R-973
13.8.2026

UNIVERSITY OF CALCUTTA

Notification No. CSR/99/2026

It is notified for information of all concerned that in terms of the provisions of Section 54 of the Calcutta University Act, 1979, (as amended), and, in the exercise of his powers under 9(6) of the said Act, the Vice-Chancellor has, by an order dated 05.08.2026, approved the syllabus of 2-year (Four Semester) M.Sc. Course of Study in Genetics, under NEP guidelines, as laid down in the accompanying pamphlet.

The above syllabus shall take effect from the academic session 2026-2027 and onwards.

12/08/2026

Prof.(Dr.) Debasis Das
Registrar

SENATE HOUSE
Kolkata-700073
12.08.2026

SEMESTER 1

Code	*Course Title*	*Marks*	*Credits*
GNT 101	Principles of Genetics	40	2
GNT 102	Cell and Developmental Biology	40	2
GNT 103	Chromosomes, Genes and Genomes	40	2
GNT 104	Molecular Biology and Genetic Engineering	40	2
GNT 105	Experimental Genetics and Laboratory Techniques I (Practical based on theory papers)	90	12
Total		250	20

SEMESTER 2

Code	*Course Title*	*Marks*	*Credits*
GNT 201	Microbial Genetics and Industrial Biotechnology	40	2
GNT 202	Regulation of Gene Expression	40	2
GNT 203	Immunogenetics	40	2
GNT 204	Quantitative, Population and Statistical Genetics	40	2
GNT 205	Experimental Genetics and Laboratory Techniques II(Practical based on theory papers)	90	12
Total		250	20

SEMESTER 3: Course Work

Code	*Course Title*	*Marks*	*Credits*
GNT 301	Applied Plant Genetics and Biotechnology	35	2
GNT 302	Human Genetics and Translational Genomics	35	2
GNT 303	Experimental and Comparative Animal Genetics	25	1
GNT 304	Bioinformatics and Genomic Data Analysis	25	1
GNT 305	Experimental and Applied Proteomics	25	1
GNT 306	Translational Biotechnology, Genomic Medicine and Bioethics	25	1
GNT 307	Advanced Experimental Genetics and Research Methodologies(Practical based on theory papers)	80	12
Total		250	20

SEMESTER 4: Research

Code	*Course Component*	*Marks*	*Credits*
GNT401	Research Project, Dissertation and Seminar	250	20

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Department of Genetics
University of Calcutta

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Detailed Syllabus for two years M.Sc Course in Genetics, CU - 2026

FIRST SEMESTER

GNT 101: Principles of Genetics 40 marks; 2 credits

Unit 1. Mendelian Genetics and Its Extensions

- Cell division: mitosis and meiosis; evolutionary significance of meiosis
- Mendel's laws of inheritance
- Extensions of Mendelism:
    - Co-dominance and incomplete dominance
    - Epistasis and pleiotropy
    - Lethal and sub-lethal alleles
    - Multiple alleles: ABO blood group system in humans
    - Rh incompatibility and its genetic basis

Unit 2. Chromosomal Basis of Heredity

- Chromosome theory of inheritance
- Sex-linked, sex-limited, and sex-influenced traits
- Sex determination mechanisms
- Dosage compensation of X-linked genes

Unit 3. Chromosome Segregation and Genetic Mapping

- Linkage, recombination, and crossing over
    - Crossing over as a measure of genetic distance
    - Two-point and three-point test crosses
    - Recombination frequency and genetic map units
- Detection and analysis of linkage:
    - Tetrad analysis in fungi
    - Ordered tetrads and centromere mapping in Neurospora
    - Balancer chromosomes in Drosophila
    - Cytogenetic mapping in Drosophila
    - Pedigree analysis for linkage detection in humans

Unit 4. Deviations from Mendelian Inheritance and Complex Traits

- Polygenic and multifactorial inheritance
- Genetic basis of complex diseases
- Gene–environment interactions
- Maternal effects
- Cytoplasmic inheritance
- Genomic imprinting

Recommended Readings

- Concepts of Genetics: Klug, W. S., Cummings, M. R., Spencer, C. A., & Palladino, M. A. — Prentice Hall / Pearson
- Genetics: A Conceptual Approach: Pierce, B. A. — W. H. Freeman
- Genetics: Analysis of Genes and Genomes: Hartl, D. L., & Jones, E. W. — Jones & Bartlett
- Principles of Genetics: Snustad, D. P., & Simmons, M. J. — John Wiley & Sons
- An Introduction to Genetic Analysis: Griffiths, A. J. F., Wessler, S. R., Carroll, S. B., & Doebley, J. — W. H. Freeman
- Strickberger's Evolution (commonly cited as Genetics by Strickberger): Strickberger, M. W. — Prentice Hall

GNT 102: Cell and Developmental Biology 40 marks; 2 credits

Unit 1: Origin and Evolution of Cellular Life

- Chemical evolution and origin of biomolecules (Haldane–Oparin hypothesis)
- RNA world hypothesis; ribozymes and evolution of catalytic systems
- Evolution of cellular organization; endosymbiotic origin of mitochondria and chloroplasts
- Thermodynamic principles governing living systems

Unit 2: Structure and Dynamics of Cellular Membranes
- Composition and organization of biological membranes: lipids, proteins, and carbohydrates
- Fluid mosaic model; membrane asymmetry and microdomains (lipid rafts)
- Membrane transport mechanisms:
    - Passive and active transport
    - Carrier proteins and ion channels
    - Electrical properties and membrane excitability
- Cell junctions, adhesion molecules, extracellular matrix, and basement membrane

Unit 3: Cell Cycle and Its Regulation
- Phases of the cell cycle and molecular regulators (cyclins and CDKs)
- Cell cycle checkpoints and DNA damage response
- Regulation of cell cycle in model systems (Saccharomyces cerevisiae and Schizosaccharomyces pombe)
- Introduction to apoptosis and its regulation

Unit 4: Cell Signalling and Communication
- General principles of signal transduction
- G-protein coupled receptors (GPCRs)
- Receptor tyrosine kinases (RTKs)
- Serine/threonine kinase pathways and histidine kinase systems
- Second messengers and signal amplification

