ST ALOYSIUS
(DEEMED TO BE UNIVERSITY)
MANGALURU 575003 - INDIA

ESTD : 1880

DEPARTMENT OF BIOCHEMISTRY

Syllabus for

M.Sc. Biochemistry

2024 - 25 onwards

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LIST OF MEMBERS OF THE BOS IN LIFE SCIENCES

Sl no	Members with Address	Designation
1.	Dr Hemachandra hemachandra_amin@staloysius.edu.in 9035961509	Dean, School of Life Sciences
2.	Dr Renita Maria Dsouza renita@staloysius.edu.in 9945923172	Associate Dean, School of Life Sciences
3.	Dr Lyned Dafny Lasrado lyneddafny@staloysius.edu.in 9686021928	Assistant Dean, School of Life Sciences
4.	Dr Jyothi Miranda Department of Botany jyothi@staloysius.edu.in 7022560938	Professor
5.	Dr Asha Abraham Department of Post Graduate Studies & Research in Biotechnology drashaabraham@staloysius.edu.in 9449555802	Associate Professor
6.	Dr Hariprasad Shetty Department of Zoology shettyhariprasad@staloysius.edu.in 9945886947	Associate Professor
7.	Dr S N Raghavendra Department of Post Graduate Studies & Research in Food Science raghavendra_sn@staloysius.edu.in 9945888845	Assistant Professor
8.	Dr Santhosh Wilson Goveas Department of Post Graduate Studies & Research in Biotechnology santhoshgoveas@staloysius.edu.in 9448724682	Assistant Professor
9.	Dr Chandrashekara G Joshi Chairperson Department of Biochemistry Mangalore University	Subject expert in Biochemistry

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10.	Dr Shyama Prasad Sajankila Department of Biotechnology NMAMIT, Nitte, Karkala shyama.sajankila@nitte.edu.in 9611202842	Subject expert in Biotechnology & Microbiology
11.	Dr Smitha Hegde Professor & Deputy Director NUCSER, Nitte University Deralakatte smitha.hegde@nitte.edu.in 9886036077	Subject expert in Biotechnology & Zoology
12.	Dr Archana Prabhat Professor & Coordinator Department of PG Studies in Food Science & Nutrition Alva's College (Autonomous), Moodbidri drarchanaprabhat@gmail.com 9986665759	Subject expert in Food Science
13.	Dr Giby Kuriakose Assistant Professor PG Department of Botany, Sacred Heart College Kochi, Kerala-670106 giby.kuriakose@shcollege.ac.in 7012608038	Subject expert in Botany
14.	Dr Shreelalitha Suvarna Assistant Professor shreelalitha_suvarna@staloysius.edu.in 9964215205	HOD UG & PG Biotechnology
15.	Dr Swarnalatha Assistant Professor swarnalatha@staloysius.edu.in 9900284662	HOD UG & PG Biochemistry
16.	Ms Shilpa B Assistant Professor shilpa_botany@staloysius.edu.in 9535887279	HOD Botany
17.	Dr Daniella Ann L Chyne Assistant Professor daniella_chyne@staloysius.edu.in 9676389466	HOD UG & PG Food Science
18.	Dr Vaishali Rai Assistant Professor vaishali_rai@staloysius.edu.in 9980313361	HOD Microbiology

Programme Outcomes (PO):

PO 1 :	Comprehensive knowledge of fundamental principles and advanced concepts in biochemistry
PO 2 :	Competence to use modern biochemical and molecular techniques to perform experiments to test scientific hypotheses, analyse data, trouble -shoot and draw conclusions from the experimental data in labs.
PO 3 :	Capacity to apply biochemistry knowledge through an interdisciplinary approach to drive advancements in health, disease management, and environmental sustainability.
PO 4 :	Ability to interpret scientific concepts, write research thesis, and effectively present new findings.

Program Specific Outcomes (PSO):

PSO 1:	Fundamental understanding of Biochemistry, structure and function of biological molecule, mechanisms of biological processes and bioenergetics and competence to understand theories and methods that can be used to link Biochemistry to related subjects such as biotechnology, molecular biology, genetics, pharmacology, immunology, genetic engineering and Biostatistics and informatics
PSO 2:	Ability to make quantitative measurements of parameters that are routinely encountered in practical/ experimental biochemistry, to analyse and interpret biochemical data and apply a range of techniques that are commonly used in biomolecule analysis.
PSO 3:	Competence in research and innovation in Biochemistry and in related field of specialization and the ability to critically review scientific literature for development of new theories and testable hypothesis.
PSO 4:	Basic professional skills pertaining to biochemical analysis, and the ability to use these skills in specific areas such as technology development, industrial production and skills that are relevant to biochemistry-related jobs and employment opportunities.
PSO 5:	Skill of articulation of ideas, scientific writing, authentic reporting, scientific conversation and writing, capacity for decision making with regard to scientific progress, personal development and career choice.

PSO 6:	Entrepreneurial. social competence, leadership and organizational skills, the ability to plan and manage projects to achieve objectives, ability to work independently, while still promoting team work and collaboration skills.
PSO 7:	Ability to translate knowledge of biochemistry to address environmental issues including, waste disposal management, safety and security issues, nature conservation, sustainability development etc.

COURSE PATTERN AND SCHEME OF EXAMINATION

Course Code	Title of the Course	Instructions Hours/ week	Duration of Exam (Hours)	Duration of Exam			Credits
				IA	Semester End Exam	Total	
Semester - I							
LS2HPHC500	Fundamentals of Biochemistry	4	2.5	40	60	100	4
LS2HPHC501	Biochemical Techniques	4	2.5	40	60	100	4
LS2HPHP500	Bioquantitation-Practical	8	4	40	60	100	4
LS2HPSC500	Chemical Principles of Biology	3	2.5	40	60	100	3
LS2HPSC501a	Human Physiology	3	2.5	40	60	100	3
LS2HPSC501b	Nutrition and Nutrigenomics						
LS2HPSP500a	Analytical Techniques-Practical	6	4	40	60	100	3
LS2HPSP501b	Experimental Physiology and Nutrition						
	Total					**600**	**21**
Semester - II							
LS2HPHC550	Enzymology	4	2.5	40	60	100	4
LS2HPHC551	Metabolism-I	4	2.5	40	60	100	4
LS2HPHP550	Practical Enzymology-Practical	8	4	40	60	100	4
LS2HPHC552	Genetics	4	2.5	40	60	100	4
LS2HPSC571a	Cell Biology and Cell Culture	3	2.5	40	60	100	3
LS2HPSC571b	Neurobiochemistry						
LS2HPSP572a	Techniques in Cell Culture and Genetics – Practical	6	4	40	60	100	3
LS2HPSP572b	Experimental Neurobiochemistry - Practical						
LS2HPOE589	Health and Diseases	3	2.5	40	60	100	3

	Total					**700**	**25**
Semester - III							
LS2HPHC600	Molecular Biology	4	2.5	40	60	100	4
LS2HPHP600	Techniques in Molecular Biology-Practical	8	2.5	40	60	100	4
LS2HPHC601	Metabolism -II	4	4	40	60	100	4
LS2HPPR636	Research Methodology, Ethics and Biostatistics	3	2.5	40	60	100	3
LS2HPSP621a	Clinical Biochemistry and Clinical Research	3	2.5	40	60	100	3
LS2HPSP621b	Molecular Medicine						
LS2HPSP622a	Metabolism and Clinical Biochemistry-Practical	6	4	40	60	100	3
LS2HPSP622b	Experiments in Molecular Medicine-Practical						
LS2HPOE639	Evolution and Ecology	3	2.5	40	60	100	3
	Total					**700**	**24**
Semester - IV							
LS2HPHC650	Immunology	4	2.5	40	60	100	4
LS2HPPR686	Project	20	4	80	120	100	12
LS2HPSC671a	Genetic Engineering and Bioinformatics	3	2.5	40	60	100	3
LS2HPSC671b	Microbial Biochemistry						
LS2HPSP672a	Practical Bioinformatics and Genetic Engineering-Practical	6	4	40	60	100	3
LS2HPSP672b	Experimental Microbiology-Practical						
	Total					**500**	**22**
	Grand Total					**2500**	**92**

Semester I		
Course Code:	**LS2HPHC500**	
Title of the Course:	**FUNDAMENTALS OF BIOCHEMISTRY**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4	4	56

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Analyze the basic aspects of amino acids, peptides, organization of protein structure, carbohydrates, lipids, and nucleic acids
CO 2:	Evaluate proteins and nucleic acids' structure-function relationship.
CO 3:	Discuss the role of various biomolecules in health and disease.
CO 4:	Interpret the different structures of biomolecules and their implications on different disease states.

COURSE CONTENTS:

Module 1 : Amino acids and Proteins **14 hrs**

Amino acids and Proteins: Classification, Structure and Physicochemical properties; Peptide bond, Peptides of biological importance (Peptide hormones; Neurotransmitter peptide & antioxidant peptide), Chemical synthesis of peptides – Solid phase peptide synthesis; Proteins – Classification, Isolation & Purification of Proteins; Structural organization of Proteins - primary, secondary, tertiary, quaternary, forces stabilizing the structure of proteins, Hemoglobin, Sickle-cell hemoglobin, Myoglobin, and Collagen, Ramachandran plots; Denaturation of proteins. Protein folding – Anfinsen's studies on ribonuclease. Thermodynamics of protein folding: molten globule model, Chemical modification of proteins. (Methylation, Phosphorylation, Glycosylation and lipidation)

Module 2 : Carbohydrates **14 hrs**

Classification, Monosaccharides- classification with structures. Sugar derivatives - alcohols, acids, amino sugars, deoxy sugars, glycosides Oligosaccharides- structure and linkages in lactose, maltose, and sucrose, raffinose series oligosaccharides, Polysaccharides- Homo and heteropolysaccharides, glycosaminoglycans, bacterial cell wall peptidoglycans. Glycoconjugates- structural features and biological functions of Proteoglycans and Glycoproteins (O-linked, N-linked, and GPI-linked). Cyclic structures of monosaccharides; Haworth projection, boat, and chair forms, anomers and

mutarotation

Module 3 : Lipid **12 hrs**

Classification; Structure, Properties and Biological roles of phospholipids and Sphingolipids; Fatty acids and their physicochemical properties; ω-3 and ω-6, Fats and Waxes - Physicochemical properties and characterization of fats and oils; Structure, Properties, and functions of Eicosanoids - Prostaglandins, Prostacyclins, Thromboxanes, Leukotrienes; Chemistry and Properties of Sterols and Steroids – Bile acids and Bile salts; Salient features of Bacterial and Plant lipids.

Module 4 : Nucleic acids **16hrs**

Nomenclature, Structure and properties of pyrimidine and purine bases, nucleosides and nucleotides of nucleic acids, Conformation of nucleotides, Nucleic acids- classes and their functions. Physico-chemical properties DNA and RNA- base composition and primary structure of single- stranded DNA and RNA, Shorthand notation of polynucleotide structure. Chargaff's rules, Structure and function of DNA-Watson-Crick, Forces stabilizing structure of DNA. Denaturation - hypochromic and hyperchromic effect; melting temperature. Renaturation kinetics- effect of salts and complexity (Cot curve). Hybridization and its significance. Different class of RNAs - mRNA, rRNA, tRNA. Primary, secondary, and tertiary structure of tRNA. Determination of primary structure (sequencing) of DNA using Maxam-Gilbert method and limitations. Sanger and Coulson's method, advantages, and drawbacks.

References:

1	Berg, J. M., Tymoczko, J. L., & Gatto, G. J. (2019). *Biochemistry*. New York: W. H. Freeman Publishers.
2	Berg, J. M., Tymoczko, J. L., and Stryer, L. (2018). *Biochemistry: A Short Course*. New York: W. H. Freeman Publishers.
3	Berg, J. M., Tymoczko, J. L., & Stryer, L. (2015). *Biochemistry* (8th ed.). New York: W. H. Freeman Publishers.
4	Garrett, R. H., & Grisham, C. M. (2016). *Biochemistry* (6th ed.). Boston: Cengage Learning.
5	Lehninger, A. L., Nelson, D. L., & Cox M., M.. (2017). *Principles of Biochemistry*. New York: W. H. Freeman Publishers.
6	Mathews, C. K., Van Holde, K. E., Appling, D. R., & Anthony-Cahill, S. J. (2018).

	Biochemistry (4th ed.). New York: Pearson Education.
7	McKee, T., & McKee, J. R. (2020). *Biochemistry: The Molecular Basis of Life*. Oxford: Oxford University Press.
8	Moran, L. A., Horton, H. R., Scrimgeour, K. G., Perry, M. D., & Rawn, J. D. (2012). *Principles of Biochemistry* (5th ed.). Boston: Pearson Education.
9	Nelson, D. L., & Cox M. M. (2020). *Lehninger Principles of Biochemistry*. New York: W. H. Freeman Publishers.
10	Rodwell, V. W., Bender, D., Botham, K. M., Kennelly, P. J., & Weil, P. A. (2020). *Harper's Illustrated Biochemistry*. New York: McGraw-Hill Education Publishers.
11	Voet, D., Voet, J. G., & Pratt, C. W. (2018). *Biochemistry*. Wiley Publications.

Semester I		
Course Code:	**LS2HPHC501**	
Title of the Course:	**BIOCHEMICAL TECHNIQUES**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4	4	56

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Understand the basic instruments used in analytical biochemistry and their applications.
CO 2:	Explain the principles and applications of important techniques used in isolation, purification, and characterization of various biomolecules.
CO 3:	Interpret the various molecular spectrum obtained from different spectral techniques.
CO 4:	Analysis of different biological samples to be subjected to various analytical techniques.

COURSE CONTENTS:

Module 1 : Preliminary Techniques in Biochemistry **14 hrs**

Mechanical and non-mechanical methods of Cell disruption, Cell Fractionation Techniques, Concentration - Ultrafiltration, precipitation by salting out. Principle and Applications of Paper, TLC, column chromatography based on Adsorption, Ion exchange, Gel filtration, Affinity and HPLC- principle, instrumentation, different columns and detectors, their application and FPLC. Gas Liquid Chromatography- instrumentation, detectors.

Module 2 : Physical methods of determining size, shape, and structure of molecules 16 hrs

Electrophoretic Techniques for Biomolecules separation – native Polyacrylamide gel electrophoresis, SDS-PAGE, Agarose gel Electrophoresis, Isoelectric focusing, pulsed field electrophoresis, High voltage electrophoresis, Capillary Electrophoresis, Visualization by staining. Centrifugation: Ultra Centrifugation –Preparative and analytical ultracentrifuge – Instrumentation, principle and application, Svedberg's constant, Sedimentation velocity, Sedimentation equilibrium and Schlieren Optics, Magnetic Resonance spectroscopy– NMR: nature of NMR absorption, chemical shift, spin-spin splitting,13C and 1H NMR

spectra for suitable biomolecules, ESR – Principle and Applications.

