Department of Systems and Computational Biology
School of Life Sciences
University of Hyderabad

Vision

"The Whole is Greater than the Sum of its Parts." – Aristotle

To explore spatio-temporal organisation of different biomolecular components, their regulation and interactions that give rise to different emergent properties of living systems in different milieu and niche.

Mission

Being interdisciplinary in nature, the department wishes to embrace the following mission statements:

MS-1: To provide education that commensurate with high international standard in the area of computational and systems biology.

MS-2: To carry out research in the frontier areas of computational and systems biology.

MS-3: To develop novel tools/protocols/pipelines to help advance research and development in the allied areas.

MS-4: To collaborate with premier research institutes/universities to advance interdisciplinary research.

MS-5: To help/assist underprivileged institutions and universities to undertake academic and R & D activities in the area of computational and systems biology.

Department of Systems & Computational Biology
School of Life Sciences
University of Hyderabad

Integrated Master of Science in Systems Biology

Qualification Descriptors (Program objectives)

The objectives of the I.M.Sc. program in Systems Biology are:

QD-1: To **impart** comprehensive skills in interdisciplinary areas of Life Sciences and their applications to understand biological systems.

QD-2: To **apply** "systems" approach such as, mathematical modeling or networks, to understand complex biological systems.

QD-3: To **use** computational skills such as, programming and data analytics, to analyze large sized biological data and to develop prediction/classification protocols.

QD-4: To **research/investigate** a biological problem by finding gaps, designing experiments, carrying out relevant wet/dry lab experiments and analyzing results.

QD-5: To **communicate** effectively the concept, logic, interpretation and applicability of research outcomes and acquired knowledge.

Mapping Qualification Descriptors with Mission Statements

	MS-1 (quality education)	**MS-2** (research in frontier areas)	**MS-3** (tools/pipeline development)	**MS-4** (collabotations/ network)	**MS-5** (academic responsibility)
QD-1 (knowledge)	3	3	1	1	1
QD-2 (systems approach)	3	3	2	1	1
QD-3 (Computational skills)	3	3	3	2	1
QD-4 (Research skills)	2	3	2	3	2
QD-5 (communicatio n skills)	3	3	1	3	1

'3' – *High-level*
'2' – *Medium-level*
'1' – *Low-level*

Department of Systems and Computational Biology
School of Life Sciences
University of Hyderabad

Integrated M.Sc. in Systems Biology

Program Learning Outcomes

After completion of this program the students will be able to:

PLO 1: Disciplinary Knowledge: Demonstrate comprehensive skills in interdisciplinary areas of Life Sciences and their applications to understand complex biological systems.

PLO 2: Communication Skills: Communicate effectively the concept, logic, interpretation and applicability of research outcomes and acquired knowledge.

PLO 3: Critical Thinking: Analyze and evaluate the results obtained from various laboratory experiments (including computational studies) and published literature.

PLO4: Problem Solving: Set hypothesis followed by design and execution of experiments and analyze and interpret results.

PLO 5: Research-related Skills: Investigate a biological problem by finding gaps, designing experiment, carry out relevant wet/dry lab experiments, and analyze results.

PLO 6: Collaboration/Cooperation/Teamwork: Collaborate with students or investigators within and outside the department for research projects/journal club/exhaustive assignments.

PLO 7: Information/ Digital Literacy: Write scripts/programs in programming languages such as C/python/R. Retrieve, analyze, interpret data from biological databases. Understand the working of public domain tools in the area of computational systems biology.

PLO 8: Self-directed learning: Understand, discuss and apply the knowledge gained from published literature.

PLO 9: Moral and Ethical Awareness/Reasoning: Demonstrate good laboratory practices as well as good academic ethics.

PLO 10: Leadership Readiness/Qualities: Undertake independent research and development activities**.**

PLO 11: Lifelong Learning: Demonstrate the ability to work in teams, objectivity in research, critical thinking, problem solving, ethical awareness.

Mapping Program Learning Outcomes with Qualification Descriptors

	QD-1	QD-2	QD-3	QD-4	QD-5
PLO-1	3	3	3	3	2
PLO-2	3	1	1	2	3
PLO-3	3	3	3	3	2
PLO-4	3	3	3	3	2
PLO-5	3	3	3	3	2
PLO-6	1	2	2	2	2
PLO-7	3	3	3	3	3
PLO-8	2	2	3	3	2
PLO-9	1	1	1	1	1
PLO-10	1	1	1	2	2
PLO-11	2	2	2	3	3

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

UNIVERSITY OF HYDERABAD
DEPARTMENT OF SYSTEMS AND COMPUTATIONAL BIOLOGY (DoSCB)
School of Life Sciences (SLS)

IMSc (Systems Biology) 5 years

COURSE TITLES

Please note: Semester Courses I to IV are offered at Centre for Integrated Studies

First Year: SEMESTER: I

S.No	Course Code	Course title	Credits	School /Department offering the course
1	EN101	English-I	4	English
2	ES101	Environmental Studies	3	CEOAS/Guest faculty
3	PY101	Physics-1A: Mechanics Physics-1B: Mechanics (Compulsory for Physics Students and optional For Students with Mathematics in class 12)	4	Physics
4	CY101	Chemistry 1 Stiochiometry, Solutions & Gases	3	Chemistry
5	MM103	Maths1 (complex numbers, Vectors, Matrices, elementary functions, analytical geometry)	4	Mathematics
6a*	SB102	Foundation Biology (for Math students)	3	SLS
6b*	MM102	Bridge Maths (for Biology students) (for students with no Mathematics in class 12)	3	Mathematics
6c*	EC101	Introductory Economics (for students who have done Biology and Maths) * Students choose any one of the three courses	4	Economics
7	IPY102	Mechanics Lab	1.5	Physics and Chemistry
	CY102	Qualitative Analysis lab	1.5	**Total cr: 24**

First Year: SEMESTER: II

8	English-II	English-2	4	English
9	SB151	Introductory Biology	3	SLS
10	PY 201	Physics (Waves and Oscillations; Light and Sound)	4	Physics
11	CY151	Chemistry (Energetics and Kinetics)	3	Chemistry
12	MM152	Maths2 (Multivariable calculus, Mathematical analysis)	4	Mathematics
13	IT-1	Information Technology IT-1	2	Computer Science
14	SB 152	Biology Laboratory I: Introductory Biology	1.5	SLS
	PY152	Waves, Oscillations, Sound and Light Lab	1.5	Physics
	CY152	Quantitative Analysis lab	1.5	**Total Cr: 24.5**

Second Year: SEMESTER: III

15	PY201	Physics (Electricity and Magnetism)	4	Physics
16	CY201	Structural Chemistry	3	Chemistry
17	SB201	Structure and Function of Macromolecules	3	SLS
18	MM202	Maths 3A: Ordinary Differential Equations (ODE), Laplace transforms& Fourier series	4	Mathematics
19	MM203	Math-3(B) Introductory Probability and Statistics	4	Mathematics
20	IT	IT MatLab	2	Computer Science

21	SB202	Biology Laboratory II	4.5	SLS
	PY202	Phys Lab: Electricity and Magnetism Lab		Physics
	CY202	Chem Lab: Physical Chemistry Lab	1.5	**Total Cr: 24.5**
Second Year: SEMESTER: IV				
22	PY251	Physics: Modern Physics (including Special Theory of Relativity)-	4	Physics
23	CY 251	Chemistry 4: Basic Organic Chemistry	3	Chemistry
24	SB251	Molecules & Information Processing (Molecular Biology)	3	SLS
25	MM252	Maths 4B (Algebra: Group theory and vector spaces)	4	Mathematics
26	MM251	ELECTIVE Math 4A (Analysis)	4	Mathematics
27	SB253	ELECTIVE: Evolution and Diversity	2	SLS
28	SB 254	ELECTIVE: Neuroscience of behavior	2	CNCS
29	ELECTIVE	Statistical Thermodynamics/ mathematical methods for Physics (in place of Math 4B)	4	Physics
30	CY253	ELECTIVE : Basic supramolecular Chemistry	2	Chemistry
31	CY254	ELECTIVE: Basic Polymer Chemistry	2	Chemistry
32	SB252	Biology Lab: Structure and Function of Macromolecules Lab	1.5	SLS
	PY252	Phys Lab: Heat & Thermodynamics Lab	1.5	Physics
	CY252	Chem Lab: Identification of Organic compounds Lab	1.5	**Total Cr: 22.5**
Third Year: SEMESTER: V				
33	SB 301	Microbiology	3	SLS
34	SB302	Computers and programming	3	SLS
35	SB303	Genetics	3	SLS
36	SB 304	Metabolic Pathways (Intermediary Metabolism)	3	SLS
37	SB 305	Biophysical Chemistry	3	SLS
38	SB 306	Lab Techniques (Microbiology/Genetics/ Cell Biology/ Comp.Prog)	6	**Total Cr: 21**
Third Year: SEMESTER: VI				
39	SB 351	Cell Biology	3	SLS
40	SB 352	Enzymology and Bioenergetics	3	SLS
41	SB 353	Developmental Biology (Plants and Animals)	4	SLS
42	SB 354	Physiological processes (Plants and Animals)	3	SLS
43	SB355	Biological Host defense: Systems Immunology	3	SLS
44	SB356	Lab Techniques (Biochemistry Lab (Enzy and Bio)/ Plant Physiology & Dev Biol Lab/ Biological Host defense/ R programming practicals)	6	**Total Cr: 22**
Fourth Year: SEMESTER: VII				
45	SB 401	Recombinant DNA technology and Gene Regulation	3	SLS
46	CA501	Computer Based Numerical Methods	3	SLS
47	SB403	Bioinformatics	3	SLS
48	SB404	Statistical Physics for Biologists	3	Physics/SLS
49	SB405	Proteomics	4	SLS
50	SB 406	LAB Techniques (Mol.Bio/Proteomics /CBNM/Bioinformatics)	6	**Total Cr: 22**
Fourth Year: SEMESTER: VIII				
51	SB451	Genomics	3	SLS
52	SB452	Computational systems biology	4	SLS

53	SB453	Machine Learning and Data analytics	3	SLS
54	SB454	Molecular Modeling and simulations	3	SLS
55	Elective-I	Elective – I any from School of Life Sciences	2	SLS
56	SB456	Lab Techniques (Genomics/Computational Systems Biology/Machine Learning Methods and Data Analytics/ Molecular Modeling and Simulations)	6	**Total cr: 21**
Fifth Year: SEMESTER: IX				
57	SB 501	Comparative Systems Modeling	2	SLS
58	Elective – II	Elective – II any from School of Life Sciences	2	SLS
59	SB506	Laboratory Techniques (Comparative systems modeling)	2	SLS
60	SB507	Seminars (To be evaluated by a panel of faculty)	2	SLS
61A	Project	Project	6	**Total cr: 14**
Fifth Year: SEMESTER: X				
61B	SB551	Project	16	SLS
62	SB552	Comprehensive Viva	2	SLS
63	SB553	Formal and Computational Approaches in Cognition	4	**Total Cr: 22**

1st SEMESTER**

**** Please note: The details of the courses offered by School of Life Sciences are given below. The details of the other courses for this semester could be obtained from Centre for Integrated Studies (CIS)**

Department of Systems and Computational Biology
School of Life Sciences
University of Hyderabad

Integrated M.Sc Systems Biology

Course Code	**:**SB 102	**Credits**	**:** 3
Title of the Course	**:** Foundation Biology (for Maths students)	**L-T-P**	**:** 3-0-0
Prerequisite Course	**:** Intermediate		

After the completion of this course, the students will be able to

CLO 1: Explain the Science of life and its chemical basis of biology

CLO 2: Describe the basics of biomolecules and their importance

CLO 3: Explain microscopy-visualized by light microscopy to fluorescence to confocal to electron microscopy

CLO 4: Discuss Cells as units of life which cover unicellular and multicellular architecture

CLO5: Explain the cellular organization function in both plant and animal cells

CLO6: Describe the basics of membrane structure and function in both animal and plant

CLO7: Understand the Cellular communication and signals

CLO8:

Mapping with PLOs

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO10	PLO11
CLO 1	3										
CLO 2	3										
CLO 3	3			3							
CLO 4	3										
CLO 5	3										
CLO 6	3										
CLO 7	3										
CLO 8											

'3' – *High-level*
'2' – *Medium-level*
'1' – *Low-level*

Syllabus

- **Science of life and its chemical basis**: introduction to what is life, how biology is studied and importance of studying biology (2hr).
- **Chemistry of life:** importance of water, brief mention of macromolecules that make life forms (4hr). Nucleic acids and origin of life (4hr)
- **Brief introduction to microscopy:** taking examples of a couple of structures as visualized by light microscopy to fluorescence to confocal to electron microscopy (2 hr)
- **Cells as units of life:** Features of fundamental units of life, prokaryotic and eukaryotic cell, organization of prokaryotic cell, organelles in eukaryotes (nucleus, cytoplasm, mitochondria, lysosome, peroxisomes, endomembrane system, cytoskeleton, chloroplast, cell wall, extracellular matrix) (6)
- **Cell membranes:** basic structures, specialization of membranes: adherence, selective permeability, active process of transport and communication between organelles, communication between cells and between cells and environment. Other specialized functions of membranes (8)
- **Cell communication and multicellularity**: signals, signal receptors, response to signals (10)

Total credits: 36hr

2nd SEMESTER**

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Department of Systems and Computational Biology
School of Life Sciences
University of Hyderabad

Integrated M.Sc Systems Biology

Course Code	**:**SB 151	**Credits**	**:** 3
Title of the Course	**:** Introductory biology	**L-T-P**	**:** 3-0-0
Prerequisite Course	**:** Intermediate		

After the completion of this course, the students will be able to

CLO 1: Understand and explain the structure of different amino acids, carbohydrate, nucleic acids and lipid molecules.

CLO 2: Explain the role of biomolecules in living organism.

CLO 3: Understand the concept of Plant with environmental challenges and role of plants under different environmental conditions.

CLO 4: Understand and explain the cell cycle, cell division and basics of Mendelian Genetics.

CLO5: Understand the enzyme action and metabolism in the cellular system

CLO6: Explain physiological and temperature regulation mechanisms with knowledge on endocrine and defense system.

CLO7: Explain the energetics in respiration and photosynthesis

CLO8: Understand and explain the apoptosis and cancer related mechanism.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3										
CLO 2	3										
CLO 3	3										2
CLO 4	3				3						
CLO 5	3				3						
CLO 6	3				3						
CLO 7	3				3						
CLO 8	3				3						

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus

- **Energy, enzymes and metabolism**: Start with Thermodynamics and move to ATP in biochemical energetics; Enzymes and how they work, introduction to respiration and photosynthesis (8 hrs)
- **Cell cycle** (basic regulation and introduction to apoptosis and cancer) (2 hrs);
- **Inheritance biology**: mitosis and meiosis (2hr); Mendelian genetics (2 hrs)
- **Plant responses to environmental challenges** (4 hrs)
- **Animal physiology**, homeostasis and temperature regulation; endocrine system and defense systems (6 hrs)
- **Amino acids**: chemical structures and classification, peptide bond, uncommon amino acids and their roles, titration curves of amino acids, isoelectric point, oligo peptides (3Hrs)
- **Carbohydrates**: monosaccharides, disaccharides, aldoses and ketoses, chiral properties and structural representations, reducing sugars, glycosidic bonds, phosphodiester bonds (4 hrs)
- **Nucleotides**: purines and pyrimidines, nucleosides and nucleotides chemical and physical properties, chargaff rules (4 hrs)
- **Lipids**: storage lipids, triacyl glycerols, fatty acids and their properties and nomenclature (3 hrs)

Textbooks:

a) Life: The Science of Biology by Sadava et al
b) Biology by Raven and Johnson
c) Campbells Introduction to biology

Department of Systems and Computational Biology
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Integrated M.Sc Systems Biology

Course Code	**:**SB 152	**Credits**	**:** 1.5
Title of the Course	**:** Biology Lab I (Introductory Biology)	**L-T-P**	**:** 0-0-2
Prerequisite Course	**:** Intermediate		

After the completion of this course, the students will be able to

CLO 1: Explain the different organelle of a typical flower and their functional role in sexual reproduction and identify different cellular events in the growing cells such as Stomata, Anatomical features, stages of mitosis cell division etc.

