

ST. JOSEPH'S UNIVERSITY

BENGALURU-27



DEPARTMENT OF BIOCHEMISTRY

**PROPOSED SYLLABUS FOR
POST-GRADUATE PROGRAMME IN BIOCHEMISTRY**

For Batch 2026-2028 onwards

SYLLABUS DRAFT

List of theory and practical papers

Semester	Paper title	No. of teaching hours	No. of credits	Total marks	Theory/practical
Semester 1 (24 credits)	Bio-organic chemistry	60	4	100	Theory
	Biophysical chemistry	60	4	100	Theory
	Metabolism and bioenergetics - I	60	4	100	Theory
	Scientific Writing	45	3	100	Theory
	Extraction and partial purification of biomolecules	88	4	100	Practical
	Characterization of biomolecules	88	4	100	Practical
Semester 2 (28 credits)	Enzymology and enzyme technology	60	4	100	Theory
	Metabolism and bioenergetics - II	60	4	100	Theory
	Biopharmaceutical chemistry and toxicology	60	4	100	Theory
	Neurochemistry and biosignalling	60	4	100	Theory
	<i>Registered NPTEL course-1</i>	-	4	-	<i>Theory (Elective)</i>
	Enzymology lab	88	4	100	Practical
	Food and nutrition lab	88	4	100	Practical
Semester 3 (27 credits)	Basic bioinformatics and allied techniques	60	4	100	Theory
	Genetics, genetic engineering and cancer biology	60	4	100	Theory
	Immunology and immunological techniques	60	4	100	Theory
	Plant and microbial biochemistry	60	4	100	Theory
	<i>Registered NPTEL course-2</i>	-	4	-	<i>Theory (Elective)</i>
	Plant and microbial biochemistry lab	88	4	100	Practical
	Molecular biology lab	88	4	100	Practical
Semester 4 (20 credits)	Biochemistry project	360	12	350	Project
	IGNITORS / OUTREACH	-	4	-	
	<i>Registered NPTEL course-3</i>	-	4	-	<i>Theory (Elective)</i>
TOTAL			99		

Note: The framework has been passed by the BOS members with a remark that the number of credits could be reduced. This is only a draft the syllabus needs to be fine tuned and passed in the subsequent BOS.

SEMESTER 1

BIO-ORGANIC CHEMISTRY (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 disulphide 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, fusion proteins - eg. GFP, enzyme-protein conjugation and emerging protein technologies. Click chemistry and its use in protein modifications.

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.

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.

BIOPHYSICAL CHEMISTRY (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, properties of Gibb's free energy, dependence of Gibb's free energy on temperature and pressure, Gibb's free energy and phase equilibria, the Clapeyron and Clausius-Clapeyron equations, phase diagram – water and carbon dioxide as an example, phase rule, limitations of thermodynamics. (4h)
2. **Non electrolyte solutions:** colligative properties – osmotic pressure and its applications (including numericals). Colligative properties of real solutions. Solubility of proteins – effect of salt concentration, effect of organic solvents, effect of pH, crystallization (2h)
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 (all 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. (4h)
6. **Acids and bases:** 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, maintaining pH in blood. (2h)
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. (3h)
9. **Spectroscopy:** 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) – 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: 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 – ORD and infrared dichroism.

Chromatographic separations – Ion exchange chromatography – principle, gradient elutions, types of ion exchangers. Gel filtration – principle, application, materials used, dialysis (special case of molecular filtration). Affinity chromatography – principle, types and application. Other chromatographic techniques – adsorption, hydroxyapatite, HPLC-TLC, reverse phase – improved resolution – advantages.

Electrophoresis- Principle, mathematical relation, electrophoretic mobility, types of electrophoresis- gel (agarose, polyacrylamide), disc (detection of bands), Isoelectric focusing, capillary electrophoresis.

Sedimentation in the ultracentrifuge – sedimentation velocity, sedimentation equilibrium, density gradient sedimentation, viscosity, electrophoresis.

Ultracentrifugation- sedimentation (mathematical formula) - sedimentation rate, sedimentation coefficient, frictional ratio (indicative of molecular solvation and shape), preparative ultracentrifugation-zonal and density gradient. (16h)

METABOLISM AND BIOENERGETICS- 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)

What is bioenergetics? How is it closely linked to metabolic processes? What is the metabolic map?

