Learning Outcomes based Curriculum Framework

(LOCF)

for

Biochemistry (Honours)

Undergraduate Programme

2019

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

Foreword

UGC has been taking several initiatives for quality improvement in higher education system in the country. Curriculum revision is one of the focus areas of these initiatives. Curriculum development is defined as planned, a purposeful, progressive, and systematic process to create positive improvements in the higher educational system. The ever evolving and fast changing educational technology have posed various challenges as far as curriculum in the Higher Educational Institutions (HEIs) is concerned. The curriculum requires to be updated more often keeping in view the latest developments in the society and to address the society's needs from time to time.

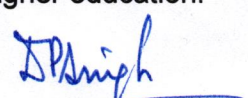
The Quality Mandate notified by UGC was discussed in the Conference of Vice-Chancellors and Directors of HEIs during 26-28th July, 2018; wherein it was inter-alia resolved to revise the curriculum based on Learning Outcome Curriculum Framework (LOCF).

Learning Outcome Curriculum Framework (LOCF) aims to equip students with knowledge, skills, values, attitudes, leadership readiness/qualities and lifelong learning. The fundamental premise of LOCF is to specify what graduates completing a particular programme of study are expected to know, understand and be able to do at the end of their programme of study. Besides this, students will attain various 21st century skills like critical thinking, problem solving, analytic reasoning, cognitive skills, self directed learning etc.. A note on LOCF for undergraduate education is available on the UGC website www.ugc.ac.in. It can serve as guiding documents for all Universities undertaking the task of curriculum revision and adoption of outcome based approach.

To facilitate the process of curriculum based on LOCF approach, UGC had constituted subject specific Expert Committees to develop model curriculum. I feel happy to present the model curriculum to all the HEIs. Universities may revise the curriculum as per their requirement based on this suggestive model within the overall frame work of Choice Based Credit System (CBCS) and LOCF.

I express my gratitude and appreciation for the efforts put in by the Chairperson/Member/Co-opted members/experts of the committees for developing model curriculum. I also take the opportunity to thank Prof. Bhushan Patwardhan, Vice-Chairman, UGC for providing guidance to carry forward this task. My sincere acknowledgement to Prof. Rajnish Jain, Secretary, UGC for all the Administrative support. I also acknowledge the work done by Dr. (Mrs.) Renu Batra, Additional Secretary, UGC for coordinating this important exercise.

All the esteemed Vice-Chancellors are requested to take necessary steps in consultation with the Statutory Authorities of the Universities to revise and implement the curriculum based on the learning outcome based approach to further improve the quality of higher education.



New Delhi
30th July, 2019

(Prof. D. P. Singh)
Chairman
University Grants Commission

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Learning Outcomes based Curriculum Framework
B.Sc. (Hons.) in Biochemistry

Preamble

The UGC Committee constituted for Learning Outcomes based Curriculum Framework for B.Sc.in Biochemistry is pleased to submit its report.

The Committee suggests that the following global remarks may be taken into account by the faculty members, departments/schools, Boards of Studies in Biochemistry, Institutes and Universities, while considering the recommendations for their use:

i. The learning outcomes are designed to help learners understand the objectives of studying B.Sc.(Hons.) Biochemistry that is, to analyse, appreciate, understand the basic concepts of chemical reactions that occur in living systems, which enable them to understand the various perspectives of applied sciences that benefit the mankind.

ii. It is significant to mention here that the B.Sc.(Hons.) Biochemistry syllabus under CBCS remains the point of reference for the LOCF recommendations. However, stakeholders (departments or universities or institutions) may make suitable alterations with justifications while selecting texts, finalizing objectives and organizing principles keeping in view global, national and regional contexts of applications in life sciences.

iii. To this end, the texts mentioned in the LOCF document are indicative. Similarly, the organization of divisions/themes/genres/periods/authors/areas, etc. is specific to contexts identified in the course(s) and does not pre-empt further rethinking or selection with clear justification for the choices exercised therein.

iv. The organization of the courses/papers may be worked into semesters/years keeping in consideration the credit load in a given semester with the ultimate end of outcomes of the course/programme. However, it makes sense to include courses/papers that demand more attention in the second and third years (third to sixth semester as may be required) of the B.Sc.(Hons.) Biochemistry course.

v. Learning outcomes are modifiable with due justification in view of contexts, content selected in the course and requirements of the regional stakeholders, which are as diverse as are regions in the country.

vi. The overarching concern of the LOCF committee in Biochemistry is to have definite and justifiable course outcomes and their realization by the end of the course/programme.

vii. The Department/Institute/University is expected to encourage its faculty concerned to make suitable pedagogical innovations, in addition to teaching/learning processes suggested in the LOCF recommendations, so that the Course/Programme learning outcomes can be achieved.

B.Sc.(Hons) in Biochemistry

(Three years full time programme)

Part I

1.1.Introduction

This Learning Outcomes based Curriculum Framework (LOCF)-Biochemistry for undergraduate education has been prepared in consonance with the generic guidelines prepared by UGCthat provides the basic template for Universities to follow.

Universities across India can use this as a template and can modify it to suite their specialized expertise, infrastructural facilities, etc. Since individual State has its own State Board to frame syllabus and regulate the teaching of 11 and 12 standard/pre-university/ +2 courses, the students passing out of these classes/courses have different levels of understanding for Chemistry and/or Biology curriculum. Taking all these aspects into consideration the basic template for undergraduate biochemistry curriculum has been developed.

It was severely felt that students from class X and XII standards though studied fundamentals especially the basics of chemistry and mathematics, face great difficulties in understanding the concept of Biochemistry. Therefore some fundamentals are again included in the current template in order to train them to become profitable biochemists in Biotechnology Industries. Through the present curriculum attempt has been made to generate enough interest among students so that they can pursue higher education in Biochemistry to take up the career of teaching, research or to serve the needs of medicine, agriculture related industrial establishments.

The discipline of Biochemistry involves the study of the structure and function of biomolecules and the vital processes that occur in living organisms. It is regarded as Mother of all Biological Sciences disciplines because it unveils the chemical basis of life in all living organisms including plants, animals and microorganisms. Biochemistry has contributed enormously to the growth of modern medical and health science and agriculture. Biochemistry has applications in clinical diagnosis, understanding pathology of diseases, treatment of diseases, designing of drugs and understanding their metabolism and manufacture of various biological products like amino acids, proteins, antibiotics, hormones, enzymes, nutrients, etc. Understanding the biochemical basis of vital processes of plants such as photosynthesis, respiration, hormonal regulation, nutrient assimilation have helped in developing superior varieties of crop plants with better growth attributes and yield. For the

estimation of pesticide residues in soil or food grain one has to rely on biochemical tests. The functions and roles of various nutrients are described only by biochemistry. The composition of food materials including the quality-milk and possible adulterations can be checked by biochemical tests. This discipline has played valuable role in farming, fishery, poultry, sericulture, bee keeping and in environmental remediation.

Keeping in pace with the developmental trends in various subareas of Biochemistry it is expected that the students undertaking Biochemistry (Honours) course at undergraduate level become conversant with the fundamentals of Biochemistry and at the same time at the end of the programme they exhibit certain levels of learning outcomes. Such learning outcomes like understanding of discipline, critical thinking, problem solving, analytical and scientific reasoning, research/industry related skills, etc. will empower the students to develop their future career with a much better and meaningful orientation.

With this background LOCF-Biochemistry undergraduate model curriculum has been developed, which is a template and includes 14 Core Courses comprising of theory papers and corresponding practical papers. The course contents include fundamentals as well as upcoming developments in the discipline of Biochemistry and interfacial sciences.

The LOCF for Biochemistry is prepared on the contours and curricular structure provided by the UGC and may be modified without sacrificing the spirit of CBCS and LOCF.

1.2. Learning Outcomes-based Approach to Curricular Planning

In the learning outcome based approach, extensive deliberation has been made to identify the minimum learning outcome from a student after completing each course. This entire outcome shall be substantiated by the practical components. To achieve this expected outcome the committee felt strongly that the teaching community which handles these LOCF needs an orientation programme. Apart from these, UGC has some kind of regulation to monitor the minimum requirement with respect to laboratory facilities, which need to be worked out. Biochemistry can be better understood with parallel practical components. In this regard the committee strongly felt that there shall be a guideline to maintain the students' teacher ratio for both theory and practical classes.

1.3. Nature and extent of the B.Sc. (Hons.) Programme:

The course is designed as per the UGC regulation for a period of three years where the students have to study 14 Core courses in Biochemistry, 4 advance courses in Biochemistry known as Discipline Specific Elective Courses, 4 Generic Elective Courses to which the students will study in other departments, 2 skill Enhancement Elective Courses and 2 Ability Enhancement Compulsory Courses.Generic Elective Courses will be opted by the students depending on their choice in other departments as per the courses available in other departments of the particular university/institution. In first four semesters the students are provided basics of Biochemistry syllabus,besides the courses which they have to opt in other departments. In V and VI semester hard core biochemistry discipline specific courses are included.

1.4. Aims of Bachelor's degree (Honours) programme in Biochemistry:

The overall aims of Bachelor's degree (Hons) programmein Biochemistry are to:

- Providestudents with learning experiences that helpinstill deep interests in learning biochemistry; develop broad and balanced knowledge and understanding of biomolecules, key biochemical concepts, principles and theories related to biochemistry;and equip students with appropriate tools of analysis and with theoretical, technical and analytical skills to tackle issues and problems in the field of biochemistry.
- expose the students to a wide range of careers that combine biology, plants and medicine.
- provide students with some work experience, for example a summer internship or a research project in a research laboratory to further boost the career prospects.
- develop in students the ability to apply the knowledge and skills they have acquired to the solution of specific theoretical and applied problems in biochemistry,
- providestudents with the knowledge and skill base that would enable them to undertake further studies in biochemistry and related areas or in multidisciplinary areas that involve biochemistry and help develop a range of generic skills that are relevant to wage employment, self-employment and entrepreneurship.

While it is easy to set up a PCR reaction or even make a knock out mouse effectively since these are highly skill-based events, it is difficult to understand metabolism, gene regulation,

basics of Immunology, mechanism of hormone action etc.Industries often look towards Universities to fill that gap. Considering all these, the basic template has been designed for undergraduate programme in Biochemistry. Practicals covering the state of the art experiments imbibing finer skills shall definitely make these students in greater demand in Biotech Industriesor academic research institutions and universities.

1.5.Graduate Attributes

A graduate student shall be able to develop skill and acquire knowledge in fundamentals of Chemistry, Biology and will develop disciplinary theory and practical knowledgein the diversified areas of Biochemistry. The students are given fundamentals in each course and they are encouraged to become unique by allowing them to perform experiments in the areas of their interest. This will enable the students to equip themselves with the basic practical training in different areas of Biochemistry ranging from Metabolism, Nutrition, Plant Biochemistry, Enzymology, Clinical Biochemistry,Molecular Biology to Genetic Engineering, Biotechnology, etc. to take up further specialized Master level courses in these areas or to take up suitable assignments/jobs in Biotech/Biochemical industries. The students shall enjoy the academic freedom which will bring out the best from each student. These attributes are elaborated as under:

Disciplinary Knowledge:

a) Ability to understand fundamental concepts of biology, chemistry and biochemistry.

b) Ability to apply basic principles of chemistry to biological systems and molecular biology.

c) Ability to relate various interrelated physiological and metabolic events.

d) A general awareness of current developments at the forefront in biochemistry and allied subjects.

e) Ability to critically evaluate a problem and resolve to challenge blindly accepted concepts.

f) Zeal and ability to work safely and effectively in a laboratory.

g) Good experimental and quantitative skills encompassing preparation of laboratory reagents, conducting experiments, satisfactory analyses of data and interpretation of results.

h) Awareness of resources, and their conservation.

i) Ability to think laterally and in an integrating manner and develop interdisciplinary approach.

j) Overall knowledge of the avenues for research and higher academic achievements in the field of biochemistry and allied subjects.

Communication Skills:

a) Ability to speak and write clearly in English

b) Ability to listen to and follow scientific viewpoints and engage with them.

Critical Thinking:

a) Ability to substantiate critical readings of scientific texts in order to persuade others.

b) Ability to place scientific statements and themes in contexts and also evaluate them in terms of generic conventions.

Problem Solving:

a) Ability to closely observe the situation, and apply lateral thinking and analytical skills.

Analytical Reasoning:

a) Ability to evaluate the strengths and weaknesses in scholarly texts spotting flaws in their arguments.

b) Ability to use critics and theorists to create a framework and to substantiate one's argument in one's reading of scientific texts.

Research-Related Skills:

a) Ability to problematize; to formulate hypothesis and research questions, and to identify and consult relevant sources to find answers.

b) Ability to plan and write a research paper.

Teamwork and Time Management:

a) Ability to participate constructively in class room discussions.

b) Ability to contribute to group work.

c) Ability to meet a deadline.

Scientific Reasoning:

a) Ability to analyze texts, evaluating ideas and scientific strategies.

b) Ability to formulate logical and convincing arguments.

Reflective Thinking:

Ability to locate oneself and see the influence of location—regional, national, global— on critical thinking.

Self-Directing Learning:

a) Ability to work independently in terms of organizing laboratory, and critically analyzing research literature.

b) Ability to postulate hypothesis, questions and search for answers.

Digital Literacy:

a) Ability to use digital sources, and apply various platforms to convey and explain concepts of biochemistry.

Multicultural Competence:

a) Ability to engage with and understand cultures of various nations and respect and transcend differences.

Moral and Ethical Values:

a) Ability to interrogate one's own ethical values, and to be aware of ethical and environmentalissues.

b) Ability to read values inherited in society and criticism vis a vis, the environment, religion and spirituality, as also structures of power.

Leadership Readiness:

Ability to lead group discussions, to formulate questions related to scientific and social issues.

Life-long Learning:

a) Ability to retain and build on critical thinking skills, and use them to update scientific knowledge and apply them in day to day business.

1.6.Qualification descriptors for a Bachelor's degree in Biochemistry:

In the learning outcome based approach, extensive deliberation has been made to identify the minimum learning outcome from a student after completing each course. This entire outcome shall be substantiated by the practical components. To achieve this expected outcome the committee felt strongly that the teaching community which handles these LOCF needs an orientation programme. Apart from these, UGC has some kind of regulation to monitor the minimum requirement with respect to laboratory facilities, which need to be worked out. Biochemistry can be better understood with parallel practical components. In this regard the committee strongly felt that there shall be a guideline to maintain the students' teacher ratio for both theory and practical classes.

The qualification descriptors for the B.Sc. programme in Biochemistry shall be five learning attributes such as understanding, use, communication, and demonstration of experimental and theoretical knowledge with a clear understanding. The key qualification descriptor for undergraduate Biochemistry shall be clarity of concepts, experimentation, communication as well as critical thinking and ethical awareness. Each undergraduate in Biochemistry should be able to

• demonstrate a coherent and systematic approach to the experimental and theoretical aspects of biochemistry. This would also include the student's ability to understand and engage with critical concepts, theories and dogmas.

• demonstrate the ability to understand the role of scientific developments, particularly, biological sciences in a changing world from the disciplinary perspective as well as in relation to its professional and everyday use.

• communicate ideas, opinions and values—both scientific themes and values of life in all shades and shapes—in order to expand the knowledge of the subject as it moves from the classroom/laboratory to industry and society.

• demonstrate the ability to share the results of academic and disciplinary learning through different forms of communication such as essays, dissertations, reports, findings, notes, seminars etc, on different platforms of communication such as the classroom, the media and the internet.

• recognize the scope of biochemistry in terms of career opportunities, employment and lifelong engagement in teaching, publishing, communication, media, soft skills and other allied fields.

The programme will strengthen the student's competence, help identify, analyze and evaluate keys issues of current science around in the world and think of ways to find logical and viable solutions. Students will have the ability to understand and articulate with clarity and critical thinking one's position in the world as a biochemistry graduate and as an Indian citizen of the world.The qualification descriptors for the B.Sc. (Biochemistry) programme shall thus include understanding of fundamentals, acquiring practical training and application of the subject knowledge in diversified areas of Biochemistry with a clear understanding that this knowledge will equip the students to make them suitable for various Biotech, Pharma, Medicine,Agri-Biotech, Biochemical related laboratories/industries. The key qualification descriptor for Biochemistry shall be acquiring practical training as well as critical knowledge of the Biochemistry subject.

1.7.Programme Learning Outcomes (B.Sc.Hons. in Biochemistry)

The learners who complete three years of full time undergraduate (Honours) programme in Biochemistry would earn a Bachelor's (Honours) degree in Biochemistry. The learning outcomes that a student should be able to demonstrate on completion of a degree level programme may involve academic, personal and behavioral as well as entrepreneurial and social competencies. These outcomes will provide insight to the faculty members teaching the course. This is the most critical part and therefore it is essential that faculty members undergo rigorous orientation programme prior to teaching the course. It is expected that a student completing a particular course must have a level of understanding of the Biochemistry subject and its sub-areas in consonance with the learning outcomes mentioned at the end of that course.The programme learning outcomes relating to B.Sc.(Honours) degree programme in Biochemistry can be summarized as under :

1. **Academic Competence**
   - 1.1 Disciplinary knowledge and understanding of biochemistry, structure and function of biological molecules
   - 1.2 explain biological mechanisms, such as the processes and control of bioenergetics and metabolism, as chemical reactions
   - 1.3 explain the biochemical processes that underlie the relationship between genotype and phenotype

1.4 demonstrate an experiential learning and critical thinking of the structure and function of both prokaryotic and eukaryotic cells (including the molecular basis and role of sub-cellular compartmentalization)

1.5 demonstrate an understanding of the principles, and have practical experience of, a wide range of biochemical techniques (e.g. basic molecular biology, cell biology and microbiology methods, spectrophotometry, the use of standards for quantification, enzyme kinetics; macromolecular purification, chromatography electrophoresis, etc.).

1.6 analyse biochemical data (e.g. in enzyme kinetics, molecular structure analysis and biological databases.

2. Personal and Behavioural Competence

2.1 carry out laboratory-orientated numerical calculations (e.g. inter-conversion of masses, moles, and molarity, preparation of solutions and accurate dilutions), be capable in data visualization and analysis, including the application of data transformations (e.g. logarithmic, exponential)

2.2 basic professional skills pertaining to biochemical analysis,carrying out clinical diagnostic tests

2.3 ability to use skills in specific areas related to biochemistry such as industrial production, technology development, clinical, health, agriculture, community development, etc.

2.4 curiosity and ability to formulate biochemistry related problems and using appropriate concepts and methods to solve them.

2.5 ability to use various e-resources in order to solve challenges related to biochemistry.

2.6 articulation of ideas, scientific writing and authentic reporting, effective presentation skills.

2.7 having conversational competence including communication and effective interaction with others, listening, speaking, and observational skills.

3. Entrepreneurial and social competence

3.1 collaboration, cooperation and realizing the power of groups and community, ability to work in a group, community

3.2 the ability to plan and manage projects in order to achieve objectives

3.3 ability to grasp ideas and to turn ideas into action related to biochemical mechanisms and processes related to industries, industrial production, health, agriculture, etc.

3.4 creativity, innovation and risk-taking ability

3.5 social skills to build great teams

3.6 multilevel commitment to health and well being

1.8. Course Level Learning Outcomes

The programme learning outcomes for B.Sc.(Hons.) Biochemistry programme are attained by learners through the essential learnings acquired on completion of selected courses of study of this programme. The term 'course' is used to mean the individual courses of study that makes up the scheme of study for B.Sc.(Hons.) Biochemistry programme. Course learning outcomes are specific to the learning for a given course of study in the discipline of Biochemistry or interdisciplinary/multi-disciplinary/ allied subject areas. B.Sc(Hons.)Biochemistry programme has been designed in such a way that the core courses, 14 in number,comprise of highly structured courses each with 6 credits (4 credit theory and 2 credit practical). These coursesrepresent closely laid down progression of courses which are to be taken at various semesters/particular phases/stages of learning. Under CBCS, B.Sc. (Hons) Biochemistry programme allows learners much more freedom to take a combination of courses of study from Biochemistry as well as from the allied/other disciplines. These Elective courses comprise of Discipline Specific Electives (4 Courses with 24 credits) and Generic Electives (4 Courses with 24 credits). Discipline Specific Courses are specialized/advanced courses in Biochemistry, whereas Generic Elective Courses shall be derived from the allied/other disciplines such as from Chemistry, Botany, Zoology, Biotechnology, Bioscience, Microbiology, Sugar Technology, Food Technology, Industrial Microbiology, Environmental Biology, etc. depending on the subjects expertise available in the respective College, University or Institutions. Further, 8 credit courses shall be Skill Enhancement Elective Courses (2 courses with 4 credits each) and Ability Enhancement Compulsory Courses (2 courses with 4 credits each).According to the preferences of individual studentsthe elective courses offered by one student may be very different from the elective courses offered by another student of the same programme.

Course-level learning outcomes will be finally aligned to programmelearning outcomes. Course-level learning outcomes are specific to a course of study within a given programme of study. The achievement by students of course-level learning outcomes leads to the attainment

of the programme learning outcomes. At the course level, each course may well have links to some but not all graduate attributes as these are developed through the totality of student learning experiences across the years of their study. A course map would indicate the linkage between course learning outcomes and each programme learning outcome (Table 1a to 1c)).

