LIFE SCIENCES

Programme Code: LIFE04

Programme Outcome:

- The programme aims to equip students with knowledge and skills in different fields enabling research in interdisciplinary fields related to biological sciences.
- Basic concepts and fundamental understanding of microbiology, cell and molecular biology.
- Understanding of interaction of radiation /light with biological system.
- Basic understanding of Lasers, material science, optics and fundamental concepts in physics and chemistry.
- Foundation for mathematical and statistical analysis relevant for biologists.
- Application of computational methods in biology.
- Knowledge of Microbiology, immunology, molecular and cancer biology.
- Concepts, fundamentals and applications in Biophotonics.
- Hands-on experiments in various fields of Biology and Biophotonics.
- Fundamentals of material characterization.
- Skill development in critical thinking, problem solving and scientific methods
- Development of skills to clearly articulate scientific problem and execute it, followed by proper communication of results in both oral as well as written formats.
- Expertise development in advanced interdisciplinary research areas will lead towards nation building both through contributions in academics and industries.

COURSE STRUCTURE

Elective Courses (Total credits to be earned = 18)					
S. No.	**Course Code**	**Course Name**	**Course Type**	**Total Hours**	**Credits**
1.	03-LIFE04-501-E	Basic Concepts in Cell and Cancer Biology	E	30	2
2.	03-LIFE04-502-E	Fundamentals of Genetics and Molecular Biology	E	30	2
3.	03-LIFE04-503-E	Basic Concepts of Microbiology and Immunology	E	30	2
4.	03-LIFE04-504-E	Basic Laser Physics and Technology	E	30	2
5.	03-LIFE04-505-E	Basic Solid-State Physics and Material Science	E	30	2
6.	03-LIFE04-506-E	Basic Optics	E	30	2
7.	03-LIFE04-507-E	Basic Fiber Optics and Fiber Sensors	E	30	2
8.	03-LIFE04-508-E	Basic Concepts in X-Ray Physics	E	30	2
9.	03-LIFE04-509-E	Basic Chemistry	E	15	1
10.	03-LIFE04-510-E	Basic Mathematics for Biologists	E	15	1
11.	03-LIFE04-601-E	Advanced Biochemistry	E	30	2
12.	03-LIFE04-602-E	Advanced Microbiology	E	45	3
13.	03-LIFE04-603-E	Advanced Molecular Biology	E	45	3
14.	03-LIFE04-604-E	Advanced Cell Biology	E	45	3
15.	03-LIFE04-605-E	Advanced Immunology	E	30	2
16.	03-LIFE04-606-E	Cancer Biology	E	45	3
17.	03-LIFE04-607-E	Structural Biology	E	30	2
18.	03-LIFE04-608-E	Bioinformatics	E	30	2
19.	03-LIFE04-609-E	Food and Medicinal Biochemistry	E	30	2
20.	03-LIFE04-610-E	Radiation Biology	E	45	3
21.	03-LIFE04-611-E	Experimental Techniques in Biology	E	60	2
22.	03-LIFE04-612-E	Biophotonics	E	45	3
23.	03-LIFE04-613-E	Application of Computational and Numerical Techniques in Biology	E	45	3
24.	03-LIFE04-614-E	Mathematical Methods in Biology	E	30	2
25.	03-LIFE04-615-E	Radiation and Biosafety	E	30	2
26.	03-LIFE04-616-E	Biomaterials and	E	30	2

		Instrumentation for its Characterization			
27.	03-LIFE04-617-E	Biostatistics	E	30	2
28.	03-LIFE04-618-E	Experimental Techniques in Biophotonics	E	60	2
29.	03-LIFE04-601-C	Research Methodology		30	2
30.	03-LIFE04-601-PR	Minor project relevant to PhD Topic –I	PR		6
31.	03-LIFE04-602-PR	Minor project relevant to PhD Topic –II	PR		6

E: Elective; PR: Project

COORDINATORS

Program Coordinators:

Prof. Shovan Majumdar, E-mail: shkm@rrcat.gov.in

Course Coordinators:

Course	Coordinator	E-mail
Basic Concepts in Cell and Cancer Biology	Dr. Khageswar Sahu	khageswar@rrcat.gov.in
Fundamentals of Genetics and Molecular Biology	Dr. Rashmi Shrivastava	rshrivastava@rrcat.gov.in
Basic Concepts of Microbiology and Immunology	Dr. Khageswar Sahu	khageswar@rrcat.gov.in
Basic Laser Physics and Technology	Dr. Ajit Upadhyay	ajitup@rrcat.gov.in
Basic Solid-State Physics and Material Science	Dr. M. K. Chattopadhyay	maulindu@rrcat.gov.in
Basic Optics	Dr. 85 Verma	sverma@rrcat.gov.in
Basic Fiber Optics and Fiber Sensors	Dr. Om Prakash	oprakash@rrcat.gov.in
Basic Concepts in X-Ray Physics	Dr. Gurvinderjit Singh	gjit@rrcat.gov.in
Basic Chemistry	Dr. S. K. Majumder	shkm@rrcat.gov.in
Basic Mathematics for Biologists	Dr. Sunil Verma	sverma@rrcat.gov.in
Advanced Biochemistry	Dr. Rashmi Shrivastava	rshrivastava@rrcat.gov.in
Advanced Microbiology	Dr. Hem C. Jha	hemcjha@iiti.ac.in
Advanced Molecular Biology	Dr. Rashmi Shrivastava	rshrivastava@rrcat.gov.in
Advanced Cell Biology	Dr. Khageswar Sahu	khageswar@rrcat.gov.in
Advanced Immunology	Dr. Khageswar Sahu	khageswar@rrcat.gov.in
Cancer Biology	Dr. Hem C. Jha	hemcjha@iiti.ac.in
Structural Biology	Dr. Sharad Gupta	shgupta@iiti.ac.in
Bioinformatics	Dr. Rashmi Shrivastava	rshrivastava@rrcat.gov.in
Food and Medicinal Biochemistry	Dr. S. K. Majumder	shkm@rrcat.gov.in
Radiation Biology	Dr. S. K. Majumder	shkm@rrcat.gov.in
Experimental Techniques in Biology	Dr. S. K. Majumder	shkm@rrcat.gov.in
Biophotonics	Dr. S. K. Majumder	shkm@rrcat.gov.in
Application of Computational and Numerical Techniques in Biology	Dr. Ajit Upadhyay	ajitup@rrcat.gov.in
Mathematical Methods in Biology	Dr. Sunil Verma	sverma@rrcat.gov.in
Radiation and Biosafety	Dr. S. K. Majumder	shkm@rrcat.gov.in
Biomaterials and Instrumentation for its Characterization	Dr. Srinibas Satapathy	srinu73@rrcat.gov.in
Biostatistics	Dr. S. K. Majumder	shkm@rrcat.gov.in
Experimental Techniques in Biophotonics	Dr. S. K. Majumder	shkm@rrcat.gov.in
Research Methodology	Dr. V. B. Tiwari	vbtiwari@rrcat.gov.in
Minor project relevant to PhD Topic –I	Respective Guide	--
Minor project relevant to PhD Topic –II	Respective Guide	--

COURSES

03-LIFE04-501-E: Basic Concepts In Cell And Cancer Biology (30 Lecture Hrs)

Coordinators: Dr. Khageswar Sahu
(khageswar@rrcat.gov.in)

Course Details:

Basic Cell and Tissue Structure
Fundamentals of cell structure, organization and function in plants and animals, Origin of cell, structure and function of extracellular matrix, introduction to stem cells. Plant and animal tissue organization.

Cellular Metabolism
Anabolism, catabolism, photosynthesis, cellular respiration, secondary metabolites

Cell Cycle and Division
Fundamentals of cell cycle, Chromatin, microtubules, chromosomes, mitosis, meiosis and chromosomal abnormalities.

Cancer Cell Biology
Mutations, tumorigenesis, invasion and metastasis, tumor cell receptors. Basics of tumor diagnosis and therapy.

Course Outcomes:

- Introduced to the cellular structure and organization.
- Knowledge about cellular metabolism and cell division
- Fundamental understanding of mutations and tumor growth.
- Knowledge about tumor diagnosis and therapeutic strategies.

