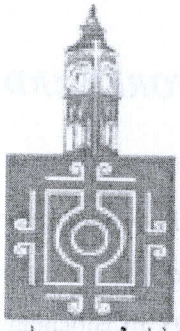

BENGALURU CITY UNIVERSITY

SYLLABUS For B.Sc. BIO-CHEMISTRY
(I to VI Semester)

CHOICE BASED CREDIT SYSTEM

2020-2021

FOREWARD

With the trifurcation of Bangalore University, the existing CBCS syllabus for under graduate Biochemistry as part of triple majors under the Bengaluru Central University was reviewed by a core committee involving members of BOS in Biochemistry (UG) and experienced teachers from affiliated colleges offering Biochemistry as a cognate subject. The committee met thrice and recommended a revised syllabus, giving emphasis to fundamental concepts of chemistry and their application to biology. Thus, the revised syllabus has a balance between new topics in Biochemistry and core concepts of Chemistry. The final draft syllabus was thoroughly discussed in the BOS (UG) meeting held on 5th March, 2019. The final BOS approved syllabus is enclosed herewith for further perusal and approval of the Academic council of Bengaluru Central University. The Dept. of Biochemistry places on record, valuable contributions of committee members in the preparation of revised Biochemistry UG syllabus.

The meeting started with the Chairman welcoming the members to the meeting. The draft syllabus for B.Sc. Biochemistry for 2018-19, prepared in consultation with teachers was placed before board to discuss any modification. The members after thorough discussion of the draft suggested various modifications and approved the syllabus for all 6 semesters. The board also made slight changes to the scheme of question paper. The chairman thanked the members for their valuable inputs and cooperation.

Members Present

		Signature
1. Prof. V. R. Devaraj, Chairman, Dept. of Biochemistry, Bangalore University.	Chairman	
2 Dr. Mahesh Arvind, Dept. of Chemistry, Vijaya College, RV Road Bangalore -560004	Member	
3. Mr. Srikanta, S.A. Dept. of Chemistry, Vijaya College, RV Road Bangalore -560004.	Member	
4. Dr. (Mrs.) Kavitha Singh Dept. of Biochemistry, Mount Carmel College # 58, Palace Road, Bangalore – 560052	Member	
5. Dr. R. Nagesh Babu, Dept. of Chemistry, Maharani's Science College for women, Palace Road, Bangalore-560001	Member	
6. Mr. Prasanna Kumar, S.G. Dept. of Chemistry, M.S Ramaiah College of Arts, Science & Commerce Bangalore-54	Member	

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Co-opted members -2-

1. DR. Mythili,
   Dept. of Chemistry
   Maharani's Science College for Women
   Bengaluru-560001
2. Dr. Renuka shrihari,
   Dept. of biochemistry,
   MLA College for Women
   Malleswaram
3. Dr. Kantharaju
   Dept. of Chemistry
   KLE College
   Bangalore -560010

Members Absent

1. Dr. A.C. Sharada,
   Dept. of Biochemistry, Member
   Uvaraja's College
   Ramavilas Road, Mysore, 570005.
2. Dr. Rajadurai
   Dept. of Biochemistry, Member
   M.S Ramaiah College of Arts, Science & Commerce
   Bangalore

Members of the Core Committee for preparation of the B.Sc. Biochemistry syllabus

1. Prof. V. R. Devaraj, Chairman, DOS in Biochemistry,
   Bengaluru Central University, Central College Campus, Bangalore -560 001.

2. Dr. C.K. Mythily, Associate Professor, Dept. of Chemistry,
   Maharani's Science College for Women, Bangalore.

3. Dr. Mahesh Aravind, Associate Professor, Dept. of Chemistry and Biochemistry,
   Vijaya College, Bangalore -560 004.

4. Sri. S.A. Srikanta, Associate Professor, Dept. of Chemistry and Biochemistry,
   Vijaya College, Bangalore -60 004.

5. Dr. (Mrs.) Kavitha singh Dept. of Biochemistry, Mount Carmel College
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6. Dr. Renuka Srihari, Associate Professor, Dept. of Biochemistry,
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   Malleswaram, Bangalore – 560 012.

6. Dr. R. Nagesh Babu, Assistant Professor, Dept. of Chemistry,
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7. Dr. S. Kantharaju, Associate Professor, Dept. of Chemistry,
   SJR. College, Ananda Rao Circle, Bangalore – 560 009.

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   Bengaluru, 560054.

SCHEME OF EXAMINATION

Title of the paper	Contact h/week	Exam. hours	I A	Marks	Total Marks	Credits
First Semester						
Biochemistry-I	4	3	30	70	100	2
Biochemistry practical-I	3	3	15	35	50	1
Second Semester						
Biochemistry-II	4	3	30	70	100	2
Biochemistry practical-II	3	3	15	35	50	1
Third Semester						
Biochemistry-III	4	3	30	70	100	2
Biochemistry practical-III	3	3	15	35	50	1
Fourth Semester						
Biochemistry-IV	4	3	30	70	100	2
Biochemistry practical-IV	3	3	15	35	50	1
Fifth Semester						
Biochemistry-V	3	3	30	70	100	2
Biochemistry-VI	3	3	30	70	100	2
Biochemistry practical-V	3	3	15	35	50	1
Biochemistry practical-VI	3	3	15	35	50	1
Sixth Semester						
Biochemistry-VII	3	3	30	70	100	2
Biochemistry-VIII	3	3	30	70	100	2
Biochemistry practical-VII	3	3	15	35	50	1
Biochemistry practical-VIII	3	3	15	35	50	1

Pattern of Internal assessment of Practical and Practical Examination

1. Internal assessment Marks:		
Attendance: 5 Marks		
More than 91% attendance	:	5 Marks
86– 90% attendance	:	4 Marks
81– 85% attendance	:	3 Marks
75– 80% attendance	:	2 Marks

Tests: 10 Marks (two internal tests to be conducted for)

2. Scheme of Practical Examination:

Duration	3 hours
Max. Marks	35 Marks
Marks for practical record	5 Marks
Marks for procedure writing	5 Marks
Marks for Viva – Voce	5 Marks
Marks for performing experiment	**20** Marks

Practical Record:

Recording 8 or more different experiments	5 Marks
Recording 6-7 different experiments	4 Marks
Recording 4-5 different experiments	3 Marks
Recording 3 different experiments	2 Marks
Recording Less than 3 experiments	0 Marks
II Procedure writing:	**5 Marks**

B.Sc. Biochemistry First Semester

Biochemistry – I

52 h

Unit-I

1. Measurement

SI Units -International System of Units -Basic Units, Derived Units. Simple problems relating to derived units (conversions) - Prefixes, subsidiary units -Non-SI units and their SI equivalents.

