MASTER OF SCIENCE IN BIOCHEMISTRY

A Two-Year Full Time Programme
(Rules, Regulations and Course Contents)

June 2015

Department of Biochemistry
Faculty of Interdisciplinary and Applied Sciences
University of Delhi South Campus
Benito Juarez Road
New Delhi-110021

MASTER OF SCIENCE IN BIOCHEMISTRY

Two Year Full Time Programme

(July 2015 onwards)

The Masters' programme in Biochemistry endeavours to provide the students with excellent training in Biochemistry emphasizing on solid background of basic concepts as well as rapid advancement in the field. In addition to theoretical knowledge, considerable emphasis is also given to offer the students hands on experience in the forefront areas of Biochemistry.

The two years programme is prescribed according to the semester system of Delhi University for the post-graduate courses beginning 2009 and is divided into four semesters. The programme has 16 papers in total, 4 in each semester. Each paper has a maximum marks of 100 (4 credits). These 16 papers include 2 multidisciplinary papers and 2 special papers based on the seminars to be delivered by the students. In addition, semester 1 and 2 would have practicals (maximum marks 200, 8 credits) for each semester. In Semester 3 and 4, the practicals would be replaced by dissertation work (maximum marks 200, 8 credits) for each semester.

Thus, the programme will comprise of 2400 marks in total.

16 Theory papers of 100 marks each with 30% allocated for internal assessment	=	1600
Practicals / dissertation work with 30% allocated for internal assessment	=	800
Total	=	2400

Two multidisciplinary courses have been included to leverage the advantage to students keeping in mind the interdisciplinary nature of the faculty and repertoire of expertise available. Alternative interdisciplinary courses may be chosen as and when required. Two papers on seminars by the students (one paper each year) have been part of our current M.Sc. programme also, for which students deliver open seminars on important scientific topics and are collectively evaluated by the departmental faculty members. In our experience, it is tremendously beneficial to students in terms of learning how to critically review the scientific literature, to churn out the best of the available information and present it in a concise and clear manner. It also gives them experience of public speaking and instills confidence. Hence, we have continued with this practice in our new syllabus.

Besides, an important feature of this programme pertains to the dissertation carried out by every student during the second year in the supervision of a mentor. The past experience of the department is that this provides the students with tremendous opportunity for hands on training in research. It exposes them to various aspects pertaining to research including the habit of scientific reading, research methodology, analytical ability, organizational capability, independent thinking and scientific writing. Thus, they are well trained to join any laboratory of modern biology and start right away without much lag period. Over the years, the department has received tremendous positive feedback in this regard from the students as well as from various institutions, wherever the students have

joined after completing M.Sc. from this department. Hence, we have persisted with the dissertation during the Part II. However, for this exercise to be meaningful, it has to be given enough time as considerable period in the beginning has to be devoted for review of literature, discussions with the mentor, planning of the research project and standardization of methods etc. Hence, the dissertation would have to continue throughout Part II i.e. Semester 3 and 4 and would be evaluated by the faculty members at the end of Semester 4 as prescribed in the scheme of examinations.

The syllabus for each theory paper is appended with a list of suggested readings. Students would also consult the latest editions of the books prescribed. In addition, this list for every course would be further supplemented with other books and scientific papers every year in consultation with the teacher concerned and would be modified as new advancements in a particular area are made.

In addition, the department regularly organizes seminars by national and international researchers to expose the students to a repertoire of scientific areas and scientific methodology. The department also runs a journal club in which students (both Ph.D. and M.Sc.) regularly present scientific papers throughout the year. Although summer training is not a compulsory part of the curriculum, students are encouraged to undergo summer training in other institutions during summer vacation. The faculty members help the students in making these arrangements.

UNIVERSITY OF DELHI
Examination Branch

Course: **M. Sc. Biochemistry**

Check list of New Course Evaluation for AC consideration

S.No.	Parameters	Status
1.	Affiliation	Included
2.	Programme structure	Included
3.	Codification of papers	Included
4.	Scheme of examinations	Included
5.	Pass percentage	Included
6.	Promotion criteria	Included
7.	Division criteria	Included
8.	Qualifying papers	Not applicable
9.	Span period	Included
10.	Attendance requirements	Included
11.	Course content for each paper	Included
12	List of readings	Included

MASTER OF SCIENCE IN BIOCHEMISTRY

TWO-YEAR FULL TIME PROGRAMME

AFFILIATION

The proposed programme shall be governed by the Department of Biochemistry, Faculty of Interdisciplinary and Applied Sciences, University of Delhi South Campus, New Delhi-110021.

PROGRAMME STRUCTURE

Part I: Semester I

BIOCHEM 0701:	Proteins – Structure, Folding and Engineering	(100) (70/30)
BIOCHEM 0702:	Essentials of Cell Biology	(100) (70/30)
BIOCHEM 0703:	Membrane Biology	(100) (70/30)
BIOCHEM 0704:	Immunology and Immunotechniques	(100) (70/30)
BIOCHEM 0705:	Practicals based on theory papers	(200) (140/60)

Total marks	Theory	400
	Practicals	200

	Total	600

Part I : Semester II

BIOCHEM 0801:	Enzymes and Techniques in Biochemistry	(100) (70/30)
BIOCHEM 0802:	Seminar Paper	(100) (70/30)
BIOCHEM 0803:	Molecular Biology: Gene Structure, Expression and Regulation	(100) (70/30)
PMBB 0804:	*Bioinformatics	(100) (70/30)
BIOCHEM 0805	Practicals based on theory papers	(200) (140/60)

**multi-disciplinary course offered by the Department of Plant Molecular Biology and Biotechnology.*

Total marks	Theory	400
	Practicals	200

	Total	600

Part II : Semester III

BIOCHEM 0901:	Cellular Signalling	(100) (70/30)
BIOCHEM 0902:	Recombinant DNA Technology and Applications	(100) (70/30)
BIOCHEM 0903:	Seminar Paper	(100) (70/30)

BIOCHEM 0904:	Molecular Biology: Genome Replication, Repair and Eukaryotic Transcription	(100) (70/30)
BIOCHEM 0905:	**Dissertation	(200) (140/60)

Total marks	Theory	400
	Dissertation	200

	Total	600

Part II : Semester IV

BIOCHEM 1001:	Developmental Biology	(100) (70/30)
BIOCHEM 1002:	Advanced Techniques in Genomics	(100) (70/30)
MICROBIO0803:	*Microbial Pathogenicity	(100) (70/30)
BIOCHEM 1003:	Proteomics and Metabolomics	(100) (70/30)
BIOCHEM 1004:	**Dissertation	(200) (140/60)

**multi-disciplinary course to be offered by the Department of Microbiology.*

***As described in the preamble to the programme as well as in the scheme of examinations, the dissertation work will begin at the start of semester III and complete at the end of semester IV. The evaluation would be carried out at the end of semester IV.*

Total marks	Theory	400
	Dissertation	200

	Total	600

Grand Total

Theory (including 30% internal assessment)	1600
Practicals / Dissertation work including 30% internal assessment	800

Total	2400

SCHEME OF EXAMINATION

1. English shall be the medium of instruction and examination.

2. Examinations shall be conducted at the end of each Semester as per the Academic Calendar notified by the University of Delhi.

3. The system of evaluation shall be as follows:

3.1 Each theory paper will carry 100 marks of which 30% marks shall be reserved for internal assessment based on classroom participation, seminar, term courses, tests, viva-voce and attendance. The weightage given to each of these components shall be decided and announced at the beginning of the semester by the individual teacher responsible for the course. Any student who fails to participate in classes, seminars, term courses, test and viva-voce will be debarred from appearing in the end-semester examination in the specific course and no internal assessment marks will be awarded. His/her internal assessment marks will be awarded as and when he/she attends regular classes in the courses in the next applicable semester. No special classes will be conducted for him/her during other semesters. The duration of written examination for each paper shall be three hours.

3.2 Examinations for practicals for each semester 1 and 2 will comprise of 200 marks of which 30% marks will be reserved for internal assessment. Practical examination for each semester 1 and 2 would be for 8 hours duration in total.

3.3 Dissertation work would comprise of research work carried out by each student during the semesters 3 and 4 in the supervision of a particular faculty member. Each student will be assigned to a particular faculty member (mentor) at the beginning of semester 3 to plan and execute a research project. The student would carry out the review of literature on the topic of research and formulate the plan of work in consultation and in the supervision of the mentor. The student would then conduct the research experiments for the remaining part of semester 3 and total duration of semester 4 in the supervision of the mentor. Towards the end of semester 4, the student will compile the research work including review of literature, aims and objectives, methodology and results and discussion in the form of a dissertation in the supervision of the mentor. At the end of semester 4, students would make presentations in the presence of all faculty members and would be collectively judged by the faculty members. Marks will be assigned to each student collectively by the faculty based on his/her performance, work and continuous assessment throughout the year by the mentor.

3.4 Total marks for dissertation shall be 400 and evaluation will be as follows:

Continuous evaluation (IA)[$]	=	120 marks
Content and organization	=	140 marks
Presentation including viva-voce	=	140 marks
Total	=	400 marks

[$]*Continuous evaluation / internal assessment will be based on attendance, intellectual ability, creativity, independent thinking, motivation, record keeping, laboratory discipline and planning & execution of experiments.*

4 Examinations for courses shall be conducted only in the respective odd and even Semesters as per the Scheme of Examination. Regular as well as Ex-Students shall be permitted to appear/reappear/improve in courses of odd semesters only at the end of odd semesters and for even semester with the even.

