UNIVERSITY OF DELHI

MASTER OF GENETICS

(M.Sc. Genetics)

(Effective from Academic Year 2018-19)

PROGRAMME BROCHURE

DRAFT FOR FEEDBACK

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M.Sc. Genetics Revised Syllabus as approved by Academic Council on XXXX, 2018 and Executive Council on YYYY, 2018

CONTENTS

I. About the Department

The Department of Genetics was established in 1984, as a part of the Faculty of Inter-disciplinary & Applied Sciences at the University of Delhi South Campus (UDSC). The department over the years has emerged as a strong hub for training students and for pursuing quality research in two broad areas of food and health, both with significant societal impact.

Notable scientific contributions from the department in the recent past include i) screening of 200,000 newborns for inborn errors of metabolism collaborating with 20 hospitals across the Delhi state, and generating the first ever epidemiological and genetic data for over 45 common and rare genetic disorders in the country- a good example of translational research and technology for the masses; ii) discovery of putative causal genes for a few brain disorders; iii) spearheading research on transgenic mustard for hybrid seed production, approved by the Genetic Engineering Approval Committee (GEAC) - a first such translational product from any university in India; and iii) development of non-transgenic hybrids of mustard with improved oil quality which has already reached the farmer's field.

The two-year post-graduate (M.Sc.) program and the M.Phil/Ph.D program offered by the department are based on this strong foundation of research. The department enjoys a unique strength of having teaching faculty with research specialization using a range of model systems such as *Drosophila*, *Arabidopsis*, Yeast, *Dictyostelium*, and human induced pluripotent stem cells. The M.Sc. program is open to students with Bachelor's degree in any area of science (biological/chemical/physical) through a national level entrance test. The curriculum spread over four semesters, aims at teaching not only the basics of the science of heredity but also emerging concepts in almost all related disciplines of biology. Another distinct feature of this course is the hands-on-training imparted to the students. Emphasis is given to laboratory based learning including a small project work during the fourth semester wherein students are encouraged to conceptualize, design and perform experiments to answer a basic question related to their respective mentors' research programme, trouble shoot, interpret their data, write a report and also give an oral presentation at the end of the semester. The approach of a restrictive practical performed in a narrow time-frame is not supported, thus giving all students an opportunity to hone their skills across semesters.

The department has just initiated a one-year program in M.Phil. in Genetics for candidates curious to understand the nuances of research before starting on a Ph.D. Students with Master's degree in any area of sciences with an aptitude to work in the broad research programs of the department are selected for the M.Phil/Ph.D program based on a national level entrance test/interview and have to complete a 12 credit course before they can proceed with their experimental work. M.Phil course culminates with the completion of a short project work followed by a *viva-voce* examination, while Ph.D work generally spans over five to six years followed by a rigorous thesis defense and *viva-voce* examination.

Research is an integral part of the departmental academic activity. Research programs of the

faculty using cutting edge technology are focused on basic aspects of genetics, genomics and molecular biology with direct implications for crop improvement and health/disease. Specific projects under the plant sciences include high resolution mapping and marker assisted breeding in mustard; development of pathogen and pest resistant food crops using RNAi technology; understanding plant-pathogen interactions using conventional and contemporary OMICS approaches in *Arabidopsis* and Tobacco; and unraveling promoter architecture for regulation of transgene expression in plants. Biomedical research projects include discovery of putative disease causal genes in common genetic disorders such as intellectual disability, schizophrenia, Parkinson's disease, rheumatoid arthritis etc using informative families and next generation sequencing technologies and their functional characterization providing leads for novel therapeutics; determining molecular mechanisms underlying cellular toxicity and polyQ induced neurodegeneration in Huntington's and Parkinson's diseases using *Drosophila* as a model system; and epigenetic and molecular mechanisms in cancer stemness, progression and therapy in gliomas and lung cancer. Ongoing projects on understanding cell signaling in stress and development with *Dictyostelium* as a test system; and mitochondrial genetics and ribosomal biology using yeast provide insights into important basic biological processes.

Research projects in the department have attracted generous funding support from various agencies including Department of Biotechnology (DBT), Science and Engineering Research Board and University Grants Commission (UGC). The department houses two Centres of Excellence supported by DBT. The department has also been recognized and supported by UGC-SAP (DRS-III) and DST-FIST (level II) programs. Ph.D. scholars in the department are encouraged to avail independent fellowships and are also supported with fellowships from the university or extramural grants. A well-equipped instrumentation facility for imaging, genomics, proteomics and transcriptomics both in the department as well as the Central Instrumentation Facility of South Campus have been an exemplary support for carrying out high quality research.

Finally, contemporarily relevant syllabi for the Master's course, ongoing research projects of societal relevance together with dedicated and high performing doctoral students and faculty have enabled the department of genetics to emerge and stay in the forefront of teaching and research in different branches of Genetics in the country.

II. Introduction to CBCS (Choice Based Credit System)

Choice Based Credit System:

The CBCS provides an opportunity for the students to choose courses from the prescribed courses comprising core, elective/minor or skill-based courses. The courses can be evaluated following the grading system, which is considered to be better than the conventional marks system. Grading system provides uniformity in the evaluation and computation of the Cumulative Grade Point Average (CGPA) based on student's performance in examinations which enables the student to move across institutions of higher learning. The uniformity in evaluation system also enable the potential employers in assessing the performance of the candidates.

Definitions:

(i) 'Academic Programme' means an entire course of study comprising its programme structure, course details, evaluation schemes etc. designed to be taught and evaluated in a teaching Department/Centre or jointly under more than one such Department/ Centre

(ii) 'Course' means a segment of a subject that is part of an Academic Programme

(iii) 'Programme Structure' means a list of courses (Core, Elective, Open Elective) that makes up an Academic Programme, specifying the syllabus, Credits, hours of teaching, evaluation and examination schemes, minimum number of credits required for successful completion of the programme etc. prepared in conformity to University Rules, eligibility criteria for admission

(iv) 'Core Course' means a course that a student admitted to a particular programme must successfully complete to receive the degree and which cannot be substituted by any other course

(v) 'Elective Course' means an optional course to be selected by a student out of such courses offered in the same or any other Department/Centre

(vi) 'Open Elective' means an elective course which is available for students of all programmes, including students of same department. Students of other Department will opt these courses subject to fulfilling of eligibility of criteria as laid down by the Department offerring the course.

(vii) 'Credit' means the value assigned to a course which indicates the level of instruction; One-hour lecture per week equals 1 Credit, 2 hours practical class per week equals 1 credit. Credit for a practical could be proposed as part of a course or as a separate practical course

(viii) 'SGPA' means Semester Grade Point Average calculated for individual semester.

(ix) 'CGPA' is Cumulative Grade Points Average calculated for all courses completed by the students at any point of time. CGPA is calculated each year for both the semesters clubbed together.

(x) 'Grand CGPA' is calculated in the last year of the course by clubbing together of CGPA of two years, i.e., four semesters. Grand CGPA is being given in Transcript form. To benefit the student a formula for conversation of Grand CGPA into %age marks is given in the Transcript.

III. M. Sc Programme Details:

Programme Objectives (POs):

This program is aimed at graduate students from any field of science who want to pursue research careers in the area of science. The program focuses at developing strong foundational skill in various fields of genetics. The students are exposed to core areas in Molecular Genetics (microbial, *Drosophila,* plants and humans) as well as related areas like Biochemistry, Biostatistics, Developmental Biology, Recombinant DNA Technology and Computer Applications. Apart from the core courses, students can select few courses of their choice from a bunch of elective courses. Some of the courses are offered by other departments. Additionally, special emphasis is on intensive lab practical sessions, as well as hands on for bioinformatics data analysis where every student get a chance to independently perform the experiments and gain experience with standard molecular biology and genetic tools. Class room seminars, discussions, written tests, project work and hands on practical training are integral components of the course. The course is updated regularly to reflect the important advances in the related field. Students are continuously evaluated during the course. Various scholarships viz., Merit Scholarship, All India Post Graduate Scholarship and Monsanto Post Graduate Scholarship are also available for the M.Sc. students. Students are encouraged to clear UGC/CSIR-NET while pursuing their M.Sc. course.

Programme Specific Outcomes (PSOs):

GECC101 Introduction to Genetics

Genetic analysis is studied with reference to reverse and forward genetics and use of phenotypic, biochemical and molecular markers. Emphasis is laid on sources of genetic variation, which forms the basis of understanding diversity in a population.

GECC102 Chromosome, Genes and Genomes

Genome organization in model organisms, techniques for studying chromosomes and applications such as comparative genome hybridization and somatic cell hybrids are taught.

GECC103 Cell Biology

Cell structural organization, regulation of biochemical pathways and networks with special

attention to physiological conditions such as stress, exercise and starvation as well as diseased conditions such as Diabetes.

GECC104 Molecular Biology

The students learn of the transport of biomolecules in eukaryotes, turnover of regulatory molecules, signaling, crosstalk between basic processes and cell cycle, and basics on programmed cell death.

GECC105 Experiments in Genetics-I (practical based on theory)

Experimental and hands-on knowledge on bacterial culture, mutagenesis, studying chromosomal aberration, protein estimation and enzyme kinetics, SDS-PAGE analysis

GECC201 Population, evolutionary and quantitative genetics

Forces that have an impact on levels of genetic variations in natural and/or experimental populations for both qualitative and quantitative traits, and the tools to study these traits are

taught.

GECC202 Bioinformatics and Biostatistics

This course is aimed at imparting knowledge of application of computational methods in order to address biological problems. Web-based programs to obtain and manipulate biological data (both sequence and structure) are taught to highlight sequence-structure-function relationship to further understanding of biological systems.

GECC203 Regulation of Gene Expression

Gene expression is regulated at various stages of transcription, translation and post- translation and epigenetic regulation is taught by using examples from various model organisms.

GECC204 Recombinant DNA Technology

This paper provides the details of the various techniques and tools used as well as theirapplication in the generation of commercial products of myriad usage (Biotechnology).

GECC205 Experiments in genetics- III (Based on theory)

With these set of practicals, students learn the basic Recombinant DNA technology skills required for any molecular biology work. This includes running agarose gel, plasmid preparations, nucleic acid isolation, restriction enzyme digestion, primer design & PCR and Southern hybridization. They also learn to perform recent techniques such as bisulphite conversion of DNA for methylation analysis. , usage of gene prediction, and basic tools such as ClustalW, BLAST, PDB etc. Phylogenetic analysis, multiple sequence alignment and homology modeling tools are also taught.

GECC301 Microbial Genetics

This paper deals with the strength of microbial genetics: both prokaryotic as well as eukaryotic systems. Current molecular tools involved in microbial genetic analysis such as construction of vectors and artificial chromosome systems are also studied.

GECC302 Human Genetics

This introductory course attempts to walk the students through classical genetics and molecular genetics. Application of mapping tools, cloning strategies culminating in the, new/current knowledge on genetic variations in health and disease across populations and their clinical/diagnostic implications are dealt with

GECC303 Plant Genetics and Breeding

This course primarily deals with how to undertake plant genome analysis and gene mappingthrough the use of DNA markers and how this information could be utilized in bringing the efficiencies in selection methods of plant breeding and gene isolation through forward genetics approach.

GECC304 Plant Tissue Culture and Transgenic Technology

This course is designed to provide students with specialized knowledge of the theory andpractical skills of plant tissue culture, somatic cell genetics and genetic engineering relevant

to crop improvement.

GECC305 Experiments in genetics- III (Based on theory)

Study of gene expression is performed to achieve phenotypic and biochemical characterization of wild type and mutant E.coli and yeast strains. Students are taught to work with phages and yeast. Cytogenetics and chromosome preparation for studying banding is also taught. Additionally, genotyping using PCR based fingerprinting methods is also a feature of the hands-on curriculum. A field trip to a plant breeding station is a popular practical among the students. Plant tissue culture is extensively taught and individually performed by the students.

GECC401 Developmental Biology and Immunology

The course envisages giving an insight into how developmental patterns arise using examples from different model systems and highlighting regulatory networks involved in these processes.

