Centre for Human Genetics

M.Sc. (Human Disease Genetics) (CBCS)

Scheme of Instruction & Examination, Semester System (Last Updated Feb 2025)

Course code	Course title	Course Type	Hours/week	Duration of Exam (hrs)	Marks IA	Marks EA	Marks Total	Credits
I Semester								
HDG01	Cell biology	Theory , H Core	2	2	15	35	50	2
HDG02	Fundamentals of genetics	Theory , H Core	2	2	15	35	50	2
HDG03	Human cytogenetics	Theory , H Core	2	2	15	35	50	2
HDG04	Biostatistics	Theory , H Core	2	2	15	35	50	2
HDG05	Human embryology, anatomy and physiology	Theory , H Core	4	3	30	70	100	4
HDG06	Principles of development _ Part I	Theory , H Core	2	2	15	35	50	2
HDGP1	Practical module I – Genetics	Lab , H Core	8		30	70	100	4
HDGP2	Practical module II – Basic cell immortalization techniques	Lab , H Core	4		15	35	50	2
HDGP3	Practical module III – Human cytogenetics	Lab , H Core	8		30	70	100	4
HDGP4	Practical module IV – Biostatistics and programing in R	Lab , H Core	4	3	15	35	50	2
		Total hours of instruction/week	**38**		**Total marks and credits**		**650**	**26**
II Semester								
HDG07	Biochemistry	Theory , H Core	2	2	15	35	50	2
HDG08	Molecular biology	Theory , H Core	4	3	30	70	100	4
HDG09	Principles of development _ Part II	Theory , H Core	4	3	30	70	100	4
HDG10	Bioinformatics	Theory , H Core	2	2	15	35	50	2
HDG11	Principles of evolution and population genetics	Theory, H core	2		15	35	50	2
HDG12	Science writing and presentation	Theory , S Core	2	2	15	35	50	2
HDGP5	Practical module V – Biochemistry and molecular biology	Lab , H Core	8		30	70	100	4
HDGP6	Practical module VI – Cell biology	Lab , H Core	4		15	35	50	2
HDGP7	Practical Module VII – Bioinformatics with R	Lab, H Core	4	3	15	35	50	2
		Total hours of instruction/week	**30**		**Total marks and credits**		**600**	**24**
III Semester								
HDG13	Human molecular genetics	Theory , H Core	4	3	30	70	100	4
HDG14	Biology of inherited metabolic disorders	Theory , H Core	4	3	30	70	100	4
HDG15	Essentials in immunology	Theory , H Core	2	2	15	35	50	2
HDG16	Genetic counselling and ethics	Theory , H Core	2	2	15	35	50	2
HDGP8	Practical Module VIII – Research methodology	Lab , H Core			15	35	50	2
HDGP9	Practical Module IX - Molecular diagnostics	Lab , H Core	8		30	70	100	4
HDGP10	Practical Module X – Genetic counselling and ethics	Lab , H Core	4		15	35	50	2
HDGP11	Scientific writing and presentation – term paper submission	Lab , H Core			15	35	50	2
HDG17	Course will be held in other suitable departments	OE	4	3	30	70	100	4
		Total hours of instruction/week	**31**		**Total marks and credits**		**650**	**26**
IV Semester								
HDG18	Cancer biology	Theory , H Core	2	2	15	35	50	2
HDG19	Advanced techniques in genetic research	Theory , H Core	4		30	70	100	4
HDG20	Advances in treatment of disease _ cancer and infertility	Theory, H Core	2		15	35	50	2
HDGP12	Dissertation work	Lab , H Core			75 15	175 35	250 50	10 2
		Total hours of instruction/week	**6**		**Total marks and credits**		**500**	**20**
					Grand total of marks and credits		**2400**	**96**

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Centre for Human Genetics

Syllabus

SEMESTER 1

Course code and title		Type	Core	Credits
HDG01	Cell Biology	T	H	2
HDG02	Fundamentals of Genetics	T	H	2
HDG03	Human cytogenetics	T	H	2
HDG04	Biostatistics	T	H	2
HDG05	Human Embryology, Anatomy and Physiology	T	H	4
HDG06	Principles of Development_ Part I	T	H	2
HDGP1	Practical Module I – Genetics	L	H	4
HDGP2	Practical Module II – Basic cell immortalization techniques	L	H	2
HDGP3	Practical Module III – Human cytogenetics	L	H	4
HDGP4	Practical Module IV – Biostatistics and programing in R	L	H	2

Abbreviations: T- Theory, L- Lab, H- Hard core, S- Soft core

HDG01. CELL BIOLOGY TH2

Unit I - Cell Theory and Introduction to Cell Biology (2hrs): 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, origin of life- evolutionary perspective, cell theory, organelles, origin of organelles (mention of endosymbiont theory).

Unit II - Biological membranes (2hrs): Origin and evolution of primitive cells; composition of biological membranes: phospholipids, lipid bilayer, structure and organisation of cell membranes, fluid-mosaic model, membrane fluidity and rigidity, role of cholesterol, proteins in membranes, integral and peripheral membrane proteins and their functions; techniques used to study membranes and membrane proteins: SDS PAGE, microscopy including electron microscopy, fluorescence recovery after photobleaching (FRAP) technique, freeze fracture, etc.; sub cellular fractionation, introduction to cell organelles and their functions.

Unit III - Cell organelles (2 hrs): Structure, function and diseases associated with cell organelles such as mitochondria; mitochondrial membranes, their composition and function, cristae, the mitochondrial genome – features and genetic code.

Organisation and structure of endoplasmic reticulum (ER) and Golgi apparatus, role in protein processing and transport to appropriate compartment, secretory pathways, protein sorting to ER and Golgi, protein modification –glycosylation, ER stress response, homeostasis and human diseases.

Unit IV - Nuclear Architecture and Organization (3 hrs): Main features of the nucleus, structure and organisation, nuclear membranes, nuclear pores; Lamins and LINC complexes, nucleoporins, nuclear transport of proteins and RNA, genetic defects and diseases, dystrophy, laminopathies; nuclear organizer region, kinetochore and centrosome;

Unit V - Cell Division (5 hrs): The cell cycle, phases of the cell cycle, mitosis and meiosis, stages in mitosis and meiosis, cell cycle controls, signals and regulation, START in yeast, cell cycle mutants, discovery of MPF, CDC kinases and cyclins, role of Condensin and Cohesin, cell cycle check points, techniques to study the cell cycle – flow cytometer, fluorescence activated cell sorting (FACS).

Unit VI - Cytoskeleton and cell motility (3hrs): Components of the cytoskeleton, organization in stationary and motile cells; functioning of the cytoskeleton and molecular motors; diseases associated with the cytoskeleton.

Unit VII - Protein and Small Molecule Trafficking (3 hrs): 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 (5 hrs): 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 detection.

Unit IX - Senescence and Programmed cell death (1 hr): 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.

HDG02. FUNDAMENTALS OF GENETICS **TH2**

Unit I - Heredity and Variation (2 Hrs): 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.

Unit II – Mendelism: Brief overview of Mendel's work (law of segregation, law of independent assortment); principle of equivalence of reciprocal hybrids; application of laws of probability (product and sum rule); chi-square test and its application in analysis of genetic data; pattern of inheritance in haploid organisms like Chlamydomonas and Neurospora

Unit III – Extensions of Mendelian principles: Incomplete dominance, codominance, interaction of genes (epistasis, suppressors), lethal alleles, penetrance and expressivity, pleiotropy, phenocopies

Unit IV – 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;

Unit V – Mapping of Genetic Loci: Linkage, crossover and map distance, Sturtevant's linkage map, interference and coincidence; mitotic recombination, sister chromatid exchanges; mobile genetic elements.

Unit VI – Genetics of complex traits: Polygenic (quantitative) inheritance, effects of inbreeding.

Unit VII – Fine structure of the gene: Multiple alleles, pseudo alleles, Beadle and Tatum's one-gene one-enzyme concept, one-gene one-polypeptide concept; complementation (cis-trans) test; cistron, muton, recon (eg. *Drosophila*, rII locus in T4 bacteriophage)

Unit VIII – Overview of Gene Mutations: Types - transitions and transversions; missense, non-sense, frameshift mutations; loss-of function, gain-of function mutations - amorphic, hypopmorphic, neomorphic, hypermorphic, antimorphs.

Unit IX – An Overview of cytogenetics: Implications of structural and numerical chromosomal variations.

Unit X – Sex Chromosomes: Sex linked, sex influenced and sex limited inheritance; sex determination; dosage compensation (in *Drosophila*, *C. elegans* and human)

Unit XI – An introduction to Epigenetics and Genome imprinting.

Unit XII – An 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.

Unit XIII – 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 XIV – 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.

Unit XV – Introduction to Microbial Genetics (2 Hrs): Exchange of genetic material in bacteria: conjugation, transformation and transduction; mapping of bacterial genes using phage, fine structure of bacteriophage genes; bacterial and viral gene maps. Natural gene transfer of antibiotic resistance, horizontal gene transfer.