References:

1. Cell and Molecular Biology 8Ed, De Robertis
2. Cell and Molecular Biology by G. Karp.

03-LIFE04-502-E: Fundamentals Of Genetics And Molecular Biology (30 Lecture Hrs)

Coordinators: Dr. Rashmi Shrivastava
(rshrivastava@rrcat.gov.in)

Course Details:

Basic principle of genetics, laws of genetics and central dogma of molecular biology.
Genome organization
Basic structure of DNA, RNA. Organization of prokaryotic and eukaryotic genome: Comparative overview on genome architecture in prokaryotes and eukaryotes
Fundamentals of genetic recombination and variation

Gene Expression
Fundamentals of Gene expression, Operon, epigenetics and regulation

Genetic engineering
An overview. Plasmids, different types of vectors, cloning, Genetic manipulation techniques: Mutagenesis, Overexpression, genomic integration

Basic structure of proteins
Fundamentals of protein structure (primary, secondary, tertiary, quaternary), structure-function relationship, protein synthesis

Course Outcomes:

- Insight into the principles of genetics, gene transfer, central dogma of molecular biology.
- Knowledge of structure and functions of various biomolecules.
- Basics of recombinant DNA technology.
- Understanding of regulation of gene expression and structure function relationship of proteins.

References:

1. "Molecular Cell Biology" 6th Edition by Lodish
2. "Gene X" By Lewin
3. Molecular Biology of the Gene (7^{th} edition), 2017, James Watson., Pearsons Education, India.

03-LIFE04-503-E: Basic Concepts Of Microbiology And Immunology (30 Lecture Hrs)

Coordinators: Dr. Khageswar Sahu
(khageswar@rrcat.gov.in)

Course Details:

Basic Microbiology
Classification of micro-organisms, structure, function and replication of microorganisms, microbial growth.Classical and molecular identification of virus, prokaryotic and eukaryotic micro-organisms.
Mechanism of genetic exchange in microbes (vertical and horizontal gene transfer), industrially important microbes
Basic concept of commensalism, symbiosis and pathogenesis

Basic Immunology
Innate and adaptive, immune cells: types and function, Major histocompatibility complex, antigen presentation, allergy,
Basics of anti-microbial and anti-tumoral immunity

Course Outcomes:

- Introduction to cell structure, function, growth and metabolism in microorganisms.
- Basics of commensalism, symbiosis and pathogenesis.
- Understanding of basic immunology and defence mechanism in host against pathogens.
- Insight into anti-tumor and anti-microbial immunity

References:

1. Prescott's Microbiology – 11th Edition
2. Kuby IMMUNOLGY 7th Edition by Richard A. Goldsby, Barbara Anne Osborne, Janis
3. Kuby. Publisher: W.H. Freeman

03-LIFE04-504-E: Basic Laser Physics And Technology (30 Lecture Hrs)

Coordinators: Dr. Ajit Upadhyay
(ajitup@rrcat.gov.in)

Course Details:

Basic Formalism: Spontaneous and induced transitions, Einstein's approach, A and B coefficients, conditions for light amplification and oscillations, and characteristics of laser light. Homogeneous and inhomogeneous broadening of the transitions, spectral narrowing in laser. Optical resonators, concept of cavity modes, resonators with spherical mirrors, resonance frequencies of optical resonators, losses in optical resonators, stable/unstable resonators.

Methods for Obtaining Population Inversion: Optical pumping, coherent and incoherent pumping, pumping geometries, pump sources, electrical pumping by discharge in gases, excitation mechanisms.

Laser Dynamics: Laser oscillation, three and four level lasers, rate equation modeling, power in laser oscillators, optimum output coupling low- and high-loss regimes, multimode laser oscillation and mode locking and Q-switching.

Physics and Technology of Specific Laser Systems: Solid state lasers, vibronic lasers, semiconductor diode lasers, diode pumped solid state lasers, fiber lasers, dye lasers, atomic and molecular gas lasers, chemical lasers, excimer lasers, free electron lasers. Measurement of parameters of a laser system.

Applications of lasers in science and engineering: Laser matter interaction

Course Outcomes:

- Basic understanding of Lasers and other light sources.
- Knowledge of different types of lasers and their properties.
- Basic understanding of light-matter interaction**.**
- Applications of lasers in various fields with emphasis on biological and medical areas.

References:

1. "Laser Fundamentals", W. T. Silfvast
2. "Laser Electronics", J. T. Verdeyen
3. "Lasers", A. E. Siegman
4. "Quantum Electronics", A. Yariv
5. "Laser Physics and Technology, Proc. of the school on Laser Physics and Tech." Eds. P. K
6. Gupta, R. Khare

03-LIFE04-505-E: Basic Solid-State Physics And Material Science (30 Lecture Hrs)

Coordinators: Dr. M. K. Chattopadhyay
(ajitup@rrcat.gov.in)

Course Details:

Atomic Structures of Crystals: Crystal systems, Choice of unit cell and symmetry consideration, Bravais lattice: 2D, 3D and Symmetry operations; Reciprocal lattice; Structure determination by scattering: structure factor, concept of Ewald sphere; Types of bonding in solid.

Lattice dynamics and thermal properties: Classical vibration in one and three dimensions, Specific heat: Einstein, Debye model and beyond (correction from actual phonon dispersion curve); Thermal conductivity: Effect of Phonon scattering and mean free path, Graphene, carbon nanotube and polymer

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Electronic properties of solids: Concept of holes and effective mass, electronic properties of selected crystals, Optical properties.

Electronic states at the surface: Work function, Contact potential, Thermoionic emission, electronic surface levels.

Magnetism: Diamagnetism, paramagnetism and ferromagnetism. Origin of ferromagnetism and anti-ferromagnetism, magnetic nanoparticles and its applications in biology.

Dielectric properties of materials: Polarization mechanisms in dielectrics, Dispersion in dielectric material; Principles of piezoelectricity, transducers and energy harvesting materials; Piezoelectricity and Ferro electricity.

Course Outcomes:

- Understanding of basics of crystal structure.
- Knowledge about electronic structure and interactions in solids.
- Introduction to magnetism and magnetic properties of materials and their varied biological applications.
- Basic understanding of dielectric properties of materials.

References:

1. Solid State Physics, N. W. Ashcroft and N. D. Mermin
2. Condensed Matter Physics, M. P. Marder
3. Solid State Physics, An introduction to the Principles of Materials Science, H. Ibach and H. Luth
4. Atomic and Electronic Structure of Solids, E. Kaxiras

03-LIFE04-506-E: Basic Optics (30 Lecture Hrs)

Coordinators: Dr. Sunil Verma
(sverma@rrcat.gov.in)

Course Details:

Fundamentals of geometric and wave Optics: Concepts of Wave front and phase, image formation and spatial resolution, optical path and spatial coherence, monochromaticity and temporal coherence, wave front aberrations, basics of interference and diffraction, contrast/visibility of fringes; concept of spatial filtering, amplitude and phase filters in spatial frequency domain, image processing.

Modern Optical Instruments: Basics of Michelson, Fabry-Perrot, Mach-Zender, Fizeau, Twyman-Green, and lateral shear interferometer, concept of coherence and white light interferometry, scanning white light interferometer (SWLI), Sagnac (cyclic) interferometer, Shack-Hartman wave-front sensor, basics of diffraction gratings and spectrometers.
Surface imperfections and ISO 1011 standard: Definitions of surface form, parallelism, scratch and Dig and RMS roughness their measurements using surface profilometers, white light confocal microscopy.

Optical coatings: Introduction, antireflection coating, beam splitters, neutral density filters, high-reflection mirror coatings, edge filters, band pass interference filters, deposition of optical thin film multilayer coatings, infrared optical coatings, characterization of coatings.

