DR. RAMMANOHAR LOHIA AVADH UNIVERSITY, AYODHYA
NEP-2020 Biochemistry (UG-PG) Course structure of
BIOCHEMISTRY
Date of Implementation: Academic Session 2025-26

Year/ Program	Sem.	Course Code	Paper Title (Major/ Core /SWAYAM)	Credits	Teaching (hours)	Evaluation	
						CIE	ETE
Year-1 Certificate in Biochemistry	I	B110101T	Fundamentals of Biochemistry	4	60	25	75
		B110102P	Biosafety Measures, Preparation of Solutions and Qualitative Analysis of Biomolecules	2	60	25	75
	II	B110201T	Human Physiology and Clinical Biochemistry	4	60	25	75
		B110202P	Clinical Biochemistry Lab	2	60	25	75
Year-2 Diploma in Biochemistry	III	B110301T	Tools and Techniques in Biochemistry	4	60	25	75
		B110302P	Biochemical Tools and Techniques Lab	2	60	25	75
	IV	B110401T	Enzymology and Immunology	4	60	25	75
		B110402P	Enzymes and Immunological Techniques Lab	2	60	25	75
		B110403R	Research Project/Dissertation/ Internship/Field or Survey Work	3	60	25	75
Year-3 3 Year UG Degree in Biochemistry	V	B110501T	Bioenergetics and Metabolism	4	60	25	75
		B110502T	Fundamentals of Microbiology	4	60	25	75
		B110503P	Microbial Techniques and Metabolism Lab	2	60	25	75
	VI	B110601T	Cell, Molecular Biology and Genetic Engineering	4	60	25	75
		B110602T	Biostatistics, Bioinformatics and computer application in Biochemistry	4	60	25	75
		B110603P	Genetic Engineering and Bioinformatics Lab	2	60	25	75
Year-4 4 Year UG Degree in Biochemistry (Honours)/ 4 Year UG Degree in Biochemistry (Honours with Research)	VII	B110701T	Molecules of Life	4	60	25	75
		B110702T	Bioanalytical Techniques	4	60	25	75
		B110703T	Essentials of Molecular Biology	4	60	25	75
		B110704T	Essentials of Metabolism	4	60	25	75
		B110705P	Biochemistry Laboratory Course-I	4	120	50	50

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		B110706R	Research Project/Dissertation/ Internship/Field or Survey Work	4	120	50	50
	VIII	B110801T	Cell Biology and Signaling Pathways	4	60	25	75
		B110802T	Genetic Engineering	4	60	25	75
		B110803T	Enzymology and Clinical Biochemistry	4	60	25	75
		B110804T	Fundamentals of Environmental Sciences	4	60	25	75
		B110805P	Biochemistry Laboratory Course -II	4	120	50	50
		B110806R	Research Project/Dissertation/ Internship/Field or Survey Work	4	120	50	50
Note/ Attention for FYUP	The students pursuing **Four Year UG degree in Biochemistry (Honours)** will have to take **Four Theory papers and One laboratory course.** The students pursuing **Four Year UG degree in Biochemistry (Honours with Research)** can opt for any **Three Theory papers plus One laboratory course and a Research Project/Dissertation/ Internship/Field.**						
Year-5 Masters in Biochemistry	IX	B110901T	Elements in Microbiology	4	60	25	75
		B110902T	Fundamentals of Immunology/ **Course from **Swayam Portal**	4	60	25	75
		B110903T	Protein Biochemistry, IPR and Biosafety/ **Course from **Swayam Portal**	4	60	25	75
		B110904P	Biochemistry Laboratory Course -III	4	120	50	50
		B110905R	Research Project/Dissertation/ Internship/Field or Survey Work	4	120	50	50
	X	B111001T	Applied Biotechnology	4	60	25	75
		B111002T	Bioinformatics and Biostatistics/ ** Course from **Swayam Portal**	4	60	25	75
		B111003T	Research Methodology/ ** Course from **Swayam Portal**	4	60	25	75
		B111004P	Biochemistry Laboratory Course -IV	4	120	50	50
		B111005R	Research Project/Dissertation/ Internship/Field or Survey Work	4	120	50	50
Note/ Attention	**The semester IX and X** has provisions of taking up courses from SWAYAM. These courses will be of equivalent credits as well as dealing with the related content. **A list of courses picked up from SWAYAN will be provided to the students by the convenor of BoS.**						

***CIE:** Continuous Internal Evaluation which will involve written test/assignments/seminar/class performance/attendance.
***ETE:** End term Exam which will involve written test/practical/seminar presentation/projects/ dissertation
**Swayam: The courses that can be done from Swayam will be notified to the students by the Head/ Convenor of BoS.

This course framework has been designed according to the instructions and guidelines mentioned in पत्रांक: लो0अ0वि0/Academic/ 4273/ 2025 dated 29.03.2025 and will be implemented from Academic Session 2025-26.

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BoS Meeting held on 25-06-2025

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DR. RAM MANOHAR LOHIA AVADH UNIVERSITY, AYODHYA
Uttar Pradesh NEP-2020 UG-PG Syllabus of subject BIOCHEMISTRY aligned with FYUGP of UGC (To be in effect from 2025-26 session)

Year-1 Certificate in Biochemistry

Year: First | Semester: I
Course Code: B110101T | **Course Title: Fundamentals of Biochemistry**
Credits: 4 | **Marks: [25 Internal+75 External] Evaluation**

Unit- I (5 L)
Basics of Biochemistry
History of biochemistry with special reference to contribution of Indian biochemists. General idea about normality, molarity, molality, percentage solutions, mole fraction. W/v and v/v solutions. Concept of pH determinations using indicators, buffer solutions and their biological importance. Water as universal solvent.

Unit- II (10 L)
Amino acids and proteins
Structural features and classification, Physical properties, optical properties (Stereoisomerism), Chemical properties of amino acids, Uncommon amino acids and their function. Classification of protein, structural organization as primary, secondary, tertiary and quaternary structure of protein and characteristics of the peptide bond.

Unit- III (10 L)
Carbohydrate
Monosaccharides - structure of aldoses and ketoses, Ring structure of sugars, conformations of sugars, mutarotation, anomers, epimers and enantiomers, Structure of biologically important sugar derivatives, oxidation and reduction of sugars, Formation of disaccharides, reducing and non-reducing disaccharide, Polysaccharides – homo- and heteropolysaccharides, structural and storage polysaccharides.

Unit- IV (10 L)
Lipids
Building blocks of lipids - fatty acids, glycerol, ceramide, Storage lipids - triacyl glycerol and waxes, Structural lipids in membranes – glycerophospholipids, galactolipids and sulpholipids, sphingolipids and sterols, Plant steroids.

Unit- V (10 L)
Nucleic acids
Nucleotides - structure and properties, Nucleic acid structure – Watson-Crick model of DNA, Structure of major species of RNA - mRNA, tRNA and rRNA, Nucleic acid chemistry - UV absorption, effect of acid and alkali on DNA, Other functions of nucleotides - source of energy, component of coenzymes, second messengers.

Unit- VI (5 L)
Vitamins
Structure and active forms of water soluble and fat-soluble vitamins, Deficiency diseases and symptoms, hypervitaminosis, Sources, dietary requirements.

Unit- VII (5 L)
Plant Hormones
Classification, structural features & functions in Plants: Auxins, gibberellins, Ccytokinins, ethylene, and abscisic acid.

Unit- VIII (5 L)
Animal Hormones
Classification, structural features &Functions of hormones secreted by endocrine glands: Hypothalamus, pituitary gland- anterior pituitary and posterior pituitary, thyroid gland, adrenal gland, Pancreas, gonads.

Year: First | Semester: I

Course Code: B110102P | **Course Title: Biosafety Measures, Preparation of Solutions and Qualitative Analysis of Biomolecules**

Credits: 2 | **Marks: [25 Internal+75 External] Evaluation**

Unit- I (60 L)
Laboratory exercises:

1. Safety measures in laboratories
2. Preparation of normal and molar solutions
3. Preparation of buffers
4. Determination of pKa of acetic acid and glycine
5. Qualitative tests for carbohydrates, lipids, amino acids,
6. proteins and nucleic acids
7. Estimation of vitamin C
8. Perform spot test for amino acids in a given sample

Year: First	**Semester: II**
Course Code: B110201T	**Course Title: Human Physiology and Clinical Biochemistry**
Credits: 4	**Marks: [25 Internal+75 External] Evaluation**

Unit- I (8 L)
Digestion and Respiration
Structural organization and functions of gastrointestinal tract and associated glands, Mechanical and chemical and enzymatic digestion of food, Absorptions of carbohydrates, lipids, proteins, water, minerals and vitamins, Mechanism of respiration, Pulmonary ventilation, Respiratory volumes and capacities, Transport of oxygen and carbon dioxide in blood Respiratory pigments, Dissociation curves and the factors influencing it, Control of respiration.

Unit- II (8 L)
Circulation and Excretion
Components of blood and their functions, Haemostasis: Blood clotting system, Blood groups: Rh factor, ABO and MN, Cardiac cycle, Cardiac output and its regulation, Electrocardiogram, Blood pressure and its regulation, Structure of kidney and its functional unit, Mechanism of urine formation.

Unit- III (8 L)
Nervous System and Muscular System
Structure of neuron, and physiology of nerve impulse transmission, Histology of different types of muscle, Ultra structure of skeletal muscle, Molecular and chemical basis of muscle contraction, Control of muscle contraction by nerve impulses.

