

SYLLABUS FOR

**MSc. AND M.Sc.-Ph.D. COMBINED DEGREE PROGRAM IN
BIOMEDICAL SCIENCES**

**FOR THE POST-GRADUATE CURRICULUM FRAMEWORK UNDER
THE NEW EDUCATION POLICY**

SEMESTER-III AND SEMESTER-IV

STRUCTURE 1, 2 AND 3

Course Credit Scheme M.Sc. Biomedical Science**Programme Structure-1: (PG with only coursework)**

Semester	Core Courses		Elective Course		Skill-Based Courses		Total Credits
	No. of courses	Total credits	No. of courses	Total credits	No. of courses	Total credits	
I	3	12	2	8	1	2	22
II	3	12	2	8	1	2	22
III	2	8	3	12	1	2	22
IV	2	8	3	12	1	2	22
Total Credits for the course	40		40		8		88

Programme Structure-2: (PG with coursework and research)

Semester	Core Courses		Elective Course		Skill-Based courses		Project work		Total Credits
	No. of courses	Total credits	No. of courses	Total credits	No. of courses	Total credits	No. of courses	Total credits	
I	3	12	2	8	1	2	-	-	22
II	3	12	2	8	1	2	-	-	22
III	2	8	2	8	-	-	1	6	22
IV	2	8	2	8	-	-	1	6	22
Total Credits for the course	40		32		4		12		88

Programme Structure-3: (PG with research)

Semester	Core Courses		Elective Course		Skill-Based courses		Research Methodology		Project work		Total Credits
	No. of courses	Total credits	No. of courses	Total credits	No. of courses	Total credits	No. of courses	Total credits	No. of courses	Total credits	
I	3	12	2	8	1	2			-	-	22
II	3	12	2	8	1	2			-	-	22
III	1	4	1	4	-	-	2	4	1	10	22
IV	-	-	1	4	-	-	1	2	1	16	22
Total Credits for the course	28		24		4		6		26		88

List of PGCF courses of M.Sc. in Biomedical Sciences

(Semester I and II of the two-year programme)

Type of Course	Type	Semester	Name of the Courses	Credits in each course			
				Lecture	Tutorial	Practical	Total
Semester – I							
Discipline Specific Core Course	DSC-1	I	Biochemistry of macromolecules	3	0	1	4
Discipline Specific Core Course	DSC-2	I	Biological Chemistry - I	3	0	1	4
Discipline Specific Core Course	DSC-3	I	Medical Microbiology	3	0	1	4
Discipline Specific Elective Course	DSE-1	I	From the Pool of DSEs given below*	4	0	0	4
Discipline Specific Elective Course	DSE-2	I	From the Pool of DSEs given below*	4	0	0	4
Generic Elective Course	GE-1	I	Biology of Aging	4	0	0	4
Skill Based Course	SC-1	I	Biomedical Laboratory Techniques – I	0	0	2	2
Semester -II							
Discipline Specific Core Course	DSC-4	II	Immunology	3	0	1	4
Discipline Specific Core Course	DSC-5	II	Genetics: Principles and Applications	3	0	1	4
Discipline Specific Core Course	DSC-6	II	Human Physiology -I	3	0	1	4
Discipline Specific Elective Course	DSE-3	II	From the Pool of DSEs given below**	4	0	0	4
Discipline Specific Elective Course	DSE-4	II	From the Pool of DSEs given below**	4	0	0	4
Generic Elective Course	GE- 2	II	Cancer Biology	4	0	0	4
Skill Enhancement Course	SEC-2	II	Biomedical Laboratory Techniques - II	0	0	2	2
Pool of Discipline Specific Elective Courses to be offered in 1st Semester*	i. Cell Biology						
	ii. Bioethics and Biosafety						
	iii. Application of Statistics in Biology						
Pool of Discipline Specific Elective Courses to be offered 2nd Semester**	iv. Molecular Biology						
	v. Topics in Clinical Research						
	vi. Biological Chemistry -II						
	vii. Research Methodology						

List of Courses to be offered to students opting for Structure-I of M.Sc. in 3 rd and 4 th Semester of two year course							
Type of Course	Type	Semester	Name of the Courses	Credits in each course			
				Lecture	Tutorial	Practical	Total
Semester – III							
Discipline Specific Core Course	DSC-7	III	Advanced Biomedical Techniques & Instrumentation	3	0	1	4
Discipline Specific Core Course	DSC-8	III	Pharmacology & Toxicology	3	0	1	4
Discipline Specific Elective Course	DSE-5	III	From the Pool of DSEs given below[#]	3	1	0	4
Discipline Specific Elective Course	DSE-6	III	From the Pool of DSEs given below[#]	3	1	0	4
Discipline Specific Elective Course	DSE-7	III	From the Pool of DSEs given below[#]	3	1	0	4
General Elective Course	GE- 3	III	From the Pool of GEs given below^{##}	3	1	0	4
Skill Based Course	SBC-3	III	Biomedical Laboratory Techniques - III	0	0	2	2
Semester-IV							
Discipline Specific Core Course	DSC-9	IV	Recombinant DNA Technology	3	0	1	4
Discipline Specific Core Course	DSC-10	IV	Bioinformatics, Computational Biology and Drug Design	3	0	1	4
Discipline Specific Elective Course	DSE-8	IV	From the Pool of DSEs given below^{##}	3	1	0	4
Discipline Specific Elective Course	DSE-9	IV	From the Pool of DSEs given below^{##}	3	1	0	4
Discipline Specific Elective Course	DSE-10	IV	From the Pool of DSEs given below^{##}	3	1	0	4
General Elective Course	GE- 4	IV	From the Pool of GEs given below[*]	3	1	0	4
Skill Based Course	SBC-4	IV	Biomedical Laboratory Techniques - IV	0	0	2	2
Pool of Discipline Specific Elective Courses to be offered in the 3rd semester[#]	viii. Human Physiology II						
	ix. Medicinal Chemistry						
	x. Neurobiology						
	xi. Advanced Immunology						
	xii. Genome Biology						
Pool of Discipline Specific Elective Courses to be offered in the 4th Semester^{##}	xiii. Molecular Oncology						
	xiv. Viral & Fungal Diseases						
	xv. Advanced Toxicology						
	xvi. New Methods in Organic Synthesis						
	xvii. Applications of ML, DL and AI in Biomedical Science						
	xviii. Advances in Protein Sciences						
Generic Elective Courses to be offered in 3rd and 4th Semesters[*]	iii. Structural Biology (in 3rd semester)						
	iv. Cardiovascular Biology (in 4th Semester)						

List of Courses to be offered to students opting for Structure-2 of M.Sc. in 3 rd and 4 th Semester							
Type of Course	Type	Semester	Name of the Courses	Credits in each course			
				Lecture	Tutorial	Practical	Total
Semester – III							
Discipline Specific Core Course	DSC-7	III	Advanced Biomedical Techniques & Instrumentation	3	0	1	4
Discipline Specific Core Course	DSC-8	III	Pharmacology & Toxicology	3	0	1	4
Discipline Specific Elective Course	DSE-5	III	From the Pool of DSEs given below [#]	3	1	0	4
Discipline Specific Elective Course	DSE-6	III	From the Pool of DSEs given below [#]	3	1	0	4
General Elective Course	GE- 3	III	From the Pool of GEs given below ^{##}	3	1	0	4
Dissertation Project/Entrepreneurship	DP-1	III	Dissertation	0	0	6	6
Semester-IV							
Discipline Specific Core Course	DSC-9	IV	Recombinant DNA Technology	3	0	1	4
Discipline Specific Core Course	DSC-10	IV	Bioinformatics, Computational Biology and Drug Design	3	0	1	4
Discipline Specific Elective Course	DSE-7	IV	From the Pool of DSEs given below ^{##}	3	1	0	4
Discipline Specific Elective Course	DSE-8	IV	From the Pool of DSEs given below ^{##}	3	1	0	4
General Elective Course	GE- 4	IV	From the Pool of GEs given below [*]	3	1	0	4
Dissertation Project/Entrepreneurship	DP-2	IV	Dissertation	0	0	6	6
Pool of Discipline Specific Elective Courses to be offered in the 3 rd semester [#]	viii. Human Physiology II						
	ix. Medicinal Chemistry						
	x. Neurobiology						
	xi. Advanced Immunology						
	xii. Genome Biology						
Pool of Discipline Specific Elective Courses to be offered in the 4 th Semester ^{##}	xiii. Molecular Oncology						
	xiv. Viral & Fungal Diseases						
	xv. Advanced Toxicology						
	xvi. New Methods in Organic Synthesis						
	xvii. Applications of ML, DL and AI in Biomedical Science						
	xviii. Advances in Protein Sciences						
Generic Elective Courses to be offered in 3 rd and 4 th Semesters [*]	iii. Structural Biology (in 3 rd semester)						
	iv. Cardiovascular Biology (in 4 th Semester)						

List of Courses to be offered to students opting for Structure-3 of 'M.Sc. with Research' in the 3 rd and 4 th Semester							
Semester III							
Type of Course	Type	Semester	Name of the Courses	Credits in each course			
				Lecture	Tutorial	Practical	Total
Discipline-Specific Core course related to the area identified for research	DSC-11	III	Emerging Techniques and Applications in Biomedical Research	3	1	0	4
Discipline-Specific Elective course related to the area identified for research	DSE-5*	III	DSE (Student may opt for any of the papers related to the area of research from the 3 rd semester)	3	1	0	4
Advanced Research Methodology of the core discipline	ARM-I	III	Advanced Research Methodology	2	0	0	2
Tools for Research	TR-I	III	Tools for Research	2	0	0	2
Project Work	IP-1	III	Research project	0	0	10	10
Semester IV							
Discipline-Specific Elective course related to the area identified for research	DSE-6**	IV	DSE (Student may opt for any of the papers related to the area of research from the 3 rd semester)	3	1	0	4
Techniques of research writing	TRW	IV	Techniques of research writing	2	0	0	2
Project Work	IP-2	IV	Research project	0	0	16	16
Pool of Discipline Specific Elective Courses to be offered in the 3 rd semester [#]	viii.	Human Physiology II					
	ix.	Medicinal Chemistry					
	x.	Neurobiology					
	xi.	Advanced Immunology					
	xii.	Genome Biology					
Pool of Discipline Specific Elective Courses to be offered in the 4 th Semester ^{##}	xiii.	Molecular Oncology					
	xiv.	Viral & Fungal Diseases					
	xv.	Advanced Toxicology					
	xvi.	New Methods in Organic Synthesis					
	xvii.	Applications of ML, DL and AI in Biomedical Science					
	xviii.	Advances in Protein Sciences					

SEMESTER-II**DSE-vii****RESEARCH METHODOLOGY****4 credits****Duration: 45 Hours + 15 Hours (Tutorial)**

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Research Methodology (DSE-vii)	4	3	1	0	Graduation	NIL

LEARNING OBJECTIVES:

The goal of this paper is to make students:

- Understand the fundamental concepts and principles of research methodology
- Identify and apply different research designs and methods
- Develop skills in critically evaluating research literature and identifying research gaps
- Learn to formulate research questions, objectives, and hypotheses
- Understand the importance of ethics in research and apply ethical principles

LEARNING OUTCOMES:

It will help students to:

- Define research methodology and its significance in research
- Identify and explain different types of research designs and methods
- Recognize the importance of ethics in research and identify potential ethical issues
- Formulate research questions, objectives, and hypotheses.
- Appreciate the importance of research methodology in advancing knowledge

Unit I: Research Methodology**(11 Hours)**

Introduction, Objectives and motivation in research, Approaches to scientific research- Experimental vs Theoretical; Descriptive vs Analytical; Fundamental vs Applied; Quantitative vs Qualitative; Conceptual vs Empirical; Survey vs Experimental. Pilot studies, Inter and Multidisciplinary Research, Clinical Research

Essential Reading

1. Swaroopani. K, An Study of Research Methodology, International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Volume 9, Issue 3, pp.537-543, May-June-2022. Doi : <https://doi.org/10.32628/IJSRSET2293175>.

Unit II: Research Design**(12 Hours)**

Identifying gaps in knowledge through literature mining, identifying area of societal need like health/technology/anticipated crisis such as epidemic, energy, water. Elements for outlining a research problem. Developing an approach strategy, feasibility testing. Selection of research topic and its national and international scenario. Techniques involved in research plan using an illustration, Sampling and Sampling Techniques, data analysis and Interpretation.

Essential Reading

1. Khanday and Khanam, The Research Design, Journal of Critical Reviews, Volume 06, Issue 03, 2019.

Unit III: Intellectual Property: Patent, trademarks, copyright, trade secrets**(10 Hours)**

Introduction to IP, Types of IP, IP laws in India, Patent law, trademark law, copyright law and trade secrets (Protection, Requirements, Key benefits), Importance of academia-industry interaction, Marketing of research outcome.

Essential Reading:

1. Patents Act, 1970 India; Trademarks Act, 1999 India; Copyright Act, 1957 India; WIPO Guide to Intellectual Property; Indian patent Office website (ipindia.gov.in)

Unit IV. Scientific Documentation**(12 Hours)**

Introduction to Scientific Documentation (Background and context), Importance of Scientific Documentation (Transparency and reproducibility, Validity and credibility, Collaboration, Knowledge transfer, Error prevention, Ethical and legal compliance), Types of Scientific Documentation (Primary and Secondary Sources), Writing Scientific documents (IMRAD), Scientific Reports and Thesis, Abstracts and Presentations, Citations and Referencing, Plagiarism and Ethics, Editing and Proofreading.

Essential Reading:

1. Delving E, Pillay TS, Newman A. How to Write a Scientific Paper: Practical Guidelines. EJIFCC. 2014 Oct 24;25(3):259-68. PMID: 27683473; PMCID: PMC4975199.

Tutorial:**(15 Hours)**

- Seminars by students on recent papers/trends published in relevant journals.
- Quizzes and Debates.
- Revision of Specific topics; reinforcement of key concepts.
- Case studies, where applicable.
- Group Discussion.
- Theoretical critiques and hypotheses development.

SUGGESTED READINGS:

1. Research in Education (2005) 10th ed., Best, J.W. and Kahn, J.V., Prentice Hall of India Pvt. Ltd. (ISBN-13: 978-0205458400)

2. At the Bench: A Laboratory Navigator (2005) Barker, K., Cold Spring Harbor Laboratory Press (New York). ISBN: 978-087969708-2.
3. Research Methodology - Methods and Techniques (2004) 2nd ed., Kothari C.R., New Age International Publishers. (ISBN-13 / EAN: 9788122415223)
4. Research Methodology: A Step by Step Guide for Beginners (2010) 3rd ed., Kumar R., Pearson Education. (ISBN-13: 978-1849203012)
5. The Craft of Research (Guides to writing, editing and publishing) (2008), Booth, W.C., Colomb, G.G., Williams, J.M., University of Chicago Press, 2008. (ISBN-13: 978-0226065663)

Detailed contents of

SYLLABUS FOR 3rd and 4th semester

**MSc. and M.Sc.-Ph.D. COMBINED DEGREE PROGRAM IN
BIOMEDICAL SCIENCES**

**FOR THE POST-GRADUATE CURRICULUM FRAMEWORK UNDER
THE NEW EDUCATION POLICY**

SEMESTER-III**DSC-7 ADVANCED BIOMEDICAL TECHNIQUES & INSTRUMENTATION****Duration: 45 Hours + 30 Hours (Practical)**

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Advanced Biomedical Techniques and Instrumentation (DSC-7)	4	3	0	1	Graduation	NIL

LEARNING OBJECTIVES:

The course on Analytical and Biomedical Techniques and Instrumentation will be offered as a CORE course in the 3rd Semester, covering various analytical and Biomedical analysis techniques. The course will enable students to understand the theoretical basis of these techniques as well as train them in handling various instruments and analyzing the data. The students will be given hands-on training to learn these techniques and apply the knowledge in developing skills that are essentially needed to work in clinical diagnostic and research laboratories in the fields of biology and analytical biochemistry. The course has been designed to help them gain theoretical knowledge, practical handling of instruments, and analysis of the results obtained from these techniques for biomedical research.

LEARNING OUTCOMES:

- The students of the course will be able to learn the theoretical basis of various analytical and biomedical techniques. They will be trained in spectroscopic techniques such as UV-visible, Infrared, Fluorescence, Circular Dichroism, and their applications in Biomedical Analysis.
- Students will learn analytical separation techniques such as Gas Chromatography, High-Performance Liquid Chromatography, and Supercritical Fluid Chromatography.
- Students will understand the theoretical basis of Magnetic Resonance Spectroscopy (MRS) and Imaging (MRI). They will be able to understand the application of NMR in drug analysis and diagnosis using MRI etc.
- Students will also learn about MASS spectroscopy and its application in analytical and biomedical research. Students will be able to solve structures of small drug molecules using analytical data based on IR, NMR, and MASS spectroscopic techniques.
- Students can analyze and interpret results obtained from fluorescence-assisted flow cytometry (FACS), confocal microscopy, and tracer techniques in this field.

Unit I: Optical Methods and their applications in Biomedical Sciences 10 hours

Ultraviolet / Visible molecular absorption spectroscopy, Theoretical basis, transitions, Lambert-Beer's Law, factors affecting Absorption, Fluorescence and Phosphorescence (Jablonski diagram), Fluorescence quenching (dynamic, static, Stern-Volmer constant, FRET with examples from the Biomedical field, Biomolecular interactions using spectroscopic methods.

Infrared –vibrational spectroscopy introduction, Functional group identification, Effects of various factors on IR frequencies and biomedical application.

Concept of circularly polarized light and principles of CD, CD instrumentation, concepts of bandwidth, slit width, scan speed, and other factors in getting proper resolution of bands, Application of CD in macromolecular structure determination, binding studies and other applications.

Essential Readings:

1. Chapter 1,2 and 4; Organic spectroscopy by William Kemp; Ed. 3rd; Palgrave; 2008.

Unit II: Nuclear Magnetic Resonance Spectroscopy and Biomedical applications 14 hours

Theory of NMR: Quantum description, Classical description – Protonal motion, Larmor frequency, Relaxation processes, T1 and T2 and their measurement. Fourier Transform NMR: Pulsed excitation, FID, Types of NMR Spectra – Wide line and high - resolution spectra.

NMR Spectrometers: Instrumentation. Environmental Effects: Types, Chemical shift theory, Magnetic anisotropy, Spin–spin splitting, first order and second order spectra, Double Resonance Techniques, Proton on heteroatom. Application of proton NMR: Identification of compounds.

Introduction to ¹³C NMR: Proton decoupling: Broad band, off-resonance, Pulsed decoupling, NOE, application to structure determination.

The concept of MRI, BOLD imaging, fMRI, Application in Muscle Physiology, functional mapping of brain. Other nuclei: ³¹P, ¹⁹F, ²³Na, ¹⁵N, metabolomics studies using NMR

Essential Readings:

1. Chapter 3; Organic spectroscopy by William Kemp; Ed. 3rd; Palgrave; 2008.
2. Chapters 4 and 5; Spectrometric identification of organic compounds by Robert M. Silverstein and Francis X. Webster; Ed. 8th; John Wiley; 2015.
3. Chapters 1-5; MRI: Basic Principles and Applications Dale, Brian M., Brown, Mark A.; Semelka, Richard C. John Wiley & Sons, Inc. (US). 2015.

Unit III: Separation methods and Mass Spectrometry 10 hours

Separation Methods An introduction to chromatographic separation, Gas Chromatography, Pressure Liquid Chromatography and FPLC, Supercritical fluid chromatography

Mass Spectrometry. Forming charged particles: Electron impact (EI) and Chemical Ionization (CI), Fast Atom Bombardment (FAB), Field Desorption (FD), Electrospray Ionization, Matrix Assisted Laser Desorption Ionization (MALDI). Mass Analyzers: Magnetic sector mass spectrometers, Double focusing mass spectrometers, Quadrupole pole mass spectrometers, ion cyclotron resonance, Time of Flight mass analyzers. Combine the mass spectrometer with Gas Chromatography (GC/MS) and with liquid chromatography (LC/MS). Applications of mass spectrometry in Biomedical field- Peptide mass fingerprinting, protein sequencing using MASS spectrometry.

Essential Readings

1. Chapter 5; Organic spectroscopy by William Kemp; Ed. 3rd; Palgrave; 2008.
2. Chapter 2; Spectrometric identification of organic compounds by Robert M. Silverstein and Francis X. Webster; Ed. 8th; John Wiley; 2015.

Unit IV: Flow Cytometry, Magnetic Assisted Cell Sorting and miscellaneous techniques 11 hours

Introduction to flow cytometer: Need and versatility of FACS. Fluidics and Optics in FACS, Filters and detectors in FACS: choosing the right fluorochromes, compensation of overlapping emissions. Plotting of data in various formats (Histograms/dot plots/ contour plots), Gating, Principles of cell sorting by FACS and MACS.

Tracer Techniques in Biology: Tumor diagnosis and imaging, infectious diseases such as tuberculosis. Biomolecular Structure determination techniques: X-Ray crystallography.

