Punyashlok Ahilyadevi Holkar Solapur University, Solapur

NAAC Accredited-2015
'B' Grade (CGPA 2.62)

Name of the Faculty: Science & Technology

CHOICE BASED CREDIT SYSTEM

Syllabus: Bioinformatics

Name of the Course: M.Sc. I (Sem.– I & II)

(Syllabus to be implemented from w.e.f. June 2020)

Punyashlok Ahilyadevi Holkar Solapur University, Solapur
M. SC. BIOINFORMATICS
Syllabus (Choice Based Credit System Syllabus)
(w. e. f. June, 2020-21)

1) Course Title: M. Sc. Bioinformatics

2) Introduction: Recent developments of the sciences have produced a wealth of experimental data of sequences and three-dimensional structures of biological macromolecules. With the advances of computer and information science, these data are available to the public from a variety of databases on the Internet. This course will provide the knowledge of bioinformatics to interpret the rapidly expanding amount of biological information. It will discuss the basic concepts of bioinformatics and focus how to identify, seek, establish, maintain and exchange research information in biology. It will review the major scientific databases needed for research problems in biology. Students will learn Bioinformatics tools.

3) Objectives of the course:

- To equip the students with the requisite background in areas of modern biology (biochemistry,
- cell biology, genetics and molecular biology) and computer science (programming languages,
- databases, algorithms, graphics, data mining, data security, etc.).
- Gain familiarity with computational methods in order to address problems in molecular biology.
- Become knowledgeable about the storage, retrieval, sharing and use of biological data, information, and tools.
- To launch the students into core areas of Bioinformatics like multiple sequence alignment, phylogenetic trees, genomics, proteomics etc.
- To explore the students to applied areas of Bioinformatics like Protein-protein interaction, drug design, metabolic pathway engineering etc.
- To provide practical experience to students by giving them an opportunity to pursue project work in an identified area of Bioinformatics.
- Students should gain substantial competency in content, skills, and awareness within the field of bioinformatics.

4) Advantages of the course:

- Students will learn through applying the strategies and tools used in bioinformatics to topical problems drawn from ongoing research and applications in a variety of fields.
- A number of recent workforce studies have shown that there is a high current and unmet demand for people trained to various levels of expertise in bioinformatics.
- The emergence of new Internet technologies, new and more accurate algorithms and the development of High Performance Computing coupled with DNA sequencing, serial analysis of gene expression, microarrays, and new mass spectrometry has enabled bioinformatics to address the biological problems from several different angles. It is this change in paradigm that has led to the development of Bioinformatics as a separate skill oriented discipline.
- This course provides scope for employment opportunities in various industries in the applied aspects Biotechnology, Microbiology, Molecular biology, Drug discovery and Drug designand Information technology.

5) Eligibility of the Course

- **Eligibility:** Candidates who have passed (a) 10+2 with Science and (b) Bachelor's degree in any Science / Engineering /Technology/ Agriculture / Medicine / Veterinary Science / Pharmaceutics from recognized University and as per the eligibility criteria lay down by Punyashlok Ahilyadevi Holkar Solapur University, Solapur will be eligible for admission to M.Sc. course in Bioinformatics.
- **Admission**: Merit list based on average of B. Sc. aggregate and entrance exam conducted by PAH Solapur University. For other university student merit list only on basis of entrance examination conducted by PAH Solapur University.

6) Duration: The course will be of two years duration and shall be completed in four semesters.

7) Medium of instruction: English

8) Structure of the Course:

- Structure of M.Sc. course in faculty of Science has total of 4 semesters for 2 years.
- M. Sc. I comprises of total two semesters and M. Sc. II comprises of total two semesters.
- Semester I includes four theory papers (3 Hard Core and 1 Soft Core) and practical course as per theory papers.
- Semester II & III includes four theory papers (2 Hard Core, 1 Soft Core and 1 Open Elective) and practical course as per theory papers.
- Semester IV includes four theory papers (3 Hard Core and 1 Soft Core) and a Major project substituting the practical course.
- Each theory paper comprising of 5 units which are distributed in total 60 Lecture hours having weightage of 4 credits.
- Practical papers are to be conducted at the end of their respective semester.
- Final year Major project work should begin in III semester and the complete thesis should be submitted at the end of the IV semester.
- Student would have to present his/her project work during the project report submission which would be evaluated by the internal as well as the external examiner.
- As per the credit system, the assessment of Theory paper of 100 marks weightage will be as: 80 marks theory assessment by University examination (UA) and 20 marks internal assessment by the college (CA). The internal assessment are conducted in the formats of home assignments and written tests for each theory paper respectively with equal weightage of marks.
- As per the credit system, the assessment of practical paper of 50 marks weightage will be as: 40 marks practical assessment by University examination (UA) and 10 marks internal assessment by the college (CA).
- In each semester student has to compulsorily undergo one tutorial which has weightage of 25 marks and 1 credit. Seminar/Tutorial/ Industrial Visit/Field Tour etc. may be suitably adopted for the tutorial.
- As per the credit system, the assessment of Major project of 200 marks weightage will be as: 160 marks project assessment by University examination (UA) and 40 marks internal assessment by the college (CA) at the end of fourth semester.

