MASTER OF SCIENCE (GENETICS)

TWO YEAR FULL TIME PROGRAMME

AFFILIATION

The proposed Programme shall be offered and governed by the Department of Genetics, Faculty of Interdisciplinary and Applied Sciences, University of Delhi South Campus, New Delhi – 110 021.

PROGRAMME STRUCTURE

The M.Sc. Programme is divided into two parts as under. Each part will consist of two semesters totaling to four semesters.

PART I: Semester – 1

Paper Gen 0701 -	**Introduction to Genetic Analysis**		**100**
Paper Gen 0702 -	**Chromosomes, Genes and Genomes**		**100**
Paper Gen 0703 -	**Cell Biology and Biochemistry**		**100**
Paper Gen 0704 -	**Bioinformatics and Biostatistics**		**100**
Paper Gen 0705 -	**Practicals (Based on Theory)**		**200**
Total Marks	**Theory**	**400**	
	Practicals	**200**	
Grand Total			**600**

PART I: Semester – 2

Paper Gen 0801 -	**Population, Evolutionary and Quantitative Genetics**		**100**
Paper Gen 0802 -	**Molecular Biology**		**100**
Paper Gen 0803 -	**Regulation of Gene Expression**		**100**
Paper Gen 0804 -	**Recombinant DNA Technology**		**100**
Paper Gen 0805 -	**Practicals (Based on Theory)**		**200**
Total Marks	**Theory**	**400**	
	Practicals	**200**	
Grand Total			**600**

PART II: Semester – 3

Paper Gen 0901 -	**Microbial Genetics**		**100**
Paper Gen 0902 -	**Human Genetics**		**100**
Paper Gen 0903 -	**Plant Genetics and Breeding**		**100**
Paper Gen 0904 -	**Plant Biotechnology**		**100**
Paper Gen 0905 -	**Practicals (Based on Theory)**		**200**
Total Marks	**Theory**	**400**	
	Practicals	**200**	
Grand Total			**600**

PART II: Semester – 4

Paper Gen 1001 -	**Developmental Biology**		**100**
Paper Gen 1002 -	**Immunology**		**100**
Paper Gen 1003 -	**Two Optional Courses (Details given below)**		**150**
Paper Gen 1004 -	**Project Work**		**200**
Paper Gen 1005	**Practical (Based on Theory)**		**50**
	(on core courses – 50 marks)		
Total Marks	**Theory**	**350**	
	Project Work	**200**	
	Practicals	**50**	
Grand Total			**600**

Each theory paper will be of 70 marks in the final examination and 30 marks are for

Each theory paper will be of 70 marks in the final examination and 30 marks are for internal assessment (25 marks for class tests / seminar / dissertation + 5 marks for attendance).

List of Optional Courses: Any two optional courses to be selected from the following list (Each optional paper will be of 52½ marks in the final examination and 22½ marks are for internal assessment (18¾ marks for class tests / seminar + 3¾ marks for attendance):

1. **Advances in *Drosophila* Genetics**
2. **Biology of *Dictyostelium***
3. **Cancer Biology and Genetics**
4. **Medical Genomics**
5. **Plant-Microbe Interactions**
6. **RNAi: Biology and Applications**
7. **Yeast Molecular Genetics**

Note: Minimum of three students necessary to offer an optional course.

Gen 0701 – INTRODUCTION TO GENETIC ANALYSIS

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.

History of Genetics [2]

Mendel's paper on "Experiments in Plant Hybridization" (1865) - segregation, independent assortment**,** the concept of probability in genetic analysis [4]

Chromosome theory of inheritance [4]

Analyzing inheritance patterns:

Model organisms, e.g. Bacteriophage, *E. coli*, *Aspergillus*, *Neurospora*, Yeast, *Drosophila melanogaster* and *Arabidopsis thaliana* [2]

Methods of analysis (organisms with haplontic, diplontic and haplodiplontic lifecycles); forward versus reverse genetics [1]

Sources of genetic variation- mutation, recombination**,** independent assortment, polyploidy [2]

Markers for genetic analysis: Phenotypic, biochemical and molecular markers [1]

Single gene inheritance pattern: allelic interactions; sex-linkage; penetrance and expressivity; test for allelism-complementation [8]

Inheritance of two genes: independent assortment versus linkage, gene interactions [8]

Pedigree analysis in humans [4]

Introduction to polygenic inheritance [2]

Extranuclear inheritance [2]

Mapping genes:

Prokaryotes – temporal and recombination-based mapping in *E. coli*, transformation and transduction-based mapping, gene mapping in bacteriophage	[10]
Eukaryotes – mapping by recombination, based on test cross and F_2 progeny; Yeast as a model system- life cycle, mating types, tetrad analysis, parasexual analysis in fungi	[10]
Fine structure mapping (Experiments of Seymour Benzer)	[3]
Physical versus genetic maps	[1]

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

Gen 0702 - CHROMOSOMES, GENES AND GENOMES

The students are expected to have basic knowledge of chromosome structure, genome organization and cell division. Therefore, the syllabus includes advanced aspects of chromosome biology, genome organization and genetics of cell cycle regulation. Emphasis would be given to explain the topics with the help of classical experimental strategies, examples from different model organisms and contemporary genetic approaches and methods.