Dimensional analysis for volume, density, mass, surface tension and viscosity (numerical problems in SI units). Mass in terms of Kg, g, mg, µg, ng and pg. Exponential notation - expression of a large number in an exponential form; purposes, positive and negative powers of 10. Graphical representation of data -Types of graphs - linear graphs with positive, negative slopes and through origin, interpolation, extrapolation and limiting value, intercept and slope. Curves - graphs of higher powers of x -parabola and its significance. Errors in quantitative analysis -types, sources, minimization of errors. Calculation of absolute error and relative errors (mean and standard deviation). Precision and accuracy. Significant figures and its computation

6 h

2. Atomic structure

Electromagnetic radiation - (wave length, frequency, velocity, wave number) electromagnetic spectrum, Nature of wave particle. Quantum numbers- their significance. Principal quantum number, Azimuthal quantum number (1), Magnetic quantum number (m) and Spin quantum number (s) Problems on n, s and l Shapes of Atomic orbital -s, p and d orbitals. Pauli Exclusion Principle, Aufbau Principle, Hund's rule of maximum multiplicity-cause of stability of half-filled and completely filled energy levels. Electronic configuration of elements up to At No.54, (n+l rule, 2n2, order of energy levels to be followed).

Stoichiometry: Definition of Molecular weight and Equivalent weights, mole concept and Avogadro number. Calculation of equivalent weights of acids, bases, salts, reducing and oxidizing agent. Oxidation numbers-concept, difference between valency and oxidation number, and its computation. Calculation of equivalent weights of oxidizing and reducing agents based on electron change. Concentration units - Concentration based on volume; -molarity, normality, and concentration based on weight; molality, mole fraction. Concentration in terms of weight/volume percent (%w/v =weight in g per 100 ml),milligram percent (weight in mg per 100 ml of solution), weight percent (%w/w) and volume percent (%v/v),in ppm and ppb, osmolarity (the molarity of particles in solution),calculation of weight of commercial sample required in terms of its specific gravity and percent purity– simple problems.

7 h

Unit-II

3. Chemical bonding

Ionic bond - Lattice energy. Energetics of Ionic bond formation- Born – Haber cycle, calculation of lattice energy for NaCl. Factors favoring formation of ionic compounds. Characteristics of ionic compounds.Covalent bond -Sigma and pi bond, covalent bond formation in H2, HCl, NH3, CO2 and N2. Concept of resonance - explain with H2 and Benzene.Valence bond theory - postulates, Hybridization of orbitals and directional characteristics -sp, sp2, sp3, sp3d, sp3d2, (acetylene, ethane, methane, phosphorous pentachloride and sulphur hexachloride). VSPER theory- Shapes of H2O, NH3, H3O+, and SF4.Molecular Orbital Theory – postulates, Atomic orbitals and molecular orbitals, conditions for the combination of atomic orbitals. LCAO - Bonding and anti-bonding molecular orbitals; comparison between bonding and antibonding molecular orbitals. Nature of molecular orbitals formed by s-s, s-p, p-p overlap - pictures to be given. Energy level diagram of different molecular orbitals.

Molecular orbital diagrams for the formation of H2, He and O2 (stability, bond order and magnetic properties). Problems on bond order. Polarity in covalent bonds - polar and non - polar molecules- Fajan's rule, dipole moment -definition and problems. Characteristics of covalent bond - bond length, bond angle and bond energy or bond strength. Properties of covalent compoundsCoordinate bond –Donor, acceptor concept, formation of co-ordinate bond in H3O+, NH4+. Theories -Werner's theory and Valence bond theory (hybridization, geometry, magnetic properties - high spin and low spin complexes). Hydrogen bond -Nature of hydrogen bond, types of hydrogen bond- anomalous properties of HF, H2O, NH3 and nitro phenols Van der Waals forces - types of interaction with examples. Hydrophobic interactions with examples.

7 h

4. Nuclear chemistry and Radioactivity

Nucleus-Structure - nucleons, nuclear forces, nuclear density, N/P ratio, packing fraction, mass defect, binding energy, stability of nuclei – in terms of binding energy curve. Problems on mass defect and binding energy. Radioactivity -Nature of radiations from radioactive elements and their properties. Law of Radioactive Decay- Soddy's-Fajan's Group displacement law. Chemical equations for nuclear changes. Problems. Kinetics of Radioactive Decay (Decay Law) - Rate of nuclear disintegration and Half -life period. Average life of a radioactive element. Problems on decay constant, half-life period. Detection of radioactivity -Principle and applications of GM counter and scintillation counter Artificial radioactivity- Artificial transmutation of elements, examples of nuclear reactions induced by alpha, neutron and deuterons, Production of ^{32}P, ^{14}C, ^{3}H, ^{131}I, Autoradiography- theoretical aspects, Tracer techniques - Applications of ^{32}P, ^{14}C, ^{3}H, ^{131}I & ^{60}Co, Safety measures

6 h

Unit III

5. Solutions and Colligative properties

Solutions; factors influencing solubility-nature of solvent, solute, temperature, pressure and particle size. Solubility curves-of sodium chloride, potassium nitrate, lead nitrate and sodium sulphate. Solutions of gases in liquids -Factors affecting solubility of gas, Henry's law statement,

Applications. Colligative properties and determination of molar mass-Concept of lowering of vapour pressure. Raoult's law of relative lowering of vapour pressure. Osmosis-preparation of copper ferrocyanide semi permeable membrane, Osmotic pressure - measurement by Berkely-Hartley method Molecular weight polymers by osmotic pressure measurements. Theory of dilute solutions - Laws of osmotic pressure- Van't Hoff Boyle's law, Van't Hoff Charles' law and Avogardro's law. Hypo- hyper- and isotonic solutions- Problems. Donnan membrane equilibrium and its applications. Elevation in boiling point- ebullioscopic constant. Depression in freezing point- cryoscopic constant- Problems on molar mass determinations. Limitations of colligative properties. Abnormal molecular weights and the Van't Hoff factor -degree of association, Degree of dissociation-Problems.