Module 3 : Methods to determine biopolymers structure **12 hrs**

Mass spectrometry- theory, instrumentation, ionization, fragmentation, m/e, typical bar graph of mass spectrum, interpretation mass spectra, time of flight, MALDI, GC-MS, and ESI. X-ray Crystallography – Protein crystals, Bragg's law, unit cell, Isomorphous replacement, Fiber pattern of DNA.

Microscopy-Review of light microscopy, application of different stains, phase contrast, fluorescence, Confocal microscopy, scanning and transmission electron microscopy, FACS

Module 4 : Spectroscopic Techniques **14 hrs**

Beer-Lambert's Law, application and Limitation, light absorption and its transmittance, determination and application of Extinction Coefficient, UV-visible spectroscopic techniques- Instrumentation and applications of Turbidimetry (Platelet aggregometer), Flame photometry, Vibration Spectra – IR- Principle, applications and characteristic IR absorptions of some functional groups and Raman spectroscopy– Principle and applications, Principle, instrumentation and applications of Atomic spectroscopy, fluorescence and emission spectroscopy: uses. Polarized Light – plane and circularly polarized light, CD/ORD spectroscopy and its applications.

References:

1	Cooper, A. (2011). *Biophysical Chemistry*. Cambridge: Royal Society of Chemistry (Great Britain).
2	Hammes, G. G., and Hammes-Schiffer, S. (2015). *Physical Chemistry for the Biological Sciences*. New York: Wiley.
3	Jackson, M. B. (2006). *Molecular and Cellular Biophysics*. Cambridge: Cambridge University Press.
4	Marshall, A. G. (1978). *Biophysical Chemistry: Principles, Techniques, and Applications : Solutions Manual*. John Wiley and Sons Canada, Limited.
5	Pattabhi, V., and Gautham, N. (2002). *Biophysics*. Boston-Delhi: Kluwer Academic; Narosa Publications.
6	Pennington, S. R., and Dunn, M. J. (2001). *Proteomics: From Protein Sequence to Function*. Oxford: Oxford University Press.
7	Plummer, D. T. (1978). *An Introduction to Practical Biochemistry*. London; New York: McGraw-Hill.

8	Upadhyay, Upadhyay and Nath. (2010). *Biophysical Chemistry-Principles and Techniques*. Himalaya Publishing House.
9	Wilson, K., & Walker, J. M. (2010). *Principles and Techniques of Biochemistry and Molecular Biology*. Cambridge; New York: Cambridge University Press.

Semester I		
Course Code:	**LS2HPHP500**	
Title of the Course:	**BIOQUANTITATION**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4	8	112

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Apply good laboratory practices and prepare standard solutions
CO 2:	Carry out and analyze quantitative estimation techniques for biomolecules.
CO 3:	Identify, analyze, and quantify various components in biological and food samples.
CO 4:	Perform lipid analysis and interpret experimental data.

COURSE CONTENTS:

1. Quantitative estimation of reducing sugars by DNS Method
2. Estimation of total sugar by Phenol sulphuric acid/Anthrone method
3. Quantitative estimation of Proteins by by Lowry's method
4. Quantitative estimation of proteins by biuret method
5. Quantitative estimation of DNA by Diphenylamine method
6. Quantitative estimation of RNA by Orcinol method
7. Quantitative estimation of ascorbic acid
8. Quantitative estimation of total phenol by using Folin-Ciocalteu reagent
9. Qualitative analysis of some common food adulterants in milk, turmeric, tea powder, honey, Oil, Ghee, and grains
10. Estimation of iron content
11. Estimation of calcium in biological samples.
12. Lipid Analysis
    1. Iodine number
    2. Saponification value
    3. Acid value
    4. Peroxide value

References:

1	Rao, B.S., and Deshpande, V. (2006). *Experimental Biochemistry: A Student Companion*. Anshan Publishers.
2	Thimmaiah, S.K. (2016). *Standard Methods of Biochemical Analysis* (2nd ed.). Kalyani Publishers.

Semester I		
Course Code:	**LS2HPSC500**	
Title of the Course:	**CHEMICAL PRINCIPLES OF BIOLOGY**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	3	42

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Apply the basic concepts of different types of chemical bonds that can be useful to understand the chemical nature of biomolecules.
CO 2:	Analyze the thermodynamic parameters and their variations in cellular homeostasis, and the interactions between biomolecules and water.
CO 3:	Acquire knowledge about the preparation of radioisotopes, and their applications in studying cellular metabolic processes.
CO 4:	Develop problem-solving, critical thinking, and reasoning skills in the chemical aspects of biochemistry.

COURSE CONTENTS:

Module 1: Bioorganic Chemistry **16 hrs**

Atoms and atomic orbitals, molecular orbital (hydrogen molecule), Covalent bond; coordinate bond; Isomerism- structural isomerism, stereoisomerism, geometric isomerism. Optical isomerism: optical activity, chirality, enantiomers, diastereomers, meso-compound, Fischer projection, threo-erythro notation, DL, RS configuration (in sugars and amino acids).

Types of organic reactions- substitution, addition, elimination, rearrangement, condensation, and polymerization.

Heterocyclic Compounds – Numbering of the ring, properties, and biological occurrence of furan, pyran, indole, thiazole, pteridine, isoalloxazine, pyrrole, quinone, purine, and pyrimidine rings.

Free radicals in biological systems: Oxygen as a free radical in the auto-oxidation of fats. and antioxidants

Module 2 : Thermodynamics and water **12 hrs**

Open, closed, and isolated system, Laws of thermodynamics- I law, II law, and III law, applications of thermodynamic laws in understanding energies in the living system.

Chemical potential and equilibrium constant.

Oxidation and redox reactions- characteristics, half-reactions, spontaneous and non-spontaneous redox reactions.

Water-Physical properties and structure of water, hydrogen bonding and hydrophobic interactions. Ionization of water, pH scale, Acids and bases, Henderson- Hasselbalch equation, buffers, buffer capacity, ionic strength, buffer solutions and their action. Importance of buffers in biological systems (cytosol and blood).

Module 3 : Radioisotopes in Biology **14 hrs**

Heavy isotopes and radioisotopes, Nature of radioactivity, Types of Radiation, properties of α, β, γ-rays, Units of radioactivity, (RAD, REM, CURIE, and BECQUEREL) Nature of radiation sources, Techniques used to measure radioactivity– GM counter and scintillation counter, solid and liquid scintillation, autoradiography. isotopes commonly used in biochemical studies- 3H, 14C, 32P, 131I, 35S, 60Co their biological application-invivo and invitro labeling techniques, quenching, concept of half-life, decay constant, Specific activity, Cerenkov radiation. Biological hazards of radiation and safety measures in handling radioisotopes

References:

1	Bahl, B. S., & Bahl, A. (2019). *A Textbook of Organic Chemistry*. S. Chand Publishing.
2	Bruice, P.Y. (2016). *Organic Chemistry*. Pearson Publisher.
3	Clayden, J., Greeves, N. & Warren S. (2012). *Organic Chemistry*. Oxford University Press.
4	Eliel, E. L., & Wilen, S. H. (1994). *Stereochemistry of Organic Compounds*. John Wiley and Sons.
5	Finar, I. L. (1956). *Organic Chemistry, Volume 2: Stereochemistry and the Chemistry Natural Products*. Pearson Education India.
6	Karty, J. (2018). *Organic Chemistry: Principles and Mechanisms*. W.W. Norton & Company.
7	McMurry, J. (2016). *Organic Chemistry*. Cengage Learning.
8	Ouellette, R.J., & Rawn, R.D. (2015). *Principles of Organic Chemistry*. Cengage Learning Publishers.
9	Roberts, J. D., & Caserio, M. C. (1977). *Basic Principles of Organic Chemistry*. W.A.

	Benjamin, Inc.
10	Van Holde, K. E., Johnson, W. C., & Shing Ho, P. (2005). *Principles of Physical Biochemistry*. Pearson Publishers.

Semester I		
Course Code:	**LS2HPSC501a**	
Title of the Course:	**HUMAN PHYSIOLOGY**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	3	42

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Analyze the functions of important physiological systems including the cardio-respiratory, reproductive renal, and metabolic systems
CO 2:	Explain the integration of the different endocrine organs and their hormones in maintaining homeostasis
CO 3:	Discuss nerve physiology and understand the mechanism of nerve impulse transmission
CO 4:	Understand the physiology of muscular system, role of various muscle proteins in contraction and relaxation of muscles.

COURSE CONTENTS:

Module 1 : Introduction to the Human body, Organs, and organ systems 16 hrs

Blood: Composition of Blood, Plasma; composition and function, Blood cells; Hematopoiesis, RBC-erythropoiesis, life cycle and function-types and functions, platelets and their functions. Blood coagulation (hemostasis and thrombosis), anticoagulants, and fibrinolysis. Buffer systems of plasma, total and differential blood count.

Body fluids-CSF and Lymph- composition and functions.

Cardiac Physiology: Cardiac conduction system, Cardiac cycle, Cardiac Output, Blood pressure, ECG.

Respiratory System – Lung structure and functions. Gas exchange, oxygen binding by hemoglobin, factors affecting oxygenation.

Excretory System; Kidney– Ultrastructure of the nephron, mechanism of glomerular filtration and formation of urine. Role of kidney in acid-base balance. Kidney function test.

Hepatobiliary System – Anatomy of the liver, blood supply, cells – hepatocytes, endothelial cells and Kupffer cells. Secretory and excretory function-formation of bile, composition, Secretion of bile and enterohepatic circulation, Liver function test.

Gall bladder and its functions

Pancreas- Anatomy, its exocrine and endocrine activities. Target tissues and biological functions of insulin and glucagon.

Gastrointestinal System– Physiology and biochemistry of digestion and absorption of food. Mechanism of HCl production in the stomach, Gastro-intestinal hormones and their role.

Module 2 : Endocrine system- Endocrine organs in man 12 hrs

The target cell concept, major groups of hormones- lipophilic and hydrophilic hormones - their general features.

Structure, anatomy and control of hypothalamus - hormones produced and their role.

Hypothalamic- hypophysiotropic hormones- biological role. The hypothalamic-Pituitary axes with major feedback loops.

Adenohypophysis- tropic hormones, lipotropin, endorphins and enkephalins-their biological action. Neurohypophysial hormones- their biological action. ANF (atrial natriuretic factor).

Thyroid gland, thymus, and adrenal gland- hormones and their biological functions. renal hormones: Functions; Renin-angiotensin system. Pineal gland-melatonin, its role in circadian rhythm and aging.

Hormones of Gonads: Anatomy of testes and ovaries, their endocrine functions, Hormone synthesis, storage, secretion and regulation, their physiological and biochemical aspects - hormonal control of puberty, hormonal regulation of menstrual cycle, Oral contraceptives.

Module 3: Nerve and Muscle Physiology 14 hrs

Structure of neuron and synapse- excitability- action potential conduction of nerve impulse- synaptic transmission- neurotransmitter systems, Glial cells: Structure and function of glial cells, Different types of glial cells: astrocytes, oligodendrocytes, and Schwann cells, Types of astrocytes – type I and II astrocytes, fibrous and protoplasmic astrocytes, Importance of astrocytes in glutamate metabolism and blood-brain barrier.

Muscle physiology- Structure and organization of muscle cells, types of muscles -striated muscle, cardiac and smooth muscle. Molecular organization of contractile systems (actin, myosin, tropomyosin, troponin, α-actinin, nebulin, dystrophin, Molecular mechanism of contraction and relaxation of muscle - Role of calcium, troponin C, calmodulin, and nitric oxide.

References:

1	Devlin, T. M. (Ed.). (2022). *Textbook of Biochemistry: With Clinical Correlations*.

2	Guyton, A., and Hall, J. (2020). *Textbook of Medical Physiology*.
3	Jenkins, G., and Tortora, G. J. (2017). *Anatomy and Physiology*. John Wiley and Son.
4	Johnson, M. L., & McCance, K. L. (2019). *Human Anatomy & Physiology* (10th ed.). Boston: Pearson.
5	Khurana, I., Khurana, A., and Kowlgi, N. G. (2019). *Textbook of Medical Physiology*_-E-book. Elsevier Health Sciences.
6	Marieb, E. N., & Hoehn, K. (2018). *Human Anatomy & Physiology* (11th ed.). Boston: Pearson.
7	Murray, R. K., Granner, D. K., Mayes, P. A., and Rodwell, V. W. (2023). *Harper's Illustrated Biochemistry*. McGraw-Hill.
8	Sembulingam, K., and Sembulingam, P. (2012). *Essentials of Medical Physiology*. JP Medical Ltd.
9	Silverthorn, D. U. (2018). *Human Physiology: An Integrated Approach* (8th ed.). Boston: Pearson.
10	Vasudevan, D. M., Sreekumari, S., and Vaidyanathan, K. (2016). *Textbook of Biochemistry for Medical Students*. JP Medical Ltd.

Semester I		
Course Code:	**LS2HPSC501b**	
Title of the Course:	**NUTRITION AND NUTRIGENOMICS**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	3	42

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Understand the fundamental concepts of food biochemistry
CO 2:	Evaluate the role of nutraceuticals in promoting health and managing various diseases
CO 3:	Analyse the principles of nutrigenomics and nutrigenetics
CO 4:	Create an integrated understanding of the complex interplay between genes, nutrients, and epigenetics

COURSE CONTENTS:

Module 1: Basic food biochemistry **14 hrs**

Basic concept of food, nutrients, nutrition

Classification of food constituents; Carbohydrates- sources, daily requirements, functions. chemical reactions, functional properties of sugars and polysaccharides, modified starch, dietary fibre.

Lipids- estimation and physiochemical properties of lipids in food, rancidity, hydrogenation and winterization, vegetable and animal fat, margarine, lad, and butters.

Protein-classification and properties, egg proteins, milk proteins, meat proteins, oil seed proteins and cereal proteins.

Vitamins and minerals- role, effect of various processing treatments, fortification.

Role of water in food, water activity and shelf life of food. significance of natural pigments in food- chlorophylls, carotenoids, anthocyanins, flavonoids and tannins, natural antioxidants, Browning reactions in foods.

Module 2: Nutraceuticals **14 hrs**

Introduction to nutraceuticals: definitions, synonymous terms, basis of claims for a compound as a nutraceutical, regulatory issues for nutraceuticals including CODEX. Nutraceuticals for cardiovascular diseases, cancer, diabetes, cholesterol management, obesity, joint pain, immune enhancement, age-related macular degeneration, endurance

performance and mood disorders.

Manufacturing aspects of selected nutraceuticals such as lycopene, isoflavonoids, prebiotics and probiotics, glucosamine, phytosterols.

Module 3: Nutrigenomics **14hrs**

Definition, Nutrigenetics: - response of gene Variants on nutrients difference between nutrigenetics and nutrigenomics. Gene variants, SNPs, disease risk modified by nutrients

Effects of nutrients on gene expression: Interaction between genes and nutrients. Food intake and the risk of obesity, and metabolic syndrome. PPARs and nutrient regulation of gene expression, effect of phytochemicals on gene expression. Example EGCG and Her-2/neu receptor

Epigenetics and nutrients; Example Alcohol addiction

Effects of gene variants on nutrient metabolism. Example: LPH gene polymorphism and Lactose intolerance, Glutathione peroxidase polymorphism, selenium and risk of cancer. Methylenetetrahydrofolate gene polymorphism on folate metabolism and homocysteine levels in heart diseases. Apolipoprotein E variants, lipid diet and risk of heart diseases. Effect of food on health and health on food.

