This document contains the course structure and course content of MSc Biochemistry and Integrated MSc-PhD in Biochemistry and Molecular Biology programs

M.Sc. Biochemistry

Semester: I

S.No.	Course No.	Course Title	Credits
1	BC401	Intermediary Metabolism I	3
2	BC402	Biophysical Chemistry	3
3	BC403	Basic Bioinformatics and Computational Biology	3
4	BC404	Biochemical Techniques - I	4
5	BC405	Microbiology	3
6	BC406	Genetics	3
7		Foundation course 1	3
		Total	**22**

Semester: II

S.No.	Course No.	Course Title	Credits
1	BC451	Enzymology	3
2	BC452	Molecular Biology - I	3
3	BC453	Structural Biology	2
4	BC454	Intermediary Metabolism - II	3
5	BC455	Biochemical Techniques - II	5
6	BC456	Cell Biology	3
7		Foundation course 2	3
		Total	**22**

Semester: III

S.No.	Course No.	Course Title	Credits
1	BC501	Basic Immunology	3
2	BC502	Molecular Biology - II	3
3	BC503	Bioenergetics and Biomembranes	3
4	BC 505	Nutritional and Clinical Biochemistry	2
5	BC504	Biochemical Techniques - III	5
6	BC521	Endocrine Biochemistry (Elective)	2
7	BC523	Developmental Biology (Elective)	2
		Total	**20**

Semester: IV

S.No.	Course No.	Course Title	Credits
1	BC553	Project	16
2	BC575	Principles in Cancer and Cancer Stem Cell Biology (Elective)	2
3	BC576	Glycoconjugate: Role in Biology and Biomedical Relevance (Elective)	2
		Total	20

Students have to earn 20 credits in Semester IV. They can earn all of it through project or have the option of earning 4 credits through electives. Students who earn all through project will have to submit a review paper that will be evaluated. This is in addition to the project requirements.

Integrated MSc/PhD in Biochemistry and Molecular Biology

Semester: I

S.No.	Course No.	Course Title	Credits
1	BC401	Intermediary Metabolism I	3
2	BC402	Biophysical Chemistry	3
3	BC403	Basic Bioinformatics and Computational Biology	3
4	BC404	Biochemical Techniques - I	4
5	BC405	Genetics	3
6	BC406	Microbiology	3
7		Foundation course 1	3
		Total	**22**

Semester: II

S.No.	Course No.	Course Title	Credits
1	MB451	Enzymology and Bioenergetics	3
2	BC452	Molecular Biology - I	3
3	BC453	Structural Biology	2
4	BC454	Intermediary Metabolism - II	3
5	BC455	Biochemical Techniques - II	5
6	BC456	Cell Biology	3
7		Foundation course 2	3
		Total	**22**

Semester: III

S.No.	Course No.	Course Title	Credits
1	BC501	Basic Immunology	3
2	BC502	Molecular Biology - II	3
3	MB503	Molecular Biology -III	3
4	BC504	Biochemical Techniques - III	5
5	BC505	Nutritional and Clinical Biochemistry	2
6	BC521	Endocrine Biochemistry **(Elective)**	2
7	BC523	Developmental Biology **(Elective)**	2
		Total	**20**

Semester: IV

S.No.	Course No.	Course Title	Credits
1	BC553	Project	14
2	MB576	Molecular Biology- IV	3
3	MB578	Advanced molecular biology practical	1
4	MB579	Comprehensive viva	1
		Total	**19**

Academic Program: MSc in Biochemistry

Vision:

1) To provide quality post-graduate education to prepare them to enter PhD/research programs or pursue positions in biotechnology and pharmaceutical industry and other fields
2) To equip students to contribute to national mission for health, hygiene and sustainable development

Mission:

1) To develop the best Master's in Biochemistry program in the country
2) Train students to ask scientific questions and seek answers
3) Skilled in modern techniques of biology
4) Develop a scientific temper that can be applied in diverse fields
5) Effectively communicate scientific knowledge to the community
6) Good laboratory practices and ethics in scientific research
7) Contribute to global and local health challenges

Qualification Descriptors (QDs)

After the completion of the program, students will be able to demonstrate

QD-1 **Clarity of concepts:** Understand structure, building and function of biomolecules, means of energy generation, information processing and complexity in the cell and organisms.

QD-2 **Analytical skills:** To understand experimental basis of generating information in biology, to be able to read and interpret the methodologies and hypotheses tested in generating data. To analyse data statistically and to quantify observations/results

QD-3 **Critical and logical thinking:** To critically examine data that lead to hypothesis, to be able to extrapolate observations to conclusions

QD-4 **Application of knowledge:** To be able to apply learned concepts in correct situations. To formulate hypothesis and design methods to test hypothesis

QD-5 **Communication skills:** To be able to explain concepts clearly in written and oral forms. To be able to articulate their understanding and interests in simple yet scientific terms.

QD-6 **Employability:** To be skillful in the laboratory techniques learnt. To be able to apply it in the context of academic research laboratories, biotechnology and pharmaceutical industry, diagnostic centers etc. To be skilled in data analysis and interpretation.

Mapping Qualification Descriptors (QDs) with Mission Statements (MS)

	MS-1	MS-2	MS-3	MS-4	MS-5	MS-6	MS-7
QD-1	3	3	3	3	3	3	2
QD-2	3	3	3	2	3	2	2
QD-3	3	3	2	3	3	3	3
QD-4	3	3	2	3	3	2	3
QD-5	3	2	2	2	3	2	3
QD-6	3	3	3	3	3	3	3

Name of the Academic Program: MSc Biochemistry

Program Learning Outcomes (PLOs)

The students at the end of the program would have acquired knowledge in following program specific parameters:

PLO-1 Biochemistry, structure and function of biological molecules
PLO-2 Chemical reactions and Bioenergetics

PLO-3 Enzyme mechanisms and kinetics
PLO-4 Genetic regulation of cellular process
PLO-5 Information processing in the cell
PLO-6 Genetic and biochemical basis of disease
PLO-7 Cellular organization, communication and functions
PLO-8 Cellular and organismal complexity
PLO-9 Basic computational biology, statistical analysis and data interpretations
PLO-10 Proficiency in laboratory biochemical and molecular techniques
PLO-11 Hypothesis building, testing and experimentation
PLO-12 Comprehension and communication of scientific data

Course Learning Outcomes (CLOs) (5 to 8) for all courses

Each CLO is mapped with one or more PLOs. '3' in the box for 'High-level' mapping, 2 for 'Medium-level' mapping, 1 for 'Low-level' mapping

Semester I

Course Code : BC 401 : Title of the Course – **Intermediary Metabolism – I**

L.T.P: 3-0-0 **Credits** – 3

Prerequisite course : Knowledge at B.Sc. level Chemistry or Biochemistry mandatory as one of the subjects.

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

CLO 1: Understand the basis of macromolecular digestion to monomeric units in the human body, absorption of the products and assimilation to other parts of the body.
CLO 2: Study how the monosaccharides, predominantly glucose can be converted by human cells under anaerobic and aerobic conditions to generate ATP, the energy currency of the cell required for biosynthetic processes.
CLO 3: Role of specific enzymes in regulating the above processes and diseases involved due to metabolic lock in reaction sequences.
CLO 4: Brain requires glucose for its energy needs under low blood glucose levels, liver can form glucose by gluconeogenesis and can supply to brain.
CLO 5: Role of glucose 6-phosphate in providing NADPH, the reducing agent for fatty acid biosynthesis and formation of different sugar intermediates useful in various metabolic pathways.
CLO 6: Importance of dietary lipids, their digestion and absorption and distribution into different tissues in the body.
CLO 7: The degradation of fatty acids in the cells for the production of Acetyl CoA that can further lead to energy production in the cells
CLO 8: Importance of NADPH in fatty acid biosynthesis, production of unsaturated fatty acids and assembly of triacylglycerol's.
CLO 9: Lipid derivatives as functional units in cellular architecture, intracellular organelles, importance of cholesterol, its role in formation of important vitamins.

Mapping of CLOs with 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	PLO 12
CLO1	3	3	2	2	2	2	3	2	1	1	2	3
CLO2	3	3	2	2	2	2	3	2	1	1	2	3
CLO3	3	3	3	3	3	3	3	2	1	2	2	3
CLO4	3	3	2	2	2	2	3	2	1	2	2	3

CLO5	3	3	2	2	2	2	3	2	1	3	2	3
CLO6	3	3	2	2	2	2	3	2	1	2	2	3
CLO7	3	3	2	2	2	2	3	2	1	2	2	3
CLO8	3	3	2	2	2	2	3	2	1	2	2	3
CLO9	3	3	2	2	2	2	3	2	1	2	2	3

Unit 1: Methods to study Metabolism. Dietary Carbohydrates – Digestion and absorption from the intestinal tract into other parts of the body 3H

Unit 2 : Reactions of glycolysis and TCA cycle with emphasis on regulation, anaplerotic reactions, tracing reactions of TCA cycle using radio isotopes pyruvate dehydrogenase complex and its mechanism substrate level phosphorylation, lactate fermentation, malate/aspartate shuttle, glycerol-phosphate shuttle, and Warburg effect. Glyoxylate cycle 6H

Unit 3 : Pentose phosphate pathway reactions and its importance. metabolic role: source or disposal of pentoses, reducing power for biosynthesis. The reactions of gluconeogenesis, hormonal and metabolite con trol of glycolysis and gluconeogenesis in liver. The Hormonal regulation of blood glucose: insulin, glucagon, cortisol, defects in glycaemia control and altered metabolic events; non-enzymatic glycation and polyolpathway.
7H

Unit 4 : General scheme of carbohydrate metabolism in liver and extra-hepatic tissues, phosphorylation of glucose, glycogen synthesis and glycogenolysis and their regulation in liver and muscle. Including inborn errors of carbohydrate metabolism.
5H

Unit 5: Special emphasis on the interrelations between metabolic pathways and human diseases such as diabetes and obesity arise from defects in metabolic pathways. Biosynthesis of Lactose, Starch and Cellulose. 3H

Unit 6 : Structure of important lipids. Digestion, absorption and transport of dietary lipids, role of bile salts, hormone-dependent triglyceride lipase. Fatty acid activation, transport to the mitochondrial matrix and role of carnitine, steps of beta-oxidation. Oxidation of odd-chain and of unsaturated fatty acids, energetics of fatty acids oxidation, fasting and ketogenesis and relation with gluconeogenesis 4H

Unit 7 : De novo synthesis of palmitate, energetics and reducing power. Elongation and desaturation of fatty acids, essential fatty acids and derivatives (ω3 and ω6 families). Biosynthesis of glycerol lipids, synthesis of phosphatidic acid. Synthesis of triacylglycerols and the major glycerophospholipids. Brief account on the synthesis of plasmalogens, sphingomyelin and glycolipids. Brief account of Prostaglandins
4H

Unit 8 : Reactions of cholesterol biosynthesis, synthesis of cholesteryl esters. Derivatives of cholesterol: bile acids, vitamin D3, and steroid hormones. Structure and classification of lipoproteins, composition, transport, and cholesterol export in lipoproteins.
3H

Unit 9: Hormonal regulation of lipid levels, Defects in fatty acid metabolism in relation to obesity and metabolic syndrome, connection between glucose and fatty acid metabolism; Randle cycle, inborn errors in lipid metabolism
1H

Reference Books:

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

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Course Code: **BC402** Title of the Course: **Biophysical Chemistry**
L-T-P: 3-0-0 Credits: **3 credits**
Prerequisite Course / Knowledge (If any):

Course Learning Outcomes (CLOs) (5 to 8)

After completion of this course successfully, 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 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**	**PLO 12**
CLO1	3	3	3	1	2	2	1	1	3	3	1	1
CLO2	3	3	3	1	1	1	1	1	2	2	1	1
CLO3	3	3	2	1	2	1	2	1	2	1	2	2
CLO4	3	2	3	1	1	2	1	1	2	1	2	2
CLO5	3	3	3	1	1	2	1	1	1	2	2	2
CLO6	3	3	3	1	2	2	1	1	1	2	2	2

Unit1. Interactions in Biological Systems, Intra and inter molecular forces electrostatic interactions and Hydrogen bonding interactions, van der Waals and Hydrophobic interactions, Disulphide bridges, Role of water and weak interactions. Bimolecular structures 5h

Unit2. Principle of biophysical chemistry- pH, buffer, pKa, equilibrium and colligative properties. Oxidation and reduction phenomenon in biological systems, redox potential calculation 4h

Unit3. Separation and characterization of macromolecules, detergent, electrophoresis and chromatography, membrane proteins 5h

Unit4. Hydrodynamic methods: Sedimentation- Ultracentrifugation, basic principle, sedimentation rate analysis, sedimentation velocity, sedimentation equilibrium and application 4h

Unit5. Spectroscopy technique-I: Quantum mechanics, basic principle of absorption and fluorescence spectroscopy and their applications 5h

Radio-isotopic technique: measurement, detection and application in biology 3h

Unit6. Bio-thermodynamics: basics and application of thermodynamic in biology, ITC, DSC 5h

Understanding biological system using physical chemistry: signal transduction, rhodopsin, Bacteriorhodopsin, membrane potential, transporter and channels 5h

Reference Books:

1. Physical Biochemistry by David Frefeilder
2. Physical Biochemistry Principles and Application by David Sheehan
3. Principles and Techniques of Biochemistry and Molecular Biology by Keith Wilson and John Walker
4. Physical Chemistry of Macromolecules Basic Principles and Issues by S. F.Sun

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Course Code: BC403 Title of the Course: Basic Bioinformatics and Computational Biology

L-T-P: 0-1-2 Credits: 3

Prerequisite Course / Knowledge (If any): Biology, Chemistry, Physics, Mathematics

Course Learning Outcomes (CLOs) (5 to 8)

Basic Bioinformatics and Computational Biology:

After completing this course, students will be able to:

CLO-1: discuss the use of bioinformatics in addressing a range of biological questions

CLO-2: describe how bioinformatics methods can be used to relate sequence, structure and function

CLO-3: discuss the technologies for modern high-throughput DNA sequencing and their applications

CLO-4: use and describe some central bioinformatics data and information resources.

CLO-5: describe basic principles and algorithms of pairwise and multiple alignments, and sequence database searching

CLO-6: perform pattern matching in biomolecular sequences

CLO-7: describe the most important principles in gene prediction methods

CLO-8: describe basic principles of hidden Markov models and their application in sequence analysis

CLO-9: implement solutions to basic bioinformatics problems

CLO-10: Understand probability concepts

CLO-11. Apply exploratory data analysis methods to describe/summarise a distribution and assess whether data are normally distributed.

CLO-12. Calculate and interpret Confidence Intervals for means and proportions and state the assumptions on which they are based.

CLO-13. Conduct hypothesis tests relating to means and proportions and explain the role of the test statistic, p-value, and significance/Type I error rate.

CLO-14. Discuss the difference between statistical significance and clinical significance.

CLO-15. Describe the importance of considering power and the Type II error rate during study design.

CLO-16. Perform sample size calculations relating to means and proportions for common study designs

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**	**PLO 12**
CLO1	3	2	3	3	3	2	2	3	3	2	3	3
CLO2	3	2	3	3	3	2	2	3	3	2	3	3
CLO3	3	2	3	3	3	2	2	3	3	2	3	3
CLO4	3	2	3	3	3	2	2	3	3	2	3	3

CLO5	3	2	3	3	3	2	2	3	3	2	3	3
CLO6	3	2	3	3	3	2	2	3	3	2	3	3
CLO7	3	2	3	3	3	2	2	3	3	2	3	3
CLO8	3	2	3	3	3	2	2	3	3	2	3	3
CLO9	3	2	3	3	3	2	2	3	3	2	3	3
CLO10	1	2	2	2	2	2	2	2	3	2	3	3
C11O12	1	2	2	2	2	2	2	2	3	2	3	3
CLO13	1	2	2	2	2	2	2	2	3	2	3	3
CLO14	1	2	2	2	2	2	2	2	3	2	3	3
CLO15	1	2	2	2	2	2	2	2	3	2	3	3
CLO16	1	2	2	2	2	2	2	2	3	2	3	3

Syllabus

Unit 1. Introduction to Bioinformatics and Computational Biology: History and major developments 3h

Unit 2. Introduction to sequence, structure, pathways, and other Biological Databases and Computational Tools 3 h

Unit 3. Database development: The basics 2h

Unit 4. Nucleic acid sequence analysis: Sequence alignment, substitution matrices, secondary structure elements, motifs 4h

Unit 5. Protein sequence analysis: Sequence alignment, substitution matrices, secondary structure elements, motifs 4h

Unit 6. Evolutionary analysis: Phylogenetic tree construction using Distance-based, Maximum parsimony and maximum likelihood methods; Tree reliability analyses; Tree visualization. 3h

Unit 7. Molecular modelling: RCSB PDB database, Protein tertiary structure prediction using homology modelling and threading, small molecules, force fields, energy minimization and molecular docking 2 h

Unit 8. Applications to biological problem solving 3h

Module 2: (Theory 12 hours)

Statistical analysis of biological experiments:

Unit 8. Samples and Populations, Measures of central tendency and dispersal 2 h

Unit 9. Sampling distribution 1h

Unit 10. Probability distributions (Binomial, Poisson and Normal) 1h

Unit 11. Confidence Interval 1h

Unit 12. Difference between parametric and non-parametric statistics 1h

Unit 13. Levels of significance: Null hypothesis, Alternative hypothesis 3h

Unit 14. Errors (Type I and type II errors) 1h

Unit 15. p-value, adjusted p-value; Student's T-test 1h

Unit 16. Regression and Correlation; Analysis of variance; $\chi 2$ test 1h

Reference Books:

1. Attwood,T. and Parry-Smith, D. Introduction to Bioinformatics. Pearson Education Asia. 2001. ISBN:978-0582327887
2. Krane, D.E. and Raymer, M.L. Fundamental Concepts of Bioinformatics. Pearson Education. 2003. ISBN:978-8177587579
3. Biostatistics For Dummies by John Pezzullo, John Wiley & Sons, ISBN-13: 978-1118553985.
4. Essential Medical Statistics by Betty R. Kirkwood and Jonathan S.C. Sterne, Blackwell Publishing **ISBN-13:** 978-0865428713
5. *Schaum's Outline Series on Statistics, latest edition.*

Advanced studies

6. Mount, D.W. Bioinformatics: Sequence and Genome Analysis, Second Edition Publisher: Cold Spring Harbor Laboratory Press, 2004. ISBN:978-0879697129.

