CURRICULUM

OF

BIO INFORMATICS

BS/MS

(Revised 2015)
CURRICULUM DIVISION, HEC

Prof. Dr. Mukhtar Ahmed  Chairman
Mr. Fida Hussain  Director General (Acad)
Ms. Ghayur Fatima  Director (Curr)
Mr. Rizwan Shoukat  Deputy Director (Curr)
Mr. Abid Wahab  Assistant Director (Curr)
Mr. Riaz-ul-Haque  Assistant Director (Curr)

Composed by: Mr. Tanveer Ali, HEC
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PREFACE

The curriculum, with varying definitions, is a plan of the teaching-learning process that students of an academic programme are required to undergo. It includes objectives and learning outcomes, course contents, scheme of studies, teaching methodologies and methods of assessment of learning. Knowledge in all academic disciplines is expanding and even new disciplines are also emerging, it is imperative that curriculum are developed and revised regularly.

University Grants Commission (UGC) was designated as the competent authority to develop, review and revise curricula beyond Class-XII vide Section 3, Sub-Section 2 (ii), Act of Parliament No. X of 1976 titled “Supervision of Curricula and Textbooks and Maintenance of Standard of Education”. With the repeal of UGC Act, the same function was assigned to the Higher Education Commission (HEC) under its Ordinance of 2002, Section 10, Sub-Section 1 (v).

In compliance with the provisions, the Curriculum Division of HEC undertakes the revision of curricula after every three years through respective National Curriculum Revision Committees (NCRCs) which consist of eminent professors and researchers of relevant fields from public and private sector universities, R&D organizations, councils, industry and civil society nominated by their organizations.

In order to impart education at par with quality international standards, HEC NCRCs have developed unified templates as guidelines for the development and revision of curricula in the disciplines of Basic Sciences, Applied Sciences, Social Sciences, Agriculture and Engineering in 2007 and 2009.

It is hoped that this curriculum document, prepared by the respective NCRC’s, would serve the purpose of meeting our national, social and economic needs, and it would also provide the level of competency specified in Pakistan Qualification Framework to make it compatible with international educational standards. The curriculum is also placed on the website of HEC (www.hec.gov.pk).

(Fida Hussain)
Director General (Academics)
CURRICULUM DEVELOPMENT PROCESS

STAGE-I
CURRI. UNDER
CONSIDERATION
COLLECTION OF
REC
CONS. OF CRC.
PREP. OF DRAFT
BY CRC
PREP. OF DRAFT
BY CRC
APPROVAL OF
CURRI. BY V.C.C.
APPROVAL OF
CURRI. BY CRC
FINALIZATION
OF DRAFT BY CRC
FINAL STAGE
PREP. OF FINAL
CURRI.
INCORPORATION
OF REC. OF V.C.C.
FOLLOW UP
STUDY
QUESTIONNAIRE
COMMENTS
PRINTING OF
CURRI.
PRINTING OF
CURRI.
REVIEW
IMPLE. OF CURRI.
ORIENTATION
COURSES
BACK TO STAGE-I

STAGE-II
CURRI. IN
DRAFT STAGE
APPRASAL OF 1ST
DRAFT BY EXP. OF
COL./UNIV

STAGE-III
FINAAL STAGE
PREP. OF FINAL
CURRI.

STAGE-IV
FOLLOW UP
STUDY
QUESTIONNAIRE
COMMENTS
PRINTING OF
CURRI.
PRINTING OF
CURRI.
REVIEW
IMPLE. OF CURRI.
ORIENTATION
COURSES
BACK TO STAGE-I

Abbreviations Used:
CRC. Curriculum Revision Committee
VCC. Vice Chancellor's Committee
EXP. Experts
COL. Colleges
UNI. Universities
PREP. Preparation
REC. Recommendations
INTRODUCTION

The final meeting of the National Curriculum Revision Committee in Bioinformatics was held on May 17-19, 2014 at HEC, Regional Centre, Karachi to review and finalize the curriculum for BS (4-years) and MS (2-years) degree programs in Bioinformatics. Following members and experts attended the meeting:

1. Dr. Nazeer Ahmed
   Professor / Chairman,
   Department of Biotechnology & Informatics,
   Balochistan University of Information Technology,
   Engineering & Management Sciences,
   Takatoo Campus, Airport Road, Quetta

2. Dr. Muhammad Ayub
   Assistant Professor,
   Department of Biochemistry,
   University of Balochistan, Seriab Road, Quetta

3. Dr. Syed M. Jahangir Matti
   CEO (Matti-K-Jahangir, Pvt Ltd.)
   Family Suit # 8, Old MNA Hostel,
   Sector G-5/1, Islamabad

4. Dr. Isharat Jabeen
   Assistant Professor,
   Department of Bioinformatics,
   National University of Science & Technology,
   Research Centre for Modeling & Simulation (RCMS),
   H-12, Islamabad

5. Dr. Faisal F. Khan
   Assistant Professor / Director,
   Institute of Integrative Biosciences,
   CECOS University of IT & Emerging Sciences,
   Phase-VI, Hayatabad, Peshawar

6. Dr. Muhammad Inam ul Haq
   Assistant Professor,
   Department of Computer Sciences,
   Khushal Khan Khattak University, Karak, KPK

7. Dr. Aftab Ali Shah
   Assistant Professor,
   Department of Biotechnology,
   University of Malakand, KPK.
8. Dr. Shahida Hasnain  
Member  
Professor / Vice Chancellor,  
Department of Microbiology & Molecular Genetics,  
The Women University, Katchery Road, Multan

9. Dr. Mehbboob Ahmed  
Member  
Assistant Professor,  
Department of Microbiology & Molecular Genetics,  
University of the Punjab, New Campus, Lahore

10. Dr. Muhammad Wasim  
Member  
Associate Professor,  
Institute of Biochemistry & Biotechnology,  
University of Veterinary & Animal Sciences, Lahore

11. Dr. Masroor Ellahi Babar  
Member  
Professor,  
Department of Bioinformatics,  
Virtual University of Pakistan, MA Jinnah Campus, Defence Road, Lahore

12. Dr. Samreen Amir  
Member  
Associate Professor,  
Hamdard Institute of Engineering & Technology, Hamdard University, Madinat-al-Hikmah, Shahrah-e-Madinat-al-Hikmah, Muhammad Bin Qasim Avenue, Karachi-74600

13. Dr. Muhammad Arif  
Member  
Assistant Professor,  
Department of Biomedical Engineering, Mehran University of Engineering & Technology, Jamshoro, Sindh

14. Dr. Farhat Naureen Memon  
Member  
Assistant Professor,  
Institute of Mathematics & Computer Science, University of Sindh, Jamshoro

15. Dr. Aziz Mithani  
Member  
Assistant Professor,  
Department of Biology, Syed Babar Ali School of Science & Engineering, Lahore University of Management Sciences, Sector U, DHA, Lahore Cantt. 54792
16. Dr. Muhammad Nauman Aftab  
Assistant Professor,  
(Secretary NCRC 2011),  
Institute of Industrial Biotechnology,  
Government College University, Lahore

17. Ms. Iffat Farzana Anjum  
Lecturer,  
Department of Bioinformatics & Biotechnology,  
Room # 11, Maryam Block,  
International Islamic University, Islamabad

18. Mr. Rizwan Shaukat  
Deputy Director (Curriculum Division)  
Higher Education Commission,  
Sector H-9,  
Islamabad

19. Dr. Sajid Rashid  
Assistant Professor,  
National Centre for Bioinformatics,  
Quaid-i-Azam University, Islamabad
Mission Statement
To train the next generation professionals and researchers to gain advanced knowledge in the interdisciplinary field of Bioinformatics that is required to design and implement novel methods and tools to provide a better understanding of biological systems.

Program Objectives
At the end of four years BS program, the graduates should have strong understanding of:

1. Various aspects of biological systems.
2. Different areas of computer science including programming languages.
3. Existing bioinformatics tools and databases.
4. Computational applications related to biological systems.
5. Analysis and interpretation of biological data.

Learning outcomes
At the completion of this program, students are expected to know the relationship between genes and proteins and use of computer to handle biological data.—Students should have a deeper insight into various tools and techniques commonly used in bioinformatics. Students should be able to appreciate diversified areas and applications like genomics, drug designing, agri- and health informatics, biotechnology, systems biology and others.

Admission Requirements

Eligibility
Higher Secondary School certificate or equivalent (2nd division with at least 50% marks) in pre-engineering/pre-medical/Intermediate in computer sciences/relevant subjects

Duration
Four years program spread over 8 semesters, two semesters per year.

