ST. JOSEPH'S UNIVERSITY

BENGALURU-27

DEPARTMENT OF BIOCHEMISTRY

SYLLABUS FOR

POST-GRADUATE PROGRAMME IN BIOCHEMISTRY

For Batch 2026-2028 onwards

SYLLABUS

Board of Studies

MSc Biochemistry syllabus: The credit summary and tentative syllabus was passed in the BoS meeting in February 2025. MSc Biochemistry course is being commenced from 2026. The former members of the board who greatly helped in shaping the MSc syllabus are:

1. Prof. V. R. Devaraj, Professor of Biochemistry, Bangalore City University.
2. Prof. Sarada Subramanian, Professor of Neurochemistry, National Institute of Mental Health and Neurosciences (NIMHANS) Bangalore
3. Mr. Anup Chandra Kant Production controller and quality control analyst, India Fine Chemicals
4. Prof. Mohanadas, Professor of Biochemistry, Department of Biochemistry, St. Joseph's University, Bangalore.
5. Dr. Libi Thomas, Dean of Chemical Sciences; Associate Professor, Department of Chemistry, St. Joseph's University, Bengaluru.
6. Prof. Sandra Misquith, Professor of Biochemistry, HoD, Department of Biochemistry, St. Joseph's University Bangalore.
7. Dr. Shraddha K. N. Asst. Professor of Biochemistry, Department of Biochemistry, St. Joseph's University Bangalore.
8. Dr. Daniel Andrew Gideon, Asst. Professor of Biochemistry, Department of Biochemistry, St. Joseph's University, Bangalore.
9. Dr. Sangita Das, Asst. Professor of Biochemistry, Department of Biochemistry, St. Joseph's University, Bangalore.

On 12th February 2026, the initial two semesters of this syllabus draft were passed in the BoS meeting comprised of the following members (who are the current members of the BoS):

1. Dr. Debdip Ghosh, Senior Global Product Manager, Biochemistry, Sigma Aldrich Chemicals Pvt. Ltd. (Merck), Bengaluru.
2. Dr. Rajiv Bhardwaj, Principal Mass Spectrometry Development Specialist, Waters Corporation, Hyderabad.
3. Dr. KS Chadrashekaraiah, Professor, Department of Biochemistry, Jnana Bharathi Campus, Bangalore University, Bengaluru.
4. Mr Rakshit, illustrious alumnus of the department of Biochemistry, PhD Scholar at NIMHANS, Bengaluru.
4. Dr. Libi Thomas, Dean of Chemical Sciences; Associate Professor, Department of Chemistry, St. Joseph's University, Bengaluru.
5. Dr. Shraddha K. N. Asst. Professor of Biochemistry, HoD, Department of Biochemistry, St. Joseph's University Bangalore.
6. Dr. Daniel Andrew Gideon, Asst. Professor of Biochemistry, PG Coordinator (and HoD i/c), Department of Biochemistry, St. Joseph's University, Bangalore.
7. Dr. Sangita Das, Asst. Professor of Biochemistry, Department of Biochemistry, St. Joseph's University, Bangalore.
8. Dr. Austin Richard S, Asst. Professor of Biochemistry, Department of Biochemistry, St. Joseph's University, Bangalore.

9. Dr. Lekha M. A., Asst. Professor of Biochemistry, Department of Biochemistry, St. Joseph's University, Bangalore.
10. Dr. C. N. Rahul, Asst. Professor of Biochemistry, Department of Biochemistry, St. Joseph's University, Bangalore.

Advisory Board Members:

The department would also like to place on record that the syllabus was designed keeping in mind the wide scope of the subject, the job market and the future of the students who graduate in the subject. Several syllabi around the world were considered for framing this programme. and obtaining the opinion of many prominent people in the field the syllabus was designed.
The members of the department would like to acknowledge all those who have greatly contributed to the framing of the syllabus. These include:

1. Prof. Jenny Loertscher, Prof. of Biochemistry, University of Seattle, USA
2. Prof. Drubojyothi Chatterjee Professor of Biochemistry, Vice Chancellor Amity University Kolkata.
3. Prof. Siddhartha Sarma, Chairman, Molecular Biophysics Unit, Indian Institute of Science, Bangalore
4. Prof. D. N. Rao. Hon. Professor of Biochemistry, IISc, Convenor, Talent Development Centre, The Advisor, Challakere campus
5. Prof. Harpreet Singh, Director of Physiology, Ohio State University, USA.
6. Prof. Devaraj, Chairman and Professor of Biochemistry, BCU
7. Prof. Sarada Subramanian, Professor of Neurochemistry, NIMHANS
8. Dr. Vishnu Janardhan Scientist II Protein Biology, Thermo Fisher Scientific
9. Mr. Anup Chandra Kant, Production controller and quality control analyst, India Fine Chemicals

Credits summary: List of theory and practical papers

Semester	Paper title	Paper code	No. of teaching hours	No. of credits	Total marks	Theory/ practical
Semester 1 (23 credits)	Bio-organic chemistry and chemical biology	BCH 7126	60	4	100	Theory
	Biophysics and analytical biochemistry	BCH 7226	60	4	100	Theory
	Metabolism and bioenergetics - I	BCH 7326	60	4	100	Theory
	Biomolecules and biomolecular structures	BCH7426	60	3	100	Theory
	Extraction and partial purification of biomolecules	BCH 7P126	88	4	100	Practical
	Characterization of biomolecules	BCH 7P226	88	4	100	Practical
Semester 2 (25 credits)	Enzymology and enzyme technology	BCH 8126	60	4	100	Theory
	Metabolism and bioenergetics - II	BCH 8226	60	4	100	Theory
	Advanced cell and molecular biology	BCH 8326	60	3	100	Theory
	Biomembranes, neurochemistry and biosignalling	BCH 8426	60	3	100	Theory
	MERCK theory course – Biopharmaceutical chemistry	BCH8526	60	3	100	Theory
	Enzymology lab	BCH 8P126	88	4	100	Practical
	Food and nutrition lab	BCH 8P226	88	4	100	Practical
Semester 3 (25 credits)	Bioinformatics and computational biology	BCH 9126	60	3	100	Theory
	Genetics, genetic engineering and cancer biology	BCH9226	60	4	100	Theory
	Immunology and immunological techniques	BCH9326	60	4	100	Theory
	Plant and microbial biochemistry	BCH9426	60	3	100	Theory
	Research methodology and scientific writing	BCH9526	60	3	100	Theory
	Plant and microbial biochemistry lab	BCH 9P126	88	4	100	Practical
	Molecular biology and genetic engineering lab	BCH 9P226	88	4	100	Practical
Semester 4 (19 credits)	Biochemistry project	BCH 0126	360	12	350	Project
	IGNITORS / OUTREACH		-	4	-	
	Registered NPTEL course		-	*3*	-	*Theory (Elective)*
			TOTAL	**92**		

PROGRAMME-SPECIFIC OUTCOMES

PSO No.	Programme Specific Outcome
PSO1	*Perform* isolation, purification, characterization and quantitative analysis of biomolecules using advanced biochemical methods.
PSO2	*Analyze* gene expression, regulation and genetic modifications using recombinant DNA and genome-editing technologies.
PSO3	*Interpret* metabolic and bioenergetic pathways in health, disease and physiological adaptation.
PSO4	*Apply* multi-omics, bioinformatics and computational biology tools for biological data analysis and biomarker discovery.
PSO5	*Understand* molecular mechanisms of disease including cancer, neurodegeneration and metabolic disorders.
PSO6	*Conduct* independent research culminating in a dissertation aligned with national and international research standards.

PROGRAMME OUTCOMES

PO No.	Programme Outcome
PO1	*Demonstrate* advanced conceptual understanding of biochemical principles including biomolecular structure, metabolism, molecular biology, enzymology, genetics and cell signalling.
PO2	*Apply* biochemical, analytical and molecular techniques to design, execute and interpret laboratory experiments with scientific rigor.
PO3	*Integrate* knowledge across multi-omics, bioinformatics and systems biology to analyze complex biological problems.
PO4	*Design* research projects using appropriate experimental strategies, controls, statistical tools and ethical practices.
PO5	Critically *evaluate* scientific literature and communicate research findings effectively through written and oral formats.
PO6	*Apply* computational tools, modelling approaches and data analysis techniques relevant to modern biochemical research.
PO7	*Demonstrate* professional ethics, reproducibility standards and responsible conduct in research and publication.
PO8	*Develop* interdisciplinary competence for careers in academia, research institutes, biotechnology, healthcare and allied industries.

Bloom's Taxonomy level mapping for the Course Outcomes (COs) (minimum 5 COs per paper).

Bloom's levels used:
R – Remember | U – Understand | Ap – Apply | An – Analyze | E – Evaluate | C – Create

In CO-PO-PSO mapping table, None – not directly relevant; 1 – low; 2 – medium; 3 – high

SEMESTER 1

BCH 7126: BIO-ORGANIC CHEMISTRY AND CHEMICAL BIOLOGY (60 h)

1. Stereochemistry of biomolecules (15 h)

Conformational analysis of cyclohexane, decalin and their derivatives – specific biological examples; mechanism and stereochemistry of nucleophilic addition reactions to carbonyl compounds with examples. Curtin-Hammett principle, its significance and applications. Haloketone rules as applicable to biochemical reactions.

Chirality of biomolecules: terminologies and definitions, significance of chirality in biomolecular structures and metabolism. Fundamentals of chirality generation: necessary conditions for stereoselectivity, concept of enantiomer/diastereomer – differentiation, methods of inducing stereoselectivity, strategies for stereoselective synthesis, kinetics and thermodynamics of stereoselective reactions. Optical activity – chirality, asymmetric centres, dextrorotatory and levorotatory, specific rotation (numericals), Fischer convention, Cahn-Ingold-prelog system.

2. Peptide Synthesis, labelling and chemical modifications (20 h)

Primary structure determination- end group analysis, cleavage of disulphide bonds, separation, purification and characterization of polypeptide chains, amino acids composition, special peptide cleavage reactions, separation and purification of peptide fragments, sequence determination (classical and modern methods), ordering of peptide fragments, assignment of disuphide bond positions.

Peptide and protein labelling using chromogenic and fluorogenic dyes – eg. Cy3 and Cy5 labelling, ICAT and ITRAQ labelling in mass spectrometry-based proteomics, SILAC, fusion proteins - eg. GFP, enzyme-protein conjugation and emerging protein technologies. Click chemistry and its use in protein modifications. Bioorthogonal reactions – relevant examples and applications.

In vitro post-translational modifications of proteins – phosphorylation and glycation as salient examples. N-terminal, internal and C-terminal modification reactions of peptides and proteins. Proximity labelling, biotinylation, chiral amines and peptide designing. Selective chemical protein modification – mention specific amino acids. Murburn PTMs.

Protection and deprotection: General aspects, need for protection, minimal versus global protection, protection of amino group by acid and base labile groups, protection of carboxyl group, the concept of orthogonal protection in peptide synthesis.

Side reactions in peptide synthesis: Deletion peptides, side reactions initiated by proton abstraction, protonation, over-activation and side reactions of individual amino acids.

Modern methods of peptide synthesis – solid phase and solution phase methods.

Protein sequencing, basics of protein sequencing and analysis, classical methods of protein sequencing, Edman degradation method, mass spectrometry-based techniques, challenges and limitations in protein sequencing, brief mention of recent advancements and future prospects.

3. Nucleic acids - synthesis and sequencing (10 h)

DNA and RNA synthesis and modification –eg. labelling (tagged by using fluorogenic and chromogenic material). Nucleic acid sequencing – basic strategy, restriction endonucleases (RE) and their characteristic features, how RE recognize DNA sequences; restriction maps; RFLP and its use, chemical cleavage methods – chain terminator method and its automation, latest methods of sequencing. Chemical synthesis of oligonucleotides. Modern sequencing methods- NGS and shotgun sequencing.

4. Carbohydrates: structure, reactions and applications (10 h)

Monosaccharides

a) Classification
b) Configuration and conformations- Haworth projection formula, anomeric C atoms, conformational variability (pyranose and furanose forms)
c) Sugar derivatives- glycosidic linkages, oxidation- reduction reactions, other biologically important sugar derivatives – deoxy sugars, amino sugars.

Synthesis of carbohydrate macromolecules through dehydration of sugars. Chemical synthesis: highlights on the need for synthesis; various approaches adopted for the chemical methods of oligosaccharide synthesis with examples. Chemical modifications of carbohydrate functional groups – applications. Dehydration synthesis, synthesis of carbohydrate polymers by dehydration.

Reactions at the anomeric centre: methods of glycosylation; details on the various types of glycosyl donors used. Solid-phase oligosaccharide synthesis: relevance & its importance; different strategies used; applications.

5. Heterocyclic aromatic compounds from nature (5 h)

Heterocyclic aromatic compounds, aromatic compounds in biochemistry (phenylalanine, tyrosine, tryptophan, indole, purines, pyrimidines), role of NAD^+ in metabolism, some heterocyclic compounds have important roles in nature.

Reference books

1. Clayden – Organic Chemistry
2. Bodanszky – Principles of Peptide Synthesis
3. Hermanson – Bioconjugate Techniques
4. Blackburn & Gait – Nucleic Acids in Chemistry and Biology
5. Varki – Essentials of Glycobiology
6. Joule & Mills – Heterocyclic Chemistry

Course Outcomes

CO	Course Outcome	Bloom's Level
CO1	Explain stereochemical principles, chirality, conformational analysis, and their significance in biomolecular structure and function.	U
CO2	Analyze organic reaction mechanisms and stereochemical outcomes in biological systems.	An
CO3	Analyze peptide synthesis, sequencing methods, and chemical modification strategies.	An
CO4	Evaluate chemical labeling, bioorthogonal reactions, and protein modification techniques in biochemical research.	E
CO5	Design strategies for selective synthesis and chemical modification of biomolecules.	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	1	1	–	1	3	2	–
CO2	3	3	2	2	–	2	3	3	2
CO3	3	3	3	2	–	2	3	3	2
CO4	2	3	3	3	1	2	3	3	3
CO5	2	3	3	3	1	3	3	3	3

BCH 7226: BIOPHYSICS AND ANALYTICAL BIOCHEMISTRY (60h)

(Reference text book – Raymond Chang)

1. **Thermodynamics:** 1st law of thermodynamics – work and heat with simple problems, enthalpy, bomb calorimeter and determination of calorific value of foods, heat capacity at constant pressure and constant volume – derivation and significance of equations.

