RAMAKRISHNA MISSION VIVEKANANDA EDUCATIONAL AND RESEARCH INSTITUTE (RKMVERI)

(Deemed-to-be-University)

(Declared by Government of India under section 3 of UGC Act, 1956)

P.O. Belur Math, District- Howrah, West Bengal: 711202

SCHOOL OF AGRICULTURE & RURAL DEVELOPMENT

FACULTY CENTRE FOR INTEGRATED RURAL DEVELOPMENT AND MANAGEMENT (IRDM)

Ramakrishna Mission Ashrama, Narendrapur

Two year M. Sc. in 'Agricultural Biotechnology'

PROPOSED COURSE CONTENT (with effect from academic year 2020-21)

Semester-I

Code	Title of the Course	Credits
ABT101	General Biochemistry	3+0=3
CBT101	Molecular Biology	3+0=3
ABT102	Genetics, Cytogenetics and Epigenetics	3+0=3
ABT103	Molecular Cell and Plant Developmental Biology	3+0=3
CBT102	Biophysical Principles and Analytical Techniques	3+0=3
ARD106	Spiritual and Cultural Heritage of India-I	2+0=2
ABT104	Laboratory-I: General Biochemistry	0+3=3
ABT105	Laboratory-II: Techniques in Cell Biology	0+3=3
	TOTAL	17+6=23

Semester-II

Code	Title of the Course	Credits
CBT201	Genetic Engineering	3+0=3
CBT202	OMICS: Genomics, Transcriptomics, Proteomics and Metabolomics	3+0=3
ABT201	Basics of Microbiology and Plant Immunity	3+0=3
CBT203	Introduction to Bioinformatics	2+1=3
CBT204	Basics of Mathematics and Statistics	2+1=3
ARD207	Spiritual and Cultural Heritage of India-II	2+0=2
CBT205	Laboratory-III: Microbiology	0+3=3
CBT206	Laboratory-IV: Molecular Biology and Genetic Engineering	0+3=3
	TOTAL	15+8=23

Semester-III

Code	Title of the Course	Credits
ABT301	Fundamentals of Plant Biotechnology	3+0=3
GPB103	Fundamentals of Plant Breeding	2+1=3
ABT302	Molecular Breeding	2+0=2
ABT303	Environmental Biotechnology	2+0=2
ABT304	Plant Physiology and Stress Biology	2+0=2
ABT305	Agricultural Statistics: Experimental Design and Data Analysis	1+1=2
ABT306	Laboratory-V: Molecular Breeding	0+2=2
ABT307	Laboratory-VI: Plant Tissue Culture Techniques	0+3=3
ABT308	Laboratory-VII: Environmental Biotechnology	0+2=2
ABT309	Seminar-I: Project Proposal Preparation & Presentation	0+2=2
	Recommended Electives (Optional/Compulsory)	3*
	TOTAL	12+11=23*

Semester-IV

Code	Title of the Course	Credits
CBT401	Intellectual Property Rights, Biosafety and Bioethics	2+0=2
ABT401	Seminar-II: Project Presentation	0+1=1
ABT402	Project	0+20=20
	TOTAL	2+21=23

Recommended Electives

Code	Title of the Course	Credits
ABT310	Fundamentals of Crop Production Technology (Compulsory Course for the Non-Agricultural Students)	2+1=3
GPB105	Principles of Seed Production	3+0=3
ABT311	Pharmacognosy: Phytochemistry and Medicinal Plant Biology	3+0=3

Course Structure at a Glance

Core Courses:

Code	Title of the Course	Credits
ABT101	General Biochemistry	3+0=3
ABT104	Laboratory-I: General Biochemistry	0+3=3
ABT105	Laboratory-II: Techniques in Cell Biology	0+3=3
CBT101	Molecular Biology	3+0=3
ABT102	Genetics, Cytogenetics and Epigenetics	3+0=3
ABT103	Molecular Cell and Plant Developmental Biology	3+0=3
CBT102	Biophysical Principles and Analytical Techniques	3+0=3
ABT201	Basics of Microbiology and Plant Immunity	3+0=3
CBT201	Genetic Engineering	3+0=3
CBT202	OMICS: Genomics, Transcriptomics, Proteomics and Metabolomics	3+0=3
CBT205	Laboratory-III: Microbiology	0+3=3
CBT206	Laboratory-IV: Molecular Biology and Genetic Engineering	0+3=3

Discipline-specific Courses:

Code	Title of the Course	Credits
ABT301	Fundamentals of Plant Biotechnology	3+0=3
ABT302	Molecular Breeding	2+0=2
ABT306	Laboratory-V: Molecular Breeding	0+2=2
ABT307	Laboratory-VI: Plant Tissue Culture Techniques	0+3=3

Ability Enhancement Courses:

Code	Title of the Course	Credits
ARD106	Spiritual and Cultural Heritage of India-I	2+0=2
ARD207	Spiritual and Cultural Heritage of India-II	2+0=2
CBT401	Intellectual Property Rights, Biosafety and Bioethics	2+0=2

Generic-elective Courses:

Code	Title of the Course	Credits
CBT204	**Basics of Mathematics and Statistics**	**2+1=3**
GPB103	**Fundamentals of Plant Breeding**	**2+1=3**
ABT303	**Environmental Biotechnology**	**2+0=2**
ABT304	**Plant Physiology and Stress Biology**	**2+0=2**
ABT305	**Agricultural Statistics: Experimental Design and Data Analysis**	**1+1=2**
ABT308	**Laboratory-VII: Environmental Biotechnology**	**0+2=2**

Skill Enhancement Courses:

Code	Title of the Course	Credits
ABT104	**Laboratory-I: General Biochemistry**	**0+3=3**
ABT105	**Laboratory-II: Techniques in Plant Cell Biology**	**0+3=3**
CBT203	**Introduction to Bioinformatics**	**2+1=3**
CBT205	**Laboratory-III: Microbiology**	**0+3=3**
CBT206	**Laboratory-IV: Molecular Biology and Genetic Engineering**	**0+3=3**
ABT307	**Laboratory-VI: Plant Tissue Culture Techniques**	**0+3=3**
ABT308	**Laboratory-VII: Environmental Biotechnology**	**0+2=2**
ABT309	**Seminar-I: Project Proposal Preparation & Presentation**	**0+2=2**
ABT401	**Seminar-II: Project Presentation**	**0+1=1**

Bridge Course:

Code	Title of the Course	Credits
ABT310	**Fundamentals of Crop Production Technology**	**2+1=3**

Semester-I [Total: 17 (T) + 6 (P) = 23 Credits]

ABT101: General Biochemistry — 3 Credits Theory

Course Objectives: The objectives of this course are to build upon undergraduate level knowledge of biochemical principles with specific emphasis on different metabolic pathways. The course shall make the students aware of various disease pathologies within the context of each topic.

Student Learning Outcomes: On completion of this course, students should be able to:

- Gain fundamental knowledge in biochemistry;
- Understand the molecular basis of plant protection from the perspective of biochemical reactions.

Syllabus:

Unit-I **Chemical Basis of Life** **3 Lectures (6 hours)**	Chemical basis of life: Miller-Urey experiment, abiotic formation of amino acid oligomers, composition of living matter; Water: properties of water, essential role of water for life on earth pH, buffer, maintenance of blood pH and pH of gastric juice, pH optima of different enzymes (pepsin, trypsin and alkaline phosphatase), ionization and hydrophobicity, emergent properties of biomolecules in water, bio-molecular hierarchy, macromolecules, molecular assemblies.
Unit-II **Protein Structure** **6 Lectures (12 hours)**	Structure-function relationships: amino acids: structure and functional group properties, peptides and covalent structure of proteins, elucidation of primary and higher order structures, Ramachandran plot, evolution of protein structure, protein degradation and introduction to molecular pathways controlling protein degradation, structure-function relationships in model proteins like ribonuclease A, myoglobin, hemoglobin, chymotrypsin etc.; basic principles of protein purification; tools to characterize expressed proteins; Protein folding: Anfinsen's Dogma, Levinthal paradox, co-operativity in protein folding, free energy landscape of protein folding and pathways of protein folding, molten globule state, chaperons, diseases associated with protein folding, introduction to molecular dynamic simulation.
Unit-III **Enzyme Kinetics**	Enzyme catalysis: general principles of catalysis; quantitation of enzyme activity and efficiency; enzyme characterization and Michaelis-Menten kinetics; relevance of enzymes in metabolic regulation, activation, inhibition

5 Lectures (10 hours)	and covalent modification; single substrate enzymes; concept of catalytic antibodies; catalytic strategies with specific examples of proteases, carbonic anhydrases, restriction enzymes and nucleoside monophosphate kinase; regulatory strategies with specific example of hemoglobin; isozymes; role of covalent modification in enzymatic activity; zymogens.
Unit-IV **Glycobiology** **2 Lectures (4 hours)**	Sugars: mono, di, and polysaccharides with specific reference to glycogen, amylose and cellulose; glycosylation of other biomolecules: glycoproteins and glycolipids.
Unit-V **Lipid Structure** **1 Lecture (2 hours)**	Structure and properties of important members of storage and membrane lipids; lipoproteins; Self-assembly of lipids, micelle, biomembrane organization.
Unit-VI **Bioenergetics & Metabolism** **6 Lectures (12 hours)**	Bioenergetics: Laws of thermodynamics, entropy, enthalpy, free energy, free energy and equilibrium constant, Gibbs free energy equation, determination of free energy of hydrolytic and biological oxidation reduction reactions, under standard and non-standard conditions, high energy compounds, coupled reactions, determination of feasibility of reactions; ATP and other different groups of high energy phosphate compounds. Metabolism: Citric acid cycle, entry to citric acid cycle, citric acid cycle as a source of biosynthetic precursors; Oxidative phosphorylation; importance of electron transfer in oxidative phosphorylation; Fatty acid metabolism; Nucleotide biosynthesis; logic and integration of central metabolism; entry/ exit of various biomolecules from central pathways; principles of metabolic regulation; steps for regulation.
Unit-VII **Biochemistry of Plant Secondary Metabolites** **4 Lectures (8 hours)**	Secondary metabolites: Types, Importance in plants and for mankind; Major secondary metabolism pathways in plants; Brief outline of occurrence, and synthesis of phenolics, alkaloids, terpenoids, flavonoids, and glycosides.

Recommended Textbooks:

1. Stryer, L. *Biochemistry*. New York: Freeman.

2. Lehninger, A. L. *Principles of Biochemistry* (4th ed.). New York, NY: Worth.
3. Voet, D., & Voet, J. G. *Biochemistry* (4th ed.). Hoboken, NJ: J. Wiley & Sons.
4. Segel, I. H. *Biochemical Calculations* (2nd ed.). J. Wiley & Sons.

CBT101: Molecular Biology — 3 Credits Theory

Course Objectives: The objectives of this course are to make students understand how molecular machines are constructed and regulated so that they can accurately copy, repair, and interpret genomic information in prokaryotes and eukaryotic cells. Further, to appreciate the subject of molecular biology as a dynamic and ever-changing experimental science.

Student Learning Outcomes: On completion of this course, students should be able to:

- Gain fundamental knowledge on molecular architecture of prokaryotic and eukaryotic genomes;
- Understand the various molecular events that lead to duplication of DNA, recombination of genes, transcription and translation following a central dogma;
- Understand molecular mechanisms behind different modes of gene regulation in bacteria and eukaryotes.

