COURSES OFFERED IN BIOLOGY

BIO110	Basic Biology (Refresher Course)	0 Credits

Objectives & Outcomes: Students attending this course need not have taken biology at the high school level. This course aims to introduce you to fundamental concepts of biology from its very basics for any beginner in Biology, and prepare the student for a course with more detailed description of Biology to follow in BIO111.

Contents:
Basic Biology: Biological Levels-Species, organisms, Tissues, Cells & Cellular Constituents. Describe examples/designs and simple organizational principles. **Diversity of life:** Prokaryotes *versus* Eukaryotes; Plants *versus* Animals; Explain the main differences and relate them to functions. **Cellular constituents:** Structure & function relationship in relation to different stages of cell cycle. **Biomolecules:** Structure & Function relationship in the context of Biological processes they participate in. **Genetics:** Mendel's Laws of heredity in Monohybrid and dihybrid crosses. **Evolution:** Basic definition & underlying mechanism focusing on dispelling the mistaken notions associated with Darwinian evolution.

Textbooks/References:
1) Campbell, N. A. et al. (2021). *Biology: A global approach* (12th ed.). Pearson.

BIO111	Foundations of Biology I: Basic Principles	3 Credits

Objectives & Outcomes: The course is intended as an introduction to the main conceptual framework of biology as a science, outlining the diversity, organization and fundamental principles of living systems. This course also aims to introduce you to several fundamental concepts in biology. It is aimed to give an insight on how organisms work at the single and multicellular levels (cellular aspects) by initially providing a molecular framework to understand the basic intermolecular interactions (biochemical aspects) that drive underlying cellular processes.

Contents:
Basic Biology: Salient features of life; Importance of biology on the frontiers of science and technology; Brief history of biology; Structure-function relationship, theme and variations, individual variability and plasticity. **Evolution:** History and evolution of life on earth; Concept of adaptive versus neutral evolution; Genetic basis of natural selection; The logical structure of biology: Concepts of complexity, emergent properties, adaptation, biological species diversity, chance and necessity; How plants, animals and microorganisms shaped human history; Introduction to the world of living organisms; Levels of biological organization (molecular, cellular, organismal and population levels); Diversity of life. **Plant Biology:** Origin and classification of plants; Aquatic to land plants; Nomenclature of flowering plants; Plant adaptations; Differences between Prokaryotic and Eukaryotic Cells; Plant cell structure; Cell wall and Cell membrane; Plastid; Peroxisome; Photosynthesis. **Biomolecules:** Water, buffers; Amino acids, peptide bond, conformation, protein structure; Nucleotides and nucleic acid; Carbohydrates and polysaccharides; Lipids and membranes; Conjugated macromolecules and biomolecular complexes. **Cell Biology:** Compaction and organization of

the genetic material (DNA) into chromatin, Bacterial and eukaryotic chromatin; Cell Division including mitosis and meiosis; Role of various organelles: Nucleus, Centrioles, Microtubules, Microfilaments, Endoplasmic reticulum, Golgi complex.

Textbooks/References:

1) Campbell, N. A. et al. (2021). *Biology: A global approach* (12th ed.). Pearson.
2) Voet, D. & Voet, J. G. (2010). *Biochemistry* (4th ed.). Wiley.
3) Alberts, B. et al. (2015). *Molecular biology of the cell* (6th ed.). Garland Science.
4) Judd, W. S. et al. (2015). *Plant systematics: A phylogenetic approach* (4th ed.). Oxford University Press.

BIO112	Biology Lab I: Basic Biology	3 Credits

Objectives & Outcomes: This course aims to introduce different interesting concepts in biology: Microbiology, Genetics and Plant biology. Students from non-biology background will also appreciate this basic lab course, which emphasizes on observation, data collection and describe. Systematic observation, Good laboratory practice will be emphasized during the lab sessions. Every student who takes this course will surely be fascinated by the diversity presence in biology which helps life to sustain in an orderly manner. Students will learn to methodically observe a biological experiment, record it in their notebooks and draw conclusion. The viva will train them to defend their observations and inferences from the experiment.

Contents:

Module 1: General Biology-Microbiology-Orientation, Good lab practices. Introduction to microscope and hanging drop to demonstrate different organisms and their motility. Sterilization, preparation of liquid media, solid agar. Isolation, Grams staining. **Module 2:** Plant science: Plant Morphology, Plant Anatomy, Plant Movement, Plant biochemistry. **Module 3:** Genetics: Cell division, Blood cell types, Hemocytometer/blood cell counting, Barr body staining.

Textbooks/References:

1) Pelczar, M. J., Chan, E. C. S. & Krieg, N. R. (2004). *Microbiology* (5th ed.). McGraw- Hill.
2) Madigan, M. T. et al. (2018). *Brock biology of microorganisms* (15th ed.). Pearson.
3) Willey, J. M., Sandman, K. & Wood, D. (2020). *Prescott's microbiology* (11th ed.). McGraw-Hill.
4) Koelling, C. (2016). *Plant anatomy, morphology and physiology*. Syrawood Publishing House.

BIO121	Introductory Biology II: Genetics and Molecular Biology	3 Credits

Objectives & Outcomes: This course would enable students to develop their understanding of basic concepts of molecular biology and genetics. Students would learn basics of genetics and classical genetics. On covering all classical concepts of Mendelian genetics, students will be exposed to concepts of population genetics, quantitative genetics encompassing complex traits, clinical genetics and genetics of evolution. Students would

learn about the molecular basis of transmission of genetic information and its role in determining the function of cells. They will gain knowledge about the aspects of gene expression and the molecular complexity that regulates differential gene expression.

Contents:

Module 1. Biological information: Nature of biological information. Mechanisms of transmission of information: genetic, epigenetic, cultural and other mechanisms of inheritance. Central dogma of molecular biology. How the genetic information is processed into cellular functionality. Mutations. **Module 2:** Mendelian genetics (segregation and independent assortment); Bacteriophage genetics and Drosophila crosses; Introduction to polytene and lampbrush chromosomes; sex determination and sex linkage in diploids; cytoplasmic inheritance; pedigrees, markers, mapping and genetic disorders; gene frequencies and Hardy-Weinberg principle. **Module 3:** Basic aspects of gene expression and regulation. Transcriptional, translational and post-transcriptional control of gene regulation.

Textbooks/References:

1) Krebs, J. E., Goldstein, E. S. & Kilpatrick, S. T. (2018). *Lewin's genes XII* (12th ed.). Jones & Bartlett Learning.
2) Alberts, B. et al. (2015). *Molecular biology of the cell* (6th ed.). Garland Science.
3) Watson, J. D. et al. (2014). *Molecular biology of the gene* (7th ed.). Pearson.
4) Nelson, D. L. & Cox, M. M. (2017). *Lehninger principles of biochemistry* (7th ed.). Macmillan International Higher Education.
5) Voet, D. & Voet, J. G. (2010). *Biochemistry* (4th ed.). Wiley.

BIO122	Biology Lab II - Biochemistry and Molecular Biology Lab	3 Credits

Objectives & Outcomes: To make the students familiar about basic Molecular Biology and Biochemical Experimental methods. The students are expected to gain basic training in conducting Molecular Biology and Biochemical experiments

Contents:

Preparation of solutions, dilutions etc. Protein Estimation and Enzyme assay (acid phosphatase enzyme assay), Genomic DNA isolation- estimation using Nano drop method, RNA isolation and estimation using Nano drop method, Agarose Gel Analysis of DNA and RNA, SDS-PAGE analysis of Proteins, PCR experiment, PCR product purification (Gel extraction), Gel analysis and Restriction Digestion, Analysis and Purification of Digested DNA, Gel analysis of the Purified DNA and Ligation, Transformation, Plasmid isolation (rDNA), Confirmation of Recombinant Plasmid DNA by Restriction digestion, Animal Cell culture Demo

Textbooks/References:

1. Plummer, D. T. (2004). *Introduction to practical biochemistry* (3rd ed.). McGraw-Hill.
2. Jayaraman, J. (2011). *Laboratory manual in biochemistry* (2nd ed.). New Age International.
3. Green, M. R. & Sambrook, J. (2012). *Molecular cloning: A laboratory manual*, *3 vols.* (4th ed.). Cold Spring Harbor Laboratory Press.
4. Segel, I. H. (1976). *Biochemical calculations: How to solve mathematical problems in general biochemistry* (2nd ed.). Wiley.

BIO211	Foundations of Biology III: Evolution and Ecology	3 Credits

Objectives & Outcomes: This course will provide students with a basic understanding of ecology and evolution. It will cover an introduction to ecology, ecosystems and adaptations, the study of relationships between organisms and their environment, species distribution and communities, populations, species interactions and behavioral strategies of individuals and populations. The course will also cover the basics of evolution, relatedness amongst species and biogeography, and will touch upon conservation biology. The course will be global, while also highlighting the Indian context, bringing attention to the local ecology of the Eastern Ghats.

