BS-MS SYLLABUS

Biological Sciences

Department of Biological Sciences: Core Courses

BIO101: Biology I: Basic properties of living organisms

Course Content:

1. Excitement and relevance of Biology with a few examples
2. Definition and properties of life
3. Origin and evolution of living organisms
4. Concept of tree of life
5. Chemical basis of life: Biological macromolecules
6. Cell as the building blocks of life
7. Perpetuation of life
8. Organisms and their environment
9. Chemical and neuronal coordination:
10. How Biologists work: science of Biology, and a few key philosophical issues

Suggested Reading:

Textbooks:

Sadava, D. E., Hillis, D. M., & Heller, H. C. (2011). *Life: The science of biology*. Macmillan. 9th Ed.

Freeman, S., Quillin, K., Allison, L., Black, M., Taylor, E., Podgorski, G., & Carmichael, J. (2017). *Biological science*. Pearson Higher Ed. 6th Ed.

Campbell, N. A., Reece, J. B., Ury, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Jackson, R. B. (2014) Biology: A Global Approach. 10th Ed.

Reference books:

Lehninger, A. L. (2017). *Lehninger Principles of Biochemistry: David L. Nelson, Michael M. Cox*. New York: Recording for the Blind & Dyslexic. 7th Ed.

Freeman, S., & Herron, J. C. (2013). Evolutionary analysis. 5th Ed.

Hill, R. W., Wyse, G. A., Anderson, M., & Anderson, M. (2016). *Animal physiology*. Sunderland, MA: Sinauer associates. 4th Ed.

Pechenik, J. (2014). *Invertebrates*. McGraw Hill: Singapore. 7th Ed.

Kardong, K. V. (2018). *Vertebrates: comparative anatomy, function, evolution*. New York: McGraw-Hill. 8th Ed.

Odum, E. P., & Barrett, G. W. (2017). Fundamentals of ecology. 5th Ed.

Alberts, B., Heald, R., Johnson, A., Morgan, D., Raff, M., Roberts, K., & Walter, P. (2022). *Molecular biology of the cell.* WW Norton & Company. 7th Ed.

BIO102: Biology II: Flow of Biological information

A. Basics of transmission genetics
1. Mendelian Genetics
2. Linkage and mapping
3. Epistasis, and other complexities in Genotype-phenotype
4. Chromosomal theory of inheritance
5. Genes: A concept and its physical form, chemical nature of genes
6. How genome is packaged: Nucleosome
7. Bacterial genome and its organization, horizontal gene transfer in multi-drug resistance evolution

B. Central dogma of Molecular Biology
8. Transmission of information
9. Expression of information
10. Brief overview of regulation of gene expression (genetic and epigenetic)

C. Embryonic development
11. Overview of the process fertilization and early development of a zygote
12. Formation of germ layers, and body axis
13. Organ formation (a very brief overview, referring to a classical case study)
14. Importance of gene expression in development

D. Connecting Development and Evolution: Mutations and their consequences
15. Introduction to modularity and parsimony at the DNA sequence and cellular level driving diversity in body forms.
16. Enhancers and their regulation in development
17. Developmental Constraints in body forms

Suggested Reading:

Textbooks:

Sadava, D. E., Hillis, D. M., & Heller, H. C. (2011). *Life: The science of biology*. Macmillan. 9th Ed.

Freeman, S., Quillin, K., Allison, L., Black, M., Taylor, E., Podgorski, G., & Carmichael, J. (2017). *Biological science*. Pearson Higher Ed. 6th Ed.

Lodish, Harvey F. (2008) *Molecular cell biology*. Macmillan, 8th Ed.

Reference books:

Watson, James D. (2017) *Molecular biology of the gene.* Pearson Education. 7th Ed.

Gilbert, Scott F. and Barresi, Michael J. F. (2017) *Developmental Biology.* Oxford Univ. Press. 7th edition

Pierce, B. A. (2012). *Genetics: A conceptual approach.* Macmillan. 7th Ed.

Alberts, B., Heald, R., Johnson, A., Morgan, D., Raff, M., Roberts, K., & Walter, P. (2022). *Molecular biology of the cell*. WW Norton & Company. 7th Ed.

BIO103 Introductory Biology laboratory

Course Content:

Part I:

1. Introduction to Biology lab: various instruments and how to use them
2. Microscopic observation: Cells (animal, plant), tissue section (animal and plant), gram staining of bacteria
3. Chemical test of protein, lipid, and carbohydrates (qualitative detection)
4. Quantitative test: protein and nucleic acid estimation using bradford method
5. Identification of different animal, and plant groups
6. Natural selection game

Part II:

1. Study of Drosophila, and mutants
2. Monohybrid and dihybrid cross and proof of Mendel's laws
3. Cell division and visualization of chromosome: Mitosis using Onion root tip, Meiosis using grasshopper or Drosophila testes, polytene chromosome in Drosophila salivary gland
4. Genomic DNA isolation and DNA quantification
5. Polymerase chain reaction and Gel electrophoresis
6. Demonstration of gene expression: lac Z staining in E. coli. Heat shock response in Drosophila
7. Study of developmental stages in a Chicken embryo: study of initial cleavages (developmental disc), primitive groove and primitive streak, late developmental stage
8. Human fingerprint analysis: patterns and forms

Suggested Reading:

Manuals:

Course manual shared by the instructor

Lakhotia SC and Ranganath HA (2024) Experiments with Drosophila for Biology Courses. Indian Academy of Sciences, Bengaluru). 2nd Ed.

Sambrook, J., & Russell, D. W. (2001). Molecular Cloning: a Laboratory Manual. Cold Spring Harbor. 4th Ed.

Reference books:

Sadava, D. E., Hillis, D. M., & Heller, H. C. (2011). *Life: The science of biology*. Macmillan. 9th Ed.

Freeman, S., Quillin, K., Allison, L., Black, M., Taylor, E., Podgorski, G., & Carmichael, J. (2017). *Biological science*. Pearson Higher Ed. 6th Ed.

Campbell, N. A., Reece, J. B., Ury, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Jackson, R. B. Biology: A Global Approach. 10th Ed.

BIO201: Biology III: Introduction to Evolution, Ecology and Ethology

A. Principles of Evolution

1. Evolution and Natural selection recalled
2. Evidences of evolution
3. Evolution in action - case studies
4. Common myths about evolution
5. Hardy-Weinberg equilibrium
6. Mechanism of Adaptive evolution
7. Other mechanism of evolutionary changes: Genetic drift, mutation, gene flow
8. Origin of species
9. Introduction to quantitative traits, heritability, different modes of selection on quantitative traits

B. Ecology

10. Population Ecology: population growth, competition, age structure, and life history
11. Community and Ecosystem ecology: Niche model, Species interactions
12. Wildlife and Conservation ecology: Biodiversity and its types, threats and benefits, Indian context

C. Behaviour

13. Introduction to Ethology
14. Instinctive and learnt behaviour, inheritance of behaviour
15. Communication
16. Optimality models in Animal Behaviour
17. Habitat selection and migration
18. Mating system and mate choice, parental care
19. Cooperation and conflict in animals, social animals
20. Ecology and Evolution in human welfare

Suggested Reading:

Textbooks:

Sadava, D. E., Hillis, D. M., & Heller, H. C. (2011). *Life: The science of biology*. Macmillan. 9th Ed.

Freeman, S., Quillin, K., Allison, L., Black, M., Taylor, E., Podgorski, G., & Carmichael, J. (2017). *Biological science*. Pearson Higher Ed. 6th Ed.

Campbell, N. A., Reece, J. B., Ury, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Jackson, R. B. (2014) *Biology: A Global Approach*. 10th Ed.

Reference books:

Freeman, S., & Herron, J. C. (2013). *Evolutionary analysis*. 5th Ed.

Odum, E. P., & Barrett, G. W. (2017). *Fundamentals of ecology*. 5th Ed.

Alcock, J. (2009). *Animal behavior: An evolutionary approach*. Sinauer associates. 10th Ed.

BIO202: Biology V: Microbiology & Immunology

Course Content:

A. Microbiology

1. Overview and History of Microbiology.
2. Microbial diversity
3. Microbial reproduction and growth.
4. Microbial nutrition
5. Microbial interactions
6. Microbial pathogens and control measures.
7. Importance and application of microbiology, Epidemic, Pandemic, and Multidrug resistant microbes.

B. Immunology

8. Introduction to vertebrate immune system
9. Foundations of Immunology - overview, cells, key players, and their generation
10. Natural and adaptive immune responses
11. Antibody Structure and B Cell Receptor
12. Antigen Recognition and Antibody Antigen Interaction
13. T Cell Biology and Immune Regulation

Suggested Reading:

Textbooks:

Sadava, D. E., Hillis, D. M., & Heller, H. C. (2011). *Life: The science of biology*. Macmillan. 9th Ed.

Freeman, S., Quillin, K., Allison, L., Black, M., Taylor, E., Podgorski, G., & Carmichael, J. (2017). *Biological science*. Pearson Higher Ed. 6th Ed.

Campbell, N. A., Reece, J. B., Ury, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Jackson, R. B. (2014) Biology: A Global Approach. 10th Ed.

Reference books:

Punt, Jenni et al. (2019) *Kuby Immunology*. Eighth edition. New York: W.H. Freeman/Macmillan Learning.

Willey, Joanne M., et al. (2014) *Prescott's Microbiology*. Ninth edition., McGraw-Hill,

BIO203: Biology IV: Fundamentals of Cell and Molecular Biology

Course Content:

1. A Tour of the Cell: The fundamental Units of Life, Cell organelles structures and their functions
2. Membrane Structure and Function
3. Cell signalling and transport across cell membranes
4. Membrane trafficking
5. Cell cycle
6. DNA replication.
7. Transcription and processing of RNA.
8. Translation and post-translational modifications.
9. Protein targeting and sorting.
10. RNA replication, reverse transcription.
11. Regulation of gene expression.

Suggested Reading:

Textbooks:
Sadava, D. E., Hillis, D. M., & Heller, H. C. (2011). *Life: The science of biology*. Macmillan. 9th Ed.
Freeman, S., Quillin, K., Allison, L., Black, M., Taylor, E., Podgorski, G., & Carmichael, J. (2017). *Biological science*. Pearson Higher Ed. 6th Ed.
Molecular Cell Biology, 8th Edition. by Harvey Lodish

Reference books:
Watson, James D. Molecular biology of the gene Edition: 7th
Bruce Alberts et al., Molecular Biology of the cell 6th Edition

BIO204: Biology VI: Basic Biochemistry

Course Content:

A. Fundamentals of Biochemistry:

1. Thermodynamics and Bioenergetics
2. Enzyme kinetics
3. Enzyme Catalytic mechanisms
4. Metabolic Regulation and Allostery

B. Physiological Biochemistry:

5. Basic concepts of metabolism
6. Catabolism and anabolism, energy generation and storage
7. Glycolysis, citric acid cycle, oxidative phosphorylation
8. Pentose phosphate pathway
9. Gluconeogenesis, glycogen metabolism
10. Fatty acid metabolism
11. Amino acid metabolism

C. Introduction to Computational Biology

12. The central dogma in the era of big data
13. Genome and genome structure
14. Introduction to genome sequencing and annotation
15. Introduction to comparative genomics
16. Gene prediction and functional annotation

Suggested Reading:

Textbooks:

Sadava, D. E., Hillis, D. M., & Heller, H. C. (2011). *Life: The science of biology*. Macmillan. 9th Ed.

Freeman, S., Quillin, K., Allison, L., Black, M., Taylor, E., Podgorski, G., & Carmichael, J. (2017). *Biological science*. Pearson Higher Ed. 6th Ed.

Campbell, N. A., Reece, J. B., Ury, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Jackson, R. B. (2014) Biology: A Global Approach. 10th Ed.

Reference books:

Lehninger, A. L. (2017). *Lehninger Principles of Biochemistry: David L. Nelson, Michael M. Cox*. New York.

Irwin H Segel (2010) *Biochemical Calculations How to Solve Mathematical Problems in General Biochemistry.* 2nd Ed.

Stryer L (2002) *Biochemistry.* W.H.Freeman & Co Ltd. 5th Ed.

Koonin EV, Galperin MY. (2003) Sequence - Evolution - Function: Computational Approaches in Comparative Genomics. Boston: Kluwer Academic.

Saitou, N (2018) *Introduction to Evolutionary Genomics*. Springer. 2nd Ed.

Ohno, S. (2013). *Evolution by gene duplication.* Springer Science & Business Media.

