness.</td>
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<th>Unit V</th>
<th>Quantitative genetics of complex traits (QTLs)</th>
<th>2 lectures</th>
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<tr>
<td>Complex traits, mapping QTLs, yeast genomics to understand biology of QTLs.</td>
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<tr>
<th>Unit VI</th>
<th>Plant genetics</th>
<th>2 lectures</th>
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<tr>
<td>Laws of segregation in plant crosses, inbreeding, selfing, heterosis, maintenance of genetic purity, gene pyramiding.</td>
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**Recommended Textbooks and References:**


**Course Objectives**

The objective of this course is to introduce to statistical methods and to understand the underlying principles, as well as practical guidelines of “how to do it” and “how to interpret it” statistical data particularly for bio systems.

**Student Learning Outcomes**

On completion of this course, students should be able to:

- Understand how to summarise statistical data;
- Apply appropriate statistical tests based on an understanding of study question, type of study and type of data;
- Interpret results of statistical tests and application in biological systems.
<table>
<thead>
<tr>
<th>Unit I</th>
<th>Introduction</th>
<th>5 lectures</th>
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</thead>
<tbody>
<tr>
<td>Types of biological data (ordinal scale, nominal scale, continuous and discrete logical systems data), frequency distribution and graphical representations (bar graph, histogram, box plot and frequency polygon), cumulative frequency distribution, populations, samples, simple random, stratified and systematic sampling.</td>
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<thead>
<tr>
<th>Unit II</th>
<th>Descriptive statistics</th>
<th>5 lectures</th>
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<tbody>
<tr>
<td>Measures of Location, Properties of Arithmetic Mean, median, mode, range, Properties of the Variance and Standard Deviation, Coefficient of Variation, Grouped Data, Graphic Methods, Obtaining Descriptive Statistics on the Computer, Case study.</td>
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<thead>
<tr>
<th>Unit III</th>
<th>Probability and distribution</th>
<th>4 lectures</th>
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<tbody>
<tr>
<td>Introduction to probability and laws of probability, Random Events, Events-exhaustive, Mutually exclusive and equally likely (with simple exercises), Definition and properties of binomial distribution, Poisson distribution and normal distribution.</td>
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<tr>
<th>Unit IV</th>
<th>Correlation and regression analysis</th>
<th>6 lectures</th>
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</thead>
<tbody>
<tr>
<td>Correlation, Covariance, calculation of covariance and correlation, Correlation coefficient from ungrouped data, Spearon’s Rank Correlation Coefficient, scatter and dot diagram, General Concepts of regression, Fitting Regression Lines, regression coefficient, properties of Regression Coefficients, Standard error of estimate.</td>
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<thead>
<tr>
<th>Unit V</th>
<th>Statistical hypothesis testing</th>
<th>4 lectures</th>
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</thead>
<tbody>
<tr>
<td>Making assumption, Null and alternate hypothesis, error in hypothesis testing, confidence interval, one-tailed and two-tailed testing, decision making.</td>
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<thead>
<tr>
<th>Unit VI</th>
<th>Tests of significance</th>
<th>8 lectures</th>
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<tbody>
<tr>
<td>Steps in testing statistical significance, selection and computation of test of significance and interpretation of results; Sampling distribution of mean and standard error, Large sample tests (test for an assumed mean and equality of two population means with known S.D.), z-test; Small sample tests (t-test for an assumed mean and equality of means of two populations when sample observations are independent); Parametric and Non parametric tests (Mann-Whitney test); paired and unpaired t-test, chi square test.</td>
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<tr>
<th>Unit VII</th>
<th>Experimental designs</th>
<th>8 lectures</th>
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<tbody>
<tr>
<td>Introduction to study designs: Longitudinal, cross-sectional, retrospective and prospective study, Principles of experimental designs, Randomized block, and Simple factorial designs, Analysis of variance (ANOVA) and its use in analysis of RBD, introduction to meta-analysis and systematic reviews, ethics in statistics.</td>
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</table>

**Recommended Textbooks and References:**

Course Objectives
The objectives of this course are to introduce students to the field of microbiology with special emphasis on microbial diversity, morphology, physiology and nutrition; methods for control of microbes and host-microbe interactions.

Student Learning Outcomes
Students should be able to:
1. Identify major categories of microorganisms and analyze their classification, diversity, and ubiquity;
2. Identify and demonstrate structural, physiological, genetic similarities and differences of the major categories of microorganisms;
3. Identify and demonstrate how to control microbial growth;
4. Demonstrate and evaluate interactions between microbes, hosts and environment.

Unit I
Microbial characteristics
6 lectures
Introduction to microbiology and microbes, history & scope of microbiology, morphology, structure, growth and nutrition of bacteria, bacterial growth curve, bacterial culture methods; bacterial genetics: mutation and recombination in bacteria, plasmids, transformation, transduction and conjugation; antimicrobial resistance.

Unit II
Microbial diversity
9 lectures
Microbial taxonomy and evolution of diversity, classification of microorganisms, criteria for classification; classification of bacteria; Cyanobacteria, acetic acid bacteria, Pseudomonads, lactic and propionic acid bacteria, endospore forming bacteria, Mycobacteria and Mycoplasma. Archaea: Halophiles, Methanogens, Hyperthermophilic archaea, Thermoplasm; eukarya: algae, fungi, slime molds and protozoa; extremophiles and unculturable microbes.

Unit III
Control of microorganisms
3 lectures
Sterilization, disinfection and antisepsis: physical and chemical methods for control of microorganisms, antibiotics, antiviral and antifungal drugs, biological control of microorganisms.

Unit IV
Virology
5 lectures
Virus and bacteriophages, general properties of viruses, viral structure, taxonomy of virus, viral replication, cultivation and identification of viruses; sub-viral particles – viroids and prions.

Unit V
Host- microbe interaction
5 lectures
Host-pathogen interaction, ecological impacts of microbes; symbiosis (Nitrogen fixation and ruminant symbiosis); microbes and nutrient cycles; microbial communication system; bacterial quorum sensing; microbial fuel cells; prebiotics and probiotics.

Recommended Textbooks and References:
Course Objectives
This course has been designed to acquaint students with plant bioresources, their traditional and non-traditional uses, current status and recent developments in value addition and future prospects.

Student Learning Outcomes
On completion of this course, students should be able to:
- Identify different plant bioresources;
- Understand the importance of the plant bioresources;
- Apply knowledge gained for betterment of mankind.

Unit I
Plant bioresources: origin, domestication and improvement
10 lectures

Prehistoric plant human interactions; discovery of plant use to humans, hunter-gathering to practice of agricultural plant exploitation, resurgence of interest in plant bioresources due to plant explorations and ethnobotanical studies during 19th and 20th centuries; Importance of classification and taxonomy of plants; Classification systems of plants with emphasis on Angiosperm Phylogeny Group IV (APG IV) classification; Origin of cultivated plants; Vavilovian concept of Centres of origin of crop plants; Centres of origin of maize, rice and wheat; concept of primary and secondary Centres of origin of crop plants; Domestication of crop plants; beginning of agriculture; dissemination and spread of agriculture; domestication and evolution of crop plants; Plant improvement: development of improved agricultural crops through plant breeding; evolution of high yielding crop varieties through genetic engineering; uses and production of improved varieties in wheat, rice and maize.

Unit II
Plant bioresources: traditional uses
7 lectures

Food supplements: Solanum tuberosum, Ipomoea batatas, Agaricus bisporus and Hippophae rhamnoides (distribution, classification, parts used and method of use, nutritive value); spices and condiments: Crocus sativus, Piper nigrum, Zingiber officinale and Apium graveolens (distribution, classification, parts used and method of use). Sources of beverages: non-alcoholic: Camellia sinensis (tea) and Coffea arabica (coffee); alcoholic: Vitis vinifera (grapes) (distribution, classification, parts used and method of use). Fodders, fibres, timbers: Avena byzantina, Grewia optiva and Morus alba (distribution, classification and method of use); Fibers: Gossypium spp., Chorchorus capsularis, Cocos nucifera, (distribution, classification, part used and durability); Timbers: Pinus roxburghii, Tectona grandis and Dalbergia sissoo (distribution, classification, wood structure and properties), non-timber forest products (bamboos and canes); Dye-yielding plants: Definition; history and sources of natural dyes, commonly used dye plants: Bixa orellana, Butea monosperma, Lawsonia inermis and Indigofera tinctoria; less used colouring matter: balsam, marigold, and pomegranate (distribution, part used and commercial importance); Biofuels: Waste to wealth.

Unit III
Medicinal and other useful plants
7 lectures

Medicines: antioxidants (Ginkgo biloba, Camellia sinensis, Hippophae rhamnoides); adaptogens (Eleutherococcus senticosus, Cordyceps sinensis); anodynes (Atropa belladona, Zingiber officinalis); laxatives (Aloe vera and Plantago ovata); nervines (Melissa officinalis, Avena sativa); aromatic oils (Thymus serpyllum and Lavandula angustifolia); immunostimulants (Euaptorium perforatum, Acanthopanax senticosus); anti-cancerous (Taxus wallichiana, Podophyllum hexandrum); anti-malarial (Artemisia annua) (distribution, classification, part used and method of use, and medicinal value); Bio-sweeteners (Stevia rebaudiana and Glycyrrhiza glabra); bio-flavors (Vanilla planifolida and Fragaria virginiana); bio-alginates (Laminaria hyperborea, Ascophyllum nodosum); bio-gums (Caesalpinia spinosa, Trigonella foenum-graecum) (distribution, classification, part used and method of use, and efficacy); Bio-cosmetics (Aloe vera, Crocus sativus and Santalum album); bio-preservatives (vinegar, sugar) (distribution, classification, part used and method of use; efficacy); Current scenario and recent advancements in pharmaceutical and cosmeceutical industries.
Principle and applications of steam distillation for medicinal and aromatic plants; Solvent extraction principle and methods; Super critical CO₂ extraction principle and applications.

Recommended Textbooks and References:
nomenclature, publication of scientific names, typification and kinds of types, principle of priority.

Unit II
Aquatic animals, insects and earthworms
8 lectures

Edible species of fishes; fish culture: sources of fish seed, types of culture practices, selection of species; Indian and exotic cultivable fish species; layout of a typical fish pond, types of fish ponds, management techniques, control of aquatic weeds and predators; maturing, supplementary and artificial feeding; Edible species of aquatic invertebrates, prawn, lobster, mollusks and crabs; shell fish prawn and pearl oyster farming; Sericulture, apiculture, lac culture, vermiculture, milliculture; diseases associated with various cultures, advances in insect-based industries in India; Insects as food and nutrition.

Unit III
Animal products and management
8 lectures

Pharmaceuticals from animals; (sea food): value addition and export, role of Marine Product Export Development Authority (MPEDA) in promoting production and export of marine products; Meat, leather and wool industries and their production with special emphasis on their export potential; poultry farming (chicken, duck and quail); commercial poultry breeds in India, poultry diseases; egg industry - present status in India; Dairy farming in India: breeds of cattle and buffalo, milk production andpasteurization techniques; Animal waste recycling: biogas and its production, types of biogas plants; slaughter house wastes and their utilization; fish byproducts; fish meal-methods of processing and uses.

Recommended Textbooks and References:

Course Objectives
The objective of this laboratory course is to introduce students to experiments in biochemistry. The course is designed to teach students the utility of set of experimental methods in biochemistry in a problem oriented manner.

Student Learning Outcomes
On completion of this course, students should be able to:
• To elaborate concepts of biochemistry with easy to run experiments;
• To familiarize with basic laboratory instruments and understand the principle of measurements using those instruments with experiments in biochemistry.

Syllabus
1. Preparing various stock solutions and working solutions that will be needed for the course.
2. To prepare an Acetic-Na Acetate Buffer and validate the Henderson-Hasselbach equation.
3. To determine an unknown protein concentration by plotting a standard graph of BSA using UV-Vis Spectrophotometer and validating the Beer-Lambert's Law.
4. Titration of Amino Acids and separation of aliphatic, aromatic and polar amino acids by thin layer chromatography.
5. Purification and characterization of an enzyme from a recombinant source (such as Alkaline Phosphatase or Lactate Dehydrogenase or any enzyme of the institution's choice)
   a) Preparation of cell-free lysates
   b) Ammonium Sulfate precipitation
   c) Ion-exchange Chromatography
   d) Gel Filtration
   e) Affinity Chromatography
   f) Dialysis of the purified protein solution against 60% glycerol as a demonstration of storage method
   g) Generating a Purification Table (protein concentration, amount of total protein; Computing specific activity of the enzyme preparation at each stage of purification)
   h) Assessing purity of samples from each step of purification by SDS-PAGE Gel Electrophoresis
   i) Enzyme Kinetic Parameters: Km, Vmax and Kcat
   j) Dialysis of the purified protein solution against 60% glycerol as a demonstration of storage method
6. Experimental verification that absorption at OD_{260} is more for denatured DNA as compared to native double stranded DNA.
7. Identification of an unknown sample as DNA, RNA or protein using available laboratory tools (Optional Experiments).

Laboratory II: Microbial Bioresources

Course Objectives
The objective of this laboratory course is to provide the students practical skills in basic microbiological techniques.

Student Learning Outcomes
Students should be able to:
• Isolate, characterize and identify common bacteria;
• Determine bacterial load of different samples;
• Perform antimicrobial sensitivity test;
• Preserve bacterial cultures.

Syllabus
1. Sterilization, disinfection and safety in microbiological laboratory.
2. Preparation of media for cultivation of bacteria.
3. Isolation of bacteria in pure culture by streak plate method.
4. Study of colony and growth characteristics of some common bacteria: Bacillus, E. coli, Staphylococcus, Streptococcus, etc.
5. Preparation of bacterial smear and Gram's staining.
7. Antimicrobial sensitivity test and demonstration of drug resistance.
9. Determination of phenol co-efficient of antimicrobial agents.
10. Determination of Minimum Inhibitory Concentration (MIC).
11. Isolation and identification of bacteria from soil/water samples.

2. Introduction to intraspecific variability against backdrop of concept of invariability of a species: maize, beans, brinjal, dogs, poultry.

3. Variability beyond level of species
   ii. Intra-familial variability. Solanaceae, Poaceae.

4. Collect, describe, identify and classify wild bioresources, including wild relatives of crop plants and look for similarities and differences with the cultivated relatives. Wild relatives of: Pear, Indian gooseberry, Olive, Okra, Fig, Grape and Rice.

5. Variability introduced in cultivated plants and animals to suit human fancy, taste and need through classical methods of plant improvement—selection and hybridization: rose, dog, apple, mango, rice, maize, seedless guava and grapes.

6. Spottings on plant and animal bioresources produced through biotechnological interventions - photograph of GM plants and animals like Bt cotton, Flavr savr tomato, Golden rice, Noori.


10. Study of characteristics of important bioresources - Timbers: hard and soft woods, fuels, medicine, fodder, foliage: silkworm, food, Rubber; Shrubs: food, fodder, medicinal, fruits, fibres, dyes; Herbs: food, fodder, medicinal, fruits, fibres, dyes.

11. Study of characteristics of bioresources used to produce multiple products through processing: Maize - maize floor, Popcorn, Cakes; Soyabean; Potato; Camelia sp.; Wheat; Linum sp. and Silk.


13. Determination of species diversity by using Shanon-Wiener’s index and Simpson Index.
14. Understanding principle and functioning of Global Positioning System (GPS) and its use.
15. Marking and mapping different sites of University campus with help of Global Positioning System.

**Recommended Textbooks and References:**


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**Semester Two**

**Genetic Engineering**

**Course Objectives**
The objectives of this course are to teach students with various approaches to conducting genetic engineering and their applications in biological research as well as in biotechnology industries. Genetic engineering is a technology that has been developed based on our fundamental understanding of the principles of molecular biology and this is reflected in the contents of this course.

**Student Learning Outcomes**
Given the impact of genetic engineering in modern society, the students should be endowed with strong theoretical knowledge of this technology. In conjunction with the practicals in molecular biology and genetic engineering, the students should be able to take up biological research as well as placement in the relevant biotech industry.

**Unit I**
**Introduction and tools for genetic engineering**
6 lectures
Impact of genetic engineering in modern society; general requirements for performing a genetic engineering experiment; restriction endonucleases and methylases; DNA ligase, Klenow enzyme, T4 DNA polymerase, polynucleotide kinase, alkaline phosphatase; cohesive and blunt end ligation; linkers; adaptors; homopolymeric tailing; labelling of DNA: nick translation, random priming, radioactive and non-radioactive probes; hybridization techniques: northern, southern, south-western and far-western and colony hybridization, fluorescence *in situ* hybridization.

**Unit II**
**Different types of vectors**
7 lectures
Plasmids; Bacteriophages; M13 mp vectors; PUC19 and Bluescript vectors, phagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Principles for maximizing gene expression: expression vectors, pMal, GST, pET-based vectors; Protein purification: His-tagged/GST-tagged/MBP-tagged proteins etc.; Intein-based vectors; Inclusion bodies; methodologies to reduce formation of inclusion bodies; mammalian expression and replicating vectors; Baculovirus and *Pichia* vectors system, plant based vectors, Ti and Ri plasmids as vectors, yeast vectors, shuttle vectors.

**Unit III**
**Different types of PCR techniques**
7 lectures
Principles of PCR: primer design; fidelity of thermostable enzymes; DNA polymerases; types of PCR – multiplex, nested; reverse-transcription PCR, real time PCR, touchdown PCR, hot start PCR, colony PCR, asymmetric PCR, cloning of PCR products; TA cloning vectors; proof reading enzymes; PCR based site specific mutagenesis; PCR in molecular diagnostics; viral and bacterial detection; sequencing methods; enzymatic DNA sequencing; chemical sequencing of DNA; automated DNA sequencing; RNA sequencing; chemical synthesis of oligonucleotides; mutation detection: SSCP, DGGE, RFLP.
Unit IV

cDNA analysis
7 lectures

- Insertion of foreign DNA into host cells; transformation, electroporation, transfection; construction of libraries; isolation of mRNA and total RNA; reverse transcriptase and cDNA synthesis; cDNA and genomic libraries; construction of microarrays – genomic arrays, cDNA arrays and oligo arrays; study of protein-DNA interactions: electrophoretic mobility shift assay; DNase footprinting; methyl interference assay, chromatin immunoprecipitation; protein-protein interactions using yeast two-hybrid system; phage display.

Unit V

Gene silencing and genome editing technologies
13 lectures

- Gene silencing techniques; introduction to siRNA; siRNA technology; Micro RNA; construction of siRNA vectors; principle and application of gene silencing; gene knockouts and gene therapy; creation of transgenic plants; debate over GM crops; introduction to methods of genetic manipulation in different model systems e.g. fruit flies (Drosophila), worms (C. elegans), frogs (Xenopus), fish (zebra fish) and chick; Transgenics - gene replacement; gene targeting; creation of transgenic and knock-out mice; disease model; introduction to genome editing by CRISPR-CAS with specific emphasis on Chinese and American clinical trials.

Recommended Textbooks and References:
5. Technical Literature from Stratagene, Promega, Novagen, New England Biolab etc.

Course Objectives

The objectives of this course are to make students learn about the structural features of the components of the immune system as well as their function. The major emphasis of this course will be on the development of the immune system and mechanisms by which our body elicit the immune response. This will be imperative for the students as it will help them to think like an immunologist and predict about the nature of immune response that develops against bacterial, viral or parasitic infection, and prove it by designing new experiments.

Student Learning Outcomes

On completion of this course, students should be able to:
- Evaluate the usefulness of immunology in different pharmaceutical companies;
- Identify the proper research lab working in the area of their own interests;
- Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out the kind of immune responses in the setting of infection (viral or bacterial) by looking at cytokine profile.

Unit I

Immunology: fundamental concepts and anatomy of the immune system
6 lectures

- Components of innate and acquired immunity; phagocytosis; complement and inflammatory responses; pathogen recognition receptors (PRR) and pathogen associated molecular pattern (PAMP); innate immune response; mucosal immunity; antigens - immunogens, haptons; Major Histocompatibility Complex - MHC genes, MHC and immune responsiveness and disease susceptibility.

Unit II

Immune responses generated by B and T lymphocytes

- Immunoglobulins - basic structure, classes & subclasses of immunoglobulins, antigenic determinants; multigene organization of immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; principles of cell signaling; basis of self & non-self discrimination; kinetics of immune response, memory; B cell maturation, activation
and differentiation; generation of antibody diversity; T-cell maturation, activation and differentiation and T-cell receptors; functional T Cell subsets; cell-mediated immune responses, ADCC; cytokines-properties, receptors and therapeutic uses; antigen processing and presentation- endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens; cell-cell co-operation, Hapten-carrier system.

Precipitation, agglutination and complement mediated immune reactions; advanced immunological techniques - RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence, flow cytometry and immunoelectron microscopy; surface plasmon resonance, biosenor assays for assessing ligand–receptor interaction, CMI techniques-lymphoproliferation assay, mixed lymphocyte reaction, cell cytotoxicity assays, apoptosis, microarrays, transgenic mice, gene knock outs.

Active and passive immunization; live, killed, attenuated, subunit vaccines; vaccine technology- role and properties of adjuvants, recombinant DNA and protein based vaccines, plant-based vaccines, reverse vaccinology; peptide vaccines, conjugate vaccines; antibody genes and antibody engineering- chimeric, hybrid monoclonal antibodies; catalytic antibodies and generation of immunoglobulin gene libraries, idiotypic vaccines and marker vaccines, viral-like particles (VLPs), dendritic cell based vaccines, vaccine against cancer, T cell based vaccine, edible vaccine and therapeutic vaccine.

Immunity to infection: bacteria, viral, fungal and parasitic infections (with examples from each group); hypersensitivity – Type I-IV; autoimmunity; types of autoimmune diseases; mechanism and role of CD4+ T cells; MHC and TCR in autoimmunity; treatment of autoimmune diseases; transplantation – immunological basis of graft rejection; clinical transplantation and immunosuppressive therapy; tumor immunology – tumor antigens; immune response to tumors and tumor evasion of the immune system, cancer immunotherapy; immunodeficiency - primary immunodeficiencies, acquired or secondary immunodeficiencies, autoimmune disorder, anaphylactic shock, immune senescence, immune exhaustion in chronic viral infection, immune tolerance, NK cells in chronic viral infection and malignancy.

Major histocompatibility complex genes and their role in autoimmune and infectious diseases, HLA typing, human major histocompatibility complex (MHC), Complement genes of the human major histocompatibility complex: implication for linkage disequilibrium and disease associations, genetic studies of rheumatoid arthritis, systemic lupus erythematosus and multiple sclerosis, genetics of human immunoglobulin, immunogenetics of spontaneous control of HIV, KIR complex.

Recommended Textbooks and References:
# Genomics and Proteomics

## Course Objectives
The objective of this course is to provide introductory knowledge concerning genomics, proteomics and their applications.

## Student Learning Outcomes
Students should be able to acquire knowledge and understanding of fundamentals of genomics and proteomics, transcriptomics and metabolomics and their applications in various applied areas of biology.

## Unit I
**Basics of genomics and proteomics**
3 lectures

- Brief overview of prokaryotic and eukaryotic genome organization; extra-chromosomal DNA: bacterial plasmids, mitochondria and chloroplast.

## Unit II
**Genome mapping**
4 lectures

- Genetic and physical maps; markers for genetic mapping; methods and techniques used for gene mapping, physical mapping, linkage analysis, cytogenetic techniques, FISH technique in gene mapping, somatic cell hybridization, radiation hybrid maps, *in situ* hybridization, comparative gene mapping.

## Unit III
**Genome sequencing projects**
3 lectures

- Human Genome Project, genome sequencing projects for microbes, plants and animals, accessing and retrieving genome project information from the web.

## Unit IV
**Comparative genomics**
5 lectures

- Identification and classification of organisms using molecular markers- 16S rRNA typing/sequencing, SNPs; use of genomes to understand evolution of eukaryotes, track emerging diseases and design new drugs; determining gene location in genome sequence.

## Unit V
**Proteomics**
5 lectures

- Aims, strategies and challenges in proteomics; proteomics technologies: 2D-PAGE, isoelectric focusing, mass spectrometry, MALDI-TOF, yeast 2-hybrid system, proteome databases.

## Unit VI
**Functional genomics and proteomics**
8 lectures

- Transcriptome analysis for identification and functional annotation of gene, Contig assembly, chromosome walking and characterization of chromosomes, mining functional genes in genome, gene function- forward and reverse genetics, gene ethics; protein-protein and protein-DNA interactions; protein chips and functional proteomics; clinical and biomedical applications of proteomics; introduction to metabolomics, lipidomics, metagenomics and systems biology.

## Recommended Textbooks and References:
**Bioinformatics**

**Course Objectives**

The objectives of this course are to provide students with theory and practical experience of use of common computational tools and databases which facilitate investigation of molecular biology and evolution-related concepts.

**Student Learning Outcomes**

Student should be able to:

- Develop an understanding of basic theory of these computational tools;
- Gain working knowledge of these computational tools and methods;
- Appreciate their relevance for investigating specific contemporary biological questions.

**Unit I**

**Biological databases**

3 lectures

Introduction, Primary & Secondary database, Sequence file formats, Introduction to structures, Protein Data Bank (PDB), Molecular Modelling Database (MMDb), Structure file formats, Visualizing structural information, Database of structure viewers, Collection of sequences, sequence annotation, sequence description.

**Unit II**

**Sequence alignment and database searching**

3 lectures

Evolutionary basis of sequence alignment, Optimal alignment methods, Substitution scores & gap a, Statistical significance of alignments, Database similarity searching, FASTA, BLAST, Low complexity regions, Repetitive elements, Multiple Sequence Alignment: Progressive alignment methods, Motifs and patterns, Clustalw, Muscle; Scoring matrices, Distance matrices.

**Unit III**

**Phylogenetic analysis**

3 lectures

Alignment, tree building and tree evaluation, Comparison and application of Unweighted Pair Group Method with Arithmetic Mean (UPGMA), Neighbour Joining (NJ), Maximum Parsimony (MP), Maximum Likelihood (ML) methods, Bootstrapping, Jackknife; Software for Phylogenetic analysis. DNA barcoding: Methods tools and databases for barcoding across all species, Applications and limitations of barcoding, Consortium for Barcode of Life (CBOL) recommendations, Barcode of Life Database (BOLD).

**Unit IV**

**Structural biology**

3 lectures

3-D structure visualization and simulation, Basic concepts in molecular modeling: different types of computer representations of molecules; External coordinates and Internal Coordinates, Molecular Mechanics, Force fields etc. Secondary structure elucidation using Peptide bond, phi, psi and chi torsion angles, Ramachandran map, anatomy of proteins – Hierarchical organization of protein structure –like CATH (class, architecture, topology, homology), SCOP (Structural Classification of Proteins), FSSP (families of structurally similar proteins).

**Unit V**

**Classification and comparison of 3D structures**

3 lectures

DNA & RNA secondary and tertiary structures, t-RNA tertiary structure; Protein Secondary structure prediction: Algorithms viz. Chou Fasman, GOR methods, Tertiary Structure prediction: Fundamentals of the methods for 3D structure prediction (sequence similarity/identity of target proteins of known structure, fundamental principles of protein folding etc.) Homology/comparative modeling, fold recognition, threading approaches, and ab initio structure prediction methods; CASP (Critical Assessment of protein Structure Prediction); Computational design of promoters, proteins & enzymes.

**Unit VI**

**Applications in drug design**

3 lectures

Chemical databases like NCI/PUBCHEM; Fundamentals of Receptor-ligand interactions; Structure-based drug design: Identification and Analysis of Binding sites and virtual screening; Ligand based drug design: Structure Activity Relationship – QSARs & Pharmacophore; In silico predictions of drug activity and ADMET.
Designing of oligo probes; Image processing and normalization; Microarray data variability (measurement and quantification); Analysis of differentially expressed genes; Experimental designs.

Comparison with computer algorithms, string structures, Introduction to programming in computational biology through C/Perl/Java.

System-level understanding of biological systems, use and integration of data from transcriptomics, proteomics and metabolomics; concepts in glycomics, interactomics and fluxomics.

Recommended Textbooks and References:
4. Web-resources and suggested reviews/research papers.
5. Dov Stekel, (2003); Microarray Bioinformatics; Cambridge University Press.

Course Objectives
The objectives of this course are to give a background on the history of science, emphasizing the methodologies used to do research, use the framework of these methodologies for understanding effective lab practices and scientific communication and appreciate scientific ethics.

Student Learning Outcomes
Students should be able to:
- Understand the history and methodologies of scientific research, applying these to recent published papers;
- Understand and practice scientific reading, writing and presentations;
- Appreciate scientific ethics through case studies.

Empirical science; the scientific method; manipulative experiments and controls; deductive and inductive reasoning; descriptive science; reductionist vs holistic biology.

Choosing a mentor, lab and research question; maintaining a lab notebook.

Concept of effective communication- setting clear goals for communication; determining outcomes and results; initiating communication; avoiding breakdowns while communicating; creating value in conversation; barriers to effective communication; non-verbal communication-interpreting non-verbal cues; importance of body language,
power of effective listening; recognizing cultural differences; Presentation skills - formal presentation skills; preparing and presenting using over-head projector, PowerPoint; defending interrogation; scientific poster preparation & presentation; participating in group discussions; Computing skills for scientific research - web browsing for information search; search engines and their mechanism of searching; hidden Web and its importance in scientific research; internet as a medium of interaction between scientists; effective email strategy using the right tone and conciseness.

Technical writing skills - types of reports; layout of a formal report; scientific writing skills - importance of communicating science; problems while writing a scientific document; plagiarism, software for plagiarism; scientific publication writing: elements of a scientific paper including abstract, introduction, materials & methods, results, discussion, references; drafting titles and framing abstracts; publishing scientific papers - peer review process and problems, recent developments such as open access and non-blind review; plagiarism; characteristics of effective technical communication; scientific presentations; ethical issues; scientific misconduct.

Recommended Textbooks and References:

Course Objectives
The objective of this laboratory course is to provide practical skills on basic microbiological and genetic engineering techniques.

Student Learning Outcomes
On completion of this lab course, students should be able to:
- Acquire basic microbiology techniques and principles;
- Get first-hand experience that will coincide with what is taught in the lecture portion of the class;
- Gain hands-on experience in gene cloning, protein expression and purification.

Syllabus
1. Concept of lac-operon:
   a) lactose induction of β-galactosidase.
   b) Glucose Repression.
   c) Diauxic growth curve of E.coli
2. UV mutagenesis to isolate amino acid auxotroph
3. Phage titre with λ phage/M13
4. Genetic Transfer-Conjugation, gene mapping
5. Plasmid DNA isolation and DNA quantitation
6. Restriction Enzyme digestion of plasmid DNA
7. Agarose gel electrophoresis
8. Polymerase Chain Reaction and analysis by agarose gel electrophoresis
9. Vector and Insert Ligation
10. Preparation of competent cells
11. Transformation of E.coli with standard plasmids, Calculation of transformation efficiency
12. Confirmation of the insert by Colony PCR and Restriction mapping
13. Expression of recombinant protein, concept of soluble proteins and inclusion body formation in E.coli, SDS-PAGE analysis
14. Purification of His-Tagged protein on Ni-NTA columns
   a) Random Primer labeling
   b) Southern hybridization.

Recommended Textbooks and References:

Laboratory V: Immunology

Course Objectives
The objectives of this laboratory course are to make students develop an understanding about practical aspects of the components of the immune system as well as their function. Basic as well as advanced methods will be taught to detect different antigen and antibody interactions, isolation of different lymphocyte cells etc. and how they can be used in respective research work.

Student Learning Outcomes
Students should be able to:
• Evaluate the usefulness of immunology in different pharmaceutical companies;
• Identify proper research lab working in area of their own interests;
• Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out kind of immune responses in setting of infection (viral or bacterial) by looking at cytokine profile.

Syllabus
1. Selection of animals, Preparation of antigens, Immunization and methods of bleeding, serum separation and storage.
2. Antibody titre by ELISA method.
5. Isolation and purification of IgG from serum or IgY from chicken egg.
6. SDS-PAGE, Immunoblotting, Dot blot assays.
8. Separation of leucocytes by dextran method.
9. Demonstration of Phagocytosis
10. Separation of mononuclear cells by Ficoll-Hypaque.

Recommended Textbooks and References:
Laboratory VI: Bioinformatics and Biostatistics

Course Objectives
The aim is to provide students practical training in bioinformatics and statistical methods including accessing major public sequence databases.

Student Learning Outcomes
On completion of this course, students should be able to:
- Describe the contents and properties of important bioinformatics databases, perform text- and sequence-based searches and analyse and discuss the results in light of molecular biological knowledge;
- Explain the major steps in pairwise and multiple sequence alignment, explain its principles and execute pairwise sequence alignment by dynamic programming;
- Predict the secondary and tertiary structures of protein sequences;
- Perform and analyse various statistical tools available to analyse the data.

Credits
2

Syllabus
1. Using NCBI and Uniprot web resources.
2. Introduction and use of various genome databases.
4. Similarity searches using tools like BLAST and interpretation of results.
5. Multiple sequence alignment using ClustalW.
7. Use of gene prediction methods (GRAIL, Genscan, Glimmer).
8. Using RNA structure prediction tools.
9. Use of various primer designing and restriction site prediction tools.
10. Use of different protein structure prediction databases (PDB, SCOP, CATH).
11. Construction and study of protein structures using Deepview/PyMol.
13. Use of tools for mutation and analysis of energy minimization of protein structures.
14. Use of Statistical packages like SPSS (Statistical Package for the Social Sciences)/SAS (Statistical Analysis System) & Maple
15. MATLAB (Matrix Laboratory)
16. Performing various statistical analysis like T-test, ANOVA, Regression, Chi-square, PLS (Partial Least Squares) and PCA (Principle Component Analysis).
Semester Three

Bioresources: Characterization and Conservation

Course Objectives

Bioresources are being overexploited to meet market demand, threatening their existence. The present course aims at introducing students to approaches for documentation of biodiversity, nature and magnitude of threat to bioresources and imparting knowledge about their conservation.

Student Learning Outcomes

On completion of this course, students should be able to:

- Understand various bioresource assessment methods;
- Understand methods of characterization of bioresources;
- Understand and employ various bioresource conservation techniques.

Unit I

Survey and documentation of biodiversity and bioresources

8 lectures

Biodiversity and bioresources: concept and scope; evolution of biodiversity, factors promoting biodiversity; levels of biodiversity - genetic, species and ecosystem diversity; measuring organismal diversity: species richness index, species evenness index, Shannon-Wiener Index and Simpson Index; measurement of biodiversity at spatial level: alpha, beta and gamma diversity; Remote sensing and Geographical Information System (GIS): introduction, scope, history, components, functions, advantages and limitations; Application of remote sensing for bioresources management: land cover and land use, forestry, agriculture and wildlife.

Unit II

Loss of bioresources

10 lectures

Estimate of biodiversity loss; Means of biodiversity loss: species extinction, genetic erosion; loss of ecosystem diversity; Causes of biodiversity loss: habitat destruction, unsustainable exploitation, biological invasion, environmental pollution and poverty. Species threat status: IUCN threat categories and criteria; concept of rarity; RED Data Book; Biodiversity hotspots; effect of climate change on biodiversity; Biopiracy: factors and reasons, biopiracy - vis - a - vis IPR regime; steps to check biopiracy - vigil, applicability of modern technologies in checking biopiracy.

Unit III

Conservation of bioresources

10 lectures


Unit IV

Conservation strategies

12 lectures

In situ conservation sites: Protected areas - Biosphere Reserves, National Parks, Wildlife Sanctuaries; Reserve Forests; Community conserved areas - Sacred groves and community forests; In situ conservation of aquatic ecosystems: lakes, wetlands, mangroves, coral reefs, and ponds. Ex situ conservation sites: Botanical Gardens and Arboreta, Field gene banks, Seed banks, Zoological parks, zoos and aquaria, role of Animal Breeding Centres in conservation; In vitro conservation and cryopreservation: principles, infrastructure and experimental protocols for in vitro conservation and
cryopreservation of cells, tissues and organs; advantages and disadvantages; in vitro and cryobanks; DNA and genomic resource banks, conservation in permafrost conditions. Gene banks: IBPGR, Indian gene banks for plant, animal, fish, microbial and insect genetic resources; NBPGR, National Genetic Resource Advisory Council.

**Unit V**
**Molecular characterization of bioresources**
8 lectures

Molecular markers - definition, properties, classification, importance and scope; Molecular marker techniques: RAPD, SSR, ISSR, SSAP and AFLP, Expressed Sequence Tags, and their utility; merits and demerits of different molecular marker techniques. Proteins, isozymes and allozymes as markers, their significance in characterization; methods of isozyme and allozyme analysis. Biotechnology and its role in biodiversity conservation; software for molecular characterization and diversity analysis; role of taxonomy in assessment, conservation and sustainable use of biodiversity.

**Recommended Textbooks and References:**
Course Objectives
To impart theoretical knowledge on various techniques of plant and animal biotechnology like tissue culture, plant genetic transformation and their application in industries.

Student Learning Outcomes
Student should gain strong understanding of plant and animal based cell cultures system. This should help them to take up plant and animal biological research as well as placement in relevant biotech industry. They should be able to analyse bioprocess from an economics/market point of view.

Unit I
Plant tissue culture and plant transformation techniques
6 lectures
Plant tissue culture- history; totipotency of plant cells; Principles for aseptic culture techniques, culture media, plant growth regulators. Plant regeneration: somatic embryogenesis, importance of haploid production through pollen culture and triploid production through endosperm culture in crop improvement; In vitro pollination; wide hybridization; somatic cell hybridization (hybrids and cybrids); embryo culture; Synthetic seeds and their importance; Methods of gene transfer- Agrobacterium mediated gene transfer and electroporation.

Unit II
Plant biotechnology for abiotic and biotic stress resistance
6 lectures
Plant biotechnology for enhancing cold and heat stress tolerance; secondary effects of abiotic stress – production of ROS; genes involved in scavenging of ROS; Plant biotechnology in enhancing drought and salt stress tolerance; Plant biotechnology for enhancing resistance against fungal pathogens; anti-microbial proteins; Plant biotechnology to enhance viral resistance- pathogen derived resistance; coat protein, antisense, SiRNA and ribozyme approaches to enhance resistance for extending shelf life of fruits and flowers (ACC synthase gene and polygalacturonase).

Unit III
Plant biotechnology for improving crop yield and quality
4 lectures
Plant biotechnology in improving fruit ripening and enhancing photosynthesis; Golden rice- nutritionally improved rice through biotechnology; transgenic sweet potato; Modification of taste and appearance- sweetness, starch and preventing discoloration; Bioplastics- biodegradable plastic from plants through biotechnological intervention.

Unit IV
Animal cell culture and scaling up
6 lectures
Primary and established cell line cultures; equipment and materials for cell culture; Cell culture-suspension cultures, culture media, natural and artificial media, initiation of cell cultures, evolution of continuous cell lines; Measurement of viability and cytotoxicity of cultured cells; Scaling up of animal cell cultures and their applications.

Unit V
Animal tissue culture and hybridoma technology
6 lectures
Organ culture- techniques, advantages, limitations and applications; Stem cell lines: origin and types of cultures and maintenance of stem cell lines; stem cell therapy and its applications; Hybridoma technology and somatic cell fusion technology its importance in medicine, cell cloning, manipulation and cell synchronization; flow cytometry techniques; Cell culture products: viral vaccines, interferons, recombinant proteins, hybrid antibodies.

Unit VI
Animal assisted reproductive techniques
6 lectures
In-vitro fertilization in humans, wild animals and cattle, embryo transfer in wild animals and cattle, applications of embryo transfer technology, story of Noori, Garima, etc; Ovum pick-up and applications of animal cloning; Production of transgenic animals with special reference to transgenic mice, cow and sheep; identification and transfer of genes influencing milk quality and disease resistance; production of pharmaceuticals; Transfection methods- Ca phosphate precipitation, DEAE-Dextran mediated
transfection, lipofection, fusion with bacterial protoplasts, electroporation; targeted gene transfer- gene disruption and gene replacement.

**Recommended Textbooks and References:**

Course Objectives
The objectives of this course are to educate students about fundamental concepts of bioprocess technology and its related applications, thus, preparing them to meet challenges of new and emerging areas of biotechnology industry.

Student Learning Outcomes
Students should be able to:
• Appreciate relevance of microorganisms from industrial context;
• Carry out stoichiometric calculations and specify models of their growth;
• Give an account of design and operations of various fermenters;
• Present unit operations together with fundamental principles for basic methods in production technique for bio-based products;
• Calculate yield and production rates in biological production process, and also interpret data;
• Calculate need for oxygen and oxygen transfer in a bioproduction process;
• Critically analyze any bioprocess from an economics/market point of view;
• Give an account of important microbial/enzymatic industrial processes in food and fuel industry.

Unit I
Basic principles of biochemical engineering
4 lectures
Isolation, screening and maintenance of industrially important microbes; microbial growth and death kinetics (an example from each group, particularly with reference to industrially useful microorganisms); strain improvement for increased yield and other desirable characteristics.

Unit II
Bioreactor design and analysis
6 lectures
Batch and continuous fermenters; modifying batch and continuous reactors: chemostat with recycle, multistage chemostat systems, fed-batch operations; conventional fermentation v/s biotransformations; immobilized cell systems; large scale animal and plant cell cultivation; fermentation economics; upstream processing: media formulation and optimization; sterilization; aeration, agitation and heat transfer in bioprocess; scale up and scale down; measurement and control of bioprocess parameters.

Unit III
Downstream processing and product recovery
6 lectures
Separation of insoluble products - filtration, centrifugation, sedimentation, flocculation; Cell disruption; separation of soluble products: liquid-liquid extraction, precipitation, chromatographic techniques, reverse osmosis, ultra and micro filtration, electrophoresis; final purification: drying; crystallization; storage and packaging.
Unit IV
Fermentation economics
4 lectures

Isolation of microorganisms of potential industrial interest; strain improvement; market analysis; equipment and plant costs; media; sterilization, heating and cooling; aeration and agitation; bath-process cycle times and continuous cultures; recovery costs; water usage and recycling; effluent treatment and disposal.

Unit V
Applications of enzyme technology in food processing
4 lectures

Mechanism of enzyme function and reactions in process techniques; enzymatic bioconversions e.g. starch and sugar conversion processes; high-fructose corn syrup; interesterified fat; hydrolyzed protein etc. and their downstream processing; baking by amylases, deoxygenation and desugaring by glucose oxidase, beer mashing and chill proofing; cheese making by proteases and various other enzyme catalytic actions in food processing.

Unit VI
Applications of microbial technology in food process operations and production, biofuels and biorefinery
4 lectures

Fermented foods and beverages; food ingredients and additives prepared by fermentation and their purification; fermentation as a method of preparing and preserving foods; microbes and their use in pickling, producing colours and flavours, alcoholic beverages and other products; process wastes-whey, molasses, starch substrates and other food wastes for bioconversion to useful products; bacteriocins from lactic acid bacteria – production and applications in food preservation; biofuels and biorefinery.

Recommended Textbooks and References:

Course Objectives
Research and business belong together and both are needed. In a rapidly developing life science industry, there is an urgent need for people who combine business knowledge with the understanding of science & technology. Bio-entrepreneurship, an interdisciplinary course, revolves around the central theme of how to manage and develop life science companies and projects. The objectives of this course are to teach students about concepts of entrepreneurship including identifying a winning business opportunity, gathering funding and launching a business, growing and nurturing the organization and harvesting the rewards.

Bioentrepreneurship

Credits

2

Student Learning Outcomes
Students should be able to gain entrepreneurial skills, understand the various operations involved in venture creation, identify scope for entrepreneurship in biosciences and utilize the schemes promoted through knowledge centres and various agencies. The knowledge pertaining to management should also help students to be able to build up a strong network within the industry.
Introduction and scope in Bio-entrepreneurship, Types of bio-industries and competitive dynamics between the sub-industries of the bio-sector (e.g. pharmaceuticals vs. Industrial biotech), Strategy and operations of bio-sector firms: Factors shaping opportunities for innovation and entrepreneurship in bio-sectors, and the business implications of those opportunities, Alternatives faced by emerging bio-firms and the relevant tools for strategic decision, Entrepreneurship development programs of public and private agencies (MSME, DBT, BIRAC, Make In India), strategic dimensions of patenting & commercialization strategies.

Negotiating the road from lab to the market (strategies and processes of negotiation with financers, government and regulatory authorities), Pricing strategy, Challenges in marketing in bio business (market conditions & segments; developing distribution channels, the nature, analysis and management of customer needs), Basic contract principles, different types of agreement and contract terms typically found in joint venture and development agreements, Dispute resolution skills.

Business plan preparation including statutory and legal requirements, Business feasibility study, financial management issues of procurement of capital and management of costs, Collaborations & partnership, Information technology.

Technology – assessment, development & upgradation, Managing technology transfer, Quality control & transfer of foreign technologies, Knowledge centers and Technology transfer agencies, Understanding of regulatory compliances and procedures (CDSCO, NBA, GCP, GLA, GMP).

Recommended Textbooks and References:

Course Objectives
The objectives of this course are:
• To provide basic knowledge on intellectual property rights and their implications in biological research and product development;
• To become familiar with India’s IPR Policy;
• To learn biosafety and risk assessment of products derived from biotechnology and regulation of such products;
• To become familiar with ethical issues in biological research. This course will focus on consequences of

Student Learning Outcomes
On completion of this course, students should be able to:
• Understand the rationale for and against IPR and especially patents;
• Understand why India has adopted an IPR Policy and be familiar with broad outline of patent regulations;
• Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents;
biomedical research technologies such as cloning of whole organisms, genetic modifications, DNA testing.

- Gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research and environmental release of genetically modified organisms, national and international regulations;
- Understand ethical aspects related to biological, biomedical, health care and biotechnology research.

**Unit I**

**Introduction to IPR**

5 lectures

Introduction to intellectual property; types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of ‘prior art’: invention in context of “prior art”; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation.

**Unit II**

**Patenting**

5 lectures

Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure - patent application- forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting-requirement, procedures and costs; financial assistance for patenting-introduction to existing schemes; publication of patents-gazette of India, status in Europe and US; patent infringement- meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing – outright sale, licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives.

**Unit III**

**Biosafety**

5 lectures

Biosafety and Biosecurity - introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants – sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk – environmental risk assessment and food and feed safety assessment; problem formulation – protection goals, compilation of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops vs cisgenic plants or products derived from RNAi, genome editing tools.

**Unit IV**

**National and international regulations**

5 lectures

International regulations – Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations – EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – biosafety levels and category of rDNA experiments; field trails – biosafety research trials – standard operating procedures - guidelines of state governments; GM labeling – Food Safety and Standards Authority of India (FSSAI).

**Recommended Textbooks and References:**

2. *National IPR Policy*, Department of Industrial Policy & Promotion, Ministry of Commerce, GoI
5. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/
Project Proposal Preparation & Presentation

Course Objectives
The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.

Student Learning Outcomes
Students should be able to demonstrate the following abilities:
- Formulate a scientific question;
- Present scientific approach to solve the problem;
- Interpret, discuss and communicate scientific results in written form;
- Gain experience in writing a scientific proposal;
- Learn how to present and explain their research findings to the audience effectively.

Syllabus

Project Proposal Preparation
Selection of research lab and research topic: Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them select a topic for their project. The topic of the research should be hypothesis driven.
Review of literature: Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources.
Writing Research Proposal: With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc. Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.

Poster Presentation
Students will have to present the topic of their project proposal after few months of their selection of the topic. They should be able to explain the novelty and importance of their research topic.

Oral Presentation
At the end of their project, presentation will have to be given by the students to explain work done by them in detail. Along with summarizing their findings they should also be able to discuss the future expected outcome of their work.

Laboratory VII: Industrial Biotechnology

Course Objectives
This course will give students a practical exposure to various techniques used in industries. It will provide training to students in upstream and downstream unit operations.

Student Learning Outcomes
On completion of this course, students should be able to:
- Perform various techniques used in industries;
- Understand the differences between industrial and research oriented lab work;
- Perform basic genomics searches and experiments.
- Analyze and interpret data, and apply laboratory skills to solve complex bioprocess engineering problems.
- Solving problems typical of bio industries and research.
Syllabus

1. Basic Microbiology techniques
   a) Scale up from frozen vial to agar plate to shake flask culture.
   b) Instrumentation: Microplate reader, spectrophotometer, microscopy.
   c) Isolation of microorganisms from soil samples.

2. Experimental set-up
   a) Assembly of bioreactor and sterilization.
   b) Growth kinetics.
   c) Substrate and product inhibitions.
   d) Measurement of residual substrates.

3. Data Analysis
   a) Introduction to Metabolic Flux Analysis (MFA).

4. Fermentation
   a) Batch.
   b) Fed-batch.
   c) Continuous.

5. Unit operations
   a) Microfiltrations: Separation of cells from broth.
   b) Bioseparations: Various chromatographies and extractions.

6. Bioanalytics
   a) Analytical techniques like HPLC, FPLC, GC, GC-MS etc. for measurement of amounts of products/substrates.

7. Transfer of DNA fragments from Agarose gel to Nitrocellulose membrane (Southern blotting)

8. Monitoring bacterial growth through measurement of turbidity in spectrophotometer and plotting of growth curve.

9. Determination of thermal death point of different bacteria.

10. Immobilization of yeast biomass in sodium alginate gel.

11. Isolation of industrially important microorganisms.

12. Screening bacterial and fungal isolates for amylase, cellulase and protease activity by plate array method.

13. Preparation of YA agar, starch Agar and skimmed milk media.


Recommended Textbooks and References:


Course Objectives

The objective of this laboratory course is to provide practical skills on basic plant and animal biotechnology.

Student Learning Outcomes

On completion of this course, students will be able to perform basic experiments on plant and animal biotechnology.

Syllabus

Plant Biotechnology

1. Prepare culture media with various supplements for plant tissue culture.
2. Prepare explants of *Valeriana wallichii* for inoculation under aseptic conditions.
3. Attempt *in vitro* andro and gynogenesis in plants (*Datura stramonium*).
4. Isolate plant protoplast by enzymatic and mechanical methods and attempt fusion by PEG (available material).
5. Culture *Agrobacterium tumefaciens* and attempt transformation of any dicot species.
6. Generate an RAPD and ISSR profile of *Eremurus persicus* and *Valeriana wallichii*.
7. Prepare karyotypes and study morphology of somatic chromosomes of *Allium cepa*, *A. sativum*, *A. tuberosum* and compare them on the basis of karyotypes.
8. Pollen mother cell meiosis and recombination index of select species (one achiasmate, and the other chiasmate) and correlate with generation of variation.
9. Undertake plant genomic DNA isolation by CTAB method and its quantitation by visual as well as spectrophotometric methods.
10. Perform PCR amplification of ‘n’ number of genotypes of a species for studying the genetic variation among the individuals of a species using random primers.
11. Study the genetic fingerprinting profiles of plants and calculate the polymorphic information content.

Animal Biotechnology

1. Count the cells of an animal tissue and check their viability.
2. Prepare culture media with various supplements for plant and animal tissue culture.
3. Prepare single cell suspension from spleen and thymus.
5. Chromosome preparations from cultured animal cells.
6. Isolate DNA from animal tissue by SDS method.
7. Attempt animal cell fusion using PEG.

Recommended Textbooks and References:

**Course Objectives**

The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.

**Student Learning Outcomes**

Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:

- In-depth knowledge of the chosen area of research;
- Capability to critically and systematically integrate knowledge to identify issues that must be addressed within framework of specific thesis;
- Competence in research design and planning;
- Capability to create, analyse and critically evaluate different technical solutions;
- Ability to conduct research independently;
- Ability to perform analytical techniques/experimental methods;
- Project management skills;
- Report writing skills;
- Problem solving skills;
- Communication and interpersonal skills.

**Syllabus**

**Planning & performing experiments**

Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

**Thesis writing**

At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.

**Recommended Mode of Assessment**

Assessment may be done by thesis evaluation, viva voce and final presentation.
Course Objectives
The objectives of this course are:
• To impart knowledge of basic understanding about climate system: its attributes, underlying processes, and drivers of climate change and perspectives in analyzing constraints and opportunities for sustainable development
• To give basic information of associated laws and policies of climate change.

Student Learning Outcomes
On completion of this course, students should be able to:
• Understand basics of climate science;
• Appreciate chemistry and geology behind the climate change;
• Understand laws governing climate policy in India and world;
• Learn about climate vulnerability and impacts of advancing climate change, different adaptation and resilience possibilities and various challenges and conflicts of implementation.

Unit I
Introduction to climate science
7 lectures
Fundamentals of meteorology, atmospheric vertical profile of temperature and pressure, microphysical processes in atmosphere climate system and interaction among components of climate system and feedback mechanisms, Atmospheric thermodynamics, radiation in atmosphere, greenhouse gases and climate forcing, weather systems: extreme weather events and western disturbances; Introduction to climate models, types of GCM/RCM models and its importance.

Unit II
Climate change: vulnerability, impact, adaptation and resilience
10 lectures
Introduction to concept of vulnerability; Focused discussion on vulnerability of different ecological and social systems, coastal vulnerability, particular issues for developing countries, refer to tipping points in the Earth system; Qualitative to semi-quantitative methods to evaluate vulnerability and impacts; Impact of climate change: Introduction to extreme events and gradual changes of the climate; impacts on different natural and managed systems/sectors (ecosystem, agricultural, freshwater, urban infrastructure and society) and regions; Mitigation and Adaptation: Introduction to concept, indicators of adaptation, problems of its operationalization; Mitigation of Green House Gases and stabilization scenario; Potential adaptation options for issues of food security, energy security, and transport in developing and developed countries; Factors influencing adaptation strategies (technical, institutional, financial) and constraints to developing strategies; Resilience to climate change possibilities.

Unit III
Policy for climate change and sustainable development
7 lectures

Recommended Textbooks and References:
Course Objectives

The course aims at providing general and broad introduction to multi-disciplinary field of nanotechnology. It will familiarize students with combination of top-down approach of microelectronics and micro-mechanics with bottom-up approach of chemistry/biochemistry; a development that is creating new and exciting cross-dis

Student Learning Outcomes

On successful completion of this course, students should be able to describe basic science behind the properties of materials at the nanometre scale, and the principles behind advanced experimental and computational techniques for studying nanomaterials.
Unit I
**Introduction to Nanobiotechnology**
5 lectures

Introduction to Nanobiotechnology; Concepts, historical perspective; Different formats of nanomaterials and applications with example for specific cases; Cellular Nanostructures; Nanopores; Biomolecular motors; Bio-inspired Nanostructures, Synthesis and characterization of different nanomaterials.

Unit II
**Nano-films**
5 lectures

Thin films; Colloidal nanostructures; Self Assembly, Nanovesicles; Nanospheres; Nanocapsules and their characterisation.

Unit III
**Nano-particles**
6 lectures

Nanoparticles for drug delivery, concepts, optimization of nanoparticle properties for suitability of administration through various routes of delivery, advantages, strategies for cellular internalization and long circulation, strategies for enhanced permeation through various anatomical barriers.

Unit IV
**Applications of nano-particles**
5 lectures

Nanoparticles for diagnostics and imaging (theranostics); concepts of smart stimuli responsive nanoparticles, implications in cancer therapy, nanodevices for biosensor development.

Unit V
**Nano-materials**
6 lectures

Nanomaterials for catalysis, development and characterization of nanobiocatalysts, application of nanoscaffolds in synthesis, applications of nanobiocatalysis in the production of drugs and drug intermediates.

Unit VI
**Nano-toxicity**
5 lectures

Introduction to Safety of nanomaterials, Basics of nanotoxicity, Models and assays for Nanotoxicity assessment; Fate of nanomaterials in different strata of environment; Ecotoxicity models and assays; Life cycle assessment, containment.

**Recommended Textbooks and References:**

5. Recent review papers in the area of Nanomedicine.

**Course Objectives**

The objectives of this course are to provide fundamental understanding of synthetic biology *i.e.* basic cellular processes, design and implement new cellular behaviors by applying mathematical, analytical and engineering tools for studying biological systems.

**Student Learning Outcomes**

Students should be able to acquire knowledge and improve quantitative understanding of natural phenomenon as well as foster an engineering discipline for obtaining new complex cell behaviors, also should enable them to perform research in interdisciplinary fields like systems biology and synthetic biology and know how to engineer live organisms to display novel functions using engineering practices.
Synthetic biology – definitions and concepts; History and evolution of synthetic biology and engineering perspectives; Natural vs. Engineering systems.

Key enabling technologies in synthetic biology; BioBricks - Definition of a BioBrick, black-box encapsulation, PoPs and RiPs; The Registry of Standard Biological Parts; Signal carrier, modularity, Abstraction hierarchy: Tools for analysing and controlling Biological Systems; Simulation tools - stochastic simulators, BioJADE, MATLAB.

Writing DNA: DNA synthesis, artificial genes, never born proteins, non-natural nucleic acids; Devices and circuits: Bacterial camera, Construction of toggle switches, logic gates, oscillators, pulse generators, time delayed circuits.

Applications of synthetic biology - Bioplastics, Artemisinin, DNA origami, RNA based designs, genome engineering, biofuel - microbial and minimal synthetic cell, Reconstructing viruses, 3D bioprinting; Directed evolution of chemical sensors.


Recommended Textbooks and References:
DBT Supported Teaching Programme

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of University</th>
<th>Contact Details of Course Coordinator</th>
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| 1.    | Baba Gulam Shah Baadshah University, Rajauri | Prof. G. H. Dar  
School of Biosciences & Biotechnology  
09419421096, 09596190336  
profdar99@gmail.com |

Annexure I

Subject Specific Subcommittee of M.Sc. Bioresource Biotechnology

Chairperson
1. Dr. Saroj Barik, Director, National Botanical Research Institute, Lucknow

Members
2. Dr. Paramvir Singh Ahuja, Former Director General, Council of Scientific and Industrial Research, New Delhi and Former Director, Institute of Himalayan Bioresource Technology, Palampur
3. Dr. A. K. Koul, Dean, Academic Affairs, Baba Ghulam Shah Badshah University, Rajouri
4. Dr. Manmohan Singh Chauhan, Director, Central Institute for Research on Goats, Mathura

Member Secretary
5. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi
M.Sc. Environmental Biotechnology
Introduction

Background

Promotion of Indian Biotechnology sector is high on policy agenda of Government of India. Biotechnology has also been recognized as one of the key priority sectors under ‘Make in India,’ ‘Skill India’ and ‘Startup India’ initiatives of Government of India, as it is one of sectors expected to contribute towards enterprise creation, innovation and economic growth. Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India has immensely contributed to this dynamism through various policies and initiatives, establishment of innovation clusters, academia-industry partnerships, increasing capabilities for technology development, etc. The National Biotechnology Development Strategy (2015 – 2020) released by DBT provides a strategic roadmap for India’s emergence as a global biotechnology innovation and manufacturing hub. It has also highlighted importance of human resource development and need for nurturing tailor-made human capital for advanced scientific research and entrepreneurship.

DBT has taken a number of initiatives aimed at integrated human resource development to evolve an ecosystem where scientists, innovators and future entrepreneurs can be nurtured. Keeping in mind requirement for trained manpower in various areas of Biotechnology, DBT initiated Post-Graduate Teaching Programme way back in 1985 with 5 universities which has expanded to 74 universities imparting M.Sc./M.Tech./M.V.Sc. degrees in general, agricultural, animal, food, environmental, industrial marine, medical, neuroscience and pharmaceutical biotechnology. 10 programmes are being phased out. These universities and institutes are provided liberal financial support towards strengthening of laboratory facilities, equipment, consumables, fellowships to students, dissertation grant per student etc. Post-Graduate Teaching Programme selects best students and trains them to join research or industry workforce contributing significantly to biotechnology workforce.

About the Course Curriculum Revision Exercise

Taking into cognizance the changing needs of the economy and to keep abreast with latest developments in the field of biotechnology, DBT proactively initiated revision of course curricula of Post-Graduate Programmes in biotechnology. The present exercise has been undertaken by Biotech Consortium India Limited (BCIL), New Delhi. Earlier exercise was carried out in 2008. The Course Curriculum Revision Exercise has been carried out for 13 Post-Graduate programmes in Biotechnology supported by DBT.

The revision of course curriculum of M.Sc. Environmental Biotechnology aims to address mismatch between ‘knowledge’ gained by students and appropriate skill set required for technology development and implementation including present contemporary needs of economy.

Methodology

A meticulous and structured approach has been adopted to accomplish the Course Curriculum Revision exercise. BCIL had initiated the exercise with a review of literature of relevant national and international documents on curriculum design and planning for biotechnology programmes of premier national as well as international universities, guidelines by University Grants Commission, recent curricular guidelines released by Indian Council of Agricultural Research, Ministry of Health and Family Welfare and Indian Institute of Science Education & Research and other relevant research papers on curriculum development in peer-reviewed journals.
The findings of the literature review were adopted to design questionnaires for eliciting feedback from stakeholders of Biotechnology community i.e. academicians, scientists, industry representatives and students. Feedback was received from 165 experts and 20 students belonging to academic institutions, research organizations and industry regarding addition of advanced topics, deletion of elementary, redundant and overlapping topics, updation of laboratory practicals, re-adjustment of credit load, incorporating 'technology' component in the curriculum, among others. It was also suggested that re-orientation of curricula should be done keeping in view the needs of the industry.

### Strategic Approach

A Core Committee along with 9 subject specific subcommittees comprising of 63 academicians, scientists and industry representatives were constituted to revise and update the curricula. The constitution of subject specific subcommittee for M.Sc. Environmental Biotechnology is given at Annexure-1.

The salient recommendations identified from stakeholder survey were presented to the Committee. Several brainstorming discussion sessions were held for achieving the desired balance between the foundation courses, recent developments in biotechnology and updation needs identified during the stakeholder survey. Core Committee finalized broad contours for revising all the course curricula. The guidelines set by the Core Committee were taken up by the subject specific subcommittee of M.Sc. Environmental Biotechnology for updating the curriculum. The subject specific subcommittee incorporated latest advancements in areas of Environmental Biotechnology in the curriculum. Separate meeting was held to discuss and deliberate the updations to be made in the curriculum. The revised curriculum was vetted and finalized by the Core Committee.

### Course Curriculum Revision

The members of Committee agreed that revised course curriculum should provide skill and outcome based education and help the students to gain domain knowledge, ability to design and interpret research experiments and acquire effective communication skills. The course curriculum has been re-designed accordingly to promote skill-based and outcome-based education. The revised course curriculum totals to 94 credits comprising of theory, practical, technology-based topics, electives and dissertation. Each course includes learning objectives, student learning outcomes, course plan (number of lectures/unit) and reference textbooks/resources. Theory and practical courses include relevant examples, case scenarios and tutorials for inculcating critical thinking against rote learning. Several new courses have been included and content for existing courses has also been updated. Specialized areas such as Environment Engineering, Environment Risk Assessment, Ecotoxicology, Treatment Technologies for Water, Wastewater and Solid and Hazardous Wastes and Environment Policy and Legislation have been included to bridge the gap between environmental sciences and biotechnology. With importance of students being able to execute research projects independently, separate credits have been allotted for proposal preparation and presentation before initiating dissertation and also credits for dissertation have been increased accordingly.

We hope that model course curriculum shall serve as guidelines for academicians and researchers from different parts of the country for adoption in their institutions with modifications as per availability of expertise, infrastructure and specific needs.

We wish to put on record our sincere appreciation for constant guidance and encouragement received from Dr. K. VijayRaghavan, Secretary, DBT for bringing out this publication. We wish to acknowledge whole-hearted support of Core Committee and subject specific subcommittees members. Sincere thanks are due to Dr. Manoj Singh Rohilla, Scientist- D, DBT, Ms. Shweta for creative design, Mrs. Rita Bhatla, DBT and Shri. Dilip Joy, BCIL.
The two-pronged objective of this course comprises of giving students a thorough understanding of basic science behind the salient biological processes related to environmental degradation and protection as well as familiarize them with the possible applications leading to biotechnology for protection of environment. This revised syllabus carefully combines fundamental theory and practical aspects. The syllabus provides an overview of the different biological processes so as to equip students with an integrated approach to the so-called environmental pollution and remediation. This curriculum hopes to focus the ecosystem services in a rather fundamental manner from both the perspectives of science and technology. Effort has been made to impart a working knowledge to support various industries which are involved in application, implementation or even in development of biotechnological processes for environmental assessment and protection. I take this opportunity to thank the entire Committee for offering the “expert opinion” as well as for providing the valuable inputs and timely help. The overall management and facilitation of various tasks was diligently provided by Biotech Consortium India Limited and the Committee is appreciative of their efforts.

Professor Shyam R. Asolekar
Centre for Environmental Science and Engineering
Indian Institute of Technology Bombay
Powai, Mumbai 400 076
+91 22 2576 7867 (Office)
asolekar@gmail.com
# M.Sc. Environmental Biotechnology

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**Recommended Electives:**
Course Objectives
The objectives of this course are to build upon undergraduate level knowledge of biochemical principles with specific emphasis on different metabolic pathways in microorganisms. The course shall make students aware about various microbial interactions within context of each topic.

Student Learning Outcomes
On completion of this course, students should be able to:
• Gain fundamental knowledge in microbial biochemistry;
• Understand molecular basis of various pathological conditions from perspective of biochemical reactions in micro-organisms.

Unit I
Microbial diversity and systematics
6 lectures
Types of microorganisms; Classical and modern concepts and methods to study microbial diversity; Domain and Kingdom concepts in classification of microorganisms, classification of bacteria according to Bergey's Manual, Molecular methods such DGGE, TGGE, ADRA, T-RFLP in assessing microbial diversity, 16S rDNA sequencing and Ribosomal database; Metagenomics and Genome sequencing –methods and its importance in biotechnology.

Unit II
Microbial growth and physiology
6 lectures
Microbial growth: Ultrastructure of Archaea (Methanococcus), Eubacteria (Escherichia coli), unicellular eukaryotes (yeast), and viruses. Microbial growth requirements (nutrients, oxygen, temperature, pH, growth factors, etc.), Bacterial groups according to growth requirements; Microbial growth: batch, fed batch, continuous, synchronous, growth kinetics, yield constants, methods of growth estimation. Microbial physiology: Physiological adoption, Life style of prokaryotes, unicellular eukaryotes and extremophiles with suitable example from each group.

Unit III
Microbial interactions and infections
6 lectures
Microbes infecting humans and animals; host-pathogen interaction; antimicrobial compounds and their uses in control of microbial infections; Vaccines and their importance; Plant –Microbe Interaction –rhizosphere, rhizoplane, mycorrhiza, symbiotic and asymbiotic nitrogen fixation, biofertilizers and biopesticides, bioinsecticides, etc.

Unit IV
Chemical basis of life
7 lectures
Miller-Urey experiment, abiotic formation of amino acid oligomers, composition of living matter; Water – properties of water, essential role of water for life on earth pH, buffer, maintenance of blood pH and pH of gastric juice, pH optima of different enzymes (pepsin, trypsin and alkaline phosphatase), ionization and hydrophobicity, emergent properties of biomolecules in water, biomolecular hierarchy, macromolecules, molecular assemblies; amino acids and protein– structure and functional group properties, peptides and covalent structure of proteins, elucidation of primary and higher order structures.

Unit V
Enzyme catalysis and technology
7 lectures
General principles of catalysis; quantitation of enzyme activity and efficiency; enzyme characterization and Michaelis-Menten kinetics; relevance of enzymes in metabolic regulation, activation, inhibition and covalent modification; single substrate enzymes; concept of catalytic antibodies; catalytic strategies with specific examples of proteases, carbonic anhydrases, restriction enzymes and nucleoside monophosphate kinase; regulatory strategies with specific example of hemoglobin; isozymes; role of covalent modification in enzymatic activity; zymogens, enzyme immobilization and its applications.

Unit VI
Bioenergetics
8 lectures
Bioenergetics-basic principles; equilibria and concept of free energy; coupled interconnecting reactions in metabolism; oxidation of carbon fuels; recurring motifs in metabolism; Introduction to GPCR, Inositol/DAG//PKC and Ca++ signaling pathways;
glycolysis and gluconeogenesis; reciprocal regulations and non-carbohydrate sources of glucose; Citric acid cycle, entry to citric acid cycle, citric acid cycle as a source of biosynthetic precursors; Oxidative phosphorylation; importance of electron transfer in oxidative phosphorylation; F1-F0 ATP Synthase; shuttles across mitochondria; regulation of oxidative phosphorylation; Photosynthesis – chloroplasts and two photosystems; proton gradient across thylakoid membrane; Calvin cycle and pentose phosphate pathway.

Recommended Textbooks and References:

Course Objectives
The aim of course is to provide students with basic knowledge of common analytical techniques for analysis of inorganic ions, natural substances, metabolites and toxicants in environmental matrices.

Student Learning Outcomes
On completion of this course, students should be able to:
• Identify structure from environmental point of view of relevant organic compounds;
• Account for most common reactions of functional groups;
• Relate structure of an organic compound to physical properties such as boiling point, solubility and viscosity;
• Discuss problems around most common types of organic pollutants;
• Identify and describe steps that are included in a complete analysis as sampling, sample preparation, separation, detection and data evaluation;
• Account for common sampling techniques for inorganic and organic compounds in soil, water and air.

Segments of environment; Principles and cyclic pathways in environment; Chemistry of air, water, soil and waste water; Chemical composition of air and air pollutants, sources, sinks, classification and effects of air pollutants on living and non-living things; Chemistry of water: unusual physical properties of water, hydrogen bonding in biological systems, unusual solvent properties, changes in water properties by addition of solute, pH and buffer, water and water quality parameters, industrial water pollution; Chemistry of soil: formation, constituents and properties of soils, composition of types of soil, chemical factors affecting the soil quality, adsorption of contaminants in soil; Industrial waste; urban waste, chemical and metallic pollutants, radioactive waste, trace heavy metals, pesticides, fertilizers, effect of modern agro-technology on quality of soil, process of waste water, origin and effect of waste water on aquatic environment.
### Unit II
**Chemistry of organic and inorganic chemicals in environment**

6 lectures

Organic chemicals in environment; Aliphatic/aromatic hydrocarbons (hydrocarbon decay, environmental effects); Soaps, surfactants (cationic, anionic and non-ionic detergents, modified detergents); Pesticides (classification, degradation, analysis, pollution due to pesticides); Polymers (microbial decomposition, polymer decay), drugs, dyes, oils, grease; Inorganic chemicals in environment; Inorganic gaseous pollutants; Particulate matter; Trace level toxic metals; Inorganic pesticides & fertilizers, acids, alkalis, salts, complexes.

### Unit III
**Environmental monitoring and sample analysis**

5 lectures

Sampling of air and water pollutants; Monitoring techniques and methodology, pH, Dissolved Oxygen (DO); Chemical Oxygen Demand (COD); Biological Oxygen Demand (BOD); TS, TDS, VS, TVS, VSS, MLSS, MLVSS, ASH; Speculation of metals, monitoring & analysis of CO, NO, CO₂, SO₂; Pesticide residue; Phenols and petrochemicals.

### Unit IV
**Chemistry of degraded hazardous substances**

6 lectures

Introduction to hazardous waste; Degradation products of trade waste; Degradation of agro based chemicals; Solid waste management and environment; Destruction of hazardous substances: acid halides and anhydrides, alkali metals, cyanides and cyanogens bromides, chromium, allatoxins and halogenated compounds; Toxic chemicals in environment, Atmospheric toxicants; Toxic heavy metals; Radionuclides; Pesticides and pesticide residues; Solvents and other organic chemicals; Petroleum and other related compounds; Carcinogens; Assessment of toxicity; Assessment of environmental risks; Chemistry of toxic chemicals and hazardous substances in environment.

### Unit V
**Spectroscopy techniques**

5 lectures

UV, Visible and Raman Spectroscopy; Theory and application of Circular Dichroism; Fluorescence; MS, NMR, PMR, ESR and Plasma Emission spectroscopy.

### Unit VI
**Chromatography and electrophoretic techniques**

7 lectures

Chromatography techniques: TLC and paper chromatography; Chromatographic methods for macromolecule separation - Gel permeation, Ion exchange, Hydrophobic, Reverse-phase and Affinity chromatography; HPLC and FPLC; Criteria of protein purity, Instruments used in chemical analysis of environmental samples, Introduction to separation techniques; Neutron activation analysis; Atomic Absorption Spectroscopy (AAS); Emission flame photometry; Inductively couple plasma emission spectroscopy; X-ray; Fluorescence; Non-dispersive IR Spectroscopy (NDIR); UV-Visible spectrophotometer; High performance liquid chromatography (HPLC); Gas chromatography (GC); Electro analytical methods; NMR and Mass Spectroscopy; Electrophoretic techniques: Theory and application of Polyacrylamide and Agarose gel electrophoresis; Capillary electrophoresis; 2D Electrophoresis; Disc gel electrophoresis; Gradient electrophoresis; Pulsed field gel electrophoresis.

### Unit VII
**Centrifugation**

5 lectures

Basic principles; Mathematics & theory (RCF, Sedimentation coefficient etc.); Types of centrifuge - Microcentrifuge, High speed & Ultracentrifuges; Preparative centrifugation; Differential & density gradient centrifugation; Applications (Isolation of cell components); Analytical centrifugation; Determination of molecular weight by sedimentation velocity & sedimentation equilibrium methods.

### Recommended Textbooks and References:

Cell & Molecular Biology

Course Objectives
The objectives of this course are to sensitize the students to the fact that as we go down the scale of magnitude from cells to organelles to molecules, the understanding of various biological processes becomes deeper and inclusive.

Student Learning Outcomes
Student should be equipped to understand three fundamental aspects in biological phenomena: a) what to seek; b) how to seek; c) why to seek?

Unit I
Dynamic organization of cell
6 lectures

Universal features of cells; cell chemistry and biosynthesis: chemical organization of cells; internal organization of the cell - cell membranes: structure of cell membranes and concepts related to compartmentalization in eukaryotic cells; intracellular organelles: endoplasmic reticulum and Golgi apparatus, lysosomes and peroxisomes, ribosomes, cellular cytoskeleton, mitochondria, chloroplasts and cell energetics; nuclear compartment: nucleus, nucleolus and chromosomes.

Unit II
Chromatin structure and dynamics
12 lectures

Chromatin organization - histone and DNA interactome: structure and assembly of eukaryotic and prokaryotic DNA polymerases, DNA-replication, repair and recombination; chromatin control: gene transcription and silencing by chromatin-Writers,-Readers and –Erasers; Transcriptional control: Structure and assembly of eukaryotic and prokaryotic RNA Polymerases, promoters and enhancers, transcription factors as activators and repressors, transcriptional initiation, elongation and termination; post-transcriptional control: splicing and addition of cap and tail, mRNA flow through nuclear envelope into cytoplasm, breakdown of selective and specific mRNAs through interference by small non-coding RNAs (miRNAs and siRNAs), protein translation machinery, ribosomes-composition and assembly; universal genetic codes, degeneracy of
### Course Objectives

The objectives of this course are to teach various approaches to conducting genetic engineering and their applications in biological research as well as in biotechnology industries.

### Student Learning Outcomes

Given the impact of genetic engineering in modern society, students should be endowed with strong theoretical knowledge of this technology. In conjunction with practicals in molecular biology and genetic engineering, students should be able to take up biological research as well as placement in relevant biotech industry.

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### Unit III

#### Cellular signalling, transport and trafficking

- Molecular mechanisms of membrane transport, nuclear transport, transport across mitochondria and chloroplasts; intracellular vesicular trafficking from endoplasmic reticulum through Golgi apparatus to lysosomes/cell exterior.

### Unit IV

#### Cellular processes

- Cell cycle and its regulation; cell division: mitosis, meiosis and cytokinesis; cell differentiation: stem cells, their differentiation into different cell types and organization into specialized tissues; cell-ECM and cell-cell interactions; cell receptors and transmembrane signalling; cell motility and migration; cell death: different modes of cell death and their regulation.

### Unit V

#### Manipulating and studying cells

- Isolation of cells and basics of cell culture; observing cells under a microscope, different types of microscopy; analyzing and manipulating DNA, RNA and proteins.

### Unit VI

#### Genome instability and cell transformation

- Mutations, proto-oncogenes, oncogenes and tumour suppressor genes, physical, chemical and biological mutagens; types of mutations; intra-genic and inter-genic suppression; transpositions- transposable genetic elements in prokaryotes and eukaryotes, role of transposons in genome; viral and cellular oncogenes; tumor suppressor genes; structure, function and mechanism of action; activation and suppression of tumor suppressor genes; oncogenes as transcriptional activators.

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### Recommended Textbooks and References:

## Unit I
**Introduction and tools for genetic engineering**
6 lectures

Impact of genetic engineering in modern society; general requirements for performing genetic engineering experiment; restriction endonucleases and methylases; DNA ligase, Klenow enzyme, T4 DNA polymerase, polynucleotide kinase, alkaline phosphatase; cohesive and blunt end ligation; linkers; adaptors; homopolymeric tailing; labelling of DNA: nick translation, random priming, radioactive and non-radioactive probes; hybridization techniques: northern, southern, south-western and far-western and colony hybridization, fluorescence *in situ* hybridization.

## Unit II
**Different types of vectors**
7 lectures

Plasmids; Bacteriophages; M13 mp vectors; PUC19 and Bluescript vectors, phagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Principles for maximizing gene expression: expression vectors, pMal, GST, pET-based vectors; Protein purification: His-tagged/GST-tagged/MBP-tagged proteins *etc.*; Intein-based vectors; Inclusion bodies; methodologies to reduce formation of inclusion bodies; mammalian expression and replicating vectors; Baculovirus and *Pichia* vectors system, plant based vectors, Ti and Ri plasmids as vectors, yeast vectors, shuttle vectors.

## Unit III
**Different types of PCR techniques**
7 lectures

Principles of PCR: primer design; fidelity of thermostable enzymes; DNA polymerases; types of PCR – multiplex, nested; reverse-transcription PCR, real time PCR, touchdown PCR, hot start PCR, colony PCR, asymmetric PCR, cloning of PCR products; TA cloning vectors; proof reading enzymes; PCR based site specific mutagenesis; PCR in molecular diagnostics; viral and bacterial detection; sequencing methods; enzymatic DNA sequencing; chemical sequencing of DNA; automated DNA sequencing; RNA sequencing; chemical synthesis of oligonucleotides; mutation detection: SSCP, DGGE, RFLP.

## Unit IV
**cDNA analysis**
7 lectures

Insertion of foreign DNA into host cells; transformation, electroporation, transfection; construction of libraries; isolation of mRNA and total RNA; reverse transcriptase and cDNA synthesis; cDNA and genomic libraries; construction of microarrays – genomic arrays, cDNA arrays and oligo arrays; study of protein-DNA interactions: electrophoretic mobility shift assay; DNaseI footprinting; methyl interference assay, chromatin immunoprecipitation; protein-protein interactions using yeast two-hybrid system; phage display.

## Unit V
**Gene silencing and genome editing technologies**
13 lectures

Gene silencing techniques; introduction to siRNA; siRNA technology; Micro RNA; construction of siRNA vectors; principle and application of gene silencing; gene knockouts and gene therapy; creation of transgenic plants; debate over GM crops; introduction to methods of genetic manipulation in different model systems *e.g.* fruit flies (*Drosophila*), worms (*C. elegans*), frogs (*Xenopus*), fish (zebra fish) and chick; Transgenics - gene replacement; gene targeting; creation of transgenic and knock-out mice; disease model; introduction to genome editing by CRISPR-CAS with specific emphasis on Chinese and American clinical trials.

### Recommended Textbooks and References:

# Ecology and Biodiversity

## Course Objectives
The objective of this course is to teach students:
- How organisms interact with each other and their environment;
- How species are distributed throughout the world;
- Key threats and approaches to conserving biodiversity.

## Student Learning Outcomes
On completion of this course, students should be able to:
- Understand and appreciate major living and non-living components of regional and global environment, and how they interact; identify threats to them; and know how these threats can be mitigated;
- Understand and appreciate variety of life in India's natural habitats, and become equipped to study, manage and protect the diversity.

## Unit I
**Ecological principles**
6 lectures

- Basic ecological concepts and principles, our environment: geological consideration; Atmosphere, hydrosphere, lithosphere; Scope of ecology; Development and evolution of ecosystem; Principles and concepts of ecosystem; Structure of ecosystem; Strata of an ecosystem; Types of ecosystem; Cybernetics and homeostasis; Biological control of chemical environment; Energy transfer in an ecosystem; Food chain, food web; Energy budget; Production and decomposition in a system; Ecological efficiencies; Trophic structure and energy pyramids; Ecological energetics; Principles pertaining to limiting factors; Biogeochemical cycles (N, C, P cycles).

## Unit II
**Types of ecosystems**
4 lectures

- Habitat approach, freshwater ecology; Marine ecology; Estuarine ecosystem, terrestrial ecosystem; Natural resources and their conservation.

## Unit III
**Dynamics of ecosystems**
6 lectures

- Biotope-Biocenose interactions (Climate and plants, Soil and living things); Interactions among organisms (Types of interactions, Consequences for population dynamics, Man in Biocenoses); Man and Ecosystems (Managing land, resources, waste; Global impact of human activities; Man as a partner in the Ecosystem).

## Unit IV
**Biodiversity**
7 lectures

- Biodiversity definition; Historical and geographical causes for diversity; Types of diversity; Genetic diversity; Species diversity, ecosystem diversity; Quantifying biodiversity; Molecular taxonomy; Maintenance of ecological biodiversity; Biodiversity and centers of origins of animals; Biodiversity hot spots in India; Collection and conservation of biodiversity; Conservation of animal genetic resources; Methods of biodiversity conservation; Gene banks; Cryopreservation; Assessing, analyzing and documenting biodiversity; Morphological and molecular characterization of biodiversity; Vulnerability and extinction of biodiversity; Introduction to biodiversity database: endangered animals, endemism and Red data book; Global biodiversity information system.

## Recommended Textbooks and References:

## Biostatistics

**Course Objectives**
The objective of this course is to introduce to statistical methods and to understand the underlying principles, as well as practical guidelines of “how to do it” and “how to interpret it” statistical data particularly for bio systems.

**Student Learning Outcomes**
On completion of this course, students should be able to:
- Understand how to summarise statistical data;
- Apply appropriate statistical tests based on an understanding of study question, type of study and type of data;
- Interpret results of statistical tests and application in biological systems.

### Unit I
**Introduction**
- Types of biological data (ordinal scale, nominal scale, continuous and discrete logical systems data), frequency distribution and graphical representations (bar graph, histogram, box plot and frequency polygon), cumulative frequency distribution, populations, samples, simple random, stratified and systematic sampling.

### Unit II
**Descriptive statistics**
- Measures of Location, Properties of Arithmetic Mean, median, mode, range, Properties of the Variance and Standard Deviation, Coefficient of Variation, Grouped Data, Graphic Methods, Obtaining Descriptive Statistics on the Computer, Case study.

### Unit III
**Probability and distribution**
- Introduction to probability and laws of probability, Random Events, Events-exhaustive, Mutually exclusive and equally likely (with simple exercises), Definition and properties of binomial distribution, Poisson distribution and normal distribution.

### Unit IV
**Correlation and regression analysis**
- Correlation, Covariance, calculation of covariance and correlation, Correlation coefficient from ungrouped data Spearon’s Rank Correlation Coefficient, scatter and dot diagram, General Concepts of regression, Fitting Regression Lines, regression coefficient, properties of Regression Coefficients, Standard error of estimate.

### Unit V
**Statistical hypothesis testing**
- Making assumption, Null and alternate hypothesis, error in hypothesis testing, confidence interval, one-tailed and two-tailed testing, decision making.

### Unit VI
**Tests of significance**
- Steps in testing statistical significance, selection and computation of test of significance and interpretation of results; Sampling distribution of mean and standard error, Large sample tests (test for an assumed mean and equality of two population means with known S.D.), z-test; Small sample tests (t-test for an assumed mean and equality of means of two populations when sample observations are independent); Parametric and Non parametric tests (Mann-Whitney test); paired and unpaired t-test, chi square test.
Unit VII
Experimental designs
8 lectures

Introduction to study designs: Longitudinal, cross-sectional, retrospective and prospective study, Principles of experimental designs, Randomized block, and Simple factorial designs, Analysis of variance (ANOVA) and its use in analysis of RBD, introduction to meta-analysis and systematic reviews, ethics in statistics.

Recommended Textbooks and References:

Laboratory I: Microbial Biochemistry and Analytical Techniques

Course Objectives
The objective of this laboratory course is to introduce students to experiments in microbial biochemistry. The course is designed to teach students the utility of a set of experimental methods in microbial biochemistry in a problem oriented manner.

Student Learning Outcomes
On completion of this course, students should be able:
- To elaborate concepts of microbial biochemistry with easy to run experiments;
- To familiarize with basic laboratory instruments and understand the principle of measurements using those instruments with experiments in biochemistry.

Credits
4

Syllabus
1. Preparing various stock solutions and working solutions that will be needed for the course
2. Sterilization, disinfection and safety in microbiological laboratory
3. Preparation of media for cultivation of bacteria
4. Isolation of bacteria in pure culture by streak plate method
5. Study of colony and growth characteristics of some common bacteria: *Bacillus*, *E. coli*, *Staphylococcus*, *Streptococcus*, etc.
6. Preparation of bacterial smear and Gram's staining.
8. Antimicrobial sensitivity test and demonstration of drug resistance
9. Maintenance of stock cultures: slants, stabs and glycerol stock cultures
10. Determination of phenol co-efficient of antimicrobial agents
11. Determination of Minimum Inhibitory Concentration (MIC)
12. Isolation and identification of bacteria from soil/water samples
13. To prepare an Acetic-Na Acetate Buffer and validate the Henderson-Hasselbach equation
14. To determine an unknown protein concentration by plotting a standard graph of BSA using UV-Vis Spectrophotometer and validating the Beer-Lambert’s Law
15. Titration of Amino Acids and separation of aliphatic, aromatic and polar amino acids by thin layer chromatography
16. Purification and characterization of an enzyme from a recombinant source (such as Alkaline Phosphatase or Lactate Dehydrogenase)
   a) Preparation of cell-free lysates
   b) Ammonium Sulfate precipitation
   c) Ion-exchange Chromatography
   d) Gel Filtration
   e) Affinity Chromatography
   f) Generating a Purification Table (protein concentration, amount of total protein)
   g) Computing specific activity of enzyme preparation at each stage of purification
   h) Assessing purity of samples from each step of purification by SDS-PAGE
   i) Enzyme Kinetic Parameters: Km, Vmax and Kcat
   j) Dialysis of purified protein solution against 60% glycerol as a demonstration of storage method

17. Experimental verification that absorption at OD₂₆₀ is more for denatured DNA as compared to native double stranded DNA.

18. Identification of an unknown sample as DNA, RNA or protein using available laboratory tools

19. (Optional Experiments)

20. Biophysical methods (Circular Dichroism Spectroscopy, Fluorescence Spectroscopy)


Recommended Textbooks and References:
3. Tille, P. M., & Forbes, B. A., Bailey & Scott's Diagnostic Microbiology.

Course Objectives
The objective of this laboratory course is to provide the students practical skills on basic microbiological and genetic engineering techniques.

Student Learning Outcomes
On completion of this molecular biology lab course, students should be:
- Acquire basic techniques and principles;
- Get first-hand experience that will coincide with what is taught in lecture portion of the class;
- Gain hands-on experience on gene cloning, protein expression and purification.

Syllabus
1. Concept of lac-operon:
   a) lactose induction of β-galactosidase
   b) Glucose Repression
   c) Diauxic growth curve of E.coli
2. UV mutagenesis to isolate amino acid auxotroph
3. Phage titre with λ phage/M13
4. Genetic Transfer-Conjugation, gene mapping
5. Plasmid DNA isolation and DNA quantitation
6. Restriction Enzyme digestion of plasmid DNA
7. Agarose gel electrophoresis
8. Polymerase Chain Reaction and analysis by agarose gel electrophoresis
9. Vector and Insert Ligation
10. Preparation of competent cells
11. Transformation of E.coli with standard plasmids, Calculation of transformation efficiency
12. Confirmation of the insert by Colony PCR and Restriction mapping
13. Expression of recombinant protein, concept of soluble proteins and inclusion body formation in E.coli, SDS-PAGE analysis
14. Purification of His-Tagged protein on Ni-NTA columns
   a) Random Primer labeling
   b) Southern hybridization.

Recommended Textbooks and References:

Semester Two

Environmental Engineering

Course Objectives
The objective of this course is to build a solid foundation in mathematics and sciences along with technical skills needed to analyse and design environmental engineering systems.

Student Learning Outcomes
On completion of this course, students should know how to stay updated in environmental science and technologies by applying information resources and industrial contacts.

Unit I
Introduction to environmental engineering
8 lectures
Wastewater – collection, characteristics, treatment methods for domestic and industrial wastewater, disposal and management; sanitation; environmental impact assessment; thermal and marine pollution; common effluent treatment plants, pollution control.

Unit II
Principles of aerobic treatment processes
8 lectures
Microbial growth rates; substrate specificities; biochemical interactions; treatment kinetics; food/microorganism ratio; oxygen and nutrient requirements; theory of aeration; oxygen transfer; types of aeration; substrate removal efficiency; removal of nitrogen and phosphorus; treatment methods including activated sludge, extended aeration, sequencing batch reactors, trickling filters, rotating bio-disc systems, nitrification-denitrification systems.

Unit III
Principles of anaerobic and advanced treatment processes
10 lectures
General perspective – substrate specificities, biochemical interactions, environmental factors; Anaerobic process design parameters - volumetric organic loading rate, hydraulic and solid retention time, temperature, waste characters; Anaerobic reactor configuration- suspended growth anaerobic reactors (conventional, anaerobic contact, covered anaerobic lagoons), fixed film anaerobic reactors (fixed bed, fluidized bed, hybrid) upflow anaerobic sludge blanket; typical arrangements, design approach, design parameters, nutrient removal, gas recovery, post-treatment methods; Sludge treatment
Mechanically aerated lagoons - types, design of facultative, aerobic flow-through, dual-powered and extended aeration lagoons; algal ponds - types, typical flow sheets, algal growth dynamics, nitrogen and phosphorus removal, advanced integrated pond system; Hyacinth ponds; duckweed ponds; sewage-fed fish ponds; natural wetlands; constructed wetlands (reed beds), design and aspects of municipal and industrial wastewater irrigation system.

**Recommended Textbooks and References:**


**Course Objectives**

The objectives of this course are to present general procedures, methods, theories and some techniques in monitoring programmes for different environments. Students will learn basic environment assessment procedures.

**Student Learning Outcomes**

On completion of this course, students should be able to:

- Understand basic principles of environmental monitoring;
- Identify the pros and cons of various approaches to monitoring environment;
- Be aware of common bio-indicators and how they are used;
- Understand concepts in effective study design and apply them to a monitoring question of concern;
- Improve ethical conduct whilst undertaking field research.
global level; Bioindicator, keystone species, endangered species, behavioural stress responses, Life-history and higher level responses; Air pollution: Concept of air pollution; Major air pollutants and their sources; Suspended particulate matter (different sizes, their relevance to human health and equipment use for monitoring); Biomass burning, Formation of fog and photochemical smog, Meteorological aspects of air pollution; exhaust gases, (Oxides of nitrogen and sulphur);  Air pollution standards; Indoor and outdoor air pollution; Vehicular air pollution; Air pollution episodes and disasters; Effects of air pollution on human health, animals, plants, material and climate; acid rain; Monitoring of air pollution; Control on release of smoke; Gaseous contaminants and odour; VOC monitoring; Control equipment for air pollution.

<table>
<thead>
<tr>
<th>Unit II</th>
<th>Noise pollution</th>
<th>5 lectures</th>
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<tbody>
<tr>
<td>Sources of noise; measurement of noise; religious festivals and noise; standards of noise; effects of noise on plants, animals and human beings; Control of noise at source; Industrial noise control; Prevention of public noise; Community noise control; Radiation pollution; Electromagnetic waves monitoring and hazards; Types and possible hazards of radioactive substances; Measurement of radiation intensity; Effects of radioactive waste pollution on environment and impact of radiation on life; Monitoring and control of radiation pollution.</td>
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<thead>
<tr>
<th>Unit III</th>
<th>Soil pollution</th>
<th>4 lectures</th>
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<tbody>
<tr>
<td>Importance of soil; major soil types; physicochemical characterization of soil, causes of soil salinity; methods for soil remediation, microbial assisted phytoremediation; Different causes of agricultural soil degradation and pollution; Mining and soil pollution; Soil pollution and air quality; Control of soil pollution.</td>
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<tr>
<th>Unit IV</th>
<th>Remote sensing and geographical information system (GIS)</th>
<th>6 lectures</th>
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<tbody>
<tr>
<td>Principles of remote sensing, its applications in environmental monitoring; Concept of Remote sensing; EMR &amp; its interaction with matter; Aerial Photography: Types, Camera, Elements of photo interpretation (Aerial Photography/image recognition); Sensors &amp; platforms; IRS satellites &amp; their sensors; Application of remote sensing in environmental studies; Concept of GIS; Types of geographical data; Data structure; Vector and Raster data; their advantages and disadvantages; Input, verification, storage and output of geographical data; Importance of Geographical Information System in environmental studies.</td>
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<tr>
<th>Unit V</th>
<th>Environmental assessment</th>
<th>7 lectures</th>
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<tr>
<td>Environmental quality assessment and monitoring: Overview of environmental quality; Methods of assessment of environmental quality; Short term studies/surveys; Rapid assessment; Continuous short and long term monitoring; Cumulative Impact Assessment (CIA), Preparing Greenhouse Emission Assessment, Preparing Risk Assessments and Accident Analyses, Social Impact Assessment (SIA) and Environmental Justice; Environmental Impact Assessment (EIA): Need of EIA; Scope and objectives; Resource status and waste management; Types of environmental impacts; Steps involved in conducting the EIA Studies; Impact prediction and measurement; Environmental Impact Assessment techniques-Ad-hoc method, checklist method, overlay mapping method, network method, simulation and modelling technique, matrix method, and system diagram technique; Merits and Demerits of EIA studies.</td>
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<tr>
<th>Unit VI</th>
<th>Policies and regulation</th>
<th>4 lectures</th>
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<tr>
<td>Environmental law and civil liabilities; Legislation on Environmental Assessment; State and pollution control regulatory structure; Quality control and accreditation for EIA studies; Role of EIA in town/city planning.</td>
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</tr>
</tbody>
</table>

**Recommended Textbooks and References:**

1. G. Bruce Wiersma (2004); *Environmental Monitoring*; by CRC Press
Components of innate and acquired immunity; phagocytosis; complement and inflammatory responses; pathogen recognition receptors (PRR) and pathogen associated molecular pattern (PAMP); innate immune response; mucosal immunity; antigens - immunogens, hapten; Major Histocompatibility Complex - MHC genes, MHC and immune responsiveness and disease susceptibility.

Immunoglobulins - basic structure, classes & subclasses of immunoglobulins, antigenic determinants; multigene organization of immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; principles of cell signaling; basis of self & non-self discrimination; kinetics of immune response, memory; B cell maturation, activation and differentiation; generation of antibody diversity; T-cell maturation, activation and differentiation and T-cell receptors; functional T Cell subsets; cell-mediated immune responses, ADCC; cytokines-properties, receptors and therapeutic uses; antigen processing and presentation- endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens; cell-cell co-operation, Hapten-carrier system.

Precipitation, agglutination and complement mediated immune reactions; advanced immunological techniques - RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence, flow cytometry and immunoelectron microscopy; surface plasmon
resonance, biosensor assays for assessing ligand–receptor interaction, CMI techniques-
lymphoproliferation assay, mixed lymphocyte reaction.

Unit IV
Introduction to ecotoxicology
7 lectures

Definition; classification of toxicants in environment; Basic principles of toxicology,
Factors affecting toxicity; Mutagenesis; Teratogenesis; Carcinogens; Hallucinogens;
Phytotoxins and animal toxins; Toxic response of different body system like respiratory,
gastro-intestinal tract, liver, kidney, immune system and reproductive system; Toxicants
types; Absorption and distribution of toxicants in animal body; Bio-transformation of
toxicants; Antidotes treatment and detoxification of toxicants; Bio-accumulation;
Toxicity evaluation using various tests for genomic (comet assay), plants (seed
germination, growth of plemule and radical), aquatic animals (fish) and soil parameters
for soil fertility.

Unit V
Effects of toxicity on environment
8 lectures

Toxicology of gaseous pollutants; Toxic metals in environment; Toxicity of pesticides;
solvents, ionizing radiations; Soil toxicology.

Recommended Textbooks and References:
   New York: W.H. Freeman.
   London: Gower Medical Pub.
   Ecotoxicology (4th Edition); CRC Press.

Course Objectives
The broad objectives of this course are to make students:

• Knowledgeable in environmental regulation;
• Understand how these policies affect our daily interaction with environment;
• View issues of policy through critical and geographic viewpoint often adopted by scientists and academics.

Student Learning Outcomes
Upon successful completion of this course, students should be able to:

• Identify and articulate scope, interconnections, and multiple roles of environmental policy across different scales and sectors (local, state, national, international and corporate policy);
• Critically reflect on theories and methods that inform environmental policy-making, implementation, and evaluation and how they shape different policy approaches and outcomes.

Unit I
Introduction to environmental pollution and systems approach
7 lectures

Definition of “environmental pollution”; case studies on local, regional and global
environmental pollution; short-term and long-term implications of air pollution, water
pollution and contamination of soils and food; significant threats to public health; natural
processes and disasters impacting ecology and environment on local and regional scale
including volcanic eruption, earthquake, landslide, flood, drought, tsunami, tornado,
forest fire; threat to ecology and environment on global scale including ozone hole, global
climate change; global warming, extinction of species, loss of biodiversity, deforestation,
marine pollution; threat to ecology and environment from manmade sources and actions
including municipality, industry, agriculture, power generation, war, population, illegal
hunting and animal trade; genetically modified organisms, crops and bio-
products; Meaning of important terminologies including environment, ecology, science, technology, engineering, pollution (pollutant, polluter), contamination (contaminant), abatement, treatment, prevention, public health, toxicity, hazard, accident, disaster, standards, regulation, law, act, notification, Gazette of India, policy, international treaty, international convention, international protocol, environmental governance, environmental jurisprudence; sustainable development; Constitutional Provisions for Environmental Protection: Historical background of constitutional provisions; substance and significance of the Constitution of India; Article 14, 15, 19, 21, 32, 39, 47, Article 48(A), 49, 51A(g) as fundamental duties of citizen and directive principles of state policy, Article 243, 243(G) and (W); Art. 246, 248 and other articles related to environment; writ provisions for protection of environment.

Unit II
National policies/laws for protection of environment
6 lectures


Unit III
Indian environmental governance and regulations
5 lectures

Solid waste management rules, 2016; Plastic waste (management and handling) Rules, 2016; Hazardous and other wastes (management and transboundary movement) Rules, 2016; E-Waste (management) Rules, 2016; Construction and demolition waste management Rules, 2016; Bio-medical waste management Rules, 2016; Need of CRZ rules for regulating the activities in coastal zone, 2011; Environmental administration: The Supreme Court of India; State High Courts; National Green Tribunals; concept and need of public interest litigation; Natural Biodiversity Board; CPCB; SPCBs; Authorities for protection of trees and forests; accreditation of analytical laboratories for analysis of environmental samples; accreditation of transporters of wastes; environmental taxes, cess, levies and duties.

Unit IV
International institutions/initiatives for protection of ecology and environment
6 lectures

International institutions: United Nations Organisation (UNO); United Nations Environment Programme (UNEP); United Nations Development Programme (UNDP); International Labour Organisation (ILO); International Maritime Organization (IMO); international NGOs for global action; International initiatives: Concept of international agreement and treaty; interdependence of degradation of ecology and environment with poverty, gender inequity, imbalance of development, lack of education and public health; protection and improvement of ecology and environment as the drivers for promoting peace, prosperity and justice in the world; Detailed discussion on: Stockholm Conference (1972); Rio Conference (UNCED)(1992); Johannesburg Conference (WSSD in 2002); Agenda 21; Millennium Development Goals (2000); Sustainable Development Goals (2015); GAAT; CITES; Biodiversity Convention; IPCC; Kyoto Protocol and subsequent progress up to COP in Paris; habitat-related international initiatives; Montreal Protocol; Basel Convention: Market-based initiatives for Protection of Ecology and Environment: Clean development mechanism; carbon credits; global monitoring fund; international trade and environmental taxes, cess, levies and duties.

Recommended Textbooks and References:
1. Web page of Ministry of Environment, Forest and Climate Change, Govt. of India.
Course Objectives
To impart theoretical knowledge on various techniques of plant biotechnology like tissue culture and plant genetic transformation and their application in industries.

Student Learning Outcomes
Student should gain strong understanding of plant based cell cultures system. This should help them to take up plant based biological research as well as placement in relevant biotech industry. They should be able to analyse bioprocess from an economics/market point of view.

Unit I
Plant tissue culture and plant transformation techniques
6 lectures
Plant tissue culture- history; totipotency of plant cells; Principles for aseptic culture techniques, culture media, plant growth regulators. Plant regeneration: somatic embryogenesis, importance of haploid production through pollen culture and triploid production through endosperm culture in crop improvement; in vitro pollination; wide hybridization; somatic cell hybridization (hybrids and cybrids); embryo culture; Synthetic seeds and their importance; Methods of gene transfer- Agrobacterium mediated gene transfer and electroporation.

Unit II
Plant biotechnology for abiotic and biotic stress resistance
6 lectures
Plant biotechnology for enhancing cold and heat stress tolerance; secondary effects of abiotic stress – production of ROS; genes involved in scavenging of ROS; Plant biotechnology in enhancing drought and salt stress tolerance; Plant biotechnology for enhancing resistance against fungal pathogens; anti-microbial proteins; Plant biotechnology to enhance viral resistance- pathogen derived resistance; coat protein, antisense, SiRNA and ribozyme approaches to enhance resistance for extending shelf life of fruits and flowers (ACC synthase gene and polygalacturonase).

Unit III
Plant biotechnology for improving crop yield and quality
4 lectures
Plant biotechnology in improving fruit ripening and enhancing photosynthesis; Golden rice- nutritionally improved rice through biotechnology; transgenic sweet potato; Modification of taste and appearance- sweetness, starch and preventing discoloration; Bioplastics- biodegradable plastic from plants through biotechnological intervention.

Recommended Textbooks and References:

Bioinformatics

Credits

Unit I
Biological databases
4 lectures
Introduction, Primary & Secondary database, Sequence file formats, Introduction to structures, Protein Data Bank (PDB), Molecular Modelling Database (MMDb), Structure file formats, Visualizing structural information, Database of structure viewers, Collection of sequences, sequence annotation, sequence description.

Unit II
Sequence alignment and database searching
4 lectures
Evolutionary basis of sequence alignment, Optimal alignment methods, Substitution scores & gap a, Statistical significance of alignments, Database similarity searching, FASTA, BLAST, Low complexity regions, Repetitive elements, Multiple Sequence Alignment: Progressive alignment methods, Motifs and patterns, Clustral, Muscle; Scoring matrices, Distance matrices.

Unit III
Phylogenetic analysis
4 lectures
Alignment, tree building and tree evaluation, Comparison and application of Unweighted Pair Group Method with Arithmetic Mean (UPGMA), Neighbour Joining (NJ), Maximum Parsimony (MP), Maximum Likelihood (ML) methods, Bootstrapping, Jackknife; Software for Phylogenetic analysis. DNA barcoding: Methods tools and databases for barcoding across all species, Applications and limitations of barcoding, Consortium for Barcode of Life (CBOL) recommendations, Barcode of Life Database (BOLD).

Course Objectives
The objectives of this course are to provide students with theory and practical experience of use of common computational tools and databases which facilitate investigation of molecular biology and evolution-related concepts.