Some examples of course-level learning outcomes relating to courses within B.Sc. (Honours) degree programmein Biochemistry are indicated in the following sections:

Biochemistry Core Course -1(BCH C-1): Introduction to Biochemistry

Course-level learning outcomes that a student of this course is required to demonstrate are:

- Understanding of Biochemistry as a disciplineand milestone discoveries in life sciences that led to establishment of Biochemistry as separate discipline.
- Fundamental properties of elements, their role in formation of biomolecules and in chemical reactions within living organisms.
- Understanding of the concepts of mole, mole fraction, molarity, etc. and to apply them in preparations of solutions of desired strengths.
- Unique property of water as a universal solvent and its importance in biological system.
- Understanding of fundamentals of physical phenomena associated with Adsorption, Viscosity, Distribution law, Osmotic pressure, etc. and their importance in living organisms.
- Understanding of concepts of acids, bases, indicators, pKa values, etc. Acquiring skill to determine pKa value of amino acids.
- Fundamental laws relating to photochemistry and applications of UV-visible, Fluorescence and IR spectrophotometry in analytical determination and characterization of biomolecules.
- Appreciation of the roles of metals, non-metals, transition metals and coordination compounds in biological systems.
- Apply the principles of radiochemistry to analytical determination of biomolecules and life processes.

Biochemistry Core Course -1 Practical (BCH C-1P): Introduction to Biochemistry

- Understanding Good laboratory practices in a chemistry/biochemistry laboratory.
- Learn safety and precautionary measures for working in a laboratory.
- Develop skill and proficiency in preparation of laboratory reagents.
- Use of handling of glass wares, minor equipment for conducting experiments.
- Develop skills to prepare standard chemical solutions and secondary standards.
- Demonstration of basic oxidation and reduction reactions.

Biochemistry Core Course -2(BCH C-2): Bioorganic Chemistry and Metabolites

- Understand the significance of organic reactions with reference to biological systems.
- Apply the principles of electrochemistry to conductance, voltaic, and electrolytic systems.
- Understanding chemical bonding, strong and weak interactions, hydrogen bondingand to apply these principles in various biomolecules and biological reactions.
- To develop understanding of aliphatic and aromatic compounds, IUPAC nomenclature, reactivity of functional groups and the importance of stereoisomers in biological systems.
- Understanding the formation of polymers and their importance; difference between biodegradable and non-biodegradable polymers and biohazards of polymers.
- Apply concept of stereochemistry in determining conformations of biomolecules.

Biochemistry Core Course -2 Practical (BCH C-2P) :Bioorganic Chemistry and Metabolites

- Analyse common organic reagents and compounds based on their properties.
- Analyse organic compounds from unknown mixture/origin.
- Apply the properties of functional groups of organic compounds to carry out selective organic reactions.
- Verify reactivity of organic functional groups.
- Develop skills to prepare useful organic compounds in the laboratory.

Biochemistry Core Course -3(BCH C-3) :Cell Biology

- Understanding of the structure of cell and various cellular events.
- Understanding of the function of various subcellular organelles.

- Students will learn about cell theory and techniques for fractionation of sub-cellular organelles.
- They will be acquainted to various microscopic techniques to visualize subcellular organelles.
- Students will have an understanding of the composition of cytoskeleton and extracellular matrix.
- Students will acquire knowledge of cell cycle, cell division and cell death mechanisms.

Biochemistry Core Course -3 Practical (BCH C-3P): Cell Biology

- Students will learn the handling of microscope.
- Obtain hands-on training in basic separation techniques in biochemistry
- Gain expertise in the isolation of various cell organelles and staining of cellular biomolecules..

Biochemistry Core Course -4 (BCH C-4): Biochemical Techniques

- Develop competence in handing various chromatographic techniques and apply them in isolating and characterizing different biological molecules.
- Understanding the applications of centrifugation and chromatography in biological investigations.
- Purify proteins by affinity chromatography using epitope tags such as histidine tag, GST tag, Flag tag etc.
- Understanding the principles of Electrophoresis, Spectrophotometry and ELISA and their applications in biological investigations/experiments.

Biochemistry Core Course -4 Practical (BCH C-4P): Biochemical Techniques

- The students will obtain hands-on training in basic separation techniques in biochemistry like electrophoresis, chromatography, etc.
- Gain expertise in the isolation of various biomolecules and organelles.

Biochemistry Core Course -5 (BCH C-5): Biomolecules

- Exposure with the nature of various biomolecules present in living cells.
- Get exposed to key contributions of scientists such as Hans Kreb, G. N. Ramachandran, Melvin Calvin, Louis Pasteur, HarGobind Khorana, Watson and

Crick andVenkyRamakrishnan, etc. in order to create scientific interest amongst students in life processes.

- To understand the properties of carbohydrates, proteins, lipids, cholesterol, DNA, RNA, glycoproteins and glycolipids and their importance in biological systems.
- To understand the process of fermentation and manufacture of Biodiesel.
- To develop skills to determine amino acid and nucleotide sequences of proteins and DNA respectively.

Biochemistry Core Course -5 Practical (BCH C-5P): Biomolecules

- Exposure to basic reactions of biomolecules.
- Determine presence of biomolecules like carbohydrates, proteins, lipids, etc. in known and unknown samples.
- Determine the extent of adulteration in samples containing biomolecules.

Biochemistry Core Course -6 (BCH C-6): Nutrition

- To learn glycemic index, balanced diet, micronutrient deficiencies and the remedies, nutraceuticals and their importance, junk foods and their hazards.
- To understand the need for specialized food for people with special needs - diabetes, pregnancy, inherited genetic disorders.
- To know the use of alternate crops – cereals and pulses and their importance.
- To know about cattle industry and its contribution to greenhouse gases.
- Understanding merits and demerits of vegetarian and non-vegetarian foods.

Biochemistry Core Course -6 Practical (BCH C-6P): Nutrition

- Trainingin the determination of moisture in food.
- To test adulteration in food and determination of minerals, amino acids and sugars in foods.
- To acquire training to determine saponification value and iodine value of oil and different types of fats.

Biochemistry Core Course - 7 (BCH C-7): Metabolism

- To understand the importance of lipids as storage molecules and as structural component of biomembranes.
- Understanding the importance of high energy compounds, electron transport chain, synthesis of ATP under aerobic and anaerobic conditions.
- To acquire knowledge related to the role of TCA cycle in central carbon metabolism, importance of anaplerotic reactions and redox balance.
- Students will be exposed with the fact that perturbations in the carbon metabolism can lead to various disorders such as diabetes and cancer.
- Appreciation of the fact that differences in the properties of metabolic enzymes of the host and pathogens can be exploited for the development of new drugs.
- To gain insights into metabolic engineering for the production of useful biomolecules.

Biochemistry Core Course - 7 Practical (BCH C-7P): Metabolism

- To understand the concepts of preparation of buffers.
- To estimate biomolecules such as glucose , proteins,cholesterol in clinical samples.
- To isolate of lipids from egg.

Biochemistry Core Course - 8 (BCH C-8): Bioenergetics and Membrane Biology

- To learn basic concepts of Bioenergetics, mechanisms of oxidative phosphorylation and photophosphorylation.
- To understand composition and structure of biomembranes, transport mechanisms across biological membranes.
- To learn the concept and mechanism of ATP synthesis.

Biochemistry Core Course - 8 Practical (BCH C-8P): Bioenergetics and Membrane Biology

- To acquire practical training to determine CMC of detergents.
- To estimate photosynthetic pigments in a given plant sample
- To separate photosynthetic pigments using chromatographic tools.
- To develop skills to isolate mitochondria from tissues, membrane proteins from RBC, etc.

Biochemistry Core Course - 9 (BCH C-9): Human Physiology

- Exposure with the mechanism of signal transduction by steroid and polypeptide hormones and the role of second messengers in signal transduction.
- Exposure with the process of gaseous exchange in tissues and lungs, respiratory adaption to high altitude.
- Understanding the difference between hemoglobin and myoglobin.
- To gain awareness on muscular dystrophies, the role of steroids in muscle building and the use of hormones in cattle and poultry industry.
- To gain insight into nitrogen metabolism in aquatic and terrestrial animals and the role of kidney in erythropoiesis.

Biochemistry Core Course - 9 Practical (BCH C-9P): Human Physiology

- Acquire practical training for qualitative and quantitative analysis of biological materials/molecules such as RBC, WBC, hemoglobin, protein, uric acid, creatinine, urea, phosphorus,etc. and their estimation using multiple methods

Biochemistry Core Course - 10 (BCH C- 10): Clinical Biochemistry

- To learn about the normal constituents of urine, blood and their significance in maintaining good health.
- Exposure to the mechanisms of causation of diseases of liver and kidney.
- Develop understanding of the current concepts related to mechanism of Cancer.
- To become aware with the variations in the levels of trigycerides and lipoproteins and their relationship with various diseases.

  To get acquainted with the role of enzymes in diagnosis of various diseases.

Biochemistry Core Course – 10 Practical (BCH C- 10P): Clinical Biochemistry

- To learn qualitative and quantitative analysis of constituents of biological fluids such as urine, blood and their estimation using standard methods.

Biochemistry Core Course - 11 (BCH C- 11): Microbiology

- To become aware with the contributions of Louis Pasteur, Edward Jenner and Robert Koch in microbiology and immunology.
- To get acquainted with the discovery of antibiotics and their targets, drug/antibiotic resistance, preventive and therapeutic approaches of infectious diseases, hospital acquired infections.
- Understanding the importance of microorganisms as model systems in genetics and biochemistry.
- To know the contribution of gut microbiome in human health.
- Exposure to the basic concepts of metabolic engineering and synthetic biology.
- To understand the concepts of fight against major killer diseases – tuberculosis, HIV and malaria.

Biochemistry Core Course - 11 Practical (BCH C- 11P): Microbiology

- To isolatemicrobes from providedsamples and to perform bacterial cultures in different media.
- To get trained in performing routine microbiological practices such as sterilization, media preparation, maintenance of microbial culture, stainingetc.
- To acquire expertise to culture and screen microbes for antibioticresistance.

Biochemistry Core Course - 12 (BCH C- 12): Immunology

- Understanding of the overview of immune system including cells, organs and receptors.
- To learn structure and functions of different classes of immunoglobulins, the genetic basis of antibody diversity and the importance of humoral, cell-mediated and innate immune responses in combating pathogens.
- To understand mechanisms involved in different types of hypersensitivity, and the importance of conventional *vs.*recombinant vaccines.
- To get acquainted with the importance of antigen-antibody interaction in disease diagnosis.
- To understand the principles of tolerance, autoimmunity and the role of immunity in protection against pathogens.

Biochemistry Core Course - 12 Practical (BCH C- 12P): Immunology

- Students will develop skills to isolate lymphocytes from blood/spleen and to perform various immunoassays such as Ouchterlony double immunodiffusion (DID), Western Blotting, ELSA, DOT ELISA for diagnosis of various diseases.
- To learn techniques to purify immunoglobulins and to learn the principles of blood typing.

Biochemistry Core Course - 13 (BCH C- 13): Enzymology

- To acquire fundamental knowledge on enzymes and their importance in biological reactions.
- To understand ability to difference between a chemical catalyst and biocatalyst.
- Exposure to the concept of activation energy and its importance in biological reactions.
- Exposure to the nature of non-protein enzymes such as ribozymes.
- Understanding the role of enzymesin clinical diagnosis and industries.

Biochemistry Core Course - 13Practical (BCH C- 13P): Enzymology

- Acquiring training to estimate activity of enzymes.
- To determine pH optimum, Km and Vmax of enzymes and to analyse enzyme kinetics.
- To determine optimum temperature for the activity of an enzyme.

Biochemistry Core Course - 14 (BCH C- 14): Molecular Biology and Genetic Engineering

- Study the discovery of DNA as genetic material, DNA replication, transcription, DNA repair and translation.
- Analyse coding and non-coding regions of eukaryotic genome and their importance.
- Exposure with the importance of *E. coli lac* operon, PCR, expression vectors and their importance in Biotechnology.
- To produce insulin using recombinant DNA technology.
- Acquaintance with the merits and demerits of transgenic crops.
- Exposure to the concepts of genomics, proteomics, metabolomics and their importance in human health.

Biochemistry Core Course – 14 Practical (BCH C- 14P): Molecular Biology and Genetic Engineering

- Acquire learning to isolate RNA, DNA, total nucleic acids and total RNA from bacteria, yeast and plant tissues and to characterize them.

1.9. Teaching learning process

In order to make learning an enjoyable activity, learners should be encouraged to engage in a rigorous process of learning and self-discovery by adopting a highly focused and yet flexible approach to education as opposed to rote learning. Learners should be encouraged to focus on key areas of the course and spend time on learning the course fundamentals and their application. In teaching and learning pedagogy, there should be a shift from domain or conclusions based approach to the experiential or process/es based approach.

The teaching of undergraduate biochemistry for each course, except ability enhancement ability courses, shall include lectures followed by Laboratory exercise for that particular course. Lectures can have good proportion of visuals learning component and ICT enabled delivery. In order to achieve its objective of focused process based learning and holistic development, the Institution/University may use a variety of knowledge delivery methods. Teaching and learning are essential components to accomplish the goal of education in any discipline. Only with effective teaching one can expect desired learning outcome. The quality of a teacher is of utmost importance in rendering effective teaching. For overall understanding of the subject Biochemistry, multiple teaching tools can be used.

1.9.i Lectures

Class room lectures and use of black/green/white boards are the traditional ways of teaching Biochemistry, but still it holds its importance. However there has been a paradigm shift in the teaching process with the development of information and communication technology (ICT). ICT tools involving smart boards, power point presentations, live demonstrations, videos, animations, models, improve the understanding and make the teaching sessions enjoyable.These can be used by the teachers as and when needed. Basic molecular interactions in the living systems at cellular and whole organism level can be better explained using ICT tools.Lectures should be designed to provide the learners with interesting and fresh

perspectives on the subject matter. Lectures should be interactive in a way that students work with their teachers to get new insights in the subject area, on which they can build their own bridges to higher learning.

1.9.ii. Discussions

Discussions are critical components of learning, and can be used as a platform for students to be creative and critical with old and new ideas. To develop critical thinking, reasoning, interactive skills in students the teaching sessions should be made more interactive. Tutorial classes should be frequently organized as it will promote more interaction of the students with teachers.Besides developing critical skills, arriving at consensus on various scientific issues and discussionswill lead to development of innovative problem solving attitude which will ultimately contribute to success.

1.9 iii.Practical:

As biochemistry graduates in their career opt for research, industrial jobs, more attention need to be given for practical training to the students. After completion of experiments in practical class, students should be given related problems. This will enhance the ability of problem based learning (PBL).

1.9.iv.Case Studies:

To express acquired knowledge, skills and attitudes, case based learning (CBL) can be used where students can be given case specific problems both for theory and practical coursesto find creative solutions to complex problems of individual, community, society and various aspects of knowledge domain in the concernedareas of life sciences.

1.9. v. Project work

The students are encouraged to carry out small project work of their choice to quench their curiosity. In order to understand research,student can undertake a small dissertation work where he/she exhaustively performs the literature search and compiles them as a meaningful presentation.

1.9.vi. Team Work

Positive collaboration in the form of team work is critical in the classroom environment, for which it is necessary to transcend one’s prejudices and predilections so as to achieve the desired outcomes. In the process of team work, learners will acquire the skills of managing

knowledge acquisition and other collaborative learners, thereby understanding how to incorporate and balance personalities.

1.9. vi. Study Tours/Field Visits:

Study Tours/field trips provide opportunities to the students to explore further their theory and practical learning to understand the basic and applied aspects of different sub-areas of Biochemistry. These may include visits to Premier Research Institutesand Industrial establishments. A list of such Research/Industrial institutions has been appended at the end of this curriculum.

1.10.ASSESSMENT METHODS:

1.10. i. Alignment of Programme Learning Outcomes and Course Learning Outcomes:

The assessment of learners' achievement in B.Sc.(Hons.) Biochemistry will be aligned with the following:

- programme learning outcomes (graduate descriptors)
- course learning outcomes (qualification descriptors)
- academic and professional skills suggested in the graduate learning descriptors in the LOCF recommendations (indicated and illustrated in the Learning Outcomes in respect of select courses)

1.10.ii.Assessment priorities: Institutions will be required to prioritize formative assessments (in-semester activities including tests done at the department or instructor level) rather than giving heavy and final weightage to summative assessments (end-semester and/or mid-semester tests traditionally done centrally). Progress of learners towards achieving learning outcomes may be assessed making creative use of the following, either independently or in combination: time-constrained examinations (say 1-hour or 2-hour tests); closed-book and open-book tests (if applicable, rather than doing as a rule); problem based assignments; real life simulations; observation of practical skills (speaking, listening, problem solving within a peer group or a class); individual project reports (case-study or term papers within a given word limit); team project reports; oral presentations, including seminar presentation; viva voce, interviews; computerized adaptive testing for MCQ; peer and self-assessment etc. and any other pedagogic approaches as may be relevant keeping in view the learners' level, credit load and class size.

1.10.iii. Diversity in Assessment Methods: Allowing for the diversity in learning and pedagogical methods adopted by different universities and institutions, stakeholders (Academic Councils, Boards of Studies or statutory bodies) are expected to ensure that the objectives of the course(s) are clearly aligned to learning outcomes. It is expected that the curricula developed by institutions will maintain a transparent roadmap of (a) pedagogical methods and priorities and (b) learning outcomes that reflect the weightage points given to different aspects of skills and achievements identified in the recommendations.

1.10.iv. Learning Outcomes Index: While devising assessment modes and criteria, institutions may look to gridlock course learning outcomes and programme learning outcomes as indicated in the LOCF, and work out ways to assign credit loads and distribute weightage points for each. The following tables (Table 1a to 1c) show one possible way to develop a Learning Outcomes index for the Biochemistry Core Courses (Foundation Courses):

1.11. Index for program learning outcome for Biochemistry Core Courses

Table No. 1a) Biochemistry Core courses : Academic competence
Table No. 1b) Biochemistry Core courses : Personal and Behavioral Competence
Table No. 1c) Biochemistry Core courses : Entrepreneurial and Social Competence

Table 1 (a)

Programme outcomes	BIOCHEMISTRY CORE COURSES																	
	Introd. Biochemistry	BiorganicChem Metab	Cell Biology	Biochemical Techniques	Biomolecules	Nutrition	Metabolism	Bioenergetics& Membrane Biology	Human Physiology	Clinical Biochemistry	Microbiology	Immunology	Enzymology	MolBiol& Genetic Engg				
Academic Competence (1.1 to 1.6)																		
1.1 DisciplinaryKnowledge	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
1.2 To explain biochemical mechanisms	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
1.3 Application to biochemical processes	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓				
1.4 Experiential Learning &Critical Thinking	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
1.5 Practical experience of biochemical techniques	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓				
1.6 Analysis of biochemical data	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓				

Programme outcomes	TABLE 1 (b) BIOCHEMISTRY CORE COURSES																	
	Introd. Biochemistry	Bio-organic Chem	Cell Biology	Biochemical Techniques	Biomolecules	Nutrition	Metabolism	Bioenergetics and Membrane Biol.	Human Physiology	Clinical Biochemistry	Microbiology	Immunology	Enzymology	Mol Biology & Genetic Engg.				
2. Personal & Behavioural Competence (2.1 to 2. 6)																		
2.1 Lab oriented calculations	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓				
2.2 Skills to biochemical analysis, tests	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
2.3 Use of skills in specific areas of Biochemistry	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
2.4 Ability to use e-resources	✓	✓	✓	✓	✓			✓	✓		✓		✓	✓				
2.5Articulation, scientific writing, reporting	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
2.6 Conversational competence, communication skills				✓		✓	✓	✓		✓				✓				

Programme outcomes	TABLE 1 (c) BIOCHEMISTRY CORE COURSES																	
	Introd. Biochemistry	Bio-organic Chem	Cell Biology	Biochemical Techniques	Biomolecules	Nutrition	Metabolism	Bioenergetics and Membrane Biol.	Human Physiology	Clinical Biochemistry	Microbiology	Immunology	Enzymology	Mol Biology & Genetic Engg.				
3.Entrepreneurial and social competence (3.1 to 3.5)																		
3.1 Collaboration, Cooperation & Community feel						✓		✓	✓	✓	✓	✓		✓				
3.2 Ability to plan and manage projects	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
3.3 To grasp ideas and to turn ideas into action	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓				
3.4 Creativity, innovation and risk-taking ability			✓	✓	✓	✓			✓	✓	✓	✓	✓	✓				
3.5 Social skills to build great teams				✓		✓		✓	✓	✓	✓	✓		✓				
3.6 Multilevel Commitment to health and wellbeing	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				

1.12.Innovation and Flexibility:

Within each category, institutions are expected to encourage instructors to bring in innovative and flexible methods to guarantee the fullest realization of Learning Outcomes outlined in the document. All such instructional and assessment requirements must be clearly communicated to all stakeholders at the time of course registration. Any subsequent change or minor modification necessary for fuller realization of learning outcomes must be arranged with due notice and institutional arrangement at the relevant level.

1.13.Freedom and Accountability:

Freedom and accountability of the stakeholder are key attributes that determine the success of the Learning Outcomes framework. For example, in research work, learners may be asked to pay attention to library work and survey of literature, originality of ideas, formulation of arguments, and creativity. Components may be assigned weightage points accordingly (say, x:y:z for different components out of 15 points). The excellence of institutions will be increasingly determined by Learning Outcomes rather than programme or course objectives. Hence it is necessary to innovate continually in learning and assessment in order to ensure meaningful and socially relevant learning (with transparent Learning Outcomes indices) rather than rote learning.