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 .

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- use of cell free system by Buchner, metabolic inhibitors as tools, mutations that create metabolic blocks, Isotopic tracers as metabolic probes, NMR as a metabolic probe.

Compartmentalization of metabolic pathways within cells- fundamentals of centrifugal techniques- differential and isopycnic centrifugation.

2. Nutrition and Diet

15h

How do organisms decide on what material can be used as food? What should our diet be composed of? 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)

Vitamins- solubility and overview of their role in biological processes. Structure and important reactions they are involved in. Diseases caused by their deficiency.

- a) Vitamin B1- Thiamine and Thiamine pyrophosphate
- b) Vitamins containing adenine nucleotides- Flavin dinucleotides, pyridine dinucleotides and CoA
- c) Vitamin B6 (pyridoxine and pyridoxal phosphate)
- d) Vitamin B12 (Cyanocobalamin)
- e) Vitamin C
- f) Biotin
- g) Lipoic acid
- h) Folic acid
- i) Vitamin A group
- j) Vitamin D group
- k) Vitamin E

1) Vitamin K

3. Bioenergetics

10h

E.T.C – Theory with carriers and details of electron shuttles. ATP synthase – structure and function. Energy generation in mechanochemical systems: muscle contraction. Mechanism of oxidative phosphorylation, chemiosmotic hypothesis- ATP yield and balanced equation, respiratory chain inhibitors, energy coupled reactions- all types with suitable examples, uncouplers, biological energy transducers.

4. Metabolism of Proteins

12h

Amino acids as precursors
Glucose metabolism- Transamination, hydrolysis, carbamoylphosphate synthesis.
Formation of uric acid
Metabolism of carbon skeletons- creatinine, melanin and iodotyrosines
Formation of one carbon compounds
Formation of gluconeogenic intermediates
Formation of ketone bodies
Formation of niacin, formation of phospho and sphingolipids, formation of carnitine
Biosynthesis of amino acids (apart from those obtained by transamination process)- Glycine, serine, tyrosine, aspartic acid, glutamic acid, cysteine, proline and hydroxyproline.

5. 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.

6. 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).

SCIENTIFIC WRITING (45 h)

This entire paper shall be done as a workshop

Theoretical unit 1: Fundamentals of scientific writing – a background (9 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 (12 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 (12 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.

SEMESTER 2

ENZYMOLOGY AND ENZYME TECHNOLOGY (60 h)

I. Enzymology

46 h

1. Classification, comparison between chemical and biological (enzyme) catalysis, coenzyme, cofactors, concept of rate enhancement in intermolecular vs intramolecular reactions i.e. extent of randomness and reaction rate with an example, how is the enhanced rate of an enzyme catalyzed reaction explained with the help of that concept. Importance of effective collisions, orientation factor 'P', Functional groups (R-groups of amino acids) involved in enzyme catalysis, classical approach to identify crucial amino acid(s) involved in enzyme catalysis (use of specific inhibitors of amino acids followed by limited proteolysis) (4h)
2. Mechanism of enzyme reactions: serine protease, carbonic anhydrase (metalloenzyme) and restriction endonuclease.
3. Reactions (and mechanisms) of coenzymes – NAD⁺ NADP⁺, folic acid, Vit.B₁₂ FMN/FAD, coenzyme A, lipoic acid, biotin, tetrahydrofolate, thiamine pyrophosphate, pyridoxal phosphate and metal ions as biocatalysts. Biocatalysts from extreme thermophilic and hyperthermophilic archaea and bacteria (10h)
4. Regulation of enzyme activity: Covalent modifications (examples) [post translational modifications and proteolytic activation of enzymes] Blood clotting cascade, Zymogens, isozymes and their significance (LDH) (5h)
5. Allosteric enzymes, Sigmoidal kinetics; aspartate transcarbamoylase (ATCase), T & R states 8 (quaternary structures), positive and negative modulators; protein kinase A (PKA) and role of cAMP (5h)
6. Cooperativity, allosteric enzymes and their modes of action; concerted, sequential and morphoein theory of allostereism; Ensemble models for allostereism Design of protein switches based on an ensemble model of allostery. (4h)
7. Transition state analogue, catalytic antibodies, suicide inactivation. (2h)
8. Thermodynamics of enzyme-substrate interactions, Binding energy in catalysis; Fundamental principles of reaction kinetics and equilibria. (3h);
9. Measurement and magnitude of enzyme rate constant; Transient kinetic methods Detection of intermediate in reactions-Relaxation methods. (2h)
10. Steady state enzyme kinetics; differences between a chemical equilibrium and steady state kinetics; Limitation of Michealis-Menten equation, Briggs Haldane kinetics ; Van Slyke-Cullen behavior, Physiological significance of kinetic parameters. Non-productive binding. (4h)
11. Multisubstrate systems and their kinetics; Multienzyme complexes (2h)
12. Enzyme Inhibition: Reversible (competitive, uncompetitive, non competitive and mixed inhibition) – kinetics of inhibition with suitable examples; Irreversible inhibitors – with suitable examples (2h)
13. Enzyme reconstitution, enzyme assays, isolation, purification and criteria for determining purity of enzymes. (3h)

