

**PARVATIBAI CHOWGULE COLLEGE OF ARTS & SCIENCE
(AUTONOMOUS)
DEPARTMENT OF BIOCHEMISTRY (SELF FINANCED)
COURSE STRUCTURE**

Semester	Core		Elective			
I	BCH-I.C-1 Molecules of Life	BCH-I.C-2 Cell Biology	-----	-----	-----	-----
II	BCH-II.C-3 Protein chemistry	BCH-II.C-4 Biophysics	-----	-----	-----	-----
III	BCH-III.C-5 Enzymology		BCH-III.E-1 Tools & Techniques in Biochemistry	BCH-III.E-2 Microbiology	BCH-III.E-3 Bioethics and Bio-safety	BCH-III.E-4 Plant Biochemistry
IV	BCH-IV. C-6 Metabolism of Biomolecules		BCH-IV.E-5 Human physiology	BCH-IV.E-6 Nutritional Biochemistry	BCH-IV.E-7 Hormone: Biochemistry and Function	BCH-IV.E-8 Advanced Cell Biology
V	BCH-V.C-7 Molecular biology		BCH-V.E-9 Concepts in genetics	BCH-V.E-10 Regulation of gene expression	BCH-V.E-11 Genetic Engineering and Biotechnology	BCH-V.E-12 Bioinformatics
VI	BCH-VI.C-8 Immunology		BCH-VI.E-13 Biochemical correlation of Diseases	BCH-VI.E-14 Clinical Biochemistry	BCH-VI.E-15 Environmental Biochemistry	BCH-VI.E-16 Industrial Biochemistry

SEMESTER I

COURSE TITLE: MOLECULES OF LIFE (THEORY)

COURSE CODE: BCH-I.C-1

MARKS: 75

CREDITS: 3

COURSE OBJECTIVES: This paper provides basic foundation on biomolecules of life with reference to their properties, and biological functions. The course also provides detailed knowledge on how cellular structure and function arise as a result of the properties of cellular macromolecules.

LEARNING OUTCOMES: Students will understand the importance of proteins, carbohydrates, lipids and nucleic acids and their role in living organisms. It will also help to understand the clinical significance of vitamins.

BCH-I.C-1(THEORY)

Total hours: 45

Unit 1 The foundations of biochemistry

No. of Hours: 2

Cellular and chemical foundations of life

Unit 2 Water

No. of Hours: 3

Unique properties, weak interactions in aqueous systems, ionization of water, water as a reactant and fitness of the aqueous environment

Unit 3 Carbohydrates

No. of Hours: 10

Monosaccharides: structure of aldoses and ketoses, ring structure of sugars, conformations of sugar, stereochemistry: mutarotation, anomers, epimers and enantiomers, formation of disaccharides, reducing and non-reducing disaccharides, Polysaccharides: homo and heteropolysaccharides, structural and storage polysaccharides

Unit 4 Proteins

No. of Hours: 8

Types of amino acids and their chemistry, derivatives of amino acids and their biological role; Introduction to biologically important peptides, polypeptides and proteins.

Unit 5 Lipids

No. of Hours: 7

Various classes of lipids and their distribution, storage lipids, structural lipids in membranes, lipids as signal molecules, cofactors and pigments

Unit 6 Nucleic acids

No. of Hours: 10

Structures and chemistry: DNA structures and their importance, different types of RNA, unusual DNA structures, other functions of nucleotides: source of energy, component of coenzymes, second messengers.

Unit 7 Vitamins

No. of Hours: 5

Structure and active forms of water soluble and fat soluble vitamins, deficiency diseases and symptoms, hyper-vitaminosis.

BCH-I.C-1: MOLECULES OF LIFE (PRACTICALS)

COURSE TITLE: MOLECULES OF LIFE (PRACTICALS)

COURSE CODE: BCH-I.C-1

MARKS: 25 MARKS

CREDITS: 1

TOTAL HOURS: 30

Introduction to safety measures in laboratories	1P
Preparation of solutions (normal, molar, ppm , %)	1 P
Mutarotation of sugars	2P
Determination of pKa of acetic acid and glycine	2 P
Qualitative tests for carbohydrates, lipids, amino acids, proteins and nucleic acids	5 P
Preparation of TLC plates and separation of amino acids and sugars by thin layer chromatography	3 P
Estimation of vitamin C	1 P

REFERENCES

- Nelson, D. L. & Cox, M.M. (2000), Lehninger's Principles of Biochemistry (3rd Edition), Worth Publishers, New York, USA.
- Stryer, L. (1995). Biochemistry, W.H. Freeman and Co., New York, USA.
- Jain, J.L (1999), Fundamentals of Biochemistry, S.Chand and Company, Ltd., New Delhi.
- Murray, R.K., Granner, D.K., Mayes, P.A. & Rodwell, V.W. (2003), Harper's Illustrated Biochemistry, McGraw-Hill Companies.
- Donald Voet, Judith G. Voet & Charlotte W. Pratt, Principles of Biochemistry, John Wiley & Sons.
- S. Sadasivam and A. Manickam (1996), Biochemical Methods, New Age International (P) Limited
- J. Jayaraman (1971), Laboratory Manual in Biochemistry, John Wiley & Sons, Limited.

SEMESTER I

COURSE TITLE: CELL BIOLOGY (THEORY)

COURSE CODE: BCH-I.C-2

MARKS: 75

CREDITS: 3

COURSE OBJECTIVES: The course will give a detailed description of the organization of the cell, the structure and functions of various organelles. The course also focuses on the communication cells and the importance of cell division

LEARNING OUTCOMES: Students will have a clear knowledge on the function of each cell organelle with proper coordination and establish the concept of how proper conformations of lipids and proteins in a membrane are needed for optimum functioning

BCH-I.C-2 (THEORY)

TOTAL HOURS: 45

Unit 1 Introduction to cell biology

No. of Hours: 6

Cell theory, ultra-structure of prokaryotic and eukaryotic cell; cell matrix proteins; components of extracellular matrix

Unit 2 Ultra- structure and function of organelles

No. of Hours: 15

Cilia and flagella; endoplasmic reticulum, golgi apparatus, lysosomes, microbodies, mitochondria, chloroplast, ribosomes, centrioles and basal bodies, nucleus, chloroplasts and peroxisomes

Unit 3 Cell wall & Plasma membrane

No. of Hours: 10

Chemical composition, structure and functions of the cell wall and plasma membrane, monolayer, planer bilayer and liposomes as model membrane systems. Fluid mosaic model, lipid rafts, caveolae, membrane fluidity, factors affecting membrane fluidity, techniques used to study membrane dynamics – FRAP

Unit 4: Cell cycle

No. of Hours: 4

Overview of the cell cycle; prokaryotic & eukaryotic cell cycle; events of mitotic & meiotic phases, cytokinesis.