Chromatin structure: Histones, DNA, nucleosome morphology and higher level organization; Functional states of chromatin and alterations in chromatin organization [6]

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 remodelling [10]

Giant chromosomes: Polytene and lampbrush chromosomes [2]

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 with examples from yeast [10]

Chromosomal anomalies: Numerical and structural alterations, induced chromosomal aberrations in somatic cells [4]

Techniques in the study of chromosomes and their applications: 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 [8]

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, Retrotransposons, LINES, SINES, Alu family and their application in genome mapping [12]

Concept of gene: Conventional and modern views; Fine structure of gene, split genes, pseudogenes, non-coding genes, overlapping genes and multi-gene families [2]

Sex determination: Genetic determination of sex in *Caenorhabditis elegans*, *Drosophila melanogaster*, mammals and flowering plants [4]

Dosage compensation: In *Caenorhabditis elegans*, *Drosophila melanogaster* and mammals [4]

Genome mapping: Physical maps - an overview and approaches [1]

Genome evolution [1]

Suggested readings:

1.	Essential Cell Biology	Alberts B *et al.*	Garland
2.	Molecular Biology of The Cell	Alberts B *et al.*	Garland
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
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 & Wi
9.	Genome 3	Brown TA	Garland

Gen 0703 – Cell Biology and Biochemistry

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. 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. While tracing the origin of life and its subsequent evolution, special emphasis has been given to proteins as biocatalysts, in cellular reactions.

Methods in the study of Cell Biology and Biochemistry: An overview of microscopy, spectrophotometry, electrophoresis, fractionation, differential centrifugation, genetic approaches, autoradiography, pulse-chase experiments etc. [4]

Biomolecules: Chemical bonds; Building blocks - carbohydrates, lipids, fats, proteins, nucleic acids [2]

Origin of life: Origin of biomolecules, primitive life forms, RNA world, biological evolution [2]

Cellular energetics: Energy rich compounds, ATP synthesis, thermodynamics of cellular reactions [4]

Enzymes: As biocatalysts, specificity and kinetics, assay and inhibition of enzyme activity, mechanism of action, regulation of enzyme activity; Allosteric enzymes [14]

Informational molecules: DNA as genetic material, DNA structure and topology, RNA as genetic material, types of RNA, role of RNA in information transfer, concept of central dogma [6]

Biochemical Pathways: Nucleic acid chemistry and nucleotide metabolism; Sub cellular distribution of metabolic pathways; Biosynthesis of ATP; Respiratory chain; Generation of NADPH + H^+; Metabolism of carbohydrates; Regulation and integration of metaboli networks, examples from fasting and starvation, Diabetes mellitus, ketone body formation obesity. [16]

Protein structure: Primary, secondary, tertiary and quaternary; Processing and transport; Versatility of proteins in biological processes [8]

Cell structure and organization: Plasma membrane; Fluid mosaic model; Nuclear organization, information compartment; ER and Golgi, Cytoskeleton, mitochondria and chloroplast [8]

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.	Fundamentals of Enzymology	Price NC & Lewis ST	Oxford University Press
8.	Molecular Biology of the Cell	Bruce Alberts *et al.*	Garland

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Gen 0704 - BIOINFORMATICS AND BIOSTATISTICS

BIOINFORMATICS

This course is aimed at imparting knowledge of application of computational methods in order to address biological problems. This includes the ability to execute local as well as web-based programs to obtain and manipulate biological data (both sequence and structure) on a computer. The course has broadly two sections, first, dealing with the sequence analysis and will cover the use of NCBI's Entrez, BLAST, PSI-BLAST, ClustalW, Pfam, PRINTS, BLOCKS, Prosite; the second section deals with the analysis and prediction of 3-D structures of macromolecules like protein, DNA & RNA. The course is designed to highlight sequence-structure-function relationship to further our understanding of biological systems. Class assignments and practicals will familiarize students with biological data and tools for understanding the data and will help to gain a solid understanding of principles behind the design of algorithms and analysis of result. Class projects will bring together students with different backgrounds to apply ideas from the course to a problem in biology.

Introduction to Computers: Introduction to different operating systems, concepts of UNIX/LINUX; Introduction to programming languages [4]

Sequence Analysis

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 [4]

Pair-wise Sequence Alignment and Database Searching: Scoring matrices, local and global alignment concept, scoring functions, data base search for homologous sequences (FASTA and BLAST), motifs and domain searching; Understanding identity, homology and similarity with reference to evolutionary relationships (notion of homology orthologues, paralogues, analogues) [4]

Multiple Sequence Alignment: Sum of Pairs measure, Clustal W, Clustal X, progressive alignment, scoring MSAs, iterative methods of MSA [2]

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 [2]

Sequencing Annotation and Analyses: *in silico* methods of finding genes and regulatory regions [2]

Metabolic engineering: Introduction to EcoCyc, Metacyc, KEGG, EMP databases, LIGAND, BRENDA; Searching and analysis of enzyme data [2]

Microarray: An introduction to microarray analysis; Image processing; Normalizing expression measurements, Cluster analysis [2]

Structural Bioinformatics

Protein structure: Amino acid properties, levels of protein structure, general properties and characteristics [2]

Nucleic acid structure: Types of DNA structures, motifs and repeats; Structures, properties and characteristics of structural RNA like tRNA, Small and non-coding RNA; Programs for prediction of RNA secondary structure - M fold, RNA fold, S fold, Vienna RNA package [4]

Structure determination methods: ***a) X-ray crystallography:*** Introduce crystallography as microscopy, methods (molecular replacement vs isomorphous replacement); Principles and techniques of macromolecular crystallization; Validation of structures using Procheck, ProsaII; ***b)NMR:*** Principles of magnetic resonance, biological applications, relaxation studies, ESR [5]

Protein structure databases: Understanding structures using Protein Data Bank (PDB); Accessing and mining other protein classification databases, example SCOP, CATH [3]

Protein structure comparison: Superimposition and RMSD calculations, multiple structure alignment methods such as DALI and VAST [3]

Basics of Molecular Modeling: Protein secondary structure prediction, basic principles of tertiary structure prediction, homology modeling, threading and *ab-initio* protein structure prediction [5]

Suggested Readings:

1.	Proteomics- from protein structure to 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

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.