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 degrading enzymes. (4h)
2. Clinical enzymes- Enzymes as thrombolytic agents, Anti-inflammatory agents,

strptokinasae, asparaginase, Isoenzymes like CK and LDH, Transaminases (AST, ALT), Amylases, Cholinesterases, Phosphatases. Immobilization of enzymes, ELISA. Biosensors. Enzyme engineering and site directed mutagenesis, designer enzymes (5h)

3. Enzyme Structure Activity Relationship (SAR) and Drug discovery- Properties of enzymes. Lead compound, Structure based drug design, combinatorial chemistry, High-throughput screening, Case study of DHFR etc. (5h)

Reference Books:

1. Fundamentals of Ezymology; 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.

BCH8225-METABOLISM AND BIOENERGETICS - 2 (60 h)

- 1. Carbohydrate metabolism** **18h**

Glucose by glycogenesis, by gluconeogenesis (production of new glucose from other carbohydrates or gluconeogenesis (i.e from any substrate excluding other carbohydrates. Mention of glycogenesis from galactose, fructose and mannose
Glycogenolysis
Glycogen storage diseases or inborn errors of glycogen metabolism- brief very general overview (no questions to be asked about specific problems)
Regulation of glycogen metabolism
Biosynthesis of lactose and fructose
Uronic acid pathway- fate of uronic acids
Amino sugar biosynthesis
Phosphogluconate oxidative pathway or hexose monophosphate shunt pathway or pentose phosphate pathway and its regulation
Energy balance sheet of the above mentioned processes.
- 2. Lipid Metabolism** **18h**

Oxidation of fatty acids –beta, omega, alpha and unsaturated.
Formation of ketone bodies
Fatty acid biosynthesis- cytoplasmic (prototype), denovo, mitochondrial chain elongation, microsomal chain elongation and desaturation.
Triglyceride synthesis
Biosynthesis of prostaglandins and their biological significance
Phospholipid metabolism – phosphatidylethanolamines, phosphatidylcholines, phosphatidylinositols, sphingomyelin, cardiolipin, plasmalogens, cerebroside.
Energy balance sheet of the above mentioned processes.
- 3. Nucleic acid metabolism:** **12 h**

Purine and pyrimidine nucleotides: biosynthesis and its regulation.
Deoxyribonucleotides: biosynthesis and regulation. Biosynthesis of nucleotide coenzymes. Catabolism of purine and pyrimidine nucleotides.
- 4. Metabolic disorders and inborn metabolic defects:** **12 h**

Hemoglobin, Met-Hb, embryonic-Hb, heme metabolism associated diseases, sickle cell anemia, thalassemia, 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.