Syllabus:

Unit-I **Structure of DNA and RNA** **5 Lectures (10 hours)**	Structure of DNA: A, B, Z and triplex DNA; Central dogma, DNA and RNA as genetic material; DNA contents and C-value paradox; melting and buoyant density; Tm; DNA reassociation kinetics (Cot curve analysis); Repetitive and unique sequences; Satellite DNA. RNA: Structure, and Function.
Unit-II **DNA Replication, Repair and Recombination** **6 Lectures (12 hours)**	Replication: initiation, elongation and termination in prokaryotes and eukaryotes; Enzymes and accessory proteins and mechanisms; Fidelity; Replication of single stranded circular DNA; link with cell cycle; DNA damaging agents: Physical, chemical and biological mutagens; types of damage caused by endogenous and exogenous agents; Mutations: nonsense, missense, silent and point mutations, frameshift mutations; Intragenic and Intergenic suppression. DNA repair mechanisms: direct reversal,

	photoreactivation, base excision repair, nucleotide excision repair, mismatch repair, double strand break repair, SOS repair; Recombination: Chi sequences in prokaryotes; Homologous, non-homologous and site specific recombination.
Unit-III **RNA Transcription, RNA Processing and Regulation in Prokaryotes** **6 Lectures (12 hours)**	Structure and function of prokaryotic mRNA, tRNA (including initiator tRNA) and rRNA (and ribosomes); Prokaryotic Transcription: RNA polymerase and sigma factors, Transcription unit, Promoters, Promoter recognition, Initiation, Elongation and Termination (intrinsic, Rho and Mfd dependent); Processing of mRNA, rRNA and tRNA transcripts; Gene regulation: Repressors, activators, positive and negative regulation, Constitutive and Inducible, small molecule regulators, operon concept: lac, trp, his operons, attenuation, anti-termination, stringent control, translational control, DNA re-arrangement, two component system; regulatory RNA: riboswitch, tmRNA, antisense RNA; transcriptional control in lambda phage.
Unit-IV **RNA Transcription, RNA Processing and Regulation in Eukaryotes** **6 Lectures (12 hours)**	Structure and function of eukaryotic mRNA, tRNA (including initiator tRNA) and rRNA (and ribosomes). Eukaryotic transcription: RNA polymerase I, II and III mediated transcription: RNA polymerase enzymes, eukaryotic promoters and enhancers, General Transcription factors; TATA binding proteins (TBP) and TBP associated factors (TAF); assembly of pre-initiation complex for nuclear enzymes, interaction of transcription factors with the basal transcription machinery and with other regulatory proteins, mediator, TAFs; Processing of hnRNA, tRNA, rRNA; 5'-Cap formation; 3'-end processing of RNAs and polyadenylation; loop model of translation; Splicing of tRNA and hnRNA; snRNPs and snoRNPs in RNA processing; Regulation of RNA processing: capping, splicing, polyadenylation; mRNA stability and degradation: degradation and surveillance pathways; RNA editing; Nuclear export of mRNA; Catalytic RNA: Group I and Group II introns splicing, Peptidyl transferase; Regulatory RNA and RNA interference mechanisms, miRNA, non-coding RNA; Silencers and insulators, enhancers, mechanism of silencing and activation; Families of DNA binding transcription factors: Helix-turn-helix, helix-loop-helix, homeodomain; C2H2 zinc finger, multi cysteine zinc finger, basic DNA binding domains (leucine zipper, helix-loop-helix), nuclear receptors; Interaction of regulatory transcription factors with DNA: properties and mechanism of activation and repression including Ligand-mediated transcription regulation by nuclear receptors; Nuclear

receptor; histone modifications and chromatin remodeling.

Unit-V **Protein Translation, Post-translational Modifications and Control in Prokaryotes and Eukaryotes** **4 Lectures (8 hours)**	Ribosomes; Composition and assembly; universal genetic code; Genetic code in mitochondria; Degeneracy of codons; Termination codons; Wobble hypothesis; Isoaccepting tRNA; Translational machinery; Mechanism of Translation in prokaryotes and eukaryotes; Co- and Post-translational modifications of proteins; Translational control; Protein stability; Protein turnover and degradation.

Recommended Textbooks:

1. Watson, J. D. (2008). *Molecular Biology of the Gene* (5th ed.). Menlo Park, CA: Benjamin/Cummings.
2. Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2008). *Molecular Biology of the Cell* (5th Ed.). New York: Garland Science.
3. Lodish, H. F. (2016). *Molecular Cell Biology* (8th Ed.). New York: W.H. Freeman.

ABT102: Genetics, Cytogenetics and Epigenetics — 3 Credits Theory

Course Objectives: The objectives of this course are to take the students through the basics of genetics and classical genetics encompassing prokaryotic/phage genetics to yeast and higher eukaryotic domains and will cover all classical concepts of Mendelian genetics. It will also cover epigenetic phenomena: heritable alternate states of gene activity that do not result from an alteration in nucleotide composition (mutations).

Student Learning Outcomes: On completion of this course, students should be able to:

- Describe the fundamental molecular principles of genetics;
- Understand the relationship between phenotype and genotype in plants;
- Describe the basics of genetic mapping;
- Understand the ploidy change and its role in crop plant evolution.
- Evaluate the genetic code and the role epigenetic modification plays in complex heritable traits.

Syllabus:

Unit-I **Mendelian Genetics** **3 Lectures (6 hours)**	History of Genetics (Pre and post Mendelian era), Mendelism, Monohybrid & dihybrid crosses, back-crosses, test-crosses, Law of Segregation in plant crosses, Multiple alleles, Epistasis, Heterosis, Heritability and genetic advance, genotype-environment interaction, types of gene actions.
Unit-II **Drosophila Genetics** **3 Lectures (6 hours)**	Chromosomal theory of inheritance; analyses of autosomal and sex linkages, Linkage Detection, Linkage estimation by various methods, recombination and genetic mapping; mutation mapping based on phenotypes, hypomorphy, genetic mosaics; Testing gene mutations for allelism: complementation test, intragenic complementation, pleiotropy; Sex determination.
Unit-III **Genetics of Bacteria and Bacteriophages** **3 Lectures (6 hours)**	Concept of a gene in pre-DNA era; mapping of genes in bacterial and phage chromosomes by classical genetic crosses; fine structure analysis of a gene; genetic complementation and other genetic crosses using phenotypic markers; phenotype to genotype connectivity prior to DNA-based understanding of gene.
Unit-IV **Yeast Genetics** **2 Lectures (4 hours)**	Meiotic crosses, tetrad analyses, non-Mendelian and Mendelian ratios, gene conversion, models of genetic recombination, yeast mating type switch; dominant and recessive genes/mutations, suppressor or modifier screens, complementation groups, synthetic lethality, genetic epistasis.
Unit-V **Quantitative Genetics** **2 Lectures (4 hours)**	Continuous variation, Complex traits, mapping QTLs, yeast genomics to understand biology of QTLs.
Unit-VI **Population Genetics and Evolution** **2 Lectures (4 hours)**	Introduction to the elements of population genetics: genetic variation, genetic drift, neutral evolution; mutation selection, balancing selection, Fishers theorem, Hardy-Weinberg equilibrium, linkage disequilibrium; in-breeding depression & mating systems; population bottlenecks, migrations.
Unit-VII **Human Genetics** **3 Lectures (6 hours)**	History of human genetics; Pedigrees: gathering family history, pedigree symbols, construction of pedigrees, presentation of molecular genetic data in pedigrees, Monogenic traits; Autosomal inheritance: dominant, recessive Sex-linked inheritance, Sex-limited and sex-influenced traits,

	Mitochondrial inheritance, OMIM number, Complications to the basic pedigree patterns: nonpenetrance, variable, expressivity, pleiotropy, late onset, dominance problems, anticipation, genetic heterogeneity, genomic imprinting and uniparental disomy, male lethality, X-inactivation.
Unit-VIII **Cytogenetics** **4 Lectures (8 hours)**	Structural and Numerical variations of chromosomes and their implications; Deletion, Duplication, Inversion and Translocation, heterozygote; Symbols and terminologies for chromosome numbers: euploidy- haploids, diploids and polyploids; Polyploidy: Classification, cytological and genetic method of identification of autopolyploids and allopolyploids; Polyploidy and role of polyploids in crop breeding; Interspecific hybridization and allopolyploids; Synthesis of new crops (wheat, triticale and brassica); Chromosome manipulations in wide hybridization; Classification, method of production, identification and meiotic behaviour of aneuploids (Monosomics, Nullisomics and trisomics).
Unit-IX **Epigenetics** **5 Lectures (10 hours)**	Chromatin architecture; modifying chromatin structure, architectural proteins, DNA methylation, post-translational histone, histone modification machinery, histone variants, DNA methylation/imprinting, RNA-directed DNA methylation, RNA-based silencing, polycomb repression, epigenetic inheritance, preservation of epigenetic marks during DNA replication, reprogramming DNA methylation, chromatin states, stem cells and pluripotency, genomic imprinting in mammals, dosage compensation, epigenetic regulation and disease, drugs used in diseases (HDAC inhibitors).

Recommended Textbooks:

1. Gardner *et. al* (1991). *Principles of Genetics*. John Wiley.
2. Snustad *et. al* (1998). *Principles of Genetics*. Wiley and sons.
3. Strickberger (1985). *Genetics*. McMillan.
4. Pierce, B. A. (2005). *Genetics: A Conceptual Approach*. New York: W.H. Freeman.

ABT103: Molecular Cell and Plant Developmental Biology 3 Credits Theory

Course Objectives: The cells are "the fundamental building blocks of all organisms". Therefore, a comprehensive understanding of the cell and cellular function is essential for all biologists. The objectives of this course are to sensitize the students to the fact that as we go down the scale of magnitude from cells to organelles, the understanding of various biological processes becomes deeper and inclusive. Subsequently, it is equally important to understand how a single cell, develop into an embryo, grow into plants with special emphasis in plant tissue development.

Student Learning Outcomes: On completion of this course, students should be able to:

- Understand major ideas in cell biology and plant developmental biology;
- Familiarize with experimental approaches, and how they are applied to specific problems in cell and plant developmental biology;
- Carry out and interpret experiments in cell and plant developmental biology.

Syllabus:

Unit-I **Cell Ultrastructure** **1 Lecture (2 hours)**	Cell theory; diversity of cell size and shape; Prokaryotic and Eukaryotic cell ultrastructure; Similarities and differences; cell wall composition.
Unit-II **Structure and Function of Biological Membranes** **6 Lectures (12 hours)**	Membrane structure and function: Structural models; Composition and dynamics; Transport of ions and macromolecules; Pumps, carriers and channels; Endo and Exocytosis; Cellular junctions and adhesions; Membrane carbohydrates and their significance in cellular recognition; Structure and functional significance of plasmodesmata; Mechanism of cellular recognition and communication.
Unit-III **Cell Organelles** **5 Lectures (10 hours)**	Nucleus: structure and function of nuclear envelope, lamina and nucleolus; Nuclear matrix in chromosome organization and function; Macromolecular trafficking; Mitochondria: structure, origin and evolution, organization of respiratory chain complexes, Structure-function relationship; structure and function of peroxisome; mitochondrial genome; Chloroplast: chloroplast biogenesis; structure-function relationship; chloroplast genome; origin and evolution.
Unit-IV **Endo-membrane System, Cytoskeleton, Motility and Cellular Signalling**	Structure and function of microbodies, Golgi apparatus, lysosomes and endoplasmic reticulum; Protein processing, sorting; vesicle transport, secretion; Overview of cellular cytoskeleton, Organization and role of microtubules and microfilaments; Intermediate filaments; Muscle

6 Lectures (12 hours)	organization and function; Cellular motility; Molecular motors; Extracellular matrix in plants and animals; Signal transduction: Intracellular receptor and cell surface receptors; Signalling via G-protein linked receptors (PKA, PKC, CaM kinase); Overview of various cellular signalling cascades with examples such as EGFR, Notch, Wingless, JAK-STAT etc.
Unit-V **Cell Division** **3 Lectures (6 hours)**	Cell division: mitosis, and meiosis; Cell cycle and its regulation: Molecular events at G1, S, G2 and M phase, Cytokinesis; Extracellular and Intracellular control of cell division; Types and regulation of cyclins; sister chromatid cohesion, differential regulation of cohesion complex during mitosis and meiosis; abnormal cell division; Cancer and role of oncogenes and tumour suppressor genes in cancer development; Programmed cell death (Apoptosis).
Unit-VI **Cell Differentiation & Plant Tissue Development** **4 Lectures (8 hours)**	Cellular differentiation; Cellular movements and Pattern Formation: Model plants like *Fucus* and *Volvox*; Embryogenesis and early pattern formation in plants; Plant Meristem Organization and Differentiation: Organization of Shoot Apical Maristem (SAM); Organization of Root Apical Meristem (RAM); ABC model of Flower Development; Embryo and endosperm development.
Unit-VII **Chromosome Structure** **2 Lectures (4 hours)**	Organization of bacterial genome; Chromatin structure: Histones, DNA, nucleosome and higher level organization, functional state of chromatin; Heterochromatin and Euchromatin; Position Effect Variegation (PEV); Chromosome organization: Metaphase chromosome, centromere, kinetochore, telomere and its maintenance; Chromosome banding and karyotyping.