PUNYASHLOK AHILYADEVI HOLKAR
SOLAPUR UNIVERSITY, SOLAPUR

Syllabus for M. Sc. Bioinformatics

M. Sc. Bioinformatics Part I, Semester-I and II (STRUCTURE) w. e. f. 2020-21

Semester	Code	Title of the Paper	Semester Examination			L	T	P	Credits
			Theory UA	IA	Total				
Sem-I		**Hard Core**							
	HCT1.1	Basic Bioinformatics	80	20	100	4	--	--	4
	HCT1.2	Cell Biology and Genetics	80	20	100	4	--	--	4
	HCT1.3	Introduction to HTML and Biostatistics	80	20	100	4	--	--	4
		Soft Core (Any one)							
	SCT1.1	Introduction to Programming languages & programming through C & C++	80	20	100	4	--	--	4
	SCT1.2	Cytogenetics and Genome Organization	80	20	100	4	--	--	4
		Seminar/Tutorial/ Industrial Visit/ Field Tour	---	25	25	--	1	--	1
	HCP1.1	Practical Course HCP 1.1	40	10	50	--	--	03	2
	HCP1.2	Practical Course HCP 1.1	40	10	50	--	--	03	2
	HCP1.3	Practical Course HCP 1.3	40	10	50	--	--	03	2
	SCP 1.1/1.2	Practical Course SCP 1.1/1.2	40	10	50	--	--	03	2
	Total for Semester-I		**480**	**145**	**625**	**--**	**--**	**--**	**25**
Sem-II		**Hard Core**							
	HCT2.1	Advanced Bioinformatics	80	20	100	4	--	--	4
	HCT2.2	Microbiology and Immunology	80	20	100	4	--	--	4
		Soft Core (Any one)							
	SCT2.1	Biochemistry and Biotechnology	80	20	100	4	--	--	4
	SCT2.2	Enzyme Technology	80	20	100	4	--	--	4
		Open Elective(Any one)							
	OET2.1	Programming in Object Oriented languages	80	20	100	4	--	--	4
	OET2.2	Plant Breeding and Tissue culture	80	20	100	4	--	--	4
		Seminar/Tutorial/ Industrial Visit/ Field Tour	---	25	25	--	1	--	1
	HCP2.1	Practical Course HCP 2.1	40	10	50	--	--	03	2
	HCP2.2	Practical Course HCP 2.2	40	10	50	--	--	03	2
	SCP2.1/2.2	Practical Course SCP 2.1/2.2	40	10	50	--	--	03	2
	OEP2.1/2.2	Practical Course OEP2.1/2.2	40	10	50	--	--	03	2
	Total for Semester-II		**480**	**145**	**625**	**--**	**--**	**--**	**25**

** L = Lecture T = Tutorials P = Practical
** IA=Internal Assessment
** UA= University Assessment
** 4 Credits of Theory = 4 Hours of teaching per week
** 2 Credits of Practical = 4 hours per week

** HCT = Hard core theory
** SCT = Soft core theory
** HCP = Hard core practical
** SCP = Soft core practical
** OET = Open elective theory
** OEP = Open elective practical

M. SC. BIOINFORMATICS (SEMESTER – I)

HCT-1.1 BASIC BIOINFORMATICS 4 Credits (60 L)

Learning Outcomes:

- The primary goal of this course is to uncover the basic tools and biological databases to the students and make them familiar with the same.
- At the end of this course students will be able to classify the molecular data in the respective data and file formats with machine learning approach.

UNIT-I: Introduction to Bioinformatics [**15]**

Definition, History and application of Bioinformatics, need of Bioinformatics, introduction to internet and its role in bioinformatics. Algorithms- Characteristics, design and analysis; complexity: Time and space, asymptotic notation, greedy algorithms, divide and conquer.

UNIT-II: Biological Databases **[15]**

Biological database and its importance with functioning, Types of Biological database, Introduction to NCBI, Sequence and structure database, Nucleic acid database (NCBI GENBANK, EMBL, DDBJ), Protein database(PIR, MIPS, SWISS-PROT, TrEMBL, NRL- 3D, PRINTS, Pfam), specialized database, Genome database, Literature database(Pubmed and PMC). Database searching methods (Entrez).

UNIT-III: Sequence analysis **[15]**

Need for sequence analysis, Pairwise alignment, dot plot, dynamic programming, global and local alignment algorithms, Detailed deviation of Needleman-Wunsch algorithm and Smith-Waterman algorithm , PAM and BLOSUM, BLAST and FASTA, Multiple sequence alignment types, Clustal, T-coffee, Multialign, Domain, Motifs Patterns, Sequence file format(Plain, GenBank, FASTA, GCG, MSF, Ig, EMBL)

UNIT-IV: Phylogenetic analysis **[08]**

Introduction, Taxonomy and Phylogeny, Types of Phylogenetics tree, clustering methods, distance-based and character-based methods, UPGMA, NJ, Maximum likelihood method, Parsimony, Bayesian inference, Searching for trees, Evaluating trees and data, Bootstrapping strategies, Phylogenetic software

UNIT-V: Introduction to Machine learning methods **[07]**

Architecture of neural networks, Application of neural networks, Support Vector machines-introduction and applications, Hidden markov model, markov chain, application of HMM in sequence and structure analysis

Suggested Readings

1. Claverie, J.M. and Notredame C. 2003 Bioinformatics for Dummies. Wiley Editor.
2. Letovsky, S.I. 1999 Bioinformatics. Kluwer Academic Publishers.
3. Baldi, P. and Brunak, S. 1998 Bioinformatics. The MIT Press.
4. Setubal, J. and Meidanis, J. 1996 Introduction to Computational Molecular Biology. PWS Publishing Co., Boston.
5. Lesk, A.M. 2002 Introduction to Bioinformatics. Oxford University Press.
6. Rastogi, S.C., Mendiratta, N. and Rastogi, P. 2004 Bioinformatics: Concepts, Skills & Applications.CBS Publishers & Distributors, New Delhi.

7. Fogel, G.B. and Corne, D.W., Evolutionary Computation in Bioinformatics.
8. Patterson, B.K., Techniques in Quantification and Localization of Gene Expression.
9. Mont, D.W., Bioinformatics: Sequence and Genome Analysis.
10. Evens, W.J. and Grant, G.R., Statistical Methods in Bioinformatics: An Introduction.
11. Pierre Baldi and Soren Brunak, Bioinformatics: The Machine Learning Approach.

HCT-1.2 CELL BIOLOGY AND GENETICS 4 Credits (60 L)

Learning Outcomes:

- In particular, this course will focus on different basic attributes of living cells, cell formation, cell-cell interaction along with the cell adhesion and cellular signaling.
- The course will introduce the basic concepts of genetics, genetic material, types, their structure and organization.
- The course also introduces to all the basic molecular process including central dogma of molecular biology.

UNIT-I: Biology of cells [15]

Cells as a unit of life, structure of prokaryotic and eukaryotic cells. Cellular membrane: structure, transport, channels, carriers, receptors, endocytosis, membrane potentials. An overview of organelles (Mitochondria, chloroplasts, ER, Golgi, ribosomes, lysosomes and peroxysomes, nucleus and nucleolus). Differences and similarities in plant, animal and microbial cells.

UNIT-II: Cell cycle [15]

Cell division (Mitosis & Meiosis), Molecular events in cell cycle and regulation. Cell senescence and death: molecular basis and pathways of cell ageing and programmed cell death (Apoptosis). Cell-cell interactions and signal transductions: Intercellular junctions, signaling by hormones and neurotransmitters; receptors, G-proteins, protein kinases and secondary messengers. Protein traffic in cells.