2nd law of thermodynamics: spontaneous processes, entropy – thermodynamic definition, entropy change as a result of phase transition and as a result of heating, 3rd law of thermodynamics – concept of absolute entropy. Gibb's free energy (in biochemical systems alone) – properties, dependence on temperature and pressure, relation with phase equilibria. Importance of the Clapeyron and Clausius-Clapeyron equations – significance and biochemical applications. Phase diagram – water and carbon dioxide as an example, phase rule. (4h) [*limitations of thermodynamics – self study.*]

2. **Non electrolyte solutions:** colligative properties – osmotic pressure and its applications (including numericals). Solubility of proteins – effect of salt concentration, effect of organic solvents, effect of pH, crystallization (2h)
   Self-study – Definition and application of colligative properties – relative lowering of vapour pressure, depression of freezing point, elevation of boiling point and osmotic pressure. Molecular crowding.
3. **Electrolyte solutions:** electrical conduction in solution; applications of conductance measurements – acid-base titrations, solubility determination, ions in aqueous solutions, ionic activities, Debye-Huckel theory of electrolytes – salting in and salting out effects, colligative properties of electrolyte solutions – Donnan effect (specific biochemical cases), biological membranes – structural aspects, simple diffusion, facilitated diffusion and active transport, Donnan equilibrium involving proteins bearing multiple charges. (4h)
4. **Chemical equilibrium:** reactions in solutions, heterogeneous equilibria, influence of temperature, pressure and catalyst on equilibrium constant. Binding of ligands and metal ions to macromolecules – one binding site per macromolecule; n equivalent sites per macromolecule – direct plot, double reciprocal plot and Scatchard plot, equilibrium dialysis. (5h)
5. **Electrochemistry:** electrochemical cells, thermodynamics of electrochemical cells – the Nernst equation, single electrode potential, temperature dependence of EMF, applications of EMF measurements; pH measurements. Potentiometric titration of redox reactions. Membrane potential determination. Microbial fuel cells and clinical applications (4h)
6. **Acids, bases and buffers:** Titration of a weak monoprotic acid with a strong base and titration of a weak diprotic acid with a strong base. Isoelectric point and titration of proteins, buffers (2h)
   Self-study: Biological buffer systems – phosphate, protein and bicarbonate, applications of buffers for biochemical studies.
7. **Chemical kinetics:** Complex reactions – opposing reactions, consecutive reactions, chain reactions. Effect of temperature on reaction rates, potential-energy surfaces – collision theory, absolute rate theory (qualitative treatment), kinetic isotope effect, reactions in solutions, fast reactions in solutions – stop flow method and relaxation method. (6h)
8. **Intermolecular forces:** equation and explanation of – dipole-dipole interactions, ion-dipole interactions, ion induced dipole and dipole induced dipole interactions, dispersion or London interactions, hydrogen bond. Contextual interpretation in

protein-small molecule and protein-protein interactions (3h)

9. **Spectroscopy:**
   Self-study: terms in spectroscopy – absorption and emission, Beer's law, line width and resolution, intensity. Selection rules – spin forbidden transitions, symmetry forbidden transitions, regions of spectrum.
   NMR spectroscopy, ESR spectroscopy, microwave spectroscopy, IR spectroscopy, electronic spectroscopy. Interpretation of protein X-ray and NMR structures – simple understanding of the basic principles of X-ray crystallography, electron density maps, protein crystal structures exhibit less than atomic resolution (compare with crystal structures of organic molecules)- evidences that most crystalline proteins maintain their native structure. Protein structure determined by 2D-NMR (also 3D and 4D to be briefly mentioned). Protein folding and dynamics with H/D exchange NMR. limitations and advantages of NMR over X-ray crystallography.
   Mass spectrometry – MALDI and SELDI, fluorescence and phosphorescence, chemiluminescence, bioluminescence. (14h)
10. **Macromolecules and macromolecular separation methods:**
    Self-study: *methods for determining size, shape and molar mass of macromolecules – number average molar mass, weight average molar mass.*
    Techniques for the study of protein conformation in solution – label technique – spin label and fluorescence label, solvent perturbation technique – circular dichroism and infrared dichroism.
    Chromatographic separations – Ion exchange chromatography – principle, gradient elutions, types of ion exchangers. Gel filtration – principle, application, materials used, dialysis (specials case of molecular filtration). Affinity chromatography – principle, types and application. Other chromatographic techniques – adsorption, hydroxyapatite, HPLC-TLC, reverse phase – improved resolution – advantages. Isoelectric focusing, capillary electrophoresis, 2D-GE and DIGE.
    Self-study: Electrophoresis- Principle, mathematical relation, electrophoretic mobility, types of electrophoresis- gel (agarose, polyacrylamide), disc (detection of bands).
    Sedimentation in the ultracentrifuge – sedimentation velocity, sedimentation equilibrium, density gradient sedimentation, viscosity. Ultracentrifugation-sedimentation (mathematical formula) - sedimentation rate, sedimentation coefficient, frictional ratio (indicative of molecular solvation and shape), preparative ultracentrifugation-zonal and density gradient. (16h)

Course Outcomes

CO	Course Outcome	Bloom's Level
CO1	Explain the thermodynamic, kinetic and electrochemical principles governing biochemical systems.	U
CO2	Apply physicochemical principles to analyze solution behavior, equilibria, membrane potentials and macromolecular interactions.	Ap
CO3	Analyze spectroscopic data (UV–Vis, NMR, ESR, MS, fluorescence) to interpret biomolecular structure and dynamics.	An
CO4	Evaluate chromatographic, electrophoretic and ultracentrifugation techniques for separation and characterization of biomolecules.	E
CO5	Interpret quantitative binding, kinetic and equilibrium data using appropriate mathematical and graphical methods.	An
CO6	Design experimental strategies integrating biophysical and analytical tools for biomolecular research.	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	1	1	–	1	3	2	–
CO2	3	3	2	2	–	2	3	3	1
CO3	3	3	3	2	–	2	3	3	2
CO4	2	3	3	3	–	2	2	3	2
CO5	2	3	3	3	1	2	2	3	3
CO6	2	3	3	3	1	3	3	3	3

BCH 7326: METABOLISM AND BIOENEREGETICS- 1 (60 h)

1. Introduction to Metabolism and Bioenergetics 15 h

Self study: Basic aspects of thermodynamics (Laws, Gibbs free energy and its relationship to equilibrium constant and electrode potential- problems related to the same)

Relationship between bioenergetics and metabolism. Metabolic maps.

Metabolic pathways in general are common yet there is metabolic diversity?

The role of O_2 in metabolism- $CaCO_3$ is a biological sink for CO_2. Murburn concept, a new theory!

The flow of energy in the biosphere and its relationship to the carbon – oxygen cycles.

Metabolism- catabolism and anabolism- energy relationships between catabolic and anabolic pathways. The convergence and divergence of catabolic and anabolic pathways. Amphibolic intermediates.

Differences in corresponding pathways of catabolism and anabolism. Pseudocycles.

Metabolic regulation of pseudocycles.

The ATP cycle, roles of NAD^+ and NADPH in catabolic and anabolic processes.

Experimental methods to reveal metabolic pathways, metabolic inhibitors as tools, mutations that create metabolic blocks, Isotopic tracers as metabolic probes, metabolomics and metabolic flux analysis. Compartmentalization of metabolic pathways within cells.

Intracellular and extracellular metabolite quantification.

Bioenergetics 10h

Structure-function aspects of high energy compounds. E.T.C – Theory with carriers and details of electron shuttles.

Mechanism of oxidative phosphorylation, chemiosmotic hypothesis and murburn model- ATP yield and balanced equation, respiratory chain inhibitors, energy coupled reactions- all types with suitable examples, uncouplers, biological energy transducers. Energy generation in mechanochemical systems: muscle contraction.

2. Nutrition and Diet 15h

Glucogenic and ketogenic amino acids, storage and fate of amino acids, nitrogen balance.

Role of carbohydrates- simple sugars and complex carbohydrates. The fate of sugars and their storage. Glucose essential metabolic fuel for the brain. Lipids as fuel and essential components of cell membrane. Consequences of both low and high fat intake- essential fatty acid deficiency.

Normal and FAD diets- low carbs, high protein, high fat- short term and long term results of such diets.

Fiber or dietary fiber- material that cannot be digested- cellulose, hemicellulose, lignins, pectins and gums and their role in health and disease.

Diet variation- expectant mothers, children, diabetics and geriatrics (biochemical reasons why the diets are different)

Fat soluble (A, D, E, K) and water-soluble vitamins (C and B vitamins, particularly thiamine, flavin, folate, niacin, biotin, cyanocobalamine)- solubility and overview of their role in biological processes. Structure and important reactions they are involved in. Diseases caused by their deficiency.

3. Metabolism of Proteins 12h

Transamination, hydrolysis, carbamoylphosphate synthesis.

Formation of uric acid

Metabolism of carbon skeletons- creatinine, melanin and iodothyronines

Formation of one carbon compounds

Formation of gluconeogenic intermediates and ketogenic intermediates from amino acids.

Biosynthesis of amino acids (apart from those obtained by transamination process)- Glycine, serine, tyrosine, aspartic acid, glutamic acid, cysteine, proline and hydroxyproline.

4. Exercise and its effect on metabolism – 3 h

Metabolic rate, factors influencing metabolic rate, effect of exercise on basal metabolic rate (how BMR is affected by exercise), types of exercise and their influence on metabolic rate.

5. Sleep wake cycle and its role in metabolism: - 5 h

Introduction to the sleep wake cycle; importance of sleep wake cycle; regulation of sleep wake cycle – molecular and genetic control – neurotransmitters (melatonin, acetylcholine), prostaglandins etc and genes that have been identified - *BMAL1*/*BMAL2*, *CLOCK*, *CRY1*/*CRY2*, and *PER1*/*PER2*/*PER3* – their role in regulation at the transcription and translation level and their involvement in the metabolic processes and cell signalling. Function of sleep; mechanism of sleep. Effect of sleep on BMR. Synthesis of molecules affected by the circadian clock (one or two examples to illustrate the point).

Reference books:

1. Lehninger Principles of Biochemistry – Nelson & Cox
2. Voet & Voet – Fundamentals of Biochemistry
3. Harper's Illustrated Biochemistry – Murray et al.
4. Bioenergetics – Nicholls & Ferguson
5. Advanced Nutrition and Human Metabolism – Gropper & Smith
6. Molecular Biology of the Cell – Alberts et al.

Course Outcomes

CO	Course Outcome	Bloom's Level
CO1	Demonstrate comprehensive knowledge of thermodynamic principles and energy transformation in biological systems.	U
CO2	Apply principles of metabolic integration and redox biochemistry in cellular metabolism.	Ap
CO3	Analyze metabolic flux and experimental approaches used to investigate metabolic networks and energy balance.	An
CO4	Critically evaluate regulatory mechanisms governing metabolism and human physiology.	E
CO5	Integrate metabolic and bioenergetic concepts to design experimental strategies in living systems.	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	1	1	–	1	3	2	–
CO2	3	3	2	2	–	2	3	3	2
CO3	3	3	3	2	–	2	3	3	2
CO4	2	3	3	3	–	2	2	3	3
CO5	2	3	3	3	1	2	3	3	3

BCH7426: BIOMOLECULES AND BIOMOLECULAR STRUCTURES (60 h)

(Ref: Voet & Voet, Garrett and Grisham)

I. Amino acids and proteins (20 h)

1. **Amino acids-** What are amino acids, L-α- amino acids of proteins, classification based on R group at pH 6.5, non-standard amino acids 4-OH pro and 5-OH lys in collagen, ribosomal proteins and histones- acetylated methylated and/or phosphorylated, N-formyl-Met, γ-carboxyglu. Calculation of amino acid pKa, pI value. D-amino acids in plants and microorganisms (not in higher vertebrates), essential and non-essential amino acids. Specialized roles of amino acids. (5 h)
2. **Protein structure, folding and dynamics** (15 h)

a) Secondary structure of proteins - peptide bond and its characteristics, Ramachandran plot analysis; helical structures, β- structures, non-repetitive structures. Fibrous proteins- α-keratin- a helix of helices, silk fibroin – a β- pleated sheet, collagen- a triple helical coil, elastin- a non-repetitive coil. Globular proteins- Interpretation of protein X ray and NMR structures, tertiary structures.

b) Interpretation of protein X-ray and NMR structures- simple understanding of the basic principles – limitations and advantages of NMR over X-ray crystallography.

c) Tertiary structure- Features of tertiary structures- domains and super secondary structures.

d) Protein stability- electrostatic forces- ionic interactions, dipole-dipole interactions, hydrogen bonding, hydrophilic forces, disulphide bonds.

e) Quaternary structures - subunit interactions. Symmetry in proteins - cyclic symmetry, dihedral symmetry, other rotational symmetries, helical symmetry.

f) Protein folding, dynamics and structural evolution- protein folding - theory and experiment. Protein renaturation, protein folding pathways-

Self-study: *hypothetical folding pathway of a dimeric protein, eg. bovine pancreatic trypsin inhibitor (BPTI), role of primary structures in determining protein folding pathways. Role of folding accessory proteins- Types. Protein disulphide isomerases and peptidyl prolyl-cis trans isomerases. Molecular chaperones.*

g) Protein dynamics- General concepts- classification of intramolecular motions of proteins- atomic fluctuation, collective motions, triggered conformational changes. Protein core mobility - aromatic ring flipping. Monitoring protein folding - pulsed H/D exchange methods.