HDG03. HUMAN CYTOGENETICS **TH2**

Unit I - Introduction to Cytogenetics and Clinical Cytogenetics (2 Hrs): 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 (3 Hrs): 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 (**3 Hrs):** 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 (2 Hr): 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 (2 Hrs): 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 leukaemias (CML, AML, APML, myelodysplastic syndromes etc.,) and solid tumours (Sarcomas and carcinomas).

Unit VI - Introduction to Molecular Cytogenetics (1 Hr): 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) (2 Hrs): 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 (2 Hrs): 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 (3 Hrs): Principles and procedure, details of FISH probes used in detecting various markers [(BCR/ABL, t(15;17), t(8;21) etc.,] found in Leukaemia and solid tumours(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 tumours, 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 (3 Hrs): Principles and procedures involved and their applications in clinical diagnosis of genetic abnormalities (including complex chromosomal translocations – CCRs etc.,) - Primed *in situ* labelling (PRINS), comparative genomic

hybridization (CGH), Spectral karyotyping (SKY), multicolour FISH (mFISH) and multicolour banding (mBAND), Fiber FISH, etc., using appropriate examples.

Unit XI - Quality Assurance (2 Hrs): Interpretation and Reporting of normal and abnormal reports using International System for Human Cytogenetic Nomenclature (ISCN) for FISH.

HDG04. BIOSTATISTICS TH2

Unit I - General Introduction and Probability (4 Hrs): 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 (3 Hrs): 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 III - Estimation (3 Hrs): 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 (4 Hrs): 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 $\chi 2$ 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 (4 Hrs): 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, R×C contingency tables; chi-square goodness-of-fit test, the kappa statistic.

Unit VI - Nonparametric Methods (2 Hrs): the sign test, the Wilcoxon signed-rank test, the Wilcoxon rank-sum test.

Unit VII - Regression and Correlation Methods (4 Hrs): 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 (4 Hrs): 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.

HDG05 HUMAN EMBRYOLOGY, ANATOMY AND PHYSIOLOGY TH4

PART 1 - HUMAN ANATOMY and EMBRYOLOGY

Unit I – Introduction (2hrs):
Human Cell (parts and the functions of each), tissues (define & classify surface and glandular epithelium, functions and type with examples), connective tissue (classification, functions), gametogenesis (oogenesis, spermatogenesis, meiotic disturbances, cause for teratoma) and microscopic structure of uterus.

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Unit II - Fertilization and assisted reproductive technologies, early embryogenesis (2hrs):
Process of fertilization (penetration of corona radiata, acrosomal reaction, capacitation, effects of fertilization, sterility and in-vitro fertilization), cleavage & implantation (hydatidiform mole, conditions and syndromes associated with parental imprinting, twinning & ectopic pregnancy)

Unit III – Early embryogenesis – formation of germ layers and early derivatives, establishment of the basic embryonic body plan (2hrs)
Changes in the second week of fertilization, gastrulation (primitive streak, primitive node, notochord, prechordal plate, neural plate formation, embryological basis for situs inversus and Kartagene's syndrome), Neurulation, segmentation of neural tube, neural crest, development of mesodermal germ layers, paraxial mesoderm, organization of somite and basic segmental body plan, intermediate and lateral plate mesoderm, formation of the coelom, extraembryonic mesoderm and the umbilical cord, early stages in the formation of the circulatory system, development of the endodermal germ layer and derivatives of the embryonic germ layers

Unit IV – Placenta and extraembryonic membranes, developmental disorders- causes, mechanism and patterns (2hrs)
Amnion, yolk sac, allantois, chorion and formation of mature placenta, placental circulation, formation of umbilical cord and pathological conditions of placenta.
Developmental disorder – general principles and causes for malformation. Diagnosis and treatment of birth defects

Unit V – Development of integumentary, skeletal and muscular system (2hrs)
Microscopic structure of skin along with its functional components, embryological basis for ectodermal dysplasia/Ichthyosis.
Anatomy of axial skeleton and appendicular skeleton, endochondral and intramembranous ossification, development of axial skeleton, embryological basis for Klippel-Feil syndrome, Accessory ribs, split xiphoid process and Cleidocranial dysplasia.
Development of skull, embryological basis for craniosynostosis, scapho-cephaly and Oxycephaly
Anatomy of appendicular skeleton, initiation of limb development, outgrowth of limb bud, apical ectodermal ridge, mesoderm of the early limb bud, meso-ectodermal interactions & morphogenesis, musculature, vascularity and nerve innervation.
Embryological basis for phocomelia, amelia, syndactyly and polydactyly
Skeletal muscle- type of muscles, microscopic structure of muscle, morphogenesis of muscle and embryological of muscular dystrophy

Unit VI – Development of Nervous system, Development of special sense organs (4hrs)
Anatomy – Central nervous & Peripheral Nervous system with few important functional aspects. Neurulation process, cross-sectional organization of the developing neural tube, craniocaudal pattern formation and segmentation, patterning in the forebrain, midbrain, hindbrain and spinal cord. Structural organization and development of the peripheral & autonomic nervous system. Neural crest cells and their derivatives. Embryological basis for congenital aganglionic megacolon (Hirschsprung's Disease), microcephaly and defects in closure of the neural tube
Parts of eye, embryological basis for cyclopia, anopthalmia, coloboma of the iris and congenital cataract
Parts of ear, embryological basis for congenital deafness and auricular anomalies

Unit VII – Development of Head and Neck, Development of Respiratory system (4hrs)
Parts of facial bones, development of the facial region, palate and salivary glands. Embryological basis of cleft lip and palate, proboscis and hypertelorism
Development of Pharynx. Embryological basis of Pierre Robin syndrome, Treacher Collins syndrome, agnathia, cervical sinus, cyst and fistula. Embryological basis of thyroglossal cyst, ankyloglossia, DiGeorge syndrome, ectopic parathyroid or thymic tissue
Parts of respiratory system along with development. Embryological basis for tracheoesophageal fistula, pulmonary atresia, respiratory distress syndrome and congenital cysts in the lung

Unit VIII – Development of Gastro-intestinal system and diaphragm (4hrs)
Part of GIT (both gross & microscopic) with important functional aspects. Development of foregut, midgut and hindgut along with pancreas, liver and spleen. Embryological basis of duodenal atresia, Meckel's diverticulum, omphalocele, congenital umbilical hernia, abnormal rotation of the gut, imperforate anus, annular pancreas and biliary atresia.
Formation of the coelom and mesentery, formation of the septum transversum and pleural canals. Development of diaphragm along with embryological basis of ventral body wall defects and diaphragmatic hernias

Unit IX – Development of cardio-vascular system (4hrs):
Parts of heart, formation of the heart fields and the heart tube, cardiac loop, formation of the septa
Embryological basis of interatrial septal defect, persistent atrioventricular canal, tricuspid atresia, mitral atresia, interventricular septal defect, malformation of the outflow tract, persistent truncus arteriosus, transposition of the great vessels
Aortic and pulmonary stenosis and tetralogy of Fallot.
Vascular development: vasculogenesis and angiogenesis; formation of aortic arches and derivatives; formation of the venous system; foetal circulation and circulatory changes after birth

Embryological basis of double aortic arch, right aortic arch, right subclavian artery arising from the arch of aorta, interruption of the left aortic arch, patent ductus arteriosus , coarctation of aorta, malformation of venae cavae, anomalous pulmonary return and malformation of the lymphatics

Unit X – Development of urogenital system (4hrs)
Parts and important functional aspects of kidney – both gross and microscopic, Parts of male and female genital tracts with important functional aspects, microscopic structure of the above. Development and fate of the pronephros, mesonephros and metanephros. Development of the gonads. Hormonal influence on development of the genital system.
Embryological basis of renal agenesis, renal hypoplasia, renal duplications, anomalies of renal migration and rotation, horse-shoe kidney, polycystic kidney, anomalies of renal arteries, ectopic uretral orifice, extrophy of the bladder, epispadias and urachal cysts, sinuses and fistula
Embryological basis of Turner's syndrome, Hermaphroditism, testicular feminization, mesonephric duct & paramesonephric duct remnants, persistent Mullerian duct syndrome, agenesis of vagina, cryptorchidism, ectopic testis, congenital inguinal hernia, hypospadias, epispadias, duplication of penis, congenital absence of penis and enlargement of clitoris

Unit XI – Endocrine system (2hrs)
Location, structure (both gross and microscopic) and functions of different endocrine glands.

Unit XII – Concluding sessions (4 hrs)
Overview of genetic abnormalities, a clinical perspective; visit to the anatomy department museum.

PART 2 - HUMAN PHYSIOLOGY

Unit I - Introduction to human physiology (2 Hrs): Levels of organization and organ systems of the body; Body fluid compartments, intracellular, extracellular and interstitial**.**

Unit II - Cardiovascular and lymphoid system (2 Hrs): maintenance of blood pressure, conduction system of heart; blood capillaries, movement of blood cells through capillaries; drainage of fluid from tissues; genetic disease that affect the cardiovascular system.

