General Aptitude Syllabus		30 Marks
Section	**Topics**	**No. of Questions**
1. Quantitative Aptitude:	Number Systems, Percentage, Profit and Loss, Simple and Compound Interest, Ratio and Proportion, Time, Speed, and Distance, Time and Work, Average, Algebra, Geometry, Mensuration, Data Interpretation.	6
2. Logical Reasoning:	Analogy , Classification, Series Completion, Coding-Decoding, Blood Relations, Direction Sense Test, Logical Venn Diagrams, Alphabet Test, Number Ranking and Time Sequence Test, Mathematical Operations, Logical Sequence of Words, Arithmetical Reasoning, Inserting the Missing Character, Data Sufficiency.	6
3. Verbal Ability:	Reading Comprehension, Vocabulary, Synonyms and Antonyms, Fill in the Blanks, Error Correction, Sentence Correction, Para-jumbles, Sentence, Completion, Idioms and Phrases, One-word Substitution.	6
4. General Awareness:	Current Affairs (National and International), History, Geography, Indian Polity, Indian Economy, Science and Technology, Environmental Studies, Important Dates, Events and Persons, Books and Authors, Awards and Honors, Sports, Abbreviations, Indian Constitution.	6
5. Data Interpretation:	Tabular Data Interpretation, Bar Graphs, Line Graphs, Pie Charts, Caselet Data Interpretation, Data Sufficiency.	6
Life Sciences Syllabus		**70 Marks**
Section	**Topics**	**No. of Questions**
Section 1: Biochemistry	• **Biochemical Techniques:** Principles and applications of various biochemical techniques such as chromatography (paper chromatography, TLC, column chromatography, HPLC), electrophoresis, centrifugation, spectroscopy (UV-Vis, fluorescence, NMR, mass spectrometry), immunochemical techniques (ELISA, immunoblotting), PCR, DNA sequencing, protein purification techniques. • **Biomolecules:** Structure, properties, and functions of carbohydrates, lipids, proteins, and nucleic acids. • **Enzymology:** Classification, mechanism of action, kinetics (Michaelis-Menten kinetics, allosteric enzymes), enzyme inhibition, regulation of enzyme activity. • **Metabolism:** Overview of metabolism: Anabolism and catabolism. Carbohydrate metabolism: Glycolysis, gluconeogenesis, pentose phosphate pathway, glycogen metabolism. Lipid metabolism: Fatty acid oxidation and synthesis, cholesterol metabolism. Amino acid metabolism: Protein catabolism, urea cycle, biosynthesis of amino acids. Nucleotide metabolism: Purine and pyrimidine metabolism. Bioenergetics: ATP synthesis, oxidative phosphorylation, electron transport chain. • **Biochemical Genetics:** Mendelian genetics and its application in biochemistry. Gene expression: Transcription, translation, regulation of gene expression (transcriptional and post-transcriptional regulation). Recombinant DNA technology: Gene cloning, PCR, DNA sequencing, gene expression vectors. • **Hormones and Signal Transduction:** Overview of hormones and their functions. Mechanisms of hormone action: Receptor-mediated signal transduction pathways (G-protein coupled receptors, receptor tyrosine kinases, intracellular receptors). Second messengers: cAMP, IP3, DAG, calcium ions. • **Biochemical Basis of Diseases:** Molecular basis of genetic disorders, metabolic disorders, and cancer. Biomarkers and diagnostic tests for various diseases. Therapeutic interventions targeting biochemical pathways in diseases. • **Immunochemistry:** Structure and function of antibodies and antigens. Immune response: Innate and adaptive immunity, antigen presentation, humoral and cellular immunity. Immunological techniques: ELISA, immunoblotting, immunoprecipitation.	7
Section 2 : Molecular Biology	• **DNA Structure and Function:** DNA replication: Enzymes involved, replication fork, leading and lagging strands, replication origins, and termination. DNA repair mechanisms: Mismatch repair, base excision repair, nucleotide excision repair, homologous recombination, non-homologous end joining. DNA packaging: Chromatin structure, nucleosomes, histones, chromatin remodeling complexes. • **Transcription:** RNA synthesis: RNA polymerase, transcription factors, promoter elements, enhancers, terminators. Transcriptional regulation: Operons, transcriptional activators and repressors, transcriptional co-regulators, RNA interference. • **RNA Processing:** mRNA processing: Capping, splicing, polyadenylation. tRNA and rRNA processing. • **Translation:** Ribosome structure and function. tRNA charging, initiation, elongation, termination. Post-translational modifications: Protein folding, glycosylation, phosphorylation, proteolysis.	7