Course and Credit Requirements
A total of 124-136 credit hours are required to complete BS in Bioinformatics.
**STANDARDIZED FORMAT/SCHEME OF STUDIES FOR FOUR-YEAR INTEGRATED CURRICULA FOR BACHELOR DEGREE IN BIOINFORMATICS**

**STRUCTURE**

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Categories</th>
<th>No. of Courses Min – Max</th>
<th>Credit Hours Min – Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>General Courses to be chosen from other departments</td>
<td>7 – 8</td>
<td>21 – 24</td>
</tr>
<tr>
<td>3.</td>
<td>Discipline Specific Foundation Courses</td>
<td>9 – 10</td>
<td>30 – 33</td>
</tr>
<tr>
<td>4.</td>
<td>Major Courses including research project/Internship</td>
<td>11 – 13</td>
<td>36 – 42</td>
</tr>
<tr>
<td>5.</td>
<td>Electives within the major</td>
<td>4 – 4</td>
<td>12 – 12</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>40 – 44</strong></td>
<td><strong>124 – 136</strong></td>
</tr>
</tbody>
</table>

Total numbers of Credit hours 124-136  
Duration 4 years  
Semester duration 16-18 weeks  
Semesters 8  
Course Load per Semester 15-18 credit hours  
Number of courses per semester 4-6 (not more than 3 lab/practical courses)
## LAYOUT

<table>
<thead>
<tr>
<th>Compulsory Requirements (student has no choice)</th>
<th>General Courses to be chosen from other departments</th>
<th>Discipline Specific Foundation Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 courses</td>
<td>7-8 courses</td>
<td>9-10 courses</td>
</tr>
<tr>
<td>25 Credit hours</td>
<td>21-24 Credit hours</td>
<td>30-33 Credit hours</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Subject</th>
<th>Cr. hr.</th>
<th>Subject</th>
<th>Cr. hr.</th>
<th>Subject</th>
<th>Cr. hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. English I</td>
<td>3</td>
<td>1. Data Structure and Algorithms</td>
<td>4</td>
<td>1. Linear Algebra and Differential Equations</td>
<td>3</td>
</tr>
<tr>
<td>2. English II</td>
<td>3</td>
<td>2. Object oriented programming</td>
<td>4</td>
<td>2. Essentials of Genetics</td>
<td>4</td>
</tr>
<tr>
<td>9. Chemistry</td>
<td></td>
<td></td>
<td></td>
<td>9. Recombinant DNA technology</td>
<td></td>
</tr>
</tbody>
</table>

<p>| | 25 | 24 | 32 |</p>
<table>
<thead>
<tr>
<th>Major courses including research project/internship</th>
<th>Elective Courses within the major</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-13 courses</td>
<td>4 courses</td>
</tr>
<tr>
<td>36-42 Credit hours</td>
<td>12 Credit Hours</td>
</tr>
<tr>
<td>Subject</td>
<td>Cr. hr.</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>1. Bioinformatics Computing I</td>
<td>4</td>
</tr>
<tr>
<td>2. Genomics</td>
<td>3</td>
</tr>
<tr>
<td>3. Proteomics</td>
<td>3</td>
</tr>
<tr>
<td>4. Graphics and Visualization</td>
<td>3</td>
</tr>
<tr>
<td>5. Bioinformatics Computing II</td>
<td>3</td>
</tr>
<tr>
<td>6. Artificial Intelligence</td>
<td>3</td>
</tr>
<tr>
<td>7. Bioinformatics software Engineering</td>
<td>3</td>
</tr>
<tr>
<td>8. Special topics in Bioinformatics</td>
<td>3</td>
</tr>
<tr>
<td>9. Research Project</td>
<td>3</td>
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<tr>
<td>10. Systems Biology</td>
<td>4</td>
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<tr>
<td>11. Modeling and Simulation</td>
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<tr>
<td>12. Probability and Biostatistics</td>
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| Cr. hr. | 42 | 12 |
## Scheme of Studies for BS (Bioinformatics)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Semester 1</th>
<th>Credit hours</th>
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<tbody>
<tr>
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<td>Courses</td>
<td>Lectures</td>
</tr>
<tr>
<td>Hum-101</td>
<td>English Comprehension</td>
<td>3</td>
</tr>
<tr>
<td>Hum-105</td>
<td>Pakistan Studies</td>
<td>2</td>
</tr>
<tr>
<td>Hum-***</td>
<td>Islamic Studies/Ethics</td>
<td>2</td>
</tr>
<tr>
<td>Bio-101 OR MTH-101</td>
<td>Basic Biology* OR Basic Mathematics*</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Bio-102</td>
<td>Chemistry</td>
<td>2</td>
</tr>
<tr>
<td>CS-101</td>
<td>Computer Fundamentals</td>
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*Deficiency courses

Total Credit Hours

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<th>Lectures</th>
<th>Lab</th>
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<td>13 OR 14</td>
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<th>Semester 2</th>
<th>Credit hours</th>
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<tbody>
<tr>
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<td>Courses</td>
<td>Lectures</td>
</tr>
<tr>
<td>Bio-203</td>
<td>Probability and Biostatistics</td>
<td>3</td>
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<tr>
<td>Bio-103</td>
<td>Basic Cell Biology</td>
<td>3</td>
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<tr>
<td>CS-102</td>
<td>Programming Fundamentals</td>
<td>3</td>
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<tr>
<td>BSI-191</td>
<td>Basic Calculus</td>
<td>3</td>
</tr>
<tr>
<td>Bio-104</td>
<td>Biochemistry I</td>
<td>3</td>
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Total Credit Hours

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<th>Lectures</th>
<th>Lab</th>
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<tbody>
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<td>Credit hours</td>
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<td></td>
<td>Courses</td>
<td>Lectures</td>
</tr>
<tr>
<td>Hum-201</td>
<td>Technical Report Writing</td>
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</tr>
<tr>
<td>MTH-201</td>
<td>Linear Algebra and Differential Equations</td>
<td>3</td>
</tr>
<tr>
<td>Bio-201</td>
<td>Essentials of Genetics</td>
<td>3</td>
</tr>
<tr>
<td>Hum-103</td>
<td>Communication skills</td>
<td>3</td>
</tr>
<tr>
<td>CS-201</td>
<td>Data Structure and Algorithms</td>
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<tr>
<td>Total Credit Hours</td>
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<tr>
<td>BI-201</td>
<td>Bioinformatics I</td>
<td>2</td>
</tr>
<tr>
<td>Bio-204</td>
<td>Biochemistry II</td>
<td>3</td>
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<tr>
<td>Bio-202</td>
<td>Molecular Biology</td>
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<tr>
<td>CS-202</td>
<td>Object Oriented Programming</td>
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<td>SS-***</td>
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<th>Credit hours</th>
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<td>Courses</td>
<td>Lectures</td>
</tr>
<tr>
<td>CS-301</td>
<td>Discrete Structures</td>
<td>3</td>
</tr>
<tr>
<td>GEN-***</td>
<td>Recombinant DNA technology</td>
<td>2</td>
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<tr>
<td>CS-302</td>
<td>Database Management Systems</td>
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<td>Credit hours</td>
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<tr>
<td></td>
<td>Courses</td>
<td>Lectures</td>
</tr>
<tr>
<td>BI-302</td>
<td>Bioinformatics Computing I</td>
<td>3</td>
</tr>
<tr>
<td>CS-303</td>
<td>Modeling and Simulation</td>
<td>2</td>
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<tr>
<td>Bio-303</td>
<td>Proteomics</td>
<td>3</td>
</tr>
<tr>
<td>CS-304</td>
<td>Graphics and Visualization</td>
<td>3</td>
</tr>
<tr>
<td>Bio-304</td>
<td>Systems Biology</td>
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<td>CS-401</td>
<td>Artificial Intelligence</td>
<td>3</td>
</tr>
<tr>
<td>BI-402</td>
<td>Bioinformatics Software Engineering</td>
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<tr>
<td>***</td>
<td>Elective I</td>
<td>3</td>
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<tr>
<td>***</td>
<td>Elective II</td>
<td>3</td>
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<tr>
<td>BI-403</td>
<td>Special Topics in Bioinformatics</td>
<td>3</td>
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<td></td>
<td>Research Project</td>
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<tr>
<td><strong>Total Credit Hours</strong></td>
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<td>Semester 8</td>
<td>Credit hours</td>
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<tr>
<td></td>
<td>Courses</td>
<td>Lectures</td>
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<tr>
<td>BI-401</td>
<td>Bioinformatics Computing II</td>
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<tr>
<td>***</td>
<td>Elective III</td>
<td>3</td>
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<td>Elective IV</td>
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<td>Research Project</td>
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<td></td>
<td>Total Credit Hours</td>
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DETAIL OF COURSES

Semester-I

Hum-101  English Comprehension  3+0  Annexure - A
Hum-105  Pakistan Studies       2+0  Annexure - B
Hum-***  Islamic Studies/Ethics 2+0  Annexure - C
Bio-101  Basic Biology          2+1

Prerequisite: None
Specific objectives of the course:
To provide students with a biological foundation on which they can build a graduate degree in natural and physical science.

Course Outline
Basic concepts of life science: origin of life; biological time scales, branches of biology, prokaryotic and eukaryotic cells, viruses, structure of viruses and bacteriophages, bacteria, bacterial structure and classification; algae, fungi. Introduction to plant and animal biology, role of biology in medicine.

Lab Outline
Study of plant and animal cell structure using compound microscope, culture and staining of microorganisms, study of mitosis and meiosis, study of flowers.

Recommended Books
Latest editions of following books

MTH-101  Basic Mathematics      3+0

Prerequisite: None
Specific objectives of the course
This is a deficiency course for students who have not studied mathematics at the intermediate level. The basic concepts of trigonometry, linear algebra and vectors are introduced in this course.
Course Outline
Basic concepts of Linear Algebra, Introduction of Trigonometry, Using graphs, Graph transforms, Combination and Permutations, Introductory concepts in Integration and Derivatives, Exponentials, Logarithms, Basic concepts related to Complex Numbers, Basic probability, Introduction to Linear Equations and Algebraic Functions, Sequence and series, Introductory concepts of Vectors and various applications of Vector calculus.

