MSc (Human Disease Genetics)

A course-outline submitted by
Centre for Human Genetics

To

Bangalore University

July 2018
Outline of the MSC course in ‘Human Disease Genetics’

ADMISSIONS

CHG conducts an admission process, detailed below, which has been followed since the institute's MSc programme was initiated in 2015, with the concurrence of the Government of Karnataka and the Governing Body of the institute.

Eligibility
1. The student is required to obtain at least 50% in his/her Bachelor's programme overall.
2. Bachelor’s degree in any branch of science/technology/medicine (with degrees such as BSc, BE, BTech, BPharm, MBBS, BDS, BVSc and BAMS)
3. The eligible subject areas are: Life sciences (zoology, botany, genetics, human biology, general life sciences, ecology, environmental biology), bioinformatics, biotechnology, chemistry, physics, mathematics, statistics, any branch of engineering, pharmaceutical sciences, agriculture, medicine, dentistry, horticulture, forestry and veterinary sciences.
4. There is no age bar for applying.
5. Applicants who have had a break in their education or have been working for a few years are also eligible.

Entrance Test

CHG conducts a national level online entrance test.
It is an objective type test (without negative marking). The syllabus for the test is basic physics, maths, chemistry, biology and English language comprehension.

Interview

Students are called for a personal interview based on the cut off marks in the entrance test.
Approximately 60 students are called for the interview.
The interview is held at CHG in Bangalore.
Interviews of students through Skype call is allowed.

Admission Score
1. The Admission Score is based on the interview and the candidate's previous academic performance.
2. The interview contributes 50% to the Admission Score.
3. An average of the candidate's marks secured in 10th, 12th and the Bachelor's degree contributes to the remaining 50% of the Admission Score.

Reservation Policy

The reservation policy applicable in Karnataka is followed.

Fee Structure

The fee structure of the institute will be decided in consultation with the University.

SCHEME OF EVALUATION

Theory
1. Each theory course will be evaluated by both internal assessment (30%) and final assessment (70%).
2. Two internal assessments will be conducted for each 4 credit theory course and one internal assessment for each 2 credit theory course. Internal assessments will consist of tests/seminars/assignments or can be based on class participation.
3. For the hard core theory course HDG11 and the soft core course HDG16, the final assessment will be based on essays (two essays of 2500 and 1000 words each or one essay of 3000 to 4000 words) submitted by each student. Details of the final assessment for the remaining theory courses are mentioned below.
4. A minimum attendance of 75% is compulsory for every theory course.

Laboratory
1. Each practical course will be evaluated by both internal assessment (30%) and final assessment (70%).
2. The internal assessment will be as follows: For the 4–credit practical courses, 20 marks will assigned for the record and 10 for laboratory participation/assignments. For course HDGP2, which is a 2 credit laboratory course, 10 marks will be allotted for the record and 5 for laboratory participation/assignments.
3. For HDGP4, 7 and 10 'dry lab' courses where there are no records, internal assessment will be conducted in the form of assignments.
4. For HDGP10 the final exam will involve a sitting at a clinical session, followed by solving of problems. Details of the final assessments for the remaining laboratory courses are mentioned below.
5. A minimum attendance of 75% is compulsory for every laboratory course.

**Term paper**
1. The term paper will be researched and written individually.
2. The topic will be allotted during semester III to facilitate students to initiate it during the semester break and continue during semester IV.
3. Faculty members of CHG will serve as guides.
4. This course in writing will be evaluated both by internal assessment (30%) and final assessment (70%).
5. The internal assessment will be as follows: the first assessment for 15 marks will be conducted by the guide, based on his/her interactions with the student. The second assessment for 15 marks will be based on a presentation on the proposed plan of the paper judged by a minimum of three CHG faculty members.
6. The term paper will be evaluated by two examiners from CHG for 70 marks.

**Research methodology paper**
1. The research methodology paper will be written and submitted by the end of the semester III and will comprise a research proposal on the project work that the student intends to undertake during the fourth semester.
2. It will be written individually.
3. Faculty members of CHG will serve as guides.
4. Students may wish to conduct the research in collaboration with other research institutes, start-ups or larger companies. In these cases, representatives from these other institutions could serve as co-guides.
5. This course will be evaluated both by internal assessment (30%) and final assessment (70%).
6. The internal assessment will be as follows: 15 marks for a presentation on the research proposal judged by a minimum of three CHG faculty members.
7. The research proposal will be evaluated by two examiners from CHG for 35 marks. In the event that the student is guided by more than one faculty member of CHG, or by representatives from other institutions, the research proposal will be evaluated separately by all guides and an additional faculty member from CHG.

**Project work**
1. Project work will be carried out individually.
2. Projects will be allotted by the end of semester II. Some preliminary work may be carried out during semester III, to aid in the writing of the research methodology paper.
3. In-house projects are preferred.
4. Faculty members of CHG will serve as guides.
5. Students may be allowed to carry out the project work in collaboration with other research institutes, start-ups or larger companies.
6. Co-guides from the collaborating institution/company are allowed.
7. Internal assessment on project work will be made by the guide/s for 30 marks and will be based on the student’s day to day performance in the laboratory.
8. The dissertation will be evaluated by two examiners from CHG for 70 marks.
9. The project viva voce examination will be held at CHG by a minimum of three faculty members for 50 marks (35 marks for the presentation and 15 marks for the viva voce).
### SCHEME OF FINAL THEORY EXAMINATION

(Hard Core – 4 credits)

<table>
<thead>
<tr>
<th>Time 3 Hours</th>
<th>Max. Marks 70</th>
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<tbody>
<tr>
<td><strong>Section A</strong>&lt;br&gt;Answer the following objective type questions (10/12)</td>
<td>10 x 1 =10</td>
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<tr>
<td><strong>Section B</strong>&lt;br&gt;Answer the following short answer type questions (10/12)</td>
<td>10 x 2 = 20</td>
</tr>
<tr>
<td><strong>Section C</strong>&lt;br&gt;Answer the following long answer type questions (8/10)</td>
<td>8 x 5 = 40</td>
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### SCHEME OF FINAL THEORY EXAMINATION

(Soft Core – 2 credits or Hard Core – 2 credits)

<table>
<thead>
<tr>
<th>Time 2 Hours</th>
<th>Max. Marks 35</th>
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<tbody>
<tr>
<td><strong>Section A</strong>&lt;br&gt;Answer the following objective type questions (5/6)</td>
<td>5 x 1 =05</td>
</tr>
<tr>
<td><strong>Section B</strong>&lt;br&gt;Answer the following short answer type questions (5/6)</td>
<td>5 x 2 = 10</td>
</tr>
<tr>
<td><strong>Section C</strong>&lt;br&gt;Answer the following long answer type questions (4/5)</td>
<td>4 x 5 = 20</td>
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### SCHEME OF FINAL PRACTICAL EXAMINATION

(For courses HDGP1, HDGP3, HDGP5, HDGP6 and HDGP9)

<table>
<thead>
<tr>
<th>Experiment type</th>
<th>Marks (70)</th>
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<tbody>
<tr>
<td>Major Experiment/s</td>
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<tr>
<td>Minor Experiment/s</td>
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<tr>
<td>Viva voce</td>
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### SCHEME OF FINAL PRACTICAL EXAMINATION

(For course HDGP2)

<table>
<thead>
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<td>Minor Experiment/s</td>
<td>10</td>
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<tr>
<td>Viva voce</td>
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### SCHEME OF FINAL PRACTICAL EXAMINATION

(For courses HDGP4, HDGP7 and HDGP10)

<table>
<thead>
<tr>
<th>Experiment type</th>
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<tbody>
<tr>
<td>Major problem/s or code/s</td>
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</tr>
<tr>
<td>Minor problem/s or code/s</td>
<td>10</td>
</tr>
<tr>
<td>Viva voce</td>
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# M.Sc. (Human Disease Genetics) (CBCS)
Effective from the academic year 2018-2019

## SCHEME OF INSTRUCTION AND EXAMINATION, SEMESTER SYSTEM

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course title</th>
<th>Course Type</th>
<th>Hours/week</th>
<th>Duration of Exam (hrs)</th>
<th>Marks</th>
<th>Total</th>
<th>Credits</th>
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<tbody>
<tr>
<td>HDG01</td>
<td>Fundamentals of Genetics</td>
<td>Theory, H Core</td>
<td>2</td>
<td>2</td>
<td>15</td>
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<td>50</td>
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<td>HDG02</td>
<td>Human cytogenetics</td>
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<td>Biostatistics</td>
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<td>35</td>
<td>50</td>
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<td>HDG04</td>
<td>Human Embryology, Anatomy and Physiology</td>
<td>Theory, H Core</td>
<td>4</td>
<td>3</td>
<td>30</td>
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<td>100</td>
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<td>HDGP1</td>
<td>Lab Module I – Genetics</td>
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<td>8</td>
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<td>HDGP2</td>
<td>Lab Module II – Basic cell immortalization techniques</td>
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<td>HDGP3</td>
<td>Lab Module III – Human cytogenetics</td>
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<td>HDGP4</td>
<td>Lab Module IV – Biostatistics and programing in R</td>
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<td>Science writing and presentation</td>
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**Total hours of instruction/week** 37  
**Total credits** 24

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course title</th>
<th>Course Type</th>
<th>Hours/week</th>
<th>Duration of Exam (hrs)</th>
<th>Marks</th>
<th>Total</th>
<th>Credits</th>
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<tbody>
<tr>
<td>HDG06</td>
<td>Biochemistry</td>
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<td>HDG07</td>
<td>Molecular Biology</td>
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<td>HDG08</td>
<td>Cell Biology</td>
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<td>HDG09</td>
<td>Principles of Development</td>
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<tr>
<td>HDG10</td>
<td>Bioinformatics</td>
<td>Theory, H Core</td>
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<td>2</td>
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<tr>
<td>HDG11</td>
<td>Principles of evolution and population genetics</td>
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<td>2</td>
<td>Essay evaluation</td>
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<tr>
<td>HDGP5</td>
<td>Lab Module V – Biochemistry and Molecular Biology</td>
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<td>6</td>
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<tr>
<td>HDGP6</td>
<td>Lab Module VI – Cell Biology</td>
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<td>HDGP7</td>
<td>Lab Module VII – Bioinformatics</td>
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<td>2</td>
<td>15</td>
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**Total hours of instruction/week** 36  
**Total credits** 26
## III Semester

<table>
<thead>
<tr>
<th>Course Title</th>
<th>Course Title</th>
<th>Course Type</th>
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<th>Marks</th>
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<tbody>
<tr>
<td>HDG12 Human Molecular Genetics</td>
<td>Theory, H Core</td>
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<td>3</td>
<td>30</td>
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<tr>
<td>HDG13 Biochemical genetics</td>
<td>Theory, H Core</td>
<td>4</td>
<td>3</td>
<td>30</td>
<td>70</td>
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<tr>
<td>HDG14 Essentials in Immunology</td>
<td>Theory, H Core</td>
<td>2</td>
<td>2</td>
<td>15</td>
<td>35</td>
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<td>HDG15 Genetic counselling and ethics</td>
<td>Theory, H Core</td>
<td>2</td>
<td>2</td>
<td>15</td>
<td>35</td>
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<tr>
<td>HDG16 Use of model organisms to study human disease</td>
<td>Theory, S Core</td>
<td>3</td>
<td>Essay evaluation</td>
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<td>35</td>
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<tr>
<td>HDGP8 Lab module VIII – Research methodology</td>
<td>Lab, H Core</td>
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<td>6</td>
<td>30</td>
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<tr>
<td>HDGP9 Lab Module IX - Molecular Diagnostics</td>
<td>Lab, H Core</td>
<td>4</td>
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<td>HDGP10 Lab module X – Genetic counselling and ethics</td>
<td>Lab, H Core</td>
<td>OE</td>
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**Total hours of instruction/week** 31