6 h

6. Properties of matter

Properties of liquids -vapour pressure, viscosity and surface tension. (equations to be given and explanation of the terms involved in it) Relationship between vapour pressure and boiling point, freezing point - heat of fusion. Viscosity- Definition, units, experimental determination using Ostwald's viscometer. Viscosity and shape/size of molecules. Molecular weights of polymers by viscosity measurements. Surface tension; Definition, units, experimental determination using stalagmometer. Surfactants– effect of surfactants on surface tension. Viscosity and Surface tension in everyday life, Adsorption-Adsorbent, adsorbate, desorption. Types of adsorption, factors affecting adsorption, heat of adsorption, applications of adsorption. Colloids -Types of colloidal systems (based on dispersed phase and dispersion medium),based on interaction between dispersed phase and dispersion medium. Properties of colloids -Tyndall effect Brownian movement, Electrical properties of colloid -Zeta potential, coagulation, Electro-kinetic properties-electrophroresis. Emulsions and emulsifiers; Gels; Applications of emulsions in lipid chemistry. Protoplasm as a colloidal system. Liquid Crystals- General characteristics and its applications.

7 h

Unit - IV

7. Electrochemistry

Strong and weak electrolytes -Explanation with examples. classification of electrolytes as 1:1, 2:2, 2:1 electrolyte with examples. Activity and activity coefficient and mean ionic activity of electrolyte. Ionic strength. Electrolytic cells- conductance, specific conductivity, molar and equivalent conductivity, ionic mobility, transport number. Conductometric titrations of acid v/s base, Electrochemical cells: conventions of representing galvanic cells, half-cell reactions and cell reaction. Reversible electrodes and cells – definition. Single electrode potential – Nernst equation, Factors affecting single electrode potential. Standard Electrode Potential (definition)-problems. Types of electrodes - Cation reversible electrode, anion reversible electrode, redox electrode. (Examples and electrode reactions to be given). Reference electrodes - primary reference (Standard hydrogen electrode), secondary reference electrode (Calomel). Determination of pH using quinhydrone and glass electrodes and problems based on these. Ion selective electrodes- concept, types and applications. Electrochemical series-to predict the ease of oxidation, displacement reaction to calculate standard emf of cell.

7 h

8. Acids, Bases and Buffers

Modern concepts of acids and bases- Lowry- Bronsted and Lewis concepts. Limitations of each concept. Strong and weak acids -ionization constant Ka and pKa of weak acids, comparison of acid strength on this basis. Ionic product of water, common ion effect, ionic product and solubility product of sparingly soluble salts (problems) and its applications in selective precipitation of cations in qualitative analysis. Hydrolysis of salts- pH of salt solutions. Hydrogen ion concentration- pH, pH metric titrations -1) between acids and bases 2) pKa value of weak acid. pH of some biological fluids and its importance. Buffers-definition, types, buffer action and buffer capacity. pH of buffers- Henderson-Hasselbalch equation-derivation, preparation of buffers, problems.

6 h

Biochemistry Practical - I 3 h /week

List of Experiments:

1. Calibration of glass wares - pipettes, burettes and volumetric flasks (demonstration)
2. Preparation of standard sodium oxalate and estimation of potassium permanganate.
3. Preparation of standard potassium bipthalate and estimation of alkali
4. Preparation of standard potassium dichromate solution and estimation of $Na_2S_2O_3$.
5. Estimation of hardness of water using EDTA (Standard EDTA to be provided)
6. Estimation of nitrogen in ammonium salts using sodium hydroxide and standard oxalic acid
7. Estimation of chloride by Mohr's method
8. Estimation of Fe2+ using standard potassium dichromate and diphenyl amine indicator
9. Estimation of borax using standard sodium carbonate.
10. Estimation of carbonate and bicarbonate in a given mixture.

B.Sc. Biochemistry – Second Semester

Biochemistry – II.

52 h.

Unit –I

1. Solids

Types- Crystalline and Amorphous. Size and Shapes. Definition of Space lattice and Unit cell. Symmetry elements in crystals. Laws of crystallography - law of rational indices, law of constancy of interfacial angles, law of constancy of symmetry. Weiss and Miller Indices with simple numericals. Crystal systems with examples. Defects in crystalline solids -Schottky & Frenkel defects. X -ray diffraction of crystals-Braag's equation. (Derivation required)

5h

2. Phase Rule

Definitions of Phase & Components, Criterion of phase equilibrium, Gibb's phase rule (no derivation)problems on phase rule. Application of phase rule to one component system -water system, two component system-water-potassium iodide. Freezing mixtures. Solutions of liquids in liquids- Raoult's law of dilute solutions. Ideal solutions and non-ideal solutions-vapour pressure-composition and temperature-composition curves of ideal and non-ideal solutions- azeotropes -HCl -H_2O and water-ethanol system. Distillation of solutions-Lever rule. Partial miscibility of liquids (Water – Phenol). Critical Solution Temperature (lower and upper. Only examples to be mentioned). Effect of addition of salt on CST of phenol-water system. Immiscibility of liquids. Steam distillation.-Principle and. its applications. Nernst distribution law- statement, deviations from distribution law due to association and dissociation of the solute in one of the solvents. (Examples to be mentioned, no derivation) Applications of distribution law -solvent extraction.

3. Catalysis 6h

Characteristics of catalysts, Types of catalysis - Homogeneous and heterogeneous with both biological and non-biological examples. Theories of catalysis - intermediate compound formation theory and adsorption theory (No mechanism required).

2h

Unit-II

5. Chemical Equilibrium

Reversible reactions with examples. Law of mass action, Chemical equilibrium – definition and its characteristics. Relationship between Kc and Kp (problems) Homogenous and heterogeneous systems with examples. Le Chatlier principle. Equilibrium constant and free energy change. Relation between ΔG and Kp. Redox equilibria with example Fe^{2+} Fe^{3+} system. (Simple Problems).

6. Reaction Kinetics 3h

Rate of reaction, Factors influencing the rate of reaction -temperature, pressure, concentration and catalyst, rate law expression, Molecularity and order of a reaction (definition and differences) velocity constant or rate constant and half- life period. Definitions and rate equations of

zero, first and second order reactions with examples. Derivation of an expression for velocity constant of second order reaction (a=b and a≠b).

Expression for half-life period of a second order reaction and problems. Influence of temperature on rate of reaction-Temperature co-efficient. Theories of reaction rates -Arrhenius theory, Concept of threshold energy and activation energy. Arrhenius equation. Elementary treatment of transition state theory.