Students will learn the modes of inquiry in the investigation of ecological and evolutionary questions; using both natural history studies and experimental ecology. Normally there is at least one field trip to Eastern Ghats to collect primary data from the field so that students understand data collection in this field of biological research. However, this may depend on logistics

Contents:

Module 1: What is Ecology. Data management workflow. Ecosystems, biomes & biogeography: Ecosystems, habitats, the diversity of life, niches and resources, food webs, biogeography. **Module 2:** Evolution, natural selection, sexual selection, speciation, phylogenetic trees. **Module 3:** Population ecology: Survivorship curves, Life-tables, Simple population dynamics models and their behavior, spatial ecology. **Module 4:** Community ecology: Species interactions, competition; predation; resource partitioning. **Module 5:** Life history strategies, behavioral ecology – approaches and overview, mating systems. **Module 6:** Conservation biology: climate change, extinction, threats to species, fragmentation, habitat loss. Case studies from India. Perceptions of conservation class project.

Textbooks/References:

1. Ecology - From Individuals to Ecosystems: M. Begon,C.R. Townsend, and J.L. Harper (2005) Blackwell Publishing
2. Ecology: Concepts and Applications. Manuel C Molles Jr (2016). McGraw-Hill Education.

BIO213	Biology for Society	3 Credits

Objectives & Outcomes: To convey how the research advances in biology has impacted the society. Awareness of the social context of biological sciences - understanding how biological sciences has impacted society and policy.

Contents:

Infection & Immunity: Vaccines/Ab therapies. Antibiotics/probiotics/biosimilar/New approaches against multi-drug resistance. Genetic disorders, fight against cancer and neurological disorders. Life style disorders and therapies. Regenerative medicine: Tissue Engineering/Stem cell therapy/Tissue regeneration as therapy approaches against tissue disease. Plant Biotechnology and Trait improved agricultural produce.

Textbooks/References:

Recent literatures will be shared.

BIO221	Introductory Biology IV: Systems Biology	3 Credits

Objectives & Outcomes: Biological systems are comprised of many components which often interact in a regulated manner to affect outcomes. This course will offer a systems-level perspective at various scales of biology to capture the underlying function of each component and its sum. Using thematic examples from molecular, cellular, organ/organismal and ecosystem scales, we will try to derive organizational principles that mediate interactions between components. This course will illustrate the concept that Systems biology involves developing the understanding of a biological system through mathematical and computational modeling of the interactions of components of the system. This understanding is expected to give a glimpse of living systems as non-linear dynamic designs where the whole exceeds the linear sum of the components it is made of.

Contents:
Module 1: Introduction to complex systems; Emergent properties; Robustness and evolution of biological systems; Scales in biological systems. **Module 2:** Introduction to Molecular Systems, Signaling and gene regulatory networks. **Module 3:** Introduction to Cellular Systems, Interaction between different subcellular components, Cell-cell communication and tissue organization. **Module 4:** Organ Systems: Physiology and models of the immune system and nervous system. **Module 5:** Communities and ecosystems: Communities, Social behavior and eco-systems

Textbooks/References:

1. An Introduction to Systems Biology: Design principles of biological circuits (2019), Chapman & Hall/CRC
2. Molecular Biology of the Cell: B. Alberts, A. Johnson, J. Lewis, M. Raff, K. Roberts and P. Walter (2002) 4th edition, Garland Science
3. An Introduction to Systems Biology: Design Principles of Biological Circuits: U. Alon (2006) 1st edition, Chapman & Hall/CRC
4. Mathematical Biology: J.D. Murray (2007) Vol. I. 3rd edition, Springer

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BIO311/611	Introductory Immunology	4 Credits

Objectives & Outcomes: The Objective is to enable students to gain basic idea about the immune system. To teach the basic aspects of the central dogma of immune system. The students are expected to gain a basic understanding of the immune system by the end of this course.

Contents:
Module 1. Development of the immune system, introductory aspects of Innate and the adaptive immunity. **Module** 2. Primary and the Secondary Lymphoid Organs and the cellular subtypes of the Immune system **Module** 3. Hematopoiesis and the Importance of Bone marrow and the Thymus in the immune system. Antigens and Antigenicity, Antibodies and their structure and function. T cell Receptor (TCR) structure and function. RAG genes and an introduction into TCR and the B-cell Receptor (BCR) generation. **Module** 4. Complement system. Major Histocompatibility complex and basic aspects of antigen presentation. Positive

and Negative selection – the central dogma of the immune system. **Module** 5. Basic aspects of immune response to infection (foreign antigens). Autoimmunity and allergy. Vaccines and Vaccination. An introduction into immunological methods.

Textbooks/References:

1. Murphy, K. M. & Casey, W. (2017). *Janeway's immunobiology* (9th ed.). Garland Science.
2. Punt, J. et al. (2019). *Kuby immunology* (8th ed.). Macmillan International Higher Education.
   Also we may provide some reading material from literature in the form of reviews or research articles as and when required.

BIO312/612	Biochemistry	4 Credits

Objectives & Outcomes: This course aims to provide students with a comprehensive grounding in the fundamentals of Biochemistry. We start with the very basic molecule necessary for life and go on to discover the structure, function and interrelationships between important biomolecules that collectively carry out the essential functions of life. Next modules discus the concept of enzyme catalysis and introduces the concepts underlying routine and advanced methodologies that are used in analyzing biomolecules. The last module constitutes an overview of metabolic pathways.

Contents:

Module 1. Biomolecules: Structural and functional aspects of proteins, nucleic acids and carbohydrates; RNA, ribozymes. **Module 2. Thermodynamic principles:** Free energy and equilibrium and binding; Protein folding, dynamics and interaction; Introduction to techniques for analysis of biomolecular structures. **Module 3. Enzyme biochemistry:** Catalysis, Inhibition, Activation, Mechanism, Allosteric enzymes. **Module 4. Biochemical/analytical techniques:** Isolation, Purification, Electrophoresis, Chromatography, Mass spectrometry, Micro-calorimetry. **Module 5. Metabolism and** metabolic pathways - glycolysis, TCA cycle, electron transport chain and oxidative phosphorylation.

Textbooks/References:

1. Biochemistry: Jeremy M. Berg, Lubert Stryer , John L. Tymoczko, Gregory J. Gatto
2. Lehlinger's principles of Biochemistry: D L Nelson and M M Cox, 6th Edition
3. Biochemical Calculations: How to Solve Mathematical Problems in General Biochemistry. Irwin Segel. 2nd Edition.

BIO313/613	Evolution	4 Credits

Objectives & Outcomes: This course will encourage a deeper understanding of evolutionary biology and processes, and material covered will span from classic theories to recent developments in the field. The content will reflect the advances in technology and computational abilities that are allowing for a much more nuanced understanding of evolutionary processes. An understanding of evolution will also be applied to several aspects of human society (medicine, psychology, etc). This 4-credit course will involve mathematical and statistical computations, along with regular readings and classroom activities. This course will provide students with a basic understanding of the principles of evolutionary

biology. The course will also cover the basics of evolution, relatedness amongst species and populations. Within species. This course will integrates the computational and theory modules which will focus on understanding the modes of inquiry in the investigation of evolutionary questions.

Contents:
Module 1. Evolutionary thought: History of evolutionary thought, Canvases to study evolution, Review of concepts from BIO 211 (phylogenetics). **Module 2. Selection, Limits and Constraints:** Adaptations & fitness, Units and levels of selection in populations, Phenotypic selection on quantitative traits, Limits and constraints to evolution, Phenotypic plasticity, Evolution of life histories **Module 3. Genes and genomes:** Molecular clock, Neutral theory, Genome evolution and comparative genomics, Epigenetics, Evolutionary developmental biology, Genetics and trait evolution. **Module 4. Speciation and macroevolution:** Species evolution, Speciation and selection, Historical biogeography and phylogeography, Adaptive radiations, Ancient DNA, Macroevolutionary rates and trends. **Module 5. Evolution of behaviour and societies:** Game theory, Sexual selection and mating systems, Behaviours as adaptations, Evolution of behaviours like communication, parental care, cooperation and conflict. **Module 6. Evolution of humans and modern societies:** Human evolution, Evolutionary psychology, Evolutionary medicine and parasites, Evolution of language, Evolution of culture, Evolution and conservation, Directed evolution.

Textbooks/References:
The Princeton Guide to Evolution. 2014. Edited by Jonathan B. Losos, David A. Baum, Douglas J. Futuyma, Hopi E. Hoekstra, Richard E. Lenski, Allen J. Moore, Cahterine L. Peichel, Dolph Schluter and Michael C. Whitlock.

BIO315/615	Molecular Plant physiology	4 Credits

Objectives & Outcomes: The objective of this course is to acquaint students with the fundamentals of plant biology. This course will help the students to acquire basic knowledge about plant's life, get insights into the plant growth and stress responses at the physiological level to molecular level. The students will have an in-depth understanding to follow contemporary research in plant sciences.