The immunology course provides a comprehensive overview of basic immunology, innate immune responses, followed by a study of the main aspects of acquired immunity and genetics of antibody development.

GECC402 Project Work

This course provides hands-on experience to the students about handling a research problem independently. Additionally, they develop presentation and communication skills.

GEEC403 to - ELECTIVE COURSE -

Teaching specialized courses covering the advances in specialized fields of genetics in various model systems used in research.

Programme Structure:

The M. Sc programme is a two-year course divided into four-semester. A student is required to complete 96 credits for the completion of course and the award of degree.

		Semester	***Semester***
Part – I	First Year	Semester I	Semester II
Part – II	Second Year	Semester III	Semester IV

Course Credit Scheme

Semester	**Core Courses**			**Elective Course**			**Open Elective Course**			Total Credits
	No. of papers	Credits (L+P)	Total Credits	No. of papers	Credits (L+P)	Total Credits	No. of papers	Credits (L+P)	Total Credits	
I	5 (4L+1P)	16L +8P	**24**	0	0	**0**	0	0	**0**	**24**
II	5 (4L+ 1P)	16L +6P	**22**	0	0	**0**	1	2L	**2**	**24**
III	5 (4L+ 1P)	16L +8P	**24**	0	0	**0**	0	0	**0**	**24**
IV	1L+ 1 project	4L +12	**16**	2L	8L	**8**	0	0	**0**	**24**
Total Credits for the Course			**86**			**8**			**2**	**96**

L= Lecture, P = Practical

*For each Core and Elective Course there will be 4 lecture hours of teaching per week.

* Open Electives to the maximum total of 8 credits.

IV: Course Wise Content Details for M.Sc Genetics Programme

Masters in Genetics
Semester I

GECC101: INTRODUCTION TO GENETIC ANALYSIS

Marks: 100 **Duration: 60 Hrs.**

Course Objectives:

The science of Genetics has come to occupy a pivotal position in the entire field of Biology, as it is central to numerous aspects of human affairs. Deeply rooted in strong concepts, it has provided the unifying themes for all living organisms. While on one hand, the science centers around a phrase "like begets like", it also explains the inherent variability that differentiates one individual from the other. Though the discipline of Genetics has moved far ahead from simple inheritance of the characters, it is absolutely essential to have a clear understanding of the underlying concepts. This paper deals with these basic concepts that form the building block for any further understanding of genetics.

Course Learning Outcomes:

CO1: Students will be able to comprehend the fundamentals of genetics

CO2: Will be able to develop strategies to create genetic variation as well as methods for analyzing the existing ones.

CO3: Students will be able to analyse the different patterns od inheritance observed across biological systems

CO4: Students will understand the various strategies employed to map a gene in different model systems.

Contents:

Unit I [8]

Genetic basis of life

Sexual life cycles, meiosis leading to segregation and independent assortment, Chromosomal basis of segregation and independent assortment; Reading: Mendel's paper on "Experiments in Plant Hybridization" (1865) ; introduction to the concept of probability in genetic analysis.

Unit II [6]

Genetic variations

Sources of genetic variation: mutations, recombination (including models of recombination), independent assortment**;** analyzing genetic variation by using markers: phenotypic, biochemical and molecular (isozymes and DNA markers)

Unit III [22]

Analyzing inheritance patterns

Single gene inheritance pattern: allelic interactions; sex-linkage; penetrance and expressivity; test for allelism-complementation ; Inheritance of two genes: independent assortment versus linkage, gene; Introduction to quantitative traits: Continuous and discontinuous variation: polygenic inheritance; genetic variance, heritability interactions; Pedigree analysis in humans; Extranuclear inheritance

Unit IV [24]

Genetic analysis and mapping in model systems

E. coil and its phages: temporal and recombination-based mapping in *E. coli*, transformation and transduction-based mapping, gene mapping in bacteriophage; *Neurospora* and *Aspergillus nidulans*: tetrad analysis and parasexual recombination; *Drosophila* – mapping by recombination, based on test cross and F_2 progeny; Fine structure mapping (Experiments of Seymour Benzer) ; Physical versus genetic maps

Suggested readings:

1.	Introduction to Genetic Analysis	Griffith AF *et al.*	W H Freeman & Co
2.	Concepts of Genetics	Klug WS & Cummings MR	Prentice-Hall
3.	Genetics – a conceptual approach	Pierce BA	W H Freeman & Co
4.	Principles of Genetics	Sunstad DP & Simmons MJ	John Wiley & sons
5.	Genetics	Strickberger MW	Prentice-Hall
6.	Genetics Analysis of Genes & Genomes	Hartl, D.L. Jones, E.W.	Jones & Barlett
7.	Genetics: A Molecular Approach	Peter J Russel	Pearson
8.	Genetic Analysis	Phillip Meneely	Oxford

Masters in Genetics
Semester I

GECC102: CHROMOSOMES, GENES AND GENOMES

Marks: 100 **Duration: 60 Hrs.**

Course Objective:

This paper has been designed to provide fundamental and advanced aspects of chromosome biology, genome organization, concept and mapping of gene, and outshoots. The students are expected to develop a holistic notion about the dynamic nature of chromosome and its influence in regulating various aspects of cellular functioning as well and organism as whole. Emphasis would be given to explain the topics with the help of interactive classroom sessions including classical experimental strategies, examples from different model organisms and contemporary genetic approaches and methods.

Course Learning Outcomes:

CO1: To equip the students with the information of various classical and contemporary techniques and their applications to study in-depths of cells and chromosomes.

CO2: To develop an understanding about the structure and organization of the dynamic chromosomes, and to also study about various chromosomal anomalies and their consequences on cellular functioning.

CO3: To become aware of the various essential classical and contemporary methods to study chromosome, genes and genome, and to also develop conventional and modern concept about gene.

CO4: To understand the dynamic role and involvement of chromosomes during various stages of cell division, and to comprehend the genetic control of meiosis.

CO5: To cultivate perception about various features of genome organization in prokaryotic and eukaryotic organisms, and to appreciate the diversity and contribution of transposable elements in genome evolution.

CO6: To develop concept about chromosomal aspects of sex determination in animal and plants, and to become aware of the strategies involved in achieving dosage compensation in various organisms

Contents:

Unit I [4]

Methods to study cells and chromosomes

An overview of various microscopy methods and applications, centrifugation techniques, fractionation, spectrophotometry, autoradiography techniques

Unit II [16]

Chromatin structure

Histones, DNA, nucleosome morphology and higher level organization, Functional states of chromatin and alterations in chromatin organization.

Chromosome organization

Metaphase chromosomes**:** centromere and kinetochore, telomere and its maintenance, Holocentric chromosomes, Heterochromatin and euchromatin, position effect variegation, Chromosomal domains (matrix, loop domains) and their functional significance, Chromatin remodeling.

Giant chromosomes

Polytene and lampbrush chromosomes, and their biological significance.

Chromosomal anomalies

Overview of numerical and structural alterations, and their impact on cellular functioning and development, induced chromosomal aberrations in somatic cells.

Unit III [12]

Methods to study chromosome and genes

Short term (lymphocyte) and long term (fibroblast) cultures, chromosome preparations, karyotyping, banding, chromosome labeling, *in situ* hybridization, chromosome painting, comparative genome hybridization, somatic cell hybrids and gene mapping, premature chromosome condensation.

Concept of gene

Conventional and modern views, Fine structure of gene, split genes, pseudogenes, non-coding genes, overlapping genes and multi-gene families.

Unit IV [8]

Cytogenetic aspects of cell division

Chromosome labeling and cell cycle analysis, overview of mitosis and meiosis, sister chromatid cohesion remodeling, regulation of exit from metaphase, chromosome movement at anaphase, genetic control of meiosis.

Unit V [12]

Genome organization

Viruses and prokaryotes, Eukaryotes- Organization of nuclear and organellar genomes, C-value paradox, Repetitive DNA - satellite DNAs and interspersed repeat DNAs.

Transposable elements

Barbara McClintocks experiment of maize, Autonomous and non-autonomous transposons, clonal selection, retrotransposons, LINES, SINES, Alu family, Application of transposons in mutagenesis, genome mapping and evolution.

Unit VI [8]

Sex determination

Genetic determination of sex in *Caenorhabditis elegans*, *Drosophila melanogaster*, mammals and flowering plants.

Dosage compensation

Various approaches of dosage compensation in *Caenorhabditis elegans*, *Drosophila melanogaster* and mammals.

X chromosome inactivation

Lyon's hypothesis, genetic control of X-chromosome inactivation.

Suggested readings:

1.	Essential Cell Biology	Alberts B *et al.*	Garland Publishing
2.	Molecular Biology of The Cell	Alberts B *et al.*	Garland Publishing
3.	The Eukaryotic Chromosome	Bostock CJ & Summer AT	Elsevier
4.	The Chromosome	Harrison HJS & Flavell RB	Bios
5.	Advanced Genetic Analysis	Hawley RS & Walker MY	Blackwell Publishing
5.	Structure & Function of Eukaryotic Chromosomes	Hennig W	Springer
6.	Genes IX	Lewin B	Pearson
7.	Molecular Cell Biology	Lodish H *et al.*	Freeman
8.	Cell and Molecular Biology	De Robertis & De Robertis	Lippincott & Wikins
9.	Genome 3	Brown TA	Garland Publishing

Masters in Genetics
Semester I

GECC103: CELL BIOLOGY

Marks: 100 **Duration: 60 Hrs.**

Course Objectives:

Life on this earth has evolved through a set of simple biochemical reactions, which has subsequently given rise to specific cell types. Cells are made out of some building blocks which when bonded together produce the various structural and functional constituents. The paper will also discuss the transport of biomolecules in eukaryotes, turnover of regulatory molecules, crosstalk between basic processes and cell cycle, basics on signaling pathways and programmed cell death.

Course Learning Outcomes:

CO1: Introduction of the biomolecules necessary for building and sustenance of the cell

CO2: This section deals with understanding the overall establishment of cellular architecture, transport of macromolecules with the cells and its regulation

CO3: Introduction to protein structure-function, folding and degradation

CO4: This unit will give fundamentals of cell division, cell signaling and their controls

Contents:

Unit I: [6]

Biomolecules

Chemical bonds; Building blocks- carbohydrates, lipids, fats, proteins, nucleic acids.

Cellular energetics

Energy rich compounds, ATP synthesis, thermodynamics of cellular reaction

Unit II [18]

Cell structure and organization

Plasma membrane; Fluid mosaic model; Nuclear organization, Information compartment; ER and Golgi, Cytoskeleton, Mitochondria and Chloroplast

Trafficking of biomolecules

mRNA transport, Nucleo-cytoplasmic transport; Transport into ER, Mitochondria; Secretory pathways; Protein sorting; Endocytosis; Unfolded protein response; Cholesterol homeostasis-cellular transport, regulation of biosynthetic genes

Unit III [16]

Proteins

Protein structure; Primary, Secondary, Tertiary and Quaternary; Protein misfolding, Chaperones; Versatility of proteins in biological processes

Cellular proteolysis

Autophagy, Proteosomes, Ubiquitin pathway

Unit IV [20]

Cell cycle and its regulation

Cell signalling pathways

Signal molecules**,** Signalling pathways**,** Mechanism of signal transduction, Crosstalk among different signalling pathways, Programmed cell death

Suggested readings:

1.	Principles of Biochemistry	Lehninger *et al.*	W. H. Freeman
2.	Biochemistry	Devlin TM	Wiley-Liss
3.	Biochemistry	Berg JM, Tymoczko JL & Stryer LT	W. H. Freeman
4.	Molecular Cell Biology	Lodish H *et al.*	W. H. Freeman
5.	The World of the Cell	Becker WM *et al.*	Benjamin Cummings
6.	Biochemical Calculation	Seigel IH	Wiley
7.	Cell and Molecular Biology: Concepts and Experiments	Karp G.	Wiley
8.	Molecular Biology of the Cell	Bruce Alberts *et al.*	Garland

Masters in Genetics
Semester I

GECC104: MOLECULAR BIOLOGY

Marks: 100 **Duration: 60 Hrs.**

Course Objective:

From a geneticist's point of view, the understanding of informational molecules, such as DNA, RNA, and proteins is central as they provide information on life and its processes. This paper deals with the structural and informational molecules, and their role in information transfer. This paper will focus on basic processes of copying, restructuring, readout and decoding of genetic information both in prokaryotes and in eukaryotes with emphasis on discussions of seminal experiments and discoveries. Detailed mechanisms of each processes will be discussed with components of machinery, factors and steps involved. Special emphasis has been given to proteins as biocatalysts, in cellular reactions.

