BANASTHALI VIDYAPITH

Master of Science (Bioscience)

Curriculum Structure

First Semester Examination, December-2019
Second Semester Examination, April/May-2020
Third Semester Examination, December-2020
Fourth Semester Examination, April/May-2021

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

July, 2019

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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.

M.Sc. Bioscience-Animal Science

Programme Educational Objectives

The M.Sc Bioscience-Animal Science programme aims for the holistic development of the students through the unique and innovative five fold educational ideology of Banasthali Vidyapith.

Animal Science is the study of nature of each kind of animal that helps the zoologist to learn evolution of animal species on earth and their processes and behaviour. The programme focuses on specific knowledge about animal biology and the associated academic disciplines including physiology, ecology, diversity, embryonic development, evolution, immunology, animal tissue culture, entomology, fish biology and animal biotechnology. The program fulfills the requirement of the students to become familiar with basic and advanced concepts of the subject thus providing them the scientific background they need to find career opportunities in any related field of zoology. On completion of the Programme, the student will be able to:

- develop aptitude for learning about the biology and significance of fauna ranging from single cell to multicellular system
- compare and contrast the characteristics of animals that differentiate them from other forms of life
- explain theory of evolution and how descent with modification has shaped animal morphology, physiology, life history, and behavior
- explain how organisms function at the level of the gene, genome, cell, tissue, organ and organ-system
- apply zoological science in aquaculture, agriculture and modern medicine
- gain the ability to work as taxonomist, paleontologist and evolutionary biologist
- access the primary literature, recognize relevant works for a particular topic, and evaluate the scientific content of these works
- demonstrate ability in the experimental techniques and methods of analysis appropriate for their area of specialization within zoology.

M.Sc. Bioscience-Animal Science
Programme Outcomes

PO1: Knowledge: Students will be equipped with an in-depth knowledge in the area of basic and applied zoology including evolution, taxonomy, physiology, molecular biology, genetics, cell biology, and environment.

PO2: Planning abilities: Develop efficient planning abilities with time management, analytical and decisive skills to reach achievable goals.

PO3: Problem analysis: Devise and sustain logical thinking to tackle detailed problem-solving and analytical tasks associated with questions in core and applied zoology.

PO4: Modern tool usage: Learn, select, and apply traditional taxonomy, practical field skills and modern molecular laboratory expertise. Develop competence in the handling of research facilities and operate safely in a laboratory environment, both individually and as a team member.

PO5: Leadership skill: Develop leadership skills to work in a team and take initiative for fulfillment of professional and societal responsibilities.

PO6: Professional Identity: Understand, analyze and communicate the value of their professional roles in different analytical and forensic laboratory, Zoological Survey of India, archeology, wild life management, aquaculture and food processing etc.

PO7: Animal Ethics: Develop empathy and love towards the animals. Apply principles of animal ethics and commit to professional and social responsibilities.

PO8: Communication: Develop skills used in reasoning and communication with scientific community and society. To synthesize information from literature and its communication in form of scientific papers, reports, poster and oral presentations.

PO9: The Zoologist and society: Contribute to society, in the realms of the environment, agriculture, natural resource management, human and animal health well being.

PO10: Environment and sustainability: Utilization of zoological research to enhance sustainable development of programs for conservation and preservation of biodiversity.

PO11: Life-long learning: Develop independent, critical and creative thinker who has a self-motivated passion for life-long learning.

M.Sc. Bioscience-Plant Science
Programme Educational Objectives

The M.Sc. Bioscience-Plant Science programme aims at holistic development of the students through the innovative and unique Five fold Educational ideology of Banasthali Vidyapith.

As a component of the ecosystem, botanists are instrumental regarding their all inclusive and widespread understanding of plants and their importance. Botanists require an understanding of the identification of various plant groups, their taxonomy, physiology, biochemistry, genetics, ecology and economic importance along with the modern approach of plant biotechnology, secondary metabolite production and their medicinal value. The program has identified necessary competencies in the respective areas for which all essential theoretical, practical and field based skills will be provided. On completion of the Programme, the student will be able to:

- become competent botanists at different levels
- elevate understanding regarding professional ethical codes of conduct, societal values and respect for all
- demonstrate standards of digital literacy that would support professional needs in botanical studies
- create awareness in society about the efficient, safe and sustainable use of plants and plant parts
- create awareness about environmental and anthropological threats on plant species, especially pollution and habitat loss
- develop a lifelong respect and perfect coordination towards all other species on this planet
- nurture a temperament that would enable our students to set and work towards self-driven performance-goals, entrepreneurial ventures and overall leadership.

M.Sc. Bioscience-Plant Science
Programme Outcomes

PO1: Botanical Knowledge: Possess acquaintance and command of the core and basic knowledge associated with the botany, including systematics, morphology, anatomy, physiology, genetics, biochemistry, plant pathology, economic botany, ecology, embryology; and lower plants.

PO2: Planning ability: Demonstrate effective planning abilities, including time and resource management, delegation skills and organizational skills. Develop and execute plans and organize work to meet deadlines.

PO3: Problem analysis: Utilize the principles of scientific enquiry, thinking analytically, clearly and critically, while solving problems and making decisions during routine work. Find, analyse, appraise and apply information logically and will make justifiable decisions.

PO4: Modern tool usage: Learn, select, and apply appropriate methods and procedures, resources, and modern botanical science-related computing tools with an understanding of their limitations.

PO5: Leadership skills: Recognize and believe the as a most gifted species on earth we have to change and motivate others for the betterment of all life on this green planet. For this students will raise related issues, and appear as leaders of the team building when planning changes required for fulfilment of practice, professional and societal responsibilities.

PO6: Professional Identity: Understand, analyse and communicate the value of their professional roles in society (e.g. botanists, ecologists, researchers, educators, managers, employers, employees).

PO7: Botanical Ethics: Honour personal values and apply ethical principles in professional and social contexts. Demonstrate behaviour that recognizes cultural and personal variability in values, communication and lifestyles. Use ethical frameworks; apply ethical principles while making decisions and take responsibility for the outcomes associated with the decisions.

PO8: Communication: Communicate efficiently with the botanical community and with society at large, such as, being able to realize and write effectively, make effective presentations and documentation, and give and receive clear instructions.

PO9: The Botanist and society: Apply reasoning informed by the contextual acquaintance to assess societal, environmental, health, safety and legal issues and the consequent responsibilities relevant to the professional botanical practice.

PO10: Environment and sustainability: Understand the impact of the professional botanical solutions to societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development in eco-friendly manner.

PO11: Life- long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change. Self access and use feedback effectively from others to identify learning needs and to satisfy theses needs on an ongoing basis.

Curriculum Structure

Master of Science (Biosciences - Animal Science)

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*
BT	507	Cell and Tissue Culture Technology	4	0	0	4
ZOO	517	Biology of Non-Chordates	4	0	0	4
ZOO	518	Biosystematics, Taxonomy and Evolution	4	0	0	4
ZOO	522D	Literature Dissertation	0	0	8	4
ZOO	513L	Animal Science Lab - I	0	0	12	6
		Discipline Elective	4	0	0	4
		Semester Total:	**16**	**0**	**20**	**26**

Semester - IV

Course Code		Course Name	L	T	P	C*
ZOO	512	Animal Physiology and Endocrinology	4	0	0	4
ZOO	516	Biology of Chordates and Histology	4	0	0	4
ZOO	523	Neurobiology and Animal Behavior	4	0	0	4
ZOO	524	Reproduction and Developmental Biology	4	0	0	4
ZOO	514L	Animal Science Lab - II	0	0	12	6
		Open Elective	4	0	0	4
		Reading Elective	0	0	0	2
		Semester Total:	**20**	**0**	**12**	**28**

List of Discipline Elective

Course Code		Course Name	L	T	P	C*
ZOO	521	Insect Diversity, Morphology, Physiology and Ecology	4	0	0	4
ZOO	520	Fish Biology	4	0	0	4
BT	525	Animal Biotechnology-I	4	0	0	4
BT	526	Animal Biotechnology-II	4	0	0	4
BT	532	Immunotechnology	4	0	0	4
BT	533	Immunotechnology-I	4	0	0	4
ZOO	515	Applied Entomology and Insect Pest Management	4	0	0	4
ZOO	519	Capture Fishery	4	0	0	4
PHY	532	Biophysics-I	4	0	0	4
PHY	533	Biophysics-II	4	0	0	4
ENVS	502	Biodiversity and Conservation	4	0	0	4
ENVS	402	Ecology and Environment	4	0	0	4

List of Online Discipline Elective

Course Name	L	T	P	C*
Fundamentals of Ecology for Sustainable Ecosystem	4	0	0	4

List of Reading Elective

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

Curriculum Structure

Master of Science (Biosciences - Plant Science)

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*
BOT 519	Phycology, Mycology and Lichenology	4	0	0	4
BOT 517	Bryophyta, Pteridophyta and Gymnosperms	4	0	0	4
BT 507	Cell and Tissue Culture Technology	4	0	0	4
BOT 518D	Literature Dissertation	0	0	8	4
BOT 522L	Plant Science Lab - I	0	0	12	6
	Discipline Elective	4	0	0	4
	Semester Total:	**16**	**0**	**20**	**26**

Semester - IV

Course Code	Course Name	L	T	P	C*
BOT 512	Angiosperms	4	0	0	4
BOT 504	Cytogenetics and Plant Breeding	4	0	0	4
BOT 507	Plant Pathology	4	0	0	4
BOT 508	Plant Physiology	4	0	0	4
BOT 523L	Plant Science Lab - II	0	0	12	6
	Open Elective	4	0	0	4
	Reading Elective	0	0	0	2
	Semester Total:	**20**	**0**	**12**	**28**

Alternative Online Courses

M.Sc. Bioscience (Plant Science) Semester IV Plant Physiology			
1	Plant Physiology and Taxonomy	Core Course	https://www.acs.edu.au/courses/botany-i-plant-physiology-and-taxonomy-199.aspx

List of Discipline Elective

Course Code		Course Name	L	T	P	C*
BOT	520	Phycology-I	4	0	0	4
BOT	521	Phycology-II	4	0	0	4
BOT	515	Bryology-I	4	0	0	4
BOT	516	Bryology-II	4	0	0	4
BOT	513	Angiosperms Taxonomy and Systematics-I	4	0	0	4
BOT	514	Angiosperms Taxonomy and Systematics-II	4	0	0	4
BT	521	Plant Biotechnology	4	0	0	4
PHY	532	Biophysics-I	4	0	0	4
PHY	533	Biophysics-II	4	0	0	4
ENVS	402	Ecology and Environment	4	0	0	4
BT	524	Advanced Plant Biotechnology	4	0	0	4
ENVS	502	Biodiversity and Conservation	4	0	0	4

Online Discipline Elective

Course Name	L	T	P	C*
Fundamentals of Ecology for Sustainable Ecopystem	4	0	0	4

List of Reading Elective

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

*** 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

Fine Arts	Physical Education and Sports
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
	BVFF 213 Hockey
Social Service and Extension Activities	BVFF 214 Judo
BVFF 301 BanasthaliSewa Dal	BVFF 215 Kabaddi
BVFF 302 Extension Programs for Women Empowerment	BVFF 216 Karate – Do
BVFF 303 FM Radio	BVFF 217 Kho-Kho
BVFF 304 Informal Education	BVFF 218 Net Ball
BVFF 305 National Service Scheme	BVFF 219 Rope Mallakhamb
BVFF 306 National Cadet Corps	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

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	CG
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

Master of Science (Bioscience-Animal Science)
Master of Science (Bioscience-Plant Science)

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.
- Develop understanding of enzymes and their mechanism of action.

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* (5thed.). Belmont, USA: Wadsworth Publishing Co Inc.
- Nelson, D. L. & Cox, M.M. (2012). *Lehninger Principles of Biochemistry* (6th ed.). 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 signalling mechanisms.
- Develop comprehensive understanding of endo-membrane system.
- Understand molecular mechanisms of 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:

- Describe different methodologies for classification of microbes.
- Understand structural, functional and metabolic diversity of bacteria.
- 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 & 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 & retroviruses.
- Plant virus: structure & life cycle of geminivirus, caulimovirus & tobacco mosaic virus; virus-vector relationship.
- Virus assay: Plaque, pock, hemagglutination & transformation assays and concept of ID_{50}.
- Cultivation of viruses.

Suggested Books:

- Atlas, R.M. & Bartha, R. (1998), *Microbial Ecology: Fundamentals and Applications* (4th.). UK: Pearson Education.
- Cann, A.J. (2015). Principles of Molecular Virology (6th ed.). Massachusetts, USA: Academic Press.
- Dimmock, N.J., Easton, A.J. & Leppard, K.N. (2016). *Introduction to Modern Virology* (8th ed.). Hoboken, NJ: Wiley Blackwell.
- Kungo, R. (Ed.). (2017). Nanthnarayanand 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* (13thed.). UK: Pearson Education.
- Moat, A. G., Foster, J.W. & Spector, M.P. (2003). *Microbial Physiology* (4th ed.). US: WileyLiss 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:

- Demonstrate use of various tools and techniques for detection and quantification of biomolecules.
- Perform various biochemical assays for fats, carbohydrate, protein and enzymes.
- Demonstrate microbiological techniques.
- 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., & 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%202020 11/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.
- Identify ethics in 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 and Khanum (2012). *Fundamentals of Biostatistics.* Ukaz Publications.

- Marcello P. and 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* (10th 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* (5thed.). 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:

- Understand 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* (8^{th} 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* (11^{th}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 TH, TC, 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 and characteristics and mechanism of immunologic tolerance, factors affecting immunologic 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 immunogold labelling.

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* (12thed.). 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* (2nded.). 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:

- Demonstrate techniques used in immunology and genetic engineering.
- 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

Master of Science (Bioscience-Animal Science)

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 will be able to:

- Virtually develop an idea of cell culture laboratory.
- To learn different techniques/methods of cell culture like primary cell culture, subculturing, cryopreservation, thawing etc. along with their applications.
- Basics of animal and plant cell culture knowledge will help them to join any of the cell culture based research institution and industry of repute besides the academics employability.
- The students can establish their own cell culture laboratory as an entrepreneur.

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, 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

ZOO 517 Biology of Non-Chordates

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

Learning Outcomes:

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

- Identify and classify the major groups of organisms belonging to different non chordate phyla.
- To compare and contrast different systems evolved in non-chordates.
- Understand general organization and affinities of minor phyla.

Section A

- Protozoa: Classification and characteristic features up to order, osmoregulation, locomotory organelles, locomotion and reproduction.
- Porifera: Classification and characteristic features up to order, cell types, canal system, reproduction in sponges.
- Origin of metazoan.
- Coelenterata: Classification and characteristic features up to order, nematocysts and feeding mechanisms, locomotion, polymorphism, corals and coral reefs.
- Platyhelminthes: Classification and characteristic features up to order, general organization and larval stages of trematodes and cestodes, parasitic adaptations and economic importance.
- Aschelminthes: Classification and characteristic features up to order, general organization of nematodes, parasitic adaptations and economic importance.