PASS PERCENTAGE AND PROMOTION CRITERIA

(a) The minimum marks required to pass any paper in a semester shall be 40% in theory and 40% in Practical, wherever applicable. The student must secure 40% in the End semester Examination and 40% in the total of End Semester Examination & Internal Assessment of the paper for both theory & practical separately.

(b) No student will be detained in I or III Semester on the basis of his/her performance in I or III Semester examination; i.e. the student will be promoted automatically from I and II and III to IV semester.

(c) A student shall eligible for promotion from 1st year to 2nd year of the course provided he/she has passed 50% papers of I and II semester taken together. However, he/she will have to clear the remaining paper/s while studying in the 2nd year of the programme.

(d) Students who do not fulfill the promotion criteria (c) above shall be declared fail in the Part concerned. However, they shall have to option to retain the marks in the papers in which they have secured Pass marks as per Clause (a) above.

(e) A student who has to reappear in a paper prescribed for semester I/III may do so only in the odd semester examinations to be held in November / December. A student who has to reappear in a paper prescribed for Semester II/IV may do so only in the even Semester examinations to be held in April / May.

REAPPEARANCE IN PASSED PAPERS

(a) A student may reappear in any theory paper prescribed for a semester, on foregoing in writing his/her previous performance in the paper/s concerned. This can be done once only in the immediate subsequent semester examination only (for example, a student reappearing in a paper prescribed for Semester I examination, may do so along with the immediate next Semester III examinations only).

(b) A candidate who has cleared the papers of Part II (III & IV Semesters) may reappear in any paper of III or IV Semester only once, at the immediate subsequent examination on foregoing in writing his/her previous performance in the paper/s concerned, within the prescribed span period.

(Note: The candidate of this category will not be eligible to join any higher course of study).

(c) In the case of reappearance in a paper, the result will be prepared on the basis of candidate's current performance in the examination.

(d) In the case of a candidate, who opts to re-appear in any paper/s under the aforesaid provisions, on surrendering his/her earlier performance but fails to reappear in the paper/s concerned, the marks previously secured by the candidate in the paper/s in which he/she has failed to re-appear shall be taken into account while determining his/her result of the examination held currently.

(e) Reappearance in Practical examinations, dissertation, project and field work shall not be allowed.

(f) A student who reappears in a paper shall carry forward the internal assessment marks, originally awarded.

DIVISION CRITERIA

Successful candidates will be classified on the basis of the combined results of Part I and Part II examinations as follows:

Candidates securing 60% and above	:	1st Division
Candidates securing 50% and above but less than 60%	:	2nd Division
Candidates securing 40% and above but less than 50%	:	3rd Division

SPAN PERIOD

No student shall be admitted as a candidate for the examination for any of the Parts/Semesters after the lapse of **four years** from the date of admission to the Part I/Semester 1 of the M.Sc. program.

ATTENDANCE REQUIREMENT

No student shall be considered to have pursued a regular course of study and be eligible to take examination unless he/she has attended 75% of the total number of lectures, tutorials, seminars and practicals conducted in each semester, during his/her course of study. Under special circumstances, the Head of the Department may allow students with at least 65% attendance to take the examination.

NOTE:

The promotion/passing/attendance/other rules are subject to change from time to time by the University, and the rules prevailing at that time will be applicable.

Part I – Semester I

BIOCHEM 0701

Proteins – Structure, Folding and Engineering

1. Introduction: Genesis; History; Importance and Significance of proteins; Functional diversity, Ubiquity, Classes and Dynamism; Structure-function relationship; Key Features.
2. Amino acids as constituents: Ways of representation, Classification, Acid/Base properties, Stereochemistry, Codes, Chemical and structural features, Numerical problems.
3. Physico-chemical interactions in biological systems: Covalent & non-covalent interactions, Importance of water, Importance of weak interactions in protein structures.
4. Levels of protein structure: *Primary structure*: Importance of amino acid sequence, Peptide bond and polypeptide, Importance of H-bonding and cross-linking, Flexibility and conformational restrictions, Characteristics of peptide bond, Ramachandran plot, Thermodynamic considerations. *Secondary structure*: H-bonding scheme, Diversity in alpha-helices, Helix capping, Beta-stand and sheet, Turns and loops, Importance of loops. *Supersecondary structure*: Domains and motifs. *Tertiary structure*: General properties and characteristics, Protein Data Bank (PDB). *Quaternary structure*: Concept of subunits and protomers and their association, Importance of quaternary structure, Various examples.
5. Fibrous and Globular proteins, Structural Features of Membrane proteins
6. Protein Classification and Structure Prediction: Importance, Assumptions, Classes and Databases; Terminologies; Examples; Secondary structure prediction; Theories and tools; Tertiary structure prediction (Modeling).
7. Protein Folding: Genesis and definition; The "protein folding problem"; Denaturants and their mode of action; Anfinsen's classical experiment; Folding curves and transitions; Types of protein folding and intermediates; Models of protein folding; Assisted protein folding (Chaperones); Misfolding and diseases; Intrinsically disordered proteins.
8. Protein Engineering: Basic principles; Types and Methods; Strategies in protein engineering (Directed evolution, Comparative design, Rational design); Applications.
9. Solvent Engineering: Solubility / stability of proteins in solutions: Importance of solvents; Physical basis for protein denaturation/ stability; Preferential binding and preferential hydration models; Effect of primary structure on stabilization; Thermodynamics of unfolding; Various stabilizers and their applications.
10. Techniques to investigate protein structure and folding: *Spectroscopic methods* : Absorbance, Fluorescence, Circular dichroism; *Electrophoretic methods* : Limited proteolysis and SDS-PAGE, Transverse Urea gradient gel electrophoresis; *Structural methods* : NMR; X-ray crystallography.

Suggested study material

1. D. Sheehan. 2009. Physical Biochemistry: Principles and Applications (2nd Ed.), John Wiley and Sons Ltd, Chichester, England.
2. C. Branden, T. Tooze. 1999. Introduction to Protein Structure (2nd Ed.), Garland Science, Taylor and Francis Group, New York, USA.
3. T.E. Creighton. 2002. Proteins: Structures and Molecular Properties (3rd Ed.), W.H. Freeman and Company, New York, USA.
4. R. H. Pain. 2000. Mechanisms of Protein Folding, Oxford University Press, Oxford, England.
5. J. Cavanagh, W.J. Fairbrother, A.G. Palmer III, M. Rance, N. J. Skelton. 2007. Protein NMR Spectroscopy: Principles and Practice, Academic Press, San Diego, USA.
6. S. Lutz, U. T. Bornscheuer. 2008. Protein Engineering Handbook, Wiley-VCH, Weinheim, Germany.
7. D. W. Mount. 2004. Bioinformatics: Sequence and Genome Analysis, Cold Spring Harbor Laboratory, Plainview, New York, USA.
8. V. N. Uversky, A.L. Fink. 2006. Protein Misfolding, Aggregation and Conformational Diseases: Part A: Protein Aggregation and Conformational Diseases (Protein Reviews), Springer, New York, USA.
9. M. Zvelebil, J.O. Baum. 2007. Understanding Bioinformatics (1s Ed.), Garland Science, Taylor and Francis Group, New York, USA.
10. Gale Rhodes. 2006. Crystallography Made Crystal Clear (3rd Ed.), Academic Press, Burlington, USA.

BIOCHEM 0702

Essentials of Cell Biology

1. The Cell Theory of Life: Historical background, Difference between Prokaryotic and Eukaryotic cells.
2. Sub-Cellular organelles: Isolation and characterization of sub-cellular organelles. Structure and function of sub-cellular organelles.
3. Cell Culture: Primary culture and secondary culture, Monolayer and suspension culture, Preparation of primary culture from tissues or organs, counting of mammalian cells, cell freezing and reconstitution. Dye exclusion test for cell viability assay.
4. Cell lines, a clone of mammalian cells, cloning of mammalian cells- importance of cloning, Hybridization of mammalian cells, Application of hybrid cells. Marker proteins on mammalian cells.
5. Cytoskeleton: Role in control of cell shape and motility, role in intracellular transport, mitosis. Structure and movement of cilia and flagella. Microtubules, structure and dynamics.
6. Extracellular Matrix: Assembly of various extracellular matrix and their role in integrating cells into tissues and cell-cell interactions.
7. Cell cycles: G_0, G_1, S, G_2 and M-phases of cell cycles-Characteristics of each phase of cell cycles. Restriction point of cell cycle and Quiescent cells, Synchronization of mammalian cells-its importance. Determination of the length of each phase of cell cycle.
8. Control of cell cycle in yeast and mammalian cells. Role of various cycle-CDK complexes in the transition of various check point of cell cycle. Role of ubiquitin-protein ligase –SCF and APC/C in the control of cell cycle.
9. Mitosis: Different stages of mitosis- prophase, metaphase, anaphase and telophase and molecular mechanism of each stage of mitosis.
10. Transport across cell membranes: Understanding membrane transport phenomenon using artificial membrane (Liposomes). Preparation of liposomes –hand shaken and detergent dialysis methods for membrane transport studies, Passive and active transport, comparison of a carrier protein with membrane bound enzymes, Symport, uniport and antiport.
11. Endocytosis:-Classification of endocytosis, phagocytosis and pinocytosis, clathrin-independent endocytosis, receptor-mediated endocytosis. Mechanism of formation clathrin coated pits and vesicles, role of assembly particles in receptor-mediated endocytosis. Caveosomes and dynamics of caveolae and the kinases involved in regulation.
12. Endosome-endosome fusion assay. Identification and mechanism of action of various molecular factors (like Rab5, PI-3-Kinase) involved in endosome-endosome fusion.
13. Transport of cholesterol in mammalian cells: LDL-receptor structure adopted for its function. Signal/key for entry into clathrin coated pits. Regulation of cellular level of cholesterol in mammalian cells. Transport of iron into mammalian cells.
14. Polypeptide toxins: Source of polypeptide toxins, Structure and mechanism of action of plant and bacterial toxins. Retrograde transport of ricin from TGN to ER.
15. Protein targeting: Historical background, Protein translocation across ER-membrane. Modification and quality control of protein in ER: Golgi vesicular traffic, Biogenesis of sub-cellular organelles.
16. Glycosylation in mammalian cells, origin, nature and types of Glycosylation. Role of Glycosylation in protein stability and folding with reference to ER exit.

