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BENGALURU
CENTRAL UNIVERSITY

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Syllabus

for

M. Sc. Biochemistry
Choice based credit system (CBCS)

With effect from 2019 – 2019

Department of Biochemistry
Central College Campus
Bengaluru-560001

Preamble

Curriculum updating and adoption of innovative pedagogy are major components of academic excellence aimed at providing exposure to cutting edge technological advancements. The Board of Studies in Biochemistry (PG) is pleased to submit the revised syllabus for M.Sc. Biochemistry course of the Bengaluru Central University with effect from 2019-2020.

Keeping in mind, the advancements in the subject over the past decade, the board has gone through the existing syllabus and has incorporated few recent developments to provide a broader perspective of the subject to the students.

Introduction

Seeds of the current fruits of modern biology, such as genomics, metabolomics, proteomics so on, were sown during previous century in the form of interdisciplinary collaborations among basic science disciplines contributing to landmark technological innovations. One of the basic science disciplines which lead to biotechnological advancement is Biochemistry, a hybrid of biology and chemistry. Considering its pivotal role in biological sciences, it is imperative to strengthen the fundamental concepts of biochemistry at Postgraduate level with clear and tangible pedagogical approaches.

The present curriculum for M.Sc. Biochemistry has been prepared with the objective of providing comprehensive knowledge of biochemistry including biochemical mechanistic basis of genetic and physiological processes, metabolism under normal and pathological conditions, drug discovery and drug design, and clinical research. Apart from its traditional approach of providing more weightage to metabolism and molecular physiological aspects, the curriculum has greater emphasis on recent advancement in techniques of biochemistry and molecular biology which enable the students to better understand the core biochemistry and the offshoots such as genomics, metabolomics, proteomics, and bioinformatics.

It is hoped, that during the two year program, typical attributes of a competent science postgraduate such as; spirit of inquiry, critical thinking, problem solving, analytical and scientific reasoning, research/industry related skills are discovered and nurtured.

Proceedings of the meeting of the Board of Studies in Biochemistry (PG) held on 10th January, 2019 in the Department of Biochemistry, Central College Campus, Bengaluru Central University, Bengaluru -560001.

The meeting of the Board of Studies in Biochemistry (PG) was held on Thursday, the 10th January, 2019 at 10.30 am in the Department of Biochemistry to approve the M.Sc. CBCS Biochemistry syllabus for Bengaluru Central University. After welcoming the members, the chairman placed the draft syllabus prepared in consultation with the members before them for discussion. After thorough scrutiny, the board approved the M.Sc. Biochemistry CBCS syllabus with incorporation of appropriate modifications.
The meeting concluded with the chairman thanking all the members for their active participation and valuable inputs.

Members:		**Signature**
1.	Prof. C.S. Karigar, Dept. of Biochemistry, Bangalore University Bangalore -560056	Member
2.	Prof. Mnohar Shinde Dept. of Biochemistry, Tumkur University Tumakuru -572101	Member
3.	Prof. G.J. Satisha Dept. of Biochemistry KuvempuUniversity Jnanasahyadri,Shankarghatta Shimoga- 577451	Member
4.	Prof. V.R. Devaraj Chairman, Dept. of Biochemistry, Bengaluru Central University Bangalore -560001	Chairman
	Members absent	
5.	Prof. K.R. Siddalinga Murthy Dept. of Biochemistry, Bangalore University Bangalore -560056	Member
6.	Prof. K. Sreeramulu Dept. of Biochemistry, Gulbarga University Gulbarga -585106	Member

Name of the Course:	**M. Sc. Biochemistry**
Duration of the course:	The course for the degree of M.Sc. shall consist of two academic years divided into four semesters.
Objective:	To Provide an in depth understanding of modern biology in terms of biochemistry, and the state of the art technological developments and their applications in metabolomics, genomics, proteomics, bioinformatics, clinical research, developmental biology and allied research and development domains. To hone practical skills, encourage intuitive and analytical skills, and research aptitude in order to prepare students for careers in research and development, academia and Pharma, biotech-based industries, and food processing industries.
Eligibility for Entrance/Admission:	Candidate must have secured **40%** in aggregate and studied ***Chemistry OR Biochemistry*** as one of the cognate subjects securing 50% marks at B.Sc. level, and studied Biology at PUC OR 10 + 2 level.
Intake:	As per the Regulations of the University
Admission:	Based on the performance in the Entrance test/ Guidelines prescribed by the University

SCHEME OF STUDY AND EXAMINATION								
Semester	Subject code	Title of the paper	Instruction hr/week	Exam marks			Duration of exam (hrs)	Credits
				Exam	CIA	Total		
I	BCHT- 01	Basic Biophysical and general chemistry	4	70	30	100	3	4
	BCHT- 02	Metabolism-I	4	70	30	100	3	4
	BCHT-03	Analytical Biochemistry – I	4	70	30	100	3	4
	BCHT-04	General Physiology	4	70	30	100	3	4
	BCHSCT-05	Clinical Biochemistry and Nutrition	3	70	30	100	3	2
	BCHP – 06	Gen. Biochemistry	8	70	30	100	4	4
	BCHP – 07	Bioanalytical techniques	8	70	30	100	4	4
Total credits for the semester								**26**
II	BCHT- 08	Protein structure and Enzymology	4	70	30	100	3	4
	BCHT- 09	Analytical Biochemistry – II	4	70	30	100	3	4
	BCHT-10	Immunology and Microbiology	4	70	30	100	3	4
	BCHT-11	Metabolism-II	4	70	30	100	3	4
	BCHSCT-12	Bioinformatics and Research methodology	3	70	30	100	3	2
	BCHP – 13	Immunochemistry and Informatics	8	70	30	100	4	4
	BCHP – 14	Enzymology	8	70	30	100	4	4
Total credits for the semester								**26**
III	BCHT-15	Molecular Biology	4	70	30	100	3	4
	BCHT-16	Biochemistry of Cell Signaling	4	70	30	100	3	4
	BCHT-17	Membrane Biochemistry	4	70	30	100	3	4
	BCHT-18	Open elective	4	70	30	100	3	3
	BCHP -19	Clinical Biochemistry	8	70	30	100	4	4
	BCHP -20	Molecular Biology	8	70	30	100	4	4
Total credits for the semester								**23**
IV	BCHT-21	Gene Regulation and Genomics	4	70	30	100	3	4
	BCHT-22	Molecular Genetics	4	70	30	100	3	4
	BCHT-23	Genetic Engineering	4	70	30	100	3	4
	BCHT-24	Drug Discovery and Clinical Research	4	70	30	100	3	4
	BCHP-25	Genetic Engineering and Protein chemistry	8	70	30	100	4	4
	BCHPR- 26	Project (Report and Viva-Voce; 45+25)	12	70	30	100	-	5
Total credits for the semester-IV								**25**
Total credits for the course								**100**

Scheme for Continuous Evaluation:

Theory Paper (each)	
Attendance:	5 Marks
Tests[#]:	20 Marks
Seminar/assignment	05 Marks
Total:	**30 Marks**

[#]Two tests will be conducted and average of marks from two tests shall be computed for continuous evaluation

Practical (each Practical)	
Attendance:	5 Marks
Tests[#]:	20 Marks
Record	05 Marks
Total:	**30 Marks**

[#]Two tests shall be conducted and average of marks from two tests shall be computed for continuous assessment.

Question paper pattern for End semester theory Examination

Instruction to the students: *Answer Question No. 1 and* ***any five*** *from section-**B** and,* ***any three*** *from section-C.*

Question No. 1 shall have **nine** sub questions ***a*** **to** ***i*** of two marks each, and the student has to answer ***any seven*** of them. **(2X7=14)**

Section-B

Question No. 2 to 6 carry **four marks** each and the student has to answer ***any four*** of them.

(4X4=16)

Section-C

Question No.7 to 11 will have two sub questions of **5+5** or **6+4** marks; student has to answer ***any four*** main questions.

(10X4=40)

Question paper pattern for end semester Practical Examination

Time: 4h **Max. Marks: 70**

1. Give the principle and procedure for …. 10
2. Perform any one of the experiments listed in the syllabus for the semester. 35
3. Viva-Voce. 15
4. Practical record. 10

Project Evaluation: **Max. Marks: 100**

Internals Max.30	Report Max. 50	Viva-Voce (Max.20)
to be provided by the Supervisor through the Chairman/Principal	To be evaluated for overall objective and quality of work presented in the report.	performance of the candidate

BCHT – 101: Basic Biophysical and General Chemistry

4 units (52 hrs)

Properties of water: Physical and chemical properties of water, ionization and ionic product of water, structure of liquid water and ice. Unusual properties of water. Hydrophilic, hydrophobic and amphipathic molecules in aqueous solution. Effect of solutes on colligative properties of water. Importance of water in biological systems with special reference to the maintenance of native structure of biological molecules. Biological relevance of pH and pKa, determination of pKa of weak acid. Buffers, buffer action, and buffer capacity. Henderson–Hasselbalch equation, preparation of buffers. Importance of buffers in biological systems (cytosol and blood).

7 hrs

Thermodynamics: First law of thermodynamics, basic concepts of entropy and second law of thermodynamics, free energy changes, standard free energy change and its relation to equilibrium constant. Oxidation – reduction reactions in biological systems. **5 hrs**

Stereochemistry: Optical isomerism, chirality, symmetry elements, enantiomers, diastereomers, DL and RS notations, racemization, stereoisomerism and geometrical isomerism, *cis* – *trans* and E – Z conventions. **5hrs**

Mechanism of Bio-organic reactions: Introduction, meaning of the term, kinetic and non-kinetic. Fundamental aspects: Homo and heterolytic cleavage, structure and reactivity of carbocation (C^+), carbanion (C^-) and carbon free radical ($C^\cdot$) characteristic aspects of ionic, radical and concerted reactions, substitution, addition, elimination and rearrangements. Energy profiles of reactions, transition state theory, kinetically and thermodynamically controlled reactions. Reactions SN^1, SN^2, SN^i neighbouring group participation. E_2, E_i, Curtin-Hammett principle. Electrophilic addition to C=O, detailed discussion of all aspects of aldol condensation, related condensations, Cannizaro and Manich reactions, Michael addition. Esterification and hydrolysis. **12 hrs**

Rearrangements: Migration to electron deficient C, N and O; Wagner-Meerwein, Pinacol, Beckmann, Hoffmann, Bayer-Villiger reactions, allylic rearrangements. Benzilic acid rearrangement.

6 hrs

Free radicals: Introduction, formation– photolysis, thermolysis, redox reactions, radical reactions with biomolecules. **3 hrs**

Heterocyclic systems: Occurrence in biological systems, structure and properties, and reactivities of furon, pyrrole. Indole, thiazole, imidazole, pyridine, pyrimidine, purine, quinone, pteridine and isoalloxazine containing biomolecules.

8 hrs

Bioinorganic chemistry: Ligand field theory of complexes, stability of complex ions in solution, kinetics and mechanism of reactions of complexions. Ligand replacement reactions and electron transfer reactions of organometallic moieties of biological macromolecules (cytochromes, chlorophyll and hemoglobin). **6 hrs**

References

1. Physical Biochemistry, Kansal Edward Van Halde. Prentice Hall.
2. Physical Biology of the Cell, 2nd Edn. Rob Phillips, Jane Kondev, Julie Theriot, Hernan Garcia, Garland Publishers (2012).
3. Bioinorganic Chemistry; Ei-Ichiro Ochiai, Elsevier (2008).
4. Physical Biochemistry. David Frifielder. 2nd Edn. W.G.Freeman and Co ( )
5. Organic Chemistry. Vol. I. Fundamental principles. I. L .Finar. 6th Edn. ELBS
6. Inorganic Biochemistry. G.L. Eicharn. Elsevier.
7. Organic Mechanisms, Peter Sykes, Longman, (1977).
8. Biochemical Calculations, Irwin H. Segel (1976) 2nd Ed. John Wiley and Sons.
9. Introduction to Biophysical Chemistry, Bruce Martin
10. Organic Chemistry. R.T. Morrison and R.N.Boyd. 6th Edn. Prentice Hall, India.
11. Lehninger- Principles of Biochemistry; DL Nelson and MM Cox [Eds), 6th Edn. Macmillan Publications (2012).
12. Chemistry- An Introduction to General, Organic and Biological Chemistry, 7th Edn. Karen C. Timberlake, Benjamin Cummings, (1999).
13. Physical Chemistry of Macromolecules, C. Tanford.
14. Reaction Mechanisms at a glance, ed. M. Moloney, Blackwell Science (2000).

BCHT– 102: Metabolism-I

4 units (52 hrs)

Biological oxidation: Integration of intermediary metabolism, Biological redox couplers, participation in oxidative metabolism. Free energy changes in electron transfer reactions. Mitochondrial electron transfer system- Chemical nature, topology and thermodynamic design of electron carriers. Sequence of electron carriers-isolation of mitochondrial complexes, reconstitution experiments and study of specific inhibitors of Electron Transport Chain. **6 hrs**

Oxidative phosphorylation: Mechanism of proton pumping. Proton motive force and the Mitchell hypothesis. FoF1-ATPase- structure and mechanism, O^{18} exchange. Coupling of electron transfer to ATP synthesis. Uncouplers, inhibitors and ionophores, partial reactions of OP, P/O ratios and their use in localization of sites of ATP synthesis along the chain. Mechanism of oxidative phosphorylation, mitochondrial specific transport systems and energy charge. Microsomal electron transport. Proton motive force in Halobacteria, ATP synthesis in bacteria. H^+ pumping by bacteriorhodopsin, Photosynthetic electron transport. Structure and function of chloroplast ATP- synthase.

8 hrs

Carbohydrates: Brief review of configurational and conformational aspects of carbohydrates. Structure, properties and importance of structural (cellulose and chitin) and storage polysaccharides (starch and glycogen), glycosaminoglycans, Structure elucidation of polysaccharides (starch, glycogen and cellulose). Glycoproteins – structure and functions, blood group antigens, sequence analysis of oligosaccharides. Lectins – characteristics and functions in biological system.

8 hrs

Carbohydrate metabolism; Introduction, glycolytic pathway and regulation. Gluconeogenesis. and regulation. Role of LDH. The TCA cycle and its regulation. Alternate pathways: HMP pathway, Enter – Doudoroff, Glucuronate and Glyoxylate pathway, Cori's cycle, Futile cycles and anaplerotic reactions. Shuttle systems; glycerol-3-phosphate and malate-aspartate shuttle, Pasteur Effect, fermentative pathways in microorganisms.

13 hrs

Glycogen and starch metabolism: Degradation, synthesis and regulation. Regulation of blood glucose level, hypo- and hyperglycemia.

3 hrs

Photosynthesis: Introduction, chloroplast/thylakoid structure. Ultra structure and organization of chloroplast membranes, lipid composition of chloroplast membranes. Chlorophylls and accessory pigments, Photosynthetic reaction centre, photosynthetic apparatus, Hill reaction, light reaction, cyclic- and non-cyclic photophosphorylation. Dark reactions, CO_2 fixation into C_4-dicarboxylic acids, RUBISCO. Biosynthesis of Starch Sugars and Cellulose from Glucose. Photosynthesis in Bacteria, fungi, and algae.

8 hrs

Plant Hormones –Growth regulators and their mode of action, molecular effects of auxin in regulation of cell extension, effects of gibberllic acid, abscisic acids and cytokinins in regulation of seed dormancy, germination, growth and development.