Recommended Textbooks:

1. Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2008). *Molecular Biology of the Cell* (5th Ed.). New York: Garland Science.
2. Lodish, H. F. (2016). *Molecular Cell Biology* (8th Ed.). New York: W.H. Freeman.
3. Alberts, B., Bray, D., Hopkin, K., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. Essentials in Cell Biology (4th Ed.). New York: Garland Science.
4. Cooper, G. M., & Hausman, R. E. (2009). *The Cell: a Molecular Approach*. Washington: ASM ; Sunderland.

CBT102: Biophysical Principles and Analytical Techniques 3 Credits Theory

Course Objectives: The course is designed to provide a broad exposure to all basic techniques (Biochemical & Biophysical) used in current Modern Biology research. The goal is to impart basic conceptual understanding of principles of these techniques and emphasize on Biochemical utility of same & underlying Biophysics. At the end of the course, student is expected to have enough understanding of all the analytical techniques such that the barrier to implement the same is abated to a great extent.

Student Learning Outcomes: On completion of this course, students should be able to:

- Understand the principles and basic theory behind several popular Biophysical techniques;
- Learn how to combine previously acquired knowledge of physical chemistry and biochemistry in order to understand biochemical processes at molecular level;
- Apply these techniques successfully in practical situations.

Syllabus:

Unit-I **Basics** **2 Lectures (4 hours)**	Units of measurement of solutes in solution; Normality, molality, molarity, millimol and ppm; Length scales in biological systems: proteins, multiprotein complexes, organelles & cells; Basic thermodynamics; Basic chemical kinetics & reaction rates: Theory of chemical reactions.
Unit-II **Electromagnetic Radiation & Spectroscopic Techniques** **4 Lectures (8 hours)**	Energy, wavelength, wave number and frequency; Absorption and emission spectra, Beer-Lambert's law, light absorption and its transmittance; UV and visible spectrophotometry-principles, instrumentation and applications on enzyme assay and kinetic assays, protein structural studies, nucleic acid structural studies; Basic principles, instrumentation and applications of UV-visible, IR, fluorimetry, atomic absorption and emission spectrophotometry; Basic principles, instrumentation and applications of ESR, NMR; Biochemical applications of fluorescence, emission, Fluorescence life-times, Anisotropy, time-resolved fluorescence methods and their applications, IR-Raman Spectroscopic applications in biology.
Unit-III **Radioactivity & Radioisotopic**	Radioactivity, stable and radioactive isotopes, concepts of half-life and decay, principles of scintillation counting, GM counters, applications of isotopes, Isotope dilution

Techniques **4 Lectures (8 hours)**	technique, autoradiography, turnover studies, precursor-product relationship, production of radio-labelled biomolecules, calculations involving isotopes, radiation hazards and methods for contaminant prevention; Nature of radioactivity, properties of α, β and γ-rays, measurement of radioactivity, use of radioisotopes in research, *In vivo* and *in vitro* labelling techniques, double labelling, quenching, internal standard, channel ratio, external standard ratio, emulsion counting, radioactive decay; Application of radioactive isotopes in biochemical reaction mechanisms.
Unit-IV **Electrophoresis** **2 Lectures (4 hours)**	Principles of electrophoretic separation, zonal and continuous electrophoresis, paper, cellulose acetate/nitrate, gel and capillary electrophoresis, use of native and denaturating gels, Protein subunit molecular weight determination using SDS-PAGE, Anomalous protein migration of some proteins in SDS-PAGE, Acid-urea PAGE and their physical basis, Isoelectric focussing and two dimensional gel electrophoresis, electroporation, pulse field gel electrophoresis, gradient gels.
Unit-V **Hydrodynamic Methods** **2 Lectures (4 hours)**	Basic principles and types of centrifugation-rotors, boundary, differential, density gradient, zonal isopycnic centrifugation, equilibrium; Sedimentation–sedimentation velocity, preparative and analytical ultracentrifugation techniques: principles & applications in biochemical fractionation methods.
Unit-VI **Chromatography and X-ray Crystallography** **3 Lectures (6 hours)**	Chromatography, principles of adsorption, partition and ion-exchange chromatography, gel permeation chromatography, GC, GC-MS and HPLC; X-ray Crystallography: protein crystals, Bragg's law, unit cell, isomorphous replacement, fiber pattern of DNA; Small-angle X-ray diffraction methods: Principles & applications; Basic protein structure prediction methods.
Unit-VII **Optical Tweezers** **3 Lectures (6 hours)**	Principles & applications; single-molecule measurements, Atomic Force microscopy, Near-field Microscopy: Principles & applications. Force measurements at single molecule to cell level using optical tweezers, mechanobiology.
Unit-VIII **Optical Microscopy Methods**	Light Microscopy: lenses and microscopes, resolution: Rayleigh's Approach, Dark field; Phase Contrast; Differential Interference Contrast; fluorescence and fluorescence microscopy; Confocal microscope: confocal

4 Lectures (8 hours)	principle, resolution and point spread function; nonlinear microscopy: multiphoton microscopy; principles of two-photon fluorescence, advantages of two-photon excitation, tandem scanning (spinning disk) microscopes, deconvolving confocal images; image processing, three-dimensional reconstruction; Total Internal reflection microscopy, STED microscopy.
Unit-IX **Mass Spectroscopy** **3 Lectures (6 hours)**	Ionization techniques; mass analyzers/overview MS; FT-ICR and Orbitrap, fragmentation of peptides; proteomics, nano LC-MS; Phospho proteomics; interaction proteomics, mass spectroscopy in structural biology; imaging mass spectrometry.

Recommended Textbooks:

1. Atkins, de Paula. (2011) *Physical Chemistry for the Life Sciences* (2nd Edition). W.H. Freeman.
2. C. R. Cantor and P. R. Schimmel, *Biophysical Chemistry* (Part 1-3), 2nd Edn.
3. Branden C and Tooze J, *Introduction to Protein Structure*, Garland Science.
4. K. E. van Holde, C. Johnson, P. S. Ho (2005) *Principles of Physical Biochemistry*, 2nd Edn., Prentice Hall.
5. Tinoco, Sauer, Wang, and Puglisi. (2013) *Physical Chemistry: Principles and Applications in the Biological Sciences*. Prentice Hall, Inc.

ARD106: Spiritual and Cultural Heritage of India-I — 2 Credits Theory

Course Objectives: This course is designed to familiarize the student with Swami Vivekananda's comprehensive philosophy of education and its scope in its individual and social dimensions. The student will be exposed to the high ideals of education through selected hymns and be guided to understand and approach their role as a student with the right attitude. The student would be given a clear picture of the challenges faced by the society and the effective method for addressing them. The course would cover in detail the idea of education in all its aspects– the effective method for acquiring and transferring knowledge, the way to apply education to solve the problems of the individual, and the role of education in addressing the short-term and long-term needs of the society.

Student Learning Outcomes:

On completion of this course, students should be able to:

- Embrace their role as a student and an individual-in-the-making holding immense promise to the society;
- Understand the problems faced by the society/nation and the effective approach for solving them;
- Develop a comprehensive idea of education in all its aspects in light of Swami Vivekananda's teachings;
- Understand how to apply education to solve the challenges faced in life;
- Develop an understanding of the effective method of acquiring and transferring knowledge.

Syllabus:

Unit-I

Introduction

1 Lecture (2 hours)

Shanti Mantras and Selected Vedic Hymns: Shraddha Suktam, Sangha Mantra etc.

Unit-II

Message to Youth by Swami Vivekananda

5 Lectures (10 hours)

It is youth who will transform this nation; take up an ideal and give your whole life to it; stand your own feet; awaken the spirit of 'Rajas' within you; believe in yourself; be bold and fearless; expand your heart; be open to learning from anyone; develop a gigantic will.

Unit-III

Message to Reformers by Swami Vivekananda

6 Lectures (12 hours)

Liberty is the first condition for growth, affirm; do not condemn; don't lead but serve; act with unselfish motives; create 'sanction' from the people; the Indian Nation will rise only when the self-esteem of the masses is raised; real social reform will happen when the people learn to help themselves.

Unit-IV

Message to Educationists by Swami Vivekananda

6 Lectures (12 hours)

Manifestation of infinite knowledge within; man-making education; strengthen faith and pride in ourselves as a nation; focus on character-building assimilation of ideas, enable the student to learn; enable individuals to find solutions to the challenges of life; give ideas and culture; develop the power of concentration; condition necessary for the teacher, the teaching and for effective transfer of learning.

Recommended Textbooks:

1. Swami Tejasananda. (1995). *A Short Life of Swami Vivekananda*. Advaita Ashrama.
2. Swami Vivekananda. (2008). *My Idea of Education*. Advaita Ashrama.
3. Swami Vivekananda. (1918). *Lectures from Colombo to Almora*. Advaita Ashrama.

ABT104: Laboratory-I General Biochemistry 3 Credits Practical

Course Objectives: The objective of this laboratory course is to introduce students to experiments in biochemistry more specifically in relation to plant sciences. The course is designed to teach utility of experimental methods in biochemistry in a problem oriented manner.

Student Learning Outcomes: On completion of this course, students should be able to:

- Elaborate concepts of biochemistry with easy to run experiments;
- Familiarize with basic laboratory instruments and understand principle of measurements using those instruments with experiments in biochemistry.

Syllabus

1. Preparing various stock solutions and working solutions that will be needed for the course.
2. To prepare an Acetic-Na Acetate Buffer and validate the Henderson-Hasselbach equation.
3. To determine an unknown protein concentration by plotting a standard graph of BSA using UV-Vis Spectrophotometer and validating the Beer-Lambert's Law.
4. Estimation of

a) Reducing sugar content of given plant sample.

b) Non-reducing sugar content of given plant sample.

c) Oil content of seeds.

5. Purification and characterization of an enzyme from a recombinant source.

a) Preparation of cell-free lysates

b) Ammonium Sulfate precipitation

c) Ion-exchange Chromatography

d) Gel Filtration

e) Affinity Chromatography

f) Dialysis of the purified protein solution against 60% glycerol as a demonstration of storage method

g) Generating a Purification Table (protein concentration, amount of total protein; Computing specific activity of the enzyme preparation at each stage of purification)

h) Assessing purity of samples from each step of purification by SDS-PAGE Gel Electrophoresis

i) Enzyme Kinetic Parameters: Km, Vmax and Kcat.

ABT105: Laboratory-II Techniques in Cell Biology 3 Credits Practical

Course Objectives: The major objective of this course is to understand of fundamental cell biological research in relation to plant cells and tissues.

Student Learning Outcomes: On completion of this course, students should be able to:

- Acquire basic concepts of structure and functionality of the plant cell along with basics of microscopy.

Syllabus

1. Principles of microscopy and optics; Observation of suitable specimen under bright field, phase contrast, dark field and DIC microscope.
2. Observation of plant cell cultures under microscope. Measurement of cell size by oculometer and stage micrometer.
3. Observation of Mitosis, and the Cell Cycle in Onion root-tip cells.
4. Histology: Hand-sectioning of stem and leaf.
5. Microtomy: Fixation of tissues, dehydration, wax-embedding, sectioning and staining.
6. Isolation of lysosomes, nuclei and ER membranes from plant samples by isotonic sucrose method.
7. Isolation of mitochondria from plant tissue samples.
8. Lecture demonstration of live cell image and dynamics of cellular organelles in relation to a function by using web-tutorials and online movies.