UNIT-III: Mendel's laws of inheritance and genome organization [08]

Mendel's laws: Monohybrid and dihybrid cross, Extrachromosomal inheritance. Prokaryotic and eukaryotic genome organization, C-Value paradox, repetitive DNA. DNA as genetic material, classical experiments – Hershey and chase; Avery McLeod & McCarty. Structure of gene- intron, exon and their relationships, overlapping genes.

UNIT-IV: Central Dogma [15]

Unit of Replication, Enzymes, proteins and mechanism of DNA replication in prokaryotes (D-loop and rolling circle mode of replication) and eukaryotes, replication of linear viral DNA. DNA proof reading, Transcription: features of promoters and enhancers, transcription factors, mechanism of transcription in prokaryotes and eukaryotes, inhibitors, post-transcriptional modification-RNA editing, ribozyme. Translation: initiation factors, mechanism of translation in prokaryotes and eukaryotes. Elucidation of genetic code, posttranslational modifications.

UNIT-V: Regulation of gene expression [07]

Gene expression in prokaryotes and eukaryotes, Lactose and tryptophan operons. Mutation and DNA repair: Types of mutation, mutagens, site-directed mutagenesis, transposons in mutation, repair mechanisms- photoreactivation repair, Base excision repair (BER),Nucleotide excision repair (NER), Mismatch repair (MMR) and SOS repair. Introduction to cancer genetics and genetic disorders.

Suggested Readings

1. Alberts *et. al.,* 2002, Molecular Biology of the Cell. Garland.
2. Lewin 2004, Genes VIII. Pearson.
3. Lodish *et. al.,* 2004, Molecular Cell Biology. Freeman.
4. Karp 2002, Cell and Molecular Biology. John Wiley.

5. Pollard & Earnshaw 2002, Cell Biology. Saunders.
6. Tobin & Morcel 1997, Asking about Cells. Saunders.
7. Watson *et. al.*,2004, Molecular Biology of the Gene. Pearson.
8. Atherly *et. al.*,1999, The Science of Genetics. Saunders.
9. Griffiths *et. al.*,2004, An Introduction to Genetic Analysis.
10. Hartl & Jones 1998, Genetics - Principles & Analysis. Jones & Bartlett.
11. Snustad *et. al.*,1998, Principles of Genetics. Wiley & Sons.
12. Strickberger 1985, Genetics. Macmillan.
13. Russell 2002, Genetics. Benjamin

HCT-1.3 INTRODUCTION TO HTML AND BIOSTATISTICS 4 Credits (60 L)

Learning Outcomes:

- The course will introduce students to different types of data, collection and representation.
- The course will also highlight the basic sampling techniques with measures of central tendency.
- Students will also gain the knowledge of web designing using HTML tags.

UNIT-I- Introduction to HTML [10]

Introduction to HTML, History, Web browsers, HTML Page structure, HTML Versions (HTML1.0, 2.0, 3.0, 4.0, 5.0), HTML editors (HTML-Kit, PS Pad, UltraEdit), documents (Web pages, URLs), HTML elements (Nested, Attribute, Text).

UNIT-II- Basic tags of HTML [15]

Headers tags, Body tags, Text fonts and styles, background colors and images, Marquee Behavior, Paragraphs, Formatting tags(bold, italic, underlined), Image tags, Lists, Numbered list, Non-Numbered lists, Anchor tag (href tag), E-Mail (Electronic Mail), Hyperlinks: FTP/HTTP, Links with images and buttons.

UNIT-III- Table Frameset & Form [10]

Table attributes, caption, table code, Frames, Frameset, NOFRAMES, Targets, Forms, Form elements, Checkbox, Radio button, Push, Submit button, File upload, Introduction to MATLAB (Syntax, Structure, Functions and Applications).Introduction to CSS(Syntax, rules, Background- color, Images, GIF).

UNIT-IV- Fundamentals of Biostatistics [10]

Introduction, history and applications of statistics for the biological problems, Scope of biostatistics, Statistical organization in India, population and sample, collection and organization of data, Presentation of data, Frequency distribution, Cumulative frequency, Graphical representation of data (Histogram, Pie chart, Bar Graph).

UNIT-V- Measures of central tendency [15]

Introduction, Types of measures of Central tendency, Mean(Merits and demerits), Median, Mode, Measures of dispersion, Range, Mean Deviation, Variance, Standard Deviation, Coefficient of variation, Correlation, Types of correlation, test for significance(Types of Hypothesis)

Suggested Readings

1. Ewens, W.J. and Grant, 2001 Statistical Methods in Bioinformatics: An Introduction. Springer- Verlag.
2. Devore, J.L., 2002 Probability and Statistics, 5th edition, Thomson Asia.
3. Hoel, Port and Stone, Introduction to Statistics.
4. Chung, Kai Lai, Elementry Probability Theory with Statistical Processes (Student Edition) Springer International
5. Feller, W., An Introduction to Probability :Theory and its Applications, Wiley Eastern Limited.
6. Thomas Powell, The Complete *Reference HTML* & XHTML.
7. Larson, H.J., Introduction to Probability Theory and Statistical Inference, John Wiley & Sons.
8. Warren J.J., Ewens Warren, Ewens Gregory Grant, Statistical Methods in Bioinformatics: An Introduction, Springer-Verlag.
9. Gupta, S.C. and Kapoor, V.K.: Fundamentals of Mathematical Statistics, Sultan Chand & Sons.

SCT-1.1 INTRODUCTION TO PROGRAMMING LANGUAGES AND PROGRAMMING THROUGH C & C++ 4 Credits (60L)

Learning Outcomes:

- The course will introduce students to basic computing hardware and software skills.
- The course will also impart programming skills with basic programming languages.
- It will also provide the scope for file handling using OOPs concepts.

UNIT-I: Introduction to computing and Programming Languages [10]

Introduction to fundamentals of computer (Memory Units, Number System, OS), Introduction to Programming, levels of programming languages (Syntax, Semantics), Implementations of programming languages (Compilers and interpreters), Data Abstractions, Paradigms, Language design principles, OOP basics, Logic Programming.

UNIT-II: **Introduction to C Programming [15]**

Introduction to C, History, Flowchart, Variable, Data types, Constants, Keywords and Identifiers, Operators, Types of operators, Decision control statements, Loops, Arrays, Types of arrays, Strings, String handling functions, Pointer, Dynamic memory allocation, Manipulating Strings, String Handling Functions, Intro to Pointers, Pointers Arithmetic, Pointers and Arrays.