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Course Code: BC404 **Title of the Course: Biochemical Techniques- I**

L-T-P: 0-0-4 **Credits:** 4

Prerequisite Course / Knowledge (If any): none

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

CLO-1: learn basic methodology of buffer preparation

CLO-2: account to measure and detect the biomolecules and molecules involved in a reaction using the calorimeter

CLO-3: learn the application of UV-visible spectroscopy

CLO-4: learn different methods of protein estimation

CLO-5: Isolate glycogen from goat liver and estimate the total carbohydrate content by multiple assay methods

CLO-6: Prepare phosphatidyl choline from egg yolk, purify it by chromatography and quantify it.

CLO-7: Isolate cholesterol from brain and confirm by assay;

CLO-8: Separate sugars (mono and disaccharides) and amino acids by paper chromatography.

CLO-9: Handle yeast and perform mutagenesis and chromosome loss experiments, study Mendelian inheritance patterns with yeast.

CLO-10: To solve problems on Mendelian inheritance, gene interactions, genetic mapping through linkage analysis, tetrad analysis, sex-linked inheritance and extranuclear inheritance.

Mapping of CLOs with 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
CLO 1	3	3	3	3	3	3	-	3	3	-
CLO 2	3	3	3	3	3	3	-	3	3	-
CLO 3	3	3	3	3	3	3	-	3	3	-
CLO 4	3	3	3	3	3	3	-	3	3	-
CLO 5	3	3	3	3	3	3	-	3	3	-
CLO 6	3	3	3	3	3	3	-	3	3	-
CLO 7	3	3	3	3	3	3	-	3	3	-
CLO 8	3	3	3	3	3	3	-	3	3	-
CLO 9	3	3	3	3	3	3	-	3	3	-
CLO 10	3	3	3	3	3	3	-	3	3	-

Syllabus:

1. Preparation of buffers (volatile & nonvolatile) pH measurement; pH indicators, accurate measurement of pH-Various common buffers used in biochemical research.
2. Determination of the pKa of Bromothymol Blue and Amino acids
3. Colorimetry. Use of colorimeter, its limitations Description of colorimeters Filter; grating relation between O.D & Transmittance Beers law; absorbance curves of two dyes.
4. Colorimetric estimation of P and organic PO4 (by digestion) Fiske & Subbarao method/Bartlett or other
5. Estimation of DNA by diphenylamine method
6. Estimation of RNA by orcinol reaction
7. Spectrophotometry: UV and Visible Spectrophotometer. The absorption spectrum of P-nitrophenol U.V absorption of nucleic acids, amino acids and proteins.
8. Building a calibration curve of protein through Bradford method and applying errors.

9. *Genetics Dry Lab:* a. Mendelian analysis b. Gene interactions c. Chromosomal basis of inheritance d. Linkage and crossing over e. Tetrad analysis f. Non-Mendelian Genetics (extra-nuclear inheritance)

10. *Genetics wet Lab:* a. Radiation Sensitivity of yeast b. UV mutagenesis c. Mating, zygote selection sporulation and tetrad analysis d. Yeast position effect assays/ chromosomal loss assays

COMPONENT 2: Isolation and characterization of Carbohydrates & Lipids

11. Isolation of glycogen from Liver/Muscle Total carbohydrate Estimation by Anthrone method.
12. Determination of reducing sugar in glycogen (by 3,5 dinitro salicylic acid)
13. Preparation of phosphatidyl choline from egg yolk-purification by chromatography and lipid phosphorus estimation.
14. Isolation of cholesterol from brain.
15. Paper chromatography: Separation of sugars (mono and disaccharides)
16. 2-dimensional paper chromatography, Amino acid
17. T.L.C separation of phospholipids (Extracts of E.coli, Liver and leaf identification by iodine and ninhydrin.

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Course Code : BC 406 : Title of the Course – **Genetics**
L.T.P: 3-0-0 **Credits** – 3
Prerequisite course : None

After 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.

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10	PLO 11	PLO 12
CLO 1	2	2	1	2	2	2	3	3	1	1	2	2
CLO 2	2	3	2	3	3	2	3	3	1	2	3	2
CLO 3	2	2	2	3	3	2	3	3	1	2	3	2
CLO 4	2	2	2	3	3	2	3	3	1	1	3	2
CLO 5	2	2	2	3	3	2	3	3	1	2	3	2
CLO 6	2	2	2	3	2	2	3	3	1	2	3	2
CLO 7	2	2	2	3	3	3	3	3	2	3	3	3
CLO 8	3	2	2	2	3	3	3	3	2	2	3	3

Syllabus GENETICS (BC-406)

Unit 1: Principles of heredity and extensions to basic principles: Mendelian Genetics and analysis: Extensions and modifications of basic principles of heredity, Chromosomal basis of inheritance.(4 h)

Unit 2: Chromosome characteristics and transposable elements: Chromosome structure, Euchromatin and heterochromatin, Coding and Non-coding sequences, Characteristics of transposons, mechanism of transposition and mutagenic effects of transposition. (3 h)

Unit 3: Genetic recombination in eukaryotes: Linkage and Crossing Over, Chromosome mapping, tetrad analysis and gene conversion, uses of genetic maps. (4 h)

Unit 4: Mutations and mutagenesis: Detection, Molecular basis and Applications. (3 hours)

Unit 5: Chromosomal changes: Number variation – Euploidy (auto and allopolyploidy), aneuploidy; Structural variations – Deficiences, duplications, Inversions, translocations. (3 h)

Unit 6: Interaction of genotype and environment, Twin studies, genetic environment, non-genetic environment, phenocopies, penetrance and expressivity (2 h)

Unit 7: Gene expression regulation during differentiation and growth: Heterochromatization in human beings, Drosophila and Yeast, position effect: Dosage compensation mechanism, sex chromatin and sex chromosomal inheritance. (6 h)

Unit 8: Quantitative inheritance: Continuous traits – multigenic variability, dominance – additivity, norms of reaction, quantitative trait loci. (3 h)

Unit 9: Non-Mendelian Inheritance; Plastid mutations – nature and mode of transmission Mitochondrial traits – nature and mode of transmission. (2h)

Unit 10: 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. (3 h)

Unit 11: Developmental genetics: Model system Drosophila, Genetic screen, pattern formation, maternal effect, homeotic transformations. . (3 h)

References

1. Griffiths, A. J. F., Miller, J. H., Suzuki, D. T., Lewontin, R. C., Gelbart, W. M. An Introduction to Genetic Analysis, W. H. Freeman & Company, New York.
2. Strickberger, M. W. Genetics, 3rd Edition, Macmillan Publishing co., New York.

3. Gardner, E. J., Simmons, M. J. and Snustad, D. P. Principles of Genetics, 8th Edition,
4. An Introduction to genetic analysis. Anthony A. J. F. Griffiths; Susan R. Wessler; Sean B. Carroll; John Deebly. 11th Edition
5. Genetics: A Conceptual approach. Benjamin A. Pierce. 5th Edition
6. Genetics: analysis of genes and genomes. Daniel L Hartl; Maryellen Ruvolo. 8th edition.
7. iGenetics by Peter J. Russell

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Course Code: BC407 **Title of the Course:** Microbiology

L-T-P: 0-0-4 **Credits:** 4

Prerequisite Course / Knowledge (If any): BSc in any subject of Biology

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	PLO 10
CLO 1	3	2	2	2	2	2	2	2	2	2
CLO 2	3	2	2	2	2	3	3	3	3	3
CLO 3	3	2	2	2	2	3	3	3	3	3
CLO 4	3	2	2	2	3	3	3	3	3	3
CLO 5	3	3	3	3	3	3	3	3	3	3
CLO 6	3	2	2	2	2	3	3	3	3	3
CLO 7	3	2	2	2	2	3	3	3	3	3
CLO 8	3	2	2	2	2	3	3	3	3	3

Detailed Syllabus

Unit 1: Beginnings of microbiology: Discovery, Evolution of microbiology as a discipline. Importance of microorganisms in environment and industry.

Unit 2: Overview of bacterial systematics and taxonomy. Classification of bacteria and general characters of a few bacterial phyla.

Unit 3: Nutritional requirements of microorganisms: Nutritional types, Requirements, Design and types of nutrient media. Growth modes, Culture techniques, Microbial growth: Principles, Kinetics and Methods of measuring growth. Batch and continuous growth, Synchronous culture, Diauxic growth. Uptake of nutrients, Transport systems and protein secretion in prokaryotes.
Unit 4: Bacterial cell structure and morphology – Nucleoid, Cytoplasm, Cytoplasmic membrane, Cell wall, Capsules, Flagella, Pili, Inclusion bodies, Endospores – structure and the process of sporulation. Structure function relation in bacterial cell – Focus on cell wall and cell membrane (a comparative account with Archaea).
Unit 5: Introduction to metagenomics. VBNC and strategies to cultivate the yet-to-be-cultivated bacterial taxa.
Unit 6: Bacterial responses to chemical signaling. Microbial locomotion – Flagellar structure and different types of bacterial movement.
Unit 7: Overview of Plant-Microbe interactions: Symbiotic nitrogen fixation, Mycorrhizae, Plant pathogens.
Unit 8: Physical and chemical control of microorganisms.
Unit 9: History/Foundations of virology, Structure and functional Characteristics. Culturing, detection and Purification protocols of viruses. Nomenclature and recent classification. Viroids and prions. Over view of virus Life cycle.
Unit 10: Culture collection centers and preservation of microorganisms.

References

1. 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

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Semester II

Name of the Academic Program: MSc Biochemistry

Course Code: BC 451 Title of the Course: Enzymology
L-T-P: 3-0-0 Credits: 3
Prerequisite Course / Knowledge (If any): B.Sc. with Chemistry or Biochemistry as one of the subjects.

Course Learning Outcomes (CLOs) (5 to 8)

After completion of this course successfully, 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 reaction 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;
CLO-4 Understand the enzymatic regulations and specificity;
CLO-5 Explain the chemical principles of enzyme catalysis, including cofactor chemistry, and design experiments to investigate the enzyme mechanism;
CLO-6 Understand methods of enzyme immobilization and application of immobilized enzymes.

CLO-7 Analyze enzyme kinetics and mechanistic data, research approaches to characterize new enzymes and comprehensively present the understanding of the subject.

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	PLO 12
CLO1	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**3**	**3**
CLO2	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**3**	**3**
CLO3	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
CLO4	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
CLO5	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
CLO6	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**3**	**3**
CLO7	**3**	**3**	**3**	**2**	**2**	**3**	**2**	**2**	**3**	**3**	**3**	**3**

Syllabus:

Unit 1: Enzyme nomenclature and classification: The naming and classification of enzymes

Unit 2: Enzyme isolation and purification: Origin of enzymes, Extraction of enzymes, Enzyme assay methods, Protein assay methods, Enzyme purification, Chromatographic methods.

Unit 3: Enzyme kinetics: Introduction to catalysis and kinetics, Kinetics of single-substrate enzyme-catalyzed reactions, Significance of kinetic constants, Experimental measurement of kinetic parameters. Enzyme inhibition (competitive, non-competitive, uncompetitive and mixed inhibition), Kinetics of multi-substrate enzyme-catalyzed reactions.

Unit 4: Enzyme specificity and regulation: Enzyme specificity, Zymogens, Isozymes, Allosteric regulation, Haemoglobin and Myoglobin, Feedback inhibition.

Unit 5: Mechanism of enzyme action: Mechanisms of catalysis, Investigation of active site structure, Mechanisms of reactions catalyzed by enzymes without cofactors, Metal activated enzymes and metalloenzymes, Coenzymes in enzyme catalyzed reactions.

Unit 6: Methods of immobilization, Properties and industrial applications of immobilized enzymes.

Reference Books:

1. Nicholas C Price and Lewis Stevens, *Fundamentals of Enzymology, The cell and molecular basis of catalytic proteins*., 3rd edition, 2001, Oxford University Press, Great Britain.
2. Trevor Palmer and Philip Bonner, *Enzymes: Biochemistry, Biotechnology, Clinical Chemistry*., 2nd Edition, 2008, East-West Press Private Limited, New Delhi.
3. Robert A. Copeland, *Enzymes: A Practical Introduction to Structure, Mechanism, and Data Analysis*. 2nd Edition, 2000, Wiley-VCH, Inc. NY.
4. Alejandro G. Marangoni, *Enzyme Kinetics: A Modern Approach*, Wiley online library
5. Hans Bisswanger, *Practical Enzymology*, 2nd Edition, Wiley Online Library
6. Garrett R.H., Grisham C.M, *Biochemistry*, 4th Edition, 2010, Brooks Cole.

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Course Code: BC452 **Title of the Course: Molecular Biology I**

L-T-P: **Credits:** 3

Prerequisite Course / Knowledge (If any): none

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

CLO1: Understand biochemical and biophysical basis of DNA transactions
CLO2: Acquainted with both qualitative and quantitative aspects of molecular biology
CLO3: Acquire in-depth and up-to-date knowledge of DNA replication, repair and recombination
CLO4: Able to ask searching questions in the field of DNA replication, repair and recombination
CLO5: Able to propose most appropriate recombinant-DNA techniques and other contemporary molecular techniques to address biological problems
CLO6: Able to understand, analyse and critically evaluate published journal articles in the field of molecular biology

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10	PLO 11	PLO 12
CLO1	3	2	3	3	3	3	3	2	3	1	2	2
CLO2	3	2	3	3	3	3	3	2	3	1	2	2
CLO3	3	2	3	3	3	3	3	2	3	2	3	3
CLO4	1	2	3	3	3	3	3	2	3	2	3	3
CLO5	1	2	3	3	3	3	3	2	3	3	3	3
CLO6	2	2	3	3	3	3	3	2	3	3	3	3

Unit 1. Discovery of DNA. Early experiments in molecular genetics. Historical events that lead to the conclusion of DNA is the genetic material. [3 hours]

Unit 2. Structure of DNA and RNA. Chemical and physical properties of nucleic acids (stability of nucleic acids, buoyant density, purity of DNA, effect of acids, alkali, on DNA, viscosity, spectroscopic and thermal properties of nucleic acids). [3 hours]

Unit 3 Genome Analysis and complexity, Cot analysis, organization of protein coding genes, gene duplication, discovery of repetitious DNA fractions. Lines, Sines and Alu sequences. [2 hours]

Unit4. Chromosomes, Chromatin and the nucleosome. Chromosome sequence, genome size, density and diversity; duplication and segregation; building blocks of chromosomes or nucleosomes, higher order structure and regulation of chromatin structure. [2 hours]

Unit5. DNA replication in prokaryotes and eukaryotes: origin of replication, replication fork, replisome. Enzymes in DNA synthesis, structure, function and mechanisms of action. Methods for studying DNA replication and determination of origin of replication. Chromosome segregation: random versus biased segregation. Topological problems during replication. DNA supercoiling and topoisomerases in eukaryotes and prokaryotes. Mechanisms of actions of topoisomerases. [6 hours]

Unit6. Mutations: Replication errors in DNA, chemical mutagens, spontaneous versus induced mutation. Types of DNA damages. Transposons and mechanisms of transposition. [3 hours]

Unit7. DNA repair: direct repair system, excision repair (NER and BER), Mismatch repair (MMR), double stranded DNA break repair (DSB): non-homologous end joining and homologous recombination. [4 hours]

Unit8. Biochemistry of Recombination; types of homologous recombination: Gene conversion and mating type switching, Site-specific recombination, VD-J recombination, applications of homologous recombination. CRISPR-Cas system [3 hours]

Unit 9. Recombinant DNA technology: Restriction digestion; applications of DNA polymerases and PCR.; DNA modifying enzymes in cloning; DNA sequencing; Cloning vectors and hosts, gene libraries, Screening libraries. [6 hours}

Reference Books:

1.Genomes 3 by T. A. Brown
2.Molecular Biology by D. Freifelder, latest edition
3.Molecular Biology of the Gene by J. D. Watson et al., latest edition
4.Molecular Biology of the Cell by Lodish et al., latest edition
5.Recombinant DNA by J. D. Watson, latest edition
6. Reviews and original research articles from journals

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Course Code: **BC453** Title of the Course: **Structural Biology**
L-T-P: 3-0-0 Credits: **3 credits**
Prerequisite Course / Knowledge (If any):

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO-1: account have detailed understanding of parameters responsible maintaining the 3-dimension of biomolecules.
CLO-2: account to learn basic conformational properties of biomolecules and how their conformation varies under different environmental conditions.
CLO-3: account for the understanding of advance spectroscopic techniques and their application to establish structure function relationship in biomolecules.
CLO-4: to learn and develop basic understanding of all techniques of modern structural biology and biophysics
CLO-5: to read relevant scientific literatures critically and also understand laboratory work.

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**	**PLO 11**	**PLO 12**
CLO1	3	3	2	1	2	2	1	1	3	3	1	1
CLO2	3	3	3	1	1	1	1	1	2	2	1	2
CLO3	3	3	3	1	2	2	2	1	2	1	2	2
CLO4	3	2	2	1	1	2	1	1	2	1	2	2
CLO5	3	3	3	1	1	2	1	1	2	2	2	3

Unit1. Structure of Biomolecules: Proteins Structures: Introduction and General Overview, Secondary, tertiary and quaternary structure of protein, super secondary structure, Ramachandran plot, protein folding
3h

Unit2. Structural overview of nucleic acids. Structure and conformational properties of bases, furanose sugars and phosphate groups, geometry of bases, preferred sugar puckering modes, bond distances and angles in furanoses, syn/anti conformation and other conformation aspects of nucleotides.
3h

Unit3. Primary and secondary structure of RNA: Watson-Crick and Hoogsteen base pairing and Primary and secondary structure DNA: A-DNA, B-DNA, C-DNA conformation, DNA-RNA hybrids, Z-DNA formation.
2h

Unit4. Spectroscopic technique –II: Basic principle of 1. Circular Dichroism Spectroscopy (CD ORD), 2. ESR, 3. IR 4. Raman and 5. SPR.
8h

Unit5. Techniques used for structural analysis of proteins and nucleic acid: X-ray Crystallography (Symmetry, space group crystal lattices, brag's law in real & reciprocal space), Nuclear magnetic resonance (NMR) and Cryo-electron-microscopy, their limitation and precautions. Mass spectrometry
8h

Reference Books:

1. Protein Structures and Molecular properties by Thomas C Creighton
2. Principles of nucleic acid Structure by Charles R Cantor
3. Physical Biochemistry Principles and Application by David Sheehan
4. Crystallography made crystal clear By Gale Rhodes
5. Outline of Crystallography for Biologists by David Blow

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Course Code : BC 454 Title of the Course – Intermediary Metabolism –II

L.T.P: 3-0-0 Credits – Three

Prerequisite course / Knowledge at B.Sc. level Chemistry or Biochemistry mandatory as one of the subjects.

