Goa University
Goa University, Taleigao Plateau, Goa 403 206, India

Syllabus of M.Sc. (Biochemistry) Programme

The Department of Microbiology offers two years full time M.Sc. Programme in Biochemistry.

Purpose: This is a full time Programme introduced in the Academic Year of 2014 as a need-based Programme, to serve as an opportunity for higher study and to impart knowledge and training in the field of Biochemistry with emphasis on biochemistry of human metabolism, microbial physiology and health, clinical and physiological aspects of the human system, analytical tools, biotechnology, industrial biochemistry and pharmaceutics, amongst several other front line topics, wherein students undergo hands-on training with state-of-the art technologies and are trained so as to develop an aptitude for independent research, so as to equip them for higher research leading to the Ph.D. Degree in India or in International Universities overseas, or for employment in Research Institutes, in teaching, and in Industry.

Prerequisites:B. Sc. Microbiology/ Biochemistry/ Botany/ Zoology/ Biotechnology.

Course Structure of M.Sc. Biochemistry

Semester 1 – Core Papers				
Code	**Title of paper**	**Theory/ Practical**	**Credit**	**CH**
BCC 101	Fundamentals of Biochemistry	Theory	3	36
BCC 102	Enzymology	Theory	3	36
BCC 103	Analytical Biochemistry - I	Theory	3	36
BCC 104	Biostatistics	Theory	3	36
BCC 105	Practical I	Practical	4	96
Semester 2 – Core Papers				
BCC 201	Clinical Biochemistry	Theory	3	36
BCC 202	Molecular Biology	Theory	3	36
BCC 203	Analytical Biochemistry – II	Theory	3	36
BCC 204	Immunology- I	Theory	2	24
BCC 205	Membrane Biochemistry	Theory	1	12
BCC 206	Practical II	Practical	4	96
Semester 3 & 4 – Optional Papers				
BCO 101	Hormones	Theory	2	24
BCO 102	Neurochemistry	Theory	2	24
BCO 103	Genetic Engineering [T]	Theory	3	36
BCO 104	Genetic Engineering [P]	Practical	1	24
BCO 105	Nutrition and Food Biochemistry [T]	Theory	3	36
BCO 106	Nutrition and Food Biochemistry [P]	Practical	1	24
BCO 107	Microbes In Health and Disease [T]	Theory	3	36
BCO 108	Microbes In Health and Disease [P]	Practical	1	24
BCO 109	Drug Metabolism	Theory	1	12
BCO 110	Immunology - II	Theory	3	36
BCO 111	Biochemistry of Environmental Pollution and Remediation [T]	Theory	3	36
BCO 112	Biochemistry of Environmental Pollution and Remediation [P]	Practical	1	24
BCO 113	Industrial Biochemistry [T]	Theory	3	36
BCO 114	Industrial Biochemistry [P]	Practical	1	24
BCO 115	Frontiers in Biotechnology [T]	Theory	3	36
BCO 116	Frontiers in Biotechnology [P]	Practical	1	24
BCO 117	Bioprospecting	Theory	4	48
BCO 118	Nanobiotechnology [T]	Theory	3	36
BCO 119	Nanobiotechnology [P]	Practical	1	24
BCO 120	Pharmaceutics [T]	Theory	3	36
BCO 121	Pharmaceutics [P]	Practical	1	24
BCO 122	Research Methodology [T]	Theory	3	36
BCO 123	Research Methodology [P]	Practical	1	24

BCO 201	Field Trip/Study Tour [P]	Practical	1	24
BCO 202	Training in an Institute/ Industry/ University		1	
BCD	Dissertation		8	

Under Optional Courses:

- The theory course is a prerequisite for any practical course.
- Students of M.Sc. Biochemistry shall be required to take both Theory and Practical Courses under a given Course Title.

Programme: M.Sc. (Biochemistry)

Course Code: BCC 101

Title of the Course: FUNDAMENTALS IN BIOCHEMISTRY [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	Basic knowledge of biomolecules.	
Objective:	To develop concepts about structures and functions of different biomolecules.	
Content:		
1.		**(12)**
1.1	**Protein** Amino acids: features and properties Protein structure: peptide linkage, covalent backbone, three-dimensional conformation; quarternary structure of oligomeric proteins. Protein functions	
1.2	**Carbohydrate** Monosaccharides: types, characteristics and properties; disaccharides, oligosaccharides, polysaccharides – biological significance	
1.3	**Lipid** Classification, structure, properties; biological significance.	
2.		**(12)**
2.1	**Bioenergetics** Thermodynamics, exergonic and endergonic reactions, redox potential, high energy compounds, ATP structure and significance.	
2.2	**Oxidative Phosphorylation** Redox enzymes, aerobic electron transport and oxidative phosphorylation	
2.3	**Carbohydrate metabolism** Central pathways of carbohydrate metabolism – regulatory mechanisms, bioenergetics and significance – EMP, HMP shunt, TCA cycle. Utilization of sugars such as lactose, galactose, maltose and of polysaccharides such as starch, glycogen. Gluconeogenesis from TCA intermediates / amino acids / acetyl-CoA. Biosynthesis of polysaccharides and sugar interconversions.	
3.		**(12)**
3.1	**Lipid metabolism** Catabolism: Oxidation of fatty acids Anabolism: (a) Biosynthesis of fatty acids: saturated, unsaturated (b) Biosynthesis of triglycerides, phospholipids, sterols	

3.2	**Nucleotides and Nucleic Acids** Purine and pyrimidine nucleotides: biosynthesis and its regulation. Deoxyribo nucleotides: biosynthesis and regulation. Biosynthesis of nucleotide coenzymes. Catabolism of purine and pyrimidine nucleotides.	
3.3	**Amino acids** Overview of biosynthethic pathways of amino acids and their regulation; Overview of catabolism of amino acids. Urea cycle.	
Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	
References/ Readings	Lehninger, A., Cox, M., & Nelson, D. L., Lehninger Principles of Biochemistry edited by Freeman, W. H. & Company	
	Stryer, L., Biochemistry. Freeman, W. H. & Company	
	Conn, E., Stumpf, P., Bruening, G. & Doi, R. H. Outlines of Biochemistry by John Wiley & Sons.	
	Voet, D., Voet, J.G. & Pratt, C. W. Principles of Biochemistry John Wiley & Sons	
	Bernard L. Oser. Hawk's Physiological Chemistry edited by McGraw-Hill Book Company	
	Harper, H. A., Physiological Chemistry. University Medical Publishers	
	Mu, P, & Plummer, D.T., Introduction to Practical Biochemistry. Tata McGraw-Hill Education.	
	Sadasivam, S. & Manickam, A. Biochemical Methods. Publisher, New Age International (P) Limited	
	Jayaraman, J., Laboratory Manual in Biochemistry. John Wiley & Sons, Limited	
Learning Outcomes	Apply the concepts of biomolecules in a range of situations.	

Programme: M.Sc. (Biochemistry)

Course Code: BCC 102

Title of the Course: ENZYMOLOGY [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that students have a basic understanding of biomolecules, their structure and function and catalysis.	
Objective:	The course develops concepts in enzymology including enzyme activity, kinetics, mechanism of action and techniques for purification of enzymes	
Content:		
1.	**Enzymes: Classification and kinetics**	**(15)**
1.1	Nomenclature and classification of enzymes	
1.2	Enzymes as catalysts: role of enzymes to increase reaction rates.	
1.3	Coenzymes and cofactors and their role in enzyme activity	
1.4	Enzyme structure; enzyme-substrate complex, binding sites, concept of active site, stereo-specificity.	
1.5	Enzyme activity – units; specific activity; effect of pH, temperature and inhibitors.	
1.6	Enzyme kinetics: Michaelis - Menten Equation - form and derivation, Line-Weaver Burk plot for one substrate reactions; significance of Vmax and Km.	
1.7	Enzyme turnover: Ks and Kd, and measurement of enzyme turnover, correlation between the rates of enzyme turnover and structure function of enzymes; mechanism of enzyme degradation, significance of enzyme turnover.	
1.8	Bi-substrate reactions.	
1.9	Enzyme Inhibition – Reversible and irreversible inhibition: competitive, uncompetitive, non-competitive.	
2.	**Enzyme Mechanism of Action, Regulation, Multienzyme systems.**	**(13)**
2.1	Enzyme catalysis mechanism: Determination of active centre– Identification of functional groups, factors affecting catalytic efficiency - proximity and orientation effects, covalent and acid - base catalysis, strain in catalysis.	
2.2	Enzyme Regulation: control of activity, availability of substrate and, inhibitor or enhancer molecules, change in the covalent structure of enzyme	

2.3	Regulatory enzymes: Allosteric (aspartate transcarbamylase)and Covalently Modulated Enzymes(glycogen phosphorylase, glutamine synthetase); Mechanism of action – and their significance in metabolism.	
2.4	Zymogens and Isozymes.	
2.5	Multienzyme systems: disassociated system (catabolic enzymes), multienzyme complex (pyruvate dehydrogenase); membrane-bound system (electron carrying enzymes).	
3.	**Enzyme purification**	**(08)**
3.1	Isolation and purification of enzymes: salt precipitation; dialysis; ultrafiltration; molecular exclusion chromatography; affinity chromatography; ion exchange chromatography. Specific activity and fold purification as criteria of purity. Zymograms.	
3.2	Molecular weight determination: Exclusion chromatography; PAGE, SDS-PAGE	
Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	
References/ Readings	Dixon & Webb., Enzymology	
	Harper, H., Review of Physiological Chemistry, Marusan Co	
	Stryer, L., Freeman, W.H., Biochemistry San Francisco.	
	Lehninger, A.L., Nelson, D.L., Cox, M.M. Principles of Biochemistry, Worth Publishers, New York.	
	Price & Stevens. Fundamentals of Enzymology.	
	Guyton & Hall. Textbook of Medical Physiology	
	Plummer, D.T., An introduction to practical biochemistry	
	Sadasivam, S. & Manickam A., Biochemical Methods. Publisher, New Age International (P) Limited.	
	Jayaraman J. Laboratory Manual in Biochemistry, John Wiley & Sons,Limited, Australia.	
	Sambrook, J., Fritsch, E.F., Maniatis, T. 1989. Molecular cloning: a laboratory manual, 2nd edn. Cold Spring Harbor Laboratory Press, New York.	
Learning Outcomes	1. A better understanding of enzymes, their mechanism of action, regulation and kinetics 2. Apply biochemical techniques for purification of enzymes for their study and application	

Programme: M.Sc. (Biochemistry)

Course Code: BCC 103

Title of the Course: ANALYTICAL BIOCHEMISTRY – I [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that students have a basic knowledge of fundamentals in biochemistry.	
Objective:	This course develops concepts in techniques used for routine biochemical work such as chromatography, spectrophotometry, centrifugation, microscopy, electrophoresis.	
Content:		
1		**(12)**
1.1	Concept of pH, Eh, Acid-Base associations, Buffers, Buffering capacity, Mechanism of Dissociation of Macromolecules, Dissociation constants, pKa, pI, Solvents (eleutropic series), Peroxide values, solubility and affinity constants.	
1.2	**Chromatographic techniques:** Thin-layer, paper chromatography, Column chromatography, Separation matrixes - Ion-exchange, Affinity, Molecular exclusion and Adsorbtion. Concept of Mobile phases; gradient elution (concave, convex and linear)	
2		**(12)**
2.1	**Spectrophotometry:** Beer-Lambert's law, UV-VIS, fluorimetry, Atomic Absorption Spectrophotometry (AAS)	
2.2	**Microscopy:** Compound microscope: Light, Dark and Phase-contrast, Inverted	
2.3	**Centrifugation:** Principles, methodology, application; Density gradient centrifugation; Ultracentrifugation, Preparative and Analytical centrifugation	
3		**(12)**
3.1	**Electrophoretic techniques:** Principles of electrophoresis	
3.2	**Protein Gels:** Slab gel, tube: Continuous and discontinuous, PAGE;SDS- PAGE, Isoelectric Focusing and ampholytes, 2-D, Staining strategies and procedures: Coomassie Brilliant blue R/G 250, Silver, Fluorescent stains Flamingo, Oriole, SYPRO-Ruby; Stain-free gels	
Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	

References/ Readings	Colowick, S. P., Kaplan, Nathan O., Methods in Enzymology, Academic Press.	
	Norris, R., Ribbons, D.W., Molecular Cellular Microbiology. *In* Methods in Microbiology	
	Parakhia, Manoj V., Tomar, Rukam S., Patel, Sunil., Golakiya, B. A., Molecular Biology and Biotechnology: Microbial Methods	
	Wilson, K, Walker, J.: Principles and Techniques of Practical Biochemistry. Kluwer Academic Publishers	
Learning Outcomes	Explain the principles of various techniques and apply the knowledge of the techniques for designing various experiments in research and development.	