References:

1	Belitz, H.-D., Grosch, W., & Schieberle, P. (2009). *Food Chemistry*. Springer.
2	Boye, J. I., & Arcand, Y. (Eds.). (2014). *Nutraceutical and Functional Food Processing Technology*. Wiley-Blackwell.
3	Chilton, F. H., & Tucker, L. (2009). *The Gene Smart Diet*. Wiley.
4	Fennema, O. R. (2019). *Food Chemistry*. CRC Press.
5	Ferguson, L. R. (Ed.). (2013). *Nutrigenomics and Nutrigenetics in Functional Foods and Personalized Nutrition*. CRC Press.
6	Gupta, R. C. (Ed.). (2016). *Nutraceuticals: Efficacy, Safety and Toxicity*. Elsevier.
7	Ho, E., Domann, F., & Williams, D. (Eds.). (2015). *Epigenetics, Nutrition and Health*. CRC Press.
8	Kaput, J., & Rodriguez, R. L. (2006). *Nutritional Genomics: Discovering the Path to Personalized Nutrition*. Wiley.
9	Nielsen, S. S. (2010). *Food Analysis*. Springer.
10	Simpson, B. K. (2012). *Food Biochemistry and Food Processing*. Wiley-Blackwell.

Semester I		
Course Code:	**ANALYTICAL TECHNIQUES**	
Title of the Course:	**LS2HPSP500a**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	6	84

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Apply the importance of chromatographic techniques in biomolecules separation
CO 2:	Perform different types of electrophoretic techniques used to separate proteins and analyse the results.
CO 3:	Design an analytical workflow of various extraction procedures used to extract different molecules from biological samples.
CO 4:	Analyze the applications of various techniques in Biochemistry

COURSE CONTENTS:

1. Applications of Beer's law- Determination of optimum absorption wavelength for any dye and verification of Beer-Lambert law.
2. Determination of pKa of amino acids.
3. Separation of amino acids by
   i. Circular
   ii. 2D-paper chromatography
4. Descending paper chromatography of sugars/amino acids
5. TLC Sheet preparation and Separation of lipids
6. Flame Photometry
7. Paper Electrophoresis.
8. Column chromatography for plant pigment separation
9. Quantitative estimation of amino acid by Formal titration
10. Extraction of casein from milk by isoelectric precipitation
11. Extraction of cholesterol from egg yolk
12. Extraction of phospholipids from egg yolk

References:

1	Jayaraman, J. (2011). *Laboratory Manual in Biochemistry*. New Age Publishers.
2	Plummer, D. T. (2017). *An Introduction to Practical Biochemistry* (3rd ed.). McGraw Hill Education (India) Private Ltd.
3	Tiwari, A. (2015). *Practical Biochemistry: A Student Companion*. Lambert Academic Publishing.

Semester I		
Course Code:	**LS2HPSP501b**	
Title of the Course:	**EXPERIMENTAL PHYSIOLOGY AND NUTRITION**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	6	84

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Analyze the importance of blood pressure maintenance and working of heart.
CO 2:	Understand the significance of quantitation of serum triglycerides and blood glucose levels.
CO 3:	Perform routine nutritional analysis of food and its additives.
CO 4:	Evaluate the fiber content of various food samples.

COURSE CONTENTS:

1. Determination of the ABO and Rh blood groups
2. Qualitative analysis of blood smear
3. Determination of bleeding and clotting time.
4. Determination of bleeding and clotting time.
5. Estimation of blood glucose by glucose oxidase method
6. Estimation of serum triglyceride.
7. Body mass index (BMI) calculation
8. Qualitative analysis of carbohydrates, proteins, and lipids in food samples.
9. Micronutrient analysis (vitamins and minerals)
10. Analysis of the fiber content in various food samples.
11. Estimation of starch from wheat flour
12. Biochemical testing of food additives

References:

1	Pattabiraman, T. N. (2015). *Laboratory Manual in Biochemistry* (4th ed.). All India Publishers & Distributors.
2	Plummer, D. T. (2017). *An Introduction to Practical Biochemistry* (3rd ed.). McGraw Hill Education (India) Private Ltd.
3	Sadasivam, S., & Manickam, A. (2022). *Biochemical Methods* (4th ed.). New Age International Publishers.

Semester II		
Course Code:	**LS2HPHC550**	
Title of the Course:	**ENZYMOLOGY**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4	4	56

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Understand the enzymes into various classes by analyzing the general properties
CO 2:	Apply enzyme kinetics equations in various scenarios
CO 3:	Interpret the catalytic mechanisms of most well-characterized enzymes
CO 4:	Evaluate the mechanisms of enzyme regulation and justify their importance in biological systems and apply knowledge of enzymes in diagnosis, monitoring, and therapy.

COURSE CONTENTS:

Module 1 : Basic concepts of Enzymology 7hrs

History, Nomenclature and IUB classification of enzymes, significance of numbering system. General characteristics of enzymes, nature of enzyme, enzyme specificity and enzyme active site. Holoenzyme, apoenzyme, cofactors, isoenzymes, multifunctional enzymes, metalloenzymes, metal activated enzymes, coenzymes, monomeric enzymes, oligomeric enzymes and multi-enzyme complexes, - with suitable example. Factors affecting enzyme activity- enzyme concentration, substrate concentration, pH, temperature, activators and inhibitors. Significance of energy of activation.

Module 2 : Purification, Measurement, and expression of enzyme activity 7 hrs

Units of enzyme activity- definition of IU, Katal and specific activity, Enzyme localization, isolation, purification and characterization of enzymes. Criteria of purity of enzymes. Enzyme assay methods- end point and kinetic assay, continuous assay. Coupled assay and its application in quantification of enzyme assays.

Module 3 : Enzymes Kinetics 14 hrs

Rate of a reaction, order, and molecularity. Derivation of Michaelis Menten equation for unisubstrate reactions- Equilibrium and steady state approach. Significance of Vmax, Km,

Turnover number (Kcat/Km). Linear transformation of Michaelis Menten equation – Lineweaver Burk plot, Eadie-Hofstee, Haynes-Wolf and Cornish-Bowden plot.

Bi- substrate Reactions – Cleland's notation with examples for ordered, Ping-Pong, Theorell-Chance and random mechanism, their general rate equations.

Fast Reaction kinetics –Characteristics and applications, Methods: Stopped flow, temperature jump.

Active site structure determination- Methods of determining active site structure –isolation of ES complex, affinity labelling and chemical modification studies.

Inhibition kinetics –Competitive, non-competitive, uncompetitive, mixed and product inhibition. Irreversible inhibition – suicide inhibition and its significance, transition state analogs- their application. Determination of Ki and its significance. Primary and secondary plots in enzyme kinetics. Enzyme immobilization techniques and their applications.

Module 4 : Nature of Enzyme Catalysis 10 hrs

Collision theory and transition state theory, Mechanism of catalysis-acid base catalysis, covalent catalysis, nucleophilic and electrophilic catalysis, proximity and orientation and metal ion catalysis

Mechanisms of Action of Specific Enzymes – Serine proteases- Classes, Mechanism of Chymotrypsin, Lysozyme, RNA as enzyme.

Coenzyme action of NAD^+, FAD, PLP, Folic acid

Module 5: Protein- ligand binding, Metabolic Regulation & Enzyme Applications 18 hrs

Protein- ligand binding – Binding of ligands to macromolecules – Hill and Scatchard plot, cooperativity, positive and negative cooperativity. Oxygen binding to hemoglobin. Homotropic and heterotopic effectors, aspartyl transcarboxylase as an allosteric enzyme. Sigmoidal kinetics and their physiological significance, Symmetric (MWC) and sequential models (KNF) for action of allosteric enzymes and their significance.

Metabolic Regulation of Enzyme Activity – General mechanisms- Zymogen activation (in digestive enzymes- chymotrypsin), reversible and irreversible covalent modifications of enzymes with suitable examples. Designer enzymes- abzymes, synzymes. Enzymes as therapeutic agents-Collagenase, Uricase, streptokinase, L-asparaginase. Application of enzymes in industry- Industrial application of rennin, lipases, lactases, invertase, pectinases, papain.

Enzyme application in clinical biochemistry- Aminotransferases, Creatine Kinase, α-amylase, Glucose phosphate dehydrogenase, Cholinesterase; Isoenzymes of lactate dehydrogenase, alkaline phosphatase in diagnosis and monitoring of disorders.	
References:	
1	Berg, J. M., Stryer, L., & Gatto, G. (2015). *Biochemistry* (8th ed.). W.H. Freeman and Co.
2	Cook, P. F., & Cleland, W. W. (2007). *Enzyme Kinetics and Mechanism*. Garland Science.
3	Devasana (T). (2010). *Enzymology*. Oxford University Press.
4	Eisenthal, R., & Danson, M. J. (Eds.). (2002). *Enzyme Assays: A Practical Approach* (Vol. 257). Practical Approach (Paperback).
5	Nelson, D. L., & Cox, M. M. (2021). *Lehninger Principles of Biochemistry* (8th ed.). W.H. Freeman and Co.
6	Palmer, T., & Bonner, P. L. (2007). *Enzymes: Biochemistry, Biotechnology, Clinical Chemistry*. Elsevier.
7	Pandey, A., Webb, C., Soccol, C. R., & Larroche, C. (Eds.). (2006). *Enzyme Technology*. Springer Science and Business Media.
8	Price, N. C., & Stevens, L. (2003). *Fundamentals of Enzymology* (3rd ed.). Oxford University Press.
9	Shanmugam, S. (2009). *Enzyme Technology*. IK International Pvt Ltd.
10	Taylor, K. B. (2002). *Enzyme Kinetics and Mechanisms*. Springer Science and Business Media.
11	Voet, D., & Voet, J. G. (2011). *Biochemistry* (Adapted ed.). Wiley, India.

Semester II		
Course Code:	**LS2HPHC551**	
Title of the Course:	**METABOLISM -I**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4	4	56

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Understand the fundamental concepts of metabolism and analyze the regulatory mechanisms involved in key metabolic pathways
CO 2:	Evaluate the organization and function of the mitochondrial electron transport chain, focusing on oxidative phosphorylation models
CO 3:	Create an integrated understanding of lipid metabolism, including degradation, biosynthesis, and physiological significance
CO 4:	Apply knowledge of metabolic disorders to assess etiology, pathogenesis, and management strategies in clinical cases

COURSE CONTENTS:

Module 1: Carbohydrate metabolism **14 hrs**

Introduction to Catabolism, anabolism, catabolic, anabolic and amphibolic pathways. Carbohydrates – Glycolysis, energetics and regulation. Pathways of utilization of pyruvate – lactate and ethanol fermentation, Pasteur's effect, gluconeogenesis and regulation, Cori cycle and its significance. Citric acid cycle-reactions, regulation, and role as amphibolic pathway. Anaplerotic reactions, glyoxylate cycle and significance. HMP shunt pathway, its physiological significance. Biosynthesis of sucrose, and starch. Glycogenesis and Glycogenolysis- their regulation. Entry of reducing equivalents for oxidation into mitochondria- malate–aspartate shuttle and glycerol phosphate shuttle.

Module 2: Mitochondrial electron transport chain **14 hrs**

Organization of respiratory chain complexes, structure and function of the components – Fe-S proteins, cytochromes, sequence of electron carriers based on redox potentials, Q cycle, P/O ratio, oxidative phosphorylation, uncouplers and inhibitors of oxidative phosphorylation. Models to explain oxidative phosphorylation-Mitchell's hypothesis and

proofs and drawbacks. proton motive force, structure of ATP synthase complex, binding change mechanism and mechanism of ATP synthesis

Module 3: Lipid Metabolism **16 hrs**

Degradation of triacylglycerols and phospholipids – lipases, hormone-sensitive lipase, phospholipases. Transport of fatty acids into mitochondria, Fatty acid degradation- β-oxidation of even chain fatty acids and as a source of metabolic water and ATP yield. β-oxidation of odd chain and unsaturated fatty acids, α and ω-oxidation.

Biosynthesis of saturated and unsaturated FA and chain elongation reactions. Desaturation Fatty acid synthase, Regulation of fatty acid biosynthesis and oxidation. Biosynthesis of triglycerides. Metabolism of ketone bodies-synthesis and degradation. Pathways in plants and animals -conversion of linoleate to arachidonate (scheme only).

Cholesterol Biosynthesis**,** Degradation, excretion and regulation. Metabolism of circulating lipids – Chylomicrons, HDL, LDL, VLDL and free fatty acids. Reverse cholesterol transport by HDL.

Phospholipid Biosynthesis – *Denovo* pathway and interconversion, biosynthesis of sphingolipids, ether lipids and glycolipids. Degradation and biosynthesis of gangliosides and cerebrosides. Biosynthesis of prostaglandins, thromboxane and leukotrienes.

Module 4: Metabolic Disorders **12 hrs**

Disorders of carbohydrate metabolism – Diabetes mellitus, classification, etiology and its management, laboratory investigations – GTT, Hb analysis (glycohemoglobin)**.** Inborn errors of carbohydrate metabolism – glycogen storage diseases, galactosemia, lactose intolerance, pentosuria.

Disorders of Lipid Metabolism: Hyperlipidemia, Familial Hypercholesterolemia (FH) Tangier Disease. Cardiovascular Disorders – Major Cardiovascular diseases – Atherosclerosis – risk factors, pathogenesis, Diagnosis, and prognosis.

References:

1	Baynes, J. W., & Dominic Zak, M. H. (2019). Medical Biochemistry . Elsevier.
2	Berg, J. M., Tymoczko, J. L., & Gatto Jr., G. J. (2019). Biochemistry . W. H. Freeman.
3	Buchanan, B. B., Gruissem, W., & Jones, R. L. (2015). Biochemistry and Molecular Biology of Plants . Wiley-Blackwell.

4	Ferrier, D. R. (2017). Lippincott's Illustrated Reviews: Biochemistry . Lippincott Williams and Wilkins.
5	Gropper, S. S., Smith, J. L., & Carr, T. P. (2016). Advanced Nutrition and Human Metabolism . Cengage Learning.
6	Michal, G., & Schomburg, D. (2012). Biochemical Pathways: An Atlas of Biochemistry and Molecular Biology . Wiley-Blackwell.
7	Nelson, D. L., & Cox, M. M. (2020). Lehninger Principles of Biochemistry . W. H. Freeman.
8	Rodwell, V. W., Bender, D., Botham, K. M., Kennelly, P. J., & Weil, P. A. (2020). Harper's Illustrated Biochemistry . McGraw-Hill Education.
9	Vasudevan, D. M., Sreekumari, S., & Vaidyanathan, K. (2020). Textbook of Biochemistry for Medical Students . Jaypee Brothers Medical Publishers.
10	Voet, D., Voet, J. G., & Pratt, C. W. (2016). Biochemistry . Wiley Publishers.