Suggested study material

1. H. Lodish, A. Berk, C.A. Kaiser, M. Kreiger, M. P. Scott, A. Bretscher, H. Ploegh, P. Matsudaria. 2008. Molecular Cell Biology, W.H. Freeman and Company, New York., USA.
2. B. Alberts, A. Johnson, J. Lewis, M. Raff, K. Roberts, P Walter. 2002. Molecular Biology of the Cell, Garland Publishing, Inc. New York. USA.
3. G.M. Cooper. 2000. The Cell: Molecular Approach, ASM Press, Washington, D.C. USA.
4. M. Butler. 2004. Animal Cell Culture and Technology, BIOS Scientific Publishers, Taylor and Francis Group. U. K.
5. R.I. Freshney. 1989. Animal Cell Culture: A Practical Approach, IRL Press, Oxford. U.K.
6. J.M. Graham and R. Rickwood. 1997. Subcellular Fractionation: A Practical Approach, IRL Press, Oxford University Press. U.K.
7. D.L. Nelson, M.M. Cox. 2008. Lehninger Principles of Biochemistry, W.H. Freeman and Company, New York, USA.
8. J.M. Berg, J.L. Tymoczko, L. Stryer. 2008. Biochemistry, W.H. Freeman and Company, New York.
9. G. Zubey. 1993. Biochemistry, Wm. C. Brown Publishers, Oxford. U.K.

BIOCHEM 0703

Membrane Biology

1. Historical development of the lipid bilayer model of biological membrane. Salient features of bio-membrane, comparison with model membrane/liposome. Detection of phospholipid bilayer microheterogenity and domains by fluorescence spectroscopy. Role of cholesterol and fatty acid composition in membrane fluidity. Supramolecular membrane structure. Live cell microscopy, FRAP and dynamics of cell surface receptors using TIRFM and confocal microscopy.
2. Liposome technology and its application in biotechnology. Preparation of liposomes. Charecterization of liposomes. Covalent attachment of protein/ligand to liposome surface. Biophysical study of methods of liposome membrane. Liposome in biological systems and its application in Biotechnology such as targeted drug delivery.
3. The molecular assembly of biomembranes. Structures of membrane proteins in normal and cancer cells. Interchange of proteins between membranes and their soluble environment. Studies on membrane fluidity. Membrane receptors and responses. Membranes in cancer. Membrane biology of glycolipids in normal and neoplastic cells.
4. Membrane permeability. Metabolite transport in normal and cancer cells. Bioenergetics of transport. Active transport by ATP-powered pumps. Membrane transport and tumor therapy. Electron transport in membranes with special emphasis in mitochondrial and chloroplast membranes. Cell contact and cell recognition.
5. Structure and function of various biological membranes. Lipid- protein and protein-protein interactions, dynamics of lipid-protein interactions, driving forces. Molecular and patch-clamp approaches to the structure function relationship of voltage gated channels. Ion channels in cancer cells. Membrane technology applied to laboratory diagnosis. Membrane rafts in normal and disease conditions. Detail of various classes of membrane proteins and their role in normal/abnormal cell physiology.
6. Structure and function of various enveloped animal viruses. Their entry mechanisms, use as a probe in cell biology. Use of fluorescence probes in membrane fusion. Detail studies on Influenza virus hemagglutinin (HA) and Sendai virus fusion (F) protein as a model. Kinetics of viral envelope protein-induced cell fusion by continuous monitoring of fluorescent dyes. Their applications in targeted drug/gene delivery.
7. Structure-function interplay of some typical membrane receptors like ASGP-R, LDL, Ferritin etc. Membrane biology of receptor-mediated endocytosis. Role of cytoskeletal components in membrane structure/organization.
8. Membrane asymmetry and its significance in membrane structure and function. Various techniques to determine asymmetry. Its implications in health and disease. Its role in membrane signalling.
9. The structural organization of Gap Junction. Role of complement proteins in making membrane pores. Mechanism of complement-mediated lysis of membrane. Structure and function of various hemolysins. Hemolysins and membrane active peptides in therapeutics.

Suggested study material

1. J.M. Berg, J.L. Tymoczko, L. Stryer. 2008. Biochemistry, WH Freeman and Company, New York and England.
2. R. Verna. 1989. Membrane Technology, Raven Press, New York., USA**.**
3. H. Lodish, A. Berk, S.L. Zipursky, P. Matsudaira, D. Baltimore, J. Darnell. 2000. Molecular Cell Biology, WH Freeman and Company, NY and England
4. H.R. Petty. 1993. Molecular Biology of Membranes Structure and Function, Plenum Press, New York, USA and London.
5. D.F.H. Wallach. 1975. Membrane Molecular Biology of Neoplastic Cells, Elsevier Scientific Publishing Company, Amsterdam, Oxford and New York., USA**.**
6. R.R.C. New. 1990. Liposomes a Practical Approach, IRL Press, Oxford, New York., USA**.** and Tokyo.
7. A.L. Lehninger, D.L. Nelson, M.M. Cox. 1993. Principles of Biochemistry, Worth Publisher, New York., USA**.**
8. A. Azzi, L. Masotti, A. Vecli. 1986. Membrane Proteins Isolation and Characterization, Spriger-Verlag, New York, USA**.**

BIOCHEM 0704

Immunology and Immunotechniques

1. Historical development of the branch "Immunology". Overview of the immune system. Cells and organs involved in immunity. Hematopoiesis.
2. Antigens, Immunogens, Haptens, Epitopes. Antigen-Antibody interactions. Discovery of immunoglobulins, blood group substances. Structure and function of various classes of immunoglobulins. Humoral immune response, Concept of neutralizing antibodies. Epitope mapping, Development of monoclonal antibodies, single chain antibodies.
3. Applications of antibodies in diagnostics and routine laboratory assay systems. Agglutination reaction, principles of western blots, radioimmunoassay, ELISA, immunohistochemistry, immunoelectron microscopy, Flow cytometry. Various immunocytes, their identification/purification and function.
4. Immunogenetics, Generation of antibody diversity, class switching among constant-region genes.
5. The complement systems, mechanism of complement activation, pathology related to complement proteins.
6. T-cell receptors, maturation, activation and differentiation. B-cell activation and differentiation, B-cell receptor and the immunoglobulin superfamily.
7. Cell mediated immunity, MHC restriction and mechanism of antigen presentation.
8. Generation of B and T cells Responses, Immunological memory.
9. Properties of cytokines, receptors, Immune effector mechanisms.
10. Immune response to infectious diseases.
11. Concepts of vaccines, Designing vaccines for active immunization, whole-organism vaccines, recombinant vaccines, DNA vaccine, synthetic peptide and multivalent sub unit vaccines. Vaccine delivery. Development of vaccines against various infectious diseases with special emphasis on tuberculosis, malaria, leishmania etc.
12. Allergy, Cell biology of hypersensitivity reactions.
13. Immunodeficiencies, AIDS, Transplantation immunology.
14. Tumor antigens and cancer immunotherapy.
15. Mechanisms of induction of autoimmunity, treatment of autoimmune diseases

Suggested study material

1. J. Owen, J. Punt, S. Stranford, (2012) Kuby Immunology (8th Edition), WH Freeman and Company, USA.
2. J.M. Berg, J.L. Tymoczko, L. Stryer. (2012) Biochemistry (7th Edition), W.H. Freeman and Company, USA**.**
3. D. Male, J. Brostoff, D. Roth, I. Roitt, (2012) Immunology (8th Edition), Saunders, Elsevier, USA.
4. K. Murphy (2011) Janeway's Immunobiology (8th Edition), Garland Science, USA.
5. A. Abbas, A. Lichtman, S. Pillai, (2014) Cellular and Molecular Immunology (8th Edition), Saunders, Elsevier, USA.