Student Learning Outcomes
Student should be able to:
• Develop an understanding of basic theory of these computational tools.
• Gain working knowledge of these computational tools and methods.
• Appreciate their relevance for investigating specific contemporary biological questions.
<table>
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<tr>
<th>Unit IV</th>
<th>Structural biology</th>
<th>4 lectures</th>
<th>3-D structure visualization and simulation, Basic concepts in molecular modeling: different types of computer representations of molecules; External coordinates and Internal Coordinates, Molecular Mechanics, Force fields etc. Secondary structure elucidation using Peptide bond, phi, psi and chi torsion angles, Ramachandran map, anatomy of proteins – Hierarchical organization of protein structure – like CATH (class, architecture, topology, homology), SCOP (Structural Classification of Proteins), FSSP (families of structurally similar proteins).</th>
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<tr>
<td>Unit V</td>
<td>Classification and comparison of 3D structures</td>
<td>4 lectures</td>
<td>DNA &amp; RNA secondary and tertiary structures, t-RNA tertiary structure; Protein Secondary structure prediction: Algorithms viz. Chou Fasman, GOR methods, Tertiary Structure prediction: Fundamentals of the methods for 3D structure prediction (sequence similarity/identity of target proteins of known structure, fundamental principles of protein folding etc.) Homology/comparative modeling, fold recognition, threading approaches, and ab initio structure prediction methods; CASP (Critical Assessment of protein Structure Prediction); Computational design of promoters, proteins &amp; enzymes.</td>
</tr>
<tr>
<td>Unit VI</td>
<td>Applications in drug design</td>
<td>4 lectures</td>
<td>Chemical databases like NCI/PUBCHEM; Fundamentals of Receptor-ligand interactions; Structure-based drug design: Identification and Analysis of Binding sites and virtual screening; Ligand based drug design: Structure Activity Relationship – QSARs &amp; Pharmacophore; in silico predictions of drug activity and ADMET.</td>
</tr>
<tr>
<td>Unit VII</td>
<td>Analysis of microarray data</td>
<td>4 lectures</td>
<td>Designing of oligo probes; Image processing and normalization; Microarray data variability (measurement and quantification); Analysis of differentially expressed genes; Experimental designs.</td>
</tr>
<tr>
<td>Unit VIII</td>
<td>Biological algorithms</td>
<td>2 lectures</td>
<td>Comparison with computer algorithms, string structures, Introduction to programming in computational biology through C/ Perl / Java.</td>
</tr>
<tr>
<td>Unit IX</td>
<td>Systems biology</td>
<td>3 lectures</td>
<td>System-level understanding of biological systems, use and integration of data from transcriptomics, proteomics and metabolomics; concepts in glycomics, interactomics and fluxomics.</td>
</tr>
</tbody>
</table>

**Recommended Textbooks and References:**

4. Web-resources and suggested reviews/ research papers.
6. Web-resources and suggested reviews/ research papers.
Laboratory III: Ecotoxicology and Immunology

Course Objectives
The objectives of this laboratory course are to develop an understanding about practical aspects of components of immune system as well as their function. This course will also give a general overview of assessment of Environmental toxicology.

Student Learning Outcomes
On completion of this course, students should be able to:
• Evaluate usefulness of immunology in different pharmaceutical companies;
• Identify proper research lab working in area of their own interest;
• Evaluate biological, ecological and chemical factors affecting toxicity testing.

Credits
4

Syllabus
Ecotoxicology
1. Evaluation of genetic damage caused by toxicants using Comet assay (Exposure to root cells of Allium cepa).
2. Effect of toxicants/metabolites on seed germination and growth (Plumule and radical).
3. Determination of LC 50 of toxicants using aquatic animals (Fish, molluscs). Effect on gill structure, and architectural distortions, lamellar curling and blood congestion.
4. Effect of toxicants on microbial growth (zone of growth inhibition).
5. Effect on plan growth: chlorophyll a, b and carotenoids content in plants growing in normal conditions and in presence of recalcitrant/toxic chemicals.
6. Estimation of soil parameters viz. Electric conductivity (mS), Organic carbon (%), Nitrogen (mg/kg), Phosphrous (mg/kg), Potassium (mg/kg). Effect on soil parameters when effluent is used for watering crop.
7. Toxicity impact assessment of wetland/CETP/contaminated site.

Immunology
1. Selection of animals, Preparation of antigens, Immunization and methods of bleeding, serum separation and storage.
2. Antibody titre by ELISA method.
5. Isolation and purification of IgG from serum or IgY from chicken egg.
6. SDS-PAGE, Immunoblotting, Dot blot assays.
8. Separation of leucocytes by dextran method.
10. Separation of mononuclear cells by Ficoll-Hypaque.

Laboratory IV: Bioinformatics and Biostatistics

Course Objectives
The aim is to provide practical training in bioinformatics and statistical methods including accessing major public sequence databases.

Student Learning Outcomes
On completion of this course, students should be able to:
• Describe contents and properties of important bioinformatics databases, perform text- and sequence-based searches and analyse and discuss the results in light of molecular biological knowledge;
• Explain major steps in pairwise and multiple sequence alignment, explain its principles and execute...
pairwise sequence alignment by dynamic programming;
• Predict secondary and tertiary structures of protein sequences;
• Perform and analyse various statistical tools available to analyse data.

Syllabus

1. Using NCBI and Uniprot web resources.
2. Introduction and use of various genome databases.
4. Similarity searches using tools like BLAST and interpretation of results.
5. Multiple sequence alignment using ClustalW.
7. Use of gene prediction methods (GRAIL, Genscan, Glimmer).
8. Using RNA structure prediction tools.
9. Use of various primer designing and restriction site prediction tools.
10. Use of different protein structure prediction databases (PDB, SCOP, CATH).
11. Construction and study of protein structures using Deepview/PyMol.
13. Use of tools for mutation and analysis of the energy minimization of protein structures.
14. Use of miRNA prediction, designing and target prediction tools.
15. Use of Statistical packages like SPSS (Statistical Package for the Social Sciences)/SAS (Statistical Analysis System) & Maple
16. MATLAB (Matrix Laboratory)
17. Performing various statistical analysis like T-test, ANOVA, Regression, Chi-square, PLS (Partial Least Squares) and PCA (Principle Component Analysis).

Laboratory V: Plant Biotechnology

Course Objectives
The objectives of this course are to provide students with experimental knowledge of plant biotechnology.

Student Learning Outcomes
Students should be able to gain hands-on experience on micro-propagation, tissue culture, gene cloning, protein expression and purification.

Credits

2

Syllabus

1. Prepare culture media with various supplements for plant tissue culture.
2. Prepare explants of Valeriana wallichii for inoculation under aseptic conditions.
3. Attempt in vitro andro- and gynogenesis in plants (Datura stramonium).
4. Isolate plant protoplast by enzymatic and mechanical methods and attempt fusion by PEG (available material).
5. Culture Agrobacterium tumefaciens and attempt transformation of any dicot species.
6. Generate an RAPD and ISSR profile of Eremurus persicus and Valeriana wallichii.
7. Prepare karyotypes and study the morphology of somatic chromosomes of Allium cepa, A. sativum, A. tuberosum and compare them on basis of karyotypes.
8. Pollen mother cell meiosis and recombination index of select species (one achiasmate, and the other chiasmate) and correlate with generation of variation.
9. Undertake plant genomic DNA isolation by CTAB method and its quantitation by visual as well as spectrophotometric methods.
11. Study genetic fingerprinting profiles of plants and calculate polymorphic information content.

Semester Three

Course Objectives
The objectives of this course are to teach basic principles and characteristics of biochemical technology in environmental studies particularly water and wastewater treatment technologies. Biochemical technology in water and wastewater treatment engineering is essential in field of water treatment.

Student Learning Outcomes
On completion of this course, students should be able to learn-
• Basic principles and characteristics of biochemical technology in water and wastewater treatment;
• Composition of structures and operation characteristics;
• Technological advancements in water and wastewater treatment technology.

Unit I
Drinking water: treatment and technologies
5 lectures
Quality of source water for supply and distribution system; Microbiology of drinking water treatment; Home treatment devices and water quality; Pathogenic organisms in drinking water; Methods and monitoring of drinking water.

Unit II
Concept in water resource pollution and wastewater treatment
6 lectures
Principal forms of water pollutants and their sources; Pollution of stream, lakes and phenomenon of eutrophication; Water pollution monitoring and water quality standards; Ocean pollution – oil pollution; Ground water pollution and its control; Water pollution prevention; Biological treatment: stabilization pond, aerated lagoon, activated sludge process, trickling filter anaerobic treatment.

Unit III
Water pollution monitoring
7 lectures
Overview of standards of water in relation to public health Methods of water sampling for pollution analysis; Biological methods; Detection methods for DO, BOD, Pathogen monitoring by heterotrophic plate count; Multiple tube method; Membrane filtration methods; Other emerging techniques such as enzyme detection, hybridization, PCR, Gene probe technology etc.; Strategies for controlling pathogen transfer; Chemical methods- Detection methods for COD, pH, alkalinity, TSS, TDS, Total organic carbon, oil, grease etc.; Biosensors of pollution Biosensors - types and applications in environmental pollution detection and monitoring.

Unit IV
Effluent treatment systems
8 lectures
Sewage and waste water treatment systems; Primary, secondary and tertiary treatments; Measurement of treatment efficiencies; Biological treatments - aerobic vs. anaerobic treatments; Environmental pollution control- Bioremediation, Bioaugmentation and Biostimulation; Biofilms in treatment of waste water; Biofilm development and biofilm Kinetics; Aerobic Biofilms; Bioreactors for waste water treatments; Reactor types and design; Reactors in series; Development and optimization of membrane bioreactor process for use in sanitary and industrial sewage treatment.
Advance oxidation technologies; High rate transpiration system (HRTS); Plant assisted wastewater treatment; Physicochemical characteristics and treatment strategies for effluent generated by distillery and fermentation industry; Fertilizers and pesticide manufacturing industries; Dyes and dye intermediate producing industries and textile industries; Paper and pulp industries; Tanneries; Pharmaceuticals; Thermal power plants; Food and dairy industries; Iron and steel industries; Organic solvents; Chlorinated minerals and inorganic chemical industries and petrochemicals; Biotechnological application of hazardous waste management of water; Use of microbial systems; Phytoremediation: Waste water treatment using aquatic plants; Root zone treatment; Development of new biocatalysts to be applied in waste water biotechnology; Zero-discharge option.

Water resource assessment and management; Water security planning; water conservation in urban planning (groundwater recharge and water harvesting); grey water recycle; water-shed development.

Recommended Textbooks and References:

Course Objectives
The objective of this course is to provide sound background in all aspects related to management, technologies and treatment systems of solid and hazardous wastes.

Student Learning Outcomes
On completion of this course, students should be able to:
- Understand implications of production, resource management, and environmental impact of solid waste management;
- Understand how components of solid waste management infrastructure systems can minimise these effects;
- Be aware of significance of recycling, reuse, and reclamation of solid wastes.
### Unit I: Solid waste management
6 lectures
- Non-hazardous solid waste; Domestic solid waste; Agricultural solid waste; Municipal solid waste; Major sources of solid wastes; Effects of solid waste generation on quality of air, water and public health; Technical approach for solid waste management; Disposal of organic waste; Recovery and recycling of metallic waste and plastic waste.

### Unit II: Municipal solid waste management
6 lectures
- Basic aspects of solid waste management; Current practices in India; Aerobic and anaerobic treatments of solid wastes; Composting; Vermiculture; Biogas generation; Comparison of aerobic and anaerobic methods.

### Unit III: Biomedical waste management
6 lectures
- Overview of biomedical wastes; Types of biomedical wastes; Hazards caused by biomedical wastes; Treatment strategies for biomedical wastes.

### Unit IV: Hazardous waste management
8 lectures
- Overview of hazardous waste management; Prevention and reduction of hazardous waste, Inventory management; Recovery; Internal due diligence audit; hazardous material and waste handling and storage; Treatment of hazardous wastes; Origin, sources and treatment strategies for polychlorinated biphenyls, pesticides, toxic pollutants, polymers, Textile chemical residues etc., stabilisation of hazardous waste through landfill; incineration and pyrolysis; Heavy metal and oil spill bioremediation. Sources of heavy metal pollution; Microbial interactions with inorganic pollutants - Microbial metal resistance; Microbial transformation; Accumulation and concentration of metals; Biosorption - Biotechnology and heavy metal pollution; Oil field microbiology; Improved oil recovery; Biotechnology and oil spills; Hydrocarbon degradation.

### Unit V: Biotechnology for management of resources
8 lectures
- Resource recycle and utilization; Need for management of waste as resources; Role of environmental biotechnology in management of resources; Reclamation of wasteland; Biomass production; Biogas and biofuel production; Development of environmentally friendly processes such as integrated waste management; Biodegradation: Factors affecting process of biodegradation; Methods in determining biodegradability; Contaminant availability for biodegradation; Xenobiotics: Persistence and biomagnification of xenobiotic molecules; Microbial interactions with xenobiotics; Phase I and Phase II reactions; Cyt P 450 mediated reactions; Use of microbes (bacteria and fungi) and plants in biodegradation and Biotransformation; Bioremediation: Biotransformation and Biodegradation; Bioremediation; in situ and ex situ bioremediation; Constraints and priorities of bioremediation; Evaluating Bioremediation; Bioremediation of VOCs.

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**Recommended Textbooks and References:**

# Health, Safety and Environmental Management

## Course Objectives
This multidisciplinary course shall provide students with information on risk and safety management and occupational injury, disease prevention and environmental protection.

## Student Learning Outcomes
At the end of the course, students should be able to:
- Identify key hazards in workplace;
- Identify importance of health and safety rules;
- Design safe practices and procedures;
- Implement best-in-class standards in health and safety management.

## Credits

<table>
<thead>
<tr>
<th>Unit I</th>
<th>System analysis</th>
<th>5 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Environmental system; relationship of ecological, economic and social systems; corporate and international charters and protocols; role of chemical dynamics in aquatic systems; case studies; engineering tools for assessment and design for environment and sustainability.</td>
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</tbody>
</table>

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<tr>
<th>Unit II</th>
<th>Environmental management tools</th>
<th>5 lectures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Environmental auditing; environment risk assessment; environmental impact assessment, life cycle assessment; eco-labelling of products; performance indicators; environmental management systems particularly ISO 14000 series.</td>
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</table>

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<tr>
<th>Unit III</th>
<th>Environmental management initiatives</th>
<th>5 lectures</th>
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<tr>
<td></td>
<td>Pollution prevention and waste minimization; cleaner production; greener chemistry and cleaner technologies – green redox technologies, catalysts and bio catalysts; greener choices – eco-friendly solvents, reactants, bio-fuels and fuel cells; recycle and reuse of wastewater; sustainable and intelligent consumption; extended producer responsibility, eco-industrial development; industrial ecology.</td>
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<tr>
<th>Unit IV</th>
<th>Capacity building</th>
<th>5 lectures</th>
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<td></td>
<td>Integrated policy for production and consumption; capacity building as an integral part of corporate action; evaluation of eco-efficiency and opportunities for improvement; sustainability ratings as a driver; worldwide initiatives; Indian initiatives; capacity building framework for India; nexus between trade and environment.</td>
<td></td>
</tr>
</tbody>
</table>

## Recommended Textbooks and References:
Course Objectives
The objectives of this course are:
• To provide basic knowledge on intellectual property rights and their implications in biological research and product development;
• To become familiar with India’s IPR Policy;
• To learn biosafety and risk assessment of products derived from biotechnology and regulation of such products;
• To become familiar with ethical issues in biological research.

Student Learning Outcomes
On completion of this course, students should be able to:
• Understand the rationale for and against IPR and especially patents;
• Understand why India has adopted an IPR Policy and be familiar with broad outline of patent regulations;
• Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents;
• Gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research and environmental release of genetically modified organisms, national and international regulations;
• Understand ethical aspects related to biological, biomedical, health care and biotechnology research.

Unit I
Introduction to IPR
7 lectures
Introduction to intellectual property; types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of ‘prior art’: invention in context of “prior art”; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation.

Unit II
Patenting
5 lectures
Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure - patent application- forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting-requirement, procedures and costs; financial assistance for patenting-introduction to existing schemes; publication of patents-gazette of India, status in Europe and US; patent infringement- meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing – outright sale, licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives.

Unit III
Biosafety
5 lectures
Biosafety and Biosecurity - introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants – sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk – environmental risk assessment and food and feed safety assessment; problem formulation – protection goals, compilation
of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops vs cisgenic plants or products derived from RNAi, genome editing tools.

### Unit IV
**National and International regulations**
5 lectures

International regulations – Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations – EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – biosafety levels and category of rDNA experiments; field trails – biosafety research trials – standard operating procedures - guidelines of state governments; GM labeling – Food Safety and Standards Authority of India (FSSAI).

### Unit V
**Bioethics**
5 lectures


### Recommended Textbooks and References:

2. National IPR Policy, Department of Industrial Policy & Promotion, Ministry of Commerce, GoI
5. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/
Course Objectives
Research and business belong together and both are needed. In a rapidly developing life science industry, there is an urgent need for people who combine business knowledge with the understanding of science & technology. Bio-entrepreneurship, an interdisciplinary course, revolves around the central theme of how to manage and develop life science companies and projects. The objectives of this course are to teach students about concepts of entrepreneurship including identifying a winning business opportunity, gathering funding and launching a business, growing and nurturing the organization and harvesting the rewards.

Student Learning Outcomes
Students should be able to gain entrepreneurial skills, understand the various operations involved in venture creation, identify scope for entrepreneurship in biosciences and utilize the schemes promoted through knowledge centres and various agencies. The knowledge pertaining to management should also help students to be able to build up a strong network within the industry.

Unit I
Innovation and entrepreneurship in bio-business
8 lectures
Introduction and scope in Bio-entrepreneurship, Types of bio-industries and competitive dynamics between the sub-industries of the bio-sector (e.g. pharmaceuticals vs. Industrial biotech), Strategy and operations of bio-sector firms: Factors shaping opportunities for innovation and entrepreneurship in bio-sectors, and the business implications of those opportunities, Alternatives faced by emerging bio-firms and the relevant tools for strategic decision, Entrepreneurship development programs of public and private agencies (MSME, DBT, BIRAC, Make In India), strategic dimensions of patenting & commercialization strategies.

Unit II
Bio markets: business strategy and marketing
8 lectures
Negotiating the road from lab to the market (strategies and processes of negotiation with financers, government and regulatory authorities), Pricing strategy, Challenges in marketing in bio business (market conditions & segments; developing distribution channels, the nature, analysis and management of customer needs), Basic contract principles, different types of agreement and contract terms typically found in joint venture and development agreements, Dispute resolution skills.

Unit III
Finance and accounting
8 lectures
Business plan preparation including statutory and legal requirements, Business feasibility study, financial management issues of procurement of capital and management of costs, Collaborations & partnership, Information technology.

Unit IV
Technology management
8 lectures
Technology – assessment, development & upgradation, Managing technology transfer, Quality control & transfer of foreign technologies, Knowledge centers and Technology transfer agencies, Understanding of regulatory compliances and procedures (CDSCO, NBA, GCP, GLA, GMP).

Recommended Textbooks and References:
### Field Studies I: Monitoring of Environmental Parameters

**Course Objectives**
This course is designed to give the students hands-on experience regarding monitoring of environmental parameters as part of field studies.

**Student Learning Outcomes**
On completion of this course, students should be able to identify and appreciate the parameters for assessing environment.

**Syllabus**
Three representative samples of different environmental ecosystems and their analysis: physico-chemical characteristics such as pH, conductivity, TDS, DO, BOD, COD, CO₂, alkalinity, nutrients, chlorides, hardness, settlability of solids, zooplankton and phytoplankton and their biodiversity index analysis and contaminated soil analysis.

### Field Studies II: Bioremediation and Evaluation of Sewage/Wastewater Treatment Plant

**Course Objectives**
This course is designed to give hands-on experience on sewage/water treatment and bioremediation as part of field studies.

**Student Learning Outcomes**
At the end of this course, students should be able to come up with new ways for remediation of biological resources both biotic and abiotic in nature.

**Syllabus**
1. Study of biodiversity of microorganisms
2. Microbial degradation of textile dyes/pesticides/hydrocarbons and oils
3. Assay of enzymes involved in biotransformation
4. Effect of heavy metals on microbial growth
5. Analysis of metals
6. Effluent treatment plant (ETP): Primary, chemical and biological treatment
7. Bioreactors/Phytoreactors.
Course Objectives
The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.

Student Learning Outcomes
Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:
- In-depth knowledge of the chosen area of research.
- Capability to critically and systematically integrate knowledge to identify issues that must be addressed within framework of specific thesis.

Syllabus

Project Proposal Preparation & Presentation

Course Objectives
The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.

Student Learning Outcomes
Students should be able to demonstrate the following abilities:
- Formulate a scientific question;
- Present scientific approach to solve the problem;
- Interpret, discuss and communicate scientific results in written form;
- Gain experience in writing a scientific proposal;
- Learn how to present and explain their research findings to the audience effectively.

Syllabus

Project Proposal Preparation

Selection of research lab and research topic: Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them select a topic for their project. The topic of the research should be hypothesis driven. Review of literature: Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources. Writing Research Proposal: With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc. Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.

Syllabus

Poster Presentation

Students will have to present the topic of their project proposal after few months of their selection of the topic. They should be able to explain the novelty and importance of their research topic.

Syllabus

Oral Presentation

At the end of their project, presentation will have to be given by the students to explain work done by them in detail. Along with summarizing their findings they should also be able to discuss the future expected outcome of their work.

Semester Four

Dissertation

Course Objectives
The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.

Student Learning Outcomes
Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:
- In-depth knowledge of the chosen area of research.
- Capability to critically and systematically integrate knowledge to identify issues that must be addressed within framework of specific thesis.
Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.

**Syllabus**

**Planning & performing experiments**

Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

**Syllabus**

**Thesis writing**

At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.

**Recommended Electives**

**Genomics and Proteomics**

**Course Objectives**

The objectives of this course are to provide introductory knowledge concerning genomics & proteomics and their applications.

**Student Learning Outcomes**

Students should be able to acquire knowledge and understanding of fundamentals of genomics and proteomics, transcriptomics and metabolomics and their applications in various applied areas of biology.

**Unit I**

**Basics of genomics and proteomics**

3 lectures

Brief overview of prokaryotic and eukaryotic genome organization; extra-chromosomal DNA: bacterial plasmids, mitochondria and chloroplast.

**Unit II**

**Genome mapping**

4 lectures

Genetic and physical maps; markers for genetic mapping; methods and techniques used for gene mapping, physical mapping, linkage analysis, cytogenetic techniques, FISH technique in gene mapping, somatic cell hybridization, radiation hybrid maps, *in situ* hybridization, comparative gene mapping.
Human Genome Project, genome sequencing projects for microbes, plants and animals, accessing and retrieving genome project information from web.

Identification and classification of organisms using molecular markers- 16S rRNA typing/sequencing, SNPs; use of genomes to understand evolution of eukaryotes, track emerging diseases and design new drugs; determining gene location in genome sequence.

Aims, strategies and challenges in proteomics; proteomics technologies: 2D-PAGE, isoelectric focusing, mass spectrometry, MALDI-TOF, yeast 2-hybrid system, proteome databases.

Transcriptome analysis for identification and functional annotation of gene, Contig assembly, chromosome walking and characterization of chromosomes, mining functional genes in genome, gene function- forward and reverse genetics, gene ethics; protein-protein and protein-DNA interactions; protein chips and functional proteomics; clinical and biomedical applications of proteomics; introduction to metabolomics, lipidomics, metagenomics and systems biology.

Recommended Textbooks and References:

Course Objectives
The objectives of this course are to sensitize students about recent advances in molecular biology and various facets of molecular medicine which has potential to profoundly alter many aspects of modern medicine including the pre- or post-natal analysis of genetic diseases and identification of individuals predisposed to disease ranging from common cold to cancer.

Student Learning Outcomes
Students should be able to understand various facets of molecular procedures and basics of genomics, proteomics and metabolomics that could be employed in early diagnosis and prognosis of human diseases.

Testing DNA variation for Disease association: SNPs; Methods of typing: Traditional approaches (PCR-Sequencing), Microchips (Affymetrix) and Taqman; Microarray in analysis of gene expression; DNA microarray platforms: cDNA analysis, oligonucleotide arrays: Introduction to SAGE, CGH, array CGH and SNP arrays: Analysis of DNA methylation; Methylation in health and disease; Principle and inheritance; DNA methylation in pathology and cancer: PCR based methods in detection of methylation; Bisulphite modification and methylation specific PCR and Restriction analysis; real Time PCR methodologies (MethyLight), Profiling and arrays: Primer Designing for MSPs; Application of DNA methylation in disease diagnosis: cancer (malignancies) and imprinting disorders.

Flow Cytometry and LCM: Principle; Clinical applications: enumeration of peripheral blood cells in HIV infection and Immunophenotype Characterization in various blood disorders; Laser Capture Microdissection and separation of normal and aberrant cells: application and perspective in molecular diagnostics; Molecular Cytogenetic: Chromosomal abnormalities and indications of chromosomal evolution; Fluorescence in situ Hybridization; General procedures of FISH, M-FISH, SKY and CGH; Clinical applications of FISH: Correlation with the pathobiology of disease, disease prognosis and monitoring, correlation with molecular data; protein based molecular diagnostics: Immunoproteomics and detection methods based on Antigen-Antibody interactions; ELISA; western Blotting and Far Western Blotting applications and perspectives; Immunohistochemistry and Immunocytochemistry: Methods and interpretations: application in tumour diagnosis and infectious diseases; correlation with molecular data.

Quality assessment, pre-analytic, analytic and post analytic phases; Verification of Molecular Assays: Standards and Standardization of Molecular Diagnostics; Laboratory development of molecular diagnostics: Implementation, validation, verifications (analytical and clinical), quality control and quality assurance of the testing process; Examples of molecular diagnostics of some common genetic and non-genetic diseases (Trinucleotide Repeats: Fragile X syndrome, DMD, Endocrine disorders- Diabetes mellitus, Cystic Fibrosis, Chronic Myeloid Leukemia, Human HIV-1.

HLA Typing: HLA/MHC genetic; Molecular methods of HLA typing; PCR –Sequence specific Primers; Sequence Specific Oligonucleotide probe Hybridization, Forensic Diagnosis: DNA typing: Overview; Techniques for human identification; Evidence collection and sample preparation; PCR amplification of STR loci: Electrophoresis and data analysis: Molecular Diagnosis and Genetic Counselling: Clinical genetic services; Uses of genetic testing; components of genetic counselling process; Genetic Counselling and Genetic testing: Ethical, social and legal issues related to molecular genetic testing; Informed consent for clinical testing and research; Confidentiality and Discrimination; Gene patenting.

Recommended Textbooks and References:
Course Objectives
The course aims at providing general and broad introduction to multi-disciplinary field of nanotechnology. It will familiarize students with combination of top-down approach of microelectronics and micro-mechanics with bottom-up approach of chemistry/biochemistry; a development that is creating new and exciting cross-disciplinary research fields and technologies. The course will also give an insight into complete systems where nanotechnology can be used to improve everyday life.

Student Learning Outcomes
On successful completion of this course, students should be able to describe basic science behind the properties of materials at the nanometre scale, and the principles behind advanced experimental and computational techniques for studying nanomaterials.

<table>
<thead>
<tr>
<th>Unit I</th>
<th>Introduction to nanobiotechnology</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Credits</td>
<td>6 lectures</td>
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</tr>
<tr>
<td>Course Objectives</td>
<td>Introduction to Nanobiotechnology; Concepts, historical perspective; Different formats of nanomaterials and applications with example for specific cases; Cellular Nanostructures; Nanopores; Biomolecular motors; Bio-inspired Nanostructures, Synthesis and characterization of different nanomaterials.</td>
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<tr>
<th>Unit II</th>
<th>Nano - films</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Credits</td>
<td>5 lectures</td>
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<tr>
<td>Course Objectives</td>
<td>Thin films; Colloidal nanostructures; Self Assembly, Nanovesicles; Nanospheres; Nanocapsules and their characterisation.</td>
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<tr>
<th>Unit III</th>
<th>Nano - particles</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Credits</td>
<td>6 lectures</td>
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</tr>
<tr>
<td>Course Objectives</td>
<td>Nanoparticles for drug delivery, concepts, optimization of nanoparticle properties for suitability of administration through various routes of delivery, advantages, strategies for cellular internalization and long circulation, strategies for enhanced permeation through various anatomical barriers.</td>
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<tr>
<th>Unit IV</th>
<th>Applications of nano - particles</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Credits</td>
<td>5 lectures</td>
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<tr>
<td>Course Objectives</td>
<td>Nanoparticles for diagnostics and imaging (theranostics); concepts of smart stimuli responsive nanoparticles, implications in cancer therapy, nanodevices for biosensor development.</td>
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<tr>
<th>Unit V</th>
<th>Nano - materials</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Credits</td>
<td>6 lectures</td>
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<tr>
<td>Course Objectives</td>
<td>Nanomaterials for catalysis, development and characterization of nanobiocatalysts, application of nanoscaffolds in synthesis, applications of nanobiocatalysis in the production of drugs and drug intermediates.</td>
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<tr>
<th>Unit VI</th>
<th>Nano - toxicity</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Credits</td>
<td>5 lectures</td>
<td></td>
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<tr>
<td>Course Objectives</td>
<td>Introduction to Safety of nanomaterials, Basics of nanotoxicity, Models and assays for Nanotoxicity assessment; Fate of nanomaterials in different stratas of environment; Eco-toxicity models and assays; Life cycle assessment, containment.</td>
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</table>

Recommended Textbooks and References:
5. Recent review papers in the area of Nanomedicine.
# Course Objectives

The objective of this course is to familiarize students with several plant-based mechanisms which can be used to promote rejuvenation of surrounding environment.

# Student Learning Outcomes

Students should be able to acquire knowledge and understanding of fundamentals for dealing with plant biotechnology assisted methods for promoting rejuvenation of surrounding environment.

## Unit I

### Introduction to Plant Biotechnology

History of plant biotechnology, concept of totipotency, heterogeneity, cytodifferentiation, preparation of explant; Incubation systems: culture room, green house and shade house, advantages and limitations of each system; Tissue culture media: introduction, composition, sterilization; Role of macro and micro nutrients in plant growth and effects of their deficiency; Plant hormones: types, role in plant development & mechanism of action; Plant physiology and its significance in agriculture.

## Unit II

### Cell and Tissue Culture

Initiation, maintenance and importance of callus culture, suspension culture and single cell culture, types and applications of single cell culture, organ culture, protoplast culture and its applications, isolation and types of protoplasts fusion, seed dormancy and germination, somatic embryogenesis: its types and applications, encapsulation and production of synthetic seeds, development of somatic hybrids to overcome incompatibility barriers.

## Unit III

### Micropropagation

Anther culture and production of haploid plants and homozygous lines, embryo culture and embryo rescue, pollen, ovary culture and their applications, germplasm preservation; Micropropagation: principle, vegetative regeneration by-shoot tip, meristem, axillary and adventitious shoot initiation, organogenesis and production of pathogen free plants, hardening of tissue culture plants, industrial applications of micropropagation technique.

## Unit IV

### Agricultural Microbiology

Contributions of Beijerinck and Winogradsky-Role of microbes in carbon and nitrogen cycles-Influence of Rhizosphere on soil microorganism-various types of nitrogen fixing microorganism-Production of bacterial biofertilizers: Rhizobium, Azospirillum, Phosphobacteria etc.- Fungal biofertilizers; Ecto- and Endomycorrhizae- Azolla and BGA-

## Unit V

### Transgenic Techniques in Plant Biotechnology

Introduction of foreign gene into plants, basics of tumor formation, hairy root culture and its uses, features of Ti & Ri plasmid, mechanism of DNA transfer, role of virulence gene, use of reporter gene, multiple gene transfers, vector less or direct DNA transfer, particle bombardment, electroporation, microinjection, chloroplast transformation; Applications of plant transformation for enhancing resistance to pests, productivity & performance, nutritional value, modification of ornamental plants, bioengineered food, edible vaccines, plantbiodies, biopharming; Phytoremediation: Plants used in remediation of lands contaminated with metals, organics, and recalcitrant; Plant-plant and plant-microbe consortium for synergistic effect in remediation.

## Recommended Textbooks and References:


DBT Supported Teaching Programme

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of University</th>
<th>Contact Details of Course Coordinator</th>
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</table>
| 1.    | Shivaji University, Kolhapur | Prof. (Mrs) A. U. Arvindekar  
Deptt. of Biochemistry  
0231-2690571, 2609152 (O)  
9822840094 (M)  
aua_biochem@unishivaji.ac.in; auarvindekar@rediffmail.com. |

Annexure I

Subject Specific Subcommittee of M.Sc. Environmental Biotechnology

Chairperson
1. Dr. Shyam Asolekar, Professor, Centre for Environmental Science and Engineering, Indian Institute of Technology, Bombay

Members
2. Dr. S. Felix, Professor and Dean, Fisheries College and Research Institute, Tamil Nadu Fisheries University, Chennai
3. Dr. S. P. Govindwar, Professor, Department of Biochemistry, Shivaji University, Kolhapur
4. Dr. Hemant Purohit, Chief Scientist, National Environmental Engineering Research Institute, Nagpur
5. Dr. Sanjeev C. Ghadi, Professor, Department of Biotechnology, Goa University, Goa
6. Dr. Dilip R. Ranade, Consultant, Microbial Culture Collection, National Centre for Cell Science, Pune
7. Dr. Lidita Khandeparker, Senior Scientist, National Institute of Oceanography, Goa

Member Secretary
8. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi
M.Sc. Industrial Biotechnology
Introduction

Background

Promotion of Indian Biotechnology sector is high on policy agenda of Government of India. Biotechnology has also been recognized as one of the key priority sectors under ‘Make in India,’ ‘Skill India’ and ‘Startup India’ initiatives of Government of India, as it is one of sectors expected to contribute towards enterprise creation, innovation and economic growth. Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India has immensely contributed to this dynamism through various policies and initiatives, establishment of innovation clusters, academia-industry partnerships, increasing capabilities for technology development, etc. The National Biotechnology Development Strategy (2015 – 2020) released by DBT provides a strategic roadmap for India’s emergence as a global biotechnology innovation and manufacturing hub. It has also highlighted importance of human resource development and need for nurturing tailor-made human capital for advanced scientific research and entrepreneurship.

DBT has taken a number of initiatives aimed at integrated human resource development to evolve an ecosystem where scientists, innovators and future entrepreneurs can be nurtured. Keeping in mind requirement for trained manpower in various areas of Biotechnology, DBT initiated Post-Graduate Teaching Programme way back in 1985 with 5 universities which has expanded to 74 universities imparting M.Sc./M.Tech./M.V.Sc. degrees in general, agricultural, animal, food, environmental, industrial marine, medical, neuroscience and pharmaceutical biotechnology. 10 programmes are being phased out. These universities and institutes are provided liberal financial support towards strengthening of laboratory facilities, equipment, consumables, fellowships to students, dissertation grant per student etc. Post-Graduate Teaching Programme selects best students and trains them to join research or industry workforce contributing significantly to biotechnology workforce.

About the Course Curriculum Revision Exercise

Taking into cognizance the changing needs of the economy and to keep abreast with latest developments in the field of biotechnology, DBT proactively initiated revision of course curricula of Post-Graduate Programmes in biotechnology. The present exercise has been undertaken by Biotech Consortium India Limited (BCIL), New Delhi. Earlier exercise was carried out in 2008. The Course Curriculum Revision Exercise has been carried out for 13 Post-Graduate programmes in Biotechnology supported by DBT.

The revision of course curriculum of M.Sc. Industrial Biotechnology aims to address mismatch between ‘knowledge’ gained by students and appropriate skill set required for technology development and implementation including present contemporary needs of economy.

Methodology

A meticulous and structured approach has been adopted to accomplish the Course Curriculum Revision exercise.

BCIL had initiated the exercise with a review of literature of relevant national and international documents on curriculum design and planning for biotechnology programmes of premier national as well as international universities, guidelines by University Grants Commission, recent curricular guidelines released by Indian Council of Agricultural Research, Ministry of Health and Family Welfare and Indian Institute of Science Education & Research and other relevant research papers on curriculum development in peer-reviewed journals.
The findings of the literature review were adopted to design questionnaires for eliciting feedback from stakeholders of Biotechnology community i.e. academicians, scientists, industry representatives and students. Feedback was received from 165 experts and 20 students belonging to academic institutions, research organizations and industry regarding addition of advanced topics, deletion of elementary, redundant and overlapping topics, updation of laboratory practicals, re-adjustment of credit load, incorporating 'technology' component in the curriculum, among others. It was also suggested that re-orientation of curricula should be done keeping in view the needs of the industry.

**Strategic Approach**

A Core Committee along with 9 subject specific subcommittees comprising of 63 academicians, scientists and industry representatives were constituted to revise and update the curricula. The constitution of subject specific subcommittee for M.Sc. Industrial Biotechnology is given at Annexure-1.

The salient recommendations identified from stakeholder survey were presented to the Committee. Several brainstorming discussion sessions were held for achieving the desired balance between the foundation courses, recent developments in biotechnology and updation needs identified during the stakeholder survey. Core Committee finalized broad contours for revising all the course curricula. The guidelines set by the Core Committee were taken up by the subject specific subcommittee of M.Sc. Industrial Biotechnology for updating the curriculum. The subject specific subcommittee incorporated latest advancements in areas of Industrial Biotechnology in the curriculum. Separate meeting was held to discuss and deliberate the updations to be made in the curriculum. The revised curriculum was vetted and finalized by the Core Committee.

**Course Curriculum Revision**

The members of Committee agreed that revised course curriculum should provide skill and outcome based education and help the students to gain domain knowledge, ability to design and interpret research experiments and acquire effective communication skills. The course curriculum has been re-designed accordingly to promote skill-based and outcome-based education. The revised course curriculum totals to 100 credits comprising of theory, practical, technology-based topics, electives and dissertation. Each course includes learning objectives, student learning outcomes, course plan (number of lectures/unit) and reference textbooks/resources. Theory and practical courses include relevant examples, case scenarios and tutorials for inculcating critical thinking against rote learning. Several new courses have been included and content for existing courses has also been updated. Special emphasis on courses like Industrial Microbiology, Genetic Engineering, Fermentation Technology, Enzyme Engineering and Downstream Processing, Metabolic Engineering, OMICS Technologies and Environmental Biotechnology are part of curriculum given their importance in modern bio-manufacturing. With importance of students being able to execute research projects independently, separate credits have been allotted for proposal preparation and presentation before initiating dissertation and also credits for dissertation have been increased accordingly.

We hope that model course curriculum shall serve as guidelines for academicians and researchers from different parts of the country for adoption in their institutions with modifications as per availability of expertise, infrastructure and specific needs.

We wish to put on record our sincere appreciation for constant guidance and encouragement received from Dr. K. VijayRaghavan, Secretary, DBT for bringing out this publication. We wish to acknowledge whole-hearted support of Core Committee and subject specific subcommittees members. Sincere thanks are due to Dr. Manoj Singh Rohilla, Scientist- D, DBT, Ms. Shweta for creative design, Mrs. Rita Bhatla, DBT and Shri. Dilip Joy, BCIL.
It is my privilege to introduce the revised course structure for M.Sc Industrial Biotechnology to students and faculty members. This revision was necessitated by the feedback obtained from many stakeholders including students looking for employment in the Biotech industry as well as industrial houses wishing to employ skilled manpower in their companies. There was a sense of disconnect, where the expectations of both parties were not being met. It was felt that the training imparted to the students was inadequate to meet the problems faced in the design and operation of a modern Biotech facility. Biotechnology today, is one of the fastest growing disciplines, where everyday research ideas are being converted to novel technologies. For the Indian Biotech Industry to be globally competitive they need to assimilate these ideas and convert them into commercially viable propositions—a strategy that requires the availability of extremely competent manpower. I hope my faculty colleagues and students will rise to this challenge. This course revision is only a small step, a first among the many upgrades required to remain at the cutting edge of technology. In this work I was fortunate to get the help of many of the best minds in industry and academia. Their inputs and feedback has helped in shaping the course and making it relevant to an industrial setting. We have struggled to obtain the right balance between teaching basic concepts and introducing the latest developments, between teaching theory and providing practical hands-on training. I hope we have had a measure of success, and I request my faculty colleagues who will implement this course and most importantly the students who will study this subject, to approach it with the right mindset. Today, when almost all major breakthroughs are taking place at the interface of different disciplines, the world of Biotechnology with its diversity of specializations represents both a challenge and a wonderful opportunity—and you my students are the most well placed to make full use of it.

Prof. K.J. Mukherjee, Ph.D
School of Biotechnology
Jawaharlal Nehru University,
New Delhi, INDIA
# M.Sc. Industrial Biotechnology

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td></td>
<td><strong>SEMESTER ONE</strong></td>
<td></td>
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<tr>
<td>1</td>
<td>Microbial Biochemistry</td>
<td>3</td>
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<tr>
<td>2</td>
<td>Industrial Microbiology</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Genetic Engineering</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Bioinformatics</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Statistics</td>
<td>3</td>
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<tr>
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<td>Industrial Visit</td>
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<tr>
<td>7</td>
<td>Laboratory I: Microbial Biochemistry</td>
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</tr>
<tr>
<td>8</td>
<td>Laboratory II: Molecular Biology and Genetic Engineering</td>
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<tr>
<td>9</td>
<td>Laboratory III: Bioinformatics and Statistics</td>
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<td><strong>SEMESTER TWO</strong></td>
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<tr>
<td>1</td>
<td>Fermentation Technology</td>
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<tr>
<td>2</td>
<td>Downstream Processing</td>
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<tr>
<td>3</td>
<td>Enzyme Engineering</td>
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<td>4</td>
<td>Immunotechnology</td>
<td>3</td>
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<tr>
<td>5</td>
<td>Bioentrepreneurship</td>
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<tr>
<td>6</td>
<td>Intellectual Property Rights, Biosafety and Bioethics</td>
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<tr>
<td>7</td>
<td>Laboratory IV: Fermentation Technology</td>
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<tr>
<td>8</td>
<td>Laboratory V: Downstream Processing</td>
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<tr>
<td>9</td>
<td>Laboratory VI: Enzyme Engineering</td>
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<td><strong>TOTAL</strong></td>
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<tr>
<td></td>
<td><strong>SEMESTER THREE</strong></td>
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<tr>
<td>1</td>
<td>Animal and Plant Biotechnology</td>
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<tr>
<td>2</td>
<td>Environmental Biotechnology</td>
<td>3</td>
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<tr>
<td>3</td>
<td>Biomanufacturing Principles and Practice</td>
<td>3</td>
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<tr>
<td>4</td>
<td>Metabolic Engineering</td>
<td>3</td>
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<td>5</td>
<td>Elective</td>
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<tr>
<td>6</td>
<td>Seminar/Journal Club/ Communication Skills</td>
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<td>7</td>
<td>Laboratory VII: Cell Culture</td>
<td>4</td>
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<td>8</td>
<td>Laboratory VIII: Environmental Biotechnology</td>
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<td><strong>TOTAL</strong></td>
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<td></td>
<td><strong>SEMESTER FOUR</strong></td>
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<tr>
<td>1</td>
<td>Project in Collaboration with Industry</td>
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<td>2</td>
<td>Presentation of Project Completion</td>
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<td><strong>TOTAL</strong></td>
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<tr>
<td></td>
<td><strong>TOTAL CREDITS</strong></td>
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**Recommended Electives:**
1. Advanced Biomanufacturing
2. Computational Biology
3. Fundamentals of Technology Transfer
4. Introduction to Omics Technologies
# Semester One

## Microbial Biochemistry

**Credits**

<table>
<thead>
<tr>
<th>Course</th>
<th>Lectures</th>
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<tbody>
<tr>
<td>Microbial diversity</td>
<td>5</td>
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<tr>
<td>Introduction to biomolecules</td>
<td>3</td>
</tr>
<tr>
<td>Microbial nutrition</td>
<td>3</td>
</tr>
<tr>
<td>Cell membranes</td>
<td>4</td>
</tr>
<tr>
<td>Bio-energetic principles</td>
<td>4</td>
</tr>
<tr>
<td>Major catabolic pathways</td>
<td>4</td>
</tr>
<tr>
<td>Metabolic diversity</td>
<td>5</td>
</tr>
<tr>
<td>Microbial photosynthesis</td>
<td>4</td>
</tr>
</tbody>
</table>

### Course Objectives

The objective of this course is to give an insight in applicability of microbial biochemistry in different fields of industry.

### Student Learning Outcomes

On completion of this course, students should be able to:

- Discuss microbial signal transduction and homeostasis;
- Describe microbial genome;
- Describe mutation, mutagenesis, mutants and mutation analysis;
- Discuss molecular basis of mutations;
- Compare prokaryotic and eukaryotic genomes.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Title</th>
<th>Lectures</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Microbial diversity</td>
<td>5</td>
</tr>
<tr>
<td>II</td>
<td>Introduction to biomolecules</td>
<td>3</td>
</tr>
<tr>
<td>III</td>
<td>Microbial nutrition</td>
<td>3</td>
</tr>
<tr>
<td>IV</td>
<td>Cell membranes</td>
<td>4</td>
</tr>
<tr>
<td>V</td>
<td>Bio-energetic principles</td>
<td>4</td>
</tr>
<tr>
<td>VI</td>
<td>Major catabolic pathways</td>
<td>4</td>
</tr>
<tr>
<td>VII</td>
<td>Metabolic diversity</td>
<td>5</td>
</tr>
<tr>
<td>VIII</td>
<td>Microbial photosynthesis</td>
<td>4</td>
</tr>
</tbody>
</table>

### Unit I - Microbial diversity

Structural/physiological/biochemical differences between different basic microbial cell types, Biochemical/microscopic/molecular methods used to differentiate between archae, eubacteria and eukaryotes, Estimation of microbial biodiversity, Diversity in some ecosystems.

### Unit II - Introduction to biomolecules

Sugars - mono, di, and polysaccharides with specific reference to glycogen, amylose and cellulose, glycosylation of other biomolecules - glycoproteins and glycolipids; amino acids – structure and functional group properties, peptides and covalent structure of proteins, nucleosides, nucleotides, nucleic acids - structure, a historical perspective leading up to proposition of DNA double helical structure.

### Unit III - Microbial nutrition

Microbial nutrition, Different types of culture medium, C/N/P balance and making of culture medium.

### Unit IV - Cell membranes

Outer membrane of Gram –ve bacteria and control of its synthesis (potential targets for drug design), Different types of transport within the cell.

### Unit V - Bio-energetic principles

Oxidation-reduction reactions, Electron carriers and cellular metabolism, High energy compounds and their role in microbial fermentation, Enzymes as catalysts.

### Unit VI - Major catabolic pathways

Glycolysis, Pentose Phosphate Pathway, Citric Acid cycle, Oxidative Phosphorylation; Cellular metabolites and interconnectivity in biochemical pathways, Respiration and electron transport.

### Unit VII - Metabolic diversity

Energy from oxidation of inorganic electron donors, Methanotrophy and methylotrophy, Nitrate and Sulfate reduction, Acetogenesis, Methanogenesis, Fermentations-energetics and redox constraints, Anaerobic respiration.

### Unit VIII - Microbial photosynthesis

Chlorophylls and other pigments involved in microbial photosynthesis, Anoxygenic and oxygenic photosynthesis, Autotrophic CO₂ Fixation: Calvin cycle, Reverse Citric Acid cycle, Hydroxy-propionate cycle.
Unit IX
Microbial genetics
4 lectures
Mutations and their chemical basis, Mutagens and their use in Biotechnology, Modes of recombination, Comparative prokaryotic genomics.

Unit X
Applications of genetic engineering
6 lectures
Vectors and Expression systems (only bacteria and fungi), Case studies in microbial derived products.

Recommended Textbooks and References:

Course Objectives
The objectives of this course are-
• Equip students with theoretical and practical understanding of industrial microbiology;
• Encourage students to appreciate exploitation of microorganisms in industries as a viable alternative to use of chemicals to production of useful products.

Student Learning Outcomes
On completion of this course, students should be able to:
• Describe the main steps and processes used to produce biological products in industry;
• Discover new useful microorganisms and store them reliably for later use;
• Evaluate which molecular techniques are applicable to improve production.

Unit I
Characteristics of microbes
4 lectures
Introduction to Microbiology and Microbes, Morphology, Structure and Growth, Bacterial and other Microbial growth curves.

Unit II
Isolation of microbes from nature and screening of biological activities
4 lectures
Actinomycetes, Bacteria, Fungi, Developing and Semi-automating Screening Tests.

Unit III
Culture preservation and inoculum development
4 lectures
Culture Preservation, Cryopreservation, Inoculum Development.

Unit IV
Small scale liquid fermentation
5 lectures
Introduction and Scope, Fermentation Vessels, Shakers, Media /Composition and Gas Exchange, Sampling and Analysis.

Unit V
Small scale solid state fermentation
4 lectures

Different types of Immobilizations (entrapment, cross linking, covalent etc.), Performance and case studies.

Recombinant Methods, Non recombinant (Mutagenesis, fusion, recombination etc.), Operational Conditions, Statistical analysis.

GMD's for Culture and Assays, Open GMD's, Closed GMD's.

Culture strategies and Challenges, Preservation, Batch and Continuous cultivation etc.

Recommended Textbooks and References:

Course Objectives
The objectives of this course are to teach various approaches to conducting genetic engineering and its applications in biological research as well as in biotechnology industries.

Student Learning Outcomes
Given the impact of genetic engineering in modern society, students should be endowed with strong theoretical knowledge of this technology. In conjunction with the practicals in molecular biology & genetic engineering, the students should be able to take up biological research as well as placement in the relevant biotech industry.

Impact of genetic engineering in modern society; general requirements for performing a genetic engineering experiment; restriction endonucleases and methylases; DNA ligase, Klenow enzyme, T4 DNA polymerase, polynucleotide kinase, alkaline phosphatase; cohesive and blunt end ligation; linkers; adaptors; homopolymer tailing; labelling of DNA: nick translation, random priming, radioactive and non-radioactive probes,
hybridization techniques: northern, southern, south-western and far-western and colony hybridization, fluorescence in situ hybridization.

Unit II

Different types of vectors
7 lectures

- Plasmids; Bacteriophages; M13mp vectors; pUC19 and pBluescript vectors, phagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Principles for maximizing gene expression vectors; pMal; GST; pET-based vectors; Protein purification; His-tag; GST-tag; MBP-tag etc.; Intein-based vectors; Inclusion bodies; methodologies to reduce formation of inclusion bodies; mammalian expression and replicating vectors; Baculovirus and Pichia vectors system, plant based vectors, Ti and Ri as vectors, yeast vectors, shuttle vectors.

Unit III

Different types of PCR techniques
7 lectures

- Principles of PCR: primer design; fidelity of thermostable enzymes; DNA polymerases; types of PCR – multiplex, nested; reverse-transcription PCR, real time PCR, touchdown PCR, hot start PCR, colony PCR, asymmetric PCR, cloning of PCR products; TA cloning vectors; proof reading enzymes; PCR based site specific mutagenesis; PCR in molecular diagnostics; viral and bacterial detection; sequencing methods; enzymatic DNA sequencing; chemical sequencing of DNA; automated DNA sequencing; RNA sequencing; chemical synthesis of oligonucleotides; mutation detection: SSCP, DGGE, RFLP.

Unit IV

cDNA analysis
7 lectures

- Insertion of foreign DNA into host cells; transformation, electroporation, transfection; construction of libraries; isolation of mRNA and total RNA; reverse transcriptase and cDNA synthesis; cDNA and genomic libraries; construction of microarrays – genomic arrays, cDNA arrays and oligo arrays; study of protein-DNA interactions: electrophoretic mobility shift assay; DNase footprinting; methyl interference assay, chromatin immunoprecipitation; protein-protein interactions using yeast two-hybrid system; phage display.

Unit V

Gene silencing and genome editing technologies
13 lectures

- Gene silencing techniques; introduction to siRNA; siRNA technology; Micro RNA; construction of siRNA vectors; principle and application of gene silencing; gene knockouts and gene therapy; creation of transgenic plants; debate over GM crops; introduction to methods of genetic manipulation in different model systems e.g. fruit flies (Drosophila), worms (C. elegans), frogs (Xenopus), fish (zebra fish) and chick; Transgenics - gene replacement; gene targeting; creation of transgenic and knock-out mice; disease model; introduction to genome editing by CRISPR-CAS with specific emphasis on Chinese and American clinical trials; Cloning genomic targets into CRISPR/Cas9 plasmids; electroporation of Cas9 plasmids into cells; purification of DNA from Cas9 treated cells and evaluation of Cas9 gene editing; in vitro synthesis of single guide RNA (sgRNA); using Cas9/sgRNA complexes to test for activity on DNA substrates; evaluate Cas9 activity by T7E1 assays and DNA sequence analysis; Applications of CRISPR/cas9 technology. Applications gene therapy/gene editing - antiviral strategies, cancer immunotherapy, hematologic disorders, liver-targeted gene editing, neuromuscular disorders, ocular disorders etc., examples of Chinese and American clinical trials.

Recommended Textbooks and References:

5. Technical Literature from Stratagene, Promega, Novagen, New England Biolabs.
<table>
<thead>
<tr>
<th>Course Objectives</th>
<th>Student Learning Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>The objective of this course is to introduce students to statistical methods and to understand underlying principles, as well as practical guidelines of “how to do it” and “how to interpret it” statistical data.</td>
<td>On completion of this course, students should be able to:</td>
</tr>
<tr>
<td>• Understand how to summarise statistical data;</td>
<td>• Apply appropriate statistical tests based on an understanding of the study question, type of study and type of data;</td>
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<tr>
<td>• Interpret results of statistical tests.</td>
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<table>
<thead>
<tr>
<th>Unit I</th>
<th>Introduction</th>
<th>5 lectures</th>
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</thead>
<tbody>
<tr>
<td>Types of biological data (ordinal scale, nominal scale, continuous and discrete data), frequency distribution and graphical representations (bar graph, histogram, box plot and frequency polygon), cumulative frequency distribution, populations, samples, simple random, stratified and systematic sampling.</td>
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<table>
<thead>
<tr>
<th>Unit II</th>
<th>Descriptive statistics</th>
<th>5 lectures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measures of Location, Properties of Arithmetic Mean, median, mode, range, Properties of Variance and Standard Deviation, Coefficient of Variation, Grouped Data, Graphic Methods, Obtaining Descriptive Statistics on Computer, Case study.</td>
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<thead>
<tr>
<th>Unit III</th>
<th>Probability and distribution</th>
<th>4 lectures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to probability and laws of probability, Random Events, Events-exhaustive, Mutually exclusive and equally likely (with simple exercises), Definition and properties of binomial distribution, poisson distribution and normal distribution.</td>
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<thead>
<tr>
<th>Unit IV</th>
<th>Correlation and regression analysis</th>
<th>6 lectures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation, Covariance, calculation of covariance and correlation, Correlation coefficient from ungrouped data Spearson’s Rank Correlation Coefficient, scatter and dot diagram, General Concepts of regression, Fitting Regression Lines, regression coefficient, properties of Regression Coefficients, Standard error of estimate.</td>
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<thead>
<tr>
<th>Unit V</th>
<th>Statistical hypothesis testing</th>
<th>4 lectures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Making assumption, Null and alternate hypothesis, error in hypothesis testing, confidence interval, one-tailed and two-tailed testing, decision making.</td>
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<thead>
<tr>
<th>Unit VI</th>
<th>Tests of significance</th>
<th>8 lectures</th>
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</thead>
<tbody>
<tr>
<td>Steps in testing statistical significance, selection and computation of test of significance and interpretation of results; Sampling distribution of mean and standard error, Large sample tests (test for an assumed mean and equality of two population means with known S.D.), z-test; Small sample tests (t-test for an assumed mean and equality of means of two populations when sample observations are independent); Parametric and Non parametric tests (Mann-Whitney test); paired and unpaired t-test, chi square test.</td>
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<table>
<thead>
<tr>
<th>Unit VII</th>
<th>Experimental designs</th>
<th>8 lectures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to study designs: Longitudinal, cross-sectional, retrospective and prospective study, Principles of experimental designs, Randomized block, and Simple factorial designs, Analysis of variance (ANOVA) and its use in analysis of RBD, introduction to meta-analysis and systematic reviews, ethics in statistics.</td>
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</table>

| Recommended Textbooks and References: |
# Bioinformatics

**Course Objectives**
The objectives of this course are to provide students with theory and practical experience of use of common computational tools and databases which facilitate investigation of molecular biology and evolution-related concepts.

**Student Learning Outcomes**
Student should be able to:
- Develop an understanding of basic theory of these computational tools.
- Gain working knowledge of these computational tools and methods.
- Appreciate their relevance for investigating specific contemporary biological questions.

## Unit I: Biological databases

5 lectures

- Introduction, Primary & Secondary database
- Sequence file formats, Introduction to structures
- Protein Data Bank (PDB), Molecular Modelling Database (MMDb)
- Structure file formats, Visualizing structural information
- Database of structure viewers, Collection of sequences, sequence annotation, sequence description.

## Unit II: Sequence alignment and database searching

5 lectures

- Evolutionary basis of sequence alignment
- Optimal alignment methods, Substitution scores & gap penalties
- Statistical significance of alignments, Database similarity searching
- FASTA, BLAST, Low complexity regions, Repetitive elements
- Multiple Sequence Alignment: Progressive alignment methods
- Motifs and patterns, Clustral, Muscle; Scoring matrices, Distance matrices.

## Unit III: Phylogenetic analysis

5 lectures

- Alignment, tree building and tree evaluation
- Comparison and application of Unweighted Pair Group Method with Arithmetic Mean (UPGMA), Neighbour Joining (NJ), Maximum Parsimony (MP), Maximum Likelihood (ML) methods
- Bootstrapping, Jackknife; Software for Phylogenetic analysis
- DNA barcoding: Methods tools and databases for barcoding across all species, Applications and limitations of barcoding
- Consortium for Barcode of Life (CBOL) recommendations
- Barcode of Life Database (BOLD)

## Unit IV: Structural biology

5 lectures

- 3-D structure visualization and simulation
- Basic concepts in molecular modeling: different types of computer representations of molecules; External coordinates and Internal Coordinates, Molecular Mechanics, Force fields etc.
- Secondary structure elucidation using Peptide bond, phi, psi and chi torsion angles, Ramachandran map
- Anatomy of proteins – Hierarchical organization of protein structure – like CATH (class, architecture, topology, homology), SCOP (Structural Classification of Proteins), FSSP (families of structurally similar proteins).

## Unit V: Classification and comparison of 3D structures

5 lectures

- DNA & RNA secondary and tertiary structures, t-RNA tertiary structure
- Protein Secondary structure prediction: Algorithms viz. Chou Fasman, GOR methods
- Tertiary Structure prediction: Fundamentals of the methods for 3D structure prediction (sequence similarity/identity of target proteins of known structure, fundamental principles of protein folding etc.)
- Homology/comparative modeling, fold recognition, threading approaches, and ab initio structure prediction methods
- CASP (Critical Assessment of protein Structure Prediction)
- Computational design of promoters, proteins & enzymes.
## Unit VI
### Applications in drug design
5 lectures
- Chemical databases like NCI/PUBCHEM; Fundamentals of Receptor-ligand interactions;
- Structure-based drug design: Identification and Analysis of Binding sites and virtual screening; Ligand based drug design: Structure Activity Relationship – QSARs & Pharmacophore; *In silico* predictions of drug activity and ADMET.

## Unit VII
### Analysis of microarray data
5 lectures
- Designing of oligo probes; Image processing and normalization; Microarray data variability (measurement ad quantification); Analysis of differentially expressed genes; Experimental designs.

## Unit VIII
### Biological algorithms
2 lectures
- Comparison with computer algorithms, string structures, Introduction to programming in computational biology through C/ Perl / Java.

## Unit IX
### Systems biology
3 lectures
- System-level understanding of biological systems, use and integration of data from transcriptomics, proteomics and metabolomics; concepts in glycomics, interactomics and fluxomics.

## Recommended Textbooks and References:
4. Dov Stekel, (2003); Microarray Bioinformatics; Cambridge University Press.
5. Web-resources and suggested reviews/ research papers.

## Laboratory I: Microbial Biochemistry
### Credits
2

**Course Objectives**
The objective of this laboratory course is to learn how to handle cells, culture them, prepare mutants, do biochemical analysis of proteins, primary and secondary metabolites.

**Student Learning Outcomes**
On completion of this course, students should be able to:
- Isolate, characterize, and classify microorganisms;
- Discuss microbial signal transduction and homeostasis;
- Identify various microbes;
- Estimate amount of various biochemical contents in the microbes.

### Syllabus
1. Identify Bacteria, Yeasts, Filamentous fungi, Actinomycetes by Microscopy, Cultivate Bacteria and Other Microbes in Liquid Culture and Solid Media
2. Isolation of Pure Cultures by Streaking
3. Isolation of Auxotrophic Mutants of Bacteria, Replica Plating
4. Antimicrobial Sensitivity and Demonstration of Drug Resistance
5. Estimation of Lipids
6. Estimation of Carbohydrates
7. Estimation of Proteins (Bradford, Lowry's Method)
8. Estimation of alcohol, Acetic Acid by Gas chromatography
9. Isolation of Carotenoids (and lipids) and Analysis by Thin Layer Chromatography (TLC)
10. Isolation of Secondary Metabolites and analysis by TLC
Laboratory II: Molecular Biology and Genetic Engineering

Course Objectives
The objectives of this course are to provide students with the experimental knowledge of molecular biology and genetic engineering.

Student Learning Outcomes
Students should be able to gain hands-on experience on gene cloning, protein expression and purification. This experience would enable them to begin a career in industry.

Credits
4

Syllabus

1. Concept of lac-operon:
   a) lactose induction of β-galactosidase.
   b) Glucose Repression.
   c) Diauxic growth curve of *E. coli*.
2. UV mutagenesis to isolate amino acid auxotroph.
4. Genetic Transfer-Conjugation, gene mapping.
5. Plasmid DNA isolation and DNA quantitation.
6. Restriction Enzyme digestion of plasmid DNA.
7. Agarose gel electrophoresis.
8. Polymerase Chain reaction.
9. DNA Ligation.
11. Transformation of *E.coli* with standard plasmids, Calculation of transformation efficiency.
12. Confirmation of the insert by Colony PCR and Restriction mapping
13. Expression of recombinant protein, concept of soluble proteins and inclusion body formation in *E.coli*, SDS-PAGE analysis
14. Purification of His-Tagged protein on Ni-NTA columns
   a) Random Primer labeling
   b) Southern hybridization.

Recommended Textbooks and References:


Recommended Textbooks and References:

Laboratory III: Bioinformatics and Statistics

Course Objectives
The aim is to provide practical training in bioinformatics and statistical methods including accessing major public sequence databases.

Student Learning Outcomes
On completion of this course, students should be able to:

- Describe contents and properties of important bioinformatics databases, perform text- and sequence-based searches and analyse and discuss results in light of molecular biological knowledge;
- Explain major steps in pairwise and multiple sequence alignment, explain its principles and execute pairwise sequence alignment by dynamic programming;
- Predict secondary and tertiary structures of protein sequences;
- Perform and analyse various statistical tools available to analyse data.

Syllabus

1. Using NCBI and Uniprot web resources.
2. Introduction and use of various genome databases.
4. Similarity searches using tools like BLAST and interpretation of results.
5. Multiple sequence alignment using ClustalW.
7. Use of gene prediction methods (GRAIL, Genscan, Glimmer).
8. Using RNA structure prediction tools.
9. Use of various primer designing and restriction site prediction tools.
10. Use of different protein structure prediction databases (PDB, SCOP, CATH).
11. Construction and study of protein structures using Deepview/PyMol.
13. Use of tools for mutation and analysis of energy minimization of protein structures.
14. Use of miRNA prediction, designing and target prediction tools.
15. Use of Statistical packages like SPSS (Statistical Package for Social Sciences)/SAS (Statistical Analysis System) & Maple.
16. MATLAB (Matrix Laboratory).
17. Performing various statistical analysis like T-test, ANOVA, Regression, Chi-square, PLS (Partial Least Squares) and PCA (Principle Component Analysis).

Semester Two

Fermentation Technology

Course Objectives
This course provides an understanding of exploitation of microorganisms and other cell lines in manufacture of therapeutic, diagnostic and bulk commodity biological products.

Student Learning Outcomes
On successful completion of this course, students should be able to:

- Gain understanding of variety of fermentation and subsequent processing approaches available for manufacture of biological products and design and operation of these systems;
- Appreciate regulatory framework of biopharmaceutical industry.
### Unit I
**Reaction engineering**  
5 lectures  
Homogeneous reactions Basic reaction theory, calculation of reaction rates, general reaction kinetics for biological systems, yields in cell culture, cell growth kinetics, production kinetics, kinetics of cell death; Continuous stirred tank reactor as a tool for calculating kinetic parameters of growth and product formation; Concept of maintenance and calculation of maintenance coefficient.

### Unit II
**Process initialization**  
5 lectures  
Types of sterilization, thermal death kinetics of microorganism; Heat sterilization of liquid medium in batch and continuous mode; Air sterilization; Inoculum development; Various types of fermentation, submerged and solid state fermentation, aerobic and anaerobic fermentation; Overview of biosynthetic mechanisms; Metabolic stoichiometry.

### Unit III
**Reactor engineering**  
5 lectures  
Bioreactor configurations, practical considerations for bioreactor construction, monitoring and control of bioreactors, ideal reactor operations, batch operation of a mixed reactor.

### Unit IV
**Bioprocess scale up**  
5 lectures  
Heat and mass transfer issues in bioreactors, Estimation of KLa, Scale up with constant parameters like oxygen transfer rate, mixing, shear stress, flow regime, Reactor volume, etc. Scale-up methods by currently used rules-of-thumb viz. constant P/V, kLa, Various approaches to scale-up including regime analysis and scale-down; Analysis of alternate bioreactor configurations including cell-recycle, air-lift and immobilized-cell bioreactors, Problems on scale-up methods.

### Unit V
**Commercial product processing**  
5 lectures  
Bulk organics (ethanol), Biomass (Bakers Yeast), Organic acids (Citric Acid), Amino Acids (L-Lysine), Microbial Transformations (Steroids), Antibiotics (Penicillin), Extra Cellular Polysaccharides (Xanthan Gum), Nucleotides (5-GMP), Vitamins (B12), Pigments (Shikonin).

### Unit VI
**Process technology**  
5 lectures  
Production of cell biomass and some primary metabolites, e.g. ethanol, acetone-butanol, citric acid, dextran and amino acids; Microbial production of industrial enzymes-glucose isomerase, cellulase & lipases.

### Unit VII
**Bioconversions**  
5 lectures  
Applications of bioconversion, transformation of steroids and sterols; Transformation of non-steroidal compounds, antibiotics and pesticides; Bioenergy-fuel from biomass, production and economics of biofuels.

### Unit VIII
**Biosafety and Biosecurity**  
5 lectures  
Biological Risk Assessment, Laboratory Biosafety Level 1 to 4, Animal Biosafety for recombinant research, Biosecurity, development of biosecurity program, Containment for biohazards.

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**Recommended Textbooks and References:**

### Course Objectives
The objective of this course is to provide an overview of various aspects of recovery and processing of biological products.

### Student Learning Outcomes
Students should be able to identify and design relevant unit operations for recovery of biological products.

### Unit I
**Screening and design purification strategies**
5 lectures
Overview of down-stream processing, Establishment of design space for biopharmaceutical process, High-throughput process development, Media selection in ion-exchange chromatography in single microplate, high-throughput screening of dye-ligand for chromatography.

### Unit II
**Low-resolution protein purification methods**
7 lectures
Aqueous two phase partitioning systems, A platform for isolation of process related impurities from therapeutic proteins, Simultaneous purification refolding of protein by affinity precipitation and macro (Affinity ligand)-facilitated three-phase partitioning (MLFTPP), Co-expression and co-purification of antigen-antibody complexes in bacterial cytoplasm and periplasm, immunoglobulin purification by caprylic acid; Filtration, chromatography (comparison), rationale of choosing between quality and cost of different products.

### Unit III
**Protein purification and characterization**
6 lectures
Introduction, initial recovery of proteins, removal of whole cells and cell debris, concentration and primary purification, protein inactivation and stabilization, protein characterization.

### Unit IV
**Large scale protein purification**
3 lectures
Some general principles, range and medical significance of impurities potentially present in protein based therapeutic products, labeling and packing of finished products.

### Unit V
**Animal based products**
4 lectures
General DSP, Case studies of: monoclonal antibodies, Tissue plasminogen activator, insulin, erythropoietin.

### Unit VI
**Plant based products**
3 lectures
General DSP, Case studies of: shikonin, Protein extracts from Seed material and green tissues.

### Unit VII
**Microbial based products**
3 lectures
General DSP, Case studies of: lipase, cellulose, amylase, horse radish peroxidase, subtilisin, ethanol, citric acid, xanthan gum.

### Recommended Textbooks and References:
## Course Objectives
This course will enable students to understand concepts in enzymology and enzyme techniques.

## Student Learning Outcomes
On completion of this course, students should be able to:
- Gain clear understanding in isolation, purification and characterization of enzymes;
- Understand enzyme engineering technologies.

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<thead>
<tr>
<th>Unit</th>
<th>Title</th>
<th>Lectures</th>
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<tbody>
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<td>I</td>
<td>Introduction to enzymes</td>
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<tr>
<td>II</td>
<td>Specificity and mechanism of enzyme action</td>
<td>6</td>
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<td>III</td>
<td>Enzyme kinetics</td>
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<td>IV</td>
<td>Immobilization of enzymes</td>
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<td>V</td>
<td>Industrial applications of enzymes</td>
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<tr>
<td>VI</td>
<td>Industrial enzymes</td>
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<td>VII</td>
<td>Additional industrial enzymes</td>
<td>5</td>
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<tr>
<td>VIII</td>
<td>Enzyme Engineering</td>
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</tbody>
</table>

### Unit I: Introduction to enzymes
- What are enzymes,
- Brief history of enzymes,
- Nomenclature and classification of enzymes,
- Properties of enzymes,
- Structure of enzymes,
- Active site of enzymes,
- Factors influencing enzyme activity,
- Enzyme assays.

### Unit II: Specificity and mechanism of enzyme action
- Types of specificity,
- Koshland “induced fit” hypothesis,
- Strain or transition – state stabilization hypothesis;
- Mechanism of catalysis,
- Mechanism of reaction catalyzed by enzyme without cofactors,
- Metal-activated enzyme and metalloenzyme,
- Coenzymes in enzyme catalyzed reactions.

### Unit III: Enzyme kinetics
- Kinetics of enzyme-catalyzed reaction,
- Methods for investigating kinetics of enzyme-catalyzed reactions,
- Interpretation of Km, Vmax, Turnover number and Kcat,
- Specific activity of enzymes,
- Enzyme units,
- Inhibition of enzyme activity,
- Regulation of enzyme activity.

### Unit IV: Immobilization of enzymes
- Concept,
- Methods of immobilization,
- Kinetics of immobilized enzymes,
- Effects of immobilization on enzymes,
- Use of immobilized enzymes,
- Bioreactors using immobilized enzyme.

### Unit V: Industrial applications of enzymes
- Industrial enzymes:
  - Sales value of industrial enzymes,
  - Traditional (non-recombinant) sources of industrial enzymes,
  - Impact of genetic engineering on enzyme production,
  - Engineered enzymes,
  - Extremophiles: hyperthermophiles,
  - Enzymes from hyperthermophiles,
  - Enzymes from additional extremophiles,
  - Enzymes in organic solvents.

### Unit VI: Industrial enzymes
- Proteases and Carbohydrases,
- Proteolytic enzymes: Carbohydrases,
- Lignocellulose degrading enzymes,
- Pectin and Pectic enzymes.

### Unit VII: Additional industrial enzymes
- Lipases,
- Penicillin acylase,
- Amino acylase and Amino acid production,
- Cyclodextrins and cyclodextrin glycosyl transferase,
- Enzymes in animal nutrition,
- Enzymes in molecular biology; Clinical applications of enzymes.

### Unit VIII: Enzyme Engineering
- Prediction of enzyme structure,
- Design and construction of novel enzymes.

### Recommended Textbooks and References:
Course Objectives
The objectives of this course are to learn about structural features of components of immune system as well as their function. The major emphasis of this course will be on development of immune system and mechanisms by which our body elicit the immune response. This will be imperative for students as it will help them to think like an immunologist and predict about nature of immune response that develops against bacterial, viral or parasitic infection, and prove it by designing new experiments.

Student Learning Outcomes
On completion of this course, students should be able to:
• Evaluate the usefulness of immunology in different pharmaceutical companies;
• Identify the proper research lab working in the area of their own interests;
• Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out the kind of immune responses in the setting of infection (viral or bacterial) by looking at cytokine profile.

Unit I
Lymphocyte maturation and cell-mediated immune response
9 lectures
Components of innate and acquired immunity; Important organs and cells of immune responses, complement and inflammatory responses; pathogen recognition receptors (PRR) and pathogen associated molecular pattern (PAMP); innate immune response; mucosal immunity; antigens - immunogens, haptons; Major histocompatibility complex (MHC) genes, Role of MHC in infectious diseases and disease susceptibility, HLA typing; Immunoglobulins-basic structure, classes & subclasses of immunoglobulins, antigenic determinants; multigene organization of immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; principles of cell signaling; basis of self & non-self discrimination; kinetics of immune response, memory; B cell maturation, activation and differentiation; generation of antibody diversity; T-cell maturation, activation and differentiation and T-cell receptors; functional T Cell subsets; cell-mediated immune responses, ADCC; cytokines-properties, receptors and therapeutic uses; antigen processing and presentation- endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens; cell-cell co-operation.

Unit II
Antigen-antibody interactions
8 lectures
Precipitation, agglutination and complement mediated immune reactions; advanced immunological techniques - RIA, ELISA, Western blotting, T cell epitope prediction and ELISPOT assay, immunofluorescence, flow cytometry and immunoelectron microscopy; surface plasmon resonance, biosenor assays for assessing ligand–receptor interaction, CMI techniques- lymphoproliferation assay, mixed lymphocyte reaction, cell cytotoxicity assays, apoptosis, microarrays, transgenic mice, gene knock outs, Hybridoma and monoclonal antibodies, Applications of monoclonal antibodies; HLA-tetramer complex, Application of HLA-tetramer complex in analyzing antigen/peptide –specific T cell responses using flow cytometer.

Unit III
Vaccinology
7 lectures
Active and passive immunization; live, killed, attenuated, subunit vaccines; vaccine technology- role and properties of adjuvants, recombinant DNA and protein based vaccines, reverse vaccinology; peptide vaccines, conjugate vaccines; antibody genes and antibody engineering- chimeric, hybrid monoclonal antibodies; catalytic antibodies and
generation of immunoglobulin gene libraries, idiotypic vaccines and marker vaccines, viral-like particles (VLPs), dendritic cell based vaccines, vaccine against cancer, T cell based vaccine, edible vaccine and therapeutic vaccine; Success stories in vaccinology e.g. Hepatitis, Polio, Small pox, DPT.

Immunity to infection: bacteria, viral, fungal and parasitic infections (Tuberculosis, HIV/AIDS, Schistosomiasis, Kala Azar, Chickungunya, Dengue); hypersensitivity reactions—Type I-IV; autoimmunity; types of autoimmune diseases; mechanism and role of CD4+ T cells; MHC and TCR in autoimmunity; transplantation —immunological basis of graft rejection; clinical transplantation and immunosuppressive therapy; tumor immunology – tumor antigens; immune response to tumors and tumor evasion of the immune system, cancer immunotherapy; immunodeficiency—primary immunodeficiencies, acquired or secondary immunodeficiencies, anaphylactic shock; immunosenescence: a challenge for an aging population; Immune exhaustion in the setting of chronic infections and malignancies; chronic Inflammation (Inflamming) and immune activation; mucosal immunity and Gut Associated Lymphoid Tissue (GALT) in various gastrointestinal (GI) infections; complement deficiencies and human health; role of regulatory B cells (Bregs) in human disease. Monoclonal antibodies and their therapeutic role in reversing T cell functionality, Fab, F(ab)2 fragments; single-chain variable fragment (scFv), A trifunctional antibody; Bi-specific T-cell engagers (BiTEs) as artificial bispecific monoclonal antibodies for the use as anti-cancer drug.

Recommended Textbooks and References:

Course Objectives
Research and business belong together and both are needed. In a rapidly developing life science industry, there is an urgent need for people who combine business knowledge with the understanding of science & technology. Bio-entrepreneurship, an interdisciplinary course, revolves around the central theme of how to manage and develop life science companies and projects. The objectives of this course are to teach students about concepts of entrepreneurship including identifying a winning business opportunity, gathering funding and launching a business, growing and nurturing the organization and harvesting the rewards.

Student Learning Outcomes
Students should be able to gain entrepreneurial skills, understand the various operations involved in venture creation, identify scope for entrepreneurship in biosciences and utilize the schemes promoted through knowledge centres and various agencies. The knowledge pertaining to management should also help students to be able to build up a strong network within the industry.
Introduction and scope in Bio-entrepreneurship, Types of bio-industries and competitive dynamics between the sub-industries of the bio-sector (e.g. pharmaceuticals vs. Industrial biotech), Strategy and operations of bio-sector firms: Factors shaping opportunities for innovation and entrepreneurship in bio-sectors, and the business implications of those opportunities, Alternatives faced by emerging bio-firms and the relevant tools for strategic decision, Entrepreneurship development programs of public and private agencies (MSME, DBT, BIRAC, Make In India), strategic dimensions of patenting & commercialization strategies.

Negotiating the road from lab to the market (strategies and processes of negotiation with financers, government and regulatory authorities), Pricing strategy, Challenges in marketing in bio business (market conditions & segments; developing distribution channels, the nature, analysis and management of customer needs), Basic contract principles, different types of agreement and contract terms typically found in joint venture and development agreements, Dispute resolution skills.

Business plan preparation including statutory and legal requirements, Business feasibility study, financial management issues of procurement of capital and management of costs, Collaborations & partnership, Information technology.

Technology – assessment, development & upgradation, Managing technology transfer, Quality control & transfer of foreign technologies, Knowledge centers and Technology transfer agencies, Understanding of regulatory compliances and procedures (CDSCO, NBA, GCP, GLA, GMP).

Recommended Textbooks and References:
# Intellectual Property Rights, Biosafety and Bioethics

**Credits** 3

## Course Objectives
The objectives of this course are:
- To provide basic knowledge on intellectual property rights and their implications in biological research and product development;
- To become familiar with India's IPR Policy;
- To learn biosafety and risk assessment of products derived from biotechnology and regulation of such products;
- To become familiar with ethical issues in biological research.

## Student Learning Outcomes
On completion of this course, students should be able to:
- Understand the rationale for and against IPR and especially patents;
- Understand why India has adopted an IPR Policy and be familiar with broad outline of patent regulations;
- Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents;
- Gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research and environmental release of genetically modified organisms, national and international regulations;
- Understand ethical aspects related to biological, biomedical, health care and biotechnology research.

## Units

### Unit I
**Introduction to IPR**
5 lectures

Introduction to intellectual property; types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of ‘prior art’: invention in context of “prior art”; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation.

### Unit II
**Patenting**
5 lectures

Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure - patent application - forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting-requirement, procedures and costs; financial assistance for patenting-introduction to existing schemes; publication of patents-gazette of India, status in Europe and US; patent infringement- meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing – outright sale, licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives.

### Unit III
**Biosafety**
5 lectures

Biosafety and Biosecurity - introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants – sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk – environmental risk assessment and
food and feed safety assessment; problem formulation – protection goals, compilation of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops vs cisgenic plants or products derived from RNAi, genome editing tools.

Unit IV
National and international regulations
5 lectures

International regulations – Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations – EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – biosafety levels and category of rDNA experiments; field trails – biosafety research trials – standard operating procedures - guidelines of state governments; GM labeling – Food Safety and Standards Authority of India (FSSAI).

Unit V
Bioethics
5 lectures


Recommended Textbooks and References:

2. National IPR Policy, Department of Industrial Policy & Promotion, Ministry of Commerce, GoI
5. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/
### Laboratory IV: Fermentation Technology

**Course Objectives**
This laboratory course provides students with opportunity to gain hands on wine making experience that expands on areas of fermentation technology.

**Student Learning Outcomes**
On successful completion of this course, students should:
- Become familiar with operation of fermentation machinery;
- Develop understanding of necessity for routine chemical, sensory and microbiological analyses during the wine making process.

**Syllabus**
1. Assembly of bioreactors
2. Sterilization
3. Calibration of Probes (pH and Dissolved Oxygen)
4. Understanding control
5. Controller tuning
6. Cascade control of Dissolved Oxygen
7. Growth of control
8. Batch/Fed batch with concentrated feed
9. Continuous Stirred Tank Reactor running at different dilution rates
10. Estimation of Growth/Product formation & Substrate utilization kinetics
11. Estimation of Kla by dynamic gasing out and gas balancing.

### Laboratory V: Downstream Processing

**Course Objectives**
The objectives of this course are to provide students with hands on knowledge of the primary unit operations involved in downstream processing.

**Student Learning Outcomes**
Students should be able to gain hands-on experience on approaches to cell disruption, centrifugation, filtration, and precipitation.

**Syllabus**
1. Conventional filtration
2. Centrifugation in batch and continuous centrifuge
3. Cell disruption
4. Protein precipitation and its recovery
5. Ion-exchange chromatography
6. Membrane based filtration-ultra filtration in cross flow modules and micro filtration
7. Adsorption process in batch and continuous mode.

### Recommended Textbooks and References:
## Laboratory VI: Enzyme Engineering

### Course Objectives
This course will provide hands on experience of various enzyme purification techniques along with enzyme quantification techniques.

### Student Learning Outcomes
On completion of this course, students should be able to:
- Understand the underlying principles of enzyme purification;
- Purify an enzyme using various chromatography techniques;
- Estimate the purity of enzymes.

### Syllabus

1. Purification of enzyme by Ion Exchange (anion and cation), gel filtration and Hydrophobic Interaction Chromatography
2. Immobilization by entrapment and surface immobilization
3. Running of immobilization energy column
4. Estimation of mass transfer effect (diffusion control reaction, Enzyme pellet efficiency, comparison with free enzyme system)
5. Estimation of stability of enzyme (thermal, operational and pH).

## Semester Three

### Animal and Plant Biotechnology

### Course Objectives
The objective of this course is to educate students about fundamental concepts of animal and plant cell system, bioprocess technology using eukaryotic system and their related applications, thus, preparing them to meet challenges of new and emerging areas of biotechnology industry.

### Student Learning Outcomes
On completion of this course, students should be able to:
- Demonstrate knowledge of techniques related to basic cell culture, cloning and hybridoma production;
- Differentiate and describe establishment of primary cell culture and cell lines and enlist methods for quantitation and validation. Applications of various techniques of animal biotechnology in medical, farmland, industrial research and assessment of its social and ethical concerns;
- Recognize and assess need for ethical standards and professional codes of conduct in animal and plant biotechnology research, Intellectual property rights.

#### Unit I
**Culture media for animal cell culture**  
3 lectures

Introduction and history; Media and supplements, serum, serum free media, natural media, feeder layer on substrate, Gas Phase for tissue culture, source of tissue, primary culture; Stages of commitment and differentiation, proliferation and malignancy.

#### Unit II
**Subculture and cell lines**  
3 lectures

Cross contamination, terminology, naming and choosing cell line and its maintenance. Criteria for subculture, growth cycle and split ratio, propagation in suspension and attached culture.
<table>
<thead>
<tr>
<th>Unit III</th>
<th>Cloning and hybridoma technology</th>
<th>3 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Vectors and cloning, somatic cell fusion, hybridomas, HAT selection, Medium suspension fusion, selection of hybrid clones, organ culture, tumorigenesis.</td>
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<table>
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<tr>
<th>Unit IV</th>
<th>Cell separation and quantitation</th>
<th>3 lectures</th>
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<td></td>
<td>Separation techniques based on density, size, sedimentation velocity, antibody based techniques- immuno panning, magnetic sorting, fluorescence activated cell sorting; Quantitation-cell counting, cell weight, DNA content, protein, rate of synthesis, measurement of cell proliferation.</td>
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<tr>
<th>Unit V</th>
<th>Cell characterization and differentiation</th>
<th>4 lectures</th>
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<tr>
<td></td>
<td>Authentication, record keeping, provenance, parameters of characterization, lineage and tissue markers, cell morphology, karyotyping, chromosome banding; Differentiation-commitment, terminal differentiation; Lineage selection, proliferation and differentiation, commitment and lineage, markers of differentiation, induction of differentiation, cell interaction-homotypic and heterotypic; Cell-matrix interaction.</td>
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<table>
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<tr>
<th>Unit VI</th>
<th>Application of animal biotechnology and related problems</th>
<th>3 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Artificial animal breeding, cloning and transgenic animals, medicines, vaccines, diagnosis of diseases and disorders, gene therapy, forensic application.</td>
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<tr>
<th>Unit VII</th>
<th>Cell and tissue culture in plants</th>
<th>7 lectures</th>
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<td>Callus cultures; <em>in vitro</em> morphogenesis-organogenesis and embryogenesis; Artificial seeds, Micropropagation (clonal propagation); Haploidy; anther and ovule culture, Embryo culture; Protoplast isolation, culture protoplast fusion and somatic hybridization, cybrids, somaclonal variation; <em>in-vitro</em> mutation methods; virus elimination, pathogen indexing; cryopreservation; production of secondary metabolites; sources of plant secondary metabolites; criteria for cell selection, factors affecting culture of cells; different bioreactors and their use in secondary metabolite production; biochemical pathways for production of different secondary metabolites; and biotransformation.</td>
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<tr>
<th>Unit VIII</th>
<th>Genetic engineering and applications</th>
<th>6 lectures</th>
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<td>Principles and methods of genetic engineering and its applications in agriculture especially transgenic plants; Molecular markers-hybridization and PCR based markers, RFLC, RAPD, STS, SSR, AFLP, SNP markers; DNA fingerprinting- Principles and applications, introduction to mapping of genes/QTLS, marker assisted selection-Strategies for introducing genes of biotic and abiotic stress resistance in plants; Molecular diagnosis of pathogens in plants.</td>
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<tr>
<th>Unit IX</th>
<th>Plant and animal genomics</th>
<th>4 lectures</th>
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<td>Overview of genomics- definition, complexity and classification, need for genomic level analysis, methods of analyzing genome at various levels- DNA, RNA, Protein, metabolites and phenotype, genome projects and bioinformatics- sources for genome research- database overview of forward and reverse genetics for assigning function of gene; Social, cultural, economic, legal problems; bioethics.</td>
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**Recommended Textbooks and References:**

### Course Objectives
The course describes role of microorganisms in recycling soil nutrients, biodegradation of complex plant polymer, sustaining and improving plant growth through improving nutrient availability, production of plant growth promoting substances and inhibiting pathogens. This course also deals with various aspects and impact of our interactions with environment, waste treatment technologies, kinetics and reactors. The biodegradation and bioremediation mechanisms provided by plants and microbes are dealt in detail.

### Student Learning Outcomes
On completion of this course, students should gain understanding of the basic microbiological, molecular and analytical methods extensively used in environmental biotechnology.

### Unit I
**Biological nitrogen fixation**
- 4 lectures
- Physiology and biochemistry of nitrogen fixing organisms, genetics and regulation of gene expression, signaling factors and molecular interaction in establishing rhizobia legume symbiosis.

### Unit II
**Biofertilizers**
- 4 lectures

### Unit III
**Plant growth promoting rhizobacteria (PGPR)**
- 4 lectures
- PGPR in improving plant growth, mechanism in plant growth promotion, factors affecting rhizosphere colonization.

### Unit IV
**Environmental problems and monitoring**
- 5 lectures
- Pollution and its classification; Effluent standards- examination of waste water, characteristics, municipal and industrial waste water; Global environmental problems, global warming, acid rain, ozone depletion; Sampling and analysis; Environmental monitoring and audit; Environmental laws and policies in India.

### Unit V
**Biotreatment, kinetics and reactor design**
- 6 lectures
- Principles of biological treatments; Biological treatment- composting, suspended growth systems, attached growth systems; Bioreactor design- activated sludge process, trickling filters, fluidized bed and packed bed reactor, rotating biological contactors, oxidation ponds and ditches, lagoons, anaerobic reactors.

### Unit VI
**Bioremediation and biodegradation**
- 6 lectures
- Bioremediation principles and processes, Biosorption, bioaccumulation, biotransformation, bioremediation, biodegradation, detoxification, activation, accumulation and co-metabolism; Strategies and techniques of bioremediation in situ and ex situ of hydrocarbons, pesticides and dyes; GMOs in bioremediation and...
biodegradation, Microbial enhanced oil recovery.

### Unit VII
**Principles of microbial diversity**
6 lectures

Evolution of life, principles and concept of microbial diversity, ecological diversity, structural and functional diversity; Methods of studying microbial diversity - Morphological, biochemical/physiological and molecular techniques; Microbial classification and taxonomy; Phenetic, phylogenetic, and genotypic classification, numerical taxonomy, taxonomic ranks, phylogenetic tree, techniques for determining microbial taxonomy and phylogeny - classical and molecular characteristics.

### Unit VIII
**Fundamental of ecology**
5 lectures

Ecosystem, energy in ecological systems, energy participating in food chains and food webs; Interactions among microbial populations, interaction between microbes and plants and between microbes and animals.

#### Recommended Textbooks and References:

### Course Objectives
This course will help students to develop conceptual clarity and knowledge about systems which brings and guarantee quality in products (Biopharmaceuticals, diagnostics and foods) manufactured for human use. The knowledge of GMP and GLP requirements is critical for students who opt for careers in biomanufacturing.

### Student Learning Outcomes
On completion of this course, students should:
- Understand basics of biomanufacturing, GMP and GLP requirements;
- Understanding quality control measurements taken for biomanufacturing in industries.

### Unit I
**Biomanufacturing principles**
6 lectures

Overview and design of biomanufacturing, quality by design approach, technical considerations, phases and scale up: life cycle of manufacturing, raw material considerations, compliance and quality in biomanufacturing, lean biomanufacturing; Process analytical technology (PAT) during biomanufacturing: background and need tools for data acquisitions (software in fermenters, flow filtrations, chromatography, analysis and design process analyzers, process control tools and continuous improvement and knowledge management; Standard manufacturing operating procedures of
biotechnology, including upstream and downstream processing of proteins, and quality control of protein production, and final fill and finish of product; Case studies to be included at least: therapeutic proteins, monoclonal antibodies, human vaccines.

Unit II
Quality system
4 lectures

Introduction to quality system, main elements of a quality system; Essential of quality system; Practical implementation of a quality system; Structure of quality manual, correlation between GMP requirements (WHO) and ISO 9001:2000.

Unit III
Principles and practice of GMP
10 lectures

Personnel: Principles of human resource management, duties of senior management, organizational structures, qualification and profiles requirement, workplace and job descriptions, health monitoring and occupational health safety, training, function owners subject to public law; Premises: Official requirements, material & personnel flow and layout, air cleanliness classes and grades, construction elements, barrier systems, isolators and safety cabinets, building services, heating ventilation air conditioning (HVAC), process gases, qualification of premises and HVAC systems, pharma monitoring of HVAC systems, particle monitoring; Facilities and Equipment: Facility planning, materials, hygienic design in solid handling, system controllers and process control systems, technical documentation, calibration, maintenance, cleaning of facilities, containment (personnel protection) in solid handling; Pharmaceutical water: Water quality, generation of pharmaceutical water, distribution and storage of pharmaceutical water, qualification of water supplies, operation of water supplies, pure steam systems; Qualification: Official requirements, preparation of qualification, qualification documentation, design qualification (DQ), Installation qualification (IQ), operational qualification (OQ), Performance qualification (PQ), special cases of qualification; Process Validation: Official requirements, Validation - a key element of quality management, validation planning and procedure, validation documentation, process validation and product lifecycle; Cleaning Validation: Official requirements, how to validate cleaning procedures, cleaning validation master plan, establishing scope of validation, acceptance criteria and limit calculation, sampling procedures, analytical procedure, documentation, maintenance of validated status, cleaning validation documentation; Production: Sanitation, personnel hygiene, production hygiene, sanitation programme, environmental monitoring, GMP in production process, weigh-in, identification, in-process control prevention of cross-contamination, empty chapter, reworking, warehouse and logistics; Sterile Production and Packaging: Introduction, Air lock concepts, manufacture of terminally sterilised products, sterilisation processes, aseptic processing, freeze-drying, testing for sterility, testing for endotoxins, testing for leakage and for particles, microbiological monitoring, packaging materials, packaging process, qualification of a servo-controlled blister packaging line, blow-fill-seal technology (BFS technology); Documentation: Official requirements, GMP-compliant documentation, batch documentation, standard operating procedures (SOPs), site master file, electronic batch recording and batch release, CAPA, document management systems.

Unit IV
GMP in regulation
2 lectures

Information, national bodies and pharmaceutical associations; Pharmacopeia; EU directives and guidelines, USA: CFR and FDA guidelines, ICH-guidelines, PIC/S guidelines, GMP of other regions, WHO guidelines.

Recommended Textbooks and References:

Metabolic Engineering

Course Objectives
The objective of this course is to provide a quantitative basis, based on thermodynamics, enzyme kinetics, metabolic flux analysis and metabolic control analysis, for understanding of metabolic networks in single cells and at organ level.

Student Learning Outcomes
On successful completion of this course, students should be able to:
• Identify the appropriate host and/or metabolic pathways to produce a desired product or remediate a toxin;
• Compare potential metabolic engineering strategies using quantitative metabolic modeling.

Unit I
Introduction
2 lectures
Stoichiometry, kinetics and thermodynamics of cellular reactions.

Unit II
Material balances and data consistency
2 lectures
Material balances on pathways and whole cell balances; Over and under-determined systems; Data consistency for over-determined systems.

Unit III
Regulation of metabolic pathways
2 lectures
Regulation of metabolic pathways; role of enzymes, substrate, product and regulatory molecules; Hierarchical control in cellular systems.

Unit IV
Manipulation of metabolic pathways
5 lectures
Pathway manipulation strategies for overproduction of various metabolites, examples of ethanol overproduction, overproduction of intermediates in main glycolytic pathway and TCA cycle like pyruvate, succinate etc.; Need for multiple genomic modifications; Modulating fluxes in desired pathways; Tools for multiple genomic modifications examples- TALENS CRISPR-Cas systems as well as traditional systems of gene knock ins and knock outs and promoter engineering.

Unit V
Synthetic biology
3 lectures
Metabolic pathway synthesis; Relation with bioprocess design; BIOBRICKS approaches; Introduction to tools of synthetic biology.

Unit VI
Metabolic flux analysis
4 lectures
Metabolic flux analysis; Building stoichiometric matrix; Steady state and pseudo steady state assumptions; Using different optimizing functions to solve linear programming problem; FBA, understanding flux cone and constraints; Introducing additional constraints from thermodynamics; Brief introduction to developments in this area; MOMA (Minimization of Metabolic Adjustment), iFBA (Integrated Flux Balance Analysis) etc.

Unit VII
Determination of metabolic flux
2 lectures
Experimental determination of metabolic fluxes; C^{13} labeling, NMR and GC-MS based methods for flux determination.
Laboratory VII: Cell Culture

Course Objectives
The objective of this laboratory course is to introduce students to cell culture basics, covering topics such as requirements of a laboratory dedicated to cell culture experiments, laboratory safety, aseptic technique, and microbial contamination of cell cultures, as well as providing basic methods for passaging, freezing, and thawing cultured cells.

Student Learning Outcomes
On completion of this course, student should be able to:

• Gain working knowledge of these techniques and understanding of good cell culture practices for healthcare and biotechnology product development;
• Obtain good biosafety practices and familiarize with basic cell culture laboratory equipment.

Syllabus
1. Orientation to animal mammalian cell culture
2. Aseptic techniques for cell culture
3. Preparation of media and other reagents
4. Establishing primary cell culture
5. Preparation of monolayer and suspension cultures
6. Preparation and thawing cells
7. Checking viability and counting
8. Subculture, feed both adherent and suspension cultures
9. Growth curve analysis and use of fluorescent microscope for identification and analysis of cell cycle
10. Cell line cryopreservation
11. Preparation of cells for microscopy
12. Identification of apoptosis
13. Demonstration of mammalian cell culture in research and towards development of a variety of applications, such as large scale culture, production of monoclonal antibodies, production of viral vaccines and amniocentesis studies
14. Gene transfer experiments
15. Virus infection studies and virus quantification
16. Blood cell preparation such as macrophages, RBC etc.

Recommended Textbooks and References:
3. Current Protocols in Immunology, Wiley publications
Laboratory VIII: Environmental Biotechnology

Course Objectives
This course will give hands on experience of various emerging technologies used for pollution control and bioremediation.

Student Learning Outcomes
On completion of this course, students should be able to:
• Gain basic knowledge of bioremediation techniques;
• Understand procedures involved in water, air and land pollution control.

Syllabus
1. Assay for dissimilatory nitrate reductase activity
2. Estimation of nitrogenase activity of free living bacteria in soils
3. Study of biooxidation of ferrous and sulphur by chemolithotrophic bacteria
4. Adaptation of soil bacteria to metals
5. Biosorption of heavy metals from industrial effluents
6. Enrichment and isolation of Azodye degrading bacteria and their application in treatment of dye containing effluents
7. Enrichment and isolation of 2,4-D degrading bacteria
8. Study of microbial mineral phosphate solubilisation activity
9. Enrichment and isolation of naphthalene degrading bacteria
10. Analysis of biosurfactant production by hydrocarbon degrading organisms
11. Estimation of microbial activity of soil by dehydrogenase assay
12. Waste water treatment:
   a. Biological Oxygen Demand, Chemical Oxygen Demand measurement
   b. Running of anaerobic and aerobic fluidized bed reactors
   c. Upflow Anaerobic Sludge Blanket reactor startup and running
   d. Analysis of reactor operation.

Recommended Electives

Advanced Biomanufacturing

Course Objectives
The objectives of this course is to introduce students with Bio-manufacturing program. Existing biotechnology degree programs focus on product understanding during research and early development stages but there is need to educate students on the program that will address later stages of development and production process understanding.

Student Learning Outcomes
Student should be able to:
• Understand how a product can be developed;
• Knowledge on regulatory and Quality aspects of product development;
• Demonstrate good laboratory procedures and practices;
• Describe standard operating procedures for biotechnology research and assign Biosafety levels;
• Perform activities in compliance with the cGMP’s (Current Good Manufacturing Practices) that are mandated by the FDA (Food & Drug Administration);
• Hands-on training on microbiological
methods, cell biological methods, bioprocess development with industrial oriented approach;

- Become an entry-level biomanufacturing scientist, who can produce new drug discoveries, biologics, biomedical devices used in surgeries, and food products in a very clean environment.

<table>
<thead>
<tr>
<th>Unit I</th>
<th>Survey of various microscopic agents of particular importance to humans</th>
<th>4 lectures</th>
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<tr>
<td></td>
<td>Emphasis on those involved in infectious disease, host defenses against disease, and elements of infection chains and means utilized for breaking chains, monoclonal antibodies etc.</td>
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<tr>
<th>Unit II</th>
<th>Clean rooms and biosafety levels</th>
<th>5 lectures</th>
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<tbody>
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<td></td>
<td>Clean Room classification, gowning, Introduction to clean room gowning, proper sanitation techniques, regulations and recommendations for biosafety, ascending levels of containment, Defining microbiological practices, safety equipment, and facility safeguards for the corresponding level of risk associated with handling a particular agent. Introduction to Safe Laboratory Practices: Guidelines for safe laboratory practices, role of institution’s safety committee and local rules and regulations pertaining to laboratory safety.</td>
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<tr>
<th>Unit III</th>
<th>Scientific communication in biomanufacturing</th>
<th>3 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Analysis and preparation of protocols and standard operating procedures (SOPs), report and present data and experimental conclusion, analysis of articles about scientific research and developments in biotechnology.</td>
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<tr>
<th>Unit IV</th>
<th>Biomanufacturing production</th>
<th>8 lectures</th>
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<td></td>
<td>Emphasis on growth and monitoring of fermenters and bioreactors, including cleaning, media preparation, aseptic inoculation, cell harvesting, lysis, protein recovery and purification of proteins using centrifugation, ultrafiltration and chromatography techniques.</td>
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<tr>
<th>Unit V</th>
<th>Development, production, recovery and analysis of biotechnology products</th>
<th>8 lectures</th>
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<tr>
<td></td>
<td>Case studies of Vaccine manufacturing process that briefly involves generation of antigen/virus/bacteria/recombinant product, purification, testing product, evaluating efficacy of product, stability of product, formulating product and its stability etc.,(Tracing the path of a drug or biologic from cell through production facility, final processing, and in human body), growth characteristics of organisms used to produce pharmaceutical proteins, and techniques used. Fundamentals in biotechnology laboratory techniques: Emphasis on developing skillful use of applicable instruments; protein purification and assays; recombinant DNA work; isolation and tracking techniques; laboratory notebook, spreadsheet data analysis; written protocols and familiarity with standard operating procedures.</td>
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<tr>
<th>Unit VI</th>
<th>Business and regulatory practices</th>
<th>4 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Sound manufacturing procedures and basic business principles: Key concepts for product quality and safety as it moves through a biomanufacturing production pipeline, roles of governmental oversight and regulation during discovery, development and manufacturing of new products for biopharmaceutical industry.</td>
<td></td>
</tr>
</tbody>
</table>
Computational Biology

Credits

Course Objectives
The objective of this course is to provide students with theory and practical experience of essentials to aid for genomic, proteomic and metabolomics courses and drug design program.

Student Learning Outcomes
On completion of this course, students are expected to:

- Develop an understanding of basic theory of these computational tools;
- Develop required database extraction, integration, coding for computational tools and methods necessary for all Omics;
- Formation of hypothesis for investigating specific contemporary biological questions, provide help to experiment with or develop appropriate tools;
- Critically analyze and interpret results of their study with respect to whole systems.

Unit I
Introduction to computational biology basics and biological databases
4 lectures
Computers in biology and medicine; Overview of biological databases, nucleic acid & protein databases, primary, secondary, functional, composite, structural classification database, Sequence formats & storage, Access databases, Extract and create sub databases, limitations of existing databases.

Unit II
Pairwise and multiple sequence alignments
5 lectures

Unit III
Genome analysis
6 lectures
Polymorphisms in DNA sequence, Introduction to Next Generation Sequencing technologies, Whole Genome Assembly and challenges, Sequencing and analysis of large genomes, Gene prediction, Functional annotation, Comparative genomics, Probabilistic functional gene networks, Human genome project, Genomics and crop improvement; Study the available GWAS, ENCODE, HUGO projects, extract and build sub databases; Visualization tools including Artemis and Vista for genome comparison; Functional genomics case studies.

Recommended Textbooks and References:
Fundamentals of Technology Transfer

Credits

3

Course Objectives
The ‘Transfer of Technology’ (Know how about Processes & material) from one site to other site takes place at some stage of product life-cycle. It may be from Discovery/basic R&D, Process R&D, scale-up, manufacturing, production to launch and approval phase. This course will be beneficial for students and researchers who are interested to working in industries from R&D to commercial manufacturing.

Student Learning Outcomes
On completion of this course, students should:
- Have basic understanding of principles of technology transfer;
- Be aware of process involved in transfer of technology during all the stages of drug development.

Unit IV
Structure visualization
3 lectures

Retrieving and drawing structures, Macromolecule viewing platforms, Structure validation and correction, Structure optimization, Analysis of ligand-protein interactions; Tools such as PyMol or VMD.

Unit V
Molecular modelling
6 lectures

Significance and need, force field methods, energy, buried and exposed residues; side chains and neighbours; fixed regions; hydrogen bonds; mapping properties onto surfaces; RMS fit of conformers and protein chains, assigning secondary structures; sequence alignment: methods, evaluation, scoring; protein curation: backbone construction and side chain addition; different types of protein chain modeling: ab initio, homology, hybrid, loop; Template recognition and alignments; Modeling parameters and considerations; Model analysis and validation; Model optimization; Substructure manipulations, annealing, protein folding and model generation; loop generating methods; loop analysis; Analysis of active sites using different methods in studying protein–protein interactions.

Unit VI
Structure-based drug development
6 lectures


Unit VII
Ligand-based drug development
6 lectures

Quantitative structure activity relationships. Introduction to chemical descriptors like 2D, 3D and Group-based; Radar plots and contribution plots and Activity predictions, Pharmacophore modeling, Pharmacophore-based screenings of compound library, analysis and experimental validation.

Recommended Textbooks and References:
It will also strengthen in additional domains such as project management, Clinical, Regulatory affairs, Quality Control and Quality Assurance.