**Total credits** 26

## IV Semester

<table>
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<tr>
<th>Course Title</th>
<th>Course Title</th>
<th>Course Type</th>
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<th>Marks</th>
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<tr>
<td>HDG18 Cancer biology</td>
<td>Theory, H Core</td>
<td>2</td>
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<tr>
<td>HDG19 Human genome organization</td>
<td>Theory, H Core</td>
<td>2</td>
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<tr>
<td>HDG20 Genetics of infertility and assisted reproduction technology</td>
<td>Theory, H Core</td>
<td>2</td>
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<tr>
<td>HDG21 Introduction to disease biology</td>
<td>Theory, H Core</td>
<td>2</td>
<td>2</td>
<td>15</td>
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<tr>
<td>HDGP11 Scientific writing and presentation – term paper submission</td>
<td>Lab, H Core</td>
<td>Paper evaluation</td>
<td>30</td>
<td>70</td>
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<tr>
<td>HDGP12 Dissertation work</td>
<td>Lab, H Core</td>
<td>Report evaluation viva</td>
<td>30</td>
<td>70</td>
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**Total hours of instruction/week** 8

**Total credits** 22

**Grand total of programme credits** 98
Syllabus

SEMESTER 1

HDG01. FUNDAMENTALS OF GENETICS

(Lecture CREDITS-2)

Unit I

**Hereditry and Variation:** definition of heredity and terminology used in the study of genetics; history and significance of the study of genetics; the different branches of genetics including an introduction to genetic diversity and evolution; the future of genetics.

2 Hrs

Unit II

**Mendelian laws or Principles of heredity and the Inheritance of Mendelian traits in Humans:** Mendel’s success in studying inheritance; principles of segregation and independent assortment; concept of dominance and recessivity of traits, dihybrid crosses and their genetic outcomes; qualitative and quantitative traits; patterns of inheritance in humans using well known examples such as the ABO blood group locus.

3 Hrs

Unit III

**Chromosomal basis of Inheritance:** Historical experiments establishing chromosomes to be the basis of inheritance; the relationship between Mendel’s laws and chromosome transmission in mitosis and meiosis; effect of meiosis and recombination on the results of genetic crosses; mode of inheritance: autosomal and allosomal inheritance; X linked loci, for example, white gene inheritance in *Drosophila*; sex linkage, sex influenced characters, genes located on human sex chromosomes and associated diseases; an introduction to sex determination, in particular, XX and XY sex determination in humans.

3 Hrs

Unit IV

**Extensions and modifications of the Basic principles of Heredity:** Types of dominance, interaction between genes, modified di-hybrid ratios resulting from presence of lethal alleles, multiple alleles, genetic epistasis; inheritance of complex traits, genetics of multifactorial traits, locus/allelic/clinical heterogeneity; effects of inbreeding; extra-chromosomal inheritance: maternal inheritance in humans (mitochondrial inheritance, Leigh syndrome), cytoplasmic inheritance; environmental effects on phenotypes, concept of penetrance (illustrated by Huntington’s disease) and expressivity; X inactivation, mosaicism and chimerism; pleiotropic gene function.

6 Hrs

Unit V

**Mapping of Genetic Loci:** Linkage, crossover and map distance, Sturtevant’s linkage map, interference in crossover, X^2 test of linkage, mapping functions, genetic polymorphisms, chromosomal mapping.

2 Hrs

Unit VI

**Introduction to Human Pedigree analysis:** Constraints and special features of human biology and culture, constructions of pedigrees and symbols used, analysis of pedigrees; autosomal recessive traits, autosomal dominant traits, X- linked recessive traits, X- linked dominant traits and Y-linked traits; interpretations of pedigree analysis, genetic testing and risk assessment; studies of twins to assess the importance of genes and environment.

2 Hrs
Unit VII

**Identifying Human Disease Genes:** Discussion on positional cloning illustrated using as examples, Duchenne muscular dystrophy, cystic fibrosis and Huntington’s disease; discussions on concepts of genome wide association, new genome technologies for discovering disease genes, the role of genetic variations in understanding human disease and personalized medicine.

Unit VIII

**Identification of the Genetic Material and the Concept of a Gene:** Classical experiments: by Griffith; Avery, MacLeod and McCarty; Hershey and Chase; Beadle and Tatum; Benzer’s deletion mapping and complementation; McClintock’s jumping genes.

Unit IX

**Introduction to Microbial Genetics:** Exchange of genetic material in bacteria: conjugation, transformation and transduction; natural gene transfer of antibiotic resistance, horizontal gene transfer, mapping of bacterial genes using phages, fine structure of bacteriophage genes; bacterial and viral gene maps.

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**HDG02. HUMAN CYTOGENETICS**

(Lecture CREDITS-2)

Unit I

**Introduction to Cytogenetics and Clinical Cytogenetics:** History of human cytogenetics, confirmation of human chromosome number, morphology of human chromosomes, non-banding techniques, classification of human chromosomes into different groups (A-G), international system for human cytogenetic nomenclature, various conferences held to discuss chromosome nomenclature; karyotyping.

Unit II

**Introduction to Cytogenetic Techniques:** Conventional banding patterns of chromosomes; specialized banding techniques – Q-banding, G-banding, C banding, silver staining for nucleolus organizer region (NOR), R-banding, sister chromatid exchange (SCE), chromosome analysis, chromosome band nomenclature, Identification and definition of chromosome landmarks, regions, bands and sub-bands, high resolution banding (HRB); immortalization of cells - Epstein-Barr virus (EBV) transformation of lymphocytes to generate lymphoblastoid cell lines.

Unit III

**Application of Cytogenetics in Medical Genetics:** General principles, Chromosome abnormalities and human genetic diseases: numerical and structural (markers, isochromosomes, ring chromosomes, deletion, duplication, insertions, translocations and inversions) abnormalities; sex chromosome abnormalities, autosomal abnormalities, uniparental disomy, Chromosome breakage Studies (chromatid and chromosome breaks) and their Applications.

Unit IV

**International System for Human Cytogenetic Nomenclature (ISCN) and Quality Assurance:** General principles, specification of breakpoints, designating structural chromosome aberrations by breakpoints and band composition, short system for designating structural chromosome aberrations, two break rearrangements, three break,
four break rearrangements and more complex rearrangements, detailed system for designating structural chromosome aberrations, additional symbols, derivative chromosomes, recombinant chromosomes, questionable identification, uncertain breakpoint designations, alternative interpretations. Variations in heterochromatic segments, satellite stalks and satellites, fragile sites, inversions as normal variations.

Unit V
Introduction to Cancer Cytogenetics: Application of cytogenetics in cancer diagnosis (karyotyping), analysis and interpretation of results, quality assurance, Clones and clonal evolution, definition of a clone, clone size, mainline, stemline, sideline, clonal evolution, composite karyotype, unrelated clones, modal number, constitutional karyotype, chromosome markers found in different lymphomas and leukemias (CML, AML, APML, myelodysplastic syndromes etc..) and solid tumors (Sarcomas and carcinomas).

Unit VI
Introduction to Molecular Cytogenetics: History of molecular cytogenetics, various molecular techniques applied in clinical cytogenetics, advantages and applications in clinical cytogenetics.

Unit VII
Clinical Applications of Fluorescence in situ Hybridization (FISH): Principles, procedure, labelling of DNA (Direct and Indirect methods), antibodies used to detect the probe signals, probe amplification, advantages of FISH, various tissue samples used for FISH study.

Kinds of FISH probes – Alpha satellite, telomeric, NOR specific, chromosome specific paint probes, unique sequence specific, repetitive sequence etc., and their applications in clinical diagnosis of various syndromes giving examples of normal and abnormal results.

Unit VIII
Application of FISH in Prenatal Diagnosis and confirming Microdeletion syndrome: Principles and procedure involved, alpha satellite and unique sequence FISH probes used in prenatal diagnosis of genetic abnormalities on cultured and uncultured cells using appropriate examples. Prenatal diagnosis of trisomies that could lead to live birth. Postnatal diagnosis of microdeletion syndromes (Prader-Willi, Angelman, Williams, DiGeorge etc..) using FISH probes, confirmation of cryptic translocations by FISH using appropriate examples.

Unit IX
Application of FISH in Cancer Diagnosis: Principles and procedure, details of FISH probes used in detecting various markers [(BCR/ABL, t(15;17), t(8;21) etc..,) found in Leukemia and solid tumors( HER-2/neu, C-myc, p53 etc..), use of single fusion, dual fusion, break apart and multipanel probes used in cancer detection, confirmation of probe amplifications seen in breast cancer and solid tumors, section in situ hybridization used to study probe amplifications on tissue sections, RNA in situ hybridization on tissue sections using appropriate examples.

Unit X
Advanced Molecular Cytogenetic Techniques: Principles and procedures involved and their applications in clinical diagnosis of genetic abnormalities (including complex chromosomal translocations – CCRs etc..) - Primed in situ labeling (PRINS), comparative genomic hybridization (CGH), Spectral karyotyping (SKY), multicolor FISH (mFISH) and multicolor banding (mBAND), Fiber FISH, etc., using appropriate examples.
Unit XI
Quality Assurance: Interpretation and Reporting of normal and abnormal reports using International System for Human Cytogenetic Nomenclature (ISCN) for FISH.

HDG03. BIOSTATISTICS

(Lecture CREDITS-2)

Unit I
General Introduction and Probability: Data types, descriptive statistics versus inferential statistics; measures of central tendency: mean, median, mode; measures of spread: variance, standard deviation, coefficient of variation; tabulation and visual display of data; introduction to probability: sample space, events, definition of probability, permutations and combinations, events and operations on events, conditional probability, concept of independence, Bayes’ rule and screening tests, Bayesian inference; ROC curves; prevalence and incidence.

Unit II
Distributions: Introduction; random variables and their properties; permutations and combinations; the Binomial distribution: expectation (mean) and variance; the Poisson distribution: expectation and variance, computation of Poisson probabilities; the Gaussian distribution and its properties

Unit I II
Estimation: Introduction; the relationship between population and sample; random-number tables, randomized studies; estimation of the mean of a distribution; estimation of the variance of a distribution; estimation for the Binomial distribution; estimation for the Poisson distribution; the Central Limit Theorem; the concept of confidence interval; confidence interval for the mean and its interpretation.