Self-study: *Structural evolution of proteins - Structures of cytochromes – c- type cytochromes structural features, prokaryotic c- type cytochromes are structurally related to cyt c.*

II. Sugars and polysaccharides (10h)

1. **Polysaccharides (glycans)** –Disaccharides. Structural polysaccharides- cellulose and chitin. Storage polysaccharides- starch and glycogen. Glycosaminoglycans- hyaluronic acid, chondroitin sulphate, dermatan sulphate, keratan sulphate and heparin. (3h)
2. **Glycoproteins** – proteoglycans - mechanical properties of cartilages and modulation of protein growth factors (2 h)

Bacterial cell walls. Glycoproteins structure and function – reason for high diversity, N and O linked glycoproteins and their role, intercellular interactions. Recognition of carbohydrates by proteins: how cells talk to each other, relevance in disease; infection by microorganisms and possible methods of intervention; specific examples- cholera, flu, etc. (4 h)

III. Lipids and membranes (10 h)

a) Lipid classification – Saturated and unsaturated fatty acids, triacylglycerols, glycerophospholipids, sphingolipids and cholesterol

b) Properties of lipid aggregates – micelles and bilayers, liposomes

c) Biological membranes – membrane proteins, fluid mosaic model - Erythrocyte membrane,

Blood groups, Gap junction

d) Membrane assembly and protein targeting –

Generation of new membranes, lipid distribution in membranes – membrane protein role in phospholipids' flip flops, origin of the characteristic composition of lipids in a membrane.

a. Lipid linked proteins – Prenylated proteins, fatty acylated proteins, GPI linked proteins
b. Lipoprotein characteristics, composition in plasma – chylomicrons, VLDL, IDL and LDL, HDL, apolipoproteins.
c. Fate and functions of lipoproteins – chylomicrons and VLDL, cholesterol and HDL

IV. Structure-function of nucleic acids and unusual nucleic acid structures (15 h)

Structure of nitrogenous bases in nucleic acids- common and uncommon bases, conformations of nucleosides. Chemical structure and base composition of DNA and RNA – DNA's base composition - Chargaff's law, modified nucleic acids, RNA base hydrolysis. Sugar-Phosphate chain conformations – torsion angles; sugar ring pucker. Base-pairing – Unconstrained A-T base pairs assume Hoogsteen geometry; Non Watson-Crick base pairs. Base stacking and hydrophobic interactions in aqueous medium; stabilization by hydrophobic interactions. Ionic interactions. (8 h)

Double helical structures – Watson and Crick structure- B-DNA; deviations from ideal Watson and Crick structures. A and Z forms of DNA. Forces stabilizing DNA structure, acid-base chemistry and tautomerism in nucleobases, formation of major and minor groove (2 h).

Self-study: *Unusual DNA structures- Z DNA, triple helical DNA, cruciform DNA, G-quadruplex DNA and Holliday junctions.*

Factors stabilizing nucleic acid structures – denaturation-renaturation (cooperative process and reversibility). DNA melting temperature, c_0t curves, C-value paradox, DNA hybridization (2 h). Spectroscopy of nucleic acids- absorption of UV light (3 h).

Self-study: *Supercoiled DNA – superhelix topology; toroidal or interwound and relaxation by nicking one strand. Measurements of supercoiling – role of intercalating agents in controlling supercoiling, separation of DNA by gel electrophoresis according to their linking number; physiological solution of DNA - 10.4 base pairs per turn.*

Characteristic reactions of nitrogenous bases and nucleic acids- nucleophilic and electrophilic reactions, reactions causing sugar-phosphate backbone cleavage (2 h). Levels of RNA structure, types of RNA (hnRNA, mRNA, rRNA, tRNA, snoRNA, snRNA, lncRNA, miRNA) and their cellular functions (in brief) (2 h).

1. Voet, D., Voet, J. G., & Pratt, C. W.
   Fundamentals of Biochemistry: Life at the Molecular Level. Wiley.
2. Garrett, R. H., & Grisham, C. M.
   Biochemistry. Cengage Learning.
3. Nelson, D. L., & Cox, M. M.
   Lehninger Principles of Biochemistry. W.H. Freeman.
4. Berg, J. M., Tymoczko, J. L., Gatto, G. J., & Stryer, L.
   Biochemistry. W.H. Freeman.
5. Cantor, C. R., & Schimmel, P. R.
   Biophysical Chemistry. W.H. Freeman.
6. Alberts, B. et al.
   Molecular Biology of the Cell. Garland Science.

Course Outcomes

CO	Course Outcome	Bloom's Level
CO1	Describe the structural organization, their chemical properties and hierarchical levels of structure.	U
CO2	Interpret structural information obtained from biophysical techniques to understand biomolecular architecture and dynamics.	An
CO3	Analyze structure–function relationships in biomolecules, correlating molecular features with biological roles.	An
CO4	Evaluate the physicochemical forces and molecular involved in intermolecular interactions.	E
CO5	Predict the structural and functional consequences of mutations and chemical modifications.	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	1	1	–	1	3	2	–
CO2	3	3	2	2	–	2	3	3	2
CO3	3	3	3	2	–	2	3	3	2
CO4	2	3	3	3	1	2	2	3	3
CO5	2	3	3	3	1	3	3	3	3

BCH 7P126: EXTRACTION AND PARTIAL PURIFICATION OF BIOMOLECULES (88 h)

Each student shall maintain continuity of samples between Practical 1 and Practical 2 wherever feasible. Extraction and partial purification from sources will be done in practical 1 and analysis as well as estimation will be carried out in practical 2.

Module 1: Pigments & Phenolics

1. Extraction of plant pigments
2. Extraction of lycopene and β-carotene
3. Extraction of flavonoids and total phenols

Module 2: Proteins

4. Isolation of heme from chicken blood
5. Extraction and purification of casein
6. Extraction of lectins

Module 3: Carbohydrates

7. Extraction of starch and glycogen
8. Extraction of agarose

Module 4: Lipids

9. Extraction of triglycerides and phospholipids
10. Extraction of essential oils

Module 5: Nucleic Acids

11. DNA extraction using CTAB

Course Outcomes

CO	Course Outcome	Bloom's Level
CO1	Perform systematic extraction of various biomolecules from biological sources using appropriate solvents and standardized laboratory protocols.	Ap
CO2	Apply suitable partial purification techniques to enhance the purity of extracted biomolecules.	Ap
CO3	Analyze the yield, recovery efficiency, and preliminary purity of biomolecules using quantitative estimations.	An
CO4	Identify sources of experimental error and troubleshoot procedural limitations to optimize extraction efficiency and reproducibility.	An
CO5	Maintain accurate laboratory records, and document experimental observations following scientific and ethical standards.	Ap

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2	2	–	2	3	3	1
CO2	2	3	3	2	–	2	3	3	2
CO3	2	3	3	3	1	2	3	3	3
CO4	2	2	3	3	2	2	2	3	3
CO5	1	2	2	3	3	2	2	2	2

BCH 7P226: CHARACTERIZATION OF BIOMOLECULES (88 h)

Emphasis will be placed on calibration, standard curve construction, error analysis, and interpretation of spectral and chromatographic data. Standard curve preparation, calibration, error calculation, yield calculation and statistical analyses of data will be carried out wherever necessary for each of the experiments.

Module 1: Spectral and Chromatographic Analysis of Pigments

1. Characterization of plant pigments using UV–Visible spectroscopy and thin layer chromatography (TLC)
2. Characterization of lycopene and β-carotene using UV–Visible spectroscopy

Module 2: Protein Characterization

3. Characterization and estimation of heme from chicken liver/blood using UV–Visible spectroscopy
4. PAGE and UV estimation of casein
5. Preliminary characterization of lectin polysaccharides

Module 3: Carbohydrate Quantification

6. Characterization and quantification of starch and glycogen
7. Determination and purity assessment of agarose

Module 4: Lipid Analysis

8. Characterization of triglycerides and phospholipids using TLC and lipid estimation methods
9. Qualitative and quantitative analysis of essential oils

Module 5: Nucleic Acid Analysis

10. UV estimation of DNA extracted using CTAB method
11. Quality and quantity assessment using spectroscopy and agarose gel electrophoresis

REFERENCES

1. Sawhney, S. K., & Singh, R. *Introductory Practical Biochemistry*. Narosa Publishing House, New Delhi.
2. Plummer, D. T. *An Introduction to Practical Biochemistry*. McGraw-Hill Education.
3. Wilson, K., & Walker, J. *Principles and Techniques of Biochemistry and Molecular Biology*. Cambridge University Press.
4. Sadasivam, S., & Manickam, A. *Biochemical Methods*. New Age International Publishers.
5. Jayaraman, J. *Laboratory Manual in Biochemistry*. New Age International Publishers.
6. Harborne, J. B. *Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis*. Springer.
7. Dey, P. M., & Harborne, J. B. *Methods in Plant Biochemistry*. Academic Press.
8. Christie, W. W. *Lipid Analysis: Isolation, Separation, Identification and Structural Analysis of Lipids*. Oily Press.
9. Goodwin, T. W. *Plant Pigments*. Academic Press.
10. Aspinall, G. O. *Polysaccharides*. Pergamon Press.
11. Sambrook, J., & Russell, D. W. *Molecular Cloning: A Laboratory Manual*. Cold Spring Harbor Laboratory Press.
12. Brown, T. A. *Gene Cloning and DNA Analysis: An Introduction*. Wiley-Blackwell.

13. Hames, B. D., & Rickwood, D. *Gel Electrophoresis of Proteins: A Practical Approach*. Oxford University Press.
14. Cantor, C. R., & Schimmel, P. R. *Biophysical Chemistry*. W. H. Freeman and Company.

CO	Course Outcome	Bloom's Level
CO1	Perform spectroscopic, electrophoretic, and chromatographic characterization of biomolecules.	Ap
CO2	Construct and validate standard curves using appropriate calibration methods and apply them for quantitative estimation of biomolecules.	Ap
CO3	Interpret spectral, chromatographic, and electrophoretic data to determine concentration, purity, and qualitative characteristics.	An
CO4	Evaluate experimental accuracy, precision, sources of error, and statistical reliability of analytical measurements.	E
CO5	Present analyzed data systematically using graphs, statistical summaries, and scientific documentation formats.	An

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2	2	–	2	3	3	1
CO2	2	3	3	2	–	2	3	3	2
CO3	2	3	3	3	1	2	3	3	3
CO4	1	2	3	3	3	2	2	3	3
CO5	1	2	2	3	3	2	2	2	3

SEMESTER 2

BCH 8126: ENZYMOLOGY AND ENZYME TECHNOLOGY (60 h)

I. Classical Enzymology **46 h**

1. IUB Classification, comparison between chemical and biological (enzyme) catalysis, coenzyme, cofactors
   Collision theory - intermolecular vs intramolecular reactions i.e. extent of randomness and reaction rate; fruitful collisions, orientation factor 'P'
   Functional groups (R-groups of amino acids) involved in enzyme catalysis, classical approaches to identify crucial amino acid(s) involved in enzyme catalysis (4h)
2. Mechanism of enzyme reactions: General & specific acid-base catalysis, covalent catalysis, metal ion catalysis, catalysis by orientation, catalysis by approximation, induced fit and desolvation; transition state stabilization. Relevant examples - serine protease, carbonic anhydrase (metalloenzyme) and restriction endonuclease. (4h)
3. Transition state analogue, catalytic antibodies, suicide inactivation. (2h)
4. Thermodynamics of enzyme-substrate interactions, Binding energy in catalysis; Fundamental principles of reaction kinetics and equilibria. (3h);
5. Measurement and magnitude of enzyme rate constant; Transient kinetic methods Detection of intermediate in reactions-Relaxation methods. (2h)
6. Steady state enzyme kinetics; differences between a chemical equilibrium and steady state kinetics; Limitation of Michaelis-Menten equation, Briggs Haldane kinetics; Van Slyke-Cullen behavior, Physiological significance of kinetic parameters. Non-productive binding. (4h)
7. Multisubstrate systems and their kinetics; Multienzyme complexes (2h)
8. Enzyme Inhibition: Reversible (competitive, uncompetitive, non-competitive and mixed inhibition). Lineweaver Burk plot, Dixon, Eadie-Hofstee, Hanes-Woolf plots. Kinetics of inhibition with suitable examples; Irreversible inhibitors – with suitable examples of different kinetic plots. (6h)
9. Reactions (and mechanisms) of coenzymes – NAD^+ $NADP^+$, folic acid, Vit.B_{12} FMN/FAD, coenzyme A, lipoic acid, biotin, tetrahydrofolate, thiamine pyrophosphate, pyridoxal phosphate and metal ions as biocatalysts.
   Assignment and self-study topic: Biocatalysts from extreme thermophilic and hyperthermophilic archaea and bacteria (4h)
10. Regulation of enzyme activity: Covalent modifications (examples) [post translational modifications and proteolytic activation of enzymes] Blood clotting cascade, Zymogens, isozymes and their significance (LDH) (3h)
11. Allosteric enzymes and their modes of action; concerted, sequential and morpheein theory of allosterism. Sigmoidal kinetics; aspartate transcarbamoylase (ATCase), T & R states (quaternary structures), positive and negative modulators; protein kinase A (PKA) and role of cAMP. Ensemble models for allosterism. Design of protein switches based on an ensemble model of allostery. (9h)
12. Enzyme reconstitution, enzyme assays, isolation, purification and criteria for determining purity of enzymes. (3h)

II. Novel mechanistic ideas and treatments in enzymology: Murzymes and their mechanisms

II. Industrial and Clinical uses of Enzymes (Applied Enzymology) **14 h**

1. Industrial Enzymes- Thermophilic enzymes, amylases, lipases, proteolytic enzymes in meat and leather industry, enzymes used in various fermentation processes, cellulose

degrading enzymes, Metal reducing and metal chelating enzymes. (4h)

2. Clinical enzymes- Enzymes as thrombolytic agents, Anti-inflammatory agents, streptokinase, asparaginase, Isoenzymes like CK and LDH, Transaminases (AST, ALT), Amylases, Cholinesterases, Phosphatases. Immobilization of enzymes, ELISA. Biosensors. Enzyme engineering - site directed mutagenesis, directed evolution, designer enzymes (5h)
3. Enzyme Structure Activity Relationship (SAR) and Drug discovery- Properties of enzymes. Molecular dynamics and molecular docking in enzyme studies. Lead compound, Structure based drug design, combinatorial chemistry, High-throughput screening, Case study of DHFR etc. Enzyme promiscuity, moonlighting enzymes (5h)

Reference Books:

1. Fundamentals of Enzymology; 3rd Edn. Nicholas C. Price and Lewis Stevens, Oxford University Press (2012).
2. Enzymes; Trevor Palmer, East – West Press Pvt. Ltd., Delhi (2004).
3. Enzymes: A Practical Introduction to Structure, Mechanism, and Data Analysis; Robert A. Copeland, Wiley-VCH Publishers (2000).
4. Enzyme Kinetics and Mechanism; Paul F. Cook, W. W. Cleland, Garland Science (2007).
5. Biochemical Calculations, Irwin H. Segel (1976) 2nd Ed. John Wiley and Sons.