Unit 5: Cell-Cell interaction

No. of Hours: 10

Interactions of cells with extracellular materials: integrins, focal adhesions and hemidesmosomes; interactions of cells with other cells: selectins, the immunoglobulin

superfamily, cadherins, adheren junctions and desmosomes; tight junctions, gap junctions and plasmodesmata

BCH-I.C-2 CELL BIOLOGY (PRACTICAL)

COURSE TITLE: CELL BIOLOGY (PRACTICALS)

COURSE CODE: BCH-I.C-2

MARKS: 25

CREDITS: 1

TOTAL HOURS: 30

Examination of prokaryotic cell, eukaryotic cell and cell organelles using Photomicrographs	2P
Visualization of animal and plant cell using methylene blue.	2P
Study of cell viability using phenol red and trypan blue	1P
Visualization of Permanent slides of:	1P
A. Different cell types: Epithelium, Endothelium, Muscle cells, Nerve cell	
B. Different stages of cell division	
Identification of different stages of mitosis in onion root tip `	1P
Identification of different stages of meiosis in grasshopper testis	1P
Isolation of chloroplast from spinach leaves and estimation of chlorophyll	2P
Prokaryotic cell harvesting & lysis using osmotic (salt) and Chemical (detergent) methods	3P
RBC and WBC count using haemocytometer	2P

REFERENCES

- Karp, G. & Harris, D. (2008) Cell and Molecular Biology – Concepts and Experiments, John Wiley & Sons Inc, New York.
- Robertis, E.D.P. & Robertis, E.M.F. (1998). Cell Biology and Molecular Biology, 8th edition, Sauder College.
- Cooper, G.M. and Hausman, R.E. 2009. The Cell: A Molecular Approach. 5th edition. ASM Press & Sunderland, Washington, D.C.
- Gupta, P.K. (1999). A Text-book of Cell and Molecular Biology. Rastogi Publications, Meerut, India.
- Verma P.S. and Agarwal V. K. (1998).Cell Biology, Genetics, Molecular Biology, Evolution and ecology. Edn.14

SEMSESTER II

COURSE TITLE: PROTEIN CHEMISTRY (THEORY)

COURSE CODE: BCH-II.C-3

MARKS: 75

CREDITS: 3

COURSE OBJECTIVES: The main objective of the course is to understand the importance of structure of proteins for their biological functions and the analytical techniques to isolate and characterize proteins.

LEARNING OUTCOMES: Students will be able to describe the four levels of protein structure, types of bonding and how a protein's structure relates to its cellular function. Also students will be familiar with many of the biophysical techniques used in research and industry for analyzing the structure and function of proteins.

BCH-II.C-3 (THEORY)

TOTAL HOURS: 45

Unit 1 Protein structure

No. of Hours: 15

Bonds in protein structure (covalent, non covalent, peptide), importance of primary & secondary structure, tertiary and quaternary structures, bond lengths and configuration, Dihedral angles, psi and phi, helices, sheets and turns, Ramachandran map; techniques used in studying 3-D structures - X-ray diffraction and NMR; motifs and domains; structures of myoglobin and haemoglobin, multimeric proteins and conjugated proteins, diversity of function.

Unit 2 Isolation and analysis of proteins

No. of Hours: 12

Techniques to isolate and analyze proteins: salt fractionation, ion-exchange chromatography, gel permeation, HPLC, SDS-PAGE, IEF; Protein primary structure: sequencing by Edman degradation, use of enzymes and chemical reagents to obtain overlap peptides, synthesis of peptides using Merrifield method

Unit 3 Characterization of proteins

No. of Hours: 5

Determination of purity, molecular weight, extinction coefficient, sedimentation coefficient, 2-D electrophoresis

Unit 4 Enzymes

No. of Hours: 5

Nature of enzymes: protein and non-protein (ribozyme); cofactor and prosthetic group, apoenzyme, holoenzyme; IUBMB classification of enzymes

Unit 5 Membrane proteins**No. of Hours: 8**

Integral and membrane associated proteins, hydropathy plots to predict transmembrane domains; significance of membrane proteins; bacteriorhodopsin, myoglobin and haemoglobin: structure and function (Oxygen binding curves, cooperativity models for haemoglobin)

BCH-II.C-3 PROTEIN CHEMISTRY (PRACTICALS)**COURSE TITLE: PROTEIN CHEMISTRY (PRACTICALS)****COURSE CODE: BCH-II.C-3****MARKS: 25****CREDITS: 1****TOTAL HOURS: 30**

Determination of the absorption maxima and molar extinction coefficient of protein sample	2P
Protein assay by Lowry/Bradford method	2P
Ammonium sulphate fractionation of crude homogenate from mung bean	1P
Ammonium sulphate fractionation of serum proteins	2P
Protein dialysis	1P
Solubility of proteins in distilled water and salt solutions	2P
Separation of proteins by SDS-PAGE (demonstration)	2P
Gel filtration chromatography	2P
Denaturation of proteins by heat	1P

REFERENCES

- Nelson D.L and Cox M.M (2013). Lehninger's Principles of Biochemistry, Worth Publishers, New York, USA.
- Cooper T.G (2011). The Tools of Biochemistry, Wiley India Pvt. Ltd, New Delhi.
- Voet, D. and Voet, J.G (2004). Biochemistry, 3rd Edition, John Wiley & Sons, Inc. USA.
- Plummer D. T (1998). An Introduction to Practical Biochemistry, 3rd ed., Tata McGraw Hill Education Pvt. Ltd. New Delhi.
- Sadasivam S. and A. Manickam (1996), Biochemical Methods, New Age

International (P) Limited, New Delhi.

- J. Jayaraman (1971), Laboratory Manual in Biochemistry, John Wiley & Sons, Limited, New Delhi.

SEMESTER II

COURSE TITLE: BIOPHYSICS (THEORY)

COURSE CODE: BCH-II.C-4

MARKS: 75 MARKS

CREDITS: 3

COURSE OBJECTIVES: The course will give a detailed description of the physical concepts required to study various biochemical aspects, to understand the basic concepts of origin and evolution of life and the concepts of bioenergetics.