Section B

- Annelida: Classification and characteristic features up to order, metamerism and coelom, adaptive radiation in polychaetes, economic importance.
- Trochophore larva: Structure and significance.

- Arthropoda: Classification and characteristic features up to order, exoskeleton, sense organs in arthropoda, crustacean larvae and their significance, general organization of tradigrada, pycogonida and trilobitomorpha.
- Mollusca: Classification and characteristic features up to order, shell diversity, filter feeding mechanism, respiration, nervous system, modifications of foot, larval forms.

Section C

- Echinodermata: Classification and characteristic features up to order, water vascular system, hemal and perihemal system, larval forms and their significance.
- General organization and affinities of minor phyla: Mesozoa, ctenophora, entoprocta, phoronida, bryozoa, barachiopoda, chaetognatha.
- General organization and affinities of hemichordata.

Suggested Books:

- Barnes, R.D. *Invertebrate Zoology* (3rd ed.). Philadelphia, USA: W.B. Saunders Co.
- Barrington, E.J.W. *Invertebrate structure and function* (2nd ed.). London, UK: Thomas Nelson and Sons Ltd.
- Hymen, L.H. (1940-1967). *The invertebrates* (all volumes). Philadelphia, USA: McGraw Hill.
- Meglitsch, P.A. & Schram, F.R. (1991). *Invertebrate Zoology*. Oxford, UK: Oxford University Press.
- Parker, T.J. & Haswell, W.A (1972). *Text book of zoology, Vol I., Invertebrates* (7th ed.). London, UK: Macmillan co.
- Ruppert, E.E., Fox, R. & Barnes R.D. (2003). *Invertebrate Zoology: A functional evolutionary approach*. (7th ed.). CA, USA: Brooks Cole.

Suggested e-Resources:

- **Porifera**

  www.ucmp.berkeley.edu/porifera/porifera.html

- **Coelenterata**

  www.ucmp.berkeley.edu/cnidaria/cnidaria.html

- **Corals and coral reef**

  www.reefbase.org/

- **Bryozoa**

  http://bryozoa.net/

- **Mollusca**

  www.ucmp.berkeley.edu/taxa/inverts/mollusca/mollusca.php

- **Echinodermata**

  www.ucmp.berkeley.edu/echinodermata/echinodermata.html

ZOO 518 Biosystematics, Taxonomy and Evolution

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

Learning Outcomes:

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

- Understand the principles, methods of taxonomy and systematics.
- Explain key concepts in evolutionary biology.
- Develop an understanding of the geological time scale and paleontology.

Section-A

- Basic concept of taxonomy.
- Definition, history, basic concepts and application of biosystematics.
- Current trends in taxonomy: Morphological, embryological, ecological, behavioural, cytological, biochemical and numerical taxonomy.
- Zoological classification: International code of zoological nomenclature, principles of nomenclature, kinds of classification, Linnaean hierarchy.

Section-B

- Theories of origin of life, concept of organic evolution during pre and post Darwin era.
- Concepts of evolution: Micro and macro evolution.
- Mechanism of evolution: Species & speciation, variation, mutation, isolation, natural selection, adaptations.
- Hardy-Weinberg law, molecular tools in phylogeny.

Section-C

- The evolutionary time scale: Eras, periods and epochs, distribution of animals in time and space.
- An introduction to the science of Paleontology, fossil record, dating and significance.
- Evolution of Horse and Man.

Suggested Books:

- Barton, N.H., Briggs, D.E.G., Eisen, J.A., Goldstein, A.E., & Patel, N.H. (2007). *Evolution*. New York, USA: Cold Spring Harbor Laboratory Press.
- Futuyma, D.J. (2013). *Evolution* (3rd ed.). Sunderland, USA: Sinauer Associates, Inc.
- Kapoor, V.C. (2017). *Theory and practice of animal taxonomy* (8th ed.). New Delhi, India: Oxford & Ibh.
- Mayr, E. (1991). *Principles of systematic* (2nd ed.). New York, USA: McGraw-Hill Inc.
- Strikberger M.W. (2005). *Evolution* (3rd ed.). Boston, London: Jones and Bartett Publishers.
- Wilson E.O. (1961). *Principal of animal taxonomy*. New Delhi, India: Oxford, IBH Publishing Company.

Suggested e-Resources:

- **Zoological Nomenclature**

  http://bio.slu.edu/mayden/systematics/bsc420520lect2.html

- **Origin of life, Theories of origin of life**

  http://www.evolution-textbook.org

- **Evolution of Man**

  https://www.britannica.com/science/human-evolution

- **Evolution of Horse**

  https://www.britannica.com/animal/horse/Evolution-of-the-horse

ZOO 522D Literature Dissertation

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**0**	**0**	**8**	**4**

Learning Outcomes:

After successful completion of course students will be able to:

- Develop the competency in identifying the scientific problem.
- Access the primary literatures, understand the scientific reports and extract the useful information from it.
- Write a scientific document highlighting introduction of the research problem, review of literature, conclusions, future prospects and literature cited.
- Communicate significant findings in the form of scientific papers, reports, poster and oral presentations.

ZOO 513L Animal Science 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 will be able to:

- Identify and classify museum specimens belonging to non-chordate phyla.
- Explain various adaptations evolved in some representative non chordate animals.
- Demonstrate practical application of tissue culture techniques.

1. Study of protista on the basis of locomotory organs.
2. Study of parazoans on the basis of skeletal, canal and reproductive systems.

3. Study of metazoans on the basis of morphology, germ layer and coelom taking the examples of each class or order as necessary.
4. Study of the salient features of non-chordate connecting links with the help of specimens or models available in the lab.
5. Study of some representative of non-chordate showing protective, feeding and parasitic adaptations.
6. Study and preparation of mouthparts of house fly/honey bee/cockroach and mosquito.
7. Study of the life cycles of honey bee, silk moth and lac insect through models.
8. Study of the evidences of evolution (analogy, homology, and embryology) through charts/ models.
9. Preparation and sterilization of complete media from powdered medium for animal cell culture.
10. Preparation and sterilization of serum from the given blood sample for animal cell culture.
11. Disaggregation and initiation of primary cell culture.
12. Cell viability count using Trypan blue stain.
13. Preparation of freezing media for preservation of the animal cells.
14. Short term culture of whole blood and preparation of metaphase chromosome.
15. Preparation of G and C banding in chromosome.

Suggested Books:

- Ghose, K., & Manna, B. (2016). *Practical Zoology* (4th ed.). Kolkata, India: New Central Book Agency.
- Lal, S.S. (2015). *Practical Zoology: Invertebrates* (11th ed.). Meerut, India: Rastogi Publication.
- Verma, P.S. (2010). *A Manual of Practical Zoology: Invertebrates* (11th ed.). New Delhi, India: S Chand Publishing.

Fourth Semester

ZOO 512 Animal Physiology and Endocrinology

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

Learning Outcomes:

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

- Understand the process of nutrition and respiration in mammals.
- Comprehend the physiology of mammalian circulatory, respiratory and excretory systems.
- Explain the role of hormones and their endocrine and neural control.

Section A

- Thermoregulation in ectotherms and endotherms.
- Nutritional pattern in animals, mechanism of digestion, absorption and assimilation of different food materials, digestive enzymes and the regulation of their secretion in mammals, physiology of defecation.
- Mechanism of respiration and its regulation in mammals, mechanism of exchange of CO_2 and O_2 at cellular level, respiratory pigments in animals, respiratory quotient, oxygen equilibrium curves, Bohr's effect, Haldane effect.

Section B

- An idea about types of circulating systems in animals, cardiac cycle, cardiac output and its nervous and hormonal regulation in mammals.
- Composition and functions of mammalian blood, blood volume, blood pressure, mechanism of blood coagulation, blood group system.
- Concept of excretion and nitrogenous wastes, functional structure of nephron, ornithine cycle, production of urine and its regulation, counter current mechanism, micturition and its control.
- Fluid, electrolytes and acid base balance, homeostasis in mammals.

- Mechanism of muscle contraction of different types of vertebrate muscles, energy supply and heat production, mechanical properties of muscles, invertebrate muscles and mechanism of their contraction.

Section C

- Introduction and scope of endocrinology, classes of hormones, biosynthesis of hormones.
- Hormonal receptors and mechanism of hormonal action.
- General survey of endocrine glands in vertebrates, structure and functions of pituitary, hypophysial- hypothalamus complex, pineal, thyroid, parathyroid, adrenal and pancreas.

Suggested Books:

- Babsky, E., Khodorov, B., Kositsky, G. & Zubkov, A. (1970). *Human physiology*, Vol. I and Vol. II. Moscow: MIR Publishers.
- Bentley, P.J. (1998). *Comparative vertebrate endocrinology* (3rd ed.). Cambridge, UK: Cambridge University Press.
- Chatterjee, C.C. (2005). *Human physiology*, Vol. I and Vol. II. New Delhi, India: CBS Publishers & Distributors.
- Guyton, A.C. (2006). *Textbook of medical physiology* (11th ed.). Philadelphia, USA: W.B. Saunders Co.
- Hadley, M.E. (2007). *Endocrinology* (6th ed.). New Delhi, India: Pearson Education.
- Mereib, E.N., & Hoehn, K. (2016). *Human anatomy & physiology* (10th ed.). London, UK: Pearson Education.
- Prosser, L.C., & Brown, F.A. (1973). *Comparative animal physiology*. Philadelphia, USA: W. B. Saunders Co.
- Roy, R.N. (2018). *Textbook of physiology: with biochemistry & biophysics* Vol-I. Kolkata: New Central Book Agency.
- Sherwood, L. (2007). *Human physiology: From cells to systems* (6th ed.). CA, USA: Thomson Brooks/Cole.
- Tortora, G.M., & Derrickson, B. (2009). *Principles of anatomy and physiology* (12th ed.). NJ, USA: John Wiley and Sons.

➢ Turner, C.D. *General Endocrinology* (6th ed.). New Delhi, India: Affiliated East-West Press Pvt. Ltd.

Suggested e-Resources:

➢ **Thermoregulation**

https://www.nature.com/scitable/knowledge/library/homeostatic-processes-for-thermoregulation-23592046

➢ **Circulatory System**

https://en.wikibooks.org/wiki/Human_Physiology/The_cardiovascular_system

➢ **Muscular System**

https://opentextbc.ca/anatomyandphysiology/chapter/10-3-muscle-fiber-contraction-and-relaxation

➢ **Urinary System**

https://www.innerbody.com/image/urinov.html

➢ **Endocrine System**

https://www.endocrineweb.com/endocrinology/about-endocrine-system

ZOO 516 Biology of Chordates and Histology

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

Learning Outcomes:

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

- Identify and classify the major groups of organisms belonging to chordate phylum.
- Compare and contrast the characteristics of fishes, amphibians, reptiles, birds, and mammals.
- Describe the histological techniques and basic structure of different tissues.

Section A

- Modern interpretation of origin of early chordates.
- Characteristic features and affinities of urochordata and cephalochordata.
- Transition from agnatha to gnathostomes.
- Fish: Origin and classification up to order, general organization and affinities of ostracoderms and placoderms, general organization of elasmobranchii, holocephali, crossopterygii, dipnoi.
- Amphibia: Origin and classification up to order, general organization of amphibia, adaptive radiation, parental care.

Section B

- Reptiles: Origin and classification up to order; general organization and affinities of chelonia, rhynococephalia, squamata, crocodalia, dinosaurs, venom in ophidians.
- Birds: Origin and classification up to order, origin of flight, flight adaptations, flightless birds.
- Mammals: Origin and classification up to order, characteristic features of prototheria and metatheria, adaptive radiation.

Section C

- Introduction to histology, methods for the study of histology and observation of living and killed tissue.
- Epithelial tissue: Classification, special structural features, and specialization of free surface epithelia.
- Connective tissue: General types and special, properties of connective tissue with special reference to cartilage and bone.
- Muscular tissue: Structure of different types of muscular tissue (Skeletal, Cardiac & Smooth muscles).

Suggested Books:

➢ Bloom, W. & Fawcett, D.W. *A Textbook of histology* (10^{th} ed.). Philadelphia, USA: W.B. Saunders Company.

- Hildebrand, (1995). *Analysis of vertebrate structure* (4th ed.). New Jersey, USA: John Wiley.
- Junqueira, L.C. & Carneiro, J. (2005). *Basic histology*: *Text and Atlas* (11th ed.). New York, USA: McGraw Hill Medical.
- Parker, T.J. & Haswell, W.A (1978). *Text book of zoology,* Vol II., *Vertebrates.* London, UK: Macmillan co.
- Pugh, F.H., Heiser, J.B., McFarland, W.N. (1979). *Vertebrate life* (4th ed.). London, UK: Macmillan Publishing.
- Rej, S.K. (2015). *General concepts of histology & endocrinology*. Kolkata, India: New Central Book Agency.
- Young, (1981). *The life of vertebrates* (3rd ed.). Oxford, UK: Oxford University Press.

Suggested e-Resources:

- **Mammals**

  https://courses.lumenlearning.com/boundless-biology/chapter/mammals/

- **Birds**

  https://courses.lumenlearning.com/boundless-biology/chapter/birds/

- **Methods for the study of histology**

  https://www.microscopemaster.com/histochemistry.html

- **Epithelial tissue and Connective tissue**

  www.academia.edu/25115428/Histology_of_animal_tissue

- **Muscular tissue**

  http://medcell.med.yale.edu/histology/muscle_lab.php

ZOO 523 Neurobiology and Animal Behavior

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

Learning Outcomes:

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

- Understand nervous system anatomy and physiology.
- Describe neural and genetic control of animal behavior.
- Explain learning, sexual, social behavior and animal communication.

Section-A

- An introduction to the field of neurobiology.
- Introduction to nervous system: Anatomy of brain, spinal cord and nerve, physiology of nerve impulse conduction, synapse and neuromuscular junction.
- Classification & anatomy of receptors, mechanism of reception: mechanoreception, equilibrium reception phonoreception, chemoreception, electroreception and photoreception.
- An idea about the physiology of sleep and pain.

Section-B

- Definition of ethology, ethological approach to the study of behaviour, a brief outline of classical and modern theories of ethology.
- Development of behaviour-Instinct, learning, imprinting and motivation.
- Neural mechanism of learning.
- Genes and behaviour.

Section-C

- Biological communication, biological clocks and rhythms, migration in birds and fishes.
- Social behaviour: The advantages of grouping, sociology, social insects, social organisation of vertebrates; primates.