Part I – Semester I

BIOCHEM 0705

Practicals

1. **Buffers: theory and practice**. **Preparation and storage of buffers and protein stock solutions**: Concept of pH, buffers and pKa; Preparation of buffers in the laboratory over a pH range (2 to 11); Additives for buffers; Use of pH meters. Handling of proteins and storage concerns.
2. **Protein quantitation and characterization:** Protein estimation by reagent, dye and non-invasive methods; Concept of extinction coefficient. Spectroscopic characterization of proteins; Strategy, design and measurement of protein stability and folding; Generation of transition curves; Calculation of transition mid-points
3. ***In silico* protein sequence and structure analysis.** Mining and retrieval of sequences and structures from PDB; Prediction of physical and intrinsic parameters; Sequence alignment and phylogenetic analysis; Homology modeling.
4. **Estimation of Biomolecules:** Estimation of inorganic phosphate by Fiske-Subbarow's method-known and unknown sample; Estimation of phospholipids by acid digestion and by estimating inorganic phosphate; Estimation of carbohydrate using Phenol-Sulphuric method- known and unknown sample; Estimation of protein and sugar content of a glycoprotein; Estimation of phospholipids by Stewart's method.
5. **Sub-cellular fractionation** of liver homogenate by differential centrifugation method and identification of the organelles by measuring marker enzymes.
6. **Enzyme Assays and Inhibition Studies:** Determination of specific activity of Succinate dehydrogenase, Lactate dehydrogenase and Acid phosphatase from mouse liver extract; Inhibition studies of Succinate dehydrogenase by malonic acid.
7. **ELISA**. Indirect and sandwich ELISA
8. **Agglutination**. Latex bead/Heamagglutination on slide and in microtitre plate
9. **Electrophoresis and Western Blotting.** SDS-PAGE analysis of proteins. Visualization of protein bands by Coomassie and Silver staining. Western blot analysis of the proteins using antibodies (immunoblotting), development by DAB/ECL.
10. **Introduction to Sendai virus**. Determination of Viral activity (host-virus interaction/membrane fusion) by Haemagglutination and Hemolysis.
11. **Kinetics of Membrane fusion** (by hemolytic) induced by Sendai virus. Effect of pH and Temperature

Part I - Semester II

BIOCHEM 0801

Enzymes and Techniques in Biochemistry

1. Enzymology: Introduction, General characteristics of enzymes, Activation energy, Coupled reactions, Active site and its importance, Thermodynamics and Equilibrium; Enzyme activity; Specific activity and Units; Isozymes; Ribozymes; Zymogens; Abzymes; Classification and nomenclature of enzymes.
2. Enzyme assays: Types, Continuous and discontinuous assays; Optimization of enzyme assays. Factors influencing catalytic efficiency and the mechanisms employed.
3. Enzyme kinetics: Significance; Rapid Equilibrium and Steady State approach, Henry-Michaelis-Menten's and Haldane equations, Significance of K_m, Catalytic efficiency and turnover number; Kinetic perfection. Order of kinetics.
4. Methods of plotting enzyme kinetics data: Lineweaver-Burk, Hanes-Woolf, Woolf-Augustinsson-Hofstee, Eadie-Scatchard; Direct linear plot; Advantages and disadvantages; Integrated form of the Henry-Michaelis-Menten equation; Effect of pH and temperature.
5. Equilibrium dialysis, Principles and applications; Scatchard plot for equilibrium binding
6. Formation of E. S covalent intermediates, transient kinetics, flow techniques (continuous, stopped, quenched), Temp-Jump relaxation experiments.
7. Enzyme Inhibition, Models and types of inhibition; Kinetics and diagnostic plots
8. Multisubstrate enzymes; Multisite and allosteric enzymes; Models and examples.
9. Regulation and control of enzyme activity: reversible covalent modification, irreversible covalent modification, Half-site reactivity; Bifunctional enzymes; Compartmentalization.
10. Applied enzymology: Application of enzymes in industry, diagnostics and medicine, agriculture, research; Immobilized enzymes.
11. Enzyme purification & Chromatography: Gel filtration, ion-exchange, hydrophobic interaction chromatography, hydroxyapatite and affinity chromatography, FPLC HPLC
12. Hydrodynamic methods, Centrifugation, Sedimentation
13. Molecular spectroscopy, IR, ESR, FRET, Biomolecular fluorescence complementation assay; Chemiluminescance and Phosphoresence
14. Calorimetric methods – Differential Scanning Calorimetry (DSC) and Isothermal titration Calorimetry (ITC)
15. Radioisotope and their use in biology, autoradiography, radioactive labeling of biological macromolecules.

Suggested study material

1. I.H. Segel. 2010. Biochemical Calculations (2nd Ed), John Wiley and Sons, California, USA.
2. P. F. Cook, W.W. Cleland. 2007. Enzyme Kinetics and Mechanism, Garland Science Publishing, London, England and New York, USA.
3. T. Palmer, P. Bonner. 2007. Enzymes: Biochemistry, Biotechnology, Clinical Chemistry (2nd Ed.), Woodhead Publishing House, Chichester, England.
4. R. Burgess, M. P. Deutcher. 2009. Guide to Protein Purification, Academic Press, San Diego, USA.
5. D. Purich. 2010. Enzyme Kinetics: Catalysis and Control (1st Ed.), Academic Press, San Diego, USA.
6. D. Sheehan. 2009. Physical Biochemistry: Principles and Applicatons (2nd Ed.), John Wiley and Sons Ltd, Chichester, England.
7. N.C. Price, L. Stevens. 2000. Fundamentals of Enzymology: The Cell and Molecular Biology of Catalytic Proteins, Oxford University Press, USA.

BIOCHEM 0802

Seminar Paper

(Students, in this paper, would present open seminars on important scientific topics assigned to them, which would be collectively evaluated by the departmental faculty).

BIOCHEM 0803

Molecular Biology: Gene Structure, Expression And Regulation

1. Introduction: Characteristics of living beings, brief historical review, The structure of DNA and RNA; Melting of DNA, Organization of Microbial Genomes, Organization of Eukaryotic Genomes, Chromatin arrangement, nucleosome formation.
2. Genetic code: Relationship between genes and proteins, concept of tRNA, triplet nature of genetic code, concept of mRNA, development of cell free system for protein synthesis by Nirenberg, discovery of 1st codon for phenyl alanine, discovery of codons for other amino acids.
3. Triplet binding assay, Hargobind Khorana's work on genetic code, discovery of initiation and termination codons, universality of genetic code, colinearity of genes and proteins, Wobble hypothesis and exceptions, degeneracy of genetic code, mitochondrial genetic code.
4. Protein synthesis in prokaryotes and eukaryotes: Complexity of protein synthesis and general features of the process, direction of protein synthesis, direction of mRNA translation, activation of amino acids, fidelity of protein synthesis.
5. Initiation: Special features of initiator tRNAs, RBS and its interactions with 16S rRNA in bacteria, initiation complex formation, role of bacterial and eukaryotic initiation factors, regulation at initiation.
6. Elongation: Elongation factors in prokaryotes and eukaryotes, entry of amino acyl tRNA to A site, peptide bond formation, nature of peptidyl transferase, translocation, translocation factors in prokaryotes and eukaryotes.
7. Role of antibiotics in understanding protein synthesis, recognition of cognate amino acyl tRNA, mechanism of action of elongation factors.
8. Termination: Recognition of termination codons by release factors, role of molecular mimicry, mechanism of peptidyl tRNA hydrolysis, ribosome release factors, differences between prokaryotes and eukaryotes
9. Mode of action of various antibiotics in the inhibition of protein synthesis.
10. ER coupled translation of secretory proteins, role of signal sequence.
11. Biosynthesis of RNA (Transcription) in prokaryotes: General features of the process, coupling of transcription and translation in prokaryotes, direction of transcription, various stages of the process.
12. Discovery and assay of RNA polymerase, Bacterial RNA polymerase - core and holoenzyme, Importance of sigma factor in initiation.
13. Isolation and characterization of promoters, consensus sequences, up and down mutations. Role of -10 and -35 sequences in open complex formation. Conserved regions of sigma factors and their role in DNA binding.
14. Elongation, RNA polymerase – structure and function
15. Termination of transcription, intrinsic and rho dependent termination, mechanism of action of rho. Anti-termination and gene regulation, role of anti-termination proteins and their interaction with RNA polymerase, mechanism of anti-termination. Inhibitors of transcription and applications as anti-microbial drugs.
16. Principles of gene regulation, negative and positive regulation, concept of operons, regulatory proteins, activators, repressors, induction of SOS response.

Suggested study material

1. D.L. Nelson, M.M. Cox. (2013). Lehninger Principles of Biochemistry (6th Edition), W.H. Freeman and Company, New York, USA.
2. J.M. Berg, J.L. Tymoczko, L. Stryer. (2012) Biochemistry (7th Edition), W.H. Freeman and Company; New York, USA.
3. B. Lewin, J. Krebs, S.T. Kilpatrick, E.S. Goldstein (2011). Genes X, (10th Volume) Jones and Bartlett Publishers, Sudbury, Massachusetts, USA.
4. J.D. Watson, T.A. Baker, S.P. Bell, A. Gann, M. Levin, R. Losick. (2013). Molecular Biology of the Gene (7th edition). Benjamin Cummings, San Francisco, USA.
6. R.F. Weaver (2007). Molecular Biology. (4th edition). McGraw Hill. New York. USA.

PMBB 0804

Introduction to Bioinformatics*

1. **Introduction to Computers and Bioinformatics** -- Types of operating systems, concept of networking and remote login, basic fundamentals of working with Unix.
2. **Biological Databases** -- Overview, modes of database search, mode of data storage (Flat file format, db-tables), flat-file formats of GenBank, EMBL, DDBJ, PDB.
3. **Sequence Alignment** -- Concept of local and global sequence alignment; Pairwise sequence alignment, scoring an alignment, substitution matrices, multiple sequence alignment.
4. **Phylogenetic Analysis** -- Basic concept of phylogenetic analysis, rooted/uprooted trees, approaches for phylogenetic tree construction (UPGMA, neighbour joining, maximum parsimony, maximum likelihood).
5. **Generation and Analysis of High Throughput Sequence Data** -- Assembly pipeline for clustering of HTGS data, format of '.ace' file, quality assessment of genomic assemblies; International norms for sequence data quality; Clustering of EST sequences, concept of Unigene.
6. **Annotation Procedures for High Through-put Sequence Data** -- Identification of various genomic elements (protein coding genes, repeat elements); Strategies for annotation of whole genome; Functional annotation of EST clusters, gene ontology (GO) consortium, phylogenomics.
7. **Structure Predictions for Nucleic Acids and Proteins** -- Approaches for prediction of RNA secondary and tertiary predictions, energy minimization and base covariance models; Basic approaches for protein structure predictions, comparative modeling, fold recognition/ 'threading', and *ab- initio* prediction.

