SRM
INSTITUTE OF SCIENCE & TECHNOLOGY
(Deemed to be **University** *u/s 3 of UGC Act, 1956)*

M. Tech. Genetic Engineering (Full Time)
Curriculum & Syllabus (2019-2020)

Department of Genetic Engineering
SRM Institute of Science and Technology
Faculty of Engineering & Technology
SRMIST, Kattankulathur, Chennai
Tamil Nadu, India 603 203

M.Tech GENETIC ENGINEERING (FULL TIME)
CURRICULUM & SYLLABUS (2019-2020)

SEMESTER-I

Code	Category	Course	L	T	P	C
GN2011	C	Molecular Cloning	3	0	3	4
GN2012	C	Regulation of Gene Expression	3	0	3	4
GN2013	C	Human Genetics	3	0	3	4
GN2014	C	Plant Genetic Engineering	3	0	3	4
GN2015	S	Statistical Methods	2	0	3	3
GN2016	C	Research Methodology	2	0	0	2
CAC2001		Career Advancement Course for Engineers - I	1	0	1	1
TOTAL			**17**	**0**	**16**	**22**
Total Contact Hours: 33						

SEMESTER-II

Code	Category	Course	L	T	P	C
GN2017	C	Developmental Genetics	3	0	3	4
GN2018	C	Cancer Genetics	3	0	3	4
PE-1	PE	Program Elective-1	3	0	0	3
PE-2	PE	Program Elective-2	3	0	0	3
PE-3	PE	Program Elective-3	3	0	0	3
IE-1	IE	Interdisciplinary Elective	3	0	0	3
CAC2002		Career Advancement Course for Engineers - II	1	0	1	1
TOTAL			**19**	**0**	**7**	**21**
Total Contact Hours: 26						

SEMESTER- III

Code	Category	Course	L	T	P	C
CE-1	PE	Program Elective-4	2	0	3	3
CE-2	PE	Program Elective-5	3	0	0	3
CE-3	PE	Program Elective-6	3	0	0	3
CAC2003		Career Advancement Course for Engineers - III	1	0	1	1
GN2048	C	Project - Phase I	0	0	12	6
TOTAL			**9**	**0**	**16**	**16**
Total Contact Hours: 25						

SEMESTER-IV

Code	Category	Course	L	T	P	C
GN2049	C	Project - Phase II	0	0	32	16
TOTAL			**0**	**0**	**32**	**16**
Total Contact Hours: 32						
TOTAL CREDITS TO BE EARNED TO AWARD THE DEGREE						**75**

C - Core Course
PE - Program Elective
S - Supportive Course
IE - Inter-disciplinary Elective

CONTACT HOUR/CREDIT:

L : Lecture Hours per week
P : Practical Hours per week
T : Tutorial Hours per week
C : Credit

PROGRAM ELECTIVES

SEMESTER-II

Code	Course	L	T	P	C
	Human Genetics Module 1				
GN2121	Human Physiology	3	0	0	3
GN2122	Stem Cell Biology	3	0	0	3
GN2123	Clinical Genetics	3	0	0	3
	Plant Genetics Module 1				
GN2124	Plant Physiology	3	0	0	3
GN2125	Biochemistry of Secondary Metabolites	3	0	0	3
GN2126	Plant Developmental Genetics	3	0	0	3
	Microbial Genetics Module 1				
GN2127	Microbial Physiology	3	0	0	3
GN2128	Metabolic Engineering of Microbes	3	0	0	3
GN2129	Microbial Genetics	3	0	0	3

SEMESTER-III

Code	Course	L	T	P	C
	Human Genetics Module 2				
GN2130	Human Genomics	2	0	3	3
GN2131	Pharmacogenetics	3	0	0	3
GN2132	Neurogenetics	3	0	0	3
	Plant Genetics Module 2				
GN2133	Plant Genomics	2	0	3	3
GN2134	Plant Environment Interaction	3	0	0	3
GN2135	Molecular Plant Breeding	3	0	0	3
	Microbial Genetics Module 2				
GN2136	Microbial Genomics	2	0	3	3
GN2137	Molecular Virology	3	0	0	3
GN2138	Molecular Pathology of Infectious Diseases	3	0	0	3

SEMESTER I

GN2011	MOLECULAR CLONING	L	T	P	C
	Total Contact Hours - 90	**3**	**0**	**3**	**4**

PURPOSE

To learn the molecular techniques, which are required to be a successful genetic engineer of plants, animals and microorganisms.

INSTRUCTIONAL OBJECTIVES

1.	To learn the gene cloning methods in theory and practice
2.	To learn genetic engineering of living organisms for the benefit of human

UNIT I: ENZYMES AND VECTORS USED IN GENE CLONING (10 hours)

Restriction enzymes, DNA polymerases, reverse transcriptase, terminal transferase, alkaline phosphatase, polynucleotide kinase, ligase, DNases, RNases, and topoisomerase. Plasmid vectors, phage vectors, BAC vectors and plasmid incompatibility, and vectors for cloning in yeast, and mammalian cells.

UNIT II: POLYMERASE CHAIN REACTION (10 hours)

PCR, factors affecting PCR, design of gene-specific and degenerate primers, semi quantitative Reverse transcriptase-PCR, real-time PCR with SYBR and TaqMan probe, site directed mutagenesis by PCR, LAMP-PCR

UNIT II: GENE CLONING METHODS (9 hours)

Cohesive end cloning, blunt end cloning, checking the direction of cloning by PCR and restriction digestion, cloning using adapters, and cloning adding restriction site by PCR. TA cloning, TOPO-TA cloning. Ligation independent cloning and single step cloning of multiple fragments by Gibson Assembly

UNIT IV: GENE & PROMOTER ISOLATION (8 hours)

Construction of cDNA library, genomic DNA library, screening the libraries using heterologous probes, functional screening, screening by complementation. Constitutive and inducible promoters, tissue specific promoters, promoter identification from gene expression data, reporter genes for promoter deletion studies, promoter deletion studies

UNIT V: EXPRESSON OF RECOMBINANT PROTEINS (8 hours)

Components of an expression plasmid vector, strategies for cloning in proper reading frame, codon optimization, optimization of induction of protein expression, factors affecting inclusion body formation, factors affecting protein folding, solubilizing recombinant protein in inclusion bodies, purification of recombinant proteins with and without purification ligands. Immobilization of recombinant proteins.

LABORATORY EXPERIMENTS
Total Hours: 45

1. Competent cell preparation and estimation transformation efficiency
2. Preparation of plasmid vector
3. Cloning using restriction enzymes
4. Primer design
5. PCR
6. Cloning of PCR products
7. In-frame cloning in expression vector
8. Ligation independent cloning
9. Verification of cloning and direction of cloning by restriction digestion
10. DNA sequencing

REFERENCES:

1. Primrose S.B and Twyman R.M. "Principles of Gene Manipulation and Genomic", Blackwell Publishing Company, Oxford, UK Third Edition (2006).
2. Brown T.A. "Gene Cloning and DNA Analysis an Introduction", Wiley Blackwell, UK. Seventh Edition (2016).
3. Innis M, White T, and Sninsky J.J. "PCR Protocols: A Guide to Methods and Applications", Academic Press, First Edition (1990).
4. Green M.R and Sambrook J. "Molecular Cloning", a Laboratory Manual, Cold Spring Harbor Laboratory Press, New York, USA. Fourth Edition (2012).
5. Ausubel F.M, Brent R, Kingston R.E and Moore D.D. "Current Protocols in Molecular Biology" John Wiley & Sons, New York, First Edition (1987).
6. Lab manual.

GN2012	REGULATION OF GENE EXPRESSION	L	T	P	C
	Total Contact Hours - 90	**3**	**0**	**3**	**4**
PURPOSE					
To understand the mechanisms of control of gene expression, including epigenetic gene regulations					
INSTRUCTIONAL OBJECTIVES					
To learn the basics of the factors that control gene expression					
To learn the transcriptional, translational, post-transcriptional and post-translational regulation of gene expression					
To learn about the epigenetic regulation of gene expression					

UNIT I: INTRODUCTION TO GENE EXPRESSION (9 hours)

Nucleic acids, fine structure of gene, the genetic code, mechanisms of transcription in prokaryotes and eukaryotes and RNA splicing, translation in prokaryotes and eukaryotes, *Cis*-acting elements and *trans*-acting factors.

UNIT II: TRANSCRIPTIONAL REGULATION (9 hours)

Activators and repressors, cooperative binding and allostery mechanisms, control of *lac* and *ara* operons, layers of regulation in λ bacteriophage, types of DNA-binding domains, recruitment of transcriptional machinery by activators, DNA loops, locus control regions and insulators, signal integration, control of HO gene by two regulators, combinatorial control, mating-type genes from yeast and mechanism of repressors.

UNIT III: REGULATORY RNAs (9 hours)

Riboswitches, RNAs as defense agents, CRISPR system in bacteria, CRISPR-Cas9 for genome editing, CRISPRi and CRISPRa for gene regulation, synthesis and function of miRNA molecules, silencing of gene expression by small RNAs, RNAi, long noncoding RNAs and X-inactivation

UNIT IV: POSTTRANSLATIONAL REGULATION (9 hours)

Posttranslational modifications, enhancing proteome complexity, addition of hydrophobic groups for membrane localization, prenylation, palmitoylation, myristoylation, protein phosphorylation, methylation, N-acetylation, hydroxylation, carboxylation, amidation, glycosylation, sulfuryl transfers, modifications of cysteine and methionine, ubiquitin and ubiquitin-like protein tags.

UNIT V: EPIGENETIC GENE REGULATION (9 hours)

Histone modifications and their effects on gene expression, acetylation, methylation, role of polycomb group and trithorax group proteins in epigenetic regulation, genomic imprinting in mammals, DNA methylation and epigenetic inheritance.

LABORATORY EXPERIMENTS
Total Hours: 45

1. RNA isolation from plant and animal tissues
2. Quality checking of RNA by using agarose gel electrophoresis, spectrophotometer, fluorimeter and Bioanalyzer
3. DNase treatment a nd purification RNA
4. Semi-quantitative Reverse transcriptase PCR
5. Primer design for real-time PCR
6. Real time PCR
7. Digital PCR
8. Expression of recombinant protein in E. coli

REFERENCES:

1. Watson J.D, Bake T.A, Bell S.P, Gann A, Levine M and Losick R. "Molecular Biology of the Gene", Pearson Education, Seventh Edition (2014).
2. Huang S, Litt M.D and Blakey C.A. "Epigenetic Gene Expression and Regulation", Academic Press, First Edition (2015).
3. Walsh C.T. "Posttranslational modification of Proteins: Expanding Nature's inventory", Roberts & Company Publishers, First Edition (2005).
4. Green M.R and Sambrook J. "Molecular Cloning" A Laboratory Manual, Cold Spring Harbor Laboratory Press, New York, USA. Fourth Edition (2012).
5. Ausubel F.M, Brent R, Kingston R.E and Moore D.D. "Current Protocols in Molecular Biology", John Wiley & Sons, New York, First Edition (1987).
6. Lab manual.

GN2013	HUMAN GENETICS	L	T	P	C
	Total Contact Hours - 90	**3**	**0**	**3**	**4**

PURPOSE

To learn the fundamentals of human genetics and its application in human disease diagnosis and management.

INSTRUCTIONAL OBJECTIVES

1.	To understand the relationship between classical genetics and genotypes
2.	To learn the concepts of inheritance and associated complications in human
3.	To understand the regulation of human gene expression
4.	To understand the nature of human chromosome abnormalities
5.	To learn different methods of human disease gene identification and screening

UNIT I: PATTERNS OF INHERITANCE (9 hours)

Mendelian monogenic inheritance, non-Mendelian inheritance (incomplete dominance, co-dominance), uniparental disomy, penetrance, non-penetrance, expressivity, mitochondrial inheritance, late-onset diseases, anticipation, imprinting, heterogeneity, consanguinity, phenocopy, pleiotropy, mosaicism, multifactorial inheritance, quantitative traits of polygenic inheritance, gene and genotype frequencies, and pedigree analysis.