LEARNING OUTCOMES: Students will have a clear concept on thermodynamic principles which are essential to carry out the cellular reactions. It will also help to understand the mechanism of deriving energy through bioenergetic reactions in living cells.

BCH-II.C-4 (THEORY)

TOTAL HOURS: 45

Unit 1 The chemical basis of life

No. of Hours: 5

Introduction, prebiotic earth, theories of origin and evolution of life; covalent bonds, non-covalent bonds: ionic bonds, hydrogen bonds, hydrophobic interactions, van der Waals forces

Unit 2 Basic principles of biochemical studies

No. of Hours: 7

Units of measurement; weak electrolytes- the biochemical importance of weak electrolytes, ionisation of weak acids and bases, calculation of pH, ionisation of a weak electrolyte, buffer solutions, buffer capacity, buffer action and pH of blood, measurement of pH

Unit 3 Introduction to bioenergetics

No. of Hours: 10

Laws of thermodynamics, equilibrium constant, coupled reactions, ATP cycle, phosphoryl group transfers; chemical basis of high standard energy of hydrolysis of ATP, other phosphorylated compounds and thioesters. Redox reactions, standard redox potentials and Nernst equation, universal electron carriers

Unit 4 Ion channels

No. of Hours: 4

Sodium, Potassium, Calcium, Chlorine, ligand gated, Donnan's equilibrium experiments

Unit 5 Oxidative phosphorylation

No. of Hours: 7

Mitochondrial electron transport chain: its organization and function, inhibitors of ETC and uncouplers, Peter Mitchell's chemiosmotic hypothesis, proton motive force, structure and mechanism of ATP synthesis, regulation of oxidative phosphorylation

Unit 6 Photo-phosphorylation

No. of Hours: 12

General features of photophosphorylation, Hills reaction, photosynthetic pigments, light harvesting systems of plants and microbes; bacterial photophosphorylation in purple bacteria, green sulfur bacteria. Photophosphorylation in plants - structure of chloroplast, molecular architecture of Photosystem I and Photosystem II, Z-scheme of photosynthetic electron flow, oxygen evolving complex and action of herbicides; cyclic photo-phosphorylation and its significance; photo inhibition, evolution of oxygenic photosynthesis

BCH-II.C-4 BIOPHYSICS (PRACTICAL)

COURSE TITLE: BIOPHYSICS (PRACTICALS)

COURSE CODE: BCH-II.C-4

MARKS: 25

CREDITS: 1

TOTAL HOURS: 30

Preparation of buffers	2P
Determination of buffering capacity	1P
To determine Osmolarity of solutions proteins/ sugars/ lipids/ nucleic acids using Osmometer	4P
Effect of detergents and other membrane active substances on cells (Erythrocytes)	2P
Determination of λ_{max} and Molar extinction coefficient of a given compound	2P
Determination of pka of Bromophenol blue	2P
Photooxidation of photosynthetic pigments	1P
Oxygen evolution (by hydrilla)	1P

REFERENCES

- Nelson D.L and Cox M.M (2013). Lehninger's Principles of Biochemistry, Worth Publishers, New York, USA.
- Cooper T.G (2011). The Tools of Biochemistry, Wiley India Pvt. Ltd, NewDelhi.
- Voet, D. and Voet, J.G (2004). Biochemistry, 3rd Edition, John Wiley & Sons, Inc, USA.
- Stryer, L. (1995). Biochemistry, W.H. Freeman and Co., New York, USA.
- Jain, J.L (1999), Fundamentals of Biochemistry, S.Chand and Company, Ltd., New Delhi.

- Wilson K and Walker J (2010). Principles and Techniques of Biochemistry and Molecular Biology, Seventh edition Cambridge University Press, UK

SEMESTER III

COURSE TITLE: ENZYMOLOGY (THEORY)

COURSE CODE: BCH-III.C-5

MARKS: 75

CREDITS: 3

COURSE OBJECTIVES: The course will introduce students to various theoretical and practical aspects of enzymology; and stimulate their interest in learning the structure, function and kinetics of enzyme. Serve as foundation for more advanced enzymology courses.

LEARNING OUTCOMES: Students will have a clear knowledge to explain relationship between the structure and function of enzymes; explain how enzymes are able to increase speed of the biochemical reaction, differentiate between equilibrium and steady state kinetics and to estimate important parameters such as K_m , V_{max} , K_{cat}

BCH-III.C-5 ENZYMOLOGY (THEORY)

TOTAL HOURS: 45

Unit 1 Introduction to enzymes

No. of Hours: 6

Nature of enzymes - protein and non-protein

Co-enzymes, Cofactor and prosthetic group, apoenzyme, holoenzyme, ribozymes & isoenzymes

Specificity of enzymes, concept of active site

Nomenclature and Classification of enzymes

Unit 2 Features of enzyme catalysis

No. of Hours: 6

Fischer's lock and key hypothesis

Koshland's induced fit hypothesis

Factors affecting the rate of reactions, (time, enzyme concentration, substrate concentration, pH, temperature)

Unit 3 Enzyme kinetics

No. of Hours: 8

Enzyme activity - international units, specific activity, turnover number

Principles of reaction rates, order of reactions and equilibrium constants. Derivation of Michaelis-Menten equation and Lineweaver- Burk plot

Significance of K_m and V_{max} , K_{cat} and turnover number

Unit 4 Enzyme inhibition

No. of Hours: 8

Reversible inhibition (competitive, uncompetitive, non-competitive, mixed and suicide, end product)

Types of irreversible Inhibition, Allosteric inhibition

Unit 5 Mechanisms of enzyme action and regulation

No. of Hours: 6

Mechanism of action of chymotrypsin

Regulation of enzyme activity and its importance - aspartate transcarbamoylase

Unit 6 Enzyme purification

No. of Hours: 6

Purification of enzymes: salt precipitation; dialysis; molecular exclusion chromatography;

Molecular weight determination by PAGE, SDS-PAGE

Unit 7 Applications of enzymes

No. of Hours: 5

Enzymes in diagnostics (SGPT, SGOT, creatine kinase, alkaline and acid phosphatases), enzyme immunoassay (HRPO)

Immobilized enzymes

BCH-III.C-5 ENZYMOLOGY (PRACTICAL)

COURSE TITLE: ENZYMOLOGY (PRACTICAL)