UNIT-III: **Functions structure & file handling [10]**

Introduction to functions, creating simple functions, Library and User-defined functions, Types of functions, Call by value and Call by reference, Introduction to Structures, working with structure, Pointers and Structures. Introduction to Disk I/O Function, File Manipulation, Declaring and Opening a File, Closing file

UNIT-IV: **Introduction to Object Oriented Programming [15]**

Introduction of object oriented programming, OOP's concepts, History, Features Of C++, Difference between C and C++, Classes and Objects & function in C++, C Structures and C++ classes, Specifying a class, Defining member Function and member Variable of class, Call by value, Call-by-reference, Static Variables and function, friend function, Introduction to Constructor, types of constructor, Constructor Overloading.

UNIT-V: **Polymorphism & Inheritance [10]**

Introduction to Static Polymorphism, Function Overloading, Operator Overloading, Operator Overloading using Relational operator, type conversion, Introduction to Inheritance and its types, Virtual Base Class, Pointers in C++, pure virtual function. Working with files, Templates, Opening a file with open (), Opening a file with Constructors, End-of-file detection, File modes and pointers Introduction to Templates.

Suggested Readings

1. Sethi, R., 1996, Programming Languages, Addison-Wesley.
2. Appleby, D. and Vandkopple, J.J., 1991, Programming Languages, Tata McGraw-Hill.
3. Kernighan, B.W. and Ritchie, D.M., The C Programming Language, PHI.
4. Hutchinson, R.C. and Just, R.B., Programming using the C Language, McGraw-Hill.
5. Gottfried, B.S., Schaum's Outline of Theory and Problems of Programming with C, McGraw- Hill.
6. Schildt, H., C Made Easy, Osborne McGraw-Hill.
7. Tisdall, J.D. 2001 Beginning Perl for Bioinformatics. O'Reilly & Associates

SCT-1.2 CYTOGENETICS AND GENOME ORGANIZATION 4 credits (60 L)

Learning Outcomes:

- The course will introduce students to concepts of chromosomes with types and strucutres.
- The course will also impart knowledge of inhertance pattern and related consequences.
- It will also provide the scope for gaining insights into mapping of genomes with applications.

UNIT I: Chromosome structure, Organization [14]

Chromatin structure, Nucleosomal and Higher order, Telomere and its maintenance. Mitotic and Meiotic Chromosomes. Heterochromatin and euchromatin, Special types of chromosomes – Polytene chromosome, Lamp-brush chromosome. B chromosome, Sex chromosome.

UNIT II: Chromosome Banding [10]

Chromosome Banding – (G, Q, C, R) and Painting, Karyotyping, *In-situ* hybridization (FISH and GISH), Somatic cell hybridization, Somaclonal Variation.

UNIT III: Extra Nuclear inheritance [12]

Maternal inheritance, Mitochondrial, and Chloroplast, P-element in *Drosophilla*. Plasmids: Types, detection, replication, incompatibility, partitioning, copy number control and transfer. Properties of some known plasmids.

UNIT IV: Genome organization [12]

Genome organization in viruses, bacteria, animals and plants. Mechanisms of sex determination in plants, animals and *Drosophila* (Dosage compensation), Organization of nuclear and organellar genomes.

UNIT V: Genome mapping (Physical maps) and functional genomics [12]

Repetitive DNA-satellite (minisatellite, microsatellite DNA). Introduction to Transposable Elements in Prokaryotes and Eukaryotes, C-value paradox, LINES, SINES, Alu family, Fine structure of gene, multigene families.

Suggested Readings

1. Essential Cell Biology -Alberts B. et al. Garland
2. Molecular Biology of The Cell- Alberts B et al. Garland
3. The Eukaryotic Chromosome- TBostock C. J. & Summer A. T.T Elsevier
4. The Chromosome- Hamsew and Flavell Bios
5. Advanced Genetic Analysis- Hawley & Walker Blackwell
6. Structure & Function of Eukaryotic Chromosomes- Hennig Springer
7. Genes IX- Lewin B. Pearson
8. Molecular Cell Biology -Lodish, H. et al. Freeman
9. Cell and Molecular Biology- De Robertis& De Robertis Lippincott & Wilkins
10. Genome 3 -Brown T. A. Garland

HCP-1.1 BASIC BIOINFORMATICS **2 Credits**

1.Introduction to Genome Information resources- EMBL, DDBJ, GENBANK
2.Introduction to Protein Information resources- PIR, SWISS-PROT, PRINTS, PFAM
3.Analysis of biological data using: BLAST, FASTA, Clustal W, Clustal omega and Treeview
4.Phylogenetic analysis using Omega, Phylip and online tools.
5.Structure of database entry and file format Genbank, PIR, ENA, IG, MSF and FASTA.
6.Search engines: Entrez.
7.Dynamic programming algorithm using online tool
8.Primer analysis using OLIGO, Primer3
9.Hidden markov model for sequence analysis using tools(Genscan and Hmmer)
10.Vector analysis using SVM

HCP-1.2 CELL BIOLOGY & GENETICS **2 Credits**

1. Study of Mitosis.
2. Study of Meiosis.
3. Study of Micrometry and measurement of given biological sample.
4. Study of cell counting methods by Haemocytometry.
5. Isolation of cell organelles (Mitochondria & Chloroplast).
6. Isolation of genomic DNA.
7. Study of giant chromosomes.
8. Strain improvement by physical & chemical methods.
9. Analysis of monohybrid & dihybrid ratio.
10. Study of Karyotype.
11. Problems related to sex linked inheritance.
12. Study of Polyploidy.
13. Study Barr bodies.

HCP-1.3 INTRODUCTION TO HTML AND BIOSTATISTICS **2 Credits**

1. Design a simple web page using basic tags.
2. Design a simple web page using frameset.
3. Design a simple web page using Image tag with attributes.
4. Design simple login page using form with attributes.
5. Design simple registration form using all form tags.
6. Design simple website using hyperlink
7. Basic program on CSS.
8. Study of sampling techniques using biological data: Mean, Median, Mode, (using MS. Excel) Mean deviation, Standard deviation, Variance, Coefficient of Variance
9. Graphical representation of biological data. (Using MS. Excel)
10. Study of Chi-square test.