BIO205: Biology pre-major lab I

Course Content:

1. Microscopes and their use
2. Evolution, Ecology, Ethology lab
   a. Demonstration of selection and drift using Drosophila
   b. Quantitative trait and heritability using sternopleural bristles and sex comb in Drosophila
   c. Sexual selection and mate choice using a model system
   d. Habitat selection and optimization of resource use using an insect model
   e. Campus biodiversity study
   f. Preparation of Drosophila life table
3. Cell Biology lab:
   a. Microscopic observation of different types of cells
   b. Visualization of cell organelles
   c. Immuno-histochemistry of tissues
4. Molecular Biology lab:
   a. Competent cell preparation,
   b. Transformation
   c. Plasmid DNA isolation
   d. Agarose gel electrophoresis
   e. DNA isolation & characterization

Suggested Reading:

Manual:

Course manual shared by the instructor

Lakhotia SC and Ranganath HA (2024) Experiments with Drosophila for Biology Courses. Indian Academy of Sciences, Bengaluru). 2nd Ed.

Sambrook, J., & Russell, D. W. (2001). Molecular Cloning: a Laboratory Manual. Cold Spring Harbor. 4th Ed.

Reference books:

Sadava, D. E., Hillis, D. M., & Heller, H. C. (2011). *Life: The science of biology*. Macmillan. 9th Ed.

Freeman, S., Quillin, K., Allison, L., Black, M., Taylor, E., Podgorski, G., & Carmichael, J. (2017). *Biological science*. Pearson Higher Ed. 6th Ed.

Campbell, N. A., Reece, J. B., Ury, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Jackson, R. B. Biology: A Global Approach. 10th Ed.

BIO206: Biology pre-major lab II

Course Content:

Biochemistry lab

a) Principle of Absorbance spectroscopy, Beer-Lambert's law for concentration estimation.
b) Enzyme assays and kinetics: Assay Design, Specific activity calculation, estimation of kinetic parameters.
c) Amino acid analysis by paper chromatography and Thin layer chromatography.
d) Principle of Salting out of proteins by ammonium sulfate precipitation.
e) Floating leaf disc assay to demonstrate Photosynthesis.

Microbiology & Immunology lab

a) Identification of microorganisms, staining techniques (Gram's, acid fast)
b) Bacterial plating
c) Tests for antibiotic resistance,
d) Plaque assay, preparation of bacterial competent cells, transformation,
e) Total Leukocyte Count using Leishman's Stain
f) ABO Blood Grouping and Rh Testing
g) Serum Separation from Whole Blood
h) Single Radial Immunodiffusion
i) Double Radial Immunodiffusion

Suggested Reading:

Textbooks:
1. Laboratory Manual to be made by the instructor(s).

Reference books:
1. Wilson, Keith, and John M. Walker. (2006) *Principles and Techniques of Practical Biochemistry*. 8th ed., Cambridge University Press.

Department of Biological Sciences: Professional courses

BIO 301: Advanced Cell Biology (Credit, 4)

Course Contents:

Module 1 [8 lectures]

A tour to Cell: Exploring Eukaryotic and plant cell; cell components, their structure and function; cytoskeleton network: components and structural functions; Cell-Cell and cell- matrix adhesion; Extracellular Matrix, Animal cell membrane; Cell junctions, plasmodesmata, gap junctions, desmosomes and tight junction

Module 2 [8 lectures]
Membrane structure and function: Membrane models; evolution of different membrane lipids, Membrane proteins and their functions, Membrane carbohydrates and their roles in cell-cell recognition; The permeability of the bi-layers: transport proteins; Passive, active and co transport by antiporters and symporters, transporter proteins in plant vacuoles exocytosis and endocytosis

Module 3 [8 lectures]
Cell signalling and transport across cell membranes: Signalling molecules and cell surfacereceptors; intracellular signal transduction; G protein coupled receptors; cytokines and others passive and active transport; endocytosis, exocytosis; entry of viruses and toxins into cells

Module 4 [8 lectures]
Membrane trafficking: Translocation of secretory proteins across the ER membrane; proteinmodifications, folding and quality control in the ER; export and sorting of proteins to mitochondria, chloroplast and peroxisomes.

Module 4 [10 lectures]
Eukaryotic cell cycle: Biochemical and genetics studies on cell cycle; mechanisms regulating mitotic events; meiosis - a special type of cell division; Cell Birth, lineage and death: Asymmetrical cell division, patterns of stem cell division; Biological description ofapoptosis; Molecular basis of cancer, oncogenes and tumor suppressor genes

Suggested Reading:

- Molecular Cell Biology, by Lodish et al (5th edition or recent), W.H. Freeman andCompany, New York
- Molecular Biology of the Cell, by Alberts et al (4th edition or later), GarlandSciences, New York
- Lehninger Principles of Biochemistry (6th edition) by David L. Nelson, Michael M.Cox
- Biochemistry. L. Stryer W. H. Freeman & Company, New York (4^{th} Edition)

- Additional material from recent scientific papers/reviews will be provided

BIO 302: Biochemistry I - Advanced Enzymology (*Credit,* 4)

Course Contents:

Enzyme Structure and Catalysis: A historical perspective of enzymes, fundamentals rate of a reaction, Free Energy and Entropy. Activation energy, Coenzymes. NAD, FAD, [Classes/Hours:4]

Types of Enzymes: Enzyme classification: with description of reaction mechanism of types of enzyme in each class of enzymes. Enzymatic reactions for Types of Oxidoreductases, Types of Transferases, Types of hydrolases, Isomerases, Ligases, Lyases [Classes/Hours:10]

Enzyme kinetics: Km, Vmax and Kcat calculation, Enzyme inhibition mechanism and derivations using MM curve, LB Plot, Hanes Plot (Competitive, Uncompetitive, non-competitive), IC50, Allostery, cooperativity, Hill's coefficient; Mechanism of enzyme action. [Classes/Hours:12]

Molecular mechanisms of enzyme function: Pyruvate dehydrogenase complex, Pyruvate carboxylase, Substrate channeling enzymes. [Classes/Hours:5]

Ribozymes: discovery, mechanism of action, structural and evolutionary perspective, RNA World Hypothesis. [Classes/Hours:5]

Basics of Metabolic Dynamic Measurement Techniques: Pulse chase, Autoradiography, 13C Metabolism strategy [Classes/Hours:3]

Suggested Reading:

Principles of Biochemistry: Lehninger, Nelson and Cox; 5th edition, W.H. Freeman; 2008.

Biochemistry: Lubert Stryer; W. H. Freeman; 7th Edition; 2010.

Biochemistry by Donald Voet, Judith G. Voet; Wiley; 4th edition; 2010.

The Biophysical Chemistry of Nucleic Acids and Proteins: Thomas E. Creighton; Helvetian Press; 2010.

BIO 303: Structural Biology (*Credit,* 4)

Course Contents:

Proteins from primary to quaternary structures: Amino acids, primary sequence, peptide bond, dihedral angle, Geometry and chemistry of di-peptide, Ramachandran map, Secondary structural elements and their geometric description.

Structural biology and evolution; Protein domain evolution

Protein Data Bank

Thermodynamics

Protein structure, function and mechanism, Structural classification of proteins, Examples of protein three dimensional structures, Protein-Ligand and Protein-Protein interactions, chaperones, membrane proteins; Collagen triple helix, Super secondary structure, Structural domains, Quaternary association of globular proteins.

Protein purification and quantification

Current topics in structural biology: membrane protein structure, protein folding and degradation.

Basics of nucleic acid structure: The building blocks, DNA secondary structure: the Double Helix, Deviation from the ideal geometry, tertiary structure of RNA;

Suggested Reading:

- Biochemistry: Lubert Stryer; W. H. Freeman; 7th Edition; 2010.
- Introduction to Protein Structure: Carl Branden and John Tooze; Garland Science; 2nd edition; 1999

BIO 304: Molecular Biology (*Credit,* 4)

Course Contents:

DNA replication: Unit of replication, Enzymes involved, origin of replication and replication fork, Fidelity of replication, extrachromosomal replicons;
DNA damage and repair- mechanisms, homologous and site-specific recombination;
RNA Synthesis: transcription factors and machinery; initiation complex formation, activators and repressors of transcription, RNA polymerases, capping, elongation, and termination, RNA processing, RNA editing, splicing, and polyadenylation, different types RNA: structure and functions, RNA transport;
Protein synthesis: Ribosome, formation of initiation complex and regulation of initiation factors, elongation and elongation factors, termination, concept of genetic code, translation: aminoacylation of tRNA, tRNA-identity, aminoacyl tRNA synthetase, and proof-reading, inhibitors of translation, post- translational modification of proteins;
Protein structure-function correlation: DNA recognition, enzyme catalysis, membrane proteins, proteins of the immune system, viruses; Protein degradation;
Protein engineering and design;
Techniques for study of protein structures;
Regulation of gene expression: Gene expression control at transcription and translational level; Chromatin and gene expression;
Gene silencing. siRNA and microRNA; Restriction endonucleases, Recombinant DNA technology and applications: Cloning, plasmid vectors (shuttle and expression vector, RFLP, electrophoresis, heterologous protein expression and promoters). Hybridization processes (Northern, southern and Western)

Suggested Reading:

Genes – Benjamin Lewin; Jones & Bartlett Learning, 10th edition; 2009.

Molecular biology of the gene: James D. Watson, Tania A. Baker, Stephen P. Bell, Alexander Gann, Michael Levine, Richard Losick; Benjamin Cummings; 6th edition; 2007

Molecular Biology of the Cell: Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, Peter Walter; New York: Garland Science; 5th edition; 2008.

The Biophysical Chemistry of Nucleic Acids and Proteins: Thomas E. Creighton; Helvetian Press; 2010.

Introduction to Protein Structure: Carl Branden and John Tooze; Garland Science; 2nd edition; 1999.

Latest/classic research articles and reviews relevant to various topics.

BIO 305: Plant forms and functions (*Credit*, 4)

Course Contents:

1. Plants: Evolutionary history and diversity
   1.1 Introduction to Plant phylogeny. **[1 class]**
   1.2 Evolution and diversity of growth forms. **[3 classes]**
2. Plant forms: Morphology and anatomy of flowering plants
   2.1 Introduction to plant body structure. **[3 classes]**
   2.2 Development and function of plant organs. **[3 classes]**
3. Plant cell biology and growth regulators
   3.1 Plant cell, cell wall and tissue types. **[2 classes]**
   3.2 Cell division, growth, differentiation and senescence. **[2 classes]**
   3.3 Phytohormones: types and functions. **[3 classes]**
4. Plant reproduction and phase transition
   4.1 Introduction to plant reproduction. **[2 classes]**
   4.2 Regulation of flowering in plants. **[2 classes]**
5. Photosynthesis and plant respiration
   5.1 Photosynthesis. **[2 classes]**
   5.2 Plant respiration. **[2 classes]**
6. Plant nutrition and transport systems
   6.1 Introduction to plant vascular system. **[2 classes]**
   6.2 Water uptake and transport.t **[1 class]**
   6.3 Nutrient uptake and transport. **[1 class]**
7. Plant interactions and adaptations
   7.1 Plant-plant interactions. **[1 class]**
   7.2 Plant- microbe interaction (plant-pathology). **[1 class]**
   7.3 Plant symbiosis. **[1 class]**
8. Plant Biotechnology and applications
   8.1 GMOs. **[1 class]**

Suggested Reading:

1.Plant Systematics: a Phylogenetic Approach. 3rd edition. Judd, W.S.; Campbell, C.S.; Kellogg, E.A.; Stevens, P.F. & Donoghue, M.J.

2.The Evolution of Plants (2013) by Kathy Willis, Jennifer McElwain. Oxford 2nd edition.

3.Plant Form: An Illustrated Guide to Flowering Plant Morphology by Adrian D. Bell, Alan Bryan. Published in 2008 by Timber Press Inc.

4.Anatomy of Seed Plants, 2nd edition by Katherine Esau. John Wiley & sons ISBN:

5.The Embryology of Angiosperms, 6th Edition. S.S Bhojwani, S.P. Bhatnagar& P.K. Dantu.Vikas Publishing House

6.An Introduction to Plant Structure and Development: Plant Anatomy for the Twenty-First Century 2nd Edition by Charles B. Beck. Cambridge University Press.

7.Plant Physiology and Development.6th Edition. by Lincoln Taiz, Eduardo Zeiger, Ian M. Møller, Angus Murphy.