Semester-II [Total: 15 (T) + 8 (P) = 23 Credits]

CBT201: Genetic Engineering — 3 Credits Theory

Course Objectives: The objectives of this course are to teach various approaches to genetic engineering that students can apply in their future career in biological research as well as in biotechnology industry. Genetic engineering is a technology that has been developed based on our fundamental understanding of the principles of molecular biology and this is reflected in the contents of this course. This technology has revolutionized the way modern biological research is done and has impacted mankind with a number of biological products and processes.

Student Learning Outcomes: On completion of this course, students should be able to:

- Endow themselves with strong theoretical knowledge of this technology;
- Gain working knowledge of gene silencing and editing tools and methods and appreciate their relevance for investigating specific contemporary biological questions;
- Take up biological research as well as find placement in the relevant biotech industry.

Syllabus:

Unit-I

Introduction and Tools for Genetic Engineering

5 Lectures (10 hours)

Impact of genetic engineering in modern society; general requirements for performing a genetic engineering experiment; restriction endonucleases and methylases; DNA ligase, Klenow enzyme, T4 DNA polymerase, polynucleotide kinase, alkaline phosphatase; cohesive and blunt end ligation; linkers; adaptors; homopolymeric tailing; labeling of DNA: nick translation, random priming, radioactive and non-radioactive probes, hybridization techniques: northern, southern, south-western and far-western and colony hybridization, fluorescence in situ hybridization.

Unit-II

Different Types of Vectors

5 Lectures (10 hours)

Plasmids; Bacteriophages; M13mp vectors; pUC19 and Bluescript vectors, phagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Principles for maximizing gene expression expression vectors; pMal; GST; pET-based vectors; Protein purification; His-tag; GST-tag; MBP-tag etc.; Intein-based vectors; Inclusion bodies; methodologies to reduce formation of inclusion bodies; mammalian expression and replicating vectors; Baculovirus and Pichia

	vectors system, plant based vectors, Ti and Ri as vectors, yeast vectors, shuttle vectors.
Unit-III **Different Types of PCR Techniques** **5 Lectures (10 hours)**	Principles of PCR: primer design; fidelity of thermostable enzymes; DNA polymerases; types of PCR: multiplex, nested; reverse-transcription PCR, real time PCR, touchdown PCR, hot start PCR, colony PCR, asymmetric PCR, cloning of PCR products; T-vectors; proof reading enzymes; PCR based site specific mutagenesis; PCR in molecular diagnostics; viral and bacterial detection; sequencing methods; enzymatic DNA sequencing; chemical sequencing of DNA; automated DNA sequencing; RNA sequencing; chemical synthesis of oligonucleotides; mutation detection: SSCP, DGGE, RFLP.
Unit-IV **Gene Manipulation and Protein-DNA Interaction** **6 Lectures (12 hours)**	Insertion of foreign DNA into host cells; transformation, electroporation, transfection; construction of libraries; isolation of mRNA and total RNA; reverse transcriptase and cDNA synthesis; cDNA and genomic libraries; construction of microarrays: genomic arrays, cDNA arrays and oligo arrays; study of protein-DNA interactions: electrophoretic mobility shift assay; DNase I footprinting; methyl interference assay, chromatin immunoprecipitation; protein-protein interactions using yeast two-hybrid system; phage display.
Unit-V **Gene Silencing and Genome Editing Technologies** **6 Lectures (12 hours)**	Gene silencing techniques; introduction to siRNA; siRNA technology; Micro RNA; construction of siRNA vectors; principle and application of gene silencing; gene knockouts and gene therapy; creation of transgenic plants; debate over GM crops; introduction to methods of genetic manipulation in different model systems *e.g.* fruit flies (*Drosophila*), worms (*C. elegans*), frogs (*Xenopus*), fish (zebra fish) and chick; Transgenics: gene replacement; gene targeting; creation of transgenic and knock-out mice; disease model; introduction to genome editing by CRISPR-CAS.

Recommended Textbooks:

1. Brown, TA. (2006). *Genomes* (3rd ed.). New York: Garland Science Pub.
2. Old, R.W.; Primrose, S.B.; & Twyman, R.M.; (2001). *Principles of Gene Manipulation: An Introduction to Genetic Engineering*. Oxford: Blackwell Scientific Publications.
3. Green, MR., & Sambrook, J. (2012). Molecular Cloning: a Laboratory Manual. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.

CBT202: OMICS: Genomics, Transcriptomics, Proteomics and Metabolomics
3 Credits Theory

Course Objectives: The objective of this course is to give an introduction to Genomics and other global OMICS technologies, the theory and practical aspects of these technologies and the applications of these technologies in biology. The student should be able to gain working knowledge of these technologies and appreciate their ability to impart a global understanding of biological systems and processes in health and disease.

Student Learning Outcomes: On completion of this course, students should be able to:

- Gain overview of genome variation in the population including technologies to detect these variations;
- Understand how High-throughput DNA sequencing (HTS) can be used to identify genetic variants;
- Understand how HTS technologies can be used to explore changes in gene expression;
- Endow with application of various OMICS technologies.

Syllabus:

Unit-I

Introduction to Genomics

5 Lectures (10 hours)

Structure and organization of prokaryotic and eukaryotic genomes: nuclear, mitochondrial and chloroplast genomes; Computational analysis, Databases, Finding genes and regulatory regions; Tools for genome analysis: PCR, RFLP, DNA fingerprinting, RAPD, SNP detection, SSCP, FISH to identify chromosome landmarks; Human Genome Project-landmarks on chromosomes generated by various mapping methods, BAC libraries and shotgun libraries preparation, Physical map, Cytogenetic map, Contig map, Restriction map, UCSC browser.

Unit-II

Microarray Technology

3 Lectures (6 hours)

Introduction, Basic principles and design, cDNA and oligonucleotide arrays, DNA microarray, Instrumentation and structure; Designing a microarray experiment: The basic steps, Types of microarray: expression arrays, protein arrays, Comparative Genomic Hybridization (CGH) arrays, Resequencing arrays; Different platforms (Affymetrix, Agilent *etc.*); Applications of Microarray technology; case studies.

Unit-III

Sequencing Technologies

Introduction to sequencing, Maxam and Gilbert method, Sanger Sequencing techniques and applications; Next Generation sequencing (NGS), Introduction to NGS,

6 Lectures (12 hours)	Experimental protocol (Isolation of DNA/RNA), quality check, Library Preparations, Sequencing reaction; Platform overview and comparison: Illumina, 454 (Roche), SOLiD (Life technology), Specific Biosciences, Ion Torrent, Nanopore, PacBio; Types of NGS, DNA-sequencing: Whole genome sequencing, exome sequencing, Deep sequencing, ChIP sequencing, RNA-sequencing and the types (small RNA sequencing, non-coding RNA sequencing), Whole transcriptome sequencing; Data Processing and Analysis: Data Quality Check, filtering and Genome assembly and mapping to reference genomes, mapping tools (bowtie, maqetc), Sequence Alignment formats: Sequence Alignment/Map (SAM) format, Binary Alignment/Map (BAM) format, Functional Analysis: Pathway analysis, Gene Ontology analysis; Application of different sequencing technique, methylomics, *in vivo* protein binding, genome wide association studies (GWAS), Histone modification, microbial sequencing, Comparison of Microarray technology and High throughput sequencing technology.
Unit-IV **Proteomics** **6 Lectures (12 hours)**	Overview of protein structure-primary, secondary, tertiary and quarternary structure, Relationship between protein structure and function; Outline of a typical proteomics experiment, Identification and analysis of proteins by 2D analysis, Spot visualization and picking; Tryptic digestion of protein and peptide fingerprinting, Mass spectrometry: ion source (MALDI, spray sources), analyzer (ToF, quadrupole, quadruple ion trap) and detector; Post translational Modifications: Quantitative proteomics, clinical proteomics and disease biomarkers, mass spectral tissue imaging and profiling; Protein-protein interactions: Surfaceomes and Secretomes, Solid phase ELISA, pull-down assays (using GST-tagged protein) tandem affinity purification, far western analysis, by surface plasmon resonance technique; Yeast two hybrid system, Phage display, Protein interaction maps, Protein arrays-definition; Applications: diagnostics, expression profiling.
Unit-V **Pharmacogenomics** **3 Lectures (6 hours)**	Pharmacogenomics; Pharmacogenetics; Benefits; Practical applications of pharmacogenomics; The Promise of Pharmacogenomics today leading to personalized medicines; Human genetic variation: examples of CYP gene variations leading to variable metabolism of drugs.
Unit-VI **Metabolomics** **4 Lectures (8 hours)**	Introduction and overview of metabolites, sample collection and processing, Non tracer and tracer (radio labelled)-based techniques in metabolomics (HPLC, NMR, LC-MS and GC-MS); Metabolome data processing derived by various techniques, analysis of databases (MetaboLight, Meta Cyc, MMCD *etc.*),

Analysis tools, Metabolic pathways and network analysis Metabolic flux analysis (TCA, Amino acids, fatty acids, intermediary metabolites), Stoichiometric metabolic flux analysis, 13C metabolic flux analysis (MFA), Metabolic control analysis (MCA); Applications of metabolomics; Integration of metabolomics data sets with other data (*eg.* Transcriptomics, enzyme activity, *etc.*).

Recommended Textbooks:

1. Brown, TA. (2006). *Genomes* (3rd ed.). New York: Garland Science Pub.
2. Old, R.W.; Primrose, S.B.; & Twyman, R.M.; (2001). *Principles of Gene Manipulation: An Introduction to Genetic Engineering*. Oxford: Blackwell Scientific Publications.
3. Campbell AM and Heyer LJ (2007) *Discovering Genomics, Proteomics and Bioinformatics*. Benjamin Cummings
4. Twyman RM. (2013) *Principles of Proteomics*. Second Edition by Garland Science Taylor & Francis Group New York and London.

ABT201: Basics of Microbiology and Plant Immunity — 3 Credits Theory

Course Objectives: The objectives of this course are to introduce field of microbiology with special emphasis on microbial diversity, morphology, physiology and nutrition; methods for control of microbes and host-microbe interactions. The objectives of this course are also to understand the modern concepts of molecular biology and biotechnology in relation to host-pest/pathogen interactions.

Student Learning Outcomes: On completion of this course, students should be able to:

- Identify major categories of microorganisms and analyze their classification, diversity, and ubiquity;
- Identify and demonstrate structural, physiological, genetic similarities and differences of major categories of microorganisms;
- Identify and demonstrate how to control microbial growth;
- Demonstrate and evaluate interactions between microbes, hosts and environment;
- Formulate scientific questions about how plants and pathogens interact to result in disease or resistance;

- Evaluate experimental approaches for how to distinguish cause from effect;
- Describe the current hypotheses on how plants and microbes interact.