SCP-1.1 INTRODUCTION TO PROGRAMMING LANGUAGES AND PROGRAMMING THROUGH C & C++ **2 Credits**

1. C program using operators.
2. C program using conditional statements. (If, else if, nested if, switch case)
3. C program using Iterative Statements (while, do while, for loop, star pattern)
4. C program using Arrays (one dimensional, two dimensional, multidimensional)
5. C program using String.
6. C program using function.
7. C program using structure.
8. C++ program using class & object.
9. C++ program using constructor & destructor
10. C++ program using constructor overloading
11. C++ program using function overloading & operator overloading.
12. C++ program using virtual function
13. C++ program using friend function
14. C++ program using operator overloading
15. C++ program using inheritance
16. C++ program using file
17. C++ program using template

SCP-1.2 CYTOGENETICS AND GENOME ORGANIZATION **2 Credits**

1. Preparation of *Drosophila*/*Chironomas* polytene Chromosomes
2. *Drosophila* genetic crosses.
3. Study of different morphology of nucleus.
4. Chromosome preparation from human blood lymphocytes.
5. Identification of inactivated X chromosome as Barr body.
6. G-banding /O-banding and
7. Karyotype analysis
8. Problems on extrachromosal inheritance.
9. Quantitative analysis of DNA using DPA method.
10. Qualitative analysis of DNA - Physical Property (Tm Melting Temperature).

M.SC. BIOINFORMATICS (SEMESTER – II)

HCT-2.1 ADVANCED BIOINFORMATICS 4 Credits (60 L)

Learning Outcomes:

- The course will introduce students to advanced tools and resources in bioinformatics.
- The course will also impart new skill based training in genomics and proteomics.
- It will also provide the scope for understating the concept of big data and its analysis.

UNIT-I: Sequence Patterns and Profile analysis [15]

Algorithms for generation of sequence profiles, various types of pattern representations viz.consensus, regular expression(prosite type)and profiles, Tools for prediction of sequence pattern and profiles, Types of Scoring matrices, BLAST variant-Mega Blast, PSI Blast, Gapped Blast, EMBOSS package for sequence analysis

UNIT-II: **Genomics [10]**

Prediction of genes, promoters, splice sites, regulatory regions, basic principles and application to prokaryotic and eukaryotic genomes and interpretation of results, Genome projects of model organism, Structural genomics, functional genomics, Concepts in DNA microarray data analysis and tools, gene expression analysis using statistical methods, Basic concepts on identification of disease genes, OMIM database, reference genome sequence, gene expression profiling, identification of SNPs, SNP database.

UNIT-III: **Proteomics [15]**

Introduction and application of Proteomics, Primary structure Prediction, secondary structure prediction, tertiary structure prediction, Structure visualization tool, Molecule validation software package, Protein structure classification database CATH and SCOP, Protein arrays: basic principles and applications, Protein structure database, Structure comparison, Metabolic pathways such as KEGG, EMP. Plant, animal and pathogen databases, Proteomics tools using ExPasy server.

UNIT-IV: **System Biology [10]**

Introduction, History, Associated disciplines, Reaction kinetics, non linear dynamics and its biological examples, network analysis, Generation of regulatory network using WGCNA, Generation of protein interaction network, Pathway and regulatory network, the changing pace of data generation with time, the relevance of system biology to synthetic biology and other applications, and discussions on current trends via selected research reports as case studies.

UNIT-V- Big Data Analytics [10]

Data mining, techniques used in data mining, Components of Data Science, use of data science and technology in bioinformatics, Hadoop, google cloud, Ondem and computing, scalable distributed computing, mapreduce, docker, setting up secured accounts, pipeline creation and automation for largescale analysis.

Suggested Readings

1. K. Rosen, 2001 Application of Discrete Mathematics, 5th Edition, New York, McGraw Hill.
2. S. Wiitala, 1987 Discrete Mathematics, A Unified Approach, McGraw Hill.
3. C.L. Liu, 2000 Elements of Discrete Mathematics, McGraw Hill Book Co.

4. Jain, Iyenger & Jain, 2003 Numerical Methods for Scientific & Engineering Computation 4thEdition. Wiley Eastern Limited.
5. S.S. Sastry, 2003 Introductory Methods of Numerical Analysis 3rd Edition. Prentice Hall.
6. Pierre Baldi and Soren Brunak, Bioinformatics: The Machine Learning Approach.
7. Jae K. Lee, Statistical Bioinformatics, John Wiley & Sons Inc.

HCT-2.2 MICROBIOLOGY AND IMMUNOLOGY 4 Credits (60 L)

Learning Outcomes:

- The course will introduce students to biodiversity of microbes with classification.
- The students will be able to understand the detailed life cycle and features of major microbes.
- It will also provide the scope for understanding all the components of immune system.
- Students will gain the insights of functions and disorders of immune system.

UNIT-I: Biodiversity [15]

Introduction to microbial biodiversity – distribution, abundance, ecological niche. Three domains of life. Major groups of micro-organisms: General characteristics of Archaea, Eubacteria, Mycoplasma, Rickettsiae, Chlamydias and Fungi. Bacterial classification based on 16S rRNA, cellular metabolism and fatty acids. The International Committee on Systematic Bacteriology (ICSB).

UNIT-II: Biology of Bacteria and Viruses [10]

General structure of prokaryotic cell. Growth kinetics in batch cultures. Genetic recombination in bacteria: Conjugation, Transformation and Transduction; Construction of genetic maps in bacteria. General characteristics and classification of plant and animal viruses (any two examples of recently being discovered and out breaks); Structure and replication of Bacteriophage (T4 and λ), Viroids & Prions.

UNIT-III: Techniques in Microbiology [10]

Aseptic techniques in microbiology- different methods of sterilization. Techniques for isolation of microorganisms- serial dilution, streak plate, spread plate and pour plate methods. Isolation of bacteriphages. Staining techniques (simple staining, differential staining). Structural staining- cell wall, capsule and endospore staining.

UNIT IV: Introduction to Immunology [10]

Innate and adaptive immunity; Cells, tissues and organs of immune system - macrophages, B and T lymphocytes, dendritic cells, eosinophils, basophils, mast cells, haematopoiesis; Humoral and cell-mediated immunity, Cytokines and their function.

UNIT V: Antigens and Antibodies [10]

Molecular structure of antibodies and their interactions with antigens; Complement system and its activation; Major Histocompatability Complex: Introduction, classes of MHC, antigen processing and presentation. Disorders of Human Immune System: Self tolerance and autoimmunity; Acquired immunodeficiency; Hypersensitivity and its types. Hybridoma technology and vaccines.