Programme: M.Sc. (Biochemistry)

Course Code: BCC 104

Title of the Course: BIOSTATISTICS [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	Basic ability to handle numbers and calculation.	
Objective:	The paper develops concepts about types of data observed in biological experiments, its handling and processing. It develops concepts of hypothesis and formulation of experiments. It gives understanding of various statistical operations needed to carryout and process the biological data.	
Content:		
1.		
1.1	**Characteristics of biological data:** Variables and constants, discrete and continuous variables, relationship and prediction, variables in biology (measurement, ranked, attributes), derived variables (ratio, index, rates), types of measurements of biological data (interval scale, ratio scale, ordinal scale, nominal scale, discrete and continuous data). **Elementary theory of errors:** exact and approximate numbers, source and classification of errors, decimal notation and rounding off numbers, absolute and relative errors, valid significant digits, relationship between number of valid digit and error, the error of sum, difference, product, quotient, power and root, rules of calculating digits.	**(03)** **(04)**
1.2	**Data handling:** Population and samples, random samples, parameter and statistics, accuracy and precision, accuracy in observations, Tabulation and frequency distribution, relative frequency distribution, cumulative frequency distribution. **Graphical representation:** types of graphs, preparation and their applications.	**(05)**
2.		
2.1	**Measures of central tendency:** characteristics of ideal measure, Arithmetic mean – simple, weighted, combined, and corrected mean, limitations of arithmetic mean; Median – calculation for raw data, for grouped data, for continuous series, limitations of median; Mode – computation of mode for individual series, by grouping method, in a continuous frequency distribution, limitations of modes; Relationship between mean, median and mode; mid-range.	**(03)**
2.2	**Measure of dispersion:** variability, Range, mean deviation, coefficient of mean deviation, standard deviation (individual observations, grouped data, continuous series), variance, coefficient of variance, limitation.	**(04)**

	Skewness – definition, positive, negative, purpose, measure, relative measure, Karl Pearson's Coefficient, Bowley's Coefficient, Kelly's Measure, Moments.	
2.3	**Correlation analysis** – Correlation, covariance, correlation coefficient for ungrouped and grouped data, Pearson's Rank Correlation coefficient, scatter and dot diagram (graphical method). **Regression analysis -** Linear and exponential function **-** examples: DNSA conversion by reducing sugar, survival/growth of bacteria, regression coefficients, properties, standard error of estimates, prediction, regression analysis for linear equation.	**(05)**
3.		
3.1	Probability: Probability, Combinatorial Techniques, Elementary Genetics, Binomial, Poisson, Normal Distributions.	**(04)**
3.2	Hypothesis Testing – parameter and statistics, sampling theory, sampling and non-sampling error, estimation theory, confidence limits, testing of hypothesis, test of significance; Students' T-test, t-distribution, computation, paired t-test.	**(04)**
3. 3	Chi-square test, F-test and ANOVA.	**(04)**
Pedagogy:	Lectures/tutorials/assignments/self-study/MOODLE/Videos	
References/ Readings	Kothari, C. R., Quantitative Techniques, Vikas Publishing House.	
	Arora, P. N. and Malhan, P. K., Biostatistics, Himalaya Publishing House.	
	Danilina, N.I., Computational Mathematics, Mir Publishers.	
	Surya, R. K., Biostatistics, Himalaya Publishing House.	
Learning outcomes	Able to collect, handle, process and present the Biological Data. Apply the principles of statistics on biological experiments.	

Programme: M.Sc. (Biochemistry)

Course Code: BCC 105

Title of the Course: Practical I

Number of Credits: 4

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that students have a basic understanding of biochemistry.	
Objective:	This course develops basic understanding and skills of various instruments and techniques in biochemistry, analytical biochemistry, enzymology and biostatistics.	
Content:		
I	**Fundamentals in Biochemistry**	**24**
1.	Standard curve for glucose by DNSA and quantitative estimation of test sample.	
2.	Comparison of colorimetric methods for protein estimation – Biuret and Folin-Ciocalteau methods.	
3.	Estimation of total sugar by anthrone method.	
4.	Estimation of amino acids (ala, tyr, trp) and protein by direct spectroscopy.	
5.	Estimation of nucleic acid by direct spectroscopy.	
II	**Enzymology**	**24**
1.	Assay of enzyme activity, rate of reaction.	
2.	Determination of specific activity.	
3.	Determination of Km, Vmax.	
4.	Purification of enzyme: salting out; dialysis; gel filtration; determination of fold purification, percentage recovery of protein.	
5.	Molecular weight determination by SDS-PAGE.	
III	**Analytical Biochemistry – I**	**24**
1.	Preparation of buffers, use of pH meter	
2.	Spectrophotometric demonstration of Beer Lambert Law and determination of extinction coefficient	
3.	Separation of lipids by reverse phase thin layer chromatography	
4.	Column chromatography of organic molecule.	

IV	**Biostatistics**	**24**
1.	Excel spreadsheet and data analysis.	
2.	Linear equation analysis (regression analysis).	
3.	Normal distribution.	
4.	Hypothesis testing.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under respective Theory Courses BCC 101-T to BCC 104-T	
Learning Outcomes	1. Skillful handling and estimating biomolecules and other metabolic products. 2. Learning techniques involved to determine enzyme activity and kinetics; purification of enzyme for further research and applications 3. Explain the principle and working of basic instruments in analytical laboratory. 4. Ability to collect data, processing and statistical interpretation of microbiology-related experiments.	

Programme: M.Sc. (Biochemistry)

Course Code: BCC 201

Title of the Course: CLINICAL BIOCHEMISTRY [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	Basic knowledge of biochemistry.	
Objective:	To develop an understanding of the metabolic disorders and basic clinical investigations and analyses of human samples.	
Content:		
1.	**Analysis of Blood, Serum and Urine**	**(12)**
1.1	Composition of Blood, Serum, Cerebrospinal Fluid and Urine	
1.2	Collection of clinical samples – blood, serum, urine; safety measures involved.	
1.3	Analysis of Blood, Serum and Urine	
A.	Blood:Haemoglobin, Total cell and Differential cell (TC/DC) counts, Erythrocyte sedimentation Rate (ESR); Clotting time. Gas transport, transport of oxygen, carbon dioxide and hydrogen by haemoglobin; blood buffers, acid-base regulation/homeostasis Glucose; Lipid profile; Urea; Gases: Oxygen and Carbon dioxide levels; Ph	
B.	Serum: Proteins, Albumin/Globulin Ratio; Bilirubin; Creatinine; Uric acid; Electrolytes; Enzymes:Serum Glutamate Pyruvate Transaminase (SGPT)/Alanine amino transferase (ALT); Serum Glutamic Oxaloacetic Transaminase (SGOT)/ Aspartate Aminotransferase (AST); Alkaline phosphatase (ALP); Lactate dehydrogenase (LDH); Creatine Phospho Kinase (CPK); gamma-Glutamyl transpeptidase (GGT); Amylase.	
C.	Urine: Colour, odour, sediment, crystals, glucose; protein/albumin.	
2.	**Metabolic Disorders**	**(12)**
2.1	Disorders in metabolism	
A.	Carbohydrate –Glucose Tolerance Test, Diabetes mellitus Type 1 and Type 2; Ketosis; Diabetic coma.	
B.	Lipids – Dyslipidemia	
C.	Proteins – Albuminuria	
D.	Blood – Anaemia: Red blood cell deficiency, haemolytic, pernicious, sickle cell anaemias; acidosis, alkalosis	

E.	Heart – Hypertension, Arterosclerosis	
F.	Liver – Hepatitis	
G.	Kidney – Water and electrolyte balance; Diabetes insipidus.	
2.2	Inborn errors of metabolism	
	Congenital metabolic disorders involving chromosomal aberrations / enzyme deficiency; newborn screening test.	
A.	Carbohydrate –Lactose intolerance, Galactosemia, Glycogen storage disease	
B.	Lipid: Lipid storage/lipidosis – Gangliosides (Brain): Tay-Sach's disease; Glucosylceramide (Lysosome): Gaucher's disease; Sphingomyelin (Lysosome): Niemann Pick disease	
C.	Amino acids –phenylketonuria	
D.	Organic Acid – alcaptonuria	
E.	Purine/pyramidine – Lesch-Nyhan Syndrome	
F.	Porphyrins – acute intermittent porphyria	
G.	Chromosome – Down Syndrome	
H.	Blood – Thallasemia, Sickle cell anaemia	
I.	Skin – Xeroderma pigmentosum	
3.		**(12)**
3.1	**Tests for diseases and/or therapeutics**	
A.	Liver Disorders and Liver Function Tests (LFT): Bilirubin metabolism and clinical assessment. Types of jaundice; Acute and chronic liver diseases: cirrhosis, viral, metabolic and drug induced. LFT: Serum Protein, Albumin and Globulin; SGPT; SGOT; ALP; Bilirubin	
B.	Kidney Disorders and Renal Function Tests (RFT) Renal threshold and clearance values, disorders of kidney, renal failure and proteinuria, renal tubular disorders. RFT: Urinalysis – Red and white blood cells; Protein – Creatinine and Albumin: Creatinine Ratios; Serum Creatinine,electrolytes and uric acid; Blood urea; Glomerular filtration rate (GFR).	
C.	Heart Ischemic heart disease. Role of enzymes/ proteins in assessment of myocardial infarction: SGOT; CPK; LDH isozyme.	
3.2	**Cancers and apoptosis**	
A.	Biochemistry of cancerous growth	
B.	Biochemistry of aging	
Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	

References/ Readings	Pattabiraman, R.N. Text book of Biochemistry, All India Publisher distribution.	
	Chatterjee, M.N., Shinde, R. Text book of Medical Biochemistry, Jaypee Publishers.	
	Vasudevan, D.M., Sreekumari, S., Text book of Biochemistry for Medical Students, Jaypee Publishers.	
	Berg, Jeremy, M., Tymoczko, John, L., Stryer L., Biochemistry, W.H. Freemann, N. York.	
	David, L.N., Michael, M.C., Lehninger, A., Biochemistry, Kalyani Publications, N. Delhi.	
	Murray, Robert, K., Bender, David A., Botham K.,M. *et al.* Harper's Illustrated Biochemistry, Appleton & Lange.	
	Kaplan, L.,A., Amadeo, J. Clinical Chemistry: Theory, Analysis, Correlation, Mousby Publisher, Missouri.	
	Chawla, R., Practical Clinical Biochemistry, Jaypee publishers Harold Varley, Guwnelock, A.H. et al. Varley's Practical Clinical Biochemistry	
Learning Outcomes	In depth knowledge on the diagnostic parameters, methods, analyses and interpretations of human clinical samples.	

