Open Elective Courses

for

Master of Science Programmes

in

Faculty of Interdisciplinary and Applied Sciences (FIAS)

2019

Biochemistry, Biophysics, Electronics, Genetics, Informatics, Microbiology, Plant Molecular Biology and Biotechnology

MASTER OF SCIENCE, BIOCHEMISTRY

Semester IV

BCOE401: Basics of Biochemistry

Marks: 100 (4 Credits) **Duration: 60 Hrs**

Course Objectives:

The objective is to offer basic concepts of biochemistry to students with diverse background in life sciences including but not limited to the structure and function of various biomolecules and their metabolism.

Course Learning Outcomes:

- Students will learn about various kinds of biomolecules and their physiological role.
- Students will gain insight into the synthesis and breakdown of the various biomolecules
- Students will gain knowledge about various metabolic disorders and will help them to know the importance of various biomolecules in terms of disease correlation.

Content

Unit I: Carbohydrates and Lipids: Monosaccharides, disaccharides, Polysaccharides, storage polysaccharides, Building blocks of lipids - fatty acids, glycerol, triacyl glycerol (TAG), Digestion, mobilization and transport of cholesterol and triacylglycerols.

Unit II: Carbohydrate metabolism: Glycolysis, pentose phosphate pathway, citric acid cycle, Synthesis of glucose from non-carbohydrate sources, glycogen metabolism, glycogen storage diseases.

Unit III : Fatty acid metabolism**:** β oxidation of fatty acids, regulation of fatty acid oxidation, Fatty acid synthesis and regulation.

Unit IV: Amino acid metabolism**:** Role of essential and non-essential amino acids in growth and development, Catabolism of amino acids, Overview of amino acid synthesis, Protein calorie malnutrition - Kwashiorkar and Marasmus, Disorders of amino acids metabolism.

Unit V: Nucleotide metabolism**:** *De novo* synthesis and breakdown of purine and pyrimidine nucleotides, regulation and salvage pathways. Disorders of nucleotide metabolism.

Unit VI: Proteins and Enzymes: Concepts of acids, bases, pH, pKa and buffers, Water & its role in life; Introduction to Protein structures and Protein folding; Structure-function relationship in proteins with Hemoglobin as an example; Enzyme as bio-catalysts: general introduction; Enzyme Kinetics, Inhibition and Regulation; Applications of Proteins and Enzymes.

Unit VII: Vitamins and Hormones**:** Different types of vitamins, their diverse biochemical functions and deficiency related diseases. Overview of hormones. Hormone mediated signaling. Mechanism of action of steroid hormones, epinephrine, glucagons and insulin. Role of vitamins and hormones in metabolism; Hormonal disorders; Therapeutic uses of vitamins and hormones.

Suggested readings

1. Lehninger: Principles of Biochemistry (2013) 6th ed., Nelson, D.L. and Cox, M.M., W.H. Freeman and Company (New York), ISBN:13:978-1-4641-0962-1 / ISBN:10:1-4641-0962-1.
2. Biochemistry (2012) 7th ed., Berg, J.M., Tymoczko, J.L. and Stryer L., W.H. Freeman and Company (New York), ISBN:10:1-4292-2936-5, ISBN:13:978-1-4292-2936-4.
3. Harper's Biochemistry (2012) 29th ed., Murray, R.K., Granner, D.K., Mayes and P.A., Rodwell, V.W., Lange Medical Books/McGraw Hill. ISBN:978-0-07-176-576-3.

Teaching Plan*:

Week 1: Introductory classes: General introduction to the course; Carbohydrate and lipids; Monosaccharides, disaccharides, Polysaccharides, storage polysaccharides
Week 2: Building blocks of lipids - fatty acids, glycerol, triacyl glycerol (TAG), Digestion, mobilization and transport of cholesterol and triacylglycerols.
Week 3: Carbohydrate metabolism: Glycolysis, pentose phosphate pathway, citric acid cycle,
Week 4: Synthesis of glucose from non-carbohydrate sources, glycogen metabolism, glycogen storage diseases.
Week 5: Fatty acid metabolism: β oxidation of fatty acids, regulation of fatty acid oxidation
Week 6: Fatty acid synthesis and regulation
Week 7: Amino acid Metabolism: Role of essential and non-essential amino acids in growth and development, Catabolism of amino acids
Week 8: Overview of amino acid synthesis, Protein calorie malnutrition - Kwashiorkar and Marasmus, Disorders of amino acids metabolism.
Week 9: Mid-term Internal Assessment test.
Week 10: Nucleotide Metabolism: *De novo* synthesis and breakdown of purine and pyrimidine nucleotides
Week 11: Regulation and salvage pathways. Disorders of nucleotide metabolism.
Week 12: Proteins and Enzymes: Concepts of acids, bases, pH, pKa and buffers, Water & its role in life; Introduction to Protein structures and Protein folding.
Week 13: Structure-function relationship in proteins with Hemoglobin as an example; Enzyme as bio-catalysts: general introduction; Enzyme Kinetics, Inhibition and Regulation; Applications of Proteins and Enzymes.
Week 14: Vitamins and Hormones: Different types of vitamins, their diverse biochemical functions and deficiency related diseases. Overview of hormones. Hormone mediated signaling.
Week 15: Mechanism of action of steroid hormones, epinephrine, glucagons and insulin. Role of vitamins and hormones in metabolism; Hormonal disorders; Therapeutic uses of vitamins and hormones. Course revision, End-term internal assessment test, solving problems.

(* The weekly design of teaching plan is indicative in nature and there may be deviations based on teaching requirements and batch to batch variations in basic understanding and responsiveness)

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I.	Students will learn about dietary and storage form of carbohydrates. They will gain insight into the synthesis and breakdown of carbohydrates and about various metabolic disorders.	Power point presentations, discussions.	Quiz, internal assessment tests will be conducted.
II.	Students will learn about dietary and storage form of lipds. They will gain insight into the synthesis and breakdown of fatty acids and about various metabolic disorders.	Power point presentations, discussions.	Quiz, internal assessment tests will be conducted.
III.	Students will learn about the essential and non-essential amino acids. They will gain insight into the synthesis and breakdown of the amino acids and about various metabolic disorders.	Students will be asked to orally revise the previous class before every new class helping them in better understanding and their doubts cleared, if any. Teaching will be conducted both through black board mode and power point presentation mode.	Mid-term internal assessment tests will be conducted.
IV	Students will learn about the essential and non-essential amino acids. They will gain insight into the synthesis and breakdown of the amino acids and about various metabolic disorders.	Teaching will be conducted both through black board mode and power point presentation mode. Previous day's class revised before start of teaching.	Mid-term internal assessment tests will be conducted.

V	Students will gain knowledge about the synthesis and breakdown of purines and pyrimidines and their associated metabolic disorders.	Previous day's class revised before start of teaching. Teaching will be conducted both through black board mode and power point presentation mode.	Internal assessment tests (mid-term and end-term) will be conducted.
VI	Students will develop basic concepts related to buffers and pKa; Significance of water in biochemistry of life ; Students will learn about protein structures and folding, about structure-function relationship in proteins; Students will learn about enzyme function, enzyme kinetics, inhibition and regulation; Students will learn about the applications of proteins and enzymes in biotechnology.	Basic models will be used to explain stereochemistry and protein structures; Chalk and board teaching; Power point presentations and videos for augmenting basic concepts; Interactive discussion and problem solving	Analytical problems related to pH, pKa, buffers; Identification of amino acids from ball and stick, space-filling models; Protein structure visualization; Analytical problems related to enzyme kinetics; assignments; internal assessment.
VII	Students will learn about the biochemical functions of various vitamins and hormones and their deficiency related diseases. Knowledge will be imparted about the therapeutic uses of vitamins and hormones as well.	Both chalk and board and PowerPoint presentations will be used for teaching. There will be interactive learning through class discussions.	Assignments will be given related to class teaching, oral question answer sessions will help in evaluation of student's understanding.

MASTER OF SCIENCE, BIOPHYSICS

Semester IV

BPOE401: Theoretical and Mathematical Biology

Marks: 100 (4 credits) **Duration: 60 Hrs.**

COURSE OBJECTIVES:

At the end of the course, the student should be able to

- Enumerate applications of different branches of Mathematics to Biology.
- Understand the complexity of biological systems and the appropriate mathematical tools to analyze those.
- Understand the collective behavior of biological systems from molecular level to ecosystem.