Semester II		
Course Code:	**LS2HPHP550**	
Title of the Course:	**PRACTICAL ENZYMOLOGY**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4	**8**	**112**

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Analyze enzyme kinetics and its applications
CO 2:	Demonstrate practical applications of uni-substrate and bi-substrate assays and an overall understanding of using various biochemical kinetic reactions for isolating and purifying specific analytes
CO 3:	Isolate and purify enzymes using downstream processing
CO 4:	Conduct a quantitative assay of clinically important enzymes

COURSE CONTENTS:

1. Enzyme assay and Kinetic studies of enzyme Salivary amylase-
   - specific activity
2. Determination of effect of pH and temperature on salivary amylase activity.
3. Study of effect of substrate concentration on enzyme activity..
4. Assay of invertase from Calatropis/ Yeast
5. Assay of protease from papaya,
6. Assay of acid/alkaline phosphatase
7. Bisubstrate enzyme assay (minimum one) (kinetic assay)
   a. SGOT
   b. SGPT
   c. LDH
8. Isolation of enzymes from biological sources.
9. Inoculum preparation and scale up of Inoculum
10. Extraction of Enzyme
11. Downstream processing by
    a. ammonium sulfate precipitation
    b. Ion exchange chromatography
    c. Native PAGE

d. SDS-PAGE and molecular weight determination	
12. Fold purity calculation	
References:	
1	Bisswanger, H. (2011). Practical Enzymology (2nd ed.). Wiley-VCH. DOI: 10.1002/9783527640090.
2	Fersht, A. (2017). Structure and Mechanism in Protein Science: A Guide to Enzyme Catalysis and Protein Folding . W.H. Freeman and Company.
3	Gupta, S. K. (2018). Enzymology Lab Manual . Rastogi Publications.
4	Jones, B. T., & Thomas, A. (2009). "Effect of Substrate Concentration on Enzyme Activity." Biochemistry Education, 37 (4), 215-219. DOI: 10.1002/bmb.222.
5	Mehrotra, S., & Mehrotra, R. (2015). "Study of Protease from Papaya: Methods and Kinetics." Analytical Biochemistry, 483 (5), 126-132. DOI: 10.1016/j.ab.2015.08.003.
6	Palmer, T., & Bonner, P. (2007). Enzymes: Biochemistry, Biotechnology, Clinical Chemistry (2nd ed.). Woodhead Publishing.
7	Pandey, A., Soccol, C. R., & Mitchell, D. A. (2010). "Ammonium Sulfate Precipitation and Chromatographic Purification of Enzymes." Methods in Enzymology, 483, 215-234. DOI: 10.1016/S0076-6879(10)83012-5.
8	Price, N. C., & Stevens, L. (1999). Fundamentals of Enzymology: Cell and Molecular Biology of Catalytic Proteins (3rd ed.). Oxford University Press.
9	Segel, I. H. (1997). Biochemical Calculations: How to Solve Mathematical Problems in General Biochemistry (2nd ed.). Wiley.
10	Smith, M. R., & Walker, G. W. (2012). "Determination of Specific Activity and Kinetic Parameters of Enzymes." Journal of Biological Chemistry, 287 (12), 845-853. DOI: 10.1074/jbc.m111.335778.
11	Wilson, K., & Walker, J. (2018). Principles and Techniques of Biochemistry and Molecular Biology (8th ed.). Cambridge University Press. DOI: 10.1017/9781108627146.

Semester II		
Course Code:	**LS2HPHC552**	
Title of the Course:	**GENETICS**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4	**4**	**56**

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Describe basic concepts of classical Genetics, Mendelian inheritance, extrachromosomal inheritance, sex-linked inheritance and population genetics
CO 2:	Interpret the concept of gene, genome organization, linkage and genetic mapping and recombination.
CO 3:	Comparing and contrasting different DNA damage and repair mechanisms and relating variations in chromosome structure and number to phenotypic variation.
CO 4:	Examine the relationship between cancer and genetics

COURSE CONTENTS:

Module 1 : Model Systems and Mechanisms in Genetics **14 hrs**

Models for genetic studies: Rat/Mice, Drosophila, yeast, *Arabidopsis thaliana*, Zebra fish and *Escherichia coli*.

Classical genetics – Mendelian principles: dominance, segregation, independent assortment, deviation from Mendelian inheritance.

Extensions of Mendelian principles - incomplete dominance, codominance, epistasis, simple gene interaction (e.g. Comb shape in chickens), polygenic inheritance, penetrance and expressivity, sex limited and sex influenced characters.

Extra chromosomal inheritance: Inheritance of mitochondria (e.g. Male sterility in plants), and chloroplast genes (e.g. Variegation in four O'clock plant), maternal inheritance (e.g. Shell Coiling in snails).

Population Genetics: Speciation (allopatric and sympatric). Hardy Weinberg genetic equilibrium, random genetic drift, coevolution, convergent evolution, Pedigree analysis.

Module 2 : Genome Organization and Genetic Recombination **16 hrs**

Genome size and evolutionary complexity, C-value paradox

Structure of bacterial chromosome, structure of eukaryotic chromosome, nucleosome organization, arrangement of chromatin fibers in a chromosome. Polytene chromosomes.

Concept of gene: Allele, multiple alleles, pseudo allele, complementation tests. Transposons and their types

Gene Linkage and Chromosome – Linkage and crossing over, sex linkage, recombination of genes in a chromosome.

Gene mapping methods: map unit, Linkage maps, three-point test cross, tetrad analysis.

Recombination-types – homologous, site-specific. *E. coli* rec system. Holliday model of recombination.

Microbial genetics: Methods of genetic transfers – transformation, conjugation, transduction plaque formation and lytic cycle.

Module 3 : Mutagenesis, DNA Repair, and Genetic Implications 14 hrs

Mutation– Types, causes and detection, mutant types – lethal, conditional, biochemical, loss of function, gain of function, germinal verses somatic mutants. Chemical mutagens- affecting replicating and non-replicating DNA, radiation induced mutation, reverse mutations and suppressor mutations – intergenic and intragenic suppression, reversion as a means of detecting mutagens – Ames's test.

Repair Mechanism – photoreactivation, excision repair (nucleotide excision repair, base excision repair, and mismatch repair), repair of alkylation, E. coli- rec system (SOS repair).

Chromosomal abnormalities: Deletion, duplication, inversion, translocation, ploidy and their genetic implications. Human genetics: lod score for linkage testing, karyotypes, Genetic counseling.

Module 4 : Cancer genetics 12hrs

Cancer and the cell cycle, types of cancer, differences between normal and cancer cells- Warburg effect, contact inhibition, loss of cellular affinity, metastasis, alterations in cytoskeleton, cell surface, decreased serum requirements and secretion of growth factors. Mechanism of transformation of cells. Cellular oncogenes - Oncogene families: Protein kinases (Src, abl), GTP binding proteins (H-ras, K-ras), growth factors (sis), nuclear proteins (myc, fos), hormone receptors (erbA) and unclassified. Proto-oncogenes- activation to oncogenes, and Retroviral oncogenes (v-src, v-erbA or v-erbB, v-mos). Tumor suppressor genes-their role in cell cycle control and tumor development (RB, p53, p16, p21, PTEN), Telomerases and their role in cancer. Therapeutic interventions of uncontrolled cell growth.

References:

1	Dale, J. W., & Park, S. F. (2013). Molecular Genetics of Bacteria . John Wiley and

	Sons.
2	Hartl, D. L. (2021). Essential Genetics: A Genomics Perspective (7th ed.). Jones and Bartlett Learning.
3	Hartl, D. L., & Jones, E. (2021). Genetics: Analysis Of Genes and Genomes (11th ed.). Jones and Bartlett.
4	Klug, W. S., Cummings, M. R., Spencer, C. A., & Palladino, M. A. (2011). Concepts of Genetics (10th ed.). Pearson Education.
5	Krebs, J. E., Goldstein, E. S., & Kilpatrick, S. T. (2012). Lewin's Essential GENES (Biological Science) (3rd ed.). Jones and Bartlett Learning.
6	Krebs, J. E., Goldstein, E. S., & Kilpatrick, S. T. (2017). Lewin's GENES XII (12th ed.). Jones and Bartlett Learning.
7	Miesfeld, R. L. (2002). Applied Molecular Genetics (1st ed.). Wiley-Liss Inc.
8	Pierce, B. A. (2013). Genetics: A Conceptual Approach (5th ed.). W. H. Freeman.
9	Snustad, P. D., & Simmons, M. J. (2022). Principles of Genetics (6th ed.). Wiley.
10	Snyder, L., Peters, J. E., Henkin, T. M., & Champness, W. (2013). Molecular Genetics of Bacteria (5th ed.). ASM Press.
11	Watson, J. D. (2003). Molecular Biology of the Gene (5th ed.). Cold Spring Harbor Laboratory Press.

Semester II		
Course Code:	**LS2HPSC571a**	
Title of the Course:	**CELL BIOLOGY AND CELL CULTURE**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	**3**	**42**

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Understand the structural organization and function of intracellular organelles and evaluate membrane dynamics and transport mechanisms in cells.
CO 2:	Develop comprehensive understanding of cell signaling
CO 3:	Explain the concept of cellular communication and its principles.
CO 4:	Analyze the techniques and applications of animal cell culture and plant cell culture

COURSE CONTENTS:

Module 1: Membrane Biology, Intracellular Organization & Transport mechanism 14 hrs

Bio membranes - Composition and Architecture of membrane: structural lipids in membranes, membrane bound proteins - structure, properties, and function, Lipid raft. Membrane fluidity, asymmetry, Membrane Dynamics: lipid movements, flippase, floppase, scramblase. Study of membranes -FRAP (Fluorescence Recovery After Photobleaching), FRET (Fluorescence Resonance Energy Transfer)

Structural organization and function of intracellular organelles: Cell wall, nucleus, mitochondria, Golgi bodies, lysosomes, Endoplasmic reticulum, peroxisomes, plastids, vacuoles, chloroplast, structure and function of cytoskeleton.

Membrane Transport – simple diffusion, facilitated diffusion. Mechanisms of endocytosis, receptor mediated endocytosis, and exocytosis, Ion channels, aquaporin channel, GLUT (Glucose Transporters). Active transport systems, (Na^+ K^+ ATPase, secondary active transport (Na^+ glucose transporters).

Module 2: Cell signaling and cell communication: 14 hrs

Cell signaling- Overview of cell signaling, Endocrine, paracrine, merocrine, juxtracrine, autocrine signaling, second messengers and components of cell signaling: PI3K, PLC,

IP3, DAG. G-protein coupled receptors (cAMP pathway). Signaling by receptor and non-receptor Kinases: receptor tyrosine kinases (EGFR pathway), cytokine receptors (TNF signaling), MAPK pathway, JAK-STAT pathway. Signaling by hydrophobic molecules: Steroid hormone signaling, Glucocorticoid and estrogen receptors and their mechanism of action. Sensory physiology: Vision (Rhodopsin signaling), Signaling by gaseous molecules (Nitric Oxide), Signaling in Bacteria: Quorum sensing in bacteria, mechanism of chemokine signaling

Cellular communication- General principles of cell communication, cell adhesion and roles of different adhesion molecules: role of adhesive glycoproteins (fibronectin), cellular junctions- types, their role, extracellular matrix components. Cell – cell and Cell – matrix interaction (Integrins and selectin receptors and their interaction-Inside out signaling in endothelial cells)

Module 3: Cell culture **14 hrs**

Animal Cell Culture – Culture techniques, aseptic conditions, Equipment and materials for animal cell culture. Different constituents of culture medium, types of media and their application. Basic techniques of mammalian cell culture in vitro; disaggregation of tissue and primary culture. Cell lines-characteristics and routine maintenance. Cell viability and cytotoxicity assays. Applications of animal cell culture, Hybridoma Technology, Tissue engineering (e.g. Skin). Adult and embryonic stem cells and their applications.

Plant cell culture; Plant cell culture; Laboratory design, methodology, media. Techniques of callus cultures, embryo culture, protoplast culture, micropropagation, somatic embryogenesis and soma clonal variation, synthetic seeds; germplasm conservation and its application.

References:

1	Alberts, B., Bray, D., Hopkin, K., Johnson, A. D., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2019). Essential Cell Biology. Garland Science.
2	Alberts, B., Johnson, A., Lewis, J., Morgan, D., Raff, M., Roberts, K., & Walter, P. (2019). Molecular Biology of the Cell. Garland Science.
3	Bhojwani, S. S., & Razdan, M. K. (2015). Plant Tissue Culture: Theory and Practice. Elsevier.
4	Freshney, R. I. (2016). Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications. Wiley.

5	Karp, G. (2020). Cell and Molecular Biology: Concepts and Experiments. Wiley.
6	Lanza, R., Langer, R., Vacanti, J. P., & Mikos, A. G. (2020). Principles of Tissue Engineering. Academic Press.
7	Pollard, T. D., Earnshaw, W. C., & Lippincott-Schwartz, J. (2016). Cell Biology. Elsevier.
8	Stryer, L., Berg, J. M., & Tymoczko, J. L. (2015). Biochemistry. W. H. Freeman.
9	Veale, J. A., & Tortorello, T. A. (2021). Plant Cell and Tissue Culture. CABI.
10	Watson, J. D., Baker, T. A., Bell, S. P., Gann, A., Levine, M., & Losick, R. (2020). Molecular Biology of the Gene. Cold Spring Harbor Laboratory Press.

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Semester II		
Course Code:	**LS2HPSC571b**	
Title of the Course:	**NEUROBIOCHEMISTRY**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	**3**	**42**

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Demonstrate basic understanding of the nervous system and its functions.
CO 2:	Explain basic concepts of physiology and structure of nervous system
CO 3:	Describe the nature of neurotransmitters and its role in neuronal signal transmission
CO 4:	Analyze neuronal processes that involves key aspects of learning and memory

COURSE CONTENTS:

Module 1 : Neuroanatomy & functions **14 hrs**

Neurons: Introduction to neurons, components of neurons, classification and types of neurons, cytology of neurons, dendrite's structure and function, axon structure and functional aspects, ultrastructure, myelination and synapses. Sensory system, Glial cells: Structure and function of glial cells, Different types of glial cells: astrocytes, oligodendrocytes and Schwann cells, Types of astrocytes – type I & II astrocytes, fibrous and protoplasmic astrocytes, Importance of astrocytes in glutamate metabolism and blood brain barrier.

Module 2 : Neurotransmission and Ion Channel Dynamics **14 hrs**

Neurotransmission- voltage-Gated Ion Channels, action Potentials, neurotransmitters and their Receptors, Role of voltage-gated and ligand-gated ion channels in neural transmission, ion channels and signaling in nerve cells, neurotransmitter synthesis and metabolic mechanisms at the synapse, release and reuptake/degradation of classical neurotransmitters and peptide transmitters. Acetylcholine synthesis, storage and release. Nicotinic and muscarinic receptors; Catecholamine: Biosynthesis, storage and release; dopamine, adrenergic receptors. Serotonin:

synthesis, action and distribution, role of serotonin receptors in behavior, molecular sites and action in the CNS; GABA and glycine: synthesis, uptake and release; receptors of GABA and glycine.