8.Introductory Plant Physiology. Authors, G. Ray Noggle, George J. Fritz. Edition, 2. Publisher, Prentice-Hall.

9.Biochemistry and Molecular Biology of Plants 2nd Edition by Bob B. Buchanan, Wilhelm Gruissem, Russell L. Jones.

10.Raven Biology of Plants Eighth Editionby Ray F. Evert, Susan E. Eichhorn

11.Botany: An Introduction To Plant Biology 4th Edition. By James D. Mauseth.

12.The Ecology of Plants, Second Edition 2nd Edition by Jessica Gurevitch, Gordon A. Fox. Sinauer Associates Inc.

13.American Horticultural Society Plant Propagation: The Fully Illustrated Plant-by-Plant Manual of Practical Techniques Hardcover by Alan Toogood.

14. Plant Pathology, Fifth Edition 5th Edition by George N. Agrios.Elsevier Academic Press

15. Plant Abiotic Stress Hardcover by Matthew A. Jenks (Editor), Paul M. Hasegawa (Editor) Wiley-Blackwell; 2nd Revised edition

16. Genetically modified by Nigel G. Halford Published by Imperial College London

BIO 306: Animal forms and functions (Minimum 34 lecture hours/classes)

Course Contents:

1. Origin and evolution of animal body plans: Characteristic features of Animal body plans including the axis of symmetry, phylogenetic relationships among animals, Body Cavity, Segmentation, Cephalization, Germ layers. **(3 lectures)**
2. Invertebrates:
    - Origin and evolution of different major organ systems. Sponges, Cnidarians, Lophotrochozoans, Ecdysozoans, Echinoderms and Hemichordates. **(3 lectures)**
3. Vertebrates:
    - Origin and evolution of different major organ systems, Tetrapods, Amniotes, Mammals and Humans. (**3 lectures)**
4. Animal Nutrition:
    - Essential Nutrients, Stages of food processing - Ingestion, Digestion, Absorption and Assimilation of food. **(2 lectures)**
    - A brief introduction to the diversity in Invertebrate and vertebrate digestive systems. **(2 Lectures)**
5. Circulation and Gas exchange:
    - Integration of respiratory and circulatory systems in animals, respiratory pigments. **(1 Lecture)**
    - Different kinds of respiratory systems: Gills, Trachea, Vertebrate lungs, including air sacs in birds. **(2 lectures)**
    - Vertebrate circulation: Blood and circulation; anatomy of heart, ECG, cardiac cycle, regulation of cardiac output and blood pressure, transport of gasses in blood, regulation of body pH. **(2 Lectures)**
6. Osmoregulation and Excretion: **(4 Lectures)**
    - Osmoregulation, osmoregulators and osmoconformers
    - Obligatory exchanges of ions and water
    - Osmoregulation in water and terrestrial environment
    - Human excretory system as a model: Glomerular filtration, Tubular re-absorption and secretion, counter current mechanism, hormonal regulations.
7. Nervous System, Sensory and Motor Mechanisms: **(5 Lectures)**
    - Neuron structure and functions, Genesis of membrane potential and action potential, conduction of action potentials, Sodium-potassium pump, calcium pump, Transmission at synapse, Neurotransmitters.
    - Eye-retinal components and photo-receptors.
    - Ear-cochlea, basilar membrane.
    - Vertebrate skeletal muscle, other types of muscles,
    - Energetics of muscle contraction, sequence of events in contraction & relaxation.

8. Endocrine system: Brief introduction to hormones and their role as chemical coordinator. Vertebrate neuro-endocrine system. (**4 Lectures)**
9. Hormones and Reproduction:
    - Different modes of reproduction: Asexual and sexual reproduction, parthenogenesis. (1)
    - Mammalian reproduction as a model of sexual reproduction: Male and female reproductive physiology, fertilization, pregnancy and childbirth. AIDS, contraceptives - as special topics. **(3 Lectures)**

Suggested Reading:

- Introduction to Animal Physiology: Ian Kay; Bios Scientific Publishers; 1999
- Animal Physiology: Hill, Wyse and Anderson; Sinauer Associates, Inc; 3rd 2012.
- Animal Physiology by Randall Burggren & French; W. H. Freeman; 5th edition; 2001.
- Principles of Anatomy and Physiology: Tortora and Derrickson; John Wiley and Sons; 13th edition, 2012.
- Text book of Medical physiology: Guyton and Hall; Saunders; 12th edition; 2011.

BIO 307: Biology Laboratory I (*Credit,* 3)

Course Contents:

1 Lecture on Good Laboratory Practices

2. Introduction to Bioinformatics & Protein sequence analysis

3 Creating protein and protein-nucleic acid models using AlphaFold3 and analyzing them.

4. Mammalian cell culture maintenance

5. Cell viability Assays

6. Immunofluorescence for organelle markers

7. Fluorescence Microscopy and image analysis

8. FACS demonstration

9. Plant DNA extraction and quality analysis

10. Microbiology Differential staining experiment demonstration

Suggested Reading:

BIO 308: Biology Laboratory II (*Credit,* 3)

Course Content: Biochemistry I, Molecular Biology

Biochemistry Part:

Experiment 01: Alpha Amylase (Salivary Amylase) activity assay:

a. Activity of enzyme at different time points
b. Effect of temperature on the activity of enzyme
c. Effect of pH on the activity of enzyme

Experiment 02: Determination of Blood related parameters: Blood grouping by ABO and Rh system

Experiment 03: Blood smear preparation & WBC staining by Giemsa's method

Experiment 04: RBC and WBC counting by using hemocytometer

Experiment 05: Quantifying Oxidative stress in Cancer Cells: ROS Assay

Experiment 06: Hemoglobin Estimation (Sahli's Method)

Molecular Biology Part:

Experiment 01: PRIMER DESIGNING BASICS

Experiment 02:MOLECULAR CLONING_1: PCR

Experiment 03:MOLECULAR CLONING_2: RESTRICTION DIGESTION AND ELUTION

Experiment 04:MOLECULAR CLONING_3: LIGATION AND TRANSFORMATION

Experiment 05:MOLECULAR CLONING_4:CLONE SCREENING

Experiment 06:GENE EXPRESSION ANALYSIS_RNA ISOLATION AND SEMI QUANTITATIVE RT-PCR

Experiment 07:QUANTITATIVE RT-PCR DEMO

Suggested Reading:

1) Sambrook and Russell: Molecular Cloning.

2) T. A. Brown: Gene cloning and DNA analysis

3) Glick, Pasternak and Patten: Molecular Biotechnology

BIO 309: Microbiology (*Credit,* 3)

Course Contents:

1. **Microbial taxonomy:** Classification, Nomenclature, Taxonomy, Numerical Taxonomy, Bergey's Manual of Systematic Bacteriology **[2 classes]**
2. **Microbial metabolism:** Introduction to metabolism, Catabolism energy release and conservation, Anabolism, Energy production in eubacteria, Energy production in archaea **[4 classes]**
3. **Microbial genetics:** Modes of DNA transfer in bacteria, conjugation, transduction, transformation **[3 classes]**
4. **Bacteriophage biology:** Bacteriophage classification and examples, Structure and life cycle of bacteriophages, Bacteriophage genetics and gene regulation; Research and application of bacteriophage genetics, Phage display and lambda DNA library **[4 classes]**
5. **Virus classification:** Lytic and temperate phage, latency period **[2 class]**
6. **Microbial Ecology**: Biogeochemical cycles, Nitrogen cycle; Sulphur cycle, Methods in Microbial Ecology **[4 classes]**
7. **Microbial Physiology**: Mechanism of drug resistance, Signal Transduction in bacteria; Quorum sensing and Two component system; Stringent response in bacteria **[5 classes]**
8. **Applied Microbiology:** Food microbiology, Microbes and agriculture, Biotechnology and Industrial microbiology, Applied Environmental Microbiology **[3 classes]**

Suggested Reading:

Microbiology by Prescott, Harley and Klein; McGraw-Hill Science/Engineering/Math; 7th edition; 2007.

Modern Microbial Genetics by Streips and Yasbin; Wiley-Liss; 2nd edition; 2002.

Bacterial and Bacteriophage Genetics: Edward Birge; Springer; 5th edition (December 8, 2005.

E. coli and Salmonella Typhimurium- Vol 1-2: Cellular and Molecular Biology by Neidhardt and Curtiss; American Society for Microbiology; 2 Volume Set edition. 1987.

BIO 312: Biology of Infectious Diseases (*Credit*, 3)

Course Contents:

1. **Overview of Viral diseases**: Generalized overview of viral infections with emphasis on viral infections with global epidemiological burden including Influenza, AIDS, congenital and arboviral infections. Brief discussion on immunology of viral infections including role of innate, cell mediated and humoral immunity in evasion and clearance of viral infections. **[7 classes]**

2. **Bacterial infections:** Generalized overview of viral infections with emphasis on viral infections with global epidemiological burden including tuberculosis, typhoid, systemic and hospital acquired infections. Brief discussion on immunology of bacterial infections including immune responses to intracellular and extracellular bacteria and evasion on antagonistic mechanisms devised by bacteria to evade such responses. Special note on the contribution of immune responses on bacterial pathogenesis. **[7 classes]**

3. **Parasitic diseases:** Parasitic organisms come in many shapes and sizes, Protozoan parasites account for huge worldwide disease burden. Examples of malaria, African sleeping sickness and Leishmaniasis. Epidemiologically prevalent disease associated with Helminths (tapeworm, hookworm and filaria) **[5 classes]**

4. **Fungal Diseases:** Generalized overview of fungal infections with emphasis on mycoses. Brief discussion on the role of innate immunity in control of fungal infections. **[3 classes].**

5. **Emerging and Re-emerging infectious diseases:** diseases may re-emerge for various reasons, Overview of some recently appearing fatal diseases. The SARS and Ebola outbreak triggered a rapid international response. **[3 classes].**

6. **Opportunistic infections:** bacterial, viral, parasitic and fungal (Classical opportunistic pathogens) **[3 classes]**

Suggested Reading:

- Jawetx, Melnick & Adelberg's Medical Microbiology, 25e
- Infectious Diseases: pathogenesis, prevention and case studies. Authors: Nandini Shetty, Julian W Tang, Julie Andrews (2009)
- Kuby Immunology 7ed, 7th revised international edition; Authors Sharon Stanford, judy Owen and Jenny Punt
- Immunobiology, 6E: The immune system in health & disease 6th Editionp Janeway C. A.

BIO 313: Biostatistics (*Credit,* 4)

Course Contents:

Probability Distributions: Normal distribution: Properties, Measures of location and dispersion: Descriptive statistics: (Mean, mode, median, quartile, standard deviation, standard error, coefficient of variation, skewness and kurtosis) Poisson distribution and Binomial distribution
Confidence Intervals and Hypothesis testing (Confidence levels; concept and rationale of null hypothesis; Type- I and Type-II errors and their interpretation and measurement)
Field Sampling and Experimental Designs (random, systematic, and stratified sampling; replication, pseudoreplication, controls, paired-sample designs, factorial designs, etc.)
Null hypothesis and significance testing
One sample test: Student's t-test
Paired-sample t-test
Analysis of Variance: One-way ANOVA (Analysis and F-testing; Multiple comparisons among means – a priori and a posteriori tests; Assumptions of ANOVA)
Analysis of Variance: Two-way ANOVA (Significance testing for factor interaction)
Analysis of variance: Randomized block designs and Repeated Measures designs
Correlation
Linear Regression
Brief introduction to logistic, curvilinear and multiple regressions
Analysis of frequencies: Tests for goodness of fit and for independence (2 and Likelihood ratio tests)
Power of a statistical test
Nonparametric Tests (Mann-Whitney U-test, Wilcoxon signed-rank test, Spearman's Rank Correlation test, Kruskall-Wallis Test)
Brief introduction to Bayesian Statistics

Suggested Reading:

• Baldi, B., and D. S. Moore, 2017. The practice of statistics in the life sciences. 3 rd ed. Freeman Publisher
• Lee, J. H., 2003. Introductory Biostatistics, Wiley-Interscience.
• Pagano, M., and K. Gauvreau, 2000. Principles of Biostatistics. 2 nd ed. Indian Edition. Brooks/Cole
• Sokal, R. R., and F. J. Rohlf, 1995. Biometry. 3 rd ed., Freeman Publishers.
• Whitlock, M.C. and D. Schluter, 2015, The analysis of biological data. W. H. Freeman Publishers.
• Zar, J. H., 2014. Biostatistical analysis. 5 th ed. Pearson Publ.