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

CLO 1: Importance of dietary protein, its digestion in the human body by specific enzymes and absorption of amino acids for utilisation in other parts of the body.
CLO 2: The role of transaminase enzymes in the over all degradation of amino acids and further conversion of glutamate to alpha-ketoglutarate and ammonia.
CLO 3: Removal of excess ammonia by specialized cycle such as urea cycle.
CLO 4: Salvaging of various metabolic products for synthesis of amino acids in cells and understanding how microrganisms and plants are able to synthesise all the amino acids and human beings need to obtain from their diets about 10 amino acids and regulation of various biosynthetic processes.
CLO 5: Importance of amino acids in the synthesis of complex porphyrins as well as various important hormones in the body.
CLO 6: Importance of nucleotides, ribo and deoxyribonucleotides, their biosynthesis and metabolism in cells. Metabolism of pyrimidine and purine nucleotides will be understood.
CLO 7: Regulation of the pyrimidine and purine metabolism and role of tetrahydrofolae in one carbon metabolism as well as the disorders associated with nucleotide metabolism will be understood.
CLO 8: Types of reactions involved in xenobiotic metabolism and their significance will be understood.

Mapping of CLOs with 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	PLO 12
CLO1	3	3	2	2	2	2	3	2	1	1	2	3
CLO2	3	3	2	2	2	2	3	2	1	1	2	3
CLO3	3	3	3	3	3	3	3	2	1	2	2	3
CLO4	3	3	2	2	2	2	3	2	1	2	2	3
CLO5	3	3	2	2	2	2	3	2	1	3	2	3
CLO6	3	3	2	2	2	2	3	2	1	2	2	3
CLO7	3	3	2	2	2	2	3	2	1	2	2	3
CLO8	3	3	2	2	2	2	3	2	1	2	2	3

Syllabus

Protein and Metabolism

Unit 1. Dietary protein digestion and absorption of amino acids, intracellular protein degradation, mechanism of transaminase reactions, nonoxidative and oxidative deamination 6H

Unit 2 : Fate of ammonia in extra hepatic tissues, glutamine synthesis and transport, alanine cycle, urea cycle reactions and regulation. Biological nitrogen fixation. 4H

Unit 3 : Fate of the carbon skeleton of amino acids, glucogenic and ketogenic amino acids, relation with TCA cycle and lipogenesis. Amino acid decarboxylation: biogenic amines, polyamines. 5H

Unit 4 : Biosynthesis of amino acids. Synthesis of essential and non-essential amino acids and regulation of amino acid biosynthesis. Precursor functions of amino acids including Porphyrin metabolism. Inborn errors of amino acid metabolism. 9H

Nucleic acids & Xenobiotic Metabolism

Unit 5 : Degradation of nucleic acids: deoxyribonucleases and ribonucleases. Nucleotide biosynthesis: de novo purine ribonucleotide biosynthesis and its regulation, purine ribonucleotide biosynthesis from purine bases and ribonucleosides (salvage pathway). Inter conversion of purine ribonucleotides, catabolism of purine bases. 3H

Unit 6 : Pyrimidine ribonucleotide metabolism: de novo biosynthesis of pyrimidine ribonucleotides and regulation, pyrimidine ribonucleotide biosynthesis from bases and ribonucleotides (salvage pathway). Catabolism of pyrimidine bases. 3H

Unit 7 : Regulation of purine and pyrimidine nucleotide metabolism; Formation of NDPs and NTPs; Biosynthesis of deoxy-ribonucleotides and its regulation; Inborn errors of nucleotide metabolism; Nucleotide coenzymes. Inborn errors of nucleotide metabolism. 3H

Unit 8 : Metabolism of 1C units, role of FH4. Methionine and methyl group transfer, Role of vitamin B12 in nucleic acid synthesis. Xenobiotic metabolism: Significance; Phases of xenobiotic metabolism; Types of reactions involved. 3H

Reference Books:

1. Principles of Biochemistry Authors - Abraham White, Philip Handler and Emil L. Smith
2. Lehninger Principles of Biochemistry
3. Biochemistry – Author - Lubert Stryer

4. Review of Physiological Chemistry Author - Harold Anthony Harper

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Course Code: BC455 **Title of the Course: Biochemical Techniques II**

L-T-P: 0-0-10 **Credits**: 5

Prerequisite Course / Knowledge (If any):

After completion of this course successfully, 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

CLO 3: Able to clone a gene for recombinant expression

CLO 4: Able to create transgenic yeast strains having various applications

CLO-5: learn practical aspect of the characterization of biomolecules

CLO-6: use biophysical techniques to analyze biomolecules in term of secondary structure and able to learn to establish structure function relationship.

CLO-7: learn to crystallize the proteins for 3-dimensional structure determination by X-ray crystallography

CLO-8: learn how to perform and analyze biochemical and biophysical data and report in the scientific way.

CLO-9: Quantify and analyze the serum contents of metabolic byproducts.

CLO-10: Understand the clinical significance of abnormal profile of serum contents.

Mapping of CLOs and with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO 1	3	3	3	3	3	3	-	3	-	3
CLO 2	3	3	3	3	3	3	-	3	-	3
CLO 3	3	3	3	3	3	3	-	3	-	3
CLO 4	3	3	3	3	3	3	-	3	-	3
CLO 5	3	3	3	3	3	3	-	3	-	3
CLO 6	3	3	3	3	3	3	-	3	-	3
CLO 7	3	3	3	3	3	3	-	3	-	3
CLO 8	3	3	3	3	3	3	-	3	-	3
CLO 9	3	3	3	3	3	3	-	3	-	3
CLO 10	3	3	3	3	3	3	-	3		3

Syllabus

Biochemical Techniques-II Lab Course

Enzymology

1. Assay of alkaline phosphatase from *E.coli* using *p*-nitrophenyl phosphate as substrate.
2. Partial purification of alkaline phosphatase from *E.coli*.
3. Characterization of alkaline phosphatase.
    a. Effect of pH
    b. Effect of substrate concentration (Calculation of Km)
    c. Effect of Temperature (Q 10)
    d. Inhibition studies

Molecular Biology

4. Isolation of yeast genomic DNA (or from any other organism)
5. Amplification of your favourite gene (YFG) by PCR
6. Isolation of plasmid DNA from *E. coli*
7. Restriction digestion of plasmid DNA for cloning/restriction mapping
8. Ligation of DNA insert into cloning vector
9. Transformation in bacteria
10. Knocking out of a non-essential yeast gene by homologous recombination.

Protein technology

11. Purification of a protein by ion-exchange chromatography.
12. Purification of a protein by affinity chromatography
13. Analysis of oligomerization state of a protein by Gel-filtration chromatography
14. Analyzing the purity of isolated protein by SDS-PAGE.
15. Crystallization of Lysozyme
16. Demonstration of fluorescence spectroscopy

Clinical Biochemistry

17. Estimation of blood glucose
18. Estimation of cholesterol in serum
19. Estimation of Bilirubin in serum
20. Estimation of creatine in serum
21. Estimation of creatinine in serum
22. Estimation of urea in blood & urine

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Course Code: BC456 Title of the Course: **Cell Biology**
L-T-P : 3-0-0 **Credits:** 3
Prerequisite Course / Knowledge (If any): none

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO-1 the structure and organization of eukaryotic and prokaryotic cells
CLO-2 how macromolecules are transported between various organelles

CLO-3 how the cell cycle is regulated
CLO-4 the basic machinery for mitosis and establishment of asymmetry
CLO-5 how organelles are distributed during cell division
CLO-6 cell death mechanisms and autophagy
CLO-7 Understand and analyze how cell biology questions are framed and addressed experimentally
CLO-8 Communicate research papers effectively and suggest future course of experiments

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	PLO 12
CLO1	3	2	2	2	2	2	3	3	1	2	2	2
CLO2	2	2	2	3	3	2	3	3	2	2	3	2
CLO3	3	3	3	3	3	2	3	3	2	2	3	2
CLO4	3	3	2	3	3	2	3	3	2	2	3	2
CLO5	3	2	2	3	3	2	3	3	2	2	3	2
CLO6	3	2	3	3	2	2	3	3	2	2	3	2
CLO7	3	2	2	3	3	3	3	3	2	3	3	3
CLO8	3	2	2	2	3	3	3	3	2	2	3	3

Syllabus:

Unit 1: Introduction to cell biology and cell architecture: variety in size, shape and function. Structure and function of subcellular organelles (2h)
Unit 2: Introduction to structure and function of cytoskeleton and cell-cell adhesion (4h)
Unit 3: Intracellular trafficking: Transport of proteins into ER lumen and membranes. Vesicular transport; transport across golgi, lysosomes, protein secretion and receptor mediated endocytosis. (8h)
Unit 4: Transport across nuclear membrane and peroxisomes Regulation of protein transport (3h)
Unit 5: Regulation of cell cycle in yeast and mammals (5h)
Unit 6: Checkpoints. Mitosis and meiotic cell division (5h).
Unit 7: Mechanisms of cell death and autophagy (3h)
Unit 8: Chromosome segregation and spindle assembly; Nuclear envelope assembly and disassembly; mechanism of cytokinesis (6)
Unit 9: Organelle division and mitotic segregation (mitochondria, ER, Golgi, peroxisomes, lysosomes) (4).
Unit 10: Methods in cell biology: Microscopy (2)

Reference Books:

1. Bruce Alberts, Alexander D. Johnson, Julian Lewis, David Morgan, Martin Raff, Keith Roberts. Molecular Biology of the Cell. W. W. Norton & Company. 6th edition. 18 November 2014
2. Arnold Berk, Chris A. Kaiser, Harvey Lodish, Angelika Amon, Hidde Ploegh, Anthony Bretscher, Monty Krieger, Kelsey C. Martin. Molecular Cell Biology. WH Freeman; 8 edition (1 April 2016)
3. Classic research papers in cell biology (Selected by Instructor)
4. Reviews of recent progress (variable; to be selected by the Instructor)

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Semester III

Course Code: 501 Title of the Course: **Basic Immunology**
L-T-P 3-0-0 **Credits:** 3
Prerequisite Course / Knowledge (If any): Knowledge of basic components of human immune system

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO-1: Understand and define terminology and concepts related to cellular and molecular components of mammalian immune system, list theories and models of self and non-self-recognitions, design explanatory frame-work towards evolutionary perspectives
CLO-2: Understand biological molecules, cellular processes, cellular communication, cell migration and regulation of innate and inflammatory responses and comprehend evasion strategies by pathogens
CLO-3: Understand interactions between the innate and adaptive immune systems through MHCs and antigen presentations, the role of regulations and evasions of such mechanisms towards generation of an immune response
CLO-4: Understand the molecular and cellular mechanisms, cellular communication, migration and regulation towards generation of B-cell and T-cell repertoires and their effector responses
CLO-5: Apply the concepts of innate and adaptive immune responses to understand the cross-talks between innate and adaptive responses, hypersensitivity, transplantation immunity and immunodeficiencies.
CLO-6: Understand and present experimental approaches that lead to development of concepts in immunology, apply concepts to immune-techniques, critically analyze immunology-related data and, design their own experiment

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**	**PLO 12**
CLO1	3	2	2	3	3	3	3	3	2	2	3	3
CLO2	3	2	2	3	3	3	3	3	3	2	3	3
CLO3	3	2	2	3	3	3	3	3	3	2	3	3
CLO4	3	2	2	3	3	3	3	3	3	2	3	3
CLO5	3	2	2	3	2	3	3	3	3	2	3	3
CLO6	3	3	3	3	3	3	3	2	3	3	3	3

Each Course Learning Outcome (CLOs) may be mapped with one or more Program Learning Outcomes (PLOs). Write ‘3’ in the box for ‘High-level’ mapping, 2 for ‘Medium-level’ mapping, 1 for ‘Low-level’ mapping

Detailed Syllabus:

Unit 1: Introductory topics (mammalian immune system)

- Introduction to immunity, basic definitions, important concepts (such as innate and acquired, humoral and cell-mediated, primary and secondary, host-pathogen interactions etc); historical and evolutionary perspectives, recent progress in immunology from basic discoveries to medical innovations

Unit 2: Components of mammalian immune system

- Introduction to cellular and humoral components of immune system, cells of innate and adaptive immune system, Cluster of differentiation, principle of isolation of immune cells
- Microenvironments of immune system: Lymphoid tissues- Primary and secondary lymphoid organs, structure and cellular organization
- Immunogens and antigens – Properties, factors governing immunogenicity, haptens, epitopes-size and identification.
- Immunoglobulins - Structure, isotypes, allotypes and idiotypes, functions of antibody in relation to structure.
- Antigen-antibody interactions: affinity of antibody, avidity, antigen-binding site of antibody, antigen-antibody complex formation, specificity and cross-reactions, principles of immune-techniques
- General concepts of receptors and signaling in immune system: Cytokines and Chemokines, Immunoglobulin and T-cell receptors

Unit 3: Innate mechanisms

- Anatomical Barriers to Infection
- Recognition and response by cells of innate immunity: responses by neutrophils, macrophages, dendritic cells, phagocytosis, oxygen-dependent/oxygen-independent mechanisms, receptors and signaling, pathogen associated molecular patterns and pattern recognition receptors, anti-microbial peptides, extracellular traps etc
- Natural killer cells: recognition and response
- Complement system- classical and alternate pathways of activation, regulation of complement activation and functions, related disorders
- Cell migration, innate and inflammatory responses, regulation and evasion of innate mechanisms

Unit 4: Interactions between the innate and adaptive immune systems

- Major Histocompatibility Complexes, structure, general organization, inheritance, expression patterns, interactions with peptides
- Antigen Presentation: pathways of antigen processing and presentation of intracellular and extracellular antigens, cross-presentation of exogenous antigens, presentation of non-peptide antigens

Unit 5: Adaptive mechanisms

- Organization and Expression of Immunoglobulin and T-cell receptors genes
- B-cell and T-cell development
- Humoral immunity: B-Cell Activation, differentiation, and memory cell generation, primary and secondary antibody responses, antibody response to haptens, enumeration of antibody-forming cells, response to T-dependent and T-independent antigens.
- Cell mediated immunity: T-Cell Activation, differentiation, and memory generation
- Effector Responses and regulations of cell and antibody-mediated immunity, adjuvant mediated responses, Immunological tolerance, Autoimmune diseases
- Cross-talk between innate and adaptive immune system

Unit 6: Brief discussion on specialized immune responses

- Hypersensitivity reactions and allergies – Classification, Type I – IV reactions

- Transplantation immunity
- Immunodeficiency

Reference Books:

1. Kuby Immunology; 10th edition; Authors: Owen, Punt, Stranford
2. Wiley: Roitt's Essential Immunology; 13th edition; Peter J. Delves, Seamus J. Martin, Dennis R. Burton, Ivan M. Roitt
3. ELSEVIER: Cellular and Molecular Immunology, 9th Edition; Authors: Abul Abbas, Andrew H. Lichtman, Shiv Pillai
4. Lippincott Williams & Wilkins: Fundamental Immunology By Willium E.Paul; 7th edition
5. Taylor & Francis group: Janeway's Immunobiology; 9th Edition
6. Reviews, research articles, animations and videos

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Course Code: 501 Title of the Course: **Molecular Biology II**
L-T-P 3-0-0 **Credits:** 3
Prerequisite Course / Knowledge (If any): Molecular Biology I

Course Learning Outcomes (CLOs) (5 to 8)

Theme of the Course: While **Molecular Biology I** covers how the cellular Genome (DNA or Deoxyribonucleic acid) is maintained /preserved for generations through a process called DNA replication and repair, **Molecular Biology II covers**, how the information in DNA or genome is processed to make different RNAs (ribonucleic acids) and a variety of proteins through processes called **transcription and translation** respectively for day-today cellular transactions/functions. This is an important theme that defines the differences in the function, physiology, development, metabolism, health and disease of cells and cell types (muscle cells, neurons, red blood cells, pancreas, plasma cells etc.) in spite of the fact that all these cell types in an organism are originated from the same mother cell and carrying the same genetic information

Course Learning Outcomes:

After completion of this course successfully, the students would have learnt

CLO1. a) the commonalities and differences in the synthesis of these biomolecules especially different RNAs and proteins b) the specific machineries and their components that include sequence information in the DNA and RNA templates that code for RNA and proteins respectively; importance of 'start' and 'stop' signals in these templates and a variety of proteins, and the complex interaction of these template molecules with different enzymes, proteins and small molecules

CLO2. The students will understand how the synthesis of these molecules RNA and proteins is a) regulated (turned on or off or enhanced or decreased) depending on the ambience, cell type and stage where one set of RNAs or proteins are expressed better than the others b) edited, c) processed or modified either during or after their synthesis and the importance of these modifications to maintain, their structure, function, degradation and for targeting to specific cellular destinations.

CLO3. Students will also learn necessary methods a) to mimic these basic cellular processes of transcription and translation in test tube reactions; and for various applications that include identification of transcriptional defects from translation, performance of various functional or defective components using reconstituted transcriptional and translational machineries; to determine the molecular mass of processed and unprocessed proteins and RNAs; the mechanism of action of novel small molecules or antibiotics that affect directly any of the steps in translation or transcription and to identify the importance of regulatory sequences on the coding sequences of in DNA and RNA

CLO4. Students will learn how to exploit some of these modifications of RNAs and proteins for any specific applications like the purification of RNAs and proteins selectively and for preparation of cDNA libraries from mRNAs and such libraries to identify the genes of our interest using hybrid arrest translational systems; to produce proteins of therapeutic interest and for the production of antibodies , to determine protein-protein interactions and to create mice that are defective for a given gene

Overall this course is an important link to understand various branches of Life Sciences such as, developmental biology, infectious biology, genetics, cellular signaling mechanisms, biotechnology, genomics, proteomics and synthetic biology and for advanced research

Linking Course, BC-521 Molecular Biology II Learning out comes to programme learning outcomes

CLOs	PLO-1	PLO-2	PLO-3	PLO-4	PLO-5	PLO-6	PLO-7	PLO-8	PLO-9	PLO-10	PLO-11	PLO-12
1	2	1	2	3	3	3	3	2	2	2	2	3
2	3	2	2	3	3	3	3	1	1	3	3	3
3	3	1	1	3	3	3	3	3	2	3	3	3
4	2	1	1	3	3	3	3	3	2	3	3	3

Syllabus

Unit 1. Expression of Genome in pro and Eukaryotes: Regulatory sequences in DNA, Chemistry of RNA synthesis, RNA polymerases, different RNAs, Transcriptional factors and the mechanism of action. Genetic code. Post-translational modification and splicing, capping, polyadenylation. Processing of rRNA, tRNA precursors. [6 hours]

Unit 2. DNA binding motif in proteins: Zinc finger, Helix-turn-helix and leucine zipper etc. [2 hours]

Regulation of RNA synthesis in lambda phage, prokaryotes (lac, ara, trp and his operons, stringent,

Unit 3. relaxed control), eukaryotes and in during development. [6 hours]

Unit 4. Epigenetic control of gene regulation. epigenetic marks: modification of DNA and histones. Methods for studying epigenetic modifications (ChIP, Chip-Seq, MNase mapping, FAIRE etc.). Interacting between distinct chromosomal loci: 3C, 4C and Hi-C techniques. [3 hours]

Unit 5. Exon shuffling, RNA editing and different RNAs and their functions (including siRNA, microRNa and dsRNA, long non-coding RNA), Riboswitch. [3 hours]

Unit 6. Translation, ribosome, initiation, elongation and termination steps in protein synthesis, regulation of factors and translation. [4 hours]

Unit 7. Secretory Protein biosynthesis, Covalent modifications of proteins (Glycosylation, iodination, methylation, oxidation, phosphorylation etc.) [3 hours]

Unit 8. DNAse hypersensitivity, Random and Site-specific mutagenesis, DNA foot printing, finger printing, RFLP, RNA synthesis, polysomes, Protein synthesis in vitro. [3 hours].