CLO 2: Can grow different plants and non-pathogenic microbes in suitable environmental conditions/media and maintain them.

CLO 3: Can explain the particular biological events, themes, concepts or problems in form of posters using research based pedagogical tools.

CLO 4: Can identify the structures of Testis and ovary in animals

CLO5: Can understand blood grouping and its related genetic pedigree.

CLO6: Can identify binary fission and meiotic division.

Mapping with PLOs

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO10	PLO11
CLO 1	3		3	3	3	2					
CLO 2	3		3	3	3	2					
CLO 3	3		3	3	3	2					
CLO 4	3		3	3	3	2					
CLO 5	3		3	3	3	2					
CLO 6	3		3	3	3	2					
CLO 7											
CLO 8											

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus

1. Sexual Reproduction in Plants. Parts of flowers: show several types from the University / local neighborhood area etc
2. Phototropism: Different types of Seed germination, growth of plants under normal and different stress conditions.
3. Peel of Onion for Mitosis cell division
4. Isolation of Starch from Potato
5. Stomata opening and closing
6. Microbes are everywhere: Growth of microorganism from Hair, key ring, Currency notes, wallet, thumb impression, mouth swab, spec, pen, hanky, watch, mobile phone, belt etc.
7. Cheek cells
8. Oxygraph:
9. Blood Grouping
10. Chromosome Preparation
11. Culture of Paramecia: Feeding, behavior, chemotaxis, conjugation (Can use any model system or combination of model systems)
12. Respiration in animals
13. Permanent slide: mitosis, meiosis, Blood cells (diff types of cells from various animals) etc.
14. Observation of colour: scales vs insects

3rd SEMESTER**

**** Please note: The details of the courses offered by School of Life Sciences are given below. The details of the other courses for this semester could be obtained from Centre for Integrated Studies (CIS)**

Department of Systems and Computational Biology
School of Life Sciences
University of Hyderabad

Integrated M.Sc Systems Biology

Course Code	**:**SB 201	**Credits**	**:** 3
Title of the Course	**:** Structure and Function of Macromolecules	**L-T-P**	**:** 3-0-0
Prerequisite Course :	Intermediate		

After the completion of this course, the students will be able to

CLO 1: Understand the primary, secondary, tertiary, and quaternary structure of a protein

CLO 2: Understand the fundamental structures of different carbohydrates

CLO 3: Correlate the biological function of proteins and carbohydrates on the basis of their structure

CLO 4: Understand the structure, composition, and classification of lipids

CLO 5: Explain the role of lipids in the cell structure and function

CLO6: Understand the composition, structure, properties, and functions of nucleic acids

CLO7: Explain the role of nucleic acids in cell structure and function

CLO8: Apply the knowledge gained on structure and function of basic biological molecules in making choices in life style

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	3	3	2	2	2	2	3	3	3	3
CLO 2	3	3	3	2	2	2	2	3	3	3	3
CLO 3	3	3	3	3	3	2	2	3	3	3	3
CLO 4	3	2	3	3	3	2	2	1	1	1	3
CLO 5	3	2	3	3	3	2	1	3	1	1	3
CLO 6	3	2	3	3	3	2	1	3	1	1	3
CLO 7	3	2	3	3	3	2	1	3	1	1	3
CLO 8	3	2	3	3	3	2	1	3	1	1	3

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus

- **Biological macromolecules**
- **Nucleic Acids**: Different forms of DNA, interaction of DNA with proteins, drugs, dyes and carcinogens, hydrogen bonding interactions, structure of RNA, basic differences between DNA and RNA structures, structure of yeast phenylalanine tRNA. Different forms of RNA, ribozyme and Riboswitch: structure and function, ribosome: subunits and structure;
- **Protein structure and function**: secondary structure, tertiary structure and quaternary structure. Forces that stabilize protein structure, Ramachandran plot, Structural classification of protein- fold/motif, class, family and superfamily, structure function correlation, functional conformation of protein, protein folding and denaturation, molecular chaperones assist protein folding, regulatory protein- transcription factor structure and function, structure of antibody, motor proteins (myocin, actin), structure and function of myoglobin and hemoglobin, proteins involve in signal transduction and structural change in receptor proteins.
- **Structure and function of higher order chromatin**: Packaging of DNA into chromosomes, Superhelicity, Linking Number, Toposiomersases, Histones and their modifications, Euchromatin, Hetrochromatin, Centromere and Telomere Structures, Regulation of different types of chromation.
- **Different types of Lipoproteins and their role in health and disease**

Recommended books:

- Biochemistry, Lehninger A.H.,
- Proteins: Structure, function and evolution. Dickerson & Geis, 2nd Edn,
- Protein: Structure and molecular properties: Thomas E. Creighton.

Department of Systems and Computational Biology
School of Life Sciences
University of Hyderabad

Integrated M.Sc Systems Biology

Course Code	**:**SB 202	**Credits:** 1.5
Title of the Course	**:** Biology Lab II (Structure &Function of Macromolecules)	**L-T-P :** 0-0-2
Prerequisite Course :	Intermediate	

After the completion of this course, the students will be able to

CLO 1: Prepare standard solution, dilution of solutions, buffer preparation and use of micropipette

CLO 2: Carry out paper chromatography.

CLO 3: Qualitative analysis of DNA, RNA, and protein

CLO 4: Estimation of protein by more than one method

CLO5: Determine the Tm of a DNA sample

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	3	3	3	3	3	2	3	3	3	3
CLO 2	3	3	3	3	3	3	2	3	3	3	3
CLO 3	3	3	3	3	3	3	2	3	3	3	3
CLO 4	3	3	3	3	3	3	2	3	3	3	3
CLO 5	3	3	3	3	3	3	2	3	3	3	3
CLO 6											
CLO 7											
CLO 8											

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus

1. Introduction to Techniques: Use of Pipetmen
2. Preparation of Standard Solutions and Dilutions
3. Preparation of Buffers
4. Separation of chlorophyll pigments by paper chromatography
5. Qualitative test for lipids
6. Qualitative test for lipids
7. Analysis of DNA, RNA and Proteins
8. Extraction of total genomic DNA from banana
9. Purification of Nucleic acids (DNA)
10. Estimation of Protein by spectrophotometer
11. Estimation of Protein by Lowry method
12. Determination of Tm of a DNA sample

4th SEMESTER**

**** Please note: Only the courses offered by School of Life Sciences are given below. The details of the other courses for this semester could be obtained from Centre for Integrated Studies (CIS)**

Department of Systems and Computational Biology
School of Life Sciences
University of Hyderabad

Integrated M.Sc Systems Biology

Course Code :SB 251	**Credits** : 3
Title of the Course : Molecules and Information processing (Mol. Bio.)	**L-T-P** : 3-0-0
Prerequisite Course : Intermediate	

After the completion of this course, the students will be able to

CLO 1: understand the concepts of a gene, DNA, genome and chromosome, the commonalities and differences in the general chemistry and make up of the biomolecules like DNA, RNA and proteins, and the different forms of DNA based on shape, structure, functions and reassociation kinetics; different forms of RNA and their functions, and the importance of proteins in various cellular functions.

CLO 2: understand the transmission of information stored in DNA sequences in parental cells to daughter cells through a process called DNA replication and repair; and the paraphernalia or the machinery that is required to carry out the this copying of DNA in a very defined and precise manner without errors preferably to understand how the **genome or the entire cellular DNA is maintained** and preserved for generations.

CLO 3: explain how the information in the nucleotide sequences in DNA is divided into coding and non coding sequences to synthesize different RNAs and in regulating their synthesis (turning on and off) through a process called transcription , and then how the sequences in RNA are decoded to the corresponding amino acid sequences in proteins by a machinery called translational machinery that contains ribosomes, tRNAs, several protein factors and enzymes. These two process transcription and translation, collectively called as **Gene Expression is required for day today cellular transactions.**

CLO 4: understand the basic methods which are developed to determine the sequences in DNA, enzymes that are discovered a) to amplify DNA in test tube reactions, b) cut the DNA precisely to enable cloning the DNA sequences of our choice with other DNAs c) prepare DNA from given RNA sample and purification selectively messenger RNAs from other RNAs using the special sequences (poly A) in mRNA at the 3' end to enable the researchers to translate these mRNAs into the corresponding proteins

Mapping with PLOs

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO10	PLO11
CLO 1	3		2		3						
CLO 2	3		2		3						
CLO 3	3		2		3						
CLO 4	3		2		3						

'3' – *High-level*
'2' – *Medium-level*
'1' – *Low-level*

Syllabus

- Flow of information in Biological Systems, Typical rules governing the synthesis of DNA, RNA and Proteins (E. coli as a model) The DNA language/chemistry, structure and the machinery of replication. Genomes, Gene-density, C value Paradox, Cot values (8 h)
- DNA Replication, Replication of chromosome ends. Repetitious DNA, Mobile/Transposan elements, mechamisms of transposition, Tm (melting temperature) of DNA and its practical application of DNA topology, Topoisomerases and Linking number. Chemicals that affect DNA structure, DNA sequencing, Methods (14 h)
- Regulatory elements in DNAs and mRNAs. Different types of (RNAs tRNA, mRNA, rRNASn RNAs, Micro RNAs and Silencing RNAs). RNA synthesis in brief in prokaryotes and eukaryotes, Co and post transcriptional modifications like alternative splicing, 5'Cap and ply A addition etc., Genetic code, and the machinery and mechanics of cytosolic and secretary protein synthesis. (14 h)

Books recommended:

- Molecular Biology of Gene: Watson et al.,
- Molecular Cell Biology: By Darnell, Lodish, Baltimore.
- Concepts of Genetics William S Klug and M. R. Cummings

Department of Systems and Computational Biology
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University of Hyderabad

Integrated M.Sc Systems Biology

Course Code	**:**SB 252	**Credits**	**: 1.5**
Title of the Course	**:** Molecules and Information processing Lab	**L-T-P**	**:** 0-0-2
Prerequisite Course	**:** Intermediate		

After the completion of this course, the students will be able to

CLO-1: Understanding the various methods involved in estimation of macromolecules.

CLO-2: Students will understand the principle involved in Spectrophotometer and Colorimeter, optical density measurements etc.

CLO-3: Principles behind specific reactions of RNA and DNA backbone

CLO-4: Estimation of proteins and sensitivity and role of various amino acids composition and peptide bonds in primary structure of protein

CLO-5: Selection of various gels for macromolecule separation and determination of pore size vs gel composition etc.

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO1 0**	**PLO1 1**
CLO 1	3	1	1					2			
CLO 2	3	1	1					2			
CLO 3	3	2	3	3	3		2				
CLO 4	3	2	3	3	3				2	3	3
CLO 5	3	2	2	2	3	3	3	2	3	3	3

Syllabus

1) Estimation of Protein by Bradford. Compare sensitivity
2) Estimation of DNA and RNA by chemical methods: orcinol and DPA.
3) Estimation of Phosphate by Fiske and Sabbarow method
4) Isolation of plasmid DNA; separation on agarose gel
5) Isolation of Protein and Separation on protein gel
6) Growth curve for bacteria andestimation of doubling time (learn to make media, streak colonies, inoculate etc)

Department of Systems and Computational Biology
School of Life Sciences
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Integrated M.Sc Systems Biology

Course Code	**:**SB 253	**Credits**	**:** 2
Title of the Course	**:** Evolution and Diversity (Elective)	**L-T-P**	**:** 2-0-0
Prerequisite Course	**:** Intermediate		

After the completion of this course, the students will be able to

CLO 1: explain the concepts of evolution, and have a broad understanding how life originated from molecules present on primitive earth to the present complex forms.

CLO 2: discuss the morphological, anatomical and behavioural diversity among prokaryotes and eukaryotes (fungi, plants and animals).

CLO 3: construct and analyze phylogenetic tress using phenotypic features or sequence information.

CLO 4: apply the concepts of evolution to provide solutions to some of the environmental/ecological problems.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	1	1					2			
CLO 2	3	1	1					2			
CLO 3	3	2	3	3	3		2				
CLO 4	3	2	3	3	3				2	3	3
CLO 5											
CLO 6											
CLO 7											
CLO 8											

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus: SB253 Evolution and Diversity (Elective; 2 credits)

1. Origin of life, evolution by Natural Selection, speciation and phylogeny.
2. Prokaryotic domain: bacteria and archea
3. Evolution of plants, colonization of land and evolution of seed plants
4. Evolution of animals and animal body plan
5. Diversity in microbial, plant, fungal and animal kingdoms.

Text books:

1) Life: The Science of Life by Sadava et al. (9th Edition; older editions may suffice)
2) Biology by Raven, Johnson, Mason et al. 10th edition (older editions may suffice)

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Integrated M.Sc Systems Biology

Course Code	**:**SB 254	**Credits**	**:** 2
Title of the Course	**:** Neuroscience of behavior	**L-T-P**	**:** 2-0-0
Prerequisite Course	**:** Intermediate		

After the completion of this course, the students will be able to

CLO 1: Understand basic neurophysiology underlying behaviour.

CLO 2: Understand how sensory and motor system works and get coupled.

CLO 3: Be able to read and understand works in the area of neuroethology.

CLO 4: Be able to understand mechanisms underlying learning and memory

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	2	3	2	2						2
CLO 2	3	2	3	2	2						2
CLO 3	3	2	3	2	2						2
CLO 4	3	2	3	2	2						2
CLO 5											
CLO 6											
CLO 7											
CLO 8											

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Module 1: Neurons as the Building Blocks of Behavior: Basic Neurobiology, Neurons, Hodkin-Huxley model, Synaptic transmission, Neurotransmitters in vertebrate and invertebrate systems and functional equivalence; Computation at the synapse; Neuronal circuits .

Module 2: Sensory Worlds: Transduction and perception of stimuli; Cases of echolocation in bats: circuits of echolocation, function of the circuit, timing in circuits; Feature analysis in toads: Edge detection and other feature detection for prey predator identification in visual pathway of toads. How decision in visual pathway affects behavioral choice.

Module 3: Motor Strategies: Circuits mediating flight in locust; Principle of control and visual feedback in flight; Escape behavior in crayfish; Principles of mechano-sensation and circuits mediating. Hennemans size principle. Optimal control principle in neuromuscular control.

Module 4: Behavioral Plasticity: Classical and operand conditioning; STDP, LTP, Hebbian principle; Associative learning in honeybees. Rescolawagner model, TD learning and reinforcement learning. Temo and Spatial navigation in rats: Place code in hippocampus, entorhinal cortex and hippocampal network with underlying grid cells and place cell network.

Reference:

Behavioral Neurobiology: The Cellular Organization of Natural Behavior: Thomas J. Carew; Sinauer

5th SEMESTER

Department of Systems and Computational Biology
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Integrated M.Sc Systems Biology

Course Code	**:**SB 301	**Credits**	**:** 3
Title of the Course	**:** Microbiology	**L-T-P**	**:** 3-0-0
Prerequisite Course	**:** Intermediate		

After the completion of this course, the students will be able to

CLO 1: Explain the historical discoveries made in the field of microbiology and the evolution of microbiology including virology.

CLO 2: Discuss the applications of microorganisms in various fields like agriculture, medicine, industry and health.

CLO 3: Apply the knowledge of techniques for isolation and cultivation (including high-throughput cultivation) of microorganisms (algae, fungi, bacteria and virus).