Unit 5: Fundamental Concepts of Development
- Gametogenesis and fertilization
- Concepts of potency, commitment, specification, determination, and differentiation
- Cell fate, lineage, and stem cells
- Mosaic versus regulative development
- Axis formation, pattern formation, induction, and competence

Unit 6: Developmental Genetics in Animals
- Genetic control of early development in Drosophila melanogaster:
    - Maternal effect and zygotic genes
    - Gap, pair-rule, and segment polarity genes
    - Homeotic genes and HOX clusters
- Morphogen gradients and gene regulatory networks
- Genetic basis of neural and ocular development
- Cellular reprogramming and developmental plasticity

Unit 7: Developmental Genetics in Plants
- Genetic approaches to plant development (*Arabidopsis thaliana* and maize)
- Phase transitions: juvenile to adult and vegetative to reproductive
- Floral development and homeotic genes (ABCDE model)
- Reproductive biology: pollination, fertilization, and incompatibility systems
- Sex determination and gender expression in plants

Unit 8: Experimental Approaches in Cell and Developmental Biology
- Microscopy:
    - Light microscopy and fluorescence microscopy (confocal)
    - Electron microscopy

- Cell and molecular techniques:
    - Subcellular fractionation
    - Immunoprecipitation and immunolocalization
    - Flow cytometry and cell sorting
    - Live-cell imaging
- Advanced techniques:
    - FRAP, FRET, FLIM, TIRF
    - Mutant screening and genetic approaches to developmental analysis

Recommended readings

 Molecular Biology of the Cell – Alberts, B. et al. (Garland Science)
 Lehninger Principles of Biochemistry – Nelson, D. L., & Cox, M. M. (W. H. Freeman)
 Biochemistry – Berg, J. M., Tymoczko, J. L., & Stryer, L. (W. H. Freeman)
 Developmental Biology – Gilbert, S. F. (Sinauer)
 Principles of Development – Wolpert, L., & Tickle, C. (Oxford)
 Molecular Genetics of Plant Development – Howell, S. H. (Cambridge)
 Langman's Medical Embryology – Sadler, T. W. (Wolters Kluwer)

GNT 103: Chromosomes, Genes, Genomes 40 marks; 2 credits

Unit 1: Chromatin Structure and Organization

- Molecular organization of chromatin: DNA, histones, nucleosome structure
- Higher-order chromatin organization and packaging
- Functional states of chromatin: euchromatin and heterochromatin
- Chromatin remodeling and epigenetic regulation (overview)
- Introduction to 3D genome organization

Unit 2: Chromosome Organization and Functional Elements

- Structural components of chromosomes:
    - Centromere and kinetochore
    - Telomeres and mechanisms of maintenance
    - Holocentric chromosomes
- Chromosomal domains:
    - Chromatin loops and matrix attachment regions
    - Functional significance of chromosomal domains
- Position effect variegation

Unit 3: Specialized Chromosomes: Structure and functional significance

- Polytene chromosomes
- Lampbrush chromosomes

Unit 4: Cytogenetics of Cell Division

- Overview of mitosis and meiosis
- Molecular mechanisms of meiosis:
    - Synaptonemal complex formation and function
    - Crossing over and chiasmata formation
    - Sister chromatid cohesion and its regulation
    - Chromosome segregation and anaphase movement
- Genetic regulation of meiosis (with examples from yeast)

Unit 5: Chromosomal Variations and Their Consequences

- Numerical changes:
    - Polyploidy and aneuploidy
- Structural changes:
    - Deletion, duplication, inversion, and translocation
- Phenotypic consequences of chromosomal abnormalities

Unit 6: Cytogenetic and Molecular Techniques

- Cell culture techniques:
  - Short-term (lymphocyte) and long-term (fibroblast) cultures
- Karyotyping and chromosome banding techniques
- In situ hybridization:
  - FISH and GISH
  - Chromosome painting
  - Comparative genomic hybridization (CGH)
- Somatic cell hybridization and gene mapping

Unit 7: Concept and Structure of the Gene

- Evolution of the gene concept:
  - Mendelian gene to one gene–one enzyme hypothesis
  - Complementation and cistron concept
- Fine structure of genes:
  - Exons, introns, UTRs
  - Split genes, pseudogenes
  - Overlapping genes and multigene families

Unit 8: Genome Organization and Dynamics

- Viral genome organization
- Bacterial genome organization
- Eukaryotic genome organization:
  - Unique and repetitive DNA sequences
  - Satellite DNA and interspersed repeats
  - LINEs, SINEs, and Alu elements
  - Mitochondrial genome
- Transposable elements:
  - Transposons in bacteria
  - Transposable elements in eukaryotes
  - P elements and hybrid dysgenesis
  - Retrotransposons
- Genome size and complexity:
  - C-value paradox

Recommended Readings

□ Essential Cell Biology: Alberts, B. et al. — Garland Science
□ Molecular Biology of the Cell: Alberts, B. et al. — Garland Science
□ The Eukaryotic Chromosome: Bostock, C. J., & Sumner, A. T. — Elsevier
□ The Chromosome: Heslop-Harrison, J. S., & Flavell, R. B. — Bios Scientific Publishers
□ Advanced Genetic Analysis: Hawley, R. S., & Walker, M. Y. — Blackwell Science
□ Structure and Function of Eukaryotic Chromosomes: Hennig, W. — Springer
□ Lewin's Genes: Lewin, B. — Pearson (Latest edition recommended)
□ Molecular Cell Biology: Lodish, H. et al. — W. H. Freeman
□ Cell and Molecular Biology: De Robertis, E. D. P., & De Robertis, E. M. F. — Lippincott Williams & Wilkins
□ Genomes: Brown, T. A. — Garland Science

GNT 104: Molecular Biology and Genetic Engineering 40marks; 2 credits

Unit 1: Informational Molecules and Central Dogma

- Structure and properties of DNA, RNA, and proteins
- DNA replication:

    - Mechanism of DNA replication in prokaryotes and eukaryotes
    - Replication of mitochondrial DNA
    - Organization and dynamics of the replication fork
    - Replication machinery: helicases, primases, DNA polymerases, ligases, sliding clamps
    - Replication fidelity and errors:
        - Base misincorporation during replication
        - Proofreading activity of DNA polymerases
        - Sources and consequences of replication errors
    - Replication stress and fork dynamics:
        - Causes of replication fork stalling
        - Replication fork reversal and restart
        - Role of recombination proteins and helicases in fork stability
- Transcription:
    - Mechanism of transcription in prokaryotes and eukaryotes
    - Types of RNA
    - RNA secondary structure
    - RNA processing: capping, splicing, and polyadenylation
- Translation:
    - Mechanism of translation in prokaryotes and eukaryotes
    - Genetic code
    - Wobble hypothesis

Unit 2: Protein Targeting, Modification and Degradation

- Protein sorting and intracellular trafficking
- Post-translational modifications (PTMs):
    - Phosphorylation
    - Glycosylation
    - Ubiquitination
    - S-nitrosylation
    - Methylation
    - Acetylation
    - Lipidation
    - Ubiquitin-like modifiers
- Protein degradation pathways:
    - Lysosomal/vacuolar degradation
    - Ubiquitin–proteasome system

Unit 3: DNA Damage and Repair Mechanisms

- Types and sources of DNA damage
- Genome stability and replication-associated damage:
    - Replication-associated DNA lesions
    - Fork collapse and formation of double-strand breaks
    - Relationship between replication stress and genome instability
- DNA repair pathways:
    - Proofreading and mismatch repair
    - Direct repair mechanisms
    - Base excision repair (BER)
    - Nucleotide excision repair (NER)
    - Post-replication repair
    - Translesion synthesis
    - Error-prone repair mechanisms
- Double-strand break repair:
    - Homologous recombination (HR)
    - Non-homologous end joining (NHEJ)
- Recombination repair and its role in maintaining genome integrity

Unit 4: Molecular Analysis of Genes and Gene Products

- Isolation and purification of nucleic acids (genomic and plasmid DNA) and proteins
- Analysis techniques:
    - Agarose gel electrophoresis
    - Polyacrylamide gel electrophoresis
    - Blotting and hybridization techniques
- Molecular cloning:
    - Cloning of DNA or RNA fragments in prokaryotic and eukaryotic systems
    - Enzymes used in molecular cloning:
        - Restriction endonucleases
        - DNA ligases
        - DNA polymerases
        - Kinases
        - Phosphatases
        - Methylases
    - Construction of genomic libraries
    - Construction of cDNA libraries
- DNA analysis techniques:
    - Restriction digestion and mapping
    - RFLP, RAPD, AFLP
- Amplification and gene identification:
    - Polymerase chain reaction (PCR)
    - Primer design
    - 5′ and 3′ RACE
    - Positional cloning
- Sequencing:
    - Sanger method of DNA sequencing
    - Overview of next-generation sequencing technologies

Unit 5: Applications of Recombinant DNA Technology

- Gene delivery methods:
    - Microinjection
    - Electroporation
    - Biolistic method (gene gun)
    - Liposome-mediated delivery
    - Viral-mediated delivery
    - Agrobacterium-mediated transformation
- Products of recombinant DNA technology:
    - Recombinant proteins of therapeutic importance
    - Examples: insulin, human growth hormone
- Overview of applications in medicine, agriculture, and biotechnology

Recommended Readings

□ Molecular Biology of the Cell: Alberts, B. et al. — Garland Science
□ Molecular Cell Biology: Lodish, H. et al. — W. H. Freeman
□ Cell and Molecular Biology: De Robertis, E. D. P., & De Robertis, E. M. F. — Lippincott Williams & Wilkins
□ Advanced Molecular Biology: Twyman, R. M. — Garland Science
□ Recombinant DNA: Genes and Genomes—A Short Course: Watson, J. D. et al. — Macmillan
□ Molecular Biotechnology: Principles and Applications of Recombinant DNA: Glick, B. R. et al. — ASM Press

GNT 105: Experimental Genetics and Laboratory Techniques I (Practical based on theory papers) ~ 90 marks; 12 credits

SECOND SEMESTER

GNT 201: Microbial Genetics and Industrial Biotechnology 40 marks; 2 credits

Unit 1: Fundamentals of Viral Genetics

- Genetic organization and mapping in bacteriophages:
  - Virulent phage: Bacteriophage T4
  - Temperate phage: Bacteriophage λ
  - Single-stranded DNA phage: Bacteriophage ΦX174
- Genetic analysis:
  - Mapping, phenotypes, recombination
  - Fine structure and deletion mapping
- Eukaryotic virus:
  - Human Immunodeficiency Virus (HIV): structure, life cycle, and course of infection

Unit 2: Fundamentals of Bacterial Genetics

- Identification and selection of mutants
- Plasmids:
  - Types, detection, replication, partitioning
  - Copy number control
  - Properties of important plasmids
  - Genetic rearrangements and evolutionary significance
- Gene transfer mechanisms:
  - Transformation:
    - Natural competence and mechanism
    - Gene mapping by transformation
    - Chemical-mediated and electroporation methods
  - Conjugation:
    - Donor strains and compatibility
    - Hfr strains and interrupted mating
    - Temporal mapping
    - F′ (F-prime) heteroduplex analysis
    - Chromosome transfer in bacteria
  - Transduction:
    - Generalized and specialized transduction
    - Gene mapping using transduction
    - Abortive transduction
- Bacterial recombination:
  - Homologous recombination
  - Site-specific recombination
  - Transpositional recombination

Unit 3: Fundamentals of Yeast Genetics

- Life cycle of yeast (Saccharomyces cerevisiae and Schizosaccharomyces pombe)
- Organization of nuclear and organellar genomes
- Mutant isolation and analysis of genetic interactions
- Genetic nomenclature and genome manipulation strategies
- Random spore analysis and complementation
- Heterothallism and mating-type switching
- Gene disruption using plasmids

Unit 4: Microbial Biotechnology

- Industrial microorganisms:
  - Saccharomyces, Aspergillus, Penicillium
- Microbial physiology in industrial processes:
  - Pasteur effect

    - Fermentation and cell growth
    - Regulation of metabolism
    - Substrate utilization and product secretion
- Industrial production:
    - Cheese and lactic acid
    - Antibiotics and vaccines
    - Alcohol and other fermentation products
- Industrial enzymes:
    - Amylases, lipases, proteases
    - Immobilized enzyme technology