Contents:
Module 1: Plant diversity; Evolution of plants, Overview of plant classification, Life-cycle regulation, Introduction to land plants, Ancestral flowering families, Monocot and dicot families, Molecular systematics. **Module 2:** Plant cell and tissue organization; Molecular basis of plant cell architecture, Cell wall, Cell membranes and organelles, Plant cytoskeleton, Membrane transport. **Module 3:** Photosynthesis and respiration; Molecular and biochemical aspects of photosynthesis, C3 and C4 plants, Photorespiration, CAM metabolism, Pentose phosphate Cycle, Cellular Respiration. **Module 4:** Plant metabolism; Gas exchange, Water and mineral transport, Nutrients remobilization, Senescence, Nitrogen and Phosphate assimilation, Lipid metabolism, Secondary metabolites.

Textbooks/References:
1. Plant Physiology and Development: L. Taiz and E. Zeiger (2010) 6th edition, Sinauer Associates Inc.
2. Biochemistry and Molecular Biology of Plants: B. Buchanon et. al. (2002) American Society of Plant Physiologists (ASPP)

3. Physiology and Behavior of Plants: P. Scott (2008) 1st edition, Wiley Publishers
4. Plant Biochemistry: H.W. Heldt and B. Piechulla (2010) 4th edition, Wiley Publishers

BIO317/617	Advanced Ecology	4 Credits

Objectives & Outcomes: This course will train students with a preliminary understanding of Ecology (for e.g. BIO211) to deeper concepts of ecology, while maintaining a combination of lab and theory mix. Students will explore some concepts in ecology deeper than in BIO211. They will experience reading, discussing and synthesizing ecological literature. They will also experience conducting field ecological studies, and analyze ecological data with open data analyses tools like R. There will also be short projects. Statistics, hypothesis testing and study design will be integrated into the course at different places. They will improve oral and written skills in presenting results from ecological studies. Students will gain a deeper understanding of Ecology, and learn to conduct ecological analyses, such that they can conduct independent projects

Contents:
Module 1: What is Ecology, how to do ecology? History of ecology, how is ecology done in practice. How does the interdisciplinary nature of ecology allow you to make broader inferences? **Module 2: Climate change-** What are the drivers of climate change? What data can we examine to understand climate change? How does climate change impact different habitats? Recent Paris accord and the details of what global leaders agreed to. Where do India and USA stand in the current political scenario? **Module 3: Landscape ecology-** Landscape dynamics, Boundary dynamics in landscapes, ecological dynamics in fragmented landscapes, Seascape patterns and dynamics, Change detection on field & in the lab. **Module 4: Biogeography-** Plate tectonics and biodiversity, Gondwana & out-of-india hypothesis, Spatial patterns of species diversity in terrestrial environment. **Module 5: Community ecology-** Evolution of communities & ecosystems, macroecological perspectives & analyses, metacommunity dynamics in biodiversity. **Module 6: Invasion ecology-** Modes of invasion and establishment, Biological control, theory and practice, **Module 7: Conservation:** Causes & consequences of species extinction, principles of reserve design, ecological economics, marine conservation, human-animal conflict in India. **Module 8: Acoustic Ecology-** Acoustics, ecological adaptations. Sources of acoustic variation in time and space. Repertoire sizes and fitness. Measuring acoustic features.

Textbooks/References:
1. Levin, S. A. (2009). *The Princeton guide to ecology.* Princeton University Press.
2. Bowman, W. D., Hacker, S. D. & Cain, M. L. (2018). *Ecology* (4th ed.). Oxford University Press.
   Other reading material will be handed out in class as required.

BIO318/618	Genetics	4 Credits

Objectives & Outcomes: The objectives of this course are to take students through basics of genetics and classical genetics covering prokaryotic/ phage genetics to yeast and higher eukaryotic domains. On covering all classical concepts of Mendelian genetics across these life-forms, students will be exposed to concepts of population genetics, quantitative genetics encompassing complex traits, clinical genetics and genetics of evolution.

Contents:
Module 1: Genetics of bacteria and bacteriophages: Concept of a gene in pre-DNA era; mapping of genes in bacterial and phage chromosomes by classical genetic crosses; fine structure analysis of a gene; genetic complementation and other genetic crosses using phenotypic markers; phenotype to genotype connectivity prior to DNA-based understanding of gene. **Module 2:** Yeast genetics: Meiotic crosses, tetrad analyses, non-Mendelian and Mendelian ratios, gene conversion, models of genetic recombination, yeast mating type switch; dominant and recessive genes/mutations, suppressor or modifier screens, complementation groups, transposon mutagenesis, synthetic lethality, genetic epistasis. **Module 3:** *Drosophila* genetics as a model of higher eukaryotes: Monohybrid & dihybrid crosses, back-crosses, test-crosses, analyses of autosomal and sex linkages, screening of mutations based on phenotypes and mapping the same, hypomorphy, genetic mosaics, genetic epistasis in context of developmental mechanism. **Module 4:** Plant genetics: Laws of segregation in plant crosses, inbreeding, selfing, heterosis, maintenance of genetic purity, gene pyramiding. **Module 5:** Population genetics and genetics of evolution: Introduction to the elements of population genetics: genetic variation, genetic drift, neutral evolution; mutation selection, balancing selection, Fishers theorem, Hardy- Weinberg equilibrium, linkage disequilibrium; in-breeding depression & mating systems; population bottlenecks, migrations, Bayesian statistics; adaptive landscape, spatial variation & genetic fitness.

Textbooks/References:

1. Hartl, D. L. & Cochrane, B. J. (2019). *Genetics: Analysis of genes and genomes* (9th ed.). Jones & Bartlett Learning.
2. Pierce, B. A. (2020). *Genetics: A conceptual approach* (7th ed.). Macmillan International Higher Education.
3. Tamarin, R. H. (2002). *Principles of genetics* (7th ed.). McGraw-Hill.
4. Smith, J. M. (1998). *Evolutionary genetics* (2nd ed.). Oxford University Press.

BIO321/621	Microbiology	4 Credits

Objectives & Outcomes: At the end of the course students should be able to (i) Classify microbes based on their physiology, (ii) Understand their metabolism and genetics, (iii) Define strategies to control microbial growth, (iv) Their use in recombinant DNA technology. The students will be able to gain knowledge on physiological processes of microbes and their regulation of gene expression. They will also understand various gene transfer mechanisms of microbes and their uses in current research developments.

Contents:
Module 1: Brief history of Microbiology with brief introduction to prokaryotes and eukaryotes. **Module 2:** Microbial metabolism and growth and their control, Microbial genetics. **Module 3:** Methods of classification of microorganisms, brief classification of microorganisms, gut microbiota. **Module 4:** Introduction to viruses, prions and recombinant DNA technology.

Textbooks/References:

1. Tortora, G. J., Funke, B. R. & Case, C. L. (2019). *Microbiology: An introduction* (13th ed.). Pearson.
2. Moat A. G., Foster, J. W. & Spector, M. P. (2002). *Microbial physiology* (4th ed.). Wiley.

3. Pelczar, M. J., Chan, E. C. S. & Krieg, N. R. (2004). *Microbiology* (5th ed.). McGraw-Hill.
4. Madigan, M. T. et al. (2018). *Brock biology of microorganisms* (15th ed.). Pearson.
5. Carroll, K. C. et al. (2019). *Jawetz, Melnick & Adelberg's medical microbiology* (28th ed.). McGraw-Hill.
6. Murray, P. R., Rosenthal, K. S. & Pfaller, M. A. (2015). *Medical microbiology* (8th ed.). Elsevier.

BIO324/624	Animal Physiology	4 Credits

Objectives & Outcomes: The course aims to impart fundamental knowledge in the physiology of vertebrates. The emphasis will be on systems level understanding and on integration of physiology, ecology and evolution. In addition to the focus on human physiology from the perspective of human health, recent understanding on physiological adaptations such as diving by marine mammals and mechanisms of navigation by migratory mammals will be discussed. The fundamentals of physiology is also key for budding ecologists, evolutionary biologists and will also be helpful to animal developmental biologists.