BIO 314: Ecosystem Ecology (*Credit,* 3)

Course Contents:

Ecosystem concepts- Classic, Systems- and Thermodynamic
• Ecosystem properties Openness, directionality, connectivity, emergent hierarchy, complex dynamics, self-regulation through feedbacks
• Major ecosystems of the world Selected, well studied ecosystems- coral reefs, mangrove swamps, deep sea, lakes, streams, alpine, etc.
• Ecosystem components Biotic components- autotroph, herbivore, primary carnivore, secondary carnivore, omnivore. And decomposer levels; Abiotic components- Important physic-chemical factors that influence the biotic components; human activities (Anthropocene concept)
• Energy Flow Primary sources of energy- sun; deep sea hydrothermal vents; geography of solar radiation; factors influencing light energy reaching the plants (latitude; cloud cover, albedo; etc.); photosynthetic efficiency; Assimilation efficiency, Production efficiency and Consumption (exploitation efficiencies) at different trophic levels; Productivity/biomass ratios; detrital pathway and microbial loop; food pyramids
• Materials cycling Biogeochemistry; Nutrient cycling- C, N, P; respiration and decomposition; soil ecosystem; detritus, Nutrient limitation in terrestrial and aquatic environments and its consequences; eutrophication; anthropogenic sources of nutrients into the ecosystem; ecological stoichiometry
• Ecosystem development Succession concepts; Primary and secondary succession; Changes in ecosystem functions during succession; Mechanism of succession-models; Concepts of climax • Biodiversity Diversity at species and ecosystem levels; Patterns of species diversity- Latitudinal gradients, Factors contributing to tropical species richness; Species-area relationships; Components of diversity- α, and γ. Measurement and interpretation of diversity- Different indices of diversity; species-abundance relationships
• Ecosystem regulation and stability Top-down and bottom-up controls; Ecosystem-level response to perturbation- natural and man-made (alien species introductions, habitat fragmentation; anthropogenic climate change); Ecosystem resilience; diversity-stability relationships
• Ecosystem health, Ecosystem services and their management Major criteria for assessing ecosystem health (productivity, organization, resilience); Human perspectives and metrics of ecosystem health; Major ecosystem services important for human wellbeing; Economic value of ecosystem services; Relation with biodiversity conservation
• Managed ecosystems- Agricultural and aquacultural ecosystems
• Remediation of degraded ecosystems (Restoration ecology) Basic principles of restoration ecology; Role of Biotechnology in restoration of degraded ecosystems; selected case studies
• Ecosystem modeling and models (Brief introduction) Analytical and simulation models; Multispecies interaction models; Whole ecosystem models; Ecosystem networks

Suggested Reading:

Chapin, F. S., P. A. Matson, and P. Vitousek, 2012. Principles of terrestrial ecosystem ecology. 2 nd ed. Springer,
N.Y. Raffaelli, D. G., and C. L. J. Frid, 2010. Ecosystem ecology: A new synthesis. Cambridge Univ. Press, Cambridge.
Weathers, K., D. Strayer, and G. Likens, 2012. Fundamentals of ecosystem science. Elsevier.

Reference books

Dickinson, G., and K. Murphy, 2007. Ecosystems. 2nd.ed. Routledge, New York, N.Y.
Jørgensen, S. E. (Ed), 2009. Ecosystem ecology. Elsevier, Amsterdam.
Loreau, M., 2010. From populations to ecosystems: Theoretical foundations for a new ecological synthesis. Princeton Univ. Press, Princeton, N.J.
Millennium Ecosystem Assessment, 2005. Island Press, Washington, DC
Mittelbach, G. G., 2012. Community ecology. Sinauer Associates.
Morin, P. J., 2010. Community ecology. 2nd ed. Wiley-Blackwell.
Sala, O.E., Jackson, R.B., Mooney, H.A., Howarth, R.W. (Eds.), 2000. Methods in ecosystem science. Springer Publ.

BIO 315: Population Ecology (*Credit,* 3)

Course Contents:

A. SINGLE-SPECIES POPULATIONS

1. Individual vs. Population
2. Factors affecting population growth: Births, deaths, Immigration, Emigration
3. Population growth- Density-independent growth: geometric and exponential growth models; finite and intrinsic rates of growth.
4. Population growth- Density-dependent growth: Concept of Carrying capacity (K); Verhulst-Pearl Logistic growth model and its assumptions; Allee Effect; Growth models with time-lag and stochasticity; Theta-model; laboratory experiments and field studies; intrinsic growth rates.
5. Growth of age-structured populations: Life tables- survivorship, fertility, reproductive value, generation time; age pyramids, age structure and stable-age distribution; Leslie Matrix growth model
6. Metapopulation ecology: Basic concepts; relation to spatial ecology; MacArthur-Wilson equilibrium theory, Levin's metapopulation;
7. Life history strategies: Longevity; age at first reproduction; frequency of reproduction, iteroparity and semelparity; Clutch size; Offspring number-size relation; cost of reproduction; Grime's model of plant life history strategies; r- and K-selection and r-K continuum; effects of predation and competition.

B. INTERSPECIFIC INTERACTIONS

1. Interspecific competition: Resource competition and interference competition; Competition and coexistence in nature; Lotka-Volterra competition model; Conditions for coexistence; Character displacement; Resource-based competition models; Competitive exclusion principle; Laboratory and field experiments.
2. Prey-predator interactions: Concept of prudent predator; Lotka-Volterra equations; Numerical and functional responses of predator to prey density; Rosenzweig-MacArthur model; Optimal foraging theory; role of predation in nature; niche dimensionality.
3. Host-parasite interactions: Basic models; disease dynamics
4. Mutualism: Models of mutualism; Plant-pollinator interactions
5. Plant-herbivore interactions: Chemical defenses; allelopathy; Constitutive and induced defenses; Plant apparency and chemical defense; herbivore responses
6. Niche theory
7. Population regulation

C. APPLIED POPULATION ECOLOGY

1. Overfishing of natural fish populations
2. Biological control of pest insects

Suggested Reading:

1. Begon, M., and C. R. Townsend, 2005. Ecology-From individuals to populations. 4th ed. John Wiley and Sons. ISBN-10: 9781405111171
2. Gotelli, N. J., 2008. A primer of ecology. 4th ed., Sinauer Assoc. Publ.
3. Kormandy, E., 2017. Concepts of Ecology. Updated 4th ed. Pearson Education, India. ISBN-10: 9332586098
4. Krebs, C J., Ecology: The experimental analysis of distribution and abundance. 6th ed. Pearson Education, India. ISBN-10: 9332575746
5. Ricklefs, R. E., and R. Relyea, 2014. Ecology: The economy of nature. 7th ed. W. H. Freeman publ. ISBN-10: 1429249951
6. Smith, 2014. Elements of Ecology. 8th ed. Pearson Education, India. ISBN-10: 9332536694
7. Stirling, P., 2014. Ecology (International 2nd edition), McGraw-Hill Education, ISBN-10: 9781259252310

Reference books:

1. Dickinson, G., and K. Murphy, 2007. Ecosystems. 2nd.ed. Routledge, New York, N.Y.
2. Jørgensen, S. E. (Ed), 2009. Ecosystem ecology. Elsevier, Amsterdam.
3. Loreau, M., 2010. From populations to ecosystems: Theoretical foundations for a new ecological synthesis. Princeton Univ. Press, Princeton, N.J.
4. Millennium Ecosystem Assessment, 2005. Island Press, Washington, DC
5. Mittelbach, G. G., 2012. Community ecology. Sinauer Associates.
6. Morin, P. J., 2010. Community ecology. 2nd ed. Wiley-Blackwell.
7. Sala, O.E., Jackson, R.B., Mooney, H.A., Howarth, R.W. (Eds.), 2000. Methods in ecosystem science. Springer Publ.

BIO 316 : Behavioural Ecology (*Credit,* 3)

Course Contents:

1. Introduction to the study of Behaviour, ultimate and proximate questions.
2. Instinctive and learned behaviour
3. Communication: Modes of Communication, Advantages and Disadvantages, Functions of Communication, Types of Signals.
4. Finding food: Optimal foraging theory, Foraging Strategies, Generalists vs Specialists, Marginal Value Theorem and Patch Residence Time
5. Finding shelter: Habitat selection, territoriality, dispersal and migration
6. Finding mates: Mating system, reproductive behaviour and its evolution
7. Sexual selection theories
8. Parental care
9. Prey-predator interactions
10. Social behaviour and evolution of Eusociality
11. Neuroethology and Behavioural Genetics: Development of Behaviour, Processing of Sensory Information, Hormonal control of behaviour, Learning, Memory and Cognition.
12. Assignments and paper presentation on recent research topics

Suggested Reading:

1. Alcock, J. (2001). *Animal behavior: An evolutionary approach* (No. QL751. A42 1984.). Sunderland: Sinauer Associates.
2. Davies, N. B., Krebs, J. R., & West, S. A. (2012). *An introduction to behavioural ecology*. John Wiley & Sons.
3. Dugatkin, L. A. (2020). *Principles of animal behavior*. University of Chicago Press.

4. Gadagkar, R. (2001). *Survival strategies: cooperation and conflict in animal societies* (Vol. 6). Harvard University Press.

BIO 401: Immunology (*Credit*, 4)

Course Contents:

Introduction to Immune System: organs, cells and molecules;
Mechanisms of barrier to entry of microbes into human body. Natural and adaptive immune responses; Differentiation of stem cells to different cellular elements in blood, role of cytokines; Introduction to inflammatory reaction, Chemokines, migration of neutrophils to the site of infection, phagocytosis and microbicidal mechanisms. Interferons and viral infections, Parasitic infections and role of Eosinophils Asthma. Basophils, IgE receptor, immediate hypersensitivity; Innate receptors (TLR, RLRs and NLRs) and sensing of PAMPs. Signal transduction. Opsonization, Fc Receptors, classification. Prostaglandins and leukotrienes. Complements structure and function. Classical and alternative pathways;
Antibody structure and function. Classification of immunoglobulins, immunoglobulin domains, concept of variability, crosses reactivity. Isotypes, allotypes and Idiotypic markers; Idiotypic network Immunoglobulin genes, VJ/VDJ rearrangements and genetic mechanisms responsible for antibody diversity, affinity maturation, allelic exclusion;
Class switching, receptor and soluble forms of immunoglobulin; Concept of Histocompatibility. Genetic organization of H2 and HLA complexes. Class I and class II MHC molecules, structure and function;
T cell receptors, APC-T cell interaction T cell activation, Th1 Th2 cells and cytokines. Intercellular antigen presentation pathways, antigen presentation and MHC restriction;
T cell differentiation in thymus, aβ and gd T cells. Thymic selection and tolerance to self. Cytotoxic T cells. Super antigens;
Natural Killer Cells, ADCC, Hybrid resistance, NK cell receptors and NK gene complex, inverse correlation with target MHC expression, missing self-hypothesis; Immunological techniques, Hybridoma and monoclonal antibodies.

Suggested Reading:

- Essential Immunology: Peter J. Delves, Seamus J. Martin, Dennis R. Burton, Ivan M. Roitt; Wiley-Blackwell; 12th edition; 2011.
- Immunobiology: The immune system in health and disease by Charles Janeway, Paul Travers, Mark Walport, Mark Shlomchik; Garland Science; 5th edition; 2001.
- Kuby Immunology; W. H. Freeman & Company; 6th edition; 2006.

BIO 402: Bioinformatics (*Credit,* 4)

Course Contents:

Introduction to Bioinformatics: Basic overview, concepts, utility, scope and applications. (1-2 Lectures)

Databases: NCBI (37 internal Databases including PubMed, GenBank, RefSeq, SRA, Taxonomy Viral-resources etc); EMBL-EBI (over 50 internal databases including Ensembl, Enzyme portal, HGNC, PDBe, Pfam, ChEMBL, Rfam, TreeFam, Interpro, UniProt/SwissProt, TrEMBL, WormBase etc); DDBJ; Expasy-Enzyme, IUBMB Enzyme Nomenclature, KEGG, MetaCyC, BRENDA; UCSC, PDB, PDB-SUM, SCOP, CATH, SUPERFAMILY, COGs and web resources; (5 lectures)

Sequence formats: FASTA, GenBank, EMBL, PDB, XML, Medline, GCG, Phylip, Nexus, Newick, Stockholm, SAM/BAM etc. Conversion from one format to another, tools available for format interconversion (Emboss Seqret). (2 lectures)

Sequence analysis: Introduction to sequence alignment, homology, similarity, identity. Local and global alignments, multiple sequence alignments, insertions, deletions, gaps, Needleman-Wunsch algorithm, Dot matrix method, dynamic programming algorithm, scoring matrices- PAM and BLOSUM, BLAST-Packages, Blat, Clustalw, MAFFT, BLOCKS, and other sequence-alignment software packages. Strengths and limitations. Sequence Profile-Building and Profile based-sequence searches: HMMER, JACKHMMER, PSI-BLAST, PSSMs etc. (5 Lectures).