Essential Readings

1. Flow Cytometry: Principles, Applications and Clinical perspectives. 2024. Ranbir Chander Sobti, Awtar Krishan, Devendra K. Agrawal. Springer.
2. Handbook of Radiopharmaceuticals: Methodology and Applications, Editor(s): Peter Scott, Michael Kilbourn, 2020, Print ISBN:9781119500544, Online ISBN:9781119500575, John Wiley & Sons, Ltd

ADVANCED BIOMEDICAL TECHNIQUES AND INSTRUMENTATION (Practical)

Course-specific learning outcome (Practicals)

- At the end of this course, students will be able to use instruments such as UV-VIS and Fluorescence spectrophotometer, and HPLC.
- They will be able to analyze samples using a flow cytometer.
- The students will also learn how to analyse characterization data of a given unknown compound/drug/analyte and interpret its structure from the data.
- They will also learn to study the biomolecular interactions using spectroscopic techniques.

Practical

30 hours

1. To verify Lambert Beer's law and calculate the concentration of the unknown analyte using UV-VIS spectroscopy.
2. To study excitation and emission spectra of a chromophore using Fluorescence spectroscopy.

3. To study the interaction of intercalating agents like ethidium bromide with DNA using UV–Visible spectroscopy.
4. To study the interaction of ethidium bromide with DNA using Fluorescence spectroscopy.
5. NMR: ^1H and ^{31}P spectroscopy of muscle physiology during exercise and calculation of pH change from spectra.
6. Spectral Identification of a simple organic compound/metabolite/drug. (two examples)
7. Cell cycle analysis using Flow Cytometry.
8. To monitor real-time influx in intercellular calcium levels

SUGGESTED READINGS:

1. Principles of instrumental analysis by Douglas Skoog and F. James Holler and Timothy A. Nieman; Ed. 7th; Saunders; 2018.
2. Contemporary instrumental analysis by Kenneth A. Rubinson and Judith F. Rubinson; Prentice Hall 2000.
3. Basic one and two dimensional NMR spectroscopy by Horst Friebolin; Ed. 5th ; Wiley-VCH; 2010.
4. Principles of Fluorescence Spectroscopy by Lacowicz, 3rd Ed. 2006, Springer US.
5. NMR and its applications to living systems by David G. Gadian; Ed. 2nd; Oxford; 1996.
6. Structure determination of organic compounds: tables of spectral data by E. Pretsch and P. Buhlmann and C. Affolter; Edn. 4th Springer; 2009.
7. HPLC: a practical user's guide; Ed.2nd by Marvin C. McMaster; Wiley-Interscience; 2007.
8. Flow Cytometry and Cell Sorting (Springer Lab Manual) A. Radbruch (Editor), Springer Verlag, January 2000, ISBN: 3540656308.

DSC-8

PHARMACOLOGY AND TOXICOLOGY**Duration: 45 Hours + 30 Hours (Practical)**

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Pharmacology and Toxicology (DSE-8)	4	3	0	1	Graduation	NIL

LEARNING OBJECTIVES:

The course develops the understanding of theoretical and practical studies in the field of Pharmacology and Toxicology. The course involves the building up the knowledge of pharmacokinetic and pharmaco-dynamic profile of drug, pharmacological classification and principle of drug action and the types of toxicity assessments of various type toxicants of chemical and biological origin and environmental pollutants on organ system and drug disposition.

LEARNING OUTCOMES:

After completing the course, students shall be able to:

- Describe the various steps involved in the interaction of a drug to its target,
- Administer the drug through various routes to the rats or mice and do toxicity assays
- Describe the pharmacokinetic and toxicokinetic profile of the drugs and chemicals respectively.
- Describe the design of treatment strategy - in animal group.
- Plan and conduct a pharmacology project and toxicological assays.
- Independently acquire and critically assess Pharmacological and Toxicological information from databases.

Unit I: Introduction to pharmacology, Pharmacokinetics and Pharmacodynamics**9 Hours**

Scope of pharmacology: Introductory class to define pharmacology, historical background and limitations. Absorption- Routes of administration of drugs, their advantages and disadvantages. Various processes of absorption of drugs and the factors affecting them

Metabolism i) Microsomal and non-microsomal mechanisms ii) Effect of Enzyme induction and inhibition on drug metabolism and the factors influencing them. Distribution - i) distribution of drugs and the factors affecting them ii) Loading and maintenance doses Excretion of drugs- i) zero order, first order and steady state kinetics and half-life of drugs

General mechanism of drug action and the factors that modify drug action (signal transduction mechanisms in general, Dose-response relationship curves and different types of antagonisms. ii) Drug receptor interaction and Theories.

Essential Readings

1. Chapter 1 & 2: Casarett & Doull's Toxicology: The Basic Science of Poisons, 9th Edition (PHARMACOLOGY), 28 November 2018
2. Chapter 1: Goodman & Gilman's the pharmacological basis of therapeutics by Laurence Brunton and John Lazo and Keith Parker; Ed. 11th; McGraw-Hill Professional, 2014
3. Section 1: Essential of medical pharmacology; 9thEd. By K.D. Tripathi; Jaypee Brothers; 2024

Unit II: Pharmacological classification of drugs; the brief introduction of drugs should emphasize the ADME profile of the following systems 13 Hours

Drugs acting on the central nervous system: Anaesthetics- History, theory, mechanism and stages of anaesthesia, Drug classification based on mechanism of action of anaesthesia, Inhalation and general anaesthesia; Local anaesthetics-classification and mechanism of local anaesthesia, adverse reactions of anaesthesia.

Psycho-pharmacological agents: Sedatives, Hypnotics, anxiolytics, anti-maniac, antidepressants

Drugs acting on the autonomic nervous system: Cholinergic drugs, anticholinergic drugs, anticholinesterase drugs, dopaminergic drugs, Adrenergic drugs and adrenergic receptor blockers, Neuron blockers and ganglion blockers, Neuromuscular blockers, drugs used in myasthenia gravis.

Cardiovascular drugs, cardiogenic, antianginal agents, antihypertensive agents, peripheral vasodilators and drugs used in atherosclerosis, coagulants and anticoagulants.

Drugs acting on the respiratory system, Expectorants and antitussive agents, Drugs acting on the digestive system, Drug acting on Renal system, Coagulants and anticoagulants, Analgesics- Opioid analgesics (Morphine) and NSAIDs (Brufen)

Hormones and hormone antagonists (Classification of hormones based on their pharmacological and physiological action), Mechanism of hormonal action (Hypothalamopituitary adrenal / thyroid axis).

Essential Readings

1. Section 2, 3, 5, 11 & 12: Goodman & Gilman's the pharmacological basis of therapeutics by Laurence Brunton and John Lazo and Keith Parker; Ed. 11th; McGraw-Hill Professional, 2014
2. Section 2, 4, 5, 7, 8, 9 & 10: Essential of medical pharmacology; 9thEd. By K.D. Tripathi; Jaypee Brothers; 2024
3. Section 2, 3 & 4: Pharmacology H. P. Rang and M.M. Dale and J.M. Ritter and P.K. Moore; Ed. 8th; Churchill Livingstone

Unit III: Principles of Toxicology, Types of toxicity and its measurement 8 Hours

Definition, scope and different branches of toxicology. A brief review of toxic substances: Synthetic organic compounds: Chemical additives in food, Chemicals in the work place, Solvents, Pesticides, Cosmetics, Drugs of abuse. Inorganic chemicals: Industrial and chemical environmental inorganic toxicants polluting air/ water/ food. Naturally occurring poisons: Mycotoxins, Bacterial toxins, Plant toxins and Animal toxins.

Acute, Sub-acute or Chronic and its manifestations. Acute toxicity: Mode of application/ administration/ exposure, in-vitro tests, Dose response relationship, Measurement of TD 50/ TC 50 and LD 50/ LC 50. Sub-acute and chronic toxicity. Risk and safety analysis: Margin of safety, Therapeutic index, Ideal therapeutic index. Inter-species extrapolation of dose-response data, NOEL, ADI, TLV, WHO standards. Special toxicity studies: Carcinogenicity, teratogenicity, in-vitro mutagenicity tests.

Epidemiology of toxicity: Cohort study, Retrospect study, Case-control study, Cross-sectional study, Confounding. Unit VIII: Pharmacokinetic aspects of toxicants

Site of metabolism, Metabolizing enzymes of liver, kidney, lung, GI tract, skin and their role in activation and detoxification of drugs and chemicals. Physiological (route of exposure, species, sex and age), Nutritional and environmental (temperature, altitude and circadian rhythms related) factors affecting metabolism, detoxification and toxic responses of drugs and chemicals.

Essential Readings

1. Unit 1 & 5: Casarett & Doull's Toxicology: The Basic Science of Poisons, 9th Edition (PHARMACOLOGY), 28 November 2018 [Unit 1, 5]
2. Section 1 & 2: Principles and practice of toxicology in public health by Ira R. Richards; Jones and Bartlett Publishers; 2013
3. Chapter 1, 2, 3 & 4: Principles of toxicology by Karen E. Stine and Thomas M. Brown; Ed. 3rd; CRC Press; 2006.

Unit IV: Organ toxicities**15 Hours**

Hepatotoxicity: A brief description of morphological and functional aspects of liver with special reference to hepatotoxicity, various hepatotoxic agents, types of liver injuries- Fatty liver formation, Necrosis, Cholestasis, Hepatitis, Fibrosis, Cirrhosis, Carcinogenesis.

Nephrotoxicity: A brief description of morphological and functional aspects of kidney in relation of nephrotoxicity, nephrotoxic agents, detailed mechanisms of chemical induced nephrotoxicity.

Cardiovascular toxicity: A brief description of mechanisms of cardiovascular toxicity and cardiotoxic agents- subcellular and biochemical mechanisms.

Neurotoxicity: A brief description neurotoxic agents and types of neurotoxic effects Axonopathy, Neuropathy, Neuronopathy, Myelopathy. Broncho-pulmonary (inhalation) toxicity.

Gastrointestinal toxicity. Skin toxicity/ photosensitivity. Therapeutic aspects: General measures and treatment of poisoning cases, Specific antidotes, Agents of first choice, Contraindications.

Essential Readings

1. Unit 4: Casarett & Doull's Toxicology: The Basic Science of Poisons, 9th Edition (PHARMACOLOGY), 28 November 2018
2. Chapter 9, 10, 11 & 12: Principles of toxicology by Karen E. Stine and Thomas M. Brown; Ed. 3rd; CRC Press; 2006 [
3. Chapter 8 & 9: Essential of medical pharmacology; 9thEd. By K.D. Tripathi; Jaypee Brothers; 2024

PHARMACOLOGY & TOXICOLOGY (Practicals)

30 Hours

1. To study the different routes of administration in different animal models.
2. Topical application of Atropine and Pilocarpine on rabbit eye
3. Analgesic effect of diclofenac on mice/rat.
4. Study the effect of general anaesthesia with ketamine in rat.
5. To determine the effect of promethazine on phenobarbitone induced sleeping time in mice.
6. Detection of organo-phosphorous pesticides
7. To test the presence of paracetamol in the given sample.
8. To determine the toxic concentration of Arsenic in Zebra fish according to OECD guidelines.

SUGGESTED READINGS:

1. Martindale: The Complete Drug Reference, Edited by Alison Brayfield and Catherine Cadart, Alison, 41st edition
2. Lu's basic toxicology: fundamentals, target organs and risk assessment byUng-Mu, Huang Sikkim, Frank C. Lu and Sam Kacew; Ed. 7th; Informa Healthcare; 2009.

DSC-9

RECOMBINANT DNA TECHNOLOGY**Duration: 45 Hours + 30 Hour (Practical)**

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Recombinant DNA Technology (DSE-9)	4	3	0	1	Graduation	NIL

LEARNING OBJECTIVES:

- The unique preposition of this subject paper is that the students learn the advancement in basic molecular techniques and different methodologies used in the diagnosis and for the various human diseases therapeutics.
- The concepts of gen cloning and its expression leading to desired gene product is explored.
- Aims of the paper are to train students towards the advancement

LEARNING OUTCOMES:**Students will:**

- be well versed with the knowledge and practical approach to pick out any gene from cell or tissues using some potential technique using PCR technology, where student can amplify the gene of interest, and to make a clone of a gene after ligating in expression vector to produce more protein, and for functional studies.
- Learn to make a clone of a gene of interest can help students to analyse the gene mutation or spliced variants of the gene. The complete sequencing of gene, will help in disease manifestation.
- Learn Applications of subject knowledge have commercial values, in diagnosis & treatment strategy
- Learn to develop a low-cost disease diagnostic technique
- Have an understanding of developing efficient disease treatment therapy

Unit I: Plasmid Vector and its application**12 Hours**

Prokaryotic Restriction Modification system, Types of Restriction endonucleases & maps, Endonucleases produces 3' Overhang and 5' Overhang, Producing new restriction endonuclease

Various RDT enzymes such as S1 nuclease, Alkaline phosphatases, polynucleotide kinase, mung bean nuclease: their mechanism and application

Plasmid Vectors-Origin of cloning vectors and various modified versions of vectors, Bacterial, yeast expression vectors, mammalian expression vector

Cloning vectors, Tetracycline regulated vectors, shuttle vectors, YAC & BAC.

Principles of selection of gene cloning, preparation of probes, Blue white selection, insertional inactivation

Essential readings:

1. Principles of Gene manipulation and Genomics by S.B Primrose and R.M Twyman: (Page 15 to 81), Wiley-Blackwell; 7th edition, 2013.

Unit II: Molecular Biology techniques

12 Hours

LacZ application, luciferase reporter system

Detection and identification of cloned DNA sequencing, methods of DNA sequencing, pyrosequencing, nanopore sequencing, Next generation sequencing.

Principles and application of Polymerase Chain Reaction, RFLP analysis, real time PCR

Disease diagnostics eg: genetic diseases (cystic fibrosis, sickle cell anaemia, haemophilia etc), detection of pathogenic strain, single nucleotide polymorphism in disease diagnosis.

Gene Mutagenesis-Different methods used to generate recombinant mutants (deletion and point mutations), exonucleases, S1 nuclease.

Essential Readings

1. LacZ beta galactosidase: Structure and function of an enzyme of historical and molecular biological importance. Protein Science 2012 Sept 25; 21(12): 1792-1807
2. DNA sequencing at 40; Past, present and future. Nature 550, 345-353 (2017)
3. Ntren P (2007), The History of Pyrosequencing: Pyrosequencing protocol Page 1-13, Methods in molecular biology, vol 373 Humana Press.
4. Techniques for the detection of Sickle cell Disease: Review. Micromachines May 2021; 12(5):519
5. Application of DNA Based Diagnosis to patient care: The example of Hemophilia A. Vol 62, page 387-404, may-1987
6. Cystic fibrosis: prenatal diagnosis and carrier detection by DNA analysis. Med J Aus. 1989 Aug 7; 151, pp 126-131
7. Chapter 7 and 8, in Principles of Gene manipulation and Genomics by S.B Primrose and R.M Twyman, Wiley-Blackwell; 7th edition, 2013.

Unit III: Techniques applications in human disease diagnosis and treatments **11 Hours**

Genome editing system using ZFN, CRISPR, TALEN.

Application of recombinant DNA technology, DNA fingerprinting in forensic sciences

Biotechnology towards therapeutics, Gene therapy, Viral and non- viral approach

Essential readings:

1. Genome editing technologies : Principles and application (2016). Cold Spring Harb Perspect Biol. 2016 Dec 8 (12);a023754.
2. DNA profiling in forensic science : A review (2021) Glob Med Genet May 31; 8(4): 135-143.
3. Viral and non viral vectors in gene therapy: current state and clinical perspectives (2025) eBiomedicine, Jul1; 118: 105834

Unit IV: Advanced Therapeutic interventions**10 Hours**

Oncolytic viruses, Adeno-associated viruses in treatment diseases

Introduction to the concept of Regenerative Medicine, Advance Pluripotent stem cell derived therapies, Induced pluripotent stem cell, mesenchymal stem cell

Exosomes: Biomarkers, Cancer diagnosis, Tissue repair

Bio-safety and ethics for recombinant DNA technology

Essential readings

- 1) Oncolytic viruses: Newest Frontier for Cancer Immunotherapy (2021), Cancer (Basel), Oct 29; 13(21); 5452.
- 2) Induced Mesenchymal stem cells: An emerging source for regenerative medicine applications (2025) J clinical Med, March 18; 14 (6): 2053.
- 3) Induced Pluripotent stem cells (iPSCs): molecular mechanisms of induction and applications (2024). Signal transduction and Targeted Therapy 9, 112(2024).
- 4) Exosomes and cancer- Diagnostic and prognostic biomarkers and therapeutic vehicle (2022), Oncogenesis 11 article number 54 (2022).
- 5) The Therapeutic potential of exosomes in soft Tissue Repair and Regeneration. Int J Mol Sci, 2022 Mar 31;23(7): 3869.

SUGGESTED READINGS:

1. Principle of Gene manipulation and Genomics, Primrose and Twyman, 7th edition, 2006.
2. Gene Cloning and DNA Analysis, TA Brown, 6th edition, 2010.
3. Molecular Biotechnology: Principles and Applications of Recombinant DNA, Glick, Paten, 4th edition, 2010. From Genes to Genomes: Concepts and Applications of DNA Technology, Dale and Schantz, 3rd edition, 2002.
4. Review articles from: Nature Reviews, journals etc.

Recombinant DNA Technology and Biotechnology Practical:

1. Primer designing for gene amplification using PCR, and different types of primers for real time PCR based detection or analysis
2. Preparation of Various solutions and Buffers, cell culture LB (Luria-Bertani) media preparation, LB-Agar Plates, Ampicillin Antibiotics preparation, autoclaving, sterilized surface, laminar flow operation.
3. Adopting the calcium chloride methodology for Competent cell preparation
4. Polymerase Chain Reaction-based gene amplification and recombinant formation using cloning vector
5. Recombinant plasmid isolation and preparation
6. Recombinant restriction digestion of DNA and excision of DNA from Agarose gel

7. Heat shock methodology-based recombinant transformation, competent efficiency calculation and Blue white colony screening
8. Application of Polymerase Chain Reaction-based infectious or non-infectious disease diagnosis
9. Concept of cell culture (Demonstration)

DSC-10 BIOINFORMATICS, COMPUTATIONAL BIOLOGY AND DRUG DESIGN**Duration: 45 Hours + 30 Hour (Practical)**

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Bioinformatics, Computational biology and Drug Design (DSC-10)	4	3	0	1	Graduation	NIL

LEARNING OBJECTIVES:

- This course has been designed for the students of Biomedical Sciences and related areas who are interested to study various technologies and tools in Bioinformatics, Computational Biology and Drug Design.
- The course has been designed to cater needs of students working in various laboratories in the field of Biomedical sciences and the students entering into this much demanding area of research.
- The aim of the course is to train the students in various tools available to aid research in the area of Bioinformatics, computational Biology and drug design.
- The students will be given training in the theoretical aspects of these methods and practical use of the computational tools available to carry out research in Biology and Drug Design.

LEARNING OUTCOMES:

- *Biological databases, Sequence Alignment and Phylogenetic Analysis.* Students will be able to learn biological and bioinformatics databases, sequence alignments, scoring the alignment, phylogeny analysis and basics of Next Gen sequencing techniques.
- *Structural Biology:* Students will learn various aspects of Protein structure. Students will be familiarized with secondary structures elements, the visualization using various online software, cavity analysis, methods of protein structure determination, predicting protein secondary and tertiary structure, oligomeric proteins.
- *Systems Biology:* Students will learn basics of system biology networks, graph theory, uses etc. Topology of networks, different types of networks, computational tools for analysing networks, clustering etc,
- *Molecular modelling and molecular dynamics:* Students will learn how molecular modelling methods have evolved and integrate into modern, multidisciplinary structure-based design. Summarise the key concepts surrounding the potential energy surface,

including methods of energy calculation and exploration, and appreciate the advantages and limitations of these methods, Describe various molecular dynamics methods.

- *Drug design using case studies* Describe computer-based 2D and 3D approaches to drug design and discovery, including functional group mapping, virtual screening, de novo design, quantitative-structure activity relationships and database analysis.
- *Structure Activity Relationships.* Compare and contrast 2D and 3D approaches QSAR and other computer-aided drug design, giving examples of their use in drug discovery projects.

Unit I: Biological databases, Sequence Alignment and structural Biology **12 hours**

Introduction to various databases and their classification (primary and secondary databases). Local and global sequence alignments (Needleman-Wunsch and Smith-Waterman algorithms), pair-wise (BLAST and FASTA algorithms) and multiple sequence alignment (Clustal W) and its importance. BLAST score, amino acid substitution, matrices, s-value and e-value, calculating the alignment score and significance of e and p value. Basics and tools for phylogenetic analysis, cladistics, tree-building methods (character and distance - based methods), Construction of phylogenetic trees (PHYLIP) and identifying homologs. Basics of Next Generation Sequencing and data analysis

Structural Biology

6 hours

Folding and flexibility, Prediction, engineering and design of protein structures. Methods to identify secondary structural elements, Structure visualization using PyMol and VMD, active site determination, Cavity analysis using CASTP or ACSITE or similar tools. Determination of protein structures by X-ray and NMR methods. Prediction of secondary structure- PHD and PSI-PRED methods. Tertiary Structure: homology modelling, fold recognition and ab-initio approaches. Structures of oligomeric proteins and study of interaction interfaces.

Essential Readings:

1. Chapter 1-7; Bioinformatics: Sequence and Genome analysis, 2nd edition (2004), David W. Mount, Cold Spring Harbour Laboratory Press. ISBN-13: 978-0879697129.