6 hrs

References

1. Lehninger- Principles of Biochemistry; DL Nelson and MM Cox [Eds), 6th Edn. Macmillan Publications (2012).
2. Biochemistry VII Edition; Jeremy M Berg, John L Toymoczko and Lubert Stryer, W H Freeman and Co. (2010).
3. Physical Biology of the Cell, 2nd Edn. Rob Phillips, Jane Kondev, Julie Theriot, Hernan Garcia, Garland Publishers (2012).
4. Biochemistry; Voet, D. and Voet, J.G. [Eds.] 3rd Ed. Jhon Wiley and sons, (1999).
5. Biochemistry; David Rawn, J, Neil Patterson Publishers (1989).
6. Complex Carbohydrates, Sharon, N. Addison Wisely, (1975).
7. Methods of Enzymatic Analysis; Berg Meyer Vol. 1-X, (1974).
8. Nucleic acid Biochemistry and Molecular Biology, Mainwaring et al., Blackwell Scientific (1982).
9. Principles of Biochemistry; Smith et al., McGraw Hill (1986).
10. Proteins Structures and Molecular Properties 2nd Edn. Thomas E. Creighton, W H Freeman and Co. (1993).
11. Principles of Protein Structure, Function, & evolution, Dickerson & Geis, 2nd Ed. Benjamin-Cummings (1983).
12. Biochemistry Ed. Donald Voet & Judith G. Voet, John Wiley & Sons Inc.(2010).
13. Practical Biostatistics; Mendel Suchmacher and Mauro Geller, Academic Press (2012).

BCHT- 103: Analytical Biochemistry – I

4 Units (52 hrs)

Introduction to Biochemistry: **1hr**

Overview of Biochemical Investigations: Introduction to biochemistry, outline of strategies in biochemical investigations employing whole animal studies, isolated organs, tissues, and cell cultures. Cell disruption methods, investigations with isolated organelles; mitochondria and ER. Model organisms; *E.coli* and its mutants, yeast, *Ceanorhabditis elegans, Arabidopsis thaliana* and *Drosophila melanogaster*. Basic equipments and methods, and safety considerations in animal cell culture. Types of animal cells and their characteristics in culture, culture media. Plant cell culture, media for plant cell culture, potential of plant cell culture in biochemical investigations.

Extractions; Preparation of extracts for biochemical investigations, physicochemical properties of metabolites and drugs extracts from biological materials. Physico-chemical properties of solvents, solubility and miscibility, ionic bonds, and salting out. Partition, ionization, buffering and their effects on extraction. Choice of solvent for solvent extraction, mixed solvents, solid phase extraction.

9 hrs

Microscopic techniques: Review of light microscope, resolution of microscopes, Optical contrast, phase contrast, and dark field microscopy, preparation of specimen for biochemical investigations. Electron microscopy; Working principle and applications, specimens for electron microscopy, fixatives, immune-gold microscopy and its advantages. Metal shadowing, design and applications of **s**canning electron microscopy (SEM), Transmission electron microscopy (TEM), and cryo-electron microscopy. 3-D images, negative staining, single particle reconstruction.

6 hrs

Fluorescence Microscopy: Fluorophores, principle and applications of fluorescence microscopy, design and uses of Epifluorescence microscoy, 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.

5 hrs

Centrifugation: Principle of centrifugation, the Swedberg equation, types of centrifuges and rotors. Density gradient centrifugation- Caesium chloride and sucrose density gradients; examples of separations, Sub-cellular fractionation. Design and working of analytical ultracentrifuges, sedimentation velocity and sedimentation equilibrium analyses. basic calculations of centrifugation.

Ultra-filtration; Principle, instrumentation and application. Dialysis, principle and uses of equilibrium dialysis. Precipitation; methods and applications.

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

7 hrs

Biocalorimetry: Arrhenius equation, determination of energy of activation from Arrhenius plots. Main thermodynamic parameters; enthalpy, and entropy. Isothermal titration calorimetry, design of experiments, determination of change in heat capacity, eg., oligomerization of valinomycin, DNA duplex. Determination of specific heat from enthalpy. Differential scanning calorimetry; design of experiment, application of DSC, microcalorimetry. Determination of thermodynamic parameters by non-calorimetric data.

5 hrs

Manometry: Instrumentation, types of manometry; Warburg constant volume manometer, Gilson's differential respirometer, applications.

3 hrs

Radioisotopic methods of analysis: Atomic stability and radiation, types of decay, rate of radioactive decay, half life, units of radioactivity. Detection and measurement of radioactivity, Design and applications of Geiger-Muller Counter, and types of scintillation counters. Disadvantages of scintillation counters, quenching, Chemiluminescence and phospholuminescence counting efficiency, channel ratio, sample preparation, scintillation cocktails, Cerenkov counting. Autoradiography; principle and applications. Radio tracer techniques; Supply storage and purity of radio-labeled compounds, specific activity, radio-labeled nucleotides, metabolites. Pulse chase experiments.

7 hrs

Quantitative biochemical measurements: Analytical considerations and experimental errors, nature of experimental errors- random and systemic errors. Identification of systemic errors, SOPs. Performance of analytical methods, precision, accuracy, detection limit, analytical range, specificity, sensitivity, and robustness. Gaussian distribution (normal) of data, quantification of precision by standard deviation, coefficient of variation and variance, (data to be provided for calculation of each parameter). Assessment of accuracy; Population statistics- confidence limits and confidence intervals, student's t-test, standard error of mean, examples for calculation. Q-tests, examples and applications, Null hypothesis, use of t-test to validate analytical methods-unpaired, paired, one-sample, two-sample tests with examples. Calibration methods; Least mean square method of fitting straight line to data with example. Correlation and regression analyses. ANOVA, one way and two-way ANOVA.

9 hrs

References

1. Analytical techniques in Biochemistry and Molecular Biology; Katoch, Rajan. Springer (2011)
2. Basic Methods for the Biochemical Lab; Martin Holtzhauer, Springer, (2007).
3. Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology 8th Edn. Andreas Hoffman and Samuel Clockie, Ed., Cambridge University Press, (2018).
4. Biochemistry LabFax, Ed. J.A.A. Chambers and D. Rickwood,, Blackwell Science, (1993),
5. Biochemical Techniques 87th Edn., John F. Roby,& Bernard J White Waveland Press Inc. (1987).
6. Laboratory Techniques in Biochemistry and Molecular Biology, Work and Work Vol. I & II, North Holland, (1969).
7. Choosing and Using Statistics; A Biologist Guide, Clavin Dythan, Blackwell Scientific (1999).

8. Basic Mathematics for Biochemists; Cornish Bowden, Oxford University Press (1998).
9. Biophysical Tools for Biologists *In Vivo* Techniques; John Correia H. Detrich, III Elsevier (2008).
10. Recent Advances in Electron Microscopy- Part-A; B.V. Venkartarmaprasad, and Steve Ludtke, Academic Press (2010).
11. Recent Advances in Electron Microscopy- Part-B; B.V. Venkartarmaprasad, and Steve Ludtke, Academic Press (2011).
12. Introduction to Electron Microscopy for Biologists; Terry Allen, Academic Press (2008).
13. Fluorescence Microscopy; Anda Carnea and P. Michael Conn; Academic Press (2014).

BCHT – 104: General Physiology

4 units (52 hrs)

Tissues: Formation of different kinds of tissues from primary germ layers. Types and functions of epithelial tissue, inter-cellular junctions. Connective tissue – extra cellular matrix, Collagens – types, composition, structure and synthesis, Elastin, fibronectins, and other proteins of the extra – cellular matrix. Basal lamina; laminins and associated proteins and their functions. **6 hrs**

Cytoskeleton and Cellular dynamics: *Microfilaments;* Assembly and polymerization of G-actin, role of Thymosin-B4, Profilin and Cofilin in polymerization, structural and functional property of F-actin, Capping proteins and assembly of actin filaments, branched and unbranched filament assemblies, Arp2/3, intracellular cellular movement and actin polymerization, use of toxins in study of actin dynamics. Role of cross-linking and adaptor proteins in actin bundling and membrane association.

Structure and organization of microtubules; dynamics of microtubules, assembly by MTOC, dynamic instability, tubulin polymerization as target of drugs. Side and end-binding proteins, capping and severing proteins. *Kinesins and dyneins;* vesicular transport along microtubule, role of kinesin-1 and dynein motors in organelle transport. Role of microfilaments and microtubules in cell migration.

Intermediate filaments; Assembly and tissue specific expression, dynamic nature of intermediate filaments, diseases associated with Lamins and Keratins defects.

7 hrs

Nervous System: Types and structure of neuron. Myelin sheath; composition and function. Resting membrane and action potent ial. Nernst and Goldman equations. Mechanism of initiation and propagation of action potential – voltage gated ion channels, ionophores and toxins in study membrane transport. Design and use of Patch-Clamp in measuring membrane potential. Neurotransmitters and receptors; synaptic transmission, post-synaptic potentials. Outline and functions of autonomic and central nervous systems. **6 hrs**

Muscular System: Ultra structure of smooth, skeletal and cardiac muscle fibers. Contractile and other proteins of muscle. Energy metabolism in muscle; Phosphagens, neuro-muscular junctions, excitation of striated muscles. Organization of sarcolemma, transverse-tubular system and sarcoplasmic reticulum, mechanism of muscle contraction. Regulation of contraction in striated and smooth muscle. Calmodulin and its regulatory role, muscular dystrophies.

6 hrs

Digestive System: Secretion, regulation of secretion, composition and functions of saliva, gastric, pancreatic and intestinal juices and bile. Gastro-intestinal hormones. Digestion, absorption and transport of carbohydrates, proteins, lipids, nucleic acids and vitamins. Liver – structure and functions. Detoxification mechanisms. Liver function tests. **5 hrs**

Cardio – vascular System: Systemic and pulmonary circulation. Structure of blood vessels. Regulation of cardiac activity. Blood volume, blood pressure. Plasma composition and functions of plasma liproproteins. Mechanism of blood clotting, role of vitamin K, clot dissolution, anti-clotting factors, Formation, counting and functions of erythrocytes, leukocytes and thrombocytes. Lymph, Cerebro spinal fluid (CSF); composition and analysis in diagnosis. **6 hrs**

Respiratory System: Mechanics and regulation of respiration, pulmonary and alveolar ventilation and its control, transport of respiratory gases, respiratory mechanism of acid-base balance. **5 hrs**

Excretory System: Mechanism of urine formation and composition of urine. Urine analysis for abnormal constituents, tubular function tests. Nephritis and nephrosis. Kidney hormones. Regulation of acid-base electrolyte and water balance. Respiratory and metabolic acidosis and alkalosis. **5 hrs**

Endocrine system: Hormones, feedback regulation, biosynthesis, storage, secretion, Circulation in blood. Degradation and peripheral transformation. Receptors and the mechanism of hormone action. Measurement of hormones, and receptors. Disorders of endocrine system. **6 hrs**

References

1. The Cell, Copper, Geoffery, M., Oxford University Press, (2001)
2. Text Book f Biochemistry with Clinical correlations; Thomas Devlin [Ed.] Wiley–Liss, (1997).
3. Lehninger- Principles of Biochemistry; DL Nelson and MM Cox [Eds], 6th Edn. Macmillan Publications (2012).
4. Principles of Human Physiology; 4th Edn. Cindy L. Stanfield Pearson, (2010).
5. Cellular Physiology & Neurophysiology 2nd Edn., Mordecai, P. Blaustein, Elsevier Sceince,(2012).
6. Human Biochemistry, Orten and Neuhans , 10th Edn. Mosbey International, (1983).
7. The Neuron,; Cell and Molecular Biology, Irwin B Lavitan, Leonard K Kaczmarck, Oxford University press (2015).
8. Human Physiology: The mechanisms of Body functions. A.J. Vander, et. Al., McGraw-Hill, (1985).
9. Molecular Biology of the Cell, Bruce Alberts, Alexander D Johnson, Julian Levis, David Morgan, Martin Raff, Garland Science (2014).
10. Cellular Physiology of Nerve and Muscle. Gary G Mathew (1998) Balckwell Scientific Inc.

BCHSCT – 105: Clinical Biochemistry and Nutrition (2 Credits)

4 units (26 hrs)

Introduction: Automation in clinical biochemistry laboratory and factors in quality control. Specimen collection and processing: Blood collection methods, anticoagulants. Collection of urine - urine preservatives, Timed urine specimens.

Tests and Clinical significance of urinary compounds with reference to sugars, proteins, ketone bodies, bilirubin and porphyrins. Stool – chemical examination and clinical significance. CSF – collection and composition, clinical significance. Origin, collection, composition and analysis of amniotic fluid.

4 hrs

Metabolic disorders

Disorders of Carbohydrate Metabolism: Diabetes mellitus - type I, II and gestational DM. metabolic abnormalities, diagnosis and management, acute and long term complications. glycogen storage diseases, galactosemia.

Disorders of Lipid Metabolism: Plasma lipoproteins, cholesterol, triglycerides & phospholipids in health and disease, hyperlipoproteinemia, Abeta lipoproteinemia. Lipid storage diseases - Taysach's and Niemann picks diseases, fatty liver. Atherosclerosis; risk factors, biochemical findings and management.

Abnormalities in Nitrogen Metabolism: hereditary Ortoticaciduria, Uremia, hyperuricemia, porphyria and factors affecting nitrogen balance. Inborn Errors of Metabolism– Phenylketonuria, alkaptonuria, albinism, tyrosinosis, maple syrup urine disease, Lesch-Nyhan syndrome, sickle cell anemia, Histidinemia.

7 hrs

Disorders of liver and kidney – Liver function test: clinical significance of AST, ALT, ALP and GGT. Jaundice – types and differential diagnosis. Pancreatic function test. Gastro intestinal function test: fractional gastric analysis, stimulation tests.

Renal function test: clearance tests, tests for renal blood flow, concentration and dilution tests. Acute and chronic renal failure, glomerulonephrities, nephritic syndrome, urinary calculi and dialysis.

3 hrs

Blood Clotting –Disturbances in blood clotting mechanisms– hemorrhagic disorders– hemophilia, von Willbrand's disease, purpura, Rendu-Osler-Werber disease, thrombotic thrombocytopenic purpura, disseminated intravascular coagulation, acquired prothrombin complex disorders, circulating anticoagulants.

3 hrs

Nutrition

Energy metabolism: Introduction on Nutrition: Food factors for human being. Nutritional classification, foods, Energy – Energy value of food and its determination, energy expenditure – components – basal metabolism, physical activity and thermogenesis- foods'

Basal metabolism: Definition, determination of basal metabolic rate (BMR). Standards of BMR factors affecting BMR, energy utilization in cells and energy balance. Dietary fiber- Definition, types of fiber in plant foods, sources, composition, role of dietary fiber and resistant starch in nutrition, effect of over consumption of fiber.

Protein nutrition: Nutritional consequences and Dietary Allowances Nutritive value of protein' Protein calorie malnutrition in children. protein and energy/ requirements Nitrogen balance and imbalance. Deficiency Disease of Vitamins and Minerals (Iron, sodium, potassium, fluoride, magnesium and calcium) Infant nutrition, nutrition for preschool children, school children, adolescents, pregnant and lactating mothers. Industrial workers. Geriatric nutrition and Lathyrism. Obesity: Etiology and occurrence, physiological regulation of foods intake assessment, complication, treatment and prevention of obesity. Therapeutic diets.
Regulation of food intake: role of hunger and satiety centers, effect of nutrients.
Basis for computing nutrient requirements: latest concepts in dietary recommendations, RDA-ICMR and WHO: their uses and limitations.

4 hrs

Malnutrition: Prevention of malnutrition, improvement of diets. Recommended dietary allowances, nutritive value of common foods. Protein-calorie malnutrition. Requirement of proteins and calories under different physiological states- infancy, childhood, adolescence, pregnancy, lactation and ageing.