**multi-disciplinary course offered by the Department of Plant Molecular Biology and Biotechnology.*

Suggested study material

1. A.D. Baxevanis, B.F.F**.** Ouellette. 2005. Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins. John Wiley and Son Inc., USA.
2. D.W. Mount. 2004. Bioinformatics Sequence and Genome Analysis. Cold Spring Harbor Laboratory Press, USA.
3. A. Tramontano. 2007. Introduction to Bioinformatics, Chapman & Hall/CRC, USA.
4. M. Zvelebil, J.O. Baum. 2008. Understanding Bioinformatics, Taylor and Francis, USA.

Part I – Semester II

BIOCHEM 0805

Practicals

1. **Competent cells, Transformation and Plasmid isolation**. Laboratory preparation of Competent cells (DH 5α). Transformation of circularized plasmid and calculation of transformation efficiency. Isolation of plasmid (midi-prep) and estimation of DNA amount and yield.
2. **Animal Tissue Culture**. Introduction to animal tissue culture and various requirements. Growing mammalian cells, trypsinization, plating, cryofreezing and general maintenance of cells. Cell counting using Hemocytometer and compare confluency.
3. **Transfection and In cell Visualization of the Ectopically Expressed Protein**. Preparation of DNA Transfection Reagents. Introduction of foreign DNA (plasmid expressing GFP) into mammalian cells. Visualization of the GFP expression in live cells using fluorescent microscope.
4. **Overexpression Analysis**. Preparation of total cell lysate of the transfected cells and Western Blot analysis of the over expressed GFP protein.
5. **Cloning, expression and purification of recombinant proteins**. Amplification of gene by PCR, cloning of gene into expression vector to produce recombinant protein (Isolation of Vector, Restriction digestion, extraction of DNA from gel, Ligation, Transformation). Screening of positive clones by colony PCR and restriction digestion analysis. Confirmation of sequence of cloned amplicon by DNA sequencing - Analysis and interpretation of sequencing result. Expression, localization and purification of recombinant protein.
6. **Measurement of kinetic parameters and inhibition studies.** Determination of K_m, V_{max}, determination of optimal pH, determination of effect of temperature on the stability and activity of the enzyme. Determination of K_i and mode of inhibition.
7. **Bacteriophages (Lambda and Filamentous):** Growing small-scale Lambda phage and filamentous phage culture, isolating single plaque of filamentous phage by titering serial dilutions, isolating single plaque of Lambda phage by titering serial dilutions.

Part II – Semester III

BIOCHEM 0901

Cellular Signalling

1. Cellular Signaling: General principles of signaling by cell surface receptors, endocrine, paracrine and autocrine signaling, types of cellular responses induced by signaling molecules, components of intracellular signal-transudation pathways.
2. Short Term Signaling: G-protein coupled receptor system, General mechanism of the activation of effectors molecules associated with G-protein-coupled receptors, G-protein coupled receptors that activate or inhibit adenylate cyclase, G-protein coupled receptors that activate phospholipase C, and G-protein coupled receptors that regulate ion channels.
3. Long Term Signaling: Signaling of growth factors (EGF and Insulin) via activation of receptor tyrosine kinases. Signaling of TGFβ by direct activating Smad proteins. Cytokine signaling via JAK/STAT pathway.
4. Cell Survival and Death Signal: Programmed cell death and role of Caspase protein in apoptosis. Various pro-apoptotic and anti-apoptotic regulators and pathways.
5. Signal for Protein Sorting: Road map of biosynthetic protein traffic. Dynamics of protein trafficking. Experimental evidences of protein translocation across ER-membrane.
6. Signal Recognition Particles: Characteristics and importance of SRP. Characterization and function of SRP-receptor, signal peptide and signal peptidase. Mechanism of movement of polypeptide through ER-membrane into the ER lumen.
7. Protein Modification in ER: GRP, PERK, Unfolded response pathway, eiF2a, PDI roles in survival and death. Role of PDI and Bip in protein maturation in ER. Biosynthesis of O-linked and N-linked sugars, Golgi antiport. Role of Dolicol-phosphate in the biosynthesis of precursor N-linked oligosaccharides.
8. Sorting of protein in Golgi: Evidences for three compartments for Golgi stack, Mapping of Golgi enzymes in stack, Sorting of resident ER-protein from other proteins, targeting of lysosomal enzymes and specificity of lysosomal enzymes phosphorylation.
9. Golgi vesicular Transport: Coated and uncoated vesicle, Composition of coated vesicles, Role of ARF and coatomer in the formation of coated bud and vesicles. Mechanisms of targeting and fusion of Golgi-derived transport vesicles to the correct target site. Role of NSF, SNAPs and SNAREs.
10. Protein Import in Mitochondria: Characteristics of signal sequences, nature of receptors, accessories proteins, co-receptors for import of mitochondrial proteins, mechanism.
11. Protein Import in Peroxisomes: Characteristics of signal sequences, nature of receptors, accessories proteins, co-receptors. Mechanism of entry of proteins into the peroxisomal matrix and insertion into peroxisomal membranes.
12. Signal for Import and Export of Macromolecules from Nucleus: Characteristics of signal sequences, nature of importins and exportins. Mechanism of entry and exit of macromolecules from nucleus. Mechanism of entry of large and small molecules into nucleus via Nucler-Pore-Complex.

Suggested Study Material

1. L. Harvey, B. Arnold, Z.S. Lawrence, M. Paul, D. Baltimore, J.E. Darnell. 1999. Molecular Cell Biology, W. H. Freeman & Co, New York, USA.
2. G.M. Cooper. 2000. The Cell - A Molecular Approach, Sunderland (MA), Sinauer Associates, Inc. USA.
3. B. Alberts, A. Johnson, J. Lewis, M. Raff, K. Roberts, P. Walter. 2000. Molecular Biology of The Cell, Garland Science, New York and London.
4. J.G. Siegel, B. W. Agranoff, A. R. Wayne, S.K. Fisher, M.D. Uhler. 1999. Basic Neurochemistry: Molecular, Cellular, and Medical Aspects, Lippincott,Williams & Wilkins, Philadelphia, USA.
5. A. Varki, R.D. Cummings, J.D Esko, H.H. Freeze, P. Stanley, C.R. Bertozzi, G.W Hart, M.E. Etzler. 2008. Essentials Of Glycobiology, Cold Spring Harbor Laboratory Press. Plainview, New York, USA.
6. J.M. Coffin, S.H. Hughes, H.E. Varmus. 1997. Retroviruses, Cold Spring Harbor Laboratory Press, Plainview, New York, USA.
7. T. Strachan, A. P. Andrew. 1999. Human Molecular Genetics, Garland Science, New York and London.
8. D. W. Kufe, R.E Pollock, R. R. Weichselbaum, R.C.J. Bast, S.H. Gansler, J. F. F. Ted, Emil. 2003. Cancer Medicine, BC Decker Inc, Hamilton, Canada.

BIOCHEM 0902

Recombinant DNA Technology and Applications

1. Restriction and Modification systems in *E. coli* and their use in recombinant library constructions.
2. Restriction and Modification enzymes and their uses.
3. Basic techniques for RDT including Agarose gel electrophoresis, PAGE, Pulse field electrophoresis.
4. Basic Biology of plasmids including their replication, copy number, Incompatibility of Plasmids, and development of Plasmid Vectors. Vectors for making RNA probes.
5. Biology of filamentous phages, development of phage and phagemid vectors.
6. Biology of Bacteriophage lambda, Promoters and control circuits, phage assembly and *in vitro* packaging and development of vectors for different types of Libraries.
7. Vectors for cloning large fragments of DNA, (Cosmid, PAC, YAC and BAC) and strategies for cloning large DNA fragments.
8. Basic DNA sequencing methods, Maxam and Gilbert's chemical and Sanger's chain termination methods, and automated DNA sequencing, Base calling and sequencing accuracy, Introduction to next generation sequencing (NGS).
9. Polymerase chain reaction and its application in research including cloning of PCR amplified fragments, mutagenesis and construction of Libraries. Real time/quantitative PCR.
10. Oligonucleotide synthesis, purification, and its application in screening of libraries, cloning and mutagenesis. Synthetic gene assembly.
11. Strategies for constructing cDNA libraries and screening using Nucleic acid and antibody probes. Subtractive Libraries, Expression based strategies for cloning of functional genes, Differential mRNA display.
12. Strategies for constructing Genomic libraries and screening using nucleic acid probes.
13. Understanding of Operons Lac, Trp, Arabinose, Tetracycline and their applications in studying biological processes and development of Vectors. Use of Tags to aid solubility and Purification.
14. Vectors and strategies for expressing heterogeneous proteins in *E. coli*, Yeast, Baculovirus, vaccinia virus and mammalian Cells.
15. DNA safety guidelines and regulatory aspects.

