Details of Biology Courses - Ashoka University

1st SEMESTER - Only from mandatory courses of the University.

2nd SEMESTER

Critical Thinking in Biology

The course is primarily intended as an introduction to the main conceptual framework of biology as a science - outlining the diversity, organization and fundamental principles of living systems. This course, more than anything, intends to spark the imagination of students and their thinking about how biological systems function and hence, lays a strong foundation for the subsequent courses.

Recommended reading:

What is Life? Erwin Schrodinger

Campbell and Reece: Biology

Major and minor core theory course:

Genetics

This course is designed to introduce the basic conceptual framework of genetics. The course will be taught with a historical timeline, introducing advances in the field of genetics as they occurred over time, with a strong emphasis on modern tools and techniques. Topics include Mendelian genetics: Mendel's law and examples; central dogma of life: the way genetic information is stored, retrieved, modified ; mitosis and meiosis; transcription and translation; mutation, epigenetics, model organisms: *Escherichia coli*, *Arabidopsis thaliana*, *Caenorhabditis elegans*, *Drosophila melanogaster* & *Mus Musculus;*

Recommended reading:

1. Anthony J F Griffiths et al., An Introduction to Genetic Analysis
2. Genetics: A Molecular Approach by Peter J Russell Peter J. Russell.
3. Watson et al., Molecular Biology of the Gene
4. Richard Knowles, Solving Problems in Genetics

Major core lab course:

Exploring life in the neighborhood

The goal of this course is to introduce students to their local ecosystem and biodiversity. It will involve both fieldwork and lab work. The course will have open ended exercises, wherein students would be asked to come out with their own questions on the ecosystem and seek answers by experimentation.

3rd SEMESTER

Major and minor core theory course:

Cell and Molecular Biology

This course will provide detailed insight into cellular structure and function and a sense of the complex regulatory mechanisms that control cellular function. The course will cover the molecular aspects of RNA processing, transcription, translation, epigenetics, protein-nucleic acid interactions, non-coding RNA, recombinant DNA technology and molecular cloning. The organizational structure and function of cell biology will also be covered, fromthe organization of the cell membrane and transport across it, intracellular trafficking, the cytoskeletal system and protein targeting; organelle biogenesis; cell-cell signalling; the cell cycle and its control; mechanisms of growth, division and death of eukaryotic cells; to the tools and techniques such as microscopy, cell sorting, fractionation, radioisotopes and antibodies used to study cellular functions. This should help students to have a sound knowledge of cellular and molecular biology that will be critical for understanding and carrying out research.

Recommended Reading:

1. Molecular Biology of the Cell: B. Alberts, A. Johnson, J. Lewis, M. Raff, K. Roberts and P. Walter (2007) 5th edition, Garland Science
2. Molecular Biology of the Gene: James Watson et al., (2007) 6th edition, Benjamin Cummings
3. Molecular Cell Biology: H. Lodish, A. Berk, C.A. Kaiser et al (2007) 6th edition
4. Molecular Biology: Weaver (2011) 5th edition, McGraw-Hill Science
5. Principles of Gene Manipulation: S.B. Primrose, R. Twyman and R.W. Old (2002) 6th edition, Wiley-Blackwell
6. Molecular Biology and Genomics: C. Mulhardt (2006) 1st edition, Academic Press
7. Genes VIII-by Benjamin Lewin.

Major core theory course:

Biochemistry

This course aims to provide students with a comprehensive understanding of the fundamental framework of Biochemistry. Students will be introduced to structure, function and inter-relationships between the important biomolecules that collectively carry out the essential functions of life. This includes coming to an understanding of RNA world theory, ribozymes, the biochemistry of enzyme function and its modification, protein folding, dynamics and interaction based on thermodynamic principles of enthalpy, entropy, free-energy and heat capacity; and the concepts underlying methodologies used to analyze biochemical data, such as Protein and nucleic acid isolation, electrophoresis, chromatography, mass spectrometry, isothermal titration calorimetry and isotope exchange. The emphasis of the course will be on understanding the ways that these biomolecules interact to produce a functional living system, rather than on memorizing content.