1.14.Clustering of Activities:

Each cluster of activity may be assigned weightage points in accordance with the priorities of the institution without diluting the principles given in the LOCF. So an institution may choose to have any or all of the following in its in-semester activities with clear and transparent methods of communication to learners: open viva voce, group quiz or individual, classroom simulations and problem solving activities, library or field visits, term papers, individual and group reports, poster presentations. Credit hour distribution shall be crucial to any such clustering.

1.15.Review and Amendment:

It is important for institutions to review, periodically and without fail, the efficacy of any method adopted to meet the learning outcomes proposed in the LOCF recommendations. Institutions are also required to make statutory provisions to adapt/modify/amend rules and clauses as may be necessary without violating the spirit of the larger programme outcomes outlined by the UGC in the CBCS guidelines.

1.16Spirit Rather than Letter of the LOCF:

The guidelines for assessment given here and elsewhere in the LOCF recommendations are indicative rather than exhaustive. So institutions are expected to frame assessment modes and criteria relevant to their situation and context, in keeping with the spirit of the LOCF. The basic idea of LOCF (Biochemistry Honours)—that learners at this level should understand their position(s) in the light of regional, national and global perspectives—must find a true and transparent reflection in the assessment.

1.17.Key words: Biochemistry, courses, practicals, metabolism, enzymes, genes, carbohydrates, proteins, lipids, DNA, RNA, vitamins, amino acids, physiology, respiration, fermentation, molecular biology, nutrition, microbiology, immunology, synthetic biology, metabolic engineering, genomics, proteomics, recombinant DNA, genetic engineering, history.

Part-II

2.1 Structure of B.Sc. (Honours) Biochemistry curriculum

To meet the objectives of undergraduate program in Biochemistry Core (Foundational) Courses, Elective Courses (Specializations from within Biochemistry andfrom allied disciplines), Skill Enhancement Elective Courses and Ability Enhancement Elective Courses are envisaged. The programme includes a variety of courses with different credits comprising ofCore Courses (CC) and elective courses. Core courses are all mandatory courses, whereas elective courses are of three types: Discipline-Specific Elective (DSE), Generic Elective (GE) and Skill Enhancement Elective (SEE). Besides, the programme also includes two compulsory courses termed as Ability Enhancement Compulsory (AEC) courses.The Core courses (CC) also termed as Foundational Courses are designed to promote common educational edifice for the discipline of Biochemistry. These courses will provide foundational knowledge of Biochemistry and its various sub disciplines to the students. Each Core Course in Biochemistry (BCH C) will be of six credits comprising offour credits theory and two credits practical.

The "Discipline-Specific Elective (DSE)" coursesarespecialized or advanced courses andare intended to cater to various specializations within Biochemistry broader discipline according to CBCS program requirements. These courses offer choices and can be opted from a pool of courses. These courses provide extensive exposure in the area chosen. Each Discipline Specific Elective Course in Biochemistry (BCH DSE) will be of six credits comprising of four credits theory and two credits practical.

Generic Elective (GE) courses designed in the present Biochemistry curriculum will be offered to non-Biochemistry students, i.e. the students of other departments, such as from Botany, Zoology, Microbiology or any other department of the institution. Students will have to opt (elect) one GE course in each of Semesters I, II, III, and IV. The GE courses will be of six credits each (four credits theory and two credits practical). Students pursuing B.Sc.(Hons) Biochemistry programme will opt 4 GE courses, one each in Semesters I, II, III and IV, run by other departments of the institution.As the discipline of Biochemistry is interdisciplinary in nature, students pursuing B.Sc.(Hons) Biochemistry will opt GE from the disciplines allied to Biochemistry, such as from Chemistry, Botany, Zoology, Biotechnology, Bioscience, Microbiology, Sugar Technology, Environment, etc.

Students will have to undertake a total of two Skill Enhancement Elective (SEE) courses, one in Semester III and the other in Semester IV. Each SEE course will be of 2 credits theory and 2 credit

practical course. A pool of such SEE Courses in Biochemistry(BCH SEE) have been suggested. The skill-based courses focus on developing skills or proficiencies in the students and are aimed at providing hands-on training.

Besides, two compulsory Ability Enhancement Courses (AEC)-AEC1 (English Communication) and AEC2 (Environmental Science) have been suggested. These Courses are mandatory for all students. Students will undertake one AEC course in Semester I and the other in Semester II. Each AEC course will be of 4 credits theory only. These courses are aimed to develop language proficiency and environmental consciousness in the students.Since a total of 8 credits (4credit for each course) has been provided to AECs under the CBCS framework, it is advisable that each AEC course be taught in different semesters.

To complete B.Sc.(Hons.) Biochemistry programme, a student has to study fourteen Core Courses (BCH C), four Discipline-Specific Electives (BCH DSE), four Generic Electives, two Skill Enhancement Elective Courses (BCH SEE) and two compulsory Ability Enhancement Elective (BCH AEE) Courses. The Core Courses, Discipline-Specific Electives and Generic Electives are six-credit courses comprising of 4 credit theory and two credit practical, whereas Skill Enhancement Courses and Ability Enhancement Courses are 4 credit courses. A student has to earn 148 credits to obtain B.Sc. (Honours) Biochemistry degree.

The curriculum proposes to have a strong interface between regular and online learning modes, thereby, actively utilizing national knowledge network resources. The faculty would utilize virtual and actual class rooms through video lectures, small group discussions, tutorials and individual presentations. Community engagement may be incorporated through socially driven small scale research projects, workshops, field/laboratory training/experiential exercises and simulations utilizing currently available knowledge systems and technological facilities. Care has been taken to bring in the elements of skill to enhance employment opportunities.

For the structure of B.Sc. (Hons.) Biochemistry, the Committee has followed the number of credits per course as suggested in the CBCS document, that is, four credits per theory paper course and two credits for each Practical paper course. The Committee is of the opinion that eachtheory course of Core course, Discipline Specific Electives and Generic Elective should be of 4 creditstheory and 2 credits practical course. However, School/Board of Studies/University should feel free to decide the number of credits to be assigned to each course. Ultimately, what matters the most is the quantum of academic transaction assigned to each credit, not the number. The Institutions can assign and calculate the credits accordingly.

Lecture (L): One hour of teaching per week in a semester is 1 credit

Practical (P): Two hours of practical per week in a semester is 1 credit

Following pattern of Core, Elective and Skill based courses for Biochemistry are suggested as per CBCS

A. Core Courses or Foundational Courses (BCH C-1 to BCH C-14): 14 courses

14 Core theory paper courses (14 x 4 = 56 credits)

14 Practical paper courses related to respective theory papers (14 x 2 = 28 Credits)

Total Credits: 56+28 = 84 credits

B. Elective Courses: 48 CreditsElectives (Specializations from Biochemistry or other/allied disciplines). These courses shall be derived from the specialized areas of Biochemistry or from the disciplines allied to Biochemistry such as from Chemistry, Botany, Zoology, Biotechnology, Bioscience, Microbiology, Sugar Technology etc. depending on the subject expertise available in the respective College, University or Institutions.

i. Discipline Specific Elective Courses (DSE): 4 Courses

4 Theory paper courses (4 x 4 = 16 credits)

4 Practical paper courses related to respective theory papers (4 x 2 = 8 Credits)

Total Credits: 16+8 = 24 credits

ii. Generic Elective (GE) Courses : 4 Courses

4 Theory paper courses (4 x 4 = 16 credits)

4 Practical paper courses related to respective theory papers (4 x 2 = 8 Credits)

Total Credits: 16+8 = 24 credits

C. Skill Enhancement Courses : Two Courses

These courses shall be considered under "Skill Enhancement Elective (SEE) Courses"

2 Theory paper courses each with 4 Credits each (2 x 4 = 8 Credits)

D. Ability Enhancement Compulsory Courses: Two Courses

2 Theory paper courses each with 4 Credits each (2 x 4 = 8 Credits)

Total Credits for All Courses: 84 + 24 + 24 + 8 + 8 = 148 Credits

2.2. Suggested Core Courses (CC) or Foundational Courses (FC) with Course Level Learning Outcomes (CLLOs)

Table 1
Structure of B.Sc. (Honours) Biochemistry Curriculum

Core Courses

BCH C-1: Introduction to Biochemistry
BCH C-2:Bioorganic Chemistry and Metabolites
BCH C-3: Cell Biology
BCH C-4: BiochemicalTechniques
BCH C-5: Biomolecules
BCH C-6: Nutrition
BCH C-7: Metabolism
BCH C-8: Bioenergetics and Membrane Biology
BCH C-9: Human Physiology
BCH C-10: Clinical Biochemistry
BCH C-11: Microbiology
BCH C-12: Immunology
BCH C-13: Enzymology
BCH C-14: Molecular Biology and Genetic Engineering

Discipline Specific Elective (*Any four*)
BCH DSE-1: Biotechnology
BCH DSE-2: Biology of Infectious Diseases
BCH DSE-3: Plant Biochemistry
BCH DSE-4: Advanced Techniques in Biochemistry
BCH DSE-5: Biochemistry and Function of Hormones
BCH DSE-6: Gene replication, expression and regulation

Generic Elective (*Any four*): For Non- Biochemistry students
BCH GE-1**:** Biomolecules
BCH GE-2: Biochemical Techniques
BCH GE-3: Nutritional Biochemistry
BCH GE-4: Biochemical basis of Diseases
BCH GE-5: Intermediary Metabolism
BCH GE-6: Gene and Recombinant DNA Technology

Skill Enhancement Elective Course (*Any two*)
BCH SEE-1: Bioinformatics
BCH SEE-2: Biostatistics
BCH SEE-3: Research Methodology

Ability Enhancement Compulsory Courses
AEC-1: English Communication
AEC-2: Environmental Science

Table 2:Proposed Semester Wise Distribution of Courses

SEMESTER I		SEMESTER II	
BCH C-1	Introduction to Biochemistry	**BCH C-3**	Cell Biology
BCH C-2	Bioorganic Chemistry and Metabolites	**BCH C-4**	Biochemical Techniques
AEC-1	English Communication	**AEC-2**	Environmental Science
BCH GE-I	Generic Elective (any one) : For non-Biochemistry students	**BCH GE-II**	Generic Elective (any one): For non-Biochemistry students
SEMESTER III		**SEMESTER IV**	
BCH C-5	Biomolecules	**BCH C-8**	Bioenergetics and Membrane Biology
BCH C-6	Nutrition	**BCH C-9**	Human Physiology
BCH C-7	Metabolism	**BCH C-10**	Clinical Biochemistry
BCH SEE-I	Skill Enhancement Elective (*Any one*)	**BCH SEE-II**	Skill Enhancement Elective (*Any one*)
BCH GE-III	Generic Elective (*any one*) For non-Biochemistry students	**BCH GE-IV**	Generic Elective (*any one*) For non-Biochemistry students
SEMESTER V		**SEMESTER VI**	
BCH C-11	Microbiology	**BCH C-13**	Enzymology
BCH C-12	Immunology	**BCH C-14**	Molecular Biology and Genetic Engineering
BCH DSE-I	Discipline Specific Elective (*Any two*)	**BCH DSE-II**	Discipline Specific Elective (*Any two*)

BCH: Biochemistry,**C**: Core Courses; **GE**: Generic Elective; **AEC**: Ability Enhancement Compulsory Courses; **SEE**: Skill Enhancement Elective Courses; **DSE**: Discipline Specific Elective Courses.

Table 3

2.3. SCHEME FOR B.Sc. HONOURS BIOCHEMISTRY COURSES AND THEIR CREDITS

SEMESTER	COURSES OFFERED	COURSE NAME	CREDITS
I	Core Course 1 (BCHC-1)	Introduction to Biochemistry	4
	Core course 1 (BCHC-1) Practical	Introduction to Biochemistry	2
	Core course 2 (BCHC-2)	Bioorganic Chemistry and Metabolites	4
	Core course 2 (BCHC-2) Practical	Bioorganic Chemistry and Metabolites	2
	Ability Enhancement Compulsory Course 1 (AEC-1)	English Communication	4
	Generic Elective -1	BCHGE – 1	4
	Generic Elective -1 Practical	BCHGE – 1 Practical	2

II	Core Course 3(BCHC-3)	Cell Biology	4
	Core course 3(BCHC-3) Practical	Cell Biology	2
	Core course 4 (BCHC-4)	Biochemical Techniques	4
	Core course 4 (BCHC-4) Practical	Biochemical Techniques	2
	Ability Enhancement Compulsory Course 2 (AEC-2)	Environmental Science	4
	Generic Elective – 2	BCHGE-2	4
	Generic Elective – 2 Practical	BCHGE-2 Practical	2
III	Core Course-5 (BCHC-5)	Biomolecules	4
	Core Course-5 (BCHC-5)Practical	Biomolecules	2
	Core course-6 (BCHC-6)	Nutrition	4
	Core course-6 (BCHC-6) Practical	Nutrition	2
	Core course-7(BCHC-7)	Metabolism	4
	Core course-7 (BCHC-7) Practical	Metabolism	2
	Skill Enhancement Elective Course -1 (BCHSEE-1)	Bioinformatics	4
	Generic Elective – 3	BCHGE-3	4
	Generic Elective – 3 Practical	BCHGE-3 Practical	2
IV	Core course-8 (BCHC-8)	Bioenergetics and Membrane Biology	4
	Core course - 8 (BCHC-8) Practical	Bioenergetics and Membrane Biology	2
	Core course - 9 (BCHC-9)	Human Physiology	4
	Core course - 9 (BCHC-9) Practical	Human Physiology	2
	Core Course-10 (BCH C-10)	Clinical Biochemistry	4
	Core course - 10 (BCHC-10) Practical	Clinical Biochemistry	2
	Skill Enhancement Elective Course – 2 (BCH SEE-2)	Biostatistics	4
	Generic Elective - 4	BCHGE- 4	4
	Generic Elective – 4 Practical	BCHGE-4 Practical	2
V	Core Course – 11 (BCH C-11)	Microbiology	4
	Core course 11 (BCH C-11)	Microbiology	2

Human Physiology 2 Human Physiology
SEC-2 2 SEC-2
GE-4 4 GE-4
Bioenergetics and Membrane Biology 4

	Practical		
	Core course-12 (BCH C-12) BCH C-12:	Immunology	4
	Core course 12 (BCH C-12) Practical	Immunology	2
	Discipline Specific Elective-1	BCH DSE-1	4
	Discipline Specific Elective-1 Practical	BCH DSE-1P	2
	Discipline Specific Elective-2	BCH DSE-2	4
	Discipline Specific Elective – 2 Practical	BCH DSE-2P	2
VI	Core Course – 13 (BCHC-13)	Enzymology	4
	Core Course-13 (BCHC-13) Practical	Enzymology	2
	Core Course-14 (BCH C-14) :	Molecular Biology and Genetic Engineering	4
	Core course -14 (BCH C-14) Practical	Molecular Biology and Genetic Engineering	2
	Discipline Specific Elective-3	BCH DSE-3	4
	Discipline Specific Elective-3 Practical	BCH DSE-3P	2
	Discipline Specific Elective-4	BCH DSE-4	4
	Discipline Specific Elective-4 Practical	BCH DSE-4P	2

Total Credits: 148

Sem I: 22, Sem II: 22, Sem III: 28, Sem IV: 28, Sem V:24, Sem VI: 24

2.4. B.Sc. (HONOURS) BIOCHEMISTRY (CBCS STRUCTURE)

CORE COURSES

Semester - I

Core Course-1 (BCH C-1): Introduction to Biochemistry

TheoryCredits: 4, Total Hours: 60

Course level learning outcomes:

Students who complete this course will be able to understand fundamental properties of elements, atoms, acids and bases, metals, non-metals, alloys and composites. They will appreciate the role of metals and radioisotopes in biology and will understand the applications of rare earth metals, transition metals and X-rays.

Course content:

- **Overview of Biochemistry:** Definition, scope and significance of Biochemistry.Important discoveries in Biochemistry. An overview of elements, chemical reactions and biomolecules in living organisms.
- **Concentration units:**Avagadro's number, mole, mole fraction, molarity, equivalent weight, normality, molality, percentage (Problems to be worked out).
- **Properties of water:**Molecular structure of water, physical properties of water. Its effect on biomolecules. Effect of non-polar compounds on water.
- **Colligative properties:** Osmotic pressure and its measurements by Berkely and Hartley's method. Laws of osmotic pressure. Hypo, hyper and isotonic solutions. Effects of osmotic pressure on living cells. Donnan membrane equilibrium.
- **Physical properties of molecules:** (1) Adsorption -Definition, Freundlich and Langmuir's adsorption isotherm. Applications of adsorption.(2) Viscosity-Definition,Determination of viscosity of liquids and solutions by Ostwalds's viscometer (solutions of gum and protein to be taken as example). (3) Distribution law -Distribution law, partition coefficient. Applications of distribution law.
- **Ionic equilibria:** Lewis concept of acids and bases. Ionic product of water. pH scale, buffers, Henderson Hasselbalch equation, buffer capacity, preparation of acidic and basic buffer solutions. Theory of acid base indicators. Choice of indicators. pH titration curves and isoelectric pH of aminoacids. Electrodes (Hydrogen Electrode &Calomel electrode), glass

electrode. Conductometric titrations [Strong acid against strong base, weak acid (amino acid) against NaOH]. Determination of pKa value of amino acid by using pH meter.

- **Photochemistry:**Laws of photochemistry, quantum efficiency, light absorption, Beer-Lambert's law, spectrophotometer, colorimeter, fluorescence, phosphorescence, chemiluminescence, bioluminescence (Elementary treatment). Applications of UV-visible and fluorescence spectra. Principle of IR spectra and its applications.
- **Co-ordination compounds:** Transition metals, properties (Colour, oxidation states, magnetic properties). Co-ordinate bond, double and complex salts – differences with examples. Postulates of Werner's theory. Types of ligands – uni, bi and polydentate with examples. Co-ordination number. Porphyrin nucleus and classification. Important metalloporphyrins occurring in nature-structure and their biological importance (Hb, cytochrome, chlorophyll, Vit-B_{12}). Bile pigments – Types, structure and chemical nature.
- **Nitrogen:**Fixation of atmospheric nitrogen – symbiotic and non-symbiotic. Nitrogen cycle. Environmental pollution by nitrogen compounds.
- **Phosphorous**:Importance of phosphorus compounds in biological system, phosphorous cycle.
- **Oxygen:** Importance of oxygen in biological system. Formation and role of ozone in maintenance of life on earth. Effects of environmental pollutants on ozone layer.
- **Sulphur and selenium:** Importance of compounds of sulphur and selenium in biological system. Effect of sulphur compounds on environmental pollution.
- **Chemical bonding:** Different types of bonds & bond characteristics. Ionic bonding, covalent bonding, co-ordinate bonding, Van der Waal's forces, ion- dipole, dipole –dipole interactions, London forces, hydrophobic interaction, hydrogen bonding. Effect of chemical forces on physical properties (Solubility, BP and MP).
- **Biochemical toxicology:** Source, entry in to biological system and toxicity of lead, mercury, cadmium and arsenic.

Suggested Readings:

- Barrow, G. M. (2007) Physical Chemistry Tata McGraw-Hill, India.
- Castellan, G. W.(2004) Physical Chemistry 4th Ed. Narosa, India.
- Kotz, J. C., Treichel, P. M. & Townsend, J. R. (2009) General Chemistry Cengage Le arning India Pvt. Ltd.: New Delhi.
- Mahan, B. H. (1998)University Chemistry 3rd Ed. Narosa, India.
- J. D. Lee, A new Concise Inorganic Chemistry, ELBS,4th Edition (2018)

- F. A. Cotton & G. Wilkinson. Basic Inorganic Chemistry, John Wiley (1998)
- Douglas, McDaniel and Alexander : Concepts and Models in Inorganic Chemistry, John Wiley, 3rd edition (1994).
- James E. Huheey, Ellen Keiter and Richard Keiter : Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Public, 4th Edition (2013).
- Pattabhi. V. and Gautham.N. (2002) Biophysics. Narosa Publishing House, India.
- Physical Chemistry – Puri, Pathania& Sharma

Core Course-1 Practical (BCH C-1P): Introduction to Biochemistry

Semester – I

Practical **Credits: 2, Total Hours: 60**

Course level learning outcomes:

Learning outcomes of students who complete this course include: understanding good laboratory practices in a chemistry/biochemistry laboratory, safety and precautions, proficiency in preparation of laboratory reagents, use of glassware, experimentation/demonstration of basic oxidation and reduction reactions, primary and secondary standards.

