List of New Course(s) Introduced

Department : *Biotechnology*

Program Name : *M.Sc.*

Academic Year : 2020-21

List of New Course(s) Introduced

Sr. No.	Course Code	Name of the Course
1.	MBT 103T	Plant and Animal Biotechnology
2.	MBT 105T	Genetics
3.	MBT 106T	Biostatistics
4.	MBT 107L	Biochemistry and Analytical Techniques
5.	MBT 109L	Plant and Animal Biotechnology
6.	MBT 201 T	Genetic Engineering
7.	MBT 203T	Bioinformatics
8.	MBT 204T	Genomics and Proteomics
9.	MBT 205T	Molecular Diagnostics
10.	MBT 206T	Research Methodology and Scientific Communication Skills
11.	MBT 208T	Biological Imaging
12.	MBT 209T	Nanobiotechnology
13.	*MBT 210S	MOOCs course to be selected/opted from SWAYAM portal (SWAYAM-BIOTECH-1)
14.	MBT 211L	Molecular Biology and Genetic Engineering
15.	MBT 302T	Emerging Technologies
16.	MBT 303T	Critical Analysis of Classical Papers
17.	MBT 305T	Intellectual Property Rights, Biosafety and Bioethics
18.	MBT 306T	Project Proposal Preparation and Presentation
19.	MBT 307T	Research Seminar
20.	MBT 308T	Microbial Technology
21.	MBT 310 T	Computational Biology
22.	MBT 311 T	Drug Discovery and Development

23.	MBT 312 T	Vaccines
24.	MBT 313 T	Protein Engineering
25.	MBT 314 T	Medical Microbiology and Infection Biology
26.	*MBT 315T	MOOCs course to be selected/opted from SWAYAM portal (SWAYAM-BIOTECH-1)
27.	MBT 316L	Laboratory VI: Bioprocess Engineering and Technology
28.	MBT 317 L	Laboratory VII: Bioinformatics
29.	MBT 401	Dissertation

विभागाध्यक्ष, जैव प्रौद्योगिकी विभाग
Head, Department of Biotechnology
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Guru Ghasidas Vishwavidyalaya, Bilaspur (C.G.)

Minutes of Meetings (MoM) of Board of Studies (BoS)

Academic Year : 2020-21

School : *School of Studies of Interdisciplinary Education and Research*

Department : *Biotechnology*

Date and Time : *09-07-2020– 12:00 Noon*

Venue : *Room of Head, Department of Biotechnology*

MINUTES O F THE MEETING OF BOARD OF STUDIES IN BIOTECHNOLOGY

GURU GHASIDAS VISHWAVIDYALAYA, BILASPPUR HELD ON 09/07/2020

A Meeting of the Board Studies in Biotechnology under School of Interdisciplinary Education and Research was held on 09/07/2020 at 12:00 Noon under the chairmanship of Dr. Renu Bhatt, Head Department of Biotechnology. The following members were present.

(i)	Dr. Renu Bhatt, Head	Chairman
(ii)	Prof. B.N. Tiwary, Professor	Member
(iii)	Prof. Keshavkant Sahu	Expert present online
(iv)	Dr. Dhananjay Shukla	Member

The following agenda were placed to discuss:

1. Pre Ph.D. syllabus as directed by UGC (syllabus of research and publication ethics) as a compulsory first paper along with Research methodology paper I.
2. To discuss CBCS Syllabus for M.Sc. programme in Biotechnology.
3. To discuss and approve the ordinance of CBCS in M.Sc. Biotechnology, w.e.f. 2020-2021.
4. Revision of Course code of CBCS B.Sc. (Hons) with revised course name IE (Interdisciplinary Education and Research) in place of LS (Life Science) w.e.f. 2020-2021.
5. To amend and approve the credit of SEC (Skill enhancement Course) in as 2 instead of 4 in CBCS B.Sc. (Hons) III semester as per ordinance for 2019-2020.

At the very outset of HOD, Chairman of Board of Studies welcomed all the BoS members and discussed the above agenda at length. Following resolutions were made in this meeting

1. The revised Pre Ph.D. course work syllabus including Research Publication Ethics in the paper I to be named as Research Methodology and Research Publication Ethics of a total of 4 credits

including 2 for Research Publication Ethics as per directives of the UGC was discussed and approved by the BoS members including subject expert of BoS.

2. The model syllabus of DBT (with 20% modification) CBCS M.Sc. Biotechnology syllabus and scheme of a examination, the course structure with course code of 2 year M.Sc. degree course was placed before the committee. The members after a thorough deliberations approved the course structure and course code of M.Sc. Biotechnology to be implemented from the Academic session 2020-2021.
3. The draft ordinance for M.Sc. Biotechnology under CBCS pattern was discussed and approved by the Board of studies and recommended to be placed before Academic Council.
4. Since the name of School of Studies has changed from SoS of Life Science to SoS of Interdisciplinary Education and Research. The approved revised draft of course code (LS to IE) of 3 years CBCS B.Sc. (Hons) was placed and approved by BoS.
5. The credit of SEC as approved by BoS for 2019-2020 was discussed and resolved to be amended to 2 instead of 4 (as per existing ordinance for 2019-2020).