Unit II: Systems Biology: **6 hours**

Systems Biology Networks- basics of computer networks, Graph Theory, Biological uses and Integration. Topology of biological networks: Random vs Scale-Free networks. Metabolic networks, Signal transduction networks, Gene regulatory networks. Databases on metabolic & signaling pathways. Creating networks and analysis, Cytoscape and Pajek, STRING, KEGGS and other annotation tools.

Introduction to computational tools for analysis (Network analysis & clustering) of high throughput data from genomics (NGS), transcriptomics (Microarray/RNASeq), proteomics & metabolomics.

Essential Readings:

1. Systems Biology: Definitions and perspectives by L. Alberghina H.V. Westerhoff, Springer. 2005
2. Chapter 1-3: Bioinformatics and Systems Biology by Frederick B. Marcus, 2008 Springer-Verlag Berlin Heidelberg.

Unit III: Molecular Modelling and Molecular Dynamics

11 hours

Molecular Mechanics: Introduction, The Morse Potential, The Harmonic Oscillator Model for Molecules, Comparison of Morse and Harmonic Potential, Types of Force Fields: AMBER, CHARMM, Merck Molecular Force Field, Consistent Force Field, MM2, MM3 and MM4 force fields.

Potential Energy Surface: Convergence Criteria, Characterizing Stationary Points, Search for Transition States. Optimization- multivariable Optimization Algorithms, level Sets, Level Curves, Gradients, Optimization Criteria, Unidirectional Search, Finding Minimum Point, Gradient based Methods -Steepest Descent and Conjugate Gradient Methods

Molecular Dynamics Simulations: Introduction, Radial distribution functions, Pair Correlation function, Newtonian dynamics, Integrators- Leapfrog and Verlet algorithm, Potential truncation and shifted-force potentials, Implicit and explicit Solvation models, Periodic boundary conditions, Temperature and pressure control in molecular dynamics simulations

Essential Readings

1. Chapter 4-6: Molecular Modelling for Beginners, (2nd Edition) by Alan Hinchliffe, John Wiley & Sons Ltd. Edn, 2nd, 2008.

Unit IV: Drug design using case studies and structure-activity relationships 10 hours

Drug discovery process. Target identification and validation, lead optimization and validation. Methods and Tools in Computer-aided molecular Design, Analog Based drug design- Pharmacophores (3D database searching, conformation searches, deriving and using 3D Pharmacophore, constrained systematic search, Genetic Algorithm, clique detection techniques, maximum likelihood method)

Structure-based drug design: Docking, De Novo Drug Design (Fragment Placements, Connection Methods, Sequential Grow), Virtual screening.

Introduction to QSAR, QSPR, Various Descriptors used in QSARs: Electronic, Topology, Quantum Chemical-based Descriptors. 3D-QSAR, Regression Analysis, The Significance and Validity of QSAR Regression Equations, Partial Least Squares (PLS) Analysis, Multi-Linear Regression Analysis.

Essential Readings:

1. Chapter 1-3: Cheminformatics in Drug Discovery (2006), edited by. T.I. Opera; Wiley Publishers, ISBN: 9783527604203.
2. Chapter 1-4; Comprehensive Medicinal Chemistry III, Editors- David P. Rotella, and Simon E. Ward, 4th Edition - May 1, 2026, Elsevier.

3. Review: Computational methods in drug discovery by Sumudu P. Leelananda and Steffen Lindert, *Beilstein J. Org. Chem.* 2016, 12, 2694–2718. doi:10.3762/bjoc.12.267.

SUGGESTED READINGS:

1. Bioinformatics: A practical guide to the analysis of genes and proteins, 3rd edition (2004), Andreas D. Baxeavanis and B.F. Francis Ouellette, John Wiley and Sons. ISBN-13: 978-0471478782.
2. Systems Biology: Definitions and perspectives by L. Alberghina H.V. Westerhoff, Springer. 2005
3. The Process of New Drug Discovery and Development, 2nd edition (2006), C.G. Smith and J.T. O'Donnell, Informa Healthcare, ISBN-13: 978-0849327797.
4. Molecular Modelling - Principles and Applications, 2nd edition (2003), A. R. Leach, Pearson Education Limited, UK. ISBN 13: 9780582382107.
5. Cheminformatics in Drug Discovery (2006), edited by. T.I. Opera; Wiley Publishers, ISBN: 9783527604203.
6. Protein structure, stability and folding Ed KP. Murphy, Humana press. 2001.
7. Cheminformatics: A textbook (2004), J. Gasteiger, Thomas Engel; Wiley-VCH. ISBN: 9783527618279.
8. Molecular dynamics simulation: elementary methods (1997), J. M. Haile, Wiley-Interscience, New York. ISBN-13: 978-0471184393.
9. Molecular Docking for Computer -Aided Drug Design, Mohane S. Coumar, Elsevier, 2021.

Practicals

30 hours

1. To understand various primary and secondary databases -NCBI, EMBL, IBDC, DDBJ.
2. To perform pairwise sequence alignment using BLAST.
3. To perform phylogeny analysis using COBALT software on NCBI.
4. To perform homology modelling of a protein using a template-based method.
5. To download and visualise a protein structure to identify the binding site of a protein.
6. To draw and minimize the energy of a small molecule using gradient methods and perform conformational analysis.
7. To perform virtual screening of a library of compounds using docking and analysing the results.
8. To develop a structure-based pharmacophore modelling and screen library of compounds.
9. To perform Molecular dynamics of a protein ligand complex and calculate binding affinities.

**Discipline-Specific Core course related to the area identified for research for Research Only
Masters in Biomedical Science (Structure 3)**

Semester 3 (Two-year M.Sc.)/Semester 1 (One-year M.Sc.)

DSC -11. Emerging Techniques and Applications in Biomedical Research

Duration: 45 Hours + 15 Hours (Tutorial)

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Emerging Techniques and Applications in Biomedical Research DSC-11.	4	3	1	0	Graduation	NIL

Learning Objectives

- This course will help students to gain knowledge in state-of-the-art, innovative newer techniques that are used in the field of Biomedical Research.
- The course has been designed to provide the basics and applications of Modern Molecular Biology Techniques, Next Generation Sequencing (NGS), advanced microscopic techniques, flow cytometry, LiquiChip, Bioinformatics to understand system biology, Applications of Machine Learning and Artificial Intelligence in the field of Biology, Biomedical Sensors, Microrobotics, Organ-on-a-chip, microfluidics, etc.

Learning Outcomes: After completing the course, the students are expected to

- Explain various methods of gene editing, creating knock-out and knock-in transgenic animals, cre-lox and CRISPR-Cas system.
- They will be able to explain NGS methods such as Transcriptomics: microarray, RNAseq, exome sequencing, epigenome analysis, ChIP-sequencing etc.
- They will be able to understand advanced tools in microscopy, such as confocal, two-photon, SEM and TEM, to study subcellular localisation and cellular architecture.
- They will understand the basics and applications of the LiquiChip assay and Fine Needle Aspiration Cytology (FNAC)
- Using siRNAs, microRNAs, circRNAs and RNA sponging etc. for studying cellular pathways.

- Use of Bioinformatics techniques to have system-level understanding of diseases through data analysis, biological networks, and clustering data from genomics and proteomics experiments.
- Describe how ML/AI are used in to regulatory genomics, variant scoring, population genetics, electronic health record and medical imaging data.
- They will be able to describe applications of modern and emerging techniques in the field of medicine such as microrobotics, organ-on-a-chip, microfluidics, and wearable biomedical sensors.

Unit I: Modern Molecular Biology Techniques

10 Hours

- **Gene editing:** Generation of disease models for Biomedical Research, Transgenic animals, targeted Knock-out and knock-in, Cre-lox and CRISPR-Cas system. Applications in the field of gene editing, understanding disease mechanisms, developing gene therapies, and engineering model organisms.
- **Next-Generation Sequencing (NGS):** Next-Generation Sequencing methods. Transcriptomics: Microarray, RNA-sequencing, exome sequencing, exome Chip, Tools for epigenome analysis: DNA methylation analysis, Chromatin Immunoprecipitation (ChIP), ChIP-sequencing. Applications including identifying genetic mutations in cancer, tracking viral evolution, and advancing personalized medicine.

Essential Readings:

1. Li, T., Yang, Y., Qi, H. et al. CRISPR/Cas9 therapeutics: progress and prospects. *Sig Transduct Target Ther* 8, 36 (2023). <https://doi.org/10.1038/s41392-023-01309-7>.
2. *Bioinformatics: A practical guide to Next Generation Sequencing Data Analysis*, Hamid D, Ismail, CRC Press, 1st Edition, 2023.

Unit II: Cellular and tissue-based techniques

15 Hours

- Advanced Microscopic applications such as confocal microscopy, two-photon microscope to pinpoint subcellular localisation of intracellular proteins and pathogens in infected cells. SEM and TEM to study cellular and microbial architecture.
- Flow cytometry principles, experimental strategies and analyses to study Immunophenotyping sorting of specific cell types, intracellular-cytokine staining in co-cultures, Real-time kinetic analyses to identify second messengers, Cytometric bead array, cytokine release assay. Cell cycle analysis, apoptosis detection, cancer stem cell identification, and cancer subtype assessment, applications in infectious and inflammatory disease markers. Overview of spectral flow imaging.
- LiquiChip assays to study cytokines in biopsies. Emerging vaccines and immune-therapeutic strategies to treat infections and lifestyle disorders.
- Haemodynamic measurements and behaviour techniques in model organisms.

Essential Readings

1. Confocal Microscopy and Multiphoton Excitation Microscopy The Genesis of Live Cell Imaging by Barry R. Masters · 2006. SPIE Press.
2. Flow Cytometry: Principles, Applications and Clinical perspectives. 2024. Ranbir Chander Sobti, Awtar Krishan, Devendra K. Agrawal. Springer.
3. Immunology & Serology in Laboratory Medicine - E-BOOK, By Mary Louise Turgeon · 2024. Elsevier.

Unit III: Computational and analytical techniques**10 Hours**

- **Bioinformatics:** Biological databases, sequence alignments, Phylogenetics, Systems Biology, Network analysis & clustering of high-throughput data from genomics (NGS), Transcriptomics (Microarray/RNA Seq), Proteomics and metabolomics. Pathway visualisation, creating networks and analysis, Cytoscape, STRING, KEGGS and other annotation tools.
- **Computational and Structural Biology:** Databases of structural data, Protein structure analysis, classification, prediction and docking, Secondary structure prediction of protein using PHD and PSI-PRED methods; techniques to determine protein structures: X-ray, Cryo-EM and NMR techniques: Basics and applications for protein structure determination.
- **Artificial intelligence (AI) and machine learning:** Overview of ML/AI in Biomedical Sciences, Applications to regulatory genomics, variant scoring, population genetics, electronic health record and medical imaging data.

Essential Readings:

1. Chapter 1-3: Bioinformatics and Systems Biology by Frederick B. Marcus, 2008 Springer-Verlag Berlin Heidelberg.
2. Gáspári, Z. (2020). Structural Bioinformatics: Methods and Protocols (Methods in Molecular Biology, 2112) (1st ed. 2020 ed.). Springer.
3. Structural Bioinformatics, 2nd Edition by [Jenny Gu \(Editor\)](#), [Philip E. Bourne \(Editor\)](#), ISBN: 978-0-470-18105-8. 2009, Wiley-Blackwell
4. Chapter 1 & 2, Artificial Intelligence and Machine Learning in Healthcare, 1st Edition 2025, [Academic Press](#), Editor: Arman Kilic, ISBN: 9780128225189, eBook ISBN: 9780128225196

Unit IV: Emerging technologies**10 Hours**

- **Wearable biomedical sensors:** Principles of biosensor operation, types of sensors (optical, chemical, electrical), and sensor characteristics like sensitivity, selectivity, and stability. Use of wearable devices with sensors for continuous, real-time health monitoring and data collection. light-based sensors such as image sensors, glucose sensors, heart rate sensors, and ExG sensors, Implantable devices for neurological disorders

- **Organoids:** Culture and maintenance of 3D-cell/tissue cultures, Applications of organoids in preclinical and biomedical research
- **Organ-on-a-chip and microfluidics:** Introduction to Biomicrofluidics, Fluidics in living systems, Surface tension driven flows, electrokinetics, On-Chip Cellular assay techniques. Applications -Genetic analysis, production of Monoclonal antibody, rapid diagnostics of diseases etc.

Essential Readings

1. Sensors in Biomedical Applications Fundamentals, Technology and Applications, By Gabor Harsanyi, 1st Edition, 2000, CRC Press.
2. Yang S, Hu H, Kung H, Zou R, Dai Y, Hu Y, Wang T, Lv T, Yu J, Li F. Organoids: The current status and biomedical applications. *MedComm* (2020). 2023 May 17;4(3):e274. doi: 10.1002/mco2.274. PMID: 37215622; PMCID: PMC10192887.
3. Chapter 1-5, *Microfluidics and Multi Organs on Chip*, P. V. Mohanan (Editor), 2022, Springer

Tutorials

15 Hours

- Seminars by students on recent papers/trends published in relevant journals.
- Quizzes and Debates.
- Revision of Specific topics; reinforcement of key concepts.
- Case studies, where applicable.
- Group Discussion.
- Theoretical critiques and hypotheses development.

Discipline-specific Electives (DSEs) to be offered in 3rd and 4th semester of two-year masters programme and 1st and 2nd semester of one-year degree programme

(For Structures 1, 2 and 3)

Pool of Discipline Specific Elective Courses to be offered in the 3rd semester[#]	viii. Human Physiology II
	ix. Medicinal Chemistry
	x. Neurobiology
	xi. Advanced Immunology
	xii. Genome Biology
Pool of Discipline Specific Elective Courses to be offered in the 4th Semester^{##}	xiii. Molecular Oncology
	xiv. Viral & Fungal Diseases
	xv. Advanced Toxicology
	xvi. New Methods in Organic Synthesis
	xvii. Applications of ML, DL and AI in Biomedical Science
	xviii. Advances in Protein Sciences

DSE-viii HUMAN PHYSIOLOGY II**Duration: 60 Hours**

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Human Physiology II (DSE-viii)	4	3	1	0	Graduation	NIL

LEARNING OBJECTIVES

The goal of human physiology is to explain the physical and chemical factors that are responsible for our origin and sustainability of life. In human physiology-II course, we attempt to explain the various features and mechanisms of the functioning of Respiratory, Excretory, Gastrointestinal, Reproductive and Endocrine system and their regulation by autonomic nervous system.

- This course deals with the detailed physiology of Respiratory, Excretory, Gastrointestinal, Reproductive and Endocrine system including their structure and functioning.
- Understanding how various organ systems are regulated by autonomic nervous system to maintain homeostasis under physiological and pathological conditions.
- Applying the basic knowledge of physiology to understand the cause and consequences of various clinical conditions associated with different organ systems.
- Further students will develop skills for scientific research to understand the mechanisms of physiological processes disrupted in disease states and exploring novel therapeutic approaches.

LEARNING OUTCOME

This course is an elective course and a continuation of Human Physiology I to be offered in the third semester. On satisfying the requirements of this course, **students will have the knowledge and skills to:**

- Describe the anatomy and histology of major organ systems.
- Explain the functioning of these organ systems in the maintenance of normal and healthy individuals
- Narrate the contribution of each organ system to the maintenance of homeostasis.
- Interpret and analyze the human physiological data and responses to experimental conditions
- Understand the physiological processes accurately with relevant scientific terminology and nomenclature leading to develop more consciousness towards a healthy body.
- List the physiological principles underlying pathogenesis and treatment of disease.

Unit I: Autonomic nervous system and Endocrine System**15 Hours**

System Introduction Anatomic Organization of Autonomic Outflow Chemical Transmission at autonomic Junctions Responses of Effector Organs to Autonomic Nerve Impulses Cholinergic and Adrenergic Discharge.

Hypothalamic Function: Autonomic Function, Cyclic Phenomena and circadian rhythm, Hunger Thirst Control of Posterior Pituitary Secretion Control of Anterior pituitary Secretion Temperature Regulation, fever.

Anatomy and structure, formation, secretion and regulation of hormones, hypo- and hyper secretions.

Diseases of the following glands Thyroid, Adrenal, Parathyroid, Pituitary Thyroid Anatomic Considerations, Formation & Secretion of Thyroid Hormones, Transport of Thyroid Hormones, Effects of Thyroid Hormones, Regulation of Thyroid Secretion, Clinical Correlates. The Parathyroid Glands, Calcitonin, Effects of Other Hormones & Humoral Agents on Calcium Metabolism, Posterior pituitary hormones Growth Hormone

Adrenal Medulla, Structure & Function of Medullary Hormones: Regulation of Adrenal Medullary Secretion, Adrenal Cortex Structure & Biosynthesis of Adrenocortical Hormones, Effects of Adrenal Androgens & Estrogens, Physiologic, Pharmacologic & Pathologic considerations

Effects of Glucocorticoids, Regulation of Glucocorticoid Secretion, Effects of Mineralocorticoids, Regulation of Aldosterone Secretion, Summary of the effects of Adrenocortical Hyper & Hypofunction in Humans.

Essential Readings:

1. Textbook of medical physiology by Arthur C. Guyton and John E. Hall; Ed.13th & 14th 2016. (Unit XI: The Nervous System: Motor and Integrative Neurophysiology-Chapter 61: The Autonomic Nervous System and Adrenal Medulla, Page no.773; Unit XIV: Endocrinology and Reproduction, Page no. 923).
2. Reviews on above topics published in Journals like Clinical Autonomic Research, Autonomic Neuroscience, Journal of Autonomic Nervous System, Nature Reviews Endocrinology and Frontiers in Endocrinology, Journal of Clinical Endocrinology & Metabolism, Endocrine Reviews etc.

Unit II: Respiratory and Excretory system

15 Hours

Respiratory System: Anatomy and Functions of respiratory passageways, pulmonary circulation, pulmonary edema and pleural fluid.

Pulmonary ventilation: mechanisms of pulmonary ventilation, pulmonary volumes and capacities, alveolar ventilation. Physical principles of gas exchange, Diffusion of gases through respiratory membrane, Transport of oxygen and carbon dioxide in blood and body fluids.

Regulation of respiration: respiratory center, peripheral chemoreceptor system, central chemoreceptor system and their regulatory function.

Respiratory Adjustments in Health & Disease: Effects of Exercise, Other Forms of Hypoxia, Oxygen Treatment, Hypercapnia & Hypocapnia, Effects of Increased Barometric Pressure, Artificial Respiration, Respiratory acidosis and alkalosis, Regulation of acid-base balance.

Body fluid and excretory system

Body fluid compartments: Basic principles of osmosis and osmotic pressure: Extracellular and intracellular fluids, Interstitial fluid and edema with its etiology.

Urine formation by kidneys: renal blood flow and their control, Glomerular filtration, Determinants of glomerular filtration rate, Tubular processing of glomerular filtrate, Reabsorption and secretion along different parts of nephron

Regulation of tubular reabsorption, Functions of kidneys in homeostasis, Diuretics, Micturition and disorders of Non-excretory function of kidney, Integration of renal mechanisms for control of blood volume and extracellular fluid volume.

Regulation of extracellular fluid osmolarity and sodium concentration, Role of thirst in controlling extracellular fluid osmolarity and sodium concentration, Renal regulation of potassium, calcium, phosphate and magnesium.

Essential Readings:

1. Textbook of medical physiology by Arthur C. Guyton and John E. Hall; Ed.13th & 14th 2016. (Unit VII: Respiration, Page no.495 to 557, Unit V: The Body Fluids and Kidney, Page no.303 to 442).
2. Reviews on above topics published in Journals like, European Respiratory, Respiratory Medicine, The Open Respiratory Medicine Journal, The Journal of Pulmonology and Respiratory Research, Journal of Body Fluids, Fluids, Journal of the American Society of Nephrology (JASN), American Journal of Kidney Diseases (AJKD), Kidney International etc.

Unit III: Gastrointestinal system

8 Hours

Histology of Gut with Characteristic features and functioning of smooth muscle lining the gastrointestinal tract.

General principles of gastrointestinal function - motility, nervous control, and blood circulation, Transport and mixing of food in the entire alimentary tract, sphincters of gastrointestinal tract.

Ingestion of food, vomiting, motor functions of stomach, Defecation and its control.

Secretory functions of alimentary tract: Secretion of saliva, Gastric secretion, pancreatic secretion, Secretion of bile by liver, Secretions of small and large intestine.

Digestion and absorption in gastrointestinal tract, Digestion of various foods, Neuronal regulation of feeding, obesity and starvation, Representative types of gastrointestinal Malfunction/disorders

Essential Readings:

1. Textbook of medical physiology by Arthur C. Guyton and John E. Hall; Ed.13th & 14th 2016. (Unit XII: Gastrointestinal Physiology, Page no. 795 to 850).
2. Reviews on above topics published in Journals like American Journal of Physiology, American Journal of Gastroenterology, World Journal of Gastroenterology, Gastroenterology etc.