BIOPHARMACEUTICAL CHEMISTRY AND TOXICOLOGY (60h)

- 1. Basic principle and drug development:** (self-study – structural elements, types and linkages of biomolecules) Introduction, significance of pharmaceutical biochemistry, fundamental aspects of drugs - forms, application, biological action, metabolism, drug interaction, adverse effects; Classification of drugs; Physicochemical properties of drug molecules in relation to biological activity; solubility, partition coefficient, hydrogen bonding; Prodrugs and drug delivery system: utility of prodrugs, types of prodrugs, mechanism of drug activation- carrier linked prodrugs, carrier linkages for various functional groups, bioprecursor prodrug. Stereochemistry and chirality in medicinal chemistry. Chirality and its importance in drug design.
Drug development: Introduction and stages of drug development. (8h)
- 2. Drug Delivery Systems:** route of administration; Sustained Release (SR) and Controlled Release (CR) formulations - Introduction & basic concepts, advantages/disadvantages, factors influencing, Mechanism of drug delivery from SR/CR formulation. Principles & fundamentals of rate-controlled drug delivery systems, Modulated drug delivery systems; Mechanically activated, pH activated, enzyme activated, and osmotic activated drug delivery systems.
Targeted drug delivery systems: Targeting Methods - introduction, nanoparticles & liposomes: types.
Events and biological process involved in drug targeting. Tumour targeting and brain-specific delivery.
Micro capsules/ Micro spheres: application of Monoclonal antibodies, niosomes, aquasomes, phytosomes, electrosomes.
Peptide Delivery: Barriers for protein delivery. Liposomal gene delivery systems. Biodistribution and pharmacokinetics. Knowledge of therapeutic antisense molecules and aptamers as drugs of future. (15h)
- 3. Pharmacokinetics and Pharmacodynamics:**
Pharmacokinetics - Absorption, Bioavailability & Distribution of drugs. Biotransformation – metabolism of drugs. Inhibition of drug metabolism. Overview of drugs as inhibitors to enzymes; ACE, leukotrienes, lipooxygenase, cyclooxygenase, DNA polymerase inhibitors, HIV - protease /reverse transcriptase, integrase.
Excretion & kinetics of elimination. Principles of permeation, clearance: capacity-limited elimination, flow-dependent elimination. Half-life of drugs. Drug accumulation. Bioavailability. The time course of drug effect.
Pharmacodynamics - the physical nature of drugs - size, reactivity and drug receptor bonds, principles & mechanism of drug action by enzymes (stimulation and inhibition) and receptors (drug receptor interaction), drug-dose response, combined effect of drugs, factors modifying drug action, drug-receptor interactions: molecular recognition principles drug binding to receptors: agonists, antagonists. (10h)
- 4. Adverse Drug Effects:** Adverse responses – Side effects, secondary effects, toxic effects, intolerance, idiosyncrasy, and allergy of drugs (mechanisms and types of allergic reactions). Photosensitivity due to drugs. Drug dependence – Drug abuse and addiction. Drug withdrawal reactions, teratogenicity, carcinogenicity, mutagenicity. Drug induced diseases. (5h)

5. **Modern techniques used in drug design:** Bioelectronic medicines, 3D printing of pharmaceuticals, telepharmacy. SAR and QSAR - Designing of analogous drugs based on original lead. Bio-isosteric replacements. Rigid analogs, ring size, alkyl chain branching, ring position, isomers etc. Alteration of stereochemistry and design of stereo and geometrical isomers, physical properties related to potency, calculation and measurements of partition coefficient. Hansch analysis and application, Craig's plot. Free Wilson analysis and application. (7h)
6. **Biochemical Toxicology:** Introduction, definition, scope and various branches of toxicology, classification of toxins, types of toxic effects, factors affecting toxicity, methods of toxicity assessment, mechanism of toxicity- Biotransformation of xenobiotics phase-I reactions (hydrolysis, reduction, oxidation), activation of xenobiotics by CYP450, phase - II reactions (glucuronidation, methylation acetylation, amino acid conjugation, glutathione conjugation, and phase - III reactions and transport mechanisms; Disturbances in calcium homeostasis and cell injury, xenobiotic induced alterations in intracellular calcium distribution, toxicological consequences of increased intracellular calcium concentrations, energy disturbances-disruption in cellular energy production, mitochondrial targets, protonophoric and uncoupling activity xenobiotics, inhibition of NADPH production, inhibition of electron transport. (15h)

NEUROCHEMISTRY AND BIOSIGNALLING (60 h)

1. 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)

2. 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).

3. 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.

4. 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.

5. Molecular mechanism of major neurological and psychiatric diseases **9 h**

Major neurological syndromes: Stroke, epilepsy, multiple sclerosis, Parkinson's disease, 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 8th Edn [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.

