LIFE SCIENCES

Programme Code: LIFE00

Programme Outcome:

- Develop a strong foundation in the fundamental principles of physical, chemical, and biological sciences.
- Understand atomic and molecular structure, radiation biology, cancer biology, microbiology, plant and animal systems, and food technology.
- Apply quantitative, statistical, and computational methods to analyze experimental data and interpret results.
- Design experiments and solve problems in biological and chemical research using theoretical and practical knowledge.
- Demonstrate knowledge of molecular and cellular processes, including DNA/RNA biology, gene regulation, cell cycle, signaling, stem cells, and cancer biology.
- Acquire skills in experimental techniques and instrumentation, such as spectroscopy, microscopy, electrophoresis, centrifugation, sequencing, and bioinformatics.
- Understand principles of radiation, radiotherapy, radiopharmaceuticals, and their applications in medicine, agriculture, and food safety.
- Gain knowledge of natural products, active pharmaceutical ingredients, functional foods, and microbial and plant-based biotechnology.
- Apply concepts of plant breeding, genetics, stress biology, and tissue culture for sustainable agriculture.
- Understand microbial engineering, antibiotic resistance, biofilms, and industrial microbiology for research and societal applications.
- Analyze and model biological and chemical systems, including cancer metabolism, tumor microenvironment, genome analysis, and systems biology.
- Follow research ethics, regulatory standards, and safety practices in laboratories, radiation, and food safety.

DETAILED COURSE STRUCTURE

Core Courses (Mandatory)				
S.No.	**Course Code**	**Subject Title**	**Hours (T)**	**Credits**
1	BS 501	Chemistry & Radiochemistry	20	1
2	BS 502	Physics, Mathematics & Statistics	45	3
3	BS 601	Biochemistry	15	1
4	BS 602	Bioinformatics	30	2
5	BS 603	Cell Biology	23	1
6	BS 604	Crop Science	30	2
7	BS 605	Food Technology	30	2
8	BS 606	Cancer Biology	23	1
9	BS 607	Microbiology & Biotechnology	21	1
10	BS 608	Molecular Biology	30	2
11	BS 609	Radiation Biology	30	2
Hours / Credits			**297**	**18**

Elective Courses (4/18)				
S.No.	**Course Code**	**Subject Title**	**Hours (T)**	**Credits**
(Any four)				
1	BS 701	Advances in enzyme technology	75	3
2	BS 702	Assessment of health effects from exposure to low levels of ionizing radiation	75	3
3	BS 703	Biology of stress and adaptive responses in bacteria	75	3
4	BS 704	Challenges for sustainable and clean environment	75	3
5	BS 705	Food borne pathogens	75	3
6	BS 706	Immunological methods in biochemical and chemical analysis	75	3
7	BS 707	Molecular markers and genomics for crop improvement	75	3
8	BS 708	Oxidative stress and redox modifiers in disease management	75	3
9	BS 709	Cancer- hallmarks, pathogenesis, microenvironment and therapeutics	75	3
10	BS 710	Plant genetic engineering	75	3
11	BS 711	Advances in genome biology	75	3

12	BS 712	Principle and practices in structural biology	75	3
13	BS 713	Advanced instrumentation for bioanalysis and imaging	75	3
14	BS 714	Molecular biology methods in tuberculosis and thyroid cancer	75	3
15	BS 715	Principles and practices of Mutation Breeding	75	3
16	BS 716	Advances in CRISPR-Cas applications for bio-medical research	75	3
17	BS 717	Nanoparticles for application of radiation in healthcare	75	3
18	BS 718	Radioisotopes in Healthcare & Radiopharmaceuticals Research	75	3

NON-SUBJECT ASSIGNMENTS				
S.No.	**Course**	**Course Code**	**Hours (T)**	**Credits**
1	Viva Voce (Mid-Term & Final)	BS 591	NA	4
2	Laboratory Techniques in Life Sciences	BS 592	[65 theory classes (T) & 260 lab hours (L)]	12
3	Seminars (Research paper & Review paper)	BS 594	NA	4
Total Hours / Credits				**20**

SUMMARY				
S.No.	**Course**	**Quantity**	**Hours (T)**	**Credits**
1	Core Course	11	297	18
2	Elective courses	4	60T+240L	12
3	Laboratory techniques in life sciences	4.	[65 theory classes (T) & 260 lab hours (L)]	12
4	Seminars	2	NA	4
5	Viva Voce (Mid-Term & Final)	2	NA	4
6	Research Methodology*	NA	20	NA
Total Hours / Credits			**942**	**50**

**For Elective Courses:
Theory:15Hrs(1Credit); Practicals: 60Hrs(2Credits)

PROGRAM COORDINATORS

Chief Coordinators:

Dr. Sudhir Singh, SO(G) (E-mail: sudhirs@barc.gov.in)
Dr. Rahul Checker, SO(G) (E-mail: rchecker@barc.gov.in)

Core courses coordinators:

Course	Coordinators	E-mail
Physics, Mathematics and Statistics	M K Ray	mkray@barc.gov.in
Chemistry and Radiochemistry	Dr. Dibakar Goswami	dibakarg@barc.gov.in
Biochemistry	Dr. Kuber C. Bhainsa	kuber@barc.gov.in
Molecular Biology	Dr. Sheetal Uppal	sheetal@barc.gov.in
Cell Biology & Immunology	Dr. Deepak Sharma	dsharma@barc.gov.in
Crop Science	Dr. (Mrs.) Archana Joshi-Saha	archanaj@barc.gov.in
Microbiology & Biotechnology	Dr. Shashidhar	shashi@barc.gov.in
Cancer Biology	Dr. Amit Kumar	amitk@barc.gov.in
Bioinformatics	Dr. D. Rath	devrath@barc.gov.in
Radiation Biology	Dr. (Mrs.) Anu Ghosh	anugh@barc.gov.in
Food Technology	Dr. (Smt.) Sweetie Kanatt	srkanatt@barc.gov.in

Elective courses coordinators:

Course	Coordinators	E-mail
Advances in Enzyme Technology	Dr. Jitendra Kumar	jkumar@barc.gov.in
Assessment of health effects from exposure to low levels of ionizing radiation	Dr. Vinay Jain	vinayj@barc.gov.in
Biology of Stress and Adaptive Response in Bacteria	Dr. (Smt.) Hema R.	hemaraj@barc.gov.in
Challenges for Clean and Sustainable Environment	Dr. S.T. Mehetre	smehetre@barc.gov.in
Food-borne pathogens	Dr. Shashidhar R.	shashi@barc.gov.in
Immunological methods in biochemical and chemical analysis	Dr. M. K. Ray	mkray@barc.gov.in
Molecular markers and genomics for crop improvement	Dr. S. K. Gupta	skgupta@barc.gov.in
Oxidative stress and redox modifiers in disease management	Dr. S. Santosh Kumar	sskumar@barc.gov.in
Cancer-Hallmarks, Pathogenesis, Microenvironment and Therapeutics	Dr. Bhavani Shankar	shankar@barc.gov.in
Plant Genetic Engineering	Dr. Himanshu Tak	hsjtak@barc.gov.in
Advances in Genome Biology	Dr. Y. S. Rajpurohit	ysraj@barc.gov.in
Principles and practices in Structural Biology	Dr. Mukesh Kumar	mukeshk@barc.gov.in
Advanced Instrumentation for Bioanalysis and Imaging	Dr. Kuber Bhainsa	kuber@barc.gov.in
Current advances in tuberculosis and thyroid cancer research	Dr. Pramod K Gupta	guptapk@barc.gov.in
Principles and Practices of Mutation Breeding	Dr. Suvendu Mondal	suvendu@barc.gov.in
Advances in CRISPR-Cas applications for bio-medical research	Dr. Devashish Rath	devrath@barc.gov.in
Nanoparticles for application of radiation in healthcare	Dr. (Smt.) Neena G. Shetake	neenavj@barc.gov.in
Radioisotopes in Healthcare & Radiopharmaceuticals Research	Dr. (Smt.) Archana Mukherjee	archanas@barc.gov.in

CORE COURSES

BS501: Chemistry and Radiochemistry (20 Lecture Hrs)

Coordinators: Dr. Dibakar Goswami
(dibakarg@barc.gov.in)

Course Details:

- **Radioactivity and interaction of radiation with matter**
  Types of radiation (ionizing and non-ionizing), laws of radioactive decay, binding energy, nuclear reactions, interaction of different types of radiation with matter. Track structure and delta rays; track structures of different radiation types. Concepts of Bragg's peak, spread over Bragg's peak, radiation exposure and absorption units, radiation weighting factors; concept of LET; sources of background radiation. Dose limits of radiation exposures.

- **Radiation dosimetry**
  Basic concepts, physical and chemical dosimetry, dose range and limitations of dosimetry techniques; scintillation counting/auto-radiography techniques; personal monitoring devices and radiation survey instruments; Ionization methods of radiation dosimetry of internally deposited radionuclides.

- **Free radical chemistry**
  Water radiolysis, free radical generation by radiation and chemical methods. Fast kinetics, mechanism of reaction, stability and detection and ESR spectroscopy

- **Structural chemistry**
  Nature of chemical bond, weak interactions and their implications in biolog

- **Synthesis mechanisms and bio-organic chemistry**
  Types of organic reactions, disconnection approach, secondary metabolites, isolation, characterization and biosynthesis.
  Green chemistry and phyto-chemistry.

- **Active Pharmaceutical Intermediate (API)**
  Importance in drug manufacturing, Chiral and achiral APIs, Strategies for cost-effective sustainable synthesis of APIs, Global scenario, Future of API synthesis.

- **Radioisotopes**
  Concept of tracers, general principles of radionuclide production, nuclear reactions, production of radioisotopes, Szillard-Chalmer reaction, separation techniques and radiochemical purity, examples of production of biologically and medically useful radioisotopes (reactor produced cyclotron produced generator produced applying transient and secular radioactive equilibria)

- **Radiopharmaceuticals chemistry**
  Radiolabelling techniques, therapeutic radiopharmaceuticals, clinical translation of in vitro to in vivo application; Principle, applications and limitations of PET-CT, SPECT etc.

Course Outcomes:

- Demonstrate understanding of radiation types, radioactive decay, interaction of radiation with matter, dosimetry principles, and safety standards relevant to biological and medical applications.
- Apply concepts of free-radical chemistry, structural chemistry, and organic synthesis—including API development, secondary metabolites, and green chemistry—to analyze and design biologically relevant chemical processes.
- Explain the principles of radioisotope production, radiolabelling, and radiopharmaceutical chemistry, and evaluate their applications in diagnostics and therapeutics such as PET-CT and SPECT.

References:

1. "Organic Chemistry" by Jerry March.
2. "Organic Spectroscopy" by William Kemp.
3. Knoll, G.F. (2010). Radiation Detection and Measurement. 4th Edition, Wiley, Hoboken, 217.
4. D. D. Sood, A. V. R. Reddy, N. Ramamoorthy (2004). Fundamentals of Radiochemistry, Edition 2, Publisher IANCAS.

BS502: Physics, Mathematics and Statistics (45 Lecture Hrs)

Coordinators: M K Ray
(mkray@barc.gov.in)

Course Details:

- **PHYSICS**

- **Atomic structure and electromagnetic radiation**

  Principles of quantization, production and properties of EM radiation, wave/ particle duality.

- **Basic Concepts of light and its principles in spectroscopy and microscopy**

  Beer Lambert's law, concept of fluorescence, Life-time and its measurement; fluorescence quenching, phosphorescence. Monochromators and optical filters, and lenses. Applications of fluorescence in structure/organization of nucleic acids, proteins and membrane. Application of fluorescent proteins in biology. Basics of lasers and their biological applications. Principle and applications of optical traps and optical tweezers.

  Concept of interference, diffraction and polarization; CD and ORD spectra, image formation on retina. Basic concept of light and its principles in photosynthesis in plants, aquatic life and marine biota.

- **Electricity concept in biology**

  Concept of voltage, current and resistance in reference to membrane potential, ion channels and electrophoresis, neuronal communication and cardiac function. Concepts and application of AC and DC in biology.

- **Concept of accelerator, cyclotron and synchrotron and their applications in biology and medicine**

- **Mechanical forces in biology**

  Linear and circular motion concepts with reference to different types of centrifugation.

- **Biosensors**

  Basic principles, applications and limitations

- **MATHEMATICS**

- **Logarithms**

  Definition, laws of logarithms, rule for change of base, common and natural logarithms, characteristic and mantissa, positive and negative bases. Accuracy and precision, number of significant digits.