Unit IV: Reproductive system**7 Hours**

Anatomical and functional aspects of human genital system: Sex Differentiation & Development, Aberrant Sexual Differentiation, Embryology of the Human Reproductive System, defects of reproductive system, Puberty: Precocious & Delayed Puberty, Menopause

Male: Gametogenesis, Development structure and function of testis with Ejaculation, Control of Testicular Function, Abnormalities of Testicular Function

Female: Gametogenesis Development structure and function of ovary The Menstrual Cycle, Control of Ovarian Function, Abnormalities of Ovarian Function

Pregnancy: conception, fetal development, placenta, parturition, Lactation, fertility and infertility, Physiological concepts for a planned family

Essential Readings:

1. Textbook of medical physiology by Arthur C. Guyton and John E. Hall; Ed.13th & 14th 2016. (Unit XIV: Endocrinology and Reproduction, Page no.1021 to 1080).
2. **Reviews** on above topics published in Journals like Reproductive health, Reproductive sciences, Fertility and Sterility, Human Reproduction, and Human Reproduction Update etc.

Suggested Readings:

1. Jain, A.K. (2020). Human Physiology In Nutshell (5th ed.). Arya Publishing Company.
2. Review of medical physiology by William F. Ganong; Ed. 26th Edition; McGraw Hill; 2019. By Kim Barrett, Susan Barman, Jason Yuan and Heddwen Brooks. ISBN10: 126012240.
3. Textbook of medical physiology by Arthur C. Guyton and John E. Hall; Ed.13th & 14th 2016.
4. Physiological Reviews, American Physiological society, journals.physiology.org, 2025
5. Human Physiology by Gillian Pocock, Christopher D. Richards, and David A. Richards Fifth Edition, 2017.
6. Principles of anatomy and physiology by Gerard J. Tortora and Bryan Derrickson; Ed.15th; John Wiley; 2016.
7. Human Physiology: An Integrated Approach Plus Mastering A&P with Dee Unglaub Silverthorn, 7th Edition, 2016.
8. Hole's Human Anatomy & Physiology, McGraw-Hill Education; 14th edition, 2015.
9. Medical Physiology: A cellular and molecular approach by Walter F. Boron and Emile L. Boulpaep; Saunders; Ed. 3rd, 2017.
10. Physiology by Robert M. Berne and Matthew N. Levy; Mosby; ELSEVIER, Ed.7th 2018.
11. Essentials of Anatomy & Physiology Plus Mastering A&P with Pearson (7th Edition) 2016.

DSE-ix

MEDICINAL CHEMISTRY**Duration: 60 Hours**

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Medicinal Chemistry (DSE-ix)	4	3	1	0	Graduation	NIL

LEARNING OBJECTIVES:

- The course includes theoretical studies in the field of Medicinal Chemistry.
- This encompasses the de-novo approach to design of drug candidates, the potential physico-chemical interaction between low molecular-weight compounds and biomolecules such as proteins and DNA, plausible biochemical transformations for elimination of small molecules.
- In addition, few examples of rational drug design to target specific protein/ receptor for the human pathologies will be studied.
- The course includes theoretical elements concerning the identification, design, synthesis and evaluation of low molecular weight organic substances for specific pathological states from a perspective of medicinal chemistry.

LEARNING OUTCOMES:

- At the end of the course, students will learn about the principles which guide, modern day medicinal chemistry and drug design, such as different types of receptors and subtypes.
- The students will learn about drug development and use of new technology which guides drug development.
- Important outcomes include understanding new concepts such as use of aptamers in drug development and advances in solid phase synthesis.

Unit I.**12 hours**

Introduction to medicinal chemistry and recent developments in this subject. Intermolecular bonding forces: hydrogen bonding, electrostatic interactions, hydrophobic interactions

A brief overview of proteins, structure of proteins; enzymes specificity and selectivity. Receptors - role of receptors, definitions, Ion channels, DNA and GPCRS, Kinase linked receptors with examples.

Nucleic acid structure and function: DNA as a drug target, Drug DNA binding : Binding via (i) electrostatic interactions (ii) Covalent bonding (iii) non covalent bonding (intercalation and groove binding)

Essential Readings

1. An introduction to Medicinal chemistry by Graham Patrick 7th Edition 2018 Oxford University Press Chapter 1 Section 1.3, Chapter 4, Chapter 9 Section 9.1, 9.2 and 9.3.

2. Relevant Review articles from Journal of Medicinal Chemistry, Nature Chemical Biology and Nature reviews drug discovery.

Unit II.**15 hours**

Pharmacodynamics and Pharmacokinetics: Definitions, enzymes as drugs targets, Intracellular receptors: nuclear receptors. Regulation of receptor activity, receptor signalling pathways

Genetic polymorphisms and receptors: genetic polymorphisms significantly impact receptor structure and function. Control of gene transcription by drugs: Drug DNA binding. Agents that act on RNA, antisense therapy, (therapy which uses short synthetic strands of DNA/ RNA to regulate gene expression

Combinatorial and parallel synthesis. Combinatorial and parallel synthesis used to build library of compounds. Automated/semi-automated process.

Solid phase technique: Reaction carried out on a solid support such as a resin bead; Range of different starting materials can be bound to separate beads

Mix and split technique: Mixed combinatorial synthesis of a mixture in vessel. Molecular structures synthesized on beads: one bead one compound concept. production of a large library of compounds.

Examples of combinatorial synthesis, scaffolds; Designing compound libraries; High throughput screening; Parallel screening

Essential Readings:

1. An introduction to Medicinal chemistry by Graham Patrick 7th Edition 2018 Oxford University Press Chapter 6 Section 6.5, Chapter 7, Chapter 8 Section 7.2
2. Principles of Medicinal Chemistry William O Foye, 8th Ed 2024 (Lippincott, Williams and Wilkens) Chapter 8
3. Relevant latest review articles from Nucleic Acid Research, Nature Biotechnology and similar journals
4. Combinatorial Chemistry: 2 Nicholas K. Terrett 2013 (Oxford Chemistry Masters)
5. Organic Chemistry of Drug Design and Drug action: Richard B Silverman 3rd Ed. 2014 (Elsevier)
6. (Elsevier)
7. An Introduction to medicinal chemistry Graham Patrick 2018 (Oxford University Press)

Unit III.**10 hours**

Quantitative structure-activity relationships (QSAR) studies: Importance in drug development. Hammett equation and Taft equation; HAMMETT parameters, quantitative method to relate structure of a molecule to its reactivity. TAFT, parameters, linear free energy relationship used to analyse the effects of substituents on reaction rates. Hansch equation: parameters used in medicinal chemistry, QSAR to correlate a compound's bioactivity with its physicochemical properties

Craig plot: TOOL to visualize and analyze the properties of substituents on a molecule. To identify bioisosters. Topliss Scheme to optimize the structure of a molecule (for drug development) especially aromatic compounds. Bioisosters. Chemical substituents/groups that can replace other groups, while improving their biological activity.

Essential Readings

1. Organic Chemistry of Drug Design and Drug action: Richard B Silverman 3rd Ed. 2014 (Elsevier)
2. Principles of Medicinal Chemistry William O Foye, 8th Ed 2024 (Lippincott, Williams and Wilkens)

Unit IV**8 hours**

Biotransformation and their mechanism. Cytochrome P450 superfamily of enzymes involved in biotransformations. Phase 1. and Phase 2. Biotransformations. Phase 1 Cyt P450 mediated. Phase 2 polar conjugates of drugs formed which can be excreted. Glucuronidation, sulfation, glutathione conjugation, amino acid conjugation

Aptamer discovery and application, Advances in solid phase synthesis

Essential Readings

1. The transformer database: Biotransformation of Xenobiotics: Michael Hoffmann , Sarah Priessner, Jannett Nickel, Mathias Dunkel, Robert Preissner, Saskia Preissner*
2. Nucleic Acids Research 42, (D1), 2014 (D1113-D1117)
3. Organic chemistry of drug design and drug action by Richard B. Silverman; 3rd Edition, 2014; ELSEVIER;

Tutorials**(15 Hours)**

- Seminars by students on recent papers/trends published in relevant journals.
- Quizzes and Debates.
- Revision of Specific topics; reinforcement of key concepts.
- Case studies, where applicable.
- Group Discussion.
- Theoretical critiques and hypotheses development..

SUGGESTED READINGS:

1. Medicinal chemistry: principles and practice by Frank D. King; Ed. 2nd; The Royal Society of Chemistry; 2002.

DSE-x

NEUROBIOLOGY

Duration: 60 Hours

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Neurobiology (DSE-x)	4	3	1	0	Graduation	NIL

LEARNING OBJECTIVES

The brain is the window to a person's physical existence with surroundings and other people; it is the medium through which a person is able to communicate and express oneself. Moreover, the brain is the organ that not only defines our physical identity but also makes each of us a unique human being.

- This course has been designed to understand the biology of the Nervous system at both molecular and cellular level, laying the foundation in the young minds to explore and solve the mysteries of the human brain.
- Understanding the process of nervous system development and the plasticity in brain in different stages of life.
- Gaining proficiency in neurobiology research techniques with the capability of designing and conducting experiments.

LEARNING OUTCOMES:

This course is an elective course offered in the fourth semester, which is a prerequisite for human physiology I & II. After completing this course, the students will be able to:

- Demonstrate knowledge of, and recognize the relationships between, the structure and function of molecules and tissues involved in neurobiological systems at all levels: molecular, cellular, and organism.
- Perform basic laboratory techniques used in neuroscience research and understand and apply principles of laboratory safety.
- Apply and integrate their knowledge of neuroscience to other areas of their studies and to their everyday life

Unit I: Neural Induction, Pattern Formation and Cell Specification

10 Hours

Neurulation, Neural induction in chicks and humans. Morphogens, Sonic Hedgehog and neural patterning, Floor Plate patterning of ventral cell types: Ventral Patterning, Wnt pathway and neural patterning forebrain development, Midrain development, hindbrain development (spinal cord), neural patterning, Motor neuron specification in vertebrates, Axon Guidance and Synaptogenesis. Bone morphogenetic protein (BMP) signaling in the neuroectoderm, Retinoic Acid Signaling.

Essential Readings:

1. Principles of Neural Science, (Kandel) 5th Edition, 2013 (Part VIII: Development and the Emergence of Behavior, Page no. 1165).
2. **Reviews** on above topics published in Journals like Nature Neuroscience, Nature Reviews Neuroscience, Brain, Neuron, Neurobiology of Disease, Current opinion in Neurobiology, Neuroscience, Progress in Neurobiology etc

Unit II: Neural signaling at molecular level and Cellular differentiation 10 Hours

Wnt signaling, Notch pathway: Lateral inhibition, Helix-loop-helix (bHLH) proteins: proneural, Sox gene expression, Transcriptional networks and silencing. From Stem Cell to Unique Neuron (drosophila and human), macroglial lineage, dopaminergic retinal, haircell, olfactory, oligodendrocytes, Schwann cell differentiation, Neuronal plasticity, Synaptogenesis, plasticity for motor cortex, sensory system and higher brain functions. Autonomic Neuroplasticity, effects of high altitude on the brain and neural plasticity

Essential Readings:

1. Principles of Neural Science, (Kandel) 5th Edition, 2013(Part VIII: Development and the Emergence of Behavior).
2. **Reviews** on above topics published in Journals like Nature Neuroscience, Nature Reviews Neuroscience, Brain, Neuron, Neurobiology of Disease, Current opinion in Neurobiology, Neuroscience, Progress in Neurobiology etc

Unit III: Neurogenesis, Neurotropism, Regeneration and Neurobiology of disease**10 Hours**

Neural cell division, CNS aging, neuronal programmed cell death, autophagy, Neurotrophic factors.

Neurogenesis and stem cells in normal brain aging, Axonal regeneration and sprouting with emphasis on spinal cord injuries and brain trauma.

Essential Readings:

1. Principles of Neural Science, (Kandel) 5th Edition, 2013(Part VIII: Development and the Emergence of Behavior, Diseases of the Nervous System).
2. **Reviews** on above topics published in Journals like Nature Neuroscience, Nature Reviews Neuroscience, Brain, Neuron, Neurobiology of Disease, Current opinion in Neurobiology, Neuroscience, Progress in Neurobiology etc

Unit IV: Methods in neuroscience research**15 Hours**

Brain tissue isolation and preparation for Immunohistochemistry

“Multiomic” approach for biomarker studies,

Neuro-optogenetics, single-cell neuronal dissection and brain slice preparation for electrophysiological studies, stereotaxic injections in various parts of the brain,

Animal models for neurological disorders, behavioral tests: Forced Swim test- Despair/ Depression Test, Elevated Plus Maze- Anxiety Test, Morris Water Maze- Spatial Memory Test, Operant Conditioning- Learning with respect to rewards or punishments

Isolation and culture of neural cell types from various model organisms

In-vitro models for neuroscience

Non-invasive neurophysiological imaging

Essential Readings

1. Principles of Neural Science, (Kandel) 5th Edition, 2013.
2. **Reviews** on above topics published in Journals like Nature Neuroscience, Nature Reviews Neuroscience, Brain, Neuron, Neurobiology of Disease, Current opinion in Neurobiology, Neuroscience, Progress in Neurobiology etc

Tutorials

(15 Hours)

- Seminars by students on recent papers/trends published in relevant journals.
- Quizzes and Debates.
- Revision of Specific topics; reinforcement of key concepts.
- Case studies, where applicable.
- Group Discussion.
- Theoretical critiques and hypotheses development.

SUGGESTED READINGS

1. Principles of Neural Science, (Kandel) 5th Edition, 2013.
2. How Emotions Are Made: The Secret Life of the Brain, Lisa Feldman Barrett January 1, 2017 by Houghton Mifflin Harcourt.
3. Developmental Neurobiology by Lynne Bianchi - Garland Science; 1st edition, October 25, 2017 .
4. Fundamental Neuroscience by Larry Squire, Darwin Berg, Floyd E. Bloom, Sascha du Lac, Anirvan Ghosh, Nicholas G. Spitzer, ELSEVIER, 4th Edition, 2013.
5. Generalized Anxiety, 2016 in Neuroscience Research by Huang-Xiong, Howard E.
6. Guide to Research Techniques in Neuroscience, by Matt Carter Jennifer C. Shieh, Academic Press, 3rd Edition - March 26, 2022.

DSE-xi

ADVANCED IMMUNOLOGY**Duration: 60 Hours**

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Advanced Immunology (DSE-xi)	4	3	1	0	Graduation	NIL

LEARNING OBJECTIVES:

- The course on Advanced Immunology is offered as an Elective paper in the IV semester that builds on the basics taught in the Immunology paper in the II semester.
- The course begins with a recap on the basics of immunology and immune responses.
- The course builds on the fundamentals of immunology acquired in the II semester. Students are taught detailed processes and regulatory mechanisms that govern each and every step in the immune response.
- Emphasis is laid on the recent advances in each aspect of immunology by constant references to peer reviewed papers published in high impact factor journals in the field of immunology.
- Teaching in this course involves discussing research papers published in Scopus Indexed high impact factor journals like Nature Immunology, Science Immunology, ImmUnity, PLoS Pathogens, Cell Host and Microbe, Journal of Immunology, Journal of Experimental Medicine, Lancet to name a few.

LEARNING OUTCOMES:

- At the end of the course the students will have a detailed knowledge of T cell differentiation, activation and regulation.
- Students will appreciate the difference between macro-level regulatory processes that govern systemic and mucosal immune responses.
- Through the referenced journals, they will also appreciate and learn ability to design experiments
- Students also analyse and present papers published in high impact factor journals, thus, additionally acquiring skills in discussing the work of leading experts in the field of immunology and gain confidence in presenting their own work at later times during their research career.
- Thus, after finishing the course a student is well trained in all the major aspects of immunology and how the body reacts and responds to invading pathogens and other antigenic stimulations.

Unit I: Introduction and Recap of Basic Immunology, T Cell and B cell Differentiation, Activation and Functions 19 Hours

Introduction to the Immune system. Adaptive and innate immunity: regulation by Immunoglobulin gene expression, Immunoglobulin loci, TLRs, complement, diversity via gene translocation at Ig loci. Factors regulating immune effector functions. Structure, Function & Antigen processing on MHC class I and MHC class II, factors governing peptide binding, loading and presentation to T cells.

Differentiation of T cells: TCR gene recombination, regulation and function therein. Positive and Negative selection of T cells. Factors regulating T cell diversity and cross-reactivity. T cell migration and turnover. T cell functions during various immune responses.

T and B Lymphocyte Differentiation, Activation and Functions

Heterogeneity in CD4 and CD8 T cell populations. CD4 T cell subsets and functions. TH1/TH2/TH9/TH17/Tfh subsets and functions in immunity and disease. Regulatory T cells and fine-tuning of immune response. Solutions and compromises of studying T cell responses. T cell memory and short-term and long-term immunity.

Differentiation of B lymphocytes. Activation of B cells by Antigens and modulations by co-stimulations. Memory B cell responses, turnover and regulation. Costimulatory networks in immune response building and maintenance. Positive and negative co-stimulation by various molecules during building up, maintenance and termination of immune response. Immune Complex formation and regulation thereof.

Signalling from innate, B cell and T cell receptors: avidity vs affinity of the interactions. Immune synapse and their regulation.

Essential Readings:

1. Fundamental Immunology William Paul (Ed) 2014. Lippincott Williams & Wilkins. Section I, Section IV.
2. Fundamental Immunology William Paul (Ed) 2014. Lippincott Williams & Wilkins. Section II, Section III, Section VI.
3. **Reviews** on above topics Published in latest issues of Journals like: Immunity, Nature Reviews Immunology, Current Opinion in Immunology and Annual Reviews Immunology

Unit II: Myeloid Cell Differentiation and Function. Mucosal Immune Responses

8 Hours

Introduction to myeloid lineage and Myelopoiesis. Role of transcription factors in macrophage and neutrophil development. Neutrophil heterogeneity and plasticity. Molecular mechanisms of neutrophil priming, activation, oxidative burst, degranulation and phagocytosis. Mechanism of NETosis and pathological implications

Introduction to Mucosal immunity vis-à-vis systemic immunity. Intrinsic and extrinsic factors affecting immunity at mucosal surfaces. Mucosal barrier physiology, sensing, and defense. Constituents of mucosal immune system and their role: Epithelial cells, Innate lymphoid cells, Mucosal dendritic cells, Macrophages, T Cells. Secretory

immunoglobulins. Redox biology in mucosal immunity. Exploitation of gaps and weaknesses in the mucosal immunity by pathogens. Mucosal vaccines and diseases.

Essential Readings:

3. Fundamental Immunology William Paul (Ed) 2014. Lippincott Williams & Wilkins. Section V, Section VI.
4. **Reviews** on above topics Published in latest issues of Journals like: ImmUnity, Nature Reviews Immunology, Current Opinion in Immunology and Annual Reviews Immunology

Unit III: Regulation and Deregulation of Immune Responses, Immuno-Therapeutics and Vaccines: 10 Hours

Allergy and systemic and organ-specific Autoimmunity. Noncoding RNAs in regulating immune responses. Role of Autophagy in mediating immune responses. Tumor immunology. Transplantation immunology.

Vaccines against infections and cancers. Current approaches for vaccine design. Short-term and long-term protection: inbuilt mechanisms of innate and adaptive memory. Alternative approaches to chemotherapy vis immuno-therapy and tweaking of the immune system.

Essential Readings:

1. Fundamental Immunology William Paul (Ed) 2024. Lippincott Williams & Wilkins. Section VII:
2. Fundamental Immunology William Paul (Ed) 2014. Lippincott Williams & Wilkins. Section V, Section VIII.
3. **Reviews** on above topics Published in latest issues of Journals like: ImmUnity, Nature Reviews Immunology, Current Opinion in Immunology and Annual Reviews Immunology

Unit IV: Organogenesis and Lymphoid Development 8 Hours

Organogenesis of secondary lymphoid organs: Overview of the immune system, localization of the lymphoid organs in the body, mouse and human. The gross anatomy and functional relevance of lymphoid organs.

Review of Timeline based experiments (literature) of development of Peyer's patches. Review of Timeline based experiments(literature) of development of lymph nodes. Literature review of Early and late patterning of lymphoid genes. Lymphotoxin signalling and secondary lymphoid organ development analysis of NALT, MALT, Peyer's patches and lymph node.

Essential Readings:

1. Fundamental Immunology William Paul (Ed) 2014. Lippincott Williams & Wilkins. Section II.
2. **Reviews** on above topics Published in latest issues of Journals like: ImmUnity, Nature Reviews Immunology, Current Opinion in Immunology and Annual Reviews Immunology

Tutorials 15 Hours

- Seminars by students on recent papers/trends published in relevant journals.
- Quizzes and Debates.
- Revision of Specific topics; reinforcement of key concepts.

- Case studies, where applicable.
- Group Discussion.
- Theoretical critiques and hypotheses development.

SUGGESTED READINGS:

- Roitt's Essential Immunology 2017. Wiley Blackwell
- Kuby Immunology 2013 W. H. Freeman and Company New York

Journals (Latest volumes). Nature Reviews Immunology, Nature Medicine, Nature Immunology, ImmUnity. Cell Host and Microbe. Journal of Experimental Medicine. Journal of Immunology. PLOS Pathogens. Infection and ImmUnity. Journal of Infectious Diseases. Journal of Infection.

DSE -xii

GENOME BIOLOGY**Duration: 60 Hours**

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Genome Biology (DSE-xii)	4	3	1	0	Graduation	NIL

LEARNING OBJECTIVES:

The course will help students to:

- Understand the structure and function of genomes.
- Analyze genome organization, evolution, and variation.
- Examine genome annotation, assembly, and analysis.
- Discuss applications of genome biology in research and medicine.