	• **Gene Regulation:** Mechanisms of gene regulation in prokaryotes and eukaryotes. Regulatory sequences, transcriptional regulators, epigenetic modifications. Transcriptional and post-transcriptional regulation of gene expression. • **Genomics and Proteomics:** Genome organization: Gene structure, introns and exons, repetitive DNA elements. Comparative genomics, functional genomics, and metagenomics. Proteome analysis: Protein separation techniques, mass spectrometry, protein-protein interactions. • **Recombinant DNA Technology:** Gene cloning: Restriction enzymes, DNA ligation, vectors (plasmids, phages, cosmids), transformation, selection, screening. Polymerase Chain Reaction (PCR) and its variations. DNA sequencing methods: Sanger sequencing, next-generation sequencing (NGS), and sequencing by synthesis. • **Gene Expression Systems:** Expression vectors and hosts: Bacterial, yeast, insect, and mammalian expression systems. Protein expression and purification techniques. • **Genome Editing and CRISPR-Cas Technology:** Principles of CRISPR-Cas systems. Applications of CRISPR-Cas for genome editing, gene regulation, and functional genomics. • **RNA Interference (RNAi) and Gene Silencing:** Mechanisms and applications of RNAi in gene silencing, functional genomics, and therapeutic interventions. • **Molecular Biology Techniques:** Principles and applications of molecular biology techniques such as Southern blotting, Northern blotting, Western blotting, DNA/RNA hybridization, gel electrophoresis, and DNA/RNA manipulation techniques.	
Section 3: Microbiology	• **Microbial Taxonomy and Diversity:** Classification and nomenclature of microorganisms: Bacteria, Archaea, Fungi, Protozoa, Algae, and Viruses. Methods for microbial identification and characterization. Microbial diversity in different environments: Soil, water, air, extreme environments. • **Microbial Structure and Function:** Bacterial cell structure: Cell wall, plasma membrane, cytoplasm, ribosomes, nucleoid, appendages (flagella, pili, fimbriae), endospores. Structure and function of viral particles: Capsid, envelope, genome types (DNA, RNA), replication cycles (lytic and lysogenic). Structure and function of eukaryotic microorganisms: Fungi, Protozoa, Algae. • **Microbial Physiology:** Metabolism: Microbial nutrition, energy generation, catabolism, anabolism, fermentation, respiration, photosynthesis. Growth kinetics: Growth curve, factors affecting microbial growth (temperature, pH, osmotic pressure, oxygen). Bacterial genetics: Gene transfer mechanisms (transformation, transduction, conjugation), plasmids, mutations, horizontal gene transfer. • **Microbial Ecology:** Microbial interactions: Mutualism, commensalism, parasitism, competition, predation. Microbial communities: Biofilms, microbial mats, microbial consortia. Microbial roles in biogeochemical cycles: Carbon, nitrogen, sulfur cycles. • **Medical Microbiology:** Pathogenesis of infectious diseases: Virulence factors, host-pathogen interactions, mechanisms of infection. Microbial diseases: Bacterial, viral, fungal, and protozoal infections, epidemiology, prevention, and control measures. Antimicrobial agents: Antibiotics, antivirals, antifungals, mechanisms of action, resistance mechanisms. • **Industrial Microbiology:** Microbial biotechnology: Microbial enzymes, biofuel production, bioremediation, biotransformation, biosurfactants, biofertilizers. • Fermentation technology: Fermentation processes, microbial culture techniques, downstream processing, scale-up, and optimization. • **Microbial Biotechnology:** Genetic engineering of