Programme: M.Sc. (Biochemistry)

Course Code: BCC 202

Title of the Course: MOLECULAR BIOLOGY [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that the students have a basic knowledge of DNA (structure and replication), transcription and protein synthesis	
Objective:	This course develops concepts in molecular biology: DNA packaging, DNA damage and repair, gene structure, expression and regulation in both prokaryotes and eukaryotes	
Content:		
1.	**Genetic material, bonds, types of DNAs, DNA packaging and model organisms**	**(12)**
1.1	**Nucleic Acids, bonds, types of DNAs, DNA packaging and model organisms**	
A.	Structure of DNA and RNA.	
B.	Bondings and different types of DNA (B-DNA & Z-DNA).	
C.	DNA packaging in bacteria (Nucleoid) and viruses.	
D.	Yeast as a minimal model eukaryote.	
1.2	**Chromosomes, Genomes and it's evolution**	
A.	Fundamental functions of DNA.	
B.	Chromosomal DNA and its packaging in the chromatin fibre.	
C.	Chromatin structure, structural features (Telomere, Centromere and Repetitive sequences) of chromosomes and their functions.	
D.	Gene duplication and mutations.	
E.	**DNA Gels:** Agarose gel electrophoresis, RNA denaturing gels, Ethidium Bromide, SYBER GOLD SYBER GREEN II, DNA and RNA ladders, Tracking dyes Methylene blue, Xylene cynol	
2.	**DNA Damage, DNA Repair and Recombination**	**(12)**
2.1	**DNA damage elements/factors**	
A.	Types of DNA damage (spontaneous and induced DNA damage).	
B.	Mechanisms/pathways to remove damaged DNA: Excision repair, mismatch repair, recombination repair in *E. coli* and SOS Repair.	
C.	Role of *RecA* in DNA damage repair, Photoreactivation repair in *E. coli* involving photolyase.	
2.2	**Mechanisms of Genetic Recombination**	
A.	General and site specific recombination.	
B.	Heteroduplex DNA formation (Homologous recombination).	
C.	Synaptonemal Complex, Bacterial RecBCD system and its stimulation of chi sequences.	
D.	Role of RecA protein, homologous recombination, Holliday junctions.	

3.	**How cells read the Genome**	**(12)**
3.1	**From DNA to Proteins**	
A.	From DNA to RNA.	
B.	From RNA to Protein.	
C.	The RNA world and origin of life.	
3.2	**Gene structure and control of gene expression in Prokaryotes and Eukaryotes**	
A.	An overview of Gene expression control, DNA binding motifs in gene regulatory proteins, genetic switches and their role in control of gene expression.	
B.	Post-transcriptional controls-transcriptional attenuation, Riboswitches, Alternate splicing, RNA editing, RNA Interference.	
C.	Translation of mRNA in Prokaryotes and Eukaryotes.	
Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	
References/ Readings	Alberts, B., Johnson, A., Lewis, J., Morgan, D., Raff, M., Roberts, K. and Walter, P., Molecular Biology of the Cell, Garland Science.	
	Darnell, J. E., Lodish, H. F. and Baltimore, D., Molecular Cell Biology, Scientific American Books, Spektrum Akademischer Verlag.	
	Watson, J. D., Molecular Biology of the Gene, Pearson/Benjamin Cummings.	
	Malacinski, G.M., Freifelder's Essentials of Molecular Biology, Narosa Book Distributors Private Limited.	
	Krebs J. E., Lewin, B., Goldstein, E. S. and Kilpatrick S.T., LEWIS Genes XI., Jones and Bartlett Publishers.	
	Gardner, E. J., Simmons, M. J. and Snustad, D. P. Principles of Genetics, John Wiley & Sons.	
	Tamarin, R. H., Principles of Genetics, McGraw-Hill Higher Education.	
	Twyman, R. M. and Wisden, W., Advanced Molecular Biology: A Concise Reference, BIOS Scientific Publishers.	
	Green, M. R. and Sambrook, J., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York.	
	Davis, L. G., Dibner, M. D. and Battey, J. F., Basic Methods in Molecular Biology, Elsevier.	
	Gerhardt, P., Methods for General and Molecular Bacteriology, Elsevier.	
Learning Outcomes	Understanding of gene structure, expression and regulation of gene expression in both prokaryotes and eukaryotes for application in molecular research.	

Programme: M.Sc. (Biochemistry)

Course Code: BCC 203

Title of the Course: ANALYTICAL BIOCHEMISTRY – II

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that students have a basic knowledge of fundamentals in biochemistry and certain basic techniques in routine laboratory analysis.	
Objective:	This course develops concepts in techniques and instruments required for macromolecule structure and interactions and other techniques such as tissue culture, tracers for metabolic pathways.	
Content:		
1		**(14)**
1.1	**Separation techniques**: Electrophoresis: Capillary, PFGE, gradient gels, DGGE, TGGE	**(04)**
1.2	**Techniques for Macromolecule structure and Interactions:** Principles, application and profile analysis of spectra of FTIR, NMR,MS, GCMS, LCMS, MALDI-TOF, ICP-MS, X-ray diffraction, optical rotatory dispersion, circular dichroism	**(10)**
2		**(12)**
2.1	**Cell and tissue culture techniques:** Stem cells, typical cell lines, establishment of primary & secondary cell lines, monolayer & suspension cultures, plant tissue culture	**(05)**
2.2	**Bioimaging:** Principles, application and profile analysis: Epifluorescence and immuno-microscopy, confocal scanning, AFM, optical tweezers, SEM, TEM	**(07)**
3		**(10)**
3.1	**Radioisotopes:** Stable and radio isotopes, Disintegration kinetics, Radio-activity counters – GM Counter, Scintillation Counter, Autoradiography, radiorespirometry, Tracer techniques for metabolic pathways	
Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	

References/ Readings	Sansonetti, P., & Zychlinsky, A, Molecular Cellular Microbiology, In: Methods in Microbiology, Volume 31.	
	Norris, R., Ribbons, D.W. Molecular Cellular Microbiology. *In* Methods in Microbiology	
	Sidney P., Colowick & Nathan O. Methods in enzymology. Volume IV: Edited by Kaplan, McCollum Pratt Institute, Johns Hopkins University, Baltimore, Maryland. Academic Press Inc., New York, New York.	
	Wilson, K & Walker, J.: Principles and Techniques of Practical Biochemistry. Kluwer Academic Publishers	
	Colowick, S.P. & Kaplan, N.O., Methods in Enzymology, Volume 2.	
	Parakhia, M.V, Tomar, R. S, Patel, S., & Golakiya, B. A., Molecular Biology and Biotechnology : Microbial Methods	
Learning Outcomes	Explain the principle and applications of various instruments used in research and development of chemical- or bio-molecules.	

Programme: M.Sc. (Biochemistry)

Course Code: BCC 204

Title of the Course: IMMUNOLOGY-I

Number of Credits: 2

Effective from Academic Year: 2018-19

Prerequisites	Basic understanding of pathogens, blood cells, and human physiology.	
Objective:	The course develops concepts in immunology including cells and organs of the immune system, complement, antigen-antibody interactions	
Content:		
1.		**(12)**
	Immunity classification – innate and acquired immunity. Cells and organs of immune system, organisation of lymphatic system Macrophage activation; phagocytosis Complement system: Complement fixation via classical and alternative pathway and its regulation, components of cascade – their structures and functions, complement fixation test Cell mediated and humoral immunity. Primary and secondary immune response	
2.		**(12)**
	Antigens: definition, haptens, antigenic determinants, polysaccharides, lipids, nucleic acids; Immunogen Antibodies: immunoglobulins (structure, classes and properties); antibody dependent cell cytotoxicity (ADCC) Antigen – antibody reactions: *in vitro* precipitation, agglutination, immunofluorescence, immunodiffusion, immunoprecipitation, immunoelectrophoresis, ELISA, RIA. Types and functions of T Cells Inflamation Hypersensitivity reaction and autoimmune disorders: definitions Immunohaematology: Blood group systems – MN, Rh, ABO; hemolytic disease of new born	
Pedagogy:	Lectures/tutorials/assignments/self-study	
References/ Readings	Roitt, I., Peter Delves., Roitt's Essential Immunology.	
	Kindt, T.J., Osborne, B.A., Goldsby R.A. & Kuby Immunology.	
	Barrett, J.T., Microbiology and Immunology Concepts.	
	Goldsby, R. A., Kindt, T. J., Kuby, J. & Osborne, B.A. Immunology.	
	Benjamini, E., Coico, R. & Sunshine, G., Immunology A Short Course.	

	Sompayrac, L.M., How the Immune System Works.	
	Sharon, J., Basic Immunology.	
	Abbas, A.K., Lichtman, A.H., & Pillai, S., Cellular and Molecular Immunology.	
	Janeway, C.A., Walport, M. J. & Travers, P.,. Immunobiology: The Immune System in Health and Disease.	
Learning Outcomes	1. A better understanding of cells, organs and functions of immune system, role of complement proteins 2. An understanding of antigen-antibody interactions and various serological techniques for immunological research	

Programme: M.Sc. (Biochemistry)

Course Code: BCC 205

Title of the Course: MEMBRANE BIOCHEMISTRY

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	Basic knowledge on cell structure in living organisms.	
Objective:	To develop an understanding of the structure and functions of cell membranes in living systems.	
Content:		**(12)**
1.	**Composition and architecture of membranes and membrane dynamics** Lipid bilayer, membrane protein, membrane carbohydrate, Phases of membrane and phase transition, lipid- lipid interaction, lipid- protein interaction. Role of Lipid raft and Caveolins in membrane function.	
2.	**Solute transport across the membrane** Passive and active transport, transporter protein (Channel protein and carriers).	
3.	**Membrane receptors**: Types of receptor, Molecular mechanism of signal transduction: Recognition of receptors and mode of action.	
Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	
References/ Readings	Giese, A. G & Sauders, W. B. Cell Physiology. Co publication.	
	De Robertis EDP & De Robertis EMP. Cell and Molecular Biology	
	Nelson D.L, Cox M M., Freeman W. H. & Co., Lehninger Principles of Biochemistry	
	Findlay, J. B. C., Evans, Biological Membranes: a practical approach. W.H. IRL Press.	
	Lodish, H., Baltimore, D., et al. Molecular Cell Biology. W. H. Freeman Publication.	
	Cooper, G. M. & Hausman, R. E.,The Cell: a molecular approach. Sinauer Assoc. Incorporated	
	Zubay, G. & Wesley, A. Biochemistry.	
Learning Outcomes	At the end of the course the students will have an in-depth knowledge on the composition of cell membranes and it's functional role towards signaling and transport in human body.	

