BANASTHALI VIDYAPITH

Master of Science (Biotechnology)

Curriculum Structure

First Semester Examination, December-2020
Second Semester Examination, April/May-2021
Third Semester Examination, December-2021
Fourth Semester Examination, April/May-2022

BANASTHALI VIDYAPITH
P.O. BANASTHALI VIDYAPITH
(Rajasthan)-304022

July, 2020

91

No. F. 9-6/81-U.3

No. F. 9-6/81-U.3
Government of India
Ministry of Education and Culture
(Department of Education)

New Delhi, the 25th October, 1983

NOTIFICATION

In exercise of the powers conferred by section 3 of the University Grants Commission Act, 1956 (3 of 1956) the Central Government, on the advice of the Commission, hereby declare that Banasthali Vidyapith, P. O. Banasthali Vidyapith, (Rajasthan) shall be deemed to be a University for the purpose of the aforesaid Act.

Sd/
(M. R. Kolhatkar)
Joint Secretary to the Government of India

NOTICE

Changes in Bye-laws/Syllabi and Books may from time to time be made by amendment or remaking, and a Candidate shall, except in so far as the Vidyapith determines otherwise, comply with any change that applies to years she has not completed at the time of change.

Programme Educational Objectives

The M.Sc Biotechnology programme aims for the holistic development of students through the unique and innovative five fold educational ideology of Banasthali Vidyapith. Biotechnology is identified as a potential technology which can impact all facets of life particularly agriculture and health sectors. The Programme has been designed to develop technically skilled personnel who as academicians, researchers, entrepreneurs and professionals can play a pivotal role in biotechnology and its allied sectors. Through a comprehensively designed course structure it is envisaged that students will realise their potential in academics as well as industry. The programme would inculcate moral values accompanied with an understanding of ethical-societal issues and safety concerns that a biotechnologist is increasingly facing. On completion of the Programme, students will be able to:

- identify, analyze and formulate solutions for complex biotechnological problems through team work and multidisciplinary approach,
- design and apply appropriate tools for biotechnological manipulations,
- apply knowledge to solve societal problems keeping in mind the legal and ethical issues concerning genetic manipulation technologies,
- develop scientific communication skills and be well versed with the latest technologies,
- improve public perception of biotechnology and its role,
- identify and generate ideas for entrepreneurial ventures,
- engage in lifelong learning in the broadest context of technological change.

Programme Outcomes

PO1: **Knowledge**: Develop skills and theories associated with reconstruction, explanation and interpretation of knowledge associated with diverse fields of biochemistry, molecular biology, immunology, microbiology, tissue culture, environmental sciences, statistics, bioinformatics, genetics and industrial biotechnology.

PO2: Planning abilities: Demonstrate, design and execute research problems to highlight skills in planning, resource management, organsization and execution in a timely manner.

PO3: Problem analysis: Interpret, compare and analyze following rules of scientific methodology to arrive at a defensible conclusion of a problem.

PO4: Modern tool usage: Learn, identify, select and apply biotechnological tools and techniques for problem solving; choose correct statistical methods for data validation and bioinformatics computational tools and techniques for further analyses and interpretation.

PO5: Leadership skills: Understand the value of organization and team support to form and build units addressed towards problem solving. Ability to motivate, encourage, support and empathize.

PO6: Professional Identity: Cognition of the professional niche to be fulfilled in society as a part of social and economic capital.

PO7: Bioethics and Biosafety: Understand principle of bioethics to govern profession behavior to enable ethical development of biotechnology. Develop thorough understanding and knowledge of levels and types of biosafety to facilitate formation and development of infrastructure and methodology which imposes minimal to no damage to the stakeholders including society and environment.

PO8: Communication: Ability to perceive and facilitate the understanding of science and its associated technology. Develop good written and oral skills, prepare effective presentations, development of standard operating procedures and publish research documents.

PO9: The biotechnologist and society: Identify problems in society related to biotechnology and its scope, formulate a solution, apply and execute it while taking responsibilities for ethical, moral and legal consequences.

PO10: Environment and sustainability: Comprehend and describe the environmental impact of biotechnology research and advancements. Identify possible solutions and methodologies to eliminate or mitigate or restore any negative influences while developing technologies as part of sustainable development highlighted by Convention of Biological Diversity.

PO11: Life- long learning: Self analysis, appraisal and constructive criticism to be used for further improvement which facilitates continued involvement and developments in mediating technological advances.

Curriculum Structure

Master of Science (Biotechnology)

First Year

Semester - I

Course Code	Course Name	L	T	P	C*
BIN 405	Bioinformatics	4	0	0	4
BIO 401	Analytical Techniques - I	4	0	0	4
BIO 418	Biochemistry	4	0	0	4
BIO 407	Cell and Molecular Biology	4	0	0	4
BIO 425	Microbiology	4	0	0	4
BIO 419L	Bioscience Lab - I	0	0	12	6
	Semester Total:	**20**	**0**	**12**	**26**

Semester - II

Course Code	Course Name	L	T	P	C*
BIO 406	Biostatistics and Research Methodology	4	0	0	4
BIO 422	Environmental Biology and Biotechnology	4	0	0	4
BIO 410	Genetics	4	0	0	4
BIO 411	Immunology	4	0	0	4
BT 408	Genetic Engineering	4	0	0	4
BIO 420L	Bioscience Lab - II	0	0	12	6
	Semester Total:	**20**	**0**	**12**	**26**

Second Year

Semester - III

Course Code	Course Name	L	T	P	C*
BIO 507S	Critical Analysis of Classical Papers, Landmark Discoveries (Seminar)	0	0	4	2
BT 504	Bioprocess Engineering and Technology	4	0	0	4
BT 507	Cell and Tissue Culture Technology	4	0	0	4
BT 550L	Biotechnology Lab - I	0	0	12	6
	Discipline Elective	4	0	0	4
	Open Elective	4	0	0	4
	Reading Elective - I	0	0	4	2
	Semester Total:	**16**	**0**	**20**	**26**

Semester - IV

Course Code	Course Name	L	T	P	C*
BT 528D	Dissertation	0	0	48	24
	Reading Elective - II	0	0	4	2
	Semester Total:	**0**	**0**	**52**	**26**

List of Discipline Elective

Course Code	Course Name	L	T	P	C*
BIO 503	Fundamentals of Bioentrepreneurship	4	0	0	4
BIO 505	Microbial Technology	4	0	0	4
BT 544	Enzyme Technology	4	0	0	4
BT 513	Food Process and Biotechnology	4	0	0	4
BT 545	Genomics and Proteomics	4	0	0	4
BT 521	Plant Biotechnology	4	0	0	4
BT 522	Recombinant DNA Technology	4	0	0	4
BT 532	Immunotechnology	4	0	0	4
BT 525	Animal Biotechnology-I	4	0	0	4
PHY 532	Biophysics-I	4	0	0	4

ENVS 402	Ecology and Environment	4	0	0	4
BT 549	Molecular Diagnostics and Emerging Techniques in Biotechnology	4	0	0	4
BT 546	Artificial Intelligence in Biotechnology and Healthcare	4	0	0	4

List of Online Discipline Elective

	Course Name	L	T	P	C*
	Fundamentals of Ecology for Sustainable Ecosystem				
	Industrial Biotechnology				
	Water and Waste Treatment Engineering: Biochemical Technology				

List of Reading Elective

Course Code	Course Name	L	T	P	C*
BT 529R	Drug Discovery	0	0	4	2
BT 531R	Human Genetics and Diseases	0	0	4	2
BT 534R	Intellectual Property Rights	0	0	4	2
BT 535R	Medical Microbiology	0	0	4	2
BT 538R	Molecular Plant Breeding	0	0	4	2
BT 539R	Protein Engineering	0	0	4	2

List of Online Reading Elective

	Course Name
	Bio- organic Chemistry
	Biocatalysis in organic synthesis
	Comprehensive Disaster Risk Management Framework
	Environmental Management - An Introduction

Enzyme Science and Engineering

General Course on Intellectual Property

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* **L - Lecture hrs/week; T - Tutorial hrs/week; P-Project/Practical/Lab/All other non-classroom academic activities, etc. hrs/week; C - Credit Points of the Course**

Student can opt open (Generic) elective from any discipline of the Vidyapith with prior permission of respective heads and time table permitting.

Every Student shall also opt for:
Five Fold Education: Physical Education I, Physical Education II,
Five Fold Education: Aesthetic Education I, Aesthetic Education II,
Five Fold Education: Practical Education I, Practical Education II
one each semester

Five Fold Activities

Aesthetic Education I/II		Physical Education I/II	
BVFF 101	Classical Dance (Bharatnatyam)	BVFF 201	Aerobics
BVFF 102	Classical Dance (Kathak)	BVFF 202	Archery
BVFF 103	Classical Dance (Manipuri)	BVFF 203	Athletics
BVFF 104	Creative Art	BVFF 204	Badminton
BVFF 105	Folk Dance	BVFF 205	Basketball
BVFF 106	Music-Instrumental (Guitar)	BVFF 206	Cricket
BVFF 107	Music-Instrumental (Orchestra)	BVFF 207	Equestrian
BVFF 108	Music-Instrumental (Sarod)	BVFF 208	Flying - Flight Radio Telephone Operator's Licence (Restricted)
BVFF 109	Music-Instrumental (Sitar)	BVFF 209	Flying - Student Pilot's Licence
BVFF 110	Music-Instrumental (Tabla)	BVFF 229	Aeromodelling
BVFF 111	Music-Instrumental (Violin)	BVFF 210	Football
BVFF 112	Music-Vocal	BVFF 211	Gymnastics
BVFF 113	Theatre	BVFF 212	Handball
Practical Education I/II		BVFF 213	Hockey
BVFF 301	Banasthali Sewa Dal	BVFF 214	Judo
BVFF 302	Extension Programs for Women Empowerment	BVFF 215	Kabaddi
BVFF 303	FM Radio	BVFF 216	Karate - Do
BVFF 304	Informal Education	BVFF 217	Kho-Kho
BVFF 305	National Service Scheme	BVFF 218	Net Ball
BVFF 306	National Cadet Corps	BVFF 219	Rope Mallakhamb
		BVFF 220	Shooting
		BVFF 221	Soft Ball
		BVFF 222	Swimming
		BVFF 223	Table Tennis
		BVFF 224	Tennis
		BVFF 225	Throwball
		BVFF 226	Volleyball
		BVFF 227	Weight Training
		BVFF 228	Yoga

Every Student shall also opt for:
Five Fold Education: Physical Education I, Physical Education II,
Five Fold Education: Aesthetic Education I, Aesthetic Education II,
Five Fold Education: Practical Education I, Practical Education II
one each semester

Evaluation Scheme and Grading System

Continuous Assessment (CA) (Max. Marks)					End-Semester Assessment (ESA) (Max. Marks)	Grand Total (Max. Marks)
Assignment		Periodical Test		Total (CA)		
I	II	I	II			
10	10	10	10	40	60	100

In all theory, laboratory and other non classroom activities (project, dissertation, seminar, etc.), the Continuous and End-semester assessment will be of 40 and 60 marks respectively. However, for Reading Elective, only End semester exam of 100 marks will be held. Wherever desired, the detailed breakup of continuous assessment marks (40), for project, practical, dissertation, seminar, etc shall be announced by respective departments in respective student handouts.

Based on the cumulative performance in the continuous and end-semester assessments, the grade obtained by the student in each course shall be awarded. The classification of grades is as under:

Letter Grade	Grade Point	Narration
O	10	Outstanding
A+	9	Excellent
A	8	Very Good
B+	7	Good
B	6	Above Average
C+	5	Average
C	4	Below Average
D	3	Marginal
E	2	Exposed
NC	0	Not Cleared

Based on the obtained grades, the Semester Grade Point Average shall be computed as under:

$$SGPA = \frac{CC_1 * GP_1 + CC_2 * GP_2 + CC_3 * GP_3 + ---- + CC_n * GP_n}{CC_1 + CC_2 + CC_3 + ---- + CC_n} = \frac{\sum_{i=1}^{n} CC_i * GP_i}{\sum_{i=1}^{n} CC_i}$$

Where n is the number of courses (with letter grading) registered in the semester, CC_i are the course credits attached to the i^{th} course with letter grading and GP_i is the letter grade point obtained in the i^{th} course. The courses which are given Non-Letter Grades are not considered in the calculation of SGPA.

The Cumulative Grade Point Average (CGPA) at the end of each semester shall be computed as under:

$$CGPA = \frac{CC_1 * GP_1 + CC_2 * GP_2 + CC_3 * GP_3 + ----+ CC_n * GP_n}{CC_1 + CC_2 + CC_3 + ----+ CC_n} = \frac{\sum_{i=1}^{n} CC_i * GP_i}{\sum_{i=1}^{n} CC_i}$$

Where n is the number of all the courses (with letter grading) that a student has taken up to the previous semester.

Student shall be required to maintain a minimum of 4.00 CGPA at the end of each semester. If a student's CGPA remains below 4.00 in two consecutive semesters, then the student will be placed under probation and the case will be referred to Academic Performance Review Committee (APRC) which will decide the course load of the student for successive semester till the student comes out of the probationary clause.

To clear a course of a degree program, a student should obtain letter grade C and above. However, D/E grade in two/one of the courses throughout the UG/PG degree program respectively shall be deemed to have cleared the respective course(s). The excess of two/one D/E course(s) in UG/PG degree program shall become the backlog course(s) and the student will be required to repeat and clear them in successive semester(s) by obtaining grade C or above.

After successfully clearing all the courses of the degree program, the student shall be awarded division as per following table.

Division	CGPA
Distinction	7.50 and above
First Division	6.00 to 7.49
Second Division	5.00 to 5.99
Pass	4.00 to 4.99

CGPA to % Conversion Formula: % of Marks Obtained = CGPA * 10

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First Semester

BIN 405 Bioinformatics

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- describe and identify various databases and tools used for phylogenetic analysis
- apply protein structure prediction
- demonstrate and apply different tools for data-mining

Section A

- Introduction and scope of bioinformatics, Introduction to biological databases: primary, composite, secondary databases and structural database. Description of specific databases: UniGene, UniProt, and RCSB – PDB). Introduction to genomics, proteomics and phylogenetics resources available at ExPassy.
- Introduction to sequence analysis: Dot Plot, scoring matrices (PAM matrix) and gap penalty.

Section B

- Description and application of global and local sequence alignment. Sequence based database searching: working algorithms of BLAST, variations of BLAST. Multiple Sequence alignment. Evolutionary significance of sequence alignment.
- Evolutionary models: Jukes – Cantor and Kimura two parameter.
- Phylogenetic Analysis: distance based (UPGMA, N-J Methods) and character based (Maximum Parsimony).

Section C

- Protein 2D structure prediction: Chou – Fasman algorithm.
- Protein 3D structure prediction: homology modeling, its advantage and limits.

- Concept of structure optimization and energy minimization.
- Forces stabilizing biomolecular interaction.
- Principle of Molecular Docking. Types of molecular docking, its advantage and limits.