Unit IV
Hypothesis Testing: One-sample inference, one-sample test for the mean of a normal distribution: one-sided alternatives; one-sample test for the mean of a normal distribution: two-sided alternatives; the relationship between hypothesis testing and confidence intervals; Bayesian inference; one-sample χ² test for the variance of a normal distribution, one-sample inference for the binomial distribution, one-sample inference for the Poisson distribution; two-sample inference; the paired t-test; interval estimation for the comparison of means from two paired samples; two-sample t-test for independent samples with equal and unequal variances, interval estimation for the comparison of means from two independent samples (equal variance case); testing for the equality of two variances.

Unit V
Categorical Data: Two-sample test for binomial proportions, Fisher’s exact test; two-sample test for binomial proportions for matched-pair data (McNemar’s test); estimation of sample size and power for comparing two binomial proportions, RxC contingency tables; chi-square goodness-of-fit test, the kappa statistic.

Unit VI
Nonparametric Methods: the sign test, the Wilcoxon signed-rank test, the Wilcoxon rank-sum test.
Unit VII

**Regression and Correlation Methods**: General concepts; fitting regression lines, assessing the goodness of fit including the method of least squares; inferences to be made from the parameters of regression lines; interval estimation for linear regression; the correlation coefficient, inferences from correlation coefficients; multiple regression, partial and multiple correlation, rank correlation, interval estimation for rank correlation coefficients.

Unit VIII

**Multisample Inference**: Introduction to the one-way analysis of variance (ANOVA): fixed effects model, hypothesis testing; comparisons of specific groups, using one-way and two-way ANOVA; The Kruskal-Wallis test; the random effects models in one-way ANOVA, the intra-class correlation coefficient; mixed models.

**HDG04 HUMAN EMBRYOLOGY, ANATOMY AND PHYSIOLOGY**

(Lecture CREDITS-4)

**PART 1 - HUMAN ANATOMY and PHYSIOLOGY**

Unit I

**Introduction to tissue organization in relation to human physiology.**
Levels of organization and organ systems of the body; different kinds of tissues; cavities of the body (cranial cavity, vertebral cavity, thoracic, abdominal and pelvic cavities).

**Epithelial tissue**: Structure of epithelia, different kinds of simple and compound epithelia and tissue specific variations, example keratinised versus non-keratinised.

**Different types of Connective tissue and special connective tissue**: Components of connective tissue, cellular and matrix components; components and features of proper connective tissue, fluid connective tissue (blood and lymph) and supporting connective tissue (cartilage and bone); distribution of these tissues in various organs; special mention on classification of bones, example Pneumatic bones, sesamoid bones, developmental classification, structural classification; growth of bones.

**Muscular tissue**: Structure, classification and function of different kinds of muscles: cardiac, smooth and different kinds of skeletal muscles according to colour and direction of organization; structure of myofibrils and the neuro-muscular junction; common diseases that affect the muscles.

**Glands**: General structure of a gland, exocrine, endocrine and paracrine glands; epithelial glands classified according to structure (simple and compound duct, tubular or alveolar structure) and secretions (example serous, mucous); diseases that affect the glands.

**Skin**: Structure, function and components of the skin; structure and function of the appendages of the skin such as nails, hair, sweat glands and sebaceous glands; diseases that affect the skin.

Unit II

**Fluid composition of the body**: body fluid compartments, intracellular, extracellular and interstitial; blood cells and their lineage

**Cardiovascular and lymphoid system**: gross anatomy of the heart and major blood vessels; arterial and venous systems, valves, structure and histology of vessels; maintenance of blood pressure, conduction system of heart; blood capillaries, movement of blood cells through capillaries; lymphatic tissue, major lymph vessels and organs, lymph capillaries, spleen, tonsils, thymus; genetic disease that affect the cardiovascular system.
Unit III
Digestive system: parts of the digestive system and their functions, innervation of gastrointestinal tract, accessory organs of digestion, gastrointestinal hormones, physiology of digestion, absorption and satiation.

Unit IV
Urinary system: parts of the urinary system and their functions, cellular organization of the kidney, physiology of urine formation, glomerular filtration, tubular reabsorption, maintenance of water balance; physiology of human urinary system compared with that of other land animals.

Unit V
Respiratory system: parts of the respiratory system and their functions, nasal cavities, tracheobronchial tree; passage of air, physiology of respiration, ventilation and gaseous exchange in lungs, oxygen-haemoglobin dissociation curve, transport of carbon dioxide; nervous control of respiration.

Unit VI
Essentials of the nervous system: structure and physiology of neurons, glia and ganglia; structure and physiology of synapses and neurotransmitters; divisions of the nervous system: central nervous system (CNS), peripheral nervous system (PNS) and autonomic nervous system (ANS), elaborating briefly on their various components and the functional areas of cerebrum, cerebellum and brainstem and special sense organs such as eyes and ears; structure of ventricles and physiology of the cerebrospinal fluid; structure and physiology of the choroid plexuses, meninges and blood brain barrier; blood supply to the brain and spinal cord.

Unit VII
Endocrine system: Structure and secretions of Pituitary gland, Thyroid gland, parathyroid glands, Suprarenal and Adrenal glands, Pancreas; Hormones regulating calcium, energy and water homeostasis, body temperature and growth.

Unit VIII
Reproductive System: Components and functions of the male and female reproductive system and accessory organs, such as the mammary gland; cellular organization of important organs of the reproductive system such as the uterus, ovary, testis and mammary glands; physiology of the male and female reproductive systems, hormonal cycles and puberty.

PART 2 - HUMAN EMBRYOLOGY

Unit I
Fertilization and assisted reproductive technologies: formation of gametes, process of fertilization; diseases causing sterility; in-vitro fertilization techniques

Unit II
Early embryogenesis: cleavage, the germinal stage, gastrulation, formation of the germ layers and body cavities; body axis specification; brief mention of the different kinds of birth defects and prenatal diagnosis; description of the phylotypic pharyngula stage.
Development of the placenta.
Unit III
**Development of the skeletal system:** vertebral column and ribs, commonly occurring genetic diseases affecting the skeletal system.

Unit IV
**Development of the bronchial apparatus, face, nose and palate:** normal development and commonly occurring diseases including cleft palate.

Unit V
**Development of the special sense organs:** eyes, ears.

Unit VI
**Development of the nervous system:** Neurulation and subsequent development of the spinal cord and major areas of the brain; commonly occurring anomalies affecting the development of the nervous system example hydrocephaly, anencephaly.

Unit VII
**Development of the gastrointestinal tract:** divisions of the gut tube and their anlage; epithelial-mesenchymal interactions in the specification of different parts of the gut tube; partitioning of foregut into oesophagus and respiratory diverticulum; formation and rotation of stomach and midgut, the occurrence of herniation; formation of liver, spleen and pancreas; commonly occurring genetic diseases resulting in deviations in normal development.

Unit VIII
**Development of the cardio-vascular system:** formation of the heart fields and then heart tube, cardiac loop; brief description of formation of the cardiac septa; vascular development: vasculogenesis and angiogenesis; formation of the aortic arches and then vascular pattern; formation of the venous system; foetal circulation and circulatory changes after birth; anomalies resulting in fused septa and thinning of capillaries.

Unit IX
**Development of the urogenital system:** development of the pronephros, mesonephros and metanephros; formation of the kidney from the metanephric mesoderm and uretic bud; development of the gonads: formation of the genital ridges, migration of germ cells to somatic gonads; development of the testis, ovary and uterus; hormonal influence on development of the genital system; genetic diseases of the urogenital system affecting kidney function and sterility.

Unit X
**Development of the respiratory system:** formation of the lung buds, branching of the trachea and formation of lung lobes; maturation of lungs, association of terminal bronchiole sacs with blood capillaries.
HDGP1. LAB MODULE I - GENETICS

1. **Introduction to Laboratory course on Genetics**: Understanding laboratory ecosystems, ‘do’s and don’ts’ of laboratory safety, familiarization with instruments to be used; measurement of weight and volume, preparation of solutions, buffers, media, sterile areas, sterilization methods; record keeping.

2. **Growth curve analysis**: Culturing bacteria to study the phases of growth; quantification of bacteria by plating serial dilutions and by spectrophotometry; plotting growth curves under different growth conditions, for example different culture media.

3. **Bacterial Conjugation**: Transfer of antibiotic resistance genes across different strains of bacteria by conjugation.

4. **Introduction to Drosophila genetics**: Life cycle of *Drosophila*, stages of growth and identification of anatomical structures; husbandry and handling of *Drosophila*; historical perspective and relevance of *Drosophila* in present day genetic analysis; an introduction to the database, Flybase.

5. **Analysis of Drosophila mutants**: Observation and identification of genetic markers of *Drosophila*, basics of setting up genetic crosses; phenotypes from monohybrid and dihybrid crosses in *Drosophila*; probability and chi square analysis of cross results.

6. **Identification of X-linked genes**: Inheritance of the *white* gene locus to demonstrate sex linkage; analysis of reciprocal crosses.

7. **Qualitative and Quantitative analysis of traits**: Phenotypes of mutants affected in movement (flight, gait), eye colour, geotaxis, photo taxis, wing shape, wing size etc.; temperature sensitive mutations.

8. **Genetic pathways, for example, genes involved in metabolism**: Demonstration of mutations or gene products involved in the synthesis of *Drosophila* eye pigments; separation of the constituent pigments of mutants using thin layer paper chromatography.

9. **Preparation of Cytogenetic map using polytene chromosomes**: Dissection of salivary glands from third instar larvae, spreading of polytene chromosomes, fixation using aceto-methanol fixative, observing banding pattern using Orcein stain and a light microscope.

10. **Creating a genetic map using Drosophila markers**: Setting recombination crosses and preparing a recombination map from recombination frequencies.

11. **Mapping of P-element insertions**: Mapping P-element insertions by segregation and linkage analysis, introduction to P-element enhancer and protein trap lines and their application in Genetics.

12. **Demonstration of the use of biochemical markers**: reporter gene (β-Galactosidase) staining or immunohistochemistry to observe tissue specific expression of vg-lacZ or wg-lacZ insertion lines.

13. **Brief discussion on the use of the currently vast Genetic tool kit in Drosophila to understand gene function**: Use of methods such as spontaneous mutations, X-ray and EMS mutagenesis, P-element based mutagenesis, Crispr-Cas9, RNA interference.

HDGP2. LAB MODULE II – BASIC CELL IMMORTALIZATION TECHNIQUES

(CREDITS -2)

1. **Basics of cell culture, Good laboratory practice (GLP), Techniques of cell cultures** – short-term lymphocyte culture, long-term culture, sub-culturing, primary and secondary cell cultures, maintenance,
culture contaminations, detection of contaminations; *in vitro* transformation of human peripheral B-lymphocytes by Epstein-Barr virus to establish lymphoblastoid cell lines (LCLs).

2. **Culture of patient tissue samples**: blood/percutaneous umbilical blood sampling (PUBS)/amniotic fluid/chorionic villus specimen (CVS)/products of conception (POC)/Skin/bone marrow (BM)/solid tumor, etc.

3. **Principles of Microscopy**: Parts of a light microscope, principle of the Koehler illumination system, phase contrast microscopy.