Course Outcomes:

- Understanding of basic ray and wave optics.
- Introduction to various optical interferometers.
- Properties and applications of various optical components used in advanced studies.
- Construction and application of confocal microscopy

References:

1. Introduction to Fourier Optics, Joseph W. Goodman
2. Handbook of Optical Design (Optical Science and Engineering), Daniel Malacara
3. Encyclopedia of Optical Engineering, Ronald G. Driggers (Editor)
4. Laser Resonators and Beam Propagation, Norman Hodgson and Horst Weber
5. The Physics and Technology of Laser Resonators, Denis Hall
6. Optical Interferometry, P. Hariharan
7. Theory and Practice of Scanning Optical Microscopy, Colin Sheppard
8. Wave Optics and its Applications, R.S. Sirohi
9. Optical Thin Films and Coatings-From Materials to Applications, Ed. Angela Piegari and François Flory

03-LIFE04-507-E: Basic Fiber Optics And Fiber Sensors (30 Lecture Hrs)

Coordinator: Dr. Om Prakash
(oprakash@rrcat.gov.in)

Course Details:

- **Fiber Optics:** Optical fiber basics, single mode fiber, multi-mode fiber, step index fiber, graded index fiber, double-cladded fiber, micro-structured fiber, modes in optical fiber, odd even TE modes, characterization of modes, TE, TM hybrid modes.
- **Characteristics of Optical Fiber:** Losses in optical fiber: intrinsic impurity absorption loss, waveguide scattering loss, macro-bending loss, coupling splicing loss; dispersion in optical fiber, dispersion management in optical fiber.
- **Fiber Optic Components and Devices:** Directional couplers, power transfer characteristics, effect of fiber dispersion, optical isolator, and optical circulators.
- **Optical Fiber Gratings:** Photosensitivity, defects in the optical fiber, photosensitivity of doped fibers, photosensitization methods for optical fiber, refractive index modulation in the optical fiber, methods of fiber grating writings e.g. phase mask based, Interferometry, point by point; Types of fiber gratings such as uniform Bragg grating, long period grating, tilted fiber Bragg grating, Type-IIa fiber grating, Type-II fiber grating, Type-Ia fiber grating etc., properties of laser sources used for fabrication of fiber gratings, Optical theory of fiber Bragg, titled and long period gratings, mode coupling, reflection and transmission spectra.
- **Optical Fiber Sensors:** Principle of fiber optic sensor, classification of fiber optic sensor, sensing region, optical modulation mechanism, fiber grating sensors, principle of sensing, fiber designs for sensing, single point sensing, multipoint/distributed sensing, measurement of temperature with FBG, measurement of strain with FBG, measurement of pressure with FBG, FBG wavelength temperature compensation techniques, chirped grating sensor, long period grating sensor, evanescent field refractive index sensor, FBG based refractive index sensors, tilted FBG based refractive index sensors, LPG based refractive index sensors, sensors based on surface plasmon resonance (SPR), Raman, Brillouin and Rayleigh scattering based fiber sensors.

Course Outcomes:

- Understanding of basic concept of optical fibers and their types.
- Knowledge about transmission through optical fibers and their properties.
- Insight of various gratings.
- Applications of optical fibers for development of biosensors.
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References:

1. Introduction to Fiber Optics, Ghatak and Tyagrajan
2. Applications of Nonlinear Fiber Optics by G. P. Agrawal
3. Fiber Optics, Physics and Technology, Fedor Mitschke
4. Fiber Bragg Gratings by Raman Kashyap
5. Fiber optics sensors: Fundamental and applications, D. A. Krohn
6. Fiber Optic Sensors, Shizhuo Yin, Paul B. Ruffin, Francis T. S. Yu

03-LIFE04-508-E: Basic Concepts In X-Ray Physics (30 Lecture Hrs)

Coordinators: Dr. Gurvinderjit Singh
(gjit@rrcat.gov.in)

Course Details:

X-ray and their Interaction with Matter: X-ray waves and photons, sources of X rays, X-ray scattering from an electron and atom, refractive index including absorption.

Refraction and Reflection of X-rays: Refraction and phase shifting in scattering, Snell's law and Fresnel equation in X-ray region, reflection from homogeneous slab and multi-layers, rough interfaces and surfaces, examples of refractive and reflective X-ray optics and curved mirrors.

Diffraction by Perfect Crystals: Kinematical reflection from few layers, basics of dynamical theory, Darwin's theory of extinction depth, integrated intensity, standing waves, higher order reflection, effect of absorption, asymmetric Bragg geometry, DuMond diagrams, applications in synchrotron X-ray monochromators, X-ray Topography.

X-Ray Absorption: X-ray absorption from isolated atoms, extended X-ray absorption fine structure (EXAFS), near edge X-ray absorption (XANES), EXAFS equation, basics of EXAFS data acquisition and sample preparation, Transmission versus fluorescence modes of EXAFS.

X-Ray Fluorescence: Theoretical details and data analysis, details of the experimental technique, sample preparation, trace element quantification and related issues.

Course Outcomes:

- Understanding of basic and advanced concepts of interaction of X-rays with –matter
- Introduction to various X-ray related analytical techniques.
- Biological applications of X-ray scattering, absorption and fluorescence

References:

1. "Elements of Modern Optics", Jens Als-Nielsen & Des McMorrow
2. "Dynamical Theory of X-ray Diffraction", Andre Authier
3. "Soft X-Rays and Extreme Ultraviolet Radiation", David Attwood

03-LIFE04-509-E: Basic Chemistry (15 Lecture Hrs)

Coordinators: Dr. S. K. Majumder
(shkm@rrcat.gov.in)

Course Details:

Atomic Structure: Thomson's and Rutherford's models of atoms, spectral emissions from atoms, Bohr's model of atom, quantization of angular momentum, discrete energy level structure, concept of quantum numbers, and Franck-Hertz experiment, electronic configuration of atoms, Rules for filling electrons in orbitals – Aufbau principle, Pauli exclusion principle and Hund's rule, stability of half-filled and completely filled orbitals, ions and radicals. Photo-electric effect, dual nature of light and matter, de-Broglie's relation, concepts of spin and orbital angular moment

Chemical Bonding: Valence bond and molecular orbital descriptions of bonding, linear combination of atomic orbitals (LCAO) approach, hybridization, bonding in $(H2)^+$ and H2

Bonding in homonuclear diatomic molecules of second period, bond orders, bond lengths and bond strengths, bonding in heteronuclear diatomic molecules, concepts of polarity and electronegativity

Chemical Kinetics: Chemical reactions of zero and first orders, factors affecting rate of reaction: concentration, temperature, catalyst; order and molecularity of a reaction, half-life (only for zero and first order reactions), concepts of entropy, free energy.

Concepts of acidity, basicity, pH pKa,

Atomic and molecular masses, mole concept and molar mass, stoichiometry and calculations based on stoichiometry, dilution factor, serial dilutions. Concepts of solution, colloids and suspensions, concentration of solutions (Molarity, molality, Normality, percent etc.)

Essentials and trace elements of life; basic reactions in the biological systems and the role of metal ions in biological systems, especially Fe^{2+}, Ca^{2+} and Zn^{2+}, electronic concepts of oxidation and reduction, redox reactions, oxidation number, Redox reactions in biological systems.

Basic organic chemistry with special emphasis to structure activity relationship of bio molecules involved in xenobiotic drug metabolism.

Course Outcomes:

- Basic understanding of atomic structure and molecular orbitals
- Concepts of chemical bonding and Kinetics
- Basic chemical calculations for everyday laboratory application
- Knowledge about various ions and their role in biological system

References:

1. T. Engel and P. Reid, Physical Chemistry, 3rd Ed., Pearson
2. J. E. House, Inorganic Chemistry, 3ed, Academic Press, 2019.
3. P. Atkins, T. Overton, J. Rourke, F. Armstrong, and M. Hagerman, Shriver and Atkins' Inorganic Chemistry, 5ed, W. H. Freeman and Company New York, 2009

03-LIFE04-510-E: Basic Mathematics For Biologists (15 Lecture Hrs)

Coordinators: Dr. Sunil Verma
(sverma@rrcat.gov.in)

Course Details:

Basic mathematics: Sets, Relations & Functions, Algebra, Trigonometric Functions, Principle of Mathematical Induction, Complex Numbers and Quadratic Equations, Coordinate geometry, Linear Inequalities, Permutations and Combinations, Binomial Theorem, Basic Ccalculus

Introduction to Data analysis: Mathematical Models, Rates of Change, Balance Laws, Regression and Curve Fitting

Calculations for molecular biology: Scientific notations, calculating bacterial growth, nucleic acid quantification

Course Outcomes:

- Basic concepts in mathematical operations and functions.
- Introduction to data analysis tools.
- Knowledge about day to day calculations related to biological experiments.