Suggested Books:

- Attwood, T.K., Parry-Smith, D.J. & Phukam, S. (2009). *Introduction to Bioinformatics* (4th ed.). UK: Pearson Education.
- Krane, D.E. & Reymer, M.L. (2003).*Fundamental Concepts of Bioinformatics*. UK: Pearson Education.
- Lesk, A.M. (2008). *Introduction to Bioinformatics.* UK: Oxford University Press.
- Rastogi, S.C. & Rastogi, P. (2013). *Bioinformatics Methods and Applications* (4th ed.). New Delhi: PHI Learning Private Limited.
- Sharma, V., Munjal, A. & Shanker, A. (2017). *A Text Book of Bioinformatics* (2nd ed.). Meerut: Rastogi Publications.

Suggested e- Resources:

- **Chou-Fasman Method for protein secondary structure prediction**

  https://pdfs.semanticscholar.org/fd8c/c95aec2d7af19ed28eea3688b3c231d0e745.pdf

- **Homology modeling**

  https://proteinstructures.com/Modeling/homology-modeling.html

- **ExPASy**

  https://www.expasy.org/

BIO 401 Analytical Techniques-I

Max. Marks : 100	L	T	P	C
(CA: 40 + ESA: 60)	4	0	0	4

Learning Outcomes:

After successful completion of the course, students should be able to:

- comprehend the principles of various instrumentation techniques.
- identify suitable and relevant tools for use in research problems.
- utilize the scope of the content for designing and performing future experiments.

Section-A

- Chromatographic methods for macromolecule separation: TLC and Paper chromatography, Gel permeation, Ion exchange, Hydrophobic, Reverse-phase & Affinity chromatography; HPLC, FPLC & GLC.
- Electrophoretic techniques:

  Theory and applications of polyacrylamide and agarose gel electrophoresis, capillary electrophoresis, 2D electrophoresis, Disc gel electrophoresis, Gradient electrophoresis, Pulse field gel electrophoresis & Isoelectric focusing.

Section-B

- Microscopy:

  Microscope and its modifications- Light, Phase contrast and interference, Fluorescence, Confocal, Electron (TEM & SEM), Electron tunneling & Atomic Force Microscopy.

- Centrifugation:

  Basic principle & theory, types of centrifuges- Micro centrifuge, High speed & Ultracentrifuges. Preparative centrifugation: differential & density gradient centrifugation. Analytical centrifugation & its applications.

Section-C

- Spectroscopy:

  Principle, instrumentation applications in biological sciences. UV-visible spectrophotometry, Florometry & Atomic absorption spectrophotometer (AAS). Principle & applications of NMR, X-ray

crystallography, Mass spectroscopy and MALDI-TOF, Circular Dichroism.

- Radioactivity:

  Radioactive and stable isotopes, Pattern and rate of radioactive decay, Measurement of radioactivity, Geiger-Muller counter, solid and liquid scintillation counters (Basic principle, instrumentation and technique), brief idea of radiation dosimetry, Cerenkov radiation & autoradiography.

Suggested Books:

- Chatanta, D.K. & Mehra, P.S. (2012). *Instrumental Methods of Analysis in Biotechnology*. New Delhi, India: I.K. International Publishing House Pvt. Ltd.
- Chatwal, G.R. & Anand, S.K. (2018). *Instrumental Methods of Chemical Analysis*. New Delhi, India: Himalaya Publishing House.
- Friefelder, D. (1982). *Physical Biochemistry: Applications to Biochemistry and Molecular Biology*. New York, USA: W.H. Freeman and Company.
- Sharma, B.K. (2004). *Instrumental methods of Chemical Analysis, In: Introduction to Analytical Chemistry*. New Delhi, India: Goel Publishing House.
- Talluri, S. (2012). *Bioanalytical techniques*. New Delhi, India: I.K. International Publishing House Pvt. Ltd.
- Wilson, K. & Walker, J. (2010). *Principles and Techniques of Biochemistry and Molecular Biology*. Cambridge, UK: Cambridge University Press.

Suggested e- Resources:

- **Chromatographic Techniques**

  https://nptel.ac.in/courses/103108100/module7/module7.pdf

- **Spectroscopic techniques**

  https://nptel.ac.in/courses/102103044/pdf/mod2.pdf

- **Microscopic techniques**

  www.nptel.ac.in/courses/102103015/pdf/mod3.pdf

BIO 418 Biochemistry

Max. Marks : 100	L	T	P	C
(CA: 40 + ESA: 60)	4	0	0	4

Learning Outcomes:

After successful completion of the course, students should be able to:

- understand the structure and role of various biomolecules
- identify, assess and explain various biochemical pathways
- gain understanding of enzymes and their mechanism of action for use in research and allied ventures

Section-A

- Bioenergetics: First and Second law of thermodynamics, concept of free energy, change in standard free energy.
- Carbohydrates: general classification, Polysaccharides: Starch, glycogen, cellulose & chitin.
- Glycolysis, Citric acid cycle. Electron transport system in mitochondria & chloroplasts. Oxidative phosphorylation, Photosynthetic phosphorylation, P/O ratio, Uncouplers.

Section-B

- Lipids - glycerophospholipids, sphingolipids, gangliosides, eicosanoids & prostaglandins.
- Proteins & amino acids – Zwitterionic properties of amino acids & titration curves. Peptide bonds, disulphide crosslinks, various levels of structural organization of proteins.
- Ramachandran plot, Alpha-helix, Beta sheet.
- Structure function relationship in model proteins like ribonuclease A, haemoglobin and chymotrypsin.
- Biosynthesis of purines and pyrimidines, *de novo* and salvage pathway,

Section-C

- Introduction to enzymes: Classification of enzymes Nomenclature of enzymes, E.C. Number

- Enzyme kinetics (Michaelis – Menten kinetics), importance and determination of Vmax and Km values, L & B plots.
- Enzyme inhibition: competitive, non-competitive and un-competitive.
- Coenzymes and Isozymes.

Suggested Books:

- Berg, J.M., Tymoczko, J.L., Gatto Jr., G.J. & Stryer, L. (2015). *Biochemistry* (8th ed.). New York, USA: W. H. Freeman and Company.
- Cantor, C.R. & Schimmel, P.R. (1980). *Biophysical Chemistry Part I, II & III*. New York, USA: W. H. Freeman and Company.
- Ferdinand, W. (1976). *The Enzyme Molecule*. New Jersey, USA: John Wiley & Sons Ltd.
- Garrett, R. H. & Grisham, C. M. (2012). *Biochemistry* (5th ed.). Belmont, USA: Wadsworth Publishing Co Inc.
- Nelson, D. L. & Cox, M.M. (2012). *Lehninger Principles of Biochemistry* (6thed.). New York, USA: W. H. Freeman and Company.
- Palmer, T. & Bonner, P. (2014). *Enzymes: Biochemistry, Biotechnology and Clinical Chemistry*. UK: Woodhead Publishing Limited.
- Rodwell, V.W., Bender, D., Botham, K.M., Kenelly, P.J. & Weil., P.A. (2018). *Harper's Illustrated Biochemistry* (31st ed.). New York, USA: McGraw-Hill Education.
- Voet, D. & Voet, J.G. (2010). *Biochemistry* (4th ed.). New Jersey, USA: Wiley.

Suggested e- Resources:

- **Metabolic pathways Biomolecules**

  https://epgp.inflibnet.ac.in/ahl.php?csrno=2

- **Mechanism of enzyme action**

  http://www.biologydiscussion.com/enzymes/enzymes-properties-and-mechanism-of-enzyme-action/6145

- **E-book for Garrett and Grisham**

  https://bit.ly/2TbDWWR

BIO 407 Cell and Molecular Biology

Max. Marks : 100	L	T	P	C
(CA: 40 + ESA: 60)	4	0	0	4

Learning Outcomes:

After successful completion of the course, students should be able to:

- understand membrane transport and cell signaling mechanisms
- develop comprehensive understanding of endo-membrane system
- understand the mechanism of DNA replication and gene expression in prokaryotes and eukaryotes

Section-A

- Molecular structure and function of plasma membrane; Transport of ions & macromolecules; Pumps, carriers and channels; Membrane carbohydrates & their significance in cellular recognition; Cellular junctions & adhesions.
- Endocytosis & exocytosis, clathrin coated vesicles, SNARE proteins.
- Cell to cell signalling: autocrine, paracrine and endocrine stimulation.
- Signaling via G-protein linked cell surface receptors, adenylate cyclase system, inositol phosphate pathway, role of Ca^{2+} ions.
- Signaling via enzyme-linked surface receptors, tyrosine kinases.
- Steroid receptors.

Section-B

- Protein sorting and targeting: Signal hypothesis, SRP, SRP Receptor, ER Resident proteins, ER chaperone proteins & their functions, glycosylation of proteins in ER.
- Golgi apparatus, role in protein glycosylation and transport.
- Lysosomes, intracellular digestion, sorting of lysosomal enzymes in Golgi, lysosomal storage diseases.
- Transport of proteins into mitochondria & chloroplasts.
- Cell Cycle & its regulation, apoptosis.

Section-C

- Replication of genetic material in prokaryotes & eukaryotes: initiation, elongation & termination; Replication of single stranded circular DNA.
- Prokaryotic transcription: Transcription units; RNA polymerase structure & assembly; Promotors, Rho-dependent & Rho-independent termination; Anti-termination.
- Eukaryotic transcription: RNA polymerase structure and assembly; RNA polymerase I, II, III; eukaryotic promoters & enhancers; general transcription factors; TATA binding proteins (TBP) and TBP associated factors (TAF).
- Post transcriptional modifications: processing of hnRNA, tRNA and rRNA; 5'-Cap formation; 3'-end processing and polyadenylation; splicing; RNA editing; nuclear export of mRNA; catalytic RNA.
- Genetic code, Isoaccepting tRNA; Translation: Translation machinery, initiation, elongation and termination; Co-and post-translational modifications.

Suggested Books:

- Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K.& Walter, P. (2007). *Molecular Biology of the Cell*. UK: Garland Science.
- Cooper, G., M. & Hausman, R. E. (2004). *The Cell: A Molecular Approach*. Washington, D.C.: ASM Press.
- De Robertis, E.D.R. & De Robertis, E.M.F. (2017). *Cell and Molecular Biology*. New York, USA: Lippincott Williams & Wilkins.
- Freifelder, D. M. (1986). Molecular Biology. USA: Jones & Bartlett Publishers.
- Hardin, J., Bertoni, G. & Lewis, K.J. (2011). *Becker's World of the Cell*. Essex, UK: Pearson Education Limited.
- Karp, G., Lwasa, J. & Larshall, W. (2015). *Cell and Molecular Biology: Concepts and Experiments*. New Jersey, USA: John Wiley & Sons Ltd.
- Lodish, H., Berk, A., Kaiser, C. A., Krieger, M., Bretsher, A., Ploegh, H., Amon, A. & Martin, K. C. (2007). *Molecular Cell Biology*. New York, USA: W. H. Freeman and Company.

Suggested e- Resources:

- **Cell Biology resources**

  https://www.nature.com/scitable

- **Sorting and trafficking of proteins**

  http://www.vcell.science/project/proteintrafficking

- **RNA editing**

  study.com/academy/lesson/rna-editing-definition-processes.html

BIO 425 Microbiology

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- gain understanding of classification, structure, functional and metabolic diversity of eubacteria and archaebacteria
- identify methods to perform bacterial identification
- explain viral structure, properties, replication and cultivation

Section-A

- History and scope of microbiology.
- Bacteria: Structural organization.
- Archaea: Structural organization and brief overview of major physiological groups (Halophiles, Methanogens, Thermophiles).
- Growth of bacteria- bacterial growth curve, factors affecting growth,
- Nutrition in bacteria- nutritional classes, modes of nutritional uptake, media (types) and culture methods.
- Modes of bacterial reproduction.
- Regulation in bacteria-operon concept-lac, trp and ara.

Section-B

- Classification of bacteria and approaches used (conventional and modern).
- Metabolic diversity in bacteria- aerobic and anaerobic respiration (suphate, nitrate), fermentation (lactic, mixed, acetone-butanol, stickland fermentations and acetogenesis), chemolithotrophy (hydrogen, sulphur, nitrate and iron oxidizers), phototrophy (oxygenic and anoxygenic).
- Unculturable microbes.
- Bacterial quorum sensing.

Section-C

- General properties, structure, taxonomy (ICTV and Baltimore classification) of virus.
- General features of viral replication, sub-viral particles – satellite virus, viroids & prions.
- Bacteriophages: One step growth curve, structure & life cycle of T_4 and lambda phages, molecular control of lytic & lysogenic cycle.
- Animal virus: Structure and life cycle of - herpes simplex virus, papovavirus, reovirus and retroviruses.
- Plant virus: Structure and life cycle of - geminivirus, caulimovirus and tobacco mosaic virus; virus-vector relationship.
- Virus assay: Plaque, pock, hemagglutination & transformation assays and concept of ID50.
- Cultivation of viruses.

Suggested Books:

- Atlas, R.M. & Bartha, R. (1998), *Microbial Ecology: Fundamentals and Applications* (4^{th} ed.). UK: Pearson Education.
- Cann, A.J. (2015). Principles of Molecular Virology (6^{th} ed.). Massachusetts, USA: Academic Press.
- Dimmock, N.J., Easton, A.J. & Leppard, K.N. (2016). *Introduction to Modern Virology* (8^{th} ed.). Hoboken, NJ: Wiley Blackwell.

- Kungo, R. (Ed.). (2017). Ananthanarayan and Paniker's *Textbook of Microbiology* (10th ed.). New Delhi, India: Universities Press.
- Madigan, M., Martinko, J., Stahl, D. & Clark, D. (2010). *Brock Biology of Microorganisms* (13th ed.). UK: Pearson Education.
- Moat, A. G., Foster, J.W. & Spector, M.P. (2003). *Microbial Physiology* (4th ed.). US: Wiley Liss Inc.
- Pelczar Jr., M.J., Chan, E.C.S. & Krieg, N.R. (2011). *Microbiology*. New York, USA: Tata McGraw-Hill.
- Willey, J. M., Sherwood, L.M. & Woolverton, C.J. (2014). *Prescott's Microbiology* (9th ed.). New York, USA: McGraw-Hill Education.