2 hrs

References:

1. Teitz Fundamentals of Clinical Chemistry, Burtis,C. and Bruns, D. 2007 3rd Edition, W.B. Saunders Company.
2. Clinical Chemistry, Principles, Techniques, Correlations with Access, 8th Edn. Michael Bishop, Edward Fody, & Larry Schoeff, Lippincott William & Wilikns (2018).
3. Biochemistry Ed. Donald Voet & Judith G. Voet, John Wiley & Sons, Inc.(2010).
4. Advanced Nutrition and Human Metabolism 7th Edn. Sareen S Gropper, Jack L Smith, & Timothy P Carr, Cenage Learning (2018).
5. Introduction to Human Nutrition, 2nd Edn. Michael J. Gibney, Susan A. Lanham-New, Aedin Cassidy, Hester H. Vorster, Wiley-Blackwell (2009).
6. Modern Nutrition in Health and Disease, 10 Ed. Shills et al;, Lippincott Williams & Wilkins (2006).
7. Nutrition: Everyday Choices, 1st Edition; Mary B. Grosvenor, Lori A. Smolin Wiley (2006).
8. Bioactive Food as Dietary Interventions for Liver and Gastrointestinal Disease; Watson Elseveir (2012).
9. Nutrition and Metabolism, 2nd Edn., Lanham S, Mac Donald I and Roche H. The Nutrition Society, London, UK, (2012).
10. Introduction to Human Nutrition, 2nd Edn., Gibney M, Lanham S, Cassidy A and Vorster H. The Nutrition Society, London, UK, (2012).

BCHP – 106: Gen. Biochemistry – I (4 Credits)

1. Preparation of buffers; Acetate, phosphate and tris buffer.
2. Determination of saponification number and acid value of oils and fats.
3. Determination of iodine number and peroxide value of oils and fats.
4. Determination of pKa of weak acids and amino acids by pH metric titration.
5. Isolation of potato starch / liver glycogen.
6. Hydrolysis of starch / glycogen and estimation of its purity by H.J. method.
7. Hydrolysis of starch / glycogen and estimation of its purity by Somogy's method.
8. Analysis of water: estimation of calcium and magnesium by EDTA method.
9. Determination of pI of casein from milk.
10. Determination of phytic acid.
11. Estimation of vitamin -C by dichlorophenol indophenol method.

References

1. Analytical techniques in Biochemistry and Molecular Biology; Katoch, Rajan. Springer (2011).
2. Basic Methods for the Biochemical Lab; Martin Holtzhauer, Springer, (2007).
3. Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology, 8th Edn. Andreas Hoffman and Samuel Clockie, Ed., Cambridge University Press, (2018).
4. Biochemistry LabFax, Ed. J.A.A. Chambers and D. Rickwood,, Blackwell Science, (1993).
5. Protein Purification Applications, S.L.V. Harris and Angal IRL Press, (1990)
6. Laboratory Techniques in Biochemistry and Molecular Biology, Work and Work Vol. I & II, North Holland, (1969).
7. Biochemical Techniques 87th Edn., John F. Roby,& Bernard J White Waveland Press Inc. (1987).

BCHP – 107: General Biochemistry – II (4 Credits)

1. Absorption spectra of proteins and nucleic acids and determination of molar extinction coefficient.
1. Estimation of reducing sugars (lactose in milk) by DNS method.
2. Estimation of protein by Lowry's method.
3. Estimation of inorganic phosphate by Fiske-Subbarao method.
4. Estimation of tyrosine by Millon's method.
5. Isolation of nucleic acid from cauliflower / sheep liver.
6. Estimation of DNA by Diphenylamine method.
7. Ascending descending and circular paper chromatography of amino acids /carbohydrates
8. Two-dimensional chromatography of amino acid / carbohydrates.
9. Thin layer chromatography of carbohydrates / amino acids.

10. Gel–permeation chromatography of pigments/proteins.
11. Separation of proteins by non-denaturing PAGE.
12. Determination of molecular weight of Proteins by SDS–PAGE
13. Separation of isoenzymes by isoelectric focusing
14. Ion exchange chromatography of nucleic acids / proteins.

References

1. Biochemical Calculations, Irwin H.Segel (1976) 2nd Ed. Jhon Wiley and Sons.
2. Methods in Enzymology; Colowick , S.P. et al., [Eds.] (1987) Vol. 152, Academic Press.
3. Modern Experimental Biochemistry R.F.Boyer [Ed.] (1986) Addition Wesley.
4. Methods of Enzymatic Analysis; Berg Meyer (1974) Vol. 1-X,
5. Basic Biochemical Laboratory Procedures and Computing, R. Cecil Jack, Oxford University (1995).
6. Analytical Biochemistry; D.J. Holme and H. Pick Longman (1983).
7. Biochemical Techniques 87th Edn., John F. Roby,& Bernard J White, Waveland Press Inc. (1987).
8. Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology 8th Edn. Andreas Hoffman and Samuel Clockie, Ed., Cambridge University Press, (2018).
9. Bioanalytics, Friedrich Lottspeich, Wiley-VCH (2018).

BCHT – 201: Protein structure and Enzymology

4 units (52hrs)

Structural properties of Proteins: Review of classification and structure of amino acids, acid – base properties of amino acids. Ionic properties of peptides and proteins. Naturally occurring peptides. Peptide synthesis– reactive ester method and modified Merrifield solid phase synthesis.
Primary structure: Elucidation of primary structure of proteins: – Determination of amino acid composition, end-group analysis, cleavage by enzymes and chemicals, separation of fragments. Manual and modern methods of sequencing and reconstructing the protein sequence. Assignment of disulfide bonds.
Secondary structure: Peptide bond – structure and conformation, Ramachandran plot. Regular α – helix and other types of helices, β– pleated sheet, irregular, turns, loops and triple helical structures. Helix stabilizing and destablizing amino acids. Structure of fibrous proteins: α-keratin, and silk fibroin. Motifs (super secondary structure– triose phosphate isomerase, concanavalin-A and Rossmann fold) and domain structure (glyceraldehyde-3-phosphate dehydrogenase). Secondary structure of insulin, ribonuclease, lysozyme, myoglobin and chymotrypsin.
Tertiary structure: Forces stabilizing tertiary structure of proteins. Protein denaturation and renaturation.
Quaternary structure and symmetry: Structure and function of myoglobin and hemoglobin. Cooperative mechanism of oxygen binding to hemoglobin. Abnormal hemoglobin– sickle-cell hemoglobin.

10 hrs

Introduction to Enzymes: Nomenclature and classification of enzymes. Specificity and active site. Enzyme assay– enzyme units, coupled kinetic assay, immobilized enzymes. Enzyme localization. Criteria of purity of enzymes. Serine proteases, zymogen activation, multifunctional enzymes, oligomeric enzymes ,and multi- enzyme complexes.

4 hrs

The investigation of active site structure: The identification of binding sites and catalytic sites –trapping the E-S complex, use of substrate analogs, enzyme modification by treatment with proteolytic enzymes, photo – oxidation and chemical modification of amino acid side chains (cys, his, ser, asp, lys, and tyr). Affinity labeling studies (chymotrypsin triose phosphate isomerase) and super reactive amino acid chains (chymotrypsin and glutamate dehydrogenase). The 3-D structural features of active sites as revealed by X-ray crystallographic and chemical studies (chymotrypsin , elastase and triose phosphate isomerase). Site directed mutagenesis.

8 hrs

Enzyme catalysis: Chemical nature of enzyme catalysis; General acid-base catalysis, electrostatic catalysis, covalent catalysis, intra-molecular catalysis and enzyme catalysis. Mechanisms of action of the following enzymes-lysozyme, ribonuclease, lactate dehydrogenase, serine proteases (chymotrypsin), sulphydryl enzymes (papain), and multi-enzyme complexes (pyruvate dehdrogenase complex). Metal– activated and metallo-enzymes (mechanism of action of pyruvate kinase, creatine kinase, carboxypeptidase – A).

5 hrs

Kinetics of enzyme-catalyzed reactions: Methods used in the investigation of the kinetics of enzyme-catalyzed reactions, initial velocity studies, rapid reaction techniques and relaxation

technique. Enzyme kinetics of single substrate reactions – Michaelis-Menten and Briggs and Haldane theory (rapid equilibrium and steady state theory). Kinetic data evaluation-linear transformation of Michaelis-Menten equation. Pre-steady state kinetics. Integrated velocity equation. Haldane equation. King-Altman procedure for deriving the rate equation. Effect of pH & temperature on enzymatic reactions, Arrhenius plot, determination of activation energy. **7 hrs**

Enzyme Inhibition: Types of reversible inhibitors; competitive, non-competitive, uncompetitive, and mixed inhibitors. Partial inhibition, substrate inhibition and allosteric inhibition. Irreversible inhibition. **4 hrs**

Kinetics of bi- substrate reactions: Sequential mechanism, compulsory order and random order mechanism, non-sequential mechanism, ping pong mechanism, distinction between different kinetic pathways using primary and secondary plots. Inhibition studies in the characterization of bi-substrate reactions. Investigations of reaction mechanisms using isotopic exchange at equilibrium. **5 hrs**

Allostery of enzyme action: Binding of ligands to proteins, Co-operativity, the Hill equation, Adair equation, Scatchard plot and equilibrium dialysis techniques. *Sigmoidal kinetics:* MWC and KNF models. Significance of sigmoidal behavior. Allosteric enzymes and metabolic regulation. Study of ATCase as typical allosteric enzyme. Other mechanisms of metabolic regulation. **5 hrs**

Enzyme Technology: Industrial application of carbohydrases, proteolytic enzyme, lignocellulose degrading enzyme, pectin and pectic enzyme. Applications of enzymes in food and allied industries : leather, textile, detergent, paper industries. Immobilization of enzymes-methods and applications.

4 hrs

References

1. Fundamentals of Ezymology; 3rd Edn. Nicholas C. Price and Lewis Stevens, Oxford University Press (2012).
2. Fundamentals of Biochemistry Donald Voet John Wiley & Sons (2016).
3. Enzyme Kinetics and Mechanism. P. F. Cook and W. W. Cleland, Garland Science (2007).
4. Enzymes; Trevor Palmer, East – West Press Pvt. Ltd., Delhi (2004).
5. Enzymes: A Practical Introduction to Structure, Mechanism, and Data Analysis; Robert A. Copeland , Wiley-VCH Publishers (2000).
6. Methods in Enzymology; Colowick S.P. et al., Vol. 152, Academic Press, (1987).
7. Enzyme Kinetics; Roberts, D.V. Cambridge University Press (1977).
8. Enzyme Kinetics; Irwin H. Segel (1976) Interscience-Wiley.
9. Enzyme Kinetics; the Steady state approach; Engel, P.C. 2nd Edn. Champman and Hall (1981).
10. Enzymes: Biochemistry, Biotechnology and Clinical Chemistry; Trevor Palmer (Edn) Horwood Chemical Science Series.
11. Introduction to Enzyme and Co-enzyme Chemistry. Ed. T. Bugg, Blackwell Science (2000).
12. An Introduction to Enzyme and Coenzyme Chemistry; Timothy B. Bugg, (1997) Jones
13. Protein Bioinformatics, Michael, G. M. Elsevier (2010).

14. Lehninger- Principles of Biochemistry; D. L. Nelson and M.M. Cox 7th Edn. Macmillan Publications (2017).
15. Discovering Genomics, Proteomics and Bioinformatics, Campbell A M & Heyer L J, 2nd Edn. Benjamin Cummings, (2007).

BCHT – 202: Metabolism-II

4 units (52hrs)

Lipids Metabolism: Introduction, major classes of lipids, hydrolysis of tri-acylglycerols, α-, β-, ω- oxidation of fatty acids. Oxidation of odd numbered fatty acids – fate of propionate, role of carnitine, degradation of complex lipids. Fatty acid biosynthesis, Acetyl CoA carboxylase, fatty acid synthase, ACP structure and function, Lipid biosynthesis, biosynthetic pathway for tri-acylglycerols, phosphoglycerides, sphingomyelin and prostaglandins. Metabolismof cholesterol and its regulation. Energetics of fatty acid cycle.

9 hrs

Nitrogen Cycle: Introduction, biological and non-biological nitrogen fixation, *nif* genes, regulation and utilization of nitrate and nitrite, regulation of nitrate reductase. Assimilation of ammonia, formation of amino acid amides by glutamine synthetase and its regulation. **4 hrs**

General metabolic reaction of amino acids: transamination (mechanism), pseudo-transamination, glucose–alanine cycle, oxidative deamination (glutamate dehydrogenase), minor pathways of amino acid degradation– transdeamination, amino acid oxidase, and non – oxidative deamination (α–deaminase, dehydrase, asparaginase and glutaminase). Urea cycle– regulation and metabolic disorders. Biosynthesis of creatine and creatine phosphate, polyamines– putrescine, spermidine and spermine, glutathione (γ-glutamyl cycle), physiologically active amines (γ– amino butyric acid, serotonin, α– histamine and catecholamines– dopamine, epinephrine and epinephrine).

7 hrs

Degradation of the individual amino acids: Pathways in animal, plant and microbial systems; Amino acids forming from pyruvate (alanine, glycine, threonine, serine, cystine and cysteine), oxaloacetate (aspartic acid and asparagine), α- ketoglutarate (glutamic acid, glutamine, arginine, histidine and proline), succinyl CoA (valine, isoleucine and methionine), acetoacetate and/or acetyl CoA (leucine and lysine), pyruvate, formaldehyde, acetoacetate and/or acetyl CoA (tryptophan), and fumarate, acetoaetate and/or acetyl CoA (phenylalanine and tyrosine). Inherited disorders associated with glycine, aromatic, branched chain, basic and sulfur containing amino acid metabolism. **9 hrs**

Biosynthesis of the individual amino acids: Pathways in animal, plant and microbial systems– biosynthesis of non – essential amino acids from pyruvate (alanine), intermediates of glycolysis (serine) and TCA cycle (aspartic acid, asparagine, glutamic acid and glutamine), essential amino acid (tyrosine), non – essential amino acid (glycine, proline and arginine), and essential & non – essential amino acid (cysteine). Biosynthesis of essential amino acids from aspartate family of amino acids (threonine, lysine and methionine), pyruvate family of amino acids (valine and leuvine), pyruvate and α–ketobutyrate family of amino acid (isoleucine), aromatic family of

amino acids (phenylalanine, tyrosine and tryptophan) and histidine. Regulation of amino acid biosynthesis by sequential & concerted feedback inhibition. **9 hrs**

Nucleotides: Review of physicochemical properties of nucleic acids. Biosynthesis and degradation of purine and pyrimidine nucleotides and its regulation. Purine salvage pathway. Role ofribonucleotide reductase (mechanism). Biosynthesis of deoxyribonucleotides and polynucleotidesincluding inhibitors of nucleic acid biosynthesis.

6 hrs

Porphyrins –Biosynthesis and degradation of porphyrins. Production of bile pigments.

4 hrs

Phenolic Metabolism: Shikimate, Phenylalanine and Phenylpropanoid pathways, Flavanoids, Lignins and Anthocyanin. Isoprenoid Metabolism; Terpenoids and Carotenoids; Alkaloids, Cyanogenic glycosides and Non-protein amino acids.