Unit- IV (8 L)
Basic concepts of Clinical Biochemistry
A Brief review of units and abbreviations used in expressing concentrations and standard solutions, Specimen collection and processing (Blood, urine, feces), Anticoagulant and preservatives for blood and urine samples, Transport of specimens.

Unit- V (8 L)
Hematology: Blood
Composition and functions of various components, Anemia: classifications, erythrocyte indices, Blood coagulation system, Clotting time, Bleeding time, Prothrombin time, RBC count, WBC count, Platelet count, Differential count, determination of Hb, PCV and ESR. Hemoglobinopathies, Thalassemia.

Unit- VI (6 L)
Disorders of Carbohydrate metabolism
Regulation of blood sugar, Glycosuria-types of Glycosuria, Oral glucose tolerance test in normal and diabetic condition, Diabetes mellitus and Diabetic insipidus - hypoglycemia, hyperglycemia. Ketonuria, ketosis.

Unit- VII (6 L)
Disorders of Lipid metabolism
Cholesterol: Factors affecting blood cholesterol level, Dyslipoproteinemia, atherosclerosis risk factor and fatty liver. Involvement of enzymes in diagnostics of heart disease including aspartate transaminase, isoenzymes of creatine kinase and lactate dehydrogenase and troponin.

Unit- VIII (8 L)

Liver Function Test

Types, differential diagnosis, Liver function test - Icteric index, Vandenberg test, plasma protein changes. Renal function test: Clearance test–Urea, Creatinine, Para- aminohippuric acid (PAH) test, Concentration, and dilution test. Enzymology: Clinical significance of SGOT, SGPT, ALP, ACP, CPK and LDH.

Year: First | Semester: II

Course Code: B110202P | **Course Title: Clinical Biochemistry Lab**

Credits: 2 | **Marks: [25 Internal+75 External] Evaluation**

Unit- I (60 L)

Laboratory exercises:

1. Qualitative and quantitative analysis of urine: proteins, Bence-Jones proteins, Cl^-, Ca+2.
2. Qualitative analysis of abnormal constituents in urine - glucose, albumin, bile pigments, bile salts and ketone bodies.
3. Experiments on blood (a) Estimation of hemoglobin by cyanmethemoglobin method (b) Determination of A/G ratio in serum
4. Isolation and estimation of serum cholesterol
5. Serum enzyme assays: alkaline phosphatase, SGOT, SGPT
6. Estimation of hemoglobin using Sahli's haemoglobinometer
7. Recording of blood pressure using a sphygmomanometer
8. Recording of blood glucose level by using glucometer
9. Ninhydrin test for Ñ-amino acids.
10. Test for sugar and acetone in urine.

Year-2 Diploma in Biochemistry

Year: Second | Semester: III

Course Code: B110301T | **Course Title: Tools and Technique in Biochemistry**

Credits: 4 | **Marks: [25 Internal+75 External] Evaluation**

Unit- I (4 L)

Basics of Biophysics

Chemical bonding – Ionic bond, covalent bond, hydrogen bond and Vander-Waals force.

Unit- II (8 L)

Chromatography

Introduction & Principle of Chromatography: Paper, thin-layer, column, HPLC, GLC and molecular sieving., Ion exchange chromatography, Affinity Chromatography.

Unit- III (8 L)

Centrifugation

Principle of centrifugation, Basic rules of sedimentation, sedimentation coefficient. Various types of centrifuges, low speed centrifuge, high speed centrifuge and ultracentrifuge, types of rotors. Application of centrifugation, differential centrifugation, density gradient centrifugation- zonal and isopycnic.

Unit- IV (8 L)

Electrophoresis

Basic Principle of electrophoresis, Gel electrophoresis, PAGE, SDS-PAGE, Native gels, denaturing gels, Agarose gel electrophoresis.

Unit-V (8 L)

Hybridization Techniques

General principals of polymerase chain reaction, Western hybridization, Southern hybridization, Western blotting, Immunoblotting

Unit- VI (8 L)

Microscopy

Principle of light microscopy, Phase contrast microscopy, Fluorescence microscopy, Electron microscopy, Permanent and temporary slide preparation, histology, and staining.

Unit- VII (8 L)

Radioactivity

Types, their importance in biological studies, Measure of radioactivity, GM counters and Scintillation counting.

Unit- VIII (8 L)

Fundamental principles and basics of instrument design of:

UV-Visible spectrophotometry and Beer-Lambert law, Fluorescence techniques, Infra-Red and Raman spectrometry, Circular Dichroism and Optical Rotatory dispersion, Nuclear Magnetic Resonance spectrometry, atomic absorption and emission spectrometry, X Ray diffraction, Mass spectrometry.

Year: Second | Semester: III

Course Code: B110302P | **Course Title: Biochemical Tools and Techniques Lab**

Credits: 2 | **Marks: [25 Internal+75 External] Evaluation**

Unit- I (60 L)

Laboratory exercises:

1. Verification of Beer's Law
2. Estimation of proteins by Biuret/Lowry method
3. Separation of amino acid acids by TLC/paper chromatography
4. To perform agarose gel electrophoresis
5. To isolate mitochondria by differential centrifugation
6. Visualization of cells by methylene blue
7. SDS PAGE

Year: Second | Semester: IV

Course Code: B110401T | **Course Title: Enzymology and Immunology**

Credits: 4 | **Marks: [25 Internal+75 External] Evaluation**

Unit- I (8 L)

Introduction to enzymes

General characteristics of enzymes, Co-factor, and prosthetic group, apoenzyme, holoenzyme. Classification and nomenclature of enzymes, Enzyme assays- Enzyme activity, specific activity, units to express enzyme activity. Features of enzyme catalysis, Catalytic power and specificity of enzymes (concept of active site), Fischer's lock and key hypothesis, Koshland's induced fit hypothesis.

Unit- II (8 L)

Enzyme kinetics

Relationship between initial velocity and substrate concentration Michaelis-Menten equation, Lineweaver-Burk plot, Eadie-Hofstee and Hanes plot, Determination of Km and Vmax, Kcat, specificity constant, Effect of pH and temperature on the activity of enzymes.

Unit- III (8 L)

Enzyme inhibition and Regulation

Reversible inhibition (competitive, uncompetitive, non-competitive and mixed), Irreversible inhibition, Substrate inhibition, Allosteric regulation, and feedback inhibition (ATPase), Isoenzymes, Enzyme immobilization and its applications.

Unit- IV (8 L)

Introduction of Immunology

Types of Immunity: Passive, Active, Innate and Acquired immunity, Humoral and Cell Mediated Immunity, Antigens: haptens, epitopes and Factors influencing immunogenicity, Antibodies: Structure, types, production, and functions of immunoglobulins Clonal selection theory.

Unit-V (8 L)

Antigen Antibody reaction: Precipitation, Immunoelectrophoresis, Haem-agglutination, RIA and ELISA. Cell and organs of immune responses and their functions, B & T cells, factors responsible for immunogenicity, Monoclonal antibodies production and applications.

Unit- VI (8 L)

Histocompatibility

Structure of MHC class I, II & III antigens and their mode of antigen presentation, MHC restriction, Complement system: Components, Classical and alternate pathways of complement activation, Hypersensitivity, Autoimmunity.

Unit VII (8 L)

Vaccines and Immunization

Passive and Active immunization, Types of Vaccines: Inactivated, Attenuated, Recombinant and Vaccines, Peptide and DNA Vaccines, RNA Vaccines.

Unit- VIII (4 L)

Transplantation immunology

Immunological basis of graft rejection, Clinical manifestations, Immunosuppressive therapy, and privileged sites.

Year: Second | Semester: IV

Course Code: B110402P | **Course Title: Enzymes and Immunological Techniques Lab**

Credits: 2 Max. | **Marks: [25 Internal+75 External] Evaluation**

Unit- I (60 L)

Laboratory exercises:

1. Isolation of enzyme and determination of enzyme activity
2. Study of the effect of pH on the enzyme activity.
3. Study of the effect of varying substrate
4. concentration on the enzyme activity and
5. determination of Km and Vmax.
6. Study of the effect of temperature on the enzyme activity.
7. Study of the effect of inhibitors on the enzyme activity.
8. Blood grouping
9. Differential Count of WBC
10. Detergent lysis of RBC
11. Dot ELISA
12. ELISA – Demonstration
13. Ouchterlony Double diffusion (ODD)
14. Separation of serum from blood & precipitation of Immunoglobulins

Year: Second | Semester: IV

Course Code: B110403R | **Course Title: Research Project/Dissertation/ Internship/Field or Survey Work**

Credits: 3 Max. | **Marks: [25 Internal+75 External] Evaluation**

This course will be decided and implemented after consultation with the faculty members of each subject. This course will include research / review paper presentation/ writing/ laboratory work / designing and execution of the projects in house or in some laboratory.

3 Year UG Degree in Biochemistry

Year: Third | Semester: V

Course Code: B110501T | **Course Title: Bioenergetics and Metabolism**

Credits: 4 | **Marks: [25 Internal+75 External] Evaluation**

Unit I (8 L)

Principle of Bioenergetics:

Bioenergetics and thermodynamics, Laws of Thermodynamics, Gibbs free energy, enthalpy, Entropy and their relationships, Free energy change, ATP as universal currency in biological system, Coenzymes, and proteins as universal electron carriers.

Unit II (4 L)

Oxidative phosphorylation

The electron transport chain - its organization and function, Peter Mitchell's chemiosmotic hypothesis and Proton motive force, Fo/F1 ATP synthase, structure and mechanism of ATP synthesis, Metabolite transporters in mitochondria, Regulation of oxidative phosphorylation, ROS production and antioxidant mechanisms, Oxidative phosphorylation and ATP synthesis uncouplers.