Suggested e- Resources:

- **Bacteria structure**

  http://www.biologydiscussion.com/bacteria/cell-structure-of-bacteria-with-diagram/47058

- **Bacterial growth & nutrition**

  http://www.biologydiscussion.com/bacteria/nutrition-and-growth-in-bacteria/47001

- **Bacterial quorum sensing**

  https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3543102/

- **Chemolithotrophy**

  https://courses.lumenlearning.com/boundless-microbiology/chapter/chemolithotrophy/

- **Bacterial metabolism**

  https://www.ncbi.nlm.nih.gov/books/NBK7919/

- **Structure and classification of Viruses**

  https://www.ncbi.nlm.nih.gov/books/NBK8174/

  https://www.pnas.org/content/101/44/15556

- **Virus replication**

  https://virology-online.com/general/Replication.htm

BIO 419L Bioscience Lab-I

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**0**	**0**	**12**	**6**

Learning Outcomes:

After successful completion of the course, students should be able to:

- gain hands-on experience in various biochemical assays used for quantification of fats, carbohydrate, protein and enzymes.
- Perform techniques for isolation of microbes, growth assessment, staining and antibiotic sensitivity
- access, retrieve, and analyze nucleotide and protein sequences using bioinformatics tools

Analytical Techniques-I

1. Demonstration: Working principle & applications of
   - Centrifuges (high speed refrigerated centrifuge & ultracentrifuge),
   - Fluorescence microscope.
   - Atomic absorption spectrophotometer, HPLC, FPLC, GC-MS
2. Separation of amino acids by TLC and Paper Chromatography.

Cell and Molecular Biology

3. Study of different stages of mitosis (onion root tip) and meiosis (onion buds/grasshopper testis) and determine the mitotic index.
4. Separation of chloroplast by sucrose density gradient centrifugation

Biochemistry

5. To prepare sodium acetate buffer and validate the Henderson-Hasselbach equation.
6. Extraction of crude enzyme from germinating mung bean seeds.
7. Estimation of total protein content by Lowry's method
8. Separation of protein by SDS PAGE.

9. Estimation of acid phosphatase activity using standard curve of p-nitrophenol.
10. Purification of the crude enzyme extract (from Expt. 6) using ammonium sulphate precipitation and ion exchange/ affinity chromatography (demonstration).
11. Determination of kinetic properties (K_m and V_{max} values) of acid phosphatase.
12. Estimation of total carbohydrates using Anthrone method.
13. Estimation of reducing sugar by Nelson-Somogyi method.
14. Estimation of fats (cholesterol).

Microbiology

15. Isolation and enumeration of microbes from soil and water.
16. Staining of selected bacterial and fungal strains.
17. Estimation of bacterial growth by turbidometric method.
18. Antibiotic sensitivity test.
19. Estimation of infectivity titre of a virus sample using Plaque assay

Bioinformatics

20. Database search: Use and analysis of BLAST tool for protein and DNA sequences.
21. Molecular evolution: Multiple sequence alignment and phylogenetic analysis (Clustal X/ Mega/ Tree-View).
22. Structure prediction: Protein secondary and tertiary structure prediction using online tools.
23. Molecular visualization: Structural analysis of PDB entries for active and inactive states of protein (Pymol).

Suggested Books:

- Aneja, K. R. (2001). *Experiments in Microbiology, Plant Pathology, Tissue Culture and Mushroom Production Technology*. New Delhi, India: New Age International Ltd.

- Cappuccino, J. G. & Welsh, C. (2019). *Microbiology: A Laboratory Manual*. New York, USA: Pearson.
- Sadasivam, S. & Manickam, A. (1996). *Biochemical Methods* (2nd ed.). New Delhi: New Age International Publishers.
- Saxena, J., Baunthiyal M. & Ravi, I. (2015). *Laboratory Manual of Microbiology, Biochemistry and Molecular Biology*. Jodhpur: Scientific Publishers.

Suggested e- Resources:

- **Harisha, S. Biotechnology procedures and experiments handbook**

  http://site.iugaza.edu.ps/mwhindi/files/BIOTECHNOLOGY-PROCEDURES-AND-EXPERIMENTS-HANDBOOK.pdf

- **Introduction to biotechnology**

  http://www.austincc.edu/awheeler/Files/BIOL%201414%20Fall%202011/BIOL1414_Lab%20Manual_Fall%202011.pdf

Second Semester

BIO 406 Biostatistics and Research Methodology

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- apply statistical analysis to biological data
- inculcate ethics and identify ethical guidelines for pursuing scientific research and associated methodologies
- develop skills in scientific writing

Section-A

- Scope of Biostatistics, variables in biology, collection, classification, tabulation of data.
- Frequency distribution, diagrammatic and graphical presentation of statistical data, sampling techniques.
- Measures of central location and dispersion, simple measure of skewness and kurtosis.
- Probability, conditional probability.

Section-B

- Binomial, Poisson and Normal Distribution.
- Correlation and Regression: Least Square method of fitting, Standard error of estimate, Correlation and regression coefficient.
- Basic idea of significance testing, level of significance, students 't' test, $\chi 2$ (chi-square) test and F-test, Analysis of variance.

Section-C

- Introduction of Research Methodology: meaning and importance, nature and areas of research in Biological Sciences.
- Formulation of a research problem (Hypothesis).

- Elements in Research Methodology; Research Designs (CRD, RBD, LSD).
- Ethical, legal and social issues in Biological Research.
- Writing of Research Report/Research Paper: various components and their organization.

Suggested Books:

- Basotia, G.R. & Sharma K.K. (1999). *Research Methodology*. Mangal Deep Publications.
- Chaudhary, C.M. (1991). *Research Methodology.* RBSA Publications.
- Dorendro, A. (2016). *Research Methodology in Zoology.* Pearlbooks.
- Gupta, S.P. (2000). *Statistical Methods.* S. Chand Publications.
- Kadam, R.M. & Allapure R. B. (2016). *Research Methodology in Botany.* Gaurav Books.
- Khan, I.A. & Khanum, A. (2012). *Fundamentals of Biostatistics.* Ukaaz Publications.
- Marcello, P. & Kimberlee, G. (2000). *Principles of Biostatistics.* Duxbury.
- Prasad, S. (2012). *Elements of Biostatistics.* Rastogi Publications.
- Rastogi, V.B. (2015). *Biostatistics*. Medtec Publications.
- Singh, S. (1988). *Statistical methods for Research.* Central Publishing, Ludhiana.
- Zerold, J. (2009). *Biostatistical Analysis.*UK: Pearson Education.

Suggested e- Resources:

- **ANOVA**

  https://www.analyticsvidhya.com/blog/2018/01/anova-analysis-of-variance/

- **Regression Analysis**

  https://bit.ly/2s9vHdM

- **Student's t Test- Interactive tutorial**

  https://www.ruf.rice.edu/~bioslabs/Stats_tutorial/index.html

BIO 422 Environmental Biology and Biotechnology

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- identify key factors responsible for ecosystem balance and explain different efforts which can be undertaken for restoration and environmental remediation
- comprehend the toxicity of various environmental pollutants and their influence on ecosystem
- understand different waste management processes and generation of energy from waste
- describe various roles played by microbes in biodegradation, bioremediation and plant growth promotion

Section A

- Structure and functions of ecosystem.
- Energy flow in organisms, energy pathways & models, energy efficiencies.
- Basic concept of Population Ecology–Inter & intra-specific interactions among populations.
- Community structure & dynamics: Ecological succession.
- Natural resources & conservation: water, soil**,** forest, wild life.
- Environmental challenges & sustainable development; Environmental Laws & Acts.

Section B

- Heavy metal toxicity, agrochemical pollutants:

  Bioremediation of heavy metal pollution and oil spills, phytoremediation.

- Radiations as environmental pollutants. Effects of radiations at cellular, molecular & genetic level. Disposal of radioactive waste.

- Waste water treatment- sources of waste water, strategies used in primary, secondary & tertiary treatments, water reclamation.

Section C

- Biofertilizers, biopesticides, compost & vermicompost.
- Biofuels: Biogas, bioethanol, biodiesel, biohydrogen. Biodegradable plastics.
- Biodegradation of xenobiotic compounds: Simple aromatics, chlorinated polyaromatic petroleum products & pesticides; role of degradative plasmids.
- Solid waste management: types, treatment & disposal strategies.
- Bioleaching of metals, microbially enhanced oil recovery. Bioindicators.

Suggested Books

- Allen, K. (2016). *Environmental Biotechnology*. New Delhi, India: CBS Publishers.
- Miller, G.T. (2004). *Environmental Science: Working With The Earth* (10^{th} ed.). Singapore: Thomson Asia.
- Milton, W. (Ed.). (1999). *An Introduction to Environmental Biotechnology*. USA: Springer.
- Modi, P. N. (2015). *Sewage treatment & disposal and waste water engineering*. New Delhi, India: Rajsons Publications Pvt. Ltd.
- Odum E. P. (2006). *Fundamentals of Ecology* (5^{th}ed.). Boston, US: Cengage.
- Sharma, P.D. (2008). *Environmental Biology and Toxicology*. Meerut, India: Rastogi Publications.
- Sodhi, G.S. (2002). *Fundamental Concepts of Environmental Chemistry*. New Delhi, India: Narosa Publishing House.
- Tripathi, B. N., Shekhawat, G. S., & Sharma, V. (Ed.). (2009). *Applications of Biotechnology*. Jaipur, India: Aavishkar Publishers.
- Vallero, D.A. (2016). *Environmental Biotechnology*: *Abiosystems approach***.** US**:** Elsevier.

- Wright, R. T. (2015). *Environmental Science: Toward a Sustainable Future*. UK: Pearson Education.

Suggested e-resources

- **Ecosystem structure**

  http://www.biologydiscussion.com/ecosystem/ecosystem-its-structure-and-functions-with-diagram/6666

- **Radioactive waste treatment**

  https://ehs.unc.edu › Manuals › Radiation Safety Manual

- **Environmental Remediation**

  https://www.iaea.org/sites/default/files/18/05/environmental_remediation.pdf

- **Biological treatment of wastewater**

  http://www.neoakruthi.com/blog/biological-treatment-of-wastewater.html

- **Biogas**

  http://www.biologydiscussion.com/biomass/production-of-biogas-from-biomass/10436

- **Biofuel**

  http://uru.ac.in/uruonlinelibrary/BioFuels/Biomass%20and%20biofuels.pdf

- **Biological treatment of wastewater**

  http://www.neoakruthi.com/blog/biological-treatment-of-wastewater.html

- **Xenobiotic compound biodegradation**

  http://www.biologydiscussion.com/microbiology-%202/bioremediation/xenobiotic-compounds-meaning-hazards-and-biodegradation/55625

BIO 410 Genetics

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- comprehend the theoretical and experimental foundations of classical and molecular genetics
- describe the basics of genetic mapping in bacteria, virus and eukaryotes.
- understand the scope of cytogenetics and its applications

Section A

- Definition of gene: genetic & biochemical view; Gene: unit of structure & function, complementation test.
- Mendelian Genetics: Mendel's experimental design; Mendelian Genetics in humans: Pedigree analysis.
- Extensions of Mendelian Genetics: Modification of dominance relationships, gene interactions and modified Mendelian ratios, multiple alleles, essential and lethal genes.
- Non Mendelian inheritance: Extrachromosomal inheritance.
- Genomic imprinting.
- Complex inheritance-genetic and environmental variation; Heritability; Twin studies; Behavioral traits; Analysis of quantitative traits.

Section-B

- Linkage & crossing over, models of genetic recombination, gene conversion, Tetrad analysis, mapping of gene order & centromere location in fungi.
- Genome organization: Organization of bacterial genome.
- Structure of eukaryotic chromosomes, organization of DNA into chromosomes; Heterochromatin and euchromatin

- Mutations: Nonsense, missense & point mutations; Frameshift mutations; Mutagens; Molecular mechanism of mutations; Suppressor mutation.
- Transposon mutagenesis, transposons as genetic tools: signature tagging mutagenesis, insertional inactivation, P-elements as genetic tool.

Section-C

- Cytogenetics: Cytogenetics introduction, karyotype analysis, chromosome banding techniques.
- Cell division & errors in cell division; Non disjunction.
- Structural and numerical chromosomal abnormalities- deletion, duplication, translocation; Sex determination; Lyon hypothesis; Role of Y chromosome; Disorders of sex chromosomes & autosomes.
- Molecular cytogenetics- Fluorescence in Situ Hybridization (FISH); Comparative Genomic Hybridization (CGH).
- Genetics of bacteria and bacteriophages; Genetic mapping in bacteria by conjugation, transformation and transduction.
- Mapping of bacteriophage gene.
- Population genetics: Hardy-Weinberg law; Genetic variation in natural populations; Forces that change gene frequency in populations; Genetic basis of speciation.

Suggested Books:

- Benjamin, A.P. (2003). *Genetics: A conceptual approach*. New York, USA: W. H. Freeman and Company.
- Brown, T.A. (1992). *Genetics- A Molecular Approach*. London, UK: Chapman & Hall.
- Gardner, E.J., Simmons, M.J., & Snustad, D.P. (2005). *Principles of Genetics* (8th ed.). New Jersey, USA: John Wiley & Sons Ltd.
- Gupta, P.K. (2010). *Genetics*. Meerut, India: Rastogi Publications.
- Klug, W. S., Cummings, M.R., Spencer, C.A. & Palladine, M.A. (2015). *Concepts of Genetics* (11th ed.). UK: Pearson Education.
- Russel, P.J. (2010). *iGenetics* (3rd ed.). UK: Pearson Education.

Suggested e- Resources:

- **Cytogenetic methods and Disease**

  www.nature.com/scitable/topicpage/cytogenetic-methods-and-disease-flow-cytometry-cgh-772

- **CGH Analysis**

  www.cs.cmu.edu/~epxing/Class/10810-05/Lecture11.pdf

- **Population Genetics**

  https://biomed.brown.edu/Courses/BIO48/6.PopGen1.HW.drift.HTML

BIO 411 Immunology

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- evaluate and compare the role of various components and mechanisms of the immune system
- describe various immune response mechanisms
- develop concept of antibody generation and various immunological techniques

Section-A

- Basic concepts of immunology: Historical background of immunology, specific and nonspecific defense mechanisms (innate and acquired immunity), cells and organs of immune system.
- Antigen and Antigenicity: Concept of immunogens, antigens, haptens, mitogens and superantigens. Properties of antigens, special group of antigens: bacterial antigens, viral antigens, cell surface antigens (MHC), autoantigens, isoantigens and frossman antigens (Heterophilic antigens).
- Immunoglobulins: Theories of antibody formation, structure and properties of immunoglobulins, immunoglobulin isotypes and their significance. Immunoglobulins as antigens: isotypes, allotypes and

idiotypes, brief idea about instructive, selective & clonal selection theory of antibody formation.

- Complement system.

Section-B

- Cell- mediated immune responses: origin, maturation and characterization of T-Lymphocytes, monocytes and macrophages, characteristics of antigen presentation and its significance, concepts of memory cell, mode of action and functioning of T_H, T_C, CTLS and NK cells, lymphokines, the product of T-cell activation.
- Humoral immune responses: Origin, maturation and characterization of B-Lymphocytes, activation and proliferation of B and T cells, antibody generation *in vivo*.
- Immunological tolerance its characteristics and mechanism. Factors affecting immunological tolerance of autoimmunity. Immune regulation, positive, negative selection, apoptosis.

Section-C

- Hypersensitivity: Type I, II, III and IV.
- Hybrid and Chimeric monoclonal antibodies, catalytic antibodies.
- Surface plasmon resonance, biosensor assay for assessing ligand-receptor interaction.
- Advanced immunological techniques: Immunofluorescent and immunogoldlabelling.

