**Potential courses for SBB students at TCIS, TIFR Hyderabad**

**Basic Courses:**

| Course Code | Name of the Course | Instructor | Credits |
|---|---|---|---|
| BIO-101.7 | Basic Cell Biology | AM | 3 |
| BIO-103.7 | Basic Molecular Biology | USK/MS | 3 |
| BIO-104.7 | Molecular Genetics | MJ | 3 |
| BIO-105.7 | Basic Neurobiology | MKM (NCBS) | 3 |
| BIO-107.7 / CHM-120.7 | Biochemistry | ATV | 3 |
| BIO-108.7 / CHM-118.7 | Biophysics | KG, KRM | 3 |
| BIO-111.7 | Basic Mathematics for Biologists | PKM | 3 |
| BIO-112.7 | Methods in Modern Biology | TD, AM, MV, MJ + other faculty | 3 |
| BIO-113.7 | Cell Signaling and Physiology | MV | 3 |

**Advanced Courses:**

| | | | |
|---|---|---|---|
| BIO-201.7 | Principles in Cancer & Cancer Stem cell biology | BM (HCU) | 3 |
| BIO-202.7 | Fluorescence Methods in Cellular Biophysics | AM | 3 |
| BIO-203.7 | Mechanobiology | TD | 3 |
| BIO-204.7 | Biology of Sensory systems | AD | 3 |
| BIO-205.7 | Biological thermodynamics | TD | 3 |
| BIO-206.7 | Basic Immunology | MV | 3 |
| BIO-207.7 | Advanced Molecular Biology | USK | 3 |
| BIO-208.7 | Chemical Biology-I | Aneesh T V + KM | 3 |

**Courses from other disciplines approved by AAC:**

| | | | |
|---|---|---|---|
| CHM-217.7 | Solid State NMR | PKM, VA | 3 |
| CHM-200.7 | Principles of NMR Spectroscopy | PV | 3 |
| PHY-215.7 | Error Analysis and Statistical Inference in Experiments | RD (TIFR) | 2 |
| CHM-254.7 | Computer Programming using Python language | JR (TIFR) | 2 |
| CHM-216.7 | Protein Structure and Synthesis | VA, KM, SR | 3 |
| PHY-103.7 / CHM-101.7 | Mathematical Methods | SKN, PKM | 3 |
| PHY-102.7 / CHM-116.7 | Numerical Methods and Algorithms in Chemical Physics (NM-1) | RR / KR | 3 |
| CHM-222.7 | Molecular dynamics simulation and application in chemical physics | JM, SG | 3 |

| | | | |
|---|---|---|---|
| CHM-255.7 | Introduction to Data Science | RR | 2 |

**Compulsory Courses:**

| | | | |
|---|---|---|---|
| BIO-100.7 | Research Methodology | SRS, AM, GR | 4 |

**Topics covered in some of the courses offered in previous semesters are presented below.**

**Basic courses - worth 3 credits each and run for > 36 contact hours (shorter/summer courses are worth 2 credits each)**

## BIO-101.7: Basic Cell Biology - AM

This course will explore biological function at the level of the cell (as opposed to the level of the full multicellular organism as in Developmental Biology or Genetics, the level of individual biomolecules as in Biochemistry, or full ecosystems as in Ecological Biology or Population Genetics). A lot of interesting biological phenomena is observed at this intermediate scale, and affects function across the different levels. Of particular interest are processes of mechanical or biochemical regulation of cellular function, which have been generating a lot of excitement in recent times. We will study these through a mix of lectures and discussions of both classic and recent papers. Topics to be covered are presented below.

- Basic processes of transcriptional, translational and post-translational regulation:
  - Endocytosis, exocytosis and protein export
  - RNA production, splicing and export
  - Regulatory roles of non-coding RNA
  - Biochemical processes in specific cellular organelles like the endoplasmic reticulum, golgi, mitochondria, nucleus and nucleolus and the plasma membrane
  - Protein sorting in the cell - discovery of the Sec and SNARE proteins and their roles in regulating subcellular trafficking.
- Physical and chemical processes regulating cellular function:
  - The cell cycle and its regulation
  - Maintenance of pluripotency in stem cells; mechanobiology, effects of substrate stiffness and mechanical forces on cell fate and development
  - Chemical modifications of DNA and histone proteins regulating gene expression (Epigenetics)
  - Phosphorylation cascades that regulate chromatin function and DNA repair
  - Nuclear architecture and its regulatory role in controlling gene expression
  - Roles of membrane heterogeneity in regulating endocytosis and signaling
  - Sources and use for noise in gene expression
- Roles of the cytoskeleton and associated motor proteins:

- Structure of actin, microtubules, cytoskeletal intermediate filaments, nuclear intermediate filaments (lamins)

- Discovery and function of molecular motor proteins like myosin, kinesin and dynein.

**Primary Text / Reference Books:**

Molecular Biology of the Cell by Bruce Alberts et al; Cell Biology by the Numbers by Milo and Phillips.

**Course Evaluation:** There will be papers assigned every week after a lecture. The students will be expected to provide written reports of what they understand from the papers and also discuss them in class. They are expected to convey not just the philosophical content of what is claimed, but the actual methods that led to the conclusions. In addition to these and other written components, the final examination will constitute of seminar presentations on specific topics chosen by the students. A student will be expected to perform extensive literature survey on the topic of their choice, write a comprehensive report and make a cogent presentation critically evaluating the current state of knowledge on the topic. A major aim that this course hopes to achieve is to inculcate students with the ability to critically evaluate studies in Cellular Biology and Biochemistry, in addition to conveying knowledge of the current state of the fields.

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
Weightage of marks - 70% from written assignments, 30% from presentations.

**Course outcome:**

| Sr. No. | On completing the course, the student will be able to: |
|---|---|
| CO 1 | Have a sound grasp of cellular organelles, their organization and functions |
| CO 2 | Have knowledge of the cell cytoskeleton and their associated motor proteins |
| CO 3 | Understand cellular processes like the cell cycle, differentiation and others |
| CO 4 | Understand the above topics not just as facts, but also appreciate the key experiments that led to the current state of knowledge in Cell Biology |

**BIO-103.7: Basic Molecular Biology**

Chromatin: 4- 5 classes (1.5-2 hours each)

- Histones and variants
- Nucleosomes and basic organization
- Epigenetic modifications
- Histone/protein modifiers (acetyl transferases, Methyl transferases, deacetylases and demethylases)
- DNA methylation and other novel modifications
- Euchromatin and heterochromatin

Gene expression: 2-3 classes (1.5-2 hours each)

- Basics of Transcription (RNA-Pol-I/II/III) assignment based
- Interplay between transcription and chromatin
- Chromatin and RNA processing

Non-coding RNAs: 2-3 classes (1.5-2 hours each)

- Types of ncRNAs
- Importance of ncRNAs in gene expression regulation
- microRNAs overview
- long non-coding RNAs overview

DNA repair: 2 classes (1.5-2 hours each)

- Basics of pathways (assignment)
- Sensors and chromatin interplay

Replication: 3 classes (1.5-2 hours)
- Basics of replication (leading versus lagging strand synthesis) (assignment)
- Replisome components, licensing of replication
- Coupling of replication with cell cycle progression

**Primary Text / Reference Books:**
Not indicated.

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
Through assignments and presentations.

