

M.Sc. Bioinformatics

Prospectus No. 20101241

संत गाडगे बाबा अमरावती विद्यापीठ

SANT GADGE BABA AMRAVATI UNIVERSITY

विज्ञान विद्याशाखा
(FACULTY OF SCIENCE)

PROSPECTUS
OF
MASTER OF SCIENCE EXAMINATION
Semester -I & III, Winter 2009
Semester -II & IV, Summer 2010
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Syllabus Prescribed for M.Sc. Part-I**Semester-I (Bioinformatics)**

- Paper: I** - Evolution, Systematics, Diversity and Genetics
Paper: II - Cell and Molecular Biology
Paper: III - Biochemistry and Biophysics
Paper: IV - Biostatistics and Applied Mathematics

Paper I**(Evolution, Systematics, Diversity and Genetics)**

50 Marks

- Unit-I : (Evolution and Systematics)**
Origin of life- Prebiotic evolution, chemical evolution, cellular evolution- assembly of macromolecules and origin of life, Endosymbiotic theory of evolution, integrated structural organization of prokaryotic and eukaryotic cells.
Systematics- Species concept, Kingdom to species, Nomenclature systems, Phylogenetic approaches and cladistic approaches to species evolution.
- Unit-II : (Introduction to Microbial world)**
Bacteria- Broad outline of classification, Types, Molecular dynamics- Transduction, Transformation and Conjugation.
Viruses- Structural biology of viruses and bacteriophages, types of viruses, replication of viral genome, Structure of HIV and TMV.
Fungi- Broad outline of classification, Reproduction, evolution and economic importance, General outline of mycoplasma and lichens.
- Unit-III : (Diversity)**
Plant Diversity- Broad outline of classification, Phylogenetic system of Angiosperm classification, Evolutionary trends amongst Algae, Fungi, Bryophyta, Pteridophyta, Gymnosperm and Angiosperm.
Animal Diversity- Broad outline of classification, Major animal phyla, Characteristic features and interrelationships among Invertebrates and Vertebrates.
- Unit-IV : (Genetics)**
Mendelian Genetics- Law of dominance, Law of Segregation, Law of independent assortment
Noe Mendelism- Interaction of Genes- Supplementary factor, Complimentary Factor, Epistasis and lethal genes.
- Unit-V : (Genetics)**
Linkage- Phenomena of linkage, Linkage Groups, Preparation of genetic and molecular maps, Problem based on linkage and crossovers.

Suggested readings:

1. Paul F. Agis "Biomolecular Structure and function"
2. Burnett H. L. "Fundamentals of Mycology"
3. Alexopolous "Introduction to Mycology"
4. Karp, G. (2005) "Cell and Molecular Biology: Concepts and Experiments"; Fourth Edition, Wiley Publishing Co. USA
5. Strikburger "Genetics"

Paper-II**(Cell and Molecular Biology)**

50 Marks

- Unit-I : (Cell Biology)**
 Architecture of prokaryotic and eukaryotic cells and tissues. Structure of cell wall, plasma membrane. Cell division- Meiosis and Mitosis. Molecular mechanism of cell cycle regulation in eukaryotes.
- Unit-II : (Cell Biology)**
Cell organelles- Ultrastructure of Mitochondria, Golgi complex, Lysosomes, Vacuoles and Plastids.
- Unit-III : (Cell Biology)**
Nucleus- Ultrastructure of nucleolus, Nuclear pore complex (NCP), Import and export mechanism through NCP.
Chromosome- Structural organization of chromosome, chromatids, nucleosome model, Histone and nonhistone protein interaction.
- Unit-IV : (Molecular Biology)**
Cell communication- Membrane transport- Principals, active transport, ion channels, protein sorting- an overview of targeting proteins to mitochondria, nucleus, Endoplasmic reticulum, Lysosome and plasmamembrane.
- Unit-V : (Molecular Biology)**
 Organization of eukaryotic and prokaryotic genomes, Regulation of gene expression in prokaryotes and eukaryotes.