Recommended readings

□ Microbial Genetics: Maloy, S. R., Cronan, J. E., & Freifelder, D. — Jones & Bartlett
□ Yeast: Molecular and Cell Biology: Horst, F. — Wiley
□ Modern Microbial Genetics: Streips, U. N., & Yasbin, R. E. — Wiley
□ A Genetic Switch: Phage Lambda Revisited: Ptashne, M. — (Latest edition recommended)
□ Microbial Biotechnology: Principles and Applications: Lee, Y. K. — World Scientific
□ Microbial Biotechnology: Progress and Trends: Harzevili, F. D., & Chen, H. — CRC Press

GNT 202 Regulation of Gene Expression 40 marks; 2 credits

Unit 1: Regulation of Gene Expression in Prokaryotes and Their Viruses

- Basic concepts of gene regulation:
    - Constitutive, inducible, and repressible expression
    - Positive and negative control mechanisms
- Operon models:
    - Lac operon
    - Tryptophan (Trp) operon
    - Arabinose (Ara) operon
    - LUX operon in bioluminescent bacteria
- Quorum sensing:
    - Concept of cell–cell communication in bacteria
    - Autoinducers and density-dependent gene regulation
    - Role of quorum sensing in regulation of LUX operon and other gene networks
- Regulation in bacteriophages:
    - Genetic switch between lysogeny and lytic cycle in Bacteriophage λ
- Translational and post-translational regulation in prokaryotes

Unit 2: Transcriptional Regulation in Eukaryotes

- Spatial and temporal regulation of gene expression
- RNA polymerases and general transcription machinery
- Cis-regulatory elements and transcription factors
- Enhancers, silencers, and promoter architecture

Unit 3: Post-Transcriptional and Translational Regulation

- RNA processing:
    - Alternative splicing
    - 5′ capping and 3′ polyadenylation
- RNA editing:
    - Types of RNA editing (insertion/deletion, substitution editing such as A→I and C→U)
    - Enzymes involved (e.g., ADARs, APOBEC family)
    - Functional consequences of RNA editing in gene expression
- Cytoplasmic control:
    - mRNA stability and degradation
    - mRNA localization
- Translational control mechanisms

- Post-translational regulation of protein activity

Unit 4: Chromatin Organization and Epigenetic Regulation
- Chromatin structure and its role in gene regulation
- Chromatin remodeling and histone modifications
- Long-range gene regulation:
    - Chromatin loops and domains
    - Matrix attachment regions
- Gene expression in specialized chromosomes:
    - Polytene chromosomes (puffs)
    - Lampbrush chromosomes
- Epigenetic mechanisms of gene regulation
- Overview of the ENCODE project

Unit 5: Environmental and RNA-Based Regulation
- Environmental regulation of gene expression:
    - Heat shock response
    - Regulation of photosynthetic genes (e.g., Rubisco)
- RNA interference (RNAi):
    - Mechanism and enzymology
    - RISC complex formation
    - microRNA (miRNA) pathways
- RNA silencing:
    - Role in plant-virus interactions
    - Post-transcriptional gene silencing

Recommended readings

□ Molecular Cell Biology: Lodish, H. et al. — W. H. Freeman
□ The Cell: A Molecular Approach: Cooper, G. M. — Sinauer Associates
□ Molecular Biology of the Cell: Alberts, B. et al. — Garland Science
□ Genomes: Brown, T. A. — Garland Science
□ Human Molecular Genetics: Strachan, T., & Read, A. P. — Garland Science
□ An Introduction to Genetic Analysis: Griffiths, A. J. F. et al. — W. H. Freeman

GNT 203: Immunogenetics 40 marks; 2 credits

Unit 1: Innate Immunity and Its Genetic Basis
- Components of innate immunity:
    - Cells: monocytes/macrophages, dendritic cells, natural killer (NK) cells
    - Pattern recognition receptors (PRRs): TLRs, NLRs, RLRs
- Genetic regulation of innate immune responses
- Inflammation and complement system
- Host–pathogen interactions and innate immune signalling pathways

Unit 2: Adaptive Immunity and Genetic Mechanisms
- B-cell development, activation, and differentiation
- Structure and classes of immunoglobulins
- Genetic organization of immunoglobulin genes
- Generation of antibody diversity:
    - V(D)J recombination
    - Junctional diversity and somatic hypermutation
- Class switch recombination
- T-cell development and differentiation:
    - T-cell receptor (TCR) gene organization and rearrangement

    - Helper T cells (Th) and cytotoxic T cells (Tc)
    - T–B cell cooperation
    - Mechanism of CTL-mediated cytotoxicity

Unit 3: Immune Regulation and Antigen Presentation
- Cytokines and chemokines: genetic regulation and signalling
- Major Histocompatibility Complex (MHC):
    - Structure, organization, and polymorphism
    - HLA diversity and disease association
- Antigen processing and presentation pathways
- Regulation of immune responses and immune tolerance

Unit 4: Clinical Immunogenetics
- Immunodeficiency disorders:
    - Primary (genetic) immunodeficiencies
    - Secondary (acquired) immunodeficiencies
- Autoimmunity and genetic susceptibility
- Transplantation immunology:
    - Graft rejection and HLA matching
- Tumor immunology and immuno-oncology:
    - Immune surveillance
    - Tumor antigens and immune evasion
    - Checkpoint pathways (e.g., PD-1, CTLA-4) (overview)
- Cytokine storm and immune dysregulation syndromes

Unit 5: Vaccines and Immune Modulation
- Principles of vaccine development
- Types of vaccines:
    - Live attenuated, inactivated, subunit, recombinant, mRNA vaccines
- Adjuvants and immune enhancement
- Genetic basis of vaccine response variability
- Immunosuppression:
    - Mechanisms and clinical applications

Unit 6: Plant and Microbial Immunogenetics
- Plant immunity:
    - Innate immune system in plants
    - Pattern-triggered immunity (PTI) and effector-triggered immunity (ETI)
    - Resistance (R) genes and gene-for-gene hypothesis
    - Genetic basis of plant–pathogen interactions
- Pathogen genetics and immune evasion:
    - Antigenic variation
    - Virulence factors and host adaptation
    - Genetic strategies used by pathogens to evade host immunity