**BIO-104.7: Molecular Genetics - MJ**

- Model organisms
  - Introduction to various models used for genetics studies
- Principles of genetics
  - Patterns of Inheritance
  - Mutations and phenotypes
  - Exception to Mendelian inheritance
- Genome organization and genetic mapping
  - Linkage and recombination
  - Genetic mapping in model organism
  - Methods for genetic and molecular mapping
- Regulation of gene expression
  - Regulation of transcription, alternative splicing, and translation
  - Gene expression regulation in the Eukaryotic and prokaryotic system
  - Epigenetic mechanisms such as imprinting
  - The epigenetic mechanism in development and diseases
  - Discovery tools to study gene regulation and epigenetics mechanisms
- Genetics to study biological processes and diseases
  - Methodologies used for genetic manipulation
  - Forward and reverse genetics
  - Dissection of gene function and genomics
  - Genetics to study development
  - Genetic regulation of behavior

- Genetics and evolution
- Detecting human disease alleles: molecular genetic diagnostics
- Model organisms in understanding human genetic diseases

**Primary Text / Reference Books:**

- An Introduction to Genetic Analysis by Anthony J. F. Griffiths.
- Genetics: A Conceptual Approach by Benjamin Pierce.
- Mechanisms of Gene Regulation by Carsten Carlberg and Ferdinand Molnár
- Human Molecular Genetics by Tom Strachan and Andrew Read.
- Genetic Mapping in Experimental Populations by J. W. Van Ooijen and J. Jansen.
- Elements of Evolutionary Genetics by Brian Charlesworth and Deborah Charlesworth.
- Genome Editing by Kursad Turksen.
- Targeted Genome Editing Using Site-Specific Nucleases: ZFNs, TALENs, and the CRISPR/Cas9 System by Takashi Yamamoto

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**

- Mid-term (20%), Final exam (30%), Case studies/assignment (30%), Presentations (20%). In the case studies students will be expected to design genetic strategies to resolve a hypothetical or a real problem. In the presentation, the students will present a recently published work or a classic work based on genetics approach.

**Course Outcome:**

| Sr. No. | On completing the course, the student will be able to: |
|---|---|
| CO 1 | Understand the basic concept of genetic and genetic analysis. |
| CO 2 | Read and understand the experiments and data interpretation that led the identification of concepts of genetics and molecular genetics. |
| CO 3 | Will learn methods of genetic manipulations. |
| CO 4 | Understand methods of genetic mapping. |
| CO 5 | Understand the basic of biochemical genetics and developmental genetics. |
| CO 6 | Understand using genetics in contemporary research. |
| CO 7 | Understand basic concept of human genetics and genetic diseases. |

**BIO-105.7: Basic Neurobiology – MKM (NCBS)**

- Historical overview of neuroscience from Empedocles to Bernstein.
- Electrical properties of the neuron: Equilibrium potential, The Nernst potential and Cable equations; Resting and action Potentials; Goldman-Hodgkin-Katz equation, Hodgkin and Huxley model. Electrophysiological recording techniques: Patch-clamp and Voltage-clamp techniques.
- Synaptic transmission: Voltage gated ion channels; Ligand gated ion channels; Electrical and chemical synapses. Synaptic plasticity, Short term potentiation, Long term potentiation.
- Sensory Physiology: Vision: Photo receptors, Rods, Cones and Retinal ganglion cells. Electrical response to light. Light signal transduction, Concept of receptive fields. Colour vision Visual pathway, lateral geniculate nucleus and visual cortex.
- Hearing: Sound perception and localization. Functional anatomy of ear and cochlea. Mechano-transduction, Converting mechanical stimulus to electrical signals. Cochlear inner and outer hair cells. Localisation of sound sources.

- Olfaction: Structure of olfactory epithelium and odorant receptors. Odor coding and perception, Olfactory signal transduction.
- Motor systems: Upper and lower motor system. Reflex and contractions, rhythmic movements, central pattern generators.
- Optical methods of detection and stimulation; Energetics of the Nervous System.
- Place and Grid Cells. Engrams and Memory. Perturbing the System

**Primary Text / Reference Books:**

- John G. Nicholls, A. Robert Martin, David A. Brown, Mathew E. Diamond, David A. Weisblat, and Paul A. Fuchs, From neuron to brain, Sinauer Associates, Inc. Fifth edition, November 2011.
- Mark F. Bear, Barry W. Connors, Michael A. Paradiso, Neuroscience: Exploring the Brain, Lippincott Williams & Wilkins, Third Edition, April 1995.
- Eric Kandel , James Schwartz , Thomas Jessell , Steven Siegelbaum, A.J. Hudspeth. Principles Of Neural Science, Fifth Edition.

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**

Assignments (I,II,III), 20% from Mid-sem and 50% from End-sem.

**BIO-107.7/CHM-206.7: Biochemistry - ATV1**

**Introduction**: Proteins, nucleotides, lipids and carbohydrates are the basic components of life, along with inorganic and organic small molecules. Interactions between these components are responsible for the existence and diversity of lifeforms on earth. These interactions can be studied at different scales – at the tissue level, at the cellular level and the molecular/atomic level. The current course will give you a flavour of the molecular and atomic level understanding of life processes.

**Syllabus:**

- Components of Life – proteins, nucleotides, carbohydrates, lipids and small molecules (ATP, metals, ions, etc).
- Proteins - amino acids, protein folding and protein structure
- Proteins - Analytical tools to study proteins (UV vis spectroscopy, chromatography, mass spec, sequencing)
- Proteins – protein function (enzymes, structural proteins, antibodies, ion channels, hormones)
- Proteins – Enzymes, ligand binding
- Proteins - Biological oxidation and reduction
- Proteins – Post-translational modifications
- Proteins – GPCRs and chemotaxis
- Nucleotides – Central dogma of life, DNA structure and replication
- Nucleotides – Transcription
- Nucleotides – RNA types, structure and chemistry, ribozyme
- Nucleotides – Translation
- Nucleotides – DNA repair
- Nucleotides – Role of nucleotides in synthesis/chemistry of ATP, GTP, NAD, etc.
- Carbohydrates – Photosynthesis, metabolism
- Carbohydrates – Glycolysis
- Carbohydrates – TCA cycle
- Carbohydrates – Oxidative phosphorylation
- *Buffer for delays in previous lectures*
- (If no delays, then I will teach 'Mutations and Diseases')
- Lipids – Biological membranes, transport of lipids
- Lipids – Metabolism of fatty acids, triglycerides
- Lipids – Membrane fusion and fission
- Special Topics – Virus
- Special Topics – Mitochondria
- Special Topics - *Open for suggestions*
- (my suggestion is Biological Toxins)

- Special Topics - *Open for suggestions*
  (my suggestion is Origins of Life)

**Primary Text / Reference Books:**
Lehninger Principles of Biochemistry by David Nelson & Michael Cox or Biochemistry by Lubert Stryer

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
Final exam - 35%, Midterm exam – 25%, Write up (summary of review papers) – 20%, Problem sets – 20%

**Course Outcome:**

| Sr. No. | On completing the course, the student will be able to: |
|---|---|
| CO 1 | Get a molecular understanding of biological processes |
| CO 2 | Download, visualize and analyze macromolecular structures using Pymol and Coot |
| CO 3 | Understand various tools to study proteins – SDS PAGE, UV-vis spectroscopy, chromatography, centrifugation, NMR, X-ray crystallography, etc. |
| CO 4 | Learn the atomic-level details of post-translational modification of proteins, redox biology and signal transduction pathways |
| CO 5 | Learn from original research papers and present them succinctly and to write summaries of research papers |

**BIO-108.7 / CHM-204.7: Biophysics – KG, KRM**

**Thermodynamics, kinetics and statistics in biophysics (Refresher):** A refresher on the basic concepts in thermodynamics and kinetics and the tools for statistical analysis in biophysics. This will also cover basic concepts in enzyme kinetics such as Michaelis-Menten and Hill equations, analysis of co-operativity, mechanisms of inhibition, etc using case studies and simulations.