Programme: M.Sc. (Biochemistry)

Course Code: BCC 206

Title of the Course: Practical II

Number of Credits: 4

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that students have a basic knowledge of fundamentals in biochemistry.	
Objective:	This course develops basic understanding and skills of various instruments and techniques in clinical biochemistry (analysis of clinical samples), molecular biology (DNA isolation, purification and amplification) and analytical biochemistry (HPLC, IR, NMR). The course also develops concepts and techniques for various serological testing.	
Content:		
I	**Clinical Biochemistry**	**27**
1.	Blood: Haemoglobin (Hb); Total cell and Differential cell (TC/DC) counts; Erythrocyte sedimentation Rate (ESR); Clotting time; Pressure (using Sphygomanometer).	
2.	Blood (a) Glucose (b) Blood cholesterol	
3. 4.	Liver function tests Serum (a) SGPT; (b) SGOT; (c) Bilirubin Renal function test (a) Blood Urea; (b) Serum Creatinine	
5.	Full urine report (a) Physical examination: Colour, odour, sediment, crystals (b) Glucose; albumin	
II	**Molecular Biology**	**24**
1.	Isolation of genomic DNA of bacterial cells, estimation of quantity and purity of DNA by spectrophotometry, and agarose gel electrophoresis.	
2.	PCR amplification of a specific gene using genomic DNA as a template and agarose gel analysis of PCR product to determine amplicon size.	
III	**Analytical Biochemistry – II**	**24**
1.	Visualization of cells by Light and Phase contrast microscopy	
2.	Measurement of fluorescence using Spectrofluorimeter.	
3.	Separation of molecules by HPLC.	
4.	Demonstration of: GC, IR, NMR, and Mass/MALDI-TOF.	
5.	Elucidation of structure of cellular metabolites using IR, NMR and Mass profiles	

IV	**Immunology - I**	**21**
1.	Blood grouping determination	
2.	Ouchterlony test	
3.	Immunodiffusion slide techniques	
4.	Widal Test	
5.	ELISA	
6.	Rapid Tests [POCTs] for	
A.	Malarial antigens Pv/Pf	
B.	Dengue IgM and IgG antibodies	
C.	Hepatitis HBsAg	
D.	Human Luteinising hormone	
7.	Rheumatoid Arthritis Factor determination	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under respective Theory Courses BCC 201-T to BCC 204-T	
Learning Outcomes	1. Estimation of different physiological parameters from human samples and clinical interpretation. 2. To learn techniques involved in genomic DNA isolation and PCR amplification for it's use in molecular research. 3. Explain the working of various instruments and interpretation of data obtained from a few of them such as SEM images, spectra obtained after various spectroscopic analysis. 4. Kit based methods for serological testing for rapid identification of various known disease conditions. 5. Concept and techniques for various immunological assays.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 101

Title of the Course: HORMONES

Number of Credits: 2

Effective from Academic Year: 2018-19

Prerequisites	Basic knowledge on cell signaling in animal systems.	
Objective:	To develop a robust knowledge on human endocrine system including it's role in physiology, mechanism of actions, regulation and clinical disorders.	
Content:		
1.		**(12)**
1.1	Introduction: History, endocrine glands, chemical messengers	
1.2	Classification of hormones	
1.3	Receptor type, Intracellular receptors - Steroid hormone receptors, Thyroid hormone receptors, sensitization & desensitization of receptors	
1.4	Stimulus of hormones, regulation of biosynthesis and release, feedback mechanism.	
1.5	Cell signaling and Mechanism of secretion of hormone, physiological and biochemical actions, pathophysiology – hyper- and hypo- secretion. 1. Hypothalamic Hormones - CRH, TRH, GnRH, PRL/PRIH, GHRH/GHRIH. 2. Pituitary Hormones - Anterior Pituitary hormones - Growth hormone, Prolactin, POMC peptide family, LH, FSH, TSH; Posterior Pituitary - Vasopressin, Oxytocin. 3. Pancreatic Hormones - Insulin, Glucagon. 4. GI tract Hormones - Gastrin, Secretin, CCK, GIP, Ghrelin.	
2.		**(12)**
2.1	Adrenal Cortex Hormones - Aldosterone (renin angiotensin system) & cortisol; Pathophysiology - Addisons disease, Conn's syndrome, Cushings syndrome; Hormones of Adrenal Medulla, Epinephrine and norepinephrine.	
2.2	Hormones regulating Ca2+ Homeostasis - PTH, Vit D, Calcitonin; Pathophysiology - Rickets, Osteomalacia, Osteoporosis.	
2.3	Reproductive Hormones - Male and female Sex hormones, interplay of hormones during reproductive cycle, Pregnancy, Parturition and Lactation; Oral Contraceptives.	
2.4	Endocrine disorders: Gigantism, Acromegaly, dwarfs; Pathophysiology - Diabetes insipidus, Thyroid Hormone (include biosynthesis) - Goiter, Graves' disease, Cretinism, Myxedema, Hashimoto's disease.	
2.5	Other organs with endocrine function - Heart (ANP), Kidney (erythropoietin), Liver(Angiotensinogen, IGF-1), Adipose tissue (Leptin, adiponectin); Growth factors: PDGF, EGF, IGF-I,II.	

Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	
References/ Readings	Berg, J.M, Tymoczko, J. L., Stryer, L., Biochemistry.	
	Mathews, C.K., van Holde, K.E. & Ahern, K.G. Biochemistry.	
	Nelson, C., Lehningers Principles of Biochemistry.	
	Norman A. W., Gerald Litwack. 1997. Hormones	
	David, G. & Dolores, S., Greenspan's Basic and Clinical Endocrinology	
	Moore, T.C. Biochemistry and Physiology of Plant Hormones	
Learning Outcomes	At the end of the course the students will have a thorough knowledge and understanding of chemical signaling through different hormones occurring in human system.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 102

Title of the Course: NEUROCHEMISTRY

Number of Credits: 2

Effective from Academic Year: 2018-19

Prerequisites	Basic knowledge on biomolecules and human body.	
Objective:	To develop a basic understanding of structure and organization of nervous system, sense organs and their functions.	
Content:		
1.		**(12)**
1.1	Organization of Nervous system, CNS, ANS, PNS, Blood Brain Barrier.	
1.2	Nerve, neuron, glial cells and synapse structure.	
1.3	CSF composition, function and circulation	
1.4	Biochemical composition of Nerve tissue. Carbohydrates, lipid and amino acid	
1.5	Transport of amino acid, protein, nucleic acid metabolites.	
1.6	Energy metabolism in Brain	
1.7	Transmission across the synapse, membrane potential in steady state, Action potential generation and propagation, pre and post synaptic events	
1.8	Synaptic transmission	
2.		**(12)**
2.1	Neurotransmitters, neuromodulators, neuropeptide turnover, metabolism regulation	
2.2	Types of neurotransmitter receptors, receptor- effector mechanisms, properties of Cholinergic receptor, acetylcholine receptors, acetylcholine esterase, Nicotinic receptors, Glutamate receptors, GABA and Glycine receptors, Catecholamine receptors, monoamine oxidase inhibitors. Serotonin receptors, antagonists and re-uptake inhibitors, properties. Nitric oxide in cells.	
2.3	Sensory modalities and sensory circuits, sensory perception of taste,vision, odor, hearing and touch.	
2.4	Biochemistry of memory	
2.6	Biochemistry of mental and neurodegenerative disease, Depression, Schizophrenia, Alzheimer's disease, Huntington's disease, senile dementia. Movement disorders, Parkinson's disease.	
2.7	CNS active drugs, their classification and mode of action. Conventional antipsychotics. Anxiolytics, Antidepressants.	
2.8	Drugs of abuse and their mechanism of action: morphine, alcohol	

Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	
References/ Readings	Siegel, G. J., Agranoff, B. W., Albers, W. S., Fisher, K. & Uhler, M. D., Basic Neurochemistry	
	Brunton, L., Chabner, B. & Knollman, B., Goodman and Gilman's, The Pharmacological Basis of Therapeutics.	
	Smith, C.U.M., Elements of Molecular Neurobiology.	
	Kandel, E. Schwartz, J., & Jessell, T., Principles of Neural Science.	
Learning Outcomes	At the end of the course the students will have an in-depth knowledge and understanding about the basic organization of nervous system in humans and the basic functions along with the biochemistry of different diseases related to nervous system and their treatments.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 103

Title of the Course: GENETIC ENGINEERING (T)

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	Knowledge of bacterial and animal genetics, basic molecular and microbiology is a prerequisite.	
Objective:	This course aims to introduce the fundamental tools and techniques required for molecular cloning, with emphasis on DNA editing to protein expression in wide variety of hosts. Applications of genetic engineering in agriculture, therapeutics and industry will be covered.	
Content:		
1.	**Introduction to genetic engineering and tools involved in genetic manipulation**	**(16)**
1.1	**Introduction to genetic engineering**	
1.2	**Tools and techniques involved in genetic manipulation**	
A.	DNA modifying enzymes: restriction endonucleases, exonucleases, DNA ligases (T4 DNA Ligase and *E.coli* DNA ligase), Terminal DNA transferase, DNA Polymerases (Taq, Amplitaq, vent, Exo-vent, Pfu, T4 etc), Reverse transcriptase, T4 polynucleotide kinases, Alkaline phosphatase, S-1 Nuclease, Mung bean nuclease, RNases.	
B.	Gene cloning systems/Hosts: Gene cloning in *E. coli* and other organisms such as *Bacillus subtilis*, *Saccharomyces cerevisiae* and other microbial eukaryotes.	
C.	Cloning vectors: plasmid (pUC19, pBR 322), λ phage based vectors, cosmid vectors, Phasmid vectors, shuttle vectors, High capacity Cloning vectors (BAC and YACs).	
D.	Sequencing Vectors: pUC 19 and M-13 Phage vector.	
E.	Expression vectors: Prokaryotic (pET, pGEX-2T and others). Characteristics of expression vectors: strong bacterial and viral promoters (lac, trp, tac, SV 40, T7, T3) for induction of gene expression.	
F.	Construction of rDNA molecule and it's transfer to appropriate host (bacteria/yeast/plant cell/animal cell) using a suitable technique: transformation, electroporation, transfection, gene gun.	
G.	Other Recombinant DNA techniques: Use of radioactive and non-radioactive nucleotides for DNA probe preparation and detection of hybrids, Gel retardation assay, Restriction mapping, RFLP, PCR, RT-PCR, Real time PCR, Microarray, DNA sequencing using Sanger's Dideoxy chain termination method and automated sequencer; chromosome walking, Hybrid release and hybrid arrest translation to screen clones, site directed mutagenesis.	

2.	**Application of Genetic Engineering in Biology, forensics and medicine**	**(10)**
2.1	**Application of genetic engineering in DNA diagnostics and production of recombinant drugs, vaccines and hormones**	
A.	Screening of Genetic diseases using DNA probes (DNA diagnostics).	
B.	Production of recombinant proteins and drugs (insulin, tissue plasminogen activator, erythropoietin, human growth hormones, Antibodies (including bispecific antibodies), vaccines, interferons, DNA vaccines: merits and demerits, Edible vaccines- merits and demerits.	
C.	Application of recombinant DNA technology in solving parental dispute and criminal cases (DNA finger printing).	
2.2		
A.	Manipulation of gene expression in Prokaryotes; , gene expression from strong and regulatable promoters, Developing fusion proteins and separation of cloned protein by protease induced cleavage.	
B.	Genetic manipulation to increase recombinant protein stability and secretion using signal sequences.	
3.	**Application of Genetic Engineering in Agriculture**	**(05)**
3.1		
A.	Development of transgenic crops resistant to insect pests, bacterial, fungal and viral pathogens.	
B.	Strategies to develop transgenic crops and horticulture plants using various tools of recombinant DNA technology: Development of Bt Brinjal, Golden Rice and flavr savr tomato.	
C.	Importance of *Agrobacterium tumefaciens* in genetic manipulation of plants (Role of Ti plasmids), Role of *Bacillus thuringiensis* (*Bt* genes) to develop insect pest resistant crops.	
4.	**Application of Genetic Engineering in Industry**	**(02)**
4.1	**Genetic engineering of microbes for production of enzymes, biomolecules and fermentation products.**	
A.	Genetic manipulation of microbes to over-produce industrially valuable enzymes.	
B.	Production of microbial SCPs.	
5.	**Application of Genetic engineering in Bioremediation, Biorecovery and Biomonitoring of xenobiotics, metals and organometals.**	**(03)**
5.1	**Genetic engineering of microbes for bioremediation and biomonitoring of toxic environmental pollutants, Biohydrometallurgy**	
A.	Microbial bioremediation of xenobiotics by recombinant microbes.	
B.	Bioremediation of toxic heavy metals and organometals by recombinant microbes.	
C.	Biohydrometallurgy using recombinant microbes for recovery of precious metals.	

Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	
References/ Readings	Old, R. W. and Primrose, S. B., Principles of Gene Manipulation: An introduction to Genetic Engineering, University of California Press.	
	Glick, B. R., Pasternak, J. J. and Patten, C. L., Molecular Biotechnology: Principles and Applications of Recombinant DNA, ASM Press.	
	Williamson, R., Genetic Engineering, Volumes 4-7, Academic Press.	
	Glover, D. M., Gene cloning: The Mechanics of DNA Manipulation, Springer-Science+Business Media, B. V.	
	Green, M. R. and Sambrook, J., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York.	
	Davis, L. G., Dibner, M. D. and Battey, J. F., Basic Methods in Molecular Biology, Elsevier.	
	Gerhardt, P., Methods for General and Molecular Bacteriology, Elsevier.	
	Grinsted, J. and Bennett, P. M., Methods in Microbiology, Vol. 21, Plasmid Technology, Academic Press.	
Learning Outcomes	1. Understanding of tools and techniques involved in molecular cloning. 2. Overall understanding about the importance of GMOs, GMPs and other engineered products in science and industry.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 104

Title of the Course: GENETIC ENGINEERING [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	Theoretical understanding of chromosomal DNA, plasmid DNA, selection media and preparatory microbiology is needed.	
Objective:	To have a hand on experience on plasmid DNA isolation, modification and insertion; basically a DNA cut-copy-paste technology that forms the basis of any genetic engineering wet lab.	
Content:		**(24)**
1.	Restriction mapping of bacterial plasmid and agarose gel analysis.	
2.	Preparation of competent cells and transformation of *E. coli* host with plasmid DNA using heat shock method and electroporator; confirmation of positive transformants.	
3.	Assessment of DNA ligation activity of T4 DNA ligase.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course MIO 105-T	
Learning Outcomes	1.A practical understanding of how the DNA modifying enzymes work. 2. Hand-on experience with plasmid and bacterial host.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 105

Title of the Course: NUTRITION AND FOOD BIOCHEMISTRY [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	Basic knowledge in Biochemistry and Microbiology.	
Objective:	To learn about the basic nutrients in foods; deficiency diseases and food preservation.	
Content:		
1	**Vitamins, Minerals, Water, Fibre**	**(15)**
1.1	Fat soluble vitamins: physiological role, deficiency disorders, toxicity.	
1.2	Water soluble vitamins: physiological role, deficiency disorders, toxicity.	
1.3	Mineral metabolism: macronutrients – calcium, magnesium, sodium, potassium, phosphorus, sulphur and chlorine; trace elements – essential and non-essential; physiologic role and deficiency disorders.	
1.4	Dehydration	
1.5	Fibre and its significance in diet.	
2	**Nutritional Disorders and Diseases**	**(09)**
2.1	Protein malnutrition disorders – Marasmus, Kwashiorkar.	
2.2	Carbohydrate excess and imbalanced diets.	
2.3	Eating disorders – Anorexia nervosa, Bulimia	
2.4	Starvation	
3	**Food Spoilage and Food Preservation**	**(12)**
3.1	Forms of food spoilage – physical, chemical, microbiological.	
3.2	Predictive food microbiology - Types of foods and their spoilage	
3.3	Factors affecting the growth and survival of microorganisms in foods: Intrinsic and extrinsic	
3.4	Food preservation technologies: Heat processing, low temperature storage, control of water activity, irradiation, high pressure processing, modified atmospheres, preservatives: chemicals, natural organic molecules (nisin) and enzymes	
3.5	Quality control and Validation	
A.	Microbiological examination of foods	
B.	Plant sanitation	
C.	Hazard Analysis and Critical Control Point (HACCP) concept.	
3.6	Good Manufacturing Practice (GMP) and Quality Systems	

Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	
References/ Readings	Frazier, W. C & Westhoff, D. C., M. C. Food Microbiology. Graw-Hill Companies, Inc., New York.	
	Hayes, P. R. Food Microbiology and Hygiene. Chapman & Hall, London	
	Montrille, T. J. & Matthews, K. R, Food Microbiology., ASM Press, NW Washington, USA. Jay, J.M., Loessner, M.J., Golden, D.A., Modern Food Microbiology. Springer Science, New York.	
	Adams, M. R. & Mass, M. O. Food Microbiology. New Age International Ltd Publishers, New Delhi.	
	Mudambi .R. Sumathi & Rajagpal M.V, "Foods & Nutrition", Willey Eastern Ltd, Second Edition, New Delhi	
	Passmone R. & Eastwood M.A,"Human Nutrition and Dietetics",English language book Society/Churchill Livingstone,Eigth edition, Hong Kong	
	Ray B., & Bhunia A., Fundamental Food Microbiology. CRC Press, Taylor Francis Group New York	
Learning Outcomes	Develop a strong knowledge and understanding on the basic nutrients of foods; deficiency diseases and food preservation mechanisms.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 106

Title of the Course: NUTRITION AND FOOD BIOCHEMISTRY [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	Basic knowledge in Biochemistry and Microbiology.	
Objective:	To learn about different types of food analysis including nutrient content, microbiological examination and spoilage.	
Content:		**(24)**
1.	Estimation of vitamin C	
2.	Estimation of minerals such as magnesium and ions such chloride	
3.	Examination of foods and determination of food spoilage microorganisms	
A.	Biochemical reactions: enzymatic browning of fruits; auto-oxidation; rancidity of fats	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course BCO 104-T	
Learning Outcomes	Hands-on experiences on analyses of food samples for nutrients, microbiological tests and testing for spoilage.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 107

Title of the Course: MICROBES IN HEALTH AND DISEASE [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	Basic knowledge in cell biology.	
Objective:	Develop concepts about pathogens and the process of infection.	
Content:		
1	**Introduction**	**(03)**
1.1	Prokaryotic and Eukaryotic cell structure, organelles and their function	
1.2	Microorganisms: Bacteria; Fungi; Viruses	
1.3	Sterilization and Disinfection: Physical sterilants; Gas vapour sterilants; Chemical sterilants	
2	**Bacteria**	**(11)**
2.1	**Growth**	
A.	Bacterial structure; Gram characteristics	
B.	Nutritional requirements	
C.	Respiration (aerobic and anaerobic) and Fermentations	
D.	Growth cycle; Biphasic growth; Continuous culture; Synchronous growth	
E.	Toxins, Enzymes; Pigments	
2.2	**Pathogens and Chemotherapy**	
A.	Commensals	
B.	Pathogens; Opportunistic pathogens; Nosocomial infections.	
C.	Infections: Gastroenteric (*E. coli, H. pylori*); Respiratory (Streptococcal); Skin (Staphylococcal); Wound infections; Deep-seated (on prosthesis/ post-surgical intervention).	
D.	Secondary infections.	
E.	Antibacterial agents; Drug resistance; Chemotherapy	
3	**Fungi**	**(11)**
3.1	Structure and Growth	
3.2	Secondary metabolites: pigments; mycotoxins; antibiotics	
3.3	Mycoses and Chemotherapy	
3.4	Applications of fungi – enzymes, bioremediation	

4	**Viruses**	**(11)**
4.1	Structure and Classification; Plant and animal viruses	
4.2	Viral multiplication	
4.3	Infections and therapy: Herpes group; Hepatitis group; H1N1 series; Rabies; HIV	
Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	
References/ Readings	Davis, B.D., Dulbecco, Renato, Eisen, Herman N., Ginsberg, Harold S., Microbiology, Lippincott Williams and Wilkins	
	Ingraham, John L., Ingraham, Catherine A., Introduction to Microbiology, Thomas Asia.	
	Pelczar Microbiology, Tata McGraw-Hill Education	
	Madigan, Michael T., Martinko, John M., Stahl D., Clark D. P., Brock Biology of Microorganisms, Benjamin Cummings (editor)	
	Moat, Albert G., Foster, John W., Spector, Michael P., Microbial Physiology. John Wiley	
	Stanier, R.Y., General Microbiology.	
Learning Outcomes	Explain the modes of infection of different groups of pathogens.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 108

Title of the Course: MICROBES IN HEALTH AND DISEASE [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	Basic knowledge in cell biology.	
Objective:	Develop techniques in handling of pathogens.	
Content:		**(24)**
1.	Gram character of bacteria.	
2.	Bacterial growth curve.	
3.	Growth of bacterial pathogens on selective media.	
4.	Antibiotic sensitivity test for bacterial pathogens.	
5.	Study and identification of fungi.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under respective Theory Courses BCO 105-T	
Learning Outcomes	Apply basic microbiological techniques in characterization of pathogens.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 109

Title of the Course: DRUG METABOLISM

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	The students should have basic knowledge about human physiology.	
Objective:	To introduce concepts of drug administration, metabolism and monitoring.	
Content:		**(12)**
1.	**Drugs**	
	Drugs – Definition; types – therapeutic, drugs of abuse, poisons. Routes of drug administration Absorption and distribution of drug through organ /tissue - factors affecting distribution Physicochemical properties of drugs, organ/tissue size, blood flow to the organ, physiological barriers to the distribution of drugs, drug binding blood/ tissue/ macromolecules. Protein/tissue binding of drugs – factors affecting protein binding of drugs, significance and kinetics, tissue binding of drugs	
2.	**Metabolism**	
	Biotransformation of drugs Organs of drug metabolism: hepatic and extrahepatic Mechanism – inactivation, bioactivation, reactive intermediates, Cytochrome P450 I (CYP I), Cytochrome P450 II (CYP II), and oxidation enzymes, epoxide hydrolase, quinoneoxidoreductation, conjugation enzymes. **Phase 1**: CYP-Catalyzed: Hydroxylation (Primarily at C, N, some at S), Dealkylation (N- and O-dealkylation), Deamination, Epoxidation, Reduction. Non-CYP-Catalyzed: Oxidation (Alcohol and Aldehyde Dehydrogenase, Flavin-Containing Monooxygenase, Monoamine Oxidase), Reductase (Quinone Reductase), Hydrolysis (Esterases, Amidases, Epoxide Hydrolase)	
	Phase 2: Glucuronidation, Sulfation, Acetylation, Glycine conjugation (minor), Glutathione conjugation (toxic substances). Extrahepatic metabolism. Excretion of drugs: renal excretion, factors affecting renal excretion, nonrenal routes of excretion & factors affecting excretion and enterohepatic circulation. Factors affecting biotransformation. Significance of drug metabolism Drug – drug interaction	

3.	**Genetic variation in drug response and toxicity**	
	Pharmacogenetics: a tool for identifying genetic factors in drug dependence and response to treatment	
4.	**Therapeutic drug monitoring**	
	A prioiri and *a posteriori* drug monitoring ; Characteristics of drugs subject to monitoring	
Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	
References/ Readings	F. J., Tukey, R. H., Drug metabolism. Gonzalez,. In: Brunton, L. L., Chabner, B., Knollmann, B. C., (Eds.), Goodman & Gilman's The pharmacological basis of therapeutics, McGraw Hill Medical.	
	Klaassen, C. D., Amdur, M. O. & Doull., Casarett and Doull's Toxicology. J. Macmillan publishing company, New York.	
	Hayes, A. W., Principles and methods of toxicology. Raven press, New York	
	Paradkar A. R., Biopharmaceutics and Pharmacokinetics. Pragati Books Pvt. Ltd.	
	Shargel, L., Wu-Pong, S. & Yu, A. Applied biopharmaceutics and pharmacokinetics, McGraw Hill, New York	
	Brahmankar, D. M. & Jaiswal S. B., Biopharmaceutics and Pharmacokinetics. Vallabh Prakashan, New Delhi	
Learning Outcomes	Apply this knowledge to monitoring of drugs.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 110