Protein annotation, classification and structure prediction: Introduction to domains, motifs, fold, family, Helices, beta-sheets, loops, coils. Primary, secondary and tertiary structure. Protein annotation using CDD-Search, Pfam-Search, HHblits, HHpred, Interproscan etc. Protein clustering using BLASTCLUST, CD-HIT, MMSEQS, and other tools. Structure visualization tools such as MOLSTAR, PYMOL etc; Protein structure similarity analysis using DALI. (5 Lectures)

Phylogenetic analysis: Concepts and Terminologies, commonly used phylogenetic tree construction software packages: IQTREE, MEGA, PHYLIP. PHyML, RAxML, MRBayes, BEAST etc. Bootstrapping: Concepts in Bootstrapping etc. Tree-reconstruction methods: Maximum parsimony, Maximum Likelihood, Distance Matrix and Bayesian methods; Advantages and disadvantages of each tree-building methodologies. (5 Lectures)

Gene prediction and annotation methods: Concept of genes, challenges in gene prediction, ORFs, reading frames, codons and codon bias, genetic code, commonly used gene prediction methods- ORF finder, Glimmer, GeneMark, Metagene, etc. Annotation using homology-based alignment using Blast or Blat, COGs and Gene ontology based functional annotation. Genome analysis: Introduction to genomes and packages for genomic analysis such as EMBOSS; Introduction to Linux and Perl. (5 Lectures)

Suggested Reading:

1) Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins (Andreas D. Baxevanis; B. F. Francis Ouellette)

2) Introduction to Bioinformatics (Arthur M. Lesk)

3) Bioinformatics and Molecular Evolution (Paul G Higgs and Teresa K Attwood)

4) From Protein Structure to Function with Bioinformatics (Daniel J. Rigden (Editor). Springer; Softcover reprint of the original 2nd ed. 2017 edition (25 July 2018)

5) Protein Families: Relating Protein Sequence, Structure, and Function (Christine A. Orengo, Alex Bateman, et al.) Wiley; 1st edition (18 March 2014)

BIO 403: Biochemistry II (*Credit,* 4)

Course Contents:

Bioenergetics, Thermodynamics and pH: Biological oxidation reduction reactions, Free Energy and Activation Energy, pH measurements, ATP and its role in various metabolic processes; Functions of various proteins: Immunoglobulin, Oxygen carrier proteins. Allostery and Ping Pong Enzyme Reaction Mechanism [Classes/Hours: 4]

Measuring Cellular Metabolism: Isotopomer analysis (NMR and Mass spectroscopic) for metabolic dynamics measurement. Measuring Cellular Metabolic dynamics associated with energy metabolism. Metabolism generated Free radicals and oxidative stress. [Classes/Hours: 4]

Carbohydrate Metabolism: Glycolysis, gluconeogenesis, pentose phosphate pathway and their regulations; TCA/Kreb's cycle and its regulation: Production of Acetyl-CoA, reactions of the Citric Acid Cycle, Glyoxylate pathway. [Classes/Hours: 5]

Fatty acid biosynthesis and degradation: Digestion, Mobilization, and Transport of Fats, Oxidation of Fatty Acids, Ketone Bodies; [Classes/Hours: 5]

Amino acid Metabolism: Biosynthesis and degradation; Branched Chain amino acid metabolism, Urea Cycle. [Classes/Hours: 5]

Nucleotide metabolism: Types of Nucleotides-structural details. Purine and Pyrimidine synthesis and breakdown. Salvage Pathway and De novo nucleotide biosynthesis. Nucleotides in Cancer Metabolism. Pathways and their regulations. [Classes/Hours: 7]

Clinical biochemistry: Normal Cell metabolism versus Cancer Metabolism. Immunometabolism, Metabolic adaptations. Metabolic Syndrome, Diabetes Insipidus and Mellitus, Hyperlipidemia. [Classes/Hours: 7]

Suggested Reading:

- Principles of Biochemistry: Lehninger, Nelson and Cox; W.H. Freeman; 5th edition; 2008.
- Biochemistry: Lubert Stryer; W. H. Freeman; 7th Edition; 2010.
- Biochemistry by Donald Voet, Judith G. Voet; Wiley; 4th edition; 2010.
- Harpers Illustrated Biochemistry, Murray, Bender, Botham, Weil

BIO 404: Neurobiology (DE, *Credit*, 4)

Course Contents:

I. **Structural Neuroanatomy:** Brodmann classification of Cortical, cytoarchitecture; structural architecture of hippocampus, Peripheral Nervous System, Cranial nerves: Nuclei, functional components and distribution of cranial nerves. Cerebrum: External features, functional areas of cerebral cortex. White matter of cerebrum: Types of fibres: Fiber connectivity, Projection Tracts, Commissural Tracts and Association Tracts, Internal capsule. Ventricular system: Parts and Boundaries of lateral, third ventricles. Circulation and formation of cerebrospinal fluid. Choroid plexus and fissure. Diencephalon Thalamus: External features, internal structure, connections. Basal ganglia: Nuclei, Limbic system: Components, connection, functions. Blood supply of brain, Blood brain barrier.

II. **Neurons and glia:** Cajal & Golgi and the history of neuron, The neuron doctrine and the reticular theory, Types of neurons, structure and function. Pyramidal Neurons, Mossy Fibers, Stellate Neurons, Types of glial cells and function, Myelin sheath.

III. **Functional Neuroanatomy:** Introduction to various terminologies with reference to the CNS (Brief), Anatomical localization of various functional regions, Resting state brain Activity (focused on default mode netrwork), Choroid plexus and CSF composition, Homunculus (Sensory and Motor) v), Speech and associated areas (Broca's and Wernicke's)

IV. **Neurotransmitters and Neurotransmission:** Transporters and Receptors. Ion Channels, Ionic potentials, depolarization. Excitatory and Inhibitory Synapses Excitatory Receptors: NMDARs, AMPA. Metabotropic. GABAa and GABAb receptors.

V. **General Principles of Sensory Systems:** Transduction, Sensory encoding, Neural pathways, Receptive fields, Topographic maps. Touch - Different kinds of receptors, Receptive field, Response properties, Innervation.

VI. **Introductory Computational Methods to study Brain Signals:** Determining brain structure and volume, Basics of Machine Learning methods in Brain Health, Feature Extraction Methods, Predictive algorithms, EEG and MRI data reading.

Suggested Books:

- Neuroscience, edited by Purves, Augustine, Fitzpatrick, Hall, LaMantia, Mooney, Platt and White. Sinauer (2018) Sixth Edition.
- Neuroscience: exploring the brain. Bear, M., Connors, B.W. and Paradiso, M.A. 3rd edition Lippincott, Williams and Wilkins (2001)
- Principles of Neural Science by Kandel
- Development of the Nervous System by Sanes (few chapters).

BIO 405: Biology Laboratory III (*Credit*, 3)

Course Contents:

Course Content: Biochemistry, Neurobiology, Genetics, Bioinformatics

1. LDH and ROS assays in mammalian cells (Biochemistry-II)
2. B-Gal Senescence Assay: Identification and quantification of Senescent cells (Biochemistry-II)
3. Cellular Metabolite Isolation and Quantification using NMR Spectroscopy (Biochemistry-II)
4. Protein quantification and western blotting. (Biochemistry-II)
5. Amino acid Titration curve to determine Isolelectric Point. (Biochemistry-II)
6. Dose response curve of Acetylcholine: Kymograph experiment quantifying contractile response of Frog's Rectus abdominus muscle (Neurobiology)
7. Y-Maze experiment to evaluate Cognition associated with Working memory and spatial navigation ability (Neurobiology)
8. Immunohistochemical methods for observing neuronal and glial subtypes (Neurobiology)
9. Transposon Mutagenesis and mapping of Transposon insertion. (Genetics)
10. Library preparation for ChIP seq and validation using qPCR. (Genetics)
11. Bioinformatics (hands-on training and practical sessions on specific topics covered in the course BIO-402) (Bioinformatics)

Suggested Reading:

BIO 406: Cancer Biology (*Credit,* 3)

Course Contents:

Section I: Introduction to Cancer Biology (6 classes)

· Aetiology and Epidemiology: History/Mechanisms that lead to cancer (2 class)
· Cell division: aneuploidy, polyploidy and chromosomal translocations, consequential uncontrolled growth and cancer; Nature of cancer (4 class)

Section II: Cancer Genetics (8 classes)

· Tumorigenesis: Environmental/Lifestyle/Genetics (1 class)
· Carcinogens, DNA damage and mutagenesis; Inherited susceptibility to cancer (2 class)
· Genomic integrity and development of cancer; Cancer cell cycle and tumor suppressor proteins (2 class)
- Cellular Oncogenes (1 class)
- Tumor viruses and mechanisms of oncogenesis (2 class)

Section III: Cancer Epigenetics, Signalling Pathways and Metabolism (12 classes)

- Hallmarks of cancer: Cell cycle, Metabolic deregulation, Cell signaling mitogens and dysregulation of pathways in cancer (5 class)

Growth factors and associated signaling pathways in cancer, (3 class)
Metastasis, (2 class)
TME: Immune cells, cytokines and growth hormones (1 class)

Section IV: Cancer Diagnosis, Therapeutics, Toxicology (6 classes)

Pathology: Detection/Diagnosis (2 classes)
Therapeutic strategies: Signalling pathways, Immune system, Genetic and Epigenetic alterations, Energetics (2 classes)
Future of cancer biology: Success in terms of early diagnosis, prevention, drug targets, challenges such as heterogeneity of cells, tumour/stroma cross talk (2 classes)

Suggested Reading:

Hallmarks of cancer (review by Hanahan and Weinberg (2011), Cell, 144: 646-74)
The biology of cancer (RA Weinberg)
Introduction to the cellular and molecular biology of cancer (Selby and Knowles)

BIO 410: Advanced Genetics (*Credit,* 4)

Course Contents:

Mendelian, Non-Mendelian Genetics:
Linkage, Crossing Over: Basic Understanding of deviations from Mendel's ratios. Crossing over, Interference. Analysis of unordered tetrads. The importance of Poisson distributions in modelling stochastic events (with special reference to modelling crossing over frequencies). Mapping functions, Haldane and Kosambi mapping functions. Genetic and Physical maps. Mapping Human disease genes; LoD score analysis.

Genetic Phenomena and their basis:
Maternal inheritance, Extra-nuclear inheritance, Sex Linked Inheritance: Historical description of these phenomena, current explanations for the same. Genetic disorders associated with all three phenomena.

Epigenetics, Dosage Compensation (DC), Genomic Imprinting (GI):
A brief introduction to the histone modifications, DNA modifications. Experiments (primarily involving yeast and ciliates) which provided evidence for histone modifications.
Genetic Experiments leading to the concept of dosage compensation (Muller, Mukherjee and others). Molecular biology associated with DC (H4K16ac), in Drosophila. Models of DC in worms and mice.
The role of Xist in mediating silencing, ICR's Disorders associated with GI, Prader-Willi and Angelman's syndrome(s).

Basic Prokaryotic Genetics: Brief revision of Conjugation, Transformation and Transduction. Genetics of bacterial phages.

a. Basic structure of Bacterial transposons. What are the different types of transposons and how are they related? The use of bacterial transposons for mutagenesis.
b. Introduction of DNA into mammalian systems; creating knock-out and knock in strains. Strategies for conditional as well as tissue specific induction of genes (Cre-LoxP systems, FLP-FRT system). RNAi and shRNA based knock down strategies.
c. To briefly describe functional as well as positional cloning in context of mapping human disease genes.
d. Molecular Cloning: Plasmids, their organization and markers required. Vectors based of bacteriophages Phagemids, Cosmids, their features, in vito virion assembly. Eukaryotic Vectors: BAC's and YAC's (Bacterial and Yeast Artificial Chromosomes), YEP's (Yeast Episomal Plasmids), YIP's (Yeast Integrative Plasmids). Certain other eukaryotic expression systems.
e. Genomics and Next Generation Sequencing: Basic idea behind library generation: (i) Genomic libraries (STS's) and (ii) cDNA libraries, chromosome walking (EST's). NGS methods; including use of reversible terminators, techniques for SBS (Sequencing by Synthesis), droplet PCR's. (i) Pyrosequencing (ii) Illumina sequencing (iii) Ion torrent (iv) SOLID and Nanopore based methods.
f. Genetic markers: RFLP's, AFLP's and SNP's. FISH

The utility of the following Model Organisms will be discussed: *Escherichia coli, Arabidopsis thaliana, Caenorhabditis elegans, Drosophila melanogaster* (Genetic Complementation. Genetic Mapping. Genetic screens as a basis for functional genomics. Deficiencies, EMS & X-ray based mutagenesis screens. Creating alleles. Enhancer traps, EP-Lines, RNA-inheritance, Nusslein-Volhard & Weischaus Zygotic and Maternal Screens. *Mus musculus* yeasts and other filamentous fungi.