**Polymer statistics and intrinsically disordered proteins,** Introduction to polymer chain properties: defining radius of gyration, end-to-end distances, entropy etc. Intrinsically disordered proteins: Definition of disorder**,** Types of IDPs**,** Functions of IDPs**,** Diseases associated with IDPs

**Single Molecule Biophysics:** Introduction to fluorescence, FRET and smFRET, Optical tweezers, Motor proteins, Super resolution microscopy

**Basic Techniques:** In depth analysis of centrifugation, chromatography, calorimetry and optical spectroscopy techniques with case studies.

**Metabolomics:** Introduction to the use of metabolomics using NMR and Mass spectrometry to elucidate biochemical pathways and function of proteins

**Biophysics of membranes**: Introduction to biological membranes, lipids, lipid protein interactions, phase transitions, membrane mimetics for biophysical studies

**Channels, carriers and pumps:** Introduction to passive and active transport across membrane, mechanisms of transport.

**Primary Text / Reference Books:**
• Fluorescence—Lackowicz,
• Advances in Chemical Physics, Volume 146:
• Single Molecule Biophysics, Single-Molecule Cellular Biophysics---Leake
• Polymer physics by Colby & Rubenstein,
• Intrinsically disordered proteins by Tompa

• Channels, carriers and pumps, Stein and Litman
• Bioenergetics, Nicholls and Fergusson

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**

| | |
|---|---|
| Assignments/Quizzes | 50 |
| Midterm | 20 |
| Final | 30 |

**BIO-111.7: Basic Mathematics for Biologists - PKM**

- Calculus: Limit, Differentiation, Integration
- Series: Convergence, divergence, Taylor series
- Determinants, Matrix Algebra
- Vector Analysis
- Error analysis
- Distribution functions, probability
- Simple differential equations

**Primary Text / Reference Books:**

- G. B. Thomas Jr. and R. L. Finney, Calculus and Analytic Geometry
- J. R. Taylor, An Introduction to Error Analysis
- E. Kreyszig, Advanced Engineering Mathematics

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
Assignments, Mid-term exam, Final exam

**BIO-112.7: Methods in Modern Biology – TD, AM, MJ, USK + other invited faculty**

The importance of statistical analysis in biological research is overwhelming, especially in a time when the consistency and reproducibility of science are under more scrutiny than ever. The conclusion of an experimental effort often depends on the precise statistical method (and its underlying assumptions) that is used to filter significant differences among the samples. However, the fact that the statistical methods can play a defining role even in the design phase of an experiment remains under-appreciated.

1. Dealing with uncertainty: Fallacy of statistical reasoning, Reproducibility error versus systematic error, laws of large numbers, central limit theorem and hypothesis testing.
2. Working with small sample size: Significance, P values and t-tests, power and sample size, interpreting the error bars, two-sample, one-sample, and paired t-tests.
3. Modern methods in statistics: Nonparametric tests, designing comparative experiments, analysis of variance (ANOVA) and blocking Microscopy is an essential tool of Cell and Developmental Biology. Going beyond structure in fixed cells and tissues, advancements like Green Fluorescent Protein (GFP) technology have opened up a whole new vista of investigating protein dynamics in live cells. On the other hand, super-resolution techniques have pushed the bounds of structural resolution to well below the diffraction limit of light. So influential have been these methods, that both have won separate Nobel Prizes in a relatively short span of time after their development. This part of the course will discuss both the classic and modern applications of fluorescence microscopy in Biology. Starting from the basics of fluorescence methods, we will go on to discuss methods for measuring dynamics like Fluorescence Recovery After Photobleaching (FRAP), Fluorescence Correlation Spectroscopy (FCS), and also newly developed super-resolution methods that have been garnering a lot of interest. The following topics are proposed to be covered:
1. Basics of fluorescence - Jablonski diagrams, Stokes shifts, structures of fluorophores, quantum yields, fluorescence instrumentation - fluorescence microscopy and spectroscopy, light sources, filters, and detectors.
2. Widefield microscopy, effects of objective numerical aperture on resolution, diffraction limit of resolution of light microscopy.
3. Confocal microscopy - point-scanning and spinning disk confocal microscopy; light sheet microscopy; Total Internal Reflection Fluorescence (TIRF) microscopy; multiphoton microscopy.
4. Basics of *Forster Resonance Energy Transfer* (*FRET*), Fluorescence polarization measurements - steady-state and

time-resolved fluorescence anisotropy.
5. GFP technology and dynamics measurements in live cells - Single Particle Tracking (SPT), Fluorescence Correlation spectroscopy (FCS), Fluorescence Recovery After Photobleaching (FRAP).
6. Super-resolution microscopy methods - stimulated emission depletion (STED), structured illumination microscopy (SIM), stochastic optical reconstruction microscopy (STORM), photo activated localization microscopy (PALM), and others.

Following topics will be covered:

1. Use of various model organism for large scale screens to study fundamental biology and diseases.
2. Technologies for genetic manipulation, genome editing and epigenetics technologies.
3. Utility of IPSC and Organoids.
4. State-of-the-art NGS and 'omics' tools in biology.

As a part of these classes some experts will be invited to deliver lectures/talk. Attending these lectures/talk will be mandatory for the students who have registered this course.

**Primary Text / Reference Books:**

- Materials: Article series entitled "Points of Significance" from Nature journals (https://www.nature.com/collections/qghhqm/pointsofsignificance)
- Principles of Fluorescence Spectroscopy - J R Lakowicz - Springer
- Fundamentals of Fluorescence Microscopy - P Mondal and A Diaspro - Springer

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
Instructor 1 (teaching a part): 100% written exam
Instructor 2 (teaching a part): There will be papers assigned after a lecture. The students will be expected to provide written reports on what they understand from the papers. They are expected to convey not just the philosophical content, but the actual methods that led to the conclusions. In addition to these written assignments, there will be a written final examination.
Weightage of marks - 50% from written assignments, 50% from examination.
Instructor 3 (teaching a part): 100% written exam

**BIO-113.7: Cell Signaling and Physiology – MV**

This course aims to give participants a somewhat comprehensive view of the molecular mechanisms of signal transduction and their significance in cell physiology and disease.