5h

7. Bio-inorganic Chemistry

Metal ions in biological systems; Transition metal ions and oxidation states; Types of ligands; Role of iron in Myoglobin, Haemoglobin and cytochromes; Copper in Hemocyanin, Magnesium in chlorophyll, Cobalt in vitamin B-12 and Molybdenum in nitrogenase; Metaloenzymes.

5h

Unit-III

8. Introduction to organic chemistry

IUPAC nomenclature bi and poly functional compounds. Inductive effect, resonance and hyper conjugation. Reactive intermediates -free radicals, electrophiles, nucleophiles, carbocations and carbanions. Relative stability of free radicals and carbocations on the basis of inductive effect and hyper-conjugative effect.

3h

9. Hydrocarbons

Markownikoff's rule. Mechanism of addition of HCl to Propene, Peroxide effect, (No mechanism) Alkenes -Ozonolysis, oxidation. Alkynes -formation of acetylides and their importance. Dienes- types with examples. Conjugate dienes, 1,3-butadiene - stability, mechanism of addition of HBr to 1,3-butadiene.Conformational analysis of ethane and n - butane.

4h

10. Cycloalkanes

Reactivity and relative stabilities on the basis of hydrogenation reaction and enthalpy of combustion. Baeyer strain theory, Sachse - Mohr theory, boat and chair forms of cyclohexane, axial and equatorial bonds.

2h

11. Arenes

Orbital structure of benzene. General mechanism of electrophilic substitution reactions in benzene (nitration, Friedal- Craft's alkylation and acylation). Orienting influence of substituents (-CH_3, -Cl, -NO_2) in toluene, chlorobenzene and nitrobenzene. towards electrophilic substitution reactions. Aromaticity -Huckel rule (4n+2 rule), structure of Naphthalene, Anthracene, Phenanthrene and Diphenyl.

4h

Unit – IV

12. Alkyl halides and organometallic compounds

N_1 and SN_2 reaction mechanisms taking 1°, 2°& 3° alkyl halides with examples. Elimination reactions, examples. E_1 and E_2 reaction mechanisms involving tertiary butyl chloride and n – butyl chloride. Organometallic compounds - examples, synthetic applications of Grignard reagents.

(Synthesis of ethanol, ethanal, ethanoic acid, propanone, methyl amine using methyl magnesium iodide.)

4h.

13. Alcohols and Phenols

Classification with examples-based on the no of -OH groups and based on the nature of carbon atom bearing -OH group. Distinguishing reactions of 1°2°and 3° alcohols - Lucas test and Dichromate test. Dihydric alcohols: Glycols -preparation of ethylene glycol by ethene and its uses. Trihydric alcohols: Glycerol – synthesis from Propene, properties- dehydration, nitration and uses.

Phenols: Classification, Acidity of phenols. Effect of electron withdrawing group($-NO_2$) and electron releasing group (CH_3) on acidity of phenol. Mechanism of Kolbe, and Reimer -Teimann reactions. Comparison of acidity of phenols with alcohols.

5h

14. Carbonyl compounds

General properties, addition of hydrogen cyanide and alcohols to aldehydes and ketones. Condensation reactions with phenyl hydrazine and hydroxyl amine. Keto-enol tautomerism. Mechanisms: Claisen and aldol condensations. Quinones: Biologically important quinines, structure of o - and p - benzoquinones.

4 h

Biochemistry Practical - II

3 h /week

1. Determination of density and viscosity of the given organic liquid using Ostwald's viscometer.
2. Determination of a binary liquid mixture by viscosity method.
3. Determination of density and surface tension of the given liquid using Stalagmometer
4. Partition Coefficient of iodine between carbon tetrachloride and water
5. Partition Coefficient of benzoic acid between toluene and water.
6. Kinetics of iodination of acetone by colorimetric method
7. Reaction kinetics of acid catalysed hydrolysis of ethyl acetate
8. Determination of molar mass of an non-electrolyte by ebullioscopic method
9. Effect of surfactants on surface tension of water.
10. Adsorption of oxalic acid on activated charcoal.

REFERENCES.

1, Organic Chemistry by Dr. Keemti Lal, Dr. Ashima Kathuria Dr. S.K. Agarwala.
2. Fundamentals of Organic Chemistry-I by S.C. Sharma M.K. Jain, Amita
3.Fundamentals of Inorganic Chemistry-I by LR Sharma.
4. Elements of physical chemistry by B.R. Puri L.R.Sharma.M.S. Pathania
5. principles of inorganic chemistry by B.R. Puri , L.R. Sharma & K.C.

B.Sc. Biochemistry – Third Semester
Biochemistry –III

52 h

Unit -I

1.Carboxylicacids

Classification, General properties: decarboxylation, oxidation and reduction; Hydroxy acids: structures of malic, citric and isocitric acids; Dicarboxylic acids; structures of malonic and succinic acid; Ketoacids; structures of pyruvic acid, alpha - ketoglutaric acid and oxaloacetic acid.

2 h

2.Amines

Classification; primary amine; reaction with HNO_2, alkylation and acylation - acetylation; distinguishing reactions of 1^0, 2^0 and 3^0 amines (with Heisenberg reagent). Reaction of secondary alkyl and aryl amines with HNO_2 forming nitro amines.

2h

3. Alkaloids:

Introduction and general characteristics; general method of extraction; structure and medicinal uses of nicotine, atropine and LSD.

2 h

4. Terpenes:

Structure and Biological roles of the following: menthol, santonin, juvenilehormone I, abscisin II, gibberilic acid and lanosterol: Steroids: basic ring system; structures of cholesterol, steroid hormones (testosterone and oestrogen); structures and biological importance of β-carotene.

2h

5.Heterocycliccompounds:

Structural and nomenclature of furan, pyran, thiophene, thizole, pyrrole, imidazole, pyridine, pyrimidine, purine, isoalloxazine and indole; Biological compounds containing the above skeletons. Reactions of imidazole and pyridine; Porphyrin ring system and iron-proto-porphyrin (heme), reactions imidazole and pyrimidine; Aromaticity of furan, thiophene, pyrrole and pyridine.

3h

6. Drugs:

Classification: sources and nature of drugs; synthesis and uses of sulphanilamide, pentathol and Ibuprofen.