<table>
<thead>
<tr>
<th>Unit I</th>
<th>Introduction to tech transfer</th>
<th>Purpose, Life cycle of product development: Technology Transfer, Drug Discovery and Development Process, Importance of Technology Transfer; Scope and Glossary in Bio-manufacturing.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit III</td>
<td>Organization strategy, planning and management</td>
<td>Stages of the Technology Transfer Process, Management of Change, Organization, Teams Supporting the TT Process, Global Technology Transfer Management Team (GTTMT), Documentation Required to Support TT, Planning, Timings.</td>
</tr>
<tr>
<td>Unit V</td>
<td>Quality control: analytical method transfer</td>
<td>Analytical T T: Principles, What, when and How? (Objective, Scope, Responsibilities), procedure including Pre-transfer activities, Transfer protocol and Report, Experimental design and Acceptance criteria, Alternate approaches.</td>
</tr>
<tr>
<td>Unit VII</td>
<td>Production: Dosage form (processing, packaging and cleaning)</td>
<td>Introduction, Stability Data, API, Excipients and Raw material, Process information, equipment description, packaging specification, facility requirement, Qualification and validation.</td>
</tr>
<tr>
<td>Unit VIII</td>
<td>Documentation</td>
<td>Batch manufacturing records (BMR), SOPs for analytical procedure, format COA, format stability data, format for testing of raw material, Validation Plan, Validation report.</td>
</tr>
<tr>
<td>Unit IX</td>
<td>Case Studies</td>
<td>Case Studies and examples.</td>
</tr>
</tbody>
</table>
Recommended Textbooks and References:
2. Technology Transfer, Good Practice Guide ISPE

Course Objectives
The objective of this course is to give an introduction to Genomics and other global Omics technologies, theory and practical aspects of these technologies and application of these technologies in biology. The students should be able to gain working knowledge of these technologies and appreciate their ability to impart a global understanding of biological systems and processes in health and disease.

Student Learning Outcomes
On completion of this course, students should have:
• Overview of genome variation in population including technologies to detect these variation;
• Understand how High-throughput DNA sequencing (HTS) can be used to identify disease causing genetic variants in monogenic diseases;
• Understand how Genome Wide Association Studies (GWAS) can detect disease associated markers in multifactorial diseases;
• Understand how HTS technologies can be used to explore changes in gene expression;
• Understand application of various Omics technologies.

Unit I
Genome mapping
6 lectures
Structure and organization of prokaryotic and eukaryotic genomes- nuclear, mitochondrial and chloroplast genomes; Computational analysis, Databases, Finding genes and regulatory regions; Tools for genome analysis- PCR, RFLP, DNA fingerprinting, RAPD, SNP detection, SSCP, FISH to identify chromosome landmarks; Human Genome Project- landmarks on chromosomes generated by various mapping methods, BAC libraries and shotgun libraries preparation, Physical map, Cytogenetic map, Contig map, Restriction map, UCSC browser.

Unit II
Microarray technology
6 lectures
Basic principles and design, cDNA and oligonucleotide arrays, DNA microarray, Instrumentation and structure; Designing a microarray experiment. Comparative Genomic Hybridization (CGH) arrays, Resequencing arrays; Different platforms (Affymetrix, Agilent etc.); Data Processing and Normalization - Algorithms of data processing and Normalization; Tools used to normalize; Microarray databases – NCBI; GEO (Gene Expression Omnibus), ArrayExpress (EBI); Functional Analysis: Differential gene expression; Gene Ontology functional enrichment tools, Pathway analysis (KEGG Database); Applications of Microarray technology; Case studies - Application of expression profiling in human disease; Comparison of Microarray technology and High throughput sequencing technology.

Unit III
Sequencing technologies
7 lectures
Introduction to sequencing, Maxam and Gilbert method, Sanger Sequencing techniques and applications; Next Generation sequencing (NGS), quality check, Library Preparations, Platform overview and comparison (Illumina, 454 (Roche), SOLiD (Life technology), Specific Biosciences, Ion Torrent, Nanopore, PacBio; Types of NGS, DNA-sequencing - Whole genome sequencing, exome sequencing, Deep sequencing, ChIP sequencing, RNA-sequencing and types (small RNA sequencing, non coding RNA sequencing),Whole transcriptome sequencing; Data Processing and
Analysis: Data Quality Check, filtering and Genome assembly and mapping to reference genomes, mapping tools (bowtie, maq etc.), Sequence Alignment formats: Sequence Alignment/Map (SAM) format, Binary Alignment/Map (BAM) format, Functional Analysis: Pathway analysis, Gene Ontology analysis; Application of different sequencing technique, methylomics, in vivo protein binding, genome wide association studies (GWAS), Histone modification, microbial sequencing.

Unit IV
Proteomics
7 lectures

Relationship between protein structure and function; Outline of a typical proteomics experiment, One- and two-dimensional gel electrophoresis (IEF and 2D electrophoresis), Alternatives to electrophoresis; Multiplexed protein analysis, Spot visualization and picking; Tryptic digestion of protein and peptide fingerprinting, Mass spectrometry: ion source (MALDI, spray sources), analyzer (ToF, quadrupole, quadruple ion trap) and detector; Post translational Modifications: Quantitative proteomics, clinical proteomics and disease biomarkers, mass spectral tissue imaging and profiling; Protein-protein interactions: Surfaceomes and Secretomes, Solid phase ELISA, pull-down assays (using GST-tagged protein) tandem affinity purification, western analysis, surface plasmon resonance technique; Yeast two hybrid system, Phage display, Protein interaction maps, Protein arrays: definition; Types of protein arrays, Applications- diagnostics, expression profiling. Protein databases, Protein databank.

Unit V
Metabolomics
6 lectures

Introduction and overview of metabolites, sample collection and processing, Non tracer and tracer (radio labelled)-based techniques in metabolomics (HPLC, NMR, LC-MS and GC-MS); Metabolome data processing derived by various techniques, analysis of databases (MetaboLight, Meta Cyc, MMCD etc.), Analysis tools, Metabolic pathways and network analysis; Metabolic flux analysis (TCA, Amino acids, fatty acids, intermediary metabolites), Stoichiometric metabolic flux analysis, 13C metabolic flux analysis (MFA), Metabolic control analysis (MCA); Applications of metabolomics; Integration of metabolomics data sets with other data (eg. Transcriptomics, enzyme activity etc.).

Recommended Textbooks and References:
DBT Supported Teaching Programme

<table>
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<tr>
<th>S.No.</th>
<th>Name of University</th>
<th>Contact Details of Course Coordinator</th>
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</table>
| 1.    | Sardar Patel University, Vallabh Vidyanagar | Prof. R. B. Subramanian
       |                                             | BRD School of Biosciences
       |                                             | 02692-234412 (O) 0989858599
       |                                             | subramanianrb@gmail.com                                                     |

Annexure I

Subject Specific Subcommittee of M.Sc. Industrial Biotechnology

Chairperson
1. Dr. K. J. Mukherjee, Professor, School of Biotechnology, Jawaharlal Nehru University, New Delhi

Members
2. Dr. Saroj Mishra, Professor, Department of Biochemical Engineering, Indian Institute of Technology, New Delhi
3. Dr. Datta Madamwar, Professor, School of BRD Biosciences, Sardar Patel University, Vallabh Vidyanagar
4. Dr. Gautam Ghosh, Sr. Vice President, Panacea Biotec Ltd., New Delhi
5. Dr. Gaurav Pandey, Associate Director, Product Development at Malaria Vaccine Development Program, New Delhi

Member Secretary
6. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi
M.Sc. Marine Biotechnology
Introduction

Background

Promotion of Indian Biotechnology sector is high on policy agenda of Government of India. Biotechnology has also been recognized as one of the key priority sectors under ‘Make in India,’ ‘Skill India’ and ‘Startup India’ initiatives of Government of India, as it is one of sectors expected to contribute towards enterprise creation, innovation and economic growth. Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India has immensely contributed to this dynamism through various policies and initiatives, establishment of innovation clusters, academia-industry partnerships, increasing capabilities for technology development, etc. The National Biotechnology Development Strategy (2015 – 2020) released by DBT provides a strategic roadmap for India’s emergence as a global biotechnology innovation and manufacturing hub. It has also highlighted importance of human resource development and need for nurturing tailor-made human capital for advanced scientific research and entrepreneurship.

DBT has taken a number of initiatives aimed at integrated human resource development to evolve an ecosystem where scientists, innovators and future entrepreneurs can be nurtured. Keeping in mind requirement for trained manpower in various areas of Biotechnology, DBT initiated Post-Graduate Teaching Programme way back in 1985 with 5 universities which has expanded to 74 universities imparting M.Sc./M.Tech./M.V.Sc. degrees in general, agricultural, animal, food, environmental, industrial marine, medical, neuroscience and pharmaceutical biotechnology. 10 programmes are being phased out. These universities and institutes are provided liberal financial support towards strengthening of laboratory facilities, equipment, consumables, fellowships to students, dissertation grant per student etc. Post-Graduate Teaching Programme selects best students and trains them to join research or industry workforce contributing significantly to biotechnology workforce.

About the Course Curriculum Revision Exercise

Taking into cognizance the changing needs of the economy and to keep abreast with latest developments in the field of biotechnology, DBT proactively initiated revision of course curricula of Post-Graduate Programmes in biotechnology. The present exercise has been undertaken by Biotech Consortium India Limited (BCIL), New Delhi. Earlier exercise was carried out in 2008. The Course Curriculum Revision Exercise has been carried out for 13 Post-Graduate programmes in Biotechnology supported by DBT.

The revision of course curriculum of M.Sc. Marine Biotechnology aims to address mismatch between ‘knowledge’ gained by students and appropriate skill set required for technology development and implementation including present contemporary needs of economy.

Methodology

A meticulous and structured approach has been adopted to accomplish the Course Curriculum Revision exercise.

BCIL had initiated the exercise with a review of literature of relevant national and international documents on curriculum design and planning for biotechnology programmes of premier national as well as international universities, guidelines by University Grants Commission, recent curricular guidelines released by Indian Council of Agricultural Research, Ministry of Health and Family Welfare and Indian Institute of Science Education & Research and other relevant research papers on curriculum development in peer-reviewed journals.
The findings of the literature review were adopted to design questionnaires for eliciting feedback from stakeholders of Biotechnology community i.e. academicians, scientists, industry representatives and students. Feedback was received from 165 experts and 20 students belonging to academic institutions, research organizations and industry regarding addition of advanced topics, deletion of elementary, redundant and overlapping topics, updation of laboratory practicals, re-adjustment of credit load, incorporating 'technology' component in the curriculum, among others. It was also suggested that re-orientation of curricula should be done keeping in view the needs of the industry.

**Strategic Approach**

A Core Committee along with 9 subject specific subcommittees comprising of 63 academicians, scientists and industry representatives were constituted to revise and update the curricula. The constitution of subject specific subcommittee for M.Sc. Marine Biotechnology is given at Annexure-1.

The salient recommendations identified from stakeholder survey were presented to the Committee. Several brainstorming discussion sessions were held for achieving the desired balance between the foundation courses, recent developments in biotechnology and updation needs identified during the stakeholder survey. Core Committee finalized broad contours for revising all the course curricula. The guidelines set by the Core Committee were taken up by the subject specific subcommittee of M.Sc. Marine Biotechnology for updating the curriculum. The subject specific subcommittee incorporated latest advancements in areas of Marine Biotechnology in the curriculum. Separate meeting was held to discuss and deliberate the updations to be made in the curriculum. The revised curriculum was vetted and finalized by the Core Committee.

**Course Curriculum Revision**

The members of Committee agreed that revised course curriculum should provide skill and outcome based education and help the students to gain domain knowledge, ability to design and interpret research experiments and acquire effective communication skills. The course curriculum has been re-designed accordingly to promote skill-based and outcome-based education. The revised course curriculum totals to 98 credits comprising of theory, practical, technology-based topics, electives and dissertation. Each course includes learning objectives, student learning outcomes, course plan (number of lectures/unit) and reference textbooks/resources. Theory and practical courses include relevant examples, case scenarios and tutorials for inculcating critical thinking against rote learning. Several new courses have been included and content for existing courses has also been updated. Specialized courses like Fisheries Resources, Conservation and Oceanography, Marine Microbiology, Aquaculture Bioprocessing and Fish Immunology have been introduced to make the curriculum focussed towards marine sciences. With importance of students being able to execute research projects independently, separate credits have been allotted for proposal preparation and presentation before initiating dissertation and also credits for dissertation have been increased accordingly.

We hope that model course curriculum shall serve as guidelines for academicians and researchers from different parts of the country for adoption in their institutions with modifications as per availability of expertise, infrastructure and specific needs.

We wish to put on record our sincere appreciation for constant guidance and encouragement received from Dr. K. VijayRaghavan, Secretary, DBT for bringing out this publication. We wish to acknowledge whole-hearted support of Core Committee and subject specific subcommittees members. Sincere thanks are due to Dr. Manoj Singh Rohilla, Scientist- D, DBT, Ms. Shweta for creative design, Mrs. Rita Bhatla, DBT and Shri. Dilip Joy, BCIL.
The two-pronged objective of this course comprises of giving students a thorough understanding of basic science behind the salient marine biological processes related to marine ecosystem and microbiology as well as familiarize them with the possible applications leading to marine biotechnology. This revised syllabus carefully combines fundamental theory and practical aspects. The syllabus provides an overview of the different biological and microbiological processes so as to equip students with an integrated approach to the so-called marine environmental system and fisheries. This curriculum hopes to focus the ecosystem services in a rather fundamental manner from both the perspectives of science and technology – especially from the perspective of gainful use of fisheries resources, conservation of marine ecosystem and oceanography. Effort has been made to impart a working knowledge to support the related industrial sector by emphasizing the relevant applications or even in development of marine biotechnological processes. I take this opportunity to thank the entire Committee for offering the “expert opinion” as well as for providing the valuable inputs and timely help. The overall management and facilitation of various tasks was diligently provided by Biotech Consortium India Limited and the Committee is appreciative of their efforts.

Professor Shyam R. Asolekar
Centre for Environmental Science and Engineering
Indian Institute of Technology Bombay
Powai, Mumbai 400 076
+91 22 2576 7867 (Office)
asleykar@gmail.com
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<tr>
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<td>2</td>
<td>Molecular Biology</td>
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<td>3</td>
<td>Fisheries Resources, Conservation and Oceanography</td>
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<td>4</td>
<td>Marine Microbiology</td>
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**TOTAL CREDITS 98**

**Recommended Electives:**
### Biochemistry

#### Credits

3

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### Course Objectives

The objectives of this course are to build upon undergraduate level knowledge of biochemical principles with specific emphasis on different metabolic pathways. The course shall make the students aware of various disease pathologies within the context of each topic.

### Student Learning Outcomes

On completion of this course, students should be able to:

- Gain fundamental knowledge in biochemistry;
- Understand the molecular basis of various pathological conditions from the perspective of biochemical reactions.

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### Unit I

#### Chemical basis of life and proteins

5 lectures

Chemical basis of life: Miller-Urey experiment, abiotic formation of amino acid oligomers, composition of living matter; Water – properties of water, essential role of water for life on earth pH, buffer, maintenance of blood pH and pH of gastric juice, pH optima of different enzymes (pepsin, trypsin and alkaline phosphatase), ionization and hydrophobicity, emergent properties of biomolecules in water, biomolecular hierarchy, macromolecules, molecular assemblies; Structure-function relationships: amino acids – structure and functional group properties, peptides and covalent structure of proteins, elucidation of primary and higher order structures, Ramachandran plot, evolution of protein structure, protein degradation and introduction to molecular pathways controlling protein degradation, structure-function relationships in model proteins like ribonuclease A, myoglobin, hemoglobin, chymotrypsin etc.; basic principles of protein purification; tools to characterize expressed proteins; Protein folding: Anfinsen's Dogma, Levinthal paradox, cooperativity in protein folding, free energy landscape of protein folding and pathways of protein folding, molten globule state, chaperons, diseases associated with protein folding, introduction to molecular dynamic simulation.

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### Unit II

#### Enzyme kinetics

5 lectures

Enzyme catalysis – general principles of catalysis; quantitation of enzyme activity and efficiency; enzyme characterization and Michaelis-Menten kinetics; relevance of enzymes in metabolic regulation, activation, inhibition and covalent modification; single substrate enzymes; concept of catalytic antibodies; catalytic strategies with specific examples of proteases, carbonic anhydrases, restriction enzymes and nucleoside monophosphate kinase; regulatory strategies with specific example of hemoglobin; isozymes; role of covalent modification in enzymatic activity; zymogens.

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### Unit III

#### Glycobiology

2 lectures

Sugars-mono, di, and polysaccharides with specific reference to glycogen, amylose and cellulose, glycosylation of other biomolecules-glycoproteins and glycolipids; lipids- structure and properties of important members of storage and membrane lipids; lipoproteins.

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### Unit IV

#### Lipids, DNA and RNA

3 lectures

Self-assembly of lipids, micelle, biomembrane organization - sidedness and function; membrane bound proteins - structure, properties and function; transport phenomena; nucleosides, nucleotides, nucleic acids - structure, a historical perspective leading up to the proposition of DNA double helical structure; difference in RNA and DNA structure and their importance in evolution of DNA as the genetic material.

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### Unit V

#### Bio-energetics

8 lectures

Bioenergetics-basic principles; equilibria and concept of free energy; coupled interconnecting reactions in metabolism; oxidation of carbon fuels; recurring motifs in metabolism; Introduction to GPCR, Inositol/DAG//PKC and Ca++ signaling pathways; glycolysis and gluconeogenesis; reciprocal regulations and non-carbohydrate sources
Calvin cycle and pentose phosphate pathway; glycogen metabolism, reciprocal control of glycogen synthesis and breakdown, roles of epinephrine and glucagon and insulin in glycogen metabolism; Fatty acid metabolism; protein turnover and amino acid catabolism; nucleotide biosynthesis; biosynthesis of membrane lipids and sterols with specific emphasis on cholesterol metabolism and mevalonate pathway; elucidation of metabolic pathways; logic and integration of central metabolism; entry/exit of various biomolecules from central pathways; principles of metabolic regulation; steps for regulation; TOR (target of rapamycin) & autophagy regulation in relation to C & N metabolism, starvation responses and insulin signaling.

Recommended Textbooks and References:

Course Objectives
The aim of this course is to obtain and understand fundamental knowledge of molecular and cellular processes: epigenetics, gene regulation, RNA transcription, protein synthesis, protein targeting and trafficking, and cell signaling. Students participate in a computer tutorial aimed at mastering basic web tools for genome and proteome analysis. The knowledge discussed in the lectures and practiced at the computer tutorial is the basis for an assignment that aims to train students in a critical evaluation of literature. Through presentation of their topic and feedback of lecturers and their peers, students become acquainted with the scientific method.

Student Learning Outcomes
Upon successful completion of this course, students should be able to:
- Explain and summarize the scientific principles of the molecular biology of DNA and RNA;
- Use specialized DNA/RNA isolation, manipulation, and cloning methods, individually and collaboratively that are typical of molecular biology laboratory investigations and communicate the results as written laboratory reports;
- Describe and explain the results of DNA and/or RNA experiments based on the scientific principles of nucleic acid structure.
### Unit II
**DNA replication, repair and recombination**
6 lectures

Replication: initiation, elongation and termination in prokaryotes and eukaryotes; Enzymes and accessory proteins and mechanisms; Fidelity; Replication of single stranded circular DNA; link with cell cycle; DNA damaging agents - Physical, chemical and biological mutagens; types of damage caused by endogenous and exogenous agents; mutations- Nonsense, missense, silent and point mutations, frameshift mutations; Intragenic and Intergenic suppression. DNA repair mechanisms- direct reversal, photoreactivation, base excision repair, nucleotide excision repair, mismatch repair, double strand break repair, SOS repair; Recombination: Chi sequences in prokaryotes; Homologous, non-homologous and site specific recombination.

### Unit III
**RNA transcription, RNA processing and regulation in prokaryotes**
10 lectures

Structure and function of prokaryotic mRNA, tRNA (including initiator tRNA) and rRNA (and ribosomes); Prokaryotic Transcription - RNA polymerase and sigma factors, Transcription unit, Promoters, Promoter recognition, Initiation, Elongation and Termination (intrinsic, Rho and Mfd dependent); Processing of mRNA, rRNA and tRNA transcripts; Gene regulation: Repressors, activators, positive and negative regulation, Constitutive and Inducible, small molecule regulators, operon concept: lac, trp, his operons, attenuation, anti-termination, stringent control, translational control, DNA re-arrangement, two component system; regulatory RNA – riboswitch, tmRNA, antisense RNA; transcriptional control in lambda phage.

### Unit IV
**RNA transcription, RNA processing and regulation in eukaryotes**
13 lectures

Structure and function of eukaryotic mRNA, tRNA (including initiator tRNA) and rRNA (and ribosomes). Eukaryotic transcription - RNA polymerase I, II and III mediated transcription: RNA polymerase enzymes, eukaryotic promoters and enhancers, General Transcription factors; TATA binding proteins (TBP) and TBP associated factors (TAF); assembly of pre-initiation complex for nuclear enzymes, interaction of transcription factors with the basal transcription machinery and with other regulatory proteins, mediator, TAFs; Processing of hnRNA, tRNA, rRNA; 5’-Cap formation; 3’-end processing of RNAs and polyadenylation; loop model of translation; Splicing of tRNA and hnRNA; snRNPs and snoRNPs in RNA processing; Regulation of RNA processing: capping, splicing, polyadenylation; mRNA stability and degradation: degradation and surveillance pathways; RNA editing; Nuclear export of mRNA; Catalytic RNA: Group I and Group II introns splicing, Peptidyl transferase; Regulatory RNA and RNA interference mechanisms, miRNA, non-coding RNA; Silencers and insulators, enhancers, mechanism of silencing and activation; Families of DNA binding transcription factors: Helix-turn-helix, helix-loop-helix, homeodomain; 2C 2H zinc finger, multi cysteine zinc finger, basic DNA binding domains (leucine zipper, helix-loop-helix), nuclear receptors; Interaction of regulatory transcription factors with DNA: properties and mechanism of activation and repression including Ligand-mediated transcription regulation by nuclear receptors; Nuclear receptor; histone modifications and chromatin remodeling; Methods for studying DNA-protein interaction: EMSA, DNase I footprinting, methylation interference assay, chromatin immunoprecipitation.

### Unit V
**Protein translation, post translational modifications and control in prokaryotes and eukaryotes**
8 lectures

Ribosomes; Composition and assembly; universal genetic code; Genetic code in mitochondria; Degeneracy of codons; Termination codons; Wobble hypothesis; Isoaccepting tRNA; Translational machinery; Mechanism of Translation in prokaryotes and eukaryotes; Co- and Post-translational modifications of proteins; triple helix of collagen; Translational control; Protein stability; Protein turnover and degradation.
Course Objectives
The objectives of this course are to:
• Introduce students to marine environment and its physical features;
• Introduce students to principal marine fisheries of India;
• Educate students on status and trends of major fish resources and their conservation in region.

Student Learning Outcomes
Upon successful completion of this course, students should be able to:
• Understand status and trends of major fish resources in the region;
• Familiarise with factors influencing primary and secondary production.

Unit I
Marine biology and ecology
10 lectures
Classification of marine environment, Types of aquatic habitats such as coral reefs, sand dunes, mangroves, sea grasses etc., Diversity and taxonomy of marine organisms (Bacteria, Phytoplankton, zooplankton, seaweeds, sea grasses, mangroves, corals etc.). Species abundance, richness and diversity indices, Biogeography, Recruitment, Growth, Mortality, Culture of microalgae and invertebrates; Habitat preferences, Adaptations in marine organisms and energy transfer, Marine biomass and productivity - primary production, photosynthetic efficiency; secondary production, productivity distribution in ocean environment, Mechanism and factors affecting primary production, Assessment of impact of changing environment on biodiversity of coastal ecosystems - delineating natural and anthropogenic impacts, Ocean acidification and impacts on marine organisms, Bio-communication in oceans, Microbe-microbe interaction, Microbe-metazoa interaction, Population connectivity, Ecology of benthic organisms, Benthic biological processes and benthic biodiversity, Benthic-pelagic coupling, Bio-invasion ecology, Food web dynamics and ecosystem functioning, Microbial loop - Role of microbes in marine food web dynamics and biogeochemical processes; Bioluminescence and indicator species, Red tides.

Unit II
Biodiversity and conservation of aquatic species
10 lectures
Principles, Importance; Fish genetic resources- survey and distribution; Marine living resources assessment - Principal methods of exploitation of marine living resources, Development of novel methods for optimisation of marine aquaculture; Influencing Factors, Planning and management; IUCN criteria-Red List; Wildlife protection Act; International Treaties & conventions; Marine protected Areas, Sanctuaries and Biosphere reserves, Establishment of Marine Parks, in situ and ex situ conservation; Cryopreservation of Gametes or Gene Banking; Institutes and societies involved in conservation; Artificial Hybridization: Heterosis, Control of fish diseases by selection; selective breeding of disease resistant fish; Marine Bioprospecting: Mining untapped potential of living marine resources; Molecular Tools in Conservation of Fisheries Resources: Molecular Markers: development of RAPD, RFLP, AFLP, ESTs, SNPs, Micro-satelites and micro-satelites.
Marine Microbiology

Course Objectives
The objective of this course is to provide information about the microbes available in aquatic environment, their role and interaction with environment.

Student Learning Outcomes
After completing this course, students should be able to -

- Explain principle features of microbial diversity in oceans;
- Describe and discuss marine microbes in terms of physiological capability and biogeochemical role;
- Synthesize microbial ecosystem function in pelagic and benthic marine habitats.

Unit I
Marine microbial ecology and diversity
11 lectures

Introduction: Marine environment, Seawater, Marine sediments, Habitats for marine microorganisms; Diversity of Marine microorganisms: Archaea, Bacteria, Cyanobacteria, Algae, Fungi, Viruses, viroids and prions and actinomycetes in coastal, shallow, deep sea, hydrothermal vents, mangrove and in coral ecosystem; Marine Symbiotic Microorganisms; Ecology: Survival of indigenous organisms and fate of non-indigenous organisms in the marine environment, Predatory-prey relationship (food-web), Degradation of complex molecules, Colonisation of surfaces Chemotaxis, Attachment, Symbiotic Association; Biogeochemical Processes: Nutrient cycling, Carbon cycle, Nitrogen cycle, sulphur cycle, Iron cycling, Phosphorus cycling and other cycles. Photosynthesis, Quorum sensing, Temperature dependent microbial growth, Lethal and mutagenic factors, Protection system from osmotic damage; Taxonomy of

Unit III
Oceanography
10 lectures

Physical Oceanography: Seawater and its properties; Air-Sea interaction; Geotrophy & large scale circulation of upper ocean; Tides, Waves, Currents, Ocean circulation and Monsoon; Chemical Oceanography: composition of sea water, including trace elements and dissolved organics, elemental and nutrient cycles, salinity & chemical transformations, Gas solubility; inorganic Characteristics of Seawater; Biological Oceanography: Living organisms of ocean: physical parameters & their effects on organisms; characteristics of organisms living in water column; Characterization of Marine Sediments - Constituents, Mass properties, Texture etc.; Molecular tool to study Bacterial diversity in sediments; Geographical and seasonal variation in plankton production and trophic dynamics; Indicator species.

Recommended Textbooks and References:
Marine Microorganisms: Prokaryotes: Phototrophs containing bacterial chlorophyll, Cyanobacteria, Prochloron, Gliding bacteria, Budding and appendaged bacteria, Aerobic gram negative rods and cocci, Facultatively anaerobic gram negative rods, Gram negative anaerobic rods and cocci, Gram negative chemolithotrophs (ammonia or nitrogen oxidizing or sulphur bacteria), Methane bacteria, Aerobic positive cocci, Actinomycetes and related bacteria, Spirochaetes, Oceanospiralles, Magnetotactic bacteria, Bdellovibrio, Sulphur and sulphurreducing bacteria. Eukaryotes: Micro algae, Diatoms, Fungi, Yeast, Protozoa; Virus: Classification; Extremophiles.

Unit II
Techniques in marine microbiology
8 lectures

Sampling: Water, Sediment and aquatic content (General Experimental Procedures and remote sensing). Direct observation and enumeration of microbes: Light and electron microscopy to study morphology and structure of microbes, Epifluorescence light microscopy - enumeration of marine microbes, confocal laser scanning microscopy - recognition of living microbes within their habitat, Flow cytometry - number and size of particles. Culture based methods for isolation and identification of microbes: Specific culture media and conditions for growth, Enrichment cultures, Phenotypic testing, Analysis of microbial components for classification and identification. Nucleic acid based methods: Sequencing of ribosomal RNA genes, Isolation of genomic DNA or RNA from the culture, PCR, Genomic finger printing, GC ratio and DNA-DNA hybridization used in taxanomy, DNA sequencing, Denaturing gradient gel electrophoresis (DGGE) and Terminal restriction fragment length polymorphism (TRFLP), Metagenomics, Fluorescent hybridization for visualization and quantification of microbes, Metatranscriptomics, Metaproteomics and Microarrays.

Unit III
Marine microbiology of organisms
11 lectures

Microbiology of healthy organisms: Plants, Invertebrates and Vertebrates; Diseases of Invertebrates: Vibriosis, Shell disease, Gaffkemia, Epibiotic associations, Fungal diseases, Viral diseases, Rickettsial diseases; Diseases of Vertebrates: Bacterial pathogens, fungi, protozoa and viruses; Sea Food Microbiology: Classification of seafood: Chilled and frozen raw fish, Chilled and frozen prepared fish products, Molluscan and crustacean shellfish, Cured, smoked and Dried fish, Fermented fish. Micro flora of seafood: Initial flora, Processing and its effect on Microflora, Spoilage and causative flora, Pathogens profile, Pathogens growth and survival; Food born infection and Intoxication caused by seafood microbes: Fish and Shellfish Toxins originated from marine microbes; Microbiological standard for seafood: HACCP in seafood product and Manufacture, EU food hygiene Legislation; Marine Microbes and Biotechnology: Pharmaceutical compounds: Antibiotic, Antiviral, Antitumor compounds; Health promoting products: probiotic, prebiotic, immune-stimulants, enzymes; Other products: Biofuels, Antifouling compounds, Surfactants; Application in different fields: Aquaculture, Food Industry, Biomimetics, Nanotechnology and Bioelectronics.

Recommended Textbooks and References:
### Course Objectives
The objective of this course is to introduce students to statistical methods and to understand underlying principles, as well as practical guidelines of "how to do it" and "how to interpret it" statistical data.

### Student Learning Outcomes
On completion of this course, students should be able to:
- Understand how to summarise statistical data;
- Apply appropriate statistical tests based on an understanding of study question, type of study and type of data;
- Interpret results of statistical tests.

## Biostatistics

| Credits | 2 |

## Course Content

### Unit I
Introduction
5 lectures

- Types of biological data (ordinal scale, nominal scale, continuous and discrete data), frequency distribution and graphical representations (bar graph, histogram, box plot and frequency polygon), cumulative frequency distribution, populations, samples, simple random, stratified and systematic sampling.

### Unit II
Descriptive statistics
5 lectures

- Measures of Location, Properties of the Arithmetic Mean, median, mode, range, Properties of the Variance and Standard Deviation, Coefficient of Variation, Grouped Data, Graphic Methods, Obtaining Descriptive Statistics on Computer, Case study.

### Unit III
Probability and distribution
4 lectures

- Introduction to probability and laws of probability, Random Events, Events-exhaustive, Mutually exclusive and equally likely (with simple exercises), Definition and properties of binomial distribution, poisson distribution and normal distribution.

### Unit IV
Correlation and regression analysis
6 lectures

- Correlation, Covariance, calculation of covariance and correlation, Correlation coefficient from ungrouped data, Spearman's Rank Correlation Coefficient, scatter and dot diagram, General Concepts of regression, Fitting Regression Lines, regression coefficient, properties of Regression Coefficients, Standard error of estimate.

### Unit V
Statistical hypothesis testing
4 lectures

- Making assumption, Null and alternate hypothesis, error in hypothesis testing, confidence interval, one-tailed and two-tailed testing, decision making.

### Unit VI
Tests of significance
8 lectures

- Steps in testing statistical significance, selection and computation of test of significance and interpretation of results; Sampling distribution of mean and standard error, Large sample tests (test for an assumed mean and equality of two population means with known S.D.), z-test; Small sample tests (t-test for an assumed mean and equality of means of two populations when sample observations are independent); Parametric and Non parametric tests (Mann-Whitney test); paired and unpaired t-test, chi square test.

### Unit VII
Experimental designs
8 lectures

- Introduction to study designs: Longitudinal, cross-sectional, retrospective and prospective study, Principles of experimental designs, Randomized block, and Simple factorial designs, Analysis of variance (ANOVA) and its use in the analysis of RBD, introduction to meta-analysis and systematic reviews, ethics in statistics.
Recommended Textbooks and References:


Course Objectives

The course is designed to provide a broad exposure to all basic techniques (Biochemical & Biophysical) used in current Modern Biology research. The goal is to impart basic conceptual understanding of principles of these techniques and emphasize Biochemical utility of same & underlying Biophysics. Student is expected to have clear understanding of all analytical techniques such that the barrier to implement same is abated to a great extent.

Unit I

Introduction to biomolecules

8 lectures

Nucleic Acid, Protein-Polymer Description of Macromolecular Structure, Intermolecular and Intramolecular forces, Non Covalent Interaction; Hydrodynamic properties: Diffusion and sedimentation, determination of molecular weight from sedimentation and diffusion; Concept and application of Chemical and Physical equilibria in Biological system, Equilibrium constant and Standard Gibbs Free energies of reactants and products, Temperature dependence of equilibrium constant. Basic Concepts: Rate, order and molecularity of a reaction, First, second and third order reactions – effect of concentration on reaction rate, rate expressions and integrated form, pseudo-unimolecular and second order autocatalytic reactions, nth order reaction of a single component, effect of temperature on reaction rate – Arrhenius equation and activation energy.

Unit II

Cellular and molecular mechanisms

6 lectures

Physical biochemistry of cell: Chemical forces translation and rotation, diffusion, directed movements, biomolecules as machines, work, power and energy, thermal, chemical and mechanical switching of biomolecules, Responses to light and environmental cues; Molecular recognition: principles of specificity in biological recognition, hormonereceptor interaction, antigenantibody interaction, transient interactions, importance of transient interaction in biology. Stochasticity in Biological systems; Overexpression and purification of protein: Bulk scale bacterial cell culture and IPTG induction for protein expression, Detection of protein by western blotting in soluble and insoluble fraction after bacterial cell lysis, Affinity purification of the protein from the soluble fraction of the bacterial cell lysate (for His-tagged protein, Ni-agarose matrix will be used), Biochemical and biophysical characterizations of the purified protein: Purified protein will be assayed for its biological activity, (Fluorescence from GFP), UV-VIS absorption and emission spectra resulting from intrinsic Tryptophan and GFP chromophores, Fluorescence quenching and polarization studies, Unfolding
and refolding studies using CD and fluorescence methods, Fluorescence correlation spectroscopy experiment to measure the protein diffusion and hydrodynamic size, Atomic force microscopy of plasmid DNA.

Unit III
Analytical instrumentation
8 lectures

Spectroscopic properties of proteins and nucleic acid: UV/Vis, Intrinsic fluorescence, Circular dichroism. Double Strand formation in nucleic acid, Ligand-protein binding, Protein denaturation and stability, Introduction of DSC and ITC; Protein folding kinetics and Biophysical methods, Misfolding and aggregation; Physical basis of conformation diseases; Introduction to basic principles of protein X-ray crystallography, protein NMR, Small Angle X-ray scattering (SAXS), and Electron microscopy (EM), cryo-EM, Graphics and structural validation, Structural databases, Other biophysical and spectroscopic techniques to understand conformations of biomolecules; Mass Spectroscopy: Ionization techniques; mass analyzers/overview MS; FT-ICR and Orbitrap, fragmentation of peptides; proteomics, nano LC-MS; Phospho proteomics; Optical Imaging Methods: Light Microscopy: fluorescence and fluorescence microscopy: confocal microscope: scanning optical microscope, confocal principle, nonlinear microscopy: multiphoton microscopy; tandem scanning (spinning disk) microscopes, deconvolving confocal images; image processing, advanced fluorescence techniques: FLIM, FRET, and FCS, Fluorescence Lifetime, Fluorescence Resonant Energy Transfer (FRET), Fluorescence Correlation Spectroscopy (FCS), Evanescent Wave Microscopy; Beyond Diffraction Limit: Stimulated Emission Depletion (STED), Super-Resolution Summary, Super-Resolution Imaging with Stochastic Optical Reconstruction Microscopy (STORM) and Photoactivated Localization Microscopy (PALM).

Recommended Textbooks and References:
1. Preparing various stock solutions and working solutions that will be needed for the course.
2. To prepare an Acetic-Na Acetate Buffer and validate Henderson-Hasselbach equation.
3. To determine an unknown protein concentration by plotting a standard graph of BSA using UV-VIS Spectrophotometer and validating the Beer-Lambert's Law.
4. Titration of Amino Acids and separation of aliphatic, aromatic and polar amino acids by thin layer chromatography.
5. Purification and characterization of an enzyme from a recombinant source (such as Alkaline Phosphatase or Lactate Dehydrogenase or any enzyme of institution's choice).
   a) Preparation of cell-free lysates
   b) Ammonium Sulfate precipitation
   c) Ion-exchange Chromatography
   d) Gel Filtration
   e) Affinity Chromatography
   f) Generating a Purification Table (protein concentration, amount of total protein)
   h) Computing specific activity of enzyme preparation at each stage of purification
   i) Assessing purity of samples from each step of purification by SDS-PAGE Gel Electrophoresis
   j) Enzyme Kinetic Parameters: Km, Vmax and Kcat.
   k) Dialysis of the purified protein solution against 60% glycerol as a demonstration of storage method
6. Experimental verification that absorption at OD260 is more for denatured DNA as compared to native double stranded DNA.
7. Identification of an unknown sample as DNA, RNA or protein using available laboratory tools. (Optional Experiments)
Course Objectives
The objectives of this course are to teach fundamental biochemical, microbiological and molecular biological laboratory techniques for investigating experimental problems. Using data generated in a range of experiments, students should be able to apply relevant theoretical concepts to analyze the data and evaluate experimental outcomes.

Student Learning Outcomes
Upon successful completion of this course, students are expected to demonstrate competence in the laboratory techniques employed in molecular biology and fisheries, conservation and oceanography experiments.

Syllabus
Microbiology
1. Sterilization, disinfection and safety in microbiological laboratory.
2. Preparation of media for cultivation of bacteria (differential and selective).
3. Isolation of bacteria in pure culture by streak plate method.
4. Study of colony and growth characteristics of some common bacteria: Bacillus, E. coli, Staphylococcus, Streptococcus, etc.
5. Preparation of bacterial smear and Gram's staining.
7. Antimicrobial sensitivity test and demonstration of drug resistance.
8. Maintenance of stock cultures: slants, stabs and glycerol stock cultures
9. Determination of phenol co-efficient of antimicrobial agents.
10. Determination of Minimum Inhibitory Concentration (MIC)
11. Isolation and identification of bacteria from soil/water samples.

Syllabus
Fisheries
1. Identification and quantification of phytoplankton (diatoms and dinoflagellates) using microscopy/FlowCAM/ HPLC
2. Qualitative and quantitative enumeration of zooplankton (microscopy/Flowcam)
3. Identification of commercially important crustaceans (prawns, Shrimps, lobsters and crabs), molluscs (plecypods, gastropods and Cephalopods) and fishes (Cartilaginous & teleost) apart from dolphins & whales.
4. Identification of larval stages of crustaceans (prawns, shrimps, lobsters and crabs), molluscan and fish eggs and larvae.
5. Qualitative and quantitative enumeration of benthos, Sediment characterization
6. Primary productivity - measurement and new production
7. Gut content analysis for assessing food and feeding habits
8. Reproductive biology and ecology of commercially important crustaceans, molluscs and fishes
9. Introduction to basic molecular tools for evaluation of community structure – DNA extraction, PCR/Q-PCR, DGGE, cloning, sequencing
10. Crafts and gears- Principles and operation of different fishing gears.
Course Objectives

The cells are "the fundamental building blocks of all organisms". Therefore, a comprehensive understanding of the cell and cellular function is essential for all biologists. Subsequently, it is equally important to understand how a single cell, develop into an embryo, grow, into an adult, sexually matures, and ages. Along with, stem cell biology which lies at intersection of developmental/cell biology and medicine has emerged as a great promise for future of regenerative medicine. In view of above, this course will provide a conceptual overview of cellular system and functioning, and also discuss how developmental patterns arise using examples from different model systems and highlighting regulatory networks involved in these processes. The course also discusses essential aspects of stem cell biology, their usage for therapeutic purposes and social implications associated with this modern technology.

Student Learning Outcomes

At the end of course students should be able to:

• Understand major ideas in cell biology and developmental biology;
• Familiarize with experimental approaches, and how they are applied to specific problems in cell and developmental biology;
• Carry out and interpret experiments in cell and developmental biology.

Unit I
Cell architecture, organisation and function of organelles
10 lectures

Cell theory; diversity of cell size and shape: Microscope and its modifications – Light, phase contrast and interference, Fluorescence, Confocal, Electron (TEM and SEM), Electron tunnelling and Atomic Force Microscopy, etc.; Membrane Structure and Function: Structural models; Composition and dynamics; Transport of ions and macromolecules; Pumps, carriers and channels; Endo- and Exocytosis; Membrane carbohydrates and their significance in cellular recognition; Cellular junctions and adhesions; Structure and functional significance of plasmodesmata; Organelles: Nucleus – Structure and function of nuclear envelope, lamina and nucleolus; Macromolecular trafficking; Chromatin organization and packaging; Cell cycle and control mechanisms; Mitochondria – structure, organization of respiratory chain complexes, ATP synthase, Structure-function relationship; Mitochondrial DNA and male sterility; Origin and evolution; Chloroplast– Structure-function relationship; Chloroplast DNA and its significance; Chloroplast biogenesis; Origin and evolution.

Unit II
Cellular motility
6 lectures

Structure and function of microbodies, Golgi apparatus, Lysosomes and Endoplasmic Reticulum; Organization and role of microtubules and microfilaments; Cell shape and motility; Actin-binding proteins and their significance; Muscle organization and function; Molecular motors; Intermediate filaments; Extracellular matrix in plants and animals; Cellular Movements and Pattern Formation- Laying of body axis planes; Differentiation of germ layers; Cellular polarity; Model plants like Fucus and Volvox; Maternal gene effects; Zygotic gene effects; Homeotic gene effects in Drosophila; Embryogenesis and early pattern formation in plants; Cell lineages and developmental control genes in Caenorhabditis.
Stem cell differentiation; Blood cell formation; Fibroblasts and their differentiation; Cellular basis of immunity; Differentiation of cancerous cells and role of proto-oncogenes; Phase changes in Salmonella; Mating cell types in yeast; Surface antigen changes in Trypanosomes; Heterocyst differentiation in Anabaena; Sex determination in Drosophila; Plant Meristem Organization and Differentiation - Organization of Shoot Apical Meristem (SAM); Organization of Root Apical Meristem (RAM); Pollen germination and pollen tube guidance; Phloem differentiation; Self-incompatibility and its genetic control; Embryo and endosperm development; Heterosis and apomixis.

Recommended Textbooks and References:

Course Objectives
The objectives of this course are to teach various approaches to conducting genetic engineering and its applications in biological research as well as in biotechnology industries.

Student Learning Outcomes
Given the impact of genetic engineering in modern society, students should be endowed with strong theoretical knowledge of this technology. In conjunction with the practicals in molecular biology & genetic engineering, the students should be able to take up biological research as well as placement in the relevant biotech industry.
Unit IV

cDNA analysis
7 lectures

Insertion of foreign DNA into host cells; transformation, electroporation, transfection; construction of libraries; isolation of mRNA and total RNA; reverse transcriptase and cDNA synthesis; cDNA and genomic libraries; construction of microarrays – genomic arrays, cDNA arrays and oligo arrays; study of protein - DNA interactions: electrophoretic mobility shift assay; DNase I footprinting; methyl interference assay, chromatin immunoprecipitation; protein-protein interactions using yeast two-hybrid system; phage display.

Unit V

Gene silencing and genome editing technologies
13 lectures

Gene silencing techniques; introduction to siRNA; siRNA technology; Micro RNA; construction of siRNA vectors; principle and application of gene silencing; gene knockouts and gene therapy; creation of transgenic plants; debate over GM crops; introduction to methods of genetic manipulation in different model systems e.g. fruit flies (Drosophila), worms (C. elegans), frogs (xenopus), fish (zebra fish) and chick; Transgenics - gene replacement; gene targeting; creation of transgenic and knock-out mice; disease model; introduction to genome editing by CRISPR-CAS with specific emphasis on Chinese and American clinical trials; Cloning genomic targets into CRISPR/ Cas9 plasmids; electroporation of Cas9 plasmids into cells; purification of DNA from Cas9 treated cells and evaluation of Cas9 gene editing; in vitro synthesis of single guide RNA (sgRNA); using Cas9/sgRNA complexes to test for activity on DNA substrates; evaluate Cas9 activity by T7E1 assays and DNA sequence analysis; Applications of CRISPR/cas9 technology.

Recommended Textbooks and References:
5. Technical Literature from Stratagene, Promega, Novagen, New England Biolab etc.

Aquaculture Bioprocessing and Marine Pharmacology

Credits

3

Course Objectives
This course is designed to give a brief outline of bioprocess methods required for obtaining essential components from marine organisms which may have pharmacological importance.

Student Learning Outcomes
On completion of this course, students should be able to identify technologies and techniques that can be employed to get bioactive compounds from marine ecosystem and use scale up technologies to process and produce them on a large scale.

Unit I

Microbial and micro-algal technologies in aquaculture
10 lectures

Bio-floc technology; Aquaponics; Zero water exchange aquaculture system; Aquamimicry; Hydroponics; Raceway system of aquaculture; Bioremediation in Aquaculture systems: Genetically modified organisms in waste water treatment; Bioremediation for soil and water quality improvement; Probiotics: Preparation and applications; Micro-algae- indoor and mass-culture methods, Biotechnological approaches for production of important microalgae. Single cell protein from Spirulina; vitamins, minerals and Omega-3 fatty acids from micro-algae; enrichment of micro-algae
with micro-nutrients; cell wall polysaccharides of micro-algae; micro algae biomass for removal of heavy metals; Biofuel production from microalgae; metabolic engineering of microalgae for biofuel production.

**Unit II**

**Industrial aquaculture technology**

10 lectures

Fish Feed Technology: Types of feed, conventional feed vs functional feeds; Principles of feed formulation and manufacturing, diets suitable for application in different aquaculture systems; feed formulation ingredients; Use of natural and synthetic carotenoids; feed additives; Role of additives; Feed processing: Gelatinization, extrusion Technology, pellet dressing with heat liable nutrients; Feed evaluation; Feeding schedule to different aquatic organisms, check tray operation and feed management, Biomass calculation based on feed intake; Post-harvest Biotechnology: Fundamental aspects of freezing, methods of freezing; Delaying of spoilage; Detection of toxic substances and pathogenic microbes; biosensors for toxin detection; Natural biomaterial used for preservation of fish, Antibiotic residual analysis techniques, detection of human pathogenic bacteria by PCR methods, Microbial and enzymatic standards of different fishery products.

**Unit III**

**Marine pharmacology**

10 lectures

Principles & mechanisms of drug action; Pharmacokinetics & pharmacodynamics; Marine derived pharmaceuticals: Marine bio-resources, secondary metabolites, marine proteins and lipids & molecular biology approaches; Marine actinobacterial metabolites & their pharmacological potential; Potential pharmaceuticals from soft and hard corals; pharmaceutical potential of marine sponges; metagenomic strategies for natural product discovery; marine biotoxins and potential pharmacological uses of phyco-toxins.

**Unit IV**

**Important marine products**

2 lectures

Green fluorescent protein (GFP) & red fluorescent protein (RFP) characteristics and their applications; Green mussel adhesive protein; Chitosan and its applications; ornamental fishes.

**Recommended Textbooks and References:**


**Fish Immunology and Health Management**

**Credits**

3

**Course Objectives**

This course is aimed to teach basic principles of fish and shell immunology along with essential principles in their health management and related issues.

**Student Learning Outcomes**

On completion of this course, students should be able to:

- Understand about common immunological threats in marine environment;
- Know brief of health management of fisheries.
Unit I

Defence mechanism in fish and shellfish
10 lectures

Non-specific defence mechanisms: Surface barriers, gastrointestinal tract; Non-specific humoral factors: Growth inhibitors, Enzyme inhibitors, Precipitins and agglutinins; Non-specific cellular factors; Adaptive and Innate immunity: cells, factors and mechanisms, Specific defence mechanism; Antibody molecule; Antibody effector mechanisms; Factors affecting immune response: intrinsic and extrinsic factors; Cellular components of crustacean immunity: Non-self recognition mechanisms, Innate immediate immune reactions; Mechanisms of cellular defence in crustaceans - Phagocytosis, Nodule formation, Encapsulation, Cytotoxicity, Cell adhesion; Humoral components of crustacean immunity: Lectins, ProPO activating system; Antimicrobial compounds; Serine proteinase inhibitors, Clotting reaction; Maternal transmission of immunity to white spot syndrome associated virus (WSSV) in shrimp (Peneaus monodon) Broad antiviral activity in tissues of crustaceans; Circulating haemocytes and haematopoiesis; Toxins as defense mechanism.

Unit II

Fish and shellfish diseases and diagnostic techniques
10 lectures

Significance of fish diseases in relation to Aquaculture; Disease development process in fish; Infectious diseases of cultured finfish and shellfish: Bacterial, viral, fungal diseases of fish and shellfish; Parasitic diseases of fish and shellfish; zoonotic and OIE listed notifiable diseases; Non-infectious diseases; Antibody Based Disease diagnostics: Antibodies, sources of antibodies; Basis of antibody based diagnostics; Conventional Antibody based Tests-Neutralisation Test, agglutination Test; Advanced antibody based Tests: ELISA, ELISPOT assay, Immunodot Assay, Western blotting; Molecular Diagnostics: PCR, RT-PCR, LAMP, Real Time PCR, Micro-Array and Probe based techniques in fish disease diagnosis; Cell culture based Diagnostics: Cell culture media & supplements, Primary cell culture, Passaging of cell culture for routine maintenance, Fish cell lines; Isolation and Identification of viruses using cell culture.

Unit III

Health management
10 lectures

Drugs, chemicals, antibiotics and probiotics used in aquaculture and their mode of action; Preventive strategies; Principles and methods of vaccine production and fish immunization; DNA and RNAi vaccines; Quarantine and health certification in aquaculture; Crop rotation, Immunostimulants, bioremediation and polyculture as strategies for health management. Probiotics; Quarantine and health certification; Bioremediators and Other prophylactic measures; Pharmacology: Terms and Definitions; Drugs, chemicals, antibiotics, probiotics and their mode of action.

Recommended Textbooks and References:
Aquatic Environmental Biotechnology

Course Objectives
The objective of this course is to impart knowledge on biotechnological applications that can be used to tackle environmental issues pertaining to marine ecology and biodiversity.

Student Learning Outcomes
On completion of this course, students should be able to:
- Identify interaction between marine organisms and environment;
- Employ environmental pollution management technologies to come up with solutions against growing marine pollution.

Unit I
Marine organisms and environment interaction
7 lectures
Types of marine environment - Physical, Chemical and Biological aspects and their interaction with marine life; Air – Sea interaction; Greenhouse gases (CO2 and Methane); Marine pollution-major pollutants (heavy metal, pesticide, oil, thermal, radioactive, plastics, litter and microbial) & sources; Biological indicators (Marine microbes, algae and crustaceans) as a tool for assessment of aquatic environment: Protein biomarkers; Biosensors and biochips; eutrophication; red tides & pesticide kills; immune responses of aquatic animals in bio-unsafe environment; Bioaccumulation and impact on aquatic fauna; Microbial Pollution: Types of aquatic microbes; autotrophs, heterotroph, saprotrophs and necrotrophs.

Unit II
Biomaterial interaction
7 lectures
Biofilm formation; Biofouling; Marine fouling and boring organisms - their biology, adaptation; Biosensor in pollution detection; Unculturable bacteria- occurrence, characteristics, characterization and exploitation; Factors influencing settlement of macrofoulers; Antifouling and Anti boring treatments; Corrosion Process and control of marine structures.

Unit III
Biotechnology in pollution management
7 lectures
BOD, COD; Marine pollution & its control; genetically modified microbes for wastewater treatment; Biosensors-types & applications; Biomolecules; membrane and transducer; Bioaugmentation- estimation of microbial load; Methods of Inorganic and Organic waste removal; treatment of Oil pollution at sea; Biodegradation; Bioremediation & Phytoremediation; Biodegradation of natural and synthetic waste materials; methods in determining bioaugmentation & biomagnification; Separation, purification and bio removal of pollutants; fermented products and Biogas from wastes; utilization of aquatic slurry for salt-resistant paddy cultivation.

Recommended Textbooks and References:
### Course Objectives
The objectives of this course are to provide students with theory and practical experience of use of common computational tools and databases which facilitate investigation of molecular biology and evolution-related concepts.

### Student Learning Outcomes
Student should be able to:
- Develop an understanding of basic theory of these computational tools.
- Gain working knowledge of these computational tools and methods.
- Appreciate their relevance for investigating specific contemporary biological questions.

### Unit I
**Biological databases**
- 5 lectures
  - Introduction, Primary & Secondary database, Sequence file formats, Introduction to structures, Protein Data Bank (PDB), Molecular Modelling Database (MMDb), Structure file formats, Visualizing structural information, Database of structure viewers, Collection of sequences, sequence annotation, sequence description.

### Unit II
**Sequence alignment and database searching**
- 5 lectures
  - Evolutionary basis of sequence alignment, Optimal alignment methods, Substitution scores & gap penalties, Statistical significance of alignments, Database similarity searching, FASTA, BLAST, Low complexity regions, Repetitive elements, Multiple Sequence Alignment: Progressive alignment methods, Motifs and patterns, Clustal, Muscle; Scoring matrices, Distance matrices.

### Unit III
**Phylogenetic analysis**
- 5 lectures
  - Alignment, tree building and tree evaluation, Comparison and application of Unweighted Pair Group Method with Arithmetic Mean (UPGMA), Neighbour Joining (NJ), Maximum Parsimony (MP), Maximum Likelihood (ML) methods, Bootstrapping, Jackknife; Software for Phylogenetic analysis. DNA barcoding: Methods tools and databases for barcoding across all species, Applications and limitations of barcoding, Consortium for Barcode of Life (CBOL) recommendations, Barcode of Life Database (BOLD).

### Unit IV
**Structural biology**
- 5 lectures
  - 3-D structure visualization and simulation, Basic concepts in molecular modeling: different types of computer representations of molecules; External coordinates and Internal Coordinates, Molecular Mechanics, Force fields etc. Secondary structure elucidation using Peptide bond, phi, psi and chi torsion angles, Ramachandran map, anatomy of proteins – Hierarchical organization of protein structure –like CATH (class, architecture, topology, homology), SCOP (Structural Classification of Proteins), FSSP (families of structurally similar proteins).

### Unit V
**Classification and comparison of 3D structures**
- 5 lectures
  - DNA & RNA secondary and tertiary structures, t-RNA tertiary structure; Protein Secondary structure prediction: Algorithms viz. Chou Fasman, GOR methods, Tertiary Structure prediction: Fundamentals of the methods for 3D structure prediction (sequence similarity/identity of target proteins of known structure, fundamental principles of protein folding etc.) Homology/comparative modeling, fold recognition, threading approaches, and ab initio structure prediction methods; CASP (Critical Assessment of protein Structure Prediction); Computational design of promoters, proteins & enzymes.

### Unit VI
**Applications in drug design**
- 5 lectures
  - Chemical databases like NCI/PUBCHEM; Fundamentals of Receptor-ligand interactions; Structure-based drug design: Identification and Analysis of Binding sites and virtual screening; Ligand based drug design: Structure Activity Relationship – QSARs & Pharmacophore; *In silico* predictions of drug activity and ADMET.
Unit VII  
Analysis of microarray data  
5 lectures  
Designing of oligo probes; Image processing and normalization; Microarray data variability (measurement and quantification); Analysis of differentially expressed genes; Experimental designs.

Unit VIII  
Biological algorithms  
2 lectures  
Comparison with computer algorithms, string structures, Introduction to programming in computational biology through C/Perl/Java.

Unit IX  
Systems biology  
3 lectures  
System-level understanding of biological systems, use and integration of data from transcriptomics, proteomics and metabolomics; concepts in glycomics, interactomics and fluxomics.

Recommended Textbooks and References:  
4. Dov Stekel, (2003); Microarray Bioinformatics; Cambridge University Press.  
5. Web-resources and suggested reviews/research papers.

Course Objectives  
The objectives of this course are to provide students with the experimental knowledge of molecular biology and genetic engineering.

Student Learning Outcomes  
Students should be able to gain hands-on experience on gene cloning, protein expression and purification. This experience would enable them to begin a career in industry.

Laboratory III: Molecular Biology and Genetic Engineering  
4 Credits

Syllabus  
1. Concept of lac-operon:  
   a) Lactose induction of β-galactosidase.  
   b) Glucose Repression.  
   c) Diauxic growth curve of E. coli.  
2. UV mutagenesis to isolate amino acid auxotroph.  
4. Genetic Transfer-Conjugation, gene mapping.  
5. Plasmid DNA isolation and DNA quantitation.  
6. Restriction Enzyme digestion of plasmid DNA.  
7. Agarose gel electrophoresis.  
8. Polymerase Chain reaction.  
9. DNA Ligation.  
11. Transformation of E.coli with standard plasmids, Calculation of transformation efficiency.
12. Confirmation of the insert by Colony PCR and Restriction mapping
13. Expression of recombinant protein, concept of soluble proteins and inclusion body formation in E.coli, SDS-PAGE analysis
14. Purification of His-Tagged protein on Ni-NTA columns
   a) Random Primer labeling
   b) Southern hybridization.

Course Objectives
This practical course aims to teach basic immunological techniques which can be used for identifying marine parasites and pathogens for health management.

Student Learning Outcomes
On completion of this course, students should be able to identify various parasites and pathogens present in marine environment and effectively perform various immunological tests used in various diagnostics labs.

Laboratory IV: Aquaculture and Fish Immunology and Health Management

Credits
4

Syllabus
1. Sampling of fish and shellfish for disease diagnosis
2. Histology techniques
3. Identification of bacteria- staining techniques and biochemical techniques
4. Observation of cellular components of Fish blood and shrimp hemolymph
5. Isolation and characterization of Fungi from fish & slide culture of fungi
6. Identification of fish parasites
7. Antibiotic sensitivity test
8. Bacterial agglutination test
9. Agar gel precipitation test
10. Antibody titre by ELISA, SDS-PAGE, immunoblotting and dot-blotting Nucleic Acid Isolation, PCR, RT-PCR
11. Hybridoma technology and monoclonal antibody production
12. Cell culture and passaging
13. Isolation of virus using cell culture.

Course Objectives
This practical course aims to impact basic skills in aquatic environmental biotechnology for environmental protection and remediation.

Student Learning Outcomes
On completion of this course, students should be able to conduct basic aquatic environmental biotechnology experiments and design experiments which can be useful in bioremediation in aquatic environment.

Laboratory V: Aquatic Environmental Biotechnology

Credits
2
Syllabus

1. Estimation of dissolved oxygen, salinity, H₂S, BOD and COD
2. Estimation of heavy metals (Cu, Cd, Pb, Hg)
3. Demonstration – estimation of pesticide residues, petroleum hydrocarbons using GC
4. Experiment on heavy metal removal using biosorbent
5. Microscopic studies of biofilm using test panels
6. Identification of organisms involved in fouling and boring
7. Methods of isolation of viable and unculturable bacteria from the sea
8. Recombinant DNA technology to construct biosensor
9. Detection of sea food associated pathogens using multiplex PCR
10. Metagenomic DNA isolation from coastal water
11. Bacterial diversity by 16S rDNA amplification of metagenomic DNA.

Semester Three

Marine Bioprocess Technology

Course Objectives

The objectives of this course are to educate students about fundamental concepts of bioprocess technology and its related applications, thus, preparing them to meet challenges of new and emerging areas of biotechnology industry.

Student Learning Outcomes

On completion of this course, students should be able to:

- Appreciate relevance of microorganisms from industrial context;
- Carry out stoichiometric calculations and specify models of their growth;
- Give an account of design and operations of various fermenters;
- Present unit operations together with fundamental principles for basic methods in production technique for bio-based products;
- Calculate yield and production rates in biological production process, and also interpret data;
- Calculate the need for oxygen and oxygen transfer in bio-production process;
- Critically analyse any bioprocess from an economics/market point of view;
- Give an account of important microbial/enzymatic industrial processes in food and fuel industry.

Unit I

Biochemical engineering

Basic principles of Biochemical engineering: Isolation, screening and maintenance of industrially important microbes; microbial growth and death kinetics (an example from each group, particularly with reference to industrially useful microorganisms); strain improvement for increased yield and other desirable characteristics; Stoichiometry and Models of Microbial Growth: Elemental balance equations; metabolic coupling – ATP and NAD+; yield coefficients; unstructured models of microbial growth; structured models of microbial growth.

Unit II

Bioprocess technology

Bioreactor Design and Analysis: Batch and continuous fermenters; modifying batch and continuous reactors: chemostat with recycle, multistage chemostat systems, fed-batch operations; conventional fermentation vs biotransformations; immobilized cell systems; large scale animal and plant cell cultivation; fermentation economics; upstream processing: media formulation and optimization; sterilization; aeration, agitation and heat transfer in bioprocess; scale up and scale down; measurement and control of
bioprocess parameters; Downstream Processing and Product Recovery: Separation of insoluble products - filtration, centrifugation, sedimentation, flocculation; Cell disruption; separation of soluble products: liquid-liquid extraction, precipitation, chromatographic techniques, reverse osmosis, ultra and micro filtration, electrophoresis; final purification: drying; crystallization; storage and packaging; Fermentation Economics: Isolation of microorganisms of potential industrial interest; strain improvement; market analysis; equipment and plant costs; media; sterilization, heating and cooling; aeration and agitation; bath-process cycle times and continuous cultures; recovery costs; water usage and recycling; effluent treatment and disposal.

Applications of enzyme technology in food processing: Mechanism of enzyme function and reactions in process techniques; enzymatic bioconversions e.g. starch and sugar conversion processes; high-fructose corn syrup; interesterified fat; hydrolyzed protein etc. and their downstream processing; baking by amyloses, deoxygenation and desugaring by glucose oxidase, beer mashing and chill proofing; cheese making by proteases and various other enzyme catalytic actions in food processing; Applications of Microbial Technology in food process operations and production, biofuels and biorefinery: Fermented foods and beverages; food ingredients and additives prepared by fermentation and their purification; fermentation as a method of preparing and preserving foods; microbes and their use in pickling, producing colours and flavours, alcoholic beverages and other products; process wastes-whey, molasses, starch substrates and other food wastes for bioconversion to useful products; bacteriocins from lactic acid bacteria – production and applications in food preservation; biofuels and biorefinery.

Recommended Textbooks and References:


Aquaculture Biotechnology

**Course Objectives**

This course is aimed to teach sustainable use of aquatic resources with various approaches in biotechnology.

**Student Learning Outcomes**

On completion of this course, students should be able to:

- Explain fundamental principles of aquaculture biotechnology;
- Identify role of aquaculture biotechnology in society.

Male and female of finfish and shellfish; Primary and secondary sex characters; Process of Oogenesis & Spermatogenesis, metabolic changes during gametogenesis; neuroendocrine system in crustacean & molluscs & its role in control of reproduction; mechanism of hormone synthesis, release, transport & action; Pheromones & reproductive behaviour; environmental factors influencing reproduction; Advances in Fish Breeding: Hypophysation, evaluation of carp milt and egg, cryopreservation technique, Genetic
basis of determination of sex; chromosome manipulation: ploidy induction, sex reversal; gynogenesis and androgenesis; Broodstock management; Application of Cross breeding in aquaculture; Selective breeding: qualitative and quantitative traits for selection, methods of selection; Inbreeding and heterosis in various economic characters; hormone induced ovulation; Synthetic hormones for induced breeding- GnRH analogue structure and function.

Unit II
Culture systems and hatchery techniques
10 lectures

Importance of coastal aquaculture; Aqua farms; Design and construction; Criteria for selecting cultivable species; Culture systems and management practices – extensive, semi intensive and intensive culture practices; Seed production in controlled condition; Types; Design and management of hatchery – induced spawning; Mass production of seeds; feed formulation; Artificial insemination - in vitro fertilization; Culture of Live food organisms: Candidate species of phytoplankton & zooplankton as live food organisms; biology & culture requirements of live food organisms: green algae, diatoms, rotifers, infusoria, tubifex, brine shrimp and earthworms.

Unit III
Advanced techniques in aquaculture management
10 lectures

Fish Cell culture Techniques: Tissue culture, cell lines, primary and secondary culture, cell culture based vaccines, organ and histotypic cultures; measurement of cell death; apoptosis; Cell Hybridization: Somatic cell fusion, hybridoma technology, Production and Application of monoclonal antibodies; Transgenic production of fishes : definition, transgenic fish, Methods of gene transfer in fishes, single gene traits, detection of transgenes, screening for transgenics, site of integration, applications; Evaluation of GFP transgenics; Genetically modified Fish Production- Prospects and Problems.

Recommended Textbooks and References:

Course Objectives
The objectives of this course are:
• To provide basic knowledge on intellectual property rights and their implications in biological research and product development;
• To become familiar with India’s IPR Policy;
• To learn biosafety and risk assessment of products derived from biotechnology and regulation of such products;
• To become familiar with ethical issues in biological research. This course will focus on consequences of biomedical research technologies such

Student Learning Outcomes
On completion of this course, students should be able to:
• Understand the rationale for and against IPR and especially patents;
• Understand why India has adopted an IPR Policy and be familiar with broad outline of patent regulations;
• Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents;
Unit I
**Introduction to IPR**
5 lectures

Introduction to intellectual property; types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of ‘prior art’: invention in context of “prior art”; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation.

Unit II
**Patenting**
5 lectures

Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure - patent application- forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting-requirement, procedures and costs; financial assistance for patenting-introduction to existing schemes; publication of patents-gazette of India, status in Europe and US; patent infringement- meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing – outright sale, licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives.

Unit III
**Biosafety**
5 lectures

Biosafety and Biosecurity - introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants – sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk – environmental risk assessment and food and feed safety assessment; problem formulation – protection goals, compilation of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops vs cisgenic plants or products derived from RNAi, genome editing tools.

Unit IV
**National and international regulations**
5 lectures

International regulations – Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations – EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – biosafety levels and category of rDNA experiments; field trails – biosafety research trials – standard operating procedures - guidelines of state governments; GM labeling – Food Safety and Standards Authority of India (FSSAI).

Recommended Textbooks and References:
2. National IPR Policy, Department of Industrial Policy & Promotion, Ministry of Commerce, GoI
5. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/

Bioentrepreneurship

Course Objectives
Research and business belong together and both are needed. In a rapidly developing life science industry, there is an urgent need for people who combine business knowledge with the understanding of science & technology. Bio-entrepreneurship, an interdisciplinary course, revolves around the central theme

Student Learning Outcomes
Students should be able to gain entrepreneurial skills, understand the various operations involved in venture creation, identify scope for entrepreneurship in biosciences and utilize the schemes promoted through knowledge centres and various agencies. The knowledge pertaining to management
of how to manage and develop life science companies and projects. The objectives of this course are to teach students about concepts of entrepreneurship including identifying a winning business opportunity, gathering funding and launching a business, growing and nurturing the organization and harvesting the rewards. Should also help students to be able to build up a strong network within the industry.

### Unit I
**Innovation and entrepreneurship in bio-business**
8 lectures

Introduction and scope in Bio-entrepreneurship, Types of bio-industries and competitive dynamics between the sub-industries of the bio-sector (e.g. pharmaceuticals vs. Industrial biotech), Strategy and operations of bio-sector firms: Factors shaping opportunities for innovation and entrepreneurship in bio-sectors, and the business implications of those opportunities, Alternatives faced by emerging bio-firms and the relevant tools for strategic decision, Entrepreneurship development programs of public and private agencies (MSME, DBT, BIRAC, Make In India), strategic dimensions of patenting & commercialization strategies.

### Unit II
**Bio markets: business strategy and marketing**
8 lectures

Negotiating the road from lab to the market (strategies and processes of negotiation with financiers, government and regulatory authorities), Pricing strategy, Challenges in marketing in bio business (market conditions & segments; developing distribution channels, the nature, analysis and management of customer needs), Basic contract principles, different types of agreement and contract terms typically found in joint venture and development agreements, Dispute resolution skills.

### Unit III
**Finance and accounting**
8 lectures

Business plan preparation including statutory and legal requirements, Business feasibility study, financial management issues of procurement of capital and management of costs, Collaborations & partnership, Information technology.

### Unit IV
**Technology management**
8 lectures

Technology – assessment, development & upgradation, Managing technology transfer, Quality control & transfer of foreign technologies, Knowledge centers and Technology transfer agencies, Understanding of regulatory compliances and procedures (CDSCO, NBA, GCP, GLA, GMP).

### Recommended Textbooks and References:

Project Proposal Preparation & Presentation

Course Objectives
The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.

Student Learning Outcomes
Students should be able to demonstrate the following abilities:
- Formulate a scientific question;
- Present scientific approach to solve the problem;
- Interpret, discuss and communicate scientific results in written form;
- Gain experience in writing a scientific proposal;
- Learn how to present and explain their research findings to the audience effectively.

Syllabus

Project Proposal Preparation
Selection of research lab and research topic: Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them select a topic for their project. The topic of the research should be hypothesis driven.

Review of literature: Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources.

Writing Research Proposal: With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc. Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.

Poster Presentation
Students will have to present the topic of their project proposal after few months of their selection of the topic. They should be able to explain the novelty and importance of their research topic.

Oral Presentation
At the end of their project, presentation will have to be given by the students to explain work done by them in detail. Along with summarizing their findings they should also be able to discuss the future expected outcome of their work.

Laboratory VI: Bioprocess Technology

Course Objectives
The objectives of this laboratory course are to provide hands-on training to students in upstream and downstream unit operations.

Student Learning Outcomes
Students should:
- Gain ability to investigate, design and conduct experiments, analyze and interpret data, and apply laboratory skills to solve complex bioprocess technology problems.
- Use acquired skills and knowledge in solving problems typical of bio industries and research.

Syllabus

1. Basic Microbiology techniques
   a) Scale up from frozen vial to agar plate to shake flask culture
   b) Instrumentation: Microplate reader, spectrophotometer, microscopy
c) Isolation of microorganisms from soil samples

2. Experimental set-up
   a) Assembly of bioreactor and sterilization
   b) Growth kinetics
   c) Substrate and product inhibitions
   d) Measurement of residual substrates

3. Data analysis
   a) Introduction of Metabolic Flux Analysis (MFA)

4. Fermentation (acids, alcohols, antibiotics)
   a) Batch
   b) Fed-batch
   c) Continuous

5. Unit operations
   a) Microfiltrations: Separation of cells from broth
   b) Bioseparations: Various chromatographies and extractions

6. Bioanalytics
   a) Analytical techniques like HPLC, FPLC, GC, GC-MS etc. for measurement of amounts of products/substrates.

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**Recommended Textbooks and References:**


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**Laboratory VII: Aquaculture Biotechnology**

**Course Objectives**

This practical course is designed to teach basics of aquaculture biotechnology including identification of various organisms and tissue culture techniques for maintenance of aquatic cell lines.

**Student Learning Outcomes**

On completion of this course, students should have gained hands on experience to maintain various cell lines and have basic identification criteria for marine organisms.

**Syllabus**

1. Dissection and location of testis and ovary in fishes
2. Dissection and location of ‘x’ and ‘y’ organs in shrimps
3. Hypophysation technique in fish
4. Maturity stages of ovary in crustaceans and finfish
5. Identification of phytoplankton and zooplankton
6. Mass culture of Live feed organisms
7. Chromosome manipulation – androgenesis, gynogenesis, triploidy, tetraploidy
8. Induced breeding of carps
9. Development of fish cell culture
10. Maintenance of fish cell lines (Passaging)
11. Methods of gene transfer.

Course Objectives
The aim is to provide practical training in bioinformatics and statistical methods including accessing major public sequence databases.

Student Learning Outcomes
On completion of this course, students should be able to:

- Describe contents and properties of important bioinformatics databases, perform text- and sequence-based searches, analyse and discuss results in light of molecular biology knowledge;
- Explain major steps in pairwise and multiple sequence alignment, explain its principles and execute pairwise sequence alignment by dynamic programming;
- Predict secondary and tertiary structures of protein sequences;
- Perform and analyse various statistical tools available to analyse the data.

Syllabus
1. Using NCBI and Uniprot web resources.
2. Introduction and use of various genome databases.
4. Similarity searches using tools like BLAST and interpretation of results.
5. Multiple sequence alignment using ClustalW.
7. Use of gene prediction methods (GRAIL, Genscan, Glimmer).
8. Using RNA structure prediction tools.
9. Use of various primer designing and restriction site prediction tools.
10. Use of different protein structure prediction databases (PDB, SCOP, CATH).
11. Construction and study of protein structures using Deepview/PyMol.
13. Use of tools for mutation and analysis of the energy minimization of protein structures.
14. Use of miRNA prediction, designing and target prediction tools.
15. Use of Statistical packages like SPSS (Statistical Package for the Social Sciences)/SAS (Statistical Analysis System) & Maple
16. MATLAB (Matrix Laboratory)
17. Performing various statistical analysis like T-test, ANOVA, Regression, Chi-square, PLS (Partial Least Squares) and PCA (Principle Component Analysis).

Semester Four

Dissertation

Course Objectives
The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.

Student Learning Outcomes
Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:

- In-depth knowledge of the chosen
Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.

Assessment may be done by thesis evaluation, viva voce and final presentation.

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**Recommended Electives**

**Genomics and Proteomics**

**Course Objectives**
The objectives of this course are to provide introductory knowledge concerning genomics & proteomics and their applications.

**Student Learning Outcomes**
Students should be able to acquire knowledge and understanding of the fundamentals of genomics and proteomics, transcriptomics and metabolomics and their applications in various applied areas of biology.
Brief overview of prokaryotic and eukaryotic genome organization; extra-chromosomal DNA: bacterial plasmids, mitochondria and chloroplast.

Genetic and physical maps; markers for genetic mapping; methods and techniques used for gene mapping, physical mapping, linkage analysis, cytogenetic techniques, FISH technique in gene mapping, somatic cell hybridization, radiation hybrid maps, in situ hybridization, comparative gene mapping.

Human Genome Project, genome sequencing projects for microbes, plants and animals, accessing and retrieving genome project information from the web.

Identification and classification of organisms using molecular markers- 16S rRNA typing/sequencing, SNPs; use of genomes to understand the evolution of eukaryotes, track emerging diseases and design new drugs; determining gene location in genome sequence.

Aims, strategies and challenges in proteomics; proteomics technologies: 2D-PAGE, isoelectric focusing, mass spectrometry, MALDI-TOF, yeast 2-hybrid system, proteome databases.

Transcriptome analysis for identification and functional annotation of gene, Contig assembly, chromosome walking and characterization of chromosomes, mining functional genes in the genome, gene function- forward and reverse genetics, gene ethics; protein-protein and protein-DNA interactions; protein chips and functional proteomics; clinical and biomedical applications of proteomics; introduction to metabolomics, lipidomics, metagenomics and systems biology.

Recommended Textbooks and References:

Course Objectives
The course aims at providing general and broad introduction to multi-disciplinary field of nanotechnology. It will familiarize students with combination of top-down approach of microelectronics and micro-mechanics with bottom-up approach of chemistry/biochemistry; a development that is creating new and exciting cross-disciplinary research fields and technologies. The course will also give an insight into complete systems where nanotechnology can be used to improve everyday life.

Student Learning Outcomes
On successful completion of this course, students should be able to describe basic science behind the properties of materials at the nanometre scale, and the principles behind advanced experimental and computational techniques for studying nanomaterials.
### Unit I
**Introduction to nanobiotechnology**
- **5 lectures**

Introduction to Nanobiotechnology; Concepts, historical perspective; Different formats of nanomaterials and applications with example for specific cases; Cellular Nanostructures; Nanopores; Biomolecular motors; Bio-inspired Nanostructures, Synthesis and characterization of different nanomaterials.

### Unit II
**Nano - films**
- **5 lectures**

Thin films; Colloidal nanostructures; Self Assembly, Nanovesicles; Nanospheres; Nanocapsules and their characterisation.

### Unit III
**Nano - particles**
- **6 lectures**

Nanoparticles for drug delivery, concepts, optimization of nanoparticle properties for suitability of administration through various routes of delivery, advantages, strategies for cellular internalization and long circulation, strategies for enhanced permeation through various anatomical barriers.

### Unit IV
**Applications of nano - particles**
- **5 lectures**

Nanoparticles for diagnostics and imaging (theranostics); concepts of smart stimuli responsive nanoparticles, implications in cancer therapy, nanodevices for biosensor development.

### Unit V
**Nano - materials**
- **6 lectures**

Nanomaterials for catalysis, development and characterization of nanobiocatalysts, application of nanoscaffolds in synthesis, applications of nanobiocatalysis in the production of drugs and drug intermediates.

### Unit VI
**Nano - toxicity**
- **5 lectures**

Introduction to Safety of nanomaterials, Basics of nanotoxicity, Models and assays for Nanotoxicity assessment; Fate of nanomaterials in different stratas of environment; Ecotoxicity models and assays; Life cycle assessment, containment.

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**Recommended Textbooks and References:**

5. Recent review papers in the area of Nanomedicine.

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### Molecular Diagnostics

**Credits**: 2

**Course Objectives**

The objectives of this course are to sensitize students about recent advances in molecular biology and various facets of molecular medicine which has potential to profoundly alter many aspects of modern medicine including the pre- or post-natal analysis of genetic diseases and identification of individuals predisposed to disease ranging from common cold to cancer.

**Student Learning Outcomes**

Students should be able to understand various facets of molecular procedures and basics of genomics, proteomics and metabolomics that could be employed in early diagnosis and prognosis of human diseases.

---

**Unit I
**

**Basic molecular diagnostics**
- **5 lectures**

Historical perspective of clinical diagnosis and molecular diagnostics; Nucleic acid based diagnosis: Extraction of Nucleic acids: sample collection, methods of extraction from various diagnostic materials, assessment of quality, storage; Nucleic acid hybridization: Blotting Techniques and their interpretations: Southern and Northern Blotting

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<thead>
<tr>
<th>Unit II</th>
<th>Advanced techniques in molecular diagnosis</th>
<th>5 lectures</th>
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<td>Testing DNA variation for Disease association: SNPs; Methods of typing : Traditional approaches (PCR-Sequencing ), Microchips (Affymetrix) and Taqman : Microarray in analysis of gene expression; DNA microarray platforms: cDNA analysis, oligonucleotide arrays: Introduction to SAGE, CGH, array CGH and SNP arrays: Analysis of DNA methylation : Methylation in health and disease; Principle and inheritance; DNA methylation in pathology and cancer: PCR based methods in detection of methylation; Bisulfite modification and methylation specific PCR and Restriction analysis; real Time PCR methodologies (MethyLight), Profiling and arrays: Primer Designing for MSPs; Application of DNA methylation in disease diagnosis: cancer (malignancies)and imprinting disorders.</td>
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<th>Unit III</th>
<th>Cytogenetic techniques</th>
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<tr>
<td>Flow Cytometry and LCM: Principle; Clinical applications: enumeration of peripheral; blood cells in HIV infection and Immunophenotype Characterization in various blood disorders; Laser Capture Microdissection and separation of normal and aberrant cells; application and perspective in molecular diagnostics; Molecular Cytogenetic: Chromosomal abnormalities and indications of chromosomal evolution; Fluorescence in situ Hybridization; General procedures of FISH, M-FISH, SKY and CGH; Clinical applications of FISH: Correlation with the pathobiology of disease, disease prognosis and monitoring, correlation with molecular data; protein based molecular diagnostics: Immunoproteomics and detection methods based on Antigen-Antibody interactions; ELISA; western Blotting and Far Western Blotting applications and perspectives; Immunohistochemistry and Immunocytochemistry: Methods and interpretations: application in tumour diagnosis and infectious diseases; correlation with molecular data.</td>
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<tr>
<th>Unit IV</th>
<th>Quality assurance in molecular diagnostics</th>
<th>4 lectures</th>
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<tr>
<td>Quality assessment, pre-analytic, analytic and post analytic phases; Verification of Molecular Assays: Standards and Standardization of Molecular Diagnostics; Laboratory development of molecular diagnostics : Implementation, validation, verifications(analytical and clinical), quality control and quality assurance of the testing process; Examples of molecular diagnostics of some common genetic and non-genetic diseases (Trinucleotide Repeats: Fragile X syndrome, DMD, Endocrine disorders-Diabetes mellitus, Cystic Fibrosis, Chronic Myeloid Leukemia, Human HIV-1.</td>
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<th>Unit V</th>
<th>Immunogenetic techniques and genetic counselling</th>
<th>5 lectures</th>
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<tbody>
<tr>
<td>HLA Typing: HLA/MHC genetic; Molecular methods of HLA typing; PCR –Sequence specific Primers; Sequence Specific Oligonucleotide probe Hybridization, Forensic Diagnosis: DNA typing : Overview; Techniques for human identification; Evidence collection and sample preparation; PCR amplification of STR loci: Electrophoresis and data analysis: Molecular Diagnosis and Genetic Counselling :Clinical genetic services; Uses of genetic testing; components of genetic counselling process; Genetic Counselling and Genetic testing; Ethical, social and legal issues related to molecular genetic testing; Informed consent for clinical testing and research; Confidentiality and Discrimination; Gene patenting.</td>
<td></td>
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</tr>
</tbody>
</table>
Recommended Textbooks and References:
6. Jochen Decker, Molecular Diagnosis of Infectious Diseases, Human press.

Marine Food Technology

Course Objectives
The objectives of this course are to teach the principles of food preservation, processing and packaging and quality management practices for food of marine origin.

Student Learning Outcomes
On completion of this course, students should be able to acquire practical knowledge of food technology for marine foods.

Unit I
Food preservation and processing
2 lectures
Preservation and processing – chilling methods, phenomena of rigor mortis, spoilage changes – causative factors; Drying – conventional methods; Salt curing, pickling and smoking; Freezing and cold storage, Canning procedures; Role of preservatives in processing.

Unit II
Food packaging
2 lectures
Packing – handling fresh fish, frozen packs, individually quick frozen (IQF), layered and shatter packs; Fishery by-products, canny waste, feeds, silage, fish gelatin, fish glue, chitin and chitosan, pearl essence, fertilizer.

Unit III
Seafood microbiology
2 lectures
Seafood microbiology – factors influencing microbial growth and activity; Seafood borne pathogens – bacteria, fungi, viruses; Spoilage factors in seafood; Toxins influencing food spoilage; Microbes as food – single cell protein (SCP), microbial neutraceuticals.

Unit IV
Quality management
3 lectures
Quality management – concepts, planning, system, quality control, quality assurance, quality improvement; Certification standards – ISO and HACCP; Principles of quality related to food sanitation, contamination, pest control, human resource and occupational hazards; Novel product development, marketing and sea food export – Marine Products Export Development Authority (MPEDA), marketing, government policies, export finance, economic importance; Novel products – nutrition promotion, consumer studies qualitative and quantitative research methods.

Recommended Textbooks and References:
Stem Cell Biology

Course Objectives
The aim of course is to bring together cellular, biochemical, anatomic, histological, physiological and evolutionary medical views to a coherent picture of stem cells in an experimental and clinical context.

Student Learning Outcomes
On completion of course, students should be able to account for basics of stem cell function in body and for their usage in medical context.

Unit I
Introduction to stem cells
2 lectures
Definition, classification and source of stem cells.

Unit II
Embryonic stem cells
2 lectures
Blastocyst and inner cell mass cells; Organogenesis; Mammalian Nuclear Transfer Technology; Stem cell differentiation; Stem cells cryopreservation.

Unit III
Application of stem cells
2 lectures
Overview of embryonic and adult stem cells for therapy, Neurodegenerative diseases; Parkinson’s, Alzheimer, Spinal Cord injuries and other Brain Syndromes; Tissue systems Failures; Diabetes; Cardiomyopathy; Kidney failure; Liver failure; Cancer; Hemophilia etc.

Unit IV
Human embryonic stem cells and society
1 lecture
Human stem cells research: Ethical considerations; Stem cell religion consideration; Stem cell based therapies: Pre clinical regulatory consideration and Patient advocacy.

Recommended Textbooks and References:
# DBT Supported Teaching Programmes

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of University</th>
<th>Contact Details of Course Coordinator</th>
</tr>
</thead>
</table>
| 1.    | Annamalai University, Parangipettai | Prof. A. Shanmugam  
Centre of Advanced Study in Marine Biology  
04144-243223, 243070  
094430 43597  
casmboffice@gmail.com, shanpappu48@gmail.com |
| 2.    | Goa University, Goa | Prof. Savita Kerkar  
Dept. of Biotechnology  
0832 – 2451184  
0832-6519358/ 6519091  
savita@unigoa.ac.in |
| 3.    | Cochin University of Science & Technology, Kochi (M.Tech. Marine Biotechnology) | Dr. I.S. Bright Singh,  
National Centre for Aquatic Health  
0484-2381120, 09447631101  
isbsingh@gmail.com |

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## Annexure I

### Subject Specific Subcommittee of M.Sc. Marine Biotechnology

**Chairperson**

1. Dr. Shyam Asolekar, Professor, Centre for Environmental Science and Engineering, Indian Institute of Technology, Bombay

**Members**

2. Dr. S. Felix, Professor and Dean, Fisheries College and Research Institute, Tamil Nadu Fisheries University, Chennai
3. Dr. S. P. Govindwar, Professor, Department of Biochemistry, Shivaji University, Kolhapur
4. Dr. Hemant Purohit, Chief Scientist, National Environmental Engineering Research Institute, Nagpur
5. Dr. Sanjeev C. Ghadi, Professor, Department of Biotechnology, Goa University, Goa
6. Dr. Dilip R. Ranade, Consultant, Microbial Culture Collection, National Centre for Cell Science, Pune
7. Dr. Lidita Khandeparker, Senior Scientist, National Institute of Oceanography, Goa

**Member Secretary**

8. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi
M.Sc. Medical Biotechnology
Introduction

Background

Promotion of Indian Biotechnology sector is high on policy agenda of Government of India. Biotechnology has also been recognized as one of the key priority sectors under ‘Make in India,’ ‘Skill India’ and ‘Startup India’ initiatives of Government of India, as it is one of sectors expected to contribute towards enterprise creation, innovation and economic growth. Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India has immensely contributed to this dynamism through various policies and initiatives, establishment of innovation clusters, academia-industry partnerships, increasing capabilities for technology development, etc. The National Biotechnology Development Strategy (2015 – 2020) released by DBT provides a strategic roadmap for India’s emergence as a global biotechnology innovation and manufacturing hub. It has also highlighted importance of human resource development and need for nurturing tailor-made human capital for advanced scientific research and entrepreneurship.

DBT has taken a number of initiatives aimed at integrated human resource development to evolve an ecosystem where scientists, innovators and future entrepreneurs can be nurtured. Keeping in mind requirement for trained manpower in various areas of Biotechnology, DBT initiated Post-Graduate Teaching Programme way back in 1985 with 5 universities which has expanded to 74 universities imparting M.Sc./M.Tech./M.V.Sc. degrees in general, agricultural, animal, food, environmental, industrial marine, medical, neuroscience and pharmaceutical biotechnology. 10 programmes are being phased out. These universities and institutes are provided liberal financial support towards strengthening of laboratory facilities, equipment, consumables, fellowships to students, dissertation grant per student etc. Post-Graduate Teaching Programme selects best students and trains them to join research or industry workforce contributing significantly to biotechnology workforce.

About the Course Curriculum Revision Exercise

Taking into cognizance the changing needs of the economy and to keep abreast with latest developments in the field of biotechnology, DBT proactively initiated revision of course curricula of Post-Graduate Programmes in biotechnology. The present exercise has been undertaken by Biotech Consortium India Limited (BCIL), New Delhi. Earlier exercise was carried out in 2008. The Course Curriculum Revision Exercise has been carried out for 13 Post-Graduate programmes in Biotechnology supported by DBT.

The revision of course curriculum of M.Sc. Medical Biotechnology aims to address mismatch between ‘knowledge’ gained by students and appropriate skill set required for technology development and implementation including present contemporary needs of economy.

Methodology

A meticulous and structured approach has been adopted to accomplish the Course Curriculum Revision exercise.

BCIL had initiated the exercise with a review of literature of relevant national and international documents on curriculum design and planning for biotechnology programmes of premier national as well as international universities, guidelines by University Grants Commission, recent curricular guidelines released by Indian Council of Agricultural Research, Ministry of Health and Family Welfare and Indian Institute of Science Education & Research and other relevant research papers on curriculum development in peer-reviewed journals.
The findings of the literature review were adopted to design questionnaires for eliciting feedback from stakeholders of Biotechnology community i.e. academicians, scientists, industry representatives and students. Feedback was received from 165 experts and 20 students belonging to academic institutions, research organizations and industry regarding addition of advanced topics, deletion of elementary, redundant and overlapping topics, updation of laboratory practicals, re-adjustment of credit load, incorporating ‘technology’ component in the curriculum, among others. It was also suggested that re-orientation of curricula should be done keeping in view the needs of the industry.

Strategic Approach

A Core Committee along with 9 subject specific subcommittees comprising of 63 academicians, scientists and industry representatives were constituted to revise and update the curricula. The constitution of subject specific subcommittee for M.Sc. Medical Biotechnology is given at Annexure-1.

The salient recommendations identified from stakeholder survey were presented to the Committee. Several brainstorming discussion sessions were held for achieving the desired balance between the foundation courses, recent developments in biotechnology and updation needs identified during the stakeholder survey. Core Committee finalized broad contours for revising all the course curricula. The guidelines set by the Core Committee were taken up by the subject specific subcommittee of M.Sc. Medical Biotechnology for updating the curriculum. The subject specific subcommittee incorporated latest advancements in areas of Medical Biotechnology in the curriculum. Separate meeting was held to discuss and deliberate the updations to be made in the curriculum. The revised curriculum was vetted and finalized by the Core Committee.

Course Curriculum Revision

The members of Committee agreed that revised course curriculum should provide skill and outcome based education and help the students to gain domain knowledge, ability to design and interpret research experiments and acquire effective communication skills. The course curriculum has been re-designed accordingly to promote skill-based and outcome-based education. The revised course curriculum totals to 96 credits comprising of theory, practical, technology-based topics, electives and dissertation. Each course includes learning objectives, student learning outcomes, course plan (number of lectures/unit) and reference textbooks/resources. Theory and practical courses include relevant examples, case scenarios and tutorials for inculcating critical thinking against rote learning. Several new courses have been included and content for existing courses has also been updated. Several specialized modules such as Biophysical Principles, OMICS Technologies, Clinical Biochemistry, Tissue Engineering, Medical Devices, Molecular Diagnostics and Therapeutics, Tissue Engineering, Stem Cell Technology, Cancer Genetics, Clinical Genetics, Oncogenomics, Diagnostics and Inflammation & Disease Biology etc. have been incorporated to introduce students to different areas and applications of medical biotechnology. With importance of students being able to execute research projects independently, separate credits have been allotted for proposal preparation and presentation before initiating dissertation and also credits for dissertation have been increased accordingly.

We hope that model course curriculum shall serve as guidelines for academicians and researchers from different parts of the country for adoption in their institutions with modifications as per availability of expertise, infrastructure and specific needs.

We wish to put on record our sincere appreciation for constant guidance and encouragement received from Dr. K. VijayRaghavan, Secretary, DBT for bringing out this publication. We wish to acknowledge whole-hearted support of Core Committee and subject specific subcommittees members. Sincere thanks are due to Dr. Manoj Singh Rohilla, Scientist- D, DBT, Ms. Shweta for creative design, Mrs. Rita Bhatla, DBT and Shri. Dilip Joy, BCIL.
The revised contents of this course try to extract the content of modern biology for medically relevant biology and biotechnology. Several new modules have been added, keeping the level accessible to an MSc student. New electives try to bring out contents that are recent and somewhat futuristic. An effective communication of the contents requires judicious use of not only the published material but also the online web tutorials/movies etc. This is especially so where the laboratory and library infrastructures are limiting.
## M.Sc. Medical Biotechnology

<table>
<thead>
<tr>
<th>S.No.</th>
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<tr>
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<td>Biochemistry</td>
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<td>Biostatistics and Population Genetics</td>
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<td>Biophysical Principles and Analytical Techniques</td>
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<td>3</td>
<td>Medical Microbiology and Infection Biology</td>
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<tr>
<td>4</td>
<td>Genetic Engineering and Genome Editing Technologies</td>
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<td>OMICS: Genomics, Transcriptomics, Proteomics and Metabolomics</td>
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<td>Laboratory III: Immunotechnology and Molecular Diagnostics</td>
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<td>Clinical Biochemistry and Disease Metabolism</td>
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<td>Tissue Engineering and Stem Cell Technology</td>
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<td>Medical Devices</td>
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<td>Intellectual Property Rights, Biosafety and Bioethics</td>
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**Recommended Electives:**
## Semester One

### Biochemistry

#### Credits

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<td>I</td>
<td>Protein structure</td>
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<tr>
<td>II</td>
<td>Enzyme kinetics</td>
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<tr>
<td>III</td>
<td>Glycobiology</td>
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<tr>
<td>IV</td>
<td>Structure and functions of DNA &amp; RNA</td>
<td>3</td>
</tr>
<tr>
<td>V</td>
<td>Bio-energetics</td>
<td>8</td>
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</tbody>
</table>

#### Course Objectives

The objectives of this course are to build upon undergraduate level knowledge of biochemical principles with specific emphasis on different metabolic pathways. The course shall make the students aware of various disease pathologies within the context of each topic.

#### Student Learning Outcomes

On completion of this course, students should be able to:

- Gain fundamental knowledge in biochemistry;
- Understand the molecular basis of various pathological conditions from the perspective of biochemical reactions.

### Unit I

**Protein structure**

5 lectures

- Chemical basis of life: Miller-Urey experiment, abiotic formation of amino acid oligomers, composition of living matter; Water – properties of water, essential role of water for life on earth pH, buffer, maintenance of blood pH and pH of gastric juice, pH optima of different enzymes (pepsin, trypsin and alkaline phosphatase), ionization and hydrophobicity, emergent properties of biomolecules in water, biomolecular hierarchy, macromolecules, molecular assemblies; Structure-function relationships: amino acids – structure and functional group properties, peptides and covalent structure of proteins, elucidation of primary and higher order structures, Ramachandran plot, evolution of protein structure, protein degradation and introduction to molecular pathways controlling protein degradation, structure-function relationships in model proteins like ribonuclease A, myoglobin, hemoglobin, chymotrypsin etc.; basic principles of protein purification; tools to characterize expressed proteins; Protein folding: Anfinsen's Dogma, Levinthal paradox, cooperativity in protein folding, free energy landscape of protein folding and pathways of protein folding, molten globule state, chaperons, diseases associated with protein folding, introduction to molecular dynamic simulation.

### Unit II

**Enzyme kinetics**

5 lectures

- Enzyme catalysis – general principles of catalysis; quantitation of enzyme activity and efficiency; enzyme characterization and Michaelis-Menten kinetics; relevance of enzymes in metabolic regulation, activation, inhibition and covalent modification; single substrate enzymes; concept of catalytic antibodies; catalytic strategies with specific examples of proteases, carbonic anhydrases, restriction enzymes and nucleoside monophosphate kinase; regulatory strategies with specific example of hemoglobin; isozymes; role of covalent modification in enzymatic activity; zymogens.

### Unit III

**Glycobiology**

2 lectures

- Sugars-mono, di, and polysaccharides with specific reference to glycogen, amylose and cellulose, glycosylation of other biomolecules-glycoproteins and glycolipids; lipids- structure and properties of important members of storage and membrane lipids; lipoproteins.

### Unit IV

**Structure and functions of DNA & RNA**

3 lectures

- Self-assembly of lipids, micelle, biomembrane organization - sidedness and function; membrane bound proteins - structure, properties and function; transport phenomena; nucleosides, nucleotides, nucleic acids - structure, a historical perspective leading up to the proposition of DNA double helical structure; difference in RNA and DNA structure and their importance in evolution of DNA as the genetic material.

### Unit V

**Bio-energetics**

8 lectures

- Bioenergetics-basic principles; equilibria and concept of free energy; coupled interconnecting reactions in metabolism; oxidation of carbon fuels; recurring motifs in metabolism; Introduction to GPCR, Inositol/DAG//PKC and Ca++ signaling pathways; glycolysis and gluconeogenesis; reciprocal regulations and non-carbohydrate sources.
Calvin cycle and pentose phosphate pathway; glycogen metabolism, reciprocal control of glycogen synthesis and breakdown, roles of epinephrine and glucagon and insulin in glycogen metabolism; Fatty acid metabolism; protein turnover and amino acid catabolism; nucleotide biosynthesis; biosynthesis of membrane lipids and sterols with specific emphasis on cholesterol metabolism and mevalonate pathway; elucidation of metabolic pathways; logic and integration of central metabolism; entry/exit of various biomolecules from central pathways; principles of metabolic regulation; steps for regulation; TOR (target of rapamycin) & autophagy regulation in relation to C & N metabolism, starvation responses and insulin signaling.

Recommended Textbooks and References:
Unit I
Cell theory, methods of study, structure and function of biological membranes
6 lectures

An overview of microscopy techniques – Bright field phase contrast, dark field, differential interference (DIC), Fluorescence, Confocal, Electron (TEM and SEM), Electron tunnelling and Atomic Force Microscopy; Cell fractionation, differential centrifugation. Structural models; Composition and dynamics; Transport of ions and macromolecules; Pumps, carriers and channels; Endo and Exocytosis; Cellular junctions and adhesions; Structure and functional significance of plasmodesmata; Mechanism of cellular recognition and communication.

Unit II
Cells and organelles
7 lectures

Nucleus: structure and function of nuclear envelope, lamina and nucleolus; Macromolecular trafficking; Chromatin organization and packaging; Cell cycle and control mechanisms; Mitochondria: structure, origin and evolution, organization of respiratory chain complexes, Structure-function relationship; structure and function of peroxisome; mitochondrial genome; Chloroplast: chloroplast biogenesis; structure-function relationship; chloroplast genome.

Unit III
Endo-membrane system, cellular cytoskeleton and motility, cellular signalling
7 lectures

Structure and function of microbodies, Golgi apparatus, lysosomes and endoplasmic reticulum; Protein processing, sorting; vesicle transport, secretion; Overview of cellular cytoskeleton, Organization and role of microtubules and microfilaments; Intermediate filaments; Muscle organization and function; Cellular motility; Molecular motors; Extracellular matrix in plants and animals; Overview of various cellular signalling cascades with examples such as EGFR, Notch, Wingless, JAK-STAT etc.

Unit IV
Overview of development and developmental processes
8 lectures

Defining developmental biology, specification, competence, induction, morphogen gradients, determination and differentiation, pattern formation, cell fate and cell lineages; Developmental processes in animals- types of fertilization, cleavage, gastrulation, fate map, direct observation of living embryos, dye marking, genetic labelling, early developmental events in vertebrates; the unique features of mammalian cleavage, comparative embryonic homologies; polarity in the oocyte, anterior-posterior, dorsal-ventral and right-left axis formation; axis specification and the avian "organizer", control of blastomere identity; Overview of homeotic genes, axis formation in sea urchin, C. elegans, D. melanogaster, amphibians and mammals; formation of vulva in C. elegans; Development of the tetrapod limb, Postembryonic development: metamorphosis, regeneration and aging; Developmental constraints on evolution.

Unit V
Developmental anomalies and role of stem cells in development
6 lectures

Developmental defects and disorders; Stem cell- introduction and types of stem cell, role of stem cells in development, Pluripotency, stem-cell plasticity, cellular signalling and maintenance of stem cells, trans-determination, isolation, expansion, genetic manipulation, genomic reprogramming, and cloning of stem cells, differences between adult and embryonic stem cells, usages of stem cells in therapies, ethical issues attached with stem cell research.

Recommended Textbooks and References:
Course Objectives

The objectives of this course are to take the students through the basics of genetics encompassing prokaryotic/phage genetics to yeast and higher eukaryotic domains and will cover all concepts of Mendelian genetics. It will also take the students through the basics of human genetics and disease gene mapping. In addition, students will also be introduced to aims and outcome of the human genome project.

Student Learning Outcomes

On successful completion of this course, students should be able to:

• Describe the fundamental molecular principles of genetics;
• Understand the relationship between phenotype and genotype in human genetic traits;
• Describe the basics of genetic mapping;
• Understand how gene expression is regulated.

Unit I

Genetics of bacteria and bacteriophages
4 lectures

Concept of a gene in pre-DNA era; mapping of genes in bacterial and phage chromosomes by classical genetic crosses; fine structure analysis of a gene; genetic complementation and other genetic crosses using phenotypic markers; phenotype to genotype connectivity prior to DNA-based understanding of a gene; Restriction modification systems – history, types of systems and their characteristics, applications of RM systems, methylation-dependent restriction enzymes, transposable elements – types, properties and applications.

Unit II

Yeast genetics
4 lectures

Meiotic crosses, tetrad analyses, non-Mendelian and Mendelian ratios, gene conversion, models of genetic recombination, yeast mating type switch; dominant and recessive genes/mutations, suppressor or modifier screens, complementation groups, transposon mutagenesis, synthetic lethality, genetic epistasis.

Unit III

Drosophila genetics as a model of higher eukaryotes
4 lectures

Monohybrid & dihybrid crosses, back-crosses, test-crosses, analyses of autosomal and sex linkages, screening of mutations based on phenotypes and mapping the same, hypomorphy, genetic mosaics, genetic epistasis in the context of developmental mechanisms; Testing gene mutations for allelism: complementation test, intragenic complementation, pleiotropy.

Unit IV

Human genetics
8 lectures

History of human genetics, Pedigrees- gathering family history, pedigree symbols, construction of pedigrees, presentation of molecular genetic data in pedigrees, Monogenic traits, Autosomal inheritance-dominant, recessive Sex-linked inheritance, Sex-limited and sex-influenced traits, Mitochondrial inheritance, OMIM number, Complications to the basic pedigree patterns- nonpenetrance, variable, expressivity, pleiotropy, late onset, dominance problems, anticipation, genetic heterogeneity, genomic imprinting and uniparental disomy, spontaneous mutations, mosaicism and chimerism, male lethality, X-inactivation; Approaches to analysis of complex traits- ‘Nature-nurture’ concept, role of Family and shared environment, monozygotic and dizygotic twins and adoption studies, Polygenic inheritance of continuous (quantitative) traits, normal growth charts, Polygenic inheritance of discontinuous (dichotomous) traits-threshold model, liability and recurrence risk, Genetic susceptibility in multifactorial disorders (alcoholism, diabetes mellitus, obesity), Estimation of genetic components of multifactorial traits: empiric risk, heritability, coefficient of relationship.
Cytogenetics: Techniques in human chromosome analysis, Human karyotype: banding, nomenclature of banding, Pathology of human chromosomes, Nomenclature of aberrant karyotypes, Common syndromes due to numerical chromosome changes, Common syndromes due to structural alterations (translocations, duplications, deletions, microdeletion, fragile sites) Common chromosome abnormalities in cancer, Genetics of fetal wastage Disorders of sex chromosomes and autosomes; Molecular cytogenetics – Fluorescence In situ Hybridization (FISH); Comparative Genomic Hybridization (CGH); Developmental genetics: Genes in early development; Maternal effect genes; Pattern formation genes; Homeotic genes; Signaling and adhesion molecules; Immunogenetics: Major histocompatibility complex; Immunoglobulin genes - tissue antigen and organ transplantation; Single gene disorders of immune system.

Unit VI
Genetic variation and gene mapping
5 lectures
Genetic variation: Mutations; kinds of mutation; agents of mutation; genome polymorphism; uses of polymorphism; Gene mapping: Physical mapping; linkage and association.

Unit VII
Human genome and comparative genomics
6 lectures
Human genome: Genome project history, organization and goals of human genome project, Mapping strategies, current status of various maps; DNA segment nomenclature, Human genome diversity, organization of human genome, gene families; Comparative genomics: Overview of prokaryotic and eukaryotic genomes, C-value, number of genes and complexity of genomes, Conservation and diversity of genomes, Comparative genomics as an aid to gene mapping and study of human disease genes.

Recommended Textbooks and References:

Course Objectives
The aim of this course is to obtain and understand fundamental knowledge of molecular and cellular processes: epigenetics, gene regulation, RNA transcription, protein synthesis, protein targeting and trafficking, and cell signaling. Students participate in a computer tutorial aimed at mastering basic web tools for genome and proteome analysis.

Student Learning Outcomes
Upon successful completion of this course, students should be able to:
• Explain and summarize the scientific principles of the molecular biology of DNA and RNA;
• Use specialized DNA/RNA isolation, manipulation, and cloning methods, individually and collaboratively that are typical of molecular biology
The knowledge discussed in the lectures and practiced at the computer tutorial is the basis for an assignment that aims to train students in a critical evaluation of literature. Through presentation of their topic and feedback of lecturers and their peers, students become acquainted with the scientific method.