**Syllabus:** Types of cell surface receptors, nuclear receptors and mechanisms underlying their expression, activation, downregulation and signaling. Receptor and non-receptor protein kinases and phosphatases. Second messengers, phospholipases and eicosanoids and their physiological relevance. Introduction to mechanisms of activation of ion channels, solute transporters and membrane pumps and their significance in the regulation of membrane potential, signaling, cellular energetics and other processes. Signaling and proteins involved in the regulation of apoptosis, cellular stress, autophagy, secretion and membrane trafficking. Examples of aberrations in specific signaling pathways and physiological process and their targeting for drug design in the context of various diseases.

**Primary Text / Reference Books:** Signal Transduction Kramer, Ijsbrand M. Third edition 2015 by Elsevier **and** Signal Transduction: Principles, Pathways and Processes 2014 by CSHL Press

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**

Class Participation and Presentations: 40%
Term Exams: 60%

**Advanced and other courses - worth 3 credits each and run for >36 contact hrs (shorter/summer courses are**

**worth 2 credits each)**

**BIO-201.7: Principles in Cancer & Cancer Stem cell biology – Prof. Brahmanandam Manavathi (HCU)**

- Normal Cell Vs. Cancer Cell
- How are tumours derived?
- Carcinogens and Tumourigensis
- Cell immortalization
- How do viruses cause cancer
- Oncogenes and tumour suppressor genes
- Maintenance of genore integrity and development of cancer
- Invasion and metastasis – epithelial to mesenchymal transition
- Cancer stem cells – Basics and how to target cancer stem cells
- Rationale treatment of Cancer
- Special emphasis on few important cancers which are prevalent in India – Breast cancer, Oral cancer etc.

**Primary Text / Reference Books:**
Not indicated

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
10% each from Internal assignments (I,II,III) and 20% from best of two, 30% from Mid-sem and 50% from End-sem.

**BIO-202.7: Fluorescence Methods in Cellular Biophysics - AM**

Fluorescence microscopy is an essential tool of Cellular Biophsyics. Going beyond structure in fixed cells and tissues, advancements like Green Fluorescent Protein (GFP) technology have opened up a whole new vista of investigating protein dynamics in live cells. On the other hand, super-resolution techniques have pushed the bounds of structural resolution to well below the diffraction limit of light. So influential have been these methods, that both have won separate Nobel Prizes in Chemistry in a relatively short span of time after their development. This course will discuss both the classic and modern applications of fluorescence in Cellular Biophysics. Starting from the basics of fluorescence methods, we will go on to discuss methods for measuring dynamics like Fluorescence Anisotropy, Fluorescence Recovery After Photobleaching (FRAP), Fluorescence Correlation Spectroscopy (FCS), and also newly developed super-resolution methods that have been garnering a lot of interest. The following topics will be covered (approximately seven hours will be spent on each of the numbered points below on average):

- Basics of fluorescence - Jablonski diagrams, Stokes shifts, structures of fluorophores, quantum yields, fluorescence instrumentation - fluorescence microscopy and spectroscopy, light sources, filters, and detectors (PMTs, APDs and camera technologies - CCD, EMCCD, CMOS, sCMOS etc.)
- Forster Resonance Energy Transfer (FRET), Time-Correlated Single Photon Counting (TCSPC), fluorescence lifetime, quenching - theoretical ideas, technical details behind measurements and applications. Fluorescence polarization measurements - steady- state and time-resolved fluorescence

anisotropy - theory, instrumentation and technical details.

- Widefield microscopy, effects of objective numerical aperture on resolution, diffraction limit of resolution of light microscopy, single molecule imaging of mRNA as an example, basics of flow cytometry.

- Confocal microscopy - point-scanning and spinning disk confocal microscopy; light sheet microscopy; Total Internal Reflection Fluorescence (TIRF) microscopy; considerations for temporal resolution; multiphoton microscopy.
- GFP technology and dynamics measurements in live cells - Single Particle Tracking (SPT), Fluorescence Correlation spectroscopy (FCS) - both APD and camera-based, Fluorescence Recovery After Photobleaching (FRAP), live cell mRNA dynamics measurements.

- Super-resolution microscopy methods - stimulated emission depletion (STED), structured illumination microscopy (SIM), stochastic optical reconstruction microscopy (STORM), photo activated localization microscopy (PALM), point accumulation for imaging in nanoscale topography (PAINT) and others.

**Primary Text / Reference Books:** Principles of Fluorescence Spectroscopy - J R Lakowicz - Springer

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
Assignments/examinations : 60 %, presentations: 40%.

**<u>BIO-203.7: Mechanobiology - TD</u>**

The field of mechanobiology explores how mechanical forces influence many cellular and multicellular processes. The main objective of mechanobiology is to eventually explain these processes with a few relatively simple mechanical laws. This course intends to cover the history of mechanobiology, provide the conceptual foundations to fluid and solid mechanics for making a mechanical approach to the biological problems, explore fundamental structural elements that generate and transmit forces within cells and tissue, and finally, discuss the experimental methods towards measuring and perturbing forces in biology. The course also intends to provide several case-studies of mechanobiology-regulated physiological processes, including morphogenesis, wound healing, and cancer.

- **Introductory part:** Concept of length and time-scales in biology. Diversity of biological forces. Classic works in mechanobiology. Rudimentary solid and fluid mechanics, with examples from biology. Introduction to viscoelasticity and surface tension and how do they operate at cellular and tissue level.
- **Biology, chemistry, and physics of cellular force-bearing structures:** How do the cells generate force? Actin filaments and actomyosin network. Actomyosin contractility and contraction of muscle and non-muscle cells. Microtubules and their force-sensitive participation in cell division. Diversity of cytoplasmic and nuclear intermediate filaments. Polymer mechanics of cytoskeletal elements. Nuclear mechanics and force transduction. Force sensitive molecular complexes, including focal adhesions and adherens junctions. Extracellular matrix (ECM) mechanics. The physiological range of ECM stiffness and its effect on cellular differentiation. Force transmitting proteins or mechanotransducers including cadherins and integrins. Molecular motors. Mechanoresponsive ion channels.
- **Techniques of mechanobiology:** How can we measure forces at molecular and cellular level? Traction force microscopy, micropillar assays, monolayer stress microscopy, atomic force microscopy, optical traps, magnetic tweezers, molecular tension sensors, DNA-based force sensing, fluorescence speckle microscopy, oil inclusions, micropipette aspiration, and indirect computational methods. Experimental perturbative approaches to cellular mechanical structures. Measuring forces on cellular organelles. Discussion on the limitations of the current techniques and on futuristic mechanobiological methods and paper presentations.
- **Forces in tissue and organism development:** Forces that shape a developing embryo. Forces in the epithelium. How the cells build the tissue stiffness: molecular assembly and collective effect. Epithelial constriction, invagination, bending, folding, and hydraulic fracture. Density-dependent and independent jamming and unjamming of the epithelium in asthma and cancer. Force measuring techniques at tissue level: current approaches and limitations. Mechanobiology of cancer.