COURSE CODE: BCH-III.C-5

MARKS: 25

CREDITS: 1

TOTAL HOURS: 30

Preparation of buffers and solutions for the study of enzyme activity	1P
Enzyme assay and rate of reaction	1P
Determination of optimal pH for enzyme activity	1P
Determination of optimal temperature for enzyme activity	1P
Effect of substrate concentration and determination of K_m and V_{max}	4P
Production and isolation of enzyme from any source (plant/microbial)	2P
Partial purification of an enzyme (salting out and Dialysis)	3P
PAGE- Preparation of reagents; Demonstration	2P

REFERENCES

- Jain, J.L (1999). Fundamentals of Biochemistry, S. Chand and Company, Ltd., New Delhi.
- Murray, R.K., Granner, D.K., Mayes, P.A. & Rodwell, V.W. (2003), Harper's Illustrated Biochemistry, McGraw-Hill Companies.
- Nelson, D. L. & Cox, M.M. (2000). Lehninger's Principles of Biochemistry (3rd Edition), Worth Publishers, New York, USA.
- Stryer, L. (1995). Biochemistry, W.H. Freeman and Co., New York, USA.
- Zubay, G. (1993). Biochemistry (3rd Edition), WCB Publishers, Iowa, USA.
- Nicholas C.P. & Lewis S. (1999). Fundamentals of Enzymology (3rd Ed), Oxford University Press Inc. New York. USA.

SEMESTER III

COURSE TITLE: TOOLS AND TECHNIQUES IN BIOCHEMISTRY (THEORY)

COURSE CODE: BCH-III.E-1

MARKS: 75

CREDITS: 3

COURSE OBJECTIVES: This course is designed to expose the students to the basic principles underlying some biochemical methods and techniques, their methodologies and applications.

LEARNING OUTCOMES: To understand the principles and applications behind major biochemical methods such as chromatography, electrophoresis, centrifugation, spectrophotometry and isotopic techniques

BCH-III.E-1 TOOLS AND TECHNIQUES IN BIOCHEMISTRY (THEORY)

TOTAL HOURS: 45

Unit 1 Separation Techniques

No. of Hours: 4

Different methods of protein precipitation: Precipitation using inorganic salts (salting out) and organic solvents, dialysis and ultra-filtration.

Unit 2 Chromatography

No. of Hours: 10

Basic principles of chromatography: Partition coefficient, concept of theoretical plates, various modes of chromatography (paper, thin layer, column), HPLC, Molecular Sieve (Gel Filtration) Chromatography, Ion Exchange Chromatography, Affinity Chromatography, Gas Liquid Chromatography.

Unit 3 Electrophoresis

No. of Hours: 10

Basic Principle of electrophoresis, Paper electrophoresis, Gel electrophoresis, discontinuous gel electrophoresis, PAGE, SDS-PAGE, Native gels, denaturing gels, agarose gel electrophoresis

Unit 4 Centrifugation

No. of Hours: 10

Principle of centrifugation, basic rules of sedimentation, sedimentation coefficient, various types of centrifuges, different types of rotors, differential centrifugation, density gradient centrifugation (Rate zonal and Isopycnic)

Unit 5 Spectrophotometry

No. of Hours: 4

UV-Visible spectrophotometry- Principle, instrumentation and applications

Unit 6 Radioisotopes in Biology

No. of Hours: 7

Concept of half-life, decay constant, detection - GM counter, solid and liquid scintillation counter, autoradiography ; Applications of radioisotopes in Biology

BCH-III.E-1 TOOLS AND TECHNIQUES IN BIOCHEMISTRY (PRACTICAL)

COURSE TITLE: TOOLS AND TECHNIQUES IN BIOCHEMISTRY (PRACTICAL)

COURSE CODE: BCH-III.E-1

MARKS: 25

CREDITS: 1

TOTAL HOURS: 30

Estimation of proteins by Biuret and Lowry's Methods	4P
Separation and identification of amino acids by paper chromatography	2P
Precipitation of protein by salt precipitation and solvent precipitation	2P
Demonstration of gel filtration chromatography	2P
SDS-PAGE analysis of proteins	3P
Determination of pKa values of glycine and aspartate/glutamate	2P

REFERENCES

- Wilson K and Walker J. 2005. Principles and Techniques of Practical Biochemistry, 6th Edition, Cambridge University Press.

- Upadhyay A, Upadhyay K and Nath N. 2009. Biophysical Chemistry: Principles and Techniques, 3rd Edition, Himalaya Publishing, New Delhi.
- Plummer D. 1988. An introduction to Practical Biochemistry, Tata McGraw Hill Publishing Company, New Delhi.
- Jayraman J. 2011. Laboratory Manual in Biochemistry. New Age International Pvt Ltd Publishers, New Delhi.
- Sadasivam S. and Manickam A. 2007. Biochemical Methods, 3rd edition, New Age International Publishers, New Delhi.

SEMSESTER III

COURSE TITLE: MICROBIOLOGY (THEORY)

COURSE CODE: BCH-III.E-2

MARKS: 75

CREDITS: 3

COURSE OBJECTIVES: This course covers topics in basic microbiology from the historical perspective to the structure and composition of microorganisms, their interactions with the environment and their impact on humans.

LEARNING OUTCOMES: Students will understand the scope and importance of Microbiology, classification schemes, cultivation, preservation and maintenance of the microbial cultures, pathogenicity of microorganisms, precautions and measures to control the same.

BCH-III.E-2 MICROBIOLOGY (THEORY) TOTAL HOURS: 45

Unit 1 History of Development of Microbiology No. of Hours: 8

Contributions of Anton von Leeuwenhoek, Louis Pasteur, Robert Koch, Joseph Lister, Alexander Fleming.

Establishment of fields of medical microbiology and immunology through the work of Paul Ehrlich, Elie Metchnikoff, Edward Jenner

Binomial Nomenclature; Classification systems of Whittaker (five kingdom) and Carl Woese (three kingdom)

Microbial Diversity: Prokaryotic (bacteria) and Eukaryotic (fungi) cell structure, organelles and their function. Viruses

Unit 2 Bacteria**No. of Hours: 10**

Bacterial cell: Organization and ultrastructure, Gram characteristics.