Unit III - Digestive system (2 Hrs): Innervation of gastrointestinal tract, accessory organs of digestion, gastrointestinal hormones, physiology of digestion, absorption and satiation.

Unit IV - Urinary system (2 Hrs): 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 - Reproductive System (2 Hrs): Physiology of the male and female reproductive systems, hormonal cycles and puberty.

Unit VI - Respiratory system (2 Hrs): 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 VII - Endocrine system (2 Hrs): 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 - Essentials of the nervous system (2 Hrs): Physiology of neurons, muscles, synapses and neurotransmitters; functions of cerebrum, cerebellum and brainstem and special sense organs such as eyes and ears; physiology of the cerebrospinal fluid; physiology of the choroid plexuses, meninges and blood brain barrier; blood supply to the brain and spinal cord.

HDG06. PRINCIPLES OF DEVELOPMENT _ Part I **TH2**

Unit I - Developmental Biology: Basic Principles and Concepts (1 Hr). 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, establishment of body axes and the germ layers in the *Xenopus* embryo (9 Hrs): Fertilization and the establishment of the dorso-ventral axis; changes that accompany the mid-blastula transition; classical transplantation and dye injection experiments demonstrating the state of commitment of cells to germ layer fates; signalling pathways associated with mesoderm induction and Spemann organizer formation; establishment of the germ layers; gastrulation.

Unit III - Origins of polarity, establishment of body axes and the germ layers in the zebrafish (*Danio rerio*) embryo (4 Hrs): Fertilization and the establishment of the dorso-ventral axis; cleavage and cell movements before gastrulation; changes that accompany the mid-blastula transition; importance of the yolk syncytial layer in germ layer specification; signalling pathways associated with mesendoderm induction and Spemann organizer formation; gastrulation.

Unit IV - Origins of polarity and the establishment of the body axes in the *C elegans* embryo (2 Hrs): Fertilization and the establishment of polarity and the body axes; concept of the mosaic mode of development; mechanisms of asymmetric cell division; early cleavage; role of PAR proteins in establishing cell polarity across the animal kingdom.

Unit V - Origins of polarity, establishment of body axes and the germ layers in the *D melanogaster* embryo (6 Hrs): Establishment of polarity and the body axes; fertilization and cleavage; cellularisation; changes that accompany the mid-blastula transition; the basic elements of body plan establishment; Dorsal protein nuclear localization gradient and establishment of the ectoderm and mesoderm; origin of the endoderm; gastrulation and accompanying cell movements.

Unit VI - Origins of polarity, establishment of body axes and the germ layers in the mammalian embryos (4 Hrs): Diversity of mammalian embryos; cleavage and the establishment of polarity and the body axes; amniote gastrulation; the function of the node as an organizer.

HDGP1. PRACTICAL MODULE I - GENETICS **LH4**

1. **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.
2. **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.
3. **Identification of X-linked genes**: Inheritance of the *white* gene locus to demonstrate sex linkage; analysis of reciprocal crosses.
4. **Deviations from Mendel's laws:** Crosses to demonstrate interaction of genes; balanced lethal system; quantitative traits; penetrance and expressivity using *eyeless* and *wingless* mutants as examples.
5. **One gene-one enzyme concept:** 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.
6. **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.
7. **Creating a genetic map using *Drosophila* markers**: Setting recombination crosses and preparing a recombination map from recombination frequencies.
8. **Human genetics**: Frequency of blood groups (ABO) and PTC tasters/non-tasters in a human population...

HDGP2. PRACTICAL MODULE II – BASIC CELL IMMORTALIZATION TECHNIQUES **LH2**

1. **Good laboratory practice (GLP) -** Safety measures to handle biological samples (blood, skin biopsy, cell lines etc.,), hazardous chemicals, electrical and fire safety measures. Handling of biosafety cabinets.
2. **Standard Operating procedure (SOP) for waste disposal and spill management** – for Solid, liquid hazardous and non-hazardous waste (glass, syringes, coloured bags for disposal, disposal of biological samples).
3. **Basics of cell culture -** principles of cell culture, preparation of culture media and other reagents, handling and maintenance of lab equipment (microscopes, centrifuges, CO2 incubators, LAF etc.,)
4. **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).

5. **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 tumour, etc.
6. **Principles of Microscopy**: Parts of a light microscope, principle of the Koehler illumination system, phase contrast microscopy, fluorescence microscopy and optical sectioning.

HDGP3. PRACTICAL MODULE III – HUMAN CYTOGENETICS LH4

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- banding 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.
4. **Quality Assurance:** Interpretation and Reporting of normal and abnormal reports using International System for Human Cytogenetic Nomenclature (ISCN).
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 (Colour) image capture and analysis.
   Multiplex fluorescent *in situ* hybridization (**mFISH**): Slide preparation, probe hybridization, probe detection, Methods in multicolour image capture and analysis.
   Multicolour banding (**mBAND**): Slide preparation, probe hybridization, probe detection, Methods in multicolour 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. PRACTICAL MODULE IV – BIOSTATISTICS AND PROGRAMMING IN R LH2

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
19. Using Excel spreadsheet for statistics calculations.
20. Using GraphPad for basic biostatistics.

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SEMESTER 2

Course code and title		Type	Core	Credits
HDG07	Biochemistry	T	H	2
HDG08	Molecular Biology	T	H	4
HDG09	Principles of Development _ Part II	T	H	4
HDG10	Bioinformatics	T	H	2
HDG11	Principles of evolution and population genetics	T	H	2
HDG12	Science writing and presentation	T	S	2
HDGP5	Practical Module V – Biochemistry and Molecular Biology	L	H	4
HDGP6	Practical Module VI – Cell Biology	L	H	2
HDGP7	Practical Module VII – Bioinformatics with R	L	H	2

Abbreviations: T- Theory, L- Lab, H- Hard core

HDG07. BIOCHEMISTRY TH2

Unit I - Fundamental Chemistry (1 Hr): 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 (4 Hrs): 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 (4 Hrs): 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 (2 Hrs): 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 - Hormones (6 Hrs): An overview of the endocrine system; general functions of hormones; the chemical nature of hormones — peptide and protein hormones, steroid hormones, amine hormones; biosynthesis of peptide hormones; regulation of hormone synthesis and secretion; utility of agonists and antagonists in the treatment of endocrine diseases.

Unit VI - Nucleic acids and their metabolism (3 Hrs): 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, rRNA and tRNA); synthesis of purines and pyrimidines: *de novo* and salvage pathways, catabolism of purines and pyrimidines.

Unit VII - Enzymes (2 Hrs): 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-catalysed 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, reversible-competitive, non-competitive and uncompetitive inhibition with graphical representations using L-B plots.

Student presentations (4 Hrs).

HDG08. MOLECULAR BIOLOGY **TH4**

Unit I - Biomolecules and central dogma of molecular biology (4 Hrs): 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.

Unit II - DNA replication in prokaryotes and eukaryotes (8 Hrs): 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 (6 Hrs): 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 (6 Hrs): 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 foot printing, 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, 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 (4 Hrs): Splicing: splicing mechanism and splicing signals, spliceosome assembly and function, self-splicing RNAs, tRNA splicing; role of RNA polymerase II CTD in mRNA processing, mRNA capping: cap structure, synthesis and function; mRNA polyadenylation: function of poly(A), polyadenylation signals and mechanism, poly(A)polymerase and turnover of poly(A); coupling transcription termination with mRNA, 3'-end processing, processing of rRNA; RNA editing and mRNA stability

Unit VI - Translation (8 Hrs): Ribosome composition and structure; discovery of tRNA and structure of tRNA, recognition during translation (second genetic code), proof reading 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 (2 Hrs): Polypeptide cleavage, brief mention of chemical modifications such as ubiquitin and ribozymes.

Unit VIII - Brief overview of eukaryotic gene regulation (10 Hrs): 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; example: *Xist* locus; packaging of DNA: structure of chromatin, heterochromatin and euchromatin, chromosomal territories, lamp brush 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, chromatin immunoprecipitation (ChIP), chromosome conformation capture (3C) and related techniques, hybridization techniques, yeast-two hybrid assay.

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Unit IX - Mutations and repair (4 Hrs): 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(BER), nucleotide excision repair(NER) and mismatch repair(MMR), photo-reactivation, non-homologous end joining (NHEJ), recombination mediated repair and translesion synthesis; defects in repair and repair-associated human diseases.

Unit X - Comparison of the Genetic features of Human Nuclear Genomes and organelle Genomes (5 Hrs).

HDG09. PRINCIPLES OF DEVELOPMENT _ Part II **TH4**

Unit I – Cell movements during early development (2 Hrs): Directed cell migration; planar cell polarity (PCP) and convergent extension; cell shape changes during epithelial folding; neural tube closure defects due to defective PCP pathway signalling.