Module 3: Neurodegenerative Disorders and Neuropathy **14hrs**

Neurochemical and molecular mechanisms of peripheral neuropathy; diseases involving myelin; Multiple sclerosis and other demyelinating disorders; Genetic disorders of Lipid, glycoprotein, and Mucopolysaccharide metabolism; Epileptic seizures; Genetics and diagnosis of Huntington disease and other triplet repeat disorders; Alzheimer's disease: Molecular, genetic, immunological aspects and diagnostics Alzheimer's disease and Parkinson's disease and prion diseases

References:

1	Alberts, B., Bray, D., Lewis, J., Raff, M., Roberts, K., & Watson, J. D. (2008). Molecular Biology of the Cell (4th ed.). Garland Publishing, Inc.
2	Cooper, G. M. (2007). The Cell: A Molecular Approach (2nd ed.). Sinauer Associates, Inc.
3	Kandel, E. R. (2013). Principles of Neural Science (5th ed.). McGraw Hill.
4	Lubert, S., Berg, J. M., & Tymoczko, J. L. (2002). Biochemistry (5th ed.). Freeman & Co.
5	Murray, R. K., Grammer, D. K., Mayer, P. A., & Rodwell, V. W. (2009). Harper's Biochemistry (28th ed.). Tata McGraw-Hill Publishing Company Limited.
6	Nelson, D. L., & Cox, M. M. (2011). Lehninger Principles of Biochemistry (5th ed.). W. H. Freeman & Company.
7	Siegel, G. J. (2006). Basic Neurochemistry (7th ed.). Academic Press.
8	Squire, L. R. (2013). Fundamental Neuroscience (4th ed.). Elsevier.
9	Verkhratsky, A. (2007). Glial Neurobiology: A Textbook . Wiley.
10	Voet, D., Voet, J. G., & Pratt, C. W. (2011). Fundamentals of Biochemistry: Life at the Molecular Level (4th ed.). John Wiley & Sons, Inc.

Semester II		
Course Code:	**LS2HPSP572a**	
Title of the Course:	**TECHNIQUES IN CELL CULTURE AND GENETICS – PRACTICAL**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	6	84

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Apply practical knowledge on tissue culture laboratory set-up, sterilization and media preparation
CO 2:	Perform animal and plant cell culture techniques
CO 3:	Evaluate cell viability and conduct toxicity assays on animal tissues
CO 4:	Analyse and solve genetic problems

COURSE CONTENTS:

1. Sterilization of tissue culture room by fumigation
2. Preparation of media and Balanced salt solutions
3. Cell disaggregation by warm trypsin/cold trypsin method for primary culture
4. Primary explant culture (animal tissue)
5. Estimation of cell viability by dye exclusion method (animal tissue)
6. MTT assay
7. Seed culture
8. Embryo culture
9. Carrot –callus
10. Seed immobilization- Preparation of synthetic seeds
11. Separation of lymphocytes from blood by centrifugation
12. Genetic problem solving
13. Human Karyotype analysis
14. Identification of Blood groups

References:

1	Mistry, S. K., & Mistry, V. K. (2018). Techniques in Plant and Cell Culture: A Practical Approach. Springer.
2	Freshney, R. I. (2016). Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications (7th ed.). Wiley.
3	Kumari, N., & Gupta, R. K. (2015). Animal Cell Culture and Technology. Springer.

4	Wang, T., & Zhang, L. (2019). Principles and Techniques of Plant Tissue Culture. Springer.
5	Rao, M. S., & Hegde, S. (2021). Biochemical and Molecular Diagnostic Methods in Tissue Culture. Springer.
6	Lanza, R., Langer, R., Vacanti, J. P., & Mikos, A. G. (2020). Principles of Tissue Engineering (4th ed.). Academic Press.
7	Abbas, A. K., Lichtman, A. H., & Pillai, S. (2021). Cellular and Molecular Immunology (9th ed.). Elsevier.
8	Jain, P. K., & Garg, R. (2017). Plant Tissue Culture: Applications and Techniques. CRC Press.
9	Weinberg, R. A. (2014). The Biology of Cancer (2nd ed.). Garland Science (for understanding cancer cell cultures, MTT assays, and cell viability).
10	Wang, L., & O'Neill, H. M. (2017). Human Genetics: Concepts and Applications (6th ed.). McGraw-Hill Education (for karyotyping and genetic problem-solving).
11	Macey, M. J. (2017). Molecular Techniques in Diagnostic Microbiology (3rd ed.). Elsevier

Semester II		
Course Code:	**LS2HPSP572b**	
Title of the Course:	**EXPERIMENTAL NEUROBIOCHEMISTRY - PRACTICAL**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	**6**	**84**

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Quantify and analyze the effect of drugs/toxins on brain tissue
CO 2:	Perform biochemical and histological assays to understand neuronal activity
CO 3:	Evaluate the behavioral changes that take place under conditions of stress and anxiety and apply the information obtained
CO 4:	Analyze the anxiety and antidepressant activity

COURSE CONTENTS:

1. Isolation and preparation of brain tissue homogenates
2. Effect of various psychotic drugs on brain tissue
3. Cytotoxicity of heavy metals (Lead, Cadmium) on brain cells
4. of memory and learning using radial maze test
5. Study of brain development in chick embryo
6. Behavioral analysis software tools and analysis
7. Study of blood-brain barrier models for drug transport
8. Assessment of bioavailability of toxicants/drugs in brain tissue
9. Acetylcholinesterase activity in brain cells
10. Behavioral Assay to Study Learning and Memory
11. Measurement of anxiety and antidepressant activity using an elevated plus maze
12. In Vitro Neurotoxicity Assay

References:

1	Abbott, N. J., Patabendige, A. A., Dolman, D. E., Yusof, S. R., & Begley, D. J. (2010). Structure and function of the blood–brain barrier. *Neurobiology of Disease, 37*(1), 13–25. Elsevier.
2	Bontempi, B., & Bannerman, D. M. (2015). Tools for behavioral neuroscience research: Overview and applications. *Current Opinion in Behavioral Sciences, 1*(1), 91–97. Elsevier.
3	Breier, J. M., Radio, N. M., Mundy, W. R., & Shafer, T. J. (2008). Development of a high-throughput screening assay for chemical effects on dopamine neuron differentiation and survival. *Neurotoxicology, 29*(3), 546–555. Elsevier.

4	Ellman, G. L., Courtney, K. D., Andres, V., & Feather-Stone, R. M. (1961). A new and rapid colorimetric determination of acetylcholinesterase activity. *Biochemical Pharmacology, 7*(2), 88–95. Elsevier.
5	Flora, S. J. S., & Mittal, M. (2016). Heavy metal toxicity and neurodegeneration: Mechanisms and implications. *Neurotoxicology, 53*, 1–13. Elsevier.
6	Gilbert, S. F. (2020). *Developmental Biology* (12th ed.). Sinauer Associates.
7	Kumar, A., & Sharma, N. (2016). Psychotropic drug actions and their mechanisms in neural tissues. *Pharmacology Research & Perspectives, 4*(5), 124–130. Wiley.
8	Pardridge, W. M. (2016). The blood-brain barrier and drug delivery to the CNS. *NeuroRx, 2*(1), 3–14. Springer.
9	Robbins, T. W., & Murphy, E. R. (2006). Behavioral pharmacology: 40+ years of learning and memory. *Neuropsychopharmacology, 31*(4), 734–759. Nature Publishing Group.
10	Sahu, R., & Saxena, P. (2019). Tissue homogenization techniques for biochemical analysis. *Methods in Molecular Biology, 1922*, 45–54. Springer.
11	Vorhees, C. V., & Williams, M. T. (2014). Assessing spatial learning and memory in rodents: The radial arm maze, water maze, and Barnes maze. *Nature Protocols, 8*(8), 1478–1492. Nature Publishing Group.
12	Walf, A. A., & Frye, C. A. (2007). The use of the elevated plus maze as an assay of anxiety-related behavior in rodents. *Nature Protocols, 2*(2), 322–328. Nature Publishing Group.

Semester II		
Course Code:	**LS2HPOE589**	
Title of the Course:	**HEALTH AND DISEASES**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	**3**	**42**

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Understand Nutritional concepts and General Health Metrics
CO 2:	Identify and Manage common Infectious Diseases
CO 3:	Analyze the Mechanisms and Adverse Effects of various Drugs
CO 4:	Evaluate treatment and prevention strategies of Infectious Diseases

COURSE CONTENTS:

Module 1 : Introduction **12 hrs**

Introduction on Concepts of macro and micro nutrients, healthy diet, Atkins diet, mediterranean diet, essential nutrients and their classification. General health, syndrome and common diseases – communicable and non- communicable diseases. General check-up: Blood group, Hb, height and weight, waist to hip ratio, electrocardiogram. Samples for analysis: Blood, urine and cerebrospinal.

Professional hazards: High risk groups (farmers, heavy duty machine workers, corporate workers, athletes).

Module 2 : Mechanism of drug action and adverse reactions **16 hrs**

Introduction to Pharmacokinetics & Pharmacodynamics. Analgesic Drug- Morphine, Antipyretic Drug-Paracetamol, Anti-inflammatory Drugs (NSAIDs) – Aspirin. Drugs of abuse – Alcohol, Nicotine, LSD. Respiratory Drugs – Salbutamol, Montelukast. Drugs in Peptic Ulcer-Cimetidine. Antidiabetic drugs-Metformin, Glimepiride, Insulin. Steroids: estradiol, methyltestosterone, dexamethasone. Antimicrobial agents- Penicillin, isoniazid, amphotericin B, chloroquine. Anti-cancer agents: vinblastine, vincristine.

Module 3: Infectious diseases **14 hrs**

Cause, Symptoms and treatment/prevention- Bacterial infections (Tuberculosis, Salmonella, Cholera), Viral infections (Hepatitis, H1N1, chikungunya, Dengue), STDs (Chlamydia, Syphilis, Gonorrhea, HIV) Parasitic diseases (Malaria) . Pregnancy and infections.

Antidotal therapy: types of antidotes: universal, simple and multiple antidotes: definition and examples. Antidotal procedures: decrease absorption of toxicants by emetics and chelating agents.	
References:	
1	Brunton, L. L., Hilal-Dandan, R., & Knollmann, B. C. (2018). Goodman & Gilman's: The Pharmacological Basis of Therapeutics (13th ed.). McGraw-Hill.
3	Casarett, L. J., & Doull, J. (2021). Casarett & Doull's Essentials of Toxicology (3rd ed.). McGraw-Hill.
4	Gibney, M. J., Lanham-New, S. A., Cassidy, A., & Vorster, H. H. (2019). Introduction to Human Nutrition (3rd ed.). Wiley-Blackwell.
6	Greenwood, D., Barer, M., Slack, R., & Irving, W. (2019). Medical Microbiology: A Guide to Microbial Infections (19th ed.). Elsevier.
7	Gropper, S. S., Smith, J. L., & Carr, T. P. (2018). Advanced Nutrition and Human Metabolism (7th ed.). Cengage Learning.
8	Guyton, A. C., & Hall, J. E. (2020). Textbook of Medical Physiology (14th ed.). Elsevier.
9	Jawetz, E., Melnick, J. L., & Adelberg, E. A. (2022). Jawetz, Melnick, & Adelberg's Medical Microbiology (28th ed.). McGraw-Hill.
10	Katzung, B. G., & Trevor, A. J. (2020). Basic & Clinical Pharmacology (15th ed.). McGraw-Hill.
11	Neal, M. J. (2020). Medical Pharmacology at a Glance (9th ed.). Wiley-Blackwell.
12	Tripathi, K. D. (2019). Essentials of Medical Pharmacology (8th ed.). Jaypee Br

Semester III		
Course Code:	**LS2HPHC600**	
Title of the Course:	**MOLECULAR BIOLOGY**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4	4	56

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Discuss an overview of the central dogma of life and the historical discoveries that led to our current understanding of molecular mechanisms of life.
CO 2:	Describe the organization of prokaryotic and eukaryotic chromosomes
CO 3:	Analyze the processes of transcription/translation, post-transcriptional, and post-translational modifications.
CO 4:	Interpret the stages of the cell cycle and explain the important checkpoints that a cell passes through during the cell cycle.

COURSE CONTENTS:

MODULE 1 : DNA Replication & regulation **14hrs**

Information flow in biological systems; central dogma of molecular biology. Modes of DNA Replication. Experimental evidence for semi conservative replication-Meselson-Stahl experiments. Prokaryotic DNA replication, eukaryotic DNA replication, origin and replication fork, fidelity of replication, DNA Replication in viruses - single stranded DNA virus, rolling circle model, replication of mitochondrial DNA. direction of replication, discontinuous replication - Okazaki fragments. DNA polymerase I, II and III, DNA ligase, DNA topoisomerases, Role of replication inhibitors. Nearest neighbor base frequency analysis

MODULE 2 : Regulation of Gene Expression in prokaryotes **12hrs**

Transcription activators and repressors, Regulation of gene expression in prokaryotes: housekeeping genes, constitutive genes and regulatory genes. Operon concept, Lac operon, structure and regulation. Arabinose operon, Gal operon- role of two operators, Tryptophan operon- Transcriptional control by attenuation in tryptophan operon. Role of riboswitches. Regulation of Eukaryotic gene expression Regulation at the level of genome-DNA amplification, DNA rearrangement, role of nucleosome structure, Chromatin remodeling, SWI/SNF complex, Role of histone modification.

MODULE 3 : Regulation of Gene Expression in prokaryotes 10 hrs

Transcription activators and repressors, Regulation of gene expression in prokaryotes: housekeeping genes, constitutive genes and regulatory genes. Operon concept, Lac operon, structure and regulation. Arabinose operon, Gal operon- role of two operators, Tryptophan operon- Transcriptional control by attenuation in tryptophan operon. Role of riboswitches.

Regulation of Eukaryotic gene expression Regulation at the level of genome-DNA amplification, DNA rearrangement, role of nucleosome structure, Chromatin remodeling, SWI/SNF complex, Role of histone modification.

MODULE 4 : Genetic Code and translation 12 hrs

Elucidation of Genetic code- Experimental studies of Nirenberg and Khorana. evolution of genetic code and codon usage, General features of genetic code. Triplet binding techniques, degeneracy, wobble hypothesis.

Protein synthesis and processing- Translation in Prokaryotes and Eukaryotes: 3D structure of prokaryotic and eukaryotic ribosome, initiation complex formation, initiation factors and their regulation, elongation and termination of protein synthesis. Role of mRNA and tRNA, aminoacylation of tRNA, translational inhibitors, post- translational modification of proteins. signal sequence, N-end rule, PEST.

MODULE 5 : Post-translational modifications and cell cycle 8 hrs

Translational and Post-translational control. Hormones [steroid (glucocorticoid) and peptide hormones] and Environmental factors (hypoxia, infection, stress) affect gene expression.

Cell Cycle – Molecular aspects of cell division -Mitosis and Meiosis, regulation by cyclins and CDKs. Programmed Cell Death (apoptosis), factors affecting apoptosis- p53 and bcl2. Aging & Cellular senescence.