2h

Unit II

7. Stereochemistry:

Stereoisomerism: types, stereochemical terminology; optical isomerism: Molecular dissymmetry; chirality: chairality in glucose, glyceraldehyde, lactic acid, tartaric acid; Nomenclature of enantiomers - the RS system and DL notation; diasteriomerism, epimers, mutarotation, racemization and resolution; Fischer's projection formulae; Geometrical isomerism: cis-trans isomerism in alkenes and ring compounds; structure and properties of maleic and fumaric acids; (E)-(Z) system of specifying geometrical isomers; significance of chirality in biological system.

10 h

8.Photochemistry

Laws of photochemistry; applications of chemiluminescence, bioluminescence; fluorescence and phosphorescence; Photocatalysis and photochemical reactions.

3 h

Unit III

9. Environmental Chemistry

Biochemical toxicology: toxicity and detoxification of Pb, Hg, Cd; water pollution – treatment of sewage and Industrial effluents (tanning containing and electroplating) Pesticides hazards – DDT, malathion, lindane and 2, 4-D; Brief introduction to bioremediation and phytoremediation with applications; Pollution control through biodegradation; Green Chemistry – general principles.

7h

10. Introduction to Biochemistry:

Aim and scope; historical account of development of biochemistry, mention of the landmark developments- contributions of Paracelsus, van Helmholtz, Karl Sheele, Lavosier, Wohler, Emil Fisher, Louis Pasteur, Embden & Meyerhoff, Hans Kreb, Michaelis – Menton, Watson & Crick, Chargaff and H. G. Khorana; biochemical composition of living organism: elemental and chemical compositions; properties of water which makes it a solvent of life.

Unit IV

11. Biochemical techniques

Separation techniques: Principle and applications of centrifugation (differential and density gradient), chromatography (column, paper, gas, thin-layer, high performance liquid and affinity chromatography) and electrophoretic techniques (SDS and PAGE). Spectroscopic methods; molar extinction coefficient, Beer Lambert law; principle and applications of UV visible, IR, ESR NMR spectroscopy; mass spectrometry.

13 h

Biochemistry Practical- III

1. Systematic Qualitative Analysis of organic compound (8 practicals)

The following compounds may be given for systematic qualitative analysis

1. Resorcinol	2. Urea	3. Glucose	4. Aniline
5. Benzoic Acid	6. Salicylic acid	7. Phenol	8. m-Cresol
9. Benzyl alcohol	10. Benzaldehyde	11. Acetophenone	12. Ethyl benzoate
13. Toluene	14. Chlorobenzene	15. Benzamide	16. Nitrobenzene

2. Determination of BOD
3. Determination of COD
4. Separation of compounds by TLC
5. Determination of λ max

B.Sc. Biochemistry – Fourth Semester
Biochemistry – IV

52 h

Unit-I

1. Tissues:

Origin of tissues from germ line cells. classification, epithelial, connective tissues, role of collagen and elastin in bone composition, growth and remodeling, factors affecting growth.

3h

2. Blood and Body fluids:

Composition of body fluids; blood; Properties, composition and functions; Separation of plasma and serum. Erythropoiesis, blood coagulation - outline of extrinsic and intrinsic pathway; Composition and functions of CSF and Lymph.

5h

3. Respiratory system:

Outlines of Respiratory system, Mechanism of respiration, Transport of gases and artificial respiration. Acid base balance by lungs. Bohr's effect, transport of gases, chloride shift.

5h

Unit – II

4. Digestive system:

Outline of digestive system; composition and functions of major digestive secretions. Digestion and absorption of carbohydrates, lipids, proteins and nucleic acids.

5h

5. Excretory system:

Structure and functions of nephron; glomorular filtration, tubular absorption and secretion; Formation of urine and tubular reabsorbtion, composition of urine, Kidney function test, renal failure, Kidney stones, Principles of dialysis.

4h

6. Endocrinology:

Endocrine glands - classification of hormones. Functions of the hormones of hypothalamus, pituitary glands, adrenal gland, thyroid, parathyroid and pancreas (Insulin, Glucagon and Somatostatin). Mechanism of action.

4h

Unit – III

7. Cardiovascular system:

Blood vessels- anatomy and physiology; ECG, Blood pressure. Regulation of heart rate, Cardiovascular disease, Myocardial infarction.

3 h

8. Nervous system:

Structure and classification of neurons, membrane potential, resting membrane potential and action potential; Mechanism of synaptic transmission, EEG; Neurotransmitters– classification, neurotransmitters receptors & Neuromodulators.

5h

9. Muscular system:

Muscle types; ultra-structure of skeletal and cardiac muscle fibers; Muscle proteins - contractile and non-contractile. sarcomeres and mechanism of contraction. Energetics of muscle contraction. Regulation of skeletal muscle contraction. Muscular dystrophies. 5 h

Unit – IV

10 Cell cycle

Cell cycle: Four phases, Cyclin dependent Kinases (CDK), cell cycle arrest, Apoptosis, Cancer: signs & symptoms, prevention and management.

2 h

11. Nutrition:

Energy content of foods, Balanced diet. proximate analysis of foods for carbohydrate, proteins, fats, fiber material and water content. Bomb calorimeter- diagram and description, Determination of calorific value of foods (Carbohydrate, fat and protein); respiratory quotient of food stuffs and significance of RQ. BMR determination by direct and indirect method; RDA for different physical activities: pregnant women, lactating woman, infants and children.

4 h

12. Macronutrients

Carbohydrate, proteins, lipid and fiber; Essential amino acids, semi essential and non-essential amino acids; complete and incomplete proteins, protein efficiency ratio; Nitrogen Balance- Positive and negative, Dietary fiber and its significance. Fortification - Definition and Biomedical importance; pre-biotics and probiotics, Protein Energy malnutrition: Marasmus & Kwashiorkor- causes, treatment and prevention.

4 h

13. Micronutrients:

Nutritional importance of vitamin, classification, source, daily requirements and functions and deficiency symptoms- hypervitaminosis of fat-soluble vitamins. Nutritional importance of Minerals- classification, source, daily requirement and deficiency symptoms.