Nutritional types: Autotrophs, Heterotrophs, Phototrophs, Chemotrophs and obligate parasite, with examples of each type

Reproduction in bacteria - Binary fission

Respiration (aerobic and anaerobic)

Bacterial growth curve- characteristics of growth phases; diauxic growth curve

Unit 3 Fungi**No. of Hours: 8**

General characteristics of fungi: habitat, nutritional requirements, cell ultra- structure, thallus organization, cell wall structure. Pigments. Mycotoxins.

Reproduction: sexual and asexual reproduction; parasexual mechanism.

Heterokaryosis, heterothallism.

Unit 4 Viruses**No. of Hours: 5**

Structure; Bacterial, plant and animal viruses

Viral multiplication (lytic and lysogenic)

Unit 5 Cultivation of microorganisms**No. of Hours: 10**

Sterilisation, disinfection, decontamination: Principle and methods

Types of culture media: Synthetic/defined, complex, solid, liquid, enrichment, selective, differential.

Cultivation of microorganisms: Broth culture, agar plate, pour plate

Determination of viable count: Serial dilution, spread plating, determination of colony forming units (cfu) and calculation of viable count

Isolation of pure cultures: Streak plate; colony morphology

Unit 6 Maintenance and preservation of microbial cultures**No. of hours: 4**

Slant and stab cultures, periodic transfer, storage in sterile soil, overlaying with mineral oil, glycerol stocks, preservation in liquid nitrogen, lyophilisation

BCH-III.E-2 MICROBIOLOGY (PRACTICALS)**COURSE TITLE: MICROBIOLOGY (PRACTICALS)****COURSE CODE: BCH-III.E-2****MARKS: 25****CREDITS: 1****TOTAL HOURS: 30**

Introduction to microbiology laboratory equipments: Autoclave, millipore filters and assembly, biological safety cabinets (Laminar air flow and HEPA filter), incubators, hot air oven, microscope, pH meter	1P
Sterilization of glassware: Flasks, test tubes, petri plates, pipettes	1P
Preparation and sterilization of media (liquid and solid)	1P
Study of different shapes of bacteria using permanent slides/pictographs	1P
Determination of viable count: Serial dilution, spread plating, determination of colony forming units (cfu) and calculation of viable count	2P
Isolation of pure cultures: Streak plate; colony morphology	2P
Pour Plate Technique	2P
Gram stain of Gram positive and Gram negative bacteria	1P
Use of biochemical tests for bacterial identification: Sugar fermentations, IMViC test	3P
Decontamination and disposal of cultures	1P

REFERENCES

- Prescott, Harley, Klein. 2008. Microbiology. McGraw-Hill Higher Education, Boston.
- Pelczar M.J, Chan E.C.S, Krieg N.R. 1993. Microbiology, McGraw-Hill, New York.
- Dubey R.C., Maheshwari D.K., A textbook of Microbiology. 2008. S. Chand and Company Ltd, New Delhi.
- Powar, C.B & Dagainawala, H.F.1982. General Microbiology – Volume II. Himalaya Publishing house: Bombay.
- Ananthanarayan R and Paniker CKJ. 2009. Text book of Microbiology, Eight edition, University Press.
- Madigan M., Martinko., Parker J. Brock's Biology of Microorganisms. 2007. Pearson Prentice Hall.

SEMESTER III

COURSE TITLE: BIOETHICS AND BIO-SAFETY (THEORY)

COURSE CODE: BCH-III.E3

MARKS: 75

CREDITS: 3

COURSE OBJECTIVES: This paper aims at introducing the importance of the basic

concepts of bioethics and bio-safety and their relationship with several fields such as ecology, agriculture, medicine, chemistry and advances brought about in the field of biology and medicine. The course deals with answers to ethical questions that arise in the relationships among the life sciences, biotechnology, medicine, politics, law, philosophy, theology and their importance in the field of biotechnology.

LEARNING OUTCOME: The students will understand the importance of bioethics and biosafety procedures to be followed, with knowledge of the basic concepts, its principles, and use.

BCH-III.E3 BIOETHICS AND BIOSAFETY TOTAL HOURS: 45

Unit 1 Introduction to Bioethics No. of Hours: 5

Introduction

Principles of bioethics and ethical conflicts

Social and ethical issues in biotechnology

Unit 2 Bioethics in Genetic Engineering No. of Hours: 5

Bioethical issues in plant and animal genetic engineering.

Bioethics in IVF

Unit 3 Introduction to Biosafety No. of Hours: 6

- Introduction, History and Definition of Biosafety

- Biosafety Guidelines and Regulations

- Operation of Biosafety Guidelines and Regulations

Unit 4 Safety in Laboratories No. of Hours: 3

Hazards: Physical, Biological and Chemical

Good laboratory practices

Unit 5 International and Indian Biosafety guidelines No. of Hours: 5

- Biosafety Guidelines in India

- International Biosafety Guidelines: OECD, FAO, WHO, CAC

Unit 6 Biosafety levels No. of Hours: 8

- Levels of Physical containment

- Levels of Biological containment

- Biosafety of GMOs and GEMs

- Planned introduction and field trials of: GMOs and GEMs

Unit 7 Introduction and Protection of Intellectual Property Right No. of Hours: 8

- Introduction, history of Intellectual Property Rights

- Trade secrets

- Copyrights, Trademarks
- Plant variety protection (PVP)
- World Intellectual Property Organization (WIPO)
- GATT & TRIPs
- Patent status – International Scenario
- Patenting of Biological materials
- Significance of Patents in India

Unit 8 Protection of Biotechnological Inventions

No. of Hours: 5

- Patenting of genes and DNA sequences
- Gene patents and Genetic resources
- Farmers rights
- Plant breeder's rights
- Patenting of life forms

BCH-III.E3 BIOETHICS AND BIO-SAFETY (PRACTICAL)

COURSE TITLE: BIOETHICS AND BIO-SAFETY (PRACTICAL)

COURSE CODE: BCH-III.E3

MARKS: 25

CREDITS: 1

TOTAL HOURS: 30

General safety measures and study of safety notices	2P
Study of symbols and warnings on reagent bottles	1P
Study of preventive measures and first aid during laboratory hazards	1P
Demonstration of handling of fire extinguisher	1P
Practice of GLP	1P
Case study on handling and disposal of radioactive waste	2P
Case study on handling and disposal of medical/microbial waste	2P
Study of components and design of a Biosafety laboratory	2P
Study of steps of a patenting process	3P

REFERENCES:

- Das, H.K. (2008). Text book of Biotechnology, 3rd edition. 3rd Edition, Wiley India (P) Ltd, New Delhi.