Practical content:

- Use of analytical balance and weighting.
- Calculation, preparation of normal, molar and percentage solutions.
- Calibration of volumetric glassware (Burette, pipette and measuring cylinder).
- Preparation of standard sodium carbonate solution, standardization of HCl (Methyl orange) and estimation of NaOH in the given solution. (Methyl orange or phenolphthalein).
- Preparation of standard oxalic acid. Standardization of NaOH and estimation of H_2SO_4 in the given solution (phenolphthalein).
- Preparation of standard oxalic acid. Standardization of $KMnO_4$ and estimation of H_2O_2 in the given solution.
- Preparation of standard $K_2Cr_2O_7$. Standardization of $Na_2S_2O_3$ and estimation of $CuSO_4$ in the given solution.
- Preparation of $ZnSo_4$. Standardization of EDTA and estimation of total hardness of water using eriochrome black-T indicator.
- Preparation of standard potassium bipthalate. Standardization of NaOH and estimation of HCl in the given solution. (Phenolphthalein).
- Conductometric titration of strong acid against strong base.
- Conductometric titration of weak acid (amino acid) against strong base.
- Determination of rate constant of decomposition of H_2O_2 using $KMnO_4$by volumetric analysis method.
- Demonstration: i) Determination of density and viscosity of the given liquid using specific gravity bottle and Ostwald's viscometer.

ii) Determination of miscibility temperature by water-phenol system.

iii) Safety hazards and disposal of wastes.

iv) Goodlaboratory practices.

Core Course-2 (BCH C-2): Bio-organic Chemistry and Metabolites
Semester – I

Theory Credits: 4, Total Hours: 60

Course level learning outcomes:

On completion of this course, students will understand the significance of organic reactions with reference to biological systems, chemical bonding in various biomolecules, strong and weak interactions. They will gain a good understanding of aliphatic and aromatic compounds, IUPAC nomenclature, reactivity of functional groups and the importance of stereoisomers in biological systems. Students will understand the formation of polymers and their importance; difference between biodegradable and non-biodegradable polymers and biohazards of polymers

Course Content:

- **Introduction to organic chemistry:**Classification of organic compounds, unique characteristics, IUPAC nomenclature of organic compounds (including bi-functional) and biomolecules.
- **Reaction mechanisms:**Concept of inductive effect, resonance and hyperconjugation. Classification of organic reactions (substitution, addition, elimination and rearrangement), with two examples for each. Concepts of the following – carbanions, carbocations, free radicals, carbenes, nucleophiles and electophiles (Formation and Stability).
- **Aliphatic hydrocarbons:** Mechanism of Markownikoff and anti-Markownikoff addition. Addition of HBr to propene. Dienes – types with examples, 1,3 butadiene –Preparation, stability and mechanism of addition of HBr. Diels-Alder reaction. Conformational analysis of ethane.
- **Cycloalkanes:**Reactivity and relative stability. Bayer's strain theory. Sachse-Mohr theory. Boat and chair forms of cyclohexanes. Axial and equatorial bonds and their relation with biological activities of carbohydrates.
- **Arenes:** Structure of benzene – by Resonance and molecular orbital theories. Aromaticity. Mechanism of Nitration and Friedel- craft reaction. Electronic interpretation of the orientating

influence of substituents in the electrophilic substitution of toluene, chlorobenzene, nitrobenzene and phenol. Resonance structures of naphthalene and anthracene.

- **Alkyl halides and organomatellic compounds:** S_N1 and S_N2 reaction, their mechanism with one example for each. Concept of elimination reactions (E1 and E2 with an example). Applications of organometallic compounds – organo lead, organo lithium, cis-platin.
- **Alcohols:** Definition, classification, monohydric alcohols-distinguishing reactions for primary, secondary and tertiary alcohols.Dihydric alcohols: Glycol, preparation (any 2 methods) and uses.Trihydric alcohols: Glycerol, synthesis from propene, properties, (reaction with conc. H_2SO_4, HNO_3, Oxalic acid and HI). Phenols: Acidity of phenols, effect of substituent on acidity.
- **Hydroxy acids and dicarboxylic acids:** Structure & properties ofhydroxy acids: Lactic acid, citric acid and isocitric acid. Dicarboxylic acid: Maleic and fumaric acid. Ketoacids: Pyruvic, α-ketoglutaric, oxalo acetic acids.
- **Amines:** Classification, properties, functional amino group – Basicity of amines, acylation. React with HNO_2& Schiff's base formation. Distinguishing reactions of primary, secondary and tertiary amines.
- **Heterocyclic compounds:** Definition, classification with examples, structure and biological importance of furan, pyrrole, thiophene, pyridine, pyran, thiazole, pyrimidine, purine, indole, imidazole, quinoline and isoquinoline. Basicity of pyrrole and pyridine.
- **Terpenes:** Definition, isoprene rule, classification, isolation, structure and biological importance of menthol, camphor, farnesol, phytol, lanosterol, lycopene and dolichols.
- **Steroids:** Basic ring structure in steroids. Structure and biological importance of cholesterol, phytosterols and ergosterol. Bile acids [Mono, Di & Tri cholic acids].
- **Alkaloids:** Definition, classification based on their structure and biological functions, isolation, structure and biological action of morphine, nicotine & atropine. Chemical synthesis of nicotine and atropine.
- **Vitamins:** Classification- Water soluble & fat soluble. Structural formulae and co-enzyme forms of B_1, B_2, B_6 and niacin. Vitamin C as red-ox reagent, Chemical synthesis of vitamin C. Structural formula of vitamin A, D, E and K.
- **Stereochemistry:** Stereoisomerism, types, Fischer-projection formulae, chiral carbon atom, asymmetry and dissymmetry, chirality, conditions for optical isomerism ex: glyceraldehyde, lactic acid, tartaric acid, Nomenclature of enantiomers, diastereomers. D and L notation, R and

S system, racemisation and resolution (Biochemical, chemical and physical methods). Geometrical isomerism.

Suggested Readings:

- ArunbBahl and B. S. Bahl:*Advanced Organic Chemistry*, S. Chand. (2019)
- L. Finar:*Organic Chemistry* (Vol. I & II), E. L. B. S. (2002)
- R. T. Morrison & R. N. Boyd:*Organic Chemistry*, Prentice Hall. (2011)

Core Course-2 Practical (BCH C-2P): Biorganic Chemistry andMetabolites

Semester - I

Practical

Credits : 2Total Hours : 60

Course level learning outcomes:

Students will analyze the properties of common organic reagents and compounds, carry out selective reactions of organic functional groups and verify reactivity of organic functional groups.

Practical content:

- **Systematic qualitative analysis of the organic compounds:**Urea, benzamide, benzaldehyde, aniline, acetophenone, m-cresol, nitrobenzene, chlorobenzene, naphthalene, *p*-toluidine, benzoic acid, salicylic acid, resorcinol, benzyl alcohol and *p*-dichoro benzene.
- **Organicpreparations:** Aspirin from salicylic acid, benzoic acid from benzaldehyde, *p*-bromo acetanilide from acetanilide and meta-dinitrobezene from nitrobenzene.

Core Course- 3 (BCH C-3): Cell Biology

Semester - II

Theory Credits: 4, Total Hours : 60

Course Level Learning Outcomes:

This course will provide an understanding of the structure of cell and function of various subcellular organelles.Students will learn about cell theory, basic cell structure, cell fractionation and cell visualization techniques. Besides, students will have an understanding of the composition of cytoskeleton and extracellular matrix. Students will acquire knowledge of cell cycle, cell division and cell death mechanisms.

Course Content:

- **Origin of life, Cell theory,** Structure of prokaryotic and eukaryotic cell. Differences in Animal and Plant cell. Mycoplasma, viruses, viroids, prions.
- **Structure and function of subcellular organelles –**Composition ofbiological membranes. Nucleus: Structure of nuclear envelope, nuclear pore complex nucleolus and chromatin. Endoplasmic Reticulum: RER - Brief overview of co-translational and post-translational transport of proteins; SER – Lipid synthesis, brief overview of export of proteins from ER; Golgi apparatus: organization, brief overview of glycosylation of proteins within Golgi, lipid and polysaccharide metabolism in Golgi apparatus.
- **Cell Fractionation techniques**: Centrifugation, Sedimentation Coefficient, Differential and Density Gradient (isopycnic and rate zonal) centrifugation. Cell Visualization techniques: Principle of Light microscope, Phase Contrast microscope, Fluorescence microscope, Confocal microscope and Electron microscope; Staining techniques for microscopy studies. Principles of identification of sub cellular organelles.
- **Lysosomes**: Different forms of lysosomes, role in cellular digestion, lysosomal storage diseases.
- **Peroxisomes:** assembly, functions, glyoxysomes.
- **Mitochondria**: structure, endosymbiont theory, genome.
- **Chloroplast**: structure, endosymbiont theory, genome.
- **Cell Wall**: Structure of prokaryotic and eukaryotic cell wall; ECM components– proteins, polysaccharides and adhesion proteins; concept of anchoring junctions, tight junctions and communication junctions (gap junctions and plasmodesmata).

- **Cytoskeleton.** Microtubules: Axonemal and cytoplasmic microtubules (cilia, flagella, centrioles, basal bodies). Microfilaments: Actin and Myosin Filaments. Role of cytoskeletal elements in the entry of infectious agents

- **Cell Cycle**, Cell Division (mitosis and meiosis); Apoptosis and necrosis; Types and potency of Stem Cells, Cancer – types, salient features of a transformed cell, causes of cancer. Apoptotic death in relation to cell cycle.

Suggested Readings:

1. The Cell: A Molecular Approach (2013) 6th ed., Cooper, G.M. and Hausman, R.E., ASM Press & Sunderland (Washington DC), Sinauer Associates, MA, ISBN:978-0- 87893-300-6.
2. Cell and Molecular Biology: Concepts and Experiments. (2010). Karp, G., 6th ed. John Wiley and Sons. Inc. ISBN: 978-1-118-65322-7
3. Principles and Techniques of Biochemistry and Molecular Biology: - Ed. K.

Wilson and J. Walker, Cambridge University Press.

4. Physical Biochemistry- Application to Biochemistry and Molecular Biology: Friefelder D. WH Freeman and Company.
5. Lehninger: Principles of Biochemistry (2017) 7th ed., Nelson, D.L. and Cox, M.M. W.H. Freeman & Company (New York), ISBN:13: 9781464126116 / ISBN:10-1464126119.
6. Molecular Biology of the Gene (2008) 6th ed., Watson, J.D., Baker, T.A., Bell, S.P., Gann, A., Levine, M. and Losick, R., Cold Spring Harbor Laboratory Press, Cold Spring Harbor (New York), ISBN:0-321-50781 / ISBN: 978-0-321-50781-5.

Core Course- 3 Practical (BCH C-3P): Cell Biology

Semester – II

Practical

Credits: 2 **Total Hours: 60**

Course level learning outcomes:

Students will learn thehandling of microscope. They will gain knowledge about the structure and function of various cell organelles. The students will obtain hands-on training in basic separation techniques in biochemistryand gain expertise in the isolation of various cell organelles and staining of cellular biomolecules.

Course Content:

1. To study different parts of microscope
2. Cytochemical staining of proteins by Methylene blue
3. Cytochemical staining of polysaccharides by PAS
4. Cytochemical staining of RNA by Methyl Green
5. Study of stages of Mitosis using onion root tip
6. Study of stages of Meiosis in onion flower buds/ grasshopper testes
7. To study cell organelles using electron micrographs
8. To study the effect of isotonic, hypotonic and hypertonic solutions on cells

Core Course- 4 (BCH C-4): Biochemical Techniques

Semester - II

Theory Credits: 4, Total Hours: 60

Course Level Learning Outcomes:

Students will be exposed to various chromatographic techniques and their applications in isolation of different biological molecules. In addition to understanding the applications of centrifugation and chromatography in biological investigations, they will gain insight into purification of proteins by affinity chromatography using epitope tags such as histidine tag, GST tag, Flag tag etc.

Course Content:

- **Chromatography:**General Principles of chromatography – adsorption and partition. Techniques: Paper chromatography –Ascending, descending and circular, 2D – chromatography, Rf values, column chromatography, principle of gel filtration, ion-exchange chromatography, affinity chromatography. Thin layer chromatography (TLC) – Principle, procedure and applications.
- **Electrophoresis**, Paper and gel electrophoresis, SDS-PAGE, 2D electrophoresis
- **Centrifugation:** Principle of differential centrifugation. Types of Rotors, Ultra centrifuge – construction and applications insubcellular fractionation.
- **Radiochemistry:** Natural and artificial radioactivity, characteristics of radioactive elements, units of radioactivity, disintegration constant, half-life, α, β and γ radiation. Detection of radioactivity by GM counter. Applications of radioisotopes – ^{3}H, ^{14}C, ^{131}I, ^{60}Co and ^{32}P. Biological effects of radiations. Safety measure in handling radio isotopes.
- **ELISA**
- **Spectrometry–**Beer and Lamberts law, Principals of colorimeter, spectrophotometer. Nephelometry and turbidimetryand its applications

Suggested Readings:

- Biophysical Chemistry, Principles & Techniques – Upadhyay, Upadhyay and Nath – Himalaya Publ. House.
- Principles & Techniques of Practical Biochemistry – Wilson, Walker- Cambridge Univ. Press.
- Chromatography – G. Abbott.

- AUpadhyay, K. Upadhyay and N. Nath Biophysical Chemistry (2000) Himalaya Publishing House.
- Principles and Techniques of Biochemistry and Molecular Biology: - Ed. K. Wilson and J. Walker, Cambridge University Press.

Core Course- 4 Practical (BCH C-4P): Biochemical Techniques

Semester – II

Practical Credits: 2 **Total Hours: 60**

Course level learning outcomes:

The student will obtain hands-on training in basic separation techniques in biochemistryand gain expertise in the isolation of various biomolecules and organelles.

Practical content:

- Identification of amino acids by paper chromatography.
- Ascending paper chromatography of amino acids.
- Separation of plant pigments using paper chromatography.
- Separation of plant pigments by column chromatography using silica gel-G.
- Polyacrylamide gel electrophoresis of proteins.
- SDS-PAGE
- Demonstration of separation of lipids by TLC.
- Demonstration of two dimensional chromatography of amino acids

Core Course- 5 (BCH C-5): Biomolecules

Semester -III

TheoryCredits: 4, Total Hours: 60

Course level learning outcomes:

Students will be exposed to the history of Biochemistry and key contributions of scientists such as Hans Kreb, G. N. Ramachandran, Melvin Calvin, Louis Pasteur, HarGobind Khorana, Watson and Crick andVenkyRamakrishnan.They will study the properties of carbohydrates, proteins, lipids, cholesterol, DNA, RNA, glycoproteins and glycolipids and their importance in biological systems. They will understand the process of fermentation and manufacture of Biodiesel. They will understand the methods of determination of amino acid and nucleotide sequence of proteins and DNA respectively.

Course Content:

- **Carbohydrates:**Definition, empirical formulae, classification, biological importance.
- **Monosaccharides:** Configuration relationship of D-aldoses, D-ketoses. General properties of aldoses and ketoses. Oxidation, reduction, reducing property, formation of glycosides, acylation, methylation, condensation – phenyl hydrazine, addition – HCN. Inter-conversion of aldoses and ketoses by chemical method. Ascending and descending the series by chemical methods. Stereochemistry of monosaccharides, (+) and (-), D and L, epimers, anomers, and diastereoisomers. Structure and biological importance of amino sugars, deoxy sugars, sugar acids, neuraminic and muramic acid.
- **Disaccharides:**Establishment of structures of sucrose and lactose, biological importance and structure of isomaltose, trehalose and maltose.
- **Polysaccharides:** Partial structure, occurrence and importance of starch, glycogen, inulin, cellulose, chitin, and pectin.
- **Glycosaminoglycans:** Occurrence, importance and the structure of the repeating units of heparin, hyaluronic acid, teichoic acid and chondroitin sulphate. Bacterial cell wall polysaccharide, peptidoglycans.
- **Amino acids:**Structure and classification of amino acids based on polarity. Reactions of the amino groups with HNO_2, LiAlH4, ninhydrin, phenyl isothiocyante, dansylchloride, flurodinitrobenzene. Zwitterionic properties. Pka values. Reaction of carboxyl group – Hydrazine. Any method for the chemical synthesis of amino acids D & L notation.

- **Peptides:** Peptide bond, structure and biological importance of glutathione, valinomycin, leu-enkaphelin, synthetic peptides- polyglutamic acid, polylysine. Chemicalsynthesis of di-peptides.
- **Proteins:**Isolation, methods of purification-dialysis salting out, pH precipitation and solventprecipitation. Classification of proteins based on solubility, structure and functions with examples. Primary Structure of proteins, methods of determining N- and C- terminal aminoacids, amino acid composition.Sequencing by Edman's degradation method. Secondary Structure – α Helix. β-sheet, β-bend. Tertiary of myoglobin and quaternary structure of hemoglobin, denaturation and renaturation of proteins. Anfinsen's experiment.
- **Lipids:**Classification and biological role. Fatty acids – Nomenclature of saturated and unsaturated fatty acids. Physiological properties of fatty acids.
- **Acylglycerols:**Mono, di and triglycerols. Saponification, saponification value, iodine value, acid value and significance.
- **Phosphoglycerides:**Structure of lecithin, cephalins, phosphotidylinosital, plasmalogens, and cardiolipin. Biological role of phosphoglycerides.
- **Sphingolipids:** Structure and importance of sphingomyelin.
- **Glycosphingolipids**: Structure and importance of gangliosides and cerebrosides.
- **Eicosanoids:** Structure of PGE_2, and $PGF_{2\alpha}$ importance of prostaglandins. Biological roles of thromboxane, leukotrienes and prostaglandins.
- **Nucleic acids:**Isolation of DNA and RNA. Composition of DNA. Nucleosides and nucleotides. Chargaff's rule. Watson and Crick model of DNA. Melting of DNA (Tm).
- **RNA:**Composition, types (mRNA, tRNAandrRNA), secondary structures of tRNA – clover leaf model. Chemical reactions of RNA and DNA with acid and alkali, colour reactions of DNA and RNA.

Suggested Readings:

- A.L., Lehninger, PRINCIPLES OF BIOCHEMISTRY (1982), Worth Publishers, Inc. New York.
- E.E. Conn and P.K. Stumpf. OUTLINES OF BIOCHEMISTRY (1976) Wiley Eastern, New Delhi.
- BIOCHEMISTRY by L. Stryer (1995) W.H. Freeman Press, San Francisco, USA.
- Biochemistry, by Voet, D. and Voet, J.G. (2004). 3rd Edition, John Wiley & Sons, Inc.USA.

- Biochemistry by U. Sathyanarayana Books and Allied (P) Ltd. Kolkata, ISBN 0-87893- 214-3, (2014).
- Text book of Biochemistry by J.L Jain (2016)
- Medical Biochemistry by Ramakrishnan (2012)
- Text Book of Biochemistry by D.M. Vasudevan (2018)
- Text Book of Biochemistry by A.C. Deb, 9th revised edition (2017)

Core Course- 5 Practical (BCH C-5P): Biomolecules

Semester - III

Practical **Credits: 2,** **Total Hours: 60**

Course level learning outcomes:

The student will gain awareness about basic reactions of biomolecules and their utility in identification of adulterants.

Practical content:

- Qualitative analysis of biomolecules
- Carbohydrates –Molisch, Benedict's / Fehling's, picric acid, Barfoed's, Bial's, Seliwanoff's, osazone tests.
- Glucose, fructose, lactose, maltose and sucrose.
- Proteins – Precipitation reactions of proteins, colour reactions of proteins, colour reactions of amino acids like tryptophan, tyrosine, cysteine, methionine, arginine, proline and histidine.
- Colour reactions of proteins – Biuret, xanthoproteic, Millon's.
- Lipids– solubility, acrolein test, Salkowski test, Lieberman-Burchard test.
- Qualitative tests for nucleic acid.

Core Course- 6 (BCH C-6): Nutrition

Semester - III

Theory **Credits: 4, Total Hours: 60**

Course level learning outcomes:

Students will learn glycemic index, balanced diet, micronutrient deficiencies and the remedies, nutraceuticals and their importance, junk foods and their hazards. They will understand the need for specialized food for people with special needs - diabetes, pregnancy, inherited genetic disorders. The use of alternate crops – cereals and pulses and their importance will be explained. The Cattle industry and their contribution to greenhouse gases, merits and demerits of vegetarian and non-vegetarian foods will be studied.

Course Content:

- **Introduction:** Concept of nutrition, calorific value of foods and its determination (Bomb calorimeter) different components of energy expenditure, respiratory quotient, basal metabolic rate (BMR), determination of BMR, factors affecting BMR. Specific dynamic action of foods. Energy expenditure at rest and work.
- **Carbohydrates:**Dietary Sources, dietary fibers,its importance and protein sparing action.
- **Proteins:**Dietary sources, nutritional classification, nutritional value of proteins – PER, NPU and biological value of proteins (BV). Essential amino acids, nitrogen balance, mutual supplementation of proteins, Malnutrition- Kwashiorkar and Marasmus.
- **Fats:**Dietary sources of fats, invisible fat, essential fatty acids and their biological importance.
- **Vitamins:** Dietary sources, requirements, deficiency symptoms and biological role of water soluble vitamins, thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, biotin, folic acid, vitamin B_{12} and vitamin C. Fat soluble vitamins: Vitamin A, D, E and K.Hypervitaminosis.
- **Minerals:** Ca, P, Fe, Zn, Cu,their distribution in the body, Digestion, Absorption, Utilization , Transport, Excretion, Balance, Deficiency, Toxicity, Sources, RDA. Iodine, Fluoride, Mg, Se, Manganese, Molybdenum, their distribution in the human body, Physiology, Function, deficiency, Toxicity and Sources.
- **Water metabolism:**Distribution of water in body fluids, Regulation of water metabolism.
- **Antinutritional factors:**Sources and harmful effects of antivitamins (egavidin, dicoumarol), natural toxicants (eg. *Lathyrussativa*) and adulterants (eg. butter yellow, lead chromate, malachite green).