Recommended readings

□ Janeway's Immunobiology: Murphy, K., & Weaver, C. — Garland Science
□ Cellular and Molecular Immunology: Abbas, A. K., Lichtman, A. H., & Pillai, S. — Elsevier
□ Kuby Immunology: Goldsby, R. A., Kindt, T. J., & Osborne, B. A. — W. H. Freeman
□ Roitt's Essential Immunology: Roitt, I. M. — Wiley
□ Human Molecular Genetics: Strachan, T., & Read, A. P. — Garland Science
□ Cancer Immunotherapy Principles and Practice: Butterfield, L. H. et al. — Demos Medical
□ Plant Pathology: Agrios, G. N. — Elsevier
□ Plant Immunity: Jones, J. D. G., & Dangl, J. L. — (Annual Reviews / compiled sources)

GNT 204 Quantitative, Population and Statistical Genetics 40 marks; 2 credits

Unit 1: Introduction to Biological Data Analysis

- Types of variables: random and non-random variables
- Data collection and sampling
- Tabulation and graphical representation of data

Unit 2: Statistical Methods in Biology

- Frequency distribution
- Measures of central tendency and dispersion
- Probability distributions:
  - Binomial
  - Poisson
  - Normal (Gaussian)
- Sampling distributions and standard error
- Parametric and non-parametric statistics
- Hypothesis testing:
  - Null and alternative hypotheses
  - Levels of significance and p-values
  - Type I and Type II errors
  - Confidence intervals
- Statistical tests:
  - t-test
  - Chi-square (χ^2) test
  - Fisher's exact test
  - Analysis of variance (ANOVA)
- Correlation and regression
- Introduction to multivariate statistics

Unit 3: Population Genetics

- Population structure and effective population size
- Hardy–Weinberg equilibrium:
  - Allele and genotype frequencies
  - Assumptions and deviations
- Factors affecting allele frequencies:
  - Natural and artificial selection
  - Mutation
  - Migration
  - Genetic drift
- Non-random mating and inbreeding:
  - Inbreeding coefficient
  - Inbreeding depression
- Sex-linked loci and equilibrium
- Linkage and linkage disequilibrium

Unit 4: Genetic Association and Genomic Analysis

- Haplotype structure and frequency estimation
- Association studies:
  - Case–control analysis
  - Genome-wide association studies (GWAS)
  - Epigenome-wide association studies (EWAS)
- Multiple testing and correction methods (e.g., Bonferroni, FDR)
- Genomics and transcriptomics:
  - Microarray and next-generation sequencing (NGS) data
  - Differential gene expression analysis
- Distance metrics and clustering:

- Comparing samples and genes
- Identification of patterns in large datasets

Unit 5: Quantitative Genetics and Molecular Evolution

- Quantitative traits and inheritance
- Genetic and environmental components of variation
- Introduction to QTL mapping strategies
- Molecular phylogenetics:
  - Genetic diversity
  - Genetic distance
  - Measures of relatedness

Unit 6: Computational Tools and Data Analysis

- Use of public domain software/tools for:
  - Chi-square test
  - Fisher's exact test
  - t-test
  - Multiple testing corrections
- Interpretation of statistical outputs in biological research

Recommended readings

□ Biostatistical Analysis: Zar, J. H. — Pearson
□ Introduction to the Practice of Statistics: Moore, D. S., McCabe, G. P., & Craig, B. A. — W. H. Freeman
□ Principles of Population Genetics: Hartl, D. L., & Clark, A. G. — Sinauer Associates
□ Introduction to Quantitative Genetics: Falconer, D. S., & Mackay, T. F. C. — Pearson
□ Genetic Data Analysis: Weir, B. S. — Sinauer Associates
□ Bioinformatics and Functional Genomics: Pevsner, J. — Wiley-Blackwell
□ Introduction to Genomics: Lesk, A. M. — Oxford University Press
□ Statistics for Biology and Health: Everitt, B. S., & Hothorn, T. — Springer

GNT 205: Experimental Genetics and Laboratory Techniques II (Practical based on theory papers) ~ 90 marks; 12 credits

THIRD SEMESTER

The third semester constitutes the coursework component of the research phase of the programme. It is designed to integrate disciplinary knowledge acquired in the first two semesters with advanced experimental, computational and analytical methodologies, thereby preparing students for independent research undertaken in the fourth semester.

GNT 301 Applied Plant Genetics and Biotechnology 35 marks; 2 credits

Unit 1: Cytogenetics in Plant Breeding

- Cytogenetic tools in plant breeding
- Chromosome structure and karyotype analysis in crop plants
- Cytogenetic architecture of major crops:
    - Rice, wheat, oat and other economically important plants

Unit 2: Molecular Markers and Marker-Assisted Breeding

- Molecular markers in plant genetics:
    - Types and applications
- Marker-assisted selection (MAS):
    - Foreground and background selection
    - Concept of graphical genotypes
    - Elimination of linkage drag

Unit 3: Genome Mapping and Mapping Populations

- Development and types of mapping populations
- Linkage map construction:
    - Genetic linkage maps
    - Integrated and comparative maps

Unit 4: Plant Tissue Culture and Somatic Cell Genetics

- Organogenesis and somatic embryogenesis
- Endosperm culture and triploid production
- Anther and pollen culture:
    - Haploid and doubled haploid production
- Protoplast culture and fusion:
    - Somatic hybridization
    - Cybrids and organelle transfer
- Micropropagation and artificial seeds
- Bioreactor technology in plant culture
- Production of virus-free plants (meristem culture)
- Somaclonal and gametoclonal variation
- In vitro mutagenesis and mutant selection
- In vitro conservation of germplasm

Unit 5: Plant Transformation and Genetic Engineering

- Plant transformation vectors:
    - T-DNA vectors and viral vectors
    - Selectable marker genes and reporter genes
- Methods of transformation:
    - Agrobacterium-mediated transformation
    - Direct gene transfer methods (gene gun, electroporation, etc.)
    - In planta transformation
    - Chloroplast transformation
- Molecular mechanism of T-DNA transfer