4 hrs

References

1. Biochemistry- R. Garret, Charles M Grisham, Belmont (2013)
2. Biochemistry; Geoffrey Zubey, WCB Publishers, (1998).
3. Biochemistry; David Rawn, Panima Publishers, (1989).
4. Fundamentals of Biochemistry Donald Voet John Wiley & Sons (2016).
5. Fundamentals of General, Organic and Biochemistry, John Mc Murry, & Donald S Ballantine & Carl A Hoeger Pearson (2017).
6. Text Book of Biochemistry with Clinical correlations; 6th Edn. Thomas M. Devlin Wiley-Liss (2012).
7. Lehninger- Principles of Biochemistry; D. L. Nelson and M.M. Cox 7th Edn. Macmillan Publications (2017).
8. Principles of Biochemistry; Smith et al., [Ed.] McGarw Hill (1986).
9. Bioenergetics; A Practical Approach, G.C. Brown and C.E. Cooper (1995) IRL- Oxford University Press.
10. Harper;s Illustrated Biochemistry, 31st Edn.Victor W Rodwell et al., (2018)
11. Biochemistry Ed. Donald Voet & Judith G. Voet, John Wiley & Sons, Inc. (2010).
12. Bioenergetics; David Nicholls and Stuart Ferguson, Elsevier (2013).

BCHT – 203: Analytical Biochemistry – II

4 units (52hrs)

Chromatography: Introduction, partition coefficient phase systems, liquid and solid phases, principle procedure and application of paper chromatography, column chromatography; retention, resolution, physical basis of peak broadening, plate height equation, capacity factors, peak symmetry.

Modes of chromatography: Ion exchange, ion exchange matrices, examples of cation and anion exchangers, chromate-focusing. Gel filtration: fractionation range and matrices, determination of native mass of protein.

Hydrophobic interactions and affinity chromatography: Affinity ligands, immobilization of ligands. Activation of matrices, coupling affinity ligands (example–GSH). Metal affinity chromatography, His tag, open column chromatography, hydroxyl apatite chromatography.
HPLC: Instrumentation, injectors, mobile phases in HPLC, two dimensional HPLC, factors affecting resolution in HPLC chromatography. Separation modes: normal and reverse, gradient reverse phase, ion suppression and ion pairing. Chiral-HPLC, chiral columns. Detectors: UV, visible fluorescence, electrochemical detectors. Fast protein liquid chromatography (FPLC).
Thin layer chromatography: Introduction; phases used in TLC preparative TLC, metabolic profiling, solvent systems for TLC. Detection of compounds on TLC plates.

12 hrs

Gas chromatography: Principle and design of instrument. Factors affecting GC, stationary phase, mobile phase, column length, diameter, film thickness, flow rate temperature, sample introduction. Detectors: flame ionization, thermal ionization, electron capture, mass selective detection. GLC; principle and application.
Capillary electrophoresis: Principle, instrumentation, electro-osmotic flow, free solution capillary electrophoresis. Choice of buffers and ionic strength. Organic modifiers electro chromatographic-electrically driven HPLC. Capillary sample introduction and detection in capillary electrophoresis.

8 hrs

Electrophoresis: Historical developments, principle, non-denaturing PAGE, activity staining for enzymes, zymogram, denaturing electrophoresis (PAGE), SDS-PAGE, SDS-PAGE in reducing conditions, chemical cross linking of proteins urea electrophoresis, isoelectrofocusing. Electrophoresis in DNA sequencing, Sanger- deoxynucleotide sequencing. Foot-printing of DNA.

6 hrs

Spectroscopic techniques: Wave particle duality of light, electromagnetic spectrum, transition in spectroscopy. Principle, design and application of UV-Vis spectrophotometry. Principle, design and application of fluorescence spectroscopy. Measurement of fluorescence and chemiluminiscence, use of fluorescence in binding studies. Spectroscopy techniques using plane polarized light, circular dichroism (CD), equipment for CD measurement, CD of biomolecules (proteins) and LD (linear dichroism) of biomolecules.
IR spectroscopy: Physical basis of IR spectroscopy. Instrumentation, use of IR in structure determination, Fourier transfer, IR spectroscopy, Raman IR spectroscopy.
ESR: Principle, measurement of ESR spectra uses of ESR in chemistry.
NMR: Principle, effect of atomic, identity on NMR, chemical shift, spin coupling NMR, measurement of NMR spectra, biochemical application of NMR.
Mass spectroscopy: Principle, overview of MS- experiment, ionization modes, equipments in MS analysis (Identification of metabolites) MS of protein/ peptides. Interfacing MS with other methods; MS/MS, LC/MS, GC/MS, electrophoresis/MS. Uses of MS in Biochemistry: MS and heterogeneity in proteins, peptide mapping, post translation modification analysis, determination of disulfide bridges, analysis of DNA compounds.

12 hrs

Proteomics: Electrophoresis in proteomics, 2D SDS–PAGE, basic principle, instrumentation, analyses of cell proteins, free flow electrophoresis, blue native gel electrophoresis, Mass spectrometry in proteomics, tagging methods for MS proteomics, isotope coded affinity tagging, tagging for tandem MS. Microarrays, protein biochips. Post translational modifications in proteomics, proteolysis, glycosylation, oxidation, protein disulfides, phospho-proteins.

7 hrs

Metabolomics: HPLC and FPLC based approaches in metabolomics. Criteria for the selection of chromatography methods and their importance in metabolomics. Application for cellular metabolomics for metabolic pathway structure. Size of metabolome, metabolite identification, pathway identification and pathway integration. Metabolite profiling for infectious disease. Metabolite profiling in heart disease-application. Metabonomics in preclinical pharmaceutical discovery and development.

7 hrs

References

1. Analytical techniques in Biochemistry and Molecular Biology; Katoch, Rajan. Springer (2011)
2. Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology 8th Edn. Andreas Hoffman and Samuel Clockie, Ed., Cambridge University Press, (2018).
3. Biochemistry and Molecular Biology; 5th Edn. D. Papachristodoulou, A. Snape, W.H. Elliott, and D. C. Elliott, Oxford University Press (2014)
4. Discovering Genomics, Proteomics and Bioinformatics, Campbell A M & Heyer L J, 2nd Edn. Benjamin Cummings, (2007).
5. Principle and Practice of Bioanalysis; Richard F. Venn (Ed.) Taylor and Francis (2000).
6. Hydrophobic interaction Chromatography, Principles and Methods, Stuart E. Builder, Amarsham-Pharmacea Biotech (1993).
7. Biochemical, Physiological, and Molecular Aspects of Human Nutrition, Stipanuk Elseveir (2012).
8. Protein Bioinformatics; M. Michael Gromiha, Academic Press (1983).
9. The Physical Basis of Biochemistry: The Foundations of Molecular Biophysics, 2nd edn. R. R. Bergethon, Springer, NY (2010).
10. Isoelectric Focusing; Theory, Methodology and Applications; P.G. Righetti , Elsevier (2013).
11. Fluorescence Microscopy; Anda Carnea and P. Michael Conn; Academic Press (2014).
12. Fluorescence Spectroscopy; Ludwig Brand and Michael Johnson, Academic Press (2008).
13. Metabolome Analysis: An Introduction, S.G. Villas-Boas. Wiley-Blackwell, USA. (2007)
14. Concepts in Plant Metabolomics, B. J. Nikolau. Wurtele, Eve Syrkin, Springer, USA (2007).
15. The Handbook of Metabonomics and Metabolomics, J. Lindon, J. Nicholson, E. Holmes. Elsevier B.V., Netherlands (2006)

BCHT – 204: Immunology and Microbiology

Infection: Types of infection and nature of infective agents. Nonspecific host defense mechanisms. Anatomical barriers; lysozyme and other antimicrobial agents. Phagocytosis and phagocytic cells, neutrophils, monocytes and macrophages. **4 hrs**

Immunity: States of immunity; innate and acquired immunity, naturally and artificial acquired passive and active immunity. Immunization practices, use of toxoids, killed and attenuated organisms. Surface components and newer vaccines, production of vaccines. **4 hrs**

Cellular basis of immunity: immunological memory, specificity, diversity, discrimination between self and non self, primary and secondary lymphoid organs, cell mediated and humoral immune responses, T and B lymphocytes, autoimmune reactions.

4 hrs

Antigen and antibody: antigen, antigenic determinant, immune-potency, structure of antibody, constant and variable regions, Fab, F(ab2) and Fc fragments, different classes of antibodies and their functions, fine structures of antibodies, X ray diffraction studies, isotypes, allotypes and idiotypes.

5 hrs

Molecular Immunology: Theories of antibody formation; clonal selection and network, Genetics of antibody diversity, germ line and somatic mutation theories, immunoglobulin, monoclonal and polyclonal antibodies, poly reactive antibodies, catalytic antibodies, abzymes. MHC a TCR gene organization and their recombination, class switch of Ig genes.

5 hrs

MHC : Organization, MHC molecules and genes, cellular distribution, regulation of MHC and immune responsiveness, MHC and susceptible deficiency diseases. Antigen processing and presentation.

T-cell : Receptor complex structure, T-cell maturation, activation and differentiation. Cell death and T-cell population.

B-cell : Receptor complex structure, T-cell maturation, activation and differentiation.

Complement activation: Pathways, regulation of complement system, Biological consequences of complement activation, complement deficiencies.

Antigen- Antibody interactions: In vivo - cross reactivity, In vitro: precipitants, agglutinants, Dot blotting and immuno-diffusion tests with antibodies, immune-electrophoresis, . Rocket electrophoresis, counter immune-electrophoresis, RIA, ELISA- techniques and applications, western blotting. FACS.

7 hrs

Cytokines : Structure and function of IL, IFN, TNF, CSF, cytokines receptors, cytokine antagonists, cytokines related diseases. Cell mediated immunity: CTL mediated cytotoxicity, NK cell mediated toxicity, delayed type hypersensitivity. Immunological tolerance.

Leukocyte mediated immune response: Cell adhesion molecule, Lymphocyte and neutrophils, extravasation, mediators of inflammation, inflammatory process.

Hypersensitivity reactions: Type- I, II, III and IV. Hypersensitivity diseases. Immunity to infectious diseases : viral - influenza, bacteria – tuberculosis, parasite – *Plasmodium falciparum*, helminthes.

Autoimmunity : Autoimmune diseases in human, animal models, mechanism of induction of

autoimmunity, therapy.

5 hrs

Transplantation : Types, Genetics of transplantation, Graft versus host reaction, tissue matching and immunosuppressive agents, clinical manifestation, therapy and bone marrow transplants, organ- transplants. Immunodeficiency diseases: B-cell, T-cell, SCID, Pathogenesis, diagnosis and treatments of AIDS.

3 hrs

Vaccines : 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, tumor evasion, cancer immunotherapy.

4 hrs

Microbial Biochemistry; Morphology and structure of bacteria, gram positive and gram negative organisms. Sterilization, nutritional requirements and growth characteristics of bacteria, media for growing bacteria and fungi. Enrichment culture techniques for isolation of chemoautotrophs, chemoheterotrophs and photosynthetic microorganisms.

3 hrs

Food and Diary Microbiology: Food spoilage, food preservation, fermented foods, exotoxins produced by bacteria. Contamination of milk by microbes, Bacterial count, reactions occurring in milk, Pasteurization and sterilization. Fermented milk products, cheese

3 hrs

Viruses: –General structure, and classification of plant, animal and bacterial viruses.
Bacteriophages; one step growth experiment, single burst and premature lysis experiments, productive cycles of λ and ϕx-174 viruses, RNA phages, isolation and cultivation of bacterial viruses. Plant viruses- transmission, effect on plants, common diseases, TMV. Slow viruses and DI viruses- discovery and importance. Animal viruses- productive cycle of DNA viruses- parvo, adeno. RNA viruses- polio, Influenza Retrovirus (RSV). Persistent chronic and acute viral infections. Inhibition and inactivation of viruses by physical and chemical agents.
Interferon- types, nomenclature and classification, induction, antiviral effect, antiviral proteins-ds RNA dependent and independent pathways. **5 hrs**

References

1. Antibodies– A Laboratory Manual; E. D. Harlow, David Lane, 2nd Edn. CSHL Press (2014).
2. Primer to the Immune Response, Tak Mak Mary Saunders Bradley Jett, Elsevier (2014).
3. Autophagy: Cancer, Other Pathologies, Inflammation, Immunity, Infection, and Aging; M. Hayat (Ed.) Elsevier (2014).
4. Cellular and Molecular Immunology (8th Edn.), A. Abbas, A. Lichtman, S. Pillai, Saunders, Elsevier, USA (2014).
5. Roitt's Essential Immunology; Ivan, M. Rohitt & Petrer J Delves (2001) Blackwell Science.
6. Immunology: Roitt et al., Mosby (2001),
7. Kuby Immunology; Oven, Punt, Stranford, 7th Edn. W. H. Freeman (2013).
8. Immunology at a Glance: J.H.L. Playfare [ed.] Blackwell Science, (1987).
9. Immunology; Jan Klein [Ed.], Blackwell Science (1990).
10. Microbiology; Prescott, Harley and Klein, McGraw-Hill (2003).

11. Understanding Immunology (Cell and Molecular Biology in Action); Peterwood, Pearson Education Ltd. (2006).
12. Microbial physiology, 4th Edn. Albert G. Moat, John W. Foster and Michael P. Spector, Wiley-Liss (2002).
13. Modern Food Microbiology; James M Jay CBS Publishers (1996).
14. A Modern Introduction to Food Microbiology; Board, R.G. (Ed.) (1983) Blackwell Scientific Publications.
15. Microbiology; Lansing M. Prescot, Hartley and Klein, 5th Edn. McGraw Hill (2002).
16. Applied Microbial Physiology: A practical approach Rhodes and Stanbury (1997) IRL Press.
17. Basic and Practical Microbiology, Ronald L. Atlas (1986) McMillan Publication Co.
18. Microbiology, Pelczer, Reid and Kreig Tata McGraw Hill (1996).
19. Biology of Microorganisms, Brock Prentice Hall (1996).

BCHSCT – 205: Bioinformatics and Research Methodology (2 Credits)

2units (26 hrs)

Introduction: Introduction, scope and basic principles of bioinformatics. Types of operating systems, networking and remote login, fundamentals of working with UNIX. Running programmes over internet, software downloading and installation.

2 hrs

Biological Databases; Overview, modes of database search, mode of data storage (Flat file format, db-tables), flat-file formats of GenBank, EMBL, DDBJ, PDB, SwissProt.

Sequence Alignment; local and global sequence alignment; (BLAST, FASTA, CLUSTALW) Pairwise sequence alignment, scoring an alignment, substitution matrices, multiple sequence alignment.

Phylogenetic Analysis; concept of phylogenetic analysis, rooted/uprooted trees, approaches for phylogenetic tree construction (UPGMA, neighbour joining, maximum parsimony, maximum likelihood).

6 hrs

High throughput Data: Generation and Analysis, Assembly pipeline for clustering of HTGS data, format of '.ace' file, quality assessment of genomic assemblies; International norms for sequence data quality; Clustering of EST sequences, concept of Unigene.

4 hrs

Annotation: Procedures for High Through-put Sequence Data; Identification of various genomic elements (protein coding genes, repeat elements); Strategies for annotation of whole genome; Functional annotation of EST clusters, gene ontology (GO) consortium, phylogenomics.

4 hrs

Structure Predictions; Nucleic Acids and Proteins structure prediction, Approaches for prediction of RNA secondary and tertiary predictions, energy minimization and base covariance models; Basic approaches for protein structure predictions, comparative modeling, fold recognition/ 'threading', and *ab- initio* prediction.

4 hrs

Research Methodology:

Collection and review of research literature, sources of literature and their evaluation. Designing research methodologies.

Reports: Significance of report writing, different steps in report writing, types of report, layout of research paper. Mechanics and precautions of writing research reports for scientific journals, popular magazines, seminars/symposia/conferences/workshops, poster session.

Presentation: Presentation – Oral & Written, Presentations in classrooms, scientific meets & public audience. Defense of research thesis.