CLO 4: Explain the diversity of bacteria, classification and identification with knowledge of general characters of various bacterial phyla.

CLO5: Discuss the insights of cellular composition, function and physiology of bacteria and viruses.

CLO6: Discuss the virus replication strategies, subgenomic RNAs, virusoids, Viroids and Prions.

CLO7: Explain the differences between cultured, uncultured, yet-to-be cultured and viable-but-not-cultivated microorganisms.

CLO8: Discuss the applications of metagenomics in microbiology and microbiomes.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3										
CLO 2	3										
CLO 3	3				3						
CLO 4	3										
CLO 5	3										
CLO 6	3										
CLO 7	3										
CLO 8	3										

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Beginnings of microbiology Discovery, Evolution of microbiology as a discipline; Microbiological techniques; Pure culture techniques; Enrichment; Anaerobic culturing; Importance of microorganisms in medicine, agriculture, environment and industry; Nutritional requirements of microorganisms. Nutritional types; Requirements; Uptake of nutrients; and, Design and types of nutrient media. Discovery of microorganisms, Bacterial and fungal diversity, Culture techniques, Bacterial systematics, Microbial growth, Principles of growth, Kinetics of growth, Methods of measuring growth, Batch and continuous growth, Synchronous culture, Diaxic growth, Cell wall of bacteria and fungi, Gram +ve cell wall, Gram –ve cell wall, Cell wall of fungi and yeasts. Microbial Ecology: Denitrification, Phosphate solubilization, Free-living nitrogen fixation, Plant-microbe interactions, Symbiotic nitrogen fixation. Mycorrhizae Plant pathogens

Reference Books:

Microbiology Edited by Prescott, 2) Microbiology Edited by Torfora 3) Microbiology Edited by Peltzar, 4) Microbiology Edited by Stanier 5) Biology of Microorganisms Edited by M.T. Medican, J.M. Martiniko and J. Parker 6) Introduction to Metabolism, Methods to study Intermediary Metabolism, Principles of Bioenergetics, Importance of ATP.

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Integrated M.Sc Systems Biology

Course Code	**:**SB 306	**Credits**	**:** 2
Title of the Course	**:** Microbiology (Lab)	**L-T-P**	**:** 0-0-2
Prerequisite Course	**:** Intermediate		

After the completion of this course, the students will be able to

CLO 1: Hands on experience in preparation of different media and growing different types of bacteria.

CLO 2: Isolation and characterization of bacteria from different sources including soil, mud and air.

CLO 3: Experience of growth kinetics of bacteria

CLO 4: Explain the diversity of bacteria, classification and identification with knowledge of general characters of various bacterial phyla.

CLO5: Knowledge on bioprocess technologies

CLO6: Discuss the virus replication strategies, subgenomic RNAs, virusoids, Viroids and Prions.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	3	3	3	3	2		2	2	3	3
CLO 2	3	3	3	3	3	3		3	2	3	2
CLO 3	3	3	3	3	3	3		3	3	2	2
CLO 4	3	3	3	3	3	2		3	3	2	3
CLO 5	3	3	3	3	3	3		3	2	3	3
CLO 6	3	3	3	3	3	3		2	2	3	3

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Tools and instruments used in microbiology practical's, Ubiquitous nature of microorganisms Commonly used medias in microbiology, EMB as a differential medium, Isolation of microorganisms from mud sample, Isolation of microorganisms from water samples using membrane filtration technique, Isolation of microorganisms using agar shake culturing, Enumeration of soil microorganisms using 10 fold serial dilution and plating techniques, Purification of microorganisms, Colony morphologies and typing, Differential staining- Gram staining, Spore staining by Malachite green, Bacterial cell shape, size and motilityBacterial growth curve, generations and doubling time (terbidometric method), Bacterial oxygen tolerance and catalase activity, Citrate utilization test, H2S test, Bacterial fermentation test, Urease test, Amylase test, 2,3-butanediol test, Antibiotic disc sensitivity test, Motility test, 16S rRNA gene sequence BLAST search analysis, Construction of phylogenetic trees using 16S rRNA gene sequences

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Integrated M.Sc Systems Biology

Course Code	**:**SB 302	**Credits**	**: 2**
Title of the Course	**:** Computers and Programming	**L-T-P**	**: 2**-0-0
Prerequisite Course :	Intermediate		

After the completion of this course, the students will be able to

CLO1: Explain the programming concepts and different programming paradigms such as Procedural programming, Object oriented programming and Functional programming.
CLO2: Understand the code in C programming to solve basic problem using if-else statements, loops, structures, unions and pointers.
CLO3: Create functions in C
CLO4: Explain the concept of HPC, grid computing and cloud computing
CLO5: Explain the components of flow charts
CLO6: Draw flowcharts for a given problem
CLO7: Write pseudo code for a given problem
CLO8: Write basic level programs in python.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	1					3				1
CLO 2	3	1	2	1			3				1
CLO 3	3	1	2	1			3				1
CLO 4	3						3				1
CLO 5	3	2					3				1
CLO 6	3	2					3				1
CLO 7	3	2					3				1
CLO 8	3	2	2	1			3				1

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Unit1: Evolution of computers. Computer fundamentals: Basic units of computer, Architecture Programing languages (modular, object oriented etc) and Programming concepts: Reduction of a given problem to a computer program; flow chart concepts; operating systems; Compilers; options and optimizations; Loading; linking and debugging

Unit 2: Key concepts in programming using C : Introduction to C: general features of a C program Arrays and pointers; memory allocation; functions; strings and string operations; string handling variables and constants; different kind or types of variables; storage needs; sequential execution; branching; conditional branching; different kinds of loops; exit cod Programing in scripting languages: Perl, Python

Unit3: Concepts of grid computing, load sharing facility, parallel computing v/s sequential computing, cloud computing and HPC architecture, data centers; vertically scaling and horizontally scaling applications and suitable computer hardware. Good programming practices

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Course Code	**:**SB 306	**Credits**	**:** 2
Title of the Course	**:** Computers and Programming (Lab)	**L-T-P**	**:** 0-0-2
Prerequisite Course :	Intermediate		

After the completion of this course, the students will be able to

CLO1: Write the code in C programming to solve basic problem using if-else statements, loops, structures, unions and pointers.
CLO2: Create functions in C
CLO3: Read and write files in C
CLO4: Work with biological sequences (DNA/Proteins) in fasta format using C program.
CLO5: Read PDB files using C
CLO6: Write basic level programs in python and work with biological sequences.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3		1				3				1
CLO 2	3						3				1
CLO 3	3						3				1
CLO 4	3		1		3		3				1
CLO 5	3		1		3		3				1
CLO 6	3		1		3		3				1

'3' – *High-level*
'2' – *Medium-level*
'1' – *Low-level*

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Integrated M.Sc Systems Biology

Course Code	**:**SB 303	**Credits**	**:** 3
Title of the Course	**:** Genetics	**L-T-P**	**:** 3-0-0
Prerequisite Course	**:** Intermediate		

After the completion of this course, the students will be able to

CLO1: explain Mendelian analysis of inheritance, extensions and development of genetic maps using linkage studies.
CLO2: explain the chromosome structure and organization including large scale mutations.
CLO3: explain sex chromosome inheritance and sex determination in eukaryotes.
CLO4: explain the inheritance of the chloroplast and mitochondrial genes, their mapping and applications.
CLO5: understand the complexity of inheritance in higher organisms where more than one gene is involved in expression of a trait and also disease in a given population.
CLO6: discuss the utilization of identical and fraternal twins in understanding the relative influence of genes and environment on different human traits.
CLO7: discuss the genetic mechanisms underlying the early development in *Drosophila*.
CLO8: understand and explain mechanisms of gene regulation including X-chromosome inactivation, genome imprinting and position effect variegation.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	3	3	2	3	2	2	3	2	3	2
CLO 2	3	3	3	3	3	3	2	3	2	3	2
CLO 3	3	3	3	2	3	3	2	3	2	3	2
CLO 4	3	3	3	3	3	3	2	2	2	3	2
CLO 5	3	3	3	3	3	3	2	3	2	3	2
CLO 6	3	3	3	3	3	3	2	3	2	3	2
CLO 7	3	3	3	2	3	3	2	3	2	3	2
CLO 8	3	3	3	3	3	3	2	3	2	3	2

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Mendelian Genetics and analysis: Extension of Mendelian analysis, Chromosomal basis of Inheritance, Chromosome characteristics, Chromosome structure, Euchromatin and heterochromatin, Coding and Non-coding sequences, transposons, Genetic Recombination in Eukaryotes Linkage and Crossing Over, Chromosome mapping, Tetrad analysis and Gene Conversion, Mutations and mutagenesis, Detection, Molecular basis and Applications, Chromosomal Changes, Number variation – Euploidy (auto and allopolyploidy), aneuploidy, Structural variations – Deficiences, duplications, Inversions, translocations, Interaction of Genotype and Environment, Twin studies, genetic environment, non-genetic environment, phenocopies, penetrance and expressivity, Gene expression regulation during differentiation and growth, Heterochromatization in human beings and other mammals, dosage compensation, mechanism, sex chromatin, position effect, Quantitative inheritance, Continuous traits – multigenic variability, dominance – additivity, norms of reaction, Non-Mendelian Inheritance, Plastid mutations – nature and mode of transmission, Mitochondrial traits – nature and mode of transmission, Applications, Population Genetics Genotype and allelic frequencies, the Hardy-Weinberg equilibrium, non-random mating, consequences of homozygosity, factors affecting gene frequencies, heterosis, mutation – effect on allele frequencies, migration and genetic drift. Developmental Genetics Model system *Drosophila*, Genetic screen, Pattern formation, Maternal effect, Homoetic transformations

Reference Books:

Griffiths, A. J. F., Miller, J. H., Suzuki, D. T., Lewontin, R. C., Gelbart, W. M. (1997) An Introduction to Genetic Analysis, W. H. Freeman & Company, New York. 2) Strickberger, M. W. (1985) Genetics, 3rd Edition, Macmillan Publishing co., New York. Gardner, E. J., Simmons, M. J. and Snustad, D. P. (1984) Principles of Genetics, 8th Edition, John Wiley & Sons, New York.

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Integrated M.Sc Systems Biology

Course Code	**:**SB 303	**Credits**	**:** 2
Title of the Course	**:** Genetics (Lab)	**L-T-P**	**:** 0-0-2
Prerequisite Course	**:** Intermediate		

After the completion of this course, the students will be able to

CLO-1: Handle yeast and perform mutagenesis and chromosome loss experiments, study Mendelian inheritance patterns with yeast.
CLO-2: To solve problems on Mendelian inheritance, gene interactions, genetic mapping through linkage analysis, tetrad analysis, sex-linked inheritance and extranuclear inheritance.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	3	3	2	3	2	3	3	3	3	2
CLO 2	3	3	3	3	3	3	2	3	3	3	3

'3' – *High-level*
'2' – *Medium-level*
'1' – *Low-level*

Syllabus:

The laboratory course in genetics is designed to reinforce the basic principles in genetics through both thought experiments and wet lab experiments.a) Analytical Problems to understand basic concepts in Genetics: Mendelian Genetics. Chromosomal theory of inheritance, Gene interactions, Linkage and crossing over, Tetrad analysis, Extra-nuclear inheritance. b) Radiation sensitivity of yeast, Comparison of radiation sensitivity of various mutants. Mating, selection of diploids, sporulation and tetrad analysis, Yeast position effect assays /chromosome loss assays.

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Integrated M.Sc Systems Biology

Course Code	**:**SB 304	**Credits**	**:** 3
Title of the Course	**:** Metabolic Pathways	**L-T-P**	**:** 3-0-0
Prerequisite Course	**:** Intermediate		

After the completion of this course, the students will be able to

CLO-1 Understand about the importance and scope of biochemistry.
CLO-2 Understand the structure and biological significance of carbohydrates, amino acids, proteins, lipids and nucleic acids.
CLO-3 Understand the concept of enzyme/hormone, its mechanism of action and regulation.
CLO-4 Learn biochemical reactions for synthesis or degradation for amino acids, carbohydrates, lipids and nucleic acids.
CLO-5 Learn regulation of intermediary metabolism of amino acids, carbohydrates, lipids and nucleic acids.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3										
CLO 2	3										
CLO 3	3		1	1							
CLO 4	3										
CLO 5	3		1	1							

'3' – *High-level*
'2' – *Medium-level*
'1' – *Low-level*

Syllabus:

Occurrence and properties of carbohydrates. Digestion and absorption of carbohydrates. ATP and its importance. Glycogen breakdown and synthesis. Overview of glycolysis, citric acid cycle and HMP shunt pathway (8h).

Digestion and absorption of lipids. Oxidation of fatty acids and biosynthesis of fatty acids. Cholesterol metabolism and receptor mediated endocytosis. Prostaglandins and their importance (8h).

Digestion and absorption of proteins. Overview of amino acid degradations. Transamination and oxidative deamination. Urea cycle and its importance. Essential and non-essential amino acids. Biosynthesis and degradation of aromatic amino acids. Precursor functions of amino acids (7h).

Introduction to nucleotide metabolism. Biosynthesis and degradation of purines and pyrimidines. deoxyribolucleoside metabolism, enzymatic reduction of ribonucleotides, thymidine metabolism regulation of deoxynucleotide metabolism. Nucleotide coenzymes (7h).

Reference Books:

1. Biochemistry Author Lubert Stryer
2. Lehninger Principles of Biochemistry
3. Text Book of Biochemistry Authors ES, West, WR Todd, HS Mason an d JT, Van Bruggen
4. Review of Physiological Chemistry Author Harold Anthony Harper

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Integrated M.Sc Systems Biology

Course Code	**:**SB 305	**Credits**	**:** 3
Title of the Course	**:** Biophysical Chemistry	**L-T-P**	**:** 3-0-0
Prerequisite Course	**:** Intermediate		

After the completion of this course, the students will be able to

CLO-1: account for the interactions that are important for the formation of macromolecular structures in the biological system
CLO-2: account to measure thermodynamic parameter for the structure and can be able to understand oxidation and reduction phenomenon in biological system
CLO-3: account for the basic concept of separation and characterization of macromolecules
CLO-4: account for and apply spectroscopic methods for study of structure and function of macromolecules from biological system
CLO-5: to develop an understanding to study biological systems using physical chemistry.
CLO-6: account to measure the radioactivity and be able to develop knowledge to use radioactivity to study biological system.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3		3								
CLO 2	3		1								
CLO 3	3		3								
CLO 4	3		1								
CLO 5	3		3								

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

1) Oxidation and reduction phenomena in biological systems, redox potential, redox indicators (stains and dyes), Formal potential and its determination.

2) Theory of detergents: structure, function and uses. Three major classes of detergents (based on charge) and their specific uses,

3) Polymers: Theory of polymerization and co-polymerisation, the cooperativity in polymerization

4) Ultracentrifugation: Basic theory of sedimentation, sedimentation rate analysis, sedimentation equilibrium, frictional resistance, Svedberg constant, molecular weight determination, type of rotors, analytical ultracentrifugation, density gradient analysis

5) Electrophoretic mobility: analytical and preparative electrophoresis, relation between gel pore size and electrophoretic mobility, electroendosmosis

6) Radioactivity: Introduction, measurement and applications. Spectroscopy: Basic principles of absorption and fluorescence spectroscopy. Thermodynamics: Free energy, entropy, enthalpy, significance of free energy of biomacromolecules in determination of stability constants.