Unit III (8 L)

Carbohydrate Metabolism:

Glycolysis, TCA cycle, Electron Transport Chain, Pentose phosphate pathway, Gluconeogenesis and Glycogen metabolism, Diseases associated with metabolic irregularities.

Unit IV (8 L)

Photosynthesis

Light harvesting and photosynthetic electron transport, Water splitting, formation of H+ gradient and Photophosphorylation, Calvin cycle, and its regulation, Photo respiration, C4 and CAM pathways in plants.

Unit V (8 L)

Lipid Metabolism:

Degradation of fatty acids, β oxidation, regulation of fatty acid oxidation, ω oxidation and α oxidation, Ketone-body metabolism, Cholesterol synthesis, Fatty acid synthase complex enzyme, Synthesis of saturated, unsaturated, odd and even chain fatty acids, Regulation of fatty acid metabolism, Diseases associated with abnormal lipid metabolism.

Unit VI (8 L)

Protein Metabolism

Urea Cycle, Transport of ammonia, Deamination and transamination reactions, Inborn errors of protein metabolism, Glucogenic and ketogenic amino acids, Overview of amino acid synthesis.

Unit VII (8 L)

Nucleic Acid Metabolism

De novo synthesis of purine and pyrimidine nucleotides, regulation and salvage pathways, degradation of purine and pyrimidine nucleotides, Inhibitors of nucleotide metabolism, Disorders of purine and pyrimidine metabolism.

Unit VIII (8 L)

Nitrogen metabolism

Biological nitrogen fixation by free living and in symbiotic association Structure and function of the enzyme nitrogenase, Nitrate assimilation: Nitrate and Nitrite reductase, Primary and secondary ammonia assimilation in plants, ammonia assimilation by glutamine synthetase-glutamine oxoglutarate amino transferase (GS-GOGAT) pathway.

Year: Third | Semester: V

Course Code: B110502T | **Course Title: Fundamentals of Microbiology**

Credits: 4 | **Marks: [25 Internal+75 External] Evaluation**

Unit I (4 L)

History of Microbiology

Spontaneous generation versus biogenesis, Contributions of Anton von Leeuwenhoek, Louis Pasteur, Robert Koch, Alexander Fleming, Various forms of microorganisms (bacteria, fungi, viruses, protozoa, PPLOs).

Unit II (8 L)

Classification of Microbiology

Nutritional classification of microorganisms, Nature of the microbial cell surface, Gram positive and Gram-negative bacteria, Growth curve.

Unit III (8 L)

Control of Microorganisms

Physical agents (Autoclave, Hot air oven, Laminar airflow and membrane filter), Chemical agents (Alcohol, Halogens and Gaseous agents, antibiotics), Radiation Methods (UV rays).

Unit IV (8 L)

Pathogenicity of Microorganisms and Antimicrobial Chemotherapy

Introduction to pathogenic microbes, Bacteria, Viruses, Algae, protozoa and fungi, General Characteristics of antimicrobial drugs, determining the level of microbial activity, dilution susceptibility test and disc diffusion test, Range of activity and mechanism of action of penicillin, vancomycin, and tetracycline.

Unit V (8 L)

Microbes in Extreme Environments and Microbial Interactions

The thermophiles alkalophiles, acidophiles, symbiosis and antibiosis among microbial population, N2 fixing microbes in agriculture and forestry.

Unit VI (4 L)

Recombination in Prokaryotes

Transformation, Conjugation, Transduction.

Unit VII (8 L)

Food and Industrial Microbiology

Importance of microbiology in food and industries, Basic design of fermenter, Continuous and discontinuous culture, Preparation of fermented food products such as yoghurt, curd and cheese. Preparation of alcoholic beverages like wine and beer, Single cell proteins, Treatment of wastewater and sewage, Bioremediation and biodegradation.

Unit VIII (8 L)

Brief Outline of Virology

Discovery of virus, Early development of virology, nomenclature, classification and taxonomy of viruses - based on host, nucleic acids and structure, Evolution of viruses.

Year: Third | Semester: V

Course Code: B110503P | **Course Title: Microbial Techniques and Metabolism Lab**

Credits: 2 | **Marks: [25 Internal+75 External] Evaluation**

Unit- I (60 L)

Laboratory exercises:

1. Enzyme assay (one example)
2. Biochemical tests–starch hydrolysis, gelatin liquefaction.
3. Assay of salivary amylase.
4. Cholesterol estimation.
5. Cleaning and sterilization of glassware.
6. Study of instruments: Compound microscope, Autoclave, Hot air oven, pH meter, Laminar airflow and centrifuge
7. Media preparation: Nutrients agar, Nutrient broth and LB.
8. Staining Techniques: Simple, Negative staining, Gram staining, Endospore staining, fungal staining.
9. Isolation of bacteria and fungi from soil/air/water – dilution and pour plate methods
10. Study of Rhizobium from root nodules of legumes
11. Growth curve of bacteria.

Year: Third | Semester: VI

Course Code: B110601T | **Course Title: Cell, Molecular Biology and Genetic Engineering**

Credits: 4 | **Marks: [25 Internal+75 External] Evaluation**

Unit I (4 L)

Cell Biology:

Intracellular organization: Cell Membrane, Fluid Mosaic Model, and membrane transport. Structure and functions of organelles, Prokaryotic and eukaryotic cell wall, Cell cycle, cell death and cell renewal: Eukaryotic cell cycle, restriction point, and checkpoints. Cell division: Mitosis and Meiosis. Apoptosis and necrosis.

Unit II (8 L)

Fundamental principles of cell signaling. Concept of signaling as a two-box system, G-Protein and Receptor Tyrosine Kinase mediated signaling, Elements of eukaryotic cytoskeleton. Organization and dynamics of actin microfilaments and microtubules, Endomembrane system, secretory pathways and vesicular trafficking.

Unit III (10 L)

Basics of Molecular Biology:

Central dogma of Life, Organization of Genetic Material, DNA Replication, Prokaryotic- Enzymes and proteins involved in replication, Spontaneous and induced mutations, Physical and chemical mutagens, Mutation at the molecular level, DNA damage & Repair, Mutations in plants, animals, and microbes for economic benefit of man.

Unit IV (8 L)

Transcription:

Transcription in prokaryotes, Mechanism, Promoters, RNA polymerase, Transcription factors.

Unit V (8 L)

Translation:

Genetic code, Properties and Wobble hypothesis. Translation: Mechanism of translation in Prokaryotes, Regulation of Gene expression: Regulation of Gene expression in Prokaryotes, Operon concept (Lac).

Unit VI (8 L)

Recombinant DNA Technology:

DNA manipulative enzymes, Restriction enzymes and DNA ligases, Gene cloning vectors: Plasmids, Bacteriophage and Chimeric plasmids, Creation of r-DNA, Transformation of r-DNA by different methods, Screening and selection of recombinant host cells, Gene Libraries: Genomic DNA and cDNA cloning techniques.

Unit VII (6 L)

Applications of r-DNA Technique in Human Health

Production of Insulin, Production of recombinant vaccines: Hepatitis B, Production of human growth hormone.

Unit VIII (8 L)

Transgenic Plants

Methods of plant transformation, Agrobacterium mediated plant transformation, Application of plant genetic engineering: Insect resistance, Disease resistance, Herbicide resistance, Abiotic stress tolerance, Delayed fruit ripening.

Year: Third	Semester: VI
Course Code: B110602T	**Course Title: Biostatistics, Bioinformatics and Computer Application in Biochemistry**
Credits: 4	**Marks: [25 Internal+75 External] Evaluation**

Unit I (4 L)

Handling of data

Tabulation and diagrammatic representation of data, Bar diagram and pie diagram. Measures of central tendency: mean, median and mode. Measures of dispersion: range, quartile deviation, mean deviation, and standard deviation. Coefficient of variation.

Unit II (8 L)

Tests of significance:

Null hypothesis and alternative hypothesis, Z-test, Student's distribution, Paired t – test, F-test for equality of population variances. Contingency table, Chi-square test for goodness of fit and independence of attributes, Correlation analysis.

Unit III (4 L)

Molecular Techniques

DNA sequencing, Polymerase Chain Reaction (PCR), Primer designing, DNA fingerprinting, site directed mutagenesis, RFLP, RAPD, Southern, Northern and Western Blotting.

Unit IV (8 L)

Basics of Computer and Bioinformatics

Operating systems, Hardware, Software, DOS, Data Access Using Data Control, Internet, LAN, WAN, Web servers. MS word office, excel, power point, Definition and need of Bioinformatics, Brief history of biological databases. International nucleotide databases (e.g., Gen Bank, European Molecular Biology Laboratory (EMBL), Bio information and DNA Data Bank of Japan (DDBJ) Center), International Nucleotide Sequence Database Collaboration (INSDC).

Unit V (8 L)

Protein Databases

Classification of protein databases (e.g., primary, secondary, and composite databases), Brief overview of ExPASy (Expert Protein Analysis System) bioinformatics resource portal, Protein 3D structural databases (e.g., RCSB-PDB (Research Collaboratory for Structural Bioinformatics Protein Data Bank), and MMDB (Molecular Modeling Database) of NCBI).

Unit VI (8 L)

Database Similarity Searches

BLAST, FASTA, PSI-BLAST, algorithms, Multiple sequence alignments - CLUSTAL, PRAS. Primer Designing, Homology Modeling, Phylogenetic analysis, Drug Designing, Determination of Secondary & Tertiary of proteins.