Syllabus:

Unit-I **Microbial Characteristics** **4 Lectures (8 hours)**	Introduction to microbiology and microbes, history & scope of microbiology, morphology, structure, growth and nutrition of bacteria, bacterial growth curve, bacterial culture methods; bacterial genetics: mutation and recombination in bacteria, plasmids, transformation, transduction and conjugation; antimicrobial resistance; microbial communication system; bacterial quorum sensing.
Unit-II **Microbial Diversity** **4 Lectures (8 hours)**	Microbial taxonomy and evolution of diversity, classification of microorganisms, criteria for classification; classification of bacteria; Cyanobacteria, acetic acid bacteria, Pseudomonads, lactic and propionic acid bacteria, endospore forming bacteria, Mycobacteria and Mycoplasma. Archaea: Halophiles, Methanogens, Hyperthermophilic archae, Thermoplasm; eukarya: algae, fungi, slime molds and protozoa; extremophiles and unculturable microbes.
Unit-III **Microbial Growth, Kinetics and Physiology** **3 Lectures (6 hours)**	Microbial growth: Batch, fed-batch, continuous kinetics, synchronous growth, yield constants, methods of growth estimation, stringent response, death of a bacterial cell. Microbial physiology: Physiological adoption and life style of Prokaryotes.
Unit-IV **Control of Microorganisms** **2 Lectures (4 hours)**	Sterilization, disinfection and antisepsis: physical and chemical methods for control of microorganisms, antibiotics, antiviral and antifungal drugs, biological control of microorganisms.
Unit-V **Virology** **2 Lectures (4 hours)**	Virus and bacteriophages, general properties of viruses, viral structure, taxonomy of virus, viral replication; cultivation and identification of viruses; sub-viral particles: viroids and prions.
Unit-VII **Molecular Basis of Host**	Introduction to molecular-plant microbe interaction. Molecular basis of host-pathogen interactions: pathogen virulence, aggressiveness, regulation of infection processes-

Plant Resistance **4 Lectures (8 hours)**	cAMP signaling and MAP kinase pathways; genetics of virulence; pathogenicity genes in plant pathogens; toxins: mode of action, role of toxins in disease development, cell wall-and cutin-degrading enzymes, hormones, extracellular polysaccharides; variability in plant pathogens, mechanisms of variability, physiological races of pathogens.
Unit-VIII **Host Plant Resistance and Signal Transduction** **5 Lectures (10 hours)**	Host plant resistance: vertical and horizontal resistance, non-host resistance: recognition system, elicitors: endogenous and exogenous elicitors, general and race-specific elicitors, receptor sites for elicitor, chemical nature of elicitors, suppressors, signal transduction: intracellular signal transduction, second messenger systems, calcium ion, protein kinases, phospholipases, proton pump, ATPases, G-proteins, H_2O_2, ethylene; systemic signal transduction: oligogalacturonides-salicylic acid, jasmonic acid-ethylene-abscissic acid-signal cross-talk, systemic acquired resistance, signal molecules, quorum sensing.
Unit-IX **Genetics of Disease Resistance** **3 Lectures (6 hours)**	Gene-for-gene theory, avirulence (avr) genes, characteristics of avr gene-coded proteins, hrp genes, protein-for-protein, Resistance (R) genes of plants, R-gene expression and transcription profiling, mapping and cloning of resistance genes, structure and classes of resistance genes, genomic organization of resistance genes.

Recommended Textbooks:

1. Pelczar, M. J., Reid, R. D., & Chan, E. C. (2001). *Microbiology* (5th ed.). New York: McGraw-Hill.
2. Willey, J. M., Sherwood, L., Woolverton, C. J., Prescott, L. M., & Willey, J. M. (2011). *Prescott's Microbiology*. New York: McGraw-Hill.
3. Matthai, W., Berg, C. Y., & Black, J. G. (2005). *Microbiology, Principles and Explorations*. Boston, MA: John Wiley & Sons.
4. Singh RS. (2013). *Introduction to Principles of Plant Pathology.* Oxford and IBH Pub. Co.

CBT203: Introduction to Bioinformatics 2 Credits Theory & 1 Credit Practical

Course Objectives: This course covers all basic details of Bioinformatics starting from sequence comparison tools to genome annotation to protein structure prediction methods. The course also touches upon *in-silico* methods of biological networks to artificial intelligence designs. Therefore, the course gives a comprehensive understanding of the entire gamut of bioinformatics and computational analyses. The instructor is expected to cover only the basic details of these topics.

Student Learning Outcomes: On completion of this course, students should be able to:

- Develop an understanding of the basic theory of computational tools;
- Gain working knowledge of computational tools and methods;
- Appreciate their relevance for investigating specific contemporary biological questions;
- Critically analyse and interpret the results of their study.

Syllabus:

Unit-I **Basics** **4 Lectures (8 hours)**	Scope and importance of bioinformatics in biology and medicine; Introduction to Unix and Linux systems and basic commands; Database concepts; Protein and nucleic acid databases; Structural databases; Biological XML DTD's; pattern matching algorithm basics; databases and search tools: biological background for sequence analysis; NCBI; publicly available tools; resources at EBI; resources on web; database mining tools.
Unit-II **DNA Sequence Analysis** **4 Lectures (8 hours)**	DNA sequence analysis: gene bank sequence database; submitting DNA sequences to databases and database searching; sequence alignment; pairwise alignment techniques; BLAST: BLASTp, BLASTn, tBLASTn, BLASTx, tBLASTx, PHI-BLAST, and PSI-BLAST; motif discovery and gene prediction; assembly of data from genome sequencing; Comparative genomics; Gene prediction: Extrinsic and intrinsic methods, applications and limitations.
Unit-III **DNA Sequence Alignment** **3 Lectures (6 hours)**	Multiple sequence analysis; multiple sequence alignment; flexible sequence similarity searching with the FASTA3 program package; use of CLUSTALW and CLUSTALX for multiple sequence alignment; submitting protein sequence to databases: where and how to submit, SEQUIN; methods of phylogenetic analysis.
Unit-IV **Protein Structure Database**	PDB: Introduction, Database searching, PDB file retrieval, mmCIF file retrieval and links; MMDB: Introduction Structure file formats; Protein structure prediction: protein

4 Lectures (8 hours)	folding and model generation; secondary structure prediction; analyzing secondary structures; Protein function prediction: sequence and domain based.
Unit-V **Drug Discovery** **3 Lectures (6 hours)**	Structure based Drug design: Rationale for computer aided drug designing, deriving 3D pharmacophore and its application; Drug design: types- structure based, Virtual screening: ligand based, optimization methods.

Practical:

Syllabus	**1.** Introduction to Major Databases: a) Nucleic Acid Sequence Database: DDBJ, GenBank and NCBI b) Protein Sequence Database: UNIPROT and NCBI c) Structure Database: PDB and MMDB **2.** Sequence Alignment: Use of FASTA format, BLAST tool for similarity searches **3.** Multiple Sequence Alignment: Clustal X, Clustal W, and EMBOSS **4.** Phylogenetic analysis of protein and nucleotide sequences. **5.** Gene Prediction: EMBOSS, GENESCAN and ORF finder **6.** Tools for Primer Designing: Primer3, and FastPCR **7.** Function Annotation: Prosite and PFAM **8.** Protein Modelling: SWISS Model **9.** Case studies: a) Saccharomyces Genome Database (Fungus) b) Rice Genome Database (Plant) c) Human Genome Database (Metazoa)

Recommended Textbooks:

1. Mount, D. W. (2001). *Bioinformatics: Sequence and Genome Analysis*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.
2. Lesk, A. M. (2002). *Introduction to Bioinformatics*. Oxford: Oxford University Press.
3. Campbell AM and Heyer LJ (2007) *Discovering Genomics, Proteomics and Bioinformatics*. Benjamin Cummings.

CBT204: Basics of Mathematics and Statistics

2 Credits Theory & 1 Credit Practical

Course Objectives: The objective of this course is to introduce the students to bio-statistical methods and to understand the underlying principles, as well as practical guidelines of "how to do it" and "how to interpret it" as the role they can play in decision making.

Student Learning Outcomes: On completion of this course, students should be able to:

- Understand how to summarise data;
- Apply appropriate statistical tests based on an understanding of the study question, type of study and type of data;
- Interpret the results of statistical tests and application in biological systems.

Syllabus:

Unit-I

Elementary Mathematics Set theory; Determinants, and Matrices.

2 Lectures (4 hours)

Unit-II

Introduction to Statistics

2 Lectures (4 hours)

Types of biological data (ordinal scale, nominal scale, continuous and discrete logical systems data), frequency distribution and graphical representations (bar graph, histogram, box plot and frequency polygon), cumulative frequency distribution, populations, samples, simple random, stratified and systematic sampling.

Unit-III

Descriptive Statistics

2 Lectures (4 hours)

Measures of Location, Properties of Arithmetic Mean, median, mode, range, Properties of the Variance and Standard Deviation, Coefficient of Variation, Skewness, Kurtosis; Grouped Data, Graphic Methods, Obtaining Descriptive Statistics on the Computer, Case study.

Unit-IV

Probability & Distribution

3 Lectures (6 hours)

Introduction to probability and laws of probability, Random Events, Events-exhaustive, Mutually exclusive and equally likely (with simple exercises), Definition and properties of binomial distribution, Poisson distribution and normal distribution.

Unit-V

Correlation & Regression

Correlation, Covariance, calculation of covariance and correlation, Correlation coefficient from ungrouped data Spearson's Rank Correlation Coefficient, scatter and dot

Analysis **2 Lectures (4 hours)**	diagram, General Concepts of regression, Fitting Regression Lines, regression coefficient, properties of Regression Coefficients, Standard error of estimate.
Unit-VI **Sampling Theory** **2 Lectures (4 hours)**	Sampling theory; probability sampling and non-probability sampling methods; sampling distributions; standard error and its uses.
Unit-VII **Statistical Hypothesis** **1 Lecture (2 hours)**	Making assumption, Null and alternate hypothesis, error in hypothesis testing, confidence interval, one-tailed and two-tailed testing, decision making.
Unit-VIII **Test of Significance** **4 Lectures (8 hours)**	Steps in testing statistical significance, selection and computation of test of significance and interpretation of results; Sampling distribution of mean and standard error, Large sample tests (test for an assumed mean and equality of two population means with known S.D.), z-test; Small sample tests (t-test for an assumed mean and equality of means of two populations when sample observations are independent); Parametric and Non parametric tests (Mann-Whitney test); paired and unpaired t-test, chi square test.

Practical:

Syllabus	1. Graphical presentation (Bar diagram, Histogram, Frequency Polygon, Ogive, Pie Chart etc.); Tabular presentation. 2. Mean, Median and Mode 3. Analysis of measures of Dispersion, Skewness and Kurtosis 4. Analysis of Correlation and Regression 5. Study on Z-test, t-test, F-test and chi-square test 6. Use of Computer in Research: Entry; Data Presentation and Analysis; Statistical Packages.

Recommended Textbooks:

1. Prem S. Mann, (2006), *Introductory Statistics*, 6th Edition, Wiley.

2. Wayne W. Daniel, (2004), *Biostatistics: A Foundation for Analysis in the Health Sciences*, (8th Edition), Wiley.

ARD207: Spiritual and Cultural Heritage of India-II 2 Credits Theory

Course Objectives: This course is designed to impart to the student a comprehensive understanding of various social challenges faced by modern India and its way forward in light of Swami Vivekananda's insightful study of these subjects. The course would familiarize the student with Swami Vivekananda's ideas on women empowerment combining ancient ideals of womanhood with scope for adapting to the needs of the modern society. The importance of improving the condition of the poorer classes, an essential feature of an enlightened society, will be discussed in detail. The greater role that an enlightened India would play in the modern world and the blueprint for its harmonious and beneficent relationship with the rest of the world will be discussed.

Student Learning Outcomes: On completion of this course, students should be able to:

- Chant selected Vedic hymns that bring the student in touch with the ideas of traditional Indian knowledge;
- Understand the traditional Indian ideal of womanhood and the way to bring back a respectable position for women in the society compatible with both the ancient ideals and the modern needs;
- Recognize the importance of serving equally the whole society, especially the lower classes, and feel inspired to dedicate their knowledge and skills to this cause;
- Understand the great future role that India has to play in the world and her relationship with other nations involving both teaching and learning, to the mutual benefit of both.

Syllabus:

Unit-I

Introduction

1 Lecture (2 hours)

Selected Vedic Hymns: Medha Suktam, Durga Suktam, Acharyopadesha etc.

Unit-II

Swami Vivekananda's Message on Women's Empowerment

5 Lectures (10 hours)

The ideal of woman as mother; womanhood personified in Sita; as warrior; eligibility for the highest knowledge; common humanity grounds; respecting the women; all round education of women; develop their own solutions.

Unit-III **Swami Vivekananda's Message on the Uplift of the Masses** **6 Lectures (12 hours)**	Dedicate yourself; develop faith in equality and oneness of man; educate the masses, solution to the caste problem.
Unit-IV **Swami Vivekananda's Message on Restoring our National Glory** **6 Lectures (12 hours)**	India's ideal is spirituality, India's mission is spiritual regeneration of the world, India's solution to life's challenges, India must share the spiritual knowledge with the West and gain material knowledge from them, India is readying for its time under the sun.