3 h

Biochemistry Practical- IV

3 h/week

List of experiments

1. Paper chromatography of amino acid by circular method
2. Preparation of m- dinitrobenzene from nitrobenzene
3. Preparation of p- nitroacetanilide from acetanilide
4. Preparation of p- bromoacetanilide from acetanilide
5. Preparation of buffers (phospate and citrate buffer)
6. Determination of titrable acidity of urine
7. Estimation of bilirubin by sulpanalic acid method
8. Estimation of haemoglobin by Wong's method
9. Qualitative analysis of non-protein nitrogenous substance in urine
10. Determination of A/G ratio in serum by biuriet method

B.Sc. Biochemistry -Fifth Semester
Biochemistry -V

40 h

Unit – I

Carbohydrates

Biological importance. Monosaccharides: open chain and Haworth ring structure of glucose, galactose, mannose, ribose, xylose, fructose. Epimers and Anomers; definition and examples. Brief review on configurational and conformational aspects of carbohydrates. Derived monosaccharides: structures and biological importance of -Amino sugars: glucosamine and galactosamine and their N-acetylated forms, N-acetylneuraminia acid and N-acetyl muramic acid-Sugar phosphates: D-ribose-5-Phosphate, β-D-ribose-5-Phosphate, glucose-6-Phosphate and fructose-1,6-diphosphate -Sugar acids: types with examples. Disaccharides: Structure of sucrose, maltose, lactose, isomaltose, cellobiose and trehalose. Brief discussion on reducing property. Polysaccharides: Classification with examples. Partial structure and importance of homo and hetero polysaccharides (starch, glycogen, cellulose, chitin, hyaluronic acid, heparin and chondroitin sulphate). Blood group antigens and bacterial glycosaminoglycans with examples, proteoglycans. Glycoproteins: structure and functions. Lectins: characteristics and biological importance, Cardioglycosides.

10 h

Unit – II

Lipids

Biological importance, classification. Fatty acids: definition, classification, examples and structures. Properties of fatty acids: melting point, solubility. Acylglycerols: mono, di-, triacylglycerols; general structure with examples. Hydrolysis of acylglycerols: acid value, Saponification, saponifactionvalue and its significance, Unsaturation in acyl glycerols- iodine number and iodine number of different oils. lipid peroxidation Phosphoglycerides: structure and biological roles of phosphatidyl choline, phospatidyl ethanolamine, phosphatidyl serine, phospatidyl inositol. Sphinogolipds: structure of 4-sphingenine, ceramides and sphingomyelin and their biological importance. Glycosphingolipids: Biological importance and general structure of cerebrosides and gangliosides. Prostaglandins: definition and example, biological role of prostaglandins in general, Structure of PGE_2 and PGF_2.Thromboxanes and leukotrienes. Waxes: definition, types, biological importance. Lipoproteins: Types and functions, clinical significance. Membrane: common features of membranes, behavior of amphipathic lipids in water, formation of micells, bilayers and vesicles. Biological membranes: fluid mosaic model, composition and functions. Role of cholesterol in biological membrane. Bile acids-origin and functions. Steroids: definition, functions of cholic acid.

10 h

Unit – III

Proteins

Structure and classification of α-amino acids based on the polarity of R group. Amino acids as ampholytes, zwitter ion structure of amino acids, Isoelectric pH. Titration curve of alanine. Reactions of amino acids with ninhydrin, FDNB, Edman's reagent and decarboxylation amino acids. Peptides: structure and conformation, example and function of biologically important peptides. Proteins: Classification based on composition, shape and function with examples. Colour reactions of proteins: bicinchoninic acid (BCA), Lowry, Sakaguchi's and Biuret reaction.
Structural organization of proteins: Primary structure, importance of primary structure by taking

sickle cell anemia as example. Secondary structure -Types: α-helix, β-pleated structure,β-bend and triple helix; example and characteristic features. Tertiary structure and factors stabilizing it. Quaternary structure. Denaturation: denaturating agents and mechanism of denaturation, Renaturation of ribonuclease - Anfinsen's experiment and lysozyme.

10 h

Unit – IV

4. Bioenergetics and Biological Oxidation

Laws of thermodynamics; I & II laws with mathematical expressions. Introduction to bioenergetics, stages of energy transformation-photosynthesis, respiration and utilization of energy. Free energy concepts: free energy change: exergonic and endergonic reactions. Free energy change (ΔG), standard free energy change ($\Delta G°$) and standard free energy change in biological systems ($\Delta G°'$). Biochemical standard state, relationship between $\Delta G°$ and Keq. Numerical problems. High energy compounds: examples, Energy coupling: explanation with suitable examples. Biological oxidation: Comparison of biological oxidation with combustion using glucose as an example. Calculation of thermodynamic efficiency of biological oxidation for a mole of glucose. Redox potential of half reactions of the components of electron transport chain. Problems on calculation of energy yield from biological Red-ox reactions. Electron transport chain: sequence of electron carriers based on $E°$ value indicating the sites of ATP yielding, P:O ratio. Four complexes and their functions, Cytochromes and Non heme iron (NHI) proteins. Reactions (no chemical equations) associated with NAD, FAD, FMN, ubiquinone and coenzyme-Q, salient features of chemiosmotic theory, oxidative phosphorylation.

10 h

Biochemistry Practical - V

3 hrs/week

1. Qualitative analysis of carbohydrates.
2. Qualitative analysis of amino acids and proteins
3. Qualitative analysis of lipids.
4. Preparation of solid derivatives of monosaccharide -osazones.
5. Determination of total Carbohydrate content in cereal by anthrone method.
6. Estimation of amino acids by formal titration.
7. Estimation of ascorbic acid from biological samples by titrimetric method.
8. Determination of iodine value of a lipid.
9. Determination of saponification value of a lipid.
10. Estimation of Calcium from milk.

B.Sc. Biochemistry – Fifth Semester
Biochemistry - VI

40h

Unit – I

1. Enzymes:

Brief Introduction, Nomenclature (E.C. No. upto 2nd digit) and classification of enzymes, Holoenzyme, apoenzyme, prosthetic group. Enzyme specificity and theories-Lock and key model, induced fit theory. Active site and its characteristics, Enzyme assay methods, enzyme Units, IU, KCAT & Katal. Chemical nature of enzymes catalysis and energy of activation, Effect of pH and temperature.

Enzyme kinetics of single substrate reactions- Michaelis theory, steady state theory. Michaelis-Menten equation (Noderivation), Significance of Km and V max and their determination using Line Weaver– Burkplots. Monomeric and oligomeric enzymes; cooperativity incatalysis, sigmoidal kinetics, allosteric effectors. Enzyme Inhibition: Types - reversible, irreversible, competitive, non-competitive, un-competitive and mixed inhibitors. Partial inhibition, substrate inhibition and allosteric inhibition. Cofactors- metal cofactors, Coenzymes; definition and role of TPP and PLP).