Course Learning Outcomes:

CO1: Students will learn of the basics of nucleic acid structure and function, mechanisms and molecules governing processes of replication the advancement in the field will be discussed

CO2: To give an account on how and what processes are involved in decoding information from DNA to RNA or Proteins in both prokaryotes and eukaryotes

CO3: Students will learn basic biochemical process and pathways in a cell

Contents:

Unit I [10]

DNA as a genetic material

Seminal experiments on its discovery, function, DNA structure and topology

DNA in biological processes

DNA replication; General features of DNA replication; Basic mechanism of DNA replication; Origin of replication and regulation of DNA replication; DNA repair**;** Types of DNA damage, mechanisms of DNA repair in prokaryotes and eukaryotes – Base excision, nucleotide excision, mismatch repair, double strand break repair, SOS response

Unit II [28]

RNA as genetic material

Types of RNA, role of RNA in information transfer, concept of central dogma

Gene expression

Transcription- Gene as a unit of function; RNA polymerases, regulatory sequences, transcription factors, process of initiation, elongation and termination; Post-transcriptional modifications - capping, poly-adenylation, splicing (*cis*- and *trans*-), other RNA processing events- transfer RNA, RNA editing; Translation- Genetic code, codon usage, ribosome structure, process of translation; Post-translational modifications; Experimental approaches

Unit III [22]

Cellular Biochemistry

Enzymes- Their role as biocatalysts, specificity and kinetics, assay and inhibition of enzyme activity, mechanism of action, regulation of enzyme activity, Allosteric enzymes; Biochemical Pathways- Biosynthesis of ATP, Metabolism of carbohydrates, Metabolism of fatty acids, Respiratory chain, Ketone body formation and utilization, Shuttle systems, Regulation and integration of metabolic networks, examples from fasting and starvation, Diabetes mellitus, obesity.

Suggested Readings:

1.	Molecular Biology of the Cell	Alberts B., Johnson A., Lewis J., Raff M., Roberts K., Walter P.	Garland Science
2.	Molecular Biology of the Gene	Watson J. D., Baker T. A., Bell S. P., Gann Alexander	C S H L Press
3.	Genes X	Krebs, J. E., Goldstein E. S., Kilpatrick S.T.	Jones & Bartlett Publishers
4.	Cell and Molecular Biology: Concepts and Experiments	Karp G.	Wiley
5.	The Cell: A Molecular Approach	Cooper G. M	Sinauer Associates
6.	Fundamentals of Enzymology	Price NC & Lewis ST	Oxford University Press
7.	Principles of Biochemistry	Lehninger *et al.*	W. H. Freeman
8.	Biochemistry	Devlin TM	Wiley-Liss
9.	Biochemistry	Berg JM, Tymoczko JL & Stryer LT	W. H. Freeman

Masters in Genetics
Semester I

GECC 0705: EXPERIMENTS IN GENETICS – I

Marks: 200 **Duration: 240 Hrs.**

LIST OF EXPERIMENTS

1. Marker characterization and genotype determination in *E. coli* and *Aspergillus nidulans*
2. Analysing growth of different strains (K12 and XL1Blue) of *E. coli* on
   i. Complete medium
   ii. Minimal medium with different carbon sources (glucose, lactose and both together)
3. UV mutagenesis of *E. coli*
   i. Survival response of *E.coli* on UV irradiation
   ii. Induced mutagenesis – Screening and selection
4. Handling, maintaining cultures and study of the life cycle of *Drosophila melanogaster,* and identifying different mutants.
5. Studying inheritance patterns (autosomal and sex-linked) by making crosses in *Drosophila.*
6. Study of mitosis (onion root tip) and meiosis (onion or Rhoeo buds).
7. Preparation of polytene chromosomes from salivary gland of *Drosophila*.
8. Human lymphocyte culture for preparation of metaphase chromosomes.
9. Studying chromosomal abnormalities.
10. To plot the titration curve for acetic acid and to calculate the buffering zone.
11. To prepare an acetate buffer of pH 5.0.
12. To plot titration curve for sodium dihydrogen phosphate (NaH_2PO_4).
13. To find the molar extension coefficient of PNP.
14. To plot a standard curve for estimation of protein using Folin-lowry method
15. To assay the activity of the enzyme acid phosphatase in extract of moong dal and to determine its specific activity.
16. To study the effect of varying substrate concentration on the activity of the enzyme acid phosphatase.
17. To estimate total protein from moong dal sprout in various subcellular fractions.
18. To purify the enzyme acid phosphatase using ion exchange chromatography
19. To perform SDS-PAGE of proteins

Masters in Genetics
Semester II

GECC201: POPULATION, EVOLUTIONARY, AND QUANTITATIVE GENETICS

Marks: 100 **Duration: 60 Hrs.**

Course Objective:

Population genetics is necessary to comprehend the students about the evolutionary processes in the natural populations. It will make the students familiar with different types of genetic markers and their detection to enable advanced molecular population genetic studies. It will also make them understand the forces that have an impact on levels of genetic variations in natural and/or experimental populations for both qualitative and quantitative traits.

Course Leaning Outcomes:

CO1: To comprehend the sources of genetic variation and methods for detecting these variations at both morphological and molecular level.

CO2: To make students understand the genetic organization and measure the genetic variation of different types of genes in a natural population.

CO3: To understand the importance of genetic mapping in natural populations.

CO4: To know different types of natural populations and their genetic characteristics.

CO5: To know and quantify the different types of evolutionary forces which bring changes in the gene frequencies in biological population.

CO6: To appreciate different theories of evolution and their molecular mechanism.

CO7: To understand the importance of quantitative traits and how to estimate their genetic effects.

Contents:

Unit I [8]

Genetic variation

Types and sources of variation; Mechanisms of mutation; Detection of polymorphism – DNA markers and their detection techniques

Unit II [10]

Organization and measurer of genetic variation

Random mating population; Hardy-Weinberg principle; Complications of dominance; Special cases of random mating – multiple alleles, sex-linked genes

Unit III [8]

Linkage and Linkage disequilibrium

Definition of linkage disequilibrium and the difference between linkage and linkage disequilibrium; Different parameters to estimate linkage disequilibrium

Unit IV

Population sub-structure [4]

Hierarchical population; Isolate breaking; inbreeding, assortative and non-assortative mating

Unit V

Gene frequencies and evolution [8]

Mutation; selection; migration; genetic drift

Unit VI [12]

Molecular evolution

Theories of evolution; neutral theory and coalescence; molecular evolution of genes and proteins; Phylogeny and systematics

Unit VII

Quantitative genetics [10]

Johannsen pure line theory; Multiple factor hypothesis; Types of quantitative traits; Components of phenotypic variation and genetic models of quantitative traits; Concept of heritability

Suggested readings:

1.	DNA Markers: Protocols Applications and Overviews	Anolles GC & Gresshoff PM	Wiley-Liss
2	Molecular Markers in Plant Genetics and Biotechnology	Vienne De D	Science Publishers
3.	Genetics of Population	Hedrick PW	Jones & Bartlett
4.	Principles of Population Genetics	Hartl DL & Clark AG	Sinauer Associates
5.	Biostatistics	Danial WW	Wiley
6.	Statistical Methods in Biology	Bailey NTJ	Cambridge Univ. Press

Masters in Genetics
Semester II
GECC202: BIOINFORMATICS AND BIOSTATISTICS

Marks: 100 **Duration: 60 Hrs.**

BIOINFORMATICS

Course Objective:

This course is aimed at imparting knowledge of application of computational methods in order to address biological problems.

Course Learning Outcomes:

CO1: Students will be able to work with public sequence repositories and use database search tools like BLAST to search similar sequences.

CO2: Students will be aware of concepts of homology and can understand select appropriate tools to perform phylogenetic analysis.

CO3: After attending the course students will be aware of the concepts of annotation of different features of genomes.

CO4: To be able to compare and classify biomolecules on the basis of structure for gaining insight into their function.

CO5: To be able to differentiate between the utility of various methods available for generating a model of protein structure.

Contents:

Unit I [10]

Databases and Sequence formats

Nucleotide and protein sequence databases - Uniprot, Swissprot, PIR. Genbank, Refseq; The NCBI resources (Entrez, Pubmed, Medline, Entrez gene, Boolean search terms and statements, NCBI bookshelf); Introduction to nucleotide and protein sequence data formats - FASTA, Genbank, flatfile, Genome annotation methods

Unit II [6]

Pair-wise Alignment and Database Searching

Scoring matrices, local and global alignment, scoring functions, data base search for homologous

sequences (FASTA and BLAST), motifs and domain searching; notion of homology orthologues, paralogues, analogues

Multiple Sequence Alignment

Sum of Pairs measure, Clustal W, Clustal X, progressive alignment, scoring MSAs, iterative methods of MSA

Unit III [4]

Molecular Phylogenetics

Concept of evolutionary trees - Branches, nodes, internal nodes, rooted and un-rooted trees; Different methods and tools for phylogenetic analysis (UPGA, NJ, Maximum Parsimony & Maximum Likelihood); Bootstrapping evaluation

Unit IV [10]

Biomolecular structures

Protein structure determination methods (X-Ray crystallography & NMR), Protein structure and classification databases, Characteristics of Nucleic acid structure, Structural RNA like tRNA, Small and non-coding. RNA

Unit V [10]

Basics of Molecular Modeling

Basic principles of tertiary structure prediction, homology modeling, threading and ab-initio protein structure prediction, Protein structure comparison, Superimposition and RMSD calculations

Suggested Readings:

1.	Proteomics- from protein structure function	Dunn M J	Viva Publisher
2.	Introduction to Bioinformatics	Lesk A	OUP- India
3.	Essential Bioinformatics	Jin Xiong	Cambridge Univ. Press
4.	Bioinformatics: Sequence and genome analysis	David mount	Cold Spring Harbor Lab Press
5.	Bioinformatics: A practical guide to the analysis of genes and proteins	Baxevanis & Outlette (Eds.)	John Wiley & Sons Inc.
6.	Microarray Bioinformatics	Dov Stekel	Cambridge Univ. Press
7.	Structural Bioinformatics	Jenny Gu & Philip E. Bourne (Eds.)	Wiley-Blackwell

BIOSTATISTICS

Course Objective:

Much of genetic analysis is based on quantitative data and therefore statistical techniques are used extensively. Some basic tools of statistics are essential in designing and analysis of data and in the interpretation of experimental results for dependable conclusion, essential to test a hypothesis.

Course Learning Outcome:

CO1: The student will be able to apply and comprehend the usage of basic concepts of commonly used statistical analysis in research applications.

Contents

Unit 1 [20]

Principles and applications of statistical methods in biological research

Basic statistics- Samples and populations, experimental design, data analysis, graphs, average, coefficient distributions (chi-square, binomial, poisson and normal); Tests of statistical significance – t-test, z-test, F-test, U-test and others; Regression and correlation; Analysis of variance

Suggested readings:

1.	Biostatistics	Danial WW	Wiley
2.	Statistical Methods in Biology	Bailey NTJ	Cambridge Univ. Press

Masters in Genetics
Semester II
GECC203: REGULATION OF GENE EXPRESSION

Marks: 100 **Duration: 60 Hrs.**

Course Objectives:

Gene expression is regulated at various stages of transcription, translation and post-translation. These topics would be taught with emphasis on discoveries, examples and experimental designs for studies. Epigenetic regulation is also a fast emerging field which has now been recognized to contribute immensely in developmental processes. Overall, students are expected to read, research and discuss papers related to topics

Course Learning Outcomes:

CO1: Enable students to discern the broad strategies used by different organisms to regulate expression of genes.