Reference Books:

1. Physical Biochemistry by David Frefeiler
2. Physical Biochemistry Principles and application by David Sheehan
3. Principle and Techniques of Biochemistry and molecular biology by Keith Wilson and John Walker
4. Physical Chemistry of Macromolecules Basic principles by S. F. Sun
5. Protein structure and Molecular properties by Thomas E. Creighton

6th SEMESTER

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Integrated M.Sc Systems Biology

Course Code	**:**SB 351	**Credits**	**:** 3
Title of the Course	**:** Cell Biology	**L-T-P**	**:** 3-0-0
Prerequisite Course	**:** Intermediate		

After the completion of this course, the students will be able to

CLO1: Conceptualize the fundamental functioning of a cell, its general and specialized functions.
CLO2: Understand protein localization and its underlying importance in controlling the release of genetic information across cellular compartments.
CLO3: Relate the functioning of single organelle and the intricate crosstalk between organelles to basic cellular function like energy production, cellular communication or cell growth.
CLO4: Identify the present day approaches to study cell processes and interpret their data

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	3	3	3	3	2		3	2	3	3
CLO 2	3	3	3	3	3	3		3	2	3	3
CLO 3	3	3	3	3	3	2		3	2	2	2
CLO 4	3	3	3	3	3	3		3	3	2	2

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Organization of prokaryotic and eukaryotic cells, Biogenesis, traffic and functions of plasma membrane, Cytoskeletal elements, Mitochondria-structure, biogenesis, function and evolution, Biogenesis, traffic and functions of lysosomes and peroxisomes, Cell cycle and division (mitosis and meiosis), Structure of nucleus and its functional dynamics, Biosynthetic process and vesicular traffic in endoplasmic reticulum and Golgi apparatus (endocytosis, exocytosis and trans-golgi network), Physiological methods to characterize and understand cellular processes, High throughput technology to study cells at systems level: Microscopy and live cell imaging, Computation methods to predict three dimensional structure of protein and modeling

Reference Books:

1. Molecular Biology of the Cell by Bruce Alberts *et al W. W. Norton & Company*
2. The Cell: A Molecular Approach by Cooper & Hausman, *Sinauer Associates Inc*
3. Cell biology (Sixth Edition) by Gerald Karp, *John Wiley & Sons Publisher*

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Integrated M.Sc Systems Biology

Course Code	**:**SB 356	**Credits**	**:** 2
Title of the Course	**:** Cell Biology (Practical)	**L-T-P**	**:** 0-0-2
Prerequisite Course :	Intermediate		

After the completion of this course, the students will be able to

CLO-1: preparation of slides for the visualization of various cells
CLO-2: Differential staining of mitochondria, DNA and RNA of various cell types
CLO-3: get hands on experience with isolation of chromosomes from mitotic and meiotic stages and preparation of polytene chromosomes from drosophila larva
CLO-4: learn various methods of cell counting, preparation of blood smear and separation of blood cells
CLO-5: learn various methods such as TEM and SEM for visualization of different internal structures and cell organelles

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	3	3	2	3	2		3	3	3	2
CLO 2	3	3	3	3	3	2		3	3	3	2
CLO 3	3	3	3	2	3	3		3	3	3	2
CLO 4	3	3	3	3	3	2		3	3	3	2
CLO 5	3	3	3	3	3	2		3	3	3	2

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’_*Low-level*

Syllabus:

Observation various Cell types through permament slides;Observation of human Cheek epithelial Cells; Staining of Mitochondria in human Cheek epithelial Cells; Differential Staining for DNA and RNA in human Cheek epithelial Cells; Study of different stages of Mitosis in Onion Root Tip Cells; Study of different stages of Meiosis in Grasshopper Testis Cells. Cell viability assay by Trypan Blue Exclusion; Blood Smears and Identification of Blood Cells; Blood Cell count; Squash preparation of Polytene Chromosomes from Drosophila larvae; Visit to SEM, TEM and Confocal Microscope Facility

Department of Systems and Computational Biology
School of Life Sciences
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Integrated M.Sc Systems Biology

Course Code	**:**SB 352	**Credits**	**:** 3
Title of the Course	**:** Enzymology & Bioenergetics	**L-T-P**	**:** 3-0-0
Prerequisite Course :	Intermediate		

After the completion of this course, the students will be able to

CLO-1 Assign systematic name to enzymes and from the E.C. number they will be able to explain the reactions that it catalyzes;
CLO-2 Perform purification, handling and characterization of proteins;
CLO-3 Discuss the kinetics of enzymatic reactions and different types of enzymatic inhibitions; Understand the enzymatic regulations and specificity;
CLO-4 Ability to purify and characterize the new enzymes
CLO-5 Define free energy and discuss its relationship to chemical equilibrium
CLO-6 Ability and knowledge to explain molecular mechanisms of energy transformation and energy accumulation in living organisms
.CLO-7 Skills to analyze the bioenergetics related problems and information

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	3	3	2	3	1		2	3	2	2
CLO 2	3	3	3	2	3	1		3	3	2	2
CLO 3	3	3	3	2	3	1		3	3	2	2
CLO 4	3	3	3	2	3	1		2	2	2	2
CLO 5	3	3	3	2	3	1		3	2	2	2
CLO 6	3	3	3	2	3	1		3	3	2	2
CLO 7	3	3	3	2	3	1		2	2	2	2

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Enzymes: basic definitions. Nomenclature (EC recommended and classical), enzyme purification, enzyme activity, specific activity and turnover number,

Bioenergetics and enzymes: Energy as understood by biochemist, energy transformations in living systems, activation energy, standard free energy change **($\Delta G^{0'}$)** and its relationship to products to substrate ratio. Additive nature of **$\Delta G^{0'}$**, calculations of free energy change (**ΔG)** of few common reactions,

Enzyme kinetics: Single substrate-single intermediate. Michaelis-Menten and laneweaver burk plots. Graphical analysis of kinetic data. Determination of Vmax and Km-Experimental aspects.

Enzyme inhibition and mechanism: Mechanisms of enzyme activity and rate, studies. Degree of inhibition. competitive, non-competitive and uncompetitive inhibition. Two substrate reactions. Sequential and Ping-pong mechanisms.

Allosteric enzymes: subunit interactions, Jocob and Monod model of allosteric enzymes.Koshland model, detailed discussion using haemoglobin, ATcase (effects of ATP and CTP) as examples. Single and Double displacement reactions.

Industrial enzymology: Immobilized enzymes, Covalent and non covalent, attachments to various substrates. Characteristics of immobilized enzymes. Applications in industry and medicine.

Coenzymes: Coenzymes structure and function in metabolism, Redox potential: redox reactions and reactions that generate reducing equivalents, (NADH, NADPH and FADH2), importance of redox potential, calculation of free energy decrease for substrate oxidation, Structure and function of individual complexes of electron transport chain. Complex I, II, III, IV and V,

Mechanisms of oxidative phosphorylation: Chemical coupling hypothesis, conformational coupling hypothesis, chemiosmotic hypothesis, mechanism of proton translocation,

Photosynthesis: Biological occurrence, various electron donors and acceptors, Photosynthetic pigments, Photosynthetic electron transport chain, and photophosphorylation

Reference Books:

1. Principles of Biochemistry by Voet, Voet and Pratt (Fourth Edition), *Wiley Publisher*
2. Biochemistry (Ninth Edition) by Berg, Stryer, Tymoczko and Gatto, *WH Freeman Publisher*
3. Cell biology (Sixth Edition) by Gerald Karp, *John Wiley & Sons Publisher*

Department of Systems and Computational Biology
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Integrated M.Sc Systems Biology

Course Code	**:**SB 356	**Credits**	**:** 2
Title of the Course	**:** Enzymology & Bioenergetics (Lab)	**L-T-P**	**:** 0-0-2
Prerequisite Course	**:** Intermediate		

After the completion of this course, the students will be able to

CLO 1: Design experiment, analyze and interpret data to study single-substrate enzyme kinetics of any uncharacterized enzyme
CLO 2: Design experiment, analyze and interpret data to identify and characterize enzymatic inhibitions by small molecules
CLO3: Isolate mitochondria from different sources and perform mitochondrial electron transport chain and ATPase functional assays.
CLO4: Analyse, interpret and evaluate the data based on the experimental values obtained either from normal and dysfunctional mitochondria.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	3	3	3	3						3
CLO 2	3	3	3	3	3						3
CLO 3	3	3	3	3	3						3
CLO 4	3	3	3	3	3						3

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Expt.1 Assay of alkaline phosphatase from E.coli using P-nitrophenyl phosphate as substrate.

Expt.2.Partial purification of alkaline phosphatase from E.Coli.

Expt.3. Characterization of alkaline phosphatase. A)Effect of pH, b) Effect of substrate concentration (Calculation of Km) b) Effect of Temperature (Q 10) c) Competetive inhibition (KH_2Po_4) d) Uncompetitive inhibition (Phenylalanine)

Expt 4. Estimation of protein in mitochondria and homogenate by Biuret method.

Expt 5. Preparation of tightly coupled mitochondria from rat liver.

Expt 6. Estimation of SDH activity in mitochondria and homogenate and calculation of recovery of mitochondria.

Expt7. Measurement of rate of respiration and oxidative phosphorylation in mitochondria using succinate as substrate using oxytherm respirometer.

Expt.8. Measurement of rate of respiration and oxidative phosphorylation in mitochondria using glutamate and malate as substrates using oxytherm respirometer.

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Integrated M.Sc Systems Biology

Course Code	**:**SB 353	**Credits**	**:** 4
Title of the Course	**:** Developmental Biology	**L-T-P**	**:** 4-0-0
Prerequisite Course :			

After the completion of this course, the students will be able to

CLO 1: To understand basic questions in the context of normal animal development and evolution of organisms.
CLO 2: To understand the molecular basis of animal development, cellular differentiation and evolution of organisms.
CLO 3: Explain the differences and similarities between plant and animal development, evolution of developmental complexity from algae to angiosperms
CLO 4: Explain the role of Plant Cell Division and Expansion in development, Plant cell cycle-endoreduplication and control of plant cell size
CLO 5: Discuss about regulation of plant architecture, shoot apical meristem, root apical meristem and positional control of root development, phyllotaxy, lateral organ
development- leaf primordia imitation, leaf development, and generation of patterns-
regulation of stomatal patterning in plants
CLO 6: Explain about Environmental regulation of plant development, photoperiodism and circadian rhythms and biological clock, phytochrome, cryptochrome, UVR8 and phototropins, shade avoidance, thermomorphogenesis, vernalization of plants.
CLO 7: Explain about seed germination and dormancy, plant senescence
CLO 8: Discuss the reproductive development of plants, inflorescence initiation, flower development in plants, embryogenesis in higher plants.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	2	3	3	2	2	1	2	2	3	2
CLO 2	3	2	3	3	2	2	1	2	2	3	2
CLO 3	3										
CLO 4	3										
CLO 5	3										
CLO 6	3										
CLO 7	3										
CLO 8	3										

'3' – *High-level*
'2' – *Medium-level*
'1' – *Low-level*

Syllabus:

Section I (Animal system)

Introduction to developmental biology: Overview of developmental biology, history and basic concepts, cell-cell communication, cell adhesion, morphogen gradients, cell specification (3h). Early embryonic development:Overview of gametogenesis, fertilization, cleavage and gastrulation. Antero-posterior axis formation and dorso-ventral patterning (Model organisms: *Cenorhabditis elegans*, *Drodophila*, Zebrafish, *Xenopus*, Mouse) (4h).The stem cell concept and organogenesis: Derivatives of ectoderm, mesoderm and endoderm. Stem cell concept and cell lineages. Chromosomal and environmental sex determination, metamorphosis, regeneration (4h).Medical implication of developmental biology:Genetic errors of human development, human syndromes, cancer as a disease of development, teratogenesis- environmental assault on human development, developmental therapies (4h). Evolution and development: Developmental mechanisms of evolutionary change- heterotopy, heterochrony, heterometry, and heterotypy. Developmental constraints on evolution- Physical, morphogenetic and phyletic constraints. Selectable epigenetic variation (4h).

Plant Developmental Biology: Introduction- A comparison of plant and animal development; Introduction- comparison of plant and animal development; Plant cell division and expansion; Plant cell cycle- Endoreduplication and control of plant cell size (one hr each); Shoot apical meristem; Root apical meristem and positional control of root development (2 hrs each) ; Phyllotaxy; (one hr); Lateral organ development- Leaf primordia imitation; Leaf development (2 hrs each) ; Generation of patterns- regulation of stomatal patterning in plants (one hr); Environmental regulation of Plant Development; Reproductive development of Plants (tw hrs each) total 17 hrs

Reference: Developmental Biology, Scott F. Gilbert, Ninth Edition. Sinauer Associates
Developmental Biology: A Guide for Experimental Study, Mary S. Tyler, Sinauer Associates, Inc.
Analysis of Biological Development, Klaus Kalthoff, McGraw Hill

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Integrated M.Sc Systems Biology

Course Code	**:**SB 354	**Credits**	**:** 3
Title of the Course	**:** Physiological Processes	**L-T-P**	**:** 3-0-0
Prerequisite Course :	Intermediate		

After the completion of this course, the students will be able to

CLO 1: Basic understanding of the physiological processes in both their evolutionary perspectives and diversification across animal kingdom.
CLO 2: Understand the concepts of interdependence of more than one physiological processes.
CLO 3: Have a broader vision to associate the physiological functioning to networking of various physiological processes in our body.
CLO 4: Explain plant cell structure and physiological functions.
CLO 5: Summarize the concepts of water transport in plants, water potential, importance of transpiration in plants, role of stomata in the regulation of transpiration
CLO 6: Describe the roles of mineral elements in plant growth and development.
CLO 7: Explain evolution of oxygenic photosynthesis on earth, concepts of photosynthesis, photosystems, C3, C4 and CAM pathways, photorespiration & cellular respiration.
CLO 8: Assess and compare the physiological roles of various plant hormones during growth and development.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3										
CLO 2	3		2								
CLO 3	3		2								
CLO 4	2										
CLO 5	3	3	2								
CLO 6	3	3									
CLO 7	3	2	2	3							
CLO 8	3	3		3							

'3' – *High-level*
'2' – *Medium-level*
'1' – *Low-level*

Syllabus:

Section I (Animal system)-

Introduction to course; Foundations of Physiology: Why study animal physiology Levels of biological organization, homeostasis of the internal milieu, time frames, evolutionary processes (2h).

Physiological responses to temperature: Basis for heat transfer with the environment, biochemical, physiological and behavioral effects of temperature, Strategies in thermal biology (endothermy versus ectothermy), Adaptations to extreme environments such as freeze tolerance, Implication of Global warming (3 h).

Digestion and metabolism: Nutrition, feeding, and digestion, aerobic and anaerobic forms of metabolism, energy balance and thermal physiology, mechanisms of ATP production, metabolism during oxygen deficiency and exercise (3h).

Circulation and respiration: Design and evolution of circulatory systems and respiratory surfaces, gas transport in blood and at gas-exchange surfaces, regulation of pH. Adaptations in various aquatic mammals to a diving lifestyle, circulatory adjustments, oxygen storage capacity, aerobic dive limit (3h).

Solute, water and nitrogen balance: Design and evolution of excretory systems, movement of water and solutes across membranes, solute regulation in freshwater and seawater vertebrates, nitrogenous waste excretion in mammals of deserts and dry savannas (3h).

Muscle and movement: Muscle structure and function, control of movement - the motor bases of animal behavior, plasticity in response to use and disuse (2h).

Nervous and endocrine integration: Patterns and evolution of nervous systems, introduction to sensory systems, endocrine physiology, integration of mineral balance, hormones and cell signaling, biological clocks; endocrine disruptors (3h).

Section I I (Plant system)- Section II (Plant system)- Introduction: Plant Cell Structure, Biomolecules. Water Relations: Soil and water,Water absorption, Transpiration, Guttation, Ascent of sap. Mineral Nutrition:Essential elements, Uptake and transport, Role of mineral elements in plant metabolism. Photosynthesis: Primary processes in photosynthesis, Photon requirement, Photophosphorylation, Carbon assimilation:C3, C4 and CAM pathways, Photorespiration, Factors affecting photosynthesis. Respiration: Glycolysis, TCA cycle, Oxidative pentose phosphate pathway.Transport of organic solutes: Structure of phloem tissue, phloem loading, Pressure flow model of assimilate transport. Plant Growth and Development: Role of Plant hormones in plant growth and development: auxins, gibberellins, cytokinins, abscisic acid, ethylene.Plant Movements:Tropisms, Nastic movements. Photoperiodism: Photoperiodic responses in plants, flowering hormone, phytochrome and florigin.