**Unit I**
**DNA structure and genome organization**
3 lectures

Structure of DNA - A,B, Z and triplex DNA; Central dogma, DNA as genetic material; Organization of bacterial genome; Structure of eukaryotic chromosomes: DNA compaction, nucleosome, 10 nm “beads-on-a-string” fibre, 30 nm chromatin fibre and metaphase chromosome; Nuclear matrix in chromosome organization and function; Heterochromatin and Euchromatin; DNA melting and buoyant density; Tm; DNA reassociation kinetics (Cot curve analysis); Repetitive and unique sequences; Satellite DNA; DNase I hypersensitive regions; DNA methylation & epigenetic effects.

**Unit II**
**DNA replication, repair and recombination**
6 lectures

Replication: initiation, elongation and termination in prokaryotes and eukaryotes; Enzymes and accessory proteins and mechanisms; Fidelity; Replication of single stranded circular DNA; link with cell cycle; DNA damaging agents - Physical, chemical and biological mutagens; types of damage caused by endogenous and exogenous agents; mutations- Nonsense, missense, silent and point mutations, frameshift mutations; Intragenic and Intergenic suppression. DNA repair mechanisms- direct reversal, photoreactivation, base excision repair, nucleotide excision repair, mismatch repair, double strand break repair, SOS repair; Recombination: Chi sequences in prokaryotes; Homologous,non-homologous and site specific recombination.

**Unit III**
**RNA transcription, RNA processing and regulation in prokaryotes**
10 lectures

Structure and function of prokaryotic mRNA, tRNA (including initiator tRNA) and rRNA (and ribosomes); Prokaryotic Transcription -RNA polymerase and sigma factors, Transcription unit, Promoters, Promoter recognition, Initiation, Elongation and Termination (intrinsc, Rho and Mfd dependent); Processing of mRNA, tRNA and rRNA transcripts; Gene regulation: Repressors, activators, positive and negative regulation, Constitutive and Inducible, small molecule regulators, operon concept: lac, trp, his operons, attenuation, anti-termination, stringent control, translational control, DNA re-arrangement, two component system; regulatory RNA – riboswitch, tmRNA, antisense RNA; transcriptional control in lambda phage.

**Unit IV**
**RNA transcription, RNA processing and regulation in eukaryotes**
13 lectures

Structure and function of eukaryotic mRNA, tRNA (including initiator tRNA) and rRNA (and ribosomes). Eukaryotic transcription - RNA polymerase I, II and III mediated transcription: RNA polymerase enzymes, eukaryotic promoters and enhancers, General Transcription factors; TATA binding proteins (TBP) and TBP associated factors (TAF); assembly of pre-initiation complex for nuclear enzymes, interaction of transcription factors with the basal transcription machinery and with other regulatory proteins, mediator, TAFs; Processing of hnRNA, tRNA, rRNA; 5’-Cap formation; 3’-end processing of RNAs and polyadenylation; loop model of translation; Splicing of tRNA and hnRNA; snRNPs and snoRNPs in RNA processing; Regulation of RNA processing: capping, splicing, polyadenylation; mRNA stability and degradation: degradation and surveillance pathways; RNA editing; Nuclear export of mRNA; Catalytic RNA: Group I and Group II introns splicing, Peptidyl transferase; Regulatory RNA and RNA interference mechanisms, miRNA, non-coding RNA; Silencers and insulators, enhancers, mechanism of silencing and activation; Families of DNA binding transcription factors: Helix-turn-helix, helix-loop-helix, homeodomain; 2C 2H zinc finger, multi cysteine zinc finger, basic DNA binding domains (leucine zipper, helix-loop-helix), nuclear receptors;
Interaction of regulatory transcription factors with DNA: properties and mechanism of activation and repression including Ligand-mediated transcription regulation by nuclear receptors; Nuclear receptor; histone modifications and chromatin remodeling; Methods for studying DNA-protein interaction: EMSA, DNase I footprinting, methylation interference assay, chromatin immunoprecipitation.

Ribosomes; Composition and assembly; universal genetic code; Genetic code in mitochondria; Degeneracy of codons; Termination codons; Wobble hypothesis; Isoaccepting tRNA; Translational machinery; Mechanism of Translation in prokaryotes and eukaryotes; Co- and Post-translational modifications of proteins; triple helix of collagen; Translational control; Protein stability; Protein turnover and degradation.

Recommended Textbooks and References:

Biostatistics and Population Genetics

Course Objectives
Students in Biotechnology are generally not well exposed to important issues of Biostatistics relevant for appreciating Population Genetics. Biostatistics is clubbed with Population Genetics as the latter is well supported by the quantitative rigors of the former. This course provides a comprehensive understanding of the basic concepts of population genetics, leading up to important aspects linking to evolution. The student is expected to gain a fuller appreciation of genetic determinants that impact population level biological diversity in the context of evolution.

Student Learning Outcomes
After successful completion of this course, students are expected to be able to:
• Define and describe important population and quantitative genetic concepts such as: genetic drift, natural selection, selective sweep, inbreeding, heritability and quantitative traits;
• Apply these population and quantitative genetic concepts to problems related to the genetic dynamics of natural, captive and artificially selected populations.

Unit I
Basics of biostatistics
5 lectures

Basic probability, venn diagrams, dependent probability, permutations and combinations, making decisions with probability, correlation & causality, tests of statistical significance, hypothesis testing & null hypothesis, two-way variables, mean/median/mode, variance and standard deviation.

Unit II
Biostatistical analysis
6 lectures

Constructing box-plots, expected values with empirical probabilities, binomial distributions, Poisson processes, scatter plots, fitting quadratic and exponential functions to scatter plots, linear regression & correlation; normal distributions, chi-square probability distribution, analyses of variance, Bernoulli distributions and margin of errors, hypothesis testing with one sample, one-tailed and two-tailed tests, T-statistic confidence interval, Anova 1, 2 & 3.

Unit III
Genetic constitution of a population

Genetic constitution of a population: (a) Gene frequencies and genotypes; (b) Hardy-Weinberg equilibrium; (c) Changes in gene frequency and continuous variation; (d) Mutation, Selection, Equilibrium, Polymorphisms; Values, means and
variance: (a) Metric characteristics, Population means; (b) Genetic components of variation; (c) Genotype and environment correlation; (d) Environmental variance.

<table>
<thead>
<tr>
<th>Unit IV</th>
<th>Basic definitions</th>
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<tbody>
<tr>
<td>2 lectures</td>
<td>Gene pool, gene drift, migration &amp; gene flow, Founder effects, extinction, speciation, reduction in gene flow and bottle-necks, reproductive isolation.</td>
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<tr>
<th>Unit V</th>
<th>Quantitative trait loci</th>
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<tbody>
<tr>
<td>5 lectures</td>
<td>(a) Major genes; (b) Methods of mapping QTLs; (c) Genetical and statistical considerations; (d) QTLs in plants, fruit fly, mouse/rats, yeast; (e) Genomic methods of mapping QTLs; (f) Haplotype mapping and genome-wide association studies (GWAS); (g) QTL interactions: genetic and environment.</td>
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<tr>
<th>Unit VI</th>
<th>Population genetics</th>
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<tbody>
<tr>
<td>3 lectures</td>
<td>In-breeding depression &amp; mating systems; population bottlenecks, migrations, Bayesian statistics; adaptive landscape, spatial variation &amp; genetic fitness.</td>
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<tr>
<th>Unit VII</th>
<th>Genetic determinants shaping population traits</th>
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<tbody>
<tr>
<td>2 lectures</td>
<td>Genetic determinants that shape population traits: (a) Overdominance (b) Pleiotropy (c) Epistasis (d) Variable selection (e) Gene Flow (f) Disease Epidemiology.</td>
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<tr>
<th>Unit VIII</th>
<th>Modes of speciation</th>
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</thead>
<tbody>
<tr>
<td>3 lectures</td>
<td>(a) Allopatric speciation (b) Parapatric speciation (c) Sympatric speciation Evolutionary processes causing speciation: (a) Natural Selection (b) Sexual selection (c) Random Genetic drift (d) Muller Incompatibility.</td>
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<tr>
<th>Unit IX</th>
<th>Phylogenetical analysis</th>
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<tbody>
<tr>
<td>2 lectures</td>
<td>Importance of mitochondrial DNA and Y-chromosome sequence derived population studies: Founder effects, human-origins and subsequent human migration patterns.</td>
</tr>
</tbody>
</table>

Recommended Textbooks and References:
Course Objectives
The major objective of this track is understanding of fundamental cell biological research in relation to human disease. This understanding comprises:

• Cell biology in context of healthy and diseased human body;
• Cellular basis of major human diseases;
• Advanced microscopy including live cell imaging, correlative light and electron microscopy, confocal microscopy and underlying biophysics.

Student Learning Outcomes
At the end of this course, students should acquire basic concepts of structure and functionality of the animal cell along with basics of microscopy.

Laboratory I: Cell Biology and Microscopy

Credits
4

Syllabus

1. Introduction to anatomy, functioning & handling of upright and inverted epifluorescence microscope & confocal microscope.
2. Observation of suitable specimen under bright field, phase contrast, dark field and differential interference contrast (DIC) microscope.
3. Observation of animal/plant cell cultures under microscope. Measurement of cell size by oculometer and stage micrometre.
4. Low speed separation of cells from animal blood or any mammalian cells from a culture.
5. To quantify number of cells present in given sample and assessment of cell viability.
6. Identification of Barr body by preparing buccal smear.
7. Isolation of lysosomes, nuclei & ER membranes from given samples (i.e. chicken liver) by isotonic sucrose method.
8. To study process of cellular osmosis in guard cells from plant leaves or animal blood.
9. To study cellular distribution of mitochondria by janus green staining.
10. Isolation of mitochondria from given tissue samples.
11. To assay activity of an enzyme in its natural source to assess organ function.
12. To examine number and morphology of nucleus in given tissue sample by DAPI/PI staining.
13. Analysis of Green Fluorescence Protein (GFP) tagged cells/tissue under fluorescence microscope. Quantifying intensity measurements after setting up thresholds, and improving contrast features.
14. Analysis of F-actin based cellular cytoskeleton by Phalloidin staining to the given tissue sample.
15. Localization of specific protein(s) inside the cells (in situ) by immunohistochemistry. (May be demonstrated to the students).
16. Lecture demonstration of live cell movements, dynamics of cellular organelles in relation to a function by using web-tutorials and online movies.

Laboratory II: Biochemistry & Analytical Techniques

Credits
3

Course Objectives
The objective of this laboratory course is to introduce students to experiments in biochemistry. The course is designed to teach the utility of set of experimental methods in biochemistry in a problem oriented manner.

Student Learning Outcomes
On completion of this course, students should be able to:

• To elaborate concepts of biochemistry with easy to run experiments;
• To familiarize with basic laboratory instruments and understand the principle of measurements using those instruments with experiments in biochemistry.
1. Preparing various stock solutions and working solutions that will be needed for the course.
2. To prepare an Acetic-Na Acetate Buffer and validate the Henderson-Hasselbach equation.
3. To determine an unknown protein concentration by plotting a standard graph of BSA using UV-Vis Spectrophotometer and validating the Beer-Lambert's Law.
4. Titration of Amino Acids and separation of aliphatic, aromatic and polar amino acids by thin layer chromatography.
5. Purification and characterization of an enzyme from a recombinant source (such as Alkaline Phosphatase or Lactate Dehydrogenase or any enzyme of the institution's choice).
   a) Preparation of cell-free lysates
   b) Ammonium Sulfate precipitation
   c) Ion-exchange Chromatography
   d) Gel Filtration
   e) Affinity Chromatography
   f) Dialysis of the purified protein solution against 60% glycerol as a demonstration of storage method
   g) Generating a Purification Table (protein concentration, amount of total protein; Computing specific activity of the enzyme preparation at each stage of purification)
   h) Assessing purity of samples from each step of purification by SDS-PAGE Gel Electrophoresis
   i) Enzyme Kinetic Parameters: Km, Vmax and Kcat.
6. Experimental verification that absorption at OD260 is more for denatured DNA as compared to native double stranded DNA. reversal of the same following DNA renaturation. Kinetics of DNA renaturation as a function of DNA size.
7. Biophysical methods (Circular Dichroism Spectroscopy, Fluorescence Spectroscopy; UV-visible absorption specturm for proteins, Dynamic Light scattering analyses of native particle sizes in protein mixture and pure proteins; Assessing the sub-unit composition of an oligomeric protein).

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Semester Two

Immunology and Immunogenetics

Course Objectives
The objectives of this course are to learn about structural features of components of immune system as well as their function. The major emphasis of this course will be on development of immune system and mechanisms by which our body elicit the immune response. This will be imperative for students as it will help them to think like an immunologist and predict about nature of immune response that develops against bacterial, viral or parasitic infection, and prove it by designing new experiments.

Student Learning Outcomes
On completion of this course, students should be able to:

- Evaluate the usefulness of immunology in different pharmaceutical companies;
- Identify the proper research lab working in the area of their own interests;
- Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out the kind of immune responses in the setting of infection (viral or bacterial) by looking at cytokine profile.
<table>
<thead>
<tr>
<th>Unit I</th>
<th>Immunology: fundamental concepts and anatomy of the immune system</th>
<th>Components of innate and acquired immunity; Important organs and cells of immune responses, complement and inflammatory responses; pathogen recognition receptors (PRR) and pathogen associated molecular pattern (PAMP); innate immune response; mucosal immunity; antigens - immunogens, haptens; Major histocompatibility complex (MHC) genes, Role of MHC in infectious diseases and disease susceptibility, HLA typing.</th>
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<tbody>
<tr>
<td>Unit II</td>
<td>Immune responses generated by B and T lymphocytes</td>
<td>Immunoglobulins—basic structure, classes &amp; subclasses of immunoglobulins, antigenic determinants; multigene organization of immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; principles of cell signaling; basis of self &amp; non-self discrimination; kinetics of immune response, memory; B cell maturation, activation and differentiation; generation of antibody diversity; T-cell maturation, activation and differentiation and T-cell receptors; functional T Cell subsets; cell-mediated immune responses, ADCC; cytokines—properties, receptors and therapeutic uses; antigen processing and presentation- endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens; cell-cell co-operation.</td>
</tr>
<tr>
<td>Unit III</td>
<td>Antigen-antibody interactions</td>
<td>Precipitation, agglutination and complement mediated immune reactions; advanced immunological techniques - RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence, flow cytometry and immunoelectron microscopy; surface plasmon resonance, biosensor assays for assessing ligand–receptor interaction, CMI techniques-lymphoproliferation assay, mixed lymphocyte reaction, cell cytotoxicity assays, apoptosis, microarrays, transgenic mice, gene knock outs, Hybridoma and monoclonal antibodies, Applications of monoclonal antibodies.</td>
</tr>
<tr>
<td>Unit IV</td>
<td>Vaccinology</td>
<td>Active and passive immunization; live, killed, attenuated, subunit vaccines; vaccine technology—role and properties of adjuvants, recombinant DNA and protein based vaccines, reverse vaccinology; peptide vaccines, conjugate vaccines; antibody genes and antibody engineering- chimeric, hybrid monoclonal antibodies; catalytic antibodies and generation of immunoglobulin gene libraries, idiotypic vaccines and marker vaccines, viral-like particles (VLPs), dendritic cell based vaccines, vaccine against cancer, T cell based vaccine, edible vaccine and therapeutic vaccine; Success stories in vaccinology e.g. Hepatitis, Polio, Small pox, DPT.</td>
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<tr>
<td>Unit V</td>
<td>Clinical immunology</td>
<td>Immunity to infection: bacteria, viral, fungal and parasitic infections (Tuberculosis, HIV/AIDS, Schistosomiasis, Kala Azar, Chickungunya, Dengue); hypersensitivity reactions—Type I-IV; autoimmunity; types of autoimmune diseases; mechanism and role of CD4+ T cells; MHC and TCR in autoimmunity; transplantation —immunological basis of graft rejection; clinical transplantation and immunosuppressive therapy; tumor immunology – tumor antigens; immune response to tumors and tumor evasion of the immune system, cancer immunotherapy; immunodeficiency—primary immunodeficiencies, acquired or secondary immunodeficiencies, anaphylactic shock.</td>
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</table>

**Recommended Textbooks and References:**

## Biophysical Principles and Analytical Techniques

### Course Objectives
The course is designed to provide a broad exposure to all basic techniques (Biochemical & Biophysical) used in current Modern Biology research. The goal is to impart basic conceptual understanding of principles of these techniques and emphasize on Biochemical utility of same & underlying Biophysics. At the end of the course, student is expected to have enough understanding of all the analytical techniques such that the barrier to implement the same is abated to a great extent.

### Student Learning Outcomes
On completion of this course, students should be able to learn how to combine previously acquired knowledge of physical chemistry and biochemistry in order to understand biochemical processes at molecular level.

### Credits

<table>
<thead>
<tr>
<th>Unit</th>
<th>Basics</th>
<th>2 lectures</th>
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<tr>
<td><strong>Unit I</strong></td>
<td><strong>Basics</strong></td>
<td>2 lectures</td>
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<tr>
<td><strong>Unit II</strong></td>
<td><strong>Basic principles of electromagnetic radiation and related spectroscopic techniques</strong></td>
<td>8 lectures</td>
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<tr>
<td><strong>Unit III</strong></td>
<td><strong>Hydrodynamic methods</strong></td>
<td>2 lectures</td>
</tr>
<tr>
<td><strong>Unit IV</strong></td>
<td><strong>Radioactivity and radioisotopic techniques</strong></td>
<td>3 lectures</td>
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</table>

### Units of measurement of solutes in solution; Normality, molality, molarity, millimol and ppm; Water- structure and properties; Principles of glass and reference electrodes, types of electrodes, complications of pH measurement (dependence of pH on ionic strength, pOH, Hendersen-Hasselbach equations, buffers, pH of body fluids, buffers in body fluids, red blood cells and tissues. Length scales in biological systems: proteins, multiprotein complexes, organelles & cells; Basic thermodynamics; Basic chemical kinetics & reaction rates: Theory of chemical reactions.

### Energy, wavelength, wave number and frequency; Absorption and emission spectra, Beer-Lambert's law, light absorption and its transmittance; UV and visible spectrophotometry-principles, instrumentation and applications on enzyme assay and kinetic assays, protein structural studies, nucleic acid structural studies; Basic principles, instrumentation and applications of UV-visible, IR, fluorimetry, atomic absorption and emission spectrophotometry; Basic principles, instrumentation and applications of ESR, NMR; Biochemical applications of fluorescence, emission, Fluorescence life-times, Anisotropy, time-resolved fluorescence methods and their applications, IR-Raman Spectroscopic applications in biology.

### Basic principles and types of centrifugation-rotors, boundary, differential, density gradient, zonal isopycnic centrifugation, equilibrium; Sedimentation - sedimentation velocity, preparative and analytical ultracentrifugation techniques: principles & applications in biochemical fractionation methods.

### Radioactivity, stable and radioactive isotopes, concepts of half-life and decay, principles of scintillation counting, GM counters, applications of isotopes, Isotope dilution technique, autoradiography, turnover studies, precursor-product relationship, production of radio-labelled biomolecules, calculations involving isotopes, radiation hazards and methods for contaminant prevention; Nature of radioactivity, properties of α, β and γ-rays, measurement of radioactivity, use of radioisotopes in research, In vivo and in vitro labelling techniques, double labelling, quenching, internal standard, channel ratio, external standard ratio, emulsion counting, radioactive decay; Application of radioactive isotopes in biochemical reaction mechanisms.
<table>
<thead>
<tr>
<th>Unit V</th>
<th>Electrophoresis</th>
<th>2 lectures</th>
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<tr>
<td></td>
<td>Principles of electrophoretic separation, zonal and continuous electrophoresis, paper, cellulose acetate/nitrate, gel and capillary electrophoresis, use of native and denaturing gels, Protein subunit molecular weight determination using SDS-PAGE, Anomalous protein migration of some proteins in SDS-PAGE, Acid-urea PAGE and their physical basis, Isoelectric focusing and two dimensional gel electrophoresis, electroporation, pulse field gel electrophoresis, gradient gels.</td>
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<tr>
<th>Unit VI</th>
<th>Chromatography and X-ray crystallography</th>
<th>2 lectures</th>
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<td>Chromatography, principles of adsorption, partition and ion-exchange chromatography, gel permeation chromatography, GC, GC-MS and HPLC; X-ray Crystallography - protein crystals, Bragg's law, unit cell, isomorphous replacement, fiber pattern of DNA; Small-angle X-ray diffraction methods: Principles &amp; applications; Basic protein structure prediction methods.</td>
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<tr>
<th>Unit VII</th>
<th>Optical tweezers</th>
<th>3 lectures</th>
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<tr>
<th>Unit VIII</th>
<th>Molecular and chemical biology</th>
<th>4 lectures</th>
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<td>DNA cloning; bacterial transformation; transfection; chromosome integration; screening for transformants; Polymerase Chain Reaction; PCR types; Gel electrophoresis; DNA sequencing; Molecular hybridization: Southern blot; Northern blot. Protein analyses: Western blot &amp; Immunoprecipitation; Rewriting DNA: mutations; random mutagenesis; point mutation; Site-specific mutations; Genome Editing Technology; DNA array &amp; protein array; Click-chemistry: Principles &amp; applications; Chemical sensors for in-cell biochemistry.</td>
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<tr>
<th>Unit IX</th>
<th>Optical microscopy methods</th>
<th>4 lectures</th>
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<td>Light Microscopy: lenses and microscopes, resolution: Rayleigh's Approach, Darkfield; Phase Contrast; Differential Interference Contrast; fluorescence and fluorescence microscopy; Confocal microscope: confocal principle, resolution and point spread function; nonlinear microscopy: multiphoton microscopy; principles of two-photon fluorescence, advantages of two-photon excitation, tandem scanning (spinning disk) microscopes, deconvolving confocal images; image processing, three-dimensional reconstruction; Total Internal reflection microscopy, STED microscopy.</td>
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<tr>
<th>Unit X</th>
<th>Mass spectroscopy</th>
<th>3 lectures</th>
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<td>Ionization techniques; mass analyzers/overview MS; FT-ICR and Orbitrap, fragmentation of peptides; proteomics, nano LC-MS; Phospho proteomics; interaction proteomics, mass spectroscopy in structural biology; imaging mass spectrometry.</td>
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**Recommended Textbooks and References:**

Medical Microbiology and Infection Biology

Credits

Course Objectives
This course will provide a perspective and exposure to medical aspects of bacteriology, virology, mycology, parasitology and infectious diseases along with concepts of symptoms, pathogenesis, transmission, prophylaxis and control, a conceptual understanding of host – pathogen interactions using well characterized systems as examples. The student should have a good grasp of disease causing microbes and their interactions with host.

Student Learning Outcomes
On completion of this course, students should be able to:
- Compare and contrast different microbial diseases, including properties of different types of pathogens, and mechanisms of pathogenesis;
- Summarize role of host in infectious disease, including natural barriers to infection, innate and acquired immune responses to infection, and inflammation;
- Compare and contrast experimental approaches for identifying virulence genes and advantages/disadvantages of each approach for specific pathogens.

Unit I
Bacterial diseases
8 lectures
Normal microflora (microbiome) of human body and its role – Skin, mouth and respiratory tract, intestinal tract, urogenital tract; Pathogenesis and virulence factors - Koch's postulates, Adherence and invasion, Toxins, Enzymes, Antiphagocytic factors, Antigenic heterogeneity, Iron acquisition; Bacillus anthracis, Clostridium spp., Corynebacterium diphtheriae; E. coli, Vibrio cholerae, Helicobacter pylori, Salmonella typhi and paratyphi, Shigella dysenteriae; Listeria monocytogenes, Mycobacterium spp., Ricketsial diseases; Haemophilus influenzae, Bordetella pertussis, Brucellosis, Streptococcal and Staphylococcal infections; Antibacterial chemotherapy (with examples of antibiotics) - Inhibition of cell wall synthesis, inhibition of cell membrane function, inhibition of protein and nucleic acid synthesis, antimetabolites; Drug resistance - origin (genetic and non-genetic), mechanisms, antimicrobial activity in vitro and in vivo, Multi-drug resistance and its mechanisms e.g. MDR-TB.

Unit II
Viral diseases
7 lectures
Viral Pathogenesis - Routes of entry, Viral spread (local and systemic infection), Viral persistence (chronic and latent infection); Polio, Chicken pox, Mumps, Measles, Rubella; Viral hemorrhagic fever, viral encephalitis, Dengue and Yellow fever; Influenza virus infection (emphasis on Avian and swine flu), Rabies and Prion diseases; Hepatitis and Human Cancer viruses; Emerging viral diseases – Ebola, Marburg, SARS, Hanta, Chikungunya, Zika, Chandipura; Antiviral chemotherapy and Viral vaccines; Nucleotide and nucleoside analogs, Reverse transcriptase inhibitor, protease inhibitor, fusion inhibitor etc., Interferons, Killed and attenuated vaccines.

Unit III
Fungal and protozoan infections
7 lectures
Types of Mycoses (with specific example of causative fungi) – Superficial, Cutaneous, Sub-cutaneous; Types of Mycoses (with specific example of causative fungi) - Endemic and Opportunistic; Mycotoxins and Antifungal chemotherapy – Mycetismus, Allatoxins, classes of currently available drugs and new inhibitors in the pipeline; Protozoan diseases - Giardiasis, Amoebiasis; Leishmaniasis, African sleeping sickness; Malaria, Cryptosporidiosis; Infection by Helminths – Nematodes, Trematodes, Cestodes.

Unit IV
Sexually transmitted diseases and congenital infections
6 lectures
Syphilis and Gonorrheal infections; AIDS and Lentiviral infection; Herpes infections; Chlamydial infections (Chlamydia trachomatis); Mycoplasma and Ureaplasma infection; Toxoplasmosis; Congenital viral infections – Cytomegalovirus, Varicella zoster, HBV, Enterovirus, Parvovirus B19 etc.
Intracellular and extracellular pathogens, Principles of microbial pathogenesis, host damage, inflammatory responses, adaptation strategies of pathogen–impact of host and pathogen metabolism on immunity and pathogen survival; Chronic pathogens and mechanisms of persistence; Evasion mechanisms of pathogens; Bacterial – host interaction - *Mycobacterium tuberculosis*, *Borrelia burgdorferi*; Viruses – host interaction: HIV, Influenza; Protozoan – host interaction: *Plasmodium* spp., *Leishmania major*.

**Recommended Textbooks and References:**


**Course Objectives**

The objectives of this course are to teach various approaches to conducting genetic engineering and its applications in biological research as well as in biotechnology industries.

**Student Learning Outcomes**

Given the impact of genetic engineering in modern society, students should be endowed with strong theoretical knowledge of this technology. In conjunction with the practicals in molecular biology & genetic engineering, the students should be able to take up biological research as well as placement in the relevant biotech industry.
Unit III
Different types of PCR techniques
5 lectures

Principles of PCR: primer design; fidelity of thermostable enzymes; DNA polymerases; types of PCR – multiplex, nested; real time PCR, touchdown PCR, hot start PCR, colony PCR, cloning of PCR products; T - vectors; proof reading enzymes; PCR based site specific mutagenesis; PCR in molecular diagnostics; viral and bacterial detection; sequencing methods; enzymatic DNA sequencing: chemical sequencing of DNA; automated DNA sequencing; RNA sequencing; chemical synthesis of oligonucleotides; mutation detection: SSCP, DGGE, RFLP.

Unit IV
cDNA analysis
6 lectures

Introduction of foreign DNA into host cells; transformation, electroporation, transfection; construction of genomic and cDNA libraries, phage display; strategies for library screening; radioactive and non-radioactive probes; hybridization techniques: Northern, Southern, South-western and Far-western and colony hybridization, fluorescence in situ hybridization.

Unit V
Gene silencing and genome editing technologies
12 lectures

Gene silencing techniques; introduction to siRNA; siRNA technology; Micro RNA; construction of siRNA vectors; principle and application of gene silencing; gene knockouts and gene therapy; creation of transgenic plants; debate over GM crops; introduction to methods of genetic manipulation in different model systems e.g. fruit flies (Drosophila), worms (C. elegans), frogs (Xenopus), fish (zebra fish) and chick; Transgenics - gene replacement; gene targeting; creation of transgenic and knock-out mice; disease model; introduction to genome editing by CRISPR-CAS with specific emphasis on Chinese and American clinical trials; Cloning genomic targets into CRISPR/ Cas9 plasmids; electroporation of Cas9 plasmids into cells; purification of DNA from Cas9 treated cells and evaluation of Cas9 gene editing; in vitro synthesis of single guide RNA (sgRNA); using Cas9/sgRNA complexes to test for activity on DNA substrates; evaluate Cas9 activity by T7E1 assays and DNA sequence analysis; Applications of CRISPR/cas9 technology. Applications gene therapy/gene editing - antiviral strategies, cancer immunotherapy, hematologic disorders, liver-targeted gene editing, neuromuscular disorders, ocular disorders etc., examples of Chinese and American clinical trials.

Recommended Textbooks and References:
4. Selected papers from scientific journals, particularly Nature & Science.
5. Technical Literature from Stratagene, Promega, Novagen, New England Biolabs
OMICS: Genomics, Transcriptomics, Proteomics and Metabolomics

Course Objectives
The objective of this course is to give an introduction to Genomics and other global Omics technologies, theory and practical aspects of these technologies and applications of these technologies in biology. The student should be able to gain working knowledge of these technologies and appreciate their ability to impart a global understanding of biological systems and processes in health and disease.

Student Learning Outcomes
On completion of this course, students should be able to:
- Overview of genome variation in population including technologies to detect these variation;
- Understand how High-throughput DNA sequencing (HTS) can be used to identify disease causing genetic variants in monogenic diseases;
- Understand how Genome-wide association study (GWAS) can detect disease associated markers in multifactorial diseases;
- Understand how HTS technologies can be used to explore changes in gene expression;
- Application of various Omics technologies.

Credits
3

Unit I
Introduction to genomics
6 lectures
Structure and organization of prokaryotic and eukaryotic genomes- nuclear, mitochondrial and chloroplast genomes; Computational analysis, Databases, Finding genes and regulatory regions; Tools for genome analysis- PCR, RFLP, DNA fingerprinting, RAPD, SNP detection, SSCP, FISH to identify chromosome landmarks; Human Genome Project- landmarks on chromosomes generated by various mapping methods, BAC libraries and shotgun libraries preparation, Physical map, Cytogenetic map, Contig map, Restriction map, UCSC browser.

Unit II
Microarray technology
6 lectures
Introduction, Basic principles and design, cDNA and oligonucleotide arrays, DNA microarray, Instrumentation and structure; Designing a microarray experiment - The basic steps, Types of microarray - expression arrays, protein arrays, Comparative Genomic Hybridization (CGH) arrays, Resequencing arrays; Different platforms (Affymetrix, Agilent etc.); Data Processing and Normalization - Algorithms of data processing and Normalization; Tools used to normalize; Microarray databases – NCBI; GEO (Gene Expression Omnibus), ArrayExpres (EBI); Functional Analysis: Differential gene expression; Gene Ontology functional enrichment tools, Pathway analysis (KEGG Database); Applications of Microarray technology; case studies.

Unit III
Sequencing technologies
7 lectures
Introduction to sequencing, Maxam and Gilbert method, Sanger Sequencing techniques and applications; Next Generation sequencing (NGS), Introduction to NGS, Experimental Protocol (Isolation of DNA/RNA), quality check, Library Preparations, sequencing reaction); Platform overview and comparison (Illumina, 454 (Roche), SOLiD (Life technology), Specific Biosciences, Ion Torrent, Nanopore, PacBio; Types of NGS, DNA-sequencing - Whole genome sequencing, exome sequencing, Deep sequencing, ChiP sequencing, RNA-sequencing and the types (small RNA sequencing, non-coding RNA sequencing), Whole transcriptome sequencing; Data Processing and Analysis: Data Quality Check, filtering and Genome assembly and mapping to reference genomes, mapping tools (bowtie, maq etc.), Sequence Alignment formats: Sequence Alignment/Map (SAM) format, Binary Alignment/Map (BAM) format, Functional Analysis: Pathway analysis, Gene Ontology analysis; Application of different sequencing technique, methylomics, in vivo protein binding, genome wide association studies (GWAS), Histone modification, microbial sequencing, Comparison of Microarray technology and High throughput sequencing technology, case studies.
Overview of protein structure—primary, secondary, tertiary and quaternary structure, Relationship between protein structure and function; Outline of a typical proteomics experiment, Identification and analysis of proteins by 2D analysis, Spot visualization and picking; Tryptic digestion of protein and peptide fingerprinting, Mass spectrometry: ion source (MALDI, spray sources), analyzer (ToF, quadrupole, quadruple ion trap) and detector; Post translational Modifications: Quantitative proteomics, clinical proteomics and disease biomarkers, mass spectral tissue imaging and profiling; Protein-protein interactions: Surfaceomes and Secretomes, Solid phase ELISA, pull-down assays (using GST-tagged protein) tandem affinity purification, far western analysis, by surface plasmon resonance technique; Yeast two hybrid system, Phage display, Protein interaction maps, Protein arrays-definition; applications- diagnostics, expression profiling.

Introduction and overview of metabolites, sample collection and processing, Non tracer and tracer (radio labelled)-based techniques in metabolomics (HPLC, NMR, LC-MS and GC-MS); Metabolome data processing derived by various techniques, analysis of databases (MetaboLight, Meta Cyc, MMCD etc.), Analysis tools, Metabolic pathways and network analysis Metabolic flux analysis (TCA, Amino acids, fatty acids, intermediary metabolites), Stoichiometric metabolic flux analysis, 13C metabolic flux analysis (MFA), Metabolic control analysis (MCA); Applications of metabolomics; Integration of metabolomics data sets with other data (eg. Transcriptomics, enzyme activity, etc.).

Recommended Textbooks and References:

Course Objectives
The objectives of this laboratory course are to develop an understanding about practical aspects of components of immune system as well as their function. Basic as well as advanced methods will be taught to detect different antigen and antibody interactions, isolation of different lymphocyte cells etc. and how they can be used in respective research work.

Student Learning Outcomes
On completion of this course, students should be able to:
- Evaluate the usefulness of immunology in different pharmaceutical companies;
- Identify proper research lab working in area of their own interests;
- Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out kind of immune responses in setting of infection (viral or bacterial) by looking at cytokine profile.
Syllabus

1. Handling of animals like rabbits, mice.
2. Preparation of antigens, immunization and methods of bleeding, serum separation and storage.
3. Antibody titre by ELISA method.
5. Complement fixation test.
6. Isolation and purification of IgG from serum or IgY from chicken egg.
7. SDS-PAGE, Immunoblotting, Dot blot assays.
10. Separation of mononuclear cells by Ficoll-Hypaque.
12. Cryopreservation of cells.
14. Metabolite profile for biomarker detection in body fluids/tissues under various metabolic disorders by making use of any biochemical methods.
15. Lecture-demonstration of any two inherited diseases for which molecular diagnosis has provided a dramatic improvement of quality of medical care: take through web-tutorial using online content.
16. Lecture demonstration of recognized genetic aberrations in clinical samples from cancer patients and detail a test-case using next-generation sequencing of a patient sample using web-tutorials and online content.

Course Objectives

The objective of this laboratory course is to provide the students practical skills on basic microbiological and genetic engineering techniques.

Student Learning Outcomes

On completion of this lab course, students should be able to:

- Acquire basic microbiology techniques and principles;
- Get first-hand experience that will coincide with what is taught in the lecture portion of the class;
- Gain hands-on experience on gene cloning, protein expression and purification.

Laboratory IV: Microbiology and Molecular Biology

Credits

3

Syllabus

1. Pure culture technique e.g. streaking, colony purification and sub-culturing.
2. Growth curve using viable count; Total cell count by measuring turbidity by spectrophotometer and Petroff-Hauesser chamber.
3. Identification of microbes in a local sample (soil/water/skin etc).
4. Determination of antibiotic sensitivity by Kirby-Bauer method and antibiotic resistance.
5. Isolation of auxotrophs and Ames test using any chemical mutagen and testing the mutagenicity of routine cosmetics and drugs.
6. Replica plate assay.
7. Isolation of specific mutants (gain of function & loss of function phenotypes) using UV light, chemical mutagens, etc.
8. Isolation of microbial DNA (e.g. from E. coli) and plasmid DNA, purification and quantification by DNA agarose gel, UV-visible spectrophotometer, NanoDrop method.
9. Isolation of total RNA; gel separation of all ribosomal RNA species.
Course Objectives
The objectives of this course are to build upon previous knowledge of biochemical pathways and immunology to develop an appreciation of applications of these knowledge in clinical diagnostics and treatment. The course shall make students aware about various disease diagnostic techniques, disease pathologies and clinical case studies within the context of each topic.

Student Learning Outcomes
Students should be able to:
• Understand applications of clinical biochemistry in diagnostics;
• Understand the molecular basis of various pathological conditions from the perspective of biochemical reactions.

Clinical specimen Considerations - Types of Samples, Sample Processing, Sample Variables, Chain of Custody; Infection control, the vascular system, composition and types of blood specimens, venipuncture, pediatric and geriatric venipuncture, capillary specimen collection, capillary puncture procedures. Place and time of sample collection, preservation, influence of nutrition, drugs, posture, etc. Choice and correct use of anticoagulants; Care of the specimens, identification, transport, storage, influence of temperature, freezing/thawing; Laboratory safety and regulations – Safety awareness, safety equipment, biological, chemical, fire and radiation safety; Method evaluation and quality management, Basic concepts, Reference interval study, Diagnostic efficiency, Method evaluation, Quality Control and quality management.

Amino acids - Basic Structure, Metabolism, Essential Amino Acids, Non essential Amino Acids, Body amino acid pool, Aminoacidopathies, Amino Acid Analysis, glutathione hyperglycinemias, formation of taurine, homocystinuria, cystinuria and cystinosis, phenyl ketonuria and alkaptonuria, albinism, tyrosinemia; Proteins – Importance, Molecular Size, Catabolism and Nitrogen Balance, Structure, Classification, Dynamic state of body proteins; Plasma proteins - Prealbumin (Transthyretin), Albumin, Globulins; Total Protein abnormalities – Hypoproteinemia, Hyperproteinemia; Methods of analysis – Total nitrogen, Total proteins, Fractionation, Identification and Quantification of specific proteins, Serum protein electrophoresis, High-resolution protein electrophoresis, Immunoochemical methods; Proteins in other body fluids – Urinary proteins and Cerebrospinal fluid proteins; Non-protein nitrogen compounds (Physiology, clinical application, methods and pathophysiology) – Urea, Uric acid, Creatine, Creatinine, Ammonia, Synthesis of thyroid hormones, Synthesis and catabolism of catecholamines.
Unit III
Clinically important enzymes and related pathophysiology
3 lectures

Enzymes of clinical significance - Creatine Kinase, Lactate Dehydrogenase, Aspartate Aminotransferase, Alanine Aminotransferase, Alkaline Phosphatase, Acid Phosphatase, Glutamyl transferase, Amylase, Lipase, Glucose-6-Phosphate Dehydrogenase, Drug-Metabolizing Enzymes, Tumour markers, Bone markers, Cardiac markers, liver markers, Inborn errors associated with carbohydrate metabolism; Inborn errors of metabolism - Glycogen storage diseases, Fructosuria, Fructose intolerance, Pentosuria, Galactosuria, Urine screening.

Unit IV
Diagnosis and treatment of carbohydrate disorders
5 lectures


Unit V
Transport mechanism and associated disorders
4 lectures

Transport of plasma lipids, lipoprotein metabolism, lipid profile and diet, PUFA and dietary fiber, Serum triglycerides; Diagnosis and treatment of lipid disorders – Arteriosclerosis, Hyperlipoproteinemia, Hypercholesterolemia, Hypertriglyceridemia, Combined Hyperlipoproteinemia, Lipoprotein(a) Elevation, Hypolipoproteinemia, Hypoalphalipoproteinemia; Lipid and lipoprotein analyses - Lipid Measurement, Cholesterol Measurement, Triglyceride Measurement, Lipoprotein Methods, High-Density Lipoprotein Methods, Low-Density Lipoprotein Methods, Compact Analyzers, Apolipoprotein Methods, Phospholipid Measurement, Fatty Acid Measurement.

Unit VI
Assessment of organ system function
10 lectures

Pituitary function - Introduction to Hormones and Pituitary Function - hypophysiotropic or hypothalamic hormones; Anterior pituitary hormones; Pituitary tumors; Growth hormone; Actions of growth hormone; Testing, Acromegaly; Growth hormone deficiency; Prolactin; Prolactinoma; Other causes of hyperprolactinemia; Clinical evaluation of hyperprolactinemia; Management of prolactinoma; Idiopathic galactorrhea; Hypopituitarism - Etiology of hypopituitarism; Treatment of panhypopituitarism; Posterior pituitary hormones – Oxytocin and Vasopressin. Liver Function - Anatomy - Gross Anatomy, Microscopic Anatomy, Biochemical functions - Excretory and Secretory, Synthetic, Detoxification and Drug Metabolism, Liver function alterations during disease – Jaundice, Cirrhosis, Tumors, Reye Syndrome, Drug- and Alcohol-Related Disorders Assessment of liver function/liver - Function tests: Bilirubin, Urobilinogen in Urine and Faeces, Serum Bile Acids, Enzymes, Tests Measuring Hepatic Synthetic Ability, Tests Measuring Nitrogen Metabolism, Hepatitis. Cardiac Function - Anatomy and function of the heart - Anatomy Function, Pathologic conditions of the heart, Cardiovascular Disease, Congenital Cardiovascular Defects, Heart Failure, Acute Coronary Syndromes, Hypertensive Heart Disease, Infective Heart Disease, Diagnosis of heart disease - Laboratory Diagnosis of Myocardial Infarction, Markers of Inflammation and Coagulation Disorders, Markers of Congestive Heart Failure, Patient-Focused Cardiac Tests, Disease. Renal Function - Renal anatomy, Renal physiology - Glomerular Filtration, Tubular Function, Elimination of Nonprotein Nitrogen Compounds, Water, Electrolyte, and Acid-Base Homeostasis, Endocrine Function, 1,25-Dihydroxy Vitamin D3, Analytic procedures, Clearance Measurements, Urine Electrophoresis, 2-Microglobulin, Myoglobin, Microalbumin, Urinalysis, Pathophysiology – Glomerular Diseases, Tubular Diseases, Urinary Tract Infection/Obstruction, Renal Calculi, Renal Failure. Pancreatic Function and Gastrointestinal Function - Physiology of pancreatic function, Diseases of the pancreas, Tests of pancreatic function - Secretin/Cholecystokinin Test, Fecal Fat Analysis, Sweat Electrolyte Determinations, Serum Enzymes, Physiology and biochemistry of gastric secretion, Clinical aspects of gastric analysis, tests of gastric
function - Measuring Gastric Acid in Basal and Maximal Secretory Tests, Measuring Gastric Acid, Plasma Gastrin, Intestinal physiology, Clinicopathologic aspects of intestinal function, Tests of intestinal function - Lactose Tolerance Test, D-Xylose Absorption Test, Serum Carotenoids, Other Tests of Intestinal Malabsorption.

Recommended Textbooks and References:

### Course Objectives
Tissue engineering is progressively being accepted as beneficial means for lessening global disease burden. This course would provide a combined overview of genetic engineering and molecular cell biology to develop fundamental understanding to manipulate cell and tissue properties rationally to alter, restore, maintain, or improve cell and tissue functions. Further, this course also describes strategies of tissue engineering, stem cells, diseases that tissue engineering can address, and also focuses on various ethical issues attached with tissue engineering and stem cell research. This understanding is expected to manipulate cell and tissue properties rationally to alter, restore, maintain, or improve cell and tissue functions as well as to design artificial tissue substitutes.

### Student Learning Outcomes
On completion of this course, student is expected to:
- Explain significance, current status and future potential of tissue engineering;
- Identify key challenges in tissue engineering of different human tissues;
- Describe design, fabrication and biomaterials selection criteria for tissue engineering scaffolds;
- Describe sources, selection, potential manipulations and challenges of using stem cells for tissue engineering.

### Credits
3

#### Unit I
**Introduction to bioengineering**
3 lectures

- Historical overview and fundamentals of tissue engineering, tissue dynamics/homeostasis, Introduction to Biomaterials used in tissue engineering, Role of scaffolds and growth factors in tissue engineering: Importance and scope of tissue engineering.

#### Unit II
**Biomaterials and scaffolds**
5 lectures

- Introduction to biomaterials and scaffolds; Requirement of biomaterials as Tissue Engineering scaffolds, Properties and types of scaffolds, Tissue specific scaffolds; Scaffold Preparation: Different methods employed in synthesis of scaffolds and ways to process them; Cell/Tissue-scaffold interaction: Animal cell culture on scaffolds, consequences, optimization strategies and important considerations.

#### Unit III
**Tissue engineering applications**
5 lectures

- Skin tissue engineering, Liver tissue engineering, Bone and cartilage tissue engineering, Nerve tissue engineering, Vascular tissue engineering, Muscle tissue engineering, Kidney tissue engineering.
Unit IV
Basics of stem cells and molecular manipulation techniques
8 lectures
Stem cells in tissue engineering, types of stem cells, cellular signalling and maintenance of stem cells, isolation, expansion, genetic manipulation, genomic reprogramming, and cloning of stem cells, clinical applications, adult and embryonic stem cells, germline stem cells, ethical issues. Gene silencing technology; Antisense therapy; miRNA, siRNA; Tissue and organ transplantation; Transgenics and their uses; Gene therapy; selection of the right gene, cloning vectors and strategies, intracellular barriers to gene delivery; overview of different vehicles for gene delivery, Retro and adenovirus mediated gene transfer; Liposome and nanoparticles mediated gene delivery; Overview of inherited and acquired diseases for gene, Cell and Tissue Culture, Ex-vivo and in vivo gene therapy, post therapy immune response, success rate, ethical issues.

Unit V
Tissue and animal level manipulation & therapy
8 lectures
Embryonic stem cells, pluripotency, blastocyst and inner cell mass cells; Organogenesis; Mammalian nuclear transfer technology; Stem cell differentiation; Stem cell cryopreservation, animal cloning and ethical considerations. Overview of embryonic and adult stem cells for therapy of human neurodegenerative diseases, Spinal cord Injuries and other Brain Syndromes; Tissue systems Failures; Diabetes; Cardiomyopathy; Kidney failure; Liver failure; infertility, Cancer; Haemophilia etc; Regenerative medicine using biomaterials, Cardiovascular tissue engineering, Connective tissue engineering, Musculoskeletal tissue engineering, Neural tissue engineering.

Unit VI
Therapy & ethical issues
3 lectures
Potential applications of human embryonic stem cells; Human embryonic stem cells and society, Ethical considerations in stem cells research; Stem cells and religion consideration; Pre-clinical regulatory consideration in stem cell based therapies and patient advocacy.

Recommended Textbooks and References:
2. Boer JD et al.; Tissue Engineering; Academic Press
3. Pallua N, Suschek CV; Tissue Engineering: from Lab to Clinic; Springer
5. Minuth WW. Strehl R. Schumacher K; Tissue Engineering: from Cell Biology to Artificial Organs; Wiley VCH
7. Zhao RC; Stem Cells: Basics and Clinical Translation (Translational Medicine Research); Springer
8. Knoepfler; Stem Cells: An Insider's Guide; World Scientific Publishing Company
10. Attala & Lana; Methods of Tissue Engineering; Academic Press
11. Lanza, Langer, Vacanti; Principles of Tissue Engineering; Academic Press
12. Patrick, Mikos, McIntire; Frontiers in Tissue Engineering; Pergamon
13. Ratner, Hoffman, Schoen; Biomaterials Science; Academic Press
14. Palsson & Bhatia; Tissue Engineering; Prentice Hall.
Course Objectives
The objectives of this course are to sensitize students about recent advances in molecular biology and various facets of molecular medicine which has potential to profoundly alter many aspects of modern medicine including pre- or post-natal analysis of genetic diseases and identification of individuals predisposed to disease ranging from common cold to cancer.

Student Learning Outcomes
Students should be able to understand various facets of molecular procedures and basics of molecular diagnostics and therapeutics that could be employed in early diagnosis and prognosis of human diseases.

Unit I
Genome: resolution, detection & analysis
5 lectures
DNA polymorphism: human identity; clinical variability and genetically determined adverse reactions to drugs; PCR: Real-time; ARMS; Multiplex; ISH; FISH; ISA; RFLP; DHPLC; DGGE; GSCE; SSCP; Nucleic acid sequencing: new generations of automated sequencers; Microarray chips; EST; SAGE; microarray data normalization & analysis; molecular markers: 16S rRNA typing; Diagnostic proteomics: SELDI-TOF MS; Bioinformatics data acquisition & analysis.

Unit II
Diagnostic metabolomics
3 lectures
Metabolite profile for biomarker detection in the body fluids/tissues under various metabolic disorders by making use of LCMS & NMR technological platforms.

Unit III
Detection of diseases
5 lectures
Detection & identity of microbial diseases: Direct detection & identification of pathogenic-organisms that are slow growing or currently lacking a system of in vitro cultivation as well as genotypic markers of microbial resistance to specific antibiotics; Detection of inherited diseases: Exemplified by two inherited diseases for which molecular diagnosis has provided a dramatic improvement of quality of medical care: Fragile X Syndrome: Paradigm of the new mutational mechanism of the unstable triplet repeats, von-Hippel Lindau disease: recent acquisition in growing number of familial cancer syndromes.

Unit IV
Molecular oncology
5 lectures
Detection of recognized genetic aberrations in clinical samples from cancer patients; types of cancer-causing alterations revealed by next-generation sequencing of clinical isolates; predictive biomarkers for personalized onco-therapy of human diseases such as chronic myeloid leukemia, colon, breast, lung cancer and melanoma as well as matching targeted therapies with patients and preventing toxicity of standard systemic therapies.

Unit V
Molecular therapeutics
10 lectures
Gene therapy; Intracellular barriers to gene delivery; Overview of inherited and acquired diseases for gene therapy; Retro and adenovirus mediated gene transfer; Liposome and nanoparticles mediated gene delivery; Cellular therapy; Recombinant therapy; Clinical applications of recombinant technology; Erythropoietin; Insulin analogs and its role in diabetes; Recombinant human growth hormone; Streptokinase and urokinase in thrombosis; Recombinant coagulation factors; Immunotherapy; Monoclonal antibodies and their role in cancer; Role of recombinant interferons; Immunostimulants; Immunosuppressors in organ transplants; Role of cytokine therapy in cancers; Types of recombinant vaccines and clinical applications; Gene silencing technology; Antisense therapy; siRNA; Tissue and organ transplantation; Transgenics and their uses; Cloning; Ethical issues.
Unit VI
Quality assurance & control
1 lectures

Quality oversight; regulations and approved testing.

Recommended Textbooks and References:

Medical Devices

Credits

3

Course Objectives
The objective of the course is to familiarize students with emerging trends in medical devices for early detection, selection of appropriate treatment, monitoring treatment effectiveness and disease surveillance.

Student Learning Outcomes
On successfully completing this course, students are expected to be able to:
- Extend principles of engineering to the development of medical devices and design of sensors;
- Appreciate basic configuration and distinction among biosensor systems.

Unit I
Sensors
5 lectures

Rationale of electronic biosensors; Essence of three types of electronic biosensors (i.e., potentiometric, amperometric, and cantilever-based sensors); Three essential metrics that define modern electronic sensors; detection time, sensitivity, and selectivity; Physics of detection time that allows one to organize every available sensor in a systematic way; Fundamental limits of detection of various classes of sensors; Opportunities and challenges of integrating sensors in a system platform.

Unit II
Transducers
5 lectures

Principles and applications of Calorimetric, Piezoelectric, semiconductor, impedimetric, based transducers; Biochemical Transducers: Electrode theory: electrode-tissue interface, metal-electrolyte interface, electrode-skin interface, electrode impedance, electrical conductivity of electrode jellies and creams.

Unit III
Optical sensors
5 lectures

Photo detectors, optical fiber sensors, indicator mediated transducers; General principles of optical sensing, optical fiber temperature sensors; Pulse sensor: photoelectric pulse transducer, strain gauge pulse transducer.

Unit IV
Bio recognition systems
5 lectures

Enzymes; Oligonucleotides Nucleic Acids; Lipids (Langmuir-Blodgett bilayers, Phospholipids, Liposomes); Membrane receptors and transporters; Immunoreceptors; Chemoreceptors.

Unit V
Electrodes and immobilization
5 lectures

Microelectrodes, body surface electrodes, needle electrodes, pH electrode, specific ion electrodes/ Ion exchange membrane electrodes, enzyme electrodes; Reference electrodes: hydrogen electrodes, silver-silver chloride electrodes, Calomel electrodes; Enzyme
immobilization; Peptide immobilization; Antibody immobilization; Oligonucleotides and Nucleic Acid immobilization; Cell immobilization; Mono-enzyme electrodes; Bi-enzyme electrodes: enzyme sequence electrodes and enzyme competition electrodes.

Unit VI
Fundamentals and applications of microfluidics
5 lectures

Capillary flow and electro kinetics; Micro pump, Micro mixers, Micro reactors, Micro droplets, Micro particle separators; Micro fabrication techniques (different types of lithography methods); Application of micro-fluidics (eg. Lab-in–Chip).

Unit VII
Applications
5 lectures

Biomarkers: Disease and pathogen specific information, availability by sample type (blood, serum, urine, sputum, saliva, stool, mucus); Specificity, sensitivity, shelf life, portability; Clinical chemistry; Test-strips for glucose monitoring; Urea determination; Implantable Sensors for long-term monitoring; Drug development and detection; Environmental monitoring; Examples of various diseases (Cancer, HIV/AIDS, Tuberculosis, Malaria, Lymphatic Filariasis, Schistosomiasis, Dengue, Chikungunya).

Recommended Textbooks and References:

Course Objectives
The objectives of this course are:
- To provide basic knowledge on intellectual property rights and their implications in biological research and product development.
- To become familiar with India’s National IPR Policy.
- To learn biosafety and risk assessment of products derived from biotechnology and regulation of such products.
- To become familiar with ethical issues in biological research. This course will focus on the consequences of biomedical research technologies such as cloning of whole organisms, genetic modifications, DNA testing.

Student Learning Outcomes
On completion of this course, students should be able to:
- Understand the rationale for and against IPR and especially patents;
- Understand why India has adopted National IPR Policy and be familiar with broad outline of patent regulations;
- Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents;
- Gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research environment release of genetically

Credits
2

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**Unit I**  
**Introduction to IPR**  
7 lectures  
Introduction to intellectual property; types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of ’prior art’: invention in context of “prior art”; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation.; Review of Government of India’s “National Intellectual Property Rights Policy”.

**Unit II**  
**Patenting**  
3 lectures  
Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure - patent application- forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting-requirement, procedures and costs; financial assistance for patenting- introduction to existing schemes; publication of patents-gazette of India, status in Europe and US; patent infringement- meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing – outright sale, licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives.

**Unit III**  
**Biosafety**  
3 lectures  
Biosafety and Biosecurity - introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants – sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk – environmental risk assessment and food and feed safety assessment; problem formulation – protection goals, compilation of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops vs cisgenic plants or products derived from RNAi, genome editing tools.

**Unit IV**  
**National and international regulations**  
3 lectures  
International regulations – Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations – EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – biosafety levels and category of rDNA experiments; field trails – biosafety research trials – standard operating procedures - guidelines of state governments; GM labeling – Food Safety and Standards Authority of India (FSSAI).

**Unit V**  
**Bioethics**  
7 lectures  
Introduction, ethical conflicts in biological sciences - interference with nature, bioethics in health care - patient confidentiality, informed consent, euthanasia, artificial reproductive technologies, prenatal diagnosis, genetic screening, gene therapy, transplantation.

Recommended Textbooks and References:
2. National IPR Policy, Department of Industrial Policy & Promotion, Ministry of Commerce, GoI
5. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/

Bioinformatics

Course Objectives
The objectives of this course are to provide students with the theory practical experience of the use of common computational tools and databases which facilitate investigation of molecular biology and evolution-related concepts.

Credits
2

Student Learning Outcomes
On completion of this course, students should be able to:
- Develop an understanding of the basic theory of these computational tools;
- Gain working knowledge of these computational tools and methods;
- Appreciate their relevance for investigating specific contemporary biological questions;
## Unit I
### Bioinformatics basics
5 lectures

Bioinformatics basics: Computers in biology and medicine; Importance of Unix and Linux systems and its basic commands; Database concepts; Protein and nucleic acid databases; Structural databases; databases and search tools: biological background for sequence analysis; Identification of protein sequence from DNA sequence; searching of databases for similar sequences; NCBI; publicly available tools; resources at EBI; resources on the web; database mining tools.

## Unit II
### DNA sequence analysis
5 lectures

DNA sequence analysis: gene bank sequence database; submitting DNA sequences to databases and database searching; sequence alignment; pairwise alignment techniques; motif discovery and gene prediction; local structural variants of DNA, their relevance in molecular level processes, and their identification; assembly of data from genome sequencing.

## Unit III
### Multiple DNA sequence analysis
4 lectures

Multiple sequence analysis; multiple sequence alignment; flexible sequence similarity searching with the FASTA3 program package; use of CLUSTAL W and CLUSTAL X for multiple sequence alignment; submitting DNA protein sequence to databases: where and how to submit, SEQUIN, genome centres; submitting aligned set of sequences, updates and internet resources; methods of phylogenetic analysis.

## Unit IV
### Protein modelling
5 lectures

Protein modelling: introduction; force field methods; energy, buried and exposed residues; side chains and neighbours; fixed regions; hydrogen bonds; mapping properties onto surfaces; fitting monomers; RMS fit of conformers; assigning secondary structures; sequence alignment- methods, evaluation, scoring; protein completion: backbone construction and side chain addition; small peptide methodology; software accessibility; building peptides; protein displays; substructure manipulations, annealing.

## Unit V
### Protein Structure prediction and virtual library
6 lectures

Protein structure prediction: protein folding and model generation; secondary structure prediction; analyzing secondary structures; homology modelling: potential applications, description, methodology, homologous sequence identification; align structures, align model sequence; construction of variable and conserved regions; threading techniques; topology fingerprint approach for prediction; evaluation of alternate models; sequence based methods of structure prediction, prediction using inverse folding, fold prediction; significance analysis, scoring techniques, sequence-sequence scoring; protein function prediction; elements of in-silico drug design; Virtual library: Searching Medline, PubMed, current content, science citation index and current awareness services, electronic journals, grants and funding information.

### Recommended Textbooks and References:
## Project Proposal Preparation & Presentation

### Course Objectives
The main purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.

### Student Learning Outcomes
Students should be able to demonstrate the following abilities:

- Formulate a scientific question;
- Present scientific approach to solve the problem;
- Interpret, discuss and communicate scientific results in written form;
- Gain experience in writing a scientific proposal;
- Learn how to present and explain their research findings to the audience effectively.

### Syllabus

<table>
<thead>
<tr>
<th>Project Proposal Preparation</th>
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<tr>
<td><strong>Selection of research lab and research topic:</strong> Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them select a topic for their project. The topic of the research should be hypothesis driven. Review of literature: Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources. With the help of the supervisor/guide, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc. Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.</td>
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<tr>
<th>Poster Presentation</th>
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<tr>
<td>Students will have to present the topic of their project proposal after few months of their selection of the topic. They should be able to explain the novelty and importance of their research topic.</td>
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<tr>
<th>Oral Presentation</th>
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<tbody>
<tr>
<td>At the end of their project, presentation will have to be given by the students to explain in detail the work done by them. Along with summarizing their findings they should also be able to discuss the future outcomes of their work.</td>
</tr>
</tbody>
</table>

## Laboratory V: Clinical Biochemistry and Disease Metabolism

### Course Objectives
The objectives of this course are to build upon previous knowledge of biochemical pathways and immunology to develop an appreciation of applications of these knowledge in clinical diagnostics and treatment. The course shall equip students with basic skills in practicals for clinical biochemistry.

### Student Learning Outcomes
Students should be able to:

- Learn basic hands-on skills for blood and urine biochemistry practicals;
- Understand applications of clinical biochemistry in diagnostics;
- Understand the molecular basis of various pathological conditions from the perspective of biochemical reactions through practical case studies.

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Remodelled Biotech Curricula | 301
### Unit I
**Blood Practicals**
1. Sugar estimation (fasting/post-prandial-random)- Alkaline copper reduction method
2. Total lipid profile & CBC.
4. Protein Estimation: Total Protein- Biuret method, Albumin- BCG method
5. Lipid: Cholesterol – by CHOD-POD Method
7. Liver Function Test: Bilirubin(total, direct and indirect)- Diazo Method, SGPT, ALP

### Unit II
**Urine Practicals**
Sugar, Protein, Ketone bodies, Bile salts and Bile acids.

### Unit III
**Case Studies**

**Case history-1: Diabetic Ketoacidosis**
A 32-year-old male with type 1 diabetes since the age of 14 years was taken to the emergency room because of drowsiness, fever, cough, diffuse abdominal pain, and vomiting.
Fever and cough started 2 days ago and the patient could not eat or drink water. On examination, he was tachypneic, his temperature was 39° C, pulse rate 104 beats per minute, respiratory rate 24 breaths per minute, supine blood pressure 100/70 mmHg. He was slightly confused. Perform suitable tests in the blood/urine sample provided and give probable diagnosis on the basis of your findings. Interpret the result accordingly.

**Case history-2: Nephrotic Syndrome**
A five year old child was brought in paediatric OPD with complaints of weakness and polyuria. On physical examination it was observed that he was having periorbital oedema and swelling over legs. Perform suitable tests in blood/urine sample provided and interpret your findings.

**Case history-3: Chronic Renal Failure**
A 70 years old man presented in nephro OPD with complaints of weakness, loss of appetite and breathlessness. He was diabetic and taking anti-diabetic drugs since last 15 years. His blood pressure was 140/100 and there was oedema over face. Perform suitable tests on blood sample provided and interpret your findings accordingly.

**Case history-4:**
Choose a case of a genetic disorder, describe the basics of disease biochemistry, study patient case history to assess the disease phenotype, discuss the available treatment modalities, study the patient case-history after the successful completion of prescribed treatment.

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**Laboratory VI: Bioinformatics**

**Course Objectives**
The aim is to provide practical training in bioinformatics methods including accessing the major public sequence databases, use of the different computational tools to find sequences, analysis of protein and nucleic acid sequences by various software packages.

**Student Learning Outcomes**
On completion of this course, students should be able to:
- Describe the contents and properties of the most important bioinformatics databases;
- Perform text- and sequence-based searches and analyze and discuss the results in light of molecular biological knowledge;
- Explain the major steps in pairwise and multiple sequence alignment,
Syllabus

1. Using NCBI and Uniprot web resources.
2. Introduction and use of various genome databases.
4. Similarity searches using tools like BLAST and interpretation of results.
5. Multiple sequence alignment using ClustalW.
7. Use of gene prediction methods (GRAIL, Genscan, Glimmer).
8. Using RNA structure prediction tools.
9. Use of various primer designing and restriction site prediction tools.
10. Use of different protein structure prediction databases (PDB, SCOP, CATH).
11. Construction and study of protein structures using Deepview/PyMol.
13. Use of tools for mutation and analysis of the energy minimization of protein structures.
14. Use of miRNA prediction, designing and target prediction tools.

Course Objectives

This course aims at providing hands-on experience of basic aspect of methods for handling animal cell culture. Online tools and resources are highly recommended, especially when infrastructure facility is limiting factor.

Student Learning Outcomes

On completion of this course, students should be able to gain hands on experience of handling and maintaining various animal cell lines. Students should also be able to learn materials and substances which cause toxicity in animal cells.

Syllabus

1. Culturing a given cell line (primary or transformed), maintaining the same using serial passaging, safety methods employed to minimise contaminations while culturing and maintaining the culture.
2. Various cell culture media, culturing methods for adherent and suspension cultures, counting cells, quantifying cell viability in the culture, freeze-storing the cultures;
3. Staining cells using nuclear stains such as DAPI/PI or membranes or mitochondria using specific dyes, followed by fluorescence imaging.
4. Detecting contamination (bacterial/fungal/micoplasma etc.) in animal cell cultures. Cross-contamination of cell-lines.
5. Trypsinizing cells: Trypsinization is a technique that uses the proteolytic enzyme trypsin to detach adherent cells from the surface of a cell culture vessel. This procedure is performed whenever the cells need to be harvested (e.g., for passaging, counting, or for nucleic acid isolation).
6. Low speed centrifugation of cultured cells, followed by detergent lysis and fractionation of cell lysates into cytoplasmic, nuclear soluble and chromatin fractions. Assessing the purity of cell fractionation by staining with marker-specific Abs using Immunoflorescence or westernblot methods.
7. Assessing culture instability: This is generally overlooked in busy labs, but is a
very important facet of cell culturing. The growth rate of cells that have been repeatedly subcultured may sometimes unexpectedly decrease, and the cytotoxicity of, for example, a transfection process may unexpectedly increase. This instability can result from variations in cell culture conditions, genomic variation, and selective overgrowth of constituents of the cell population. Importance of using cells with a low passage number (<10 splitting cycles). To safeguard against instability in continuous cell lines, avoid senescence or transformation in finite cell lines, and maintain consistency in transfection experiments, and create cell banks by freezing aliquots of cells to recall into culture if and when necessary.

8. Also important to learn about procedures of sterilizing potentially biohazardous materials (e.g., cells, culture medium, etc.) before disposal, and disposed of according to your institution's guidelines.

Recommended Textbooks and References:

Semester Four

Dissertation

Course Objectives
The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.

Student Learning Outcomes
Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:
- In-depth knowledge of the chosen area of research.
- Capability to critically and systematically integrate knowledge to identify issues that must be addressed within framework of specific thesis.
- Competence in research design and planning.
- Capability to create, analyse and critically evaluate different technical solutions.
- Ability to conduct research independently.
- Ability to perform analytical techniques/experimental methods.
- Project management skills.
- Report writing skills.
- Problem solving skills.
- Communication and interpersonal skills.
Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.

### Syllabus

#### Planning & performing experiments

Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

### Syllabus

#### Thesis writing

At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.

### Recommended Electives

#### Cancer Genomics

**Course Objectives**

The objectives of this course are:

- To provide basic knowledge of cancer genomics;
- To become familiar with relevant technologies, public databases and informatics methods that are used to determine driver mutations and oncogenic pathways;
- To provide the rationale for personalized cancer treatment;
- To provide basic information regarding underlying biology of common cancers.

**Student Learning Outcomes**

On completion of this course, students should be able to:

- Understand genomic basis of cancer;
- Explain key technologies and interact with public databases;
- Understand biology of various cancers and role of environment in carcinogenesis.

#### Unit I

**Cancer genomics: perspective and new technologies**

8 lectures

Historical perspective on development of cancer genomics; Cancer characterization using sequencing approaches; Advances in sequencing technologies; Discoveries using second-generation sequencing technologies; Cancer transcriptome sequencing and analysis; Identifying pathogen presence in cancer samples.

#### Unit II

**Significance of transcriptome sequencing in personalized cancer medicine**

6 lectures

Importance of RNA; Role of MicroRNAs and Ultra-conserved Non-Coding RNAs in cancer; From microarray to RNA sequencing; Workflow for RNA sequencing; RNA sequencing data analysis in cancer genome research; Incorporating transcriptome sequencing analysis to identify genomic driver mutations; Transcriptome sequencing: from bench to bedside; Tissue Microarrays in studying gynecological cancers.

#### Unit III

**Cancer pharmacogenomics & biomarker discovery and development**

4 lectures

Pharmacogenomics; Cancer pharmacogenomics in children; Active ADR surveillance and future directions; Uses of biomarkers in cancer research and cancer care; Biomarker discovery and qualification; Assay validation, clinical validity, clinical utility; Incorporation of biomarkers into clinical trial design.
Unit IV
Bioinformatics for cancer genomics & genomic resource projects
4 lectures

Data Types in cancer genomics, Data management & data analysis, Data Interpretation TCGA and other sources of cancer genomic data; Key large-scale cancer genomics projects; other notable genomics projects.

Unit V
Genomics of specific cancers
8 lectures

Genetic basis of hereditary cancer syndromes; Retinoblastoma, Wilms tumor, Non-syndromic tumors and susceptibility Loci, Cancer predisposition syndromes, Genomics of adult and pediatric cancers; Special focus on common solid tumors of the Lung, Prostate, Colon and Breast:- Genomics and Molecular Profiling, Epidemiology, Standard Treatment and Prognosis; Somatic gene mutations, Personalized targeted therapy, Molecular diagnostics and treatment guidance; Special focus on common liquid tumors of the hematopoietic system- Acute myeloid leukemia: epidemiology, etiology, genetic and epigenetic alterations, somatic mutations and their contribution to survival in childhood acute myeloid leukemia; Disease-associated mutations in signal transduction pathways.

Unit VI
Impact of environment on cancer genomics
2 lectures

Important components of the exposome; Mechanisms of environmental carcinogenesis.

Recommended Textbooks and References:

Clinical Genetics and Diagnostics

Course Objectives
This course has been designed with goal to provide preclinical medical education which has important applications in clinical medicine, public health and medical research. The objective is to help the students to appreciate the importance of genetics in medicine with emphasis on the general principles of disease inheritance, pathogenesis, diagnosis, and counselling.

Student Learning Outcomes
On completing this course, students should be able to:
• Elicit and document a family history and pedigree;
• Understand clinical genetic risk assessments;
• Be able to convey genetic information and discuss risk;
• Have an appreciation of molecular, cytogenetic and biochemical laboratory testing utilised in clinical genetics;
• Have an appreciation for the approaches to treatment for specific genetic disorders;
• Understand the role of prenatal screening and testing in pregnancy management and care and the options available when fetal abnormality is detected;
• Understand the role of genetics as the underlying cause of various disorders of the human body;
• Understand the role of genetics in cancer.
### Unit I
**History and classification of genetic disorders**
7 lectures

- Origin of medical genetics, major developments and its impact on clinical practice;
- Single gene disorders, Patterns of inheritance, Classical and non-classical;
- Clinical cytogenetics: Principles and mechanisms of chromosome abnormalities; Numerical Chromosome Aberrations, Structural Chromosomal Aberrations; Common autosomal and the sex Chromosomes abnormalities; Cancer genetics: common cancers and diagnostics; Genetics of complex/polygenic disorders and diagnostics.

### Unit II
**Molecular basis of genetic diseases**
9 lectures

- Types of mutations, factors causing mutations and effects; Common single gene disorders: Disorders of haematological system- thalassemia, hemophilia, sickle cell disease;
- Common disorders of neurological system- Huntington disease, Fragile X syndrome, Hereditary ataxias, Neuromuscular disorders like Duchenne muscular dystrophy, Spinal muscular atrophy; Diseases associated with dynamic mutations - Myotonic dystrophy (MD); fragile X chromosome syndrome (Martin–Bell syndrome); Huntington’s chorea, Kennedy’s disease, Spinocerebellar ataxia 1 (SCA1); Machado-Joseph Disease (MJD) Friedreich’s Ataxia; Biochemical basis of Genetic diseases; Inborn errors of metabolism;
- Disorders of immune system; Genomic Imprinting defects, Microdeletion syndromes nature, molecular characterization, mechanisms of phenotypic expression of the Prader-Willi Syndrome (PWS), Angelman Syndrome (AS) and other diseases associated with chromosome imprinting; Congenital anomalies of development – dysmorphology and teratogenesis; Congenital malformations, deformations and disruptions, dysplasia, large and small malformations, Types of combined anomalies, disorders in sexual differentiation, intersexual conditions; Mitochondrial Diseases – Leber Hereditary optic neuropathy (LHON); Myoclonic Epilepsy with Ragged Red Fibres (MERRF); Mitochondrial encephalomyopathy, lactic acidosis, and stroke-like episodes (MELAS); Kearns–Sayre syndrome, etc.

### Unit III
**Diagnostics**
6 lectures

- Cytogenetic testing- Karyotype, Molecular-cytogenetic testing-FISH, MLPA, QFPCR, CMA; Testing for single gene disorders-common molecular techniques and advanced techniques for known and unknown mutations; Inherited variation and Polymorphism, RFLP, Microsatellite, Minisatellite; Genetic screening, carrier testing; Predictive testing - Newborn screening; Antenatal screening, population screening; Treatment of genetic disorders.

### Unit IV
**Genetic counselling and methods of prenatal testing**
5 lectures

- Genetic counselling and principles in practice – case studies and risk assessment, pedigree analysis; Antenatal diagnosis: Indications for prenatal diagnosis, invasive methods, ethical issues, different techniques for diagnosis; Non-invasive methods of prenatal testing: Pre-implantation and preconception diagnosis-indications, assisted reproduction techniques, methods of pre-implantation and preconception genetic diagnosis, Pre-implantation genetic screening; Therapy of genetic diseases - conventional therapy of genetic diseases, gene therapy of monogenic diseases, antisense therapy of diseases associated with somatic mutations, cancer and viral infections; targeted therapy.

### Unit V
**Personalised medicine: future scope**
2 lectures

- Recent advances in human molecular genetics paving ways towards potential application of personalised therapies/medicines: pharmacogenomics/drug metabolism in relation to individual genetic makeup.

### Unit VI
**Ethical issues and genetic services**
3 lectures

- Ethical issues in medical genetics, legal and social issues; Genetics and society; Genetic services in India.
### Recommended Textbooks and References:


### Course Objectives

The course aims at providing general and broad introduction to multi-disciplinary field of nanotechnology. It will familiarize students with combination of top-down approach of microelectronics and micro-mechanics with bottom-up approach of chemistry/biochemistry; a development that is creating new and exciting cross-disciplinary research fields and technologies. The course will also give an insight into complete systems where nanotechnology can be used to improve everyday life.

### Student Learning Outcomes

On successful completion of this course, students should be able to describe basic science behind the properties of materials at the nanometre scale, and the principles behind advanced experimental and computational techniques for studying nanomaterials.

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**Unit I**

**Introduction to Nanobiotechnology**

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<th>Lecture</th>
<th>Topic</th>
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<tr>
<td>5</td>
<td>Introduction to Nanobiotechnology; Concepts, historical perspective; Different formats of nanomaterials and applications with example for specific cases; Cellular Nanostructures; Nanopores; Biomolecular motors; Bio-inspired Nanostructures, Synthesis and characterization of different nanomaterials.</td>
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**Unit II**

**Nano - films**

<table>
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<tr>
<th>Lecture</th>
<th>Topic</th>
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<tr>
<td>5</td>
<td>Thin films; Colloidal nanostructures; Self Assembly, Nanovesicles; Nanospheres; Nanocapsules and their characterisation.</td>
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**Unit III**

**Nano - particles**

<table>
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<tr>
<th>Lecture</th>
<th>Topic</th>
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<tbody>
<tr>
<td>6</td>
<td>Nanoparticles for drug delivery, concepts, optimization of nanoparticle properties for suitability of administration through various routes of delivery, advantages, strategies for cellular internalization and long circulation, strategies for enhanced permeation through various anatomical barriers.</td>
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**Unit IV**

**Applications of nano - particles**

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<th>Lecture</th>
<th>Topic</th>
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<tr>
<td>5</td>
<td>Nanoparticles for diagnostics and imaging (theranostics); concepts of smart stimuli responsive nanoparticles, implications in cancer therapy, nanodevices for biosensor development.</td>
</tr>
</tbody>
</table>
Nanomaterials for catalysis, development and characterization of nanobiocatalysts, application of nanoscaffolds in synthesis, applications of nanobiocatalysis in the production of drugs and drug intermediates.

Introduction to Safety of nanomaterials, Basics of nanotoxicity, Models and assays for Nanotoxicity assessment; Fate of nanomaterials in different stratas of environment; Ecotoxicity models and assays; Life cycle assessment, containment.

Recommended Textbooks and References:
1. GeroDecher, Joseph B. Schlenoff, (2003); Multilayer Thin Films: Sequential Assembly of Nanocomposite Materials, Wiley-VCH Verlag GmbH & Co. KGaA
5. Recent review papers in the area of Nanomedicine.

Pharmacogenomics
Credzts 2

Course Objectives
This course will give a broad perspective on emergence of pharmacogenomics as a new field and provide them with insight into growing importance it will play in clinical therapeutics and future drug design.

Student Learning Outcomes
Students will gain an understanding of how genetic differences between individuals can impact the outcome of drug therapy in a positive and negative way. The course will also help students to understand how drug therapy based on a person's genetic makeup can optimize effectiveness of therapy while reducing unwanted drug effects.

Unit I
Pharmacogenomics 10 lectures
Pharmacogenomics; Pharmacogenetics; Benefits; Practical applications of pharmacogenomics; The Promise of Pharmacogenomics today leading to personalized medicines; Human genetic variation - examples of CYP gene variations leading to variable metabolism of drugs; Distribution of variation; Mutations & its kind; Natural selection; Variation in ethnic groups, races.

Unit II
Pharmacology 10 lectures
Pharmacology; Clinical pharmacology; Drugs; Drug Legislation & safety; Types of Drugs - examples of latest drugs; Drug potency and Efficacy; ADME of Drug- Drug absorption; Drug distribution; Drug metabolism & Drug Excretion; Drug efficacy & toxicity; drug therapeutic levels; Therapeutic Index; Drug abuse; Drug response in patients by correlating gene expression; Regulation of gene expression; Polymorphism; Alleles; Single nucleotide polymorphism; Genotyping; example of TPMT and DPD gene mutation and their impact in treatment strategy.

Unit III
Biomarkers 3 lectures
Genetic markers-Biomarkers in early drug development; Biomarkers in Clinical development; Biomarkers.

Recommended Textbooks and References:
2. Yan Q, (2008), Pharmacogenomics in Drug Discovery and Development, Springer-Verlag New York, LLC.
4. Innocenti F, (2005), Pharmacogenomics: Methods and Applications,
## Course Objectives
The objective of this course is to provide knowledge on managing and analysis workflows for Omics data from various technologies. The students should not only gain knowledge on tools and software but also principles of omics data analysis.

## Student Learning Outcomes
After completing course students should be able to:
- Understand and perform basics of a data analysis workflow for omics expression data (transcriptomics, proteomics, metabolomics);
- Understand aspects of study design, experimental planning and sample selection;
- Know what normalization, data transformation etc. means and what it does to your data.

### Unit I
**Data management**
4 lectures
- Technology Awareness - Computer clusters (HPC), Super computers, Cloud Computing, Storage platforms, Network Attached Storage (NAS); Programming for High Performance Computing - Basics of Linux operating system, Introduction to Programming languages (Perl and/or Python); Introduction to R; Data Awareness - Databases - NCBI, GEO, UCSC Browser; High-volume data and its management, Data size, format and type, policies – IPR and ethics, Data Compression and archiving strategies.

### Unit II
**Microarray data and analysis principles**
6 lectures
- Statistics - Distributions, Statistical Inference, Dimensionality Reduction (Principal Component Analysis, Multidimensional Scaling), Unsupervised Clustering (Dissimilarity Metrics, Hierarchical Clustering, K-Means and K-medoid Clustering, Self Organizing Maps); Single/Dual Channel Microarray Technologies, Quality Check, Normalization, Quantifying Gene Expression, Quantifying Differential Expression, Multiple Hypothesis Testing and False Discovery; Functional Analysis and applications - Gene Ontology and pathway analysis, Promoter analysis and gene regulatory network, CGH & Genotyping chips, polymorphism via genome-wide scanning; Online Software and databases for analysis - DAVID, GSEA, Gorilla, Amigo etc.

### Unit III
**Next generation sequencing: RNA and DNA**
6 lectures
- Raw data file formats, sequence quality evaluation - Phred quality score, GC content etc. (tools/softwares - FastQC, NGS QC toolkit etc.); filtering and trimming of bad quality reads (tools/softwares – FastX tool kit, trimmomatic, NGS QC toolkit etc.) and data visualization; Genome assembly, mapping of reads to reference genome (tools - bowtie, maq etc.); data formats (SAM, BAM etc.); Basic analysis post mapping to reference genome - DNA seq, RNA seq, ChIP-seq, exome seq etc; Functional analysis (as mentioned in unit II) and Application in various studies; Galaxy tool to analyze sequencing data.

### Unit IV
**Proteome**
6 lectures
- Proteomics data processing and analysis: data identification - Raw data formats : Viewers (TOPPView tools/softwares - mzXML, mzML and mzData etc.), [Spectra Viewer, Mascot Distiller. Converters (tools/softwares - Hermers, MS convert, CompassXpert, Masstransit); Protein identificationDatabase search algorithms (tools/softwares - MassWiz, MASCOT, SEQUEST, etc.), Platforms, Pipelines and libraries(tools/softwares – MassyPuP, etc.), Peak picking and Deconvolution (tools/softwares - Decon tools, esimsa2D, etc.), De novo sequence algorithms(tools/softwares - CycloBranch, Lutefisk, DenovoX, etc.), Homology Search (tools/softwares - MS-homology, SPIDER, Labsolutions LCMS, Xcalibur).
Inflammation and Disease Biology

Course Objectives
Objective of this course is to provide basic contours of inflammation and disease biology in context of associated diseases. Acute inflammatory response is body's first system of alarm signals that are directed toward containment and elimination of disease causing perturbation. Uncontrolled inflammation is a pathophysiological basis for many widely occurring diseases, including cardiovascular disease, asthma, arthritis, and even cancer, including infectious diseases.

Student Learning Outcomes
On completion of this course, students should be able to understand human body response to different diseases and pathogens encountered. They should also be able to identify role of different cell types during an inflammatory response.

Unit I
Inflammatory response
4 lectures

An overview in the context of overall body physiology: Acute & chronic inflammation; Resolution of Acute Inflammation & wound healing; Links between innate and adaptive immunity; Chronic inflammatory diseases such as rheumatoid arthritis, ankylosing spondylitis, multiple sclerosis, inflammatory bowel diseases, and others typically stimulate a systemic response of the entire body.

Unit II
Individual cell types
2 lectures

Neutrophils, mast cells, basophils, eosinophils, macrophages, lymphocytes, fibroblasts & stromal cells.

Unit III
Inflammation and diseases
15 lectures

Glomerulonephritis & Ischemia Reperfusion injury; asthma; animal models of rheumatoid arthritis; ocular inflammation models; atherosclerosis in experimental animal models; oral inflammation percentage periodontitis; pathogens & inflammation; inflammation biomarkers & cardiometabolic risk; Diabetes Mellitus & metabolic syndrome; Cardiometabolic Risk Inflammation and Neurodegenerative Disorders.

Unit IV
Brain disease and cancer
3 lectures

Roles of innate immunity and inflammation in aging brain/infectious disease; Role of Inflammation in cancer development.

Recommended Textbooks and References:
Aspects of anti-inflammatory lifestyle.

Recommended Textbooks and References:
DBT Supported Teaching Programmes

<table>
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<tr>
<th>S.No.</th>
<th>Name of University</th>
<th>Contact Details of Course Coordinator</th>
</tr>
</thead>
</table>
| 1.    | All India Institute of Medical Sciences, New Delhi | Dr. Jaya Sivaswami Tyagi  
Deprt. of Biotechnology  
011-26589654  
Jstyagi@aiims.ac.in |
| 2.    | Maharishi Dayanand University, Rohtak    | Dr. Hari Mohan Saini  
Centre for Biotechnology  
9671027033, 9416863575  
01262-393101, 393105, 273820  
harimohansaini@gmail.com  
cmbtmdu@gmail.com |

Annexure I

Subject Specific Subcommittee of M.Sc. Medical Biotechnology

Chairperson
1. Dr. B. J. Rao, Senior Professor, Tata Institute of Fundamental Research, Mumbai

Members
2. Dr. Jaya Tyagi, Professor, Department of Biotechnology, All India Institute of Medical Sciences, New Delhi
3. Dr. Pramod Mehta, Professor, Centre for Biotechnology, Maharshi Dayanand University, Rohtak
4. Dr. Alok Ray, Consultant Professor, School of International Biodesign and Former Head of Biomedical Engineering, Indian Institute of Technology, New Delhi
5. Dr. Madhumita Roy Chowdhury, Senior Scientist, Department of Pediatrics, Division of Genetics, All India Institute of Medical Sciences, New Delhi
6. Dr. Mousumi Mutsuddi, Assistant Professor, Department of Molecular and Human Genetics, Banaras Hindu University, Varanasi
7. Dr. Surajit Sarkar, Assistant Professor, Department of Genetics, University of Delhi
8. Dr. Arjun Surya, Chief Scientific Officer, Curadev Pharma, New Delhi
9. Dr. Vibhu Kanchan, Senior Scientist, MSD Wellcome Trust Hilleman Labs Pvt. Ltd., New Delhi

Member Secretary
10. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi
M.Sc. Molecular and Human Genetics
Introduction

Promotion of Indian Biotechnology sector is high on policy agenda of Government of India. Biotechnology has also been recognized as one of the key priority sectors under ‘Make in India,’ ‘Skill India’ and ‘Startup India’ initiatives of Government of India, as it is one of sectors expected to contribute towards enterprise creation, innovation and economic growth. Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India has immensely contributed to this dynamism through various policies and initiatives, establishment of innovation clusters, academia-industry partnerships, increasing capabilities for technology development, etc. The National Biotechnology Development Strategy (2015 – 2020) released by DBT provides a strategic roadmap for India’s emergence as a global biotechnology innovation and manufacturing hub. It has also highlighted importance of human resource development and need for nurturing tailor-made human capital for advanced scientific research and entrepreneurship.

DBT has taken a number of initiatives aimed at integrated human resource development to evolve an ecosystem where scientists, innovators and future entrepreneurs can be nurtured. Keeping in mind requirement for trained manpower in various areas of Biotechnology, DBT initiated Post-Graduate Teaching Programme way back in 1985 with 5 universities which has expanded to 74 universities imparting M.Sc./M.Tech./M.V.Sc. degrees in general, agricultural, animal, food, environmental, industrial marine, medical, neuroscience and pharmaceutical biotechnology. 10 programmes are being phased out. These universities and institutes are provided liberal financial support towards strengthening of laboratory facilities, equipment, consumables, fellowships to students, dissertation grant per student etc. Post-Graduate Teaching Programme selects best students and trains them to join research or industry workforce contributing significantly to biotechnology workforce.

About the Course Curriculum Revision Exercise

Taking into cognizance the changing needs of the economy and to keep abreast with latest developments in the field of biotechnology, DBT proactively initiated revision of course curricula of Post-Graduate Programmes in biotechnology. The present exercise has been undertaken by Biotech Consortium India Limited (BCIL), New Delhi. Earlier exercise was carried out in 2008. The Course Curriculum Revision Exercise has been carried out for 13 Post-Graduate programmes in Biotechnology supported by DBT.

The revision of course curriculum of M.Sc. Molecular and Human Genetics aims to address mismatch between ‘knowledge’ gained by students and appropriate skill set required for technology development and implementation including present contemporary needs of economy.

Methodology

A meticulous and structured approach has been adopted to accomplish the Course Curriculum Revision exercise.

BCIL had initiated the exercise with a review of literature of relevant national and international documents on curriculum design and planning for biotechnology programmes of premier national as well as international universities, guidelines by University Grants Commission, recent curricular guidelines released by Indian Council of Agricultural Research, Ministry of Health and Family Welfare and Indian Institute of Science Education & Research and other relevant research papers on curriculum development in peer-reviewed journals.
The findings of the literature review were adopted to design questionnaires for eliciting feedback from stakeholders of Biotechnology community i.e. academicians, scientists, industry representatives and students. Feedback was received from 165 experts and 20 students belonging to academic institutions, research organizations and industry regarding addition of advanced topics, deletion of elementary, redundant and overlapping topics, updation of laboratory practicals, re-adjustment of credit load, incorporating 'technology' component in the curriculum, among others. It was also suggested that re-orientation of curricula should be done keeping in view the needs of the industry.

**Strategic Approach**

A Core Committee along with 9 subject specific subcommittees comprising of 63 academicians, scientists and industry representatives were constituted to revise and update the curricula. The constitution of subject specific subcommittee for M.Sc. Molecular and Human Genetics is given at Annexure-1.

The salient recommendations identified from stakeholder survey were presented to the Committee. Several brainstorming discussion sessions were held for achieving the desired balance between the foundation courses, recent developments in biotechnology and updation needs identified during the stakeholder survey. Core Committee finalized broad contours for revising all the course curricula. The guidelines set by the Core Committee were taken up by the subject specific subcommittee of M.Sc. Molecular and Human Genetics for updating the curriculum. The subject specific subcommittee incorporated latest advancements in areas of Molecular and Human Genetics in the curriculum. Separate meeting was held to discuss and deliberate the updations to be made in the curriculum. The revised curriculum was vetted and finalized by the Core Committee.

**Course Curriculum Revision**

The members of Committee agreed that revised course curriculum should provide skill and outcome based education and help the students to gain domain knowledge, ability to design and interpret research experiments and acquire effective communication skills. The course curriculum has been re-designed accordingly to promote skill-based and outcome-based education. The revised course curriculum totals to 100 credits comprising of theory, practical, technology-based topics, electives and dissertation. Each course includes learning objectives, student learning outcomes, course plan (number of lectures/unit) and reference textbooks/resources. Theory and practical courses include relevant examples, case scenarios and tutorials for inculcating critical thinking against rote learning. Several new courses have been included and content for existing courses has also been updated. Recent advancements in Human Biology and specialized courses like Human Genome Project, Epigenetics, Cytogenetics, Population Genetics, Developmental Genetics, Clinical Genetics, Cancer Genomics, Infection Biology, Tissue Engineering and Disease Metabolism have been included. With importance of students being able to execute research projects independently, separate credits have been allotted for proposal preparation and presentation before initiating dissertation and also credits for dissertation have been increased accordingly.

We hope that model course curriculum shall serve as guidelines for academicians and researchers from different parts of the country for adoption in their institutions with modifications as per availability of expertise, infrastructure and specific needs.

We wish to put on record our sincere appreciation for constant guidance and encouragement received from Dr. K. VijayRaghavan, Secretary, DBT for bringing out this publication. We wish to acknowledge whole-hearted support of Core Committee and subject specific subcommittees members. Sincere thanks are due to Dr. Manoj Singh Rohilla, Scientist- D, DBT, Ms. Shweta for creative design, Mrs. Rita Bhatla, DBT and Shri. Dilip Joy, BCIL.
MESSAGE

This course combines two most important facets, namely, the recent excitements in human biology after successful delineation of human genome project as well as large body of biological insights we have gained over decades by probing several model organisms, whose genomes are also well characterized now. Several new modules have been added, keeping the level accessible to an M.Sc. student. New electives try to bring out contents that are recent and somewhat futuristic. An effective communication of the contents requires judicious use of not only the published material but also the online web tutorials/movies etc. This is especially so where the laboratory and library infrastructures are limiting.

(Prof. B.J.Rao)
# M.Sc. Molecular and Human Genetics

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<tr>
<th>S.No.</th>
<th>Title</th>
<th>Credits</th>
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<tr>
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<tr>
<td>1</td>
<td>Biochemistry</td>
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<td>2</td>
<td>Molecular Biology</td>
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<td>3</td>
<td>Cell Biology and Cytogenetics</td>
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<td>4</td>
<td>Genetics and Epigenetics</td>
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<td>5</td>
<td>Laboratory Techniques and Biophysical Principles</td>
<td>3</td>
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<tr>
<td>6</td>
<td>Laboratory I: Biochemistry and Analytical Techniques</td>
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<td>7</td>
<td>Laboratory II: Molecular Biology and Cytogenetics</td>
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<tr>
<td>8</td>
<td>Seminar and Communication Skills</td>
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<td><strong>TOTAL</strong></td>
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| **SEMESTER TWO**                                                                                           |         |
| 1     | Immunology and Immunogenetics                                        | 3       |
| 2     | Biostatistics and Population Genetics                                | 3       |
| 3     | Genetic Engineering and Genome Editing Technologies                  | 3       |
| 4     | Developmental Genetics                                               | 3       |
| 5     | Omics: Genomics, Transcriptomics, Proteomics and Metabolomics        | 3       |
| 6     | Laboratory III: Cell Biology and Microscopy                           | 3       |
| 7     | Laboratory IV: Immunology and Immunogenetics                         | 3       |
| 8     | Laboratory V: Developmental Genetics                                  | 3       |
| 9     | Journal Club and Communication Skills                                 | 2       |
| **TOTAL**                                                                                                  | **26**  |

| **SEMESTER THREE**                                                                                          |         |
| 1     | Molecular Human Genetics                                             | 3       |
| 2     | Clinical Genetics and Diagnostics                                    | 3       |
| 3     | Human Genome Project                                                 | 2       |
| 4     | Bioinformatics                                                        | 2       |
| 5     | Neurogenetics                                                         | 2       |
| 6     | Intellectual Property Rights, Biosafety and Bioethics                | 2       |
| 7     | Project Proposal Preparation and Presentation                        | 2       |
| 8     | Laboratory VI: Molecular Human Genetics                              | 3       |
| 9     | Laboratory VII: Clinical Genetics and Diagnostics                     | 2       |
| 10    | Laboratory VIII: Bioinformatics                                       | 2       |
| 11    | Dissertation                                                          | 4       |
| **TOTAL**                                                                                                  | **27**  |

| **SEMESTER FOUR**                                                                                           |         |
| 1     | Dissertation                                                          | 20      |
| 2     | Elective                                                              | 2       |
| **TOTAL**                                                                                                  | **22**  |
| **TOTAL CREDITS**                                                                                           | **100** |

**Recommended Electives:**
1. Cancer Genomics
2. High-Volume Omics Data: Management & Analytics
3. Infection Biology
4. Medical Devices and Diagnostics
5. Nanobiotechnology
6. Tissue Engineering
7. Disease Metabolism
Semester One

Biochemistry

Credits

Course Objectives
The objectives of this course are to build upon undergraduate level knowledge of biochemical principles with specific emphasis on different metabolic pathways. The course shall make the students aware of various disease pathologies within the context of each topic.

Student Learning Outcomes
On completion of this course, students should be able to:

• Gain fundamental knowledge in biochemistry;
• Understand the molecular basis of various pathological conditions from the perspective of biochemical reactions.

Unit I
Protein structure
5 lectures

Chemical basis of life: Miller-Urey experiment, abiotic formation of amino acid oligomers, composition of living matter; Water – properties of water, essential role of water for life on earth pH, buffer, maintenance of blood pH and pH of gastric juice, pH optima of different enzymes (pepsin, trypsin and alkaline phosphatase), ionization and hydrophobicity, emergent properties of biomolecules in water, biomolecular hierarchy, macromolecules, molecular assemblies; Structure-function relationships: amino acids – structure and functional group properties, peptides and covalent structure of proteins, elucidation of primary and higher order structures, Ramachandran plot, evolution of protein structure, protein degradation and introduction to molecular pathways controlling protein degradation, structure-function relationships in model proteins like ribonuclease A, myoglobin, hemoglobin, chymotrypsin etc.; basic principles of protein purification; tools to characterize expressed proteins; Protein folding: Anfinsen’s Dogma, Levinthal paradox, cooperativity in protein folding, free energy landscape of protein folding and pathways of protein folding, molten globule state, chaperons, diseases associated with protein folding, introduction to molecular dynamic simulation.

Unit II
Enzyme kinetics
5 lectures

Enzyme catalysis – general principles of catalysis; quantitation of enzyme activity and efficiency; enzyme characterization and Michaelis-Menten kinetics; relevance of enzymes in metabolic regulation, activation, inhibition and covalent modification; single substrate enzymes; concept of catalytic antibodies; catalytic strategies with specific examples of proteases, carbonic anhydrases, restriction enzymes and nucleoside monophosphate kinase; regulatory strategies with specific example of hemoglobin; isozymes; role of covalent modification in enzymatic activity; zymogens.

Unit III
Glycobiology
2 lectures

Sugars - mono, di, and polysaccharides with specific reference to glycogen, amylase and cellulose, glycosylation of other biomolecules - glycoproteins and glycolipids; lipids - structure and properties of important members of storage and membrane lipids; lipoproteins.

Unit IV
Structure and functions of DNA & RNA
3 lectures

Self-assembly of lipids, micelle, biomembrane organization - sidedness and function; membrane bound proteins - structure, properties and function; transport phenomena; nucleosides, nucleotides, nucleic acids - structure, a historical perspective leading up to the proposition of DNA double helical structure; difference in RNA and DNA structure and their importance in evolution of DNA as the genetic material.

Unit V
Bio-energetics
8 lectures

Bioenergetics-basic principles; equilibria and concept of free energy; coupled interconnecting reactions in metabolism; oxidation of carbon fuels; recurring motifs in metabolism; Introduction to GPCR, Inositol/DAG//PKC and Ca++ signaling pathways; glycolysis and gluconeogenesis; reciprocal regulations and non-carbohydrate sources
Calvin cycle and pentose phosphate pathway; glycogen metabolism, reciprocal control of glycogen synthesis and breakdown, roles of epinephrine and glucagon and insulin in glycogen metabolism; Fatty acid metabolism; protein turnover and amino acid catabolism; nucleotide biosynthesis; biosynthesis of membrane lipids and sterols with specific emphasis on cholesterol metabolism and mevalonate pathway; elucidation of metabolic pathways; logic and integration of central metabolism; entry/exit of various biomolecules from central pathways; principles of metabolic regulation; steps for regulation; target of rapamycin (TOR) & Autophagy regulation in relation to C & N metabolism, starvation responses and insulin signaling.

### Recommended Textbooks and References:

### Unit II
**DNA replication, repair and recombination**
6 lectures

Replication: initiation, elongation and termination in prokaryotes and eukaryotes; Enzymes and accessory proteins and mechanisms; Fidelity; Replication of single stranded circular DNA; link with cell cycle; DNA damaging agents - Physical, chemical and biological mutagens; types of damage caused by endogenous and exogenous agents; mutations- Nonsense, missense, silent and point mutations, frameshift mutations; Intragenic and Intergenic suppression. DNA repair mechanisms- direct reversal, photoreactivation, base excision repair, nucleotide excision repair, mismatch repair, double strand break repair, SOS repair; Recombination: Chi sequences in prokaryotes; Homologous,non-homologous and site specific recombination.

### Unit III
**RNA transcription, RNA processing and regulation in prokaryotes**
10 lectures

Structure and function of prokaryotic mRNA, tRNA (including initiator tRNA) and rRNA (and ribosomes); Prokaryotic Transcription - RNA polymerase and sigma factors, Transcription unit, Promoters, Promoter recognition, Initiation, Elongation and Termination (intrinsic, Rho and Mfd dependent); Processing of mRNA, tRNA and tRNA transcripts; Gene regulation: Repressors, activators, positive and negative regulation, Constitutive and Inducible, small molecule regulators, operon concept: lac, trp, his operons, attenuation, anti-termination, stringent control, translational control, DNA re-arrangement, two component system; regulatory RNA – riboswitch, tmRNA, antisense RNA; transcriptional control in lambda phage.

### Unit IV
**RNA transcription, RNA processing and regulation in eukaryotes**
13 lectures

Structure and function of eukaryotic mRNA, tRNA (including initiator tRNA) and rRNA (and ribosomes). Eukaryotic transcription - RNA polymerase I, II and III mediated transcription: RNA polymerase enzymes, eukaryotic promoters and enhancers, General Transcription factors; TATA binding proteins (TBP) and TBP associated factors (TAF); assembly of pre-initiation complex for nuclear enzymes, interaction of transcription factors with the basal transcription machinery and with other regulatory proteins, mediator, TAFs; Processing of hnRNA, tRNA, rRNA; 5’-Cap formation; 3’-end processing of RNAs and polyadenylation; loop model of translation; Splicing of tRNA and hnRNA; snRNPs and snoRNPs in RNA processing; Regulation of RNA processing: capping, splicing, polyadenylation; mRNA stability and degradation: degradation and surveillance pathways; RNA editing; Nuclear export of mRNA; Catalytic RNA: Group I and Group II introns splicing, Peptidyl transferase; Regulatory RNA and RNA interference mechanisms, miRNA, non-coding RNA; Silencers and insulators, enhancers, mechanism of silencing and activation; Families of DNA binding transcription factors: Helix-turn-helix, helix-loop-helix, homeodomain; 2C 2H zinc finger, multi cysteine zinc finger, basic DNA binding domains (leucine zipper, helix-loop-helix), nuclear receptors; Interaction of regulatory transcription factors with DNA: properties and mechanism of activation and repression including Ligand-mediated transcription regulation by nuclear receptors; Nuclear receptor; histone modifications and chromatin remodeling; Methods for studying DNA-protein interaction: EMSA, DNase I footprinting, methylation interference assay, chromatin immunoprecipitation.

### Unit V
**Protein translation, post translational modifications and control in prokaryotes and eukaryotes**
8 lectures

Ribosomes; Composition and assembly; universal genetic code; Genetic code in mitochondria; Degeneracy of codons; Termination codons; Wobble hypothesis; Isoaccepting tRNA; Translational machinery; Mechanism of Translation in prokaryotes and eukaryotes; Co- and Post-translational modifications of proteins; triple helix of collagen; Translational control; Protein stability; Protein turnover and degradation.
Recommended Textbooks and References:

Course Objectives
Cells are made of several distinct building blocks which when assembled together produce the various structural and functional constituents. This course includes basic as well as advanced aspects of cell biology, chromosome biology and genome organization. Emphasis has been given to explain the topics with the help of classical experimental strategies, examples from different model organisms and contemporary cellular and genetic approaches and methods.

Student Learning Outcomes
At the end of the course, students should be able to apply classical cytogenetic techniques used in cytotgenetic investigation.

Unit I
Structure and composition of cell
8 lectures
Methods to study cells: an overview of various microscopy and centrifugation techniques; Plasma Membrane: organization and dynamics of transport across membrane; Mechanism of endocytosis and exocytosis; structure and function of microbodies, Golgi apparatus, Lysosomes and Endoplasmic Reticulum; Protein processing, sorting; vesicle transport, secretion; Overview of cellular cytoskeleton; Microfilaments: Structural organization, cell motility and cell shape; Microtubule: structural and functional organization; Cilia, flagella, centriole; Intermediate filaments; Mitochondria – ultrastructure, origin and evolution, organization of respiratory chain complexes, Structure-function relationship; Structure and function of peroxisome; Mitochondrial genome; Chloroplast- Chloroplast biogenesis, origin and evolution, structure-function relationship, chloroplast genome. Nucleus – Structure and function of nuclear envelope, lamina and nucleolus; Macromolecular trafficking; Nucleolus and biosynthesis of ribosome; Muscle organization and function; Cellular motility; Molecular motors; Extracellular matrix in plants and animals.

Unit II
Cell signalling
6 lectures
Cell-Cell interactions: Cellular junctions and adhesions; structure and functional significance of plasmodesmata; Mechanisms of cellular recognition and communication. Extracellular matrix; Signal transduction: Intracellular receptor and cell surface receptors; Signalling via G-protein linked receptors (PKA, PKC, CaM kinase); Overview of various cellular signalling cascades with examples such as Egfr, Notch, Wingless, JAK-STAT etc.; Enzyme linked receptor signalling pathways; Network and cross-talk between different signal mechanisms; Programmed cell death.

Unit III
Mitosis and meiosis
6 lectures
Overview of mitosis and meiosis; chromosome labeling and cell cycle analysis; cell cycle and control mechanisms; types and regulation of cyclins, sister chromatid cohesion remodelling; differential regulation of cohesion complex during mitosis and meiosis; mitotic spindle and arrangement of chromosomes on equator; regulation of exit from metaphase, chromosome movement at anaphase; Genetic control of meiosis with examples from yeast.
Chromatin structure: Histones, DNA, nucleosome and higher level organization, functional state of chromatin; Chromosome organization: Metaphase chromosome: centromere, kinetochore, telomere and its maintenance; Holocentric chromosomes and supernumerary chromosomes; giant chromosomes: polytene and lampbrush chromosome. Chromosomal domains (matrix, loop domains) and their functional significance; Heterochromatin and euchromatin; position effect variegation; Functional states of chromatin and alterations in chromatin organization; chromatin remodelling; Metaphase chromosome, chromosome bandings and karyotyping; Spectral karyotyping (SKY); chromosome painting; Comparative genomic hybridization (CGH).

Chromosomal anomalies: Numerical and structural alterations, Concept of gene: Conventional and modern views; Fine structure of gene, split genes, pseudogenes, non-coding genes, overlapping genes and multi-gene families; Overview of genome mapping; Sex determination in Caenorhabditis elegans, Drosophila melanogaster, mammals and flowering plants; Dosage compensation in Caenorhabditis elegans, Drosophila and mammals.

Recommended Textbooks and References:

Course Objectives
The objectives of this course are to take the students through the basics of genetics and classical genetics encompassing prokaryotic/phage genetics to yeast and higher eukaryotic domains and will cover all classical concepts of Mendelian genetics. It will also cover epigenetic phenomena: heritable alternate states of gene activity that do not result from an alteration in nucleotide composition (mutations). Epigenetic mechanisms are known to regulate normal development and their deregulation has been implicated in a variety of diseases including cancer and behavioral diseases.