Unit 9. Methods for studying RNA and transcriptome: northern hybridization; RT-PCR; microarray analysis; SAGE. [3 hours]

Unit10. Studying protein-protein interaction: Yeast two hybrid systems, Co-immunoprecipitation; GST-pull down; FRET and SPR (surface plasmon resonance) [2 hours

Reference Books:

1.Principles of Gene Manipulation and Genomics by Primrose.
2.Genetics and Genomics by Hartl
3.Genomes 3 by T. A. Brown
4.Recombinant DNA by J. D. Watson, latest edition

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Course Code: BC 503 Title of the Course: **Bioenergetics & Biomembranes**
L-T-P: 3-0-0 **Credits**: 3

Prerequisite Course / Knowledge (If any): B.Sc. with Chemistry or Biochemistry as one of the subjects.

CLO-1. Define free energy and discuss its relationship to chemical equilibrium
CLO-2. Ability and knowledge to explain molecular mechanisms of energy transformation and energy accumulation in living organisms.
CLO-3. Skills to analyze the bioenergetics related problems and information
CLO-4. To understand the general structure and functional properties of natural and synthetic membranes
CLO-5. To be able to critically evaluate the topology of membrane proteins and use of various scientific techniques to understand the basic membrane structure.
CLO-6. To learn about the various types of transport mechanisms such as energy dependent and energy independent phenomena operating across the membrane.
CLO-7. Analytical skills to reconstitute a membrane protein to determine its topology and transport mechanism

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	PLO 12
CLO1	3	3	3	2	2	2	2	2	2	3	3	3
CLO2	3	3	3	2	2	2	2	2	2	3	3	3
CLO3	3	3	3	3	3	3	3	3	3	3	3	3
CLO4	3	3	3	3	3	3	3	3	3	3	3	3
CLO5	3	3	3	3	3	3	3	3	3	3	3	3
CLO6	3	3	3	2	2	2	2	2	2	3	3	3
CLO7	3	3	3	2	2	3	2	2	3	3	3	3

Each Course Learning Outcome (CLOs) may be mapped with one or more Program Learning Outcomes (PLOs). Write ‘3’ in the box for ‘High-level’ mapping, 2 for ‘Medium-level’ mapping, 1 for ‘Low-level’ mapping

Detailed Syllabus:

Bioenergetics:

Unit1. Scope of the subject and course: energy as understood by biochemist, energy transformations in living systems.

1h

Unit 2. Structure and localization of enzymes in mitochondria, marker enzymes, redox reactions and reactions that generate reducing equivalents (NADH, NADPH and FADH2).

3h

Unit 3. Constituents of electron transport chain: Pyridine and flavin linked enzymes, Iron sulfur proteins, Cytochromes **b, c_1, c, a**, and **a_3,** role of Coenzyme Q in electron transfer. Role of cytochromeC other than in electron transfer. 4h

Unit 4. Electron Transport Chain: History, Structure, sites of action for various inhibitors on ETC, importance of redox potentials, calculation of free energy decrease for substrate oxidation, Studies with sub-mitochondrial particles.

2h

Unit 5. Structure and function of individual complexes of electron transport chain. Complex I, II, III, IV and V.

4h

Unit 6. Mechanism of action of various ionophores, uncouplers and inhibitors of phosphorylation. Electrochemical gradient for protons, Different states of respiration (state 1-6), acceptor control, effect of ionophores and inhibitors on acceptor control.

2h

Unit 7. Mechanisms of oxidative phosphorylation: Chemical coupling hypothesis, conformational coupling hypothesis, binding change model and rotational hypothesis.

3h

Unit 8. Chemiosmotic hypothesis: Characteristics of oxidative phosphorylation that support this hypothesis, mechanism of proton translocation, Q cycle and experimental evidence for this hypothesis. Experimental evidences against the hypothesis. Delocalized versus localized proton coupling. Role of cardiolipin in energy transduction. Energy charge of the cell and its regulation. 3h

Unit 9. 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.

3h

Unit 10. Photosynthesis: Biological occurrence, various electron donors and acceptors, Photosynthetic pigments, Photosynthetic electron transport chain, and photophosphorylation.

4h

Biomembranes:

Unit 11. Structure and organization of membranes. 1h

Unit 12. Transport of NADH, ATP, ADP, Pi, fatty acids and various metabolites across mitochondrial inner membrane.

2h

Unit 13. Structure and function of ion gated channels. Operation of these channels at neuromuscular junction.

2h

Unit14. Transport by **P** type, **V** type and **F** type ATPases. Other ABC family transporters. Amino acid transport and glucose transport by glucose transporters. Anion and cation symport and antiport systems.

2h

Unit 15. Active transport in bacteria, Group translocation, lactose permease for lactose transport. 2hkmsl

References:
Biochemistry by Reginald H. Garret/Charles M.Grisham 6th Edition
Principles of Biochemistry by Lehninger 7th Edition

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Course Code: **BC505** Title of the Course: **Nutritional and Clinical Biochemistry**
L-T-P: 2-0-0 Credits: **2**
Prerequisite Course / Knowledge (If any):

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO-1 To develop understanding about the fundamental concepts and processes underlying the field of nutritional biochemistry and Malnutrition.
CLO-2 Study the value of food and nutrients in health and disease .
CLO-3 Understand disorders of carbohydrates, lipid and amino acid metabolism.
CLO-4 Demonstrate principles of clinical biochemistry in diagnosis of diseases
CLO-5 Design and conduct experiments to test diagnostic enzymology

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**	**PLO 12**
CLO1	3	2	1	3	3	2	3	3	3	3	2	3
CLO2	3	1	1	3	3	2	3	3	3	3	3	3
CLO3	3	2	1	3	3	3	3	3	3	3	3	3
CLO4	3	3	1	3	3	3	3	3	3	3	3	3
CLO5	3	2	1	3	3	3	3	3	3	3	3	3

Detailed Syllabus:

Unit 1. An overview of specific aspects of metabolism in different organs and tissues (brain, kidney, liver, skeletal muscle, heart, adipose tissue, blood). 4 h
Unit 2. General concepts and nutritional requirements of proteins and calories for growth, maintenance and physiologically altered states, nitrogen balance and muscle protein turnover. 3 h
Unit 3. Disorders of carbohydrates: Diabetes mellitus, non-enzymatic glycation, sorbitol formation, glycohemoglobins, hypoglycemias, galactosemia, various types of glucose tolerance tests, glycogen storage diseases. 3 h
Unit 4. Disorders of lipids metabolism: Plasma lipoproteins, cholesterol, triglycerides & phospholipids in health and disease, hyperlipidemia, hyperlipoproteinemia, Gaucher's disease, Tay- Sach's and Niemann-Pick disease, ketone bodies. 2 h
Unit 5. Biochemistry of fasting and feeding conditions, interrelations between metabolic pathways, interrelations between liver and peripheral tissues, alcohol metabolism. 2 h
Unit 6. Malnutrition – Prevention of malnutrition, improvement of diets. Recommended dietary allowances, nutritive value of common foods. Protein-calorie malnutrition. Requirement of proteins and calories under different physiological states- infancy, childhood, adolescence, pregnancy, and lactation. 3 h
Unit 7. Hypo- and hyperthyroidism and goiter, hypo- and hyper-adrenocorticism, hypo- & hyper-pituitarism, haemoglobinopathies; anemia, thalassemia, sickle cell anemia, jaundice, rheumatoid arthritis; kidney and liver function tests. 3 h

Unit 8. Scope of clinical biochemistry in diagnosis, collection and preservation of biological fluids (blood, urine & CSF), normal values of important constituents of blood, CSF and urine. Collection preparation, preservation, and handling of clinical samples, quality control, Safety measures in clinical laboratory. 3 hUnit 9. Principles of diagnostic enzymology; definition of functional and non-functional plasma enzymes, problems of enzyme assay in clinical biochemistry laboratory; factors affecting enzyme levels in plasma or serum; selection of enzyme tests; enzyme and enzymes pattern in health and diseases with special mention of plasma lipase, amylase, cholinesterase; alkaline and acid phosphates, SGOT, SGPT, LDH & CPK. 4 h

Reference Books:

1. Nutritional Elements and Clinical Biochemistry by A. Brewster & Marge
2. Nutritional Biochemistry and Metabolism: With Clinical Applications by Maria C Linder
3. Handbook of Nutritional Biochemistry: Genomics, Metabolomics and Food Supply by Sondre Haugen and Simen Meijer

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Code: 504 Title of the Course: **Biochemical Techniques-III-lab**
L-T-P 0-0-5 **Credits**: 5
Prerequisite Course / Knowledge (If any):

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO1: Independently perform, standardize, analyse and interpret data using immunodiffusion assays, Western blot, ELISA (both direct and indirect ELISA)
CLO2: Independently perform, standardize, analyse and interpret data using immunoprecipitation and apply the same to different experimental set-ups
CLO3: How to express a foreign gene in bacteria and purify to homogeneity. Determine the differential gene expression by various cells/tissues.
CLO4: Protein-protein interactions by genetic approach using yeast as a model system.
CLO5: Isolate mitochondria from different sources and perform mitochondrial electron transport chain and ATPase functional assays.
CLO6: Analyse, interpret and evaluate the data based on the experimental values obtained either from normal and dysfunctional mitochondria.

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**	**PLO 12**
CLO1	3	3	3	1	1	1	1	1	3	3	3	2
CLO2	3	3	3	1	1	1	1	1	3	3	3	2
CLO3	3	3	2	3	1	1	1	1	3	3	3	2
CLO4	3	3	2	3	1	1	1	1	3	3	3	2
CLO5	3	3	3	1	1	1	1	1	3	3	3	2
CLO6	3	3	3	1	1	1	1	1	3	3	3	2

Each Course Learning Outcome (CLOs) may be mapped with one or more Program Learning Outcomes (PLOs). Write '3' in the box for 'High-level' mapping, 2 for 'Medium-level' mapping, 1 for 'Low-level' mapping

Detailed Syllabus: BC504

COMPONENT 1: Immunology

1. Immunodiffusion: to learn visual precipitation reaction and reactivity patterns
2. Western blotting
3. Enzyme-linked immunosorbent assays (ELISA): antigen down ELISA / Sandwich ELISA
4. Immunoprecipitation
5. Isolation of immunoglobulin from serum using affinity chromatography

COMPONENT 2: Molecular Biology-II

1. Over-expression of your favorite gene (YFG) in bacterial system
a) Induction of recombinant protein by IPTG

b) Analysis on SDS-PAGE
2. Purification of protein on Ni-NTA column and analysis of purification by SDS-PAGE.
3. Isolation of RNA from yeast (or from any other organism)
4. RT-PCR analysis
5. Yeast two-hybrid analysis to investigate protein- protein interaction

COMPONENT 3: Studies on Mitochondria

1. Preparation of tightly coupled mitochondria from rat liver.
2. Estimation of protein in mitochondria and homogenate by Biuret method.
3. Estimation of SDH activity in mitochondria and homogenate and calculation of recovery of mitochondria (INT and DCIP methods).
4. Estimation of NADH dehydrogenase activity in mitochondria and homogenate and calculation of recovery of mitochondria.
5. Measurement of rate of respiration and oxidative phosphorylation in mitochondria using succinate, glutamate and malate as substrates.
6. Measurement of rate of respiration and oxidative phosphorylation in mitochondria using glutamate and malate as substrates using oxytherm respirometer.
7. Estimation of cytochrome oxidase activity in mitochondria
8. Estimation of cytochromes in mitochondria
9. Estimation of ATPase activity in mitochondria with and without uncouplers.
10. Separation of the components of electron transport chain using blue native page.

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Course Code: BC521 Title of the Course: ***Endocrine Biochemistry***
L-T-P: 2-0-0 Credits: 2
Prerequisite Course / Knowledge (If any): *Basics of Human Anatomy*

Course Learning Outcomes (CLOs) (5 to 8)

After completion of this course successfully, 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 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**	**PLO 12**
CLO1	3	2	3	3	3	3	2	3	2	2	2	2
CLO2	3	3	3	3	3	3	2	3	2	2	2	2
CLO3	3	3	3	3	3	3	3	3	2	2	2	2
CLO4	3	3	3	3	3	3	2	3	3	2	3	3
CLO5	3	2	3	3	3	3	2	3	2	3	3	3
…..	3	3	3	3	3	3	3	3	3	3	3	3
…..												

Each Course Learning Outcome (CLOs) may be mapped with one or more Program Learning Outcomes (PLOs). Write '3' in the box for 'High-level' mapping, 2 for 'Medium-level'mapping, 1 for 'Low-level'mapping

Detailed Syllabus:

Unit1: Endocrine system: General features
Unit:2: Mechanism of action of hormones.
Unit3: 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.
Unit4: Digestive processes in various regions of digestive system.
Unit5: Gastrointestinal hormones, their synthesis and function.
Unit6: Structure and function of Insulin like growth factors and their receptors.

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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Course Code: BC523 Title of the Course: **Developmental Biology**
L-T-P: 2-0-0 **Credits**: 2
Prerequisite Course / Knowledge (If any):

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO-1 Develop understanding about the fundamental concepts and processes underlying the field of Developmental biology

CLO-2 Study the Model Organisms for morphogenesis and organogenesis.
CLO-3 Understand Gametogenesis, fertilization and early development
CLO-4 Demonstrate developmental principles underlying evolution, health and disease
CLO-5 Design and conduct experiments to test development related hypothesis
CLO-6 Use modern techniques to explain concepts such as lineage specification.

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	PLO 12
CLO1	3	2	1	3	3	2	3	3	3	3	2	3
CLO2	3	1	1	3	3	2	3	3	3	3	3	3
CLO3	3	2	1	3	3	3	3	3	3	3	3	3
CLO4	3	3	1	3	3	3	3	3	3	3	3	3
CLO5	3	2	1	3	3	3	3	3	3	3	3	3
CLO6	3	2	1	3	3	3	3	3	3	3	3	3

Detailed Syllabus:

Unit 1: Basic concepts of development : Potency, commitment, specification, induction, competency, determination and differentiation, morphogenetic gradients, cell fate and cell lineages, Stem Cells, genomic equivalence and the cytoplasmic determinants, imprinting; mutants and transgenics in analysis of development

Unit 2: Gametogenesis, fertilization and early development: Production of gametes, cell surface molecules in sperm-egg recognition in animals; zygote formation, cleavage, blastula formation, embryonic fields, gastrulation and formation of germ layers in animals; embryogenesis.

Unit 3: Morphogenesis and organogenesis in animals: Animal models of Cell aggregation and differentiation, axes and pattern formation, organogenesis, eye lens induction, limb development and regeneration, differentiation of neurons, post embryonic development- larval formation, metamorphosis, environmental regulation of normal development.

Unit 4: Programmed cell death, aging and senescence.

Reference Books:

1. Gerhart, J. *et al*. (1997) Cells, Embryos and Evolution. Blackwell Science

2. Gilbert, S.F. (2010) Developmental Biology (9th edition). Sinauer

3. Wolpert, L. (2007) Principles of Developmental Biology (3rd edition). Oxford University Press

4. Campbell, N. and Reece, J. (2014) Biology (10th edition). Benjamin Cummings

5. Ridley, M. (2004). *Evolution*. III Edition. Blackwell Publishing.

6. Barton, N. H., Briggs, D. E. G., Eisen, J. A., Goldstein, D. B. and Patel, N. H. (2007). E*volution*. Cold Spring, Harbour Laboratory Press.

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Semester IV

Course Code: …BC575……Title of the Course: **PRINCIPLES IN CANCER AND CANCER STEM CELL BIOLOGY;** L-T-P…**Credits**…2 Elective
Prerequisite Course / Knowledge (If any): *Basics of Human Anatomy*

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO-1 Understanding the hall marks of cancer; How a cancer cell is different from a normal cell
CLO2 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
CLO6 understanding various molecular therapies treating cancer
CLO7 Why certain specific cancers are prevalent in India such as Breast, Oral and Cervical cancers and therapies to treat them

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**	**PLO 12**
CLO1	3	2	3	3	3	3	2	3	2	2	2	2
CLO2	3	3	3	3	3	3	2	3	1	2	2	2
CLO3	3	3	3	3	3	3	3	3	2	1	2	2
CLO4	3	3	3	3	3	3	2	3	3	2	2	3
CLO5	3	2	3	3	3	3	2	3	2	3	3	3
CLO6	3	3	3	3	3	3	3	3	3	3	3	3
CLO7	3	3	3	3	3	3	3	3	3	3	3	3

Each Course Learning Outcome (CLOs) may be mapped with one or more Program Learning Outcomes (PLOs). Write ‘3’ in the box for ‘High-level’ mapping, 2 for ‘Medium-level’mapping, 1 for ‘Low-level’mapping

Detailed Syllabus:

1. Normal cell versus Cancer cell
2. Cell immortalization and tumorigenesis
3. 3. Oncogenes and tumor suppressor genes
4. 4. Maintenance of Genomic integrity and development of cancer

5. 5. Invasion and metastasis- Epithelial to mesenchymal transition
6. Cancer stem cells-Basics and targeting cancer stem cells
7. Rationale treatment of cancer
8. 8. Special emphasis on few imp cancers which are prevalent in IndiaBreast cancer, Oral cancer, etc

(Number of Units may be decided by the School / Department / Centre)

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. Cancer Biology by Raymond Ruddon

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Course Code : BC 576 : Title of the Course – **Glycoconjugates Role in Biology and Biomedical Relevance**

L.T.P: 2-0-0 **Credits** – 2

Prerequisite course / M.Sc. Biochemistry level Intermediary Metabolism-I and II

CLO 1: Understand the basic concepts of carbohydrates, glycoconjugates and specific disorders that affect lysosomal enzyme sorting

CLO 2: Will learn about the core glycosylations that occur in the cells addition of specific sugars, formation of glycan structures, processing and specific sorting of processed glycoproteins.