- **Linear and polynomial equations**

Linear and quadratic equations and identities, slope, roots, relation between roots and coefficients (will be covered in practicals in the context of IRMA assays where polynomials are relevant)

- **Permutations and combinations**

  Permutation and combination, nCr and nPr notations, factorials

- **STATISTICS**

- **Basic concepts**

  Probability, a priori and posteriori probabilities. Statistical significance of probabilities, sample and population, determination of sample size, variables, classification of variables, nominal, ordinal, interval and ratio, fixed and random (examples of different biological research for applications of these concepts)

- **Population distributions**

  Binomial distributions and Poisson distribution – their properties, parameters and applications in biological experiments.

  Normal and‘t’ distributions–population and sample parameters, measures of central tendency, measures of dispersion, variance, degrees of freedom, confidence limits and intervals.

- **Sampling, estimates and hypothesis testing**

  Sampling methods, random sampling and estimates of population parameters from samples, sample statistics, hypothesis testing, drawing inferences and confidence limits, P values. Special cases where variances are unequal, central limit theorem. (examples of different biological research problems for applications of these tests)

  Pearsons’ product moment correlation coefficient, partial and multiple correlation, linear regression analysis; Interpretation of regression coefficients, application of correlation and regression, multiple regression, logistic regression, outliers, multicollinearity and missing data, analysis of covariance. (examples of different biological research problems for applications of these tests)

- **Nonparametric statistics**

  Spearman's coefficient of rank correlation, Chi square test, and nonparametric methods for hypothesis testing based on ranks. (examples of different biological research problems for applications of these tests)

- **Statistics in diagnostic tests and cohort studies**

  ROC curves; Youden’s index, Likelihood ratios; nomogram analysis, determination of cut-off values. Cohort and case- control studies, measures of risk (attributable risk, relative and odds ratio)

- **Tutorials in biostatistics**

Course Outcomes:

- Demonstrate understanding of fundamental physical principles—including EM radiation, optics, electricity, mechanics, and accelerator technologies—and their applications in biological systems and instrumentation.
- Apply mathematical and statistical concepts such as logarithms, equations, probability, distributions, and hypothesis testing to analyze and interpret biological data.
- Integrate physical, mathematical, and statistical approaches to evaluate experimental techniques, biological processes, and diagnostic methods with scientific rigor.

References:

1. Biostatistical Analysis by Jerrold H Zar
2. Essential of Biostatistics by Robert C Elston & William D Johnso
3. Basic and Clinical Biostatistics by Susan E White

BS601: Bio Chemistry (15 Lecture Hrs)

Coordinators: Dr. Kuber C. Bhainsa
(kuber@barc.gov.in)

Course Details:

- **Protein and domain structures, folding and post- translational modification**
  Basics of protein structures (primary, secondary and tertiary): soluble, fibrous, intrinsically Disordered and membrane proteins; Protein ligand interactions; Protein dynamics, folding, chaperones; Protein engineering: rational and; directed evolution; Post-transnational modifications and targeting.

- **Enzymology: Enzyme catalysis and kinetics**
  Determination of kinetic constants; Enzyme inhibition: reversible and irreversible.

- **Irreversible inhibition**
  Mechanisms and therapeutic use with examples Acetyl choline esterase inhibitors.

- **Reversible inhibition**
  Types and mechanisms, determining inhibitory constants with reference to their applications in drug designing and therapeutic applications.

- **Irreversible metabolism**
  Overview of different pathways-their linkages, key intermediates, cellular location of the reactions; importance in human physiology, Diseases linked to metabolic error.

- **Bioenergetics**
  Concepts of enthalpy, entropy, free energy, equilibrium constant and free energy relationship, sequential reaction energy coupling, chemical basis of high energy compounds or bonds, polyphosphates, group transfer and transient signals, redox reactions in biology.

Course Outcomes:

- Helps to understand the interaction of metabolic pathways through their linkages and establish their important roles in various cellular metabolic processes.
- How proteins and their post-translational modifications lead to diverse structure and function
- Understanding organization of the enzyme complex and their role.
- Understanding and application of non-aqueous enzymology
- How biological oxidation and reduction contribute towards electron transport and energy transduction

Reference Books:

1. Fundamentals of Biochemistry, 6th Edition Destin Heilman, Stephen Woski, Donald Voet, Judith G. Voet, Charlotte W. Pratt ISBN: 978-1-119-90348-2, March 2024.
2. Verma, A., Lindroth, A.M. The emerging intertwined activities of metabolism and

epigenetics unveils culprits and prospects in cancer. Exp Mol Med 57, 1928–1939 (2025). https://doi.org/10.1038/s12276-025-01537-7.

3. Wang, H., Shen, M., Shu, X. et al. Cardiac Metabolism, Reprogramming, and Diseases. J. of Cardiovasc. Trans. Res. 17, 71–84 (2024). https://doi.org/10.1007/s12265-023-10432-3

BS602: Bioinformatics (30 Lecture Hrs)

Coordinators: Dr. D. Rath
(devrath@barc.gov.in)

Course Details:

- **Introduction to databases**
  Primary and Derived databases: GenBank, EMBL/EBI, DDBJ, PDB, Swiss-Prot. PRINTS, BLOCKS, rDNA databases. Specialized databases e.g. BioCyc etc.
- **Sequence analysis/alignment techniques**
  Pair wise sequence alignment: local and global alignment, consensus sequence (sequence logo), motifs, patterns, frequency matrices (PAM, BLOSUM), PSSM, log odds score, penalty, introduction to graphical, dynamic programming (Needleman-Wunsch and Smith-Waterman algorithm) and heuristic methods, database similarity searches-BLAST/FASTA algorithms.

  Multiple sequence alignment, clustering, dendrogram/tree construction, molecular phylogeny.
- **Genomics and high-throughput analysis**
  Next generation sequencing (NGS) and different platforms (pyrosequencing, ion-torrent, Illumina, SOliD, SMRT, Nanopore), exome sequencing, transcriptome sequencing, NGS data quality assessment and introduction to de-novo or reference-based assembly, comparative genomics, microarrays and applications.
- **Bioinformatics applications in proteomics**
  Introduction to mass spectrometry-based proteomics, MASCOT, protein sequence database and their use, gel based and gel free quantitative proteomic approaches, interpretation and validation of proteomics results, functional proteomics.
- **Structural biology and structural bioinformatics**
  Theory and practices of protein crystallography, introduction to the protein structural databases (PDB, CATH, SCOP etc.).
  Instrumentation: structural/functional genomics initiatives, evolution of structural motifs and molecular evolution (convergent/divergent evolution), structure prediction methods with particular focus on homology/comparative modelling and threading, structural validation approaches, protein structures in biotechnology (rational drug design/protein engineering etc.)

Course Outcomes:

- Demonstrate understanding of major biological databases, sequence alignment methods, phylogenetic analysis, and NGS-based genomics workflows for data interpretation and comparison.
- Apply bioinformatics tools in proteomics and structural biology—including mass spectrometry analysis, structure prediction, modelling, and validation—to study protein function and molecular evolution.
- Integrate computational approaches across genomics, proteomics, and structural bioinformatics to support biological research, biotechnology, and rational drug design.

References:

1. Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins Editor(s): Andreas D. Baxevanis, B. F. Francis Ouellette First published:22 July 1998 Print ISBN:9780471324416 |Online ISBN:9780470110607, DOI:10.1002/9780470110607
2. Essential Bioinformatics, Author: Jin Xiong, Publisher: Cambridge University Press, ISBN:9780511806087, DOI: https://doi.org/10.1017/CBO9780511806087
3. Introduction to Bioinformatics Fifth Edition by Arthur Lesk, ISBN: 9780198794141, Publisher: Oxford University Press.
4. Bioinformatics: Sequence and Genome Analysis, Second Edition By David Mount ISBN 978-087969712-9 Cold Spring Harbor Laboratory Press

BS603: Cell Biology & Immunology (23 Lecture Hrs)

Coordinators: Dr. Deepak Sharma
(dsharma@barc.gov.in)

Course Details:

- **Cell cycle and cell death**

  Predivision stages, G1, S, G2 and M phases and their significance. Genetic regulation of cell cycle and experimental approaches for cell cycle regulations. Different modes of cell death and its assessment.

- **Signal transduction in animal systems**

  Receptors (membrane linked and cellular) receptors with enzyme activity, G proteins, tyrosine kinase related transduction, preview of three modes of signaling (MAP kinase pathway, NFKB pathway and JAK/STAT signaling), Radiation induced signal transduction and cell death pathways, Cytoprotective and cytotoxic pathways, Cross communication, Bystander effects.

- **Immunology**

  Innate and acquired immunity; Cell and organs of the immune system; Immunocompetent cells and their sub populations; Antigen presentation; T cell and B cell maturation and activation; Cytokines; Tolerance and autoimmunity.

  Antibodies structure and diversity; affinity and avidity; hybridomas; T cell receptor, structure and diversity; MHC structure and polymorphism; MHC restriction; Immuno-deficiency; vaccines and immune-therapeutics.

- **Stem Cell Biology**

  Stem cell characteristics and regenerative potential; Sources of stem cells (embryonic, umbilical cord and adult tissues); stemness associated genes, asymmetric division; Stem cell therapy; Methods of identification, isolation and characterization.

Course Outcomes:

- Demonstrate understanding of cell cycle regulation, modes of cell death, and major signaling pathways—including radiation-induced responses—and their roles in cellular homeostasis and stress adaptation.
- Explain the components and mechanisms of innate and adaptive immunity, including antigen recognition, lymphocyte activation, cytokine networks, immunodeficiency, and principles of vaccines and immunotherapies.
- Describe the biology, sources, molecular regulation, and therapeutic potential of stem cells, along with methods for their identification, isolation, and characterization.

References:

1. Molecular Cell Biology 7th Edition (Alberts)
2. Molecular Biology of the Cell (Lodish)
3. Kuby Immunology 8th Edition

BS604: Crop Science (30 Lecture Hrs)

Coordinators: Dr. (Mrs.) Archana Joshi-Saha
(archanaj@barc.gov.in)

Course Details:

- **Mendelian genetics, Genetic maps and heteroploids in crop improvement**
  Mendelian Genetics, gene interaction, recombination, DNA markers, simple sequence repeats, SNPs, linkage maps, MutMap, cytoplasmic inheritance, male sterility, transposible elements; Gene transfer methods, chromosome engineering for crop improvement.

- **Quantitative genetics**
  Qualitative Vs quantitative traits, nature of variability, components of variation; heritability; genetic advance, genotype x environment interaction and genetic advance. Types of gene actions and its implications in plant breeding. Hardy-Weinberg principle and gene frequency. Genetic basis of breeding self- and cross-pollinated crops.

- **Principles of plant breeding**
  Plant Introduction, germplasm exchange and plant quarantine. Breeding methods in self-pollinated crops-pure line selection, mass selection, pedigree, bulk and single seed descent method. Breeding methods in cross pollinated crops: Mass selection, progeny testing, recurrent selections, synthetics and composites; heterosis breeding.

- **Mutation breeding**
  Nature and classification of mutations, spontaneous mutations and induced mutations, methodology for mutant screening for oligogenic and polygenic traits, estimating mutagenic efficiency and effectiveness. Procedure for release of crop varieties for commercial cultivation.

- **Breeding for biotic stress tolerance**
  Concepts in pathogen resistance; Host defense response to pathogen invasions-Biochemical and molecular mechanism; acquired and induced immunity and systemic acquired resistance (SAR). Host pathogen interaction, gene for gene hypothesis, Horizontal and vertical resistance in crop plants.
  Epigenetic modifications and speed breeding procedures for crop improvement.

- **Abiotic stress tolerance**
  Stress inducing factors-Drought, salinity, heat and heavy metal toxicity; Physiological and phenological response, genetics of abiotic stress tolerance and breeding methodologies.

- **Radiation in insect pest control**
  Importance of insect pests, vectors and their management, IPM concepts, insect resistance in crop plants, mechanism, sources, screening methodologies and strategies

use of radiation and endosymbionts in pest control-SIT and F1 inherited sterility.

- **Soil science**

  Types of soil, manures and fertilizers, testing and analysis of soil nutrients, behaviour and fate of pesticides in ecosystem, pesticide residue analysis, isotope application in soil nutrient management and reclamation of saline and alkaline soils

- **Plant tissue culture**

  Methods in plant cell tissue and organ culture, regeneration pathways-organogenesis and somatic embryogenesis, haploid production in crop plants and in vitro mutagenesis, apomixis, secondary metabolites in in vitro culture, plant metabolic engineering.