**HDGP3. LAB MODULE III – HUMAN CYTOGENETICS**

(CREDITS -4)

1. **Karyotyping using karyotype workstation**— chromosome preparations from short term cultures and long term cultures and G-Banding. Identification of chromosomes under the microscope, use of software in capturing G-banded metaphases, chromosome analysis and karyotyping.

2. **Conventional and specialized cytogenetic techniques (C-bandling and NOR staining)**: peripheral blood (PB) cytogenetics, prenatal cytogenetics (AF/CVS/POC/PUBS), culture from skin biopsy, cancer cytogenetics from Bone marrow, FNA culture and culture from tissue biopsy and chromosome preparations and karyotyping: case study analysis and inference. Analysis and interpretation of results.

3. **Chromosome breakage study**: Mitomycin C induced cultures, principles, procedure, applications and case studies.


5. **Fluorescence Microscopy** – Principles and use of Fluorescence microscopy

6. **FISH**: Specimen culture; preparation of slides for fluorescence *in situ* hybridization (FISH). Selection of probes, *in situ* hybridization, washings, detection of probes by antibodies, washings, observations using Fluorescence microscope, image capture and analysis using FISH workstation.

7. **Advanced FISH techniques**: SKY, mFISH and mBANDING
   - **SKY**: Slide preparation, probe hybridization, probe detection, Methods in spectral (Color) image capture and analysis.
   - **Multiplex fluorescent *in situ* hybridization (mFISH)**: Slide preparation, probe hybridization, probe detection, Methods in multicolor image capture and analysis.
   - **Multicolor banding (mBAND)**: Slide preparation, probe hybridization, probe detection, Methods in multicolor image capture and analysis. Analysis and interpretation of results.

8. **Quality assurance**: Interpretation and Reporting of normal and abnormal reports using International System for Human Cytogenetic Nomenclature (ISCN) for FISH.
HDGP4. Lab Module IV – Biostatistics and Programming in R

(Credits: 2)

1. R software installation and basic R usage.
2. Mathematical operations and string manipulation
3. Basic data structures: Vectors, data frames, lists and matrices
4. Logical statements and loops: If-else statements, for and while loops, break
5. Writing user defined functions and packages
6. Reading and writing tables and files
7. R graphics library: Line plots, histograms, pie charts, bar plots and other plots
8. Computation of statistical parameters
9. Correlation studies of data
10. Error analysis and error bars
11. Binomial, Poisson and Gaussian distributions and deviates
12. Demonstrations and study of Central Limit Theorem through data
13. Hypothesis testing and p-value computation
14. Parametric tests – Performing one and two parametric Z tests, family of t-tests, tests for proportion, chi-square tests
15. Analysis of variance – Performing one factor and two factor ANOVA
16. Non-parametric tests – Wilcoxon Mann Whitney tests, Kruskal Wallis test
17. Regression analysis: Least square linear regression with errors and non-linear regression of data
18. Using Biostrings library for RNA and DNA sequence analysis
20. Using GraphPad for basic biostatistics.

HDG05. Science Writing and Presentation

(Lecture Credits-2, Soft Core)

Unit I

Basics of good writing: English grammar in the current context of writing: nouns and pronouns; adjectives; verbs; adverbs; prepositions; conjunctions, articles; order of words; sentence structure, clauses, punctuation, vocabulary; idioms; figures of speech; active vs. passive voice, etc.; writing skills: paragraph construction; common mistakes while writing, better sentences, story writing; precis writing.

Unit II

Structure of scientific articles: differences in structure between reviews and papers; composition of an abstract, title, introduction, methods, results and discussion; preparing figures and figure legends, citations; importance of engaging the reader, telling a story and providing the right emphasis on important results; avoiding plagiarism; adapting to different journal requirements; attempts will also be made to critique published articles.
Unit III

**Constructing arguments:** Learning how to recognize the argument being made in a passage, learning how to represent it graphically using rationale online software and then paraphrasing it. Learning how to critically analyse the strengths and weaknesses of an argument and then to write such that sufficient emphasis is given to each. Articles from editorial sections of the journal *Science* will be used to practice these exercises.

Unit IV

**Other forms of professional writing:** composing professional emails and letters for various purposes; preparing an effective resume.

Unit V

**Effective oral presentations:** essential principles of a good talk, importance of engaging the audience, telling a story and providing the right emphasis on important results; preparing effective presentations: preparing images, graphs and tables, appropriate use of colour and font size; talks for different audiences.

Unit VI

**Other modes of scientific communication:** Short accounts of scientific discoveries for the layman; social media and science communication; using social media to transmit a scientific discovery that has influenced you; the importance of engaging with the community and communicating scientific knowledge to the community.

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SEMESTER 2

**HDG06: BIOCHEMISTRY**

(Lecture CREDITS-2)

Unit I

**Fundamental Chemistry:** Atomic structure; chemical bonds and interactions (types of chemical bonds, bond angles, bond length and bond rotation, weak forces); properties of organic compounds, chirality in biomolecules; mole and molecular mass. Chemical properties of water; hydrogen bonding; the pH scale, acids, bases and buffers.

Unit II

**Carbohydrates and Carbohydrate Metabolism:** Structure and properties of monosaccharides; D and L sugars; derivatives of sugars; glycosidic bond; oligosaccharides (disaccharides and trisaccharides); polysaccharides: homopolysaccharides (e.g., starch, cellulose and glycogen) and hetero polysaccharides (e.g., glycosaminoglycans); glycoproteins and peptidoglycans; functions of carbohydrates. Synthesis and degradation of glucose and glycogen in humans (including glycolysis, tricarboxylic acid cycle, glycogenesis, glycogenolysis, gluconeogenesis, and pentose phosphate pathway).

Unit III

**Proteins and Protein Metabolism:** Classification, structure and properties of amino acids; peptide bond; classification of proteins; structural organization of proteins (primary, secondary, tertiary and quaternary) with haemoglobin and myoglobin as examples; the Ramachandran plot.

Amino acid metabolism- General reactions of amino acid metabolism- transamination, deamination and decarboxylation; the urea cycle and its regulation; amino acid biosynthesis.
Unit V
Lipids and their metabolism: Classification; fatty acids (properties and types); triacyl glycerol; phospholipids; glycolipids (with cerebrosides and gangliosides as examples); glycosylphosphatidylinositol; cholesterol; prostaglandins; properties and reactions of lipids; the β-oxidation pathway- even and odd numbered saturated and unsaturated fatty acids; energetics of total oxidation; general scheme of biosynthesis of fatty acids.

Unit VI
Nucleic acids and their metabolism: Structure of nitrogenous bases, nucleosides and nucleotides; phosphodiester bond; polynucleotides; double helical form of DNA (A, B and Z forms); triplex and quadruplex structures in DNA; RNA (mRNA, tRNA and rRNA); synthesis of purines and pyrimidines: de novo and salvage pathways, catabolism of purines and pyrimidines.

Unit VII
Enzymes: Properties, classification and nomenclature; co-enzymes and co-factors; isozymes; regulation of enzyme activity; mechanism of enzyme catalysis; enzyme immobilization; enzyme kinetics: factors affecting the rate of enzyme-catalyzed reactions such as enzyme concentration, substrate concentration, pH and temperature, Michaelis-Menten equation, significance of Km and Vmax and their determination using Lineweaver-Burk (L-B) plots; enzyme inhibition: reversible and irreversible, non-competitive and uncompetitive inhibition with graphical representations using L-B plots.

Unit VIII
Bioenergetics: Laws of thermodynamics, the concept of Gibb’s free energy; generation and utilization of the energy currency, ATP in cells; mitochondrial electron transport chain- components and oxidative phosphorylation.

HDG07. MOLECULAR BIOLOGY

(Lecture CREDITS-4)

Unit I
Biomolecules and central dogma of molecular biology: Historical overview of discoveries identifying DNA as hereditary material and its structural organization (contributions of Mischer, Kossel, Levene, Griffith, Avery’s group, Hershey and Chase, Chargaff, Franklin, Wilkins, Pauling, Watson and Crick); structure of DNA, RNA and proteins; central dogma; genetic code

Unit II
DNA replication in prokaryotes and eukaryotes: Modes of replication: conservative, semi-conservative and dispersive, Meselson and Stahl’s experiment; defining a replicon and the origins of replication; leading and lagging strand synthesis at a growing replication fork, Okazaki’s experiment; DNA polymerase and replication machinery in prokaryotes and eukaryotes; processes of initiation, elongation and termination; trombone model of replication; end replication problem of linear DNA, telomerase and the Shelterin complex; early and late replicating DNA; visualizing replication; isolation of autonomous replicating sequences (ARS); coordinating regulation of DNA replication initiation with the prokaryotic and eukaryotic cell division cycle

Unit III
DNA Recombination: Overview of recombination and gametogenesis, genetic and cytological evidence of crossing
over; mechanisms of recombination: the Holliday model, the Meselson-Radding heteroduplex model and the double-strand-break model; gene conversion and branch migration; molecules in recombination: synaptonemal complex, ruvABC, recA and recBCD

Unit IV

**Transcription in prokaryotes and eukaryotes**: Subunit organization and structure of prokaryotic RNA polymerase and eukaryotic RNA Polymerase I, II and III; core promoter elements; analysis of promoters: deletion analysis, DNase footprinting, base-modification and mutational assays; transcription initiation, prokaryotic initiation and role of sigma factor; general transcription factors (GTFs) and initiation in eukaryotes; binary and ternary complexes of RNA polymerase (RNAP); abortive initiation and DNA scrunching; transcription elongation, catalytic synthesis of RNA; role of bridge helix and trigger loop in nucleotide addition cycle and translocation; role of pol II carboxy terminal domain (CTD) in mRNA processing, proofreading and backtracking of RNA polymerase; role of prokaryotic GRE factor and eukaryotic TFIIS in release of RNA polymerase arrest; transcription termination: intrinsic and rho-dependent termination in prokaryotes, PAS-dependent termination in eukaryotes

Unit V

**Post-transcriptional processing and nuclear transport**: Splicing: evidence of split genes, splicing mechanism and splicing signals, spliceosome assembly and function; role of RNA polymerase II CTD, self-splicing RNAs, tRNA splicing; mRNA capping: cap structure, synthesis and function; mRNA polyadenylation: function of poly(A), mechanism of polyadenylation, polyadenylation signals, poly(A)polymerase and turnover of poly(A); coordination of mRNA processing events: effect of individual events on the other events, coupling transcription termination with mRNA 3'-end processing, mechanism of termination; processing of tRNA; RNA editing, editing by nucleotide deamination; mRNA stability, stability of specific mRNAs such as Casein mRNA and transferrin receptor mRNA; gene silencing by RNA interference.

Unit VI

**Translation**: Ribosome composition and structure; discovery of tRNA and structure of tRNA, recognition during translation (second genetic code), proofreading and editing by amino-acyl-tRNA synthetases; prokaryotic translation initiation: tRNA charging, dissociation of ribosomes, formation of initiation complexes, control of translation at the level of initiation; eukaryotic translation initiation: initiation factors, scanning model of initiation, regulation of translation at the level of initiation; prokaryotic and eukaryotic translation elongation and termination: direction of polypeptide synthesis, genetic code and codon bias, steps in elongation, structure of EF-Tu and EF-G, regulation by GTPases, termination codons, release factors; dealing with aberrant termination.