CO2: Enable students to analyze the ways by which genes are regulated in bacteria and yeast.

CO3: Enable students to analyze the ways by which genes are regulated in eukaryotes

CO4 & 5: Students will be able to discern the broad strategies used by different organisms for epigenetic regulation and utilize them for analysis.

Contents

Unit I [4]

Strategies in gene regulation

An overview on the levels of regulation – evidences and experimental designs to study regulation at different levels; concept of positive and negative regulators and building inducible and repressible systems using these components; tools to analyze activity of genes

Unit II [14]

Lessons from bacteria and yeast

Jacob and Monod's seminal paper; Analyzing gene regulation with examples from *lac*, *trp* and *ara* operons; Genetic switch for lysis and lysogeny in λ phage**;** Global control by sigma factors; *GAL1* in yeast

Unit III [8]

Gene regulation in eukarotes

Perceiving signals- overview of cell signaling pathways; analyzing transcriptional control using examples of constitutive, inducible and tissue specific promoters; post-transcriptional regulation with examples of alternative splicing, RNA editing, mRNA stability and degradation; translational regulation- initiation, codon usage; post-translational modifications; control by small RNA

Unit IV [18]

An introduction to epigenetics

Concept and overview of epigenetics; Chemical changes - DNA methylation and histone modification in determining the chromatin structure; DNA binding proteins; Techniques for studying epigenetic modifications; Polycomb and Trithorax group of proteins; Histone variants in chromosomal inheritance and in stress; Chromatin remodelers, their families and functions; Position Effect Variegation, Heterochromatin spreading and gene silencing in *Drosophila*.

Unit V [16]

Epigenetic events in biology

Genomic imprinting in humans; Imprinting defects in humans; Transgenerational inheritance in mammals; Vernalization in plants; Non coding RNA and X chromosome inactivation; miRNA and cell fate in *Caenorhabditis elegans*; Heterochromatin and mating types in *Saccharomyces cerevisiae*; Cellular memory and homeotic transformations in various organisms; Stem cell reprogramming

Suggested readings:

1	Genes and Signals	Mark Ptashne & Alexander Gann	CSHL Press
2	A Genetic Switch	Mark Ptashne	CSHL Press
3	Gene Regulation	David S. Latchmann	Chapman & Hall
4	The *lac* operon	Benno Muller-Hill	Walter de Gruyter
5	Genes	Benjamin Lewin	Prentice Hall
6	Molecular Cell Biology	Lodish H *et al.*	W.H Freeman
7	Molecular Biology of the Cell	Alberts B *et al.*	Garland Science
8	Epigenetics	David Allis C	CSHL Press

Masters in Genetics
Semester II
GECC204: RECOMBINANT DNA TECHNOLOGY

Marks: 100 **Duration: 60 Hrs.**

Course Objective:

Recombinant DNA technology is a set of molecular techniques for location, isolation, alteration and study of DNA segments or genes. Commonly called genetic engineering it encompasses ways to analyze, alter and recombine virtually any DNA sequences. Parting away from the classical gene-phenotype relationship, this technology provides information through direct reading of the nucleotide and/or protein sequences. This paper provides the details of the various techniques and tools used as well as their application in the generation of commercial products of myriad usage (Biotechnology). Looking at the vast implications, topics on Bioethics and Biosafety, implicit in such a technology will also be covered.

Course Learning Outcomes:

CO1: To understand methods to analyze DNA/RNA/proteins be contemporary genetic engineering techniques

CO2: Students would have learnt the basics of gene cloning, construction of various libraries and gene identification.

CO3: To understand the gene expression analysis by PCR -, Hybridization-, and Sequencing-based techniques.

CO4: Familiarize them with the various techniques to engineer and express recombinant proteins, for studying the dynamics of protein- protein and protein-DNA interaction and proteome analysis

CO5: To appreciate the importance and application of recombinant DNA technology in biology.

Contents:

Unit I

Methods of DNA, RNA and protein analysis: [8]

Electrophoretic techniques – agarose and polyacrylamide gel electrophoresis, native-, SDS-, and 2-D PAGE; Blotting techniques - Southern, northern, and western blots; Preparation of probes; RFLP analysis, DNA fingerprinting and its application

Unit II

Gene cloning and identification [18]

Basics of cloning: Restriction and DNA modifying enzymes; Isolation and purification of nucleic acids; cloning methods; Cloning vectors – plasmids, phages, lambda vectors, phagemids, cosmids, fosmids, PAC, BAC and YAC; Selection and screening of clones

Construction of DNA libraries

Genomic and cDNA libraries; Screening of genomic and expression libraries

Gene identification

Subtractive hybridization, chromosome walking and jumping

Genome sequencing

DNA sequencing by Maxam and Gilbert method, Sanger's method, whole genome shotgun sequencing, next generation sequencing; Genome annotation: an overview

Unit III

Expression Analysis [14]

Analysis of gene expression- Northern blotting, RT-PCR, EST analysis, Promoter analysis; Mapping transcriptional start sites, Transcriptome analysis – cDNA- and oligo arrays; Serial Analysis of Gene Expression (SAGE); Polymerase Chain Reaction (PCR)- Concept of PCR, various kinds of PCR, Real Time PCR, Ligation Chain Reaction; Applications of PCR

Unit IV : [16]

Protein expression, engineering and interactions

Expression of recombinant proteins- Expression and tagging of recombinant proteins in E. coli, Other expression systems; Protein engineering- Insertion and deletion mutagenesis, site-directed mutagenesis; Proteome analysis - MALDI, protein arrays and their applications; Analysis of protein-DNA and Protein-protein interactions- Gel retardation assay, DNA footprinting, Yeast one-two- and three-hybrids assay; ChIP on chip assay; Split and reverse hybrids, Co-immuno precipitations; Phage display

Unit V [4]

Applications of recombinant DNA technology in biology and medicine

Gene editing technologies

Suggested readings:

1. Gene Cloning and DNA Analysis: An Introduction — Brown TA — Blackwell Publications
2. Gene Cloning and Manipulation — Howe C — Cambridge University

			Press
3.	Principles of Gene Manipulation and Genomics	Primrose SB & Twyman RM	Blackwell Publications
4.	Principles of Gene Manipulation	Primrose SB Twyman RM & Old RW	Wiley Blackwell
5.	Molecular Cloning: A Laboratory Manual (3- Volume Set)	Sambrook J *et al.*	CSHL Press
6.	Calculations for Molecular Biology and Biotechnology	Stephenson FH	Academic Press

Masters in Genetics

Semester II

GECC205: Experiments in Genetics –II

Marks: 200 **Duration: 180 Hrs.**

LIST OF PRACTICALS

1. Analyse the expression of β-galactosidase gene during growth of *E. coli* in presence of different carbon sources

2. Analysis of methylation status of genomic DNA.

3. Preparation of the polytene chromosome after heat shock to observe stress induced puffing.

4. Primer to recombinant DNA practical.
   i. Handling micro volumes: use of micropipettes and determining their accuracy by gravimetric method
   ii. Preparation of dilution of a given DNA sample and measure the absorbance at 260 nm to check accuracy of dilutions.

5. Preparation of competent cells of *E. coli* (XL1-Blue) by $MgSO_4$ -PEG OR $CaCl_2$ method and its transformation.

6. Preparation of plasmid DNA by alkaline lysis (mini and midi preparation). Calculating yield and purity of DNA by studying its absorbance and digestion with restriction enzyme.

7. Experiments with agarose gel electrophoresis to analyze relationship between mobility of DNA fragments of different sizes and the percentage of the gel.

8. Making a restriction map of a given DNA sample.

9. Digestions and ligation of plasmid DNA. Studying ligations following single digest, double digest and de-phosphorylation.

10. Elution of DNA from agarose gel using elution kit, electro elution and DEAE membrane.

11. Creating recombinant DNA: directional and non-directional cloning of a DNA fragment in a plasmid vector.

12. Designing primers for a given DNA template and analyzing the role of different reaction components/conditions ($MgCl_2$ conc., temperature, conc. of template and number of cycles) on the efficiency of PCR.

13. Isolation and digestion of genomic DNA with different restriction enzymes (4, 6 and 8 base cutters).

14. Demonstration of Southern hybridization, and DNA sequencing methods.

15. Isolation of RNA.

16. Using NCBI and Uniprot web resources
    a. Similarity searches using tools like BLAST.
    b. Multiple sequence alignment using ClustalW
    c. Phylogenetic analysis of protein and nucleotide sequences
    d. Use of gene prediction methods (GRAIL, Genscan, Glimmer)
    e. Using RNA structure prediction methods.
    f. Use of different protein structure databases (PDB, SCOP, CATH)
    g. Visualization/Studying protein structures using Deepview/PyMol
    h. Mutating and Energy minimization of protein structures
    i. Ab-initio structure prediction of proteins
    j. Homology modelling of proteins

Masters in Genetics
Semester II

GEOE206: GENETICS IN CROP IMPROVEMENT AND HUMAN HEALTH

Marks: 50 **Duration: 30 Hrs.**

Course Objective:

This course intends to familiarize the students with the potential of Genetic studies and its application in agriculture and human health.

Course Learning Outcomes:

CO1: Students will be familiarized with the basic concepts underlying inheritance of traits

CO2: Students will be introduced to the application of genetics and biotechnology in crop improvement.

CO3: Students will be able to comprehend how genetics is used in human health

Contents:

Unit I [6]

Fundamental of Genetics

Concepts of Mendelian inheritance, Chromosome theory of Inheritance, Concept of gene, allelic and gene interactions, test of allelic complementation ; Introduction to linkage, crossing over and developing genetic maps

Unit II [12]

Genetics in crop Improvement

Crop improvement- Scope, nature and history; Conventional methods for crop improvement - Various breeding strategies; Molecular genetic breeding - Genetic mapping of traits, Marker assisted breeding for important traits (Case study); Biotechnology for crop improvement- Application of genetic transformations in crop improvement, marker and reporter genes used; case studies of transgenic traits in plants, Resistance to pests and Pathogens

Unit III [12]

Genetics in Human health

Analysis of human genetic diseases - Overview of pedigree analysis, determination of inheritance pattern, phenotypic and molecular markers, karyotyping chromosomal banding and analysis, molecular genetic analysis, physical/genetics mapping and cloning of disease causing gene; Genetic variation and diseases - Chromosomal disorders/syndromes, monogenic and polygenic disorders,

nature vs nurture, epigenetics and human health, twin studies, introduction to behavioural genetics; Human disease modeling - Modelling and analysis of human genetic disorders in *C. elegans*, *Drosophila*, zebrafish (*Danio rerio*), mouse. Genetic screening and identification of drug targets; Management of genetic diseases - Prenatal, neonatal and adult diagnosis, Introduction to genetic counseling, Calculation of risk factor, Available methods of therapy.

Masters in Genetics
Semester III

GECC301: MICROBIAL GENETICS

Marks: 100 **Duration: 60 Hrs.**

Course Objective:

Though microorganisms have had a late entry in the field of genetics, once that happened, they quickly occupied the center stage. Combining the structural simplicity with the unifying genetic basis, they offered immediate advantages in studying all the three aspects of heredity: the generation, expression, and transmission of biological variation. This paper deals with the strength of microbial genetics: both prokaryotic as well as eukaryotic

Course Learning Outcomes:

CO1: Introduce students to various techniques of gene transfer in bacteria and life cycle of bacteriophages.

CO2: Introduce students to life cycle of Yeast, a single cell eukaryote and the different molecular tools available to study various biological processes.