microorganisms: Recombinant DNA technology, gene cloning, expression vectors, gene editing tools (CRISPR-Cas), synthetic biology. Microbial production of biomolecules: Recombinant proteins, vaccines, antibiotics, industrial enzymes. • **Environmental Microbiology:** Microbial interactions in ecosystems: Role of microorganisms in nutrient cycling, degradation of pollutants, bioremediation strategies. • Microbial indicators of environmental quality: Indicator microorganisms for water and soil quality assessment. • **Food Microbiology:** Microorganisms in food production, preservation, and spoilage. Foodborne pathogens: Sources, transmission, prevention, and control measures. • **Microbial Genetics and Genomics:** Microbial genome structure and organization. Comparative genomics, metagenomics, and systems biology approaches in microbial research.	7
Section 4: Genetics	• **Mendelian Genetics:** Laws of inheritance: Mendel's laws, deviations from	7

and Genomics	Mendelian genetics (incomplete dominance, codominance, multiple alleles, pleiotropy, epistasis). Pedigree analysis: Autosomal and sex-linked inheritance patterns, genetic disorders. • **Molecular Genetics:** DNA structure and replication: Double helix model, DNA replication mechanisms (semi-conservative, conservative, dispersive). DNA repair mechanisms: Mismatch repair, base excision repair, nucleotide excision repair. DNA recombination and repair: Homologous recombination, site-specific recombination, transposition. DNA packaging: Chromatin structure, nucleosomes, histone modifications, chromatin remodeling. • **Gene Expression and Regulation:** Transcription: RNA polymerase, transcription factors, promoters, enhancers, transcriptional regulation (activators, repressors). RNA processing: Splicing, capping, polyadenylation, RNA editing. Translation: Ribosome structure, initiation, elongation, termination, regulation of translation. • Post-translational modifications: Protein folding, glycosylation, phosphorylation, ubiquitination. • **Genomics:** Genome organization: Gene structure, introns and exons, gene families, repetitive sequences. Comparative genomics: Genome evolution, orthologs, paralogs, synteny, genome duplication events. • Functional genomics: Transcriptomics, proteomics, metabolomics, high-throughput sequencing technologies (RNA-seq, ChIP-seq, DNA microarrays). • **Epigenetics and Chromatin Dynamics:** Epigenetic modifications: DNA methylation, histone modifications, non-coding RNAs. Epigenetic inheritance: Role of epigenetics in development, disease, and environmental responses. Chromatin remodeling complexes: SWI/SNF, ISWI, histone acetyltransferases, histone deacetylases. • **Genetic Engineering and Biotechnology:** Recombinant DNA technology: Gene cloning, expression vectors, gene editing tools (CRISPR-Cas), synthetic biology. Genetic manipulation techniques: Gene knockout, gene knock-in, gene silencing (RNA interference). • Applications of genetic engineering: Transgenic organisms, gene therapy, genetically modified crops, molecular diagnostics. • **Population and Evolutionary Genetics:** Population genetics: Gene frequency, Hardy-Weinberg equilibrium, genetic drift, gene flow, natural selection. Molecular evolution: Molecular clocks, neutral theory, adaptive evolution, phylogenetics, molecular markers. • **Genetic Diseases and Genetic Counseling:** Human genetic disorders: Monogenic disorders, chromosomal abnormalities, multifactorial diseases. Principles of genetic counseling: Pedigree analysis, risk assessment, ethical issues in genetic testing. • **Genome Editing and Gene Therapy:** CRISPR-Cas9 system: Mechanism, applications in genome editing and gene therapy. Gene therapy approaches: Gene addition, gene correction, gene silencing, ex vivo and in vivo gene therapy. • **Systems Biology and Network Analysis:** Systems biology approaches: Modeling biological systems, network analysis, signaling pathways, regulatory networks. Computational methods in genomics: Sequence alignment, gene prediction, motif discovery, genome annotation.	