Recommended Books
Latest editions of following books
1. Hebeorn and Littlewood, “Modular Math”, Heinemann,

Bio-102 Chemistry 2+1

Prerequisite: None

Specific objectives of the course
This course will familiarize students with basic principles, concepts and theories in chemistry.

Course Outline
Periodic table, nature of chemical bonding, state of matter, properties of solutions; properties of liquid vapor pressure, surface tension viscosity, optical activity, refractometry, liquid properties of water as solvent structure and interaction, chemical reactivity, acid, bases, oxidation-reduction reactions, chemical kinetics, first, second, and third order reactions, influence of temperature on reaction rates, polymers and colloids, introduction to organic chemistry.

Lab Outline
Preparation of molar and normal solutions, use of pH meter to determine pH of various solutions, acid base titration, use of spectrophotometer to determine the absorbance, determination of melting point and boiling point.

Recommended Books
Latest editions of following books

CS-101 Computer Fundamentals 2+1

Prerequisite: None

Specific objectives of the course
This course focuses on introducing computing environments, general application software, basic computing hardware, operating systems, desktop publishing, Internet, software applications and tools and computer usage concepts.

Course Outline
History, classification, computer and society, overview of numbering system with various Boolean functions, flow chart techniques, storage, programs & software, system software, application software, operating systems, office automation tools: word processing, graphics packages, databases and spreadsheets, various operating systems, current trends and research prospects. Legal and moral aspects of computing.

Lab Outline
Computation of Number system, Implementation of Boolean Functions, Basic machines organization including motherboard, memory, I/O cards, Networking devices, Use of flow charts, Introduction to office tools, overview of different browsers including open source browsers, Introduction to various operating systems.

Recommended Books
Latest editions of following books
1. P.K Sinha, “Introduction to Computer Science”,

Semester-II

Bio-203 Probability and Biostatistics 3+1

Prerequisite: None

Specific objectives of the course
This course introduces the concepts of statistical methods used in analyzing biological data.
Course Outline
Frequency distribution and probabilities, measure of central tendencies and dispersion, Elementary probability theory, Laws of Probability, Conditional Probability, Introduction to Bayes Theorem Introduction to Random Variable and Probability Distributions, Binomial Distribution, Properties of binomial distribution, Poisson distribution, Normal distribution area under the normal curves, Introduction to sampling and various sampling design, Applications of Normal distributions and tests of significance,. Test of independence or association, method related to one and two means, variance and covariance, heritability and its uses, analysis of variance (ANOVA), regression analysis, Pedcheck and merlin for LOD score calculation.

Lab Outline
Collection of data, acquisition of random samples, graphical/tabular representation of data, MS-Excel, SPSS/R, problems related to combining probabilities, central tendencies and dispersion, problems related to chi-square, problems of goodness of fit and independent events, verification of genetic ratios and test of association.

Recommended Books
Latest editions of following books

Bio-103 Basic Cell Biology  3+1

Prerequisite: None

Specific objectives of the course
This course provides the basic concepts of life science, with emphasis on diversity of life, physical and chemical nature of living matter, the form and function of the cell and organisms.

Course Outline
An introduction to cell biology, differences between prokaryotes and eukaryotes, physio-chemical properties of protoplasm, cell wall, cell membrane, structure and transport properties, fluid mosaic model, organelles: mitochondria, endoplasmic reticulum, golgi bodies, plastids, lysosomes, peroxisomes, cell internal structure, cytoskeleton, microtubules, microfilaments, intermediate filaments, structure of chromosomes, cell division and cell cycle.

Lab Outline
Study of cell structure using compound microscope and elucidation of ultra-structure from electron microphotographs, measurement of cell size, study of mitosis and meiosis by smear/squash method and from prepared slides, study of chromosome morphology and variation in chromosome number.

Recommended Books
Latest editions of following books
4. Lodish H. “Molecular Cell Biology”, Media Connected
5. Lewin B. “Genes X”, Pearson/Prentice Hall.

CS-102 Programming Fundamentals 3+1
Prerequisite: Basic Math

Specific objectives of the course
The course is designed to familiarize students with the basic programming skills. It emphasizes upon problem analysis, algorithm designing, program development and testing.

Course Outline
Overview of programming, overview of computer languages and translators, basics of structured and modular programming, basics of
algorithms and problem solving logics, fundamentals of programming constructs, translation of algorithms to programs, data types, control structures, functions, arrays, records, files, pointers, program development.

**Lab Outline**
Introduction to various programming paradigms, coding, executing and debugging simple programs, implementation of simple control structures, implementation of functions, arrays, records, file input / output techniques implementation of pointers and memory allocation/deallocation.

**Recommended Books**
Latest editions of following books

**BS-191 Basic Calculus 3+0**

**Prerequisite:** None

This course will familiarize students with the basic principles of calculus and their application to problem solving.

**Course Outline**

**Recommended Books**
Latest editions of following books
Bio-104       Biochemistry I       3+1

**Prerequisite:** None

**Specific objectives of the course**
The course will provide fundamental knowledge about chemistry of biomolecules.

**Course Outline**
Water, pH and buffer systems, molecules of life: structure, function and classification, nucleic acids as genetic material, lipids, bilayers and membranes, saccharide chemistry, mono, di and polysaccharides, amino acids the building block of proteins, levels of protein structures, protein structure and folding, physiological role of proteins, role in catalysis and signaling

**Lab Outline**
Hydrolysis of a protein and qualitative tests for amino acids; paper chromatography of amino acids; estimation of proteins by Lowry’s, dye-binding, titration curves of amino acids. Distinction between pentoses and hexoses, reducing and non-reducing sugars, acid value, saponification and iodine values of fat.

**Recommended Books**
Latest editions of the following books


**Semester-III**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Annexure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hum-201</td>
<td>Technical Report Writing</td>
<td>3+0</td>
<td>ANNEXURE - A</td>
</tr>
<tr>
<td>Hum-103</td>
<td>Communication Skills</td>
<td>3+0</td>
<td>ANNEXURE - A</td>
</tr>
</tbody>
</table>
MTH-201  Linear Algebra and Differential Equations  3+0

Prerequisite:  None

Specific objectives of the course
This course introduces matrices, determinants and differential equations for solving linear equations.

Course Outline
Introduction to matrices, elementary row operations and vector spaces: Brief introduction to matrices, system of linear equations, system of non-homogeneous and homogeneous linear equation, introduction to determinants, properties of determinants of order, axiomatic definition of a determinant, multiple integrals, double integrals, differential equations of first order, initial and boundary conditions, methods of solution of differential equation of first order and first-degree, separable equation, homogeneous equations, linear equations, Bernoulli equations, applications of first order differential equations. Higher order linear differential equations, homogeneous linear equations, solution of higher order differential equations.

Recommended Books
Latest editions of following books

Bio-201  Essentials of Genetics  3+1

Prerequisite:  Biochemistry 1

Specific objectives of the course
This course provides the basic principles of inheritance and students will gain experience in variety of techniques used in gene analysis.

Course Outline
Introduction, heredity and variations, Mendelian and non-Mendelian inheritance, chromosomal structure, chromosomal theory of heredity, multiple allelic, linkage and gene mapping, polygenic inheritance, epistasis, epigenetics, penetrance and expressivity, Sex-linked inheritance, chromosomal aberrations, gene mutation, genetic disorders; DNA polymorphism, cytoplasmic inheritance, population genetics [Hardy-Weinberg equilibrium, selection, inbreeding and heterosis]
Lab Contents
Chromosome staining, Problems solving related to topics covered – ABO blood grouping,

Recommended Books
Latest editions of following books

CS-201  Data Structure and Algorithms  3+1
Prerequisite: Programming Fundamentals

Specific objectives of the course
It describes data structures and explains some common data structures and their implementation.

Course Outline
Introduction to data structures and algorithms, array based algorithms: storage, retrieval and search, computational complexity, uses of arrays, concept of binary and linear search, Stacks and queues, priority queues, store, retrieve and search functionalities in stacks and queues, linked list, double ended links, linked list efficiency, sorted list. Recursion application, Triangular Numbers, Factorials, Trees, heaps, graphs and their algorithms, sorting techniques: selection sort, insertion sort, bubble sort, merge sort and quick sort. Comparison of sorting techniques and their applications.

Lab Outline
Implementation of arrays, storing and searching data in arrays, implementation of Linear Search, implementation of Binary Search in Arrays, Using different sorting techniques on sample data, implementing Stacks, Queues and priority queues, implementation of different types of Linked Lists, tree and graph algorithms.

Recommended Books
Latest editions of following books
2. Gary Benson and Roderic Page, “Algorithms in Bioinformatics”.
Semester-IV

SS-*** Social sciences subject 3+0

BI-201 Bioinformatics-I 2+1

Prerequisite: Computer science 101

Specific objectives of the course
This course presents the basic principles and concepts in exploring sequence storage, retrieval and analysis.

Course Outline
Introduction, history, timeline, databases, sequence storage, retrieval and analysis, similarity and homology, creating alignments, local and global alignment, pairwise and multiple sequence alignments, phylogenetic analysis, dot matrix plots, dynamic programming algorithm, word (k-tuple) methods, substitution matrices PAM and BLOSUM, scoring algorithms, gap penalties, online tools BLAST, BLAT and FASTA, PDB file structure.

