Syllabus

for the two year Master Degree programme

MSc in 'Bioinformatics and Applied Biotechnology'

offered by the

Institute of Bioinformatics and Applied Biotechnology

Biotech Park, Electronics City Phase 1, Bangalore 560 100

and recognized by the

University of Mysore

July 2013

Preamble

For the last few decades, advances in the sciences have been dominated by biology. In no small measure these have been enabled by technical advances in various fields. Among these, the sequencing of the human genome in the year 2000 was a milestone. The huge amount of information, ~3 billion nucleotides from a single human cell, meant that biology had to move beyond biologists. Computer scientists, information technology professionals, and statisticians were some of the very different professionals who would be involved in the new biology. The past decade has seen the emergence of *Systems Biology* as a new branch of biology. The sum is greater than the parts: One cannot put together all the organelles and expect them to behave like a fully functional cell. Having understood the properties of the molecules of a cell, putting them into a model helps us (a) check whether our understanding is complete; (b) observe emergent properties, where the system behaves differently from that predicted based on knowledge about the parts, and (c) predicting how systems will behave. *Synthetic Biology*: To build anything, one needs a list of parts that is readily available off the shelf, so called the 'parts list'. This engineering concept has been extended to biology. Do we understand the component genes and proteins of a cell well enough to create a 'parts list'? *Genomics*: The human genome was a big step. It was followed by the genomes of several large organisms, and thousands of microbial genomes. The collection of large datasets has generated a new 'omics' vocabulary: Genomics, epigenomics, proteomics, transcriptomics, metabolomics, and so on. Each involves vast amounts of data that are now much more easily generated than analyzed or put to use. Illustratively, in 2009 it was estimated that next generation sequencing techniques alone were generating 2 Gigabytes of data per day globally, and these numbers are expected to climb rapidly.

These major advances have necessitated a new way of thinking about biology and teaching the life sciences. The life scientist will need to be comfortable and proficient with the tools and techniques of information technology, mathematics, and statistics, aside from specialist knowledge in various 'omics' domains. The two-year MSc in 'Bioinformatics and Applied Biotechnology' will train a new generation of young people in the various disciplines needed to do modern biology. Further details are provided in the pages that follow.

Credit matrix for the MSc programme

Semesters	Theory courses (Biotechnology)	Theory courses (Bioinformatics)	Lab courses (Biotechnology)	Lab courses (Bioinformatics)	Theory courses (enablers)	Lab courses (enablers)	Total Credits
I	10	0	2	0	7	3	**22**
II	9	1	2	1	4	4	**21**
III	4	7	3	4	1	1	**20**
IV	1	0	2	2	0	2	**7**
	24	**8**	**9**	**7**	**12**	**10**	**70**
In addition, semester IV has a 2-credit seminar and an 8-credit project. **TOTAL CREDITS: 80**							

Credit break up for the MSc programme

I Semester

Paper Code	Title of the course	L	T	P	Credits	Name of faculty
	Foundation course in biology	3	1	0	4	Dr. Kshitish Acharya, Dr. Bibha Choudhary
	Introduction to molecular biology	2	0	0	2	Dr. Kshitish Acharya
	Biopolymer chemistry & function	3	1	0	4	Dr. N. Yathindra, Dr. S. Thiyagarajan
	Mathematics for biology	2	1	0	3	Dr. R. Srivatsan
	Computer languages I (Linux, Shell scripting, C)	3	0	0	3	Mr. Nagesh Rao
	Computer languages II (Perl)	1	0	1	2	Mr. Nagesh Rao
	Experimental biology I	0	0	2	2	Dr. Bibha Choudhary, Dr. S. S. Shivakumar
	Practicals of computer languages I	0	0	2	2	Mr. Nagesh Rao
	TOTAL CREDITS				**22**	

II Semester

Paper Code	Title of the course	L	T	P	Credits	Name of faculty
	Advanced biochemistry and physiology	4	0	0	4	Dr. Bibha Chaudhary, Dr. Deepti Jain
	Cell and immunobiology	2	1	0	3	Dr. Bibha Choudhary, Dr. Nandini Arunkumar
	General microbiology	2	0	0	2	Dr. S. S. Shivakumar
	Basic bioinformatics	1	0	1	2	Dr. Subha Srinivasan
	Biostatistics and R	2	0	2	4	Dr. R. Srivatsan
	Computer languages III (C++, Java)	2	0	0	2	Mr. Nagesh Rao
	Experimental biology II	0	0	2	2	Dr. Bibha Choudhary, Dr. S. S. Shivakumar

	Practicals of computer languages III	0	0	2	2	Mr. Nagesh Rao, Dr. Srivatsan
	TOTAL CREDITS				**21**	

III Semester

Paper Code	Title of the course	L	T	P	Credits	Name of faculty
	Genetic engineering and biotechnology	2	0	0	2	Dr. Kshitish Acharya
	Developmental and reproductive biology	2	0	0	2	Dr. Kshitish Acharya, Dr. Bibha Choudhary
	Omics of DNA, RNA and proteins	2	1	0	3	Dr. S S Shivakumar, Dr. Subha Srinivasan, Dr. Kshitish Acharya
	Structural bioinformatics	2	0	0	2	Dr. S. Thiyagarajan, Dr. Subha Srinivasan, Mr. G.Goldsmith
	Data analysis in genomics & transcriptomics	2	0	0	2	Dr. Subha Srinivasan
	Practicals of structural bioinformatics	0	0	2	2	Dr. S. Thiyagarajan, Mr. G.Goldsmith Dr. Subha Srinivasan
	Practicals of data analysis in genomics & transcriptomics	0	0	2	2	Dr. Subha Srinivasan
	Experimental biology III	0	0	3	3	Dr. Bibha Choudhary, Dr. S. S. Shivakumar
	Computer programming IV (SQL, MySQL, databases, HTML, XML, CGI/PERL)	1	0	1	2	Mr. Nagesh Rao
	TOTAL CREDITS				**20**	

IV Semester

Paper Code	Title of the course	L	T	P	Credits	Name of faculty
	Fermentation and downstream processing	1	0	2	3	Dr. Shefali Gupta
	Systems biology	0	0	2	2	Dr. R Srivatsan, Dr. Kshitish Acharya
	Data access and analysis for biological research	0	0	2	2	Dr. Kshitish Acharya
	Seminar	0	2	0	2	All faculty
	Project	0	0	8	8	All faculty
	TOTAL CREDITS				**17**	

SEMESTER I

1. Foundation course in biology	4 credits
2. Introduction to molecular biology	2 credits
3. Biopolymer chemistry & function	4 credits
4. Mathematics for biology	3 credits
5. Computer languages I (Linux, Shell scripting, C)	3 credits
6. Computer languages II (Perl)	2 credits
7. Experimental biology I	2 credits
8. Practicals of computer languages I	2 credits
TOTAL	**22 credits**

1. Foundation Course in Biology 4 credits

Unit I: Basic structure and function of cells and their organelles
Differences in the basic structure and composition of prokaryotic cells and eukaryotic animal and plant cells; structure and function of eukaryotic (plant and animal) cell organelles. Diversity in the size and shape of cells depending on functions within different tissues; variations in the number and structure of organelles depending on the type of cells (e.g., rich smooth endoplasmic reticulum in lipid secreting cells).

Unit II: Cell cycle and divisions
Introduction to cell cycle, cell division and types: mitosis and meiosis; typical phases of mitosis and meiosis; brief discussions on the molecular mechanisms, relationship with growth, differentiation, and reproduction.

Unit III: Genetics
Mendelian laws of inheritance, examples of multiple alleles governing one phenotype; overview of cytogenetics and genetic linkage; brief overview of molecular genetics, overview of Central Dogma of molecular biology; epistasis, models for dominance, co-dominance and pseudo-dominance, epigenetics; major human genetic disorders.

Unit IV: Biodiversity, ecology and evolution
Biodiversity and fundamental concepts in evolution: phylogeny, cladistic systematics, molecular basis of evolution, types of mutations and their role in evolution; Significance of taxonomy and brief description of types of species: prokaryotes, protozoans, chromista, plants, animals; NCBI as a taxonomy source; important research models, fundamental concepts in ecosystem; urban ecosystems and impact of modern human lifestyles on various ecosystems and natural resources; community ecology, population ecology.