CO3: Discussion of primary literature to understand how molecular genetics can be applied in yeast to discover gene function

CO4: Discussion of primary literature to understand how molecular genetics can be applied in bacteria to understand basic process that deal with cell-cell communication

Contents:

Unit I [14]

Methods used in bacterial genetics

Conjugation - Discovery, nature of donor strains and compatibility, interrupted mating and temporal mapping, Hfr, F', map of F plasmid, mechanism of chromosome transfer, molecular pathway of recombination; Chromosome transfer in other bacteria; Transformation- Natural transformation systems, biology and mechanism of transformation, transformation and gene mapping, chemical-mediated and electrotransformation; Transduction: Discovery, generalized and specialized or restricted transduction, phage P1 and P22-mediated transduction, mechanism of generalized transduction, abortive transduction; Temperate phage lambda and mechanism of specialized transduction; Gene mapping, Fine-structure mapping; Techniques for studying bacteriophages - Virulent phage (T4) and temperate phage (phage lambda); Important aspects of lytic cycle, phage-host relationships, immunity and repression; site specific recombination (lambda and P1)

Unit II [12]

Yeast Biology

Introduction and an overview of yeast in daily life; Cellular architecture and function; Yeast as an experimental system for eukaryotic molecular biology

Molecular tools

Yeast cloning and expression vectors; Regulatable promoters; Construction of genetically modified strains; Generation of conditional alleles; Cosmids and yeast artificial chromosomes; Yeast one-, two- and three-hybrid systems

Unit III [22]

Art and design of genetic screens

Choice of mutant phenotypes; Cloning by complementation; Isolation of bypass and allele specific-suppressors; Synthetic lethal screens; use of these tools to isolate genes in the protein secretion pathway in yeast

Determination of mating types

Mating-Type Genes and MAT Switching in Saccharomyces cerevisiae; HML, HMR and MAT loci, HO endonuclease, regulation of switching

Unit IV

Quorum sensing in bacteria [12]

Examples from Vibrio harveyi and Vibrio fischeri; Regulation of biofilm formation in Vibrio cholera; Two component signal transduction system

Discovery of CRISPR-CAS

Suggested Reading

1.	Microbial Genetics	Maloy S, Cronan J & Freifelder D	Jones and Bertlett
2.	Fundamental Bacterial Genetics	Trun N & Trempy J	Blackwell Publ.
3.	Modern Microbial Genetics	Streips U N & Yasbin RE	Wiley-Liss
4	Molecular Genetics of Bacteria	Sneider L & Champness W	ASM Publishers
5.	Genetics of Bacteria	Scaife J	Academic Press
6.	Genetics of Bacteria and Viruses	Birge EA	Springer
7.	Guide to Yeast Genetics and Molecular Biology, Methods Enzymol. Vol. 194	Guthrie C & Fink GR (Eds.)	Elsevier

Masters in Genetics
Semester III

GECC302: HUMAN GENETICS

Marks: 100 **Duration: 60 Hrs.**

Course Objective:

Human Genetics is a subject of considerable interest and tremendous relevance to every individual and society. This rapidly growing subject is continuing to revolutionize our early understanding of the basic concepts of genetics, genome organization, gene structure, function and implications for disease. This introductory course attempts to walk the students through classical genetics and molecular genetics with a cautionary endnote on range of ethical, legal and social issues which are also the logical consequences of such unparalleled scientific progress. Beginning with constructing genetic hypothesis from pedigree data and population sampling, application of a variety of conventional and modern tools to test such hypothesis, constraints/ limitations of genetic methodology when applied to humans would be discussed in the early part of the paper. Application of early mapping tools and cloning strategies culminated in the successful completion of the Human genome project; and the next generation sequencing technologies have now opened up exciting, unimagined scale of discovery genomics and these would be covered next. New/current knowledge on genetic variations in health and disease across populations and their clinical/diagnostic implications would be dealt with subsequently. Considering that purview of medical genetics is now all of medicine and involves ethical issues, this study will remain incomplete without serious discussion on these issues.

Course Learning Outcomes:

CO1: Gain knowledge of i) the basic conventional and contemporary methodologies which are essential for studying genetics of health and disease; ii) Markers and methods to identify putative disease causing genes- the most important for predictive and preventive medicine/genetic health

CO2: Gain factual knowledge on genetic disorders including chromosomal, single gene and polygenic affecting humans by utilizing the tools as mentioned in CO1

CO3: Gain insights into patterns of human migration, population specific genome architecture and with implications for population specific disease susceptibilities

CO4: An update on all the available genetic/molecular diagnostics available for a wide range of disorders which highlight the translational potential and clinical relevance of human genetics research findings. Students can be ready for clinical genetics/medical diagnostics market

CO5: Awareness of the risks and benefits of genetic testing; ethical issues in medical genetics; human rights and societal implications

Contents:

Unit I [34]

Introduction to human genetics

History; Early perception, development and documentation

Study tools in human genetics

Pedigree analysis - Mendelian inheritance and exceptions; Chromosomal analysis (*in vitro, in vivo*); Biochemical analysis; Somatic cell genetics (somatic cell hybrids, monochromosome hybrid panels, gene mapping); Molecular genetic analysis; Next generation sequencing, target capture, exome sequencing, whole genome sequencing

Human genome mapping methods

Physical mapping- Introduction to physical map markers - chromosomal, G/Q - banding, radiation hybrids, Fluorescence *in situ* hybridization; Comparative genome hybridization; Long range restriction mapping; High resolution mapping - STS/EST/MS/SNP/sequencing**;** Genetic mapping- Linkage analysis (RFLP/MS/SNP); Applications of mapping in normal and disease genome analysis; Gene identification using positional and functional cloning approach, next generation sequencing technologies

Human genome analysis

Conception, mapping, cloning and sequencing; Outcome- generation of 'OMICS' era; Significant leads

Unit II [10]

Genetic variation in health and disease

Chromosomal disorders -Structural and numerical; Autosomal/sex chromosomal/sex reversal; Mechanisms – mitotic/meiotic non-disjunction/ chromosomal rearrangements; Some examples (Syndromes/Cancer/ Infertility); Single gene and disease: Inborn errors of metabolism; Haemoglobinopathies**;** Multifactorial disorders: Introduction; Methods of study (Epidemiological, Twin/adoption and family studies); Etiology - genetic and non-genetic determinants; Common examples; Epigenetics and disease: Mechanisms (Imprinting/methylation; Chromatin remodeling); Current understanding; Some examples; Mitochondrial myopathies

Unit III [4]

Human genetic diversity

Methods of study – Biochemical/molecular genetic markers; Some examples; Tracing human migrations with autosomal, Y-chromosomal and mitochondrial markers

Unit IV [6]

Diagnostic genetics

Cytogenetics/Molecular Cytogenetics/Biochemical/Molecular methods; Screening for mutation/ chromosomal anomaly - Adult/Prenatal/Newborn screening; Pre-implantation screening (Assisted reproductive technology - *in vitro* fertilization and embryo transfer); Forensic testing - DNA fingerprinting, paternity testing, individual identification

Unit V: [6]

Ethical, legal and social issues in human genetics

Prenatal/Adult (Individual/Family/Population) screening of mutation/risk factor for genetic diseases; Confidentiality/privacy; Discrimination; Ethical dilemma; Human rights; Surrogate mothers; Human cloning and eugenics; Organ banking and transplantation; Research ethics; Medical ethics in India

Suggested readings:

1.	Human Genetics: Problems and Approaches	Vogel F & Motulsky A	Springer Verlag
2.	Human Molecular Genetics	Strachan T & Read A	Garland Science
3.	An Introduction to Human Molecular Genetics: Mechanism of Inherited Diseases	Pasternak J	Fitzgerald Science Press
4	Chromosome Structural analysis: A Practical Approach	Bickmore WA (Ed.)	Oxford University Press
5.	The AGT Cytogenetics Lab Manual	Barch, Knutsen & Spurbeck	Lippincott Raven Publ.
6.	Human Cytogenetics: Constitutional analysis	Rooney DE (Ed.)	Oxford University Press

Classical papers in human genetics

Masters in Genetics
Semester III
GECC303: PLANT GENETICS AND BREEDING

Marks: 100 **Duration: 60 Hrs.**

Course Objective:

This course primarily deals with how to undertake plant genome analysis and gene mapping through the use of DNA markers and how this information could be utilized in bringing the efficiencies in selection methods of plant breeding and gene isolation by forward genetics approach

Course Learning Outcomes:

CO1: To make aware the students the importance of plant breeding through giving a historical perspective.

CO2: To comprehend the students the natural breeding systems of different agriculturally important plant species used as food and feed.

CO3: To make aware the concept of gene pool and the germplasm resources that are fundamental to crop improvement.

CO4: To know how chromosomes could be manipulated for genetic improvement of crop plants.

CO5: To give a brief knowledge about different breeding methods depending their breeding systems.

CO6: To make students understand the genetic and molecular basis of hybrid vigor and how this hybrid vigour could be utilized for developing hybrid varieties.

CO7: To expose the students how the different molecular tools particularly DNA markers could be used in genetic analysis and also be used for bringing efficiencies in plant breeding processes.

Contents:

Unit 1 [4]

Historical perspective

Importance of plant breeding and its history; genetic diversity in plant breeding

Unit II [10]

Natural breeding systems

Breeding systems in plants and their application in plant breeding

Unit III [4]

Gene pool concept

Primary, secondary and tertiary gene pools and methods of using them in genetic manipulation

Unit IV [8]

Chromosome breeding

Haploidy, polyploidy and wide hybridization and their applications in plant breeding; Cytogenetic tools and their application in plant breeding

Unit V [8]

Conventional breeding methods

Different breeding methods for self-pollinated, cross-pollinated and vegetatively propagated crop plants

Unit VI [8]

Heterosis breeding

Genetic and molecular basis of heterosis (hybrid vigour); Development of hybrid varieties through exploitation of hybrid vigour

Unit VII [18]

Molecular plant genetics and breeding

Introduction; Molecular markers as efficient tools in plant breeding; Principle of genetic linkage; Concept of genetic distance; Development and choice of mapping populations; Linkage map construction; Integrated and comparative maps; Dissection of quantitative traits - Principles and methods of QTL mapping (linkage and association mapping); Fine mapping of QTL and map-based gene cloning; Marker-assisted breeding - Gene tagging; Marker-aided selection (foreground and background selection); Concept of graphical genotype; Elimination of linkage drags; Marker-assisted recurrent selection (MARS), Genomic Selection (GS)

Suggested readings:

1.	Plant Breeding theory and practice	Stoskoff NC, Tomes DT & Christie BR	Westview Press
2.	Principle of Crop improvement	Simmonds NW & Smart J	Blackwell Science
3.	Principle of Plant Genetics and Breeding	Aquaah G	Blackwell Publishing
4	Plant Molecular Breeding	Newbury HJ	Blackwell Publishing
5.	Genome mapping in plants	Paterson AH	Academic Press

Semester III

GECC304: PLANT TISSUE CULTURE AND TRANSGENIC TECHNOLOGY

Marks: 100 **Duration: 60 Hrs.**

Course Objective:

The course is designed to provide students with specialized knowledge of the theory and applications of various plant cell and tissue culture technologies as well as the concepts of developing plant transformation vectors and their utilization to develop transgenic plants with new traits for crop improvement and health care.

Course Learning Outcomes:

CO1: Acquaint with the importance of various components of tissue culture nutrient media and develop skills for preparing nutrient media and plant regeneration procedures.

CO2: Gaining practical knowledge in various culture methods and learning their importance in agriculture.

CO3: Appreciation and importance of various plant cell and tissue cultures for crop improvement.

CO4: Understanding the concepts of vectors and their preparation for plant transformation.

CO5: Learning various gene delivery systems in plants for developing genetically modified (GM) plants and their molecular characteization.

CO6: To become aware of various potential applications of GM plants in agriculture and health care as well as the regulations and issues in bio-safety of consumption of GM foods.

Contents:

Unit I [5]

Plant Tissue Culture Media and Regeneration

Historical developments; Laboratory organization; Sterilization methods; Nutrient media; Culture conditions; Role of plant hormones and growth regulators in differentiation and development; Plant regeneration pathways - Organogenesis and somatic embryogenesis, Some examples - tobacco, carrot, cotton and rice.

Unit II [8]

Plant Cell and Tissue Culture Methods

Culture methods for organ, root, ovule, embryo, endosperm, anther and pollen; Callus culture; Cell culture – Batch and continuous cultures; Protoplast isolation, purification and culture, Somaclonal and gametoclonal variation; *In vitro* pollination and fertilization; *In vitro* mutagenesis and mutant selection.