Unit VII (8 L)

Biological File Formats and Literatures Databases

Brief overview of biological sequence and 3D structure file formats (e.g., GenBank/GenPept, EMBL, FASTA, PIR, and PDB), NCBI's literature databases (e.g., PubMed, PubMed Central, PubChem Project and OMIM database.

Unit VIII (8 L)

Database Similarity Searching and Phylogenetics

Requirements of database searching, BLAST (Basic Local Alignment Search Tool) algorithm, Statistical significance and variants of BLAST, FASTA algorithm and its statistical significance, Comparison of BLAST and FASTA, Brief Overview of phylogenetic analysis.

Year: Third | Semester: VI

Course Code: B110603P | **Course Title: Genetic Engineering and Bioinformatics Lab**

Credits: 2 Max. | **Marks: [25 Internal+75 External] Evaluation**

Unit- I (60 L)

Laboratory exercises:

1. Isolate genomic DNA from bacteria, plant and animal tissues
2. Isolate plasmid DNA (E. coli)
3. Perform restriction digestion of DNA
4. Perform Agarose Gel Electrophoresis
5. Learning to analyze data using SPSS or R software
6. Introduction to types of sequence databases (Nucleotides & Protein)
7. Pair wise Sequence Alignment (NW and SW approach)
8. FASTA & BLAST search
9. Multiple Sequence Alignment (Clustal X &Tree view)

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Syllabus

PROGRAM: [4 Year UG Degree in Biochemistry (Honours)/ 4 Year UG Degree in Biochemistry (Honours with Research)]

Year: Fourth | Semester: VII

Course Code: B110701T | **Course Title: Molecules of Life**

Credits: 4 Max. | **Marks: [25 Internal+75 External] Evaluation**

Unit- I (12 L)

Contribution of Indian scientists to biological sciences: Jagdish Chandra Bose, Har Gobind Khorana, Ananda Mohan Chakrabarty, Birbal Sahni, Lalji Singh; Physical & Chemical properties of Water, pH and buffer system, titration curves, basic biochemical calculations.

Unit- II (12 L)

Carbohydrates: Classification and properties of simple carbohydrates; monosaccharide, oligosaccharide, and polysaccharides; Reducing and Non-Reducing Sugar, Enantiomers, Structural Polysaccharides: Cellulose, Chitin, Storage Polysaccharides: Starch and Glycogen, Glycoproteins and Glycolipids. Biological Importance of carbohydrates.

Unit- III (12 L)

Proteins: Amino acids: Chemical structure and general properties; Protein classification – globular, fibrous & membrane proteins, Ramachandran plot, Protein folding & denaturation, sequencing; Biological Importance of amino acids and proteins. **Lipids:** Fatty acids: General formula, nomenclature, and chemical properties; Lipid classification: simple, complex; General structure and functions of major lipid subclasses - acyl glycerols, phosphoglycerides, sphingolipids, waxes, terpenes, steroids, and prostaglandins & free fatty acids; Circulating lipids - chylomicrons. LDL, HDL and VLDL.

Unit- IV (12 L)

Nucleic Acids: Structure of purines, pyrimidines, nucleosides and nucleotides; Physical & biochemical properties of DNA; Types of DNA: A, B and Z DNA & Triplet DNA, their structure and significance; Chargaff's Rule, DNA denaturation and Tm value, Types of repetitive nucleic acid sequences, Satellite DNA, DNA topology: Supercoiling, Linking number, Twist and Writhe, Classification structure and function of different types of RNA: mRNA, tRNA, rRNA, hnRNA; snRNA, snoRNA, miRNA, gRNA, Primary, secondary, and tertiary structures of RNA.

Unit- V (12 L)

Vitamins and Hormones: Vitamins – internal & external sources, structure, properties, and functions including biochemical reactions, symptoms of hyper & hypo-vitaminosis. Hormones-Source organs, Structure, classification, properties & functions of animal & plant hormones.

Year: Fourth | Semester: VII

Course Code: B110702T | **Course Title: Bioanalytical Techniques**

Credits: 4 | **Marks: [25 Internal+75 External] Evaluation**

Unit- I (12 L)

Spectroscopy: Concepts of spectroscopy, Visible and UV spectroscopy, Beer-Lambert's Law, Principles and applications of NMR, ESR, Raman, Mass atomic absorption and atomic emission spectroscopy and X-ray crystallography.

Unit- II (12 L)

Chromatography and Microscopy: Principles of partition chromatography, Paper, Thin layer, Ion exchange and affinity chromatography, Gel permeation Chromatography, HPLC & FPLC. Transmission and scanning EM: Freeze fracture techniques, Specific staining of biological materials.

Unit- III (12 L)

Centrifugation & Radioactive Techniques: Principles of centrifugation, Concepts of RCF, Different types of instruments and rotors, Preparative, Differential and density gradient centrifugation, Analytical Ultra-centrifugation, Determination of molecular weights and other application, subcellular fractionation.

Unit- IV (12 L)

Electrophoretic Techniques & Viscosity: Principles of electrophoretic separation. Continuous, Zonal and Capillary electrophoresis, Different types of electrophoresis including paper, cellulose, acetate/nitrate and gel. Electroporation, Pulse field gel electrophoresis. Viscosity- Viscosity of macromolecules, Relationship with conformational changes.

Unit- V (12 L)

Radioactive Techniques: Introduction to radiations and their uses in biology, Safety measures, Principles and Applications o23f Liquid scintillation counting (LSC), Gamma counting and Autoradiography.

Year: Fourth | Semester: VII

Course Code: B110703T | **Course Title: Essentials of Molecular Biology**

Credits: 4 | **Marks: [25 Internal+75 External] Evaluation**

Unit- I (12 L)

Organization of Genetic materials in prokaryotes and Eukaryotes: Genetic material, Genome type, Size, Genome Organization - Structural Maintenance of Chromosomes (SMC) Protein, Eukaryotic Nucleosomes, Histones, Chromatin, Concept of Gene, mono-cistronic and poly-cistronic genes, Gene Structure with various functional units - replicon, muton, recon, C-value and C-value paradox; Unique sequences and Cot value, reassociation kinetics, Split genes: Exons and Introns, DNA transposon.

Unit- II (12 L)

Replication: Modes of replication: Details of Meselson and Stahl experiment; Prokaryotic DNA replication: Origin and Initiation, elongation and termination; Roles, properties and mechanism of action of DnaA, Helicase, Primase, DNA gyrase, Topoisomerases, DNA Polymerases, DNA ligase, Leading and lagging strands; Okazaki fragments; RNA primers; Regulation of replication; Fidelity of replication; Viral replication, σ or Rolling circle replication in ϕX174.

Unit- III (12 L)

Eukaryotic DNA replication: Initiation, elongation and termination; Multiple replicons/initiation sites; Autonomously replicating sequence; Mechanism and significance of Origin recognition complex, Mini-chromosome maintenance proteins, DNA dependent DNA polymerases α, δ, ε, Nucleases, DNA ligase and Telomeres in eukaryotic nuclear DNA replication; Regulation of eukaryotic DNA replication; Mitochondrial and Chloroplast DNA replication.

Unit- IV (12 L)

Transcription in prokaryotes: Initiation, elongation and termination; Prokaryotic promoter; weak and strong promoters, DNA dependent RNA polymerase: Physical properties, Templet strand, non-template strand, coding strand, Subunits, σ factor, its types and function; Recognition of promoter; Transcription bubble, Direction of Transcription; Abortive initiations; Promoter clearance; Elongation factor Gre and its role, Rho dependent and Rho independent termination of transcription; Sigma cycle; RNA - dependent DNA polymerase and Reverse transcription.

Unit- V (12 L)

DNA damage and DNA Repair: Types of DNA damages, Types of DNA Repair systems, Photoreactivation, BER, NER, Mismatch Correction, Homologous recombination and NHEJ method, SOS Repair.

Year: Fourth | Semester: VII

Course Code: B110704T | **Course Title: Essentials of Metabolism**

Credits: 4 | **Marks: [25 Internal+75 External] Evaluation**

Unit- I (12 L)

Principle of bioenergetics: Laws of Thermodynamics, Energy cycle and specialized role of ATP as universal currency of energy, **Energy transduction:** energy transducing membranes from organelles in animals, plants and bacteria, Phosphorylation – Oxidative and Photophosphorylation, Chemiosmotic theory of phosphorylation. Photosynthetic light receptors and light harvesting complexes, Hill reaction, its components and products, Redox potential and electron flow through electron transport chain complexes in bacteria, chloroplast & mitochondria, Uphill and downhill flow of electrons, difference between cyclic and non-cyclic phosphorylation, regulation of ETC, Inhibitors of ETC, uncouplers, Bioluminescence.

Unit- II (12 L)

Carbohydrate metabolism: Catabolic pathways- Glycolysis and Non- glycolytic pathways, Hexose monophosphate shunt and its modes, Tricarboxylic acid cycle. Anaplerotic reactions sequences in metabolism, fate and role of metabolic byproducts -NADH, $FADH_2$, Glycogenolysis, Krebs-Kornberg pathway Glyoxylate pathway. Glucose catabolism in cancerous tissue, aerobic and anaerobic catabolism of glucose in terms of respiration, Biosynthesis/Anabolic pathways with Regulation –Gluconeogenesis, Biosynthesis of disaccharides – sucrose, lactose, Biosynthesis of polysaccharides - glycogen synthesis, Starch synthesis, Cellulose synthesis, Glucosaminoglycans synthesis and their biological roles.