Principles and applications of statistical methods in biological research: [20]
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

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Suggested readings:

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

Gen 0705 – PRACTICALS (Based on Theory)

LIST OF PRACTICALS

1. Marker characterization and genotype determination in *E.coli*and*Aspergillusnidulans*
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 *Drosophilamelanogaster,* 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.
20. Using NCBI and Uniprot web resources

21. Similarity searches using tools like BLAST.
22. Multiple sequence alignment using ClustalW
23. Phylogenetic analysis of protein and nucleotide sequences
24. Use of gene prediction methods (GRAIL, Genscan, Glimmer)
25. Using RNA structure prediction methods.
26. Use of different protein structure databases (PDB, SCOP, CATH)
27. Visualization/Studying protein structures using Deepview/PyMol
28. Mutating and Energy minimization of protein structures
29. Ab-initio structure prediction of proteins
30. Homology modelling of proteins

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Gen 0801 – POPULATION, EVOLUTIONARY AND QUANTITATIVE GENETICS

A thorough understanding of the population genetics is necessary to comprehend the evolutionary processes. This course will make the students familiar with different types of DNA markers and the range of tools for their detection to enable advanced studies on molecular population genetics. 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.

Genetic variation: Types and sources of variation; Mechanisms of mutation; Detection of polymorphism - DNA markers and their detection techniques [8]

Organization and measure of genetic variation: Random mating population, Hardy-Weinberg principle, complications of dominance, special cases of random mating – multiple alleles, sex-linked genes [10]

Linkage and linkage disequilibrium [6]

Population sub-structure: Hierarchical populations, isolate breaking, inbreeding, assortative and non-assortative matings [4]

Gene frequencies and evolution: Mutation, selection, migration and random genetic drift [8]

Neutral theory and coalescence [8]

Molecular evolution: Theories of evolution, molecular evolution of genes and proteins; Phylogeny and systematics; Molecular clock [10]

Quantitative genetics: Johannsen pure line theory; Multiple factor hypothesis; Types of quantitative traits; Components of phenotypic variation and genetic models for quantitative traits; Concept of heritability [10]

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

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Gen 0802 – MOLECULAR BIOLOGY

This paper will focus on basic processes of copying, restructuring, readout and decoding of genetic information both in prokaryotes and eukaryotes with emphasis on discussion of important discoveries such as discoveries of messenger RNA, RNA polymerase etc. Detailed mechanisms of each processes will be discussed with components of machinery, factors and steps involved. The paper will also discuss the transport of biomolecules in eukaryotes, turnover of regulatory molecules, crosstalk between basic processes and cell cycle, basics on programmed cell death.

DNA replication: General features of DNA replication, DNA polymerases, other replication proteins, mechanism of DNA replication [6]

DNA repair: DNA damage, repair and underlying mechanisms [4]

Models of recombination [2]

Gene expression in prokaryotes and eukaryotes: [16]
Gene as a unit of function; Transcription - 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 [12]

Trafficking of biomolecules: mRNA transport, nucleo-cytoplasmic transport; transport into ER, Mitochondria; Secretory pathways; Protein sorting; Endocytosis; Cholesterol homeostasis- cellular transport, regulation of biosynthetic genes [12]

Cellular proteolysis: Autophagy, proteosomes, ubiquitin pathway [4]

Cell Cycle and its regulation [4]

Programmed cell death [4]

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.	Compilation of Original research papers and reviews		

Gen 0803 – REGULATION OF GENE EXPRESSION

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.

Introduction to gene regulation: Tools for studying gene activity, levels of regulation - evidences and experimental designs, role of genetic analysis in understanding gene function and regulation [4]

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 [20]

Perceiving signals: Cell signaling pathways; Quorum sensing in bacteria and *Candida* [6]

Regulation by DNA rearrangement: Yeast mating type and VDJ recombination [4]

Transcriptional control in eukaryotes: Examples from tissue specific, developmental and stress response [6]

Post-transcriptional regulation: Examples of alternative splicing, RNA editing, localization of mRNA; RNA stability and degradation – nonsense mediated decay [6]

Translational regulation: Control at initiation of translation**;** Codon usage; Riboswitches; Small RNAs [4]

Post-translational modifications: RNA-mediated control - miRNA, polyadenylation, ubiquitinylation [4]

Chromatin structure and epigenetic controls: Concept and historical overview ; Epigenetic triggers; DNA methylation, genomic imprinting, cellular memory; Heterochromatin and mating types in *Saccharomyces cerevisiae*; PEV and gene silencing in *Drosophila* [14]

Protein interactions in epigenetic control: Polycomb and Trithorax - regulation of *hox* genes; Histone variants in chromosomal inheritance [4]

Epigenetic regulation in plants [2]

Epigenetics in disease: Imprint defects in humans, chromatin structure defects, cancer [4]

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

Gen 0804 – RECOMBINANT DNA TECHNOLOGY

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.