Unit III [12]

Applications of Plant Cell and Tissue Culture Technology

Micropropagation, Virus-free plants**,** Artificial seeds; Embryo rescue and *in vitro* fertilization for hybrid development; Breakage of seed dormancy; Haploids, double haploids and triploids; Somatic hybrids, cybrids and asymmetric hybrids; *In vitro* mutants and somaclones for crop improvement; Production of secondary metabolites; *In vitro* gene banks and germplasm conservation; Other applications.

Unit IV [6]

Plant Transformation Vectors

Historical developments; Tumour inducing principle in *Agrobacterium* - structure and function of Ti-plasmids, Ri-plasmids and T-DNA, Molecular mechanism of T-DNA transfer and integration in the plant genome; Ti-plasmid based co-integrate and binary vectors, RNA silencing vectors.

Unit V [12]

Plant Transformation Methods

Agrobacterium transformation of dicots, monocots and other kingdoms, Agroinfection, Marker and reporter genes; Methods of characterization of promoters using reporter genes; T-DNA mutagenesis; Non-*Agrobacterium* methods of genetic transformation – Gene gun and other methods; *In planta* transformation; Chloroplast transformation - vectors, gene integration through homologous recombination, Advantages; Characterization of transgenics through molecular and genetic means; Transgene silencing; Marker-free transgenics; Multigene engineering.

Unit VI [17]

Applications of plant transgenic technology

Scope; Insect resistance - case study of Bt cotton, Bt and other antifeedant genes; Resistance management; Herbicide resistance - study of glyphosate resistance; Transgenic resistance against viral, bacterial, fungal pathogens and nematode parasites; Abiotic stress tolerance; Engineering crops for male sterility, delayed fruit ripening and fatty acid composition; Nutritional quality and quantity improvement, Metabolic engineering - Golden rice, Hairy roots and secondary products; Molecular pharming - Production of antibodies, edible vaccines, recombinant proteins, bioplastics, biosteel and other products, Transgenics for cleaning environmental pollutants and production of bio-fuels; RNAi applications in agriculture; Other applications; Global status of GM crops; Regulations and issues in

bio-safety of commercialization and consumption of GM plants and foods.

Suggested readings:

1.	Plant Tissue Culture: Theory and Practice	Bhojwani SS. & Razdan MK	Elsevier
2.	Plant Biotechnology: The Genetic Manipulation of Plants	Slater A, Scott N & Fowler M	Oxford University Press Inc.
3.	Plants, Genes and Crop Biotechnology	Chrispeels MJ & Sadava DE	Jones and Barlett Publishers
4.	Plant Cell Culture: Essential Methods	Davey MR & Anthony P	Wiley-Blackwell
5.	Practical Applications of Plant Molecular Biology	Henry RJ	Chapman & Hall
6.	Plant Biotechnology: An Introduction to Genetic Engineering	Adrian Slater, Nigel W. Scott & Mark R. Fowler	Oxford University Press
7.	Biochemistry & Molecular Biology of Plants	Bob Buchanan, Wilhelm Gruissem & Russell Jones	John Wiley & Sons
8.	Molecular Biotechnology	Glick BR & Pasternak JJ	ASM Press
9.	Review and research articles		

Masters in Genetics
Semester III

GECC305: Experiments in Genetics –III (Practical paper)

Marks: 200 **Duration: Hrs.**

LIST OF PRACTICALS

1. Study of gene expression in bacteria using lac operon in *E. coli* as a model.
    i. Phenotypic characterization of wild type and some mutants on: M9 – Glucose, M9 – lactose, M9 – Glycerol, Mac Conkey Agar, X-Gal containing medium.
    ii. Biochemical characterization based on β-galactosidase assay
        a. Induction kinetics
        b. Difference between wild type and mutants
        c. Difference under uninduced and induced conditions in the wild type strain
        d. Difference between glucose and glycerol grown cells of the wild-type strain
    iii. Isolation of lac constitutive mutants and their biochemical characterization.
2. Conjugal cross analysis and temporal mapping of a gene in *E. coli*
3. Phage titration and preparation of phage lysate.
4. Test the ability of WT and mutant strains of *S. cerevisiae* to utilize glycerol as the sole carbon source.
5. Test for the presence of mtDNA in the mutant *S. cerevisiae* strain.
6. Chromosome preparations from human lymphocyte cultures
    i. G- and Q- banding of metaphase chromosomes
    ii. Karyotyping with G- banded metaphase chromosomes
7. Chromosomal and interphase FISH of human chromosomes
8. DNA isolation from lymphocytes
    i. Quantitative and qualitative analysis
    ii. Genotyping with (a) Microsatellite markers and (b) SNPs
    iii. Mutation screening by (a) PCR- RFLP and (b) PCR- sequencing
9. LOD score analysis with microsatellite data from genome wide scans of pedigrees segregating for a disease
10. Diversity analysis using program NTSYS.
11. Construction of linkage map using program JoinMap4.
12. Demonstration of program used for QTL mapping.
13. Field trip to plant breeding station.
14. Shoot tip and nodal bud culture for multiplication of tobacco.
15. Plant regeneration in tobacco (organogenesis).
16. Induction of embryogenic callus and plant regeneration in rice
17. Induction of hairy roots in tobacco leaf explants by Agrobacterium rhizogens.
18. Agrobacterium-mediated genetic transformation of tobacco using leaf disc method
19. Histochemical assay for GUS activity from the transformed tissue of tobacco

20. Isolation of genomic DNA (by CTAB method) from transformed and un-transformed tissue of tobacco.
21. Analysis of transgene integration in the tobacco transformants by PCR analysis

Masters in Genetics
Semester IV

GECC401: DEVELOPMENTAL BIOLOGY AND IMMUNOLOGY

Marks: 100 **Duration: 60 Hrs.**

DEVELOPMENTAL BIOLOGY

Course Objective:

The course envisages giving an insight into how developmental patterns arise using examples from different model systems and highlighting regulatory networks involved in these processes. The students are however expected to have studied the basic processes of development (animal and plant embryology). The emphasis would be on experiments done which led to various concepts.

Course Learning Outcomes:

CO1. Students will learn the basic mechanism of developmental processes
CO2. Developmental processes in various animal model systems will be taught in this course
CO3: Students will be able to appreciate the various techniques used in plant biology to study the cause and effect relationship during plant development processes

Contents

Unit I [8]

Concepts of development

Specification, induction, competence, determination and differentiation, morphogen gradients, pattern formation, cell fate and cell lineages, cell to cell communication.

Unit II [10]

Strategies in animal development

Fertilization in sea urchins and mammals; early developmental processes like cleavage, gastrulation and axis formation using examples of sea urchin, *C. elegans, D. melanogaster,* amphibians and mammals; Morphogenesis and organogenesis of cell aggregation and differentiation in *Dictyostelium discoideum* formation of vulva in *C. elegans* and development of the tetrapod limb; introduction to stem cells; regeneration.

Unit III [12]

Developmental processes in plants

Salient features, comparison between plant and animal development pattern; Understanding plant

development through examples – regulation of transition to flowering, floral meristem and the ABC model of flower development in Arabidopsis.

Suggested readings:

1.	Developmental Biology	Scott F. Gilbert	Sinauer Associates, Inc.
2.	Principles of Development	Lewis Wolpert *et al.*	Oxford University Press
3.	The Art of the Genes: How organisms make themselves	Enrico Coen	Oxford University Press

IMMUNOLOGY

Course Objective:

The course provides a comprehensive overview of basic immunology in a manner that is understandable for students from different backgrounds. Topics of clinical relevance, such as microbial immunity, allergy, autoimmunity, tumor immunology, congenital and acquired immunodeficiencies, transplantation immunology, and immunotherapy will also be covered.

Course Learning Outcomes:

CO1: On completion of this unit, students will get familiar with all components of the immune system- their structure and function during immune response.

CO2: Students will learn of the importance of a balanced immune system by studying both depletion and excess of the immune action.

CO3: Immune products (such as antibody) have been a mainstay of diagnosis and therapy. Recent advancements in use of immune cells and molecules will be introduced to the students

Contents:

Unit I [12]

Our immune system and its function

Fundamental concepts in immunology; Immune cells and organs; Innate Immunity; Inflammation; Pattern recognition; Complements; Antigen presentation; T and B cell development and activation; Cytokines; Antibody structure and function; Molecular mechanisms of generating antibody diversity; Genetic organization of MHC-I and MHC-II molecules; Peptide loading and function of MHC; Generating immune response against virus, bacteria and other pathogens; Immune cell receptors; Collaborations between B and T cells.

Unit II [12]

Disease and deficiencies associated with immunity

Tolerance and autoimmunity, Immunological disorders; Hypersensitivity, Transplantation; Tumor immunology

Unit III [6]

Advancement in technology

Hybridoma technology and monoclonal antibodies, antibody engineering, Using dendritic cells for cancer therapy, Chimeric Antigen receptor therapy

Suggested readings:

1.	Kuby Immunology	Kindt TJ, Goldsby RA, Osborne BA, Kuby J	W H Freeman & Co
2.	Immunobiology: The immune system in health and disease	Janeway CA,Travers, P,Walport M, Shlomchik MJ	Garland Science Publishing
3.	Roitt's Essential Immunology	Delves PJ, Martin SJ, Burton DR, Roitt IM	Blackwell Publishing/ Oxford Univ. Press

Masters in Genetics
Semester IV
GECC402: PROJECT WORK

Marks: 300 **Duration: 360 Hrs.**

Course Objective:

The objective of this project work is to provide hands-on experience to the students about handling a research problem independently. The students will be encouraged to design a small research project around a topic being investigated in the allotted lab. Critical intellectual inputs and other facilities will be provided to the students by the assigned faculty member. The students are expected to present their objectives and experimental design before initiation of the experimental work. After completion, the students are expected to present their findings as a presentation and report.

Masters in Genetics
Semester IV

GEEC403: ADVANCES IN *DROSOPHILA* GENETIC

Marks: 100 **Duration: 60 Hrs.**

Course Objective:

This specialized paper has been designed to provide advanced understanding about contemporary Drosophila genetics and related area. Drosophila has been one of the favoured model organisms of the geneticists since T. H. Morgan decided to use it to investigate the chromosomal theory of inheritance. Thereafter, succeeding generations of "drosophilists" have developed an ever-increasing repertoire of techniques that make Drosophila one of the most tractable multicellular organisms for biomedical research.

Course Learning Outcomes:

CO1: To develop a comprehensive understanding about *Drosophila* as a prime model organism, strategies to deigns genetic crosses and available resources.

CO2: To become aware of the various mutagenesis techniques, strategies to characterize mutant lines and to generate transgenic lines.

CO3: To understand the genetics of gametogenesis, cellular signaling, axis formation in oocyte, cellular remodeling and differentiation during germ cell development.

CO4: To develop an inclusive concept about developmental program, body axis formation, cellular signaling, differentiation, specification, imaginal discs and organogenesis.

CO5: To cultivate perception about various features of somatic and germline stem cells, stem cell niches, cellular signaling involved maintenance of stemness, differentiation and application.

CO6: To equip the students with the information of various powerful classical and contemporary genetic tools and techniques for genetic, cellular and molecular analysis in *Drosophila*.

CO7: To develop an understanding about utilization of *Drosophila* as a model for human genetic disorders, drug screening, aging and behavioral studies, and to discuss some *Drosophila* based breakthrough research papers which shaped the modern biology.

Contents:

Unit I [8]

***Drosophila* as a model organism**

Historical prospective, An overview - life cycle and advantages in genetic analysis, developmental studies and biomedical research. Nomenclature of gene mutations; balancer and marker chromosomes and associated common phenotypes, strategies to design genetic crosses, an overview of *Drosophila* specific online databases, stock centers and other resources.

Unit II [8]

Mutagenesis and isolation of new variants

Radiation and chemical mutagenesis; P-element and insertional mutagenesis; Mapping of new mutations by recombination, deletion, complementation mapping and molecular approaches. Generation of novel GFP line by Protein Trap Transposon. Screening of gene functions

Generation of transgenic lines

P-element based vectors; Vector selection; Germ-line transformation, microinjection, transgenic screening and characterization.