Section 5: Cell Biology	• **Cell Structure and Function:** Cell theory: Historical perspective, modern cell theory. Cellular compartments: Structure and function of cell organelles (nucleus, endoplasmic reticulum, Golgi apparatus, mitochondria, chloroplasts, lysosomes, peroxisomes). Cytoskeleton: Microtubules, microfilaments, intermediate filaments, their structure, function, and dynamics. Cell membrane: Structure, fluid mosaic model, membrane proteins, membrane transport (passive and active transport), cell-cell interactions, cell junctions. • **Cell Cycle and Division:** Cell cycle phases: Interphase (G1, S, G2), mitosis, cytokinesis. Regulation of the cell cycle: Checkpoints, cyclins, cyclin-dependent kinases (CDKs), tumor suppressor genes. Cell division: Mitosis, meiosis, comparison between mitosis and meiosis, gametogenesis. • **Cell Signaling:** Types of cell signaling: Endocrine, paracrine, autocrine, juxtacrine. Signal transduction pathways: Receptor-mediated signaling, intracellular signaling cascades (e.g., G-protein coupled receptors, receptor tyrosine kinases). Second messengers: cAMP, cGMP, IP3, DAG, calcium ions. Signaling molecules: Growth factors, cytokines, hormones. • **Cellular Energetics:** Cellular respiration: Glycolysis, citric acid cycle (Krebs cycle), oxidative phosphorylation, electron transport chain. Photosynthesis: Light-dependent and light-independent reactions, Calvin cycle, chloroplast structure and function. Energy metabolism: ATP synthesis, energy storage and utilization, metabolic pathways (anabolism and catabolism). • **Cellular Membrane Dynamics:** Membrane trafficking: Endocytosis (phagocytosis, pinocytosis, receptor-mediated endocytosis), exocytosis, vesicle	7

	transport. Membrane fusion and fission: Mechanisms and regulation. Membrane remodeling: Lipid rafts, membrane curvature, membrane-associated proteins. • **Cellular Adhesion and Motility:** Cell adhesion molecules (CAMs): Integrins, selectins, cadherins. Cell migration: Mechanisms of cell motility, cytoskeletal dynamics in cell migration (lamellipodia, filopodia), extracellular matrix (ECM) interactions. Cell-cell and cell-matrix adhesion: Role in tissue development, wound healing, and cancer metastasis. • **Cell Differentiation and Stem Cells:** Stem cell biology: Types of stem cells (embryonic stem cells, adult stem cells, induced pluripotent stem cells), stem cell niches, stem cell markers. Cell fate determination: Signaling pathways involved in cell differentiation, transcription factors, epigenetic regulation. Tissue regeneration and repair: Role of stem cells in tissue homeostasis and regeneration. • **Cellular Responses to Environmental Stimuli:** • Cellular stress responses: Heat shock response, unfolded protein response, oxidative stress response. Apoptosis and cell death: Mechanisms of programmed cell death, caspase activation, apoptotic signaling pathways. • **Cell senescence:** Molecular mechanisms, role in aging and age-related diseases.	
Section 6: Pharmaceutical Biotechnology	• **Introduction to Pharmaceutical Biotechnology :** Overview of biotechnology applications in the pharmaceutical industry. Importance and impact of biopharmaceuticals. Regulatory aspects and ethical considerations in pharmaceutical biotechnology. • **Recombinant DNA Technology:** • Techniques for gene cloning, including restriction enzymes, vectors, and gene libraries. Gene expression systems: prokaryotic and eukaryotic hosts, expression vectors, and promoters. • Strategies for recombinant protein production and purification. Monoclonal Antibodies and Therapeutic Proteins Production of monoclonal antibodies: hybridoma technology and recombinant antibody techniques. Therapeutic proteins: insulin, growth factors, cytokines, and hormones. Purification and characterization of therapeutic proteins. • **Vaccine Technology :** Types of vaccines: live attenuated, inactivated, subunit, DNA, and vector-based vaccines. Vaccine production methods: cell culture, recombinant technology, and adjuvants. Vaccine