Unit VII

**Post-translational processing of proteins**: Polypeptide cleavage, brief mention of chemical modifications such as ubiquitin and ribozymes.

Unit VIII

**Brief overview of eukaryotic gene regulation**: Basic concepts of gene regulation, cis and trans regulators, positive and negative gene regulation, operons, lac operon as example; organization of the genome: size, complexity, coding and non-coding sequences, repeat sequences; packaging of DNA: structure of chromatin, heterochromatin and euchromatin, chromosomal territories, lampbrush and polytene chromosomes, higher order packaging and fractal globules; expression of the genome: activators and repressors, DNA-binding motifs, promoter proximal elements, enhancers, insulators and barrier elements, mediators, transcription factories, chromatin remodelling during transcription; epigenetic modifications and their role in gene expression: DNA modifications and histone modifications, histone code; molecular basis of imprinting and X-inactivation; the role of transcription factors in
cellular differentiation, identity and reprogramming; RNA mediated gene regulation: microRNA, long non-coding RNA; techniques used to study gene expression and regulation: promoter assays, reporter assays, chromatin immunoprecipitation (ChIP), chromosome conformation capture (3C) and related techniques, hybridization techniques, yeast-two hybrid assay.

**Unit IX**

**Mutations and repair**: types of mutations; chemical and physical mutagens and mode of action: induction of mutations by tautomerization, base analogues, deamination, base damaging agents such as aflatoxins, alkylating agents, oxidative damage and formation of pyrimidine dimers; mutations induced at repeat sequences: replication slippage, unequal crossing-over and unequal sister chromatid exchange; cellular repair pathways: base excision repair, nucleotide excision repair and mismatch repair, photo-reactivation, non-homologous end joining (NHEJ), recombination mediated repair and translesion synthesis; defects in repair and associated human diseases.

**Unit X**

**Mitochondrial DNA**: Genome organization and codon usage; mitochondrial mutations and associated diseases.

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**HDG08 CELL BIOLOGY**

*(Lecture CREDITs-2)*

**Unit I**

**Cell Theory and Introduction to Cell Biology**: History and breakthroughs in cell biology properties and behaviour of cells, diversity of cell types; differences and similarities in the basic structure and functioning of prokaryotic and eukaryotic cells.

**Unit II**

**Biological membranes**: Origin and evolution of primitive cells; composition of biological membranes: Lipids and lipid modification, membrane proteins; functions, techniques used to study membranes and membrane proteins introduction to cell organelles and functions, covering mitochondria in detail.

**Unit III**

**Cell organelles**: Structure, function and diseases associated with cell organelles such as mitochondria, ER, Golgi.

**Unit IV**

**Nuclear Architecture and Organization**: Nuclear membrane, nuclear transport, nuclear organizer region, kinetochore and centrosome.

**Unit V**

**Cell Division**: Mitosis and meiosis, cell cycle, cell cycle controls, phases of cell cycle, techniques to study cell cycle.

**Unit VI**

**Cytoskeleton and cell motility**: Components of the cytoskeleton, organization in stationary and motile cells; functioning of the cytoskeleton and molecular motors; diseases associated with cytoskeleton.
Unit VII
Protein and Small Molecule Trafficking: Receptor-mediated endocytosis; intra-cellular transport, lysosomes, organelle biogenesis; extra-cellular transport: biogenesis of membrane proteins, protein modification, glycosylation; pumps, channels and transporters.

Unit VIII
Principles of Cell Signalling: Basics of signal transduction—ligands, receptors, second messengers, effector molecules; regulation of signalling pathways—negative and positive regulation, feed-back regulation; major known signalling pathways and their functions; techniques to study cell signalling—reporter assays, phosphoprotein analysis

Unit IX
Senescence and Programmed cell death: Replicative Senescence, Hayflick limit and telomere maintenance; intrinsic and extrinsic pathways of apoptosis; de-regulation of these pathways in diseases; techniques to study senescence and apoptosis

HDG09 PRINCIPLES OF DEVELOPMENT
(Lecture CREDITS-4)
Unit I
Developmental Biology: Basic Principles and Concepts. Introduction to the evolution of the body plan: acoelomate to coelomate, diploblastic and triploblastic organization of body plan; introduction to information flow from mother to egg; different sized embryos, yolk density and cleavage patterns; transition from a plastic, uncommitted state to a determined and then differentiated state; introduction to the development of four model organisms, namely nematodes (C elegans), fruit flies (D melanogaster), fish (D rerio), frog (X laevis), and mammals (mouse and human); life cycles of these organisms.

Unit II
Origins of polarity in the embryo: Differences in the origins of polarity between different kinds of embryos namely nematodes (C elegans), fruit flies (D melanogaster), fish (D rerio), frog (X laevis), and mammals (mouse and human); inheritance in most cases of polarity from the egg; specification of polarity in mammalian zygotes; differences in time at which dorso-ventral and antero-posterior polarity is specified in all above five kinds of embryos.
Student discussions, schematic preparations and presentations

Unit III
Basics of pattern Formation: Formation of protein gradients during development, pattern formation within syncitia (syncytial Drosophila embryo) versus simple epithelia (cellularised Drosophila embryo); introduction to long range and short-range pattern formation.
Student discussions, schematic preparations and presentations

Unit IV
Formation of the germ layers: Early specification of germ layers and the derivatives of each germ layer in insects (fruit fly) and vertebrates (fish, frog, mammals); long germ band and short germ band insects; Spemann’s organizer in frog, fish and mammalian embryos; gastrulation in invertebrates and vertebrates; morphogenetic movements and cell shape changes accompanying the formation of each germ layer, apical constriction, cell movement during

Syllabus: MSc in Human Disease Genetics
July 2018

20
convergent extension (involvement of planar cell polarity and specific signalling pathways), delamination of cells; cytoskeletal distribution accompanying certain cell movements such as apical constriction and dorsal closure in Drosophila embryos; induction between germ layers

**Student discussions, schematic preparations and presentations**

**Unit V**

**Emergence of the Body Plan:** Segmentation in insects and vertebrates across the different germ layers; mechanisms and signalling pathways involved in segment formation in Drosophila embryos, somitogenesis and rhombomere formation in vertebrates; formation of compartment boundaries during development; segment identity specification by Hox genes; the emergence, development and patterning of limbs in Drosophila (wings) and vertebrates (formation and patterning of limb bud and formation of digits), signalling pathways involved during these processes.

**Student discussions, schematic preparations and presentations**

**Unit VI**

**Cell Migration:** role of migration during development, epithelial to mesenchymal transition and vice versa during somitogenesis, neural crest formation and directed migration of individual cells; branching of tubular structures, for example, trachea formation in insect embryos and lung development in mammalian embryos.

**Student discussions, schematic preparations and presentations**

**Unit VII**

**Specification of Cell Fate:** Signalling events accompanying cell fate specification in certain well characterized contexts, for example, Notch-Delta signalling in neuroblast specification; the role of lineage, asymmetric and symmetric cell divisions.

**Unit VIII**

**Determination of size:** Regulation of body size, organ size and cell size; concept of allometry; coordination of growth with development; coordination of growth with cell division; regulation of cell size versus cell number; using Drosophila imaginal discs as an example, organ intrinsic and extrinsic (systemic) regulation of size; pathways that regulate growth (eg. insulin/TOR signalling pathways); bone development and growth in vertebrates.

**Unit IX**

**Germ cell development:** Specification and migration of germ cells to form gonads in invertebrates and vertebrates; specification of germ cells in different regions of the Drosophila, fish, frog and mammalian embryos; conserved molecules involved in germ cell development across species (eg. vasa, nanos, mitochondrial ribosomes), suppression of somatic programme in primordial germ cells; signalling pathways that guide migration of primordial germ cells to the gonads during development.

**Unit IX**

**Techniques used to study development:** Making transgenic Drosophila, D. rerio and mouse embryos; different kinds of mutagenesis methods: chemical mutagenesis, use of transposons (different kinds of transposable elements used in the different model organisms) and site directed mutagenesis (different uses for Cripr-Cas9 technology); in vivo expression of tagged wild type and mutant proteins; FLP-FRT and CRE-LOX technology in generating mosaics.
HDG10. BIOINFORMATICS

(Lecture CREDITS-2)

Unit I
Introduction to Bioinformatics and its Scope: An overview of activities in bioinformatics with emphasis on the types of information in modern biology and the need for databases and software.

Unit II
Operating Systems, Basics of Computer Programming, Languages, and Commands: Use of Linux operating system and commonly used open software; introduction to basic Linux commands, programming concepts and commonly used programming languages

Unit III
Databases: General concepts of databases; an overview of database types; common databases, related software and their utilities (PubMed, Entrez Gene, Gene cards, Uniprot, dbEST, OMIM, Unigene, HPRD, NEBcutter, Primer3plus, Primer Blast); using DNA sequence databases for PCR primer designing and restriction site analysis.

Unit IV
Human genome analysis: NGS analysis for single nucleotide polymorphism (SNP) detection; case studies; significance of SNPs; understanding the relationship between mutations, SNPs, insertions or deletions (indels), copy number variations (CNVs) and alleles; SNP and other variant databases and analysis of reference and sample sequences using the databases (dbSNP, Clinvar, dbVar, and Cosmic); genome wide association studies (GWAS); genomic versus exomic analysis. Concept of metagenomics; types of metagenomic approaches and their relative significances; significance of microbiomes to human health.

Unit V
Sequence analysis: importance of sequence analysis; common methods used in sequence analysis and alignment; basic concepts of sequence similarity, identity and homology, definitions of homologs, orthologues and paralogs; common databases used to retrieve gene, mRNA and protein sequences; phylogenetic analysis with reference to nucleic acids and proteins, and their significance; comparison of operation and applications of BLAST and MSA, and interpretation of results; concepts in DNA and RNA motif analysis, relevant databases and software.

Unit VI
Transcriptome Analysis: Significance of data and analysis at various levels: genome vs. exome vs transcriptome and proteome; commonly used databases for obtaining and analysing transcriptomic data; micro-array technology and analysis; discussions on RNA-seq analysis; miRNA analysis; ChIP-seq technology and related data analysis; DNA motif analysis.

Unit VII
Bioinformatics for Proteins: Review of protein structures and domains; use of databases for analysing protein-structures, gene ontologies, protein-interactions and pathways; domain analysis; significance of interaction analysis and systems biology; concepts in homology modelling, drug discovery and design; biologicals, biosimilars vs. traditional active pharmaceutical ingredients (APIs) and concept of clinical trials.
HDG11. PRINCIPLES OF EVOLUTION AND POPULATION GENETICS
(Lecture CREDITS-2)

Unit I
Origins: an introduction to the concept of evolution and the idea that all living forms are related; evidence for evolution, fossil record, classification and phylogeny, evolutionary transitions among genera, major transitions during evolution, Cambrian explosion and terrestrial life.

Unit II
Adaptation and Natural Selection: phenotypic variation vs. genetic variation; theory of Natural Selection; the ‘selfish gene’ concept; individual selection vs. group selection; patterns in adaptation for example, parasite-host adaptation; biogeographic evidence for evolution, major patterns of distribution of species.