Contents:

Module 1: Introduction- Importance of physiology; Central questions – mechanism and origin, the concept of homeostasis; physiological functions adapted to environment; origin of physiological adaptations; Energy metabolism- Animal Energetics; metabolic rate; metabolic scaling; aerobic and anaerobic metabolism; responses to impaired O2 influx; Thermal relations- Ectothermy; homeothermy. **Module 2:** Nervous system - Neurons; action potential; synapses; neurotransmitters; nervous system organization; Biological clocks. **Module 3:** Endocrine and neurocrine physiology - Endocrine principles; control of endocrine response; endocrine control of homeostasis; mammalian stress response; hypothalamus; the thyroid, adrenal, and hormones of the islets of Langerhans; calcium regulation; sex hormones, regulation of menstrual cycle, hormones of the placenta. **Module 4:** Gastrointestinal physiology - Principles of gastrointestinal function – associated glands and secretions, motility, nervous control and blood circulation; enteric nervous system; transport of food in alimentary tracts, digestion and absorption. **Module 5:** Control of movement - Skeletal muscle physiology, neuromuscular junction; muscle atrophy in microgravity; absence of disuse atrophy in some animals. **Module 6**: Cardiovascular system - Cardiac muscle, the heart as a pump, rhythmic excitation, autonomic control of heart, blood flow and its hormonal regulation, coronary circulation and ischemia. **Module 7:** The blood and lymphatic systems - Red blood cells, anemia, lymph formation and circulation. **Module 8:** The kidney and excretion - Body fluid compartments, urine formation – glomerular filtration and tubular processing, renal blood flow, renin-angiotensin system, sodium and water excretion, diabetes insipidus. **Module 9:** The gas exchange, transport and tissue respiration - Pulmonary ventilation, pulmonary circulation, physical principles of gas exchange; transport of oxygen and carbon dioxide in the blood and body fluids; neural regulation of respiration; diving in marine mammals. **Module 10:** Pushing the envelope: Contemporary research and novel concepts - Inter organ communication network; mechanisms of navigation in migratory animals.

Textbooks/References:

1. Hill, R. W., Wyse, G. A., & Anderson, M. (2016). *Animal physiology* (4th ed.). Sinauer Associates/Oxford University Press.

BIO328/628	Advanced Molecular Biology	4 Credits

Objectives & Outcomes: Learning of this course gives you in depth knowledge of biological processes and the underlying molecular mechanisms. Through this course one will gain insight into the most significant molecular and cell-based methods used today to understand the biology. This course also provides knowledge about genetic engineering and its importance in solving environmental problems and curing human diseases.

Contents:

Module 1: Genome organization, Chromosomal elements, DNA supercoiling, Topoisomerases, DNA replication, Extrachromosomal replicons, DNA damage and repair, DNA recombination, Transposable elements and retroviruses. **Module 2:** Transcription and Translation mechanisms in Eukaryotes, RNA processing, Reverse transcription, catalytic RNA and Regulatory RNA, Posttranslational modifications. Regulation of gene expression. **Module 3:** Restriction and Modification system, Cloning vectors- Plasmids, bacteriophages, cosmids, phagemids, shuttle vectors and expression vectors. **Module 4:** Gene delivery, Southern – and Northern – blotting techniques, PCR, DNA fingerprinting, RFLP and RAPD. Cloning of PCR products, Ligation, Construction of genomic libraries, DNA sequencing, Importance of rDNA technology.

Textbooks/References:

1. Krebs, J. E., Goldstein, E. S. & Kilpatrick, S. T. (2018). *Lewin's genes XII* (12th ed.). Jones & Bartlett Learning.
2. Alberts, B. et al. (2015). *Molecular biology of the cell* (6th ed.). Garland Science.
3. Watson, J. D. et al. (2014). *Molecular biology of the gene* (7th ed.). Pearson.
4. Glick, B. R. & Patten, C. L. (2017). *Molecular biotechnology: Principles and applications of recombinant DNA* (5th ed.). ASM Press.
5. Green, M. R. & Sambrook, J. (2012). *Molecular cloning: A laboratory manual* (4th ed.). Cold Spring Harbor Laboratory Press.
6. Brown, T. A. (2020). *Gene cloning and DNA analysis: An introduction* (8th ed.). Wiley.
7. Primrose, S. B., & Twyman, R. (2006). *Principles of gene manipulation and genomics* (7th ed.). Wiley.

BIO337/637	Pandemics – Disease & Intervention	3 Credits

Objectives & Outcomes:

The course will help students to analyze the impact of an infection on a population scale. The course will help them to assess the importance of research done in laboratories on human lives through development of diagnostics or biomarkers or drug development. The course will also make students aware of different regulations followed for containment of a pandemic and how it impacts society as a whole. The students will be able to learn about different bacterial and viral pandemics in new and old world and mortality associated with these pandemics, methods of identification of pathogen responsible for pandemic, various approaches for development of diagnostics, biomarkers, study regulatory guidelines for societal management during pandemic, repurposing drugs for treatment and vaccine against pathogens

Contents:
Module 1: Introduction- difference between endemic, epidemic, and pandemic, Criteria for infections to be called as pandemic, Role of human and environmental factors for infection to become pandemic, Examples of pandemic diseases (old and new world), serum epidemiology, strain to strain variations, vaccine efforts, secondary and tertiary waves of infection. **Module 2:** Identification of the causative agent for a pandemic- genomics and proteomics approach, development of diagnostics and biomarkers, probes, Molecular Imaging, Target validation etc. **Module 3:** Infection cycle of a pathogen, transmission of pathogen, Management of pandemic through National Epidemic disease act of 1897, WHO and ICMR guidelines by social methods: contact tracing, quarantine, lockdown, Mathematical modelling of Pandemics. **Module 4:** Clinical management through designing of effective drugs, new Synthetic methods, process automation, drug delivery, sustainable manufacturing.

Textbooks/References:
1. Medical Microbiolgy An introduction to Infectious disease by Ryan and Ray. McGraw Hill, 2004, ISBN-13: 978-0838585290
2. S. Jane Flint, Vincent R Racaniello, Glenn F Rall, Anna Marie Skalka, Lynn W Enquist. Principles of Virology, ASN Press, 4th edition, 2015, ISBN13: 978-1555819330
3 Viruses, A Very Short Introduction - Dorothy H Crawford, Oxford University Press, 2018, ISBN: 9780198811718
4. Spillover, Animal Infections and the Next Human Pandemic - David Quammen, W.W. Norton & Company, ISBN-13 978-0393346619
5. The Psychology of Pandemics, Preparing for the Next Global Outbreak of Infectious Disease - Steven Taylor, Cambridge Scholars Publishing, 2019, ISBN-13:978-1-5275-3959-4

BIO339/639	Separation Science and Techniques	3 Credits

Objectives & Outcomes: Gain a thorough understanding of the basic molecular aspects of separation processes. At the end of the course, the student should be able to understand similarities and differences in operating aspects of various separation techniques useful in both chemistry and biology. Gain a thorough knowledge of general chromatographic processes. Training sessions on HPLC, Flash Chromatography (Combi Flash system), GC and GC MS, Centrifugation, Electrophoresis, ultracentrifugation, and few other Chromatographic techniques will be undertaken; if the number of students who take this course are large then, we will restrict to demonstrations only.

Contents:
Separation of mixtures - two solids, two liquids, two gases or any combination. Solvent extraction, distillations, Liquid- Liquid extraction and other methods of separation. Types of Chromatography: GC, HPLC, Column, Hyphenated techniques. Size-Exclusion Chromatography (SEC), Electrophoresis, Centrifugation, DNA/Protein separations/purifications. Chiral separations, Molecular recognition, Molecule imprinting. Use of Cyclodextrins for separation and other bio-separations. Spectroscopic techniques demonstrations

Textbooks/References:
1. Harvey, D. T. (2009). *Analytical chemistry 2.0*. Free online version

2. Karger, B. L., Snyder, L. R. & Horvath, C. (1973). *An introduction to separation science*. Wiley.

Other required course reference material (if any) will be announced/distributed during the lectures.

BIO341/641	Cell Biology	3 Credits

Objectives & Outcomes: The objective of this course are to sensitize the students to the fact that as we go down the scale of magnitude from cells to organelles to molecules, the understanding of various biological processes becomes deeper and inclusive. Students who successfully complete this course will be able to outline the structure of the biomolecules found in all living organisms**,** describe the function and structure of cellular organelles**,** describe the mechanisms of transport across organelles**,** discuss the mechanisms of cell to cell signaling, discuss how to isolate cells, and how to isolate their organelles and constituent macromolecules.

Contents:

Module 1: Dynamic organization of cell: Universal features of cells; cell chemistry and biosynthesis: chemical organization of cells; internal organization of the cell - cell membranes: structure of cell membranes and concepts related to compartmentalization in eukaryotic cells; intracellular organelles: endoplasmic reticulum and Golgi apparatus, lysosomes and peroxisomes, ribosomes, cellular cytoskeleton, mitochondria, chloroplasts and cell energetics; nuclear compartment: nucleus, nucleolus and chromosomes. **Module 2:** Cellular signaling, transport and trafficking Molecular mechanisms of membrane transport, nuclear transport, transport across mitochondria and chloroplasts; intracellular vesicular trafficking from endoplasmic reticulum through Golgi apparatus to lysosomes/cell exterior. **Module 3:** Cellular processes cell differentiation: stem cells, their differentiation into different cell types and organization into specialized tissues; cell-ECM and cell-cell interactions; cell receptors and trans- membrane signaling; cell motility and migration; cell death: different modes of cell death and their regulation. **Module 4:** Manipulating and studying cells Isolation of cells and basics of cell culture; observing cells under a microscope, different types of microscopy; analyzing and manipulating DNA, RNA and proteins.

