UNIVERSITY OF CALCUTTA

Notification No. CSR/ 59 /18

It is notified for information of all concerned that the Syndicate in its meeting held on 13.07.2018 (vide Item No.11) approved the Syllabus and Regulations of Two-Year (Four-Semester) M.Sc. Course of Study in Genetics under CBCS in the Post-Graduate Departments of the University and in the affiliated Colleges offering Post-Graduate Courses under this University, as laid down in the accompanying pamphlet.

The above shall be effective from the academic session 2018-2019.

SENATE HOUSE
KOLKATA-700073
The 17th August, 2018

(Debabrata Manna)
Deputy Registrar (Acting)

Syllabus and Regulations

M.Sc. Genetics University of Calcutta

2018

The regulations for the Two-year M.Sc. course in the Department of Genetics

1. ADMISSION CRITERIA: The University of Calcutta shall provide instructions leading towards two year M.Sc. degree. A candidate who has passed the 3-year B.Sc. (Hons.) Examination will be eligible to seek admission to the course as may be approved and notified from time to time by the University. Reservation of seats will be governed by the rules of the University of Calcutta or as mentioned in admission regulations framed by the University time to time. At present, applicants from University of Calcutta will get admission to the sixty percent of seats (Part-A) and forty percent of the seats (Part-B) will be filled up from candidates from both CU and non CU from a common merit list. Non-CU students, however, will have to satisfy the same eligibility criteria applicable to the students of University of Calcutta.

2. EXAMINATION STRUCTURE: The duration of the course shall be two academic years and the examination for the M.Sc. degree shall be held over four semesters over a total of 1000 marks and 80 credits. The duration of the semesters shall be as follows:

1st Semester	**July - December**
2nd Semester	**January - June**
3rd Semester	**July – December**
4th Semester	**January – June**

Examinations would be held after the completion of curriculum at the end of each semester. However, evaluation of the practical will be based on continuous assessment as well as on the final Viva-Voce examination of the students on the experiments.

Examination timing:
Theory
Up to 25 marks: 1 hour
26 to 40 marks: 1.5 hours
41 to 50 marks: 2 hours
51 to 75 marks: 3 hours
76 to 100 marks: 4 hours

Practical examination shall be based on continuous assessment as well as final viva-voce examination to be conducted by internal and/or external examiners

3. FEES STRUCTURE: Monthly and yearly fees to be collected from a student as per academic year July to June. Examination fees and other related fees are payable by the candidates as may be prescribed by university from time to time.

4. ATTENDANCE: A candidate shall be eligible for appearing at the examination provided he/she prosecutes a regular course of studies in the concerned Post Graduate (PG) Department for that semester in the subject and attends at least 65% of the total number of the Theoretical, Practical and Seminars separately held during the semester. A candidate failing to secure pass marks in a specific paper(s) shall not have to attend classes for appearing in the corresponding back paper(s) in a subsequent semester.
Condonable Limit: A student who has attended at least 55% of the classes but less than 65% of the classes shall, however, be eligible to appear in the examination upon payment of condonation fee as may be prescribed by the university from time to time and after obtaining condonation order from the Vice Chancellor.

A candidate who becomes ineligible to appear in a semester examination due to shortage of attendance will have to attend the classes in the corresponding semester of the following academic session by paying prescribed fees.

5. MAXIMUM PERMISSIBLE TIME FOR COMPLETING THE COURSE: Students have to clear the entire course within 4 years from the year of first admission.

6. EXAMINER: Paper setters, moderators, examiners, scrutineers for each paper will be appointed on the recommendations of the Board of Post Graduate studies in the concerned subject. Scripts will be examined by single/multiple examiner(s) for all theory papers and double/multiple (internal and external) for all practical papers, dissertation, viva voce etc.

7. PASSING CRITERIA: A candidate is required to appear at the examination in each and every paper/course/module/part/group of the respective syllabus. A candidate in order to be declared to have passed an examination, must obtain at least 40% marks in each paper/course/module/part/group. In case of a paper/course/module/part/group containing both theoretical and practical portions, a candidate is required to secure at least 35% marks separately in the theoretical and practical portions and at least 40% marks in aggregate in that paper. Candidates shall not be allowed to appear at any higher semester examination without appearing and clearing the minimum number of requisite paper(s) of all the previous semester examinations as mentioned here in after.

8. CRITERIA FOR RE-APPEARING AT SUPPLEMENTARY EXAMINATION: If a student gets 'F' in a particular paper, he/she shall be deemed to have failed in that paper only and shall be required to appear in a supplementary examination to be offered within six months of the original examination. Candidate who fails in one or two papers can clear the paper/s in two more consecutive chances **(excluding the main examination)** along with higher semester examination. If the candidate is unable to clear the same within two consecutive chances, he/she shall be dropped from the concerned course.

A candidate who has **failed** in more than two papers will have to appear at the same semester without appearing at the higher semester. In that case, attendance in the theoretical classes will not be mandatory; however, the candidate has to attend practical classes, considering the evaluation of practical is through continuous assessment. A failed candidate, intending to re-appear in a subsequent semester has to take permission from the concerned Faculty Secretary through the Head of the Department immediately after publication of result.

If all the chances of a candidate (Main + 2) has been exhausted, he/she has to drop or leave the course. He may apply for re-admission in the same course of study in the 1st Semester of the next academic session along with the fresh applicants. In any case, the candidate has to clear the entire course within 4 years from the year of first admission.

9. ABSENT CRITERIA: Failure to fill up the examination form shall be considered as missing a chance and such candidates who have not filed up the examination form shall have to appear at the same semester examination with required attendance. A candidate who has filled up the examination form but remains absent in the entire examination or more than two courses will be considered to have lost a chance and shall be required to re-appear at the same semester examination. A candidate remaining absent in one or two papers/courses but clearing the other papers/courses shall be considered to have failed in those papers/courses in which he remains absent and shall be eligible to clear those as stated above.

10. READMISSION CRITERIA: If a student is dropped from the respective course of study because of his failure to clear a particular course within 4 years, he/she may apply for readmission in the same course of study in the 1st semester of the next academic session along with the fresh applicants.