LEARNING OUTCOMES:

Upon completing this course on Genome Biology, you can expect to achieve the following learning outcomes:

- Understand genome structure and function: Describe the organization, architecture, and function of genomes.
- Analyze genome variation and evolution: Explain the types and consequences of genome variation, and understand genome evolution and phylogenetics.
- Apply genome annotation and assembly: Use genome annotation and assembly methods and tools to analyze genomic data.
- Design genome-based experiments: Design experiments using genome editing and other genome-based approaches to investigate biological questions.

UNIT I: Genome Structure, Annotation, Assembly and Function**14 hours**

Genome organization and architecture : Gene structure and function
 Non-coding regions and regulatory elements
 Genome evolution and comparative genomics
 Pedigree Analysis and Deviations from basic pedigree patterns
 Genome annotation methods and tools
 Genome annotation, Genome assembly strategies algorithms and challenges
 Applications of genome annotation and assembly
 Human Genome Project: History, Goals, Outcomes and ethical issues

Essential readings:

1. Alberts B, Johnson A, Lewis J, Raff M, Roberts K, Walter P. Molecular Biology of the Cell. 7th ed. Garland Science; 2025. Chapter 1, 4, 6 and 7.
2. Klug WS, Palladino MA, Killian D. Concepts of Genetics. 13th ed. Pearson Education; 2025. Chapter 3, 4 and 8.
3. Strachan T, Read AP. Human Molecular Genetics. 5th ed. Routledge; 2023. Part 1 and Part 2

UNIT II: Genome mapping**11 hours**

Constructing Genetic maps at whole genome level.
 Whole genome mapping strategies
 Different types of Physical mapping
 Tools (Vectors- BAC, PAC, YAC and sequencing techniques) and approaches
 (Hierarchical and Shotgun sequencing)
 Visualizing genome maps using databases: UCSC and related browsers

Essential readings:

1. Klug WS, Palladino MA, Killian D. Concepts of Genetics. 13th ed. Pearson Education; 2025. Chapter 5, 6, 10 and 12.

UNIT III: Genome Analysis and Interpretation**12 hours**

Genome data analysis and interpretation
 Phase I and Phase II ENCODE project: Theme, Tools and outcome.
 Genome-wide association studies (GWAS), Exome Sequencing
 Genome editing techniques such as Zinc finger nuclease, TALENS and CRISPR-Cas
 System etc.
 Applications of genome/epigenome analysis in research and medicine

Essential readings:

1. Primrose SB, Twyman RM. Principles of Genome Analysis and Genomics. 3rd ed. Wiley-Blackwell; 2025. Chapter 1, 4, 5 and 6.
2. NHGRI. The ENCODE Project. <https://www.encodeproject.org/>.

UNIT IV: Applications of Genome Biology**8 hours**

Personalized medicine and genomics
 Ayurgenomics, Pharmacogenomics
 Cancer genomics and precision oncology
 Genome editing and gene therapy
 Synthetic biology and genome engineering

Essential readings:

1. Sahin E, Korgaonkar S, editors. Innovations in Precision Medicine and Genomics. IGI Global; 2024. Chapter 1, 5, 8 and 12.
2. Mukerji M. Ayurgenomics-based Frameworks in Precision Medicine. Cambridge Prisms; 2023. Chapter 2 and 4.

Tutorials**15 Hours**

- Seminars by students on recent papers/trends published in relevant journals.
- Quizzes and Debates.
- Revision of Specific topics; reinforcement of key concepts.
- Case studies, where applicable.
- Group Discussion.
- Theoretical critiques and hypotheses development.

SUGGESTED READINGS:

1. Brown, T. A. (2018). Genomes 4. 4th ed. Garland Science.
2. Hartwell et. al. (2017) Genetics: From genes to genomes McGraw Hill; 6th Edition
3. Nussbaum et al (2016) Genetics in Medicine Elsevier Publ ; 8th Edition
4. Jobling, M. A., et al. (2014). Human Evolutionary Genetics. 2nd ed. Garland Science.
5. Primrose, S. B., & Twyman, R. M. (2013). Genomics: Applications in Human Biology. 2nd ed. Wiley-Blackwell.
6. Strachan & Read (2010) Human Molecular, Genetics John Wiley & Sons ; 4th Edition
7. M.R. Speicher, S.E. Antonarakis A.G. Motulsky (2010) Vogel & Motulsky's Human Genetics: Problems and Approaches, 4th Edition Springer Verlag
8. Maroni (2005) Molecular and Genetic Analysis of Human Traits, Blackwell Publishers; 1st Edition

ADDITIONAL RESOURCES:

Original research papers and reviews

DSE-xiii

MOLECULAR ONCOLOGY**Duration: 60 Hours**

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Molecular Oncology (DSE-xiii)	4	3	1	0	Graduation	NIL

LEARNING OBJECTIVES:

- With increase in incidence of cancer in our country, it is considered important to have a basic background of molecular basis of cancer.
- The students will be taught various risk factors and types of cancer. Basic concept of mechanism of carcinogenesis will be taught where in important proteins and pathways will be taught.
- At the end of the course some of the research papers related to these topics will be presented and discussed in the class.

LEARNING OUTCOMES:

- By the end of the course students will be familiar with common carcinogens and how life style can contribute to increase in cancer incident.
- They will also be aware of various steps and different mechanisms that form the basis of differences in cancer progression and drug response.
- A basic understanding of various techniques that can be used so as to do decipher these pathways and to identify the proteins involved in cancer will help them in pursuing research in this important area.

Unit I: The Cancer Problem and different stages in cancer:**10 Hours**

Introduction to Cancer, various types of cancers, Environmental carcinogens, chemical and physical carcinogens types with examples; Mechanisms of Carcinogenesis (Smoking, tobacco, radiation, alcohol), Various theories, multi-step and multistage processes in cancer, Prognostic factor in cancer patient survival; Schemes of classification, WHO classification, staging and grading of a tumor.

Essential Readings:

1. Roger J.B King, Mike W.Robins, Cancer Biology (Third edition) Chapter 1 to 8, Page 1 to 138.
2. Holland-Frei Cancer Medicine, 6th edition. Kufe DW,Pollock re, Weichselbaum RR et al; BC Decker, 20023; Chapter 17.

Unit II: Cell cycle and Cell death**12 Hours**

Role of DNA damage, Role of RB proteins in cancer, Altered mechanisms of action of Rb protein in cancer cells, Other tumour suppressor proteins, Mismatch repair proteins, Oncoproteins and their examples; Basic concept of proto-oncogene, discovery, gain of function mutations etc. methods to identify; Interaction of various agents in cancer, Differentiation: hyperplasia and precancerous lesions. Strategies of chemoprevention; Cell cycle & Apoptosis, Modulation of the Eukaryotic Cell Cycle check points and related mutations and cell death in cancer, Method to study cell cycle alteration, Oncogene Induced senescence (OIS), Proapoptotic and Antiapoptotic proteins and mechanism of action in controlling apoptosis (Caspases, Bax, Bad, Bid, Mcl), Antiapoptotic Proteins, IAP family proteins. Methods used to study apoptosis (western blotting, Flow cytometry, tunnel assay)

Essential readings (Review Articles):

1. Sajal Raj Singh et al, Exploring the Genetic Orchestra of cancer: The interplay between oncogenes and tumor suppressors. *Cancers* 2025, 17 (7),1082
2. Claire M Pfeffer et al. Apoptosis : A target for anticancer therapy. *Int J Mol Sci*, 2018 Feb 2; 19 (2) 448
3. Haoran Zhu et al. Oncogene induced senescence: From biology to therapy. Mechanism of ageing and development, Vol, 187, 2020, 111229

Unit III: Cell-Cell Interactions and Angiogenesis in development of cancer: 13 Hours

Cell-cell interaction, integrins, and other proteins involved in cellular adhesion, Concept of invasion, changes in cellular proteins, Mechanism of invasion by cancerous cells. Metalloproteases and their role in cancer metastasis, Concepts and molecular mechanism of Neoangiogenesis, Methods to study angiogenesis. Role and mechanism of viral oncogenes with 1-2 examples; Role of cellular oncogenes in altered gene regulation (basic mechanisms of action)

Essential readings (Review articles):

1. N.V Krakhmal. Cancer Invasion: Patterns and mechanisms. *Acta Naturae*, 2015 Apr-Jun; 7 (2): 17-28
2. Na Xie et al. Neoantigens: promising targets for cancer therapy. *Signal transduction and targeted therapy* 8 Article number: 9 (2023).
3. Michael W Irvin. Techniques and assays for the study of angiogenesis. *Exp Bio Med (Maywood)*. 2014 May 28;239(11):1476-1488.
4. Laila C. Roudsari. Studying the influence of angiogenesis in invitro cancer mode lsystems. *Advanced Drug Delivery Reviews*, Vol 97, Feb 2016 pages: 250-259.
5. Qing Xiao et al. Viral oncogenesis in cancer: From mechanism to therapeutics. *Signal Tranduction and targeted Therapy* 10, article 151 (2025)

Unit IV: Growth factor-signalling pathways in cancer & Chemo-resistance 10 Hours

Relationship between oncogene products and growth factors, Understanding altered pathways using example of receptor kinases, EGFR, Src, Wnt signalling and Ras

factors, Various drugs used to treat cancer, challenges to deal with Tumor reoccurrence and relapse. The relevant new occurred mutation upon treatment with EGFR inhibitors, allosteric inhibitors to treat cancer, E3 ligase ligands in PROTAC technique to target oncoprotein. Immunotherapeutic, Immune check point control mechanism in cancer progression

Essential readings (Review Articles):

1. Hua-Chuan Zheng. The Molecular mechanisms of chemo-resistance in cancers. *Oncotarget* 2017, 8:59950-59964.
2. Anti apoptotic PROTACS in cancer Therapy: A review Anti apoptotic proteolysis Targeted chimeras (PROTACs) in Cancer therapy. 31 Jan 2025 *Europeoan Society of Medicine*.
3. Shuzhen Tan et al. Cancer immunotherapy: Pros,cons and beyond. *Biomedicine & Pharmacotherapy* Vol 124, April2020, 109821
4. Fangli Ma et al. Allosteric inhibitors for the treatment of cancers (22021): A review from medicinal chemistry perspectives. *Journal of Molecular structure*, vol 1344, 2025, 142985.
5. Tanzida Zubair et al. Small Moleculae EGFRInhibitors as anti- cancer agents: Discovery, Mechanism of actions and opporUnities. *Int J Mol Sci*, 2023 Jn 31;24(3): 2651

Tutorials

15 Hours

- Seminars by students on recent papers/trends published in relevant journals.
- Quizzes and Debates.
- Revision of Specific topics; reinforcement of key concepts.
- Case studies, where applicable.
- Group Discussion.
- Theoretical critiques and hypotheses development.

SUGGESTED READINGS:

1. Principles of Cancer biology, Lewis J Kleinsmith, First Edition - 29 July 2016
2. ISBN-13: 978-9332577480 ISBN-10: 933257748X.
3. Fundamentals of Cancer metabolism: Science Advances 2016.
4. Recent Nature and Cancer review journals articles 2010 to 2025, for example:
 - a. Tumor initiation and early tumorigenesis: molecular mechanisms and interventional targets, 2024
 - b. The evolving tumor microenvironment: From cancer initiation to metastatic outgrowth. *Cancer cell* 2023
 - c. A guide to cancer immunotherapy: from T cell basic science to clinical practice, *Nature review Immunology*, 2020.
 - d. Alterations in Cell-Extracellular Matrix Interactions during Progression of Cancers, 2012

DSE-xiv VIRAL AND FUNGAL DISEASES**Duration: 60 Hours**

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Viral and Fungal Diseases (DSE-xiv)	4	3	1	0	Graduation	NIL

LEARNING OBJECTIVES:

- Medical Virology and Mycology is one of the elective courses for the biomedical sciences students.
- Students will be taught the insights on the nature of various infectious agents and diseases pathologies caused by common fungi and viruses.
- In addition, they will also be acquainted with understanding of pathogenesis, diagnosis, clinical features, virulence factors and treatment strategies of medically important fungi and viruses.
- The structure and function of medically important viruses such as Dengue and Chikungunya viruses will also be studied.
- In addition the detail study of human fungal infections such as fungal Eye, Nail and Skin Infections will be studied in detail.

LEARNING OUTCOMES:

- Students will gain a thorough knowledge on the nature of various infectious agents and diseases pathologies caused by common fungi and viruses (for eg. Candidiasis, aspergillosis small pox, HPV etc.)
- The students will be able to understand the structure and function of medically important viruses such as Zika, Dengue and Chikungunya viruses.
- They will also understand pathogenesis, diagnosis, clinical features, virulence factors and treatment strategies of medically important fungi and viruses.

Unit I: MEDICAL VIROLOGY**9 hours**

Concept of viroids, virusoids, satellite viruses and prions. Theories of viral origin.
 Detail study of DNA Viruses: for e.g. Small pox, Herpes viruses, Human Papilloma viruses, Parvoviruses, adenoviruses, chickenpox, Papova viruses, Hepatitis virus
 Detail study of RNA viruses: for e.g. HIV, Influenza virus, poliovirus, Reoviruses, Rhinovirus, Ebola virus, Enterovirus. Zika virus, Dengue and Chikungunya viruses and SARS CoV2

Essential readings:

1. Prescott's Microbiology by Joanne Willey, Kathleen Sandman, and Dorothy Wood; 12th Edition, McGraw-Hill Education, 2022. Chapter 16, Chapter 17, Chapter 18,
2. Medical Microbiology by Patrick R. Murray, Ken S. Rosenthal, and Michael A. Pfaller; 10th Edition. Elsevier Health Sciences, 2022. Section 5.

Gene regulation and immune responses**8 Hours**

DNA virus transcription and replication, Positive-strand RNA virus replication, Negative-strand RNA virus replication. Regulation of retrovirus replication. Virulence factors and evasion strategies of viruses. Use of viral vectors in cloning and expression, current uses of viruses in gene therapy and vaccine applications.

Essential readings:

1. Louten, J., 2022. Essential human virology. Academic Press. Chapter 4,
2. V'kovski, P., Kratzel, A., Steiner, S. et al. Coronavirus biology and replication: implications for SARS-CoV-2. Nat Rev Microbiol **19**, 155–170 (2021). <https://doi.org/10.1038/s41579-020-00468-6>

Unit II: Epidemiology and Pathogenesis of Viral infections**8 Hours**

Global prevalence and distribution of various medically important viral infections. Tools to study epidemiological data and their analyses. Pathogenesis caused by structural, non-structural and envelop proteins of any three viral infections. The conventional and current methods of diagnosis of viral infections along with the limitations. Alternative strategies towards developing newer tools and technologies in developing diagnostic platforms for viruses.

The current modes of treatment and alternative strategies to combat viral infections *w.r.t* increased reports of resistance. Classical Antiviral compounds, interferons, designing and screening for new antivirals, mechanisms of action, antiviral libraries, antiretrovirals-mechanism of action and drug resistance.

Essential readings:

1. Prescott's Microbiology by Joanne Willey, Kathleen Sandman, and Dorothy Wood; 12th Edition, McGraw-Hill Education, 2022. Chapter 36, Chapter 37.
2. Louten, J., 2022. Essential human virology. Academic Press. Chapter 5.
3. Burrell, C.J., Howard, C.R. and Murphy, F.A., 2017. Epidemiology of viral infections. Fenner and White's Medical Virology. Chapter 13.
4. Holmes, E.C., 2022. The ecology of viral emergence. Annual Review of Virology, 9(1), pp.173-192.

Unit III: Immune responses to viral infections**5 Hours**

The immune responses, both innate and adaptive will be extensively covered. As a prelude the intricacies involved in host-pathogen interactions at the cellular and molecular levels will be discussed in detail. This will include the involvement of cell surface receptors on the pathogen and the host cell and their interactions.

Signal transduction from the pathogen receptors and the immune evasion strategies evolved by different viruses will be discussed.

Essential readings:

1. *Medical Microbiology* by Patrick R. Murray, Ken S. Rosenthal, and Michael A. Pfaller; 10th Edition. Elsevier Health Sciences, 2022. Section 3.

Unit IV: MEDICAL MYCOLOGY

13 Hours

Fungi and their significance, Relationship of fungi with plants and animals, Milestones in mycological and pathological studies. Fungal cell-structure and composition, Physiology of fungal growth, Ecological groups of Fungi, Fungal spores, Molecular method of fungal taxonomy, Fungi as model organism for genetic studies. Cryptococcosis, Candidiasis, Blastomycosis, Aspergillosis, Blastomycosis, Histoplasmosis, Coccidiomycosis, Mucormycosis. Pneumocystis pneumonia

Fungal Eye, Nail and Skin Infections, Central nervous system. Antifungal Therapeutic Agents. Fungal allergies and types of Mushroom Poisoning and other Mycotoxins. Prognosis and Treatment.

Essential readings:

1. *Medical Microbiology* by Patrick R. Murray, Ken S. Rosenthal, and Michael A. Pfaller; 10th Edition. Elsevier Health Sciences, 2022. Section 6.
2. *Prescott's Microbiology* by Joanne Willey, Kathleen Sandman, and Dorothy Wood; 12th Edition, McGraw-Hill Education, 2022. Chapter 39

SUGGESTED READINGS:

1. Fundamental Virology: Fields and Knipe, ed. Raven Press, 1991
2. Strauss, E. G. and Strauss, J. H., "Viruses and Human Disease", Academic Press, 2002
3. Antiviral Drug Discovery for Emerging Diseases and Bioterrorism Threats. Paul F. Torrence (Editor), Wiley, John & Sons, Incorporated. 2005
4. Vaccines. Stanley A. Plotkin, Walter A. Orenstein. Elsevier Health Sciences 2003
5. Flint, S.J., Enquist, L.W., Krug, R. M., Racaniello, V. R., and Skalka, A. M., "Principles of Virology: Molecular Biology, Pathogenesis and Control", ASM Press. 2000
6. Medical microbiology: a guide to microbial infections: pathogenesis, immunity, laboratory diagnosis and control by David Greenwood and Richard C. B. Slack and John F. Peutherer, ed. 17th Ed. Churchill Livingstone; 2007.
7. Essentials of diagnostic microbiology by Lisa Anne Shimeld and Anne T. Rodgers; Delmar Publishers, 1999.
8. Medical Microbiology by Geo. Brooks and Karen C. Carroll and Janet Butel and Stephen Morse; Ed. 24th; McGraw-Hill Medical, 2007

DSE-xv

ADVANCED TOXICOLOGY**Duration: 60 Hours**

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Advanced Toxicology (DSE-xv)	4	3	1	0	Graduation	NIL

LEARNING OBJECTIVES:

- Students will be taught an understanding the basic toxicological principles.
- Students will be taught regarding adverse drug reaction and therapeutic drug monitoring, risk assessment/safety assessment.
- Students will be taught regulation of metabolism for inducing toxicity and different mechanisms for drug, toxicological substances, heavy metal and pesticide.
- The student is expected to own such knowledge and skills on completion of the course that she/he in an independent way can process and present different problems within the subject area.

LEARNING OUTCOMES:

- After completion of the course students will be able to develop the awareness of general
- Principles of environmental, occupational toxicology including toxicovigilance; demonstrate in-depth knowledge of the interaction between exposure to exogenous chemicals and toxic effects in humans. Students will be able to demonstrate a good ability to independently find, summarize and assess scientific information within the field of toxicology, and to be able to use this information in other problems and in assessing the health risks of chemical substances.
- Students develop awareness about adverse drug reactions, therapeutic drug monitoring and Forensic Toxicology.

Unit I: ADVERSE DRUG REACTION AND THERAPEUTIC DRUG MONITORING**6 Hours**

Classifications, adverse interactions, and pharmacokinetic drug interactions, spontaneous case reports, and Adverse drug reaction reporting and management; human risk assessment, Toxicological database. Need for Therapeutic Drug Monitoring, factors to be considered during the Therapeutic Drug Monitoring. Concepts of Toxicogenomics and personalized medicine

Essential readings

1. *Unit 1 & 7: Casarett and Dull's toxicology: the basic science of poisons by Curties D. Klaassen; Ed. 7th; McGraw Hill; New York; 2007*
2. *Section 1: Goodman & Gillman's The Pharmacological Basis Of Therapeutics, Laurence Brunton, Bruce A. Chabner, McGraw Hill Education; 11 edition, 2011*

3. *Section 1 & 4: Principles and practice of toxicology in public health by Ira R. Richards; Jones and Bartlett Publishers;2007*

Unit II: TOXICOLOGY OF HEAVY METALS AND PESTICIDES

17 Hours

Source, exposure, absorption, target site interactions and health hazards of Metallic Pollutants, Mechanisms of heavy metal toxicity- Mercury, lead, arsenic, cadmium, Chromium. Induction of metallothionein, heat shock proteins, cytoskeletal effects, lipid peroxidation, Metal protein interactions, metal nucleic acid interactions.

Source, exposure, absorption, target site interactions and health hazards of trace elements- Iodine, iron, zinc, copper, manganese, selenium.