Suggested Books:

- Abbas, A.K. & Lichtman, A.H. (2001). *Basic Immunology: Functions and Disorders of Immune System.* US: W.B. Saunders.
- Delves, P.J., Martin, S.J., Burton, D.R., & Roitt, I.M (2011). *Roitt's Essential Immunology* (12th ed.). New Jersey, USA: John Wiley & Sons Ltd.
- Goldsby, R. A., Kindt, T.J. & Osborne, B. A. (2006). *Kuby Immunology* (6th ed.). New York, USA: W.H. Freeman & Co. Ltd.
- Paul, W.E. (1999). *Fundamental Immunology* (14thed.). USA: Lippincott-Raven.

- Peakman, M. & Vergani, D. (2009). *Basic and Clinical Immunology* (2nd ed.). US: Elsevier Health Sciences.
- Tizard, I.R. (2017). *Veterinary Immunology* (10th ed.). US: Elsevier Health Sciences.

Suggested e- Resources:

- **Basic Immunology**

  https://bit. y/2E6Zz16l

- **Monoclonal Antibodies**

  https://www.genscript.com/how-to-make-monoclonal-antibodies.html

- **Complement system**

  https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3956958/

BT 408 Genetic Engineering

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- develop comprehensive understanding of gene manipulation techniques
- describe various cloning and expression vectors
- develop skills for primer designing, gene amplification and expression

Section-A

- Basic concepts of DNA structure and properties, restriction enzymes, DNA ligase, Klenow enzyme, T_4 DNA polymerase, polynucleotide kinase, alkaline phosphatase.
- Cohesive & blunt end ligation, linkers, adapters, homopolymeric tailing, labeling of DNA, nick translation, random priming, radioactive & non-radioactive probes.
- Hybridization techniques: Colony hybridization, Northern, Southern, South-Western & Far-Western blotting.

- DNA-Protein Interaction: Chromatin immunoprecipitation, electromobility shift assay, DNaseI footprinting, methyl interference assay.
- Protein-protein interaction: Yeast two hybrid system, split ubiquitin system, co-immunoprecipitation, Forster Resonance Energy Transfer, phage display.
- Isolation of genomic DNA from prokaryotes and eukaryotes, isolation of Plasmid DNA and Bacteriophage DNA. Isolation of total RNA and mRNA.

Section-B

- Plasmids, Bacteriophages, pBR322 & pUC series of vectors, M13 based vectors.
- High capacity vectors: Cosmids, phagemids, BAC, animal & plant virus based cloning vectors, shuttle vectors; expression vectors: pMal, GST, pET-based vectors; *Baculovirus* and *Pichia* vectors.
- Introduction of DNA into mammalian cells.
- cDNA& genomic libraries, expression, cloning, jumping & hopping libraries.

Section-C

- Primer designing, fidelity of thermostable enzymes.
- Types of PCR- multiplex, nested, reverse transcriptase, real time PCR, touchdown PCR, hot start PCR, colony PCR, *in situ* PCR, T-vectors.
- Principles in maximizing gene expression, gene expression analyses, differential gene expression methods.

Suggested Books:

- Brown, T. A. (2006). *Genomes* (3rd ed.). New York: Garland Science.
- Glick, B.R. & Pasternak, J.J. (1998). *Molecular Biotech: Principles and Application of Recombinant DNA*. US: ASM Press.
- Green, M. R. & Sambrook, J. (2012). *Molecular Cloning: a Laboratory Manual*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.

- Old, R. W., Primrose, S. B. & Twyman, R. M. (2001). *Principles of Gene Manipulation: an Introduction to Genetic Engineering*. Oxford: Blackwell Scientific Publications.
- Richard J. R. (2004). *Analysis of Genes and Genome*. New Jersey, USA: John Wiley & Sons Ltd.

Suggested e- Resources:

- **Genetic engineering – Basics, New Applications and Responsibilities**

  http://library.umac.mo/ebooks/b28055287.pdf

- **Construction of genomic libraries**

  https://nptel.ac.in/courses/102103013/20

- **Enzymes in genetic engineering**

  https://nptel.ac.in/courses/102103013/7

BIO 420L Bioscience Lab-II

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**0**	**0**	**12**	**6**

Learning Outcomes:

After successful completion of the course, students should be able to:

- perform techniques used in immunology
- gain skills in isolation and estimation of nucleic acids, and PCR
- perform key experiments for water quality analysis and other contaminants.
- solve problems based on gene mapping and population genetics.

Environmental Biology and Biotechnology

1. Determination of total hardness of water.
2. Determination of fluoride content in water.
3. Determination of BOD values.
4. Determination of LD_{50} for common pesticides/weedicides.

5. Bacteriological analysis of waste water.

Immunology

6. To perform differential leucocytes count.
7. Lymphoid organs and their microscopic organization
8. To perform immune diffusion by ouchterlony double diffusion method.
9. To perform immunoelectrophoresis.
10. ELISA: Determination of antibody titre.
11. Immunodiagnostics (Demonstration using commercial kits).

Genetic Engineering

12. Extraction of genomic DNA by CTAB method and determination of its purity.
13. Estimation of DNA content by diphenyl amine (DPA) method.
14. PCR amplification of 'n' number of genotypes of a species using random primers (Demonstration).
15. Extraction of RNA by Phenol-Chloroform method and estimation by orcinol method.

Genetics

16. Study of sex chromatin from buccal epithelial/ hair bud cells.
17. Genetic exercise:
    - Chromosome mapping, two and three point cross.
    - Quantitative genetics/ population genetics.

Biostatistics and Research Methodology

18. Biostatistics problems based on following:
    - Measures of dispersion (variance).
    - Correlation analysis.
    - Probability and probability distribution.
    - Testing hypothesis by student t- test, Fisher's test, chi-square test and one way analysis of variance.

Suggested Books:

- Aneja, K.R. (1996). *Experiments in Microbiology, Plant Pathology, Tissue Culture and Mushroom Cultivation* (2nd ed.). New Delhi: Wishwa Prakashan.
- Green, M. R., & Sambrook, J. (2012). *Molecular Cloning: a Laboratory Manual.* Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.
- Gupta S.P. (2000). *Statistical Methods.* S. Chand Publications.

Suggested e- Resources:

- **Harisha, S. Biotechnology procedures and experiments handbook**

  https://bit.ly/2U0e39D

- **Introduction to biotechnology**

  https://bit.ly/2IICkzE

Third Semester

BIO 507S Critical Analysis of Classical Papers, Landmark Discoveries (Seminar)

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**0**	**0**	**4**	**2**

Learning Outcomes:

After successful completion of the course, students should be able to:

- analyze and give a critical description of the papers studied
- discuss the significance of the research work

Suggested Reading:

- Studies on the chemical nature of the substance inducing transformation of Pneumococcal types: Induction of transformation by a deoxyribonucleic acid fraction isolated from *Pneumococcus* type III. Avery OT, Macleod CM, McCarty M.; J Exp Med. 1944 Feb 1; 79(2): 137-158.
- Independent functions of viral protein and nucleic acid in growth of bacteriophage. Hershey AD and Chase M.; J Gen Physiol. 1952 May; 36(1): 39-56.
- Molecular structure of nucleic acids; a structure for deoxyribose nucleic acid. Watson JD and Crick FH; Nature. 1953 Apr 25; 171(4356):737-738.
- Transposable mating type genes in *Saccharomyces cerevisiae.* James Hicks, Jeffrey N. Strathern & Amar J.S. Klar; Nature 282, 478-483, 1979.
- Messelson & Stahl experiment demonstrating semi-conservative replication of DNA. Meselson M and Stahl FW.; Proc Natl Acad Sci U S A. 1958 Jul 15; 44(7): 671-682.
- In vivo alteration of telomere sequences and senescence caused by mutated *Tetrahymena* telomerase RNAs. Guo-Liang Yu, John D. Bradley, Laura D. Attardi & Elizabeth H. Blackburn; Nature 344, 126-132, 1990.

- A protein-conducting channel in the endoplasmic reticulum. Simon SM AND Blobel G.; Cell. 1991 May 3; 65(3): 371-380.
- Identification of 23 complementation groups required for post-translational events in the yeast secretory pathway Novick P, Field C, Schekman R.; Cell. 1980 Aug; 21(1): 205-215.
- A yeast mutant defective at an early stage in import of secretory protein precursors into the endoplasmic reticulum. Deshaies RJ and Schekman R.; J Cell Biol. 1987 Aug; 105(2): 633-645.
- Reconstitution of the Transport of Protein between Successive Compartments of the Golgi. Balch WE, Dunphy WG, Braell WA, Rothman JE.; Cell. 1984 Dec; 39(2 Pt 1): 405-416.
- A complete immunoglobulin gene is created by somatic recombination. Brack C, Hirama M, Lenhard-Schuller R, Tonegawa S.; Cell. 1978 Sep; 15(1): 1-14.
- A novel multigene family may encode odorant receptors: a molecular basis for odor recognition. Buck L and Axel R; Cell. 1991 Apr 5; 65(1): 175-187.
- Kinesin walks hand-over-hand. Yildiz A, Tomishige M, Vale RD, Selvin PR.; Science. 2004 Jan 30; 303(5658): 676-678.
- Mutations affecting segment number and polarity in *Drosophila.* Christiane Nusslein-Volhard and Eric Weischaus; Nature 287, 795-801, 1980.
- Information for the dorsal--ventral pattern of the *Drosophila* embryo is stored as maternal mRNA. Anderson KV and Nüsslein-Volhard C; Nature. 1984 Sep 20-26; 311(5983): 223-227.
- Hedgehog signalling in the mouse requires intraflagellar transport proteins. Huangfu D, Liu A, Rakeman AS, Murcia NS, Niswander L, Anderson KV.; Nature. 2003 Nov 6; 426(6962): 83-87.

BT 504 Bioprocess Engineering and Technology

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- identify bioreactor design and differentiate between types
- explain kinetics of scale up and sterilization along with processes of downstreaming
- demonstrate large scale production of biomolecules

Section – A

- General concept of fermentation, Types of bioreactors (CSTR, Bubble driven bioreactor, Packed bed bioreactor, Fluidized Bed bioreactor).
- Basic concept of mass balance & yield coefficient.
- Unstructured & structured growth model.
- Batch, continuous & fed batch processes with substrate utilization & product formation kinetics.
- Sterilization kinetics.

Section-B

- Volumetric mass transfer coefficient (kLa).
- Medium Rheology in bioprocesses engineering.
- Downstream processing: Bioseparation- ultrafiltration, precipitation, Cell disruption, Liquid-liquid extraction, chromatography, drying, crystallization.
- Upscaling of bioprocess.
- Enzyme immobilization & immobilized cell systems.

Section-C

- Screening, maintenance & strain improvement of industrially important microbes.
- Analysis of a few industrially important bioprocesses/products (taking into consideration- the raw material, media, organism, metabolic pathway, bioreactor, product separation and uses):

(i) Organic acids (acetic acid, citric acid).

(ii) Solvents (butanol, acetone, ethanol).

(iii) Enzymes (α amylase, proteases, lipase).

(iv) Antibiotics (penicillin, streptomycin).

(v) Recombinant product (humulin, erythropoietin).

Suggested Books:

- Bailey, J.E. & Ollis, D.F. (1986). *Biochemical Engineering Fundamentals* (2nd ed.). New York, USA: McGraw-Hill Education.
- Clark, D.S. & Blanch, H.W. (1997). *Biochemical Engineering*. USA: CRC Press.
- Crueger, W. & Crueger, A. (1990). *Biotechnology, A Text Book of Industrial Microbiology* (2nd ed.). U.S.: Sinauer Associates Inc.
- Shuler, M.L., & Kargi, F. (2002). *Bioprocess Engineering Basic Concepts* (2nd ed.). New Jersey, USA: Prentice Hall PTR Upper Saddle River.
- Stanbury, P.F., Whitaker, A. & Hall, S.J. (1995). *Principles of Fermentation Technology* (2nd & 3rd ed.). US: Elsevier Science Ltd.

Suggested e- Resources:

- **Microbial Enzymes**

  https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5387804/pdf/BMRI2017-2195808.pdf

- **Acetone-Butanol Fermentation**

  https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4894279/pdf/fnw134.pdf

- **Microbial culture fermentation**

  https://pdfs.semanticscholar.org/b4d3/7ed66ef2e37ce22ff7a3be09e3df7568fe49.pdf

- **Reverse Osmosis**

  https://www.oas.org/dsd/publications/unit/oea59e/ch20.htm

BT 507 Cell and Tissue Culture Technology

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- develop comprehensive concepts of cell and tissue culture techniques and methodology
- understand use of various plant and animal tissue culture techniques
- identify areas of applications of cell and tissue culture in research, agriculture, horticulture, medicine and pharmaceutical industries

Section-A

- Historical background and terminologies used in cell & tissue culture.
- Basic techniques of cell and tissue culture, sterilization, aseptic tissue transfer, concept of totipotency.
- Nutritional requirement of cell in vitro, various types of nutrient media.
- Contamination and cytotoxicity.
- Cryopreservation and cell storage.
- Isolation of plant cells, single cell cultures and cloning.

Section-B

- Organogenesis and somatic embryogenesis, applications in agriculture, horticulture & forestry.
- Haploid production: androgenesis, gynogenesis, various techniques and applications.
- Production of disease free plants by tissue culture methods.
- Protoplast isolation and culture, fusion of protoplasts.
- Somatic hybrids, selection methods, gene expression in somatic hybrids.

Section-C

- Disaggregation of animal tissue, isolation of cells, single cell culture, routine maintenance of animal cell lines.
- Cloning & selection of specific animal cell types.
- Transfection: gene transfer methods for adherent and non-adherent cell culture.
- Cell fusion: fusogen, animal somatic cell fusion and selection of cybrids.
- Animal organ culture.
- Elementary idea about animal cell culture products.

Suggested Books:

- Bhojwani, S.S. & Razdan, M.K. (1996). *Plant Tissue Culture*. USA: Elsevier Science.
- Buler, M. (2003). *Animal Cell Culture and Technology* (2nd ed.). UK: Taylor & Francis.
- Chawla, H. S. (2000). *Introduction to Plant Biotechnology*. US: Science Publishers.
- Clynes, M. (Ed.) (1998). *Animal Cell Culture Techniques*. Germany: Springer-Verlag Berlin Heidelberg.
- Davis, J. M. (2011). *Animal Cell Culture: Essential Methods*. New Jersey, USA: John Wiley & Sons Ltd.
- Freshney, R. I. (2011). *Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications* (6th ed.). USA: Wiley-Blackwell.
- John, R. W. (2000). *Animal Cell Culture: A Practical Approach* (3rd ed.). UK: Oxford University Press.
- Mathur, S. (2006). *Animal Cell and Tissue Culture*. India: Agrobios.
- Pollard, J.W., & Walker**,** J.M. (Eds.). (1990). *Animal Cell Culture*. USA: Humana Press
- Razdan, M. K. (2006). *Introduction to Plant Tissue Culture*. New Delhi, India: Oxford and IBH Pub.