Suggested Books:

- Alcock, J. (2009). *Animal Behavior: An evolutionary approach* (9th ed.). Sunderland, USA: Sinauer Associates
- Hall, J. E. (2011). *Guyton and Hall Textbook of Medical Physiology* (6th ed.). Philadelphia, USA: Saunders Elsevier.
- Mathur, R. (2014). *Animal behaviour* (5th ed.). Meerut, India: Rastogi publications
- Shukla, J. P. (2010). *Fundamentals of Animal Behaviour* (1st ed.). New Delhi, India: Atlantic Publishers & Distributors
- Tortora, G.M., & Derrickson, B. (2009). *Principles of Anatomy and Physiology* (12th ed.). New Jersey, USA: John Wiley and Sons

Suggested e-Resources:

- **Anatomy of Brain and Spinal cord**

  https://www.seattlecca.org/diseases/brain-spinal-cord-cancers/brain-spinal-cord-cancers-facts/anatomy-brain-and-spinal-cord

- **Neuroglia and Blood brain barrier**

  https://www.wikilectures.eu/w/Glial_cells,_brain_barrier_systems

- **Physiology of sleep and pain**

  https://www.myvmc.com/anatomy/sleep-physiology/

- **Neural mechanism of learning**

  https://kundoc.com/pdf-neural-mechanisms-of-learning-and-memory-.html

- **Biological clock**

  http://www.exactlywhatistime.com/psychology-of-time/biological-clock/

ZOO 524 Reproduction and Developmental 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 will be able to:

- Understand events that lead up to the process of fertilization, differentiation and organogenesis in animals.
- Describe reproductive organs and their functions.
- Develop an understanding of methods for assisted reproductive technologies.

Section-A

- History and scope of reproduction and developmental biology.
- General concept of potency, commitment, specification, induction, competence and determination.
- Gametogenesis: Spermatogenesis, oogenesis, hormonal regulation of gametogenesis.
- Fertilization: Hormonal control of gamete interaction, recognition of gametes and acrosomal reaction, prevention of polyspermy and gamete fusion, activation of egg metabolism.
- Cleavage patterns and formation of blastula in amphibians and birds.
- Gastrulation: fate maps, cell movement and formation of germ layers in amphibians and birds.

Section B

- Differentiation and Pattern formation: Stalk and fruiting body formation in *Dictyostellium*, origin of anterior-posterior and dorsal-ventral polarity in drosophila (role of maternal, segmentation and homeotic genes).
- Axis formation in amphibians (Nieuwkoop centre and primary organizer), axis formation in birds and mammals: role of pattern forming genes.

- Neurogenesis and neural tube in vertebrates, development of limb in vertebrates: role of HOX and other pattern forming genes.

Section C

- Ovary: Anatomy, histological structure, female accessory sex organs in mammals (oviduct, uterus, vagina, mammary gland).
- Testes: Anatomy, histological structure, structural organization and endocrine regulation of prostate, functions of male accessory sex glands in mammals.
- Regulation of reproduction processes: breeding seasons, menstrual cycle/estrous cycle, endocrine control of implantation, gestation, lactation and parturition in mammals.
- Assisted reproductive techniques: principles, methods and types of ART, cryopreservation of gametes, modern contraceptive technologies.

Suggested Books:

- Carlson, B.M. (1999). *Patten's foundations in embryology*. (6th ed.). New York, USA: McGraw Hill.
- Chattopadhyay, S. (2017). *An introduction to developmental Biology*. Kolkata, India: Books and Allied
- Findlay, J.K. (Ed.). (1994). *Molecular biology of the female reproductive system*. London, UK: Academic Press.
- Gillbert, S.F. (2006). *Developmental biology* (8th ed.). Sunderland, USA: Sinauer Associates.
- Kalthoff, K. (2001). *Analysis of biological development* (2nd ed.). New York, USA: McGraw Hill.
- Lamming**,** G.E. (1992). *Marshall's physiology of reproduction.* Volume 2: *Reproduction in the male* (4th ed.). London, Churchill Livingstone
- Plant, T.M., & Zeleznik, A.J. (2014). *Knobil and Neill's Physiology of reproduction Vol. I & II* (4th ed.). London, UK: Academic Press
- Wolpert, L., & Tickle, C. (2007). *Principles of development* (3rd ed.). Oxford, London: Oxford University Press.

Suggested e-Resources:

- **Origin of anterior-posterior and dorsal-ventral polarity in *Drosophila***

  https://people.ucalgary.ca/~browder/D_m_segment_I.html

- **Nieuwkoop centre**

  http://life.bio.sunysb.edu/biochem/holdener/ho16_s99.html

- **Ovary**

  https://courses.lumenlearning.com/boundless-ap/chapter/the-female-reproductive-system/

- **Testes**

  https://courses.lumenlearning.com/boundless-ap/chapter/the-male-reproductive-system/

- **Assisted reproductive techniques**

  https://www.varta.org.au/information-support/assisted-reproductive-treatment

ZOO 514L Animal Science 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 will be able to:

- Identify and classify museum specimens belonging chordate class.
- Observe and describe ecological adaptations in chordates.
- Perform clinical procedures for blood and urine analysis.
- Develop skill in tissue preservation, microtomy and preparation of permanent microscopic slides.

1. Evolution of chordates on the basis of skeletal and integumentary systems.

2. Study of connecting links of chordates with the help of specimens or models available in the lab.
3. Study of types of scales in fish
4. Study of some representatives of chordates showing following adaptations
   (i) Aquatic
   (ii) Desert
   (iii) Fossorial and curssorial
   (iv) Aerial and arboreal
5. Haematological determinations:
   (i) Estimation of blood sugar
   (ii) Estimation of serum total proteins
   (iii) Estimation of serum cholesterol
   (iv) Estimation of blood calcium
   (v) SGPT and SGOT
   (vi) Estimation of haemoglobin by light absorbance method
   (vii) Complete Blood Count (CBC) using hematoanalyzer
   (viii) TLC (WBC count), DLC
   (ix) ESR
6. Examination of abnormal or pathological constituents of urine
   (i) Reducing sugars
   (ii) Proteins
   (iii) Blood
   (iv) Bile pigment and salts
7. Experiments based on reproduction biology
   (i) Study of vaginal smear of rat or mice to detect various stages of estrous cycle.
   (ii) Pregnancy test.

8. Microscopic study of different developmental stages of blastula and gastrula.
9. Identification of stages of oogenesis and spermatogenesis.
10. Microscopic study of endocrine glands: pituitary, parathyroid adrenal, thymus, hypothalamus.
11. Preparation of histological slides of different tissues.
12. Study of permanent histological slides of skin, stomach, intestine, pancreas, liver, kidney, lungs, ear, testes, and ovary.
13. Preparation of report on local/wild fauna.

Suggested Books:

- Ghose, K., & Manna, B. (2016). *Practical Zoology* (4th ed.). Kolkata, India: New Central Book Agency.
- Lal, S.S. (2015). *Practical Zoology: Vertebrates* (11th ed.). Meerut, India: Rastogi Publication.
- Verma, P.S. (2010). *A Manual of Practical Zoology: Chordates* (11th ed.). New Delhi, India: S Chand Publishing.

Discipline Elective

ZOO 521 Insect Diversity, Morphology, Physiology and Ecology

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

Learning Outcomes:

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

- Identify, classify and describe insect morphology and physiology.
- Understand insect life cycle and development.
- Describe incest social behavior and effect of various biotic and abiotic factors on insect population.

Section-A

- Insect diversity-Origin and evolution of insects; historical aspects of entomology in India, classification of phylum arthropoda; classification of insects up to orders.
- Characteristic features of economically important families of insect orders (orthoptera, hemiptera isoptera; diptera; coleoptera; lepidoptera; hymenoptera); collection and preservation of insects.
- Insect morphology: Segmentation and tagmosis; integument; head; thorax; abdomen; appendages; mouth parts; antennae; types of wings; wing coupling apparatus.

Section-B

- Insect anatomy-Structure and functions of insect cuticle and molting.
- Circulatory system; respiratory system; digestive system; excretory system and waste disposal; reproductive system; nervous system and co-ordination; endocrine system and function of hormones; sensory systems-mechanical stimuli.
- Thermoregulation; chemical stimuli; insect vision; sound and light producing organs.

Section-C

- Insect development and life history- Types of larvae and pupae; types of reproduction; metamorphosis and diapause in insects; polymorphism and polyphenism.
- Social life of insects: Termite and honey bee.
- Insect ecology: Effect of abiotic factors (temperature, moisture, humidity, rainfall, light, atmospheric pressure and air currents) and biotic factors (food competition, natural and environmental resistance).

Suggested Books:

- Blum, M.S. (1985). *Fundamentals of insect physiology*. New York, USA: John Willey & Sons.
- Chapman, R.F. (2013). *The insects structure and function* (5th ed.). Cambridge, UK: Cambridge Univ. Press.
- Imms, A.D. (1992). *A general text book of entomology*. Vol. I and II. London, UK: Chapman & Hall.
- Klowden, M. (2007). *Physiological systems in insects* (2nd ed.). London, UK: Academic Press.
- Singh, R. (2018). *Elements of entomology* (2nd ed.). Meerut, India: Rastogi publication.
- Snodgrass, R.E. (1935). *Principles of insect morphology*. New York, USA: Mc Graw Hill.
- Wigglesworth, V.B. (1982). *Principles of insect physiology* (7th ed.). Netherland: Springer, ELBS edition.

Suggested e- Resources:

- **Origin and Evolution of Insects**

  https://www.sciencedirect.com/science/article/pii/S0960982215009276

- **General Characters of Insect Orders**

  https://texasinsects.tamu.edu/insect-orders

- **Identification of Insects**

  https://www.insectidentification.org/orders_insect.asp

- **Insect Anatomy and Physiology**

  http://krishikosh.egranth.ac.in/handle/1/2049010?mode=full

ZOO 520 Fish 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 will be able to:

- Understand aquatic adaptations in fish.
- Describe general organization, diversity and different systems of fish.
- Develop an understanding of fish endocrinology and behavior.

Section A

- Skin: Structure, pigmentation and barbels, scales and tails, fins and locomotion, gills, air breathing organs, swim bladder, weberian ossicles, sound producing organs, electric and luminescence organs.

Section B

- Digestive system, blood vascular system, respiration: aquatic respiration, gills and mechanisms of respiration, excretion and osmoregulation: glomerular and aglomerular kidneys, excretion of nitrogenous wastes, water and ion balance and urea cycle.
- Nervous system: brain and cranial nerves, sense organs: eye: structure and function; acoustico-lateralis system: labyrinth, lateral line organs, chemoreceptors: gustatory and olfactory and electroreceptors.

Section C

- Function of pituitary, thyroid, ultimobranchials, pancreas, adrenal, corpuscles of stannius, urophysis, pineal.
- Reproduction and development, sex dimorphism, courtship, mating and parental care and migration.

Suggested Books:

- Khanna, S.S., & Singh, H.R. (2014). *A text book of fish biology and fisheries*. New Delhi, India: Narendra Publishing House
- Pandey, K. C. (2012). *Concepts of indian fisheries*. New Delhi, India: Shree Publishers & Distributors

- Khanna, S.S. (2019). *An introduction to fishes*. New Delhi, India: Surjeet Publications.
- Gupta S.K., & Gupta P.C. (2006). *General & applied ichthyology*. New Delhi, India: S chand
- Krishnaveni, G., Rao, V. N., & Veeranjaneyulu, K. (2016). *Recent technologies in fish and fisheries*. Punjab, India: Rigi Publications
- Brown, M.E. (1957). *Physiology of fishes*, Vols. I and II. London, UK: Academic press.

Suggested e-Resources:

- **Electric and Luminescence organs**

  http://www.yourarticlelibrary.com/fish/anatomy-and-physiology/luminous-organs-or-photophore-of-the-fishes-with-diagram/88411

- **Alimentary canal**

  http://www.yourarticlelibrary.com/fish/anatomy-and-physiology/digestive-system-in-fishes-with-diagram/88195

- **Respiratory system**

  https://www.britannica.com/animal/fish/The-respiratory-system

- **Excretory system**

  https://www2.estrellamountain.edu/faculty/farabee/biobk/BioBookEXCRET.html

- **Nervous system, Sensory organs**

  http://www.yourarticlelibrary.com/fish/anatomy-and-physiology/sensory-organs-of-fishes-with-diagram/88385

BT 525 Animal Biotechnology-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 will be able to:

- Comprehend 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.
- Demonstrate 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://bit.ly/2GX5SXW

- **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/

BT 526 Animal Biotechnology-II

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

Learning Outcomes:

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

- Explain the basic concepts and methods of animal breeding.
- Understand importance of new generation vaccines in animal biotechnology.
- Pursue research using animal models for human and animal diseases.

Section-A

- Sex determination; principles of animal breeding; structure of the livestock breeding industry: dairy cattle, sheep and poultry.
- Selection for qualitatively inherited characters-gene frequency and selecting against recessive genes; detecting heterozygotes for recessives.
- Parental determination and verification; the use of markers and/or molecular probes, selection criteria: multiple records, pedigree selection, family selection.

Section-B

- Principles and methods of hybridoma technology, production and characterization of monoclonal antibodies and their application in animal health and production.
- Biotechnological approaches to vaccine production: Development of animal vaccines for rabbies and anthrax. subunit-vaccines; peptide vaccines; DNA vaccines; recombinant vaccines; edible vaccines; fusion protein vaccines; synthetic peptide vaccines; anti-ideotype antibody vaccines.

Section-C

- Animal right activities; Blue cross in India: Society for prevention of cruelty against animals.
- Cloning of domestic animals (Dolly, Molly and Polly); Somatic Cell Nuclear Transfer (Conventional & HMC); ICSI and preservation of endangered species. Transgenic animal as models for human diseases and genetic disorders.

- In utero testing of foetus for genetic defects, anti-fertility animal vaccines.

Suggested Books:

- Babink, L.A., & Phillips, J.P. (Ed.). (1989). *Animal biotechnology*: *Comprehensive biotechnology first supplement*. Oxford, UK: Pregamon press.
- Gordon, I. (2005). *Reproductive techniques in farm animals*. Oxford, UK: Oxford University Press.
- Levine, M.M., Kaper, J.B., Rappuoli, R., Liu, M.A., & Good, M.F. (2004). *New generation vaccines* (3rd ed.). London, UK: Informa Healthcare.
- Sasidhara, R. (2006). *Animal biotechnology*. Tamil Nadu, India: MJP publishers
- Sateesh, M.K. (2010). *Biotechnology: V: (Including Animal Cell Biotechnology, Immunology and Plant Biotechnology)* (2nd ed.). New Delhi, India: New Age International Pvt. Ltd. Publishers.
- Singh, B., Gautam, S.K., & Chauhan, M.S. (2015). *Textbook of animal biotechnology*. New Delhi, India: Teri Publication.

Suggested e- Resources:

- **Principles of animal breeding; structure of the livestock breeding, Selection for qualitatively inherited characters**

  https://www.britannica.com/science/animal-breeding

- **Animal vaccines**

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

- **Blue cross in India**

  bluecrossofindia.org

- **Cloning of domestic animals**

  https://www.msdvetmanual.com/management-and-nutrition/cloning-of-domestic-animals

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:

- Describe various theories describing 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 533 Immunotechnology-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 will be able to:

- Perform various experiment using different techniques covered in the course.
- Understand how clinical immunology is performed.
- Compare and describe various diagnostic techniques.