Pesticides: Brief classification with examples, residual and non-residual pesticides. Mode of entry and mode of action of pesticides in target and non-target organisms. Pesticide bioaccumulation, biomagnification through the food chain

Environmental alteration of pesticides - microbial and solar, fate and dissipation of pesticide residues under tropical and temperate conditions.

Pesticide hazards to man Accidental and occupational exposure, entry through air, food and water, Residue levels in man: Indian experience Vs developed countries; Residues in tissues and organs – distribution and redistribution; Pregnancy and transfer to fetus.

Environmental problems by organochlorine pesticides, Toxicity of pesticides in man - Case studies of DDT, endosulphan, benzene hexachloride (Lindane). Case studies, Handigodu syndrome, Benzene Hexachloride poisoning in Turkey, and endosulphan toxicity in Kerala.

Essential readings:

1. Unit 5: Casarett and Dull's toxicology: the basic science of poisons by Curties D. Klaassen; Ed. 7th; McGraw Hill; New York; 2007
2. Section 15: Goodman & Gillman's The Pharmacological Basis Of Therapeutics, Laurence Brunton, Bruce A. Chabner, McGraw Hill Education; 11 edition, 2011
3. Section 1: Principles and practice of toxicology in public health by Ira R. Richards; Jones and Bartlett Publishers;2007
4. Section 1: Handbook of human toxicology by E.J. Massaro; CRC Press; 1997.

Unit III: APPLIED TOXICOLOGY

5 Hours

Cosmetic toxicology (General overview): Toxicity of shampoos, conditioners, bleachers, dyes, allergic and respiratory disorders.

Forensic toxicology (General overview): Specimen sample collection, types of testing, detection of poisons, applications of forensic toxicology

Toxicology of chemical warfare agents-(General overview): Chemical weapons, mustard gas, lewisite, nerve agents, hydrogen cyanide, management of chemical warfare agents.

A brief review of Radioactive hazard

Essential readings:

1. Chapter 16: Principles of toxicology by Karen E. Stine and Thomas M. Brown; Ed. 3rd; CRC Press; 2006.
2. Chapter 30: Casarett and Dull's toxicology: the basic science of poisons by Curties D. Klaassen; Ed. 7th; McGraw Hill; New York; 2007
3. Chapter 16: Hayes' Principles and Methods of Toxicology, Edited By A. Wallace Hayes, Tetyana Kobets, Seventh Edition

Unit IV: OCCUPATIONAL AND INDUSTRIAL TOXICOLOGY**17 Hours**

Brief review of Occupational hazards and diseases- Pneumoconiosis, silicosis, asbestosis, anthracosis, byssinosis, bagassosis, Farmers' lung, Skin cancer, Lung cancer, Bladder cancer, Leukemia.

Industrial toxicology- History and basic features, Industrial hygiene, Risk assessment – Risk assessment for industrial chemicals in EU, OECD and USA.

Concepts of Industrial hygiene, Threshold Limit Value and Occupational Safety Health Administration etc.

Principles of risk assessment and the role of safety pharmacology in the drug development process and the methodology associated with drug evaluation.

Regulatory toxicology: Regulatory agencies, Regulation of pesticides, pharmaceuticals, and food additives; Narcotic Drugs and Psychotropic substances Act 1985 and Rules. Drugs and cosmetic acts; Food and Drug Administration, Organization of Economic Corporation Development, International conference on harmonization, Schedule Y: Design non-clinical toxicity studies and clinical development. Clinical risk/benefit analysis.

Concept of Good Laboratories Practices, Good Manufacturing Practices, good Clinical Practices.

Essential readings:

1. Unit 7: Casarett and Dull's toxicology: the basic science of poisons by Curties D. Klaassen; Ed. 7th; McGraw Hill; New York; 2007
2. Chapter 15: Principles of toxicology by Karen E. Stine and Thomas M. Brown; Ed. 3rd; CRC Press; 2006.
3. Chapter 19: Principles and practice of toxicology in public health by Ira R. Richards; Jones and Bartlett Publishers; 2007.

Tutorials**15 Hours**

- Seminars by students on recent papers/trends published in relevant journals.
- Quizzes and Debates.
- Revision of Specific topics; reinforcement of key concepts.
- Case studies, where applicable.
- Group Discussion.
- Theoretical critiques and hypotheses development.

SUGGESTED READINGS:

1. Toxicology by Hans Marquardt and S.G. Schafer and R.D. McClellan and Academic Press; 1999.
2. Toxicogenomics-Based Cellular: Alternatives to Animal Testing for Safety Assessment Models, Jos Kleinjans, Academic Press, 1st Ed 2014.
3. Environmental Pollution: Health and Toxicology, S.V.S. Rana , Narosa Publishing House 2nd Edition 2011,
4. Textbook of Forensic Medicine and Toxicology, Anil Aggrawal, Avichal Publishing Company, 2017.
5. Poisoning & Drug Overdose, Kent R. Olson, Ilene B. Anderson, Neal L. Benowitz et al, McGraw-Hill Education, 2018
6. Goldfrank's Toxicologic Emergencies Hardcover, Lewis Goldfrank , Neal Lewin , McGraw Hill Education/Exclusively distd. By Jaypee; 10 edition (2014)
7. Principles of toxicology by Karen E. Stine and Thomas M. Brown; Ed. 3rd; CRC Press; 2006.
8. Lu's basic toxicology: fundamentals, target organs and risk assessment by Ung-Mu, Huang Sikkim, Frank C. Lu and Sam Kacew; Ed. 7th; Informa Healthcare; 2009.
9. Principles and practice of toxicology in public health by Ira R. Richards; Jones and Bartlett Publishers; 2013.

DSE-xvi NEW METHODS IN ORGANIC SYNTHESIS

Duration: 60 Hours

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
New Methods in Organic Synthesis (DSE-xvi)	4	3	1	0	Graduation	NIL

LEARNING OBJECTIVES:

- The course aims at understanding the methods by which chemically and biologically important molecules and macromolecules are synthesized and characterized.
- This course includes an overview of nucleotide synthesis, peptide synthesis alkene metathesis, green chemistry and total synthesis of pharmaceutically beneficial compounds.

LEARNING OBJECTIVES:

- At the end of the course students will be well acquainted with the modern methods of organic synthesis and its importance in biomedical sciences

Unit 1 Methods in nucleotide synthesis**10 hours**

Advantages of chemical synthesis. Nucleotides synthesized chemically and enzymatically. Solid phase method for chemical synthesis: sequential addition of nucleotides, attached to a solid support, to form oligonucleotides. Protecting groups: groups which mask reactive functional groups to prevent formation of unwanted byproducts, examples acetyl, benzoyl and silyl groups for protecting hydroxyl group. Nucleoside -3-phosphoramidates: modified nucleoside derivatives and building blocks used in the synthesis of DNA and RNA oligonucleotides. Oligonucleotide synthesis cycle: 4 steps detritylation, coupling oxidation and capping, process repeated for each nucleotide. Automated oligonucleotide synthesizer.

DNA microarrays: DNA chips, miniature analytical devices, containing libraries of oligonucleotides robotically synthesized on solid support, identity of each oligo defined by its location. Light directed chemical synthesis: UV light used to selectively deprotect photolabile protecting groups. Achieved using photolithographic masks to control light exposure. Microarray synthesis using micromirrors maskless array synthesis using digital micromirror devices, Structure validation

Essential Reading:

1. Recent Advances in Chemical synthesis and evaluation of anticancer nucleoside analogs, Mieke Guinan, Caecilie Benckendorff, Mark Smith and Gavin J Miller, *Molecules*, 2020, 25(9), 2050 (MDPI)

Unit 2 Methods in peptide synthesis**8 hours**

Solid phase synthesis of peptides, using solid support, advantages of solid phase synthesis. Protecting groups deprotection: preventing undesired by-product. Structure validation

Essential Readings:

1. From precision synthesis to cross-industry applications. The future of emerging peptide technologies
Ping Wang et al *Pharmacological Research* 218, 2025, 107839

Unit 3 Alkene metathesis**10 hours**

Mechanism: carbon Carbon double bonds formation and cleavage, redistribution of alkene fragments. Metal carbenes contain transition elements bonded to carbene ligands useful in catalyst development e.g. Schrock's catalyst. Schrock's catalyst: a class of highly reactive, transition metal catalysts, primarily used in alkene metathesis reactions. Grubb's catalyst: series of transition metal carbene complexes, used in alkene metathesis. Ruthenium catalysts: used in various reactions including alkene metathesis

Ring closing metathesis: metal catalysts to facilitate intramolecular cyclization of a compound containing two terminal alkenes, forming a cyclic alkene and ethene as a byproduct. Cross metathesis: chemical reaction involving exchange of alkene fragments between 2 different alkene molecules. Macrocyclization: chemical process that leads to the formation of a macrocycle.

Essential Readings:

1. Handbook of Metathesis 3 volumes Edited by Robert H Grubbs, Anna Wenzel, Daniel J O 'Leary
Second Edition (Wiley VCH)
2. Alkene metathesis Edited by Alois Fuerstner (Springer) 2013

Unit 4 Green Chemistry and Total Synthesis**17 hours**

Introduction to Green Chemistry. Principles of Green Chemistry: waste prevention, less hazardous chemical synthesis, safer solvents, renewable feed stocks, green catalysis, atom economy and energy efficiency, designing safer chemicals, real time analysis of pollution prevention. Examples from industry: Synthesis of ethylene oxide-traditional vs green route. Examples for atom economy: Grignard reaction, A3 coupling, Diels-Alder reaction etc. Examples for green organic synthesis: Cope rearrangement, coupling reactions, C-H activation reactions, Grubbs metathesis, Horner-Wadsworth-Emmons reaction

Examples of green methods of molecular design, use of green solvents such as reactions using water, solventless systems, supercritical fluids, ionic liquids etc.

Examples of energy efficient methods: Use of renewable energy in biofuel production, organic, inorganic and hybrid solar cells, Proton exchange membrane fuel cells.

Concept of Total synthesis, constructing natural molecules, retrosynthetic strategies, A few examples of retrosynthetic analysis and total synthesis: Strychnine, Penicillin V, Reserpine, Prostaglandins, progesterone etc.

Essential Readings

1. Green Chemistry: Process Technology and sustainable development Tatsiana savitskaya, Iryna Kim Lenka, Yin Lu et al 2021 (Springer)
2. Green Chemistry: An Introductory Text, Mike Lancaster RSC books 2016
3. Green Chemistry: Principles and Practice, Paul Anastas and Nicolas Eghbali, *Chem. Soc. Rev.*, 2010,39, 301-312.
4. Classics in Total Synthesis, Targets, Strategies, Methods, K.C. Nicolaou and E.J. Sorensen, 6th reprint 2014, Wiley-VCH Publishers.

Tutorials

15 Hours

- Seminars by students on recent papers/trends published in relevant journals.
- Quizzes and Debates.
- Revision of Specific topics; reinforcement of key concepts.
- Case studies, where applicable.
- Group Discussion.
- Theoretical critiques and hypotheses development.

DSE-xvii APPLICATIONS OF ML, DL, AND AI IN BIOMEDICAL SCIENCE

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Applications of ML, DL and AI in Biomedical Science (DSE-xvii)	4	3	1	0	Graduation	NIL

LEARNING OBJECTIVES:

- This course will help students to understand basic concepts of machine learning, deep learning, and its implementation.
- The course has been designed to provide an overview of various methods and algorithms in ML/DL, such as classification, regression, image analysis, etc.
- The course will also cover the implementation of these algorithms with special emphasis on biomedical applications.

LEARNING OUTCOMES: After completing the course, the students are expected to

- Explain the fundamental concepts, goals, and types of machine learning, including supervised, unsupervised, and reinforcement learning.
- Apply probability concepts and Naive Bayes classification to solve basic machine learning problems.
- Implement classification and regression models using logistic regression, decision trees, random forests, boosting, and SVM.
- Evaluate model performance using cross-validation techniques and performance metrics while addressing overfitting and underfitting.
- Describe the architecture of deep learning networks and apply backpropagation for model optimization.
- Utilize CNNs for image analysis tasks such as recognition, object detection, and segmentation.
- Build and fine-tune deep learning models using the Keras library.
- Analyze real-world applications of ML/DL in biology and drug discovery through research papers.
- Describe how ML/DL techniques are used for regulatory genomics, variant scoring, and population genetics.
- Use research papers to demonstrate practical applications of ML/DL in electronic health records and medical imaging.
- Interpret the effectiveness of ML/DL in drug discovery tasks like target identification, bioactivity prediction, and biomolecular interactions.
- Critically review research papers to identify strengths, limitations, and future directions of ML/DL in biomedical sciences.

Unit I. Introduction to ML, Probability, Classification, and Regression Problems

12 hours

History of machine learning; its goals and applications. Types of machine learning: Supervised, Unsupervised, and Reinforcement learning. Types of Supervised learning Methods (classification and regression). Overview of clustering methods with applications in disease classification, Introduction to outlier detection and impact of the curse of dimensionality in biomedical data. Dimensionality reduction using PCA.

Probability and estimation- Random variable independence; Bayes rule; Estimators, Maximum likelihood estimator (MLE), Maximum a posteriori estimator (MAP). Naive Bayes - Bayes Optimal Classifiers, Conditional Independence, Naive Bayes. Learning for Naive Bayes, Gaussian Naive Bayes, Naive Bayes use case: E.g prevalence of a disease.

Classification and Regression methods (LR), Linear regression, Classification using the logistics function, Gradient methods to solve LR (Logistic Regression): gradient descent, stochastic gradient descent, MLE and MAP estimates for LR. Introduction to other Classification and Regression methods such as decision trees, random forest, boosting algorithm, SVM.

Essential Readings:

1. Brownlee, J. (2018). Basics of Linear Algebra for Machine Learning. Machine Learning Mastery.
2. Ponteves, H. D. (2019). AI Crash Course: A fun and hands-on introduction to machine learning, reinforcement learning, deep learning, and artificial intelligence with Python. Packt Publishing.
3. Alpaydin, E. (2020). Introduction to Machine Learning, fourth edition (Adaptive Computation and Machine Learning series) (fourth edition). The MIT Press.

Unit II. Basics of Model Learning and Deep Learning

12 hours

Training, testing, and validation datasets. The criteria to divide these datasets. Techniques for cross-validation- N-fold cross-validation, holdout cross-validation, leave-one-out cross-validation. Hyperparameter tuning. Performance measures for classification and regression (accuracy, precision, sensitivity, specificity, ROC, AUC, MAE, RMSE, R^2 etc.). Overfitting, underfitting, and bias-variance trade-off, regularization techniques.

Basics of deep learning- Introduction of neural network. History of neural network. Layers in deep learning (Input, Hidden and Output layers). Types of deep learning networks (ANN, Feedforward neural network, RNN, CNN), Introduction of Autoencoders for feature extraction and data compression. Backpropagation algorithm. Limitations of deep learning.

Essential Readings:

1. Deitel, P., & Deitel, H. (2019). Intro to Python for Computer Science and Data Science: Learning to Program with AI, Big Data and The Cloud (1st ed.). Pearson.
2. Moolayil, J. (2018). Learn Keras for Deep Neural Networks: A Fast-Track Approach to Modern Deep Learning with Python (1st ed.). Apress.

UNIT III: Convolutional Neural Networks and implementation**11 hours**

Introduction to CNNs and their role in biomedical image analysis (e.g., tumor detection, medical imaging, and pathology slide analysis). Overview of three layers of CNN (Convolution, Pooling, and fully connected). Importing images using matplotlib/open-cv, storing colored images in 3-D arrays.

Construct deep learning models with Keras library- Loading of data using numpy. Defining the model (layers (number and types), number of neurons in each layer etc.) Keras model compilation (loss function, optimizer, metrics), training and assessment. Fine-tuning Keras models- Important steps to fine-tune the model- removing the connected nodes, replacing the old nodes with new ones, freezing the layers, creating the new model, and training.

Essential Readings:

1. Géron, A. (2019). Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems (2nd ed.). O'Reilly Media.
2. Moolayil, J. (2018). Learn Keras for Deep Neural Networks: A Fast-Track Approach to Modern Deep Learning with Python (1st ed.). Apress.
3. Russell, R. (2018). Machine Learning: Step-by-Step Guide to Implement Machine Learning Algorithms with Python. CreateSpace Independent Publishing Platform.

UNIT IV: Application of Machine Learning/Deep learning with examples using research papers.**10 hours**

An overview of ML/DL in Biology: deep learning applications to regulatory genomics, variant scoring and population genetics, pharmacogenomics, electronic health records, and medical imaging data, A brief introduction of AlphaFold (DeepMind)

An overview of ML/DL in drug discovery: Target identification and prediction of structure, prediction of bioactivity, predicting ADMET/Toxicity, Biomolecular interactions, drug design and drug repurposing. Introduction to tools like - MegaMolBART, ChemGPT / MolGPT.

Essential Readings:

1. Alhazmi et al. Application of artificial intelligence and machine learning for prediction of oral cancer risk. J Oral Pathol. Med. May 2021. (DOI: 10.1111/jop.13157)
2. Senior et al. Improved protein structure prediction using potentials from deep learning. Nature 2020. (DOI: 10.1038/s41586-019-1923-7)
3. Stokes et al. A Deep Learning Approach to Antibiotic Discovery. Cell. 2020. (DOI: 10.1016/j.cell.2020.01.021)

Tutorials**15 Hours**

- Seminars by students on recent papers/trends published in relevant journals.
- Quizzes and Debates.

- Revision of Specific topics; reinforcement of key concepts.
- Case studies, where applicable.
- Group Discussion.
- Theoretical critiques and hypotheses development.

SUGGESTED READINGS

1. Chan et al. Deep Learning in Medical Image Analysis. *Adv Exp Med Biol*. 2020. (DOI: 10.1007/978-3-030-33128-3_1).
2. Lee et al. An explainable deep-learning algorithm for the detection of acute intracranial haemorrhage from small datasets. *Nat Biomed Eng*. 2019. (DOI: 10.1038/s41551-018-0324-9)
3. Zaharchuk et al. Deep Learning in Neuroradiology. *AJNR Am J Neuroradiol*. 2018
4. Kalinin et al. Deep learning in pharmacogenomics: from gene regulation to patient stratification. *Pharmacogenomics*. 2018. (DOI: 10.2217/pgs-2018-0008).
5. Currie et al. Machine Learning and Deep Learning in Medical Imaging: Intelligent Imaging. *J Med Imaging Radiat Sci*. October 2019. (DOI: 10.1016/j.jmir.2019.09.005).
6. Sakellaropoulos et al. A Deep Learning Framework for Predicting Response to Therapy in Cancer. *Cell Rep*. 2019. (DOI: 10.1016/j.celrep.2019.11.017)
7. Wang et al. Using Electronic Health Records and Machine Learning to Predict Postpartum Depression. *Stud Health Technol Inform*. 2019. (DOI: 10.3233/SHTI190351)
8. Shickel et al. Deep EHR: A Survey of Recent Advances in Deep Learning Techniques for Electronic Health Record (EHR) Analysis. *IEEE J Biomed Health Inform*. 2018. (DOI: 10.1109/JBHI.2017.27670

DSE-xviii ADVANCES IN PROTEIN SCIENCES**Duration: 60 Hours**

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Advances in Protein Sciences (DSE-XVII)	4	3	1	0	Graduation	NIL

LEARNING OBJECTIVES:

Students will be made aware of the strides in the area of Protein sciences. They will be taught to appreciate:

- Growing number of human diseases are due to protein misfolding.
- Mutations and various unwanted post-translational modifications are known to cause aberrant protein folding. Protein amyloidosis additionally covers a large bulk of human diseases due to protein misfolding.
- Large spectrum of diseases again is due to defects in protein trafficking and translocation.
- Keeping in mind that subtle alteration in the protein folding environment is crucial toward the proper foldability of a protein, it is important to understand how protein folding, turn-over and quality control system is finely tuned in the intracellular environment.
- Advances in Protein Science has been designed specially to cover all aspects of protein folding to protein quality control system and their inter-relations to human diseases.
- Extensive knowledge on protein aggregates or amyloids and their managements by the cellular systems have been largely dealt.
- It also covers recent advances on protein engineering and basic tools used to analyse protein oligomers.

LEARNING OUTCOME:

- Students will have comprehensive understanding on cellular protein biochemistry especially, the importance of the fidelity of protein folding and quality control system and how they are linked with human diseases.
- Students will also develop skills on methods and treatment strategies of the large spectrum of human diseases caused due to protein misfolding.

Unit I. Basic Principles of protein folding in cell & Chaperone systems**22 Hours**

Introduction to protein folding, Levinthal paradox, protein folding problem, models of protein folding

Mechanism of Protein folding in Endoplasmic reticulum, calnexin, calreticulin

their role in ER protein folding, co-translational protein folding and post-translational protein folding

Protein folding in the cytosol, role of NAC/RAC and prefoldin, functions of TRiC.

Protein folding in bacteria and archaea

Transmembrane protein folding: mechanism of translocon-mediation of protein insertion, overview of chaperones assisting in membrane proteins, single pass transmembrane protein insertion, double pass transmembrane protein insertion.

Introduction to small and large heat shock proteins, chaperonins, alpha crystalline domain, different chaperones systems or orthologs present in human, bacteria and *Saccharomyces cerevisiae*.