Suggested Reading: Introduction to Genetic Analysis (Griffiths), Genetics (Snustad and Simmons), Genetics (Hartl and Clark), Genomes TA Brown. Human Molecular Genetics, Strachan and Read Gene Cloning TA Brown.

The art and design of genetic screens series (Nature Review Genetics) St Johnston D., Nature Reviews Genetics (3): 176–188 (2002)

- Jorgensen EM and Mango SE Nature Reviews Genetics (3): 356–369 (2002)
- Patton EE and Zon LI Nature Reviews Genetics (2): 956–966 (2001)
- Casselton LE and Zolan M Nature Reviews Genetics volume 3, pages 683–697 (2002)

BIO 412: Developmental Biology (*Credit,* 4)

Course Contents:

History of Embryology and Developmental Biology.

Cell specification, chromosomal theory of inheritance and concept of genome equivalence.

Meiosis, gametogenesis (animals), fertilization and cleavage, morphogen gradients, differentiation, Cell-Cell Communication, cell fate and lineage determination.

Evolutionary Developmental Biology: Modularity, Recruitment and Molecular Parsimony. Developmental constraints on evolution of body forms.

Role of morphogens and their gradient in axis patterning and determination.

Concept of anterior-posterior, dorso-ventral and medio-lateral axis formation;

Development of model organisms like *D. melanogaster*, *C. elegans*, *X. laevis*, *G. gallus* and *M. musculus*

Metamorphosis and Regeneration.

Suggested Reading:

- Developmental Biology: Scott F. Gilbert; Sinauer Associates Inc; 2010.
- Essential Developmental Biology: J. Slack; Wiley Blackwell Scientific. 2nd edition; 2005.

BIO 413: Stem Cell Biology (DE, *Credit,* 3)

Course Contents:

I.Introduction to Stem Cell Biology (6 classes)

- Stem Cells: Definition and Characteristics
- Pluripotency and Differentiation
- Types of Stem Cells: Embryonic, Adult, and Induced Pluripotent Stem Cells (iPSCs)

II.Embryonic Stem Cells (6 classes)

- Molecular Mechanisms of Pluripotency
- Epigenetic Modifications and Stem Cell Renewal
- Spontaneous and Directed Differentiation
- Embryonic Carcinoma Cells (ECC) and Embryonic Germ Cells (EGC)

III.Adult Stem Cells (6 classes)

- Stem Cell Niche and Microenvironment
- Localization and Identification of Stem Cells in Various Tissues and Organs
- Examples from Skin, Intestine, Blood, Brain, Retina, and Muscle

IV.Techniques in Stem Cell Biology (6 classes)

- Methods for Identifying and Isolating Stem Cells
- Induced Pluripotent Stem Cells (iPSCs) and Yamanaka Factors
- Lineage Tracing and Tracking Stem Cell Differentiation

V.Therapeutic Strategies and Regenerative Medicine (5 classes)

- Cancer Stem Cells: Implications in Cancer Therapy
- Disease Modeling using Stem Cells
- Applications of Stem Cell and Tissue Engineering in Skin Grafts, Corneal and Retinal Regeneration
- Stem Cell Therapy for Sickle Cell Anemia, Central Nervous System Repair, Heart Regeneration, and Diabetes

VI.Ethical Considerations and Guidelines (3 classes)

- Ethical Issues in Stem Cell Research
- Ethical Guidelines and Regulatory Frameworks
- Responsible Conduct in Stem Cell Research

Suggested Reading:

Essentials of Stem cell Biology (Robert Lanza)
Research papers and review articles

BIO 416: Biology Laboratory IV (*Credit,* 3)

Course Content: Dev Biology, Immunology

- Differential leukocyte count
- Enzyme linked immunosorbent assay
- Radial immunodiffusion
- Double immunodiffusion test
- Immunofluorescence

- Cuticle Mount to observe Denticular bands in Drosophila embryos or first instar larva
- Reporter Gene Assay, B-gal staining for wingless expression (might replace with in situ)
- Chick embryo staging
- RNA isolation, Semi quantitative PCR
- qRT-PCR
- Tutorial on Gene Expression Analysis
- Spectroscopy

Suggested Reading:

1) Sambrook and Russell: Molecular Cloning.

2) T. A. Brown: Gene cloning and DNA analysis

3) Glick, Pasternak and Patten: Molecular Biotechnology

BIO 418: Advanced Evolutionary Biology (*Credit,* 3)

Course Contents:

1. Review of Basic concepts of Evolution.
2. Population genetics. Advanced topics in H-W principle- Infinite alleles, X-linkage, Models of selection (additivity, dominance, overdominance, underdominance), viability selection, gametic selection; Mutation, Gene flow, Genetic Drift, Effective population size. Linkage disequilibrium and recombination.
3. Quantitative Genetics: Metric traits or continuous traits. Partitioning of phenotypic variance. Breeding value. Additive variation. Heritability. Artifical selection. Trade-offs. Quantitative Trait loci.
4. Molecular Population genetics Neutral Theory, Coalescence and genealogies. Molecular clock, tests of neutral theory. Molecular Phylogenetics, QTL mapping.
5. Origin and Evolution of Sex. Cost of sex and benefits. Sexual Conflict and Sexual Selection.
6. An overview of Life History Evolution. Trade-offs, Aging, Density dependent selection, Frequency dependent selection.
7. Introduction to macroevolution. Evolution of humans, horse, three spined stickleback.
8. Sociobiology and evolutionary psychology.
9. Evolution, culture and health.

Suggested Reading:

1. Freeman, S., & Herron, J. C. (2007). *Evolutionary analysis* (No. QH 366.2. F73 2007). Upper Saddle River, NJ: Pearson Prentice Hall.
2. Hall, B., & Strickberger, M. W. (2008). *Strickberger's evolution*. Jones & Bartlett Learning.
3. Hartl, D. L., Clark, A. G., & Clark, A. G. (1997). *Principles of population genetics* (Vol. 116). Sunderland, MA: Sinauer associates.
4. Hedrick, P. (2011). *Genetics of populations*. Jones & Bartlett Learning.
5. Templeton, A. R. (2021). *Population genetics and microevolutionary theory*. John Wiley & Sons.
6. Falconer, D. S. (1996). *Introduction to quantitative genetics*. Pearson Education India.

BIO 425: Comparative and Evolutionary Genomics (*Credit,* 3)

Course Contents:

Concepts in Genome Mining: Basic concepts and approaches in genome mining; varied approaches in comparative genomics analysis between the prokaryotic and eukaryotes,
Phylogenomic approaches: Phylogenomic approaches in creating large-scale species trees (examples with Bacteria, Archaea, and Eukaryotes) and evolutionary dating; Alignment correction using statistical inference approaches and overcoming of tree artefacts. Estimation of phyletic profiles and approaches in tracing the evolution of gene families to LUCA (as well as Pre-LUCA), LECA and LHCA, among others;
Comparative genomics approaches: Establishing functional landscape of gene families and systems using genomic contextual information (Gene neighborhoods); Retrieval of gene-neighborhoods in prokaryotes using PERL scripts; Functional network reconstruction using gene neighborhoods and protein domain architectures; Whole Genome alignment and Synteny inference; Identifying shared and unique genome content; Synteny to infer genome organization and constraint; Tools for Synteny computation and alignment; Orthology and Paralogy corrections using Synteny;
Estimation of Lineage specific expansions and HGT events: Curation of lineage specific expansions of gene families and analysis using CAFÉ; Identification of horizontal gene transfer events using a standalone PERL Script;
Functional divergence and Selection analysis: Estimation of functional divergence after gene duplication (Type-1 Divergence and Type-II divergence) using the Diverge software package; Estimating the rate of evolution in protein families using positional entropy analysis using R; Selection analysis on protein families and inferences on the evolution of structural scaffold;
Arms-Race and Co-evolutionary trends: Using host and viral proteins as exemplars: Vertebrate viruses and estimation of viral diversification using phylogenomic approaches; Early vertebrate whole genome duplication and estimation of when and where novel genes arose; Arms-race between proteins deployed by vertebrate hosts and counter defense mechanisms by vertebrate viruses: How to study such Co-evolutionary trends of fast-evolving proteins?
Genome annotation pipelines: NCBI Prokaryotic genome annotation pipelines; NCBI Eukaryotic genome annotation pipeline; Genome annotation pipelines such as Augustus, Maker and other pipelines.

Suggested Reading:

Sequence, Evolution, Function: Computational Approaches in Comparative Genomics. by Eugene V. Koonin and Michael Galperin.
Introduction to Evolutionary Genomics, Saitou, Naruya
Evolution by Gene Duplication. Susumu Ohno
Evolutionary Genomics and Systems Biology, Editor(s): Gustavo Caetano-Anollés
Statistical Theory and Methods for Evolutionary Genomics. Xun Gu
Evolutionary Systems Biology. Editors: Soyer, Orkun S. (Ed.)
Phylogenomics An Introduction by Christoph Bleidorn
Evolutionary Genomics Statistical and Computational Methods, Volume 2 Editors: Anisimova, Maria (Ed.)
Foundations of Comparative Genomics. Arcady R. Mushegian (Author). Academic Press; 1st edition (24 May 2007)

BIO 426: Neuroimaging (*Credit,* 3)

Course Contents:

Magnetic Resonance Imaging- Applications in Brain Structure Investigations: Nuclear properties, Longitudinal Relaxation (T1), Transverse Relaxation (T2) and Spin Echoes. Fourier Transformation and FID Manipulation, Magnetic Field Gradients, Slice Selection and Frequency Encoding, Phase Encoding, T1 and T2 Relaxation Mapping, Magnetic Field B_0 and B_1 Mapping, Basic Imaging Sequences: Spin-echo and Gradient Echo, T1 weighted imaging, T2/T2*-weighted imaging, Fluid Attenuated Inversion Recovery (FLAIR), Proton Density Imaging (PD), Susceptibility Weighted Imaging (SWI), Echo-planar Imaging.

Functional Magnetic Resonance Imaging: Functional Neuroimaging Principle, Neuronal Activity and Hemodynamics, Blood-Oxygen Level Dependent fMRI, T2 and T2* weighted BOLD signal changes, Block designs and Even Related Paradigms, Echo-planar fMRI acquisition methods: Gradient echo and Spin echo, Functional Connectivity Analysis (DMN, ECN, SN, DAN, SMN).

Perfusion and Diffusion MRI: Cerebral Perfusion and Neurovascular Coupling, Cerebral Blood Volume (CBV) and Cerebral Blood Flow (CBF), Exogenous Perfusion MRI, Dynamic Susceptibility Contrast Enhanced perfusion MRI, Endogenous Perfusion MRI, MR Perfusion: Acquisition and Processing Methods, Arterial Spin Labeling (ASL) MR Perfusion: Continuous ASL and pseudo-Continuous ASL (pCASL). Diffusion Tensor Imaging and derived scalars, MR Tractography and Biological applications.

Magnetic Resonance Spectroscopy and Spectroscopic Imaging: Introduction to in vivo MR Spectroscopy, Localization methods: Single-voxel MRS, STEAM, PRESS, LASER, Introduction to Spectroscopic Imaging (CSI):2D and 3D, Spectral Editing, Advanced Pulse Sequences and Techniques, Biomedical applications of MRS, Processing MRS Data: Analysis and Quantification, Advanced Pulse Sequences and Techniques. Matlab basics and Numerical Simulations.

Suggested Reading:

Malcom H. Levitt, Spin Dynamics, Basics of Nuclear Magnetic Resonance, 7th Edition, WILEY, April 2008.