- **Digestion,** absorption and transport of carbohydrates proteins and fats, GI tract, secretions, composition and function of – saliva, gastric, bile, pancreatic and intestinal juices. Appetite, gastrointestinal hormones.

Suggested Readings:

- Nutritional Biochemistry – MS Swaminathan (2015)
- Nutrition and Dietetics by Davidson S and Pasmor JR (2001)
- Food science by B. Sreelakshmi (2010)
- Food facts and principles –SakunthalaManay, Sadhakshara Swami. (2008)

Core Course- 6 Practical (BCH C-6P): Nutrition

Semester – III

Practical **Credits: 2,Total Hours: 60**

Course level learning outcomes:

The students will acquire expertise in the determination of moisture in food, adulteration in food and determination of minerals, amino acids and sugars in various foods. They will acquire training to determinesaponification value andiodine value of oilsand fats.

Practical content:

- Determination of
  a. Moisture content of foods
  b. Adulterants in food
  c. Calcium in ragi
  d. Iron in drumsticks.
- Estimation of vitamin-C in lemon and gooseberries.
- Gravimetric estimation of sulphate as barium sulphate.
- Estimation of amino acid by formal titration.
- Estimation of reducing sugars by Hedgedon and Jensen method.
- Determination of saponification value of oil or fat.
- Determination of iodine value of oil or fat.

Core Course- 7 (BCH C-7): Metabolism

Semester - III

TheoryCredits: 4, Total Hours: 60

Course level learning outcomes:

Students will acquire the concept of anabolism, catabolism and role of high energy compounds in the cell. They will acquire knowledge related to regulation of various pathways. The importance of lipids as storage molecules and structural component of biomembranes will be ascertained. The importance of high energy compounds, electron transport chain, synthesis of ATP under aerobic and anaerobic conditions will be understood. The role of TCA cycle in central carbon metabolism, importance of anaplerotic reactions, redox balance will be explained.

The fact that perturbations in the carbon metabolism can lead to various disorders such as diabetes and cancer will be explained. The student will appreciate the fact that differences in the properties of metabolic enzymes of the host and pathogens can be exploited for the development of new drugs. Finally, the student will gain insights into metabolic engineering for the production of useful biomolecules.

Course Content:

- **Types of metabolism:**Anabolism and catabolism, compartmentalization of metabolic pathways.
- **Bioenergetics:**Laws of Thermodynamics - first and second law. Concept of enthalphy, entropy and free energy. Standard free energy. Endergonic and exergonic reactions. Coupled reactions. High energy compounds – structural features of ATP and its free energy change during hydrolysis, other high energy compounds.
- **Biological oxidation:** Ultra structure of mitochondrion, electron transport chain. Electron transport complexes Complex I, II, III and IV. Uncouplers and inhibitors of respiration (Rotenone, antimycin. cyanide and 2,4 DNP). Oxidative phosphorylation, P/O ratio. Formation of ATP-Outline of Mitchell's hypothesis. Substrate level phosphorylation with examples.
- **Metabolism of carbohydrates:** Glycogen metabolism – glycogenolysis, glycogen synthesis. Glycolysis, energetic of glycolysis. Entry of other carbohydrates into glycolytic pathway. Fates of pyruvate – conversion of pyruvate to lactae, alcohol and acetyl Co-A. Citric acid cycle and

it's energetic. Amphibolic integrating roles of TCA cycle. Anaplerotic reactions. Pentose phosphate pathway and its significance. Cori cycle. Gluconeogenesis.

- **Metabolism of lipids:** Oxidation of fatty acids – α, β and ω types, β-oxidation of even number saturated fatty acids. Energetics of β-oxidation. Biosynthesis of even number saturated fatty acids. Ketone bodies formation. Outline of cholesterol biosynthesis.
- **Metabolism of amino acids:**General reaction of amino acid degradation – Transamination, deamination and decarboxylation. Ketogenic and glucogenic amino acids. Urea cycle and its significance.
- **Metabolic engineering and metabolic enzymes as drug targets.** Engineering metabolic pathways for the production of useful biomolecules. Metabolic enzymes of pathogens as drug targets.

Suggested Readings:

- R.K.Murray, D.K. Granner, P.A. Mayes and V.W. Rodwell, HARPER'S BIOCHEMISTRY, 22nd edn. (1990), Prentice-Hall, International, USA.
- P.K. Stumpf, OUTLINES OF BIOCHEMISTRY, 4th edn. (1994), Wiley Eastern, New Delhi, (Chapters7 & 8).
- Nelson and Cox, LEHNINGER's PRINCIPLES OF BIOCHEMISTRY, (2000), KalyaniPublishers,Ludhiana/Worth Publishers, Inc., New York.
- L. Stryer BIOCHEMISTRY 4th Ed. (1995) W.H. Freeman Co., San Francisco, USA
- G.L. Zubay BIOCHEMISTRY 4th Ed. (1998) W.C. Brown Publishers, USA.
- Voet, D and Voet, J.G, (2009) Biochemistry, John Wiley and Sons, N.Y. USA.
- Garret, R.H. and Grisham, C.M. (2005) Biochemistry, 3rd Edition. Thomson Learning INC.

Core Course- 7 Practical (BCH C-7P): Metabolism

Semester III

Practical Credits: 2, Total Hours: 60

Course level learning outcomes:

The learning outcomes include: preparation of buffers, estimation of glucose , proteins in serum samples, isolation of lipids from egg and estimation of serum cholesterol.

Practical Content:

- Preparation of acidic and basic buffers
- Determination of pH using pH meter.
- Determination of pKa value of amino acid using pH meter.
- Estimation of blood glucose by DNS method.
- Protein by Biuret method.
- Assay of salivary amylase.
- Isolation of lipids from egg yolk and separation by TLC.
- Estimation of serum cholesterol

Core Course- 8 (BCH C-8): Bioenergetics and Membrane Biology

Semester IV

Theory **Credits: 4, Total Hours: 60**

Course level learning outcomes:

The students will learn basic concepts of Bioenergetics, mechanisms of oxidative phosphorylation and photophosphorylation. They will understand composition and structure of biomembranes, transport mechanisms across biological membranes and will learn the concept and mechanism ofATP synthesis.

Course Content:

- **Bioenergetics**: Concepts of free energy, state functions, equilibrium constant. Coupled reactions, energy charge, ATP cycle, phosphorylation potential. Standard energy of hydrolysis of ATP, PEP, 1,3 BPG and thioesters. Redox reactions, standard redox potentials and Nernst equation. Universal electron carriers.
- **Biomembranes**: Historical background, membrane models. Membrane functions. Composition of biomembranes: Lipids -Phospholipids, Glycolipids, sterols; Proteins - Peripheral Proteins, Integral Membrane Proteins and Lipid-Anchored proteins, and carbohydrates. Comparison of the composition of various cellular and subcellular membranes. Role of Flippase, Floppase and Scramblase.
- **Model systems to study membranes**: Lipid Monolayers, Planar Bilayer and Liposome, and their application. Polymorphic Lipid-Water Systems. The various determinants of polymorphic phases: CMC, lipid shape, critical packing parameter.
- **Membrane fluidity**: lateral, transverse and rotational motion of lipids and proteins. Factors affecting membrane fluidity- composition, barriers (tight junctions), cytoskeleton interactions, microdomains – rafts, caveolae. Fence and gate model. Techniques to study membrane dynamics: FRAP, TNBS, SPT.
- **Transport across membranes**: Simple diffusion and facilitated diffusion. Passive transport- glucose transporter and anion transporter. Primary active transporters- P type ATPases, V type ATPases, F type ATPases. Secondary active transporters - lactose permease, Na+ - glucose symporter. ABC family of transporters – MDR and CFTR. Bacteriorhodopsin. Ion channels: voltage-gated ion channels (Na+ /K+ voltage-gated

channel) and ligand-gated ion channels (acetyl choline receptor), and aquaporins. Ionophores: valinomycin, gramicidin.

- **Oxidative phosphorylation**: The electron transport chain - its organization and function. Sequence of electron transport, Peter Mitchell's chemiosmotictheory and Proton gradient. F_oF_1 ATP synthase, mechanism of ATP synthesis. Transporters in mitochondria. Regulation of oxidative phosphorylation.
- **Photophosphorylation**, Hill reaction. Photosynthetic pigments and light harvesting complexes in plants. Photosystem I and Photosystem II. Z-scheme of photosynthetic electron flow Photophosphorylation,Cyclic and non-cyclic photophosphorylations and its significance.

Core Course- 8 Practical (BCH C-8P): Bioenergetics and Membrane Biology

Semester IV

Practical **Credits: 2, Total Hours: 60**

Course level learning outcomes:

Students will acquire practical training to determine CMC of detergents, estimation of photosynthetic pigments, their separation using chromatographic tools. Besides, students will develop skills to isolate mitochondria from tissues, membrane proteins from RBC, etc.

Course Content:

- Determination of Critical Micelle Concentration of detergents.
- Study the photosynthetic O_2 evolution using Hydrillaplant.
- Estimation of chlorophyll and carotenoids in leaves.
- Isolation of chloroplast pigments from spinach leaves.
- Separation of chloroplast pigments by paper chromatography and TLC.
- To study Hill reaction by using artificial electronacceptor.
- Separation of RBC membrane proteins bySDS-PAGE.
- Isolation of mitochondria from liver and assay of SDH as marker enzyme.

Suggested Readings:

1. Molecular Cell Biology (2016) 8th ed., Lodish, H., Berk, A., Kaiser, C.A., Krieger, M., Bretscher, A., Ploegh, H., Amon, A. and Scott, M.P., W.H. Freeman & Company (New York).
2. Biochemistry (2016) 6th ed., Garret, R. H. and Grisham, C.M., Cengage Learning (Boston),
3. Principles of Biochemistry (2008) 3rd ed., Voet, D.J., Voet, J.G. and Pratt, C.W., John Wiley & Sons, Inc. (New York), ISBN:13: 978-0470-23396-2
4. Lehninger: Principles of Biochemistry (2017) 7th ed., Nelson, D.L. and Cox, M.M., W.H. Freeman and Company (New York).

Core Course- 9 (BCH C-9): Human Physiology

Semester IV

Theory **Credits: 4, Total Hours: 60**

Course level learning outcomes:

Students will gain insights into the mechanism of signal transduction by steroid and polypeptide hormones and the role of second messengers in signal transduction. The process of gaseous exchange in tissues and lungs, respiratory adaption to high altitude and the difference between hemoglobin and myoglobin will be explained. Students will gain awareness on muscular dystrophies, the role of steroids in muscle building and the use of hormones in cattle and poultry industry. Role of kidneyin erythropoiesis will be explained.

Course Content:

- **Neurotransmission:** Types of neurons, generalized structure of multipolar neuron. Resting membrane potential, Action potential, Transmission of nerve impulse along an axon and across a synapse. Neurotransmitters and inhibitors of neurotransmission.
- **Muscle:**Types of muscles and their structure. Ultra structure of skeletal muscle. Contractile and regulatory proteins of muscle. Sliding filament model of skeletal muscle contraction.
- **Bone:** Composition and structure of long bone, growth and remodelling of long bone. Factors affecting its growth.
- **Excretory system:** Structure of the nephron, formation of urine – Glomerular filtration, tubular reabsorption and secretions.
- **Body fluids:** Blood volume, composition and functions, RBC, WBC and platelets, their structure and functions. Mechanism of blood coagulation. Biochemical events in transport of CO_2 and O_2 in blood. Cerebrospinal fluid, lymph and its function. Blood brain barrier.
- **Heart and lungs –**Structure and function of cardiac tissue and lungs
- **Acid-base balance:**Maintenance of normal pH of the body fluids. Blood buffers. Role of lungs and kidney in acid base balance.
- **Endocrine system:**Endocrine organs, classification of hormones. Hierarchy, interplay and dynamic balance and regulation of hormone secretions. Functions of the hormones of hypothalamus, pituitary, adrenal, thyroid, pancreas and gonads. General mechanism of steroid

hormone action. Mechanism of hormone action. Concept of messengers. Eg: cAMP, DAG, IP3, G-protein.

- **GIT and Liver:** Structure and function of gastrointestinal tract**,** Structure of a lobule, functions – metabolic, storage and detoxification.

Suggested Readings:

- Human Physiology, Vol. I & II, - C. C. Chatterjee – Medical Allied Agency – Calcutta.
- Concise Medical Physiology – Choudhary – New Central Book Agency – Calcutta.
- TextBook of Medical Physiology – Guyton – Prism Books Pvt. Ltd. – Bangalore.
- Harper's Biochemistry – Murray, Granner, Mayes, and Rodwell – Prentice Hall International Inc.
- Textbook of medical physiology: A. C. Gyton, and J. E HallSaunders Elsevier Publications, A division of Reed Elsevier India Pvt .Ltd.New Delhi ISBN 81-8147-084-2
- Human physiology: Chatterjee, Medical Allied Agency.

Core Course- 9 Practical (BCH C-9P): Human Physiology

Semester IV

Practical **Credits: 2, Total Hours: 60**

Course level learning outcomes:

The learning outcomes include: Qualitative and quantitative analysis of biological molecules and their estimation using multiple methods

Practical content

- Preparation of blood smear and differential leucocyte count.
- RBC and WBC counting, Calculation of blood Indices.
- Estimation of hemoglobin
- Colorimetric estimation of Protein by Lowry's method.
- Estimation of Uric acid.
- Urea by DAMO method.
- Creatinine by Jaffe's method.
- Phosphorous by Fiske and Subbarow's method.
- Iron by Wong's method.
- Qualitative analysis of urine - detection of urea, uric acid and creatinine.

Core Course- 10 (BCH C-10): Clinical Biochemistry

Semester IV

Theory **Credits: 4, Total Hours: 60**

Course level learning outcomes:

Students will learn about the normal constituents of urine, blood and their significance in maintaining good health. The mechanisms of causation of diseases of liver, kidney and of Cancer will be explained. Students will become aware with the variations in the levels of trigycerides and lipoproteins and their relationship with various diseases. Students will get acquainted with the role of enzymes in diagnosis of various diseases.

Course Content

- **Urine:** Normal composition of urine – volume, pH, colour, specific gravity. Constituents-urea, uric acid, creatinine, pigment. Abnormal constituents – glucose, albumin, ketone bodies, variations in urea, creatinine, pigments and their clinical significance in brief.
- **Abnormalities in Nitrogen Metabolism –** Uremia, hyperuricemia, porphyria and factors affecting nitrogen balance.
- **Blood:** Normal constituents of blood and their variation in pathological conditions - urea, uric acid, creatinine, glucose, bilirubin, total protein, albumin/globulin ratio. Lipid profile – cholesterol, triglycerides, lipoproteins - HDL and LDL.
- **Blood Clotting –** Disturbances in blood clotting mechanisms – haemorrhagic disorders – haemophilia, von Willebrand's disease, purpura, Rendu-Osler-Werber disease, thrombotic thrombocytopenic purpura, disseminated intravascular coagulation, acquired prothrombin complex disorders, circulating anticoagulants.
- **Diagnostic Enzymes –** Enzymes in health and diseases. Biochemical diagnosis of diseases by enzyme assays – SGOT, SGPT, alkaline phosphatase, CPK, cholinesterase, LDH
- **Disorders of liver and kidney –** Jaundice, fatty liver, normal and abnormal functions of liver and kidney. Inulin and urea clearance.
- **Electrolytes and acid-base balance –** Regulation of electrolyte content of body fluids and maintenance of pH, reabsorption of electrolytes.
- **Biochemistry of Cancer,** Cellular differentiation in cancer, carcinogens and cancer therapy
- **Inborn errors of metabolism:** Sickle cell anaemia, phenyl ketonuria, Neimann – Pick disease and Gaucher's disease.

Suggested Readings:

- Concise Medical Physiology – Choudhary – New Central Book Agency – Calcutta.
- TextBook of Medical Physiology – Guyton – Prism Books Pvt. Ltd. – Bangalore.
- Harper's Biochemistry – Murray, Granner, Mayes, and Rodwell – Prentice Hall International Inc.
- Textbook of medical physiology: A. C. Gyton, and J. E HallSaunders Elsevier Publications, A division of Reed Elsevier India Pvt .Ltd.New Delhi ISBN 81-8147-084-2
- T.M. Delvin (editor), Text book of biochemistry with clinical correlation, (1982), John Wiley & Sons Inc. USA.

Core Course- 10Practical (BCH C-10P): Clinical Biochemistry

Semester IV

Practical Credits: 4, Total Hours : 60

Course level learning outcomes:

The learning outcomes include: Qualitative and quantitative analysis of constituents of biologicalfluids such as urine, blood and their estimation using standard methods.

Course content

- Qualitative and quantitative analysis of urine : proteins, Bence-Jones proteins, Cl^-, Ca^{+2}
- Qualitative analysis of abnormal constituents in urine - glucose, albumin, bile pigments,bile salts and ketone bodies.
- Experiments on blood

  (a) Estimation of haemoglobin by cyanmethemoglobin method

  (b) Determination of A/G ratio in serum
- Isolation and estimation of serum cholesterol
- Serum enzyme assays: alkaline phosphatase, SGOT, SGPT
- Gel Electrophoresis of serum proteins

Core Course- 11 (BCH C-11): Microbiology

Semester V

Theory **Credits: 4, Total Hours: 60**

Course level learning outcomes:

The students will get acquainted with the contributionsof Louis Pasteur, Edward Jenner and Robert Koch in microbiology. Discovery of antibiotics and their targets, drug/antibiotic resistance, preventive and therapeutic approaches of infectious diseases, hospital acquired infections will be studied.The importance of microorganisms as model systems in genetics andbiochemistry will be explained. The contribution of gut microbiome to human health will be discussed. Students will be exposed to basic concepts of metabolic engineering and synthetic biology. The fight against major killer diseases – tuberculosis, HIV and malaria will be discussed.

Course Content:

- **Morphology and structure** of bacteria, gram positive and gram negative organisms. Microscopy (Bright field, Dark field, Phase contrast and Fluorescence microscopy), sterilization, nutritional requirements and growth characteristics of bacteria, media for growing bacteria and fungi.
- **Staining of micro-organisms** – principle and procedure of gram stain and acid fast stain.
- **Microbial nutrition:** Growth of micro-organisms, measurement of growth, factors influencing growth – Nutrition, carbon source, nitrogen source, temperature, pH and oxygen. Batch and continuous culture. Growth curve, phases of growth curve. Synchronous growth.
- **Bacterial toxins –** Classification, structure and mode of action of bacterial protein toxins
- **Industrial microbiology:** Production and importance – Alchoholic beverages (Beer and wine), fermented products of milk cheese, antibiotic production – penicillin, single cell protein – *Spirulina*. Fermentors – types and components.
- **Antibiotics:** Definition, mechanism of action of penicillin streptomycin, and chloramphenicol, antibiotic resistance in brief.
- **Viruses:** Classification based on genetic material with examples.Plant viruses – TMV, morphology, general characteristics and its replication.

- **Bacteriophages:** Morphology, general characteristics, life cycle (lysogeny and lytic cycle) of T-even bacteriophage.

Suggested Readings:

- M. Pelczar, E.C.S. Chan and M.R. Krieg, MICROBIOLOGY, McGraw Hill Inc., Singapore (1997).
- General Microbiology, Vol. I & II – Powar, Daginawala – Himalaya Publishing House. (2015).
- General Microbiology – Stanier, Adelberg, Ingraham – The Macmillan Press – London (1987)

Core Course- 11Practical (BCH C-11P): Microbiology

Semester V

PracticalCredits: 2, Total Hours: 60

Course level learning outcomes:

Students will acquire knowledge to identify differentmicrobes and to perform bacterial cultures in different media. They will get acquainted with routine microbiological practices including sterilization, media preparation, maintenance of microbial culture, stainingetc. They will acquire expertise to culture and screen microbes for antibioticresistance.

Practical content :

- Preparation and sterilization of culture media
- To perform culture transfer techniques: Solid to solid (streaking), liquid to solid (spreading), liquid to liquid, solid to liquid and determineCFU/ml
- To stain bacteria using methyleneblue.
- To perform gram staining
- Isolation of microbes from soil and sewage water.
- To prepare temporary mount of algae(Spirogyra)
- To prepare temporary mount of fungi(Penicillium)
- Study of different shapes of bacteria, fungi, algae, protozoa using permanent slides
- To prepare growth curve of bacteria.

Core Course- 12 (BCH C-12): Immunology

Semester V

Theory Credits: 4, Total Hours: 60

Course level learning outcomes:

Students will gain an overview of the immune system including cells, organs and receptors. They will understand structure and functions of different classes of immunoglobulins, the genetic basis of antibody diversity and the importance of humoral, cell-mediated and innate immune responsesin combating pathogens. They will also understand mechanisms involved in different types of hypersensitivity, and the importance of conventional *vs*recombinant vaccines. They will be acquainted with the importance of antigen-antibody interaction in disease diagnosis. Students will be in a position to explainthe principles of tolerance, autoimmunity and the role of immunity in protection against pathogens.