11. CONSOLIDATED MARK SHEET: After passing all the semesters a candidate may apply for a consolidated mark sheet to the Controller of Examinations upon payment of such fees as prescribed by the university.

12. DATE OF PUBLICATION OF FINAL RESULT: For a regular student who has cleared all the semesters in normal course the date of publication of final result shall be the date of publication of result of the 4th semester. The final date of publication of result for students clearing previous semester(s) subsequent to their clearing 4th semester examination will be **date of publication of the last result clearing all papers.**

13. CALCULATION OF GRADE POINTS, SGPA AND CGPA: The schedule of papers, distribution of marks and credits, for the M.Sc course shall be determined by the concerned department duly approved by the respective Faculty Council/PG Board of studies. Credit-weighted grade point system will be followed and therefore only the grade points but not the overall percentage of marks either in individual paper or in aggregate marks will be provided. The grade points will be given according to the following computation.

Grading of students' performance:
Grade scores will be calculated in a scale of 6 (six) as per the following table:

Marks (%)	Grade Score Brackets	Grade Score added per each additional mark to minimum grade score in the bracket
80-100	5.00 - 6.00	0.05
70-79	4.50 – 4.99	0.05
60-69	4.00 – 4.49	0.05
55-59	3.75 – 3.99	0.05
50-54	3.50 – 3.74	0.05
40-49	3.00 – 3.49	0.05
00-39	Below 3.00	0.075

Award of Grade Points:
For example, if a student scores 53% in theory and 68% in practical in a 3-credit course (2+1), his/her grade point for the course will be as follows:

$$\text{Grade point} = \frac{2x(3.5+0.05x3)+1x(4.0+0.05x8)}{2+1} = 3.90$$

For a credit course with no practical component, for example a 2-credit course, if a student scores say, 56%, then the grade point will be:

$$\text{Grade point} = \frac{2x(3.75+0.05x1)}{2} = 3.80$$

Semester Grade Point Average (SGPA):
The computation of average grade point of a student in a semester will be worked out as follows:

Nth Semester

Course	Credits	Grade Scored
1	3+1	5.65
2	3+1	5.33
3	2+0	3.99
4	2+0	5.05
5	3+1	4.22
6	3+1	4.46

Semester Grade Point Average (SGPA) = 4.836

$$SGPA = \frac{(5.65x4)+(5.33x4)+(3.99x2)+(5.05x2)+(4.22x4)+(4.46x4)}{20} = 4.836$$

Cumulative Grade Point Average (CGPA) over four semesters:
Working out simple average of SGPA obtained over four semesters, cumulative grade point average will be given after four semesters.

Significance of grades:
On the basis of the cumulative results of the student's performance, the following grades will be given in each semester as well as over four semesters.

Grade points	Grades	Class
5.00 - 6.00	Outstanding (O)	First (I)
4.50 – 4.99	Excellent (A+)	First (I)
4.00 – 4.49	Very good (A)	First (I)
3.75 – 3.99	Good (B+)	Second (II)
3.50 – 3.74	Fair (B)	Second (II)
3.00 – 3.49	Satisfactory(C)	Second (II)
Below 3.00	Fail (F)	Fail

If a candidate gets "F" grade in one or more courses/modules/groups in a semester examination, his SGPA in that semester shall be temporarily withheld and GPW (Grade Point Withheld) shall be marked against SGPA on the mark sheet. A fresh mark sheet with duly calculated SGPA shall be issued only when a candidate clears the course subsequently but within the stipulated period.

14. GRACE MARKS: A candidate failing to obtain the pass marks in a semester examination shall be given benefit of one additional mark in the paper in which he/she secured lowest marks and the same shall be shown in the Tabulation Rolls. However, in the mark sheet, only the marks shall be shown after such addition.

A candidate failing to obtain 50% or 55% or 60% marks in the aggregate of all the semesters by one mark only shall be given the benefit of one additional mark in the result of final semester and the same shall be reflected both in the Tabulation Roll as well as in the mark sheet.

15. RANKING: Candidate unable to clear each part of all the semester examinations in one chance shall not be entitled to any position in order of merit. To be eligible for award of rank in order of merit, a candidate must pass all the semesters at first chance as regular candidate.

16. CANCELLATION OF EXAMINATION: Candidates may apply to the Controller of Examinations for cancellation of enrolment of the said examination within fifteen days from the date of completion of theory papers. The said cancelled examination will also be counted as a chance.

17. DIPLOMA: A candidate shall be declared to have obtained the degree of M.Sc (2 year course) shall get a degree certificate in the format specified hereunder (a candidate who has passed his/her undergraduation with honours in B.Sc will get the M.Sc degree)

"This is to certify that _____ obtained the degree of Master of Science in this university in ____ , under semester examination system, the special branch in which he/she was examined having been_____ and that he/she was placed in the class attaining grade_____ ."

Senate house

Dated *Vice Chancellor*

18. CHOICE BASED CREDIT COURSE: A student will have to take two courses from Choice Based Credit Courses (CBCCs) in addition to courses offered by the department. The students will have to choose one course each from two prescribed groups. Each course is of 50 marks and carries 4 credits. No student is allowed to choose the course offered by his/her parent department. Students would be given the opportunity to choose the optional courses on the basis of their M. Sc. 1st semester marks or any process framed by the parent department/university from time to time. Attendance for the optional course would be maintained by the parent departments. Percentage of attendance will be as per University rules.