Recommended Reading:

1. Lehninger Principles of Biochemistry 6th Edition by David L. Nelson (Author), Michael M. Cox.
2. Biochemistry: D. Voet and J.G. Voet (2010/2004), 4th/3rd edition, Wiley
3. Biochemistry: by Jeremy M. Berg, John L. Tymoczko, Lubert Stryer.
4. Biochemistry: The chemical reactions of living cells: D.E. Metzler (2003) Volumes I & II, 2nd edition, Academic Press

Major core lab course:

Cell and Molecular biology

Students will receive hands-on experience of basic cell biology and molecular biology techniques such as microscopy, cell culture, cell fractionation, biochemical and physiological analysis to understand the structure and function of cells, and molecular biology tools such as cloning, PCR, RNA-interference, electrophoresis and isolation and quantification of DNA, RNA and proteins. Students will also receive hands-on experience in basic microbiological techniques of assessing Microbial growth kinetics, motility; antibiotics susceptibility, MIC etc. and techniques to estimate levels of Glucose, Lipids, Amino acids and proteins; chromatography and protein purification; enzyme assay and kinetics; buffer preparation; PI value analysis of proteins; protein profiling by SDS-PAGE; and the identification of proteins by Western blotting.

Optional course:

Neurobiology

This course is also offered to Psychology students as Biological Psychology and aims to introduce neuroscience as a specialized discipline, and to enable students to understand how a biological system is able to signal information, perform computations and produce behaviour. We will start with an introduction to the nervous systems of humans and other animals and then move from understanding how single neurons work to how complex information processing and calculation can happen as a result of the ways in which multiple neurons signal to and connect to one another. We will cover the electrical properties of nerve cells and voltage dependent membrane permeability; channels, transporters, neurotransmitters and their receptors; synaptic transmission; the brain and its development, plasticity and its properties of learning and information processing. We will also study complex brain functions and related disorders.

Recommended Reading:

1. D. Purves, G. J. Augustine, D. Fitzpatrick, W. C. Hall, A. S. LaMantia, J. O. McNamara and L. E. White (eds) *Neuroscience* 4th Edn., Sinauer Associates, Inc. (2008).
2. E. Kandel, J. Schwartz and T. Jessell (eds) *Principles of Neural Science*, 4th Edn., McGraw-Hill (2000).
3. J. G. Nicholls, A. R. Martin, B. G. Wallace and P. A. Fuchs, *From Neuron to Brain*, 4th Edn., Sinauer Associates Inc. (2001).

A course from physics or mathematics

4th SEMESTER

Major and minor core theory course:

Evolution

This course will focus on the processes of evolution and the patterns generated by these processes. The primary aim is to develop a scientific and critical way of thinking about biological diversity and evolution rather than suggesting that students memorize the history of living things. The course will introduce the history of evolutionary thought and the history of life on earth and explain the theory of evolution by natural selection; the genetic and developmental bases of evolutionary change; molecular evolution and quantitative genetics; species, speciation, systematics, phylogenetic trees; the concepts of population genetics: selection, mutation, drift, fitness, adaptation, selection, Fisher's adaptive landscapes, Price's equation, Wright's shifting balance theory, migration, inbreeding, and linkage; life history evolution, macroevolutionary trends, experimental evolution, modes of selection, evolutionary developmental biology; evolutionary psychology, the evolutionary ecology of immunity, extinction and human evolution and evolutionary medicine. In addition to the lectures, the course will include paper reading, group discussions, some demonstrations, debates and assignments.