- Smith, R. H (Ed.). (2013). *Plant tissue culture: Techniques and experiments*. Amsterdam: Academic Press.

Suggested e- Resources:

- **Background of Tissue Culture Technology**

  http://www.biologydiscussion.com/botany/tissue-culture/tissue-culture-definition-history-and-importance/42944

- **Embryogenesis and organogenesis**

  https://nptel.ac.in/courses/102103016/module1/lec8/3.html

- **Single cell cultures and cloning**

  http://www.biologydiscussion.com/botany/tissue-culture/methods-for-obtaining-single-cell-clones-from-callus-culture-plant-tissue-culture/43004

- **Protoplasm isolation and regeneration**

  https://nptel.ac.in/courses/102103016/12

- **Haploid plant production**

  http://www.biologydiscussion.com/plants/haploid-plants/production-of-haploid-plants-with-diagram/10700

- **Preservation of cell lines**

  https://www.ukessays.com/essays/biology/techniques-for-cell-preservation-biology-essay.php

- **Somatic hybridization**

  http://www.biologydiscussion.com/somatic-hybridization/somatic-hybridization-aspects-applications-and-limitations/10686

- **Animal cell culture products**

  http://www.biologydiscussion.com/biotechnology/animal-biotechnology/applications-of-animal-cell-cultures/10457

- **Cell Culture Technology**

  https://onlinecourses.nptel.ac.in/noc17_bt21/preview

BT 550L Biotechnology Lab-I

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**0**	**0**	**12**	**6**

Learning Outcomes:

After successful completion of the course, students should be able to:

- perform production and scale up of some industrially relevant bioactive molecules from microbes
- perform gene transfer techniques
- gain hand-on experience in cell and tissue culture techniques

Bioprocess Engineering and Technology

1. Production of citric acid from *Aspergillus* sp. and its estimation by titration.
2. Estimation of K_{La} by sodium sulphite method.
3. Production of alpha amylase from *Bacillus* sp. and its estimation.
4. Scale up of alpha amylase production from 100 ml to 1 L.
5. Immobilization of enzyme by sodium alginate method.
6. Estimation of growth and product yield in a bioconversion process.
7. Comparison between aerobic and anaerobic process.

Genetic Engineering

8. Preparation of competent cells (*E. coli* DH5α strain).
9. Transformation of *E. coli* with plasmid and calculation of transformation efficiency.
10. Isolation of plasmid DNA from *E. coli* by alkaline lysis method.
11. Restriction digestion of plasmid DNA and its electrophoretic separation.
12. To transfer plasmid PJB3JI from J53 strain of *E. coli* to HB101 strain of *E.coli.*

Cell and Tissue Culture Technology

13. To perform embryo culture from germinated mung bean seeds.

14. Shoot tip culture.
15. Protoplast culture and somatic hybridization.
16. Blood cell culture and determination of cell viability using Trypan blue method.
17. Preparation of metaphase chromosome from whole blood culture.

Suggested Books:

- Cappuccino, J. G., & Welsh, C. (2016). *Microbiology: A laboratory Manual*. USA: Benjamin-Cummings Publishing Company.
- Collins, C. H., Lyne, P. M., Grange, J. M., &Falkinham, J.O. (2004). *Collins and Lyne's Microbiological Methods* (8th ed.). London, UK: Arnold.
- Green, M. R., & Sambrook, J. (2012). *Molecular Cloning: a Laboratory Manual.* Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.
- Kulandaivel, S. & Janarthanan, S. (2012). *Practical Manual of Fermentation Technology*. New Delhi, India: I.K. International Publishing House Pvt. Ltd.

Suggested e- Resources:

- **Harisha, S. Biotechnology procedures and experiments handbook**

  https://bit.ly/2U0e39D

- **Introduction to biotechnology**

  https://bit.ly/2IICkzE

Fourth Semester

BT 528D Dissertation

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**0**	**0**	**48**	**24**

Learning Outcomes:

After successful completion of the course, students should be able to:

- gain an exposure of working in the academic institutions/research laboratories/industries
- gain in-depth knowledge of the chosen area of research
- identify, formulate and execute a research hypothesis
- develop report writing skills
- inculcate communication and interpersonal skills

List of Discipline Elective

BIO 503 Fundamentals of Bioentrepreneurship

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- understand role of entrepreneurship in promoting innovation and wealth generation
- develop skills for writing business models for new ideas and market segments
- explain various financial, marketing, sales and legal issues associated with entrepreneurship

Section-A

- Concept of entrepreneurship; Classification and types of entrepreneurship, Myths about entrepreneurship; Role of entrepreneurship in wealth building and creating an impact; Society, Technology and Entrepreneurship.
- Creativity and Innovation; Types and forms of Innovation; Sources of innovative opportunity; Entrepreneurship as a career option.

Section-B

- Introduction to the Design Thinking Process; Problem identification; Idea Generation; Value Proposition; Lean Canvas.
- Identifying Customer Segments; Idea Validation; Developing Business Model; Sizing the opportunity; Building MVP; Concept of Start-up, Importance of Incubation.

Section-C

- Financial and Non financial support**:** Revenue streams; Pricing and Costs; Sources of funds; Importance of project management.
- Marketing and Sales: Positioning; Channels and Strategy; Sales Planning.

- Team: Importance of teambuilding; Complementary skill sets.
- Legal issues: Brief overview of- intellectual property rights, patents, trademarks, copy rights, trade secrets, licensing and GI.
- Business Plan writing.
- Policies and Initiatives to promote Entrepreneurship in India.

Suggested Books:

- Desai, V. (2011) *Dynamics of Entrepreneurial Development & Management* (6th ed.). Mumbai: Himalaya Publishing House.
- Drucker, P. (2015). *Innovation and Entrepreneurship* (1st ed.). Routledge Classics.
- Gupta, A.K. (2016). *Grassroots Innovations (Minds on the Margin Are Not Marginal Minds).* Random House.
- Gupta, C.B. & Srinivasan N.P. (2013). *Entrepreneurship Development in India.* Sultan Chand & Sons.
- Hisrich, R. D., Manimala, M. J., Peters M. P. & Shepherd D. A. *Entrepreneurship* (9th ed.). McGraw Hill Publication.
- Jain, P.C. (2001). *Hand Book for New Entrepreneurs*. UK: Oxford University Press.
- Khanka, S.S. (2007) *Entrepreneurial Development.* New Delhi: S. Chand & Company Ltd.
- Kotler, P. & Keller, K.L. (2017).*Marketing Management* (15th ed.). Pearson Publications.
- Mohanty, S. K. (2005). *Fundamentals of Entrepreneurship*. EEE Prentice Hall India Learning Private Limited.
- Patzelt, H., & Bernner, T. (Eds.). (2008). *Handbook of Bioentrepreneurship*. Berlin, Germany: Springer.
- Robert, D. H., & Peters, M. P. (2002). *Entrepreneurship*. New York, USA: McGraw-Hill Education.
- Roy, R. (2011). Entrepreneurship (2nd ed.). UK: Oxford University Press.

- Shane, S. (2004). *Academic Entrepreneurship: University Spinoffs and Wealth Creation*. Northampton, M.A.: Edward Elgar.

Suggested e-Resources:

- **Entrepreneurship**

  https://www.startupcommons.org/what-is-startup-ecosystem.html

  https://getproductmarketfit.com/how-to-select-test-to-get-market-validation-for-new-product-or-business-idea/

  https://www.coursera.org/learn/wharton-launching-startup

  https://www.coursera.org/learn/wharton-entrepreneurship-opportunity

  http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.463.4354&rep=rep1&type=pdf

- **Accounts and Bioentrepreneur**

  https://www.nature.com/bioent/2003/031101/full/bioent779.html

- **Bioentrepreneurship**

  www.birac.nic.in/webcontent/jk.pdf

- **Biotechnology and entrepreneurship**

  http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.463.4354&rep=rep1&type=pdf

BIO 505 Microbial Technology

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- utilize various strategies for strain improvement, overexpression, maintenance and containment of microbes
- comprehend and apply strategies used for large scale production of various industrially relevant bioactive molecules from microorganisms

Section-A

- Biotechnological innovation in pharmaceutical, health, agricultural & industrial sectors.
- Strategies for selection & improvement of industrial strains.
- Measurement & control of bioprocess parameters.
- Genetic & environmental control of metabolic pathways.

Section-B

- Industrial production of Biofuel, Biotransformation of Steroids, Single Cell Protein.
- Biofertilizers (*Rhizobium* and BGA); Biopesticides (Bt toxin).
- Biosensors (NH_4, Sulphide); Biofilms.
- Biopolymers (PHB, Xanthum gum).

Section-C

- Microbial overproduction of recombinant molecules: Selection of suitable promoter sequences, ribosome binding sites, fusion protein tags, purification tags, protease cleavage sites and enzymes, inducible expression systems, limitations of metabolic engineering.
- Large scale production using recombinant microorganisms: peptic hormones (secretin), metabolic engineering of antibiotics, basic idea of biohydrometallurgy.
- Maintenance and containment of recombinant microorganisms.

Suggested Books:

- BIOTOL, Currell, B.C., & Dam-Miera, R.C.E. (1997). *Biotechnological Innovations in Chemical Synthesis (BiotolSer)*. Oxford, UK: Butterworth-Heinemann, Elsevier.
- Braun,V. & Gotz, F. (Eds.). (2002). *Microbial Fundamentals of Biotechnology*. Germany: Wiley-VCH.
- Crueger, W. & Crueger, A. (1990). *Biotechnology, A Text Book of Industrial Microbiology* (2nd ed.). U.S: Sinauer Associates Inc.

- Glazer, A.N., & Nikaido, H. (2008). *Microbial Biotechnology*. UK: Cambridge University Press.
- Gupta, V.K. (Ed.), Sharma, G.D. (Ed.),Tuohy, M.G. (Ed.), Gaur, R. (Ed.). (2016). *The Handbook of Microbial Bioresources* (1st ed.). New Delhi, India: CABI Publishing.
- Kun, L.Y. (Ed.) (2003). *Microbial Biotechnology: Principles and Applications*. Singapore: World Scientific Publication Co.Ptv. Ltd.
- Reed, G. (2004). Prescott and Dunn's Industrial Microbiology. New Delhi, India: CBS Publishers.

Suggested e- Resources:

- **Microbial Biotechnology**

  https://bit.ly/2XmRZs2

- **Biosensor**

  https://www.edgefx.in/biosensors-types-its-working-and-applications/

- **Biofertilizer**

  www.krishisewa.com/articles/organic-agriculture/115-biofertilizers.html

- **Biopesticide**

  www.agriinfo.in/default.aspx?page=topic&superid=3&topicid=1950

BT 544 Enzyme Technology

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- develop understanding of enzymes and their mechanism of action and regulation
- explain the production of enzymes
- learn wide applications of enzymes and their future potential for applications in various industries and research

Section-A

- Enzymes: Scope, historical developments, distinguishing features.
- Mechanisms of enzyme action: Concept of active site, specificity of enzyme action.
- Methods of characterization of enzymes – Development of enzymatic assays.
- Bisubstrate reactions-ordered & random sequential mechanism. Theorell chance mechanism, ping pong mechanism, products of inhibition in bisubstrate reactions.
- Regulation of enzyme activity, various controls (metabolic compartmentation, covalent modifications and others), feedback regulation, allosteric enzymes.

Section-B

- Extraction of soluble and membrane bound enzymes from microbial, plant and animal tissues.
- Purification of enzymes: salt precipitation, gel filtration, ion exchange, affinity chromatography, enzyme crystallization, drying and freeze drying.
- Large scale production of enzymes including genetic engineering approaches for their over production.
- Methods of storing enzymes.
- Multienzyme complexes.
- Designer enzymes, Thermophilic enzymes, Metal degrading enzymes.

Section-C

- Enzyme engineering; identification of active sites, approaches for modification of catalytic properties. Synzymes.
- Techniques of enzyme immobilization: Adsorbtion, Covalent bonding, Gel Entrapment and Microencapsulation.
- Applications of enzymes in:
    i. Food industry- Baking industry, Dairy industry, Beverage industry

ii. Antibiotics and other pharamaceuticals

iii. Medical applications

iv. Analysis of substances

v. Leather industry

vi. Textile industry

- Enzyme biosensors.

Suggested Books:

- Blanch, H.W., & Clark, D.S. (1997). *Biochemical Engineering*, Marcel Dekker.
- Buchholz, K., Kasche, V. and Bornscheuer, U. (2005). *Biocatalysts and Enzyme Technology*, WILEY–VCH.
- Purich, D.L. (2009). *Contemporary Enzyme Kinetics and Mechanism.* Atlantic Publishers and Distributers.
- Drauz, K., Gröger, H. & May, O. (2012). *Enzyme Catalysis in Organic Synthesis: A Comprehensive Handbook*, Volume 1, Wiley-VCH Verlag & Co.
- Palmer, T. & Bonner, P. (2014). *Enzymes: Biochemistry, Biotechnology and Clinical Chemistry*. UK: Woodhead Publishing Limited.
- Pandey, A., Webb C., Soccol, C. R. & Larroche, C. (2006). *Enzyme Technology.* Springer.
- Price, N. & Stevenson L. (1999). *Fundamentals of Enzymology: Cell and Molecular Biology of catalytic Proteins*, Oxford University Press.

Suggested e-resources:

- **Enzymes: Properties and Mechanisms:**

  http://www.biologydiscussion.com/enzymes/enzymes-properties-and-mechanism-of-enzyme-action/6145

- **Enzyme Technology: Metagenomics, Evolution and Biocatalysis:**

  https://searchworks.stanford.edu/view/8775255

BT 513 Food Process and Biotechnology

Max. Marks : 100	L	T	P	C
(CA: 40 + ESA: 60)	4	0	0	4

Learning Outcomes:

After successful completion of the course, students should be able to:

- explain strategies of food preservation, spoilage and quality assessment
- understand various policies related to gm food and its safety assessment
- comprehend and utilize the principles for production of various processed food

Section-A

- Introduction and development of food biotechnology; Current status of transgenic crops for crop improvement & enhanced agronomic performance.
- International and National guidelines for safety assessment of genetically modified (GM) foods.
- Contemporary food related policy issue & their implications.
- General principles of food spoilage, factors affecting spoilage; Methods of food preservation. Food products with enhanced shelf-life.

Section-B

- Mechanism of enzyme function and reactions in food processing; Enzymic bioconversions e.g. starch and sugar conversion process; HFCS; Interesterified fat, hydrolysed protein etc. and their downstream processing.
- Baking by amylases; Deoxygenation and desugaring by glucose oxidases; Beer mashing and chill proofing.
- Various enzyme catalysed actions in food processing - Fermented dairy products (cheese, yogurt, kefir), alcoholic beverages, fermented vegetables, oriental foods, meat products, fish & poultry products. Bacteriocin from lactic acid bacteria.

Section-C

- Bioconversion of process wastes to useful products -whey, molasses, starch substrates and other food wastes.