Orientation of courses in four semesters for M.Sc in Genetics

1st Semester

		Marks	***Credits***
GN C101	Principles of Genetics	40	3
GN C102	Cell and Developmental Biology	40	3
GN C103	Chromosomes, Genes and Genomes	40	3
GN S104	Molecular Biology and Recombinant DNA Technology	40	3
GN C105	Practicals (based on theory papers)	90	8
		160 (Theoretical) + 90 (Practical) = 250	12 (Theoretical) + 8 (Practical) = 20

2nd semester

		Marks	***Credits***
GN C201	Microbial Genetics and Biotechnology	40	3
GN C202	Regulation of Gene Expression	40	3
GN S203	Immunology	25	2
GN S204	Biostatistics	25	2
GN C205	Practicals (based on theory papers)	120	10
		130 (Theoretical) + 120 (Practical) = 250	10 (Theoretical) + 10 (Practical) = 20

3rd Semester

		Marks	***Credits***
GN C301	Plant Genetics and Biotechnology	40	3
GN C302	Human Genetics and Genomics	40	3
GN C303	Practicals (based on theory papers)	45	4
GN S304	Summer Internship	25	2
CBCCA	Choice Based Credit Course A	50	4
CBCCB	Choice Based Credit Course B	50	4
		180 (Theoretical) + 70 (Practical) = 250	14 (Theoretical) + 6 (Practical) = 20

4th Semester

Core courses		***Marks***	***Credits***
GN C401	Animal Genetics and Biotechnology	40	3
GN C402	Quantitative and Statistical Genetics	25	2
GN S403	Proteomics	25	2
GN S404	Bioinformatics	25	2
GN C405	Practicals (based on theory papers)	60	5
GN S406	Review Paper in Genetics	25	2
GN S407	Seminar	25	2
GN C408	Grand Viva	25	2
		115 (Theoretical) + 135 (Practical) = 250	9 (Theoretical) + 11 (Practical) = 20
	Total Marks/Credits	585 (Theoretical) + 415 (Practical) = 1000	45 (Theoretical) +35 (Practical) = 80

Detailed Syllabus for two years M.Sc Course in Genetics, CU - 2018

First Semester

GNC 101: Principles of Genetics~ 40 marks; 3 credits; 40 Lecture hours

Model organisms in genetic analysis:

a) Reproduction as the basis of heredity: Cell Division, evolutionary significance of meiosis

b) Viruses, bacteria, Neurospora, Drosophila, maize, Arabidopsis and human as model genetic organisms [6 lecture hours].

Mendelism and its extensions:

a) Mendel's Laws of Inheritance with examples from plants, Drosophila and human

b) Extensions to Mendelism- co-dominance and incomplete dominance; Epistasis and pleiotropism; lethals and sub-lethals; Multiple alleles-ABO blood groups in humans, Rh blood group incompatibility [8 lecture hours].

Chromosomal basis of heredity:

a) The Chromosome theory of heredity

b) Sex linked, sex-limited and sex-influenced characters, Sex Chromosome and sex determination, dosage compensation of X-linked genes [5 lecture hours]

Chromosome segregation and mapping:

a) Linkage, recombination and crossing over: Crossing over as a measure of genetic distance; Recombination mapping with two-point and three-point test cross, recombination frequency and genetic map distance

b) Detection of linkage in experimental organisms: Tetrad analysis in fungi, balancer chromosome technique to assign a gene to a chromosome in Drosophila, centromere mapping in ordered tetrads in Neurospora, cytogenetic mapping in Drosophila, detection of linked loci by pedigree analysis in humans, the chi square test for linkage, coincidence and interference [15 lecture hours].

Deviation from Mendelism and inheritance of complex trait:

Complex patterns of inheritance, quantitative traits, Inbreeding and resemblance between relatives; Genes and environment [3 lecture hours].

Non-Mendelian inheritance:

Maternal Effect; Cytoplasmic inheritance: mitochondria and chloroplasts, Imprinting [3 lecture hours].

Recommended readings:

1. Concepts of Genetics, Klug WS and Cummings MR – Prentice Hall
2. Genetics: a Conceptual Approach, Pierce BA – Freeman
3. Genetics: Analysis of Genes and Genomes, Hartle DL and Jones EW – Jones and Bartlett
4. Principles of Genetics, Snustad DP and Simmons MJ – John Wiley & Sons
5. An introduction to Genetic Analysis, Griffith AF et al., - Freeman
6. Genetics, Strickberger MW – Prentice Hall

GN C102: Cell and Developmental Biology ~ 40 marks; 3 credits; 40 lecture hours

Origin of life:

a) Haldane's Experiment, origin of biomolecules, primitive life forms
b) RNA world, concept of ribozyme and evolution of enzymes
c) Endosymbiotic origin of mitochondria and chloroplast
d) Law of thermodynamics and sustenance of life [3 lecture hours].

Structure and dynamics of cell membrane:

a) Membrane constituents- phospholipids, glycolipids, cholesterol, membrane proteins, receptors and phospholipases, asymmetrical structure of phospholipid bilayer, fluid mosaic model of random diffusion of membrane components, domains in membrane- natural and artificial membranes,
b) Membrane transport: Ionic basis of membrane excitability; principles of membrane transport; carrier proteins and active membrane transport; ion channels and electrical properties of membranes, Cell junctions and cell adhesion molecules; basement membrane; extracellular matrix [10 lecture hours].

Cell cycle and its regulation:

Cell cycle check points and regulation in *S. cerevisiae* and *S. pombe* [3 lecture hours].

Cell signalling:

G-protein coupled receptors, Tyrosine, Serine, Threonine and Histidine Kinases mediated signalling pathways [3 lecture hours].