Textbooks/References:

1. Alberts, B. et al. (2015). *Molecular biology of the cell* (6th ed.). Garland Science.
2. Lodish, H. F. et al. (2016). *Molecular cell biology* (8th ed.). Macmillan International Higher Education.
3. Cooper, G. M. (2018). *The cell: A molecular approach* (8th ed.). Oxford University Press.
4. Hardin, J., Bertoni, G. & Kleinsmith, L. J. (2016). *Becker's world of the cell* (9th ed.).
5. Watson, J. D. et al. (2014). *Molecular biology of the gene* (7th ed.). Pearson.

BIO412/712	Animal Developmental Biology	4 Credits

Objectives & Outcomes:

The course is designed to introduce the basic concepts and the general principles of animal development. Then, specific examples will be discussed to underscore how these principles operate to bring about embryonic development. Following the exposure of students to

reductionism through molecular and cell biology courses, this curse will allow a holistic perspective and systems level understanding of life.

Contents:
Module 1. The anatomy of development- Descriptive embryology: The cycle of life; stages of embryonic development; introduce the parts of embryos; fate mapping to address developmental anatomy. **Module** 2. Genetics of development- Genome equivalence, differential gene expression – mechanisms. **Module** 3. Cell-cell Communication in development - Cell-cell adhesion, migration, cell signaling (paracrine, juxtacrine), multicellular organization (epithelia, mesenchyme), epithelial-mesenchymal transition, Early Development. **Module** 4. Cell fate commitment: Autonomous and conditional specification. **Module** 5. Morphogen gradients and cell fate specification. **Module** 6. Gastrulation and anterior-posterior body axis specification in vertebrates Organogenesis. **Module** 7. Stem cells and progenitors (general principle). **Module** 8. Mesoderm development. **Module** 9. Ectodermal placode, Evolution through developmental changes **Module** 10. Modularity of development and molecular parsimony as preconditions; mechanisms of evolutionary change; developmental constraints on evolution.

Textbooks/References:
Developmental Biology by Scott F. Gilbert – Edition 11

BIO413/713	Big Data in Biology	3 Credits

Objectives & Outcomes: The aim of this course is to introduce students to different concepts of high throughput biology, including experimental design, different technologies to generate data and limitations of each approach. During tutorial sessions practical exercises on retrieving and analyzing different types of high throughput data will be undertaken. At the end of the course the students should be well versed with the different approaches to generate diverse facets of biological data ranging from DNA, RNA and protein sequence, mRNA and protein abundance, molecular interactions, imaging and phenotyping. This would immensely help students when they design experiments for their research work.

Contents: Module 1: Genome Sequencing and Genotyping – (a) Short gun library construction, (b) Sanger sequencing, (c) Next generation sequencing, (d) Single nucleotide polymorphism genotyping**. Module 2:** mRNA detection and sequencing – (a) qRTPCR, (b) Microarrays: single vs two channel, (c) RNA sequencing, (c) Ribosome profiling**. Module 3:** Protein abundance and mapping interactions – (a) Proteomics based approaches for identifying and quantifying proteins, (b) Different approaches to map- (i) Protein-protein interactions (ii) Protein-DNA interactions, (iii) Protein-RNA interactions**. Module 4:** Genome-wide screening – (a) Mapping Genetic interactions, (b) Phenotyping, (c) High content microscopy.

Textbooks/References:
1. Lesk, A. M. (2017). *Introduction to genomics* (3rd ed.). Oxford University Press.
2. Twyman, R. M. (2014). *Principles of proteomics* (2nd ed.). Garland Science.

BIO414/714	Neurobiology	4 Credits

Objectives & Outcomes: Neurobiology will be introduced as a specialized discipline but will be kept to basic level in this semester where different concepts will be introduced and step by step complexity will be built. This course will introduce mammalian nervous system in a systematic manner, emphasizing the structural and functional organization of the mammalian brain. The overall goal of the course is to provide a detailed description of the logic of the nervous system starting from evolution, organization, development, physiology, and its emergent properties. Therefore, this course is a prerequisite to the advanced course. The course is aimed at students interested in understanding the fundamental basis of the neural function and those interested in pursuing neuroscience in the future.

Contents:
Module 1: Evolution and organization of the nervous system – CNS and PNS. Structure and function of neuron. **Module 2:** Development of nervous system: The brain and its distinct regions, Different cell types in the brain. Specialized cellular components of the brain: Myelin, axolemma, growth cone. **Module 3:** Nervous system physiology: introduction to electrical properties of nerve cells and its voltage dependency. Ionic basis of membrane potentials and the action potential. **Module 4:** Signaling in brain-how do brain cells connect with each other: channels and receptors, neurotransmitters; synaptic transmission and plasticity. Protein synthesis, endocytosis, exocytosis, synaptic vesicle recycling. Pre and post synapse. **Module 5:** Degeneration and regeneration: Disorders of the brain; Introduction to neural stem cells. **Module 6:** Basics of brain imaging: Introduction to imaging of the brain microscopically and histopathology. Whole brain imaging. **Module 7:** Introduction to literature reading: Group activity, papers have to be read and criticized in class. It can be in the form of debate. The topics will be pertaining to neuroscience.

Textbooks/References:

1. Sanes, D. H. et al. (2019). *Development of the nervous system* (4th ed.). Elsevier Academic Press.
2. Kandel, E. R. et al. (2013). *Principles of neural science* (5th ed.). McGraw-Hill.

Class notes are mandatory and Papers/reviews shared in the class.

BIO415/715	Applied Plant Biology	4 Credits

Objectives & Outcomes:
This course would enable students to learn applied aspects of plant science. Students would gain knowledge of a variety of techniques as well as their direct applications in crop improvement program. The methods and principles in making transgenic plants will be covered in the module as well as looking at more traditional breeding strategies. Case studies in this course would give students the exposure to several tools, which are essential in plant biotech industries. The training will equip the students with necessary intellectual background and the skills to undertake research in cutting edge areas of plant biology.

Contents:
Module 1: Research skills in plant biology; Insertional mutagenesis, Gene silencing, CRISPR-Cas9, RNAi, antisense technology, Applications; **Module 2:** Genetic manipulation of plants; Plant cell, tissue and organ culture (micropropagation, somatic embryogenesis, organogenesis, protoplasts and somatic hybridization); plant genetic transformation and transgenic and transplastomic plants. **Module 3:** Plant metabolites and engineering of plant metabolic pathways; Developing herbicide and insect resistance in crops. Transgenic plants in medical applications, phytoremediation and biofortification. **Module 4:** Crop improvement tools;

biotechnology in crop improvement (biotic and abiotic stress, nutritional quality, defense responses); Molecular markers and marker-mediated applications in plant breeding. Biodiversity utilization and conservation.

Textbooks/References:

1. Plant Physiology and Development: L. Taiz and E. Zeiger (2010) 6th edition, Sinauer Associates Inc.
2. Introduction to Plant Tissue Culture: M.K. Rajdan (2003) 3rd edition, Science Publishers
3. Plant Biotechnology-the genetic manipulation of plants: A. Slater (2008) 2nd edition, Oxford University Press
4. Genetically Modified Crops (2011) 2nd edition, Imperial College Press, Worlds Scientific Publishers)
5. Physiology and Behavior of Plants: P. Scott (2008) 1st edition, Wiley Publishers

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BIO416/716	Biophysical Chemistry	4 Credits

Objectives & Outcomes: Correlate laws of physics and chemistry to the structure and function of bio-macromolecules. Learn the principles underlying the operation of analytical techniques which are used to study/monitor these functions.

Contents:

Introduction to macromolecular structure, Ribosome and protein synthesis, Structure of proteins, Optical activity and Circular dichroism (CD) of biomacromolecules, Far and Near-UV CD; Principles and models of protein folding, Thermodynamics, kinetic principles, Stopped flow techniques; Protein-protein interactions, Ligand binding and cooperativity in biological systems, Drug binding by proteins, Estimation of Equilibrium constant, K_{off} and K_{on}; Nucleic Acids Structure, Double strand formation in Nucleic acids, DNA packing, Interaction of Nucleic Acid with Proteins, Drugs; Isothermal Titration Calorimetry, Surface plasmon resonance, Inferometry. End to end distance and radius of gyration of a polymer chain, Statistics of random coils, persistence length, helix-coil transition, Brownian motion and the random walk model, application of random walk model in single molecule force spectroscopy; Fick's law of diffusion, Diffusion at steady state, Friction, Stoke's Law, Diffusion constants of macromolecules, Lateral diffusion in membranes; Mass spectrometry: Basic concept of Mass spectrometry: ionization methods and mechanism, ion detection.