Section A

- Cytokines: Introduction, general properties & structure, classification of cytokines, cytokines receptors and cytokines antagonists, therapeutic uses of cytokines.
- Chemokines: General structure, classification, function, chemokine receptor, chemokine- chemokine receptor interaction, diseases associated with receptor expression.
- Interferons: Introduction, types, effect of interferons on immune system and therapeutic uses.

Section B

- Autoimmunity: introduction, autoimmune diseases (hashinoto diseases, SLE, autoimmune hemolytic anemia, multiple sclerosis, rheumatoid arthritis, psoriasis, insulin dependent diabetes mellitus, myasthenia gravis).
- Tumor immunology: Introduction, types, origin, stages of tumor formation, metastasis, oncogenes, tumor ags, effector mechanism, tumor immunity, escape of tumor cells from immune surveillance & immunotherapy in cancer.
- Transplantation: immunologic basis of graft rejection, clinical manifestation, tissue typing, general immunosuppressive therapy, Mab therapy.

Section C

- Antigen antibody reaction, cross reactivity, immunoprecipitation, Western Blot (Immunoplot), FACS, cytotoxicity, immunodiffusion, immunoelectrophoresis, rocket immunoelectrophoresis, counter immunoelectropheresis.
- Agglutination: Direct & indirect; Widal test; VDRL test; Radioimmunoassay; ELISA- principle, methodology & applications.
- Immunoflorescence- Direct, indirect & sandwich; ELISPOT.

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:

➢ **Laboratory techniques**

https://nptel.ac.in/courses/102103038/39

➢ **Cellular and molecular immunotechnology**

https://nptel.ac.in/courses/102103038/40

➢ **Transplantation immunology**

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

ZOO 515 Applied Entomology and Insect Pest Management

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

Learning Outcomes:

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

- Comprehend role of insects in agriculture.
- Describe types of insecticides and evaluate their toxicity.
- Develop skill in insect pest management.

Section-A

- Distribution, habitat, appearance, life history, importance and control measures of house hold insects- Cockroaches and house fly. Polyphagous insects (locust; termites; white grub and red hairy caterpillar).
- Characteristic features, life cycle, nature of damage and control measures of- important insect pests of cotton; sugarcane; paddy; wheat; cereals & pulses; maize; vegetables; oil seeds; fruit trees; store grains pest and their management.

Section-B

- Classification of insecticides; Structure and mode of action of various chemical insecticides-Organochlorides; organophosphates; carbamates; pyrethroides; neonicotinoids. Insect growth regulators; Concepts of I, II and III generation of insecticides.
- Evaluation of toxicity of insecticides; toxicity parameters- LD_{50}, LC_{50}, LT_{50}, KD_{50}, ED_{50}/EC_{50}, formulation of insecticides; insect resistance, insecticidal act-1968. Insecticide poisoning- symptoms first aid and antidotes.

Section-C

- Methods of Insect Pest Management (IPM): Concepts, scope and limitations of IPM, different IPM strategies (physical; mechanical; cultural; genetic; botanical; legal/regulatory control and chemical control).
- Methods of biological control- Parasitoids; parasitic nematodes; microbial agents- baculoviruses; bacteria; fungi and protozoans. insect attractants, repellents and antifeedants.
- Industrial entomology- Apiculture, sericulture, lac culture.

Suggested Books:

- Atwal, A.S. (1986). *Agricultural Pests of INDIA and South East ASIA* (2nd ed.). New Delhi, India: Kalyani Publishers.
- Awasthi, V.B. (2009). *Introduction to General and Applied Entomology* (3rd ed.). New Delhi, India: Scientific Publishers.
- Eldridge, B. (2004) *Medical Entomology* (2nd ed.). Netherland: Springer.
- Fenemore, P.G., & Prakash, A. (2009). *Applied Entomology* (2nd ed.). New Delhi, India: New Age Publishers.
- Pedigo, L.P. (2004). *Entomology and pest management* (6th ed.). New Jersey, US: Prentice Hall Inc.
- Singh, R. (2018). *Elements of Entomology* (2nd d.). Meerut, India: Rastogi publication.
- Srivastava, K.P., & Dhaliwal, G.S. (2010). *A Text Book of Applied Entomology* Vol I & II. New Delhi, India: Kalyani Publishers.

Suggested e-Resources:

- **Insect Ecology and Integrated Pest Management**

  http://www.agrimoon.com/insect-ecology-integrated-pest-management-pdf-book/

- **Applied Entomology**

  https://www.researchgate.net/publication/327282644_A_Text-book_of_Economic_Entomology_M_Dayib

- **Chemical Insecticides**

  https://www.britannica.com/technology/insecticide

  http://npic.orst.edu/ingred/ptype/index.html

ZOO 519 Capture Fishery

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

Learning Outcomes:

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

- Identify highly diverse capture fisheries resources.
- Understand sustainable harvesting and responsible aquaculture practices.
- Pursue a career in fisheries research, resource management, instruction, extension and production.

Section A

- Fishes of deep sea: characteristics of deep sea, adaptations, bioluminescence, inland fisheries, hill streams fishes: characteristics, adaptations, exotic and transplanted fishes, marine, coastal and estuarine.

Section B

- Fishing techniques: technologies for localizing catches- remote sensing, sonar and radar; crafts and gears, construction and maintenance of fish farm, polyculture, monoculture and integrated fish farming, fish culture:

fresh water, paddy fields and manmade lakes, plankton and its role in fisheries.

- Common diseases of fishes (Red pest, mouth fungus, tail rot/fin rot, ictthyosporidium, ergasilus, lymphocystis and tumor/cancer) and economic value of fishes.

Section C

- Post harvest technology: Fish spoilage, rigor mortis, rancidity, enzymatic spoilage and microbial spoilage.
- Fish preservation and processing: Handling of fish at harvest/on board, principles of fish preservations, methods of preservation, problems associated with fish preservations, quality control and fishery by-products.

Suggested Books:

- Brown, M.E. (1957). *Physiology of fishes*, Vols. I and II. London, UK: Academic press.
- Gupta S.K., & Gupta P.C. (2006). *General & Applied Ichthyology*. New Delhi, India: S Chand
- Khanna, S.S. (2019). *An Introduction to Fishes*. New Delhi, India: Surjeet Publications.
- Khanna, S.S., & Singh, H.R. (2014). *A Text Book of Fish Biology and fisheries*. New Delhi, India: Narendra Publishing House
- Krishnaveni, G., Rao,V. N. & Veeranjaneyulu, K. (2016). *Recent Technologies in Fish and Fisheries*. Punjab, India: Rigi Publications
- Pandey, K. C. (2012). *Concepts of Indian fisheries*. New Delhi, India: Shree Publishers & Distributors

Suggested e-Resources:

- **Fishes of deep sea**

  https://news.nationalgeographic.com/2018/04/fish-black-oceans-deep-sea-animals/

- **Hill streams fishes**

  http://www.fishfarmingtechniques.com/fish-types/hill-stream-fishes

- **Fishing techniques**

  http://www.historyoffishing.com/fishing-facts/types-of-fishing-techniques/

- **Fish Culture**

  https://krishijagran.com/featured/all-about-fish-farming-in-india/

- **Economic value of fishes**

  http://www.notesonzoology.com/phylum-chordata/fishes/economic-importance-of-fish-vertebrates-chordata-zoology/8038

PHY 532 Biophysics-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 will be able to:

- Understand the concepts of physical principles in the biomolecular systems.
- Know properties and conformations of biomolecules.
- Understand 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 transportchain, 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 hydrophobicinteraction 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 supersecondary 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 energysurface, 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

PHY 533 Biophysics-II

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

Note: The paper is divided into three sections. Students are required to attempt five questions in all, selecting not more than two questions from each section.

Learning Outcomes:

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

- Understand the concepts of physical principles in the biomolecular systems.
- Know Properties and conformations of biomolecules.
- Understand the interaction between physics and biology.

Section A

- Physics of macromolecules: Biological polymers, modeling polymers as elasticity models, Random walk model, radius of gyration, freely jointed chain, calculation of the distribution of end-to-end distances, statistical segment, persistence length, relation to characteristic ratio, worm like chain, behavior of chain dimension, DNA Elasticity, Application of Porod-Kraty model to DNA.
- Protein folding: Anfinsen's thermodynamic hypothesis, Case study: Ribonuclease A, renaturation and denaturation, mechanism of disulphide exchange, determinants of protein folding, Levinthal's paradox, classical view of protein folding, the hydrophobic collapse, Energy landscape theory, Protein Folding problem as a NP-hard problem.

Section B

- Self assembly and membrane equilibria: Self assembly in miscelles as monolayers and bilayers, Thermodynamics of miscelle formation, co-operativity, packing parameter,Tanford's free energy model, Packing model, influence of tail packing, Fluid mosaic model, Langmuir adsorption model.

- Electrical conduction in the nervous system: Structure of the neuron, Hodgkin-Huxley model and generation of action potential, Nernst relation in membrane potentials, Donnan equilibrium, ion pumping, voltage gating. Transport in cells: Diffusion, Fick's law, cells with sources, low Reynolds-number, friction in fluids, Transport across cells - osmosis.

Section C

- Blood flow: Blood as non-Newtonian fluid, Blood flow models, Navier Stokes equation, Dissipative particle dynamics, Erythrocyte model, elastic model.
- Energy in muscle: Cytoskeleton, Muscle Contraction, biopolymers of the cytoskeleton, Tubulin, microtubules, associated protein, micro filaments, actin and Myosin. Molecular motors, Kinesin and Dyenin. Sliding filament model of contraction, ATP and muscle contraction, stochastic model of contraction.
- Radiation Physics: Dosimetery, Photon interaction coefficients, Relations between exposure, Kerma and absorbed dose, Measurement of exposure, Bragg-Gray Cavity theory, determination of absorbed dose in a medium, radiotherapy, geometrical factors, specification of dose ratios, nuclear medicine.

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.
- Smith, F. A. (2000). *A primer in applied radiation physics*. World Scientific Publishing Company.
- Tuszynski, J. A., & Kurzynski, M. (2003). *Introduction to molecular biophysics*. CRC press.

- Van Holde, K. E., Johnson, W. C., & Ho, P. S. (2006). Principles of physical biochemistry.
- 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:

https://www.coursera.org/learn/dynamicalmodeling?specialization=systems-biology

ENVS 502 Biodiversity and Conservation

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

Learning Outcomes:

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

- Explain importance of biological diversity.
- Describe major threats to biodiversity.
- Recognize and implement the various methods of biodiversity conservation with co-existence of various environmental pressures.
- Identify different geographical biodiversity hotspots and mega-diversity centers.

Section A

- Introduction to biodiversity concepts, significance, magnitude and distribution.
- Biodiversity trends, diversity gradients and related hypotheses methods for monitoring biodiversity trends.
- Threats to biodiversity, major causes, extinction's, vulnerability of species to extinction, IUCN threat categories, Red data book.

Section B

- Principles of biodiversity conservation Ex situ and In situ methods of conservation, Genetical and evolutionary principles in conservation.

Conservation of biological diversity and its significance- source of food, medicine, raw material, aesthetic, cultural and ecosystem services.

- Concepts, distribution and importance of Hot spots.
- Strategies for sustainable exploitation of biodiversity.

Section C

- Conservation – efforts in India, Endangered flora & fauna of India.
- Ethno botany in India & selected medicinal plants.
- Wildlife conservation in India- Project Tiger, Project crocodile, silent valley controversy.
- Conservation of Himalayan, Gangetic ecosystems.

Suggested Books:

- Kumar, U. &Asija, M.J. (2007). *Biodiversity – Principles and Conservation* (2nd ed.). Jodhpur, India: Agrobios.
- Mishra, R. (1968). *Ecology Workbook* (2nd ed.). Calcutta, India: Oxford and IBH.
- Odum, E.P. (1983). *Basic Ecology* (2nd ed.). Philadelphia,PA: Holt-Saunders International.
- Odum, E.P. (2004). *Fundamentals of Ecology*. Dehradun, India: Natraj.
- Singh, M.P., Singh, J.K., Mohanka, R., &Sah, R.B. (2007). *Forest Environment and Biodiversity (*2nded.*)*. New Delhi, India: Daya.
- Sinha, B.N. (1990). *Ecosystem Degradation in India*. New Delhi, India: Ashish.
- Tewari, D.N. (1994) *Biodiversity and Forest Genetic Resources*. Dehradun, India: International Book.

Suggested e-resources:

- **Aquatic Biodiversity and Environmental Pollution, IISc, Bangalore**

  https://nptel.ac.in/courses/120108002/16
- **Wildlife Conservation, Indira Gandhi National Forest Academy, Dehradun**

  https://nptel.ac.in/noc/individual_course.php?id=noc18-bt26

ENVS 402 Ecology and Environment

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

Note: The paper is divided into three sections. Students are required to attempt five questions in all, selecting not more than two questions from each section.

Learning Outcomes:

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

- Describe the interaction of organisms with their environment.
- Identify the various threats to biodiversity.
- Explain the concept of biomes.
- Describe the various biogeochemical cycles.

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

Online Discipline Electives

Sr. No.	Name of Course	URL
1	Fundamentals of Ecology for Sustainable Ecosystem	https://www.extension.harvard.edu/academics/courses/fundamentals-ecology/12779

Reading Elective

BT 529R Drug Discovery

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

Learning Outcomes:

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

- Understand basics of R&D in drug discovery and should be able to apply knowledge gained in respective fields of pharmaceutical industry.
- Understand the role of synthetic chemistry in the development of pharmaceutical agents; and the modification of chemical structures to develop new drug molecules.
- Have an advanced understanding of the chemical structure of a pharmaceutical agent and determine the chemical group/s responsible for a given biological effect.
- Demonstrate a basic understanding of pharmacogenomics and bioinformatics as it relates to drug design and discovery.
- Develop an understanding of drug targets as a recognition site for pharmaceutical agents; how the chemical structure of a substance influences interaction with a drug target; and the identification of new drug targets for future drug 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**	**0**	**2**

Learning Outcomes:

After successful completion of the course, students will 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. Fitzgerald. (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 and Thompson. (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**	**0**	**2**

Learning Outcomes:

After successful completion of the course, students will 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.

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**	**0**	**2**

Learning Outcomes:

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

- Identify various bacterial, fungal, viral and protozoan diseases and their epidemiology.
- Understand the relevance of emerging and reemerging diseases.