Suggested Readings

1. Prescott, L.M., Harley, J.P. and Klein, D.A. Microbiology. 5th Ed. 2002 WmC Brown Publishers, McGraw.
2. Madigan, M.T., Martinko, J.M. and Parker, J. Brocks. Biology of Micro-organism. 10th Ed. 2003, Prentice Hall.
3. Snyder, L and Champress, W.. Molecular Genetics of Bacteria .2nd Ed. 2003. ASWashington.
4. J.G. Black. Microbiology Principles and Explorations. 5th Ed. 2002. John Wiley and Sons.
5. Stanier, R.Y., Ingrahm, J.L. Wheelis, M.L. and Painter, P.R. General Microbiology 5th Ed. 1987, Macmillan.
6. Tortora, C.J., Funke, B.A. and Case, C.L. Mircrobiology An Introduction. 8th Ed. 2004.

Pearson Education.
7. Streips & Yasbin 2002 Modern Microbial Genetics. Wiley.
8. Turn & Trumpy 2004 Fundamental of Bacterial Genetics. Blackwell.
9. Vold et. al. 1991 Essentials of Medical Microbiology. Lippincott & Co.
7. Roitt et. al., 2000 Immunology. Mosloy.
8. Roitt et. al., 2003 Essential Immunology. Blackwell.
9. Kuby, 2003 Immunology. Freeman.
10. Benjamin et. al., 2000 Immunology – A Short Course. Wiley-Liss.
11. Barrett, 1988 Text Book of Immunology. Mosloy.
12. Abbas et. al., 2001 Cellular and Molecular Immunology. Saunders.

SCT-2.1 BIOCHEMISTRY AND BIOTECHNOLOGY 4 Credits (60 L)

Learning Outcomes:

- The course will introduce students to types of biomolecules with classification and functions.
- The students will be able gain basic knowledge of small molecules with their importance.
- It will also provide the scope for exploring different aspects of plant and animal tissue culture.
- Students will be able to understand tools, techniques and wide applications of r-DNA technology

UNIT I: Bioenergetics [10]

Introduction to Bioenergetics, Laws of Thermodynamics and its Applications; Concept of free energy; High energy compounds; biological energy transducers, Cellular metabolism and ATP as the main source of free energy in biological systems.

UNIT II: Amino Acids, Peptides and Proteins [15]

Structure of Proteins: Primary, Secondary, Tertiary and Quaternary; Protein Folding; Structure-Conformation Function relationship Enzymes: Classification, nomenclature, mechanism of action, factors controlling enzyme activity, allosteric enzymes, isoenzymes, multienzyme complex, enzyme inhibitors.

UNIT III: Carbohydrates and Lipids [10]

Introduction to carbohydrates, classification, basic structures and functions. Classification of Lipids and their biological functions. Metabolic disorders and diseases. Nucleic acids - structure, diversity and function. Vitamins & Secondary metabolites: general classification and importance. Hormones and their importance.

UNIT IV: Plant and animal cell & tissue culture [10]

General introduction, concept of cellular differentiation, totipotency and pluripotency. Introduction to aseptic techniques, different media used for plant and animal tissue culture, tissue culture techniques. Cloning vectors: pUC18, pBR322, Cosmids, phagemids, expression vectors, bacterial artificial chromosomes (BACs) and yeast artificial chromosomes (YACs). Enzymes used in rDNA technology. Gene transfer in plant and animal systems.

UNIT V: Applications of recombinant DNA Technology [10]

Crop and live-stock improvement; Molecular genetic analysis of human diseases; Gene therapy- somatic and germline gene therapy: DNA drugs and vaccines. Single Cell Protein (SCP) and Single Cell Oil (SCO); GMOs and their advantages and disadvantages.

Suggested Readings

1. Murray et. al., 2003 Harpers Illustrated Biochemistry. Prentice Hall Int.
2. Nelson, D.L. & Cox, M.M., 2004 Lehninger's Principles of Biochemistry 4th Edition. Macmillan UK, Worth Publishers, USA.
3. Berg, J.M., Tymoczko, J.L., Stryer, L., 2002 Biochemistry 5th Edition. W.H. Freeman & Co. New York.
4. Zubay, Geoffrey L., 1998 Biochemistry 4th Edition. Wm C. Brown Publishers, USA.
5. Lodish, H., Berk, A., Matsudaira, P., Kaiser, C.A., Krieger, M., Scott, M.P., Zipurskey, S.L., Darnell, J., 2004 Molecular Cell Biology 5th Edition, Freeman.
6. Voet, Donald & Voet, J.G.., 2004 Biochemistry 3rd Edition. John Wiley & Sons Inc., USA.

7. Jackson, J.F. and Linskens 2003 Genetic Transformation of Plants. Springer.
8. Butler 2004 Animal Cell Culture and Technology.
9. Bhojwani, S.S. and Rajdan, M.K. 2004 Plant Tissue Culture. Elswea
10. Glick – Molecular Biotechnology
11. Primrose 7th Edtn. & Twyman – Blackwell publication.

SCT-2.2 ENZYME TECHNOLOGY 4 Credits (60 L)

Learning Outcomes:

- The course will introduce students to world of enzymes with classification and properties.
- The students will be able gain thorough knowledge of enzyme kinetics and inhibition.
- It will also provide the scope for understanding the strucuture function relationships of enzymes
- Students will be able to know the applications of enzymes and related technology.

UNIT I Enzymes [14]

Historical aspect, Nomenclature and Classification – IUB system, rationale, overview andspecific examples. Characteristics of enzymes, enzyme substrate complex. Concept of active centre, binding sites, stereospecificity and ES complex formation. Effect of temperature, pH and substrate concentration on reaction rate. Activation energy. Transition state theory. Enzyme Catalysis: Factors affecting catalyticefficiency - proximity and orientation effects, distortion orstrain, acid - base and nucleophilic catalysis. Methods for studying fast reactions. Chemical modification of enzymes. Isoenzymes, Ribozymes, Abzymes. Multienzyme complex: Properties, pyruvate dehydrogenase system (*E. coli* and mammalian), Tryptophan synthetase, multienzyme complex from *E. coli*, fatty acid synthetase.

UNIT-II: Enzyme Kinetics [12]

Michaelis - Menten Equation - form and derivation, steady state enzyme kinetics. Significance of Vmax and Km. Bisubstrate reactions. Graphical procedures in enzymology - advantages and disadvantages of alternate plotting. Enzyme inhibition - types of inhibitors – competitive, noncompetitive and uncompetitive, their mode of action and experimental determination. Enzyme activity, international units, specific activity, turnover number, end point kinetic assay.