References:

1. Easy Mathematics for Biologists – Peter C. Foster
2. Maths from Scratch for Biologists – Alan J. Cann
3. Basic Mathematics for the Biological and Social Sciences – F. H. C. Marriott
4. Mathematics for Biological Scientists – Mike Aitken, Bill Broadhurst & Stephen Hladky
5. Mathematics for the Life Sciences: Calculus, Modeling, Probability, and Dynamical Systems – Glenn Ledder
6. Biocalculus: Calculus, Probability, and Statistics for the Life Sciences – James Stewart (and co-authors)
7. Mathematics in Biology – Markus Meister, Kyu Hyun Lee & Ruben Portugues
8. Mathematics for Biologists – Arun Kumar

03-LIFE04-601-E: Advanced Biochemistry (30 Lecture Hrs)

Coordinators: Dr. Rashmi Shrivastava
(rshrivastava@rrcat.gov.in)

Course Details:

Basic Biochemistry

Proteins: post-translational modification and protein targeting − types of post translational modification and organelle targeting. Protein folding and degradation.

Enzymology

Enzymes: Mechanism of action, kinetics (equation and modeling: Michaelis-Menten, Lineweaver-Burk, Eadie-Hofstee)
Inhibitors and types of inhibition and regulation: competitive, non-competitive and uncompetitive

Metabolism

Overview of linking of central metabolic pathways such as glucose, lipid and amino acid metabolism (anabolism and catabolism).

Plant Biochemistry

Overview of energy yielding metabolic pathways in microbes, chloroplast and mitochondria
Oxidative phosphorylation, Photosynthesis and photo phosphorylation

Course Outcomes:

- Detailed understanding of biochemical processes.
- Knowledge about protein translation, post-translationala modifications and folding.
- Insight into various metabolic pathways and enzymology.

References:

1. Principles of Biochemistry Global Edition -- by Donald Voet, Judith G. Voet, Charlotte W. Pratt
2. Principles of Biochemistry: International Edition -- by David L. Nelson, Michael Cox
3. Enzymology (HB 2016) by Krintel C.
4. Basic Concepts in Enzymology by Dr. P. Palanivelu.
5. Posttranslational Modification of Proteins: Tools for Functional Proteomics edited by Christoph Kannicht

03-LIFE04-602-E: Advanced Microbiology (45 Lecture Hrs)

Coordinators: Dr. Hem C. Jha
(hemcjha@iiti.ac.in)

Course Details:

Microbial Survival in Natural Environments
Biofilms: structure and detection of biofilm, quorum sensing; persister cells; viable but non-culturable cells (VBNC). Microbial Interactions, quorum sensing

Molecular Pathogenesis
Pathogenicity islands, virulence factors (cellular structures, degradative enzymes, toxins, secretion systems)

Microbiome and antimicrobial resistance
Overview of microbiome and its importance, plant and animal microbiome, human intestinal viriome Antimicrobial resistance (definition, mechanism and current scenario), Antibiosis, Chromosome and plasmid coded resistance

Food Microbiology
Overview of food-borne pathogens, spoilage and fermentative organisms. Industrially relevant spoilage and fermentation process, Microbial death kinetics during processing, Concept of D10 value (during thermal and irradiation processing), Calculation of D_{10} value and its application during food processing.

Course Outcomes:

- Understanding mechanisms of microbial adaptations.
- Insight into-host-pathogen interactions.
- Understanding anti-biotic resistance.
- Recent advances in different fields of microbiology involving both prokaryotic and eukaryotic organisms.

References:

1) Brock's Biology of Microorganisms by Madigan et al.
2) Fundamental bacterial genetics by Trun & Trumphy.
3) Molecular medical microbiology by Sussman M.
4) Microbiology: diversity, disease and the environment Salyers, AA.
5) Medical microbiology by Murray PR**.**
6) Prescott's Microbiology − 10th Edition, By Joanne Willey, Linda Sherwood and Christopher J. Woolverton, McGraw-Hill Education
7) Microbiology by Tortora, Funke and Case, Pearson Education India, 11th edition
8) The Biofilm Mode of Life − Mechanisms and Adaptations, by Staffan Kjelleberg and Micahel Givskov

03-LIFE04-603-E: Advanced Molecular Biology (45 Lecture Hrs)

Coordinators: Dr. Rashmi Shrivastava
(rshrivastava@rrcat.gov.in)

Course Details:

Genome organization
Organization of prokaryotic and eukaryotic genome: Comparative overview on genome architecture in prokaryotes and eukaryotes

Gene Expression and Genetic Engineering
Gene expression, epigenetics and regulation: An overview. Plasmids, different types of vectors, cloning, Genetic manipulation techniques: Mutagenesis, Overexpression, genomic integration, Experimental approaches to understanding DNA-protein and protein-protein interactions, CRISPR-Cas9

DNA Repair Mechanisms
Different DNA repair pathways (Homologous, NHEJ, UV repair), Regulation, A comparative study in prokaryotes and eukaryotes

RNA Biology
Different types of RNA, role of RNAs. Structure-function aspects of tRNA. Regulatory roles of siRNA, snRNA, interference RNA

Yeast Molecular Biology and applications
Yeast two-hybrid system.

Viral genetics and applications

Course Outcomes:

- Detailed understanding of genomic organization and regulation.
- Recent advances in molecular biology and genetic engineering.
- Insight on structure-function relationship in biomolecules.
- Understanding biomolecular interactions.

References:

1) "Molecular Cell Biology" 6th Edition By Lodish
2) "Gene X" By Lewin
3) Molecular Biology of the Cell (6th edition), 2014, Bruce Alberts, Alexander Johnson, Julian Lewis, David Morgan, Martin Raff, Keith Robert sand Peter Walter, Garland Science: New York;
4) Molecular Biology of the Gene (7th edition), 2017, James Watson., Pearsons Education, India.

03-LIFE04-604-E: Advanced Cell Biology (45 Lecture Hrs)

Coordinators: Dr. Khageswar Sahu
(khageswar@rrcat.gov.in)

Course Details:

Cell communication, cell cycle and differentiation
Cell to cell communication, Types of signaling - Surface and intracellular receptors, Amplification of signal etc; Cell cycle, Cell cycle regulation, Phases, Check points, Latest techniques to detect cell cycle phases; Cell death − Apoptosis, Necrosis, Autophagy.

Differentiation and Development - Basic processes of development, Signals guiding development, Differentiation, Determination and Stem cells, Experimental approaches.

Cancer Biology
Cancer cell biology, causes (genetic and environmental), Tumor suppressors, Oncogenes, Hallmarks and enabling characteristics of a tumor, Metastasis, Targets for therapeutic interventions, Tumor microenvironment, Latest developments in diagnosis and treatment

Genetic manipulation techniques for animal cells and animals
Methods for genetic manipulation of mammalian cells and animals, Recent advances in transgenic, congenic and conditional knockout mice, Ethical issues related to genetic manipulation and research in experimental rodents and stem cells.

Course Outcomes:

- In-depth understanding of cellular processes, evolution of cell organelles.
- Importance of cellular processes in health and disease.
- Detailed understanding of tumorigenesis.
- Knowledge about ethics in animal handling and stem cells.

References:

1) Molecular Biology of the Cell by Bruce Alberts, Dennis Bray, James Watson, Julian Lewis, Keith Roberts, and Martin Raff
2) Gerald Karp Cell and Molecular Biology
3) Developmental Biology by Gilbert Hallmarks of Cancer: The Next Generation- Cell Review| Volume 144, ISSUE 5, P646-674, March 04, 2011
4) Programmed cell death pathways in cancer: a review of apoptosis, autophagy and programmed necrosis. Cell Proliferation. 2012 Dec; 45(6):487-98.

03-LIFE04-605-E: Advanced Immunology (30 Lecture Hrs)

Coordinators: Dr. Khageswar Sahu
(khageswar@rrcat.gov.in)

Course Details:

Immune System

Introduction to immune system: Cells and Organs of the Immune system and systemic functions of immune system, Innate immunity, Non-specific host immunity, Cells of the innate immune system, Complement system, Pattern recognition by innate immune system, Antigen presentation, Major Histocompatibility complex, Antigen presenting cells, Endogenous and Exogenous antigen presenting pathways, Humoral immunity, Antibody structure and diversity, Antibody mediated effector functions, Antibody classes and biological activity.

Cell Mediated immunity
T-cell receptor, alloreactivity, T-cell maturation, and Thymic selection, T-cell activation and differentiation, dynamics of adaptive immunity, Properties of effector T-cells and T-cell mediated cytotoxicity.

Advances in applied and clinical immunology
Immunotherapy for treatment of cancer- using inhibitors or antibodies; Vaccines and personalized therapy for immune disorders, chimeric antigen receptor T cells for treatment of lymphoma

Autoimmune and immunodeficiency diseases and immunotherapy

Course Outcomes:

- Understating of the basic and advanced concepts of immunological processes.
- Knowledge of altered host immune system as well as immune reactions towards infections.
- Update to recent advances in immunotherapy and other relevant clinical immunology methods.