Recommended Reading:

1. Evolutionary Analysis: S. Freeman and J.C. Herron (2007) Prentice Hall

2. Evolution: D.J. Futuyma (1997) Sinauer Associates

3. Evolution: N.H. Barton, D.E.G. Briggs, J.A. Eisen, D.B. Goldstein and N.H. Patel (2007) Cold Spring Harbor Laboratory Press

4. Principles of Population Genetics: D.L. Hartl and A.G. Clark (1997) Sinauer Associates

5. Evolution—The Extended Synthesis: M. Pigliucci and G.B. Muller (2010) MIT Press

6. Strickberger's Evolution by Monroe W. Strickberger Brian K. Hall, Benedikt Hallgrimsson.

Major core theory course:

Microbiology

The microbial world covers a wider spectrum of biodiversity than the world of multicellular animals. This course will cover both a range of microbial life that extend our understanding of life itself and address the value of applied microbiology of prokaryotic and eukaryotic microorganisms. The scope of the course will cover microbial diversity: cultural and culture independent methods, taxonomy, the functional anatomy of prokaryotic and eukaryotic microbial cells; microbial genetics and physiology: unique biochemical pathways; microbial growth kinetics, development and differentiation; *Dictyostelium* development, myxobacterial development, biofilms and signalling among microbial cells; disease and epidemiology: mechanisms of pathogenicity, host-parasite interactions, disease transmission dynamics, antimicrobial drugs, public health and prophylaxis; microbial biotechnology and bioengineering.

Recommended Reading:

1. Microbiology: An Introduction: G.J. Tortora, B.R. Funke and C.L. Case (2004) 8th edition, Pearson Education

2. Bacterial and Bacteriophage Genetics: E.A. Birge (2006) Springer

3. Microbiology: J. Nicklin, N. Khan, and R. Killington (2006) 3rd edition, Taylor and Francis

4. Fermentation Microbiology and Biotechnology: M.E. Mansi and C.F.A. Bryce (2007) 2nd edition, Taylor and Francis

5. Microbiology by Michael Pelczar.

Major core lab course:

Genetics

Students will be introduced to methods and techniques of experimental genetics using bacteria and fruit flies as model systems. Techniques taught include bacterial conjugation, transduction; transcription; transposon mutagenesis and construction of bacterial gene deletions by homologous recombination; transformation and screening for knockouts; *Drosophila* genetics - setting up a cross, dominant vs. recessive mutations, external phenotypes (eye, wing and bristle), other simple genetic crosses, Gal4-UAS systems, etc.

Optional theory course:

Advanced Neuroscience

This course is also offered to Psychology students as a Neuroscience course and it aims to take forward an understanding of neuroscience. The introductory Neurobiology/Biological Psychology course offered every monsoon semester is a pre-requisite. This course will explore how multi neuron circuits work, through reading primary scientific material on a series of topics in neuroscience.

A course from physics and mathematics

5th SEMESTER

Major core theory course:

Ecology

This course will cover the basic theoretical framework of ecology. The basic organizing structure of the course is centred on various levels of biological organization: from individuals to populations, species interactions, communities and finally ecosystems. The topics covered will start with an introduction to the history, philosophy and practice of ecology; and move on to the ecology of individual organisms: physiological ecology; population ecology: population growth and regulation, species interactions, trophic interactions; community ecology, succession and disturbance; ecosystem ecology, biodiversity, and biogeochemistry. In addition, students will also be acquainted with applied ecology: conservation biology, behavioural ecology and recreational ecology. This course will also require reading and discussing scientific papers and some practical demonstrations.

Recommended Reading:

1. Ecology: from individuals to ecosystems: M. Begon, C.R. Townsend, and J.L. Harper (2006) 4th edition, Blackwell Publishing

2. Ecology: R.E. Ricklefs and G.L. Miller (2000) 4th edition, W.H. Freeman

3. The Ecology of Plants: J. Gurevitch, S.M. Schener, and G.A. Fox (2006) 2nd edition, Sinaeur and Associates

Major core lab course:

Ecology and Evolution

Students will be introduced to quantitative methods of research in ecology and evolution including experimental design, data collection, analysis, interpretation and scientific writing using field and laboratory studies. Students will be introduced to plant and animal models from local ecosystems to empirically test major concepts in population growth, predation, competition, migration, biodiversity, social behaviour, communication; ecological parameters on bacterial growth (e.g. pH & temperature), effect of nutritional and phage selection on bacterial growth; impact of pathogens on life-history evolution, chemical ecology and its impact on insect population dynamics; behavioral Ecology.