Textbooks and Reference Books:

1. **Molecular cell biology**; *H. Lodish, A. Berk, S.L. Zipursky, P. Matsudaira, D. Baltimore and J. Darnell*; W.H Freeman & Comp., 6th edition, 2007.
2. **Molecular biology of the cell**; *B. Alberts et. al*.; Taylor & Francis Publishers, 5th edition, 2008.
3. **The cell: A molecular approach;** *G. M. Cooper and R. E. Hausman*; ASM Press, 5th edition, 2009.
4. **Typologies and taxonomies: An introduction to classification techniques (quantitative applications in the social sciences)**; *K.D. Bailey*, Sage Publications, 1994.
5. **Evolution;** *M.W. Strickberger.* Jones and Barlett publishers Inc., London, 1996**.**

6. **Organizing knowledge: taxonomies, knowledge and organizational effectiveness**; *P. Lambe*; Chandos Publishers, 2007.
7. **Ecology, concepts and applications**; *M.C. Molles*; McGraw-Hill Higher Education, 2nd edition, 2002.
8. **Ecology: from individuals to ecosystems**; *M. Begon, C.R. Townsend and J.L. Harper*; Blackwell Publishing, 4th edition, 2005.
9. **Lewin's Genes X;** *J E. Krebs, E S. Goldstein, S T. Kilpatrick.* **Jones & Bartlett Publishers, Inc. 2009.**
10. **An introduction to genetic analysis**; *J.F. Griffiths et.al*; W. H. Freeman & Co, 8th edition, 2000.

2. Introduction to Molecular Biology 2 credits

Unit I: The central dogma of biology
DNA as a genetic material across species and RNA in retroviruses. Utilization of genetic information by cells: DNA to RNA to proteins. The concept of 'gene expression': molecular basis of biochemical events and phenotypes. Significance of proteins, non-coding RNAs and other biomolecules in cellular functions. Examples of early molecular discoveries as case studies of research approaches: DNA as genetic material from hypothesis to proof; identification of basic mechanism (polymerase isolation); establishing the genetic code.

Unit II: DNA replication, repair and recombination
General features of chromosomal replication, DNA replication machinery, fidelity of replication, extra chromosomal replicons. DNA damage and repair mechanisms and their role in carcinogenesis. Recombination between homologous DNA sites.

Unit III: RNA synthesis and processing
Gene organization. Transcription process, from initiation to termination. Molecular control of transcription initiation. Capping and poly-adenylation of transcripts. Types of alterative splicing and significance of splicing in cell functions.

Unit IV: Protein synthesis and processing
Reading frames and codons. Translation process, and significance of ribosome structure and role of various factors and enzymes in translation process. Post-translational modifications of proteins and protein trafficking.

Unit V: Regulation of gene expression
Stages of gene expression regulation. Relationship of gene-expression-control with cellular and physiological events. Comparison of prokaryotic vs. eukaryotic gene expression mechanisms and regulations.

Text and Reference Books:

1. **Molecular cell biology**; *H. Lodish, A. Berk, S.L. Zipursky, P. Matsudaira, D. Baltimore and J. Darnell*; W.H Freeman & Comp., 6th ed., 2007.
2. **Molecular biology of the cell**; *B. Alberts et. al*.; Taylor & Francis Publishers, 5th ed., 2008.
3. **The cell: a molecular approach**; *G.M. Cooper and R.E. Hausman*; ASM Press, 5th ed., 2009.
4. **Recombinant DNA**; *J.D. Watson*; Scientific Amercian Books, 1992.
5. **Molecular biology of the gene**; *J.D. Watson et.al.*; Pearson Education, 6th edition, 2008.
6. **Lewin's Genes X;** *J E. Krebs, E S. Goldstein, S T. Kilpatrick.* **Jones & Bartlett Publishers, Inc. 2009.**

3. Biopolymer Chemistry and Function 4 credits

Unit I: Bonding and interactions
Atomic structure and chemical bonding, Elements of Stereochemistry, Intermolecular interactions, Basics of thermodynamics.

Unit II: Structure and function of nucleic acids
Chemistry of the composite Nucleic acids structure, Structures and properties of nucleosides, nucleotides and dinucleosides, base pairs, base triples and base quartets; Watson & Crick pairs and duplex DNA, Structural polymorphism of DNA, DNA-Drug interactions; Examples of a few DNA-protein interacting structural motifs. Structure of yeast $tRNA^{Phe}$; Other RNA structural motifs.

Unit III: Structure and function of proteins
Structure, properties and classification of amino acids, dipeptide conformation and Ramachandran Map, secondary, super secondary, tertiary and quaternary structures, Globular proteins, a few examples of structure-function correlation, protein folding.

Unit IV: Structure of lipids and membranes
Structure of different lipids, fatty acids and steroids, membrane structure and function.

Unit V: Structure and function of carbohydrates
Open and closed forms of sugars; stereochemistry of hexapyranose sugars, structural diversity of polysaccharides, hydrogen bonded conformation of maltose, cellobiose, laminaribiose and their polymers, bacterial cell wall polysaccharides-glycoconjugates- proteoglycans, glycoproteins, glycolipids.

***Textbooks and Reference Books*:**

1. **Lehninger - Principles of Biochemistry; Fifth Edition**, *D.L. Nelson and M.M. Cox*, Freeman & Co. NY, 2008
2. **Biochemistry**; *L. Stryer*; W H Freeman & Co, 5th edition, 2002.
3. **Physical chemistry**; *A. G. Whittaker*; Viva Books Pvt. Ltd., 2002.
4. **Chemistry for biologists**; *J. Fisher*; Viva Books Pvt. Ltd., 2002.
5. **Organic chemistry**; *R.T. Morrison and R.N. Boyd*; Pearson Education, 6th edition, 2005.
6. **Chemistry: Molecules, matter and change**; *L. Jones and P. Atkins*; W.H. Freeman and Company, 4th edition, 2000.
7. **Biophysical chemistry**, **I, II & III;** *C. Cantor and P. Schimmel,* W. H. Freeman and Co., San Francisco, 1980.
8. **Principles of Biochemistry;** *D. Voet, J. G. Voet and C. W. Pratt*, John Wiley, 2007.
9. **Introduction to Protein Structure;** *C. Branden and J. Tooze*, Garland Publishing, NY, 1991.
10. **Principles of Nucleic Acid Structure;** *W. Saenger,* Springer-Verlag, NY, 1984.
11. **Proteins: Structure and Molecular Properties;** *T. E. Creighton*, W.H. Freeman and Co. San Francisco, 1992.

4. Mathematics for Biology 3 credits

Unit I: Basic concepts
Cartesian and polar coordinate systems, concept of radian and series expansion of trigonometric functions. Functions, domain and range, plotting of functions and inequalities. Linear, polynomial, exponential, logarithmic, trigonometric functions and their properties. Concept of limit, rules followed by limits, methods of finding the limits of polynomials and rational functions, one-sided and two-sided

limits, continuity and differentiability, continuity at a point, continuous extension to a point, continuity on intervals, the intermediate value theorem.

Unit II: Derivatives
Derivative of a function, differentiation, second and higher order derivatives, L'Hospital's rule for finding limits, implicit differentiation, partial derivatives. The tangent and normal lines to a curve at a point. Finding extreme values of functions, local and global extrema. Linear approximations to functions at a point. Differentials, computing absolute, relative and percentage changes in formulas. The mean value theorem for derivatives.

Unit III: Integration
Indefinite integrals, integration methods. Summation of series, Riemann sums and definite integral, evaluation of definite integrals. Area under the curve, Mean value theorem, average values of continuous functions. First order differential equations and their solutions, variable-separable method, general form and solution of first order linear differential equations, use of differential equations in biology with examples.

Unit IV: Linear algebra
Vector algebra: Vector spaces, Linear transformations, Dot product and cross product of vectors, vector and scalar triple products, vector and scalar functions and fields, derivatives. Matrix algebra: Simultaneous equations and matrices, matrix addition and multiplication, matrix properties, determinants, Cramer's rule and the solution of homogeneous and inhomogeneous linear algebraic equations, Eigen values, Eigen vectors and their applications.

Unit V: Biological applications of the above concepts
Graphical representations of experimental results, Extraction of information from experimental curves by finding derivatives and area under the curve. Exponential growth and decay curves, logarithmic plots of data, Applications of periodic functions, First order time derivatives and enzyme kinetics, Modeling metabolic networks with Ordinary Differential Equations, Eigen value problems in Principal Component Analysis,Cartesian co-ordinates and vectors in molecular dynamics simulation, Error analysis of biological data.