References:

1) Kuby IMMUNOLGY 6th Edition by Richard A. Goldsby, Barbara Anne Osborne, Janis Kuby. Publisher: W.H. Freeman
2) Cellular and Molecular Immunology by Abul K. Abbas, Andrew H. Lichtman, Shiv Pillai. Publisher: Saunders/Elsevier

03-LIFE04-606-E: Cancer Biology (45 Lecture Hrs)

Coordinators: Dr. Hem C. Jha
(hemcjha@iiti.ac.in)

Course Details:

Cancer origin and terminology

- Molecular and cellular origin of cancer
- Clonal vs. mutational origin of cancer
- Stem cells and cancer

Different classes of cancers

- Carcinoma, Sarcoma
- Leukemia, Lymphoma and myeloma
- Central nervous system cancers

Malignant transformation of cells

- General causes of cancer, mechanisms
- Characteristics and phenotypes of cancer cells
- Process of metastasis and its significance

Cancer induction and oncogenes

- Stages in the development of tumorigenesis: initiation and promotion
- Tumor-suppressor genes and oncogenes and their differences
- The connection between oncogenes and proto-oncogenes
- Cancer stem cell

Cellular response to Tumors

- Signal transductions in cancer, G protein coupled-receptors and secondary
- messengers
- Receptor tyrosine kinases and SH2-containing proteins
- Ras protein and the MAP kinase cascade in the control of cell function and
- aberrations in cancer
- Convergence, divergence and crosstalk among different signaling pathways
- Concept of apoptosis and its role in cancer

Tumor Antigens and tumor immunity

- Tumor-specific transplantation antigens (TSTAs) and tumor-associated
- transplantation antigens (TATAs)
- Tumor induced altered Immune response and immune-suppression

Tumor Evasion mechanism

- Changes in tumor cells
- Alteration in antigen presenting cells
- Dysfunction of host effector cells

Cancer Therapy

- Chemotherapy
- Radiation therapy
- Surgery
- Cancer immuno-therapy
- Other treatment methods including targeted therapy

Course Outcomes:

- Basic understanding of molecular and cellular mechanisms of carcinogenesis.
- In-depth knowledge of oncogenes, tumor antigens and tumor immunity
- Knowledge on current and prospective therapeutic interventions.
- Recent advances in targeted therapy for various cancers.

References:

1) "Molecular Biology of the Cell" by Alberts, Bruce; Johnson, Alexander; Lewis, Julian; Raff, Martin; Roberts, Keith; Walter, Peter
2) "Molecular Cell Biology" by Lodish, Harvey; Berk, Arnold; Zipursky, S. Lawrence; Matsudaira, Paul; Baltimore, David; Darnell, James E
3) "The Biology of Cancer" by Weinberg, Robert A

03-LIFE04-607-E: Structural Biology (30 Lecture Hrs)

Coordinators: Dr. Sharad Gupta

Course Details:

Overview of structural biology—structural features of biomolecules in three-dimensional space, structure

Determination methods and recent developments
Troubleshooting the recombinant protein expression and purification
Principles and methods of protein crystallization, Crystal symmetry
Theory of diffraction and Fourier synthesis, X-ray sources
Diffraction data collection and processing
Diffraction data to structure: Solving the crystallographic phase problem
Diffraction data to structure: Electron density map and model building
Diffraction data to structure: Refinement and validation
Structure-based drug design - a rational approach
Principles of CD and fluorescence spectroscopy in protein structure analysis

Course Outcomes:

- Basic understanding of structure determination of biological macro-molecules.
- Knowledge about protein purification and structure determination methods.
- Understanding concept of crystal symmetry
- Various steps of protein structure determination from X-ray diffraction data colletion to refinement and validation.
- Concepts of structure-based drug design.

References:

1) “Biomolecular Crystallography” by Bernhard Rupp.
2) “Introduction to protein structure” by Carl Branden and John Tooze
3) “Textbook of Structural Biology” by Anders Liljaset al.

03-LIFE04-608-E: Bioinformatics (30 Lecture Hrs)

Coordinators: Dr. Rashmi Shrivastava
(rshrivastava@rrcat.gov.in)

Course Details:

Introduction to Bioinformatics Introduction, History and importance, Field and scope

Databases and Database searching Importance, classification, Annotation and File formats
Demo: NCBI, SWISS-PROT, PDB

Locating Coding regions and Gene prediction6-frame translation, parameters governing prokaryotic and eukaryotic translation, Concept, neural networks and its importance in gene prediction as example

AlignmentsSignificance and importance, types, classification, Dot-plot matrix, Substitution Matrices, Significance, types,derivation of BLOSUM and PAM, Application of Substitution Matrices Algorithms behind pair wise sequence alignments
Dynamic programming, Smith-Watermann, Needleman-Wunsch, Heuristic, BLAST, FASTA
applications, statistical parameters governing BLAST results Demo: database searching using BLAST Multiple sequence alignments (Importance, progressive sequence alignment, ClustalW, statistical parameters governing clustalW, applications Demo: ClustalW

Phylogenetic tree construction and different approaches Introduction, importance, classification and parts of tree, predicting number of root and unrooted trees, orthologs and paralogs, transitions and transversions, substitution matrices, different methods to construct phylogenetic tree, Neighbour-Joining (star decomposition method), Bootstrapping Demo : MEGA software

Pattern matching/position specific scoring matrices
Importance of patterns, motifs, deriving PSSM, sequence logo
Demo: Prosite, Pfam

Structural Bioinformatics
Introduction to structural bioinformatics and protein structure, Ramachandran
Plot, Secondary structure prediction and methods, Hydropathy plot, helical wheel, signal peptide prediction, transmembraneprediction, Tertiary structure prediction: RMSD and Homology modeling Demo: Swiss Model and evaluation, Concepts related to Drug design: Lipinski Rule of 5 and Molecular docking

Course Outcomes:

- Knowledge about biological databases and sequence analysis.
- Understanding sequence-structure relationship and protein structural prediction and modeling.
- Principles and concepts of protein-ligand interaction**.**
- Phylogenetic tree building and evolution analysis

References:

1) Introduction to bioinformatics by Arthur M. Lesk
2) Bioinformatics by David Mount
3) Essential bioinformatics byJinXiong

03-LIFE04-609-E: Food And Medicinal Biochemistry (30 Lecture Hrs)

Coordinators: Dr. S. K. Majumder
(shkm@rrcat.gov.in)

Course Details:

Medicinal Biochemistry: Definitions and classifications, Pharmaceutical, pharmacokinetic, and pharmacodynamic phases, Drug-receptor interactions, Intra- and intermolecular forces, Solvent effects, Ligand binding, Docking and design,

Molecular basis of drug action: Receptor specificity and signal transduction, Channel containing receptors, intracellular receptors, Receptor desensitization, Drug action in cell not mediated through receptors.

Lipophilicity and drug action: Thermodynamics of van der Waals interactions, thermodynamics of hydrophobic interactions, Molecular lipophilicity potential. Physicochemical and biological factors that influence drug permeability by passive diffusion, lipophilicity of metabolites.

Drug-Receptor thermodynamics: Thermodynamic models of drug-receptor interactions, Effect of receptor interactions. Basics of correlations, relevance to enthalpy-entro compensation.

Drug metabolism: Inhibitions, induction, species and sex differences in drug metabolism, age on drug metabolism, CYP 450, Glutathone S-transferases, UDP- Glucuronosyl transferase.

Food Biochemistry:
Carbohydrates: structure and functional properties of mono-oligo-polysaccharides including starch, cellulose, pectic substances, and dietary fibers, Essential amino acids, proteins, and lipids in food and their impact on functional properties, vitamins and minerals, Food flavours: terpenes, esters, ketones, and quinines; Food additives, Bioactive constituents in food: isoflavones, phenol, and glycosides; Enzymes: enzymatic and non-enzymatic browning, enzymes in food processing, oxidative enzymes, Food biochemistry: balanced diet, PER, anti-nutrients and toxins, nutrition deficiency diseases.
Food Processing: Standards and regulations, FSSAI regulations regarding food irradiation, Radiation processing of food products, applications, chemical changes and wholesomeness, Basic process of food irradiation, Isotopes and technologies used for food irradiation, Low medium and high dose applications of food irradiation, Effect of radiation on macro and micro nutrients in food products,

Optical spectroscopic techniques for the analysis of pharmaceuticals and food.