UNIT-III: Structure Function Relations [10]

Lysozyme, ribonuclease, trypsin, carboxypeptidase, phosphorylase, aspartate transcarbamylase and Na - K ATPase. Clinical aspects of enzymology: LDH isozymes, SGOT, SGPT, creatine kinase, alpha amylase, phosphatase.

UNIT-IV: Allosteric Interactions [10]

Allosteric sites, Modulators, Protein ligand binding including measurements, analysis of binding isotherms, cooperativity, Hill and Scatchard plots and kinetics of allosteric enzymes. Enzyme Regulation: Product inhibition, feedback control, enzyme induction and repression and covalent modification. Allosteric regulation.

UNIT-V: Engineering Techniques [14]

Metabolic engineering, enzyme engineering. Immobilized Enzymes: Relative practical and economic advantage for industrial use, effect of partition on kinetics and performance with particular emphasis on charge and hydrophobicity (pH, temperature and Km). Various methods of immobilization - ionic bonding, adsorption, covalent bonding (based on R groups of amino acids), microencapsulation and gel entrapment. Immobilized multienzyme systems. Biosensors - glucose oxidase, cholesterol oxidase, urease and antibodies as biosensors.

Suggested Readings

1) Fundamentals of Enzymology- Price and Stevens

2) Enzymes -Dixon and Webb
3) Isoenzymes By D. W. Moss
4) Immobilized Biocatalysts- W. Hartneir
5) Selected papers Allosteric Regulation -M. Tokushige
6) Enzymes: Biochemistry, Biotechnology and Clinical Chemistry, Trevor Palmer, (2004)
7) Principles and Applications in Engineering Series: Biotechnology for Biomedical Engineers - Martin L.Yarmush, CRC Press, Boca Raton London New York Washington,D.C.
8)Textbook of Medical Physiology by Guyton. A.C., H. Sanders Philadelphia. 1988

OET-2.1 PROGRAMMING IN OBJECT ORIENTED LANGUAGES

4 Credits (60 L)

Learning Outcomes:

- The course will introduce students to basic concepts of Java and Bio-Java.
- The course will also impart programming skills in Perl and Bio-Perl.
- It will also provide the scope for applications of Java and Perl in Bioinformatics.

UNIT I: Introduction to Java **[15]**

Introduction to java, History, Features in Java, Java and the Internet, Java an-OOP Language, C++ Vs. Java, Java tools, Application programming, Data types and variables, Keywords and identifiers, Operators, Decision Making, Arrays, Strings, Basic concepts of OOP's , Methods in Java, Constructors, Inheritance, Polymorphism, Interfaces, Packages.

UNIT II: Applets **[10]**

Introduction to Applets: Applications of applet, the applet lifecycle; loading applets. introduction to AWT, Event handling: Action Event; Introduction to JDBC, Connecting to databases using JDBC; creating and executing statements; working with result sets, Java Drivers, java.sql Package. Concepts of Biojava, Applications.

UNIT III: Perl Basics **[15]**

History of Perl, Introduction to Perl - Data types – Operators – variables –Variable Interpolation- If, If-else, else if, For loops ,While loops , Until loop–Scalars, Lists, Hashes - Arrays – Array functions – Push and Pop , Shift and un shift – Hashes.

UNIT IV: **Subroutines** **[10]**

Subroutines for calculation, Reference to subroutine, Passing arrays and hashes to subroutines. File Handling – Writing to Files. Perl and Databases – Perl and DBM. Regular Expression – Working with regular expression.

UNIT V: Perl object oriented: BioPERL **[10]**

Sequences (Bio::Seq Class, Sequence Manipulation),Features and Location Classes (Extracting CDS), Alignments (AlignIO), Analysis (Blast,Genscan), Perl database access, Databases (Database Classes, Accessing a local Database).Sequences and Strings – Representing Sequence data, store a DNA sequence, concatenating DNA fragments,

Suggested Readings

1. Object Oriented Programming through C++ , E.BALAGURUSWAMY McGrawa Hill.
2. Letus C++, Yeswanth Kanetkar, BPB publications.
3. Tisdall, J.D. 2001 Beginning Perl for Bioinformatics. O'Reilly & Associates.
4. Hutchinson, R.C. and Just, R.B., Programming using the C++ Language, McGraw-Hill.
5. Gottfried, B.S., Schaum's Outline of Theory and Problems of Programming with C++, McGraw- Hill.
6. Schildt, H., C++ Made Easy, Osborne McGraw-Hill.
7. The Complete Reference in C++, McGraw-Hill.
8. Object oriented Programming through Java, E.BALAGURUSWAMY McGrawa Hill.
9. Simon Cozens and Peter Wainwright, "Beginning Perl", Shroff publishers, Mumbai,2005.
10. Perl By Examples, Ellie Quigley
11. James Tisdall, "Beginning Perl for Bioinformatics", Fourth Indian reprint, O'Reilly Publications, USA, 2005.

OET-2.2 PLANT BREEDING AND TISSUE CULTURE 4 Credits (60 L)

Learning Outcome:

- Knowledge of this subject helps students to identify characteristics of self and cross pollinated plants.
- Students were able to identify sources of genetic variation to conduct a breeding programme .
- Students get practical knowledge of plant tissue culture and apply the technology for clonal propagation, assisting plant breeding and plant improvement.

UNIT I: History; Genetic resources [10]

centers of diversity and origin of crop plants, Law of Homologous variation, genetic resources. Component, recombinational and transgressive breeding. Single seed descent. Populations, their improvement methods and maintenance, Hybrid breeding and genetic basis of heterosis. Ideotype breeding. Mutation breeding.

UNIT II: Objectives of plant breeding, Principles of plant breeding, Methods of plant breeding [20]

Introduction and acclimatization, selection- natural selection, artificial selection- mass selection, pure line selection and clonal selection, Hybridization; Breeding in self and cross pollinated crops, Plant Breeding for Stress Resistance and Nutritional Quality: Genetic basis and breeding for resistance to diseases and insect-pests. Breeding for vertical and horizontal resistance to diseases. Genetic and physiological basis of abiotic stress tolerance. Breeding for resistance to heat, frost, flood, drought and soil stresses. Important quality parameters in various crops, their genetic basis and breeding for these traits. Role of molecular markers in stress resistance breeding: MAS, MARS and MABB.