Lab Outline
Accessing NCBI, ENSEMBL, UniProt, Genbank, EMBL, SWISS-PROT, Accessing structural databases including PDB, SCOP and CATH, EXPASY and FASTA using tools for pairwise and multiple sequence alignment, Phylogenetic analysis, Bioedit.

Recommended Books
Latest editions of following books

Bio-204 Biochemistry II 3+0

Prerequisite: Biochemistry I

Specific objectives of the course
This course focuses on macromolecules and their metabolisms with emphasis on various cellular pathways.

Course Outline
Study of bioenergetics, introduction to metabolic pathways, metabolism of carbohydrates, Glycolysis, Citric acid cycle, Pentose pathway, electron
transport chain, and oxidative phosphorylation, lipid metabolism, β-oxidation, ketone bodies formation and biosynthesis of triglyceride, protein metabolism, oxidative deamination and decarboxylation, transamination, amino acids metabolism, urea cycle, nucleic acid metabolism, break down and synthesis of purine and pyrimidine bases

Recommended Books
Latest editions of following books

Bio-202 Molecular Biology 3+1

Prerequisite: Biochemistry 1

Specific objectives of the course
This course is designed to teach the students about organization of genetic material, regulation of gene expression and translation.

Course Outline
Basic concepts about DNA, RNA and proteins with special emphasis on nature of genetic material and its organization in viruses, prokaryotes and eukaryotes, DNA replication, recombination, mutations and repair, Gene structure, transcription, regulatory elements, regulation of gene expression. RNA processing, splicing and editing, translation and post-translational modifications, control of gene expression in prokaryotes and eukaryotes. Introduction to plasmids and vectors.

Lab Outline
Isolation of plasmid and genomic DNA from eukaryotes and prokaryotes, Primer designing, PCR, gel electrophoresis and its interpretation.

Recommended Books
Latest editions of following books

CS-202 Object Oriented Programming 3+1

Prerequisite(s): Programming Fundamentals

Specific objectives of the course
The course focuses on object-oriented concepts, analysis and software development.

Course Outline
Concept of object oriented programming (OOP), characteristics of OOP, simple programs, dynamic initializing, scope and lifetime of variables, type conversion and casting, the type promotion rules, arrays, string data type, operator and its types. Introducing classes, declaring objects, object reference, control access, specified, public, private, static, data member and methods. Creating packages, constructors, function overloading, constructor overloading, reference, members, inheritance, polymorphism, dynamic method binding, inner class definitions, Friend function, virtual functions, inline functions, Abstract classes, Interfaces, exception handling.

Lab Outline: Programs formulation according to the Course outlines.

Recommended Book
Latest editions of following books

Semester V

CS-301 Discrete Structures 3+0

Prerequisite: Basic Calculus

Specific objectives of the course
Introduces the fundamentals of discrete mathematics as they apply to Computer Science, focusing on providing a solid theoretical foundation

**Course Outline**
Logic and proofs, direct proofs, proof by contradiction, Sets, combinatorics, sequences, formal logic, prepositional and predicate calculus, methods of proof, mathematical induction and recursion, loop invariants, relations and functions, Pigeonhole principle, trees and graphs, elementary number theory, optimization and matching, Fundamental structures, functions, relations (more specifically recursions), cardinality and countability, probabilistic methods.

**Recommended Books**
Latest editions of following books


**GEN-507 Recombinant DNA technology 2+1**

**Prerequisite:** None

**Specific objectives of the course**
The course objectives are to provide information on techniques used to manipulate genetic materials; and to discuss applications of recombinant DNA technology in medicine, agriculture and environment.

**Course Outline**
Basic concepts in recombinant DNA technology, Gel electrophoresis, hybridization, PCR and gene transformation, Restriction and modification system: types, enzymes, classifications, nomenclature and application: isolation and purification of DNA, cutting of DNA molecules, ligation of DNA molecules, blunt ends and cohesive termini, homopolymer tailing, Cloning vectors: plasmids (bacteria and yeast), viruses (CMV, SV40, BPV, Lambda, Mu, M13), Cosmids and Phosmids, YAC’s, BACs and PACs. Cloning strategies (Prokaryotic and Eukaryotic); selection and characterizations of recombinant molecules, verifications and amplifications of desired genes, Construction and analysis of DNA
libraries, Maximizing the cloned expression, site directed mutagenesis, DNA sequencing techniques, Applications of genetic engineering in medicine, agriculture and environment.

**Lab Contents**
Isolation of plasmid and chromosomal DNA from bacteria and yeast, Screening of bacteria from plasmid by electrophoresis of total cell lysate, Gel electrophoresis of plasmid DNA (supercoiled, linear and digested with restriction enzyme) and chromosomal DNA, Plasmid transformation of *E. coli*, comparing plasmids of different molecular weights using molecular weight markers, DNA amplification by PCR, Numerical problems related to recombinant DNA.

**Recommended Books**
Latest editions of following books

**CS-302 Database Management Systems 3+1**

**Prerequisite:** None

**Specific objectives of the course**
The course aims to introduce basic database concepts, different data models, storage and retrieval techniques, database design techniques.

**Course Outline**
Basic database concepts, conceptual modeling, hierarchical, network and relational data models, relational theory and languages, databases design, database security and integrity, query languages, relational calculus, relational algebra, SQL, query processing and optimization, normalization, concurrency and recovery, front-end and back-end databases.

**Lab Outline**
Structured query language commands, creating and populating tables, design of simple databases, database normalization techniques, query optimization, indexing techniques, partial and full recovery techniques,
developing GUI techniques, implementation of database security mechanisms, MySQL.

Recommended Books
Latest editions of following books

BI-202 Ethical & Legal Issues in Bioinformatics 2+0

Prerequisite (s): None

Specific objectives of the course
This course introduces the ethical and legal aspects related to bioinformatics practices and products.

Course Outline
Social context of computing and biology, Intellectual property, Privacy and civil liberties, Economic issues in bioinformatics, monopolies and their economic implications, effect of skilled labor supply and demand on the quality of bioinformatics products, pricing strategies in the bioinformatics domain, differences in access to bioinformatics resources and the possible effects thereof. Health, psychological and legal issues in GMOs, biosafety and bio-security issues

Recommended Book
Latest editions of following books
BI-301   Bioinformatics II  3+1

Prerequisite (s): Bioinformatics I

Specific objectives of the course
This course is designed to develop understanding of gene and protein at structural level using computational tools.

Course Outline
Introduction to genome, gene prediction in prokaryotes and eukaryotes, ORF, TFBS, codon usage table, EST and SNP databases, primer designing, restriction enzyme databases, RNA structure prediction, computational secondary and tertiary protein structure prediction methods, structure optimization and refinement methods, hydrogen bonding, PTMs of proteins, Chou Fasman, PHD and PSIPred, neural network, X-ray crystallography, NMR, ab initio, threading and homology modeling methods, protein fold identification using Pfam (A & B) and other tools.

Lab Contents
Online tools: Gene finder, ORF finder, EST database, SNP data, Primer 3, protein structure prediction using online server, protein structure visualizing using visualization programs, Secondary structure prediction, using pfam database.

Recommended Books
Latest editions of following books

Bio-302   Genomics  3+0

Prerequisite: Biochemistry I/Molecular Biology

Specific objectives of the course
Students will be trained to grasp knowledge about structural and functional genomics and their applications.

Course Outline
Introduction, types of genome, genome evolution, genome organization and structure, global expression profiling, microarray data analysis, genome mapping, DNA markers, linkage analysis, genome-wide screening, mutation, type of mutations, mutation identification, DNA repeats, QTL, Human Genome Project, Genevestigator, Non-coding RNAs and their regulation, siRNA, completed genomes, applications of genome analysis, Next generation sequencing.

Recommended Books
Latest editions of following books

Semester-VI
BI-302 Bioinformatics Computing-I 3+1

Prerequisite: Programming Fundamentals

Specific objectives of the course
This course aims to introduce the concepts of data representation, searching, security and ownership. Develop techniques for pattern matching, recognition and their applications in bioinformatics.

Course Outline
Databases: Data management, networks, geographical scope, communications models, transmissions technology, protocols, bandwidth, topology, hardware, contents, security, ownership, implementation, Search engines. search process, search engine technology, searching and information theory, computational methods, knowledge management, sequence and structure visualization, data mining methods and technology, pattern recognition and discovery, pattern matching, dot matrix analysis, substitution matrices, dynamic programming, Scripting
Lab Outline
Simulation of various bioinformatics entities, application of various bioinformatics methods, scripting languages Python, Perl and PHP, and their applications in Bioinformatics

Recommended Books
Latest editions of following books

CS-303  Modeling & Simulation  2+1

Prerequisite: Programming Fundamentals, Probability and Biostatistics

Specific objectives of the course
This course emphasizes the development of modeling and simulation concepts and analytical skills necessary to design, program and implement various biological models.