Concept of folding and holding chaperones, General structure of small heat shock proteins, Mechanism of Hsp12, Hsp10, Hsp26 etc in substrate recognition and aggregation suppression, Mechanism of protein folding catalyzed by Hsp70, Hsp60, Hsp90, Hsp104, their structure and nucleotide exchange mechanisms, cross-talk between small Hsps and large Hsps.

Mechanism of correct disulfide bond formation by protein disulfide isomerase (PDI) and peptidyl proline isomerase (PPI), catalytic mechanisms and different isoforms, tubulin specific chaperones

Structure of bacterial chaperonin, GRoEL/GRoEL complex, their catalytic mechanism and its comparison with mammalian TRiC chaperone.

Role of chaperones in protein degradation (CHIP, Hsp90, Hsp26 etc), concept of refoldosome complex and their roles in fixing misfolding errors.

Essential readings:

1. Creighton – Proteins (3rd Ed., 2010): Chapters 6-11
2. Alberts – Molecular Biology of the Cell (6th Ed., 2013): Chapters 4, 6, 12
3. Voet & Voet – Biochemistry (4th Ed., 2021): Chapter 6, 7, 28, 30
4. Lodish – Molecular Cell Biology (9th Ed., 2021): Chapters 3, 11, 13, 14

Unit II. Protein Quality control system (PQC)

8 Hours

Overall mechanism of PQC, ERAD-mediated degradation, protein sequestration by JUNQ and IPOD, protein trafficking defect with appropriate examples.

Introduction to unfolded protein response (UPR), different stress sensors present in ER membrane; PERK, ATF6, IRE1 α , their mechanism of activation and molecular cascades to adaptive ER homeostasis and apoptotic ER pathways, different stress sensing mechanisms by ER stress sensors.

Protein quality control system in yeast and bacteria.

UPR in the development and progression of some human diseases (dementia, emphysema, cancer, obesity etc.)

Essential readings:

1. Creighton – Proteins (3rd Ed., 2010): Chapters 9, 11, 12
2. Alberts – Molecular Biology of the Cell (6th Ed., 2013): Chapters 6, 7, 12, 15

3. *Voet & Voet – Biochemistry (4th Ed., 2021): Chapters 28-30*
4. *Lodish – Molecular Cell Biology (9th Ed., 2021): Chapters 3, 11, 13, 15*

Unit III. Protein misfolding, aggregation and diseases

10 Hours

Introduction to protein misfolding, pathways of protein aggregation, aggregation kinetics: introduction to nucleation phase, oligomerization and fibrillation phase, different mechanisms of protein aggregation

Protein oligomers and cellular toxicity: membrane disruption, mitochondria dysfunction, calcium dysregulation, oxidative stress and inflammation.

Key factors to protein misfolding, mutations, post-translational modifications (phosphorylation, glycation, homocystinylation), cellular stress including oxidative stress pH, temperature, molecular crowding

Protein misfolding diseases: Cystic fibrosis- enhanced degradation, Huntingtin's disease- polyglutamine repeats extension, Alzheimer's disease- accumulation of amyloidogenic proteins, Tay-sach disease- trafficking defect or lysosomal storage disorder,

Strategies to misfolding rescue: definition of pharmacological chaperone, rescue mechanism, current state and challenges (with at least 2 examples); concept of proteostatic modulation, introduction to some Hsp inhibitors and activators used for disease intervention along with their target chaperones, definition of chemical chaperone, their applications and limitations.

Introduction to functional amyloids, functional amyloids in Humans and Prokaryotes with appropriate examples.

Essential readings:

1. *Creighton – Proteins (3rd Ed., 2010): Chapters 6-9, 12*
2. *Alberts – Molecular Biology of the Cell (6th Ed., 2013): Chapters 6, 7, 12, 15*
3. *Voet & Voet – Biochemistry (4th Ed., 2021): Chapters 6, 7, 28, 30, 34*
4. *Lodish – Molecular Cell Biology (9th Ed., 2021): Chapters 3, 11, 13, 15, 23*

Unit IV. Basic methods for identification of protein oligomers

5 Hours

Tools to analyse protein misfolding and aggregation: Principle of DLS and SAXs, their potential to analyse aggregates;

Introduction to various extrinsic fluorescence dyes (ANS, ThT, Congo red, acrylodan, Nile red etc.), binding mechanisms and type of aggregate stained. Use of fluorescence microscopy and confocal microscopy for quantification and visualisation.

Atomic force microscopy and transmission electron microscopy, to understand the morphology of protein oligomers.

Challenges in Biophysical Characterization of Amyloidogenic Protein Oligomer

ESSENTIAL READINGS:

1. Creighton – Proteins (3rd Ed., 2010): Chapters 2, 5, 6, 12
2. Alberts – Molecular Biology of the Cell (6th Ed., 2013): Chapters 9, 10, 15
3. Voet & Voet – Biochemistry (4th Ed., 2021): Chapter 3, 5, 7, 33
4. Lodish – Molecular Cell Biology (9th Ed., 2021): Chapters 4, 9, 21

Tutorials**15 Hours**

- Seminars by students on recent papers/trends published in relevant journals.
- Quizzes and Debates.
- Revision of Specific topics; reinforcement of key concepts.
- Case studies, where applicable.
- Group Discussion.
- Theoretical critiques and hypotheses development.

SUGGESTED READINGS:

1. Protein Folding in the Cytoplasm and the Heat Shock Response. R. Martin Vabulas, Swasti Raychaudhuri, Manajit Hayer-Hartl, and F. Ulrich Hartl; Cold Spring Harbor Laboratory Press: 2(12), 2018.
2. Proteostasis and Chaperone Surveillance by Laishram Rajendrakumar Singh, Tanveer Ali Dar, and Parvaiz Ahmad; Ed. 1st Springer India; 2015.
3. Knowles, T. P. J., Vendruscolo, M., & Dobson, C. M. (2023). The amyloid state and protein aggregation kinetics. *Nature Reviews Molecular Cell Biology*, 24, 321-338.
4. Xu, S., Powers, E. T., & Kelly, J. W. (2023). Fluorescent probes in protein misfolding research. *Journal of the American Chemical Society*, 145(14), 7821-7834.

GENERIC ELECTIVE COURSES

GE-3

STRUCTURAL BIOLOGY

Duration: 60 Hours

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Structural Biology (GE-3)	4	3	1	0	Graduation	NIL

COURSE OBJECTIVES:

- This course aims to equip students with fundamental knowledge of structure determination techniques for biological macromolecules, focusing on experimental methods.
- Students will also learn to analyze structural data and apply these concepts in research.

LEARNING OUTCOMES:

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

- Demonstrate protein extraction, purification, and characterization methods for structural studies.
- Explain the key principles of X-ray crystallography, including its theoretical foundations.
- Describe the essential techniques used in macromolecular crystallography for structural analysis.
- Construct macromolecular models using electron density maps and assess potential errors in these models using various validation methods.
- Critically evaluate and analyze structures obtained through X-ray crystallography, NMR, or cryo-EM, assessing their accuracy and reliability.
- Explain the structural roles of proteins, DNA, and RNA in biological functions.
- Describe the core theories and concepts underlying structure determination using single particle cryo-electron microscopy (cryo-EM).

UNIT 1: Macromolecular Structure Determination by X-Ray crystallography 15 Hours

Overview and history of structural biology

Basics of molecular interactions and stability

Protein crystallization techniques: Methods for macromolecular sample preparation and optimization. Methods of crystallization; factors affecting crystal growth; Phase diagram for protein crystallization.

Principles of X-ray crystallography – Production of X-rays, Bragg's law, and diffraction principle; Crystal structure and symmetry.

Diffraction of macromolecular crystals: Diffraction principles, data collection (Synchrotron radiation and X-ray sources), Fourier methods; Diffraction limits (Å); Introduction to X-ray Free-Electron Laser (XFEL).

Phasing methods, density assignment, and validation: Isomorphous & Molecular replacement method, Single and Multiple Wavelength Anomalous Dispersion (SAD & MAD) methods; Electron density map and density assignment; Ramachandran plot.

Biomedical Applications – Role in drug discovery – Structure-based drug design, ligand binding, and catalytic mechanisms.

Essential Readings:

1. Chapters 1–6, 9: Structure determination by X-ray Crystallography. M.F.C Ladd & R.A. Palmer. Springer 2013.
2. Chapters 1–6, 8: Rupp, Bernhard, Biomolecular crystallography: principles, practice, and application to structural biology, New York, Garland Science, 2009.
3. Chapman et al., 2011 XFEL / data collection sections: Chapman, H., Fromme, P., Barty, A. et al. Femtosecond X-ray protein nanocrystallography. Nature 470, 73–77 (2011). <https://doi.org/10.1038/nature09750>
4. Cryo-EM integration section: Cryo-EM. Topf, M., Lasker, K., Webb, B. et al. (2008) Protein structure fitting and refinement guided by cryo-EM density. Structure, 16, 295–307. An article on combining high-resolution and cryo-EM data.

Unit II: NMR for Macromolecular Structure Determination

8 Hours

Nuclear Magnetic Resonance (NMR) Spectroscopy – Basic principles, nuclear spin, and magnetic properties; Isotope labelling strategies (^{15}N , ^{13}C); Instrumentation & Techniques – NMR spectrometer components, pulse sequences, and data acquisition
NMR and Structure Determination: Spectral Interpretation – Chemical shifts, spin-spin coupling, and relaxation mechanisms.

NMR experiments: One-, Two-, and Three- dimensional NMR experiments, COSY, TOCSY, NOESY, and multi-dimensional heteronuclear NMR experiments

Biomedical Applications of NMR: Structural analysis of peptides and proteins.

Essential Readings:

1. Chapters 1–6, 11: Cavanagh, J., Fairbrother, W.J., Palmer, A.J. et al. (2007). Protein NMR Spectroscopy: Principles and Practice, 2nd edn, Elsevier. A detailed description of the physical basis of biomolecular multidimensional NMR.
2. Chapters 1–5: Basic one and two dimensional NMR spectroscopy by Horst Friebolin; Ed. 5th ; Wiley-VCH; 2010.
3. David Sheehan; Physical Biochemistry: Principles and Applications. Latest Edition, 2009.

Unit III: Methods of Single Particle Cryo-EM for Macromolecular Structure Determination

10 Hours

Introduction to Cryo-EM: Principles, TEM and SEM principles, advantages over X-ray crystallography, sample preparation

Cryo-EM Data Collection and Image Processing: Negative staining for screening, data collection and automation, principles of 2D to 3D reconstruction, refinement and determination of image reconstruction resolution using FSC.

Cryo-Electron Tomography (CryoET): Introduction, principles of cryogenic preservation, and tilt-series imaging. Applications in 3D cellular reconstruction, resolution, and molecular interaction studies; Fundamentals of MicroED, high-energy electron diffraction principles.

Biomedical Applications and Advances: Protein structure determination, structure determination of membrane proteins; heterogeneity, and recent technological developments.

Essential Readings

1. Cryo-EM. Topf, M., Lasker, K., Webb, B. et al. (2008) Protein structure fitting and refinement guided by cryo-EM density. Structure, 16, 295–307. An article on combining high-resolution and cryo-EM data.

Unit IV: Complementary Tools in Structural Biology**12 Hours**

Introduction to Protein Generation and purification: Protein extraction from native, heterologous and recombinant expression systems; Chromatographic methods to purify proteins.

Methods for preliminary structure determination: HDX, XL-MS, SAXS, SEC-MALS.

Introduction and Structural Databases: Role of bioinformatics in structural biology, PDB, UniProt, and structural data retrieval

Data Processing and Model Building: Phenix & CCP4 ; Data processing, phasing, model building, refinement, visualization, and automation in macromolecular structure determination; Homology modeling and ab initio structure prediction; PyMOL, Chimera for visualization; RELION, CryoSPARC for Cryo-EM; NMRPipe, Sparky for NMR analysis.

Advanced Biomedical Techniques and Future Trends: Hybrid modeling, AI-driven structure prediction, and big data applications in structural biology; Integrating structural data with functional studies; AlphaFold, Rosetta; Future trends in structural biology. Developing Data Interpretation Skills, Structure Validation and Submission to the PDB.

Essential reading:

1. Ch 1–5: Structure determination by X-ray Crystallography. M.F.C Ladd & R.A. Palmer. Springer 2013.
2. HDX, XL-MS, SAXS, SEC-MALS: Method reviews: Relevant sections; Structural databases; and Ch 1, 10: Rupp, Bernhard, Biomolecular crystallography: principles, practice, and application to structural biology, New York, Garland Science, 2009.
3. Data processing & model building: Ch 6–8: Rupp, Bernhard, Biomolecular crystallography: principles, practice, and application to structural biology, New York, Garland Science, 2009.
4. Cryo-EM map fitting: Topf et al., 2008: Cryo-EM sections
5. NMR data analysis: Cavanagh / Friebolin: NMR processing sections
6. AI & hybrid modeling: Reviews / AlphaFold papers: Relevant sections
7. Validation & PDB submission: Ch 8: Rupp, Bernhard, Biomolecular crystallography: principles, practice, and application to structural biology, New York, Garland Science, 2009.

Tutorials**15 Hours**

- Seminars by students on recent papers/trends published in relevant journals.
- Quizzes and Debates.
- Revision of Specific topics; reinforcement of key concepts.
- Case studies, where applicable.
- Group Discussion.
- Theoretical critiques and hypotheses development.

SUGGESTED READING:

1. David Sheehan; Physical Biochemistry: Principles and Applications. Latest Edition, 2009.
2. Patterson, B. D. (2014). Crystallography using an X-ray free-electron laser. *Crystallography Reviews*, 20(4), 242–294. <https://doi.org/10.1080/0889311X.2014.939649>

3. Hammond, Christopher, *The Basics of Crystallography and Diffraction*, 4th edn (Oxford, 2015; online edn, *Oxford Academic*, 20 Aug. 2015), <https://doi.org/10.1093/acprof:oso/9780198738671.001.0001>
4. Branden, C. and Tooze, J. (1999) *Introduction to Protein Structure*, 2nd edn, Garland Press, New York. A very readable overview of protein structure and methods used in its analysis.
5. McPherson A, Gavira JA. Introduction to protein crystallization. *Acta Crystallogr F Struct Biol Commun*. 2014 Jan;70(Pt 1):2-20. doi: 10.1107/S2053230X13033141. Epub 2013 Dec 24. PMID: 24419610; PMCID: PMC3943105.
6. Hrabe, Thomas and Friedrich G. Förster. "Structure Determination by Single Particle Cryo-electron Tomography." (2011).
7. Mu, X., Gillman, C.D., Nguyen, C.K., & Gonen, T. (2021). An Overview of Microcrystal Electron Diffraction (MicroED). *Annual review of biochemistry*, 90, 431-450.
8. Vanhecke, D., Asano, S., Kochovski, Z., Fernandez-busnadiego, R., Schrod, N., Baumeister, W. And lučić, V. (2011), Cryo-electron tomography: methodology, developments and biological applications. *Journal of Microscopy*, 242: 221-227. <https://doi.org/10.1111/j.1365-2818.2010.03478.x>

GE-4

CARDIOVASCULAR BIOLOGY**Duration: 60 Hours**

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Cardiovascular Biology (GE-4)	4	3	1	0	Graduation	NIL

LEARNING OBJECTIVES:

- This course is designed to provide students with a comprehensive understanding of human cardiovascular biology at both cellular and systemic levels.
- It aims to build foundational knowledge of human cardiac physiology, vascular biology, electrophysiology, cardiac development, pathophysiology, current diagnosis, and research methodologies.
- Through this course, students will integrate theoretical knowledge with translational and experimental perspectives relevant to cardiovascular health and disease.

LEARNING OUTCOMES:**Upon successful completion of the course, students will be able to:**

- Describe the structural and functional organization of the human heart, including chamber anatomy, myocardial perfusion, and the cardiac conduction system.
- Explain the biophysical and metabolic properties of cardiac muscle, including excitation–contraction, ion channel dynamics, and myocardial energetics.
- Interpret the principles of hemodynamics, blood flow regulation, vascular resistance, and regional circulatory adaptations.
- Analyze the electrophysiological basis of cardiac function, including action potentials, ECG interpretation, and arrhythmogenesis.
- Identify and differentiate common cardiovascular diseases, such as cardiomyopathies, hypertension, myocardial infarction, heart failure, and congenital heart defects, along with their underlying mechanisms.
- Apply knowledge of experimental models and diagnostic tools, including ECG, echocardiography, cardiac imaging, and molecular biology techniques for cardiovascular research.
- Demonstrate competency in laboratory methodologies related to cardiovascular research, including in vitro and in vivo experimental design, biomarker analysis, and tissue characterization.

Unit 1: Introduction to Cardiovascular Biology, Development, and Adaptations.**7 hours**

Overview of the human cardiovascular system and its physiological significance.

Embryonic Development of the Heart: Origin of heart tube, looping, chamber formation.

Septation and Valve Formation: Molecular cues in atrial, ventricular, and outflow tract septation.

Postnatal Adaptations: Fetal circulation vs. adult circulation; closure of fetal shunts.

Gender Differences in Cardiovascular Physiology: Hormonal influences on cardiac structure and function.

Ageing and Cardiovascular Changes: Altered compliance, fibrosis, vascular stiffness.

Cardiovascular Adaptation to Exercise: Changes in stroke volume, heart rate, vascular resistance under physical stress.

Essential reading:

1. Chapters 9, 10, 14, 15, 16, 20, 21, 23: Guyton and Hall Textbook of Medical Physiology, 14th edition, 2020.
2. Chapters 29, 30, 31, 32, 33: Ganong's Review of Medical Physiology, 26th edition, 2019.
3. Chapters 13, 14, 15, 16, 17: Essential Physiology by C.C. Chatterjee, 14th edition, 2022.
4. Chapters 37, 38, 39, 40, 41, 42: Textbook of Medical Physiology by A.K. Jain, 7th edition, 2017.
5. Chapters 4, 13, 14: Langman's Medical Embryology (14th/15th edition)
6. Essential of medical pharmacology; 9th Ed. By K.D. Tripathi; Jaypee Brothers; 2024

Unit II: Human Heart Structure, Function, and Electrophysiology.

15 hours

Structure and Function of the Heart: Cardiac anatomy, chamber-specific roles and adaptations; myocardial perfusion; valvular anatomy and physiology.

Histological and Biophysical Properties of Cardiac Muscle: Characteristics of cardiomyocytes, conduction system, auto-rhythmicity, excitability, contractility, and the role of intercalated discs in impulse propagation.

Cardiac Cycle: Sequential events of systole and diastole; pressure-volume relationships; mechanical events underlying heart sounds.

Cardiac Output: Regulation via preload, afterload, myocardial contractility, and heart rate; determinants and measurement techniques.

Myocardial Metabolism: Energy substrates (glucose, fatty acids, ketone bodies), oxygen consumption, ischemia-induced metabolic shifts.

Coronary Circulation: Anatomy and regulation; autoregulation, metabolic and myogenic responses.

Specialized Conducting Tissue: SA node, AV node, His-Purkinje system – structure, functional hierarchy, and electrophysiological roles.

Ion Channel Dynamics and Cardiac Action Potentials: Types of ion channels and their roles, pacemaker potential, phases of the action potential.

Excitation–Contraction Coupling: Role of calcium ions, ryanodine receptors, L-type Ca²⁺ channels; muscle contraction and relaxation.

Autonomic Regulation of Heart Rate and Rhythm: Role of sympathetic and parasympathetic input; neurotransmitter pathways.

Electrocardiography (ECG): Principles, interpretation of waves and intervals, clinical significance.

Essential Readings:

1. Chapters 9, 10, 11, 13, 20, 21: Guyton and Hall Textbook of Medical Physiology, 14th edition, 2020.

2. Chapters 29, 30, 32, 33: Ganong's Review of Medical Physiology, 26th edition, 2019.
3. Chapters 13, 14, 15, 17: Essential Physiology by C.C. Chatterjee, 14th edition, 2022.
4. Chapters 37, 38, 39, 42: Textbook of Medical Physiology by A.K. Jain, 7th edition, 2017.
5. Essential of medical pharmacology; 9thEd. By K.D. Tripathi; Jaypee Brothers; 2024

Unit III: Hemodynamics and Vascular Physiology.

8 hours

Principles of Hemodynamics: Blood flow, pressure, resistance, Poiseuille's and Laplace's laws.

Structure and Function of Blood Vessels: Arteries, veins, and capillaries; endothelial cell biology.

Microcirculation and Capillary Exchange: Starling forces, transcapillary filtration, tissue fluid balance.

Lymphatic System: Anatomy, fluid transport, and immune functions.

Vascular Smooth Muscle Regulation: Role of NO, endothelin, angiotensin II, and local autoregulation.

Regional Circulations: Unique features of cerebral, renal, coronary, and splanchnic circulations.

Essential Readings:

1. Chapters 14, 15, 16, 17, 18, 21, 22: Guyton and Hall Textbook of Medical Physiology, 14th edition, 2020.
2. Chapters 31, 32, 33: Ganong's Review of Medical Physiology, 26th edition, 2019.
3. Chapters 15, 16, 17: Essential Physiology by C.C. Chatterjee, 14th edition, 2022.
4. Chapters 40, 41, 42, 43: Textbook of Medical Physiology by A.K. Jain, 7th edition, 2017.
5. Essential of medical pharmacology; 9th Ed. By K.D. Tripathi; Jaypee Brothers; 2024

Unit IV: Cardiovascular Disorders, Diagnostic Techniques, and Treatment. 15 hours

Arrhythmias: Mechanisms (re-entry, triggered activity), classification, electrophysiological basis, ion channel dysfunctions, and clinical implications.