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 [6]

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

Polymerase Chain Reaction (PCR): Concept of PCR, various kinds of PCR, Real Time PCR, Ligation Chain Reaction; Applications of PCR [4]

Construction of DNA libraries: Genomic and cDNA libraries; Screening of genomic and expression libraries [4]

Gene identification: Subtractive hybridization, chromosome walking and jumping [2]

Genome sequencing: DNA sequencing by Maxam and Gilbert method, Sanger's method, whole genome shotgun sequencing, next generation sequencing; Genome annotation: an overview [6]

Analysis of gene expression: Northen blotting, RT-PCR, EST analysis, Promoter analysis; Mapping transcriptional start sites, Transcriptome analysis – cDNA- and oligo arrays; Serial Analysis of Gene Expression (SAGE) [8]

Expression of recombinant proteins: Expression and tagging of recombinant proteins in *E. coli*; Other expression systems [4]

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-immunoprecipitations; Phage display [6]

Protein engineering: Insertion and deletion mutagenesis, site-directed mutagenesis, proteome analysis - MALDI, protein arrays and their applications [3]

Proteome analysis [3]

Applications of recombinant DNA technology in biology and medicine [4]

Suggested readings:

1.	Gene Cloning and DNA Analysis: An Introduction	Brown TA	Blackwell Publi.
2.	Gene Cloning and Manipulation	Howe C	Cambridge University Press
3.	Principles of Gene Manipulation and Genomics	Primrose SB & Twyman RM	Blackwell Publi.
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

Gen 0805 – PRACTICALS (Based on Theory)

LIST OF PRACTICALS

1. 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)

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

3. Analysis of methylation status of genomic DNA.

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

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

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

7. 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.

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

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

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

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

12. Creating recombinant DNA: directional and non-directional cloning of a DNA fragment in a plasmid vector.
13. Designing primers for a given DNA template and analysing the role of different reaction components/conditions ($MgCl_2$ conc., temperature, conc. of template and number of cycles) on the efficiency of PCR.
14. Isolation and digestion of genomic DNA with different restriction enzymes (4, 6 and 8 base cutters).
15. Demonstration of Southern hybridization, and DNA sequencing methods
16. Isolation of RNA.

Gen 0901 – MICROBIAL GENETICS

Though microorganisms have had a late entry in the field of genetics, once that happened, they quickly occupied the centre 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 systems.

Bacteria as model systems in genetic analysis: Mutation, recombination, test of allelism, gene mapping [4]

Methods of gene transfer in bacteria:

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 [8]

Transformation: Natural transformation systems, biology and mechanism of transformation, transformation and gene mapping, chemical-mediated and electrotransformation [6]

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 [4]

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) [6]

Plasmids: Types, detection, replication, incompatibility, partitioning, copy-number control and transfer; Properties of some known plasmids [6]

Introduction to yeast: An overview of yeast in daily life; Cellular architecture and function; Yeast as an experimental system for eukaryotic molecular biology [4]

Art and design of genetic screens: Choice of mutant phenotypes; Cloning by complementation; Isolation of bypass and allele specific-suppressors; Synthetic lethal screens [16]

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 [10]

Suggested readings:

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 Academic Press
8.	Getting started with yeast, Methods Enzymol. Vol. 350, pp. 3-41 (2002)	Sherman F	
9.	Yeast Research: A Historical Overview	James A. Barnett & Linda Barnett	A S M Press

Gen 0902 – HUMAN GENETICS

Human Genetics is a very wide as well as a rapidly advancing subject and one which interests even a layman. Last two decades have revolutionized our early understanding of the basic concepts of Genetics, genome organization, gene structure and function. 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 mapping tools and cloning strategies culminating in the successful completion of the Human genome project and exciting, unimagined areas of research which have emerged in the post-sequencing era would be covered next. New/ current knowledge on genetic variations in health and disease across populations and their clinical/diagnostic implications would be dealt 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.

Introduction to human genetics: History; Early perception, development and documentation [2]

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 [12]

Human genome mapping methods: [16]

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 [8]

Genetic variation in health and disease: [10]

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

Human genetic diversity: Methods of study – Biochemical/molecular genetic markers; Some examples; Tracing human migrations with autosomal, Y-chromosomal and mitochondrial markers [4]

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 [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 [2]

Classical papers in human genetics [4]

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

Gen 0903 – PLANT GENETICS AND BREEDING

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 through forward genetics approach

Historical perspective; Genetic diversity in plant breeding [3]

[6]

Natural breeding systems in plants and their applications in plant breeding

[2]

Gene pool concept

[6]

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

[6]

Conventional breeding methods: Self and cross-pollinated, and vegetatively propagated crop plants

[4]

Genetic basis of heterosis and development of hybrid varieties

[2]

Plant variety development; Registration of varieties and seed production

[4]

Molecular plant breeding: Introduction – Molecular markers as efficient tools in plant breeding

[10]

Molecular markers for genome mapping: Principle of genetic linkage; Concept of genetic distance; Development and choice of mapping populations; Linkage map construction; Integrated and comparative maps