Textbooks/References:

1. S. Neidle, Principles of Nucleic Acid Structure, Oxford press, Oxford 2012
2. John Kuriyan, Boyana Konforti, and David Wemmer, The Molecules of Life: Physical and Chemical Principles,
3. C. R. Cantor, P. R. Schimmel, Biophysical Chemistry I, II, III, Freeman, San Fransisco, 1980.
4. Rob Phillips, Jane Kondev, Julie Theriot, Hernan Garcia-Physical Biology of the Cell (2nd Edition)-Garland Science (2012)

BIO421/BIO721	Elements of Structural Biology	3 Credits

Objectives: The objective of this course work is to introduce the students to the properties and conformations of biomolecules like amino acids, nucleic acids and lipid membranes. Related physical phenomena such as structural/conformational dynamics, lipid-protein

interactions will be discussed. The course will also cover principles of important experimental techniques, molecular dynamics simulation and visualization tools used to understand the structure of these biomolecules. A brief introduction will be given structural DNA nanotechnology and its application. As an outcome of this course, the students will be exposed to scientific aspects of biomolecules in three dimension, how structure governs function and interactions. The students will also get the flavor of experimental and simulation techniques to determine and analyze the structure of complex molecules.

Contents:
Module 1: Introduction to biomolecules: proteins, nucleic acids and cell membranes as a refresher. Composition, structure, and properties of Biological Membrane. Lipid bilayers, Ion channel, pumps, gates and receptors. **Module 2:** Membrane proteins, their structure. Example study: Retinal Proteins, Bacteriorhodopsin, Membrane proteins of known structures. Protein-Lipid interactions. **Module 3:** Structure-Function-Dynamics relation. Examples of functional versatility of protein and nucleic acids depending on structure. Ultrafast conformational dynamics and introduction to related techniques. NMR. Brief introduction to molecular dynamics (MD) simulations and visualization tools. Case study on Protein-Lipid interactions using MD simulation. **Module 4:** Protein crystallization, introduction to Cryo-EM introduction to synthetic structural biology, recent developments, Structural DNA nanotechnology and its application. X-ray crystallography.

Textbooks/References:

1. Cantor, C. R. & Schimmel, P. R. (1980). *Biophysical chemistry*. W.H. Freeman.
2. Alberts, B. et al. (2015). *Molecular biology of the cell* (6th ed.). Garland Science.
3. Friebolin, H. (2011). *Basic one- and two-dimensional NMR spectroscopy* (5th ed.). Wiley-VCH.
4. Allen, M. P. & Tildesley, D. J. (2017). *Computer simulation of liquids* (2nd ed.). Oxford University Press.
5. Allen, M. P. (2004). Introduction to molecular dynamics simulation. In N. Attig et al. (Eds.), *Computational soft matter: From synthetic polymers to proteins* (pp. 1-28).
6. Rupp, B. (2010). *Biomolecular crystallography: Principles, practice and application to structural biology*. Garland Science.

BIO425/725	Plant Developmental Biology	4 Credits

Objectives & Outcomes: The objective of this course is to acquaint students with the physiological, biochemical, and molecular genetic bases of plant growth and development. This course focuses on initiation and development of plant organs, transition to flowering and senescence, signal perception and transduction, plant hormones. Basic concepts of plant developmental biology as well as principles and mechanisms that help form and shape the organism by signaling cascade will be taught and discussed. The course also deals with developmental biology of plants by focusing on the regulation of meristem activity, plant organ development, embryogenesis and organogenesis, signal transduction and plant hormones. It is designed to give a vision into how a single cell becomes a complex multicellular organism with specialized cell types organized into coherent functional patterns. This course also provides an overview of plant receptors, receptor kinases and their signal transduction systems that function in plant development. The students are expected to gain immense knowledge of molecular and cellular biology, genetics and biochemistry through this course. Emphasis will be given to elucidate the topics by providing detailed examples that might

benefit all students in designing their future experiments and interpretation of their observations.

Contents:
Module 1: Making of a plant body; The central role of Phytohormones in plant development, Phytohormone metabolism and signaling pathways, Phytochromes, light perception and developmental responses to light. **Module 2:** Molecular and genetic aspects plant development; Receptors and receptor like kinases, MAP kinase signal amplification cascade, Secondary messengers, Signaling by receptor like kinases. **Module 3:** Plant Vegetative development; Developmental plasticity, Molecular mechanism of plant vegetative meristems and cell fate, Root, shoot and leaf development, Secondary growth, Vascular development. **Module 4:** Plant Reproductive development; Mechanisms of gametogenesis and fertilization, Flower, fruit and seed development, Embryogenesis in plants.

Textbooks/References:

1. Taiz, L. et al. (2015). *Plant physiology and development* (6th ed.). Sinauer Associates/Oxford University Press.
2. Howell, S. H. (1998). *Molecular genetics of plant development*. Cambridge University Press.
3. Li, J., Li, C. & Smith, S. M. (2017). *Hormone metabolism and signaling in plants*. Elsevier Academic Press.
4. Hakeem, K. R., Rehman, R. & Tahir, I. (2014). *Plant signaling: Understanding the molecular crosstalk.* Springer.

BIO427/727	Bioinformatics Laboratory	4 Credits

Objectives & Outcomes: To get trained on high throughput biological data retrieval, handling, visualization and data analysis/ interpretation. At the end of the course the students should be confident to retrieve, handle, visualize and analyse high throughput biological data. Pre-requisite: Students should have knowledge on different aspects of biological information flow.

Contents:
Module 1: Sequence information - Introduction to High throughput biology (Reductionist vs systems-level view), Scaling up in Biology (Non-linearity); Introduction to 'Omes': From Gene to Genomes, Transcript to Transcriptomes, Protein to Proteomes, Variation to Variomes, Phenotype to Phenomes; Demonstration of online/free tools/databases to access and visualize these data; Sequence alignment methods; phylogenetic analyses; Introduction and retrieval of protein structural information (Secondary & tertiary structures); Practical exercises. **Module 2:** Molecular Interactions - Introduction to mapping molecular interactions: Genetic interactions, Protein-protein interactions, Protein-DNA interactions, Protein-RNA interactions; Demonstration of online/free tools/databases to access these data; Practical exercises **Module 3:** Reconstructing, visualizing and interpreting biological networks - Introduction to Graph Theory; Introduction to Network properties: Topological measures and network motifs; Demonstration of reconstruction of different molecular interaction networks and different visualization methods using Cytoscape; Network analysis; Practical exercises.

Textbooks/References:

1. Lesk, A. M. (2019). *Introduction to bioinformatics* (5th ed.). Oxford University Press.
2. Lesk, A. M. (2017). *Introduction to genomics* (3rd ed.). Oxford University Press.
3. Barabási, A-L. (2016). *Network science*. Cambridge University Press.

BIO431/731	Fluorescence in Biology	3 Credits

Objectives & Outcomes: This course will expose students to various cutting-edge fluorescence spectroscopic and microscopic techniques that advanced quantification of biology in accelerated pace. Knowing spectroscopic and microscopic techniques not only enable students to use them more efficiently but also will facilitate interdisciplinary research. Upon completion of this course, the students will be able to learn basics of fluorescence and related phenomena, principles applied to spectroscopic and microscopic techniques, advanced fluorescence techniques including Super Resolution Microscopy, FCS, TIRF, FLIM, SPT, identify appropriate spectroscopic and microscopic techniques while designing their experiments.

Contents:
Module 1: Introduction to Fluorescence, Fluorescent probes and selection of fluorescent probes, Solvent and environmental effect on fluorescence, Quenching of fluorescence, Fluorescence Anisotropy, Energy Transfer. Examples in proteins and DNA. **Module 2:** Steady-state spectroscopic techniques and application: spectrophotometer, fluorimeter. Time resolved spectroscopic techniques: Time Correlated Single Photon Counting (TCSPC), Fluorescence Up Conversion, Transient Absorption to study ultrafast dynamics in DNA and proteins. **Module 3:** Basics of microscopy, Fluorescence Microscopy, Confocal Laser Scanning Microscopy, Fluorescence Lifetime Imaging Microscopy (FLIM), Two photon excitation, Introduction to Super Resolution Microscopy. Applications to study molecular interaction in cells. **Module 4:** Single Molecule Detection techniques: Fluorescence Correlation Spectroscopy (FCS), Total Internal Reflection Fluorescence Microscopy (TIRFM), Single Particle Tracking (SPT). Applications in Riboswitches, Cell membranes, DNA nanostructures.

Textbooks/References:

1. Lakowicz, J. R. (2006). *Principles of fluorescence spectroscopy* (3rd ed.). Springer.
2. O' Connnor, D. V. & Phillips, D. (1984). *Time-correlated single photon counting. Elsevier Academic Press.*
3. Rigler, R. & Elson, E. S. (2001). *Fluorescence correlation spectroscopy: Theory and applications.* Springer.
4. Erfle, H. (2017). *Super-resolution microscopy: Methods and protocols*. Springer Humana Press.