Suggested reading:

1. Karp, G. (2005) "Cell and Molecular Biology: Concepts and Experiments"; Fourth Edition, Wiley Publishing Co. USA
2. Lodish, H., Scott, M.P., Matsudaira, P., Darnell, J., Zipursky, L., Kaiser, C.A., Berk, A. and
3. Krieger, M. (2003) "Molecular Cell Biology"; Fifth Edition, W.H. Freeman and Co., New York.

4. Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K and Walter, P. (2002) "Molecular Cell Biology of the Cell", Fourth Edition, Garland Science, Taylor and Francis Group, USA.
5. Lewin, B. (2004) "Genes VIII"; Eighth edition, Pearson Education International.
6. De Robertes and De Robertis (2002) "Cell and Molecular Biology", Saunders College, Philadelphia, USA

Paper-III
(Biochemistry and Biophysics)

50 Marks

Unit-I : (Biochemistry)

Water- Water as the universal biological solvent, concept of osmolarity, water relationship.

Carbohydrates- Monosaccharides, oligosaccharides, polysaccharides, peptidoglycans, proteoglycans and glycoproteins, biological importance of carbohydrates.

Lipids- Fatty acids, acylglycerols, phospholipids, sphingolipids, sterols, membrane Icoprenoids, Icosanoids and their biological significance.

Unit-II : (Biochemistry)

Levels of protein structure – primary, secondary, tertiary and quaternary with examples; alpha helix, beta sheet and beta turn; domains and structural motifs; Ramchandran plot, Rossmann fold, Immunoglobulin fold; Double helical structure of DNA – DNA polymorphism; types of RNA and its secondary and tertiary structure

Unit-III : (Biochemistry)

Transcription- Prokaryotic and eukaryotic Transcription- RNA polymerases- general and specific transcription factors- regulatory elements- mechanism of transcription regulation- Transcription termination; Post transcriptional modification

Translation- Genetic code- Prokaryotic and eukaryotic translation- translational machinery- Mechanism of initiation- elongation and termination- Regulation of translation.

Unit-IV : (Biophysics)

Breakdown of classical mechanics; Planck theory of blackbody radiation; photoelectric effect; Bohr model of the atom; atomic spectra; De Broglie theory of matter waves; Schrodinger wave equation; interpretation of wave function; atomic orbitals; molecular orbitals; hybrid

orbitals; valency of carbon atom; covalent bond; bond order; resonance structure of benzene; partial double bond; character of peptide bond.

Unit-V : (Biophysics)

Mechanics – Newton's Law of motion – Mechanics of a particle – Work-energy principle – Rotational dynamics – Static and dynamic equilibrium – Conservation laws.
Thermodynamics – Concept of temperatures – Thermodynamic equilibrium: Zeroth law – Conservation of energy: first law – Concept of entropy: second law – Absolute zero of temperature: third law of thermodynamics

Suggested reading:

1. Resnick, R., Halliday, D. and Walker (2001) "Fundamentals of Physics", Sixth edition, John Wiley and Sons, USA.
2. Tipler, P.A. (1999) "Physics for Engineers and Scientists"; Fourth edition, W.H. Freeman and Company, USA.
3. Vasantha Pattabhi and N. Gautham. (2001) "Biophysics"; Narosa Publishing Company, New Delhi, India.
4. Narayanan, P (1999) "Introductory Biophysics"; New Age Publishing House, Mumbai, India.
5. Cantor, C.R. and Schimmel, P. (1985) "Biophysical Chemistry Vol. 1 and 2"; W.H. Freeman and Company, New York, US.
6. Freifelder, D. (1982) "Physical Biochemistry"; W.H. Freeman and Company, New York, USA.
7. Banwell, C.N. (1983) "Fundamentals of Molecular Spectroscopy"; Tata McGraw Hill Publishing Company, New Delhi, India.
8. Leach, A.R. (1992) "Molecular Dynamics Simulation", John Wiley and Sons, New York, USA.