Course Outline
Performance modeling and evaluation, bench marking, performance evaluation of high parallel systems architecture, application of performance evaluation, measurement techniques, hardware monitoring, software monitoring, hybrid monitoring, fundamentals of queuing models, structure and performance parameters, operational analysis of queuing models, general features of queuing models, birth and death processes, m/m/i and m/g/1 systems, dependability modeling, analysis of reliable, available and high assurance systems, fault-tolerant techniques, software reliability modeling, adaptive modeling, agent based modeling, Types of simulations, applications of simulations

Lab Outline
Introduction to modeling techniques using simulation tools like MATLAB toolbox for various performance modeling and evaluation of high parallel systems.

Recommended Books
Latest editions of following books
Bio-303 Proteomics 3+0

Prerequisite: Biochemistry I/Molecular Biology

Specific objectives of the course
This course intends to provide basic concepts regarding proteome and protein chemistry with special focus on protein identification techniques.

Course Outline
Introduction, techniques in proteomics, amino acids structures, properties and function, one dimensional and two dimensional PAGE and analysis, Mass spectrometry and its types. Protein-protein interaction, Bioinformatics tools for analysis of proteomics data, proteomics databases, MS data analysis, peptide mass and fragment fingerprinting, protein identification, post-translational modification, applications of proteomics, protein microarrays.

Recommended Books
Latest editions of following books
2. Rigden D. J., “From protein structure to function with bioinformatics”, Springer.
3. Hubbard S. J., “Proteome Bioinformatics”, Humana Press.

CS-304 Graphics and Visualization 3+1

Prerequisite: Programming Fundamentals

Specific objectives of the course
This course introduces algorithms and tools for data visualization and its applications to data manipulation.

Course Outline
Introduction, Graphics hardware, fundamental algorithms, applications of graphics, interactive graphics programming, graph plotting, windows, clipping and segmentation, programming raster display systems, panning
and zooming, raster algorithms and software, scan-converting lines, characters and circles, region filling, two and three dimensional imaging geometry and transformations, curve and surface design, rendering, shading, colour and animation.

Lab Outline
Line drawing techniques, clipping effects, 2D and 3D representations and transformations using open GL, development of graphical user interface with various blocks and modules, elliptical and curve creation exercises.

Recommended Books
Latest editions of following books

BIO-304 Systems Biology 3+0

Prerequisite
Probability & Statistics, Linear Algebra & Differential Equations, Genomics

Specific objectives of the course
The purpose of the course is to introduce the students to the field of systems biology and to provide an understanding of the cell at systems level.

Course Outline
Introduction to systems biology; modeling of biochemical systems; kinetic modeling of enzymatic reactions; law of mass action; Michaelis-Menten Kinetics; rate equation; model systems: lac operon, phages, plasmids and chemotaxis; analysis of high throughput data; gene expression models; stochastic modeling of biological systems; chemical master equation. stochastic simulation, fluctuations in gene expression; biological networks; network structure, network dynamics and function; network motifs, network modularity

Recommended Books
Latest editions of following books

Semester-VII

CS-402 Artificial Intelligence 3+0

Prerequisite
Programming Fundamentals, Data Structures and Algorithms

Course objectives
Presentation of artificial intelligence as a coherent body of ideas and methods to acquaint the student with basic programs in the field and their underlying theory.

Course Contents

Recommended Books
Latest editions of following books
Bio-406  Bioinformatics Software Engineering  2+1

**Prerequisite**

**Specific objectives of the course**
This course introduces the software engineering principles and methodologies with the goal of developing bioinformatics applications.

**Course Outline**
System analysis and design, UML, software development methodology, waterfall model, iterative model, rapid application development, prototyping, software life cycle, development of software projects for bioinformatics problems, overview of software architecture, web-based applications, architecture, developing front end applications, database connectivity, software testing and validation, software robustness, software quality assurance.

**Lab Outline**
Introduction to software development techniques, developing use cases, implementation of various software models using simple case studies, introduction to HTML, XML, use of front end application tool. Designing database driven applications

**Recommended Books**
Latest editions of following books

BI-407  Special Topics in Bioinformatics  3+0

**Prerequisite:**  Bioinformatics-I

**Specific objectives of the course**
This course intends to introduce recent advances in bioinformatics.

**Course Outline**
The course will review the major advances in bioinformatics and the topics will be selected by the faculty members / Coordinator conducting Bioinformatics Program.
Elective-I
Prerequisite: None
Course Outline
To be chosen from the list of electives

Elective-II
Prerequisite: None
Course Outline
To be chosen from the list of electives

Research Project
Prerequisite: None
Course Outline
An independent research project and directed by the student and directed by a full time faculty member of the department.

Semester-VIII
BI-401 Bioinformatics Computing-II
Prerequisite: Bioinformatics Computing-I
Specific objectives of the course
This course introduces advanced concepts of neural networks and pattern recognition for solving bioinformatics problems.

Course Outline
This course is emphasized on cellular, tissue, organ and system modeling, simulation, analysis, Bio-inspired computation, evolutionary algorithms, Swarm Intelligence, neural networks, application of neural networks to Bioinformatics, neural computation, approximate matching algorithm and their applications for DNA Matching.

Lab Outline
Simulation and application of neural network related techniques for bioinformatics, implementation of approximate matching algorithms, DNA matching algorithms and applications.

Recommended Books
Latest editions of following books
2. Lacroix Zor, Terence Critchlow, “Bioinformatics: Managing Scientific Data”, Morgan Kaufmann.

*** Elective-III 3+0
Prerequisite: None

Course Outline
To be chosen from the list of electives.

*** Elective-IV 3+0
Prerequisite: None

Course Outline
To be chosen from the list of electives.

*** Research Project 0+3
Prerequisite: None

Course Outline
An independent research project and directed by a full time faculty member of the department.

List of Electives

1. Enzyme Kinetics
2. Functional genomics
3. Human Computer Interaction
4. Nanotechnology
5. Environmental Biotechnology
6. Special Topics in Biochemistry
7. Immuno-Informatics
8. Microbial genomics and proteomics
9. Network Biology
10. Biophysics
11. Modern programming languages
12. Methods in protein modeling
13. Pharmacoinformatics
14. Statistical methods in bioinformatics
15. Design and analysis of algorithms
16. Epigenetics and gene regulation
17. Protein chemistry
18. Microbial genetics
19. Molecular oncology
20. Immunology
Note
In addition to the above, the universities can offer any elective which they feel necessary subject to the availability of resources.

RECOMMENDED BOOKS
The latest editions of

Cell and Molecular Biology: Concepts and Experiments
Gerald Karp
John Wiley and Sons

Introduction to Computational Molecular Biology
Setubal, Meidanis
Brooks/Cole

Principles and Techniques of Biochemistry and Molecular Biology
Keith Wilson, John Walker
Cambridge University Press

Instant Notes: Biochemistry
B D Hames
Viva Books Pvt. Ltd.

Basics of Theoretical and Computational Chemistry
BM Rode
John Willey and Sons

Instant Notes: Genetics
P C Winter
Viva Books Pvt. Ltd.

Instant Notes: Molecular Biology
P C Turner
Viva Books Pvt. Ltd.

Molecular Cloning: A laboratory manual
Sambrook
Cold Spring Harbor, Laboratory Press.

Instant Notes: Bioinformatics
David R. Westhead, J. Howard Parish and Richard M. Twyman
Viva Books Pvt. Ltd.

Bioinformatics for Dummies
Jean-Michel Claverie,Cedric Notredame
Wiley Publishing, Inc.
Essential Bioinformatics
Jin Xiong
Cambridge University Press.

Bioinformatics
Bal
Tata McGraw-Hill.

Bioinformatics
Andrzej Polański, Marek Kimmel
Springer.

Bioinformatics: An Introduction
Jeremy Ramsden
Springer.

Bioinformatics: A Concept-based Introduction
Venkatarajan Subramanian Mathura, Pandjassarame Kangueane
Springer.

Bioinformatics: Tools and Applications
David Edwards, Jason Eric Stajich, David Hansen
Springer.

Bioinformatics: Principles and Basic Internet Applications
Hassan A. Sadek
Trafford Publishing, Canada.

Bioinformatics: Applications in Life and Environmental Sciences
M. H. Fulekar
Springer.

Bioinformatics: A Practical Approach
Shui Qing Ye
Chapman & Hall / CRC.

Applied Bioinformatics: An Introduction
Paul M. Selzer, Richard J. Marhöfer, Andreas Rohwer
Springer.

Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins
Andreas D. Baxevanis, B. F. Francis Ouellette
John Wiley and Sons, USA.
Bioinformatics: a Swiss perspective
Ron D. Appel, Ernest Feytmans
World Scientific, Singapore.

Bioinformatics: Genomics and Post-genomics
Frédéric Dardel, François Képès, Translated by Noah Hardy
John Wiley and Sons, France.

Bioinformatics: Methods and Applications: Genomics, Proteomics and Drug Discovery
S. C. Rastogi, Namita Mendiratta, Parag Rastogi
PHI Learning Pvt. Ltd.

Bioinformatics and drug discovery
Richard S. Larson
Humana Press.

Computational molecular biology: an algorithmic approach
Pavel Pevzner
MIT Press.

Bioinformatics algorithms: techniques and applications
Ion Măndoiu, Alexander Zelikovsky
Wiley-Interscience.

Bioinformatics: problem solving paradigms
Volker Sperschneider, Jana Sperschneider, Lena Scheubert
Springer.

Parallel computing for bioinformatics and computational biology
Zomaya A. Y.
John Wiley & Sons, Inc.