10 h

Unit – II

2. Nucleic acids:

Nucleosides and nucleotides, configuration and conformation, Composition of RNA and DNA, Physico- chemical properties of nucleic acids - effect of alkali, acid and heat (denaturation and renaturation), features of phosphodiester bond, endonucleases. Complementary base pairing, secondary structure of RNA, features of DNA double helix (Watson-Crick model),Nucleoproteins - histone and nonhistone. Isolation of nucleic acids and sequencing.

10 h

Unit – III

3. Genetic material:

Experimental proofs; Genome organization- from nucleotide to chromatin; the versatility of RNA. Basic features of DNA replication in vivo: semi - conservative replication, bidirectional replication-visualization of replication forks by autoradiography, unique origins of replication, DNA polymerases and DNA synthesis in vitro: Discovery of DNA polymerases, multiple DNA polymerases; the complex replication apparatus: semi- discontinuous synthesis, replication initiation, elongation and termination- Enzymology, outline of DNA replication in eukaryotes.

7 h

4. Mutation:

Mutagens– chemical and physical, Molecular basis of mutation: spontaneous and induced mutations. Types of mutation, reversion and suppression, DNA repair mechanisms- repair systems, direct (photoactivation), excision repair - base excision and nucleotide excision repair.

3 h

Unit – IV

5. Transcription:

Transfer of genetic information: the central dogma, RNA polymerases, different types of RNA polymerases, promoters, regulatory elements, constitutive and inducible promoter, operators.

Initiation (role sigma factor), elongation and termination (rho dependent and independent);regulation of gene expression in prokaryotes: positive and negative control using lac operon as an example, attenuation: trp operon. Overview of eukaryotic transcription, post transcriptional processing: capping, splicing and polyadenylation.

6 h

6. Translation:

Genetic code– features; Translation machinery– ribosomes, composition and assembly. Translation - overview, mechanism, iso-accepting tRNA, wobble hypothesis, outline of translation in eukaryotes. Inhibitors of translation.

4 h

Biochemistry Practical-VI

3 h /week

List of experiments:

1. Determination of total activity of α/β amylase
   a) Standard curve for maltose
   b) Determination of rate of amylase activity
2. Determination of optimum temperature for α/β amylase
3. Determination of optimum pH for α/β amylase
4. Determination of total activity of acid phosphatase
   a) Standard curve for p-nitro phenol
   b) Determination of rate of acid phosphatase activity
5. Determination of optimum temperature for acid phosphatase
6. Determination of optimum pH acid phosphatase
7. Determination of total activity Urease
   a) Standard curve for ammonium sulfate
   b) Determination of rate of Urease activity
8. Determination of optimum temperature for Urease
9. Determination of optimum pH Urease
10. Estimation of DNA by Diphenylamine method
11. Isolation and Separation of Genomic DNA
12. Separation of Proteins by SDS-PAGE

B.Sc. Biochemistry -Sixth Semester

Biochemistry-VII

40h

UNIT-I

1. Introduction to metabolism

Definition, Anabolism and Catabolism- definition, differences, schematic representation of stages in metabolism.

1h

2.Carbohydrate metabolism

Glycolysis; definition, individual reactions. Irreversible and reversible reactions.Energy requiring and releasing reactions.. Net reaction of glycolysis. Fate of pyruvate- formation of Acetyl-CoA, Ethanol and Lactate. Energetics of Glycolysis. Regulation of Glycolysis. TCA cycle-Individual reactions. Net reaction of TCA cycle. Number of ATP molecule production. Functions of TCA cycle- Amphibolic roles (Anapleorosis)and Biosynthesis of other molecules. Regulation of TCA cycle, energetics of TCA cycle. Pentose phosphate pathways (PPP/ HMP)- Significance, reactions only names of intermediates with flow chart. Gluconeogenesis- Definition and significance, flow chart for gluconeogenesis. CORI cycle-explanation, diagram, CORI diseases. Glycogenolysis- definition, reactions- flow chart. Diabetes, types and the role of Hormones.

9 h

UNIT – II

2. Lipid metabolism:

β-oxidation of saturated fatty acids; individual reactions, enzymes, coenzymes. Energetics of β- oxidation of palmitic acid and stearic acid, role of carnitine, Oxidation fatty acids-with odd number of carbon atoms, fate of propionyl coA, oxidation of unsaturated fatty acids - oleic acid, importance of alpha and omega Oxidation. Fatty acid synthetases; structure and functions. Biosynthesis of fatty acids-general flow chart, difference between fatty acid oxidation and fatty acid synthesis. cholesterol biosynthesis- (chemical reactions up to the formation of mevalonate, remaining reactions may be given as flow scheme). Atherosclerosis-causes. Ketone bodies-examples, cause for the production, utilization, ketonemia and ketonuria.

10 h

UNIT-III

3. Amino acid metabolism:

General reactions: transamination- definition, reactions catalyzed by SGOT and SGPT, Deamination - definition, oxidative and non-oxidative, examples for oxidative deamination- L-glutamate and non-oxidative- serine, aspartic acid and glutamine. Decarboxylation - definition, decarboxylation of glutamic acid, Histidine and DOPA to Dopamine. Urea cycle- individual reactions, Compartmentation in mitochondria and cytosol, regulation of urea cycle. Interrelationship between urea cycle and TCA cycle. Biosynthesis of glycine from serine and choline. Biosynthesis of alanine from transamination reaction. Biosynthesis of cysteine from L- serine. Epinephrine and Nor-epinephrine- importance and biosynthesis from tyrosine. PKU and AKU characteristic features.

6 h

4. Nucleic acid metabolism:

Biosynthesis of purine and pyrimidine nucleotides- origin of nitrogen and carbon atoms of purine and pyrimidine ring. Precursors of purine and pyrimidine biosynthesis. Reactions of conversion of AMP to IMP and Adenosine to inosine. Orotic acid uria- general features. Gout; general features.

4h

Unit – IV

5. Photosynthesis:

Types of Photosynthetic pigments and Photosynthetic unit. Light reactions- photosystem- I and II and their interactions. Synthesis of NADPH, photolysis of water, synthesis of ATP in cyclic and non-cyclic photophosphorylation. Dark reactions - chemical reactions upto the synthesis of fructose-6-phosphate. Trans- ketolation and aldolation reactions (shall be given in the form of flow chart). Interdependence of light and dark reactions. C3 and C4 plants- definition and C4 pathway.

8h

6. Biological Nitrogen Fixation:

Nitrogen cycle, components of nitrogenase complex, stoichiometry of nitrogen fixation, nif genes.