Textbooks and Reference Books:

1. **Mathematics: from the birth of numbers**; *J. Gullberg*; W.W. Norton & Company, Inc, 1997.
2. **Painless** a**lgebra** (Barron's Painless); *L. Long.* Barron's Edicational Series. 1998.
3. **Practical algebra: a self-teaching guide;** 2nd edition. *P. H. Selby and S. Slavin.* John Wiley & Sons. 1991.
4. **Calculus made easy;** *S. P. Thompson and M. Gardner.* St. Martin's Press. 1998.
5. **Calculus for dummies;** *M. Ryan.* Wiley Publishing. 2003.
6. **Calculus & analytic geometry**; *G.B. Thomas, R.L. Finney*; Pearson Education Publications, 2001.

5. Computer Languages I (Linux, Shell scripting, C) 3 credits

Unit I: Linux
Introduction to Computers, Software and Operating Systems; History and features of UNIX and GNU/Linux. Unix file system,file and directory commands, file permissions. Basic commands, I/O redirection and piping, simple and advanced filters, *sed* command, *vi* as text editor. archives and file compressions. Processes: background processes and scheduled processes. *alias* and environmental variables.

Unit II: Shell Programming
Multiple commands as a shell script simple shell script creation and execution. Variables: System variables and User defined variables, read values to variables, Mathematic and String handling. Decisions and loopings: *if, for* and *while* loops, *case* statement; *awk* programming, terminal formatting using echo and tput. Functions: calling functions; passing arguments; receiving parameters; local variables; returning values from functions; unsetting functions. Signals: handling signals; ignoring signals.

Unit III C Programming
Programming basics: algorithm and flowcharts, compiling, linking, executing, testing and debugging. C: Variables and Data types in C, Operators: Arithmetic, Relational, Boolean and Bitwise operators. I/O and formatted I/O. Loops: *if, for* and *while* loops, *goto* and *switch* statements. Functions, subroutines, recursions. Application to simple problems. The pre-processor; simple macros; macros with arguments; macros v/s functions; #include; conditional compilation. Passing command line arguments

Unit IV Arrays, Strings, Storage classes and Pointers
Arrays in C; defining and using 2D arrays; multi-dimensional arrays; array operations. Strings: string operations using string.h storage of strings in arrays. Extern, static, auto and register; linking modules. Pointers: declaring and using pointers; operations on pointers; void pointers; NULL pointers; function pointers; pointers and functions – passing by value, passing by pointers; pointers and arrays – array storage and properties, array and pointer conversions; pointers and strings – string operations using pointers; passing arrays to functions.

Unit V Structures and Unions, Memory allocation and File handling
Structures: Defining, instantiating and operating on structures, pointers to structures; structure memory organisation; nested structures; arrays of structures; bit-fields; need for unions; memory organisation of unions. Memory allocation: static memory allocation; need for dynamic memory allocation; malloc() and calloc(); free(); memory problems – memory leaks, dangling pointers, invalid deallocation. File Handling: Opening files in various modes; closing files; reading and writing characters; reading and writing strings; formatted I/O on files; raw I/O on files; seeking in files. Application to bioinformatics problems.

***Textbooks and Reference Books*:**

1. **Red Hat linux 7.2 Bible**; *C. Negus*; Wiley India Pvt Ltd., 2004.
2. **Learning Red Hat linux**; *B. McCarty*; O'Reilly & Associates Inc., 1999.
3. **Computer programming in C**; *V. Rajaraman*; Prentice-Hall of India, 1994.
4. **The C programming language**; *D. Ritchie*; Pearson Education, 2007.
5. **Let us C;** *Y. Kanetkar*; BPB Publications, 1999.

6. Computer Languages II (Perl) 2 credits

Unit I: Introduction to Perl and working with Scalars
Features of perl; simple perl scripts; I/O in perl using print, printf and <STDIN>; chopping using chop and chomp. Operators and expressions; contexts; the default scalar.

Unit II: Decisions, Loops, Lists and Arrays in Perl Programming
if; unless; && and ||; 'and' and 'or'; modifiers. while; until; do-while; for; foreach; last, next and redo; labelling and goto; labelling and loops. Creating lists; list assignments; creating arrays; array assignments; accessing array elements; the default array; array operations – push, pop, shift, unshift,

splice, sort, reverse, chop, delete; split and join; map.

Unit III: Hashes, Strings and Regular Expressions in Perl Programming
Need and concept; lists and hashes; keys and values; iterating through hashes using foreach and each; deleting and element using delete. String functions – length, index and rindex, substr; case conversion using uc, lc, ucfirst, lcfirst and escape characters. Match; substitute; translate; special operators and escape sequences; extracting matches; back-references; split revisited.

Unit IV: Subroutines, File handling, Files and Directories
Defining subroutines; calling subroutines; argument passing; receiving parameters, local and my variables; returning values; wantarray; declaring subroutines. Obtaining file handles; closing file handles; reading from file handles; writing to file handles; the default file handle; implementing filters; providing input to external commands; collecting output of external commands. Finding the current directory; chdir, mkdir and rmdir; file globbing; file tests; file operations - unlink, chmod. Bioperl applications.

Unit V: UNIX Features and Report Generation
system(); command substitution using back-quotes; fork. The format definition; picture elements; special variables - $~, $%, $=, $-; write; select.

Unit VI: References, Packages and Modules
Concept; references to scalars; references to arrays; references to hashes; references to subroutines; anonymous arrays; anonymous hashes; anonymous subroutines. Meaning of packages, namespaces and symbol tables; the package statement; modules; creating modules; using modules.

Textbooks and Reference Books:

1. **Beginning Perl for bioinformatics**; *J. Tisdall*; Wrox Press Ltd., 2000.
2. **Genomic Perl**; *R.A. Dwyer*; Cambridge University Press, 2003.

7. Experimental Biology I 2 credits

Unit I: Basics of laboratory work and safety
Safe laboratory practices (handling reagents and instrumentation; preparing to handle biohazards, and hazards by radioactivity, electricity and fire), calculations, designing experiments, purchasing procedures, potential suppliers of lab-requirements, stock maintenance (sensitive reagents, and routine chemicals and consumables) and record keeping.

Unit II: Concepts in cleanliness, sterility, and molecular stability
Basic procedures for clean vs. sterile vs. RNase/DNase free consumables and bench space; solution preparations for routine purposes; reagent types for different purposes (study of catalogs); significance of temperature control and swiftness in experiments: experiments with molecular stability at different temperatures.

Unit III: Precision and accuracy
Study of factors influencing precision and accuracy of results in general. Concepts of pH, acidic, neutral, and alkaline solutions. Chromatography (thin layer and paper chromatography).

Unit IV: Experiment designing
Designing experiments to find answers to specific questions; exercises in relating scientific questions to appropriate techniques, selection of controls, statistical aspects, etc. (Basic experiments such as

dissolved oxygen (DO) estimation, bacterial isolation, culturing, growth curve, standard curve, estimation of DNA and protein.)

Unit V: Microscopy and Spectroscopy
Basics of microscopy and types of microscopes, histology: major plant and animal tissues, cell counting, Gram staining, Concepts of wavelength, absorbance, and fluorescence. Beer Lambert Law, UV-VIS spectroscopy.

Textbooks and Reference Books:

1. **Laboratory reference**; *J. Roskams and L. Rodgers*; I K International Pvt Ltd, 2004.
2. **Lab math**; *D. Adams and L. Spencer*; I K International Pvt Ltd, 2004.

8. Practicals of Computer Languages I 2 credits
Practicals of theory topics listed above.

SEMESTER II

1. Advanced biochemistry and physiology	4 credits
2. Cell and immunobiology	3 credits
3. General microbiology	2 credits
4. Basic bioinformatics	2 credits
5. Biostatistics and R	4 credits
6. Computer languages III (C++, Java)	2 credits
7. Experimental biology II	2 credits
8. Practicals of computer languages III (C++, Java)	2 credits
TOTAL	**21 credits**

1. Advanced Biochemistry and Physiology 4 credits

Unit I: Methods in biochemistry
Salting, dialysis, gel filteration chromatography, ion-exchange chromatography, affinity chromatography, HPLC, Gel electrophoresis, protein sequencing, production of monoclonal and polyclonal antibodies, ELISA, western blotting, MALDI-TOF, mass spectroscopy, x-ray crystallography, NMR.