The following new courses were introduced in the syllabus of M.Sc.:

Course Code	Name of the Course
MBT 103T	Plant and Animal Biotechnology
MBT 105T	Genetics
MBT 106T	Biostatistics
MBT 107L	Biochemistry and Analytical Techniques
MBT 109L	Plant and Animal Biotechnology
MBT 201 T	Genetic Engineering
MBT 203T	Bioinformatics
MBT 204T	Genomics and Proteomics
MBT 205T	Molecular Diagnostics
MBT 206T	Research Methodology and Scientific Communication Skills
MBT 208T	Biological Imaging
MBT 209T	Nanobiotechnology
*MBT 210S	MOOCs course to be selected/opted from SWAYAM portal (SWAYAM-BIOTECH-1)
MBT 211L	Molecular Biology and Genetic Engineering
MBT 302T	Emerging Technologies
MBT 303T	Critical Analysis of Classical Papers
MBT 305T	Intellectual Property Rights, Biosafety and Bioethics

MBT 306T	Project Proposal Preparation and Presentation
MBT 307T	Research Seminar
MBT 308T	Microbial Technology
MBT 310 T	Computational Biology
MBT 311 T	Drug Discovery and Development
MBT 312 T	Vaccines
MBT 313 T	Protein Engineering
MBT 314 T	Medical Microbiology and Infection Biology
*MBT 315T	MOOCs course to be selected/opted from SWAYAM portal (SWAYAM-BIOTECH-1)
MBT 316L	Laboratory VI: Bioprocess Engineering and Technology
MBT 317 L	Laboratory VII: Bioinformatics
MBT 401	Dissertation

The meeting ended with a vote of thanks by the Chairman

Signature & Seal of HoD
विभागाध्यक्ष, जैव प्रौद्योगिकी विभाग
Head, Department of Biotechnology
गुरू घासीदास विश्वविद्यालय, बिलासपुर (छ.ग.)
Guru Ghasidas Vishwavidyalaya, Bilaspur (C.G.)

Scheme and Syllabus

Proposed Syllabus for M.Sc based on CBCS system

(Two years/Four semesters)

(Biotechnology)

(To be implemented from the academic session 2020-2021)

Department of Biotechnology

School of Interdisciplinary Education and Research

Guru Ghasidas Vishwavidyalaya

Syllabus for M.Sc program in Biotechnology 2020-21

M.Sc Biotechnology PG Semester I					
code	Course opted	Subjects	Hours/ semester	Hours/ week	Credits
MBT 101 T	Core -1	Biochemistry	48	03	3
MBT 102T	Core -2	Cell and Molecular Biology	48	03	3
MBT 103T	Core -3	Plant and Animal Biotechnology	48	03	3
MBT 104T	Core -4	Microbiology	32	02	2
MBT 105T	Core-5	Genetics	32	02	2
MBT 106T	Core-6	Biostatistics	48	03	3
		Laboratory			
MBT 107L	Lab 01	Biochemistry and Analytical Techniques	128	08	4
MBT 108L	Lab 02	Microbiology	64	04	2
MBT 109L	Lab 03	Plant and Animal Biotechnology	64	04	2
		Total	512	32	24
M.Sc Biotechnology PG Semester II					
Code	Course opted	Subjects	Hours/ semester	Hours/ week	Credits
MBT 201 T	Core -1	Genetic Engineering	48	03	3
MBT 202T	Core -2	Immunology	48	03	3
MBT 203T	Core -3	Bioinformatics	48	03	3
MBT 204T	Core-4	Genomics and Proteomics	32	02	2
MBT 205T	Core -5	Molecular Diagnostics	32	02	2
MBT 206T	Core -6	Research Methodology and Scientific Communication Skills	32	02	2
MBT 207T	Elective-1	Environmental Biotechnology	32	02	2
MBT 208T	Elective-1	Biological Imaging			
MBT 209T	Elective-1	Nanobiotechnology			
*MBT 210S	Elective	MOOCs course to be selected/opted from SWAYAM portal (SWAYAM-BIOTECH-1)			
		Laboratory			
MBT 211L	Lab 01	Molecular Biology and Genetic Engineering	128	08	4
MBT 212 L	Lab 02	Immunology	96	06	3
		Total	496	31	24
M.Sc Biotechnology PG Semester III					
Code	Course opted	Subjects	Hours/ semester	Hours/ week	Credits

Dbhatt 9/7/2020 Dhananjay 9/7/20 Bmj 9/7/2020

MBT 301 T	Core -1	Bioprocess Engineering and Technology	48	03	3
MBT 302T	Core -2	Emerging Technologies	32	02	2
MBT 303T	Core -3	Critical Analysis of Classical Papers	32	02	2
MBT 304T	Core-4	Bioentrepreneurship	32	02	2
MBT 305T	Core -5	Intellectual Property Rights, Biosafety and Bioethics	32	02	2
MBT 306T	Core -6	Project Proposal Preparation and Presentation	32	02	2
MBT 307T	Core -7	Research Seminar	32	02	2
MBT 308T	Elective	Microbial Technology	48	03	3
MBT 309 T	Elective	Animal Biotechnology			
MBT 310 T	Elective	Computational Biology			
MBT 311 T	Elective	Drug Discovery and Development			
MBT 312 T	Elective	Vaccines			
MBT 313 T	Elective	Protein Engineering			
MBT 314 T	Elective	Medical Microbiology and Infection Biology			
*MBT 315T	Elective	MOOCs course to be selected/opted from SWAYAM portal (SWAYAM-BIOTECH-1)			
		Laboratory			
MBT 316L	Lab 01	Laboratory VI: Bioprocess Engineering and Technology	128	08	4
MBT 317 L	Lab 02	Laboratory VII: Bioinformatics	64	04	2
		Total	480	30	24

M.Sc Biotechnology PG Semester IV

Code	Course opted	Subjects	Hours/ semester	Hours/ week	Credits
MBT 401	Core -1	Dissertation	512	32	22
		Total	512	32	22
Credits				Total	94

*M.Sc. Biotechnology students will select Massive Open Online Course (MOOCs)-SWAYAM course in the II and III semester available at http://ugcmoocs.inflibnet.ac.in/courses.php in consultation with Coordinator.