[9]

Dissection of quantitative traits: Principles and methods of QTL mapping - based on linkage and association mapping, fine mapping of QTLs

[8]

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)

[4]

Map based gene cloning

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
6.	Molecular Plant breeding	Xu Y	CAB International

Gen 0904 – PLANT BIOTECHNOLOGY

Human society is confronted with a multitude of challenges, including the rapid loss of phytodiversity, environmental perturbations, and the ever-increasing human population. Needless to highlight, food security for the ever-increasing population will be a major challenge in present and future times. In fact, it would be necessary to produce more and more food in the coming years. Although conventional breeding has contributed its share, we need to adopt newer technologies, particularly biotechnological strategies to boost the yield and quality of our crop plants. This course is designed to provide students with specialized knowledge of the theory and practical skills of plant tissue culture, somatic cell genetics and genetic engineering relevant to crop improvement. It deals with the various cell and tissue culture systems and their applications, plant transformation vectors and methods, and potential applications of transgenic technology in agriculture and healthcare.

Plant cell and tissue culture: Historical developments; Culture conditions; Organ culture, callus culture and cell lines; Plant regeneration pathways - organogenesis and somatic embryogenesis; Some examples - tobacco, carrot, cotton and rice; Embryo, endosperm, anther and pollen culture and their applications; Cell and root culture and production of secondary metabolites; Protoplast isolation and culture, somatic cell hybridization and its applications; Micropropagation; Somaclonal and gametoclonal variation; *in vitro* fertilization; *in vitro* mutagenesis and mutant selection; Preservation of plant germplasm *in vitro* [22]

Plant transformation vectors and methods: Historical developments; Tumour inducing principle in *Agrobacterium* - structure and function of Ti-plasmids and T-DNA, T-DNA transfer and integration in the plant genome; Ti-plasmid based cointegrate and binary vectors; *Agrobacterium* transformation of dicots, monocots and other kingdoms; 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; Characterization of transgenics through molecular and genetic means; Plastid transformation - vectors, gene integration through homologous recombination; Transgene silencing; Marker-free transgenics; Multigene engineering [22]

Applications of plant transgenic technology: Scope; Insect resistance - case study of Bt cotton, resistance management, Bt and other antifeedant genes; Herbicide resistance - study of glyphosate resistance, Basta resistance and use of mutant *ALS* gene, strategies for dealing with superweeds; Transgenic resistance against viral, fungal, bacterial pathogens and nematode parasites; Abiotic stress tolerance; Engineering crops for male sterility, delayed fruit ripening, fatty acid composition and other traits; Nutritional quality and quantity improvement, Golden rice as a case of metabolic engineering; Molecular pharming, Other applications; Issues in biosafety [20]

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.	Review and research articles		

Gen 0905 – PRACTICALS (Based on Theory)

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
5. carbon source.
6. Test for the presence of mtDNA in the mutant *S. cerevisiae* strain.
7. Chromosome preparations from human lymphocyte cultures
   i. G- and Q- banding of metaphase chromosomes
   ii. Karyotyping with G- banded metaphase chromosomes
8. Chromosomal and interphase FISH of human chromosomes
9. 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
10. LOD score analysis with microsatellite data from genome wide scans of pedigrees segregating a disease
11. Diversity analysis using program NTSYS.
12. Construction of linkage map using program JoinMap4.

13. Demonstration of program used for QTL mapping.
14. Field trip to plant breeding station.
15. Shoot tip and nodal bud culture for multiplication of tobacco.
16. Plant regeneration in tobacco (organogenesis).
17. Induction of embryogenic callus and plant regeneration in rice
18. Induction of hairy roots in tobacco leaf explants by *Agrobacterium rhizogens*.
19. *Agrobacterium*-mediated genetic transformation of tobacco using leaf disc method
20. Histochemical assay for GUS activity from the transformed tissue of tobacco
21. Isolation of genomic DNA (by CTAB method) from transformed and un-transformed tissue of tobacco
22. Analysis of transgene integration in the tobacco transformants by PCR analysis

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Gen 1001 – DEVELOPMENTAL BIOLOGY

There are proximal and ultimate explanations for development. Importantly, today for the first time one can begin to see how they might link up. These are based on molecular biology, genetics, biochemistry and mechanical properties of cells on the one hand, and evolutionary arguments on the other, with much of interplay between the two. Keeping this in mind, 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. The students are urged to read: "The art of the genes –How organisms make themselves by Enrico Coen".

Introduction to developmental biology: Developmental anatomy and genetics; Cell-cell communication in development [2]

Concepts of development: Specification, induction, competence, determination and differentiation, morphogen gradients, pattern formation, cell fate and cell lineages [4]

Fertilization: External fertilization in sea urchins and internal fertilization in mammals [2]

Early developmental processes in animals: Cleavage, gastrulation and axis formation using examples of sea urchin, *C. elegans, D. melanogaster*, amphibians, birds and mammals [22]

Stem cells: An overview [2]

Morphogenesis and organogenesis in animals: Cell aggregation and differentiation in *Dictyostelium discoideum;* Formation of vulva in *C. elegans*; Development of the tetrapod limb [12]

Post-embryonic development: Metamorphosis and regeneration [4]

Germ cells: Determination, migration and maturation [2]

Medical aspects of developmental biology [2]