Course Content

- **Immunity:** Historical Perspective, Cellular and humoral immunity. Role of immunologically important organs and cells, bone marrow, thymus, spleen and lymphocytes. Formation and functions of T and B Lymphocytes. Helper T-cells and killer T-cells. Macrophages. Complement activation by classical, alternate and MB lectin pathway, biological consequences of complement activation, regulation and complementdeficiencies.
- **Antigens:** Definition, epitopes, haptens, carriers, adjuvants, antigenicity.
- **Antibodies:** Definition, types and structure of immunoglobulins (IgG – light chain, heavy chain, hyper variable region, constant domains, Fab and Fc). Effector functions of antibody, antigenic determinants on Ig, Ig super family. Monoclonal antibodies production and applications.
- **Major histocompatibility complex (MHC) genes and products –** Polymorphism of MHC genes, role of MHC antigens in immune responses, MHC antigens in transplantation.
- **Antigen–antibody reaction *in vitro*:** Formation of antigen-antibody complex. Application of immunodiffusion, RIA, ELISA (Basic principles only).
- **Immunization:** Vaccination – vaccines and their preparations, primary and secondary immune response, active and passive immunization, types of vaccines, immunosuppressive therapy.
- **Autoimmunity and hypersensitivity**: Self-tolerance and possible mechanisms of induction of autoimmunity, Organ specific and systemic autoimmune diseases, Types of hypersensitivity.
- **Immunological disorders:** Allergy and AIDS. Structure of HIV, mode of transmission.

Core Course- 12Practical (BCH C-12P): Immunology

Semester V

PracticalCredits: 2, Total Hours : 60

Course level learning outcomes:

Students will develop skills to isolate lymphocytes from blood/spleen and to perform various immunoassays such as Ouchterlony double immunodiffusion (DID), Western Blotting , ELSA, DOT ELISA for diagnosis of various diseases. Students will also learn techniques to purify immunoglobulins and the principles of blood typing.

Course content

1. Isolation of lymphocytes from blood / spleen.
2. Ouchterlony double immunodiffusion (DID)
3. Purification ofimmunoglobulins
4. Demonstration of Western Blotting
5. Assays based on agglutination reactions - Blood typing (active) and passive agglutination.
6. Enzyme linked immunosorbent assay (ELISA) & DOTELISA

Suggested Readings:

- I.M. Riott, J. Brostoff, D. Male “Immunology” 3rd edn. W.H. Freeman and Pub. Company, USA.
- J. Kuby “Immunology” 3rd edn., Mosby Year Book Co., England
- Introduction to Immunology – NandiniShetty (2003)
- Immunology – Janis Kuby – W. H. Freeman and Co. 7th edition (2019)
- Janeway’sImmunobiology 2012 8th ed., Murphy, K., Mowat, A., and Weaver, C.T., Garland Science (London & New York), ISBN:978-0-8153-4243-4

Core Course- 13 (BCH C-13): Enzymology

Semester VI

TheoryCredits: 4, Total Hours: 60

Course level learning outcomes:

This course will provide fundamental knowledge on enzymes and their importance in biological reactions. Students will understand the difference between a chemical catalyst and biocatalyst and understand activation energy. They will study non-protein enzymes such as ribozymes and will be exposed to the Industrial and biomedical applications of enzymes.

Course Content:

- **Enzymes:**Definition, historical perspective, general characteristics, co-factors – coenzymes and metal ions.
- **Classification and units of enzymes**: Based on IUB with examples. Unit of enzyme activity – definition of IU, enzyme turn over number and nature of non-enzymatic and enzymatic catalysis. Specific activity. Enzyme specificity. Concept of active site, ES complex, specificity,
- **Theories of enzyme catalysis**: Lock and key model, Koshland's induced fit theory. Enzyme kinetics: Factors affecting rate of enzyme catalyzed reactions.
- **Characterization**: Effect of enzyme concentration, substrate concentration, pH and temperature. Michaelis – Menten equation,Lineweaver – Burk(L-B) plot. Determination of Vmax& Km from L-B plot and their significance.Enzyme inhibition –competitive, non-competitive and uncompetitive. Graphical representation by L-B plot. Evaluation of Km, Ki and Vmax in presence of inhibitor.
- **Chemical modification** of active site groups. Site directed mutagenesis of enzymes. Mechanism of action of chymotrypsin
- **Allosteric enzymes**:Sigmoidal curve, positive and negative modulators, qualitative description of "concerted" & "sequential" models for allosteric enzymes. Half site reactivity, Flipflop mechanism, positive and negative co-operativity with special reference to aspartate transcarbamylase and phosphofructokinase.
- **Isoenzymes:**Detection, nature, importance. Lactate dehydrogenase as an example. Multi enzyme complex – Pyruvate dehydrogenase complex. – Composition, subunits, assembly, enzymatic reaction functions.RNA as an enzyme. (Ribozymes).Industrial and medical application of enzymes.

- **Applications of Enzymes**: Enzymes as reagents, Marker enzymes in diagnostics, Immobilized enzymes, Industrial applications of enzymes.

Suggested readings:

- Fundamentals of Enzymology (1999) 3rd ed., Nicholas C.P. and Lewis S., Oxford University Press Inc. (New York), ISBN:019 850229X.
- R.K.Murray, D.K. Granner, P.A. Mayes and V.W. Rodwell, HARPER'S BIOCHEMISTRY, 22nd edn. (1990), Prentice-Hall, International, USA.
- P.K. Stumpf, OUTLINES OF BIOCHEMISTRY, 4th edn. (1994), Wiley Eastern, New Delhi, (Chapters7 & 8).
- Nelson and Cox, LEHNINGER's PRINCIPLES OF BIOCHEMISTRY, (2000), KalyaniPublishers,Ludhiana/Worth Publishers, Inc., New York.
- L. Stryer BIOCHEMISTRY 4th Ed. (1995) W.H. Freeman Co., San Francisco, USA
- G.L. Zubay BIOCHEMISTRY 4th Ed. (1998) W.C. Brown Publishers, USA.

Core Course- 13Practical (BCH C-13P): Enzymology

Semester VI

PracticalCredits: 2, Total Hours : 60

Course level learning outcomes:

The learning outcomes include: estimation of enzyme activity, determination of pH optimum, Km and Vmax of enzymes and analysis of enzyme kinetics.

Practical Content:

- Isolation of urease and demonstration of its activity
- Isolation of acid phosphatase and demonstration of its activity
- Determination of specific activity of salivary amylase by DNS
- Purification of urease
- Time course of urease reaction
- Influence of substrate concentration and pH on the rate of enzymatic reaction
- Determination of Km and Vmax of salivary amylase
- Determination of initial velocity [time kinetics] of salivary amylase
- Determination of optimum temperature of salivary amylase

Core Course- 14 (BCH C-14): Molecular Biology and Genetic Engineering

Semester VI

TheoryCredits: 4, Total Hours: 60

Course level learning outcomes:

Students will acquire knowledge related to discovery of DNA as genetic material, DNA replication, transcription, DNA repair and translation. Coding and non-coding regions of eukaryotic genome and their importance will be analyzed. *E. coli lac* operon, PCR, expression vectors and their importance in Biotechnology will be studied.

Production of insulin using recombinant DNA technology, transgenic crops-merits and demerits will be studied. Students will acquire basic knowledge related to processes of transcription and translation in prokaryotes andeukaryotes. They will develop understanding of the molecular basis of RNA processing and RNAsplicing and also the ways in which the biological processes are regulated and the significance of regulation in maintaining different life forms.

Course Content:

Molecular biology

- **Basic concepts of genetic information:**Nucleic acids as genetic information carriers, experimental evidences e.g. bacterial genetic transformation, Hershey Chase experiment. Central dogma of molecular biology and its modification.
- **Replication of DNA:** Semi conservative mechanism. Meselson and Stahl experiment. Mechanism of replication in prokaryotes.
- **Prokaryotic RNA synthesis:** Role of RNA polymerase. Initiation, elongation and termination, reverse transcription.
- **Genetic code:** General features, Wobble hypothesis.
- **Prokaryotic protein biosynthesis:** Activation of Amino acids, amino acyl tRNA synthesis. Initiation, elongation and termination of protein synthesis. Inhibitors of protein biosynthesis. Comparison of protein biosynthesis in prokaryotes with eukaryotes.
- **Post translational processing**: Proteolytic cleavage, covalent modifications, glycosylation of proteins, disulfide bond formation, ER bound ribosome, co- and post-translational protein synthesis, PRE and PRO proteins, Signal hypothesis.

- **Mutations:** Concept of mutation and mutagens – effect of HNO_2, alkylating agents, intercalating agents and UV-radiation. Concept of miss-sense, nonsense, point mutation and frameshift mutation.
- **Concept of gene:** Gene expression in prokaryotes - concept of lac-operon.Functional units in a typical eukaryotic gene-promoter, introns and exons.

Genetic Engineering

- **Historical development:**Aim and scope of genetic engineering. Isolation of DNA, cutting of DNA by restriction endonucleases – staggered cut and blunt end.
- **Outline of techniques of genetic engineering.** Cutting genomic DNA, separation of fragments by agarose gel electrophoresis. Vectors, plasmid PBR^{322}, insertion of foreign DNA into vectors. Transfections of vectors into host cells. cDNA. Principle of polymerase chain reaction and applications.
- **Blotting techniques:** Principle and procedure of Southern, Northern and Western blotting.
- **Applications of genetic engineering:** Transgenic plants, transgenic animals and gene therapy. Human genome project.

Suggested Readings:

- Nelson and Cox, Lehninger's Principles of Biochemistry (2000), Worth Publish., Inc. NewYork.
- L. Stryer. BIOCHEMISTRY, 4th Edn., (1995), W.H. Freeman Press, San Fransisco, USA.
- E.J. Gardner and D.P. Snustad. PRINCIPAL OF GENETICS (1984), John Wiley & Sons, Ney York.
- Watson, J. D., Baker T.A., Bell, S. P., Gann, A., Levine, M., and Losick, R., 2008Molecular Biology of the Gene 6th edition. Cold Spring Harbour Lab. Press,Pearson Pub.
- Molecular Biology – Freifelder

Core Course- 14 Practical (BCH C-14P): Molecular Biology and Genetic Engineering

Semester VI

PracticalCredits: 2, Total Hours: 60

Course level learning outcomes:

Students will learn the to isolate RNA, DNA, total nucleic acids and total RNA from bacteria, yeast and plant tissues.

Practical Content:

- Extraction and estimation of DNA from coconut endosperm.
- Extraction of RNA from spinach leaves and its estimation by OrcinolMethod
- Determination of absorption maxima of nucleic acids
- Extraction of total nucleic acids from planttissues
- Isolation of total RNA frombacteria/yeast

2.5. B.Sc. (HONOURS) BIOCHEMISTRY (CBCS STRUCTURE) DISCIPLINE SPECIFIC ELECTIVE (BCH DSE) COURSES

Discipline Specific Elective Course -1 (BCH DSE-1): Biotechnology

Semester – V

Theory **Credits: 4, Total Hours : 60**

Course level learning outcomes:

The studentswill acquire basic knowledge ofrecombinant DNA technology, DNA manipulation in prokaryotes and eukaryotes, engineering of DNA molecules using restriction and modification enzymes. They will get acquainted with the use of cloning and expressionvectors, creation of genomic and cDNA libraries and their applications. Students will also understand the methods for production of proteins using recombinant DNA technology and their application in industrial systems.

Course content

- **Principles of gene cloning**: Restriction and modification systems, restriction endonucleases and other enzymes used in manipulating DNA molecules. Ligation of DNA molecules, DNA ligase, sticky ends, blunt ends, linkers and adapters, homopolymer tailing, Synthetic oligonucleotides.
- **Plasmids and bacteriophages** as vectors for gene cloning. Cloning vectors based on *E. coli* plasmids, pBR322, pUC8, pGEM3Z. Viruses as vectors, cloning vectors based on M13 and λ bacteriophage.
- **Uptake of DNA by cells**, Selection and identification for transformed cells, Transfection. Chemical and physical methods of DNA introduction into cells. Direct selection, marker rescue. cDNAandGenomiclibraries, Southern and Northern hybridization.
- **Plant genetic engineering**: gene isolation, gene transfer systems, Ti plasmid, plant virus vectors, electroporation, microinjection, microprojectile technology, gene expression, regeneration. Application in relation to protein quality, photosynthetic

efficacy, nitrogen fixation efficiency and resistance to environmental stresses.

- **Protein engineering** (T4-lysozyme), Site–directed mutagenesis, yeast two hybrid systems, Production of recombinant pharmaceuticals such as insulin, human growth hormone, factorVIII. Recombinant vaccines.
- **Tissue culture** – Plant tissue culture, anther and pollen culture, protoplast culture, protoplast fusion, embryo rescue, animal cell lines and organ culture.
- **Transgenic plants and animals**
- **Production of recombinant proteins** by eukaryotic cells. Fusion tags such as, poly-histidine, glutathione, maltose binding proteins and their role in purification of recombinant proteins.
- **Fermentation technology** – Fermentors, general design of fermentor, fermentation processes, production of alcohols, antibiotics, steroids and enzymes.
- **Enzyme Technology** - Large scale production of enzymes, enzyme reactors. Enzyme electrodes, biosensors.

Suggested readings :

1. Principles of Gene Manipulation and Genomics (2006) 7th ed., Primrose, S.B., and Twyman, R. M., Blackwell publishing (Oxford, UK)
2. Gene Cloning and DNA Analysis (2010) 6th ed., Brown, T.A., Wiley-Blackwell publishing (Oxford, UK)
3. Molecular Biotechnology: Principles and Applications of Recombinant DNA (2010) 4th ed., Glick B.R., Pasternak, J.J. and Patten, C.L., ASM Press (Washington DC)
4. Molecular Cloning: A laboratory manual (2014), 4nded., Michael R Green and J. Sambrook Cold spring Harbor laboratory press (3vol.)

Discipline Specific Elective Course -1 Practical (BCH DSE-1P):Biotechnology

Semester – V

PracticalCredits: 2, Total Hours: 60

Course level learning outcomes:

Students will learn the experimental techniques of recombinant DNA technology and their biotechnological applications, such as separation of DNA fragments by Agarose gel electrophoresis, isolation of plasmid DNA from *E. coli,* transformation of *E. coli* cells, digestion of plasmid DNA, amplification of a DNA fragment byPCR, etc.

Practical content

1. Agarose gel electrophoresis for separation of DNA fragments.
2. Isolation of plasmid DNA from *E. coli.*
3. Transformation of *E. coli* cells with plasmidDNA.
4. Digestion of plasmid DNA with restrictionenzymes.
5. Amplification of a DNA fragment byPCR.
6. Complementation of β−galactosidase for Blue and Whiteselection.

Discipline Specific Elective Course -2(BCH DSE-2):Biology of Infectious Diseases

Semester – V

Theory **Credits: 4, Total Hours: 60**

Course level learning outcomes:

Students will get acquainted with various classes of microbial infectious agents, their mode of action, biology of the diseases, transmission of diseases, the concepts of treatment, and drug resistance for various antimicrobial agents. Students will learn molecular basis of diagnosis and treatment of diseases as well as strategies for development of vaccines against these diseases. Students will be exposed to the details of important infectious diseases such as tuberculosis, AIDS, malaria, filariasis, etc. which are highly prevalent in tropical countries. Students will also understand the significance of hygiene, sanitation, vaccination in prevention of infectious diseases.

Course content:

- **Infectious diseases**: Classification, Nosocomial infections; Past and present emerging and re-emerging infectious diseases and pathogens. Source, reservoir and transmission of pathogens. Safety measures when working with pathogens, biosafety levels, infection and evasion.
- **Bacterial diseases:**classification of bacterial pathogens, virulence factors and host-pathogen interaction. Bacterial toxins, enterotoxins and their mode of action, diarrhea, cholera; Tuberculosis, infection and pathogenicity, diagnostics, therapeutics and vaccines, drug resistance. Other bacterial diseases such as - Typhoid, Diphtheria, Pertussis, Tetanus, Botulism Anthrax and Pneumonia; their virulence factors and host pathogen interactions.
- **Viral diseases**: Structure and classification of viruses, viral virulence factors, host pathogen interactions; AIDS: history, causative agent, pathogenesis, diagnostics, drugs; Other viral diseases such as Hepatitis, Influenza, Rabies, Dengue and Polio; Chicken Pox, Herpes Virus.
- **Parasitic diseases**: Classes of parasites and diseases caused by them, Malaria: causative agents, vectors, etiology, diagnostics, drugs, vaccine development.

Leishmaniasis and Amoebiasis, Giardiasis and Trypanosomainfections.

- **Fungal diseases**: Etiology, characteristics and diagnosis of Candidiasis, Sporotrichosis, Aspergillosis and Ring worm.
- **Role of drugs**, vaccines and sanitation in prevention and treatment of infectious diseases.

Suggested readings:

1. Jawetz, Melnick and Adelbergs Medical Microbiology 27th ed., McGraw Hill Education
2. Klien's Microbiology (2008) 7th ed., Prescott, Harley, Wiley, J.M., Sherwood, L.M., Woolverton, C.J. McGraw Hill International Edition (New York)
3. Sherris Medical Microbiology: An introduction to infectious diseases (2010) Kenneth

J. Ryan, C.,George Ray, Publisher: McGraw-Hill.

Discipline Specific Elective Course -2Practical (BCH DSE-2P):

Biology of Infectious Diseases

Semester – V

PracticalCredits: 2, Total Hours: 60

Course level learning outcomes:

Students will acquire the knowledge to isolate bacteria from water/sewage samples, to stain bacteria, fungi, acid fast bacilli and to perform important diagnostic tests for infectious diseases such as WIDAL test. Students will be exposed to permanent slides of pathogens in order to get hands-on training to know nature of various pathogens causing diseases.

Practical content

1. Grams staining for bacteria
2. Isolation and culture of bacteria from water/sewage samples.
3. Demonstration of various media for bacterial culture
4. Isolation and enumeration of bacteriophages (PFU) from water/sewagesamples
5. WIDALtest
6. Acid faststaining
7. Permanent slides of pathogens: *Mycobacterium tuberculosis*, Leishmania, *Plasmodiumfalciparum*
8. Fungalstaining

Suggested readings:

1. Klien's Microbiology (2008) 7th ed., Prescott, Harley, Wiley, J.M., Sherwood, L.M., Woolverton, C.J. McGraw Hill International Edition (New York)
2. Sherris Medical Microbiology: An introduction to infectious diseases (2010) Kenneth J. Ryan, C.,George Ray, Publisher: McGraw-Hill.
3. Jawetz, Melnick&Adelbergs Medical Microbiology 27th ed., McGraw Hill Education

Discipline Specific Elective Course -3 (BCH DSE- 3):

Plant Biochemistry

Semester – VI

Theory **Credits: 4, Total Hours: 60**

Course level learning outcomes:

Learning outcomes for this course include detailed understanding of metabolic processes specific for plants such as nitrate assimilation, photosynthesis, respiration, nitrogen fixation and the role of different metabolic pathways in plant growth and development. Students will also gain insight to various stressful conditions of the environment that affect plant growth and productivity as well as the defense mechanisms in plants due to which plants survive under stresses.

Course content

- **Electron transport system in plants:** oxidative phosphorylation, mitochondrial respiratory complexes, order and organization of electron carriers, electrochemical gradient, chemiosmotic theory, ATP synthase and mechanism of ATP synthesis.
- **Nitrogen metabolism:** assimilation of nitrate,structural features of nitrate reductase and nitrite reductase, incorporation of ammonia into organic compounds, regulation of nitrate assimilation. Biological nitrogen fixation by free living and in symbiotic association; structure and function of the enzyme nitrogenase.
- **Photosynthesis –** Photosynthetic apparatus, pigments of photosynthesis, role of carotenoids, photosystems I and II, their location; Hill reaction, photosynthetic electron transport and generation of NADPH & ATP, cyclic and non-cyclic photophosphorylations, complexes associated with thylakoid membranes; light harvesting complexes, path of carbon in photosynthesis – C_3 and C_4 pathway of carbon reduction and its regulation, Photorespiration.
- **Special features of secondary plant metabolism,** terpenes (classification, biosynthesis), lignin, tannins, pigments, phytochrome, waxes, alkaloids, biosynthesis of nicotine, functions of alkaloids, cell wall components.
- **Toxins of plant origin –** mycotoxins, phytohemagglutinins, lathyrogens, nitriles, protease inhibitors, protein toxins.

- **Stress metabolism in plants –** Environmental stresses, salinity, water stress, heat, chilling, anaerobiosis, pathogenesis, heavy metals, radiations and their impact on plant growth and metabolism, criteria of stress tolerance.
- **Antioxidativedefense system in plants –** reactive oxygen species and their generation, enzymic and non-enzymic components of antioxidativedefense mechanism.

Suggested readings:

- Buchann (2015), Biochemistry and Molecular Biology of Plants, 2nded. Publisher: I KInternational. ISBN-10: 8188237116, ISBN- 978047 0714218
- Taiz and Zeiger, Plant Physiology, 5thedition, Sinauer Associates Inc.ISBN-13: 978- 0878938667, ISBN-10:0878938664
- Caroline Bowsher, Martin steer, Alyson Tobin (2008), Plant Biochemistry, Garland science ISBN978-0-8153-4121-5.
- P.M Dey and J.B. Harborne (Editors) (1997), Plant Biochemistry, Publisher: Academic Press ISBN-10:0122146743,ISBN-13:978-0122146749

Discipline Specific Elective Course -3 Practical (BCH DSE – 3P):

Plant Biochemistry

Semester – VI

PracticalCredits: 2, Total Hours: 60

Course level learning outcomes:

Students will gain expertise to determine the contents of photosynthetic pigments, ascorbic acid, phenols, tannins, hydrogen peroxide in plant samples. They will understand the spectral patterns of photosynthetic pigments and will get training to extract and assay enzymes like urease from Jack bean.