Unit II - Segmentation in vertebrates and insects (9 Hrs): Segmentation in insects (*D melanogaster)* and vertebrates across the different germ layers _ mechanisms and signalling pathways involved in segment formation in *Drosophila* embryos; somitogenesis in vertebrates; axis elongation; formation of boundaries during development; genetic disorders that arise due to aberrant segmentation.

Unit III – Specification of segment identity (3 Hrs): Segment identity specification by Hox genes _ regulation of expression of Hox genes; the concept of posterior dominance; the Hox code; conservation of the Hox code across invertebrates and vertebrates; genetic disorders that arise due to mutations in the Hox genes.

Unit IV – Basics of organogenesis (4 Hrs): The development and signalling pathways involved in the specification of two organ systems: skeletal muscles and small intestine in *D melanogaster* and mammals.

Unit V – Brain development vertebrates (4 Hrs): Brief comparative anatomy of the brain in vertebrates; different stages of brain development: neurogenesis, axonal outgrowth, synaptogenesis, synaptic pruning, myelination; the development of different regions of the brain in vertebrates; the development of cognition and learning.

Unit VI – Limb development in vertebrates and insects (9 Hrs): the emergence, development and patterning of limbs in *Drosophila* and vertebrates _ establishment of the limb fields; establishment of proximo-distal, dorso-ventral and anterior-posterior polarity; cartilage and bone formation in vertebrate limbs; conservation of signalling pathways involved in limb patterning across insects and vertebrates; genetic disorders that affect limb development.

Unit VII - Determination of size (4 Hrs): Regulation of body size, organ size and cell size _ the concept of allometry; coordination of growth with development; coordination of growth with cell division; regulation of cell size versus cell number; organ intrinsic and extrinsic (systemic) regulation of size; pathways that regulate growth (eg. insulin/mTOR signalling pathways); bone growth in vertebrates.

Unit VIII - Germ line development (3 Hrs): Specification and migration of germ cells to form gonads in invertebrates and vertebrates _ specification of germ cells in different regions of the embryo in *Drosophila*, fish, frog and mammals; 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 – Stem cell biology (6 Hrs): Features of stem cells: stem cell niche, asymmetric cell division, epigenetic regulation of stemness, pluripotency markers; stem cells in skin, muscle, brain and intestine; control of stem cell number in different tissue types.

Unit X – Brain development invertebrates (4 Hrs): Brief anatomy of the ganglia/brain of *C elegans* and *Drosophila melanogaster;* different stages of development of neurons and the brain: neurogenesis and the molecular players involved in the process of development of *C. elegans and Drosophila* neurons/brain; axonal outgrowth, synaptogenesis, synaptic pruning; development of the larval versus the adult brain in insects.

Unit XI – Biology of aging (2 Hrs): Definition of aging; evolutionary theories of aging; biochemical and cellular processes that influence aging; systemic ageing; the genetic basis of aging and longevity; experimental model systems used to study aging; physiology of human aging.

TH2

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HDG10. BIOINFORMATICS

Unit I - Introduction to Bioinformatics and its Scope (1 Hr): Importance of analysing DNA and protein sequences in modern biology; introduction to "OMICS" studies namely genomics, proteomics and transcriptomics and their role in biology and medicine; reductionist versus systems biology approaches.

Unit II - Sequence analysis (4 Hrs): An overview of sequence analysis; sequence comparison, dot plot, global and local alignments, Needleman-Wunsch algorithm for global alignment, Smith-Waterman algorithm for local alignment, BLAST algorithm, Multiple Sequence Alignments (MSA).
Basic concepts of sequence similarity, identity and homology, definitions of homologs, orthologs and paralogs; mRNA and protein sequences; significance of data and analysis at various levels: genome vs. exome vs transcriptome and proteome; commonly used databases for obtaining and analysing transcriptomic data; DNA and RNA motif analysis; gene discovery by sequence comparison, introduction to hidden Markov models for gene discovery; phylogenic analysis with reference to nucleic acids and proteins and their significance;

Unit III – Human Genome organisation and analysis (4 Hrs): The evolution of technology that helped in genome sequence analysis, Next Generation Sequencing (NGS) Technology, diversity in techniques and types of data analysis; identifying mutations, single nucleotide polymorphisms (SNPs), insertion or deletions (indels), copy number variations (CNVs) and alleles, and their significance in the genomics context; types of repeat elements and their significance; non-coding RNAs and their functions; DNA binding site of proteins and their signature in the genome; epigenetic landscape of human genome, human epigenome project; use of ENCODE and modENCODE to understand regulatory epigenetic landscape dynamics during development and disease

Introduction and overview of microarray technology; differential gene expression analysis using microarrays, and RNA-seq; expression libraries; CHIP-seq technology and related data analysis; introducing relevant data bases in various analysis mentioned above.

Unit IV - Bioinformatics for Proteins (4 Hrs): Review of protein structures and domains; use of databases for analysing protein-structures, gene ontologies, protein-interactions and pathways; large-scale protein exploration methods: mass spectrometry, antibody-based screening; domain analysis; significance of interaction analysis; concepts in homology modelling, drug discovery and design; biologicals, biosimilars vs. traditional active pharmaceutical ingredients (APIs) and concept of clinical trials.

Unit V– Genome projects (4 Hrs): Human genome project; the human genome draft sequence, significance of reference genome sequences; recent major initiatives in human genome analysis, 1000 genome projects, impact on human population genetics; a review of studies on Indian population genomics, particularly in the context of human diseases; current data from understanding human genome libraries; genome wide association studies (GWAS).

Unit VI – Other large scale technical approaches (2 Hrs): Comparative genomics and metagenomics: comparisons of the human genome with the genomes of model organisms, metagenomic approaches in microbiome analysis, significance of microbiomes to human health; introduction to epigenomics, lipidomics, metabolomics and pharmacogenomics; introduction to proteomics, systems biology and big data biology; discussions on the relevance of machine learning and artificial intelligence to genetics.

HDG11. PRINCIPLES OF EVOLUTION AND POPULATION GENETICS TH2

Unit I - Origins (1 Hr): 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 (2 Hrs): 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 (1 Hr): mutation rate, adaptive vs deleterious mutations, mutations with no selective advantage, consequences of gene duplication, genetic variation and evolution.

Unit IV - Basic population genetics (2 Hrs): 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 (4 Hrs): 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 (1 Hr): 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 (1 Hr): selective advantages of asexual reproduction versus sexual reproduction, sex ratios, evolution of sexual dimorphism, mate choice, signal detection.

Unit VIII - Evolution of Social behaviour (1 Hr): evolution of cooperation and apparent altruism.

Unit IX - Evolution of Life Histories (2 Hrs): life history traits, life span and senescence.

Unit X - Evolution of Homo sapiens (2 Hrs): 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)**

HDG12. SCIENCE WRITING AND PRESENTATION **TS2**

Unit I - Basics of good writing (13 Hrs): 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 (11 Hrs): 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 (11 Hrs): 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 (1 Hr): composing professional emails and letters for various purposes; preparing an effective resume.

Unit V - Effective oral presentations (2 Hrs): 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 (1 Hr): 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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HDGP5. PRACTICAL MODULE V: BIOCHEMISTRY & MOLECULAR BIOLOGY **LH4**

1. **Isolation and quantitation of DNA**: Isolation of genomic DNA from human blood; quantitation and agarose gel electrophoresis.
2. **Isolation and quantitation of RNA**: Isolation of total RNA from human blood; quantitation and assessment of integrity of the preparation by gel electrophoresis.
3. **Polymerase chain reaction**: Amplification of specific regions from human genomic DNA.
4. **Purification and characterisation of proteins**: Purification by ion exchange chromatography, electrophoresis and affinity chromatography. Estimation of proteins by Lowry/Bradford methods. Detection and characterisation of proteins by SDS-gel electrophoresis, ELISA and Western blotting.
5. **Expression and purification of recombinant proteins**: Preparation of *E. coli* DH5α competent cells and transformation for preparation of plasmid DNA. Isolation of plasmid DNA. Transformation of BL21 (DE3) cells with the plasmid, induction with IPTG/lactose, analysis of protein expression. Purification of proteins on Ni-NTA column and characterization by electrophoresis and Western blotting.

HDGP6. PRACTICAL MODULE VI - CELL BIOLOGY **LH2**

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. **Image analysis:** Understanding 3-dimensional image stacks of fluorescently labelled samples, Using ImageJ and Zeiss Zen Blue software to visualise orthogonal views of z-stacks.