Unit III
Genes and evolution: mutation rate, adaptive vs deleterious mutations, mutations with no selective advantage, consequences of gene duplication, genetic variation and evolution.

Unit IV
Basic population genetics: frequencies of alleles and genotypes, Hardy-Weinberg principle and its significance in evolution; genetic variation in natural populations, geographic variation and genetic distance.

Unit V
Genetic drift: theory of genetic drift; inbreeding and its effects on genetic drift; models of gene flow and genetic drift; the ‘neutral theory of molecular evolution’; alternatives to natural selection.
Population structure and Speciation: population structure and gene trees.

Unit VI
Phylogeny and Ontogeny: developmental patterns of evolutionary change, developmental constraints, non-adaptive characters and discontinuity of evolutionary change, evolution of novelty.

Unit VII
Evolution of Sex and Sexual selection: selective advantages of asexual reproduction versus sexual reproduction, sex ratios, evolution of sexual dimorphism, mate choice, signal detection.

Unit VIII
Evolution of Social behaviour: evolution of cooperation and apparent altruism.

Unit IX
Evolution of Life Histories: life history traits, life span and senescence.

Unit X
Evolution of Homo sapiens: Phylogenetic relationships, fossil record and origin of modern human populations, migration and genetic variation in human populations; the evolutionary future of humans; evolution of human behaviour and cultural evolution.
Unit XI
Human Disease and Evolution. 3 Hrs

Unit XIII
Presentations by students on recent papers on evolution and human health. 6 Hrs

HDGP5 LAB MODULE V: BIOCHEMISTRY & MOLECULAR BIOLOGY  
(CREDITS -4)

1. Isolation and Estimation of Proteins: Preparation of cell lysates from E. coli/ adenocarcinoma cell line (MCF7); estimation of total protein (Lowry/Bradford); analysis of protein of interest by western blotting.
2. Isolation and Estimation of DNA: Isolation of DNA from E. coli and human blood; estimation and agarose gel electrophoresis.
3. Isolation and Estimation of RNA: Isolation of RNA from adenocarcinoma cell line (MCF7) and blood; estimation and agarose gel electrophoresis.
4. Molecular cloning: Preparation of competent cells, transformation of E. coli DH5α, preparation of plasmid DNA; restriction enzyme digestion, analysis of products through agarose gel electrophoresis; gel elution of restriction enzyme digested fragments; ligation, transformation and analysis of clones.
5. Polymerase chain reaction (PCR): Amplification of DNA sequences from genomic DNA/plasmid DNA/cDNA; optimization of conditions, eg. MgCl2 concentration and annealing temperature.

HDGP6. LAB MODULE VI - CELL BIOLOGY  
(CREDITS-4)

1. Basics of cell culture: Media preparation and filtration; sub-culturing and reviving frozen stocks.
2. Cell counting, cell viability assay: Trypan blue exclusion.
3. Transfection using lipids: A demonstration of the technique
4. Cell viability assays: MTT assay, IC50 determination
5. Wound healing assay: Scratch test performed using a confluent culture of a human cell line.
6. Cell separation and sub-cellular fractionation methods: A lecture on the theory behind and the usefulness these techniques
7. Early development of Drosophila melanogaster: collecting synchronised eggs, watching cellularisation and gastrulation in live embryos; fixing and staining staged embryos with nuclear dyes; using GFP-expressing strains that label organelles, cytoskeleton, and mitotic spindles during early development of Drosophila embryos and/or larvae.
8. Later development of Drosophila melanogaster: studying coordination of growth and cell division in mosaic wing imaginal discs: analysis of the size and cell number in wildtype clones marked with GFP-expression with the size and cell number in two sets of clones one co-expressing RBF and the other E2F induced at the same time in larval development as the wild type clones.
HDGP7. LAB MODULE VII – BIOINFORMATICS
(DATA MINING AND ANALYSIS USING BIOINFORMATICS RESOURCES)
(CREDITS-2)

1. Operating Systems and Basics of Computer Languages and Commands: Use of Linux operating system, commonly used open software; introduction to Shell, Perl
2. Case studies to use common data mining resources: Pubmed, Entrez Gene, Genbank, Uniprot, HPRD, PubMed & Google Scholar
3. Phylogenetic analysis with reference to nucleic acids and proteins, and their significance; comparison of operation and applications of BLAST and MSA, and interpretation of results; demonstration of DNA and RNA motif analysis using relevant databases and software (JASPER, MEME).
4. Use of major tools for molecular cloning work: NEBcutter, Primer3plus, Primer Blast
5. Case studies of analysis using SNP databases (dbSNP); NGS analysis for SNP detection.
6. Case studies in clinically relevant databases (clinvar and OMIM).
7. Use of databases for protein-structures (PDB), gene ontologies (GO), protein-interactions (STRING) and pathways (KEGG and reactome).
8. Demonstration of data analysis in genomics, transcriptomics (mRNA and miRNA analysis), and metagenomics

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SEMESTER 3

HDG12. HUMAN MOLECULAR GENETICS
(Lecture CREDITS-4)

Introduction to Human Genetics

Unit I

Genetic Disorders and Single Gene Inheritance: Overview of genetic disorders: consequences and mechanisms; nomenclature of mutations, importance of the position of a base, databases of known mutations; from genotype to phenotype: loss of function mutations, gain of function mutations, expanding repeats.

Unit II

Complications to basic-Mendelian pedigree patterns: Inbreeding and pseudo-dominant inheritance, locus heterogeneity, incomplete and age-related penetrance, phenocopies, de-novo mutations and mosaicism

Unit III

Molecular methodologies: DNA polymorphisms, molecular markers and genotyping: restriction site polymorphisms (RSP), minisatellites, microsatellites, single nucleotide polymorphisms (SNP), heterozygosity of a marker, DNA-fingerprinting; polymerase chain reaction (PCR); Sanger and next-generation sequencing (NGS).

Unit IV

Genetic Mapping of Monogenic Traits: Parametric linkage analysis: markers in mapping, recombinants and non-recombinants, phase-known and phase-unknown pedigree, informative and uninformative meiosis, two-point
mapping, multipoint mapping: calculation of logarithm of odds (LOD) scores, haplotype analysis and defining critical linked interval in large pedigrees; autozygosity mapping; principles and strategies of identifying disease genes: positional cloning and position independent approaches, prioritization of candidates, whole-exome and whole genome sequencing in gene-hunting, assigning pathogenicity to sequence variants: genetic and bioinformatic criteria, functional validation of variants; computation exercises for two-point LOD scores for a Mendelian disorder using Mlink program; linkage, manual haplotype construction for large family Mendelian segregating phenotype

Unit V
Multifactorial Traits or Complex Disorders: Polygenic theory of quantitative traits; partitioning of variance, heritability; polygenic theory of discontinuous characters; genetic component assessment in families: risk-ratio, twin and adoption studies; mapping of complex traits by parametric linkage analysis in near-Mendelian families and affected sib-pair analysis; non-parametric linkage analysis: association-mapping studies: role of linkage disequilibrium in association studies, odds ratio and chi² test, tag-SNPs, genome-wide association studies (GWAS), Transmission disequilibrium test (TDT); identifying susceptibility variation through association studies, common disease-common variant hypothesis and mutation selection hypothesis.

Unit VI
Sex Linked Disorders, Sex Limited, Sex Influenced Traits, Genomic Imprinting

Unit VII
Gene Action _ Tracing Defects in Gene Function: (a) haemoglobinopathies-, beta-thalassemia and sickle cell anaemia (b) fragile X syndrome (c) hearing impairment (d) epilepsy (e) Gauchers Disease and Glycogen Storage disorders (f) Noonan syndrome and Rasopathies.

HDG13. BIOCHEMICAL GENETICS

The course shall cover various aspects of inborn errors of metabolism (IEM), a large class of genetic diseases in humans. Through the study of IEM, the students can widen their understanding of the biology of human genetic disorders. The course is divided into nine units.

Unit I
Inborn errors of metabolism (IEM)
Basic concepts/ general features

Classes of IEM

Classes of IEM — an overview. Classification of IEM based on organelle involved, metabolite/ pathway affected, organs affected, etc. Major classes of IEM.

General clinical features

Symptoms; age of onset; and clinical heterogeneity.
**Diagnosis**

1 Hr

Clinical suspicion, biochemical methods (examples: tests for the metabolites and the activity of specific enzymes), molecular genetics methods, and new-born screening; recent advances in the methods for diagnosis of IEM.

**Unit II**

**Phenylketonuria (PKU)**

PKU as a model to learn about IEM in general, and about disorders of amino acid metabolism.

**Biology of PKU**

4 Hrs

Discovery of PKU; incidence; causes — (1) mutations in the phenyl alanine hydroxylase (PAH) gene and (2) deficiency of tetrahydrobiopterin; symptoms; “maternal” PKU; diagnosis; the catabolism of phenylalanine in individuals with untreated PKU; how the individual symptoms manifested in patients may be explained on the basis of the various biochemical aberrations; molecular genetics of PKU; structure and regulation of PAH.

**Treatment options**

3 Hrs

Treatments available and those under development: Dietary management; intake of large neutral amino acids; enzyme replacement therapy (with PAH and phenylalanine ammonia lyase); co-factor therapy; the advantages and disadvantages of each of these therapies.

**Group activity**

1 Hr

Screening of the documentary film *The forgotten children*, followed by a discussion.

**Unit III**

**Glycans in mammalian systems**

Study of some aspects of glycobiology as background for the IEM covered in later sections.

**Glycosylation in mammalian systems**

1 Hr

Salient points; protein glycosylation — the biochemistry of N- and O-linked glycosylation and cellular organelles where reactions occur. Functions of glycans — an overview.

**Glycosaminoglycans and proteoglycans**

6 Hrs

General properties and functions of glycosaminoglycans; chemical structures of common glycosaminoglycans (heparan sulphate, dermatan sulphate, keratin sulphate, chondroitin sulphate and hyaluronic acid); an overview of proteoglycans; sources of chemical diversity among glycosaminoglycans and proteoglycans; the general scheme of biosynthesis and breakdown of glycosaminoglycans. The general composition, properties, and functions of proteoglycans; common cellular and anatomical locations of glycosaminoglycans and proteoglycans.

**Unit IV**

**Diseases due to aberrations in anabolic reactions**

Study of some disorders as models to understand this class of IEM.

**Congenital disorders of glycosylation**

1 Hr

An overview of this group of disorders; disorders due to deficiency of N-linked glycosylation, deficiency of O-linked glycosylation, and deficiency of multiple types of glycosylation; von Willebrand disease in the RIIIS/J mouse as an example of diseases due to faulty glycosylation resulting from gain-of-function mutations.
Hereditary multiple osteochondromas (HMO)  2 Hrs
Study of hereditary multiple osteochondromas — a disorder resulting from a deficiency in the biosynthesis of heparan sulphate. Symptoms; molecular genetic basis; biochemical basis; possible molecular mechanisms underlying the pathophysiology of the disease.

Unit V
Lysosomes  1 Hr
Discovery; properties; functions; trafficking of proteins into lysosomes.