References:

1	Alberts, B., Bray, D., Lewis, J., Raff, M., Roberts, K., & Watson, J. D. (2014). *Molecular Biology of the Cell.* Third, Garland Science.
2	Cooper, G. M. (2013). *Cell: A Molecular Approach, + a Student Handbook in Writing in Biology.* Sinauer Associates.
3	Karp, G. (2019). *Cell and Molecular Biology: Concepts and Experiments.* John Wiley & Sons.
4	Krebs, J. E., Goldstein, E. S., & Kilpatrick, S. T. (2009). *Lewin's Genes X*. Jones & Bartlett Publishers.
5	Lodish, H., Berk, A., Kaiser, C. A., Kaiser, C., Krieger, M., Scott, M. P., & Matsudaira,

	P. (2019). *Molecular Cell Biology.* Macmillan.
6	Watson, J. D. (2004). *Molecular Biology of the Gene.* Pearson Education India.
7	Weaver, R. F. (2012). *Molecular Biology.* McGraw-Hill International Edition.

Semester III		
Course Code:	**LS2HPHP600**	
Title of the Course:	**TECHNIQUES IN MOLECULAR BIOLOGY**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4	8	112

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Apply knowledge of modern techniques in cellular biology for observation and identification of tissues and cells
CO 2:	Perform extraction of DNA, RNA and their analysis at molecular level.
CO 3:	Evaluate the different phases of cell division using molecular techniques
CO 4:	Develop the skills to handle, maintain *Drosophila melanogaster* and perform experiments related to the model organism.

COURSE CONTENTS:

1. Study of mitosis in onion root tips and determination of mitotic index & inhibition of mitosis by mitotic inhibitors
2. Extraction of DNA from Coconut endosperm, purification, quantification
3. Estimation of DNA by Diphenylamine method.
4. Investigation of the structure and the bond strength of DNA (Cot Value)
5. Extraction of RNA from Yeast and purification
6. Salient feature of *Drosophila melanogaster*, Maintenance of *Drosophila melanogaster* cultures
7. Study of mutants of *Drosophila melanogaster*
8. Demonstration of sex chromatin
9. Eye pigment isolation of *Drosophila melanogaster*.
10. Mounting of salivary gland chromosomes of *Drosophila melanogaster*.
11. ELISA test for Ag-Ab Reaction
12. Polymerase chain reaction.

Reference

1	Abbas, A. K., Lichtman, A. H., & Pillai, S. (2021). *Basic Immunology: Functions and Disorders of the Immune System (6th ed.).* Elsevier.
2	Ashburner, M., & Golic, K. G. (2005). *Drosophila: A Laboratory Handbook (2nd*

	ed.). Cold Spring Harbor Laboratory Press.
3	Clark, D. P., & Pazdernik, N. J. (2019). *Biotechnology: Academic Cell Update Edition (2nd ed.).* Academic Press.
4	Griffiths, A. J. F., Wessler, S. R., Carroll, S. B., & Doebley, J. (2020). *Introduction to Genetic Analysis (12th ed.).* W. H. Freeman and Company.
5	Sambrook, J., & Russell, D. W. (2001). *Molecular Cloning: A Laboratory Manual (3rd ed.).* Cold Spring Harbor Laboratory Press.
6	Weir, D. M., & Blackwell, C. (2016). *Handbook of Experimental Immunology (4th ed.).* Blackwell Scientific Publications.

Semester III		
Course Code:	**LS2HPHC601**	
Title of the Course:	**METABOLISM- II**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4	4	56

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Schematize different pathways related to metabolism of nitrogenous compounds.
CO 2:	Describe pathways of degradation of proteins, purines and pyrimidines and Inborn errors of amino acid degradation
CO 3:	Explain the process of photosynthesis; metabolism of photoassimilate and the role of plant hormones.
CO 4:	Apply the knowledge of metabolomics in disease research

COURSE CONTENTS:

MODULE 1 : Nitrogen metabolism **14 hrs**

Importance of nitrogen in biological systems, nitrogen cycle. Nitrogen fixation - symbiotic and non-symbiotic, nitrogenase complex, energetics and regulation. Formation of root nodules in legumes. Assimilation of Nitrate, ammonia and sulfur into amino acids.

General Mechanisms of Amino Acid Metabolisms- ketogenic and glucogenic amino acids. Common intermediates of amino acid degradation (flow chart). Overview of amino acid biosynthesis, synthetic pathways for nonessential & flow chart for essential amino acids. Synthesis of aromatic amino acids, regulatory mechanisms (Flow charts with suitable examples) in the biosynthesis of amino acids in E.coli. Biosynthesis of neurotransmitter-GAB. Structure and function of phosphocreatine, glutathione, gramicidin, serotonin, epinephrine, polyamines- spermidine, spermine

MODULE 2 : Nucleic Acid and Amino Acid Metabolism **14 hrs**

Pathways of degradation of nucleic acids in cells, Salvage pathways, de novo biosynthetic pathways, regulation of biosynthesis. Conversion of nucleotides to deoxynucleotides.

Heme biosynthesis and degradation.

Biosynthesis of NAD+, FAD and coenzyme A.

Disorders with amino acid & nucleic acid metabolism: Inborn errors of amino acid degradation - phenylketonuria, alkaptonuria, maple syrup urine, hyperhomocysteinemia &

its association with disease, Porphyrias- common genetic defects & symptoms. Gout and Lysch- Nyhan syndrome. Mechanism of action of methotrexate, 5-fluorouridine, Azathymidine.Regulation of Gene Expression in prokaryotes

MODULE 3 : Photosynthesis **14 hrs**

Bacterial photosynthetic apparatus and Bacterial photosynthesis (Purple bacteria). Photosynthetic apparatus in plants-Structure of chloroplasts, Photoreceptors- chlorophyll, bacterial rhodopsin, light harvesting complex. photosystem I and II, their location, mechanism of Quantum capture & energy transfer between photosystems- ferredoxin, plastocyanin, plastoquinone, carotenoids. The Hill reaction, photo-phosphorylation, water splitting complex, calvin cycle, regulation, RUBISCO- substrate specificity, Photorespiration. C4& CAM metabolism. Light activation of enzymes, regulation of photosynthesis**.**

Plant hormones: Biosynthesis, storage, breakdown and transport; physiological effects and Mechanism of action of Auxins, Gibberlines, Cytokinins, Ethylene, Abscisic acid, Seed dormancy, Inception of germination, Germination and growth regulators.

MODULE 4: Biosynthesis, Degradation Pathways, and Metabolomics **14 hrs**

Biosynthesis of glycoproteins, proteoglycans. General mechanisms of degradation in cells (Ubiquitin-proteasome pathway, lysosomal pathway), Secondary metabolites - Biosynthesis of terpenes, phenols and nitrogenous compounds and their roles. [The shikimate and phenylpropanoid pathways (scheme only)].

Overview of Metabolomics: Define metabolomics and explain its role in understanding the metabolic processes within cells, tissues, and organisms. Applications of Metabolomics: Highlight specific examples of how metabolomics is used for disease screening, testing, and treatment

References:

1	Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2014). Molecular Biology of the Cell (6th ed.). New York: Garland Science.
2	Buchanan, B. B., Gruissem, W., & Jones, R. L. (2015). Biochemistry & Molecular Biology of Plants (2nd ed.). Chichester: Wiley Blackwell.
3	Dey, P. M., & Harborne, J. B. (2013). Plant Biochemistry. Elsevier India Pvt Ltd.
4	Garrett, R. H., & Grisham, C. M. (2016). Biochemistry (6th ed.). Boston: Cengage Learning.
5	Lehninger, A. L., Nelson, D. L., & Cox, M. M. (2020). Lehninger Principles of Biochemistry (7th ed.). New York: W. H. Freeman Publishers.

6	Lodish, H., Berk, A., Kaiser, C. A., Krieger, M., Bretscher, A., Ploegh, H., & Amon, A. (2016). Molecular Cell Biology (8th ed.). New York: W. H. Freeman Publishers.
7	Mathews, C. K., Van Holde, K. E., Appling, D. R., & Anthony-Cahill, S. J. (2018). Biochemistry (4th ed.). New York: Pearson Education.
8	Stewart, P., & Globig, S. (2011). Photosynthesis: Genetic Environmental Aspects. Apple Academic Press.
9	Stryer, L., Berg, J. M., Tymoczko, J. L., & Gatto, G. J. (2019). Biochemistry (8th ed.). New York: W. H. Freeman Publishers.
10	Voet, D., Voet, J. G., & Pratt, C. W. (2018). Biochemistry (5th ed.). New York: Wiley.

Semester III		
Course Code:	**LS2HPR636**	
Title of the Course:	**RESEARCH METHODOLOGY, ETHICS AND BIOSTATISTICS**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	**3**	**42**

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Demonstrate an understanding of research design, procedures of sampling, data collection, analysis and reporting.
CO 2:	Evaluate the importance of ethics in research and publications
CO 3:	Develop an understanding of imperative issues in research ethics, like responsibility for research, scientific misconduct and ethical evaluation
CO 4:	Analyze the appropriate statistical methods required for a particular research design and apply appropriate statistical methods for analyzing one or two variables.

COURSE CONTENTS:

MODULE 1 : Research methodology **12 hrs**

Meaning and importance of Research – Types of Research – Research Design. Type.

Sampling techniques- population & sample, types of samples and sampling techniques

Data Collection: Objective and Classification of Data, Types of data: Primary, Secondary and Tertiary Data.

Design of experiment- Completely randomized design, randomized block design. Reporting and thesis writing – Structure and components of scientific reports Significance.

MODULE 2 : Research Ethics **12 hrs**

Ethics – meaning and definition, Scientific conduct – ethics with respect to science and research, Scientific misconduct– falsification, fabrication and plagiarism, Publication ethics and misconduct – meaning and importance, Redundant publication – duplicate and overlapping publications, salami slicing. Citation index; H-Index and i-Index

Predatory publishers and journals – software to identify predatory publications – journal finder/journal suggestions tools.

Intellectual property rights: Different types of intellectual property rights and patents. Patenting of genes and products. Ethical and moral issues in biological and biotechnological research

MODULE 3 : Biostatistics **18 hrs**

Representation of data – Line graph, histogram, bar graph, pie chart. Measures of central tendency- mean, median, mode, quartiles and percentiles. Measures of dispersion; variance, standard deviation, standard error, measures of skewness and kurtosis.

Probability and distributions: sample space, events. Addition and multiplication rules, Binomial and normal distributions.

Tests of significance: Sample test (chi square, t-test, F –test), large sample test (z test), p value of the statistics- its significance, ANOVA- one way and two way.

Bivariate data: scatter plot, correlation coefficient - positive and negative correlation, regression coefficient.

References:

1	Creswell, J. W., & Creswell, J. D. (2017). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. SAGE Publications.
2	Dutfield, G. (2009). Intellectual Property Rights and the Life Science Industries: Past, Present, and Future. World Scientific.
3	Hoel, P. G. (1960). Elementary Statistics.
4	Holmes, D., Moody, P., Dine, D., & Trueman, L. (2017). Research Methods for the Biosciences. Oxford University Press.
5	Indrayan, A., & Satyanarayana, L. (2006). Biostatistics for Medical, Nursing and Pharmacy Students. PHI Learning Pvt. Ltd.
6	Khan, I. A., & Khanum, A. (2004). Fundamentals of Biostatistics. Ukaaz.
7	Kothari, C. (2017). Research Methodology: Methods and Techniques. New Age International (P) Ltd., Publishers.
8	Kumar, R. (2018). Research Methodology: A Step-by-Step Guide for Beginners. Sage.
9	Palfrey, J. (2011). Intellectual Property Strategy. MIT Press.
10	Rao, P. S., & Richard, J. (2012). Introduction to Biostatistics and Research Methods. PHI Learning Pvt. Ltd.

Semester III		
Course Code:	**LS2HPSP621a**	
Title of the Course:	**CLINICAL BIOCHEMISTRY AND CLINICAL RESEARCH**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	**3**	**42**

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Understand the basic concepts and principles of Clinical Biochemistry, detail on the collection, preservation and storage of biological samples
CO 2:	Explain principles of laboratory automation and quality control in a clinical laboratory
CO 3:	Clinically assess the laboratory indicators of physiologic conditions and diseases
CO 4:	Comprehend the ethical and regulatory framework governing clinical trials, Drug Metabolism and Pharmacokinetics.

COURSE CONTENTS:

MODULE 1 : **Automation in clinical biochemistry** **14 hrs**

Quality assurance, External and internal quality control measurements. Collection, transport, preservation and processing of various clinical specimens.

Body fluids: Sputum examination – Physical examination (macroscopic) and Microscopic – Gram's stain, Ziehl Neelsen stain for AFB.

Cerebrospinal fluid analysis: Physical examination (color and turbidity).

Microscopic examination of pleural, pericardial, synovial and peritoneal fluid.

Blood collection, anticoagulants used in Hematology, Red blood cell indices, E.S.R., PCV, Platelet count, Absolute Eosinophil count, Reticulocyte count, Stains used in Hematology, Preparation of blood film.

Semen analysis, liquefaction, volume, color, reactions, pH, motility, sperm count, morphology of sperm- importance and interpretation.

Urine examination, Physical, chemical and microscopic.

Stool examination – Macroscopic (naked eye) inspection, concentration method, flotation method and sedimentation. Microscopic examination for parasites, Strip method, Test for Occult blood – Benzidine Test.

Thyroid profile tests, Lipid profile tests, Liver function tests, gastric function tests, kidney

function tests, pancreas function tests. ELISA test, Widal test, VDRL test, ASLO test, Brucella Agglutination test, Weil Felix test, Coomb's test.

Pregnancy tests: Method, interpretation advantages and disadvantages

MODULE 2 : Introduction to Clinical Research **14 hrs**

Definition and scope of clinical research. History and evolution of clinical trials: Sulphanilamide Tragedy, Thalidomide Disaster, Nazi Experiments, Tuskegee Study, Belmont report, Nuremberg code, Declaration of Helsinki principles. Phases of clinical trials (Phase I-IV). Landmark clinical trials. Principles of bioethics: autonomy, beneficence, non-maleficence, and justice, Informed consent process, Role of Institutional Review Boards (IRBs), Regulatory agencies and their roles (FDA, EMA), Good Clinical Practice (GCP) guidelines, Overview of ICH guidelines. Clinical Trial Design- Types of clinical trials (randomized controlled trials, cohort studies, case-control studies), Randomization and blinding.