- Dubey, R.C. (1993). A Textbook of Biotechnology, 1st Edition, S. Chand and Company (P), Ltd. Delhi. Hill Publishing Company Limited, New Delhi.
- Krishna, V.S. (2007). Bioethics & Biosafety in Biotechnology, New Age Publishers, Bangalore.
- Plummer, D.T. (1988). An Introduction to Practical Biochemistry, 3rd Edition, Tata McGraw
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SEMESTER III

COURSE TITLE: PLANT BIOCHEMISTRY (THEORY)

COURSE CODE: BCH III.E-4

MARKS: 75

CREDITS: 3

COURSE OBJECTIVES: The course will give a detailed description of the structural organization of plant cells, overview of photosynthesis and its significance, secondary metabolites and their potentials and the role of plant hormones.

LEARNING OUTCOMES: Students will be able to understand the biochemical processes that take place in plant such as photosynthetic reactions, importance of plant hormones and secondary metabolites to plant growth and development.

BCH III.E-4 PLANT BIOCHEMISTRY (THEORY)

TOTAL HOURS: 45

Unit 1 Introduction to Plant cell structure

No. of Hours: 4

Structural and functional organization of a plant cell

Unit 2 Photosynthesis and Carbon assimilation

No. of Hours: 10

Structure of organelle involved in photosynthesis, Structure of PSI and PSII complexes, proton gradient and electron transfer in plants and purple bacteria, Light reaction (Cyclic and non cyclic photophosphorylation), Calvin cycle and regulation; C4 cycle and Crassulacean acid metabolism (CAM), Photorespiration

Unit 4 Nitrogen metabolism**No. of Hours: 8**

Biological Nitrogen fixation by free living and in symbiotic association, structure and function of nitrogenase enzyme.

Nitrate assimilation: Nitrate and Nitrite reductase

Primary and secondary ammonia assimilation in plants; ammonia assimilation by glutamine synthetase-glutamine oxoglutarate amino transferase (GS-GOGAT) pathway.

Unit 5 Regulation of plant growth**No. of Hours: 6**

Plant growth hormones and their effect on plant growth and development

Unit 6 Secondary metabolites**No. of Hours: 10**

Representatives alkaloid group and their amino acid precursors, function of alkaloids.

Examples of major phenolic groups; simple phenylpropanoids, coumarins, benzoic acid derivatives, flavonoids, tannins and lignin, biological role of plant phenolics

Classification of terpenoids and representative examples from each class, biological functions of terpenoids

Unit 6 Plant tissue culture**No. of Hours: 7**

Cell and tissue culture techniques, types of cultures: organ and explants culture, callus culture, cell suspension culture and protoplast culture.

Plant regeneration pathways: organogenesis and somatic embryogenesis.

Applications of cell and tissue culture and somoclonal variation.

BCH III.E-4 PLANT BIOCHEMISTRY (PRACTICAL)**COURSE TITLE: PLANT BIOCHEMISTRY (PRACTICAL)****COURSE CODE: BCH III.E-4****MARKS: 25****CREDITS: 1****TOTAL HOURS: 30**

Induction and assay of hydrolases: proteinase /amylase/lipase during germination	3P
Extraction and assay of urease	2P
Estimation of β -carotene and ascorbic acid in fruits and vegetables	3P
Estimation of phenols and tannins in fruits and vegetables	2P
Extraction and separation of photosynthetic pigments by TLC	2P
Tissue culture of plant (explants)	3P

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SEMESTER IV

COURSE TITLE: METABOLISM OF BIOMOLECULES (THEORY)

COURSE CODE: BCH-IV. C-6

MARKS: 75

CREDITS: 3

COURSE OBJECTIVE: The aim of this paper is to understand simple concepts related to metabolism, its importance in the proper functioning of each cell and its regulation by enzymes.

LEARNING OUTCOME: Students will understand the metabolism of biomolecules of life, their contribution to body requirements of calories and energy, and comprehend how any defect in a pathway could lead to diseases.

BCH-IV.C-6 METABOLISM OF BIOMOLECULES

TOTAL HOURS: 45

Unit 1 Basic concepts and design of metabolism

No. of Hours: 4

Metabolism: catabolism and anabolism, ATP as energy currency, energy relationship between catabolic and anabolic pathways, ATP cycle

Unit 2 Carbohydrate metabolism

No. of Hours: 10

Glycolysis, Tri-Carboxylic Acid cycle, Pentose-phosphate pathway, Gluconeogenesis, glycogen synthesis and breakdown, glyoxylate pathway

Unit 3 Oxidative phosphorylation

No. of Hours: 8

The respiratory chain in mitochondria, proton gradient powering ATP synthesis

Transfer of cytosolic reducing equivalents to mitochondria: glycerol-3- phosphate and malate-aspartate shuttle

Unit 4 Fatty acid synthesis and degradation

No. of Hours: 10

Digestion, mobilisation and transport of cholesterol and triacyl glycerols

β -oxidation of fatty acids, ketone bodies

Biosynthesis of saturated and unsaturated fatty acids, and elongation of fatty acids

Unit 5 Amino acid metabolism

No. of Hours: 6

Overview of biosynthesis and catabolism of amino acids; regulation of amino acid biosynthesis, Urea cycle

Unit 6 Nucleotide metabolism

No. of Hours: 7

Biosynthesis - *de novo* and salvage pathways, degradation

BCH- IV. C-6 METABOLISM OF BIOMOLECULES (PRACTICAL)

COURSE TITLE: METABOLISM OF BIOMOLECULES (PRACTICAL)

COURSE CODE: BCH-IV. C-6

MARKS: 25

CREDITS: 1

TOTAL HOURS: 30

Alcohol fermentation by yeast	2P
Estimation of blood glucose	1P
Separation of fatty acids by TLC	2P
Isolation of lecithin and its estimation	3P
Isolation of cholesterol from egg yolk and its estimation	3P
Estimation of protein and nucleic acid by direct spectroscopy	1P
Urea estimation	1P
Uric acid estimation	1P

REFERENCES

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- Jain, J.L (1999). Fundamentals of Biochemistry, S.Chand and Company, Ltd., New Delhi.
- Murray, R.K., Granner, D.K., Mayes, P.A. & Rodwell, V.W. (2003), Harper's Illustrated Biochemistry, McGraw-Hill Companies.