COURSE OUTCOMES:

CO1: Should be able to analyse nonlinear systems in biology.
CO2: Should be able to apply Information Theory to biology.
CO3: Should be able to apply stochastic models in biology.
CO4: Should be able to predict future of a complex biological system.
CO5: Should understand the physical principles of biological evolution.
CO6: Should be able to analyse biological network, e.g. cellular, biochemical, ecological.
CO7: Should be able to apply topology to biological problems.

CONTENTS:

UNIT 1. Non Linear Systems Analysis: Definition of Non-linearity, Non-linear differential equations, examples, critical points, Stability & Liyapunov's Theorem, Near Equilibrium Solutions, Behaviour in the Phase plane, Feed Back Process and Oscillations, B-Z equations, Lotka Volterra and other Models with examples.

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UNIT 2. Information Theory and its Application in Biology: Basic concept of information and the related theorems, information theory and protein structure, coding of genetic information, information and sensory perception.

[8]

UNIT 3. Statistical Mechanics and its application in Biology: Basic Foundation, Canonical & Grand Canonical Ensembles, Biomolecular System as an analogue of many body system. Quantitative analysis of a co-operative process. Ising Model and DNA melting, drug-DNA interaction and other cooperative process, Lipid phase Transitions, Collective Process in Cell Membranes and application of statistical Mechanics.

Stochastic Processes in Biology: Examples of Stochastic Behaviour, Stochastic Models, Markovian Processes in Biology, Stochastic Resonance.

[10]

UNIT 4. Time Series Analysis: The Background and Necessity, Correlation Coefficient, Fourier Analysis, Wavelet Analysis, Application in the analysis of Electrophysiological recordings e.g. EEG, ECG, Fractals and Evolution of a System, Examples from Biological Systems, Difficulties and Limitation of Analysis.

[8]

UNIT 5. Prebiotic Evolution: Theories and Models, Eigen's Hypercycle, Kimura's idea, Non Linearity and Biological Evolution.

[6]

UNIT 6. Networks: Neural Network, Artificial Neural Networks, Metabolic Networks, Brain as a Complex network, Theories and Analytical Methods, Cellular Automata and its application in microbial and lower Organismic Population.

[8]

UNIT 7. Elements of Topology: Elementary Concepts and Theorems, Topology of DNA, Supercoiling, Knots, Twists etc., Catastrophe Theory and Applications to Morphogenesis.

[6]

TEACHING PLAN:

The teaching will be done as per the above-mentioned sequence of units and corresponding number of classes.

Facilitating the achievement of Course Learning Outcomes

Unit	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1	Should be able to analyze nonlinear systems in biology.	Lectures + Numerical Problem Solving	Short answer type test +Numerical Problem Solving/ Short presentation (group activity)
2	Should be able to apply Information Theory to biology.	Lectures + Numerical Problem Solving	Short answer type test +Numerical Problem Solving /Short presentation (group activity)
3	Should be able to apply stochastic models in biology.	Lectures + Numerical Problem Solving	Short answer type test +Numerical Problem Solving /Short presentation (group activity)
4	Should be able to predict future of a complex biological system.	Lectures + Numerical Problem Solving	Short answer type test +Numerical Problem Solving /Short presentation (group activity)
5	Should understand the physical principles of biological evolution.	Lectures + Numerical Problem Solving	Short answer type test + Numerical Problem Solving /Short presentation (group activity)

Eligibility: Background of Mathematics till XIIth Standard.

MASTER OF SCIENCE, ELECTRONICS

ESOE101: Data Acquisition Systems

Marks: 100 (4 credits) **Duration: 60 Hrs**

Course Objective:

In essence, the objective of this course is to reliably and accurately acquire and record data from a variety of sensors and external devices.

Course Outcomes:

- Understanding the concepts of acquiring the data from transducers/input devices, their interfacing and instrumentation system design.
- After the successful completion of the course the students will be able to elucidate the elements of data acquisition techniques.
- The course aims at developing the understanding of design and simulation of signal conditioning circuits.
- To develop and specialize the applications of a data acquisition, compose and organize new applications and to evaluate the system performance.

Unit I: Data Acquisition Techniques: Analog and digital data acquisition, Sensor/Transducer interfacing, unipolar and bipolar transducers, Sample and hold circuits, Interference, Grounding and Shielding.