Research and trends in data mining technologies and applications
David Taniar
Idea Group Inc (IGI).

Machine learning in bioinformatics
Yan-Qing Zhang, Jagath Chandana Rajapakse
John Wiley and Sons.

Computational Intelligence in Bioinformatics
Árpád Kelemen, Ajith Abraham, Yuehui Chen
Springer.
Bioinformatics and the Cell: Modern Computational Approaches in Genomics, Proteomics and Transcriptomics
Xuhua Xia
Springer.

Bioinformatics for Dummies
Jean-Michel Claverie and Cerdric Notredame

Bioinformatics-Sequence and Genome Analysis
David W. Mount.

Introduction to Bioinformatics
T K Attwood and D J Parry-Smith.

Bioinformatics-Gene, Proteins and Computers
MASTER OF SCIENCE (MS) in Bioinformatics

Introduction
The purpose of MS degree program in bioinformatics is to provide the students with an advanced knowledge and practices that will train them to decipher the biological processes with the help of computational tools and to prepare them for further research and/or industry.

Program objectives
At the end of MS program, the graduates should be able to:

1. Develop innovative computer applications to solve biological problems
2. Facilitate other researchers using bioinformatics tools and databases
3. Undertake problem-based research
4. Tackle research based problems in various industries such as pharmaceutical, biotechnology, software industry etc

Learning Outcomes
After completion of MS program in bioinformatics, the graduates will be able to:

- Answer questions about molecular evolution, biological functions and control of biological systems
- Use bioinformatics skills to predict functions from structures, networks, complexes, transcriptome and proteome data
- Develop advanced computational applications related to bioinformatics

Admission Requirements

Eligibility
1. BS in Bioinformatics/Biological Sciences/Computer Sciences/Biotechnology or equivalent in relevant disciplines (deficiency courses to be completed if needed).
2. Any other criteria set by the University.

Duration
2 years (course work may be completed in two semesters and one year for research work).

Total Credit Hrs
30 (24 credit hours course work + 6 credit hours thesis)
Scheme of Studies for MS Program in Bioinformatics

Semester I and II

Note:
Students coming from computer and physical sciences background must take 1-2 courses from group A and may take at most one course from group B. Similarly, students coming from biological sciences background must take 1-2 courses from group B and may take at most one course from group A.

Students coming from bioinformatics background may take at most 1 course each from groups A and B.

Remaining credit hours for all students must be completed from group C.

Group A- Biological Sciences
1. Molecular Biology
2. Cell Biology
3. Genomics
4. Proteomics
5. Metabolomics
6. Microbial Genetics
7. Biochemistry
8. Gene Manipulation
9. Enzymology
10. Epigenetics
11. Biotechnology
12. Immunology
13. Biostatistics

Group B- Computer Sciences
1. Fundamentals of Programming
2. Object Oriented Programming
3. Data structure
4. Algorithm development
5. Database design
6. Software engineering
7. Graphics and visualization
8. Probability

Group C- Bioinformatics
1. Genome Informatics/Computational Genomics
2. Advanced Bioinformatics/Computational Biology
3. Systems Biology
4. Protein Informatics/Computational Proteomics
5. Computational Drug Design
6. Computational Molecular Evolution
7. Biophysics
8. Molecular Modelling and Simulation
9. Mathematical Models in Biology
10. Machine Learning
11. Metagenomics
12. Data Mining
13. Stochastic Processes
14. Computational Neuroscience
15. Synthetic Biology
16. Functional genomics
17. Cheminformatics
18. Health informatics
19. Big data analysis and management

Note
In addition to the above, the universities can offer any other course in the respective groups according to their specialization.

Semester III and IV

Research Thesis (6 Credit Hours)

Research Project
1. Duration of the research project will be at least two regular semesters. An independent research topic chosen by the student and supervised by a full-time faculty member of the department is required for all students in M.S Bioinformatics.
2. The research work of each student will be reviewed periodically by the supervisor/head of department to ensure the objectives laid down for study are being met.
3. All students must present and defend their research work before the panel of examiners as per the rules of the university.

Recommended Textbooks for MS Bioinformatics Program

<table>
<thead>
<tr>
<th>Textbook</th>
</tr>
</thead>
<tbody>
<tr>
<td>DW Mount, Bioinformatics: Sequence and Genome Analysis</td>
</tr>
<tr>
<td>AD Baxevnis &amp; BF Francis Quellet, Bioinformatics: A practice Guide to Analysis of Gene and Proteins, Wiley</td>
</tr>
<tr>
<td>C Gibas &amp; P Jambeck, Developing Bioinformatics Computer Skills, O'Reilly Media</td>
</tr>
<tr>
<td>AM Campbell &amp; LJ Heyer, Discovering Genomics, Proteins and Bioinformatics, Benjamin Cummings</td>
</tr>
</tbody>
</table>
4. D Stekel, Microarray Bioinformatics, Cambridge University Press
5. AM Lesk, Introduction to Bioinformatics, Oxford University Press
6. BP Bergeron, Bioinformatics Computing, Prentice Hall
7. G Gibson, A Primer of Genome Science, Sinauer Associates
8. HJ Parish, Instant Notes on Bioinformatics
11. NC Jones & PA Persner, An Introduction to Bioinformatics Algorithms
12. CW Sensen, Essentials of Genomics and Bioinformatics
14. W Ewens & G Grant, Statistical Methods in Bioinformatics
15. IS Kohane, A Kho & AJ Butte, Microarrays for An Integrative Genomics
16. D Higgins & W Taylor, Bioinformatics; Sequence and Databanks: A Practical Approach
17. RA Dwyer, Genomic Perl: From Bioinformatics Basic To Working Code
18. T Lengauer, Bioinformatics: From Genomes To Drugs, Wiley
19. T Atwood and D Perry-Smith, Introduction To Bioinformatics, Benjamin Cummings
20. P Bourne and H Weissig, Structured Bioinformatics
21. S Misener and S Krawetz, Bioinformatics Methods and Protocols
22. A Tozeren and SW Byers, New Biology for Engineers and scientists
23. P Clote & R Backofen, Computational Molecular Biology: An Introduction
24. J Augen, Bioinformatics in Post-Genomic Era: Genomic Transcription, Proteome and Information Based Medicine
25. U Seiffert, LC Jain & Pschwetzer, Bioinformatics: Using Computational Intelligence Paradigms
27. MR Banners & IC Gray, Bioinformatics for Geneticists
28. LO Nielsen, Immunological Bioinformatics
31. PG Higgs, Bioinformatics and Molecular Evolution
33. R Hofestadt, Bioinformatics
34. AF Batiza, B Schacter & K Mullis, Bioinformatics, Genomics and Proteomics: Getting the Big Picture
35. J Jerisca, Dennis Wigle, Knowledge Discovery in Proteomics
36. G Waksman, Proteomics and Protein-Protein Introductions: Biology, Chemistry, Bioinformatics and Drug Design
37. J Ramsden, An introduction to Bioinformatics
38. H Rashidi & L Buehler, Bioinformatics Basics: Application in Biological Science and Medicine
39. LB Jorde, JC Carey, M Bamshad & RL White, Medical Genetics
40. WS Klug & MR Cummings, Essential of Genetics
41. RI Nussbaum, RR McInnes & HF Willard, Genetics in Medicine, Thompson & Thompson
42. PA Hoffe, Medical Molecular Genetics
43. SB Primrose & R Twyman, Principles of Gene Manipulation and Genomics
44. A Emery & R Mueller, Essential of Medical Genetics.
45. B Lewin, Gene X
46. G Acquaah, Understanding Biotechnology
47. W Klug, Michael Cumming and Charlotte Spencer, Concept of Genetics
48. B Lewin, Essential Genes
49. G Karp, Cell and Molecular Biology: Concepts and Experiments, Wiley
50. E Nester, Denise Anderson, C. Evans Robert Jr., Microbiology; A Human Perspective
51. BA Pierce, Genetics
52. J Hanford, Ethics from a Faith Perspective
53. J Burrley & J Harris, A companion to Genetics
54. D Mathews, Vernon Farewell, Understanding Medical Statistics
55. R Weaver, Molecular Biology
56. PC Champe, RA Harvey and DR Ferrier, Lippincott’s Biochemistry
57. M Grammer and M Rodwell, Harper’s Biochemistry
58. Nelson & Cox, Lehninger; Principles of Biochemistry
59. D Voet, Biochemistry
60. R Schalkoff, Pattern Recognition, Statistical, Structural & Neural Approached
61. AS Pandya & RB Macy, Pattern Recognition with Neural Networks in C++
62. Duda, Hart & Stork, Pattern Classification
63. M Pavel, Fundamentals of Pattern Recognition
64. MK Pietikainen, Texture Analysis in Machine Vision
65. SK Pal & PP Wang, Genetic Algorithms for Pattern Recognition
66. RC Gonzales, Digital Image Processing
67. RC Gonzales, Digital Image Processing using Matlab
68. JC Russ, Hand Book of Image Processing
69. JR Parker, Algorithms for Image Processing & Computer Vision
English I (Functional English)

Objectives: Enhance language skills and develop critical thinking.