HDGP7. PRACTICAL Module VII – BIOINFORMATICS with R **LH2**

PART I _ USE OF AVAILABLE DATABASES

1. Case studies to use common data mining resources: Entrez Gene, Genbank, Uniprot, PubMed & Google Scholar
2. 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).
3. Case studies of analysis using SNP databases (dbSNP); NGS analysis for SNP detection.
4. Case studies in clinically relevant databases (clinvar and OMIM).
5. Use of databases for protein-structures (PDB), Gene Ontologies (GO), protein-interactions (STRING) and pathways (KEGG and Reactome)

PART II _ BIOINFORMATICS DATA ANALYSIS WITH R/BIOCONDUCTOR

1. Sequence Alignment basics:
   Comparing individual sequences by dot plot; creating nucleotide substitution matrices; accessing BLOSUM matrices; global alignment with Needleman-Wunsch algorithm; local alignment with Smith-Waterman algorithm.

2. FASTA sequence analysis with Biostrings library:
   Creating DNA-RNA string objects; reading FASTA sequence files; sequence length distribution; string search in sequence files and string substitution; reverse complements of sequences; computing nucleotide frequencies; estimating GC content; triplet codon analysis; translating nucleotide sequences into proteins.

   FASTQ sequence analysis with FastQC tool and Bioconductor
   Understanding FASTQ file format; running FastQC tool to generate QC report parameters like per base sequence quality, per sequence quality score, per base sequence content, per sequence GC content, per base N content, sequence length distribution, duplicate sequences, over-represented sequences, adapter content and K-mer content.
   Estimation of all the above QC parameters from FASTQ file using Bioconductor libraries like Biostrings, ShortRead, qrqc, stringr and Rsubread.

3. Comparison and identification of sequences:
   Usage of Basic Local Alignment Search Tool (BLAST) in NCBI website; compare and identify nucleotide and protein sequences using Bioconductor package rBLAST; interpretation of results; sending a blast query to NCBI for finding multiple alignments using blastSequences function of Bioconductor; multiple sequence alignments with msa package; gene discovery using Hidden Markov Models; phylogenetic tree analysis with R/Bioconductor libraries.

   SNP and copy number variation analysis with Bioconductor libraries and open source tools; analysis of methylation arrays (CHIP-seq data) using Bioconductor tools.

4. Differential gene expression analysis:
   Differential gene expression analysis using microarrays; Affymetrix and Illumina data analysis with R/Bioconductor libraries; developing pipelines for performing data processing, normalization, differential expression using statistical methods, false discovery rate estimation, gene annotation and selection of differentially expressed genes.
   Differential gene expression analysis of NGS data using R/Bioconductor libraries; development of pipelines for performing steps including quality control of sequence files, filtering, mapping, gene annotation and differential expression analysis using statistical methods; use of mapping tools like Bowtie, TopHat and Kallisto; handling of various mapped file formats like BAM, SAM etc.; creating index files for sequences using Bioconductor tools; visualization of genomic regions and mapped reads using open source tools and Bioconductor libraries.

5. Pathway Analysis and protein interaction networks:
   Gene set enrichment analysis; gene enrichment and pathway analysis with DAVID and enricher tools; statistical methods for enrichment analysis.
   Study of various protein interaction data bases; creation and study of protein interaction and transcription regulatory networks using graph theoretical methods with Bioconductor libraries.

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SEMESTER 3

Course code and title		Type	Core	Credits
HDG13	Human Molecular Genetics	T	H	4
HDG14	Biology of inherited metabolic disorders	T	H	4
HDG15	Essentials in Immunology	T	H	2
HDG16	Genetic counselling and ethics	T	H	2
HDGP8	Research Methodology	L	H	2
HDGP9	Practical Module IX - Molecular Diagnostics	L	H	4
HDGP10	Practical Module X – Genetic counselling and ethics	L	H	2
HDGP11	Scientific writing and presentation – term paper submission	L	H	2
HDG17	Course will be held in other suitable departments	T	OE	4

Abbreviations: T- Theory, L- Lab, H- Hard core, S- Soft core, OE- Open elective

HDG13. HUMAN MOLECULAR GENETICS TH4

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Unit I - Introduction to Human Genetics, Genetic Disorders and Single Gene Inheritance (4 Hrs): 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 – Complexities of Basic-Mendelian Pedigree Patterns (2 Hrs): Inbreeding and pseudo-dominant inheritance, locus heterogeneity, incomplete and age-related penetrance, phenocopies, *de-novo* mutations and mosaicism

Unit III - Molecular Methodologies (9 Hrs): DNA polymorphisms, molecular markers and genotyping: restriction site polymorphisms (RSP), minisatellites, microsatellites, single nucleotide polymorphisms (SNP), heterozygosity of a marker, DNA-fingerprinting; Sanger and next-generation sequencing (NGS).

Unit IV - Genetic Mapping of Monogenic Traits (15 Hrs): 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 (15 Hrs): 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 chi^2 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 - Gene Action -Tracing Defects in Gene Function (5 Hrs): (a) Haemoglobinopathies-, Beta-thalassemia and Sickle cell anaemia (b) Fragile X syndrome and other repeat disorders (c) Noonan syndrome and Rasopathies

HDG14. BIOLOGY OF INHERITED METABOLIC DISORDERS TH4

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 broaden their understanding of the biology of human genetic disorders. The course is divided into nine units.

Unit I - Inborn errors of metabolism (IEM) (6 hours):

***Basic concepts/ general features* (2 Hrs):** Basic concepts; history; inheritance patterns; incidence of IEM; challenges in the management of IEM.

***Classes of IEM* (2 Hr):** 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* (1 Hr):** 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) (10 hours):

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

***Biology of PKU* (5 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 symptoms manifested in patients may be explained on basis of the various biochemical aberrations; molecular genetics of PKU; structure and regulation of PAH.

Treatment options **(4 Hrs):** Treatment options available and those under development: Dietary management; intake of large neutral amino acids; enzyme replacement/ substitution therapy (with PAH and phenylalanine ammonia lyase); co-factor therapy; 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 (6 hours):

Study of certain 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 cell organelles where the reactions occur. Functions of glycans — an overview.

Glycosaminoglycans and proteoglycans **(5 Hrs):** General properties and functions of glycosaminoglycans; chemical structures of common glycosaminoglycans (heparan sulfate, dermatan sulfate, keratan sulfate, chondroitin sulfate 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 - Lysosomes (2 hours): Discovery; properties; functions; trafficking of proteins into lysosomes.

Unit V - Lysosomal storage disorders (LSD) (7 hours):

Biology (**2 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 a popular movie pertaining to treatment of LSDs, followed by discussion.

Unit VI – Gaucher and MPS group of diseases (7 hours):

- Study of Gaucher disease as a typical lipid storage disorder.
- Study of 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, diagnosis, symptoms and treatment of the MPS disorders; salient features of each type of MPS, 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 to monitor the efficacy of enzyme replacement therapy.

Unit VII - IEM due to defects post-translational modifications (1 Hr): The study of the biochemical basis of multiple sulfatase deficiency as a model to learn about this group of disorders. Study of mucolipidosis II and mucolipidosis III (Unit VIII) would serve as additional models for diseases due to defects in post-translational modifications.

Unit VIII - IEM due to defects in intracellular trafficking (1 Hr): 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.

Unit IX - Classroom presentations by students (12 Hrs)

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HDG15. ESSENTIALS IN IMMUNOLOGY **TH2**

Unit I - Organs and cells of the Immune system (1 Hr): Primary lymphoid organs, Secondary lymphoid organs, B lymphocytes, T lymphocytes, mononuclear phagocytes, granulocytes, mast cells, dendritic cells, natural killer cells.

Unit II - Innate immunity (2 Hrs): Anatomical barriers, inflammation, anti-microbial peptides, acute phase proteins, toll like receptors

Unit III - B cell immunity (4 Hrs): Development of B cells, B cell activation, proliferation & differentiation, structure and Functions of Immunoglobulins

Unit IV - Complement system (2 Hrs): Components of the classical, alternate, lectin pathways, complement cascade, biological consequences of complement cascade, regulation of the complement system

Unit V - Antibody diversity (2 Hrs): Organization of immunoglobulin genes, mechanism of gene rearrangements, class switching, regulation of immunoglobulin genes

Unit VI - The major histocompatibility complex and antigen presentation (2 Hrs): 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 (4 Hrs): Development of T cells and their education, T cell activation, proliferation & differentiation, T cell types, T cell receptor and co receptors, signalling in T cells, helper and cytotoxic T cells, cytokines

Unit VIII - Hypersensitivity (2 Hrs): IgE antibody-mediated hypersensitivity, antibody-mediated cytotoxicity, immune complex mediated hypersensitivity, delayed type hypersensitivity

Unit IX - Autoimmunity (2 Hrs): Organ specific autoimmune diseases, systemic autoimmune diseases, mechanisms of autoimmunity, treatment of autoimmune diseases

Unit X - Immunodeficiency disorders (2 Hrs): Primary immunodeficiency diseases of lymphoid cells, myeloid cells and granulocytes, complement components, acquired immunodeficiency diseases

Unit XI - Cancer and immune system (1 Hr): Tumour evasion of the immune system, cancer immunotherapy

Unit XII - Vaccines (2 Hrs): Active and passive immunization, vaccine designs, subunit vaccines, DNA vaccines

HDG16. GENETIC COUNSELLING AND ETHICS **TH2**

PART 1-GENETIC COUNSELLING

Unit I - Introduction to genetic counselling (2Hrs)

Unit II - Impact of illness on patients and families (4Hrs): 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 (4Hrs): 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 (3Hrs): 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 - Predictive counselling for late onset disorders, e.g., Huntington's disease, breast and ovarian cancer (3Hrs): 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 (1 Hr): for example, children of intellectually incapacitated individuals, consent and confidentiality

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

Unit VI –Role and Scope of Institutional review board in scientific research (1 Hr)
Unit VII - Global & Population Ethics (1 Hr): global disparities in health and public health, global pandemics, population growth, human rights to health and health care, role of foreign aid.