References:

Introduction to Plant Physiology by W G Hopkins and N P Huner, John Wiley & Sons (Fourth Edition), 2010Plant Physiology by L. Taiz and E. Zeiger, Sinauer Associates, USA,2010

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Course Code	**:**SB 356	**Credits**	**:** 2
Title of the Course	**:** Physiological Processes (Lab)	**L-T-P**	**:** 0-0-2
Prerequisite Course	**: Intermediate**		

After the completion of this course, the students will be able to

CLO1: Basic understanding of the physiological processes in both their evolutionary perspectives and diversification across animal kingdom.
CLO2: Understand the concepts of interdependence of more than one physiological processes.
CLO3: Have a broader vision to associate the physiological functioning to networking of various physiological processes in our body.
CLO4: Compare plant growth and development under light and dark.
CLO5: Estimate/quantify the Biomolecules from plants using different biochemical methods.
CLO6: Design experiments to study the effects of mineral deficiencies and abiotic stresses in plants.
CLO7: Design experiments to study the phenomenon of osmosis, amylase activity, and hormone bioassays.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	2	1						1		
CLO 2	3	2	1					2	1		
CLO 3	3	2	1					2	2		
CLO 4	3	3	2	3				1	2		3
CLO 5	3	3	3			3		2	2		3
CLO 6	3	3			3	3		2	1		3
CLO 7	3	3			3	3					

'3' – *High-level*
'2' – *Medium-level*
'1' – *Low-level*

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Integrated M.Sc Systems Biology

Course Code	**:**SB 355	**Credits**	**:** 3
Title of the Course	**:** Biological Host Defense	**L-T-P**	**:** 3-0-0
Prerequisite Course	**: Intermediate**		

After the completion of this course, the students will be able to

CLO 1: Understand phytopathogens, pathogenesis and mechanism of resistance and susceptibility in plants.

CLO 2: Understand immunity in plants and mechanisms underlying different interactions of biotic factors in plants.

CLO 3: Describe the role of phytohormones in plant defense and mechanism of preformed and induced defense responses against pests and pathogens

CLO 4: Devise strategies to target various biotic stresses caused in plants through modern state-of-art techniques to analyze response of the host plant to biotic stresses.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3		3	3							
CLO 2	3		3	3							
CLO 3	3		3	3							
CLO 4	2		3	3		3					

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Evolution of host defense: from unicellular to multicellular organisms Why defense mechanisms evolved and how are they manifested; The tug of war between the host and the pathogen for survival; Concept of colonization, persistence and latency of pathogen; Innate and adaptive mechanisms; Recognition of self vs non-self; Recognition of small and large molecules; Receptors and defense signaling; Specificity and diversity in recognition; Generation of receptor diversity and basis of specific recognition; Immunological tolerance; Chemical mediators of immune response; Bacterial defense molecules; Cytokines: lymphokines, interleukins, and chemokines and mode of chemical communications amongst immune cells; Antimicrobial chemicals and proteins in plant defence; Unity and diversity in immune mechanisms of unicellular and multicellular organisms; Networking and redundancy in chemical signaling; Impact of microflora in immunity and concept of metagenomics.

Reference Books:

1. Kuby Immunology (Sixth Edition) by Kindt, Osborne and Goldsby *W. H. Freeman Publisher*

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Integrated M.Sc Systems Biology

Course Code	**:**SB 355	**Credits**	**:** 2
Title of the Course	**:** Biological Host Defense (Lab)_	**L-T-P**	**:** 2-0-0
Prerequisite Course	**: Intermediate**		

After the completion of this course, the students will be able to

CLO-1: get hands on experience in the performance of immunodiffusion
CLO-2: get hands on experience in the performance of the blood typing, quantification of IgG from serum, isolation of heavy chain and light chain from IgG
CLO-3: get hands on experience with isolation of B and T cells
CLO-4: learn various separation methods such as ion exchange chromatography and affinity chromatography to purify immunoglobulins from serum
CLO-5: learn various methods such as fluorescence microscopy and FACS based methods to analyze different blood compartments

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	1	2	2	3	2		2	2	2	1
CLO 2	3	1	2	2	3	2		2	2	2	1
CLO 3	3	1	2	2	3	2		2	2	2	1
CLO 4	3	2	2	2	3	2		2	2	2	1
CLO 5	3	2	2	2	3	2		2	2	2	1

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Expt1. Isolation of IgG from serum using ion exchange chromatography.
Expt.2. Isolation of IgG from serum using affinity chromatography.
Expt.3. Separation of heavy and light chains of IgG.
Expt.4. Study of antigen-antibody interaction by double immunodiffusion.
Expt.5. Electrophoresis (SDS - PAGE) of purified IgG.
Expt.6. Single radial immunodiffusion for quantitative estimation of human serum IgA.
Expt.7. Production of polyclonal antibodies to Tetanus toxoid in rat.
Expt.8. Identification and quantitation of B and T cells using direct immunofluorescence.
Expt.9. Estimation of serum Igs by sandwich ELISA.
Expt10. Hemagglutination assay

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Integrated M.Sc Systems Biology

Course Code	**:**SB 471	**Credits**	**:** 2
Title of the Course	**:** R-programming (Lab)	**L-T-P**	**:** 0-0-2
Prerequisite Course	**:** Basic in computers		

After the completion of this course, the students will be able to

CLO1: Understand variables, data types and use R for calculations
CLO2: Write scripts/programs for various problems
CLO3: Apply various statistical tests and interpret the results obtained

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	3	3	3	2	3	3	3	3	3	2
CLO 2	3	3	3	3	2	3	3	1	3	3	2
CLO 3	3	3	3	3	2	3	3	1	3	3	2

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus

PART 1: Background and Basics: Download and installing R; Writing Code / Setting Your Working Directory; Introduction, Overview and History of R; Getting Help; R Console Input and Evaluation; Data Types - R Objects and Attributes; Data Types - Vectors and Lists; Data Types – Matrices; Data Types – Factors; Data Types - Missing Values; Data Types - Data Frames; Data Types - Names Attribute; Data Types – Summary; Reading Tabular Data; Reading Large Tables; Textual Data Formats; Subsetting – Basics; Subsetting – Lists; Subsetting – Matrices; Subsetting - Partial Matching; Subsetting - Removing Missing Values

PART 2: Programming with R and using Loops: Control Structures – Introduction; Control Structures – If-else; Control Structures - For loops; Control Structures - While loops; Control Structures - Repeat, Next, Break; Loop Functions – lapply; Loop Functions – apply; Loop Functions – mapply; Loop Functions – tapply; Loop Functions - split

References:

- Learning R: A Step-by-Step Function Guide to Data Analysis by Richard Cotton published by O'reilly
- R for Data Science by Hadley Wickham and Garrett Grolemund published by O'reilly

7th SEMESTER

Department of Systems and Computational Biology
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Integrated M.Sc Systems Biology

Course Code	**:** SB 401	**Credits**	**:** 3
Title of the Course	**:** Gene Regulation and Recombinant DNA Technology	**L-T-P**	**:** 3-0-0
Prerequisite Course	**: UG**		

After the completion of this course, the students will be able to

After completion of the course work students would able to

CLO1: List out the tools used for gene exploration such as cloning and site directed mutagenesis of genes

CLO2: Utilize the knowledge on preparation of genomic library

CLO3: Know about generation of transgenic plants and animals

CLO4: Gain complete knowledge on molecular biology and gene regulation

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	3	3	3	3	2		3	2	2	2
CLO 2	3	3	3	2	3	2		3	2	2	2
CLO 3	3	2	3	2	3	2		3	2	2	2
CLO 4	3	2	3	2	3	2		3	2	2	2

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

The course is divided in four units. The content of each unit is shown below:

Unit1: The power of recombinant DNA technology, the historical work that led to the preparation of recombinant DNA molecules; Preparation and construction of genomic, CDNA and subtraction libraries; Transformation and Transfection Assays; Different Vectors

Unit 2: DNA sequencing, Protein-DNA interactions etc., (Mobility and Gel retardation assays, Nick translation, PCR Importance; enzymes involved in biotechnology research like polymerases, nucleases ligases, restriction endonucleases etc., Isolation and identification of genes; Markers to identify cloned mammalian genes, bacterial and yeast genes, reporter genes. Mutagenesis of cloned genes by different means, Random and Site-specific Mutagenesis;

Unit 3: Different types of expression systems for the expression of recombinant proteins Yeasts, mammals and plants for expression of recombinant proteins. Examples that involve various strategies in the expression of recombinant proteins of therapeutic importance in bacteria and strategies to develop transgenic plants and animals; Targeted gene replacement or creation of knockout mice and its potentialities to evaluate the role genes in growth, development, differentiation and death.

Unit 4: Regulation of Gene Expression: Transcriptional Regulation; Selective models like Ara, Lac, Trp, His operon transcription from bacteria, Translational Regulation with suitable model systems and examples in development, splicing, importance of small nuclear RNAs, micro RNA and Silencing RNAs etc.

References

3) Recombinant DNA Technology: A short Course by Watson et al.,
4) Molecular Biology by Watson et al.
5) Principles of Gene manipulation and Genomics by Richard M Twyman and S.B. Primrose
6) Molecular cloning A Laboratory Manual by Green and Sambrook
7) GENES XII by Lewin

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Integrated M.Sc Systems Biology

Course Code : SB 406	**Credits** : 2
Title of the Course : Gene Regulation and Recombinant DNA Technology (Lab Techniques)	**L-T-P** : 0-0-2
Prerequisite Course : UG	

After the completion of this course, the students will be able to

CLO-1: get hands on experience in the isolation of plasmid DNA and genomic DNA
CLO-2: get hands on experience in the performance of the cloning experiments such as PCR, restriction digestion and ligation
CLO-3: get hands on experience with working on inducible systems in order to induce the gene expression
CLO-4: learn various molecular biology tools such as southern blotting, northern blotting etc
CLO-5: isolation of mutant yeast strains and learn different transfection methods.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	3	3	3	3	3		2	3	2	3
CLO 2	3	3	3	3	3	3		3	2	2	3
CLO 3	3	3	3	3	3	3		3	3	2	3
CLO 4	3	3	3	3	3	3		3	3	2	3
CLO 5	3	3	3	3	3	3		2	3	2	2

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Expt 1: Trasnformation of bacteria
Expt.2 Plasmid DNA isolation
Expt.3 Restriction endonuclease digestion & Agarose gel electrophoresis
Expt 4: Inserting a DNA fragments into a vector by ligation
Expt 5: Induction of Beta galactosidase in E.coli-effect of various inducers.
Expt.6: PCR amplification of a segment of DNA.
Expt 7. Knock out of a gene in yeast SDS-PAGE, Native PAGE, Northern, southern, western blots.

References

1. Molecular cloning A Laboratory Manual by Green and Sambrook

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Integrated M.Sc Systems Biology

Course Code	**:** CA501	**Credits**	**:** 3
Title of the Course	**:** Computer Based Numerical Methods	**L-T-P**	**:** 3-0-0
Prerequisite Course	**: UG**		

After the completion of this course, the students will be able to

CLO-1: Calculate the root of polynomials as well as transcendental functions using various iterative methods (Apply)
CLO-2: Compare different methods for their efficacy and accuracy in finding the roots. (Analyze)
CLO-3: Apply various techniques to interpolate the given data. (Apply)
CLO-4: Compare interpolation techniques for their efficacy and accuracy. (Analyze)
CLO-5: Solve system of linear equations using various iterative and direct techniques. Also compute eigen values and eigenvectors using direct methods. (Apply)
CLO-6: Design a scheme that can calculate the derivatives of a function given a set of values of that function using methods based on interpolation and methods based on undetermined coefficients. Also they will be able to determine the order of the scheme (Create)
CLO-7: Calculate the value of a definite integral using Trapezoidal and Simpson's 1/3 rule (Analyze)
CLO-8: Compute numerical solution of first order differential equation with initial conditions using Euler's, Modified Euler's, Piccard's method of successive approximations, and Runge-Kutta methods (Apply)

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	1	1	1	1					1	2
CLO 2	3	1	1	1	1					1	2
CLO 3	3	1	1	1	1					1	2
CLO 4	3	1	1	2	1					1	2
CLO 5	3	1	2	2	2	1				1	2
CLO 6	3	1	2	2	2	1	2	3		1	2
CLO 7	3	1	2	2	2	1	2	3		2	2
CLO 8	3	1	2	2	2	1	2	3		2	2

'3' – *High-level*
'2' – *Medium-level*
'1' – *Low-level*

Syllabus:

· Quantify absolute and relative errors. · Distinguish between round-off and truncation errors. · Interconvert binary and base-10 number representations. · Define and use floating-point representations. · Quantify how errors propagate through arithmetic operations. · Implement the bisection method for solving equations. · Implement both Newton-Raphson and secant methods. · Perform basic matrix operations. · Define and perform Gaussian elimination to solve a linear system. · Identify pitfalls of Gaussian elimination. · Define and perform Gauss-Seidel method for solving a linear system. · Define and identify special types of matrices. · Use LU decomposition to find the inverse of a matrix. · Define and perform singular value decomposition; explain the significance of singular value decomposition. · Define interpolation. · Define and use direct interpolation to approximate data and find derivatives. · Define and use Newton's divided difference method of interpolation. · Define and use Lagrange and spline interpolation. · Derive and apply the trapezoidal rule and Simpson's rule of integration. · Distinguish Simpson's method from the trapezoidal rule. · Estimate errors in trapezoidal and Simpson integration. · Derive and apply Romberg and Gaussian quadrature for integration. · Investigate how step size affects accuracy in Euler's method. · Implement and use the Runge-Kutta 2nd order method for solving ordinary differential equations.

References

1. Erwin Kreyszig (1993) "Advanced Engineering Mathematics" Wiley
2. Press, Teukolsky, Vellerling and Flannery (1992) "Numerical Recipes in C - the Art of Scientific Computing" Cambridge
3. Abromowitx and Stegum (1972) "Handbook of Mathematical Functions with formulas, Graphs and Methematical Tables" National Bureau of Standards Applied Mathematics Series . 55 Siperintendent of Documents U.S. Government Printing Office Washington, DC 20402
4. Jaan Kiusalaas (2009) " Numerical Methods in Engineering with MATLAB" Cambridge University Press
(http://mhbb2012.persiangig.com/.uxdhABZETd/Numerical%20Methods%20in%20Engineering%20with%20MATLAB,%202nd%20Edition%20Sep%202009.pdf)

Note: Recommended to use MATLAB for Demos explaining/visualizing the concepts

Department of Systems and Computational Biology
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Integrated M.Sc Systems Biology

Course Code	**:** CA501	**Credits**	**:** 2
Title of the Course	**:** Computer Based Numerical Methods	**L-T-P**	**:** 0-0-2
Prerequisite Course	**: UG**		

After the completion of this course, the students will be able to

CLO-1: Develop iterative algorithms for finding a root of a polynomial or a transcendental function (Create)
CLO-2: Develop various interpolating algorithms (Create)
CLO-3 Design and develop algorithms for solving a system of linear equations (Create)
CLO-4 Develop algorithms to calculate the value of a definite integral. (Create)
CLO-5 Develop methods for solving the first order differential equation with initial conditions. (Create)

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	2	3	3	1	3				1	2
CLO 2	3	2	1	3	1	3				1	2
CLO 3	3	2	1	1		3			2	1	2
CLO 4	3	2	1	1		3			2	1	1
CLO 5	3	2	1	1		3			2	1	1

'3' – *High-level*
'2' – *Medium-level*
'1' – *Low-level*

Syllabus:

UNIT - I: Transcendental and Polynomial equations Practical problems: (i) Bisection Method (ii) Newton's Method (iii) Iteration Methods .