Basic concepts of development in plants and animals:

a) Gametogenesis
b) Potency, commitment, specification, determination and differentiation; cell fate and cell lineages; mosaic versus regulative development
c) Fertilization and early development; axis and pattern formation; induction and competence [5 lecture hours]

Developmental genetics in animals:

a) Genes for development in Drosophila: maternal effect genes and zygotic genes, coordinate genes, gap genes, pair-rule genes, segment polarity genes, homeotic genes, HOX genes;
b) Genetic basis of ocular and neural development in Drosophila; programming and reprogramming in development; morphogen gradients and gene regulatory mechanisms. [6 lecture hours]

Developmental genetics in plants:

Approaches to study genes involved in plant development in Arabidopsis and maize; genetic control of phase changes in plant development; juvenile to adult plant; transition to flowering - vegetative to reproductive evocation, floral homeotic mutations in Arabidopsis, Antirrhinum and Petunia, gender expression in monoecious and dioecious plants; pollination and fertilization; gametophytic and sporophytic incompatibility [6 lecture hours]

Techniques to study cellular fine structure and dynamics:

a) Microscopy: Bright field, fluorescent (confocal and deconvolution) and electron microscopy
b) Fractionation, immunoprecipitation, immunolocalization, live cell imaging, flow cytometery; mutant hunts; FRAP, FRET, FLIM, TIRF [4 lecture hours]

Recommended readings

1. Principles of Biochemistry, Lehninger et al., - Freeman
2. Biochemistry, Berg JM, Tymoczko JL and Stryer LT – Freeman
3. Biochemistry, Devlin TM – Wiley-Liss
4. Molecular Genetics of Plant Development, Howell SP – Cambridge
5**.** Developmental Biology of Flowering Plants,V Raghavan - Springer
6. Developmental Genetics and Plant Evolution, Quentin C.B. Cronk, Richard M. Bateman, Julie A. Hawkins - CRC Press
7. Principles of Development, Wolpert L and Tickle C - Oxford
8. Developmental Biology, Gilbert SF, - Sinauer
9. Medical Embryology, TW Sadler – Wolters Kluver Ind Pvt Ltd.

GN C103: Chromosomes, Genes, Genomes ~ 40 marks; 4 credits; 40 lecture hours

Chromatin structure:

a) Histones, DNA, nucleosome morphology and higher level organization;
b) Functional states of chromatin and alterations in chromatin organization [4 lecture hours].

Chromosome organization:

a) Centromere and kinetochore, telomere and its maintenance; Holocentric chromosomes; Heterochromatin and euchromatin, position effect variegation.
b) Chromosomal domains (matrix, loop domains) and their functional significance. [4 lecture hours]

Giant chromosomes:
Polytene and lampbrush chromosomes. [1 lecture hour]

Cytogenetic aspects of cell division:
Overview of mitosis and meiosis, mechanism of meiosis: Formation and function of synaptonemal complex, crossing over and chiasmata formation, sister chromatid cohesion remodeling, regulation of exit from metaphase, chromosome movement at anaphase, genetic control of meiosis with examples from yeast [3 lecture hours].

Chromosomal anomalies: Changes in Chromosome number and structure:
Polyploidy; Aneuploidy; Chromosomal rearrangements - deletion, duplication, inversion, and translocation; Phenotypic effects of chromosome rearrangements [4 lecture hours].

Techniques to study chromosomes:
a) Short term (lymphocyte) and long term (fibroblast) cultures
b) Karyotyping,
c) Chromosome Banding
d) *in situ* hybridization (FISH and GISH), chromosome painting, comparative genome hybridization (CGH),
e) Somatic cell hybrids and gene mapping [6 lecture hours].

Concept of gene:
a) Evolution of the concept of gene: Mendel to Beadle and Tatum; Complementation test as an operational definition of the gene, cistron concept
b) Fine structure of gene: exons, introns, UTRs; Split genes; pseudogenes; overlapping genes and multi-gene families [6 lecture hours]

Genome organization:
a) Viral genome organization
b) Bacterial genome organization
c) Eukaryotic Genome organization; Repetitive DNA-satellite DNAs and interspersed repeated DNAs, LINES, SINES, Alu family, mitochondrial genome
c) Transposable genetic elements, Transposable elements in bacteria; Transposable elements in eukaryotes, P element and Hybrid dysgenesis; Retrotransposons;
b) C-value paradox [12 lecture hours]

Recommended 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 and Summer AT – Elsevier
4. The Chromosome, Hamsew and Flavell Bios
5. Advanced Genetic Analysis, Hawley and Walker – Blackwell
6. Structure and Function of Eukaryotic Chromosomes, Hennig – Springer
7. Genes IX, Lewin B – Pearson
8. Molecular Cell Biology, Lodish H et al., - Freeman
9. Cell and Molecular Biology, De Robertis and De Robertis – Lippincott and Wilkins
10. Genomes, Brown TA - Garland

GN S104: Molecular Biology and Recombinant DNA Technology ~ 40marks; 3 credits; 40 lecture hours

Informational molecules and Central Dogma:

a) Structure of DNA, RNA and protein

b) DNA replication in prokaryotes and eukaryotes; Mitochondrial DNA replication

c) Transcription in prokaryotes and eukaryotes; Types of RNA, RNA secondary structure, capping and polyadenylation

d) Translation in prokaryotes and eukaryotes; Genetic code and wobble hypothesis

e) Protein sorting and transport; Structural and functional aspect of different PTMs (phosphorylation, glycosylation, ubiquitination, S-nitrosylation, methylation, N-acetylation, lipidation, ubiquitin-like modifiers) Protein degradation: vacuolar and proteasomal (including ubiquitination) [20 lecture hours].

Mechanisms of DNA damage repair:

a) Mechanisms of DNA damage

b) Proof reading activity of DNA polymerases, Direct reversal of damaged DNA, Post-replication repair, Error-prone repair, Repair of double-strand breaks, Recombination repair [5 lecture hours].

Molecular Analysis of Genes and gene products:

a) Isolation and purification of nucleic acids (genomic and plasmid) and proteins

b) Analysis of nucleic acids and proteins by gel electrophoresis and Hybridization techniques

c) Molecular cloning of DNA or RNA fragments in bacterial and eukaryotic systems: Enzymes used in molecular cloning: Endonuclease, Kinase, Methylase, Ligase, Polymerase, Phosphatase etc.; Generation of genomic and cDNA libraries

d) Fundamental concepts of Restriction Digestion and mapping; RFLP, RAPD and AFLP;

e) Amplification of nucleic acids, PCR, primer designing, 5’ and 3’ RACE

e) Positional Cloning

f) Methods of DNA and RNA sequencing [12 lecture hours]

Applications of Recombinant DNA Technology:

a) Gene delivery: Microinjection, electroporation, biolistic method (gene gun), liposome and viral-mediated delivery, Agrobacterium - mediated delivery
b) Products of recombinant DNA technology: Products of human therapeutic interest - insulin, hGH [3 lecture hours].