Paper-IV
(Biostatistics and applied Mathematics)

50 Marks

Unit-I : (Biostatistics)

Measures of central tendency : Tabulation of data - Construction of a frequency table – Measures of central tendency – Arithmetic Mean, Median Mode, Geometric mean and Harmonic mean. Partition Values – Quartiles, Deciles and Percentiles. Weighted arithmetic average.

Measures of dispersion : Range – Inter quartile range – Mean deviation - Standard deviation and Coefficient of variation – Application of Lorenz curve.

Unit-II : (Biostatistics)

Linear correlation and regression : Scatter diagram – Correlation – Types of correlation - The coefficient of correlation – Properties of the coefficient of correlation – Rank correlation - Estimation using time series data - Linear regression - Fitting a straight line – Multiple regression

Probability and probability distributions : The concept of probability – Sample space – Independent events – Mutually exclusive events – Addition law of probability – Conditional probability – Bayes formula – Expected value – Variance – Binomial distribution – Poisson distribution – Normal distribution, Large sample tests, Applications of Chi square distribution, t distribution and F distribution.

Unit-III : (Biostatistics)

Theory of Sampling and Theory of Queues : The concept of sampling – Type s of sampling – Techniques of probability sampling – Techniques of non-probability sampling – Sample size – Sampling error **Queues** – Types of queues – Markov chains - The concept of dynamic programming – The use of statistics in information systems - The use of spread sheets

Computing Algorithms – Algorithms in Computing, Analyzing algorithms, Designing algorithms, Asymptotic notation, Standard notations, Big ‘O’ notations, Time and space complexity of algorithms and common functions

Sets: Union and Intersections, Differences, Disjoint Sets, Counting Elements, Relations Matrices: Adding and Multiplying, Extracting a sub-matrix, Combining, Inverting

Unit-IV : (Applied Mathematics)

Computing Algorithms – Algorithms in Computing, Analyzing algorithms, Designing algorithms, Asymptotic notation, Standard notations, Big ‘O’ notations, Time and space complexity of algorithms and common functions

Sets: Union and Intersections, Differences, Disjoint Sets, Counting Elements, Relations Matrices: Adding and Multiplying, Extracting a sub-matrix, Combining, Inverting

Sorting– Sorting: Bubble Sort, Insertion sort, Selection sort, Quick Sort, Radix sort, Exchange sort, Shellsort, Mergesort. External sort (K-way mergesort, balanced mergesort, polyphase mergesort) Sorting in Linear time, Heaps (Binary Heaps, Janus Heap, Heap sort, Binomial Heaps, Fibonacci Heaps)

Unit-V : (Applied Mathematics)

Searching: Binary Search, Fibonacci Search, Hash Search, Lookup Searches, Generative Searches

String Matching: Naive algorithm, Boyer-Moore algorithm, Knuth-Morris-Pratt algorithm

Graphs – Representation of Graphs, Breadth First Search, Depth First Search, Topological Sort, Connected Components, Minimum Spanning Tree, Single-Source Shortest Path (Dijkstra’s and Bellman Fort Algorithm), All-Pairs Shortest Paths (Floyd-Warshall algorithm), Coloring of Graphs (Kruskal’s Algorithm, Prim’s Algorithm)

Suggested readings:

1. Narayanan, S. and Manicavachaagam Pillai, T.S. (1993) “Calculus, Vol. I and II”; Vishwanathan Printers and Publishers.
2. Veerarajan, T. (2003) “Engineering mathematics”; Third Edition, Tata McGraw Hill Publishing Co. Ltd, New Delhi.
3. Veerarajan, T. (2003) “Trigonometry, Algebra and Calculus”; Third Edition, Tata McGraw Hill Publishing Co. Ltd, New Delhi.
4. Sharma, A.K. (2005) “Text Book of Integral Calculus”, Discovery Publishing House.
5. Grewal, B.S. (2000) “Higher Engineering Mathematics”; Thirty seventh edition, Khanna Publishers, New Delhi.
6. E. Horowitz and S. Sahani, “Fundamentals of Data structures”, Galgotia Booksource Pvt. Ltd., (1999)
7. Ellis Horwitz, Sartaz Sahani and Sanguthevar Rajasekaran, (1999), “Computer Algorithms”, Galgotia Publications
8. T. H. Cormen, C. E. Leiserson, R. L. Rivest (2001) “Introduction to Algorithms”, 3rd Ed PHI