Student Learning Outcomes
On successful completion of this course, students should be able to:
• Describe the fundamental molecular principles of genetics;
• Understand the relationship between phenotype and genotype in human genetic traits;
• Describe the basics of genetic mapping.
• Understand how gene expression is regulated;
• Evaluate the genetic code and the role epigenetic modification plays in common complex disease.
<table>
<thead>
<tr>
<th>Unit I</th>
<th>Genetics of bacteria and bacteriophages</th>
<th>10 lectures</th>
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<td></td>
<td>Concept of a gene in pre-DNA era; mapping of genes in bacterial and phage chromosomes by classical genetic crosses; fine structure analysis of a gene; genetic complementation and other genetic crosses using phenotypic markers; phenotype to genotype connectivity prior to DNA-based understanding of a gene; Restriction modification systems – history, types of systems and their characteristics, applications of RM systems, methylation-dependent restriction enzymes, transposable elements – types, properties and applications.</td>
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<tr>
<th>Unit II</th>
<th>Yeast genetics</th>
<th>5 lectures</th>
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<td>Meiotic crosses, tetrad analyses, non-Mendelian and Mendelian ratios, gene conversion, models of genetic recombination, yeast mating type switch; dominant and recessive genes/mutations, suppressor or modifier screens, complementation groups, transposon mutagenesis, synthetic lethality, genetic epistasis. Complex traits, mapping QTLs, yeast genomics to understand biology of QTLs.</td>
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<tr>
<th>Unit III</th>
<th>Drosophila genetics as a model of higher eukaryotes</th>
<th>5 lectures</th>
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<td>Monohybrid &amp; dihybrid crosses, back-crosses, test-crosses, analyses of autosomal and sex linkages, screening of mutations based on phenotypes and mapping the same, hypomorphy, genetic mosaics, genetic epistasis in the context of developmental mechanisms; Testing gene mutations for allelism: complementation test, intragenic complementation, Pleiotropy.</td>
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<th>Unit IV</th>
<th>Epigenetics</th>
<th>10 lectures</th>
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<td>DNA transcription in eukaryotes, chromatin architecture, modifying chromatin structure, architectural proteins, DNA methylation, post-translational histone, histone modification machinery, histone variants, DNA methylation/imprinting, RNA-directed DNA methylation, RNA-based silencing, polycomb repression, epigenetic inheritance, preservation of epigenetic marks during DNA replication, reprogramming DNA methylation, chromatin states, stem cells and pluripotency, genomic imprinting in mammals, dosage compensation, epigenetic regulation and disease, drugs used in diseases (HDAC inhibitors).</td>
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**Recommended Textbooks and References:**


**Course Objectives**

The course is designed to provide a broad exposure to all basic techniques (Biochemical & Biophysical) used in current Modern Biology research. The goal is to impart basic conceptual understanding of the principles of these techniques and emphasize on the Biochemical utility of the same & the underlying Biophysics.

**Student Learning Outcomes**

On completion of this course, students should learn how to combine previously acquired knowledge of physical chemistry and biochemistry to understand biochemical processes at molecular level.
At the end of the course, the student is expected to have enough understanding of all the analytical techniques such that the barrier to implement the same is abated to a great extent.

Unit I
Basics
2 lectures
Units of measurement of solutes in solution; Normality, molality, molarity, millimol and ppm; Water- structure and properties; Principles of glass and reference electrodes, types of electrodes, complications of pH measurement (dependence of pH on ionic strength, pH, pOH, Henderson-Hasselbach equations, buffers, pH of body fluids, buffers in body fluids, red blood cells and tissues; Length scales in biological systems: proteins, multi-protein complexes, organelles & cells; Basic thermodynamics; Basic chemical kinetics & reaction rates: Theory of chemical reactions.

Unit II
Basic principles of electromagnetic radiation and related spectroscopic techniques
8 lectures
Energy, wavelength, wave number and frequency; Absorption and emission spectra, Beer-Lambert's law, light absorption and its transmittance; UV and visible spectrophotometry-principles, instrumentation and applications on enzyme assay and kinetic assays, protein structural studies, nucleic acid structural studies; Basic principles, instrumentation and applications of UV-visible, IR, fluorimetry, atomic absorption and emission spectrophotometry. Basic principles, instrumentation and applications of ESR, NMR; Biochemical applications of fluorescence, emission, fluorescence life-times, anisotropy, time-resolved fluorescence methods and their applications, IR-Raman Spectroscopic applications in biology.

Unit III
Hydrodynamic methods
2 lectures
Basic principles and types of centrifugation-rotors, boundary, differential, density gradient, zonal isopycnic, introduction to equilibrium; Sedimentation - sedimentation velocity, preparative and analytical ultracentrifugation techniques; principles & applications in biochemical fractionation methods.

Unit IV
Radioactivity and radioisotopic techniques
3 lectures
Radioactivity, Stable and radioactive isotopes, concept of half-life and decay, principles of scintillation counting, GM counters, applications of isotopes, Isotope dilution technique, autoradiography, turnover studies, precursor-product relationship, production of radio-labelled biomolecules, calculations involving isotopes, radiation hazards and methods for contaminant prevention; Nature of radioactivity, properties of α, β and γ-rays, measurement of radioactivity, use of radioisotopes in research, in vivo and in vitro labelling techniques, double labelling, quenching, internal standard, channel ratio, external standard ratio, emulsion counting, radioactive decay; Application of radioactive isotopes in biochemical reaction mechanisms.

Unit V
Electrophoresis
2 lectures
Principles of electrophoretic separation, zonal and continuous electrophoresis, paper, cellulose acetate/nitrate, gel and capillary electrophoresis, use of native and denaturing gels, Protein subunit molecular weight determination using SDS-PAGE, Anomalous protein migration of some proteins in SDS-PAGE, Acid-urea PAGE and their physical basis, Isoelectric focussing and two dimensional gel electrophoresis, electroporation, pulse field gel electrophoresis, Gradient gels.

Unit VI
Chromatography and X-ray crystallography
2 lectures
Chromatography, principles of adsorption, partition and ion-exchange chromatography, gel permeation chromatography, GC, GC-MS and HPLC; X-ray Crystallography - protein crystals, Bragg's law, unit cell, isomorphous replacement, fiber pattern of DNA; Small-angle Xray diffraction methods: Principles & applications; Basic protein structure prediction methods.
Principles & applications; single-molecule measurements, Atomic Force microscopy, Near-field Microscopy: Principles & applications; Force measurements at single molecule to cell level using optical tweezers; Mechanobiology.

DNA cloning; bacterial transformation; transfection; chromosome integration; screening for transformants; Polymerase Chain Reaction; PCR types; Gel electrophoresis; DNA sequencing; Molecular hybridization: Southern blot; Northern blot; Protein analyses: Western blot & Immunoprecipitation; Rewriting DNA: mutations; random mutagenesis; point mutation; Site-specific mutations; Genome Editing Technology; DNA array & protein array; Click-chemistry: Principles & applications; Chemical sensors for in-cell biochemistry.

Light microscopy: lenses and microscopes, resolution: Rayleigh's Approach, Darkfield; Phase Contrast; Differential Interference Contrast; fluorescence and fluorescence microscopy; Confocal microscope: confocal principle, resolution and point spread function; nonlinear microscopy: multiphoton microscopy; principles of two-photon fluorescence, advantages of two-photon excitation, tandem scanning (spinning disk) microscopes, deconvolving confocal images; image processing, three-dimensional reconstruction; Total Internal reflection microscopy, STED microscopy.

Ionization techniques; mass analyzers/overview MS; FT-ICR and Orbitrap, fragmentation of peptides; proteomics, nano LC-MS; Phospho proteomics; interaction proteomics, mass spectroscopy in structural biology; imaging mass spectrometry.

Recommended Textbooks and References:

Course Objectives
The objective of this laboratory course is to introduce students to experiments in biochemistry. The course is designed to teach students the utility of set of experimental methods in biochemistry in a problem oriented manner.

Student Learning Outcomes
On completion of this course, students should be able to:
• To elaborate concepts of biochemistry with easy to run experiments;
• To familiarize with basic laboratory instruments and understand the principle of measurements using those instruments with experiments in biochemistry.

Syllabus
1. Preparing various stock solutions and working solutions that will be needed for the course.
2. To prepare an Acetic-Na Acetate Buffer and validate the Henderson-Hasselbach equation.
Laboratory II: Molecular Biology and Cytogenetics

Course Objectives
The objective of this laboratory course is to introduce students to experiments in cytogenetics & molecular biology. The course is designed to teach the utility of set of experimental methods in cytogenetics & molecular biology in a problem oriented manner.

Student Learning Outcomes
On completion of this course, students should be able to:

• To elaborate concepts of cytogenetics & molecular biology with easy to run experiments;
• To familiarize with basic laboratory instruments and understand the principle of measurements using those instruments with experiments in cytogenetics & molecular biology.

Syllabus

Handling & processing of DNA

1. Genomic DNA (from human/chicken blood or mouse tissues) isolation, purification and quantification of DNA by DNA agarose gel, UV-visible spectrophotometer and NanoDrop method
2. EcoRI, BamH1 and HindIII digestion of total genomic DNA/plasmid DNA comparison of the patterns, calculation of restriction endonuclease units, optimization of DNA ligation: comparison of the same across DNA nicks, cohesive ends & blunt ends,
3. Cloning, expression of a gene in E.coli host cells; Purification of His-tag protein on Ni-NTA columns.
4. Southern hybridization by non-radioactive Dig-labelled probe.
5. To determine an unknown protein concentration by plotting a standard graph of BSA using UV-Vis Spectrophotometer and validating the Beer- Lambert’s Law.
6. Titration of Amino Acids and separation of aliphatic, aromatic and polar amino acids by thin layer chromatography.
7. Purification and characterization of an enzyme from a recombinant source (such as Alkaline Phosphatase or Lactate Dehydrogenase or any enzyme of the institution’s choice).
   a) Preparation of cell-free lysates
   b) Ammonium Sulfate precipitation
   c) Ion-exchange Chromatography
   d) Gel Filtration
   e) Affinity Chromatography
   f) Dialysis of the purified protein solution against 60% glycerol as a demonstration of storage method
   g) Generating a Purification Table (protein concentration, amount of total protein; Computing specific activity of the enzyme preparation at each stage of purification)
   h) Assessing purity of samples from each step of purification by SDS-PAGE
   i) Enzyme Kinetic Parameters: Km, Vmax and Kcat.
8. Experimental verification that absorption at OD260 is more for denatured DNA as compared to native double stranded DNA. reversal of the same following DNA renaturation. Kinetics of DNA renaturation as a function of DNA size.
Semester Two

Immunology and Immunogenetics

Course Objectives
The objectives of this course are to make students learn about the structural features of the components of the immune system as well as their function. The major emphasis of this course will be on the development of the immune system and mechanisms by which our body elicit the immune response. This will be imperative for the students as it will help them to think like an immunologist and predict about the nature of immune response that develops against bacterial, viral or parasitic infection, and prove it by designing new experiments.

Student Learning Outcomes
On completion of this course, students should be able to:

- Evaluate the usefulness of immunology in different pharmaceutical companies;
- Identify the proper research lab working in the area of their own interests;
- Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out the kind of immune responses in the setting of infection (viral or bacterial) by looking at cytokine profile.

Unit I
Introduction to immune system
6 lectures

Unit II
Immunoglobulin, T-cell receptor genes and HLA complex
8 lectures

Credits

Analysis of RNA
1. Isolation of total RNA from mouse liver/blood using guanidine isothiocyanate method
2. Quantitation of RNA by spectrophotometer
3. Reverse transcriptase-PCR.

Polymerase chain reaction and its applications
1. cDNA synthesis from the total RNA using oligo dT primers
2. Quantitative PCR using real-time PCR machine
3. Nested-PCR, Multiplex PCR
4. RFLP, RAPD, DNA fingerprinting.

Conditional expression of genes
1. In Drosophila using the Gal4-UAS system (e.g. crossing Dpp-Gal4 and UAS-eyeless flies for induction of ectopic eyes in legs and wings in progeny or crossing HS-Gal4 and UAS-GFP flies and examining GFP expression in progeny following heat shock).

Cytogenetics laboratory
1. Identification of normal and mutant flies (Drosophila melanogaster)
2. Preparation of Drosophila polytene Chromosomes (temporary and permanent preparations)
3. Drosophila genetic crosses
4. In situ hybridization using DIG labeled Hsp gene probe on polytene chromosomes
5. Separation and short term culture of lymphocytes using Ficoll-Hypaque from normal & sickle cell anemia/thalassemia (wherever available) samples.
6. Chromosome preparation from mouse bone marrow and human blood lymphocytes
7. G-banding and karyotyping
8. Identification of inactivated X chromosome as Barr body.
Biostatistics and Population Genetics

Credits

3

Unit I
Basics of biostatistics
5 lectures

Basic probability, venn diagrams, dependent probability, permutations and combinations, making decisions with probability, correlation & causality, tests of statistical significance, hypothesis testing & null hypothesis, two-way variables, mean/median/mode, variance and standard deviation.

Unit II
Generation and regulation of immune responses
7 lectures

Antigen processing and presentation; Cytokines and signalling; T Cell Maturation, its activation and differentiation; B Cell Generation, its activation and differentiation; Clonal selection and immunological memory; Complement system; Leukocyte activation and migration; Chemotaxis; Cell mediated cytotoxic responses; ADCC, Regulation of immune responses; Immunological tolerance.

Unit III
Disorders of human immune system
5 lectures

T-cell immunodeficiencies; B-cell immunodeficiencies; Combined T and B-cell deficiencies, Defects in antigen presenting cells, Deficiencies of complement and neutrophil defects, Secondary immunodeficiencies; Autoimmune disorders; Hypersensitive reactions (Type I to Type IV) with suitable examples; Cytokine related diseases.

Unit IV
Immune system in human health
8 lectures

Immune response to infectious diseases (Tuberculosis, Typhoid fever, HIV/AIDS, Schistosomiasis, Kala Azar, Swine Flu, Chikungunya, Dengue) and malignancy (breast cancer, Lung cancer, Leukemia); Concept of immunotherapy; Vaccines (Recombinant, DNA, live and attenuated, subunit); Herd immunity; Success stories in vaccinology e.g. small pox, polio, Hepatitis, DPT; Transplantation immunology: immunologic basis of graft rejection, clinical manifestation of graft rejection, immunosuppressive therapy; applications of monoclonal antibodies, single chain & humanised antibodies.

Recommended Textbooks and References:

Course Objectives

Students in Biotechnology are generally not well exposed to important issues of Biostatistics relevant for appreciating Population Genetics. Biostatistics is clubbed with Population Genetics as the latter is well supported by the quantitative rigors of the former. This course provides a comprehensive understanding of the basic concepts of population genetics, leading up to important aspects linking to evolution. The student is expected to gain fuller appreciation of genetic determinants that impact population level biological diversity in the context of evolution.

Student Learning Outcomes

After successful completion of this course, students are expected to:
• define and describe important population and quantitative genetic concepts such as: genetic drift, natural selection, selective sweep, inbreeding, heritability and quantitative traits;
• apply these population and quantitative genetic concepts to problems related to the genetic dynamics of natural, captive and artificially selected populations.
Unit II
Biostatistical analysis
6 lectures
Constructing box-plots, expected values with empirical probabilities, binomial distributions, Poisson processes, scatter plots, fitting quadratic and exponential functions to scatter plots, linear regression & correlation; normal distributions, chi-square probability distribution, analyses of variance, Bernoulli distributions and margin of errors, hypothesis testing with one sample, one-tailed and two-tailed tests, T-statistic confidence interval, Anova 1, 2 & 3.

Unit III
Genetic constitution of a population
4 lectures
Genetic constitution of a population: (a) Gene frequencies and genotypes; (b) Hardy-Weinberg equilibrium; (c) Changes in gene frequency and continuous variation; (d) Mutation, Selection, Equilibrium. Polymorphisms; Values, means and variance: (a) Metric characteristics, Population means; (b) Genetic components of variation; (c) Genotype and environment correlation; (d) Environmental variance.

Unit IV
Basic definitions
2 lectures
Gene pool, Gene drift, Migration & gene flow, Founder effects, extinction, Speciation, Reduction in gene flow and bottle-necks, Reproductive isolation.

Unit V
Quantitative trait loci
5 lectures
Quantitative trait loci: (a) Major genes; (b) Methods of mapping QTLs; (c) Genetical and statistical considerations; (d) QTLs in plants, fruit fly, mouse/rats, yeast; (e) Genomic methods of mapping QTLs; (f) Haplotype mapping and genome-wide association studies (GWAS); (g) QTL interactions: genetic and environment.

Unit VI
Population genetics
3 lectures
In-breeding depression & mating systems; population bottlenecks, migrations, Bayesian statistics; adaptive landscape, spatial variation & genetic fitness.

Unit VII
Genetic determinants shaping population traits
2 lectures
Genetic determinants that shape population traits: (a) overdominance (b) pleiotropy (c) epistasis (d) variable selection (e) gene flow.

Unit IX
Modes of speciation
3 lectures
Modes of speciation: (a) allopatric speciation (b) parapatric speciation (c) sympatric speciation; Evolutionary processes causing speciation: (a) natural selection (b) sexual selection (c) random genetic drift (d) Muller incompatibility.

Unit X
Phylogenetic analysis
2 lectures
Importance of mitochondrial DNA and Y-chromosome sequence derived population studies: Founder effects, human-origins and subsequent human migration patterns.

Recommended Textbooks and References:
5. Falconer and Mackay: Introduction to Quantitative Genetics
6. Lynch and Walsh: Genetics and Analysis of Quantitative Traits
Course Objectives
The objectives of this course are to teach various approaches to genetic engineering that students can apply in their future career in biological research as well as in biotechnology industry. Genetic engineering is a technology that has been developed based on our fundamental understanding of the principles of molecular biology and this is reflected in the contents of this course. This technology has revolutionized the way modern biological research is done and has impacted mankind with a number of biological products and processes.

Student Learning Outcomes
Given the impact of genetic engineering in modern society, the students should be endowed with strong theoretical knowledge of this technology. The student should also be able to gain working knowledge of gene silencing and editing tools and methods and appreciate their relevance for investigating specific contemporary biological questions. In conjunction with the practicals in molecular biology & genetic engineering, the students should be able to take up biological research as well as find placement in the relevant biotech industry.

Unit I
Introduction and tools for genetic engineering
4 lectures
General requirements for performing a genetic engineering experiment; biology of restriction, types and properties of restriction endonucleases and methylases; DNA ligase, Klenow enzyme, T4 DNA polymerase, polynucleotide kinase, alkaline phosphatase; cohesive and blunt end ligation; linkers; adaptors; homopolymeric tailing; labelling of DNA: nick translation, random priming.

Unit II
Different types of vectors
9 lectures
Biology of plasmids and bacteriophages; Plasmids & M13 mp vectors; pUC19 series and Bluescript vectors, phagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Principles for maximizing gene expression (RNA and protein), protein expression vectors; pMal; GST; pET-based vectors; Protein purification; His-tag; GST-tag; MBP-tag etc.; Intein-based vectors; Inclusion bodies; methodologies to reduce formation of inclusion bodies; protein refolding; mammalian expression and replicating vectors; Baculovirus and Pichia vector system, wheat germ line expression system, plant based vectors, Ti and Ri as vectors, yeast vectors, shuttle vectors, reporters and reporter assays; Yeast two-hybrid system.

Unit III
Different types of PCR techniques
5 lectures
Principles of PCR and alternative methods to PCR (LAMP, NASBA, SDA, RCA, LCR); Primer design; properties of thermostable DNA polymerase enzymes and proofreading; types of PCR – multiplex, nested, inverse, reverse-transcription PCR, real time PCR, touchdown PCR, hot start PCR, colony PCR, asymmetric PCR, RNA isolation, reverse transcriptase, cDNA synthesis, RNA quantitation, cloning of PCR products; T-vectors; PCR-based site directed mutagenesis and protein engineering.

Unit IV
cDNA analysis
6 lectures
Introduction of foreign DNA into host cells; transformation, electroporation, transfection; construction of genomic and cDNA libraries, phage display; strategies for library screening; radioactive and non-radioactive probes; hybridization techniques: Northern, Southern, South-western and Far-western and colony hybridization, fluorescence, in situ hybridization.

Unit V
Gene silencing and genome editing technologies
12 lectures
Gene knockout/knockdown/mutation, conditional knockouts, gene deletion, gene insertion, gene correction; Gene silencing techniques: principles, approaches - antisense, ribozymes, RNAi, microRNA; siRNA technology; delivery systems for genes, vectors; Mechanisms of genome editing: targeted DNA double strand breaks repair (DSBs), major pathways— homology-directed repair (HDR), nonhomologous end-joining (NHEJ); Cre-lox technology, Zinc finger nucleases, TALENs, CRISPR/Cas9 system; delivery of genome editing tools: transfection of plasmid and viral vectors for gene targeting.
Creation of transgenic organisms eg. plants, mice; introduction to methods of genetic manipulation in different model systems eg. fruit flies (*Drosophila*), worms (*C. elegans*), frogs (*Xenopus*), fish (zebra fish) and chick; disease models; applications of gene therapy/gene editing - antiviral strategies, cancer immunotherapy, hematologic disorders, liver-targeted gene editing, neuromuscular disorders, ocular disorders etc., examples of Chinese and American clinical trials.

**Recommended Textbooks and References:**

4. Selected papers from scientific journals, particularly Nature & Science.
5. Technical Literature from Stratagene, Promega, Novagen, New England Biolabs.

**Course Objectives**

It is essential for biologists to understand how a single cell develops into a multicellular organism which involves complex process of synchronised cell division, differentiation, and proper positioning of cells relative to one another. This course will provide a conceptual overview on how developmental patterns arise using examples from different model systems and highlighting regulatory networks involved in these processes. Special emphasis has been given to human development and medical aspects of developmental biology.

**Student Learning Outcomes**

On completion of this course, students should be able to:

- Understand modern approaches to developmental genetics, including the logic of experiments and the inferences drawn from them;
- Develop key skills in imaging and manipulating embryos in genetics experiments.

### Unit I

**Introduction to developmental biology**

5 lectures

Defining development, Overview of developmental anatomy and genetics; Role of cell-cell communication in development; Concepts of development: Specification, induction, competence, morphogen gradients, pattern formation, determination and differentiation, cell fate and cell lineages. Germ cell determination and differentiation: spermatogenesis, oogenesis, maturation of germ cells, ovulation and implantation; Fertilization: External fertilization in sea urchins and internal fertilization in mammals; Polyspermy.

### Unit II

**Early developmental events in animals**

6 lectures

Cleavage; Pattern of Cleavage, Gastrulation, Cell specification and axis formation with examples of sea urchin, *C. elegans*, *D. melanogaster*, amphibians, birds and mammals. Primary axis formation during oogenesis; Maternal genes; Anterior-posterior and Dorsal-ventral patterning; Genetic control of gap genes, segment polarity genes,
homeotic selector genes during *Drosophila* development; Segmentation genes; Homeotic selector genes; Homeobox and its evolutionary significance; Vulva formation in *C. elegans*; Development of the tetrapod limb; Metamorphosis and regeneration.

### Unit III

**Developmental processes in vertebrates and plants**  
6 lectures

Neural tube formation, tissue architecture of CNS; Role of programmed cell death in development; Limb development in vertebrates: Formation of Limb Bud; Proximal Distal axis of the limb; Cell death and formation of digits and joints; Regeneration and Senescence: Epimorphic, morphallactic and compensatory regeneration; Ageing: causes and regulation. Developmental process in plants: overview of plant development with examples from *Arabidopsis*, Apomixis, comparison between pattern of plant and animal development; Understanding plant development through examples.

### Unit IV

**Human development**  
6 lectures

Brief account of embryonic development, blastulation, gastrulation, formation of notochord and establishment of body axis, Embryonic germ layers and their derivatives; Fetal development and placentation (development, structure and function); Fetal membrane in twins; developmental malformation; Teratogen induced reproductive complications; Gene-teratogen interaction; Environmental factors and genetics; Abnormal gametogenesis and infertility; Abnormal implantation: contribution of maternal and paternal genes; Teratogenesis and tumours associated with gastrulation; Birth defects: erythroblastosis fetalis, foetal hydrops and twin defects; Craniofacial and skeletal dysplasia; Neural crest and craniofacial defects; Vertebral defects: spina bifida and scoliosis; Spontaneous abortions and still birth.

### Unit V

**Genetic defects**  
6 lectures

Overview of Human Hox genes and genetic defects due to mutation in Hox genes; Somite differentiation and homeobox genes (anterior-posterior patterning); Limb development & limb defects; Eye development and eye defects; Development of spinal cord and neural tube defects; Brain development and cranial defects; Cardiac development and heart defects; Facial development and facial cleft defects; Muscle development; Kidney development and kidney defects; Defects in sex differentiation; Genomic imprinting: Parent-of-origin effect; Gene silencing; Prader-Willi syndrome, Angelman syndromes and Beckwith-Wiedemann Syndrome.

### Unit VI

**Introduction to stem cells**  
5 lectures

Stem cells: introduction and overview, role of stem cells in development, Pluripotency, stem-cell plasticity, cellular signalling and maintenance of stem cells, trans-determination, isolation, expansion, genetic manipulation, genomic reprogramming, and cloning of stem cells, differences between adult and embryonic stem cells, therapeutic applications of stem cells, *in-vitro* fertilization and assisted reproductive techniques (ARTs); Developmental cancer therapies.

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**Recommended Textbooks and References:**

6. Sadler et. al., *Langman’s Medical Embryology*, Lippincott Williams and Wilkins
7. Jones, *Smith’s Recognizable Patterns of Human Malformation*, Elsevier Health
## OMICS: Genomics, Transcriptomics, Proteomics and Metabolomics

### Course Objectives

The objective of this course is to give an introduction to Genomics and other global Omics technologies, the theory and practical aspects of these technologies and the applications of these technologies in biology. The student should be able to gain working knowledge of these technologies and appreciate their ability to impart a global understanding of biological systems and processes in health and disease.

### Student Learning Outcomes

On completion of this course, students should be able to gain:

- Overview of genome variation in the population including technologies to detect these variations;
- Understanding how High-throughput DNA sequencing (HTS) can be used to identify disease causing genetic variants in monogenic diseases;
- Understanding how Genome-wide association study (GWAS) can detect disease associated markers in multifactorial diseases;
- Understanding how HTS technologies can be used to explore changes in gene expression;
- Application of various Omics technologies.

### Unit I

**Introduction to genomics**

6 lectures

- Structure and organization of prokaryotic and eukaryotic genomes- nuclear, mitochondrial and chloroplast genomes; Computational analysis, Databases, Finding genes and regulatory regions; Tools for genome analysis- PCR, RFLP, DNA fingerprinting, RAPD, SNP detection, SSCP, FISH to identify chromosome landmarks; Human Genome Project- landmarks on chromosomes generated by various mapping methods, BAC libraries and shotgun libraries preparation, Physical map, Cytogenetic map, Contig map, Restriction map, UCSC browser.

### Unit II

**Microarray technology**

6 lectures

- Introduction, Basic principles and design, cDNA and oligonucleotide arrays, DNA microarray, Instrumentation and structure; Designing a microarray experiment - The basic steps, Types of microarray - expression arrays, protein arrays, Comparative Genomic Hybridization (CGH) arrays, Resequencing arrays; Different platforms (Affymetrix, Agilent etc.); Data Processing and Normalization - Algorithms of data processing and Normalization; Tools used to normalize; Microarray databases – NCBI; GEO (Gene Expression Omnibus), ArrayExpres (EBI); Functional Analysis: Differential gene expression; Gene Ontology functional enrichment tools, Pathway analysis (KEGG Database); Applications of Microarray technology; case studies.

### Unit III

**Sequencing technologies**

7 lectures

- Introduction to sequencing, Maxam and Gilbert method, Sanger Sequencing techniques and applications; Next Generation sequencing (NGS), Introduction to NGS, Experimental protocol (Isolation of DNA/RNA), quality check, Library Preparations, sequencing reaction); Platform overview and comparison (Illumina, 454 (Roche), SOLiD (Life technology), Specific Biosciences, Ion Torrent, Nanopore, PacBio; Types of NGS, DNA-sequencing - Whole genome sequencing, exome sequencing, Deep sequencing, ChIP sequencing, RNA-sequencing and the types (small RNA sequencing, non-coding RNA sequencing),Whole transcriptome sequencing; Data Processing and Analysis: Data Quality Check, filtering and Genome assembly and mapping to reference genomes, mapping tools (bowtie, maqetc.), Sequence Alignment formats: Sequence Alignment/Map (SAM) format, Binary Alignment/Map (BAM) format, Functional Analysis: Pathway analysis, Gene Ontology analysis; Application of different sequencing technique, methylomics, in vivo protein binding, genome wide association studies (GWAS), Histone modification, microbial sequencing, Comparison of Microarray technology and High throughput sequencing technology, case studies.
Overview of protein structure—primary, secondary, tertiary and quaternary structure, Relationship between protein structure and function; Outline of a typical proteomics experiment, Identification and analysis of proteins by 2D analysis, Spot visualization and picking; Tryptic digestion of protein and peptide fingerprinting, Mass spectrometry: ion source (MALDI, spray sources), analyzer (ToF, quadrupole, quadruple ion trap) and detector; Post translational Modifications: Quantitative proteomics, clinical proteomics and disease biomarkers, mass spectral tissue imaging and profiling; Protein-protein interactions: Surfaceomes and Secretomes, Solid phase ELISA, pull-down assays (using GST-tagged protein) tandem affinity purification, far western analysis, by surface plasmon resonance technique; Yeast two hybrid system, Phage display, Protein interaction maps, Protein arrays—diagnostics, expression profiling.

Introduction and overview of metabolites, sample collection and processing, Non tracer and tracer (radio labelled)-based techniques in metabolomics (HPLC, NMR, LC-MS and GC-MS); Metabolome data processing derived by various techniques, analysis of databases (MetaboLight, Meta Cyc, MMCD etc), Analysis tools, Metabolic pathways and network analysis; Metabolic flux analysis (TCA, Amino acids, fatty acids, intermediary metabolites), Stoichiometric metabolic flux analysis, 13C metabolic flux analysis (MFA), Metabolic control analysis (MCA); Applications of metabolomics; Integration of metabolomics data sets with other data (e.g. Transcriptomics, enzyme activity, etc.)

Recommended Textbooks and References:

Course Objectives
The major objective is understanding of fundamental cell biological research in relation to human disease. This understanding comprises:
• Cell biology in the context of the healthy and diseased human body;
• Cellular basis of major human diseases;
• Advanced microscopy including live cell imaging, correlative light and electron microscopy, confocal microscopy and the underlying biophysics.

Student Learning Outcomes
At the end of this course, students should acquire the basic concepts of the structure and functionality of the animal cell along with basics of microscopy.
1. Introduction to the anatomy and functioning and handling of upright and inverted epifluorescence microscope & confocal microscope.
2. Observation of suitable specimen under bright field, phase contrast, dark field and differential interference contrast (DIC) microscope.
3. Observation of animal/plant cell cultures under microscope. Measurement of cell size by oculometer and stage micrometre.
4. Low speed separation of cells from animal blood or any mammalian cells from a culture.
5. To quantify the number of cells present in the given sample and assessment of cell viability.
6. Identification of Barr body by preparing buccal smear.
7. Isolation of lysosomes, nuclei & ER membranes from given samples (i.e. chicken liver) in isotonic sucrose method.
8. To study the process of cellular osmosis in guard cells from plant leaves or animal blood.
9. To study the cellular distribution of mitochondria by janus green staining.
10. Isolation of mitochondria from given tissue samples.
11. To assay the activity of an enzyme in its natural source to assess organ function.
12. To examine the number and morphology of nucleus in given tissue sample by DAPI/PI staining.
13. Analysis of Green Fluorescence Protein (GFP) tagged cells/tissue under fluorescence microscope. Quantifying intensity measurements after setting up thresholds, and improving the contrast features.
14. Analysis of F-actin based cellular cytoskeleton by Phalloidin staining to the given tissue sample.
15. Localization of specific protein(s) inside the cells (in situ) by immunohistochemistry. (May be demonstrated).
16. Demonstration of live cell movements, dynamics of cellular organelles in relation to a function by using web-tutorials and online movies.

**Course Objectives**

The objectives of this laboratory course are to develop an understanding about practical aspects of the components of the immune system as well as their function. Basic as well as advanced methods will be taught to detect different antigen and antibody interactions, isolation of different lymphocyte cells etc. and how they can be used in respective research work.

**Student Learning Outcomes**

On completion of this course, students should be able to:
- Evaluate the usefulness of immunology in different pharmaceutical companies;
- Identify proper research lab working in the area of their own interests;
- Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out the kind of immune responses in the setting of infection (viral or bacterial) by looking at cytokine profile.
1. Study of animal embryonic development: stages, timing, study of morphological and cellular dynamics (egg-to-embryo transition, pattern formation, organogenesis etc.) using dye-staining and other techniques and microscopy.

2. Study of genetic perturbations leading to developmental defects: Studies involving germline mutants, SiRNA, ShRNA mutations, chemical or radiation mutation approaches. Characterization of a chosen mutant organism.

3. Study of cellular and molecular analysis of the mutant organism with particular emphasis on a tissue system underlying the mutant phenotype.

4. Study of genetic complementation experiments to restore the wildtype phenotype in a mutant organism: Germ line transfection or Mendelian crosses to restore the genetic defects and basic cellular characterization of the restored tissue defects.
score and linkage disequilibrium to the students. In addition, mapping and identification of genetics causes underlying complex traits has been included.

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**Unit I**

**History of human genetics**

8 lectures

Pedigrees- gathering family history; Pedigree symbols; Construction of pedigrees; Presentation of molecular genetic data in pedigrees; Pedigree analysis of monogenic traits: Autosomal inheritance-dominant, recessive; Sex-linked inheritance- X-linked recessive, dominant; Y-linked; Sex-limited and sex-influenced traits; Mitochondrial inheritance; MIM number; Complications to the basic pedigree patterns: Non-penetrance, variable expressivity, pleiotropy, onset, dominance problem; Anticipation; Compound heterozygosity.

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**Unit II**

**Complications to basic pedigree patterns**

8 lectures

Genomic imprinting and uniparental disomy; Spontaneous mutations; Mosaicism and chimerism; Male lethality; X-inactivation; Consanguinity and its effects in the pedigree pattern; Allele frequency in population; Complex traits-polygenic and multifactorial: Approaches to analysis of complex traits- ‘Nature vs nurture’; Role of family and shared environment; Monozygotic and dizygotic twins and adoption studies; Polygenic inheritance of continuous (quantitative) traits, normal growth charts, Dysmorphology; Polygenic inheritance of discontinuous (dichotomous) traits - threshold model, liability and recurrence risk; Genetic susceptibility in complex traits; Alcoholism, cardiovascular disease, diabetes mellitus, obesity & epilepsy; Estimation of genetic components of multifactorial traits: empiric risk; Heritability; Coefficient of relationship; Application of Bayes’ theorem.

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**Unit III**

**Genetic mapping of Mendelian and complex characters**

8 lectures

Identifying recombinants and non-recombinants in pedigrees; Genetic and physical map distances; Genetic markers; Mapping of genetic traits: Two-point mapping- LOD score analysis; Multipoint mapping; Homozygosy mapping; Genetic mapping of complex traits; Difficulties in mapping: Allele sharing methods- affected sib pair analysis; Allelic association, Linkage disequilibrium mapping, Transmission disequilibrium test; Human Genome Mapping: Physical mapping of the human genome: Low resolution mapping- Cell hybrids, mini- and microcells, synteny of genes, Radiation hybrid mapping; Human genome mapping: Assembly of clone contigs and identifying genes in cloned DNA; Integration of cytogenetic, genetic and physical maps; DNA testing; Direct and indirect testing (gene tracking) in individuals; DNA tests for identity and relationships including forensic applications; Population screening: ethics, organization and advantages.

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**Unit IV**

**Identifying human disease genes**

10 lectures

Principles and strategies for identifying human disease genes; Position-independent and positional cloning; Candidate gene approaches; Confirming a candidate gene, mutation screening, testing in animal models; Molecular pathology: Nomenclature of mutations and their databases; Loss of function and gain of function mutations in diseases; Molecular pathology: Instability of the human genome and diseases- pathogenicity associated with repeated sequences; Slipped strand mispairing; Unequal crossover and unequal sister chromatid exchange; Gene conversion; Retrotransposition; Illegitimate recombination; Approaches to treat genetic diseases: Pharmacogenetics, cell based treatment, recombinant protein and vaccines; Gene Therapy: Strategies, role of viral vectors, non-viral vectors; Repairing and inactivating pathogenic gene; RNAi: General idea and applications.

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**Recommended Textbooks and References:**

Clinical Genetics and Diagnostics

Credits

3

Course Objectives
This course has been designed with goal to provide preclinical medical education which has important applications in clinical medicine, public health and medical research. The objective is to help the students to appreciate the importance of genetics in medicine with emphasis on the general principles of disease inheritance, pathogenesis, diagnosis, and counselling.

Student Learning Outcomes
On completing this course, students should be able to:
- Elicit and document a family history and pedigree;
- Understand clinical genetic risk assessments;
- Be able to convey genetic information and discuss risk;
- Have an appreciation of molecular, cytogenetic and biochemical laboratory testing utilised in clinical genetics;
- Have an appreciation for the approaches to treatment for specific genetic disorders;
- Understand the role of prenatal screening and testing in pregnancy management and care and the options available when fetal abnormality is detected;
- Understand the role of genetics as the underlying cause of various disorders of the human body;
- Understand the role of genetics in cancer.

Unit I
History and classification of genetic disorders
7 lectures

Origin of medical genetics, major developments and its impact on clinical practice;
Single gene disorders, Patterns of inheritance, Classical and non-classical; Clinical cytogenetics: Principles and mechanisms of chromosome abnormalities; Numerical Chromosome Aberrations, Structural Chromosomal Aberrations; Common autosomal and the sex Chromosomes abnormalities; Cancer genetics: common cancers and diagnostics; Genetics of complex/polygenic disorders and diagnostics.

Unit II
Molecular basis of genetic diseases
9 lectures

Types of mutations, factors causing mutations and effects; Common singe gene disorders: Disorders of haematological system- thalassemia, hemophilia, sickle cell disease; Common disorders of neurological system- Huntington disease, Fragile X syndrome, Hereditary ataxias, Neuromuscular disorders like Duchenne muscular dystrophy, Spinal muscular atrophy; Diseases associated with dynamic mutations -Myotonic dystrophy (MD); fragile X chromosome syndrome (Martin–Bell syndrome); Huntington’s chorea, Kennedy’s disease, Spinocerebellar ataxia 1 (SCA1); Machado-Joseph Disease (MJD) Friedreich’s Ataxia; Biochemical basis of Genetic diseases; Inborn errors of metabolism; Disorders of immune system; Genomic Imprinting defects, Microdeletion syndromes nature, molecular characterization, mechanisms of phenotypic expression of the Prader-Willi Syndrome (PWS), Angelman Syndrome(AS) and other diseases associated with chromosome imprinting; Congenital anomalies of development–
dysmorphology and teratogenesis; Congenital malformations, deformations and disruptions, dysplasia, large and small malformations, Types of combined anomalies, disorders in sexual differentiation, intersexual conditions; Mitochondrial Diseases–Leber Hereditary optic neuropathy (LHON); Myoclonic Epilepsy with Ragged Red Fibres (MERRF); Mitochondrial encephalomyopathy, lactic acidosis, and stroke-like episodes (MELAS); Kearns–Sayre syndrome, etc.  

Unit III  
**Diagnostics**  
6 lectures  
Cytogenetic testing- Karyotype, Molecular-cytogenetic testing-FISH, MLPA, QFPCR, CMA; Testing for single gene disorders-common molecular techniques and advanced techniques for known and unknown mutations; Inherited variation and Polymorphism, RFLP, Microsatellite, Minisatellite; Genetic screening, carrier testing; Predictive testing - Newborn screening; Antenatal screening, population screening; Treatment of genetic disorders.  

Unit IV  
**Genetic counselling and methods of prenatal testing**  
5 lectures  
Genetic counselling and principles in practice – case studies and risk assessment, pedigree analysis; Antenatal diagnosis: Indications for prenatal diagnosis, invasive methods, ethical issues, different techniques for diagnosis; Non-invasive methods of prenatal testing: Pre-implantation and preconception diagnosis-indications, assisted reproduction techniques, methods of pre-implantation and preconception genetic diagnosis, Pre-implantation genetic screening; Therapy of genetic diseases -conventional therapy of genetic diseases, gene therapy of monogenic diseases, antisense therapy of diseases associated with somatic mutations, cancer and viral infections; targeted therapy.  

Unit V  
**Personalised medicine: future scope**  
2 lectures  
Recent advances in human molecular genetics paving ways towards potential application of personalised therapies/medicines: pharmacogenomics/drug metabolism in relation to individual genetic makeup.  

Unit VI  
**Ethical issues and genetic services**  
3 lectures  
Ethical issues in medical genetics, legal and social issues; Genetics and society; Genetic services in India.  

Recommended Textbooks and References:  
The objectives of this course are to take the students through the initiation and primary goals of human genome sequencing. Make them familiar with the human genome organization and structure. The course shall cover the advent of human genome variation projects and their use. As well as the importance of comparative genomics and how it aids in identification and understanding of human disease causing genes. This will facilitate in understanding the structure and function of genome in health and disease.

On completion of this course, students should be able to:

- Describe the two experiments that led molecular biologists to conclude that genes are made of DNA, and state the limitations of each experiment;
- Describe the content of the human nuclear genome;
- Discuss the importance of the Human Genome Project.

Unit I
The Genome project
6 lectures
History, organization and goals of human genome project, Mapping strategies, current status of various maps; DNA segment nomenclature, Human genome diversity, Human Genome Variation, 1000 Genome project.

Unit II
Organization of human genome
4 lectures
Mitochondrial genome, Gross base composition of nuclear genome, Gene density, CpG islands, RNA-encoding genes, Functionally identical/similar genes, Diversity in size and organization of genes, Annotation.

Unit III
Gene families
4 lectures
Multigene families – Classical gene families, families with large conserved domains families with small conserved domains, Gene super families, Gene families in clusters, Pseudogenes, Repetitive DNA and transposable elements, Origin of gene families.

Unit IV
Comparative genomics
8 lectures
Overview of prokaryotic and eukaryotic genomes, C-value, number of genes and complexity of genomes, Conservation and diversity of genomes, Comparative genomics as an aid to gene mapping and study of human disease genes.

Unit V
Functional genomics
8 lectures
Transcriptome and its analysis include microarrays and RNA sequencing, Proteome and Proteomics, gene silencing, genome and disease gene mapping using next generation sequencing, whole genome and exome sequencing and RNA sequencing.

Unit VI
Pharmacogenomics from human genome
2 lectures
Exemplify specific cases that highlight potential use of individual-specific genomic features that impact disease relevance and treatment modalities.

Recommended Textbooks and References:
2. Strachan and Read (2003), *Human Molecular Genetics*. Wiley
Course Objectives
This course covers all basic details of Bioinformatics starting from sequence comparison tools to genome annotation to protein structure prediction methods. The course also touches upon in silico methods of biological networks to artificial intelligence designs. Therefore, the course gives a comprehensive understanding of the entire gamut of bioinformatics and computational analyses. The instructor is expected to cover only the basic details of these topics.

Student Learning Outcomes
On completion of this course, students should be able to:
• Develop an understanding of the basic theory of computational tools;
• Gain working knowledge of computational tools and methods;
• Appreciate their relevance for investigating specific contemporary biological questions;
• Critically analyse and interpret the results of their study.

Unit I
Bioinformatics basics
6 lectures
Computers in biology and medicine; Importance of Unix and Linux systems and its basic commands; Database concepts; Protein and nucleic acid databases; search tools used in database search: biological background required for proper sequence analysis: extracting biologically relevant features; Identification of protein sequences from DNA sequence; DNA sequence analysis: Sequence pairwise alignment techniques; Retrieving peptide/protein sequences from Mass-spec databases and mapping the same in annotated genomes.

Unit II
Multiple sequence analysis tools
5 lectures
Multiple sequence analysis; flexible sequence similarity searching with the FASTA3 program package; use of CLUSTAL W and CLUSTAL X for multiple sequence alignment; methods of phylogenetic analysis, construction of phylogenetic trees.

Unit III
Protein modelling
8 lectures
Introduction to protein modelling; force field methods; (Molecular Mechanics), Conformational Space, Molecular Dynamics (MD), Metropolis Monte Carlo (MC); energy minimization methods, Applying Ramachandran Plot constraints. Buried and exposed residues and water-of-hydration; side chains and neighbours; hydrogen bonds; mapping electrostatic properties onto surfaces; RMS fit of conformers; assigning secondary structures; Protein structure prediction: protein folding and model generation.

Unit IV
Computational biology in drug design
6 lectures
Computational Structural Biology with application to Drug Design; Methods and applications that use computation to model biological systems and human diseases; Signalling and gene-regulatory networks; in silico cell and tissue models; Neural networks & artificial intelligence models; Self-emergent behaviour in physical systems: comparison to biological systems.

Recommended Textbooks and References:
Course Objectives
The aim of this course is to provide a comprehensive overview of exciting developments in neurogenetics research and molecular and cellular mechanisms that are disrupted in disorders that affect the nervous system.

Student Learning Outcomes
After completion of this course, students should be able to:
• Describe the complete range of monogenetic defects that result in neurodevelopmental disorders;
• Describe the epigenetic modifications that affect learning, memory, behavior and discuss trans-generational epigenetic inheritance;
• Apply the principles of neurophysiology to study synaptic plasticity in rodent models for neurodevelopmental disorders.

Unit I
Neuronal assembly
6 lectures

Major regions of human brain; Cellular components of nervous tissue; Sub cellular organization of nervous system; Membrane potential and action potential; neurotransmitters.

Unit II
Genetic aspect of learning and memory
5 lectures

Genetics of Learning and memory; Genetic approaches to Circadian rhythms.

Unit III
Modern sequencing techniques & their applications
7 lectures

Modern sequencing technique: applications in neuroscience; Transgensics and their application in neurogenetic analysis; Gene targetting technologies and their application in neuroscience; Optogenetics and Pharmacogenetics in neuroscience.

Unit IV
Nature-nurture and behaviour
8 lectures

Genetic experiments to investigate animal behaviour: Selection Studies, Inbred strain studies, studies in genetic model organisms; Identifying genes for controlling behavior: Induced mutations; Quantitative trait loci; Synteny/orthology; Investigating the genetics of human behavior; Twin and adoption study designs, interpreting heritability; Linkage and association studies; Environmental influence- shared and non-shared environment.

Unit V
Genetics of psychopathology
6 lectures

Schizophrenia, Mood disorders, Disorders of childhood; Neurogenetic disorders; Spinal muscular atrophy; Syndromes due to triplet nucleotide expansion; Alzheimer’s disease; Parkinson’s disease.

Recommended Textbooks and References:
# Intellectual Property Rights, Biosafety and Bioethics

## Credits

2

## Course Objectives

The objectives of this course are:

- To provide basic knowledge on intellectual property rights and their implications in biological research and product development;
- To become familiar with India’s IPR Policy;
- To learn biosafety and risk assessment of products derived from biotechnology and regulation of such products;
- To become familiar with ethical issues in biological research. This course will focus on consequences of biomedical research technologies such as cloning of whole organisms, genetic modifications, DNA testing.

## Student Learning Outcomes

On completion of this course, students should be able to:

- Understand the rationale for and against IPR and especially patents;
- Understand why India has adopted an IPR Policy and be familiar with broad outline of patent regulations;
- Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents;
- Gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research and environmental release of genetically modified organisms, national and international regulations;
- Understand ethical aspects related to biological, biomedical, health care and biotechnology research.

## Unit I

**Introduction to IPR**

### 7 lectures

- Introduction to intellectual property; types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmer’s rights act; concept of ‘prior art’: invention in context of “prior art”; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation.; Review of Government of India’s “National Intellectual Property Rights Policy”.

## Unit II

**Patenting**

### 3 lectures

- Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure - patent application- forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting-requirement, procedures and costs; financial assistance for patenting-introduction to existing schemes; publication of patents-gazette of India, status in Europe and US; patent infringement- meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing – outright sale, licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives.

## Unit III

**Biosafety**

### 3 lectures

- Biosafety and Biosecurity - introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants – sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk – environmental risk assessment and food and feed safety assessment; problem formulation – protection goals, compilation.
of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops vs cisgenic plants or products derived from RNAi, genome editing tools.

**Unit IV**

**National and international regulations**
3 lectures

International regulations – Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations – EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – biosafety levels and category of rDNA experiments; field trials – biosafety research trials – standard operating procedures - guidelines of state governments; GM labeling – Food Safety and Standards Authority of India (FSSAI).

**Unit V**

**Bioethics**
7 lectures


**Recommended Textbooks and References:**

2. National IPR Policy, Department of Industrial Policy & Promotion, Ministry of Commerce, GoI
5. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/
Course Objectives
The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.

Student Learning Outcomes
Students should be able to demonstrate the following abilities:

- Formulate a scientific question;
- Present scientific approach to solve the problem;
- Interpret, discuss and communicate scientific results in written form;
- Gain experience in writing a scientific proposal;
- Learn how to present and explain their research findings to the audience effectively.

Project Proposal Preparation & Presentation

Selection of research lab and research topic: Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them select a topic for their project. The topic of the research should be hypothesis driven.

Review of literature: Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources.

Writing Research Proposal: With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc. Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.

Syllabus

Project Proposal Preparation

Students will have to present the topic of their project proposal after few months of their selection of the topic. They should be able to explain the novelty and importance of their research topic.

Poster Presentation

At the end of their project, presentation will have to be given by the students to explain work done by them in detail. Along with summarizing their findings they should also be able to discuss the future expected outcome of their work.

Laboratory VI: Molecular Human Genetics

Course Objectives
The course is aimed at giving the student a theoretical overview of basic concepts in human molecular genetics. The course will include activities that will familiarise the student with basic study design in human molecular genetics.

Student Learning Outcomes
After completion of the course, students should be able to:

- Explain and place problems from human genetics into context;
- Explain basic concepts in genetics: mutation /polymorphism, heredity, Mendelian genetics, complex genetics;
- Plan and conduct simple experiments;
- Critically interpret and evaluate the results.

Syllabus

1. Preparation of Pedigree chart of some human genetic disorders.
2. Risk assessment by Pedigree analysis, Binomial probability and Bayesian calculation.
3. Calculation of coefficient of relationship (r) in pedigree
4. Analysis of facial landmarks and dermatoglyphia.
Laboratory VII: Clinical Genetics and Diagnostics

Course Objectives
This course is outlined to treat the organisation and inheritance of the genetic make-up, genetic conditioned diseases, advanced knowledge in use of molecular biological methodology for gene diagnostics and analysis and methods for chromosome analysis.

Student Learning Outcomes
On completion of the course, students should be able to:
- Demonstrate skills for the basic laboratory technology within clinical genetics;
- Show ability to interpret microscopical preparations and analyse the results.

Credits
2

1. Study of Sex-chromatin from buccal smear and hair root cells.
2. Short term lymphocyte culture and preparation of metaphase plate.
5. Chromosomal and interphase FISH of human chromosomes.
6. Mutation screening by (a) PCR- RFLP and (b) PCR- sequencing.
7. PCR-based detection of allelic inheritance of a DNA marker.
8. LOD score analysis with microsatellite or any suitable data of pedigrees segregating in a genetic disease.
9. Analysis of methylation status of genomic DNA or a specific locus by bisulphite method.
10. Experiment/demonstration of DNA fingerprinting.

Laboratory based

1. Investigations for common genetic disorders to plan a strategy for lab and under take analysis. This needs to be planned in advance since getting patient samples will be difficult for ethical reasons.
2. Common genetic disorders such as Down syndrome, Turner syndrome, etc. for cytogenetic analysis which will include: inoculation of culture, harvesting, slide preparation, slide staining, chromosome identification & making a karyotype.
3. Common single gene disorders such as Beta Thalassemia, Duchhne muscular dystrophy, etc. for molecular analysis which will include: DNA extraction, quantification of DNA, PCR (amplification refractory mutation system ARMS PCR, multiplex PCR), gel electrophoresis, analysis and interpretation of results.

Assignment based

1. Case scenarios will be provided to interpret the mode of inheritance and to draw detailed pedigree.
2. Case situations will be given for calculating and assessing risk of having another child with genetic disease.
3. Case scenarios will be given for genetic counselling.

Laboratory VIII: Bioinformatics

Course Objectives
The aim of this course is to provide practical training in bioinformatics including accessing the major public sequence databases, use of the different computational tools to find sequences, analysis of protein and nucleic acid sequences by various software packages.

Student Learning Outcomes
On completion of this course, students should be able to:
- Describe the contents and properties of most important bioinformatics databases;
- Perform text- and sequence-based searches and analyse and discuss the results in light of molecular biological knowledge;
Syllabus

1. Using NCBI and Uniprot web resources.
2. Introduction and use of various genome databases.
4. Similarity searches using tools like BLAST and interpretation of results.
5. Multiple sequence alignment using ClustalW.
7. Use of gene prediction methods (GRAIL, Genscan, Glimmer).
8. Using RNA structure prediction tools.
9. Use of various primer designing and restriction site prediction tools.
10. Use of different protein structure prediction databases (PDB, SCOP, CATH).
11. Construction and study of protein structures using Deepview/PyMol.
13. Use of tools for mutation and analysis of energy minimization of protein structures.
14. Use of miRNA prediction, designing and target-prediction tools.

Course Objectives
The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.

Student Learning Outcomes
Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:

- In-depth knowledge of the chosen area of research.
- Capability to critically and systematically integrate knowledge to identify issues that must be addressed within framework of specific thesis.
- Competence in research design and planning.
- Capability to create, analyse and critically evaluate different technical solutions.
- Ability to conduct research independently.
- Ability to perform analytical techniques/experimental methods.
- Project management skills.
- Report writing skills.
- Problem solving skills.
- Communication and interpersonal skills.
Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.

Assessment may be done by thesis evaluation, viva voce and final presentation.

**Course Objectives**

The objectives of this course are:
- To provide basic knowledge of cancer genomics;
- To become familiar with relevant technologies, public databases and informatics methods that are used to determine driver mutations and oncogenic pathways;
- To provide the rationale for personalized cancer treatment;
- To provide basic information regarding underlying biology of common cancers.

**Student Learning Outcomes**

On completion of this course, students should be able to:
- Understand genomic basis of cancer;
- Explain key technologies and interact with public databases;
- Understand biology of various cancers and role of environment in carcinogenesis.

### Unit I
**Cancer genomics: perspective and new technologies**

8 lectures

Historical perspective on the development of cancer genomics; Cancer characterization using sequencing approaches; Advances in sequencing technologies; Discoveries using second-generation sequencing technologies; Cancer transcriptome sequencing and analysis; Identifying pathogen presence in cancer samples.

### Unit II
**Significance of transcriptome sequencing in personalized cancer medicine**

6 lectures

Importance of RNA; Role of MicroRNAs and Ultra-conserved Non-Coding RNAs in cancer; From microarray to RNA sequencing; Workflow for RNA sequencing; RNA sequencing data analysis in cancer genome research; Incorporating transcriptome sequencing analysis to identify genomic driver mutations; Transcriptome sequencing: from bench to bedside; Tissue Microarrays in studying gynecological cancers.
Unit III
Cancer pharmacogenomics & biomarker discovery and development
4 lectures

Pharmacogenomics; Cancer pharmacogenomics in children; Active ADR surveillance and future directions; Uses of biomarkers in cancer research and cancer care; Biomarker discovery and qualification; Assay validation, clinical validity, clinical utility; Incorporation of biomarkers into clinical trial design.

Unit IV
Bioinformatics for cancer genomics & genomic resource projects
4 lectures

Data Types in cancer genomics, Data management & data analysis, Data Interpretation TCGA and other sources of cancer genomic data; Key large-scale cancer genomics projects; other notable genomics projects.

Unit V
Genomics of specific cancers
8 lectures

Genetic basis of hereditary cancer syndromes; Retinoblastoma, Wilms tumor, Non-syndromic tumors and susceptibility Loci, Cancer predisposition syndromes, Genomics of adult and pediatric cancers; Special focus on common solid tumors of the Lung, Prostate, Colon and Breast:- Genomics and Molecular Profiling, Epidemiology, Standard Treatment and Prognosis; Somatic gene mutations, Personalized targeted therapy, Molecular diagnostics and treatment guidance; Special focus on common liquid tumors of the hematopoietic system- Acute myeloid leukemia: epidemiology, etiology, genetic and epigenetic alterations, somatic mutations and their contribution to survival in childhood acute myeloid leukemia; Disease-associated mutations in signal transduction pathways.

Unit VI
Impact of environment on cancer genomics
2 lectures

Important components of the exposome; Mechanisms of environmental carcinogenesis.

Recommended Textbooks and References:
Statistics - Distributions, Statistical Inference, Dimensionality Reduction (Principal Component Analysis, Multidimensional Scaling), Unsupervised Clustering (Dissimilarity Metrics, Hierarchical Clustering, K-Means and K-medoid Clustering, Self Organizing Maps); Single/Dual Channel Microarray Technologies, Quality Check, Normalization, Quantifying Gene Expression, Quantifying Differential Expression, Multiple Hypothesis Testing and False Discovery; Functional Analysis and applications - Gene Ontology and pathway analysis, Promoter analysis and gene regulatory network, CGH & Genotyping chips, polymorphism via genome-wide scanning; Online Software and databases for analysis - DAVID, GSEA, Gorilla, Amigo etc.

Raw data file formats, sequence quality evaluation - Phred quality score, GC content etc. (tools/softwares - FastQC, NGS QC toolkit etc.); filtering and trimming of bad quality reads (tools/softwares – FastX tool kit, trimmomatic, NGS QC toolkit etc.) and data visualization; Genome assembly, mapping of reads to reference genome (tools - bowtie, maq etc.); data formats (SAM, BAM etc.); Basic analysis post mapping to reference genome - DNA seq, RNA seq, ChIP-seq, exomeseq etc; Functional analysis (as mentioned in unit II) and Application in various studies; Galaxy tool to analyze sequencing data.

Proteomics data processing and analysis: data identification - Raw data formats: Viewers (TOPPView (tools/softwares - mzXML, mzML and mzData etc.), [Spectra Viewer, Mascot Distiller. Converters (tools/softwares - Herms, MS convert, CompassXpert, Masstransit); Protein identificationDatabase search algorithms (tools/softwares - MassWiz, MASCOT, SEQUEST, etc.), Platforms, Pipelines and libraries (tools/softwares – Decon tools, esimsa2D, etc.), De novo sequence algorithms (tools/softwares - CycloBranch, Lutesisk, DenovoX, etc.), Homology Search (tools/softwares - MS-homology, SPIDER, Labsolutions LCMS, Xcalibur); Post Translational Modification (tools/softwares - ProSight PTM, Crosstalk DB etc.) Quantification for Quantitative Proteomics (tools/softwares - MassChroQ, IsoBariQ, Multi-Q MaxQuant etc.), protein structure (tools/softwares - StavroX, XcomB MS2pro, etc.), Mass spectrometry Imaging (tools/softwares - Axima2Analyze, BioMap, etc.).

Recommended Textbooks and References:
Course Objectives
This course will provide a perspective and exposure to medical aspects of bacteriology, virology, mycology and parasitology and infectious diseases along with concepts of symptoms, pathogenesis, transmission, prophylaxis and control, a conceptual understanding of host-pathogen interactions using well-characterized systems as examples. The students should have a good grasp of disease causing microbes and their interactions with host.

Student Learning Outcomes
On completion of this course, students should be able to:
• Compare and contrast different microbial diseases, including properties of different types of pathogens, and mechanisms of pathogenesis;
• Summarize the role of host in infectious disease, including natural barriers to infection, innate and acquired immune responses to infection, and inflammation;
• Compare and contrast experimental approaches for identifying virulence genes and advantages/disadvantages of each approach for specific pathogens.

Unit I
Bacterial diseases
7 lectures
Normal microflora (microbiome) of human body and its role – Skin, mouth and respiratory tract, intestinal tract, urogenital tract; Pathogenesis and virulence factors - Koch's postulates, Adherence and Invasion, Bacillus anthracis, Clostridium botulinum, Corynebacterium diphtheriae; E. coli, Vibrio cholerae, Salmonella typhi and paratyphi, Shigella dysenteriae; Mycobacterium tuberculosis and NTM; general view of Rickettsial and Chlamydia diseases, Syphilis and Gonorrhea infections Streptococcal and Staphylococcal infections; Antibacterial chemotherapy - Inhibition of cell wall synthesis, cell membrane function, protein and nucleic acid synthesis, antimetabolites; Drug resistance - origin (genetic and non-genetic), mechanisms, antimicrobial activity in vitro and in vivo, Multi-drug resistance and its mechanisms e.g. MDR-TB.

Unit II
Viral diseases
7 lectures
Viral Pathogenesis - Routes of entry, Viral spread (local and systemic infection), Viral persistence (chronic and latent infection); Polio, Chicken pox, Mumps, Measles, Rubella; Viral hemorrhagic fever, viral encephalitis, Dengue and Yellow fever; Influenza virus infection (emphasis on Avian and Swine flu), Herpes infections, Cytomegalovirus, Varicella zoster, HBV, HIV/AIDS, Rabies and Prion diseases; Hepatitis and Human Cancer viruses; Emerging viral diseases – Ebola, Marburg, SARS, Hanta, Chikungunya, Zika, Chandipura.

Unit III
Fungal and protozoan infections
7 lectures
Types of Mycoses (with specific example of causative fungi) – Superficial, Cutaneous, Sub-cutaneous; Types of Mycoses (with specific example of causative fungi) - Endemic and Opportunistic; Mycotoxins and Antifungal chemotherapy – Mycetismus, Aflatoxins, classes of currently available drugs and new inhibitors in the pipeline; Protozoan diseases - Giardiasis, Amoebiasis; Leishmaniasis, African sleeping sickness; Malaria, Cryptosporidiosis; Infection by Helminths – Nematodes, Trematodes, Cestodes.

Recommended Textbooks and References:

Remodelled Biotech Curricula I 353
Course Objectives

The objective of the course is to familiarize students with emerging trends in medical devices and diagnostics for early detection, selection of appropriate treatment, monitoring treatment effectiveness and disease surveillance.

Student Learning Outcomes

After successfully completing this course, students should be able to:

- Extend principles of engineering to development of medical devices and design of sensors;
- Appreciate basic configuration and distinction among biosensor systems;
- Understand various facets of medical devices and diagnostics that could be employed in early diagnosis and prognosis of human diseases.

Unit I

Sensors

5 lectures

Rationale of electronic biosensors; Essence of three types of electronic biosensors (i.e., potentiometric, amperometric, and cantilever-based sensors); Three essential metrics that define modern electronic sensors; detection time, sensitivity, and selectivity; Physics of detection time that allows one to organize every available sensor in a systematic way; Fundamental limits of detection of various classes of sensors; Opportunities and challenges of integrating sensors in a system platform.

Unit II

Transducers

5 lectures

Principles and applications of Calorimetric, Piezoelectric, semiconductor, impedimetric, based transducers; Biochemical Transducers: Electrode theory: electrode-tissue interface, metal-electrolyte interface, electrode-skin interface, electrode impedance, electrical conductivity of electrode jellies and creams.

Unit III

Optical sensors

5 lectures

Photo detectors, optical fiber sensors, indicator mediated transducers, General principles of optical sensing, optical fiber temperature sensors; Pulse sensor: photoelectric pulse transducer, strain gauge pulse transducer.

Unit IV

Bio-recognition systems

5 lectures

Enzymes; Oligonucleotides and Nucleic Acids; Lipids (Langmuir-Blodgett bilayers, Phospholipids, Liposomes); Membrane receptors and transporters; Immunoreceptors; Chemoreceptors.

Unit V

Electrodes and immobilization

5 lectures

Microelectrodes, body surface electrodes, needle electrodes, pH electrode, specific ion electrodes/ Ion exchange membrane electrodes, enzyme electrode; Reference electrodes: hydrogen electrodes, silver-silver chloride electrodes, Calomel electrodes; Enzyme immobilization; Peptide immobilization; Antibody immobilization; Oligonucleotides and Nucleic Acid immobilization; Cell immobilization; Mono-enzyme electrodes; Bi-enzyme electrodes: enzyme sequence electrodes and enzyme competition electrodes.
### Unit VI
**Fundamentals and applications of microfluidics**
5 lectures

- Capillary flow and Electro kinetics; Micro pump, Micro mixers, Micro reactors, Micro droplets, Micro particles separators; Micro fabrication techniques (different types of lithography methods); Applications of microfluidics (eg. Lab- in –Chip).

### Unit VII
**Applications**
5 lectures

- Biomarkers: Disease and pathogen specific information, availability by sample type (blood, serum, urine, sputum, saliva, stool, mucus); Specificity, sensitivity, shelf life, portability; Clinical chemistry; Test-strips for glucose monitoring; Urea determination; Implantable Sensors for long-term monitoring; Drug development and detection; Environmental monitoring; eg. various diseases (Cancer, HIV/AIDS, Tuberculosis, Malaria, Lymphatic Filariasis, Schistosomiasis, Dengue, Chikungunya).

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### Recommended Textbooks and References:

6. Graham Ramsay Editor, *Commercial Biosensors*, John Wiley& Sons,
7. Ursula Spichiger-Keller, *Chemical Sensors and Biosensors for Medical and Biological Applications*, Wiley-VCH

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### Nanobiotechnology

#### Credits
2

### Course Objectives
The course aims at providing general and broad introduction to multi-disciplinary field of nanotechnology. It will familiarize students with combination of top-down approach of microelectronics and micro-mechanics with bottom-up approach of chemistry/biochemistry; a development that is creating new and exciting cross-disciplinary research fields and technologies. The course will also give an insight into complete systems where nanotechnology can be used to improve everyday life.

### Student Learning Outcomes
On successful completion of this course, students should be able to describe basic science behind the properties of materials at the nanometre scale, and the principles behind advanced experimental and computational techniques for studying nanomaterials.

### Unit I
**Introduction to nanobiotechnology**
5 lectures

- Introduction to Nanobiotechnology; Concepts, historical perspective; Different formats of nanomaterials and applications with example for specific cases; Cellular Nanostructures; Nanopores; Biomolecular motors; Bio-inspired Nanostructures, Synthesis and characterization of different nanomaterials.

### Unit II
**Nano - films**
5 lectures

- Thin films; Colloidal nanostructures; Self Assembly, Nanovesicles; Nanospheres; Nanocapsules and their characterisation.
Nanoparticles for drug delivery, concepts, optimization of nanoparticle properties for suitability of administration through various routes of delivery, advantages, strategies for cellular internalization and long circulation, strategies for enhanced permeation through various anatomical barriers.

Nanoparticles for diagnostics and imaging (theranostics); concepts of smart stimuli responsive nanoparticles, implications in cancer therapy, nanodevices for biosensor development.

Nanomaterials for catalysis, development and characterization of nanobiocatalysts, application of nanoscaffolds in synthesis, applications of nanobiocatalysis in the production of drugs and drug intermediates.

Introduction to Safety of nanomaterials, Basics of nanotoxicity, Models and assays for Nanotoxicity assessment; Fate of nanomaterials in different stratas of environment; Ecotoxicity models and assays; Life cycle assessment, containment.

Course Objectives
The objective of this course is to learn fundamental principles, methods, and applications of tissue engineering. This understanding will help to manipulate cell and tissue properties rationally to alter, restore, maintain, or improve cell and tissue functions as well as to design artificial tissue substitutes.

Student Learning Outcomes
On completion of this course, students should be able to:
- Explain significance, current status and future potential of tissue engineering;
- Identify key challenges in tissue engineering of different human tissues;
- Describe design, fabrication and biomaterials selection criteria for tissue engineering scaffolds.

Unit I
Introduction to tissue engineering
3 lectures
Introduction, importance and scope of tissue engineering.

Unit II
Biomaterials and scaffolds
7 lectures
Introduction to biomaterials and scaffolds; Requirements of biomaterials as Tissue Engineering scaffolds, Properties and types of scaffolds, Tissue specific scaffolds.

Unit III
Scaffold Preparation
5 lectures
Different methods employed in the synthesis of scaffolds and ways to process them.
Animal cell biology, stem cells, organization of cells into tissues, tissue microenvironment, tissue injury and wound healing.

Review of basic immunology, response of body to foreign materials.

Animal cell culture on scaffolds, consequences, optimization strategies and important considerations.

Skin tissue engineering, Liver tissue engineering, Bone and cartilage tissue engineering, Nerve tissue engineering, Vascular tissue engineering, Muscle tissue engineering and Kidney tissue engineering; Regulatory Affairs, Ethical issues and their impact on tissue engineering.

Recommended Textbooks and References:
2. Langer, Vacanti; *Principles of Tissue Engineering*; Lanza, Academic Press
3. Patrick, Mikos, McIntire; *Frontiers in Tissue Engineering*; Pergamon
4. Ratner, Hoffman, Schoen; *Biomaterials Science*; Academic Press
5. Palsson & Bhatia; *Tissue Engineering*; Prentice Hall.

Course Objectives
The objectives of this course are to build upon previous knowledge of biochemical pathways and human molecular genetics to develop an appreciation of applications of this knowledge in disease metabolism.

Student Learning Outcomes
After going through this course, students should be able to understand molecular basis of various pathological conditions from perspective of biochemical reactions.

Clinical specimen considerations - Types of Samples, Sample Processing, composition and types of blood specimens, venipuncture, pediatric and geriatric venipuncture, choice and correct use of anticoagulants; Method evaluation, Quality Control and quality management.

Amino acids - Basic Structure, Metabolism, Essential Amino Acids, Nonessential Amino Acids, Body amino acid pool, Aminoacidopathies, Amino Acid Analysis, glutathione hyperglycinemias, formation of taurine, homocystinuria, cystinuria and cystinosis, phenyl ketonuria and alkaptonuria, albinism, tyrosinemia; Proteins – Importance, Molecular Size, Catabolism and Nitrogen Balance, Structure, Classification, Dynamic state of body proteins; Plasma proteins - Prealbumin (Transthyretin), Albumin, Globulins; Total Protein abnormalities – Hypoproteinemia, Hyperproteinemia; Proteins in other body fluids – Urinary proteins and Cerebrospinal fluid proteins; Non-protein nitrogen compounds (Physiology, clinical application, methods and pathophysiology) – Urea, Uric acid, Creatine, Creatinine, Ammonia, Synthesis of thyroid hormones, Synthesis and catabolism of catecholamines.
Unit III
Clinically important enzymes and related pathophysiology
3 lectures

Enzymes of clinical significance - Creatine Kinase, Lactate Dehydrogenase, Aspartate Aminotransferase, Alanine Aminotransferase, Alkaline Phosphatase, Acid Phosphatase, Glutamyltransferase, Amylase, Lipase, Glucose-6-Phosphate Dehydrogenase, Drug-Metabolizing Enzymes, Tumour markers, Bone markers, Cardiac markers, liver markers, Inborn errors associated with carbohydrate metabolisms; Inborn errors of metabolism - Glycogen storage diseases, Fructosuria, Fructose intolerance, Pentosuria, Galactosuria; Urine screening.

Unit IV
Diagnosis and treatment of carbohydrate disorders
3 lectures


Unit V
Transport mechanism and associated disorders
3 lectures

Transport of plasma lipids, lipoprotein metabolism, lipid profile and diet, PUFA and dietary fiber, Serum triglycerides; Diagnosis and treatment of lipid disorders – Arteriosclerosis, Hyperlipoproteinemia, Hypercholesterolemia, Hypertriglyceridemia, Combined Hyperlipoproteinemia, Lipoprotein (a) Elevation, Hypolipoproteinemia, Hypoalphalipoproteinemia.

Unit VI
Assessment of organ system function
8 lectures

Pituitary function - Introduction to Hormones and Pituitary Function - hypophysiotropic or hypothalamic hormones; Anterior pituitary hormones; Pituitary tumors; Growth hormone; Actions of growth hormone; Testing: Acromegaly; Growth hormone deficiency; Prolactin; Prolactinoma; Other causes of hyperprolactinemia; Clinical evaluation of hyperprolactinemia; Management of prolactinoma; Idiopathic galactorrhea; Hypopituitarism - Etiology of hypopituitarism; Treatment of panhypopituitarism; Posterior pituitary hormones – Oxytocin and Vasopressin; Liver function - Anatomy - Gross Anatomy, Microscopic Anatomy, Biochemical functions - Excretory and Secretory, Synthetic, Detoxification and Drug Metabolism, Liver function alterations during disease – Jaundice, Cirrhosis, Tumors, Reye Syndrome, Drug- and Alcohol-Related Disorders, Assessment of liver function/liver - Function tests: Bilirubin, Urobilinogen in Urine and Faeces, Serum, Bile Acids, Enzymes, Tests Measuring Hepatic Synthetic Ability, Tests Measuring Nitrogen Metabolism, Hepatitis; Cardiac Function - Anatomy and function of the heart - Anatomy Function, Pathologic conditions of the heart, Cardiovascular Disease, Congenital Cardiovascular Defects, Heart Failure, Acute Coronary Syndromes, Hypertensive Heart Disease, Infective Heart Disease, Diagnosis of heart disease - Laboratory Diagnosis of Myocardial Infarction, Markers of Inflammation and Coagulation Disorders, Markers of Congestive Heart Failure, Patient-Focused Cardiac Tests, Disease; Renal Function - Renal anatomy, Renal physiology - Glomerular Filtration, Tubular Function, Elimination of Nonprotein Nitrogen Compounds, Water, Electrolyte, and Acid-Base Homeostasis, Endocrine Function, 1,25-Dihydroxy Vitamin D3, Analytic procedures, Clearance Measurements, Urine Electrolytes, 2-Microglobulin, Myoglobin, Microalbumin, Urinalysis, Pathophysiology – Glomerular Diseases, Tubular Diseases, Urinary Tract Infection/Oclusion, Renal Calculi, Renal Failure.

Recommended Textbooks and References:
DBT Supported Teaching Programme

<table>
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<tr>
<th>S.No.</th>
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<th>Contact Details of Course Coordinator</th>
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<tr>
<td>1.</td>
<td>Banaras Hindu University, Varanasi</td>
<td>Dr. Ashim Mukherjee&lt;br&gt;Dept. of Molecular &amp; Human Genetics&lt;br&gt;0542-6702490 (Office)&lt;br&gt;09919351888&lt;br&gt;<a href="mailto:ashim04@gmail.com">ashim04@gmail.com</a>; <a href="mailto:amukherjee@bhu.ac.in">amukherjee@bhu.ac.in</a></td>
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Annexure I

Subject Specific Subcommittee of M.Sc. Molecular and Human Genetics

Chairperson
1. Dr. B. J. Rao, Senior Professor, Tata Institute of Fundamental Research, Mumbai

Members
2. Dr. Jaya Tyagi, Professor, Department of Biotechnology, All India Institute of Medical Sciences, New Delhi
3. Dr. Pramod Mehta, Professor, Centre for Biotechnology, Maharshi Dayanand University, Rohtak
4. Dr. Alok Ray, Consultant Professor, School of International Biodesign and Former Head of Biomedical Engineering, Indian Institute of Technology, New Delhi
5. Dr. Madhumita Roy Chowdhury, Senior Scientist, Department of Pediatrics, Division of Genetics, All India Institute of Medical Sciences, New Delhi
6. Dr. Mousumi Mutsuddi, Assistant Professor, Department of Molecular and Human Genetics, Banaras Hindu University, Varanasi
7. Dr. Surajit Sarkar, Assistant Professor, Department of Genetics, University of Delhi
8. Dr. Arjun Surya, Chief Scientific Officer, Curadev Pharma, New Delhi
9. Dr. Vibhu Kanchan, Senior Scientist, MSD Wellcome Trust Hilleman Labs Pvt. Ltd., New Delhi

Member Secretary
10. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi
M.Sc. Neuroscience
Introduction

Background

Promotion of Indian Biotechnology sector is high on policy agenda of Government of India. Biotechnology has also been recognized as one of the key priority sectors under ‘Make in India,’ ‘Skill India’ and ‘Startup India’ initiatives of Government of India, as it is one of sectors expected to contribute towards enterprise creation, innovation and economic growth. Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India has immensely contributed to this dynamism through various policies and initiatives, establishment of innovation clusters, academia-industry partnerships, increasing capabilities for technology development, etc. The National Biotechnology Development Strategy (2015 – 2020) released by DBT provides a strategic roadmap for India’s emergence as a global biotechnology innovation and manufacturing hub. It has also highlighted importance of human resource development and need for nurturing tailor-made human capital for advanced scientific research and entrepreneurship.

DBT has taken a number of initiatives aimed at integrated human resource development to evolve an ecosystem where scientists, innovators and future entrepreneurs can be nurtured. Keeping in mind requirement for trained manpower in various areas of Biotechnology, DBT initiated Post-Graduate Teaching Programme way back in 1985 with 5 universities which has expanded to 74 universities imparting M.Sc./M.Tech./M.V.Sc. degrees in general, agricultural, animal, food, environmental, industrial marine, medical, neuroscience and pharmaceutical biotechnology. 10 programmes are being phased out. These universities and institutes are provided liberal financial support towards strengthening of laboratory facilities, equipment, consumables, fellowships to students, dissertation grant per student etc. Post-Graduate Teaching Programme selects best students and trains them to join research or industry workforce contributing significantly to biotechnology workforce.

About the Course Curriculum Revision Exercise

Taking into cognizance the changing needs of the economy and to keep abreast with latest developments in the field of biotechnology, DBT proactively initiated revision of course curricula of Post-Graduate Programmes in biotechnology. The present exercise has been undertaken by Biotech Consortium India Limited (BCIL), New Delhi. Earlier exercise was carried out in 2008. The Course Curriculum Revision Exercise has been carried out for 13 Post-Graduate programmes in Biotechnology supported by DBT.

The revision of course curriculum of M.Sc. Neuroscience aims to address mismatch between ‘knowledge’ gained by students and appropriate skill set required for technology development and implementation including present contemporary needs of economy.

Methodology

A meticulous and structured approach has been adopted to accomplish the Course Curriculum Revision exercise.

BCIL had initiated the exercise with a review of literature of relevant national and international documents on curriculum design and planning for biotechnology programmes of premier national as well as international universities, guidelines by University Grants Commission, recent curricular guidelines released by Indian Council of Agricultural Research, Ministry of Health and Family Welfare and Indian Institute of Science Education & Research and other relevant research papers on curriculum development in peer-reviewed journals.

The findings of the literature review were adopted to design questionnaires for eliciting feedback from stakeholders of Biotechnology community i.e. academicians,
Strategic Approach

A Core Committee along with 9 subject specific subcommittees comprising of 63 academicians, scientists and industry representatives were constituted to revise and update the curricula. The constitution of subject specific subcommittee for M.Sc. Neuroscience is given at Annexure-1.

The salient recommendations identified from stakeholder survey were presented to the Committee. Several brainstorming discussion sessions were held for achieving the desired balance between the foundation courses, recent developments in biotechnology and updation needs identified during the stakeholder survey. Core Committee finalized broad contours for revising all the course curricula. The guidelines set by the Core Committee were taken up by the subject specific subcommittee of M.Sc. Neuroscience for updating the curriculum. The subject specific committee incorporated latest advancements in areas of Neuroscience in the curriculum. Separate meeting was held to discuss and deliberate the updations to be made in the curriculum. The revised curriculum was vetted and finalized by the Core Committee.

Course Curriculum Revision

The members of Committee agreed that revised course curriculum should provide skill and outcome based education and help the students to gain domain knowledge, ability to design and interpret research experiments and acquire effective communication skills. The course curriculum has been re-designed accordingly to promote skill-based and outcome-based education. The revised course curriculum totals to 96 credits comprising of theory, practical, technology-based topics, electives and dissertation. Each course includes learning objectives, student learning outcomes, course plan (number of lectures/unit) and reference textbooks/resources. Theory and practical courses include relevant examples, case scenarios and tutorials for inculcating critical thinking against rote learning. Several new courses have been included and content for existing courses has also been updated. Several areas of basic and clinical studies at the forefront of neuroscience like Development of Sensory and Motor Systems, Regeneration, Pathway Finding by Axons, Synaptic Function and Plasticity, Neurotrophin Gene Expression and Trophic Regulation, Aging, Neuron-Glia Interactions, Neural Circuits and Neural Modelling, Regulation of Neurotransmitter and Receptor Expression, Neurogenesis Neurodegenerative Disorders, Computational Neuroscience, Neuroinformatics, etc. have been introduced. With importance of students being able to execute research projects independently, separate credits have been allotted for proposal preparation and presentation before initiating dissertation and also credits for dissertation have been increased accordingly.

We hope that model course curriculum shall serve as guidelines for academicians and researchers from different parts of the country for adoption in their institutions with modifications as per availability of expertise, infrastructure and specific needs.

We wish to put on record our sincere appreciation for constant guidance and encouragement received from Dr. K. VijayRaghavan, Secretary, DBT for bringing out this publication. We wish to acknowledge whole-hearted support of Core Committee and subject specific subcommittees members. Sincere thanks are due to Dr. Manoj Singh Rohilla, Scientist- D, DBT, Ms. Shweta for creative design, Mrs. Rita Bhatla, DBT and Shri. Dilip Joy, BCIL.
Message

We need brains trained enough to understand the brain, how it works, the disorders and how to assist those suffer from a brain disorder. The M.Sc. Neuroscience with an integrated approach intends to provide training on a wide range of skills enabling the students to ask questions and motivate them to take-up a career in research towards understanding the structure and function of the nervous system.

The major and visible Institutes for neuroscience are National Brain Research Centre, National Institute of Mental Health and Neuroscience, All India Institute of Medical Sciences, Indian Institutes of Technology, Indian Institute of Science, Jawaharlal Nehru University, Indian Institute of Toxicology Research, Central Drug Research Institute, Banaras Hindu University, Jiwaji University, University of Hyderabad etc. and the list is growing. We have more than 300 PIs undertaking neuroscience research activity and several R&D and industrial setups have the subject as their priority area.

We need human resource with cross-disciplinary training in basic and clinical studies at the cutting edge enabling them for research in the forefront of neuroscience. The curriculum being presented would ensure developing hands with background covering cellular, molecular and systems neuroscience, behavior and cognitive aspects. The concept has been timely adopted in India but needs expansion. The teaching programmes have been developed and a common curriculum was projected by the Department of Biotechnology, Govt. of India. This is a revised version of the earlier one. Two centers, National Brain Research Centre and School of Studies in Neuroscience, Jiwaji University, are providing training to the next generation of neuroscientists with DBT support. The students have since been enthusiastically accepted by the neuroscience academia and industries.

Neurobiology has been a part of the Life Sciences syllabi of several University Teaching Departments. Some Institutes are expected to introduce M.Sc. Neuroscience programme soon and this document will be useful for them.

Our team has made a humble effort, trust this will be accepted by the academia.

(Ishan Patro)
# M.Sc. Neuroscience

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**Recommended Electives:**
1. Computational Neuroscience  
2. Neurogenetics
## Semester One

### Biochemistry

**Credits**: 3

#### Unit I: Protein structure

5 lectures

- Chemical basis of life: Miller-Urey experiment, abiotic formation of amino acid oligomers, composition of living matter; Water – properties of water, essential role of water for life on earth pH, buffer, maintenance of blood pH and pH of gastric juice, pH optima of different enzymes (pepsin, trypsin and alkaline phosphatase), ionization and hydrophobicity, emergent properties of biomolecules in water, biomolecular hierarchy, macromolecules, molecular assemblies; Structure-function relationships: amino acids – structure and functional group properties, peptides and covalent structure of proteins, elucidation of primary and higher order structures, Ramachandran plot, evolution of protein structure, protein degradation and introduction to molecular pathways controlling protein degradation, structure-function relationships in model proteins like ribonuclease A, myoglobin, hemoglobin, chymotrypsin etc.; basic principles of protein purification; tools to characterize expressed proteins; Protein folding: Anfinsen’s Dogma, Levinthal paradox, cooperativity in protein folding, free energy landscape of protein folding and pathways of protein folding, molten globule state, chaperons, diseases associated with protein folding, introduction to molecular dynamic simulation.

#### Unit II: Enzyme kinetics

5 lectures

- Enzyme catalysis – general principles of catalysis; quantitation of enzyme activity and efficiency; enzyme characterization and Michaelis-Menten kinetics; relevance of enzymes in metabolic regulation, activation, inhibition and covalent modification; single substrate enzymes; concept of catalytic antibodies; catalytic strategies with specific examples of proteases, carbonic anhydrases, restriction enzymes and nucleoside monophosphate kinase; regulatory strategies with specific example of hemoglobin; isozymes; role of covalent modification in enzymatic activity; zymogens.

#### Unit III: Glycobiology

2 lectures

- Sugars - mono, di, and polysaccharides with specific reference to glycogen, amylose and cellulose, glycosylation of other biomolecules - glycoproteins and glycolipids; lipids - structure and properties of important members of storage and membrane lipids; lipoproteins.

#### Unit IV: Structure and functions of DNA & RNA

3 lectures

- Self-assembly of lipids, micelle, biomembrane organization - sidedness and function; membrane bound proteins - structure, properties and function; transport phenomena; nucleosides, nucleotides, nucleic acids - structure, a historical perspective leading up to the proposition of DNA double helical structure; difference in RNA and DNA structure and their importance in evolution of DNA as the genetic material.

#### Unit V: Bio-energetics

8 lectures

- Bioenergetics-basic principles; equilibria and concept of free energy; coupled interconnecting reactions in metabolism; oxidation of carbon fuels; recurring motifs in metabolism; Introduction to GPCR, Inositol/DAG//PKC and Ca++ signaling pathways; glycolysis and gluconeogenesis; reciprocal regulations and non-carbohydrate sources.
Calvin cycle and pentose phosphate pathway; glycogen metabolism, reciprocal control of glycogen synthesis and breakdown, roles of epinephrine and glucagon and insulin in glycogen metabolism; Fatty acid metabolism; protein turnover and amino acid catabolism; nucleotide biosynthesis; biosynthesis of membrane lipids and sterols with specific emphasis on cholesterol metabolism and mevalonate pathway; elucidation of metabolic pathways; logic and integration of central metabolism; entry/exit of various biomolecules from central pathways; principles of metabolic regulation; steps for regulation; target of rapamycin (TOR) & Autophagy regulation in relation to C & N metabolism, starvation responses and insulin signaling.

Recommended Textbooks and References:

Course Objectives
Neurons contain the same intracellular components, as do other cells. Understanding of brain function would absolutely need a clear understanding of cellular and molecular organization of neurons and glia as units. Thus, in this paper, student is expected to learn, in greater details, sub-cellular and molecular organization of mammalian cells in general, and that of neurons and glia cells in particular. Greater emphasis will be on cell structure of function, and to develop skill sets for reading and understanding scientific literature and to interpret experimental data in cell biology.

Student Learning Outcomes
On successful completion of this course, student should be able to:
- Gain comprehensive understanding of classical and advanced topics in cell biology;
- Design experimental models to address mechanistic question in cell biology;
- Comprehensive understanding on neuronal architecture and its interactions with glia, and underlying molecular mechanisms communication;
- Ability to understand and analyze contemporary cell biology studies reported in research papers.
Unit III
Cell organelles and functions
7 lectures
Nucleus – Structure and function of nuclear envelope, lamina and nucleolus; Macromolecular trafficking; Mitochondria – Structure; Organization of respiratory chain complexes; ATP synthase; Structure-function relationship; Mitochondrial DNA. Structure and function of microbodies, Golgi apparatus, Lysosomes and Endoplasmic Reticulum – structure and function; Cellular stress (ER, oxidative, unfolded protein stress etc.) and stress response mechanism - chaperones and ubiquitin-proteasome system; autophagy and lysosome-mediated proteolysis; mitophagy.

Unit IV
Cell organization and movement
7 lectures
Organization and role of microtubules and microfilaments; Cell shape and motility; Actin-binding proteins and their significance; Muscle organization and function; Molecular motors; Intermediate filaments; Extracellular matrix in animals.

Unit V
Neurons
7 lectures
Introduction to neurons; The Neuron Doctrine; Components of neurons; Classification of neurons; The Nissl and Golgi stains; Types of neurons; Cytology of neurons; Dendrites structure and function; Axon structure and functional aspects; Ultrastructure; Myelination and synapses.

Unit VI
Glial cells
7 lectures
Structure and function of glial cells; Different types of glial cells: astrocytes, oligodendrocytes and Schwann cells; Types of astrocytes – type I & II astrocytes, fibrous and protoplasmic astrocytes; Function of other glial cells: oligodendrocyte and microglial cells; Overview of glial and neuronal relationship in the CNS; Importance of astrocytes in glutamate metabolism and blood brain barrier; Microglial phenotypes; Glial –neuronal interplay in the CNS.

Recommended Textbooks and References:

Course Objectives
Cells are fundamental units of body and this course aims at providing an introduction to experimental methods that scientists have used to discover mechanisms by which cells, at molecular level, control their specific functions, growth and differentiation into specialized tissues. Greater emphasis will be on fundamentals of molecular biology and to develop skill sets for reading and understanding scientific literature and to interpret experimental data.

Student Learning Outcomes
On successful completion of this course, students should be able to:
• Gain understanding of the genome and its regulation;
• Appreciate methodology used to decipher central dogma of molecular biology;
• Gain understanding of gene regulation – at transcriptional, post-transcriptional, translational and post-translational levels – and underlying molecular mechanisms;
• Analyse contemporary molecular biology studies reported in research papers.
Unit I
Molecular genetic techniques & genomics
5 lectures
DNA cloning and characterization; Genome wide analyses of gene structure and gene expression; Inactivating function of specific genes in eukaryotes; Identifying and locating human disease genes.

Unit II
Molecular structure of genes & chromosomes
5 lectures
Chromosomal organization genes and non-coding DNA; Mobile DNA; Structural organization of eukaryotic chromosomes; organelle DNAs.

Unit III
Transcriptional control of gene expression
6 lectures
Eukaryotic gene control and RNA polymerase; regulatory sequences in protein coding genes; activators and repressors of transcription; mechanism of transcription activation and repression.

Unit IV
Post-transcriptional gene control
6 lectures
Processing of eukaryotic pre-mRNA; transport across nuclear envelope; cytoplasmic mechanism of post-transcriptional control; processing of rRNA and tRNA.

Unit V
Cell signalling
6 lectures
Signalling molecules and cell surface receptors; intracellular signal transduction; G protein coupled receptors.

Unit VI
Membrane trafficking
6 lectures
Translocation of secretory proteins across ER membrane; protein modifications, folding and quality control in the ER; export and sorting of proteins.

Unit VII
Eukaryotic cell cycle
6 lectures
Biochemical and genetic studies on cell cycle; mechanism regulating mitotic events; meiosis - a special type of cell division; Oncogenes and Tumor suppressor genes.

Recommended Textbooks and References:

Course Objectives
The course is designed to provide a broad exposure to all basic techniques (biochemical & biophysical) used in current Modern Biology research. The goal is to impart basic conceptual understanding of principles of these techniques and emphasize on Biochemical utility of the same & underlying Biophysics. At the end of the course, student is expected to have clear understanding of all analytical techniques such that the barrier to implement the same is abated to a great extent.

Student Learning Outcomes
Students should be able to learn how to combine previously acquired knowledge of physical chemistry and biochemistry in order to understand biochemical processes at molecular level.
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<td>Units of measurement of solutes in solution. Normality, molality, molarity, millimol and ppm. Water-structure and properties; Principles of glass and reference electrodes, types of electrodes, complications of pH measurement (dependence of pH on ionic strength, pH, pOH, Henderson-Hasselbach equations, buffers, pH of body fluids, buffers in body fluids, red blood cells and tissues. Length scales in biological systems: proteins, multiprotein complexes, organelles &amp; cells; Basic thermodynamics; Basic chemical kinetics &amp; reaction rates: Theory of chemical reactions.</td>
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<td>Basic principles and types of centrifugation-rotors, boundary, differential, density gradient, zonal isopycnic, equilibrium; Sedimentation - sedimentation velocity, preparative and analytical ultracentrifugation techniques: principles &amp; applications in biochemical fractionation methods.</td>
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<td></td>
<td>Principles of electrophoretic separation, zonal and continuous electrophoresis, paper, cellulose acetate/nitrate, gel and capillary electrophoresis, use of native and denaturing gels, Protein subunit molecular weight determination using SDS-PAGE, Anamalous protein migration of some proteins in SDS-PAGE, Acid-urea PAGE and their physical basis, Isoelectric focussing and two dimensional gel electrophoresis, electroporation, pulse field gel electrophoresis, gradient gels.</td>
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<thead>
<tr>
<th>Unit IV</th>
<th>Chromatography and X-ray crystallography</th>
<th>2 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Chromatography, principles of adsorption, partition and ion-exchange chromatography, gel permeation chromatography, GC, GC-MS and HPLC; X-ray Crystallography - protein crystals, Bragg's law, unit cell, isomorphous replacement, fiber pattern of DNA; Small-angle X-ray diffraction methods: Principles &amp; applications; Basic protein structure prediction methods.</td>
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<thead>
<tr>
<th>Unit V</th>
<th>Molecular and chemical biology</th>
<th>4 lectures</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>DNA cloning; bacterial transformation; transfection; chromosome integration; screening for transformants; Polymerase Chain Reaction; PCR types; Gel electrophoresis; DNA sequencing; Molecular hybridization: Southern blot; Northern blot. Protein analyses: Western blot &amp; Immunoprecipitation; Rewriting DNA: mutations; random mutagenesis; point mutation; Site-specific mutations; Genome Editing Technology; DNA array &amp; protein array; Click-chemistry: Principles &amp; applications; Chemical sensors for in-cell biochemistry.</td>
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<table>
<thead>
<tr>
<th>Unit VI</th>
<th>Optical microscopy methods</th>
<th>4 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Light Microscopy: lenses and microscopes, resolution: Rayleigh's Approach, Darkfield; Phase Contrast; Differential Interference Contrast; fluorescence and fluorescence microscopy; Confocal microscope: confocal principle, resolution and point spread function; nonlinear microscopy: multiphoton microscopy; principles of two-photon fluorescence, advantages of two-photon excitation, tandem scanning (spinning disk) microscopes, deconvolving confocal images; image processing, three-dimensional reconstruction; Total Internal reflection microscopy, STED microscopy.</td>
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<thead>
<tr>
<th>Unit VII</th>
<th>Mass spectroscopy</th>
<th>3 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Ionization techniques; mass analyzers/overview MS; FT-ICR and Orbitrap, fragmentation of peptides; proteomics, nano LC-MS; Phospho proteomics; interaction proteomics, mass spectroscopy in structural biology; imaging mass spectrometry.</td>
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</tr>
</tbody>
</table>

**Recommended Textbooks and References:**

### Course Objectives

The objective of this course is to give conceptual exposure of essential contents of mathematics and statistics to students.

### Student Learning Outcomes

Students should be able to:
- Gain broad understanding in mathematics and statistics;
- Recognize importance and value of mathematical and statistical thinking, training, and approach to problem solving, on a diverse variety of disciplines.

### Unit I

**Data representation**

6 lectures

- Representation of Data: Histograms, Pie charts, 3D representation, Frequency distribution, Standard deviation, Skewness and Peakedness; Correlation and Regression: Correlation coefficients, Regression coefficients, Regression equation.

### Unit II

**Probability and uncertainty**

6 lectures

- Binomial formula, Probability-mutual and conditional, Gaussian and Poissonian distributions, Probability density function.

### Unit III

**Random variables and sampling**

6 lectures

- Random number generation and tables, Randomization experiments, Sampling survey, Error and Standard error, Double blind approach.

### Unit IV

**Inference of experimental data**

6 lectures

- The Null and Alternate hypothesis; Degree of significance and confidence; The Student t-test and t-distribution, Fisher’s F distribution, The Chi-square test, Goodness of fit; Analysis of variance (ANOVA) and related tools.

### Unit V

**Design and analysis of experiments**

6 lectures

- Design and analysis of experiments: Block design, One array/muti array design, Multi-factor design, Response plotting; Nonparametric statistics: Difficult populations and uncertain parameters, Distribution free methods.

### Recommended Textbooks and References:

Course Objectives

The objective of this laboratory course is to introduce students to experiments in biochemistry. The course is designed to teach students the utility of set of experimental methods in biochemistry in a problem oriented manner.

Student Learning Outcomes

On completion of this course, students should be able to:

• To elaborate concepts of biochemistry with easy to run experiments;
• To familiarize with basic laboratory instruments and understand the principle of measurements using those instruments with experiments in biochemistry.

Syllabus

1. Preparing various stock solutions and working solutions that will be needed for the course.
2. To prepare an Acetic-Na Acetate Buffer and validate the Henderson-Hasselbach equation.
3. To determine an unknown protein concentration by plotting a standard graph of BSA using UV-Vis Spectrophotometer and validating the Beer- Lambert's Law.
4. Titration of Amino Acids and separation of aliphatic, aromatic and polar amino acids by thin layer chromatography.
5. Purification and characterization of an enzyme from a recombinant source (such as Alkaline Phosphatase or Lactate Dehydrogenase or any enzyme of the institution's choice).
   a) Preparation of cell-free lysates
   b) Ammonium Sulfate precipitation
   c) Ion-exchange Chromatography
   d) Gel Filtration
   e) Affinity Chromatography
   f) Dialysis of the purified protein solution against 60% glycerol as a demonstration of storage method
   g) Generating a Purification Table (protein concentration, amount of total protein; Computing specific activity of the enzyme preparation at each stage of purification)
   h) Assessing purity of samples from each step of purification by SDS-PAGE Gel Electrophoresis
   i) Enzyme Kinetic Parameters: Km, Vmax and Kcat.
6. Experimental verification that absorption at OD_{260} is more for denatured DNA as compared to native double stranded DNA. reversal of the same following DNA renaturation. Kinetics of DNA renaturation as a function of DNA size.
7. Biophysical methods (Circular Dichroism Spectroscopy, Fluorescence Spectroscopy; UV-visible absorption specturm for proteins, Dynamic Light scattering analyses of native particle sizes in protein mixture and pure proteins; Assessing the sub-unit composition of an oligomeric protein).

Laboratory II: Cell and Molecular Biology

Course Objectives

The objective of this laboratory course is to introduce students to experiments in cell biology & molecular biology. The course is designed to teach students utility of set of experimental methods in cell biology & molecular biology in a problem oriented manner.

Student Learning Outcomes

On completion of this course, students should be able:

• To elaborate concepts of cell biology & molecular biology with easy to run experiments;
• To familiarize with basic laboratory instruments and understand principle
Credits

3

Syllabus

Cell Biology

1. Introduction to anatomy and functioning of upright and inverted microscope.
2. Handling and maintenance of microscopes.
3. Preparation of temporary and permanent slides of given samples.
4. Observation of suitable specimen under bright field, phase contrast, dark field and differential interference contrast (DIC) microscope.
5. Measurement of cell size by oculometer and stage micrometre.
6. To quantify number of cells present in given sample and assessment of cell viability.
7. Identification of Barr body by preparing buccal smear.
8. Low speed separation of cells from animal blood.
9. Isolation of lysosome from given samples (i.e. chicken liver) in isotonic sucrose method.
10. To study process of cellular osmosis in guard cells from plant leaves or animal blood.
11. To study cellular distribution of mitochondria by janus green staining.
12. Isolation of mitochondria from given tissue samples.
14. To assay activity of acid phosphatase enzyme in extract of wheat germ/moong dal and to determine its specific activity.

Syllabus

Molecular Biology

Isolation of Genomic DNA from Chicken blood or mouse tissues
1. Genomic DNA isolation, purification and quantification of DNA by DNA agarose gel, UV-visible spectrophotometer and NanoDrop method
2. EcoRI, BamH1 and HindIII digestion of total DNA, calculation of restriction endonuclease units, DNA ligation, Purification of His-tag protein on Ni-NTA columns

Analysis of RNA
1. Isolation of total RNA from mouse liver/blood using guanidine isothiocyanate \ method
2. Quantitation of RNA by spectrophotometer
3. Reverse transcriptase-PCR.

Polymerase chain reaction and its applications
1. cDNA synthesis from the total RNA using oligo dT primers
2. Quantitative PCR using real-time PCR machine
3. Nested-PCR, Multiplex PCR
4. RFLP, RAPD, DNA fingerprinting.

Conditional expression of genes
1. In Drosophila using the Gal4-UAS system (e.g crossing Dpp-Gal4 and UAS-eyeless flies for induction of ectopic eyes in legs and wings in progeny or crossing HS-Gal4 and UAS-GFP flies and examining GFP expression in progeny following heat shock).
# Semester Two

## Genetics

### Course Objectives
The primary objective of course is to provide strong fundamentals, and to broaden knowledge and understanding of genetics and genetic principles and their applications in genomics with an aim to develop skill sets required for independent and critical thinking.

### Student Learning Outcomes
On successful completion of this course, student is expected to have:
- Detailed understanding of molecular basis of heredity and genome;
- Comprehensive understanding of methodology used to decipher genetic process;
- Comprehensive understanding on quantification of heritable traits and underlying molecular mechanism;
- Ability to understand and analyze contemporary genetic studies reported in research papers.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Course Title</th>
<th>Credits</th>
<th>Lectures</th>
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<tbody>
<tr>
<td>I</td>
<td>Principle of segregation</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>II</td>
<td>Mendelian and non-mendelian genetics</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>III</td>
<td>Cytogenetics and developmental genetics</td>
<td>3</td>
<td>8</td>
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<tr>
<td>IV</td>
<td>Genetic variation and population genetics</td>
<td>3</td>
<td>8</td>
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<tr>
<td>V</td>
<td>Genetic linkage, chromosome mapping and inheritance</td>
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<td>8</td>
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</table>

### Introduction to genetics and its history, Structure of DNA, DNA as genetic material, Mechanism of DNA Replication, Cell Division, Mitosis and Meiosis, Recombination, DNA repair mechanism, Allele, Traits, Dominant and recessive.

### Mendelian Genetics: Introduction to human genetics; Background and history; Types of genetic diseases; Role of genetics in medicine; Human pedigrees; Patterns of single gene inheritance - autosomal recessive; autosomal dominant; X linked inheritance; Complicating factors - incomplete penetrance; variable expression; Multiple alleles; Codominance; Sex influenced expression; Hemoglobinopathies - Genetic disorders of hemoglobin and their diseases. Non-Mendelian inheritance patterns: Mitochondrial inheritance; genomic imprinting; Lyon hypothesis; isodisomy. Complex inheritance - genetic and environmental variation; Heritability; Twin studies; Behavioral traits; Analysis of quantitative and qualitative traits.

### Cytogenetics: Cell division and errors in cell division; Non disjunction; Structural and numerical chromosomal abnormalities – deletion; duplication; translocation; Sex determination; Role of Y chromosome; Genetic recombination; Disorders of sex chromosomes and autosomes; Molecular cytogenetics – Fluorescence In Situ Hybridization (FISH); Comparative Genomic Hybridization (CGH). Developmental genetics: Genes in early development; Maternal effect genes; Pattern formation genes; Homeotic genes and Signalling and adhesion molecules.

### Genetic variation: Mutations; kinds of mutation; agents of mutation; genome polymorphism; uses of polymorphism; Gene mapping and human genome project; Physical mapping; linkage and association. Population genetics and evolution: Phenotype; genotype; gene frequency; Hardy Weinberg law; Factors distinguishing Hardy Weinberg equilibrium; Mutation selection; Migration; Gene flow; Genetic drift; Human genetic diversity; Origin of major human groups.

### Genetic linkage and chromosome mapping: Genetic recombination, Principle and mechanism of genetic recombination, homologous recombination and its application in research, Map units, Markers, LOD values. Genetics of complex inheritance: Introduction to complex trait inheritance, establish inheritance pattern, Model population for studying complex inheritance, Multifactorial inheritance, Genetic Heterogeneity, Heritability, Mapping complex trait genes, Introduction to statistical methods.
### Course Objectives
The objectives of this course are to learn about structural features of components of immune system as well as their function. The major emphasis of this course will be on development of immune system and mechanisms by which our body elicits immune response. This will be imperative for students as it will help them to predict about nature of immune response that develops against bacterial, viral or parasitic infection, and prove it by designing new experiments.

### Student Learning Outcomes
On completion of this course, students should be able to:
- Evaluate usefulness of immunology in different pharmaceutical companies;
- Identify proper research lab working in area of their own interests;
- Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out kind of immune responses in the setting of infection (viral or bacterial).