Unit III [10]

Axis specification and cellular signaling during oogenesis

Drosophila female reproductive system, overview of oogenesis and stage identification, selection of potential oocyte, somatic and germ cell derivatives; Delta, JAK/STAT, Notch signaling and specification of A/P polar cells and axis determination, ring canals, transportation and localization of transcripts and protein in oocyte, Gurken signaling and axis determination, border cell migration, cytoplasmic dumping and oocyte maturation. Analysis of some female sterile mutant lines.
Cellular remodeling and differentiation during spermatogenesis

Drosophila male reproductive system, mitotic and meiotic cell divisions, spermatogonia, spemtocytes, cyst cell, mitochondrial remodeling, nebenkern, nuclear shaping, actin polymerization, sperm individualization.

Unit IV [12]

Genetics of development

Overview of embryogenesis, axis formation, fate map. Genetic hierarchy of development in *Drosophila*- egg polarity genes, establishment of morphogen gradient, gap genes, pair rule genes, specification of stripes, regulation of pair-rule gene expression, segment polarity genes, establishment of segment polarity, homeotic genes and mutations, antennapedia/bithorax complex and specification of body organs. Larval stages and tissue types, imaginal discs - development and differentiation, axis determination in imaginal discs, regeneration and trans-differentiation, adult morphology and internal organs.

Unit V [6]

Stem cells and their maintenance

Somatic and germ line stem cells. Components and functions of stem cell niches. Stemness. Various cellular signaling (i.e. Delta-Notch, JAK-STAT etc.) and maintenance of stemness. Differentiation of stem cell and maintenance of organ homeostasis. Therapeutic usages of stem cells.

***Drosophila*- a model system to study immune responses**

Induction of immune response, antimicrobial defense, Toll and Immune deficiency (IMD) signaling

pathways.

Unit VI [8]

Tools for genetic, cellular and molecular analysis

Genetic tools for studies on gene expression; Generation and analysis of FLP/FRT mediated somatic clones. Generation and analysis of ovoD mediated germ-line clones; Conditional and/or targeted over-expression/ablation of genes/transcripts (e.g. UAS/GAL4/GAL80 system)**;** RNAi-based screening of gene functions. *Drosophila* genome editing by CRISPR-Cas9.

Unit VII [8]

***Drosophila* as a model for human genetic disorders, drug screening, aging and behavioral studies**

Modeling of neurodegenerative disorders (i.e. Parkinson's, Huntington's, Alzheimer's diseases etc.), fragile-X syndrome, cancer, mitochondrial dysfunction etc. Screening and identification of modifier genes, drug targets and drug molecules. Circadian rhythm in *Drosophila*. Usages of *Drosophila* in behavioural genetics and aging research. Discussion on some breakthrough research papers.

Suggested readings:

1. Developmental Biology	Gilbert SF	Sinauer Press
2. Development of *Drosophila melanogaster* (Vol. I & II)	Bates & Arias	CSHL Press
3. *Drosophila* Guide	Demerec & Kaufmann	Carnegie Press
4. *D. melanogaster:* Practical Uses in Cell and Molecular Biology	Goldstein & Fyrberg	Academic Press
5. The making of a fly: The genetics of animal design	Lawerence	Blackwell
6. *Drosophila*: Methods and Protocols	Dahmann C	Humana Press
7. Fly Pushing: The Theory and Practice of *Drosophila* Genetics	Greenspan RJ	CSHL Press
8. *Drosophila*: A Practical Approach	Roberts DB	CSHL Press
9. Compiled reviews and research papers		

Masters in Genetics
Semester IV

GEEC404: BIOLOGY OF DICTIOSTELLIUM

Marks: 100 **Duration: 60 Hrs.**

Course Objective:

The course is designed to provide some fundamental principles to form an integrated view of various genetic and molecular processes using Dictyostelium discoideum as a model system. Tutorials would be in the form of discussions on research and review papers related to each topic, highlighting the advances made in the field.

Course Learning Outcomes:

CO1: To introduce the organism and its family, past findings, about its genome and present techniques

CO2: To give an account on *D. discoideum* cellular structure, growth-specific processes and regulation operating prior to nutrient starvation

CO3: To develop the understanding of how *D. discoideum* respond to nutrient starvation, processes and events in development, role of important molecules and signaling pathways during development

CO4: To emphasize the use of *D. discoideum* as an emerging model in studies to understand various processes and human diseases

Contents:

Unit I [8]

Brief introduction

An overview; Dictyostelium discoideum and its relatives

History of research on *D. discoideum*

Classical experiments of Kenneth Raper; Chemotaxis and aggregation; Molecular techniques

Evolution and Genome

Unit II [12]

Cellular organization and Dynamics

Plasma membrane, channels and pumps, macropinocytosis, phagocytosis; Lysosomes; The autophagic vacuoles; Cytoskeletal proteins,; Cytokinesis; Cell motility

Initiation of Development

Transition from growth to development, detection of starvation, events after starvation, Cellular and molecular mechanisms; Factors controlling early development; Sexual development, macrocyst

formation

Unit III [36]

Chemotaxis and Aggregation

Components of cAMP signal transduction and relay pathway, Secondary messengers and cytoskeletal events; Role of PKA; Developmental regulation of chemotactic components; Role of cGMP and calcium in chemotaxis; Polarity of movement

Cell adhesion and Recognition

Cell adhesion molecules, cell-cell contact and gene expression; Cell recognition in the sexual development

Signal transduction

Diffusible molecules; cAMP signaling, cAMP oscillation and signal relay, control of aggregation, cell sorting, coordinated cell movement during multicellular morphogenesis; Prespore gene expression; Peptide signaling

Cell differentiation and Pattern formation

Initial cell type choice, cell type specific markers, Cell fate determination; DIF signaling, DIF-1 and prestalk gene expression; Prestalk and stalk cell heterogeneity; Calcium in pattern formation and various models for pattern formation

Coordinated cell movement and Morphogenesis

Unit IV **[**4]

***Dictyostelium* in biology and medicine**

Suggested Readings:

1. Dictyostelium, Evolution, Cell Biology, and the Development of Multicellularity — Richard H Kessin — Cambridge University Press
2. Dictyostelium-A model system for cell and developmental biology — Yasuo Maeda, Kei Inouye and Ikuo Takeuchi (Eds) — Universal Academic Press, Inc. Tokyo Japan
3. *Dictyostelium discoideum*: molecular approaches to cell biology. *Volume 28 of Methods in Cell Biology* — James A Spudich — Academic Press
4. Original Research papers

Masters in Genetics
Semester IV

GEEC405: CANCER BIOLOGY AND GENETICS

Marks: 100 **Duration: 60 Hrs.**

Course Objective:

Comprehensive genetic and molecular analysis of tumor progression and advances in technology, have contributed to our understanding of various pathways and molecules. These have been exploited for their therapeutic leading to considerable improvement in patient survival and management for some cancers. In this course, the students get familiar with various aspects of oncology with an emphasis on genetics, biology, diagnosis, prevention and therapy of cancers.

Course Learning Outcome:

CO1: The students will have an enhanced understanding of epidemiology and incidence of cancer in India and the world. They will learn of pathological changes that a normal cell and tissue undergoes when transformed to a tumor, and get familiar with nomenclature and basic diagnosis.

CO2: Students will learn about mechanisms of oncogenesis in a historical perspective of seminal discoveries of cancer biology in a timeline.

CO3: Molecular and cellular changes while the tumor is progressing will enhance the student's knowledge on basic biology and therapeutic potential of molecular carcinogenesis.

CO4: In this emerging and advanced area of cancer immunotherapy, the students will learnt to correlate their basic knowledge in immunology with that of cancer and how it has led to therapeutic intervention.

CO5: This portion will familiarize the students with standard therapy in practice. Further with examples from the molecular pathways of cancer progression studied in the previous unit, they will learn about progression of that knowledge from bench to bedside.

Contents:

Unit I [10]

Epidemiology and molecular pathology of cancer

Biology of a cancer cell; Pathology of tumor/cancer tissues; Classification of tumor/cancers; Diagnostic tools for cancer detection; Molecular pathology; Molecular and diagnostic marker

Unit II [16]

Mechanistic basis of oncogenesis

Hallmarks of cellular transformation; Genetic basis of oncogenesis; Influence of environment and lifestyle changes; Chromosomal rearrangements; Mutations; Aneuploidy; Multistage tumorigenesis; Viral theory of carcinogenesis; Tumor suppressors, Oncogenes, DNA repair defects; Knudson's two-hit hypothesis; Mutator hypothesis**;** Loss of heterozygosity analysis, allelotyping, microsatellite instability

Unit III [16]

Biology of tumor progression

Signalling pathways of cancer; Cancer progression; Metastasis; Angiogenesis; Epithelial to mesenchymal transformation; Tumor microenvironment; Oncogene addiction; Current papers on advances in the field.

Unit IV [8]

Tumor immunology

Role of immune system in preventing tumor growth; Escape mechanisms against immune surveillance; Tumor antigens; Therapy based on the immune response.

Unit V [14]

Advances in cancer therapy

Molecular diagnostics, imaging; Types of cancer therapy in routine use; Overview of different chemotherapy used as standard-of-care; Molecular basis of targeted therapy; Examples of success stories in cancer treatment and their evolution based on molecular and technological advances.

Suggested readings:

1.	The Biology of Cancer	Robert A. Weinberg (Ed.)	Garland Sciences
2.	The Molecular Biology of Cancer	Pelengaris S, Khan M (Eds.)	Blackwell Publishing, Oxford
3.	The Genetic Basis of Human Cancer	Vogelstein & Kinzler	McGraw-Hill
4.	Review and research articles		

Masters in Genetics
Semester IV

GEEC406: GENETIC COUNSELLING

Marks: 100 **Duration: 60 Hrs.**

Course Objectives:

This era in medical genetics and molecular diagnostics is the most exciting in medical practice and research due to unprecedented technical advances. At the same time it has also become very challenging. In view of the ever growing knowledge on genetics of diseases, tremendous scope to develop suitable tests for prediction and prevention of diseases, dissemination of scientific advances to the common man, through the internet and a range of freely available websites, genetic counseling by trained professionals is becoming increasingly important. Knowledge explosion with free accessibility with little understanding of the deeper principles for application is a major social concern. This paper is aimed at motivating the students of genetics to take up genetic counseling as a career option, which will generate the much needed manpower in this field not only in India but globally. A didactic approach and problem based tutorial exercises which seem to be the most effective method of introducing and training students in this branch of applied genetics would be followed.