Practical content:

1. Estimation of chlorophylls and carotenoids from grass/spinach leaves
2. Estimation of ascorbic acid, phenols, tannins in fruits andvegetables
3. Determination of radical scavenging activity of plant extracts
4. Estimation of hydrogen peroxide in tissue extracts
5. Extraction and assay of urease from Jackbean
6. Separation of photosynthetic pigments byTLC and determination of absorption Spectra

Discipline Specific Elective Course -4 (BCH DSE - 4):

Advanced Techniques in Biochemistry

Semester – VI

Theory **Credits: 4, Total Hours : 60**

Course level learning outcomes:

Students will acquire a sound background of latest methods used in biochemistry for purification of enzymes, isolation and characterization of proteins, nucleic acids, etc. Students will also develop practical skills related to applications of microscopy, labeling DNA, proteins and whole cells and their applications inbiochemistry research. The students will get equipped with the latest techniques used in analysis of biomolecules and this will help them in undertaking further research in the area of biochemistry in any research/industrial institution.

Course content:

- **Enzyme purification methods**: Salt precipitation, salting in and salting out, ultrafiltration, organic solvent precipitation, gel filtration and ion exchange chromatography, affinity chromatography.

- **Methods for protein analysis**: Protein-Protein interaction, Immunoprecipitation, Yeast two hybrid, Protein fragment complementation assay, Western blotting, Far western blotting, Protein microarrays, ELISA. Proteomics : Isoelectric focusing, 2D protein gel electrophoresis, 2D-DIGE, Pulse field Electrophoresis; Structural analysis: MALDI-TOF, MS/MS,LC/MS.
- **Methods for nucleic acid analysis:** Comet assay**,** Hybridization methods: Southern blotting, Northern blotting, *In situ* hybridization, Colony hybridization. DNA pull down assays, Electrophoretic Mobility Shift Assay (EMSA), DNA foot-printing, Chromatin immunoprecipitation (ChIP),Gene expression analysis: Reporter assays - example luciferase assay, DNA Microarrays, RNA seq.

- **Microscopy** : Compound light microscopy, Phase contrast microscopy, Fluorescence microscopy, Scanning electron microscopy, Transmission electron microscopy, Confocal microscopy
- **Cell biology** techniques: Cell culture and transfection, Immunohistochemistry,

Immunofluorescence, Flow cytometry, FACS, TUNEL assay, Non-invasive scanning of soft tissue

- **Labeling methods**: Radioactive and Non-radioactive labeling: DNA, Proteins, Whole cells. Fluorescent labeling : DNA, Proteins, bacteria, living cells; Metabolic labeling, Pulse chase analysis

Discipline Specific Elective Course -4 Practical (BCH DSE – 4P)

Advanced Techniques in Biochemistry

Semester – VI

PracticalCredits: 2, Total Hours: 60

Course level learning outcomes:

Students will develop laboratory/practical skills to perform various experiments related to purification of enzymes, analysis of proteins, nucleic acids, etc. They will acquire hands-on-training with the latest techniques in Biochemistry such as 2D protein gel electrophoresis, WesternBlotting, Southern hybridization, DNA Labeling, Microarray profiling or2D-DIGE. This will lead to development of practical skills to undertake future analytical/research activities in Biochemistry.

Practical content:

1. Gel filtration Chromatography
2. Determination of molecular weight of protein/enzyme using gel filtration
3. 2D protein gel electrophoresis
4. WesternBlotting
5. Southernhybridization
6. Labeling DNA with Biotinylated primers usingPCR
7. EMSA (virtuallab)
8. Protein Pull downassay
9. Virtual lab on Microarray profiling or2D-DIGE

Suggested readings:

1. The Ultimate Guide to Your Microscope (2008) Levine, S. and Johnstone, L., Sterling,
2. Physical Biochemistry: Principles and Applications (2010) 2nd ed., Sheehan, D., Wiley Blackwell (West Sussex),
3. Principles and Techniques of Biochemistry and Molecular Biology (2010) 7th ed., Wilson, K., and Walker, J. (eds), Cambridge University Press (New Delhi),
4. Introduction to Instrumentation in Life Sciences (2012) Bisen, P.S. and Sharma, A., CRC Press/Taylor and Francis Group (California), ISBN:978-1-4665-1240-5.
5. Molecular Cloning: A Laboratory Manual (2012) Vol. 1-3, 4th ed., Green M.R. and Sambrook J., Cold Spring Harbour Laboratory Press (New York).
6. Biophysical Chemistry (2013), Schimmel, C.R.C., Macmillan Higher Education,
7. Current Protocols in Molecular Biology (2013) Ausubel, F.M. et al., John Wiley

and Sons (Somerset, NJ), Print ISSN: 1934-3639 / Online ISSN:1934-3663.
8. Current Protocols in Immunology (2013) Coligan, J.E. et al., John Wiley and Sons (Somerset, NJ).

Discipline Specific Elective Course -5 (BCH DSE - 5)

Biochemistry and Function of Hormones

Semester – V or VI

Theory **Credits: 4, Total Hours: 60**

Course level learning outcomes:

The students will understand the different modes of communication between cells includingsignal reception, transduction, amplification and response. They will understand the role of endocrine system in maintaining ionic and glucose homeostasis and the communications that regulate growth appetite, metabolism and reproduction in humans. The students will be able to decipher molecular and biochemical mechanisms of all hormones and will be in a position to interpret hormonal levels in individuals with health and disease conditions. Besides, students will also understand the role of various plant hormones in growth and development of plants.

- **Hormones:** Chemical classification of hormones, Functions of hormones and their regulation. Chemical signaling - endocrine, paracrine, autocrine, intracrine and neuroendocrine mechanisms. General introduction to Endocrinology. Hormone receptors - extracellular and intracellular. Receptor - hormone binding, G protein coupled receptors, second messengers - cAMP, cGMP, IP3, DAG, Ca^{2+}, Effector systems - adenylcyclase, guanylcyclase, PDE, PLC. Protein kinases (PKA, PKB, PKC, PKG). Receptor tyrosine kinases - EGF, insulin and Ras - MAP kinase cascade. Non receptor tyrosine kinase- erythropoietin receptor JAK - STAT pathway. Steroid hormone Receptor. Receptor regulation and crosstalk.

- **Hypothalamic-Hypophysialsystem**, Pituitary: anatomy, histology, vasculature and secretions. Physiological and biochemical actions of hypothalamic hormones and anterior pituitary hormones; Feed- back regulation.Posterior pituitary hormones – structure, physiology and biochemical actions of AVP and Oxytocin.
- **Thyroid gland** - Histology; Biosynthesis of thyroid hormone and its regulation: Role of TRH and TSH in T4 synthesis and response. Physiological and biochemical action of Thyroxine. Pathophysiology of thyroxine secretion: Hyper and hypothyroidism, Goiter, Graves' disease, Cretinism, Myxoedema.
- **Regulation of calcium homeostasis**: PTH, Vitamin D and calcitonin. Mechanism of Ca^{2+} regulation.Regulation of Growth: growth hormone and somatomedin, Endocrine disorders - gigantism, acromegaly, dwarfism, pygmies. Physiology and biochemical actions of Growth factors- EGF, PDGF andErythropoietin.
- **Hormones of adrenal gland:** Physiology and action of Aldosterone; the Renin Angiotensin System. Physiology and Biochemical actions of Cortisol. Adrenal medullary Hormones: Epinephrine and Norepinephrine. General adaptation syndrome: acute and chronic stress response. Pathophysiology – Addison's disease, Conn's syndrome.
- **Cells involved in the release of gastrointestinal hormones**; the gastrin family of hormones and CCK: the secretin family of hormones; Incretins; Ghrelin; Summary of hormone metabolite control of GI function. Hormones of the Pancreas: Structure, synthesis, physiology and biochemical actions of insulin and glucagon. Adipocyte hormones: Adiponectin and leptin; Appetite and satiety control.
- **Male and female sex hormones**. Hormones during ovarian and uterine phases of menstrual cycle; Placental hormones; role of hormones during parturition and lactation.

Discipline Specific Elective Course -5 (BCH DSE – 5P)

Biochemistry and Function of Hormones

Semester – V or VI

PracticalCredits: 2, TotalHours: 60

Course level learning outcomes

Students will acquirepractical training to undertake clinical tests like Glucose Tolerance test, estimation of serumCa^{2+}, serumT4, serumelectrolytes and HCG based pregnancy test. They will be in a position to interpret hormonal level with clinical conditions of the individuals.

Practical content

1. Estimation of serumCa^{2+}.
2. Estimation of serumT4
3. HCG based pregnancytest.
4. Estimation of serumelectrolytes.
5. Casestudies

Suggested readings :

1. Lehninger:PrinciplesofBiochemistry(2017)7thed.,Nelson,D.L.andCox,M.M. W.H. Freeman & Company (New York
2. Vander'sHumanPhysiology(2019)15thed.,Widmaier,E.P.,Raff,H.andStrang, K.T. McGraw Hill International Publications (USA)
3. Endocrinology (2007) 6thed., Hadley, M.C. and Levine, J.E. Pearson Education (New Delhi), Inc.
4. The Cell: A Molecular Approach (2009) 5th Ed. Cooper, G.M. and Hausman, R.E. ASM Press & Sunderland, (Washington DC), Sinauer Associates. (MA).

Discipline Specific Elective Course -6 (BCH DSE - 6)

Gene replication, expression and regulation

Semester – V or VI

Theory **Credits: 4, Total Hours: 60**

Course level learning outcomes:

The students will acquire basic knowledge related to replication of DNA as the genetic material, how genes are transcribed and translated in prokaryotes and eukaryotes. Students will also understand special features of genetic code and the molecular mechanisms involved in RNA processing and RNA splicing. Besides, students will learn the regulation of biological processes and the significance of such regulation in maintaining life.

Course content:

- **DNA replication**: Features of replication, the chemistry of DNA synthesis, DNA polymerase, the replication fork, enzymes and proteins in DNA replication, E coli DNA polymerases, stages of replication-initiation, elongation and termination, replication in eukaryotes end replication problem, telomerase, various modes of replication. Comparison of replication in prokaryotes and eukaryotes. Inhibitors of DNA replication.
- **Transcriptionin prokaryotes**: RNA polymerases, transcription cycle in bacteria, sigma factor, bacterial promoters, identification of DNA binding sites by DNA footprinting, various stages of RNA synthesis, initiation, elongation and termination, rho-dependent and rho-independent termination. Inhibitors of transcription and applications as antimicrobialdrugs.

- **Transcriptionin eukaryotes**: Comparison between prokaryotic and eukaryotic transcription. The three classes of eukaryotic RNA polymerases, transcription by RNA polymerase II, RNA polymerase II core promoters, general transcription factors, transcription by RNA polymerase I and III. Inhibitors of eukaryotic transcription and their applications

- **RNA Processing**: Types of RNA processing- polyadenylation and capping, processing of rRNA and tRNA. Chemistry of RNA splicing, the spliceosome machinery, splicing pathways, group I and group II introns, alternative splicing, exon shuffling and RNA editing.

- **Translation:** Genetic code and its characteristics, triplet nature, degenerate, deciphering the genetic code, Wobble hypothesis. Suppressor tRNAs.

Exceptions to the nearly universal genetic code. Messenger RNA, transfer RNA, charging of tRNA. The structure of ribosome. Three stages of translation-initiation, elongation and termination. Translation in eukaryotes. Regulation of translation. Comparison of prokaryotic and eukaryotic protein synthesis. Inhibitors of translation and their clinicalimportance.

- **Regulation of gene expressionin prokaryotes**: Principles of gene regulation, negative and positive regulation, concept of operons, regulatory proteins, activators, repressors, DNA binding domains, regulation of lac operon and trp operon. Regulatory RNAs in bacteria, small RNA and riboswitches.

- **Regulation of gene expression in eukaryotes**: Gene regulation by chromatin remodeling, regulation of galactose metabolism in yeast, action of enhancers and insulators, working of activators and repressors, concept of combinatorial control. Regulatory RNAs in eukaryotes: synthesis and mechanism of siRNA and miRNA.

Discipline Specific Elective Course -6Practical (BCH DSE – 6P):

Gene replication, expression and regulation

Semester – V or VI

PracticalCredits: 2, Total Hours: 60

Course level learning outcomes:

The students will acquire practical training related to quantitative determination of nucleic acids and more importantly they will be trained with the modern techniques of DNA manipulation such as isolation of native DNA, restriction digestion of isolated DNA, its characterization by agarose gel electrophoresis, amplification of DNA fragment by PCR, etc. They will learn the importance of DNA manipulation and its applications.

Practical content:

1. Estimation of RNA by Orcinolmethod
2. DNA estimation by UVspectrophotometry
3. Isolation of plasmid DNA from *E. coli.*
4. Restriction digestion and agarose gelelectrophoresis.
5. Amplification of a DNA fragment byPCR.
6. Extraction of total nucleic acids from planttissues
7. To study the effect of inhibitors on proteinsynthesis

2.6. B.Sc. (Hons) Biochemistry Generic Elective Courses

Generic Elective Course -1 (BCH GE -1): Biomolecules

Semester - I

Theory Credits: 4, Total Hours: 60

Course level learning outcomes:

The students opting this course will be from other than Biochemistry disciplines. The students will acquire knowledge about various biomolecules which constitute the living organisms. Students will be able to understand structure and function of proteins, nucleic acids, carbohydrates, fats, Vitamins,co-enzymes, etc. Students will

understand the chemical properties of these biomolecules and their functions. Students will get an idea about importance of biomolecules for living systems.

Course content:

- **Cell:** Structure and function of a cell, prokaryotic and eukaryotic cell and its subcellular components, structure and properties of water molecule, pH, Buffers, biological buffer systems, body fluids.
- **Amino acids, peptides and proteins**: Classification and general properties of amino acids, importance of amino acids, optical properties of aminoacids, ionization of amino acids, peptide bond, biologically important peptides, Primary (peptide conformation, N- and C- terminal, peptide cleavage), Secondary (α-helix, sheet, random coil), Tertiary and Quaternary structures of proteins.
- **Carbohydrates –**Classification, general properties, structure and functions ofcarbohydrates, monosaccharides, disaccharides, polysaccharides, homo polysaccharides, hetero polysaccharides; Structure of glucose, isomerism; ketoaldo, D-and L- isomerism, optical isomerism,epimerism; polysaccharides and complex carbohydrates; amino sugars, proteoglycans and glycoproteins.
- **Lipids –** Classification, structure, properties and functions of fatty acids, essential fatty acids, fats, phospholipids, sphingolipids, cerebrocides, steroids, prostaglandins, lipoamino acids, lipoproteins, phosphatidopeptides, lipopolysaccharides.
- **Nucleic acids –** Introduction, nucleotides, Structure and Functions of DNA and RNA, Types of DNA; Organization of DNA; RNA structure and function, Nucleic acids as genetic information carriers, experimental evidence, genetic transformation, DNA forms and conformations, Denaturation of DNA.
- **Vitamins and Coenzymes**: Classification of vitamins, water soluble vitamins, fat soluble vitamins, occurrence and nutritional role. Coenzymes and their role in metabolism.

Generic Elective Course -1 Practical (BCH GE -1P): Biomolecules

Semester - I

PracticalCredits: 2, Total Hours: 60

Course level learning outcomes:

The students will gain experimental training for preparation of solutions of different strengths, and buffers. They will be able to qualitatively and quantitatively analyse different biomolecules such as RNA, DNA, protein, carbohydrates, etc.

Course content:

1. Preparation of solutions and buffers
2. Estimation of RNA using orcinol reagent
3. Estimation of DNA using diphenylamine
4. Determination of protein concentration by ultraviolet spectroscopy
5. Separation of amino acids and sugars in a mixture by paper chromatography
6. Qualitative tests for carbohydrates, amino acids, proteins and nucleicacids.

Suggested readings:

1. A.L., Lehninger, PRINCIPLES OF BIOCHEMISTRY (2017), 7thEdn,Nelson,D.L.andCox,M.M.W.H. Freeman & Company (New York).
2. E.E. Conn and P.K. Stumpf. OUTLINES OF BIOCHEMISTRY (1976) Wiley Eastern, New Delhi.
3. BIOCHEMISTRY by L. Stryer (1995) W.H. Freeman Press, San Francisco, USA.
4. Biochemistry, by Voet, D. and Voet, J.G.(2004). 3rd Edition, John Wiley & Sons, Inc.USA.
5. Textbook of Biochemistry with Clinical Correlations (2011) 7th ed., Devlin, T.M., John Wiley & Sons, Inc. (New York), ISBN:978-0-470-28173-4

Generic Elective Course -2 (BCH GE -2): Biochemical Techniques

Semester - II

Theory **Credits: 4, Total Hours: 60**

Course level learning outcomes:

Students will learn about the principle and applications of spectrophotometry, different chromatographic techniques like gel filteration, Ion exchange, thin layer, etc. Students will also learn about various electrophoretic techniques such as cellulose acetate, gel, PAGE, etc. and their applications in analyzing proteins and nucleic acids. Students will learn the basic principles of centrifugation, various types of centrifuges, rotors and methods for subcellular fractionation. They will also learn the principles of electron microscopy more specially of SEM and TEM and their applications in characterizing biological samples.

Course content

- **Spectroscopy –** Concepts of spectroscopy, Visible and UV spectroscopy, Beer-Lambert's law, Principles and applications of colorimetry.
- **Chromatography –** Principles of partition chromatography; paper, thin layer, ion exchange and affinity chromatography, gel permeation chromatography.
- **Centrifugation –** Principles of centrifugation, concepts of RCF, preparative, differential and density gradient centrifugation, ultra-centrifugation, subcellular fractionation.
- **Electrophoretic techniques –** Principles of electrophoretic separation. Different types of electrophoresis including paper, cellulose acetate/nitrate and gel. PAGE and SDS-PAGE.
- **Electron microscopy –** Transmission and scanning, freeze fracture techniques, specific staining of biological materials.

Suggested readings:

1. Wilson K. and Walker J., Principles and Techniques ofBiochemistry and Molecular Biology, 7thed., Cambridge University Press, 2010.
2. Boyer, R.F., Biochemistry Laboratory: Modern Theory and Techniques, 6thed., Boston, Mass: Prentice Hall, 2012.
3. Plummer D. T., An Introduction to Practical Biochemistry 3rd ed., Tata McGraw Hill Education Pvt. Ltd. (New Delhi), 1998.
4.

Generic Elective Course -2 Practical (BCH GE -2P): Biochemical Techniques

Semester - II

PracticalCredits: 2, Total Hours: 60

Course level learning outcomes:

Students will acquire practical training to handle the instruments like colorimeter, spectrophotometer and to use them for biochemical determinations. Using the techniques of paper/thin layer chromatography, students will be able to separate amino acids, sugars. They will acquire practical skill to separate proteins by gel filtration and PAGE.

Course content

1. Verification of Beer's Law
2. Determination of absorption maxima (λ_{max}) of proteins and nucleic acids
3. Determination of protein concentration using UV-Vis spectrophotometer
4. Determination of molar extinctioncoefficient.
5. Fractionation of sub cellular organelles from leaves using differential centrifugation
6. Separation of amino acid acids/sugars by thin layer/paper chromatography
7. Separation of proteins by gel filtrationchromatography
8. Separation of nucleic acids using agarose gelelectrophoresis
9. Separation of proteins by PAGE and SDS-PAGE.

Generic Elective Course -3(BCH GE -3): Nutritional Biochemistry

Semester - III

Theory **Credits: 4,Total Hours: 60**

Course level learning outcomes:

Students will acquire the understanding of the basic concept of nutrition for maintaining normal health, role of nutrients for the body, dietary requirements of carbohydrates, proteins, fats, vitamins, minerals, etc. They will understand the importance of essential amino acids, essential fatty acids and vitamins for the body. This course integrates learning between Biochemistry andNutrition.

Course content

- **Basic concepts of nutrition**, Nutrients,Function of nutrients. Measurement of the fuel values of foods. Basal metabolic rate: factors affecting BMR, measurement and calculation of BMR.
- **Elements of nutrition –** Dietary requirement of carbohydrates, lipids and proteins. Balanced diet, Concept of protein quality. Essential amino acids, essential fatty acids and their physiological functions.
- **Minerals –** Nutritional significance of dietary calcium, phosphorus, magnesium, iron, iodine, zinc and copper.
- **Vitamins –** Dietary sources, biochemical functions, requirements and deficiency diseases associated with vitamin B complex, C and A, D, E and K vitamins.
- **Malnutrition –**Recommended dietary allowances, nutritive value of common foods. Protein-calorie malnutrition.
- **Obesity –** Definition, Genetic and environmental factors leading to obesity.

Suggested readings :

1. Nutritional Biochemistry. Author, Tom Brody. Edition, 2. Publisher, Harcourt Braces, 1999.
2. Principles of Nutritional Assessment (2005) Rosalind Gibson. Oxford University Press.

3. Krause's Food and Nutrition Care process.(2012);Mahan, L.K Strings, S.E, Raymond, J. Elsevier's Publications.
4. The vitamins, Fundamental aspects in Nutrition and Health (2008); G.F. Coombs Jr. Elsevier's Publications.