**Primary Text / Reference Books:**
Physical Biology of the Cell by Rob Phillips et al., Garland Science
Biological Physics: Energy, Information, Life by Philip Nelson, W.H.Freeman & Co Ltd
Biological Physics of the Developing Embryo by Gabor Forgacs and Stuart A. Newman, Cambridge University Press. Introduction to the Physics of Fluids and Solids by James S. Trefil, Dover Books on Physics.

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):** Assignments and Presentations: 60, Mid-term exam: 20, and End-term exam: 20.

**Course Outcome:**

| Sr. No. | On completing the course, the student will be able to: |
|---|---|
| CO 1 | Appreciate the quantitative thinking in biology and that it is essential to measure parameters in order to gain a deeper understanding of the biological events |
| CO 2 | Understand the relevance of physical/mechanical principles in biology |
| CO 3 | Think beyond the conventional chemical approaches to biology |
| CO 4 | Design experiments for measuring forces and geometric parameters in the biological context |
| CO 5 | Apply interdisciplinary approaches to the problems in biology |
| CO 6 | Keep him/her updated about the recent developments in the field and summarize the content effectively in form of a presentation |

**BIO-204.7: Biology of Sensory Systems - AD**

Sensory systems enable organisms to interact with their environment, such as to assess food and social interactions. Sensory biology is a fascinating study of how evolution has led to the specialization of myriad sensory pathways that provide input to the brain. This course will focus on the molecular and cell biology of various sensory systems and detection of sensory stimuli in the periphery.

Where-ever possible the course will cover comparative studies from vertebrate and invertebrate model organisms.

Each of the sensory systems are an active area of investigation. The course will include presentations and critical discussions of classical as well as recent publications.

Topics to be covered:
- GPCRs, Ion channels.
- Chemo-sensation (olfaction, taste),
- Somato-sensation (Touch, pain, temperature),
- Auditory sensation (inner ear),
- Vision.
- Development and critical periods

Assessment will be based on paper discussions and reports. Other formal assessments include a final presentation and research proposal.
**Primary Text / Reference Books:**
Not indicated.

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
Assessment will be based on paper discussions and reports. Other formal assessments include a final presentation and research proposal.

**BIO-205.7: Biological Thermodynamics - TD**

Thermodynamics is the study of heat, energy, and work. Originally introduced to maximize the work-efficiency of heat engines, thermodynamics soon became one of the most fundamental branches of physics. Its laws are so general that they are applicable to all systems from inanimate machines to living cells. In this course, we will visit the core concepts of thermodynamics and statistical mechanics and explore their applicability to numerous biochemical and biophysical phenomena.

- *Brief review of thermodynamics*: Introduction to the laws of thermodynamics. Thermodynamics and statistical mechanics. Phase transition and equilibria. Enthalpy and free energy of reaction. Gibbs free energy.
- *Significance of free energy and statistical mechanics in biology*: Energetics of biochemical reactions. Protein stability. DNA melting and polymerase chain reaction (PCR). Analysis of thermodynamic data and multistate equilibriums in biology. Heat capacity of proteins. Cooperative transitions. Free energy of protein-protein interactions. Applications in Molecular pharmacology.
- *Applications of the first and second laws in biology*: Specific examples from biochemistry. Energy, information, and life. Non-equilibrium thermodynamics and living systems. Cells as active gels. Special emphasis on the distinction between equilibrium states and steady states of the nonequilibrium variety with relevance to cellular processes.
- *Metabolism as energy flow*: Investigation of hypotheses related to primordial metabolism. Energy conversion at Hydrothermal vents. Acquisition of mitochondria – endosymbiotic event that broke the energy constraint for creating complex structures. Glycolysis and oxidative phosphorylation. ATP synthesis. Donnan equilibrium. Membrane transport.
- *Thermodynamics and chemical kinetics of enzymes:* Binding equilibria and reaction kinetics. Single-site model. Scatchard and Hill plots. Rate constant and order of reaction. Multiple independent sites. First and second order reactions. Transition state theory. Enzyme kinetics, inhibition, and allosteric effect.
- *Thermodynamics of molecular machines inside cell:* Polymerization of various and thermodynamics of acto-myosin contractile system. Thermodynamics of molecular motors.

**Primary Text / Reference Books:**

- Biological Thermodynamics by D. T. Haynie, Cambridge University Press. Understanding Thermodynamics by H. C. Van Ness, Dover Publication. Statistical Physics by F. Mandl, Wiley.

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**

- Evaluation method: Assignments and Presentations: 40, one mid-term: 30, and one final exam: 30

**BIO-206.7: Basic Immunology - MV**

- Introduction to Innate Immunity, Innate Immune Cells and Inflammation
- Complement system
- Histocompatibility and Organ Transplantation
- Antigen Presentation
- Overview of Thymic Development, T Cell Subsets and Biology
- T cell Memory, Tissue Resident Memory and Vaccines
- Overview of B cell Development and Biology
- Affinity Maturation
- TCR and BCR Signaling
- Mast Cells and Allergy
- Autoimmunity
- Case Discussions and Landmark Papers in Immunology

**Primary Text / Reference Books:**
Janeway's Immunobiology (9th edition)

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
Attendance, participation in class discussions and paper presentations (40%) and term exams (60%)

**BIO-207.7: Advanced Molecular Biology - USK**

Syllabus:

Seminar/Presentation and Discussion oriented course based on classical and emerging literature

Topics covered:

1. Fundamental principles of Protein-DNA interactions: Transcription factors, architectural proteins & Repair factors (Classical literature and its relevance in the genomics era)
2. Importance of DNA-binding domains and Disordered regions in transcription and repair (emerging literature)
3. Chromatin remodeling during transcription and repair (Overview & parallels)
4. Epigenetics and gene expression control: enhancers, silencers and boundary elements (detailed cis-versus-trans control)
5. Chromatin looping: functional versus architectural (detailed)
6. Imprinting and transgenerational inheritance (overview)

**Pre-requisites:**

None but those who have not taken basic molecular biology course could go through the presentations.

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
Based on presentations, assignments and a short exam.

**Course Outcome:**

| Sr. No. | On completing the course, the student will be able to have a deep perspective on the following topics from emerging literature: |
|---|---|
| CO 1 | Fundamental principles of Protein-DNA interactions: Transcription factors, architectural proteins & Repair factors |
| CO 2 | Importance of DNA-binding domains and Disordered regions in transcription and repair (emerging literature) |
| CO 3 | Epigenetics and gene expression control: enhancers, silencers and boundary elements (detailed cis-versus-trans control) |
| CO 4 | Signaling to chromatin (intracellular and extracellular cues and modifications) |
| CO 5 | Role of ncRNA in chromatin organization and genome functions |
| CO 6 | Imprinting and transgenerational inheritance |

# Courses from other disciplines approved by AAC

**CHM-217.7: Solid State NMR - PKM, VA**

- Principles of solid-state NMR: Spin interactions, anisotropy of interactions, Frame transformations, magic-angle spinning, heteronuclear spin decoupling, cross polarisation

- Sensitivity enhancement in spins-1/2: Cross polarisation, theory and pulse schemes, transient oscillations, dipolar coupling information, spectral editing, adiabatic /ramped CP, Scalar coupling transfers in solids.