Matt Bernstein, Kevin King, Xiaohong Zhou, Handbooks of MRI Pulse Sequences, 1st Edition, ELSEVIER, 2004

Richard B. Buxton, Introduction to Functional Magnetic Resonance Imaging: Principles and Technique, 2nd Edition, Cambridge Press

Robin A. de Graaf; In vivo NMR Spectroscopy Principles and Techniques, 3rd Edition, WILEY, 2008

BIO503: Metabolic Engineering (BIO503/EBI503)

Course Contents:

Module 1 [15 Lectures]

Introduction to Metabolic Engineering: Definition and scope of metabolic engineering, Importance and applications in biotechnology and medicine. [3 Lectures]

Fundamentals of Cellular Metabolism and their regulation: Overview of cellular metabolism. Insulin production as model of metabolic engineering. [3 Lectures].

Metabolic pathways for production of organic acids, amino acids, alcohol, monomers, and polymers etc. [3 Lectures].

Metabolic Regulation, Feedback inhibition, Covalent modification: Phosphorylation, dephosphorylation, acetylation. [3 Lectures].

Hormonal regulation of metabolism. Metabolic disorders and human diseases. Cellular redox and energy balance. [3Lectures].

Module 2 [15 Lectures]

State-of-the-art techniques and approaches for Metabolic Engineering: Fluxomics and Metabolomics. [3 Lectures].

Metabolic flux analysis using stable isotopes and measurement of steady state metabolite concentrations by mass spectrometry (Gas chromatography-mass spectrometry, Liquid chromatography-mass spectrometry). [3 Lectures].

Integration of experimental data with metabolic models, Data Analysis in Metabolomics. [3 Lectures].

Statistical methods for metabolomics data. Multivariate analysis techniques e.g. PCA, PLS-DA. [3 Lectures].

Pathway analysis and interpretation. Multi-OMICS integration. [3 Lectures].

Module 3 [12 Lectures]

Applications of Metabolic Engineering through pathway manipulation: Biofuel Production: Engineering microbial hosts for enhanced biofuel production. Case studies: Ethanol, biodiesel, and advanced biofuels. [3 Lectures].

Pharmaceutical Applications: Amino acid production via metabolic engineering, Antibiotic synthesis pathways and optimization strategies, Vitamin synthesis through microbial fermentation, Case studies: Antibiotics, vitamins, and pharmaceutical intermediates. [6 Lectures].

Industrial Enzyme Production and Optimization: Metabolic engineering approaches for enzyme production, Strategies for optimizing enzyme activity and stability, Case studies: Enzyme cocktails for biomass conversion and biocatalysis.

[3 Lectures].

Reference Books

1. Metabolic Engineering: Concepts and Application by Jens Nielsen, Gregory Stephanopoulos, Sang Yup Lee. Wiley (2021).

2. Metabolic Engineering: Principles and Methodologies. Aristos A. Aristidou, Gregory Stephanopoulos, Jens Nielsen. Academic Press (1998).

3. Systems Metabolic Engineering. Christoph Wittmann, Sang Yup Lee. Springer (2012)

4. Pathway Analysis and Optimization in Metabolic Engineering. Néstor V. Torres and Tenerife Eberhard O. Voit. Cambridge University Press (2002).

BIO505: Cellular Fuel and Cellular Communication

Course Contents:

Module 1 [15 Lectures]

Cellular fate of nutrients metabolism: Glucose metabolism; Glucose transporters, Glycolysis, TCA cycle, glycogen synthesis, gluconeogenesis, and glycogenolysis. Metabolism of amino acids and proteins, Metabolism of lipids; oxidation of fatty acids, ketone bodies, ketosis, de-novo synthesis of fatty acids, Metabolism of nucleic acids; Biosynthesis, and breakdown of purine and pyrimidine nucleotides, Salvage pathways.

Module 2 [15 Lectures]

The cellular internet: The essential elements of cellular transduction mechanisms that allow signaling from the cell surface to the nucleus; reception, transduction, and response. Types of signals: Endocrine, Paracrine, Neural, and Juxtacrine. Receptors and receptor trafficking, Types of Cell surface receptors: G-protein coupled receptors, Receptor tyrosine kinase receptors, Cytokine receptors and Non-tyrosine kinase receptors Toll-like receptors, Ligand-gated ion-channels receptors, Receptors with other enzymatic activities. Second messengers; Type of secondary molecules; diacylglycerol, phosphatidylinositols, cAMP, cGMP, IP3, and Ca2+.

Module 3 [12 Lectures]

Hormone and Endocrine system: Body's long-distance regulator; Hormones, Local regulators, Neurotransmitters, Neurohormones, and Pheromones. Type of hormones, Major endocrine gland, Hormone transport, Hormone receptors - cell surface and intracellular, Mechanisms of hormone action, Neuroendocrine interactions.

Suggested Reading:
Text Book:

1. Molecular Biology of the Cell (6th edition) by Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff , Keith Roberts , Peter Walter

2. Lehninger Principles of Biochemistry (7th edition) by David L. Nelson, Michael M. Cox

3. Endocrinology (6th Edition) by Mac Hadley (Author), Jon E. Levine (Author), Pearson Prentice Hall Publication can be proposed for the endocrinology portion.

Reference Book

1. Campbell Biology (10th Edition) by Jane B. Reece, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, Robert B. Jackson, Benjamin Cummings, 2013

BIO 424: Techniques in Biology (*Credit, 4*)

Course Contents:

1. Genes and genomes:
    - Gene identification and genome assembly:
    - Sequencing techniques:
    - DNA library prep:
    - NGS (different platforms):
    - Genome editing CRISPR, TALENS, Z-Fingers:
    - QTL Analysis:
    - GWAS:
    - Marker assisted Selection (MAS):
2. Genetics
3. Gene expression
    - RNA In situ & FISH:
    - qPCR:
    - ChIP & ChIPseq:
    - Ribosome profiling:
    - Northern & Southern blotting:
    - Microarray:
    - RNA seq & Introduction to data analysis:
    - Reporter Assays:
    - RNAi & Artificial MicroRNA:
4. Cell biology
    - FACS:
    - Imaging (confocal, FLIM, FRET, FRAP etc):
5. Protein Sequence, Structure, Function, interaction
    - Protein purification, Protein Analysis (2DGE, Western blotting):
    - Optical methods for protein interaction analysis (ITC):
    - Hydrodynamic properties (DLS):
    - ITC
    - DSC:
    - Phosphoproteomics:
    - Protein Array
6. Molecular Spectroscopy

    Absorbance and fluorescence spectroscopy, Beer-Lambert's law, Chromophore, Fluorophore.

    Mass spectrometry, basics, design principles.

    Elemental metabolomics-qualitative and quantitative

    Protein analysis by mass spectrometry- Mass and PTM analysis, Proteomics.

Suggested Reading:

Sambrook and Russel, Molecular cloning: A Laboratory Manual

Principles and Techniques of Biochemistry and Molecular Biology, Wilson and Walker

EBI301: Recombinant DNA technology

Course Contents:

Total: Lectures: 33; Lab hours: NA; Tut: 2; SS: 6 Credits: 3

I. Introduction to Genetic Engineering and Synthetic Biology

Overview of genetic engineering and synthetic biology

- Historical perspective and current advancements.
- Basics and principles of gene cloning
- Basics and principles of gene synthesis
- Basics and principles of artificial gene synthesis (Lectures: 6, Lab/Practical Session Hours: NA, Tutorials: NA)

II. Gene Editing and Genome Engineering

- Principles and techniques of gene editing (e.g., CRISPR-Cas9 , TALENs)
- Applications of gene editing in engineering biology (Lectures: 4, Lab/Practical Session Hours: NA, Tutorials: 3)

III. Genetic Circuits and Synthetic Gene Networks

- Design principles and components of genetic circuits
- Engineering synthetic gene networks for specific functions (Lectures: 4, Lab/Practical Session Hours: NA, Tutorials: NA)

IV. Synthetic Biology in Medicine

- Applications of synthetic biology in medicine and healthcare (e.g., gene therapy, drug discovery)
- Challenges and future prospects

(Lectures: 4, Lab/Practical Session Hours: NA, Tutorials: NA)

V. Synthetic Biology in Agriculture and Environmental Engineering

- Applications of synthetic biology in agriculture (e.g., crop improvement, pest control)
- Environmental applications of synthetic biology (e.g., bioremediation, biofuels) (Lectures: 4, Lab/Practical Session Hours: NA, Tutorials: NA)

VI. Computational Design and Modeling of Synthetic Biological Systems

- Introduction to computational tools for designing and modeling synthetic biological systems (Lectures: 3, Lab/Practical Session Hours: NA, Tutorials: 3)

VII. Ethical Considerations and Safety in Genetic Engineering

- Ethical considerations in genetic engineering and synthetic biology
- Safety protocols and regulations in laboratory and industrial settings (Lectures: 4, Lab/Practical Session Hours: NA, Tutorials: NA)

VIII. Integration of Engineering Principles in Biological Systems

- Principles of systems engineering applied to biological systems

- Engineering design methodologies for complex biological challenges (Lectures: 4, Lab/Practical Session Hours: NA, Tutorials: NA)

Suggested Reading:

1. "Molecular Biology of the Gene" by James D. Watson, et al.
2. "Synthetic Biology: A Primer" by Paul S. Freemont and Richard I. Kitney.
3. "Principles of Gene Manipulation and Genomics" by Sandy B. Primrose and Richard M. Twyman.
4. "Systems Biology: Properties of Reconstructed Networks" by Bernhard Ø. Palsson.
5. "Biohacking: Synthetic Biology in the Lab" by Patrik D'haeseleer.

EBI302: Applications of Genetic Engineering and Genome Editing

Course Contents: **Total Lectures: 28 (1.5 hrs)**

I. Introduction to history and basics of genetic engineering. Key concepts including definitions, milestones, scope, and the evolution of genetic engineering techniques. Benefits and limitations.
(Lectures: 2)

II. Tools and techniques for manipulation of genomes of different model organisms used in biology and applied research- *E. Coli*, *Saccharomyces crevices*, *Drosophila*, *Arabidopsis*, Mice etc.
(Lectures: 6)

III. Genetic engineering and genome editing in microbes – a powerful way to tailor-make important products for various applications. Applications in microbial production, such as tailoring microbes for industrial enzymes, biofuels, and bioplastics. Production of therapeutic molecules like insulin, antibiotics, and vaccines. Advances in synthetic biology, including the design and assembly of synthetic genomes. Environmental applications such as bioremediation and bio-mining, and health applications like developing microbial consortia for probiotics
(Lectures: 4)

IV. Genetic engineering and genome editing in animals – to create or alter specific traits. Generation of transgenic animals such as Drosophila, zebrafish, and Mouse. Creation of knockout and knock-in models in cell lines for disease studies. Biomedical applications, including development of organoids and xenotransplantation models.
(Lectures: 4)

V. Genetic engineering and genome editing of agricultural crops – target traits such as yield, disease resistance, biotic and abiotic stress tolerance. Case studies like golden rice, Bt cotton, and non-browning apples. Discussion of regulations, focusing on global policies and debates around genetically modified crops.
(Lectures: 4)

VI. Overexpression of genes in heterologous systems; advantages and disadvantages of different heterologous systems for production of proteins, enzymes, monoclonal antibodies, vaccines; gene pharming and human pharmaceutical proteins. Vaccine development approaches such as mRNA, subunit, and DNA vaccines. Virus-like particles, their engineering and production in heterologous systems like *E. coli*, yeast, and insect cells, and applications in vaccines and nanomedicine.
(Lectures: 6)

VII. Bioethics and biosafety guidelines and protocols. Handling and disposal of genetically modified organisms. Understand the ethical, moral and legal issues associated with usage of Genetically Engineered Organisms. Emerging threats, including genetically engineered viruses in bioterrorism and challenges in addressing zoonotic diseases and global pandemics.
(Lectures: 2)

Suggested Reading:

1. Sambrook and Russell: Molecular Cloning.
2. T. A. Brown: Gene cloning and DNA analysis
3. Glick, Pasternak and Patten: Molecular Biotechnology
4. Genetic Engineering of Animals 1986 ISBN : 978-1-4684-5112-2

EBI303_ Bioprocess Technology and Fermentation

Course Contents:

Total: Lectures: 33; Tut: 8; Credits: 3

I. Introduction to Bioprocess Technology

Overview of bioprocessing and its significance in engineering biology

- Historical perspective and milestones in bioprocess technology
- Ethical considerations and regulatory frameworks