Course Outcomes:

- Demonstrate understanding of Mendelian, quantitative, and molecular genetics—including mapping, gene interactions, breeding methods, mutation breeding, and stress-tolerance mechanisms—for effective crop improvement.
- Apply principles of plant breeding, plant–pathogen interactions, abiotic and biotic stress management, and radiation-based pest control to develop resilient and high-yielding crop varieties.
- Explain and utilize key techniques in soil science, plant tissue culture, metabolic engineering, and isotope applications to support sustainable agriculture and advanced crop biotechnology.

References:

1. Falconer (1996, 4th Ed.): Falconer, D.S., & Mackay, T.F.C. (1996). Introduction to Quantitative Genetics (4th ed.). Addison Wesley Longman.
2. Principles of Genetics by Eldon John Gardner
3. Plant Breeding - Principals & Methods by BD Singh
4. Insecta: An Introduction and Principles of Applied Entomology by K.N. Ragumoorthi
5. Elements of Applied Entomology by B.V. David
6. Plant Tissue Culture: Theory & Practice by MK Razdan & SS Bhojwani
7. Abiotic Stress Signaling and Responses in Plants (http://dx.doi.org/10.1016/j.cell.2016.08.029)
8. Designing salt stress-resilient crops: Current progress and future challenges (https://doi.org/10.1111/jipb.13599)

BS605: Food Technology (30 Lecture Hrs)

Coordinators: Dr. (Smt.) Sweetie Kanatt
(srkanatt@barc.gov.in)

Course Details:

- **Food processing & preservation**
  - Post- harvest losses of food: Causes and impact.
  - Processing and preservation: Basic concepts, Conventional and advance methods (hurdle technologies, Pasteurization, sterilization, canning and retort, extrusion processing -type and components of extrusion and applications of technology).
  - Effects of processing on nutritional and other quality parameters of food.
  - Emerging technologies: Applications of UV, microwave, infrared, radio waves, ultrasonic waves in food processing, high pressure, ozone processing, Ohmic heating and pulse electric field in food processing.

- **Radiation processing of food for Safety, Security and International trade**
  - Overview and Basic concept of food irradiation Applications of food irradiation and underlying mechanism Dose limit, regulatory approval and labelling Wholesomeness and safety of irradiated food Global and Indian scenario of food irradiation
  - Interaction of radiation with food components
  - Radiation sources used (Gamma/ E- beam/ X-rays): Production and decay, Concept of half-life and energy level, Comparative advantages and limitations of these radiation sources, Basic principles of food irradiation dosimetry
  - Effect of radiation processing on major (carbohydrate, protein, Fat) and minor food ingredients (Vitamins etc.)
  - Effects of radiation processing on different quality parameters of food
  - Detection of irradiated food

- **Radiation processing plant**
  - Design, throughput, regulatory approvals and safety.

- **Microbial spoilage of Food**
  - Food spoilage-causes and factors, spoilage microorganisms, food borne pathogens
  - Methods for rapid detection of microorganism in food
  - Radiation inactivation of microorganisms, target theory, concept of decimal reduction, D10 value, 12-D concept, factors affecting radiation sensitivity of microorganisms.

- **Food & Microbes**
  - Introduction to microbial strain development for industrial applications. Genetic Circuit-Assisted Smart Microbial Engineering (SME). Use of microbes for production of antibiotics, food ingredients, enzymes and nutraceuticals.
  - Inter species, intra species communication in microbes (quorum sensing).

- Phage therapy. Intracellular pathogenic bacteria, Manipulation of host immune system by bacterial pathogens (eg. Mycobacterium).

- **Human nutrition and Functional Foods**

  - Macro & micronutrients, RDA, consequences of improper intake of the nutrients, glycemic index, glycemic load
  - Overview of diet related diseases
  - Dietary intervention and gut microbiota
  - Specialized food (e.g. sports-food, space food, high-altitude food, emergency rations)
  - Functional foods, probiotics, prebiotics.
  - Nanotechnology in food and nutrigenomics
  - Microbiome in human health and emerging trends in study of gut microbiota.

- **Non-nutritional parameters of the food**

  - Food texture, Color and flavors
  - Use of food additives
  - Food flavour: isolation and encapsulation.

- **Food packaging and coating applications**

  - Packaging and biopolymer material and their properties, natural and non-natural ingredients, active packaging, Intelligent or smart packaging, MAP, edible film and coatings. Food package labelling

Course Outcomes:

- Demonstrate understanding of food processing, preservation, and emerging technologies—including radiation-based methods—for maintaining nutritional quality, safety, and global trade compliance.
- Apply knowledge of microbial spoilage, foodborne pathogens, and microbial engineering approaches to ensure food safety, develop functional foods, and utilize microbes for industrial applications.
- Analyze human nutrition, functional foods, food additives, packaging technologies, and novel applications such as nanotechnology and nutrigenomics to support health, quality, and innovation in the food industry.

References:

1. Safety of Irradiated Foods, By J.F. Diehl
2. Prescott's Microbiology ISE (Paperback), Authors: Joanne Willey, Dorothy Wood, Kathleen Sandman Publisher: McGraw-Hill Education
3. Brock Biology Of Microorganisms, Microbiology, Authors: Madigan Michael T., Martinko John M., Bender Kelly S., Buckley Daniel H., Stahl David A. Publisher: Pearson
4. Quorum Sensing and its Biotechnological Applications, Editors: Vipin Chandra Kalia,

Publisher: Springer Singapore
5. Implication of Quorum Sensing and Biofilm Formation in Medicine, Agriculture and Food Industry, Authors: Pallaval Veera Bramhachari, Publisher: Springer Singapore
6. Molecular Genetics of Bacteria, 5th Edition, Authors: Tina M. Henkin and Joseph E. Peters, Publisher: ASM Press
7. Bacteriophages: Biology, Technology, Therapy, Editors: David R. Harper, Stephen T. Abedon, Benjamin H. Burrowes, Malcolm L. McConville Publisher: Springer
8. Industrial Microbiology: An Introduction, Authors: Michael J. Waites, Neil L. Morgan, John S. Rockey, Gary Higton, Publisher: Wiley-Blackwell
9. Detection Methods for Irradiated Foods—Current Status, Article in Comprehensive Reviews in Food Science and Food Safety, January 2009, DOI: 10.1111/j.1541-4337.2008.00063.x

BS606: Cancer Biology (23 Lecture Hrs)

Coordinators: Dr. Amit Kumar
(amitk@barc.gov.in)

Course Details:

- **Introduction to cancer biology**
  Evolutionary perspective of cancer; carcinogens (biological, chemical and physical), etiology of cancer: DNA repair, genome integrity and epigenetics.

- **Cellular and molecular biology of cancer**
  Hallmarks of cancer; oncogenesis and tumour suppression; hormones and cancer; signalling pathways in cancer, cell cycle control, deregulated cell death process; telomerase, immortalisation, senescence. Tumor anatomy and hypoxia

- **Cancer cell metabolism**
  Altered glucose metabolism; altered metabolic enzyme expression: mutation of oncogenic isocitrate dehydrogenase, fumarate hydratase, succinate dehydrogenase mutation, arginine succinate synthase 1; upregulated glutaminolysis and serine addiction; metabolic symbiosis; metabolic dependencies and collateral lethality.

- **Tumor metastasis, invasion and dormancy**
  Benign and malignant tumor; stages and grading of tumor; systemic spread of cancer cells: disseminated and circulating tumor cells; epithelial-to-mesenchymal transition (EMT) during development and metastasis; cellular and molecular drivers of metastasis; the role of hematopoietic and stromal cells in metastatic progression; metastatic latency.

- **Tumor micro-environment**
  Cancer associated stroma, angiogenesis; cancer immunology: tumour resistance to immune mediated control and elimination.

- **Treatment modalities and recent advances in cancer therapy**
  Chemotherapy (natural, dietary and synthetic drugs), immunotherapy (antibody and cell-based therapy); nanoparticle- based cancer imaging and therapy; cancer stem cells: role in cancer relapse after chemo/radiotherapy, targeting CSC; metastasis treatment; development of personalized medicine.

- **Cytogenetics**
  Constitutional anomalies: Numerical and structural, causes and their implications in human health. Chromosomal disorders.

- **Molecular Genetics**
  Non-Mendelian inheritance of single gene disorders, monitoring and screening of human population, copy number variations, association studies,
  Genome Mapping: somatic cell hybrids, radiation hybrids, contigs, chromosome walking.

Course Outcomes:

- Demonstrate understanding of fundamental concepts in cancer biology, including carcinogenesis, hallmarks of cancer, genomic integrity, epigenetics, tumor metabolism, metastasis, and tumor microenvironment.
- Analyze cytogenetic and molecular genetic principles—such as chromosomal anomalies, non-Mendelian inheritance, genome mapping, and population screening—and their relevance to human health and cancer susceptibility.
- Evaluate major cancer treatment modalities and recent therapeutic advances, including chemotherapy, immunotherapy, nanoparticle-based strategies, cancer stem cell targeting, and development of personalized medicine.

References:

1. Review: Hallmarks of Cancer, Cell by Weinberg and Hanahan
2. Book: Cancer by R. Weinberg (Latest edition)
3. Book: Radiobiology for the Radiobiologists by Eric Hall

BS607: Microbiology & Biotechnology (21)

Coordinators: Dr. Shashidhar
(shashi@barc.gov.in)

Course Details:

- **Growth, identification and diversity in bacteria**

  Concept of pure culture. Bacterial growth curve- lag, log and stationary phase; growth advantage in stationary phase (GASP) phenotype, small colony variant (SCV). Viable but Non-culturable bacteria (VBNC) and dormant cells.

  The 16S rRNA based identification of bacteria.

  Effect of bacteria on plant health (bacterial plant pathogens and beneficial interactions between bacteria and plants).

- **Microbial Genomics**

  Genomic organization of bacterial viruses, integration into host genome and packaging (list types of bacterial viruses and explain one virus eg. lambda). Transformation, transduction and conjugation.

  Types of recombination. Models of recombination, genetics and biochemistry of recombination. Artificial genome synthesis and generation of Mycoplasma laboratorium (synthetic bacterium).

- **Gene mutation and applied microbiology**

  Discovery of mutations, Types of mutations, molecular events that cause different types of mutations and their properties. Methods to detect different types of mutations. Generation, detection and characterization of conditional mutations and suppressor mutations. Generation and verification of single gene knock out library in E. coli (Keio collection).

- **Antibiotic resistance: challenges and treatment**

  Antibiotic resistance: Mechanism and challenges. Persister cells. Novel methods of discovery of new antibiotics (eg. Teixobactin).

- **Biofouling**

  Biofilms: concept, types, measurement and visualization. Biofouling and bio-corrosion: cause and concern. A case study of biofouling and bio-corrosion in a nuclear reactor. Detection and remedial measures.

Course Outcomes:

- Demonstrate understanding of bacterial growth dynamics, identification methods, microbial diversity, and plant–microbe interactions, including VBNC states, dormancy, and 16S rRNA–based taxonomy.
- Explain microbial genomics, gene mutation mechanisms, horizontal gene transfer, recombination models, and applications such as synthetic genome construction and generation of knockout libraries.

- Analyze antibiotic resistance mechanisms, persister cell biology, biofilm formation, biofouling, and bio-corrosion, along with strategies for detection, prevention, and discovery of new antimicrobial approaches.

References:

1. Prescott's Microbiology ISE (Paperback), Authors: Joanne Willey, Dorothy Wood, Kathleen Sandman, Publisher: McGraw-Hill Education.
2. Brock Biology of Microorganisms, Microbiology, Authors: Madigan Michael T., Martinko John M., Bender Kelly S., Buckley Daniel H., Stahl David A., Publisher: Pearson.
3. Snyder and Champness Molecular Genetics of Bacteria, 5th Edition, Authors: Tina M. Henkin and Joseph E. Peters, Publisher: ASM Press.
4. Genetics: Analysis and Principles, 6th Edition, Authors: Robert J. Brooker, Publisher: McGraw-Hill Education.

BS608: Molecular Biology (30 Lecture Hrs)

Coordinators: Dr. Sheetal Uppal
(sheetal@barc.gov.in)

Course Details:

- **DNA replication**

  Regulation of DNA replication in prokaryotes and eukaryotes. Replication Licensing. Replication stress, fork stalling, reversal and collapse. Interplay between replication fork progress and dormant origin. Gene dosage regulation. Replication-Coupled DNA Repair, Replication-coupled recombinational repair and genomic stability, break-induced repair (BIR).

- **Regulation of gene expression**

  An overview and comparison of transcription in prokaryotes and eukaryotes covering the enzymes involved, the process of transcriptional initiation, elongation and termination.