Course Outcomes

CO	Course Outcome	Bloom's Level
CO1	Explain classical and modern enzyme kinetics models governing enzyme–substrate interactions.	U
CO2	Analyze kinetic data using appropriate graphical and mathematical approaches and interpret physiological significance of kinetic parameters.	An
CO3	Evaluate mechanisms of enzyme inhibition and regulation.	E
CO4	Apply principles of enzyme technology and enzyme engineering approaches.	Ap
CO5	Design enzyme-based experimental and translational strategies.	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	1	1	–	1	3	2	–
CO2	3	3	3	2	–	2	3	3	2
CO3	2	3	3	3	1	2	3	3	3
CO4	2	3	2	2	1	2	3	3	3
CO5	2	3	3	3	1	3	3	3	3

BCH 8226: METABOLISM AND BIOENEREGETICS - 2 (60 h)

1. **Carbohydrate metabolism** **15h**

   Glucose metabolism (glycogenesis, gluconeogenesis and feeder pathways of other monosaccharides)
   Glycogenolysis
   Glycogen storage diseases or inborn errors of glycogen metabolism- brief overview
   Regulation of glycogen metabolism
   Biosynthesis of lactose and fructose
   Uronic acid pathway- fate of uronic acids
   Amino sugar biosynthesis
   hexose monophosphate shunt pathway and its regulation
   Energy balance sheet of the above-mentioned processes.
   Metabolism of glycosaminoglycans (GAGs) – synthesis and breakdown; relevance in health and disease

2. **Lipid Metabolism** **15h**

   Oxidation of fatty acids –beta, omega, alpha and unsaturated. Energy balance sheet of fatty acid oxidation.
   Formation of ketone bodies
   Fatty acid biosynthesis- cytoplasmic (prototype), denovo, mitochondrial chain elongation, microsomal chain elongation and desaturation.
   Triglyceride synthesis and breakdown
   Biosynthesis of prostaglandins, thromboxanes and leukotrienes and their biological significance
   Phospholipid metabolism – phosphatidylethanolamines, phosphatidylcholines, phosphatidylinositols, sphingomyelin, cardiolipin, plasmalogens, cerebrosides.

3. **Nucleic acid metabolism:** **8 h**

   Purine and pyrimidine nucleotides: biosynthesis and its regulation.
   Deoxyribonucleotides: biosynthesis and regulation. Biosynthesis of nucleotide co-enzymes. Catabolism of purine and pyrimidine nucleotides.

4. **Metabolic disorders and inborn metabolic defects:** **10 h**

   Hemoglobin, Met-Hb, embryonic-Hb, heme metabolism associated diseases, sickle cell anemia, thalassemia, murburn concept and respiratory issues, malnutrition, measurement of fuel values of foods, measurement and calculation of BMR, Metabolic disorders of amino acid metabolism and urea cycle, phenylketonuria, alkaptonuria, albinism, Lesch-Nyhan syndrome, disorders of nucleic acid metabolism. Biochemical mechanism of blood clotting and hemorrhagic disorders, disseminated intravascular coagulation, acquired prothrombin complex disorders.

5. **Redox biochemistry:** **12 h**

   Electronic structure of ROS. Types of reactive species in cellular systems – ROS, RNS, RSS, RCS and reactive halide species. – ROS, RNS, RSS, RCS and reactive halide species. Oxidative and reductive stress – generation of ROS from mitochondria and other cellular redox enzymes. Cellular antioxidant defense system (SOD, catalase, glutathione peroxidase, glutathione reductase, thioredoxin system). Glutathione as a redox buffer. Glutathione redox potential calculation using Nernst equation. Plasma membrane redox system (PMRS), ATP:ADP, NAD^+: NADH ratio. Methods for

measurement of ROS – enzymatic and fluorimetric. Antioxidants – health benefits and potential harmful effects. Redox compartmentalization in cells. Diseases related to dysregulation of redox homeostasis. Murburn concept and its applications in diverse areas such as biological electron transfer.

Course Outcomes

CO	Course Outcome	Bloom's Level
CO1	Describe in detail the metabolic pathways and interconnections within cellular metabolism.	U
CO2	Analyze regulatory mechanisms governing carbohydrate, lipid, and nucleotide metabolism under normal physiological conditions and in pathological states.	An
CO3	Evaluate the influence of nutritional status, hormonal regulation, and redox balance on metabolic flux and energy homeostasis.	E
CO4	Interpret the biochemical basis of metabolic disorders and redox-related diseases.	An
CO5	Integrate metabolic networks across macromolecule pathways and redox systems.	An

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	2	1	–	1	3	2	–
CO2	3	3	3	2	–	2	3	3	2
CO3	2	3	3	2	–	2	2	3	2
CO4	2	3	3	3	1	2	2	3	3
CO5	2	3	3	3	1	3	3	3	3

BCH 8326: ADVANCED CELL AND MOLECULAR BIOLOGY

Genome organization (6 h)

Viral (bacteriophage), mitochondrial and chloroplast DNA. Topology of nucleic acids-linking number and intercalation by dyes (2 h). DNA methylation, nucleosomes and higher order chromatin structures, histone tails and their modifications (1 h). Genome organization in viruses, bacteria and eukaryotic organisms, gene density and complexity - comparison between viruses, bacteria, humans and higher plants (1 h). Motifs present in DNA and RNA-binding proteins and factors involved in nucleic acid-protein interactions (2 h).

Central dogma and information pathways (14 h)

Replication, transcription and translation - prokaryotic and eukaryotic mechanisms to be discussed in brief -

Self-study: DNA replication: Unit of replication and enzymes, replication origin and replication fork, fidelity and processivity of replication, extrachromosomal replicons (plasmid)- theta and sigma (rolling circle) replication.

Replisome and chemistry of DNA polymerase action. Types of DNA polymerases in E. coli and in eukaryotes. (2 h)

Transcription and RNA processing: Transcription factors and machinery - RNA polymerases, transcription activators and repressors. Transcription in prokaryotes and eukaryotes-initiation, elongation and termination. Eukaryotic rRNA genes, formation of eukaryotic tRNA molecules, RNA polymerase II Promoters, Eukaryotic promoters for RNA polymerase III, hypersensitive sites, Upstream activation sites and enhancers. RNA Processing: Capping and polyadenylation, Splicing mechanisms - major and minor, Alternative splicing pathways, Self splicing introns, Splicing of tRNA precursors, rRNA precursors, small RNAs, Micro RNAs, RNA editing, RNA transport, exon shuffling. (7 h)

Translation and post-translational modifications: Outline of Translation, The genetic code, Wobble hypothesis, The decoding system, codon-anticodon interaction, the special properties of the prokaryotic Initiator tRNAfMet. Protein Synthesis in prokaryotes and eukaryotes - formation of initiation complex, initiation factors and their regulation, elongation and elongation factors, termination, aminoacylation of tRNA, tRNA-identity, aminoacyltRNA synthetases, translational proofreading, suppressors, Inhibitors and Modifiers of protein synthesis. Ribosomes: the special properties of the prokaryotic and eukaryotic ribosomes. Regulation of translation. (6 h)

Stem Cells and Cellular Differentiation (6 h)

Properties of stem cells – embryonic, adult and induced pluripotent stem cells (iPSCs). Stem cell niche and self-renewal. Lineage commitment and differentiation. Cellular reprogramming. Role of transcription factors in fate determination.

Cell Adhesion, Migration and Cytoskeletal Dynamics (6 h)

Cell–cell and cell–matrix interactions. Integrins and cadherins. Focal adhesions. Actin remodeling and cell motility. Epithelial–mesenchymal transition (EMT). Cytoskeletal regulation in migration and invasion.

Cellular Stress Responses and Homeostasis (6 h)

Oxidative stress and reactive oxygen species. Unfolded protein response (UPR). Heat shock response and chaperones. Proteostasis and ubiquitin–proteasome system. Cellular adaptation to hypoxia (HIF pathway). Mechanisms of cellular aging.

4. Regulation of gene expression (10 h)

Regulation of Gene expression in Prokaryotes: General aspects of Regulation, transcriptional regulation - inducible and repressible system, positive regulation and negative regulation; Operon concept – Lactose, Tryptophan, Arabinose and galactose operon. RNA interference, mRNA half-life, riboswitches, ribozymes. (2 h)

Gene expression in Eukaryotes: Regulatory strategies in Eukaryotes, Gene alteration (Gene loss, Gene amplification, Gene rearrangement: the joining of coding sequences in the immune system), Regulation mediated through Transcription factors, Regulation of enhancer activity, role of chromatin changes in regulating gene expression, role of nucleosome remodeling and posttranslational modifications in transcription initiation, methylation and epigenetics. (3 h)

RNA processing, RNA splicing, RNA degradation and RNA interference in regulation of gene expression (2 h).

Regulation of gene expression in plant cells by light. Transcriptional control by hormones and signaling factors, Translational control, Diseases associated regulation defects (3 h).

5. DNA repair pathways and the mechanisms of DNA repair (12 h)

Cell cycle - basic overview. DNA replication and recombination.

Recombination: Homologous (General and Site specific) and non-homologous recombination in prokaryotes and eukaryotes.

Mechanisms of DNA damage and repair pathways: mention the impact of UV rays, ionizing radiation, alkylating agents, reactive electrophiles, polycylic aromatic hydrocarbons (PAHs). UV repair (UVR), base excision repair (BER), nucleotide excision repair (NER), mismatch repair (MMR), translesion synthesis, single and double strand break-repair (SSBR and DSBR). Diseases related to dysregulation of cell cycle and DNA repair.

Text Books

1. Watson, J.D., Baker, T.A., Bell, S.P., Gann, A., Levine, M., Losick, R. (2014)
2. Molecular Biology of Gene. Cold Spring harbor, New York. 2. Nelson, D.L. and Cox, M.M. (2012)
3. Lehninger's Principle of Biochemistry. W.H. Freeman, New York.

Suggested Reading

1. Lodish, H., Berk, A., Kaiser, C.A., Krieger, M., Bretscher, A., Ploegh, H., Amon, A., Martin, K.C. (2016) Molecular Cell Biology. W.H. Freeman, New York.
2. Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K. and Walter, P. Molecular biology of the cell. 4th edn.

Course Outcomes

CO	Course Outcome	Bloom's Level
CO1	Explain the organization of genomes in various biological organisms.	U
CO2	Analyze the molecular mechanisms of DNA replication, transcription, translation in prokaryotic and eukaryotic systems.	An
CO3	Evaluate regulatory strategies governing gene expression and signal-dependent modulation of gene expression.	E
CO4	Analyze DNA damage responses & repair pathways and their relationship to cell cycle regulation and genome stability.	An
CO5	Integrate molecular and cellular pathways such as stem cell regulation, differentiation to explain disease mechanisms and cellular dysfunction.	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	1	1	–	1	3	2	–
CO2	3	3	3	2	–	2	3	3	2
CO3	2	3	3	3	–	2	2	3	3
CO4	2	3	3	3	1	2	2	3	3
CO5	2	3	3	3	1	3	3	3	3

BCH8426: BIOMEMBRANES, NEUROCHEMISTRY AND BIOSIGNALLING (60 h)

Membrane Biology and Intracellular Trafficking (8 h)

Fluid mosaic model and membrane asymmetry. Lipid rafts and membrane microdomains. Membrane transport – passive diffusion, facilitated diffusion, active transport, ion channels and pumps. Vesicular trafficking – endocytosis, exocytosis, clathrin-mediated transport, COPI/COPII vesicles. SNARE proteins and vesicle targeting specificity. Receptor-mediated endocytosis. Protein targeting and sorting signals (signal peptides, nuclear localization signals, mitochondrial targeting sequences). ER-associated degradation (ERAD).

Lipid bilayer organization and asymmetry. Lipid rafts and membrane microdomains. Membrane curvature and vesicle formation. Cytoskeleton–membrane interactions. Membrane protein organization and lateral mobility. Organelle membranes and compartmental identity. Membrane contact sites (ER–mitochondria, ER–plasma membrane)

Neuronal Signalling as a Specialized Membrane System (8 h)

Neurons as excitable membrane systems. Ion gradients and action potentials. Synaptic vesicle cycle. Neurotransmitter receptors. Neuromuscular junction. Axonal transport. Plasticity and synapse elimination. Techniques involved in neurophysiology studies.

Cellular and molecular neurochemistry of the nervous system (12 h)

Major cell types of central and peripheral nervous system, brain lipids and other macromolecules, cytoskeleton, axonal transport, cell adhesion molecules, growth cone, neurotrophic factors, cell death mechanisms.
General principles of synaptic transmission, neurons at rest, excitability, action potential, axonal conduction, formation and elimination of central (excitatory & inhibitory) synapses, peripheral synapses (neuromuscular junctions) murburn model of electrophysiology

Inter and intracellular signalling-1 (8 h)
Endocrine hormones and their receptors, G-protein coupled receptors (GPCRs), cyclic nucleotides and effector enzymes - cyclases, phosphodiesterases and phospholipases. Phosphoinositides, calcium signalling and calmodulins. Serine/Threonine kinases (STKs), MAPK pathway, intrinsic tyrosine kinases (ITKs) and growth factor signalling, non-receptor protein tyrosine kinases. Neurotransmitters and their receptors (Acetylcholine, catecholamines, serotonin, histamine, glutamate, gamma amino butyric acid, purinergic signalling, neuropeptides).

Inter and intracellular signalling-2 (8 h)
JAK/STAT pathway. Signalling of insulin, growth hormone, epinephrine. Developmental signalling pathways - Wnt and Notch signalling. Factors involved in cellular differentiation in stem cells.

Nuclear receptors - types, signalling mechanisms and functions. Examples of PXR/SXR, RAR, RXR, LXR, VDR, ER and PR to be mentioned briefly. Hormone response elements, transcription factors and mediation of hormonal signalling through transcription factors.