- Biotechnology applications in the production of additives/ingredients: enzymes, carotenoids, amino acids, organic acids, vitamins, colouring flavours and nutraceuticals.
- Production of new protein foods- Single cell proteins (SCP), mushroom, algal proteins.
- Quality control of food- detection system, Enzyme Immunoassay and Radio-immunoassay.

Suggested Books:

- Adams, M. R. & Moss, M. O. (2007). *Food Microbiology*. UK: Royal Society of Chemistry.
- Banwart, G.J. (1989*). Basic Food Microbiology*. New Delhi, India: CBS Publishers.
- Frazier, W.C. & Westhoff, D.C. (2003). *Food Microbiology*. New York, USA: Tata McGraw Hill.
- Joshi, V. K. & Pandey, A. (1999). *Biotechnology: Food Fermentation*. New Delhi, India: Asiatech Publishers Inc.
- Pandey, A., Larroche, C., Soccol, C. R. & Dussap, C. (2008). *Advances in Fermentation Technology*. New Delhi, India: Asiatech Publishers, Inc.
- Robinson, R.K. (1990). *Dairy Microbiology*. London, UK: Elsevier Applied Sciences.
- Stanbury, P.F., Hall, S. J. & Whitaker, A. (1999). *Principles of Fermentation Technology*. Oxford, UK: Butterworth-Heinemann, Elsevier.

Suggested e- Resources:

- **Quality control of food detection system**

  https://www.engineersgarage.com/Contribution/Arduino-based-Smart-IoT-Food-Quality-Monitoring-System
- **Food Preservation**

  https://sciencesamhita.com/methods-of-food-preservation/
- **History of microorganisms in food**

  https://faculty.weber.edu/coberg/class/3853/3853%20HistoryofFood.htm
- **Genetically modified food**

  http://anrcatalog.ucdavis.edu/pdf/8180.pdf

BT 545 Genomics and Proteomics

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- understand the experimental methods available to study the genome and proteomes
- develop understanding of computational tools of genomics and proteomics
- learn next generation sequencing methods for genomics and transcriptomics

Section – A

- Genomics – Introduction to genome & genomics; genetics *vs.* genomics. DNA microarray; preparation, understanding of microarray data, normalizing microarray data, detecting differential gene expression, correlation of gene expression data to biological process & analysis tools. Gene Expression Omnibus (GEO).
- Large scale genome sequencing strategies. Genome assembly & annotation. Genome databases of plants, animals & pathogens.
- Metagenomics: Gene networks: basic concepts, computational model such as Lambda receptor & lac operon.
- Prediction of genes, promoters, splices sites, regulatory regions: basic principles, application of methods to prokaryotic & eukaryotic genomes.

Section – B

- Introduction to proteome and proteomics; protein chemistry *vs.* proteomics. Analytical techniques of proteomics; working principles of 2D – gel electrophoresis, mass spectrometry with their merits and demerits.
- Mass spectrometers for protein and peptide sequencing; MALDI – TOF, electospray ionization coupled tandem Mass spectrometry. Tandem mass analyzer, triple quadrupole mass analyzer, ion – trap mass analyzer and FT – ion cyclotron resonance MS. Peptide Mass Fingerprinting.

- Sequencing the protein fragments: Scoring Algorithm for Spectral analysis. Application of SALSA in amino acid – Motif searching.

Section – C

- Next generation sequencing & assembly: elements of big data analysis, NGS Platforms based on pyrosequencing, sequencing by synthesis, emulsion PCR approach with small magnetic beads & single molecule real time (SMRT) sequencing.
- Genome assembly algorithms, De-novo assembly algorithms.
- Sequence Alignment formats: Sequence Alignment/Map (SAM) format, Binary Alignment/Map (BAM) format. Protein function prediction using Machine learning tools: supervised/unsupervised learning, neural network, SVM.
- Protein-protein interactions: databases such as STRINGS, DIP, PPI server & tools for analysis of protein-protein interactions.

Suggested Books:

- Brown, S.M. (2015). *Next-generation DNA sequencing Informatics* (2nd ed.). Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.
- Lesk, A.M. (2015). *Introduction to Genomics* (2nd ed.). Oxford, UK: Oxford University Press.
- Liebler, D. C. (2001). *Introduction to proteomics tools for the new biology*. US: Humana Press.
- Pennington, S. R. & Dunn, M. J. (Eds.). (2000). *Proteomics: From protein sequence to function*. Oxford, UK: Bios Scientific Pub Ltd.
- Pevsner, J. (2017). *Bioinformatics and Functional Genomics* (3rd ed.). New Jersey, USA: John Wiley & Sons Ltd.
- Thangadurai, D. & Sangeetha, J. (2015). *Genomics and Proteomics: Principles, Technologies, and Applications*. USA: CRC Press.
- Twyman, R.M. (2004). *Principles of Proteomics*. New Delhi, India: CBS Publishers.

Suggested e- Resources:

- **Proteomics**
  https://nptel.ac.in/courses/102101055/4
- **Genomics**
  https://edu.t-bio.info/learn-to-analyze-omics-data/

BT 521 Plant Biotechnology

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- understand the concepts of various methods of gene delivery in plant cells
- utilize principles for development of various stress resistant plants
- comprehend and apply various techniques used in plant biotechnology

Section A

- Introduction, examples of current use of plant biotechnology.
- Development of pathogen resistant plants (virus & insect resistance).
- Development of plants of improved seed quality; Artificial seeds.
- Development of plants resistant to environmental stress and herbicides.
- Future outlook.

Section-B

- Immobilization of cells.
- Direct gene delivery methods.
- Vector based gene delivery methods: *Agrobacterium*, Ti plasmid based vectors, viral vectors.
- Chloroplast engineering: Advantages of transplastomics, applications in production of biopharmaceuticals, introduction of agronomic traits, viz. disease resistance, herbicide resistance, salt and drought resistance; phytoremediation etc.
- Biotechnology of biological nitrogen fixation: *nif* genes.

Section-C

- Production of metabolites; metabolic engineering and industrial products: Overview of plant secondary metabolites; control mechanisms and manipulation of phenyl propanoids and shikimate

pathways; general strategy to regulate the production of plant cell products.

- Biotransformation using plant cells.
- Cryobiology of plant cell cultures.
- Edible vaccines.
- Molecular markers - hybridization and PCR based markers RFLP, RAPD, STS, SSR, AFLP, SNP markers.

Suggested Books:

- Chawla, H.S. (2009). *Plant Biotechnology* (3rd ed.). New Delhi, India: Oxford & IBH Publishing Co. Pvt. Ltd.
- Murphy, D. (2007). *Plant Breeding and Biotechnology: Societal Context and the Future of Agriculture* (1st ed.). UK: Cambridge University Press.
- Peter, K.V., & Keshavachandran, R. (2008). Plant Biotechnology: Methods in Tissue Culture and Gene Transfer. India: Universities Press.
- Singh, B.D. (2011). *Plant Biotechnology* (2nd ed.). New Delhi, India: Kalyani Publisher.
- Singh, B.S. (2007). *Fundamentals of Plant Biotechnology*. New Delhi, India: Satish Serial Publishing House.
- Slater, A. (2008). *Plant Biotechnology: The Genetic Manipulation of Plants* (2nd ed.). Oxford, UK: Oxford Publisher.

Suggested e- Resources:

- **Chloroplast Biotechnology**

  https://onlinelibrary.wiley.com/page/journal/14677652/homepage/chloroplast_biotechnology_special_issue.htm

- **Plant transformation technologies**

  http://repository.ias.ac.in/57240/1/23-pub.pdf

- **Abiotic stress and transgenics**

  http://repository.ias.ac.in/89833/1/1-pub.pdf

BT 522 Recombinant DNA Technology

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- describe and apply techniques used for DNA synthesis, amplification and sequencing
- discuss and choose relevant strategies of cloning in both prokaryotes and eukaryotes
- identify novel diagnostic tools of rDNA and gene therapy

Section-A

- Chemical synthesis of DNA: phosphodiester, phosphotriester, phosphite triester approaches, phosphoramidite solid phase automated synthesis of DNA, post-synthetic processing.
- Sequencing of DNA: Maxam-Gilbert method, Sanger sequencing technique, automated DNA sequencing, improved gel based sequencers, primer walking method, whole genome shotgun sequencing, mass spectrometry based sequencing, pyrosequencing, 454 sequencing technologies.
- Overlap-extension PCR in gene recombination, deletion and addition.
- Mutation detection: SSCP, DGGE, RFLP, Oligo ligation assay (OLA), Mismatch chemical cleavage (MCC), High resolution melt analyses, Allele-specific amplification (ASA).
- Applications of transposons in genetic engineering: construction of R plasmids, gene tagging and isolation, mutagenesis, genome characterization etc.

Section-B

- Molecular cloning in *Bacillus subtilis*.
- Cloning in yeast.
- DNA cloning in mammalian cells with SV-40 vector.

- Cloning in plants: Direct and vector based approaches.
- Site directed mutagenesis: Oligonucleotide directed mutagenesis, PCR based mutagenesis.
- Introduction to genome editing by CRISPR-CAS and its applications.

Section-C

- New diagnostics in rDNA technology: detection of genetic disorders, PCR in molecular diagnostics: Viral and bacterial detection, DNA finger printing.
- Gene silencing techniques: RNAi, siRNA technology, construction of siRNA vectors, micro RNA, ribozymes, applications of gene silencing.
- Knockout mice.
- Gene therapy: types, viral and non viral vectors. An overview of structure and ligand based drug designing.
- Cloning and expression of human interferon gene.

Suggested Books:

- Boylan, M. & Brown, K.E. (2001). *Genetic Engineering: Science and Ethics on New Frontier*. UK: Pearson Education.
- Drlica, K. (2003). *Understanding DNA and Gene Cloning* (4th ed.). New Jersey, USA: John Wiley & Sons Ltd.
- Glick, B.R., Pasternak, J.J. & Patten, C.L. (2010). *Molecular Biotechnology: Principles and Applications of Recombinant DNA* (4th ed.). US: American Society for Microbiology.
- Kumar, H.D. (1990). *Nucleic Acid and Biotechnology*. New Delhi, India: Vikas Publication.
- Nicholl, D.S.T. (2008). *An Introduction to Genetic Engineering* (3rded.). UK: Cambridge University Press.
- Primrose, S. B. & Old, R.W. (2001). *Principles of Gene Manipulation* (6th ed.). New Jersey, USA: Wiley-Blackwell.
- Sambrook, J.F. & Russell, D.W. (2001). *Molecular Cloning: A Laboratory Manual* (3rd ed.) Vol. 1, 2 and 3. Cold Spring Harbor laboratory. NY: Cold Spring Harbor Laboratory Press.

- Watson, J.D., Meyers, R.M., Caudy, A.A. & Witkowski, J.A. (2007). *Recombinant DNA: Genes and Genomes-A short Course* (3rd ed.). Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.
- Watson, J.D., Baker, T.A. & Bell, S.P. (2014). *Molecular Biology of the Gene* (7th ed.). US: Pearson.
- Winnacker, E.L. (1987). *From Genes to Clones: Introduction to Gene Technology*. Germany: Wiley VCH.

Suggested e-Resources:

- **Solid phase oligonucleotide synthesis**

  https://www.atdbio.com/content/17/Solid-phase-oligonucleotide-synthesis

- **DNA sequencing approaches**

  https://www.ncbi.nlm.nih.gov/books/NBK21117/CRISPR/

- **Cas technology**

  https://bit.ly/2Edvm06

- **Construction of siRNA expression vectors**

  https://bit.ly/2EqNLI8

- **Gene knockout and transgenic mice**

  https://www.ncbi.nlm.nih.gov/books/NBK21632/

BT 532 Immunotechnology

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- understand various theories of antibody formation
- explain the mechanism of immune response to various stimuli
- elucidate on vaccines and their development

Section- A

- Structure, genomic organization, expression and functions of major histocompatibility complex (MHC).
- Organization and expression of immunoglobulin genes.
- T-cell receptors- genomic organization, structure and isolation of TCR.
- Antibody diversity- mini gene theory, mutation theory, germ line theory, somatic recombination, V(D) J recombination. Combinatorial diversity, junctional diversity.

Section-B

- ABO Blood groups, blood transfusion, Bombay phenotype, Rh blood group, DAT test, MN blood group.
- Immunity to infectious diseases: Viral, bacterial, fungal and parasitic infections.
- Immunodeficiency disease: Primary and secondary immunodeficiency disease (AIDS).

Section –C

- History of vaccination, immunization types and vaccination properties.
- Types of vaccines: Live, killed, subunit, recombinant viral, synthetic peptide, anti-idiotype, DNA, toxoid, conjugate, recombinant vector and plant based vaccines.
- Stages of vaccine development and some common vaccines used in human MMR, poliovaccine & BCG vaccines.

Suggested Books:

- Austyn, J.M. &Wood, K.J. (1993). *Principles Of Cellular and Molecular Immunology*. London, U.K: Oxford University Press.
- Benjaminin, E., Coico, R. & Sunshine, G. (2000).*im*: A short course (4th ed.). New York, USA: Wiley-Liss.
- Cunnigham, A.J. (1978).*Understanding Immunology*. London, U.K.: Academic Press Inc.
- Hildemann, W.H. (1984). *Essentials of Immunology*. USA: Elsevier Science Ltd.
- Johnstone, A. & Thorpe, R. (1996) *Immunochemistry In Practice* (3rded.). US: Wiley-Blackwell.

- Joshi, K.R. & Osama, N.O. (2004). *Immunology and Serology*. India: Agrobios.
- Khan, F.H. (2009). *The Elements Of Immunology*. India: Pearson Education.
- Punt, J., Stranford, S., Jones, P. & Owen, J. (2018). *Kuby Immunology (*8th ed.). New York, USA: W. H. Freeman and Company.
- Reeves, G. & Todd, I. (2001). *Lecture Notes on Immunology* (4th ed.). US: Wiley-Blackwell.
- Rich, R.R., Fleisher, T. A, Shearer, W.T., Schroeder, H., Frew, A.J. & Weyand, C.M. (2018). *Clinical Immunology: Principles and Practice* (5th ed.). USA: Elsevier Science Ltd.
- Tizard, I. R. (1995). *Immunology: Introduction,* (4th ed.). Philadelphia, USA: Saunders College Publishing.

Suggested e- Resources:

- **Antibodies and antigens**

  https://nptel.ac.in/courses/102103038/download/module2.pdf

- **Vaccines**

  https://nptel.ac.in/courses/104108055/37

- **DNA vaccines**

  https://nptel.ac.in/courses/102103041/18

- **Transplantation immunology**

  https://nptel.ac.in/courses/102103038/31

BT 525 Animal Biotechnology-I

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

At successful completion of this course students will be able to:

- describe tools of molecular biology and biotechnology for the improved production and protection of animals

- evaluate and discuss public and ethical concerns over the use of animal biotechnology
- gain an understanding of the key topics in tissue engineering

Section-A

- History and importance of animal biotechnology, cryopreservation of gametes & embryos in mammals, artificial insemination (AI) techniques & their development: estrus synchronization; semen collection, evaluation & storage.
- *In Vitro* fertilization and embryo transfer; superovulation, Microinjection & macroinjection: introduction, procedure, applications advantages and limitations. Ethical, social & moral issues related to cloning, in situ & ex situ preservation of germplasm.