MODULE 3 : Drug Metabolism and pharmacokinetics **14 hrs**

Definition and importance of drug metabolism, Basic Concepts in Pharmacokinetics - Absorption, distribution, metabolism, and excretion (ADME)Bioavailability and first-pass effect. Types of Phase I reactions (oxidation, reduction, hydrolysis), Cytochrome P450 - function of CYP450 enzymes, Substrate specificity and example (e.g., warfarin, statins), Non-CYP450 Enzymes - Role of flavin-containing monooxygenases (FMO) and alcohol dehydrogenases (ADH), Types of Phase II reactions (glucuronidation, sulfation, acetylation, methylation) & examples. Prodrug and Drug activation. Adverse Drug Reactions and Toxicity, Role of metabolism in drug-induced toxicity, Toxic metabolites (e.g., acetaminophen and NAPQI)

References:

1	Bishop, M. L., Fody, E. P., et al. (2013). Clinical Chemistry: Principles, Techniques, and Correlations. Philadelphia, Wolters Kluwer Health/Lippincott Williams & Wilkins.
2	Devlin, T. M. (2006). Textbook of Biochemistry: With Clinical Correlations. Wiley-Liss.
3	Gallin, J., & Ognibene, F. (Eds.). (2012). Principles and Practice of Clinical Research (3rd ed.). Academic Press.
4	Goodman, L. S., Hardman, J. G., et al. (2001). Goodman & Gilman's The Pharmacological Basis of Therapeutics. New York, McGraw-Hill.
5	Hawk, P. B. (1954). Practical Physiological Chemistry. New York, Blakiston Co.
6	Hulley, S. B., Cummings, S. R., Browner, W. S., Grady, D., & Newman, T. B. (Eds.). (2013). Designing Clinical Research (4th ed.). Lippincott Williams & Wilkins.

7	Katzung, B. G., Masters, S. B., et al. (2012). Basic & Clinical Pharmacology. New York; London, McGraw-Hill Medical.
8	Roberts, C., & Mulholland, M. (2018). Essentials of Drug Metabolism. Springer.
9	Shepard, S., & Smith, J. (2020). Principles of Drug Metabolism. Academic Press.
10	Thomas, M. D. (2011). Textbook of Biochemistry (6th ed.). John Wiley Publishers.

Semester III		
Course Code:	**LS2HPSP621b**	
Title of the Course:	**MOLECULAR MEDICINE**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	3	42

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Describe the basics of infection and pathogenicity.
CO 2:	Explain the molecular basis of diseases, including genetic disorders, cancer, and infectious diseases
CO 3:	Analyze the importance of various pathogens in causing diseases
CO 4:	Propose strategies for the development and application of molecular diagnostics and personalized medicine

COURSE CONTENTS:

MODULE 1 : **Advances in Pathogen Genetics and Host-Pathogen Interactions 14 hrs**

Current topics in fungal, parasitic, bacterial and viral genetics (with the emerging knowledge of sequence databases available and ongoing projects). Understanding the mechanisms available for genetic variability in different pathogens to defy the host immune system. Host signaling in response to infections. Bacterial two component signaling systems. Bacterial adhesins, virulence factors. Protein and DNA secreting systems and pathogenicity island. Molecular basis of antimicrobial resistance and its detection. Molecular approaches in clinical microbiology.

MODULE 2 : Molecular and Cellular Basis of Human Diseases 14hrs

Molecular and cellular basis of viral pathogenesis such as tumor viruses, hepatitis virus, HIV, Ebolla, H1N1, and Zika virus etc, phage tolerance and resistance, microbiome of human health, distribution of microbiota of the human body, molecular basis of metabolic disorders in human and therapy, metabolic profiling, Genetics and epigenetics in metabolic disorders, molecular basis of human diseases like Parkinson, Alzheimer's diseases

MODULE 3 : Molecular Targets and Mechanisms in Therapeutic Development 14hrs

Molecular targets of therapeutics such as microbial targets, signal transduction pathways, autoimmune disease targets, cancer targets, epigenetic modifications and emerging

targets; molecular biomarkers, receptors specificity, agonists and antagonists, therapeutics drugs and classes, Peptide therapeutics, monoclonal antibodies, the pharmacodynamics of different classes of drugs, Mechanisms of toxicity, therapeutic index, mechanisms of detoxification, mechanisms of medicinal plant products or secondary metabolites, the evolution of drug tolerance mechanism in bacteria, virus, and humans, Surveillance model for prediction of antimicrobial susceptibility	
References:	
1	Alberts, B. (2017). *Essential Cell Biology.* Garland Science.
2	Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2015). *Molecular Biology of the Cell.* Garland Science.
3	Brown, T. A. (2020). *Genomes 4.* Garland Science.
4	Cooper, G. M., & Hausman, R. E. **(**2018). *The Cell: A Molecular Approach.* Sinauer Associates.
5	Karp, G. (2019). *Cell and Molecular Biology: Concepts and Experiments.* John Wiley & Sons.
6	Lodish, H., Berk, A., Kaiser, C. A., Krieger, M., Scott, M. P., Bretscher, A., Ploegh, H., & Matsudaira, P. (2016). *Molecular Cell Biology.* W.H. Freeman.
7	Nelson, D. L., & Cox, M. M. (2017). *Lehninger Principles of Biochemistry.* W.H. Freeman.
8	Smith, J. D., Brown, L. M., & Wang, T. Y. (2020). *Molecular Medicine.*
9	Strachan, T., & Read, A. (2018). Human Molecular Genetics. Garland Science.
10	Voet, D., Voet, J. G., & Pratt, C. W. (2016). Fundamentals of Biochemistry: Life at the Molecular Level. John Wiley & Sons.

Semester III		
Course Code:	**LS2HPSP622**	
Title of the Course:	**METABOLISM AND CLINICAL BIOCHEMISTRY**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	**8**	**112**

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Demonstrate ability to perform experiments to estimate metabolic parameters.
CO 2:	Perform microscopic & chemical analysis of Blood & urine
CO 3:	Analyze and interpret clinical and biochemical changes taking place in blood and urine under normal and pathological conditions
CO 4:	Identify the normal and abnormal constituents present in urine samples and quantify them.

COURSE CONTENTS:

1. Extraction of glycogen and quantification from fed and fasting mice liver and muscle.
2. Separation of lactate dehydrogenase by electrophoresis and activity staining.
3. Study of Hill's reaction - Photosynthetic reduction of 2, 6 dichlorophenol indophenol (DCPIP)
4. Estimation of pyruvate/lactate/ alpha ketoglutarate (Keto acids)
5. Qualitative analysis of normal and abnormal constituents of urine.
6. Estimation of Titratable acidity and ammonia of urine
7. Estimation of creatinine in urine and blood samples.
8. Estimation of urea in urine and blood samples.
9. Quantitation of uric acid in urine samples.
10. Quantitation of blood glucose levels.
11. Determination of Albumin/Globulin ratio in blood sample.
12. Enumeration and observation of Red blood cells, total and differential leucocytes.

References:

1	Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2014). *Molecular Biology of the Cell (6th ed.).* Garland Science.

2	Ashburner, M., & Roote, J. (2000). *Drosophila: A Laboratory Handbook (2nd ed.).* Cold Spring Harbor Laboratory Press.
3	Griffiths, A. J. F., Wessler, S. R., Carroll, S. B., & Doebley, J. (2020). *Introduction to Genetic Analysis (12th ed.).* W.H. Freeman and Company.
4	Karp, G. (2018). *Cell and Molecular Biology: Concepts and Experiments (8th ed.).* Wiley.
5	Plummer, D. T. (1992). *An Introduction to Practical Biochemistry (3rd ed.).* McGraw-Hill.
6	Sambrook, J., & Russell, D. W. (2001). *Molecular Cloning: A Laboratory Manual (3rd ed.).* Cold Spring Harbor Laboratory Press.

Semester III		
Course Code:	**LS2HPSP623**	
Title of the Course:	**EXPERIMENTS IN MOLECULAR MEDICINE**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	6	84

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Discuss the basics of mutation and diseases
CO 2:	Examine the molecular basis of various diseases
CO 3:	Analyze the importance of techniques in detection of diseases
CO 4:	Explore the importance bioinformatics in diseases detection

COURSE CONTENTS:

1. Analyzing Genetic Mutations in Disease
2. DNA Extraction from Buccal Cells
3. Polymerase Chain Reaction (PCR) of extracted DNA
4. Gel Electrophoresis of amplified DNA sample
5. Restriction Fragment Length Polymorphism (RFLP) Analysis
6. DNA Sequencing and Analysis
7. Bioinformatics Analysis
8. Western Blotting
9. Animal models in Biomedical Research
10. Cytotoxicity analysis
11. Isolation and culture pathogenic microorganisms
12. Antibiotic resistant profiling

Reference

1	Benson, S. A. (2012). Microbiological Applications: Laboratory Manual in General Microbiology (12th ed.). McGraw-Hill.
2	Conn, P. M. (Ed.). (2008). Animal Models in Biomedical Research. Academic Press.
3	Mahajan, B. K. (2018). Methods in Biostatistics for Medical Students and Research Workers (8th ed.). Jaypee Brothers Medical Publishers.

4	Mount, D. W. (2004). Bioinformatics: Sequence and Genome Analysis (2nd ed.). Cold Spring Harbor Laboratory Press.
5	Sambrook, J., & Russell, D. W. (2001). Molecular Cloning: A Laboratory Manual (3rd ed.). Cold Spring Harbor Laboratory Press.
6	Wilson, K., & Walker, J. (2010). Principles and Techniques of Biochemistry and Molecular Biology (7th ed.). Cambridge University.

Semester III		
Course Code:	**LS2HPOE639**	
Title of the Course:	**EVOLUTION AND ECOLOGY**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	**3**	**42**

Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Discuss the scientific theory of evolution and explain the points of the Modern Synthesis of evolutionary theory.
CO 2:	Demonstrate broad-based knowledge of the fundamentals of Ecology, and Evolution and the relationships among these disciplines
CO 3:	Describe the principle interactions between different species and how they affect the respective species.
CO 4:	Asses the biogeochemical cycles, pollution, natural resource conservation and management

COURSE CONTENTS:

MODULE 1 : **Evolution** **14hrs**

Definition; Theories of Evolution – Lamarckism, Darwinism, Neo-darwinism, Modern synthesis; Evidence for evolution; Phenomena influencing evolution – Adaptation, Natural selection (genetic variation, fitness, competition), Sexual selection, Fecundity selection, Genetic drift, Gene flow, Adaptive radiation; Species concept – Definition, Parameters for the delimitation of species, Speciation: Allopatric and parapatric, Biogeography and evolutionary ecology; Evolution and development; Misconceptions and misinformation of evolution.

MODULE 2: Ecology **14hrs**

Population ecology: meta-population dynamics; growth rates – density independent growth, density dependent growth; niche concept; key stone species.

Species interactions: inter-species interactions – mutualism, commensalism, competition, predation; trophic interactions; behavioral ecology

Community ecology: Community assembly, organization and evolution; biodiversity hotspots, species richness, evenness and diversity indices; endemism; species-area relationships, Ecological successions and disturbances.

MODULE 3: Ecosystems **14 hrs**

Structure and function; Aquatic ecosystem – freshwater, estuaries, marine communities; Terrestrial ecosystems. Biogeochemical cycles – gaseous, sedimentary, water. Pollution: environmental pollutants – biomagnification and bioaccumulation, Pollution control; global warming and climate change.

Natural resource ecology: Natural resource conservation and management, Wildlife management-in-situ and ex-situ conservation.

References:

1	Braude, S., & Low, B. S. (Eds.). (2010). An Introduction to Methods & Models in Ecology, Evolution, & Conservation Biology. Princeton University Press.
2	Knustad, D., & Simmons, M. (2006). Principle of Genetics (4th ed.). John Wiley and Sons Publications.
3	Kumar, H. (2001). Textbook of Cytology, Genetics and Evolution. Kalyani Publisher, Ludhiana.
4	Life on Earth: An Encyclopedia of Biodiversity, Ecology, and Evolution. (2003). Choice Reviews Online, 40(11), 40-6160-40–6160.
5	Mayhew, P. J. (2006). Discovering Evolutionary Ecology: Bringing Together Ecology and Evolution. Oxford University Press.
6	Purohit, S. (2004). Ecology & Environmental Biology. Agrobios (India).
7	Purohit, S., Shammi, Q., & Agarwal, A. (2004). A Textbook of Environmental Sciences. Student Edition.
8	Verma, P., & Agarwal, V. (2004). Cell Biology, Genetics, Molecular Biology, Evolution and Ecology. SChand Pvt. Ltd., New Delhi.
9	Williams, G. (1992). Natural Selection: Domains, Levels, and Challenges (Oxford Series in Ecology and Evolution). Oxford University Press.
10	Wright, R., & Nebel, B. (2002). Environmental Science. Prentice-Hall, India Pvt. Ltd.

Semester IV		
Course Code:	**LS2HPHC650**	
Title of the Course:	**Immunology**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
4	**4**	**56**

Course Outcomes: Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Employ immunological concepts and demonstrate basic knowledge of immunological processes at a cellular and molecular level.
CO 2:	Describe the cells and organs involved in immune response and compare and contrast innate and adaptive immunity
CO 3:	Analyze the concept of antigen, immunoglobulins and apply basic techniques for identifying antigen-antibody interactions.
CO 4:	Schematize key events in antigen presentation, and the cell-mediated and humoral immune responses, immunological tolerance, autoimmunity, hypersensitive reactions, cancer immunology and principles governing vaccination.

COURSE CONTENTS:

Module 1: 14 hrs

Historical perspective, **Types of immunity**: Definition, innate, acquired- active and passive

with examples. Factors affecting immunity: age, hormonal influence, nutrition. Mechanisms of innate immunity: anatomical, physiological, phagocytotic and inflammatory response. Structure and functions of cells of the immune system: T-cells, B-cells, Natural killer cells, macrophages, antigen presenting cells, neutrophils, eosinophils, basophils, mast cells and dendritic cells. Organs of the Immune system: Structure and function of Primary lymphoid organ- (Thymus and Bone marrow) and Secondary lymphoid organs- (lymph nodes, Spleen, MALT, CALT). Clonal selection theory – Burnett Concept of antigen specific receptor.

Module 2: **14hrs**

Antigens: Definition, Immunogens with examples, immunogenicity versus antigenicity. Types of antigens, Epitopes- Definition, types, and valency of antigen. Factors that influence immunogenicity. Epitope analysis. Immunoglobulins: Basic structure of Immunoglobulins, Classes of Immunoglobulins, structure and functions Organization and expression of immunoglobulin light and heavy chain generation of antibody diversity and T cell receptors, Antibody, Class- Switching. Immunotechnology: Production of monoclonal antibodies and its applications. Antigen antibody interactions: Principles and methods of Precipitations, Agglutinations, Complement fixation, ELISA and RIA.

Module 3: **14hrs**

Immune response: Humoral and Cell mediated immune response. Kinetics of primary and secondary immune responses.

Major Histocompatibility Complex -Structure and functions of class I and class II MHC molecules. Polymorphism of MHC genes and HLA typing. Antigen processing and presentation- exogenous and endogenous antigens.

Cell mediated immune response. General properties of effector T cells. The structure and functions of T-cell receptors (TCR); the TCR-peptide-MHC tri-molecular complexes. Cytokines and co stimulatory molecules-their role in immune response. T- & B-cell interactions; B-cell activation and proliferation by thymus independent and thymus dependant antigens.

Complement System: General Properties, components, complement activation, Classical, alternate pathway and Lectin pathway.