Unit II: Chromatin Organisation and Transcriptional Regulation
Structure of nucleosome, histone variants and modifications, higher order chromatin structure and nuclear organisation, banding, heterochromatin euchromatin, histone acetylases and deactylases and transcriptional regulation, dosage compensation.

Unit III: Physiology
Basics of concepts in cellular vs. general physiology, digestive system, circulation, excretion, muscle structure and functions, and neural tissues and functions; examples of common disorders affecting different systems in humans, blood clotting, immunity, respiration in plants and photosynthesis.

Unit IV: Metabolism
Organic reaction mechanisms, experimental approaches to study metabolism, oxidation-reduction reactions, glycolysis, glycogen metabolism, glycogen storage disease, Citric acid cycle, ETC and oxidative phosphorylation, Pentose Phosphate pathway, Fatty acid metabolism, amino acid biosynthesis, Nitrogen fixation.

Unit V: Enzymology
Principles of catalysis, enzymes and enzyme kinetics, enzyme regulation, mechanism of enzyme catalysis, isozymes; enzyme immobilization; examples of quantitative studies; Michaelis-Menten equation, LWB plot, allostery, inhibition**.**

Unit VI: Cell signaling
Principles of signal transduction; Classification of signaling mechanisms; examples of quantitative studies; hormones and their receptors classes; signaling through G-protein coupled receptors and their effectors; Tyrosine Kinases and Ras, MAP Kinase Pathways; second messengers; steroid hormone

receptors, interaction and regulation of signaling pathways; bacterial and plant two-component signaling systems; bacterial chemotaxis and quorum sensing.

***Textbooks and Reference Books*:**

1. **Enzymes: Biochemistry, biotechnology, clinical chemistry**; *T. Palmer*; Affiliated East-West Press Private Limited, 2004.
2. **Biochemistry**; *L. Stryer*; W H Freeman & Co, 5th edition, 2002.
3. **Lehninger - Principles of Biochemistry; Fifth Edition**, *D.L. Nelson and M.M. Cox*, Freeman & Co. NY, 2008 .
4. **Biochemistry**; *D. Voet, J. G. Voet*; Wiley, 3rd edition, 2008.
5. **Principles of anatomy and physiology**; *G.J. Tortora and B.H. Derrickson*; Wiley Higher Education, 11th edition, 2006.
6. **Endocrinology: An Integrated Approach;** *Nussey, S.S. and Whitehead, S.A.* London: Taylor & Francis; 2001
7. **Plant physiology; *L. Taiz and E. Zeiger*; Palgrave Academic Publisher, 4th edition, 2006.**
8. **Biomolecular crystallography**; *B. Rupp*; Garland Science, 2009.
9. **Spectroscopy for biological sciences**; *G.G. Hammes*; Wiley, 2005.
10. **Principles of fluorescence spectroscopy***; J. R. Lakowicz*; Springer, 3rd edition, 2008.
11. **The condensed protocols from the molecular cloning: A lab manual**; *J. Sambrook*; Cold Spring Harbour Lab. Press, 2006.
12. **Outline of crystallography for biologists**; *D. Blow*; Oxford University Press, 2002.
13. **Chromatography: Concepts and contrasts**; *J. M. Miller*; Wiley, 2nd edition, 2009.
14. **Protein purification – principles and practice**; *R.K. Scopes,* Springer Verlag.
15. **BioCromatography – theory and practice**; *M. A. Vijayalakshmi,* Taylor and Francis.

2. Cell and Immunobiology 3 credits

Unit I Cytogenetics

Chromosome appearance and classification, normal karyotype, chromosomal abnormalities, idiogram, robertsonian translocation, clinical genetics.

Unit II: Cell-Cell interactions

Cellular communication: general principles of cell communication; cell adhesion and roles of different adhesion molecules; gap junctions, extracellular matrix, integrins; neurotransmission and its regulation.

Unit III. Host-parasite interaction

Recognition and entry processes of different pathogens like bacteria and viruses into animal and plant host cells; alteration of host cell behavior by pathogens, virus-induced cell transformation, pathogen-induced diseases in animals and plants; cell-cell fusion in both normal and abnormal cells.

Unit IV: Cancer biology

Hallmarks of cancer, types of cancer. Apoptosis, angiogenesis, chromosomal abnormalities, cancer therapy.

Unit V: Introduction to immunology

Innate and adaptive immune systems, humoral and cell mediated immunity, cells and molecules involved in immunity.

Unit VI: Working of the immune system
Innate Immune response: complement system, toll-like receptors, inflammation; Humoral immune response: B cells and antibodies, T helper cells and TCR, MHCs and antigen processing and presentation, humoral response. Cell mediated immune response: cytotoxic T cell response.

Unit VII: Immune system in disease
Bacterial, viral, parasitic infections; Deficiencies in Immune system - Hypersensitivity, autoimmunity, immunodeficiencies; Immunological methodologies.

Textbooks and Reference Books:

1. **Molecular cell biology**; *H. Lodish, A. Berk, S.L. Zipursky, P. Matsudaira, D. Baltimore and J. Darnell*; W.H Freeman & Comp., 6th edition, 2007.
2. **Molecular biology of the cell**; *B. Alberts et. al*.; Taylor & Francis Publishers, 5th edition, 2008.
3. **The cell: A molecular approach;** *G. M. Cooper and R. E. Hausman*; ASM Press, 5th edition, 2009.
4. **Kuby immunology;** *R.A. Goldsby, T.J. Kindt and B.A. Osborne*; W. H. Freeman & Co, 6th edition, 2000.
5. **Immunology: understanding the immune system**; *K.D. Elgert*; Wiley-Blackwell Publication, 2nd edition, 2009.
6. **Janeway's immunobiology;** *K. Murphy, P.Travers and M. Walport*; Taylor & Francis Publishers, 7th edition, 2008.

3. General Microbiology 2 credits

Unit I: Bacteriology
Broad taxonomy of microbes; chemotaxonomy (cell wall components, isoprenoid - quinones, amino acid sequence of proteins, protein profiles, cytochrome composition, ribosomal RNA, etc); genetic methods in taxonomy (PCR and DNA fingerprinting as identification tools for bacteria, DNA base composition and hybridisation, rDNA sequencing etc); Archaebacteria: taxonomic position (relatedness to eucaryotes and procaryotes, unique molecular and biochemical features). ●, lysogenic and lytic cycle.

Unit II: Mycology
Introduction to the fungi; fungal cell structure and morphology; relationship to other organisms; diversity of fungi; fungal physiology, nutrition, and growth; fungal ecology.

Unit III: Virology
History and principles of virology; virus taxonomy; introduction to replication strategies; virus structure and morphology.

Unit IV: Pathogenic microbes
Characteristics of major bacterial and viral pathogens; concepts of pathogencity and virulence; bacteria and viruses of medical importance.

***Textbooks and Reference Books*:**

1. **Todar's Online Textbook of Bacteriology;** *K Todar* (available free of cost on the internet at

http://textbookofbacteriology.net/).
2. **Microbiology 5 Edition;** *M. J. Pelczar, E.C.S Chan, N. R. Krieg*. Tata McGraw Hill, 2001.
3. **Introductory Mycology, 4th Edition;** *C J. Alexopoulos, C W. Mims, and M. Blackwell.* New York : Wiley, 1996.
4. **Principles of Virology: Molecular Biology, Pathogenesis, and Control of Animal Viruses**, 2nd Edition; *S. J Flint, L W. Enquist, V R. Racaniello, and A M Skalka.* ASM Press 2004.
5. **Microbiology: Principles and Explorations**, 7th Edition; *J. G. Black.* John Wiley and Sons. 2008.
6. **Brock biology of microorganisms**; *M.T. Madigan, J.M. Martinko, P.V.Dunlap and D.P. Clark*; Pearson Education, 12th edition, 2009.
7. **Prescott/Harley/Klein's microbiology**; *J. Willey, L. Sherwood and C. Woolverton*; McGraw-Hill Higher Education, 7th edition, 2008.

4. Basic Bioinformatics 2 credits

Unit I
Algorithms; asymptotic analysis of algorithms; NP complete problems; Algorithm types; Brute force; divide and conquer; sorting algorithms.