Unit- III (12 L)

Lipid Metabolism: Biosynthesis – synthesis of saturated and unsaturated fatty acids, biosynthesis of triacylglycerols glycerophospholipids and membrane phospholipids, sphingolipids, cholesterol. Degradation of fatty acids: Carnitine transporters, α, β, ω oxidation; Ketone bodies, acidosis, ketosis, Cholesterol degradation and production bile acids and bile salts.

Unit- IV (12 L)

Metabolism of Nitrogenous compounds: Biosynthesis of amino acids and Urea cycle, associated metabolic disorders, Kreb-Urea bicycle, Biosynthesis of Nucleotides – salvage and de-novo synthesis of purines and pyrimidines, Catabolism of amino acids and nucleosides, and nucleic acids, Inborn errors of metabolism related to amino acids and nucleosides.

Unit- V (12 L)

Biochemistry of Nitrogen fixation: Diazotrophy and its components, Nitrogen fixing organism, symbiotic and non-symbiotic modes, Physiology of nodule formation, Nitrogenase complex and its oxygen sensitivity with protection methods, Ammonia assimilation and regulation system, Ammonia and nitrate transport, nif gene, nod gene. **Photosynthesis:** Carbon fixation/reduction pathways - Calvin cycle, C3, C4 and CAM pathway, photorespiration and C2 pathway.

Year: Fourth | Semester: VII

Course Code: B110705P | **Course Title: Biochemistry Laboratory Course-I**

Credits: 4 | **Marks: [50 Internal+50 External] Evaluation**

Laboratory exercises:

1. Qualitative and Quantitative Analysis of-
   a. Carbohydrates
   b. Amino acids and Proteins
3. Fractionation of egg proteins and its quantification.
4. Isolation of casein from milk and its quantification.
5. Isolation and estimation of serum cholesterol.
6. Qualitative and quantitative analysis of (a) Saliva (alpha-amylase) (b) Urine (urea,uric acid, glucose, proteins)
7. Determination of serum enzyme assays: Alkaline phosphatase, SGOT, SGPT.

Year: Fourth
Course Code: B110706R

Credits: 4

Semester: VII
Course Title: Research Project/Dissertation/ Internship/Field or Survey Work
Marks: [50 Internal+50 External] Evaluation

This course will be decided and implemented after consultation with the faculty members of each subject. This course will include research / review paper presentation/ writing/ laboratory work / designing and execution of the projects in house or in some laboratory.

Year: Fourth | Semester: VIII

Course Code: B110801T | **Course Title: Cell Biology and Signaling Pathways**

Credits: 4 | **Marks: [25Internal+75External] Evaluation**

Unit- I (12 L)

Ultrastructure of cell and membrane transport: Structural organization and function of various subcellular organelles, Cytoskeleton (Microtubules, Microfilaments, actins etc.) **Cell membrane & Transport**: Structure and functions of cell membrane, physiochemical and electrical properties of membrane, Membrane Transport: Diffusion, Facilitated diffusion, Active transport, and its types. Techniques to study biomembranes - FRAP, FRET, Freeze Fracture Technique.

Unit- II (12 L)

Cell cycle and Cell division: Overview of cell cycle, Check points, role of cyclin and cyclin dependent kinases, Strategies of cell cycle regulation, Positive & Negative regulators, Mitosis and Meiosis; Programmed cell death, aging, and senescence.

Unit- III (12 L)

Cell communication and Cell Signaling: GPCR structure and function, Ligand binding and activation, signal amplification, heterotrimeric G-protein, adenyl cyclase, receptor tyrosine kinases, signaling pathways: AKT, c-MET, HER2, Nf-Kb, NOTCH, p53, JAKSTAT, Hedgehog, and Wnt signaling pathways (mechanisms and physiological significance), Phosphodiesterase, Phosphoinositide pathway, Calmodulin, DAG.

Unit- IV (12 L)

Protein traffic in cells: Secretory and non-secretory proteins, Endocytic and Exocytic pathways, Protein sorting and signal sequences; protein translocation in ER and vesicular transport to Golgi, Lysosomes, and plasma membrane; Protein import into nuclei, mitochondria, chloroplasts, and peroxisomes, Clathrin mediated endocytosis.

Unit- V (12 L)

Applied Cell Biology: Basic techniques in mammalian cell culture; Cell & tissue culture media; Serum free media; maintenance of the culture and cell lines; Stem cell and their applications.

Year: Fourth | Semester: VIII

Course Code: B110802T | **Course Title: Genetic Engineering**

Credits: 4 | **Marks: [25 Internal+ 75 External] Evaluation**

Unit- I (12 L)

Enzymes used in rDNA Technology: Outline of cloning procedure, Host controlled restriction and modification: Restriction endonucleases and cognate methylases, Class I, II & III restriction enzymes, Variants of Type II Restriction enzyme, Restriction digestion, Star activity, Restriction mapping, Formation of chimeric DNA, Homopolymer tailing, Synthetic Linkers, Adaptors and DNA ligase; Filling in and Trimming back; Significance of T4 DNA polymerase & Klenow Fragment, Alkaline phosphatase, Reverse transcriptase in cloning. Overview of the methods for introduction of DNA into living cells: Chemical transformation, microprojectile bombardment, electroporation and microinjection.

Unit- II (12 L)

DNA synthesis: Purification of mRNAs; mRNA abundance; Synthesis of cDNA: Various methods for first and second strand DNA synthesis; cDNA and Genomic library construction; Chemical synthesis of oligonucleotides by Phosphoramidite and Photolithographic methods; Preparation of probe DNA by radioactive and non-radioactive labelling methods: Nick translation, End filling, Random primer methods.

Unit- III (12 L)

Plasmids: Plasmid classification on basis of phenotypic traits: Relaxed and stringent control of copy number; Plasmid incompatibility; Plasmid host range, Mobilizable plasmids and Triparental mating; Plasmid as cloning vector (recombinant plasmids): Properties of ideal plasmid cloning vectors, pBR322, pUC& pGEM3Z series, Transcriptional and translational fusion vectors; Fusion proteins; Selectable markers; Reporter genes.

Unit- IV (12 L)

Phage as a cloning vector: Advantage of using phage lambda vector, Genome map of phage lambda, In vitro packaging, Insertional and replacement vectors: Cosmid vectors; M13 phage and its role in single stranded DNA production, M13 series of vectors; Phagemids; Yeast as cloning vector: Basic principles of development of yeast vectors, 2μplasmid, YEP, YRP YCP, YIP; Artificial chromosomes: YACs, BACs and PACs.

Unit- V (12 L)

Screening and selection of recombinants: Functional (genetic) complementation (Blue-white screening, Red-white screening), Nutritional complementation, Gain of function, Colony hybridization, Plaque hybridization, Southern blotting and hybridization, Dot blot, Zoo blot, Plus-Minus screening, Northern blotting, Immunological screening, Western blotting, South-Western blotting, North-Western blotting, HART, HAT.

Year: Fourth | Semester: VIII

Course Code: B110803T | **Course Title: Enzymology and Clinical Biochemistry**

Credits: 4 | **Marks: [25 Internal +75 External] Evaluation**

Unit- I (12 L)

Steady state and equilibrium hypotheses of enzyme kinetics, Michaelis-Menten and Briggs-Haldane equations, significance of Michaelis-Menten parameters i.e., Vmax, Km, Kcat and Kcat/Km; Mechanism and features of different types of enzyme inhibition; Breakdown of the Michaelis-Menten equation; Mechanism and kinetics of multi substrate reactions.

Unit- II (12 L)

Enzyme induction, répression and covalent modification; feedback inhibition; importance of isozymes and zymogen in enzyme regulation; allosteric enzymes and their regulations; Hills coefficient and the determination of enzyme-ligand binding/dissociation constant. Enzyme Immobilization: Immobilization; kinetics of immobilized systems.

Unit- III (12 L)

Body fluids: Blood-functions, composition, blood groups, Rh factor, Plasma proteins, Blood coagulation, clot formation and coagulation, Urine and its composition, Alterations under pathological conditions, role of kidney in acid-base and electrolyte balance. Biochemistry of respiration, Muscle contraction, cell motility, role of calmodulin.

Unit- IV (12 L)

Nerve impulse transmission: excitation-its conduction and synaptic transmission by neural systems, neurotransmitters, venoms and nerve poisons.

Unit- V (12 L)

Clinical and biochemical aspects of atherosclerosis, jaundice, diabetes, hepatitis, glomerular nephritis, gall stones, Addison's disease, Conn's syndrome, Cushing's syndrome, hypo & hyperthyroidism, Parkinson's disease and Alzheimer's disease.

Year: Fourth	Semester: VIII
Course Code: B110804T	**Course Title: Fundamentals of Environmental Sciences**
Credits: 4	**Marks: [25 Internal + 75 External] Evaluation**

Unit- I (12 L)

Air pollution, Sound, thermal, and radioactive pollution, harmful effects of UV-Rays, Ozone layer depletion, Ozone hole, Acid Rain, CFCs, and their substitutes. Global warming and its effect on flora and fauna. Water pollution: types of water bodies and their general characteristics, chief pollutant in domestic, industrial and agricultural wastes, effects of pollutants on flora and fauna.

Unit- II (12 L)

Nature of agriculture and industrial wastes and by-products and their treatment and recycling Microbial degradation of pesticides, Lignin, Detergents, Dyes, Petrol and petroleum products, Use of microorganism in pollution control, ways and means for abatement of environmental pollution.