Suggested study material

1. M.R.Green and J. Sambrook (2012) Molecular cloning, A Laboratory Manual Vol. I-III. (Fourth edition) Cold Spring Harbor Laboratory Press.
2. Fred M. Ausubel *et al.* editors (2015) Current Protocols in Molecular Biology. John Wiley and Sons, Inc.
3. J.D.Watson, (2007) Recombinant DNA: Genes and Genomes: A Short Course. (Third edition), W.H.Freeman and Company.
4. James D. Watson, Richard M. Myers, Amy A. Caudy and Jan Witkowski. (2007). Recombinant DNA, Genes and Genomes – A Short Course (3rd edition). Cold Spring Harbor Laboratory Press.
5. S.B. Primrose and R.M. Twyman. (2006) Principles of Genome Analysis and Genomics. (7th edition) Blackwell Publishing.
6. T.A. Brown. (2010) Gene Cloning and DNA Analysis. Wiley-Blackwell publishing (Oxford, UK).
7. Articles/Reviews from Methods in Enzymology, Methods in Molecular Biology, Nature Biotechnology, Nature Methods, Nature Protocols, Current Opinion series, Annual Review Series, Current Protocol series and various Journals.

BIOCHEM 0903

Seminar Paper

(Students, in this paper, would present open seminars on important scientific topics assigned to them, which would be collectively evaluated by the departmental faculty).

BIOCHEM 0904

Molecular Biology: Genome Replication, Repair and Eukaryotic Transcription

1. DNA Replication in prokaryote and eukaryotic systems : Semiconservative nature of replication, classic experiments of Meselson and Stahl, origin of replication, types of replicons, isolation and mapping of replication origins, relationship between genome size and number of origins. Regulation of replication initiation by methylation and licensing factors. Various modes of replication, mode of action of reverse transcriptase, discovery, properties and general structure of DNA polymerases, synthesis of leading and lagging strands, role of okazaki fragments and termination of replication.
2. DNA Repair : Different types of DNA damages, requirement of repair systems, recognition of DNA damage, types of DNA repair systems including excision repair, base flipping, mismatch repair, recombination repair, conserved repair systems in eukaryotes and diseases associated with DNA repair problems.
3. Eukaryotic Transcription : General introduction, characteristics of promoters and enhancer elements. Activators and repressors of transcription, different DNA binding domains like zinc finger, helix-turn-helix, leucine zipper, helix-loop-helix. Properties of eukaryotic RNA polymerases and their mode of action, assembly of basal transcription apparatus at the promoter, initiation, elongation and termination of transcription. General techniques used to study binding and activity of transcription factors and coactivators in eukaryotes.
4. RNA Splicing and Processing : Splice junctions, Lariat structure, role of sn RNA in splicing, Spliceosome formation, Alternative splicing and tRNA splicing. Processing and maturation of RNA.
5. Catalytic roles of RNA : Self splicing introns , catalytic activities of Ribozymes, RnaseP, Viroids and mechanisms of RNA editing.
6. Gene Silencing : Mechanism of action of RNAi and micro-RNA. Role of DNA-Methylation, Acetylation and Deacetylation in gene expression. Recent advances and applications of gene silencing.

Suggested study material

1. J.M. Berg, J.L. Tymoczko, L. Stryer. 2008. Biochemistry, W.H. Freeman and Company, New York, USA.
2. B. Alberts, A. Johnson, J. Lewis, M. Raff, K. Roberts, P.Walter. 2008. Molecular Biology of the Cell, Garland Science, New York, USA.
3. H. Lodish, B. Harvey, Arnold, S. Zipursky, S.Lawrence, P. Matsudaira, D. Baltimore, J. Darnell, E. James. 2003. Molecular Cell Biology, W.H. Freeman and Company, New York, USA.
4. G. M.Cooper. 2000. The Cell: A Molecular Approach, Sinauer Associates, Inc. Massachusetts, USA.
5. M.M. Cox, D.L. Nelson. 2008. Lehninger's Principles of Biochemistry, W.H. Freeman and Company, New York, USA.
6. B. Lewin. 2006. Genes, Jones and Bartlett Publishers, Massachusetts, USA.
7. J.D. Watson, T.A. Baker, S.P. Bell, A. Bann, M. Levine, R. Losick. 2004. Molecular Biology of the Gene, Benjamin Cummings, California, USA.
8. R.H. Garrett**,** C.M**.** Grisham**.** 2000**.** Biochemistry, Saunders College Publishers, Texas, USA.

BIOCHEM 0905

Dissertation

As described in the scheme of examinations, dissertation will start at the beginning of semester 3, continue through semester 4, and will be assessed at the end of semester 4.

Part II - Semester IV

BIOCHEM 1001

Developmental Biology

1. History and basic concepts of development, modification of development in evolution, identification of developmental genes.
2. Gametogenesis, fertilization, generation of multicellular embryo, formation of germ layers, patterning of vertebrate body plan.
3. Morphogenesis: Cell adhesion, cleavage and formation of blastula, gastrulation, neural tube formation and cell migration.
4. Molecular events of embryogenesis : Nieuwkoop center, Spemann-Mangold organizer theory and Mesodermal induction.
5. Cell-cell communication and molecular signaling in development : Concepts of induction and competence, epithelial-mesenchymal interactions, role of FGF-RTK pathway, JAK-STAT, Hedgehog family, Wnt family, TGF-β superfamily, Notch pathway and developmental signals from extracellular matrix.
6. Model systems
   A. *C. elegans*: Study of cell lineage, mosaic development and organogenesis (vulva formation).
   B. Drosophila: Pattern formation, polarity determination of embryo by maternal genes, formation of body segments and Homeotic genes.
   C. Mouse: Vertebrate development, determining function of genes during development by generation of knockout and knock-in models.
7. Stem cells in development: Definition, types and properties of stem cells, cultivation of stem cells, adult stem cells, cancer stem cells, stem cell markers, role of stem cells in development and applications of stem cells.
8. Medical implications of developmental biology: Genetic errors of human development, gene expression and human diseases, induced pluripotency, *in-vitro* fertilization, environmental assaults on human development, design of future medicines like gene therapy, therapeutic cloning and regeneration therapy.

Suggested study material

1. S. F. Gilbert. 2006. Developmental Biology, Sinauer Associates, Inc., MA, USA.
2. D.L. Riddle, T. Blumenthal, B.J. Meyer, J.R. Priess. 1997. *C. elegans* II. Cold Spring Harbor Laboratory Press, New York, USA.
3. Worm Book: The Online Review of *C. elegans* Biology. 2005. The *C. elegans* Research Community, Pasadena, USA. (www.wormbook.org)
4. G.J. Siegel, B.W. Agranoff, R.W. Alberts, S.K. Fisher, M.D. Uhler. 1999. Basic Neurochemistry: Molecular, Cellular, and Medical Aspects, Lippincott, Williams & Wilkins, New York, USA.
5. P.A. Lawrence. 1992. The making of a fly: the genetics of animal design, Blackwell Publishers, Oxford, UK.
6. L. Wolpert, R. Beddington, T. Jessell. 2001. Principles of Development, Oxford University Press, New York, USA.
7. H. Lodish, A. Berk, C.A. Kaiser, M. Krieger, M.P. Scott, A. Bretscher, H. Ploegh, P. Matsudaira. 2003. Molecular Cell Biology, W.H. Freeman, New York, USA.
8. A. Nagy, M. Gertsenstein, K Vintersten, R. Behringer. 2003. Manipulating the mouse embryo: a laboratory manual, Cold spring Harbor Press, New York, USA.

BIOCHEM 1002

Advanced Techniques in Genomics

1. Mutagenesis: Chemical, random, site-directed and Newer methods and strategies for protein engineering such as DNA shuffling to produce better variants and to study their functions.
2. Regulated vectors for controlled expression of multiple genes to study gene function in different hosts.
3. Recombinant DNA strategies to study protein interactions. (Yeast 2-hybrid system, Bacterial-2 hybrid system, Phage display, Ribosome Display, Cell Display, Protein fragment complementation).
4. Determining the Function of Individual genes (Gene deletion, over-expression and complementation, Genome-wide insertional mutagenesis).
5. Fundamentals of Whole-Genome Sequencing. Next Generation Sequencing, Sequencing of Phage, Viral and Bacterial Genomes, Human Genome sequencing, and comparative genomics.
6. High throughput genome-wide cloning and protein expression strategies and applications.
7. Antibody gene cloning and engineering, humanization and Human antibodies.
8. Strategies for large-scale expression of recombinant proteins in heterogonous hosts. Purification and downstream processing to produce Therapeutic grade recombinant proteins and regulatory aspects.
9. Microarray techniques for DNA, Proteins and Antibodies. Global expression profiling
10. Cellular Engineering.
11. Micro/si RNA technology and applications in studying gene functions. (Student seminar)
12. Gene transfer and expression in plant. (Student seminar)
13. Gene transfer in animals and human and applications. (Student seminar)

Suggested study material

1. Molecular Biotechnology: Principles and Applications of Recombinant DNA (2010) 4th ed., Glick B.R., Pasternak, J.J. and Patten, C.L., ASM Press (Washington DC).
2. Erica Golemis and Peter D. Adams (2005) Protein-Protein Interactions: A Molecular Cloning Manual. Cold Spring Harbor Laboratory Press,
3. M.R.Green and J. Sambrook (2012) Molecular cloning, A Laboratory Manual Vol. I-III. (Fourth edition) Cold Spring Harbor Laboratory Press.
4. Fred M. Ausubel *et al.* editors (2015) Current Protocols in Molecular Biology. John Wiley and Sons, Inc.
5. James D. Watson, Richard M. Myers, Amy A. Caudy and Jan Witkowski. (2007). Recombinant DNA, Genes and Genomes – A Short Course (3rd edition). Cold Spring Harbor Laboratory Press.
6. S.B. Primrose and R.M. Twyman. (2006) Principles of Genome Analysis and Genomics. (7th edition) Blackwell Publishing.
7. T.A. Brown. (2006) Genomes 3. (III edition), Garland Science,
8. Carlos F Barbas III, Dennis R Burton and Gregg J Silverman., (2001), Phage Display: A Laboratory Manual, Cold Spring Harbor Laboratory Press.
9. Robert Aitken (Editor) (2009) Antibody Phage Display: Methods and Protocols (Methods in Molecular Biology).
10. Articles/Reviews from Methods in Enzymology, Methods in Molecular Biology, Nature Biotechnology, Nature Methods, Nature Protocols, Current Opinion series, Annual Review Series, Current Protocol series and various Journals.