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 (26thed.). US: Lange Medical Books, McGraw-Hill.
- Madigan, M., Martinko, J., Stahl, D. & Clark, D. (2010). *Brock Biology of Microorganisms* (13thed.). 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://bit.ly/2SUmzum

- **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**	**0**	**2**

Learning Outcomes:

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

- Understand strategies and applications of plant breeding technologies.
- Comprehend the knowledge of different plat molecular markers.
- 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* (3rded). Cambridge: Cambridge University Press.
- Primrose, S.B., Twyman R.H. & Old R.W. (2001). *Principles of Gene Manipulation* (6thed.). 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**	**0**	**2**

Learning Outcomes:

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

- Analyse structure and construction of proteins by computer-based methods.
- Describe structure and classification of proteins.
- Analyse and compare the amino acid sequence and structure of proteins, and relate this information to the function of proteins.
- Explain how proteins can be used for different industrial and academic purposes such as structure determination, organic synthesis and drug design.
- Plan and carry out 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

Online Reading Electives

Sr. No.	Name of Course	URL
1	Bio-organic Chemistry	http://nptel.ac.in/courses/104103018/#
2	Enzyme Science and Engineering	http://freevideolectures.com/Course/85/Enzyme-Science-and-Engineering/1
3	Biocatalysis in organic synthesis	http://nptel.ac.in/courses/104105032/
4	Comprehensive Disaster Risk Management Framework	http://www.nidm.gov.in/online.asp
5	General Course on Intellectual Property	https://welc.wipo.int/acc/index.jsf?page=courseCatalog.xhtml
6	Environmental Management-An Introduction	http://www.algonquincollege.com/ccol/courses/environmental-management-an-i

Third Semester

Master of Science (Bioscience - Plant Science)

BOT 519 Phycology, Mycology and Lichenology

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

Learning Outcomes:

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

- Acquire the knowledge related to various life forms, ecological and economical importance of these plant groups.
- After completion of this course student will be able to identify these intrusting forms in their surroundings and will convey the importance to the community which will help in the conservation of these forms to get better ecosystem.

Section-A

- Introduction, scope and general principles of classification of fungi.
- Myxomycotina: Plasmodiophorales.
- Mastigomycotina: Chytridiales, Blastocladiales, Saprolegniales and Peronosporales.
- Zygomycotina: Mucorales and Entomophthorales.
- Ascomycotina: Endomycetales, Protomycetales, Taphrinales, Erysiphales, Eurotiales, Sphaeriales, Helotiales, Phacidiales and Pezizales.
- Basidiomycotina: Uredinales, Ustilaginales, Lycoperdales, Nidulariales, Sclerodermatales, Phallales,
- Agaricales, Aphyllophorales, Tremellales and Auriculariales.
- Deuteromycotina: Sphaeropsidales, Melanconiales, Moniliales and Mycelia sterilia.

Section B

- Algae-general characters, definitions and scope. Comparative survey of important systems of classification of algae, criteria for algal classification and modern trends. Diagnostic features of algal phyla: range of thallus and reproductive diversity. Life history patterns: parallelism in evolution.
- Comparative account of algal pigments; light microscopic structure, ultra structure, function and importance of cell wall, flagella chloroplasts pyrenoids eyespots, nucleus, contractile vacuole and their importance in taxonomy.
- Study of Cyanophyta (*Microcystis*, *Stigonema*), Prochlorophyta (*Prochloron*), Chlorophyta (*Chlorella Hydrodictyon*, *Nitella*) Xanthophyta (*Botrydium*), Bacillariophyta (*Navicula*), Phaeophyta (*Dictyota*)
- Algae in biotechnology.
- Economic importance of algae.

Section C

- A general account of Lichens and its symbionts, thallus structure, reproduction, physiology, classification and distribution, Chemistry of Lichens, Isolation of symbionts and synthesis of thallus, Economic importance.
- Study types: *Dermatocarpon*, *Parmelia*, *Heterodermia*.

Suggested Books:

- Alexopoulus, C.J., Mims. C.W. & Blackwel, M. (1996). *Introductory Mycology*. John Wiley & Sons Ind.
- Kumar, H.D. & Singh, H.N. (1979). *A Textbook On Algae*. Macmillan Publishers Limited.
- Mehrotra, R.S. & Aneja, R.S. (1998). *An Introduction to Mycology*.New Age Intermediate Press.
- Morris, I.(1986). *An Introduction to the Algae*. Cambridge University Press, U.K.
- Nash, T.H. 2011. *Lichen Biology*. Cambridge University Press.
- Round, F.E. (1986). *The Biology of Algae*. Cambridge University Press, Cambridge.

Suggested e-Resources:

- **Lichen: General account**

  https://www.anbg.gov.au/lichen/what-is-lichen.html

- **Introduction to Lichen**

  https://www.nybg.org/bsci/lichens/

- **Algae: General account**

  https://www.livescience.com/54979-what-are-algae.html

- **Classification, Economic Uses of Algae**

  https://naturalhistory.si.edu/research/botany

- **Fungi: General account**

  https://microbiologyonline.org/about-microbiology/introducing-microbes/fungi

- **Fungal Biology**

  https://www.highveld.com/microbiology/what-are-fungi.html

BOT 517 Bryophyta, Pteridophyta and Gymnosperms

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

Learning Outcomes:

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

- Acquire the knowledge related to various cryptogamic and gymnospermic life forms, ecological and economical importance of these groups.
- After completion of this course student will be able to identify these forms in their surroundings and will attract towards these branches of classical botany.
- Students will be able to understand the morphological diversity of Bryophytes and Pteridophytes, and evolutionary connections between gymnosperms and angiosperms.

- They will know why these plants have to conserve for the sustainable ecosystem.
- After passing this course they will be placed as researchers in research institutes and universities as these branches of botany eagerly searching for passionate young researchers.

Section A

- General characteristics of bryophytes, alternation of generation and classification. Life-cycle of bryophytes, asexual and sexual reproduction in various groups. Ecology - habitat diversity, growth forms, growth factors.
- Role of bryophytes in pollution monitoring, geobotanical prospecting, horticultural uses, economic importance.
- Moss protonema, protonemal differentiation and bud induction.
- Comparative morphological and anatomical studies of gametophytes and sporophytes in various orders of:
- Bryopsida: Sphagnales (*Sphagnum*), Andreaeales (*Andreaea*), Takakiales (*Takakia*), Buxbaumiales (*Buxbaumia*), Bryales (*Physcomitrium*), Polytrichales (*Polytrichum*).
- Hepaticcopsida: Calobryales (*Calobryum*), Metzgeriales (*Metzgeria*), Jungermanniales (*Jungermannia*), Sphaerocarpales (*Sphaerocarpous*), Monocleales (*Monoclea*), Marchantiales (*Plagiochasma*, *Lunularia*, *Dumortiera*, *Cyathodium*).
- Anthocerotopsida: Anthocerotaceae (*Anthoceros*, *Folioceros*), Notothyladaceae (*Notothylas*), Dendrocerotaceae (*Dendroceros*).

Section B

- General characteristics features and classification (Smith, 1955 and Bierhorst, 1971) of Pteridophytes. Morphology, anatomy and reproduction of Psilophyta (*Psilotum*), Lycophyta (*Lycopodium*, *Selaginella*), Sphenophyta (*Equisetum*), Pteropsida (*Marsilea*).
- Telome theory, Classification and evolution of steles. Heterospory and origin of seed habit. Apogamy, Apospory and Alternation of generations.

- General account of fossil vascular cryptogams: *Rhynia*, *Horneophyton*, *Asteroxylon*, *Calamites* and *Lepidodendron*. Origin of cryptogams. Evolution of sorus in ferns. Economic importance of Pteridophytes.

Section C

- General diagnostic features of gymnosperms with special reference to drop mechanism, vessel less and fruitless seed plants. General account of anatomical variations in gymnospermic leaves (*Abies*, *Cedrus*, *Picea*, *Cycas* and *Taxus*).
- Outline classification of gymnosperms as proposed by Sporne (1965) and Sandra Holms (1986), distribution of gymnosperms with special reference to India. Economic importance of gymnosperms.A study of morphology, internal structure, outline life history of the following:
- Cycadopsida: Medullosaceae *Medullosa*, Glossopteridaceae *Glossopteris*, Cycadeoideaceae - *Cycadeoidea* (*Bennittites*), Cycadaceae -*Cycas*
- Coniferopsida: Ginkgoaceae – *Ginkgo*, Pinaceae – *Pinus*
- Gnetopsida: Gnetales - *Gnetum*, Welwitschiales - *Welwitschia*

Suggested Books:

- Alam, A. (2015). *Textbook of Bryophyta*. New Delhi: I K International Publishers.
- Bhatnagar, S.P. & Moitra, A. (1996). *Gymnosperm*. New Delhi: New Age International Pvt. Ltd.
- Parihar, N.S. (1996). *Biology and Morphology of Pteridophytes*. Allahabad: Central Book Depot.
- Singh, M. (1978). *Embryology of Gymnosperms, Encyclopaedia of Plant Anatomy*. Berlin: X. Gebruder Bortraeger.
- Sporne, K.K. (1991). *The morphology of pteridophytes*. Mumbai : B.I. Publishing Pvt. Ltd.
- Stewart, W.N & Rathwell, G.W. (1993). *Paleobotany and the evolution of plants*. Cambridge University press.
- Sunderrajan, S. (2007). *Introduction to pteridophyta*, New Delhi: New Age International Publishers.

Suggested e-Resources:

- **Bryophytes: General account**

  http://bryophytes.plant.siu.edu/

- **Bryophytes: Classification, structure**

  https://www.toppr.com/guides/biology/plant-kingdom/bryophytes/

- **Bryophytes**: **Online lectures**

  https://www.swayamprabha.gov.in/index.php/program/

- **Pteridophytes: General account, Classification, Life cycle**

  https://www.toppr.com/guides/biology/plant-kingdom/pteridophytes/

- **Gymnosperms: General account, Classification, Life cycle**

  https://www.thoughtco.com/what-are-gymnosperms-4164250

- **Gymnosperms: Economic importance**

  https://www.toppr.com/guides/biology/plant-kingdom/gymnosperms/

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 will be able to:

- Virtually develop an idea of cell culture laboratory.
- To learn different techniques/methods of cell culture like primary cell culture, subculturing, cryopreservation, thawing etc. along with their applications.
- Basics of animal and plant cell culture knowledge will help them to join any of the cellculture based research institution and industry of repute besides the academics employability.
- The students can establish their own cell culture laboratory as an entrepreneur.

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

BOT 518D Literature Dissertation

Max. Marks : 100	**L**	**T**	**P**	**C**
(CA: 40 + ESA: 60)	**0**	**0**	**8**	**4**

Learning Outcomes:

After successful completion of course students will be able to:

- Develop the competency in identifying the scientific problem.
- Access the primary literatures, understand the scientific reports and extract the useful information from it.
- Write a scientific document highlighting introduction of the research problem, review of literature, conclusions, future prospects and literature cited.
- Communicate significant findings in the form of scientific papers, reports, poster and oral presentations.

BOT 522L Plant Science 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 will be able to:

- Explain the puzzles of lower plants i.e., crytpogams.
- Attain the knowledge about the life cycle, morphology, anatomy of important taxa of these plant groups.
- Learn microscopy, anatomy, staining techniques which are basis of botany.
- Understand the course of evolution by studying the interrelationships among cryptogams, gymnosperms and angiosperms.
- Understand the importance of fossil plants.
- Converse expertly through oral and written scientific media about these plants.
- Recognize exact ways of training regarding lower plants and can address issues related to importance of these plants in our ecosystem.

Morphological and anatomical study of representative members of the following groups using whole mount preparations, dissections and sections:

1. Algae:

Cyanophyta (*Microcystis, Stigonema*), Prochlorophyta (*Prochloron*), Chlorophyta (*Chlorella Hydrodictyon, Nitella*), Xanthophyta (*Botrydium*), Bacillariophyta (*Navicula*), Phaeophyta (*Dictyota*).

2. Lichens

Crustose, Foliose, Fruticose forms of lichens.

3. Fungi

Myxomycota (*Plasmodiophora*), Mastigomycotina (*Peronospora*), Zygomycotina (*Mucor*), Ascomycotina (*Aspergillus, Erysiphe*), Basidiomycotina (*Puccinia, Ustilago*), Deutromycotina (*Fusarium*).

4. Bryophyta

Metzgeriales (Metzgeria), Jungermanniales (Porella), Marchantiales (Plagiochasma, Lunularia, Cyathodium), Sphagnales (Sphagnum), Polytrichales (Polytrichum), Bryales (Physcomitrium).

5. Pteridophytes:

Morphology and anatomy of vegetative and reproductive part of *Psilotum*, *Lycopodium*, *Selaginella*, *Equisetum*, *Gleichenia*, *Isoetes*, *Ophioglossum*, *Botrychium*, *Pteris.*

6. Gymnosperms:

Morphology and anatomy of vegetative and reproductive part of *Cycas*, *Ginkgo*, *Cedrus*, *Abies*, *Picea*, *Cupressus*, *Araucaria*, *Cryptomeria*, *Taxodium*, *Pedocarpus*, *Agathis*, *Taxus*, *Ephedra* and *Gnetum* and the members in their natural habitat found in your locality. Study of important fossils of Pteridophytes and Gymnosperms from specimens.

7. Preparation of media for tissue culture.

8. Embryo culture.

Suggested Books:

- Bendre, A. & Kumar, A. (2018). *A Text book of Practical Botany* Vol -I. Rastogi Publications, Meerut (India).
- Chaudhary, S.S., Chaudhary, P. & Prasad, T. (2010). *Practical Botany* (Cryptogams and Gymnosperms). CBS Publishers and Distributors. India.
- Kumar, S., Mishra, S. & Mishra, A.P. (2008). *Plant Tissue Culture: Theory and Techniques*. Scientific Publishers. India.
- Pandey, B.P. (2011). *Modern Practical Botany*, Vol-I. S. Chand Publishing, India
- Pandey, B.P. (2018). *Botany for Degree Students*. S. Chand Publishing, India

Fourth Semester

BOT 512 Angiosperms

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

Learning Outcomes:

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

- Increase their capacity to think critically; ability to design and execute an experiment; confidence and ability in communicating ideas.
- This will serve as a lasting and practical basis for a career, for example, in research whether industry or academia - as well as teaching, media, law, commerce, government or management.

Section-A

- Botanical explorations, historical perspectives. Botanical survey of India, its organization and role. Botanical nomenclature, History ICBN, Familiarity with botanical literature, monographs, icones, floras, important periodicals with emphasis on Indian floristics, methods of literature consultation.
- Phytogeography with reference to discontinuous areas, endemism, floristic regions of the world. Principles of plant classification with emphasis on modern tools of taxonomy: cyto-, chemo-, palyno- and Numerical taxonomy: Taxonomy as a synthetic discipline; utility of taxonomy; biosystematics. Phylogenetic systems of classification with emphasis on comparative critical study of: Engler & Prantl, APG system of classification.
- Phylogeny of Angiosperms: Origin, evolution, and interrelationships in dicots and monocots Interesting taxonomic features and phylogeny of the following families:

– ***Dicotyledons*:** Magnoliaceae, Nymphaeaceae, Ranunculaceae, Papaveraceae, Fumariaceae, Caryophylaceae, Bombacaceae, Malvaceae, Cucurbitaceae, Capparaceae, Brassicaceae, Rosaceae, Fabaceae, Myrtaceae, Rutaceae, Apiaceae, Apocynaceae,

Asclepiadaceae, Solanaceae, Convolvulaceae, Cuscutaceae, Boraginaceae, Orobanchaceae, Acanthaceae, Rubiaceae, Asteraceae, Lamiaceae, Verbenaceae, Bignoniaceae, Moraceae, Cannabinaceae, Fagaceae, Betulaceae, Juglandaceae, Casuarinaceae, Nyctaginaceae, Chenopodiaceae, Amaranthaceae, Polygonaceae.