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Plant and Animal Biotechnology

Credits 2

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 andanimalcellculture
10 lectures

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
10 lectures

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 selectablemarkers; 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
8 lectures

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
4 lectures

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.

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, studentswill 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.

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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.

Recommended Textbooks and References:

1. Hartl, D. L., & Jones, E. W. (1998). *Genetics: Principles and Analysis*. Sudbury, MA: Jones and Bartlett.
2. Pierce, B. A. (2005). *Genetics: a Conceptual Approach*. New York: W.H. Freeman.
3. Tamarin, R. H., & Leavitt, R. W. (1991). *Principles of Genetics*. Dubuque, IA: Wm. C. Brown.
4. Smith, J. M. (1998). *Evolutionary Genetics*. Oxford: Oxford University Press.

Bio-Statistics

Credits
2

Course Objectives

The objective of this course is to give conceptual exposure of statistics, error analysis, hypothesis testing, and design of experiments in biological 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
5 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.

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Unit II
Descriptive statistics, Probability and distribution
10 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. 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 III
Correlation and regression analysis, Statistical hypothesis
10 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. Making assumption, Null and alternate hypothesis, error in hypothesis testing, confidence interval, one-tailed and two-tailed testing, decision making. Making assumption, Null and alternate hypothesis, error in hypothesis testing, confidence interval, one-tailed and two-tailed testing, decision making.

Unit IV
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 V
Experimental designs
8 lectures

Introduction to study designs: Longitudinal, cross-sectional, retrosp- ective 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:

1. Jaype Brothers, (2011), Methods in Biostatistics for Medical Students and Research Workers (English), 7th Edition
2. Norman T.J. Bailey, (1995), Statistical Methods in Biology, 3rd Edition, Cambridge University Press.
3. P. N. Arora and P. K. Malhan, (2006), Biostatistics, 2nd Edition, Himalaya Publishing House.
4. Jerold Zar, Biostatistical Analysis, 4th Edition. Pearson Education.
5. Biostatistics: a Foundation for Analysis in the Health Sciences, 7th Edition, Wiley.
6. ML Samuels, JA Witmer (2003) Statistics for the Life Sciences, 3rd edition. Prentice Hall.

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Laboratory I: Biochemistry & Analytical Techniques

Credits

4

Course Objectives

The objective of this laboratory course is to introduce students to experiments in biochemistry. The course isdesigned 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 ofbiochemistry 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.
2. 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 ofDNA size.
3. Identification of an unknown sample as DNA, RNA or protein using available laboratory tools. (Optional Experiments)
4. Biophysical methods (Circular Dichroism Spectroscopy, Fluorescence Spectroscopy).
5. Determination of mass of small molecules and fragmentation patterns by Mass Spectrometry.
6. Preparing various stock solutions and working solutions that will be needed for the course.

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Laboratory III: Plant and Animal Biotechnology

Credits: 2

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.

Syllabus

Plant Biotechnology

1. Prepare culture media with various supplements for plant tissue culture.
2. Prepare explants of Vallerianawallichii for inoculation under aseptic conditions.
3. Attempt *in vitro* androandgynogenesis in plants *(Daturastramonium)*.
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 *Eremuruspersicus* and *Vallerianawallichii*.
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 spectrophotometeric 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.

Syllabus

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.
4. Monitor and measure doubling time of animal cells.
5. Chromosome preparations from cultured animal cells.
6. Isolate DNA from animal tissue by SDS method.
7. Attempt animal cell fusion using PEG.

Semester Two

Genetic Engineering

Credits: 3

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
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 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
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

9/7/2020

Bioinformatics

Credits

3

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 specificcontemporary biological questions;
- Critically analyse and interpretresults 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:

1. Lesk, A. M. (2002). *Introductionto Bioinformatics*. Oxford: Oxford University Press.
2. Mount, D. W.(2001). *Bioinformatics: Sequence and Genome Analysis*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.
3. Baxevanis, A. D.,& Ouellette, B. F.(2001). *Bioinformatics: a Practical Guidetothe Analysis of Genes and Proteins*. New York:Wiley-Interscience.
4. Pevsner,J.(2015).*BioinformaticsandFunctionalGenomics*. Hoboken, NJ.: Wiley-Blackwell.
5. Bourne, P.E., & Gu, J. (2009). *Structural Bioinformatics*. Hoboken, NJ: Wiley-Liss.
6. Lesk, A.M.(2004).*IntroductiontoProteinScience:Architecture,Function,and Genomics*. Oxford: Oxford University Press.