BIO433/733	Plant Stress Biology for Sustainable Agriculture	4 Credits

Objectives & Outcomes:
The objective of this course is to discuss the causality of relationships between plants and their environment. The underlying mechanisms of plant sensing and signaling in response to various stresses will be dealt from the physiological level to molecular level. At the end of the course, students would understand the mechanisms underlying plant response(s) to diverse environmental stresses and how to modulate these responses for sustainable agriculture.

Contents: What's sustainable agriculture, why is it required? Dynamic environment: stress for plants. Plant cells as sensors of environmental factors. **Module 1:** Plant

responses and adaptations to abiotic stresses; Plant-environment interactions-temperature, drought, salt, hypoxia and heavy metals. **Module 2:** Plant responses and adaptations to biotic stresses; Plant-pathogen interaction, biotic stresses - virus, bacterial and fungal pathogens, nematode and insect parasites. **Module 3:** Molecular basis of plant stress responses; Transcriptional and epigenetic regulation of plant responses to biotic and abiotic stresses. Initiation and maintenance of stress memory within and across generations.

Textbooks/References:

1. Physiology and Behavior of Plants: P. Scott (2008) 1st edition, Wiley Publishers.
2. Plant Physiology and Development: L. Taiz and E. Zeiger (2010) 6th edition, Sinauer Associates Inc.
3. Biochemistry and Molecular Biology of Plants: Buchanan et al. (2002), American Society of Plant Physiologists (ASPP).
4. Epigenetics in Plants of Agronomic Importance: Fundamentals and Applications. Alvarez-Venegas et al. (2014). Springer.

BIO419/719	Data Science I	4 Credits

Objectives & Outcomes: To create awareness and excitement about Data Science; To introduce students to the topics of Data Science in an interdisciplinary manner with emphasis on basics of machine learning (ML) and artificial intelligence (AI); To train them in the ML and AI methodologies and their applications in real world problems. The hand-on sessions will give the students a chance to practice and apply all the concepts involved. Students will be able to use the techniques of machine learning and artificial intelligence in their research-oriented studies for data management, especially in areas of bioinformatics, astrophysics, complex dynamical systems, time series analysis, information technology, quantum and material chemistry, protein biology, condensed matter physics etc. The students can learn the basics of Data Science and take the next level of advanced Data Science and Machine Learning courses later. Students, being responsive to the growing demands for data analysts, data scientists can look for alternate careers related to data science.

Contents:

1. Introduction to Artificial Intelligence (AI) and Machine Learning (ML). 2. Python tutorial sessions. 3. Metrics in machine learning, Confusion matrix, Precision-Recall Curve, ROC curve. 4. dataset splitting, loss/cost function. Supervised learning techniques - 5. Regression analysis: Linear, Polynomial, Logistic regression 6. Kernel ridge regression (KRR) 7. Support vector machine (SVM) 8. Gaussian process regression 9. K-nearest neighbour 10. Decision trees 11. Ensemble methods: Random Forest (RF), AdaBoost. Unsupervised learning - 12. Association analysis 13. Clustering: K-means, Agglomerative clustering, DBSCAN 14. Gaussian mixture model 15. Dimensionality reduction techniques: Principal Component Analysis (PCA), t-SNE 16. Introduction to Bayesian networks 17. Practical considerations in ML (model building), Noise in the data, Missing values, Class imbalance

Textbooks/References:

1. Aurelien Geron, Hands-on machine learning with scikit-learn & Tensor flow, O' Reilly, 8th Indian edition (2019).
2. Bing Liu, Web Data mining: Exploring Hyperlinks, Contents, and Usage Data (Data-Centric Systems and Applications) 2nd ed. Springer (2011)

3. Andreas Muller, Introduction to Machine Learning with Python: A Guide for Data Scientists, O' Reilly 4th Indian reprint (2019)
4. Tom M Mitchell, Machine Learning, McGraw Hill (1997)
5. Stuart J R and Peter N, Artificial Intelligence: A Modern Approach, Pearson (2015).
6. Deepak K, A First Course in Artificial Intelligence, McGrawHill (2015).
7. Ivan B, PROLOG: Programming for Artificial Intelligence, 3rd Edition, Pearson (2002).

BIO435/BIO735	Infection Biology	3 Credits

Objectives & Outcomes: The objective of this course is to generate awareness about different infectious human diseases and their agents and how they manipulate human physiology for their own survival. In this course, various diseases along with –life cycle, biology and their pathogenesis and host immune responses generated against these pathogens will be discussed. We will also focus on treatment methods available and the emergence of drug resistance against these pathogens. The students after completion of this course will be able to compile principles of Initial host and pathogen interactions that help them gain entry, Mechanisms by which pathogen hijacks host machinery for their multiplication and survival, Mechanisms by which pathogens exit host cells to spread infection and cause pathogenesis, Drugs available against pathogens with their mechanisms of action along with developing resistance.

Contents:
Module 1: Malaria: *Plasmodium* sp. affecting humans, diagnosis, pathogenesis, antigenic variation, host innate immune responses, available treatment and drug resistance. **Module 2:** Viruses - viruses causing cancer - their types, mechanism of action, oncogenes, host immune responses. **Module 3:** *Mycobacterium tuberculosis*- Physiology, Infection, pathogenesis, host-pathogen interaction. **Module 4:** *Staphylococcus* and *Pseudomonas*- primary and secondary infection, diagnosis, manifestations, treatment and antimicrobial resistance. **Module 5:** Plant pathogens and plant-pathogen interaction.

Textbooks/References:
1. Carroll, K. C. et al. (2019). *Jawetz, Melnick & Adelberg's medical microbiology* (28th ed.). McGraw-Hill.
2. Ryan, K. J. & Ray, C. G. (2018). *Sherris medical microbiology* (7th ed.). McGraw-Hill.
3. Flint, S. J. et al. (2020). *Principles of virology, 2 vols.* (5th ed.). ASM Press.
4. Wahlgren, M. & Perlmann, P. (1999). *Malaria: Molecular and clinical aspects.* CRC Press.
5. Sherman, I. W. (1998). *Malaria: Parasite biology, pathogenesis and protection*. ASM Press.
6. Burchett, S. & Burchett, S. (2018). *Plant pathology*. Garland Science.
Recent literatures will be provided by instructors.

BIO441/741	Biophysics	3 Credits

Objectives & Outcomes: This course aims to provide comprehensive introduction to the fundamental aspects of cellular biophysics responsible for performing the key role of biomolecules in health, survival and sickness of a living cell. Toward this end, an introduction to macromolecular interactions in its cellular environment will be discussed followed by the forces driving to attain their three-dimensional/higher order structures. Introduction to the

diffusion, viscosity and the phenomena depending on them. Later, the membrane dynamics and diffusion through it will be introduced followed by treadmilling in microtubule dynamics and the directional transport mechanism by molecular motors. After this course, it is expected that this course will help students to understand various biophysical aspects of macromolecules in cellular context.

Contents:
Module 1: Brief introduction to the forces governing the cellular mechanisms, for example, Dipole-Dipole Interactions, van der Waals Interactions, Hydrogen Bonds, Electrostatic Interactions, Thermodynamic parameters etc., Water structure and the unique physicochemical properties of water supporting life, Biomolecular interaction with water and/or non-aqueous environment and Phase separation in cellular context. **Module 2:** Introduction to fluid, Effects of temperature, pH and salt concentration on the integrity of macromolecular structure, Viscosity, Diffusion, Reynolds number, Phenomena at low Reynolds number, Bacterial motion and Diffusion controlled enzyme kinetics. **Module 3:** Membrane as fluid of lipid layers, Fluid mosaic model, Diffusion in membrane, Brief introduction to techniques studying the diffusion in membrane, Membrane deformation, Transport through membrane. **Module 4:** Treadmilling in microtubule dynamics and actin polymerization, Molecular motors, Force generation by molecular motors, Models for motor stepping mechanism, Cargo transportation.

Textbooks/References:

1. Freifelder D. M. Physical Biochemistry- Application to Biochemistry and Molecular Biology, 2nd ed., W.H. Freeman, 1982.
2. Biophysical Chemistry, Volumes I-III by Cantor and Schimmel, W.H. Freeman and Co., New York. 1980 (Available in library)
3. Principles of Physical Biochemistry second edition by Kensal E. van Holde, W. Curtis Johnson and P. Singh Ho. 2006 Pearson Education Inc.
4. Biophysics: an introduction by Glaser Roland 2012 Springer.
5. Physical Biochemistry: Principles and Application 2nd Ed. by David Sheehan, Willey Blackwell.

BIO444/744	Chemical Biology	3 Credits

Objectives & Outcomes: This course integrates the principles of both chemistry and biology to understand the biological phenomenon. Topics from the current literature will also be used to provide an overview of chemical biology and will demonstrate the integration of chemical, biochemical and biological approaches including structure, dynamics and functions. The course will be useful for students who would like to work on interface of chemistry and biology. The course structure will empower both chemists and biologists by providing chemists the information about relevant new biological targets and biologists with useful new chemical tools.
Pre requisites: Student should have knowledge of 12^{th} level basic organic chemistry and 12^{th} level basic biology.