Developmental process in plants: Salient features, comparison between plant and animal development pattern; Understanding plant development through examples – Apomixis, regulation of transition to flowering, floral meristem and the ABC model of flower development in *Arabidopsis*. [12]

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

Gen 1002 – IMMUNOLOGY

The course provides a comprehensive overview of basic immunology beginning with the innate immune responses, followed by a study of the main aspects of acquired immunity. Specific interactions of target cells and T cells that are regulated by the MHC molecule and peptide antigens on the target cell and the antigen specific T cell receptor are discussed. The generation and molecular structure of B and T cell antigen receptors, and signaling through immune receptors are covered in details. The development of antigen specific T and B cells, and specific roles of some cytokines/lymphokines are included. In addition, the course covers in-depth, information on T-and B cell-mediated immunity and topics of clinical relevance, such as microbial immunity, allergy, autoimmunity, tumor immunology, congenital and acquired immunodeficiencies, transplantation immunology, and immunotherapy. All the topics are studied through lectures and an in-depth review of selected articles.

Three fundamental concepts in immunology: Specificity, discrimination of self from non-self and memory. [4]

Immune cell receptors: Detailed structure and development of B cell (Ig) and T cell (TcR) receptors; Structure of CD4, CD8, MHC-I, MHC-II molecules, cellular adhesion molecules (ICAM, VCAM, MadCAM, selectins, integrins); Pattern Recognition Receptors (PRRs) and Toll-like receptors (TLR); Markers of suppressor / regulatory cells - $CD4^+$ $CD25^+$ $Foxp3^+$ T_{reg} , iNKT. [12]

Genetic organization: Organization of the genes for B and T cell receptors. Genetic organization of MHC-I and MHC-II complex (both HLA and H-2). Molecular mechanisms responsible for generating diversity of antibodies and T cell receptors. Peptide loading and expression of MHC-I and MHC-II molecules; Hybridoma technology and monoclonal antibodies, antibody engineering. [12]

Immune response and signaling: Humoral and cell-mediated immune response; Innate immune response and pattern recognition; Recent advances in innate immune response especially NK-DC interactions; Major cytokines and their role in immune mechanisms: TNF, IFN, IL-1, IL-2, IL-4, 1L-6, 1L-10, 1L-12, IL-17, TGFβ; Cell signaling through MAP kinases and NF-κB. [12]

Tolerance and autoimmunity: Central and peripheral tolerance, and their mechanism; Mechanisms of autoimmunity; Autoimmune components of diabetes mellitus (DM), multiple sclerosis (MS), experimental autoimmune encephalitis (EAE); Infections leading to autoimmune diseases. [8]

Immunological disorders and hypersensitivity: Deficiencies / defects of T cells, B cells, complement and phagocytic cells; Comparative study of Type I-V hypersensitivities with examples. [8]

Transplantation and tumor immunology: Alloreactive response; Graft rejection and GVHD; HLA-matching; Transgenic animals for xenotransplantation; Tumor antigens, immune response to tumors and immunotherapy of tumors. [8]

Suggested readings:

1.	Kuby Immunology	Kindt TJ, Goldsby RA, Osborne BA, Kuby J	W H Freeman & Co
2.	Cellular and Molecular Immunology	Abbas AK, Lichtman AH, Pillai S	Elsevier
3.	Immunobiology: The immune system in health and disease	Janeway CA,Travers P,Walport M, Shlomchik MJ	Garland Science Publishing
4.	Medical Microbiology and Immunology	Levinson W, Jawetz E	Lange publication
5.	Fundamental Immunology	Paul WE	Raven Press
6.	Roitt's Essential Immunology	Delves PJ, Martin SJ, Burton DR, Roitt IM	Blackwell Publishing/Oxford Univ. Press

Gen 1003 (i) – ADVANCES IN *DROSOPHILA* GENETICS

Drosophila has been one of the favoured model organisms of 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 genetic analysis and developmental studies. Subsequently, Drosophila genetics has emerged as an indispensable area of study in classical and contemporary biological sciences. The course has been designed to provide advanced understanding of Drosophila genetics and related areas. The teaching will include both knowledge-based sessions (to facilitate understanding of concepts) and tutorials (application of knowledge and skills in designing research experiments).

***Drosophila* as a model organism:** An overview - life cycle and advantages in genetic analysis and developmental studies [2]

Genetics of development: Embryonic development, larval stages and tissue types, imaginal discs - development and differentiation, trans-differentiation, adult morphology and internal organs, spermatogenesis and oogenesis [8]

Stem cells and their maintenance: Somatic and germ line stem cells [3]

Nomenclature of gene mutations; Balancer chromosomes [2]

Mutagenesis and isolation of new variants: Radiation and chemical mutagenesis; P-element and insertional mutagenesis; Mapping of new mutations by recombination, deletion and complementation mapping [6]

Generation of transgenics: P-element based vectors; Vector selection; Germ-line transformation, microinjection and transgenic screening [4]

Tools for Genetic, Cellular and Molecular analysis: Use of Polytene chromosomes for studies on gene expression; Generation and analysis of somatic and germ-line clones; Conditional and/or targeted over-expression/ablation of genes/transcripts (e.g. UAS/GAL4 system)**;** RNAi-based screening of gene functions [9]

***Drosophila* as a model for human genetic disorders and drug screening:** Some examples - Parkinson's, Huntington's, Alzheimer's diseases, Fragile-X syndrome, Cancer etc. [6]