Unit II:
Basic concepts of sequence similarity, identity and homology, definitions of homologues, orthologues, paralogues. Introduction to PAM and BLOSUM matrices; basic concept of a scoring matrix, matrices for nucleic acid and proteins sequences, PAM and BLOSUM series; principles based on which these matrices are derived; differences between distance & similarity matrices.

Unit III:
Collecting and storing sequences. Various file formats for bio-molecular sequences: GenBank, FASTA, GCG, MSF, NBRF-PIR etc. Database searching: Using BLAST, FASTA and other sequence analysis tools to assign homology; BLAST algorithms, Various versions of basic BLAST, Use of these methods for sequence analysis including the on-line use of the tools and interpretation of results.

Unit IV:
Dynamic programming algorithm: Pairwise alignment methods such as Smith-Waterman and Needleman-Wunsch. Concepts behind multiple sequence alignment; ClustalW, TCoffee. Sequence patterns and profiles: Basic concept and definition of sequence patterns, motifs and profiles, various types of pattern representations viz. consensus, regular expression (prosite-type) and profiles.

Unit V:
Phylogenetic tree: Neighbour joining, UPGMA. Use of Hidden Markov model (HMM) in assigning homology. Advantages and disadvantages of various sequence analysis methods.

Textbooks and Reference Books:

1. **Bioinformatics Vol. 1: Data, sequence analysis & evolution;** *J. M. Keith*; Humana Press, 2008.
2. **Biological sequence analysis**; *R. Durbin*; Cambridge University Press, 1998.
3. **A cell biologists' guide to modeling and bioinformatics**; *R. M. Holmes;* Wiley Interscience, 2007.
4. **Basic biostatistics for geneticists & epidemiologists**; *R.C. Elston, W.D. Johnson*; Wiley, 2008.

5. **Data reduction and error analysis for the physical sciences.** *P. R. Bevington;* McGraw Hill. 1969.

5. Biostatistics and R 4 credits

Unit-I: R statistical package
Essentials of R-package and libraries, mathematical operations, string operations. Data structures: vectors, data frames, lists, matrices. Control loops: if, else, while for loops. File Input/output operations. R plots and the graphics library. Overview of Statistical packages and bioconductor libraries in R.

Unit II: Statistics - Fundamental concepts:
Data representation: Qualitative and quantitative data types, Tabulation and visual display of data, plotting line plot, scatter plot, frequency histograms, pie-chart, heat map and 3D plots.

Statistical parameters: Mean, median, variance, standard deviation, percentile points and their meaning. Skewness and Curtosis, correlation coefficients, moments.

Probability theory: Concept of probability, probability theorems, permutations and combinations, conditional probability, Bayes theorem, applications to bioinformatics.

Frequency distribution, discrete and continuous data types, Bernoulli trial, binomial, Poisson and normal distributions, examples of biological systems following these distributions.

Unit III: Hypothesis testing and error analysis
Random sampling, central limit theorem, confidence intervals and p-value. Testing of hypothesis, chi-square test, t-tests, Z-tests, Welch's test, Wilcoxon-Mann-Whitney test, tests for comparing proportions and the Analysis of the Variance (ANOVA). Error analysis and error estimates for formulas, Type-I and Type-II errors. Hypothesis testing of data from biological experiments with examples.

Unit IV: Regression analysis
Linear regression, least square fit to a linear, polynomial and exponential curves, error bars. Regression analysis of few data sets from biological experiments.

Unit V: Data reduction methods
Multivariate analysis, Principal Component Analysis, Markov chains and Hidden Markov Models. clustering algorithms. Demonstration of these methods with bioinformatics data.

***Textbooks and Reference Books*:**

1. **Principles of biostatistics;** *M. Pagano*; Cengage Learning Publishers, 2nd edition, 2008.
2. **Schaum's outline of probability and statistics**; Tata McGraw Hill, 2004.
3. **Basic biostatistics for geneticists & epidemiologists**; *R.C. Elston, W.D. Johnson*; Wiley, 2008.
4. **Data reduction and error analysis for the physical sciences.** *P. R. Bevington;* McGraw Hill. 1969.

6. Computer Languages III (C++ & Java)

Unit I: Introduction to OOP and C++
Introduction to Object Oriented Programming: The OOP programming model; enhancements over structured programming. C++ as a better C: Streams; manipulators; comments; variable definitions; type casts; scope resolution; improved syntax for structures, unions, enums; anonymous unions and enums; void pointers; constants and pointers; references; constant references.

Unit II: Procedural and Object-Based Programming in C++
Prototype; inline functions; default arguments; function overloading; function overload resolution.
Classes; objects; class definition; memory organisation of objects; member functions; constructors; destructors; the this pointer; static data members; static member functions; constant member functions; friend functions; friend classes.

Unit III: C++ Free Store Management and Inheritance
new and delete; benefits over malloc() and free(); free store exhaustion.
Class relationships; structural types of inheritance; private, public and protected inheritance; properties of inheritance; function overriding; memory organisation of objects; constructors and destructors; the is-a relationship; class containership and the has-a relationship; late binding and virtual functions; pure virtual functions and abstract classes; virtual inheritance and virtual base classes.

Unit IV: Introduction to Java, Java Quick Start and OOP in Java
History of Java, Features of Java, JVM, JRE and JDK.
Java Quick Start: Learning the basics of Java in comparison to C++. Object Oriented Programming in Java: Classes, interfaces and packages; access modifiers; constructors; the this and super references; inner classes and nested classes; anonymous classes.

Unit V: Exception Handling, Garbage Collection and Multithreading
Concept of exception handling; throwing and catching exceptions; handling and declaring exceptions; re-throwing of exceptions. Concept of garbage collection; overriding the finalize() method. Concept of multithreading; services provided by Thread class; implementing multithreading by extending Thread class; implementing multithreading by implementing Runnable interface; sleeping and interrupting threads; synchronized methods and statements; inter-thread communication.

Unit VI: Packages and Applets
The java.lang and java.util : Object class; Class class and the Reflection API; System and Runtime classes; Properties class; Wrapper classes; overview of other classes. Vector, ArrayList, LinkedList, HashSet, LinkedHashSet, TreeSet, HashMap, LinkedHashMap, TreeMap; Iterator and Enumeration; Collections and algorithms. The javax.swing Package: GUI development using the javax.swing Package: Class hierarchy; working with containers and layout managers; working with components; event handling; menu system; drawing and painting. The java.io Package and Database access using the java.sql Package: InputStream, OutputStream, Reader, Writer, and their sub-classes; File class; RandomAccessFile class, StreamTokenizer. Connecting to databases using JDBC; creating and executing statements; working with result sets. Applets: Applications of applet; The applet lifecycle; loading applets.

***Textbooks and Reference Books*:**

1. **The complete reference C++;** *H. Schildt*, Tata Mcgraw Hill, 1998.
2. **The complete reference Java 2;** *H. Schildt*, 5th edition, Tata Mcgraw Hill, 2002.

7. Experimental Biology II 2 credits

Unit I: Basic cell culture procedures
Concepts of cell lines, transformation, sterility and culturing mammalian cells; practicing basic procedures: seeding, passaging, sterile media preparations etc.

Unit II: Mammalian cell culture and Transfection
Passaging through multiple lines of generations using at least 2 different types of mammalian cells, chromosomal preparations, G-banding and C-banding. Transfecting with lipofectamine and other methods using a standard gene and mammalian cells.

Unit III: Biochemical tests
Catalase, oxidase, amino acid tests, indole, glucose fermentation, motility testing, hemolysis.

Unit IV: Enzymology
Basic experiments in enzyme assays and kinetics; study of factors influencing enzyme kinetics. Prototype enzymes: amylase and glutaminase

Unit V: Physiology
Blood cell counting, blood smear preparation. Liver and kidney function tests (urinalysis, blood urea nitrogen etc.).

Unit VI: Bacterial transformation
Bacterial culture techniques, preparing competent cells, chemical and electro-transformation of bacteria and selection of transformants, antibiotic resistance in bacteria.

Unit VII: Immunological techniques
Blood typing, western blotting analysis, quantitative analysis of specific antigens using ELISA, immunoprecipitations, flow cytometry, CHIP and FISH.