Unit- III (12 L)

Principle of Biochemical toxicology; Properties of Xenobiotics, Type of chemical alteration, molecular mechanism of toxicology development, dose response relationship, risk assessment of chemicals; acute, short term and chronic toxicity studies, metabolic disposition, Carcinogenicity and mutagenicity studies.

Unit- IV (12 L)

Recycling of organic waste: Major sources of recyclable materials including agricultural waste. Key technology in recycling of crop residues, human and animal wastes. Composting and vermicomposting; Production and application. Role of microbes in composting and biogas production. Municipal solid waste treatment and management.

Unit- V (12 L)

Xenobiotic toxicity/ genotoxicity, Mode of action of pesticides, fungicides and insecticides; Mutation detection by Ame's test, microsomal assay. Bioaccumulation and bioremediation, Biosensors, DNA probes and their environmental applications, Toxicogenomic.

Year: Fourth | Semester: VII

Course Code: B110805P | **Course Title: Biochemistry Laboratory Course -II**

Credits: 4 | **Marks: [50 Internal +50 External] Evaluation**

Laboratory Exercises:

1. Titration of weak acid using a pH meter, preparation of buffers.
2. Verification of Beer-Lambert's law and determination of absorption coefficients.
3. Paper Chromatography-Separation of amino acids and carbohydrates in a mixture.
4. Thin Layer chromatography of fatty acids.
5. Column Chromatography-Separation of mixture of proteins and salt using Sephadex column.
6. Electrophoresis.
7. Gel electrophoresis of serum proteins.
8. SDS-PAGE of proteins.
9. Assay of enzyme activity.
10. Isolation and purification of urease.
11. Time course of enzymatic reaction.
12. Influence of substrate concentration of the rate of enzymatic reaction.
13. Effect of pH and temp. on the rate of enzyme reaction. Inhibition of enzyme activity.

Year: Fourth | Semester: VII

Course Code: B110806R | **Course Title: Research Project/Dissertation/ Internship/Field or Survey Work**

Credits: 4 | **Marks: [50 Internal +50 External] Evaluation**

This course will be decided and implemented after consultation with the faculty members of each subject. This course will include research / review paper presentation/ writing/ laboratory work / designing and execution of the projects in house or in some laboratory.

Year-5 Masters in Biochemistry

Year: Fifth	**Semester: IX**
Course Code: B110901T	**Course Title: Elements in Microbiology**
Credits: 4	**Marks: [25 Internal +75 External] Evaluation**

Unit- I (12 L)

Prokaryotes: Bacteria: Morphology and structure of bacterial cell; Staining procedures; Criteria used in classification; Bacterial taxonomy; Phenetic and phylogenetic classification; Numerical taxonomy; General characteristics of major groups of bacteria. Bacterial Growth and Nutrition: General nutritional requirements; Culture media; Types of bacterial cultures; Measurement of bacterial growth; Control of microorganism by physical and chemical methods; Gene transfer in bacteria: Conjugation, Transformation and Transduction. Archaebacteria: Archaea as a separate lineage; Differences from eubacteria.

Unit- II (12 L)

Eukaryotic Microorganisms: Structure of fungus: yeast and mold. Fundamentals of control of microbial growth, control by physical and chemical agents. Production of mutants by chemical and physical agents and their characterizations.

Unit- III (12 L)

Viruses: General characteristics of virions; Classification; Isolation, cultivation and assay methods; One-step growth curve of bacteriophages; Lysogeny and lytic cycle; Satellite and defective viruses; Viral interference; Common viral infections. Virusoids, Viroid's, Diseases caused in plants. Prions: Characteristics; Prion diseases; Hypotheses regarding nature and pathogenesis of prions.

Unit- IV (12 L)

Microorganisms and Diseases General concepts: Normal human microbiota; Opportunistic microorganisms; Koch's postulates; River's postulates; Classification of diseases; Modes of transmission of diseases; Stages in progress of a disease.

Unit- V (12 L)

Bacterial toxins – Exotoxins, endotoxins, enterotoxins their structure and mode of action, antimicrobial agents, supha drugs, Penicillin and Cephalosporins, antibiotics, resistance to antibiotics. Media for Industrial Fermentation: Substrates for bioconversion processes, preparation, sterilization, design. Large scale production and commercial applications of enzymes: proteases and amylases.

Year: Fifth	**Semester: IX**
Course Code: B110902T	**Course Title: Fundamentals of Immunology/ Course from Swayam Portal**
Credits: 4	**Marks: [25 Internal +75 External] Evaluation**

Unit- I (12 L)

Introduction of cells and organs of immunity; basic concept of innate and acquired immunity, host specialization, granulocytes (neutrophils, eosinophils, basophils) and their functions, Antigens, immunogens and heptane, structure and classification of antibody, isotype, allotype, idiotypes.

Unit- II (12 L)

Comparison of receptors on T&B lymphocytes, CD Markers, Concept of Histocompatibility: Major Histocompatibility Complex (MHC), MHC restriction for CD4 & CD8 subset of T cells, Role of MHC complex and transplantation, Generation of diversity in immune response; clonal selection theory, the gene encoding antigen specific receptors on T&B lymphocytes immunoglobin genes, Activation of T&B lymphocytes immunoglobin genes, Activation of T&B cells by antigen, Antigen processing and presentation.

Unit- III (12 L)

The complement system; biological role of complement system, components of classical and alternative pathways, mechanism of NK cell mediated cytotoxicity, Inflammation, Its physiological basis and relevance, General properties of cytokines and interferons and their applications.

Unit- IV (12 L)

Allergy and hypersensitivity, autoimmunity, autoimmune diseases, Vaccines: preparation and delivery system, immune adjuvants, Raising of antisera and monoclonal antibodies.

Unit- V (12 L)

Measurement of antigen and antibody interaction: direct binding assay, agglutination and precipitation reaction in gels; immune electrophoresis, immunoprecipitation, RIA & ELISA, Biotin-avidin based immunoassay, immunofluorescence assay (IFA); immunohistochemistry, immunoblotting.

Year: Fifth | **Semester: IX**

Course Code: B110903T | **Course Title: Protein Biochemistry, IPR and Biosafety/ Courses from Swayam Portal**

Credits: 4 | **Marks: [25 Internal +75 External] Evaluation**

Unit- I (12 L)

The native state of proteins; denaturation and inactivation of proteins; characteristics and importance of different levels of protein structure; protein evolution; assembly of fibrous proteins; the concept and importance of domain structure in proteins.

Unit- II (12 L)

Measurement of stability of the native state; the role of short, medium, and long- range interactions in protein folding; mechanism of protein folding; the thermodynamics and kinetics of protein folding; determinants of protein folding with special reference to the roles of molecular chaperones, signal peptides and the environment in the protein folding; the problem of inclusion body formation and recovery of active proteins, Intein, Intein Splicing.

Unit- III (12 L)

The living state and role of enzymes in its substance; chemical catalysis; general acid-base, covalent and intramolecular catalysis; detection of intermediates in enzymatic reactions; features and mechanism of action of lysozyme, chymotrypsin and carboxypeptidase A.

Unit- IV (12 L)

IPR: Introduction to intellectual property rights; Intellectual property laws; significance of IPR. Forms of IPR like patent, design copyright and trademark. Requirement of a patentable novelty; Issues related to IPR protection of software and database; IPR protection of life forms. Obtaining patent; Invention step and prior art and state of art procedure; Detailed information on patenting biological products and biodiversity. trade related aspects of Intellectual Property Rights and Budapest treaty.

Unit- V (12 L)

Biosafety: Historical Background; Introduction to Biological Safety Cabinets; Primary Containment for Biohazards; Biosafety Levels; Biosafety guidelines - Government of India; Definition of GMOs; Roles of Institutional Biosafety Committee, RCGM, GEAC etc. for GMO applications in food and agriculture; Environmental release of GMOs; Risk Analysis; Risk Assessment; Risk management and communication. Bioethics: Introduction, necessity and limitation; Ethical conflicts in Biotechnology; Different paradigms of bioethics.

Year: Fifth | **Semester: IX**
Course Code: B110904P | **Course Title: Biochemistry Laboratory Course-III**
Credits: 4 | **Marks: [50 Internal +50 External] Evaluation**

Laboratory exercises:

1. Preparation of Culture media.
2. Preparation of broth and slants.
3. Sterilization of culture media by autoclave method.
4. Isolation and propagation of bacteria.
5. Staining of bacteria-Simple staining, differential staining, staining of spores and capsules.
6. Determination of growth curve of bacteria.
7. Biochemical tests and motility for the identification of bacteria.
8. Precipitin reaction by double immunodiffusion and radial immunodiffusion (Ouchterlony)
9. Detection of antibodies or antigen by ELISA.
10. Detection of antigens by immunoblotting techniques.
11. Experiments on restriction digestion, ligation and cloning.
12. Experiments on western blotting.
13. Experiments on plasmid isolation.
14. Isolation of genomic DNA from bacteria, plant and animal.
15. Amplification of DNA by PCR

Year: Fifth **Semester: IX**

Course Code: B110905R **Course Title: Research Project/Dissertation/ Internship/Field or Survey Work**

Credits: 4 **Marks: [50 Internal +50 External] Evaluation**

This course will be decided and implemented after consultation with the faculty members of each subject. This course will include research / review paper presentation/ writing/ laboratory work / designing and execution of the projects in house or in some laboratory.