UNIT II: HUMAN GENOME ORGANIZATION (9 hours)

Structure and organization of human chromosomes, mitochondrial genome organization, limited autonomy of mitochondrial genome, protein coding genes, RNA genes, microRNAs, regulatory RNAs, overlapping genes, genes-within-genes, non-coding DNA, satellite DNA, mini and microsatellite DNA, transposon derived repeats, alternative transcription, long range control of gene expression, and DNA methylation and epigenetics.

UNIT III: CHROMOSOME ABNORMALITIES (9 hours)

Karyotyping, FISH technique, and chromosome painting. Numerical chromosome abnormalities, structural chromosome abnormalities, mixoploidy, mosaicism and chimerism, and polyploidy. Autosomal abnormalities, sex chromosome abnormalities, human reproductive disorders, and congenital abnormalities. X-inactivation and mosaicism due to X-inactivation, locus heterogeneity, and clinical heterogeneity. Introduction to the international system of human cytogenetic nomenclature (ISCN).

UNIT IV: IDENTIFICATION OF DISEASE CAUSING GENES (9 hours)

Introduction to the Human Genome Variation Society (HGVN) nomenclature of human mutations. Genetic mapping, genetic markers, fine mapping analysis, segregation analysis, linkage analysis, association studies, linkage disequilibrium. Gene identification by positional cloning and genomics approaches (whole genome, whole exome, and transcriptome strategies), and candidate gene testing.

UNIT V: POPULATION SCREENING AND PRENATAL DIAGNOSIS (9 hours)

Prenatal, newborn and population genetic screening. Genetic testing, analyzing specified sequence changes, MLPA test, applications and ethical implications of DNA profiling. Pedigree construction, proband analysis, genetic counseling, and importance of genetic counseling.

LABORATORY EXPERIMENTS
Total Hours: 45

1. Culturing blood and harvesting leukocytes
2. Identification of human chromosomes.
3. GTG-banding of metaphase chromosomes and karyotype analysis
4. C-banding of metaphase chromosomes and karyotype analysis
5. NOR-banding of metaphase chromosomes and karyotype analysis.
6. Sister chromatic exchange assay
7. Micronucleus assay
8. Chromosomal breakage study

REFERENCES

1. Young I.D. “Medical Genetics” Oxford University Press, UK. First Edition (2005).
2. Gardner A and Davies T. “Human Genetics” Viva Books, Second Edition (2012).
3. Arsham M.S and Barch M.J. “The AGT Cytogenetics Laboratory Manual” Wiley- Blackwell”, New Jersey, USA, Fourth Edition (2017).
4. Lab manual

GN2014	PLANT GENETIC ENGINEERING	L	T	P	C
	Total Contact Hours - 90	3	0	0	3

PURPOSE

To learn *in vitro* regeneration, transformation, and gene editing of plants for the purpose of generating genetically modified plants for basic and applied research.

INSTRUCTIONAL OBJECTIVES

1.	To learn *in vitro* regeneration of plants from different explants
2.	To gain knowledge on the production of transgenic plants
3.	To learn about gene editing in plants
4.	To understand the applications of genetically modified crops
5.	To learn about the biosafety and regulatory issues related to genetically modified organisms

UNIT I: PLANT REGENERATION METHODS (9 hours)

History of plant tissue culture, types of media and their preparation, plant hormones, direct and indirect organogenesis, meristem, callus and suspension cell culture, micropropagation, somatic embryogenesis, protoplast fusion, somaclonal variation, and artificial seeds.

UNIT II: PLANT TRANSFORMATION METHODS (9 hours)

Biology of *Agrobacterium tumefaciens*, agrobacterium mediated plant transformation and selection of transgenic crops. Binary vectors, selection and screening markers, marker-free transgenics, gene silencing by antisense and RNAi technology, chloroplast transformation using gene gun and *in planta* transformation.

UNIT III: GENE EDITING IN PLANTS (9 hours)

Targeted genetic modification (knock-in and knock-out) using zinc finger nucleases, TALENS and CRISPR/Cas9. CRISPR/Cas9 - design, synthesis, cloning of synthetic guide RNAs in binary vector, confirmation by Sanger sequencing, validation of synthetic guide RNA and transformation into protoplasts.

UNIT IV: GENETICALLY ENGINEERED PLANTS (9 hours)

Difference between transgenic plants and genetically edited plants. Transgenic plants - Bt cotton, Roundup ready soybean, vitamin A fortified rice and pharmaceutical drugs in plants. Gene edited plants - semi-dwarf (*sd1*) mutant rice and *Zea mays* with reduced phytic acid content.

UNIT V: BIOSAFETY AND REGULATORY GUIDELINES (9 hours)

Biosafety of genetically modified plants, containment in laboratory and transgenic green house, safety assessment of genetically modified plants, Competent authorities-

Recombinant DNA Advisory Committee, Institutional Bio-safety Committee, Review Committee on Genetic Manipulation, Genetic Engineering Appraisal Committee, State Biotechnology Co-Ordination Committee and District level committee. Quarantine involved in import and export of genetically modified crops

LABORATORY EXPERIMENTS
Total hours: 45

1. Preparation of tissue culture media
2. Aseptic germination of seeds
3. Callus induction from leaf and seed explants.
4. Transformation of *Agrobacterium* with binary vector
5. *Agrobacterium*-mediated transformation of tobacco leaf discs
6. Co-cultivation, selection, and regeneration of transgenic plants
7. Screening of transgenic plants by using GUS/GFP marker
8. Screening of transgenic plants by PCR
9. Transient transformation by biolistic gene gun
10. Design of gRNA and vector construction for gene editing in plants

REFERENCES:

1. Razdan M.K. "Introduction to Plant Tissue Culture", Science Publishers, Third Edition (2005).
2. Slater A, Scott N.W and Fowler M.R. "Plant Biotechnology: The Genetic Manipulation of Plants", Oxford University Press, Third Edition (2008).
3. Gelvin S (2003) Agrobacterium-Mediated Plant Transformation: The Biology behind the Gene-Jockeying Tool, Microbiology and Molecular Biology Reviews, 67: 16-37.
4. Voytas D.F and Gao C (2014) Precision Genome Engineering and Agriculture: Opportunities and Regulatory Challenges, Plos One. 12, e1001877.
5. Laboratory Manual.

GN2015	STATISTICAL METHODS	L	T	P	C
	Total Contact Hours - 75	**2**	**0**	**3**	**3**
PURPOSE					
To learn the concepts and practical utilization of the statistical methods that are useful in biological research.					
INSTRUCTIONAL OBJECTIVES					
1.	To understand the statistical theory behind the different methods of statistical analysis				
2.	To acquire the ability to choose appropriate statistical method (s) for a given type of data and research objective				
3.	To learn statistical methods using real data				
4.	To learn how to interpret the statistical test results				

UNIT I: BASIC STATISTICAL MEASURES, CORRELATION AND REGRESSION (6 hours)

Basic concepts of measures of central tendency, measures of dispersion, skewness and kurtosis. Correlation and regression theory, testing the significance of an observed correlation coefficient, observed regression coefficient and observed partial regression coefficient, testing difference between two partial regression coefficients, Multiple regression model.

UNIT II: CONTINGENCY TABLES (6 hours)

Chi-square test-2x2 tables, RxC tables, McNemar's test, the odd ratio, Berkson's fallacy, multiple 2x2 contingency tables: Simpson's paradox, Mantel-Haenszel method, test of homogeneity, and test of association.

UNIT III: TWO SAMPLE HYPOTHESES (6 hours)

Testing for difference between two means, testing for difference between two variances, two sample rank testing, Mann-Whitney test, and testing for difference between two Median.

UNIT IV: MULTI-SAMPLE HYPOTHESIS (6 hours)

Single factor analysis of variance, Kruskal-Wallis single-factor analysis of variance by ranks. Bartlett's test for homogeneity of variances, and testing for homogeneity of coefficient of variation.

UNIT V: MULTIPLE COMPARISONS (6 hours)

Tukey test, Newman-Keuls test, Dunnett's test, and Scheffe's test for multiple contrast.

LABORATORY EXPERIMENTS
Total Hours: 45

(Training on the following methods will be offered using R / SPSS / other software)

1. Computation of mean, median, mode, standard deviation, coefficient of variation, and coefficient of skewness.
2. Test for Correlation coefficient and Regression coefficient
3. Test for partial regression coefficient and for the difference between two partial regression coefficients
4. Chi-square test and McNemar's test
5. Computation of Odds ratio and Pooled odds ratio - Mantel-Haenszel method.
6. Independent T test and Mann- Whitney U test
7. One tailed variance ratio test and two tailed variance ratio test
8. ANOVA and Kruskal-Wallis test
9. Tukey test with unequal sample sizes

10. The Newman-Keuls multiple range test
11. Dunnett's test for comparing a control mean to each other group mean
12. Scheffe's test for multiple contrast

REFERENCES:

1. Zar J.H. "Bio-Statistical Analysis" Pearson Education, Dorling Kindersley (India) Pvt. Ltd., New Delhi, Fourth Edition (2009).
2. Pagano M and Gaurveau K. "Principles of Bio-Statistics" Duxbury, Thomson Asia Pvt. Ltd., Singapore, Second Edition (2018).
3. Walpole R.E, Myers R.H, Myers S.L and Keying Ye. "Probability & Statistical for Engineers and Scientists", Pearson Education, Dorling Kindersley (India) Pvt. Ltd., New Delhi, Ninth Edition (2016).

GN2016	RESEARCH METHODOLOGY	L	T	P	C
	Total Contact Hours - 30	**2**	**0**	**0**	**2**
PURPOSE					
To learn about types of research, designs of experiment, formulation of research, presentation and publication of research findings.					
INSTRUCTIONAL OBJECTIVES					
1.	To know about different types of research				
2.	To understand how to formulate research				
3.	To know about research designs and methodologies				
4.	To learn about presentations, thesis writing and publication of research articles				

UNIT I: INTRODUCTION TO RESEARCH AND ITS TYPES (6 hours)

Motivation and objectives of research, types of research; conceptual vs. empirical, descriptive vs. analytical, applied vs. fundamental, and quantitative vs. qualitative. Data collection by observation method, interview method, experimental method, questionnaires, and case study method.

Unit II: RESEARCH RESOURCES AND FUNDING (6 hours)

Sources of information - thesis, research articles, reviews, monographs, and patents. Web resource - PUBMED, web of science, open access journal and e-books. Identifying gap areas from literature review, and writing proposals for research and funding. Funding sources in India and abroad.

UNIT III: RESEARCH DESIGN AND METHODS (6 hours)

Research problem, formulation and testing of research hypotheses. Basic experimental designs; completely randomized design, randomized block design and latin square design. Factorial designs- 2^2, 2^3 and 2^4 accuracy and error analysis. Study population, scientific control groups and variables, sampling and sample size determination.

UNIT IV: PRESENTATION OF RESEARCH FINDINGS (6 hours)

Presentation of research as research articles, reviews, books, chapters in books, thesis, reports, and conferences presentations. Preparation of illustrations and tables, do's and dont's of Powerpoint presentation, poster presentation, and basics of Photoshop. Bibliography and reference managers (Mendeley and Endnote). Language correction using Grammarly and professional editing services. Implication of plagiarism and plagiarism checking using software (Ithenticate and Turnitin).

UNIT V: PUBLICATION PROCESS (6 hours)

Fundamentals of publishing, assessing journal using journal metrics (impact factor, citation score, Scopus and SCI indexing), peer review process, Intellectual Property Rights, copy right and technology/material transfer. Ensuring visibility of your research througjh conferences, social media, Google Scholar, and Reserch Gate. Ethics in research: Institutional Biosafety Committee, Instituitional Animal Ethical Committee, Institutional Human Safety Committe, and Stem Cell Committee. Professional ethics in research.