MICROB 0803

Microbial Pathogenicity*

1. **Classical view of microbial pathogenicity**: Define pathogenicity and virulence; Quantitative measures of virulence: minimal lethal dose (MLD), LD_{50}, $ID_{50,}$ $TCID_{50.}$ Virulence determinants: colonization, toxins, enzymes and invasiveness. Facultative / obligate intracellular pathogens.
2. **Molecular microbial pathogenicity:** Molecular Koch's postulates, multiplicity of virulence features, coordinated regulation of virulence genes, two component signal transudation systems and environmental regulation of virulence determinants, antigenic variation; clonal and panmictic nature of microbial pathogens, type 1-IV secretion systems, biofilms and quorum sensing.
3. **Emerging and re-emerging pathogens:** Illustrate emerging and re-emerging pathogens using *V. cholerae* 0139, X-MDR *M. tuberculosis, Helicobacter pylori*, Enterohaemorrhagic *E. coli* (EHEC), *Cryptosoridium parvum*, Lyme disease, SARS virus, Bird flu, prions, AIDS, Dengue Hemorrhagic Fever, and *Chlamydiae*, opportunistic fungal pathogens. Mechanisms of emergence of new pathogens: microbial change and adaptation, horizontal gene transfer (HGT), pathogenicity islands (PAI), role of integrons.
4. **Molecular microbial epidemiology:** Objectives of microbial epidemiology. Biochemical and Immunological tools - biotyping, serotyping, phage typing, FAME, Curie Point PyMS, protein profiling, multilocus enzyme electrophoresis (MLEE); Molecular typing: RFLP (ribotyping, IS based), RAPD, 16S-23S IGS, ARDRA, rep (REP, ERIC, BOX)-PCR, PFGE, AFLP, MLST, MVLST, VNTR, SNP, Microarry and whole genome sequence; GIS
5. **Environmental change and infectious diseases:** Global warming lead increase in vector-borne and water-borne infectious diseases; Impact of increasing urbanization, international travel and trade on infectious diseases.
6. **Antimicrobial resistance:** Recent concepts – Multidrug efflux pumps, extended spectrum β-lactamases (ESBL), X-MDR *M. tuberculosis*, Methacillin-resistant *S. aureus* (MRSA).
7. **Newer vaccines:** Recombinant vaccines, subunit vaccines, DNA vaccines, Vaccinia, BCG and HIV– vector based vaccines
8. **Rapid diagnostic principles:** Nucleic acid probes in diagnostic microbiology, nucleic acid amplification methods, Real-time PCR, diagnostic sequencing and mutation detection, molecular typing methods, array technology.

**multi-disciplinary course offered by the Department of Microbiology.*

Suggested Study Material

1. G.F. Brooks, J.S. Butel, S.A. Morse, J.L. Melnick, E. Jawetz, E.A. Adelberg. 2004. Jawetz, Melnick & Adelberg's Medical Microbiology, Lange Publication. USA
2. P. Cossart, P. Boquet, S. Normark, R. Rappuoli. 2005. Cellular Microbiology, American Society for Microbiology Press. USA
3. A.A. Salyers, D.D. Whitt. 2002. Bacterial Pathogenesis: A molecular approach. American Society for Microbiology Press, Washington, DC USA.
4. J. Hacker, U. Dorbindt. 2006. Pathogenomics: Genome analysis of pathogenic microbes, Wiley-VCH. Germany
5. D.H. Persing, F.C. Tenover, J. Versalovic, Y. Tang, E.R. Unger, D.A. Relman, T.J. White. 2004. Molecular Microbiology: Diagnostic Principles and Practice, American Society for Microbiology Press. USA
6. K.E. Nelson, C.M. Williams, N.M.H. Graham. 2001. Infectious Disease Epidemiology: Theory and Practice, An Aspen Publication. USA

BIOCHEM 1003

Proteomics and Metabolomics

1. Introduction to proteome, proteomics technology, types and kinds of proteomics investigation, importance of proteomics.
2. Principles and applications of the separation technology (Electrophoresis, Centrifugation, Chromatography etc) in proteomics. Mass spectrometry (Ionizers, analyzers and detectors) technology and its application in proteomics.
3. General workflow for the 2-D Gel Electrophoreses, sample preparation, evolution of 2D PAGE, experimental details for the 2-D gel and high throughput 2-D PAGE.
4. Application of two-dimension gel electrophoreses in proteomics. Importance of 2-D fluorescence difference gel electrophoresis for comparative proteomics. Two-dimensional gel electrophoresis for biomarker discovery
5. Proteomic profiling for host-pathogen interaction. Sample treatment for labeling, 2D LC-MS/MS analysis, database search and relative quantification, analysis and interpretation, quantitative proteomics.
6. Protein-Protein Interaction (PPI) and its application in proteomics. Methods to study PPI.
7. Application of proteomics for drug discovery. Biomarkers and drug targets identification. Validation of drug targets and assessment of its toxicology
8. Introduction to metabolomics world. Highthroughput screening systems and utility. Lessons from metabolites, metabolic fingerprinting, and metabolic profiling. Biotechnological potentials of metabolomics.
9. Proteomics approaches in metabolomics. Analysis of differential protein expression, post-translational modifications and protein activity for metabolomics.
10. HPLC and FPLC based approaches in metabolomics. Criteria for the selection of chromatography methods and their importance in metabolomics.
11. Application for cellular metabolomics for metabolic pathway structure. Size of metabolome, metabolite identification, pathway identification and pathway integration.
12. Metabolite profiling for infectious disease.
13. Application of metabolite profiling in heart disease. Metabolic signature and metabolite profiling in heart disease.
14. Metabonomics in preclinical pharmaceutical discovery and development. Analytical considerations, and biological aspects and applications.

Suggested Study Material

1. T. Palzkill. 2002. Proteomics, Kluwer Academic Publishers, New York, USA.
2. E.D. Hoffmann, V. Stroobant. 2007. Mass Spectrometry: Principles and Applications, John Wiley & Sons Ltd. The Atrium, Southern Gate, Chichester, West Sussex PO19 8SQ, England.
3. D. Kambhampati. 2004. Protein Microarray Technology, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany.
4. E. Fung. Methods in Molecular Biology, Volume 264: Protein Arrays, Humana Press Inc., Totowa, NJ.
5. S.G. Villas-Boas. 2007. Metabolome Analysis: An Introduction, Wiley-Blackwell, USA.
6. B. J. Nikolau. 2007. Concepts in Plant Metabolomics, Wurtele, Eve Syrkin, Springer, USA.
7. J. Lindon, J. Nicholson, E. Holmes. 2006. The Handbook of Metabonomics and Metabolomics, Elsevier B.V., Netherlands.

BIOCHEM 1004

Dissertation

(continuation from Semester III - BIOCHEM 0905)

As described in the scheme of examinations, dissertation will be carried out for one full year comprising of semester 3 and semester 4. The complete work carried out during the dissertation will be evaluated at the end of semester 4. The marks would be assigned as described in the programme structure.

(226) Department of Biochemistry.

Circulate to concerned Departments. 7/9/2015

No. 29308

दिल्ली विश्वविद्यालय

परिषद शाखा-2
कमरा संख्या - 211
नया प्रशासनिक खंड,
दिल्ली - 110007

दूरभाष - 011-27001156

Ref. No. CNC-II/098/2015/

Date: 02-09-2015

The Dean/The HOD,

Faculty of Inter-Disciplinary and Applied Sciences (FIAS)
University of Delhi
Delhi-110007

Sir,

This is to inform you that consequent upon the recommendations of the Faculty/ Committee of courses & studies and its subsequent approval by Academic Council in its meeting held on 13.07.2015 the Vice-Chancellor in exercise of his emergency powers, under Clause (4) of the Statute 11(G) of the Statutes of the University, has approved the courses/papers as per list attached herewith.