2h

Biochemistry Practical-VII

3 h/week

List of experiments:

1. Estimation of protein by FC method
2. Estimation of Iron using ammonium thiocyanate by Colorimetric method
3. Colorimetric Estimation of Inorganic Phosphate by Fiske Subbarow method
4. Colorimetric Estimation of Creatine and Creatinine by Jaffe's method
5. Colorimetric Estimation of Lactose in milk by D.N.S method
6. Estimation of amino acid (alanine/glycine) using ninhydrin by colorimetric method
7. Estimation of serum cholesterol by Zak's method
8. Extraction of DNA from onions
9. Conductometric titration of amino acid against NaOH.
10. Conductometric titration of amino acid against HCl

B.Sc. Biochemistry – Sixth Semester

Biochemistry –VIII

40 h

Unit – I

1. Industrial Microbiology:

Principles and methods of sterilization; physical and chemical methods with examples.Isolation of pure cultures; enrichment, dilution-plating, streak- and spread-plate and micromanipulations. preservation of pure cultures - sub culturing, lyophilization. Microbial growth kinetics: Growth curve, Measurement of growth (cell count), immobilization of microbes. Fermentation Technology; Use of microorganisms in fermentation, design of fermenters, types, media inoculation. Fermentation types; single, batch, submerged and solid state. Industrial production and uses of the following: Alcohol- ethanol, Organic acids - citric acid, Amino acid - Glutamic acid, Antibiotics-penicillin, Enzymes- amylase and microbial fuel cells.

10 h

Unit-II

2. Immunology:

Organs and cells of Immune system - Primary and secondary Lymphoid organs, Dual nature of the immune system. Immunity- Types, Innate immunity: First Line of Defense - skin, mucous membrane and normal micro biota in nonspecific defense. Second Line of Defense - Components of Blood, innate immunity -complement, acute phase proteins and interferons. Mechanism of immune response - phagocytosis and inflammation. Adaptive immunity: cell mediated and humoral immunity, Complement system - Functions, classical and alternate pathways. Antigens - Chemical nature of antigens, hapten, antigenicity, immunogenicity, epitope, idiotopes, super antigens. Antigen processing and presentation. Immunoglobulins - Isotypes, structures and functions IgG, IgM, IgE; Subunit organisation and structure of IgG. Methods of raising antibodies – adjuvants, immune sera. Monoclonal antibodies - production and application. Major histocompatibility complex proteins (MHC): Types, physiological role.Antigen-antibody reactions - Agglutination, Precipitation, Neutralisation, Complement fixation and Opsonisation. Hyper sensitivity reactions- Types and examples, Allergy, Type-I HS reaction and its mechanism. Vaccines- classification, methods of production of live, attenuated vaccines, toxoids, adjuvants. modern vaccines -recombinant, peptide and DNA vaccines.

10 h

Unit III

3. Recombinant DNA Technology:

Concepts and scope of genetic engineering. Basic principles and importance of gene cloning and Recombinant DNA Technology. Tools in Recombinant Technology: Enzymes - Role of DNA polymerase, Class II restriction endonucleases,DNA ligase and RNA ligase, phosphatases and terminal transferases in cloning.Cloning vectors: - Characteristic features of plasmid vectors - pBR322, pUC18., Phage vectors- M13 phage vectors, Cosmids- features and advantages. Shuttle vectors - YAC and BAC vectors. Preparation, Manipulation and Insertion of desired DNA into vector. Transformation, Transduction, Transfection of r-DNA into target host organisms: Calcium chloride mediated gene transfer, Agro bacterium mediated DNA transfer, Electroporation, Microinjection, Liposome fusion and Micro particle bombardment. Cloning and expression in bacteria, Screening and selection of transformants by colony hybridization, Insertional inactivation. Genomic and c-DNA Libraries - outline of their construction and applications.

10 h

Unit IV

4. Molecular and Immunological techniques:

Blotting techniques: principle and applications of Western, Southern and Northern blotting. Probes – Types and characteristics. Molecular biology techniques: PCR- types – RT PCR and Direct PCR - principle, applications. Hybridization techniques - types and applications. Fluorescent In situ Hybridization (FISH), DNA finger printing - RFLP, RAPD, microarrays, Immunochemical techniques: principle and applications of Precipitation-VDRL, agglutination- Widal test, Immunodiffusion, Immuno-electrophoresis, RIA and ELISA- Types, Autoradiography - principle and applications.

10 h

Biochemistry Practical-VIII

3 h / week

1. Identification of antigen by Ouchterlony Immunodiffussion technique.
2. Immunoelectrophoresis of serum or any biological sample.
3. Restriction digestion of DNA and separation by agar-gel-electrophoresis.
4. Ammonium sulphate fractionation of serum proteins. (Demonstration)
5. Separation of serum and plasma from blood.
6. Serum uric acid estimation.
7. Determination of the melting temperature and GC content of DNA.
8. Estimation of serum Ca^{2+}.
9. Study of cell viability /death assay by use of trypan blue and tutorial for MTT assay.
10. Estimation of homocysteine levels in serum
11. Effect of detergents and other membrane active substances on erythrocytes
12. Molecular Visualization Softwares: Pymol and Rasmol for protein structures from PDB
13. Continuous assay of an enzyme
14. Visualization of cells by methylene blue

REFERENCES

1. Atlas RM. (1997). Principles of Microbiology. 2nd edition. W.M.T. Brown Publishers.
2. Madigan MT, Martinko JM and Parker J. (2009). Brock Biology of Microorganisms. 12th edition. Pearson/Benjamin Cummings.
3. Pelczar MJ, Chan ECS and Krieg NR. (1993). Microbiology. 5th edition. McGraw Hill Book Company.
4. Stanier RY, Ingraham JL, Wheelis ML, and Painter PR. (2005). General Microbiology. 5th edition.McMillan.
5. Tortora GJ, Funke BR, and Case CL. (2008). Microbiology: An Introduction. 9th edition. Pearson Education.
6. Vashishta BR. (2005). Algae. 3rd edition. S. Chand and Company Limited, New Delhi.
7. Willey JM, Sherwood LM, and Woolverton CJ. (2008). Prescott, Harley and Klein's Microbiology.7th edition. McGraw Hill Higher Education.
8. Ananthanarayan R and Paniker CKJ. (2005). Textbook of Microbiology. 7th edition (edited by Paniker CKJ).University Press Publication.