REFERENCES

1. Garg B.L, Karadia R, Agarwal F and Agarwal U.K. "An Introduction to Research Methodology", RBSA Publishers, (2002).
2. Watson F.L and Lom B (2008) More than a Picture: Helping Undergraduates Learn to Communicate through Scientific Image, CBE Life Science Education. 7: 27-35.
3. Pautasso M (2013) Ten Simple Rules for Writing a Literature Review, PLoS Computational Biology 9: e1003149.
4. Dodson B.T (2015) Writing a Scientific Paper Is Not Rocket Science, Journal of Oral and Maxillofacial Surgery 73: 160-169.
5. Jha K.N (2014) How to Write Articles that Get Published, Journal of Clinical Diagnostic Research, 8: XG01–XG03.

CAC2001	CAREER ADVANCEMENT COURSE FOR ENGINEERS - I	L	T	P	C
	Total Contact Hours - 30	**1**	**0**	**1**	**1**

PURPOSE	
To enhance holistic development of students and improve their employability skills	
INSTRUCTIONAL OBJECTIVES	
1.	To improve aptitude, problem solving skills and reasoning ability of the student
2.	To collectively solve problems in teams & group
3.	Understand the importance of verbal and written communication in the workplace
4.	Understand the significance of oral presentations, and when they may be used
5.	Practice verbal communication by making a technical presentation to the class

UNIT I: BASIC NUMERACY

Types and properties of numbers, LCM, GCD, fractions and decimals, Surds

UNIT II: ARITHMETIC – I

Percentages, profit and loss, equations

UNIT III: REASONING - I

Logical reasoning

UNIT IV: SOFT SKILLS - I

Presentation skills, E-mail etiquette

UNIT V: SOFT SKILLS – II

Goal setting and prioritizing

ASSESSMENT

Soft Skills (Internal)

Assessment of presentation and writing skills.

Quantitative Aptitude (External)
Objective Questions- 60 marks
Descriptive case lets- 40 marks*
Duration: 3 hours
*****Engineering problems will be given as descriptive case lets.

REFERENCE

1. Khattar D. "Quantitative Aptitude", Pearsons Publicaitons, Third Edition (2015).
2. Praveen R.V. "Quantitative Aptitude and Reasoning", EEE Publications, Third Edition (2016)
3. Guha A. "Quantitative Aptitude", TATA McGRAW Hill Publications, Sixth Edition (2017).
4. Butterfield J. "Soft Skills for Everyone", Cengage Learning India Private Ltd, First Edition (2011).
5. Bono E.D. "Six Thinking Hats is a book", Little Brown and Company, First Edition (1981)
6. Arihant. "IBPS PO - CWE Success Master", Arihant Publications (I) Pvt.Ltd – Meerut, First Edition (2018).

SEMESTER II

GN2017	DEVELOPMENTAL GENETICS	L	T	P	C
	Total Contact Hours - 90	**3**	**0**	**3**	**4**

PURPOSE

To understand the genetics of animal embryogenesis and development

INSTRUCTIONAL OBJECTIVES

1.	To learn the types of cell specification and cell signaling mechanisms
2.	To learn the molecular basis of body axis formation
3.	To learn about germ layer specification and organogenesis
4	To learn the biology of regeneration and ageing.

UNIT I: ESSENTIAL CONCEPTS IN ANIMAL DEVELOPMENT (9 hours)

Overview of early development, Karl von Baer's principles, embryonic homologies, cell specification, cell differentiation, differential gene expression in development, cell-to-cell communication, differential cell affinity, induction and competence, juxtacrine signaling, paracrine factors, and extracellular matrix as a source of signals.

UNIT II: FERTILIZATION AND EARLY DEVELOPMENT (9 hours)

Patterns of sex determination, mammalian gametogenesis, structure of gametes, external and internal fertilization, early development in *Drosophila* and *C. elegans*, genetic mechanisms of patterning the *Drosophila* body, early amphibian development, and early development in mammals.

UNIT III: VERTEBRATE NERVOUS SYSTEM AND EPIDERMIS (9 hours)

Primary neurulation, secondary neurulation, patterning of central nervous system, brain growth, neural crest cells, axonal specificity, and cranial placodes and epidermis and their cutaneous appendages.

UNIT IV: ORGANOGENESIS (9 hours)

Somites and their derivatives, sclerotome and dermomyotome, osteogenesis and muscle formation, development of kidney, heart and circulatory system, development of the tetrapod limb, and the digestive tube and their derivatives.

UNIT V: POSTEMBRYONIC DEVELOPMENT (9 hours)

Amphibian metamorphosis, metamorphosis in insects, types of regeneration, regeneration in planaria, salamanders, zebrafish and mammals. Ageing, role of DNA repair enzymes, ROS, telomerase, insulin-signaling cascade, and stem cells in ageing.

LABORATORY EXPERIMENTS
Total Hours: 45

1. Culturing techniques for *Drosophila*
2. Stages of *Drosophila* embryonic and larval development
3. Observation and analysis of *Drosophila* homeotic mutants – *antennapaedia*, *ultrabithorax*
4. Dissection and observation of imaginal discs in *Drosophila* larvae
5. lacZ staining for segment polarity genes in *Drosophila* embryos
6. Maintenance & Breeding methods for zebrafish
7. Stages of zebrafish embryonic and larval development
8. Staining of cartilage and bones at different stages of zebrafish
9. Designing of CRISPR sgRNA for gene editing in zebrafish
10. Microinjection of CRISPR sgRNA in zebrafish zygotes
11. Observation and analysis of gene edited zebrafish embryos/larvae

REFERENCES

1. Gilbert S.F and Barresi M.J.F. "Developmental Biology", Oxford University Press, Eleventh Edition (2016).
2. Slack J.M.W. "Essential Developmental Biology", Wiley-Blackwell Publishers, Third Edition (2012).
3. Wolpert L, Tickle T and Arias A. "Principles of Development", Oxford Publishers, Fifth Edition (2015).
4. Westerfield M. "The Zebrafish Book: A Guide for The Laboratory Use of Zebrafish (*Danio rerio*)", University of Oregon Press, Fifth Edition (2007).
5. Ashburner M. "Drosophila: A Laboratory Handbook", Cold Spring Harbor Laboratory Press, First Edition (1989).
6. Lab Manual.

GN2018	CANCER GENETICS	L	T	P	C
	Total Contact Hours - 90	**3**	**0**	**3**	**4**
PURPOSE					
To learn the biology and genetics of cancer and the genetic basis of cancer therapy.					
INSTRUCTIONAL OBJECTIVES					
1.	To gain knowledge on biology and genetics of cancer				
2.	To understand the signaling pathways and therapeutic resistance involved in cancer				

UNIT I: BIOLOGY OF CANCER (9 hours)

Introduction and classification of cancers. Causes of cancer, genetic factors, physical and chemical agents, lifestyle, hormones, infection and inflammation, tumor viruses, bacteria and parasites, radiation and rare causes. Global and Indian scenario of cancer. Epidemiology, screening and prevention of cancer. Hallmarks of cancer, steps in

metastasis – intravasation, epithelial mesenchymal transition, and extravasation**.** Cancer stem cells.

UNIT II: ONCOGENES AND TUMOR SUPPRESSOR GENES (9 hours)

Oncogenes – transmissible cancer genes – RAS gene family, MYC gene family. Genes - proto-oncogenes, activation by gene amplification, chromosomal translocation, mutations in PIK3CA. Tumor suppressor genes - inactivation of retinoblastoma and control of cell cycle clock - p53 and apoptosis. APC inactivation in inherited and sporadic colorectal cancers, breast cancer susceptibility - BRCA1 and BRCA2. Metastasis suppressor genes.

UNIT III: GENETIC INSTABILITY AND CANCER GENOMES (9 hours)

Genetic and epigenetic causes of aneuploidy. Defects in mismatch repair, nucleotide excision repair, crosslink repair, and DNA double strand break repair. Aging and cancer - telomeres and telomerase. Types of genetic alterations in cancer - cancer associated mutations and cancer genes. Beyond the exome - the "Dark Matter" of cancer genome.

UNIT IV: SIGNALLING PATHWAYS IN CANCER (9 hours)

Basic elements and concepts of signaling. GPCRs in cancer. Estrogen, androgen and progesterone hormone signaling in cancer. Growth factor signaling and oncogenic pathways - EGFR signaling, RAS-MAPK and PI3K-AKT. Calcium signaling and Metastasis. Cell motility and Wnt-β-Catenin signaling, TNFα-NFκB signaling in inflammation and cancer, dual role of TGFβ pathway in cancer.

Targeting aberrant signaling pathways using antibodies based and small molecules. Crosstalk among pathways - a signaling conundrum.

UNIT V: GENETIC BASIS OF CANCER THERAPY (9 hours)

Types of cancer treatment - radiation therapy, chemotherapy, targeted therapy, recombinant immunotherapy, gene therapy, cancer stem cell therapy, and hormone therapy. Case studies - resistance to imatinib in CML, resistance to Trastuzumab in breast cancer and TNF-α in sensitizing cancer cells for chemotherapy and radiotherapy. Chemoresistance – increased expression of efflux pump proteins or transporters, increased expression of DNA damage repair genes, regulation of drug target gene expression and metabolizing enzymes. Radioresistance - genomic biomarkers of radiosensitivity. Role of antioxidant enzymes, autophagy related genes and hypoxia responsive genes on radioresistance.

LABORATORY EXPERIMENTS

Total Hours: 45

1. Trypsinisation and subculturing of cancer cell lines
2. Viability tests: Fluorescein diacetate and Tryphan blue
3. MTT assay

4. Clonogenic assay
5. Spheroid assay
6. Scratch assay
7. Annexin V staining and flow cytometry
8. Comet assay to analyse DNA damage
9. Chorioallantoic membrane assay for angiogenesis
10. Immunocytochemistry for cancer markers

REFERENCES:

1. Bunz F. "Principles of Cancer Genetics", Springer Science, Second Edition (2016).
2. Weinberg R. "The Biology of Cancer", Garland, Second Edition (2013).
3. Lab Manual.

CAC2002	CAREER ADVANCEMENT COURSE FOR ENGINEERS - II	L	T	P	C
	Total Contact Hours - 30	1	0	1	1
	Prerequisite				
PURPOSE					
To enhance holistic development of students and improve their employability skills					

INSTRUCTIONAL OBJECTIVES
OBJECTIVES

1. To improve aptitude, problem solving skills and reasoning ability of the student.
2. To collectively solve problems in teams & group.
3. Understand the importance of verbal communication in the workplace
4. Understand the significance of oral presentations, and when they may be used.
5. Understand the fundamentals of listening and how one can present in a group discussion
6. Prepare or update resume according to the tips presented in class.

UNIT I: ARITHMETIC – II
Ratios and proportions, mixtures and solutions

UNIT II: MODERN MATHEMATICS
Sets and functions, data interpretation, and data sufficiency

UNIT III: REASONING - II
Analytical reasoning

UNIT IV: COMMUNICATION - I
Group discussion and personal interview

UNIT V: COMMUNICATION - II

Verbal reasoning test papers

ASSESSMENT

Communication (Internal)

Individuals are put through formal GD and personal interviews.

Comprehensive assessment of individuals' performance in GD & PI will be carried out.

Quantitative Aptitude (External)

Objective Questions- 60 marks (30 Verbal +30 Quants)

Descriptive case lets- 40 marks*

Duration: 3 hours

*Engineering problems will be given as descriptive case lets.

REFERENCES

1. Khattar D. "Quantitative Aptitude", Pearsons Publicaitons, Third Edition (2015).
2. Praveen R.V. "Quantitative Aptitude and Reasoning", EEE Publications, Third Edition (2016)
3. Guha A. "Quantitative Aptitude", TATA McGRAW Hill Publications, Sixth Edition (2017).
4. Bharadwaj A.P. " General English for Competitive Examination", Pearson Education, First Edition (2013)..
5. Thorpe S. "English for Competitive Examination", Pearson Education, Sixth Edition (2012).
6. Arihant. "IBPS PO - CWE Success Master", Arihant Publications(I) Pvt.Ltd – Meerut, First Edition (2018)
7. Nishit Sinha. "Verbal Ability for CAT", Pearson India, First Edition (2018).
8. Sharma A and McGraw T. "Verbal Ability & Reading Comprehension", Hill Education, First Edition (2018).

