

MultiOMICS Technology
(Syllabus of the theory paper)

OT101: Proteomics and Metabolomics

Total lecture hours: 52

Unit 1

12 hours

Proteomics

Mass spectrometry – ionization methods (MALDI, electrospray), mass analysers, fragmentation modes (CID, HCD and ETD), intact protein analysis, protease digestion, peptide mass fingerprinting, tandem mass spectrometry, , introduction to Data Independent Analysis (DIA), Basics of chromatography and fractionation strategies; Protein sequence and spectral databases/ libraries, de-novo sequencing, search algorithms- SEQUEST, X!tandem, MS-Amanda; Proteomic data repositories

Unit 2

12 hours

Quantitative and Targeted Proteomics

Introduction to quantitative proteomics- Differential proteomics, post-translational modifications, Targeted proteomics- Parallel reaction monitoring, Multiple reaction monitoring, Targeted proteomics software- Skyline

Unit 3

12 hours

Proteogenomics

Concepts and principles of genome annotation, genome search specific peptides, alternative translation initiation, small ORFs, Analysis of transcriptomic and proteomic data for genome annotation; Gene prediction algorithms

Unit 4

9 hours

Metabolites and Metabolomics

Metabolomics-an overview, basic sample preparation strategies- extraction, derivatization, Workflow for lipidomics; Introduction to mass spectrometry and modes of data acquisition, data repositories. Targeted Vs Untargeted metabolomics; development of targeted assays for small molecules

Unit 5

7 hours

Metabolomic Data Analysis

Peak detection, retention time alignment; identification of molecular features and metabolites; structural confirmation of metabolites. Software- Multiquant, MZmine, XCMS, MarkerView, LipidSearch. Metabolic pathways and inborn errors of metabolism

OT102:Genomics and Epigenetics

Total lecture hours: 52

Unit 1

8 hours

Genes and Genomes

Gene- Eukaryotic and prokaryotic gene structure, genome databases, Coding regions (genes) and Non-coding regions (Intergenic sequences); Gene and related sequences – NTS, ETS and ITS, 3' UTR, 5' UTR, Pseudogenes; Repeat sequences: a) Interspersed repeats: LINES, SINES, LTR elements; SINES types: ALU elements, MIR, MIR3; b) Tandem repeats: Transposons; c) Microsatellites; Genetic mapping; Physical mapping (Contig maps, Restriction maps, DNA sequence maps, FISH); Molecular markers for genome analysis-Restriction enzyme sites, EST, STS, microsatellites

Unit 2

10 hours

Genomics

Sanger sequencing-principle, methodology and applications, History of genome sequencing, Human Genome sequencing project; Analysis of gene expression- qPCR, northern blot, southern blot; Transcriptome profiling; DNA microarrays; Copy number variation, sequence repeats, SNV, haplotype, and their relevance in diseases. Comparative genomics. Metagenomics

Unit 3

12 hours

Next Generation Sequencing (NGS) Technology

Whole genome - de novo sequencing or resequencing; exome sequencing; RNA sequencing; small RNA sequencing; metagenomics; NGS workflow: DNA/RNA isolation and quantitation; Fragmentation (different methods – Physical / Enzymatic/ Chemical); Library preparation-blunt end and adapter ligation, amplification, index addition; single end and paired end reads; Exome/ gene panel capture; Ribosomal RNA depletion (RNA-Seq) and small RNA enrichment; 16S rRNA based sequencing for metgenomics; Platforms for NGS sequencing; Clonal amplification- Bead-based or Emulsion-based PCR amplification, array-based or bridge amplification; Sequencing technologies-(Clone-by-clone sequencing, Shot-gun sequencing, sequencing by hybridization and sequencing by synthesis), Emerging sequencing platforms- PacBio (SMRT technology), Oxford Nanopore systems

Unit 4

12 hours

NGS data analysis

Next generation sequence analyses, Data format, Quality control-Phred score; FastQC and FastX tool kits, data analysis tools and pipeline, Read length, read depth, sequence coverage, Homology, clustering, and phylogeny, Genome alignment and analysis tools- BWA (Burrows-Wheeler Aligner), SAMtools, GATK (The Genome Analysis Toolkit), IGV (Integrative Genomics Viewer), HISAT, StringTie, Cuffcompare, Velvet, Oases, Trinity

Unit 5

10 hours

Gene Expression and Gene Regulation Networks

RNA-seq analyses. Differential expression, stochasticity, and FDR. Alternate splicing, ENCODE. Epigenomic analyses and cancer/ diseases. Bisulfite sequencing