CLO 3: Understand O-glycosylations in proteins, disorders that occur due to defective O-glycosylations. Importance of complex structural polysaccharides in the human body.

CLO 4: Sugar binding proteins in living organisms including plants, animals, bacteria, viruses, their
structures, sugar specificities and their functions will be understood.

CLO 5: Will understand how the glycoconjugates are degraded in cells and what are carbohydrate deficient glycoprotein diseases, human blood groups and glycolipids and glycosphingolipids.

Unit 1: Carbohydrates and Glycoconjugates Definition/terminology properties-hemiacetal/acetal – glycosidic linkages – classes of glycoconjugates - non-enzymatic glycation -*Diabetes mellitus.* I Cell Disease: A human disorder caused by the deficiency of a carbohydrate recognition marker-mammalian lectin – lysosomes - protein sorting - receptors - enzyme replacement.

Unit 2 : N-Glycosylation Glycosylating precursors - membrane transporter- transferases - processing glycosidases - topology – frequency – heterogeneity. Protein quality control in the endoplasmic reticulum: Role of N-glycosylation – sensing of misfolded proteins – export of misfolded glycoproteins–proteasomal degradation- stress reaction, Purification of glycosidases. .O-Glycosylation Mucins–notch/fringe signalling–collagen-nucleo cytoplasmic glycosylation. Proteoglycans and Hyaluronan Diversity - properties – biological functions - blood clotting and heparin – binding partners, Fucosylation disorders.

Unit : 3 Lectins: I. Definition, occurrence, lectin folds, structure/function of mammalian lectins and other lectins. Purification of plant and animal lectins.
Lectins: II. Mammalian and other lectins, viral lectins, biology and medical aspects of the influenza virus, bacterial adhesins (Helicobacter pylori) and toxins (cholera and neurotoxins). (7 h)

Unit 4: GPI-anchored proteins, Biosynthesis and degradation of glycoconjugates, Lysosomal storage diseases.
Congenital Disorders of Glycosylation: A rapidly emerging group of disorders, Glycolipids (A) and Blood Groups (B) Biosynthesis, genetics and applications.

Reference Books:

1. Essentials of Glycobiology Ajith Varki
2. Affinity Chromatography by PG Dean et al.
3. Lehninger Principles of Biochemistry David L Nelson, Michael M. Cox

Name of the Program: IntMSc/PhD in Biochemistry and Molecular Biology

Vision Statement:
To identify, orient and nurture young brilliant minds towards basic and applied research
Mission Statements: (3 to 4)

1) To impart the best Biochemistry and Molecular Biology education
2) Train students to ask scientific questions and seek answers
3) Develop a scientific temper that can be applied in diverse fields
4) Effectively communicate scientific knowledge to the community
5) Good laboratory practices and ethics in scientific research
6) Contribute to global and local health challenges

Qualification Descriptors (QDs)

After the completion of the program, students will be able to demonstrate
QD-1 **Clarity of concepts:** Understand structure, building and function of biomolecules, means of energy generation, information processing and complexity in the cell and organisms. To be able to understand and interpret the most advanced molecular techniques and technologies
QD-2 **Analytical skills:** To understand experimental basis of generating information in biology, to be able to read and interpret the methodologies and hypotheses tested in generating data. To analyse data statistically and to quantify observations/results
QD-3 **Critical and logical thinking:** To critically examine data that lead to hypothesis, to be able to extrapolate observations to conclusions
QD-4 **Application of knowledge:** To be able to apply learned concepts in correct situations. To formulate hypothesis and design methods to test hypothesis
QD-5 **Communication skills:** To be able to explain concepts clearly in written and oral forms. To be able to articulate their understanding and interests in simple yet scientific terms.
QD-6 **Employability:** To be skillful in the laboratory techniques learnt. To be able to apply it in the context of academic research laboratories, biotechnology and pharmaceutical industry, diagnostic centres etc. To be skilled in data analysis and interpretation.

Mapping Qualification Descriptors (QDs) with Mission Statements (MS)

	MS-1	MS-2	MS-3	MS-4	MS-5	MS-6	MS-7
QD-1	3	3	3	3	3	3	2
QD-2	3	3	3	2	3	2	2
QD-3	3	3	2	3	3	3	3
QD-4	3	3	2	3	3	2	3
QD-5	3	2	2	2	3	2	3
QD-6	3	3	3	3	3	3	3

Write ‘3’ in the box for ‘High-level’ mapping, 2 for ‘Medium-level’ mapping, 1 for ‘Low-level’ mapping.

School of Life Sciences
Department of Biochemistry
University of Hyderabad

Name of the Academic Program: IntMSc/PhD in Biochemistry and Molecular Biology

Program Learning Outcomes (PLOs) (10 to 12)

The students at the end of the program have acquired knowledge in following program specific parameters.

PLO-1 Biochemistry, structure and function of biological molecules
PLO-2 Chemical reactions and bioenergetics, enzyme mechanisms and kinetics
PLO-3 Genetic regulation of cellular process
PLO-4 Information processing in the cell
PLO-5 Genetic and biochemical basis of disease
PLO-6 Cellular organization, communication and functions
PLO-7 Cellular and organismal complexity
PLO-8 Advanced understanding of genomics, epigenomics, genome manipulation and editing technologies
PLO-9 Basic computational biology, statistical analysis and data interpretations
PLO-10 Proficiency in laboratory biochemical and molecular techniques
PLO-11 Hypothesis building, testing and experimentation
PLO-12 Comprehension and communication of scientific data

Course Learning Outcomes (CLOs) (5 to 8) for all courses

Each CLO is mapped with one or more PLOs. '3' in the box for 'High-level' mapping, 2 for 'Medium-level' mapping, 1 for 'Low-level' mapping

Semester I

Course Code : BC 401 : Title of the Course – **Intermediary Metabolism – I**

L.T.P: 3-0-0 **Credits** – 3

Prerequisite course : Knowledge at B.Sc. level Chemistry or Biochemistry mandatory as one of the subjects.

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

CLO 1: Understand the basis of macromolecular digestion to monomeric units in the human body, absorption of the products and assimilation to other parts of the body.

CLO 2: Study how the monosaccharides, predominantly glucose can be converted by human cells under anaerobic and aerobic conditions to generate ATP, the energy currency of the cell required for biosynthetic processes.

CLO 3: Role of specific enzymes in regulating the above processes and diseases involved due to metabolic lock in reaction sequences.

CLO 4: Brain requires glucose for its energy needs under low blood glucose levels, liver can form glucose by gluconeogenesis and can supply to brain.

CLO 5: Role of glucose 6-phosphate in providing NADPH, the reducing agent for fatty acid biosynthesis and formation of different sugar intermediates useful in various metabolic pathways.

CLO 6: Importance of dietary lipids, their digestion and absorption and distribution into different tissues in the body.

CLO 7: The degradation of fatty acids in the cells for the production of Acetyl CoA that can further lead to energy production in the cells

CLO 8: Importance of NADPH in fatty acid biosynthesis, production of unsaturated fatty acids and assembly of triacylglycerol's.

CLO 9: Lipid derivatives as functional units in cellular architecture, intracellular organelles, importance of cholesterol, its role in formation of important vitamins.

Mapping of CLOs with 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	PLO 12

CLO1	3	3	2	2	2	2	3	2	1	1	2	3
CLO2	3	3	2	2	2	2	3	2	1	1	2	3
CLO3	3	3	3	3	3	3	3	2	1	2	2	3
CLO4	3	3	2	2	2	2	3	2	1	2	2	3
CLO5	3	3	2	2	2	2	3	2	1	3	2	3
CLO6	3	3	2	2	2	2	3	2	1	2	2	3
CLO7	3	3	2	2	2	2	3	2	1	2	2	3
CLO8	3	3	2	2	2	2	3	2	1	2	2	3
CLO9	3	3	2	2	2	2	3	2	1	2	2	3

Unit 1: Methods to study Metabolism. Dietary Carbohydrates – Digestion and absorption from the intestinal tract into other parts of the body 3H

Unit 2 : Reactions of glycolysis and TCA cycle with emphasis on regulation, anaplerotic reactions, tracing reactions of TCA cycle using radio isotopes pyruvate dehydrogenase complex and its mechanism substrate level phosphorylation, lactate fermentation, malate/aspartate shuttle, glycerol-phosphate shuttle, and Warburg effect. Glyoxylate cycle 6H

Unit 3 : Pentose phosphate pathway reactions and its importance. metabolic role: source or disposal of pentoses, reducing power for biosynthesis. The reactions of gluconeogenesis, hormonal and metabolite con trol of glycolysis and gluconeogenesis in liver. The Hormonal regulation of blood glucose: insulin, glucagon, cortisol, defects in glycaemia control and altered metabolic events; non-enzymatic glycation and polyolpathway.
7H

Unit 4 : General scheme of carbohydrate metabolism in liver and extra-hepatic tissues, phosphorylation of glucose, glycogen synthesis and glycogenolysis and their regulation in liver and muscle. Including inborn errors of carbohydrate metabolism.
5H

Unit 5: Special emphasis on the interrelations between metabolic pathways and human diseases such as diabetes and obesity arise from defects in metabolic pathways. Biosynthesis of Lactose, Starch and Cellulose. 3H

Unit 6 : Structure of important lipids. Digestion, absorption and transport of dietary lipids, role of bile salts, hormone-dependent triglyceride lipase. Fatty acid activation, transport to the mitochondrial matrix and role of carnitine, steps of beta-oxidation. Oxidation of odd-chain and of unsaturated fatty acids, energetics of fatty acids oxidation, fasting and ketogenesis and relation with gluconeogenesis 4H

Unit 7 : De novo synthesis of palmitate, energetics and reducing power. Elongation and desaturation of fatty acids, essential fatty acids and derivatives (ω3 and ω6 families). Biosynthesis of glycerol lipids, synthesis of phosphatidic acid. Synthesis of triacylglycerols and the major glycerophospholipids. Brief account on the synthesis of plasmalogens, sphingomyelin and glycolipids. Brief account of Prostaglandins
4H

Unit 8 : Reactions of cholesterol biosynthesis, synthesis of cholesteryl esters. Derivatives of cholesterol: bile acids, vitamin D3, and steroid hormones. Structure and classification of lipoproteins, composition, transport, and cholesterol export in lipoproteins.
3H

Unit 9: Hormonal regulation of lipid levels, Defects in fatty acid metabolism in relation to obesity and metabolic syndrome, connection between glucose and fatty acid metabolism; Randle cycle, inborn errors in lipid metabolism
1H

Reference Books:

5. Biochemistry – Author - Lubert Stryer

6. Lehninger - Principles of Biochemistry
7. Text Book of Biochemistry Authors ES West, WR Todd, HS Mason and JT Van Bruggen
8. Review of Physiological Chemistry Author - Harold Anthony Harper

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Course Code: **BC402** Title of the Course: **Biophysical Chemistry**
L-T-P: 3-0-0 Credits: **3 credits**
Prerequisite Course / Knowledge (If any): Bachelor's with Chemistry or Biochemistry as one of the subjects

Course Learning Outcomes (CLOs) (5 to 8)

After completion of this course successfully, 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 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**	**PLO 12**
CLO1	3	3	3	1	2	2	1	1	3	3	1	1
CLO2	3	3	3	1	1	1	1	1	2	2	1	1
CLO3	3	3	2	1	2	1	2	1	2	1	2	2
CLO4	3	2	3	1	1	2	1	1	2	1	2	2
CLO5	3	3	3	1	1	2	1	1	1	2	2	2
CLO6	3	3	3	1	2	2	1	1	1	2	2	2

Unit1. Interactions in Biological Systems, Intra and inter molecular forces electrostatic interactions and Hydrogen bonding interactions, van der Waals and Hydrophobic interactions, Disulphide bridges, Role of water and weak interactions. Bimolecular structures 5h

Unit2. Principle of biophysical chemistry- pH, buffer, pKa, equilibrium and colligative properties. Oxidation and reduction phenomenon in biological systems, redox potential calculation 4h

Unit3. Separation and characterization of macromolecules, detergent, electrophoresis and chromatography, membrane proteins 5h

Unit4. Hydrodynamic methods: Sedimentation- Ultracentrifugation, basic principle, sedimentation rate analysis, sedimentation velocity, sedimentation equilibrium and application 4h

Unit5. Spectroscopy technique-I: Quantum mechanics, basic principle of absorption and fluorescence spectroscopy and their applications
5h
Radio-isotopic technique: measurement, detection and application in biology
3h
Unit6. Bio-thermodynamics: basics and application of thermodynamic in biology, ITC, DSC
5h
Understanding biological system using physical chemistry: signal transduction, rhodopsin, Bacteriorhodopsin, membrane potential, transporter and channels 5h

Reference Books:

1. Physical Biochemistry by David Frefeilder
2. Physical Biochemistry Principles and Application by David Sheehan
3. Principles and Techniques of Biochemistry and Molecular Biology by Keith Wilson and John Walker
4. Physical Chemistry of Macromolecules Basic Principles and Issues by S. F. Sun

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Course Code: BC403 Title of the Course: **Basic Bioinformatics and Computational Biology**
L-T-P: 0-1-2 **Credits**: 3
Prerequisite Course / Knowledge (If any): Biology, Chemistry at Bachelors and Physics, Mathematics at high school

After completing this course, students will be able to:
CLO-1: discuss the use of bioinformatics in addressing a range of biological questions
CLO-2: describe how bioinformatics methods can be used to relate sequence, structure and function
CLO-3: discuss the technologies for modern high-throughput DNA sequencing and their applications
CLO-4: use and describe some central bioinformatics data and information resources.
CLO-5: describe basic principles and algorithms of pairwise and multiple alignments, and sequence database searching
CLO-6: perform pattern matching in biomolecular sequences
CLO-7: describe the most important principles in gene prediction methods
CLO-8: describe basic principles of hidden Markov models and their application in sequence analysis
CLO-9: implement solutions to basic bioinformatics problems

Syllabus

Unit 1. Introduction to Bioinformatics and Computational Biology: History and major developments 3h
Unit 2. Introduction to sequence, structure, pathways, and other Biological Databases and Computational Tools 3 h
Unit 3. Database development: The basics 2h
Unit 4. Nucleic acid sequence analysis: Sequence alignment, substitution matrices, secondary structure elements, motifs 4h
Unit 5. Protein sequence analysis: Sequence alignment, substitution matrices, secondary structure elements, motifs 4h
Unit 6. Evolutionary analysis: Phylogenetic tree construction using Distance-based, Maximum parsimony and maximum likelihood methods; Tree reliability analyses; Tree visualization. 3h
Unit 7. Molecular modelling: RCSB PDB database, Protein tertiary structure prediction using homology modelling and threading, small molecules, force fields, energy minimization and molecular docking 2 h
Unit 8. Applications to biological problem solving 3h

Module 2: (Theory 12 hours)

Statistical analysis of biological experiments:

Unit 8. Samples and Populations, Measures of central tendency and dispersal	2 h
Unit 9. Sampling distribution	1h
Unit 10. Probability distributions (Binomial, Poisson and Normal)	1h
Unit 11. Confidence Interval	1h
Unit 12. Difference between parametric and non-parametric statistics	1h
Unit 13. Levels of significance: Null hypothesis, Alternative hypothesis	3h
Unit 14. Errors (Type I and type II errors)	1h
Unit 15. p-value, adjusted p-value; Student's T-test	1h
Unit 16. Regression and Correlation; Analysis of variance; $\chi 2$ test	1h

Reference Books:

7. Attwood,T. and Parry-Smith, D. Introduction to Bioinformatics. Pearson Education Asia. 2001. ISBN:978-0582327887
8. Krane, D.E. and Raymer, M.L. Fundamental Concepts of Bioinformatics. Pearson Education. 2003. ISBN:978-8177587579
9. Biostatistics For Dummies by John Pezzullo, John Wiley & Sons, ISBN-13: 978-1118553985.
10. Essential Medical Statistics by Betty R. Kirkwood and Jonathan S.C. Sterne, Blackwell Publishing **ISBN-13:** 978-0865428713
11. *Schaum's Outline Series on Statistics, latest edition.*

Advanced studies

12. Mount, D.W. Bioinformatics: Sequence and Genome Analysis, Second Edition Publisher: Cold Spring Harbor Laboratory Press, 2004. ISBN:978-0879697129.

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Course Code: BC404 **Title of the Course: Biochemical Techniques- I**

L-T-P: Practicals **Credits:** 4

Prerequisite Course / Knowledge (If any): none

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

CLO-1: learn basic methodology of buffer preparation

CLO-2: account to measure and detect the biomolecules and molecules involved in a reaction using the calorimeter

CLO-3: learn the application of UV-visible spectroscopy

CLO-4: learn different methods of protein estimation

CLO-5: Isolate glycogen from goat liver and estimate the total carbohydrate content by multiple assay methods

CLO-6: Prepare phosphatidyl choline from egg yolk, purify it by chromatography and quantify it.

CLO-7: Isolate cholesterol from brain and confirm by assay;

CLO-8: Separate sugars (mono and disaccharides) and amino acids by paper chromatography.

CLO-9: Handle yeast and perform mutagenesis and chromosome loss experiments, study Mendelian inheritance patterns with yeast.

CLO-10: To solve problems on Mendelian inheritance, gene interactions, genetic mapping through linkage analysis, tetrad analysis, sex-linked inheritance and extranuclear inheritance.