CAC2003	CAREER ADVANCEMENT COURSE FOR ENGINEERS - III	L	T	P	C
	Total Contact Hours - 30	**1**	**0**	**1**	**1**
	Prerequisite				

PURPOSE	
To develop professional skills abreast with contemporary teaching learning methodologies	
INSTRUCTIONAL OBJECTIVES **At the end of the course the student will be able to**	
1	acquire knowledge on planning, preparing and designing a learning program
2	prepare effective learning resources for active practice sessions
3	facilitate active learning with new methodologies and approaches
4	create balanced assessment tools
5	hone teaching skills for further enrichment

UNIT I: DESIGN **(2 hrs)**
Planning and preparing a learning program.

UNIT II: PRACTICE **(2 hrs)**
Facilitating active learning, Engaging learners

UNIT III: ASSESSMENT **(2 hrs)**
Assessing learner's progress , Assessing learner's achievement

UNIT IV: HANDS ON TRAINING **(10 hrs)**
Group activities – designing learning session, Designing teaching learning resources, Designing assessment tools , Mock teaching session.

UNIT V: TEACHING IN ACTION **(14 hours)**
Live teaching sessions and assessments

ASSESSMENT (Internal)
Weightage:
Design - 40%
Practice – 40%
Quiz – 10%
Assessment – 10%

REFERENCES

1. Barker I. "Cambridge International Diploma for Teachers and Trainers", Cambridge University Press, (2006).
2. Whitehead J (1989) Creating a Living Educational Theory from Questions of the Kind, 'How do I Improve my Practice?', Cambridge Journal of Education, 19: 41-52.

	Project Work	L	T	P	C
GN2048	Project - Phase I (III Semester)	0	0	12	6
GN2049	Project - Phase II (IV Semester)	0	0	32	16
PURPOSE					
To undertake research in an area related to the program of study					
INSTRUCTIONAL OBJECTIVES					
The student shall be capable of identifying a problem related to the program of study and carry out wholesome research on it leading to findings which will facilitate development of a new/improved product, process for the benefit of the society					

M.Tech projects should be socially relevant and research oriented ones. Each student is expected to do an individual project. The project work is carried out in two phases – Phase I in III semester and Phase II in IV semester. Phase II of the project work shall be in continuation of Phase I only. At the completion of a project the student will submit a project report, which will be evaluated (end semester assessment) by duly appointed

examiner(s). This evaluation will be based on the project report and a viva voce examination on the project. The method of assessment for both Phase I and hase II is shown in the following table

Assessment	Tool	Weightage
In Semester	I Review	10%
	II Review	15%
	III Review	35%
End Semester	Final viva voce examination	40%

Student will be allowed to appear in the final viva voce examination only if he / she has submitted his / her project work in the form of paper for presentation / publication in a conference / journal and produced the proof of acknowledgement of receipt of paper from the organizers / publishers

PROGRAM ELECTIVES
SEMESTER II

GN2121	HUMAN PHYSIOLOGY	L	T	P	C
	Total Contact Hours - 45	3	0	0	3

PURPOSE

To understand the anatomy, function and regulation of the human body and physiological integration of the organ systems to maintain homeostasis.

INSTRUCTIONAL OBJECTIVES

1	To gain knowledge on the cellular processes involved in physiology
2	To understand the basic functions of cardiovascular and respiratory systems
3	To understand the physiology of gastro-intestine system
4	To understand the concepts that constitute neuro-muscular and renal physiology
5	To understand the physiology of reproductive system

UNIT I: CELLULAR PHYSIOLOGY (9 hours)

Structural organization of cell membrane and organelles. Intercellular junctions - gap junctions, tight junctions and desmosomes. Membrane and functional transport of cell - osmosis - active and passive transport - exocytosis and endocytosis.

UNIT II: CARDIOVASCULAR AND RESPIRATORY PHYSIOLOGY (9 hours)

Action potential in cardiac muscle, cardio-vascular pathways - systemic and peripheral circulation. Cardiac cycle - diastole and systole; Relationship of electrocardiogram to cardiac cycle - cardiac output. Electrical impulse conduction in cardiac system. Cellular respiration - gaseous transport and exchange.

UNIT III: GASTRO-INTESTINAL PHYSIOLOGY (9 hours)

Structure and function of stomach, liver, pancreas, small intestine, large intestine, colon and rectum. Gastrointestinal secretions, digestion and absorption of carbohydrates, fats and proteins. Physiology of gastrointestinal disorders (peptic ulcer disease - pancreatic failure – malabsorption and constipation).

UNIT IV: NEURO-MUSCULAR PHYSIOLOGY (9 hours)

Organization of the central, peripheral and autonomic nervous systems. Neuronal structure and function - membrane excitation, resting and action potential. Neuronal communication - organization of neuromuscular junctions- basic function of synapses and transmitter substances. Structure of muscle, mechanism of muscle contraction and relaxation, phosphocreatine and creatine system.

UNIT V: RENAL AND REPRODUCTIVE PHYSIOLOGY (9 hours)

Structure and functions of kidney, formation of urine and acid base balance. Male and female reproductive organs, hormonal function and sex determination. Oogenesis and spermatogenesis. Physiology of pregnancy and lactation.

REFERENCES:

1. Guyton A.C and Hall J.E. "Medical Physiology", Elsevier Health Sciences, Thirteenth Edition (2015).

GN2122	STEM CELL BIOLOGY	L	T	P	C
	Total Contact Hours - 45	3	0	0	3
PURPOSE					
To learn the basics of stem cell biology and its application in healthcare					
INSTRUCTIONAL OBJECTIVES					
1.	To gain knowledge about stem cells and their characteristics				
2.	To gain knowledge on embryonic stem cells and stem cell niche				
3.	To learn about adult stem cells and their properties				
4.	To understand the role of signaling pathways and epigenetics in stem cell fate				
5.	To learn about the applications of stem cells in tissue engineering and treatment of human diseases				

UNIT I: BASICS OF STEM CELL BIOLOGY (9 hours)

Origin of stem cells. Early development of embryo. Unique properties of stem cells, early development of embryo. Formation of stem cells - Totipotent, Pluripotent, and multipotent cells. Types of stem cells - embryonic stem cells, adult stem cells, induced pluripotent stem cells, and cancer stem cells. Similarities and differences between embryonic and adult stem cells. Regeneration in vertebrates and invertebrates.

UNIT II: EMBRYONIC STEM CELLS (9 hours)

Introduction to ESCs and related ethical issues. Mouse embryo derived cells – EC, ES, EG, TS and NTES cells. Naïve and primed ESCs, primate and mouse ESCs. Lab tests for ESCs, isolation of human ESCs and stem cell niche.

UNIT III: ADULT STEM CELLS AND iPSCs (9 hours)

Properties and sources of adult stem cells (ASCs), lab tests for ASCs, hematopoietic stem cells, neural stem cells, germinal stem cells, and Steven's experiment. Dedifferentiation, trans-differentiation, reprogramming of iPSCs, and methods of producing of iPSCs. Somatic cell nuclear transfer – molecular mechanisms in cloning. Stem cells and aging.

UNIT IV: SIGNALLING PATHWAYS AND EPIGENETICS (9 hours)

ESC pluripotency and signaling – JAK-STAT pathway. HSC signaling pathways – Notch, Wnt and TGF-SMAD pathways. Role of DNA methylation and repression complexes on stem cells and differentiation. Stem cells, cancer and epigenetics – DNA hypermethylation, genes which regulate stem/progenitor cells, initiation of human cancer and progression of cancer.

UNIT V: APPLICATIONS OF STEM CELLS (9 hours)

Autologous approaches to tissue engineering – biological and translational challenges. Stem cell treatment for Parkinson's disease, burns, spinal cord injury and heart diseases. Recent developments in stem cell research and therapy.

REFERENCES:

1. Sell S. "Stem Cells Handbook", Humana Press, Second Edition (2004).
2. Stem Cell Information, "National Institutes of Health", Stem Cell Primer (2009).
3. Lanza R and Atala A. "Essentials of Stem Cell Biology", Academic Press, Third Edition (2014).
4. https://www.stembook.org/chapters.
5. Bendall S.C, Stewart M.H and Bhatia M (2008) Human Embryonic Stem Cells: Lessons from Stem Cell Niches in Vivo, Regenerative Medicine, 3: 365-376.
6. Jopling C, Boue S, Carlos J and Belmonte I (2011) Dedifferentiation, Transdifferentiation and Reprogramming: Three Routes to Regeneration, Nature Reviews. Molecular Cell Biology, 12: 79-89.
7. Zech N (2005) Plasticity of Stem Cells: Cell-Fusion versus Trans Differentiation, Journal of Reproduktionsmed Endokrinol, 2: 239-245.
8. Ma D.K, Bonaguidi M.A and Ming G.L (2009) So. Ault Neural Stem Cells in the Mammalian Central Nervous System, Cell Research, 19: 672-682.
9. Takahashi K and Yamanaka S (2006) Induction of Pluripotent Stem Cells From Mouse Embryonic and Adult Fibroblast Cultures by Defined Factors, Cell, 126: 663-76.

10. Huang G, Ye S, Zhou X, Liu D and Ying Q.L (2015) Molecular Basis of Embryonic Stem Cell Self-Renewal: From Signaling Pathways to Pluripotency Network, Cell Molecular Life Sciences, 72: 1741-57.
11. Blank U, Karlsson G and Karlsson S (2008) Signaling Pathways Governing Stem-Cell Fate, Blood, 111: 492-503.
12. Victoria V, Lunyak and Rosenfeld M.G. (2008) Epigenetic Regulation of Stem Cell Fate, Human Molecular Genetics, 17: 28-36.
13. Garitaonandia I, Gonzalez R, Sherman G, Semechkin A, Evans A and Kern R (2018) Novel Approach to Stem Cell Therapy in Parkinson's Disease, Stem Cells Development, 27: 951-957.
14. Müllera L.P and Robert D (2008) Stem Cell Therapy in Heart Diseases - Cell Types - Mechanisms and Improvement Strategies, Cell Physiology Biochemistry 48: 2607-2655.

GN2123	CLINICAL GENETICS	L	T	P	C
	Total Contact Hours - 45	**3**	**0**	**0**	**3**

PURPOSE

To learn the fundamentals of clinical genetics and its application in human health

INSTRUCTIONAL OBJECTIVES

1.	To learn the fundamental principles of clinical genetics
2.	To understand the genetic basis and clinical consequences of chromosomal, single gene, and multifactorial disorders
3.	To learn about the prevention and management of the genetic diseases

UNIT I: INTRODUCTION TO CLINICAL GENETICS (9 hours)

Definition and importance of clinical genetics, impact of genetic diseases on human mortality and morbidity, types of genetic disorders – single-gene, chromosomal and multifactorial disorders, family history, pedigree construction, clinical dysmorphology – malformations, deformations, dysplasia and disruptions

UNIT II: CHROMOSOMAL DISORDERS (9 hours)

Chromosomal disorders due to numerical aberrations – Down syndrome and Turner syndrome, chromosomal disorders due to microdeletions syndromes – 22q11 deletion syndrome, Prader-Willi/Angelman syndrome, Cri-du-chat syndrome, and William syndrome, consequences of chromosomal rearrangements, balanced and unbalanced – prenatal, postnatal and familial implications.

UNIT III: SINGLE GENE DISORDERS (9 hours)

Sickle cell anemia, thalassemia, Marfan syndrome, cystic fibrosis, spinal muscular atrophy, Duchenne muscular dystrophy, fragile X syndrome, Huntington disease, Leigh syndrome. Disorders of gonadal, sexual development, and sex reversal.