Title of the Course: IMMUNOLOGY II

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	The Core paper, Immunology I is necessary.	
Objective:	The course develops the advanced understanding of innate and adaptive immune system (phagocytosis, immunoglobulin domain, gene organization, ontogeny and development of B and T cells) and various immunological techniques	
Content:		
1.		
1.1	Phagocytosis – Cell surface receptors/markers and their role, killing mechanisms; NK cells – Cell to cell recognition for normal and modified cells, receptors, initiation of apoptosis and killing of target cells, malfunctioning of NK cells; role of mast cells in immunity.	**(05)**
1.2	Concept of immunoglobulin domain, distribution of immunoglobulin domain, superfamily member, structure and function of TCR, diversity of antigen binding domain, concept of segmented gene, gene organisation of Ig and TCR, generation of gene during differentiation and development of B and T Cells, expression of Ig and TCR Cistrons, class switch and regulation of expression, B and T Cell ontogeny.	**(05)**
1.3	Major Histocompatibility Cluster – Introduction to MHC I, II and III, structure and function of MHC I and II, distribution and recognition of MHC I and II, gene organisation and concept of polymorphism, expression and its regulation, processing of extracellular antigen by APC, presentation of intracellular antigen by nucleated cells, recognition of MHC I and II by TCR/CD3 complex; Members of MHC III and their roles (in brief).	**(05)**
2.		
2.1	Ontogeny of T- and B-cells, immunocompetent T and B cells, recognition, signalling and activation of T cells by APC, control and regulation of activated T-Cells, B-cell activation – Type 1 thymus-independent antigen, Type 2 thymus-independent antigen, thymus dependent antigen, co-operation with T-cells and activation of resting B-cells, antigen processing by B-cells, stimulation by cross-linking surface Ig.	**(05)**
2.2	Cytokine as messengers, receptor for cytokine – gp130 subfamily, beta-c and gamma-c receptor subfamily, signal transduction and effects, network interactions; TH1 and TH2 responses; Cytokine mediated chronic inflammatory response; Killer T Cell and its regulation; effect of antigen dose and maturation of affinity of antibodies; role of memory cells.	**(05)**

2.3	Antigen as major factor in control, feedback control of antibody production, T cell regulation – T-helper cells, T-cell suppression; Idiotypic networks, influence of genetic factors, immune regulation through hormone; T-cell tolerance.	**(04)**
3.		
3.1	Concept of inflammation (self-revision), complement fixation (self-revision), defence against intracellular bacterial pathogen, immunity to viral infection, immunity to fungi, immunity to parasitic infections; Passively acquired immunity, vaccination.	**(03)**
3.2	Immuno-techniques: Antigen antibody interactions in solution (self revision), identification and measurement of antigen (self revision), epitope mapping, hybridoma technology and monoclonal antibody revolution, catalytic antibodies, engineering antibodies, antigen-antibody based affinity chromatography (revision if done in techniques), isolation of leukocyte and subpopulations, localization of antigen *in cyto* and *in tissue*.	**(04)**
Pedagogy:	Lectures/tutorials/assignments/self-study/Moodle/videos	
References/ Readings	1. Goldsby, R. A., Kindt, T. J. and Osborne, B. A., Kuby Immunology. W.H. Freeman 2. Bona, C. A. and Bonilla, F. A., Textbook of Immunology, Fine Arts Press 3. Janeway, C. A., Travers, P., Walport, M. and Shlomchik, M. J., Immunobiology, Garland Science. 4. Delves, P., Martin, S., Burton, D. and Roitt, I., Roitt's Essential Immunology. Wiley-Blackwell. 5. Chakraborty, P. and Pal, N. K., Manual of Practical Microbiology and Parasitology, New Central Book Agency (P) Ltd, Delhi, India. 6. Goldsby, R. A., Kindt, T. J. and Osborne, B. A., Kuby Immunology. W.H. Freeman 7. Bona, C. A. and Bonilla, F. A., Textbook of Immunology, Fine Arts Press 8. Janeway, C. A., Travers, P., Walport, M. and Shlomchik, M. J., Immunobiology, Garland Science. 9. Delves, P., Martin, S., Burton, D. and Roitt, I., Roitt's Essential Immunology. Wiley-Blackwell. 10. Chakraborty, P. and Pal, N. K., Manual of Practical Microbiology and Parasitology, New Central Book Agency (P) Ltd, Delhi, India.	
Learning Outcomes	1. Explains the mechanisms of immunological responses. 2. Apply the principles of cellular ontogeny and the gene rearrangement to understand the novel and complex immune system.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 111

Title of the Course: BIOCHEMISTRY OF ENVIRONMENTAL POLLUTION AND REMEDIATION [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that the students have a basic knowledge of environment pollutants and biogeochemical cycles (water, O, C, N, S, P)	
Objective:	This course develops concepts in Environmental Pollution (Impact on air, water and soil), role of microorganisms in biogeochemical cycles and bioremediation of pollutants.	
Content:		
1.	**Environment and Pollutants**	**(14)**
	Environment: Atmosphere, soil, aquatic – fresh water, marine systems; biogeochemical cycles. Pollutants: classification, toxicity, synergistic or antagonistic action. Eco-toxicology: concept of permissible limits, ED50 & LD50; acute and chronic exposures; biochemical effects and genotoxicity. Monitoring of pollution using indicator microorganisms, biosensors: genetically modified organisms and enzymes Significance of dissolved oxygen, BOD, COD. Environment protection regulations, impact assessment and standards	
2.	**Impact of environmental pollution**	**(14)**
	Atmosphere Greenhouse gases and CFCs – sources and effect on the ozone layer; consequences; concept of carbon credit. Atmospheric particulate matter and smog – effect on respiratory system Elements such as asbestos, lead – toxicity and occupational hazards. Soil Xenobiotics, agricultural chemicals, improper waste disposal Hydrocarbons: petroleum and polynuclear aromatics such as naphthalene, benzo-pyrene, solvents, pesticides, lead and other heavy metals – significance on health. Aquatic – fresh water, marine systems. Discharge of industrial effluents such as mining, metals, pesticides, textiles, thermal waters, aquaculture, sewage; oil spills – impact on aquatic life and the food chain; consequences on human health.	
3.	**Remediation of waste**	**(08)**
	Treatment of waste Concepts of Reuse, Recycle, Recovery. Introduction:Waste water/ sewage treatment, Solid waste management, Hospital waste management	

	Bioremediation : Concept and technologies. Biological systems – plants, bacteria and fungi; microbial consortia. Microbial processes – enzymic transformations, co-metabolism, microbial adhesion, biofilms, production of extracellular polymers and emulsifiers. Removal of metal pollutants through sedimentation, sorption, precipitation, speciation conversion	
Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	
References/ Readings	Dara, S.S., A text book of Environmental Chemistry and Pollution Control. S.Chand Publishers	
	E. Enger, E. D., Smith, B. E., Environmental Science: A study of Interrelationships, WCB publication, McGraw-Hill Higher Education.	
	Khopkar, S. M., Environmental Pollution Analysis. John Wiley & Sons.	
	Mitchell, R. & Cu, J. D., Environmental MicrobiologyWiley-Blackwell Publication	
	Ramesh, K. V., Environmental Microbiology. MJP Publishers, India.	
	Maier, R., Pepper, I. & Gerba, C., Environmental Microbiology. Academic Press.	
	Moore J. W. & Moore, E. A., Environmental Chemistry. Elsevier.	
	Jadhav, H.V., Elements of Environmental Chemistry: For Undergraduate Science Students of Indian University. Himalaya Publishing House.	
	Satake, M., Sethi, S. & Eqbal, S.A., Environmental Chemistry	
Learning Outcomes	Learning of impact of various environmental pollutants on air, water and soil, role of microorganisms in biogeochemical cycles and bioremediation of pollutants and the biochemistry of remediation mechanisms for developing further abatement strategies.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 112

Title of the Course: BIOCHEMISTRY OF ENVIRONMENTAL POLLUTION AND REMEDIATION [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that the students have a basic knowledge of the environmental parameters for water analysis.	
Objective:	This course develops techniques in water analysis and biodegradation of xenobiotics.	
Content:		**(24)**
1.	Assessment of water quality – analysis of BOD, COD, dissolved oxygen.	
2.	Detection of sewage pollution by screening for indicator organisms such as *E. coli*.	
3.	Biotransformation of xenobiotics.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course BCO 108-T	
Learning Outcomes	Learning techniques for water analysis and biodegradation of xenobiotics.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 113

Title of the Course: INDUSTRIAL BIOCHEMISTRY [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	Basic understanding of biomolecules and cell biology.	
Objective:	Develop the concepts and principles for handling, processing and managing biomolecules at commercial scale.	
Content:		
1.	**Industrial bioreactor designs**	**(12)**
1.1	Fermenters: design of fermenters, types of fermenters.	
1.2	Fermentation process, maintenance of aseptic conditions, aeration and agitation	
1.3	Fermentation: batch, fed-batch and continuous. Scale up and scale down. Solid state fermentation.	
1.4	Control of various parameters – online and offline monitoring, rheological properties of fermenter, computerization offermenter operation.	
1.5	Downstream processing, recovery and purification of fermentation products.	
2.	**Food technology**	**(12)**
2.1	Characteristics of industrial microorganisms; strain improvement; use of auxotrophic mutants; Cultivation of microorganisms.	
2.2	Processed foods – cheese, cold meats	
2.3	Fermentations – wine, beer, vinegar.	
2.4	Oriental fermented foods: Soy sauce, tofu, tempeh	
2.5	Indian fermented foods: Idli, dosa, dokhla.	
2.6	Probiotics – yoghurt/ curd	
3.	**Industrial production of biochemically important products**	**(12)**
3.1	Production of protein/ carbohydrate/ lipids	
A.	Proteins from milk and SCP; Industrially important enzymes	
B.	Production of dextrins, glucose.	
C.	Preparation of fatty acids, lecithins	
3.2	Production of pharmaceuticals/neutraceuticals/ biochemicals	
A.	Antibiotics: penicillins	
B.	Vitamins: B12.	
C.	Amino acids: lysine.	
D.	Alcohol: ethanol	
E.	Organic acid: citric acid	

Pedagogy:	Lectures/tutorials/assignments/self-study/Moodle/Video	
References/ Readings	Patel,A.H., Industrial Microbiology –McMillan India Ltd, 1st Edition	
	Frazier &Westhoff., Food Microbiology –Tata McGraw Hill Publishers, New Delhi	
	Jay,J. M., Food Microbiology	
	Apsinon,J., Total synthesis of natural products, Vol I	
	Hilditch,J.P. I,ndustry chemistry of Fats and Waxes	
	Guenther,E., Essential Oils, Vol I	
	Furnas,C.C. (ed.) Roger's Industrial Chemistry Vol I & II	
	Agarwal& Sharma. Chemistry of Natural Products	
	Shreeve, N.&Brink,J. Chemical Process Industries	
Learning Outcomes	1. Apply the principles of tools and techniques of biochemistry in various setting of industrial processes. 2. Able to develop strategies for production of various types of biomolecules.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 114

Title of the Course: INDUSTRIAL BIOCHEMISTRY [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	Basic understanding of biomolecules and cell biology.	
Objective:	This course develops the skills for techniques and instrumentation in industrial microbiology and biochemistry.	
Content:		**(24)**
1.	Designing of fermentor – stirred tank reactor	
2.	Fermentation processes – production and estimation of ethanol	
3.	Production of biochemically important product	
A.	Casein from milk	
B.	Sugar from sugarcane	
C.	Lecithin from egg yolk	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course BCO 109-T	
Learning Outcomes	Apply principles of industrial microbiology and biochemistry for development and assessment of process and products.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 115