- Transgene integration, expression, and silencing
- Marker-free and novel selection strategies
- Gene manipulation approaches:
    - Multigene engineering
    - Gene tagging
    - Gene knockdown:
        - Antisense RNA
        - Ribozymes
        - RNA interference (RNAi)
- Positional cloning and comparative genomics

Unit 6: Applications of Plant Transgenic Technology

- Overview of Genetically Modified (GM) Crops:
    - Definition and classification
    - Major GM crops and traits (e.g., Bt crops, herbicide tolerance)
    - Global adoption and current status
- Transgenic crops for:
    - Resistance to biotic and abiotic stresses
- Engineering traits:
    - Male sterility
    - Flowering and flower colour
    - Fruit ripening and senescence
- Nutritional improvement:
    - Biofortification
    - RNAi-mediated crop improvement
- Molecular farming and production of pharmaceuticals
- Metabolic engineering and secondary metabolite production
- Hairy root culture systems
- Biosafety, regulation, and ethical considerations of GM crops

Recommended Reading:

Principles of Plant Breeding: Allard, R. W. — Wiley
□ Plant Breeding Theory and Practice: Stoskopf, N. C., Tomes, D. T., & Christie, B. R. — Westview Press
□ Genome Mapping in Plants: Paterson, A. H. — Academic Press
□ Molecular Markers in Applied Plant Genetics and Biotechnology: de Vienne, D. — INRA Editions
□ Quantitative Genetics, Genomics and Plant Breeding: Kang, M. S. — CABI Publishing
□ Plant Molecular Breeding: Newbury, H. J. — CRC Press

GNT 302 Human Genetics and Translational Genomics 35 marks; 2 credits

Unit 1: Human Genome Organization

- Genes, hereditary traits, mutations, and polymorphisms
- Human Genome Project and its significance
- Organization of the human genome:
    - Repetitive DNA and simple sequence repeats
    - Gene structure: exons, introns, UTRs, regulatory elements
    - Non-coding RNAs
    - Mitochondrial genome

Unit 2: Methods for Identification of Disease Genes

- Mendelian inheritance and pedigree analysis
- Penetrance and expressivity
- Cytogenetic analysis:
    - Karyotyping and chromosomal abnormalities

    - Nucleic acid hybridization and cytogenetic mapping
- Gene mapping approaches:
    - Linkage analysis and LOD scores
    - Physical mapping
- Complex trait analysis:
    - Association studies

Unit 3: Genetic Basis of Human Diseases

- Monogenic disorders:
    - Cystic fibrosis (membrane transport defects)
    - Duchenne and Becker muscular dystrophy (structural protein defects)
    - Collagen disorders (e.g., osteogenesis imperfecta)
- Complex diseases:
    - Coronary heart disease
    - Diabetes
    - Neuropsychiatric disorders
- Genetic heterogeneity:
    - Locus heterogeneity
    - Allelic heterogeneity (inter- and intra-allelic)
    - Phenotypic heterogeneity
- Triplet repeat expansion disorders

Unit 4: Behavioral and Complex Trait Genetics

- Genetic basis of complex human traits
- Gene–environment interactions and heritability
- Polygenic traits and behavioural genetics:
    - Cognitive traits and intelligence
    - Personality traits (e.g., risk-taking, impulsivity)
- Genetics of social and behavioural traits:
    - Musical ability and auditory perception
    - Social behavior: cooperation, trust, and social decision-making
    - Communication traits and language
- Genetics of affective and psychological traits:
    - Happiness and well-being
    - Mood regulation and susceptibility to psychiatric conditions
- Approaches to study behavioral genetics:
    - Twin and adoption studies
    - Genome-wide association studies (GWAS)
    - Polygenic risk scores

Unit 5: From Genetics to Genomics

- Structural, functional, and comparative genomics
- Rationale for whole-genome approaches
- Genomic technologies:
    - Microarray-based gene expression analysis
    - Overview of next-generation sequencing (NGS)

Unit 6: Cancer Genetics and Genome Stability

- Somatic mutations and cancer pathways
- Oncogenes and tumor suppressor genes
- Loss of heterozygosity (LOH)
- Cell cycle regulation and genome stability
- Epithelial–mesenchymal transition (EMT)
- Molecular analysis of gene expression in cancer

Unit 7: Pharmacogenomics and Microbiome Genetics

- Pharmacogenomics:
    - Genetic variation in drug response
    - Individual susceptibility and variability
- Role of human microbiota in health and disease
- Genetic interactions between host and microbiome

Unit 8: Somatic Cell Genetics, Gene Therapy and Stem Cells

- Somatic cell genetics:
    - Use of cell culture to study gene structure, expression, and function
- Gene therapy:
    - Viral vectors (lentiviral and adenoviral systems)
    - Applications in single-gene disorders
    - Safety considerations
- Stem cell biology:
    - Induced pluripotent stem cells (iPSCs)
    - Applications in human genetics and regenerative biology

Unit 9: Epigenetics in Human Health and Disease

- Epigenetic mechanisms:
    - DNA methylation
    - Histone modifications
- Techniques:
    - Bisulfite sequencing
    - Chromatin immunoprecipitation (ChIP-based methods)
    - Genome-wide epigenetic analysis
- Epigenetics in human disease

Unit 10: Human Evolutionary Genetics

- Human evolution and migration:
    - Out-of-Africa hypothesis
- Molecular evolution:
    - Nucleotide and amino acid substitutions
    - Synonymous and non-synonymous changes
- Molecular clock and divergence

Recommended Reading

□ Human Molecular Genetics: Strachan, T., & Read, A. P. — Garland Science
□ Genomes: Brown, T. A. — Wiley-Liss
□ Human Genetics and Translational Genomics: Korf, B. R. — Wiley
□ Medical Genetics: Jorde, L. B., Carey, J. C., & Bamshad, M. J. — Elsevier
□ The Book of Genes and Genomes: Willard, H. F., & Haga, S. B. — Springer
□ An Introduction to Genetic Analysis: Griffiths, A. J. F. et al. — W. H. Freeman

GNT 303 Experimental and Comparative Animal Genetics 25 marks; 1 credit

Unit 1: Genetics of Model Organisms – Drosophila

- Drosophila melanogaster as a genetic model system
- Karyotype and genome organization
- Wild-type and mutant phenotypes
- Genetic analysis:
    - Genetic crosses and mapping
    - Creation of isogenic lines
    - Autosomal linkage analysis
- Functional genetics:

    - Neurogenetics of courtship and mating behavior
    - Natural behavioral variation and its genetic basis
- Immune genetics:
    - Cellular immune response against parasitoids
    - Genetic basis of innate immunity in Drosophila

Unit 2: Genetics of Model Organisms – Caenorhabditis elegans

- C. elegans as a model organism
- Genetic approaches:
    - Mutant isolation and screening
    - Complementation analysis
    - Genetic mapping
- Advanced genetic analysis:
    - Suppressor and enhancer mutations
    - Synthetic lethal mutations
- Functional genetics:
    - Genes affecting nervous system function and behavior
    - Innate immunity in C. elegans

Unit 3: Mammalian Genetics (Non-human Models)

- Mouse as a model organism:
    - Genome organization
    - Inbred strains and genetic standardization
    - Mouse genome databases
- Functional genetics in mammals:
    - Gene knockout and mutant analysis
    - Behavioural genetics (e.g., fosB mutant mice and parental behaviour)
- Comparative genomics:
    - Insights from genome sequencing of diverse mammals (e.g., whale, horse, dog)

Unit 4: Animal Behaviour and Evolution – Genetic Perspectives

- Genetic basis of behaviour:
    - Gene–environment interactions
    - Behavioural traits and their inheritance
- Evolutionary genetics:
    - Speciation (allopatric and sympatric)
    - Gene flow and reproductive isolation
    - Sexual selection and co-evolution
- Introduction to evolutionary game theory
- Zahavi's handicap principle
- Comparative genomics and evolution:
    - Zoonomia project and insights into mammalian evolution and constraint

Recommended Reading

□ Drosophila: A Laboratory Handbook: Ashburner, M. — Cold Spring Harbor Laboratory Press
□ C. elegans: A Practical Approach: Hope, I. A. — Oxford University Press
□ Mouse Genetics: Concepts and Applications:Silver, L. M. — Oxford University Press
□ Principles of Neural Science: Kandel, E. R. et al. — McGraw-Hill
□ Evolution: Futuyma, D. J. — Sinauer Associates
□ Molecular Biology and Evolution: Graur, D., & Li, W.-H. — Sinauer Associates

GNT 304 Bioinformatics and Genomic Data Analysis 25 marks; 1 credit

Unit 1: Biological Databases and Sequence Analysis

- Overview and applications of biological databases

- Major databases:
    - Nucleotide databases: GenBank, EMBL, DDBJ
    - Protein databases
    - Structural databases: Protein Data Bank (PDB)
- Data storage formats:
    - Flat files and relational databases
- Sequence alignment:
    - Local and global alignment
    - Pairwise and multiple sequence alignment
    - Scoring systems and substitution matrices (PAM, BLOSUM)
- Sequence similarity:
    - Homology and analogy
    - Database search tools (BLAST)

Unit 2: High-Throughput Sequencing and Genome Analysis

- Overview of next-generation sequencing (NGS) technologies
- Sequence assembly:
    - Concepts of contigs and scaffolds
    - Assembly strategies for genomic data
- Quality assessment:
    - Quality control of sequencing data
    - Standards for genomic data quality
- Transcriptomics:
    - EST sequencing and clustering
    - Concept of Unigene
    - Overview of differential gene expression analysis

Unit 3: Genome Annotation and Functional Genomics

- Structural annotation:
    - Gene prediction and identification of coding regions
    - Detection of repetitive elements
- Functional annotation:
    - Gene ontology (GO) and functional classification
- Strategies for whole-genome annotation
- Automated annotation pipelines (conceptual overview)

Unit 4: Variant Analysis and Computational Genomics

- Types of genetic variants:
    - SNPs, insertions/deletions, structural variants
- Variant detection:
    - Conceptual overview of variant calling pipelines
- Variant annotation:
    - Coding and non-coding variants
    - Functional classification
- Prediction of pathogenicity:
    - Effects of variants on protein structure and function
    - Role of evolutionary conservation
- Regulatory genomics:
    - Variants in promoters, enhancers, and regulatory regions
    - Prediction of regulatory potential of variants
- Introduction to databases and tools for variant interpretation

Unit 5: Structural and Systems-Level Bioinformatics

- Protein structure prediction:
    - Secondary structure prediction
    - Homology modelling

- Introduction to:
    - Molecular modelling
    - Molecular dynamics
- Integration of genomic and functional datasets
- Systems-level understanding of biological networks (overview)

Recommended Reading:

Bioinformatics and Functional Genomics: Pevsner, J. — Wiley-Blackwell
□ Introduction to Bioinformatics: Mount, D. W. — Cold Spring Harbor Laboratory Press
□ Essential Bioinformatics: Jin, X. — Cambridge University Press
□ Genomes: Brown, T. A. — Garland Science
□ Bioinformatics: Sequence and Genome Analysis: Durbin, R., Eddy, S. R., Krogh, A., & Mitchison, G. — Cambridge University Press
□ Statistical Genomics: Methods and Protocols: Mathé, E., & Davis, S. — Humana Press
□ Human Molecular Genetics: Strachan, T., & Read, A. P. — Garland Science
□ Introduction to Genomics: Lesk, A. M. — Oxford University Press

GNT 305 Experimental and Applied Proteomics 25 marks; 1 credit

Unit 1: The Dynamic Proteome and Its Biological Significance

- Concept of the proteome and its dynamic nature
- Post-translational modifications (PTMs):
    - Types and functional significance
    - Role in cellular processes and signalling
- Experimental and Applied Proteomics in biology:
    - Understanding cellular function and pathophysiology
    - Biomarker discovery and clinical applications
- Integration with genomics:
    - DNA based methods to understand protein function
    - Role of proteomics in functional validation of genes
    - Proteogenomics and systems biology approaches

Unit 2: Protein Separation, Identification and Quantification

- Principles of protein purification and characterization
- Protein separation techniques:
    - One-dimensional and two-dimensional gel electrophoresis
    - Differential gel electrophoresis (DIGE)
- Protein identification:
    - Peptide mass fingerprinting
    - Microsequencing approaches
- Quantitative proteomics:
    - iTRAQ, SILAC and label-based methods
    - Label-free approaches (overview)
- Protein–protein interactions:
    - Yeast two-hybrid system
    - Mammalian systems
- Enrichment of modified proteins