– ***Monocotyledons:*** Alismatacea, Commelinaceae, Cyperaceae, Poaceae, Cannaceae, Arecaceae, Araceae, Lillaceae, Amaryliidaceae, Agavaceae, Smilacaceae and Orchidaceae.

Section B

- Origin, growth, differentiation and ultra structure of cells and tissues. Meristems: structure and kinds; theories concerning root and shoot apices; organogenesis. Structure, ultra structure ontogeny and evolution of primary secondary xylem and phloem indicating their phylogenetic role.
- Normal and anomalous functioning of vascular cambium: cork cambium-periderm formation, abscission and wound healing.
- Structural variability in leaves, leaf histogenesis, leaf meristem, origin, development and ultra structure of trichomes and stomata.
- Comparative anatomy of typical dicot and monocot roots, stems and leaves.
- Anomalies in the primary and secondary root and stem structures.
- Organogamy of floral parts and floral biology.

Section C

- Historical perspective of the development of our knowledge in Embryology.
- Microsporangium-structure and function of wall layers, nuclear behaviour in tapetum, microsporogenesis, microgametogenesis.
- Megasporangium-structure, development and kinds of ovules, Morphological nature of ovules, megasporogenesis and megagametogenesis, embryo sac types and morphological nature of the embryo sac.

- Pollination- natural and artificial, self and interspecific incompatibility, methods of overcoming incompatibilities. Fertilization-syngamy and triple fusion, post fertilization changes in ovules and embryo sac.
- Endosperm: structure, kinds and morphological nature, endosperm haustoria, pseudo-embryo sac, xenia, metaxenia. mosaic endosperm, endosperm culture.
- Embryo: structure and kinds of embryo development, embryo culture.
- Apomixis: vegetative propagation and agamospermy (adventive embryony, apospory and diplospory), parthenogenesis.
- Polyembryony: origin, kinds and significance.

Suggested Books:

- Alam, A., & Sharma, V. (2013). *Text Book of Economic Botany*. India: Pointer Publishers.
- Bhojwani, S.S., Bhatnagar , S.P. & Dantu, P.K. (1979). *The Embryology of Angiosperms* (6^{th} ed.). India: Vikas Publishing House.
- Gary, L. (2011). *Flowering Plants: A Pictorial Guide to the World Flora*. Firefly Books, Canada: Richmond Hill.
- Hill, A.F. (1952). *Economic Botany A Textbook of Useful Plants and Plant Products*. McGraw-Hill.
- Judd, W.S., & Campbell, C.S. (2007). *Plant Systematics A Phylogenetic Approach*. New York: Sinarue Publication.
- Lawrence, G.H.M. (2017). *Taxonomy of Vascular Plants.* Jodhpur (Raj.): SENTIFIC Publishers.
- Zomlefer, W.B. (1995). *Flowering Plant Families*. USA: University of North Carolina Press.

Suggested e-Resources:

- **Angiosperms: General account and Classification**

  https://www.toppr.com/guides/biology/plant-kingdom/angiosperms/

- **Angiosperms: Taxonomy and evolution**

  https://www.britannica.com/plant/angiosperm

- **Angiosperms: Tree of Life Web project**

  http://tolweb.org/Angiosperms

- **Angiosperms: General account**

  http://landau.faculty.unlv.edu//angiosperms.htm

- **Angiosperm: Recent nomenclatural**

  www.theplantlist.org

- **Angiosperm: Palynology**

  https://www.floridamuseum.ufl.edu/index.php/paleobotany/palynology/about/

  https://www.environmentalscience.org/palynology

BOT 504 Cytogenetics and Plant Breeding

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

Learning Outcomes:

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

- Understand the chromosomal theory of inheritance and cytological & evolutionary consequences of polyploidy and aneuploidy on fertility in plants.
- Learn about the fundamental concepts in cytogenetics.
- Gain knowledge of the basic diagnostic tools of cytogenetics.
- Familiarize with the common chromosomal aberrations and their evolutionary consequences in plants and animals.
- Understand the implications of chromosomal structural variation to plant breeding.
- Attain the ability to operate basic consideration in order to analyze genetic data from cytogenetic diagnostic. An ability to incorporate cytogenetic considerations in breeding programs, in evolutionary studies, and in genetic analyses.

Section A

- Architecture of chromosome in prokaryotes and eukaryotes; Chromonemata, chromosome matrix, chromomeres, centromere, secondary constriction and telomere; artificial chromosome construction and its uses; special types of chromosomes.
- Introduction to techniques for karyotyping; Chromosome banding and painting - *in situ* hybridization and various applications
- Origin, cytology, effect & uses of structural chromosomal aberrations.
- Numerical variations of chromosomes and their implications.

Section B

- History of Plant Breeding (Pre and post-Mendelian era); objectives of plant breeding, characteristics improved by plant breeding; patterns of evolution in Crop Plants; Centres of Origin; biodiversity and its significance.
- Genetic basis of breeding self- and cross - pollinated crops, including mating systems and response to selection - nature of variability, components of variation; Heritability and genetic advance, genotype environment interaction.
- General and specific combining ability.
- Self-incompatibility and male sterility in crop plants and their commercial exploitation.

Section C

- Plant introduction and role of plant genetic resources in plant breeding.
- Pure line theory, pure line selection and mass selection methods; Line breeding, pedigree, bulk, backcross, single seed descent and multiline method; Population breeding in self-pollinated crops
- Breeding methods in cross pollinated crops; Population breeding-mass selection and ear-to-row methods; S1 and S2 progeny testing, progeny selection schemes, recurrent selection schemes for intra and interpopulation improvement and development of synthetics and composites; Hybrid breeding - heterosis and inbreeding.
- Improvement of Rice, Wheat & Maize through breeding in India.

Suggested Books:

- Allard, R. W. (1999). *Principles of Plant Breeding* (II ed.). Willey.
- Brown, J., Caligari, P.D.S. & Campos, H.A. (2014). Plant Breeding (II ed.). Wiley Blackwell.
- Gupta, P.K. (2005). *Cytology Genetics and Evolution*. Meerut: Rastogi Publications
- Gupta, P.K. (2007). *Cyotgenetics*. Meerut: Rastogi Publications.
- Hayes, H. & Immer, F.R. (2015). *Methods of Plant Breeding*. Create Space Independent Publishing Platform¸ Scotts Valley, California, United States.
- Mahabal, R. (2014). *Plant Breeding Methods*. Delhi: PHI Learning Private Ltd.
- Singh, B.D. (2009). *Plant Breeding, Principles & Methods*. Kalyani Publications.

Suggested E resources:

- **Resource documents of the Genetic Engineering Appraisal Committee, Govt. of India**.

  http://www.geacindia.gov.in/resource-documents.aspx

- **Biology of Rice, Series of Crop specific Biology Documents, Ministry of Environment and Forests, DBT, Govt. of India**

  http://www.geacindia.gov.in/resource-documents/biosafety-regulations/resource-documents/Biology_of_Rice.pdf

- **Biology of Maize, Series of Crop specific Biology Documents, Ministry of Environment and Forests, DBT, Govt. of India**

  http://www.moef.gov.in/divisions/csurv/geac/Biology_of_Maize[1].pdf

- **Impact of Public and Private Sector Maize Breeding Research, CYMMYT.**

  https://repository.cimmyt.org/bitstream/handle/10883/1034/75341.pdf?sequence=1&isAllowed=y

BOT 507 Plant Pathology

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

Learning Outcomes:

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

- Facilitate to develop learning goals and objectives in their courses and programs, in prioritizing and focusing the learning experiences, and in the selection of appropriate assessment tools.
- Potential students and outside agencies to assess the quality of our academic programs.
- These learning outcomes areas include: Scholar, content and technical expertise, social accountability, communicator, and professional.

Section A

- Host parasite relationship, Infection, development and establishment of the disease.
- Epiphytotics: Compound and simple interest diseases, mathematical model, essential condition and analysis.
- Effect of environment in epidemiology of the disease.
- Genetic variability of plant pathogens.
- Genetic basis of host pathogen interactions, its role in specificity of plant disease.

Section-B

- Plant disease control: Physical, Chemical and Biological (Biocontrol, Breeding, Genetic Engineering).
- A general account of diseases caused by Bacteria, Viruses and *Mycoplasma*.
- Bacterial diseases: Red stripe of sugarcane, Angular leaf spot of cotton, Soft rot of vegetables.
- Viral diseases: Leaf roll of potato & tomato, Mosaic disease of tomato.

- Mycoplasma diseases: Sandal spike, Sesamum phyllody, Little leaf of Brinjal.

Section-C

- Fungal diseases of cereals and millets: Rusts of wheat, Loose and covered smut of wheat and Barley, fungal diseases of Bajra, Charcoal rot of Maize.
- Fungal diseases of vegetables and fruits: Early blight of Potato, Wart disease of Potato, Powdery mildew of Cucurbits & Pea, Die back of Chillies, Tikka disease of Groundnut, Wilt & root rot of Gram, Red rot and smut of Sugarcane.
- Nematode diseases: Root knot of vegetable (Cucumber), Molya disease of Wheat and Barley.
- Insect diseases: General account of plant and animal galls with special reference to Mango & Ziziphus.

Suggested Books:

- Agrios, G.N. (2005). *Plant Pathology*. USA: Elsevier Publication.
- Alexopoulus, C.M. (1996). *Introductory Mycology*. New York: John Wiley and Sons.
- Bilgrami, K.S. & Dubey, H.C. (1998). *Text Book of Modern Pathology*. India: Vikas Publishing House Pvt. Ltd.
- Biswas, S. B. & Biswas, A. (2006) *An Introduction to Viruses*. India: Vikas Publishing House Pvt. Ltd.
- Butler, E.J. (1918). *Fungi and Diseases in Plants*. Kolkata: Thanker Spink and Co.
- Mehrotra, R.S. (1990). *Plant Pathology*. Tata McGraw Hill Publication Co.
- Mundkur, B. (1967). *Fungi and Plant Diseases*. Macmillan and Co. Limited
- Singh, R.S. (2017). *Plant Disease*. IBH, New Delhi: Oxford.

Suggested e-Resources:

- **Fungi: *Aspergillus***

  https://www.aspergillus.org.uk/content/mycology-online

- **Plant Pathology**

  https://www.apsnet.org/publications/apsnetfeatures/Pages/ICPP98PlantPath.aspx

- **Plant diseases: Identification and Control**

  https://www.planetnatural.com/pest-problem-solver/plant-disease/

- **Plant disease control**

  http://cemerced.ucanr.edu/files/40658.pdf

BOT 508 Plant Physiology

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

Learning Outcomes:

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

- Demonstrate understanding of the organization of plants from the level of cells through tissues, tissue systems, and organs.
- Demonstrate understanding of developmental patterns and processes of plants.
- Demonstrate understanding of organellar function at the cellular level of architecture.demonstrate understanding water potential and its effect on cellular function.
- Demonstrate detailed understanding of the physiological mechanisms involved in the uptake and transport of water and the translocation of food by plants.
- Demonstrate understanding of the cellular establishment of membrane potential and its role in solute transport.

- Demonstrate understanding of the mechanisms for procurement of mineral ions by plants and mineral nutrition and the role these minerals play in organic molecule synthesis and use.

Section-A

- Assimilation of Carbon in Plants.
- Photosynthetic pigments, their distribution & functions.
- Mechanism of Photosynthesis, Photosynthetic electron transport chain (Photophosphoryation).
- Carbon dioxide reduction cycles in C3 & C4 Plants: Enzymes of C3 & C4 cycles & their location in the chloroplast.
- Photorespiration: pathway, enzymes & metabolic significance.
- Crassulacean acid metabolism (CAM) in plants.

Section-B

- Cell wall: Structure & functions, microfibril & matrix polysaccharides, proteins, lignins.
- Plant growth regulators: Physiological importance & mechanism of action of (a) Auxins (b) Gibberellins (c) Cytokinins (d) Abscissic acid (e) Ethylene.
- Nitrogen Metabolism: Nitrate and nitrite reduction; Nitrogen fixation; mechanism and enzymes.
- Role of temperature and light in plant development with reference to Photoperiodism & vernalization.
- Phytochrome: Structure, function and mechanism of action.

Section-C

- Dormancy: Nature and forms of dormancy, Mechanism of dormancy, Methods of breaking dormancy, Physiological basis of dormancy.
- Macro & Micronutrients: Availability & Uptake, Role & specific functions of plant nutrients.
- Biosynthesis of secondary metabolites, Major pathways: Shikimic acid, Acetate-malonate & acetate - mevalonate pathways.

- Physiological importance of secondary metabolites.

Suggested Books:

- Buchanan, B.B., Greissum, G., & Jones, R.L. (2015*). Biochemistry and Molecular Biology of Plants*. Wiley Blackwell.
- Devlin, R.M. & Witham, F.H. (1969). *Plant Physiology*. New York: Van Norstand.
- Hopkins, W.G., & Huner, N.P.A. (2009). *Introduction to Plant Physiology*. John Wiley and Sons Inc.
- Noggle, G.R. & Fritz, J.F. (1976). *Introductory Plant Physiology*. New Delhi: Prentice Hall of Pvt.
- Pandey, S.N., & Sinha, B.K. (2005). *Plant Physiology*. New Delhi: Vikas Publishing House Pvt. Ltd.
- Salisburry, F.B. & Ross, CW (1974). *Plant Physiology*. New Delhi: Prentice Hall of India.
- Taiz, L. & Zeiger, E. (2010). *Plant Physiology*. London: Sinauer Associate.

Suggested e-Resources

- **Plant Physiology: Online course**

  https://has.nl/en/training/online-course-plant-physiology

- **Plant Physiology: Recent researches**

  http://www.plantphysiol.org/

- **Plant Physiology: Online content**

  http://www.plantphysiol.org/content/by/year

BOT 523L Plant Science 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 will be able to:

- Explain and justify the use of advanced techniques in taxonomy, microscopy, cytology, cyto-genetics, genotyping, plant physiology, and plant pathology especially mycology, and to interpret the results of such analyses.
- Utilize technical skills acquired through lab experience and apply these skills in formulating solutions to life science questions.
- Communicate proficiently through oral and written scientific media.
- Identify specific ways training in plant science that can address issues of earthly stewardship and sustainability, and demonstrate a strong desire to help Mankind in a socio-scientific way.

1. Morphotaxonomical and anatomical study of available plants mentioned in the syllabus.
2. Emasculation technique.
3. Preparation of various chemicals used for fixation, dehydration, staining and cleaning etc. for light microscopy.
4. Chromosome banding technique.
5. Study of Mitosis and Meiosis.
6. Study of endomitosis using endosperm of *Cocos nucifera*.
7. Preparation of MS media and demonstration of efficacy of growth hormones for the induction of shoot & root.
8. Estimation of Chlorophyll pigments.
9. Separation of plant pigments by TLC/Paper chromatography.
10. Isolation of chloroplast and demonstration of Hill's activity.
11. Calculation of RQ of Carbohydrates, fatty acids, and organic acids by Ganong's respirometer.