- **Gene regulation**

  Differences in the promoter elements of prokaryotes eukaryotes. In prokaryotes: Operon concept in brief, tyrosine phosphorylation, noncoding RNA's in regulation, antisense RNAs, secondary structure of mRNAs, riboswitches. In eukaryotes: Epigenetic changes, chromatin remodelling, stress responsive alternate splicing, yeast gal gene as template for eukaryotic regulation.
  Mechanistic and structural aspects protein synthesis and its regulation.

- **RNA biology**

  An overview of functional diversity of RNAs, Structure and function of important non-coding RNAs (tRNAs, rRNAs, snRNAs, snoRNAs). Secondary and tertiary RNA motifs and their importance. Sub-cellular trafficking of RNAs. Mechanisms of tRNA maturation. RNA protein complexes (ribosome, telomerase, spliceosome). RNA interference, Small and long ncRNAs: biogenesis, mechanism of action and biotechnological applications. RNA aptamers and SELEX protocol. DNA/RNA nanostructures and applications.

- **DNA damage and repair**

  Radiation and chemical mutagens induced DNA damages and their detection. Repair mechanisms in bacteria and higher eukaryotes, cell cycle specific repair, pathway choice and their regulation. Real time assessment of DNA repair in in live cells. DNA repair proteins at single molecular leve

  - **Molecular biology tools**

    Enzymes in molecular biology and their applications. Cloning and expression approaches (vectors, affinity tags, expression systems). Gene knockdown/knockout technologies in prokaryotes and eukaryotes with a special emphasis on RNAi and CRISPR-Cas technologies.

Course Outcomes:

- Demonstrate understanding of DNA replication, gene expression, gene regulation, and RNA biology, including mechanisms that maintain genomic stability and control cellular function in prokaryotes and eukaryotes.
- Apply knowledge of DNA damage, mutagenesis, and diverse DNA repair pathways to evaluate genome maintenance processes and experimental approaches for assessing repair dynamics in live cells.
- Utilize molecular biology tools, such as cloning, expression systems, RNAi, and CRISPR-Cas, to analyze, manipulate, and regulate genes and RNAs for research and biotechnological applications.

References:

1. Molecular Biology of the Cell (by Alberts Bruce)
2. Molecular Biology (by David and Freifelder)
3. Genes by Benjamin Lewin

BS609: Radiation Biology (30 Lecture Hrs)

Coordinators: Dr. (Mrs.) Anu Ghosh
(anugh@barc.gov.in)

Course Details:

- **Introduction to radiation biology**
  Radiation-induced free radical generation in biological systems; radiation units; direct and indirect effect; concepts of LET and RBE. Survival curves of different radiation types; concept of D10, D0, Dq, extrapolation number, linear quadratic model of radiation damage.

- **Effects of radiation on microbes & plants**
  Radiation response and molecular mechanisms of extreme radioresistance in microbes, Internal and external radiation exposure to plants. Effect of radiation on photosynthesis and respiration. Bio-indicator plants.

- **Radiation injury and radioprotection**
  Biological effects of free radicals; biological defense against free radicals. O2 effect, radiosensitive and resistant tissues, acute radiation syndromes – bone marrow syndrome, gastrointestinal syndrome and cerebrovascular system syndrome. Sub-lethal and potentially lethal damage and recovery, physical, chemical and biological factors modifying radiation damage. Chemical and cell- based radio-protection.

- **Heavy metal radionuclides**
  Chemical and radiobiological toxicity of internalized radio-nuclides and their mechanisms of interaction with biomolecules. Biological strategies for decorporation and medical management of internalized radio-nuclides.

- **Radio-sensitization and radiotherapy of cancer**
  Basic concepts, concept of four Rs in radiation biology, chemical radio-sensitizers and their applications in radiotherapy of cancer. Particle beam therapy. End points for in vitro and in vivo cell survival. Dose fractionation, biologically effective dose for teletherapy, IGRT, IMRT, brachytherapy, MFD and CHART. Radio- resistance of tumor cells: cellular and molecular mechanisms of radio-resistance. Hyperthermia and modification of radiation injury.

- **Bio-dosimetry for radiation exposure**
  Dose response relationship, utero exposure, risk estimation of genetic diseases and malformations. Biological dosimetry: partial and whole-body exposure, calibration curves, cytogenetic and molecular end points: dicentrics, translocations, CBMN assay, pancentromeric, telomeric and whole chromosome FISH, premature chromosome condensation, HPRT assay, comet assay, gamma-H2AX foci.

- **Radiation risk assessment, low dose radiation effects and bystander effect**
  Epidemiological studies in radiation risk assessment. Estimation of radiation risk estimation at population level; radiobiology of major radiological incidents/nuclear accidents (A-bomb survivors, Mayak Plant, Chernobyl and Fukushima, Mayapuri Incident). High background radiation areas and low dose radiation effects; concept

of DDRF, LNT and radiation hormesis. Radiation induced bystander and abscopal effects.

Course Outcomes:

- Demonstrate understanding of fundamental radiation biology concepts—including radiation interactions, survival curves, radioprotection, radiosensitization, and cellular responses to low- and high-dose radiation.
- Analyze the biological effects of radiation on microbes, plants, humans, and radionuclide toxicity, along with mechanisms of injury, defense, decorporation, and therapeutic applications such as radiotherapy.
- Apply principles of biodosimetry, radiation risk assessment, epidemiological evidence, and cytogenetic/molecular endpoints to evaluate radiation exposure and its health consequences.

References:

1. Radiobiology For the Radiologist: Authors: Eric J Hall & Amato J. Giaccia (Wolters Kluwer).

NON-SUBJECT ASSIGNMENTS

BS592: Laboratory Techniques in Life Sciences (12 Credits)

Course Details:

- **Cell Biology Techniques**
  Chromosomal analysis with mammalian cells metaphase preparation, micronuclei, G-banding, chromosomal aberrations, cytogenetic effects of radiation.
  Immunology: ELISA, isolation of lymphocytes from lymphoid tissues and peripheral blood, immunophenotyping of T and B cells, E-rosettes and PFC assays, tissue culture methods, blast transformation, cytokine assays. Flow cytometry
  Radio-immunoassay and related procedures and tracer distribution in animals.

- **General techniques**
  Confocal microscopy, TLC, GC-MS, mass spectrometry, ESR, IR, NMR/ FT-NMR, Affinity purification of tagged proteins, Polyacrylamide Gel Electrophoresis, Electrophoretic resolution of proteins (1D & 2D), western blotting & immunodetection Pulse field gel electrophoresis (PFGE) Enzyme and cell Immobilization, permeabilization.

- **Molecular Biology and Microbiology**
  Transduction, conjugation, repair of UV induced damage, screening of markers Isolation and Purification of DNA from Plants (difference in protocol of DNA isolation from bacteria and mammalian cell-demonstration) & MicroRNA isolation and characterization demonstration of Southern Hybridization Total RNA From Mammalian Cells, Polymerase Chain Reaction, Amp-FLP, silver staining, cDNA synth, RT-PCR, Microbiology: Enumeration of bacteria –plating techniques, radiation survival curve.

- **Radiation Techniques**
  Radiation Biology & Radiation Measurements:
  Radioisotope tracer techniques and radiation measurements, GM counting system, counting statistics; half-life, absorption and scattering, isotope dilution, crystal scintillation counting Chemical dosimetry& ESR.

  - **Food Irradiation**
    Hurdle technology (water activity, antioxidants, packaging & gamma irradiation), analysis (microbial, chemical & sensory)

  - **Plant tissue culture and biotransformation**

  - **Drug delivery/liposome preparation**

  - **SEM**

- **TEM**

- **Stem cell culture**

Course Outcomes:

- Learning of experimental design
- Learning of experimental design
- Planning and execution of experiments
- Data interpretation and data presentation
- Special training in handling of radioactive materials in biological experiments
- Hands on experience of latest instrumentation.
- This course would impart latest and relevant practical approach to address the biological research problems.
- To cultivate the art of communication and presentation
- To make them understand and present scientific papers
- To add professional ability and personality development in trainees.

BS594: Seminars (4 Credits)

Course Details:

This module is designed for cultivating the art of communication and presentation in the trainees and helps towards value addition to the professional ability and personality development of the trainees.

- **Paper Seminar**

  Seminar on a selected paper published by reputed scientists. The purpose of the paper seminar is to prepare the trainee to acquire skills in the presentation of published research work. Aspects such as analysis of the experimental data, details discussion on the results and hypothesis presented and drawing of meaningful conclusions are expected to be inculcated during the process. In addition, the trainee is encouraged to point out the strengths and lacunae if any in the publication and suggest feasible steps to enhance the quality of the publication.

- **Review Seminar**

  Seminar on a review to be presented by trainees. Broad areas/processes/topics/concepts of current research interest are communicated to the trainees for choosing a topic for review. The seminar committee allocates the review topic to the trainee from amongst the topics submitted by him/her based upon the suitability, interests and aptitude of the trainee. The trainee is expected to review as many papers as feasible on the specified topic and submit a brief summary on the review topic assigned followed by an open defense. A senior HBNI faculty in Biosciences is assigned as a mentor to each trainee to guide them.

RESEARCH METHODOLOGY (20 Lecture Hrs)

Course Details:

- **Scientific research and documentation**

  - **Scientific research:** Definition, characteristic, types and need of research, Identification of problem, Literature survey and assessment of its current status, formulating objectives, approach to solve the problem, designing the experiment, actual investigation to achieve the objectives, results and discussion.

  - **Documentation and writing:** Types of report; research paper, project reports, thesis, Seminar presentation. Preparation of manuscript for publication- research, review paper and thesis writing.

- **Application of computer in research, data handling and presentation**
  Use of word processing, spreadsheet and database software. Plotting of graphs. Internet and its application: Email, WWW, Web browsing, acquiring technical skills, drawing inferences from data, multimedia and power points.

- **Occupational safety, health and environment at work place**
  Regulatory framework of BARC, Atomic Energy Act 1962, Atomic Energy Factory Rules, Radiation Protection Rules, Surveillance of occupational health, Medical care and management of Internal contamination. Radiation safety, Fire safety, Electrical safety and Chemical safety.

- **IPR and research ethics**
  Ethical issues – ethical committees - Commercialization - Copy right - Royalty - Intellectual property rights and patent law – Trade Related aspects of Intellectual Property Rights - Reproduction of published material - Plagiarism - Citation and acknowledgement - Reproducibility and accountability

Course Outcomes:

- To give the idea of scientific research and documentation
- To explain them various approaches for research data handling and presentation
- To make them aware about IPR, research ethics and safety at workplace

References:

1. Research Methodology: Methods and Techniques by C.R. Kothari,
2. The Craft of Research" by Booth, Colomb, & Williams,
3. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches" by John W. Creswell,
4. Hofmann, Angelika H. — Scientific Writing and Communication: Papers, Proposals, and Presentations
5. Academic Research Writing Artistry by Srujan MJ
6. Act, Rules available in the websites of BSC (BTS), DAE and AERB. (http://bts.barc.gov.in/AuthStatic/auth_static.php/BSCweb/actsrules.html)
7. BSC Safety Manual on ‘Radiation Protection Manual for BARC Facilities’ BSC

Safety Manual No. (BSC/SM/2020/3 Rev.-0 http://bts.barc.gov.in/AuthStatic/auth_static.php/BSCweb/bscpubli.html)

8. Electrical Safety, Fire Safety Engineering and Safety Management Author Prof. Sunil S. Rao, R.K. Jain and Prof. H.L. Saluja.

ELECTIVE COURSES

BS701: Advances In Enzyme Technology (75 Lecture Hrs)

Coordinators: Dr. Jitendra Kumar
(jkumar@barc.gov.in)

Course Details:

- **Enzyme application in Biosensors**

  Concept and methods, its application in agriculture, food, environment and medical.

  - Overview of Enzymes applications in the field of Biotechnology, Trend of market for enzyme in Industry (Agriculture, Clinical/pharmaceuticals, Xenobiotics metabolism and bioremediation, other industrial applications like textiles, detergents, paper and leather)

  - Computational enzymology, Non-aqueous enzymology and understanding molecular docking and drug design

Enzyme production, Enzymes from extremophiles, Enzyme stabilization through immobilization and enzyme engineering and pathway design for novel products.

Course outcome:

The students will learn production of enzymes from both natural resources and extremophiles, how to stabilize them through immobilization, how to engineer and design pathways for new products, how they are used in biotechnology, and how the market for enzymes in industry is trending, including how they could potentially be used in biosensors. In order to comprehend non-aqueous interactions, molecular docking, and drug creation, advanced computational enzymology is also incorporated.