UNIT IV: MULTIFACTORIAL DISORDERS (9 hours)

Autism spectrum disorder, Alzheimer disease, nonsyndromic deafness, hypercholesterolemia, hepatocellular carcinoma, insulin-dependent and non-insulin-dependent diabetes mellitus.

UNIT V: PREVENTION AND TREATMENT OF GENETIC DISEASE (9 hours)

Carrier analysis by drawing family pedigree, clinical observations (ocular albinism, retinitis pigmentosa, and others), and assay for biochemical markers (G6PD – Tay-Sachs disease). Prevention of genetic diseases by prenatal diagnosis and genetic counseling (Down syndrome). Treatment of genetic diseases using drugs (osteogenesis imperfecta, sickle cell disease, and Marfan syndrome), using diet supplements (Phenyketonuria and Maple syrup urine disease), by enzyme replacement therapy (Gaucher disease, Hunter syndrome, and Fabry disease), and by gene therapy (sickle cell anemia, cystic fibrosis, and muscular dystrophy).

REFERENCES

1. Jones, K.L., Jones, M.C and del Campo, M. "Smith's Recognizable patterns of human malformation", Saunders Publishers, USA, Seventh Edition (2013).
2. Donnai D and Read A. "New Clinical Genetics", Scion Publishing Limited, Oxford, UK, Third Edition (2015).
3. Nussbaum R.L, McInnes R.R, Willard H.F and Hamosh A. "Genetics in Medicine", Elsevier, USA, Eighth Edition (2016).

GN2124	PLANT PHYSIOLOGY	L	T	P	C
	Total Contact Hours - 45	**3**	**0**	**0**	**3**
PURPOSE					
To understand the physiological functions and biological clock in plants					
INSTRUCTIONAL OBJECTIVES					
1.	To understand the mechanism of water and nutrient absorption in plants				
2.	To learn about the photosynthetic organs in plants				
3.	To learn photobiology and photoperiodism in plants				
4.	To understand the biological clock in plants				

UNIT I: ABSORPTION OF WATER AND TRANSPIRATION (10 hours)

Bulk flow and diffusion. Osmosis – Osmotic system, components of water potential, units of water potential, membrane, colloids. Transpiration – measurement of transpiration, paradox of pore, stomatal mechanics, stomatal mechanisms – environmental effects on stomates, guarcell uptake of potassium ions, light quality and stomatal response.

UNIT II: MINERAL NUTRITIONAND TRANSPORT (10 hours)

Essential elements, nutrient deficiency symptoms, roots as absorbing surfaces, soils and their mineral elements, ion traffic in root, principles of solute absorption, characteristics of solute absorption, mechanisms of solute absorption – diffusion, facilitated diffusion, passive and active transport, cotransport and countertransport. Transport of organic solutes, and pressure flow mechanism.

UNIT III: PHOTOSYNTHESIS AND PHOTORESPIRATION (9 hours)

Structure of chloroplast, photosynthetic pigments, principles of light absorption, Emerson's effect, photosystem I and II, transport of electrons, photophosphorylation, factors affecting photosynthesis, structure of mitochondria, photorespiration, Warburg effect, and significance of photorespiration.

UNIT IV: PHOTOBIOLOGY AND PHOTOPERIODISM (8 hours)

Detecting seasonal time, short-day, long-days and day-neutral plants, principles of photoperiodism, photoperiod during plants life cycle, response types, phytochrome, detecting dawn and dusk, time measurement in photoperiodism, and Florigen concept.

UNIT V: BIOLOGICAL CLOCK (8 hours)

History of biological clock research in plants. Biological rhythms in plants - ultradian, circadian, and infradian, Effect of light, temperature, chemicals on rhythm characteristics. Clock mechanisms, biological clock in nature, time memory, and celestial navigation.

REFERENCES

1. Salisbury F and Ross C. "Plant Physiology", Brooks Cole Publisher, Fourth Edition (2004).
2. Taiz L and Zeiger E. "Plant Physiology", Sinauer Associates Inc. Sixth Edition (2014).
3. Varma V.K and Varma M. "Text Book of Plant Physiology, Biochemistry and Biotechnology", S Chand & Co Ltd, (2008).

GN2125	BIOCHEMISTRY OF SECONDARY METABOLITES	L	T	P	C
	Total Contact Hours - 45	**3**	**0**	**0**	**3**
PURPOSE					
To learn about the biochemical pathways of the secondary metabolites in plants.					
INSTRUCTIONAL OBJECTIVES					
1.	To gain knowledge on the metabolite function and biogenesis.				
2.	To understand metabolic pathways in plants.				

UNIT I: ALKALOIDS (10 hours)

Physiological and ecological functions, transport, storage, and turnover of secondary metabolites. Biosynthesis of alkaloids and betalains - pyrrolizidine alkaloids, benzylisoquinoline alkaloids, monoterpene indole alkaloids, ergot alkaloids, acridone alkaloids biosynthesis, purine alkaloids, and taxol.

UNIT II: CYANOGENIC GLYCOSIDES, GLUCOSINOLATES AND NON-PROTEIN AMINO ACIDS (9 hours)

Structure of cyanogenic glycosides, cyanogenesis, and biosynthesis of cyanogenic glycosides. Structure, biosynthesis, and ecological significance of glucosinolates. Formation mustard oil from glucosinolates. Structure, metabolism, and ecological significance of non-protein amino acids.

UNIT III: PHENYLPROPANOIDS (9 hours)

General phenylpropanoid pathway and formation of hydroxycinnamate conjugates. Phenylpropanoid-derived aroma and fragrance compounds. Coumarins, umbelliferones, and furanocoumarins. Lignans - biosynthesis of monolignols, lignan and norlignan. Gallotannins and ellagitannins - biosynthesis of gallic acid, pentagalloylglucose, gallotannins, and ellagitannins.

UNIT IV: TERPENOIDS (7 hours)

Classification and functions of terpenoids. Terpenoid biosynthesis - mevalonate pathway, pyruvate pathway, and terpenoid pathway.

UNIT V: STEROLS (10 hours)

Biosynthesis, and biotransformation of sterols and cardiac glycosides. Biosynthesis of brassinosteroids, phytoecdysteroids, steroid saponins and steroid alkaloids.

REFERENCES:

1. Wink M. "Biochemistry of Plant Secondary Metabolism- Annual Plant reviews" Wiley Blackwell, Second Edition (2010).

GN2126	PLANT DEVELOPMENTAL GENETICS	L	T	P	C
	Total Contact Hours - 45	3	0	0	3
PURPOSE					
To understand growth and development of various organs of a plant.					
INSTRUCTIONAL OBJECTIVES					
1.	To understand the structure and function of the plant reproductive systems				
2.	To learn about the seed and fruit development				
3.	To learn about the genes controlling the various developmental process				
4.	To understand the factors affecting growth and development in plants				

UNIT I: FLOWER DEVELOPMENT (9 hours)

Acquisition of competence to flower, floral evocation and its molecular control, determination of floral organs, change from vegetative to reproductive growth - induction of the floral meristem, initiation of flower primordial, regulation of floral organ development. Male gametophyte development, formation of female gametophytes, megasporogenesis, and gene expression in differentiated female gametophyte.

UNIT II: FERTILIZATION AND EMBRYOGENESIS (9 hours)

Pollen biology, pollen maturation, pollen-stigma interactions, pollen tube traffic in style, fertilization limiting genes, double fertilization, male sterility, self-incompatibility, double fertilization, *in vitro* fertilization, endosperm, nutrition and growth of embryos, gene action during embryogenesis, embryo development and maturation, and genetic control of embryo development.

UNIT III: SEED AND FRUIT DEVELOPMENT (9 hours)

Seed coat development and differentiation – structure of integuements and the role of regulation of flavonoid biosynthesis. Fruit growth - size, shape, fruit development pattern, fruit expansion, environmental and hormonal factors affecting fruit growth, fruit maturation and ripening – climacteric and non-climacteric fruit, and changes in fruit composition. Induction and overcoming seed dormancy.

UNIT IV: GERMINATION AND ROOT DEVELOPMENT (9 hours)

Nucleic acid and protein metabolism during seed germination, mobilization of stored food reserves during germination, tropisms – gravitropism, phototropism, thigmotropism, photomorphogenesis of seedling, hormonal regulation in seed germination, and gene expression during seedling growth. Plant root systems, patterning events, root apical meristem, differentiation – vascular tissue, root hair formation, lateral root formation.

UNIT V: SHOOT DEVELOPMENT (9 hours)

Organization of shoot apex, regulation of cell fate in meristem, and tissue differentiation of xylem and phloem. Leaf growth - determination of leaf primordia, evolution of leaf forms, heteroblasty, and heterophylly. Differentiation of leaf cells - epidermis and mesophyll, regulatory pathways involved in shoot branching – carotenoid derived signaling, polyamines, and inositol phosphates. Senescence and abscission of leaves.

REFERENCES:

1. Pua E.C and Davey M.R. “Plant developmental biology – biotechnological perspectives”, Springer, First Edition (2010).
2. Raghavan V. “Developmental Biology of Flowering Plants” Springer, (2000).
3. Howell S.H. “Molecular Genetics of Plant Development” Cambridge University Press, (2000).

GN2127	MICROBIAL PHYSIOLOGY	L	T	P	C
	Total Contact Hours - 45	3	0	0	3

PURPOSE

To learn the fundamental concepts of microbial physiology

INSTRUCTIONAL OBJECTIVES

1.	To know about the structure and organization of microorganisms
2.	To know about the response of microbes to environmental stress
3.	To know about signal transduction and communication in microbes

UNIT I: CELL STRUCTURE AND FUNCTION (9 hours)

Cell structure – bacterial nucleoid, nucleosomes, mitochondria, surface layers of bacteria, outer membrane, teichoic acids, flagella and mechanism of flagellar rotation, cytoplasmic membrane, pili, fimbriae, S-layer and enterobacterial antigens. Biosynthesis of peptidoglycan and exopolysaccharides.

UNIT II: MICROBIAL GROWTH (9 hours)

Phases of growth curve, measurement of growth, calculations of growth rate, generation time, synchronous growth, induction of synchronous growth, and synchrony index. Factors affecting growth – pH, temperature, substrate and osmotic condition. Survival at extreme environments, starvation, adaptive mechanisms in thermophilic, alkalophilic, osmophilic and psychrophilic microbes. Bioluminescence - mechanism and advantages

UNIT III: MEMBRANE TRANSPORT (9 hours)

Metabolite transport - facilitated diffusion, ion channels, ion mediated transport, ion pumps and ABC transporters. Composition and architecture of membranes - Model membranes and liposomes.

UNIT IV: MICROBIAL STRESS RESPONSES (9 hours)

Osmotic stress and osmoregulation, osmotic control of gene expression, oxidative stress response and its regulation, pH stress and acid tolerance, thermal stress and heat shock response, stringent control and gene expression in response to nutrient and starvation stress.

UNIT V: CELL DIVISION AND SIGNAL TRANSDUCTION (9 hours)

Bacterial cell division in Gram negative rods , Gram positive rods, and Gram positive cocci. Global control networks - two component regulatory systems, regulation of nitrogen assimilation and fixation, and phosphate uptake and regulation. Quorum sensing and proteomic control.

REFERENCES:

1. Moat and Foster. "Microbial Physiology", John Wiley & Sons, Fourth Edition (2003).
2. Willey J.M, Sherwood L and Woolverton C.J. "Prescott Microbiology" McGraw Hill, Eight Edition (2011).
3. Kim B.H and Gadd G.M. "Bacterial Physiology and Metabolism" Cambridge University Press, First Edition (2008).