UNIT – II:Systemof Linear Algebraic equations and eigenvalue problems Practical problems: (iv) L U decomposition (v) Gauss Elimination Method (vi) Computation of eigenvalues and eigenvectors

UNIT - III: Interpolation and Approximation Practical problems: (vii) Lagrange Interpolation (viii) Hermite Interpolation (ix) Least Square Approximation (x) Rational Approximation

UNIT - IV: Differentiation and Integration Practical problems: (xi) Numerical Integration based on Interpolation (xii) Romberg Integration (xiii) Quadrature method

UNIT – V: Ordinary differential equations Practical problems: (xiv) Single step and multiple step method (xv) Predictor-Corrector Methods

Department of Systems and Computational Biology
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Integrated M.Sc Systems Biology

Course Code	**:** SB 403	**Credits**	**:** 3
Title of the Course	**:** Bioinformatics	**L-T-P**	**:** 3-0-0
Prerequisite Course	**: UG**		

After the completion of this course, the students will be able to

CLO1: Understand concept of sequence similarity and biological database search
CLO2: Apply knowledge of basic principles of mathematics and computer science in understanding concepts of biology
CLO3: Analyse an analytical approach for its efficiency and robustness
CLO4: Evaluate existing software, pipelines and databases for extracting biological information
CLO5: Create new algorithms and programs by developing problem-solving skills

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	1	1	1	3	1	3	2	2	1	2
CLO 2	3	1	2	3	3	1	3	3	2	1	2
CLO 3	3	1	3	3	3	3	3	3	3	1	2
CLO 4	3	2	3	3	3	3	3	3	3	2	2
CLO 5	3	2	3	3	3	3	3	3	3	2	2

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Unit 1: Historical perspective of Bioinformatics; introduction to biological databases: concepts of primary and secondary databases; EMBL, Genbank; Metaservers: Entrez
Pairwise sequence alingment: Pair-wise sequence comparison by DOTMatrix approach; Pair-wise substitution scoring matrices; PAM, BLOSSUM etc Gap penalties (Linear and Affine gap models); Pair- wise sequence alignment by Dynamic programming ; Global (Needleman and Wunsch) and Local alignments (Smith & Waterman); Measures of similarity (Alignment score, % sequence identity, % similarity, Statistical scores E, P and Z scores); Heuristic approaches for pair-wise sequence alignments; BLAST and FastA methods; Karlin-Altschul Statistics (Extreme Value Distribution; HSPs etc); Limitation of pair-wise methods; PSI-BLAST; PSSM, PHI-BLAST

Unit 2:Multiple sequence alignment; comparison to pair-wise method; SP scoring; complexity of multidimensional DP; progressive sequence alignment approach and its limitations; Identification of patterns from MSA; PROSITE; regular expressions; calculation of sequence profiles and their application

Unit 3:Molecular Phylogenetics: Tree of Life; Molecular clock hypothesis; Rooted and unrooted trees; Nodes, branches, Topology of a tree, Methods: Maximum parsimony; Distance-based (UPGMA and NJ) and Maximum likelihood; Boot-strapping method.

Reference Books:

1. Bioinformatics: Sequence and Genome Analysis (Second Edition) by David W Mount *CBS Publishers & Distributors Pvt Ltd*.
2. Essential Bioinformatics (First Edition) by Jin Xiong *Cambridge University Press*

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Integrated M.Sc Systems Biology

Course Code	**:** SB 406	**Credits**	**:** 2
Title of the Course	**:** Bioinformatics (Lab Techniques)	**L-T-P**	**:** 0-0-2
Prerequisite Course	**:** UG		

After the completion of this course, the students will be able to

CLO1: Understand concept of sequence similarity and biological database search
CLO2: Apply knowledge of basic principles of mathematics and computer science in understanding concepts of biology
CLO3: Analyse an analytical approach for its efficiency and robustness
CLO4: Evaluate existing software, pipelines and databases for extracting biological information
CLO5: Create new algorithms and programs by developing problem-solving skills

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	1	1	1	3	1	3	2	2	1	2
CLO 2	3	1	2	3	3	1	3	3	2	1	2
CLO 3	3	1	3	3	3	3	3	3	3	1	2
CLO 4	3	2	3	3	3	3	3	3	3	2	2
CLO 5	3	2	3	3	3	3	3	3	3	2	2

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Department of Systems and Computational Biology
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Integrated M.Sc Systems Biology

Course Code	**:** SB 404	**Credits**	**:** 3
Title of the Course	**:** Statistical Physics for Biologist	**L-T-P**	**:** 3-0-0
Prerequisite Course : UG			

After the completion of this course, the students will be able to

CLO1: Review what is thermal equilibrium, first law of thermodynamics, second law of thermodynamics, entropy and fundamental relation.
CLO2: Apply entropy postulates to given problems to determine the equilibrium configuration of systems.
CLO3: Apply the concept of phase space to the microcanonical and canonical ensemble approaches to study equilibrium systems.
CLO4: Apply uncertainty principle, Maxwell Boltzmann, Bose-Einstein and Fermi-Dirac statistics.
CLO5: Calculate probabilities and the moments of discrete and continous random variables including law of large numbers; central limit theorem.
CLO6: Review Markov chains and find the equilibrium probability distributions includes binomial, poisson and normal distribution.
CLO7: Review basics of Monte carlo simulation.
CLO8: Simulate 2D Ising model to demonstrate ferromagnetic to paramagnetic phase transition.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3		2	1	1						
CLO 2	3		2	3	1						
CLO 3	3		2	3	1						
CLO 4	3		2	3	1						
CLO 5	3		2	3	1						
CLO 6	3		2	1	1						
CLO 7	3		2	1	1						
CLO 8	3		2	3	1		2				

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

- **Probability Theory: Preliminaries**
  Intuitive notion of probability; frequency or occurrence; Bayes' probability; samplespace; events; probability of an event; equally probable events; conditionalprobability : P(AjB). joint probability; null event; sure event; axioms of probabilitytheory; Maxwell's ensembles; random variable; discrete random variable;continuous random variable; mean; variance; moments; moment generating/partition function; characteristic function; sum of two random variables; convolution; Chebyshev inequality; law of large numbers; central limit theorem
- **Binomial distribution : B(n).**
  Coin tossing; Binomial coeffcients; Pascal triangle; mean; variance; moment generating function; Boltzmann entropy; maximum entropy principle; equivalence of Boltzmann entropy to thermodynamic entropy
- **Poission distribution**
  Binomial to Poisson distribution; Master equation : derivation of Poisson distribution; mean and variance of Poisson distribution; radioactive decay.
- **Quantum Statistics**
  uncertainty; wave function; eigenfunctions; eigenvalues; Pauli exclusion; MaxwellBoltzmann, Bose-Einstein, and Fermi-Dirac Statistics
- **Monte Carlo Simulation**
  random numbers; sampling from distribution; inversion; rejection; Metropolis rejection; Markov chain; time homogeneous Markov chains; balance and detailed balance. Chebyshev inequality; law of large numbers; Gaussian distribution; central limit theorem; sum of random variables; statistical error /one-sigma confidence interval; reducing statistical error in Monte Carlo simulation; variance reduction methods; importance sampling; Monte Carlo simulation of a closed system; Boltzmann and non-Boltzmann Monte Carlo; free energy computations.
- **DIGRESSION : Thermodynamics**
  thermodynamic work; adiabatic process; internal energy; heat; First law; Carnot engine; exact and in exact differentials; state variables; process variables; entropy; the second law; consequences of the second law : heat flows from hot to cold; quasi static reversible processes; irreversible processes; Statistical entropy of Boltzmann; equivalence of Boltzmann entropy to thermodynamic entropy; Gibbs paradox; Boltzmann counting;
- **Isolated system**
  microcanonical ensemble; Gibbs paradox and its resolution; microcanonical entropy; temperature; pressure; chemical potential; ideal gas law; equipartition;
- **Closed system**
  canonical ensemble; Maxwell-Boltzmann distribution; thermodynamic work; free energy; ideal gas; energy fluctuations; heat capacity; microscopic interpretation of heat and work; harmonic oscillators : classical and quantum.

  References:
1. A Papoulis, Probability Theory, Random Variables, and Stochastic Processes, McGraw Hill (1965)
2. G B Benedek, and F M H Villars, Physics with Illustrative Examples from Medicine and Biology : Statistical Physics (second edition) Springer (1973)
3. James P Sethna, Entropy, Order Parameters, and Complexities, Clarendon Oxford (2008)
4. H C van Ness, Understanding Thermodynamics, Dover (1969)
5. H B Callen, Thermodynamics and Introduction to Thermostatistics, Second Edition, Wiley (2005

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Integrated M.Sc Systems Biology

Course Code	**:** SB 405	**Credits**	**:** 4
Title of the Course	**:** Proteomics	**L-T-P**	**:** 4-0-0
Prerequisite Course	**:** UG		

After the completion of this course, the students will be able to

CLO1: Understand the structural principles governing the protein structures and their classifications.

CLO2: Identification of key motifs and domains in protein structures, and their interaction with ligands or substrates; DNA-protein interactions.

CLO3: Understand the basic principles of thermodynamics and their implications in biological reactions.

CLO4: Learn the methods of measurement of kinetic parameters including enzyme kinetics and inhibitor reactions

CLO5: Acquire the knowledge for interactions of proteins and other macromolecules along with methods for their identification.

CLO6: Comprehend the basics of determination and prediction of three-dimensional structure of proteins.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3		2	2			2				1
CLO 2	3		2	2			2				1
CLO 3	3		2	2			2				1
CLO 4	3		2	2			2				1
CLO 5	3		2	2			2				1
CLO 6	3		2	2			2				1

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Unit1: Proteins to proteomes: Amino acids structure and general properties, types of structures of proteins, Protein classification, alpha-helix, beta-strands, loops and coils, Evolution of protein structures, protein stability and folding, Ramachandran plot, hydrophobicity and its applications; proteins enriched with disordered regions and their evolution and functions

Unit 2: Introductory thermodynamics and kinetics: Handling and analyzing kinetic data and free energy: Graphical analysis of single and double substrate reactions, Enzyme inhibition and rate studies related to inhibition, allosteric enzymes, mutational analysis, subunit interactions and regulation

Unit 3: Sequence and structure determination: Mass Spectrometry, Protein digestion, Sample preparation, sample ionization, Mass analysis, types of mass spectrometers, Peptide fragmentation, approach to mass spectrometry, Tandem mass spectrometry and SALSA, Peptide mass fingerprinting and protein identification, Database Utilization, de novo peptide sequence information, amino acid sequence database searching, un-interpreted MS/MS data searching, spectrophotometry, circular dichroism, fluorescence.

Unit 4: Protein interactions: Yeast two-hybrid system, protein-protein interaction, protein-DNA interaction, Protein chips technology, post-translational modifications; protein degradation. Two dimensional PAGE for proteome analysis

Unit 5: Basics of three-dimensional structure determination and predictions: Small-and macromolecular crystallography, structure solution, phase problem and direct methods, model building and refinement methods, temperature and occupancy factors, data and model quality –R-factor and resolution, Interpretation and use of X-ray crystallographic and NMR structures, protein structure predictions -homology modeling, fold recognition and ab inito structure prediction methods, structure consistency and validation tools; Procheck, WhatIF and verify3D.

Suggested reading:

(i) Structural Bioinformatics by P. E. Bourne and H. Weissig, Wiley-Liss
(ii) Crystal Structure Analysis: A Primer by J. P. Glusker & K. N. Trueblood, Oxford University Press
(iii) Introduction to protein structure by Carl Branden & John Tooze, Garland Science

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Integrated M.Sc Systems Biology

Course Code	**:** SB 405	**Credits**	**:** 2
Title of the Course	**:** Proteomics **(Lab)**	**L-T-P**	**:** 0-0-2
Prerequisite Course	**: UG**		

After the completion of this course, the students will be able to

CLO1: Express and purify recombinant protein in bacterial systems.
CLO2: Characterize purified protein through enzymatic activity and kinetics.
CLO3:Determine the secondary structure of protein using circular dichroism.
CLO4:Predict the three-dimensional structure of protein by bioinformatics approach.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	1		2		3				1		1
CLO 2	1		2		3				1		1
CLO 3	1		2		3				1		1
CLO 4	1		2		3				1		1

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

8th SEMESTER

Department of Systems and Computational Biology
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Integrated M.Sc Systems Biology

Course Code	**:**SB 451	**Credits**	**:** 3
Title of the Course	**:** Genomics	**L-T-P**	**:** 3-0-0
Prerequisite Course	**: UG**		

After the completion of this course, the students will be able to

CLO-1: explain and distinguish various genomic features

CLO-2: explain molecular markers, various approaches for genetic and physical mapping of genomes; and also analyze recombinant frequency of molecular markers to create genetic maps.

CLO-3: describe various chemistries/platforms for Next-generation sequencing (NGS); and analyze NGS data to assemble genomes, annotate the assembly, and predict various kinds of variants.

CLO-4: identify genes/pathways/biological processes underlying a phenotype through differenatial gene expression analysis (using RNA-seq).

CLO-5: discuss various other NGS based approaches, such as, BS-seq for genome wide methylation, chip-seq for finding DNA binding regions.

CLO-6: explain and distinguish features of various kinds of non-coding RNAs (ncRNAs).

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3		2		1	1					
CLO 2	3		2	2	1	1					
CLO 3	3		2	2	1	1					
CLO 4	3		2	2	1	1					
CLO 5	3		2	2	1	1					
CLO 6	3		2		1	1					

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Unit 1 **Structural genomics**: Organisation of prokaryotic and eukaryotic (nuclear & organelle) genomes, Repeats; Genome mapping, Genetic markers (RFLP, AFLP, SNP etc.), genetic and physical mapping; Genome sequencing and assembly, contigs, genome sequencing projects; NGS whole genome sequencing technology and methods; Gene annotation, finding genes and regulatory regions, Prediction of gene function, Gene ontology, Annotations by comparison of sequence; Genotyping: SNP, INDEL and Structural variant detection; Horizontal gene transfer, Genome synteny, Comparative genomics

Unit 2: **Functional genomics**: Mapping-by-sequencing; Gene expression profiling, Basic principles, methods and technology for gene expression profiling; northern blotting, qRT-PCR analysis, SAGE, DNA Microarrays, NGS based RNA seq methods including whole transcriptome analysis; Data normalization; Differential gene expression, Clustering gene expression profiles, Gene expression atlas; Enrichment analysis of functional/GO terms; High-throughput profiling of DNA binding elements using ChIP-seq; Encode project

Unit 3: **Small RNA and epigenomics**: Introduction to epigenetics; Various kinds of small non-coding RNAs, their biogenesis, and their functional role; Computational methods of discovery of microRNA and their targets. Profiling methylated sites in genome

Books recommended:

Genomes 4 by T A Brown
Genes XII by Benjamin Lewin
Introduction to Genetic Analysis 11e by Anthony Griffiths et al.

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Integrated M.Sc Systems Biology

Course Code	**:**SB 456	**Credits**	**:** 2
Title of the Course	**:** Genomics (Lab)	**L-T-P**	**:** 0-0-2
Prerequisite Course	**: UG**		

After the completion of this course, the students will be able to

CLO-1: predict some of the basic features of a genome by using fresh scripts or standard Bioinformatics softwares.

CLO-2: analyze NGS data for generating whole genome/transcriptome assembly, genome annotation, variant discovery, digital gene expression and differential expression, coexpression and over-represented ontology terms.