Unit II: Data Acquisition with Op-Amps: Operational Amplifiers, CMRR, Slew Rate, Gain, Band-width. Zero crossing detector, Peak detector, Window detector. Difference Amplifier, Instrumentation Amplifier AD 620, Interfacing of IA with sensors and transducer, Basic Bridge amplifier and its use with strain gauge and temperature sensors, Filters in instrumentation circuits

Unit III: Data Transfer Techniques: Serial data transmission methods and standards RS 232-C: specifications connection and timing, 4 - 20 mA current loop, GPIB/IEEE - 488, LAN, Universal serial bus, HART protocol, Foundation -Fieldbus, ModBus, Zigbee and Bluetooth.

Unit IV: Data Acquisition System using computers (DAS): Single channel and multichannel, Graphical Interface (GUI) Software for DAS, RTUs, PC - Based data acquisition system

Suggested Reading:

1. H. Rosemary Taylor,"Data Acquisition for Sensor Systems",Chapman and Hall.
2. J. Park, S. Mackay,"Data Acquisition for Instrumentation and Control Systems", Elsevier.
3. H. Austerlitz,"Data Acquisition Techniques using Personal Computers", Academic Press.
4. Coughlin, R.F., Operational Amplifiers and Linear Integrated Circuits, Pearson Education.
5. Mathivanan, N., Microprocessor PC Hardware and Interfacing, Prentice Hall of India Private Limited

MASTER OF SCIENCE, GENETICS

Semester II
GENOE206: Genetics in Crop Improvement and Human Health

Marks: 100 (4 credits) **Duration: 60Hrs.**

Course Objective:

This elective paper has been designed to introduce students from other departments to basic concepts in genetics with specific reference to plants and humans. It also aims to provide an overview of the classical and contemporary genetic tools for improvement of overall life quality. The students would develop an inclusive understanding of various breeding and transgenic strategies for improvement of crops. The section on medical genomics would focus on the tools for genetic analysis of human disorders, translation of the findings for predictive, preventive, personalized and participatory (P4) medicine; cellular and animal model of disease for enhanced understanding of disease biology and thereby new therapeutics.

Course Learning Outcomes:

CO1: Students will be familiarized with the basic concepts underlying inheritance of traits and genetic analysis.
CO2: Students will be introduced to the application of various genetic tools, breeding approaches and biotechnology in crop improvement.
CO3: The students would develop an inclusive understanding about various genetic approaches to strengthen our understanding about genetic disorders and their management strategies.

Contents:

Unit I: Fundamental of Genetics. Concepts of Mendelian inheritance; Pedigree analysis; Chromosome theory of Inheritance, Concept of gene, allelic and gene interactions, test of allelic complementation; Introduction to linkage, crossing over and developing genetic maps; Cytoplasmic inheritance.

[20]

Unit II: Genetics in Crop Improvement. Crop improvement- Scope, nature and history; Conventional methods for crop improvement -Various breeding strategies; Molecular genetic breeding - Genetic mapping of traits, Marker assisted breeding for important traits (Case study); Application of genetic transformations in crop improvement- case studies of transgenic traits in plant; Biosafety issues.

[20]

Unit III: Genetics in human health. Introduction to chromosomal, single gene and complex disorders; tools and techniques in the study of genetic disorders – karyotyping, chromosomal banding and analysis, molecular markers, physical and genetic mapping, identification of disease causing gene; epigenetics and human health, nature vs nurture (using twin studies); Human disease modeling in *C. elegans*, *Drosophila*, zebrafish (*Daniorerio*), mouse and its applications; Molecular diagnostics - Prenatal, neonatal and adult diagnosis; Introduction to genetic counseling and ethical, legal and social issues.

[20]

Suggested readings:

1.	iGenetics A Molecular Approach	Russell PJ	Pearson
2.	Introduction to Genetic Analysis	Griffith AF *et al.*	W H Freeman & Co
3.	Human Molecular Genetics	Strachan T & Read A	Garland Science
4.	Principle of Crop improvement	Simmonds NW & Smart J	Blackwell Science
5.	Research papers for case studies		

MASTER OF SCIENCE, INFORMATICS

ITOE01: IT Policy Framework and Standards

Marks: 100 (4 credits) **Duration: 60 Hrs**

Course Objectives:

IT policies help organizations to properly articulate the organization's desired behavior, mitigate risk and contribute to achieving the organization's goals. This course describe the evolution of IT policies and standards. This course covers the advanced study of Information Security Policy and Governance at an organizational level. It will help understanding of standards and policies as well as international, national and local regulatory requirements governing organizational information technology systems. The unit will address relevant data protection legislation, industry best practices, risk management techniques and develop the necessary skills to evaluate and measure organizational compliance and to determine appropriate organizational strategy to best support the information security needs.