SEMESTER 3

BASIC BIOINFORMATICS AND ALLIED TECHNIQUES (60 h)

1. Omics and multi-omics methods and applications

10 h

Genomics - concepts, methods and applications. Genome databases. Retrieval of sequences and analyses. GWAS- QTL, Transcriptomics and epigenomics - Gene expression in normal and disease conditions - analysis using DNA microarray, RNAseq, DNAase footprinting, SAGE and CHIP-seq.

Proteomics - gel-based and mass-spectrometry based proteomics. Discovery proteomics and targeted proteomics methods. Proteome databases.

Metabolomics - HPLC and other chromatographic methods for metabolite separation. Choice of solvent in metabolomics studies. MS and MS/MS. GCMS and LCMS. Metabolome databases.

Use of NMR in proteomics and metabolomics studies.

Other omics to be mentioned briefly - interactomics, ionomics and immunomics. Multiomics and its role in disease identification, biomarker discovery and drug design.

2. Sequence Alignment Tools and molecular phylogeny

7

hSequence analysis of biological data - Pairwise sequence alignment - Local and Global alignment; FASTA and BLAST programs – Statistics of alignment score – P value and E value. Introduction to multiple sequence alignment – Methods of multiple sequence alignment- Progressive method, iterative method, genetic algorithm- applications of multiple sequence alignment. Tools for multiple sequence alignment - Clustal W, T-Coffee, DIALIGN, Clustal Omega. Phylogenetic analysis - Phylogenetic tree and terminology, Phylogram vs. cladogram. Methods for phylogenetic tree construction - Distance matrix methods-UPGMA, NJ, Character based methods - Maximum parsimony, Maximum likelihood.

3. Protein structure prediction tools

8 h

Identification of motif and domains in multiple sequence alignment

Motif and domain database using regular expressions – PROSITE-eMotif- motif and domain database using statistical models – PRINTS – BLOCKS – ProDom – Pfam – SMART – InterPro – Reverse-CDART

Protein secondary structure prediction – Chou-Fasman, GOR methods (SOPMA)

Secondary structure prediction - Prediction methods-PHDacc and PROfacc-Jpred.

Transmembrane segments- Prediction methods-TopPred, PHDhtm, ProfTMB, SOSUI, TMHMM and DAS.

Protein Tertiary structure prediction methods: homology modelling, fold recognition, Ab initio Method. AlphaFold and I-TASSER.

Protein dynamics- General concepts- classification of intramolecular motions of proteins- atomic fluctuation, collective motions, triggered conformational changes. Proteins have mobile structures. Protein core mobility is revealed by aromatic ring flipping. Infrequent motions can be detected through hydrogen exchange. Protein folding can be monitored by pulsed H/D exchange methods.

4. Gene Prediction Tools

6 h

Gene prediction methods: Ab Initio Gene prediction in prokaryotic and eukaryotic Genomes- genome annotation, gene prediction tools - similarity based and ab-initio prediction- GENSCAN, GRAIL, FGENES- SMART. Prediction using neural networks, Homology

based gene prediction programs.

5. Biological networks and pathways – Basic principles

6 h

Pathway and Molecular Interaction Databases: Reactome, KEGG, EcoCyc, OMIM
Molecular Interaction Databases: BioGRID, IntAct, STRING, STITCH, GeneMANIA
Pathway Visualization and Analysis: Network Visualization and Analysis, Cytoscape

6. Computer-aided drug design

8 h

CADD - concepts and principles – applications – success – limitations - Database resources for CADD - therapeutic target information - PDB, chemical information – pubchem – drug bank.

ADMET prediction - ADMET prediction methods and tools.

Drug design – structure-based drug design – modelling - molecular docking – virtual screening.

Ligand based drug design – pharmacophore – QSAR

Text Book(s)

1. Jin Xiong, Essential Bioinformatics, Low Price Edition, Cambridge Press, 2019.
2. Baxevanis, A.D. and Francis Ouellette, 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.

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/baculo 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, Homologous and Non-homologous 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.

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, adjuvants, 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.

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.
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, gibberellins, 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

9. Metabolic pathways in archaee (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.