Genomics and Proteomics

Credits

2

Course Objectives

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

Student Learning Outcomes

Studentsshould beabletoacquire 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:

1. Primrose, S. B., Twyman, R. M., Primrose, S. B., & Primrose, S. B. (2006). *Principles of Gene Manipulation and Genomics*. Malden, MA: Blackwell Pub.
2. Liebler, D. C. (2002). *Introduction to Proteomics: Tools for the New Biology*. Totowa, NJ: Humana Press.
3. Campbell, A. M., & Heyer, L. J. (2003). *Discovering Genomics, Proteomics, and Bioinformatics*. San Francisco: Benjamin Cummings.

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 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, Protein: An overview; chromosomal structure & mutations; DNA polymorphism: human identity; clinical variability and genetically determined adverse reactions to drugs.
Unit II **Genome: resolution, detection & 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 the body fluids/tissues in various metabolic disorders by making using LCMS & NMR technological platforms.
Unit IV **Detection and identity of microbial diseases** 4 lectures	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 **Detection of inherited diseases** 4 lectures	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 cancersyndromes.
Unit VI **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 VII **Quality assurance and control** 1 lecture	Quality oversight; regulations and approved testing.

Recommended Textbooks and References:

1. Campbell, A. M., & Heyer, L. J. (2006). *Discovering Genomics, Proteomics, and Bioinformatics*. San Francisco: BenjaminCummings.
2. Brooker, R. J. (2009). *Genetics: Analysis & Principles*. New York, NY: McGraw-Hill.

3. Glick, B. R., Pasternak, J. J., & Patten, C. L. (2010). *Molecular Biotechnology: Principles and Applications of Recombinant DNA*. Washington, DC: ASM Press.
4. Coleman, W. B., & Tsongalis, G. J. (2010). *Molecular Diagnostics: for the Clinical Laboratorian*. Totowa, NJ: Humana Press.

Research Methodology and Scientific Communication Skills

Credits: 2

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 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** 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:

1. Valiela, I. (2001). *Doing Science: Design, Analysis, and Communication of Scientific Research*. Oxford: Oxford University Press.
2. *On Being a Scientist: a Guide to Responsible Conduct in Research*. (2009). Washington, D.C.: National Academies Press.
3. Gopen, G. D., & Smith, J. A. *The Science of Scientific Writing*. American Scientist, 78 (Nov-Dec 1990), 550-558.
4. Mohan, K., & Singh, N. P. (2010). *Speaking English Effectively*. Delhi: Macmillan India.
5. Movie: Naturally Obsessed, The Making of a Scientist.

Laboratory IV: Molecular Biology and Genetic Engineering

Credits: 4

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.

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 acidauxotroph
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-PAGEanalysis
14. Purification of His-Tagged protein on Ni-NTAcolumns
    a) Random Primer labeling
    b) Southern hybridization.

Recommended Textbooks and References:

1. Green, M. R., & Sambrook, J. (2012). *Molecular Cloning: a Laboratory Manual*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.

5 El-Mansi,M.,&Bryce,C.F.(2007).*FermentationMicrobiologyandBiotechnology.* Boca Raton: CRC/Taylor & Francis.

Emerging Technologies

Credits 2

Course Objectives

This course is broad-based in nature encompassingseveralnewtechnologies that current experimental researchers areemployingtoprobecomplexsystem biologyquestionsinlife-sciences.The objectivesofthiscoursearetoteachbasics 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 thesetechnologies.Thestudentsmayalso learn one application in depth through an assignment and/orseminar.

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.
Unit II **Mass spectroscopy** 4 lectures	Ionizationtechniques;massanalyzers/overviewMS;FT-ICRandOrbitrap,fragmentation ofpeptides;proteomics,nanoLC-MS;Phosphoproteomics;interactionproteomics,mass spectroscopy in structural biology; imagingmassspectrometry.
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	X-raydiffractionmethods,solution&solid-stateNMR,cryo-electronmicroscopy,small-angle X-ray scattering, Atomic forcemicroscopy.
Unit V **CRISPR-CAS** 6 lectures	History of its discovery, elucidation of the mechanism including introduction to all themolecularplayers,developmentofapplicationsfor*invivo*genomeengineeringfor geneticstudies,promiseofthetechnologyasanextgenerationtherapeuticmethod.

Unit VI

Nanobodies

4 lectures

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:

1. Campbell, I. D. (2012). *Biophysical Techniques*. Oxford: Oxford University Press.
2. Serdyuk, I. N., Zaccai, N. R., & Zaccai, G. (2007). *Methods in Molecular Biophysics: Structure, Dynamics, Function*. Cambridge: Cambridge University Press.
3. Phillips, R., Kondev, J., & Theriot, J. (2009). *Physical Biology of the Cell*. New York: Garland Science.
4. Nelson, P. C., Radosavljević, M., & Bromberg, S. (2004). *Biological Physics: Energy, Information, Life*. New York: W.H. Freeman.
5. Huang, B., Bates, M., & Zhuang, X. (2009). *Super-Resolution Fluorescence Microscopy*. Annual Review of Biochemistry, 78(1), 993-1016. doi:10.1146/annurev.biochem.77.061906.092014.
6. Mohanraju, P., Makarova, K. S., Zetsche, B., Zhang, F., Koonin, E. V., & Oost, J. V. (2016). *Diverse Evolutionary Roots and Mechanistic Variations of the CRISPR-Cas Systems*. Science, 353(6299). doi:10.1126/science.aad5147.
7. Lander, E. (2016). *The Heroes of CRISPR*. Cell, 164(1-2), 18-28. doi:10.1016/j.cell.2015.12.041.
8. Ledford, H. (2016). *The Unsung Heroes of CRISPR*. Nature, 535(7612), 342-344. doi:10.1038/535342a.
9. Jinek, M., Chylinski, K., Fonfara, I., Hauer, M., Doudna, J. A., & Charpentier, E. (2012). *A Programmable Dual-RNA-Guided DNA Endonuclease in Adaptive Bacterial Immunity*. Science, 337(6096), 816-821. doi:10.1126/science.1225829.
10. Hamers-Casterman, C., Atarhouch, T., Muyldermans, S., Robinson, G., Hammers, C., Songa, E. B., Hammers, R. (1993). *Naturally Occurring Antibodies Devoid of Light Chains*. Nature, 363(6428), 446-448. doi:10.1038/363446a0.
11. Sidhu, S. S., & Koide, S. (2007). *Phage Display for Engineering and Analyzing Protein Interaction Interfaces*. Current Opinion in Structural Biology, 17(4), 481-487. doi:10.1016/j.sbi.2007.08.007.
12. Steyaert, J., & Kobilka, B. K. (2011). *Nanobody Stabilization of G Protein-Coupled Receptor Conformational States*. Current Opinion in Structural Biology, 21(4), 567-572. doi:10.1016/j.sbi.2011.06.011.
13. Vincke, C., & Muyldermans, S. (2012). *Introduction to Heavy Chain Antibodies and Derived Nanobodies*. Single Domain Antibodies, 15-26. doi:10.1007/978-1-61779-968-6_2.
14. Verheesen, P., & Laeremans, T. (2012). *Selection by Phage Display of Single Domain Antibodies Specific to Antigens in their Native Conformation*. Single Domain Antibodies, 81-104. doi:10.1007/978-1-61779-968-6_6.
15. Li, J., Xia, L., Su, Y., Liu, H., Xia, X., Lu, Q. Reheman, K. (2012). *Molecular Imprint of Enzyme Active Site by Camel Nanobodies*. Journal of Biological Chemistry J. Biol. Chem., 287(17), 13713-13721. doi:10.1074/jbc.m111.336370.
16. Sohier, J., Laurent, C., Chevigné, A., Pardon, E., Srinivasan, V., Wernery, U. Galleni, M. (2013). *Allosteric Inhibition of VIM Metallo-β-Lactamases by a Camelid Nanobody*. Biochemical Journal, 450(3), 477-486. doi:10.1042/bj20121305.
17. Chakravarty, R., Goel, S., & Cai, W. (2014). *Nanobody: The "Magic Bullet" for Molecular Imaging?* Theranostics, 4(4), 386-398. doi:10.7150/thno.8006.

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.

Credits
2

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

1. Studies on the chemical nature of the substance inducing transformation of Pneumococcal types: Induction of transformation by a desoxyribonucleic acid fraction isolated from *Pneumococcus* type III.
   Avery OT, Macleod CM, McCarty M.; J Exp Med. 1944 Feb 1;79(2):137-58.
   Note: This paper demonstrates that DNA is the transforming Principle originally described by Fredrick Griffith.
2. Independent functions of viral protein and nucleic acid in growth of bacteriophage
   Hershey AD and Chase M.; J Gen Physiol. 1952 May;36(1):39-56.
   Note: 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.
5. Messelson & Stahl experiment demonstrating semi-conservative replication of DNA.
   Meselson M and Stahl FW.; Proc Natl Acad Sci U S A. 1958 Jul 15;44(7):671-82
   Note: The experiment demonstrating semi-conservative mode of DNA replication is referred to as "the most beautiful experiment in biology"
6. *In vivo* alteration of telomere sequences and senescence caused by mutated *Tetrahymena* telomerase RNAs
   Guo-Liang Yu, John D. Bradley, Laura D. Attardi & Elizabeth H. Blackburn; Nature 344, 126-132, 1990
   Note: This paper demonstrates that the telomerase contains the template for telomere synthesis

Syllabus
Cell Biology

1. A protein-conducting 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
Novick P, Field C, Schekman R.; Cell. 1980 Aug;21(1):205-15
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
Deshaies RJ and Schekman R.; J Cell Biol. 1987 Aug;105(2):633-45
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
Brack C, Hirama M, Lenhard-Schuller R, Tonegawa S.; Cell. 1978 Sep;15(1):1-14
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 followingrecombination.
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 ATPhydrolysis.

Syllabus
Developmental Biology/ Genetics

1. Mutations affecting segment number and polarity in *Drosophila*
Christiane Nusslein-Volhard and Eric Weischaus; Nature 287, 795-801, 1980
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 intraflagellar transport proteins
Huangfu D, Liu A, Rakeman AS, Murcia NS, Niswander L, Anderson KV.; Nature. 2003 Nov 6;426(6962):83-7
Note: One of the architects of original fly mutagenesis screens conducted a mouse mutagenes screen which identified a gene Kif3a 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 cillia in it.
Suggested Reference paper - Design and execution of a embryonic lethal mutation screen in mouse.