Recommended Readings

1. Molecular Biology of the Cell, Alberts B et al., - Garland
2. Molecular Cell Biology, Lodish H et al., - Freeman
3. Cell and Molecular Biology, De Robertis and De Robertis – Lippincott and Wilkins
4. Advanced Molecular Biology, Richard Twyman - Garland Science
5. Recombinant DNA: Genes and Genomes, A Short Course – Watson JD et al.-Macmillan
6. Molecular Biotechnology: Principles and Applications of Recombinant DNA, Glick BR et al.-ASMScience

GN C105: Practicals (based on theory papers) ~ 90 marks; 8credits

Second Semester

GN C201: Microbial Genetics and Biotechnology ~ 40 marks; 3 credits; 40 lecture hours

Fundamentals of viral genetics

a) Mapping, phenotypes, genetic recombination, genetic fine structure and deletion mapping in Virulent Phage ~ Bacteriophage T4, Temperate Phage ~ Bacteriophage lambda, Bacteriophage ΦX174

b) HIV: a eukaryotic virus ~ Structure, life cycle, course of infection [6 lecture hours]

Fundamentals of bacterial genetics:

a) Identification and selection of mutants

b) Plasmids - types, detection, replication, partitioning, copy-number control, properties of some known plasmids; genetic rearrangements and their evolutionary significance

c) Methods of gene transfer in Bacteria: *Transformation* - natural transformation systems, mechanism, gene mapping by transformation, chemical-mediated and electro-transformation; *Conjugation* - nature of donor strains and compatibility, interrupted mating and temporal mapping, Hfr, F12 heteroduplex analysis, chromosome transfer in other bacteria; gene mapping using conjugation data; *Transduction* - Generalized and specialized transduction; gene mapping by specialized transduction, abortive transduction

d) Bacterial recombination: Models for Homologous, Site specific and Transpositional recombination [15 lecture hours]

Fundamentals of yeast genetics:

a) Life cycle, organization of nuclear and organellar genomes, making mutants and analyzing genetic interactions, genetic nomenclature and genome manipulation strategies, random spore analysis, complementation, heterothallism and mating type switches, gene disruption plasmids in *S. cerevisiae* and *S. pombe* [6 lecture hours]

Microbial Biotechnology

a) Biology of industrial microorganisms ~ Saccharomyces, Aspergillus, Penicillium

b) Idea of Pasteur effect, fermentation, cell growth, regulation of metabolism, substrate assimilation, product secretion

c) Production of cheese, lactic acid, antibiotics, vaccines, alcohol

d) Industrially important enzymes (amylase, lipase, protease) and immobilized enzyme technology [13 lecture hours]

Recommended readings

1. Microbial Genetics, Maloy SR, Cronan JE and Freifelder D – Jones and Bartlett
2. Yeast: Molecular and Cell Biology, Horst – Wiley
3. Modern Microbial Genetics, Streips UN and Yasbin RE – Wiley
4. A Genetic Switch: Phage Lambda Revisited Ptashne M – Kindle edition
5. Microbial Biotechnology: Principles And Applications, Lee KY - World Scientific
6. Microbial Biotechnology: Progress and Trends, Harzevilli and Chen – CRC Press

GN C202 Regulation of Gene Expression ~ 40 marks; 3 credits; 40 lecture hours

Regulation of gene expression in prokaryotes and their viruses:

a) Constitutive, Inducible, and Repressible Gene Expression; Positive and Negative Control of gene expression

b) Operons: Lac, Trp, Ara in Bacteria

c) Switch between lysogeny and lysis in Bacteriophage Lambda

d) Translational control of gene expression and post translational regulatory mechanism [15 lecture hours].

Regulation of Gene expression in Eukaryotes:

a) Spatial and temporal gene regulation of gene expression

b) Transcriptional control: RNA polymerases, cis-elements, transcription factors

c) Post transcriptional control: Alternate splicing, capping and poly-adenylation, RNA –editing, cytoplasmic control of mRNA stability

d) Environmental impact on transcription: Heat shock genes and Rubisco

e) Chromosome organization and long range control: Transcription in lampbrush and polytene chromosomes and chromatin loops, puffs and domains, matrix attachment regions, remodeling of chromatin structure, enhancers, long range and epigenetic control mechanisms, ENCODE project

f) Translational control of gene expression and post translational regulatory mechanism

g) RNA interference: mechanisms and enzymology; RISC complex formation; regulation of gene expression by miRNP pathway; plant-virus interactions and silencing of RNA [25 lecture hours].

Recommended readings

1. Molecular Cell Biology, Lodish H et al., - Freeman
2. The Cell: A Molecular Approach, Cooper GM - Sinauer
3. Molecular Biology of the Cell, Alberts B et al., - Garland
4. Genomes, Brown TA – Garland
5. Human Molecular Genetics, Strachan T and Read AP – Garland Science
6. Modern Genetic Analysis, Griffiths AJF et al., - Freeman

7. Biochemistry Berg JM, Tymoczko JL and Stryer L – Freeman

GN S203: Immunology ~ 25 marks; 2 credit; 25 lecture hours

Innate immunity:

Cells (monocytes/macrophages; dendritic cells; NK cells) and organs of the innate immune system; Inflammation; complements [6 lecture hours].

Acquired immunity:

a) B cells maturation, activation and differentiation; Immunoglobulin, subclasses, immunoglobulin genes, generation of antibody diversity, VDJ recombination; Antibody Class switching

b) T-cell maturation, T_H and T_c activation and differentiation; T-B cooperation; CTL-mediated target cell killing [8 lecture hours].

Immune Mechanisms:

Cytokines; Major Histocompatibility Complex; antigen processing and presentation [5 lecture hours].

Clinical Immunology:

Inherited and acquired immunodeficiency disorders; Tolerance and autoimmunity; Transplantation and Tumor Immunology [6 lecture hours].