UNIT III: Plant regeneration pathways [10]

Organogenesis and Somatic embryogenesis; Endosperm culture and triploid production; Anther and pollen culture, and production of haploid and doubled haploid plants; Protoplast culture and fusion, Somatic hybrids; Organelle transfer and cybrids; Micropropagation, Artificial seed and bioreactor technology, Virus-free plants by meristem culture; Use of somaclonal and gametoclonal variation for crop improvement; In vitro mutagenesis and mutant selection; Preservation of plant germ plasm *in-vitro*.

UNIT IV: Cryopreservation [10]

Principle and types. Biosynthesis- batch, continuous cultures, immobilized plant cell, Biotransformation of precursors by cell culturing, metabolic engineering for production of secondary metabolites, Hairy root culture, elicitation.

UNIT V: Transgenic crops for resistance against biotic and abiotic stresses; Transgenic plants [10]

Edible vaccine, Golden rice; Engineering crops for male sterility and modification of flower colour, flowering, fruit ripening and senescence; GM crops for nutritional quality and quantity; RNAi-mediated crop improvement; Molecular pharming; Other applications; Global status and biosafety of transgenic plants.

Suggested Reading:

1. Principles of Plant Breeding, Allard RW – Wiley
2. Plant Breeding Theory and Practice, Stoskopf NC, Tomes DT and Christie BR – Westview Press
3. Quantitative Genetics, Genomics and Plant Breeding, Kang MS – CABI Publishing

4. Plant Molecular Breeding, Newbury HJ – CRC Press
5. Plant Cells in liquid culture (1991), Payne Shuler Hanser Publishers.
6. Introduction to plant tissue culture- M.K. Razdan
7. Plant tissue culture-Theory & practice-S.S.Bhojwani& M.K. Razdan
8. Plant tissue culture-KalyankumarDey
9. Biotechnology- H.S. Chawla

HCP-2.1 ADVANCED BIOINFORMATICS **2 Credits**

1. Sequence analysis using: Mega BLAST, Blast 2, PSI Blast, BLAT.
2. Sequence patterns and profile analysis using: ELM resource,EuPathDB, eMotif
3. Finding Protein and nucleic acid properties by EMBOSS and Expasy server.
4. Development of protein interaction networks.
5. Structure visualization using Rasmol, Pymol, Jmol and Cn3D
6. OMIM, SNP database (dbSNP).
7. Metabolic pathway analysis using KEGG, EC databases.
8. Genome analysis and comprasion using Genome and UCSC browser.
9. Prediction of protein structure by DALI server.
10. Secondary structure prediction-GOR, SOPMA, PSI PRED and Jpred
11. Tertiary structure prediction- Swiss Model, Modeller and Phyre2,
12. Structure validation and energy minimization-Procheck, Verify 3D , amber and Charm.
13. Big data analysis by using DOCKER and online tool.

HCP-2.2 MICROBIOLOGY AND IMMUNOLOGY **2 Credits**

1. Aseptic technique- Disinfection, preparation of cotton plugs, sterilization of used & unused glasswares, chemical and media disposal.
2. Isolation of bacteria from given sample (water, soil & air).
3. Simple and Differential staining technique.
4. Structural staining of bacteria.
4. Study of motility of bacteria by Hanging drop technique.
5. Study of bacterial growth kinetics (*E.coli*).
6. Study of gene transfer methods in bacteria.
7. Differential WBC count.
8. Blood grouping.
9. Ouchterlony Double Diffusion test.
10. Widal test for typhoid antigens.
11. Test for Rh Factor.

SCP2.1 BIOCHEMISTRY AND BIOTECHNOLOGY **2 Credits**

1. Preparation of reagents and buffers for laboratory experiments.
2. Qualitative analysis of carbohydrates.
3. Qualitative analysis of amino acids.
4. Quantitative analysis of nucleic acids/carbohydrates/proteins.
5. Determination of activity of given enzyme.
6. Effect of pH and temperature on enzyme activity.
7. Isolation of plasmid DNA.
8. Preparation of stock solutions.
9. Preparation of MS Medium & explant inoculation.
10. Restriction Digestion.
11. Agarose gel electrophoresis of DNA sample.
12. Isolation of Single Cell protein/Oil.

SCP-2.2 ENZYME TECHNOLOGY **2 Credits**

1. Isolation and quantification of activity of – amylase / invertase / alkaline phosphatase (salivary / plant source)
2. Determination of specific activity of enzyme.
3. Determination of activity of enzyme inpresence of activator and inhibitor.
4. Determination of Km and Vmax of Invertase.
5. Determination of optimum parameter of enzyme – pH and temperature.
6. Induction and estimation of beta- galactosidase.
7. Immobilization of enzyme/Cell

OEP-2.1 PROGRAMMING IN OBJECT ORIENTED LANGUAGES **2 Credits**

1. Java Program using operators
2. Java Program using classes & objects
3. Java Program using constants.
4. Java Program using array.
5. Java Program using vector class.
6. Java Program using string functions.
7. Java Program using thread.
8. Java Program using interface.
9. Java Program using applet.
10. Java Program using exception.
11. Programs based on Biojava.
12. Program to store a DNA sequence
13. Program to convert DNA to RNA.
14. Program to calculate reverse compliment of DNA sequence
15. Program to read protein sequence data from a file
16. Program to take an element off the end of an array
17. Program to take an element off the beginning of an array
18. Program to put an element at the beginning of an array
19. Program to put an element at the end of an array

20. Program to reverse an array
21. Program to get the length of an array
22. Program to find motifs in a protein sequence
23. Program to count nucleotides in a sequence
24. Program to find the percentage of hydrophobic amino acids in a sequence
25. Program to find the percentage of G and C in a DNA sequence
26. Program to count the number of given motifs
27. Program to convert DNA to RNA using subroutines
28. Program to find if a DNA is stable or not

OEP-2.2 PLANT BREEDING AND TISSUE CULTURE **2 Credits**

1. Induction of polyploidy using colchicines. (Root Tip)
2. Cytological analysis of polyploidy plants. (Root Tip)
3. Study of Pollen fertility.
4. Isolation of Ti Plasmid from Agrobacterium.
5. Media preparation, sterilization and callus culture.
6. Induction of callus.
7. Cell suspension culture.
8. Isolation of protoplast by chemical and mechanical methods.
9. Synthetic seeds preparation.
10. Breeding in Malvaceae, Poacae,
11. Breeding in Brassicacae and Fabaceaen