Course Contents
Basics of Grammar
Parts of speech and use of articles
Sentence structure, active and passive voice
Practice in unified sentence
Analysis of phrase, clause and sentence structure
Transitive and intransitive verbs
Punctuation and spelling

Comprehension
Answers to questions on a given text

Discussion
General topics and everyday conversation (topics for discussion to be at the discretion of the teacher keeping in view the level of students)

Listening
To be improved by showing documentaries/films carefully selected by subject teachers

Translation skills
Urdu to English

Paragraph writing
Topics to be chosen at the discretion of the teacher

Presentation skills
Introduction

Note: Extensive reading is required for vocabulary building

Recommended Books
1. Functional English
   a) Grammar

b) Writing

c) Reading/Comprehension

d) Speaking

**English II (Communication Skills)**

**Objectives:** Enable the students to meet their real life communication needs.

**Course Contents:**

**Paragraph writing**
Practice in writing a good, unified and coherent paragraph

**Essay writing**
Introduction

**CV and job application**
Translation skills
Urdu to English

**Study skills**
Skimming and scanning, intensive and extensive, and speed reading, summary and précis writing and comprehension

**Academic skills**
Letter/memo writing, minutes of meetings, use of library and internet
**Presentation skills**  
Personality development (emphasis on content, style and pronunciation)

*Note: documentaries to be shown for discussion and review*

**Recommended Books**

**Communication Skills**

a) **Grammar**

b) **Writing**

c) **Reading**
   2. Reading and Study Skills by John Langan

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**English III (Technical Writing and Presentation Skills)**

**Objectives:** Enhance language skills and develop critical thinking

**Course Contents**

**Presentation skills**

**Essay writing**  
Descriptive, narrative, discursive, argumentative

**Academic writing**  
How to write a proposal for research paper/term paper
How to write a research paper/term paper (emphasis on style, content, language, form, clarity, consistency)

**Technical Report writing**

**Progress report writing**

*Note: Extensive reading is required for vocabulary building*

**Recommended Books**

Technical Writing and Presentation Skills

a) Essay Writing and Academic Writing

b) Presentation Skills
c) Reading
   The Mercury Reader. A Custom Publication. Compiled by Northern Illinois University. General Editors: Janice Neulib; Kathleen Shine Cain; Stephen Ruffus and Maurice Scharton. (A reader which will give students exposure to the best of twentieth century literature, without taxing the taste of engineering students).
Pakistan Studies (Compulsory)

Introduction/Objectives

- Develop vision of historical perspective, government, politics, contemporary Pakistan, ideological background of Pakistan.
- Study the process of governance, national development, issues arising in the modern age and posing challenges to Pakistan.

Course Outline

1. Historical Perspective
   b. Factors leading to Muslim separatism
   c. People and Land
      i. Indus Civilization
      ii. Muslim advent
      iii. Location and geo-physical features.

2. Government and Politics in Pakistan
   Political and constitutional phases:
   a. 1947-58
   b. 1958-71
   c. 1971-77
   d. 1977-88
   e. 1988-99
   f. 1999 onward

3. Contemporary Pakistan
   a. Economic institutions and issues
   b. Society and social structure
   c. Ethnicity
   d. Foreign policy of Pakistan and challenges
   e. Futuristic outlook of Pakistan

Recommended Books

ISLAMIC STUDIES  
(Compulsory)

Objectives

This course is aimed at:
1. To provide Basic information about Islamic Studies
2. To enhance understanding of the students regarding Islamic Civilization
3. To improve Students skill to perform prayers and other worships
4. To enhance the skill of the students for understanding of issues related to faith and religious life.

Detail of Courses

Introduction to Quranic Studies
1. Basic Concepts of Quran
2. History of Quran
3. Uloom-ul-Quran

Study of Selected Text of Holy Quran
1. Verses of Surah Al-Baqara Related to Faith (Verse No-284-286)
2. Verses of Surah Al-Hujrat Related to Adab Al-Nabi (Verse No-1-18)
3. Verses of Surah Al-Mumanoon Related to Characteristics of faithful (Verse No-1-11)
4. Verses of Surah al-Furqan Related to Social Ethics (Verse No.63-77)
5. Verses of Surah Al-Inam Related to Ihkam (Verse No-152-154)

Study of Selected Text of Holy Quran
1. Verses of Surah Al-Ihzab Related to Adab al-Nabi (Verse No.6, 21, 40, 56, 57, 58.)
2. Verses of Surah Al-Hashar (18,19,20) Related to thinking, Day of Judgment
3. Verses of Surah Al-Saf Related to Tafakar, Tadabar (Verse No-1,14)

Seerat of Holy Prophet (S.A.W) I
1. Life of Muhammad Bin Abdullah (Before Prophet Hood)
2. Life of Holy Prophet (S.A.W) in Makkah
3. Important Lessons Derived from the life of Holy Prophet in Makkah
Seerat of Holy Prophet (S.A.W) II
1. Life of Holy Prophet (S.A.W) in Madina
2. Important Events of Life Holy Prophet in Madina
3. Important Lessons Derived from the life of Holy Prophet in Madina

Introduction to Sunnah
1. Basic Concepts of Hadith
2. History of Hadith
3. Kinds of Hadith
4. Uloom –ul-Hadith
5. Sunnah & Hadith
6. Legal Position of Sunnah

Selected Study from Text of Hadith

Introduction to Islamic Law & Jurisprudence
1. Basic Concepts of Islamic Law & Jurisprudence
2. History & Importance of Islamic Law & Jurisprudence
3. Sources of Islamic Law & Jurisprudence
4. Nature of Differences in Islamic Law
5. Islam and Sectarianism

Islamic Culture & Civilization
1. Basic Concepts of Islamic Culture & Civilization
2. Historical Development of Islamic Culture & Civilization
3. Characteristics of Islamic Culture & Civilization
4. Islamic Culture & Civilization and Contemporary Issues

Islam & Science
1. Basic Concepts of Islam & Science
2. Contributions of Muslims in the Development of Science
3. Quran & Science

Islamic Economic System
1. Basic Concepts of Islamic Economic System
2. Means of Distribution of wealth in Islamic Economics
3. Islamic Concept of Riba
4. Islamic Ways of Trade & Commerce

Political System of Islam
1. Basic Concepts of Islamic Political System
2. Islamic Concept of Sovereignty
3. Basic Institutions of Govt. in Islam

Islamic History
1. Period of Khlaft-E-Rashida
2. Period of Ummayyads
3. Period of Abbasids

Social System of Islam
1. Basic Concepts of Social System of Islam
2. Elements of Family
3. Ethical Values of Islam

Reference Books
1. Hameed ullah Muhammad, “Emergence of Islam”, IRI, Islamabad
2. Hameed ullah Muhammad, “Muslim Conduct of State”
3. Hameed ullah Muhammad, ‘Introduction to Islam
4. Mulana Muhammad Yousaf Islahi,”
Annexure - D

*Note: One course will be selected from the following six courses of Mathematics.*

**COMPULSORY MATHEMATICS COURSES FOR BS (4 YEAR)**

*(FOR STUDENTS NOT MAJORING IN MATHEMATICS)*

1. **MATHEMATICS I (ALGEBRA)**

   **Prerequisite(s):** Mathematics at secondary level

   **Credit Hours:** 3 + 0

   **Specific Objectives of the Course:** To prepare the students, not majoring in mathematics, with the essential tools of algebra to apply the concepts and the techniques in their respective disciplines.

   **Course Outline:**

   *Preliminaries:* Real-number system, complex numbers, introduction to sets, set operations, functions, types of functions. *Matrices:* Introduction to matrices, types, matrix inverse, determinants, system of linear equations, Cramer’s rule.

   *Quadratic Equations:* Solution of quadratic equations, qualitative analysis of roots of a quadratic equations, equations reducible to quadratic equations, cube roots of unity, relation between roots and coefficients of quadratic equations.


   **Recommended Books**


2. **MATHEMATICS II (CALCULUS)**

   **Prerequisite(s):** Mathematics I (Algebra)
   **Credit Hours:** 3 + 0

   **Specific Objectives of the Course:** To prepare the students, not majoring in mathematics, with the essential tools of calculus to apply the concepts and the techniques in their respective disciplines.

   **Course Outline:**
   *Preliminaries:* Real-number line, functions and their graphs, solution of equations involving absolute values, inequalities. *Limits and Continuity:* Limit of a function, left-hand and right-hand limits, continuity, continuous functions.
   *Derivatives and their Applications:* Differentiable functions, differentiation of polynomial, rational and transcendental functions, derivatives.
   *Integration and Definite Integrals:* Techniques of evaluating indefinite integrals, integration by substitution, integration by parts, change of variables in indefinite integrals.

   **Recommended Books**

3. **MATHEMATICS III (GEOMETRY)**

   **Prerequisite(s):** Mathematics II (Calculus)
   **Credit Hours:** 3 + 0

   **Specific Objectives of the Course:** To prepare the students, not majoring in mathematics, with the essential tools of geometry to apply the concepts and the techniques in their respective disciplines.
**Course Outline**

*Geometry in Two Dimensions*: Cartesian-coördinate mesh, slope of a line, equation of a line, parallel and perpendicular lines, various forms of equation of a line, intersection of two lines, angle between two lines, distance between two points, distance between a point and a line.

*Circle*: Equation of a circle, circles determined by various conditions, intersection of lines and circles, locus of a point in various conditions.