Mapping of CLOs with 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
CLO 1	3	3	3	3	3	3	-	3	3	-
CLO 2	3	3	3	3	3	3	-	3	3	-
CLO 3	3	3	3	3	3	3	-	3	3	-
CLO 4	3	3	3	3	3	3	-	3	3	-
CLO 5	3	3	3	3	3	3	-	3	3	-
CLO 6	3	3	3	3	3	3	-	3	3	-
CLO 7	3	3	3	3	3	3	-	3	3	-
CLO 8	3	3	3	3	3	3	-	3	3	-
CLO 9	3	3	3	3	3	3	-	3	3	-
CLO 10	3	3	3	3	3	3	-	3	3	-

Syllabus:

9. Preparation of buffers (volatile & nonvolatile) pH measurement; pH indicators, accurate measurement of pH-Various common buffers used in biochemical research.
10. Determination of the pKa of Bromothymol Blue and Amino acids
11. Colorimetry. Use of colorimeter, its limitations Description of colorimeters Filter; grating relation between O.D & Transmittance Beers law; absorbance curves of two dyes.
12. Colorimetric estimation of P and organic PO4 (by digestion) Fiske & Subbarao method/Bartlett or other
13. Estimation of DNA by diphenylamine method
14. Estimation of RNA by orcinol reaction
15. Spectrophotometry: UV and Visible Spectrophotometer. The absorption spectrum of P-nitrophenol U.V absorption of nucleic acids, amino acids and proteins.
16. Building a calibration curve of protein through Bradford method and applying errors.

9. *Genetics Dry Lab:*

a. Mendelian analysis

b. Gene interactions c. Chromosomal basis of inheritance d. Linkage and crossing over e. Tetrad analysis f. Non-Mendelian Genetics (extra-nuclear inheritance)

10. *Genetics wet Lab:*

a. Radiation Sensitivity of yeast b. UV mutagenesis c. Mating, zygote selection sporulation and tetrad analysis d. Yeast position effect assays/ chromosomal loss assays

COMPONENT 2: Isolation and characterization of Carbohydrates & Lipids

11. Isolation of glycogen from Liver/Muscle Total carbohydrate Estimation by Anthrone method.
12. Determination of reducing sugar in glycogen (by 3,5 dinitro salicylic acid)
13. Preparation of phosphatidyl choline from egg yolk-purification by chromatography and lipid phosphorus estimation.
14. Isolation of cholesterol from brain.
15. Paper chromatography: Separation of sugars (mono and disaccharides)
16. 2-dimensional paper chromatography, Amino acid

17. T.L.C separation of phospholipids (Extracts of E.coli, Liver and leaf identification by iodine and ninhydrin.

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Course Code : BC 406 : Title of the Course – **Genetics**
L.T.P: 3-0-0 **Credits** – 3
Prerequisite course : None

After 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.

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**	**PLO 11**	**PLO 12**
CLO 1	2	2	1	2	2	2	3	3	1	1	2	2
CLO 2	2	3	2	3	3	2	3	3	1	2	3	2
CLO 3	2	2	2	3	3	2	3	3	1	2	3	2
CLO 4	2	2	2	3	3	2	3	3	1	1	3	2
CLO 5	2	2	2	3	3	2	3	3	1	2	3	2
CLO 6	2	2	2	3	2	2	3	3	1	2	3	2
CLO 7	2	2	2	3	3	3	3	3	2	3	3	3
CLO 8	3	2	2	2	3	3	3	3	2	2	3	3

Syllabus

Unit 1: Principles of heredity and extensions to basic principles: Mendelian Genetics and analysis: Extensions and modifications of basic principles of heredity, Chromosomal basis of inheritance.(4 h)
Unit 2: Chromosome characteristics and transposable elements: Chromosome structure, Euchromatin and heterochromatin, Coding and Non-coding sequences, Characteristics of transposons, mechanism of transposition and mutagenic effects of transposition. (3 hours)

Unit 3: Genetic recombination in eukaryotes: Linkage and Crossing Over, Chromosome mapping, tetrad analysis and gene conversion, uses of genetic maps. (4 hours)
Unit 4: Mutations and mutagenesis: Detection, Molecular basis and Applications. (3 hours)
Unit 5: Chromosomal changes: Number variation – Euploidy (auto and allopolyploidy), aneuploidy; Structural variations – Deficiences, duplications, Inversions, translocations. (3 h)
Unit 6: Interaction of genotype and environment, Twin studies, genetic environment, non-genetic environment, phenocopies, penetrance and expressivity (2 h)
Unit 7: Gene expression regulation during differentiation and growth: Heterochromatization in human beings, Drosophila and Yeast, position effect: Dosage compensation mechanism, sex chromatin and sex chromosomal inheritance.
(6 h)
Unit 8: Quantitative inheritance: Continuous traits – multigenic variability, dominance – additivity, norms of reaction, quantitative trait loci.
(3 h)
Unit 9: Non-Mendelian Inheritance; Plastid mutations – nature and mode of transmission Mitochondrial traits – nature and mode of transmission. (2)
Unit 10: 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.
(3 h)
Unit 11: Developmental genetics: Model system Drosophila, Genetic screen, pattern formation, maternal effect, homoetic transformations. .
(3 h)

References

4. Griffiths, A. J. F., Miller, J. H., Suzuki, D. T., Lewontin, R. C., Gelbart, W. M. An Introduction to Genetic Analysis, W. H. Freeman & Company, New York.
5. Strickberger, M. W. Genetics, 3rd Edition, Macmillan Publishing co., New York.
6. Gardner, E. J., Simmons, M. J. and Snustad, D. P. Principles of Genetics, 8th Edition,
4. An Introduction to genetic analysis. Anthony A. J. F. Griffiths; Susan R. Wessler; Sean B. Carroll; John Deebly. 11th Edition
5. Genetics: A Conceptual approach. Benjamin A. Pierce. 5th Edition
6. Genetics: analysis of genes and genomes. Daniel L Hartl; Maryellen Ruvolo. 8th edition.
7. iGenetics by Peter J. Russell

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Course Code: BC407 **Title of the Course:** Microbiology

L-T-P: 0-0-4 **Credits:** 4

Prerequisite Course / Knowledge (If any): BSc in any subject of Biology

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**	**PLO 10**
CLO 1	3	2	2	2	2	2	2	2	2	2
CLO 2	3	2	2	2	2	3	3	3	3	3
CLO 3	3	2	2	2	2	3	3	3	3	3
CLO 4	3	2	2	2	3	3	3	3	3	3
CLO 5	3	3	3	3	3	3	3	3	3	3
CLO 6	3	2	2	2	2	3	3	3	3	3
CLO 7	3	2	2	2	2	3	3	3	3	3
CLO 8	3	2	2	2	2	3	3	3	3	3

Detailed Syllabus

Unit 1: Beginnings of microbiology: Discovery, Evolution of microbiology as a discipline. Importance of microorganisms in environment and industry.
Unit 2: Overview of bacterial systematics and taxonomy. Classification of bacteria and general characters of a few bacterial phyla.
Unit 3: Nutritional requirements of microorganisms: Nutritional types, Requirements, Design and types of nutrient media. Growth modes, Culture techniques, Microbial growth: Principles, Kinetics and Methods of measuring growth. Batch and continuous growth, Synchronous culture, Diauxic growth. Uptake of nutrients, Transport systems and protein secretion in prokaryotes.
Unit 4: Bacterial cell structure and morphology – Nucleoid, Cytoplasm, Cytoplasmic membrane, Cell wall, Capsules, Flagella, Pili, Inclusion bodies, Endospores – structure and the process of sporulation. Structure function relation in bacterial cell – Focus on cell wall and cell membrane (a comparative account with Archaea).
Unit 5: Introduction to metagenomics. VBNC and strategies to cultivate the yet-to-be-cultivated bacterial taxa.
Unit 6: Bacterial responses to chemical signaling. Microbial locomotion – Flagellar structure and different types of bacterial movement.
Unit 7: Overview of Plant-Microbe interactions: Symbiotic nitrogen fixation, Mycorrhizae, Plant pathogens.
Unit 8: Physical and chemical control of microorganisms.
Unit 9: History/Foundations of virology, Structure and functional Characteristics. Culturing, detection and Purification protocols of viruses. Nomenclature and recent classification. Viroids and prions. Over view of virus Life cycle.
Unit 10: Culture collection centers and preservation of microorganisms.

References

1. 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

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Semester II

Course Code: MB 451 Title of the Course: **Enzymology & Bioenergetics**
L-T-P: 3-0-0 **Credits:** Three

Prerequisite Course / Knowledge (If any): B.Sc. with Chemistry or Biochemistry as one of the subjects

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 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	PLO 12
CLO1	3	3	3	2	2	2	2	2	2	3	3	3
CLO2	3	3	3	2	2	2	2	2	2	3	3	3
CLO3	3	3	3	3	3	3	3	3	3	3	3	3
CLO4	3	3	3	3	3	3	3	3	3	3	3	3
CLO5	3	3	3	3	3	3	3	3	3	3	3	3
CLO6	3	3	3	2	2	2	2	2	2	3	3	3
CLO7	3	3	3	2	2	3	2	2	3	3	3	3

Syllabus:

Unit 1. Enzymes: basic definitions. Nomenclature (EC recommended and classical), enzyme purification, enzyme activity, specific activity and turnover number
3h

Unit 2. 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
4h

Unit 3. Enzyme kinetics: Single substrate-single intermediate. Michaelis-Menten and Lineweaver Burk plots. Graphical analysis of kinetic data. Determination of Vmax and Km-Experimental aspects.

Unit 4. Enzyme inhibition and mechanism: Mechanisms of enzyme activity and rate studies. Degree of inhibition. competitive, non-competitive and uncompetitive inhibition. 4h

Unit 5. 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.
3h

Unit 6. Coenzymes: Coenzymes structure and function in metabolism
1h

Unit 7. 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 4h

Unit 8. Structure and function of individual complexes of electron transport chain. Complex I, II, III, IV and V 6h

Unit 9. Mechanisms of oxidative phosphorylation: Chemical coupling hypothesis, conformational coupling hypothesis, chemiosmotic hypothesis, mechanism of proton translocation 3h

Unit 10. Photosynthesis: Biological occurrence, various electron donors and acceptors, Photosynthetic pigments, Photosynthetic electron transport chain, and photophosphorylation. 4h

References:

1. Nicholas C Price and Lewis Stevens, *Fundamentals of Enzymology, The cell and molecular basis of catalytic proteins*., 3rd edition, 2001, Oxford University Press, Great Britain.
2. Trevor Palmer and Philip Bonner, *Enzymes: Biochemistry, Biotechnology, Clinical Chemistry*., 2nd Edition, 2008, East-West Press Private Limited, New Delhi.
3. Biochemistry by Reginald H. Garret/Charles M.Grisham 6th Edition.
4. Principles of Biochemistry by Lehninger 7th Edition.

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Course Code: BC452 **Title of the Course: Molecular Biology I**

L-T-P: 3-0-0 **Credits:** 3

Prerequisite Course / Knowledge (If any): none

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

CLO1: Understand biochemical and biophysical basis of DNA transactions
CLO2: Acquainted with both qualitative and quantitative aspects of molecular biology
CLO3: Acquire in-depth and up-to-date knowledge of DNA replication, repair and recombination
CLO4: Able to ask searching questions in the field of DNA replication, repair and recombination
CLO5: Able to propose most appropriate recombinant-DNA techniques and other contemporary molecular techniques to address biological problems
CLO6: Able to understand, analyse and critically evaluate published journal articles in the field of molecular biology

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10	PLO 11	PLO 12
CLO1	3	2	3	3	3	3	3	3	3	1	2	2
CLO2	3	2	3	3	3	3	3	3	3	1	2	2
CLO3	3	2	3	3	3	3	3	3	3	2	3	3
CLO4	1	2	3	3	3	3	3	3	3	2	3	3
CLO5	1	2	3	3	3	3	3	3	3	3	3	3
CLO6	2	2	3	3	3	3	3	3	3	3	3	3

Syllabus

Unit 1. Discovery of DNA. Early experiments in molecular genetics. Historical events that lead to the conclusion of DNA is the genetic material. [3 hours]

Unit 2. Structure of DNA and RNA. Chemical and physical properties of nucleic acids (stability of nucleic acids, buoyant density, purity of DNA, effect of acids, alkali, on DNA, viscosity, spectroscopic and thermal properties of nucleic acids). [3 hours]

Unit 3 Genome Analysis and complexity, Cot analysis, organization of protein coding genes, gene duplication, discovery of repetitious DNA fractions. Lines, Sines and Alu sequences. [2 hours]

Unit4. Chromosomes, Chromatin and the nucleosome. Chromosome sequence, genome size, density and diversity; duplication and segregation; building blocks of chromosomes or nucleosomes, higher order structure and regulation of chromatin structure. [2 hours]

Unit5. DNA replication in prokaryotes and eukaryotes: origin of replication, replication fork, replisome. Enzymes in DNA synthesis, structure, function and mechanisms of action. Methods for studying DNA replication and determination of origin of replication. Chromosome segregation: random versus biased segregation. Topological problems during replication. DNA supercoiling and topoisomerases in eukaryotes and prokaryotes. Mechanisms of actions of topoisomerases. [6 hours]

Unit6. Mutations: Replication errors in DNA, chemical mutagens, spontaneous versus induced mutation. Types of DNA damages. Transposons and mechanisms of transposition. [3 hours]

Unit7. DNA repair: direct repair system, excision repair (NER and BER), Mismatch repair (MMR), double stranded DNA break repair (DSB): non-homologous end joining and homologous recombination. [4 hours]

Unit8. Biochemistry of Recombination; types of homologous recombination: Gene conversion and mating type switching, Site-specific recombination, VD-J recombination, applications of homologous recombination. CRISPR-Cas system [3 hours]

Unit 9. Recombinant DNA technology: Restriction digestion; applications of DNA polymerases and PCR.; DNA modifying enzymes in cloning; DNA sequencing; Cloning vectors and hosts, gene libraries, Screening libraries. [6 hours}

Reference Books:

1.Genomes 3 by T. A. Brown
2.Molecular Biology by D. Freifelder, latest edition
3.Molecular Biology of the Gene by J. D. Watson et al., latest edition
4.Molecular Biology of the Cell by Lodish et al., latest edition
5.Recombinant DNA by J. D. Watson, latest edition
6. Reviews and original research articles from journals

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Course Code: **BC453** Title of the Course: **Structural Biology**
L-T-P: 3-0-0 Credits: **3 credits**
Prerequisite Course / Knowledge (If any):

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO-1: account have detailed understanding of parameters responsible maintaining the 3-dimension of biomolecules.
CLO-2: account to learn basic conformational properties of biomolecules and how their conformation varies under different environmental conditions.
CLO-3: account for the understanding of advance spectroscopic techniques and their application to establish structure function relationship in biomolecules.
CLO-4: to learn and develop basic understanding of all techniques of modern structural biology and biophysics
CLO-5: to read relevant scientific literatures critically and also understand laboratory work.

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**	**PLO 11**	**PLO 12**
CLO 1	3	3	2	1	2	2	1	1	3	3	1	1
CLO 2	3	3	3	1	1	1	1	1	2	2	1	2
CLO 3	3	3	3	1	2	2	2	1	2	1	2	2
CLO 4	3	2	2	1	1	2	1	1	2	1	2	2
CLO 5	3	3	3	1	1	2	1	1	2	2	2	3

Unit1. Structure of Biomolecules: Proteins Structures: Introduction and General Overview, Secondary, tertiary and quaternary structure of protein, super secondary structure, Ramachandran plot, protein folding
3h

Unit2. Structural overview of nucleic acids. Structure and conformational properties of bases, furanose sugars and phosphate groups, geometry of bases, preferred sugar puckering modes, bond distances and angles in furanoses, syn/anti conformation and other conformation aspects of nucleotides. 3h

Unit3. Primary and secondary structure of RNA: Watson-Crick and Hoogsteen base pairing and Primary and secondary structure DNA: A-DNA, B-DNA, C-DNA conformation, DNA-RNA hybrids, Z-DNA formation.
2h

Unit4. Spectroscopic technique –II: Basic principle of 1. Circular Dichroism Spectroscopy (CD ORD), 2. ESR, 3. IR 4. Raman and 5. SPR.
8h

Unit5. Techniques used for structural analysis of proteins and nucleic acid: X-ray Crystallography (Symmetry, space group crystal lattices, brag's law in real & reciprocal space), Nuclear magnetic resonance (NMR) and Cryo-electron-microscopy, their limitation and precautions. Mass spectrometry
8h

Reference Books:

1. Protein Structures and Molecular properties by Thomas C Creighton
2. Principles of nucleic acid Structure by Charles R Cantor
3. Physical Biochemistry Principles and Application by David Sheehan
4. Crystallography made crystal clear By Gale Rhodes
5. Outline of Crystallography for Biologists by David Blow

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Course Code : BC 454 Title of the Course – Intermediary Metabolism –II

L.T.P: 3-0-0 Credits – Three

Prerequisite course / Knowledge at B.Sc. level Chemistry or Biochemistry mandatory as one of the subjects.

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

CLO 1: Importance of dietary protein, its digestion in the human body by specific enzymes and absorption of amino acids for utilisation in other parts of the body.
CLO 2: The role of transaminase enzymes in the over all degradation of amino acids and further conversion of glutamate to alpha-ketoglutarate and ammonia.
CLO 3: Removal of excess ammonia by specialized cycle such as urea cycle.
CLO 4: Salvaging of various metabolic products for synthesis of amino acids in cells and understanding how microrganisms and plants are able to synthesise all the amino acids and human beings need to obtain from their diets about 10 amino acids and regulation of various biosynthetic processes.
CLO 5: Importance of amino acids in the synthesis of complex porphyrins as well as various important hormones in the body.
CLO 6: Importance of nucleotides, ribo and deoxyribonucleotides, their biosynthesis and metabolism in cells. Metabolism of pyrimidine and purine nucleotides will be understood.
CLO 7: Regulation of the pyrimidine and purine metabolism and role of tetrahydrofolae in one carbon metabolism as well as the disorders associated with nucleotide metabolism will be understood.
CLO 8: Types of reactions involved in xenobiotic metabolism and their significance will be understood.

Mapping of CLOs with 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	PLO 12
CLO1	3	3	2	2	2	2	3	2	1	1	2	3
CLO2	3	3	2	2	2	2	3	2	1	1	2	3
CLO3	3	3	3	3	3	3	3	2	1	2	2	3
CLO4	3	3	2	2	2	2	3	2	1	2	2	3
CLO5	3	3	2	2	2	2	3	2	1	3	2	3
CLO6	3	3	2	2	2	2	3	2	1	2	2	3
CLO7	3	3	2	2	2	2	3	2	1	2	2	3
CLO8	3	3	2	2	2	2	3	2	1	2	2	3

Syllabus

Unit 1. Dietary protein digestion and absorption of amino acids, intracellular protein degradation, mechanism of transaminase reactions, non-oxidative and oxidative deamination,

Unit 2 : Fate of ammonia in extra hepatic tissues, glutamine synthesis and transport, alanine cycle, urea cycle reactions and regulation. Biological nitrogen fixation.