Unit VI
Lysosomal storage disorders (LSD)

Disease biology  4 Hrs
Types of LSD; milestones in research on LSD; modes of inheritance; diagnosis of LSD, challenges in the management of LSD; symptoms; biomarkers.

Treatment options  3 Hrs
Treatments available and those under development: Dietary management; treatment of specific symptoms; enzyme replacement therapy; substrate reduction therapy; hematopoietic stem cell transplantation; pharmacological chaperone therapy (a.k.a. enzyme enhancement therapy); gene therapy; other treatments suitable for specific LSD.

Group activity  2 Hrs
Screening of the feature film Extraordinary Measures, followed by a discussion.

Unit XII
IEMs due to impairments in catabolic reactions
- Study of Gaucher disease and MPS disorders to learn about this group of IEM and about LSD.
- Gaucher disease as a typical lipid storage disorder.
- The MPS group as a model for disorders of carbohydrate metabolism.

Gaucher disease  1 Hr
Causes, classification, molecular genetics, diagnosis, symptoms, and treatment; the connection between Gaucher disease and Parkinson’s disease.

Mucopolysaccharidoses (MPS)  6 Hrs
Definition and types of MPS; biochemical basis, molecular genetic basis, clinical features, diagnosis, symptoms and treatment of the MPS disorders, namely, MPS I (Hurler syndrome, Scheie syndrome and Hurler-Scheie syndrome), MPS II (Hunter syndrome), MPS III (Sanfilippo syndrome) subtypes A–D, MPS IV (Morquio syndrome) subtypes A and B, MPS VI (Maroteaux-Lamy syndrome), MPS VII (Sly syndrome) and MPS IX; basic properties of the enzymes each of whose deficient activity causes an MPS disorder; animal models specifically designed for monitoring the efficacy of enzyme replacement therapy.

Unit VII
IEM due to defects in post-translational modifications of proteins  1 Hr
The study of the biochemical basis of multiple sulfatase deficiency as a model to learn about this group of disorders.

Unit VII

IEM due to defects in intracellular trafficking

Study of mucolipidosis II (I-cell disease) and mucolipidosis III (pseudo-Hurler dystrophy) as models for this group of diseases. Study of the biochemical basis of aberrant targeting of proteins into lysosomes in patients with these diseases.

Study of mucolipidosis I and II would serve as additional models for diseases due to defects in anabolic reactions, and diseases due to defects in post-translational modifications.

Unit IX

Presentations by students

HDG14. ESSENTIALS IN IMMUNOLOGY

(Lecture CREDITS-2)

Unit I

Organs and cells of the Immune system: Primary lymphoid organs, Secondary lymphoid organs, B lymphocytes, T lymphocytes, mononuclear phagocytes, granulocytes, mast cells, dendritic cells, natural killer cells.

Unit II

Innate immunity: Anatomical barriers, inflammation, anti-microbial peptides, acute phase proteins, toll like receptors

Unit III

B cell immunity: Development of B cells, B cell activation, proliferation & differentiation, structure and Functions of Immunoglobulins

Unit IV

Complement system: Components of the classical, alternate, lectin pathways, complement cascade, biological consequences of complement cascade, regulation of the complement system

Unit V

Antibody diversity: Organization of immunoglobulin genes, mechanism of gene rearrangements, class switching, regulation of immunoglobulin genes

Unit VI

The major histocompatibility complex and antigen presentation: General organization of the MHC genes, cellular expression of MHC genes, MHC and immune responsiveness, MHC antigens and antigen processing

Unit VII

T cell immunity: Development of T cells and their education, T cell activation, proliferation & differentiation, T cell types, T cell receptor and co receptors, signaling in T cells, helper and cytotoxic T cells, cytokines
Unit VIII

**Hypersensitivity:** IgE antibody-mediated hypersensitivity, antibody-mediated cytotoxicity, immune complex mediated hypersensitivity, delayed type hypersensitivity

Unit IX

**Autoimmunity:** Organ specific autoimmune diseases, systemic autoimmune diseases, mechanisms of autoimmunity, treatment of autoimmune diseases

Unit X

**Autoimmunity:** Organ specific autoimmune diseases, systemic autoimmune diseases, mechanisms of autoimmunity, treatment of autoimmune diseases

Unit XI

**Immunodeficiency disorders:** Primary immunodeficiency diseases of lymphoid cells, myeloid cells and granulocytes, complement components, acquired immunodeficiency diseases

Unit XII

**Cancer and immune system:** Tumor evasion of the immune system, cancer immunotherapy

Unit XIII

**Vaccines:** Active and passive immunization, vaccine designs, subunit vaccines, DNA vaccines

**HDG15. GENETIC COUNSELLING AND ETHICS**

**(Lecture CREDITS -2)**

**PART 1-GENETIC COUNSELLING**

Unit I

**Introduction to genetic counselling**

Unit II

**Impact of illness on patients and families:** Morbidity and support services, access to education and economic support, social practices and health cost issues. Incidental detection of other genetic disorders on pedigree evaluation and NGS testing, manifesting carriers, later onset genetic disorders including neuro-genetic disorders, e.g., Huntington’s disease, Myotonic dystrophy and Inherited cancers

Unit III

**Congenital anomalies and rare medical disorders, its impact on community health and health priorities:** Incidence of common congenital anomalies and risk factors, pre-pregnancy evaluation and intervention strategies, new-born screening for rare metabolic disorders, Consanguinity and its impact on genetic disorders, registries and support groups for rare medical disorders

Unit IV

**Social and cultural issues in rare medical disorders:** Evaluation of social attitudes and customs, caste, consanguinity, economic status and cultural perceptions in the evaluation of genetic disorders. Impact of disorders of
sexual development (DSDs) and genetic counselling in these disorders, eg. sex reversal, androgen insensitivity disorder and Klinefelter and Turner syndrome. Impact of rare disorders on decisions about marriage, reproduction, prenatal diagnosis and integration in mainstream education and society

Unit V

3Hrs
Predictive counselling for late onset disorders, e.g., Huntington’s disease, breast and ovarian cancer: Principles about predictive counselling and testing in late onset disorders, imparting results of predictive testing, counselling and management in follow up sessions, ethical issues in testing of minors, prenatal diagnosis in late onset disorders, ethical and social issues

PART 2-ETHICS

Unit I:
Clinical Ethics 1 Hr

Unit II:
Ethical issues in prenatal diagnosis and newer reproductive technologies 1 Hr

Unit III:
Genetic testing in adult onset disorders 1 Hr

Unit IV:
Testing of vulnerable populations, for example, children of intellectually incapacitated individuals, consent and confidentiality. 1 Hr

Unit V:
Research Ethics: the use of placebos, conflicts of interest and clinical trials, research on animals and vulnerable populations, research in developing countries 1 Hr

Unit VI:
Role and Scope of Institutional review board in scientific research. 1 Hr

Unit VII:
Global & Population Ethics: global disparities in health and public health, global pandemics, population growth, human rights to health and health care, role of foreign aid. 1 Hr

Unit VIII:
Ethics of New Technologies: embryonic stem cells, animal cloning, genetic engineering, synthetic biology. 1 Hr

Unit IX:
Environmental & Animal Ethics: species preservation, biodiversity loss, ecosystem services, the use and misuse of animals, ethics 1 Hr

Unit X:
Medico-legal Issues: Surrogacy, Organ donation, Paternity testing. 1 Hr
HDG16. USE OF MODEL ORGANISMS TO STUDY HUMAN DISEASE
(DISCUSSIONS AND SEMINARS)
(Lecture CREDITS-2, SOFT CORE, Hours: 39)

This course is aimed at an interactive learning experience for the students and will consist of seminars and discussions led by invited speakers who use model organisms in their research. Students will also make presentations and write essays defending a particular choice of model organism.

The following topics will be covered:

Unit I
*Planaria:* Using a simple micro-organism to study the cell biology of regeneration.

Unit II
*C. elegans:* Overall advantages of *C. elegans* as a system to study human diseases, ease of culture, ease of performing cellular and genetic studies, conservation in signalling pathways, use of the system to study the biology of metabolic disorders such as diabetes and ageing; use of the system in drug screening.

Unit III
*D. melanogaster:* Overall advantages and disadvantages of *D. melanogaster* as a system to study human diseases, ease of culture, short generation time, ease of performing cellular and genetic studies, formidable range of genetic tools available, conservation of signalling pathways and cellular mechanisms; limitations of the system (for example, innate immunity versus adaptive immunity, specialized organ diseases such as those affecting vision and hearing; disadvantages of using invertebrate models) use of the system to study the biology of diseases such as Alzheimer’s disease, neurodegenerative disorders, Parkinson’s disease, triplet repeat expansion diseases, Fragile X syndrome, metabolic disorders and diabetes, tumour formation; use of the system in drug screening.

Unit IV
*Zebrafish:* Overall advantages and disadvantages of the zebra fish *D. rerio* as a system to study human diseases, economy and ease of culture, ease of performing cellular and genetic studies, formidable range of genetic tools available, conservation of signalling pathways and cellular mechanisms; advantages of vertebrate models, similarity in organ systems across different vertebrates; using vertebrate orthologous genetic, mutant models to study haematological diseases such as *sideroblastic anaemia*, polycythaemia, and porphyria; *T*-cell leukaemia models, Melanomas, heart defects resembling human dilated cardiomyopathies (DCMs), modelling *Duchenne muscular dystrophy*, Polycystic kidney disease (PKD), etc.; use in drug screening.

Unit V
*Mouse and other mammals:* Overall advantages and disadvantages of using mammalian systems, similarity in physiology and organ function with humans, similarity in organization and function of the brain and sense organs between mammals and humans, use as models to study behaviour and diseases that affect behaviour, learning and memory; high genetic conservation; ethical issues concerning use of mice, primates and dogs. Studying humanised mouse models containing transplanted human cells or the human orthologues of specific genes; modelling cancers; genetic disorders such as hearing-loss disorders; uses in drug testing and treatment of early onset cancers such as acute promyelocytic leukaemia (APL), role of the protein Leptin in controlling obesity.
Unit VI

**Human Induced Pluripotent Stem Cells**: as tools in drug development and modelling diseases; the ability to create patient and disease specific stem cells.

**HDGP8. LAB MODULE VIII- RESEARCH METHODOLOGY**
(CREDITS -2)

This course is designed to teach students how to address a research problem of interest. It is an opportunity to explore plausible problems and then define more specifically the project that will be undertaken during the fourth semester. This exercise will be carried out in one of the research laboratories in CHG. The students will be expected to conduct a literature survey, define project objectives, collect material required for the project and conduct preliminary investigations. They will then present their results through a seminar and written report.