GN2128	METABOLIC ENGINEERING OF MICROBES	L	T	P	C
	Total Contact Hours - 45	**3**	**0**	**0**	**3**

PURPOSE	
To learn about metabolic pathways and metabolic engineering in microbes	
INSTRUCTIONAL OBJECTIVES	
1.	To understand the basic metabolic pathways in microbes
2.	To understand the regulation of metabolic pathways
3.	To learn about the metabolically engineered organisms and products
4.	To know about the methods involved in metabolic Engineering

UNIT I: CELLULAR METABOLISM OVERVIEW (9 hours)

Overview of cellular metabolism, transport processes, fuelling reactions: glycolysis, fermentative pathways, biosynthetic reactions - polymerization and cellular energetics. Different models for cellular reaction for primary and secondary metabolites.

UNIT II: REGULATION OF METABOLIC PATHWAYS (9 hours)

Regulation of enzyme activity- enzyme concentration, control of transcription initiation, control of translation and regulation at whole cell level and metabolic networks.

UNIT III: METABOLIC ENGINEERING IN PRACTICE (9 hours)

Enhancement of product yield and productivity - solvents and amino acid. Extension of substrate utilization - pentose and cellulose. Extension of product spectrum and novel products - antibiotics, vitamins, pigments and biopolymers. Engineering of xenobiotic degradation pathways.

UNIT IV: TOOLS OF METABOLIC ENGINEERING (9 hours)

Classical mutagenesis, gene shuffling, gene knockout, intron mediated gene silencing-transformation with vectors, stimulation by precursors and heterologous expression of gene clusters.

UNIT V: IMPORTANT ASPECTS OF METABOLIC ENGINEERING (9 hours)

Metabolic flux analysis, metabolic control analysis, analysis of structure of metabolic networks, experimental determination of flux using isotope labeling and thermodynamics of cellular processes.

REFERENCES

1. Stephanopoulos G.N and Aristidou A.A. "Metabolic Engineering – Principles and Methodologies", Jens Nielsen Academic Press, First Edition (1998).
2. Cheng Q. "Microbial Metabolic Engineering: Methods and Protocols", Humana Press, First Edition (2011).
3. Dien S.V. "Metabolic Engineering for Bioprocess Commercialization", Springer, First Edition (2016).

GN2129	MICROBIAL GENETICS	L	T	P	C
	Total Contact Hours - 45	**3**	**0**	**0**	**3**
PURPOSE					
To acquire knowledge about genetic organization and gene regulation in microbes					
INSTRUCTIONAL OBJECTIVES					
1.	To know about the genetic organization of bacteria				
2.	To know about the gene regulation in bacteria				
3.	To know about various gene transfer mechanisms in microbes				

UNIT I: DNA REPLICATION AND REPAIR MECHANISMS (9 hours)

Bidirectional and rolling circle replication, and differences in prokaryotic and eukaryotic replication. Plasmids and types plasmid replication and segregation- plasmid maintenance by host killing, role of ccd genes. DNA repair mechanism - excision repair- SOS repair and mismatch and recombination repair cis-trans complementation tests.

UNIT II: DNA RECOMBINATION AND MUTATION (9 hours)

DNA recombination and models - general recombination, site specific recombination, restriction and modification systems. Mutations and types, mutagens mechanism, and Ames test.

UNIT III: GENETICS OF BACTERIOPHAGE (9 hours)

General characteristics of bacteriophages phage T4 - structure, gene expression and genome organization. λ phage - replication, lytic and lysogenic cycles, transcription of phage genes, mechanisms of repressor synthesis and autoregulation.

UNIT IV: GENE TRANSFER MECHANISMS (9 hours)

Transformation, Conjugation - mechanism, F plasmid conjugation, conjugation in other bacteria. Transduction - generalized and specialized. Recombination - homologous and

site specific. Transposon structure, insertion sequences and mechanism of replicative and non-replicative transposition.

UNIT V: STRAIN CONSTRUCTION (9 hours)

Construction of bacterial strains - sugar utilization mutants, thymine requiring mutants and autotrophic deletion mutants. Strain construction - strains isolation, transposon insertions in genes and localized mutagenesis. Production of phage mutants, isolation of λ mutants and use of phage to isolate operon and gene fusions.

REFERENCES

1. Moat and Foster. "Microbial Physiology" John Wiley Publishers, Fourth Edition (2002).
2. Snyder L, Peters J.E, Henkin T.M and Champness W. "Molecular Genetics of Bacteria" John Wiley and Sons, Fourth Edition (2004).
3. Birge E.A. "Bacterial and Bacteriophage Genetics" Springer, Fifth Edition (2006).

SEMESTERN III

GN2130	HUMAN GENOMICS	L	T	P	C
	Total Contact Hours -75	**2**	**0**	**3**	**3**
PURPOSE					
To learn about different sequencing technologies and methods for sequence analysis of human genome					
INSTRUCTIONAL OBJECTIVES					
1.	To learn different sequencing technologies				
2.	To learn about human genome sequencing and sequence analysis				
3.	To practice genomic data analysis				
4.	To learn the application of genomics in diagnosis and treatment of human diseases				

UNIT I: INTRODUCTION TO SEQUENCING TECHNOLOGIES (6 hours)

Principle and workflow of sanger sequencing, sequencing by synthesis method (Illumina), ion semiconductor sequencing, single molecule sequencing (PacBio and Nanopore), optical mapping (Bionano Genomics), high throughput chromosome confirmation capture technologies (Chicago and Hi-C- Dovetail Genomics), and linked-read sequencing and sing cell RNA sequencing (10X Genomics).

UNIT II: GENOME AND TRANSCRIPTOME SEQUENCING (6 hours)

Introduction to human reference genome, whole genome versus exome sequencing, short-read versus long read sequencing, human genome re-sequencing, whole exome sequencing, targeted sequencing, amplicon sequencing, bisulphite sequencing, and Chip-

Seq. Designing sequencing strategy considering the objective of the study, type and throughput of sequencing, cost, and time needed for sequencing.

UNIT III: DATA ANALYSIS AND SCRIPTING LANGUAGES (6 hours)

Introduction to R package, Cytoscape and Galaxy. Introduction to the basics of using Perl and Python.

UNIT IV: SEQUENCE ANALYSIS (6 hours)

Principle and tools for quality assessment of sequence data, reference mapping of genome/exome data, variant calling, and annotation. Principle and tools for mapping of RNAseq data, generating count tables, calculation of RPKM (Reads Per Kilobase Million reads) FPKM (Fragments Per Kilobase Million reads), and TPM (Transcripts Per Kilobase Million reads). Biological replicates and tools for the identification and analysis of differentially expressed genes (DEGs), pairwise and time course DEG analysis. Annotation, gene ontology, and enrichment analysis of DEGs. Heatmaps, clustering and co-expression networks from DEGs. Principal component analysis.

UNIT V: CLINICAL APPLICATION OF GENOMICS (6 hours)

Genomics approach to identify disease causing gene mutations, differential gene expression, and gene fusion. Diagnosis of diseases using whole genome sequencing, exome sequencing, and targeted sequencing. NGS based pre-implantation genetic screening and non-invasive prenatal testing (NIPT). Introduction to ClinVar, ClinGen, COSMIC, dbSNP, 1000 Genomes Project, Exome Sequencing Project, OMIM, and ExA browser.

LABORATORY EXPERIMENTS

Total Hours: 45

To be conducted using workstations (64GB RAM) and desktops/laptops connected to the Genome Server (512 GB RAM) of SRMIST's High Performance Computing Cluster. Labs will have hands-on individual training using sample data from SRM-DBT Partnership Platform for Advanced Life Sciences Technologies.

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1. Practice with R- Cytoscape and Galaxy
2. Practice with Perl and Python
3. Quality control of NGS data
4. Reference assembly and variant calling of genomic data
5. De novo assembly of RNA Seq data
6. Analysis of gene expression by estimating RPKM- FPKM- and TPM
7. Identification of differentially expressed genes (DEGs) using RNA Seq data
8. Annotation and enrichment analysis of DEGs
9. Heatmaps and other types presentation of DEGs data
10. Clustering and network analysis using DEG

REFERENCES

1. Shendure J et al (2017) DNA sequencing at 40: Past- Present and Future, Nature, 550: 345-353.
2. https://en.wikibooks.org/wiki/Next_Generation_Sequencing_(NGS)/Print_version
3. Sati S and Cavalli G (2017) Chromosome Conformation Capture Technologies and their Impact in Understanding Genome Function, Chromosoma, 126: 33-44.
4. Jørgensen L et al (2017) Enrichment of Megabase-Sized DNA Molecules for Single-Molecule Optical Mapping and Next-Generation Sequencing, Scientific Reports, 7: 17893.
5. Matloff N. "The Art of R Programming", No Starch Press, (2011).
6. https://www.perl.org/books/beginning-perl/
7. https://www.python.org/
8. https://usegalaxy.org/
9. Goodwin S, McPherson J.D and McCombie W.R (2016) Coming of Age: Ten Years of Next-Generation Sequencing Technologies, Nature Reviews Genetics, 17: 333-351.
10. Silva C.J, Domingues D and Lopes F.M (2017) RNA-Seq Differential Expression Analysis: An Extended Review and a Software Tool", PLoS ONE, 12: e0190152.
11. Conesa A (2016) A Survey of Best Practices for RNA-Seq Data Analysis, Genome Biology, 17: 13.
12. Lab Manual

GN2131	PHARMACOGENETICS	L	T	P	C
	Total Contact Hours - 45	**3**	**0**	**0**	**3**

PURPOSE

To learn about pharmacology, pharmacogenetics and its application in treating human diseases

INSTRUCTIONAL OBJECTIVES

1.	To learn the concept of pharmacology as basis for understanding pharmacogenetics
2.	To learn the pharmacokinetic and pharmacodynamics principles
3.	To gain knowledge on pharmacogenetic approach in drug metabolism and drug transport
4.	To apply pharmacogenetic knowledge in evaluating the drug response
5.	To study the regulatory aspects and management of pharmacogenetics

UNIT I: INTRODUCTION TO DRUG AND PHARMACY (9 hours)

History of drug and pharmacy, drug nomenclature, pharmacopoeias, formularies, and martindale. Routes of drug administration, New drug development - exploration from natural sources, chemical synthesis, molecular modeling, rational approach, combinatorial chemistry and recombinant DNA technology. Introduction to clinical trials.

UNIT II: CLINICAL PHARMACOLOGY (9 hours)

Membrane transport, adsorption, distribution, bioavailability, metabolism and elimination kinetics of drug. Mechanism of drug action - factors affecting drug action, drug receptors, ion channels, and drug interaction. Toxicology, therapeutic window, dosage calculation, drug efficacy, and adverse drug reactions.

UNIT III: PHARMACOGENETICS OF DRUG METABOLISM AND TRANSPORT (9 hours)

Historical perspectives and current status of pharmacogenetics. Effect of genetic variations in cytochrome-P450 genes (CYP2A6, CYP2B6, CYP2C9, CYP2C19, CYP2D6, CYP1A2, CYP4F2, and CYP3A4/5) and non-cytochrome-P450 genes (UDP-glucuronosyltransferase, thiopurine-S-methyltransferase, dihydropyrimidine dehydrogenase, N-acetyltransferase, and glutathione-S-transferase) on drug metabolism. Effect of genetic variations in ABC transporters and SLC transporters on drug transport.

UNIT IV: PHARMACOGENETICS OF DRUG RESPONSE (9 hours)

Effect of genetic variations on drug response to treatment for cancer (*HER2*, *EGFR*, *TPMT*, and *DPD*), and Polymorphism heart diseases (*ADRB1, ADRA2C, VKORC1*, *ACE, AMPK*, *KCNMB1*, *ENAC*, *KCNJ11* and *ABCC8)*

UNIT V: REGULATORY PERSPECTIVES AND MANAGEMENT OF PHARMACOGENETIC INFORMATION (9 hours)

Clinical validity and utility of pharmacogenetic information. Evaluation of the cost effectiveness of pharmacogenetic diagnostic tests and issues in obtaining regulatory approval and integration with healthcare. Ethical, legal, and social issues in pharmacogenetic studies. Resrources for pharmacogenetic information - Pharmacogenetics and Pharmacogenomics Knowledge Base (Pharm GKB), Systems for the Management of Pharmacogenomic Information, Clinical Pharmacogenitics Implementation Consortium (CPIC), and Metabolism and Transport Drug Interaction Database (DIDB).