Recommended readings

1. Essential Immunology, Roitt IM - Wiley
2. Kuby Immunology, Goldsby RA, Kindt TJ and Osborne BA - Freeman

GN S204 Biostatistics ~ 25 marks; 2 credit; 25 lecture hours

Introduction to Biological Data analysis: Random and non-random variables; Collection, tabulation and representation of data (graphical and tabular) [2 lecture hours]

Statistical Methods: Frequency distribution, measures of central tendency and dispersion; Probability distributions (Binomial, Poisson and Gaussian); Sampling distribution; Difference between parametric and non-parametric statistics; Confidence Interval; Errors; Levels of significance; Regression and Correlation; t-test; X2 test; Analysis of variance; Basic introduction to Multivariate statistics [23 lecture hours]

Recommended readings

1. Biostatistics, Daniel WW- Wiley
2. Statistical methods in Biology, Bailey NTJ – Cambridge Univ. Press

GN C205: Practicals (based on theory papers) ~ 120 marks; 10 credits

Third Semester

GN C301 Plant Genetics and Biotechnology ~ 40 marks; 3 credits; 40 lecture hours

Cytogenetic tools in Plant breeding

Cytogenetic architecture of rice, wheat, oat and other crops [3 lecture hours].

Marker assisted breeding:

Molecular markers as new efficient tools in breeding, marker aided selection – foreground and background selection, concept of graphical genotypes, elimination of linkage drags. [7 lecture hours].

Molecular markers for genome mapping:

Development and choice of mapping populations, linkage map construction – relational, integrated and comparative maps. [6 lecture hours].

Plant tissue culture and somatic cell genetics:

Organogenesis and Somatic embryogenesis; Endosperm culture and triploid production; Anther and pollen culture, production of haploid and doubled haploid plants; Protoplast culture and fusion, Somatic hybrids; Organelle transfer and cybrids; Micropropagation, artificial seed and bioreactor technology, Virus-free plants by meristem culture; Use of somaclonal and gametoclonal variation for crop improvement; In vitro mutagenesis and mutant selection; Preservation of plant germ plasm *in-vitro*. [6 lecture hours].

Plant transformation vectors and methods:

a) Plant transformation vectors - T-DNA and viral vectors, direct gene transfer vectors; Selectable marker and reporter genes

b) Plant transformation by Agrobacterium sp., non-Agrobacterium sp., and in planta transformation, c) Molecular mechanism of T-DNA transfer; Direct gene transfer methods in plants - Gene gun and other methods; Chloroplast transformation; Transgene analysis, silencing and targeting;

c) Marker-free and novel selection strategies

d) Multigene engineering; Gene tagging; Gene knock-down by ribozymes, antisense RNA and RNA interference.

e) Comparative genomics and cloning, positional cloning [10 lecture hours].

Applications of plant transgenic technology:

a) Transgenic crops for resistance against biotic and abiotic stresses;

b) Engineering crops for male sterility and modification of flower colour, flowering, fruit ripening and senescence

c) GM crops for nutritional quality and quantity; RNAi-mediated crop improvement; Molecular pharming; Metabolic engineering and hairy root culture for secondary plant products; Global status and biosafety of transgenic plants [8 lecture hours].

Recommended readings

1. Principles of Plant Breeding, Allard RW – Wiley
2. Plant Breeding Theory and Practice, Stoskopf NC, Tomes DT and Christie BR – Westview Press
3. Genome Mapping in Plants, Paterson AH – Academic Press
4. Molecular markers in Plant Genetics and Biotechnology, Vienne D – INRA
5. Quantitative Genetics, Genomics and Plant Breeding, Kang MS – CABI Publishing
6. Plant Molecular Breeding, Newbury HJ – CRC Press

GN C302: Human Genetics and Genomics *~ 40 marks; 3 credits; 40 lecture hours*

History and Development of Human Genetics

Genes, Hereditary traits, Genetic Disease, Mutations and polymorphisms, Human Genome Project [2 lecture hours].

Organization of Human Genome:

Repetitive DNA in Human Genome, Simple sequence repeat loci; Intron, exon, UTR, regulatory sequence, non-coding RNAs, mitochondrial genome [3 lecture hours].

Identification of disease gene/locus: Methods of Genetic Study in Human

a) Mendelian pedigree pattern and analysis, Penetrance and Expressivity
b) Chromosomal Basis of Genetic Disorders: Chromosomal Analysis, Karyotypes and identification of chromosome variation; Nucleic Acid Hybridization Assays, cytogenetic mapping
c) Single gene disorders: Genetic mapping and LOD score; Physical mapping,
d) Complex diseases and association study [7 lecture hours].

Genetic Factors in common Diseases and techniques needed to decipher those:

a) Congenital defects: Coronary heart disease; Late onset disease: diabetes, mental diseases, Defects in membrane Transport: Cystic Fibrosis; Defects in structural proteins: DMD and BMD; collagen disorders: Osteogenesis Imperfecta;
b) Locus Heterogeneity; Inter-allelic and intra-allelic heterogeneity; phenotypic heterogenity
c)Genetics of triplet repeat disorders [8 lecture hours].

Transition from Genetics to Genomics:

Structural, Functional and Comparative Genomics; Need to study whole genome [1 lecture hour].

Cancer Genetics:

Somatic Mutations and affected pathways, Oncogenes and TSGs, LOH, Control of Cell Cycle, Epithelial mesenchymal transition; Control of Genome stability, methods to study alterations of gene expression in cancer (through Microarray) [4 lecture hours].

Pharmacogenomics:

Microbiota shaping human traits and diseases; Effects of drugs in individual and susceptibility; personalized medicine [2 lecture hours].

Somatic Cell Genetics

Studying Human Gene structure, Expression and function using cell culture [2 lecture hours].

Gene Therapy:

Lentiviral and adenoviral vectors for correction of single gene disorders; trials in animal models of human disease; safety concerns in clinical applications [1 lecture hour].