**HDGP9. LAB MODULE IX- MOLECULAR DIAGNOSTICS**
(CREDITS -4)

1. **Polymerase chain reaction (PCR)**: Types of PCRs and its multiple applications; Gradient PCR, Multiplex PCR, GC rich PCR, ARMS PCR
2. **Primer design**: Guidelines for primer designing; tools for designing primers- NCBI primer BLAST and Oligocalc; Primer design for genes to be used for PCR and sequencing.
3. DNA gel electrophoresis of PCR amplified products
4. Purification of PCR amplified products.
5. Sanger sequencing of gene exons for mutation detection.
6. Analysis of Sequence-electropherograms and analysis of identified sequence variations. Sequencher software for data analysis; Use of NCBI database and mutation Database (HGMD) for analysis of variants; Online prediction tools –SIFT, PROVEAN, PolyPhen and mutation Taster.
7. **Screening for Y microdeletion**: polymorphic markers in AZF region; multiplex PCR
8. **Restriction Fragment length Polymorphism**: SMN exon 7 and exon 8 deletion
9. **Quantitative PCR (qPCR) for estimation of gene copy or transcript expression level**: Detection of SMN gene copy number – to identify heterozygous or homozygous status. Analysis of qPCR data, calculation of double delta Ct value.
10. Genotyping with PCR for deletion screening.
11. STR-based Human Identification; GeneMarker software.
12. Detection of Fragile X mutation though capillary electrophoresis; Calculation of CGG repeat size

**HDGP10. LAB MODULE X - GENETIC COUNSELLING AND ETHICS**
(CREDITS -2)

Time spent in clinics (clinical rotations) during the semester.

This course consists of visits to the clinic, where students obtain first-hand experience of the symptoms presented and patients’ concerns. These rotations will provide an opportunity for students to learn directly about medical genetic
conditions and their impact on individuals and families and interpretation of medical diagnosis in real life clinical sessions based in a hospital outpatient setting. They will gain practical insight in pedigree evaluation, recent advances in medical genetics, therapy options, prenatal diagnosis and practical genetic counselling.

The students then participate in the discussions that ensue, that helps in the diagnosis of the disease and decisions on possible courses of action.

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SEMESTER 4

HDG18. CANCER BIOLOGY

(Lecture CREDITS-2)

Unit I

1 Hr

Basics about Cancer: Introduction to cancer, origin, types (types of tumours, stages of malignancy), basic terminology.

Unit II

5 Hrs

Hallmarks of Cancer: Basic mechanisms regulating normal tissue homeostasis: regulation of cell-proliferation, growth, differentiation and apoptosis; aberrations in regulatory mechanisms that result in cancer.

Unit III

13 Hrs

Genetic and Epigenetic Alterations in Cancer: The nature of commonly occurring mutations in cancerous tissue: gain of function, loss of function, copy number variation (CNV), chromosomal-translocations etc.; signalling pathways commonly affected in cancers; oncogenes: mechanisms of activation and action, different functions of oncogenes, rationale for therapeutic targeting. Tumour suppressor genes: mechanisms of loss of function, loss of heterozygosity, Knudsen’s two hit hypothesis, different functions of tumour suppressor genes. Caretaker and gatekeeper genes. Epigenetic alterations: role of the Polycomb group (PcG) and Trithorax (Trx) proteins in carcinogenesis; basis of epigenetic therapy. Methods of detecting genetic alterations and their use as diagnostic/prognostic tools; targeting genetic alterations for therapy; mouse models for understanding the role of these gene products in the development of cancer.

Unit IV

1 Hr

Viral causes of cancer: History of discovery, mechanism of action of commonly seen viruses such as HPV, EBV, HBV, HCV.

Unit V

1 Hr

Familial cancer syndromes: NF1, FAP, VHL, etc.

Unit VI

1 Hr

Molecular mechanisms of metastasis: Different steps and cellular state transitions in metastases; genes responsible for metastases; organ specific metastases.
Unit VII

Tumour microenvironment: Composition of the tumour microenvironment; mechanisms of tumour angiogenesis, targeting angiogenesis for therapy; mechanisms of immune evasion, targeting immune evasion for therapy.

Unit VIII

Metabolic reprogramming in cancer: The phenomenon known as Warburg effect.

Unit IX

Challenges in treatment of cancer: The development of therapeutic resistance, the occurrence of a relapse; current developments in treating cancers.

HDG19. HUMAN GENOME ORGANIZATION

(Lecture CREDITS-2)

Unit I

Mapping the Human Genome (techniques used and historical perspective): DNA markers in human genetic mapping, RFLP, occurrence of single nucleotide polymorphisms; current data from understanding human genome libraries, expression libraries, DNA microarray and CHIP technology for genome wide analysis; linkage analysis and genetic mapping; an over view of genome sequencing technology, assembling genomic DNA sequences, the human genome draft sequence.

Unit II

Organization of the human genome (an overview): Complexity, size, heterochromatin vs euchromatin; comparisons with genomes of model organisms; case study annotation of human genes and visualization of gene tracks using UCSC genome browser; examples: non coding RNA Xist locus, Myc locus, Promoters (Ink4a) , Enhancer elements ( P300)

Unit III

Understanding genome function: Studying the human transcriptome and proteome Coding vs non-coding sequences in humans: Regulatory sequences, open reading frame (ORF) organization; microRNA and other non-coding RNAs; mobile genetic elements and repeats.

Unit IV

Comparison of the Genetic features of Human Nuclear Genomes and organelle Genomes.

Unit V

Chromatin modification and gene expression in humans: Epigenetic landscapes of human genome; use of ENCODE and modENCODE to understand regulatory epigenetic landscape dynamics during development and disease; DNA modification and gene expression, analysis of DNA elements in human genome, DNA binding sites of proteins and their signature in the genome; examples of current CHIP-seq analyses in humans; transcriptional initiation through a genomic perspective, enhancer-promoter interactions, chromatin contact mapping in 3D as visualized in hi-seq/5C or FISH (3D architecture) taking examples of human studies.
HDG20. GENETICS OF INFERTILITY AND ASSISTED REPRODUCTION TECHNOLOGY

(Lecture CREDITS-2, Hours-26)

Unit I.
Oogenesis and Folliculogenesis: Oocyte retrieval and selection. Preparation and evaluation of oocytes for ICSI. Hyaluronic acid binding-mediated sperm selection for ICSI.

Unit II.

Unit III.

Unit IV.
Endometrial Receptivity and Female Factor Sterility: Window of implantation, endometrial cycle, Assessment of Receptivity, Impact of Ovarian Stimulation.

Unit V.

Unit VI.
Genetics of Infertility: Cytogenetic Abnormalities, Genetics of y chromosome-Derived Infertility, Molecular Genetic Testing.

Unit VII.
Female Factor Infertility: Uterine, Cervical, Tubal and Fallopian tube factors.

Unit VIII.
Infertility and Molecular Genetics in Females.

Unit IX.
Advances and Dilemmas in Assisted Reproductive Technologies.

Unit X.
Preimplantation Genetic Screening of Embryos.

Unit XI.
Preimplantation Genetic Diagnosis.

Unit XII.
Preimplantation Genetic Diagnosis and HLA typing.
Unit XIII. 
OMICS in Infertility.

HDG21. INTRODUCTION TO DISEASE BIOLOGY  
(Lecture CREDITS -2, Hours-26)

PART 1: CANCER BIOLOGY (EMPHASIS ON BREAST CANCER)

1. General Introduction to pathways in cancer, methods and experimental approaches in a lab.
2. Tissue processing, Embedding and microtomy and Histological examination
3. RNA/DNA extraction from biological samples, quantification, cDNA and qPCR.
5. Tissue Micro array and Fluorescent In-Situ hybridization (Introduction and demonstration)
6. Bioinformatic approaches used in patient sample analysis.
7. Ethical guidelines and importance of follow-up in clinical research

PART 2: BIOLOGY OF KIDNEY DISEASES

1. Introduction to Kidney diseases (special emphasis on Nephrotic syndrome)
2. SNP and population genetics- Genotype and allele frequency calculation- (Vitamin A pathway gene polymorphism and kidney size)
3. Mutation nomenclature and classification
4. High resolution melting analysis with qPCR – analysis and applications
5. Practical guide to use of various SNP databases

HDGP11. SCIENTIFIC WRITING AND PRESENTATION - TERM PAPER SUBMISSION  
(CREDITS-4)

The student will write and present an up to date review of literature on a selected topic or alternately, a project proposal. This would serve as a platform to enhance the student’s skills in reading scientific literature, critical analysis of the literature and communication skills. Special attention will be given to discouraging plagiarism.

HDGP12. DISSERTATION  
(CREDITS-8) (VIVA VOCE AND PRESENTATION-2)

This course consists of an individual research project to be carried out in one of the research laboratories in CHG. The students will be expected to complete the project and present their results through a seminar and written dissertation.

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References

SEMESTER1
HDG01. Fundamentals of Genetics


**HDG02. Human cytogenetics**

10. S Heim, F Mitelman (2011) Cancer Cytogenetics: Chromosomal and Molecular Genetic Aberrations of Tumor Cells, John Willey and Sons Publications

**HDG03 and HDGP4: Biostatistics and R programming**


**HDG04. Human Embryology, Anatomy and Physiology**

1. TW Sadler (2011) Langman’s Medical Embryology, Lippincott Williams and Willkins Publication

**HDGP1. Lab Module I-Genetics**


**HDGP2. Lab Module II-Basic cell immortality techniques**


**HDGP3. Lab Module III-Human cytogenetics**


**HDG05. Science writing and presentation**

11. ONLINE SOFTWARE: [https://www.rationaleonline.com](https://www.rationaleonline.com)

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**SEMESTER2**

**HDG06. Biochemistry**


**HDG07. Molecular Biology**


**HDG08. Cell Biology**


**HDG09. Principles of Development**

HDG10. Bioinformatics

5. ONLINE COURSE: ExPASy: http://www.expasy.org/
6. web portal of multiple sources: www.startbioinfo.com

Databases:

2. UCSC Genome Browser: http://genome.ucsc.edu/
5. Protein Catalogue Uniprot: http://www.uniprot.org/

HDG11. Principles of Evolution and Population genetics


HDGP5. Lab Module V-Biochemistry and Molecular Biology

2. Protocols Online: http://www.protocol-online.org/
5. Protocols Online: http://www.protocol-online.org/

HDGP6. Lab Module VI-Cell Biology

2. Protocols Online: http://www.protocol-online.org/

HDGP7. LAB MODULE VII – BIOINFORMATICS

2. EMBL: www.embl.de/
3. UCSC: genome.ucsc.edu/
4. collection of case studies and reviews at www.startbioinfo.com

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SEMESTER 3

HDG12. Human Molecular Genetics

2. For information on Mendelian phenotypes: http://www.omim.org

HDG13. Biochemical Genetics

4. Review articles published in journals.

HDG14. Essentials in Immunology


HDG16. Use of Model Organisms to study human disease

5. Online resource-Model organisms for Biomedical research: http://www.nih.gov/science/models/
HDGP9. Lab Module IX - Molecular Diagnostics

5. S Heim, F Mitelman (2011) **Cancer Cytogenetics: Chromosomal and Molecular Genetic Aberrations of Tumor Cells**, John Willey and Sons Publications

HDG15 and HDGP10. Lab Module X - Genetic Counselling and Ethics

3. T Strachan and A Read (2011), **Human Molecular Genetics**, Garland

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SEMESTER4

HDG18. Cancer Biology

4. Relevant research articles, reviews and online resources

Syllabus: MSc in Human Disease Genetics
July 2018
HDG19. Human Genome Organization


HDG21. Introduction to Disease Biology


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