- Resolution enhancement in spins-1/2: Decoupling, various pulse schemes, experimental strategies, refocussed and non-refocussed transverse relaxation times

- Distance and Geometry information via recoupling: Separated local field experiments, pulse schemes based on symmetry of spin interactions, applications to correlation/distances/bond and torsional angles/assignments

- Quadrupolar spins: Introduction to half-integer and integer spin quadrupolar nuclear spins, comment on resolution and sensitivity issues, applications

- Solid-state NMR for bio-molecular applications.

**Primary Text / Reference Books:**

- Introduction to Solid-State NMR Spectroscopy, Melinda J. Duer, Blackwell Publishing, Oxford (2004).
- Multidimensional Solid-state NM ~lymers -Rohr and Hans WoIfgang Spiess, Academic, London (1994).
- Principles of Nuclear Magnetic Resonance in one and Two Dimensions, R. R. Ernst,G. Bodenhausen, and A. Wokaun, Clarendon, Oxford (1990).
- Principles of Magnetic Resonance, 3rd edition, Charles P. Slichter, Springer, Berlin (1996).
- High Resolution NMR Spectroscopy in Solids, Michael Mehring, Springer-Valag, Berlin (1983).
- The Principles of Nuclear Magnetism, Anatole Abragam, Oxford University Press, Oxford (1983).

**(Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
6 assignments, a midterm exam and a final exam with a weight age of 20,30 and 50% respectively.

**<u>CHM-205.7: Principles of NMR Spectroscopy – PV</u>**

The goal of the course is to introduce one to NMR spectroscopy, so that one can understand standard solution state experiments and also follow the literature. No knowledge of NMR spectroscopy is assumed.

The following topics will be covered:

Bloch Equations, Review of Quantum Mechanics, Angular momentum, Hamiltonians in NMR, Multiple spins, Energy levels, Different basis sets, Density matrix formalism, Pulsed NMR, Fourier Transform, Line shape/width, phasing, Ernst Angle, Hahn Echoes, Studying diffusion, Finite Pulses, INEPT, 2D NMR: J resolved, COSY etc, Adiabatic pulses, Basic Solids: Pake Pattern, Magic Angle Spinning, Basics of relaxation, measuring T1, T2 etc, Solomon equations, NOESY, Chemical Exchange, Multi Quantum Spectroscopy, DQF COSY, Coherence Selection: Phase Cycling/Gradients, INADEQUATE Experiment, Product Operators. Hahn echo, Average Hamiltonian theory, Decoupling, Basic Hetero nuclear experiments HSQC, HMQC, CT-HSQC etc, Water Suppression, Protein NMR: Triple resonance, Deuteration etc. Amide/Methyl TROSY, Residual Dipolar Couplings

**Primary Text / Reference Books:**
- Levitt: Spin Dynamics (2nd Edition), Wiley 2008 (ML)
- Keeler: Understanding NMR Spectroscopy (2nd Edition), Wiley 2010 (JK)
- Goldman: Quantum Description of High-Resolution NMR, Oxford, 1988 (MG)
- Harris: Nuclear Magnetic Resonance Spectroscopy, Longman Scientific, 1986 (RH)
- Cavanagh et al.: Protein NMR Spectroscopy (2nd Edition), Elsevier. 2006 (PNS)
- Any Quantum Mechanics textbook, (For example: Shankar) (QM)

- Slichter: Principles of Magnetic Resonance 3rd Edition Springer (CS)
- Ernst, Bodenhausen, Wokum: Principles of Nuclear Magnetic Resonance in One and Two Dimensions, Oxford (EBW)

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
Midterm: 30
Paper: 20 (Present a summary on one recent NMR paper.
(Paper should be selected in consultation with the instructor.)
Final: 50

**PHY-215.7: Error Analysis and Statistical Inference in Experiment – Ranjan Das (TIFR)**

**Errors in experimental science:** Errors as uncertainties. Inevitability of uncertainty. Importance of knowing the uncertainties. Estimating uncertainties in repeatable measurements.

- **How to report and use uncertainties:** Best estimate ± Uncertainty. Significant figures. Discrepancy. Comparison of measured and accepted values. Comparison of two measured numbers. Fractional uncertainties. Significant figures and fractional uncertainties. Multiplying two measured numbers.

- **Propagation of uncertainties:** Uncertainties in direct measurements. Sums and differences, products and quotients. Independent uncertainties in a sum. Arbitrary function of one variable. General formula for error propagation.

- **Statistical analysis of random uncertainties:** Random and systematic errors. The mean and standard deviation. The standard deviation as the uncertainty in a single measurement. The standard deviation of the mean.
- **The normal distribution:** Histogram and distributions. Limiting distributions. The normal distribution. The standard deviation as 68% confidence limit. Justification of the mean as the best estimate. Justification of addition in quadrature. Standard deviation of the mean. Confidence.

- **Averaging data:** Weighted averages

- **Rejection of data:** The problem of rejecting data. Chauvenet's criterion.

- **Least-square fitting:** Maximum likelihood and Fitting data to a straight line.

- **The binomial distribution and the Poisson distribution:** Probabilities in dice throwing. Definition of the binomial distribution. Properties of binomial distribution. Definition of the Poisson distribution. Properties of Poisson distribution

- **The $\chi^2$ test for a distribution:** Introduction to $\chi^2$. General definition of $\chi^2$. Degrees of freedom and reduced $\chi^2$. Probabilities of $\chi^2$.

- **Some special topics:** Use of covariance. Confidence limits on estimated parameters.

**Primary Text / Reference Books:**
Not indicated.

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
Final exam: Pass or fail

**CHM-254.7: Computer Programming using Python language - Jaikumar Radhakrishnan (TIFR)**

- Simple programs with input and output
- Variables, operations, expressions, statements
- Numbers, characters, strings
- Tuples, lists, dictionaries, sets
- Functions
- Scoping
- Conditionals
- Iteration
- Manipulating text
- Files
- Packages
- Computing with random numbers Along the way, we will learn some simple algorithms.

**Primary Text / Reference Books:**
Python programming

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
3 weekly quiz (70% overall) and 3 projects (10% each)

**CHM-216.7: Protein Structure and Synthesis – VA, KM, SR**

1. **Fundamentals of protein structure**
- Primary structure
- Secondary structure
- Super-secondary structure (motifs)
- Tertiary structure
- Quaternary structure
2. **Chemical protein synthesis**
- Solid phase peptide synthesis
- Peptide ligation
- Case studies
3. **Protein synthesis using recombinant DNA technology**
- Protein Engineering (DNA manipulation and vector design)
- Protein expression
- Protein purification and analysis
- Protein Crystallization
4. **Protein structure determination by X-ray crystallography**
- Introduction to X-ray Crystallography
- X-ray diffraction of protein crystals
- Space group determination from diffraction intensity
- Phase problem
- Structure solution methods
- Case studies
5. **Protein structure determination by NMR spectroscopy**
- NMR interactions

- Polarization transfer methods
- Assignments of protein resonances
- Distance restraints
- Structure calculation

Case studies: small hydrophobic domain.