Apoptosis and autophagy **(8 h)**

Cell survival and growth signal pathways and apoptosis pathway - intrinsic and extrinsic pathway, caspases and factors promoting and preventing apoptosis. Molecular mechanisms of apoptosis - role of p53, Bcl family of proteins. Role of mTOR signalling in cell survival and proliferation.

Autophagy - basic overview. Autophagosome formation and its regulation.

Molecular mechanism of major neurological and psychiatric diseases **(8 h)**

Major neurological syndromes: Stroke, epilepsy, multiple sclerosis, Parkinson's disease, neuropathy, neuropathy, neuromuscular disorders, Alzheimer's disease, Creutzfeldt-Jakob disease, motor neuron disease, polyglutamine disorders, pain, disorders of sleep and circadian rhythms, mitochondrial disorders, neuroinfections.

Major psychiatric diseases: Schizophrenia, unipolar depression, bipolar disorder, anxiety disorders, obsessive-compulsive disorders, personality disorders.

References:

1. Basic Neurochemistry: Principles of Molecular, Cellular, and Medical Neurobiology 8thEdn [Eds. Brady ST, Siegel GJ, Albers RW, Price DL] Academic Press
2. Principles of Neural Science, Sixth Edition [eds. Kandel ER, Koester JD, Mack SH, Siegelbaum SA] McGraw Hill publishers.
3. Molecular Neurology Ed. Stephen G Waxman Academic Press
4. Kaplan and Sadock's Comprehensive Textbook of Psychiatry 10thEdn [Eds. Sadock BJ, Sadock VA, Ruiz P] Wolters Kluwer
5. Lippincott Illustrated Reviews: Neuroscience 2ndEdn (2018) [Eds. Krebs C, Weinberg J, Akesson E, Dilli E] Wolters Kluwer
6. Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K. and Walter, P. Molecular biology of the cell. 4th edn.
7. Hancock, J. T. (2017). *Cell signalling*. Oxford University Press.

Course Outcomes

CO	Course Outcome	Bloom's Level
CO1	Explain the structural organization of biomembranes and the molecular mechanisms underlying membrane transport, vesicular trafficking, and receptor-mediated signalling processes.	U
CO2	Analyze intracellular and intercellular signalling cascades, including GPCR, kinase-mediated, nuclear receptor, and developmental pathways, in normal cellular physiology.	An
CO3	Evaluate pathway cross-talk, feedback regulation, and integration of signalling networks governing cell survival, apoptosis, autophagy, and differentiation.	E
CO4	Interpret neurochemical and molecular alterations underlying major neurological and psychiatric disorders using mechanistic and signalling-based frameworks.	An
CO5	Integrate membrane dynamics, neurochemistry, and biosignalling pathways to predict coordinated cellular and systemic responses.	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	1	1	–	1	3	2	–
CO2	3	3	2	2	–	2	3	3	2
CO3	2	3	3	3	1	2	2	3	3
CO4	2	3	3	3	1	2	2	3	3
CO5	2	3	3	3	1	3	3	3	3

BCH8526: MERCK course - Pharmaceutical Drug Discovery and API Development

BCH8526: MERCK course - Pharmaceutical Drug Discovery and API Development	
Prerequisites	Basic knowledge of organic chemistry, biochemistry, pharmacology and molecular biology
Objectives	• To provide an in-depth understanding of the drug discovery and development process from target identification to Active Pharmaceutical Ingredient (API) commercialization. • To explore the principles of medicinal chemistry and techniques, lead optimization, and structure-activity relationships. • To gain insights into the role of synthetic and natural products in pharmaceutical development. • To gain insights into the development and manufacturing of Active Pharmaceutical Ingredients (APIs) and regulatory and market pathways for APIs.
Syllabus	**Introduction to Drug Discovery** • Overview of Drug Discovery and Development Pipeline ▪ Historical perspective ▪ Modern drug discovery process • Role of Biology and Chemistry in Drug Discovery ▪ Interdisciplinary approaches • Key Players in the Pharmaceutical Industry ▪ Major pharmaceutical companies and their roles **Target Identification and Validation** • Biological Targets: Enzymes, Receptors, Nucleic Acids ▪ Mechanisms of action • Genomics, Proteomics, and Bioinformatics Tools ▪ Data analysis and interpretation • High-Throughput Screening (HTS) and Target Validation Techniques ▪ Screening methods and technologies **Medicinal Chemistry and Lead Optimization** • Structure-Activity Relationships (SAR) and Pharmacophore Modeling ▪ Identifying and optimizing lead compounds • Rational Drug Design and Computational Approaches ▪ Computer-aided drug design (CADD) • Prodrugs and Bioisosterism ▪ Enhancing drug properties **Synthetic and Natural Products in Drug Discovery** • Role of Combinatorial Chemistry and Natural Products ▪ Diversity-oriented synthesis • Biocatalysis and Biosynthesis in API Development ▪ Enzyme-catalyzed reactions • Case Studies of Successful Drug Molecules ▪ Examples of breakthrough drugs **Preclinical Development and Toxicology** • Pharmacokinetics (ADME) and Pharmacodynamics ▪ Drug absorption, distribution, metabolism, and excretion • In Vitro and In Vivo Models for Drug Testing

BCH8526: MERCK course - Pharmaceutical Drug Discovery and API Development

- Experimental models and techniques
- Toxicological Considerations in Drug Development
  - Safety assessment

Process Development and Scale-Up

- API Synthesis and Optimization for Large-Scale Production
  - Synthetic routes and process chemistry, SYNTHIA™
- Green Chemistry Approaches in API Synthesis
  - Sustainable practices, DOZN™
- Industrial Challenges in Manufacturing and Quality Control
  - Ensuring product quality and consistency

Regulatory and Market Pathways

- Drug Approval Process: FDA, EMA, and ICH Guidelines
  - Regulatory requirements
- Patents, Intellectual Property, and Market Exclusivity
  - Protecting innovations
- Post-Market Surveillance and Pharmacovigilance
  - Monitoring drug safety

Future Trends in Drug Discovery

- AI and Machine Learning in Drug Discovery
  - Predictive models and data analysis, AIDDISON™
- Personalized Medicine and Gene Therapy
  - Tailored treatments
- Emerging Technologies and Novel Drug Modalities
  - Innovative approaches

References

1. **Drug Discovery: Practices, Processes, and Perspectives** by Jie Jack Li and E. J. Corey.
2. **Organic Chemistry of Drug Design and Drug Action** by Silverman.
3. **Active Pharmaceutical Ingredients: Development, Manufacturing, and Regulation** by Stanley Nusim.
4. **Biopharmaceutical Drug Design and Development** by Susanna Wu-Pong and Yon Rojanasakul.
5. **Basic Principles of Drug Discovery and Development** by Benjamin Blass.
6. **The Organic Chemistry of Drug Design and Drug Action** by Richard B. Silverman and Mark W. Holladay (2020).
7. **Drug Discovery and Development: Technology in Transition** by Raymond Hill (2021).
8. **Medicinal Chemistry: The Modern Drug Discovery Process** by Erland Stevens (2023).
9. **Burger's Medicinal Chemistry, Drug Discovery, and Development** by Donald J. Abraham (2017).
10. **Foye's Principles of Medicinal Chemistry** by Thomas L. Lemke and David A. Williams (2019).
11. **Introduction to Biologic and Biosimilar Product Development and Analysis** by Karen M. Nagel (2018).
12. **The Process of New Drug Discovery and Development** by Charles G. Smith and James T. O'Donnell (2019).

CO	Course Outcome	Bloom's Level
CO1	Explain the complete drug discovery and development pipeline, preclinical evaluation, and regulatory approval pathways.	U
CO2	Analyze structure–activity relationships and computational approaches used in rational drug design and lead optimization.	An
CO3	Evaluate synthetic, biocatalytic, and green chemistry strategies employed in the development and manufacturing of APIs.	E
CO4	Interpret pharmacokinetic, pharmacodynamic, toxicological, and regulatory data involved in drug commercialization.	An
CO5	Design strategic frameworks integrating medicinal chemistry such as AI in modern pharmaceutical innovation.	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	1	1	–	1	3	2	1
CO2	3	3	2	2	–	2	3	3	2
CO3	2	3	3	3	1	2	2	3	3
CO4	2	3	3	3	1	2	2	3	3
CO5	2	3	3	3	2	3	3	3	3

BCH8P126: PRACTICAL 3. ENZYMOLOGY LAB (88 h)

1. **Assay of salivary α-amylase**
   – Effect of substrate concentration
   – Determination of V_{max} and K_m using Michaelis–Menten and LB plots

2. Effect of physicochemical parameters on salivary α-amylase activity
   – Effect of temperature (Arrhenius plot and determination of activation energy)
   – Effect of pH
   – Effect of buffer ion concentration
3. Thermal stability and denaturation kinetics of an enzyme
   – Determination of half-life and residual activity
4. Assay of acid and alkaline phosphatase from different biological sources
   – Determination of optimum pH
   – Total activity and specific activity determination
5. Assay of catalase from plant or animal tissue
   – Determination of enzyme activity
6. Activity assay of horseradish peroxidase (HRP)
   – Using TMPD and pyrogallol as substrates
   – Initial velocity measurements and Michaelis–Menten kinetics
7. Assay of glutathione peroxidase activity
   – Role of glutathione in peroxide detoxification
8. Determination of type of enzyme inhibition of α-amylase
   – Using acarbose, heavy metal ions and phenolic compounds as inhibitors
   – Analysis using Michaelis–Menten, Dixon, Lineweaver–Burk, Eadie–Hofstee and Hanes–Woolf plots
9. Effect of EDTA and other metal chelators on metalloenzyme activity
   – Using catalase or horseradish peroxidase
   – Reversibility of inhibition
10. Isoenzymes of lactate dehydrogenase (LDH)
    – $NADH/NAD^+$-dependent activity assay
    – Separation and activity staining by gel electrophoresis
11. Substrate specificity and catalytic efficiency of an enzyme
    – Comparison of k_{cat}/K_m for multiple substrates using phosphofructokinase or aspartokinase
12. Enzyme inhibition screening using
    – Determination of IC_{50} values
    – Using plant extracts or drug molecules
13. Enzyme immobilization
    – Immobilization using suitable matrices
    – Comparison of activity between free and immobilized enzyme preparations
14. Coupled assay of Glucose oxidase / peroxidase for blood glucose estimation
15. Peroxidases – simple murzymes at work.

References

1. Introductory Practical Biochemistry.
   Sawhney, S. K., & Singh, R. Narosa Publishing House, New Delhi.

2. An Introduction to Practical Biochemistry.
   Plummer, D. T. McGraw-Hill Education.
3. Biochemical Methods.
   Sadasivam, S., & Manickam, A. New Age International Publishers.
4. Laboratory Manual in Biochemistry.
   Jayaraman, J. New Age International Publishers.
5. Enzyme Assays: A Practical Approach.
   Eisenthal, R., & Danson, M. J. Oxford University Press.
6. Practical Enzymology.
   Copeland, R. A. Academic Press.
7. Fundamentals of Enzyme Kinetics.
   Cornish-Bowden, A. Wiley-Blackwell.
8. Enzymes.
   Dixon, M., & Webb, E. C. Academic Press.
9. Methods in Enzymology.
   Academic Press, Selected Volumes.
10. Principles and Techniques of Biochemistry and Molecular Biology.
    Wilson, K., & Walker, J. Cambridge University Press.
11. Gel Electrophoresis of Proteins.
    Hames, B. D., & Rickwood, D. Oxford University Press.
12. Immobilized Enzymes.
    Trevan, M. D. Wiley.
13. Tietz Textbook of Clinical Chemistry.
    Burtis, C. A., Ashwood, E. R., & Bruns, D. E. Elsevier.

CO	Course Outcome	Bloom's Level
CO1	Perform quantitative enzyme assays and determine kinetic parameters (Km, Vmax, activation energy, optimum pH and temperature) using standard biochemical techniques	Ap
CO2	Analyze enzyme kinetics data using Michaelis–Menten, Lineweaver–Burk, Eadie–Hofstee and Hanes–Woolf plots	An
CO3	Apply inhibition studies, IC_{50} determination, chelator effects and substrate specificity experiments to evaluate enzyme regulation	Ap
CO4	Evaluate enzyme stability, isoenzyme patterns, immobilization effects and catalytic efficiency to interpret functional properties	E
CO5	Integrate experimental results to design enzyme-based screening strategies and propose applications in biotechnology or therapeutics	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2	1	–	2	3	3	2
CO2	2	3	3	2	–	2	2	3	2
CO3	2	3	3	2	1	2	2	3	3
CO4	2	3	3	3	1	2	2	3	3
CO5	2	3	3	3	2	3	3	3	3

BCH8P226: FOOD AND NUTRITION LAB

1. Proximate analysis of food samples
– Determination of moisture, ash, crude protein, fat and carbohydrate
– Comparison of cereals / pulses / processed foods
2. Estimation of protein in food samples
– Lowry / Biuret / Kjeldahl method
– Comparison of plant vs animal protein sources
3. Estimation of total fat in food samples
– Soxhlet extraction
– Oils, nuts, fried foods
4. Estimation of total carbohydrates in foods
– Anthrone method
– Fruits, cereals, beverages
5. Estimation of reducing and non-reducing sugars
– DNS / Benedict's method
– Honey, fruit juice, jaggery
6. Determination of dietary fiber content
– Crude fiber / enzymatic-gravimetric method
– Comparison of refined vs whole foods
7. Estimation of free fatty acids and acid value of edible oils
– Assessment of oil quality and rancidity
8. Determination of peroxide value of oils and fats
– Oxidative rancidity assessment
– Fresh vs repeatedly heated oils
9. Detection of adulteration in fats and oils using HPLC and GC-MS
– Argemone oil, vanaspati, mineral oil tests
10. Estimation of vitamin C in fruits and vegetables
– DCPIP titrimetric method
– Effect of cooking and storage
11. Estimation of calcium or iron in food samples
– Titrimetric / colorimetric methods
– Milk, leafy vegetables, cereals
12. Determination of metanil yellow and carcinogenic dyes in common food items
13. Microbiological quality assessment of foods
– Total viable count in milk or street foods
– Effect of refrigeration / boiling

References

1. **AOAC Official Methods of Analysis**.
   Association of Official Analytical Chemists (AOAC).
2. **Food Analysis**.
   Nielsen, S. S. Springer.
3. **Food Analysis Laboratory Manual**.
   Nielsen, S. S. Springer.
4. **Biochemical Methods**.
   Sadasivam, S., & Manickam, A. New Age International.