3. Onetti, A., & Zucchella, A. *Business Modeling for Life Science and Biotech Companies: Creating Value and Competitive Advantage with the Milestone Bridge.* Routledge.
4. Jordan, J.F.(2014). *Innovation, Commercialization, and Start-Ups in Life Sciences.* London: CRC Press.
5. Desai, V.(2009). *The Dynamics of Entrepreneurial Development and Management.* New Delhi: Himalaya Pub. House.

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 researchand product development;
- To become familiar withIndia'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 technologiessuch 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 especiallypatents;
- 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
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

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. Bioethics in research – cloning and stem cell research, Humanand animal experimentation, animal rights/welfare, Agricultural biotechnology - Genetically engineered food, environmental risk, labeling and public opinion. Sharing benefits and protecting future generations - Protection of environment and biodiversity – biopiracy.

Recommended Textbooks and References:

1. Ganguli, P.(2001). *Intellectual Property Rights: Unleashingthe Knowledge Economy.* New Delhi: Tata McGraw-Hill Pub.
2. *National IPR Policy*, Department of Industrial Policy & Promotion, Ministry of Commerce, GoI
3. *Complete Reference to Intellectual Property Rights Laws.*(2007). Snow White Publication Oct.
4. Kuhse, H. (2010). *Bioethics: an Anthology*. Malden, MA: Blackwell.
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/
6. Karen F. Greif and Jon F. Merz, *Current Controversies in the Biological Sciences -Case Studies of Policy Challenges from New Technologies*, MIT Press
7. World Trade Organisation. http://www.wto.org
8. World Intellectual Property Organisation. http://www.wipo.int
9. International Union for the Protection of New Varieties ofPlants. http://www.upov.int
10. National Portal of India. http://www.archive.india.gov.in
11. National Biodiversity Authority. http://www.nbaindia.org
12. Recombinant DNA Safety Guidelines, 1990 Department of Biotechnology, Ministry of Science and Technology, Govt. of India. Retrieved from http://www.envfor.nic.in/divisions/csurv/geac/annex-5.pdf
13. Wolt, J. D., Keese, P., Raybould, A., Fitzpatrick, J. W., Burachik, M., Gray, A., Wu, F.(2009).*ProblemFormulationinthe EnvironmentalRiskAssessmentforGenetically Modified Plants*. TransgenicResearch, 19(3), 425-436. doi:10.1007/s11248-009-9321-9
14. Craig, W., Tepfer, M., Degrassi, G., & Ripandelli, D. (2008). *An Overview of General Features of Risk Assessments of Genetically Modified Crops*. Euphytica, 164(3), 853-880. doi:10.1007/s10681-007-9643-8

15 Guidelines for Safety Assessment of Foods Derived from Genetically Engineered Plants. 2008.
16 Guidelines and Standard Operating Procedures for Confined Field Trialsof Regulated Genetically Engineered Plants. 2008. Retrieved from http://www.igmoris.nic.in/guidelines1.asp
17 Alonso, G. M. (2013). *Safety Assessment of Food and Feed Derived from GM Crops:UsingProblemFormulationtoEnsure"FitforPurpose"RiskAssessments*. Retrieved from http://biosafety.icgeb.org/inhousepublicationscollectionbiosafetyreviews.

Project Proposal Preparation& Presentation

Credits

2

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

PosterPresentation

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 VII: Bioinformatics

Credits: 2

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.
3. Sequence information resource: Using NCBI, EMBL, Genbank, Entrez, Swissprot/ TrEMBL, UniProt.
4. Similarity searches using tools like BLAST and interpretation of results.
5. Multiple sequence alignment using ClustalW.
6. Phylogenetic analysis of protein and nucleotidesequences.
7. Use of gene prediction methods (GRAIL, Genscan, Glimmer).
8. Using RNA structure prediction tools.
9. Use of various primer designing and restriction site predictiontools.
10. Use of different protein structure prediction databases (PDB, SCOP, CATH).
11. Construction and study of protein structures using Deepview/PyMol.
12. Homology modelling of proteins.
13. Use of tools for mutation and analysis of the energy minimization of protein structures.
14. Use of miRNA prediction, designing and target predictiontools.

Semester Four

Dissertation

Credits: 24 *(Semester III: 4 Credits; Semester IV: 20 Credits)*

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 alsoenablestudents 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 systematicallyintegrate knowledge to identify issues that must be addressed within framework of specific thesis.
- Competence in research design

and planning.
- Capability to create, analyse and criticallyevaluatedifferenttechnical solutions.
- Ability to conductresearch independently.
- Ability to perform analytical techniques/experimentalmethods.
- Project managementskills.
- Report writingskills.
- Problem solvingskills.
- 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 Electives

Biological Imaging

Credits
2

Course Objectives

Theobjectivesofthiscoursearetoprovide 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 ofinformation without stressing outcells.

Student Learning Outcomes

On completion of this course, students shallbeabletogainacompleteoverviewof super-resolution field from fundamentals to state-of-art methods andapplications 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 usingmicroscopes.