### Recommended Textbooks and References:
2. *An Introduction to Genetic Analysis* by Griffiths, Wessler, Carroll and Doebley, (11th Edition), Macmillan Learning

### Immunology

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<th>Credits</th>
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**Unit I**
**Immunology: fundamental concepts and anatomy of the immune system**
6 lectures

- Components of innate and acquired immunity; phagocytosis; complement and inflammatory responses; pathogen recognition receptors (PRR) and pathogen associated molecular pattern (PAMP); innate immune response; mucosal immunity; antigens: immunogens, haptons; Major Histocompatibility Complex: MHC genes, MHC and immune responsiveness and disease susceptibility, HLA typing.

**Unit II**
**Immune responses generated by B and T lymphocytes**
7 lectures

- Immunoglobulins - basic structure, classes & subclasses of immunoglobulins, antigenic determinants; multigene organization of immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; principles of cell signaling; basis of self & non-self discrimination; kinetics of immune response, memory; B cell maturation, activation and differentiation; generation of antibody diversity; T-cell maturation, activation and differentiation and T-cell receptors; functional T Cell subsets; cell-mediated immune responses, ADCC; cytokines: properties, receptors and therapeutic uses; antigen processing and presentation- endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens; cell-cell co-operation, Hapten-carrier system.

**Unit III**
**Antigen-antibody interactions**
6 lectures

- Precipitation, agglutination and complement mediated immune reactions; advanced immunological techniques: RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence microscopy, flow cytometry and immunoelectron microscopy; surface plasmon resonance, biosensor assays for assessing ligand – receptor interaction; CMI techniques: lymphoproliferation assay, mixed lymphocyte reaction, cell cytotoxicity assays, apoptosis, microarrays, transgenic mice, gene knock outs.

**Unit IV**
**Vaccinology**
6 lectures

- Active and passive immunization: live, killed, attenuated, subunit vaccines; vaccine technology: role and properties of adjuvants, recombinant DNA and protein based vaccines, plant-based vaccines, reverse vaccinology; peptide vaccines, conjugate vaccines; antibody genes and antibody engineering: chimeric, generation of monoclonal antibodies, hybrid monoclonal antibodies; catalytic antibodies and generation of immunoglobulin gene libraries, idiotypic vaccines and marker vaccines, viral-like particles (VLPs), dendritic cell based vaccines, vaccine against cancer, T cell based vaccine, edible vaccine and therapeutic vaccine.
## Course Objectives

The objectives of this course are to inculcate understanding of anatomical organization of nervous system so that student is able to correlate functional aspects in subsequent stages of learning. Comparative approaches across species may be integrated to demonstrate homology and diversification.

## Student Learning Outcomes

On completion of this course, students should be able to demonstrate a solid understanding of basic neuroanatomy and nervous system function on a molecular, cellular and systems level.

### Unit I

**Structure of brain and CNS-I**

<table>
<thead>
<tr>
<th>Credits</th>
<th>6 lectures</th>
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</table>
| Gross anatomy of adult brain; organization of nervous system; Subdivisions of nervous system; Concept of CNS, ANS & PNS; The scalp, skull and meninges; Cerebrospinal fluid; Constitutions of CNS: Overview, Neuronal elements, basic circuit, synaptic action, dendritic properties and functional operation of axons.

### Unit II

**Structure of brain and CNS-II**

<table>
<thead>
<tr>
<th>Credits</th>
<th>6 lectures</th>
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</table>
| Peripheral nervous system: General organization, nerves, roots and ganglia; sensory endings; Spinal cord: Gross anatomy, internal structure, tracts of ascending and descending fibers, spinal reflexes; Brainstem: Medulla oblongata, pons, fourth ventricle, Midbrain, nuclei and tracts, reticular formation; Cranial nerves: Functional aspects, classification of cranial and spinal nerve components.

### Recommended Textbooks and References:


### Neuroanatomy

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<th>Credits</th>
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Immunity to infection: bacteria, viral, fungal and parasitic infections (with examples from each group); hypersensitivity: Type I-IV; autoimmunity; types of autoimmune diseases; mechanism and role of CD4+ T cells; MHC and TCR in autoimmunity; treatment of autoimmune diseases; transplantation: immunological basis of graft rejection; clinical transplantation and immunosuppressive therapy; tumor immunology; tumor antigens; immune response to tumors and tumor evasion of the immune system, cancer immunotherapy; immunodeficiency: primary immunodeficiencies, acquired or secondary immunodeficiencies, autoimmune disorder, anaphylactic shock, immunosenescence, immune exhaustion in chronic viral infection, immune tolerance, NK cells in chronic viral infection and malignancy.

Major histocompatibility complex genes and their role in autoimmune and infectious diseases, HLA typing, human major histocompatibility complex (MHC), Complement genes of the human major histocompatibility complex: implication for linkage disequilibrium and disease associations, genetic studies of rheumatoid arthritis, systemic lupus erythematosus and multiple sclerosis, genetics of human immunoglobulin, immunogenetics of spontaneous control of HIV, KIR complex.
Thalamus: Neuronal elements, basic circuit, synaptic action, dendritic properties and functional operation of thalamus; Scheme of thalamic organization, nuclei of thalamus; Functional aspects, classification of cranial and spinal nerve components; Neuronal elements, basic circuit, synaptic action, dendritic properties and functional operation of Basal ganglia: Corpus striatum, subthalamic nucleus, substantia nigra; Neuronal elements, basic circuit, synaptic action, dendritic properties and functional operation of Cerebellum: Gross anatomy, cerebellar cortex, central nuclei, cerebellar peduncles Functional anatomy of cerebellum; Neuronal elements, basic circuit, synaptic action, dendritic properties and functional operation of Cerebral cortex: Histology, general organization, functional localization.

Ascending sensory pathways; Descending motor pathways; Neuronal elements, basic circuit, synaptic action, dendritic properties and functional operation of Auditory system; Neuronal elements, basic circuit, synaptic action, dendritic properties and functional operation of Visual system; Neuronal elements, basic circuit, synaptic action, dendritic properties and functional operation of olfactory system and Limbic system.


Recommended Textbooks and References:

Course Objectives
Neural development is a complex process starting with specification of neurons from undifferentiated ectoderm. This course is designed to explore early events shaping the birth of neurons and signals necessary for the neurons to differentiate from one another to become brain.

Student Learning Outcomes
On completion of course, students should:
- Be conversant with basic areas of developmental neurobiology including neurogenesis, cell fate assignment, cell death, axon pathfinding and synaptogenesis;
- Understand techniques in developmental biology and neurobiology research.
**Unit I**  
**Early embryonic development and neural induction**  
5 lectures  
Major events in early embryonic development: Role of nucleus and cytoplasm, cleavage, formation of blastula and gastrula; Embryonic origin of nervous system; Early neural morphogenesis in vertebrates and invertebrates; Compensatory phenomenon in embryonic forms; Neural Induction: The organizer concept; Molecular nature of the Neural inducer; Conservation of neural induction; Dorsal neural tube and neural crest; Neural crest cells and its derivatives; Neural stem cells, Induced pluripotent stem cells (iPSCs) and stem cell therapies for neuroregenerative medicine.

<table>
<thead>
<tr>
<th>Unit II</th>
<th><strong>Patterning, polarity, determination and differentiation</strong></th>
<th>7 lectures</th>
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<td>Patterning; Polarity and regionalization of the nervous system: The anterior-posterior axis and Hox genes; Forebrain development; prosomeres and Pax genes; Patterning; Polarity and regionalization of nervous system: Dorsal-ventral polarity in neural tube; Neuronal determination and differentiation: Fate mapping of cell determination, Differentiation of nerve cells and cell lineage; Acquisition of neurotransmitter property and electrical excitability; Neurotrophic factors: Nerve growth factor (NGF), biological system of NGF; Agents analogous to NGF in functions; Role of NGF as trophic agents; Survival factors.</td>
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<tr>
<th>Unit III</th>
<th><strong>Genesis and migration of neurons</strong></th>
<th>7 lectures</th>
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<td></td>
<td>Birth and migration of neurons; Mechanism of cell movement; Migration of neurons in PNS and CNS; Control of neuronal and glial cell population; Histogenesis of cerebral cortex and cerebellar cortex; Neurogenesis in post-embryonic and adult age; Neuronal death during development: Programmed cell death, target dependent and innervation dependent neuronal death.</td>
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<tr>
<th>Unit IV</th>
<th><strong>Axon growth, guidance and synapse formation</strong></th>
<th>6 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Axon growth, path finding and nerve patterns: Axonal navigation, cell adhesion molecules; Factors influencing axon guidance; Target recognition; Synapse formation and elimination: Initiation of synaptic contacts, structure and function of newly formed synapses; Presynaptic and postsynaptic elements, target selection and synapse elimination; Selective synaptic connections: Skeletal muscle, autonomic ganglia, spinal cord and CNS.</td>
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<tr>
<th>Unit V</th>
<th><strong>Refinement and regeneration of synaptic connections</strong></th>
<th>5 lectures</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Rearrangement of developing neuronal connections: Synaptic rearrangement in different parts of nervous system; Refinement of synaptic connections; Maintenance of synapses; Denervation and regeneration of synaptic connections; Effects of Denervation on postsynaptic cell; Denervation super-sensitivity, susceptibility to innervation, and axonal sprouting; Regeneration in lower vertebrates and mammalian nervous system.</td>
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</table>

**Recommended Textbooks and References:**

Neurophysiology and Biophysics

Course Objectives
This course deals with study of electrical properties of neurons and signal processing at electrical and chemical synapses.

Student Learning Outcomes
At end of this course, students should be able to be familiar with neurophysiological basis of sensory, motor and higher functions in humans.

Unit I
Neural signals
7 lectures
Overview of neurons, synapses and networks; Stimulus to sensory perception to motor action / higher brain function; Chemical and electrical signalling within a circuit; Methods to record electrical activity of a neuron.

Unit II
Membrane potential and electrical activities of neurons
8 lectures
Electrical properties of excitable membranes: Basic electricity and electric circuits; Neurons as conductors of electricity; Equivalent circuit representation; Electrical properties of excitable membranes: Membrane conductance, linear and nonlinear membrane, ionic conductance, current-voltage relations; Ion movement in excitable cells: Physical laws, Nerst-Planck Equation, active transport of ions, movement of ions across biological membranes; Membrane potential and role of sodium and potassium pumps.

Unit III
Ion channels and action potential generation
8 lectures
Action potential; Non-gated ion channels and generation of action potential; Electrical properties of neurons, quantitative models of simulations; Hodgkin & Huxley's analysis of squid giant axon: Voltage-clamp experiments; Voltage gated channels; Biophysical, biochemical and molecular properties of voltage gated channels; Methods to record action potential.

Unit IV
Synaptic transmission
8 lectures
Principles of synaptic transmission: Electrical and chemical synapses; Calcium hypothesis; Synaptic vesicles; Control of transmitter release; Synaptic transmission at central synapses; Transmission at nerve-muscle junction; Ligand gated channels, their structures and major types; Second messengers and synaptic transmission; Methods for quantifying channels; Methods to study channel structure.

Recommended Textbooks and References:

Laboratory III: Neuroanatomy

Course Objectives
This course will give hands on experience of various techniques and procedures used to carry out dissection and analysis of nervous system related organs.

Student Learning Outcomes
On completion of this course, students should be able to:
- Dissect nervous system of model organisms;
- Study anatomy of dissected organs;
- Perform analysis of nervous system.
Syllabus

1. Dissection of nervous system in invertebrates and permissible vertebrates
2. Virtual dissection of nervous system of rat as experimental model
3. Procedure for removal of various parts of brain in rat and other experimental animals for further study
4. Perfusion techniques
5. Processing and handling of tissue for microanatomy of brain
6. Study of gross anatomy and pre-dissected human brain
7. Immunocytochemistry: Tissue processing, Immunoenzymatic and immunofluorescence methods
8. Whole mount immunofluorescence of fly embryo or zebrafish larvae

Course Objectives

This course will give hands on experience of various neuronal data analysis. It will also give brief overview to students on various techniques used for determination of different physiological parameters in neuroscience.

Student Learning Outcomes

On completion of this course, students should be able to:

- Acquire data from various sources;
- Determine and analyze various physiological parameters;
- Study different model organisms.

Credits

4

Laboratory IV: Neuro-physiology

Student Learning Outcomes

On completion of this course, students should be able to:

- Acquire data from various sources;
- Determine and analyze various physiological parameters;
- Study different model organisms.

Credits

4

Recommended Textbooks and References:

1. Practicals using low cost kits provided by Backyard Brains (https://backyardbrains.com/). Detailed experimental protocols are available at this website which may be modified to suit local needs.
2. Simulation exercises using the free online Nerve programme (http://nerve.bsd.uchicago.edu/). Pre-developed exercises are available at this website.
Semester Three

Neurochemistry and Neuropathology

Course Objectives
The goal is to introduce the basics of neurochemistry and relate it to neurochemical bases of brain disorders and neuropathology.

Student Learning Outcomes
On completion of course, students should be able to:
• Familiarize with current literature related to functions and diseases associated with neurotransmitter/neuromodulator;
• Formulate a hypothesis about structure-activity relationships between endogenous neurotransmitter, agonists and antagonists.

Unit I
Biosynthesis release and action of neurotransmitters
9 lectures
Biosynthesis, storage, release, distribution and action of excitatory amino acid neurotransmitters; Biosynthesis, storage, release and action of inhibitory neurotransmitters; Biosynthesis, storage, release and action of acetylcholine, dopamine, histamine and serotonin; Biosynthesis, storage, release and action of peptidergic neurotransmitters; Neurotransmitter receptor diversity, distribution, signalling mechanisms; G protein coupled receptors (GPCRs) and intracellular signalling and Neurotransmitter systems and behaviour.

Unit II
Brain metabolism
10 lectures
Cerebrospinal fluid; Microcirculation and blood brain and CSF barriers; Metabolism: Energy metabolism of brain.

Unit III
Neurochemistry of neurological disorders
11 lectures
Ischaemia and hypoxia; Epileptic seizure; Diseases involving myelin and demyelination; Nutritional and metabolic diseases; Neurotransmitters and disorders of basal ganglia; Biochemical aspects of psychotic disorders; Biochemical basis of mental illness: Anxiety disorders; Mood disorders; Schizophrenia; Drug addiction, drug abuse and adverse drug reaction; Genetic disorders of lipid, glycoprotein, mucopolysaccharide metabolism; Repeat expansion diseases; Proteinopathies; Disorders of RNA metabolism and Prion disease.

Recommended Textbooks and References:

Sensory and Motor Systems

Course Objectives
Sensory and motor systems are two important subfield of neuroscience that deals with anatomy and physiology of neuron that are part of different sensory and motor system. Understanding function of sensory and motor system will allow students to understand brain function in general.

Student Learning Outcomes
On completion of this course, students should be able to have a comprehensive understanding of sensory and motor systems including prevailing concepts on systems-level organization and neural signal mechanisms.
### Course Objectives

This subfield of neuroscience focuses on how different parts of our brain regulate function of important organs and some of our complex behaviour.

### Student Learning Outcomes

On completion of this course, students are expected to have a comprehensive understanding of chemical and electrical signal mechanisms of regulatory systems.

### Unit I

**Somatosensory system**  
6 lectures  
Introduction to systems approach to understand brain function; Peripheral receptors and sensory coding. Modality specific spinal pathways; Medullary, thalamic and cortical somatosensory structures and pathways; Somatosensory areas in cortex and their connection.

### Unit II

**Visual system**  
6 lectures  
Eye; Retina; Organization and connections of thalamic and midbrain visual areas; Cortical visual areas; Dorsal vs. ventral stream.

### Unit III

**Auditory system**  
6 lectures  
Tonotopy in the cochlea; Brainstem auditory nuclei; Delay lines; Thalamic nuclei and cortical auditory areas.

### Unit IV

**Olfactory and gustatory systems**  
7 lectures  
Peripheral receptors for each of chemical senses; Pathways to brain.

### Unit V

**Motor system**  
7 lectures  
Spinal, cerebellar and cortical motor pathways; Role of basal ganglion; Oculomotor pathways; Plasticity of nervous system.

### Recommended Textbooks and References:

### Course Objectives

Students will be exposed to basic understanding of evolution of human brain and behaviour, cognitive development, neural control of attention, sensory-motor integration, language acquisition and language processing, neural basis of learning and memory, and cognitive functions like thought, cognitive dysfunctions in aging & neurodegenerative disorders, and consciousness. These biological models of brain function will be linked with behavioural, affective and cognitive function and dysfunction. While this is the front line of neuroscience research today, students will be given basic elementary exposure to subject to stimulate them to undertake further research in this challenging area. It is essential to repeat that only introductory aspects of subject shall be dealt.

### Student Learning Outcomes

On completion of this course, students should be able to:

- Develop an awareness in learning and memory, control of movement, language, visual processing;
- Apply psychological concepts, theories, and research findings to solve problems in everyday life and in society;
- Understand major areas of applied psychology and neuroscience;
- Understand how basic research in psychopharmacology and neuroscience gives rise to treatment for addictions, movement and memory disorders and other neurological disorders;
- Develop capacity for independent learning that will sustain personal and professional development in rapidly changing field of neuroscience;
- Self-assess performance accurately; incorporates feedback for improved performance.
### Unit II
#### Cognition, aging and perception
14 lectures

Physical aspects of aging and cognition, lifestyles, habits and actions; Pathological processes in cognitive dysfunction like AD, PD and aging; Cognitive functions of motor system: understand how different parts of nervous system interact in higher cognitive functions, how neurological disturbances and illnesses can influence sensory, motor, cognitive and executive functions, Motor control and movements; Visual perception of objects: Neuronal basis of object recognition, Perception and recognition of specific classes of objects; Visual recognition disorders; Spatial cognition: Neural system of spatial cognition- Parietal cortex, Frontal cortex, Hippocampus and adjacent cortex.

### Unit III
#### Molecular basis of memory
14 lectures

Theories of learning and memory: Animals models system to study memory and mechanisms of short-term and long-term memory; lesson and Memory: Basic Systems: Basic mechanisms of learning, key insights from invertebrate studies, Classical / operant conditioning in vertebrates; Long-term potentiation (NMDAR dependent and NMDAR independent LTP, LTP between CA3-CA1 synapse, Different phases of LTP, properties of LTP)and long-term depression (NMDAR and Ca2+ dependence, LTD at CA3-CA1 synapse); Learning and memory: Brain systems, Major memory systems in mammalian brain, Multiple memory systems and behavior; Spatial memory; Memory consolidation, reconsolidation, extinction; Dynamic interplay between cognitive control & memory.

### Unit IV
#### Language, communication and consciousness
12 lectures

Attention: Varieties of attention and Neglect syndrome, Visual system and attention; Language and communication: Animal communication, Human language, Neuronal organization for language; Decision making executive brain functions: Role of prefrontal cortex, Neurophysiology of prefrontal cortex, Theories of prefrontal cortex function; Neurobiology of consciousness and unconsciousness.

### Recommended Text Books and References:


### Course Objectives

The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.

### Student Learning Outcomes

Students should be able to demonstrate the following abilities:

- Formulate a scientific question;
- Present scientific approach to solve the problem;
- Interpret, discuss and communicate scientific results in written form;
- Gain experience in writing a scientific proposal;
- Learn how to present and explain their research findings to the audience effectively.
Selection of research lab and research topic: Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them select a topic for their project. The topic of the research should be hypothesis driven. Review of literature: Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources. Writing Research Proposal: With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc. Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.

Students will have to present the topic of their project proposal after few months of their selection of the topic. They should be able to explain the novelty and importance of their research topic.

At the end of their project, presentation will have to be given by the students to explain work done by them in detail. Along with summarizing their findings they should also be able to discuss the future expected outcome of their work.

Course Objectives
This course will provide a collaborative learning experience, through a critical discussion of journal papers and writing assignments. This will develop understanding of what “neural systems” are, and value of this kind of analysis.

Student Learning Outcomes
Upon successful completion of this course, students should be able to:
- Identify “general systems properties” of neural mechanisms described in text form and formulate flow diagram descriptions of their processes;
- Relate concepts from systems theory and applied mathematics to analysis of models of neural function.

1. The instructor will assign papers from scientific literature on topic, unless otherwise stated.

2. Everyone is expected to complete reading before class for which it is assigned, assuming it has been assigned at least three days in advance.

Course Objectives
This course will give practical overview of the neuronal histochemistry of various model organisms.

Student Learning Outcomes
On completion of this course, students should be able to:
- Study and understand the basis of various neurodegenerative diseases;
- Stain various neurodegenerative diseases;
- Understand the histochemistry of various model organisms.
1. Study of brain pathology (using permanent slides) from different neurodegenerative disorders (Alzheimer’s, Huntington’s, Parkinson’s disease, ALS, Lafora disease)
2. Immunohistochemical staining of neurodegenerative disease brain using ubiquitin/other markers
3. Cellular model of neurodegeneration: Rotenone or paraquat model of cell death; study of apoptosis, Immunoblot analysis of important apoptotic markers.
4. Drosophila as a model organism to study neurodegeneration: Maintenance of transgenic fly for any neurodegenerative disorders (AD, PD or HD), Fly eye to study the process of neurodegeneration, genetic screening.

**Syllabus**

**Course Objectives**
This course will give brief information on experiment design, controls, analysis and interpretation of data rather than demonstrations.

**Student Learning Outcomes**
On completion of this course, students should be able to:
• Study various neurons associated with behavioural changes;
• Analyse the changes using various techniques on model organisms.

**Laboratory VI: Behavioural Biology**

**Credits**

3

**Syllabus**

1. Automated exploratory behaviour recording using activity monitor
2. Assessment of neuromuscular function/performance using Grip Strength Meter
3. Studies on locomotor behaviour in rats using Open Field test
4. Studies on spatial learning behaviour using T-maze with help of any Maze software
5. Studies on spatial learning behaviour using Y-maze with help of any Maze software
6. Elevated Plus maze for anxiety like behaviour with help of any Maze software
7. Morris water maze for learning and memory with help of any Maze software
8. Studies on locomotory development like: pivoting, traversing, homing, etc.
9. Behavioral studies using Drosophila or C. elegans (courtship, olfactory conditioning or aggression is easily demonstrable and quantifiable)
10. Optogenetic control of behaviour using Drosophila larvae or C. elegans.

**Recommended Textbooks and References:**

Course Objectives
The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.

Student Learning Outcomes
Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:

- In-depth knowledge of the chosen area of research.
- Capability to critically and systematically integrate knowledge to identify issues that must be addressed within framework of specific thesis.
- Competence in research design and planning.
- Capability to create, analyse and critically evaluate different technical solutions.
- Ability to conduct research independently.
- Ability to perform analytical techniques/experimental methods.
- Project management skills.
- Report writing skills.
- Problem solving skills.
- Communication and interpersonal skills.

Syllabus
Planning & performing experiments
Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

Syllabus
Thesis writing
At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.
**Course Objectives**
The course concentrates on technology, knowledge and business management aspect of intellectual property, including patenting aspect so as to:

- Focusses on use of IP to drive business models and value propositions;
- Provides insights to align IP strategies with overall corporate strategies;
- Shares best practice models for IP valuation.
- Learn biosafety and risk assessment of products derived from biotechnology and regulation of such products.
- Understand ethical issues in biological research.

**Student Learning Outcomes**
Students should be able to:

- Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents;
- Understand policy of companies and other technology-intensive organizations to build, manage and govern technology-based business;
- Understand systemic and cross-functional identification, control and governance of IP assets in sourcing, collaboration and exploitation.
- Gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research and environment release of genetically modified organisms, national and international regulations.
- Understand ethical aspects related to biological, biomedical, health care and biotechnology research.

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**Unit I**
**Introduction to intellectual property rights**
8 lectures

Concepts of IPR; Types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, plant variety protection and farmers rights act, International framework for the protection of IP (Introduction to history of GATT, WTO, WIPO and TRIPS), The economics behind development of IPR: Company perspective, IP as a factor in R&D and of relevance to biotechnology.

**Unit II**
**Patenting**
8 lectures

Basics of Patents, Indian Patent Act 1970 with Patent Rules 2003 (including recent amendments and Budapest Treaty), Patent application - forms and guidelines including those of National Biodiversity Authority (NBA) and other regulatory bodies, fee structure, time frames; provisional and complete specifications, filing of a patent application; precautions before patenting - disclosure/non-disclosure, concept of “prior art”, patent databases including patent search, analysis and report formation., Patent Cooperation Treaty (PCT) and procedure for filing a PCT application and costs (PCT and conventional patent applications), Patent infringement- meaning, scope, litigation, case studies and examples.

**Unit III**
**Business of intellectual property**
8 lectures

Concept of using intellectual property and identifying intellectual assets and link them to business strategy to maximize value generation, commercialization of patented innovations; licensing – outright sale, licensing, royalty; collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives; Aligning of IP strategies with overall corporate strategies; Development of organizational capabilities to strengthen IP management as a core business activity; Addressing issues such as R&D collaboration, strategic partnering, standards, patent pools, licensing and open business models; Value creation in knowledge-based business with valuation of intellectual property.
Risks common to most everyday work places such as electrical and fire hazards, specific hazards associated with handling and manipulating human or animal cells and tissues, as well as toxic, corrosive or mutagenic solvents and reagents, accidental punctures with syringe needles or other contaminated sharps, spills and splashes onto skin and mucous membranes, ingestion through mouth pipetting, and inhalation exposures to infectious aerosols.

Regulations and recommendations for biosafety, ascending levels of containment, Defining microbiological practices, safety equipment and facility safeguards for corresponding level of risk associated with handling a particular agent.

Safety Data Sheet (SDS), also referred to as Material Safety Data Sheet (MSDS), physical data such as melting point, boiling point, and flash point, information on substance’s toxicity, reactivity, health effects, storage, and disposal, as well as recommended protective equipment and procedures for handling spills. Introduction to Safety equipment in a laboratory includes primary barriers personal protective equipment (PPE).

Guidelines for safe laboratory practices, role of institution’s safety committee and rules and regulations pertaining to laboratory safety.

History and philosophy of bioethics, clinical ethics, research ethics, law and bioethics, neuroethics; Practical issues of bioethics, awareness about ethical guidelines and regulations to be followed when human participants are involved in biomedical research etc.

**Recommended Textbooks and References:**


**Recommended Electives**

**Computational Neuroscience**

**Course Objectives**

The objective of this course is to study information processing in brain using mathematical modelling.

**Student Learning Outcomes**

On completion of this course, students should understand key concepts concerning electrical properties underlying information processing in nervous system, how networks of individual neurons can together perform computations, and how systems of such networks operate together to solve tasks such as visual perception and motor behaviour.
Introduction to dynamical system; Spiking neuron as a dynamic system; Phase portraits, why is it useful to study ion channel dynamics in phase space; Bifurcations, resting, spiking, periodic spiking, bursting.

Linear systems, Differential equations, Hodgkin-Huxley model, Fitzhugh-Nagumo model.


Neuronal populations, macroscopic recording, pulse to wave conversion, basics of EEG and MEG, neuro-electromagnetism, Field theoretical approaches.

Introduction to neuronal decoding and information theory, entropy, mutual information.

Recommended Textbooks and References:

Course Objectives
The aim of this course is to provide a comprehensive overview of exciting developments in neurogenetics research and molecular and cellular mechanisms that are disrupted in disorders that affect nervous system.

Student Learning Outcomes
After completion of this course, students should be able to:
- Describe complete range of monogenetic defects that result in neurodevelopmental disorders;
- Describe epigenetic modifications that affect learning, memory, behavior and discuss trans-generational epigenetic inheritance;
- Apply principles of neurophysiology to study synaptic plasticity in rodent models for neurodevelopmental disorders.

Unit I
Neuronal assembly
6 lectures
Major regions of human brain; Cellular components of nervous tissue; Sub-cellular organization of nervous system; Membrane potential and action potential; neurotransmitters.

Unit II
Genetic aspect of learning and memory
5 lectures
Genetics of learning and memory; Genetic approaches to circadian rhythms.
Modern sequencing technique: applications in neuroscience; Transgenics and their application in neurogenetic analysis; Gene targeting technologies and their application in neuroscience; Optogenetics and Pharmacogenetics in neuroscience.

Nature-nurture and behaviour; Genetic experiments to investigate animal behaviour: Selection Studies, Inbred strain studies, studies in genetic model organisms; Identifying genes for controlling behavior: Induced mutations, Quantitative trait loci; Synteny/orthology; Investigating genetics of human behaviour; Twin and adoption study designs, interpreting heritability; Linkage and association studies; Environmental influence-shared and non-shared environment.

Genetics of psychopathology: Schizophrenia, mood disorders, disorders of childhood neurogenetic disorders; Spinomuscular atrophy; Syndromes due to triplet nucleotide expansion; Alzheimer’s disease; Parkinson’s disease.

Recommended Textbooks and References:
DBT Supported Teaching Programme

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<tr>
<th>S.No.</th>
<th>Name of University</th>
<th>Contact Details of Course Coordinator</th>
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</table>
| 1.    | Jiwaji University, Gwalior              | Prof. Ishan Patro  
School of Studies in Neuroscience  
0751-2442789, 4016789  
09425110063 (M)  
ishanpatro@gmail.com |

Annexure I

Subject Specific Subcommittee of M.Sc. Neuroscience

Chairperson
1. Dr. Ishan Patro, Professor and Coordinator, School of Studies in Neuroscience, Jiwaji University, Gwalior

Members
2. Dr. S. Ganesh, Dean, Research & Development and Professor, Department of Biological Sciences and Bioengineering, Indian Institute of Technology, Kanpur
3. Dr. Nihar Ranjan Jana, Professor and Scientist-VI, National Brain Research Centre, Manesar
4. Dr. Aurnab Ghose, Associate Professor, Department of Biology, Indian Institute of Science Education and Research, Pune
5. Dr. Amal Mondal, Associate Professor, School of Life Sciences, Jawaharlal Nehru University, New Delhi

Member Secretary
6. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi
M.V.Sc. Animal Biotechnology
Introduction

Background

Promotion of Indian Biotechnology sector is high on policy agenda of Government of India. Biotechnology has also been recognized as one of the key priority sectors under ‘Make in India,’ ‘Skill India’ and ‘Startup India’ initiatives of Government of India, as it is one of sectors expected to contribute towards enterprise creation, innovation and economic growth. Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India has immensely contributed to this dynamism through various policies and initiatives, establishment of innovation clusters, academia-industry partnerships, increasing capabilities for technology development, etc. The National Biotechnology Development Strategy (2015 – 2020) released by DBT provides a strategic roadmap for India’s emergence as a global biotechnology innovation and manufacturing hub. It has also highlighted importance of human resource development and need for nurturing tailor-made human capital for advanced scientific research and entrepreneurship.

DBT has taken a number of initiatives aimed at integrated human resource development to evolve an ecosystem where scientists, innovators and future entrepreneurs can be nurtured. Keeping in mind requirement for trained manpower in various areas of Biotechnology, DBT initiated Post-Graduate Teaching Programme way back in 1985 with 5 universities which has expanded to 74 universities imparting M.Sc./M.Tech./M.V.Sc. degrees in general, agricultural, animal, food, environmental, industrial marine, medical, neuroscience and pharmaceutical biotechnology. 10 programmes are being phased out. These universities and institutes are provided liberal financial support towards strengthening of laboratory facilities, equipment, consumables, fellowships to students, dissertation grant per student etc. Post-Graduate Teaching Programme selects best students and trains them to join research or industry workforce contributing significantly to biotechnology workforce.

About the Course Curriculum Revision Exercise

Taking into cognizance the changing needs of the economy and to keep abreast with latest developments in the field of biotechnology, DBT proactively initiated revision of course curricula of Post-Graduate Programmes in biotechnology. The present exercise has been undertaken by Biotech Consortium India Limited (BCIL), New Delhi. Earlier exercise was carried out in 2008. The Course Curriculum Revision Exercise has been carried out for 13 Post-Graduate programmes in Biotechnology supported by DBT.

The revision of course curriculum of M.VSc. Animal Biotechnology aims to address mismatch between ‘knowledge’ gained by students and appropriate skill set required for technology development and implementation including present contemporary needs of economy.

Methodology

A meticulous and structured approach has been adopted to accomplish the Course Curriculum Revision exercise.

BCIL had initiated the exercise with a review of literature of relevant national and international documents on curriculum design and planning for biotechnology programmes of premier national as well as international universities, guidelines by University Grants Commission, recent curricular guidelines released by Indian Council of Agricultural Research, Ministry of Health and Family Welfare and Indian Institute of Science Education & Research and other relevant research papers on curriculum development in peer-reviewed journals.
The findings of the literature review were adopted to design questionnaires for eliciting feedback from stakeholders of Biotechnology community i.e. academicians, scientists, industry representatives and students. Feedback was received from 165 experts and 20 students belonging to academic institutions, research organizations and industry regarding addition of advanced topics, deletion of elementary, redundant and overlapping topics, updation of laboratory practicals, re-adjustment of credit load, incorporating ‘technology’ component in the curriculum, among others. It was also suggested that re-orientation of curricula should be done keeping in view the needs of the industry.

**Strategic Approach**

A Core Committee along with 9 subject specific subcommittees comprising of 63 academicians, scientists and industry representatives were constituted to revise and update the curricula. The constitution of subject specific subcommittee for Animal Biotechnology is given at Annexure-1.

The salient recommendations identified from stakeholder survey were presented to the Committee. Several brainstorming discussion sessions were held for achieving the desired balance between the foundation courses, recent developments in biotechnology and updation needs identified during the stakeholder survey. Core Committee finalized broad contours for revising all the course curricula. The guidelines set by the Core Committee were taken up by the subject specific subcommittee of M.V.Sc. Animal Biotechnology for updating the curriculum. The subject specific subcommittee incorporated latest advancements in areas of Animal Biotechnology in the curriculum. Separate meeting was held to discuss and deliberate the updations to be made in the curriculum. The revised curriculum was vetted and finalized by the Core Committee.

**Course Curriculum Revision**

The members of Committee agreed that revised course curriculum should provide skill and outcome based education and help the students to gain domain knowledge, ability to design and interpret research experiments and acquire effective communication skills. The course curriculum has been re-designed accordingly to promote skill-based and outcome-based education. The revised course curriculum totals to 94 credits comprising of theory, practical, technology-based topics, electives and dissertation. Each course includes learning objectives, student learning outcomes, course plan (number of lectures/unit) and reference textbooks/resources. Theory and practical courses include relevant examples, case scenarios and tutorials for inculcating critical thinking against rote learning. Several new courses have been included and content for existing courses has also been updated. Applications of biotechnological interventions for animal production and healthcare including Genome Editing, Embryo Manipulation, Reproductive Biotechnology, Modern Drug and Vaccine Delivery Systems, etc. to name a few have been included. With importance of students being able to execute research projects independently, separate credits have been allotted for proposal preparation and presentation before initiating dissertation and also credits for dissertation have been increased accordingly.

We hope that model course curriculum shall serve as guidelines for academicians and researchers from different parts of the country for adoption in their institutions with modifications as per availability of expertise, infrastructure and specific needs.

We wish to put on record our sincere appreciation for constant guidance and encouragement received from Dr. K. VijayRaghavan, Secretary, DBT for bringing out this publication. We wish to acknowledge whole-hearted support of Core Committee and subject specific subcommittees members. Sincere thanks are due to Dr. Manoj Singh Rohilla, Scientist- D, DBT, Ms. Shweta for creative design, Mrs. Rita Bhatla, DBT and Shri. Dilip Joy, BCIL.
Rapid technological advancements in the recent time and development of new nucleic acid based molecular tools have made a great impact on research and development in all areas of biological sciences. As a multidisciplinary area of research, biotechnology has also undergone a rapid change in the recent past. With the introduction of novel technologies in animal production and healthcare, the area of animal biotechnology has brought to the fore the potential application of these tools and techniques for improving productivity of livestock to ensure food security to the burgeoning population.

Keeping in view the evolving face of biotechnological applications in the recent time, it is very essential to review the academic curricula in biotechnology so as to acquaint the students to the latest advancements in their field of study. It is with this objective that the current exercise of revising the course curricula of DBT-supported Biotechnology programmes was initiated. In the process of revision of the Animal Biotechnology curriculum, in one hand, it has been our attempt to include all the foundation courses relevant to the multidisciplinary area of biotechnology, while on the other, special attention has also been paid to incorporate the latest developments in the specialized area of Animal Biotechnology including application of the emerging tools for biotechnological intervention in animal production and healthcare which include the modern tools for genome editing, embryo manipulation and reproductive biotechnology, modern drug and vaccine delivery systems, etc. to name a few. A few new courses like Research Methodology and Scientific Communication Skills, Critical Analysis of Landmark Discoveries, Bioentrepreneurship, and Intellectual Property Rights, Biosafety and Bioethics have also been introduced with a view to make the students more industry ready for ensuring better employability. The elective courses have been divided into three groups so that a student may opt for any two elective courses from a single group and can develop additional skill in a particular area of animal biotechnology.

I gratefully acknowledge the active participation and suggestions from all the learned members of the Animal Biotechnology Sub-committee during the process of revision. I also thank the Chairman and the members of the Core Committee for their suggestions and support. Special appreciations are due to Ms. Shreya Malik and her team from BCIL, New Delhi for their proactive role and efficient coordination throughout the entire process of revision.
M.V.Sc. Animal Biotechnology

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<td>Laboratory I: Techniques in Molecular Biology and Genetic Engineering</td>
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<td>Introduction to Bioinformatics</td>
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<td>Bioprocess Engineering and Technology</td>
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<td>Research Methodology and Scientific Communication Skills</td>
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<td>Critical Analysis of Landmark Discoveries</td>
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**Recommended Electives:**
(Elective-I and Elective-II should preferably be selected from the same group)

**Group A:**

**Group B:**

**Group C:**
Course Objectives
The objectives of this course are to build upon undergraduate level knowledge of biochemical principles with specific emphasis on different metabolic pathways. The course shall make the students aware of various disease pathologies within the context of each topic.

Student Learning Outcomes
Students should be able to:
- Gain fundamental knowledge in biochemistry;
- Understand the molecular basis of various pathological conditions from the perspective of biochemical reactions.

Unit I
Protein structure
5 lectures
Chemical basis of life: composition of living matter; Water – properties of water, essential role of water for life on earth, pH, buffer, pH optima of different enzymes (pepsin, trypsin and alkaline phosphatase), ionization and hydrophobicity, emergent properties of biomolecules in water, biomolecular hierarchy, macromolecules, molecular assemblies; Structure-function relationships: amino acids – structure and functional group properties, peptides and covalent structure of proteins, elucidation of primary and higher order structures, Ramachandran plot, evolution of protein structure, protein degradation and introduction to molecular pathways controlling protein degradation, structure-function relationships in model proteins like ribonuclease A, myoglobin, hemoglobin, chymotrypsin etc.; Protein folding: Anfinsen's Dogma, Levinthal paradox, cooperativity in protein folding, free energy landscape of protein folding and pathways of protein folding, molten globule state, chaperons, and diseases associated with protein folding, introduction to molecular dynamic simulation.

Unit II
Enzyme kinetics
4 lectures
Enzyme catalysis – general principles of catalysis; quantitation of enzyme activity and efficiency; enzyme characterization and Michaelis-Menten kinetics; relevance of enzymes in metabolic regulation, activation, inhibition and covalent modification; single substrate enzymes; concept of catalytic antibodies; catalytic strategies with specific examples of proteases, carbonic anhydrases, restriction enzymes and nucleoside monophosphate kinase; regulatory strategies with specific example of hemoglobin; isozymes; role of covalent modification in enzymatic activity; zymogens.

Unit III
Glycobiology
2 lectures
Sugars - mono, di, and polysaccharides with specific reference to glycogen, amylose and cellulose, glycosylation of other biomolecules - glycoproteins and glycolipids; lipids - structure and properties of important members of storage and membrane lipids; lipoproteins.

Unit IV
Structure and functions of DNA and RNA
3 lectures
Self-assembly of lipids, micelle, biomembrane organization - sidedness and function; membrane bound proteins - structure, properties and function; transport phenomena; nucleosides, nucleotides, nucleic acids - structure, a historical perspective leading up to the proposition of DNA double helical structure; difference in RNA and DNA structure and their importance in evolution of DNA as the genetic material.

Unit V
Bio-energetics
14 lectures
Bioenergetics-basic principles; equilibria and concept of free energy; coupled interconnecting reactions in metabolism; oxidation of carbon fuels; recurring motifs in metabolism; Introduction to GPCR, glycolysis and gluconeogenesis; reciprocal regulations and non-carbohydrate sources of glucose; Citric acid cycle, entry to citric acid cycle, citric acid cycle as a source of biosynthetic precursors; Oxidative phosphorylation; importance of electron transfer in oxidative phosphorylation; F\textsubscript{1}-F\textsubscript{0} ATP Synthase; shuttles across mitochondria; regulation of oxidative phosphorylation; pentose
phosphate pathway; glycogen metabolism, reciprocal control of glycogen synthesis and breakdown, roles of epinephrine, glucagon and insulin in glycogen metabolism; Fatty acid metabolism; protein turnover and amino acid catabolism; nucleotide biosynthesis; biosynthesis of membrane lipids and sterols with specific emphasis on cholesterol metabolism and mevalonate pathway; logic and integration of central metabolism; entry/exit of various biomolecules from central pathways; principles of metabolic regulation; steps for regulation.

Practicals:
1. Preparing various stock solutions and working solutions that will be needed for the course.
2. To prepare an Acetic-Na Acetate Buffer and validate the Henderson-Hasselbach equation.
3. To determine an unknown protein concentration by plotting a standard graph of BSA using UV-Vis Spectrophotometer and validating the Beer-Lambert’s Law.
4. Titration of Amino Acids and separation of aliphatic, aromatic and polar amino acids by thin layer chromatography.
5. Purification and characterization of an enzyme from a recombinant source (such as Alkaline Phosphatase or Lactate Dehydrogenase or any enzyme of the institution’s choice).
   a) Preparation of cell-free lysates
   b) Ammonium Sulfate precipitation
   c) Ion-exchange Chromatography
   d) Gel Filtration
   e) Affinity Chromatography
   f) Generating a Purification Table (protein concentration, amount of total protein)
   g) Computing specific activity of the enzyme preparation at each stage of purification
   h) Assessing purity of samples from each step of purification by SDS-PAGE Gel Electrophoresis
   i) Enzyme Kinetic Parameters: Km, Vmax and Kcat.
   j) Dialysis of the purified protein solution against 60% glycerol as a demonstration of storage method
6. Experimental verification that absorption at OD_{260} is more for denatured DNA as compared to native double stranded DNA.

Recommended Textbooks and References:

Course Objectives
The objectives of this course are to sensitize the students to the fact that as we go down the scale of magnitude from cells to organelles to molecules, the understanding of various biological processes becomes deeper and inclusive.

Student Learning Outcomes
Student should be equipped to understand three fundamental aspects in biological phenomena: a) what to seek; b) how to seek; c) why to seek?
Universal features of cells; cell chemistry and biosynthesis: chemical organization of cells; internal organization of the cell - cell membranes: structure of cell membranes and concepts related to compartmentalization in eukaryotic cells; intracellular organelles: endoplasmic reticulum and Golgi apparatus, lysosomes and peroxisomes, ribosomes, cellular cytoskeleton, mitochondria, chloroplasts and cell energetics; nuclear compartment: nucleus, nucleolus and chromosomes.

Chromatin organization - histone and DNA interactome: structure and assembly of eukaryotic and prokaryotic DNA polymerases, DNA-replication, repair and recombination; chromatin control: gene transcription and silencing by chromatin-Writers, Readers and Erasers; Transcriptional control: Structure and assembly of eukaryotic and prokaryotic RNA Polymerases, promoters and enhancers, transcription factors as activators and repressors, transcriptional initiation, elongation and termination; post-transcriptional control: splicing and addition of cap and tail, mRNA flow through nuclear envelope into cytoplasm, breakdown of selective and specific mRNAs through interference by small non-coding RNAs (miRNAs and siRNAs), protein translation machinery, ribosomes-composition and assembly; universal genetic codes, degeneracy of codons, Wobble hypothesis; Iso-accepting tRNA; mechanism of initiation, elongation and termination; co- and post-translational modifications, mitochondrial genetic code translation product cleavage, modification and activation.

Molecular mechanisms of membrane transport, nuclear transport, transport across mitochondria and chloroplasts; intracellular vesicular trafficking from endoplasmic reticulum through Golgi apparatus to lysosomes/cell exterior.

Cell cycle and its regulation; cell division: mitosis, meiosis and cytokinesis; cell differentiation: stem cells, their differentiation into different cell types and organization into specialized tissues; cell-ECM and cell-cell interactions; cell receptors and transmembrane signalling; cell motility and migration; cell death: different modes of cell death and their regulation.

Isolation of cells and basics of cell culture; observing cells under a microscope, different types of microscopy; analyzing and manipulating DNA, RNA and proteins.

Mutations, proto-oncogenes, oncogenes and tumour suppressor genes, physical, chemical and biological mutagens; types of mutations; intra-genic and inter-genic suppression; transpositions- transposable genetic elements in prokaryotes and eukaryotes, role of transposons in genome; viral and cellular oncogenes; tumor suppressor genes; structure, function and mechanism of action; activation and suppression of tumor suppressor genes; oncogenes as transcriptional activators.

Recommended Textbooks and References:
### Animal Cell Culture Technology

#### Course Objectives
The objectives of this course is to educate students about the fundamental concepts of animal cell system, bioprocess technology using eukaryotic system and their related applications, thus preparing them to meet the challenges of the new and emerging areas of biotechnology industry.

#### Student Learning Outcomes
Students should be able to gain strong understanding on animal based cell cultures system. This will help them to take up animal based biological research as well as placement in the relevant biotech industry. They will be able to analyse the bioprocess from an economics/market point of view.

<table>
<thead>
<tr>
<th>Unit I</th>
<th>Cell culture laboratory design and equipments</th>
<th>5 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Planning, construction and services; Layout; Sterile handling area; Incubation; Hot room; Air circulation; Service bench; Laminar flow; Sterilizer; Incubator; CO2 incubator; Refrigerators and freezers; Centrifuge; Inverted stage microscope; Magnetic stirrer; Liquid nitrogen freezers; Slow cooling system for cell freezing; Water bath; Autoclaves and hot air oven; Pipette washers; Water purification system; Fluid handling systems and other equipments; Washing, packing and sterilization of different materials used in animal cell culture; Aseptic concepts; Maintenance of sterility; Cell culture vessels.</td>
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<tr>
<th>Unit II</th>
<th>Media and reagents</th>
<th>5 lectures</th>
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<td></td>
<td>Types of cell culture media; Ingredients of media; Physiochemical properties; CO2 and bicarbonates; Buffers; Oxygen; Osmolarity; Temperature; Surface tension and foaming; Balance salt solutions; Antibiotics, growth supplements; Foetal bovine serum; Serum free media; Trypsin solution; Selection of medium and serum; Conditioned media; Other cell culture reagents; Preparation and sterilization of cell culture media, serum and other reagents.</td>
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<tr>
<th>Unit III</th>
<th>Different types of cell cultures</th>
<th>6 lectures</th>
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<td>History of animal cell culture; Different tissue culture techniques; Types of primary culture; Chicken embryo fibroblast culture; Chicken liver and kidney culture; Secondary culture; Trypsinization; Cell separation; Continuous cell lines; Suspension culture; Organ culture; Behaviour of cells in culture conditions: division, growth pattern, metabolism of estimation of cell number; Development of cell lines; Characterization and maintenance of cell lines, stem cells; Cryopreservation; Common cell culture contaminants.</td>
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<th>Unit IV</th>
<th>Applications</th>
<th>6 lectures</th>
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<tr>
<td></td>
<td>Cell cloning and selection; Transfection and transformation of cells; Commercial scale production of animal cells, stem cells and their application; Application of animal cell culture for in vitro testing of drugs; Testing of toxicity of environmental pollutants in cell culture; Application of cell culture technology in production of human and animal viral vaccines and pharmaceutical proteins.</td>
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<tr>
<th>Unit V</th>
<th>Scale-up</th>
<th>5 lectures</th>
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<td></td>
<td>Cell culture reactors; Scale-up in suspension; Scale and complexity; Mixing and aeration; Rotating chambers; Perfused suspension cultures; Fluidized bed reactors for suspension culture; Scale-up in monolayers; Multisurface propagators; Multiaxial rollers and tubes; Roller culture; Microcarriers; Perfused monolayer cultures; Membrane perfusion; Hollow fibre perfusion; Matrix perfusion; Microencapsulation; Growth monitoring.</td>
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Infection and Immunity

Course Objectives
The objectives of this course are to impart knowledge about host-parasite interactions and immune-biology of infectious diseases of domestic animals.

Student Learning Outcomes
On completion of this course, students should be able to:

• Gain in-depth knowledge of infection biology;
• Gain information of immune mechanisms against infectious agents;
• Understand skills in measuring immunity against infectious agents in vitro and in vivo;
• Get sensitized to ‘One-Health’ concept of infectious disease management.

Unit I
Infectious agents and infection biology
9 lectures

Origin and conceptual history of infection and immunity; Nature and categories of infectious agents; Host-parasite-environment interactions; Pathogenicity and virulence determinants of infectious agents; Omics and systems biology approaches to host-pathogen interactions.

Unit II
Host Immunity
9 lectures

Common themes of barrier defenses, innate and adaptive immune mechanisms against infectious diseases in domestic animals; Immune escape/subversion by pathogens and immune-mediated pathology; Immunobiology of major viral, bacterial and fungal diseases of animals.

Unit III
Immunological approaches to prevention and control of infectious diseases
9 lectures

Immune interventions of infectious diseases; Preventive immunization with traditional and modern vaccines against infectious diseases of domestic animals; Immune correlates of protection against infectious disease; Pathogenesis-informed approaches to therapeutics and vaccines against infectious diseases.

Practicals:
1. Demonstration of innate immune responses in vitro in infected animal models:
   a) Phagocytosis by neutrophils and macrophages

Recommended Textbooks and References:
b) Complement activation by lectin and alternate pathways

c) LPS-mediated TLR4 activation of macrophages

2. Demonstration of humoral immune responses in animals exposed to infection:
   a) Antibody levels in serum, milk and other fluids by ELISA

3. Demonstration of cellular immune responses in animals exposed to infection:
   a) Delayed Type Hypersensitivity in laboratory animal models
   b) Th1 and Th2 cytokines by sandwich ELISA
   c) CTLs by granzyme B ELISPOT assay

4. Laboratory animal immunization to demonstrate primary and secondary immune response curves

5. Toxin neutralization by antitoxin in vitro

6. Pathogen challenge of vaccinated laboratory animals.

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**Recommended Textbooks and References:**


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**Course Objectives**

The course is intended to provide an overview and current developments in different aspects of vaccine biotechnology.

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**Student Learning Outcomes**

On completion of this course, students should be able to gain knowledge about

- Conventional and new generation vaccines;
- Adjuvants, immunomodulators and modern vaccine delivery systems.

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**Unit I**

**History & evolution of vaccines**

5 lectures

History and evolution of vaccines; Overview of vaccine immunology: how vaccines work; Human vs veterinary vaccines.

---

**Unit II**

**Classification of vaccines**

11 lectures

Types of vaccines: Conventional vaccines; Live, attenuated and killed vaccines; New generation vaccines; Subunit vaccines; Synthetic peptide vaccines; Anti-idiotype vaccines; Recombinant DNA vaccines; Deleted mutant vaccines; Reassortment vaccines; Marker vaccines; DNA vaccines; Edible vaccines; Virus like particles, Core like particles, Design of Microneedles Formulations for Vaccine Delivery.

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**Unit III**

**Vaccine delivery**

8 lectures

Adjuvants: Conventional and New generation vaccine adjuvants; Carriers; Haptens; Vaccine delivery using nanoparticles; Non-specific immunostimulators; low molecular weight immuno-modulators, Micro-fractional delivery of powdered vaccines into the
Genetic Engineering

Course Objectives
The objectives of this course are to teach various approaches to conducting genetic engineering and their applications in biological research as well as in biotechnology industries. Genetic engineering is a technology that has been developed based on our fundamental understanding of the principles of molecular biology and this is reflected in the contents of this course.

Student Learning Outcomes
Given the impact of genetic engineering in modern society, the students should be endowed with strong theoretical knowledge of this technology. In conjunction with the practicals in molecular biology & genetic engineering, the students should be able to take up biological research as well as placement in the relevant biotech industry.

Unit I
Introduction and tools for genetic engineering
6 lectures
Impact of genetic engineering in modern society; general requirements for performing a genetic engineering experiment; restriction endonucleases and methylases; DNA ligase, Klenow enzyme, T4 DNA polymerase, polynucleotide kinase, alkaline phosphatase; cohesive and blunt end ligation; linkers; adaptors; homopolymeric tailing; labelling of DNA: nick translation, random priming, radioactive and non-radioactive probes, hybridization techniques: northern, southern, south-western and far-western and colony hybridization, fluorescence in situ hybridization.

Unit II
Different types of vectors
7 lectures
Plasmids; Bacteriophages; M13 mp vectors; PUC19 and Bluescript vectors, hagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Principles for maximizing gene expression expression vectors; pMal; GST; pET-based vectors; Protein purification; His-tag; GST-tag; MBP-tag etc.; Intein-based vectors; Inclusion bodies; methodologies to reduce formation of inclusion bodies; mammalian expression and replicating vectors; Baculovirus and Pichia vectors system, plant based vectors, Ti and Ri as vectors, yeast vectors, shuttle vectors.

Unit IV
Safety of vaccines
2 lectures
Standardization of vaccines; Safety, sterility and potency testing.

Practicals:
1. Propagation of bacterial/viral cultures for antigen preparation
2. Attenuation and inactivation methods
3. Preparation of adjuvants
4. Preparation of live or killed vaccine
5. Immunization of animals, bleeding and testing antibody response by serological methods like ELISA/Western blot.

Recommended Textbooks and References:
Unit III
Different types of PCR techniques
7 lectures
Principles of PCR: primer design; fidelity of thermostable enzymes; DNA polymerases; types of PCR – multiplex, nested; reverse-transcription PCR, real time PCR, touchdown PCR, hot start PCR, colony PCR, asymmetric PCR, cloning of PCR products; T-vectors; proof reading enzymes; PCR based site specific mutagenesis; PCR in molecular diagnostics; viral and bacterial detection; sequencing methods; enzymatic DNA sequencing; chemical sequencing of DNA; automated DNA sequencing; RNA sequencing; chemical synthesis of oligonucleotides; mutation detection: SSCP, DGGE, RFLP.

Unit IV
cDNA analysis
7 lectures
Insertion of foreign DNA into host cells; transformation, electroporation, transfection; construction of libraries; isolation of mRNA and total RNA; reverse transcriptase and cDNA synthesis; cDNA and genomic libraries; construction of microarrays – genomic arrays, cDNA arrays and oligo arrays; study of protein-DNA interactions: electrophoretic mobility shift assay; DNase I footprinting; methyl interference assay, chromatin immunoprecipitation; protein-protein interactions using yeast two-hybrid system; phage display.

Unit V
Gene silencing and genome editing technologies
13 lectures
Gene silencing techniques; introduction to siRNA; siRNA technology; Micro RNA; construction of siRNA vectors; principle and application of gene silencing; gene knockouts and gene therapy; creation of transgenic plants; debate over GM crops; introduction to methods of genetic manipulation in different model systems e.g. fruit flies (Drosophila), worms (C. elegans), frogs (Xenopus), fish (zebra fish) and chick; Transgenics - gene replacement; gene targeting; creation of transgenic and knock-out mice; disease model; introduction to genome editing by CRISPR-CAS with specific emphasis on Chinese and American clinical trials.

Recommended Textbooks and References:
4. Selected papers from scientific journals, particularly Nature & Science.
5. Technical Literature from Stratagene, Promega, Novagen, New England Biolab etc.

Course Objectives
The objective of this course is to introduce the students to biostatistical methods and to understand the underlying principles, as well as practical guidelines of “how to do it” and “how to interpret it” as the role they can play in decision making for public health majors.

Student Learning Outcomes
By the end of this course students should be able to:
- Understand how to summarise data;
- Apply appropriate statistical tests based on an understanding of the study question, type of study and type of data;
- Interpret the results of statistical tests.

Unit I
Probability and variance
5 lectures
Fundamental concepts in applied probability; Exploratory data analysis and statistical inference; Probability and analysis of one and two way samples; discrete and continuous probability models; Expectation and variance; Central limit theorem; Inference; Hypothesis; Critical region and error probabilities; Tests for proportion; Equality of proportions; equality of means of normal populations (variance known, variance unknown); Chi-square test for independence; P-value of the statistic; Confidence limits;
Introduction to one way and two-way analysis of variance; Data transformations.

Unit II
Correlation and regression analysis
5 lectures
Correlation, Covariance, calculation of covariance and correlation, Correlation coefficient from ungrouped data, Pearson's Rank Correlation Coefficient, scatter and dot diagram, General Concepts of regression, Fitting Regression Lines, regression coefficient, properties of Regression Coefficients; Standard error of estimate.

Unit III
Experimental designs
8 lectures
Introduction to study designs: Longitudinal, cross-sectional, retrospective and prospective study. Principles of experimental designs, Randomized block, and Simple factorial designs. Analysis of variance (ANOVA) and its use in the analysis of RBD, introduction to meta-analysis and systematic reviews, ethics in statistics.

Unit IV
Data normalization
4 lectures
Goals of a Microarray experiment; Normalization of Microarray data; Detecting differential gene expression; Principle component analysis; Clustering of microarray data.

Recommended Textbooks and References:

Course Objectives
The objectives of this course are to provide students with the experimental knowledge of molecular biology and genetic engineering.

Student Learning Outcomes
Students should be able to gain hands-on experience on gene cloning, protein expression and purification. This experience would enable them to begin a career in industry.

Laboratory I: Techniques in Molecular Biology and Genetic Engineering

Credits

3

Syllabus
1. Concept of lac-operon:
   a) lactose induction of β-galactosidase.
   b) Glucose Repression.
   c) Diauxic growth curve of *E. coli*.
2. UV mutagenesis to isolate amino acid auxotroph.
4. Genetic Transfer-Conjugation, gene mapping.
5. Plasmid DNA isolation and DNA quantitation.
6. Restriction Enzyme digestion of plasmid DNA.
7. Agarose gel electrophoresis.
8. Polymerase Chain reaction.
9. DNA Ligation.
11. Transformation of *E.coli* with standard plasmids, Calculation of transformation efficiency.
12. Confirmation of the insert, Miniprep of recombinant plasmid DNA, Restriction mapping.
13. Purification of His-Tagged protein on Ni-NTA columns.

Recommended Textbooks and References:

Semester Two

**Reproductive Biotechnology**

**Course Objectives**
The objectives of this course are to acquaint the students to the recent advances in animal reproductive technologies used for manipulation and exploitation of reproductive potential of livestock for faster multiplication of superior germplasm.

**Student Learning Outcomes**
On completion of this course, students should be able to:
- Gain knowledge about recent advances in animal reproduction;
- Acquire practical exposure to application of reproductive biotechniques and technologies in livestock.

**Unit I**
**History and introduction to reproductive biotechnology**
4 lectures

History, importance of assisted reproductive biotechnology in man and animal, introduction to embryo biotechnology, endocrine therapeutics.

**Unit II**
**Assisted reproductive technologies**
12 lectures

Biotechnological approaches to reproduction, methodology of super ovulation, Oestrus Synchronization and Timed Artificial Insemination, *In vitro* maturation; Fertilization and culture of embryos; embryo splitting, embryo sexing by different methods and their limitations; Genetics and Epigenetic alterations involved in Assisted Reproductive Technologies (ARTs), preparation of sperm for IVF; Multiple Ovulation and Embryo Transfer; Open Nucleus Breeding System; Rate of Genetic Improvement using AI, MOET, ONBS; Ultrasound guided Ovum pickup; Embryo transfer in large and small ruminants. Laparoscopic and Laparoscope guided ET.

**Unit III**
**Transgenesis**
4 lectures

Different methods of gene transfer and their limitations, Pronuclear micro-injection of DNA, Production of transgenic livestock by nuclear transfer and its application, regulatory issues.

**Unit IV**
**Cloning, stem cells and cryopreservation**
10 lectures

Cloning of domestic animals, Somatic Cell Nuclear Transfer (Conventional & HMC); Conservation of endangered species; Isolation and Characterization of embryonic stem cells; Different applications of embryonic stem cells; Methods in semen freezing and evaluation of sperm fertilizing ability; Cryopreservation of sperm and embryos; International trade of semen and embryos; Sperm and Embryo sexing; Disease transmission through semen and embryos; International standards.
Practicals:
1. Synchronization and superovulation protocols
2. Collection of embryos using non-surgical procedures
3. Transferring embryos using non-surgical procedures
4. Embryo freezing protocols
5. Oocyte collection and evaluation from slaughterhouse ovaries
6. In vitro fertilization protocols
7. Micromanipulation of early embryos.

Recommended Textbooks and References:

Course Objectives
The aim of the course is to provide introductory knowledge concerning genomics and proteomics, and their applications.

Student Learning Outcomes
Through this course, students should be able to acquire knowledge and understanding of the fundamentals of genomics and proteomics, transcriptomics and metabolomics and their applications in various applied areas of biology.

Genomics and Proteomics

Credits
3

Unit I
Basics of genomics and proteomics
2 lectures

Brief overview of Prokaryotic and Eukaryotic genome organization, Extra-chromosomal DNA: bacterial plasmids, mitochondria and chloroplast.

Unit II
Genome mapping
4 lectures

Genetic and physical maps; Markers for genetic mapping; Methods and techniques used for gene mapping, physical mapping, linkage analysis, cytogenetic techniques, FISH technique in gene mapping, somatic cell hybridization, radiation hybrid maps, in-situ hybridization, comparative gene mapping.

Unit III
Genome sequencing projects
3 lectures

Human Genome Project, Genome Sequencing Projects for Microbes, plants and animals, Accessing and retrieving genome project information from the web.

Unit IV
Comparative genomics
3 lectures

Identification and classification of organisms using molecular markers- 16S rRNA typing/sequencing, SNPs. Use of genomes to understand the evolution of eukaryotes, to track emerging diseases and to design new drugs; Determining gene location in genome sequence.

Unit V
Proteomics
4 lectures

Aims, strategies and challenges in proteomics; Proteomics technologies: 2D-PAGE, Isoelectric focusing, mass spectrometry, MALDI-TOF, yeast 2-hybrid system, Proteome databases.

Unit VI
Functional genomics and proteomics
6 lectures

Transcriptome analysis for identification and functional annotation of gene, Contig assembly, Chromosome walking and characterization of chromosomes, Mining functional genes in the genome, Gene function- forward and reverse genetics, gene ethics; Protein-protein and protein-DNA interactions; Protein chips and functional
Molecular Diagnostics

Course Objectives
The overall aim of the course is to provide theoretical knowledge and practical skills on molecular techniques used for diagnosis of diseases in animals and their applications.

Student Learning Outcomes
At the end of the course, students should be able to demonstrate adequate knowledge and skill on common molecular diagnostic techniques and their applications for diagnosis of animal diseases.

Unit I
Introduction
2 lectures

Importance and historical perspective of development of molecular diagnostics; Advantages of using molecular diagnostics over conventional techniques, Concept of development of group-specific and strain-specific nucleic acid based diagnostics.

Unit II
Hybridization techniques
4 lectures

Southern and Northern hybridization, dot/slot blot, colony blot, fluorescent in-situ hybridization (FISH), Principle of development of pathogen-specific DNA probes, Restriction endonuclease analysis for identification of pathogens; Principles of development of bacterial, viral and parasitic pathogen specific nucleic acid probes; Southern and Northern hybridization assays for diagnosis of animal and poultry diseases.

Unit III
Nucleic acid amplification techniques
8 lectures

PCR and its variants, Real time PCR, reverse transcription PCR, application of PCR for diagnosis of infectious diseases; Alternative methods of DNA amplification: loop-mediated isothermal amplification, transcription mediated amplification, ligase chain reaction; Application of PCR for diagnosis of infectious diseases of cattle, buffalo, sheep, goats, dogs, equines, swine and poultry; Nucleic acid sequence based diagnostics; Microarray technology: types and applications; biosensors and their applications.

Recommended Textbooks and References:
**Unit I**

**Introduction**

4 lectures

Bioinformatics basics: Computers in biology and medicine; Importance of Unix and Linux systems and its basic commands; Database concepts; Protein and nucleic acid databases; Structural databases; databases and search tools: biological background for molecular evolution.

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**Unit IV**

**Molecular epidemiological methods for microbial typing**

4 lectures

Molecular epidemiological methods for typing of common viral and bacterial pathogens; RAPD, RFLP, PFGE & pulsed type, rep-PCR, ribotyping.

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**Unit V**

**Technologies for specific applications**

4 lectures

Molecular diagnostics for detection of tumors; Molecular diagnostics for animal forensics; Detection of meat adulteration; DNA based methods for identification of animal species; DNA biosensor chips for GMO detection.

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**Practicals:**

1. Collection of clinical and environmental samples from animal and poultry farms for molecular detection of pathogens.
2. Isolation of bacterial pathogens from the samples.
3. Extraction of nucleic acids from bacteria and clinical specimens.
4. Restriction digestion and analysis by agarose gel electrophoresis.
5. Development of animal pathogen-specific nucleic acid probes.
7. PCR for detection of pathogens in blood and other animal tissues.
8. RT-PCR for detection of RNA viruses.
9. Real-time PCR for detection of pathogens in semen and other animal tissues.
10. DNA fingerprinting for identification of animal species.
11. PCR-based detection of potential pathogens in food (milk, eggs, meat, vegetables, and fruits).
12. Molecular typing of specific bacterial and viral pathogens using nucleic acid based methods.

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**Recommended Textbooks and References:**

sequence analysis; Identification of protein sequence from DNA sequence; searching of databases for similar sequences; NCBI; publicly available tools; resources at EBI; resources on the web; database mining tools.

Unit II
Basic DNA sequence analysis
4 lectures
DNA sequence analysis: gene bank sequence database; submitting DNA sequences to databases and database searching; sequence alignment; pairwise alignment techniques; motif discovery and gene prediction; local structural variants of DNA, their relevance in molecular level processes, and their identification; assembly of data from genome sequencing.

Unit III
Advanced DNA sequence analysis
4 lectures
Multiple sequence analysis; multiple sequence alignment; flexible sequence similarity searching with the FASTA3 program package; use of CLUSTAL W and CLUSTAL X for multiple sequence alignment; submitting DNA protein sequence to databases: where and how to submit, SEQUIN, genome centres; submitting aligned set of sequences, updates and internet resources; methods of phylogenetic analysis.

Unit IV
Protein modelling
5 lectures
Protein modelling: introduction; force field methods; energy, buried and exposed residues; side chains and neighbours; fixed regions; hydrogen bonds; mapping properties onto surfaces; fitting monomers; RMS fit of conformers; assigning secondary structures; sequence alignment- methods, evaluation, scoring; protein completion: backbone construction and side chain addition; small peptide methodology; software accessibility; building peptides; protein displays; substructure manipulations, annealing.

Unit V
Structure prediction
6 lectures
Protein structure prediction: protein folding and model generation; secondary structure prediction; analyzing secondary structures; homology modelling: potential applications, description, methodology, homologous sequence identification; align structures, align model sequence; construction of variable and conserved regions; threading techniques; topology fingerprint approach for prediction; evaluation of alternate models, sequence based methods of structure prediction, prediction using inverse folding, fold prediction; significance analysis, scoring techniques, sequence-sequence scoring; protein function prediction; elements of in-silico drug design; Virtual library: Searching Medline, PubMed, current content, science citation index and current awareness services, electronic journals, grants and funding information.

Practicals:
1. Sequence retrieval from NCBI, EMBL, Genbank, Swissprot/ TrEMBL, UniProt and other web resources.
2. Similarity searching using BLAST and interpretation of results.
3. Multiple sequence alignment using ClustalW/Clustal X.
5. Use of gene prediction methods (GRAIL, Genscan, Glimmer).
6. Using RNA structure prediction tools.
7. Primer designing and restriction mapping using online/offline tools.
8. Protein Structure Visualization using RASMOL/UCSF Chimera
9. Protein Tertiary structure prediction by homology modeling using Swiss Model workspace/Modeller
10. Use of miRNA prediction, designing and target prediction tools.

Recommended Textbooks and References:
Course Objectives
The objectives of this course are to educate students about the fundamental concepts of bioprocess technology and its related applications, thus preparing them to meet the challenges of the new and emerging areas of biotechnology industry.

Student Learning Outcomes
Students should be able to:
• Appreciate relevance of microorganisms from industrial context;
• Carry out stoichiometric calculations and specify models of their growth;
• Give an account of design and operations of various fermenters;
• Present unit operations together with the fundamental principles for basic methods in production technique for bio-based products;
• Calculate yield and production rates in a biological production process, and also interpret data;
• Calculate the need for oxygen and oxygen transfer in a bioproduction process;
• Critically analyze any bioprocess from an economics/market point of view;
• Give an account of important microbial/enzymatic industrial processes in food and fuel industry.

Unit I
Basic principles of biochemical engineering
4 lectures
Isolation, screening and maintenance of industrially important microbes; microbial growth and death kinetics (an example from each group, particularly with reference to industrially useful microorganisms); strain improvement for increased yield and other desirable characteristics.

Unit II
Stoichiometry and models of microbial growth
3 lectures
Elemental balance equations; metabolic coupling – ATP and NAD+; yield coefficients; unstructured models of microbial growth; structured models of microbial growth.

Unit III
Bioreactor design and analysis
6 lectures
Batch and continuous fermenters; modifying batch and continuous reactors: chemostat with recycle, multistage chemostat systems, fed-batch operations; conventional fermentation v/s biotransformations; immobilized cell systems; large scale animal and plant cell cultivation; fermentation economics; upstream processing: media formulation and optimization; sterilization; aeration, agitation and heat transfer in bioprocess; scale up and scale down; measurement and control of bioprocess parameters.
### Unit IV
**Downstream processing and product recovery**
6 lectures

- Separation of insoluble products: filtration, centrifugation, sedimentation, flocculation;
- Cell disruption; separation of soluble products: liquid-liquid extraction, precipitation, chromatographic techniques, reverse osmosis, ultra and micro filtration, electrophoresis;
- Final purification: drying; crystallization; storage and packaging.

### Unit V
**Fermentation economics**
3 lectures

- Isolation of micro-organisms of potential industrial interest; strain improvement; market analysis; equipment and plant costs; media; sterilization, heating and cooling; aeration and agitation; bath-process cycle times and continuous cultures; recovery costs; water usage and recycling; effluent treatment and disposal.

### Unit VI
**Applications of enzyme technology in food processing**
3 lectures

- Mechanism of enzyme function and reactions in process techniques; enzymatic bioconversions e.g. starch and sugar conversion processes; high-fructose corn syrup; inter esterified fat; hydrolyzed protein etc. and their downstream processing; baking by amylases, deoxygenation and desugaring by glucose oxidase, beer mashing and chill proofing; cheese making by proteases and various other enzyme catalytic actions in food processing.

### Unit VII
**Applications of microbial technology in food process operations and production, biofuels and biorefinery**
3 lectures

- Fermented foods and beverages; food ingredients and additives prepared by fermentation and their purification; fermentation as a method of preparing and preserving foods; microbes and their use in pickling, producing colours and flavours, alcoholic beverages and other products; process wastes - whey, molasses, starch substrates and other food wastes for bioconversion to useful products; bacteriocins from lactic acid bacteria – production and applications in food preservation; biofuels and biorefinery.

#### Practicals:

1) Basic Microbiology techniques
   a) Scale up from frozen vial to agar plate to shake flask culture.
   b) Instrumentation: microplate reader, spectrophotometer, microscopy.
   c) Isolation of microorganisms from soil samples.

2) Experimental set-up
   a) Assembly of bioreactor and sterilization.
   b) Growth kinetics.
   c) Substrate and product inhibitions.
   d) Measurement of residual substrates.

3) Data Analysis
   a) Introduction to Metabolic Flux Analysis (MFA).

4) Fermentation
   a) Batch.
   b) Fed-batch.
   c) Continuous.

5) Unit operations
   a) Microfiltrations: Separation of cells from broth.
   b) Bioseparations: Various chromatographies and extractions.

6) Bioanalytics
   a) Analytical techniques like HPLC, FPLC, GC, GC-MS etc. for measurement of amounts of products/substrates.

#### Recommended Textbooks and References:

## Research Methodology and Scientific Communication Skills

### Course Objectives
The objectives of this course are to give a background on the history of science, emphasizing the methodologies used to do research, use the framework of these methodologies for understanding effective lab practices and scientific communication and appreciate scientific ethics.

### Student Learning Outcomes
Students should be able to:
- Understand the history and methodologies of scientific research, applying these to recent published papers;
- Understand and practice scientific reading, writing and presentations;
- Appreciate scientific ethics through case studies.

### Credits

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<th>Unit I</th>
<th>History of science and science methodologies</th>
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<td>Empirical science; the scientific method; manipulative experiments and controls; deductive and inductive reasoning; descriptive science; reductionist vs holistic biology.</td>
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<tr>
<th>Unit II</th>
<th>Preparation for research</th>
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<td>Choosing a mentor, lab and research question; maintaining a lab notebook.</td>
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<tr>
<th>Unit III</th>
<th>Process of communication</th>
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<td>Concept of effective communication- setting clear goals for communication; determining outcomes and results; initiating communication; avoiding breakdowns while communicating; creating value in conversation; barriers to effective communication; non-verbal communication-interpreting non-verbal cues; importance of body language, power of effective listening; recognizing cultural differences; Presentation skills - formal presentation skills; preparing and presenting using over-head projector, PowerPoint; defending interrogation; scientific poster preparation &amp; presentation; participating in group discussions; Computing skills for scientific research - web browsing for information search; search engines and their mechanism of searching; hidden Web and its importance in scientific research; internet as a medium of interaction between scientists; effective email strategy using the right tone and conciseness.</td>
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<th>Unit IV</th>
<th>Scientific communication</th>
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<td>Technical writing skills - types of reports; layout of a formal report; scientific writing skills - importance of communicating science; problems while writing a scientific document; plagiarism, software for plagiarism; scientific publication writing: elements</td>
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of a scientific paper including abstract, introduction, materials & methods, results, discussion, references; drafting titles and framing abstracts; publishing scientific papers - peer review process and problems, recent developments such as open access and non-blind review; plagiarism; characteristics of effective technical communication; scientific presentations; ethical issues; scientific misconduct.

Recommended Textbooks and References:

Course Objectives
The objectives of this course are to familiarize the students with classic literature to make them appreciate how ground-breaking discoveries were made without, necessarily using high-end technologies.

Student Learning Outcomes
Students should be able to get trained in the exercise of hypothesis building and methods of addressing the hypothesis with readily available technology.

Syllabus
How does the Course Module work? A list of 16 landmark papers is given below. Students may be divided into groups of 2 or more and each group may be assigned one selected paper. Each week there may be a 2 hour presentation cum discussion for each of the papers. At the end of the semester each student will be asked to write a mini-review (2-3 pages long) on any of the sixteen papers, other than the one he/she presented/discussed.

A list of sixteen landmark papers and some suggested reference materials:
1. Molecular Biology
   a) Molecular structure of nucleic acids; a structure for deoxyribose nucleic acid
      Watson JD and Crick FH; Nature. 1953 Apr 25;171(4356):737-8
      Note: In this one page paper Watson and Crick first described the structure of DNA double helix
      Study help - Watson_Crick_Nature_1953_annotated
   b) Messelson and Stahl experiment demonstrating semi-conservative replication of DNA
      Note: The experiment demonstrating semi-conservative mode of DNA replication is referred to as “the most beautiful experiment in biology”
   c) In vivo alteration of telomere sequences and senescence caused by mutated Tetrahymena telomerase RNAs
Note: This paper demonstrates that the telomerase contains the template for telomere synthesis

2. Animal Cloning
   c) Atsuo Ogura, Kimiko Inoue, Teruhiko Wakayama. Recent advancements in cloning by somatic cell nuclear transfer. Philosophical Transactions of The Royal Society B 2013; 368: 20110329

3. Genomic Selection

4. Hybridoma Technology

5. Induced Pluripotent Stem Cells

6. Modification of Milk

Course Objectives
The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain

Student Learning Outcomes
Students should be able to demonstrate the following abilities:
• Formulate a scientific question;
• Present scientific approach to solve the problem;
• Interpret, discuss and communicate
Selection of research lab and research topic: Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them select a topic for their project. The topic of the research should be hypothesis driven.

Review of literature: Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources.

Writing Research Proposal: With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc. Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.

Students will have to present the topic of their project proposal after few months of their selection of the topic. They should be able to explain the novelty and importance of their research topic.

At the end of their project, presentation will have to be given by the students to explain work done by them in detail. Along with summarizing their findings they should also be able to discuss the future expected outcome of their work.

Course Objectives
The objectives of this course are to train the students to evaluate research papers, to assess quality of the papers and how the papers are refereed and published as well as learn how to get the papers published.

Student Learning Outcomes
Students should be able to:
- Critically analyse the research papers from different upcoming topics;
- Understand the weaknesses and strengths of the paper and what additional experiments could have been done to strengthen the research study;
- Understand the context of the paper and identify important questions;
- Acquire the skills in paper writing and getting it published.

Student presentations: Each student will need to present one paper during the term. They should select research papers, which deal with upcoming or most recent scientific findings/breakthrough and technologies developed.

Class evaluations and discussions: Every week, each student will be asked to write a short review and evaluations of the paper presented in the class and then indulge in discussion with flaws of the paper, important questions and impact of the overall paper. Recent technologies, can be discussed, where it can be applied.
Course Objectives
Research and business belong together and both are needed. In a rapidly developing life science industry, there is an urgent need for people who combine business knowledge with the understanding of science & technology. Bio-entrepreneurship, an interdisciplinary course, revolves around the central theme of how to manage and develop life science companies and projects. The objectives of this course are to teach students about concepts of entrepreneurship including identifying a winning business opportunity, gathering funding and launching a business, growing and nurturing the organization and harvesting the rewards.

Student Learning Outcomes
Students should be able to gain entrepreneurial skills, understand the various operations involved in venture creation, identify scope for entrepreneurship in biosciences and utilize the schemes promoted through knowledge centres and various agencies. The knowledge pertaining to management should also help students to be able to build up a strong network within the industry.

Unit I
Innovation and entrepreneurship in bio-business
6 lectures
Introduction and scope in Bio-entrepreneurship, Types of bio-industries and competitive dynamics between the sub-industries of the bio-sector (e.g. pharmaceuticals vs. Industrial biotech), Strategy and operations of bio-sector firms: Factors shaping opportunities for innovation and entrepreneurship in bio-sectors, and the business implications of those opportunities, Alternatives faced by emerging bio-firms and the relevant tools for strategic decision, Entrepreneurship development programs of public and private agencies (MSME, DBT, BIRAC, Make In India), strategic dimensions of patenting & commercialization strategies.

Unit II
Bio markets: business strategy and marketing
6 lectures
Negotiating the road from lab to the market (strategies and processes of negotiation with financiers, government and regulatory authorities), Pricing strategy, Challenges in marketing in bio business (market conditions & segments; developing distribution channels, the nature, analysis and management of customer needs), Basic contract principles, different types of agreement and contract terms typically found in joint venture and development agreements, Dispute resolution skills.

Unit III
Finance and accounting
6 lectures
Business plan preparation including statutory and legal requirements, Business feasibility study, financial management issues of procurement of capital and management of costs, Collaborations & partnership, Information technology.

Unit IV
Technology management
6 lectures
Technology – assessment, development & upgradation, Managing technology transfer, Quality control & transfer of foreign technologies, Knowledge centers and Technology transfer agencies, Understanding of regulatory compliances and procedures (CDSCO, NBA, GCP, GLA, GMP).

Recommended Textbooks and References:
Course Objectives
The objectives of this course are:
- To provide basic knowledge on intellectual property rights and their implications in biological research and product development;
- To become familiar with India’s IPR Policy;
- To learn biosafety and risk assessment of products derived from biotechnology and regulation of such products;
- To become familiar with ethical issues in biological research.

Student Learning Outcomes
On completion of this course, students should be able to:
- Understand the rationale for and against IPR and especially patents;
- Understand why India has adopted an IPR Policy and be familiar with broad outline of patent regulations;
- Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents;
- Gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research and environmental release of genetically modified organisms, national and international regulations;
- Understand ethical aspects related to biological, biomedical, health care and biotechnology research.

Unit I
Introduction to IPR
7 lectures
Introduction to intellectual property; types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of ‘prior art’: invention in context of “prior art”; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation.; Review of Government of India’s “National Intellectual Property Rights Policy”.

Unit II
Patenting
5 lectures
Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure - patent application- forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting-requirement, procedures and costs; financial assistance for patenting-introduction to existing schemes; publication of patents-gazette of India, status in Europe and US; patent infringement- meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing – outright sale, licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives.
Unit III
Biosafety
5 lectures

Biosafety and Biosecurity - introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants – sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk – environmental risk assessment and food and feed safety assessment; problem formulation – protection goals, compilation of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops vs cisgenic plants or products derived from RNAi, genome editing tools.

Unit IV
National and international regulations
5 lectures

International regulations – Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations – EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – biosafety levels and category of rDNA experiments; field trials – biosafety research trials – standard operating procedures - guidelines of state governments; GM labeling – Food Safety and Standards Authority of India (FSSAI).

Unit V
Bioethics
5 lectures


Recommended Textbooks and References:

2. National IPR Policy, Department of Industrial Policy & Promotion, Ministry of Commerce, GoI
5. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/


Semester Four

Dissertation

Course Objectives
The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.

Student Learning Outcomes
Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:

• In-depth knowledge of the chosen area of research.
• Capability to critically and systematically integrate knowledge to identify issues that must be addressed within framework of specific thesis.
• Competence in research design and planning.
• Capability to create, analyse and critically evaluate different technical solutions.
• Ability to conduct research independently.
• Ability to perform analytical techniques/experimental methods.
• Project management skills.
• Report writing skills.
• Problem solving skills.
• Communication and interpersonal skills.

Credits
40
(Semester III: 20 Credits; Semester IV: 20 Credits)

Syllabus
Planning & performing experiments
Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

Syllabus
Thesis writing
At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may...
This course provides a comprehensive understanding of the basic concepts of population genetics, leading up to important aspects linking to evolution. The student is expected to gain a fuller appreciation of genetic determinants that impact population level biological diversity in the context of evolution.

**Student Learning Outcomes**

After successful completion of this course, students are expected to be able to:

- define and describe important population and quantitative genetic concepts such as: genetic drift, natural selection, selective sweep, inbreeding, heritability and quantitative traits;
- apply these population and quantitative genetic concepts to problems related to the genetic dynamics of natural, captive and artificially selected populations.

**Recommended Electives**

(Group A)

**Quantitative & Population Genetics**

**Course Objectives**

Individual vs population; Genetic Structure of population; Hardy Weinberg law; Approach to equilibrium under different situations: single autosomal locus with two alleles, single sex-linked locus, and two pairs of autosomal linked and unlinked loci; Factors affecting changes in gene and genotypic frequencies and their effect on genetic structure of animal populations; Linkage disequilibrium.

**Student Learning Outcomes**

Upon successful completion of this course, students are expected to be able to:

- define and describe important population and quantitative genetic concepts such as: genetic drift, natural selection, selective sweep, inbreeding, heritability and quantitative traits;
- apply these population and quantitative genetic concepts to problems related to the genetic dynamics of natural, captive and artificially selected populations.

**Recommended Mode of Assessment**

Assessment may be done by thesis evaluation, viva voce and final presentation.

**Practicals:**

1. Problems relating to gene and genotypic frequencies under different conditions
2. Estimation of inbreeding coefficient, Coefficient of relationship
3. Estimation of effective population size
4. Computation of quantitative genetic effects values and means
5. Estimation of variance components
6. Computation of heritability and repeatability
7. Computation of genetic, environmental and phenotypic correlations.
Recommended Textbooks and References:

Course Objectives
This course is designed to give the students a basic knowledge of principles of genetics, types of matings, animal selection, hybrid vigor, pedigree, animal reproductive systems, and principles of artificial insemination and pregnancy testing.

Student Learning Outcomes
On completion of this course, students should be able to:
• Apply quantitative genetics theories and molecular genetics in animal breeding;
• Use the most important statistical methods;
• Use the information in designing evolutionary research and breeding programmes.

Credits
2

Unit I
Selection
3 lectures
Type of selection and their genetic consequences; Response to selection, its prediction and improvement of response to selection; Basis of selection, Accuracy and efficiency of different bases of selection; Combined selection; Correlated characters, correlated response to selection and efficiency of indirect selection; Selection of several traits.

Unit II
Breeding
2 lectures
Prediction of breeding value using different criteria, Sire evaluation, Conventional and Genomic breeding.

Unit III
Evaluation of selection
3 lectures

Unit IV
Genetics in mating
3 lectures
Genetic aspects and consequences of various mating systems; Application of various mating systems in animal improvement, Heterosis; Selection for general and specific combining ability.

Unit V
Quantitative genetics in mating
3 lectures
Genetic polymorphism and its application in genetic improvement, Quantitative Trait Loci (QTL), Marker Assisted Selection, Genomic Selection- basic concept and its application in animal breeding

Practicals:
1. Prediction of direct and correlated response to different basis of selection
2. Estimation MPPA
3. Computation of breeding values using different sources of information for female and male selection
4. Computation of realized heritability
5. Selection index: Computation, Accuracy and response in component traits.
7. Sire evaluation.

Recommended textbooks and References:

(Group A)
Evolutionary Genetics

Credits
2

Unit I
Classical genetics
1 lectures
Classical theory of abiogenesis with introduction to Urey-Miller experiment; RNA world hypotheses, Fixation of Genetic Material, Function Molecule – Protein, Darwinian, Lamarckian and Mendelian theory introduction.

Unit II
Genome Evolution
3 lectures
Evolution of genomes – Modes of evolution, Genome size and C-value paradox, Gene organization in genomes, (how has the genome expanded from the primitive organisms – presence of non-coding DNA, heterochromatin, B-Chromosomes, and repetitive sequences throughout the evolutionary history) synteny and the Isochore theory, Frozen accidents in Genome evolution, Evolution of Chromosomes, Viruses, Mitochondria, Plasmids, Endosymbiont theory.

Unit III
Epigenetics
2 lectures
Genetic and epigenetic consequences of polyploidy, Hybrid sterility-reproductive isolation, Polyploidy and speciation, Coevolution.

Unit IV
Reproductive evolution
1 lecture
Evolutionary advantage of sex, Reproduction and Fitness, Phenotypic Plasticity, Mate Selection.

Unit V
Genetic evolution
3 lectures
Evolution of genes – anatomy of genes, mechanisms of evolution of new genes, origins of intron – early or late, gene families, pseudogenes, orphan genes, Horizontal and lateral transfer; Evolution of polygenic traits; Heritability.

Unit VI
Molecular evolution
2 lectures
Molecular Evolution – Modes of variation introduction, Neutrality and direction of mutation, Permissive and Disruptive evolution, selective sweeps and hitchhiking, background selection, signatures of natural selection and Mc Donald Kreitman test.
Artificial selection and experimental evolution.

Practicals:
1. Concepts in Evolutionary Biology – Classification and Comparison, Cladistics and Systematics, Quantifying characters, Distance measurement and Tree Building, Tree Support and Substitution Models, Limitations of Computation Phylogenetics, MEGA Software.
2. Evolution of Characters against selection pressure in Lymnaea stagnalis, Perionyx ceylanesis or Zebrafish/Drosophila.
3. Frequentist and Bayesian Inference, Phylodynamics.

Recommended Textbooks and References:
4. Introduction to Genetics and Evolution, Duke University, Coursera.

Course Objectives
The objectives of this course are to acquaint the students to recent trends in microbial biotechnology used for manipulation of microbes and microbial genomes for production of biotherapeutic agents, comprehension of microbiome of domestic animals for enhancing their health and production and understanding the host-pathogen relationship through infectomics.

Student Learning Outcomes
On completion of this course, students should be able to:
- Gain knowledge about recent advances in microbial biotechnologies;
- Acquire practical exposure to recombinant DNA technologies in microbes to enhance animal health and production.

History and introduction to microbial biotechnology, Importance of microbial biotechnology in animal sciences, new technologies to study microbial genomics and proteomics

Metagenomics and its applications, Metagenomics in animal gastro intestinal ecosystems, Methods of studying microbial diversity and microbiome of production animals, Prospects of biome engineering in enhancing animal health and production.

Infectomics and Eco-infectomics for the study interaction between host, pathogen and environment, Production of recombinant bacterial and viral vaccines against important animal diseases, Bacterial ghost platform for vaccines, Recombinant purified protein vaccines.
## Course Objectives

The objectives of this course are to gain understanding of the applications of DNA based techniques in animal forensics.

## Student Learning Outcomes

On completion of this course, students should be able to:

- Define the molecular techniques used in forensic science;
- Comprehend the importance of ethical issues in forensic biology.

## Recommended Textbooks and References:


## Unit I

### Introduction

2 lectures

General history of forensic science, introduction to DNA forensics, scope and application of DNA forensics in animals and human criminal investigations in variety of situations.

## Unit II

### DNA-based techniques

5 lectures

Isolation methods and techniques such as DNA fingerprinting, PCR, nucleic acid hybridization, restriction endo-nuclease analysis and sequencing, Individual Animal Identification using DNA fingerprinting, Real Time PCR, Multiplex PCR for adulterated or mixed samples, DNA sequence based identification & analysis.

## Unit III

### Protein-based techniques

4 lectures

Protein detection methods, immunological techniques including ELISA, immunoelectrophoresis and immunofluorescence, mass spectroscopy, biosensors, nano-based methods.

## Unit IV

### Applications

2 lectures

Animal species identification in religious disputes, adulteration of meat, theft of farm animals and pets etc., advantages, disadvantages and limitations of DNA forensics.

## Practicals:

1. Collection of material for forensic analysis
2. Dispatch of material for forensic investigations
3. Storage and processing of forensic material
4. Preparation of different bio-reagents for animal forensic laboratory
5. Isolation and extraction of nucleic acid from tissue & blood samples

## Production of biotherapeutic agents

2 lectures

Production of recombinant therapeutic proteins and hormones in microbial systems, Use of recombinant microbes as biotherapeutic agents

### Practicals:

1. Collection and examination of goat ruminal fluid.
2. Extraction of DNA from ruminal fluid and cloning and sequencing of 16S rDNA for taxonomic identification of microbes.
3. Production of bacterial ghost for vaccines.

### Recommended Textbooks and References:

6. Isolation and extraction of nucleic acid from wild animal scat, hair follicles
7. Isolation of nucleic acid from reminiscent samples like skin, meat, milk, hair and cooked and putrefied tissues
8. Detection of adulteration in meat by PCR and nucleic acid hybridization assay
9. Confirmation of species by DNA sequencing
10. Study of immunological techniques viz. immunoelectrophoresis, immunofluorescence and ELISA
11. Audiovisual based approaches of biosensors, spectroscopy and nanotechnology in forensic science.

Recommended Textbooks and References:
1. D Bailey, (2016), Practical Veterinary Forensics, UK

Course Objectives
This course is intended to provide practical skills to students on advanced techniques in microbiology.

Student Learning Outcomes
On completion of this course, student should be able to:
• Isolate, characterize and identify common bacterial and viral pathogens;
• Understand molecular characterization of important bacterial and viral pathogens of animals;
• Preserve bacterial cultures and animal viruses.

Unit I
Bacteriological techniques
16 lectures
Preparation of different media for bacterial culture; isolation and identification of some important bacteria (Escherichia coli, Salmonella, Pasteurella, Clostridium, Staphylococcus, Streptococcus, etc.); antimicrobial sensitivity test by Kirby–Bauer method and determination of MIC; maintenance and preservation of bacteria by slant/stab culture, glycerinated broth culture and freeze drying; Identification of bacteria by 16S rRNA amplification and sequencing; molecular typing of bacteria by plasmid profiling, PFGE, rep-PCR and ribotyping.

Unit II
Virological techniques
10 lectures
Cryopreservation and reconstitution of preserved cell lines; Preparation of primary chicken embryo fibroblast cell culture, Live and dead cell count using trypan blue; Isolation and propagation of animal viruses in cell culture; Storage of animal viruses by freeze drying and ultra-freezing. Molecular characterization of important animal viruses like FMD virus, CSF virus, Rotavirus, etc.

Recommended Textbooks and References
# Course Objectives
The objectives of this course are to acquaint the students to recent advances in biotechnologies in foods to produce new products with desirable characteristics. These include characteristics such as disease and drought-resistant plants, leaner meat and enhanced flavor and nutritional quality of foods.

# Student Learning Outcomes
On completion of this course, students should have gained knowledge about recent advances in biotechnologies related to food technology.

## Unit I
### History & introduction to food biotechnology
3 lectures
Introduction, History and scope of food Biotechnology, development and prospects of biotechnology in animal products, ancient and traditional food processing techniques; Biochemical and metabolic pathways of biological systems used in food production.

## Unit II
### Methods in food technologies
3 lectures
Role of biotechnology in productivity of livestock, Modern biotechnological methods and processes in animal product development, chemical and physical factors required for growing microbial cultures in nutritive substrate; Meat species identification, Quality control, Screening products for contaminants.

## Unit III
### Biotechnological method in food processing
5 lectures
Use of biotechnology in production of food additives, use of biotechnological tools for the processing and preservation and foods of animal origin, use of biotechnology improved enzymes in food processing industry, Basic principles of the industrial use of bio-reactions for production of biomass-upstream and downstream processing-application of micro-organisms as starter cultures in meat industry, microbial production of food ingredients; Biosensors and novel tools and their application in food science.

## Unit IV
### Food safety & security
3 lectures
Consumer concerns about risks and values, biotechnology & food safety, Ethical issues concerning GM foods; testing for GMOs; current guidelines for the production, release and movement of GMOs; Future and applications of food biotechnology in India.

### Pricals:
1. Isolation of food borne bacteria (Campylobacter, Salmonella, Yersinia, E. coli) from various food sources using differential media.
2. Confirmation of food borne isolates by biotechnological tools.
3. Isolation and characterization of food borne viruses (rotavirus, hepatitis virus, polio virus, enterovirus) using biotechnological tools.

### Recommended Textbooks and References
Course Objectives
This course will give a brief understanding of various methods and applications involved in processing of prebiotics, probiotics and feed. It will also give a general outline of various safety norms that should be taken care of.

Student Learning Outcomes
On completion of this course, students should be able to:
- Have basic understanding of the biotechnology involved in prebiotics, probiotics and feed;
- Apply this knowledge for future research.

Unit I
Introduction to prebiotics, probiotics and feed biotechnology
3 lectures

Introduction, history, scope of prebiotics, Probiotics and Feed Biotechnology, normal micro flora of GI tract; Introduction to feed processing and preservation, microbial bioconversion of lignin and cellulose rich feeds, factors affecting delignification; Role of microbes in rumen fermentation in ruminant animals; Methane gas production manipulation by biotechnology tools.

Unit II
Methods in prebiotics, probiotics and feed biotechnology
5 lectures

Methods for analysis of intestinal micro flora, microorganisms and proteins used in probiotics, Mechanism of action of prebiotics and probiotics, immune response to probiotics, anti-mutagenic and anti-tumour activities of lactic acid bacteria, probiotics and immune system, lactic acid bacteria as live vaccines; Genetic modification of intestinal lactobacilli and bifidobacteria, recombinant probiotics; Genetic manipulation of organisms to enhance bioconversion ability, manipulation of rumen fermentation by selective removal of protozoa and fungi.

Unit III
Feed processing and technology
3 lectures

Methods of feed processing - physical, chemical and biological effect of processing on nutritional quality and utilization; Diversity of organisms involved, fermentation techniques, large scale bioconversion of substrates, pretreatment of feeds, chemical vs. microbial treatment of feeds, anti-nutritional factors present in feeds, microbial detoxification of aflatoxins, mimosine and other anti-metabolites present. Role of probiotics and prebiotics in inducing gut immunity.

Unit IV
Applications and safety concerns
3 lectures

Application of probiotics for humans, farm animals and poultry, probiotics and intestinal infections, lactose intolerance, probiotics regulatory issues; Symbiotics, traditional probiotic products, probiotics-industrial perspective, contradictions, precautions and adverse reactions; Effect of feed additives like antibiotics, methane inhibitors, genetic manipulation of rumen micro flora to improve feed utilization, single cell protein as animal feed. Health hazards due to residual pesticides in feeds.

Practicals:
1. Isolation of rumen microflora and their characterization by molecular tools
2. Isolation of microbes from fermented foods and molecular characterization
3. Study of antioxidant properties of different foods and food additives.

Recommended Textbooks and References:
Course Objectives
The course is designed to introduce the students to the scientific and technological aspects related to the concept of ecosystem and its management, environmental degradation and its effect on the living systems, bioremediation and waste management.

Student Learning Outcomes
On completion of this course, students should be able to use basic microbiological, molecular and analytical methods in environmental biotechnology.

Unit I
Introduction
5 lectures
Concept of ecosystems and ecosystem management, Response of microbes, plant and animals to environmental stresses; Environmental problems - ozone depletion, pesticides, green house effect, water, air and soil pollution, radioactive pollution, land degradation.

Unit II
Bioremediation
8 lectures
Role of environmental biotechnology in management of environmental problems, Bioremediation, advantages and disadvantages; In-situ and ex-situ bioremediation; slurry bioremediation; Bioremediation of contaminated ground water and phyto remediation of soil metals; microbiology of degradation of xenobiotics.

Unit III
Waste water treatment
8 lectures
Sewage and waste water treatment, Solid waste management, chemical control of water pollution, role of microphyte and macrophytes in water treatment; Recent approaches to biological waste water treatment, Treatment of waste water from dairy, distillery, tannery, sugar and antibiotic industries.

Unit IV
Air pollution control
4 lectures
Biofuels and biological control of air pollution, plant-derived fuels, biogas, landfill gas, bioethanol, biohydrogen; use of biological techniques in controlling air pollution; Removal of chlorinated hydrocarbons from air.

Recommended Textbooks and References:
1. P Nicholas Cheremisinoff. (2001), Biotechnology for Wastewater Treatment. Prentice Hall of India.
## DBT Supported Teaching Programmes

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<tr>
<th>S.No.</th>
<th>Name of University</th>
<th>Contact Details of Course Coordinator</th>
</tr>
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| 1.    | Assam Agricultural University, Guwahati     | Prof. Probodh Borah  
Dept. of Veterinary Microbiology  
College of Veterinary Science  
09435116191  
borahp@rediffmail.com |
| 2.    | G.B. Pant University of Agriculture and Technology, Pantnagar | Prof. Anil Kumar  
Deptt. of Biochemistry, Molecular Biology & Genetic Engineering  
05944- 233898  
09411195450 |
| 3.    | Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar | Prof. Trilok Nanda  
Deptt. of Animal Biotechnology  
01662-256130  
nandatrilok1@gmail.com  
hod.abt@luvas.edu.in |

## Annexure I

### Subject Specific Subcommittee of M.V.Sc. Animal Biotechnology

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
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<tbody>
<tr>
<td>Chairperson</td>
<td>Dr. Probodh Borah, Professor and Head of Department, Department of Animal Biotechnology, Assam Agricultural University, Guwahati</td>
</tr>
<tr>
<td>Members</td>
<td>Dr. Satish Kumar, Scientist and Group Leader, Centre for Cellular and Molecular Biology, Hyderabad</td>
</tr>
<tr>
<td></td>
<td>Dr. Riaz Shah, Professor and Head, Division of Biotechnology, Sher-e-Kashmir University, Srinagar</td>
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<td>Dr. Minakshi Prasad, Sr. Scientist and Head, Department of Animal Biotechnology, Lala Lajpat Rai University, Hisar</td>
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<td>Dr. Ramneek Verma, Professor and Director, School of Animal Biotechnology, Guru Angad Dev University, Ludhiana</td>
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<tr>
<td>Member Secretary</td>
<td>Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi</td>
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M.Tech.
Biotechnology
Introduction

Background

Promotion of Indian Biotechnology sector is high on policy agenda of Government of India. Biotechnology has also been recognized as one of the key priority sectors under ‘Make in India,’ ‘Skill India’ and ‘Startup India’ initiatives of Government of India, as it is one of sectors expected to contribute towards enterprise creation, innovation and economic growth. Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India has immensely contributed to this dynamism through various policies and initiatives, establishment of innovation clusters, academia-industry partnerships, increasing capabilities for technology development, etc. The National Biotechnology Development Strategy (2015 – 2020) released by DBT provides a strategic roadmap for India’s emergence as a global biotechnology innovation and manufacturing hub. It has also highlighted importance of human resource development and need for nurturing tailor-made human capital for advanced scientific research and entrepreneurship.

DBT has taken a number of initiatives aimed at integrated human resource development to evolve an ecosystem where scientists, innovators and future entrepreneurs can be nurtured. Keeping in mind requirement for trained manpower in various areas of Biotechnology, DBT initiated Post-Graduate Teaching Programme way back in 1985 with 5 universities which has expanded to 74 universities imparting M.Sc./M.Tech./M.V.Sc. degrees in general, agricultural, animal, food, environmental, industrial marine, medical, neuroscience and pharmaceutical biotechnology. 10 programmes are being phased out. These universities and institutes are provided liberal financial support towards strengthening of laboratory facilities, equipment, consumables, fellowships to students, dissertation grant per student etc. Post-Graduate Teaching Programme selects best students and trains them to join research or industry workforce contributing significantly to biotechnology workforce.

About the Course Curriculum Revision Exercise

Taking into cognizance the changing needs of the economy and to keep abreast with latest developments in the field of biotechnology, DBT proactively initiated revision of course curricula of Post-Graduate Programmes in biotechnology. The present exercise has been undertaken by Biotech Consortium India Limited (BCIL), New Delhi. Earlier exercise was carried out in 2008. The Course Curriculum Revision Exercise has been carried out for 13 Post-Graduate programmes in Biotechnology supported by DBT.

The revision of course curriculum of M.Tech. Biotechnology aims to address mismatch between ‘knowledge’ gained by students and appropriate skill set required for technology development and implementation including present contemporary needs of economy.

Methodology

A meticulous and structured approach has been adopted to accomplish the Course Curriculum Revision exercise.

BCIL had initiated the exercise with a review of literature of relevant national and international documents on curriculum design and planning for biotechnology programmes of premier national as well as international universities, guidelines by University Grants Commission, recent curricular guidelines released by Indian Council of Agricultural Research, Ministry of Health and Family Welfare and Indian Institute of Science Education & Research and other relevant research papers on curriculum development in peer-reviewed journals.
The findings of the literature review were adopted to design questionnaires for eliciting feedback from stakeholders of Biotechnology community i.e. academicians, scientists, industry representatives and students. Feedback was received from 165 experts and 20 students belonging to academic institutions, research organizations and industry regarding addition of advanced topics, deletion of elementary, redundant and overlapping topics, updation of laboratory practicals, re-adjustment of credit load, incorporating ‘technology’ component in the curriculum, among others. It was also suggested that re-orientation of curricula should be done keeping in view the needs of the industry.

**Strategic Approach**

A Core Committee along with 9 subject specific subcommittees comprising of 63 academicians, scientists and industry representatives were constituted to revise and update the curricula. The constitution of subject specific subcommittee for M.Tech. Biotechnology is given at Annexure-1.

The salient recommendations identified from stakeholder survey were presented to the Committee. Several brainstorming discussion sessions were held for achieving the desired balance between the foundation courses, recent developments in biotechnology and updation needs identified during the stakeholder survey. Core Committee finalized broad contours for revising all the course curricula. The guidelines set by the Core Committee were taken up by the subject specific subcommittee of M.Tech. Biotechnology for updating the curriculum. The subject specific subcommittee incorporated latest advancements in areas of Biotechnology and Biochemical Engineering in the curriculum. Separate meeting was held to discuss and deliberate the updations to be made in the curriculum. The revised curriculum was vetted and finalized by the Core Committee.

**Course Curriculum Revision**

The members of Committee agreed that revised course curriculum should provide skill and outcome based education and help the students to gain domain knowledge, ability to design and interpret research experiments and acquire effective communication skills. The course curriculum has been re-designed accordingly to promote skill-based and outcome-based education. The revised course curriculum totals to 96 credits comprising of theory, practical, technology-based topics, electives and dissertation. Each course includes learning objectives, student learning outcomes, course plan (number of lectures/unit) and reference textbooks/resources. Theory and practical courses include relevant examples, case scenarios and tutorials for inculcating critical thinking against rote learning. Several new courses have been included and content for existing courses has also been updated. Specialized courses such as Bioprocess Engineering and Technology, Downstream Processing in Biotechnology, Bioreactor Operations, Bioprocess Equipment Design and Economics and Instrumentation and Control have been introduced to give more focus in the revised curriculum. With importance of students being able to execute research projects independently, separate credits have been allotted for proposal preparation and presentation before initiating dissertation and also credits for dissertation have been increased accordingly.