- Nelson, D. L. & Cox, M.M. (2000). Lehninger's Principles of Biochemistry (3rd Edition), Worth Publishers, New York, USA.
- Stryer, L. (1995). Biochemistry, W.H. Freeman and Co., New York, USA.
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SEMESTER IV

COURSE TITLE: HUMAN PHYSIOLOGY (THEORY)

COURSE CODE: BCH-IV.E-5

MARKS: 75

CREDITS: 3

COURSE OBJECTIVES: This course is designed to provide students with an understanding of the function & regulation of the human body and physiological integration of the organ systems to maintain homeostasis.

LEARNING OUTCOMES: Students will develop in-depth insight into the function of the major organs and organ systems of the human body and will understand the unique role of each organ and organ system in maintaining constancy of the internal environment.

BCH-IV.E-5 HUMAN PHYSIOLOGY (THEORY)

TOTAL HOURS: 45

Unit 1 Homeostasis and the organization of body fluid compartments No. of Hours: 8

Intracellular, extracellular and interstitial fluid, Plasma,

Homeostasis

Blood coagulation: molecular mechanism, role of vitamin K.

Anemias, polycythemia, haemophilia and thrombosis

Unit 2 Digestion

No. of Hours: 6

Gastrointestinal tract, secretory functions, digestion, absorption

Liver metabolism: glycogen storage, bile secretion, detoxification

Liver function tests, jaundice, fatty liver, liver cirrhosis.

Unit 3 Muscular System

No. of Hours: 5

Introduction to the muscular system

Types of Muscles, Physiology of muscle contraction

Unit 4 Respiration and Circulation**No. of Hours: 6**

The Respiratory system – organs and their function

The Circulatory system: cardiovascular and lymphatic systems- components and their function

Unit 5 Excretory system**No. of Hours: 6**

The excretory system and associated functions

Anatomy of the kidney and the nephron

Renal function tests

Unit 6 Nervous system**No. of Hours: 6**

The nervous system and associated functions

Membrane potential, Synaptic transmission, Neurotransmitters

Unit 7 Reproductive physiology**No. of Hours: 8**

Spermatogenesis and Oogenesis

Mammalian reproductive physiology – male and female reproductive system

BCH-IV.E-5 HUMAN PHYSIOLOGY (PRACTICAL)**COURSE TITLE: HUMAN PHYSIOLOGY (PRACTICAL)****COURSE CODE: BCH-IV.E-5****MARKS: 25****CREDITS: 1****TOTAL HOURS: 30**

Study of the physiology systems in human using charts	1P
Determination of blood group	1P
RBC and WBC counting	1P
Differential leucocyte count	1P
Determination of Clotting time	1P
Estimation of haemoglobin	1P
Determination of ESR	1P
Determination of PCV	1P
Observation of permanent slides – Transverse section of mammalian gonads	2P
Analysis of human blood pressure and pulse rate in man	1P
Osmolarity of RBC's (Effect of different salt solutions of RBC's)	2P

Determination of glucose in urine	1P
Determination of albumin in urine	1P

REFERENCES

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- Guyton A.C and Hall J.E. (2011). Textbook of Medical Physiology, 10th ed., Reed Elseviers India Pvt. Ltd. New Delhi.

SEMSESTER IV

COURSE TITLE: NUTRITIONAL BIOCHEMISTRY (THEORY)

COURSE CODE: BCH-IV.E-6

MARKS: 75

CREDITS: 3

COURSE OBJECTIVES: The course will give a detailed description of the knowledge and understanding of human nutrition, nutritional aspects of the various classes of food with the nutritional requirements.

LEARNING OUTCOMES: Students will acquire detailed knowledge regarding the biological basis of nutrition and the mechanisms by which diet can influence health, and understand the implications of nutritional status and nutritional disorders.

BCH-IV.E-6 NUTRITIONAL BIOCHEMISTRY (THEORY) TOTAL HOURS: 45

Unit 1 Introduction to Nutrition and Energy Metabolism No. of Hours: 6

Defining Nutrition, role of nutrients, Unit of energy, Biological oxidation of foodstuff, measurement of energy content of food, Physiological energy value of foods

Antioxidants and their role

Recommended Nutrient Intakes (RNI) and Recommended Dietary Allowances (RDA) for different age groups

Basal Metabolic Index (BMI)

Unit 2 Dietary Carbohydrates

No. of Hours: 8

Dietary requirements and source of carbohydrates, Hormonal regulation of blood glucose, hypo- and hyper-glycemic disorders

Fibre and its significance in diet

Unit 3 Dietary Lipid

No. of Hours: 8

Essential Fatty Acids (EFA); Functions and deficiency

Significance of: a) Mono- and Poly-unsaturated fatty acids, b) Saturated fatty acids, c) Omega fatty acids, d) Phospholipids, e) Triglycerides, f) Cholesterol.

Unit 4 Dietary Proteins

No. of Hours: 8

Essential and Nonessential amino acids, Food source, Nitrogen balance

Supplements – risk of imbalance and toxicity of amino acids

Protein deficiency: Protein energy malnutrition (PEM) – Kwashiorkar

Unit 5 Vitamins

No. of Hours: 8

Fat soluble vitamins: physiological role, deficiency disorders, toxicity of Vitamin A.

Water soluble vitamins: physiological role, differential diagnosis of B12 and folate, deficiency disorders

Unit 6 Mineral metabolism

No. of Hours: 7

Physiologic role and deficiency disorders of Macro- and micro-nutrients – calcium, magnesium, sodium, potassium, iron, phosphorus, sulphur and chlorine and trace elements

Assessment of anaemia, glycosylated Hb

BCH-IV.E-6 NUTRITIONAL BIOCHEMISTRY (PRACTICAL)

COURSE TITLE: NUTRITIONAL BIOCHEMISTRY (PRACTICAL)

COURSE CODE: BCH-IV.E-6

MARKS: 25

CREDITS: 1

TOTAL HOURS: 30

Preparation of Probiotics, microscopy and sensory evaluation

2P

Assessment of food constituents

10P

- Vitamin C

- Lycopene from tomatoes
- β -carotene from carrot
- Calcium from milk
- Phosphorus

Assessment of nutritional disorders:

3P

- Hyperglycemia
- Cholesterol
- Anaemia

REFERENCES

- Gibson R. (2005). Principles of Nutritional Assessment. Oxford University Press.
- Frazier W.C & Westhoff D.C. (2015). Food Microbiology. 5th edition. McGraw Hill Education (India) Private Limited: New Delhi
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- Williams M.H, Anderson D.E, Rawson E.S. (2013). Nutrition for health, fitness and sport; McGraw Hill international edition.