5. **Food Adulteration and Quality Control**.
   Khanna, S. K. New Age International.
6. **Food Microbiology**.
   Frazier, W. C., & Westhoff, D. C. McGraw-Hill.

Course Outcomes

CO	Course Outcome	Bloom's Level
CO1	Perform proximate analysis and quantitative estimation nutrients in food samples using standard analytical methods	Ap
CO2	Analyze experimental data to compare nutritional composition of plant- and animal-based foods and processed products	An
CO3	Apply chemical and microbiological assays to assess food quality, rancidity, adulteration and microbial load	Ap
CO4	Evaluate dietary fiber content, oxidative stability of oils and effects of processing or storage on nutrient quality	E
CO5	Integrate analytical results to interpret food safety, nutritional value and propose quality improvement strategies	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2	1	–	2	3	3	2
CO2	2	3	3	2	–	2	2	3	2
CO3	2	3	3	2	1	2	2	3	3
CO4	2	3	3	3	1	2	2	3	3
CO5	2	3	3	3	2	3	3	3	3

SEMESTER 3

BCH 9126: BIOINFORMATICS AND COMPUTATIONAL BIOLOGY (60 h)

1. Omics and Multi-Omics: Methods and Applications (15 h)

Self-study: Conceptual foundations of omics – systems biology perspective, transition from reductionist biology to high-throughput integrative approaches, regulatory hierarchies and biological networks, data generation versus biological interpretation.

Genomics – genome organization and structural variation; sequencing - Sanger sequencing, second-generation (Illumina) and third-generation platforms (PacBio, Nanopore); next-generation sequencing (NGS) workflow; genome assembly (reference-based and de novo); variant detection (SNPs, indels, CNVs); genome-wide association studies (GWAS) and quantitative trait loci (QTL) mapping – statistical basis and interpretation; genome databases and browsers such as NCBI, Ensembl and UCSC Genome Browser.

Transcriptomics and epigenomics – strategies for gene expression profiling; microarray versus RNA-Seq technologies; principles of differential gene expression analysis; epigenetic regulation including DNA methylation and histone modifications; chromatin immunoprecipitation sequencing (ChIP-Seq); DNase footprinting and chromatin accessibility assays; introduction to single-cell transcriptomics and its applications in normal and disease states.

Proteomics – complexity and dynamic range of the proteome; gel-based proteomics (2D-PAGE); mass spectrometry-based proteomics including LC-MS/MS; discovery versus targeted proteomics approaches; quantitative proteomics methods such as ICAT, SILAC and iTRAQ (overview); analysis of post-translational modifications; proteome databases such as UniProt and PRIDE.

Metabolomics – targeted and untargeted metabolomics strategies; chromatographic platforms including LC-MS and GC-MS; NMR-based metabolomics; sample preparation and solvent selection considerations; metabolic fingerprinting versus metabolic profiling; metabolome databases such as HMDB and METLIN.

Multi-omics integration – rationale for integrating genomics, transcriptomics, proteomics and metabolomics data; vertical and horizontal integration strategies; network-based integration approaches; introduction to machine learning methods for multi-omics analysis; applications in disease identification, biomarker discovery, precision medicine and drug response prediction.

Self-study: Brief overview of emerging omics approaches including interactomics, ionomics, immunomics, microbiomics and spatial transcriptomics, with emphasis on their expanding role in systems-level understanding of biological processes.

2. Sequence Alignment and Molecular Phylogeny (4 h)

Pairwise alignment – global vs local
FASTA, BLAST – alignment statistics (P-value, E-value)

Self-study and worksheet modules: Multiple sequence alignment – progressive, iterative methods. Tools – Clustal W, Clustal Omega, T-Coffee, DIALIGN
Phylogenetic tree construction – UPGMA, NJ, Maximum parsimony, Maximum likelihood

3. Protein Structure Prediction and Modelling (10 h)
Motif and domain identification – PROSITE, Pfam, SMART, InterPro
Secondary structure prediction – Chou-Fasman, GOR, SOPMA, JPred
Transmembrane prediction – TMHMM, SOSUI, DAS
Self-study and worksheet modules: Homology modelling – principles and workflow, Fold recognition (threading), Ab initio modelling, I-TASSER.
AlphaFold (4 h):
Principles of deep learning in structure prediction, attention-based neural networks, training data (PDB), confidence metrics (pLDDT score). Limitations and future prospects.

4. Molecular Dynamics (Basics) (6 h)
Introduction to molecular dynamics simulation. Force fields (AMBER, CHARMM – overview). Energy minimization, simulation steps (equilibration, production runs). RMSD, RMSF, radius of gyration - Applications in protein stability and ligand binding. Limitations of MD.

5. Gene Prediction and Genome Annotation (4 h)
Ab initio gene prediction. Similarity-based methods; GENSCAN, GRAIL, FGENES. Neural network-based gene prediction. Genome annotation workflows.

6. Biological Networks and Systems Biology (6 h)
Pathway databases – KEGG, Reactome, EcoCyc. Interaction databases – STRING, BioGRID, IntAct. Network visualization – Cytoscape. Basic graph theory concepts (nodes, edges, centrality)

7. Computer-Aided Drug Design (CADD) (7 h)
Structure-based drug design – docking, scoring functions. Virtual screening. Ligand-based drug design – pharmacophore, QSAR, ADMET prediction tools, Databases – PDB, PubChem, DrugBank.

8. Artificial Intelligence in Biomedicine (4 h)
Machine learning vs deep learning – basics. AI in genomics and variant prediction. AI in radiomics and digital pathology. AI in drug discovery and repurposing. Protein structure prediction via deep learning. Ethical considerations and limitations.

Text Book(s)

1. Jin Xiong, Essential Bioinformatics, Low Price Edition, Cambridge Press, 2019.
2. Baxevanis, A.D. and Francis Ouellellette, Bioinformatics a Practical Guide to the Analysis of Genes and Proteins, 3rd Edition, B.F.,Wiley India Pvt Ltd 2009.
3. Leach, AR (2001) "Molecular Modeling – Principles and Applications"; Second Edition, Prentice Hall, USA.

4. Alan Hinchliffe, Modeling Molecular Structures, 2nd Edition, John,Wiley, 2000.
5. Alan Hinchliffe, Molecular Modeling for Beginners, John,Wiley, 2003.

Reference Book(s)

1.Mount D. Bioinformatics: Sequence and Genome Analysis, Cold Spring Harbor Laboratory Press, New York.2004.
2. Teresa K. Attwood, David J. Parry-Smith. Introduction to bioinformatics, Pearson Education,1999.
3. Cohen (Ed.), Guide Book on Molecular Modeling in Drug Design, Academic Press, San Diego,1996.

Course Outcomes

CO	Course Outcome	Bloom's Level
CO1	Retrieve, curate and perform computational analysis of biological sequence and structural data using bioinformatics tools and databases.	Ap
CO2	Analyze genomics, transcriptomics, proteomics and metabolomics datasets to interpret molecular mechanisms and biological variation.	An
CO3	Apply computational approaches for protein structure prediction, gene annotation and molecular modelling.	Ap
CO4	Evaluate biological networks and molecular interactions using systems biology and simulation approaches.	E
CO5	Integrate multi-omics data and AI-based tools to generate biological insights for disease research and drug discovery.	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2	2	–	2	3	3	2
CO2	3	3	3	2	–	2	3	3	2
CO3	2	3	3	3	–	2	2	3	3
CO4	2	3	3	3	1	3	2	3	3
CO5	2	3	3	3	1	3	3	3	3

BCH 9226: GENETICS, GENETIC ENGINEERING AND CANCER BIOLOGY (60 h)

1. Basic principles of Mendelian genetics 9 h

Segregation and Independent assortment, alleles and multiple alleles; human pedigrees and inheritance; Chromosomal basis of inheritance; Gene interactions; Chromosome and its structure; sex determination and sex-linked inheritance; Dosage compensation, Mitochondrial and chloroplast inheritance, Hardy-Weinberg equilibrium; Calculation of allele frequency, Genes in early development; Maternal effect genes; Pattern formation genes; Homeotic genes. Linkage and crossing over.

2. Non-Mendelian inheritance, gene mutations and chromosomal aberrations 7 h

Eye colour, ABO blood grouping, codominance, incomplete dominance, polygenic traits and pleiotropy, epistasis.

Types of mutations- point, insertion and deletion mutations. Spontaneous and induced mutations; Mechanisms of mutagenesis; Assay of mutagenic agents (Ames test).

Chromosomal mutations and aberrations- numerical (trisomy, polyploidy and aneuploidy) and structural changes and detection methods, somatic and germ line mutations, transposable elements.

3. Genetic engineering - principles and methods 18 h

rDNA Technology: Restriction enzymes, restriction modification system, DNA ligase, E. coli DNA polymerase I and Klenow enzyme, T4 DNA polymerase, reverse transcriptase, DNA modifying enzymes - polynucleotide kinase, alkaline phosphatase, terminal transferase. (6 h)

Cloning Methodologies: Plasmids and plasmid vectors, new generation of plasmid cloning vectors, Lambda vectors - insertion and replacement vectors, cosmids. High capacity cloning vectors – YACs, BACs and PACs. Shuttle vectors. Expression vectors - pMAL, GST, pET-based vectors. Eukaryotic expression vectors. Protein purification: His-tag, GST-tag, MBP-tag etc. Vectors used for cloning in animal cells: SV-40, vaccinia/bacculo and retroviral vectors. Plant based vectors, Ti vectors. Gateway cloning and other advancements in cloning.

Methods for construction of genomic and cDNA libraries – vectors used, generation of cDNAs, preparation of genomic DNA for library construction. Lambda in vitro packaging. (6 h)

Methods used in the identification and analyses of recombinant DNA clones- colony PCR, blue and white screening, blotting and electrophoresis techniques. Protein-protein interaction and yeast two hybrid system. Phage display. Principles of maximizing protein expression RNA interference & rDNA therapy: Introduction to siRNA, siRNA technology, microRNA, construction of siRNA vectors, principle and application of gene silencing. Production of insulin, drug, vaccines, diagnostic probe of genetic diseases. Gene therapy.

Transgenic Technology: Gene knockout and knock-in, Generation of transgenic animals and its application, Cre-loxP recombination technology, Homologus and Non-homologus recombination, RNA silencing technology. (6 h)

4. Gene transfer and advanced genetic engineering tools. (12 h)

Gene isolation, gene transfer systems, Ti plasmid, plant virus vectors, electroporation, microinjection, microprojectile technology, lipofection, polycation-mediated gene transfer, impalefection, transfection and viral transduction. Generation of transgenic plants and its application, Plant tissue culture-protoplast culture, protoplast fusion, cybrid, somatic hybrid, somatic embryogenesis, applications of recombinant DNA technology in photosynthetic

efficacy, nitrogen fixation efficiency and resistance to environmental stresses (only applications). CRISPR/Cas9, ZFNs and TALENs – applications and overview of methodology.
Directed evolution as a tool for synthesizing modified proteins and enzymes - error-prone PCR (epPCR), homology-directed and non-homology based DNA shuffling & exon shuffling, chemical mutagenesis - alkylating agents and nitration, use of mutator strains, use of nucleotide analogs, etc. for random mutagenesis. Site-directed mutagenesis of DNA templates to yield modified proteins. Methods involved in screening cloning libraries of mutants for novel mutants. Methods for characterization of successful mutants. Latest methods for artificial gene synthesis - Gibson assembly - overview of the method and its applications. Aptamers for the detection of diseases and environmental pollutants.

5. Cancer Biology **14 h**

Introduction to Cancer Biology: Definition and classification; evolution of cancer cells; cellular oncogenes; oncogene, viral-oncogene, tumorigenicity, tumor suppressor genes; p53, Rb and PTEN, micro RNAs and regulation of cancer growth; tumor suppressor microRNAs and oncomiRs. Cancer metastasis, migration & invasion, metastasis steps, epithelial to mesenchymal transition (EMT), angiogenesis; hypoxia and crosstalk between autophagy and apoptosis in mammalian cells. (5 h)
Stem cells in cancer: Properties of stem cells, embryonic stem cells, mesenchymal stem cells, hematopoietic stem cells, inducible pluripotent stem cells (iPSC), epithelial to mesenchymal transition (EMT), cancer stem cells, embryonic signature in cancer stem cells, stem cell markers and factors.
Microenvironment of Tumor cells: Stroma interaction, adipose stromal cells, cancer associated fibroblast, tumor associated macrophages, mesenchymal stem cells, impact of tumor-stroma interaction on tumor development, tumor immunology; interferons, T cells, cancer stem cells; origin, isolation and culture of cancer stem cells, animal models of cancer study; xenograft and metastasis models.
Cancer growth and metastasis: Growth factor, receptors and cancer; in vitro testing of stemness property of cancer stem cells; detection and monitoring of metastasis process in animal models; osteoblastic & osteolytic metastasis, Success and failure of chemotherapy, targeted specific therapy, monoclonal antibody for cancer treatment, micro-RNA mediated cancer treatment and targeted drug delivery, drug resistance, molecular diagnosis and stem cell therapy.

Books recommended

1. T.A. Brown, Gene Cloning and DNA Analysis: An Introduction. Fifth Edition, WileyBlackwell, 2006.
2. S.B. Primrose, R.M. Twyman and R.W.Old; Principles of Gene Manipulation. 6th Edition, S.B.University Press, 2011.
3. J. Sambrook and D.W. Russel; Molecular Cloning: A Laboratory Manual, Vols 1-3, CSHL, 2001.