Yours faithfully,

Deputy Registrar (Council)

Encl:

1. List of courses/papers as stated above.
2. Resolutions of the Academic Council (dated 13.07.2015) concerned.

Baba Nand. Please circulate to all the faculty members & the Dept. Thanx. 8/9/15

Mailed to faculty members 8/9/15

S.No.	Course	A.C. dated 13.07.2015 Res. No.
1.	M. Pharma I and II	06(01)
2.	M.A. Philosophy	06(02)
3.	Master of Business Administration (Business Economics)	06(03)
4.	PG Diploma in Counseling and Mental Health	06(04)
5.	GE-I Certificate Course in Education of Gifted Students	06(5)
6.	GE-II Diploma Course in Education of Gifted Students	06(5)
7.	2 year M.Ed. Programme	06(06)
8.	2 year B.Ed. Programme	06(06)
9.	2 year B.Ed. Special Education Programme	06(06)
10.	B.A.(Hons.) Course of (Humanities and Social Sciences) Semester-VI	06(07)
11.	B.Tech. (IT & Mathematical Innovations)	06(09)
12.	M.A. Political Science	06(10)
13.	Semester IV in M.A. Geography	9
14.	Promotion criteria for full time one year PG Intensive Diploma in Chines, Japanese and Korean	10
15.	Ph. D. Programme in East Asian Studies	11(1)
16.	Sociology (Minor changes in the course)	12
17.	Change in nomenclature of the degree B.A. Multimedia and Mass Communication	18
18.	M.A. Hindustani Music (Vocal/Instrument)	21(1)
19.	M.A. Karnatak Music	21(2)
20.	M.A. Percussion Music (Tabla/Pakhawaj)	22
21.	M.A./M.Sc. Mathematics paper	23
22.	Modification of Vth and VIth semester of B.Sc. (H) Physics	24
23.	One year full-time Intensive Advance Diploma in Russian	25(1)
24.	Part time Certificate course in Bulgarian, Croation, Czech, Hungarian and Polish	25(2)
25.	Part time Diploma course in Bulgarian, Croation, Czech, Hungarian and Polish	25(3)
26.	Part time advanced Diploma course in Bulgarian, Croation, Czech, Hungarian and Polish	25(4)
27.	M.Sc. (Bio-chemistry)(Minor changes)	26
28.	M.Sc.(Genetics)(Syllabus and eligibility criteria)	28
29.	B.P.Ed.	29
30.	M.A. English (New Interdisciplinary course)	32(11)

UNIVERSITY OF DELHI

ACADEMIC COUNCIL
DATED : 13.07.2015
RESOLUTION NO. 26

Resolution No. 26

26/ Resolved that the recommendation of the **Faculty of Inter-Disciplinary and Applied Sciences (FIAS)** made at its meeting held on 11.06.2015 regarding minor change/reorganization of the courses in M.Sc. (Bio-chemistry) of Department of Bio-chemistry from the academicsession2015-2016 be accepted and recommended to the Executive Council for approval. **(vide Appendix-126)**

COURSES OFFERED FOR Ph.D. CURRICULUM

July 2016 onwards

Department of Biochemistry
Faculty of Interdisciplinary and Applied Sciences
University of Delhi South Campus
Benito Juarez Road
New Delhi-110021

Passed in DRC held on 3rd February, 2016

The courses offered for the Ph.D. curriculum aim to provide the students with excellent knowledge in various Tools, Techniques and Research methodologies in Biochemistry emphasizing on solid background of basic concepts as well as rapid advancement in the field, providing them an initiation into their respective research fields. The department will offer the following three papers for Ph.D. course work:

Paper I (BIOCHEM P-I): RESEARCH METHODOLOGY

Paper II (BIOCHEM P-II): TOOLS AND TECHNIQUES IN BIOCHEMISTRY- I

Paper III (BIOCHEM P-III): TOOLS AND TECHNIQUES IN BIOCHEMISTRY- II

These courses are also open for Ph.D. students from other departments in FIAS. The Ph.D. students of the biochemistry department are also free to choose from Ph.D. courses offered by the other departments. A student has to pass all the three papers in one academic year (two semesters) to successfully complete the Ph.D. course work.

Evaluation: All the three papers will have components of end semester examination and continuous evaluation. The total marks for each paper will be 100. A student has to score 50 marks to pass a paper. The distribution of marks will be as follows:

Paper	Continuous evaluation	End-semester evaluation	Total Marks
BIOCHEM P-I	50	50	100
BIOCHEM P-II	30	70	100
BIOCHEM P-III	30	70	100

All three courses will be offered in the July to December semester.

RESEARCH METHODOLOGY

(BIOCHEM P-I)

Unit 1. Biosafety and Bioethics in Research
Guidelines for Biosafety and Bioethics; Safety practices and Bio-waste in the laboratory; Radioactivity and safety; Fire hazards and safety; Institutional Biosafety, Ethics and Animal Ethics compliance and concerns; Genetically modified organisms; Patents and Intellectual property rights; Plagiarism; Reproduction of published material, Citation and acknowledgement; Guidelines for Ph.D. thesis.

Unit 2. Defining the Research Problem
Identification of broad area of research; Review of literature using appropriate sources – reviews, patents, research papers, books; Utilization of tools for literature source – web and libraries; Defining a research problem

Unit 3. Experimental Approaches and Methodology
Experimental designs to address the research problem; Pros and cons of the experiments; Alternative plans for experimental design; Tools and techniques to execute experiments; Means to validate and analyze data; Methods of record keeping.

Unit 4. The art of Presentation
Development of writing skills – Plan of research, Research project, Research report, Research article and review, Term paper; Bibliography, referencing and footnotes; Creation of reference libraries; Plagiarism check; Development of Oral presentation skills – Planning, Preparation, Practice, Oration; Use of visual aids and software like MS Word, MS powerpoint, MS Excel, EndNote; Importance of effective Communication.

Students are expected to undertake the following assignments, exercises and evaluations.

1. Identify the broad area of research in consultation with Ph.D. supervisor.
2. Review literature, collate information, identify scope of research, formulate a research plan and prepare and submit a term paper including references.
3. Present and defend their research plan orally.
4. Evaluation will be based on term paper and oral presentation.

SUGGESTED READINGS

1. Research Methodology - Methods and Techniques (2004) 2nd ed., Kothari C.R., New Age International Publishers.
2. Research Methodology: A Step-by-Step Guide for Beginners (2005) 2nd ed., Kumar R., Pearson Education.

TOOLS AND TECHNIQUES IN BIOCHEMISTRY- I
(BIOCHEM P-II)

Unit 1. Biochemical Reagents and Solutions

Preparation of solutions; Concepts of solution strength (concentration); Sterilization of solutions; Buffer preparation - Concept of pKa and Henderson-Hasselbach equation, Concept of conjugate acid and base.

Unit 2. Spectroscopy and Spectrometry

Principle, instrumentation and applications of absorbance, fluorescence and circular dichroism spectroscopic techniques; Mass spectrometry and its applications including /2D PAGE and basic proteomics. Estimation of biomolecules.

Unit 3. Recombinant DNA

Amplification of DNA using PCR; Design of primers; Use of Restriction and modification enzymes in cloning, Plasmid vector, Ligation, Transformation and Plasmid isolation, 8. Basic DNA sequencing methods, Sanger's chain termination method, and automated DNA sequencing, Base calling and sequencing accuracy, Introduction to next generation sequencing (NGS).

Unit 4. Genomics

Global expression profiling; Whole genome analysis of mRNA and protein expression; Real time PCR to monitor changes in expression levels; Concept of microarrays and its applications for DNA, RNA and proteins.

SUGGESTED READINGS

1. Physical Biochemistry: Applications to Biochemistry and Molecular Biology (1982) 2nd ed., Freifelder, D., W.H. Freeman and Company (New York), ISBN:0-7167-1315-2 / ISBN:0-7167-1444-2.
2. An Introduction to Practical Biochemistry (1998) 3rd ed., Plummer D. T., Tata McGraw Hill Education Pvt. Ltd. (New Delhi), ISBN:13: 978-0-07-099487-4 / ISBN:10: 0-07-099487-0.
3. Molecular Cloning: A laboratory Manual (2012) Vol. 1-3, 4th ed., Green M.R. and Sambrook J., Cold Spring Harbour Laboratory Press (New York). ISBN: 978-1-936113-41-5 / ISBN: 978-1-936113-42-2.

TOOLS AND TECHNIQUES IN BIOCHEMISTRY- II
(BIOCHEM P-III)

Unit 1. Growth and Maintenance of Mammalian cells
Classification of cell culture; Preparation of primary culture from tissues or organs; Requirements for *in vitro* cell culture, determination of doubling time, live cell staining and counting, freezing, thawing and synchronization of mammalian cells.

Unit 2. Characterization and Genetic engineering of animal cells in culture
Various ways of overexpressing and silencing genes in mammalian cells; Generation of transient and stable lines. Application of FACS for detection of cell surface markers, apoptotic cells and cell cycle phases. Analysis of cell signaling pathways by Western blotting, Immunoprecipitation and Pull down assays; Use of radioisotopes in cell biology.

Unit 3. Cell Fractionation and Cell-cell Interaction Methods
Cell fractionation; Centrifugation; Isolation and purification of membrane proteins and lipids; Various methods to study cell-cell and cell-virus fusion, Electrophoresis.

Unit 4. Animal Handling
Handling and maintenance of animals, cages, feed, animal house; Life cycle of mouse; Dissection and anatomy. Immunization of animals, various routes of injection, blood collection and euthanisation.

Unit 5. Purification, Characterization of proteins and Drug discovery
Expression vectors; Expression, isolation and purification of heterologous proteins; Chromatography techniques for protein purification; Mapping of protein interactions: two hybrid, Protein fragment complementation, Concepts of drug discovery and development.

SUGGESTED READINGS

1. Animal Cell Culture & Technology (2004) 1st ed., Butler, M., Tailor & Francis Publishers (UK), ISBN-1: 859960499.
2. Principles and Techniques of Biochemistry and Molecular Biology (2010) 7thed., Keith Wilson and John Walker, Cambridge University Press India Pvt. Ltd., ISBN-13: 978-0-521-17874-7 / ISBN:10: 0-07-099487-0.
3. Molecular Cloning: A laboratory Manual (2012) Vol. 1-3, 4th ed., Green M.R. and Sambrook J., Cold Spring Harbour Laboratory Press (New York). ISBN: 978-1-936113-41-5 / ISBN: 978-1-936113-42-2.
4. R. Burgess, M. P. Deutcher. 2009. Guide to Protein Purification, Academic Press, San Diego, USA.