Antiarrhythmic Drugs: Classification, mechanisms of action, and clinical applications.

Cardiomyopathies: Dilated, hypertrophic, restrictive: etiologies, clinical features, genetic basis.

Hypertensive Heart Disease: Vascular resistance, cardiac remodeling, molecular mechanisms.

Myocardial Infarction: Ischemia-reperfusion injury, biomarkers, cellular injury response.

Congenital Heart Defects: Common defects, embryologic basis, clinical presentation and diagnostic approaches.

Cardiac toxicity: types (e.g., drug-induced, radiation-induced), causes, mechanisms, and management of heart-related toxicities induced by various substances or treatments.

Atherosclerosis: Endothelial dysfunction, plaque formation, lipid metabolism, inflammation, and oxidative stress.

Heart Failure: Systolic vs. diastolic dysfunction, neurohormonal compensations, management strategies & therapeutics.

Ex vivo Models: Cardiomyocyte cultures, cell lines, organoid systems.

In vivo Models: Zebrafish, rodents, and large-animal models for cardiac research.

Gene and Protein Expression Studies: Cardiac Biomarkers (Troponins, natriuretic peptides, CK-MB, BNP/NT-proBNP, high-sensitivity CRP, galectin-3 diagnosis & importance of early detection), RT-PCR, Western blotting, ELISA, immunohistochemistry in cardiac tissue.

Imaging Modalities: Functional and structural insights into Echocardiography, MRI, CT, PET - applications and interpretation.

Functional Assessments: Treadmill tests, catheter-based hemodynamic studies, ECG telemetry.

Emerging Technologies in Cardiovascular Research: CRISPR, optogenetics, stem cell therapy, and organ-on-chip systems.

Essential Readings:

1. Chapters: 10, 11, 12, 19, 20, 21, 22, 23: Guyton and Hall Textbook of Medical Physiology, 14th edition, 2020.
2. Chapters: 29, 30, 31, 32, 33: Ganong's Review of Medical Physiology, 26th edition, 2019.
3. Chapters: 13, 14, 16, 17: Essential Physiology by C.C. Chatterjee, 14th edition, 2022.
4. Chapters: 37, 38, 39, 40, 41, 42: Textbook of Medical Physiology by A.K. Jain, 7th edition, 2017.
5. Essential of medical pharmacology; 9thEd. By K.D. Tripathi; Jaypee Brothers; 2024
6. Cardiomyopathies: Braunwald's Heart Disease – Ch 31–33
7. Cardiotoxicity: Braunwald's Heart Disease – Ch 57–58
8. Biomarkers: Braunwald's Heart Disease – Ch 44–46

Tutorials

15 Hours

- Seminars by students on recent papers/trends published in relevant journals.
- Quizzes and Debates.
- Revision of Specific topics; reinforcement of key concepts.
- Case studies, where applicable.
- Group Discussion.
- Theoretical critiques and hypotheses development.

SUGGESTED READINGS:

1. Human Physiology by R.L. Bijlani, 5th edition, 2010.
2. Cardiovascular Physiology Concepts by Richard E. Klabunde, 2nd edition, 2011.
3. The Cardiovascular Physiology Concepts Website: (<https://www.cvphysiology.com/>).
4. PubMed & Google Scholar for latest cardiovascular research articles and reviews.

SKILL-BASED COURSE

SBC-3 BIOMEDICAL LABORATORY TECHNIQUES-3

Duration: 30 hours

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Biomedical laboratory Techniques-3 (SBC-3)	2	0	0	2	Graduation	NIL

LEARNING OBJECTIVES:

- This course has been designed to train students in practical aspects of spectroscopic techniques, such as circular dichroism (CD) and Infrared (IR) spectroscopic techniques.
- They will have hands-on experience in using these instruments and develop skills in handling the experiments themselves, collecting and analyzing the data for applications such as Protein secondary structures and studying protein denaturation using CD.
- The application of Infrared Spectroscopy for identifying functional groups of a drug/metabolite will be taught.
- The second module will cover a detailed training in handling HPLC and performing experiments such as analyte identification, drug purity analysis, and handling the instruments.
- This type of training aims to prepare students for developing skills required for research laboratories, the food and drug industry, and other quality assurance labs.

LEARNING OUTCOMES:

- Students will learn the handling of optical instruments such as a CD and an IR spectrophotometer.
- Apply CD to understand the secondary structure of biomolecules and conformational changes upon denaturation.
- They will gain hands-on experience of handling high-performance liquid chromatography.
- Students will be able to perform analyte/drug/compound separation using an isocratic and a gradient mobile system
- Perform drug analysis, check for impurity in commercial drug samples
- They will learn to use HPLC for quality checks of APIs in market formulation, etc.

Hands-on Training on Optical Spectroscopic Techniques

1. Studying and analyzing the CD spectrum of a protein
2. To study biomolecular conformation change/denaturation using CD spectroscopy.

3. Infra-red Spectroscopy. Recording and interpretation of IR of a metabolite.

Hands-on-training on HPLC-Quality assurance techniques of drugs and biosimilars

4. HPLC- introduction to the working of the instrument and analysis of a sample.
Calculating concentration of unknown sample from standard curve.
5. Separating two samples using HPLC using isocratic and gradient mobile system.
6. To identify and quantify a drug molecule from its label, e.g., metoprolol, using HPLC.
7. To check a market formulation for any impurity using HPLC.
8. To study the dissolution of a pharmaceutical preparation and its API using HPLC.

Essential Readings:

1. Circular Dichroism and the Conformational Analysis of Biomolecules, Editor: G.D. Fasman (2013), ebook, Springer US.
2. Separation Science and Technology, Book Series, Volume 6: Handbook of Pharmaceutical Analysis by HPLC, Edited by Satinder Ahuja - Ahuja Consulting, Calabash, North Carolina And Michael W. Dong - Purdue Pharma, Ardsley, New York Pages 1-658 (2005)
3. HPLC: a practical user's guide; Ed.2nd by Marvin C. McMaster; Wiley-Interscience; 2007.
4. Handbook of HPLC, Edited by Danilo Corradini, CRC Press; 2nd edition (2010).
5. Organic spectroscopy by William Kemp; Ed. 3rd; Palgrave; 2008

SUGGESTED READINGS:

1. Method Development in Analytical HPLC, 1st Edition (2024), Elsevier, Serban C. Moldoveanu, Victor David.
2. HPLC and UHPLC for Practicing Scientists. Michael Dong (2019), John Wiley & Sons, Inc.

SBC-4 SKILL BASED COURSE (BIOMEDICAL LABORATORY TECHNIQUES-4)**Duration: 30 hours**

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Biomedical Laboratory Techniques-4 (SBC-4)	2	0	0	2	Graduation	NIL

Course Objectives:

- **Familiarize students with mass spectrometry-based workflows**, including protein sample preparation, enzymatic digestion, and data acquisition.
- **Provide hands-on experience in proteomics data analysis**, including charge/mass calculation, peptide mass fingerprinting (PMF), and protein identification.
- **Expose students to metabolomics data processing and interpretation**, focusing on the identification of metabolic profiles relevant to biological systems.
- **Train students in mining and analyzing omics datasets** from publicly available repositories such as NCBI-GEO and STRING for genomics and proteomics studies.
- **Develop practical skills in transcriptomics**, including RNA-Seq data preprocessing, differential gene expression analysis, and visualization.
- **Introduce fundamental techniques and tools used in multi-omics studies**, with a focus on genomics, transcriptomics, proteomics, and metabolomics.

Course Outcomes:

- Understand what precautions to take during MS sample preparation.
- Apply mass spectrometry-based techniques to analyse proteins and metabolites.
- Analyse and interpret omics data from public repositories such as GEO.
- Perform basic workflows in RNA sequencing data analysis and protein interaction mapping.
- Integrate multi-omics data to understand biological systems and disease mechanisms.

Detailed Syllabus:**Proteomics based practical:**

1. Protein sample preparation for MS experiment, including peptide digestion
2. Proteomics data analysis: charge and mass determination.
3. Identification of proteins using Peptide Mass Fingerprinting
4. Preparing a sample for metabolomics and data analysis

System Biology Practical Sessions

5. Mining the Public Repositories: Extracting and Exploring Transcriptome Data from GEO

6. Discovering Differentially Expressed Genes using data from GEO/Array express/TCGA: Statistical and Visual Analysis.
7. Connecting Differential Expression to Mechanisms of Disease through pathway analysis using R or web-based tools.
8. Unravelling protein-protein interactions using various databases (Building Biological Networks: Protein-Protein Interaction & Gene Network Construction)
9. To analyse biological networks: Network Pharmacology for Target Discovery and Drug Repurposing.

SUGGESTED REEDINGS:

1. Principles of Proteomics by Richard Twyman, Latest Edition: 2nd Edition (2014); Publisher: Garland Science; ISBN: 978-0815344728
2. Mass Spectrometry: Principles and Applications by Edmond de Hoffmann & Vincent Stroobant; Latest Edition: 3rd Edition (2007); Publisher: Wiley; ISBN: 978-0470033104
3. Metabolomics: From Fundamentals to Clinical Applications” by Jens H. J. B. Winderickx; ISBN-13. 978-3319476551; Edition. 1st ed. 2017 ; Publisher. Springer International Publishing AG.
4. Diletta Rosati, Maria Palmieri, Giulia Brunelli, Andrea Morrione, Francesco Iannelli, Elisa Frullanti, Antonio Giordano, Differential gene expression analysis pipelines and bioinformatic tools for the identification of specific biomarkers: A review, Computational and Structural Biotechnology Journal, Volume 23, 2024, Pages 1154-1168, ISSN 2001-0370, <https://doi.org/10.1016/j.csbj.2024.02.018>.
5. Peng Zhang, Dingfan Zhang, Wuai Zhou, Lan Wang, Boyang Wang, Tingyu Zhang, Shao Li, Network pharmacology: towards the artificial intelligence-based precision traditional Chinese medicine, *Briefings in Bioinformatics*, Volume 25, Issue 1, January 2024, bbad518, <https://doi.org/10.1093/bib/bbad518>
6. Bioinformatics and Systems Biology, Frederick Marcus, (2008), ebook, Springer Berlin Heidelberg
7. Network Pharmacology, Shao Li, 2021, ebook, Springer Nature Singapore.

Selection of research topic on Biomedical research with its national and international scenario. Designing of research using an illustration, Defining Standard Operating Protocols (SOPs) and Research Conditions with feasibility and reproducibility.

Statistical analysis for the reliability of results for accuracy and Precision by using basic statistical tools like SD, t-test, ANOVA, etc.

Introduction to IPR (Patent, trademarks, copyright, trade secrets), Importance of academia-industry interaction, Marketing of research outcome.

Essential readings:

1. Research Methodology in Medical Sciences. Mumbai: Himalaya Publishing House; 2023.
2. Textbook of Biostatistics and Research Methodology. New Delhi: Shashwat Publications; 2021.
3. Department of Science & Technology. Intellectual Property – A Primer for Academia. New Delhi: DST, Government of India; c2020–. Available from: <https://dst.gov.in/sites/default/files/E-BOOK%20IPR.pdf>

UNIT 2: Good Laboratory and Safety Practices, Ethical Considerations 15 hours

Introduction to Biosafety (chemical, biological and radiation), Guidelines for handling pathogenic microorganisms, toxic laboratory chemicals, and their safe disposal (IBSC/IBKP).

Labelling and Material Safety Data Sheet (MSDS), safety equipment and procedures, Fire extinguishers, First aid kit etc. (DBT Guidelines).

Discussing Pilot studies, Clinical Research, Ethical issues in clinical research; Animal (CCSEA, IAEC) and Human ethics (WHO, ICMR, DBT, IHEC). Good clinical research methodology.

Essential readings:

1. Research Methodology - Methods and Techniques by Kothari C.R., New Age International Publishers; Fourth edition (1 September 2019).
2. Institutional Biosafety Committee (IBSC) Guidelines (Handbook for Institutional Biosafety Committees, DBT, September 2020).
3. Guidelines for management of healthcare waste as per biomedical waste management rules, 2016.

SUGGESTED READINGS:

1. Research in Education by Best, J.W. and Kahn, J.V Pearson Education; Tenth edition (30 September 2016); Pearson India.
2. At the Bench: A Laboratory Navigator (2005) Barker, K., Cold Spring Harbor Laboratory Press (New York). ISBN: 978-087969708-2.
3. The Craft of Research (Guides to writing, editing and publishing) (2008), Booth, W.C., Colomb, G.G., Williams, J.M., University of Chicago Press, 2008. (ISBN-13: 978-0226065663)].
4. Adil E. Shamoo, and David B. Resnik, Responsible Conduct of Research, Oxford University Press, 2014.
5. Tony Mayer, and Nicholas H. Steneck, Promoting Research Integrity in a Global Environment, World Scientific Publishing. 2011.

6. Case Study Research: Design and Methods (Applied Social Research Methods) by Robert K. Yin (Author) 10 May 2013.
7. Historical studies like The Monster Study (<https://uh.edu/ethicsinscience/Media/Monster%20Study.pdf>).
8. Relevant research papers and articles from reputed Journals.
9. *Guidelines for Chemical Laboratory Safety in Academic Institutions*, ACS Committee on Chemical Safety, Washington, DC., 2016.
10. National ethical guidelines for biomedical and health research involving human participants (Indian Council of Medical Research 2017).
11. Institutional Biosafety Committee (IBSC) Guidelines (Handbook for Institutional Biosafety Committees, DBT, September 2020)
12. Guidelines for management of healthcare waste as per biomedical waste management rules, 2016.
13. Intellectual Property and Bioethics – An Overview, Consultation Draft World Intellectual Property Organization: WIPO Publication No. B932/IPB(E) ISBN 978-92-805-1641-8

TR-1

TOOLS FOR RESEARCH**Duration: 30 Hours**

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Tools for Research (TR-1)	2	2	0	0	Graduation	NIL

LEARNING OBJECTIVES:

The goal of this paper is to focus on:

- The principles, scope and applications of the essential tools and techniques in biomedical research.
- Comprehensive overview of the instruments, techniques and the software used for analysis with primary focus on their principles, applications, and limitations.

LEARNING OUTCOMES:

After completing this course, the students will be able to:

- Use diverse array of tools and techniques, ranging from microscopic observation to advanced genomic and translational research.
- The students will be able to set up the experiments with appropriate controls, base line settings keeping in mind the limitations.
- Conduct effective investigations and contributing to advancements in health and translational research.

UNIT I: BASIC TOOLS**15 Hours**

Microscopic techniques: Bright field, dark field, phase contrast, fluorescence, microscopy, infrared and ultraviolet microscopy. Sample preparation and troubleshooting.

Methods in protein structure and function: Brief overview of expression of proteins in bacteria and enzyme catalysis, Introduction to ligand binding and its analysis: FRET fluorescence correlation spectroscopy, Time resolved fluorescence for internal dynamics, H-exchange methods.

Model Organisms: Application of Antibody Generation, Basis of vaccines and its generation in small animals. Model systems for Research- Prokaryotic Organism: Bacteria, Bacteriophage; Eukaryotic Organism: Yeast, *C. elegans*, Drosophila, Zebra fish, mouse, rat.

Essential readings:

1. Chapter 1, Basic Methods in Microscopy Protocols and Concepts from Cells: A Laboratory Manual, By David L. Spector, Cold Spring Harbor Laboratory; Robert D. Goldman, Northwestern University Medical School, Chicago.
2. Genetic Studies in Model Organisms: From Classical to Modern Genetics by Kwang-Wook Choi, Springer Nature (Singapore), 2024

Unit II: ADVANCED TOOLS**15 Hours**

Separation Methods: An introduction to chromatographic separation, Gas Chromatography, High Pressure Liquid Chromatography and FPLC, Supercritical fluid chromatography

Advanced Immunological Technique: Techniques to study innate cell-mediated humoral immune response (concern research area with case study); Use of RNAi/FACS in Immunology. Techniques of ELISA, radio-immunoassays. Tracer techniques and applications in biomedicine.

Techniques in physiology & Pharmacology: Application of ECG, EEG and EMG in health and biomedical research, Applications of Patch Clamp technique, Drug Administration routes, cardiovascular imaging techniques.

Essential readings:

1. Human Physiology : Practical Manual Paperback – Notion Press (27 February 2023); by Dr. Savahat (Author). ISBN-13 : 979-8889865568.
2. Exploring Anatomy & Physiology in the Laboratory, Morton Publishing Company; 3 edition (2017).
3. Practical Guide to Biomedical Research: For the Aspiring Scientist, 27 Nov 2017, By: Peter Agger, J. Michael Hasenkam , Robert S. Stephenson, J Michael Hasenkam , Robert S Stephenson , Publisher: Springer. ISBN-13: 9783319635811

SUGGESTED READINGS:

1. A Guide to Methods in the Biomedical Sciences Paperback – Import, 15 October 2010, by Ronald B. Corley. Springer-Verlag New York Inc.; Softcover reprint of hardcover 1st ed. 2005 edition (15 October 2010). ISBN-10 : 1441935606..
2. Genomics and Bioinformatics: An Introduction to Programming Tools for Life Scientists Hardcover – Import, 7 June 2012 by Tore Samuelsson. Cambridge University Press; 1st edition (7 June 2012); Cambridge University Press. ISBN-10 : 1107008565
3. Clinical and Translational Medicine Hardcover – Import, 12 June 2019 by Anna Garner (Editor), Foster Academics, ISBN-10 : 1632428407.
4. De Maria Marchiano R, Di Sante G, Piro G, Carbone C, Tortora G, Boldrini L, Pietragalla A, Daniele G, Tredicine M, Cesario A, Valentini V, Gallo D, Babini G, D'Oria M, Scambia G. Translational Research in the Era of Precision Medicine: Where We Are and Where We Will Go. J Pers Med. 2021 Mar 18;11(3):216. doi: 10.3390/jpm11030216. PMID: 33803592; PMCID: PMC8002976.

TRW TECHNIQUES IN RESEARCH WRITING Duration: 30 Hours

Course title and Code	Total Credits	Credit distribution of the course			Eligibility Criteria	Prerequisite of the Course (if any)
		Lecture	Tutorial	Practical		
Techniques of Research Writing (TRW)	2	2	0	0	Graduation	NIL

LEARNING OBJECTIVES:

- Students will be taught on how to write manuscripts.
- They will also be made aware of submitting research proposals to various National and International funding agencies
- They will be made aware of the funding mechanism of DBT, DST, ICMR and CSIR – the core funding agencies in India.

LEARNING OUTCOMES:

After completing this course, the students will be able to:

- The students will learn how to apply their analysis and writing skills by constructing a clear ‘story’ and presentation of results using examples of well-written example paper to maximise their chances of publishing in international scientific journals.
- The student will follow ethical guideline and use various software for scientific writing which will introduce the basic requirements for being a good and motivated researcher.
- They will also acquire skills in formulating grant proposals to different funding agencies.

Unit 1. Scientific Writing and Ethics of Publication**15 hours**

Experimental and Survey-based report writing: formatting & citing references (APA/MLA etc). Scientific paper writing, Grant writing and data representation in various forms (Poster, power point presentations etc). Manuscript writing in journals of Biomedical research.

Standard guidelines and best practices of research writing: Committee on Publication Ethics (COPE), World Association of Medical Editors (WAME), Directory of Open Access Journals (DOAJ), Open Access Scholarly Publishers Association (OASPA), etc.

Conflicts of interest. Publication Ethics: definition, concept, plagiarism, misconduct/Unethical practices, complaints and appeals. Concept of copyright form, violation of publication ethics, authorship and contributor-ship, legal aspects. Types of publishers/journals; Subscription based, open access publishing, Hybrid, predatory journals etc.

Unit 2: Software tools for publication, databases and research metrics 15 hours

Tools for detecting plagiarism, avoiding plagiarism, consequences of plagiarism, a few case-studies using softwares like Drillbit, Turnitin, Urkund, iThenticate, and other open-source software tools.

Reference management software like Mendeley, Zotero etc. Indexing databases: Google scholar, PubMed etc., Citation databases: Web of Science, Scopus, Google-scholar etc., Impact Factor of journal as per Journal Citation Report, Metrics: h-index, g-index, i10-index, Altmetrics.

Essential readings:

1. Good Practices and Ethics in Research and Publication (Textbook for compulsory course by UGC for Ph.D. Students) by Ane Books Pvt. Ltd , 2017.
2. Science Communication: An Introduction (Frans van Dam, Liesbeth de Bakker, Anne Dijkstra, Eric A Jensen; World Scientific Publishing Co., 2020; ISBN - 978-981-120-987-1 (hardcover); 978-981-120-989-5 (ebook))

SUGGESTED READINGS:

1. Effective Science Communication: A practical guide to surviving as a scientist (Sam Illingworth and Grant Allen; IOP Publishing Ltd 2016; ISBN: 978-0-7503-1171-7(hardcover); 978-0-7503-1170-0 (ebook)).
2. Writing Research Papers: A Complete Guide (paperback) by James D. Lester (Late) (Author), James D. Lester Jr. (Author), Pearson; 15th edition (3 January 2014)