Course Outcomes

CO	Course Outcome	Bloom's Level
CO1	Explain Mendelian and non-Mendelian inheritance, gene interactions, chromosomal behavior, mutations and developmental genetics	U
CO2	Analyze genetic variations, chromosomal aberrations, linkage, Hardy–Weinberg equilibrium and mechanisms of mutagenesis	An
CO3	Apply recombinant DNA technology, cloning strategies, gene transfer methods and genome editing tools for biological applications	Ap
CO4	Evaluate advanced genetic engineering approaches including CRISPR/Cas9, RNA interference, transgenic technology and directed evolution	E
CO5	Integrate principles of genetics and cancer biology to interpret oncogenesis, tumor progression and design molecular diagnostic or therapeutic strategies	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	1	1	–	1	3	2	–
CO2	3	3	2	2	–	2	3	3	2
CO3	3	3	3	3	–	2	3	3	3
CO4	2	3	3	3	1	2	2	3	3
CO5	2	3	3	3	1	3	3	3	3

BCH 9326: IMMUNOLOGY AND IMMUNOLOGICAL TECHNIQUES (60 h)

1. Introduction to Immune system and innate immunity: (10 h)

Basic concept of immune system, cells and organs of immune system, lymphoid cells (B-lymphocytes, T- lymphocytes and Null cells), mononuclear cells (phagocytic cells and their killing mechanisms), granulocytic cells (neutrophils, eosinophils and basophils), mast cells and dendritic cell. Structure and functions of primary and secondary lymphoid organs. Innate Immunity: TLR receptors and sensing of PAMPs. Opsonization, Fc Receptors, prostaglandins and leukotrienes. Antigen, super antigens, immunogens, adjuvents, antigen processing. Classification of immunoglobulins; antibody structure-IgG, secretory IgA, IgM, IgD and IgE. Functions of antibodies, concept of variability, cross reactivity, isotypes, allotypes and idiotypic markers, class switching, receptor and soluble form of immunoglobulins. Mechanism of antigen-antibody (Ag-Ab) complex formation and role of Ag-Ab interactions in phagocytosis. Mechanism of antibody-mediated immunity.

2. B and T cell Immunology (10 h)

B and T cell development, differentiation, maturation, clonal anergy, humoral immune response, B cell differentiation, B-cell receptor (BCR) and pre-BCR, Receptor editing. Complement system- classical and alternative pathways. Concept of histocompatibility, structure and function of class I and class II MHC molecules, structure of HLA complexes. Cell adhesion molecules, T cell receptors, Antigen presentation cells, APC-T cell interaction, T cell differentiation in thymus, Th1, Th2, Th17, Treg cells and cytokines, chemokines, cytotoxic T cells, natural killer cells, dendritic cells. Naive vs. effector T-cells and their hormonal secretions.

3. Cytotoxicity and immunotherapy (10 h)

Antigen dependent cell cytotoxicity, cytotoxicity reactions, CD8+ T cell cytotoxicity, autoimmunity, acquired immunodeficiency. Allergy, Hypersensitivities, and Chronic Inflammation- types of allergies and hypersensitivity reactions, grafting and transplantation immunology, host-pathogen interaction, immunotherapy, T cell immunotherapy & B cell immunotherapy. V(D)J recombination and antibody diversity- combinatorial diversity and junctional diversity. Vaccines, different types of vaccines and its significance, monoclonal and polyclonal antibody production, hybridoma technology. Antibody-dependent cell-mediated cytotoxicity (ADCC). Mechanism of immune surveillance and tumour evasion of the immune system. Cytokines - types; Interferons, interleukins and their types and functions. Chemokines- types and functions.

4. Transplantation immunology (8 h)

Transplantation: Terminology, Auto graft, Isograft, Allograft, Xenograft, Immunological basis of transplantation reactions, GVH reaction, Immuno suppression, General mechanisms of Immune suppression, Immune suppression, drugs (azothioprine, methotrexate, cyclophosphamide, cyclosporin-A, Steroids).

5. Immunodeficiency disorders, role of immune system in cancer (8 h)

Immune Deficiencies: Introduction, primary and secondary deficiencies. T-cell, B-cell and combined immune deficiencies, Compliment system deficiency. Acquired immuno deficiency syndrome. SCID. HIV immunology. Cancer immunology - cancer evasion of the immune system.

Active and passive immunization, whole organism vaccines, recombinant vector vaccines,

DNA vaccines, synthetic peptide vaccine, multivalent sub-unit vaccines. Cancer immunology: Tumor antigens, immune response to tumors, cancer immunotherapy.

6. Immunological methods (14 h)

Precipitin curve, Immuno diffusion, one- and two-dimensional, single radial immuno diffusion, Ouchterlony immuno diffusion. Immuno-electrophoresis: Rocket immuno-electrophoresis; CIE, Graber and William technique. Agglutination: Direct and Indirect, Widal test, VDRL test. Radioimmunoassay (RIA). ELISA – Principle, Methodology and applications. Immuno-fluorescence: Direct, indirect and Sandwich types. Immunohistochemistry and fluorescence in situ localization of genetic abnormalities - FISH and GISH. Role of antibodies in blotting techniques. Preparation of polyclonal sera. Generation of chimeric antibodies and their uses.

Flow Cytometry; Principle and design of flow cytometer, cell sorting. Detection strategies in flow cytometry and parameters measured by flow cytometry.

Principle and applications of fluorescence microscopy, design and uses of epifluorescence microscopy, and immuno-fluorescence microscopy. Imaging live cells and tissues; time lapse imaging, fluorescence stains of living cells, reporter molecules, multidimensional imaging. Measuring cellular dynamics; calcium imaging in live cells, Fluorescence resonance energy transfer (FRET). Use of ion-selective electrodes, light emitting indicators and optical tweezers in study of cellular dynamics.

Books recommended

Kindt, T. J.,Osborne, B. A. and Goldsby, R. A. Kuby Immunology, 6th Edition, W. H. Freeman, 2006.

Abbas, A. K., Lichtman, A. H. and Pillai, S., Cellular and Molecular Immunology, 6th Edition, Saunders, 2007.

Roitt's, Essential Immunology. Ivan M Roitt& Peter J. Delves. 10th edition. Blackwell Publishing.

Course Outcomes

CO	Course Outcome	Bloom's Level
CO1	Explain the organization of the immune system, innate and adaptive immunity, immunoglobulin structure, antigen–antibody interactions and mechanisms of immune response	U
CO2	Analyze B-cell and T-cell development, MHC function, complement pathways, cytokine networks and immune regulation in health and disease	An
CO3	Apply principles of cytotoxicity, vaccination, transplantation immunology and immunotherapy to interpret immune-mediated disorders and host–pathogen interactions	Ap
CO4	Evaluate immunodeficiency disorders, cancer immunology, immune evasion mechanisms and therapeutic interventions	E
CO5	Integrate immunological techniques (ELISA, flow cytometry, immunofluorescence, hybridoma technology and imaging methods) for diagnosis, research and clinical applications	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	1	1	–	1	3	2	–
CO2	3	3	2	2	–	2	3	3	2
CO3	2	3	3	2	–	2	2	3	2
CO4	2	3	3	3	1	2	2	3	3
CO5	2	3	3	3	1	3	3	3	3

BCH 9426: PLANT AND MICROBIAL BIOCHEMISTRY

Part I: Plant biochemistry 30h

1. Photochemistry (10 h)
Introduction to Photosynthesis and Photosynthetic pigments
Structure of chlorophyll a & b and its biosynthesis.
Photochemical reaction system and photosynthetic electron transport chain. Murburn model
Crassulacean Acid Metabolism (CAM) pathway, Hatch-Slack (C4) pathway, Calvin cycle and its regulation, Hill's equation
Cyclic and non-cyclic photophosphorylation
Photorespiration

2. Plant hormones and phytochromes (8 h)
Introduction to plant metabolites (primary, secondary or specialized metabolites and hormones)
Structure and functions of plant hormones: Auxins, gibberllins, cytokinins, ethylene, abscisic acid and florigen
Introduction to phytochromes and plant senescence
Structure, properties and mechanisms of action of phytochromes
Calcium and calmodulin mediated Pfr responses
Different levels of senescence
Mechanism of biochemical changes during senescence

3. Specialized metabolites of plants (8 h)
Introduction to secondary metabolites and its classification
Phenols – Functions (structures not required), Shikimate Arogenate pathway, phenylalanine/ hydroxycinnamate pathway, phenylpropanoids pathway (only type of reaction – structures not required)
Structure and function of: - Hydroxycinnamate conjugates, hydroxycoumarins, hydroxy benzoates,
Functions of : - Flavonoids, lignins, lignans, neolignans, tannins and quinones.(structure not required)
Isoprenoids - Nomenclature, classification and occurrence, General pathway for terpenoid biosynthesis and functions (structures not required – type of reaction occurring must be mentioned)
Alkaloids – Function of nicotine, caffeine and cocaine (no structures)
Glucosinolates - Glucoraphanin
Toxic secondary metabolites, secondary metabolites of medicinal importance

4. Plant immunity (5 h)
Introduction to plant resistance and innate immunity
Mechanism of plant resistance and phytoalexins
Plant-pathogen interaction
Pathogen associated molecular patterns (PAMPs) and pattern recognition receptors (PRRs) and PAMP triggered immunity (PTI)
Effectors and effector-triggered immunity (ETI)

Part II: Microbial Biochemistry (30 h)

5. Microorganisms and bacterial cell wall and membrane (4 h)
Introduction to microorganisms – bacteria, viruses, fungi, mycoplasma, protozoa and algae
Gram's staining and Bacterial cell wall synthesis
Bacterial cell membrane synthesis, membrane proteins and transport

6. Nutrient cycles and nitrogen fixation (3 h)
Nutrient cycles: Carbon, sulphur, phosphorus and nitrogen cycles
Nitrogen fixation: Symbiotic and non-symbiotic nitrogen fixation, nitrogenase complex, NIF genes and NOD genes

7. Antibiotics and antibiotic resistance in bacteria (5 h)
Introduction to different classes of antibiotics and their mechanisms of action – penicillin, cephalosporins, fluoroquinolone, tetracycline, macrolides, aminoglycosides.
Antibiotic resistance in bacteria – causes, intrinsic resistance in Mycobacteria, basic mechanisms of antibiotic resistance and gene spread
Case studies of antibiotic resistance – methicillin-resistant *Staphylococcus aureus*, multidrug resistant *Mycobacterium tuberculosis* and penicillin-resistant *Enterococcus*

8. Bacteria and yeast to study protein-protein interactions (4 h)
Introduction to protein-protein interactions and why it is important
Yeast two-hybrid systems to study protein interactions
Bacterial two-hybrid systems to examine protein interactions
Gateway cloning to study protein function
Protein-protein interactions and murburn concept

9. Metabolic pathways in archeae (2 h)
Modifications of the Embden–Meyerhof (EM) and the Entner–Doudoroff (ED) pathways in Archaea.

10. Evolution of metabolic pathways (3 h)
Introduction to evolution of metabolic pathways: Role of gene duplication and horizontal gene transfer to give rise to metabolic versatility in fungi

11. Unique bacterial metabolic pathways in nature (5 h)
Introduction to photosynthetic electron transport pathways in anoxygenic phototrophs using (i) proteobacteria (anaerobic anoxygenic phototrophic and aerobic anoxygenic phototrophic) and (ii) green sulfur bacteria as examples. Applications.

12. Unique bacterial metabolic pathways in the gut microbiome (4 h)
Introduction to diverse metabolic pathways in the gut microbiota
Bile acid metabolism by gut bacteria.
The 7-α-dehydroxylation pathway and its importance as a potential therapeutic target.

Course Outcomes

CO	Course Outcome	Bloom's Level
CO1	Explain photosynthesis, plant hormones, phytochromes, specialized metabolites, plant immunity, and biochemical adaptations in plants	U
CO2	Analyze plant metabolic pathways, secondary metabolite biosynthesis, nutrient cycles, nitrogen fixation and archaeal metabolic variations	An
CO3	Apply microbial biochemical principles to understand bacterial cell wall synthesis, antibiotic mechanisms, resistance development and protein–protein interaction systems	Ap
CO4	Evaluate unique microbial metabolic pathways, gut microbiome functions, evolution of metabolism and their biotechnological applications	E
CO5	Integrate plant and microbial biochemical concepts to interpret ecological interactions and potential applications	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	1	1	–	1	3	2	–
CO2	3	3	2	2	–	2	3	3	2
CO3	2	3	3	2	–	2	2	3	2
CO4	2	3	3	3	1	2	2	3	3
CO5	2	3	3	3	1	3	3	3	3

BCH 9526: RESEARCH METHODOLOGY AND SCIENTIFIC WRITING (60 h)

This entire paper shall be done as a workshop

I. Research Methodology and Biostatistics (20 h)

Research questions and hypothesis formulation; null and alternative hypotheses. Experimental design principles including controls, variables, replication, randomization and blinding.

Types of research: descriptive, analytical and experimental studies. Observational versus interventional studies; clinical trial basics; randomized controlled trials; sampling methods. Bias, confounding variables, reproducibility and validation of results. Ethical considerations in research design.

Types of data and scales of measurement; data tabulation and organization. Measures of central tendency and dispersion; probability concepts; normal distribution. Hypothesis testing; p-value and confidence intervals. Parametric and non-parametric tests (overview). t-test (paired and unpaired); chi-square test; ANOVA (one-way overview); correlation and simple regression. Selection of appropriate statistical tests for biological experiments.
Graphical data representation and interpretation using MS Excel and GraphPad Prism.
Workshop component: statistical analysis of sample datasets and figure preparation.