Practical-I :

Practical based on Paper I and II

1. To study morphology of Bacteria by Gram staining
2. To study morphology of Fungi and Yeast
3. Preparation of pure culture by strick plate method
4. Estimation of proteins and carbohydrates
5. Restriction digestion of plant genomic DNA
6. Paper Chromatography of Chlorophyll pigments
7. Estimation of Chlorophyll
8. Ascorbic acid estimation in different tissues of plants and animals.
9. Growth curve of bacteria.
10. Estimation of cell mass of bacteria.
11. Isolation of Mitochondria

12. Isolation & Purification of genomic DNA from bacteria
13. Isolation & Purification of genomic DNA from Plants
14. Isolation of your DNA from buccal cells
15. Isolation of plasmids from bacteria
16. Agarose gel electrophoresis of chromosomal & plasmid DNA
17. Restriction Digestion of chromosomal & plasmid DNA
18. Isolation of DNA fragment from agarose gel
19. E test.
20. Estimation of DNA
21. Estimation of RNA
22. SDS PAGE electrophoresis of seed proteins
23. Isozymes separation
24. Preparation of squash and smear
25. To study salivary gland chromosome

Distribution of Marks :**Time 6 Hrs. Marks : 50**

- | | |
|-------------------------|----------|
| (1) Exercise-I | 15 Marks |
| (2) Exercise-II | 15 Marks |
| (3) Record | 05 Marks |
| (4) Viva-voce | 05 Marks |
| (5) Internal Assessment | 10 Marks |

Practical II :

Practical based on paper III and IV

1. Calculation of measures of central tendency- Arithmetic mean, median and mode.
2. Computation of partition values - Quartiles, Deciles and percentiles.
3. Geometric mean and harmonic mean.
4. Measure of dispersion- Range, Quartile deviation and mean deviation.
5. Standard deviation and coefficient of variation.
6. Calculation of coefficient of correlation.
7. Computation of rank correlation coefficient.
8. Fitting of straight line.
9. Line of regression and regression coefficient.
10. Simple problems on probability- Law of addition, law of multiplication.
11. Large sample test.
12. Application of Chi-square distribution.
13. Application of t-distribution and F-distribution.
14. Random sampling- SRSWOR and SRSWR.

15. Queuing theory.
16. Fitting of binomial distribution.
17. Fitting of normal distribution.
18. Fitting of poisson distribution.
19. Problems on sorting algorithm- Bubble sort, Insertion sort, Selection sort, Quick sort.
20. Problems on string matching algorithms.
21. Problems on searching algorithms.

Distribution of Marks :**Time 6 Hrs. Marks : 50**

- | | |
|-------------------------|----------|
| (1) Exercise-I | 15 Marks |
| (2) Exercise-II | 15 Marks |
| (3) Record | 05 Marks |
| (4) Viva-voce | 05 Marks |
| (5) Internal Assessment | 10 Marks |

**Syllabus Prescribed for M.Sc. Part-I
Semester-II (Bioinformatics)**

Paper: V	-	Structural Biology
Paper: VI	-	Computers for Biologists
Paper: VII	-	Bioinformatics-I
Paper: VIII	-	Networks and Distributed Computing