Unit 3: Mass Spectrometry in Experimental and Applied Proteomics

- Principles of mass spectrometry
- Ionization techniques:
    - MALDI-TOF
    - Electrospray ionization (ESI)
- Sample preparation and matrices
- Fragmentation patterns and peptide identification
- Data analysis and interpretation

- Advanced proteomic techniques:
    - SELDI-TOF
    - PF-2D (overview)

Unit 4: Structural Experimental and Applied Proteomics
- Relationship between protein sequence, structure, and function
- Structural analysis techniques:
    - X-ray crystallography
    - Nuclear magnetic resonance (NMR) spectroscopy
    - Circular dichroism (CD)
- Protein folding and conformational dynamics

Unit 5: Experimental and Applied Proteomics in Genomics and Systems Biology
- Role of proteomics in genome annotation
- Integration of proteomic and genomic datasets
- Experimental and Applied Proteomics in:
    - Functional genomics
    - Network biology
    - Disease pathway analysis
- Applications in:
    - Precision medicine
    - Drug target identification

Recommended Reading:

Experimental and Applied Proteomics: From Protein Sequence to Function: Pennington, S. R., & Dunn, M. J. — BIOS Scientific Publishers
□ Introduction to Experimental and Applied Proteomics: Tools for the New Biology: Liebler, D. C. — Humana Press
□ Experimental and Applied Proteomics in Practice: A Guide to Successful Experimental Design: Rehm, B. H. A. — Wiley-VCH
□ Mass Spectrometry: Principles and Applications: de Hoffmann, E., & Stroobant, V. — Wiley
□ Principles of Experimental and Applied Proteomics: Twyman, R. M. — BIOS Scientific Publishers
□ Bioinformatics and Functional Genomics: Pevsner, J. — Wiley-Blackwell
□ Genomes: Brown, T. A. — Garland Science

GNT 306 Translational Biotechnology, Genomic Medicine and Bioethics 25 marks; 1 credit

Unit 1: Animal Cell Culture – Principles and Techniques
- Introduction to animal cell culture
- Primary cultures and established cell lines
- Culture requirements:
    - Composition of culture media
    - Role of carbon dioxide
    - Role of serum and supplements
    - Serum-free and protein-free defined media
- Establishment and maintenance:
    - Disaggregation of tissues and establishment of primary cultures
    - Subculture and maintenance of cell lines
    - Cell separation and sorting
- Growth and characterization:
    - Measurement of cell viability and cytotoxicity
    - Growth kinetics and parameters of cell proliferation
    - Biological characterization of cultured cells
- Advanced techniques:
    - Scaling-up of animal cell cultures

- Cell synchronization
- Cell cloning and micromanipulation
- Cell transformation

Unit 2: Applications of Animal Cell Culture

- Stem cell culture:
  - Embryonic stem cells and their applications
- Cell culture-based production:
  - Vaccines and biologics
- Advanced culture systems:
  - Organ culture and histotypic culture
  - Three-dimensional (3D) cell culture systems
- Measurement of cell death:
  - Apoptosis and its detection

Unit 3: Genetic Engineering of Animals

- In vitro gamete maturation
- In vitro fertilization (IVF) and embryo transfer (ET)
- Assisted reproductive technologies (ART)
- Sex determination and selection:
  - Sex-specific markers
  - Sexing of sperm and embryos
- Cloning and transgenesis:
  - Somatic cell cloning
  - Creation of transgenic animals by microinjection
- Functional genomics approaches:
  - Knockout animals
  - Conditional knockouts using Cre–loxP recombination
  - Use of tissue-specific promoters

Unit 4: Applications in Genomic Medicine

- Animal models in biomedical research
- Transgenic animals for studying human diseases
- Animals as bioreactors:
  - Production of therapeutic proteins
- Genetic engineering for:
  - Improvement of animal production and quality
  - Disease modelling and drug discovery
- Overview of translational applications in genomic medicine

Unit 5: Bioethics, Biosafety and Intellectual Property Rights

- Ethical issues in:
  - Animal experimentation and transgenic animal production
  - Stem cell research and regenerative medicine
  - Assisted reproductive technologies and cloning
- Ethical and social implications of:
  - Gene therapy and genome editing
  - Genetic screening and personalized medicine
- Biosafety and biosecurity:
  - Laboratory safety and regulatory guidelines
  - Regulatory frameworks and guidelines in biotechnology and biomedical research
- Intellectual Property Rights in Biotechnology
  - Patents, copyrights and trademarks
  - IPR issues in genomics, transgenic organisms and pharmaceuticals
  - Technology transfer and commercialization of biotechnology products

Recommended Reading

□ Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications: Freshney, R. I. — Wiley-Blackwell
□ Animal Cell Culture and Technology: Pattnaik, P. K. — Springer
□ Molecular Biotechnology: Principles and Applications of Recombinant DNA: Glick, B. R., Pasternak, J. J., & Patten, C. L. — ASM Press
□ Principles of Gene Manipulation and Genomics: Primrose, S. B., & Twyman, R. M. — Blackwell Publishing
□ Medical Genetics: Jorde, L. B., Carey, J. C., & Bamshad, M. J. — Elsevier
□ Stem Cells: An Insider's Guide: Knoepfler, P. — World Scientific
□ Gene Therapy: Prospective Technology Assessment in Its Societal Context: Friedmann, T. — Elsevier
□ Biomedical Ethics: Mappes, T. A., & DeGrazia, D. — McGraw-Hill

GNT 307: Advanced Experimental Genetics and Research Methodologies (Practical based on theory papers) ~ 80 marks; 12 credits

FOURTH SEMESTER

The fourth semester constitutes the dissertation and independent research component of the programme. It is designed to provide students with comprehensive hands-on experience in conducting original research, encompassing experimental investigations, data generation and analysis, critical review of the relevant literature, scientific interpretation of findings, and scholarly communication.

GNT 401 Research Project, Dissertation and Seminar 250 marks; 12 credits