Stem Cell Research:

Induced pleuripotent stem cells in human genetics research; stem cells as agents for propagation of vectors used in gene therapy [1 lecture hour]

Genetic Counseling and Ethics:

Genetic screening and pre-implantation genetic diagnosis; Clinical, psychosocial and ethical aspects of human genetics research; case studies Carrier detection, Forensic studies and paternity testing; Cord blood banking, New born screening in genetic disorders, genome editing [3 lecture hours]

Epigenetics

a) Overview of epigenetic inheritance with regard to DNA and histone modifications,
b) Techniques to study epigenetic mechanisms such as restriction landmark genome scanning, sodium bisulphite based DNA sequencing, chromatin immunoprecipitation coupled microarrays; epigenetic phenomena in human disease [3 lecture hours]

Human Evolutionary Genetics:

Human migration and out of Africa hypothesis; Molecular Evolution-amino acids and nucleotide substitutions, synonymous codon; Molecular divergence and molecular clock [3 lecture hours]

Recommended readings

1. Human Molecular Genetics, Strachan T and Read AP – Garland Science
2. Genomes, Brown TA – Wiley Liss
3. Human Genetics and Genomics, Korf BR - Wiley
4. The Book of Genes and Genomes, Willard and Haga, - Springer
5. Modern Genetic Analysis, Griffiths AJF, Gelbart WM, Miller JH et al., - Freeman
6. An Introduction to Genetic Analysis, Griffiths AJF, Miller JH, Suzuki DT et al., - Freeman

GN C303: Practicals (based on theory papers) ~ 45 marks; 4 credits

GN S304: Summer Internship~ 25 marks; 2 credits

A project performance report based on the summer research training in a reputed laboratory of excellence will have to be submitted. A presentation of the accomplishments will be required, before a panel of experts. Evaluation will be based on the project report and the presentation.

CBCC A: Choice Based Credit Course A ~ 50 marks; 4 credits, 50 lecture hours

CBCC B: Choice Based Credit Course B ~ 50 marks; 4 credits, 50 lecture hours

Fourth Semester

GN C401: Animal Genetics and Biotechnology ~ 40 marks; 3 credits; 40 lecture hours

Animal Genetics

Drosophila Genetics:

Drosophila karyotype and genome: wild type and mutants, Genetic crosses, creation of isogenic lines, Autosomal linkage.

Immunogenetic aspects of the cellular immune response of Drosophila against parasitoids.

Neurogenetics of courtship and mating in Drosophila.

Natural behavioral variants of Drosophila.

C. elegans genetics:

Isolation, complementation and mapping of mutants of *C. elegans* with special reference to screening for suppressor/enhancer mutations and synthetic lethal mutations.

Genes affecting nervous system function and behavior.

C. elegans as a model to study innate immunity.

Mammalian genetics (non-human)

Mouse as a model mammalian genome; establishment of inbred strains; mouse genome database.

Revelations of the genome sequencing of whales and horses.

Genes and environment coming together to shape animal behavior ~ chimpanzee as a model.

Parental Behavior and fosB Mutant Mice.

Behavioral Traits in Breeds of Hunting Dogs.

Environment, Genetics and Cognitive Development.

Adaptive radiation Isolating mechanisms; Speciation-allopatric and sympatric, convergent evolution; sexual selection and gene flow, co-evolution.

Evolutionary Game Theory, Zahavi's hypothesis [20 lecture hours].

Animal Biotechnology

Cell culture technology and its applications: Introduction to animal cell culture technology; Primary and established cell line cultures; cell culture media; Role of carbon dioxide; Role of serum and supplements. Serum & protein free defined media and their application; Measurement of viability and cytotoxicity; Biology and characterization of the cultured cells; measuring parameters of growth.

Basic techniques of mammalian cell culture *in vitro*: disaggregation of tissue and primary culture, maintenance of cell culture; cell separation; scaling-up of animal cell culture; cell synchronization; cell cloning and micromanipulation; cell transformation.

Application of animal cell culture: Stem cell culture, embryonic stem cells and their applications; Cell culture based vaccines; Organ and histotypic cultures; Measurement of cell death: Apoptosis, three dimensional culture.

Genetic engineering of animals: *in vitro* gamete maturation. *In vitro* fertilization (IVF) and embryo transfer (ET), Sex determination or sex specific makers, sexing of sperm and embryos, Assisted reproductive technology (ART).
Somatic cloning of animals; Creation of transgenic animals: microinjection technology; Improvements of animal production and quality using transgenic approach with specific examples. Animals as bioreactors: Genetically engineered animals for research. Knock-out animals. Conditional knock outs using cre-loxP recombination; tissue specific promoters [20 lecture hours].

Recommended readings

1. Genetics, Strickberger MW - Garland
2. C. elegans II, Riddle DL, Blumenthal T, Meyer BJ, Priess JR – Cold Spring Harbor Press
3. Mouse Genetics and Transgenics: A Practical Approach, Jackson IJ and Abott CM – Oxford
4. Culture of Animal Cells: A manual of basic techniques and specialized applications, Freshney IR – Wiley-Blackwell

GN C402: Quantitative and Statistical Genetics ~25 marks; 2 credits; 25 lecture hours

Population Genetics and Association Mapping: Population structure and effective population size; Hardy-Weinberg Equilibrium: Allele and genotype frequency measurements, Random and non-random mating, inbreeding depression and inbreeding co-efficients; causes of changes in allele frequency through natural selection/artificial selection; migration and random genetic drift; equilibrium at sex-linked loci; Linkage and Linkage Disequillibrium; Haplotype frequency estimation with unphased genotypes; genetic association and multiple testing corrections; Case-control association analyses and Genome-wide association studies (GWAS and EWAS) [11 lecture hours].

Quantitative Genetics and QTL mapping: Quantitative traits and loci; QTL mapping strategies [3 lecture hours].

Molecular Phylogenetics: Genetic diversity, genetic distance and measures of relatedness [3 lecture hours].

Genomics and transcriptomics data analysis: Microarray and next generation sequencing technologies; various distance metrics for comparing samples and comparing genes; usefulness of clustering for identifying inherent groups in a dataset; differential gene expression [5 lecture hours]

Usage of public domain softwares: Hypothesis testing by Chi square, Fischer's exact test, T-test; multiple testing corrections [3 lecture hours].