Optional theory courses:

Biophysics

Students will be introduced to the interdisciplinary field of physical and structural biology of the cell. This topic is at the intersection of physics and biology, with connections to mathematics, physical chemistry and cell physiology. The course will start with the laws of Physics and chemistry: thermodynamics and biophysical chemistry of macromolecules; and then progress to dealing with biological reactions and interactions: functional aspects of various bio-molecules particularly ion channels, ATP synthases and motor proteins; biophysical techniques: chromatography, electrophoresis, diffusion, sedimentation, light scattering; chemical kinetics, spectroscopy, light and electron microscopy, mass spectrometry, crystallography, Nuclear Magnetic Resonance.

Recommended Reading:

1. Van Holde KE, Johnson C, and Ho PS (2005) Principles of Physical Biochemistry, 2nd Edition, Prentice-Hall;
2. Cantor CR, Schimmel PR (1980) Biophysical Chemistry: Part 1 -The Conformation of Biological Molecules. 1st Edition, WH Freeman;

3. Cantor CR, Schimmel PR (1980) Biophysical Chemistry: Part 2 - The Study of Biological Structure and Function. 1st Edition, WH Freeman

Developmental biology

The goal of this course is to introduce students to the patterns and mechanisms of animal and plant development. The course will begin with providing an overview of the history of developmental biology, and then explore more advanced topics in detail such as early development, positional information, axes, coordinates and morphogen gradients; pattern formation; modes of cell-cell interactions during tissue organization: self-organization, lateral inhibition, induction, and recruitment; growth, differentiation and cancer; evolution of body plan and evolutionary developmental biology; nervous system development; stem cell biology and tissue repair; regeneration; embryogenesis and organ specification in plants and its genetic mechanisms and regulation by molecular signalling. Commonly used experimental methods in developmental biology will be discussed and model organisms such as *Drosophila melanogaster, Xenopus, Caenorhabditis elegans* and *Arabidopsis thaliana* will be used to explain shared features of development across organisms. The course will move beyond the textbook to include the reading of research papers.

Recommended Reading:

1. Developmental Biology: S.F. Gilbert (2006) 8th edition, Sinauer Associates

2. Principles of Development: L. Wolpert, R. Beddington, T. Jessell, P. Lawrence, E. Meyerowitz and J. Smith (2008) Oxford University Press

6TH SEMESTER

Optional theory courses:

Biostatistics and Bioinformatics

This course is application oriented with a focus on the indispensable statistical techniques for biologists using R. Topics covered in biostatistics will include hypothesis testing, statistical significance, errors, experimental design; probability distributions, distribution of sample means, standards errors, analysis of variance, confidence intervals; T tests, Anova, factorial design, regression and correlation' Non-parametric statistics; multivariate tools and elementary time-series analysis; sampling design; case studies. At the end of this course, students are expected to design experiments and perform complex statistical analysis as required.

The systematic acquisition of data made possible by advances in genomics and proteomics technologies has created a gap between the available data and its analysis leading to insights from the data. Computational and theoretical approaches to understanding biological systems are an essential step in closing this gap. The course will start by introducing the concepts of data, structure, security, storage, retrieval; biological data and their sources; methods for data exploration; data mining; analysis of nucleic acid sequences- composition and asymmetry, repeats (direct, inverted and interspersed), similarity searches, both global and local algorithms, blast algorithms; analysis of protein sequences, similarity searches including remote homologue searches; motif finding algorithms; RNA structure analysis; next generation sequencing and principles of NGS data analysis.