REFERENCES

1. Tripati K.D. “Essential of Medical Pharmacology”, Jaypee Brothers Medical Publishers, India, Eighth Edition (2018).
2. Wing Y, Lam F and Scott S. “Pharmacogenomics Challenges and Opportunities in Therapeutic Implementation”, Academia Press, USA, Second Edition (2018).
3. Innocenti F. “Pharmacogenomics: Methods and Protocols (Methods in Molecular Biology)”, Humana Press, USA, Second Edition (2016).

GN2132	NEUROGENETICS	L	T	P	C
	Total Contact Hours - 45	**3**	**0**	**0**	**3**

PURPOSE

To understand the genetic basis of nervous system development and function

INSTRUCTIONAL OBJECTIVES

1.	To learn the anatomy of nervous system and neuron
2.	To learn the molecular basis of neurotransmission
3.	To learn about neuronal basis of various perceptions
4	To learn the genetic basis of neurodegenerative disorders

UNIT I: THE NERVOUS SYSTEM – AN INTRODUCTION (9 hours)

Historical perspectives, anatomy and functions of nervous system, CNS and PNS, brain and behavior, anatomy of the neuron, soma, neuronal membrane, axon and dendrites, glial cells, ion channels, resting membrane potential, and action potential.

UNIT II: GENETICS OF BRAIN DEVELOPMENT (9 hours)

Formation of neural tube, development of forebrain, diencephalon, midbrain, hindbrain, cerebral cortex, hippocampus, hypothalamus, and amygdala. Neurogenesis and neuronal diversity.

UNIT III: NEUROTRANSMISSION (9 hours)

Basics of synaptic transmission, electrical synapses, chemical synapses, properties of action potential, voltage-gated channels, nerve-muscle synapse, excitatory and inhibitory synapses, neurotransmitters, transmitter release, and second messenger pathways.

UNIT IV: PERCEPTION AND BEHAVIOR (9 hours)

Somatosensory system, mechanoreceptors and touch response, nociceptors and pain, visual processing, the organ of Corti and hearing, olfactory receptors and the chemistry of smell and taste, circuits of emotions, memory storage, the sleep cycle, the limbic system, brain's reward circuitry and addiction.

UNIT V: NEURODEGENERATIVE DISORDERS (9 hours)

Neurological and cognitive abnormalities in autism, Huntington's disease, Parkinsonism, Schizophrenia, disorders of mood, unipolar depression and bipolar disorder, epilepsies, motor neuron disorders, amyotrophic lateral sclerosis, the aging brain and dementia.

REFERENCES:

1. Kandel E.R. et al. "Principles of Neural Science", McGraw Hill Education, Fifth Edition (2012).
2. Bear M.F, Connors B and Paradiso M. "Neuroscience: Exploring the Brain", Lippincott Williams and Wilkins, Fourth Edition (2015).

GN2133	PLANT GENOMICS	L	T	P	C
	Total Contact Hours - 75	2	0	3	3

PURPOSE

To learn about different sequencing technologies and methods for sequence analysis and assembly of plant genomes.

INSTRUCTIONAL OBJECTIVES

1.	To learn different sequencing and scaffolding technologies
2.	To learn about sequencing and sequence analysis
3.	To practice genomics data analysis
4.	To learn the application of genomics in plant science and crop improvement

UNIT I: SEQUENCING AND SCAFFOLDING TECHNOLOGIES (6 hours)

Automated sequencing by Sanger method, sequencing by synthesis method (Illumina), ion semiconductor sequencing (Ion-Torrent), single molecule sequencing (PacBio and Nanopore), optical mapping (Bionano Genomics), and high throughput chromosome confirmation capture technologies (Chicago and Hi-C- Dovetail Genomics).

UNIT II: GENOME AND TRANSCRIPTOME SEQUENCING (6 hours)

De novo sequencing and re-sequencing of the genomes. Targeted genome sequencing, RAD and ddRAD sequencing, bisulphite sequencing, and Chip-Seq. Whole transcriptome sequencing and assembly, expression profiling, small RNA sequencing, and full-length transcript sequencing by IsoSeq (PacBio). Designing sequencing strategy considering the objective of the study, type and throughput of sequencing and scaffolding technology, cost, and time.

UNIT III: DATA ANALYSIS AND SCRIPTING LANGUAGES (6 hours)

Introduction to R package, Cytoscape and Galaxy. Introduction to the basics of using Perl and Python.

UNIT IV: SEQUENCE ANALYSIS (6 hours)

Principle and tools for quality assessment of genomic data. *De novo* genome assembly, gene prediction, and genome annotation. Reference assembly, variant calling, variant annotations, and genome comparisons. Principle and tools for the *de novo* assembly of whole transcriptome from RNAseq data. Tools for the generation and analysis of count tables, calculation of RPKM (Reads Per Kilobase Million reads), FPKM (Fragments Per Kilobase Million reads), and TPM (Transcripts Per Kilobase Million reads). Biological replicates and tools for the identification and analysis of differentially expressed genes (DEGs), pairwise and time course DEG analysis. Annotation, gene ontology, and enrichment analysis of DEGs. Heatmaps, clustering and co-expression networks from DEGs. Principal component analysis.

UNIT V: APPLICATION OF GENOMICS IN PLANT SCIENCE (6 hours)

Rapid *de novo* sequencing of plant genomes (diploid and polyploids), and transcriptomes. Identification and isolation of useful genes and promoters. Genome-wide association studies to identify trait-associated SNPs. Marker discovery, QTL mapping, GWAS, and genomics selection using genotype by sequencing (GBS). Case studies on applications in plant science.

LABORATORY EXPERIMENTS
Total Hours: 45

To be conducted using workstations (64GB RAM) and desktops/laptops connected to the Genome Server (512 GB RAM) of SRMIST's High Performance Computing Cluster. Labs will have hands-on individual training using sample data from SRM-DBT Partnership Platform for Advanced Life Sciences Technologies.

1. Practice with R- Cytoscape and Galaxy
2. Practice with Perl and Python
3. Quality control of NGS data
4. Reference assembly and variant calling of genomic data
5. *De novo* assembly of genomic data from a diploid plant species
6. De novo assembly of RNA Seq data
7. Analysis of gene expression by estimating RPKM- FPKM- and TPM
8. Identification of differentially expressed genes (DEGs) using RNA Seq data
9. Annotation and enrichment analysis of DEGs
10. Heatmaps and other types presentation of DEGs data
11. Clustering and network analysis using DEGs
12. GWAS – TASSEL

REFERENCES

1. Shendure et al (2017) DNA Sequencing at 40: Past- Present and Future, Nature 550: 345-353.
2. https://en.wikibooks.org/wiki/Next_Generation_Sequencing_(NGS)/Print_version
3. Sati S and Cavalli G (2017) Chromosome Conformation Capture Technologies and their Impact in Understanding Genome Function, Chromosoma, 126: 33-44.
4. Łopacińska-Jørgensen et al (2017) Enrichment of Megabase-Sized DNA Molecules for Single-Molecule Optical Mapping and Next-Generation Sequencing, Scientific Reports, 7: 17893
5. Matloff N. "The Art of R Programming" No Starch Press, (2011).
6. https://www.perl.org/books/beginning-perl/
7. https://www.python.org/
8. https://usegalaxy.org/

9. Goodwin S, McPherson J.D and McCombie W.R (2016) Coming of Age: Ten Years of Next-Generation Sequencing Technologies, Nature Reviews Genetics, 17: 333-351.
10. Silva JC, Domingues D and Lopes F.M (2017) RNA-Seq Differential Expression Analysis: An Extended Review and a Software Tool, PLoS ONE, 12: e0190152.
11. Conesa A (2016) A survey of Best Practices for RNA-Seq Data Analysis, Genome Biology, 17: 13.
12. Li and Harkess (2018) A Guide to Sequence Your Favorite Plant Genomes, Applications in Plant Science, 6: e1030.
13. Basantani et al (2017) An Update on Bioinformatics Resources for Plant Genomics Research, Current Plant Biology, 11-12: 33-40.
14. Bolger et al (2017) From Plant Genomes to Phenotypes, Journal of Biotechnology, 261: 46-52.
15. Bolger et al (2018) Plant Genome SND Transcriptome Annotations: From Misconceptions to Simple Solutions, Briefings in Bioinformatics, 19: 437-449.
16. Lab Manual

GN2134	PLANT - ENVIRONMENT INTERACTION	L	T	P	C
	Total Contact Hours - 45	3	0	0	3
PURPOSE					
To understand the response of plants to the environmental stimuli, including biotic and abiotic stress.					
INSTRUCTIONAL OBJECTIVES					
1.	To learn cognitive and deceptive behavior in plants				
2.	To learn the response of plants to biotic and abiotic stress				
3.	To understand plant-environment interaction for survival and stress mitigation				

UNIT I: COGNITION IN PLANTS (6 hours)

Memory and learning, avoidance and escape behavior, root foraging behavior, plant transmitters - auxin, glutamate and GABA. Kith and kin recognition. Allelopathy - secondary metabolites and volatiles.

UNIT II: PLANT- PGPB INTERACTION (8 hours)

Symbiotic and non-symbiotic beneficial microbes- rhizobia, plant growth promoting rhizobacteria and mycorrhizal fungi. Modulation of host immunity by rhizobia, mycorrhiza, and PGPR. Root exudates and microbial attraction.

UNIT III: PLANT AND BIOTIC STRESS TOLERANCE (13 hours)

Bacteria, fungus, virus, insects and nematodes as causal agents of biotic stress factors inplants. Pathogen derived resistance - Pathogen Associated Molecular Pattern (PAMPs), pattern recognition receptors, elicitors and signal perception by R genes. Innate resistance -ROS, phytoalexins, PR proteins, ribonucleases and silencing of foreign RNAs. Acquired resistance - induced systemic resistance (ISR) and systemic acquired resistance (SAR).

UNIT IV: PLANT AND ABIOTIC STRESS TOLERANCE (10 hours)

Molecular mechanisms of drought, heat, salinity, cold, freezing, heavy metal, and submergence tolerance in plants.

UNIT V: DECEPTIVE BEHAVIOUR IN PLANTS (8 hours)

Food deception by rewarding and non-rewarding strategies. Plant mimicry - olfactory signals, visual signals, tactile stimuli and receiver bias. Aposematism in plants-aposematic trichomes, color patterns in floras, olfactory aposematism, and aposematism in thorny, spiny and prickly plants.

REFERENCES

1. Wilkinson R.E. "Plant Environment Interactions", Marcel Dekker Inc., Second Edition (2000).
2. Lugtenberg B. "Principles of plant microbe interactions", Springer, First Edition (2015).
3. Baluska F, Gagliano M and Witzany G. "Memory and Learning in Plants", Springer, First Edition (2018).
4. Matthew A.J and Hasegawa P.M. "Plant Abiotic Stress", Wiley Publishers, Second Edition (2014).
5. Johnson S.D and Schiest F.P. "Floral Mimicry", Oxford University Press, First Edition (2016).
6. Zamioudis C and Pieterse M.J (2012) Modulation of host immunity by beneficial microbes, Molecular Plant Microbe Interaction, 25: 139-150.
7. Kroon H.D (2007) how do roots interact? Science, 318: 1562-1563.
8. Biedrzycki M.L, Jilany T.A, Dudley S.A and Bais H.P (2010) Root exudates mediate kin.
9. Rudrappa T, Czymmek K.J, Pare P.W and Bais H.P (2008) Root-secreted malic acid recruits beneficial soil bacteria, Plant Physiology, 148: 1547-1556.