Reference Books:

1. Biosensors: Fundamentals and applications – Anthony P F Turner, DOI: 10.1016/j.bios.2014.10.027.
2. Biosensors: Fundamentals and Applications Hardcover – Import, 4 March 2019 by Chandra Mouli Pandey (Author), Bansi Dhar Malhotra (Author).
3. Advances in Enzyme Technology by Ram Sarup Singh, Reeta Rani Singhania, Ashok Pandey,Christian Larroche (2019); Elsevier publication.
4. Immobilization Strategies: Biomedical, Bioengineering and Environmental Applications (Gels Horizons: from Science to Smart Materials) Hardcover – 29 October 2020 by Anuj Tripathi (Editor), Jose Savio Melo (Editor)
5. Immobilization: Then and Now January 2021 DOI: 10.1007/978-981-15-7998-1_1

BS702: Assessment Of Health Effects From Exposure To Low Levels Of Ionizing Radiation (75 Lecture Hrs)

Coordinators: Dr. K Vinay Jain
(vinayj@barc.gov.in)

Course Details:

- **Introduction to low dose ionizing radiation (LDIR)**
  Definition of low dose, units of radiation dose, Introduction to various international committees i.e UNSCEAR, ICRP etc. Sources of exposure to radiation in humans - natural and man-made, detection of ionizing radiation – physical and biological. Overview of various high-level natural radiation areas of the world.

- **Biological effects of LDIR on human population**
  Differential biological responses at high vs low doses & Chronic vs acute doses. Effect of dose-rate and prolonged exposure. Non- targeted effects, Effect on occupationally exposed population and nuclear accidents.

- **Effect of LDIR on immunity, life span and cancer risk**
  Beneficial effects of LDIR, Effect of LDIR on lifespan, DNA damage and cancer risk, etiology of cancer at different sites, dose and dose rate effects on tumor induction, Role of immune system in cancer, effects of low doses of radiation on the immune system, effect of LDIR in animal models, genetic susceptibility to cancer**.**

- **Introduction to Epidemiology & Research Methodology**
  Collection of epidemiologic data, types of epidemiological studies, cohort and case control studies, statistical power, Analysis of epidemiologic data, Linear relative risk model, Interpretation of epidemiological data, assessment of association and dose response relationship. Steps involved in planning and designing a research study, Formulating answerable questions, testable hypothesis, study designs & experiment, data collection & management, statistical analysis and conclusions.

- **Heritable and non-heritable effects of radiation in human population & Medical Radiation studies**
  Genetic diseases i.e mendelian, multifactorial and chromosomal diseases, Risk estimation of different classes of genetic diseases, Doubling dose estimates, concept of mutation component. Medical uses of radiation, Radiotherapy for malignant and benign diseases, diagnostics, evaluation of risks for specific cancer sites. Medical and Dental occupational exposures. LDIR effect on population living around nuclear facilities, population exposed atmospheric testing, fall out or other environmental release of radiation and population exposed to natural background radiation

- **Atom Bomb Survivor Studies and Risk Assessment models**

  Description of different cohorts i.e Life span study cohort etc, dosimetry, cancer data (solid, site specific), benign neoplasms and non-neoplastic disease. Risk assessment methodology and models (LNT vs threshold vs hormesis vs hypersensitive).

- **Hands on Training (Practical)**

  - Introduction to statistical packages. Preparation, exploration and analysis of sample dataset, data visualization using graphical tools. Introduction to different tools to analyze high throughput proteomics, genomics and transcriptomics data, Training on the submission of proteomics and sequencing data to public repositories - hands on training.

  - Introduction to different cytogenetic and molecular assays involved in studying radiation effects in human cells.

Course outcome:

After completing this course, students will gain a comprehensive understanding of sources, measurement, and biological effects of low-dose ionizing radiation in human populations. They will be able to critically evaluate epidemiological and experimental evidence related to cancer risk, immune modulation, heritable effects, and radiation risk models at low doses. Students will develop competency in interpreting epidemiological data, risk assessment models, and international radiation protection frameworks. The course will also equip students with practical skills in statistical analysis, omics data handling, and cytogenetic/ molecular assays relevant to radiation biology research and public health applications.

References:

1. The History of the Linear No-Threshold Model and Recommendations for a Path Forward (DOI: 10.1097/HP.0000000000001645)

2. Health Effect of Low-Dose-Rate Irradiation with Cumulative Threshold Dose: A Promising Area to Explore in Nuclear Emergency and Environmental Contamination (https://doi.org/10.3390/cells13181521).
3. High Natural Background Radiation Areas: A Literature Review that Reveals Systematic Adaptive Response but Controversial Data With Single Dose (DOI: 10.1177/15593258251330680)
4. Proposed Priorities for Low-Dose Radiation Research and Their Relevance to the Practice of Radiology (https://doi.org/10.1148/radiol.222590).

BS703: Biology Of Stress And Adaptive Response In Bacteria (75 Lecture Hrs)

Coordinators: Dr. (Smt.) Hema R
(hemaraj@barc.gov.in)

Course Details:

- General features of organization and regulation of bacterial stress response Introduction to cyanobacteria and genetic manipulations for assessment of tolerance.
- Heat-shock and cold-shock response
- Stationary Phase response
- Toxin-antitoxin systems for stress management
- DNA damage and repair in cyanobacteria
- Biotechnological Applications
- Salinity, osmotic stress Response and potassium signalling
- Enzymatic Management of Cyanobacterial Oxidative Stress
- Multiple stress tolerances of Deinococcu radiodurans and its assessment
- Biochemical characteristics of SSB and its role in DNA repair
- Microbial responses to heavy metal toxicity and uranium bioremediation

Laboratory Work 6 hours each day for 10 working days

BS704: Challenges For Clean And Sustainable Environment (75 Lecture Hrs)

Coordinators: Dr. S.T. Mehetre
(smehetre@barc.gov.in)

Course details:

Theory:

- **Introduction to sustainability**
  Introduction and concept of sustainability Sustainability: Practical way to understand the concept Sustainability in view of climate change. Carbon credit and its relevance.
- **Concept of solid waste management with special reference to Nisargruna Biogas plant**
- **Composting technology as an alternative to air pollution by burning crop residues, dry leaves etc**
- **Environmental pollution management with respect to Heavy metals bioremediation**
- **Environmental pollution management with respect to chemical pesticides**
- **Role of biopesticides and biofertilizers in sustainable agriculture**
- **Waste water treatment technology options and deployment**
- **Role of nanotechnology for sustainable agriculture**
- **Practical ways to implement sustainability. Successful examples of environment management, pollution control, waste management**

Practical's:

- **Analysis of different gases including methane by gas chromatography**
- **Pesticide residue analysis by GC, HPLC, TLC**
- **Fate and behaviour of heavy metal under rice ecosystem**
- **Demonstration of composting technology**
- **Integration of composting technology and mushroom production for effective agro residue management**
- **Development of biopesticide formulation Trichoderma virens and Neem**
- **Different models of carbon footprint calculation**

Field visits:

- **Nisargruna biogas plant at Nursery, TSH, BARC Hospital and outside location**
- **Composting site at Anushaktinagar, Mandala, Kamgarnagar etc**
- **Field visit where carbon credit/environmental management concept is used**

(Godrej supports carbon credit, farmer engaged in organic farming, society managing own waste).

Mini Project:

Each student has to complete a mini project on any one working example of environment management for understanding sustainability (example waste management in world's largest city (any one), different types of biogas digestors, different technologies of water treatment, comparison of aerobic and anaerobic processes, actual working of vermicomposting technology, organic farming, biopesticide industry etc.

Course outcome:

After successful completion of the course the students will be able to
1. Understand the fundamental concepts and practical applications of sustainability within the context of global environmental changes.
2. Evaluate the modern solid waste management techniques, with a specific focus on the operational principles of different BARC technologies for biodegradable waste management.

References:

1. Manual for Organic Farming by agrobiosonline.com ISBN: 9788177545494 Year 2014 2. 75 Years of Bio-Science Research In Indian Atomic Energy Programme Publisher: BARC
2. Toward Sustainable Agricultural Systems in the 21st Century, THE NATIONAL ACADEMIES PRESS 598 pages | 7 x 10 | HARDBACK ISBN 978-0-309-38743-9 | DOI 10.17226/12832
3. SWACHH BHARAT MISSION, MUNICIPAL SOLID WASTE MANAGEMENT MANUAL Part I and Part II available online

BS705: Food-Borne Pathogens (75 Lecture Hrs)

Coordinators: Dr. Shashidhar R.
(shashi@barc.gov.in)

Course Details:

- **Introduction to food-borne pathogens and epidemiology**
  Relevance of food borne pathogens, epidemiology; Indian agencies involved in for monitoring these pathogens: safety aspects of handling and transportation of the pathogens.

- **Detection and typing of food-borne pathogens**
  Biochemical, Molecular (PCR & Microarray) and Immunological detection; Typing - serology, DNA based - PFGE, RFLP, MLS, CRISPR based detection

- **Food-borne Bacterial pathogens**
  Classification, source, distribution, detection, pathogenicity, cure and importance in food industry with respect to Salmonella species, Vibrio species, Listeria monocytogenes, Campylobacter species, Escherichia coli.

- **Food-borne viruses and prions**
  Norwalk viruses, Hepatitis A, Hepatitis E, Rotaviruses, Prions

- **Mycotoxins**
  Aflatoxins from Aspergillus flavus and detection and prevention.

- **Protozoan**
  Taenia saginata, Toxoplasma gondii, Entamoeba histolytica.

- **Molecular mechanisms of pathogenicity–Salmonella, L. monocytogenes**
  Adhesion, Invasion and Survival inside host cell.

- **Molecular stress response of food-borne pathogens**
  Survival strategies of pathogens in extreme heat, acid and saline conditions: molecular mechanisms of stress tolerance.

- **Emerging and uncommon food-borne pathogens**
  Enterobacter sakazakii, Aeromonas species, Mycobacterium paratuberculosis, Arcobacter species, Antibiotic / food processing resistant strains and variants of already known pathogens.

- **HACCP and FSSAI**
  Principles of HACCP, FSSAI guidelines on foodborne pathogens.

Practical:

Isolation and characterization of bacterial pathogens (Salmonella species, Vibrio species, Listeria monocytogenes, Yersinia enterocolitica, Escherichia

coli, and Staphylococcus aureus); Rapid detection of Salmonella using nested PCR; Molecular characterization of Salmonella; Detection of aflatoxin.

Course outcome:

This course enables the student's two critical aspects. First, the course gives comprehensive outlook on foodborne pathogens and their stress tolerance. Secondly, the students will be familiarized on handling of pathogenic bacteria.

References:

1. Foodborne Infections and Intoxications. Editors: H. P. Riemann, D. O. Cliver (Academic Press)
2. Food Microbiology: Fundamentals and Frontiers. Editors: Michael P. Doyle, Robert L. Buchanan (ASM).
3. Modern Food Microbiology. Authors: James M. Jay, Martin J. Loessner, David A. Golden (Elsevier).
4. Bacterial adhesion and entry into host cells. Nature Reviews Microbiology (DOI: 10.1038/nrmicro1393)
5. Rapid methods for the detection of foodborne bacterial pathogens: principles, applications, advantages and limitations. Frontiers in Microbiology (DOI: 10.3389/fmicb.2014.00770)
6. Listeria: A foodborne pathogen that knows how to survive. International Journal of Food Microbiology. DOI: 10.1016/j.ijfoodmicro.2007.07.008

BS706: Immunological Methods In Biochemical And Chemical Analysis (75 Lecture Hrs)

Coordinators: Dr. M K Ray
(mkray@barc.gov.in)

Course Details:

- Antigen- antibody interactions in immunoassays
- Production of polyclonal and monoclonal antibodies
- Radioiodination, Data analysis, QC-QA in immunoassay
- Standards in immunoassay, Immunization of lab animals
- Protein chips and affinity purification
- AMA assay, ATA
- Immobilization of antibodies, Separation Methods in immunoassay, Scatchard plot, Nanobodies
- Tg asays, ATA, Scatchard plot
- Non-isotopic Immunoassays, SCFV antibodies, Abzymes and phage display

References:

1. RIA Principle and Practice by MRA Pillai & S D Bhandarkar

BS707: Molecular Markers And Genomics For Crop Improvement (75 Lecture Hrs)

Coordinators: Dr. S. K. Gupta
(skgupta@barc.gov.in)

Course Details:

- Introduction to molecular markers and application in plant breeding
- Basic concepts and methodologies of DNA marker systems
- Generation of different mapping populations for mapping important traits: Bi-parental populations & MAGIC populations.
- Genetic mapping: Linkage analysis, Bulked segregant analysis, construction of genetic linkage map
- Quantitative Trait Loci for deciphering complex traits and QTL-seq
- Genome wide association studies (GWAS) and its role in plant breeding
- Next generation genotyping technologies for accelerating crop improvement: GBS, KASP assay
- Genomic selection and Genomic assisted breeding

Practical's:

- Introduction to molecular markers and application in plant breeding
- DNA extraction from Plant and DNA quantification
- PCR amplification of Different molecular markers: RAPD/ISSR/SSR/ILP
- Agarose gel electrophoresis and Capillary electrophoresis
- SSR and ILP marker development
- Scoring of Dominant markers and co-dominant markers
- Software demonstrations on: Genetic diversity analysis: NTSYS Mapping of simple traits: Joinmap
- Construction of genetic maps: Joinmap Identification of QTLs: QTL Cartographer Structure analysis
- Detecting polymorphism without gel (low resolution melting/high resolution melting curve analysis)

Course outcome:

Completing "Molecular markers & genomics for crop improvement" course builds essential skills for modern crop improvement. Students develop proficiency in different molecular markers such as ISSR, SSR, ILP and SNPs for assessing genetic diversity and mapping traits. They also learn PCR fundamentals, DNA extraction methods, qPCR for gene expression, next-generation sequencing (NGS) and reverse genetics approaches, including

TILLING for functional genomics.