Section-B

- Introduction to stem cell-definition, classification, characteristics, differentiation and dedifferentiation, stem cell niche, stem cells vs somatic cells, mechanism of pleuripotency in stem cells, different kinds of stem cells: adult stem cells, embryonic stem cells, fetal tissue stem cell, umbilical cord blood stem cells.
- Human embryonic stem cells and society: The religious, legal, ethical and scientific debate, stem cell banking and ethical approaches on stem cells.
- Stem cell therapies: Clinical applications of stem cell therapy, parkinsons and alzheimers disease, diabetes, kidney failure, lymphoma and leukemic malignancies requiring stem cell therapy.

Section-C

- Principles of Tissue Engineering- History & scope, basics of tissue engineering, cell- ecm interaction, wound healing mechanism, tissue engineering bioreactors, models of tissue engineering, biomaterials in tissue engineering, bioartificial organs: source of cells, choosing the right scaffold material, mode of transplantation.
- Tissue Engineering & future perspectives: commercial products.

Suggested Books:

- Butler, M. (Ed.). (1991). *Mammalian Cell Biotechnology; A Practical Approach*, London, UK: Oxford university press.
- Kumaresan, V. (2008). *Applied Animal Biotechnology*. Tamil Nadu, India: Saras Publication.
- Lanza, R., Gearhart, J. & Hogan, B. (2009). *Essentials of Stem Cell Biology* (2nd ed.). London, UK: Academic Press.
- Lanza, R., Langer, R. & Vacanti, J. (2013). *Principles of Tissue Engineering* (4th ed.). London, UK: Academic Press.
- Portner, R. (2007). *Animal Cell Biotechnology*. New York, USA: Humana Press.
- Singh, B., Gautam, S.K. & Chauhan, M.S. (2015). *Textbook of Animal Biotechnology*. New Delhi, India:Teri Publication.

Suggested e-Resources

- **Cryopreservation of gametes and embryos in mammals**

  https://www.glowm.com/section_view/heading/Gamete and Embryo Cryopreservation

- **Human embryonic stem cell**

  https://www.eurostemcell.org/origins-ethics-and-embryos-sources-human-embryonic-stem-cells

- **Stem cell therapies**

  https://www.closerlookatstemcells.org/stem-cells-medicine

- **History and scope of Tissue Engineering**

  https://www.stoodnt.com/blog/tissue-engineering-applications-scopes/

PHY 532 Biophysics-I

Max. Marks : 100	L	T	P	C
(CA: 40 + ESA: 60)	4	0	0	4

Learning Outcomes:

After completion of this course, the students will be able to-

- understand the concepts of physical principles in the biomolecular systems
- learn properties and conformations of biomolecules
- Develop an understanding of the interaction between physics and biology

Section A

- Introduction: Brief introduction to all aspects of Biology, cellular automata, Conway's Game of life.
- Cell structure and function: Cell theory, cell membrane and transport, membranous organelles, Non-membranous organelles, Nuclear components and major cell types, viruses.
- Molecules in the cell: carbohydrates, lipids, proteins and nucleic acids, their structure and function.
- Code of life: Central dogma, DNA replication, transcription and translation.
- Energy in life forms: Cellular Respiration, Glycolysis, Krebs cycle, Electron transport chain, ATP calculation, Photosynthesis, C4 pathway.

Section B

- Intermolecular interactions: Covalent interactions, disulphide bonds, van der Waals interactions, bond angles and torsions. Role of hydrogen bonding and hydrophobic interaction in biomolecular structures. Examples of α-helices and β-sheets in proteins, Watson-Crick pairs in DNA, stacking interactions in DNA and RNA.
- Protein Conformation: Conformational properties of polypeptides, Ramachandran plot, Helical parameters and conformation, organization as secondary and super secondary structures in proteins, domains and

motifs. Protein folding *in vivo* and *in vitro* of globular proteins, basic idea.

Section C

- Molecular Mechanics: Force field equation, Lennard Jones Potential, Potential energy surface, Z-matrix, Molecular modeling, Energy minimization techniques, Exhaustive search method, steepest descent and conjugate gradient methods, Molecular dynamics simulation, Verlet algorithm and simulated annealing protocol.
- Experimental techniques used to determine biomolecular structure: Principles and application of UV-visible, circular dichroism and fluorescence spectroscopy.
- Case studies on Helix to coil transitions, melting curves in proteins and DNA structures. X-ray crystallography of biomolecules: Obtaining single crystals of biomolecules, Single crystal data collection, Determination of point group, space group from symmetry of diffraction patterns, deducing cell parameters, interpretation of intensity data, Calculation of electron density, Solving the phase problem, Structure validation.

Suggested Books:

- Cantor, C. R., & Schimmel, P. R. (1980). *Biophysical Chemistry: Part III: The Behavior Of Biological Macromolecules*. Macmillan.
- Jensen, J. H. (2010). *Molecular Modeling Basics*. CRC Press.
- Nelson, P. (2004). *Biological Physics*. New York: WH Freeman.
- Schlick, T. (2010). *Molecular modeling and Simulation: An Interdisciplinary Guide: An Interdisciplinary Guide* (Vol. 21). Springer Science & Business Media.
- Tuszynski, J. A. & Kurzynski, M. (2003). *Introduction to molecular biophysics*. CRC press.
- Van Holde, K. E. J. W. *Principles of Physical Biochemistry*/Kensal E. Van Holde, W. Curtis Johnson, P. Shing Ho.
- Voet, D., Voet, J. G. & Pratt, C. W. (2013). *Fundamentals of Biochemistry: Life At The Molecular Level* (No. 577.1 VOE). Hoboken: Wiley.

Suggested e-Resources:

- **Non-Conventional Energy Systems**

  https://nptel.ac.in/syllabus/1021
- **Quantum-mechanics of molecular structure**

https://bit.ly/2SoEqof

https://bit.ly/2SoEqof

ENVS 402 Ecology and Environment

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- describe the interaction of organisms with their environment
- identify the various threats to biodiversity
- critically explain the concept of biomes
- describe the various biogeochemical cycles and their significance

Section A

Introduction to Environment

- Concept of Environment, Factors of the environment: Physiographic, Climatic, Edaphic, Biotic and Anthropogenic.
- Bio Geochemical Cycles: The Carbon cycle, the Oxygen cycle, the Nitrogen cycle, The Hydrological cycle.

Section B

- Concept of Ecology, Ecosystem and Biomes.
- Concept of Ecosystem: With special reference to desert, forest and aquatic ecosystem. Food chain, Food web & succession. Ecological Pyramids and their types.
- Energy flow in ecosystem, Concepts of Biomes. Major biomes of the world: Tropical forest, Temperate forest, Grassland and Tundra.

Section C

Environmental Pollution and its Effect

- Environmental pollution-Pollutants and sources:
- Water pollution, Soil pollution, Air pollution and, Noise pollution.
- Greenhouse Effect, Global warming.
- Biodiversity: Threats and Conservation.

Suggested Books:

➢ Atkinson, Raw, M. (2007). *Biogeography*. Philip Allan Updates.

- Gautam, A. (2007). *Environmental Geography*. Allahabad, India: Sharda Pustak Bhawan.
- Huggett, R. J. (1998). *Fundamental of Biogeography*. London, UK: Routledge.
- Kayastha, S.L. & Kumra, V.K. (1986). *Environmental Studies.* Varanasi, India: Tara Book Agency.
- Mathur, H.S. (1998). *Essentials of Biogeography*. Jaipur, India: Pointer.
- Mehtani, S. & Sinha, A. (2010). *Biogeography*. Commonwealth.
- Odum, E. P. (1975). *Ecology*. Lanham, MD:Rowman and Littlefield.
- Odum, E.P. (1968). *Fundamentals of Ecology*. London, UK:W.B. Sanders Company
- Saxena, H. M. (1999). *Environmental Geography*. Jaipur, India:Rawat.
- Saxena, H. M. (2000). *Environmental Management*. Jaipur, India:Rawat.

Suggested e-Resources:

- **Environment and Ecology, IIT Delhi**
  https://nptel.ac.in/courses/122102006/16
- **Ecology and Environment, IIT Madras,**
  https://swayam.gov.in/courses/4905-july-2018-ecology-and-environment

BT 549 Molecular Diagnostics and Emerging Techniques in Biotechnology

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- develop understanding of latest techniques used in diagnostics and molecular biology
- learn analysis of clinical samples and pathogenesis
- apply the acquired knowledge to initiate a start-up venture in the field of biotechnology

Section A

- An overview of chromosomal structure & mutations; DNA polymorphism: human identity; clinical variability and genetically determined adverse reactions to drugs.
- PCR: Real-time; ARMS; Multiplex; ISH; FISH; ISA; RFLP; DHPLC; DGGE; CSCE; SSCP.
- Nucleic acid sequencing: new generations of automated sequencers; Microarray chips; EST; SAGE; microarray data normalization & analysis; molecular markers: 16S rRNA typing.
- Diagnostic proteomics: SELDI-TOF-MS; Bioinformatics data acquisition & analysis.

Section B

- Metabolite profile for biomarker detection the body fluids/tissues in various metabolic disorders by making using LCMS & NMR technological platforms.
- Direct detection and identification of slow growing or unculturable pathogenic-organisms.
- Detection of recognized genetic aberrations in clinical samples from cancer patients; types of cancer-causing alterations revealed by next-generation sequencing of clinical isolates; predictive biomarkers for personalized onco-therapy of human diseases such as chronic myeloid leukemia, colon, breast, lung cancer and melanoma, targeted therapies and preventing toxicity of standard systemic therapies.

Section- C

- High throughput screens in cellular systems, target identification, validation of experimental methods to generate the omics data, bioinformatics analyses, mathematical modeling and designing testable predictions.
- CRISPR-CAS- History of its discovery, elucidation of the mechanism including introduction to all the molecular players, development of applications for in vivo genome engineering for genetic studies, promise of the technology as a next generation therapeutic method.
- FT-ICR and Orbitrap, fragmentation of peptides; proteomics, nano LC-MS; Phospho proteomics; interaction proteomics, mass spectroscopy in structural biology; imaging mass spectrometry.

Suggested Books:

- Brooker, R. J. (2009). *Genetics: Analysis & Principles*. New York, NY: McGraw-Hill.
- Campbell, A.M., & Heyer, L.J. (2006). *Discovering Genomics, Proteomics, and Bioinformatics*. San Francisco: Benjamin Cummings.
- Campbell, I.D. (2012). *Biophysical Techniques*. Oxford: Oxford University Press.
- Coleman, W.B., & Tsongalis, G.J. (2010). *Molecular Diagnostics: for the Clinical Laboratorian*. Totowa, NJ: Humana Press.
- Glick, B.R., Pasternak, J.J., & Patten, C. L. (2010). *Molecular Biotechnology: Principles and Applications of Recombinant DNA*. Washington, DC: ASM Press.
- Nelson, P. C., Radosavljević, M., & Bromberg, S. (2004). *Biological Physics: Energy, Information, Life*. New York: W.H. Freeman.
- Phillips, R., Kondev, J., & Theriot, J. (2009). P*hysical Biology of the Cell*. New York: Garland Science.
- Serdyuk, I.N., Zaccai, N.R., & Zaccai, G. (2007). *Methods in Molecular Biophysics: Structure, Dynamics, Function*. Cambridge: Cambridge University Press.

Suggested e-Resources:

- Nanobody: The “Magic Bullet” doi:10.7150/thno.8006.
- Phage Display for Engineering and Analyzing
- Protein Interaction Interfaces. doi:10.1016/j.sbi.2007.08.007.
- Nanobody Stabilization of G Protein-Coupled Receptor Conformational States. doi:10.1016/j.sbi.2011.06.011.
- Introduction to Heavy Chain Antibodies and Derived Nanobodies. doi:10.1007/978-1-61779-968-6_2.
- Selection by Phage Display of Single Domain Antibodies Specific to Antigens in their Native Conformation. doi:10.1007/978-1-61779-968-6_6.
- Molecular Imprint of Enzyme Active Site by Camel Nanobodies. doi:10.1074/jbc.m111.336370.
- Allosteric Inhibition of VIM Metallo-β-Lactamases by a Camelid Nanobody. doi:10.1042/bj20121305.

- Diverse Evolutionary Roots and Mechanistic Variations of the CRISPR-Cas Systems. Science, 353(6299). doi:10.1126/science.aad5147.
- The Heroes of CRISPR. doi:10.1016/j. cell.2015.12.041.
- The Unsung Heroes of CRISPR. doi:10.1038/535342a.
- A Programmable Dual-RNA-Guided DNA Endonuclease in AdaptiveBacterial Immunity. doi:10.1126/science.1225829.
- Naturally Occurring Antibodies Devoid of Light Chains. Nature, 363(6428), 446-448. doi:10.1038/363446a0.

BT 546 Artificial Intelligence in Biotechnology and Healthcare

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**4**	**0**	**0**	**4**

Learning Outcomes:

After successful completion of the course, students should be able to:

- understand the fundamental of ai and its applications in biology and biomedical sciences
- develop skills of analyzing biological problems
- design algorithms and models to overcome biological challenges
- develop employability skills for healthcare industries

Section A

Introduction to artificial intelligence; Concept of Machine Learning. Neural Networks; supervised and unsupervised learning. Deep learning methods in biology. Data analysis algorithms.

Section B

Semantics of biological sequences. Artificial neural networks for structure prediction of biomolecules. Deep learning methods for predicting genes and its regulation. Machine learning methods for prediction of biomolecular interactions.

Section C

Artificial intelligence in drug discovery and biomedical image processing. Electronic health record management and clinical decision support systems. AI in big data analysis in health care.

Suggested Books:

- Banzhaf, W. *et al.* (2003). *Advances in artificial life*. Springer Pub.
- Hunter, L. (Ed.), (1993). *Artificial Intelligence in Molecular Biology*. The MIT Press.
- Malmgren, H. *et al.* (2000). *Artificial Neural Networks in Medicine and Biology*. Springer Pub.
- Smolinski, T.G. *et al.* (2008). *Applications of Computational Intelligence in Biology*. Springer Pub.
- Smolinski, T.G. *et al.* (2008). *Computational Intelligence in Biomedicine and Bioinformatics*. Springer Pub.