6 hrs

References

1. Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins. A.D. Baxevanis, B.F.F. Ouellette, (2005) John Wiley and Son Inc., USA.
2. Bioinformatics Sequence and Genome Analysis. D.W. Mount Cold Spring Harbor Laboratory Press (2004).
3. Bioanalytics, Friedrich Lottspeich Wiley –VCH (2018)
4. Introduction to Bioinformatics, A. Tramontano (2007). Chapman & Hall/CRC, USA.
5. Understanding Bioinformatics, M. Zvelebil, J.O. Baum (2008) Taylor and Francis, USA.
6. Research methods for biological science. Gurumani.N,.MJP pub (2007).
7. Biophysical Tools for Biologists *In Vivo* Techniques; John Correia H. Detrich, III Elsevier (2008).
8. Research Methodology in the Medical and Biological Sciences, Petter Laake, Haakon Breien Benestad ,Bjorn R. Olsen (Eds) AcADEMIC Press, (2007).
9. Research Methodology: For Biological Sciences, N. Gurumani, MJP Publishers (2011).
10. Introduction to Genomics, 3rd Edn. Arthur M Lesk Oxford University press (2017).
11. Research methods in biological science. Dr.S.Palanichamy, & M. Shanmugavelu,

BCHP – 206: Immunochemistry and Informatics (4 Credits)

1. Precipitin reaction by double immunodiffusion and radial immunodiffusion (Ouchterlony and Mancini's methods)
2. Detection of antibodies or antigen by ELISA (Indirect and Sandwich ELISA)
3. Detection of antigens by immune-blotting techniques
4. Demonstration of indirect agglutination reaction-latex agglutination.
5. Purification of antibodies; conventional (isolation of IgY from Egg yolk).
6. Rocket electrophoresis.
7. Sequence alignment and phylogenetics
8. Basic python programming
9. ANOWA using R
10. Data mining using R

References

1. Methods in Immunology and Immunochemistry; Curtis Williams, Academic Press (1971).
2. Immuno Assay Hand Book; David Wild, Elsevier (2013).
3. Basic Methods for the Biochemical Lab; Martin Holtzhauer, Springer, (2007).
4. Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology 8th Edn. Andreas Hoffman and Samuel Clockie, Ed., Cambridge University Press, (2018).
5. Laboratory Techniques in Biochemistry and Molecular Biology, Work and Work Vol. I & II, North Holland, (1969).
6. Principle and Techniques of Practical Biochemistry; Keith Wilson and John M. Walker, Cambridge University Press (2000).
7. Laboratory Techniques in Biochemistry and Molecular Biology, Work and Work Vol. I & II, North Holland, (1969).
8. Basic and Practical Microbiology, Ronald L. Atlas (1986) McMillan Publication Co.
9. Microbes in Action, A Laboratory Manual of Microbiology Seley et al., (19) W.H. Freeman.
10. Biophysical Tools for Biologists *In Vivo* Techniques; John Correia H. Detrich, III Elsevier (2008).

BCHP – 207: Enzymology (4 Credits)

1. Determination of total activity of pea esterase.
2. Determination of K_M and Vmax of pea esterase.
3. Determination of optimum pH of pea esterase.
4. Determination of pH stability of pea esterase.
5. Determination of optimum temperature and activation energy of pea esterase.
6. Determination of temperature stability of pea esterase.
7. Determination of type of inhibition (reversible or irreversible) of pea esterase.
8. Determination of I_{50} of pea esterase using organophosphate inhibitor.
9. Determination of total activity of salivary α-amylase /β-amylase (sweet potato or germinated ragi).
10. Determination of Km and Vmax of α-amylase / β-amylase.
11. Determination of Km and Vmax of alkaline phosphatase (potato).
12. Determination of type of inhibition (reversible or irreversible) of alkaline phosphatase.
13. Determination of I_{50} of alkaline phosphatase.
14. Determination of inhibitor constant, Ki of alkaline phosphatase.
15. Determination of optimum temperature and activation energy of urease (horsegram).

References

1. Enzymes: Biochemistry, Biotechnology and Clinical Chemistry: Trevor Palmer, Horwood, (2001).
2. Enzymes: A Practical Introduction to Structure, Mechanism, and Data Analysis: Robert A. Copeland, by Wiley-VCH Inc. (2000).
3. *Enzymes: A Practical Introduction to Structure, Mechanism and Data Analysis*: Robert A. Copeland , John Wiley & Sons (2000).
4. Enzyme Kinetics: *A Modern Approach*: Alejandro G. Marangoni, John Wiley & Sons (2002)
5. Enzyme Kinetics: *Principles and Methods:* Hans Bisswanger, Wiley–VCH (2002).
6. Fundamentals of Enzyme Kinetics: 4th edn. Athel Cornish-Bowden, Wiley-Blackwell (2012).
7. *Fundamentals of Enzyme Kinetics*: Athel Cornish-Bowden, Portland Press (2004)
8. Contemporary Enzyme Kinetics and Mechanism, D. L. Purich 3rd Edn., AP (2009).
9. Practical Enzymology, Second Revised Edtion [StormRG]: Hans Bisswanger, Wiley – Blackwell; 2 edition (2011)

BCHT – 301: Molecular Biology – I

4 units (52 hrs)

Introduction: Central dogma of molecular biology, Relationship between genes and proteins. Nature of genetic material, experiments confirming DNA as genetic material. RNA as genetic material. Variation in size and shape of genomes; ultracentrifugation and electron microscopic methods to study the shape and size of genomes. Size of genome and genetic capacity; C-value paradox. Organelle genomes, Genome sequence and gene numbers, *Topological problems;* Topo-isomerases, gyrases and helicases- assay, mechanism and classification.

6 hrs

Prokaryotic DNA Replication: Replicon, linear and circular replicons, unidirectional and bidirectional replication, experimental methods, mapping origin of replication, semi-conservative and semi-discontinuous replication; experimental demonstrations.
Priming DNA synthesis in bacteria; experimental evidence, components of primosome, Initiation at origin (*oriC*) of *E. Coli*. Isolation of replication intermediates. Regulation of initiation at origins, sequestration of origins after replication, role of helicase.
Enzymology of DNA replication; DNA polymerases, chemistry of nucleotide polymerization and in vitro assay. Properties and functions of DNA polymerase-I, Korenberg enzyme. Hand-palm structure of DNA polymerases. Processivity and fidelity of replication. Conditional lethal mutants, identification of replicative polymerase. Subunit composition of polymerase –III holoenzyme, functional characterization of subunits. Mechanism of replication of *E. coli* DNA-trombone model, termination of replication. Bacterial replication and its connection to cell cycle. Replication of DNA ϕX174 in *E.Coli.*

Eukaryotic DNA replication; Replicative and repair enzymes of eukaryotes. Initiation, elongation by eukaryotic DNA polymerases. SV-40 replication using eukaryotic replicative machinery. Isolation of ARS of yeast, ORC, Licensing factors and control of eukaryotic DNA replication, role of MCM proteins. Replication of organelle genomes, maintenance of ends of linear DNAs; telomeric DNA and telomerase. Regulation of eukaryotic DNA replication and inhibitors of DNA replication.

10 hrs

DNA repair: Experimental demonstration of repair in prokaryotes, damaging agents and damage recognition, direct repair, Miss-match repair assay for mismatch repair, Base excision repair (BER), Nucleotide excision repair (NER) systems; components and mechanism of repair, error prone repair, SOS and Rec-A. Eukaryotic BER and NER, controlling direction of mismatch repair, DNA damage in chromatin **5 hrs**

Transcription in prokaryotes: The transcriptome, prokaryotic RNA polymerase; molecular composition, and mechanism of transcription. Initiation of prokaryotic transcription; Structure of bacterial promoters. Structure and function of sigma factor, sigma cycle, FRET assay for sigma movement. Promoter clearance, role of α-subunit in upstream element recognition. Foot-printing of upstream elements with α-subunit. *Elongation:* Role of β-subunit in phosphodiester bond formation. Structure of elongation complex and core polymerase. Termination of

transcription: Rho- dependent and independent, termination, RNA product under Rho dependent termination.

6 hrs

Transcription in eukaryotes: Nuclear RNA polymerases- rat liver RNA pol. Sensitivity to α-amanitin and metal ions. Subunits of RNA pol-II (yeast pol-II). Heterogeneity of Rpb1 subunit. Formation and maintenance of transcription bubble.
Eukaryotic promoters: Class-II core promoter, modular organization, SV40 early promoter. Linker-scanning mutagenesis, TATA Box, downstream promoter elements, proximal promoter elements, TATA-less promoters and initiators. Class-I and Class-III promoters, Enhancers and silencers.
Class-II pre-initiation complex, foot-printing DAB. Components of TFIID, TBP and associated factors (TAFs). Phosphorylation of CTD of RNA pol-II, Mediator complex and RNA pol-II. Elongation factors: Effect of TFIIS, reversal of transcription arrest, proof reading of transcripts. Composition and working of transcription units at class-I and class-III promoters.

RNA processing: split genes, RNA splicing: R-looping experiments, splicing signals, effect of splicing on gene expression. Splicing of nuclear mRNA precursors. Mechanism of RNase T_1 and T_2, direct evidence for a branched nucleotide.
Spliceosomes: snRNPs, U1snRNP, detection of spliced product by RNase protection assay. U6snRNP, U2snRNP and U4snRNP. Spliceosome assembly and function. Alternative splicing, exon-intron definition. Commitment of precursor RNA to splicing, role of sr protein. Yeast two hybrid assay. Role of RNA pol-II in splicing, control of splicing. Self splicing RNase. Group-I introns, demonstration of exon ligation, Group-II introns.
Post transcriptional modification of mRNA: Structure of cap, purification of caps, capping substrate. Cap structure of Reo virus, functions of cap.
Polyadenylation: Function of poly A, mechanism and signals for polyadenylation. Cleavage and Polyadenylation for mRNA elongation of poly-A, poly-A binding protein (PABP), turnover of poly-A. Coordination of mRNA processing with Coupling termination and mRNA 3' end processing. **13 hrs**

Ribosomes: Prokaryotic ribosomes; molecular components, *in vivo* assembly, dissociation of subunits, and polysomes. Eukaryotic components and their assembly, organelle ribosomes. **3 hrs**

Translation: Initiation of protein synthesis in prokaryotes, Shine-Dalgarno sequence, formation of 30 S and 70 S initiation complexes; effect of GTP hydrolysis by IF2. exchange of ribosomal subunits. Eukaryotic translation initiation-scanning model, eukaryotic initiation factors, role of eIF4E, F, and G. Formation of stable 48S initiation complex, role of eIF1 and eIF1A, toeprint assay, direction of polypeptide synthesis and mRNA translation. Control of translation in bacteria and eukaryotes. Amino acyl-tRNA synthetases, formation of ternary complex among amino-acyl tRNA, EF-T, and GTP, three site model of ribosome, peptide bond formation, G-protein and translation, stop codon supression, release factors, aberrant termination, non-stop mRNAs, termination of transcription, termination codon, no-go-decay of mRNA. Inhibitors of prokaryotic and eukaryotic translation. Post-translational modifications of proteins. Mechanism of translational control.

Genetic code; breaking the code, experimental results leading to deciphering genetic code, coding properties of mRNA, Co-linearity of genes and proteins, Coding properties of tRNA, triplet binding assay, use of synthetic oligo nucleotides (works of Khorana and Neirenberg), base pairing between codon and ani-codon, Wobble base pairing. Properties of genetic code, deviation from universal genetic code.

9 hrs

References

1. Biochemistry; David Rawn, Panima Publishers (2012).
2. The Bacteriophages; Richard Calendar, 2nd Edition, Oxford University Press (2005).
3. Basic Virology; Wagner and Hewlett; Blackwell Science, (2004)
4. LEWINS Gene XII; Krebs, Jocelyn E.Burlington, MA : Jones & Bartlett Learning, (2018).
5. Molecular Biology of the Cell, Alberts et al., Garland Publications, (2012).
6. Molecular Biology, David Freifelder, Narosa Publishers, (1997).
7. Molecular Biology 5th Edn., Robert F. Weaver, McGraw Hill (2018).
8. Microbial Genetics; Maloy et al., Jones and Bartlett Publishers, (1994).
9. Principles of Developmental Genetics; S.A. Moody, Academic Press (2007).
10. Molecular Biology of Gene; Watson, J.D. et al.,7th Edn. Pearson Education; (2004).
11. Principles of Virology; S.J. Flint et al., ASM Press (2000).
12. Biochemistry and Molecular Biology; 5th Edn. D. Papachristodoulou, A. Snape, W.H. Elliott, and D. C. Elliott Oxford University Press (2014)
13. Biochemistry 5th Edn. Jeremy M. Berg, John L. Tymoczko, Lubert Stryer (2011).
14. Genome Stability: DNA Repair and Recombination; James Haber, Garland Science (2013)

BCHT – 302: Biochemistry of Cell signaling

4 Units (52 hrs)

Principle of Signal transduction:
Introduction, basic model of signal transduction pathways, Extracellular signals acting locally or at a distance, major types of signaling mechanisms, cell-cell contact, Cell surface receptors, major class of cell surface receptors, evolutionary origin, Diversity of Cellular responses, mechanisms of signal transduction; major components of a hypothetical signaling pathway, second messengers, signaling proteins, Signaling proteins as molecular switches Localization of signaling proteins.

5 hrs

G-protein coupled receptor system: Transmembrane Receptors, Domains of Transmembrane (TM) receptors, and Regulation of Receptor Activity. GTPase Superfamily: General Functions and Mechanism, G-domain as Common Structural Element of the GTPases. General mechanism of the activation of effectors molecules associated with G-protein-coupled receptors, G-protein coupled receptors that activate or inhibit adenylate cyclase, G-protein coupled receptors that activate phospholipase-C, and G-protein coupled receptors that regulate ion channels. Signaling via Arrestin.

6 hrs

Ser/Thr-Specific Protein Kinases and Protein Phosphatases;
Classification, Structure, and Characteristics, regulation of Protein kinases, The Protein Kinase Reaction, Control of Protein Kinase Activity, regulation of Protein Phosphorylation. Structure, substrate specificity, and regulation of Protein kinase–A (PKA), A-Kinase Anchor Proteins (AKAPs); The PI3 Kinase/Akt Pathway, Signaling by Akt Kinase. Classification, Structure, functions, and substrates of PKC, activation and regulation of PKC, Receptors of PKC.

6 hrs

Intracellular Messenger Substances: "Second Messengers": General Properties,
Cyclic AMP, cAMP Signaling. cGMP-Guanylyl Cyclases, Targets of cGMP, Inositol Phospholipid Messengers, PLC, PtdIns(3,4,5)P3, PtIns (4,5)P2 and Diacylglycerol. Ceramide, sphingosine, and Lysophosphatidic Acid as signalling molecules. InsP3 Receptor, Storage and Release of Ca^{++} . Ryanodine Receptor, cADP-Ribose and NAADP. Ca^{++} as a Signal Molecule, the EF Hand: A Ca-Binding Module, Calmodulin as a Ca^{++} Sensor, Target Proteins of Ca/Calmodulin, other Ca^{++} Sensors.
NO Signaling; NO and NOS, Physiological Functions of Nitrosylation, Nitrosylation of Metal Centers, NO-Sensitive Guanylyl Cyclase, Regulatory functions of Nitrosylation and Denitrosylation, Toxic Action of NO and Nitrosative Stress.

5 hr

Intracellular signaling proteins; adaptors, activators, bifurcators, integrators and effectors; Downstream cascades of Receptor Tyrosine Kinase, Extracellular-signal-regulated kinases, MAPK-Ras–Raf, SOS signaling pathways; Effectors of intercellular signaling- Adenylate cyclase, Phospholipase–C, Nitricoxide synthase, guanylate cyclase and their activation. Regulation of signaling cascades, positive modulation and negative modulation.