Recommended Reading:

1. Biometry: The Principles and Practice of Statistics for Biological Research: R.R. Sokal and H.A. Rohlf (1995) 3rd edition, W.H. Freeman

2. Biostatistical Analysis: J.H. Zar (1998) 4th edition, Prentice Hall

3. Dynamic Models in Biology: S.P. Ellener and J. Guckenheimer (2006) Princeton University Press

4. Mathematical Physiology: J. Keener and J. Sneyd (2008) Springer

5. Mathematical Models in Biology: L. Edelstein-Keshet (2005) Random House

Advanced biochemistry

This course covers specialized topics related to membrane biochemistry and metabolism. The first deals with understanding the physical principles underlying the formation, organization and dynamics of membranes, membrane protein insertion and folding, molecular recognition principles on membranes, lipid and protein sorting, membrane protein purification and reconstitution, membrane fusion and fission, homeoviscous adaption, and membrane-mimetic systems. The second constitutes a survey of Amino acid, lipid, carbohydrate, nucleotide and glycogen metabolic pathways from a molecular perspective, the citric acid cycle, electron transport and oxidative phosphorylation.

Recommended Reading:

1. Molecular Biology of the Cell: B. Alberts, A. Johnson, J. Lewis, M. Raff, K. Roberts and P. Walter (2002) Garland Science

2. Life - As a Matter of Fat: O. Mouritsen (2004) Springer

3. The Structure of Biological Membranes: P. Yeagle (2004) CRC Press

4. Biochemistry: The chemical reactions of living cells: D. Metzler (2001) Academic Press

5. Primary research articles and reviews will be utilized to provide contemporary insights into the field

Immunology

This course will acquaint students with the molecules, cells and organs of the invertebrate and vertebrate immune system. Students will learn about the structural features of the components of the immune system as well as their functions, but the primary emphasis of this course will be on the mechanisms involved in immune system development and responsiveness. The course will cover the organization of the immune system (lymphoid tissues and organs); immune cell development (hematopoesis, T and B cell development); innate and adaptive immunity (including cellular and humoral responses); invertebrate vs. vertebrate immunity; antigens and antibodies (antibody classes, Ag/Ab structure and function); immune signalling (T cell receptor, TLRs, inflammatory and cytokine responses); MHC and Ag presentation and T cell development; immunity mechanisms in disease (allergies, autoimmunity, immuno-deficiency); immunotherapy (clinical use of monoclonal antibodies); tumour Immunology and the evolutionary ecology of immunity.

Recommended Reading:

1. Janeway's Immunobiology: K.M. Murphy, P. Travers and M. Walport (2007) 7th edition, Garland Science

2. Kuby Immunology: T.J. Kindt, B.A. Osborne and R.A. Goldsby (2006) 6th edition, W.H. Freeman

7TH SEMESTER

Optional theory courses:

Physiology

The course aims at providing in-depth knowledge of human physiology. The goal is to provide an insight into the various organ systems, their functions, interactions, regulation and pathology: animal physiology; the nervous system and sensory processing; endocrine system and reproduction; neuroendocrine systems; reproductive physiology; circadian rhythms; feeding and digestion, energy metabolism; thermoregulation in warm and cold-blooded animals; muscular system and movement; respiratory system: physiology of breathing, transport of oxygen and carbon dioxide, oxygen and the evolution of animals; circulatory system in invertebrates and vertebrates; excretory system: managing water, salt and body fluids in animals; environment and physiological adaptation; animal navigation and migration; physiological diseases. The course will also include lab demonstrations of live systems using fish models and histological preparations. The course material will be useful to any undergraduate who is keen to understand physiological processes.