We hope that model course curriculum shall serve as guidelines for academicians and researchers from different parts of the country for adoption in their institutions with modifications as per availability of expertise, infrastructure and specific needs.

We wish to put on record our sincere appreciation for constant guidance and encouragement received from Dr. K. VijayRaghavan, Secretary, DBT for bringing out this publication. We wish to acknowledge whole-hearted support of Core Committee and subject specific subcommittees members. Sincere thanks are due to Dr. Manoj Singh Rohilla, Scientist- D, DBT, Ms. Shweta for creative design, Mrs. Rita Bhatla, DBT and Shri. Dilip Joy, BCIL.
There have been several advances of late in the field of Biotechnology, and this has necessitated that the DBT-sponsored M. Tech. programme in Biotechnology undergo a revision. Several experts from academia, research organizations, and industry, have participated in an effort to survey these advances, and to accordingly update the curriculum; it had last been revised in 2008. The M. Tech. Programme remains popular with both students and employers, but nevertheless the feedback obtained requested for the provision of further depth and breadth in terms of concepts, and increased exposure to practical aspects, especially relevant for those students wishing to undertake industrial careers.

There have been consequently several changes introduced: given the varied backgrounds of students entering the PG programme, we have introduced basic courses in chemistry, physics, mathematics, and data analysis. In addition, we have courses on research methodology, communication skills, entrepreneurship, and IPR. The process engineering courses have also been strengthened, specifically in aspects of instrumentation and process control, and on the use of appropriate downstream recovery techniques. The lab courses have also been modified to ensure familiarity with core cellular and genetic engineering concepts as well as standard process development unit operations. A set of 10 electives are also recommended: these expose the students to advanced material on product design and computational and engineering aspects of process development.
# M.Tech. Biotechnology

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**Recommended Electives:**
### Semester One

#### Biochemistry

**Credits** 3

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<tr>
<th>Unit</th>
<th>Course Objectives</th>
<th>Student Learning Outcomes</th>
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| **Unit I** | Protein structure | Chemical basis of life: Miller-Urey experiment, abiotic formation of amino acid oligomers, composition of living matter; Water – properties of water, essential role of water for life on earth pH, buffer, maintenance of blood pH and pH of gastric juice, pH optima of different enzymes (pepsin, trypsin and alkaline phosphatase), ionization and hydrophobicity, emergent properties of biomolecules in water, biomolecular hierarchy, macromolecules, molecular assemblies; Structure-function relationships: amino acids – structure and functional group properties, peptides and covalent structure of proteins, elucidation of primary and higher order structures, Ramachandran plot, evolution of protein structure, protein degradation and introduction to molecular pathways controlling protein degradation, structure-function relationships in model proteins like ribonuclease A, myoglobin, hemoglobin, chymotrypsin etc.; basic principles of protein purification; tools to characterize expressed proteins; Protein folding: Anfinsen's Dogma, Levinthal paradox, cooperativity in protein folding, free energy landscape of protein folding and pathways of protein folding, molten globule state, chaperons, diseases associated with protein folding, introduction to molecular dynamic simulation. | On completion of this course, students should be able to:  
• Gain fundamental knowledge in biochemistry;  
• Understand the molecular basis of various pathological conditions from the perspective of biochemical reactions. |
| **Unit II** | Enzyme kinetics | Enzyme catalysis – general principles of catalysis; quantitation of enzyme activity and efficiency; enzyme characterization and Michaelis-Menten kinetics; relevance of enzymes in metabolic regulation, activation, inhibition and covalent modification; single substrate enzymes; concept of catalytic antibodies; catalytic strategies with specific examples of proteases, carbonic anhydrases, restriction enzymes and nucleoside monophosphate kinase; regulatory strategies with specific example of hemoglobin; isozymes; role of covalent modification in enzymatic activity; zymogens. | |
| **Unit III** | Glycobiology | Sugars-mono, di, and polysaccharides with specific reference to glycogen, amylose and cellulose, glycosylation of other biomolecules-glycoproteins and glycolipids; lipids- structure and properties of important members of storage and membrane lipids; lipoproteins. | |
| **Unit IV** | Structure and functions of DNA, RNA and Lipids | Self-assembly of lipids, micelle, biomembrane organization - sidedness and function; membrane bound proteins - structure, properties and function; transport phenomena; nucleosides, nucleotides, nucleic acids - structure, a historical perspective leading up to the proposition of DNA double helical structure; difference in RNA and DNA structure and their importance in evolution of DNA as the genetic material. | |
| **Unit V** | Bio-energetics | Bioenergetics-basic principles; equilibria and concept of free energy; coupled interconnecting reactions in metabolism; oxidation of carbon fuels; recurring motifs in metabolism; Introduction to GPCR, Inositol/DAG/ PKC and Ca++ signaling pathways; glycolysis and gluconeogenesis; reciprocal regulations and non-carbohydrate sources | |
Calvin cycle and pentose phosphate pathway; glycogen metabolism, reciprocal control of glycogen synthesis and breakdown, roles of epinephrine and glucagon and insulin in glycogen metabolism; Fatty acid metabolism; protein turnover and amino acid catabolism; nucleotide biosynthesis; biosynthesis of membrane lipids and sterols with specific emphasis on cholesterol metabolism and mevalonate pathway; elucidation of metabolic pathways; logic and integration of central metabolism; entry/exit of various biomolecules from central pathways; principles of metabolic regulation; steps for regulation; TOR (target of rapamycin) & autophagy regulation in relation to C & N metabolism, starvation responses and insulin signaling.

Recommended Textbooks and References:

**Course Objectives**
The objectives of this course are to sensitize the students to the fact that as we go down the scale of magnitude from cells to organelles to molecules, the understanding of various biological processes becomes deeper and inclusive.

**Student Learning Outcomes**
Student should be equipped to understand three fundamental aspects in biological phenomena: a) what to seek; b) how to seek; c) why to seek?
interference by small non-coding RNAs (miRNAs and siRNAs), protein translation machinery, ribosomes-composition and assembly; universal genetic codes, degeneracy of codons, Wobble hypothesis; Iso-accepting tRNA; mechanism of initiation, elongation and termination; co- and post-translational modifications, mitochondrial genetic code.

Unit III
Cellular signalling, transport and trafficking
3 lectures

Molecular mechanisms of membrane transport, nuclear transport, transport across mitochondria and chloroplasts; intracellular vesicular trafficking from endoplasmic reticulum through Golgi apparatus to lysosomes/cell exterior.

Unit IV
Cellular processes
8 lectures

Cell cycle and its regulation; cell division: mitosis, meiosis and cytokinesis; cell differentiation: stem cells, their differentiation into different cell types and organization into specialized tissues; cell-ECM and cell-cell interactions; cell receptors and transmembrane signalling; cell motility and migration; cell death: different modes of cell death and their regulation.

Unit V
Manipulating and studying cells
3 lectures

Isolation of cells and basics of cell culture; observing cells under a microscope, different types of microscopy; analyzing and manipulating DNA, RNA and proteins.

Unit V
Genome instability and cell transformation
8 lectures

Mutations, proto-oncogenes, oncogenes and tumour suppressor genes, physical, chemical and biological mutagens; types of mutations; intra-genic and inter-genic suppression; transpositions- transposable genetic elements in prokaryotes and eukaryotes, role of transposons in genome; viral and cellular oncogenes; tumor suppressor genes; structure, function and mechanism of action; activation and suppression of tumor suppressor genes; oncogenes as transcriptional activators.

Recommended Textbooks and References:

Course Objectives
The objectives of this course are to provide an introduction to the essentials of material and energy balances, properties of materials and transport phenomena.

Student Learning Outcomes
Students should be able to execute material and energy balances over a variety of biochemical systems and model systems which simultaneously involve momentum, heat and mass transport.
## Unit I
### Energy and material balances
6 lectures
Unit operations and unit processes: historical and recent developments in chemical engineering; Process variables and degrees of freedom; Differential and integral balances; Lumped and distributed balances; Balances in systems involving physical changes.

## Unit II
### Steady state energy and material balances
8 lectures
Balances in reacting systems; Balances in systems involving recycle, purge and bypass; Computer aided calculations; Generalization to unsteady state balances.

## Unit III
### Properties of substances
6 lectures
Single component and multicomponent systems; Single and multiphase systems.

## Unit IV
### Introduction to transport phenomena: momentum transfer
10 lectures
Viscosity; Molecular theory of Gases and Liquids; Shell balance: Falling film, Circular tube; Equations of Change for isothermal systems: Continuity, Motion, Energy, Substantial derivatives; Unidirectional flows: Pipe flow, Variable viscosity falling film, Couette viscometer, Rotating Sphere; Unsteady flows: Startup Plate flow, Parallel plates etc.

## Unit V
### Introduction to transport phenomena: heat and mass transfer
10 lectures
Thermal conductivity and mechanism of energy transport; Shell energy balances and temperature distributions in solids and laminar flow; Diffusivity and the mechanisms of mass transport; Concentration distributions in solids and laminar flow; Equations of change for multicomponent systems; Introduction to the concept of heat and mass transfer coefficients; Dimensional Analysis (Buckingham Pi theorem).

### Recommended Textbooks and References:

### Course Objectives
The objectives of this course are to introduce students to the field of microbiology with emphasis on microbial diversity, morphology, physiology and nutrition, methods for control of microbes and host-microbe interactions.

### Student Learning Outcomes
On completion of this course, students should be able to:
- Identify the major categories of microorganisms and understand their classification, diversity, and ubiquity;
- Describe the structural, physiological, and genetic similarities and differences of the major categories of microorganisms;
- Demonstrate how to control microbial growth;
- Evaluate the interactions between microbes, hosts and environment.
Unit I
Microbial characteristics
6 lectures
Introduction to microbiology and microbes, history & scope of microbiology, morphology, structure, growth and nutrition of bacteria, bacterial growth curve, bacterial culture methods; bacterial genetics: mutation and recombination in bacteria, plasmids, transformation, transduction and conjugation; antimicrobial resistance.

Unit II
Microbial diversity
5 lectures
Microbial taxonomy and evolution of diversity, classification of microorganisms, criteria for classification; classification of bacteria; Cyanobacteria, acetic acid bacteria, Pseudomonads, lactic and propionic acid bacteria, endospore forming bacteria, Mycobacteria and Mycoplasma; Archaea: Halophiles, Methanogens, Hyperthermophilic archaea, Thermoplasm; Eukaryotes: algae, fungi, slime molds and protozoa; extremophiles and unculturable microbes, introduction to metagenomics.

Unit III
Control of microorganisms
3 lectures
Sterilization, disinfection and antisepsis: physical and chemical methods for control of microorganisms, antibiotics, antiviral and antifungal drugs, biological control of microorganisms.

Unit IV
Virology
5 lectures
Virus and bacteriophages, general properties of viruses, viral structure, taxonomy of virus, viral replication, cultivation and identification of viruses; sub-viral particles – viroids and prions.

Unit V
Interaction of microbes with its environment
6 lectures
Host-pathogen interaction, ecological impacts of microbes; symbiosis (Nitrogen fixation and ruminant symbiosis); microbes and nutrient cycles; microbial communication system; biofilms, bacterial quorum sensing; microbial fuel cells.

Recommended Textbooks and References:

Course Objectives
The objectives of this course is to educate students about the fundamental concepts of animal and plant cell system, bioprocess technology using eukaryotic system and their related applications, thus, preparing them to meet challenges of new and emerging areas of biotechnology industry.

Student Learning Outcomes
Student should be able to gain strong understanding of plant and animal based cell cultures system. This will help them to take up animal/plant based biological research as well as placement in relevant biotech industry. They will be able to analyse bioprocess from an economics/market point of view.

Unit I
Animal cell culture
15 lectures
Animal cell culture; media composition and growth conditions; Animal cell and tissue preservation; Anchorage and non-anchorage dependent cell culture; Primary and secondary culture; Animal cell growth characteristics and kinetics; Micro & macro-carrier culture; Hybridoma technology; Stem cell technology; Transgenic animals; Animal cloning; Mechanisms of drug resistance and cell death.
Unit II
Plant cell culture
15 lectures

Totipotency; Plant growth regulators; Regeneration and micropropagation of plants: clonal propagation, organogenesis, shoot-tip and meristem culture, haploid culture, triploid culture, protoplast culture; Somaclonal variation; Tissue culture and Cell suspension culture system: methodology, growth kinetics and nutrient optimization; Precursors and elicitors; Plant Transformation methods (emphasis on *Agrobacterium* mediated transformation); Hairy root culture; Plant products of industrial importance, Production of secondary metabolites.

Unit III
Secondary metabolite production
10 lectures

Principles, design and operation of bioreactors: specific design criteria for mammalian and plant systems; Strategies for fermentation with recombinant organisms; Isolation, characterization and production of secondary metabolites from different plant cell types; Bioprocess monitoring and control: current practices in the bioprocess industries, advanced methodologies; Overview of downstream processing: centrifugation, filtration and chromatographic techniques.

Recommended Textbooks and References:

### Basics of Mathematics and Statistics

**Credits**
2

**Basics of Mathematics and Statistics**

**Course Objectives**
The objective of this course is to give conceptual exposure of essential contents of mathematics and statistics to students.

**Unit I**
*Algebra*
6 lectures

Linear equations, functions: slopes-intercepts, forms of two-variable linear equations; constructing linear models in biological systems; quadratic equations (solving, graphing, features of, interpreting quadratic models etc.), introduction to polynomials, graphs of binomials and polynomials; Symmetry of polynomial functions, basics of trigonometric functions, Pythagorean theory, graphing and constructing sinusoidal functions, imaginary numbers, complex numbers, adding-subtracting-multiplying complex numbers, basics of vectors, introduction to matrices.

**Unit II**
*Calculus*
4 lectures

Differential calculus (limits, derivatives), integral calculus (integrals, sequences and series etc.)
Population dynamics; oscillations, circadian rhythms, developmental patterns, symmetry in biological systems, fractal geometries, size-limits & scaling in biology, modeling chemical reaction networks and metabolic networks.

Probability: counting, conditional probability, discrete and continuous random variables; Error propagation; Populations and samples, expectation, parametric tests of statistical significance, nonparametric hypothesis tests, linear regression, correlation & causality, analysis of variance, factorial experiment design.

Recommended Textbooks and References:

Course Objectives
The objectives of this course are to cover all essentials required to appreciate physico-chemical principles underlying biological processes.

Student Learning Outcomes
Students should be able to have a firm foundation in fundamentals and application of current chemical and physical scientific theories.

Physical quantities and their dynamics: definitions and dimensions; vectors & scalars, displacement, velocity, acceleration, kinematic formulas, angular momentum, torque etc. force, power, work, energy (kinetic & potential/electric charge separation, electromagnetic spectrum, photons etc.); springs & Hooke's laws; elastic and inelastic collisions; Newton's law of motions (centripetal and centrifugal forces etc.); simple harmonic motions, mechanical waves, Doppler effect, wave interference, amplitude, period, frequency & wavelength; diffusion, dissipation, random walks, and directed motions in biological systems; low Reynolds number - world of Biology, buoyant forces, Bernoulli's equation, viscosity, turbulence, surface tension, adhesion; laws of thermodynamics: Maxwell Boltzmann distribution, conduction, convection and radiation, internal energy, entropy, temperature and free energy, Maxwell's demon (entropic forces at work in biology, chemical assemblies, self-assembled systems, role of ATP); Coulomb's law, conductors and insulators, electric potential energy of charges, nerve impulses, voltage gated channels, ionic conductance; Ohms law (basic electrical quantities: current, voltage & power), electrolyte conductivity, capacitors and capacitance, dielectrics; various machines in biology i.e. enzymes, allosteric and molecular motors (molecules to cells and organisms).

Basic constituents of matter - elements, atoms, isotopes, atomic weights, atomic numbers, basics of mass spectrometry, molecules, Avogadro number, molarity, gas constant, molecular weights, structural and molecular formulae, ions and polyatomic
Laboratory I: Biochemistry & Analytical Techniques

Course Objectives
The objective of this laboratory course is to introduce students to experiments in biochemistry. The course is designed to teach utility of experimental methods in biochemistry in a problem oriented manner.

Student Learning Outcomes
Students should be able to:
• Elaborate concepts of biochemistry with simple experiments;
• Understand principle and working of basic laboratory instruments.

Syllabus
2. Titration of Amino Acids and separation of aliphatic, aromatic and polar amino acids by thin layer chromatography.

Recommended Textbooks and References:
3. Purification and characterization of an enzyme from a recombinant source (such as Alkaline Phosphatase or Lactate Dehydrogenase or any enzyme of institution's choice).
   a. Preparation of cell-free lysates
   b. Ammonium Sulfate precipitation
   c. Ion-exchange Chromatography
   d. Gel Filtration
   e. Affinity Chromatography
   f. Generating a Purification Table (protein concentration, amount of total protein)
   g. Computing specific activity of the enzyme preparation at each stage of purification
   h. Assessing purity of samples from each step of purification by SDS-PAGE
   i. Enzyme Kinetic Parameters: Km, Vmax and Kcat.
   j. Dialysis of the purified protein solution against 60% glycerol as a demonstration of storage method

4. Identification of an unknown sample as DNA, RNA or protein using available laboratory tools.


6. Determination of mass of small molecules and fragmentation patterns by Mass Spectrometry.

**Laboratory II: Microbiology**

**Course Objectives**
The objective of this laboratory course is to provide practical skills in basic microbiological techniques.

**Student Learning Outcomes**
On completion of this laboratory course, students should be able to:
- Isolate, characterize and identify common bacterial organisms;
- Determine bacterial load of different samples;
- Perform antimicrobial sensitivity test;
- Preserve bacterial cultures.

**Syllabus**

**Basic techniques**

1. Sterilization, disinfection and safety in microbiological laboratory, good laboratory practices
2. Preparation of media for cultivation of bacteria, liquid and agar.

**Culture techniques**

1. Spread plate method
2. Pour plate method
3. Streaking
4. Bacterial growth curve
5. Bacterial plate count method

**Staining techniques**

1. Preparation of bacterial smear and Gram's staining
2. Acid fast staining
3. Endospore staining
4. Capsule staining
5. Negative staining
6. Flagellar staining.
### Unit I
**Introduction and tools for genetic engineering**
- **6 lectures**

### Unit II
**Different types of vectors**
- **7 lectures**

### Course Objectives
The objectives of this course are to teach various approaches to conducting genetic engineering and their applications in biological research as well as in biotechnology industries. Genetic engineering is a technology that has been developed based on our fundamental understanding of principles of molecular biology and this is reflected in contents of this course.

### Student Learning Outcomes
Given the impact of genetic engineering in modern society, the students should be endowed with strong theoretical knowledge of this technology. In conjunction with practicals in molecular biology and genetic engineering, students should be able to take up biological research as well as placement in relevant biotech industry.

### Syllabus

#### Microscopy-related techniques
1. Bright field light microscopy
2. Hanging drop slide preparation
3. Motility of bacteria
4. Dark field light microscopy
5. Phase contrast microscopy
6. Fluorescence microscopy.

#### Biochemical and antibiotic tests
1. MR test
2. VP test
3. Sucrose fermentation
4. Lactose fermentation
5. Indole test
6. Antimicrobial sensitivity test and demonstration of drug resistance
7. Zone of clearance, zone of inhibition.

#### Environmental factors
1. Effect of pH and temperature on microbial growth
2. Determination of phenol co-efficient of antimicrobial agents
3. Determination of Minimum Inhibitory Concentration (MIC)
4. Isolation and identification of bacteria from soil/water samples.

### Recommended Textbooks and References:

### Semester Two

#### Genetic Engineering

- **3 credits**

- **Course Objectives**
  Impact of genetic engineering in modern society; general requirements for performing a genetic engineering experiment; restriction endonucleases and methylases; DNA ligase, Klenow enzyme, T4 DNA polymerase, polynucleotide kinase, alkaline phosphatase; cohesive and blunt end ligation; linkers; adaptors; homopolymeric tailing; labelling of DNA: nick translation, random priming, radioactive and non-radioactive probes; hybridization techniques: northern, southern, south-western and far-western and colony hybridization, fluorescence *in situ* hybridization.

- **Student Learning Outcomes**
  Plasmids; Bacteriophages; M13 mp vectors; PUC19 and Bluescript vectors, phagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Principles for maximizing gene expression: expression vectors, pMal, GST, PET-based vectors; Protein purification: His-tag; GST-tag; MBP-tag *etc.*
Intein-based vectors; Inclusion bodies; methodologies to reduce formation of inclusion bodies; mammalian expression and replicating vectors; Baculovirus and Pichia vectors system, plant based vectors, Ti and Ri plasmids as vectors, yeast vectors, shuttle vectors.

Unit III
Different types of PCR techniques
7 lectures
Principles of PCR: primer design; fidelity of thermostable enzymes; DNA polymerases; types of PCR – multiplex, nested; reverse-transcription PCR, real time PCR, touchdown PCR, hot start PCR, colony PCR, asymmetric PCR, cloning of PCR products; TA cloning vectors; proof reading enzymes; PCR based site specific mutagenesis; PCR in molecular diagnostics; viral and bacterial detection; sequencing methods; enzymatic DNA sequencing; chemical sequencing of DNA; automated DNA sequencing; RNA sequencing; chemical synthesis of oligonucleotides; mutation detection: SSCP, DGGE, RFLP.

Unit IV
cDNA analysis
7 lectures
Insertion of foreign DNA into host cells; transformation, electroporation, transfection; construction of libraries; isolation of mRNA and total RNA; reverse transcriptase and cDNA synthesis; cDNA and genomic libraries; construction of microarrays – genomic arrays, cDNA arrays and oligo arrays; study of protein-DNA interactions: electrophoretic mobility shift assay; DNaseI footprinting; methyl interference assay, chromatin immunoprecipitation; protein-protein interactions using yeast two-hybrid system; phage display.

Unit V
Gene silencing and genome editing technologies
13 lectures
Gene silencing techniques; introduction to siRNA; siRNA technology; Micro RNA; construction of siRNA vectors; principle and application of gene silencing; gene knockouts and gene therapy; creation of transgenic plants; debate over GM crops; introduction to methods of genetic manipulation in different model systems e.g. fruit flies (Drosophila), worms (C. elegans), frogs (Xenopus), fish (zebra fish) and chick; Transgenics - gene replacement; gene targeting; creation of transgenic and knock-out mice; disease model; introduction to genome editing by CRISPR-CAS with specific emphasis on Chinese and American clinical trials.

Recommended Textbooks and References:
5. Technical Literature from Stratagene, Promega, Novagen, New England Biolab etc.

Course Objectives
The objectives of this course are to learn about structural features of components of immune system as well as their function. The major emphasis of this course will be on development of immune system and mechanisms by which our body elicits immune response. This will be imperative for students as it will help them to predict about nature of immune response that develops against bacterial, viral or parasitic infection, and prove it by designing new experiments.

Student Learning Outcomes
On completion of this course, students should be able to:
- Evaluate usefulness of immunology in different pharmaceutical companies;
- Identify proper research lab working in area of their own interests;
- Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out kind of immune responses in the setting of infection (viral or bacterial).
<table>
<thead>
<tr>
<th>Unit I</th>
<th>Immunology: fundamental concepts and anatomy of the immune system</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Components of innate and acquired immunity; phagocytosis; complement and inflammatory responses; pathogen recognition receptors (PRR) and pathogen associated molecular pattern (PAMP); innate immune response; mucosal immunity; antigens: immunogens, hapten; Major Histocompatibility Complex: MHC genes, MHC and immune responsiveness and disease susceptibility.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit II</th>
<th>Immune responses generated by B and T lymphocytes</th>
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<tbody>
<tr>
<td></td>
<td>Immunoglobulins - basic structure, classes &amp; subclasses of immunoglobulins, antigenic determinants; multigene organization of immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; principles of cell signaling; basis of self &amp; non-self discrimination; kinetics of immune response, memory; B cell maturation, activation and differentiation; generation of antibody diversity; T-cell maturation, activation and differentiation and T-cell receptors; functional T Cell subsets; cell-mediated immune responses, ADCC; cytokines: properties, receptors and therapeutic uses; antigen processing and presentation- endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens; cell-cell co-operation, Hapten-carrier system.</td>
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<tr>
<th>Unit III</th>
<th>Antigen-antibody interactions</th>
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<tbody>
<tr>
<td></td>
<td>Precipitation, agglutination and complement mediated immune reactions; advanced immunological techniques: RIA, ELISA, Western blotting, ELISPot assay, immunofluorescence microscopy, flow cytometry and immunoelectron microscopy; surface plasmon resonance, biosensor assays for assessing ligand – receptor interaction; CMI techniques: lymphoproliferation assay, mixed lymphocyte reaction, cell cytotoxicity assays, apoptosis, microarrays, transgenic mice, gene knock outs.</td>
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<tr>
<th>Unit IV</th>
<th>Vaccinology</th>
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<tbody>
<tr>
<td></td>
<td>Active and passive immunization; live, killed, attenuated, subunit vaccines; vaccine technology: role and properties of adjuvants, recombinant DNA and protein based vaccines, plant-based vaccines, reverse vaccinology; peptide vaccines, conjugate vaccines; antibody genes and antibody engineering: chimeric, generation of monoclonal antibodies, hybrid monoclonal antibodies; catalytic antibodies and generation of immunoglobulin gene libraries, idiotypic vaccines and marker vaccines, viral-like particles (VLPs), dendritic cell based vaccines, vaccine against cancer, T cell based vaccine, edible vaccine and therapeutic vaccine.</td>
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<tr>
<th>Unit V</th>
<th>Clinical immunology</th>
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<tbody>
<tr>
<td></td>
<td>Immunity to infection: bacteria, viral, fungal and parasitic infections (with examples from each group); hypersensitivity: Type I-IV; autoimmunity; types of autoimmune diseases; mechanism and role of CD4+ T cells; MHC and TCR in autoimmunity; treatment of autoimmune diseases; transplantation: immunological basis of graft rejection; clinical transplantation and immunosuppressive therapy; tumor immunology: tumor antigens; immune response to tumors and tumor evasion of the immune system, cancer immunotherapy; immunodeficiency: primary immunodeficiencies, acquired or secondary immunodeficiencies, autoimmunity disorder, anaphylactic shock, immunosenescence, immune exhaustion in chronic viral infection, immune tolerance, NK cells in chronic viral infection and malignancy.</td>
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<tr>
<th>Unit VI</th>
<th>Immunogenetics</th>
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<tbody>
<tr>
<td></td>
<td>Major histocompatibility complex genes and their role in autoimmune and infectious diseases, HLA typing, human major histocompatibility complex (MHC), Complement genes of the human major histocompatibility complex: implication for linkage disequilibrium and disease associations, genetic studies of rheumatoid arthritis, systemic lupus erythematosus and multiple sclerosis, genetics of human immunoglobulin, immunogenetics of spontaneous control of HIV, KIR complex.</td>
</tr>
</tbody>
</table>
Course Objectives
The objectives of this course are to educate students about the fundamental concepts of bioprocess technology and its related applications, thus preparing them to meet the challenges of the new and emerging areas of biotechnology industry.

Recommended Textbooks and References:

Student Learning Outcomes
Students should be able to:
• Appreciate relevance of microorganisms from industrial context;
• Carry out stoichiometric calculations and specify models of their growth;
• Give an account of design and operations of various fermenters;
• Present unit operations together with the fundamental principles for basic methods in production technique for bio-based products;
• Calculate yield and production rates in a biological production process, and also interpret data;
• Calculate the need for oxygen and oxygen transfer in a bioproduction process;
• Critically analyze any bioprocess from an economics/market point of view;
• Give an account of important microbial/enzymatic industrial processes in food and fuel industry.

Unit I
Basic principles of biochemical engineering
4 lectures
Isolation, screening and maintenance of industrially important microbes; microbial growth and death kinetics (an example from each group, particularly with reference to industrially useful microorganisms); strain improvement for increased yield and other desirable characteristics.

Unit II
Stoichiometry and models of microbial growth
6 lectures
Elemental balance equations; metabolic coupling – ATP and NAD+; yield coefficients; unstructured models of microbial growth; structured models of microbial growth, MATLAB basics for modelling and solving the equations.

Unit III
Bioreactor design and analysis
8 lectures
Batch and continuous fermenters; modifying batch and continuous reactors: chemostat with recycle, multistage chemostat systems, fed-batch operations; conventional fermentation vs biotransformations; immobilized cell systems; large scale animal and plant cell cultivation; fermentation economics; upstream processing: media formulation and optimization; sterilization; aeration, agitation and heat transfer in bioprocess; scale up and scale down; measurement and control of bioprocess parameters.
Separation of insoluble products - filtration, centrifugation, sedimentation, flocculation; Cell disruption; separation of soluble products: liquid-liquid extraction, precipitation, chromatographic techniques, reverse osmosis, ultra and micro filtration, electrophoresis; final purification: drying; crystallization; storage and packaging.

Mechanism of enzyme function and reactions in process techniques; enzymatic bioconversions e.g. starch and sugar conversion processes; high-fructose corn syrup; interesterified fat; hydrolyzed protein etc. and their downstream processing; baking by amylases, deoxygenation and desugaring by glucose oxidase, beer mashing and chill proofing; cheese making by proteases and various other enzyme catalytic actions in food processing.

Fermented foods and beverages; food ingredients and additives prepared by fermentation and their purification; fermentation as a method of preparing and preserving foods; microbes and their use in pickling, producing colours and flavours, alcoholic beverages and other products; process wastes-whey, molasses, starch substrates and other food wastes for bioconversion to useful products; bacteriocins from lactic acid bacteria: production and applications in food preservation; biofuels and biorefinery; production of antibiotics in a reactor; single cell protein; probiotics and prebiotics.

Industrial production of penicillin via fungal route, insulin from recombinant E. coli; Production of metabolites such as shikonin using plant cell culture, astaxanthin from algae, and biotransformation routes for novel/specialty chemicals; Production of HBsAg using yeast cultures, erythropoietin using CHO cells, monoclonal antibodies such as Humira using mammalian cells.

Recommended Textbooks and References:

Course Objectives
The objective of this course is to provide an overview of various aspects of recovery and processing of biological products.

Student Learning Outcomes
Students should be able to identify and design relevant unit operations for recovery of a biological product.
### Characteristics of biological materials: pretreatment methods
Separation of cell mass: centrifugation, sedimentation, flocculation and filtration; Continuous operation.

### Mechanical approaches: sonication, bead mills, homogenizers; non-mechanical approaches: freeze/thaw, osmotic shock, chemical lysis, enzymatic lysis; measurement of cell disruption.

### Filtration theory: Micro and ultrafiltration; Reverse osmosis; dialysis; electrodialysis, diafiltration; pervaporation; perstraction; Multistage and continuous operation.

### Adsorption equilibrium, Van Deemter equation; Chromatography: size, charge, polarity, shape, hydrophobic interactions; Biological affinity; Process configurations (packed bed, expanded bed, simulated moving beds).

### Solvent extraction: phase equilibrium and distribution, counter-current operation, dissociative extraction, multiple stage analysis; Reciprocating-plate and centrifugal extractors; Reverse micellar extraction; Aqueous two phase, Supercritical fluid extraction; Aqueous two-phase extraction.

### Precipitation: effect of size and charge, solvent effects, ionic strength effects, precipitate growth and aging models. Crystallization: nucleation and growth aspects; Drying: solvent removal aspects, dryers (vacuum, freeze, spray); Scale up aspects.

### Biophysical characterization, chemical characterization, modern spectroscopy, QbD, stability Bioassays: Cell based assay, receptor mediated assay, in vivo evaluation, immunogenicity.

### Process synthesis: Identification and ordering of unit operations relevant for a case study. Analysis: comparison of different process synthesis steps. Case studies such as production and recovery of therapeutics, metabolites and antibodies.

### Recommended Textbooks and References:

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### Unit I
**Biomass removal**
3 lectures

### Unit II
**Cell disruption**
4 lectures

### Unit III
**Membrane processes**
3 lectures

### Unit IV
**Adsorption and chromatography**
5 lectures

### Unit V
**Extraction processes**
5 lectures

### Unit VI
**Concentration steps**
8 lectures

### Unit VII
**Product characterization**
4 lectures

### Unit VIII
**Process design**
8 lectures

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### Bioreactor Operations

**Course Objectives**
The course is an overview on biological reactions, elements of bioreactor design, and fundamentals of mass and energy balances in biological reactions. It gives an idea on various types of important

**Student Learning Outcomes**
Student should be able to gain strong understanding on design and applications of various bioreactors. They will be able to analyse bioprocess from an economics/market point of view.
bioreactors for microbial, animal and plant cell processes. It covers mechanical design considerations for various kinds of bioreactors.

Unit I
Introduction to bioreactor design
3 lectures

Introduction; General design information; Material and energy balance calculations; Process Flow.

Unit II
Scale up and scale down processes
12 lectures

Scale up and scale down issues: Effect of scale on oxygenation, mixing, sterilization, pH, temperature, inoculum development, nutrient availability and supply; Bioreactor scale-up based on constant power consumption per volume, mixing time, impeller tip speed (shear), mass transfer coefficients. Scale-up of downstream processes: Adsorption (LUB method); Chromatography (constant resolution etc.); Filtration (constant resistance etc.); Centrifugation (equivalent times etc.); Extractors (geometry based rules). Scale-down related aspects.

Unit III
Bioreactor equipment
11 lectures

Selection of bioprocess equipment (upstream and downstream); Specifications of bioprocess equipment; Mechanical design of reactors, heat transfer and mass transfer equipment; Design considerations for maintaining sterility of process streams and process equipment; Piping and instrumentation; Materials of construction for bioprocess plants.

Unit IV
Basic bioreactor operations
8 lectures

Spectrum of basic bioreactor operations: immobilized cell system, animal cells, plant cell cultures and waste management; Enzyme immobilization techniques; Bioconversion using immobilized enzyme preparation; Bioconversion in batch, Fed-batch and continuous bioreactors; Mass transfer in immobilized cell/enzyme reactor.

Unit V
Bioreactor facility design
6 lectures

Facility design aspects; Utility supply aspects; Equipment cleaning aspects; Culture cell banks; cGMP guidelines; Validation; Safety; Process economics; Case studies.

Recommended Textbooks and References:
8. Relevant articles from Bioprocess Journals.
Computational Biology

Course Objectives
The objective of this course is to provide students with theory and practical experience of essentials to aid for genomic, proteomic and metabolomics courses and drug design program.

Student Learning Outcomes
On completion of this course, the students are expected to:
• Develop an understanding of the basic theory of these computational tools;
• Develop required database extraction, integration, coding for computational tools and methods necessary for all Omics;
• Create hypothesis for investigating specific contemporary biological questions, provide help to experiment with or develop appropriate tools;
• Critically analyze and interpret results of their study with respect to whole systems.

Unit I
Introduction to computational biology basics and biological databases
4 lectures
Computers in biology and medicine; Overview of biological databases, nucleic acid & protein databases, primary, secondary, functional, composite, structural classification database, Sequence formats & storage, Access databases, Extract and create sub databases, limitations of existing databases.

Unit II
Pairwise and multiple sequence alignments
5 lectures

Unit III
Genome analysis
6 lectures
Polymorphisms in DNA sequence, Introduction to Next Generation Sequencing technologies, Whole Genome Assembly and challenges, Sequencing and analysis of large genomes, Gene prediction, Functional annotation, Comparative genomics, Probabilistic functional gene networks, Human genome project, Genomics and crop improvement. Study available GWAS, ENCODE, HUGO projects, extract and build sub databases; Visualization tools including Artemis and Vista for genome comparison; Functional genomics case studies.

Unit IV
Structure visualization
3 lectures
Retrieving and drawing structures, Macromolecule viewing platforms, Structure validation and correction, Structure optimization, Analysis of ligand-protein interactions; Tools such as PyMol or VMD.

Unit V
Molecular modelling
6 lectures
Significance and need, force field methods, energy, buried and exposed residues; side chains and neighbours; fixed regions; hydrogen bonds; mapping properties onto surfaces; RMS fit of conformers and protein chains, assigning secondary structures; sequence alignment: methods, evaluation, scoring; protein curation: backbone construction and side chain addition; different types of protein chain modelling: ab initio, homology, hybrid, loop; Template recognition and alignments; Modelling parameters and considerations; Model analysis and validation; Model optimization; Substructure manipulations, annealing, protein folding and model generation; loop generating methods; loop analysis; Analysis of active sites using different methods in studying protein–protein Interactions.
Unit VI
Structure-based drug development
6 lectures
Molecular docking: Types and principles, Semi-flexible docking, Flexible docking; Ligand and protein preparation, Macromolecule and ligand optimization, Ligand conformations, Clustering, Analysis of docking results and validation with known information. Extra-precision docking platforms, Use of Small-molecule libraries, Natural compound libraries for virtual high throughput screenings.

Unit VII
Ligand-based drug development
6 lectures
Quantitative structure activity relationships; Introduction to chemical descriptors like 2D, 3D and Group-based; Radar plots and contribution plots and Activity predictions, Pharmacophore modeling, Pharmacophore-based screenings of compound library, analysis and experimental validation.

Recommended Textbooks and References:

Course Objectives
The objectives of this course are to provide students with the experimental knowledge of molecular biology and genetic engineering.

Student Learning Outcomes
Students should be able to gain hands-on experience on gene cloning, protein expression and purification. This experience would enable them to begin a career in industry.

Laboratory III: Techniques in Molecular Biology and Genetic Engineering

Credits
4

Syllabus
1. Concept of lac-operon:
   a. lactose induction of β-galactosidase.
   b. Glucose Repression.
   c. Diauxic growth curve of E. coli.
2. UV mutagenesis to isolate amino acid auxotroph.
4. Genetic Transfer-Conjugation, gene mapping.
5. Plasmid DNA isolation and DNA quantitation.
6. Restriction Enzyme digestion of plasmid DNA.
7. Agarose gel electrophoresis.
8. Polymerase Chain reaction.
9. DNA Ligation.
11. Transformation of *E.coli* with standard plasmids, Calculation of transformation efficiency.
12. Confirmation of the insert, Miniprep of recombinant plasmid DNA, Restriction mapping.
13. Expression of recombinant protein, concept of soluble proteins and inclusion body formation in *E.coli*, SDS-PAGE analysis.
14. Purification of His-Tagged protein on Ni-NTA columns
   a. Random Primer labeling
   b. Southern hybridization.

Laboratory IV: Immunology

Course Objectives
The objectives of this laboratory course are to develop an understanding about practical aspects of components of immune system as well as their function. Basic as well as advanced methods will be taught to detect different antigen and antibody interactions, isolation of different lymphocyte cells etc. and how they can be used in respective research work.

Student Learning Outcomes
On completion of this course, students should be able to:
- Evaluate the usefulness of immunology in different pharmaceutical companies;
- Identify proper research lab working in the area of their own interests;
- Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out the kind of immune responses in the setting of infection (viral or bacterial) by looking at cytokine profile.

Syllabus
1. Handling of animals like rabbits, mice.
2. Preparation of antigens, immunization and methods of blood collection, serum separation and storage.
3. Antibody titre by ELISA method.
5. Complement fixation test.
6. Isolation and purification of IgG from serum or IgY from chicken egg.
7. SDS-PAGE, Immunoblotting, Dot blot assays.
10. Separation of mononuclear cells by Ficoll-Hypaque.
11. Differential leucocyte count under a microscope.
12. Cryopreservation of cells.
### Semester Three

#### Bioprocess Equipment Design and Economics

**Credits**

<table>
<thead>
<tr>
<th>Unit</th>
<th>Introduction</th>
<th>Unit II Economics</th>
<th>Unit III Case studies</th>
<th>Unit IV Heat transfer equipment</th>
<th>Unit V Mass transfer equipment</th>
<th>Unit VI Reaction equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 lectures</td>
<td>10 lectures</td>
<td>14 lectures</td>
<td>7 lectures</td>
<td>7 lectures</td>
<td>7 lectures</td>
</tr>
</tbody>
</table>

**Course Objectives**

This is an introductory course to aspects of equipment design and process economics and follows coursework on reactor design and downstream processing.

**Student Learning Outcomes**

Students should be able to become proficient in applying basic design principles towards implementing bioprocess manufacturing systems.

**Course Details**

- **Unit I**
  - **Introduction**
  - Mechanical design of process equipment: pressure vessels, process piping design; Materials and Fabrication Selection.

- **Unit II**
  - **Economics**
  - Design Strategy and Optimum Equipment Design: Economic Design criteria; Cost and Asset Accounting; Cost Estimation; Interest and Investment Costs; Taxes and Insurance; Depreciation; Profitability, Alternative Investments and Replacement.

- **Unit III**
  - **Case studies**
  - Case Study in Process Equipment Design and Costing of Equipment in each of the following categories: Material Transfer, Handling and Treatment Equipment.

- **Unit IV**
  - **Heat transfer equipment**
  - Shell and tube heat exchangers (Kern and Bell-Delaware design methods), Plate heat exchangers, Evaporators.

- **Unit V**
  - **Mass transfer equipment**
  - Absorption/ Stripping columns (packed/tray), Multicomponent distillation column (Fenske-Underwood-Gilliland correlations).

- **Unit VI**
  - **Reaction equipment**
  - Choice of reactors, non-isothermal reactors, reactor configuration, interstage heating/cooling, multi-tubular reactors, catalyst deactivation.

**Recommended Textbooks and References:**

Bioentrepreneurship

Course Objectives
Research and business belong together and both are needed. In a rapidly developing life science industry, there is an urgent need for people who combine business knowledge with the understanding of science & technology. Bio-entrepreneurship, an interdisciplinary course, revolves around the central theme of how to manage and develop life science companies and projects. The objectives of this course are to teach students about concepts of entrepreneurship including identifying a winning business opportunity, gathering funding and launching a business, growing and nurturing the organization and harvesting the rewards.

Student Learning Outcomes
Students should be able to gain entrepreneurial skills, understand the various operations involved in venture creation, identify scope for entrepreneurship in biosciences and utilize the schemes promoted through knowledge centres and various agencies. The knowledge pertaining to management should also help students to be able to build up a strong network within the industry.

Unit I
Innovation and entrepreneurship in bio-business
8 lectures
Introduction and scope in Bio-entrepreneurship, Types of bio-industries and competitive dynamics between the sub-industries of the bio-sector (e.g. pharmaceuticals vs. Industrial biotech), Strategy and operations of bio-sector firms: Factors shaping opportunities for innovation and entrepreneurship in bio-sectors, and the business implications of those opportunities, Alternatives faced by emerging bio-firms and the relevant tools for strategic decision, Entrepreneurship development programs of public and private agencies (MSME, DBT, BIRAC, Make In India), strategic dimensions of patenting & commercialization strategies.

Unit II
Bio markets: business strategy and marketing
8 lectures
Negotiating the road from lab to the market (strategies and processes of negotiation with financiers, government and regulatory authorities), Pricing strategy, Challenges in marketing in bio business (market conditions & segments; developing distribution channels, the nature, analysis and management of customer needs), Basic contract principles, different types of agreement and contract terms typically found in joint venture and development agreements, Dispute resolution skills.

Unit III
Finance and accounting
8 lectures
Business plan preparation including statutory and legal requirements, Business feasibility study, financial management issues of procurement of capital and management of costs, Collaborations & partnership, Information technology.

Unit IV
Technology management
8 lectures
Technology – assessment, development & upgradation, Managing technology transfer, Quality control & transfer of foreign technologies, Knowledge centers and Technology transfer agencies, Understanding of regulatory compliances and procedures (CDSCO, NBA, GCP, GLA, GMP).

Recommended Textbooks and References:
Course Objectives
This is an introductory course to aspects of process control and instrumentation.

Student Learning Outcomes
Students should be able to become proficient in applying the fundamental concepts of process control towards the modeling and control of practical processes.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Course Content</th>
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</thead>
<tbody>
<tr>
<td>Unit I</td>
<td>Introduction</td>
</tr>
<tr>
<td>4 lectures</td>
<td>Essentials of mathematical models and modeling considerations.</td>
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<tr>
<td>Unit II</td>
<td>Dynamic processes</td>
</tr>
<tr>
<td>10 lectures</td>
<td>Linearization of non-linear systems; Laplace transforms; Transfer functions and input-output models; Analysis of first, second, and higher-order systems.</td>
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<tr>
<td>Unit III</td>
<td>Feedback control</td>
</tr>
<tr>
<td>10 lectures</td>
<td>Dynamics of feedback-controlled processes; Stability analysis; Controller design; Frequency response analysis and its application.</td>
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<tr>
<td>Unit IV</td>
<td>Advanced control schemes</td>
</tr>
<tr>
<td>7 lectures</td>
<td>Dead time or inverse response systems; Systems with multiple loops; Feedforward and ratio control.</td>
</tr>
<tr>
<td>Unit V</td>
<td>Instrumentation</td>
</tr>
<tr>
<td>7 lectures</td>
<td>Devices for measurement of flow, temperature, pH, pressure and liquid level.</td>
</tr>
</tbody>
</table>

Recommended Textbooks and References:

Course Objectives
The objectives of this course are to give background on history of science, emphasizing methodologies used to do research, use framework of these methodologies for understanding effective lab practices and scientific communication and appreciate scientific ethics.

Student Learning Outcomes
Students should be able to:
• Understand history and methodologies of scientific research, applying these to recent published papers;
• Understand and practice scientific reading, writing and presentations;
• Appreciate scientific ethics through case studies.

Unit I
History of science and science methodologies
8 lectures
Empirical science; scientific method; manipulative experiments and controls; deductive and inductive reasoning; descriptive science; reductionist vs holistic biology.

Unit II
Preparation for research
2 lectures
Choosing a mentor, lab and research question; maintaining a lab notebook.

Unit III
Process of communication
5 lectures
Concept of effective communication - setting clear goals for communication; determining outcomes and results; initiating communication; avoiding breakdowns while communicating; creating value in conversation; barriers to effective communication; non-verbal communication - interpreting non-verbal cues; importance of body language, power of effective listening; recognizing cultural differences; Presentation skills - formal presentation skills; preparing and presenting using overhead projector, PowerPoint; defending interrogation; scientific poster preparation & presentation; participating in group discussions; Computing skills for scientific research - web browsing for information search; search engines and their mechanism of searching; hidden Web and its importance in scientific research; internet as a medium of interaction between scientists; effective email strategy using the right tone and conciseness.

Unit IV
Scientific communication
9 lectures
Technical writing skills - types of reports; layout of a formal report; scientific writing skills - importance of communicating science; problems while writing a scientific document; plagiarism, software for plagiarism; scientific publication writing: elements of a scientific paper including abstract, introduction, materials & methods, results, discussion, references; drafting titles and framing abstracts; publishing scientific papers - peer review process and problems, recent developments such as open access and non-blind review; plagiarism; characteristics of effective technical communication; scientific presentations; ethical issues; scientific misconduct.
**Recommended Textbooks and References:**


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**Course Objectives**

The objectives of this course are:

- To provide basic knowledge on intellectual property rights and their implications in biological research and product development;
- To become familiar with India's IPR Policy;
- To learn biosafety and risk assessment of products derived from biotechnology and regulation of such products;
- To become familiar with ethical issues in biological research.

**Student Learning Outcomes**

On completion of this course, students should be able to:

- Understand the rationale for and against IPR and especially patents;
- Understand why India has adopted an IPR Policy and be familiar with broad outline of patent regulations;
- Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents;
- Gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research and environmental release of genetically modified organisms, national and international regulations;
- Understand ethical aspects related to biological, biomedical, health care and biotechnology research.

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**Unit I**

**Introduction to IPR**

5 lectures

Introduction to intellectual property; types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of 'prior art': invention in context of “prior art”; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation.

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**Unit II**

**Patenting**

5 lectures

Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure - patent application- forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting-requirement, procedures and costs; financial assistance for patenting-introduction to existing schemes; publication of patents-gazette of India, status in Europe and US; patent infringement- meaning, scope, litigation, case studies and examples;
commercialization of patented innovations; licensing – outright sale, licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives.

**Unit III**

**Biosafety**

5 lectures

Biosafety and Biosecurity - introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants – sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk – environmental risk assessment and food and feed safety assessment; problem formulation – protection goals, compilation of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops vs cisgenic plants or products derived from RNAi, genome editing tools.

**Unit IV**

**National and international regulations**

5 lectures

International regulations – Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations – EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – biosafety levels and category of rDNA experiments; field trials – biosafety research trials – standard operating procedures - guidelines of state governments; GM labeling – Food Safety and Standards Authority of India (FSSAI).

**Unit V**

**Bioethics**

5 lectures


**Recommended Textbooks and References:**

2. National IPR Policy, Department of Industrial Policy & Promotion, Ministry of Commerce, GoI
5. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/


**Project Proposal Preparation & Presentation**

**Course Objectives**
The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.

**Student Learning Outcomes**
Students should be able to demonstrate the following abilities:
- Formulate a scientific question;
- Present scientific approach to solve the problem;
- Interpret, discuss and communicate scientific results in written form;
- Gain experience in writing a scientific proposal;
- Learn how to present and explain their research findings to the audience effectively.

**Syllabus**

**Project Proposal Preparation**
Selection of research lab and research topic: Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them select a topic for their project. The topic of the research should be hypothesis driven.

Review of literature: Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources.

Writing Research Proposal: With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc. Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.

**Poster Presentation**
Students will have to present the topic of their project proposal after few months of their selection of the topic. They should be able to explain the novelty and importance of their research topic.

**Oral Presentation**
At the end of their project, presentation will have to be given by the students to explain work done by them in detail. Along with summarizing their findings they should also be able to discuss the future expected outcome of their work.
Course Objectives
The objectives of this course are to provide students with hands-on knowledge of primary unit operations involved in downstream processing.

Student Learning Outcomes
Students should be able to gain hands-on experience on approaches to cell disruption, centrifugation, filtration, and precipitation.

Syllabus
1. Conventional filtration
2. Centrifugation in batch and continuous centrifuges
3. Cell disruption
4. Protein precipitation and its recovery
5. Ion-exchange chromatography
6. Membrane-based filtration-ultra filtration in cross flow modules and micro filtration
7. Adsorption in batch and continuous mode.

Recommended Textbooks and References:

Semester Four

Dissertation

Course Objectives
The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.

Student Learning Outcomes
Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:

- In-depth knowledge of the chosen area of research.
- Capability to critically and systematically integrate knowledge to identify issues that must be addressed within framework of specific thesis.
- Competence in research design and planning.
- Capability to create, analyse and critically evaluate different technical solutions.
- Ability to conduct research independently.
- Ability to perform analytical techniques/experimental methods.
- Project management skills.
- Report writing skills.
## Course Objectives

This course aims to introduce bioreaction engineering principles to students.

## Student Learning Outcomes

- Growth kinetics of cell cultures;
- Basic stoichiometry of bioreactions;
- Thermodynamic aspects of bioreactions;
- Metabolic flux analysis;
- Bioreactor design.

### Syllabus

**Unit I**

**Growth kinetics of cell cultures**

5 lectures

**Unit II**

**Biocatalysts**

5 lectures

**Unit III**

**Bioreactor design**

5 lectures

**Unit IV**

**Bioreactor process**

5 lectures

Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions.

Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.

Assessment may be done by thesis evaluation, viva voce and final presentation.

**Syllabus**

**Planning & performing experiments**

Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

**Syllabus**

**Thesis writing**

At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.

**Recommended Mode of Assessment**

Assessment may be done by thesis evaluation, viva voce and final presentation.

**Recommended Electives**

### Bioreaction Engineering

**Course Objectives**

This course aims to introduce bioreaction engineering principles to students.

**Student Learning Outcomes**

On completion of this course, students should be able to understand:

- Growth kinetics of cell cultures;
- Basic stoichiometry of bioreactions;
- Thermodynamic aspects of bioreactions;
- Metabolic flux analysis;
- Bioreactor design.

### Syllabus

**Unit I**

**Growth kinetics of cell cultures**

5 lectures

Kinetics of cell growth and product formation, mass and energy balances in biological systems, structured growth models; Compartmental models; Cybernetic models.

**Unit II**

**Biocatalysts**

5 lectures

Immobilized biocatalysts: external mass transfer; Internal diffusion; Reaction within catalysts; Kinetic analysis of batch processes.

**Unit III**

**Bioreactor design**

5 lectures

Reactor design (batch, continuous, fed-batch, plug flow, packed bed, airlift, immobilized enzyme/cell etc.); Optimal bioreactor operation using simple reaction kinetics.

**Unit IV**

**Bioreactor process**

5 lectures

Dynamic simulation of bioreactor processes (batch, fed-batch, continuous etc.);
Reactors in series.

Assessment may be done by thesis evaluation, viva voce and final presentation.
Unit V
Stoichiometry of bioreactions
5 lectures

Pathway analysis: Stoichiometric analysis; Thermodynamics-derived constraints; Flux balancing techniques; Metabolic control analysis.

Recommended Textbooks and References:

Computational Programming

Credits
2

Course Objectives
The objectives of this course are to teach students about essentials of computer programming using modern languages such as java, C++, python, and PERL.

Student Learning Outcomes
Students should be able to become proficient in applying fundamental concepts of programming in solving problems in science and engineering. This proficiency is critical towards developing research-grade tools in domains such as bioinformatics.

Unit I
Introduction
4 lectures

Higher level programming concepts, assembly level programming concepts, libraries, compilers, STDIN, STDOUT; Integrated programming environments.

Unit II
Variables
5 lectures

Number representations, Variables, data types, declarations, Operators (assignment).

Unit III
Loops & subroutines
5 lectures

Control structures and conditional statements; Do, while, until constructs. Functions, Arrays. Recursive functions.

Unit IV
Object-oriented programming
5 lectures

Structures and Objects; Object-oriented programming and Classes.

Unit V
Applications
7 lectures

Sample problems in science, engineering and text processing.

Recommended Textbooks and References:
Course Objectives
This course aims to introduce fundamentals of Environmental Biotechnology. The course will introduce students major groups of microorganisms-tools in biotechnology and their most important environmental applications. The environmental applications of biotechnology will be presented in detail and will be supported by examples from national and international literature.

Student Learning Outcomes
On completion of the course, students should be able to understand use of basic microbiological, molecular and analytical methods, which are extensively used in environmental biotechnology.

Unit I
Introduction to environment
6 lectures
Introduction to environment; pollution and its control; pollution indicators; waste management: domestic, industrial, solid and hazardous wastes; strain improvement; Biodiversity and its conservation; Role of microorganisms in geochemical cycles; microbial energy metabolism, microbial growth kinetics and elementary chemostat theory, relevant microbiological processes, microbial ecology.

Unit II
Bioremediation
6 lectures
Bioremediation: Fundamentals, methods and strategies of application (biostimulation, bioaugmentation) – examples, bioremediation of metals (Cr, As, Se, Hg), radionuclides (U, Te), organic pollutants (PAHs, PCBs, Pesticides, TNT etc.), technological aspects of bioremediation (in situ, ex situ).

Unit III
Role of microorganisms in bioremediation
6 lectures
Application of bacteria and fungi in bioremediation: White rot fungi vs specialized degrading bacteria: examples, uses and advantages vs disadvantages; Phytoremediation: Fundamentals and description of major methods of application (phytoaccumulation, phytovolatilization, rhizofiltration, phytostabilization).

Unit IV
Applications of environmental biotechnology in agriculture
11 lectures
Bioinsecticides: *Bacillus thuringiensis*, Baculoviruses, uses, genetic modifications and aspects of safety in their use; Biofungicides: Description of mode of actions and mechanisms (*e.g.* *Trichoderma, Pseudomonas fluorescens*); Biofertilizers: Symbiotic systems between plants – microorganisms (nitrogen fixing symbiosis, mycorrhiza fungi symbiosis), Plant growth promoting rhizobacteria (PGPR) – uses, practical aspects and problems in application.

Unit V
Biofuels
11 lectures
Environmental Biotechnology and biofuels: biogas; bioethanol; biodiesel; biohydrogen; Description of the industrial processes involved, microorganisms and biotechnological interventions for optimization of production; Microbiologically enhanced oil recovery (MEOR); Bioleaching of metals; Production of bioplastics; Production of biosurfactants: bioemulsifiers; Paper production: use of xylanases and white rot fungi.

Recommended Textbooks and References:
Enzyme Engineering & Technology

Course Objectives
The objectives of this course are to teach principles of enzyme engineering and enzyme technology.

Student Learning Outcomes
On completion of this course, students should be able to:
• Understand essential principles of enzyme engineering and technology;
• Become aware of applications in biotechnology processes.

Unit I
Enzymes, coenzymes and cofactors
3 lectures
Enzymes: Classification, mode of action, activation, specificity, Source of enzymes; production, isolation and purification of enzymes; Characterization in terms of pH, temperature, ionic strength, substrate and product tolerance, effects of metal ions; Coenzymes and cofactors: Coenzymes, classification of vitamins, role and mechanism of action of some important coenzyme (NAD+/NADP+, FAD, lipoic acid, tetrahydrofolate, B12-coenzyme), role of cofactors with specific examples.

Unit II
Enzyme kinetics
8 lectures
Enzyme as biological catalysts; Enzyme action, active site, functional group, enzyme substrate complex, cofactors, Michaelis-Menten equation, Km and Vmax, enzyme inhibition; order of reaction, methods of plotting enzyme kinetics data; Enzyme turnover number. competitive, non-competitive, uncompetitive, irreversible; order of reaction, methods of plotting enzyme kinetics data; determination of Kcat, Km, Vmax, Ki, Half life, activation and deactivation energy etc. Cross-linked enzyme aggregates, Cross linked enzymes, enzyme crystals, their use and preparation; Solution of numerical problems; Energy yielding and energy-requiring reactions; Calculation of equilibrium constants; Activation energy etc.; Multisubstrate enzymes and kinetics mechanisms; Enzyme induction, repression, covalent modification, Isoenzymes, allosteric effects.

Unit III
Enzyme engineering
5 lectures
Introduction, Random and rational approach of protein engineering; Directed evolution and its application in Biocatalysis; various approaches of creating variant enzyme molecules; Future of Biocatalysis; Ideal biocatalyst.

Unit IV
Applications of enzyme technology
4 lectures
Immobilized enzyme technology: Different techniques of immobilization of enzymes and whole cells; Advantages and disadvantages of immobilization; Kinetics of immobilized enzymes, design and operation of immobilized enzymes reactors; Type of reactors, classification, retention of enzymes in a reactor, kinetics of enzyme reactors; Reactor performance with inhibition, operation of enzyme reactors; case studies; starch conversion; APA production, biotransformations using soluble as well as immobilized enzymes; Calculation of diffusional resistances and Thiele's modulus, multi-step immobilized enzyme systems; Solution of numerical problems; Application and future of immobilized enzyme technology; Enzyme in organic solvents and ionic liquids: Various organic solvents and ionic liquids used in biocatalysis; Potential in organic solvents and ionic liquids; Applications of enzymes in analysis.

Recommended Textbooks and References:
### Metabolic and Systems Biology

**Course Objectives**
This course work will provide essential knowledge to make career in bioprocess industries and in field of computational systems biology.

**Student Learning Outcomes**
At the end of this course, students should be able to:
- Understand the current advances in systems biology;
- Gain insights into the field of metabolic engineering.

### Unit I
**Introduction to systems biology**
6 lectures


### Unit II
**Metabolic flux analysis**
5 lectures

*Introduction to Flux balance analysis, Construction of stoichiometric matrices, Constraint based models. Network basics, examples of mathematical reconstruction of transcriptional networks and signal transduction networks; Tools for metabolic flux analysis - Monitoring and measuring the metabolome, Methods for the experimental determination of metabolic fluxes by isotope labeling metabolic fluxes using various separation-analytical techniques; GC-MS for metabolic flux analysis, genome wide technologies: DNA /phenotypic microarrays and proteomics; Basics of MATLAB.*

### Unit III
**Kinetic modelling**
6 lectures

*Kinetic modelling of biochemical reactions, describing dynamics with ODEs, rate equations, deriving a rate equation, incorporating regulation of enzyme activity by effectors, E-cell platform and erythrocyte modelling, case studies in E. coli, S. cerevisiae metabolic network reconstruction methods, optimization of metabolic network, Identification of targets for metabolic engineering; software and databases for genome scale modelling; Use of computational techniques to solve ODEs.*

### Unit IV
**Networks in biological systems**
4 lectures

*Network motifs, Feed forward loop network motif. Gene circuits, robustness of models, Chemotaxis model, Integration of data from multiple sources: Building genome scale models.*

### Unit V
**Tools and case studies**
5 lectures

*Tools and databases for modelling: Pathway databases KEGG, EMP, Metacyc, Enzyme kinetics database BRENDA, Gene expression databases, Biomodels database, Basics of Systems Biology Markup Language (SBML), SBML editors. Transcriptomics: Microarray technology, expression profiles, data analysis; SAGE; Proteomics: 2D gel electrophoresis; Mass Spectrometry; Protein arrays; Metabolomics: 13C NMR based metabolic flux analysis.*

### Recommended Textbooks and References:
## Course Objectives
The objective of the course is to familiarize students with emerging trends in medical devices for early detection, selection of appropriate treatment, monitoring treatment effectiveness and disease surveillance.

## Student Learning Outcomes
On successfully completing this course, students are expected to be able to:
- Extend principles of engineering to the development of medical devices and design of sensors;
- Appreciate basic configuration and distinction among biosensor systems.

### Unit I: Sensors
- **5 lectures**

Rationale of electronic biosensors; Essence of three types of electronic biosensors (i.e., potentiometric, amperometric, and cantilever-based sensors); Three essential metrics that define modern electronic sensors; detection time, sensitivity, and selectivity; Physics of detection time that allows one to organize every available sensor in a systematic way; Fundamental limits of detection of various classes of sensors; Opportunities and challenges of integrating sensors in a system platform.

### Unit II: Transducers
- **5 lectures**

Principles and applications of Calorimetric, Piezoelectric, semiconductor, impedimetric, based transducers; Biochemical Transducers: Electrode theory: electrode-tissue interface, metal-electrolyte interface, electrode-skin interface, electrode impedance, electrical conductivity of electrode jellies and creams.

### Unit III: Optical sensors
- **5 lectures**

Photo detectors, optical fiber sensors, indicator mediated transducers; General principles of optical sensing, optical fiber temperature sensors; Pulse sensor: photoelectric pulse transducer, strain gauge pulse transducer.

### Unit IV: Bio recognition systems
- **5 lectures**

Enzymes; Oligonucleotides Nucleic Acids; Lipids (Langmuir-Blodgett bilayers, Phospholipids, Liposomes); Membrane receptors and transporters; Immunoreceptors; Chemoreceptors.

### Unit V: Electrodes and immobilization
- **5 lectures**

Microelectrodes, body surface electrodes, needle electrodes, pH electrode, specific ion electrodes/ ion exchange membrane electrodes, enzyme electrodes; Reference electrodes: hydrogen electrodes, silver-silver chloride electrodes, Calomel electrodes; Enzyme immobilization; Peptide immobilization; Antibody immobilization; Oligonucleotides and Nucleic Acid immobilization; Cell immobilization; Mono-enzyme electrodes; Bi-enzyme electrodes: enzyme sequence electrodes and enzyme competition electrodes.

### Unit VI: Fundamentals and applications of microfluidics
- **5 lectures**

Capillary flow and electro kinetics; Micro pump, Micro mixers, Micro reactors, Micro droplets, Micro particle separators; Micro fabrication techniques (different types of lithography methods); Application of micro-fluidics (e.g. Lab- in –Chip).

### Unit VII: Applications
- **5 lectures**

Biomarkers: Disease and pathogen specific information, availability by sample type (blood, serum, urine, sputum, saliva, stool, mucus); Specificity, sensitivity, shelf life,
portability; Clinical chemistry; Test-strips for glucose monitoring; Urea determination; Implantable Sensors for long-term monitoring; Drug development and detection; Environmental monitoring; Examples of various diseases (Cancer, HIV/AIDS, Tuberculosis, Malaria, Lymphatic Filariasis, Schistosomiasis, Dengue, Chikungunya).

Recommended Textbooks and References:

Molecular Diagnostics

Course Objectives
The objectives of this course are to sensitize students about recent advances in molecular biology and various facets of molecular medicine which has potential to profoundly alter many aspects of modern medicine including pre- or post-natal analysis of genetic diseases and identification of individuals predisposed to disease ranging from common cold to cancer.

Student Learning Outcomes
Students should be able to understand various facets of molecular procedures and basics of genomics, proteomics and metabolomics that could be employed in early diagnosis and prognosis of human diseases.

Unit I
Genome biology in health and disease
4 lectures
DNA, RNA and Protein: An overview; chromosomal structure & mutations; DNA polymorphism: human identity; clinical variability and genetically determined adverse reactions to drugs.

Unit II
Genome: resolution, detection and analysis
5 lectures
PCR: Real-time; ARMS; Multiplex; ISH; FISH; ISA; RFLP; DHPLC; DGGE; CSCE; SSCP; Nucleic acid sequencing: new generations of automated sequencers; Microarray chips; EST; SAGE; microarray data normalization & analysis; molecular markers: 16S rRNA typing; Diagnostic proteomics: SELDI-TOF MS; Bioinformatics data acquisition & analysis.

Unit III
Diagnostic metabolomics
2 lectures
Metabolite profile for biomarker detection in the body fluids/tissues under various metabolic disorders by making use of LCMS & NMR technological platforms.
Direct detection & identification of pathogenic-organisms that are slow growing or currently lacking a system of in vitro cultivation as well as genotypic markers of microbial resistance to specific antibiotics.

Exemplified by two inherited diseases for which molecular diagnosis has provided a dramatic improvement of quality of medical care: - Fragile X Syndrome: Paradigm of the new mutational mechanism of the unstable triplet repeats, von-Hippel Lindau disease: recent acquisition in the growing number of familial cancer syndromes.

Detection of recognized genetic aberrations in clinical samples from cancer patients; types of cancer-causing alterations revealed by next-generation sequencing of clinical isolates; predictive biomarkers for personalized onco-therapy of human diseases such as chronic myeloid leukemia, colon, breast, lung cancer and melanoma as well as matching targeted therapies with patients and preventing toxicity of standard systemic therapies.

Quality oversight; regulations and approved testing.

Recommended Textbooks and References:

Course Objectives
The course aims at providing general and broad introduction to multi-disciplinary field of nanotechnology. It will familiarize students with combination of top-down approach of microelectronics and micro-mechanics with bottom-up approach of chemistry/biochemistry; a development that is creating new and exciting cross-disciplinary research fields and technologies. The course will also give an insight into complete systems where nanotechnology can be used to improve everyday life.

Student Learning Outcomes
On successful completion of this course, students should be able to describe basic science behind the properties of materials at the nanometre scale, and the principles behind advanced experimental and computational techniques for studying nanomaterials.
### Unit III
**Nano - particles**
6 lectures
Nanoparticles for drug delivery, concepts, optimization of nanoparticle properties for suitability of administration through various routes of delivery, advantages, strategies for cellular internalization and long circulation, strategies for enhanced permeation through various anatomical barriers.

### Unit IV
**Applications of nano - particles**
5 lectures
Nanoparticles for diagnostics and imaging (theranostics); concepts of smart stimuli responsive nanoparticles, implications in cancer therapy, nanodevices for biosensor development.

### Unit V
**Nano - materials**
6 lectures
Nanomaterials for catalysis, development and characterization of nanobiocatalysts, application of nanoscaffolds in synthesis, applications of nanobiocatalysis in the production of drugs and drug intermediates.

### Unit VI
**Nano - toxicity**
5 lectures
Introduction to Safety of nanomaterials, Basics of nanotoxicity, Models and assays for Nanotoxicity assessment; Fate of nanomaterials in different stratas of environment; Ecotoxicity models and assays; Life cycle assessment, containment.

### Recommended Textbooks and References:
5. Recent review papers in the area of Nanomedicine.

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### Production of Biotherapeutics

**Course Objectives**
The objectives of this course are to equip students with essentials of biomanufacturing principles and good manufacturing practices for production of biotherapeutics.

**Student Learning Outcomes**
Students should develop conceptual clarity and knowledge about systems for quality manufacturing of biotherapeutics (biopharmaceuticals, diagnostics and foods) manufactured for human use. The knowledge of GMP and GLP requirements is critical for students who opt for careers in biomanufacturing.

**Credits**
2

### Unit I
**Biomanufacturing principles**
6 lectures
Overview and design of biomanufacturing, quality by design approach, technical considerations, phases and scale up: life cycle of manufacturing, raw material considerations, compliance and quality in biomanufacturing, lean biomanufacturing; Process analytical technology (PAT) during biomanufacturing: background and need tools for data acquisitions (software in fermenters, flow filtrations, chromatography, analysis and design process analyzers, process control tools and continuous improvement and knowledge management; Standard manufacturing operating procedures of biotechnology, including upstream and downstream processing of proteins, and quality control of protein production, and final fill and finish of product; Case studies to be included therapeutic proteins, monoclonal antibodies, human vaccines.

### Unit II
**Quality system**
4 lectures
Introduction to quality system, main elements of a quality system; Essential of quality system; Practical implementation of a quality system; Structure of quality manual, correlation between GMP requirements (WHO) and ISO 9001:2000.
Personnel: Principles of human resource management, duties of senior management, organizational structures, qualification and profiles requirement, workplace and job descriptions, health monitoring and occupational health safety, training, functions owners subject to public law; Premises: Official requirements, material & personnel flow and layout, air cleanliness classes and grades, construction elements, barrier systems, isolators and safety cabinets, building services, heating ventilation air conditioning (HVAC), process gases, qualification of premises and HVAC systems, pharma monitoring of HVAC systems, particle monitoring; Facilities and Equipment: Facility planning, materials, hygienic design in solids handling, system controllers and process control systems, technical documentation, calibration, maintenance, cleaning of facilities, containment (personnel protection) in solids handling; Pharmaceutical water: Water qualities, generation of pharmaceutical water, distribution and storage of pharmaceutical water, qualification of water supplies, operation of water supplies, pure steam systems; Qualification: Official requirements, preparation of the qualification, qualification documentation, design qualification (DQ), Installation qualification (IQ), operational qualification (OQ), Performance qualification (PQ), special cases of qualification; Process Validation: Official requirements, Validation - a key element of quality management, validation planning and procedure, validation documentation, process validation and product lifecycle; Cleaning Validation: Official requirements, how to validate cleaning procedures, cleaning validation master plan, establishing the scope of validation, acceptance criteria and limit calculation, sampling procedures, analytical procedure, documentation, maintenance of the validated status, cleaning validation documentation; Production: Sanitation, personnel hygiene, production hygiene, sanitation programme, environmental monitoring, GMP in the production process, weigh-in, identification, in-process control prevention of cross-contamination, empty chapter, reworking, warehouse and logistics; Sterile Production and Packaging: Introduction, Air lock concepts, manufacture of terminally sterilised products, sterilisation processes, aseptic processing, freeze-drying, testing for sterility, testing for endotoxins, testing for leakage and for particles, microbiological monitoring, packaging materials, packaging process, qualification of a servo-controlled blister packaging line, blow-fill-seal technology (BFS technology); Documentation: Official requirements, GMP-compliant documentation, batch documentation, standard operating procedures (SOPs), site master file, electronic batch recording and batch release, CAPA, document management systems.

Information, national bodies and pharmaceutical associations; Pharmacopeia; EU directives and guidelines, USA: CFR and FDA guidelines, ICH-guidelines, PIC/S guidelines, GMP of other regions, WHO guidelines.

Recommended Textbooks and References:
5. *Learn Biomanufacturing*, 1st Edition; Author Nigel Smart; Woodhead Publishing
6. *GMP Manual*; Publisher Maas & Peither America, Inc. GMP Publishing.
### OMICS Technologies

**Course Objectives**
The aim of this course is to give an overview of genomics, proteomics and metabolomics to the students. The students should be able to gain working knowledge of these technologies and appreciate their ability to impart a global understanding of biological systems and processes in health and disease.

**Student Learning Outcomes**
At the end of the course, students should be:
- Understand high throughput analysis;
- Gain knowledge of current cutting edge technologies;
- Know the application of various Omics technologies.

### Unit I
**Genomics and methods in genomics**
5 lectures

- Organization and structure of genomes in prokaryotes, eukaryotes, and organelles (chloroplast, mitochondrion);
- Genome mapping methods (genetic and physical);
- RAPD, RFLP, SNP analyses;
- Fluorescence in-situ Hybridization (FISH) techniques;
- Advances in gene finding and functional prediction;
- Chain termination and chemical degradation sequencing methods. Genome-wide association (GWA) analysis;
- Comparative Genomic Hybridization (CGH);
- Massively parallel Signature Sequencing (MPSS);
- Whole genome shot-gun sequencing and its applications;
- Introduction of Next Generation Sequencing (NGS).

### Unit II
**Transcriptomics and methods in transcriptomics**
5 lectures

- Gene expression analysis by cDNA and oligonucleotide arrays;
- Micro array experimental analysis and data analysis;
- Bioinformatic analysis of large-scale microarray data for comparative transcriptomics.

### Unit III
**Proteomics and methods in proteomics**
10 lectures

- Over-view of strategies used for the identification and analysis of proteins;
- Protein extraction from biological samples (Mammalian Tissues, Yeast, Bacteria, and Plant Tissues);
- 2-DE of proteins for proteome analysis;
- Liquid chromatography separations in proteomics (Affinity, Ion Exchange, Reversed-phase, and size exclusion);
- Over-view of strategies used for the identification and analysis of proteins;
- Protein extraction from biological samples (Mammalian Tissues, Yeast, Bacteria, and Plant Tissues);
- 2-DE of proteins for proteome analysis;
- Liquid chromatography separations in proteomics (Affinity, Ion Exchange, Reversed-phase, and size exclusion);
- Common ionization methods for peptide/protein analysis;
- Introduction to Mass spectrometers;
- MALDI-TOF and LC-MS analyses;
- Comparative proteomics based on global in-vitro and in-vivo labelling of proteins/peptides followed by Mass-spectrometry.
- Analysis of post-translational modification (PTM) of proteins;
- Characterization of protein interactions using yeast two-hybrid system and Protein microarrays;
- Proteomics informatics and analysis of protein functions.

### Unit IV
**Metabolomics and methods in metabolomics**
8 lectures

- Introduction to metabolic engineering, comprehensive models of cellular reactions with stoichiometry and reaction rates;
- Metabolic flux analysis of exactly/over/under determined systems;
- Shadow price, sensitivity analysis;
- Monitoring and measuring the metabolome.
- Methods for the experimental determination of metabolic fluxes by isotope labelling metabolic fluxes using various separation-analytical techniques;
- GC-MS for metabolic flux analysis.
Recommended Textbooks and References:
### DBT Supported Teaching Programmes

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of University</th>
<th>Contact Details of Course Coordinator</th>
</tr>
</thead>
</table>
| 1.    | Anna University, Chennai                 | Dr. Anuradha Dhanasekaran  
Centre for Biotechnology  
91-044-223250772, 22358363/8362, 09840919676  
hoddirbtauc@gmail.com, directorcbt@annauniv.edu |
| 2.    | West Bengal University of Technology, Kolkata | Dr. Subrata Kumar Dey  
Deptt. of Biotechnology  
033-23210731/204, 9830278216 (M)  
subrata.dey@wbut.ac.in |
| 3.    | Indian Institute of Technology, Guwahati | Dr. Kannan Pakshirajan  
Deptt. of Biotechnology  
0361-2582210, 2582201  
hodbio@iitg.ernet.in pakshi@iitg.ernet.in |
| 4.    | Indian Institute of Technology, Kanpur    | Dr. Dhirendra S. Katti  
Deptt. of Biological Sciences and Bioengineering  
0512-2594028, 3924028, 6794028  
dsk@iitk.ac.in |
| 5.    | Indian Institute of Technology, Kharagpur | Prof. Sudip K. Ghosh  
Deptt. of Biotechnology  
03222-282248, 282247 (O)  
sudip@hijli.iitkgp.ernet.in |
| 6.    | Indian Institute of Technology, New Delhi | Dr. Atul Narang  
Deptt. of Biochemical Engineering & Biotechnology  
011-2659 1061  
narang.at@gmail.com |
| 7.    | Institute of Chemical Technology, Mumbai | Dr. Sandeep B. Kale  
022- 33612313, 09584351422  
sb.kale@ictmumbai.edu.in |

### Annexure I

**Subject Specific Subcommittee of M.Tech. Biotechnology**

**Chairperson**  
1. Dr. Santosh Noronha, Professor, Department of Chemical Engineering,  
   Indian Institute of Technology, Bombay

**Members**  
2. Dr. U. C. Banerjee, Professor and Head, Department of Pharmaceutical Technology,  
   National Institute of Pharmaceutical Education and Research, Mohali
3. Dr. Amulya Panda, Staff Scientist VII, National Institute of Immunology, New Delhi
4. Dr. P. Gautam, Professor, Department of Biotechnology, Anna University, Chennai
5. Dr. Rakhi Chaturvedi, Professor, Department of Biosciences and Bioengineering,  
   Indian Institute of Technology Guwahati
6. Dr. Abhinav Grover, Assistant Professor, School of Biotechnology, Jawaharlal Nehru  
   University, New Delhi,
7. Dr. Neelam Chauhan, Assistant Professor, National Institute of Pharmaceutical  
   Education and Research, Ahmedabad
8. Dr. Monideepa Roy, Head, Research and Development, Invictus Oncology Pvt. Ltd.,  
   New Delhi

**Member Secretary**  
9. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi
M.Tech. Food Biotechnology
Introduction

Background

Promotion of Indian Biotechnology sector is high on policy agenda of Government of India. Biotechnology has also been recognized as one of the key priority sectors under ‘Make in India,’ ‘Skill India’ and ‘Startup India’ initiatives of Government of India, as it is one of sectors expected to contribute towards enterprise creation, innovation and economic growth. Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India has immensely contributed to this dynamism through various policies and initiatives, establishment of innovation clusters, academia-industry partnerships, increasing capabilities for technology development, etc. The National Biotechnology Development Strategy (2015 – 2020) released by DBT provides a strategic roadmap for India’s emergence as a global biotechnology innovation and manufacturing hub. It has also highlighted importance of human resource development and need for nurturing tailor-made human capital for advanced scientific research and entrepreneurship.

DBT has taken a number of initiatives aimed at integrated human resource development to evolve an ecosystem where scientists, innovators and future entrepreneurs can be nurtured. Keeping in mind requirement for trained manpower in various areas of Biotechnology, DBT initiated Post-Graduate Teaching Programme way back in 1985 with 5 universities which has expanded to 74 universities imparting M.Sc./M.Tech./M.V.Sc. degrees in general, agricultural, animal, food, environmental, industrial marine, medical, neuroscience and pharmaceutical biotechnology. 10 programmes are being phased out. These universities and institutes are provided liberal financial support towards strengthening of laboratory facilities, equipment, consumables, fellowships to students, dissertation grant per student etc. Post-Graduate Teaching Programme selects best students and trains them to join research or industry workforce contributing significantly to biotechnology workforce.

About the Course Curriculum Revision Exercise

Taking into cognizance the changing needs of the economy and to keep abreast with latest developments in the field of biotechnology, DBT proactively initiated revision of course curricula of Post-Graduate Programmes in biotechnology. The present exercise has been undertaken by Biotech Consortium India Limited (BCIL), New Delhi. Earlier exercise was carried out in 2008. The Course Curriculum Revision Exercise has been carried out for 13 Post-Graduate programmes in Biotechnology supported by DBT.

The revision of course curriculum of M.Tech. Food Biotechnology aims to address mismatch between ‘knowledge’ gained by students and appropriate skill set required for technology development and implementation including present contemporary needs of economy.

Methodology

A meticulous and structured approach has been adopted to accomplish the Course Curriculum Revision exercise.

BCIL had initiated the exercise with a review of literature of relevant national and international documents on curriculum design and planning for biotechnology programmes of premier national as well as international universities, guidelines by University Grants Commission, recent curricular guidelines released by Indian Council of Agricultural Research, Ministry of Health and Family Welfare and Indian Institute of Science Education & Research and other relevant research papers on curriculum development in peer-reviewed journals.
The findings of the literature review were adopted to design questionnaires for eliciting feedback from stakeholders of Biotechnology community i.e. academicians, scientists, industry representatives and students. Feedback was received from 165 experts and 20 students belonging to academic institutions, research organizations and industry regarding addition of advanced topics, deletion of elementary, redundant and overlapping topics, updation of laboratory practicals, re-adjustment of credit load, incorporating ‘technology’ component in the curriculum, among others. It was also suggested that re-orientation of curricula should be done keeping in view the needs of the industry.

**Strategic Approach**

A Core Committee along with 9 subject specific subcommittees comprising of 63 academicians, scientists and industry representatives were constituted to revise and update the curricula. The constitution of subject specific subcommittee for M.Tech. Food Biotechnology is given at Annexure-1.

The salient recommendations identified from stakeholder survey were presented to the Committee. Several brainstorming discussion sessions were held for achieving the desired balance between the foundation courses, recent developments in biotechnology and updation needs identified during the stakeholder survey. Core Committee finalized broad contours for revising all the course curricula. The guidelines set by the Core Committee were taken up by the subject specific subcommittee of M.Tech. Food Biotechnology for updating the curriculum. The subject specific subcommittee incorporated latest advancements in areas of food Biotechnology in the curriculum. Separate meeting was held to discuss and deliberate the updations to be made in the curriculum. The revised curriculum was vetted and finalized by the Core Committee.

**Course Curriculum Revision**

The members of Committee agreed that revised course curriculum should provide skill and outcome based education and help the students to gain domain knowledge, ability to design and interpret research experiments and acquire effective communication skills. The course curriculum has been re-designed accordingly to promote skill-based and outcome-based education. The revised course curriculum totals to 96 credits comprising of theory, practical, technology-based topics, electives and dissertation. Each course includes learning objectives, student learning outcomes, course plan (number of lectures/unit) and reference textbooks/resources. Theory and practical courses include relevant examples, case scenarios and tutorials for inculcating critical thinking against rote learning. Several new courses have been included and content for existing courses has also been updated. Specialized courses such as Principles of Food Analysis, Biotechnology of Fermented Foods, Nutrigenomics, Bioreactor Operations, Food Process Engineering, Food Allergies and Toxicology have been incorporated to introduce industry-relevant courses. With importance of students being able to execute research projects independently, separate credits have been allotted for proposal preparation and presentation before initiating dissertation and also credits for dissertation have been increased accordingly.

We hope that model course curriculum shall serve as guidelines for academicians and researchers from different parts of the country for adoption in their institutions with modifications as per availability of expertise, infrastructure and specific needs.

We wish to put on record our sincere appreciation for constant guidance and encouragement received from Dr. K. VijayRaghavan, Secretary, DBT for bringing out this publication. We wish to acknowledge whole-hearted support of Core Committee and subject specific subcommittees members. Sincere thanks are due to Dr. Manoj Singh Rohilla, Scientist- D, DBT, Ms. Shweta for creative design, Mrs. Rita Bhatla, DBT and Shri. Dilip Joy, BCIL.
As the Chairperson of the expert syllabus committee for M.Tech. Food Biotechnology, I am glad to offer this document to the academic institutes engaged in training post graduate students in applied biotechnology oriented towards industrial needs so as to have good employability of these trained manpower. Due to interdisciplinary nature of Food Biotechnology, engineering graduates from allied fields are eligible to join the program which demands extensive bridge courses - both theory and laboratories. A group of senior researchers, academicians and industry experts have worked together and spent nearly a thousand person-hours to arrive at the best possible combination of subjects, pool of electives with due emphasis on soft skills. Fulfilling demands of all stake holders was the biggest challenge. M.Tech Food Biotechnology course is highly specialized and relatively small number of students are undertaking this PG program across the nation. However, unlike other M.Sc. programs these students join industry rather than further studies and hence concept of finishing school and industrial training has been used which make this syllabus unique.

(Prof. S.S. Lele)
M.Tech. Food Biotechnology

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<tr>
<th>S.No.</th>
<th>Title</th>
<th>Credits</th>
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<tr>
<td></td>
<td><strong>SEMESTER ONE</strong></td>
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<tr>
<td>1</td>
<td>Introduction to Food Science and Technology</td>
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<tr>
<td>2</td>
<td>Biochemistry</td>
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<td>3</td>
<td>Fundamentals of Food Biotechnology, Genetics and Cell Culture Technology</td>
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<td>4</td>
<td>Microbiology</td>
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<td>5</td>
<td>Basics of Safety and Risk Management</td>
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<td>Seminar and Critical Review of Research Publication</td>
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<td>8</td>
<td>Laboratory I: Biochemistry and Laboratory Techniques</td>
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<td>Principles of Food Analysis</td>
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<td>2</td>
<td>Bioprocess Engineering and Technology</td>
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<td>3</td>
<td>Biotechnology of Fermented Foods</td>
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<td>Nutrigenomics</td>
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<td>Research Methodology and Scientific Communication Skills</td>
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<td>Bioentrepreneurship</td>
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<td>Project Proposal Preparation and Presentation</td>
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<td>Laboratory III: Food Processing and Analysis</td>
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Recommended Electives:
### Semester One

**Introduction to Food Science and Technology**

**Course Objectives**
This course will offer students a good command of basic principles of food science and technology and applying this understanding to growing and dynamic needs of food and beverage industries.

**Student Learning Outcomes**
On completion of this course, students should be able to:
- Demonstrate a level of comprehension of concepts of food science;
- Critically evaluate and solve issues or problems pertaining to food science.

**Unit I**
**Introduction to food science and technology**
10 lectures

Basics of chemistry of food constituents—carbohydrates, proteins, lipids, vitamins, minerals, water (different forms of water present in foods and their effect on quality and preservation of foods), minor constituents affecting texture, colour, taste, odour; Food microbiology, Food biochemistry, Food additives, General food composition and effect of food constituents on food quality.

**Unit II**
**Standards for food analysis**
10 lectures

Standards of identity, purity and methodology for analysis of: a) Cereals, legumes, oil seeds and their products; b) Fruits, vegetables, tubers and their products; c) Tea, coffee, cocoa, chocolate, spices, condiments; d) Milk and milk products; e) Meat, fish and poultry products; f) Miscellaneous foods e.g. fermented products.

**Unit III**
**Food processing and preservation**
10 lectures

Introduction to food processing of various foods including dairy, bakery, brewing, fruit and vegetable products, plantation products; pro and prebiotics and nutraceutical. Principles of food preservation by: Dehydration, Thermal treatments like pasteurization, sterilization, canning, retorting etc. Low temperature i.e. chilling and freezing, Chemical preservation/ bio-preservation, Traditional methods like salting/ syruping, pickling, fermentation etc. Non thermal processes like MAP, irradiation, high pressure processing etc. Hurdle technology.

**Recommended Textbooks and References:**
Biochemistry

Credits 3

Course Objectives
The objectives of this course are to build upon undergraduate level knowledge of biochemical principles with specific emphasis on different metabolic pathways. The course shall make the students aware of various disease pathologies within the context of each topic.

Unit I
Protein structure
5 lectures

Chemical basis of life: Miller-Urey experiment, abiotic formation of amino acid oligomers, composition of living matter; Water – properties of water, essential role of water for life on earth pH, buffer, maintenance of blood pH and pH of gastric juice, pH optima of different enzymes (pepsin, trypsin and alkaline phosphatase), ionization and hydrophobicity, emergent properties of biomolecules in water, biomolecular hierarchy, macromolecules, molecular assemblies; Structure-function relationships: amino acids – structure and functional group properties, peptides and covalent structure of proteins, elucidation of primary and higher order structures, Ramachandran plot, evolution of protein structure, protein degradation and introduction to molecular pathways controlling protein degradation, structure-function relationships in model proteins like ribonuclease A, myoglobin, hemoglobin, chymotrypsin etc.; basic principles of protein purification; tools to characterize expressed proteins; Protein folding: Anfinsen's Dogma, Levinthal paradox, cooperativity in protein folding, free energy landscape of protein folding and pathways of protein folding, molten globule state, chaperons, diseases associated with protein folding, introduction to molecular dynamic simulation.

Unit II
Enzyme kinetics
5 lectures

Enzyme catalysis – general principles of catalysis; quantitation of enzyme activity and efficiency; enzyme characterization and Michaelis-Menten kinetics; relevance of enzymes in metabolic regulation, activation, inhibition and covalent modification; single substrate enzymes; concept of catalytic antibodies; catalytic strategies with specific examples of proteases, carbonic anhydrases, restriction enzymes and nucleoside monophosphate kinase; regulatory strategies with specific example of hemoglobin; isozymes; role of covalent modification in enzymatic activity; zymogens.

Unit III
Glycobiology
2 lectures

Sugars - mono, di, and polysaccharides with specific reference to glycogen, amylase and cellulose, glycosylation of other biomolecules - glycoproteins and glycolipids; lipids - structure and properties of important members of storage and membrane lipids; lipoproteins.

Unit IV
Structure and functions of DNA & RNA
3 lectures

Self-assembly of lipids, micelle, biomembrane organization - sidedness and function; membrane bound proteins - structure, properties and function; transport phenomena; nucleosides, nucleotides, nucleic acids - structure, a historical perspective leading up to the proposition of DNA double helical structure; difference in RNA and DNA structure and their importance in evolution of DNA as the genetic material.

Unit V
Bio-energetics
8 lectures

Bioenergetics-basic principles; equilibria and concept of free energy; coupled interconnecting reactions in metabolism; oxidation of carbon fuels; recurring motifs in metabolism; Introduction to GPCR, Inositol/DAG//PKC and Ca++ signaling pathways; glycolysis and gluconeogenesis; reciprocal regulations and non-carbohydrate sources of glucose; Citric acid cycle, entry to citric acid cycle, citric acid cycle as a source of biosynthetic precursors; Oxidative phosphorylation; importance of electron transfer in

Student Learning Outcomes
On completion of this course, students should be able to:
• Gain fundamental knowledge in biochemistry;
• Understand the molecular basis of various pathological conditions from the perspective of biochemical reactions.
Fermentative production of enzymes used in food industry; solid state fermentation; recovery of enzymes from natural sources; cheese making and whey processing, impact of enzyme technology (bioethanol, protein hydrolysates, bioactive peptides); enzymatic processing of fruit juices. Role of enzymes in baking, meat and meat processing; comparative methods of toxicity test in (novel) foods; biosensors; enzymatic approach to tailor made fats; catabolic processes and oxygen-dependent reactions in food; use of lipases and reactions in organic solvents and two phases.

Chemical structure of nucleic acids, proteins; introduction to Genetics, DNA replication, transcription and translation; cell division, cell cycle, mitosis, meiosis; introduction to human genetics; Mendelian genetics; single cell disorders; complex traits; DNA repair mechanism; modifying enzymes; recombinant DNA technology; mutation and polymorphism and their detection; family based and case control study designs; pedigree analysis; linkage analysis and association studies.

PCR, RT-PCR, electrophoresis, electro blotting and capillary blotting; population & evolutionary genetics, gene mapping; microbial gene transfer mechanisms, mutation, types of mutations, molecular mechanism of mutations, practical applications; applications to produce genetically modified foods.
Introduction to plant and animal tissue cultures and cell cultures in general; Cell culture lab design and equipments, Media and reagents; Animal, mammalian and other cell lines for in vitro testing of drugs, toxicity of environmental pollutants, production of vaccines and therapeutic proteins & production of stem cells; Principles of cryobiology and molecular diagnostics, Technological aspects for commercial utilization of cell cultures: Reactor studies, scale up and biosafety.

Recommended Textbooks and References:

Course Objectives
The objectives of this course are to introduce the students to the field of microbiology with special emphasis on microbial diversity, morphology, physiology and nutrition; methods for control of microbes and host-microbe interactions.

Student Learning Outcomes
On completion of this course, students should be able to:
- Identify the major categories of microorganisms and understand their classification, diversity, and ubiquity;
- Describe the structural, physiological, and genetic similarities and differences of the major categories of microorganisms;
- Demonstrate how to control microbial growth;
- Evaluate the interactions between microbes, hosts and environment.

Unit I
Microbial characteristics
6 lectures
Introduction to microbiology and microbes, history & scope of microbiology, morphology, structure, growth and nutrition of bacteria, bacterial growth curve, bacterial culture methods; bacterial genetics: mutation and recombination in bacteria, plasmids, transformation, transduction and conjugation; antimicrobial resistance.

Unit II
Microbial diversity
5 lectures
Microbial taxonomy and evolution of diversity, classification of microorganisms, criteria for classification; classification of bacteria; Cyanobacteria, acetic acid bacteria, Pseudomonads, lactic and propionic acid bacteria, endospore forming bacteria, Mycobacteria and Mycoplasma; Archaea: Halophiles, Methanogens, Hyperthermophilic archaea, Thermoplasm; Eukaryotes: algae, fungi, slime molds and protozoa; extremophiles and unculturable microbes, introduction to metagenomics.

Unit III
Control of microorganisms
3 lectures
Sterilization, disinfection and antisepsis: physical and chemical methods for control of microorganisms, antibiotics, antiviral and antifungal drugs, biological control of microorganisms.

Unit IV
Virology
5 lectures
Virus and bacteriophages, general properties of viruses, viral structure, taxonomy of virus, viral replication, cultivation and identification of viruses; sub-viral particles – viroids and prions.
Unit V
Interaction of microbes with its environment
6 lectures

Host-pathogen interaction, ecological impacts of microbes; symbiosis (Nitrogen fixation and ruminant symbiosis); microbes and nutrient cycles; microbial communication system; biofilms, bacterial quorum sensing; microbial fuel cells.

Recommended Textbooks and References:
3. Gerard J. Tortora, Berdell R. Funke, Christine L. Case; (2015); Microbiology by Tortora Pearson Education.

Basics of Safety and Risk Management

Credits 2

Course Objectives
The objectives of this course are to make the students aware of risks of handling chemical and biological materials and hazardous, toxic, explosive, inflammable, infective effects of some chemical and biological substances. The students shall also be taught methods of safe handling and disposal of these substances.

Student Learning Outcomes
Students should become capable of handling chemical and biological materials in safe manner in laboratories and industry. They should also learn safe and approved methods of disposal of substances and contaminated materials as well. Students should be able gain awareness about national and international regulatory aspects of safety.

Unit I
Safety and risk management
3 lectures

Basic principles of safety and risk management; Introduction to various regulatory bodies (Central and State Government); statutory regulations; Introduction to basic terms: flammability limits, combustion, detonation, explosion, vapour cloud; dust explosions, Limiting Oxygen Concentration (LOC) used during blanketing.

Unit II
Material hazards and evaluation techniques
3 lectures

MSDS data sheets, properties, toxicology, LD50, LD10, pathogenicity and biohazards associated with biomaterials and levels of biohazards; Cause and Consequence Analysis, Cost-Benefit Analysis and other relevant techniques.

Unit III
Biosafety
3 lectures

Introduction to biosafety and biohazards and related regulatory bodies; Containment of infectious microorganisms and hazardous biological materials; Methods of disposal-disinfection, sterilization by autoclaving, irradiation and incineration; Definitions of Biosafety levels- BSL1, 2, 3, 4 and methods and equipments to attain the same.

Unit IV
Laboratory safety and storage, handling and transportation of hazardous substances
3 lectures

Introduction to Good Laboratory Practices (GLP); Laboratory safety- labelling, colour coding, precautions to be taken during handling and disposal; Safety provisions during transport of inflammables and hazardous materials by ship, rail, air cargo and roads; isolated storage; warehouses; colour coding of pipelines; inventory management, packaging and labelling.

Unit V
SHE and OSHA
3 lectures

Statutory regulations in India and abroad; Security aspects; Codes and Standards; Scenario at present and vision for future; Factory Act; Occupational Safety and Health Administration (OSHA); Applicable standards for safety, OSHAS 18000, responsible care.
Protection of equipment; electrical safety; Relief valve, Rupture disk, Flare stack. Equipment: Smoke detector, leak detector, gas sensors, flare, stack, electrical safety devices, earthing and grounding; Fire types, Agents to do fire fighting, Fire hydrant and sprinkler system, Fire tenders. Grounding and Earthing, Automatic fire fighting systems, sprinkler, remote operation etc.; Introduction to National Fire Protection Association (NFPA) standard on Explosion Prevention system, NFPA 69 (2008), DOW fire index, MOND index.

Recommended Textbooks and References:

Course Objectives
The objective of this laboratory course is to introduce students to experiments in biochemistry. The course is designed to teach utility of experimental methods in biochemistry in a problem oriented manner.

Student Learning Outcomes
Students should be able to:
- Elaborate concepts of biochemistry with simple experiments;
- Understand principle and working of basic laboratory instruments.

Syllabus
2. Titration of Amino Acids and separation of aliphatic, aromatic and polar amino acids by thin layer chromatography.
3. Purification and characterization of an enzyme from a recombinant source (such as Alkaline Phosphatase or Lactate Dehydrogenase or any enzyme of institution's choice).
   a. Preparation of cell-free lysates
   b. Ammonium Sulfate precipitation
   c. Ion-exchange Chromatography
   d. Gel Filtration
   e. Affinity Chromatography
   f. Generating a Purification Table (protein concentration, amount of total protein)
   g. Computing specific activity of the enzyme preparation at each stage of purification
   h. Assessing purity of samples from each step of purification by SDS-PAGE Gel Electrophoresis
   i. Enzyme Kinetic Parameters: Km, Vmax and Kcat.
   j. Dialysis of the purified protein solution against 60% glycerol as a demonstration of storage method
4. Identification of an unknown sample as DNA, RNA or protein using available laboratory tools.
5. Biophysical methods (Circular Dichroism Spectroscopy, Fluorescence Spectroscopy)
6. Determination of mass of small molecules and fragmentation patterns by Mass Spectrometry.

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### Laboratory II: Microbiology

**Course Objectives**
The objective of this laboratory course is to introduce students to experiments in microbiology. The course is designed to teach utility of experimental methods in microbiology in a problem oriented manner.

**Student Learning Outcomes**
On completion of this laboratory course, students should be able to:
- Isolate, characterize and identify common bacterial organisms;
- Determine bacterial load of different samples;
- Perform antimicrobial sensitivity test;
- Preserve bacterial cultures.

#### Credits
2

#### Syllabus

**Basic technique**

1. Sterilization, disinfection and safety in microbiological laboratory, good laboratory practices
2. Preparation of media for cultivation of bacteria, liquid and agar

**Staining techniques**

1. Preparation of bacterial smear and Gram's staining.
2. Acid fast staining.
3. Endospore staining.
4. Capsule staining
5. Negative staining
6. Flagellar staining.

**Microscopy-related techniques**

1. Bright field light microscopy
2. Hanging drop slide preparation
3. Motility of bacteria
4. Dark field light microscopy
5. Phase contrast microscopy
6. Fluorescence microscopy.

**Biochemical and antibiotic tests**

1. MR test
2. VP test
3. Sucrose fermentation
4. Lactose fermentation
5. Indole test
6. Antimicrobial sensitivity test and demonstration of drug resistance
7. Zone of clearance, zone of inhibition.

**Environmental factors**

1. Effect of pH and temperature on microbial growth
2. Determination of phenol co-efficient of antimicrobial agents
3. Determination of Minimum Inhibitory Concentration (MIC)
4. Isolation and identification of bacteria from soil/water samples.

#### Recommended Textbooks and References:
## Semester Two

### Principles of Food Analysis

**Course Objectives**
This course will cover areas in application and new methodology development in analytical chemistry with focus on food analysis.

**Student Learning Outcomes**
On completion of this course, students should be able to:
- Identify and determine errors and uncertainty of analytical results;
- Apply measures taken to control quality and ensure reliability of analytical results.

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<tr>
<th>Unit I</th>
<th>Introduction to food analysis</th>
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<tr>
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<td>Types of food samples analysed, steps in food analysis, choice of methods; sampling procedures, considerations and sample preparation; Evaluation of analytical data – accuracy and precision, sources of errors, specificity, sensitivity and detection limits, regression analysis, reporting results.</td>
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<th>Unit II</th>
<th>Characteristics of food analysis</th>
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<td>Analysis of chemical constituents, their characterization and significance – moisture, ash, minerals, lipids, fat, proteins, fibre, titratable acidity, starch, reducing sugars.</td>
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<th>Unit III</th>
<th>Methods in food analysis</th>
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<td>Spectroscopic analysis of foods – basic principles, UV, visible, fluorescence, IR, AAS, MS, NMR; Chromatographic analysis of foods – basic principles, HPLC, GC, GLC, principles and applications.</td>
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<th>Unit IV</th>
<th>Advanced techniques in food analysis</th>
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<tr>
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<td>Analysis of vitamins, pigments, flavours, extraneous matter, pesticides and mycotoxins; Microscopic analysis of foods, SEM and XRD; other methods- potentiometry, enzymatic, immunoassays, thermal analysis; Techniques for sensory analysis of foods and electronic tongue/ nose; Analysis of genetically modified foods.</td>
</tr>
</tbody>
</table>

### Recommended Textbooks and References:

7. Yeshajahu Pomeranz; Clifton E. Meloan, (2002), *Food Analysis- Theory and Practice*, 1st Indian Ed. CBS Publisher; Distributors, New Delhi
Course Objectives
The objectives of this course are to educate students about the fundamental concepts of bioprocess technology and its related applications, thus preparing them to meet the challenges of the new and emerging areas of biotechnology industry.

Student Learning Outcomes
Students should be able to:
• Appreciate relevance of microorganisms from industrial context;
• Carry out stoichiometric calculations and specify models of their growth;
• Give an account of design and operations of various fermenters;
• Present unit operations together with the fundamental principles for basic methods in production technique for bio-based products;
• Calculate yield and production rates in a biological production process, and also interpret data;
• Calculate the need for oxygen and oxygen transfer in a bioproduction process;
• Critically analyze any bioprocess from an economics/market point of view;
• Give an account of important microbial/enzymatic industrial processes in food and fuel industry.

Unit I
Basic principles of biochemical engineering
4 lectures

Isolation, screening and maintenance of industrially important microbes; microbial growth and death kinetics (an example from each group, particularly with reference to industrially useful microorganisms); strain improvement for increased yield and other desirable characteristics.

Unit II
Stoichiometry and models of microbial growth
4 lectures

Elemental balance equations; metabolic coupling – ATP and NAD+; yield coefficients; unstructured models of microbial growth; structured models of microbial growth, MATLAB basics for modelling and solving the equations.

Unit III
Bioreactor design and analysis
8 lectures

Batch and continuous fermenters; modifying batch and continuous reactors: chemostat with recycle, multistage chemostat systems, fed-batch operations; conventional fermentation v/s biotransformations; immobilized cell systems; large scale animal and plant cell cultivation; fermentation economics; upstream processing: media formulation and optimization; sterilization; aeration, agitation and heat transfer in bioprocess; scale up and scale down; measurement and control of bioprocess parameters.

Unit IV
Downstream processing and product recovery
4 lectures

Separation of insoluble products - filtration, centrifugation, sedimentation, flocculation; Cell disruption; separation of soluble products: liquid-liquid extraction, precipitation, chromatographic techniques, reverse osmosis, ultra and micro filtration, electrophoresis; final purification: drying; crystallization; storage and packaging.

Unit V
Applications of microbial technology in food processing and biorefineries
5 lectures

Fermented foods and beverages; food ingredients and additives prepared by fermentation and their purification; fermentation as a method of preparing and preserving foods; microbes and their use in pickling, producing colours and flavours, alcoholic beverages and other products; process wastes-whey, molasses, starch substrates and other food wastes for bioconversion to useful products; bacteriocins from lactic acid bacteria:
Industrial production of penicillin via fungal route, insulin from recombinant E. coli; Production of metabolites such as shikonin using plant cell culture, astaxanthin from algae, and biotransformation routes for novel/specialty chemicals; Production of HBsAg using yeast cultures, erythropoietin using CHO cells, monoclonal antibodies such as Humira using mammalian cells.

Recommended Textbooks and References:


Course Objectives

The course will allow students to know biological phenomena behind use of virtuous microorganisms for production of main fermented foods.

Student Learning Outcomes

On completion of this course, students should be able to gain in-depth understanding of biotechnology of fermented foods.

### Unit I

**Overview of fermented foods**

15 lectures

- Traditional applications of food biotechnology- Fermented foods: *e.g.* dairy products, oriental fermentations, alcoholic beverages, and food ingredients; role of biotechnology in fermented food products (dairy, meat, vegetable); Starter culture development, process development; Enzymes in dairy industry: cheese making and whey processing, impact of enzyme technology; Functional foods.

### Unit II

**Biotechnology of fermented foods**

15 lectures

- Enzymatic processing of fruit juices; Role of enzymes in baking, meat and meat processing; Applications of immunological techniques to food industry; Detection methods for *E. coli*, *Staphylococci*, *Yersinia*, *Campylobacter*, *B. cereus*, *Clostridium botulinum* & *Salmonella* from food samples; Newer Processing Technology, Pesticide Residues, Newer Sources of Ingredients, Nutraceuticals, Use of Antibiotics & Hormones in Food Processing & Agricultural Practices etc.