Generic Elective Course -3 Practical (BCH GE -3P): Nutritional Biochemistry

Semester - III

PracticalCredits: 2, Total Hours: 60

Course level learning outcomes:

Students will get acquainted with the techniques used in the determination of different nutrients such as vitamin C, minerals, amino acids in food samples. They will also learn to test the quality of oil/fat by determining its saponification value and iodine value. Students will acquire the concept to check the possible adulteration in food samples.

Practical content

1. Determination of moisture content of foods
2. Determination of Vitamin C content in lemon juice
3. Estimation of minerals in food samples
4. Estimation of amino acid by titration.
5. Estimation of reducing sugars by Hedgedon and Jensen method.
6. Determination of saponification value of oil or fat.
7. Determination of iodine value of oil.

Generic Elective Course -4 (BCH GE -4): Biochemical basis of Diseases

Semester - IV

TheoryCredits: 4, Total Hours: 60

Course level learning outcomes:

Students will get acquainted with various types of human diseases and their biochemical basis. They will know about disorders due to improper dietary constituents. Therefore students will get curiosity to have balanced diets to prevent many nutritional disorders/diseases. Students will acquire a good understanding of biochemical basis of diseases related to inherited metabolic disorders, digestive and infectious diseases. They will learn pathogenicity and prevention measures for microbial diseases.

Course content:

- **Inborn Errors of Metabolism –** Phenylketonuria, alkaptonuria, albinism, tyrosinosis, maple syrup urine disease, Lesch-Nyhan syndrome, sickle cell anemia, Histidinemia.
- **Disorders of Carbohydrate Metabolism –** Diabetes mellitus, glycogen storage diseases, pentosuria, galactosemia.
- **Disorders of Lipids –** Hyperlipidemia, hyperlipoproteinemia, Gaucher's disease, Tay-Sach's and Niemann-Pick disease, ketone bodies, Abetalipoproteinemia.
- **Digestive diseases –** Maldigestion, malabsorption, creatorrhoea, diarrhoea and steatorrhoea.
- **Disorders of liver and kidney –** Jaundice, fatty liver.
- **Abnormalities in Nitrogen Metabolism –** Uremia, hyperuricemia, porphyria.
- **Haemorrhagic disorders** – Haemophilia, von Willebrand's disease,Rendu-Osler-Werber disease, thrombotic thrombocytopenic purpura (TTP).
- **Infectious diseases**: Bacterial infections: Tetanus, Diphtheria, Tuberculosis, Typhoid, Cholera. Viral infection: Polio, Measles, Mumps, influenza, HIV. Protozoan: Malaria and Trypanosomiasis. Parasitic infection: Leishmaniasis.

  Suggested readings :

1. Biochemistry (2013) 4thed., Voet, D., Voet, J. & Pratt, C. Wiley & Sons, Inc. (New Jersey), ISBN:978-1-11809244-6.
2. Biochemistry (2012) 7th ed., Berg, J.M., Tymoczko, J. L. and Stryer, L.,

W.H Freeman and Company (NewYork)

3. Textbook of Biochemistry with Clinical Correlations (2011) Devlin, T.M. John Wiley & Sons, Inc. (New York)
4. Klein's Microbiology, (2008) 7 ed., Prescott, Harley, Wiley, J.M. Sherwood, L.M. Woolverton, C.J. McGraw Hill International Edition (New York) ISBN: 978-007- 126727.

Generic Elective Course -4 Practical (BCH GE -4P): Biochemical basis of Diseases

Semester - IV

PracticalCredits: 2, Total Hours: 60

Course level learning outcomes:

Students will acquire practical training for estimation of clinically important compounds like blood glucose, serum cholesterol, hemoglobin, calcium, etc. This will enable the students to perform diagnostic tests for the diseases related to varying levels of these compounds/chemicals. They will also get acquainted with routine checkup parameters such as blood pressure, BMI, Waist/Hip Ratio, Mid Arm Area (MAA) for a normal or diseased person.

Practical content:

1. Estimation of blood glucose
2. Estimation of serum cholesterol
3. Measurement of blood pressure, BMI, Waist/Hip Ratio,
   Mid Arm Area(MAA).
4. Estimation of Haemoglobin
5. Estimation of calcium
6. Gram staining of bacteria

Generic Elective Course -5 (BCH GE -5): Intermediary Metabolism

Semester – I to IV

Theory Credits: 4, Total Hours: 60

Course level learning outcomes:

Students will conceptualize how various biomolecules are metabolized inside the body in order to produce energy for various functions and how various metabolic pathways regulate growth and development of living beings. Students will know about role of high energy compounds, how carbohydrates serve as energy source to power various functions, interplay of regulatory networks in the body, hormonal regulation of metabolism, etc. They will be acquainted with the role of lipids as storage molecules, role of TCA cycle in central carbon metabolism, importance of anaplerotic reactions, and redox balance occurring in the cells.

Course content:

- **Intermediary Metabolism –** Approaches for studying metabolism.
- **Bioenergetics –** Concept of free energy, standard free energy, determination of ΔG for a reaction. Biological oxidation-reduction reactions, redox potentials, relation between standard reduction potentials and free energy change. Free energy of hydrolysis of ATP.
- **Carbohydrates –** Glycolysis, TCA cycle, ATP synthesis and oxidative phosphorylation. gluconeogenesis, glycogenesis and glycogenolysis. Hormonal regulation of carbohydrate metabolism.
- **Amino Acids –** Classification**,** General reactions of amino acids, Transamination, decarboxylation, oxidative and non-oxidative deamination of amino acids. Proteolysis.
- **Lipids –** Introduction, hydrolysis of tri-acylglycerols, α-, β-, ω- oxidation of fatty acids. Fatty acid biosynthesis, Acetyl CoA carboxylase, fatty acid synthase, ACP structure and function,
- **Nucleotides –** Biosynthesis and degradation of purine and pyrimidine nucleotides and its regulation. Purine salvage pathway. Biosynthesis of deoxyribonucleotides and polynucleotides.
- **Porphyrins –** Biosynthesis and degradation of porphyrins.

Suggested readings:

1. Biochemistry (2013) 4th ed., Voet, D., Voet, J. & Pratt, C. Wiley & Sons, Inc. (New Jersey)
2. Biochemistry (2012) 7th ed., Campbell, M.K. and Farrel, S.O. Brooks/Cole, Cengage Learning (Boston)
3. Biochemistry (2012) 7th ed., Berg, J.M., Tymoczko, J.L. and Stryer L., W.H. Freeman and Company (New York)

Generic Elective Course -5 Practical (BCH GE -5P): Intermediary Metabolism

Semester – I to IV

Practical **Credits: 2, Total Hours: 60**

Course level learning outcomes:

Students will acquire practical training for estimation of important compounds in the given samples such asglucose,proteins .They will be able to separate lipids from egg yolk. They will acquire hand-on-training to handle pH meter and to measure pH of different solutions and pKa values of amino acids.

Practical content

1. Determination of pH using pH meter.
2. Estimation of glucose by Nelson Somogyi method
3. Estimation of Protein by Biuret method
4. Estimation of protein using Bradford reagent.
5. Isolation of lipids from egg yolk and separation byTLC.
6. Determination of pKa value of amino acid using pH meter.

Generic Elective Course -6 (BCH GE -6): Gene and Recombinant DNA Technology

Semester – I to IV

TheoryCredits: 4, Total Hours: 60

Course level learning outcomes:

Students will be exposed to the latest techniques employed in recombinant DNA technology related to DNA manipulation in prokaryotes and eukaryotes. Students will get acquainted with the importance of gene cloning, methods for screening cloned genes, DNA sequencing, gene expression, etc. They will understand the importance of recombinant DNA technology in production of insulin, drugs, diagnostics, vaccines and transgenic plants.

- **Genes –** Nucleic acids as genetic material**,** Genetic code**,** Prokaryotic and eukaryotic genes, pseudogenes, split genes, super gene family, transposons. C-value paradox, packaging of DNA, satellite DNA
- **Recombinant DNA methods –** Gene isolation, Restriction enzymes and their uses, Gene transfer systems, features of commonly used vectors, strategies for cloning in various vectors, binary vectors, identification of bacterial colonies containing recombinant plasmids and bacteriophage vectors. Genetic transformation methods without using vectors.
- **Construction and analysis of c-DNA** and genome libraries, protocols and strategies for c-DNA cloning, analysis of genomic DNA by southern hybridization, amplification of DNA by polymerase chain reaction, penetration of radiolabeled DNA and RNA probes, synthetic oligonucleotide probes, expression of cloned genes in cultured cells, screening expression with antibodies and oligonucleotides.
- **DNA sequencing,** foot printing, Rapid DNA sequencing methods; Maxam-Gilbert technique, Sanger's Dideoxynucleotide sequencing, gene walking, RNA sequencing.
- **Applications of recombinant DNA technology –** Production of insulin, factor VIII drugs, vaccines.

- **Production of genetically modified transgenic plants** and the nature of transgenes, Bt cotton, Golden rice, Btbrinjal.

Generic Elective Course -6Practical (BCH GE -6P): Gene and Recombinant DNA Technology

Semester – I to IV

PracticalCredits: 2, Total Hours: 60

Course level learning outcomes:

Students will take practical training in the recent techniques of recombinant DNA technology such as quantification of DNA, isolation of chromosomal DNA, isolation of plasmid DNA from bacterial cells, restriction digestion of DNA and their separation using Agarose gel electrophoresis, amplification of DNA fragment by PCR. With learning these techniques students will gain expertise to work further in the area of recombinant DNA technology.

Practical content:

1. Determination of DNA concentration using spectrophotometer
2. Isolation of chromosomal DNA from *E coli*
3. Isolation of plasmid DNA from *E. coli.*
4. Restriction digestion of DNA and separation of DNA fragments byAgarose gelelectrophoresis.
5. Amplification of a DNA fragment byPCR.

Suggested readings :

1. Gene Cloning and DNA Analysis (2010) 6th ed., Brown, T.A., Wiley-Blackwell Publishing (Oxford, UK).
2. Molecular Biotechnology: Principles and Applications of Recombinant DNA (2010) 4th ed., Glick B.R., Pasternak, J.J. and Patten, C.L., ASM Press (Washington DC)
3. Current Protocols in Molecular Biology (2013) Ausubel, F.M. et al., John Wiley and Sons (Somerset, NJ)

2.7. B.Sc. (HONOURS) BIOCHEMISTRY (CBCS STRUCTURE)
Skill Enhancement Elective Courses

Skill Enhancement Elective Course -1 (BCH SEE-1):Bioinformatics

Semester – IV

Theory Credits: 2, Total Hours: 30

Course level learning outcomes:

By studying this course the students completing B.Sc. (Hons) Biochemistry will have an understanding of the tools of bioinformatics and computational biology and will be in a position to access biological data bases and softwares which will be helpful in understanding sequencealignments and predicting the structures of biomolecules such as proteins. Students will be exposed to available bioinformatics tools and databases. They will be in a position to comprehend the fundamental aspects of *in-silico*protein structureprediction. They will understand application of theoretical approaches to biological systems. Students will get trained in the application of programs used for database searching, protein and DNA sequence analysis, and prediction of protein structures.

Course content

- Bioinformatics: Introduction, Basics of Computer and operating systems, Hardware, Software, Introduction to programming Languages and Paradigms, PERL/R programming, role of supercomputers in biology,
- Scope of bioinformatics - Genomics, Proteomics, comparative and functional genomics, Genome annotation, gene prediction approaches andtools.Transcriptome and Proteome, Tools of proteome analysis. DNA microarray: understanding of microarray data and correlation of gene expression data to biological processes and computational analysis tools. Computer aided drug design (CADD) and Systems Biology.
- Biological databases: Introduction to biological databases - primary, secondary and composite databases, useful programs, ClustalW, BLASTp. NCBI, EBI, ExPaSy ,nucleic acid databases (GenBank, EMBL, DDBJ, NDB), protein databases (PIR, Swiss-Prot,TrEMBL, PDB), metabolic pathway database (KEGG, EcoCyc).

- Sequence alignment: Similarity, identity and homology. Concept of Alignment – Pair-wise sequence alignment, gaps, gap-penalties, scoring matrices, PAM250, BLOSUM62, local and global sequence alignment, multiple sequence alignment, Progressive Alignment Algorithm, Application of multiple sequence alignment. BLAST and CLUSTALW.
- Protein Structure: Methods for prediction of Protein structure, Homology modeling, Fold recognition and *ab-initio* methods.

Skill Enhancement Elective Course -1 Practical (BCH SEE-1P) : Bioinformatics

Semester – IV

PracticalCredits: 2, Total Hours: 60

Course level learning outcomes:

The students will acquire training in different areas of bioinformatics related to various biological databases such as protein databases, nucleic acid databases, metabolic pathway databases, etc.With training in multiple sequence alignments they will be in a position to perform *in-silico* experiments and will predict structures of proteins.

PRACTICALS

1. Downloading and analysis of the pdb file of the biomolecules.
2. Tertiary structure prediction of proteins (SWISSMODEL) and Protein structure evaluation
3. Analysis of Secondary and tertiary structure of protein using visualizing software like Rasmol.
4. Primary sequence analyses (Protparam) and Secondary structure prediction (GOR, nnPredict).
5. Sequence retrieval (protein and gene) from NCBI and Molecular file formats - FASTA,GenBank/Genpept.
6. BLAST suite of tools for pairwisealignment
7. Multiple sequence alignment (CLUSTALW/TCoffee) and construction of guidetrees
8. Gene prediction usingGENSCAN/GLIMMER

Suggested readings:

1. Bioinformatics – 2008. Principles and Applications , 1st ed. Ghosh, Z. and Mallick, B., Oxford University Press (India),
2. M. Michael Gromiha, 2010. Protein Bioinformatics: From Sequence to Function, Academic Press.
3. Bioinformatics: Sequence and Genome Analysis (2001), 1st ed., Mount, D.W. Cold Spring HarborLaborator Press (New York)
4. Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins (2005), 3rd ed., Baxevanis, A.D. and Ouellette, B.F., John Wiley & Sons, Inc. (New Jersey).

Skill Enhancement Elective Course -2 (BCH SEE-2): Biostatistics

Semester – IV

TheoryCredits: 2, Total Hours: 60

Course level learning outcomes:

The students will understand the principles of collection of data in biological experiments, proper statistical analysis of the data and its presentation. Students will understand the importance of sample size and various variables that affect data. Students will know the importance of mean, standard error, standard deviation, significance in presenting the data. Knowing statistical methods will help students in improving their analytical and interpretation skill.

Course content

- **Data CollectionandPresentation:** Biological data management using statistical tools. Concepts of population and sample, advantages of sampling, Basic concepts in sampling and designing experiments, Estimation of sample size for biological experiments, sources of errors. Sampling schemes – Simple Random sampling, Systemic sampling, Stratified sampling, Cluster sampling, Non probability sampling; Estimation of mean proportion and standard error in cluster sampling, Multistage and multiphase sampling, Types of numerical data – nominal data, ordinal data, ranked data, discrete data, continuous data; Modes of presenting data: Frequency distributions, Relative frequency.

- **Analysis of variance**: Mean, median, mode; Co-efficient of variation and standard deviation; Range and interquartile range; Grouped mean and grouped variance; Frequency distributions; One-way ANOVA; Two-way ANOVA; AMOVA; student's ttest.
- **Probability**: Operations on events, Venn diagrams, Conditional Probability; Probability distributions.
- **Hypothesis testing**: General concepts – Null hypothesis, alternative hypothesis, Rejection of hypothesis; Type I and Type II errors; P value and sample size estimation.
- **RegressionandCorrelation:** Chi Square Test – Observed and expected frequencies, Calculating p values, assumptions of a chi square goodness of fit;

Correlation –Two-way scatter plot, Pearson's correlation coefficient; Regression – regression concepts, simple linear regression; Calculation of R^2 and ρ.

Skill Enhancement Elective Course -2 (BCH SEE-2P):Biostatistics

Semester – IV

PracticalCredits: 2, Total Hours: 60

Course level learning outcomes:

Students will acquire hands-on practical training to plan biological experiments with requisite sample size. After completion of experiments based on different sample sizes students will be able to perform proper statistical analysis of the data using mean, median, mode, variance and standard deviations. Students will be able to apply the principles of biological data management in real life situations. Statistical training will improve computational, mathematical and computer skills of the students by learning the use of ANOVA, AMOVA and student t-test. Students will be able to formulate a hypothesis, relevance to type of sample collected and sample size.

Course content

1. Estimation of population means and variance in simple random sampling.
2. Collection of data - Random sampling method; Stratified sampling method; Cluster samplingmethod
3. Cluster Sampling- Equal and unequal cluster sizes. Double sampling using regression and ratio estimates and double sampling for stratification.
4. Data representation - Frequency and relative frequency distribution table, Plotting of biological data in a representative graphicalformat.
5. Data analysis - Calculating Mean, median, mode, variance, standard deviation and standard error for a given data set. Standard t-test for grouped samples. Analysis of 2 wayvariance
6. Chi square goodness of fit test. Regression analysis and calculating regression coefficient
7. Learning to analyze data using SPSS software

Suggested readings :

1. Principles of Biostatistics, M. Pagano and K. Gauvreau (2000); Duxbury Thomas learnings.
2. Analysis of Biological Data, M. Whitlock and D. Schluter (2009); Roberts and company publishers.

Skill Enhancement Elective Course -3 (BCH SEE-3): Research Methodology

Semester – III or IV

Theory **Credits: 2, Total Hours: 30**

Course level learning outcomes:

Students will understand the objectives of doing scientific research. They will learn how to identify the area of research to be conducted, how to proceed for literature survey using a variety of sources and how to write research project proposal with well laid hypothesis and objectives. They will learn the skills of research design, nature of sample size as well as collection and analysis of data. They will also know the skills of writing research report and making oral presentations.

- **Research Methods**: Scientific Research: The scientific method and problem solving. Various phases of research.Major steps in the research process: Literature review,Research proposal and aspects, Review of literature using appropriate sources – reviews, patents, research papers, books. Theoretical contexts, research problem, research hypothesis.
- **Research Designs:** Types of research designs – exploratory, descriptive, experimental, survey and case study, Sampling techniques and sample size determination.Sample - types, criteria, characteristics and steps; Tools and techniques to execute experiments.
- **Research Reports:** Data preparation and preliminary analysis, statistical analysis, model building and decision making. Types of research documents, writing and formatting of report, presentation, interpretation, art of oral presentation, format of publications in research journals; Journal Impact factor, h-index and i-10 index.
- **Bio-Ethics** – Bioethical concerns; Plagiarism; Citation and acknowledgement.

Suggested readings:

1. Bhattacharya, D. K. (2003): Research Methodology, Excel Books, New Delhi
2. Cenise F. Polit, J.B. Bemadette, P. Hungler (1984) Essential of Nursing Research Methods Lippinott Company, U.K.
3. Carol T. Bush (1985): Nursing Research, Reston Publishing C. Reston,

Skill Enhancement Elective Course -3 (BCH SEE-3P): Research Methodology

Semester – III or IV

Practical **Credits: 2, Total Hours: 60**

Course level learning outcomes:

Students will acquire the knowledge as how to write research plan proposal on a particular topic. They will gain knowledge of making power point/oral presentations. Writing reviews will help the students in writing research reports. Overall, the students will have a concise and definite view of proceeding to execute a scientific research project.

Practical content:

1. To write a research plan proposal on a particular topic
2. Power point presentation of the research project proposal
3. Writing of a review dissertation
4. Design of a research survey on a specificproblem
5. Presentations and discussions in smallgroups

2.8. Educational Tour

- Note: - The students should be taken for the visit to scientific institutions, pharma/biotech industries in the country relevant to Biochemistry and a report to be submitted.

Visit to scientific institutions/industries in the country:

- Bangalore: IISc, JNCASR, NIMHANS, UAS-NCBS, Biocon.
- Bombay: TIFR, Cancer Research Institute, BARC, IIT.
- Hyderabad – CCMB, CDFD, NIN, Reddy's lab, International crop research institute for semi-arid Tropics (ICRISAT), University of Hyderabad
- University of Pune.

- National Institute of Virology, National Chemical Laboratory, National center for cell science.
- Goa: National Institute of oceanography (NIO)
- Trivandrum – Sri ChitraTirunal Institute of Medical Sciences, Rajiv Gandhi Centre for Biotechnology.
- Kasargod : Coconut Research Institute.
- Mangalore – Fisheries college
- Manipal Centre for Higher Education, Plant biotechnology lab – St. Aloysius college.
- Hassan: Coffee estate, MCF.
- Ooty: Potato research station.
- Coonoor : TATA tea process centre, Vaccine institute
- Madras : IIT, Central Leather Research Institute, Cancer Institue, Adyar
- RSIC: Regional Sophisticated Instrumentation Centre.
- Lucknow: Central Drug Research Institute, Industrial Toxicological Research Institute,Central Institute of Medicinal and Aromatic Plants, Indian Institute of Sugarcane Research, National Botanical Research Institute
- Kanpur : National Sugar Institute,
- New Delhi : International Center for Genetic Engineering and Biotechnology, CSIR-Institute of Genomics and Integrative Biology, National Institute of Immunology, IIT
- Kolkata: Indian Institute of Chemical Biology, Indian Institute of Science Education and Research (IISER)
- Mumbai: Bhabha Atomic Research Centre, IIT, Institute of Chemical Technology
- Varanasi: Indian Institute of Vegetable Research.

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