Year: Fifth | **Semester: X**
Course Code: B111001T | **Course Title: Applied Biotechnology**
Credits: 4 | **Marks: [25 Internal +75 External] Evaluation**

Unit- I (12 L)

Principle & applications of PCR; RACE, DD-RTPCR, Degenerate PCR TA cloning, Realtime PCR, Scorpion PCR, Site Directed Mutagenesis: oligonucleotide directed, PCR based Mutagenesis, Error prone PCR. Antisense RNA technique, Sense co-suppression in plants and animals, RNAi, in gene silencing, ribozymes, Microarray techniques for DNA, Proteins and Antibodies.

Unit- II (12 L)

Rapid DNA and RNA sequencing techniques: Sanger method, Maxam and Gilbert procedure, automated DNA sequencing, pyrosequencing; High throughput Sequencing, shot gun cloning, Clone Contig cloning, Fundamentals of Whole-Genome Sequencing., Sequencing of Phage, Viral and Bacterial Genomes, Human Genome sequencing, and comparative genomics. Molecular Markers: RFLP, RAPD, AFLP, SCAR, STS, Yeast two-hybrid system, DNase I foot printing, Genome editing tools, CRISPER/cas technology in gene editing.

Unit- III (12 L)

Application of recombinant microorganism: Production of recombinant pharmaceuticals, therapeutic proteins, Production of Restriction Enzyme, Production of Antibiotics, Metabolic Engineering, Production of Biopolymer, Combating Human Diseases, Biopesticides, Bioremediation.

Unit- IV (12 L)

Ti plasmid, Binary and Cointegrate vectors derived from Ti plasmid of Agrobacterium, plant virus vectors, Transgenic plants, and their applications, improving agronomic traits, Herbicide tolerant, Insect resistance, disease resistance, viral resistance, abiotic stress resistance, Genetic Manipulation of flower pigmentation, Delaying of postharvest, softening, and discoloration of fruits, Plants as Bioreactors, Production of Biopolymers, Production of Edible Vaccines

Unit- V (12 L)

Expression of transgenes, Reproductive and Therapeutic cloning, gene knock outs, Applications of transgenic animals, Transgenic Animals as Basic Research Models, Gain-of-function, Loss-of-function, Gene Knock-out, Transgenic animals modeling human diseases, transgenic animals as bioreactors, Xenotransplantation.

Year: Fifth | **Semester: X**

Course Code: B111002T | **Course Title: Bioinformatics and Biostatistics/ Courses from Swayam Portal**

Credits: 4 | **Marks: [25 Internal +75 External] Evaluation**

Unit- I (12 L)

Basic Bioinformatics: Basics of networking, Introduction to Internet, Introduction of Genomics: Information flow in biology, Experimental approach to genome sequence data, Genome information resources.

Unit- II (12 L)

Computational Genomics: Biological data analysis and application, Nucleic acid Protein Data Banks- GenBank, EMBL, SWISSPROT, NCBI model Information retrieval system- Entrez and PubMed etc, File format, Annotation, ESTs Databases, Clustering, Gene discovery, Identification, and functional classification.

Unit- III (12 L)

Structural and Functional Proteomics: Small molecules databases, Protein information resources and secondary databases, Computational techniques in structural analysis, Structural comparison at secondary and tertiary levels, Computer aided drug designing.

Unit- IV (12 L)

Sequence alignment and Database Search: Introductory basis of sequence alignment, DNA primary sequence analysis, Pair wise sequence alignment- NEEDLEMAN and Wunsch, Smith Waterman algorithm

Unit- V (12 L)

BLAST and FASTA algorithm, Multiple sequence alignment, Database similarity search tools- BLAST, FASTA, CLUSTAL, T-Coffee (Tree-based consistency objective function for alignment evaluation).

Year: Fifth	**Semester: X**
Course Code: B111003T	**Course Title: Research Methodology/ Course from Swayam Portal**
Credits: 4	**Marks: [25 Internal +75 External] Evaluation**

Unit- I (12 L)

Research Methodology: definition, purpose, Process of Research; Objectives and Dimensions of Research, Design Tools of Research: Library, Field, Laboratory; Methods of research: Qualitative and Quantitative. Systematic review of literature, Features of good research study. Research Ethics (Issues relating to referencing and documentation, copyrights, plagiarism etc), Impact Factor, H-Index, Citation Index, references/ bibliography.

Unit- II (12 L)

Biostatistics: Data Collection, presentation, data processing, classification, and tabulation. Measures of Central tendency and Dispersion. Quantitative Techniques: Levels of significance.

Unit- III (12 L)

Scientific proposal and paper writing: An Insight into Research proposal: Definition and basic concepts, defining the problem, creating a hypothesis, objectives, work plan, significance, and techniques of research, expected outcome, finding research materials – literature survey, compiling records. Definition and kinds of scientific documents – research paper, review paper, book reviews, Thesis writing: chapter format, pagination, identification, using quotations, footnotes, abbreviations, presentation of tables and figures, referencing, documentation, use and format of appendices, indexing.

Unit- IV (12 L)

Basics of Computers- classification, computer system components (CPU, Input/output devices, internal memory i.e. RAM, ROM & Cache, and external memory i.e. secondary storage devices). Computers networks and introduction of internet. MS-Office

Unit- V (12 L)

Computer applications in Biology: Introduction to spreadsheet applications, features, using formulas and functions, Data storing, Features for Statistical data analysis, generating charts / graph and other features, Presentation of Power Point Presentation, Customizing presentation, Use of Computers in Quantitative analysis. Tools for digital image processing.

Year: Fifth | **Semester: IX**
Course Code: B111004P | **Course Title: Biochemistry Laboratory Course-IV**
Credits: 4 | **Marks: [50 Internal +50 External] Evaluation**

Laboratory exercises:

1. Preparation of competent cells.
2. PCR and elution of amplicon from gel
3. Cloning of foreign DNA into plasmid vector.
4. Transformation with recombinant plasmid DNA.
5. Isolation and visualization of plasmid DNA.
6. Screening of recombinants.
7. Isolation, separation and visualization of native DNA and RNA.
8. Transcript expression using Real Time PCR
9. *In-silico* gene and protein sequence analyses:
    - Database mining
    - Homology search (BLAST)
    - Restriction site mapping
    - Protein primary and secondary structure prediction
    - Functional annotation
    - Protein homology modeling
    - Molecular docking and related in-silico analyses

Year: Fifth | **Semester: IX**

Course Code: B111005R | **Course Title: Research Project/Dissertation/ Internship/Field or Survey Work**

Credits: 4 | **Marks: [50 Internal +50 External] Evaluation**

This course will be decided and implemented after consultation with the faculty members of each subject. This course will include research / review paper presentation/ writing/ laboratory work / designing and execution of the projects in house or in some laboratory.

Suggested Readings:

- Lehninger Principles of Biochemistry by David L. Nelson and Michael M. Cox
- Biochemistry by Donald Voet and Judith G. Voet
- Biochemistry by Berg, Tymoczko, Gatto & Stryer; Freeman Macmillan
- Principles and Techniques of Practical Biochemistry by Keith Wilson and John Walker
- Molecular Cloning: A Laboratory Manual by Joseph Sambrook, D.W. Russel, Joe Sambrook
- Research Methodology: Methods And Techniques by C R Kothari
- Study Guide for Fundamentals of Biostatistics by Bernard Rosner
- Authoring a PhD: How to Plan, Draft, Write and Finish a Doctoral Thesis or Dissertation. By Patrick Dunleavy
- Introduction to Bioinformatics by Arthur M Lesk
- Bioinformatics: Sequence and Genome Analysis by David W. Mount
- Bioinformatics and Functional Genomics by Jonathan Pevsner
- Structural Bioinformatics by Philip Bourne & Jenny Gu
- Textbook of Biochemistry with Clinical Correlations by Thomas M. Devlin
- An Introduction to Practical Biochemistry by David T. Plummer
- Gene cloning: An introduction by TA Brown
- Principles of Gene Manipulation and Genomics by M Twyman and Sandy B. Primrose
- Plant Biotechnology: A Practical Approach by H. S. Chawla
- Genetic Engineering by Rastogi and Pathak
- Animal Cell Culture Technique, Ed. Martin, Clynes. Springer
- Animal Cell Culture- Principles and Practice by Anil Kumar, Manisha Singh, Shalini Mani
- Stem Cell Biology and Gene Therapy by Peter J. Quesenberry
- Molecular Cell Biology by Harvey Lodish et al.
- The Cell: A Molecular Approach by Geoffrey M Cooper
- Molecular Biology of The Cell by Bruce Alberts
- Cell and Molecular Biology by Gerald Karp
- Biochemical Calculations by Segel
- Kuby Immunology by Jenni Punt, Sharon Stranford, Patricia Jones and Judith A Owen
- Elements of Immunology by H.F. Khan
- Lewin's Gene by Krebs, Goldstein, and Kilpatrick

DR. RAM MANOHAR LOHIA AVADH UNIVERSITY, AYODHYA
Syllabus of UG Program with Biochemistry as a Minor Course

YEAR WISE PAPER TITLES For Biochemistry (Minor)							
Certificate / Diploma	Year	Course Code	Paper Title	Theory	Credits	Evaluation	
						CIE	ETE
Certificate in Biochemistry	Year-1	M110101T	Fundamentals of Biochemistry	Theory	6	25	75
Diploma in Biochemistry	Year-2	M110201T	Essentials of Biochemicals Techniques and Immunology	Theory	6	25	75

Year: First **Semester: I+II**
Course Code: M110101T **Course Title: Fundamentals of Biochemistry**
Credits: 6 **Marks: [25 Internal+75 External] Evaluation**

This course introduces the principles of Fundamentals of Biochemistry. After completion of this course, students will be able to-

- Basic details of structure, function of carbohydrate molecules and its classification
- Details of structure, function, and classification of amino acid & structural levels of protein molecules
- Structure and function of fatty acids, storage, and structural lipids
- Details of structure and function of nucleotide, DNA and RNA
- Basic details of Vitamin molecules and its classification
- Classification, structural features, and function of Plant & Animal Hormone
- To understand disorder related with biomolecules metabolism.
- Anticoagulant preservatives for blood and urine.
- Metabolism of bilirubin, jaundice-types, differential diagnosis, and Liver function.