**Primary Text / Reference Books:**

- 'Proteins: Structure and Function' by David Whitford
- 'Molecular Cloning: A Laboratory Manual', Volume 1, by Joseph Sambrook, David William Russell
- 'Biomolecular Crystallography: Principles, Practice, and Application to Structural Biology' by Bernhard Rupp
- 'Crystallography Made Crystal Clear' by Gale Rhodes
- 'Fundamentals of Protein NMR spectroscopy' by Gordon S. Rule and Kevin Hitchen
- 'Protein NMR Spectroscopy: Principles and Practice' by John Cavanagh, Wayne J. Fairbrother, Arthur G. Palmer, III, Nicholas J. Skelton, Mark Rance

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**

Assignments (20%), Mid-term (20%), Final (60%)

- Question-answer format assignments
- Reading Assignments with short report
- Mid-term written exam/presentation
- Final written exam + presentation

**<u>PHY-103.7 / CHM-101.7: Mathematical Methods – SKN, PKM</u>**

- Linear vector space, series (convergence/divergence etc.)
- special functions such as Laguerre
- Hermite (besides Bessel and Legendre),
- spherical tensor operators (a bit of angular momentum here)
- Determinants and Matrix Algebra: Properties of determinants and matrices, Linear transformation, Eigenvector-Eigenvalue problems, Similarity and unitary transformations
- Differential Equations: Separable, Exact, and First-order homogeneous linear differential equations, Sturm-Liouville eigenvalue problem, Legendre polynomials and properties, Spherical harmonics, Bessel equations and properties
- Vector Algebra: Gradient, Divergence, Curl, Gauss and Stokes theorem, Curvilinear coordinates, Tensor analysis
- Complex Analysis : Cauchy-Riemann conditions, Analytic functions, Contour integrals, Taylor and Laurent series, Singularities, Residue theorem, Gamma and Beta function, Method of steepest descent, Stirling series, asymptotic series, Convergence tests
- Integral Transforms : Fourier series, Fourier transform, Laplace transform, Solution of initial boundary-value problem, Convolution
- Error Analysis

**Primary Text / Reference Books:**

Mathematical Physics by V. Balakrishnan

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**

Evaluation method will be standard Mid-term and End-term examinations and assignment sets

**<u>PHY-102.7 / CHM-116.7: Numerical Methods and Algorithms in Chemical Physics – RR</u>**

**1) Python:** Writing/running codes: Editors, Ipython; modules, matplotlib, numpy

**2) Linear Equations:** Gaussian elimination, LU decomposition, Direct/Iterative methods

**3) Curve Fitting:** Least squares fitting, polynomial interpolation, splines

**4) Root finding:** Graphical, bisection, Newton-Raphson

**5) Numerical Differentiation:** Finite difference; Error analysis

**6) Numerical Integration:** Newton-Cotes formulae, Romberg/Gaussian integration, Multiple integrals

**7) Initial Value Problems:** Euler/Runge-Ku

**8) Boundary Value Problems:** Shooting Method

**9) Symmetric Matrix Eigenvalue Problems:** Jacobi rotations, Power/inverse power method, Tridiagonal form

**10) Minimization/Optimiztion:** 1-D problems, N-D problems, Powell's method, Simplex method **11) Application to Chemical Physics:** Molecular thermodynamics (Ideas, harmonic oscillator, rigid rotor partition functions), Equation of states, Schroedinger equation of Hydrogen molecule cation, HartreeFock for He atom, Linear variational problems in Quantum mechanics (1D potentials, Tunneling problems), Potential energy surface fitting, Time-dependent Schroedinger equation.

**12) Optional Topic:** Krylov Subspace Techniques, Lanczos iteration

**Primary Text / Reference Books:**

- Fortran 90/95 for Science and Engineering, edition 2, S.J. Chapman, McGraw Hill
- Education India Private Limited; 2 edition (Indian Edition, ~Rs. 800).
- Numerical Methods, W. Boehm, H. Prautzsch, Universities Press, 2000. (Indian Edition,~Rs. 200).
- Introduction to Numerical Computation, L. Eldén, L. Wittmeyer-Koch, H.B. Nielsen,
- Overseas Press, 2006 (Indian Edition, ~Rs. 500).
- Numerical Methods in Chemistry, K.J. Johnson, Marcel Dekker, 1980.
- Introduction to Quantum Mechanics: A Time-dependent Perspective, D.J. Tannor, University Science books, 2007.
- Understanding Molecular Simulation, edition 2, D. Frenkel, B. Smit, Academic Press, 2001.

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
Assignment: 50 %, Exam-I: 25%, Exam –II: 25%

**<u>CHM-222.7: Molecular dynamics simulation and application in chemical physics – JM, SG</u>**

The aim of this course is to provide the students an overview of molecular aspect of numerical simulation in chemical and biological perspective. This course is designed as an elective course to provide the students a hands-on experience on key topics of molecular dynamic simulations as is being practiced in the scientific community. The course will cater to both theoretical and practical side of molecular aspect of the simulation techniques
The course will be run using a combination of regular programming language ( Fortran) and special purpose molecular dynamics simulation package ( Gromacs).

- Broad overview of Computer simulation and application of molecular dynamics simulation. (2 lecture)

- Basic linux primer, Primer on a programming language (Fortran) (6 lectures)

- Writing your first Molecular Dynamics code: Initialization of system, Force calculation from classical potential, Implementation of periodic boundary condition, Integration schemes of Newtonian equation of motion. Simple monoatomic liquids as the test system (6 lectures)

- Writing your first Monte Carlo Simulation code: Importance sampling, Metropolis algorithm, Translation and rotational moves, Simple monoatomic liquids as the test system, Other advanced Monte Carlo moves (4 lectures)

- Implementation of Thermostats and Barostat in Molecular Dynamics simulation: Introduction to Berendsen, Velocity-rescale, Nose Hoover and Parrinello Rahman protocols for NVT and NPT simulation. Implementation using Fortran and Gromacs (4 lectures)

- Handling Electrostatics in computer simulation: Implementation of Ewald summation and Particle mesh ewald summation in computer simulation. Illustration using Fortran and Gromacs (2 lectures)

- Introduction to molecular force fields and overview of the existing molecular force fields, water models as case study (1 lecture)

- Free energy calculations, Introduction to Enhanced sampling approaches, Illustration using Umbrella sampling and Metadynamics simulation using GROMACS (4 lectures)

- QM/MM: Basics; Additive vs Subtractive schemes, Different types of embedding, Adaptive QM/MM models (3 lectures)

- Ab Initio MD (1 lecture)

Beyond Born-Oppenheimer approximation (1 lecture)

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
8 Assignments (computing based): 50 %, 2 examinations (Both Pencil and Computer based ): 50%

**<u>CHM-255.7: Introduction to Data Science – RR</u>**

1) **Data Science:** Big Data, Facets of data (structured/unstructured data)
2) **Toolboxes:** Python libraries, SCIKIT-Learn, PANDAS
3) **Statistics:** Distributions, Outlier, Skewness, Pearson's/Spearman's/Kendall's coefficient, Kernel density
4) **Statistical Inference:** Hypothesis testing, Confidence Intervals
5) **Supervised Machine Learning:** What is machine learning? Learning curves, Support Vector Machines, Random Forest
6) **Regression:** Linear Regression, Logistic Regression
7) **Unsupervised Machine Learning:** Clustering, Case studies
8) **Big Data concepts:** Handling large data, Hadoop, Spark, NoSQL, Graph databases, Natural language processing, MapReduce

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
Assignment (50%), Presentations (50%)

**<u>BIO-100.7: Research Methodology – SRS, AM & GR:</u>**

Scientific research involves a mature understanding of past literature, providing contextual motivation for current work; a judicious analysis of generated data; good presentational skills; and an appreciation of the foundational role of scientific ethics and scientific method. The course will cover diverse areas such as research ethics, literature survey, quantitative methods of data and statistical analysis with practical applications to real- world data, and field visits. Because of the universal need for these research methods, values and skillings, this course is mandatory for graduate students of all the three subject-boards relevant to TIFR Hyderabad (Physics, Chemistry and Biology). The course includes topics below. (Square brackets show [No. of classes]. Smaller font is (informal teacher's notes on the topics to be covered)).