CLO-3: discover known and/or novel non-coding small RNAs from genome or high-throughput sequencing data, and predict their targets.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3		3	3	2	1	3				
CLO 2	3		3	3	2	1	3				
CLO 3	3		3	3	2	1	3				

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus

1. Predict following basic features of a genome by using fresh scripts or standard Bioinformatics softwares:
    - Codon usage bias
    - Pseudogenes
    - Simple sequence repeats
    - Horizontal gene transfer
    - Gene density
2. Analyze a sample NGS data from SRA for generating whole genome assembly, genome annotation, variant discovery.
3. Analyze a sample data from SRA for generating transcript assembly, digital gene quantification, differential expression, coexpression and over-represented ontology terms.
4. Computational discovery of known and/or novel non-coding small RNAs from genome or high-throughput sequencing data using miRDeep2, and predict their targets.

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Integrated M.Sc Systems Biology

Course Code	**:**SB 451	**Credits**	**:** 4
Title of the Course	**:** Computational systems biology	**L-T-P**	**:** 4-0-0
Prerequisite Course	**: UG**		

After the completion of this course, the students will be able to

CLO-1: understand the basic concepts of systems biology.
CLO-2: explain and discuss systems approach to solve biological problems
CLO-3: set up and solve ODEs concerning simple to advance problems such as enzymatic reactions, population dynamics etc
CLO-4: understand the concepts of networks and graphs
CLO-5: construct and analyze biological networks
CLO-6: read, understand and interpret published articles in mathematical modelling and network biology

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**	**PLO 11**
CLO1	3	1	3	1	3	1	2	3	1	1	1
CLO2	3	3	3	2	3	3	3	3	1	1	1
CLO3	3	2	3	3	3	1	3	3	1	1	1
CLO4	3	2	3	3	3	2	2	3	1	1	1
CLO5	3	2	3	3	3	1	3	3	1	1	1
CLO6	3	3	3	3	3	3	3	3	1	1	1

3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus

Unit 1:

a. Introduction to Computational Systems Biology; Types of data used in modeling; Types of models (gene regulatory, metabolic, Signal pathway, disease, population); types of modeling frameworks (Deterministic vs Stochastic; Static vs. Dynamics; Robustness and Stability of systems

b. Methods used in systems biology (Ordinary differential equations (ODE)

- Linear ODEs; Non-linear ODEs, steady states
- Stability analysis - Linear systems; Non-linear systems; Phase plane analysis; Stable and unstable limit cycles; Oscillations; Bistability; Positive and negative feedback
- Parameter estimation and validation – Data sources, Regression techniques (maximum likelihood, least squares methods), optimization algorithms
- Michaelis-Menten and Hill functions

Unit2:

a Stochastic modeling and Simulation, Chemical master equation; Gillespie algorithm; Stochastic ODEs

b Logical modeling, Logic gates; Graph construction; Boolean networks

c Metabolic control analysis (MCA), Control and elasticity coefficients; Summation theorems, connectivity relations theorems

d Biochemical Systems Theory (BST), Power law representation; S-Systems and General Mass Action; Comparison of MCA and BST modeling approaches

e Mathematical representation of metabolism, Flux Balance Analysis (FBA): Linear Programming; Constraints; Formulating an FBA problem, introducing constraints, optimization; Computational tools for FBA, examples of FBA using model networks.

f Neural Modeling: Hodgkin-Huxley model, Markov models, Action potentials, Voltage-activated Ion channels, Nernst Equation, Electrical Properties of Neurons

g Tools and databases: SBML; Modeling tools- Gepasi, Virtual cell, Cell Designer, GENESIS

Unit 3:

a. Graph Theory; Euler and Hamiltonian path/circuits; Cliques; Network motifs; bipartite networks; directed and undirected graphs/networks with examples

b. Models of networks: Random network model: Erdos-Renyi, Watts–Strogatz and Barabasi-Albert model; Real-world networks; Scale-free nature of a network; scale-free v/s random networks; robustness and fragile nature of scale-free network; modularity, heterogeneity and randomness of networks

c. Centrality measures- degree centrality, betweenness, closeness, eigen value, page-rank etc; hubs, bottlenecks, modules

Unit 4:

a. Protein-protein interaction networks; data resources; lethality-centrality rule; spatio-temporal aspect; Dichotomy of hubs: Date and party hubs; local and global hubs and their molecular characteristics; hub nodes as ensemble of various isoforms possible due to alternative splicing for genes

b. Gene networks, metabolic and signalling networks

c. Host-pathogen protein-protein interaction networks both bipartite and bridge networks

d. Disease-disease networks

e. Comparative analysis of Biological Networks

References:

1) *An Introduction to Systems Biology: Design Principles of Biological Circuits* by Uri Alon Published byChapman & Hall/CRC Mathematical and Computational Biology

2) *Analysis of Biological Networks* Edited by Björn H. Junker and Falk Schreiber Published by Wiley

3) *Network Sciences* by Albert-László Barabási Published by Cambridge University Press

4) Mathematical Modelling in Systems Biology – An Introduction by Brian Ingalls, MIT Press, Cambridge, London 2013 Edition

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Integrated M.Sc Systems Biology

Course Code	**:**SB 451	**Credits**	**:** 2
Title of the Course	**:** Computational Systems Biology (Lab)	**L-T-P**	**:** 2-0-0
Prerequisite Course : UG			

After the completion of this course, the students will be able to

CLO-1: understand the basic concepts of systems biology.
CLO-2: explain and discuss systems approach to solve biological problems
CLO-3: set up and solve ODEs concerning simple to advance problems such as enzymatic reactions, population dynamics etc
CLO-4: understand the concepts of networks and graphs
CLO-5: construct and analyze biological networks
CLO-6: read, understand and interpret published articles in mathematical modelling and network biology

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**	**PLO 11**
CLO1	3	1	3	1	3	1	2	3	1	1	1
CLO2	3	3	3	2	3	3	3	3	1	1	1
CLO3	3	2	3	3	3	1	3	3	1	1	1
CLO4	3	2	3	3	3	2	2	3	1	1	1
CLO5	3	2	3	3	3	1	3	3	1	1	1
CLO6	3	3	3	3	3	3	3	3	1	1	1

3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus

- Setting up of ODEs for simple mathematical models
- Solving ODEs using MATLAB/XPPAUT
- Phase plane, Nullclines, bifurcation analysis
- Working with published mathematical models pertaining to some biological systems
- Flux Balance Analysis
- Public domain databases on protein-protein interactions- Intact, HPRD etc
- Construction of biological networks using tools such as Cytoscape, igraph (in R) etc; calculation of various centrality measures, identification of hubs, bottlenecks etc
- Demonstration of Lethality – Centrality Principle
- Integration of gene expression data with protein-protein interaction data and building of context specific networks

Department of Systems and Computational Biology
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Integrated M.Sc Systems Biology

Course Code	**:**SB 453	**Credits**	**:** 3
Title of the Course	**:** Machine Learning Methods and Data Analysis	**L-T-P**	**:** 3-0-0
Prerequisite Course	**: UG**		

After the completion of this course, the students will be able to

CLO1: Explain the type of data analytics and how it is used for life sciences and health care data.
CLO2: Apply various machine learning algorithms such as Random forest, SVM, k-NN, ANN, HMM, Naïve Bayes classifier etc. on a given dataset to train classification and regression model.
CLO3: Interpret the results if ML based models
CLO4: Compare the efficacy of different ML algorithms on a particular dataset
CLO5: Discuss different database management systems
CLO6: Use various data repositories and databases available for biological data
CLO7: Explain the use of big data analytics
CLO8: Discuss the different architecture of big data analytic platforms such as Hadoop and Spark.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	1		1	1			3				1
CLO 2	2	2	2	2			3				1
CLO 3	2	3	3	3			3				1
CLO 4	2	3	3	3			3				1
CLO 5	2		1	1			3				1
CLO 6	3						3	3			1
CLO 7	2		1	1			3				1
CLO 8	2						3				1

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Unit 1: • Data analytics, Predictive data analytics, Descriptive data analytics, Prescriptive data analytics • Introduction to Machine learning algorithms, Supervised learning models, Unsupervised learning models, • Decision tree based classifiers, Random forest, Artificial Neural Networks; and Support Vector Machines, k-Nearest neighbor (kNN), etc. • Clustering techniques: k-Means clustering and hierarchical clustering, Dimensionality reduction with Principle component analysis. • Introduction to Markov chains, Naïve Bayes. • Introduction to Genetic Algorithms.

Unit 2: Database systems, Entity relation model, Relational model, Relational database design • Biological databases: GenBank-protein sequence database-EMBL Data Library-Brooke Heaven Database-Cambridge database • Data acquisition, data distribution • Compatibility of formats of data from different databases

Unit 3: Big data analytics What is Big Data? And introduction to Big Data analytics. Big Data in Life Sciences / Healthcare. Introduction to platforms for distributed analytics– Hadoop, Spark.

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Integrated M.Sc Systems Biology

Course Code	**:**SB 456	**Credits**	**:** 2
Title of the Course	**:** Machine Learning Methods and Data Analysis (Lab)	**L-T-P**	**:** 0-0-2
Prerequisite Course	**:** UG		

After the completion of this course, the students will be able to

CLO1: Read/write/process CSV data using R.
CLO2:Build classification/regression machine learning models using Random forest, SVM, k-NN, ANN, HMM, Naïve Bayes classifier etc. on a given dataset
CLO3:Perform feature selection using different technique in R.
CLO4:Compare the efficacy of different ML based model on a particular dataset and visualize the results by plotting in R.
CLO5:Write basic level program in R.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	2		2	2			3				1
CLO 2	3		3	3			3				1
CLO 3	3		3	3			3				1
CLO 4	3		3	3			3				1
CLO 5	3		2	3			3				1

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

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Integrated M.Sc Systems Biology

Course Code	**:**SB 454	**Credits**	**:** 3
Title of the Course	**:** Molecular Modeling and Simulations	**L-T-P**	**:** 3-0-0
Prerequisite Course	**: UG**		

After the completion of this course, the students will be able to

CLO 1: Discuss different file formats used in chemical and biological structural databases and computational tools
CLO 2: Explain the principles protein structural modeling using homology and ab initio methods
CLO 3: Discuss the docking methods and scoring functions
CLO 4: Explain different molecular mechanics based forcefields and water models
CLO 5: Evaluate thermodynamics parameters form molecular dynamics simulation

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3		3	2	3		2	2			3
CLO 2	3		3	3	3		2	2			2
CLO 3	3		3	2	3		2	2			3
CLO 4	3		3	2	3		2	2			3
CLO 5	3		3	3	3		2	2			3

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Unit 1: • IUPAC nomenclature, terms and atom-numbering for various biomolecules; coordinate systems (orthogonal/polar/cylindrical) used for conformational descriptions; geometrical parameters: bond length, angle and torsion angles, their calculations, improper and proper dihedral angles; steric criteria, Hard and soft spheres models. • Data representation and formats: Data formats for 2D, SMILES/InChI notations, matrix representation, connection tables, 3D data formats, PDB, CIF, RES, Mol2, SDF formats, Z-matrix, topology and parameter files, database redundancy • Stereochemistry: Chemical diagrams and projections, rules for Fischer projections, absolute and relative configuration, Cahn-Ingold-Prelog (CIP) rules, R/S, E/Z and cys/trans nomenclature, CORNrule, enantiomer and chirality, chirality of drugs and its consequences, diastereomers, meso compounds, stereogenic unit and stereogenic center, isomers and isomerism, puckering of alicyclic rings, group theory

Unit 2: • Molecular Mechanics: empirical potential functions; ball-and-spring model, harmonic approximation, bond length, angle, torsional, out-of-Plane and cross terms, popular, force field parameterization and various approaches for the problem, validation of force field, force fields and programs - MM, AMBER, CHARMM, OPLS, GROMOS, GROMACS, CVFF, Deriding and Universal force field, other methods of molecular energy calculations - ab initio, semi-empirical, density functional analysis • Energy minimization: Optimization methods, gradient (derivative methods): Steepest descent, Conjugate gradient and Newton-Raphson methods, constraint minimization, SHAKE and Tethering algorithms, Criteria for truncating minimization • Molecular Dynamics: Steps in typical MD simulations, minimization, equilibration and data collection, velocity scaling, periodic boundary condition, Numerical integrators verlet algorithm, analysis of trajectories, water and membrane models for simulation, Monte carlo (MC) methods, conformation search procedure, protein folding problem, Anfinsen paradigm, folding pathway, Levinthal paradox and Folding Funnel, • Electrostatics in chemistry & biology: concept of electric field, multipole expansion of a charge distribution, permanent and induced dipole and their interactions, peptide dipole, partial charge, dielectric constant, continuum and discrete solvation model, intermolecular interactions, hydrogen bonds, weak intermolecular interactions, pi-pi interactions, geometry criteria • molecular docking, scoring functions, introduction to Gold, autodock and Surflexdoc •

References

(i) Introduction to Electrodynamics by David J. Griffiths, Benjamin Cummings.
(ii) Chemoinformatics by J. Gasteiger and T. Engel, Wiley VCH
(iii) Molecular Modeling and Simulation by Tamar Schlick, Springer
(iv) Molecular Modelling: Principles and Applications by Andrew R. Leach, Pearson Edu.
(v) Stereochemistry Of Organic Compounds by Ernest L. Eliel, Wiley
(vi) Molecular modeling: basic principles and applications by H.-D. Höltje et al., Wiley-VCH.
(vii) Computational Chemistry by Errol G. Lewars, Kluwer Academic Publishers (
viii) Molecular Mechanics across Chemistry by A. K. Rappé & C. J. Casewit, University Science Book
(ix) Computational Chemistry by David C. Young, Wiley Inter Science
(x) Introduction to Computational Chemistry by Frank Jensen, John Wiley and Sons
(xi) Numerical Optimization by J. Nocedal and S. J. Wright, Springer
(xii) Computer simulation of liquids by M. P. Allen & D. J. Tildesley, Oxford Science Publ.
(xiii) Encyclopedia of Computational Chemistry by Paul von Ragué Schleyer, John Wiley & Sons.

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Integrated M.Sc Systems Biology

Course Code	**:**SB 456	**Credits**	**:** 2
Title of the Course (Lab)	**:** Molecular Modeling and Simulations	**L-T-P**	**:** 0-0-2
Prerequisite Course : UG			

After the completion of this course, the students will be able to

CLO-1: Understand the principles protein structural modeling using homology and ab initio methods
CLO-2: Learn the docking methods and scoring functions
CLO-3: Perform protein modeling and ligand docking using computational tools
CLO-4: Learn the molecular mechanics based forcefields, water models and evaluating thermodynamics parameters form molecular dynamics simulation (MDS)
CLO-5: Perform MDS for proteins and protein-ligand complexes in solvent (using Gromacs)

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3		2	3			1	2			
CLO 2	3		3	3			1	3			
CLO 3	3		3	3			1	2			2
CLO 4	3		2	3			1	3			
CLO 5	3		3	3			1	2			2

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

Mol Modelling Techniques: Techniques of three-dimensional structure determination and predictions: Small-and macromolecular crystallography, structure solution, phase problem and direct methods, model building and refinement methods, discussion on SHELX, temperature and occupancy factors, data and model quality –R-factor and resolution, Interpretation and use of X-ray crystallographic and NMR structures, protein structure predictions - homology modeling, fold recognition and *ab inito* structure prediction methods, structure consistency and validation tools; Procheck, WhatIF and verify3D**.**

9th SEMESTER

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Integrated M.Sc Systems Biology

Course Code	**:** SB 501	**Credits**	**:** 2
Title of the Course	**:** Comparative Systems Modelling	**L-T-P**	**:** 2-0-2
Prerequisite Course	**: UG**		

After the completion of this course, the students will be able to

CLO-1: demonstrate how well-characterized biological systems (either experimentally or theoretically) can be modeled mathematically to infer its functional or phenotypic behavior.