Textbooks and Reference Books:

1. **Purifying proteins for proteomics: A laboratory manual**; *R. J. Simpson*; Cold Spring Harbor Laboratory Press, 2004.
2. **Human molecular biology laboratory manual**; *S. Surzycki*; Blackwell Publications, 2003.
3. **Enzymes: Biochemistry, biotechnology, clinical chemistry**; *T. Palmer*; Affiliated East-West Press Private Limited, 2004.
4. **Culture of animal cells: A manual of basic technique;** *R. I. Freshney*, Wiley-Liss, 2000.
5. **The condensed protocols from the molecular cloning: A lab manual;** *J. Sambrook*; Cold Spring Harbour Lab. Press, 2006.

8. Practicals of Computer Languages III 2 credits

Practicals of theory topics listed above.

SEMESTER III

1. Genetic engineering and biotechnology	2 credits
2. Developmental and reproductive biology	2 credits
3. Omics of DNA, RNA and proteins	3 credits
4. Structural bioinformatics	2 credits
5. Data analysis in genomics & transcriptomics	2 credits
6. Practicals of data analysis in genomics & transcriptomics	2 credits
7. Practicals of structural bioinformatics	2 credits
8. Experimental biology III	3 credits
9. Computer languages IV (SQL, MySQL, Databases, HTML, XML, CGI/PERL)	2 credits
TOTAL	**20 credits**

1. Genetic Engineering and Biotechnology 2 credits

Unit I: Concepts in recombinant DNA technology
Basic principles; introduction to types of vectors used in recombinant DNA technology, their specific uses and comparison of their features; an overview of various enzymes used in recombinant DNA technology. Types of vectors and applications. cis and trans-genesis, Agrobacterium mediated genetic transformation and binary vectors, particle bombardment, transfections, knockouts and transgenics.

Unit II: Use of oligonucleotides and PCR
Principles, process and application of PCR, reverse-transcription-PCR and real time PCR. Application of primers, probes and PCR in various other techniques and research strategies.

Unit III: Genetic engineering
Mutagenesis: deletion mutagenesis, oligonucletoide derived mutagenesis, site directed mutagenesis. Case studies in applications of rDNA technology and genetic engineering. Concept of 'synthetic biology', and its relevance to informatics and genetic engineering. Ethical considerations, and potential negative impacts.

Unit IV: Other common molecular biology techniques
Common methods in the context of questions/problems usually addressed in molecular biology research: purification, detection and localization of DNA, RNA and proteins, and the corresponding techniques.

Textbooks and Reference Books:

1. **Molecular cell biology**; *H. Lodish, A. Berk, S.L. Zipursky, P. Matsudaira, D. Baltimore and J. Darnell*; W.H Freeman & Comp., 6th ed., 2007.
2. **Molecular biology of the cell**; *B. Alberts et. al.*; Taylor & Francis Publishers, 5th ed., 2008.
3. **The cell: a molecular approach;** *G.M. Cooper and R.E. Hausman*; ASM Press, 5th ed., 2009.
4. **Lewin's Genes X;** *J E. Krebs, E S. Goldstein, S T. Kilpatrick.* **Jones & Bartlett Publishers, Inc. 2009.**
5. **An introduction to genetic analysis;** *A.J.F. Griffiths*, W. H. Freeman & Co., 2008.
6. **Recombinant DNA;** *J.D. Watson*; Scientific Amercian Books, 1992.

7. **Molecular biology of the gene**; *J.D. Watson* et.al.; Pearson Education, 6th edition, 2008.
8. **Principles of gene manipulation and genomics;** *S.B. Primrose and R.M. Twyman*; Blackwell Publishing, 7th edition, 2006.
9. **Improving nature: The science and ethics of genetic engineering;** *M. J. Reiss, R. Straughan,* Cambridge University Press, 2002.

2. Developmental and Reproductive Biology 2 credits

Unit I: Reproduction, developmental and stem cell biology
Significance of meiosis in sexual reproduction, differences between male and female gamete generation, fertilization, role of hormones in germ cell production and early development and puberty; brief discussion on diversity in these processes across other important species, including plants (such as Arabidopsis).

Unit II: Embryogenesis
Cleavage, blastula formation, gastrulation, neurulation, genetics of axis specification in Drosophila, C. elegans, zebrafish and frog.

Unit III: Sex determination
Chromosomal, environmental and hormonal sex determination, genetics of sex determination in mammals.

Unit IV: Post embryonic development
Metamorphosis, Regeneration and aging, hormonal control of metamorphosis, mechanism of limb regeneration in axolotl.

Unit V: Stem cells
Basic concepts, unipotent, multipotent, pluripotent and totipotent. Adult and embryonic stem cells characteristics and differentiation.

Textbooks and Reference Books:

1. **Developmental Biology;** *Gilbert, Scott F. Sunderland (MA):* Sinauer Associates, Inc.; 2000**.**
2. **StemBook;** Cambridge (MA): Harvard Stem Cell Institute; 2008.
3. **Embryonic Stem Cells - Basic Biology to Bioengineering;** Editor *M. S. Kallos* InTech. 2011.
4. **Molecular Biology of the Cell;** 4th edition. *B Alberts, A Johnson, J Lewis, et al.* New York: Garland Science; 2002.
5. **Holland-Frei Cancer Medicine;** 6th edition. *DW Kufe, RE Pollock, RR Weichselbaum et al.,* editors. Hamilton (ON): BC Decker; 2003.

3. Omics of DNA, RNA and Proteins 3 credits

Unit I: Concepts of genomics
History of genomics; genome projects of model organisms; human genome structure and comparative genomics. Genomic elements, SNPs and genome-wide association studies.

Unit II: Genome sequencing technology
Principle of and output from Sanger's dideoxy method versus NGS; shotgun sequencing method and library preparations, comparative study of standard NGS methods.

Unit III: Metagenomics and Population genomics
Overview of metagenomics principles, microbial and ecological aspects underlying metagenomic experiments, applications and limitations of metagenomics, differences between metagenomics and single-cell genomics. Definition and principle of population genomics, difference between metagenomics and population genomics, applications of population genomics.

Unit IV: Epigenetics
Methylation of DNA and genetics; histone modifications, HATs & HDACs in the context of gene expression regulation. ChIP-chip and ChIP-seq techniques; miRNA, siRNA and piRNAs. Alternative splicing: basic concept and significance, prevalence across species and human tissues, types and mechanisms.

Unit V: Transcriptomics
Types of RNAs and the respective roles in cells. Transcriptome and techniques used for transcriptomics; microarray and RNA-seq. Impact of transcriptomics on biology, volume of data produced and important repositories. Comparing transcriptomics with genomics and proteomics.

Unit VI: Proteomics
Proteome profiling methods, 2-D electrophoresis image comparisons; yeast two-hybrid system, protein arrays, mass spectrometry data processing and analysis; pathway analysis and identifying protein-protein interactions with mass scale expression data.

***Textbooks and Reference Books*:**

1. **An introduction to data structures with applications**; *J.P. Tremblay and J.Paul*; T. McGraw Hill, 2nd edition,1984.
2. **Experimental design and data analysis for biologists**; *G.P. Quinn and M.J. Keough*; Cambridge University Press, 2002.
3. **Guide to analysis of DNA microarray data**; *S. Knudsen*; Wiley, 2nd edition, 2004.
4. **Mass spectrometry: Principles and applications**; *E.D. Hoffmann & V. Stroobant*; Wiley, 3rd edition, 2007.
5. **Advanced analysis of gene expression microarray data**; *A. Zhang*; World Scientific Publishing, 2006.

4. Structural Bioinformatics 2 credits

Unit I: Biopolymer modeling
Building, editing and visualizing biopolymer structures and their complexes. Rendering, , mutations, calculation of geometric parameters (bond distance, bond angle, dihedral angle). Overview of PDB and NDB databases. Identifying inter-molecular interactions from crystal structures; protein…protein, protein…nucleic acids, protein…ligand/water, nucleic acids… ligand/water, protein… carbohydrate interactions.

Unit II: Protein structure analysis and comparison
Internal, Cartesian and distance coordinate representations of protein structures. Algorithms to superimpose structures and computation of RMSD (Kabsh algorithm); SCOP database and fold potential evolution; structure-structure alignment (DALI).

Unit III: Protein structure/fold prediction
Concepts and algorithms related to homology modeling, loop modeling, sequence-structure alignment (1D-3D), protein threading, Protein 3D structure prediction using Threading approach,secondary structure prediction, predicting cellular localization; structure refinement methods like energy minimization, MD simulation; structure validation methods such as RMSD and intra/inter-molecular interaction.