12. Extraction and analysis of phytochemicals from plant samples.
13. Screening of seed borne fungi by Blotter technique/Agar plate method.
14. Study of important bacterial, fungal and viral diseases of plants mentioned in the syllabus.
15. Preparation of slides and identification of plant pathogens.
16. Effect of temperature/pH/RH on the growth of fungi.

Discipline Elective

BOT 520 Phycology-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 will be able to:

- Identify these algal forms in their surroundings and will be motivated to better understand this interesting branch of botany.
- They will know the basis of photosynthesis with amazing diversification in these plants.
- After passing this course they will be placed as researchers in marine research, space research and biofuel research institutes.

Section A

- Diagnostic characters of major algal division Cyanophyta, Glaucophyta, Chlorophyta, Dinophyta, Phaeophyta and Rhodophyta.
- Principles, criteria (pigments, cell wall, flagellation, food reserve and eye spots) and systems of classification.
- Modern criteria of algal classification with special emphasis on chloroplast ultra structure, flagella and pigments.
- Biodiversity and Conservation of Algae: Habit and Habitat diversity, Importance of Conservation: *in situ* and *ex situ* conservation.

- Wetlands and Algal assemblages: Role of Algae in Wetlands and structural Environment.
- Work done on freshwater algae with special reference to India & Contributions of Prof. M. O. P. Iyengar.
- Distribution pattern of Marine algae in Indian coasts.
- Endosymbiosis theories and origin of Eukaryotic algae.

Section B

- Cyanophyta: cell structure, heterocyst and akinete development and Physiological aspect; chromatic adaptation, thallus organization and reproduction.
- Alternation of generation in Phaeophyta and post-fertilization development and site of meiosis in Rhodophyta.

Section C

- A brief account of Xanthophyta, Chrysophyta, Bacillariophyta, Pyrrophyta, Euglenophyta, Eustigmatophyta, Prasinophyta and Prochlorophyta.
- Algae in Specialized habitats, Phytoplankton diversity, algal blooms and Phycoviruses.
- Algae as source of phycocolloids , types and Importance.
- Algal Culture: brief idea and types.
- Algae in Human welfare–Nutraceuticals, Pharmaceuticals, Biofertilizers, Biofuel , CO_2 Sequestration and pollution control.
- Algal Biotechnology: Genome shuffling and evolutionary engineering ; application of Synthetic biology in algae.

Suggested Books:

- Bilgrami, K.S. & Saha, L. (2007). *A textbook of Algae*. CBS Publishers and Distributors.
- Kumar, H.D. & Singh, H.N. (1979). A textbook on Algae. Macmillan Publishers Limited.
- Nash, T.H. (2011). *Lichen Biology*. Cambridge University Press. Cambridge.

➢ Round, F.E. (1986). *The Biology of Algae*. Cambridge University Press, Cambridge.

Suggested e-Resources:

➢ **Algae**

https://www.livescience.com/54979-what-are-algae.html

BOT 521 Phycology-II

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

Learning Outcomes:

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

- Understand the various application and career opportunities in algology.
- They will know the industrialization aspects of these plants.
- After passing this course they will be able to work in various industries or build their career in algal research

Section A

- Biochemical taxonomy of algae. Fossil algae: Major events in the geological time scale during evolution of algae in relation to corresponding environment and other life forms;
- Carbon dioxide concentrating mechanism (CCM) in algae.
- Phytoplankton Ecology: factors (light, temperature, chemical & current) and distribution.
- Terrestrial algal ecology: soil algae, cryo algae and subaerial algae
- Macroalgal and periphyton ecology: biogeography of seaweeds; influence of biological factors
- Algae of unusual habitats: thermal algae, halotolerant forms and their ecology

Section B

- Phylogeny of algal plastids.
- Ultrastructure of flagella and its taxonomic importance.
- Extracellular products of algae & toxic algae.
- Algae in Biotic associations.
- Algal biotechnology with special reference to health, food, bio cosmetics, medicine, hydrocarbon production, biomonitoring and bioremediation.
- Control of aquatic algae.
- Biogeochemical role of algae
- Isolation, purification & growth characteristics in relation to algal culture; indoor and outdoor cultivation culture; photobioreactors.

Section C

- Models (Monod and Droop) of nutrient-regulated phytoplankton growth; common methods for mass cultivation of microalgae
- Causal factors and dynamics of freshwater and marine algal blooms; physical and chemical means and biomanipulation (top-down and bottom-up) for controlling nuisance blooms
- Consequences of blooms including toxins of cyanobacteria and dinoflagellates; algal biofouling of ships and its control
- Commercial potential of *Spirulina*, *Dunaliella*, *Botryococcus* and *Porphyra*; hydrogen production by algae
- High-rate algal ponds for the treatment of wastewaters and for the production of useful biomass and energy; immobilized and inactivated algal biomass for metal and nutrient removal
- A brief account of cyanobacterial genomics and proteomics
- Paddy field cyanobacteria: Qualitative and quantitative assessment of their biodiversity using molecular tools; their use as biofertilizers, reclamation of usar (problem) lands
- Influence of salt, heavy metals and acid rain on algae: Physiological and biochemical effects; biochemical and molecular mechanisms of tolerance.

Suggested Books:

- Bilgrami, K.S. & Saha, L. (2007). *A textbook of Algae*. CBS Publishers and Distributors.
- Kumar, H.D., and Singh, H.N. (1979). *A textbook on Algae*. Macmillan Publishers Limited.
- Lee, R. E. (2008). *Phycology*. Cambridge University Press, New York.
- Nash, T.H. (2011). *Lichen Biology*. Cambridge: Cambridge University Press.
- Round, F.E. (1986). *The Biology of Algae*. Cambridge: Cambridge University Press.

Suggested e-Resources:

- **General account on Algae**

  https://www.livescience.com/54979-what-are-algae.html

- **Basic Algology**:

  http://allaboutalgae.com/what-are-algae/

- **Algal Phylogeny and origin**

  http://www.plantphysiol.org/content/116/1/9

- **Economic importance of Algae**

  http://news.algaeworld.org/2017/07/economic-importance-of-algae/

BOT 515 Bryology-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 will be able to:

- Identify these Lilliputians of plant kingdom in their surroundings and will be able to collect those from their natural habitats hence motivated to better understand this fascinating group of plants.
- They will know the basis of thallus organization with amazing diversification.
- After passing this course they will be placed as researchers in various institutes and universities.

Section A

- General characteristics of bryophytes, alternation of generations and classification.
- Evolution in bryophytes.
- Life-cycle of bryophytes, asexual and sexual reproduction.

Section B

- Comparative morphological and anatomical studies of gametophytes and sporophytes in various orders of the class Bryopsida:

– Takakiales - Takakia

– Sphagnales - *Sphagnum*

– Andreaeales - *Andreaea*

– Buxbaumiales - *Buxbaumia*

– Bryales - *Physcomitrium, Fontinalis, Splachnum*

– Polytrichales – *Polytrichum*

Section C

- Comparative morphological and anatomical studies of gametophytes and sporophytes in various orders of the class Hepaticopsida.

– Calobryales - *Calobryum*, *Haplomitrium*

– Metzgeriales - *Pallavicinia*, *Riccardia*, *Metzgeria*

– Jungermanniales - *Jungermannia*, *Porella*, *Ptychanthus*, *Radula*

– Sphaerocarpales - *Riella*, *Sphaerocarpous*

– Monocleales - *Monoclea*

– Marchantiales - *Reboulia*, *Plagiochasma*, *Asterella*, *Lunularia*, *Dumortiera*, *Targionia*, *Cyathodium*

Suggested Books:

- Alam, A. (2015). *Textbook of Bryophyta*. New Delhi: I K International Publishers.
- Chopra, R.N. (2005). *Biology of Bryophytes*. India: New Age International Publishers.
- Gangulee, H.C. (1978). *Mosses of Eastern India and adjacent regions*. India: Kalyani Publishers.
- Pope, R. (2016). *Mosses, Liverworts, and Hornworts*: *A Field Guide to Common Bryophytes of the Northeast*. Ithaca, NY: Comstock Publishing Associates.
- Schofield, W. B. (2001). *Introduction to Biology* (Reprint ed.). Caldwell, New Jersey: The Blackburn Press.

Suggested e-Resources:

- **Bryophytes: Identification, Ecology**

  https://openlibrary.org/subjects/bryophytes

- **Bryophytes: General account, classification and structure**

  http://nsdl.niscair.res.in/jspui/bitstream/123456789/150/1/BRYOPHYTES%20.pdf

- **Bryophytes: Ecology**

  https://digitalcommons.mtu.edu/bryophyte-ecology/

- **Bryophyte: Phylogenetic classification**

  http://bryophytes.plant.siu.edu/class.html

BOT 516 Bryology-II

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

Learning Outcomes:

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

- Know the various advances in the field of bryology.
- They will know the modern trends in bryology.
- After passing this course they will be able to carry on their research in India and abroad.
- This branch of botany is looking dedicated researchers for its sustenance therefore fair chance of getting good opportunities as researchers in various institutes and universities.

Section A

Comparative morphological and anatomical studies of gametophytes and sporophytes in various orders of the class Anthocerotopsida:

- Anthocerotaceae - *Anthoceros*, *Folioceros*
- Notothyladaceae - *Notothylas*, *Phaeoceros*
- Dendrocerotaceae - *Dendroceros*, *Megaceros*
- Origin, evolution, fossil history, phylogeny of principal classes: Bryopsida, Hepaticopsida and Anthocerotopsida.

Section B

- Ecology - habitat diversity, growth forms, growth factors.

- Role of bryophytes in pollution monitoring, geobotanical prospecting, horticultural uses, economic importance.
- Spore diversity, dispersal mechanism and their germination.
- Moss protonema, protonemal differentiation and bud induction.

Section C

- Ecological aspects of bryophytes: Bryophytes in relation to nutrient cycling, water restoration, bryophytes associations
- Ethnobryology
- Molecular Bryology
- Phytochemicals from bryophytes
- Horticultural uses of bryophytes.

Suggested Books:

- Alam, A. (2015). *Text book of Bryophyta*. New Delhi: I K International Publishers.
- Chopra, R.N. (2005). *Biology of Bryophytes*. India: New Age International Publishers.
- Gangulee, H.C. (1978). *Mosses of Eastern India and adjacent regions*. Kalyani Publishers, India.
- Pope, R. (2016). *Mosses, Liverworts, and Hornworts: A Field Guide to Common Bryophytes of the Northeast*. Ithaca, NY: Comstock Publishing Associates.
- Rashid, A. (1998). *An Introduction to Bryophyta*. India: Vikas Publishing,
- Schofield, W. B. (2001). *Introduction to Biology* (Reprint edition). The Blackburn Press.
- Udar, R. (1978). *Bryology in India*. Chronica Botanica Company.

Suggested e-Resources:

- **Bryophyta: Classification**

  http://bryophytes.plant.siu.edu/class.html

- **Bryophyta: Phylogenetic classification**

  https://bryology.uconn.edu/classification/

- **Bryophyta: Conventional classification**

  https://www.google.com/search?client=firefox-b&q=recent+classification%3A+liverworts

- **Bryophytes: Overall account**

  https://openlibrary.org/subjects/bryophytes

- **Bryophyta: Cryptogamic account**

  http://nsdl.niscair.res.in/jspui/bitstream/123456789/150/1/BRYOPHYTES%20.pdf

- **Bryophyta: Ecology**

  https://digitalcommons.mtu.edu/bryophyte-ecology/

BOT 513 Angiosperms Taxonomy and Systematics-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 will be able to:

- Understand methods and principles of plant classification and nomenclature.
- Learning representative plant families and genera of flowering plants will also help students to identify the plants.
- Learn the embryology, biosystematics, bryodiversity and conservation methods of economically important plants.

Section A

- Systematics: Outline of classification of Angiosperms; Hutchinson, Takhtajan, Cronquist, merits and demerits.
- Botanical nomenclature: International code of Botanic Nomenclature; ICBN, principles, Rules and recommendations; priority; typification; Rules of effective and valid publications; retention and choice of names.

- Taxonomic features, systematic phylogeny and economic importance of families: Magnoliaceae, Capparidaceae, Combretaceae, Rosaceae, Amaranthaceae, Asteraceae, Apocynaceae, Asclepiadaceae, Convolvulaceae, Scrophulariaceae, Acanthaceae, Bignoniaceae, Lamiaceae, Verbenaceae, Polygonaceae, Euphorbiaceae, Orchidacae, Zingiberaceae, Araceae, Cyperaceae and Poaceae.
- Numerical taxonomy: Aims and objectives, characters and attributes, OTUs, coding, cluster analysis, merits and demerits.
- Chemotaxonomy: Role of phytochemicals (non-protein amino acids, alkaloids, betalins, cynogenic glucosides, silica, gypsum, raphides, glucosinolate, flavonoids, terpenoids) in taxonomy.
- Embryology in relation to taxonomy.

Section B

- Molecular approaches to plant taxonomy: Application of DNA markers in angiosperm taxonomy; molecular phylogeny.
- Self incompatibility: Structural and biochemical aspects; methods to overcome incompatibility – mixed pollination, bud pollination; intra - ovarian pollination, *in vitro* pollination.
- Experimental embryology: Haploid production; diploidization of haploids, importance of haploids; embyro culture; culture of differentiated and mature embryos; role of natural plant extracts and growth hormones; embryo-nurse endosperm transplantation; culturing of embryonal segments; practical aspects of embryo culture.

Section C

- Biosystematics principles, practice, limitations and scope, phenotypic plasticity, epigenetics.
- Biodiversity: general concept, values, isolation and assessment of Genetic Diversity.
- Distribution of endemic plant families in the southern hemisphere of the globe.
- Conservation: Principles, categories of threatened plants (IUCN), strategies of conservation, Red Data Book.
- Botanical Survey of India, its contribution and functions.

- Molecular markers in taxonomy and phylogenetic analysis: Nuclear ribosomal DNA, Chloroplast DNA and Mitochondrial DNA.

Suggested Books:

- Graf, A. B. (2010). *Flora of India.* Rajat Publications, India.
- Hoorn, C., Perrigo, A., & Antonelli, A. (2018). *Mountains, Climate and Biodiversity: A comprehensive and up-to-date synthesis for students and researchers*. Wiley Science Publishers, USA.
- Judd, W.S., & Campbell, C.S. (2007). *Plant Systematics Aphyllogenetic Approach*. Sinarue Publication, New York.
- Naik, V.N. (1988). *Taxonomy of Angiosperms*. New Delhi: Tata Mc-Graw Hill Publishing Co.
- Rathod, M.M. (2016). *Floristic Ecology and Phytogeography*. Chandralok Prakashan**,** Kanpur, India

Suggested e-Resources:

- **General account of angiosperms**:

  http://www.nhptv.org/natureworks/nwep14f.htm

- **Angiosperm-Life tree**

  http://tolweb.org/Angiosperms

- **Angiosperms: Classification and Reproduction**

  https://www.toppr.com/guides/biology/plant-kingdom/angiosperms/

- **Angiosperms: Phylogeny**

  http://www.mobot.org/MOBOT/research/APweb/

- **Angiosperms: APG system of classification**

  https://academic.oup.com/botlinnean/article/181/1/1/2416499

BOT 514 Angiosperms Taxonomy and Systematics-II

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

Learning Outcomes:

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

- Describe the evolution by natural selection and other causes.
- Get knowledge about the nature of "species" and can compare contrasting concepts of species.
- Describe binomial nomenclature and use scientific names of species correctly.
- List levels of the Linnaean hierarchical classification system and use it properly.
- Discuss advantages and disadvantages of the Linnaean system describe systematics.
- Correctly interpret phylogenetic trees and explain their construction.