*Conic Sections*: Parabola, ellipse, hyperbola, the general-second-degree equation

**Recommended Books**

4. **COURSE FOR NON-MATHEMATICS MAJORS IN SOCIAL SCIENCES**

*Title of subject*: MATHEMATICS

*Discipline*: BS (Social Sciences).

*Pre-requisites*: SSC (Metric) level Mathematics

*Credit Hours*: 03 + 00

*Minimum Contact Hours*: 40

*Assessment*: written examination;

*Effective*: 2008 and onward

**Aims**: To give the basic knowledge of Mathematics and prepare the students not majoring in mathematics.

**Objectives**: After completion of this course the student should be able to:

- Understand the use of the essential tools of basic mathematics;
- Apply the concepts and the techniques in their respective disciplines;
- Model the effects non-isothermal problems through different domains;

**Contents**

1. *Algebra*

2. **Statistics**
   

**Recommended Books**


5. **MATHEMATICS FOR CHEMISTRY**

Credit Hours: 3

Prerequisites: Mathematics at Secondary level
Specific Objectives of Course:
To prepare the students not majoring in mathematics with the essential tools of Calculus to apply the concepts and the techniques in their respective disciplines.

Course Outline

Recommended Books

6. MATHEMATICS FOR PHYSICS

Contents
1. Preliminary calculus.
   - Differentiation
     Differentiation from first principles; products; the chain rule; quotients; implicit differentiation; logarithmic differentiation; Leibnitz’ theorem; special points of a function; theorems of differentiation.
   - Integration
Integration from first principles; the inverse of differentiation; integration by inspection; sinusoidal function; logarithmic integration; integration using partial fractions; substitution method; integration by parts; reduction formulae; infinite and improper integrals; plane polar coordinates; integral inequalities; applications of integration.

2. **Complex numbers and hyperbolic functions**

- The need for complex numbers
- Manipulation of complex numbers
  - Additions and subtraction; modulus and argument; multiplication; complex conjugate; division
- Polar representation of complex numbers
  - Multiplication and division in polar form
- de Moivre’s theorem
  - Trigonometrical identities; finding the nth roots of unity; solving polynomial equations
- Complex logarithms and complex powers
- Applications to differentiation and integration
- Hyperbolic functions
  - Definitions; hyperbolic-trigonometric analogies; identities of hyperbolic functions; solving hyperbolic equations; inverses of hyperbolic functions; calculus of hyperbolic functions

3. **Series and limits**

- Series
- Summation of series
  - Arithmetic series; geometric series; arithmetico-geometric series; the difference method; series involving natural numbers; transformation of series
- Convergence of infinite series
  - Absolute and conditional convergence; convergence of a series containing only real positive terms; alternating series test
- Operations with series
- Power series
  - Convergence of power series; operations with power series
- Taylor series
  - Taylor’s theorem; approximation errors in Taylor series; standard McLaurin series
- Evaluation of limits
4. **Partial differentiation**
   - Definition of the partial derivative
   - The total differential and total derivative
   - Exact and inexact differentials
   - Useful theorems of partial differentiation
   - The chain rule
   - Change of variables
   - Taylor’s theorem for many-variable functions
   - Stationary values of many-variable functions
   - Stationary values under constraints

5. **Multiple integrals**
   - Double integrals
   - Triple integrals
   - Applications of multiple integrals
     Areas and volumes; masses, centers of mass and centroids;
     Pappus’ theorems; moments of inertia; mean values of functions
   - Change of variables in multiple integrals
     Change of variables in double integrals;

6. **Vector algebra**
   - Scalars and vectors
   - Addition and subtraction of vectors
   - Multiplication by a scalar
   - Basis vectors and components
   - Magnitude of a vectors
   - Multiplication of vectors
     Scalar product; vector product; scalar triple product; vector triple product
   - Equations of lines and planes
     Equation of a line; equation of a plane
   - Using vectors to find distances
     Point to line; point to plane; line to line; line to plane
   - Reciprocal vectors

7. **Matrices and vector spaces**
   - Vectors spaces Basic vectors; the inner product; some useful inequalities
   - Matrices
   - The complex and Hermitian conjugates of a matrix
   - The determinant of a matrix
Properties of determinants

- The inverse of a matrix
- The rank of a matrix
- Simultaneous linear equations
  N simultaneous linear equations in N unknowns
- Special square matrices
  Diagonal; symmetric and antisymmetric; orthogonal; Hermitian; unitary normal
- Eigen vectors and eigen values
  Of a normal matrix; of Hermitian and anti-Hermitian matrices; of a unitary matrix; of a general square matrix
- Determination of eigen values and eigen vectors Degenerate eigen values

8. Vector calculus

- Differentiation of vectors
  Composite vector expressions; differential of a vector
- Integration of vectors
- Space curves
- Vector functions of several arguments
- Surfaces
- Scalar and vector fields
- Vector operators
- Gradient of a scalar field; divergence of a vector field; curl of a vector field
- Vector operator formulae
- Vector operators acting on sums and products; combinations of grad, div and curl
- Cylindrical and spherical polar coordinates
- Cylindrical polar coordinates; spherical polar coordinates.
Annexure - E

Statistics-I

Definition and importance of Statistics in Agriculture, Data Different types of data and variables

Classification and Tabulation of data, Frequency distribution, stem-and-Leaf diagram, Graphical representation of data Histogram, frequency polygon, frequency curve.

Measure of Central tendency, Definition and calculation of Arithmetic mean, Geometric mean, Harmonic mean, Median quantiles and Mode in grouped and un-grouped data.

Measure of Dispersion, Definition and Calculation of Range, quartile deviation, Mean deviation, Standard deviation and variance, coefficient of variation.

Practical

a. Frequency Distribution
b. Stem-and-Leaf diagram
c. Various types of Graphs
d. Mean, Geometric mean Harmonic Mean,
e. Median, Quartiles Deviation, mean Deviation.
f. Standard Deviation, Variance, Coefficient of variation,
g. Skewness and kenosis

Recommended Books

1. Introduction to Statistical Theory Part- I by Sher Muhammad and Dr. Shahid Kamal (Latest Edition)
2. Statistical Methods and Data Analysis by Dr. Faquir Muhammad

Statistics-II

Sampling Probability and non-Probability Sampling, Simple random sampling stratified random sampling Systematic sampling error, Sampling...
distribution of mean and difference between two means. Interference Theory: Estimation and testing of hypothesis, Type—I and type-II error, Testing of hypothesis about mean and difference between two means using Z-test and t-test, Paired t-test, Test of association of attributes using X2 (chi-square) Testing hypothesis about variance.

**Practical**

a. Sampling random sampling  
b. Stratified random sampling.  
c. Sampling distribution of mean  
d. Testing of hypotheses regarding population mean  
e. Testing of hypotheses about the difference between population means  
f. Chi-square test  
g. Testing of Correlation Coefficient  
h. Fitting of simple linear regression  
i. One-way ANOVA  
j. Two-way ANOVA

**Recommended Books**

1. Introduction to Statistical Theory Part-II by Sher Muhammad and Dr. Shahid Kamal (Latest Edition)  
2. Statistical Methods and Data Analysis by Dr. Faquir Muhammad  
ANNEXURE - F

Introduction to Information and Communication Technologies

**Course Structure:**
- Lectures: 2
- Labs: 1
- Credit Hours: 3
- Pre-requisite: None
- Semester: 1

**Course Description**

This is an introductory course on Information and Communication Technologies. Topics include ICT terminologies, hardware and software components, the internet and World Wide Web, and ICT based applications.

After completing this course, a student will be able to:

- Understand different terms associated with ICT
- Identify various components of a computer system
- Identify the various categories of software and their usage
- Define the basic terms associated with communications and networking
- Understand different terms associated with the Internet and World Wide Web.
- Use various web tools including Web Browsers, E-mail clients and search utilities.
- Use text processing, spreadsheets and presentation tools
- Understand the enabling/pervasive features of ICT

**Course Contents**

Basic Definitions & Concepts
Hardware: Computer Systems & Components
Storage Devices, Number Systems
Software: Operating Systems, Programming and Application Software
Introduction to Programming, Databases and Information Systems
Networks
Data Communication
The Internet, Browsers and Search Engines
The Internet: Email, Collaborative Computing and Social Networking
The Internet: E-Commerce
IT Security and other issues
Project Week
Review Week
Text Books/Reference Books

RECOMMENDATIONS

1. There is a need to encourage public and private universities/institutes to develop expertise in bioinformatics at their respective campuses.
2. HEC should provide sufficient funds and grants on priority basis in this field. More emphasis should be given to universities/institutes located in developing areas of Pakistan.
3. Both undergraduate and postgraduate courses in bioinformatics should be included in teaching curriculum of relevant disciplines of public and private sector universities and degree awarding institutes.
4. Future emphasis should be on graduate degree program in bioinformatics instead of undergraduate.
5. The option for computer sciences and biology should not be there at matric level. Instead both subjects should be compulsory for science students.
6. At intermediate level, the distinction between pre-medical and pre-engineering groups should be strongly discouraged.
7. HEC should facilitate a survey to identify the opportunities available to and challenges faced by bioinformatics graduates.
8. To promote awareness among students, scientific community and industry, series of seminars and workshops should be organized on regular basis.
9. There should be a strong link between academia and industry for the absorption of bioinformatics graduates.