OT103:Bioinformatics and Integrated OMICS Data analysis

Total hours: 52

Unit 1

12 hours

Introduction to Bioinformatics and Data Generation

Bioinformatics and its applications to biology, Bioinformatics tools – Web-based and standalone; sequence analysis (BLAST, alignment tools), phylogeny analysis (MEGA7), network analysis (Cytoscape), Gene Ontology

Unit 2

7 hours

Basics of Linux Operating System

Introduction to Linux operating system, its distribution and installation; Basic and advanced command line operations; File management and permissions; Overview of scripting languages AWK and shell; Vim text editor

Unit 3

10 hours

Fundamentals of Programming Languages

a) PERL

Data structure: scalar, array, hash; Conditional statements: if, else, elsif, unless; Loops: for, foreach, until, while, do..while; String handling: length, lc, uc, substr and regular expression; Array handling: push, pop, shift, unshift; Operators; File handling; References; Subroutine. Bio-PERL.

b) Python

Introduction to python: Overview, Environment setup, Basic syntax; Basic operations; Data types: strings, tuples, lists, dictionaries; Decision making: if, if else, nested if; Loops: while, for, nested, break, continue and pass statement; File handling; Bio-python.

Unit 4

12 hours

Biological Databases

Databases and data retrieval systems (DBMS, SQL) – primary and secondary databases, biological databases – NCBI, UniProt, PDB, KEGG, Data annotation strategies; Database development

Unit 5

11 hours

Integrated OMICS Data Analysis

Genomic, transcriptomic, proteomic and metabolomics data file format and standards, curation and gene accession mapping, Quality control for data integration, Analysis and visualization, gene set Enrichment analysis, Pathway analysis, Network analysis

OT104: Syllabus of the Elective theory paper
(Choose any one from the following)

OT104A: Product Development - Biologist

Total hours: 52

Unit 1

12 hours

Essentials of Product Development

Company protocols for research, privacy policies, institutional and professional code of ethics and standards of practice, IPR guidelines, Knowledge of basic laboratory procedures, GLP and GMP, relevant EOPs, SOPs, process flows in manufacturing, product life cycle and product properties, competitor products. Stability studies – generate stability data & prepare stability reports for innovation products

Unit 2

10 hours

Reporting and Documentation

Reporting – different standard reference materials used like drugs, products, side effects, adverse reactions, process details, statistical analysis of test data. Documentation – methods and procedures of writing and maintaining lab, research records, research performance reports, schemes and guidelines, power point presentations, tables, charts, word documents, development of research objectives and proposal writing for funding and contractual purposes, publications and technical writing, Regulatory compliance of the final documents

Unit 3

8 hours

Planning and Communication

Research planning – resource, time, timeline & budget considerations, technical feasibility analysis on the NPD ideas by analyzing current development plans, plan day to day activities. Research communications - preparation of progress reports/ research outcomes for steering groups/ bodies, principal investigator, communication with upstream and downstream teams

Unit 4

6 hours

Problem Solving and Decision Making

Research initiatives – use new areas of research, techniques and methods, extend research/ product portfolio, creative analysis & interpretation of research data. Decision making – collaborative, appropriate, optimum & best possible solution, Trouble- shoot & Resolve problems to avoid delays

Unit 5

8 hours

Safety and Security at Workplace

Different types of occupational health hazards, knowledge of chemical substances, characteristics & safety measures, use of safety gears, masks, gloves & accessories, evacuation procedures for workers & visitors. Health, safety & security issues – types (illness, fire accidents), company policies and procedures, When and how to report, summon medical assistance & emergency services

Unit 6**8 hours****Interpersonal Skills**

Understand work output requirements, company rules, guidelines & policies related to the process flow, identifying and reporting issues requiring intervention, delivery of quality work on time & report any anticipated reasons for the delay, effective interpersonal communication, conflict-resolution techniques, importance of collaborative working, multi-tasking, training the team members, knowledge of project management.

OT104B : Quality Control/Quality Assurance Biologist

Total hours: 52

Unit 1

16 hours

Essentials of Quality Control

Preparations - buffer, solvents, and solutions for running bio-analytical quality tests
Concepts of pharmacopeia like BP, USP, EP and other applicable guidelines such as WHO, ICH and EMEA, etc., statistical tools and software like combistats, safe handling of infectious materials like cultures, strains and seed strains, procedures for handling infectious spillage control, GLP/GMP, biochemical analysis of proteins, bio analytical methods, working of instruments/apparatus/equipment, biological assays, application of various analytical techniques such as HPLC, capillary electrophoresis including icIEF, FTIR, UV and Fluorescence spectroscopy, ELISAs, enzyme assays and other applicable methods for the testing of biopharmaceuticals, application of microbiological techniques such as air monitoring, water testing, surface monitoring, microbial monitoring, biosafety levels and biosafety hazards