Unit 3 :Fate of the carbon skeleton of amino acids, glucogenic and ketogenic amino acids, relation with TCA cycle and lipogenesis. Amino acid decarboxylation: biogenic amines, polyamines.

Unit 4 : Biosynthesis of amino acids. Synthesis of essential and non-essential amino acids and regulation of amino acid biosynthesis. Precursor functions of amino acids including Porphyrin metabolism. Inborn errors of amino acid metabolism.

Unit 5 : Degradation of nucleic acids: deoxyribonucleases and ribonucleases. Nucleotide biosynthesis: de novo purine ribonucleotide biosynthesis and its regulation, purine ribonucleotide biosynthesis from purine bases and ribonucleosides (salvage pathway). Inter conversion of purine ribonucleotides, catabolism of purine bases.

Unit 6 : Pyrimidine ribonucleotide metabolism: de novo biosynthesis of pyrimidine ribonucleotides and regulation, pyrimidine ribonucleotide biosynthesis from bases and ribonucleotides (salvage pathway). Catabolism of pyrimidine bases.

Unit 7 : Regulation of purine and pyrimidine nucleotide metabolism; Formation of NDPs and NTPs; Biosynthesis of deoxy-ribonucleotides and its regulation; Inborn errors of nucleotide metabolism; Nucleotide coenzymes. Inborn errors of nucleotide metabolism.

Unit 8 :Metabolism of 1C units, role of FH4. Methionine and methyl group transfer, Role of vitamin B12 in nucleic acid synthesis. Xenobiotic metabolism: Significance; Phases of xenobiotic metabolism; Types of reactions involved.

Reference Books:

1. Principles of Biochemistry Authors - Abraham White, Philip Handler and Emil L. Smith
2. Lehninger Principles of Biochemistry
3. Biochemistry – Author - Lubert Stryer
4. Review of Physiological Chemistry Author - Harold Anthony Harper

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7. **Course Code:** BC455 **Title of the Course: Biochemical Techniques II**

L-T-P: 0-0-10 **Credits**: 5

Prerequisite Course / Knowledge (If any):

After completion of this course successfully, 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
CLO 3: Able to clone a gene for recombinant expression
CLO 4: Able to create transgenic yeast strains having various applications
CLO-5: learn practical aspect of the characterization of biomolecules
CLO-6: use biophysical techniques to analyze biomolecules in term of secondary structure and able to learn to establish structure function relationship.
CLO-7: learn to crystallize the proteins for 3 dimension structure determination by X-ray crystallography
CLO-8: learn how to perform and analyze biochemical and biophysical data and report in the scientific way.
CLO-9: Quantify and analyze the serum contents of metabolic byproducts.
CLO-10: Understand the clinical significance of abnormal profile of serum contents.

Mapping of CLOs and with PLOs

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO 1	3	3	3	3	3	3	-	3	-	3

CLO 2	3	3	3	3	3	3	-	3	-	3
CLO 3	3	3	3	3	3	3	-	3	-	3
CLO 4	3	3	3	3	3	3	-	3	-	3
CLO 5	3	3	3	3	3	3	-	3	-	3
CLO 6	3	3	3	3	3	3	-	3	-	3
CLO 7	3	3	3	3	3	3	-	3	-	3
CLO 8	3	3	3	3	3	3	-	3	-	3
CLO 9	3	3	3	3	3	3	-	3	-	3
CLO 10	3	3	3	3	3	3	-	3		3

Syllabus

Biochemical Techniques-II Lab Course

Enzymology

1. Assay of alkaline phosphatase from E.Coli using P-nitrophenyl phosphate as substrate.
2. Partial purification of alkaline phosphatase from E.Coli.
3. Characterization of alkaline phosphatase.
    a. Effect of pH
    b. Effect of substrate concentration (Calculation of Km)
    c. Effect of Temperature (Q 10)
    d. Inhibition studies

Molecular Biology

4. Isolation of yeast genomic DNA (or from any other organism)
5. Amplification of your favourite gene (YFG) by PCR
6. Isolation of plasmid DNA from E. coli
7. Restriction digestion of plasmid DNA for cloning/restriction mapping
8. Ligation of DNA insert into cloning vector
9. Transformation in bacteria
10. Knocking out of a non-essential yeast gene by homologous recombination.

Protein technology

11. Purification of a protein by ion-exchange chromatography.
12. Purification of a protein by affinity chromatography
13. Analysis of oligomerization state of a protein by Gel-filtration chromatography
14. Analyzing the purity of isolated protein by SDS-PAGE.
15. Crystallization of Lysozyme
16. Demonstration of fluorescence spectroscopy

Clinical Biochemistry

17. Estimation of blood glucose
18. Estimation of cholesterol in serum

19. Estimation of Bilirubin in serum
20. Estimation of creatine in serum
21. Estimation of creatinine in serum
22. Estimation of urea in blood & urine

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Course Code: BC456 Title of the Course: **Cell Biology**
L-T-P Theory **Credits:** 3
Prerequisite Course / Knowledge (If any): none

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO-1 the structure and organization of eukaryotic and prokaryotic cells
CLO-2 how macromolecules are transported between various organelles
CLO-3 how the cell cycle is regulated
CLO-4 the basic machinery for mitosis and establishment of asymmetry
CLO-5 how organelles are distributed during cell division
CLO-6 cell death mechanisms and autophagy
CLO-7 Understand and analyze how cell biology questions are framed and addressed experimentally
CLO-8 Communicate research papers effectively and suggest future course of experiments

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**	**PLO 12**
CLO1	3	2	3	2	2	2	3	2	1	2	2	2
CLO2	2	2	3	3	3	2	3	2	2	2	3	2
CLO3	3	3	3	3	3	2	3	2	2	2	3	2
CLO4	3	3	3	3	3	2	3	2	2	2	3	2
CLO5	3	2	3	3	3	2	3	2	2	2	3	2
CLO6	3	2	3	3	2	2	3	2	2	2	3	2
CLO7	3	2	3	3	3	3	3	2	2	3	3	3
CLO8	3	2	3	2	3	3	3	2	2	2	3	3

Syllabus:
Unit 1: Introduction to cell biology and cell architecture: variety in size, shape and function. Structure and function of subcellular organelles (2h)
Unit 2: Introduction to structure and function of cytoskeleton and cell-cell adhesion (4h)
Unit 3: Intracellular trafficking: Transport of proteins into ER lumen and membranes. Vesicular transport; transport across golgi, lysosomes, protein secretion and receptor mediated endocytosis. (8h)
Unit 4: Transport across nuclear membrane and peroxisomes Regulation of protein transport (3h)
Unit 5: Regulation of cell cycle in yeast and mammals (5h)
Unit 6: Checkpoints. Mitosis and meiotic cell division (5h).
Unit 7: Mechanisms of cell death and autophagy (3h)

Unit 8: Chromosome segregation and spindle assembly; Nuclear envelope assembly and disassembly; mechanism of cytokinesis (6)
Unit 9: Organelle division and mitotic segregation (mitochondria, ER, Golgi, peroxisomes, lysosomes) (4).
Unit 10: Methods in cell biology: Microscopy (2)

Reference Books:

1. Bruce Alberts, Alexander D. Johnson, Julian Lewis, David Morgan, Martin Raff, Keith Roberts. Molecular Biology of the Cell. W. W. Norton & Company. 6th edition. 18 November 2014
2. Arnold Berk, Chris A. Kaiser, Harvey Lodish, Angelika Amon, Hidde Ploegh, Anthony Bretscher, Monty Krieger, Kelsey C. Martin. Molecular Cell Biology. WH Freeman; 8 edition (1 April 2016)
3. Classic research papers in cell biology (Selected by Instructor
4. Reviews of recent progress (variable; to be selected by the Instructor)

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Semester III

Course Code: 501 Title of the Course: **Basic Immunology**

L-T-P 3-0-0 **Credits:** 3

Prerequisite Course / Knowledge (If any): Knowledge of basic components of human immune system

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO-1: Understand and define terminology and concepts related to cellular and molecular components of mammalian immune system, list theories and models of self and non-self-recognitions, design explanatory frame work towards evolutionary perspectives
CLO-2: Understand biological molecules, cellular processes, cellular communication, cell migration and regulation of innate and inflammatory responses and comprehend evasion strategies by pathogens
CLO-3: Understand interactions between the innate and adaptive immune systems through MHCs and antigen presentations, the role of regulations and evasions of such mechanisms towards generation of an immune response
CLO-4: Understand the molecular and cellular mechanisms, cellular communication, migration and regulation towards generation of B-cell and T-cell repertoires and their effector responses
CLO-5: Apply the concepts of innate and adaptive immune responses to understand the cross-talks between innate and adaptive responses, hypersensitivity, transplantation immunity and immunodeficiencies.
CLO-6: Understand and present experimental approaches that lead to development of concepts in immunology, apply concepts to immune-techniques, critically analyze immunology-related data and, design their own experiment

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	PLO 12
CLO1	3	2	3	3	3	3	3	1	2	2	3	3
CLO2	3	2	3	3	3	3	3	1	3	2	3	3
CLO3	3	2	3	3	3	3	3	1	3	2	3	3

CLO4	3	2	3	3	3	3	3	2	3	2	3	3
CLO5	3	2	3	2	3	3	3	1	3	2	3	3
CLO6	3	3	3	3	3	3	2	1	3	3	3	3

Unit 1: Introductory topics (mammalian immune system)

- Introduction to immunity, basic definitions, important concepts (such as innate and acquired, humoral and cell-mediated, primary and secondary, host-pathogen interactions etc); historical and evolutionary perspectives, recent progress in immunology from basic discoveries to medical innovations

Unit 2: Components of mammalian immune system

- Introduction to cellular and humoral components of immune system, cells of innate and adaptive immune system, Cluster of differentiation, principle of isolation of immune cells
- Microenvironments of immune system: Lymphoid tissues- Primary and secondary lymphoid organs, structure and cellular organization
- Immunogens and antigens – Properties, factors governing immunogenicity, haptens, epitopes-size and identification.
- Immunoglobulins - Structure, isotypes, allotypes and idiotypes, functions of antibody in relation to structure.
- Antigen-antibody interactions: affinity of antibody, avidity, antigen-binding site of antibody, antigen-antibody complex formation, specificity and cross-reactions, principles of immune-techniques
- General concepts of receptors and signaling in immune system: Cytokines and Chemokines, Immunoglobulin and T-cell receptors

Unit 3: Innate mechanisms

- Anatomical Barriers to Infection
- Recognition and response by cells of innate immunity: responses by neutrophils, macrophages, dendritic cells, phagocytosis, oxygen-dependent/oxygen-independent mechanisms, receptors and signaling, pathogen associated molecular patterns and pattern recognition receptors, anti-microbial peptides, extracellular traps etc
- Natural killer cells: recognition and response
- Complement system- classical and alternate pathways of activation, regulation of complement activation and functions, related disorders
- Cell migration, innate and inflammatory responses, regulation and evasion of innate mechanisms

Unit 4: Interactions between the innate and adaptive immune systems

- Major Histocompatibility Complexes, structure, general organization, inheritance, expression patterns, interactions with peptides
- Antigen Presentation: pathways of antigen processing and presentation of intracellular and extracellular antigens, cross-presentation of exogenous antigens, presentation of non-peptide antigens

Unit 5: Adaptive mechanisms

- Organization and Expression of Immunoglobulin and T-cell receptors genes
- B-cell and T-cell development
- Humoral immunity: B-Cell Activation, differentiation, and memory cell generation, primary and secondary antibody responses, antibody response to haptens, enumeration of antibody-forming cells, response to T-dependent and T-independent antigens.
- Cell mediated immunity: T-Cell Activation, differentiation, and memory generation
- Effector Responses and regulations of cell and antibody-mediated immunity, adjuvant mediated responses, Immunological tolerance, Autoimmune diseases
- Cross-talk between innate and adaptive immune system

Unit 6: Brief discussion on specialized immune responses

- Hypersensitivity reactions and allergies – Classification, Type I – IV reactions
- Transplantation immunity
- Immunodeficiency

Reference Books:

1. Kuby Immunology; 10th edition; Authors: Owen, Punt, Stranford
2. Wiley: Roitt's Essential Immunology; 13th edition; Peter J. Delves, Seamus J. Martin, Dennis R. Burton, Ivan M. Roitt
3. ELSEVIER: Cellular and Molecular Immunology, 9th Edition; Authors: Abul Abbas, Andrew H. Lichtman, Shiv Pillai
4. Lippincott Williams & Wilkins: Fundamental Immunology By Willium E.Paul; 7th edition
5. Taylor & Francis group: Janeway's Immunobiology; 9th Edition
6. Reviews, research articles, animations and videos

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Course Code: 502 Title of the Course: **Molecular Biology II**

L-T-P 3-0-0 **Credits:** 3

Prerequisite Course / Knowledge (If any): Molecular Biology I

Course Learning Outcomes (CLOs) (5 to 8)

Theme of the Course: While **Molecular Biology I** covers how the cellular Genome (DNA or Deoxyribonucleic acid) is maintained /preserved for generations through a process called DNA replication and repair, **Molecular Biology II covers**, how the information in DNA or genome is processed to make different RNAs (ribonucleic acids) and a variety of proteins through processes called **transcription and translation** respectively for day-today cellular transactions/functions. This is an important theme that defines the differences in the function, physiology, development, metabolism, health and disease of cells and cell types (muscle cells, neurons, red blood cells, pancreas, plasma cells etc.) in spite of the fact that all these cell types in an organism are originated from the same mother cell and carrying the same genetic information

Course Learning Outcomes:

After completion of this course successfully, the students would have learnt

CLO1. a) the commonalities and differences in the synthesis of these biomolecules especially different RNAs and proteins b) the specific machineries and their components that include sequence information in the DNA and RNA templates that code for RNA and proteins respectively; importance of 'start' and 'stop' signals in these templates and a variety of proteins, and the complex interaction of these template molecules with different enzymes, proteins and small molecules

CLO2. The students will understand how the synthesis of these molecules RNA and proteins is a) regulated (turned on or off or enhanced or decreased) depending on the ambience, cell type and stage where one set of RNAs or proteins are expressed better than the others b) edited, c) processed or modified either during or after their synthesis and the importance of these modifications to maintain, their structure, function, degradation and for targeting to specific cellular destinations.

CLO3. Students will also learn necessary methods a) to mimic these basic cellular processes of transcription and translation in test tube reactions; and for various applications that include identification of transcriptional defects from translation, performance of various functional or defective components using reconstituted transcriptional and translational machineries; to determine the molecular mass of processed and unprocessed proteins and RNAs; the mechanism of action of novel small molecules or antibiotics that affect directly any of the steps in translation or transcription and to identify the importance of regulatory sequences on the coding sequences of in DNA and RNA

CLO4. Students will learn how to exploit some of these modifications of RNAs and proteins for any specific applications like the purification of RNAs and proteins selectively and for preparation of cDNA libraries from mRNAs and such libraries to identify the genes of our interest using hybrid arrest translational systems; to produce proteins of therapeutic interest and for the production of antibodies , to determine protein-protein interactions and to create mice that are defective for a given gene

Overall this course is an important link to understand various branches of Life Sciences such as, developmental biology, infectious biology, genetics, cellular signaling mechanisms, biotechnology, genomics, proteomics and synthetic biology and for advanced research

Linking Course, BC-521 Molecular Biology II Learning out comes to programme learning outcomes

CLOs	PLO-1	PLO-2	PLO-3	PLO-4	PLO-5	PLO-6	PLO-7	PLO-8	PLO-9	PLO-10	PLO-11	PLO-12
1	2	1	2	3	3	3	3	2	2	2	2	3
2	3	2	2	3	3	3	3	1	1	3	3	3
3	3	1	1	3	3	3	3	3	2	3	3	3
4	2	1	1	3	3	3	3	3	2	3	3	3

Syllabus

Unit 1. Expression of Genome in pro and Eukaryotes: Regulatory sequences in DNA, Chemistry of RNA synthesis, RNA polymerases, different RNAs, Transcriptional factors and the mechanism of action. Genetic code. Post-translational modification and splicing, capping, polyadenylation. Processing of rRNA, tRNA precursors. [6 hours]

Unit 2. DNA binding motif in proteins: Zinc finger, Helix-turn-helix and leucine zipper etc. [2 hours]

Regulation of RNA synthesis in lambda phage, prokaryotes (lac, ara, trp and his operons, stringent,

Unit 3. relaxed control), eukaryotes and in during development. [6 hours]

Unit 4. Epigenetic control of gene regulation. epigenetic marks: modification of DNA and histones. Methods for studying epigenetic modifications (ChIP, Chip-Seq, MNase mapping, FAIRE etc.). Interacting between distinct chromosomal loci: 3C, 4C and Hi-C techniques. [3 hours]

Unit 5. Exon shuffling, RNA editing and different RNAs and their functions (including siRNA, microRNa and dsRNA, long non-coding RNA), Riboswitch. [3 hours]

Unit 6. Translation, ribosome, initiation, elongation and termination steps in protein synthesis, regulation of factors and translation. [4 hours]

Unit 7. Secretory Protein biosynthesis, Covalent modifications of proteins (Glycosylation, iodination, methylation, oxidation, phosphorylation etc.) [3 hours]

Unit 8. DNAse hypersensitivity, Random and Site-specific mutagenesis, DNA foot printing, finger printing, RFLP, RNA synthesis, polysomes, Protein synthesis in vitro. [3 hours].

Unit 9. Methods for studying RNA and transcriptome: northern hybridization; RT-PCR; microarray analysis; SAGE. [3 hours]

Unit10. Studying protein-protein interaction: Yeast two hybrid systems, Co-immunoprecipitation; GST-pull down; FRET and SPR (surface plasmon resonance) [2 hours

Reference Books:

1 .Principles of Gene Manipulation and Genomics by Primrose.
2. Genetics and Genomics by Hartl
3. Genomes 3 by T. A. Brown
4. Recombinant DNA by J. D. Watson, latest edition

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Course Code: **MB503** Title of the Course: **Molecular Biology - III**
L-T-P Theory . Credits: 3
Prerequisite Course / Knowledge (If any): Molecular biology I and II

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO-1 – Appreciate size, components, functionality and complexity of genome.
CLO-2 – Appreciate role of evolution in shaping genomes of closely and distantly related organisms.
CLO-3 – Understand the process and importance of genome sequencing projects.
CLO-4 – Understand modern tools of genome editing and their applications.
CLO-5 – Correlate basics of genome organization and its interaction with proteins and RNA to cellular functions.
CLO-6 – Apply genomics to understanding of health, disease and biological diversity.