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

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

Unit X - Medico-legal Issues (1 Hr): Surrogacy, Organ donation, Paternity testing.

HDGP8. PRACTICAL Module VIII- RESEARCH METHODOLOGY **LH2**

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. PRACTICAL MODULE IX- MOLECULAR DIAGNOSTICS **LH4**

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
13. Multiplex Ligation Dependent Probe Amplification (MLPA). Analysis of MLPA data with Coffalyser software.

HDGP10. PRACTICAL MODULE X - GENETIC COUNSELLING AND ETHICS **LH2**

Time spent in clinics (clinical rotations)

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.

LH2

HDGP11. SCIENTIFIC WRITING AND PRESENTATION - TERM PAPER SUBMISSION

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.

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SEMESTER 4

Course code and title		Type	Core	Credits
HDG18	Cancer biology	T	H	2
HDG19	Advanced techniques in genetic research	T	H	4
HDG20	Advances in treatment of disease _ cancer and infertility	T	H	2
HDGP12	Dissertation work	L	H	12

Abbreviations: T- Theory, L- Lab, H- Hard core

HDG18. CANCER BIOLOGY **TH2**

Unit I - Basics about Cancer (1 Hr): Introduction to cancer, origin, types (types of tumours, stages of malignancy), basic terminology.

Unit II - Hallmarks of Cancer (5 Hrs): Basic mechanisms regulating normal tissue homeostasis: regulation of cell-proliferation, growth, differentiation and apoptosis; aberrations in regulatory mechanisms that result in cancer.

Unit III - Genetic and Epigenetic Alterations in Cancer (13 Hrs): 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 - Viral causes of cancer (1 Hr): History of discovery, mechanism of action of commonly seen viruses such as HPV, EBV, HBV, HCV.

Unit V - Familial cancer syndromes (1 Hr): NF1, FAP, VHL, etc.

Unit VI - Molecular mechanisms of metastasis (1 Hr): Different steps and cellular state transitions in metastases; genes responsible for metastases; organ specific metastases.

Unit VII - Tumour microenvironment (1 Hr): 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 (1 Hr): The phenomenon known as Warburg effect.

Unit IX - Challenges in treatment of cancer (2 Hrs): The development of therapeutic resistance, the occurrence of a relapse; current developments in treating cancers.

HDG19. ADVANCED TECHNIQUES IN GENETIC RESEARCH **TH4**

Unit I - Identification of genes and their structure (1 Hr)
Open reading frame (ORF) analysis: exon-trapping, rapid amplification of complementary DNA ends (RACE), transcription start site mapping, exon-intron boundary identification, and database homology search.

Unit II - Nucleotide hybridization, principles and its application (1 Hr)
Types of hybridization assays: dot, Southern, zoo blot, northern, colony blots, plaque lift, array hybridization, fluorescence in situ hybridization

Unit III - Cloning (2 Hrs)
Principles of cell-based cloning and cloning systems: plasmid, lambda, cosmid, bacterial artificial chromosomes (BACs), P1 derived artificial chromosomes (PACs) and yeast artificial chromosomes (YACs); expression systems: bacterial, phage and eukaryotic cells.

Unit IV – Gene Manipulation (2 Hrs)
Mutagenesis methods: chemical, radiation, site-directed, insertion mutagenesis; transgenic model systems; forward versus reverse genetic strategies.

Unit V - Analysis of gene expression (2 Hrs)
Detection of proteins *in situ*: Immunohistochemistry. Detection *ex situ* of RNA: RT-PCR, real time PCR, microarray, RNAseq.

Unit VI - Study of proteins and protein complexes (2 Hrs)
Immunoprecipitation; protein-protein interaction study: co-immunoprecipitation, phage display, yeast two-hybrid system, far-western; fluorescence-based techniques: protein co-localization using immunofluorescence, fluorescence resonance energy transfer (FRET), Fluorescence recovery after photo-bleaching (FRAP); ion channel function assays: ion-flux, dye transfer & electrophysiology.

Unit VII – Advanced human genome and chromatin organization techniques -current techniques and historical perspective (3 Hrs)
Overview of genome organization in mammals; the experimental approaches to understand the folding principles of the genome; the functional relationship between enhancer, gene regulation and genome organization.

Unit VIII – Phenotypic analysis of diseased/mutant tissue (6 Hrs)
Immunofluorescence of cell morphology; markers for abnormal cell proliferation; flow cytometry-based analysis of cancer cell cycle; in vivo tumorigenic assay; metastatic assay- tail vein injection of cells.

Unit IX – Uses of model organisms to study human diseases (19 Hrs): This part of the 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.

The following topics will be covered:

Planaria (8 hours)
Using a simple organism to study the cell biology of regeneration.

C. elegans (3 hours)
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.

D. melanogaster (2 hours)
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, metabolic disorders, tumour formation; use of the system in drug screening.

Zebrafish (2 hours)
Zebrafish will be introduced as a model system for study of development and human disease. The genetic conservation of pathways and processes will be discussed. The many genetic and chemical tools that are routinely used for zebrafish research will be discussed. Examples will be used to illustrate how zebrafish research can shed new light on human disease pathophysiology and can be used for drug discovery.

Mouse and other mammals (4 hours)
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 X - Human Induced Pluripotent Stem Cells (2 Hrs): as tools in drug development and modelling diseases; the ability to create patient and disease specific stem cells.

Unit VII – Student presentations (12 Hrs): Individual research proposals addressing a minor research question related to a genetic disorder

HDG20. ADVANCES IN TREATMENT OF DISEASE _ CANCER AND INFERTILITY TH2

PART 1 – ADVANCES in CANCER TREATMENT

Unit I – Tumour immunology and immunotherapy (2hrs):
Anti-tumor immune response of regulatory T cells, NK cells, immune surveillance theory, tumor associated antigens, evasion of immune surveillance by cancer cells, principles of immunotherapy, CART cells.

Unit II – Cancer treatment and management (2hrs):
Cancer treatment – radiation, chemotherapy and surgery, use of cell kinetics to optimize cancer treatment, principles of drug trials for new cancer treatment, monoclonal antibodies as anti-cancer agents, druggable genes in cancer, cancer vaccine.

Unit III – Techniques revolutionizing the understanding of cancer (4hrs)
Single cell RNA sequencing; patient derived xenograft models, intra vital *in vivo* imaging.

Unit IV – Introduction to drug discovery and development in cancer (1hr)
An overview of modern methods and principles; different domains and steps in drug discovery and development; challenges in modern drug discovery

Unit V – Classical and emerging targets in cancer drug discovery (1 hr)
DNA as a classical target; specific proteins as contemporary targets, identification of oncogenes through genetic profiling; high resistance of cancer stem cells (CSCs), CSC specific signaling pathways; other targets including tubulin, epigenetic regulators, DNA damage repair enzymes, proteasomes; combination therapy.

Unit VI – *In vitro* cancer drug screening systems (2hrs)
Development of Herceptin to understand the language of Screening: IC50 values; criteria for selecting an assay in cancer drug screening; analytical criteria including sensitivity, data reproducibility and reagent stability; clinical criteria depending on mode of action of drug; general considerations including time, cost, instrument availability; biochemical versus cellular assays; examples of biochemical assays include colorimetric mitochondrial metabolic activity tests, receptor-binding assays; cell based assays include proliferation rates, cytotoxicity, motility; high throughput screening methods.

PART 1I –ASSISTED REPRODUCTIVE TECHNOLOGIES (ART) and the GENETIC BASIS OF INFERTILITY

Unit I – Oogenesis and folliculogenesis (1hr)
Oocyte retrieval and selection; preparation and evaluation of oocytes for ICSI; Hyaluronic acid binding-mediated sperm selection for ICSI.

Unit II – Spermatogenesis and andrology (1hr)
Evaluation of sperm; sperm preparation techniques; sperm chromatin assessment

Unit III – Fertilization and Embryos in ART (5hrs)
Embryology, *in vitro* fertilization (IVF), analysis of fertilization, morphological assessment of embryos and oocytes, embryo transfer techniques, cryopreservation and vitrification, use of time lapse videos; embryology laboratory visit to observe embryo culture and time embryo biopsy.