formulation, stability, and delivery systems. • **Drug Delivery Systems :** Principles of drug delivery: routes of administration, pharmacokinetics, and pharmacodynamics. Nanotechnology in drug delivery: nanoparticles, liposomes, and micelles. Targeted drug delivery systems and site-specific drug release mechanisms. • **Pharmacogenomics and Personalized Medicine :** Role of genomics in drug discovery and development. Pharmacogenetics: genetic variations and drug response. Implementation of personalized medicine in clinical practice. • **Regulatory Affairs and Quality Control :** Regulatory requirements for biopharmaceutical products: FDA, EMA, and ICH guidelines. Good Manufacturing Practices (GMP) and quality control standards.Quality assurance in biopharmaceutical manufacturing. Emerging Trends in Pharmaceutical Biotechnology • Biopharmaceuticals for rare diseases and orphan drugs. Bioprospecting and natural product discovery. Future directions in precision medicine and biopharmaceutical innovation.	7
Section 7 : Bioprocess Engineering	• **Introduction to Bioprocess Engineering:** Definition, scope, and importance of bioprocess engineering. Historical development and milestones in bioprocess technology. Role of bioprocess engineering in biotechnology, pharmaceuticals, food processing, and other industries. • **Microbial Growth Kinetics:** Growth phases of microorganisms: lag phase, exponential phase, stationary phase, death phase. • Mathematical modeling of microbial growth: Monod equation, logistic equation, and other models. Factors affecting microbial growth: Nutrient availability, temperature, pH, oxygen, etc. • **Downstream Processing:** Recovery and purification of biomolecules: Solid-liquid separation, filtration, centrifugation, chromatography, etc. Unit operations in downstream processing: Extraction, precipitation, crystallization, drying, and formulation. Process optimization and efficiency enhancement in downstream processing. • **Bioreactor Design and Operation:** Design criteria for bioreactors: Reactor geometry, mixing, aeration, and agitation. Heat and mass transfer in bioreactors: Oxygen transfer, nutrient transfer, heat removal, etc. Bioreactor instrumentation and control: Sensors, transducers, actuators, feedback control systems. • **Bioprocess Scale-up and Economics:** Principles of scale-up in bioprocess	7

	engineering: Geometric similarity, dynamic similarity, and dimensionless numbers. Economic considerations in bioprocess design: Cost analysis, process optimization, return on investment. • Techno-economic analysis (TEA) of bioprocesses: Cost estimation, sensitivity analysis, profitability assessment. • **Biocatalysis and Enzyme Technology:** Enzyme kinetics and mechanisms: Michaelis-Menten kinetics, enzyme inhibition, allosteric regulation. Immobilization of enzymes: Methods, applications, and advantages. Industrial applications of enzymes: Biocatalysis, biotransformation, enzyme-based biosensors, etc. • **Bioseparation Techniques:** Principles and applications of bioseparation techniques: Centrifugation, filtration, chromatography, electrophoresis, etc. Advanced separation methods: Membrane separation, supercritical fluid extraction, affinity chromatography, etc. Purification of recombinant proteins, antibodies, and other biomolecules. • **Biological Waste Treatment:** Biological treatment of wastewater: Aerobic and anaerobic digestion, activated sludge process, biofiltration, etc. Bioremediation of environmental pollutants: Biodegradation, phytoremediation, microbial consortia, etc. Sustainable bioprocesses and green technologies in waste treatment. • **Emerging Trends in Bioprocess Engineering:** Bioprocess intensification: Miniaturization, microreactors, continuous processing, and integrated biomanufacturing. Bioprocess automation and digitalization: Industry 4.0, artificial intelligence, machine learning, and data analytics. Applications of bioprocess engineering in biopharmaceuticals, biofuels, biopolymers, and personalized medicine.	