Section A

- Plant taxonomy through ages in India: Major contributions of W. Roxburgh, N. Wallich, J.D. Hooker, C. B. Clarke, G. King and K.P. Biswas. Current status of Botanical Survey of India (B.S.I), Central National Herbarium (CAL): role in systematic study in India. Acharya Jagadish Chandra Bose Indian Botanic Garden (AJCBIBG) & National Botanical Research Institute (NBRI): activities in relation to taxonomic studies and conservation.
- Taxonomic Literature: Categories, brief concept with examples.
- Floristic regions of the world (Takhtajan, 1987); Floristic Composition of India: description and composition of Himalayan, Peninsular and Desert vegetation. Biodiversity Act, Role of National Biodiversity Authority (NBA) in biodiversity management; CBD and environmental protocols.

Section B

- Latest changes, addition and alteration in International Code of Botanical Nomenclature (ICBN); Valid Publication: provision of new taxa (Genus); Nomenclature of Hybrid Plants; Nomenclature of Cultivated Plants (ICNCP).
- Evolutionary concepts: monophyly, paraphyly, polyphyly, plesiomorphy, apomorphy, anagenesis, stasigenesis, cladogenesis, homology, analogy, homoplasy, parallelism and convergence, synapomorphy and symplesiomorphy.
- Modern trends in Taxonomy: Nodal Anatomy: structure, types, evolution and applications.
- Palynotaxonomy: pollen structure, types and evolution of pollen grains, applications. Serology, Ultra structures.

Section C

- Biodiversity: components, levels, values, Hotspots and conservation.
- Concept of Phytogeography: Endemism, Plant migration, Disjunction, Vicariance, Phytochorionomy (Brief introduction).
- Major Phytochona of the World and India.
- Ministry of Environment and Forest, India

Suggested Books:

- Graf, A. B. (2010). *Flora of India*. India: Rajat Publications.
- Hoorn, C., Perrigo, A. & Antonelli, A. (2018). *Mountains, Climate and Biodiversity: A comprehensive and up-to-date synthesis for students and researchers.* USA: Wiley Science Publishers.
- Judd, W.S. & Campbell, C.S. (2007). *Plant Systematics: A phylogenetic Approach*. New York: Sinarue Publication.
- Rathod, M.M. (2016). *Floristic Ecology and Phytogeography*. Kanpur, India: Chandralok Prakashan.

Suggested e-Resources:

- **IUCN Red List**

  https://www.iucnredlist.org/

- **Angiosperms: Herbarium resources**

  http://apps.kew.org/herbcat/gotoWhatIsHerbarium.do

- **Angiosperms: Herbarium techniques**

  https://herbarium.duke.edu/about/what-is-a-herbarium

- **International Code of Botanical Nomenclature**

  https://www.iapt-taxon.org/icbn/main.htm

- **Biodiversity**:

  https://www.greenfacts.org/en/biodiversity/l-3/1-define-biodiversity.htm

- **Conservation of Biodiversity**:

  http://enviroeducation.com/resources/biodiversity-academic-requirements-professional-outlook

- **Angiosperms: Playnotaxonomy**

  https://openlibrary.org/subjects/palynotaxonomy

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 will be able to:

- Demonstrate principles for development of various stress resistant plants.
- Understand 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* mediated, 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

PHY 532 Biophysics-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 will be able to:

- Understand the concepts of physical principles in the biomolecular systems.
- Know properties and conformations of biomolecules.
- Understand 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 energysurface, 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

PHY 533 Biophysics-II

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

Learning Outcomes:

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

- Understand the concepts of physical principles in the biomolecular systems.
- Know Properties and conformations of biomolecules.
- Understand the interaction between physics and biology.

Section A

- Physics of macromolecules: Biological polymers, modeling polymers as elasticity models, Random walk model, radius of gyration, freely jointed chain, calculation of the distribution of end-to-end distances, statistical segment, persistence length, relation to characteristic ratio, worm like chain, behavior of chain dimension, DNA Elasticity, Application of Porod-Kraty model to DNA.
- Protein folding: Anfinsen's thermodynamic hypothesis, Case study: Ribonuclease A, renaturation and denaturation, mechanism of disulphide exchange, determinants of protein folding, Levinthal's paradox, classical view of protein folding, the hydrophobic collapse, Energy landscape theory, Protein Folding problem as a NP-hard problem.

Section B

- Self assembly and membrane equilibria: Self assembly in miscelles as monolayers and bilayers, Thermodynamics of miscelle formation, co-operativity, packing parameter, Tanford's free energy model, Packing model, influence of tail packing, Fluid mosaic model, Langmuir adsorption model.
- Electrical conduction in the nervous system: Structure of the neuron, Hodgkin-Huxley model and generation of action potential, Nernst relation in membrane potentials, Donnan equilibrium, ion pumping, voltage gating. Transport in cells: Diffusion, Fick's law, cells with sources, low Reynolds-number, friction in fluids, Transport across cells - osmosis.

Section C

- Blood flow: Blood as non-Newtonian fluid, Blood flow models, Navier Stokes equation, Dissipative particle dynamics, Erythrocyte model, elastic model.

- Energy in muscle: Cytoskeleton, Muscle Contraction, biopolymers of the cytoskeleton, Tubulin, microtubules, associated protein, micro filaments, actin and Myosin. Molecular motors, Kinesin and Dyenin. Sliding filament model of contraction, ATP and muscle contraction, stochastic model of contraction.
- Radiation Physics: Dosimetery, Photon interaction coefficients, Relations between exposure, Kerma and absorbed dose, Measurement of exposure, Bragg-Gray Cavity theory, determination of absorbed dose in a medium, radiotherapy, geometrical factors, specification of dose ratios, nuclear medicine.

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.
- Smith, F. A. (2000). *A primer in applied radiation physics*. World Scientific Publishing Company.
- Tuszynski, J. A., & Kurzynski, M. (2003). *Introduction to molecular biophysics*. CRC press.
- Van Holde, K. E., Johnson, W. C., & Ho, P. S. (2006). Principles of physical biochemistry.
- 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:

https://www.coursera.org/learn/dynamicalmodeling?specialization=systems-biology

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 will be able to:

- Describe the interaction of organisms with their environment.
- Identify the various threats to biodiversity.
- Explain the concept of biomes.
- Describe the various biogeochemical cycles.

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.
- Green House 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 524 Advanced 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 will be able to:

- Gain advance knowledge in plant biotechnology and their applications in crop improvement, large scale production of plant metabolites
- They are able to get practical insight of techniques.
- They can go further in plant biotechnology research.

Section A

- Molecular Pharming - concept of plants as Biofactories, production of industrial enzymes and Pharmaceutically important compounds.
- Heavy metal toxicity in plants, metal hyperaccumulation & resistance mechanisms.
- Concept of Phytoremediation and its applications.
- Bioremediation of inorganic (Metals and radionucloides) and organics (TCE/petroleum hydrocarbons/solvents/explosives etc.) in the environment.

Section B

- The improvement of crop yield and quality;
- The genetic manipulation of fruit ripening.
- Genetic modifications of ethylene biosynthesis and ethylene based fruit sensor;
- Golden Rice.
- Role of phytohormones in improving the yield of oil seed crops.
- CRISPER-CAS and marker free technology.

Section C

- Production of bio-fuels from algal and plant based biomass.
- Regulation of abiotic and biotic stress responses by plant hormones.
- Nanobiotechnology in Plant research: Effect of different nanomaterials and nanoparticles on Plant .
- The Regulation of GM crops and products and the current status of the GM crops.
- Intellectual Property in Agriculture Biotechnology.
- The future of Plant Biotechnology.

Suggested Books:

➢ Ahmed, P (2017). Oil seeds Crops. Wiley Publication.

- Evans, G. M. & Furlong, J. C. (2011), *Environmental Biotechnology: Theory and Applications*, Wiley Publishers.
- Kumar, A. (2008) *Recent advances in plant biotechnology and its applications*. New Delhi: I.K. International Pub.
- Oksman-Caldentey, & Kirsi-Marja. (2014). *Plant biotechnology and transgenic plants*. Marcel Dekker.
- Prasad, R (2018) Mycoremediation and Environmental sustainability, Springer Publication
- Slater, A. Scott, N.W. & MR Fowler. (2014). *Plant bio technology* (2nd ed.). Oxford University Press.
- Stewart C. Neal (2018) Plant Biotechnology and Genetics Wiley Publications.

Suggested e- Resources:

- **Book Oil Seed crops**

  https://onlinelibrary.wiley.com/doi/book/10.1002/9781119048800

- **Plant environment interactions**

  http://fmipa.umri.ac.id/wp-content/uploads/2016/03/Frantisek_Baluska_Plant-Environment_InteractionsBookFi.org_.pdf

- **Biotechnology for crop improvement**

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

  https://www.intechopen.com/books/plants-for-the-future/molecular-farming-in-plants

ENVS 502 Biodiversity and Conservation

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

Learning Outcomes:

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

- Explain importance of biological diversity.

- Describe major threats to biodiversity.
- Recognize and implement the various methods of biodiversity conservation with co-existence of various environmental pressures.
- Identify different geographical biodiversity hotspots and mega-diversity centers.

Section A

- Introduction to biodiversity concepts, significance, magnitude and distribution.
- Biodiversity trends, diversity gradients and related hypotheses methods for monitoring biodiversity trends.
- Threats to biodiversity, major causes, extinction's, vulnerability of species to extinction, IUCN threat categories, Red data book.

Section B

- Principles of biodiversity conservation *Ex situ* and *In situ* methods of conservation, Genetical and evolutionary principles in conservation. Conservation of biological diversity and its significance- source of food, medicine, raw material, aesthetic, cultural and ecosystem services.
- Concepts, distribution and importance of Hot spots.
- Strategies for sustainable exploitation of biodiversity.

Section C

- Conservation efforts in India, Endangered flora & fauna of India.
- Ethnobotany in India and ethnomedicinal plants.
- Wildlife conservation in India- Project Tiger, Project crocodile, silent valley controversy.
- Conservation of Himalayan, Gangetic ecosystems.

Suggested Books:

- Kumar, U. &Asija, M.J. (2007). *Biodiversity – Principles and Conservation* (2nd ed.). Jodhpur, India: Agrobios.
- Mishra, R. (1968). *Ecology Workbook* (2nd ed.). Calcutta, India: Oxford and IBH.

- Odum, E.P. (1983). *Basic Ecology* (2nd ed.). Philadelphia,PA: Holt-Saunders International.
- Odum, E.P. (2004). *Fundamentals of Ecology*. Dehradun, India: Natraj.
- Singh, M.P., Singh, J.K., Mohanka, R., & Sah, R.B. (2007). *Forest Environment and Biodiversity (*2nd ed.*)*. New Delhi, India: Daya.
- Sinha, B.N. (1990). *Ecosystem Degradation in India*. New Delhi, India: Ashish.
- Tewari, D.N. (1994) *Biodiversity and Forest Genetic Resources*. Dehradun, India: International Book.

Suggested e-resources:

- **Aquatic Biodiversity and Environmental Pollution, IISc, Bangalore**

  https://nptel.ac.in/courses/120108002/16
- **Wildlife Conservation, Indira Gandhi National Forest Academy, Dehradun**

  https://nptel.ac.in/noc/individual_course.php?id=noc18-bt26

Online Discipline Elective

Sl. No.	Name of Course	URL
1	Fundamentals of Ecology for Sustainable Ecosystem	https://www.extension.harvard.edu/academics/courses/fundamentals-ecology/12779

READING ELECTIVE

BT 529R Drug Discovery

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

Learning Outcomes:

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

- Understand basics of R&D in drug discovery and should be able to apply knowledge gained in respective fields of pharmaceutical industry.
- Understand the role of synthetic chemistry in the development of pharmaceutical agents; and the modification of chemical structures to develop new drug molecules.
- Have an advanced understanding of the chemical structure of a pharmaceutical agent and determine the chemical group/s responsible for a given biological effect.
- Demonstrate a basic understanding of pharmacogenomics and bioinformatics as it relates to drug design and discovery.
- Develop an understanding of drug targets as a recognition site for pharmaceutical agents; how the chemical structure of a substance influences interaction with a drug target; and the identification of new drug targets for future drug 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**	**0**	**2**

Learning Outcomes:

After successful completion of the course, students will 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. Fitzgerald. (1999). *An introduction to Human Molecular Genetics-Mechanism of Inherited Diseases*. Science Press.
- Strachan T. & Read. A. (2011). *Human Molecular Genetics* (4th ed.). Garland Science.
- Thompson and Thompson. (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**	**0**	**2**

Learning Outcomes:

After successful completion of the course, students will 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.

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**	**0**	**2**

Learning Outcomes:

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

- Identify various bacterial, fungal, viral and protozoan diseases and their epidemiology.
- Understand the relevance of emerging and reemerging diseases.

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 (26thed.). US: Lange Medical Books, McGraw-Hill.
- Madigan, M., Martinko, J., Stahl, D. & Clark, D. (2010). *Brock Biology of Microorganisms* (13thed.). 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://bit.ly/2SUmzum

- **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 0 2**

Learning Outcomes:

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

- Understand strategies and applications of plant breeding technologies.
- Comprehend the knowledge of different plat molecular markers.
- 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 0 2**

Learning Outcomes:

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

- Analyse structure and construction of proteins by computer-based methods.
- Describe structure and classification of proteins.
- Analyse and compare the amino acid sequence and structure of proteins, and relate this information to the function of proteins.
- Explain how proteins can be used for different industrial and academic purposes such as structure determination, organic synthesis and drug design.
- Plan and carry out 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

Online Reading Electives

Sr. No.	Name of Course	URL
1	Bio-organic Chemistry	http://nptel.an.in/courses/104103018/#
2	Enzyme Science and Engineering	http://freevideolectures.com/Course/85/Enzyme-Science-and-Engineering/1
3	Biocatalysis in organic synthesis	http://nptel.ac.in/courses/104105032/
4	Comprehensive Disaster Risk Management Framework	http://www.nidm.gov.in/online.asp
5	General Course on Intellectual Property	https://welc.wipo.int/acc/index.jsf?page=courseCatalog.xhtml
6	Environmental Management-An Introduction	http://www.algonquincollege.com/ccol/courses/environmental-management-ac-i