Recommended Textbooks:

1. Swami Vivekananda. (1946). *Swami Vivekananda on India and Her Problems*. Compiled by Swami Nirvedananda. Advaita Ashrama.
2. Swami Vivekananda. (1918). *Lectures from Colombo to Almora*. Advaita Ashrama.
3. Swami Chidananda. (2013). *Sankshipta Sasvara Veda Mantrah (Sanskrit)*. Sri Ramakrishna Ashrama.

CBT205: Laboratory-III Microbiology — 3 Credits Practical

Course Objectives: The objective of this laboratory course is to provide the students practical skills on basic microbiological techniques.

Student Learning Outcomes: On completion of this course, students should be able to:

- Ability to isolate, characterize and identify common bacterial organisms;
- Determine bacterial load of different samples;
- Perform antimicrobial sensitivity test;
- Preserve bacterial cultures.

Syllabus

Basic Techniques

1. Sterilization, disinfection and safety in Microbiology laboratory, good laboratory practices.
2. Preparation of media for cultivation of bacteria, liquid and solid.

Syllabus

Culture Techniques

1. Spread plate method
2. Pour plate method
3. Streaking
4. Bacterial growth curve
5. Bacterial plate count method
6. Maintenance of stock cultures: slants, stabs and glycerol stock cultures.

Syllabus

Staining Techniques

1. Preparation of bacterial smear and Gram's staining.
2. Acid fast staining
3. Endospore staining
4. Capsule staining
5. Negative staining
6. Flagellar staining

Syllabus

Antibiotic Resistance Assay

1. Determination of antibiotic sensitivity by Kirby-Bauer method and antibiotic resistance.

Syllabus

Mutagenesis Assay

1. Isolation of auxotrophs and Ames test using any chemical mutagen.
2. Replica plate assay.

CBT206: Laboratory-IV Molecular Biology and Genetic Engineering
3 Credits Practical

Course Objectives: The objective of this laboratory course is to provide the students practical skills on basic molecular biology and genetic engineering techniques.

Student Learning Outcomes: On completion of this course, students should be able to:

- Acquire basic molecular biology techniques and principles;
- Get first-hand experience that will coincide with what is taught in the lecture portion of the class;
- Gain hands-on experience in gene cloning, PCR amplification, protein expression and purification.

Syllabus

1. Isolation of Genomic DNA from
   a) *E. coli* (Bacteria)
   b) *Candida* species (Fungus)
   c) Banana (Plant)
   d) Blood cells (Animal)
2. Plasmid DNA isolation and DNA quantitation
3. Restriction Enzyme digestion of plasmid DNA
4. Agarose gel electrophoresis
5. Polymerase chain reaction (PCR) and analysis by Agarose gel electrophoresis
6. Purification of DNA from Agarose gel
7. Vector and Insert ligation
8. Preparation of competent cells
9. Transformation of E. coli with standard plasmid, Calculation of Transformation efficiency
10. Confirmation of the Insert by Restriction mapping
11. SDS-PAGE gel electrophoresis
12. Expression of recombinant protein, concept of soluble proteins and inclusion bodies in *E. coli*.

Semester-III [Total: 12 (T) + 11 (P) = 23 Credits*]

ABT301: Fundamentals of Plant Biotechnology — 3 Credits Theory

Course Objectives: The objectives of this course are to impart theoretical knowledge on various techniques of plant biotechnology like tissue culture and plant genetic transformation and their application in industries.

Student Learning Outcomes: On completion of this course, students should be able to:

- Gain strong understanding of plant based cell cultures system;
- Take up plant based biological research as well as placement in relevant biotech industry;
- Analyse bioprocess from an economics/market point of view.

Syllabus:

Unit-I **Concepts and Techniques in Plant Tissue Culture** **6 Lectures (12 hours)**	Totipotency; Tissue culture media; Plant hormones and morphogenesis; Direct and indirect organogenesis; Direct and indirect somatic embryogenesis; Techniques of sterilization and use of different sterilants; Applications of plant tissue culture: Micropropagation of field and ornamental crops; National certification and Quality management of TC plants; Virus elimination by meristem culture, meristem tip culture and micrografting; Virus indexing: PCR, ELISA; Wide hybridization: embryo culture and embryo rescue techniques; Ovule, ovary culture and endosperm culture; Artificial seeds.
Unit-II ***In vitro* Culture Methods and Applications** **6 Lectures (12 hours)**	Androgenesis and gynogenesis: production of androgenic and gynogenic haploids, diploidization; Callus culture and *in vitro* screening for stress tolerance; Large-scale cell suspension culture: Production of alkaloids and other secondary metabolites, techniques to enhance secondary metabolite production; Protoplast culture: isolation and purification, Protoplast culture, Protoplast fusion; Somatic hybridization: Production of Somatic hybrids and Cybrids, Applications; Somaclonal and gametoclonal variations: causes and applications; *In vitro* germplasm storage and cryopreservation.
Unit-III **DNA Delivery Methods**	Plant genetic engineering; DNA delivery methods; Vector mediated method: *Agrobacterium tumefaciens* and direct DNA delivery methods. *Agrobacterium* mediated method: *Agrobacterium* biology, Ti plasmid-based transformation,

4 Lectures (8 hours)	crown gall and hairy root disease, Ti and Ri plasmids, T-DNA genes, borders, overdrive, chromosomal and Ti plasmid virulence genes and their functions, *vir* gene induction, mechanism of T-DNA transfer, Ti pasmid vectors, *vir* helper plasmid; super virulence and monocot transformation; binary vector; Floral dip transformation; Direct DNA delivery methods: protoplasts using PEG, electroporation, particle bombardment, Chloroplast transformation and transient expression by viral vectors.
Unit-IV **Design of Gene Construct and Advanced Technologies** **4 Lectures (8 hours)**	Factors influencing transgene expression; Designing gene constructs: Promoters and poly A signals, Protein targeting signals, Plant selectable markers, Reporter genes, Positive selection, Selectable marker elimination, Transgene silencing, Strategies to avoid transgene silencing; Analysis of transgenic plants: PCR, Southern blot hybridization analysis, northern blot analysis, reverse transcription PCR, Western blot and ELISA; Advanced technologies: *cis* genesis and intragenesis.
Unit-V **Application of Transgenic Technology** **7 Lectures (14 hours)**	Herbicide resistance; Pest resistance, Bt toxin, synthetic Bt toxin; Protease inhibitor; and other plant derived insecticidal genes; nematode resistance; Crop Engineering for disease resistance; genetic improvement of abiotic stress tolerance, Genetic engineering for male sterility: Barnase-Barstar; Delayed fruit ripening; polygalacturanase, ACC synthase, ACC oxidase. Engineering for nutritional quality: Improved seed storage proteins; Improving and altering the composition of starch and plant oils; enhancement of micro-nutrients: beta carotene, vitamin E, iron; Molecular pharming: production of antibodies and pharmaceuticals in plants; Bio-safety concerns of transgenic plants; Global status of transgenic plants.

Recommended Textbooks:

1. Bhojwani, S. S. (1990). *Plant Tissue Culture: Applications and Limitations*, Elsevier, Amsterdam.
2. Glick, B. R., & Pasternak, J. J. (2010). *Molecular Biotechnology: Principles and Applications of Recombinant DNA*. Washington, D.C.: ASM Press.
3. Singh, B. D. (2007). *Biotechnology: Expanding Horizons*. Kalyani Publishers.
4. Chawla, H. S. (2000). *Introduction to Plant Biotechnology*. Enfield, NH: Science.
5. Razdan, M. K. (2003). *Introduction to Plant Tissue Culture*. Enfield, NH: Science.

GPB103: Principles of Plant Breeding 2 Credits Theory & 1 Credit Practical

Course Objectives: This course has been designed to provide a basic introduction to concepts of plant breeding. This course also addresses insight into the crop reproductive biology and strategies to breed self and cross pollinated varieties.

Student Learning Outcomes: On completion of this course, students should be able to:

- Have a deeper insight into the genetic basis supporting plant breeding;
- Acquaint the students with the knowledge on cultivar development, plant variety protection etc.

Syllabus:

Unit-I **Introduction to Plant Breeding** **2 Lectures (4 hours)**	History of plant breeding (Pre and post-Mendelian era); Objectives of plant breeding, characteristics improved by plant breeding; Patterns of Evolution in Crop Plants; Centres of Origin: biodiversity and its significance.
Unit-II **Breeding of Self- and Cross-Pollinated Crops** **3 Lectures (6 hours)**	Genetic basis of breeding self- and cross-pollinated crops including mating systems and response to selection: nature of variability, components of variation; Heritability and genetic advance, genotype environment interaction; General and specific combining ability; Types of gene actions and implications in plant breeding. Plant introduction and role of plant genetic resources in plant breeding.
Unit-III **Genetics of Self-Incompatibility and Male Sterility** **3 Lectures (6 hours)**	Genetic basis of self-incompatibility and male sterility in crop plants and their commercial exploitation; Concept of plant ideotype and its role in crop improvement; Transgressive breeding.
Unit-IV **Selection & Breeding Methods** **3 Lectures (6 hours)**	Pure line theory, pure line selection and mass selection methods; Line breeding, pedigree, bulk, backcross, single seed descent and multiline method; Population breeding in self-pollinated crops (diallel selective mating approach).
Unit-V **Breeding Methods: Cross-**	Population breeding: mass selection and ear-to-row methods; S1 and S2 progeny testing, progeny selection schemes, recurrent selection schemes for intra and

Pollinated Crops **3 Lectures (6 hours)**	interpopulation improvement and development of synthetics and composites. Hybrid breeding: genetical and physiological basis of heterosis and inbreeding, production of inbreds, breeding approaches for improvement of inbreds, predicting hybrid performance; seed production of hybrid and their parent varieties/inbreds.
Unit-VI **Special Breeding Methods** **2 Lectures (4 hours)**	Breeding methods in asexually/clonally propagated crops, clonal selection apomixes, clonal selection; Mutation breeding; Breeding for abiotic and biotic stresses.
Unit-V **Variety: Synthesis, Release and Protection** **2 Lectures (4 hours)**	Cultivar development: testing, release and notification, maintenance breeding, Participatory Plant Breeding, Plant breeders' rights and regulations for plant variety protection and farmers rights.

Practical:

Syllabus	1. Floral biology in self and cross pollinated species, selfing and crossing techniques. 2. Selection methods in segregating populations and evaluation of breeding material. Analysis of variance (ANOVA); Estimation of heritability and genetic advance. 3. Maintenance of experimental records. 4. Learning techniques in hybrid seed production using male-sterility in field crops and visit to seed companies producing hybrid seeds.

Recommended Textbooks:

1. Singh, B. D. (2018). *Plant Breeding: Principles and Methods*. Kalyani Publishers.
2. Allard R.W. (1999). *Principles of Plant Breeding*. 2nd Ed. Wiley.
3. Singh, P. (2014). *Essentials of Plant Breeding*. Kalyani Publishers.

ABT302: Molecular Breeding — 2 Credits Theory

Course Objectives: This course introduces students to key principles of molecular breeding. In addition to this, genetic recombination as a tool for genetic map construction, theory and application of DNA markers for mapping and selection, including pros, cons and their special characteristics are discussed.

Student Learning Outcomes: On completion of this course, students should be able to:

- Understand advantages and limitations of molecular markers in plant breeding selection programmes;
- Analyse genetic segregations in plants.

Syllabus:

Unit-I **Introduction to Molecular Markers** **5 Lectures (10 hours)**	Sequence complexity in genomes: Unique and Repeat sequences, Point mutations to polyploidy, transposable elements; Causes of sequence variations; Types of molecular markers: RFLP, AFLP, SCARs, CAPS, SSRs, STMS and SNPs; Development of marker resources.
Unit-II **Mapping Populations for Genome Mapping** **4 Lectures (8 hours)**	Construction of genetic linkage maps, Linkage mapping software packages and interfaces; Types of populations: F2 populations, RILs (recombinant inbred lines), Backcross lines, NILS (Near Isogenic Lines), HIF (Heterogeneous Inbred Families), AILs (Advanced Intercross Lines), Biparental mapping versus Multi-parent mapping, NAM (Nested Association mapping), MAGIC (Multi-parent advanced generation inter-cross).
Unit-III **Molecular Mapping** **5 Lectures (10 hours)**	Mapping simple and complex traits, QTL detection methods; Bulked Segregant Analysis; Fine mapping: Map based cloning/ positional cloning for gene discovery; Pseudo-testcross mapping Association mapping– Principles and methods; GWAS (Genome Wide Association Studies); Navigating from genetic to physical map; Targeting Induced Local Lesions in Genomes (TILLING), ECOTILLING and its application in crop breeding, Allele mining, Comparative/Synteny mapping.
Unit-IV **Breeding by Design** **4 Lectures (8 hours)**	Strategies in molecular breeding: Marker Assisted Selection (MAS); Gene/QTL introgression; MABB (Marker Assisted Back cross breeding)- Foreground and background selection for introgression of QTL by SSR markers; Gene/QTL pyramiding strategies; MARS, Genomics assisted breeding: MAGIC, Genomic Selection.