Unit IV: Rational drug design
Identifying active site/drug binding pockets. Protein-protein interactions. Docking algorithms Virtual screening method in identifying potential lead molecules. Solvent accessible surfaces/properties of proteins; Creating electrostatic potential surface diagram protein-ligand docking.

***Textbooks and Reference Books*:**

1. **Structural bioinformatics;** *P. E. Bourne and J. Gu.* 2nd Edition. John Wiley and Sons. 2009.
2. **Structural bioinformatics: An algorithmic approach;** *F. J.Burkowski.* CRC Press. 2008**.**
3. **Computational molecular biology: an introduction;** *P. Clote and R. Backofen*, Wiley & Sons, 2000.
4. **Bioinformatics vol:2: Structure, function & applications;** *J. M. Keith* Humana Press. 2008**.**
5. **Compact handbook of computational biology;** *A. K. Konopka and M. J. C. Crabb*, Marcel Dekker, New York, 2004.

5. Data analysis in genomics & transcriptomics 2 credits

Unit I: Transcriptome analysis
Microarray data analysis: gene expression analysis, statistical methods; relative merits of various platforms. Primers design for downstream validation; mapping algorithms such as Burrow-Wheeler. Measuring gene, lncRNA, siRNA from RNA-seq data.

Unit II: Genome analysis
Sequence assembly concepts and challenges in assembling short reads; Algorithms for assembling short reads using graph theory such as Hamiltonian cycle and de Brujin; Writing code for assembling reads. Gene prediction and annotation; gene ontology (GO); Identification genetic variations from genome sequence: SNPs, SNVs, translocation, copy number variation. Concepts behind genome-wide association studies. Introduction to various applications.

Unit III: Computational epigenomics
Concepts and algorithms to measure transcriptional regulation; methylation and alternative splicing; relative merits of various approaches; small RNA analysis, validation of whole-genome datasets.

Unit IV: Comparative genomics
Genome-wide annotation methods; identification of synteny between various genomes and challenges.

***Textbooks and Reference Books*:**

1. **Experimental design and data analysis for biologists**; *G.P. Quinn and M.J. Keough*; Cambridge University Press, 2002.
2. **Guide to analysis of DNA microarray data**; *S. Knudsen*; Wiley, 2nd edition, 2004.
3. **Mass spectrometry: Principles and applications**; *E.D. Hoffmann & V. Stroobant*; Wiley, 3rd edition, 2007.
4. **Advanced analysis of gene expression microarray data**; *A. Zhang*; World Scientific Publishing, 2006.
5. **Bioinformatics for High Throughput Sequencing**; *N Rodriguez-Ezpeleta*; Springer; 2012.
6. **High-Throughput Next Generation Sequencing: Methods and Applications**; *Y. M. Kwon and S. C. Ricke*, Humana Press; 2011.

6. Practicals of data analysis in genomics & transcriptomics 2 credits

Unit I: Genome Analysis
Assembly and identification of SNPs from genome sequencing data, identification of repetitive elements, gene prediction and discovery cis-regulatory elements.

Unit II: Transcriptome Analysis
Analysis of DNA microarray data/RNA-seq, computing condition-specific patterns of co-expression of genes; identifying sets of co-regulated genes; constructing co-expression networks.

Unit III: Epigenetics
Analyzing chip-seq, methyl-seq and RNA-seq to identify context-specific epigenetic signatures.

Unit IV: Comparative genomics
Genome-wide identification of orthologs in newly sequenced genomes; identification of synteny between two organisms (CIRCOS); gene ontology based classification of the proteomes of species (BLAST2GO).

***Textbooks and Reference Books*:**

Same as mentioned above for the theory course.

7. Practicals of Structural Bioinformatics 2 credits

Unit I: Manipulation of structure data
Transformation from one coordinate system to the other; computing structural parameters using C/C++ programming languages.

Unit II: Structure comparison
Obtaining sequence alignment based on structure similarity for divergent proteins.

Unit III: Homology modeling and docking

Identification of a template structure/complexes, improving pair wise alignment using profiles and structural constraints etc, building model using commercial software packages, structure refinement using energy minimization and MD simulation, validating the structure by RMSD and intra-molecular interactions.

Unit IV: Fold Prediction
Proteins in the twilight zone, secondary structure prediction, predicting folds for divergent proteins using protein threading, validating the prediction by intra-molecular interaction.

Unit V: Rational drug design
Building 3D structure of ligand molecule. Inter-conversion of various formats Identification of putative drug binding pocket; computing interactions; identifying a potential candidate molecule using virtual screening approach. In silico docking studies: Docking of a ligand (small molecule) with a protein using commercial/freely available programs.

***Textbooks and Reference Books*:**

Same as mentioned above for the theory course.

8. Experimental Biology III 3 credits

Unit I: DNA handling
Isolation and quantification of genomic (plant and animal) and plasmid DNAs; analysis of DNA by electrophoresis and gel documentation methods, primer designing, PCR amplification of a target DNA.

Unit II: RNA handling
Isolation of mRNA from at least 2 types of sources, analysis by electrophoresis and gel documentation methods, RT-PCR, qRT-PCR, microarray.

Unit III: Cloning
Designing primers with mutations and restriction sites; cloning a RT-PCR product in simple vectors using restriction digestion and ligation; purification of cloned target and sequencing the same; gateway cloning.

Unit IV: Genetics
Bacterial genetics; F-plasmid, conjugation experiments; Drosophila phenotypes, mating, and hybrids.

Unit V: Basic protein handling
Basic protein extraction methods, electrophoretic (SDS, 2D gel electrophoresis) and spectrophotometric analysis (Bradford, Lowry, Biuret methods). Staining (CBB and Silver staining).

Unit VI: Expression and down-stream processing of proteins
Expression of cloned sequences in *E. coli* and *B. subtilis*; purification of proteins by standard column and batch chromatography, by salt precipitation, gel filtration and affinity chromatography; comparison of protocols for cell disruption and protein purification methods.

***Textbooks and Reference Books*:**

1. **The condensed protocols from the molecular cloning: A lab manual;** *J. Sambrook*; Cold Spring Harbour Lab. Press, 2006.
2. **Methods in biotechnology**, Taylor & Francis, 1997.
3. **Molecular biotechnology: Principles and application of recombinant DNA,** *B. R. Glick and J. J. Pasternak***,** ASM PRESS, 2004.
4. **Methods in biotechnology,** *H.P. Schmauder,* Taylor & Francis, 1997.
5. **Protein expression: A practical approach; S.** *J. Higgins and B. D. Hames, O*x**f**ord University Press, 2004.

9. Computer Languages IV (SQL, MySQL, Databases, HTML, XML, CGI/PERL) 2 credits

Unit I: SQL

Introduction to DBMS, RDBMS, SQL. Creating a database; altering a database; creating tables; altering tables; dropping tables. Entity-Relationship diagrams; normalization; primary keys and foreign keys. SQL Queries, Datatypes and Expressions: INSERT, UPDATE, DELETE, SELECT; conditions using WHERE, AND & OR, sorting using ORDER BY, grouping using GROUP BY, selecting unique records using DISTINCT. Integers, Character strings, Points, Date; boolean expressions, date expressions, numerical expressions. SQL Operators and Functions: Mathematical operators, logical operators, max(), min(), sum(), mid(), len(), round(), first(), count(), average(). Joins, views, and other miscellaneous SQL concepts.

Unit II: Database design principles and data architecture

Introduction to normalization theory query paradigms, query languages (SQL, pSQL and mySQL) similarity searches, approx.retrieval integrated data analysis & applications VIEWs across databases, pathway modeling, network queries. Developing data architecture using MySQL and oracle. Principles and developing modules on biological databases using relational system, developing genome annotation datasets, parsing, developing tables and relational systems.

Unit III: Overview of Internet, HTML & Basic HTML Tags

Overview of the Internet: Internet; web server; web browser; HTTP and HTML; domains and IP addresses. HTML Tags; pairing tags; attributes. Basic HTML Tags: html; head; body; title; headings; paragraphs; bold, italics and underline, horizontal rule. Colour models and representations; coloured text and background. Working with frames, images and tables: using frames; embedding images; creating tables; formatting tables.Creating hyperlinks to other pages; creating local hyperlinks; images as hyperlinks. Abbreviations, pre-formatted text; lists – ordered and unordered.Forms: need, form elements.