References:

1. Gupta, P.K., Varshney, R.K., Prasad, M. (2002). Molecular Markers: Principles and Methodology. In: Jain, S.M., Brar, D.S., Ahloowalia, B.S. (eds) Molecular Techniques in Crop Improvement. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-2356-5_2.
2. Braulio J. Soto-Cerda and Sylvie Cloutier (2012). Association Mapping in Plant Genomes, Genetic Diversity in Plants, Prof. Mahmut Caliskan (Ed.), ISBN: 978-953-51-0185-7, InTech., Available from: http://www.intechopen.com/books/genetic-diversity-in-plants/association-mapping-in-plant-genome.
3. B.D. Singh and A.K. Singh, (2015). Marker-Assisted Plant Breeding: Principles and Practices, Springer New Delhi. https://doi.org/10.1007/978-81-322-2316-0.

BS708: Oxidative Stress And Redox Modifiers In Disease Management (75 Lecture Hrs)

Coordinators: Dr. S. Santosh Kumar
(sskumar@barc.gov.in)

Course Details:

- **Introduction and Significance**
  ROS/RNS and their physiological significance in healthy state.

- **Detection and measurement of free radicals and their actions**
  - ESR and pulse radiolysis-their applications
  - Finger printing for DNA, proteins and lipids
  - Biochemical methods for radical scavenging and molecular damage by free radicals

- **Reactive species as useful biomolecules**
  - Radical enzymes
  - Fruit ripening and wound response
  - Role in biological defense mechanisms
  - Lipoxygenases and cyclooxygenases

- **Natural antioxidants and their dietary source**
  Antioxidants from different sources

- **Antioxidants in prevention and therapy of human ailments**
  - Cardiovascular ailments
  - Diabetes and other metabolic diseases
  - Diseases of the nervous system Cancer
  - Ageing and diseases associated with it Respiratory ailments

- **Antioxidants and Food**
  - Types and effects of rancidity
  - Measurement of oxidative rancidity
  - Methods to prevent oxidation
  - Natural and synthetic antioxidants and their extraction methods
  - Measuring of antioxidant activity in foods
  - Novel antioxidants in food preservation
  - Role of antioxidants inn radiation preservation of foods
  - Application of antioxidants in food products of animal and plant origin
  - Functionality of natural antioxidants during food preservation

- **Role of cellular redox in regulation of immune responses**
- **Manufacturing Resource Planning (MRP) and its role in food preservation**
- **Natural compounds as novel natural antimicrobials**

- **Generally Recognized As Safe (GRAS) food preservatives**

Practical's:

- **Radiation induced plasmid relaxation assay**
- **DPPH & ABTS Radical scavenging**
- **Lipid peroxidation (Thiobarbituric acid reactive substances & lipid hydroperoxides); Protein oxidation**
- **DNA damage by radiation and peroxyl radicals – possible prevention by an antioxidant**
- **Electron Spin Resonance, Pulse radiolysis,**
- **Nuclear levels of redox sensitive transcription factors**
- **DNA fragmentation – by radiation and peroxyl radicals and possible prevention**
- **ROS generation and quenching in cells**
- **Expression of antioxidant enzymes**
- **Estimation of GSH/GSSG Levels**
- **Food related antioxidant assays**

Course outcome:

The course deals with role of oxidative stress in different human diseases and intervention by antioxidants. The students will learn the basic concepts and recent advances in the of cellular redox and mitigation strategies to prevent onset of life style diseases, neurodegenerative disorders and cancer. This course will be a good foundation to students to work in the field of radiation biology and cancer biology.

References:

1. Phenolic Antioxidants in Foods: Chemistry, Biochemistry and Analysis: Chemistry, Biochemistry & analysis. Alam Zeb, Adrian Hurst, Springer
2. Natural Food Additives, Ingredients and Flavourings, Edited by: David Baines and Richard Seal. Woodhead Publishing Series in Food Science, Technology and Nutrition

BS709: Cancer-hallmarks, Pathogenesis, Microenvironment and Therapeutics (75 Lecture Hrs)

Coordinators: Dr. Bhavani Shankar
(shankar@barc.gov.in)

Course Details:

- **Genetics and pathophysiology**
  Genetic basis of cancer, hallmarks of cancer, germline mutations, driver mutations and mutational signatures, nature of cancer, staging and grading of cancer, pathophysiology of neoplasia, sequential changes during cancer pathogenesis, Genetic changes in neoplasia and multi-step tumorigenesis, intra tumor heterogeneity, Epidemiology of Cancer, Clinical manifestations of cancer.

- **Emerging hallmarks**
  Unlocking phenotypic plasticity (initiating plasticity and maintaining plasticity, molecular mechanisms underlying plasticity) contribution of senescent cells (hallmarks of senescent cells, Proliferation arrest and unresolved DDR, SASP, therapy induced senescence), Structural and metabolic changes, and non-mutational epigenetic reprogramming (reprogramming DNA methylation, aberrant histone modification, non- coding RNAs, RNA splicing dysregulation, Transfer RNAs as dynamic and critical regulators of cancer progression, Nonsense-mediated RNA decay: an emerging modulator of malignancy, epigenetic programming of ncRNA, epi drugs and epi-cell therapy).

- **Microbiota in cancer**
  Gut and tumor microbiota and oncogenesis, Influence on metabolism, cell growth and immunity, cancer therapy associated microbiota modulation and complications.

- **Tumor immunology**
  Anti-tumor immunity (cells involved and mechanism), Cancer immunoediting, immunogenic cell death, Immune-tumor interactions, cancer associated fibroblasts, different immune cell types and regulators during different stages of cancer, Modulation of immune checkpoint proteins and their networks in cancer progression, role of cytokine/chemokines and growth factors in tumor heterogeneity, Tertiary lymphoid structures as hubs of anti-tumour immunity, Stem-like exhausted and memory CD8+ T cells in cancer.
- **Hypoxia as molecular driver of cancer progression**
  Factors contributing to hypoxia in cancer, hypoxia and carcinogenesis-DNA damage and repair; hypoxia and metabolism-glycolysis, nucleotide, Acetyl co A and lipid metabolism, hypoxia and angiogenesis; hypoxia and immune tolerance, hypoxia and therapeutic resistance.

- **Deregulated transcription factors in cancer therapeutic challenge**
  Dysfunctional transcription factors in metabolism and reprogramming of cancer cells; Transcription factors and epigenetic reprogramming; transcription factors avoiding immune destruction; transcription factors in cancer stemness. Therapeutic importance of targeting deregulated transcription factors.

- **Model systems in Cancer Research**
  In vitro models (2D/3D and 4D), organoids, Tumor -on-chip, In vivo models: syngeneic,

genetically engineered, xenograft models with host-Nude mice, NOD/SCID mice, patient derived xenografts, humanized mouse models.

- **Biomarkers, Vaccines, Diagnostics and Cancer Therapeutics**
  Extracellular vesicles and biomarker discovery, Vaccines, Imaging techniques; Traditional and emerging therapies; Rationale behind new state-of-the-art cancer diagnosis, Liquid biopsy and circulating tumor cells, prognosis and treatments;

  Dietary interventions as therapy, exploiting senescence, Targeting telomeres, DNA damage response, aberrant splicing, Immunotherapy and targeted therapies. Checkpoint inhibitors; Adoptive cell therapies, CAR T cell therapy, cytokines; Combination therapies. Reprogramming the tumor microenvironment.

Practicals:

- **Clonogenic and proliferation assays**
- **Immunocytochemistry**
- **Histology (cancer diagnostics ie fnac, pap smear cytology and histopathology with ihc of biopsies and surgical excisions)**
- **Characterization of tumor infiltrating lymphocytes- Phenotype and function/ cytotoxicity assays**
- **Animal models and routes of immunization**

Course outcome:

At the end of the course the students will gain a deeper understanding of the cancer microenvironment, the different players and their interaction and understand the different mechanisms by which cancer microenvironment can be targeted for novel drug discovery.

References:

1. State-Of-The-Art Advancements on Cancer Vaccines and Biomarkers (DOI: https://doi.org/10.1200/EDBK_438592)
2. The hallmarks of cancer immune evasion (https://doi.org/10.1016/j.ccell.2024.09.010)
3. Hallmarks of cancer: The next generation (DOI 10.1016/j.cell.2011.02.013)
4. Hallmarks of cancer: New dimensions (10.1158/2159-8290.CD-21-1059)
5. Cancer models in preclinical research: A chronicle review of advancement in effective cancer research (https://doi.org/10.1002/ame2.12165).
6. Deregulated transcription factors in the emerging cancer hallmarks (https://doi.org/10.1016/j.semcancer.2023.12.001)
7. Exploring treatment options in cancer: tumor treatment strategies (https://doi.org/10.1038/s41392-024-01856-7).

BS710: Plant Genetic Engineering (75 Lecture Hrs)

Coordinators: Dr. Himanshu Tak
(hsjtak@barc.gov.in)

Course Details:

- **Plant cell and tissue culture systems for genetic transformation**
  Requirements of in vitro cultures, nutrient media, plant growth regulators, in vitro propagation systems and their applications

- **Plant gene structure, isolation and cloning, plant expression vectors**
  Popularly used binary vectors, cis and trans acting factors, types of promoters

- **Selectable marker and reporter genes**
  Antibiotic resistant marker genes, Herbicide marker genes, Reporter genes, removal of marker genes, alternate selectable marker systems.

- **Methods of plant genetic transformation**
- Direct gene transfer methods with emphasis on particle bombardment
- Agrobacterium-mediated, strains, virulence genes, mechanism of T -DNA transfer and integration, different methods of Agro- transformation, vectors used in Agro transformation

- **Enhancing and stabilizing transgene expression**
  Transgene silencing – mechanism and control

- **Genome editing approaches in plants system**
  Gene editing using CRISPRP-Cas9 system, VIGS (virus induced gene silencing)

- **Genetic manipulation for biotic and abiotic stress tolerance**
  Disease resistance (viral, fungal, bacterial), insect resistance, abiotic (salinity, drought, cold) tolerance

- **Plant metabolic engineering for quality improvement**
  Biosynthetic pathway modulation, nutritional quality improvement, functional foods. Ripening related genes, expression and control, genes for nutritional quality.

- **Bioethics and biosafety of transgenic plants**
  Guidelines and regulation of biosafety, field trials and release of transgenic crops and commercial aspects.

Practical's:

Transformation of Agrobacterium by electroporation and confirmation through colony PCR; Explant preparation for transformation, Agrobacterium-mediated transformation using GUS reporter gene; Histochemical localization of GUS in transformed tissues; Extraction of DNA from transformed tissues and PCR confirmation of transgene integration; RNA isolation and quantitative real time PCR; Confirmation and quantification of transgene expression, Demonstration of particle gun mediated plant genetic transformation, Demonstration of plant bio-reactor for secondary metabolite production.

Course outcome:

The course provides a comprehensive detail on the plant genetic engineering activities being taken at BARC campus including the basics concepts and new emerging aspects on the subject. Students are imparted knowledge and hands on training on topics such as - Plant cell and tissue culture systems, gene isolation/cloning, plant expression vectors, Selectable marker system, Methods of genetic transformation, factors on transgene expression, Genome editing approaches, transgenic approaches for stress responses and metabolic engineering and regulatory as well as biosafety aspects on transgenic plants.