Recommended Textbooks:

1. Anolles, G. C. and Gresshoff, P.M., (1997), *DNA markers– Protocols, Applications and Overviews*. Wiley-Liss, New York.
2. Henry R. J., (2005), *Plant Genotyping: the DNA Fingerprinting of Plants*. CABI, New Delhi.
3. R.K. Varshney, R. Tuberosa, (2008). *Genomics Assisted Crop Improvement,* Springer.

ABT303: Environmental Biotechnology — 2 Credits Theory

Course Objectives: The course is designed to introduce students to scientific and technological aspects related to concept of ecosystem and its management, environmental degradation and its effect on living systems, bioremediation, metabolic engineering and agriculture.

Student Learning Outcomes: On completion of this course, students should be able to:

- Understand use of basic microbiological, molecular and analytical methods, which are extensively used in environmental biotechnology.

Syllabus:

Unit-I

Introduction to Environment

2 Lectures (4 hours)

Concept of ecosystems and ecosystem management; Scope of environmental biotechnology, Response of microbes, plant and animals to environmental stresses; Environmental problems: ozone depletion, pesticides, greenhouse effect, water, air and soil pollution, radioactive pollution, land degradation; Biotechnological tools to monitor bio-treatment efficiency.

Unit-II

Bioremediation

4 Lectures (8 hours)

Bioremediation: Fundamentals, methods and strategies of application (biostimulation, bioaugmentation): examples, bioremediation of metals (Cr, As, Se, Hg), radionuclides (U, Te), organic pollutants (PAHs, PCBs, Pesticides, TNT *etc.*), technological aspects of bioremediation (*in situ*, *ex situ*); Bioremediation: using natural, genetically engineered bacterial systems and plants with examples; Biotechnology of coal Bio-mineralization: Concept, Heaps and Dumps; Phytoremediation: Fundamentals and

	description of major methods of application (phytoaccumulation, phytovolatilization, rhizofiltration, phytostabilization).
Unit-III **Metabolic Engineering** **3 Lectures (6 hours)**	Chloroplast transformation (plants and algae) and importance of this technique in the expression of Secondary Metabolism; Biotechnology of aromas: aromas produced by yeast in the main fermented beverages and biotechnological interventions; production of vanillin by chemical, enzymatic and biotechnological methods; metabolic engineering of food crops aimed to modulate the set of aromas.
Unit-IV **Environmental Biotechnology in Agriculture** **7 Lectures (14 hours)**	Biofertilizer: Definition, Symbiotic systems between plants-microorganisms (nitrogen fixing symbiosis, mycorrhiza fungi symbiosis), Plant growth promoting rhizobacteria (PGPR), uses, practical aspects and problems in application; Nitrogen fixation: Biochemistry, nif genes and regulation of nif gene expression; Endophytes and Mycorrhiza: Types, importance to plant health (nutrient uptake, resistance to stress, microbial symbiosis), importance of network analysis, role in ecosystem (Plant to plant interaction); Composting: physical and chemical factors, microbiology, health risk from pathogens, odour sources. Bioinsecticides: *Bacillus thuringiensis*, Baculoviruses, uses, genetic modifications and aspects of safety in their use; Biofungicides: Description of mode of actions and mechanisms (*e.g. Trichoderma, Pseudomonas fluorescens*); Biological Controls: Viral, fungal, and bacterial parasites for control of insect pests, and its mode of action; Neem as a potent Biopesticides: pyrethrins, mode of action on insect pests, Bio-control against fungal diseases of plants.
Unit-V **Recent Advances in Environmental Biotechnology** **2 Lectures (4 hours)**	Algal bioreactors; Bioenergy; Biofuels: Introduction, Types, hydrogen and methane (biogas), ethanol and diesel (liquid), biofuel from phytoplankton; Applications: Nano biopolymers, bioplastics, biofilms, bioleaching and biosensors.

Recommended Textbooks:

1. Singh, BKP., (2011). *Biotechnological Applications in Environment and Agriculture*. Swendea Publications.

2. Thakur. (2008). *Environmental Biotechnology: Basic Concepts and Applications*. IK International publishers, New Delhi.

3. Wang, L.K., Ivanov, V., Tay, J.H and Hung, Y.T. (2010). *Environmental Biotechnology.* Springer Publishing.

ABT304: Plant Physiology and Stress Biology 2 Credits Theory

Course Objectives: The objectives of this course are to understand basic principles of important physiological processes in plants including stress adaptation and to study functions of nutrients and plant growth regulators in crop production.

Student Learning Outcomes: On completion of this course, students should be able to:

- Acquire knowledge on important physiological processes in plants and role of nutrients and growth regulators in growth and development besides the crop's response to various abiotic stresses.

Syllabus:

Unit-I **Plant Water Relations** **3 Lectures (6 hours)**	Introduction and role of Physiology in Agriculture; Structure, properties and role of water in plants; soil and cell water terminologies; field capacity and PWP (Permanent Wilting Point); mechanism of water absorption; ascent of sap: theories; transpiration; stomatal structure: mechanism of stomatal movement; anti-transpirants.
Unit-II **Plant Nutrition** **2 Lectures (4 hours)**	Essential and beneficial nutrients: classification, functions and deficiency symptoms of primary, secondary and micro nutrients in plants; hidden hunger; mechanisms of nutrient absorption: chelates, foliar nutrition.
Unit-III **Plant Metabolism** **6 Lectures (12 hours)**	Photosynthesis: chloroplasts and two photosystems; proton gradient across thylakoid membrane; Calvin cycle and pentose phosphate pathway; sucrose-starch conversion, EMR and PAR; red drop and Emerson's enhancement effect; photochemical reactions; photolysis of water; Z scheme, photophosphorylation, reduction of CO_2 *i.e.,* carbon assimilation in C3, C4 and CAM pathways, difference between three pathways; photorespiration and its significance; phloem

	loading and unloading; munch hypothesis; source and sink strength: manipulations; respiration; glycolysis, TCA cycle, oxidative phosphorylation: differences between oxidative phosphorylation and photophosphorylation; energy budgeting in respiration, respiratory quotient.
Unit-IV **Plant Growth** **4 Lectures (8 hours)**	Growth curve; plant growth hormones/regulators (PGRs); physiological role and applications of auxins, gibberellins, cytokinin, ethylene and ABA; commercial uses of PGR's; senescence and abscission: classification, physiological and biochemical changes and its significance; photoperiodism; florigen theory of flowering; phytochrome; regulation of flowering in crops; vernalization; seed dormancy, breaking dormancy; seed germination, physiological basis of germination.
Unit-V **Stress Physiology** **3 Lectures (6 hours)**	Physiology of abiotic stresses in plants: water, drought, submergence and flooding stress, temperature; cold, heat, global warming, green-house gases and salt; salinity, sodicity and alkalinity: effects and tolerance mechanisms; Nutrients; deficiency and excess-tolerance mechanisms and Nutrient use efficiency.

Recommended Textbooks:

1. Lincoln Taiz, Eduardo Zeiger, Ian M. Moller and Angus Murphy (2015). *Plant Physiology*, 6th Edn, Sinauer Associates, Inc.
2. Bob B. Buchanan, Wilhelm Gruissem and Russell L. Jones. 2015. *Biochemistry and Molecular Biology of Plants*. Second Edition. American Society of Plant Biology. John Wiley & Sons, Ltd, UK.

ABT305: Agricultural Statistics: Experimental Design and Data Analysis
1 Credit Theory & 1 Credit Practical

Course Objectives: The objectives of this course are to provide exposure about methods on designing agricultural experiments which are widely used in agricultural sciences. This course also provides usage of various statistical packages like MS Excel, SYSTAT/SPSS and SAS/IRRISTAT for the analysis of Agricultural Research Data.

Student Learning Outcomes: On completion of this course, students should be able to:

- Acquire knowledge on designing experiments, collection and analysis of biological research data.

Syllabus:

Unit-I **ANOVA, Data Transformation and Mean Comparisons** **3 Lectures (6 hours)**	Analysis of variance: CRD, RBD and LSD; Data transformation: logarithmic, angular and square root transformations, mean comparisons, critical difference (least significant difference) and Duncan's Multiple Range Test (DMRT); missing plot technique in RBD (data with one missing observation); RBD with multi observations per cell.
Unit-II **Factorial Experiments** **3 Lectures (6 hours)**	Concept of factorial experiments: symmetrical and asymmetrical factorial experiments; 2n factorial experiments; analysis using regular method (RBD); Yates algorithm; asymmetrical factorial experiment (up to 3 factors); split-plot design, strip plot design.
Unit-III **Data Analysis** **3 Lectures (6 hours)**	Descriptive statistics, testing of hypothesis, correlation analysis and regression analysis using MS Excel: ANOVA, cross tabulation, non-parametric tests and time series analysis using SYSTAT/SPSS: Completely Randomized Design (CRD), Randomized Block Design (RBD), factorial experiments, split plot design and data transformation using SAS/IRRISTAT.

Practical:

Syllabus	1. ANOVA of a) CRD b) RBD c) LSD d) Split Plot Design e) Factorial Design 2. Analysis of Variance using appropriate software: Statistical Packages.

Recommended Textbooks:

1. Rangaswamy, R. (2009). *A Text Book of Agricultural Statistics*, New Age International (P) Ltd.

2. Das, M.N. and C. Narayan Giri. (2007). *Design and Analysis of Experiments*, New Age Publishers, New Delhi.

3. Panse, V.G. and Sukhatme P.V. (1967). *Statistical Method for Agricultural Workers*. ICAR Publication.

ABT306: Laboratory-VI Molecular Breeding — 2 Credits Practical

Course Objectives: This objective of this laboratory course is to introduce students to key principles of molecular plant breeding. This course is designed to teach utility of experimental application of DNA markers in relation to mapping and selection of agronomic traits in crop plants.

Student Learning Outcomes: On completion of this course, students should be able to:

- Elaborate concepts of DNA markers with easy to analyse genetic segregations in plants;
- Familiarize with basic laboratory instruments and understand principle of DNA markers using those instruments with experiments in molecular biology.

Syllabus

1. Handling of Statistical Package for Genetic Analysis (Genetic parameters, Heritability, Genotypic and Phenotypic correlation, Path analysis, D^2 analysis).
2. Principles and Methods involved in Nucleic acid separation from plants.
3. Designing Primers: Gene specific primers; Primers based on conserved regions; Degenerate primers.
4. Study of
   a) RAPD marker
   b) ISSR marker
   c) SSR marker
5. Genetic Diversity Analysis based on Molecular Marker.
6. Lecture Demonstration on Principle of Linkage map construction, LD, QTL mapping and Association mapping by using web-tutorials and online movies.

ABT307: Laboratory-VII Plant Tissue Culture Techniques

3 Credits Practical

Course Objectives: This objective of this laboratory course is to impart hands-on-training on various techniques of plant tissue culture and their application in crop improvement.

Student Learning Outcomes: On completion of this course, students should be able to:

- Acquire practical knowledge on the techniques involved in plant tissue culture;
- Familiarize with laboratory set up of standard plant tissue culture facilities and understand principle of plant tissue culture using those instruments with experiments.