Course Learning Outcomes:

CO1: able to understanding of the tools for staff orientation.
CO2: able to document proper delegation and define limits of authority and responsibility.
CO3: able to serve as a documentation source for regulatory compliance.
CO4: able to protect intellectual property and business continuity.
CO5: able to improve clarity and momentum in projects and operations.

Contents:

Evaluation, evidence and policy, Managing innovation and creativity, Managing strategic change, Project management, Research design OR Qualitative methods, Understanding public policy, Community empowerment and engagement, Governance and markets, IT and society, International challenges, It and Gender, Sustainable development, Understanding policy. COBIT framework.

UNIT I: Information Policies, Information Procedure, Information Standard, Information Guideline, Institutional IT Policies, Software Installation & Licensing Policy, Email Account Use Policy, Web Hosting Policy, User account and password policy, Data Retention Limits and Responsibilities, Reading website and web service agreements, Safety in BYOD setups, Understanding security dangers in public WiFi setups and staying protected, Understanding cyber bullying and its prevention, National IT policy and Cyber Law.

UNIT II: Regulatory, Advisory, Informative, Organizational, System-Specific and Issue Specific Policies and Procedures. Incident Response, Auditing, Environmental/Physical and Administrative Factors, Procedure Implementation

UNIT III: Understanding WiFi, OSI and TCP/IP Model, Common network attacks, DoS and DDOS, Man-in-the-middle attack, Phishing and Spoofing, Vulnerability Assessment and Penetration Testing Techniques and Frameworks, Vulnerability Management, Network Monitoring and Management.

Recommended Reading:

1. Information Security Policies, Procedures, and Standards: A Practitioner's Reference by Douglas J. Landoll
2. Frameworks for ICT Policy: Government, Social and legal Issues by Esharenana E.Adomi. ISBN13: 9781616920128
3. Publications of Bureau of Indian Standards (BIS)
4. Publications of International Standards Organization (ISO)
5. Publications of Telecommunication Authority of India.
6. Rules and Policy documents from Ministry of Electronics & Information Technology (MeitY)

MASTER OF SCIENCE, MICROBIOLOGY

MBOE201: Microbial Biotechnology

Marks: 100 (4 credits) **Duration: 60 hrs**

Course Objectives:

The course will help students to understand various applications of microbes for the development of various products of agriculture, industrial and clinical application. The knowledge of recombinant technology, bioreactors and optimization strategies will be beneficial in development of production processes.

Course Learning Outcomes:

Upon successful completion of the course, the student:

CO1: Will learn about various industrially relevant microbial products and their production process, role of biotechnology in environment management
CO2: Acquires knowledge about strains development, selection of hyper producers, microbial products, metabolic engineering and various industrial relevant microbial products and their production process
CO3: Learns about the designing of recombinant heterologous expression systems such as *E. coli*, yeast, mammalian and insect cells.
CO4: Learns about sterilization at reactor scale and different types of sterilization strategies
CO5: Attains knowledge about designing large scale industrial processes and types of cultivation strategies
CO6: Understands the concept of recombinant biomolecules, therapeutic proteins, vaccines**,** antibodies, bio-pesticides, bio-fertilizers, and probiotics
CO7: Understands different types of regulatory approvals required for drug development and difference between biologics, biosimilars and biobetters

Contents:

Unit I: Introduction to microbial biotechnology: Biotechnology and its applications in microbial processes. Role of microbial biotechnology in environment management **6**

Unit II Improvement of Microbial strains: Strains development, selection of hyper producers, microbial products, metabolic engineering in development of industrial products **8**

Unit III: Recombinant gene expression platforms: Development of recombinant heterologous expression systems e.g. *E. coli*, yeast, mammalian and insect cells. Plant cells as bio-factories. Control parameters in stability of these expression platforms at industrial scale. **8**

Unit IV: Designing large scale industrial processes: Application of bioprocess engineering in microbial product development, batch fermentation, fed-batch fermentation, type of bioreactors, designs and control parameters in a fermenter, high cell density cultivation strategies, continuous cultivation processes, measurement of growth and product formation kinetics, limiting parameters in large scale process development, oxygen mass transfer coefficient.