CLO-2: model major evolutionary processes through concepts of modeling, and concepts inherited from other disciplines.

CLO-3: explain design principles, behavior and application of synthetic circuits.

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3		2	3	1	1					
CLO 2	3		2	3	1	1					
CLO 3	3		3	3	1	1					

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

Syllabus:

- **Applications to Biological Models** [8 hours]: Selection of topics from
  - a) Circadian rhythms,
  - b) Quorum sensing,
  - c) Chemotaxis,
  - d) Wound healing,
  - e) Homoeostasis,
  - f) Apoptosis,
  - g) The phage λ genetic switch,
  - h) Kinetic proofreading

- **Modeling evolution and animal behavior** [8 hours]:
  - a) Evolutionary Game Theory : Evolution, Game theory, Dominant and dominated strategies, Evolutionary Stable Strategy, Prisoners' Dilemma, Hawk and Dove game, Eusociality, Spatial Games, Games in Graphs.
  - b) Modeling Natural selection, Genetic drift and Mutation for finite and infinite populations.

- **Synthetic Biology** [8 Hours]:
  - a) Introduction to Synthetic Biology,
  - b) Parts, Devices and Systems,
  - c) Modeling Synthetic Biology Systems
  - d) iGEM, Modules and Bio Bricks
  - e) Transcriptional, Translational, Post Translational and Hybrid approaches.
  - f) Examples: Toggle switch, repressilator, genetic switch board, etc.,

Reference Books:

1. *Synthetic Biology* , A Primer, by P. S. Freemont and R. I. Kitney (Eds), Imperial College Press, 2012. ISBN: 9781848168633.
2. *Evolution and the Theory of Games,* by J. Maynard Smith. Cambridge University Press. ISBN: 0521288843.
3. *Evolutionary Dynamics*, by M. A. Nowak. Belknap Press. ISBN: 9780674023383.
4. *Principles of population genetics*, by D. L. Hartl and A. G. Clark. W. H. Freeman and Company. ISBN: 9780878933082.
5. *Theoretical Neuroscience: Computational and Mathematical Modeling of Neural systems*, by P. Dayan and L. F. Abbott. The MIT Press. ISBN 0262041995
6. *Biological Sequence Analysis: Probabilistic Models of Proteins and Nucleic Acids*, by R. Durbin, S. Eddy, A. Krogh and G. Mitchison. Cambridge University Press, 1998. ISBN: 9780521629713
7. *A Genetic Switch: Phage Lambda Revisited,* by M. Ptashne. Cold Spring Harbor Laboratory Press. ISBN: 9780879697167
8. *Genes and Signals,* by M. Ptashne. Cold Spring Harbor Laboratory Press. ISBN: 97808796963377
9. *Machine Learning,* by T. M. Mitchel. McGraw-Hill. ISBN: 9780070428072.
10. *An Introduction to Systems Biology,* by U. Alon. Chapman and Hall/CRC, 2007. ISBN: 9781584886426.
11. *Computational Modelling Of Gene Regulatory Networks - A Primer,* by Hamid Bolouri. Imperial College Press, 2008. ISBN: 9781848162211.
12. *Mathematical Biology,* by J. D. Murray. Springer. ISBN: 0387952284.

Research Articles:

The following is a partial list of suggested research articles for the course and others will be suggested depending on instructor's preference.

1. *Light-Driven Changes in Energy Metabolism Directly Entrain the Cyanobacterial Circadian Oscillator* by M. J. Rust et al., Science 331 (2011) 220.
2. *Quorum sensing: cell-to-cell communication in bacteria*, by C M Waters and B L Bassler, Annu. Rev. Cell Dev. Biol. 21 (2005) 319-46.
3. *Stochastic Simulation of Chemical Kinetics* by Daniel T. Gillespie, Annual Review of Physical Chemistry 58 (2007) 35-55.
4. *Accelerating the Gillespie Exact Stochastic Simulation Algorithm Using Hybrid Parallel Execution on Graphics Processing Units* by Ivan Komarov, Roshan M. D'Souza mail, PLOS ONE (2012) 7(11).
5. *Responding to chemical gradients: bacterial chemotaxis* by Victor Sourjik, Ned S. Wingreen, CurrOpin Cell Biol. 24(2) (2012 Apr) 262-8.
6. *Dynamics of cooperativity in chemical sensing among cell-surface receptors* by Monica L. Skoge, Yigal Meir, Ned S. Wingreen, Phys Rev Lett. 107(17) (2011).
7. *Entrainment of the mammalian cell cycle by the circadian clock : Modeling two coupled cellular rhythms.* by Gérard C, Goldbeter A, PLoSComput. Biol. 8 (5) (2012).
8. *Systems biology of cellular rhythms.* byGoldbeter A, Gérard C, Gonze D, Leloup J-C, Dupont G, FEBS Lett. 586 (2012).
9. *Speed, dissipation, and error in kinetic proofreading* by Murugan A, Huse DA, Leibler S, PNAS 109(30) (2012).
10. *Synthetic Biology: Integrated Gene Circuits* by NagarajanNandagopal et al., Science 333 (2011) 1244.
11. *Mixed Messages: How Bacteria Resolve Conflicting Signals* by Jonathan W. Young and Michael B. Elowitz, Molecular Cell Previews 42 (2011) 405-406.

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Integrated M.Sc Systems Biology

Course Code	**:** SB 506	**Credits**	**:** 2
Title of the Course	**:** Comparative Systems Modelling (Lab)	**L-T-P**	**:** 0-0-2
Prerequisite Course	**: UG**		

After the completion of this course, the students will be able to

CLO-1: Generate mathematical models (deterministic and/or stochastic) of a few well characterized simple/complex dynamical systems.

CLO-2: Use knowledge of Recombinant DNA technology and mathematical modeling to investigate behavior of simple synthetic circuits, and also design novel ones theoretically.

CLO-3: implement one of the evolutionary models

Mapping with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	2			3	3	2	3				
CLO 2	2			3	3	2	3				
CLO 3	2			3	3	2	3				

‘3’ – *High-level*
‘2’ – *Medium-level*
‘1’ – *Low-level*

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Integrated M.Sc Systems Biology

Course Code	**:** SB 508 (Elective)	**Credits**	**:** 2
Title of the Course	**:** Metagenome analyses and applications	**L-T-P**	**:** 2-0-0
Prerequisite Course	**:** Basic knowledge of genomes and that of using (Bioinformatics) software		

After the completion of this course, the students will be able to

CLO-1 use high-throughput sequencing approach for taxonomic and functional profiling microbial communities.
CLO-2 analyze the diversity in a given sample, and change between or across samples
CLO-3 predict the dominant functions or metabolic activities prevalent in a community

Mapping with PLOs

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10	PLO 11
CLO1	3		2	3	3						
CLO2	3		2	3	3						
CLO3	3		2	3	3						
CLO4											
CLO5											

'3' – *High-level*
'2' – *Medium-level*
'1' – *Low-level*

Syllabus:

- Amplicon sequenicng of marker genes: Choice of marker genes, Clustering sequences into Operational taxonomic units, Taxonomy assignment, Diversity analysis (Alpha and Beta), Finding taxa which are differential abundant [10 hours]

- Whole-genome shotgun sequencing (WGS) of metagenomes: Strategies for WGS, Quality control, Assembly and Binning methods, Metabolic reconstruction analyses, Finding enriched pathways [10 hours]

- Application to agriculture, human health and environment. Dynamics of microbial communities and their modeling. [4 hours]

Books:

1. Metagenomics for Microbiology, 1st Edition, Editors: Jacques Izard Maria Rivera Paperback ISBN: 9780124104723 eBook ISBN: 9780124105089 Imprint: Academic Press Published Date: 12th November 2014
2. Metagenomics: Perspectives, Methods, and Applications 1st Edition by Muniyandi Nagarajan. Academic Press; 1 edition (November 12, 2017) Language: English ISBN-10: 0081022689

Articles:

1. HMPC (2012) Structure, function and diversity of the healthy human microbiome. Nature 486:207
2. Gevers D, Pop M, Schloss PD, Huttenhower C (2012) Bioinformatics for the Human Microbiome Project. PLoS Comput Biol 8(11): e1002779. doi:10.1371/journal.pcbi.1002779
3. Manimozhiyan Arumugam et al. (2011) Enterotypes of the human gut microbiome. Nature 473:173
4. Justin Kuczynski, et al. (2012) Experimental and analytical tools for studying the human microbiome. Nature Reviews Genetics 13:47.
5. Christopher Quince, et al. (2017) Shotgun metagenomics, from sampling to analysis. Nature Biotech 35(9):833

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Integrated M.Sc Systems Biology

Course Code	**:** Elective	**Credits**	**:** 2
Title of the Course	**:** Endocrine Biochemistry	**L-T-P**	**:** 2-0-0
Prerequisite Course	**: U**G		

After the completion of this course, the students will be able to

CLO-1 Understanding the hormone-receptor interactions
CLO2 Understanding of the role of hormones in human physiology
CLO-3 Understanding the molecular mechanisms (signaling) of hormone action
CLO-4 Connecting the hormones deficiencies with clinical significance
CLO-5 How to apply various molecular approaches to dissect the hormone deficiencies to relate the physiological functions

Mapping with PLOs

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10	PLO 11
CLO1	3	2	3	3	3	3		3	2	2	2
CLO2	3	3	3	3	3	3		3	2	2	2
CLO3	3	3	3	3	3	3		3	2	2	2
CLO4	3	3	3	3	3	3		3	3	2	3
CLO5	3	2	3	3	3	3		3	2	3	3

'3' – *High-level*
'2' – *Medium-level*
'1' – *Low-level*

Syllabus:
Endocrine Biochemistry (BC521) (24 hours or 2 credits)
Lecture schedule

Unit 1: Endocrine system: General features endocrine and excocrine systems (2 hours)
Unit 2: Mechanism of action of hormones; Hormone and ligand interactions. Agonist, antagonist. Membrane receptor action, nuclear receptor action, membrane channels. GPCR, groth factor receptor, nuclear steroid hormone receptor actions. (6 hours)
Unit 3: Biosynthesis, structures and functions of the hormones of pituitary, thyroid, adrenal, pancreas and gonads-secretion, biochemical nature of hormones, regulation of secretion, mechanism of action and biological effects. (10 hours)
Unit 4: Digestive processes in various regions of digestive system. (2 hours)
Unit 5: Gastrointestinal hormones, their synthesis and function. (2 hours)
Unit 6: Structure and function of Insulin like growth factors and their receptors. (2 hours)

Reference Books:

1.Text book if endocrine physiology by James E Griffin and Sergio R Ojeda
2.Endocrinology by Mac Hadley
3.Williams Text book of endocrinology

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Integrated M.Sc Systems Biology

Course Code : Elective	**Credits** : 2
Title of the Course : Principles In Cancer And Cancer Stem Cell Biology	**L-T-P** : 2-0-0
Prerequisite Course : UG	

After the completion of this course, the students will be able to

CLO-1 Understanding the hall marks of cancer; How a cancer cell is different from a normal cell
CLO-2 How cancers arise: agents that cause cancer
CLO-3 Molecular mechanisms of tumorigenesis: How the balance between Oncogenes and tumor suppression gene dictate the cancer outcome
CLO-4 Understanding the tumor metastasis: how and why cancer cells migrate to secondary sites
CLO-5 Understanding the mechanism of cell division
CLO-6 understanding various molecular therapies treating cancer
CLO-7 Why certain specific cancers are prevalent in India such as Breast, Oral and Cervical cancers and therapies to treat them

Mapping with PLOs

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10	PLO 11
CLO1	3	2	3	3	3	3		3	2	2	2
CLO2	3	3	3	3	3	3		3	1	2	2
CLO3	3	3	3	3	3	3		3	2	1	2
CLO4	3	3	3	3	3	3		3	3	2	2
CLO5	3	2	3	3	3	3		3	2	3	3
CLO6	3	3	3	3	3	3		3	3	3	3
CLO7	3	3	3	3	3	3		3	3	3	3

'3' – *High-level*
'2' – *Medium-level*
'1' – *Low-level*

Syllabus:

Unit 1. Normal cell versus Cancer cell: Nature of the cancer; hall marks of cancer (2 hours)
Unit 2: Cell immortalization and tumorigenesis: Cellular immortalisation, chemical and viral carcinogenesis (4 hours)
Unit 3: Oncogenes and tumor suppressor genes: RSV invention and as a case study; Ras oncogene; protooncogene; mechansism of oncogenesis; retinablastoma as a case study for tumor suppressor cocept; Rb function in cell cycle regulation; p53 as a tumor suppressor gene; apoptosis (6 hours)
Unit 4: Tumor metabolism: Compare tumor metabolism with normal cells. Warburg effect. (2 hours)
Unit 5: Maintenance of Genomic integrity and development of cancer (2 hours)
Unit 6: Invasion and metastasis- Epithelial to mesenchymal transition (2 hours)
Unit 7: Cancer stem cells-Basics and targeting cancer stem cells. What are cancer stem cells; Somatic evolution, drug resistance (2 hours)
Unit 8: Rationale treatment of cancer. Various cancer therapies (2 hours)
Unit 9: Special emphasis on few imp cancers which are prevalent in IndiaBreast cancer, Oral cancer, etc (2 hours)

Reference Books:
1.Biology of Cancer by Robert Weinberg
2.Principles Of Cancer Biology - Lewis J Kleinsmith
3. Oxford Textbook of Cancer Biology. Edited by Francesco Pezzella, Mahvash Tavassoli and David Kerr.
4. Specific review articles from Nature review cancer, Trends in Cancer etc.

10th SEMESTER

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Integrated M.Sc Systems Biology

Course Code : SB 553	**Credits** : 4
Title of the Course : Formal and Computational Approaches in Cognition	**L-T-P** : 4-0-0
Prerequisite Course : UG	

After the completion of this course, the students will be able to

CLO-1: Read and understand works on models of brain and cognition at different scales.

CLO-2: Be able to use differential and difference equations to model systems especially neurophysiological and behavioural systems.

CLO-3: Be familiar with learning mechanisms in the brain and their models

CLO-4: Be able to discuss links between neural networks, AI systems and natural cognitive ssytems.

CLO-5: Use computer simulations to implement these models

Mapping of CLOs to PLOs:

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO10**	**PLO11**
CLO 1	3	3	3	3	2						2
CLO 2	3	3	3	3	2						2
CLO 3	3	3	3	3	2						2
CLO 4	3	3	3	3	2						2
CLO 5	1	0	3	3	2		3				2

‘3’ – High-level
‘2’ – Medium-level
‘1’ – Low-level

Syllabus:

Unit I
Models of neurons and its simulation: Hodgkin and Huxley, Reduced models and Integrate and fire models. Synaptic mechanisms and their modeling.

Unit II
Artificial Neural Networks: Perceptron, Linear seperability problem, Back propagation. Deep learning. Supervised and Unsupervised learning. Hopfield network. Deep learning.

Unit III
Neural coding and plasticity: Linear nonlinear models, Information theoretic models, Reinforcement Learning. Bayesian approaches. Dynamical Causal Modeling.

Unit IV
Propositional logic. Predicate logic. HMMs. POS tagging. Co-occurancevectors. Representation of meaning. Computational discourse.

Unit V
Issues in Artificial Cognitive Systems II (High level agents): Modeling attention, memory. Making robots move, Multi Agent Systems, Modeling TOM, Designing Sociable Robots. Cognitive architectures: ACT-R, SOAR, EPIC.

Reading Material:

- Computational Neuroscience: Dayan and Abbot; MIT Press
- Speech and Language Processing: Daniel Jurafsky and James H Martin; Pearson Education
- The Logic Manual, Volker Halbach, OUP.
- Designing Sociable Robots: Cynthia L Breazeal; MIT Press