Unit VI: XML and DTD

Need for XML; differences between XML and HTML; application of XML; XML examples.
XML basics: elements; attributes; validation. DTD: DTD declarations-internal and external; use of DTD; DTD-XML building blocks; DTD basics: elements, attributes, entity- internal and external; validation; examples.

Unit V: Schema

Introduction; use of schema; examples; Simple types: elements, attributes, restrictions, examples; Complex types: elements- empty, elements only, text only, mixed, examples; indicators: order, occurrence, group, examples; data types: string, date, misc.

Unit VI: CGI, PHP and HTML forms

History of CGI; architecture and application of CGI and PHP. HTML forms revisited: HTML form elements and attributes; text fields; text areas; radio buttons; check boxes; submit button; reset button; drop down boxes; how to create an HTML form.CGI environment variables; simple responses. Sending data to the server; GET and POST method; use of CGI.pm module.

***Textbooks and Reference Books*:**

1. **MySQL and mSQL**; *Yarger*; O'Reilly Media Publishers, 1999.
2. **Mastering SQL**; *M. Gruber*; BPB Publications, 2000.
3. **CGI/Perl**; *D. Zak*; Thomson Learning, 1st edition, 2002.
4. **Database system concepts**; *A. Silberschatz*; McGraw-Hill, 4th edition, 2002.
5. **Fundamentals of database systems**; *R. Elmasari, S.B. Navathe*; 5th edition, 2006.
6. **A first course in database systems**; *J. D. Ullman and J. Widom*; Pearson Education, 3rd edition, 2008.
7. **Complete reference HTML;** *T. A. Powell*, Tata Mcgraw Hill, 1999.
8. **Beginning XML;** *D. Hunter***,** Shroff Publishers & Distributors, 2000.

SEMESTER IV

1. Fermentation and downstream processing	3 credits
2. Systems biology	2 credits
3. Data access and analysis for biological research	2 credits
4. Seminar	2 credits
5. Project	8 credits
TOTAL	**17 credits**

1. Fermentation and Downstream Processing 3 credits

Unit I: Fermentation and fermenters
Introduction (theory): Basic types and principles of fermentation and their applications. Anatomy, operation and maintenance of fermenters for bacteria and mammalian cells.

Unit II: Introduction to downstream processing
Significance of downstream processing in biotechnology; principles, procedures and economics of downstream processing, physico-chemical principles involved in bio-separation processes.

Unit III: Product purification
Intracellular and extracellular fermentation products; options for cell disruption for intracellular products, removal of insoluble, debris/biomass separation techniques, flocculation and sedimentation, centrifugation and filtration methods. Membrane-based separations (micro and ultrafiltration).

Unit IV: Precipitation and extraction processes
Precipitation using salts, organic solvents, and polymers; aqueous two-phase extraction, supercritical extraction; dialysis, crystallization, etc.

Unit V: Fermenter operation
Anatomy, operation and maintenance of fermenters for bacteria and mammalian cells.

Unit VI: Bacterial growth dynamics
Thorough bacterial growth studies and preliminary fermentation exercises.

Unit VII: Fermentation and product purification
Case studies in fermentation and product purification.

Unit VIII: Basic laboratory procedures
Use of laboratory scale fermenters to overexpress a cloned protein.

Unit IX: Downstream processing
FPLC use to purify the protein of interest.

***Textbooks and Reference Books*:**

1. **Rate controlled separations;** *P C Wankat*; Elsevier, 1990.

2. **Bioseparations**; *P A Belter and E Cussle*r; Wiley 1985.
3. **Product recovery in bioprocess technology;** BIOTOL Series, VCH, 1990.
4. **Separation processes in biotechnology**; *J. M. Asenjo*; 1993.
5. **Batch fermentation - modeling, monitoring and control**; *A. Cinar, S. J Parulekar, C. Undey and G. Birol;* Marcel Dekker, New York, NY, 2003.
6. **Culture of animal cells**; *R. Ian Freshney*; John Wiley & Sons, Inc, 1998.
7. **Downstream processing of proteins: methods and protocols (methods in biotechnology**); *M.A. Desai*; Humana Press, 2000.
8. **Principles of fermentation technology**; *P.F. Stanbury et.al*; Elseivier Science, 2nd edition, 2003.
9. **Fermentation and biochemical engineering handbook: Principles, process design and equipment**; *H.C. Vogel and C.C. Haber*; Noyes Publications, 2nd edition, 2007.

2. Systems Biology 2 credits

Unit I:
MATLAB usage: data types, data structures, conditional loops, 2D and 3D plots, matrix operations, ODE solvers, curve fitting. MM kinetics, numerical solutions to first order ordinary differential equations (ODE) using MATLAB. Introduction to system biology and mathematical modeling.

Unit II:
Static network models: Interaction graphs, Bayesian reconstruction of interaction networks, signaling networks, metabolic networks, modeling with ODE's with examples. Discrete and continuous linear system models, continuous non-linear systems, stability analysis, parameter sensitivity, parameter estimation, linear regression of several variables. Physiological modeling : simple models of oscillations with heart as an example, few more examples.

Unit III:
Gene regulation, models of regulation, transcription factors, gene interaction network, Lac Operan as an example. Protein system, proteins as enzymes, transporters and carriers, protein-protein interaction network, protein-promoter interactions, comparison of system biology between prokaryotes Vs. Complex eukaryotes.

Unit IV:
Metabolic pathways and their representation, KEGG. Mathematical formulation of elementary biochemical reactions, metabolic flux analysis, modeling metabolic pathways with ODE, Pharmaco kinetic models (PBPK) with examples, signal transduction systems. Population systems : Population growth, models of population growth, population dynamics under external perturbations.

Unit V:
Resource usage, with case studies, in protein-protein interactions, protein-promoter interactions, pathways and cross-talk between pathways. Comparison of systems biology for prokaryotes vs. complex eukaryotes.

***Textbooks and Reference Books*:**

1. **Advanced analysis of gene expression microarray data**; *A. Zhang*; World Scientific Publishing, 2006.

2. **Systems biology: A textbook**; *E. Klipp* et.al.; Wiley, 2009**.**
3. **DNA microarrays;** *M. Schena*; Scion Publishing, 2006.
4. **Computational Systems Biology of Cancer**; *E. Barillot, L. Calzone, P. Hupe and J-P Vert*; CRC Press; 2013**.**
5. **Matlab: A practical introduction to programming and problem solving;** *S. Attaway*, Butterworth-Hienemann, 2009**.**
6. **Matlab for neuroscientists: An introduction to scientific computing in matlab;** *P Wallisch, M Lusignan, M Benayoun, and T. I. Baker*, Elsevier, 2009**.**
7. **Essentials of MATLAB programming;** *S. J. Chapman*, 2nd Edition, BAE SYSTEMS, Australia.

3. Data Access and Analysis for Biological Research 2 credits

Unit I: Case studies with common bioinformatics resources
Mock-studies on important genes, proteins and diseases using OMIM, Gene Entrez, Gene ontology, Uniprot and HPRD.

Unit II: Data structure, access and application of resources
Comparisons of formats, volumes and utilities of datasets across GEO, ArrayExpress, dbEST and SRA. Specific applications of online and commercial tools with 'R' and Unigene. Exercises in data interpretation.

Unit III: Comparing major portals and common databases
Identifying specific advantages across major portals: NCBI, EMB, UCSC and Expasy. Comparing the utilities of databases for microRNA, SNPs, orthologs and alternative splice-forms.

Unit IV: Use of specialized databases and software
Gene-id conversions, specialized primer-designing software, ortholog-resources, gene, promoter and alternative-splice-form prediction tools, databases for carbohydrates, lipids and small molecules. Introduction to medical informatics and clinical research, and relevant resources.

***Textbooks and Reference Books*:**
1. NCBI: http://www.ncbi.nlm.nih.gov/
2. EMBL: www.embl.de/
3. UCSC: genome.ucsc.edu/
4. Expasy: http://www.expasy.org/
5. GEO: http://www.ncbi.nlm.nih.gov/geo/
6. Unigene: www.ncbi.nlm.nih.gov/UniGene/
7. Genecards: http://www.genecards.org/
8. Directory of bioinformatics resources: startbioinfo.com & http://www.bioinformatics.ca/links_directory

OTHER MODULES (over 2 years) non-credit

The following topics are important professional skills that will be taught in non-credit mode.

1. Bioethics	2. Intellectual property	3. Exposure to entrepreneurship	4. Spoken and written English	5. Typing