5 hrs

Cytokines—Interferon family: Major proteins/protein families that constitute the cytokine group of regulatory molecules; Structural classification of cytokines; Cytokine receptor super families; Human interferons (IFNs) and the cells that produce interferons; Interferon signal transduction; Interferon receptors; JAK–STAT pathway; Interferon JAK–STAT pathway; Biological effects of interferons. **6 hrs**

Regulation of hematopoiesis; cell adhesion and roles of different adhesion molecules; gap junctions; extracellular matrix; integrins**.** **3 hrs**

Cell Cycle: G0, G1, S, G2 and M-phases of cell cycles-Characteristics of each phase of cell cycles. Restriction point of cell cycle and Quiescent cells, Synchronization of mammalian cells-its importance. Determination of the length of each phase of cell cycle. Control of cell cycle in yeast, and mammalian cells. Role of various cycle-CDK complexes in the transition of various check point of cell cycle. Role of ubiquitin protein ligase –SCF and APC/C in the control of cell cycle.

5 hrs

Apoptosis : Overview of Apoptotic Pathways, Caspases: Death by Proteolysis, Mechanism of Caspases, Caspase Activation and Regulation, Inhibitor and Substrates, Family of Bcl-2 Proteins: Gatekeepers of Apoptosis. The Mitochondrial Pathway of Apoptosis, Permeabilization of the Mitochondrial Outer Membrane, Apoptosome and Caspase Cascade. Other Apoptogenic Proteins Released from Mitochondria.

Death Receptor-Triggered Apoptosis, Fas/CD95 Signaling Pathway, Tumor Necrosis Factor-Receptor 1 and Apoptosis.PI3 Kinase/Akt Kinase and Apoptosis, p53 and Apoptosis Transcription-Independent Induction of Apoptosis by p53.

5 hrs

Cancer : Transformation of normal cell to tumor, Basic Characteristics of Tumor Cells, Mutations in Cancer Cell, genetic and epigenetic changes in cancer, microRNA and cancer. Cancer genes; oncogenes and tumor suppressor genes, Rb and ARF proteins, carcinogenesis an volutionary process, Hallmark of cancer. Oncogene activation, Oncogeneic receptor Tyrosine kinases, Oncogneic activation of Ras signaling, Cyclin, Oncogenic transcription factors. p53 – properties and post translational modifications. Chemotherapeutic and chemo– preventive agents; antioxidants. Drug resistance in cancer chemotherapy.

6 hrs

References

1. Biochemistry of Signal Transduction and Regulation, Gerhard Krauss, 5th Edn. Wiley-VCH Verlag GmbH & Co (2014).
2. Text Book of Biochemistry with Clinical Correlations – Thomas H. Devlin
3. Biopharmaceuticals Biochemistry and Biotechnology 2nd Edn. Gary Walsh, John Wiley & Sons, Ltd, England (2003).
4. Basic Neurochemistry; George Siegel et al., Wippincott, Williams and Wilkins (1999).
5. The Biochemistry of Cell signaling; Ernst J.M. Helmreich, OUP, (2001).
6. Signal transduction and human disease; Toren Finkel, and J. Silvio Gutkind, John Wiley & Sons, Inc. (2003)
7. Greenspan's Basic and Clinical Endocrinology; 9th Edn. David Gardner and Dolores Shoback Lange Clinical Medicine (2012).
8. Biochemistry of Signal Transduction and Regulation; Gerhard Krauss, Wiley-VCH (2003).
9. Elements of Molecular Neurobiology; 3rd Edn. C. U. M. Smith, John Wiley & Sons Ltd, (2002).
10. G-Proteins coupled Receptors; P. Michael Conn Academic Press (2013).
11. Molecular Biology of the Cell; 6th Edn. Bruce Alberts, Alexander Johnson, Julian Lewis David Morgan, Martin Raff, Keith Roberts, Peter Walter; Garland Science (2014).
12. Molecular Cell Biology; Lodish et al., 7th Edn. W.H. Freeman and Co. (2012).
13. Cell Signaling; Wendell Lim, Bruce Mayer, Tony Pawson; Garland Science (2014).
14. Electrochemical methods for neuroscience; Michael AC, Borland LM, editors. Boca Raton (FL): CRC Press (2007).
15. Signal Transduction; Lewis Cantley, CSHL Press (2014).
16. When Cells Die; A Comprehensive Evaluation of Apoptosis And Programmed Cell Death; Richard, A. Lockshin, and Zahra Zakeri, Wiley Liss (2004).
17. The Biology of Cancer; Robert A. Weinberg; Garland Science (2013).

BCHT – 303: Membrane Biochemistry

4 units (52 hrs)

Introduction: Review of **s**tructure, nomenclature and properties of glycerolipids, sphingolipids, glycolipids and sterols. Properties of lipids in solution, hydrophobic and hydrophilic interactions, Polar lipids and their ability to form mono, bi-layers and micelles, Langmuir trough.
Cell and organelle membranes; Physical properties of bi-layers, Polymorphic phases and molecular shapes exhibited by lipids, use of differential scanning calorimetry (DSC) and ^{31}P NMR to study transition in phases. Effect of lipid composition and modification on viscosity and fluidity; role of cholesterol, cardiolpin, engineering membrane lipid composition. Models of membranes; Metamorphic mosaic model, Singer-Nicolson fluid mosaic model, Isolation and characterization of membrane lipids. Composition of plasma- and organelle membranes; transbilayer asymmetry; methods to determine membrane sidedness. Asymmetry of lipid distribution in bacterial, plant, and animal membranes, Lateral heterogeneity of membrane lipids; lipid domains, lipid rafts, caveoli, Non bilayer lipids and their role in membranes.
Physical organization of bilayers; human erythrocyte membrane as a prototype plasma membrane, role of cytoskeleton in organization of bilayers. *Liposomes;* preparation, properties and application in membrane biochemistry. **13 hrs**

Membrane proteins: Isolation and characterization of cell membranes. Detergent solubilization of membrane proteins. Purification and reconstitution of membrane proteins. Erythrocyte ghosts; proteins of RBC membrane and their interaction with cytoskeleton. Classification of membrane proteins based on membrane-protein interaction. Types of integral membrane protein, forces responsible for holding integral proteins in membranes, secondary structure of membrane spanning portions of integral membrane proteins; transmembrane α-helices and β-barrels, hydropathic plots. 3-D structures of typical integral membrane proteins: glycophorin, bacteriorhodopsin, photosynthetic reaction centre. Role of integral proteins in cell-cell interaction and adhesion; selectins, integrins, cadherins. Lipid-anchored membrane protein-acyl-prenyl- and GPI-anchors.
Techniques for determination of membrane protein topology: *Biophysical methods:* X-ray crystallography, Freeze-fracture electron microscopy, Spin labeled ESR, NMR. *Biochemical and molecular biological methods*: Membrane protein dynamics. Lateral and rotational diffusion of integral membrane proteins. Fluorescence photobleaching recovery (FRAP). Single particle tracking. Lipid-protein interactions. Atomic force microscopy.

10 hrs

Membrane transport: Relative permeability of pure phospholipid bilayer to various molecules. Diffusion across the plasma membrane. Partition coefficient and hydrophobicity. Energetics of moving non polar and polar molecules across lipid bilayer (PM). Experimental methods for study of membrane transport: Assay of membrane transport, use of liposomes to study single types of transporters. Mechanism for transport**:** Properties of passive diffusion**,** facilitated diffusion, active transport and co-transport. Electrically neutral and electrogenic transport, Kinetics and model of Glut-1 uniport ATP–driven pumps; classification, and working mechanism. ABC-transporters; MDR1, CFTR, Channels and pores. Transport across organelle membranes. Ion channels; working and voltage gating, ion-selectivity, electrochemical gradients, Nernst Equation, working of bacterial K-channels, aquaporins, ionophores.

Bacterial transport systems; Lactose permease, Phospho transferase and sugar binding proteins.

7 hrs

Intracellular compartments: Proteins sorting; Membrane enclosed organelles of eukaryotic cells, evolutionary origin and topological relationships. Protein trafficking: Sorting signals. Mechanisms: Gated transport, transmembrane transport, vesicular transport. Signal sequences: Experimental evidence, Genetic experiment to demonstrate protein translocation.

Transport of molecules between nucleus and cytosol. Nuclear pore, nuclear localization signals, nuclear transport receptors, nuclear export: Ras-GTPases- directionality. Regulation of nuclear import and export.

Transport of protein into mitochondria and chloroplast, signal sequence, experimental setup to study protein translocators, working of TOM & TIM complexes. Energy requirement in protein import. Signal sequence for thylakoid membranes, peroxisomes. Endoplasmic reticulum, structural and functional diversity of endoplasmic reticulum, isolation of rough ER and signal sequence for protein import.

Signal Hypothesis: Signal Sequence, SRP-receptors for protein import to ER. Organization of translocation pore, Sec61 complex.

8 hrs

Topology of membrane protein: Protein translocation, co-translational, post translational translocation. Start transfer and stop transfer signals for single pass transmembrane protein and multipass transmembrane proteins. ER retention signals, Glycosylation in ER. N-linked oligosaccharide, Dolichol-linked oligosaccharides. Folding of proteins in ER, role of chaperons – Calnexin and Calreticulin. N-linked oligosaccharides as timers for protein turnover, ubiquitination and protein degradation (improperly folded proteins), GPI-anchored proteins.

5 hrs

Biogenesis of lipid bilayers: Intracellular vesicular trafficking: Maintenance of compartmental diversity, pathways of endocytosis and secretory. Vesicles: types, study of cell free system, genetic approach, use of GFP. Clathrin coated- Assembly and disassembly, Structure and function. significance. Coatemer coated-Assembly and disassembly, Structure and function. Retromer assembly on endosomal membrane. Coat assembly control by monomeric GTPases. Role of Rab proteins in vesicular targeting. SNARE proteins and their role in vesicular transport and membrane fusion. Experimental proof for SNARE requirement in vesicular fusion. Entry of enveloped viruses into cell. Coatemer coated vesicles: COP-II-coated transport vesicles, transport of cargo from ER to Golgi, homotypic membrane fusion. Retrieval pathway to ER.

Compartments of Golgi: processing of oligosaccharide chain in Golgi, N-linked, proteoglycan assembly in Golgi. Transport through *trans* Golgi network to lysosomes. Mannose-6-phosphate receptors. Signal patch for mannose-6-phosphate lysosomal storage disease. Endocytosis: Phagocytosis, Pinocytosis- vesicles, receptor mediated endocytosis. Retrieval of proteins in endosomes, multivesicular bodies sequestration of endogenous proteins.

9 hrs

References

1. Biochemistry 5th Edn. Jeremy M. Berg, John L. Tymoczko, Lubert Stryer.
2. Textbook of Membrane Biology, Wardhan, Rashmi, Mudgal, Padmshree, Springer (2017).
3. Lipid Biochemistry; 5th Edn. Michael I. Gurr, John L. Harwood and Keith N. Frayn, Blackwell Science (2002).
4. Biochemistry of Lipids, Lipoproteins and Membranes; 6th Edn. Neale Ridgway Roger McLeod, Elsevier (2015).
5. Membrane Protein Purification and Crystallization; Carola Hunte, Gebhard von Jagow and Hermann Schagger, Academic Press (2011).
6. Membrane Proteins,; Douglas Rees, Academic Press (2003).
7. Introduction to Biological Membranes; William Stillwell, Elsevier (2013).
8. Molecular Biology of the Cell, Alberts et al., Garland Publications (2012).
9. Molecular Biology of the Cell; 6th Edn. Bruce Alberts, Alexander Johnson, Julian Lewis, David Morgan, Martin Raff, Keith Roberts and Peter Walter; Garland Science (2014).
10. Molecular Cell Biology; Lodish et al., 7th Edn. W.H. Freeman and Co. (2012).

BCHT OE–304: Open Elective

4 units (52 hrs)

BCHP – 305: Clinical Biochemistry (4 Credits)

Analysis of Blood and Urine for diagnostic investigations

1. Estimation of glucose by Folin Wu method.
2. Estimation of glucose by Dubosky's method.
3. Estimation of cholesterol by Zack's method.
4. Estimation of haemoglobin by Wong's method
5. Estimation of urea in blood by Diacetylmonoxime method.
6. Estimation of serum calcium by Clark and Collips method.
7. Determination of A/G ratio by Biuret method.
8. Analysis of SGOT-SGPT (AST, ALT) / creatine kinase / acid or alkaline phosphatase.
9. Qualitative analysis of Urine sample for normal and abnormal constituents.
10. Determination of titrable acidity of urine.
11. Estimation of uric acid in serum and urine by Caraway's method
12. Estimation of creatinine and creatine in serum and urine by Zaffe's method.
13. Estimation of urea in urine by Nesslerization method (Urease method).
14. Determination of urine Chloride by Volhard-Arnold method.
15. Estimation of 17-ketosteroid by Zimmerman's method.
16. Estimation of urine Bilirubin.

References

1. Practical Clinical Biochemistry, ed. Harold Varley, 4th edn. CBS Publishers (1988).
2. Practical Clinical Biochemistry: Methods and Interpretation, ed. Ranjna Chawla, Jaypee Brothers Medical Publishers (1996).
3. Practical and Clinical Biochemistry for Medical Students, ed. T.N. Pattabhiraman, Gajanna Publishers (1994).
4. Hawk's Physiological Chemistry, ed. Oser, 14th Edn.(1976), Tata-McGrawHill.
5. Biochemistry, ed. Plummer Tata-McGraw Hill, (1971).

BCHP – 306: Molecular Biology (4 credits)

1. Isolation, quantification and characterization (Spectrophotometric and agarose gel electrophoresis) of genomic DNA from bacteria (E. *coli*).
2. Isolation, quantification and characterization (Spectrophotometric and agarose gel electrophoresis) of genomic DNA from plant.
3. Isolation, quantification and characterization (Spectrophotometric and agarose gel electrophoresis) of plasmid DNA from bacteria.
4. Isolation, quantification and characterization (Spectrophotometric and agarose gel electrophoresis) of total RNA, mRNA from plant and microbial sources.
5. Restriction digestion and ligation of DNA.
6. Spectroscopic determination of melting temperature(Tm) of calf thymus DNA.
7. Amplification of desirable gene by Polymerase chain reaction.
8. Rapid amplification of polymorphic DNA.
9. Reverse transcriptase- Polymerase chain reaction RT-PCR

10. Southern blotting
11. Phage Titration.

References

1. Molecular Biology Techniques; Sue Carson, Heather Miller and D. Scott Witherow, Academic Press (2011).
2. Principles and Techniques of Biochemistry and Molecular Biology; 7th Edn. Keith Wilson and John Walker (2012).
3. Principles of Gene Manipulations; 6th Edn. S.B. Primrose, R.M. Twyman, and R.W. Old, Blackwell Science (2012).
4. Gene Cloning and DNA analysis- An Introduction; T. A. Brown, 5th Edition, Wiley-Blackwell (2006).
5. Laboratory methods in Enzymology; Part-A; Jon Lorsch, Academic Press (2014).
6. Gene Cloning Laboratory Manual 4th Edn. Michael R. Green and Joseph Sambrook, CSHL Press (2014).
7. Current Protocols in Molecular Biology; S Gallaghar, Wiley Interscience (2008).

BCHT – 401: Gene Regulation and genomics

4 units (52 hrs)

Gene Expression in Prokaryotes: Bacterial trascription control; Discovery and structure of lac operon, induction and diauxy. Utility of merodiploids in understanding regulation of operon. Molecular basis of repression. Isolation of repressor, assay of binding of lac operator and repressor. Positive control of lac operon; mechanism of action of CRP/CAP, transcription activation by recruitment, characterization of binding of cAMP-CAP-DNA. Catabolite repression, inducer exclusion and prevention mechanism. Anatomy and regulation of tryptophan operon. Riboswitches; discovery and models of action. *Phage strategies;* Regulatory cascade controlling lytic development. Antitermination in lambda phage, maintenance of lysogeny by lambda phage. establishment of lysogeny. Sigma switching in phage infection.