Contents:
The fundamentals of Chemical biology: The central dogma of molecular biology, Common tools of chemical biology, Prebiotic chemistry and RNA world hypothesis, Nonbonding interactions, Genes, Genomes. **Nucleic Acids:** Fundamental aspects of nucleic acids, their structure, function and interactions with small molecules, peptides and proteins. DNA oligonucleotide synthesis by phosphoramidite chemistry. Higher

order DNA/RNA structures. Chemical modifications of nucleic acids. Bio-orthognal reactions or bioconjugation. Unnatural DNA and DNA Intercalators. DNA templated reactions. Non-coding nucleic acids, siRNA, RNAi and its applications. Gene editing/Base editors e.g. CRISPR/CAS system, DNAzymes, Ribozyme evolution, Epitranscriptomics, Nucleic acids in nanotechnology. **Peptide and Proteins:** Structure and conformations of peptides. Solid Phase peptide synthesis. Proteins. Non-covalent interactions, Protein Aggregation, Folding, Misfolding. Molecular sensing. Fundamental forces that control protein secondary structure, Receptor-Ligand interaction, A mechanistic view of enzymes that catalyze multiple reactions, Post-transalation modifications. Site selective protein modification. Incorporating unnatural amino acids into proteins in vitro and in vivo; Directed evolution of enzymes, small molecular machines. **Glycobiology, polyketides and terpenes:** Structure of carbohydrate building blocks, The chemistry and enzymology of the glycosidic bond, Polysaccharides, Glycoproteins & Glycolipids Glycosylation in the cytosol, proteins that bind to carbohydrate ligands, Glycobiology, Polyketides, Nonribosomal peptide synthases & human terpenes, Lipids, Liposomes. In addition, current literature papers will be discussed related to each topic.

Textbooks/References:

1. Van Vranken, D. & Weiss, G. A. (2013). *Introduction to bioorganic chemistry and chemical biology*. Garland Science.
2. Waldmann, H. & Janning, P. (2004). *Chemical biology: A practical course*. Wiley-VCH.

BIO445/745	Advanced Neuroscience	3 Credits

Objectives & Outcomes: This course will take off from basic neuroscience course. The specialty of this course is that it will bring interdisciplinary perspective to neuroscience. Applications of non-linear dynamics and other physical principles underlying neuronal networks and image analysis.

Contents:

Module 1: Autonomous nervous system; Sensory nervous systems and sensory processing; Motor control and pattern generators. **Module 2:** Neurobiology of perception and cognition. Mirror neurons, astrocyte and glial feedback. **Module 3:** Electrophysiology and brain imaging: Basics, field recording, patch clamp, LTP, LTD. Brain imaging: electroencephalography, positron emission tomography, functional magnetic resonance imaging. **Module 4:** Dynamical models of neurons:HH Model, FHN model, HR model, Rulkov model, spiking and bursting, coupled neurons and neuronal networks. McCulloch-Pitts model and the beginning of neural network models -Wilson & Cowan's model for excitatory-inhibitory network (one of the simplest neural mass models), Learning: Hebb, LTP and spike-time dependent plasticity-modeling an entire nervous system: Caenorhabditis elegans. **Module 5 (Activity):** Each student taking up the course will choose a neuroscience research lab and read about the research work in that lab. They will follow the lab papers and publications in the last one-year. They will summarise this and present it.

Textbooks/References:

1. Kandel, E. R. et al. (2013). *Principles of neural science* (5th ed.). McGraw-Hill.

2. Izhikevich, E. M. (2010). *Dynamical systems in neuroscience: The geometry of excitability and bursting.* MIT Press.
3. Hertz, J. A., Krogh, A. & Palmer, R. G. (1991). *Introduction to the theory of neural computation*. CRC Press.
4. Sterratt, D. et al. (2011). *Principles of computational modelling in neuroscience*. Cambridge University Press.
Relevant research papers shared by the tutor.

BIO429/729	Data Science II	3 Credits

Objectives & Outcomes:
The objective of the course is to introduce the students to advanced topics of Data Science in an interdisciplinary manner, to train them in machine learning and artificial intelligence and how to apply the methods in real world problems. The hand-on sessions will give the students a chance to practice all the concepts involved. At the end of the course students will be able to use the techniques of machine learning and artificial intelligence in their research for data management, especially in areas of bioinformatics, astrophysics and astrochemistry, quantum and material chemistry, time series analysis, information technology etc. Students, being responsive to the growing demands for data analysts, can look for alternate careers related to data analytics.

Contents:
Introduction to Artificial Neural Networks (ANN): features, weights, Perceptron, hidden layers, multi layer perceptron, activation functions, bias, loss functions, parameter initialization, gradient-based learning, learning rate, back-propagation, optimizers, architecture design, feedforward network, noise and regularization, dropout layers, over and under fitting, deep learning, vanishing gradient problem, residual layers. **Introduction to Convolutional Neural Networks (CNN):** convolution operation, filter, variants of the basic convolution function, pooling, flattening, cross-entropy loss function, softmax function, structured outputs, distortions, encoders. **Introduction to Kernel Ridge Regression (KRR):** kernel trick, kernel functions, gaussian process regression. **Introduction to Recurrent Neural Networks (RNN):** recurrent neural networks, the challenge of long-term dependencies, the Long Short-Term Memory (LSTM). Nonlinear Dynamics and Machine Learning.

Textbooks/References:
1. Aurélien Géron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow. O'Reilly Media, Inc. (2019)
2. Goodfellow, Yoshua Bengio and Aaron Courville, Deep Learning. MIT Press(2017).
3. Yegnanarayana B, Artificial Neural Networks, Prentice-Hall India (1999).
4. Haykin S, Neural Networks and Learning Machines, Pearson Education (2011).
5. Peter Harrington, Machine Learning in Action, Manning Publication Co. (2012)

BIO524/824	Genome Editing	2 Credits

Objectives & Outcomes: This course aims to provide a basic understanding of genome editing technology followed by a survey of current literature creating and utilizing new genome editing tools. After completing this course, students will become aware of the numerous ingenious tools becoming available is critical for progress of both fundamental and translational biology. Additionally, students will be able to discuss and opine on these methods and their usage with other scientists and general public irrespective of whether they themselves use genome-editing techniques.

Contents:
Module 1: Introduction to genome editing methodologies; naturally occurring genome editors; roadmap of the development of designer nuclease tools for genome editing including Zn-Finger Nucleases, TALENs and Crispr-Cas systems; genome editing in model and non-model organisms; applications of genome editing in biology including gene drive. **Module 2:** Survey of current literature modifying and utilizing genome editing tools. Student presentations. **Module 3:** Analysis of potentials and limitations of genome editing tools; risks and bioethical considerations of genome editing.

Textbooks/References:

1. Appasani, K. (2018). *Genome editing and engineering: From TALENs, ZFNs and CRISPRs to molecular surgery*. Cambridge University Press.
2. Miglani, G. S. (2019). *Genome editing: A comprehensive treatise*. Narosa Publishing House.

BIO525/825	Communicating Biology	2 Credits

Objectives & Outcomes:
The course aims at training students to present literature and research in the form of review and research articles and presenting posters. Specifically, students will learn about how to represent the results in the form of illustrations (Figures and tables), organize a research article, synthesize findings from literature and present as a review article. In addition, the students will also learn how to engage audience through different interactive forums such as poster and oral presentations. By the end of the course the students will be better equipped to communicate biology in different forums using different mediums of communication.

Contents:
Module 1: Organization of information in the form of illustrations: Different types of illustrations (Tables and Figures); Organizing illustrations into main vs supplementary items; Different types of figures (work flow figures, simple cartoons, data figures, concept/synthesis figures, Graphical abstract); **Module 2:** Writing a research article: Structure of a research article- overall vs internal structure of each component: Title page; Abstract; Introduction; Results; Discussion; Materials and Methods; Figure legends; Bibliography; **Module 3:** Project proposal writing: Selling an idea than a product; Identifying funding agency/call; Key components; Contingency plans; Organizing budgets; Significance and Deliverables; **Module 4:** Writing a review: The need to write a review; Organizing complex information into simple sections; Generating supporting illustrations; Synthesizing concepts; Listing future

perspectives and challenges; **Module 5:** Poster presentation: Different components of a poster: Motivation/idea; Content vs context; Organizing information; Text vs illustrations; Take home message; Maximizing outreach in a limited space.

Textbooks/References:

1. Writing in the Biological Sciences: A Comprehensive Resource for Scientific Communication by Angelika H. Hofmann; Oxford University Press; 2018
2. Scientific Writing and Communication: Papers, Proposals, and Presentations by Angelika H. Hofmann; Oxford University Press; 2017
3. Successful grant proposals in science, technology and medicine : a guide to writing the narrative by Sandra Oster & Paul Cordo; Cambridge University Press; 2015