Unit IV – Molecular Genetics of infertility (2hr)
Genetic anomalies leading to infertility; severe male factor, maternal age and aneuploidies, Y chromosome microdeletion syndromes and genes involved in male and female infertility**.**

Unit V – Preimplantation genetic screening of embryos _PGT-A and PGT-M (2hr)
Preimplantation genetic testing for aneuploidies, techniques, criteria and advances; preimplantation genetic testing for monogenic diseases – when, why and how? Non-invasive genetic screening, techniques, and advantages**.**

Unit VI – Advances and dilemmas in assisted reproductive technology (2hr)
Techniques used in ART; recommended and others; ethical issues involved in ART and its allied practices including surrogacy, embryo selection criteria, gamete and embryo donation etc.

HDGP12. DISSERTATION **LH10**

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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SEMESTER1

HDG01. Cell Biology

1. JD Watson (2013) **Molecular Biology of the Gene,** Pearson Publication, 7th Edition
2. B Alberts, A Johnson, J Lewis, M Raff, K Roberts and P Walter (2014) **Molecular Biology of the Cell**, Taylor and Francis Publication, 6th Edition
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4. JE Krebs, ES Goldstein and ST Kilpatrick (2012) **Lewin's Gene XI**, Jones and Bartlett Learning Publication, 11th Edition

HDG02. Fundamentals of Genetics

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2. Elrod, Susan L. (2010) **Schaum's outlines: genetics**. New York: McGraw-Hill.
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HDG03. Human cytogenetics

1. Steven L. Gersen and Martha B. Keagle (1999) **The Principles of Clinical Cytogenetics** Humana Press
2. Orlando J. Miller (2000) **Human Chromosomes** Springer-Verlag New York
3. Morgan Key (2015) **Cytogenetics: Techniques and Applications** CALLISTO REFERENCE
4. Swansbury (2003) **Cancer Cytogenetics** Humana Press
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6. RL Nussbaum, RR. McInnes and HF Willard (2007) **Thomson and Thomson Genetics in Medicine**, Saunders, Elsevier Publication
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8. S Gersen and MB Keagel (2013) **The Principles of Clinical Cytogenetics**, Springer Science and Business Media Publication
9. LB Jorde, JC Carey and MJ Bamshad (2009) **Medical Genetics**, Elsevier Publication
10. S Heim, F Mitelman (2011) **Cancer Cytogenetics: Chromosomal and Molecular Genetic Aberrations of Tumour Cells**, John Willey and Sons Publications
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12. H K Garg (2023) **Laboratory Practices in Cell and Molecular Biology : A Comprehensive Manual of Cytogenetics**, Lap Lambert Academic Publishing
13. J Winzant (2023) **Epstein-Barr Virus: A Beginner's Step-by-Step Guide to Managing EBV Naturally Through Diet, With Sample Recipes and a Meal Plan**, Mindplusfood publisher

HDG04 and HDGP4: Biostatistics and R programming

1. JH Zar (2010) **Biostatistical Analysis**, Prentice Hall Publication, 5th Edition
2. W. W. Daniel (2013) **Biostatistics - Basic concepts and methodology for the health sciences**, Wiley Student edition
3. R. B. D'Agostino Sr., L. M Sullivan and A. S Beiser (2006) **Introductory Applied Biostatistics**, Thomson Brooch.
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HDG05. Human Embryology, Anatomy and Physiology

1. TW Sadler (2011) **Langman's Medical Embryology**, Lippincott Williams and Willkins Publication, 12th Edition.
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HDG06. Principles of Development _ Part I

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3. L Wolpert, C Tickle and AM Arias (2019) **Principles of Development**, Oxford University Press, 6th Edition
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HDGP1. Practical Module I-Genetics

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HDGP2. Practical Module II-Basic cell immortalization techniques

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HDGP3. Practical Module III-Human cytogenetics

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3. Fan, Yao-Shan (2003) **Molecular Cytogenetics Protocols and Applications,** Humana Press
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HDG07. Biochemistry

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HDG10. Bioinformatics

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6. web portal of multiple sources: **wws.startbioinfo.com**

Databases:

1. NCBI Genome Browser and databases: **http://www.ncbi.nlm.nih.gov/**
2. UCSC Genome Browser: **http://genome.ucsc.edu/**
3. Ensemble Genome Browser: **http://www.ncbi.nlm.nih.gov/**
4. Protein Catalogue ExPASy: **http://www.expasy.org/**
5. Protein Catalogue Uniprot: **http://www.uniprot.org/**

HDG11. Principles of Evolution and Population genetics

1. DL Hartl and AG Clark (2006) **Principles of Population Genetics,** Sinauer Associates Publication, 4th Edition
2. LL Cavalli-Sforza and WF Bodmer (2013) **The Genetics of Human Population,** Dover Publication
3. M Jobling, E Hollox, M Hurles, T Kivisild and C Tyler-Smith (2013) **Human Evolutionary Genetics**, Garland Science/Taylor and Francis Group Publication, 2nd Edition
4. D J Futuyma and M Kirkpatrick (2017) **Evolution,** Oxford University Press, 4th Edition
5. M Strickberger, B Hall and B Halgrimsson (2013) **Strickberger's Evolution,** Jones and Bartlett Publishers Inc, 5th Edition
6. J B S Haldane (1932) **The causes of Evolution,** Longmans, Green and Co.
7. C Darwin (1859) **The Origin of Species,** John Murray, London.

HDG12. Science writing and presentation

1. N. D. V. Prasada Rao (1995) **Wren & Martin's High School English Grammar and Composition Book** S. Chand & Co. Ltd, Revised edition.
2. T. L. H. Smith Pearse (1997) **English Errors of Indian Students**, Oxford, 5th revised edition
3. J. Butcher and C Drake (2006) **Butcher's Copy-editing: The Cambridge Handbook for Editors, Copy- editors and Proofreaders**, Cambridge University Press; 4th edition.
4. P. Sebranek, V. Meyer and D. Kemper (1995) **Writers INC: A Student Handbook for Writing & Learning,** Great Source Education Group Inc.
5. R. A. Day (2011) **Scientific English: A Guide for Scientists and other Professionals,** Greenwood Press; 3rd revised edition.
6. M. Raman and S. Sharma (2012) **Technical Communication; Principles and Practice**, Oxford University Press, New Delhi; 2nd edition.
7. D. Carnegie (1980) **The Quick and Easy Way to Effective Speaking**, Simon & Schuster; Reissue edition.
8. J. V. Vilanilam (2000) **More effective communication; A manual for professionals**, Response Books (SAGE Publications); 1st edition.
9. Y.N. Bui (2013) **How to Write a Master's Thesis** Paperback, 2nd edition.
10. John Swales (1990) **Genre Analysis: English in Academic and Research Settings (Cambridge Applied Linguistics)** Series editors: Carol A. Chapelle and Susan Hunston, Cambridge University Press, 1st edition.
11. ONLINE SOFTWARE: https://www.rationaleonline.com

HDGP5. Lab Module V-Biochemistry and Molecular Biology

1. K Wilson and J Walker (2010) **Principles and Techniques of Practical Biochemistry,** Cambridge University Press, 7th Edition
2. Protocols Online: **http://www.protocol-online.org/**
3. Sambrook and DM Russell (2001) **Molecular Cloning: a Laboratory Manual**. Cold Spring Laboratory Press Publication, 6th Edition

HDGP6. Practical Module VI-Cell Biology

1. JS Bonifacino (2003) **Current Protocols in Cell Biology,** John Willey & Sons Publication
2. Protocols Online: **http://www.protocol-online.org/**

HDGP7. Practical Module VII – Bioinformatics with R

1. NCBI: **http://www.ncbi.nlm.nih.gov/**
2. EMBL: **www.embl.de/**
3. UCSC: **genome.ucsc.edu/**
4. collection of case studies and reviews at **wws.startbioinfo.com**
5. R. M. Holmes (2007) **A cell biologists' guide to modelling and bioinformatics**; Wiley Interscience.

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SEMESTER 3

HDG13. Human Molecular Genetics

1. T Strachan and AP Read (2011), **Human Molecular Genetics**, Garland Science/Taylor and Francis Group Publication, 4th Edition.
2. For information on Mendelian phenotypes: **http://www.omim.org**
3. Access to Biomedical Literature: **http://www.ncbi.nlm.gov/entrez**
4. **Thompson & Thompson Genetics and Genomics in Medicine** (2023), Eds R Cohn, S Scherer and A Hamosh, Elsevier, 9th Edition.