Unit I
Widefield fluorescent microscopy
3 lectures

One of the most basic techniques for live-cell imaging is widefield fluorescent microscopy. Standard inverted research grade microscopes can yield valuable results if youareimagingadherentcells,largeregionsofinterest(suchasorganelles)orverythin tissuesections(lessthan5micrometer).Inwidefield,aCCDcameraisusuallyusedto

capture images and the epi-fluorescence illumination source can be a mercury lamp, xenon lamp, LED's, *etc.* Each of 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 contract (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)** 3 lectures	CLSM has 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 optical path of confocal microscope prevents fluorescence from outside of 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 specimen by scanning system. This spot forms a reflected epi-fluorescence image back on original pinhole. When specimen is in focus, fluorescent light from it passes through pinhole to detector. Any out-of-focus light is defocused at pinhole and very little of this signal passes through to detector meaning that background fluorescence is greatly reduced. The pinhole acts as a spatial filter for emission light from the specimen.
Unit III **Spinning discconfocal microscopy(SDCM)** 2 lectures	Thismethodutilisesa'NipkowDisc'whichisamechanicalopaquediscwhichhas aseriesofthousandsofdrilledoretchedpinholesarrangedinaspiralpattern.Each illuminated pinhole on disc is imaged by microscope objective to a diffraction-limited spot on region of interest on specimen. The emission from fluorophores passes back though 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 specimen are simultaneously illuminated. Using SDCM to examine a specimen means that real-time imaging (30-frames-per-secondorfaster)canbeachieved,whichisextremelyusefulifyouare lookingatdynamicchangeswithinlivingcellsoverawidespectrumoftime-scales.
Unit IV **Light-sheet fluorescence microscopy (LSFM, or SPIM)** 2 lectures	Thismethodenablesonetoperformlive-cellimagingonwholeembryos,tissuesand cellspheroids*invivo* inagentle mannerwithhightemporalresolutionandinthree 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** 8 lectures	Super-Resolution in a Standard Microscope: From Fast Fluorescence Imaging to Molecular Diffusion Laws in Live Cells; Photoswitching Fluorophores in Super-Resolution Fluorescence Microscopy; Image Analysis for Single-Molecule Localization Microscopy Deconvolution of Nanoscopic Images; Super-Resolution Fluorescence Microscopy of the Nanoscale Organization in cells; Correlative Live-Cell and Super-Resolution Microscopy and Its Biological Applications; SAX Microscopy and Its Application to Imaging of 3D-Cultured Cells; Quantitative Super-Resolution Microscopy for Cancer Biology and Medicine.
Unit VI **Re-scan confocal microscopy** 4 lectures	Structured Illumination Microscopy; Correlative Nanoscopy: AFM Super-Resolution (STED/STORM) ; Stochastic Optical Fluctuation Imaging.

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Recommended Textbooks and References:

1. Rajagopal Vadivambal, Digvir S. Jayas. (2015). *Bio-Imaging: Principles, Techniques, and Applications*. ISBN 9781466593671 -CAT# K20618.
2. Alberto Diaspro, Marc A. M. J. van Zandvoort. (2016). *Super-Resolution Imagingin Biomedicine*. ISBN 9781482244342 -CAT# K23483.
3. Taatjes, Douglas, Roth, Jürgen (Eds.). (2012). *Cell Imaging Techniques Methods and Protocols*. ISBN 978-1-62703-056-4.

Computational Biology

Credits: 2

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 interpretresults 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	Local alignment, Global alignment, Scoring matrices - PAM, BLOSUM, Gaps and penalties, Dot plots. Dynamic programming approach: Needleman and Wunsch Algorithm, Smith and Waterman Algorithm, Hidden Markov Model: Viterbi Algorithm. Heuristic approach: BLAST, FASTA. Building Profiles, Profile based functional identification.
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:

1. Mount, D. W. (2001). *Bioinformatics: Sequence and Genome Analysis*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.
2. Bourne, P. E., & Gu, J. (2009). *Structural Bioinformatics*. Hoboken, NJ: Wiley-Liss.
3. Lesk, A. M. (2004). *Introduction to Protein Science: Architecture, Function, and Genomics*. Oxford: Oxford University Press.
4. Campbell, M & Heyer, L. J. (2006), *Discovering Genomics, Proteomics and Bioinformatics*, Pearson Education.
5. Oprea, T. (2005). *Chemoinformatics in Drug Discovery*, Volume 23. Wiley Online Library.
6. Gasteiger, J. & Engel, T. (2003), *Chemoinformatics: a Textbook*, Wiley Online Library.

Drug Discovery and Development

Credits
2

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.

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 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 ofclinical 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:

1. Krogsgaard-Larsen *et al. Textbookof Drug Design and Discovery*. 4th Edition. CRC Press.
2. Kuhse, H. (2010). *Bioethics: an Anthology*. Malden, MA: Blackwell.
3. Nally, J. D. (2006) *GMP for Pharmaceuticals*. 6th edition. CRC Press
4. Brody, T.(2016) *Clinical Trials: Study Design, Endpointsand Biomarkers*, Drug Safety, and FDA and ICH Guidelines. Academic Press.

6 H. S. Peavy, D. R. Rowe and G. Tchobanoglous,(2013), *Environmental Engineering*, McGraw-Hill Inc.

Microbial Technology

Credits 2

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.*

Recommended Textbooks and References:

1. Lee, Y.K. (2013). *Microbial Biotechnology: Principles andApplications*. Hackensack, NJ: World Scientific.
2. Moo-Young, M. (2011). *Comprehensive Biotechnology*. Amsterdam: Elsevier.
3. Nelson, K. E. (2015). Encyclopedia of Metagenomics. *Genes, Genomes and Metagenomes: Basics, Methods, Databases and Tools*. Boston, MA: Springer US.
4. *The New Science of Metagenomics Revealing the Secrets of Our Microbial Planet*. (2007). Washington, D.C.: National Academies Press.
5. Journals: (a) Nature, (b) Nature Biotechnology, (c) Applied microbiology and biotechnology, (d) Trends in Biotechnology, (e) Trends in Microbiology, (f) Current opinion in Microbiology, (g) Biotechnology Advances, (h) Genome Research)
6. Websites: http://jgi.doe.gov/our-science/

Protein Engineering

Credits: 2

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 usedfor 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.