List of Reading Elective

BT 529R Drug Discovery

Max. Marks : 100	**L**	**T**	**P**	**C**
(ESA: 100)	**0**	**0**	**4**	**2**

Learning Outcomes:

After successful completion of the course, students should be able to:

- understand the molecular, analytical and computational techniques for identifying drug target site
- learn the basic structure of a pharmaceutical agent and determine the chemical group/s responsible for a given biological effect
- apply the knowledge of pharmacogenomics and bioinformatics as for drug designing and discovery

Modern drug discovery involves the identification of a target or drug lead using different techniques including molecular modeling, combinatorial libraries and high-throughput screening (HTS). Rational drug design is based on the understanding of the three-dimensional structures and physicochemical properties of drugs and receptors. Knowledge of molecular mechanisms, molecular dynamics simulations and homology modeling is necessary for studying drug/receptor interactions. The different conformational sampling techniques, fitness functions used in molecular docking and computational receptor-based and ligand-based drug design

approaches are mostly used to design compounds with improved biological activity in rational drug design. Quantitative drug design using QSAR models are used to correlate structural molecular properties (descriptors) with functions (i.e. physicochemical properties, biological activities, toxicity, etc.) of the compounds. Understanding the structure activity relationship between the 3D structure of a molecule and its biological activity may act as the basis for the prediction of compounds with improved biological activities. Different bio-analytical assays (LC/MS/MS, GC/MS and ELISA) could be developed further in support of *in vitro* and *in vivo* studies. Understanding the principles as well as an early characterization of drug toxicity, adsorption, distribution, metabolism and excretion (ADME) along with drug-drug interactions, plasma protein binding assays and metabolite profile studies helps in eliminating compounds with unacceptable pharmacokinetic characteristics, which is critical to successful drug discovery programs.

Suggested Books:

- Dastmalchi, S. *et. al.* (2016). *Methods and Algorithms for Molecular Docking-Based Drug Design and Discovery*. IGI Global.
- Krogsgaard-Larsen *et. al.* (2016). *Textbook of Drug Design and Discovery*. 5th Edition. CRC Press.
- Rahman, A. U., Caldwell, G. W. & Choudhary, M. I. (2007). *Frontiers in Drug Design and Discovery.* Bentham Science publishers Limited.
- Satyanarayanajois, S. D. (2011). *Drug Design and Discovery: Methods and Protocols*. Humana Press.

Suggested e- Resources:

- **Drug Discovery**

  https://bit.ly/2tCqdtE

- **Peptide therapeutics**

  https://www.sciencedirect.com/science/article/pii/S1359644614003997

- **Bio-analytical techniques**

  https://www.pharmatutor.org/articles/bioanalytical-techniques-overview

BT 531R Human Genetics and Diseases

Max. Marks : 100	**L**	**T**	**P**	**C**
(ESA: 100)	**0**	**0**	**4**	**2**

Learning Outcomes:

After successful completion of the course, students should be able to:

- understand hereditary and molecular genetics with a strong human disease perspective
- describe genetic abnormalities underlying human disease and disorders
- develop interest in biomedical research, genetic counseling, medicine, and clinical genetics

Since the rediscovery of Mendel's work in 1900, investigations on the genetic nature of human traits have gained significant importance. Understanding the genetic basis behind human disease is one of the most important reasons to study human chromosome structure, human karyotype, banding techniques, chromosome identification and nomenclature (ISCN)**.** Classical genetics has considerable importance in constructing genetic hypothesis from pedigree data analysis in monogenetic traits, autosomal dominant, autosomal recessive, sex linked dominant, sex linked recessive and sex influenced traits. The impact of consanguinity in causing sex linked anomalies (haemophilia, colour blindness and Duchenne Muscular Dystrophy) has been observed in human population. Current knowledge on genetic variations across populations is applied to study human health and diseases which include chromosomal disorders, structural and numerical chromosomal anomalies (Klinefelter syndrome, Down's syndrome, Turner syndrome, Achondroplasia), inborn errors of metabolism (Phenylketonuria (PKU), Alkaptonuria, Albinism, Galactosemia), haemoglobinopathies, Thalassemia syndromes, multifactorial disorders (diabetes, schizophrenia, huntington disease). Medical genetics involves ethical issues therefore serious discussion is required for prenatal/adult diagnosis of genetic disorders, medical ethics, risks and benefits, informed consent and right of choice.

Suggested Books:

- Pasternak J. F. (1999). *An introduction to Human Molecular Genetics-Mechanism of Inherited Diseases*. Science Press.

- Strachan T. & Read. A. (2011). *Human Molecular Genetics* (4thed.). Garland Science.
- Thompson, J.S. & Thompson, M.W. (2007). *Genetics in Medicine (*7th Ed.). saunders.

Suggested e- Resources

- **Chromosome identification and nomenclature (ISCN)**

  http://www.cydas.org/Resources/ISCN_Discussion.html

- **Pedigree data analysis**

  https://learn.genetics.utah.edu/content/disorders/

- **Genetic disorders**

  https://www.genome.gov/10001204/specific-genetic-disorders/

- **Prenatal/ adult diagnosis of genetic disorders, medical ethics**

  https://www.michiganallianceforfamilies.org/all/#sectionD

BT 534R Intellectual Property Rights

Max. Marks : 100	**L**	**T**	**P**	**C**
(ESA: 100)	**0**	**0**	**4**	**2**

Learning Outcomes:

After successful completion of the course, students should be able to:

- understand the concept of IPR and its types
- describe the steps for patenting
- discuss the role of WTO and WIPO on IPR
- apply the gained knowledge of ethical aspects and IPR in different biotechnology research sectors

Intellectual property rights (IPR) have an old history and are very relevant for economic development. Various types of IPR (patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications) are recognized with specific uses. There is currently an emergence of specific IP pertaining to plants and animals

(UPOV, Plant Breeder's rights and plant variety protection and farmers rights act, patent protection of plant and animal inventions (WTO) and Law on the protection of New plant varieties and animal breeds (WIPO)). It is important to know about types of patent applications and the process of patenting with special emphasis to India. The role of WTO (GATT and TRIPS) and WIPO in implementation of IPR is significant as is understanding the relevance of Patent Cooperation Treaty (PCT) in patenting. IPR also are associated with certain ethical dilemma and there are some interesting case studies which highlight its relevance.

Suggested Books:

- Goel, D. & Parashar S. (2013). *IPR, Biosafety and Bioethics* (1st ed.) Pearson Education India.
- Pandey, N. & Dharni, K. (2014). *Intellectual Property Rights.* PHI Learning.
- Ramakrishna, B. & Kumar, A. (2017). *Fundamentals of Intellectual Property Rights: For Students, Industrialist and Patent Lawyers* (1st ed.). Notion Press.
- Sateesh, M.K. (2008). *Bioethics and Biosafet*y. I.K. International Publishing House.

Suggested e-resources:

- **World Trade Organisation**

  http://www.wto.org

- **World Intellectual Property Organisation**

  http://www.wipo.int

- **International Union for the Protection of New Varieties of Plants**

  http://www.upov.int

- **National Portal of India**

  http://www.archive.india.gov.in

BT 535R Medical Microbiology

Max. Marks : 100	L	T	P	C
(ESA: 100)	0	0	4	2

Learning Outcomes:

After successful completion of the course, students should be able to:

- identify various bacterial, fungal, viral and protozoan diseases and their epidemiology
- understand the aspects of emerging and reemerging of diseases
- understand handling of pathogenic microbes in medical field

Medical Microbiology describes the cause, transmission, epidemiology, pathogenesis, symptoms, diagnosis and treatment of various bacterial (tuberculosis, typhoid, leprosy), fungal (superficial, subcutaneous, systemic mycosis), protozoan (Malaria, amoebiasis) and viral (AIDS, Influenza, measles) diseases. Currently, it is necessary to understand the impact of emerging and remerging diseases (cholera, dengue, multidrug resistant tuberculosis, H5N1 avian influenza, drug resistant malaria, chikungunya) on human health. Global assessment for various diseases also shows an increasing trend of nosocomial infections and opportunistic infections which cause significant mortality and health concerns.

Suggested Books:

- Brooks, G.F., Carroll, K.C., Butel, J.S., Morse, S.A. & Mietzner, T.A. (2013) *Jawetz, Melnick and Adelberg's Medical Microbiology* (26th ed.). US: Lange Medical Books, McGraw-Hill.
- Madigan, M., Martinko, J., Stahl, D. & Clark, D. (2010). *Brock Biology of Microorganisms* (13th ed.). UK: Pearson Education.
- Pelczar Jr., M.J., Chan, E.C.S. & Krieg, N.R. (2011). *Microbiology*. New York, USA:Tata McGraw-Hill.

Suggested e- resources:

- **Emerging Diseases**
  https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3701702/
- **Epidemiology**
  https://www.bmj.com/about-bmj/resources-readers/publications/epidemiology-uninitiated/1-what-epidemiology
- **Nosocomial Infections**
  https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3470069/

BT 538R Molecular Plant Breeding

Max. Marks : 100	**L**	**T**	**P**	**C**
(ESA: 100)	**0**	**0**	**4**	**2**

Learning Outcomes:

After successful completion of the course, students should be able to:

- understand strategies and applications of plant breeding technologies
- gain knowledge of DNA based molecular markers for marker assisted selection (MAS), QTL mapping and markers traits association
- gain knowledge of different molecular markers for improving crop productivity
- plan a research career in the area of plant biotechnology

Plant breeding study involves breeding methods for self and cross pollinated crops. There are several limitations of conventional breeding. Thus, there is need to have a better breeding approaches to overcome this limitation. Development of molecular markers (RFLP, RAPD, SSRs, ISSRs, SNPs), construction of molecular maps and linkage analysis, mapping populations for QTLs using molecular markers play an important role in plant breeding. In order to develop potential plant having better qualities, Marker Assisted Selection (MAS) is also a viable approach which can be done by using selection of traits and markers, trait association, marker assisted backcrossing and recurrent selection, marker assisted hybrid breeding and marker assisted improved varieties/germplasm.

Suggested Books:

- Chawla, H. S. (2000). *Introduction to Plant Biotechnology*. USA: Science Publishers.
- Glick, B.R., Pasternak, J.J. & Patten C.L. (2010). *Molecular Biotechnology: Principles and Applications of Recombinant DNA* (4th ed.). American Society for Microbiology.
- Nicholl, D.S.T. (2008). *An introduction to Genetic Engineering* (3rd ed). Cambridge: Cambridge University Press.
- Primrose, S.B., Twyman R.H. & Old R.W. (2001). *Principles of Gene Manipulation* (6th ed.). Wiley-Blackwell.
- Slater, A., Scott, N. & Fowler, M. (2008). *Plant Biotechnology: The Genetic Manipulation of Plants* (2nd ed.). UK: Oxford University Press.

- Watson, J.D., Gilman, M., Witkowski J. & Zoller, M. (1992). *Recombinant DNA* (2nd ed.). W. H. Freeman publisher.

Suggested e- Resources:

- **Plant breeding**

  https://nptel.ac.in/courses/102103013/pdf/mod6.pdf

- **Molecular marker**

  https://bit.ly/2XmNm0M

- **Gene mapping in plant**

  https://bit.ly/2TaegKm

BT 539R Protein Engineering

Max. Marks : 100	**L**	**T**	**P**	**C**
(ESA: 100)	**0**	**0**	**4**	**2**

Learning Outcomes:

After successful completion of the course, students should be able to:

- perform computational analysis of proteins
- analyze and compare the protein sequence and structure for their functional annotations
- explain applications of proteins for different industrial and academic purposes such as structure determination, organic synthesis and drug design
- plan and execute the activity measurements of isolated proteins and characterize their purity and stability

An introduction to protein engineering for developing proteins with desired functions. Various methods (rational design and directed evolution) of protein engineering are employed to manipulate the different features or characteristics (affinity, specificity and stability etc) of proteins. Engineering various physicochemical and biological properties (stability to changes in parameters as pH, temperature, amino acid sequence and aggregation propensities etc) of the proteins could be important in their use

as protein drugs and/or catalysts in bioreactors. The insight into the fundamental understanding of the mechanisms and forces (Van der waals, electrostatic, hydrogen bonding, weakly polar interactions, and hydrophobic effects), by which protein stabilizes, will help in the formulation of protein based pharmaceuticals. Protein engineering with site-specifically incorporation of unnatural or non-canonical amino acids has been used to improve protein function for medical and industrial applications. Different computational approaches (sequence and 3D structure analysis, data mining, Ramachandran map etc) to protein engineering would help to address the requirements in order to find amino acid sequences that will optimize a desired property (physicochemical property and/or biological function) of a protein. Determination of the physicochemical properties of proteins using various spectroscopic methods (Far-UV and Near-UV CD, Fluorescence, UV absorbance and Optical rotatory dispersion) would further support the drug development process. Yeast surface display (YSD) has become a valuable protein engineering tool for modifying the affinity, specificity, and stability of antibodies, as well as other proteins. YSD could be successfully used for protein epitope mapping, identification of protein-protein interactions, and uses of displayed proteins in industry and medicine. Developing vaccines and peptidomimetics will further allow the investigators to identify novel therapeutic leads for numerous unmet clinical needs.

Suggested Books:

- Cleland, J. L. & Craik, C. S. (2006). *Protein Engineering, Principles and Practice*, Vol 7. Springer Netherlands.
- Creighton, T. E. (1997). *Protein Structure: a Practical Approach*, 2nd Edition. Oxford University press.
- Kyte, J. (2006). *Structure in Protein Chemistry*, 2nd Edition. Garland publishers.
- Mueller, K., & Arndt, K. (2006). *Protein Engineering Protocols*, 1st Edition. Humana Press.
- Robertson, D., & Noel, J.P. (2004). *Protein Engineering Methods in Enzymology*, Vol 388. Elsevier Academic Press.
- Walsh, G. (2014). *Proteins: biochemistry and biotechnology*, Second edition. Chichester, West Sussex: Wiley Blackwell.
- Williamson, M.P. (2012). *How proteins Work*. New York: Garland Science.

Suggested e- Resources:

- **Protein Engineering**:
  https://nptel.ac.in/courses/102103017/pdf/lecture%2022.pdf
- **Conformational stability of proteins**:
  https://bit.ly/2y85mid
- **Protein Engineering with Non-Natural Amino Acids:**
  https://library.umac.mo/ebooks/b2805488x.pdf

List of Online Electives

- Fundamentals of Ecology for Sustainable Ecosystem:
  https://www.extension.harvard.edu/academics/courses/fundamentals-ecology/12779

- Industrial Biotechnology
  https://nptel.ac.in/courses/102/105/102105058/

- Water and Waste Treatment Engineering: Biochemical Technology
  https://www.edx.org/course/water-wastewater-treatment-engineering-tsinghuax-40050455-2x-0

List of Online Reading Elective

- Bio- organic Chemistry: https://nptel.ac.in/courses/104/103/104103018/
- Biocatalysis in organic synthesis:
  https://nptel.ac.in/courses/104/105/104105032/
- Comprehensive Disaster Risk Management Framework:
  https://nidm.gov.in/PDF/IEC/online_new.pdf
- Environmental Management - An Introduction:
  www.algonquincollege.com/ ccol/courses/environmental-management-an-introduction
- Enzyme Science and Engineering:
  https://nptel.ac.in/courses/102/102/102102033/
- General Course on Intellectual Property:
  https://welc.wipo.int/acc/index.jsf?page=courseCatalog.xhtml