References:

1. Agrobacterium-Mediated Plant Transformation: the Biology behind the "Gene-Jockeying" Tool. (DOI: 10.1128/MMBR.67.1.16–37.2003)
2. Agrobacterium-based vectors: a review. Intl J Farm & Alli Sci. Vol., 3 (9): 1002-1008, 2014.
3. Alternatives to Antibiotic Resistance Marker Genes for In Vitro Selection of Genetically Modified
4. Plants – Scientific Developments, Current Use, Operational Access and Biosafety Considerations (https://doi.org/10.1080/07352689.2013.870422)
5. Epigenetic silencing in transgenic plants (doi:10.3389/fpls.2015.00693)
6. Genome editing techniques in plants: a comprehensive review and future prospects toward zero hunger (https://doi.org/10.1080/21645698.2021.2021724)
7. Integration of Agrobacterium T-DNA into the Plant Genome. (https://doi.org/10.1146/annurev-genet-120215-035320)
8. Physical methods for genetic plant transformation. (http://dx.doi.org/10.1016/j.plrev.2012.06.002)
9. Positive, negative and marker-free strategies for transgenic plant selection. Braz. J. Plant Physiol., 14(1):1-10, 2002

BS711: Advances in Genome Biology (75 Lecture Hrs)

Coordinators: Dr. Y. S. Rajpurohit
(ysraj@barc.gov.in)

Course Details:

- **Genome structure and packaging prokaryotes and eukaryotes**
  DNA sequence and genomic complexity, DNA primary and secondary structure, higher-order DNA structures; Effect of DNA structural levels on cellular functions, nuclear architecture, 3D packaging of genome, topologically associating domains (TADs) in higher eukaryotes, chromosomal interaction domains in bacteria, Analysis of spacial organization of chromatins using Chromosome Conformation Capture methods (3C,4C & 5C techniques). Genome architectural proteins in bacteria and higher eukaryotes and their functional regulation.

- **Epigenetic aspects in genome structure and function**
  Chromatin remodeling and its role in epigenetics, DNA, RNA, histones modifications and their functional significance,
  MicroRNAs: Biogenesis and functions, Regulatory roles in gene expression
  Long non-coding RNAs: Emerging roles in epigenetic regulation
  Epigenetics in cancer: Epigenetic drugs and their mechanisms of action

- **Genome maintenance and integrity**
  Sensing, signaling, and repair of DNA damage in bacteria and eukaryotes, processing of DNA damage in the context of chromatin and chromosomes, causes and effects of genome instability, and its transmission. Single molecular studies of genome repair.
  Effect of exposure to gamma, colchicines, cisplatine, doxorubicin treatment and monitoring in vitro defect on nucleoid size during recovery periods in mammalian cells. Cytogenetics and chromosomal aberrations analysis on human chromosomes exposed to low and high LET radiation.

- **Genome dynamics and genome segregation mechanisms**
  Regulation and functional consequences of chromatin dynamics, chromosome dynamics in response to DNA damage, genome segregation mechanisms.

- **Metagenomics**
  Introduction to metagenomics and its applications in human gut microbiome diversity as well as its relation to health and disease.

- **Tools for genome and gene expression data analysis and data visualization**
  Next-generation sequencing technologies, analysis of transcriptome data, Identification of differentially expressed genes with relevant statistical tests, volcano plots and heat maps for gene expression data representation, Gene Ontology analysis apps, charts for GO enrichment results, generation of protein-protein interaction maps.

- **Genome organization in plants**
  Components of plant genome, Plant genome sizes/variations, Origin of genome variation, Genome complexity & C-value paradox, Polyploidy- types and relevance in plants, Genome obesity, Genomic alterations and crop improvement program.

Practical's:

- Study of DNA damage repair kinetics using Pulsed field gel electrophoresis, in bacterial cells under different environmental conditions using PFGE and immunofluorescence techniques.

- Visualization of spacial organization of chromosomes in multipartite bacteria and chromosome dynamics during genome segregation under normal and stressed growth conditions by chromosome tagging using fluorescence microscopy.

- Studying DNA replication by BrdU labelling, DNA damage repair kinetics by GammaH2AX foci labelling/ comet assay upon treatment with epigenetic inhibitors and gamma radiation in cancer cells by immunofluorescence in mammalian cells.

- Cytogenetics and chromosomal aberrations analysis on human chromosomes exposed to radiation.

Course outcome:

The course will strengthen the understanding of modern functional genomics. It will enhance the ability to analyze and interpret genomic outcome in the context of evolution, disease, and biotechnology. The course also developed critical thinking and research-oriented skills relevant to current trends in genome biology .

References:

1. Targeting the cancer epigenome for therapy (DOI: 10.1038/nrg.2016.93)
2. Histone chaperone networks shaping chromatin function (doi:10.1038/nrm.2016.159)
3. Organizational principles of 3D genome architecture (https://doi.org/10.1038/s41576-018-0060-8)
4. Cancer Epigenetics: From Mechanism to Therapy (http://dx.doi.org/10.1016/j.cell.2012.06.013)
5. Methods for Identifying Higher-Order Chromatin Structure (doi: 10.1146/annurev-genom-090711-163818)
6. DNA damage repair: historical perspectives, mechanistic pathways and clinical translation for targeted cancer therapy (https://doi.org/10.1038/s41392-021-00648-7)

BS712: Principle and Practices in Structural Biology (75 Lecture Hrs)

Coordinators: Dr. Mukesh Kumar
(mukeshk@barc.gov.in)

Course Details:

- **Introduction to three-dimensional structures of proteins and nucleic acids, Methods for determining 3D structures of biological macromolecules**
- **Methods of protein expression and purification**
- **Crystal symmetry and crystallisation of proteins**
- **X-ray sources and diffraction theory**
- **Methods of diffraction data collection, data processing**
- **Methods for solving the phase problem**
- **Crystallographic refinement**
- **Electron density maps, model building and validation**
- **Structure-based drug design**
- **Biophysical techniques for characterisation of proteins and protein-ligand complexes**
- **Laboratory experiments:**
    - Protein expression and purification
    - Protein crystallization
    - Crystal mounting, diffraction data collection and processing
    - Structure solution and refinement
    - Interpretation of electron density maps, model building and validation
    - Biophysical methods in structural biology: CD, fluorescence, etc.

Course outcome:
Upon completion of this course, students will gain a comprehensive understanding of the principles and methodologies used to determine and analyze three-dimensional structures of biological macromolecules. They will acquire hands-on experience in protein crystallization, structure solution, refinement, and validation, and will be able to apply structural and biophysical insights to understand functions of biological macromolecules at atomic levels.

References:

1. Protein Crystallography by T. L. Blundell and L. N. Johnson; Academic Press
2. Outline of Crystallography for Biologists by David Blow; Oxford Univ Press
3. Crystallography Made Crystal Clear by Gale Rhodes; Academic Press
4. Principles of Protein X-Ray Crystallography by Jan Drenth, Springer

BS713: Advanced Instrumentation for Bioanalysis and Imaging (75 Lecture Hrs)

Coordinators: Dr. Kuber Bhainsa (kuber@barc.gov.in)

Course Details:

- **Current perspective on advanced instrumentation for bioanalysis and imaging**
- **Principle and application of the Instruments**
  Liquid Chromatography Mass Spectrometry (LCMS)
- **Inductively Coupled Plasma Spectrophotometer (ICP), X-ray Diffraction (Powder), Scanning Electron Microscopy (SEM) and Rheometer**
- **Atomic Force Microscopy (AFM)**
- **Transmission Electron Microscopy (TEM)**
- **Confocal Laser Scanning Microscopy (CLSM)**

Course outcome:

In this course the students are exposed to several modern-day instrumentation techniques which are useful for life science research. Particularly it focusses on surface and intracellular characterisation of cells, biomolecules, biomaterial/bionanomaterials including its imaging and analysis. It also helps in identification and quantification of both organic and inorganic molecules, ions, atoms etc., and providing opportunity to investigate and understand specific property of liquid, viscous and gel materials. Further, it allows understanding the mechanism of DNA-protein interactions and protein-protein interactions.

References:

1. Principles and Techniques of Biochemistry and Molecular Biology by Keith Wilson and John Walker (7td Edition)
2. Elements of X-Ray Diffraction - B.D. Cullity, S.R. Stock
3. X-Ray Diffraction for Materials Research - From Fundamentals to Applications - Myeongkyu Lee
4. Fundamentals of Scanning Probe Microscopy by V. L. Mironov; THE RUSSIAN ACADEMY OF SCIENCES INSTITUTE FOR PHYSICS OF MICROSTRUCTURES, Nizhniy Novgorod; 2004
5. Liquid Chromatography-Mass Spectrometry, 3rd Edition" by Wilfried M.A. Niessen for comprehensive principles and applications.
6. "LC/MS: A Practical User's Guide" by Marvin C. McMaster for beginner-friendly instrumentation and troubleshooting

BS714: Current Advances in Tuberculosis and Thyroid Cancer Research (75 Lecture Hrs)

Coordinators: Dr. Pramod K Gupta
(guptapk@barc.gov.in)

Course Details:

- Introduction to TB – Disease pathology and Immune Evasion.
- Anti-TB Drugs and Molecular mechanisms of drug resistance in TB
- Host Directed Therapeutics in TB: An alternative strategy to combat Antibiotic Resistance
- Application of CRISPRi in Mycobacterium tuberculosis
- Nano bodies in TB and other infectious diseases
- Mycobacteriophages in diagnosis and alternative treatment of mycobacterial infections
- Tuberculosis Vaccines: Past, Present and Future
- Trained Immunity: Implications in development of therapy and vaccines against TB
- Biosafety Guide lines in TB research: BSL-III facility
- Genetic, epigenetic, metabolism and post-translational modification in thyroid cancer and their role in thyroids cancer prognosis.
- Molecular mechanisms of resistance to treatment in thyroid cancers.
- Molecular methods of diagnosis of thyroid cancer by peripheral blood cells NGS
- Anesthesia, Euthanasia, necropsy & histopathological techniques in Laboratory animals.

Laboratory experiments:

- **In vitro MTB infection in murine macrophage and quantification of phagocytosis (Tuberculosis)**
- **Demonstration of in vitro CFU assay.**
- **Demonstration of aerosol challenge of M.tuberculosis in BALB/c mice for the evaluation of anti-TB potential of chemical compounds (Tuberculosis)**
- **Generation of mycobacterium knockdown strains using CRISPRi (Tuberculosis)**
- **High-through put Growth fitness assay for antibiotic drug susceptibility (Tuberculosis)**
- **Isolation of nanobodies against antigens of M. tuberculosis (Tuberculosis)**
- **Isolation of mycobacteriophages from soil sample.**
  Note: All the M.tuberculosis related experiments will be carried out with avirulent strain H37Ra or vaccine strain M. bovis BCG
- **MTT assay/Cell migration /invasion assay (thyroid cancer)**
- **Tumor educated cell population detection by flow cytometry (thyroid cancer)**
- **Detection of alteration in metabolism by metabolic flux analyzer (thyroid cancer)**
- **Side population assay in thyroid cancer cell line.**
- **Aldeflour assay in thyroid cancer cell line (thyroid cancer).**

***Practical*:**

- **Necropsy and biological sample collections for histopathology & immunohistochemistry: (thyroid cancer)**

Course outcome:

Upon completion of this course, students will be able to critically analyze the recent advances in the disease pathology, diagnosis and management of TB and thyroid cancer, including merging molecular mechanisms, novel therapeutic strategies and innovative vaccine and targeted drug delivery approaches.

References:

Review articles published from time to time.

BS715: Principles and Practices of Mutation Breeding (75 Lecture Hrs)

Coordinators: Dr. Suvendu Mondal
(suvendu@barc.gov.in)

Course Details:

- **Principles of Mutation Breeding**
  - Molecular basis of mutagenesis, Mechanism of mutation in dry seed and wet tissue, Different types of mutagen (physical and chemical) and their mode of action.
  - Types of mutations, Double stranded DNA break, Repair and Associated mutations in plants.

- **Practices of Mutation Breeding**
  - Methodology & Screening techniques in mutation breeding, Genetics of mutated traits, Stabilization of mutants in self and cross pollinated crops.
  - Successful examples of mutation breeding for qualitative and quantitative traits.

- **In vitro mutagenesis**
  - Principles of mutation breeding of vegetative propagated crops, methodology for in vitro mutagenesis, Dissociation of chimeras and selection of mutants.
  - Methods for screening in vitro mutants, Artificial selection, Haploid mutagenesis. Somatic embryogenesis for mutant induction.