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**	**PLO 12**
CLO 1	3	1	3	3	3	3	3	3	1	1	2	1
CLO 2	3	1	3	3	3	3	3	3	1	1	2	2
CLO 3	3	2	3	3	2	2	3	3	3	3	2	2
CLO 4	3	3	3	3	2	3	3	3	2	3	3	3
CLO 5	3	2	3	3	2	3	3	3	2	3	3	1
CLO 6	3	2	3	3	3	3	3	3	3	2	3	3

Detailed Syllabus:

Unit 1 **Basics of Genomics:** Brief overview of prokaryotic and eukaryotic genome organization; extra-chromosomal DNA: bacterial plasmids, mitochondria and chloroplast. **(4 h)**

Unit 2 **Genome mapping:** Genetic and physical maps; markers for genetic mapping; methods and techniques used for gene mapping, physical mapping, linkage analysis, cytogenetic techniques, FISH technique in gene mapping, somatic cell hybridization, radiation hybrid maps, *in situ* hybridization, comparative gene mapping. **(5 h)**

Unit 3 **Genome sequencing projects:** Genome sequencing projects for microbes, plants and animals, Human Genome Project, accessing and retrieving genome project information from the web. **(4 h)**

Unit 4 **Comparative Genomics:** Identification and classification of organisms using molecular markers- 16S rRNA typing/sequencing, SNPs; use of genomes to understand evolution of eukaryotes, track emerging diseases and design new drugs; determining gene location in genome sequence. **(4 h)**

Unit 5 **Functional Genomics:** Transcriptome analysis for identification and functional annotation of gene, Contig assembly, chromosome walking and characterization of chromosomes, mining functional genes in genome, gene function- forward and reverse genetics, gene ethics; protein-protein and protein-DNA interactions. **(5 h)**

Unit 6 **Evolutionary genetics and genomics:** Genetic drift, drift versus selection, quantitative trait, gene family, chromosome evolution, genome evolution, selfish DNA, competition among levels of organization, species concepts, speciation, phylogeny, coalescent theory, cancer as an evolutionary process. **(6 h)**

Unit 7 **Genome manipulation techniques:** Transgenic techniques (animal and plant), metabolic engineering, gene knockout, gene knock-down and gene knock-in technologies in various model systems. genome editing (CRISPR-Cas9, ZFN, TALEN etc.) **(5h)**

Unit 8 **Molecular diagnostics:** Basic techniques used in molecular diagnostics, future of molecular diagnostics, Fluorescent in-situ hybridization for identification of chromosomal abnormalities. **(4 h)**

Reference Books:

1.Principles of Gene Manipulation and Genomics by Primrose.
2.Genetics and Genomics by Hartl
3.Genomes 3 by T. A. Brown
4.Recombinant DNA by J. D. Watson, latest edition

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Course Code: **BC505** Title of the Course: **Nutritional and Clinical Biochemistry**
L-T-P: 2-0-0 Credits: **2**
Prerequisite Course / Knowledge (If any):

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO-1 To develop understanding about the fundamental concepts and processes underlying the field of nutritional biochemistry and Malnutrition.

CLO-2 Study the value of food and nutrients in health and disease.
CLO-3 Understand disorders of carbohydrates, lipid and amino acid metabolism.
CLO-4 Demonstrate principles of clinical biochemistry in diagnosis of diseases
CLO-5 Design and conduct experiments to test diagnostic enzymology

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	PLO 12
CLO1	3	2	1	3	3	2	3	3	3	3	2	3
CLO2	3	1	1	3	3	2	3	3	3	3	3	3
CLO3	3	2	1	3	3	3	3	3	3	3	3	3
CLO4	3	3	1	3	3	3	3	3	3	3	3	3
CLO5	3	2	1	3	3	3	3	3	3	3	3	3

Detailed Syllabus:

Unit 1. An overview of specific aspects of metabolism in different organs and tissues (brain, kidney, liver, skeletal muscle, heart, adipose tissue, blood). 4 h
Unit 2. General concepts and nutritional requirements of proteins and calories for growth, maintenance and physiologically altered states, nitrogen balance and muscle protein turnover. 3 h
Unit 3. Disorders of carbohydrates: Diabetes mellitus, non-enzymatic glycation, sorbitol formation, glycohemoglobins, hypoglycemias, galactosemia, various types of glucose tolerance tests, glycogen storage diseases. 3 h
Unit 4. Disorders of lipids metabolism: Plasma lipoproteins, cholesterol, triglycerides & phospholipids in health and disease, hyperlipidemia, hyperlipoproteinemia, Gaucher's disease, Tay- Sach's and Niemann-Pick disease, ketone bodies. 2 h
Unit 5. Biochemistry of fasting and feeding conditions, interrelations between metabolic pathways, interrelations between liver and peripheral tissues, alcohol metabolism. 2 h
Unit 6. Malnutrition – Prevention of malnutrition, improvement of diets. Recommended dietary allowances, nutritive value of common foods. Protein-calorie malnutrition. Requirement of proteins and calories under different physiological states- infancy, childhood, adolescence, pregnancy, and lactation. 3 h
Unit 7. Hypo- and hyperthyroidism and goiter, hypo- and hyper-adrenocorticism, hypo- & hyper-pituitarism, haemoglobinopathies; anemia, thalassemia, sickle cell anemia, jaundice, rheumatoid arthritis; kidney and liver function tests. 3 h
Unit 8. Scope of clinical biochemistry in diagnosis, collection and preservation of biological fluids (blood, urine & CSF), normal values of important constituents of blood, CSF and urine. Collection preparation, preservation, and handling of clinical samples, quality control, Safety measures in clinical laboratory. 3 h
Unit 9. Principles of diagnostic enzymology; definition of functional and non-functional plasma enzymes, problems of enzyme assay in clinical biochemistry laboratory; factors affecting enzyme levels in plasma or serum; selection of enzyme tests; enzyme and enzymes pattern in health and diseases with special mention of plasma lipase, amylase, cholinesterase; alkaline and acid phosphates, SGOT, SGPT, LDH & CPK. 4 h

Reference Books:

1. Nutritional Elements and Clinical Biochemistry by A. Brewster & Marge
2. Nutritional Biochemistry and Metabolism: With Clinical Applications by Maria C Linder
3. Handbook of Nutritional Biochemistry: Genomics, Metabolomics and Food Supply by Sondre Haugen and Simen Meijer

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Code: 504 Title of the Course: **Biochemical Techniques-III**

L-T-P 0-0-5 **Credits**: 5
Prerequisite Course / Knowledge (If any):

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO1: Independently perform, standardize, analyse and interpret data using immunodiffusion assays, Western blot, ELISA (both direct and indirect ELISA)
CLO2: Independently perform, standardize, analyse and interpret data using immunoprecipitation and apply the same to different experimental set-ups
CLO3: How to express a foreign gene in bacteria and purify to homogeneity. Determine the differential gene expression by various cells/tissues.
CLO4: Protein-protein interactions by genetic approach using yeast as a model system.
CLO5: Isolate mitochondria from different sources and perform mitochondrial electron transport chain and ATPase functional assays.
CLO6: Analyse, interpret and evaluate the data based on the experimental values obtained either from normal and dysfunctional mitochondria.

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	PLO 12
CLO1	3	3	3	1	1	1	1	1	3	3	3	2
CLO2	3	3	3	1	1	1	1	1	3	3	3	2
CLO3	3	3	2	3	1	1	1	1	3	3	3	2
CLO4	3	3	2	3	1	1	1	1	3	3	3	2
CLO5	3	3	3	1	1	1	1	1	3	3	3	2
CLO6	3	3	3	1	1	1	1	1	3	3	3	2

Detailed Syllabus: BC504

COMPONENT 1: Immunology
1. Immunodiffusion: to learn visual precipitation reaction and reactivity patterns
2. Western blotting
3. Enzyme-linked immunosorbent assays (ELISA): antigen down ELISA / Sandwich ELISA
4. Immunoprecipitation
5. Isolation of immunoglobulin from serum using affinity chromatography

COMPONENT 2: Molecular Biology-II

1. Over-expression of your favorite gene (YFG) in bacterial system
a) Induction of recombinant protein by IPTG
b) Analysis on SDS-PAGE
2. Purification of protein on Ni-NTA column and analysis of purification by SDS-PAGE.
3. Isolation of RNA from yeast (or from any other organism)
4. RT-PCR analysis
5. Yeast two-hybrid analysis to investigate protein- protein interaction

COMPONENT 3: Studies on Mitochondria

1. Preparation of tightly coupled mitochondria from rat liver.
2. Estimation of protein in mitochondria and homogenate by Biuret method.
3. Estimation of SDH activity in mitochondria and homogenate and calculation of recovery of mitochondria (INT and DCIP methods).
4. Estimation of NADH dehydrogenase activity in mitochondria and homogenate and calculation of recovery of mitochondria.
5. Measurement of rate of respiration and oxidative phosphorylation in mitochondria using succinate, glutamate and malate as substrates.
6. Measurement of rate of respiration and oxidative phosphorylation in mitochondria using glutamate and malate as substrates using oxytherm respirometer.
7. Estimation of cytochrome oxidase activity in mitochondria
8. Estimation of cytochromes in mitochondria
9. Estimation of ATPase activity in mitochondria with and without uncouplers.
10. Separation of the components of electron transport chain using blue native page.

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Course Code: **BC521** Title of the Course: **Endocrine Biochemistry**
L-T-P: 2-0-0 Credits: 2
Prerequisite Course / Knowledge (If any): *Basics of Human Anatomy*

Course Learning Outcomes (CLOs) (5 to 8)

After completion of this course successfully, 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 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**	**PLO 12**
CLO1	3	2	3	3	3	3	2	3	2	2	2	2
CLO2	3	3	3	3	3	3	2	3	2	2	2	2
CLO3	3	3	3	3	3	3	3	3	2	2	2	2
CLO4	3	3	3	3	3	3	2	3	3	2	3	3
CLO5	3	2	3	3	3	3	2	3	2	3	3	3
…..	3	3	3	3	3	3	3	3	3	3	3	3
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Detailed Syllabus:

1. Endocrine system: General features
2. Mechanism of action of hormones.
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.
4. Digestive processes in various regions of digestive system.
5. Gastrointestinal hormones, their synthesis and function.

6. Structure and function of Insulin like growth factors and their receptors.

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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Course Code: **BC523** Title of the Course: **Developmental Biology**
L-T-P: 2-0-0 **Credits**:**2**
Prerequisite Course / Knowledge (If any):

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO-1 Develop understanding about the fundamental concepts and processes underlying the field of Developmental biology
CLO-2 Study the Model Organisms for morphogenesis and organogenesis.
CLO-3 Understand Gametogenesis, fertilization and early development
CLO-4 Demonstrate developmental principles underlying evolution, health and disease
CLO-5 Design and conduct experiments to test development related hypothesis
CLO-6 Use modern techniques to explain concepts such as lineage specification.

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**	**PLO 12**
CLO1	3	2	1	3	3	2	3	3	3	3	2	3
CLO2	3	1	1	3	3	2	3	3	3	3	3	3
CLO3	3	2	1	3	3	3	3	3	3	3	3	3
CLO4	3	3	1	3	3	3	3	3	3	3	3	3
CLO5	3	2	1	3	3	3	3	3	3	3	3	3
CLO6	3	2	1	3	3	3	3	3	3	3	3	3

Detailed Syllabus:

Unit 1: Basic concepts of development : Potency, commitment, specification, induction, competency, determination and differentiation, morphogenetic gradients, cell fate and cell lineages, Stem Cells, genomic equivalence and the cytoplasmic determinants, imprinting; mutants and transgenics in analysis of development

Unit 2: Gametogenesis, fertilization and early development: Production of gametes, cell surface molecules in sperm-egg recognition in animals; zygote formation, cleavage, blastula formation, embryonic fields, gastrulation and formation of germ layers in animals; embryogenesis.

Unit 3: Morphogenesis and organogenesis in animals: Animal models of Cell aggregation and differentiation, axes and pattern formation, organogenesis, eye lens induction, limb development and regeneration, differentiation of neurons, post embryonic development- larval formation, metamorphosis, environmental regulation of normal development.

Unit 4: Programmed cell death, aging and senescence.

Reference Books:

1. Gerhart, J. *et al*. (1997) Cells, Embryos and Evolution. Blackwell Science
2. Gilbert, S.F. (2010) Developmental Biology (9th edition). Sinauer
3. Wolpert, L. (2007) Principles of Developmental Biology (3rd edition). Oxford University Press
4. Campbell, N. and Reece, J. (2014) Biology (10th edition). Benjamin Cummings
5. Ridley, M. (2004). *Evolution*. III Edition. Blackwell Publishing.
6. Barton, N. H., Briggs, D. E. G., Eisen, J. A., Goldstein, D. B. and Patel, N. H. (2007). E*volution*. Cold Spring, Harbour Laboratory Press.

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Semester IV

Course Code: MB576 Title of the Course: **Molecular Biology - IV**
L-T-P: 3-0-0 Credits: 3
Prerequisite Course / Knowledge (If any):

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO-1 – Appreciate gene regulation beyond classical genetics.
CLO-2 – Know chemical modifications on DNA/histones affecting gene expression
CLO-3 –Understanding different levels of genome organization and its impact on gene expression.
CLO-4 – Understand roles of these modifications in genome organization.
CLO-5 –Use modern epigenetic techniques to explain biological phenotypes
CLO-6 – Apply epigenetic understanding to health and disease.

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	PLO 12
CLO1	3	2	3	3	3	3	3	3	1	1	2	2
CLO2	3	3	3	3	3	3	3	3	1	1	2	2
CLO3	3	3	3	3	3	3	3	3	1	1	2	2
CLO4	3	3	3	3	3	3	3	3	3	2	3	3
CLO5	3	2	3	3	3	3	2	3	2	3	3	3
CLO6	3	3	3	3	3	3	3	3	3	3	3	3

Detailed Syllabus:

Unit 1 Basics of Epigenetics. Differences between Mendelian and epigenetic inheritance; regulation of gene expression through DNA methylation; regulation of gene expression through chromatin modifications and remodeling.
5h

Unit 2 Non-coding RNAs: The role of non-coding RNAs in epigenetic regulation.
4h

Unit 3 Trans generational Epigenetics. Concept of epigenetic modification propagation. 3h

Unit 4 Effect of environment on epigenetic modification. Examples and molecular in-sights taken from lower to higher eukaryotes. 3h

Unit 5 RNA epigenetics :RNA modifications, RNA polymerase pausing & epitranscriptomics 3h

Unit6 Nuclear architecture: Large-scale organization of chromosomes, chromosome territories, nuclear compartmentalization, nuclear architecture in genome transactions 4h

Unit 7 Epigenetics of genome editing 2h

Unit 8: Epigenetic gene regulation in development and stem cell biology. Discussion of seminal papers. 3h

Unit 9: Techniques to study genome-wide mutations and changes in epigenetic landscape ChIP-on-CHIP; ChIP-Seq; DNA methylation detection; NGS; ACGH; CNV. 4h

Unit 10: Developing a research proposal in functional genomics and epigenomics. Generation of a testable research questions from observations; designing a controlled experiment to testing a hypothesis; presentationof findings of a primary research paper and indicate their significance/limit. 3h

Reference Books:

1. Nuclear organization and function: Cold spring harbour symposia on quantitative biology Volume LXXV (2010). Cold Spring Harbor Laboratory Press
2. Allis D et al., Epigenetics: Cold Spring Harbor Laboratory Press,
3. Armstrong L. Epigenetics: Garland Science publishers
4. Lewin's Genes by J. E. Krebs et al.

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Course Code: BC575 Title of the Course: **Principles in cancer and cancer stem cell biology**

L-T-P: 2-0-0 **Credits**…2

Prerequisite Course / Knowledge (If any): *Basics of Human Anatomy*

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO-1 Understanding the hall marks of cancer; How a cancer cell is different from a normal cell

CLO2 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

CLO6 understanding various molecular therapies treating cancer

CLO7 Why certain specific cancers are prevalent in India such as Breast, Oral and Cervical cancers and therapies to treat them

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	PLO 12
CLO1	3	2	3	3	3	3	2	3	2	2	2	2
CLO2	3	3	3	3	3	3	2	3	1	2	2	2
CLO3	3	3	3	3	3	3	3	3	2	1	2	2
CLO4	3	3	3	3	3	3	2	3	3	2	2	3
CLO5	3	2	3	3	3	3	2	3	2	3	3	3
CLO6	3	3	3	3	3	3	3	3	3	3	3	3
CLO7	3	3	3	3	3	3	3	3	3	3	3	3

Detailed Syllabus:

1. Normal cell versus Cancer cell
2. Cell immortalization and tumorigenesis
3. Oncogenes and tumor suppressor genes
4. Maintenance of Genomic integrity and development of cancer
5. Invasion and metastasis- Epithelial to mesenchymal transition
6. Cancer stem cells-Basics and targeting cancer stem cells
7. Rationale treatment of cancer
8. Special emphasis on few imp cancers which are prevalent in India: Breast cancer, Oral cancer, etc

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. Cancer Biology by Raymond Ruddon

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Core Course Code: **MB578** Title of the Course: **Advanced Molecular Biology Techniques**
L-T-P: 0-0-1 Credits: 1
Prerequisite Course / Knowledge (If any): Molecular Biology I and II

Course Learning Outcomes (CLOs) (5 to 8)

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

CLO-1 – Understand the importance and scope of biochemistry and Molecular Biology
CLO-2 – Understand the process of cDNA synthesis and quantitative Real-time PCR.
CLO-3 – Familiarization with techniques of handling cloned genes in plasmids and transfection, followed by reporter assays.
CLO-4 – Understand differential gene expression and microarray analysis.
CLO-5 – Learn the ChIP-seq to analyze protein interactions with DNA
CLO-6 – Learn about data analysis, interpretation and statistical significance.

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10	PLO 11	PLO 12
CLO1	3	1	2	2	2	3	3	3	1	3	2	2
CLO2	3	1	3	1	3	1	1	1	1	3	1	2

CLO3	3	1	3	1	3	3	2	2	3	3	3	2
CLO4	3	1	3	1	3	3	2	2	3	3	3	2
CLO5	3	1	3	1	3	3	2	2	3	3	3	2
CLO6	3	3	3	3	3	3	3	3	3	3	3	3

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

Detailed Syllabus:

1. Real-time PCR
2. Tagging am eukaryotic gene at its genomic locus
3. Transfection of a plasmid harboring a tagged gene in eukaryotic system
4. Measurement of reporter gene activity
5. Analysis of micro-array data set
6. Analysis of ChIP-Seq data set