**1.SKILLING STUDENTS TO:**

* Sketch a Function [2] (Function *and* slope. Symmetries, Special pts, asymptotes, draw segments. Join up!)

* Write a CV [1] (First impression. Show professionalism! CV content. Fonts, topics, and sequencing.)

* Write a Letter [1] (Apply for postdoc. Ask to visit. Request to be cited.)

* Talk about research work [1] (10 minute talk, 1 minute talk, coffee conversation, the elevator pitch,140-character tweet.)

* Give a Research Talk [2] (Judge audience! 1 slide ~ 2 mins. Intro/Motivation/Methods/Results/Takeaways.

Questions.)

* Write a Research Paper [2] (Abstract, Text, Fig Caps, Refs, Acknowledgements. Proof-reading. Good/Bad writing examples.)

* Read a Research Paper [1] (Quick-read. Skim text, main refs. Go to Origins, trace Evolutions. Detailed reading.)

* Make Quantitative Estimates [2] (Memorize basic constants, sizes. Internal conversation. Compare others, on Log scale.)

**2. METHOD OF SCIENCE** [2] (Theoretical model, predictQuantitative experimental testKeep/ Modify model, predict...Ideas of Bacon, Occam, Popper, Kuhn.)

**3. RESEARCH ETHICS AND AVOIDING PLAGIARISM** [2] (Dangers of copy-paste. Plagiarism. Proper citing. Indian Academy of Sciences Report)

**4. VISUAL REPRESENTATION OF RESEARCH DATA** [2] (Optimal design of plots, charts, schematics, posters etc for graphic display of empirical relationships in complex data.)

**5. ERROR ANALYSIS OF RESEARCH DATA** [3] (Random and systematic errors. Statistical errors and probability distributions. Error propagation or addition of errors.)

**6. STUDENT PRESENTATIONS**

(Research Literature. *25+5 min talks,3 per class. Graded. Two cycles, if class-size permits*.)

**7. LAB VISITS**

(Students split up for Bio/ Chem/ Phys tours, guided by Senior PhD students)

**Primary Text / Reference Books:**

- Scientific Writing and Communication, Angelika Hofmann, (Oxford 2014).
- Back-of-the-Envelope Physics, Clifford Swartz, (Johns Hopkins 2003).
- The Visual Display of Quantitative Information, Edward Tufte (Graphics Press 1982); Bang Hong, Nature Methods articles.
- Measurements and their Uncertainties, IG Hughes and TPA Hase, (Oxford 2014)
- Advice to a Young Scientist, Peter B Medawar, (Basic Books 2008)
- A PhD Is Not Enough, Peter Feibelman (Basic Books 2011)

**Evaluation Method (Weightage for Internal Assessment, Mid Term / Term End exams, Presentations etc.):**
Based on student written hand-ins (50%) and student oral presentations (50%)

**Course Outcome:**

| Sr. No. | On completing the course, the student will be able to have a deep perspective on the following topics from emerging literature: |
|---|---|
| CO 1 | Students are taught what senior people already know from experience, namely how to survive a PhD programme, and how to function as an academic professional. |
| CO 2 | There are lectures on Scientific Method and Scientific Ethics. But the core of the course is a series of How To lectures telling them things that, for earlier students at least, were not written down anywhere. |
| CO 3 | How to sketch a function. How to do a CV. How to give a talk. How to write a paper. How to read a paper. How to converse with others about your work. How to write an application letter. How to give an interview, including an online one. How to think,and to feed and keep healthy, your two minds (M1 eats logic. M2 eats analogies.) |
| CO 4 | The course ends with 10 min talks by students on topics that are Not in their area of specialization, that count for 50% of the grade. |
| CO 5 | The RM course is unusual, but seems to work, with students giving quite positive comments |

# Courses at the University of Hyderabad

**A student may take specific courses at the University of Hyderabad (Hyderabad Central University (HCU)) if a course is thought to be particularly beneficial for the training of the student as determined by the AAC at TIFR Hyderabad.**

**Courses offered at University of Hyderabad (most of these are MSc level courses and only few on specialized topics may be of interest as advanced courses):**

**Plant Sciences**
The basic courses offered during the four semesters are: Cell and Molecular Biology, Genetics, Macromolecules Structure and Function, Microbiology (I Semester); Plant Physiology, Environmental Biotechnology, Molecular Biology and Genetic Engineering, Plant Biochemistry (II Semester); Genomics and Proteomics, Plant Developmental Biology, Plant Biotechnology (III Semester).

**Molecular Microbiology**
The basic courses offered during the four semesters are: Cell and Molecular Biology, Genetics, Macromolecules Structure and Function, Microbiology (I Semester); Microbial Physiology & Biochemistry, Immunology, Molecular Biology and Genetics Engineering (II Semester); Genomics and Proteomics, Bioprocess Engineering & Technology Processing, Microbial Metabolomics (III Semester).

**Biochemistry**
Basic - Intermediary Metabolism-1, Biophysical Chemistry, Computer Applications in Biology, Genetics, Microbiology (I semester), Intermediary Metabolism II, Enzymology, Molecular Biology I, Structural biology (II Semester), Basic Immunology, Molecular Biology II, Bioenergetics and Biomembranes (III Semester), Nutritional and Clinical Biochemistry (IV Semester). In addition, the Department also offers **elective advanced** courses such as Endocrine Biochemistry, Cell and Nuclear division, Cancer stem Cell biology, Protein Phosphorylation and Signal Transduction (III/IV Semester).

**Animal Sciences**
Apart from the basic courses that they take jointly with either plant sciences or biochemistry, they offers Developmental biology, Stem cell Biology, Epigenetics and nuclear organization, bioprocess technology and neurobiology.

**Biotechnology**
Additional courses: Bioprocess Engineering, Genetic engineering, vaccinolgy, neurogenetics, model system genetics.

**Graduate level courses ("PhD course work") at University of Hyderabad:**

1) A very technique/practical oriented course called Analytical Techniques
2) Biostatistics
3) Scientific writing and Ethical practices in Science
4) Laboratory course in which a few selected experiments from a basket are to be completed.
5) Presentation of Research papers