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Unit V Sterilization: Different types of sterilization strategies, sterilization of large scale bioreactors, calculation of heating, holding and cooling time

8

Unit VI: Development of microbial products: Fermented milk products, probiotics, malt beverages, wines, distilled liquors, recombinant biomolecules and therapeutic proteins, vaccines production**,** DNA based vaccines, antibody production, therapeutic enzymes, industrially important enzymes and green fuel production, Development of bio-pesticides and bio-fertilizers

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Unit VII: Regulatory approvals and clinical trials: *Good laboratory practice (GLP),* Current Good Manufacturing Practice (CGMP), different phases of clinical trials, difference between biologics, biosimilar and bio-better, development of biosimilars and generic biomolecules, analysis of process economics.

8

Suggested Readings:

1. Stanbury, P.F., Whitaker, A. and Hall, S.J. (2016). *Principles of Fermentation Technology*. 3rd edition. Elsevier Science, Netherlands.
2. Crommelin, J.A.D., Sindelar, R.D. and Meibohm, B. (2013). *Pharmaceutical Biotechnology: Fundamentals and Applications*. 4th edition. Springer, USA.
3. Okafor, N. and Okeke, B.C. (2017). *Modern Industrial Microbiology and Biotechnology*. 2nd edition. CRC press, UK.
4. Glazer, A.N. and Nikaido, H. (2007). *Microbial Biotechnology: Fundamentals of Applied Microbiology*. 2nd edition. Cambridge University Press, UK.
5. Walsh, G. (2007). *Pharmaceutical Biotechnology: Concepts and Applications.* John Wiley & Sons Ltd, UK.

MASTER OF SCIENCE, PLANT MOLECULAR BIOLOGY AND BIOTECHNOLOGY

Semester II

PBOE 204: Data Analytics and Biocuration

Marks = 100 (4 credits) **Duration : 60 hrs**

Course objectives

This paper is designed to provide basic requisite skills for core computer programming, in-depth data analysis, database development and management.

Course outcome

The candidate would develop skills in basic statistical analysis of biological data as well as the usage of programming languages. The candidate would be able to handle and analyze 'Big Data' analysis. They would develop skills for the management and development of highly curated biological databases.

Contents

Unit 1: Data Analytics using 'R' Statistical Package – Basic statistics for biologists; Introduction to the 'R' data analysis package, basic work environment, syntax, introduction to the 'Bioconductor' packages for data analysis.

Unit 2: Application of the Bioconductor Packages -- Application of bioconductor packages in the analysis of RNA-seq, chromatin immune-precipitation, bisulphite sequencing data, data analysis and visualization.

Unit 3: Basics of Programming and Database Management -- Perl, Bioperl and MySQL.

Unit 4: Data standards, Integration and Visualization -- BioDbCore guide lines, FAIR sharing. Ethics in data sharing, Introduction to machine-learning and artificial intelligence approaches in data integration and interpretation and predictive modeling. Visualization tools such as Gbrowse.

Unit 5: Introduction to Biocuration -- Basics, International society of Biocuration, various methods of biocuration,

Unit 6: Ontologies -- Basics and importance of ontology development, OBO (Open Biological and Biomedical Ontology) format, OBO foundary, biomedical and plant based ontologies.

Unit 7: Literature-Based Curation -- Text/Literature-based curation, text mining approaches, introduction to tools such as Textpresso.

Unit 8: Data Digitization Aspects -- Importance of digitization of experimental data, experimental data submission repositories and formats.

Suggested readings

1. Bessant, C., Shadforth, I. and Oakley, D. (2009) Building Bioinformatics Solutions: with Perl, R and MySQL. Oxford University Press, UK.
2. Tisdall, J. (2001). Beginning Perl for Bioinformatics. O'Reilley Media, USA.
3. Tisdall, J. (2010). Mastering Perl for Bioinformatics: Perl programming for Bioinformatics. O'Reilley Media, USA.
4. Buffalo, V., (2015) Bioinformatics Data Skills: Reproducible and robust research with open source tools. O'Reilley Media, USA.
5. Web link: www.bioconductor.org.
6. Web link: www.obofoundary.org; www.oboedit.org
7. Web link: www.biocuration.org