**Paper-V
(Structural Biology)**

50 Marks

- Unit-I** : Structural features of biomolecules; techniques used to determine the structure of biomolecules; Methods for single crystal X-ray Diffraction of macromolecules: molecular replacement method and direct method – Fiber diffraction; analysis of structures and correctness of structures; submission of data to PDB: atomic coordinates and electron density maps.
- Unit-II** : Energy and Cellular Work – Energy input and output in cell; The role of ATP; Electron transfer reactions; Electron transfer molecules; Electron transport chains; Light-driven electron flow; Catabolism and Metabolism; Metabolic pathways; Anatomy of DNA; A, B, Z-DNA, DNA bending. Structure of RNA. Structure of Ribosome.
- Unit-III** : Methods for prediction of secondary and tertiary structures of proteins – knowledge-based structure prediction; fold recognition; *ab initio* methods for structure prediction, Comparative protein modeling.
- Unit-IV** : Methods for comparison of 3D structures of proteins; Methods to predict three dimensional structures of nucleic acids, rRNA; Electrostatic energy surface generation.
- Unit-V** : Molecular Mechanics and Molecular dynamics of Oligopeptides, Proteins, Nucleotides and small molecules – Mechanism and dynamics of bio-macromolecules, Simulation of molecular mechanics and dynamics, Simulations of Free energy changes; Force fields. Molecular interactions of protein-protein, protein-DNA, protein-carbohydrate and DNA-small molecules.

Suggested readings:

- Andrew R. Leach (2001) “Molecular Modeling – Principles and Applications”; Second Edition, Prentice Hall, USA.
- Creighton, T.E. (1993) “Proteins: structure and molecular properties”; Second edition, W.H. Freeman and Company, New York, USA.

- Mount, D. (2004) “Bioinformatics: Sequence and Genome Analysis”; Cold Spring Harbor Laboratory Press, New York.
- Lesk, A.M. (2001) “Introduction to Protein Architecture”, Oxford University Press, UK.
- McPherson, A. (2003) “Introduction of Molecular Crystallography”, John Wiley Publications, USA.

**Paper-VI
(Computers for Biologists)**

50 Marks

- Unit-I** : **Computer Organization** – Fundamentals of computers – Block diagram of computer (input and output devices) – Generations - Advantages and Limitations of Computers - Basics of operating systems DOS, Windows NT & XP, UNIX – Application Softwares.
- Unit-II** : **Network Basics** – Communication Technology – Networking – LAN, WAN & MAN, Intranet–Wireless communication – Internet.
- Unit-III** : **Introduction to Database systems** – Fundamentals of database - Database models (Hierarchical, Network, Relational, Object-Oriented Models) – RDBMS - Database System Applications and Security.
- Unit-IV** : **Ms-Office** – Introduction to M.S. office package - Word – creating a new document – templates and wizards – scientific data representation and basic calculations with EXCEL - Creating Tables and databases using Access – interactive presentations creating using Power Point
- Unit-V** : **Internet Technologies** – Web Services – WWW, URL, DNS - Servers-E-mail server, WEB servers, Browsers-IP Addressing, IPV6.

Suggested reading:

- Sherman, J. (2001) “Basic Computer Skills made easy”, Butterworth-Heinemann Ltd, USA
- Balaguruswamy, E. (1985) “Computer Fundamentals and Applications”, Second Edition, TataMcGraw-Hill Publishing Co. Ltd., India.
- Horwitz, E. and Sahni, S. (1978) “Fundamentals of Computers”, Second Edition, WH Freeman & Co., USA.
- Microsoft Office Manual