Section 8 : Fermentation Technology	• **Introduction to Fermentation Technology:** • Definition, scope, and importance of fermentation in biotechnology, pharmaceuticals, food, and other industries. Historical development and milestones in fermentation technology. Role of microorganisms in fermentation processes: Bacteria, fungi, yeast, and algae. • **Microbial Growth and Metabolism:** • Growth kinetics of microorganisms: Growth phases, factors affecting growth, and mathematical modeling. Metabolic pathways in microorganisms: Glycolysis, TCA cycle, pentose phosphate pathway, and fermentation pathways. Regulation of microbial metabolism: Enzyme induction, repression, feedback inhibition, and metabolic control mechanisms. • **Substrate Utilization and Product Formation:** Utilization of carbon and energy sources by microorganisms: Sugars, alcohols, organic acids, and hydrocarbons. Formation of microbial products: Primary metabolites (ethanol, lactic acid, citric acid, etc.) and secondary metabolites (antibiotics, enzymes, pigments, etc.). • Optimization of substrate utilization and product formation in fermentation processes. • **Fermentation Process Design and Operation:** • Design considerations for fermentation reactors: Reactor types, vessel geometry, mixing, aeration, and sterilization. Parameters affecting fermentation process operation: pH control, temperature control, oxygen transfer rate, and agitation speed. Monitoring and control of fermentation parameters: Online and offline monitoring techniques, feedback control systems. • **Fermentation Kinetics and Scale-Up:** Kinetics of fermentation reactions: Monod equation, substrate inhibition, product inhibition, and other kinetic models. Scale-up of fermentation processes: Principles of geometric similarity, dynamic similarity, and dimensionless numbers. Challenges and strategies in scaling up fermentation processes from laboratory to pilot and production scale. • **Downstream Processing in Fermentation:** • Recovery and purification of fermentation products: Cell disruption, solid-liquid separation, filtration, and centrifugation. • Separation techniques: Chromatography (affinity, ion exchange, size exclusion), crystallization, evaporation, and drying. Optimization of downstream processing operations: Yield improvement, purity enhancement, and cost reduction. • **Sterilization and Aseptic Techniques:** Sterilization methods for fermentation media and equipment: Heat sterilization (autoclaving), filtration, chemical sterilization. Aseptic techniques in fermentation: Cleanroom design, air filtration, gowning procedures, and environmental monitoring. Prevention and control of contamination in fermentation processes: Bacterial, fungal, viral, and phage contamination. • **Industrial Applications of Fermentation Technology:** Bioproduction of biofuels: Ethanol, biodiesel, methane, hydrogen, and other renewable fuels. Production of industrial enzymes: Amylases, proteases, lipases, cellulases, and	7

	other enzyme products. • Fermentation-based production of pharmaceuticals, antibiotics, organic acids, amino acids, vitamins, and specialty chemicals. • **Emerging Trends in Fermentation Technology:** • Biorefinery concept and integrated bioprocessing: Utilization of biomass for the production of multiple products. Metabolic engineering and synthetic biology approaches in fermentation: Strain improvement, pathway engineering, and genome editing. • Sustainable fermentation processes: Waste minimization, energy efficiency, and environmental impact assessment.	
Section 9: Immunology	• **Introduction to Immunology:** Historical perspectives and milestones in immunology. Basic concepts: Immune system, immunity, antigens, antibodies, and antigens-antibody interactions. • Types of immunity: Innate immunity and adaptive immunity. • **Innate Immunity:** Components of the innate immune system: Physical barriers, cellular components (macrophages, neutrophils, dendritic cells), and soluble factors (complement system, cytokines). Recognition of pathogens by pattern recognition receptors (PRRs). Phagocytosis and intracellular killing mechanisms. • **Adaptive Immunity:** Cells of adaptive immunity: T cells, B cells, and antigen-presenting cells (APCs). Antigen recognition and activation of lymphocytes: Major histocompatibility complex (MHC), T cell receptor (TCR), and B cell receptor (BCR). • T cell activation and differentiation: Helper T cells (Th1, Th2, Th17), cytotoxic T cells (CTLs), and regulatory T cells (Tregs). • B cell activation, antibody production, and class switching. • **Humoral Immune Response:** Structure and function of antibodies: Immunoglobulin classes (IgG, IgM, IgA, IgD, IgE), antibody diversity, and antibody-mediated effector functions. Generation of antibody diversity: Somatic recombination, somatic hypermutation, and affinity maturation. Mechanisms of antibody-mediated immunity: Neutralization, opsonization, complement activation, and