Recommended Textbooks and References:

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<thead>
<tr>
<th>Course</th>
<th>Objectives</th>
<th>References</th>
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</thead>
<tbody>
<tr>
<td><strong>Unit I</strong></td>
<td>Genetic interactions</td>
<td>Gene- environment interaction; gene- diet interaction; principals and practice behind dietary management of genetically transmitted disorders.</td>
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<tr>
<td><strong>Unit II</strong></td>
<td>Genetic disorders</td>
<td>Phenylketonuria, galactosemia; G6PD deficiency; lactose intolerance; complex traits; birth disorders; signal transduction; epigenetic mechanism.</td>
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<tr>
<td><strong>Unit III</strong></td>
<td>Importance of nutrigenomics</td>
<td>Bioactive components of food; nutraceuticals; effective gene expression; epigenetic process; signal transduction; recent developments in field of nutrigenomics.</td>
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<th>Course</th>
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| **Research Methodology and Scientific Communication Skills** | The objectives of this course are to give background on history of science, emphasizing methodologies used to do research, use framework of these methodologies for understanding effective lab practices and scientific communication and appreciate scientific ethics. | Students should be able to:  
- Understand history and methodologies of scientific research, applying these to recent published papers;  
- Understand and practice scientific reading, writing and presentations;  
- Appreciate scientific ethics through case studies. |
| **Unit I** | History of science and science methodologies | Empirical science; scientific method; manipulative experiments and controls; deductive and inductive reasoning; descriptive science; reductionist vs holistic biology. |
| **Unit II** | Preparation for research | Choosing a mentor, lab and research question; maintaining a lab notebook. |
Unit III
Process of communication
6 lectures

Concept of effective communication - setting clear goals for communication; determining outcomes and results; initiating communication; avoiding breakdowns while communicating; creating value in conversation; barriers to effective communication; non-verbal communication-interpreting non-verbal cues; importance of body language, power of effective listening; recognizing cultural differences; Presentation skills - formal presentation skills; preparing and presenting using over-head projector, PowerPoint; defending interrogation; scientific poster preparation & presentation; participating in group discussions; Computing skills for scientific research - web browsing for information search; search engines and their mechanism of searching; hidden Web and its importance in scientific research; internet as a medium of interaction between scientists; effective email strategy using the right tone and conciseness.

Unit IV
Scientific communication
8 lectures

Technical writing skills - types of reports; layout of a formal report; scientific writing skills - importance of communicating science; problems while writing a scientific document; plagiarism, software for plagiarism; scientific publication writing: elements of a scientific paper including abstract, introduction, materials & methods, results, discussion, references; drafting titles and framing abstracts; publishing scientific papers - peer review process and problems, recent developments such as open access and non-blind review; plagiarism; characteristics of effective technical communication; scientific presentations; ethical issues; scientific misconduct.

Recommended Textbooks and References:

Bioentrepreneurship

Course Objectives
Research and business belong together and both are needed. In a rapidly developing life science industry, there is an urgent need for people who combine business knowledge with the understanding of science & technology. Bio-entrepreneurship, an interdisciplinary course, revolves around the central theme of how to manage and develop life science companies and projects. The objectives of this course are to teach students about concepts of entrepreneurship including identifying a winning business opportunity, gathering funding and launching a business, growing and nurturing the organization and harvesting the rewards.

Student Learning Outcomes
Students should be able to gain entrepreneurial skills, understand the various operations involved in venture creation, identify scope for entrepreneurship in biosciences and utilize the schemes promoted through knowledge centres and various agencies. The knowledge pertaining to management should also help students to be able to build up a strong network within the industry.
Introduction and scope in bio-entrepreneurship, Types of bio-industries and competitive dynamics between the sub-industries of the bio-sector (e.g. pharmaceuticals vs. Industrial biotech), Strategy and operations of bio-sector firms: Factors shaping opportunities for innovation and entrepreneurship in bio-sectors, and the business implications of those opportunities, Alternatives faced by emerging bio-firms and the relevant tools for strategic decision, Entrepreneurship development programs of public and private agencies (MSME, DBT, BIRAC, Make In India), strategic dimensions of patenting & commercialization strategies.

Negotiating the road from lab to the market (strategies and processes of negotiation with financers, government and regulatory authorities), Pricing strategy, Challenges in marketing in bio business (market conditions & segments; developing distribution channels, the nature, analysis and management of customer needs), Basic contract principles, different types of agreement and contract terms typically found in joint venture and development agreements, Dispute resolution skills.

Business plan preparation including statutory and legal requirements, Business feasibility study, financial management issues of procurement of capital and management of costs, Collaborations & partnership, Information technology.

Technology – assessment, development & upgradation, Managing technology transfer, Quality control & transfer of foreign technologies, Knowledge centers and Technology transfer agencies, Understanding of regulatory compliances and procedures (CDSCO, NBA, GCP, GLA, GMP).

Recommended Textbooks and References:

Course Objectives
The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.

Student Learning Outcomes
Students should be able to demonstrate the following abilities:
- Formulate a scientific question;
- Present scientific approach to solve the problem;
- Interpret, discuss and communicate scientific results in written form;
- Gain experience in writing a scientific proposal;
- Learn how to present and explain their research findings to the audience effectively.
Selection of research lab and research topic: Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them select a topic for their project. The topic of the research should be hypothesis driven.

Review of literature: Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources.

Writing Research Proposal: With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc. Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.

Students will have to present the topic of their project proposal after few months of their selection of the topic. They should be able to explain the novelty and importance of their research topic.

At the end of their project, presentation will have to be given by the students to explain work done by them in detail. Along with summarizing their findings they should also be able to discuss the future expected outcome of their work.

Course Objectives
This course will equip students with basic hands-on information of food processing and analysis.

Student Learning Outcomes
On completion of this course, students should be able to understand various aspects of food processing and different processes used for different type of food products. They should also be able to analyse quality of processed and raw food products.

1. Fruit Processing: fruit squash
2. Fruit processing: jelly, jam, marmalade
3. Vegetable processing: pickles, juices, dehydrated vegetables
4. Tomato processing: ketchup/sauce, soup, juice
5. Milk processing
6. Dehydration
7. Baking: biscuits/cookies
8. Traditional food
9. Premix formulation
10. Demo of spray drier, extruder, SCFE, tray drier.

1. Analysis of milk (liquid)
2. Analysis of wheat flour
3. Analysis of tea
4. Analysis of coffee
5. Analysis of alcoholic beverages
6. Detection of Food adulteration
Introduction to enzymes used in Food industry, Objectives of using enzymes in food processing and in food product development, Merits and demerits of using enzymes, Sources of enzymes, Microbial enzymes and their advantages/ disadvantages, Commercially important enzymes used in Food industry and their mode of action, Overview of applications of enzymes in Food industry, Newer enzymes and their actual
and potential applications, Fermentative production of enzymes used in food industry by SSF or SmF, Recovery and purification of enzymes.

Unit II
Enzyme applications in foods
4 lectures
Use of enzymes in: Dairy, Bakery, Brewery, Fruit and Vegetable Processing, Plantation Products, Starch industry and confectionery, Protein hydrolysis for protein hydrolysate and bioactive peptides, Oilseeds processing, formation of TAGs, extraction of fish oil, Meat, seafood (like surimi product), poultry, eggs, Animal feed, treatment of wastes from food industry, flavor bio-transformations.

Unit III
Applications of enzymes in feed industry
4 lectures
Use of enzymes in poultry feed, animal feed.

Unit IV
Advances in utilization of enzymes
5 lectures
Enzymes in biosensors, Enzymes as additives e.g. antioxidant or antimicrobial, Novel food applications of enzymes, Enzymes in active packaging and in edible coatings and films, safety of enzymes used in foods, food grade enzymes, Immobilization of enzymes for food applications, Recombinant enzymes from GMO.

Recommended Textbooks and References:

Bioreactor Operations
Credits

Unit I
Introduction to bioreactor design
3 lectures
Introduction; General design information; Material and energy balance calculations; Process Flow.

Unit II
Scale up and scale down processes
8 lectures
Scale up and scale down issues: Effect of scale on oxygenation, mixing, sterilization, pH, temperature, inoculum development, nutrient availability and supply; Bioreactor scale-up based on constant power consumption per volume, mixing time, impeller tip speed (shear), mass transfer coefficients. Scale-up of downstream processes: Adsorption (LUB method); Chromatography (constant resolution etc.); Filtration (constant resistance etc.); Centrifugation (equivalent times etc.); Extractors (geometry based rules). Scale-down related aspects.

Course Objectives
The course is an overview on biological reactions, elements of bioreactor design, and fundamentals of mass and energy balances in biological reactions. It gives an idea on various types of important bioreactors for microbial, animal and plant cell processes. It covers mechanical design considerations for various kinds of bioreactors.

Student Learning Outcomes
Student should be able to gain strong understanding on design and applications of various bioreactors. They will be able to analyse bioprocess from an economics/market point of view.
Course Objectives
The objectives of this course are to introduce students to unit operations in food process engineering and machines/equipment used in food processing. Some inputs on product development and process flow sheet also need to be given.

Student Learning Outcomes
By end of the course, students should be familiar with basic unit operation, principles of several food processing methods including thermal pasteurization, blanching, freezing, dehydration, non-thermal processing, separation, concentration and extrusion.

Unit I
Principles of food process engineering
6 lectures
Transport phenomenon; heat transfer, mass transfer in food processing; problems of equipment design with reference to common food processing unit operations such as drying, freezing, evaporation, membrane filtration.

Unit II
Methods in food process engineering
5 lectures
Principles of thermal processing; calculation of process time temperature-schedules; other important principles of preservation of food.

Recommended Textbooks and References:
8. Relevant articles from Bioprocess journals
Processing of fruits, vegetables, grains; effect of genetic modifications in crops and linkage with processing; non-thermal methods; high pressure processing; transgenic animals and subsequent implications on dairy, meat and fish products; pro and prebiotics; Legal and safety issues.

Product and process development approaches; Flow sheets and preliminary cost analysis.

**Recommended Textbooks and References:**

**Course Objectives**
The objective of this course is to introduce to statistical methods and to understand the underlying principles, as well as practical guidelines of “how to do it” and “how to interpret it” statistical data particularly for bio systems.

**Student Learning Outcomes**
On completion of this course, students should be able to:
- Understand how to summarise statistical data;
- Apply appropriate statistical tests based on an understanding of study question, type of study and type of data;
- Interpret results of statistical tests and application in biological systems.

**Unit I**
**Introduction**
2 lectures
Types of biological data (ordinal scale, nominal scale, continuous and discrete logical systems data), frequency distribution and graphical representations (bar graph, histogram, box plot and frequency polygon), cumulative frequency distribution, populations, samples, simple random, stratified and systematic sampling.

**Unit II**
**Descriptive statistics**
2 lectures
Measures of Location, Properties of Arithmetic Mean, median, mode, range, Properties of the Variance and Standard Deviation, Coefficient of Variation, Grouped Data, Graphic Methods, Obtaining Descriptive Statistics on the Computer, Case study.

**Unit III**
**Probability and distribution**
3 lectures
Introduction to probability and laws of probability, Random Events, Events-exhaustive, Mutually exclusive and equally likely (with simple exercises), Definition and properties of binomial distribution, Poisson distribution and normal distribution.

**Unit IV**
**Correlation and regression analysis**
3 lectures
Correlation, Covariance, calculation of covariance and correlation, Correlation coefficient from ungrouped data Spearson's Rank Correlation Coefficient, scatter and dot diagram, General Concepts of regression, Fitting Regression Lines, regression coefficient, properties of Regression Coefficients, Standard error of estimate.

**Unit V**
**Statistical hypothesis testing**
3 lectures
Making assumption, Null and alternate hypothesis, error in hypothesis testing, confidence interval, one-tailed and two-tailed testing, decision making.
### Course Objectives

The objectives of this course are to provide students with theory and practical experience of use of common computational tools and databases which facilitate investigation of molecular biology and evolution-related concepts.

### Student Learning Outcomes

Student should be able to:

- Develop an understanding of basic theory of these computational tools.
- Gain working knowledge of these computational tools and methods.
- Appreciate their relevance for investigating specific contemporary biological questions.

### Unit I

**Biological databases**

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Introduction, Primary & Secondary database, Sequence file formats, Introduction to structures, Protein Data Bank (PDB), Molecular Modelling Database (MMDb), Structure file formats, Visualizing structural information, Database of structure viewers, Collection of sequences, sequence annotation, sequence description.

### Unit II

**Sequence alignment and database searching**

| 3 lectures |

Evolutionary basis of sequence alignment, Optimal alignment methods, Substitution scores & gap penalties, Statistical significance of alignments, Database similarity searching, FASTA, BLAST, Low complexity regions, Repetitive elements, Multiple Sequence Alignment: Progressive alignment methods, Motifs and patterns, Clustal, Muscle; Scoring matrices, Distance matrices.

### Unit III

**Phylogenetic analysis**

| 4 lectures |

Alignment, tree building and tree evaluation, Comparison and application of Unweighted Pair Group Method with Arithmetic Mean (UPGMA), Neighbour Joining (NJ), Maximum Parsimony (MP), Maximum Likelihood (ML) methods, Bootstrapping, Jackknife; Software for Phylogenetic analysis. DNA barcoding: Methods tools and databases for barcoding across all species, Applications and limitations of barcoding, Consortium for Barcode of Life (CBOL) recommendations, Barcode of Life Database (BOLD).

### Unit VI

**Tests of significance**

| 3 lectures |

Steps in testing statistical significance, selection and computation of test of significance and interpretation of results; Sampling distribution of mean and standard error, Large sample tests (test for an assumed mean and equality of two population means with known S.D.), z-test; Small sample tests (t-test for an assumed mean and equality of means of two populations when sample observations are independent); Parametric and Non parametric tests (Mann-Whitney test); paired and unpaired t-test, chi square test.

### Unit VII

**Experimental designs**

| 4 lectures |

Introduction to study designs: Longitudinal, cross-sectional, retrospective and prospective study, Principles of experimental designs, Randomized block, and Simple factorial designs, Analysis of variance (ANOVA) and its use in analysis of RBD, introduction to meta-analysis and systematic reviews, ethics in statistics.

### Recommended Textbooks and References:

Unit IV
Structural biology
3 lectures

3-D structure visualization and simulation, Basic concepts in molecular modeling: different types of computer representations of molecules; External coordinates and Internal Coordinates, Molecular Mechanics, Force fields etc. Secondary structure elucidation using Peptide bond, phi, psi and chi torsion angles, Ramachandran map, anatomy of proteins – Hierarchical organization of protein structure –like CATH (class, architecture, topology, homology), SCOP (Structural Classification of Proteins), FSSP (families of structurally similar proteins).

Unit V
Classification and comparison of 3D structures
3 lectures

DNA & RNA secondary and tertiary structures, t-RNA tertiary structure; Protein Secondary structure prediction: Algorithms viz. Chou Fasman, GOR methods, Tertiary Structure prediction: Fundamentals of the methods for 3D structure prediction (sequence similarity/identity of target proteins of known structure, fundamental principles of protein folding etc.) Homology/comparative modeling, fold recognition, threading approaches, and ab initio structure prediction methods; CASP (Critical Assessment of protein Structure Prediction); Computational design of promoters, proteins & enzymes.

Unit VI
Analysis of microarray data
4 lectures

Designing of oligo probes; Image processing and normalization; Microarray data variability (measurement ad quantification); Analysis of differentially expressed genes; Experimental designs.

Recommended Textbooks and References:
4. Web-resources and suggested reviews/ research papers.

Intellectual Property Rights, Biosafety and Bioethics

Course Objectives
The objectives of this course are:
• To provide basic knowledge on intellectual property rights and their implications in biological research and product development;
• To become familiar with India’s IPR Policy;
• To learn biosafety and risk assessment of products derived from biotechnology and regulation of such products;
• To become familiar with ethical issues in biological research.

Student Learning Outcomes
On completion of this course, students should be able to:
• Understand the rationale for and against IPR and especially patents;
• Understand why India has adopted an IPR Policy and be familiar with broad outline of patent regulations;
• Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents;
• Gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research and environmental release of genetically modified organisms, national and international regulations;
• Understand ethical aspects related to biological, biomedical, health care and biotechnology research.

Credits 2

Unit I
**Introduction to IPR**
5 lectures

Introduction to intellectual property; types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of ‘prior art’: invention in context of “prior art”; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation.

Unit II
**Patenting**
5 lectures

Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting disclosure/non-disclosure - patent application forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting - requirement, procedures and costs; financial assistance for patenting - introduction to existing schemes; publication of patents - gazette of India, status in Europe and US; patent infringement - meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing – outright sale, licensing, royalty; patenting by research students and scientists - university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives.

Unit III
**Biosafety**
5 lectures

Biosafety and Biosecurity - introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants – sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk – environmental risk assessment and food and feed safety assessment; problem formulation – protection goals, compilation of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops vs cisgenic plants or products derived from RNAi, genome editing tools.

Unit IV
**National and international regulations**
5 lectures

International regulations – Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations – EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – biosafety levels and category of rDNA experiments; field trails – biosafety research trials – standard operating procedures - guidelines of state governments; GM labeling – Food Safety and Standards Authority of India (FSSAI).

Unit V
**Bioethics**
5 lectures

Recommended Textbooks and References:
4. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/

Semester Four

Dissertation

Course Objectives
The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.

Student Learning Outcomes
Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:

- In-depth knowledge of the chosen area of research.
- Capability to critically and systematically integrate knowledge to identify issues that must be addressed within framework of specific thesis.
- Competence in research design and planning.
- Capability to create, analyse and critically evaluate different technical solutions.
This course will provide an integrated overview of physiological requirements and functions of protein, energy, and major vitamins and minerals that are determinants of health and diseases in human population.

Course Objectives
This course will provide an integrated overview of physiological requirements and functions of protein, energy, and major vitamins and minerals that are determinants of health and diseases in human population.

Student Learning Outcomes
On completion of this course, students should be able to:
- Apply knowledge of role of nutrition and healthy eating for disease prevention and wellness;
- Understand principles of biochemistry and physiology to human nutrient metabolism;
- Explain rationale for nutrient intake recommendations across lifespan.

Unit I
Introduction to human nutrition
5 lectures
Introduction to human nutrition, energy value of foods and its determination by calorimetry and from proximate principles, daily caloric needs for basal metabolism, physical activity and diet induced thermogenesis.

Unit II
Dietary requirements of nutrients
5 lectures
Requirements and role of carbohydrates, lipids, water, vitamins and minerals in human health, recommended dietary allowance (RDA), dietary sources.

Credits
3

Syllabus
Planning & performing experiments
Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

Syllabus
Thesis writing
At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.

Recommended Mode of Assessment
Assessment may be done by thesis evaluation, viva voce and final presentation.

Recommended Electives

Basics of Human Nutrition

Credit
3

Unit I
Introduction to human nutrition
5 lectures
Introduction to human nutrition, energy value of foods and its determination by calorimetry and from proximate principles, daily caloric needs for basal metabolism, physical activity and diet induced thermogenesis.

Unit II
Dietary requirements of nutrients
5 lectures
Requirements and role of carbohydrates, lipids, water, vitamins and minerals in human health, recommended dietary allowance (RDA), dietary sources.
Requirements and role of proteins in human health, RDAs, dietary sources and estimation of protein quality - *in vitro* and *in vivo* methods, anti-nutritional factors in plant foods.

Diet vs Disease, therapeutic diets, dietetic foods, health foods, formulation of diets and foods for special needs, sports nutrition.

Techniques of diet and health surveys, assessment of nutritional status, lifecycle nutrition, infant nutrition and infant foods, geriatric nutrition and geriatric foods, maternal nutrition.

Effect of processing, preservation and storage on nutritional quality of foods, nutrient interactions, food fortification, nutritional labelling, nutraceuticals, functional foods and introduction to nutrigenomics.

**Course Objectives**

The objective of this course is to provide an overview of various aspects of recovery and processing of biological products.

**Student Learning Outcomes**

Students should be able to identify and design relevant unit operations for recovery of a biological product.

**Recommended Textbooks and References:**


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**Downstream Processing in Biotechnology**

**Credits**

3

**Unit I**

**Biomass removal**

3 lectures

Characteristics of biological materials: pretreatment methods; Separation of cell mass: centrifugation, sedimentation, flocculation and filtration; Continuous operation.

**Unit II**

**Cell disruption**

4 lectures

Mechanical approaches: sonication, bead mills, homogenizers; non-mechanical approaches: freeze/thaw, osmotic shock, chemical lysis, enzymatic lysis; measurement of cell disruption.

**Unit III**

**Membrane processes**

3 lectures

Filtration theory; Micro and ultrafiltration; Reverse osmosis; dialysis; electrodialysis, diafiltration; pervaporation; perstraction; Multistage and continuous operation.
Food Additives and Ingredients

Unit I Overview
7 lectures
Introduction to food additives and ingredients, their use in food processing, food product development and in food preservation, their functions and safety; Safety and quality evaluation of food additives and ingredients.

Unit II Food preservatives
4 lectures
Preservatives, antioxidants- chemistry, mechanism of action, properties and food applications.

Course Objectives
This course will enable students to understand about food additives and determination of toxicity and various types and chemical properties of preservatives, emulsifiers, and antioxidants.

Student Learning Outcomes
On completion of the course, students should able to:
• Understand applications of food additives and how to study toxicity of food additives;
• Understand various types and composition of food ingredients.

Credits
3

Recommended Textbooks and References:

Unit IV Adsorption and chromatography
5 lectures
Adsorption equilibrium, Van Deemter equation; Chromatography: size, charge, polarity, shape, hydrophobic interactions; Biological affinity; Process configurations (packed bed, expanded bed, simulated moving beds).

Unit V Extraction processes
5 lectures
Solvent extraction: phase equilibrium and distribution, counter-current operation, dissociative extraction, multiple stage analysis; Reciprocating-plate and centrifugal extractors; Reverse micellar extraction; Aqueous two phase, Supercritical fluid extraction; Aqueous two-phase extraction.

Unit VI Concentration steps
8 lectures
Precipitation: effect of size and charge, solvent effects, ionic strength effects, precipitate growth and aging models. Crystallization: nucleation and growth aspects; Drying: solvent removal aspects, dryers (vacuum, freeze, spray); Scale up aspects.

Unit VII Product characterization
4 lectures
Biophysical characterization, chemical characterization, modern spectroscopy, QbD, stability Bioassays: Cell based assay, receptor mediated assay, in vivo evaluation, immunogenicity.

Unit VIII Process design
8 lectures
Process synthesis: Identification and ordering of unit operations relevant for a case study. Analysis: comparison of different process synthesis steps. Case studies such as production and recovery of therapeutics, metabolites, and antibodies.
Colours, flavours - chemistry, properties, food applications.

Emulsifiers, stabilizers, sweeteners - chemistry, mechanism of action, properties, food applications.

Sequestrants, humectants, acidulants - chemistry, mechanism of action, properties, food applications.

Ingredients - carbohydrate, protein, fat based and nutraceutical ingredients, their production, properties and food applications

Recommended Textbooks and References:

Food Allergies and Allergens

Course Objectives
This course will raise awareness amongst students about various food allergens and also provide guidance on handling and preparing foods for population with allergies.

Student Learning Outcomes
On completion of this course, students should be able to recognize role of genetic, dietary and environmental factors in pathogenesis of food allergies.

Credits
3

Unit I
Introduction to food allergies and allergens
5 lectures

Overview of food allergies, allergens, immune system, antigen antibody interactions; sign & symptoms of food allergy; global prevalence of food allergies; classification of hypersensitivity reactions, use of bioinformatics in understanding and identification of potential cross allergens.

Unit II
Factors: food allergies and allergens
5 lectures

Factors affecting food allergenicity, issues related to food additives and ingredients, genetic inheritance of food allergy, Immunological response, Oral allergy syndrome, GM foods and risk of allergy.
Food Packaging

Credits: 3

Course Objectives
This course will provide a fundamental understanding of various food packaging materials and their respective properties.

Unit I
Introduction to food packaging
10 lectures

Introduction to food packaging, causes of food spoilage, Packaging as a method for preservation of foods; functions of food packaging, levels of packaging, different materials used in food packaging such as paper, board, glass, metal containers, aluminium foil, plastics, composites, traditional materials and their physico – chemical characteristics, additives used in packaging materials, packaging applications for various food commodities.

Unit II
Design and materials for food packaging
10 lectures

Testing of various packaging materials and packages for evaluation of quality, for identification, for evaluation of performance (barrier and strength properties) for transport worthiness, for biodegradability, for migration etc.; Package design; Criteria for selection of packaging materials and package design for food products; shelf life testing of packaged foods; food labelling.

Student Learning Outcomes
On completion of this course, students should be able to:

• State functions of packaging;
• Describe various forms of packaging materials in common use contemporarily;
• Describe risks associated with potential food contamination.

Unit III
Characteristics of food allergenicity
5 lectures

Natural sources and chemistry of food allergens, handling of food allergies; Detection & Diagnostic techniques for allergy, limitations of food allergy diagnostic techniques; Characterization of allergens, food sensitivities (anaphylactic reactions, metabolic food disorders and idiosyncratic reactions).

Unit IV
Management of food allergenicity
5 lectures

Principles of management of food allergens including detailed knowledge of avoidance measures; Application of Genetic modification to reduce allergenicity; Methods used in safety evaluation-risk assessments.

Unit V
Preventive measures for food allergies
5 lectures

Prevention of allergic disease by primary, secondary and tertiary methods including aspects of epidemiology, hygiene and allergic march hypotheses, evidence for food desensitization; Case studies of reported food allergies and related food recalls.

Unit VI
Regulatory and labelling procedures
5 lectures

Hypoallergenic foods and dietary management of allergy, effect of processing treatments on food allergenicity; Regulatory procedures for food allergens at national and international level; Labelling guidelines.

Recommended Textbooks and References:
Packaging materials for newer techniques like radiation processing, microwave and radiowave processing, high pressure processing, CAP/MAP and thermal processing as retortable pouches, aseptic packaging; biodegradable packaging; active packaging; intelligent packaging; migration; flavor scalping, application of nanotechnology in food packaging, environmental concerns and life cycle assessment.

Recommended Textbooks and References:

Course Objectives
This course will give a brief introduction about different food safety issues and hazards associated with it.

Student Learning Outcomes
On completion of this course, students should be able to understand various food safety parameters and also different toxicity issues in food industry.

Food Safety & Toxicology

Credits
3

Unit I
Food safety
10 lectures
Types of food hazards: biological, chemical and physical; Risk assessment; Existing and emerging pathogens due to globalisation of food trade; Newer systems of safety evaluation such as HACCP.

Unit II
Food testing
10 lectures
Testing of food ingredients & additives; Animal studies including LD50; Ames test for teratogenicity; Natural toxic constituents in plant foods; Shellfish poisoning; Chemicals from processing such as fumigants, chlorinated solvents, autoxidation products, carcinogens in smoked foods and pyrolysis, pesticides and herbicides.

Unit III
Food toxicity
10 lectures
Intentional and unintentional additives; Toxicity due to microbial toxins including botulinum and staphylococcal toxins, mycotoxin and due to other food pathogens; Food allergy and intolerance; Detoxication strategy.

Recommended Textbooks and References:
1. S. S. Deshpande, (2002), Handbook of Food Toxicology. CRC Press.
2. Tannenbaum SR, (1979), Nutritional and Safety Aspects of Food Processing. Marcel Dekker Inc
5. A. Wallace Hayes, Claire L. Kruger, (2014), Hayes’ Principles and Methods of Toxicology. CRC Press.
# Nanobiotechnology

## Course Objectives
The course aims at providing general and broad introduction to multi-disciplinary field of nanotechnology. It will familiarize students with combination of top-down approach of microelectronics and micro-mechanics with bottom-up approach of chemistry/biochemistry; a development that is creating new and exciting cross-disciplinary research fields and technologies. The course will also give an insight into complete systems where nanotechnology can be used to improve everyday life.

## Student Learning Outcomes
On successful completion of this course, students should be able to describe basic science behind the properties of materials at the nanometre scale, and the principles behind advanced experimental and computational techniques for studying nanomaterials.

## Unit I
### Introduction to nanobiotechnology
5 lectures
Introduction to Nanobiotechnology; Concepts, historical perspective; Different formats of nanomaterials and applications with example for specific cases; Cellular Nanostructures; Nanopores; Biomolecular motors; Bio-inspired Nanostructures, Synthesis and characterization of different nanomaterials.

## Unit II
### Nano-films
5 lectures
Thin films; Colloidal nanostructures; Self Assembly, Nanovesicles; Nanospheres; Nanocapsules and their characterisation.

## Unit III
### Nano-particles
5 lectures
Nanoparticles for drug delivery, concepts, optimization of nanoparticle properties for suitability of administration through various routes of delivery, advantages, strategies for cellular internalization and long circulation, strategies for enhanced permeation through various anatomical barriers.

## Unit IV
### Applications of nano-particles
5 lectures
Nanoparticles for diagnostics and imaging (theranostics); concepts of smart stimuli responsive nanoparticles, implications in cancer therapy, nanodevices for biosensor development.

## Unit V
### Nano-materials
5 lectures
Nanomaterials for catalysis, development and characterization of nanobiocatalysts, application of nanoscaffolds in synthesis, applications of nanobiocatalysis in the production of drugs and drug intermediates.

## Unit VI
### Nano-toxicity
5 lectures
Introduction to Safety of nanomaterials, Basics of nanotoxicity, Models and assays for Nanotoxicity assessment; Fate of nanomaterials in different stratas of environment; Ecotoxicity models and assays; Life cycle assessment, containment.

## Recommended Textbooks and References:
5. Recent review papers in the area of Nanomedicine.
DBT Supported Teaching Programme

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of University</th>
<th>Contact Details of Course Coordinator</th>
</tr>
</thead>
</table>
| 1.    | Institute of Chemical Technology,  | Dr. A. Laxmi  
Mumbai                            | Deptt. of Food Engineering & Technology  
022-33612506  
laxmi.ananth.iyer@gmail.com |

Annexure I

Subject Specific Subcommittee of M.Tech. Food Biotechnology

Chairperson
1. Dr. Smita Lele, Registrar and Professor, Department of Biochemical Engineering, Institute of Chemical Technology, Mumbai

Members
2. Dr. Ashok Pandey, Eminent Scientist, Center of Innovative and Applied Bioprocessing, Mohali
3. Dr. Gautam Ghosh, Sr. Vice President, Panacea Biotec Ltd., New Delhi
4. Dr. Aditya Basu, Manager, Protein and Assay Technology, Novozymes South Asia Pvt. Ltd., Bangalore

Member Secretary
5. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi
M.Tech.
Pharmaceutical Biotechnology
Introduction

Background

Promotion of Indian Biotechnology sector is high on policy agenda of Government of India. Biotechnology has also been recognized as one of the key priority sectors under ‘Make in India,’ ‘Skill India’ and ‘Startup India’ initiatives of Government of India, as it is one of sectors expected to contribute towards enterprise creation, innovation and economic growth. Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India has immensely contributed to this dynamism through various policies and initiatives, establishment of innovation clusters, academia-industry partnerships, increasing capabilities for technology development, etc. The National Biotechnology Development Strategy (2015 – 2020) released by DBT provides a strategic roadmap for India’s emergence as a global biotechnology innovation and manufacturing hub. It has also highlighted importance of human resource development and need for nurturing tailor-made human capital for advanced scientific research and entrepreneurship.

DBT has taken a number of initiatives aimed at integrated human resource development to evolve an ecosystem where scientists, innovators and future entrepreneurs can be nurtured. Keeping in mind requirement for trained manpower in various areas of Biotechnology, DBT initiated Post-Graduate Teaching Programme way back in 1985 with 5 universities which has expanded to 74 universities imparting M.Sc./M.Tech./M.V.Sc. degrees in general, agricultural, animal, food, environmental, industrial marine, medical, neuroscience and pharmaceutical biotechnology. 10 programmes are being phased out. These universities and institutes are provided liberal financial support towards strengthening of laboratory facilities, equipment, consumables, fellowships to students, dissertation grant per student etc. Post-Graduate Teaching Programme selects best students and trains them to join research or industry workforce contributing significantly to biotechnology workforce.

Taking into cognizance the changing needs of the economy and to keep abreast with latest developments in the field of biotechnology, DBT proactively initiated revision of course curricula of Post-Graduate Programmes in biotechnology. The present exercise has been undertaken by Biotech Consortium India Limited (BCIL), New Delhi. Earlier exercise was carried out in 2008. The Course Curriculum Revision Exercise has been carried out for 13 Post-Graduate programmes in Biotechnology supported by DBT.

The revision of course curriculum of M.Tech. Pharmaceutical Biotechnology aims to address mismatch between ‘knowledge’ gained by students and appropriate skill set required for technology development and implementation including present contemporary needs of economy.

About the Course Curriculum Revision Exercise

A meticulous and structured approach has been adopted to accomplish the Course Curriculum Revision exercise.

BCIL had initiated the exercise with a review of literature of relevant national and international documents on curriculum design and planning for biotechnology programmes of premier national as well as international universities, guidelines by University Grants Commission, recent curricular guidelines released by Indian Council of Agricultural Research, Ministry of Health and Family Welfare and Indian Institute of Science Education & Research and other relevant research papers on curriculum development in peer-reviewed journals.
The findings of the literature review were adopted to design questionnaires for eliciting feedback from stakeholders of Biotechnology community i.e. academicians, scientists, industry representatives and students. Feedback was received from 165 experts and 20 students belonging to academic institutions, research organizations and industry regarding addition of advanced topics, deletion of elementary, redundant and overlapping topics, updation of laboratory practicals, re-adjustment of credit load, incorporating ‘technology’ component in the curriculum, among others. It was also suggested that re-orientation of curricula should be done keeping in view the needs of the industry.

Strategic Approach

A Core Committee along with 9 subject specific subcommittees comprising of 63 academicians, scientists and industry representatives were constituted to revise and update the curricula. The constitution of subject specific subcommittee for M.Tech. Pharmaceutical Biotechnology is given at Annexure-1.

The salient recommendations identified from stakeholder survey were presented to the Committee. Several brainstorming discussion sessions were held for achieving the desired balance between the foundation courses, recent developments in biotechnology and updation needs identified during the stakeholder survey. Core Committee finalized broad contours for revising all the course curricula. The guidelines set by the Core Committee were taken up by the subject specific subcommittee of M.Tech. Pharmaceutical Biotechnology for updating the curriculum. The subject specific committee incorporated latest advancements in areas of Pharmaceutical Biotechnology in the curriculum. Separate meeting was held to discuss and deliberate the updations to be made in the curriculum. The revised curriculum was vetted and finalized by the Core Committee.

Course Curriculum Revision

The members of Committee agreed that revised course curriculum should provide skill and outcome based education and help the students to gain domain knowledge, ability to design and interpret research experiments and acquire effective communication skills. The course curriculum has been re-designed accordingly to promote skill-based and outcome-based education. The revised course curriculum totals to 95 credits comprising of theory, practical, technology-based topics, electives and dissertation. Each course includes learning objectives, student learning outcomes, course plan (number of lectures/unit) and reference textbooks/resources. Theory and practical courses include relevant examples, case scenarios and tutorials for inculcating critical thinking against rote learning. Several new courses have been included and content for existing courses has also been updated. Specialized courses such as Pharmaceutical Research and Development, Formulation of Biologicals, Enzyme Technology, Quality Control, Quality Assurance and Quality by Design for Biologicals, Downstream Processing of Biological Products, Manufacturing of Biopharmaceuticals, Pharmacogenomics and Clinical Trials have been brought in. With importance of students being able to execute research projects independently, separate credits have been allotted for proposal preparation and presentation before initiating dissertation and also credits for dissertation have been increased accordingly.

We hope that model course curriculum shall serve as guidelines for academicians and researchers from different parts of the country for adoption in their institutions with modifications as per availability of expertise, infrastructure and specific needs.

We wish to put on record our sincere appreciation for constant guidance and encouragement received from Dr. K. VijayRaghavan, Secretary, DBT for bringing out this publication. We wish to acknowledge whole-hearted support of Core Committee and subject specific subcommittees members. Sincere thanks are due to Dr. Manoj Singh Rohilla, Scientist- D, DBT, Ms. Shweta for creative design, Mrs. Rita Bhatla, DBT and Shri. Dilip Joy, BCIL
Recent advances in the fields of Biotechnology and the Pharmaceutical Sciences have made it imperative that the DBT-sponsored M. Tech. programme in Pharmaceutical Biotechnology be revised. Consequently, DBT has sought feedback from several experts towards identifying those modifications that would be considered appropriate towards updation of the curriculum. The M. Tech Programme itself remains popular among students and also with employers; these employers however have sought improved exposure to practical aspects of relevance to industry, as well as awareness of emerging topics.

Accordingly, several changes have been introduced. Basic courses have been brought in to cover the essentials of data analysis, research methodology, communication skills, entrepreneurship, and IPR. The process courses have been updated to describe essential aspects of the manufacture and recovery of biopharmaceuticals and other biological products. Pharmacogenomics and Clinical Trials have been brought in as topics which would broaden the knowledge-base of the students. The lab courses have been updated to reflect the use of relevant unit operations for product recovery. A set of electives provide perspective on the identification and development of the next generation of products of therapeutic relevance.
# M.Tech. Pharmaceutical Biotechnology

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<td>Research Methodology and Scientific Communication Skills</td>
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<td>Formulation of Biologicals</td>
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<td>Enzyme Technology</td>
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## Recommended Electives:
1. Molecular Therapeutics
2. Nanobiotechnology
3. OMICS Technologies
4. Vaccines
Course Objectives
The objectives of this course are to sensitize the students to the fact that as we go down the scale of magnitude from cells to organelles to molecules, the understanding of various biological processes becomes deeper and inclusive.

Student Learning Outcomes
Student should be equipped to understand three fundamental aspects in biological phenomena: a) what to seek; b) how to seek; c) why to seek?

Unit I
Dynamic organization of cell
6 lectures
Universal features of cells; cell chemistry and biosynthesis: chemical organization of cells; internal organization of the cell - cell membranes: structure of cell membranes and concepts related to compartmentalization in eukaryotic cells; intracellular organelles: endoplasmic reticulum and Golgi apparatus, lysosomes and peroxisomes, ribosomes, cellular cytoskeleton, mitochondria, chloroplasts and cell energetics; nuclear compartment: nucleus, nucleolus and chromosomes.

Unit II
Chromatin structure and dynamics
12 lectures
Chromatin organization - histone and DNA interactome: structure and assembly of eukaryotic and prokaryotic DNA polymerases, DNA-replication, repair and recombination; chromatin control: gene transcription and silencing by chromatin-Writers, Readers and -Erasers; Transcriptional control: Structure and assembly of eukaryotic and prokaryotic RNA Polymerases, promoters and enhancers, transcription factors as activators and repressors, transcriptional initiation, elongation and termination; post-transcriptional control: splicing and addition of cap and tail, mRNA flow through nuclear envelope into cytoplasm, breakdown of selective and specific mRNAs through interference by small non-coding RNAs (miRNAs and siRNAs), protein translation machinery, ribosomes-composition and assembly; universal genetic codes, degeneracy of codons, Wobble hypothesis; Iso-accepting tRNA; mechanism of initiation, elongation and termination; co- and post-translational modifications, mitochondrial genetic code.

Unit III
Cellular signalling, transport and trafficking
3 lectures
Molecular mechanisms of membrane transport, nuclear transport, transport across mitochondria and chloroplasts; intracellular vesicular trafficking from endoplasmic reticulum through Golgi apparatus to lysosomes/cell exterior.

Unit IV
Cellular processes
8 lectures
Cell cycle and its regulation; cell division: mitosis, meiosis and cytokinesis; cell differentiation: stem cells, their differentiation into different cell types and organization into specialized tissues; cell-ECM and cell-cell interactions; cell receptors and trans-membrane signalling; cell motility and migration; cell death: different modes of cell death and their regulation.

Unit V
Manipulating and studying cells
3 lectures
Isolation of cells and basics of cell culture; observing cells under a microscope, different types of microscopy; analyzing and manipulating DNA, RNA and proteins.
Mutations, proto-oncogenes, oncogenes and tumour suppressor genes, physical, chemical and biological mutagens; types of mutations; intra-genic and inter-genic suppression; transpositions- transposable genetic elements in prokaryotes and eukaryotes, role of transposons in genome; viral and cellular oncogenes; tumor suppressor genes; structure, function and mechanism of action; activation and suppression of tumor suppressor genes; oncogenes as transcriptional activators.

Recommended Textbooks and References:

Course Objectives
The objectives of this course are to acquaint the students with general microbiological principles and practices prevalent in industries. This course will also allow students to understand the different physiological processes of various industrially important microbes.

Student Learning Outcomes
On completion of this course, students should be able to:
- Identify and isolate industrially important microbes;
- Various biological processes which regulate the growth of microbes;
- Different metabolites produced by the microbes.

Unit I
**Basics of microbiology**
6 lectures
Introduction, aims and scope: Organization and function of prokaryotic and eukaryotic cells; Structure and function of cell organelles-surface structure, special organelles, cellular reserve materials; Distinguishing features of various groups of micro-organisms: Actinomycetes, bacteria, moulds, yeasts and algae and their broad classification; Characteristics of selected groups of microbes: Archaeabacteria and microorganisms of extreme environment; Control of micro-organisms by physical and chemical agents; pure culture concept and cultural characteristics.

Unit II
**Microbial nutrition and interactions**
5 lectures
Microbial nutrition and growth principles: Growth measurement techniques; Assimilation of carbon, nitrogen and sulphur; Isolation and preservation: Isolation of organisms from various sources and long term preservation and improvement of cultures; Host–Pathogen interactions: Microbes infecting humans, veterinary animals and plants; Pathogenicity islands and their role in bacterial virulence.

Unit III
**Pathways and pathogenicity**
6 lectures
Biochemical pathways: Energy transduction in microbial systems, phosphoketolase, Entner doudoroff and glyoxylate pathways; Anaerobic respiration; Microbial pathogenicity; Recycling of energy sources: Bioassays; Recycling of carbon, nitrogen and sulphur; Role of microbes in agriculture, public health, medicine and industry.
Industrially important microbial metabolites: Process technology for the production of primary metabolites e.g. baker’s yeast, ethanol, acetone-butanol, citric acid, lactic acid, amino acids, polysaccharides, nucleosides and bioplastics; Production of secondary metabolites—penicillin, cephalosporins, streptomycin, vitamins etc.

Industrially important bioprocesses: Applications of enzymes in pharmaceutical industry, therapeutics and clinical analysis; Production and use of glucose isomerase, amidase/aminopeptidase; amylase, cellulase, penicillin acylase, lipase, oxido-reductase; protease, hydantoinase, epoxide hydrolase; nitralase, hydroxylase, aldolases; decarboxylase, etc. for the production of different types of drugs and drugs intermediates, future directions; Biomass production from agro-residues; Biofertilizers and biopesticides.

Recommended Textbooks and References:

Course Objectives
The objectives of this course are to educate students about the fundamental concepts of bioprocess technology and its related applications, thus preparing them to meet the challenges of the new and emerging areas of biotechnology industry.

Student Learning Outcomes
Students should be able to:
• Appreciate relevance of microorganisms from industrial context;
• Carry out stoichiometric calculations and specify models of their growth;
• Give an account of design and operations of various fermenters;
• Present unit operations together with the fundamental principles for basic methods in production technique for bio-based products;
• Calculate yield and production rates in a biological production process, and also interpret data;
• Calculate the need for oxygen and oxygen transfer in a bioproduction process;
• Critically analyze any bioprocess from an economics/market point of view;
• Give an account of important microbial/enzymatic industrial processes in food and fuel industry.

Unit I
Basic principles of biochemical engineering
4 lectures
Isolation, screening and maintenance of industrially important microbes; microbial growth and death kinetics (an example from each group, particularly with reference to industrially useful microorganisms); strain improvement for increased yield and other desirable characteristics.
Unit II
Stoichiometry and models of microbial growth
6 lectures
Elemental balance equations; metabolic coupling – ATP and NAD+; yield coefficients; unstructured models of microbial growth; structured models of microbial growth; MATLAB basics for modelling and solving the equations.

Unit III
Bioreactor design and analysis
8 lectures
Batch and continuous fermenters; modifying batch and continuous reactors: chemostat with recycle, multistage chemostat systems, fed-batch operations; conventional fermentation v/s biotransformations; immobilized cell systems; large scale animal and plant cell cultivation; fermentation economics; upstream processing: media formulation and optimization; sterilization; aeration, agitation and heat transfer in bioprocess; scale up and scale down; measurement and control of bioprocess parameters.

Unit IV
Downstream processing and product recovery
4 lectures
Separation of insoluble products - filtration, centrifugation, sedimentation, flocculation; Cell disruption; separation of soluble products: liquid-liquid extraction, precipitation, chromatographic techniques, reverse osmosis, ultra and micro filtration, electrophoresis; final purification: drying; crystallization; storage and packaging.

Unit V
Applications of enzyme technology in food processing
4 lectures
Mechanism of enzyme function and reactions in process techniques; enzymatic bioconversions e.g. starch and sugar conversion processes; high-fructose corn syrup; interesterified fat; hydrolyzed protein etc. and their downstream processing; baking by amyloses, deoxygenation and desugaring by glucose oxidase, beer mashing and chill proofing; cheese making by proteases and various other enzyme catalytic actions in food processing.

Unit VI
Applications of microbial technology in food processing and biorefineries
4 lectures
Fermented foods and beverages; food ingredients and additives prepared by fermentation and their purification; fermentation as a method of preparing and preserving foods; microbes and their use in pickling, producing colours and flavours, alcoholic beverages and other products; process wastes-whey, molasses, starch substrates and other food wastes for bioconversion to useful products; bacteriocins from lactic acid bacteria: production and applications in food preservation; biofuels and biorefinery; production of antibiotics in a reactor; single cell protein; probiotics and prebiotics.

Unit VII
Applications of biotechnology in production of biologicals
12 lectures
Industrial production of penicillin via fungal route, insulin from recombinant E. coli; Production of metabolites such as shikonin using plant cell culture, astaxanthin from algae, and biotransformation routes for novel/specialty chemicals; Production of HBsAg using yeast cultures, erythropoietin using CHO cells, monoclonal antibodies such as Humira using mammalian cells.

Recommended Textbooks and References:
## Plant and Animal Cell Technology

### Course Objectives
The objectives of this course is to educate students about the fundamental concepts of animal and plant cell system, bioprocess technology using eukaryotic system and their related applications, thus preparing them to meet the challenges of the new and emerging areas of biotechnology industry.

### Student Learning Outcomes
Student should be able to gain strong understanding on plant and animal based cell cultures system. This will help them to take up animal/plant based biological research as well as placement in the relevant biotech industry. They will be able to analyse bioprocess from an economics/market point of view.

### Unit I
#### Animal cell culture
15 lectures

- Animal cell culture; media composition and growth conditions; Animal cell and tissue preservation; Anchorage and non-anchorage dependent cell culture; Primary and secondary culture; Animal cell growth characteristics and kinetics; Micro & macro-carrier culture; Hybridoma technology; Stem cell technology; Transgenic animals; Animal cloning; Mechanisms of drug resistance and cell death.

### Unit II
#### Plant cell culture
15 lectures

- Totipotency; Plant growth regulators; Regeneration and micropropagation of plants: clonal propagation, organogenesis, shoot-tip and meristem culture, haploid culture, triploid culture, protoplast culture; Somaclonal variation; Tissue culture and Cell suspension culture system: methodology, growth kinetics and nutrient optimization; Precursors and elicitors; Plant Transformation methods (emphasis on *Agrobacterium* mediated transformation); Hairy root culture; Plant products of industrial importance, Production of secondary metabolites.

### Unit III
#### Secondary metabolite production
10 lectures

- Principles, design and operation of bioreactors: specific design criteria for mammalian and plant systems; Strategies for fermentation with recombinant organisms; Isolation, characterization and production of secondary metabolites from different plant cell types; Bioprocess monitoring and control: current practices in the bioprocess industries, advanced methodologies; Overview of downstream processing: centrifugation, filtration and chromatographic techniques.

### Recommended Textbooks and References:
10. Selected papers from scientific journals, particularly Nature & Science.
**Biophysical Techniques**

**Unit I**
**Spectroscopic techniques**
5 lectures


**Unit II**
**Advanced spectroscopic techniques**
5 lectures


**Unit III**
**Chromatographic techniques**
5 lectures

Distribution coefficients, Quantification, Standards; Low Pressure column chromatography, High Pressure liquid chromatography; Hydrophobic Interaction chromatography (HIC); Partition Chromatography- Normal, Reverse phase, Chiral and Counter current chromatography; Affinity chromatography, Gas-Liquid Chromatography (GLC) and thin layer chromatography (TLC).

**Unit IV**
**Mass spectroscopic techniques**
5 lectures

Principle, Components of Mass spectrometer, Ionization techniques, Electrospray and ion spray techniques; Analysers- Magnetic, Electric, Quadrupole mass filter (Q); Detectors- Faraday Cup, Array detectors.

**Unit V**
**Radio-isotopic techniques**
5 lectures

Nature of Radioactivity, Interaction with matter; Detection and measurement of radioactivity; Advantages and Restrictions of Radiotracer experiments; Applications in aspects of metabolomic investigations.

**Recommended Textbooks and references:**

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**Analytical Techniques**

**Course Objectives**
The objectives of this course are to introduce basic analytical techniques and explain their principle and methodology and to understand their applications in academic research and industries.

**Student Learning Outcomes**
At the completion of this course, students should be able to:
- Understand the principles and basic theory behind several popular Biophysical techniques;
- Apply these techniques successfully in practical situations.
Unit I
Immunological techniques
5 lectures
Precipitin reaction and its uses; Qualitative and quantitative analysis of Antigens; Immunodiffusion Assay; Radioimmunoassay (RIA), ELISA Enzyme Linked Immunosorbent Assay, Fluorescent Immunoassay- Flow Cyto-fluorimetry and FACS; Avidin-Biotin mediated Assays, Immunochemistry.

Unit II
Electrophoretic techniques
5 lectures
Agarose and Polyacrylamide gels; SDS PAGE, Native Gels, Isoelectric Focussing gels; Two Dimensional PAGE (2D PAGE), Cellulose Acetate Electrophoresis and Continuous Flow Electrophoresis; Pulsed field gel Electrophoresis (PFGE) and Electrophoresis of RNA; Capillary Electrophoresis (CE).

Unit III
Electrochemical methods and kinetic methods of analysis
5 lectures
Concepts of pH, Redox Reactions, Redox Couples; Introduction to Potentiometry and Voltammetry; Ion selective and Gas sensing Electrodes; Biosensors- 1st, 2nd and 3rd Generation Biosensors; Cell based and Enzyme sensors; Steady state Enzyme Kinetics, Enzyme assay techniques- Spectrofluorimetric techniques, Luminescence methods, Manometric methods, Ion-selective methods and Microcalorimetric methods; Enzymology in vivo.

Unit IV
Animal assays
5 lectures
Pharmacological screening models for therapeutic areas such as hypertension, cerebral ischaemia, pain, epilepsy, depression, Parkinson's disease, Alzheimer's disease, diabetes, Leishmaniasis.

Unit V
In-silico analysis
5 lectures
High through put screening; High through put pharmacokinetic analysis; Use of reference drugs and interpretation of results.

Recommended Textbooks and References:

Course Objectives
The objective of this course is to give conceptual exposure of statistics, error analysis, hypothesis testing, and design of experiments.

Student Learning Outcomes
Students should be able to:
• Gain broad understanding in mathematics and statistics;
• Recognize the importance and value of mathematical and statistical thinking, training, and approach to problem solving, on a diverse variety of disciplines.
Unit I
Introduction to statistics
2 lectures

Statistics: Introduction, its role and uses; Collection; Organization; Graphics and pictorial representation of data; Measures of central tendencies and dispersion; Coefficient of variation.

Unit II
Introduction to probability
3 lectures

Probability: Basic concepts; Common probability distributions and probability distributions related to normal distribution; Sampling: Simple random and other sampling procedures; Distribution of sample mean and proportion.

Unit III
Parameter estimation and parametric hypothesis testing
10 lectures

Estimation and Hypothesis testing: Point and interval estimation; Concepts of hypothesis testing and types of errors; Student-t and Chi square tests; Sample size and power; Experimental design and analysis of variance: Completely randomized, randomized blocks; Latin square and factorial designs; Post-hoc procedures.

Unit IV
Nonparametric hypothesis testing
5 lectures

Non-parametric tests: Sign; Mann-Whitney U; Wilcoxon matched pair; Kruskal Wallis and Friedman two way ANOVA tests; Spearman rank correlation; Statistical techniques in pharmaceutics: Experimental design in clinical trials; Parallel and crossover designs; Statistical test for bioequivalence; Dose response studies; Statistical quality control.

Unit V
Regression
5 lectures

Correlation and regression: Graphical presentation of two continuous variables; Pearson's product moment correlation coefficient; its statistical significance; Multiple and partial correlations; Linear regression; Regression line; Coefficient of determination; Interval estimation and hypothesis testing for population slope; Introduction to multiple linear regression models; Probit and logit transformations.

Recommended Textbooks and References

Course Objectives
The objective of this laboratory course is to provide the students practical skills on basic microbiological techniques.

Student Learning Outcomes
On completion of this laboratory course, students should be able to:
• Ability to isolate, characterize and identify common bacterial organisms;
• Determine bacterial load of different samples;
• Perform antimicrobial sensitivity test;
• Preserve bacterial cultures.

Syllabus
Basic techniques
1. Sterilization, disinfection and safety in microbiological laboratory, good laboratory practices
2. Preparation of media for cultivation of bacteria, liquid and agar.

Syllabus
Culture techniques
1. Spread plate method
2. Pour plate method
3. Streaking
Laboratory II: Biophysical and Analytical Techniques

Course Objectives
The objectives of this laboratory course are to prepare the students in all the latest preparative and analytical techniques required in research or industry.

Student Learning Outcomes
At the end of the course, students should be able to perform the basic biochemical tests and analytical techniques in the field of pharmaceutical sciences.

Credits
3

Syllabus
1. Preparation of bacterial smear and Gram's staining.
2. Acid fast staining
3. Endospore staining
4. Capsule staining
5. Negative staining
6. Flagellar staining.

Syllabus
Staining techniques
1. Bright field light microscopy
2. Hanging drop slide preparation
3. Motility of bacteria
4. Dark field light microscopy
5. Phase contrast microscopy
6. Fluorescence microscopy.

Syllabus
Microscopy
1. MR test
2. VP test
3. Sucrose fermentation
4. Lactose fermentation
5. Indole test
6. Antimicrobial sensitivity test and demonstration of drug resistance
7. Zone of clearance, zone of inhibition.

Syllabus
Biochemical and antibiotic tests
1. Effect of pH and temperature on microbial growth
2. Determination of phenol co-efficient of antimicrobial agents
3. Determination of Minimum Inhibitory Concentration (MIC)
4. Isolation and identification of bacteria from soil/water samples.

Recommended Textbooks and References:

1. Bacterial growth curve
2. Bacterial plate count method

Syllabus
Staining techniques
1. Preparation of bacterial smear and Gram's staining.
2. Acid fast staining
3. Endospore staining
4. Capsule staining
5. Negative staining
6. Flagellar staining.

Syllabus
Microscopy
1. Bright field light microscopy
2. Hanging drop slide preparation
3. Motility of bacteria
4. Dark field light microscopy
5. Phase contrast microscopy
6. Fluorescence microscopy.

Syllabus
Biochemical and antibiotic tests
1. MR test
2. VP test
3. Sucrose fermentation
4. Lactose fermentation
5. Indole test
6. Antimicrobial sensitivity test and demonstration of drug resistance
7. Zone of clearance, zone of inhibition.

Recommended Textbooks and References:
2. To determine an unknown protein concentration by plotting a standard graph of BSA using UV-Vis Spectrophotometer and validating the Beer-Lambert's Law.


5. Estimation of protein concentration using Lowry's method, Dye-binding method. DNA determination by UV-Vis Spectrophotometer – hyperchromic effect. Separation of lipids by TLC.

6. Purification techniques
   a) Preparation of cell-free lysates
   b) Ammonium Sulfate precipitation
   c) Ion-exchange Chromatography
   d) Gel Filtration
   e) Affinity Chromatography
   f) Generating a Purification Table
   g) Assessing purity by SDS-PAGE Gel Electrophoresis
   h) Assessing purity by 2-D gel Electrophoresis
   i) Enzyme Kinetic Parameters: Km, Vmax and Kcat.

7. Biophysical methods (Circular dichroism spectroscopy, fluorescence spectroscopy).

8. Determination of mass of small molecules and fragmentation patterns by Mass Spectrometry.

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**Recommended Textbooks and References:**


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**Semester Two**

**Pharmacetical Research and Development**

**Course Objectives**

This course will give a broad overview of research and developments carried out in industrial setup.

**Student Learning Outcomes**

On completion of this course, students should be able to understand basics of R&D and should be able to apply knowledge gained in respective fields of pharmaceutical industry.

**Unit I**

**Target identification and molecular modelling**

7 lectures

Identification of target or drug leads associated with a particular disease by a number of different techniques including combinations of molecular modeling, combinatorial libraries and high-throughput screening (HTS); Conceptualizing the automation of the HTS process and the importance of bioinformatics and data processing in identification of lead compounds; Rational drug design, based on understanding the three-dimensional...
structures and physicochemical properties of drugs and receptors; Modelling drug/receptor interactions with the emphasis on molecular mechanisms, molecular dynamics simulations and homology modelling; Conformational sampling, macromolecular folding, structural bioinformatics, receptor-based and ligand-based design and docking methods, in silico screening of libraries, semi-empirical and ab-initio methods, QSAR methods, molecular diversity, design of combinatorial libraries of drug-like molecules, macromolecular and chemical databases.

**Unit II**  
**Lead optimization**  
5 lectures  
Identification of relevant groups on a molecule that interact with a receptor and are responsible for the biological activity; Understanding structure activity relationship; Structure modification to increase potency and therapeutic index; Concept of quantitative drug design using Quantitative structure–activity relationship models (QSAR models) based on the fact that the biological properties of a compound are a function of its physicochemical parameters such as solubility, lipophilicity, electronic effects, ionization, stereochemistry, etc.; Bioanalytical assay development in support of *in vitro* and *in vivo* studies (LC/MS/MS, GC/MS and ELISA).

**Unit III**  
**Preclinical development**  
5 lectures  
Principles of drug absorption, drug metabolism and distribution - intestinal absorption, metabolic stability, drug-drug interactions, plasma protein binding assays, metabolite profile studies, Principles of toxicology, Experimental design for preclinical and clinical PK/PD/TK studies, Selection of animal model; Regulatory guidelines for preclinical PK/PD/TK studies; Scope of GLP, SOP for conduct of clinical & non clinical testing, control on animal house, report preparation and documentation, integration of non-clinical and preclinical data to aid design of clinical studies.

**Unit IV**  
**Drug manufacturing**  
4 lectures  
Requirements of GMP implementation, Documentation of GMP practices, CoA, Regulatory certification of GMP, Quality control and Quality assurance, concept and philosophy of TQM, ICH and ISO 9000; ICH guidelines for Manufacturing, Understanding Impurity Qualification Data, Stability Studies.

**Unit V**  
**Clinical trial design**  
4 lectures  
Objectives of Phase I, II, III and IV clinical studies, Clinical study design, enrollment, sites and documentation, Clinical safety studies: Adverse events and adverse drug reactions, Clinical PK, pharmacology, drug-drug interaction studies, Statistical analysis and documentation.

**Unit VI**  
**Fundamentals of regulatory affairs and bioethics**  
4 lectures  
Global Regulatory Affairs and different steps involved, Regulatory Objectives, Regulatory Agencies; FDA guidelines on IND and NDA submissions, Studies required for IND and NDA submissions for oncology, HIV, cardiovascular indications, On-label vs. off-label drug use GCP and Requirements of GCP Compliance, Ethical issues and Compliance of current ethical guidelines, Ethical Committees and their set up, Animal Ethical issues and compliance.

**Recommended Textbooks and References:**

Course Objectives
The objectives of this course are to learn about structural features of components of immune system as well as their function. The major emphasis of this course will be on development of immune system and mechanisms by which our body elicit the immune response. This will be imperative for students as it will help them to think like an immunologist and predict about nature of immune response that develops against bacterial, viral or parasitic infection, and prove it by designing new experiments.

Student Learning Outcomes
On completion of this course, students should be able to:
• Evaluate the usefulness of immunology in different pharmaceutical companies;
• Identify the proper research lab working in the area of their own interests;
• Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out the kind of immune responses in the setting of infection (viral or bacterial) by looking at cytokine profile.
T cells; MHC and TCR in autoimmunity; transplantation – immunological basis of graft rejection; clinical transplantation and immunosuppressive therapy; tumor immunology – tumor antigens; immune response to tumors and tumor evasion of the immune system, cancer immunotherapy; immunodeficiency-primary immunodeficiencies, acquired or secondary immunodeficiencies, anaphylactic shock.

**Recommended Textbooks and References:**


**Course Objectives**

The objectives of this course are to teach various approaches to conducting genetic engineering and their applications in biological research as well as in biotechnology industries. Genetic engineering is a technology that has been developed based on our fundamental understanding of the principles of molecular biology and this is reflected in the contents of this course.

**Student Learning Outcomes**

Given the impact of genetic engineering in modern society, the students should be endowed with strong theoretical knowledge of this technology. In conjunction with the practicals in molecular biology & genetic engineering, the students should be able to take up biological research as well as placement in the relevant biotech industry.

**Unit I**

*Introduction and tools for genetic engineering*

6 lectures

Impact of genetic engineering in modern society; general requirements for performing a genetic engineering experiment; restriction endonucleases and methylases; DNA ligase, Klenow enzyme, T4 DNA polymerase, polynucleotide kinase, alkaline phosphatase; cohesive and blunt end ligation; linkers; adaptors; homopolymeric tailing; labelling of DNA: nick translation, random priming, radioactive and non-radioactive probes, hybridization techniques: northern, southern, south-western and far-western and colony hybridization, fluorescence *in situ* hybridization.

**Unit II**

*Different types of vectors*

7 lectures

Plasmids; Bacteriophages; M13 mp vectors; PUC19 and Bluescript vectors, hagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Principles for maximizing gene expression expression vectors; pMal; GST; pET-based vectors; Protein purification; His-tag; GST-tag; MBP-tag etc.; Intein-based vectors; Inclusion bodies; methodologies to reduce formation of inclusion bodies; mammalian expression and replicating vectors; Baculovirus and *Pichia* vectors system, plant based vectors, Ti and Ri as vectors, yeast vectors, shuttle vectors.

**Unit III**

*Different types of PCR techniques*

7 lectures

Principles of PCR: primer design; fidelity of thermostable enzymes; DNA polymerases; types of PCR – multiplex, nested; reverse-transcription PCR, real time PCR, touchdown PCR, hot start PCR, colony PCR, asymmetric PCR, cloning of PCR products; T-vectors; proof reading enzymes; PCR based site specific mutagenesis; PCR in molecular diagnostics; viral and bacterial detection; sequencing methods; enzymatic
Unit IV

**cDNA analysis**

Insertion of foreign DNA into host cells; transformation, electroporation, transfection; construction of libraries; isolation of mRNA and total RNA; reverse transcriptase and cDNA synthesis; cDNA and genomic libraries; construction of microarrays – genomic arrays, cDNA arrays and oligo arrays; study of protein-DNA interactions: electrophoretic mobility shift assay; DNase I footprinting; methyl interference assay, chromatin immunoprecipitation; protein-protein interactions using yeast two-hybrid system; phage display.

Unit V

**Gene silencing and genome editing technologies**

Gene silencing techniques; introduction to siRNA; siRNA technology; Micro RNA; construction of siRNA vectors; principle and application of gene silencing; gene knockouts and gene therapy; creation of transgenic plants; debate over GM crops; introduction to methods of genetic manipulation in different model systems e.g. fruit flies (*Drosophila*), worms (*C. elegans*), frogs (*Xenopus*), fish (zebra fish) and chick; Transgenics - gene replacement; gene targeting; creation of transgenic and knock-out mice; disease model; introduction to genome editing by CRISPR-CAS with specific emphasis on Chinese and American clinical trials.

**Recommended Textbooks and References:**

4. Selected papers from scientific journals, particularly Nature & Science.
5. Technical Literature from Stratagene, Promega, Novagen, New England Biolab etc.

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**Computational Biology**

**Credits**

**Course Objectives**

The objective of this course is to provide students with theory and practical experience of essentials to aid for genomic, proteomic and metabolomics courses and drug design program.

**Student Learning Outcomes**

On completion of this course, the students are expected to:

- Develop an understanding of the basic theory of these computational tools;
- Develop required database extraction, integration, coding for computational tools and methods necessary for all Omics;
- Create hypothesis for investigating specific contemporary biological questions, provide help to experiment with or develop appropriate tools;
- Critically analyze and interpret results of their study with respect to whole systems.

**Unit I**

**Introduction to computational biology & biological databases**

Computers in biology and medicine; Overview of biological databases, nucleic acid & protein databases, primary, secondary, functional, composite, structural classification database, Sequence formats & storage. Access databases, Extract and create sub databases, limitations of existing databases.
## Unit II
### Pairwise and multiple sequence alignments
5 lectures


## Unit III
### Genome analysis
6 lectures

- Polymorphisms in DNA sequence, Introduction to Next Generation Sequencing technologies, Whole Genome Assembly and challenges, Sequencing and analysis of large genomes, Gene prediction, Functional annotation, Comparative genomics, Probabilistic functional gene networks, Human genome project, Genomics and crop improvement. Study available GWAS, ENCODE, HUGO projects, extract and build sub databases; Visualization tools including Artemis and Vista for genome comparison; Functional genomics case studies.

## Unit IV
### Structure visualization
3 lectures

- Retrieving and drawing structures, Macromolecule viewing platforms, Structure validation and correction, Structure optimization, Analysis of ligand-protein interactions; Tools such as PyMol or VMD.

## Unit V
### Molecular modelling
6 lectures

- Significance and need, force field methods, energy, buried and exposed residues; side chains and neighbours; fixed regions; hydrogen bonds; mapping properties onto surfaces; RMS fit of conformers and protein chains, assigning secondary structures; sequence alignment: methods, evaluation, scoring; protein curation: backbone construction and side chain addition; different types of protein chain modelling: ab initio, homology, hybrid, loop; Template recognition and alignments; Modelling parameters and considerations; Model analysis and validation; Model optimization; Substructure manipulations, annealing, protein folding and model generation; loop generating methods; loop analysis; Analysis of active sites using different methods in studying protein–protein Interactions.

## Unit VI
### Structure-based drug development
6 lectures

- Molecular docking: Types and principles, Semi-flexible docking, Flexible docking; Ligand and protein preparation, Macromolecule and ligand optimization, Ligand conformations, Clustering, Analysis of docking results and validation with known information. Extra-precision docking platforms, Use of Small-molecule libraries, Natural compound libraries for virtual high throughput screenings.

## Unit VII
### Ligand-based drug development
6 lectures

- Quantitative structure activity relationships; Introduction to chemical descriptors like 2D, 3D and Group-based; Radar plots and contribution plots and Activity predictions, Pharmacophore modeling, Pharmacophore-based screenings of compound library, analysis and experimental validation.

### Recommended Textbooks and References:

Research Methodology and Scientific Communication Skills

Credits
2

Unit I
History of science and science methodologies
8 lectures

Empirical science; scientific method; manipulative experiments and controls; deductive and inductive reasoning; descriptive science; reductionist vs holistic biology.

Unit II
Preparation for research
2 lectures

Choosing a mentor, lab and research question; maintaining a lab notebook.

Unit III
Process of communication
5 lectures

Concept of effective communication - setting clear goals for communication; determining outcomes and results; initiating communication; avoiding breakdowns while communicating; creating value in conversation; barriers to effective communication; non-verbal communication-interpreting non-verbal cues; importance of body language, power of effective listening; recognizing cultural differences; Presentation skills - formal presentation skills; preparing and presenting using overhead projector, PowerPoint; defending interrogation; scientific poster preparation & presentation; participating in group discussions; Computing skills for scientific research - web browsing for information search; search engines and their mechanism of searching; hidden Web and its importance in scientific research; internet as a medium of interaction between scientists; effective email strategy using the right tone and conciseness.

Unit IV
Scientific communication
9 lectures

Technical writing skills - types of reports; layout of a formal report; scientific writing skills - importance of communicating science; problems while writing a scientific document; plagiarism, software for plagiarism; scientific publication writing: elements of a scientific paper including abstract, introduction, materials & methods, results, discussion, references; drafting titles and framing abstracts; publishing scientific papers - peer review process and problems, recent developments such as open access and non-blind review; plagiarism; characteristics of effective technical communication; scientific presentations; ethical issues; scientific misconduct.

Recommended Textbooks and References:
# Formulation of Biologicals

## Credits

<table>
<thead>
<tr>
<th>Unit</th>
<th>Course Title</th>
<th>Lectures</th>
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<tbody>
<tr>
<td>I</td>
<td>Basic characteristics of biologicals</td>
<td>5</td>
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<tr>
<td>II</td>
<td>Excipients and additives</td>
<td>4</td>
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<tr>
<td>III</td>
<td>Formulation processing</td>
<td>4</td>
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<tr>
<td>IV</td>
<td>Particulate formulation for biologicals</td>
<td>4</td>
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<tr>
<td>V</td>
<td>Examples of biological formulation</td>
<td>3</td>
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</table>

## Course Objectives

This course will give students a brief overview of formulation of biological compounds citing various examples and processes involved.

## Student Learning Outcomes

On completion of this course, students should be able to understand the basis of formulation and development of biologicals and should also be able to formulate basic compounds.

Temperature and stress sensitive, sensitive to pressure and solvent, water activity and biological activity, storage stability, aggregation behavior, dormant forces causing aggregation of biologicals, degradation pattern, difference between degradation, aggregation and precipitation. Specific requirements for stabilization of protein, carbohydrate, lipids and nucleic acids.

Role of excipients and additives on stabilizing biologicals; Pharmacopoeia approved excipients, additives and stabilizers, mechanism of action of additives, excipients and stabilizers; Chemical modification to improve stability, pegylation and silylation.

Preparation and powder and liquid formulation; Methods of preparation; Use of crystallization, polymorphs for improving stability of biological; Characteristics of liquid and powder formulation.

Polymeric particle based formulation, liposomal formulation and solid lipid nanoparticle formulation. Different nano carrier based formulation; Examples of nano formulation in industry.

Insulin formulation, formulation of monoclonal antibodies, vaccines, anticancer drugs and antibiotics.

## Recommended Textbooks and References:

**Enzyme Technology**

**Course Objectives**
This course will describe various technologies used in enzyme engineering and purification. It will also give an overview of the technologies used in pharmaceutical industries.

**Student Learning Outcomes**
On completion of this course, students should be able to understand the basics of enzyme technologies used in pharmaceutical industry.

<table>
<thead>
<tr>
<th>Unit I</th>
<th>Enzymes and enzymology</th>
<th>4 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Classification, mode of action, activation, specificity, Source of enzymes; production, isolation and purification of enzymes; Characterization in terms of pH, temperature, ionic strength, substrate and product tolerance, effects of metal ions etc.</td>
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<tr>
<th>Unit II</th>
<th>Coenzymes and cofactors</th>
<th>4 lectures</th>
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<tr>
<td></td>
<td>Coenzymes, classification of vitamins, role and mechanism of action of some important coenzyme (NAD+/NADP+, FAD, lipoic acid, tetrahydrofolate, B12-coenzyme), role of cofactors with specific examples.</td>
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<tr>
<th>Unit III</th>
<th>Enzyme kinetics</th>
<th>6 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Enzyme as biological catalysts; Enzyme action, active site, functional group, enzyme substrate complex, cofactors, Michaelis-Menten equation, Km and Vmax, enzyme inhibition; order of reaction, methods of plotting enzyme kinetics data; enzyme turnover number, competitive, non-competitive, uncompetitive, irreversible; order of reaction, methods of plotting enzyme kinetics data; determination of Kcat, Km, Vmax, Ki, Half life, activation and deactivation energy etc. Cross-linked enzyme aggregates, Cross linked enzymes, enzyme crystals, their use and preparation. Solution of numerical problems; Energy yielding and energy-requiring reactions; Calculation of equilibrium constants; Activation energy etc.; Multisubstrate enzymes and kinetics mechanisms; Enzyme induction, repression, covalent modification, Isoenzymes, allosteric effects.</td>
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<tr>
<th>Unit IV</th>
<th>Enzyme engineering</th>
<th>4 lectures</th>
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<tr>
<td></td>
<td>Random and rational approach of protein engineering; Directed evolution and its application in the biocatalysis; various approaches of creating variant enzyme molecules; Future of Biocatalysis; Ideal biocatalyst.</td>
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<tr>
<th>Unit V</th>
<th>Immobilized enzyme technology</th>
<th>5 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Different techniques of immobilization of enzymes and whole cells; Advantages and disadvantages of immobilization; Kinetics of immobilized enzymes, design and operation of immobilized enzymes reactors; Types of reactors, classification, retention of enzymes in a reactor, kinetics of enzyme reactors; Reactor performance with inhibition, operation of enzyme reactors; case studies; starch conversion; 6APA production, biotransformations using soluble as well as immobilized enzymes; Calculations of diffusional resistances and Thiele’s modulus, multi-step immobilized enzyme systems; Solution of numerical problems; Application and future of immobilized enzyme technology.</td>
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<tr>
<th>Unit VI</th>
<th>Enzyme in organic solvents and ionic liquids</th>
<th>3 lectures</th>
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<tbody>
<tr>
<td></td>
<td>Various organic solvents and ionic liquids used in biocatalysis; Potential in organic solvents and ionic liquids; Applications of enzymes in analysis.</td>
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</table>

**Recommended Textbooks and References:**
Laboratory III: Immunology

Course Objectives
The objectives of this laboratory course are to develop an understanding about practical aspects of components of immune system as well as their function. Basic as well as advanced methods will be taught to detect different antigen and antibody interactions, isolation of different lymphocyte cells etc. and how they can be used in respective research work.

Student Learning Outcomes
Students should be able to:
• Evaluate the usefulness of immunology in different pharmaceutical companies;
• Identify proper research lab working in area of their own interests;
• Apply their knowledge and design immunological experiments to demonstrate innate, humoral or cytotoxic T lymphocyte responses and figure out kind of immune responses in setting of infection (viral or bacterial) by looking at cytokine profile.

Syllabus

1. Handling of animals like rabbits, mice.
2. Preparation of antigens, immunization and methods of blood collection, serum separation and storage.
3. Antibody titre by ELISA method.
5. Complement fixation test.
6. Isolation and purification of IgG from serum or IgY from chicken egg.
7. SDS-PAGE, Immunoblotting, Dot blot assays.
10. Demonstration of Phagocytosis of latex beads.
12. Lymphoproliferation by mitogen / antigen induced.
13. Lymphnode Immunohistochemistry (direct and indirect peroxidase assay).

Laboratory IV: Molecular Biology and Genetic Engineering

Course Objectives
The objective of this laboratory course is to provide practical skills on basic microbiological and genetic engineering techniques.

Student Learning Outcomes
On completion of this lab course, students should be able to:
• Acquire basic microbiology techniques and principles;
• Get first-hand experience that will coincide with what is taught in the lecture portion of the class;
• Gain hands-on experience in gene cloning, protein expression and purification.
Syllabus

1. Concept of lac-operon:
   a) lactose induction of β-galactosidase.
   b) Glucose Repression.
   c) Diauxic growth curve of E.coli
2. UV mutagenesis to isolate amino acid auxotroph
3. Phage titre with λ phage/M13
4. Genetic Transfer-Conjugation, gene mapping
5. Plasmid DNA isolation and DNA quantitation
6. Restriction Enzyme digestion of plasmid DNA
7. Agarose gel electrophoresis
8. Polymerase Chain Reaction and analysis by agarose gel electrophoresis
9. Vector and Insert Ligation
10. Preparation of competent cells
11. Transformation of E.coli with standard plasmids, Calculation of transformation efficiency
12. Confirmation of the insert by Colony PCR and Restriction mapping
13. Expression of recombinant protein, concept of soluble proteins and inclusion body formation in E.coli, SDS-PAGE analysis
14. Purification of His-Tagged protein on Ni-NTA columns
   a) Random Primer labeling
   b) Southern hybridization.

Semester Three

Quality Control, Quality Assurance and Quality by Design for Biologicals

Course Objectives
The objective of course is to give ability to achieve standards in manufacture of quality products in pharmaceutical industry.

Student Learning Outcomes
At the end of the course, student should be able to:
- Understand and implement quality assurance and quality control for particular operation during drug development;
- Understand useful concepts like Six Sigma and its application in pharmaceutical industry;
- Understand drug development process and its importance in pharmaceutical industry.

Unit I
Introduction to QC and QA
6 lectures

Good Practices in QC laboratory, Schedule L1, standardization of reagents, labeling of reagents, control samples, controls on animal house, data generation and storage, QC documentation, LIMS Sampling Techniques, Sampling Plans, Good warehousing practices. Pest and rodent controls; Temperature mapping and monitoring of warehouses; Good Distribution Practices, Waste disposal, disposal procedures and records, current regulations for waste disposal.

Unit II
Quality management models
6 lectures


Designing of manufacturing facilities for Excipients, API, Drug Formulations, Medical Devices; ISPE Baseline guidelines; Designing requirements for HVAC systems; Quality Planning in Product Life cycle; Product Quality Life cycle implementation (PQLI); In-process quality control on various dosage forms- Sterile and non-sterile; Packaging and labeling controls.

Contract manufacturing and analysis, Present status and scope of Pharmaceutical industry in India; Analytical Method Transfers; Complaints handling; Root cause analysis; Keppener Trego technique for investigations; Establishment of CAPA; Handling of Recall and recall procedures; Mock recalls.

Recommended Textbooks and references:
2. Laws of Drugs in India, Hussain

Course Objectives
The objectives of this course are:
• To understand business opportunities, and aspects of finance and operation of business;
• To provide basic knowledge on intellectual property rights and their implications in biological research and product development;
• To learn biosafety and risk assessment of products derived from biotechnology and regulation of such products;
• To understand ethical issues in biological research.

Student Learning Outcomes
Students should be able to:
• Gain entrepreneurial skills, and awareness of operations involved in venture creation;
• Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents;
• Gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research and environmental release of genetically modified organisms, national and international regulations;
• Understand ethical aspects related to biological, biomedical, health care and biotechnology research.
<table>
<thead>
<tr>
<th>Unit I</th>
<th>Introduction to entrepreneurship</th>
<th>5 lectures</th>
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<tr>
<th>Unit II</th>
<th>Introduction to IPR</th>
<th>5 lectures</th>
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<tr>
<td>Introduction to intellectual property; types of IP: patents, trademarks, copyright &amp; related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for protection of IP; IP as a factor in R&amp;D; IPs of relevance to biotechnology and few case studies; history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of 'prior art': invention in context of &quot;prior art&quot;; patent databases - country-wise patent searches (USPTO, EPO, India); analysis and report formation.</td>
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<tr>
<th>Unit III</th>
<th>Patenting</th>
<th>5 lectures</th>
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<tr>
<td>Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure - patent application- forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting - requirement, procedures and costs; financial assistance for patenting-introduction to existing schemes; publication of patents - gazette of India, status in Europe and US; patent infringement - meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing – outright sale, licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad, collaborative research - backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives.</td>
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<tr>
<th>Unit IV</th>
<th>Biosafety</th>
<th>5 lectures</th>
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<tr>
<td>Biosafety and Biosecurity - introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs &amp; LMOs; principles of safety assessment of transgenic plants – sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk – environmental risk assessment and food and feed safety assessment; problem formulation – protection goals, compilation of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops vs cisgenic plants or products derived from RNAi, genome editing tools.</td>
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<table>
<thead>
<tr>
<th>Unit V</th>
<th>National and international regulations</th>
<th>5 lectures</th>
</tr>
</thead>
<tbody>
<tr>
<td>International regulations – Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations – EPA act and rules, guidance documents, regulatory framework – RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India - containments – biosafety levels and category of rDNA experiments; field trials – biosafety research trials – standard operating procedures - guidelines of state governments; GM labeling – Food Safety and Standards Authority of India (FSSAI).</td>
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<table>
<thead>
<tr>
<th>Unit VI</th>
<th>Bioethics</th>
<th>5 lectures</th>
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</table>

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engineered food, environmental risk, labeling and public opinion. Sharing benefits and protecting future generations - Protection of environment and biodiversity – biopiracy.

Recommended Textbooks and References:
6. Office of the Controller General of Patents, Design & Trademarks; Department of Industrial Policy & Promotion; Ministry of Commerce & Industry; Government of India. http://www.ipindia.nic.in/

Course Objectives
The objective of this course is to provide an overview of various aspects of recovery and processing of biological products.

Student Learning Outcomes
Students should be able to identify and design relevant unit operations for recovery of a biological product.

Credits
3
<table>
<thead>
<tr>
<th>Unit</th>
<th>Biomass removal</th>
<th>Characteristics of biological materials: pretreatment methods; Separation of cell mass: centrifugation, sedimentation, flocculation and filtration; Continuous operation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit II</td>
<td>Cell disruption</td>
<td>Mechanical approaches: sonication, bead mills, homogenizers; non-mechanical approaches: freeze/thaw, osmotic shock, chemical lysis, enzymatic lysis; measurement of cell disruption.</td>
</tr>
<tr>
<td>Unit III</td>
<td>Membrane processes</td>
<td>Filtration theory; Micro and ultrafiltration; Reverse osmosis; dialysis; electrodialysis, diafiltration; pervaporation; perstraction; Multistage and continuous operation.</td>
</tr>
<tr>
<td>Unit IV</td>
<td>Adsorption and chromatography</td>
<td>Adsorption equilibrium, Van Deemter equation; Chromatography: size, charge, polarity, shape, hydrophobic interactions; Biological affinity; Process configurations (packed bed, expanded bed, simulated moving beds).</td>
</tr>
<tr>
<td>Unit V</td>
<td>Extraction processes</td>
<td>Solvent extraction: phase equilibrium and distribution, counter-current operation, dissociative extraction, multiple stage analysis; Reciprocating-plate and centrifugal extractors; Reverse micellar extraction; Aqueous two phase, Supercritical fluid extraction; Aqueous two-phase extraction.</td>
</tr>
<tr>
<td>Unit VI</td>
<td>Concentration steps</td>
<td>Precipitation: effect of size and charge, solvent effects, ionic strength effects, precipitate growth and aging models. Crystallization: nucleation and growth aspects; Drying: solvent removal aspects, dryers (vacuum, freeze, spray); Scale up aspects.</td>
</tr>
<tr>
<td>Unit VII</td>
<td>Product characterization</td>
<td>Biophysical characterization, chemical characterization, modern spectroscopy, QbD, stability Bioassays: Cell based assay, receptor mediated assay, in vivo evaluation, immunogenicity.</td>
</tr>
<tr>
<td>Unit VIII</td>
<td>Process design</td>
<td>Process synthesis: identification and ordering of unit operations relevant for a case study. Analysis: comparison of different process synthesis steps. Case studies such as Industrial production of penicillin via fungal route, insulin from recombinant E. coli; Production of metabolites such as shikonin using plant cell culture, astaxanthin from algae, and biotransformation routes for novel/specialty chemicals; Production of HBsAg using yeast cultures, erythropoietin using CHO cells, monoclonal antibodies such as Humira using mammalian cells.</td>
</tr>
</tbody>
</table>

**Recommended Textbooks and References:**

### Course Objectives
The objectives of this course are to equip students with biomanufacturing principles and good manufacturing practices for production of biopharmaceuticals.

### Student Learning Outcomes
Students should develop conceptual clarity and knowledge about systems for quality manufacturing of biotherapeutics (biopharmaceuticals, diagnostics and foods) manufactured for human use. The knowledge of GMP and GLP requirements is critical for students who opt for careers in biomanufacturing.

### Unit I
**Biomanufacturing principles**
- Overview and design of biomanufacturing, quality by design approach, technical considerations, phases and scale up: life cycle of manufacturing, raw material considerations, compliance and quality in biomanufacturing, lean biomanufacturing; Process analytical technology (PAT) during biomanufacturing: background and need tools for data acquisitions (software in fermenters, flow filtrations, chromatography, analysis and design process analyzers, process control tools and continuous improvement and knowledge management; Standard manufacturing operating procedures of biotechnology, including upstream and downstream processing of proteins, and quality control of protein production, and final fill and finish of product; Case studies to be included: therapeutic proteins, monoclonal antibodies, human vaccines.

### Unit II
**Quality system**
- Introduction to quality system, main elements of a quality system; Essential of quality system; Practical implementation of a quality system; Structure of quality manual, correlation between GMP requirements (WHO) and ISO 9001:2000.

### Unit III
**Principles and practice of GMP**
- Personnel: Principles of human resource management, duties of senior management, organizational structures, qualification and profiles requirement, workplace and job descriptions, health monitoring and occupational health safety, training, functions owners subject to public law; Premises: Official requirements, material & personnel flow and layout, air cleanliness classes and grades, construction elements, barrier systems, isolators and safety cabinets, building services, heating ventilation air conditioning (HVAC), process gases, qualification of premises and HVAC systems, pharma monitoring of HVAC systems, particle monitoring.; Facilities and Equipment: Facility planning, materials, hygienic design in solid handling, system controllers and process control systems, technical documentation, installation qualification, maintenance, cleaning of facilities, containment (personnel protection) in solid handling; Pharmaceutical water: Water quality, generation of pharmaceutical water, distribution and storage of pharmaceutical water, qualification of water supplies, operation of water supplies, pure steam systems; Qualification: Official requirements, preparation of qualification, qualification documentation, design qualification (DQ), Installation qualification (IQ), operational qualification (OQ), Performance qualification (PQ), special cases of qualification; Process Validation: Official requirements, Validation - a key element of quality management, validation planning and procedure, validation documentation, process validation and product lifecycle; Cleaning Validation: Official requirements, how to validate cleaning procedures, cleaning validation master plan, establishing scope of validation, acceptance criteria and limit calculation, sampling procedures, analytical procedure, documentation, maintenance of validated status, cleaning validation documentation; Production: Sanitation, personnel hygiene, production hygiene, sanitation programme, environmental monitoring, GMP in production process, weigh-in, identification, in-process control prevention of cross-contamination, empty chapter, reworking, warehouse and logistics; Sterile Production and Packaging: Introduction, Air lock
concepts, manufacture of terminally sterilised products, sterilisation processes, aseptic processing, freeze-drying, testing for sterility, testing for endotoxins, testing for leakage and for particles, microbiological monitoring, packaging materials, packaging process, qualification of a servo-controlled blister packaging line, blow-fill-seal technology (BFS technology); Documentation: Official requirements, GMP-compliant documentation, batch documentation, standard operating procedures (SOPs), site master file, electronic batch recording and batch release, CAPA, document management systems.

### Unit IV
**GMP in regulation**
2 lectures

Information, national bodies and pharmaceutical associations; Pharmacopeia; EU directives and guidelines, USA: CFR and FDA guidelines, ICH-guidelines, PIC/S guidelines, GMP of other regions, WHO guidelines.

### Recommended Textbooks and References:
5. *Learn Biomanufacturing*, 1st Edition; Author Nigel Smart; Woodhead Publishing
6. *GMP manual*; Publisher Maas & Peither America, Inc. GMP Publishing

### Course Objectives
This course will give a broad perspective about emergence of pharmacogenomics as a new field and provide them with insight into its growing importance in clinical therapeutics and future drug design.

### Student Learning Outcomes
Students completing this course should be able to gain an understanding of how genetic differences between individuals can impact outcome of drug therapy in a positive and negative way. The course will also help students understand how personalised drug therapy based on a person's genetic makeup can optimize the effectiveness of therapy while reducing unwanted drug effects.

### Unit I
**Pharmacogenomics**
10 lectures

Pharmacogenomics; Pharmacogenetics; Benefits; Practical applications of pharmacogenomics; The Promise of Pharmacogenomics today leading to personalized medicines; Human genetic variation - examples of CYP gene variations leading to variable metabolism of drugs; Distribution of variation; Mutations & its kind; Natural selection; Variation in ethnic groups, races.

### Unit II
**Pharmacology**
10 lectures

Pharmacology; Clinical pharmacology; Drugs; Drug Legislation & safety; Types of Drugs - examples of latest drugs; Drug potency and Efficacy; ADME of Drug- Drug absorption; Drug distribution; Drug metabolism & Drug Excretion; Drug efficacy & toxicity; drug therapeutic levels; Therapeutic Index; Drug abuse; Drug response in patients by correlating gene expression; Regulation of gene expression; Polymorphism; Alleles; Single nucleotide polymorphism; Genotyping; example of TPMT and DPD gene mutation and their impact in treatment strategy.
Unit III
Biomarkers
3 lectures

Genetic markers—Biomarkers in early drug development; Biomarkers in Clinical development; Biomarkers.

Recommended Textbooks and References:
2. Yan Q, (2008), Pharmacogenomics in Drug Discovery and Development, Springer-Verlag New York, LLC.
4. Innocenti F, (2005), Pharmacogenomics: Methods and Applications, Springer-Verlag New York, LLC.

Project Proposal Preparation & Presentation

Course Objectives
The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.

Student Learning Outcomes
Students should be able to demonstrate the following abilities:
• Formulate a scientific question;
• Present scientific approach to solve the problem;
• Interpret, discuss and communicate scientific results in written form;
• Gain experience in writing a scientific proposal;
• Learn how to present and explain their research findings to the audience effectively.

Syllabus
Project Proposal Preparation

Selection of research lab and research topic: Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them select a topic for their project. The topic of the research should be hypothesis driven.

Review of literature: Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources.

Writing Research Proposal: With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc. Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.

Syllabus
Poster Presentation

Students will have to present the topic of their project proposal after few months of their selection of the topic. They should be able to explain the novelty and importance of their research topic.

Syllabus
Oral Presentation

At the end of their project, presentation will have to be given by the students to explain work done by them in detail. Along with summarizing their findings they should also be able to discuss the future expected outcome of their work.
Laboratory V: Downstream Processing in Biotechnology

Course Objectives
The objectives of this course are to provide students with hands-on knowledge of primary unit operations involved in downstream processing.

Student Learning Outcomes
Students should be able to gain hands-on experience on approaches to cell disruption, centrifugation, filtration, and precipitation.

Credits
3

Syllabus
1. Conventional filtration
2. Centrifugation in batch and continuous centrifuges
3. Cell disruption
4. Protein precipitation and its recovery
5. Ion-exchange chromatography
6. Membrane-based filtration-ultra filtration in cross flow modules and micro filtration
7. Adsorption in batch and continuous mode.

Recommended Textbooks and References:

Semester Four

Dissertation

Course Objectives
The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.

Student Learning Outcomes
Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:
- In-depth knowledge of the chosen area of research.
- Capability to critically and systematically integrate knowledge to identify issues that must be addressed within framework of specific thesis.
- Competence in research design and planning.
- Capability to create, analyze and critically evaluate different technical solutions.
- Ability to conduct research independently.
- Ability to perform analytical techniques/experimental methods.
- Project management skills.
- Report writing skills.
Clinical Trials and Bioethics

Course Objectives
This course will give a broad perspective of requirements and procedures followed in different stages of clinical trials along with ethics which are to be taken care of.

Student Learning Outcomes
By the end of this course, students should be able to:

- Understand fundamental concepts in design of clinical trials;
- Describe study designs commonly used and pre-study requirements;
- Describe roles of Regulatory Affairs in clinical trials;
- Identify key issues in data management for clinical trials;
- Utilize a systematic framework for evaluating the ethics of a clinical research protocol;
- Apply appropriate codes, regulations, and other documents governing the ethical conduct of human subject research to their own research.

Credits
2

Syllabus
Planning & performing experiments

Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

Syllabus
Thesis writing

At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.

Recommended Mode of Assessment

Assessment may be done by thesis evaluation, viva voce and final presentation.

Unit I
Fundamentals of clinical trials
5 lectures

Fundamentals of clinical trials; Clinical trials in practice; Reporting and reviewing clinical trials; Legislation and good clinical practice - overview of European directives and legislation governing clinical trials in 21st century; International perspectives; Principles of International Committee on Harmonisation (ICH)-GCP; CDSCO Guidance.

Unit II
Clinical trial design and requirements
10 lectures

Drug development and trial planning - pre-study requirements for clinical trials; Regulatory approvals for clinical trials; Regulatory submissions; Consort statement; Trial responsibilities and protocols - roles and responsibilities of investigators, sponsors and others; Requirements of clinical trial protocols; Legislative requirements for investigational medicinal products. Consent - principles of informed consent; Consent processes; Medical Writing, Clinical Study Report; Investigational New Drug Application
(INDs); Biologics License Application (BLA); Common Technical Document (CTD) for application dossiers.

### Unit III
**Project management and ethics**
6 lectures

- Project management in clinical trials - principles of project management; Application in clinical trial management; Risk assessment; Research ethics and Bioethics - Principles of research ethics; Ethical issues in clinical trials; Use of humans in scientific experiments; Ethical committee system including a historical overview; informed consent; Introduction to ethical codes and conduct; Introduction to animal ethics; Animal rights and use of animals in the advancement of medical technology; Introduction to laws and regulation regarding use of animals in research.

### Unit IV
**Data management**
5 lectures

- Data protection; Legislation and its application; Data management – Introduction to trial master files and essential documents; Data management, Data listing; C-DISC (Clinical Data Management), medDRA, Statistical evaluation - Basic statistics for clinical trials.

### Unit V
**Reporting and reviewing clinical trials**
5 lectures

- Quality assurance and governance - quality control in clinical trials; Monitoring and audit; Inspections; Pharmacovigilance; Research governance; Trial closure and pitfalls-trial closure; Reporting and legal requirements; Common pitfalls in clinical trial management; Adverse event & serious adverse event reporting; Drug Recall.

#### Recommended Textbooks and References:
1. *Fundamentals of Clinical Trials.* (Authors: Friedman, Lawrence M., Furberg, Curt D., DeMets, David; LA; Latest Edition; Publisher: Springer).
4. ICH: Structure and Content of Clinical Study Reports (E3)

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### Recommended Electives

#### Molecular Therapeutics

**Course Objectives**
The objectives of this course are to give broad overview of molecular basis of therapy. This course will talk about various challenges and opportunities in this recent field of molecular medicine.

**Student Learning Outcomes**
On completion of this course, students should be able to:
- Identify different types of molecular therapies;
- Understand barriers involved;
- Apply knowledge to better treatment procedures.

#### Unit I
**Gene therapy**
5 lectures

- Gene therapy; Intracellular barriers to gene delivery; Overview of inherited and acquired diseases for gene therapy; Retro and adenovirus mediated gene transfer; Liposome and nanoparticles mediated gene delivery.
### Unit I
**Introduction to Nanobiotechnology**
5 lectures

Introduction to Nanobiotechnology; Concepts, historical perspective; Different formats of nanomaterials and applications with example for specific cases; Cellular Nanostructures; Nanopores; Biomolecular motors; Bio-inspired Nanostructures; Synthesis and characterization of different nanomaterials.

### Unit II
**Nano - films**
5 lectures

Thin films; Colloidal nanostructures; Self Assembly, Nanovesicles; Nanospheres; Nanocapsules and their characterisation.

### Unit III
**Nano - particles**
6 lectures

Nanoparticles for drug delivery, concepts, optimization of nanoparticle properties for suitability of administration through various routes of delivery, advantages, strategies for cellular internalization and long circulation, strategies for enhanced permeation through various anatomical barriers.

### Unit IV
**Immunotherapy**
5 lectures

Immunotherapy; Monoclonal antibodies and their role in cancer; Role of recombinant interferons; Immunostimulants; Immunosupressors in organ transplants; Role of cytokine therapy in cancers; Vaccines: types, recombinant vaccines and clinical applications.

### Unit V
**Applications**
5 lectures

Gene silencing technology; Antisense therapy; siRNA; Tissue and organ transplantation; Transgenics and their uses; Cloning; Ethical issues.

### Recommended Textbooks and References:
### Unit IV
**Applications of nano-particles**
5 lectures

Nanoparticles for diagnostics and imaging (theranostics); concepts of smart stimuli responsive nanoparticles, implications in cancer therapy, nanodevices for biosensor development.

### Unit V
**Nano-materials**
6 lectures

Nanomaterials for catalysis, development and characterization of nanobiocatalysts, application of nanoscaffolds in synthesis, applications of nanobiocatalysis in the production of drugs and drug intermediates.

### Unit VI
**Nano-toxicity**
5 lectures

Introduction to Safety of nanomaterials, Basics of nanotoxicity, Models and assays for Nanotoxicity assessment; Fate of nanomaterials in different strata of environment; Ecotoxicity models and assays; Life cycle assessment, containment.

### Recommended Textbooks and References:
5. Recent review papers in the area of Nanomedicine.

### OMICS Technologies

#### Credits
2

**Course Objectives**

The aim of this course is to give an overview of genomics, proteomics and metabolomics to students. The students should be able to gain working knowledge of these technologies and appreciate their ability to impart a global understanding of biological systems and processes in health and disease.

**Student Learning Outcomes**

At the end of the course, students should:
- Understand high throughput analysis;
- Gain knowledge of current cutting edge technologies;
- Know the application of various Omics technologies.

#### Unit I
**Genomics and methods in genomics**
5 lectures

Organization and structure of genomes in prokaryotes, eukaryotes, and organelles (chloroplast, mitochondrion); Genome mapping methods (genetic and physical); RAPD, RFLP, SNP analyses; Fluorescence In Situ Hybridization (FISH) techniques; Advances in gene finding and functional prediction; Chain termination and chemical degradation sequencing methods. Genome-wide association (GWA) analysis; Comparative Genomic Hybridization (CGH); Massively parallel Signature Sequencing (MPSS); Whole genome shot-gun sequencing and its applications; Introduction to Next Generation Sequencing (NGS).

#### Unit II
**Transcriptomics and methods in transcriptomics**
5 lectures

Gene expression analysis by cDNA and oligonucleotide arrays; Micro array experimental analysis and data analysis; Bioinformatic analysis of large-scale microarray data for comparative transcriptomics.

#### Unit III
**Proteomics and methods in proteomics**
10 lectures

Overview of strategies used for identification and analysis of proteins; Protein extraction from biological samples (mammalian tissues, yeast, bacteria, and plant tissues); 2-DE of proteins for proteome analysis; Liquid chromatography separations in proteomics (Affinity, Ion Exchange, Reversed-phase, and size exclusion); Enzymatic cleavage of proteins. Analysis of complex protein mixtures using Nano-liquid chromatography.

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(Nano-LC) coupled to Mass-spectrometry analysis; Overview of strategies used for identification and analysis of proteins; Protein extraction from biological samples (Mammalian Tissues, Yeast, Bacteria, and Plant Tissues); 2-DE of proteins for proteome analysis; Liquid chromatography separations in proteomics (Affinity, Ion Exchange, Reversed-phase, and size exclusion); Enzymatic cleavage of proteins. Analysis of complex protein mixtures using Nano-liquid chromatography (Nano-LC) coupled to Mass-spectrometry analysis; Common ionization methods for peptide/protein analysis; Introduction to Mass spectrometers; MALDI-TOF and LC-MS analyses; Comparative proteomics based on global in-vitro and in-vivo labeling of proteins/peptides followed by Mass-spectrometry; Analysis of post-translational modification (PTM) of proteins; Characterization of protein interactions using yeast two-hybrid system and Protein microarrays; Proteomics informatics and analysis of protein functions.

Unit IV
Metabolomics and methods in metabolomics
8 lectures

Introduction to metabolic engineering, comprehensive models of cellular reactions with stoichiometry and reaction rates; metabolic flux analysis of exactly/over/under determined systems; Shadow price, sensitivity analysis; Monitoring and measuring metabolome. Methods for experimental determination of metabolic fluxes by isotope labeling metabolic fluxes using various separation-analytical techniques; GC-MS for metabolic flux analysis.

Recommended Textbooks and References:

Course Objectives
This course will provide students with an overview of current developments in different areas of vaccines.

Student Learning Outcomes
By the end of this course, students should be able to:
• Understand fundamental concepts of human immune system and basic immunology;
• Differentiate and understand immune responses in relation to infection and vaccination;
• Understand requirement and designing of different types of vaccines;
• Understand importance of conventional and new emerging vaccine technologies.

Unit I
Fundamentals of immune system
6 lectures

Overview of Immune system; Human Immune system: Effectors of immune system; Innate & Adaptive Immunity; Activation of the Innate Immunity; Adaptive Immunity; T and B cells in adaptive immunity; Immune response in infection; Correlates of protection.
### Unit II
**Immune response to infection**
9 lectures

- Protective immune response in bacterial; viral and parasitic infections; Primary and Secondary immune responses during infection; Antigen presentation and Role of Antigen presenting cells: Dendritic cells in immune response; Innate immune response; Humoral (antibody mediated) responses; Cell mediated responses: role of CD4+ and CD8+ T cells; Memory responses: Memory and effector T and B cells, Generation and Maintenance of memory T and B cells.

### Unit III
**Immune response to vaccination**
8 lectures

- Vaccination and immune response; Adjuvants in Vaccination; Modulation of immune responses: Induction of Th1 and Th2 responses by using appropriate adjuvants and antigen delivery systems - Microbial adjuvants, Liposomal and Microparticles as delivery systems; Chemokines and cytokines; Role of soluble mediators in vaccination; Oral immunization and Mucosal Immunity.

### Unit IV
**Vaccine types and design**
3 lectures

- History of vaccines, Conventional vaccines; Bacterial vaccines; Viral Vaccines; Vaccines based on routes of administration: parenteral, oral, mucosal; Live attenuated and inactivated vaccine; Subunit Vaccines and Toxoids; Peptide Vaccine.

### Unit V
**Vaccine technologies**
4 lectures

- New Vaccine Technologies; Rationally designed Vaccines; DNA Vaccination; Mucosal vaccination; New approaches for vaccine delivery; Engineering virus vectors for vaccination; Vaccines for targeted delivery (Vaccine Delivery systems); Disease specific vaccine design: Tuberculosis Vaccine; Malaria Vaccine; HIV/AIDS vaccine; New emerging diseases and vaccine needs (Ebola, Zika).

### Recommended Textbooks and References:
2. Thomas J. Kindt, Barbara A. Osborne, Richard A. Goldsby; *Kuby Immunology*.
DBT Supported Teaching Programmes

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of University</th>
<th>Contact Details of Course Coordinator</th>
</tr>
</thead>
</table>
| 1.    | Institute of Chemical Technology, Mumbai | Dr. Padma V. Devarajan  
Dept. of Pharmaceutical Technology  
022-33612201, Extn. 2201  
09820518009 |
| 2.    | National Institute of Pharmaceutical Education and Research, Mohali | Prof. U.C. Banerjee  
Dept. of Pharmaceutical Technology  
0172—2214682-87/ 2142, 2061  
9417474790 ucbannerje@gmail.com |

Annexure I

Subject Specific Subcommittee of M.Tech. Pharmaceutical Biotechnology

Chairperson
1. Dr. Santosh Noronha, Professor, Department of Chemical Engineering, Indian Institute of Technology, Bombay

Members
2. Dr. U.C. Banerjee, Professor and Head, Department of Pharmaceutical Technology, National Institute of Pharmaceutical Education and Research, Mohali
3. Dr. Amulya Panda, Staff Scientist VII, National Institute of Immunology, New Delhi
4. Dr. P. Gautam, Professor, Department of Biotechnology, Anna University, Chennai
5. Dr. Rakhi Chaturvedi, Professor, Department of Biosciences and Bioengineering, Indian Institute of Technology Guwahati
6. Dr. Abhinav Grover, Assistant Professor, School of Biotechnology, Jawaharlal Nehru University, New Delhi,
7. Dr. Neelam Chauhan, Assistant Professor, National Institute of Pharmaceutical Education and Research, Ahmedabad
8. Dr. Monideepa Roy, Head, Research and Development, Invictus Oncology Pvt. Ltd., New Delhi

Member Secretary
9. Ms. Shreya Malik, Deputy Manager, Biotech Consortium India Limited, New Delhi
Contact Us

DEPARTMENT OF BIOTECHNOLOGY
Block 2, 7th Floor, CGO Complex, Lodhi Road,
New Delhi-110003

DR. SUMAN GOVIL
Advisor
suman@dbt.nic.in

BIOTECH CONSORTIUM INDIA LIMITED
5th Floor, Anuvrat Bhawan
210, Deen Dayal Upadhay Marg
New Delhi -110002

DR. PURNIMA SHARMA
Managing Director
ceo.bcil@nic.in

MS. SHREYA MALIK
Deputy Manager
shreya@biotech.co.in