10 hrs

Gene Expression in Eukaryotes:

Analysis of gene expression; mapping and quantifying transcripts; Northern blots; S1 mapping of 5' and 3' ends of transcripts. Primer extension, Runoff transcription and G-less cassette transcription, measuring *in-vivo* transcription rate- nuclear run on transcription. Quantification of gene expression by measuring protein product.

Levels of regulation of gene expression in eukaryotes; Chromatin structure and its effect on transcription. Effect of histones on transcription activation. Nucleosome positioning; SV 40 mini chromosome, experimental location of nucleosomal positions; DNase hypersensitive sites and mapping. Locus control regions.

Histone modifications; Acetylation of histone tails. Identification of histone acetyl transferases (HATs). Properties and roles of P_{55} and Gcn-5 HATs. Histone deacetylases; experimental demonstration of HDACs in repressor complexes.

Chromatin remodeling; Major classes of remodeling complexes; assay of remodeling; ChIP. Composition of SWI2/SNF2 and ISWI complexes. Model of SWI2/SNF2 mechanism. Remodeling in yeast HO gene and human IFN-β promoter. Histone code. Heterochromatin silencing; chromo and bromo domains, histone methylation, HMTases, SFR and RAP-proteins.
Transcription elongation through nucleosomes; FACT and PARP.

12 hrs

Transcriptional activators; classification, structure and function, domains of activators. DNA binding motifs; Zn fingers- Gal 4 activator of yeast. Nuclear receptor- structure and function of glucocorticoid, thyroid and orphan receptors. Domains of nuclear receptors; homeo, bZIP and bHLH domains. Modularity of domains of activators; chimeric transcription factors- Gal4-LexA, two hybrid assay. Dimerization of activators, modular arrangement of enhanceosomes. Recruitment of TFIID and holoenzyme; evidence, role of enhancers, interaction between enhancer and promoter-control region of human metallothionine gene. Insulators-working, insulator bodies, working of imprinting control region (ICR). Transcription factories, detection. Co-activators and mediators; mediators factors; activation of CRE-linked gene model for nuclear receptor activation. Regulation of transcription factors; modification of activation by ubiquitination, sumoylation and acetylation.

Regulation of gene expression via stability of mRNA; Casein mRNA and transferring-receptor mRNA, gel mobility shift assay for IRE binding protein, model for TFR mRNA destabilization by iron. Gene Expression and Gene Regulation Networks RNA-seq analyses. Differential expression, stochasticity, and FDR. Alternate splicing, ENCODE. Epigenomic analyses and cancer/ diseases. Bisulfite sequencing

10 hrs

RNA interference; post transcriptional gene silencing (PTGS) and quelling. Definition, mechanism of RNAi. Classical experiments with petunia and *C. elegans.* Simplified model, composition and function of Dicer and RISC. Role of Argonaute. siRNAs, role of RNAi machinery in heterochromatin formation and gene silencing- EF1A gene. miRNAs; control of gene expression by miRNAs example and experimental proofs, pathways of gene silencing by miRNA. Stimulation of translation by miRNAs. Translation repression; processing bodies.

5 hrs

Genomics

Fundamentals of Whole-Genome Sequencing. Sequencing of Phage (ϕX 174), Viral and Bacterial Genomes. Positional cloning, identification of mutation in Huntington disease, significance of RFLP and CAG repeats. Human Genome sequencing, the human genome project, vectors for largescale genome pojects, VNTR and STS markers and microsatellies, maping with STS, Shotgun sequencing. Next Generation Sequencing (NGS) Technology Whole genome - *de novo* sequencing or resequencing; exome sequencing; RNA sequencing; small RNA sequencing; metagenomics; NGS workflow, Ribosomal RNA depletion (RNA-Seq) and small RNA enrichment; 16S rRNA based sequencing for metgenomics, comparative genomics, personal genomics, minimal genome, barcode of life.

Functional genomics: Transcriptomics, Microarray and microchips, SAGE, and CAGE, Whole Chromosome Transcriptional Mapping, genomic functional profiling, Genome-wide search for DNA–protein interactions in yeast by ChIP-chip analysis, mapping transcription factor bindingsite by ChIP, locating enhancers and promoters, in situ expression pettern,SNP and pharmacogenomics. Micro/si RNA technology and applications in studying gene functions. (Student seminar)

15 hrs

References

1. Molecular biology and Biotechnology; 4th Edn., J.M. Walker and R. Rapley, RSC (2000).
2. Molecular Biology of Gene; Watson, J.D. et al., 5th Edn. Pearson Education; (2004).
3. LEWINS Gene XII; J.E. Krebs, E.S. Goldstein, and S.T. Kilpatrick, Jones and Barlett Publishers (2018).
4. Molecular Biology; Robert F. Weaver, Mc Graw-Hill (2018).
5. Epigenetics and Epigenomics; Christopher J. Payne, INTECH, (2014).
6. Gene Control; David Latchman, Garland Science (2010).
7. Molecular Cell Biology; Harvey Lodish, Arnold Berk, Chris A. Kaiser, 7th Edition, W. H. Freeman (2012).
8. Molecular Biology of the Cell; 7th Edn. Bruce Alberts et al., (2008), Garland Publications

9. Evolution of the Human Genome I, Saitou, The Genome and Genes**,** Naruya (Ed.) Springer (2017).
10. Nuclear Organization; Chromatin Structure and Gene Expression, Roen Van Driel and Arie P. Otte (1997) Oxford University Press.
11. Genome 2; T.A. Brown, John Wiley & sons (2002).
12. Principles of Developmental Genetics; SA Moody, Academic Press (2007).
13. Developmental Biology; S. P. Gilbert, 8th Edn. Sinauer Associates Inc. (2006).
14. Human Molecular Genetics; Peter Sudbery, (2002) Printice Hall.
15. Discovering Genomics, Proteomics and Bioinformatics, Campbell A M & Heyer L J, 2nd Edn. Benjamin Cummings, (2007).
16. Long Range Control of gene Expression; Veronica van Heyningen and Robert Hill, Academic Press (2008).

BCHT – 402: Molecular Genetics

4 units (52 hrs)

Introduction: Nature of genetic material, Chromosomes and genes; LINES, SINES, Alu family and their applications in genome mapping. Split genes, pseudogenes, non-coding genes, overlapping genes and gen families. Mutation: types of mutation, mutagens, mechanism of mutation, induction and isolation of mutants and their role in genetic studies. Model systems for genetic analysis; Bacteriophage, *E. coli*, *Neurospora crassa*, yeast, Arabidopsis, Drosophila, C. elegans, Zebra fish, Homo sapiens - General outline of life cycle, importance in Genetic analysis.

9 hrs

Classical Genetics: Review of Mendelian laws, concept of dominance, segregation, independent assortment, chromosome theory of inheritance. Allelic and non-allelic interactions, lethal, multiple alleles, test of allelism, complementation; Epistasis. Inheritance; Sex-linked inheritance, Sex determination, Morgan's discovery of sex-linked inheritance of sex-linked genes, extranuclear inheritance.

7 hrs

Quantitative Genetics: Human quantitative traits, discontinuous traits and continuous traits, X-linked traits in humans. Identification of sex chromosomes, XX, XY, mechanism of sex determination. Breeding analysis, genetics basis of quantitative variation, Multiple factor hypothesis and analysis of polygenes. Genotype-Environment Interaction and models for their measurement, estimation of Heritability Index. Human genetic diversity- Methods of study – Biochemical/molecular genetic markers.

8 hrs

Human Genetics: Genome organization, Structure of chromosome, Pedigree analysis-Pedigree analysis- Mendelian inheritance and exceptions; Chromosomal analysis (in vitro, in vivo), gene mapping, physical mapping, mapping markers, G/Q banding, FISH, comparative genome hybridization, long range restriction mapping, high resolution mapping STS/EST/MS/SNP/sequencing; Genetic mapping: Linkage analysis (RFLP/MS/SNP), Chromosome mapping based on recombination frequency data.

Human genome analysis: cloning and sequencing, Generation of 'OMICS' era, significant leads. Chromosomal disorders: Structural and numerical; Autosomal/sex chromosomal/sex reversal; Mechanisms– mitotic/meiotic non-disjunction/chromosomal rearrangements; some examples. Ethical, legal and social issues in Human genetics: Prenatal/adult (individual/family/population) screening of mutation/risk factor for genetic diseases;

13 hrs

Population genetics: Calculation of genotypic and allelic frequencies, Hardy-Weinberg Law, assumptions, implications and extensions. Evolutionary forces affecting allelic frequencies; mutation, migration, genetic drift and natural selection.

4 hrs

Bacterial and Viral Genetics: Genome organization of viruses, and bacteria, Recombination in bacteria. Mechanism of recombination, transposable genetic elements. Transformation and conjugation in bacteria. Linkage map of bacterial chromosomes. Lytic cycle and lysogeny and its regulation. Transduction; specialized, generalized and abortive. Fine structure analysis of T-phages; Benzers work, concept of cistrons.

10 hrs

References

1. Genetics, Strick Berger, M.W. (1990) 3rd edn. McMillan.
2. Human Molecular Genetics; Peter Sudbery, (2002) Printice Hall.
3. Genetics and Molecular Biology; Robert Schleif, The Johns Hopkins University Press Baltimore, (1993).
4. Discovering Genomics, Proteomics and Bioinformatics, Campbell A M & Heyer L J, 2nd Edn. Benjamin Cummings, (2007).
5. Introduction to Genetics: A Molecular Approach; T A Brown, Garland Science (2011).
6. Molecular Cell Biology; Lodish et al., 7th Edn. W.H. Freeman and Co. (2012).
7. Nuclear Organization; Chromatin Structure and Gene- Expression, Roen Van Driel and Arie P. Otte Oxford University Press (1997).
8. Principles of Developmental Genetics; S.A. Moody, Academic Press (2007).
9. The Cell; Geoffrey Cooper, and Robert E.; 5th edn. Hausman Sinauer Associates (2009).
10. The Science of Genetics, George W. Burns and Paul J. Bottino (1989), Maxwell-McMillan.
11. Human Genetics; Lewis, 7th Edn. WCB & McGraw Hill (2007).
12. Essential Genetics: A Genomics Perspective; Daniel L. Hartl, 6th Edition, Jones and Barlett Learning (2012).
13. Bacterial and Bacteriophage Genetics; Edward A. Birge, 5th Edition, Springer (2006).
14. Nucleosome Histone, and Chromatin; Part-A; Carl Wu and C. Allis, Academic Press (2012).
15. Evolution of the Human Genome I, Saitou, The Genome and Genes**,** Naruya (Ed.) Springer (2017).

BCHT – 403: Genetic Engineering

4 credits (52 hrs)

Restriction and modifying enzymes: Restriction enzymes Discovery, classification, properties, and applications. Reactions, application of the following modifying enzymes employed in rDNA technology; DNA- and RNA ligase, Phosphatases and kinases DNase (DNase-I) and RNases (RNase A, H), S1- and Micrococcal numclease. DNA and RNA polymerases (Klenow fragment), template independent RNA polymerases. Linkers and adapters, TA-cloning.

6 hrs

Cloning: Basic properties of plasmids vectors. Directional cloning in plasmid vectors, blunt end cloning in to plasmids. Bacteriophage lambda vectors; Insertional and replacement lambda vectors, transfection, *in vitro* packaging, screening recombinant phages. Cloning in M13 vector and COSMID vectors and their applications.

Expression vectors: Characteristics of expression vectors, expression vectors for cloning and expression in bacteria, yeast and mammalian cells. Super vectors; characteristic features and utility of BAC and YAC vectors.

Preparation of recombinant DNA, transformation of competent hosts. Screening colonies using X-gal and IPTG (α-complementation), screening by hybridization. Characterization of plasmid clones, restriction digestion.

7 hrs

Genomic and cDNA libraries: Outline of methodology for genomic library construction using lambda and cosmid vectors. Evaluation and storage of genomic libraries. cDNA libraries; methodology, random arrayed and ordered cDNA libraries, screening cDNA libraries; probe selection, hybridization. Screening with antibodies, rescreening and sub-cloning. southern blot, PCR and sequence analysis.

5 hrs

PCR: Discovery, principle and procedure, variants of PCR- RT-PCR. Application of PCR; Rapid amplification of cDNA ends (5'and 3' RACE), Cloning PCR products. Diagnostic application of PCR.

4 hrs

Gene transfer to animals cells: over view of strategies, transfection methods, phospholipids as delivery vehicles, electroporation and direct transfer, transient and stable transformation, Cotransformation and selection of stable transformants, selectable markers for animal cells. Mammalian plasmid expression vectors, reporter genes. Gene transfer by viral vectors; adeno and baculo virues, retroviral vectors. Gene therapy andGene editing; CRISPR.

6 hrs

Gene transfer to plants: plant cell culture and proptoplast, callus and their manipulations. *Agarobacterium* mediated transformation, Ti plasmid, mechanism of T-DNA transfer, Function of T-DNA genes, Ti-plasmid derivatives as plant vectors (disarmed T-DNA), cointegrate and binary vectors, high capacity binary vectors, selectable markers for plants, control of transgene expression in plants. Direct DNA transfer to plants; protoplast transformation, particle bombardment, *in-planta* and chloroplast transformation. Plant expression vectors; CaMV and TMV vectors.

6 hrs

Bioprocess technology: Fermentation: Fermentation process design, operation and characteristics of fermentation processes; batch, fed-batch and continuous culture systems, instrumentation and bioprocess control.

3 hrs

Downstream process: Introduction to various downstream process operations in biopharmaceutical manufacturing such as centrifugation, filtration, tangential flow filtration, cell disintegration, solvent-solvent extraction, supercritical fluid extraction etc.

3 hrs

Industrial Biotechnology: Major areas of biotechnology in the pharmaceutical industry such as antibiotics, vaccines, diagnostics, antibodies, biopharmaceuticals (insulin, interferon, GSF, CSF and therapeutic proteins etc.); commercial aspects, priorities for future biotechnological research.

3 hrs

Nanobiotechnology: Definition and methods of preparation of nano-bioparticles. Applications in drug designing, drug delivery & protein engineering. Biosensors – Construction, uses in industrial and environmental processes and medical applications.

3 hrs

Intellectual property: Concepts and fundamentals; Concepts regarding intellectual property (IP), intellectual property protection (IPP) and intellectual property rights (IPR);
Mechanisms for protection of intellectual property-patents, copyrights, trademark; Factors effecting choice of IP protection; Penalities for violation. WTO (World Trade Organisation), WIPO (World Intellectual Property Organization) GATT (General Agreement on Tariff and Trade), TRIPs (Trade Related Intellectual Property Rights), TRIMS.

4hrs

Ethical values in IP: IP and ethics-positive and negative aspects of IPP; Societal responsibility; Avoiding unethical practices; Echo-responsibility-economic, social and environmental benefits of modern biotechnology.

2 hrs.