Course Outcomes:

- Knowledge about food biochemistry and processing
- Concepts of pharmaceutical drug analysis.
- Understanding of drug interactions and targeting in biological systems.
- Insight into advances in the upcoming area of research in techniques of food products.

References:

1) Food Biochemistry and Food Processing, Second Edition by Benjamin K.
2) Burger's Medicinal Chemistry and Drug Discovery (1 to-5 vol) Wolff Manfred 5 Medicinal Chemistry
3) Medicinal Chemistry- A Molecular and Biochemical Approach by Nagrady T, Weaver DF
4) Foye's Principles of Medicinal Chemistry by Williams DA & Lemke TL
5) Comprehensive Medicinal Chemistry Vol.I by Hansh Corwin
6) Biochemistry of Foods, 3rd Edition by N.A. Eskin, Fereidoon Shahidi

03-LIFE04-610-E: RADIATION BIOLOGY (45 Lecture Hrs)

Coordinators: Dr. S. K. Majumder
(shkm@rrcat.gov.in)

Course Details:

Basics in radiation biology
Physics and Chemistry of radiation absorption, Radiation types, units, doses and measurements, Interaction of radiation with matter, Free radical biology, Radiation biology − Cell survival curves, Radiosensitivity and
its factors, Oxygen effect, Radio-modulation, Linear Energy transfer and Radiobiological Effectiveness (LET and RBE)

Genetic effects of radiation
Genetic effects of radiation, Biological and clinical dosimetry, Cytogenetics and molecular biomarkers

Biological effects of radiation
Biological effects of radiation (Deterministic, stochastic), Radiation safety and protection: Personal Protective Equipment, regulatory guidelines and exposure limits, Adaptive response, Radiation hormesis, Application of different types of radiation in diagnosis and therapy, Fractionation in radiotherapy, International bodies related to radiation safety, High natural radiation areas and their significance.

Photobiology and its applications

Course Outcomes:

- Basic understanding of interaction of radiation with biological system.
- Concepts of photobiology.
- Applications of radiation and photo-chemical photobiological phenomenon in health care

References:

1) Basic Clinical Radiobiology; Michael Joiner and Albert van der Kogel -Fourth Edition

03-LIFE04-611-E: Experimental Techniques In Biology (60 Lecture Hrs)

Coordinators: Dr. S. K. Majumder (shkm@rrcat.gov.in)

Course Details:

Biophysical

Overview of advanced Instrumentation in biological research
Principle, instrumentation and application of:
Biosensors, NSOM, Scanning Electron Microscopy (SEM), Transmission Electron microscopy (TEM), X-ray Diffraction (Powder and protein)
Rheometer, Atomic Force Microscopy (AFM), Surface Plasmon
Microscopic techniques: Light, compound, phase-contrast, fluorescence, Confocal laser scanning microscopy (CLSM)
Image analysis
Spectroscopy: Fluorescence, Raman, FTIR, NMR, ESR, Circular dichroism, Infrared spectroscopy, fluorescence correlation spectroscopy
Flow cytometry and high throughput screening
Dynamic light scattering

Biochemical
Separation techniques: Electrokinetics methods: electrophoresis, electrophoretic mobility (EPM), factors affecting EPM, Paper, PAGE, Capillary, Iso-Electric focusing, Agarose gel electrophoresis applications in biology and medicine.
pH determination,
Solution preparations of different concentrations
Chromatography
HPLC: mobile phase systems, modes of operations, application,
Centrifugation, Ultracentrifugation and their applications in molecular weight, size determination.

Microbiology
Bacterial, viral and fungal culture, growth curves, colony counting, viability determination, biofilm formation, anti-microbial assays, culture preservation and propagation.

Molecular biology: DNA/plasmid isolation and detection, RNA isolation and detection, Protein purification and detection, cloning, PCR, RT-PCR, transfection, transformation and related methods like Animal cell Culture techniques, Immunoasays like ELISA. Protein crystallization and X-ray diffraction, Molecular modelling and interaction

Course Outcomes:

- Understanding basic principles, operations and applications of various modern-day analytical instruments required for scientific analysis of cells, biomolecules, bioanalytes
- Knowledge of precautions while working in laboratory.

- Hands-on experience and learning of various laboratory techniques.

References:

1) "Molecular Cloning: A Laboratory Manual" by David W. Russell and Joseph Sambrook.
2) "Fundamentals and Techniques of Biophysics and Molecular Biology" by Pranav Kumar
3) "Handbook of Analytical Techniques" by Prof. Dr. Helmut Günzler, Alex Williams
4) "Techniques in Microbiology: A Student Handbook" by John Lammert

03-LIFE04-612-E: Biophotonics (45 Lecture Hrs)

Coordinators: Dr. S. K. Majumder
(shkm@rrcat.gov.in)

Course Details:

Introduction: Scope of Bio-photonics, interaction of light with cells and tissues: absorption, scattering and depolarization of light.

Light Propagation in Tissues: Rayleigh and Mie scattering, multiple scattering and propagation of light in tissues, Radiative transport and diffusion approximation, effect of boundary conditions, numerical approaches for determining irradiance at surface and interior of scattering objects, techniques for determination of optical properties of biological samples.

Optical Imaging Through Turbid Medium: Trade-off between resolution and depth of imaging, use of spatial filtering, polarization gating and time-gating for optical imaging, high resolution imaging using coherence gating, Optical coherence tomography (OCT) and diffuse optical tomography.

Optical Spectroscopy for Biomedical Diagnosis: Elastic scattering spectroscopy for disease diagnosis, Fluorescence and Raman spectroscopy for diagnosis.

Optical Techniques for Micro-manipulation: Optical tweezers and micro-beams, radiation pressure and force on microscopic objects, gradient and scattering force, applications of optical tweezer.

Optical Microscopy: Recent Developments: Contrast methods in optical microscopy, techniques for single molecule imaging, scanning laser microscopy, multi-photon microscopy and near-field techniques.

Optical Methods for Bio-sensing Applications: Surface plasmon resonance based sensors, quantum dots and functionalized nanoparticles as biosensors approaches for label-free sensing, opto fluidics and lab-on-a-chip approach.

Effect of Light on Biological Tissue: Basic principles of photobiology, photo-acceptors, action spectra and light induced signaling mechanism, Light effect based on endogenous photosensitizers, use of exogenous photosensitizers for photodynamic therapy and photo anti-microbial therapy, biological effects of narrow bandwidth light.
Nano Biophotonics: Basics about nanoparticles and their properties, Surface modification for specific targeting, Principle of photon therapy, Surface Plasmon Resonance (SPR), Nanomaterials based optics and spectroscopy, applications in sensing, diagnostics and remediation. Nanoparticle localization and toxicity. Photonic materials for biological applications, Principles of bio-inspired nanomaterials, common biologically active molecules as suitable ligand for nanomaterials synthesis, surface modification of nanomaterials for highly specific targeting, biomarker detection and quantification for early stage

Course Outcomes:

- In-depth understanding of various principles governing interaction of light with biological cells and tissues.
- Introduction to various applications of biophotonic principles for disease diagnosis and therapy.
- Knowledge about nanoparticles and their properties for biological applications.

References

1) "Biomedical Photonics Handbook", Editor-in-Chief Tuan Vo-Dinh
2) "Optical Tweezers: Methods and Applications", Ed. Miles J. Padgett, Justin Molloy, David McGloin
3) "Introduction to Biophotonics", Paras N. Prasad

03-LIFE04-613-E: Application Of Computational And Numerical Techniques In Biology (45 Lecture Hrs)

Coordinators: Dr. Ajit Upadhyay
(ajitup@rrcat.gov.in)

Course Details:

System of Linear Algebraic Equations: Direct methods - Gauss elimination and Gauss Jordan methods. Iterative methods - Jacobi, Gauss-Seidel methods.

System of Nonlinear Equations: Newton-Raphson and Secant methods. Roots of polynomials, synthetic division of polynomials, and Baristow method.

Interpolation, **Extrapolation, Error and Regression Analysis**: Types of errors their analysis.
Numerical Integration: Newton-Cotes, Gauss quadrature, trapezoidal, Simpson's1/3 and 3/8 rule. Numerical differentiation - forward, backward and central difference quotient.