Recommended readings

1. Statistical Genetics: Linkage, Mapping and QTL analysis, Ben Hui Liu – CRC Press

2. Statistical Genetics: Gene Mapping Through Linkage and Association, ed. By B Neale, M Ferreira, S Medland, D Posthuma – Taylor Francis
3. The Fundamentals of Modern Statistical Genetics NM Lairdand, C Lange - Springer
4. Computational Molecular Evolution, Z Yang, 2006, Oxford University Press.

GN S403- Proteomics ~ 25 marks; 2 credits; 25 lecture hours

The dynamic proteome: Protein modifications and their importance in cell functions; proteomes and an overview of their importance in studying cellular pathophysiology and biomarker discovery and applications [5 lecture hours]

Overview of proteome analysis: Basic principles of protein purification, separation and characterization; 2D Gel-electrophoresis, tryptic fingerprinting followed by microsequencing, Protein-protein interactions*:* Yeast two hybrid and mammalian cell hybrids*,* and techniques for enrichment of modified proteins; DIGE, *SELDI-TOF, iTRAQ,SILAC, PF-2D, ESI ~ Sample* preparation and data analysis.

Principles of Mass spectroscopy, MALDI-TOF ~ *sample* preparation, types of matrices, fragmentation patterns and data analysis, structural proteomics [15 lecture hours].

Concepts in structural proteomics: Protein sequence, fold and function; Basic idea of X-ray crystallography, Circular Dichroism and Nuclear Magnetic Resonance [5 lecture hours]

Recommended readings

1. Introduction to Proteomics, Liebler DC – Humana Press
2. Introduction to Proteomics: Principles and Applications, Mishra NC - Wiley
3. Proteomics: Human Diseases and Protein Functions, Man TK and Flores RJ
4. Genomics, Proteomics and Bioinformatics, Yu J - Elsevier
5. Molecular Biology, Friefelder D

GN S404 - Bioinformatics ~ 25 marks; 2 credits; 25 lecture hours

Biological Databases: Overview, Applications, Prospects; Modes of database search, data storage (flat file, db-tables); Gene and protein sequence databases; GenBank, EMBL, DDBJ, PDB; access to sequence databases via internet [3 lecture hours]

Sequence alignment and sequence analysis: Concept of local and global sequence alignment, Pairwise sequence alignment, scoring an alignment, substitutional matrices, Pattern recognition, BLAST; Multiple sequence alignment, homology, analogy (ClustalW, T-Coffee, GeneDoc) [6 lecture hours]

Generation and analysis of high through-put sequence data: Assembly pipeline for clustering of HTGS data, format of '.ace' file, quality assessment of genomic assemblies, International norms for sequence data quality, Clustering of EST sequences, concept of Unigene; Sequence assembly, Staden package; assembly strategies for next generation sequencing [6 lecture hours]

Automated sequence analysis and annotation pipelines (MAGPIE, Blujay); Annotation procedures for high through-put sequence data: Identification of various genomic elements (Protein coding genes, repeat elements, Strategies for annotation of whole genome, functional annotation of EST cluster, gene ontology (GO) consortium. [6 lecture hours]

Higher order structure prediction: Secondary structure prediction, Homology Model, Molecular simulation and dynamics [4 lecture hours]

Recommended readings

1. Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins, Baxevanis AD and Ouellette – Wiley
2. Bioinformatics Sequence and Genome Analysis, Mount DW – CSHL
3. Introduction to Bioinformatics, Tramontano A – Chapman and Hall
4. Understanding Bioinformatics, Zvelebil M and Baum JO – Taylor and Francis

GN C405: Practicals (based on theory papers) ~ 60 marks; 5 credits

GN S406: Review Paper in Genetics ~25 marks; 4 credits

Students will be required to select a seminal topic in Genetics, gather information on the same from library or web based resources, prepare and submit a Review Paper. A panel of examiners shall evaluate the Review Paper.

GN S407: Seminar ~25 marks; 2 credits

The students will be required to give a seminar based on a published paper. A panel of examiners shall evaluate the work performed and the presentation.

GN C408: Grand Viva ~25 marks; 2 credits

Students will be evaluated on all topics discussed in two years program by a panel of experts.

CBCC offered by Department of Genetics.

Human Genetics: Concepts and Paradigms

1. Traits of interest

Inheritance pattern of Mendelian and complex trait: pigmentation, intelligence and creativity as models of complex trait; Microbiota shaping human traits.

2. Clinical Genetics and Genetic disorders

a) Concept of mutation and polymorphism

b) Single gene vs complex disorder: Cystic Fibrosis, Beta-thalassemia, ADHD, Haemophilia as models

c) Gene-environment interplay in diseases: cancer as model

d) Genetic variations and susceptibility of horizontal disease: Malaria as a case study.

3. Population Genetics and Evolution

a) Concepts of allele frequency, genotype frequency, HW equilibrium and genetic drift;

b) Human migration and 'Out of Africa' hypothesis and evolution of *Homo sapiens*.

4. Immunogenetics and Network Ecology

Evolution of genes involved in immune response to parasites; Genetics of diseases resistance.

5. Pharmacogenetics

Concept of personalized medicine.

6. Tools in human genetic research

a) PCR-sequencing based screening of disease genes; association study; Microarray analysis; b) Gene therapy, gene editing and gene replacement therapy;

c) Study of database in relation to human disorders: OMIM as a model.

7. Genetics and Society

a) Genetic counseling and risk assessment; Carrier detection

b) IVF and stem cell genetics

c) Forensic studies and paternity testing; Cord blood banking, New born screening in genetic disorders.

8. Community Genetics and legal issues

Ethics in genetic research; Case studies.

9. Genetic models of human diseases

Disease Models in *Drosophila melanogaster* and the role of the fly in therapeutic drug discovery; Humanized mice; Canine model of eye disorders].

10. Epigenetics

Methylation and histone modification in causation of disorders; Inheritance of fear as a case study.