Unit I

History of biochemistry with special reference to contribution of Indian biochemists. General idea about normality, molarity, molality, percentage solutions, mole fraction. W/v and v/v solutions. Concept of pH determinations using indicators, buffer solutions and their biological importance. Water as universal solvent.

Unit II

Amino acids and proteins: Structural features and classification, Physical properties, optical properties (Stereoisomerism) Chemical properties of amino acids Uncommon amino acids and their function. Classification of protein, structural organization as primary, secondary, tertiary, and quaternary structure of protein and characteristics of the peptide bond.

Unit III

Carbohydrate and Lipids: Monosaccharides - structure of aldoses and ketoses, Ring structure of sugars, conformations of sugars, mutarotation, anomers, epimers and enantiomers, Structure

of biologically important sugar derivatives, oxidation, and reduction of sugars, Formation of disaccharides, reducing and non-reducing disaccharide, Polysaccharides– homo- and heteropolysaccharides, structural and storage polysaccharides, Building blocks of lipids -fatty acids, glycerol, ceramide, Storage lipids-triacylglycerol and waxes. Structural lipids in membranes–glycerophospholipids, galactolipids, and sulpholipids, sphingolipids and sterols, Plant steroids

Unit IV

Nucleotides and Vitamins: Nucleotides-structure and properties, Nucleic acid structure–Watson-Crick model of DNA, Structure of major species of RNA-mRNA, tRNA and rRNA. Nucleic acid chemistry- UV absorption, effect of acid and alkali on DNA, Other functions of nucleotides-source of energy, component of coenzymes, second messengers, Structure and active forms of water soluble and fat-soluble vitamins, Deficiency diseases and symptoms, hypervitaminosis, Sources, dietary requirements

Unit V

Plants and Animal Hormones: Classification, structural features & functions in Plants: Auxins, gibberellins, cytokinin, ethylene, and abscisic acid. Classification, structural features & Functions of hormones secreted by endocrine glands: Hypothalamus, pituitary gland-anterior pituitary and posterior pituitary, thyroid gland, adrenal gland, Pancreas, gonads.

Unit VI

Basic concepts of Clinical Biochemistry

A Brief review of units and abbreviations used in expressing concentrations and standard solutions Anticoagulant and preservatives for blood and urine samples. Composition and functions of various components, Anemia: -classifications, erythrocyte indices, Blood coagulation system, Clotting time, Bleeding time Prothrombin time, RBC count, WBC count, Platelet count Differential count. Hemoglobinopathies, Thalassemia

Unit VII

Disorders of Carbohydrate and Lipid metabolism

Regulation of blood sugar, Glycosuria-types of Glycosuria, Oral glucose tolerance test in normal and diabetic condition, Diabetes mellitus and Diabetes insipidus-hypoglycemia, hyperglycemia, Ketonuria, ketosis. Cholesterol: Factors affecting blood cholesterol level, Dyslipoproteinemia, atherosclerosis risk factor and fatty liver. Involvement of enzymes in diagnostics disease.

Unit VIII

Liver function test - Icteric index, Vandenberg test, plasma protein changes. Renal function test: Clearance test–Urea, Creatinine Para- amino hippuric acid (PAH) test, Concentration, and dilution test. Enzymology: Clinical significance of SGOT, SGPT, ALP, ACP, CPK and LDH.

Suggested Reading:

- Lehninger, Albert, Cox, Michael M. Nelson, David L. (2017) *Lehninger principles of biochemistry*/New York: W. H. Freeman.
- Voet, D., & Voet, J. G. (2011). Biochemistry. New York: J. Wiley & Sons
- Biochemistry–Lubert Stryer Freeman International Edition.
- Biochemistry–Keshav Trehan Wiley Eastern Publications
- Fundamentals of Biochemistry- J. L. Jain S. Chand and Company
- Voet & Voet: Biochemistry Vols 1& 2: Wiley (2004)
- Text book of Biochemistry with clinical correlation, Thomas M. Devlin, 3rd edition, A. John Wiley

CIE (Continuous Internal Evaluation): 10 marks for Test, 10 marks for presentation along with assignment, 05 marks for Class interactions.

Year: Second **Semester: III+IV**
Course Code: M110201T **Course Title:** Essentials of Biochemicals Techniques and Immunology
Credits: 6 **Marks: [25 Internal+75 External] Evaluation**

- The objective of the course is to introduce various techniques to the students, which are used in biological research.
- Students will acquire knowledge about the principles and applications of spectrophotometric and chromatography techniques used in a biochemistry lab.
- Students will learn about the principle and application of electrophoresis, centrifugation techniques, microscopic and molecular biological techniques.
- The objective of the course is to provide detailed knowledge about enzymes, the biological catalysts with remarkable properties that sustain life.
- Students will also learn to appreciate how enzymes are regulated and the physiological importance of enzyme regulation in the cell
- Students will develop the understanding of basics of Immunology, types of Immune Responses, antigens and antibodies, histocompatibility, vaccines, and immunization

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Unit I
Basics of Biophysics
Chemical bonding–Ionic bond, covalent bond, hydrogen bond and Vander-Waals force.

Unit II
Chromatography and Centrifugation
Introduction &Principle of Chromatography: Paper, thin-layer, column, HPLC, GLC and molecular sieving, Ion exchange chromatography, Affinity Chromatography. Principle of centrifugation, Basic rules of sedimentation, sedimentation coefficient. Various types of centrifuges, low speed centrifuge, high speed centrifuge and ultracentrifuge, Types of rotors. Application of centrifugation.

Unit III
Electrophoresis, Microscopy and Radioactivity
Basic Principle of Gel electrophoresis, PAGE, SDS-PAGE, Native gels, denaturing gels Agarose gel electrophoresis, Principle of light microscopy, Phase contrast microscopy, Fluorescence microscopy, Electron microscopy, Types, their importance in biological studies, Measure of radioactivity, GM counters and Scintillation counting.

Unit IV
Introduction to enzymes and Enzyme kinetics
General characteristics of enzymes, Cofactor and prosthetic group, apoenzyme, holoenzyme. Classification and nomenclature of enzymes. Enzyme assays-Enzyme activity, specific activity, units to express enzyme activity. Features of enzyme catalysis Catalytic power and specificity of enzymes (concept of active site), Fischer's lock and key hypothesis Koshland's induced fit hypothesis. Relationship between initial velocity and substrate concentration Michaelis-Menten

equation, Lineweaver-Burk plot, Eadie-Hofstee and Hanes plot, Determination of Km and Vmax, Kcat, specificity constant, Effect of pH and temperature on the activity of enzymes.

Unit V

Enzyme inhibition and Regulation

Reversible inhibition (competitive, uncompetitive, non-competitive, and mixed) Irreversible inhibition, Substrate inhibition, Allosteric regulation and feedback inhibition (ATPase), Isoenzymes, Enzyme immobilization and its applications.

Unit VI

Introduction of Immunology

Types of Immunity: Passive, Active, Innate and Acquired immunity, Humoral and Cell Mediated Immunity. Antigens: haptens, epitopes and Factors influencing immunogenicity, Antibodies: Structure, types, production, and functions of immunoglobulins Clonal selection theory. Antigen Antibody reaction: Precipitation, Immunoelectrophoresis, Haem-agglutination, RIA, and ELISA. Cell and organs of immune responses and their functions B &T cells, Factors responsible for immunogenicity, Monoclonal antibodies production and applications.

Unit VII

Histocompatibility

Structure of MHC class I, II &III antigens, and their mode of antigen presentation, MHC restriction, Complement system: Components, Classical and alternate pathways of complement activation, Hypersensitivity, Autoimmunity.

Unit VIII

Vaccines and Immunization

Passive and Active immunization, Types of Vaccines: Inactivated, Attenuated, Recombinant, Peptide and DNA Vaccines and RNA Vaccines.

Suggested Reading:

- Narayanan, P (2000) Essentials of Biophysics, New Age Int. Pub. New Delhi.
- Roy R. N. (1999) A Text Book of Biophysics New Central Book Agency.
- Plummer D.T. An Introduction to Practical Biochemistry 3rd ed., Tata McGraw Hill Education Pvt. Ltd.1998.
- Lehninger, Albert, Cox, Michael M. Nelson, David L. (2017) *Lehninger principles of biochemistry*/New York: W. H. Freeman.
- Voet, D., & Voet, J. G. (2011). Biochemistry. New York: J. Wiley & Sons
- Wilson K. and Walker J., Principles and Techniques of Biochemistry and Molecular Biology, 7th ed., Cambridge University Press, 2010
- Kuby Immunology (2007) 6th ed., Kindt, T.L., Goldsby, R.A. and Osborne, B.A., W.H Freeman and Company (New York)
- William, E. Paul (1989) Fundamental Immunology, 2nd Edition Raven Press, New York.
- William, R. Clark (1991) the Experimental Foundations of Modern Immunology (4th Edition) John Wiley and Sons, New York

CIE (Continuous Internal Evaluation): 10 marks for Test, 10 marks for presentation along with assignment, 05 marks for Class interactions.

BoS Meeting held on 25-06-2025 10

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