Numerical Differentiation: Solution of ordinary differential equations. Solution of partial differential equations. Fast Fourier transformation.

Fundamentals of Computers: Computer architecture, application of computers, input and output devices, latest processors, desktop PC and servers. Networking Basic: TCP/IP, DNS, Internet, and Intranet.

Operating System Basic: Linux, windows, shell programming, and CLI, vi, multi threading, multiuser, multitasking, hyper threading, file permissions, and ssh.

Fundamentals of programming: Algorithm, flow charts, high-level scripting languages like Python, Matlab and steps for creating a simple program.

Introduction to Python: Program structure, imports, basic data types, variables, and declarations.

Operators and Declarations in Python: Relational, logical, increment, and decrement operators. Expressions and precedence of operators. Input and output operations, control statements, iterative loops, arrays, and pointer;

Overview of Scientific Computing: Languages and compilers and scientific libraries.

Overview of Trends and Techniques: Sequential, parallel computing, cluster and grid computing.
Architecture Taxonomy: Traditional architecture, Flynn's classical taxonomy, SISD, SIMD, MISD, and MIMD Models. Steps for Creating a Parallel Program: Decomposition of the program, communication, computations, and composing the results. Parallel example-array processing.

Course Outcomes:

- Development of basic computational and programming skills.

- Knowledge of mathematical operations and approaches.
- Applications in scientific data analysis and presentation.

References

1) "Numerical Methods for Engineers with Personal Computer", S.C Chapra and R. P. Canale
2) "Numerical Analysis", R. L. Burden and J. Douglas Faires
3) "An Introduction to Numerical Analysis", K.E. Atkinson
4) "Numerical Method", E. Balagurusamy
5) "Numerical Methods for Engineers", D. V. Griffiths and I. M. Smith
6) "Data Reduction and Error Analysis for the Physical Sciences", P. R. Bevington and D. K. Robinson

03-LIFE04-614-E: Mathematical Methods In Biology (30 Lecture Hrs)

Coordinators: Dr. Sunil Verma
(sverma@rrcat.gov.in)

Course Details:

Introduction, Graphs and Functions: Introduction, Graphs and Functions, Equations as Graphs, Exponential and Periodic Functions, Logarithmic and Other Functions

Functions and its Derivatives, Computing Derivatives of Curves: Images as 2D/3D Functions, Functions and its Derivatives, Computing Derivatives of Curves, Rules for Calculating Derivatives, Understanding Derivatives.

Plotting Curves, Numerical Calculation of Derivatives, Partial Derivatives: Curvature and Second Derivative, Plotting Curves, Numerical Calculation of Derivatives, Function,Derivatives and Series, Expansion, L'Hopital's Rule and Partial Derivatives.

Integration and their Graphical Understanding: Integration, Integration Rules, Graphical Understanding, Integration Examples, Integration: Product of Two Functions.

Vectors: Position and Movement in 2D, Cell Symmetry: Use of Polar Coordinates: Exponential growth and Decay, Scalars and Vectors, Vectors:Position and Movement in 2D, Cell Symmetry:Use of Polar Coordinates, Gradient.Forces and Flows, Understanding Diffusion, Diffusion Constant and Einstein Relation, Diffusion Equation, Diffusion vs.Active Transport.

Introduction to Fourier series, Fourier Transform and Statistics: Nernst Equation, Fourier Series, Fourier Transform, Introduction to Statistics.

Basics of bio-statistics: Mean, Standard deviation and Distribution, Frequency Distribution and Probability Distribution, Binomial Distribution, Normal Distribution, Hypothesis Testing and Mathematical Modeling.

Statistical Distributions: Poisson and Gaussian distributions. Monte Carlo simulation, pseudo random numbers, and central limit theorem.

Basics of Photon Tissue Interaction Simulation: Models of absorption and scattering of photons in tissues. one dimensional finite element formulation, and problems.

Course Outcomes:

- Understanding of basic numerical methods.
- Applications of mathematical concepts in field of biology

- Insight into statistical analyses.
- Basic understanding of simulation.
- Applications in scientific data analysis and presentation.

References:

1) Mathematics for Biological Scientists, M. Aitken, B. Broadhursts, S. Haldky, Garland Science (2009)
2) Mathematical Methods in Biology and Neurobiology by JurgenJost
3) Mathematical Methods in Biology, J. David Logan, William Wolesensky
4) "Finite Element Analysis", S. Krishnamurthy
5) "Introduction to the Finite Element Method", Desai and Abel
6) "An Introduction to the Finite Element Method", J. N. Reddy

03-LIFE04-615-E: Radiation And Biosafety (30 Lecture Hrs)

Coordinators: Dr. S. K.Majumder
(shkm@rrcat.gov.in)

Course Details:

Health Physics: Radiation sources - radioisotopes, natural and manmade sources, radioactive series, reactors, accelerators, radiation facilities, solid, liquid and gaseous activity. Control measures - time, distance, decay, shielding, administrative control, radioactive discharge, waste disposal, and exposure control.

Interaction of Radiation with Matter: Interaction of light and heavy charged particles, photons, and neutrons. Interaction of high energy charged particles, electromagnetic cascade, and Hardronic cascade.

Radiation Quantities, Units, and Regulatory Recommendations: Dosimetric quantities, exposure, absorbed dose, equivalent and effective dose, committed dose, ALI, DAC, ICRP, AERB, and dose limits.

Biological Effects of Radiation: Somatic and genetic effects, stochastic and deterministic effects, and LD30/50.

Detection of Radiation: Ionization chamber, proportional counters, GM tubes, scintillation detectors, semiconductor detectors, thermoluminiscent dosimeters, direct reading dosimeters neutron detectors, BF3 and He3 tubes, Rem-meters, CR-39-foils, pulsed radiation detection. Low and high energy radiation detection.

Accelerator Safety: Types of accelerators, prompt and residual radiation, source terms, radiation hazards, radiation safety systems, shielding, radiation monitoring, non-ionizing radiation safety, RF and MW safety, magnetic field safety; ozone safety, safety at synchrotron radiation beam lines, spallation neutron sources, andaccelerator driven sub-critical systems.

Biosafety and Animal Ethics
Introduction to biosafety, Institutional Bio-Safety Committee (IBSC)-scope and objectives, pathogenic organism, Genetically Modified Organisms (GMOs) - recombinant DNA technology, microorganisms, plants and animals, release to the environments, role of Genetic Engineering Approval Committee (GEAC)Indian act for animal welfare and Prevention of Cruelty to Animal act (PCA, 1960), use of animals in research and animal care, Animal Ethics Committee (AEC), Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA)

Course Outcomes:

- In-depth understanding of interaction of radiation with biological system.
- Knowledge of dosimetry and radiation detectors.
- Safety norms and practices in high radiation zones.

- Knowledge of biosafety and ethical guidelines for handling biological specimens.

References:

1) "Health Physics", Herman Cember
2) "Radiation Detection & Measurement", G. F. Knoll
3) "Atoms, Radiation & Radiation Protection", James Turner
4) "Physics for Radiation Protection", James Martin
5) "Radiological Safety Aspects of the Operation of Electron Accelerators, IAEA Technical Report Series. 188", W. P. Swanson
6) "Radiation Protection for Particle Accelerator Facilities NCRP Report No.144"
7) "Radiological Safety Aspects of the Operation of Proton Accelerators. IAEA Technical Report Series.283", R. H.Thomas.
8) "A Guide to Radiation and Radioactivity Levels Near High Energy Particle Accelerators Nuclear Technology", A. Sullivan

03-LIFE04-616-E: Biomaterials And Instrumentation For Its Characterization (30 Lecture Hrs)

Coordinators: Dr. Srinibas Satapathy (srinu73@rrcat.gov.in)

Course Details:

Basics of biomaterials, including single crystals, nanomaterials, polymers, and composites. Methods to synthesize these classes of materials. Different characterization techniques which includes: Resistivity/Resistance measurement (Vander Pauw method, Four probe method); Impedance spectroscopy; Optical characterization (UV-Visible spectroscopy, IR spectroscopy, Raman spectroscopy); Fluorescence spectroscopy (PL); Crystal defects and its characterization (temp temp conductivity, STEM, SIMS); AFM, PFM and MFM; VSM and SQUID VSM (magnetic measurements); X-ray diffraction; HRXRD; Optical microscopy; TEM; SEM; DLS; Thermoluminescence; Thermal analysis (DTA, DSC, TGA); EDS; WDS Basics of spectroscopy: Monochromators, spectrographs, energy and wavelength dispersion techniques in spectroscopy in x-ray and IR region.