Course Learning Outcomes:

CO1: Gain knowledge to identify the group of disorders which have a genetic basis and enable risk assessment based on the inheritance pattern

CO2: Awareness of the different tools and techniques available for the different diseases

CO3: Knowledge on the range of possible tests for different diseases and at different stages of life; understanding risk and benefit; and therapeutic possibilities for different disorders

CO4: Gaining skill sets to become a good counselor

CO5: Awareness of the overall implications of the results of genetic testing

Contents:

Unit I [18]

Principles of human genetics

Modes of inheritance of common and rare diseases; autosomal dominant, autosomal recessive, X-linked dominant, X-linked recessive and complex disease conditions; exceptions to Mendelism; mitochondrial disorders; pedigree analysis

Unit II [16]

Tools and techniques in molecular medicine

Literature of human and medical genetics; Cytogenetics; Biochemical genetics; Molecular diagnosis and genomics; Dysmorphology, teratology, inherited congenital and adult onset diseases; Use of databases relevant to these areas; disease risk estimation;

Unit III [12]

Genetic testing

Prenatal/neonatal/pediatric/adult diagnosis of genetic disorders; reproductive genetics, cancer genetics; a few case studies; Risks and benefits; Informed consent; Right of choice; Dilemmas faced by counselors; Pre-prescription testing

Methods of therapy

Drug (recombinant proteins); Diet; Gene (viral vectors, delivery methods, efficacy); Some examples (Thalassemia, Phenylketonuria, Cystic fibrosis, DMD, etc)

Unit IV [6]

Development of skills

Communication and counseling skills; facilitating application of theory to practice; handling psychological issues; non-directive counseling

Unit V [8]

Ethical, legal social and cultural issues

Ethical principles; informed consent; human rights; genetic law; impact of illness on individual/family/society; insurance, employment and discrimination issues

Suggested readings:

1.	Practical genetic counselling	Harper, Peter S	London: Hodder Arnold,
2.	Genetics for the health sciences : a handbook for clinical healthcare	Skirton, Heather; Patch, Christine	Bloxham, Oxfordshire: Scion
3.	Introduction to risk calculation in genetic counseling	Young, Ian D.	New York, N.Y.: Oxford University Press
4	New clinical genetics	Read, Andrew P.; Donnai, Dian	Oxfordshire, UK: Scion,
5.	Principles of biomedical ethics	Beauchamp, Tom L.; Childress, James F.	New York: Oxford University Press,

Masters in Genetics
Semester IV
GEEC407: PLANT-MICROBE INTERACTION

Marks: 100 **Duration: 60 Hrs.**

Course Objective:

Plant pathogenic microbes are a global threat to food production and quality. With the ever increasing demand to improve agricultural yields to keep up with the global food demand this area of host – microbe interaction is becoming more and more important for sustainable agriculture. This advanced course is designed to provide the students insights into the genetic and molecular principles underlying immunity in plants and microbial pathogenesis. The interactions between microbes and plants provide fascinating examples of biological communication. The course design explores the molecular intricacies underlying the host-pathogen relationships, the virulence factors that promote colonization and survival of infecting microorganisms and virulence attributes that damage the host.

Course Learning Outcomes:

CO1: Gain an understanding of the nature and importance of immunity mechanisms in plant biology

CO2: Student will become familiarize with the latest methods used to dissect the host –microbe interaction at the genetic, cellular and molecular level and various model systems used.

CO3: Gain an understanding of the pathogenic lifestyles of necrotrophic and biotrophic plant pathogens and the molecular aspects of the virulence strategies used by the pathogen6.

CO4: Student will be able to comprehend the defense mechanisms employed by the plants against these pathogens and how the two co-evolve.

CO5: Use knowledge of molecular interactions to understand the basis for current disease

Contents:

Unit I [4]

Introduction

A historical perspective, significance of plant health, current challenges to sustainable crop production and introduction to central concepts underlying host-microbe interactions, molecular Koch's Postulates

Unit II [4]

Research tools used to study host- microbe interaction

Virulence factors, Gene for gene Model, molecular Koch's Postulates; Repertoire of effectors and their actions in pathogenesis; generation of variability.

Unit III [6]

Model pathosystems

Arabidopsis/ Nicotiana- Pseudomonas, Phytophthora- potato

Unit IV [8]

Microbial pathogenesis

Various strategies of pathogenicity, symbiosis, commensalisms and mutualism; Studying the infection processes and specificity of pathogens and their host range, Disease cycle and epidemics.

Unit V [16]

Molecular genetic basis of pathogenicity

Virulence factors, Gene for gene Model, molecular Koch's Postulates; Repertoire of effectors and their actions in pathogenesis; generation of variability.

Unit VI [16]

Molecular and cellular basis of plant defence

Non-host resistance, Plant innate immunity, Pre-formed inhibitors of pathogen invasion, Types of plant resistance – vertical and horizontal, R genes (quantitative and monogenic resistance); molecular mechanisms underlying basal and induced defense responses and systemic acquired resistance

Unit VII [6]

Disease resistance in agricultural contexts

Translational research advances and potentials**:** Chemical control, Biocontrol, Biotechnological approaches

Suggested readings:

1.	Plant Pathology	Agrios GN	Academic Press
2.	Molecular Plant pathology	Dickinson M	BIOS Scientific Press
3.	Plant Pathogenesis and Resistance: Biochemistry and Physiology of Plant-Microbe Interactions	Jeng-Sheng HT	Kluwer Academic Publ.
4.	Reviews and research paper		

Masters in Genetics
Semester IV

GECC408: NON-CODING RNA BIOLOGY, GENE SILENCING AND APPLICATIONS

Marks: 100 **Duration: 60 Hrs.**

Course Objective:

The goal of this course is to provide the in-depth knowledge about diversity of RNA world and the functional importance of various non-coding RNAs (ncRNAs) like siRNAs and miRNAs in the regulation of a wide range of biological processes, including defense and the regulation of chromatin structure and gene expression. This course also provides the use of this elegant and revolutionary reverse genetics approach in the elucidation of physiological function of genes and also for various potential applications with regard to developing new drugs and therapeutics for human diseases as well as the improvement of crop yield and quality.

Course Learning Outcomes:

CO1: Acquaint with the functional importance of various nc-RNAs, and RNA silencing mechanism and its components.

CO2: Gaining knowledge about the cellular functions of siRNAs and miRNAs and their vectors for gene silencing and its analysis.

CO3: Understanding the concept of miRNA interference (miRNAi), and the expression of miRNAs and their use as therapeutic targets for human disease control using mimic and anti- miR technologies.

CO4: Learning various genome editing tools like CRISPR-Cas9 system for genome engineering in various organisms.

CO5: The utility of RNAi in genome wide genetic screens for functional genomics studies in different systems.

CO6: To become aware of various potential applications of RNAi and miRNAi therapy for human diseases and also for crop improvement.

Contents:

Unit I [12]

Non-coding RNA biology

Biogenesis and function of different types ncRNAs - rRNAs, tRNAs, snRNAs, snoRNAs, spliceosomal snRNAs, miRNAs, piRNAs, long ncRNAs and many others. Ribozymes – Catalytic RNA molecules. Discovery of RNA interference; Discovery and overview, Post-transcriptional gene silencing - Co-suppression, Quelling and RNAi. Mechanisms of RNAi; Components of RNAi pathways (Drosha, Dicer, Argonaute and RdRP) and their evolutionary conservation and

role in gene silencing, Molecular basis of RNAi; siRNA- and miRNA- mediated gene silencing (Dicing and Slicing), RNAi in model systems – *C. elegans*, *Drosophila* and others.

Unit II [12]

Cellular functions of siRNAs and miRNAs:

Role in chromatin remodeling, control of transposon genetic elements and gene expression, dosage compensation, genomic imprinting, defense against viruses in mammals and plants; RNAi suppressors. siRNA, shRNA and amiRNA vectors and their *in vitro* and *in vivo* delivery in different systems; siRNA modifications, O'methyl, siHybrids, Use of nano-particles in siRNA target delivery; Off-target effects of siRNAs; Detection and analysis of sRNAs (siRNAs, miRNAs and amiRNAs) - RNAi microarrays, Stem-loop PCR, qPCR, Northern hybridization.

Unit III [16]

miRNA interference technologies

miRNAs targeting and targeting miRNAs – miRNA expression, mutation, polymorphism; miRNAs and human disease, miRNAs as therapeutic targets, miRNA interference (miRNAi) – A new concept; miRNAs as a regulator of cellular function; One-drug and Multiple-target; miRNA seed family; miRNA targeting technologies and Targeting miRNA technologies – miRNA mimic, transgene, Anti-miR (Antagomir) and knockout technologies.

Unit IV [10]

Genome editing tools

CRISPR locus in bacteria, Brief history, Mechanism of CRISPR pathway, CRISPR-Cas9 system for genome engineering in mammals, plants and other organisms; Zinc finger nuclease- based engineering; transcription activator-like effector- based nucleases(TALEN) in genome engineering. Synthetic RNA biology and engineering biological systems.

Unit V [12]

Large-scale genetic analysis using RNAi

Genome-wide RNAi screens in *C. elegans*, *Drosophila*, mammalian cell lines and other systems; siRNA and shRNA libraries; Virus induced gene silencing (VIGS) and its uses functional genomics studies in plants. RNomics; RNA informatics - computational tools for miRNAs discovery and their targets, design of siRNA, miRNA and artificial miRNA; high-throughput small RNA profiling - Next generation sequencing.

Unit VI [10]

Applications of RNAi in humans, animals and plants:

RNAi vectors and generation of transgenic animals and plants; Analysis of expression of dsRNA/siRNA molecules and gene silencing; Use of RNAi in the prevention of diseases in animal models; RNAi and miRNAi therapy for human diseases, Antisense RNAs, Clinical trials;

RNAi and artificial miRNAs in crop protection and improvement; Future prospects of RNAi in biology, medicine and agriculture.

Suggested readings:

1.	The RNA World	Gesteland *et al.* (Eds.)	CSHL Press
2.	RNA Interference Technology: From Basic Science to Drug Development	Fire A *et al.* (Eds.)	Cambridge University Press
3.	RNAi: A Guide to Gene Silencing	Gregory J & Hannon (Eds.)	CSHL Press
4	RNA Silencing: Methods and Protocols	Gordon G & Carmichael (Eds.)	CSHL Press
5.	RNA Interference in Practice	Ute Schepers (Ed.)	Wiley-VCH GmbH & Co. KGaA
6.	MicroRNA Interference Technologies	Zhiguo Wang	Springer
7.	RNAi and Plant Gene Function Analysis: Methods and Protocols	Hiroaki Kodama & Atsushi Komamine (Eds.)	Humana Press (Springer Science)
8.	RNA Biology – An Introduction	Gunter Meister	Wiley-VCH Verlag CRC Press
9.	Gene Silencing by RNA interference: Technology and application	Muhammad Sohail	Humana Press
10.	siRNA and miRNA Gene Silencing	Mouldy Sioud	Nova Science Publishers, Inc.
11.	Gene Silencing	Grace W. Redbery	Kluwer Academic Publishers
12.	Plant Gene Silencing	M.A. Matzke and A.J.M. Matzke	
13.	Review and research articles		

Masters in Genetics
Semester IV
GEEC409: YEAST MOLECULAR GENETICS

Marks: 100 **Duration: 60 Hrs.**

Course Objective:

The course is designed to provide some fundamental principles on which to form an integrated view of various genetic and molecular processes using yeast as a model system. Tutorials would be in the form of discussion based on primary literature available related to each topic, highlighting the advances in each filed.

Course Learning Outcomes:

CO1: Introduction to genome wide analysis experiments and synthetic biology

CO2: In-depth understanding of the regulation of the powerhouse of the cell, its creation, regulation, motility and copy number

CO3: Yeast as model for understanding cellular longevity and gene regulation upon nutrient changes

CO4: Understanding the mechanism of non-mendelian inheritance and its consequence on cellular function

CO5: Introduction to pathogenic yeast, its similarities and differences with its non-pathogenic cousins.

Contents:

Unit I [8]

The yeast genome

Life with 6000 genes; Post-genomic era - genome-wide microarrays, proteomics, genome-wide protein localization; Synthetic gene array analysis, SC2.0

Unit II [14]

Mitochondrial Physiology

Mitochondrial dynamics; Mitochondrial fusion and fission; Mitochondrial control by nuclear genome; Mitochondrial retrograde signaling; Mitochondrial gene expression; links with nuclear gene expression

Unit III [22]

Life span

Chronological and Replicative life span; calorie restriction; signaling and alteration in gene

expression

Transcription and Translational Control by nutrition

Amino acid starvation; TOR signaling; transcriptional control by GCN4

Unit IV [8]

Prions in yeast

Inheritance pattern, prion propagation, *de novo* prion formation, prion structure and biological effects

Unit V [8]

Pathogenic yeasts

Diseases caused; Introduction to *Candida albicans*; Distinctions between *S. cerevisiae* and *C. albicans* mating types, mitochondrial physiology and carbon utilization

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Suggested Readings:

1.	Guide to Yeast Genetics and Molecular Biology, Methods Enzymol. Vol. 194	Guthrie C & Fink GR (Eds.)	Elsevier Academic Press
2.	Getting started with yeast, Methods Enzymol. Vol. 350, pp. 3-41 (2002)	Sherman F	
3.	Yeast Research: A Historical Overview	James A. Barnett & Linda Barnett	A S M Press