**Paper-VII
(Bioinformatics-I)**

50 Marks

- Unit-I** : **Bioinformatics : an overview** - Introduction to Computational Biology and Bioinformatics; Emergence of bioinformatics as a separate discipline; some of the biological problems that require computational methods for their solution; Role of internet and www in bioinformatics.
- Unit-II** : **Biological Data Acquisition** – The form of biological information; DNA sequencing methods – basic DNA sequencing, automated DNA sequencing, DNA sequencing by capillary array and electrophoresis; Types of DNA sequences – genomic DNA, cDNA, recombinant DNA, Expressed sequence tags (ESTs), Genomic survey sequences (GSSs); RNA sequencing methods; Protein structure determination methods; gene expression data.
- Unit-III** : **Databases : Format and Annotation** – Conventions for databases indexing and specification of search terms; Common sequencing file formats – NBRF/PIR, FASTA, GDE; Files for multiple sequence alignment – multiple sequence format (MSF), ALN format; Files for structural data – PDB format and NMR files; Annotated sequence databases – primary sequence databases (GenBank-NCBI, the nucleotide sequence database-EMBL, DNA sequence databank of Japan-DDBJ; Subsidiary data storage (ESTs, dbESTs, GSSs), unfinished genomic sequence data, organisms specific databases (EcoGene, SGD, MatDB, TAIR, FlyBase, OMIM, etc.); Protein sequence and structure databases (PDB, SWISS-PROT and TrEMBL); List of Gateways (NCBI, GOLD, MIPS, TIGR, UniGene)
- Unit-IV** : **Data : Access, Retrieval and Submission** – Data access – standard search engines, Data retrieval tools – Entrez, DBGET and SRS (sequence retrieval systems); Software for data building; Submission of new and revised data.
- Unit-V** : **Sequence Similarity Searches** – Sequence homology as product of molecular evolution; Sequence similarity searches; Significance of sequence alignment; Sequence alignment – global, local and free-space; Alignment scores and gap penalties; Measurement of sequence similarity; Similarity and homology.

Suggested reading:

1. Mount, D. (2004) “Bioinformatics: Sequence and Genome Analysis”; Cold Spring Harbor Laboratory Press, New York. (ISBN 0-87969-712-1)

2. Baxevanis, A.D. and Francis Ouellette, B.F. (1998) “Bioinformatics—a practical guide”

**Paper-VIII
(Networks and Distributed Computing)**

50 Marks

- Unit-I** : **Nuts & Bolts in Networks** – Reference Model, Network Topologies and Protocols, Types of Networks: Local Area Network (LAN), Wide Area Network (WAN), Metropolitan Area Network (MAN), Network Security (Firewall, Packet Filtering, VPN), Uses of Computer Networks
- Unit-II** : **Network Architecture** – OSI & Internet Architecture, IEEE 802 standards, Physical Layer - Transmission Media, Switching. Data Link Layer - Design Issues, Example Data Link Protocols, Data Link layer in the Internet, Media Access Sub layer
- Unit-III** : **Network Layer and Transport Layer** – Network Layer - Design Issues, Routing Algorithms, Congestion control algorithm, Router Operation, Router Configuration, Internetworking, IP Addressing, IP Subnet Mask, IPv6 (an overview) Transport Layer – Transport Service, TCP/IP Protocols (TCP, UDP)
- Unit-IV** : **Application Layer** – Design Issues, Conventional Encryption, Classical and Modern Techniques, Encryption and Decryption Algorithms (RSA), Confidentiality, DNS, SNMP, RMON, WWW, E-mail, Digital Signatures
- Unit-V** : **Characteristics of Distributed Computing** – Introduction to Distributed Computing, Examples, Key Characteristics, Historical background, Basic design issues, User requirements Introduction to IPC, Building Blocks, Client Server Communication, Group Communication, Remote Procedure Call (RPC).

Suggested reading:

1. Tananbaum A.S.,(1999) “Computer Networks”, 3rd Ed, PHI
2. Black U.,(1996) “Computer Networks-Protocols, Standards and Interfaces”, PHI, 1996
3. George Coulouris, Jean Dollimore, Tim Kindsberg,(2000) “Distributed Systems : Concepts & Design” 3rd Ed, Addison Wesley

Practical III :

Practical based on paper V and IV

1. Advanced Visualization Software and 3D representations.
2. Coordinate generations and inter-conversions.
3. Secondary Structure Prediction