GN2135	MOLECULAR PLANT BREEDING	L	T	P	C
	Total Contact Hours - 45	**3**	**0**	**0**	**3**
PURPOSE					
To learn the principles and methods of molecular breeding for crop improvement					
INSTRUCTIONAL OBJECTIVES					
1.	To learn genes and genotypes as individual and in populations				
2.	To learn the principles and methods of conventional plant breeding methods				
3.	To learn about molecular markers and their use in molecular breeding				

UNIT I: INTRODUCTION **(9 hours)**

History of domestication and plant breeding. Current status of crop production and scope of crop improvement by plant breeding. Reproduction by self-pollination, cross pollination, apomixis, and vegetative propagation. Phenotype, genotype, micro- and macro environments, genotype-environment interaction. Qualitative and quantitative traits

UNIT II: POPULATION GENETICS **(9 hours)**

Hardy-Weinberg equilibrium, factors affecting change in gene and genotypic frequency, effects of mating systems, mutation, migration and selection. Continuous variation, additive and dominance interactions, non-allelic interactions, genotype x environmental interactions, genetic and environmental components of variance.

UNIT III: PLANT BREEDING METHODS **(9 hours)**

Breeding methods in self-pollinated and cross-pollinated crops. Heterosis breeding and production of hybrids using male sterile systems. Mutation Breeding. Polyploidy breeding.

UNIT IV: MOLECULAR MARKERS AND MAPPING **(9 hours)**

Need for molecular breeding - Plant Genome-nuclear- chloroplast and mitochondrial genomes. Markers – Types; different kinds of DNA markers for genome analysis (RFLP- RAPD- STS- SSR- AFLP- SNPs); Applications of markers; Linkage mapping; QTL mapping - Development of mapping population – RILs- NILs and DH lines-genotyping – Phenotyping – QTL Discovery – Principles and methods; Association Mapping.

UNIT V: MOLECULAR BREEDING **(9 hours)**

Marker-Assisted-Selection (MAS). Marker-Assisted Backcrossing (MABC). QTL Pyramiding; NAM- MAGIC and Genomics Selection; Case studies of MAS and MABC in rice.

REFERENCE

1. Agarwal R.L. “Fundamentals of Plant Breeding and Hybrid Seed Production”, Oxford & IBH Book Publishing, New Delhi, First Edition (1998).
2. Allard A.W. “Principles of Plant Breeding”, Science Publishers, USA, Second Edition (1999).
3. Guimaraes et al, “Marker-Assisted Selection: Current Status and Future Perspectives In Crops- Livestock- Forestry and Fish”, FAO Publication, (2007).
4. Collard et al (2008) Rice Molecular Breeding Laboratories in the Genomics Era: Current Status and Future Considerations, International Journal of Plant Genomics, 2008: 524847.

GN2136	MICROBIAL GENOMICS	L	T	P	C
	Total Contact Hours - 75	2	0	3	3

PURPOSE

To learn the fundamental concepts and applications of microbial genomics and metagenomics.

INSTRUCTIONAL OBJECTIVES

1.	To know about the properties of microbial genomes
2.	To understand the evolutionary lineages and attributes in microbial genomics
3.	To know about metagenomics approaches and concepts
4.	To learn the computational tools for microbial genomics
5.	To learn applications of metagenomics

UNIT I: INTRODUCTION TO MICROBIAL GENOMICS (6 hours)

Genome organization and gene expression in bacteria and archaea, milestones in bacterial genomics, minimal bacterial genome, bacterial genome diversity, gene synteny, codon bias and its significance.

UNIT II: EVOLUTIONARY MICROBIAL GENOMICS (6 hours)

Microbial evolution - endosymbiotic theory, classical and molecular taxonomy- molecular barcodes in microbes. Evolutionary processes influencing microbial genome content and structure, orthologs, paralogs, zenologs and cogs, prevalence of lineage specific gene loss and horizontal gene transfer in evolution and last universal common ancestor (LUCA).

UNIT III: METAGENOMICS (6 hours)

Sequencing and Annotation of prokaryotic genomes- NGS approaches to metagenomics, Construction of metagenomic libraries- DNA isolation, purity, library preparation, adapters, 16s rDNA V2 – V4 amplicon sequencing. Community level diversity analysis – alpha and beta diversity. Pangenomes and metagenomes.

UNIT IV: COMPUTATIONAL TOOLS FOR MICROBIAL GENOMICS (6 hours)

Genomic islands - prediction methods and tools. Gene Prediction and comparative genomics tools- VISTA, GLIMMER, QIIME and MGRAST. Genome assembly tools in metagenomics.

UNIT V: APPLICATIONS OF METAGENOMICS (6 hours)

Human microbiome project and related diseases. Culture dependent and independent approaches. Metagenomic applications - enzymes, antibiotics, therapeutic drugs, host - pathogen interactions and bioremediation.

LABORATORY EXPERIMENTS
Total Hours: 45

To be conducted using workstations (64GB RAM) and desktops/laptops connected to the Genome Server (512 GB RAM) of SRMIST's High Performance Computing Cluster. Labs will have hands-on individual training using sample data from SRM-DBT Partnership Platform for Advanced Life Sciences Technologies.

1. Galaxy tools to study bacterial diversity
2. Microbial Genomic Context Viewer2 Tool
3. Cluster of Orthologs
4. Phylogeny tree construction using MEGA7
5. NCBI Toolkit- FASTQC & Cutadapt
6. Bacterial genome diversity analysis using QIIME2
7. Bacterial genome diversity analysis using MGRAST
8. Gene prediction using GLIMMER
9. Comparative genomics using R-VISTA
10. Gene ontology using BLAST2GO

REFERENCES & TEXTS

1. Primrose S.B and Twyman R. "Principles of Gene Manipulation and Genomics", Wiley-Blackwell, Eight Edition (2010).
2. Marco D. "Metagenomics: Theory, Methods and Applications", Caister Academic Press, First Edition (2010).
3. Lu, Bingxin and Leong H.W (2016) Computational Methods for Predicting Genomic Islands In Microbial Genomes. Computational and Structural Biotechnology Journal, 14: 200-206.
4. Reina B, Oscar C et al (2013) Galaxy Tools to Study Genome Diversity. Gigascience, 2:1. Oxford University Press (OUP), 2: 7.
5. Koonin E.V and Galperin M.Y. (2003) Sequence - Evolution - Function: Computational Approaches in Comparative Genomics. Boston: Kluwer Academic; PMID: 21089240., Available from: https://www.ncbi.nlm.nih.gov/books/NBK20260/
6. Institute of Medicine (US) Forum on Microbial Threats. The Science and Applications of Microbial Genomics: Workshop Summary. Washington (DC): National Academies Press (US); (2013). PMID: 24069620. Available from: https://www.ncbi.nlm.nih.gov/books/NBK131809/ doi: 10.17226/18261
7. Lab Manual.

GN2137	MOLECULAR VIROLOGY	L	T	P	C
	Total Contact Hours - 45	3	0	0	3

PURPOSE

To gain knowledge on the lifecycle biology of viruses and their application in genetic engineering

INSTRUCTIONAL OBJECTIVES

1.	To gain knowledge on viral genome and its organization
2.	To get an understanding life cycle of different class of viruses
3.	To master the applications of viral based techniques in genetic engineering

UNIT I: ORGANIZATION OF VIRAL GENOMES (9 hours)

Etymology, history and structure of virus, viral genome organization, viral genetics, viral mutants and genetic and non-genetic viral interactions. Types - DNA viruses, positive strand RNA viruses, negative strand RNA viruses, Segmented and multipartite viral genomes.

UNIT II: VIRAL REPLICATION MECHANISMS (9 hours)

Host functions used by viruses - DNA, proteins and energetic. Synthesis of structural components, viral DNA replications, examples -Tobacco Mosaic Viruses(TMV) and Human Immuno deficiency Virus (HIV), Reverse transcription and transposition.

UNIT III: MOLECULAR PATHOGENESIS OF HUMAN AND ANIMAL VIRUSES (9 hours)

Foot and Mouth Disease(FMD) Virus, Polio virus, Rabies virus, Hepatitis A and B virus, Human Papilloma virus (HPV), Japanese encephalitis virus (JEV), Poxvirus, Hendra and Nipah viruses, Avian influenza virus (AIV), Bluetongue virus and African Swine fever virus.

UNIT IV: MOLECULAR PATHOGENESIS OF PLANT VIRUSES (9 hours)

Tomato spotted wilt virus (TSWV), Tomato yellow leaf curl virus (TYLCV), Cucumber mosaic virus (CMV), Potato virus Y (PVY), Cauliflower mosaic virus (CaMV), African cassava mosaic virus (ACMV), Plum pox virus (PPV), Brome mosaic virus (BMV) and Potato Virus X (PVX).

UNIT V: VIRUSES IN GENETIC ENGINEERING (9hours)

Viruses as gene cloning vehicles, sources of control elements for transgenic plants, heterologous peptides, protection of plants from systemic diseases, mild strain cross protection, satellite mediated protection and antiviral chemicals. Viral vaccines- live attenuated, inactivated, virion subunit vaccines and recombinant viral vaccines. Mass production of viruses for vaccines.

REFERENCES

1. Flint J, Vincent R. Racaniello, Glenn F.R and Skalka A.M. "Principles of Virology", ASM Press, Fourth Edition (2015).
2. Hull R. "Plant Virology", Elsevier Academic Press, Fifth Edition (2013).
3. Mettenleiter T.C. "Animal Viruses: Molecular Biology", Caister Academic Press, UK, First Edition (2008).
4. Carter J. and Saunders V. "Virology – Principles and Applications", John Wiley and Sons, Second Edition (2013).

GN2138	MOLECULAR PATHOLOGY OF INFECTIOUS DISEASES	L	T	P	C
	Total Contact Hours - 45	**3**	**0**	**0**	**3**

PURPOSE

To acquire knowledge about the molecular pathology and diagnostic methods of infectious disease.

INSTRUCTIONAL OBJECTIVES

1.	To know how molecular pathology developed from early stages
2.	To understand the host defense mechanism against pathogens
3	To understand pathogenesis of bacterial and viral disease
4	To acquire the knowledge about virulence factors of pathogens
5	To learn about the diagnostic methods for the infectious disease

UNIT I: OVERVIEW OF INFECTIOUS DISEASES (9 hours)

Historical perspective of infectious diseases, pathogen types and modes of entry, pathogenesis mechanisms, general disease symptoms, microbial toxins and assay methods and attributes and components of microbial pathogenesis.

UNIT II: HOST RESPONSE TO INFECTION (9 hours)

Host defense mechanism - skin, mucosa, cilia, secretions, physical movements, limitation of free iron, antimicrobial compounds. Mechanism of killing by humoral and cellular mediated defense, complement pathways, inflammatory response. Pathogenic adaptations to overcome host defenses.

UNIT III: VIRULENCE FACTORS (9 hours)

Virulence genes, virulence factors, virulence assays, Mechanism of virulence- adherence, invasion, cytopathic and cytotoxic effects. Criteria and tests in identifying virulence factors, molecular characterization of virulence factors, signal transduction and host responses.

UNIT IV: PATHOGENESIS OF INFECTIOUS DISEASES (9 hours)

Molecular genetics and gene regulation in virulence of pathogens - *Entamoeba histolytica*, *Mycobacterium tuberculosis*, *Vibrio cholerae*, *E. coli*, Plasmodium, HIV, Influenza virus, Human T-cell Leukemia-Lymphoma Virus (HTLV) , Japanese encephalitis virus (JEV) and Human Papilloma virus (HPV).

UNIT V: DIAGNOSIS OF FOR INFECTIOUS DISEASES (9 hours)

Classical diagnostic approaches - serotyping, ELISA and Western blot. Modern diagnostic approaches - DNA, RNA and protein based techniques. New therapeutic strategies - DNA vaccines, subunit and cocktail vaccines. Biosensor and aptamers for pathogen detection

REFERENCES

1. Pommerville J.C. “Guide to Infectious Diseases by Body System”, Jones & Bartlett Learning”, Second Edition (2012).
2. Kasper D and Fauci A. “Harrison's Infectious Diseases” McGraw-Hill Education, Third Edition (2017).