Course Outcomes:

- Understanding of various techniques for characterization of materials.
- Knowledge of analytical instruments that are used in laboratory.
- Insight into crystal defects and its characterization

References:

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1. Biomedical Materials (Springer)
2. Introduction to Biomaterials: Basic Theory with Engineering Applications (Cambridge Texts in Biomedical Engineering)
3. Comprehensive Biomaterials (Elsevier, edited by Grainger et al.)
4. Characterization of Biomaterials (Elsevier / Woodhead Publishing)
5. Characterization of Biomaterials (Amit Bandyopadhyay & Susmita Bose, Elsevier)
6. Synthesis and Characterization of Biomedical Materials (MDPI Books)
7. Handbook of Materials Characterization (Springer)
8. Handbook of Biomedical Instrumentation by R. S. Khandpur
9. Principles of Biomedical Instrumentation (Cambridge)

03-LIFE04-617-E: Biostatistics (30 Lecture Hrs)

Coordinators: Dr. S. K. Majumder
(shkm@rrcat.gov.in)

Course Details:

Probability and Statistics: Probability and Random variables, Bayes' formula, a priori and posteriori probabilities, discrete and continuous distributions, location parameters, variance, covariance and correlation, bivariate normal distribution, the central limit theorem, Measure of central tendency, mean, mode, confidence intervals, comparing two samples, estimation methods, hypothesis testing, goodness of a fit, graphical representation of data

Population Distributions: Binomial distributions and Poisson distributions – their properties, parameters and applications, Normal and 't' distributions – population and sample parameters measure of central tendency, measures of dispersion, variance, degrees of freedom, confidence limits and intervals; Probability of occurrence – use of Z and t tables,
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, Students t test for comparing means, general and paired t tests, central limit theorem.

Analysis of Variance:

One way ANOVA, comparison of means of multiple groups by partitioning of the total sum of squares as within and between sum of squares, assumptions in ANOVA, Two way ANOVA, MANOVA
Correlation and Regression: Pearsons' product moment correlation coefficient, comparison of correlation coefficients, partial and multiple correlation, linear regression analysis; Interpretation of regression coefficients,
Nonparametric Statistics: Spearman's coefficient of rank correlation, Chi square test, and nonparametric methods for hypothesis testing based on ranks, Kaplan Meyer's survival analysis
Basic data analysis and machine learning methods: Principal component analysis (PCA), fisher linear discriminant analysis, and partial least square regression.
Image analysis for biology: Basic image statistics, Image analysis strategies, image histograms, adjustments, spatial filters, edge detection filters, basic segmentation.

Course Outcomes:

- Introduction to concept of probability.
- Understanding population distribution
- In-depth understanding of statistical operations for data analysis.
- Understanding and determining significance of data.

- Introduction to image analysis.

References:

1) A Foundation for Analysis in the Health Sciences, 11th Edition by Wayne W. Daniel
2) Biostatistics for the Biological and Health Sciences, 2nd edition by Marc M. Triola
3) Intuitive Biostatistics: A Nonmathematical Guide to Statistical Thinking Paperback – Import, by Harvey Motulsky

03-LIFE04-618-E: Experimental Techniques In Biophotonics (60 Lecture Hrs)

Coordinators: Dr. S. K. Majumder
(shkm@rrcat.gov.in)

Course Details:

Demonstration and characterization of optical tweezers

1. Raman spectroscopy-based studies on biological samples
2. Imaging studies using conventional microscope and confocal microscope
3. Fluorescence measurements using fluorimeter
4. Synthesis and characterization of gold and silver nanoparticles in spherical & rod shape using chemical synthesis method
5. Impendence spectroscopy of biomaterials
6. Studies on fibre grating based temperature and biosensor
7. Synthesis of Ag nanoparticles using Nd:YAG pulsed laser irradiation
8. Testing of optical surface using interferometers, especially phase shifting interferometer
9. Calibration of cryogenics sensors
10. Electron emission from LaB6 cathode and its characterization
11. GUI software familiarization and applications

Course Outcomes:

- Skills to set up basic experiments involving lasers.
- Assembling basic set-ups for fluorescence and Raman spectroscopy.
- Hands-on experience for synthesis and characterization of nanomaterials, biomaterials and other related techniques.

References:

1. Introduction to Biophotonics – Paras N. Prasad
2. Biomedical Photonics Handbook: Fundamentals, Devices, and Techniques – Edited by Tuan Vo-Dinh
3. Biomedical Photonics Handbook: Therapeutics and Advanced Biophotonics – Edited by Tuan Vo-Dinh
4. Advanced Biophotonics: Tissue Optical Sectioning – Edited by Ruikang K. Wang & Valery V. Tuchin
5. Optical Imaging Techniques in Cell Biology – Guy Cox
6. Biophotonics: Concepts to Applications – Gerd Keiser
7. Optical Methods in Sensing and Imaging for Medical and Biological Applications – MDPI Books
8. Femtosecond Biophotonics – (Cambridge Univ. Press)
9. Biophotonics and Biosensing – Edited by Armani, Chalyan & Sampson

03-LIFE04-601-C Research Methodology (30 Lecture Hrs)

Coordinators: Dr. V. B. Tiwari
(vbtiwari@rrcat.gov.in)

Course Details:

ModuleA: Research design and methods (15 lectures)

Objectives and types of research: Motivation and objectives - Research methods vs. Methodology. Types of research – Descriptive vs. Analytical; Applied vs. Fundamental; Quantitative vs. Qualitative; Conceptual vs. Empirical.

Research Formulation: Defining and formulating the research problem - Selecting the problem - Necessity of defining the problem - Importance of literature review in defining a problem - Literature review – Primary and secondary sources - reviews, treatise, monographs-patents - web as a source - searching the web - Critical literature review - Identifying gap areas from literature review - Development of working hypothesis.

Research design: Basic Principles - Need of research design - Features of good design – Important concepts relating to research design - Observation and Facts, Laws and Theories, Prediction and explanation, Induction, Deduction, Development of Models. Developing a research plan - Exploration, Description, and Diagnosis. Experimentation: Proper approach - Importance of recording observation, maintaining the records, sample history, transparency in data recording. Determining experimental and sample designs.

Writing thesis and research papers: Structure and components of scientific reports - Types of report - Technical reports and thesis - Significance - Different steps in the preparation – Layout, structure and Language of typical reports - Illustrations and tables - Bibliography, referencing and footnotes - Oral presentation - Planning - Preparation - Practice - Making presentation - Use of visual aids - Importance of effective communication, Manuscript drafting based on 'Experimental data and Literature Survey'. Where to publish?impact factor of journals, citation databases, Metrics
Statistical treatment of data and errors: Value of Statistics; Errors and Statistics - Limitation of analytical methods; Accuracy; Precision; Classification of errors; Minimization of errors; Significant figures and computations; Standard Deviation; Normal Distribution; Comparison of results - student's t test; F-test; Chi Square test; propagation of errors.

Module B: Research ethics and Publication ethics (10 lectures)

Research ethics: Philosophy and ethics, Ethics with respect to Science and research, Intellectual honesty and research integrity, Scientific misconducts- fabrication, falsification and plagiarism, redundant publications- duplicate and overlapping publications, selective reporting and misrepresentation of data, Environmental impacts - Ethical issues - ethical committees – Commercialization

Publication ethics: Definition, introduction and importance, Best practices, standards setting initiatives and guidelines, Conflict of interest, Publication misconduct, Violation of publication ethics, authorship and contributor ship, Identification of publication misconduct, complaints and

appeals, predatory journals and publishers, 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.

Module C: Computational and experimental methods (15 lectures minimum) Computational methods: Mathematical modeling, Numerical methods of analysis,
Experimental methods: Principles of Instrumentation

Course Outcomes:

- Introduction to the methods followed in academic research.
- Insight into steps to be followed towards meaningful research.
- Understanding data analysis and error.
- Knowledge of ethical practices in both experimentation and communication**.**

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3) C.R. Kothari, Research Methodology: Methods and Techniques. New Age International (2000).
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6) M. Anthony, A.M. Graziano, and M.L. Raulin, Research Methods: A Process of Inquiry, Allyn and Bacon (2009).
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