***Drosophila* genome:** An overview, online databases and other resources [3]

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		

Gen 1003 (ii) – BIOLOGY OF *DICTYOSTELIUM*

The course is designed to provide some fundamental principles on which to form an intergrated 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

***Dictyostelium discoideum* as a model organism:** An overview; Classical experiments of Raper; Evolution and genome organisation [2]

Organismal biology:

Cellular dynamics: Cytoskeletal proteins, cytokinesis, motility and phagocytosis [4]

Cell adhesion and recognition: Cell adhesion molecules, cell-cell contact and gene expression [5]

cAMP and signal transduction: cAMP oscillation and signal relay, chemotaxis and aggregation, control of aggregation, cell sorting, coordinated cell movement during multicellular morphogenesis, prespore gene expression [12]

Cell differentiation and pattern formation: Initial cell type choice, cell type specific markers, cell fate determination; DIF, DIF-1 and prestalk gene expression; Prestalk and stalk cell heterogeneity; Role of calcium in pattern formation and various models [12]

Morphogenesis and gene expression [4]

***Dictyostelium* in biology and medicine** [4]

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 & Ikuo Takeuchi (Ed.)	Universal Academic Press, Inc. Tokyo
3. *Dictyostelium discoideum*: Molecular Approaches to Cell Biology, *Volume 28 of Methods in Cell Biology*	James A. Spudich	Academic Press
4. Review and research articles		

Gen 1003 (iii) – CANCER BIOLOGY AND GENETICS

Cancer is a multistep process often leading to a devastating phenotype and debilitating disease. While some cancers have been identified to have a strong genetic basis, others are complex and still an enigma. Over the decades, comprehensive genetic and molecular analysis of tumor progression and advances in technology, have contributed to identification of various downstream effector molecules with a therapeutic potential. This has lead to considerable improvement in patient survival and management for some cancers

Biology of a cancer cell: Pathology of tumor/cancer tissues; Classification of tumor/cancers; Clonal evolution; Tumor microenvironment; Warburg effect [6]

Genetic basis of oncogenesis: Chromosomal rearrangements, aneuploidy, chromosomal instability; Mutator hypothesis, mutations, DNA repair defects, multi-step tumorigenesis; Some examples [10]

Mechanism of oncogenesis:

Tumor suppressors: Knudson's two-hit hypothesis; Gatekeeper/ caretaker mutations - *Rb*, *apc* and *p53* in cell cycle (dys) regulation [6]

Signaling pathways: Defects in EGFR, Ras and MAPK pathway [4]

Oncogenes and viral sequences: Proto-oncogenes - *ras* and *myc* family; Tumor- and retroviruses [5]

Cancer progression and metastasis: Angiogenesis; Epithelial to mesenchymal transformation; Invasion [4]

Advances in cancer detection and therapy: Molecular diagnostics, imaging; Cancer therapy in practice; Molecular basis of targeted therapy; Classical papers [8]

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		

GEN 1003 (iv) – MEDICAL GENOMICS

This era in time is the most exciting period in medical practice and research due to unprecedented technical advances in genetics and genomics research. An effective weaving together of previously separate strands of cytogenetics / biochemical genetics/ immunogenetics/ molecular genetics/ statistical, functional and population genetics is evident in this area. Conventional tools such as pedigree analysis still remain to be a powerful starting tool for new gene identification and study of inheritance genetics. Functional genomics and understanding mechanisms underlying genetic observations together with in- silico approaches to unravel nuances in genome architecture are the contemporary tools. Introduction to new methodologies to study genetics of single gene disorders as well as the enigmatic common complex traits; variety of tools to unravel the function of genes and their variants; and finally translation of this exciting new knowledge to medical practice by diagnostic and therapeutic innovations are the contents of this paper. Genetic counseling is emerging as an area of utmost importance in this translational research era and this would also be dealt with. 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.

Identification and isolation of disease genes: [28]

Single gene disorders: Conventional and contemporary methods - Pedigree analysis, linkage mapping, positional/structural and functional cloning, next generation sequencing technologies, bioinformatic analysis; Characterisation; Mutation detection, diagnosis and therapy (with examples from autosomal dominant, autosomal recessive, X-linked dominant, X-linked recessive and complex disease conditions)

Multifactorial disorders: Familial forms - linkage analysis, candidate gene identification; Genetic polymorphism and disease susceptibility; Sporadic cases - Association studies with markers from candidate gene/pathways; Whole genome association (single nucleotide polymorphism, CNVs); Statistical methods used; Common examples

Functional genomics and animal models in human disease: An overview; cDNA/gene cloning; Site-directed mutagenesis; Mammalian tissue culture; Cell line transfections; Functional assays; Use of model organisms, methods for generation of transgenic animals/ knock-in and knock-out models (microinjection, ES cell transformation); ENU mutagenesis; RNAi approach; Some examples [6]

Treatment of genetic disorders: Methods of therapy - Drug (recombinant proteins); Diet; Gene (viral vectors, delivery methods, efficacy); Some examples (Thalassemia, Phenylketonuria, Cystic fibrosis, DMD, etc) [4]

Pharmacogenetics: History, Early evidence; Clinical determinants; Molecular insights (Genes involved in pharmacokinetics and pharmacodynamics of drugs); Applications in pre-prescription testing [3]