Syllabus

1. Preparation of stocks: macronutrients, micronutrients, vitamins and hormones, filter sterilization of hormones and antibiotics. Preparation of Murashige and Skoog medium.
2. Micro-propagation of plants (banana) by sucker and shoot tip culture.
3. Special culture techniques
   a) Embryo Culture
   b) Anther Culture
4. Callus induction, regeneration of shoots, root induction, role of hormones in morphogenesis.
5. Study of Protoplast
   a) Protoplast isolation from plant leaf
   b) Protoplast fusion and protoplast culture
6. Study of Somatic embryogenesis.
7. Production of secondary metabolites by Hairy Root Culture.
8. Acclimatization of tissue culture plants and establishment in greenhouse.

ABT308: Laboratory-VIII Environmental Biotechnology 2 Credits Practical

Course Objectives: This course will give hands on experience of various emerging technologies used for bioremediation, solid waste management. The objective of this practical course is also to impart hands-on-training on various techniques of bio-fertilizer production and its utilities in modern-day agriculture.

Student Learning Outcomes: On completion of this course, students should be able to:

- Acquire practical knowledge on the techniques involved in bioremediation and solid waste management;
- Acquire practical knowledge on production of manures, compost and bio-fertilizer.

Syllabus

1. Application of Bioremediation.
2. Compost and Vermicompost production.
3. Isolation and Production of N-fixer.
4. Isolation and Production of P-solubilizer.
5. Production of
   a) Azolla
   b) VAM
   c) BGA
6. Effect of Neem pesticides on plant pathogens.
7. Analysis of heavy metals uptake by crop plants.
8. Demonstration of Biogas production and Visit to Biogas Unit.

ABT309: Seminar-I Project Proposal Preparation & Presentation
2 Credits Practical

Course Objectives: The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.

Student Learning Outcomes: Students should be able to demonstrate the following abilities:

- Formulate a scientific question;
- Present scientific approach to solve the problem;
- Gain experience in writing a scientific proposal;
- Learn how to present and explain their research findings to the audience effectively.

Syllabus

1. Selection of Research Laboratory and Research Topic:

Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them to select a topic for their project. The topic of the research should be hypothesis driven.

2. Review of Literature:

Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources.

3. Writing Research Proposal:

With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, *etc.* Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.

Elective Course
(Compulsory Course for the Non-Agriculture Disciplines)

ABT310: Fundamentals of Crop Production Technology
2 Credits Theory & 1 Credit Practical

Course Objectives: The objectives of this course are to make students understand how various agronomic practices are commonly adopted in modern agriculture. This course shall make the students aware of soils as a mother in the context of crop production. Further, to familiarize with the crop cultivation both in theoretical and practical sense, this course would cover the production technology of few important crops along with its protection measures against insect-pests and diseases.

Student Learning Outcomes: On completion this course, students should be able to:

- Understand the various agronomic practices commonly employed in crop production;
- Gain fundamental knowledge in soil science;
- Familiarize with crop production technology of important cereals, pulses and oilseeds;
- Gain knowledge on various managements to protect the crops from insect-pests and diseases.

Syllabus:

Unit-I **Basics of Agronomy** **6 Lectures (12 hours)**	Agriculture; Agronomy and its relation with other sciences; Classification of crops; Seed, its characteristics and different sowing methods; Tillage and tillage practices, concepts of tillage and objectives; Irrigation: Soil water classification, methods of irrigation, approaches for scheduling irrigation; Weed management: definition of weed, losses and benefits of weeds, different weed control methods and their suitability under different conditions; Fertilizers, manures and their types, methods of fertilizer application; Organic farming: concepts, principles and methodology; quality, certification, marketability and export of organic products.
Unit-II **Introductory Soil Science** **3 Lectures (6 hours)**	Soil and its components; Soil morphological, physical, chemical and biological properties; Acidic, saline and alkali soils and their reclamation; Soil micro-organisms; Soil fertility and productivity; Fate of fertilizer application in soils.

Unit-III **Basics of Crop Protection** **3 Lectures (6 hours)**	Importance of insects in agriculture; Insects diversity; General symptoms of insects attack; Principles and methods of insect-pests management; Integrated Pest Management concept; Concept of disease in plants; Nature and classification of plant diseases.
Unit-IV **Crop Production Technology of Important Crops** **6 Lectures (12 hours)**	Production technology of major crops: Rice, wheat, cotton, rapeseed and mustard; Management of important insect-pests of major crops: Rice, wheat, cotton, rapeseed and mustard; Management of key diseases of major crops: Rice, wheat, cotton, rapeseed and mustard.

Practical:

Syllabus	1. Determination of soil particle size distribution, particle density and bulk density. 2. Determination of a) Soil pH b) Electrical Conductivity c) Organic carbon 3. Land measurement; Practice in seedbed preparation and seeding methods. 4. Preparation and use of low cost organic inputs like *Panchagavya*, *Shasyagavya*, *Beejamrit* etc. 5. Identification of crop seeds, crops, weeds and fertilizers. 6. Identification and use of hand tools and implements. 7. Computation of fertilizer doses and their method of application. 8. Identification of important insect-pests of cereals, oilseeds, pulses, and vegetables crops and their damage symptoms. 9. Acquaintance with various pesticidal formulations; Calculation for preparing spray material.

Recommended Textbooks:

1. Reddy TY & Reddy GHS. (2015). *Principles of Agronomy.* Kalyani Publishers.
2. Das DK. (2011). *Introductory Soil Science.* Third Edition, Kalyani Publishers.
3. Dhaliwal GS, Singh R & Chhillar BS. (2006). *Essentials of Agricultural Entomology.* Kalyani Publishers.
4. Banerjee H. (2019). *Mathematical Agronomy*. New Delhi Publication.

Semester-IV [Total: 2 (T) + 21 (P) = 23 Credits]

CBT401: Intellectual Property Rights, Biosafety and Bioethics

2 Credits Theory

Course Objectives: The course concentrates on technology, knowledge and business management aspect of intellectual property, including patenting aspect so as to focus on use of IP to drive business models and value propositions. It also provides insights to align IP strategies with overall corporate strategies and Shares best practice models for IP valuation. This course further enables students to learn biosafety and risk assessment of products derived from biotechnology and regulation of such products. It also addresses ethical issues in biological research.

Student Learning Outcomes: On completion of this course, students should be able to:

- Understand the rationale for and against IPR and especially patents;
- Understand why India has adopted National IPR Policy and be familiar with broad outline of patent regulations;
- Understand different types of intellectual property rights in general and protection of products derived from biotechnology research and issues related to application and obtaining patents;
- Gain knowledge of biosafety and risk assessment of products derived from recombinant DNA research environment release of genetically modified organisms, national and international regulations;
- Understand ethical aspects related to biological, biomedical, health care and biotechnology research.

Syllabus:

Unit-I **Introduction to IPR** **4 Lectures (8 hours)**	Types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; International framework for the protection of IP; IP as a factor in R&D; IPs of relevance to biotechnology and few case studies; introduction to history of GATT, WTO, WIPO and TRIPS; plant variety protection and farmers rights act; concept of 'prior art': invention in context of "prior art"; patent databases- country-wise patent searches (USPTO, EPO, India); analysis and report formation.
Unit-II	Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest

Patenting **3 Lectures (6 hours)**	Treaty; Patent Cooperation Treaty (PCT) and implications; procedure for filing a PCT application; role of a Country Patent Office; filing of a patent application; precautions before patenting-disclosure/non-disclosure- patent application- forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications; PCT and conventional patent applications; international patenting-requirement, procedures and costs; financial assistance for patenting introduction to existing schemes; publication of patents-gazette of India, status in Europe and US; patent infringement- meaning, scope, litigation, case studies and examples; commercialization of patented innovations; licensing–outright sale, licensing, royalty; patenting by research students and scientists-university/organizational rules in India and abroad, collaborative research- backward and forward IP; benefit/credit sharing among parties/community, commercial (financial) and non-commercial incentives.
Unit-III **Biosafety** **3 Lectures (6 hours)**	Introduction; historical background; introduction to biological safety cabinets; primary containment for biohazards; biosafety levels; GRAS organisms, biosafety levels of specific microorganisms; recommended biosafety levels for infectious agents and infected animals; definition of GMOs & LMOs; principles of safety assessment of transgenic plants– sequential steps in risk assessment; concepts of familiarity and substantial equivalence; risk – environmental risk assessment and food and feed safety assessment; problem formulation–protection goals, compilation of relevant information, risk characterization and development of analysis plan; risk assessment of transgenic crops *vs* cisgenic plants or products derived from RNAi, genome editing tools.
Unit-IV **International and National Regulations** **3 Lectures (6 hours)**	International regulations: Cartagena protocol, OECD consensus documents and Codex Alimentarius; Indian regulations: EPA act and rules, guidance documents, regulatory framework: RCGM, GEAC, IBSC and other regulatory bodies; Draft bill of Biotechnology Regulatory authority of India- containments– biosafety levels and category of rDNA experiments; field trails– biosafety research trials– standard operating procedures-guidelines of state governments; GM labeling– Food Safety and Standards Authority of India (FSSAI).
Unit-V	Introduction, ethical conflicts in biological sciences-

Bioethics

5 Lectures (10 hours)

interference with nature, bioethics in health care- patient confidentiality, informed consent, euthanasia, artificial reproductive technologies, prenatal diagnosis, genetic screening, gene therapy, transplantation. Bioethics in research– cloning and stem cell research, Human and animal experimentation, animal rights/welfare, Agricultural biotechnology– Genetically engineered food, environmental risk, labeling and public opinion. Sharing benefits and protecting future generations- Protection of environment and biodiversity– biopiracy.

Recommended Textbooks:

1. *Biosafety in Microbiological and Biomedical Laboratories*, (2009) 5th Ed, www.cdc.gov/od/ohs/biosfty/bmbl5/bmbl5toc.html.
2. V. Shree Krishna, (2007), *Bioethics and Biosafety in Biotechnology*, New Age International Pvt. Ltd. Publishers.
3. *Deepa Goel, Shomini Parashar, (2013), IPR, Biosafety and Bioethics, Pearson.*

ABT401: Seminar-II Project Presentation 1 Credit Practical

Course Objectives: The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.

Student Learning Outcomes: Students should be able to demonstrate the following abilities:

- Formulate a scientific question;
- Present scientific approach to solve the problem;
- Interpret, discuss and communicate scientific results in written form;
- Learn how to present and explain their research findings to the audience effectively.

Syllabus

1. Oral Presentation:

At the end of their project, presentation will have to be given by the students to explain work done by them in detail. Along with summarizing their findings they should also be able to discuss the future expected outcome of their work.

ABT402: Project — 20 Credits Practical

Course Objectives: The objectives of this course are to prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory. It will also enable students to learn practical aspects of research and train students in the art of analysis and thesis writing.

Student Learning Outcomes: Students should be able to learn how to select and defend a topic of their research, how to effectively plan, execute, evaluate and discuss their experiments. Students should be able to demonstrate considerable improvement in the following areas:

- In-depth knowledge of the chosen area of research;
- Capability to critically and systematically integrate knowledge to identify issues that must be addressed within framework of specific thesis;
- Competence in research design and planning;
- Capability to create, analyse and critically evaluate different technical solutions;
- Ability to conduct research independently;
- Ability to perform analytical techniques/experimental methods;
- Project management skills;
- Report writing skills;
- Problem solving skills;
- Communication and interpersonal skills.

Syllabus

1. Planning and Performing Experiments:

Based on the project proposal submitted in earlier semester, students should be able to plan, and engage in, an independent and sustained critical investigation and evaluate a chosen research topic relevant to biological sciences and society. They should be able to systematically identify relevant theory and concepts, relate these to appropriate methodologies and evidence, apply appropriate techniques and draw appropriate conclusions. Senior researchers should be able to train the students such that they can work independently and are able to understand the aim of each experiment performed by them. They should also be able to understand the possible outcomes of each experiment.

2. Thesis Writing:

At the end of their project, thesis has to be written giving all the details such as aim, methodology, results, discussion and future work related to their project. Students may aim to get their research findings published in a peer-reviewed journal. If the research findings have application-oriented outcomes, the students may file patent application.