Unit IV
Computational approaches
5 lectures

Computational approaches to protein engineering: sequence and 3D structure analysis, Data mining, Ramachandran map, Mechanism of stabilization of proteins from psychrophiles and thermophiles *vis-à-vis* those from mesophiles; Proteindesign, Directed evolution for protein engineering and its potential.

Unit V
Case studies
1 lecture

Case Studies.

Recommended Textbooks and References:

1. EditedbyTECreighton,(1997), *ProteinStructure:a PracticalApproach*, 2nd Edition, Oxford university press.
2. ClelandandCraik,(2006), *Protein Engineering,PrinciplesandPractice*, Vol7, Springer Netherlands.
3. Mueller and Arndt, *Protein Engineering Protocols*, 1st Edition, Humana Press.
4. Ed.RobertsonDE, NoelJP,(2004), *ProteinEngineering Methods in Enzymology*, 388, Elsevier Academic Press.
5. J Kyte; (2006), *Structure in Protein Chemistry*, 2nd Edition, Garland publishers.

Nano-biotechnology

Credits
2

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.

Unit IV
Applications ofnano–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 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.

Recommended Textbooks and References:

1. GeroDecher, Joseph B. Schlenoff,(2003); *Multilayer Thin Films: Sequential Assembly of Nanocomposite Materials*, Wiley-VCH Verlag GmbH & Co. KGaA
2. David S. Goodsell, (2004); *Bionanotechnology: Lessons from Nature*; Wiley-Liss
3. Neelina H. Malsch (2005), *Biomedical Nanotechnology*, CRC Press
4. Greg T. Hermanson, (2013); *Bioconjugate Techniques*, (3rd Edition); Elsevier
5. Recent review papers in the area of Nanomedicine.

Vaccines

Credits
2

Course Objectives

This course will provide students with an overview of current developments in different areas of vaccines.

Student Learning Outcomes

Bythe end of this course, students should be able to:

- Understand fundamental concepts of human immune system and basic immunology;
- Differentiateandunderstandimmune responses in relation to infection and vaccination;
- Understand requirement and designing of different types ofvaccines;
- 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 Bcells.

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; PeptideVaccine.

Unit V

Vaccine technologies

4 lectures

NewVaccineTechnologies;RationallydesignedVaccines;DNAVaccination;Mucosal vaccination; New approaches for vaccine delivery; Engineering virus vectors for vaccination;Vaccinesfortargeteddelivery(VaccineDeliverysystems);Diseasespecific vaccine design: Tuberculosis Vaccine; Malaria Vaccine; HIV/AIDS vaccine; New emerging diseases and vaccine needs (Ebola,Zika).

Recommended Textbooks and References:

1. Janeway,C.A.,Travers,P.,Walport,M.,&Shlomchik,M.J.(2005).*ImmunoBiology: theImmuneSysteminHealthandDisease*.USA:GarlandSciencePub.
2. Kindt,T.J.,Osborne,B.A.,Goldsby,R.A.,&Kuby,J.(2013).*KubyImmunology*. New York: W.H.Freeman.
3. Kaufmann,S.H.(2004).*NovelVaccinationStrategies*.Weinheim:Wiley-VCH.
4. JournalArticles(relevantissues)from:AnnualReviewofImmunology,Annual ReviewofMicrobiology,CurrentOpinioninImmunology,NatureImmunology, Expert review ofvaccines.

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Medical Microbiology and Infection Biology

Credits
3

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 specificpathogens.

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 diptheriae; E. coli, Vibrio cholerae, Helicobacter pylori, Salmonella typhi and paratyphi, Shigella dysenteriae; Listeria monocytogenes, Mycobacterium* spp., Rickettsial 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, 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.

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.*

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Unit V

Host-pathogen interaction

6 lectures

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:

1. KC Carroll, SA Morse, T Mietzner, S Miller. (2016) Jawetz, Melnick and Adelbergs's *Medical Microbiology* 27th edition, McGraw Hill.
2. J Owen, J Punt and Sharon Stranford, (2012), *Kuby Immunology*; 7th edition, W.H. Freeman and Co.
3. IT Kudva, NA. Cornick, PJ Plummer, Q Zhang, TL Nicholson, JP Bannantine and BH Bellaire. *Virulence Mechanisms of Bacterial Pathogens*, (2016) 5th edition, ASM Press.
4. V Kumar, AK. Abbas and JC Aster, (2015), *Robbins & Cotran Pathologic Basis of Disease.* 9th Edition, Elsevier.
5. K Murphy and K Weaver, (2016), *Janeway's Immunobiology*, 9th Edition, Garland Science.
6. AK Abbas, (2015), *Cellular and Molecular Immunology*. 8th Edition, Elsevier.
7. Ananthanarayan and Paniker, *Textbook of Microbiology*, 8th Edition.
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