Unit 2

10 hours

Quality Assurance

Quality checks - quality assurance samples, master sample, internal controls, statistical analysis of test data, techniques and concepts of statistical quality control and statistical process control, non-conformities. Operational aspects – calibration, accuracy checks of quality control equipments like HPLC, liquid chromatography, mass spectrometry, application software used in quality analysis

Unit 3

6 hours

Safety and Security at Workplace

Different types of occupational health hazards, knowledge of chemical substances, characteristics & safety measures, use of safety gears, masks, gloves & accessories, evacuation procedures for workers & visitors. Health, safety & security issues – types (illness, fire accidents), company policies and procedures, When and how to report, summon medical assistance & emergency services

Unit 4

6 hours

Interpersonal Skills

Understand work output requirements, company rules, guidelines & policies related to the process flow, identifying and reporting issues requiring intervention, delivery of quality work on time & report any anticipated reasons for the delay, importance of team work, resolution of conflicts, multi-tasking, training the team members, knowledge of project management

Unit 5

6 hours

Clean Work Station

Cleaning the work area and equipments, materials and equipments required for cleaning, adequate ventilation for the work area, personal protective equipments, dealing with

accidental damage, procuring and storing housekeeping equipment and supplies, disposal of wastes, maintain schedules and records for housekeeping

Unit 6

8 hours

Reporting and Documentation in Quality

Reporting – company procedures, escalation matrix for reporting identified issues - defects, problem, incidents, quality issues and test results, feedback to production manager and R&D staff. Documentation – procedures and good documentation practices, offline and online mode, accuracy, details, controlled document files and test records, regulatory and compliance requirements, inspection - procedures, protocols and checklists, inspection reports

OT105 Practical: Genomics and Proteomics

Module 1

30 hours

Next Generation Sequencing

DNA and RNA extraction and quantitation; quality control, alignment and analysis Introduction to Nanopore Sequencing and library preparation, Nanopore Sequencing; Whole Genome Sequencing; Different data formats for sequencing data including FASTQ, SFF, CSF, CSFASTA, SAM, BAM. Common sequencing and annotation file formats in use for transcriptomics analysis including GTF, GFF, BED

Module 2

40 hours

Proteomics

Protein extraction strategies for varied biological samples; in-gel and in-solution digestion; Liquid chromatography-based (SCX/bRPLC); Stop And Go Extraction (C18-based) for mass spectrometry; TMT labeling; Validation of proteomic data

Module 3

10 hours

Phosphoproteomics

Extractions of proteins; Enrichment of phosphopeptides using TiO₂, Mass spectrometric analysis of phosphopeptide enriched samples

Module 4

24 hours

Metabolomics

Extraction techniques for metabolomics; Basics of chromatography; Introduction to lipidomics; Metabolome data resources

OT106 Practical: OMICS Data Analysis

Module 1

28 hours

Genomics

Quality filter and processing raw data; Mapping tools for WGS using BWA and Bowtie; Demonstration of common SAM tools and BED tools; Transcriptome analysis using Hisat2; Transcriptome analysis using StringTie; Differential expression analysis for transcriptome data using cuffdiff package; Introduction to R and Bioconductor packages

Module 2

28 hours

Mass Spectrometry-based Proteomics Data

Data formats of mass spectrometry experiments; Qualitative data analysis; Quantitative data analysis, Normalization techniques for quantitative proteomics; Proteomic data analysis- Search algorithms, False Discovery Rates, Parsimony rules; Data resource based protein identification

Module 3

24 hours

Integrated OMICS Data Analysis

Proteogenomic data analysis using Integrative Genomics Viewer; Biological interpretation of OMICS data, Gene set Enrichment analysis, Pathway analysis, Network analysis

Module 4

24 hours

Metabolomics

Data formats of mass spectrometry derived metabolomics; Metabolomics data analysis – identification of molecular features, metabolite identification; structural confirmation of metabolites; Data resource based metabolite identification; Using NIST Standard Reference Database, METLIN database; XCMS tool, Human Metabolome Database (HMDB), Compound Discoverer, MZmine

References/Books/Journals

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- Green MR, Sambrook J (2012). Molecular cloning – A laboratory manual. Cold Spring Harbor Laboratory Press. 1885 pages
- Karp G (2009). Cell and molecular biology: Concepts and experiments, 7th edition. John Wiley & Sons. 864 pages
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- Miller K, Levine J (2010). Biology. Pearson. 1034 pages
- Wilson K, Walker J (2010). Principles and techniques of biochemistry and molecular biology, 7th edition. Cambridge University Press. 759 pages
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- Gross JH (2011). Mass spectrometry – A textbook. Springer. 716 pages
- Kulkarni S, Pfeifer J (2014). Clinical genomics. Academic Press. 488 pages
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