antibody-dependent cellular cytotoxicity (ADCC). • **Cell-Mediated Immune Response:** T cell activation and effector functions: Cytokine production, T cell proliferation, and differentiation into effector and memory T cells. T cell-mediated cytotoxicity: Recognition of target cells, perforin-granzyme pathway, and Fas-Fas ligand pathway. Role of T cells in immune regulation and tolerance. • **Immune System Development and Tolerance:** Development of lymphoid organs: Thymus, bone marrow, and secondary lymphoid tissues (spleen, lymph nodes). Central and peripheral tolerance mechanisms: Negative selection in thymus, peripheral deletion, anergy, and regulatory T cells. • **Antigen Processing and Presentation:** Intracellular antigen processing pathways: Endogenous pathway (MHC class I) and exogenous pathway (MHC class II). Antigen presentation by professional antigen-presenting cells (APCs): Dendritic cells, macrophages, and B cells. • **Hypersensitivity and Autoimmunity:** Types of hypersensitivity reactions: Type I (immediate), Type II (cytotoxic), Type III (immune complex-mediated), and Type IV (delayed-type). Mechanisms of autoimmune diseases: Loss of self-tolerance, molecular mimicry, and genetic predisposition. Examples of autoimmune diseases: Rheumatoid arthritis, systemic lupus erythematosus (SLE), multiple sclerosis, and type 1 diabetes. • **Vaccines and Immunotherapy:** Principles of vaccination: Types of vaccines (live attenuated, inactivated, subunit, conjugate, and DNA vaccines), adjuvants, and vaccination strategies. Immunotherapeutic approaches: Monoclonal antibodies, cytokine therapy, adoptive T cell transfer, and immune checkpoint inhibitors. • **Immunological Techniques:** Immunological assays: ELISA (enzyme-linked immunosorbent assay), western blotting, immunoprecipitation, and flow cytometry. Molecular techniques in immunology: Polymerase chain reaction (PCR), DNA sequencing, and gene expression analysis.	7
Section 10: Bioinformatics and Computational Biology	• **Introduction to Bioinformatics:** Definition, scope, and applications of bioinformatics. Historical development and milestones in bioinformatics. Role of computational methods in biological research. • **Biological Databases:** Types of biological databases: Nucleotide sequence databases, protein sequence databases, structure databases, and others. Retrieval and analysis of biological data from databases. Overview of major biological databases: NCBI, GenBank, UniProt, PDB, etc. Database search techniques: BLAST, FASTA, PSI-BLAST, etc. • **Sequence Analysis:** Sequence alignment algorithms: Pairwise alignment, multiple sequence alignment. Scoring matrices: BLOSUM, PAM, substitution matrices. Sequence similarity and homology. Methods for sequence motif	7

	discovery and analysis. • Phylogenetic analysis: Construction of phylogenetic trees, evolutionary relationships. • **Structural Bioinformatics:** Protein structure prediction: Homology modeling, ab initio modeling, threading. Protein structure analysis: Structural motifs, domains, and folds. Protein-ligand interactions: Docking, virtual screening, drug design. Molecular dynamics simulations and computational chemistry methods. • **Genomics and Transcriptomics:** Genome sequencing technologies: Sanger sequencing, next-generation sequencing (NGS), third-generation sequencing. Genome assembly, annotation, and analysis. Transcriptome analysis: RNA sequencing (RNA-seq), gene expression profiling, alternative splicing. Identification of non-coding RNAs: microRNAs, long non-coding RNAs (lncRNAs). • **Proteomics and Metabolomics:** • Protein identification and quantification techniques: Mass spectrometry, 2D gel electrophoresis. Protein-protein interaction networks and analysis. Metabolomics: Metabolite identification, metabolic pathway analysis. • **Systems Biology:** Integration of omics data: Genomics, transcriptomics, proteomics, metabolomics. Reconstruction and analysis of biological networks: Regulatory networks, metabolic networks, signaling networks. Modeling and simulation of biological systems: Boolean networks, ordinary differential equations (ODEs), agent-based models. • **Bioinformatics Tools and Software:** Overview of commonly used bioinformatics tools and software packages. Command-line tools, web servers, and graphical interfaces. Programming languages for bioinformatics: Python, R, Perl, etc. • **Machine Learning and Data Mining in Bioinformatics:** Applications of machine learning algorithms in bioinformatics. • Classification, clustering, and regression techniques. Feature selection, dimensionality reduction, and model evaluation. • **Ethical, Legal, and Social Issues (ELSI) in Bioinformatics:** Privacy, data security, and intellectual property rights in bioinformatics research. Ethical considerations in handling biological data and conducting computational analyses. Regulations and policies governing bioinformatics research and applications.	