Title of the Course: FRONTIERS IN BIOTECHNOLOGY [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that students have a basic understanding of techniques in microbiology and biotechnology.	
Objective:	The course develops the understanding of the applications of various concepts and techniques of biotechnology in agriculture, medicine, aquaculture, food and space.	
Content:		
1	**Introduction**	**(05)**
A.	Biotechnology: concept and principles	
B.	Hybrid technology	
C.	Tissue culture	
D.	Transgenics	
E.	Metabolomics	
F.	Prospects and concerns	
G.	Biosafety management	
H.	Bioethics in application of biotechnology	
2	**Agriculture**	**(05)**
A.	Green revolution and Crop yield increase	
B.	Rice – addition of β-carotene (golden rice), iron, amino acids, flavour, pigment	
C.	Plant growth enhancement through use of genetically modified plant growth promoting Rhizobacteria	
D.	Crops/plants –resistance to draught, salinity, cold, pathogens (bacteria, fungi, virus), insects (Bt cotton, Bt brinjal).	
E.	Plants/fruits – delayed ripening	
F.	Plants – tissue culture for obtaining desirable characteristics	
3	**Aquaculture**	**(02)**
A.	Transgenic Fish – to increase growth factors and defence against microbial infections.	
4	**Animal Husbandry**	**(04)**
A.	White revolution	
B.	Transgenic cows – production of milk: suited for lactose intolerance, or to contain high levels of "healthy" fat found in fish; insertion of human gene so as to produce milk with same properties as human breast milk	
C.	Transgenic poultry for disease resistance and animals with increased levels of growth hormones for higher production of meat	

5	**Food Industry**	**(05)**
A.	Genetically modified Foods (GMFs): Benefits and concerns	
B.	Genetically engineered microbes (GEMs) in the food industry for process improvement, enhanced nutritional value and flavour, and increased shelf life	
C.	Role of GEMS in the dairy, bakery and brewery industry	
6	Biotechnology in space – The use of microgravity as a tool for separation processes and techniques (including protein crystal growth), and production of cells for medically significant enzymes, hormones, vaccines	**(03)**
7	**Biotechnology in Medicine**	**(12)**
A.	Edible vaccines and therapeutic proteins, plants as bioreactors for antibodies, polymers, proteins	
B.	Recombinant insulin, human growth hormone	
C.	Microbiome studies through metagenomics in understanding human-microbial interactions towards improved health (probiotics, oncogenic viruses)	
D.	Gene therapy in treatment of genetic diseases – gene targeting and anti-sense therapy, with background of Human genome project	
E.	Proteomics and drug discovery	
F.	Stem cell research: Source of stem cells. Development of tissue and organs	
Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	
References/ Readings	Jogdand, S.N., Gene Biotechnology. Himalaya publishing house.	
	Jogdand, S.N., Advances in Biotechnology. Himalaya publishing house.	
	Ravi, I., Baunthiyal, M. & Saxena, J., (Eds.). Advances in Biotechnology. Springer.	
	Satyanarayana. Books & Allied (P) Ltd. Biotechnology.	
	Widholm, J. M., Kumlehn, J. & Nagata, T., Biotechnology in Agriculture and Forestry.	
	Altman, A. & Hasegawa, P., Elsevier Plant Biotechnology and Agriculture.	
	Clark, D. & Pazdernik, N. Biotechnology.	
	Bielecki, S., Tramper, J., & Polak, J. Food Biotechnology.	
	Pongracz, J. & Keen, M., Medical Biotechnology.	
	Fletcher, G. L. & Rise, M. L., (Editors). Aquaculture Biotechnology. Wiley.	
	Shenoy, M. Animal Biotechnology. Laxmi Publication.	
	Verma, A. & Singh, A. Animal Biotechnology Models in Discovery and Translation.	
Learning Outcomes	A better understanding of various techniques of biotechnology (plant and animal tissue culture, metagenomics, proteomics, transgenics) for application in agriculture, medicine, aquaculture, food and space.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 116

Title of the Course: FRONTIERS IN BIOTECHNOLOGY [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that students have a basic understanding of techniques in microbiology and biotechnology.	
Objective:	The course develops the understanding of techniques in biotechnology (plant tissue culture, screening for bioactive compounds).	
Content:		**(24)**
1.	**Plant tissue culture**	
	Explants (fenugreek seeds / rice grain/ meristematic tissue) – surface sterilization and excision, media preparation and inoculation.	
2.	Screening for antimicrobial activity	
3.	Screening isolates for a biomolecule of choice (pigment /enzyme)	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course BCO 110-T	
Learning Outcomes	Learning of various techniques in biotechnology (plant tissue culture, screening for bioactive compounds) for application in further research.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 117

Title of the Course: BIOPROSPECTING

Number of Credits: 4

Effective from Academic Year: 2018-19

Prerequisites	It assumed that students have basic knowledge about bioactive molecules like enzyme, antibiotics.	
Objective:	This course develops concept of Bioprospecting. Different sources and types for bioactive compounds and their application. Characterization using separation and analytical techniques for identification of the novel metabolites from biological sources.	
Content:		
1	**Introduction**	**(12)**
	Search for (i) newer sources (ii) newer metabolites and its significance	
2	Sources - microbes and plants	
A.	Marine ecosystem: Water and sediment; sponges; corals – microbes, thraustochytrids, others.	
B.	Coastal: mangroves; sand dunes; salterns.	
C.	Terrestrial: Forest/Ghats; industrial waste.	
D.	Extreme environments: thermophilic; psychrophilic; halophilic; alkaliphilic; others.	
3	**Sampling**	**(09)**
A.	Microorganisms.	
(i)	Samplers – Niskin water sampler and Van Veen Grab sediment sampler; aseptic collection of samples	
(ii)	Isolation: Enrichment procedures; plating on selective media.	
B.	Plants.	
(i)	Selection criteria viz. Type, physical condition, stage of growth, plant part.	
(ii)	Sample treatment – surface sterilization; excision of desired plant component; extraction.	
4	**Strain improvement**	**(03)**
A.	Microorganisms: UV radiation mutation; genetic engineering.	
B.	Plants: Hybrid technology; tissue culture	
5	**Metabolites from microbes and plants – Screening, detection and characterization**	**(09)**
A.	***Industrially important biomolecules***	

(i)	Enzymes – extremozymes; food additives/ quality enhancers; medicine.	
(ii)	Pigments – food colorants; fabric dyes	
(iii)	Biocontrol agents – herbicides; pesticides	
(iv)	Nanoparticles – medicine, drug carriers.	
(v)	Biofuels – microbially produced; plant based	
(vi)	Optical and electronic devices – archaeal metabolites: bacteriorhodopsin and cell wall S-layer as membrane for ultrafiltration	
(vii)	Biopolymers – biodegradable plastics: PHAs; EPS; biosurfactants and bioemulsifiers	
(viii)	Plant growth promoters- gibberellins	
B.	***Biologically important molecules and applications***.	**(03)**
(i)	Pharmaceuticals: Antimicrobials; Antitumour agents; drug carriers.	
(ii)	Nutraceuticals: PUFAs, β-carotenes; antioxidants	
(iii)	Cosmeceuticals: humectants (polyols).	
5.	**Metabolomics**	
(i)	Characterization using separation and analytical techniques for identification of the metabolite.	**(04)**
(ii)	Study and/or manipulation of pathways for enhanced production of a specific product.	**(04)**
(iii)	Overall chemical composition of the product	**(01)**
6	**Intellectual property and Intellectual rights**	**(03)**
A.	Patent laws – International, Indian.	
B.	Biopiracy	
Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	
References/ Readings	Jogdand, S.N. Gene Biotechnology. Himalaya publishing house.	
	Ravi, I., Baunthiyal, M. & Saxena, J., (Eds.). Advances in Biotechnology. Springer.	
	Altman, A. & Hasegawa, P. Elsevier Plant Biotechnology and Agriculture.	
	Clark, D. & Pazdernik, N. Biotechnology.	
	Pongracz, J. & Keen, M., Medical Biotechnology.	
	Shenoy, M. Animal Biotechnology. Laxmi Publication.	
	Verma, A. & Singh, A. Animal biotechnology models in discovery and translation.	
Learning Outcomes	Development of skilled person for bioprospecting of novel bioactive compounds from different biological sources. Bioprospecting and development of industrially important molecules e.g. Pharmaceuticals, nutraceuticals, Cosmeceuticals, enzymes, and biocontrol agents.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 118

Title of the Course: NANOBIOTECHNOLOGY [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that students have a basic understanding of nanobiotechnology	
Objective:	The course develops the understanding of nanoparticles and nanomaterials, their biosynthesis, characterization and industrial and medical applications.	
Content:		
1	**Introduction**	**(01)**
	Definition; historical background; concepts.	
2	**Biological cellular nanostructures**	**(06)**
	Protein and Peptide based: Proteins; bilayers and membrane arrays; ATPase; archaeal S-layers, bacteriorhodopsins; eubacterial magnetosomes – greigite, magnetite. DNA based: DNA molecule; self-assembled DNA nanotubes Virus particles; diatoms.	
3	**Nanomaterials**	**(05)**
	Shapes, size and properties: spherical, triangular, prisms, rods, cubes. Nanoparticles, nanocrystals, quantum dots, nanotubes and nanowires. Miniaturized devices in nanobiotechnology - types and applications, lab-on-a-chip (LOC).	
4	**Biosynthesis**	**(07)**
	Concept of top-down versus bottom-up approach. Uniformity and heterogeneity. Agglomeration of nanoparticles: monitoring and control of agglomerates, collision efficiencies, agglomeration. Green technologies: nanoparticle biosynthesis using microbes, plant extracts, reductases	
5	**Detection and characterization of nanoparticles**	**(04)**
	Optical: Visual colour change; UV-Vis spectrum; Fluorescence. Size imaging: Electron microscopy (SEM, TEM), light scattering, Zetapotential Surface and composition: FT-IR, Raman spectroscopy, EDAX, AFM, XRD. Magnetic resonance methods: NMR, ^{13}C-NMR	

6	**Medical Applications**	**(07)**
	Drug development – Drug discovery; toxicity evaluation: cyto-toxicity, geno-toxicity. Diagnostics – LOC technology; Imaging agents: MRI; Nanosensors for early-stage cancer detection; Nano-optics and fluorescence-based assays; Drug delivery systems –Lipid and inorganic nanoparticles. Antimicrobials – Metal/metal oxide nanoparticles against bacteria, fungi, viruses. Therapeutics – Cardiovascular diseases; neurological disorders (Alzheimer's, Parkinson's). Cancer therapy – Quantum dots for targeted drug delivery.	
7	**Industrial Applications**	**(06)**
	Electronic – Photodiodes; semiconductor Quantum dots, Water purification – Nanoadsorbents and magnetic nanoparticles Oil industry – enhanced oil recovery Food industry – Magnetosomes for detection of pathogens Environment – nanobiosensors for pollution detection. Bioremediation – Quantum dots for degradation of biological pollutants: oil	
Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	
References/ Readings	Nicolini, C. Nanobiotechnology & Nanobiosciences Pan Stanford Publishing Pte. Ltd.	
	Niemeyer C.M., & Mirkin, C.A, Nanobiotechnology, Concepts, Applications and perspectives, Wiley, Verlag GmbH & Co.	
	DeVilliers, M.M., Aramwit, P., & Kwon, G.S., Nanotechnology in Drug Delivery, Springer-American Association of Pharmaceutical Scientists Press.	
	Yao, N., & Wang, Z.L., Handbook of Microscopy for Nanotechnology. Kluwer Academic Publishers.	
	Robert, A., & Freitas, Jr. Nanomedicine, Volume I: Basic Capabilities, Landes Bioscience.	
	Pradeep T., Nano, The Essentials, Understanding Nanoscience and Nanotechnology, Tata McGraw-Hill Publishing Company Limited.	
	Mirkin, C.A. & Niemeyer, C.M. Nanobiotechnology- II, More Concepts and Applications, Wiley, Verlag GmbH &Co.	
	Bulte, J.W.M., & Modo, M.M.J., Nanoparticles in Biomedical Imaging: EmergingTechnologies and Applications, Springer Science Business Media, LLC	
	Shoseyov, O. & Levy, I., Nanobiotechnology-Bio Inspired Devices and Materials of the Future, Humana Press Inc.	
Learning Outcomes	Learning about characterization, biosynthesis, detection and application of nanoparticles; understanding the relevance of nanobiotechnology in medicine and industry.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 119