(Lectures: 4, Tutorials: 0 hours)

II. Upstream Processing

- Raw material selection and preparation
- Cell culture techniques and optimization
- Media formulation and optimization (Lectures: 4, Tutorials: 1 hour)

III. Downstream Processing

- Harvesting and cell separation techniques
- Recovery and purification of target products
- Product formulation and final product quality assessment (Lectures: 5, Tutorials: 1 hour)

IV. Fermentation Design and Optimization

- Fermentation process design and analysis
- Kinetics of microbial growth and product formation
- Optimization techniques for improved fermentation performance (Lectures: 6, Tutorials: 3 hours)

V. Bioreactor Engineering

- Types of bioreactors and their characteristics
- Bioreactor design considerations including fluid dynamics, Fluid flow patterns in bioreactors, Residence time distribution analysis
- Mixing, aeration, and agitation in bioreactors
- Mixing and heat transfer in bioreactors (Lectures: 6, Tutorials: 3 hours)

Process Control and Scale-up

- Monitoring and control of bioprocess variables
- Strategies for process optimization and automation

Scale-up principles and challenges in bioprocessing (Lectures: 4, Tutorials: NA)

VII. Commercial Production of Bio-based Products

- Economics and business aspects of bioprocess technology
- Environmental sustainability considerations

Case studies of successful commercial bioprocesses (Lectures: 4, Tutorials: NA)

Suggested Reading:

1. "Bioprocess Engineering: Basic Concepts" by Michael L. Shuler, Fikret Kargi, and Matthew DeLisa
2. "Principles of Fermentation Technology" by Peter F. Stanbury, Allan Whitaker, and Stephen J. Hall
3. "Biochemical Engineering and Biotechnology" by Ghasem Najafpour
4. "Bioprocessing: An Overview" by Pauline M. Doran
5. "Industrial Microbiology: An Introduction" by Michael J. Waites, Neil L. Morgan, John S. Rockey, and Gary Higton

EBI304 Structure guided drug discovery

Course Contents:

Total: Lectures: 36; Lab hours: 14; Tut: 5; SS: NA Credits: 4

I. Introduction to Drug Design and Development

Drug Discovery as a Process
Target Identification and Validation
Role of Genomics, Proteomics,
and Bioinformatics Target
Validation
(Lectures: 5, Lab/Practical Session Hours: 3, Tutorials: NA)

II. Drug targets

Membrane Proteins, DNA, RNA, and Enzymes
as Drug Targets Challenges in Obtaining Pure
and Correctly-Folded Proteins for Assays

(Lectures: 4, Lab/Practical Session Hours: 2, Tutorials: NA)

III. Lead Identification and Modification

Biological Assays: Lead Identification and High
Throughput Screening Lead Modifications and
Structure-Activity Relationships
Therapeutic Proteins as Biologics

(Lectures: 5, Lab/Practical Session Hours: 4, Tutorials: NA)

IV. Structure-guided Drug Design
Molecular Modeling and AI-based Structure Prediction Docking Software and Ligand-based Drug Design
Structure Determination Techniques: X-ray Crystallography, NMR Spectroscopy, and Cryo-EM Mass Spectrometry in Drug Design

(Lectures: 14, Lab/Practical Session Hours: 5, Tutorials: 5)

V. Drug Delivery
Bioavailability and Pharmacokinetics ADME Processes and Drug Bioavailability
Pro-drugs and Enhanced Drug Delivery

(Lectures: 4, Lab/Practical Session Hours: NA, Tutorials: NA)

VI. Pre-Clinical and Clinical testing
Pre-clinical Toxicology and In Vitro Toxicity Tests In Vivo Toxicity Tests and Safety Evaluation Clinical Trials and Trial Design
Ethics of Human and Animal Experimentation Intellectual Property and Commercial Considerations

(Lectures: 4, Lab/Practical Session Hours: NA, Tutorials: NA)

Suggested Reading:

1. Drug Discovery and Development; Technology in Transition. HP Rang. Elsevier Ltd 1st edition 2006.
2. Pharmacology in Drug Discovery. T. P. Kenakin. Elsevier, 1st Edition 2012.
3. An introduction to medicinal chemistry. G. L. Patrick. 5th Edition Oxford UK, Oxford University Press, 2013.
4. Crystallography Made Crystal Clear : A Guide for Users of Macromolecular Models. Gale Rhodes
5. Three-Dimensional Electron Microscopy of Macromolecular Assemblies: Visualization of Biological Molecules in Their Native State. Joachim Frank, Oxford University Press.
6. Understanding Nmr Spectroscopy. James Keeler. Wiley

EBI401: Stem Cell Biology and Regenerative Medicine

Course Contents:

Total: Lectures: 33; Lab hours: NA; Tut: 2; SS: 6 Credits: 3

I.Introduction to Stem Cell Biology

- Stem Cells: Definition and Characteristics
- Pluripotency and Differentiation
- Types of Stem Cells: Embryonic, Adult, and Induced Pluripotent Stem Cells (iPSCs)

(Lectures: 6, Lab/Practical Session Hours: NA, Tutorials: NA)

II. Embryonic Stem Cells

- Molecular Mechanisms of Pluripotency
- Epigenetic Modifications and Stem Cell Renewal
- Spontaneous and Directed Differentiation
- Embryonic Carcinoma Cells (ECC) and Embryonic Germ Cells (EGC)

(Lectures: 6, Lab/Practical Session Hours: NA, Tutorials: 3)

III. Adult Stem Cells

- Stem Cell Niche and Microenvironment
- Localization and Identification of Stem Cells in Various Tissues and Organs
- Examples from Skin, Intestine, Blood, Brain, Retina, and Muscle

(Lectures: 4, Lab/Practical Session Hours: NA, Tutorials: NA)

IV. Techniques in Stem Cell Biology

- Methods for Identifying and Isolating Stem Cells
- Induced Pluripotent Stem Cells (iPSCs) and Yamanaka Factors
- Lineage Tracing and Tracking Stem Cell Differentiation

(Lectures: 6, Lab/Practical Session Hours: NA, Tutorials: NA)

V. Therapeutic Strategies and Regenerative Medicine

- Cancer Stem Cells: Implications in Cancer Therapy
- Disease Modeling using Stem Cells
- Applications of Stem Cell and Tissue Engineering in Skin Grafts, Corneal and Retinal Regeneration
- Stem Cell Therapy for Sickle Cell Anemia, Central Nervous System Repair, Heart Regeneration, and Diabetes

(Lectures:8, Lab/Practical Session Hours: NA, Tutorials: NA)

VI. Ethical Considerations and Guidelines

- Ethical Issues in Stem Cell Research
- Ethical Guidelines and Regulatory Frameworks
- Responsible Conduct in Stem Cell Research

(Lectures: 3, Lab/Practical Session Hours: NA, Tutorials: 3)

EBI402: Neuroimaging

Course Contents:

Total: Lectures: 31; Lab hours: 11; Tut: 2; SS: NA Credits: 3

1. **Magnetic Resonance Imaging- Applications in Brain Structure Investigations:** Nuclear properties, Longitudinal Relaxation (T1), Transverse Relaxation (T2) and Spin Echoes. Fourier Transformation and FID Manipulation**,** Magnetic Field Gradients, Slice Selection and Frequency Encoding, Phase Encoding, T1 and T2 Relaxation Mapping, Magnetic Field B0 and B1 Mapping, Basic Imaging Sequences: Spin- echo and Gradient Echo, T1 weighted imaging, T2/T2*-weighted imaging, Fluid Attenuated Inversion Recovery (FLAIR), Proton Density Imaging (PD), Susceptibility Weighted Imaging (SWI), Echoplanar Imaging.

Practical and Tutorials: Brain Segmentation Toolbox: Freesurfer, FSL. Lesion segmentation, Brain Tumor Segmentation

(Lectures: 10, Lab/Practical Session Hours: 3, Tutorials: 1 hours)

2. Functional Magnetic Resonance Imaging: Functional Neuroimaging Principle, Neuronal Activity and Hemodynamics, Blood-Oxygen Level Dependent fMRI, T2 and T2* weighted BOLD signal changes, Block designs and Even Related Paradigms, Echoplanar fMRI acquisition methods: Gradient echo and Spin echo, Functional Connectivity Analysis (DMN, ECN, SN, DAN, SMN).

Practical and Tutorials: Hemodynamic Analysis Methods, DPARSB method of resting state functional connectivity. Methods of task-based brain function study

(Lectures: 8, Lab/Practical Session Hours: 2, Tutorials: 1 hours)

3. Perfusion and Diffusion MRI: Cerebral Perfusion and Neurovascular Coupling, Cerebral Blood Volume (CBV) and Cerebral Blood Flow (CBF), Exogenous Perfusion MRI, Dynamic Susceptibility Contrast Enhanced perfusion MRI, Endogenous Perfusion MRI, MR Perfusion: Acquisition and Processing Methods, Arterial Spin Labeling (ASL) MR Perfusion: Continuous ASL and pseudo-Continuous ASL (pCASL). Diffusion Tensor Imaging and derived scalars, MR Tractography and Biological applications.

Practical and Tutorials: Calculation of diffusion flux, displacement, and diffusivity. Demonstration of White fiber tracking. Brain Blood Flow Quantification (Lectures: 5, Lab/Practical Session Hours: 2, Tutorials: NA)

4. **Magnetic Resonance Spectroscopy and Spectroscopic Imaging:** Introduction to *in vivo* MR Spectroscopy, Localization methods: Single-voxel MRS, STEAM, PRESS, LASER, Introduction to Spectroscopic Imaging (CSI):2D and 3D, Spectral Editing, Advanced Pulse Sequences and Techniques, Biomedical applications of MRS, Processing MRS Data: Analysis and

Quantification, Advanced Pulse Sequences and Techniques. Matlab basics and Numerical Simulations.

Practical and Tutorials: Demonstration of Hyperfine splitting. Metabolic Signal pattern Analysis. LC Model based Quantification of Metabolite concentration (Lectures: 8, Lab/Practical Session Hours: 4, Tutorials: NA)

1. Malcom H. Levitt, Spin Dynamics, Basics of Nuclear Magnetic Resonance, 7th Edition, WILEY, April 2008.
2. Matt Bernstein, Kevin King, Xiaohong Zhou, Handbooks of MRI Pulse Sequences, 1st Edition, ELSEVIER, 2004
3. Richard B. Buxton, Introduction to Functional Magnetic Resonance Imaging: Principles and Technique, 2nd Edition, Cambridge Press

Robin A. de Graaf; In vivo NMR Spectroscopy Principles and Techniques, 3rd Edition, WILEY, 2008

EBI403: eBIO lab I

Course Contents:

1. Analysis of PDB file, visualization of Electron density map/ CryoEM map, Molecular docking tutorial and discussion.
2. Cloning of GFP or Taq polymerase (gene cloning in bacterial/ mammalian plasmids. PCR of target gene followed by restriction digestion and ligation into bacterial/mammalian plasmids. Clone confirmation by colony PCR/Insert release)
3. Transformation, Expression, and Purification of Taq polymerase.
4. Expression of target protein by SDS-PAGE and western blot.
5. SgRNA cloning: Perform the cloning of single-guide RNAs (sgRNAs) targeting specific genes using molecular cloning techniques.
6. Transfection of HEK293T cells with mCherry expression plasmid Estimation of transfection efficiency.

Suggested Reading:

Cold Spring Harbor Protocols

EBI404: eBIO lab II

Course Contents:

Neuroimaging

1) Perform Brain structure volume quantification

2) Perform white matter fiber identification and white matter tract quantification

3) Perform Radiomic Segmentation of Brain Tumors

4) Identifying and Quantitating Dopaminergic Neuronal sites: Neuromelanin based MR detection

Stem Cell Biology and Regenerative Medicine

1) ES cell maintenance and culture techniques
-Concept of feeder and feeder free culture, characterization of ES cell pluripotency by morphological and molecular marker analysis.
2) Embryoid bodies and staining for three germ layers- Generation of embryoid bodies and characterization
3) Cardioid culturing and characterization
4) Gene targeting in ES cells for transgenic purposes (theoretical aspects related to constructs and various approaches, gRNA designing and methods for targeting in ES cells)
5) Cancer Stem Cell Markers and characterization through 3D spheroidal culture system

Selected Readings:

Cold Spring Harbor Protocols

1) Sambrook and Russell: Molecular Cloning.

2) T. A. Brown: Gene cloning and DNA analysis

3) Glick, Pasternak and Patten: Molecular Biotechnology