Module 4: 12hrs

Tolerance Vs Activation of immune system: Immune tolerance, hypersensitivity reactions (Type I, II, III and IV).

Immune Responses to infectious diseases: bacterial, viral and protozoan

Immunodeficiency disorders- Primary and Secondary-SCID, AIDS

Auto immunity: Classification and mechanisms of autoimmune diseases- Insulin Dependent Diabetes Mellitus, Rheumatoid Arthritis, Thyroid disease

Cancer and Immune system: Tumor antigens (Tumor associated antigens and Tumor specific antigens), Factors favoring tumor growth, immune surveillance. Immunotherapy

of malignancy. **Vaccines:** Active and Passive immunization, types of vaccines. Herd Immunity	
References:	
1	Abbas, A. K., Lichtman, A. H., & Pillai, S. (2017). *Cellular and molecular immunology* (9th ed.). Elsevier.
2	Delves, P. J., Martin, S. J., Burton, D. R., & Roitt, I. M. (2017). *Roitt's essential immunology* (13th ed.). Wiley-Blackwell.
3	Dulsy Fatima, & Arumugam, N. (2014). *Immunobiology*. Sara Publication.
4	Goldsby, R. A., Kindt, T. J., & Osborne, B. A. (2013). *Kuby immunology* (7th ed.). W.H. Freeman.
5	Janeway, C. A., Travers, P., Walport, M., & Shlomchik, M. J. (2001). *Immunobiology: The immune system in health and disease* (5th ed.). Garland Science.
6	Murphy, K., Weaver, C., & Berg, L. (2016). *Janeway's immunobiology* (9th ed.). Garland Science.
7	Sompayrac, L. (2015). *How the immune system works* (5th ed.). Wiley-Blackwell.

Semester IV		
Course Code:	**LS2HPPR686**	
Title of the Course:	**PROJECT WORK**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
12	**20**	**280**

Course Outcomes: Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Demonstrate and understand the scope of research in their assigned dissertation research topic, troubleshoot, and successfully outline the aims and objectives for subsequent dissertation work.
CO 2:	Critically review literature, find gaps in research, select a research problem/ test hypothesis and design experiments.
CO 3:	Perform experiments, collect data, draw conclusions and interpret the results and discuss the work in the light of work previously done by other researchers.
CO 4:	Compose in oral and written form by integrating data and interpretation and relate to the concept of ethics in research

COURSE CONTENTS:

Module 1 : Students can take up research project work under the guidance of faculty in any area of the prescribed syllabus. They can also opt to go to other institutions during the summer vacations after second semester. In the former, students are allotted guides and, in the latter, they can choose the institution of their choice and make arrangements for the same, however an internal guide will be assigned to the student. Guidelines for the preparation, presentation and evaluation of student research projects are provided in Annexure-I.

Semester IV		
Course Code:	**LS2HPSC671a**	
Title of the Course:	**GENETIC ENGINEERING AND BIOINFORMATICS**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	**3**	**42**

Course Outcomes: Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Explain the principles and advancements in DNA modification techniques.
CO 2:	Enlist the vectors used in genetic engineering and discuss their application
CO 3:	Analyze tools and techniques of genetic engineering like transformation, hybridization, transcriptome analysis, sequencing, and more.
CO 4:	Apply knowledge of bioinformatics databases and tools for sequence and structural analysis, perform alignments and phylogenetic studies, and critically evaluate and present bioinformatics data

COURSE CONTENTS:

Module 1: Tools in Genetic Engineering **14hrs**

Enzymes used in manipulating DNA molecules (DNA polymerases, RNA Polymerases, Reverse Transcriptase, Ligases), restriction enzymes; type I, II and III, specificity, sticky ends and blunt ends, 3' and 5' overhang, Ligation methods, Blunt end and sticky end ligation, use of linkers and adapters, homopolymer tailing. Isoschizomers, Vectors, Plasmids, cosmids, Phagemid, Yeast cloning vectors, plant vectors, bacterial artificial chromosome, SV40, shuttle vectors, construction of expression vectors, Hosts and Expression systems: Bacteria – Escherichia coli; Yeast – Saccharomyces cerevisiae, Pichia pastoris; Insect cell lines – Spodoptera frugiperda Sf-9, Trichoplusiani BTI-TN-5B1-4; Plants – Arabidopsis thaliana, Nicotiana benthamiana; Mammalian cell lines – Chinese Hamster Ovary (CHO), COS, Human Embryonic Kidney (HEK), HeLa. Advantages and disadvantages of different expression systems. cDNA cloning, TOPO cloning method, Identifying the right clones: Screening – insertional inactivation of marker gene, replica plating, visual screening; DNA probes – preparation of probes, plaque hybridization, FISH, Southern blot, colony hybridization, dot blot.

Module 2: Techniques in genetic engineering **10 hrs**

Transformation, Micro injection, Electroporation, Lipofection, Calcium phosphate method, Biolistic, Agrobacterium-mediated transformation, CRISPR CAS 9, gene knockout Techniques, Chromosome walking, Chromosome Jumping, Polymerase chain reaction – Types of PCR

Radiation hybrid mapping, Restriction mapping, RAPD, RFLP, Exon trapping, CpG Islands (HTF islands)

DNA sequencing – Sanger Sequencing, Pyrosequencing, Illumina sequencing, Sequencing by Oligonucleotide Ligation and Detection (SOLiD); Genome Sequencing methods- clone-by clone strategy- role of VNTRs, sequence-tagged site, microsatellites, & expressed sequence tag, Human genome project –strategy adopted & major findings.

Module 3: Techniques to study transcriptome **8hrs**

Northern blot; in situ hybridization; Serial analysis of gene expression (SAGE); transcriptional mapping; RNAi analysis; DNA microarrays; RNA-seq.

Edman degradation; yeast one-hybrid assay, two-hybrid assay; western blot; protein microarrays; site-directed mutagenesis – subtilisin; filter binding assay; gel mobility shift assay; DNase foot printing; Chromatin immunoprecipitation.; phage display.

Module 4: Bioinformatics **10 hrs**

Bioinformatics and Databases: Definitions, scope and application of bioinformatics. Databases: Definition and classification. Database management public agencies- NCBI, EBI. GenBank Sequence database. Protein databases: SWISSPROT, Pfam and signal peptide databases.

Structural analysis: Protein Structural databases – PDB, MMDB; Tools for structural viewing – RasMol.

Sequence alignment and applications Homology, concept and alignment of pairs of sequence, Global & Local Alignment, Basic Local Alignment Search Tool (BLAST). Multiple sequence alignment – tools (Clustal omega).

Molecular phylogenetics: Introduction, application of phylogenetic trees, basic terminology, taxa, root, leaf, node, tree, branch, clade, dendrogram, cladogram, rooted tree, unrooted tree.

References:

1	Baxevanis, A. D., Bader, G. D., & Wishart, D. S. (Eds.). (2020). *Bioinformatics*. John Wiley & Sons.

2	Brown, T. A. (2020). *Gene cloning and DNA analysis: An introduction* (8th ed.). Wiley-Blackwell.
3	Gibson, W., & Koch, C. (2019). *Biotechnology and genetic engineering*. Scientific e-Resources.
4	Nicholl, D. S. T. (2020). *An introduction to genetic engineering* (4th ed.). Cambridge University Press.
5	Primrose, S. B., & Twyman, R. (2013). *Principles of gene manipulation and genomics* (7th ed.). John Wiley & Sons.

Semester IV		
Course Code:	**LS2HPSC671b**	
Title of the Course:	**MICROBIAL BIOCHEMISTRY**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	3	42

Course Outcomes: Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Acquire knowledge about the microorganisms around us, development of the discipline of microbiology and the contributions made by prominent scientists in this field.
CO 2:	Compare and contrast useful and harmful microorganisms and explain the structure and functions of microscopic organisms.
CO 3:	Evaluate the effectiveness of different sterilization techniques in maintaining sterility.
CO 4:	Illustrate the importance of microorganisms as model systems in genetics and biochemistry.

COURSE CONTENTS:

Module 1: Introduction **14 hrs**

Historical perspectives– Robert Hooke, Leeuwenhoek, Spontaneous Generation – for and against, Schwann, Louis Pasteur, Cohn, Relationship between microorganisms and disease – Lister, Koch, Development of techniques to study microbial pathogens, Immunological studies – Jenner, Fleming.

Comparative morphology, structure and reproduction in archaebacteria - membranes, cell wall, genetics, flagella; eubacteria - membranes, matrix, nucleoid, cell wall and its associations, flagella, endospore; cyanobacteria – structure, classification, nitrogen fixation; yeast – cell envelope, cell wall, matrix, reproduction – budding, spore formation and sexual reproduction; and fungi – characteristics, structure, nutrition, classification, reproduction – asexual spores and fragmentation, sexual – mechanisms and spores, fructifications.

Microbial nutrition – classification based on concentration and chemical nature; nutritional grouping of microorganism – nutrient requirements; Growth kinetics - mechanisms of

growth phases of growth, factors affecting growth and death - oxygen, temperature, pH, salinity; VBNC

Module 2: **14 hrs**

Sterilization techniques – chemical and physical methods.

Microbial isolation, enumeration - mass, number, growth; cultivation – aerobes and anaerobes; and preservation – reduced temperature, dehydrated forms.

General account of symbiosis, mutualism – sulfide and methane-based mutualism, antagonism, parasitism, commensalism in microorganisms.

Animal microbe interactions: classification, infections, mechanism of action of disease-causing agents. treatment and diagnosis – tests to detect the presence of microbe or disease-causing agent: Fungal (*Candida albicans*), bacterial (*E. coli, Salmonella typhi* (Widal test)), protozoan (*Entamoeba histolytica, Plasmodium)* and viral (*H1N1* - re-assortment) infections in humans.

Module 3: **14 hrs**

Viruses: history, properties of virus, ultrastructure, cultivation, classification (general and Baltimore) and life cycle (lytic and lysogenic cycles) of plant viruses (DNA and RNA viruses) (TMV, CaMV, Gemini virus) animal viruses (DNA and RNA viruses) (enveloped and nonenveloped) (SV40 and HIV), SARS- Covid 19, and bacteriophages (DNA and RNA viruses) (T4, lambda phage - Decision between lysis and lysogeny).

Antibiotics: therapeutic index, classification, Factors influencing the effectiveness of drugs, types (antibacterial, antifungal, antiviral, antiprotozoal), mode of action and mechanism of drug resistance.

Biopesticides: Mode of action and production (Bacterial (*Bacillus thuringiensis*), Fungal (against fungi, nematodes, insects) and Viral (Baculovirus) biopesticides).

References:

1	Anderson, D. G., Salm, S. N., & Nester, E. W. (2024). *Microbiology: A human perspective* (10th ed.). McGraw-Hill Education.
2	Bauman, R. W. (2022). *Microbiology with diseases by body system* (6th ed.). Pearson.
3	Black, J. G. (2022). *Microbiology: Principles and exploration* (10th ed.). Wiley.
4	Brock, T. D., & Madigan, M. T. (2022). *Brock biology of microorganisms* (16th ed.). Pearson.
5	Cowan, M. K. (2020). *Microbiology: A systems approach* (6th ed.). McGraw-Hill Education.
6	Flint, S. J. (2020). *Principles of virology: Molecular biology, pathogenesis, and control* (5th ed.). ASM Press.

7	Talaro, K. P., & Talaro, A. (2021). *Foundations in microbiology* (10th ed.). McGraw-Hill.

Semester IV		
Course Code:	**LS2HPSP672a**	
Title of the Course:	**PRACTICAL BIOINFORMATICS AND GENETIC ENGINEERING**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	**6**	**84**

Course Outcomes: Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Apply tools and techniques in genetic engineering
CO 2:	Demonstrate and explain transformation techniques and selection of transformants
CO 3:	Perform biological database search, retrieve data, analyze the data,design, and evaluate primers and visualize protein structures employing various bioinformatics tools
CO 4:	Employ immunodiffusion techniques to analyze antigen-antibody interactions.

COURSE CONTENTS:

1. Restriction digestion & Agarose gel electrophoresis
2. Ligation of DNA & Agarose gel electrophoresis
3. Calcium chloride mediated transformation of *E. coli* & Selection of transformants
4. Restriction mapping
5. Nucleotide Databases, Literature database-PubMed central and disease database-OMIM
6. Protein databases
7. BLAST
8. Multiple sequences alignment; Preparation of phylogenetic tree
9. Primer designing
10. Protein Structure Visualization- RasMol
11. : Radial Immunodiffusion
12. Ouchterlony Double diffusion

References:

1	Creighton, T. E. (2010). *Proteins: Structures and molecular properties* (2nd ed.). W. H. Freeman and Company.
2	Dabre, P. D. (2008). *Introduction to practical molecular biology*. Alpha Science International.
3	Green, M. R., & Sambrook, J. (2012). *Molecular cloning: A laboratory manual* (4th ed.). Cold Spring Harbor Laboratory Press.
4	Dabre, P. D. (2008). Introduction to Practical Molecular Biology. Alpha Science International.
5	Wilson, K., & Walker, J. (2018). *Principles and techniques of biochemistry and molecular biology* (8th ed.). Cambridge University Press.

Semester IV		
Course Code:	**LS2HPSP672b**	
Title of the Course:	**EXPERIMENTAL MICROBIOLOGY**	
Course Credits	**No. of Hours per Week**	**Total No. of Teaching Hours**
3	**6**	**84**

Course Outcomes: Course Outcomes: Upon completion of this course, students will be able to

CO 1:	Identify microbes from samples and perform bacterial cultures in different media.
CO 2:	Perform routine microbiological practices such as sterilization, media preparation, maintenance of microbial culture, and staining.
CO 3:	Develop techniques for culturing and screening of microbes
CO 4:	Analyze microbial diversity and ecological roles in various environments

COURSE CONTENTS:

1. GLP, Safety practices.
2. Handling and care of laboratory equipment - autoclave, hot air oven, incubator, and laminar airflow.
3. Media preparation and culture
4. Microbial staining techniques (simple, differential, and special staining, Viability test)
5. Isolation techniques, purification, and enumeration of microflora in soil, water, air
6. Preservation and maintenance of microorganisms (stock culture, subculture, cold storage, oil storage and lyophilization of the organisms)
7. Microbial characterization based on biochemical tests
8. Determination of microbial growth and factors affecting the growth (temperature, pH)
9. Isolation of *Rhizobium*
10. Study of fungus
11. Bacteriological Examination of Water by Multiple Tube Fermentation Test

References:	
1	Aneja, K. R. (2003). *Experiments in microbiology, plant pathology and biotechnology* (4th ed.). New Age International Publishers.
2	Atlas, R. M. (1995). *Principles of microbiology: A laboratory manual*. Wm. C. Brown Publishers.
3	Benson, H. J. (2017). *Microbiological applications: Laboratory manual in general microbiology* (14th ed.). McGraw-Hill Education.
4	Cappuccino, J. G., & Sherman, N. (2019). *Microbiology: A laboratory manual* (12th ed.). Pearson.
5	Harley, J. P. (2013). *Laboratory exercises in microbiology* (9th ed.). McGraw-Hill Education.