SEMESTER IV

COURSE TITLE: HORMONE BIOCHEMISTRY AND FUNCTION (THEORY)

COURSE CODE: BCH-IV.E-7

MARKS: 75

CREDITS: 3

COURSE OBJECTIVES: The course will give a detailed description of the roles of the endocrine system in maintaining homeostasis, integrating growth and development, and the different mechanisms of action of hormones.

LEARNING OUTCOMES: Students will understand the physiological actions of hormones, the relation to human disorders and the consequences of under- and over-production of hormones.

BCH-IV.E-7 HORMONE: BIOCHEMISTRY AND FUNCTION (THEORY)

TOTAL HOURS: 45

Unit 1 Introduction to endocrinology

No. of Hours: 7

Chemical classification of hormones

Functions of hormones and their regulation

Chemical signalling

Unit 2 Hypothalamic and pituitary hormones

No. of Hours: 8

Hypothalamic hormones

Pituitary hormones eg GH, TSH, oxytocin, vasopressin

Feedback regulation cycle

Endocrine disorders – gigantism, dwarfs and diabetes insipidus

Unit 3 Thyroid hormone

No. of Hours: 6

Biosynthesis of thyroid hormone and its regulation; its physiological and biochemical action

Pathophysiology - Goiter, Grave's disease, cretinism

Unit 4 Parathyroid hormones

No. of Hours: 6

Role of PTH, Vitamin D and calcitonin in regulation of Ca^{+} homeostatis.

Pathophysiology - rickets, osteomalacia, osteoporosis

Unit 5 Pancreatic and GI tract hormones

No. of Hours: 6

Regulation of release of insulin, glucagon, gastrin, secretin, CCK

Pathophysiology - diabetes type I and type II.

Unit 6 Adrenal hormones

No. of Hours: 6

Epinephrine and norepinephrine. Fight or flight response, stress response.

Pathophysiology – Addison's disease, Cushing syndrome.

Unit 7 Reproductive hormones

No. of Hours: 6

Male and female sex hormones, Hormones during reproductive cycle, pregnancy, parturition and lactation

BCH-IV.E-7 HORMONE: BIOCHEMISTRY AND FUNCTION (PRACTICAL)

COURSE TITLE: HORMONE: BIOCHEMISTRY AND FUNCTION (PRACTICAL)

COURSE CODE: BCH-IV.E-7

MARKS: 25

CREDITS: 1

TOTAL HOURS: 30

Histology of endocrine structures	2P
Glucose tolerance test	1P
Estimation of serum Ca ²⁺	2P
HCG based pregnancy test	1P
Estimation of serum electrolytes: sodium and potassium	2P
ELISA	2P
Case studies	5P

REFERENCES

- Talwar G.P, Srivastava L.M. and Moudgil K.D. (1989). Textbook of Biochemistry and Human Biology (2nd Edition), Prentice-Hall of India Private Limited, New Delhi, India.
- Nelson D.L. and Cox, M.M. (2013). Lehninger: Principles of Biochemistry, 3rd edition, Worth Publishers, New York, USA.
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- Cooper G.M. and Hausman R.E (2009). The Cell: A Molecular Approach 5th Ed. ASM Press & Sunderland, Washington DC.

SEMESTER IV

COURSE TITLE: ADVANCED CELL BIOLOGY (THEORY)

COURSE CODE: BCH-IV.E-8

MARKS: 75

CREDITS: 3

COURSE OBJECTIVES: The course will give a detailed description of the how eukaryotic cells receive, transmit and respond to environmental signals, cellular regulation of cell cycle progression and cell death. The principal and working of the essential tools used in cell biology will also be covered.

LEARNING OUTCOMES: Students will develop insight into the complexities of cell structure and function, the molecular controls that govern the cells' dynamic properties, and cellular interactions with the organism as a whole.

BCH-IV.E-8 ADVANCED CELL BIOLOGY (THEORY) TOTAL HOURS: 45

Unit 1 Membrane transport No. of Hours: 12

Composition and properties of cell membrane; structure of nuclear envelope; nuclear pore complex

Transport across nuclear envelope

- Simple diffusion and facilitated diffusion
- Passive transport - glucose transporter, anion transporter
- Primary active transporters - P type ATPases, V type ATPases, F type ATPases
- Secondary active transporters – Na⁺ glucose symporter
- Ion channels: voltage-gated ion channels (Na⁺/K⁺ voltage-gated channel)

Unit 2 Membrane potentials and nerve impulses No. of Hours: 4

Resting potential

Action potential

Propagation of action potentials

Neurotransmission

Unit 3 Cell Cycle and Programmed Cell Death No. of Hours: 12

Cell cycle; events of mitosis; cytokinesis;

Events of meiosis; regulation of cell division;

Apoptosis (extrinsic and intrinsic pathway)

Unit 4 Cancer Biology No. of Hours: 8

Development and causes of cancer; genetic basis; oncogenes, tumor viruses

Unit 5 Tools in Cell Biology No. of Hours: 9

Microscopy: Light microscope, Phase contrast microscope, Inverted microscope, Fluorescence microscope, Confocal microscope, Electron microscope

Centrifugation: Differential and gradient centrifugation for sub-cellular fractionation

BCH-IV.E-8 ADVANCED CELL BIOLOGY (PRACTICAL)

COURSE TITLE: ADVANCED CELL BIOLOGY (PRACTICAL)

COURSE CODE: BCH-IV.E-8

MARKS: 25

CREDITS: 1

TOTAL HOURS: 30

Identification of different stages of mitosis (in onion root tip) `	1P
Identification of different stages of meiosis (in flower buds)	1P
Study of cell viability by neutral red (viable cells) and trypan blue (non-viable cells)	1P
Identification and study of cancerous cells using permanent slides/ photomicrographs	2P
Study of plant, animal and human tumour viruses using photomicrographs	2P
Differential centrifugation for separation of cellular components	1P
Preparation of sucrose density gradient and purification of sub cellular organelles:	5P
visualization of nuclear fraction by acetocarmine stain and mitochondria by Janus green stain	
Study of electron micrographs of sub-cellular organelles	2P

REFERENCES

- Krebs, J.E., Goldstein, E.S. & Kilpatrick, S.T. (2014). Lewin's Genes XI, Jones and Bartlett India Pvt. Ltd.
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