Title of the Course: NANOBIOTECHNOLOGY [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	It is assumed that students have a basic understanding of nanobiotechnology.	
Objective:	The course develops the understanding of techniques for synthesis and applications of nanoparticles	
Content:		**(24)**
1.	**Biosynthesis of metal nanoparticles:** Growth of the culture/ obtaining plant extract; screening for nanoparticle biosynthesis using whole cells, or culture filtrate/ plant extract; detection of nanoparticle formation by change in colour and/or UV spectral data.	
2.	Antibacterial activity of nanoparticles: Gram positive and Gram negative organisms.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under Theory Course BCO 112-T	
Learning Outcomes	Learning about biosynthesis of nanoparticles and their screening for antibacterial activity for applications in medicine and industry.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 120

Title of the Course: PHARMACEUTICS [T]

Number of Credits: 3

Effective from Academic Year: 2018-19

Prerequisites	The candidates choosing this course are expected to have knowledge of basic microbiology, chemistry and instrumentation. A logical understanding of drug preparation and usage is advantageous.	
Objective:	To introduce the students to pharmacopoeia, drug synthesis, drug formates and GMP practices in a pharmaceutical set-up	
Content:		
1	**Introduction**	**(02)**
	History of Pharmaceutics; Development of pharmaceutical industry in India Origin and development of the pharmacopoeia – IP/BP/USP.	
2	**Unit operations**	**(06)**
	Introduction, classification of unit operations, fundamental principles. Mixing: liquid-liquid mixing, mixing small quantities of solids in liquids, mixing large quantities of solids in liquids Mixers: Impellers and propeller mixers, baffles in tanks, trough mixers, mixers, sigma and ribbon blenders, paddle mixers, double cone blender, cube mixers, planetary mixers. Emulsification and Homogenization: Process and equipment. Filtration and clarification- types of filters, factors influencing rate of filtration, filter aids. Filtration of air – primary filters and HEPA filters, and their evaluation.	
3	**Drugs**	**(03)**
	solvents used in extraction of drugs, processes used for extraction (infusion, decoction, maceration, percolation, hot extraction). Water as universal pharmaceutical vehicle.	
4	**Types of formulations**	**(09)**
	Tablets: advantages of tablets; granulation: methods and equipment, direct compression; excipients in tableting; types: effervescent, lozenges, chewable, buccal and sublingual, dispersible, orodispersible, soluble; problems in tableting. Capsules: Advantages and limitations of hard gelatin and soft gelatin capsules. Sustained release (SR): Delayed absorption and/or a mixture of slow- and fast-release particles to produce rapid and sustained absorption in the same dose.	

	Liquids and Gels: Formulations include solubilizers, stabilizers, buffers, tonicity modifiers, bulking agents, viscosity enhancers/reducers, surfactants, chelating agents and adjuvants. Parenteral: Intravenous, subcutaneous, intramuscular or intra-articular administration, stored in liquid form, or in lyophilized form if unstable. Topical: Cream, ointment, gel, paste, powder.	
5	**General principles of pharmacology**	**(05)**
	Routes of administration with special reference to their advantages and disadvantages. Posology: Determination of doses; dose response relationship, dosage form design, biopharmaceutical consideration, drug antagonism. Compounding and Dispensing: Weight and measures isotonic solutions, hydrophilic-lipophilic balance (HLB) values. Types of dosage forms, formulation, storage, containers and closures for products, labeling of dispensed products.	
6	**Quality assurance/ Quality management**	**(06)**
	Definition; IUPAC nomenclature; GLP, GMP and SOPs Raw material analysis (RMA), Quality control of pharmaceutical excipient. Packaging material testing (PMT): Permeability of plastic; testing of foil, bottles, carrions. Limit tests – chloride, sulphate, arsenic, lead, iron, nitrate, alkali and alkaline earth metals Limits of insoluble matter, soluble matter, nonvolatile matter, volatile matter, residue on ignition and ash value. Product labeling: Drug indication; composition; dosage; storage; instructions; cautions; contraindications; batch number; manufacture date, expiry date.	
7	**Quality control**	**(03)**
	Sources of contamination in pharmaceutical compounds (which are official in pharmacopeias). Physico-chemical and microbiological analyses: Types of errors, selection of sample, precision and accuracy.	
8	**Research and Development**	**(02)**
	Drug design: Drug discovery and development; Clinical trials.	
Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	
References/ Readings	Troy, D.B., Remington's-The Science and practice of Pharmacy (Vol.1& 2). Lippincott Williams &Wilkins	
	Carter, S.J., Cooper & Gunn's Dispensing for pharmaceutical students. Cbs Publishers & Distributers	
	Aulton, M.E., Pharmaceutics: The science of dosage form design. Churchill-Livingstone	

	Lachman, L., Herbert A., Lieberman,&Kanig, L., Theory and practice of industrial pharmacy. Lea &Febiger, Philadelphia	
	Sprowls, B.B. Prescription Pharmacy	
	Beckett, A. H. &Stenlake, J. B., Practical pharmaceutical chemistry. Vol. I 4th , The Anthlone Press of University of London	
	Connors, K.A.A., Textbook of Pharmaceutical Analysis, Wiley Interscience, NewYork	
	Howard, A., Introduction of Pharmaceutical Dosage Forms 3rd Lea &Febiger	
	Porter, R.S., The Merck Manual for Diagnosis and Therapy, 19th edition, Wiley	
Learning Outcomes	A basic idea of how drugs are manufactured in a pharmaceutical company. The guidelines and quality checks involved before it reaches to the consumer.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 121

Title of the Course: PHARMACEUTICS [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	A theoretical understanding of commonly used drugs, their usage. Preparatory microbiology techniques are a requisite.	
Objective:	To have a basic idea of how quality checks on drugs are performed.	
Content:		**(24)**
1.	Quality control of different types of pharmaceutical formulations: tablets, liquids/gels, injectables, topical	
2.	Physico-chemical analysis: dispersibility, quantitation of drug (paracetamol)	
3.	Microbiological analysis	
4.	Testing the shelf-life stability of the drug.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under respective Theory Courses BCO 113-T	
Learning Outcomes	Better understanding of pharmaceutical preparations as a chemical entity and its quality compliance.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 122

Title of the Course: RESEARCH METHODOLOGY [T]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	Basic knowledge of biochemistry and microbiology is necessary.	
Objective:	This course develops the concepts of research and covers all aspects ranging from biosafety in the laboratory, experimental protocol, presentation of data and viva voce.	
Content:		**(12)**
1.	Biosafety in laboratory	
2.	Ethics in research, Plagiarism	
3.	Defining the problem	
4.	Literature survey	
5.	Defining the Aims and Objectives	
6.	Work Plan – Time-bound Frame	
7.	Research design	
8.	Experimental protocol	
9.	Presentation of data	
10.	Analysis and Conclusions	
11.	Presentations	
12.	Research manuscript writing	
13.	Thesis Writing	
14.	Viva Voce	
Pedagogy:	Lectures/ tutorials/ assignments/ students' seminars/ interactive learning/ self-study.	
References/ Readings	Kothari, C. R., Research Methodology methods and techniques. New Age Internat.	
	Kumar, R. C., Research Methodology. APH Publ Corporation, New Delhi.	
	Good C. V. & Douglas E., Methods of Research	
	Day R.A. How to write a scientific paper. Cambridge University Press.	
	Alley & Prentice M. N.N. , The craft of scientific writing.	
	Cooray, P.G., Guide to scientific and technical writing.	
Learning Outcomes	Skills to design, conduct an experiment and successfully process and report the observations in the form of a scientific report/ manuscript/ thesis.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 123

Title of the Course: RESEARCH METHODOLOGY [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	Basics of biochemistry and microbiology laboratory techniques is necessary.	
Objective:	This course develops the experimental approach, designing of experimental protocols, presentation of data and viva voce.	
Content:		**(24)**
1.	Literature survey on a given research area.	
2.	Designing an experiment with respect to a given objective.	
3.	Experimental work.	
4.	Presentation of data.	
5.	Technical writing.	
Pedagogy:	Experiments in the laboratory	
References/ Readings	As given under respective Theory Courses BCO 114-T	
Learning Outcomes	Skills to design an experiment and process the data acquired and successfully report the observations in the form of a scientific report/ manuscript/ thesis.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 201

Title of the Course: FIELD TRIP/ STUDY TOUR [P]

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	Knowledge about research institutes and industries in Goa.	
Objective:	To provide knowledge about the on-going research in various national research institutes, and the functioning of industries and industrial processes.	
Content:		**(24)**
1.	**Visit to National Institutes:** National Centre for Antarctic and Ocean Research [NCAOR] , National Institute of Oceanography [NIO] and ICAR-Central Coastal Agricultural Research Institute (ICAR-CCARI)	
2.	**Visits to Industries:**	
2.1.	Pharmaceutical industry	
2.2.	Agricultural farming	
2.3.	Food and beverage	
3	**Report writing**	
4	**Presentation and group discussion**	
Pedagogy:	Visits to research institutes/industries/universities, demonstration of equipment available with respective laboratories, interaction with personnel working in the field of life sciences in the respective institutes.	
References/ Readings	As suggested by the demonstrator to the participating students.	
Learning Outcomes	1. Exposure to the various research being carried out in the field of life sciences. 2. Exposure to the various activities being carried out in industries related to the applications of biochemical and microbial principles.	

Programme: M.Sc. (Biochemistry)

Course Code: BCO 202

Title of the Course: TRAINING IN AN INSTITUTE / INDUSTRY / UNIVERSITY

Number of Credits: 1

Effective from Academic Year: 2018-19

Prerequisites	Knowledge about the basic techniques in biochemistry and microbiology.	
Objective:	To provide hands-on experience in the application of biochemical and microbiological techniques in research institutes/industries/universities. To experience the workings of commercial industries.	
Content:		**(24)**
	The student shall be required to: 1. Undertake training for a minimum period of ten working days or its equivalent. 2. Submit to the Department of Microbiology, Goa University, a Certificate of attendance signed by the Training Coordinator of the respective Institute / Industry / University. 3. Submit to the Department a Report of the work undertaken. 4. Make a Presentation of the work carried out, to the Department Council for evaluation.	
Pedagogy:	Short-term internship (minimum 10 days) at an institute/industry/university	
References/ Readings	As suggested by the demonstrator to the participating students.	
Learning Outcomes	Apply the techniques of biochemistry and microbiology to a range of situations.	

Programme: M.Sc. (Biochemistry)

Course Code: BCD

Title of the Course: DISSERTATION

Number of Credits: 8

Effective from Academic Year: 2018-19

Prerequisites	Laboratory training in biochemistry and microbiology.
Objective:	Develop the skills of preparing and conducting independent research.
Content:	
1.	Research to be carried out under the guidance of an assigned guide.
2.	Periodic reports (as determined at the initiation of the research work).
3.	Dissertation.
4.	Viva- Voce.
Pedagogy:	Project carried out individually by each student throughout the academic year
References/ Readings	As required for the development of review and methodology.
Learning Outcomes	Ability to apply the tools and techniques of biochemistry and microbiology in conducting independent research.