Recommended Reading:

1. Textbook of Medical Physiology: A.C. Guyton, J.C. Hall (2008) Elsevier-Saunders

2. Williams Textbook of Endocrinology: H.M. Kronenberg et al. (2008) Saunders

3. Eckert Animal Physiology: D.J. Randall et al. (2002) W.H. Freeman

4. Comparative Animal Physiology: P.C. Withers et al. (2001) Brooks Cole

5. Animal Physiology: R.W. Hill, G.A. Wyse and M. Anderson (2008) Sinauer Associates

Mathematical and **Computational Biology**

This course provides an introduction to mathematical and computational biology. Simultaneously, students will also learn to model biological processes, because quantitative methods are critically important for solving biological problems of the present century. Hence, special emphasis will be given towards quantitative methods to improve one’s understanding of experimental data: phase-plane analysis of (nonlinear) ODEs; enzyme kinetics; elementary geometric singular perturbation theory; reduction strategies for larger- dimensional systems; modeling ecological and evolution systems; stochastic models of enzymes, channels and pumps, etc.. Classical examples from neuroscience and other topics in physiology will be used to illustrate the application of various methods and techniques. Also included in this course are algorithm development and learning to use software like R, MATLAB, C++, Fortran or XPPAut for the analysis of biological data. There will be computer labs to enable hands-on learning of the algorithms being covered.

Recommended Reading:

1. Biological Sequence Analysis: Probabilistic Models of Proteins and Nucleic Acids: R. Durbin, S. R. Eddy, A. Krogh, and G. Mitchison (1999) Cambridge University Press, ISBN 0521629713

2. Algorithms on Strings, Trees, and Sequences: Computer Science and Computational Biology: D. Gusfield (2007) Cambridge University Press, ISBN 0521585198

Landmark studies in biology

This course will include classroom presentations, intense discussion and critical analysis of classic and landmark papers from diverse fields of biology. Topics will include classic and landmark papers on:

- Evolution/ Origin of Life (e.g. Darwin C, Wallace A 1859. On the tendencies of species to form varieties; and on the perpetuation of varieties and species by means of selection. J Proc Linnean Soc. 4: 45-62; Kimura 1968. Evolutionary rate at the molecular level. Nature. 217: 624-6)
- Development (e.g. Turing A 1952. The chemical basis of morphogenesis. Phil Trans R Soc Lond B. 237: 37-72)
- Molecular Biology (e.g. Luria SE, Delbruck H 1943. Mutations of bacteria from virus sensitivity to virus resistance. Genetics. 28: 491-511; Watson JP, Crick FHC 1953. Molecular structure of nucleic acid. Nature. 171: 737-738; Jacob F, Monod J 1961. Genetic regulatory mechanisms in the synthesis of proteins. J Mol Biol. 3: 318-356)
- Neurobiology (e.g. Katz B, Miledi R 1972. The statistical nature of the acetylcholine potential and its molecular components. J Physiology. 224: 665-699)

Plant biology

The objective of this course is to acquaint students with the fundamentals of plant biology - the evolution of plants, plant architecture, growth & development, phytohormones and their functions. The course will go on to provide an in depth understanding by following contemporary research topics in basic and applied plant sciences: evolutionary history and diversity of Algae, Fungi, Bryophytes, Pteridophytes, Gymnosperms, Angiosperms; the morphology of flowering plants; transport in Plants: uptake and transport of water and mineral nutrients, xylem & phloem transport, transpiration, stomata; plant nutrition: mineral requirements, soil, nitrogen metabolism, carnivorous plants, parasitic plants, fertilizers; photosynthesis: site and pigments, light reaction, electron transport, ATP and NADH, C4 pathway, photorespiration, factors influencing photosynthesis, photoreceptors; respiration in plants; regulation of plant growth: Gibberlins, Auxins, Cytokines, Ethylene, Abscisic acid, Brassinosteroids; reproduction in flowering plants; plant protection and defence against pathogens, chemical ecology, insects and herbivores; and plant-plant interaction: allelopathy.

Recommended Reading:

1. N. A. Campbell, J. B. Reece, R. B. Jackson, M. L. Cain, L. A. Urry, S. A. Wasserman and P. V. Minorsky, *Biology*, 8th Edn. Benjamin-Cummings Pub Co. (2007).

2. L. Taiz and E. Zeiger, *Plant Physiology*, 4th Edn., Sinauer Associates Inc. (2006).

Lab course

Students are expected to carry out independent research projects

8TH SEMESTER

Students are expected to continue their independent research projects leading to a thesis.