Genetic counseling: Prenatal/neonatal/ adult diagnosis of genetic disorders; Risks and benefits; Informed consent; Right of choice; Dilemmas faced by counselors. Some case studies [2]

Suggested readings:

1.	Human Molecular Genetics	Strachan T & Read A	Garland Science
2.	An introduction to Human Molecular Genetics: Mechanism of Inherited Diseases	Pasternak J	Fitzgerald Science Press
3.	Thompson and Thompson Genetics in Medicine	Robert *et al.*	Saunders
4	Landmarks in Medical Genetics	Harper PS (Ed.)	Oxford University Press
5.	Chromosome Banding	Sumner AT	Unwin Hyman
6.	Human Genetics: Problems and Approaches	Vogel F & Motulsky AG	Springer Verlag

Gen 1003 (v) – PLANT-MICROBE INTERACTIONS

The course is designed to provide the genetic and molecular principles underlying plant-microbe interactions. Tutorials would be in form of discussion and student presentations based on recent reviews available for each topic, highlighting the advances made in the respective field.

Plant pathology: History - significance of plant diseases; Types of plant-microbe associations (symbiotic and pathogenic – bacteria, virus, fungi); Pathogenecity, host range of pathogens, disease cycle and epidemics [6]

Molecular basis of plant-microbe interactions:

Benificial: Nitrogen fixing bacteria , blue green algae; PGPR; Mycorrhizal association [5]

[12]

Pathogenic: Mechanisms of virulence - pathogenicity genes in bacteria, biotrophic and necrotrophic fungi; Generation of variability [16]

Plant disease susceptibility and resistance: Types of plant resistance - R genes (quantitative and monogenic); Basal and induced defense mechanisms; Pre-formed inhibitors of pathogens; Gene for gene interaction in plant defense; Systemic Acquired Resistance and Induced Systemic Resistance; Recognition mechanism and signal transduction during plant-pathogen interactions [4]

Microbial biomolecules in plant interactions: Phytohormones and biocontrol antibiotics

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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.

Gen 1003 (vi) – RNAi: BIOLOGY AND APPLICATIONS

In the post-genomic era, the elucidation of physiological function of genes is extremely important and RNAi has rapidly become one of the key methods used in functional genomics since its discovery in 1998. RNAi is also involved in defense and the regulation of chromatin structure and gene expression as well as some other vital biological functions. In fact, this elegant and revolutionary reverse genetics approach has tremendous commercial promise with regard to developing new drugs and therapeutics for human diseases as well as the improvement of crop yield and quality. This course covers the basic aspects of RNAi biology, use of siRNAs and microRNAs for gene silencing, RNAi vectors and generation of transgenic animals and plants expressing dsRNA and the current and potential applications of RNAi in healthcare and agriculture.

Discovery of RNA interference: Discovery and overview; Post-transcriptional gene silencing and related phenomena [4]

Non-coding RNAs: Types - dsRNAs, snRNAs, snoRNAs, siRNAs, piRNAs, miRNAs and long ncRNAs; Their biogenesis and function [6]

Mechanisms of RNAi: Components of RNAi pathways and their evolutionary conservation and role in gene silencing; RNAi-like pathway in bacteria – CRISPR; Molecular basis of RNAi/ siRNA/miRNA- mediated gene silencing; Role of non-coding RNAs - in chromatin structure and gene expression, dosage compensation, genomic imprinting, defense and others; RNAi suppressors [8]

Large-scale genetic analysis using RNAi: Genome-wide RNAi screens in *C. elegans* and other systems; RNomics - high-throughput small RNA profiling, RNAi microarrays [6]

miRNAs and siRNAs: Expression and functions of microRNAs; siRNA vectors, *in vitro* and *in vivo* siRNA delivery; RNA informatics - computational tools for miRNAs discovery and their targets, design of miRNA and siRNA [8]

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 therapy for human diseases; RNAi in crop protection and improvement; Future prospects of RNAi in biology, medicine and agriculture [11]

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
9.	Review and research articles		

Gen 1003 (vii) – YEAST MOLECULAR GENETICS

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.

Introduction: An overview of yeast in daily life; Cellular architecture and function; Yeast as an experimental system for eukaryotic molecular biology [5]

Art and design of genetic screens: Choice of mutant phenotypes; Cloning by complementation; Isolation of bypass and allele specific-suppressors; Synthetic lethal screens [10]

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 [7]

The yeast genome: Life with 6000 genes; Post-genomic era - genome-wide microarrays, proteomics, genome-wide protein localization; Synthetic gene array analysis [5]

Mitochondrial dynamics [3]

Ribosome synthesis [3]

Intracellular transport [5]

Pathogenic yeasts: Diseases caused; Introduction to *Candida albicans*; Distinctions between *S. cerevisiae* and *C. albicans* mating types [5]

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

Gen 1004 – PROJECT WORK

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.

Gen 1005 – PRACTICALS (Based on Theory)

LIST OF PRACTICALS

1. Dechorionation of *Drosophila* embryos after mass collection and identification of various embryonic stages.
2. LacZ staining to study *in-situ* developmental expression pattern of a given gene.
3. Experiments with *Dictyostelium*

    i. Life cycle of *D. discoideum*
    ii. Chemotaxis
    iii. Differentiating prespore and prestalk cells by staining
4. Window preparation of fertilized chick egg to study early development.
5. Introduction to *C. elegans* and zebra fish as model organisms for developmental biology.