References

1. Molecular Cloning; A laboratory manual; Michael R. Green, CSHL Press (2012).
2. Molecular Biology of the Cell; 7th Edn. Bruce Alberts et al., (2008), Garland Publications
3. Molecular Biology; Robert F. Weaver, McGraw Hill (2018).
4. Principles and Techniques of Biochemistry and Molecular Biology; 7th Edn. Keith Wilson and John Walker (2010).
5. Principles of Gene Manipulations; 6th Edn. S.B. Primrose, R.M. Twyman, and R.W. Old, Blackwell Science (2012).
6. Gene Cloning and DNA analysis- An Introduction; T. A. Brown, 5th Edition, Wiley-Blackwell Publishing (2006).
7. Molecular biology and Biotechnology; 4th Edn., J.M. Walker and R. Rapley, RSC (2000).
8. Plant Biotechnology and Agriculture; Arie Altman and Paul Hasegawa Academic Press (2011).
9. Law Relating to Intellectual Property by B.L. Wadhera
10. IPR Handbook for Pharma Students and Researchers by P. Bansal
11. Making Innovation Happen- A simple and Effective Guide to Turning Ideas into Reality Michael Morgan.

BCHT – 404: Drug Discovery and Clinical research

4 credits (52 hrs)

Introduction: Source and nature of drugs, classification and nomenclature. Basic principles of drug action, Pharmacokinetics: Absorption, distribution and elimination of drugs, routes of drug administration. Drug–protein interactions. Pharmacogenetics; dose response curve - ED50 and LD50. Origin of Drug from plants and animals.

4 hrs

Drug targets: Enzymes, receptors, carrier proteins. Structural proteins, nucleic acids, lipids and carbohydrates. Forces involved in drug – receptor interaction, Receptor theories. Cholinergic and anticholinergic drugs, Adrenergic and adrenergic blockers, General anesthetics, Local anesthetics. Adverse reactions to drugs and common drug receptor interactions.

6 hrs

Drug metabolism: Drug metabolism: First pass metabolism – Elimination pathway – Entero – hepatic cycling of drugs. Drug biotransformation pathway – phase I – Hepatic cytochrome P450 enzyme system; Cytochrome P450 cycle – induction and inhibition;– Oxidation catalyzed by cytochrome P450 isoforms – All types of hydroxylation, Deamination; Dealkylation;– Dehalogenation. Oxidations: Microsomal and Non-microsomal oxidations.

5 hrs

Drug discovery and Development:

Biological testing and bioassays: Testing drugs in vitro and in vivo. Molecular libraries and discovery strategies, Lipinski's rule of five, lead–like libraries, Congreves's rule of three and fragment based Drug discovery, drug discovery, Ligand efficiency, important chemical indices of ligands, diverse libraries, focused, targeted structure libraries, Bioisosteres and scaffold hopping, drug repurposing. Probe compounds, assembling molecular library-Corporate collection, vendor and outsources libraries, natural products, Pan-assay interference compounds (PAIN), compound management. Screening strategies in hit discovery; *in-silico based*, Structure-based, and Biomolecular methods. Active to hit phase, hit-to- lead phase, ADMET. Lead optimization.

9 hrs

Clinical trials: New drug discovery process- purpose, main steps involved in new drug discovery process, timelines of each steps, advantages and purposes of each steps, ethics in clinical research, unethical trials, thalidomide tragedy, Various phases of clinical trials Safety monitoring in clinical trials. Various regulatory requirements in clinical trials, Schedule Y, ICMR guidelines etc. Documents in clinical study. Indian GCP guidelines (CDCSO guidelines) ICMR Guidelines - Ethical Guidelines for Biomedical Research on Human Subjects Schedule.

6 hrs

Pre clinical toxicology: General principles, Systemic toxicology (Single dose and repeat dose toxicity studies), Carcinogenicity, Mutagenicity, Teratogenicity, Reproductive toxicity, Local toxicity, Genotoxicity, animal toxicity requirements.

4 hrs

Bioavailability and Bioequivalence studies: Factors affecting bioavailability, types: absolute v/s relative, single v/s multiple dose studies, healthy volunteers vs patient studies, measurement of bioavailability, drug dissolution rate and Bioavailability, *in vitro-in vivo* correlation, methods for enhancement of bioavailability. Bases for Determining Bioequivalence, Design and

Evaluation of Bioequivalence Studies Analytical Methods, Reference Standard, Extended-Release Formulations, Combination Drug Products, Study Designs

6 hrs

Basic terminology used in clinical research: Types of clinical trials, single blinding, double blinding, open access, randomized trials and their examples, interventional study, ethics committee and its members, cross over design, Institution Ethics Committee / Independent Ethics Committee. Data Management in clinical Research

5 hrs

Pharmacovigilance: Definition and aims of pharmacovigilance *Adverse drug reactions*– Classification, mechanism, predisposing factors and causality assessment. Role of clinical pharmacist in Reporting, evaluation, monitoring, prevention and management of ADR Adverse drug reaction reporting and monitoring Drug induced diseases. *Pharmacoepidemiology*-Epidemiological approach, Measurements in epidemiology, (rates, ratios, and proportions), Measurement of mortality, morbidity. Descriptive, analytical and experimental epidemiology.

7 hrs

References

1. Pharmacology and Pharmacotherapeutics, 23 rd Edition, Popular Prakasham, Bombay.
2. Modern Pharmacology with clinical correlations, 6th Edn., Charles R. Creig, and Robert E. Stitzel, Lippincott Williams & Wilkins.
3. Foye's Principles of Medicinal Chemistry, Williams,D.A. et al., 6th Edn. Lippincott Williams & Wilkins (2008).
4. Fundamentals of Experimental Pharmacology, Ghosh,M.N. 2nd Edition, Scientific Book Agency, Kolkatta (1984).
5. Wilson and Walker's Principles and Techniques in Biochemistry and Molecular biology; 8th Edn., Andreas Hofmann and Samuel Clokie; Eds. Cambridge University Press, New Delhi (2018).
6. Applied Biopharmaceutics and Pharmacokinetics, Shar gel,L. et al ., 2012. 6th Edn., McGraw- Hill Medical,
7. Text Book of Receptor Pharmacology, Foreman,J.C. and Johansen,T.J. 2nd Edn., CRC Press (1996).
8. Drug discovery and Development 2nd Ed. Reymond G Hill, Humphry P Rang, Churchill Livingsten, Lange (2012).
9. Applied Biopharmaceutics & Pharmacokinetics, 5th Edn. Leon Shargel, Susanna Wu-Pong, Andrew B.C. Yu
10. Basic and Clinical Pharmacology, Prentice hall, International, Katzung, B.G.
11. Clinical Pharmacology, Scientific book agency, Laurence, DR and Bennet PN.
12. Clinical pharmacokinetics, D.R Krishna, & V. Klotz. Springer –Verlag ( )
13. Remington Pharmaceutical Sciences, Lippincott, Williams and Wilkins.
14. Text Book of Therapeutics Drug and Disease Management Hardbound. Richard A Helms
15. Biotechnology and Intellectual Property Rights: Legal and Social Implications, Kshitij Kumar Singh, Springer (2014).
16. IPR, Biosafety and Bioethics, Deepa Goel and Shomini Pearson (2013).

BCHP – 405: Genetic Engineering and Protein Chemistry (4 Credits)

Genetic Engineering

1. Preparation of Competent cells.
2. Transformation of DNA by $CaCl_2$ method (recombinant vectors – plasmids / phages).
3. Isolation and characterization of gene fragments for cloning
4. Restriction digestion of isolated plasmid DNA.
5. Expression of GFP in *E. coli*.
6. DNA Amplification (PCR).
7. Synthesis of cDNA.
8. Southern Blotting and Northern Blotting; Hybridization of DNA and RNA and detection by specific probes (non-radioactive).
9. Characterization of clones by restriction digestion and agarose electrophoresis.
10. Expression, Isolation and purification of recombinant proteins.

Protein Chemistry

1. Extraction and isolation of enzymes (phosphatases / esterases / amylases) from Insect / Microbial / Plant sources.
2. Fractionation and purification by conventional protein purification techniques (PAGE showed be carried out at each step).
3. Ammonium sulfate, acetone and pH precipitation
4. Ion exchange chromatography.
5. Gel filtration.
6. Kinetic characterization of the enzyme

References

1. Nucleic Acid Blotting; D C Darling, P M Bricknell; Garland Science; (1994)
2. Principles and Techniques of Biochemistry and Molecular Biology; 7th Edn. Keith Wilson and John Walker (2012).
3. Principles of Gene Manipulations; 6th Edn. S.B. Primrose, R.M. Twyman, and R.W. Old, Blackwell Science (2012).
4. Gene Cloning and DNA analysis- An Introduction; T. A. Brown, 5th Edition, Wiley-Blackwell (2006).
5. Laboratory methods in Enzymology; Part-A; Jon Lorsch, Academic Press (2014).
6. Gene Cloning Laboratory Manual 4th Edn. Michael R. Green and Joseph Sambrook, (2014) CSHL Press.
7. Current Protocols in Molecular Biology; S Gallaghar, (2008) Wiley Interscience .
8. Wilson and Walker's Principles and Techniques in Biochemistry and Molecular biology; 8th Edn., Andreas Hofmann and Samuel Clokie; Eds. (2018), Cambridge University Press, New Delhi.

BCP – 406: Project Work (4 Credits)

Open elective for Non-Biochemistry PG students

BCHOET – 304.1: Biochemistry of Common Disorders

4 credits (52 hrs)

Human Physiology: Introduction and brief description of cells, tissues and organs, their functions; Body fluids and their composition. Introduction to molecules as building blocks. Definition and differentiation of disease and disorder, types and causes. Relation between food, environment and illness. Analysis of various biochemical parameters in body fluids and specific tissues during disorders, diseases and forensics.

14 hrs

Diagnostic Techniques: Collection and storage of biological samples for clinical use. Commonly used tests for diagnosis of various diseases and their interpretation.
Blood analysis: Total blood count including ESR, Total serum proteins and their fractions. Blood glucose (GTT) (Fasting and post- prandial), serum lipid fraction–cholesterol, triglyceride, LDL and HDL, blood urea, and serum calcium.
Urine: Creatinine, Glucose and protein (albumin).
Enzymes: SGPT, SGOT and isoenzymes as markers in various disorders and diseases. **12 hrs**

Diseases and Disorders (common occurence):
Aetiology; classification (if any); causative factors; incidence, symptoms and biochemical aspects and markers for-identification, monitoring, prevention and interventions; and nutritional aspects, overweight and obesity. **5 hrs**

Cardiovascular disease: Diabetes, diseases of Liver, Gall bladder & Pancreas-Hepatitis, (A, B, and C), Cirrhosis, alcoholic liver disease, Gall stones, pancreatitis, pancreatic surgery- Causes, Prevention and dietary management. **5 hrs**

Renal disease: Nephrotic syndrome, Acute and Chronic renal failure- diagnostic procedures and dietary management. Dialysis, medical and nutrition therapy. **4 hrs**

Gastrointestinal diseases/disorders: Gastro-oesophageal reflux and esophagitis, Gastritis and Peptic ulcer. Characteristics of and comparison of the stomach and duodenal ulcers. Diagnostic tests for malabsorption, sprue and tropical sprue, Crohn's disease, diarrhoea, constipation, ulcerative colitis, diverticular disease and colon cancer. **8 hrs**

Cancer and HIV/AIDS: Biochemistry of carcinogenesis, types, stages of cancer, diagnosis and existing medicines. Biochemistry of HIV infection, ART and social issues. **4 hrs**

References:
1. Biochemistry; Donald Voet, Judith G. Voet, 4th Edition, John Wiley and sons (2010).
2. Lehninger- Principles of Biochemistry; David L. Nelson and Michael M. Cox, 6th Edition, W. H. Freeman (2013).

3. Biochemistry- The Chemical Reactions of Living Cells; David E. Metzler, 2nd Edition, Academic Press (2001).
4. Outlines of Biochemistry; Eric E. Conn, Paul K. Stumpf, George Breuning, Roy H. Doi, 5th Edition, John-Wiley and sons (2009).
5. Biochemistry- The Chemical Reactions of Living Cells; David E. Metzler, 2nd Edition, Academic Press (2001).
6. Hawk's Physiological Chemistry, ed. Oser, 14th Edn. (1976), Tata-McGraw Hill.
7. Fundamentals of Practical Biochemistry. Mohanty and Basu, BI Publications, India. 2002.
8. 2. Clinical Biochemistry, 2nd Edn. W J Marshall, F I Biol and S K Bangert. Elsevier Health-Mosby Saunders. United States of America. ISBN: 9780443101861.

BCHOET – 304.2: Biochemistry in Daily Life

4 units (52 hrs)

Definition of Biochemistry: Definition of life, The different forms of life, micro-organisms to human beings. Building blocks of life. Introduction to the common macro- and micro-constituents of unicellular and multicellular organisms. Differences encountered in plant and animal kingdoms. **5 hrs**

Food and Nutrition: Importance of food for existence of life. Modes of nutrition in life forms – Comparable and contrasting features. **3 hrs**

Human Health and Disease: Nutrition (Health), definition, classification, food and non food sources.
Nutraceuticals; use of nutraceuticals in traditional health sciences. Role of omega-3 fatty acids, carotenoids, dietary fiber, phytoestrogens; glucosinolates; organosulphur compounds in health and disease (prevention and control). **6 hrs**

Prebiotics and probiotics: Mechanics and usefulness of probiotics and prebiotics in gastro intestinal health and other benefits. Beneficiary microbes; prebiotic ingredients in foods; types of prebiotics and their effects on gut microbes.
Functional foods: Definition, development of functional foods, benefits and sources of functional foods in Indian diet. Effects of processing conditions and storage.
Development of nutraceutical and functional foods; Standards for health claims. Process of developing-preclinical & clinical studies. **10 hrs**

Food additives: Definitions, functions and uses in processed food products. Chemical, technological and toxicological aspects of acid, base buffer systems, salts and chelating/sequestering agents, leavening agents, antioxidants, emulsifying and stabilizing agents, anti-caking agents, thickeners, firming agents, flour bleaching agents and bread improvers. **Sweetening agents:** Artificial sweeteners, composition, uses. Natural and synthetic colors**,** food Flavors, Spices and flavoring constituents, flavors in food industries. **9 hrs**

Enzymes: Introduction and essentiality to life forms. Use of enzyme in beverages- fruit juices, beer, wine, and distilleries; dairy, baking, oils and fats, plantation products, animal products. Malting and germination of grains – process, characteristics, nutritional benefits and uses. Domestic use products like detergents. Textiles-Denim processing. Leather industry. **7 hrs**

Food processing and fortification: Principles, objectives and rationale, selection and basis of fortificants. Technology of fortifying cereal products. Characteristics of nutrients used in cereal fortification. Fortification methods. Fortification premixes, Design and composition of premixes and quality control. Fortification of bread, pasta, noodles, biscuits, and breakfast cereals. Beverages; importance of beverage fortification, Health benefits of fortification, Selection of nutrients for fortification, Levels to be added, Characteristics of fortificants and method of fortification, Bioavailability, Organic Vs inorganic salts. *Health foods;* selection of nutrients, Technology of incorporation of fortificants, bioavailability. **12 hrs**

References

1. Biochemistry Ed. Donald Voet & Judith G. Voet, John Wiley & Sons, Inc.(2010).
2. Lehninger- Principles of Biochemistry; D.L.Nelson and M.M. Cox, 7th Edn. MacMillan Publications (2017).
3. Nutrition: Science and Applications, 3rd Edn. Lori A. Smolin, Mary B. Grosvenor, Wiley (2013).
4. Introduction to Human Nutrition, 2nd Edn. Michael J. Gibney, Susan A. Lanham-New, Aedin Cassidy, Hester H. Vorster, Wiley-Blackwell (2009).
5. Nutrition: Everyday Choices, 1st Edition; Mary B. Grosvenor, Lori A. Smolin Wiley (2006).
6. Bioactive Food as Dietary Interventions for Liver and Gastrointestinal Disease; Watson Elseveir (2012).
7. Food, Nutrition and Health. Tapsell L. Oxford University Press (2010).

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