II. Scientific Writing (40 h)

Theoretical unit 1: Fundamentals of scientific writing – a background (8 h)
Introduction to different kinds of publications, specialized journals in Biochemistry; Types of papers - short communications, research articles, review articles, systematic review and meta-analysis. Barriers to scientific writing.
Practical module 1: Introduction to scientific writing
• Purpose – How and why scientific communication is achieved and what are the means to communicate effectively?
• Common Types of publications/scientific documents – Full-length research articles, review articles, short communications, monographs, systematic reviews & meta-analyses and books/book chapters, dissertations/theses: Structure and layout of each document.
Module exercise 1: Collect different kinds of scientific documents and categorize them into different types and provide justification for the same
• General features – Authorship and criteria for authorship, ethics in publishing, hierarchy of authorship (first author, second author, co-author and corresponding author)
• Types of scientific documents – Dissertations/theses, papers/journal publications (discussed under Common Types of Publications)
- Difficulties and constraints in scientific writing

Language barrier – Grammar, syntax and style: How to recognize and overcome it.
Time constraint barrier – How time is an important constraint and how to get documents prepared on time
Lack of knowledge and reading barrier – Lack of state-of-the art in a topic and literature survey and how to tackle this barrier with a systematic and disciplined approach

Document preparation and formatting barriers – What tools to use for specific documents and how to style, structure and format documents (in general)
Module exercise 2: Students will narrate their specific barriers to scientific writing and record a video describing their unique challenges and difficulties

Theoretical unit 2: Literature review – why and how? (12 h)
Article finding: Conducting article search using various online search tools/resources – Google Scholar, PubMed, Cochrane database, ScienceDirect, ProQuest, Embase, Web of Science, ERIC, DOAJ, JSTOR, Biological Abstracts, BioOne, CINAHL, Index Copernicus, SCOPUS, etc.; Abstract collection, preparation of index cards, collecting information for review of literature, Systematic review article search tools, PRISMA and SPIDER approaches, inclusion and exclusion criteria, clinical trials design and methodology – PRISMA, research design, Cochrane database CASP tools, data extraction and synthesis.
Practical module 2: Basics of article writing and structuring
Module exercise 3: Students will make their own list of references for a particular topic of choice and submit the main story of the paper. The exercise will involve Finding relevant information and note making.

Theoretical unit 3: Meeting journal-specific requirements – content, artwork and article structuring (10 h)
Summarising and Paraphrasing; Reference styles – quotations, referencing styles – APA, Harvard, IEEE, Vancouver, Chicago, MLA styles; Introduction to use of Endnote and Mendeley (reference managers); Use of Review Manager (RevMan); Use of journal finder & journal scoping; following journal-specific author guidelines, article image-making/image-processing tools (Microsoft PPT, GIMP, Adobe Photoshop etc.), Poster making using MS Office Publisher, CANVA, etc.; making journal-specific article templates, use of statistical software for data presentation – how to succinctly present data; graphing- chart type to choose – MS Excel and GraphPad Prism. Abstract, Introduction/background, materials and methods, results and discussion, conclusion, references, conflicts of interest statement – using MS Word.
Module exercise 4: Students will be assigned a topic based on their field of research interest and be asked to a WRITE SAMPLE ARTICLE. Marks will be provided based on a) how the articles are structured, b) language, c) style and formatting, d) art-work and e) depth of knowledge.

Theoretical unit 4: Practical aspects – article submission and ethics in research writing (10 h)
Journal author agreements, conflicts of interest and ethics violations– dangers, pitfalls and legal issues; cover letter writing; rebuttal writing to specific comments from the journal Editor & Reviewers; confidentiality agreements, collaboration and author hierarchy – first author, second author, co-author, corresponding author and first author. Practical writing skills for Biotechnology and LifeScience based papers. Creating account in journals and article submission process for various journals (practical demonstration).
Module exercise 5: Students will be asked to refine their articles; course teachers will provide inputs to students individually and they will learn to bring an article of their own MSc dissertation research into final shape and submit the same for peer-review.

References
Abbey, Edward. 1968. Desert Solitaire. McGraw-Hill. Baldwin, Bruce G. 2014. Origins of Plant Diversity in the California Floristic Province. Annual Review of Ecology, Evolution

and Systematics 45: 347-369.
Coley, P.D., J.P. Bryant, F.S. Chapin, III. 1985. Resource availability and plant anti-herbivore defense. Science. 230:895-899. Greene, Anne E. 2013. Writing Science in Plain English. University of Chicago Press.
Janzen, D.H. 1979. How to be a fig. Annual Review of Ecology and Systematics. 13-51. Leopold, Aldo. 1949. A Sand County Almanac. Oxford. McKibben, Bill (Editor). 2008.
American Earth: Environmental Writing Since Thoreau. Library of America. Wallace, David Rains 2015. Mountains and Marshes: exploring the Bay Area's Natural History. Counterpoint.
Wiens, J.J., and M.D. Donoghue. 2004. Historical biogeography, ecology, and species richness. Trends in Ecology and Evolution 19: 639-644.

Course Outcomes

CO	Course Outcome	Bloom's Level
CO1	Formulate research questions and hypotheses, and design scientifically sound experiments.	C
CO2	Apply appropriate biostatistical methods to analyze biological data and select suitable statistical tests for experimental interpretation.	Ap
CO3	Interpret statistical outputs including p-values, confidence intervals, correlation and regression analyses for biological datasets.	An
CO4	Construct well-structured scientific manuscripts, reviews and reports adhering to journal-specific guidelines and ethical standards.	C
CO5	Critically evaluate published scientific literature, including systematic reviews and meta-analyses, using structured appraisal tools.	E
CO6	Integrate research design, data analysis and scientific communication skills to prepare and submit publishable-quality manuscripts.	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	2	3	3	2	2	3	2	3	3
CO2	2	3	3	2	2	3	2	3	3
CO3	2	3	3	3	1	2	2	3	3
CO4	1	2	3	3	2	3	2	3	3
CO5	2	3	3	3	1	2	2	3	3
CO6	2	3	3	3	2	3	3	3	3

BCH9P126: PLANT AND MICROBIAL BIOCHEMISTRY LAB

Module I: Photosynthesis and Plant Primary Metabolism

1. Extraction and Spectrophotometric Estimation of Photosynthetic Pigments
Extraction and estimation of chlorophyll a, chlorophyll b and total carotenoids; absorption spectra and calculation of pigment ratios.

2. Hill Reaction – Photochemical Activity of Chloroplasts
Demonstration of light-driven electron transport using isolated chloroplasts; DCPIP reduction assay; comparison of light and dark controls.

3. Cyclic vs Non-Cyclic Photophosphorylation (Demonstration / Data-Based)
Comparative analysis of cyclic and non-cyclic electron flow; effect of inhibitors such as DCMU (data-based if required).

Module II: Plant Secondary Metabolism and Stress Biochemistry

4. Estimation of Total Flavonoids / Secondary Metabolites
Quantification using aluminum chloride colorimetric method.

5. Plant Immunity and Stress Enzymes
Estimation of peroxidase or polyphenol oxidase activity following induced stress or elicitor treatment.

6. Plant Hormones – Auxin Bioassay
Effect of indole-3-acetic acid (IAA) on growth parameters; coleoptile elongation or root inhibition assay.

Module III: Microbial Metabolism and Growth

7. Microbial Respiratory Activity and Redox Metabolism
Estimation of respiratory activity in yeast or bacteria using TTC or methylene blue reduction assays.

8. Microbial Growth Curve and Viable Count Determination
Growth curve determination; plating and calculation of CFU/mL.

Module IV: Antibiotics, Drug Sensitivity and Resistance

9. Antibiotic Sensitivity Testing (Kirby–Bauer Method)
Disc diffusion assay using antibiotics from different classes; interpretation of sensitivity and resistance patterns.

10. Determination of IC_{50} using Alamar Blue Assay
Assessment of drug susceptibility of *Escherichia coli* in the presence of various antibiotics

Module V: Advanced Microbial Physiology

11. Biofilm Formation Assay
Biofilm formation in *Escherichia coli* and evaluation of inhibitors affecting biofilm development.

References

1. Plant Biochemistry.
   Heldt, H. W., & Piechulla, B. Academic Press.
   Photosynthetic pigments, Hill reaction, photophosphorylation, electron transport, inhibitors (DCMU).
2. Methods in Plant Biochemistry.
   Dey, P. M., & Harborne, J. B. Academic Press.
   Flavonoid estimation ($AlCl_3$ method), secondary metabolites, peroxidase and polyphenol oxidase assays.
3. Plant Physiology.
   Taiz, L., Zeiger, E., Møller, I. M., & Murphy, A. Oxford University Press.
   Auxin bioassays, plant hormone responses, stress and immunity-related enzyme activity.
4. Biochemical Methods.
   Sadasivam, S., & Manickam, A. New Age International.
   TTC and methylene blue reduction assays, plant and microbial redox enzymes.
5. Microbiology.
   Prescott, L. M., Harley, J. P., & Klein, D. A. McGraw-Hill.
   Growth curve determination, CFU/mL calculation, basic microbial metabolism.
6. Mycobacterium Protocols.
   Parish, T., & Stoker, N. G. Humana Press.
   Alamar Blue assay, IC_{50} determination, biofilm formation and inhibition in Mycobacterium smegmatis.

Course Outcomes

CO	Course Outcome	Bloom's Level
CO1	Perform experimental procedures to estimate plant metabolites and microbial respiration using standard biochemical techniques	Ap
CO2	Analyze experimental data from photochemical reactions, microbiological assays to interpret metabolic and physiological responses	An
CO3	Apply microbiological methods such as CFU determination, Kirby–Bauer testing and IC_{50} assays to evaluate antimicrobial effects	Ap
CO4	Evaluate results from plant immunity, photophosphorylation and microbial inhibition experiments to draw scientifically valid conclusions	E
CO5	Integrate laboratory findings to design experimental strategies and present biochemical interpretations relevant to plant physiology and microbial metabolism	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	2	3	2	2	1	2	3	3	2
CO2	2	3	3	2	1	2	3	3	2
CO3	2	3	3	2	2	2	3	3	3
CO4	2	3	3	3	1	2	2	3	3
CO5	2	3	3	3	2	3	3	3	3

BCH9P226: MOLECULAR BIOLOGY AND GENETIC ENGINEERING LAB (88 h)

Phase I: Nucleic Acid Isolation and Quality Assessment

1. Isolation of Genomic DNA
Isolation from bacteria, yeast or plant tissue using CTAB or phenol–chloroform method. Quality and quantity assessment using A260/A280 ratio and agarose gel electrophoresis.

2. Isolation of Plasmid DNA
Alkaline lysis method; comparison of mini-prep yields; analysis of supercoiled versus nicked DNA on agarose gel.

3. Isolation of Total RNA
Isolation from yeast or plant tissue; DNase treatment; RNA integrity analysis using denaturing agarose gel.

4. DNA and RNA Quality Assessment and cDNA Synthesis
Spectrophotometric quantification; purity analysis; first-strand cDNA synthesis from total RNA.

Phase II: Basic Molecular Manipulation and Analysis

5. Restriction Digestion and Restriction Mapping
Single and double digestion of plasmid DNA; construction of restriction map.

6. Restriction Enzyme Digestion and Ligation
Sticky-end and blunt-end ligation; optimization of ligation conditions.

7. Southern / Northern Blotting (Demonstration or Data-Based)
Probe design concept; hybridization; stringency conditions; data interpretation.

Phase III: PCR and Amplification Strategies

8. Polymerase Chain Reaction (PCR)
Amplification of a target gene; primer design exercise; optimization of annealing temperature.

9. Quantitative Analysis of PCR Products
End-point versus semi-quantitative PCR; demonstration of real-time PCR (qPCR) using SYBR Green; comparative Ct analysis (data-based if required).
Phase IV: Bacterial Transformation and Cloning Workflow

10. Preparation of Competent Cells
Preparation of E. coli competent cells using $CaCl_2$ method (electroporation demo optional); calculation of transformation efficiency.

11. Cloning of PCR Product / Gene Fragment
Insertion into plasmid vector using TA cloning or restriction–ligation; transformation into competent cells; screening of recombinants using blue–white screening or colony PCR.

12. Confirmation of Recombinant Clones
Verification using restriction analysis or PCR-based confirmation.
Phase V: Gene Expression and Protein Analysis

13. Inducible Gene Expression in Bacteria
IPTG-induced expression of recombinant protein; SDS-PAGE analysis of expressed protein (partial or demo-based if needed).

14. Reporter Gene Assays (Demonstration/Data-Based)
LacZ, GFP or luciferase reporter systems; comparison of promoter strength.
Phase VI: Advanced Genome Engineering Module

15. CRISPR–Cas9 Design and Analysis (Data-Based Module)
gRNA design; off-target prediction; case-study analysis of genome editing outcomes.

References

1. Molecular Cloning: A Laboratory Manual.
   Sambrook, J., & Russell, D. W. Cold Spring Harbor Laboratory Press.
2. Current Protocols in Molecular Biology.
   Ausubel, F. M. et al. Wiley.
3. Gene Cloning and DNA Analysis.
   Brown, T. A. Wiley-Blackwell.
4. PCR.
   Mullis, K. et al. Springer.
5. RNA Methodologies.
   Farrell, R. E. Academic Press.
6. Recombinant DNA.
   Watson, J. D., Baker, T. A., Bell, S. P., et al. Pearson.
7. Protein Expression and Purification.
   Burgess, R. R. Academic Press.
8. CRISPR-Cas Systems.
   Doudna, J. A., & Charpentier, E. Academic Press.

Course Outcomes

CO No.	Course Outcome	Bloom's Level
CO1	Perform isolation and quality assessment of genomic DNA, plasmid DNA and RNA using standard molecular biology techniques	Ap
CO2	Apply restriction digestion, ligation, PCR amplification and cloning strategies to generate recombinant DNA constructs	Ap
CO3	Analyze electrophoretic profiles, PCR data, transformation efficiency and recombinant screening results	An
CO4	Evaluate gene expression, reporter assays and CRISPR–Cas9 design outputs to validate molecular engineering outcomes	E
CO5	Integrate molecular biology workflows to design cloning or genome editing strategies and interpret experimental findings	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	2	3	2	2	1	2	3	3	2
CO2	2	3	3	2	2	2	3	3	3
CO3	2	3	3	3	1	2	3	3	3
CO4	2	3	3	3	1	2	2	3	3
CO5	2	3	3	3	2	3	3	3	3

Semester 4

BCH 0126: CAPSTONE PROJECT – Entire semester

Students are free to go to a national institute / industry and do a 6 months project. The dissertation must be submitted to the University with an internal member as a co-guide. One registered NPTEL course must be completed.

CO	Course Outcome	Bloom's Level
CO1	Formulate a research problem	C
CO2	Design experimental methodology	C
CO3	Analyze experimental data	An
CO4	Evaluate research findings critically	E
CO5	Produce a dissertation and defend findings	C

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3	3	–	2	3	3	3
CO2	2	3	3	3	–	2	3	3	3
CO3	2	3	3	3	2	2	3	3	3
CO4	2	3	3	3	3	3	3	3	3
CO5	2	3	3	3	3	3	3	3	3