- **Advanced techniques of inducing mutations in plants**
  - Ion beam radiation mutagenesis, Electron beam and/or Proton beam radiation mutagenesis, Space /Cosmic radiation, Advantages/Disadvantages compared to gamma rays.

- **Molecular techniques and methods for mutation detection and screening in plants**
  - Techniques for mutation detection and screening (TILLING, Eco-TILLING, de-TILLING, HRM based TILLING, Transposon induced mutagenesis/insertional mutagenesis, Use of molecular marker techniques in mutation detection.
  - Site directed mutagenesis in plants (CRISPR-CAS, ZFN, TALEN etc.)
  - Molecular characterization of mutants: Mut-Map, Mut- Map+
  - Molecular approaches to identify novel mutants in crop plants, Gene tagging of mutated traits using molecular markers.

- **Epigenetics**
  - Generation of epimutants, Mode of actions of epimutagens and their application, Methods of dissecting epigenetic behavior of quantitative traits.

- **Statistical analysis on mutant population**
  - Handling the field data, analysis and interpretation. Design of experiment for mutant germplasm, mutant lines and their derivatives.

- **Achievements on Mutation Breeding**
  - Research experience of mutation breeding at BARC
  - Research on mutation breeding at IAEA, Vienna and world perspective.

***Practical*:**

- Irradiation of seeds, Determination of LD50 dose/GR50/GR30 calculation, Analyzing dose-response curve, Calculation of mutation frequency. Comparative study of electron beam and gamma rays mutagenesis.
- Field /Laboratory screening of mutants
- In vitro mutagenesis experiments
- Practical on TILLING, HRM and high throughput mutant screening.
- Practical on nondestructive techniques for screening of mutants.

Course outcome:

The course is designed to facilitate the basic understanding of mutation process, working principles of mutation breeding and method/practice used to develop crop varieties using such breeding method. This course is very important in the light of crop improvement program of BARC that has developed 72 crop varieties in food and horticultural crops. Apart from the basic understanding, isolation and utilization of useful mutants, this course also offers to learn various techniques used to characterize mutants to decipher the causal mutations and candidate genes for mutant traits. The course also offers usage of CRISPR-Cas techniques to modify plant traits for the development of climate resilient plant along with improved seed quality.

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References:

1. B.D. Singh and A.K. Singh, (2015). Marker-Assisted Plant Breeding: Principles and Practices, Springer New Delhi. https://doi.org/10.1007/978-81-322-2316-0.
2. FAO/IAEA. 2018. Manual on Mutation Breeding - Third edition. Spencer-Lopes, M.M., Forster, B.P. and Jankuloski, L. (eds.), Food and Agriculture Organization of the United Nations. Rome, Italy. 301 pp.

BS716: Advances in CRISPR-Cas Applications for Bio-medical Research (75 Lecture Hrs)

Coordinators: Dr. Devashish Rath
(devrath@barc.gov.in)

Course Details:

- **Overview of CRISPR systems**
  - CRISPR as a bacterial adaptive defense system
  - Mechanism of CRISPR immunity
  - Classification of CRISPR systems
  - Alternative roles of CRISPR systems
  - Anti-CRISPR proteins

- **Adaptation of CRISPR-Cas tools for different applications**
  - Genome engineering- genome editing, Gene knock-outs and knock-ins
  - CRISPR interference and activation
  - CRISPR for epigenetic modifications
  - CRISPR-based base editing
  - CRISPR for genome imaging
  - CRISPR for RNA targeting

- **CRISPR for basic and applied research in bacteria**
  - Understanding gene function
  - Identifying drug target
  - Metabolic engineering
  - CRISPR-based antimicrobials

- **CRISPR-based library screening in mammalian systems and generating disease models**
  - Identification of drug targets for cancer
  - Approaches to generate CRISPR-based libraries
  - Understanding complex signaling pathways
  - Generating disease models in cell lines and mice

- **CRISPR-based approach to screening chemical libraries**
  - Modes of CRISPR-Cas delivery
  - Applications for improving yield, disease tolerance, drought resistance, gene pyramiding in variety of crops

- **CRISPR for disease management and therapy**
  - CRISPR-based disease diagnosis
  - Modes of CRISPR-Cas delivery
  - CRISPR-based approaches to humanize organs for xenograft
  - CRISPR for CAR-T cell therapy
  - CRISPR-based therapies in clinical trials
- **Molecular design principles for CRISPR application in different hosts**

- sgRNA design for different CRISPR effectors
- Off target evaluation
- Overview of modes of expressing CRISPR components
- Design rules for donor template
- Impact of secondary structure on sgRNA activity
- In vitro cleavage assay
- Genotypic screening for edited cells (T7 endonuclease assay, sequence analysis, restriction-based screening, PCR-based screening)

- **Overcoming challenges of CRISPR system**
  - Considerations to minimize off-target effects
  - CRISPR-Cas system toxicity
  - Methods for efficient delivery
  - Utilizing endogenous CRISPR systems in non-model organisms

- **Regulation and ethics in CRISPR applications**
  - Global acceptance of CRISPR based therapies
  - Ethical concerns in modifying embryos
  - Patent complications
  - GMO vs. Genome editing

***Practicals*:**

- Bioinformatic tools for sgRNA design, Secondary structure prediction, in silico tools for evaluating off-target efficiency, Resources to explore novel CRISPR systems, in vitro sgRNA synthesis, in vitro cleavage assay, sgRNA cloning, screening and expression, CRISPR based gene knock-down in bacteria, RT-PCR based evaluation of CRISPRi, CRISPR-based disease diagnosis, T7 endonuclease assay for mutation detection.

Course outcome:

At the end of the course, the students will have a thorough knowledge regarding the cutting-edge tool, CRISPR and its adaptation for various applications. The hands-on course will empower the students to employ the CRISPR tool in bacteria, animals and plants for addressing a repertoire of questions in biological research.

References:

1. "CRISPR-Cas: A Laboratory Manual", Edited by Jennifer Doudna, Prashant Mali, and Samuel Sternberg.
2. Crispr/Cas Genome Editing: Strategies and Potential for Crop Improvement (Concepts and Strategies in Plant Sciences) by by Anjanabha Bhattacharya (Editor), Vilas Parkhi (Editor), Bharat Char (Editor). Publisher: Springer (2021). ISBN-10: 3030420248

BS717: Nanoparticles for Application of Radiation in Healthcare (75 Lecture Hrs)

Coordinators: Dr. (Smt.) Neena G. Shetake
(neenavj@barc.gov.in)

Course Details:

- **General introduction of nanoparticles and their applications in biomedical research and healthcare**

  DNA Definition of nanoparticles, nanotechnology applications in diagnostics, drug delivery, antibacterial treatments, wound treatments, cell repair, current status of applications of nanoparticles in radiation-based health care approaches.

Nanoparticles: Types, design, synthesis and characterization

Physics of nano-scale materials, classification of nanoparticles, top-down and bottom-up approaches for synthesis of nanoparticles, their characterization by different bio-physical techniques (TEM, DLS, XRD)

- **General Green Synthesis of Nanoparticles**

  Principles and advantages of green synthesis, different green synthesis methods and their limitations, characterization, biological evaluation and applications of green synthesized nanoparticles.

- **Toxicological aspects of nanoparticles**

  Bio-distribution and pharmaco-kinetics of nanoparticles, mechanism of uptake and cyto-toxicity, methods for evaluation of toxicity, toxicological parameters for assessment of safe application of nanoparticles in healthcare.

- **Nanoparticles for fluorescence imaging and drug delivery**

  Synthesis and characterization of quantum dots, applications in molecular imaging, disease diagnosis. Design of triggered release nanoparticles responding to pH, temperature, light, etc, passive and targeted nanoparticles drug delivery systems, challenges of in vivo delivery of drug using nanoparticles.

- **Nanoparticles for radiation imaging and diagnosis in cancer**

  Nanoparticles as imaging agents in magnetic resonance imaging (MRI), optical imaging, computed tomography (CT) and X-Ray imaging, ultra-sound, photo-acoustic imaging and Surface enhanced Raman spectroscopy, Design characteristics of nanoparticles used in different imaging modalities and future applications.

- **Nanoparticles in radio-sensitization and cancer combinatorial therapy**

  Limitations of conventional cancer treatment modalities, novel designs of nanoparticles for multi-modal cancer therapy including magnetic hyperthermia, photo-thermal and photodynamic therapy, mechanism of cell death, chemo-radio-sensitization by nanoparticles, role of artificial intelligence in nano-medicine, recent advances in contribution

onanoparticles for combinatorial cancer treatment.

***Practical*:**

Synthesis of metallic nanoparticles and their characterization, Hemolysis assay for toxicity evaluation of nanoparticles, Synthesis and characterization of targeted liposomes encapsulated with anti-cancer agents and their intracellular uptake in cancer cells, evaluation of cyto-toxicity of targeted liposomes in cancer cells in combination with radiation and hyperthermia.

Course outcome:

Nano-medicine is an emerging area with significant contributions in healthcare, specifically for improving the efficacy of cancer therapy and mitigation of side effects associated with conventional treatment modalities such as chemo and radiation therapy. Present elective course aims to provide deeper understanding in the varied basic and emerging applied aspects of nano-technology in healthcare with relevance to application of radiation and improvement of therapeutic outcomes.

References:

1. Application of High-Z Nanoparticles to Enhance Current Radiotherapy Treatment. (https://doi.org/10.3390/molecules29112438)
2. Nano based drug delivery by Jitendra Naik (IAPC Publishing; ISBN 978-953-56942-2-9)
3. Nanoparticles for Radiation Therapy Enhancement: the Key Parameters. (doi: 10.7150/thno.11642)
4. Smart nanoparticles for cancer therapy. (https://doi.org/10.1038/s41392-023-01642-x)
5. Nanoparticles for Biomedical Applications by Chung, Leon & Rinaldi. (ISBN: 978-0-12-816662-8)

BS718: Radioisotopes in Healthcare & Radiopharmaceuticals Research (75 Lecture Hrs)

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Course Details:

- **Applications of Radioisotopes in Healthcare**
  - In vitro diagnostics: RIA & IRMA
  - Radiotherapy: Teletherapy, Brachytherapy, BNCT, Particle Radiotherapy (Proton, Neutron, Hydron therapy), IMRT, Gamma Knife
  - Radiopharmaceuticals: Diagnostic & Therapeutic Radiopharmaceuticals
  - Radiation processing: Hydrogel, Sterilization, Biohazard treatment

- **Production of Medically useful Radioisotopes**
  - Reactor:(n,□,), (n, p), (n, α), Szilard-Chalmers (SC) process, Fission reaction Production of Reactor produced isotopes
  - Cyclotron/Accelerator: Proton, Deuteron, α particles for isotope production Production of cyclotron produced isotopes
  - Radioisotope generators
  - Generator produced isotopes: ^{99m}Tc, ^{90}Y,^{68}Ga

- **Molecular Imaging**
  - Imaging modalities: SPECT, PET, CT, MRI & OI
  - Mechanism of uptake of radiopharmaceuticals:
    - Physiologic tracers
    - Molecular targeting
  - SPECT & PET Radiopharmaceuticals:
    - Tumor targeting agents
    - Infection and Inflammation imaging agents

- **Therapeutic Radiopharmaceuticals**
  - Bone pain palliation & Radiation synovectomy agents
  - Cancer therapy
    - Radiolabeled peptides, small molecules, antibodies
    - Liver embolization Radiotherapy

- **Development of Radiopharmaceuticals**
  Radiochemistry: Radiolabeling & Characterization

- **Biological evaluation of radiopharmaceuticals**
  - In- vitro evaluation of Radiopharmaceuticals:
  - In-vivo evaluation of Radiopharmaceuticals:
  - Quality control & Quality Assurance:

- **Facility Development and Ethical/Regulatory Aspects**

- Regulation in Radiopharmaceuticals

Radiopharmaceuticals Committee (RPC) approval of products

***Practical*:**

- Radiolabeling of a biomolecule with 99mTc, 125I or 177Lu, characterization by chromatography techniques.
- In- vitro evaluation of target specific Radiopharmaceutical (Radiolabeled peptide/ antibodies in tumor cell lines, Kd, IRF determination)
- Biodistribution of a radiopharmaceutical in mice/rats and data analysis
- SPECT Imaging study of a radiopharmaceutical in mice/rats and data processing

Course outcome:

- Understanding production of radioisotopes for healthcare applications
- Radiolabeling of ligands for imaging and therapy applications
- Techniques in preclinical evaluation of radiopharmaceuticals.

References:

1. Physics and Radiobiology of Nuclear medicine. By: Gopal B Saha (Spinger)
2. Fundamentals of Nuclear Pharmacy. By: Gopal B Saha (Spinger)