HDG14. Biology of Inherited Metabolic Disorders

1. CR Scriver, A Beaudet, WS Sly, D Valle, B Childs, K W Kinzler and B Vogelstein. **The Metabolic and Molecular Basis of Inherited Disease**, McGraw-Hill Publication, 8th edition, 2000.
2. Maureen E. Taylor and Kurt Drickamer. **Introduction to Glycobiology**, Oxford University Press, 3rd edition, 2011.
3. Varki A, Cummings RD, Esko JD, et al., editors. **Essentials of Glycobiology**. Cold Spring Harbor (NY): Cold Spring Harbor Laboratory Press; 3rd edition, 2017. Available from: http://www.ncbi.nlm.nih.gov/books/NBK310274/
4. Review articles published in journals such as *Nature Reviews Genetics, Journal of Biological Chemistry, Cell Metabolism, Nature Metabolism, Trends in Endocrinology and Metabolism, Journal of Inherited Metabolic Disease, Molecular Genetics and Metabolism.*
5. ***Book review***: Finger and Christ (2014) **Pearl Buck and phenylketonuria (PKU)**. *Journal of the History of the Neurosciences Basic and Clinical Perspectives*, Vol. 13, No. 1, pp. 44–57.
6. ***General book***: *The child who never grew*. Pearl S. Buck. Woodbine House; Reprint edition, 1992. ISBN-10: 0933149492, ISBN-13: 978-0933149496 (Original edition: 1950.)
7. ***Documentary film***: *The Forgotten Children*. https://www.espku.org/2016/06/28/the-forgotten-children-untreated-pku/ A documentary by the German Association for Phenylketonuria and allied inherited disorders (DIG PKU).
8. ***IEM in commercial cinema***: *Extraordinary measures* (2010). Directed by Tom Vaughan. CBS Films.

HDG15. Essentials in Immunology

1. T J Kindt, B A Osborne, R Goldsby (2006) **Kuby Immunology**, W H Freeman publication, 6th Edition
2. W E Paul (2003) **Fundamental Immunology**, Lipincott Williams and Wilkins publication, 4th Edition
3. P J Delves, S J Martin, D R Burton, I M Roitt (2017) **Roitt's Essential Immunology,** Wiley Blackwell publication, 13th edition.

HDGP9. Practical Module IX - Molecular Diagnostics

1. JL Hamerton (2013) **Human Cytogenetics: Clinical Cytogenetics,** Academic Press
2. S Gersen and MB Keagel (2013) **The Principles of Clinical Cytogenetics,** Springer Science and Business Media Publication
3. RL Nussbaum, RR. McInnes and HF Willard (2007) **Thomson and Thomson Genetics in Medicine,** Saunders, Elsevier Publication
4. LB Jorde, JC Carey and MJ Bamshad (2009) **Medical Genetics,** Elsevier Publication
5. S Heim, F Mitelman (2011) **Cancer Cytogenetics: Chromosomal and Molecular Genetic Aberrations of Tumour Cells,** John Willey and Sons Publications
6. L Buckingham (2011) **Molecular Diagnostics: Fundamentals, Methods and Clinical Applications**, FA Davis Company Publication, 2nd Edition
7. CA Burtis, D Bruns and ER Ashwood (2007) **Fundamentals of Molecular Diagnostics,** Saunders, Elsevier Publication
8. P George, GP Patrinos and WJ Ansorge (2010) **Molecular Diagnostics**, Academic Press, Elsevier Publication, 2nd Edition
9. NCBI Genome Browser and databases: **http://www.ncbi.nlm.nih.gov/**

HDG16 and HDGP10. Practical Module X - Genetic Counselling and Ethics

1. K Park (2011) **Park's Textbook of Preventive and Social Medicine,** Banarsidas Bhanot Publication, 21st Edition.
2. J Owen, J Punt and S Stranford (2013) **Kuby Immunology**, WH Freeman Publication, 7th Edition.
3. T Strachan and A Read (2011), **Human Molecular Genetics**, Garland
4. Science/Taylor and Francis Group Publication, 4th Edition.
5. Peter Turnpenny and Sian Ellard (Eds) (2012) **Emery's Elements of Medical Genetics**, Elsevier, 14th Edition.
6. R.J. McKinlay Gardner, Grant R Sutherland, and Lisa G. Shaffer (2011), **Chromosome abnormalities and Genetic counselling**, Oxford University Press, 4th Edition.
7. David L. Rimoin, Reed E. Pyeritz and Bruce Korf. (Eds.) (2013) **Emery and Rimoin's Principles and Practice of Medical Genetics**, Elsevier, 6th Edition.
8. Peter S Harper (2010), **Practical Genetic Counselling** Elsevier, 7th Edition.
9. Jean-Marie Saudubray, Georges van den Berghe, John H. Walter, (Eds.) (2012), **Inborn Metabolic Diseases: Diagnosis and Treatment,** Springer, 5th Edition.
10. T Smith (1999) **Ethics in Medical Research: A Handbook of Good Practice,** Cambridge University Press
11. I S Shergill, A Thompson and N Temple (2011) **Ethics, Medical Research, and Medicine: Commercialism versus Environmentalism and Social Justice,** Springer Science and Business Media Publication

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SEMESTER4

HDG18. Cancer Biology

1. RA Weinberg (2012) **Biology of Cancer,** Garland, Taylor and Francis Group Publication, 2nd Edition
2. B Alberts, A Johnson, J Lewis, M Raff, K Roberts and P Walter (2008) **Molecular Biology of Cell**, Taylor and Francis group Publication, 5th Edition
3. V T DeVita, TS Lawrence and SA Rosenberg (2015) **DeVita, Hellman, and Rosenberg's Cancer: Principles & Practice of Oncology**, Wolters Kluwer Publication, 10th Edition
4. Relevant research articles, reviews and online resources

HDG19. Advanced techniques in genetic research

1. Alberts, Bruce. (2015) **Molecular biology of the cell**. New York, NY: Garland Science, Taylor and Francis Group.
2. Allis, C D., et al. (2015) **Epigenetics**. Cold Spring Harbor, New York: CSH Press, Cold Spring Harbor Laboratory Press.
3. Giardine, B. et al., (2005) 2005 Galaxy: A platform for interactive large-scale genome analysis Genome Res. 15(10): 1451–1455.
4. Brown, T. A. (2018) **Genomes**, New York, NY: Garland Science.
5. Krebs, Jocelyn E., Elliott S. Goldstein, and Stephen T. Kilpatrick. (2018) **Lewin's genes XII.** Burlington, MA: Jones & Bartlett Learning.
6. Mount, David W (2004) **Bioinformatics: sequence and genome analysis**. Cold Spring Harbor, N.Y: Cold Spring Harbor Laboratory Press.
7. Strachan, T, and Andrew P. Read. (2011) **Human molecular genetics**. New York: Garland Science.
8. Gibson, G and Spencer V. Muse (2009), A **Primer** of **Genome Science**, 2nd edition, Sinauer Associates Inc.
9. Mohr, Stephanie Elizabeth, (2018), **First in Fly** *Drosophila* research and biological discovery. Harvard University Press.
10. Gast CE, Shaw AK, Wong MH, Coussens LM. Surgical Procedures and Methodology for a Preclinical Murine Model of De Novo Mammary Cancer Metastasis. J Vis Exp. 2017 Jul 29; (125):54852. doi: 10.3791/54852. PMID: 28784976; PMCID: PMC5613781.

HDG20. Advances in treatment of disease _ cancer and infertility

1. DL Rimoin, RE Pyeritz, B Korf (2013), **Emery and Rimoin's Principles and Practice of Medical Genetics**, Elsevier Science Publication, 6th Edition.
2. Genes and Diseases (NCBI Bookshelf): **http://www.ncbi.nlm.nih.gov/books/NBK22185/**
3. L Buckingham (2011) **Molecular Diagnostics: Fundamentals, Methods and Clinical Applications**, FA Davis Company Publication, 2nd Edition
4. CA Burtis, D Bruns and ER Ashwood (2007) **Fundamentals of Molecular Diagnostics,** Saunders, Elsevier Publication
5. P George, GP Patrinos and WJ Ansorge (2010) **Molecular Diagnostics**, Academic Press, Elsevier Publication, 2nd Edition
6. NCBI Genome Browser and databases: **http://www.ncbi.nlm.nih.gov/**
7. Liu, Y., Wu, W., Cai, C. *et al.* (2023) Patient-derived xenograft models in cancer therapy: technologies and applications. *Sig Transduct Target Ther* 8, 160. https://doi.org/10.1038/s41392-023-01419-2
8. Sanjeevi Pandiyan, Li Wang, (2022) A comprehensive review on recent approaches for cancer drug discovery associated with artificial intelligence, *Computers in Biology and Medicine*, **150**, 106140, ISSN 0010-4825, https://doi.org/10.1016/j.compbiomed.2022.106140.

9. Murga M, Fernandez-Capetillo O. (2022) Emerging concepts in drug discovery for cancer therapy. *Mol Oncol*., **21**, 3757-3760. doi: 10.1002/1878-0261.13325. PMID: 36321722; PMCID: PMC9627784.

10. Ayuda-Durán, P., Hermansen, J.U., Giliberto, M. *et al.* (2023) Standardized assays to monitor drug sensitivity in hematologic cancers. *Cell Death Discov.* **9**, 435. https://doi.org/10.1038/s41420-023-01722-5

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