4. Fold Recognition, *ab initio* (Rosetta Server)
5. Homology based comparative protein modeling.
6. Energy minimizations.
7. Validation of models.
 - a. WHATIF
 - b. PROSA
 - c. PROCHECK
 - d. VERIFY3D
8. Protein Structure Alignment.
9. Modeller
10. Geno-3D
11. Discovery Studio Server.
12. DOS Commands - Internal Commands: Viewing a directory, Changing Directory, Renaming a Directory - File operations: Creating files, removing a file, renaming files, viewing a file - External commands: Copying a disk, Comparing disks
13. Overview of different versions of Windows –Working with Windows- Desktop Basic Layout, Icons, Opening Windows, Window Characteristics, Window Controls, Resize Windows, Arrange Windows, Taskbar.
14. Working with Programs: Basic Program Layout, WordPad Program, Scrolling in Documents, Moving Insertion Point, Delete & Insert Key, Selecting Text, Cut, Copy & Paste, Working with Multiple Programs.
15. Files & Folders: Organization, View Folder Structure, Working with Folders, Search for Files, Organizing Workspace - Personal Desktop, Shortcuts, Start Menu, Start Properties, Display as Menu, Taskbar, Quick Launch.
16. Windows Properties - Navigating Control Panel, Changing Theme, Desktop Settings, Screen Saver Settings, Appearance Settings, Display Settings, Mouse Settings
17. Working with documents: Creating a document, Manage files and folders for documents, working with icons, editing documents - Text formatting and alignment, Indentation.
18. Paragraph formatting - Margins, tabs and page numbering.
19. Working with tables and borders - Printing - Working with Images and Text - Find and replace text - Mail merge.
20. Creating and formatting a presentation –Creation of a new Presentation, Adding Slides and Text to a Presentation, Editing Slide Text, Saving a Presentation, and Running a Slide Show-Adding Tables and charting data – Modifying objects and adding Images, Preparing to deliver a presentation.
21. Creating and modifying a worksheet- Formatting Worksheets –

Working with multiple worksheets – Performing Calculations

22. Surfing information using Search Engines, Saving web pages to a disk, Composing E-mail, Sending E-mail.

Distribution of Marks :

Time 6 Hrs.		Marks : 50
(1)	Exercise-I	15 Marks
(2)	Exercise-II	15 Marks
(3)	Record	05 Marks
(4)	Viva-voce	05 Marks
(5)	Internal Assessment	10 Marks

Practical IV :

Practical based on paper VII and VIII

1. Entrez and Literature Searches.
 - a. PubMed
 - b. PubMed central
 - c. OMIM / OMIA
 - d. Citation matcher
2. SRS of Biological Databases
 - a. Nucleotide/ Genome Databases.
 - b. Protein Sequence Database.
 - c. Structure databases.
 - d. Protein Pattern Databases
3. File format conversion
 - a. FmtSeq
 - b. ReadSeq
 - c. Sequence manipulation Suite
4. Sequence Analysis
 - a. Dot Plot
 - b. Pairwise alignment
 - c. Multiple Sequence Alignment
5. Phylogenetic analysis using PHYLIP, Phylodraw, PAUP, Treeview, JalView.
6. Softwares
 - a. BioEdit.
 - b. GeneDoc
 - c. ClustalW / X, MEGA, MEME
7. Visualization Tool
 - a. RasMol
 - b. Cn3D
 - c. MolMol

8. **Operating System:** Overview of Linux Architecture, Installation, Booting and Shutdown Process, System Processes (an overview), User Management- Types of users, Creating Users, Granting Rights, File Quota, File-system Management and Layout, Login Process, Linux shells (bash and tcsh), Shell Programming, Printing.
9. Exercise in RDBMS (MYSQL)
- Data Definition Language (DDL) statements:
Creating database, Selecting database, Deleting database, Creating table, Modifying Table, Deleting table
 - Data Manipulation statements:
Inserting, updating and deleting records
Retrieving Records
Retrieving specific rows and columns
Use of MySQL operators – Arithmetic operators, Comparison
Operators, Logical operators
Math functions, Aggregate functions
String operations
Limiting, Sorting and grouping query results
Handling null values
Renaming or aliasing table and column names
Using subqueries
Using Joins – joining a table to itself, joining multiple tables
Use of Indexes
Security Management
Granting and Revoking rights on tables

Distribution of Marks :

Time 6 Hrs.	Marks : 50
(1) Exercise-I	15 Marks
(2) Exercise-II	15 Marks
(3) Record	05 Marks
(4) Viva-voce	05 Marks
(5) Internal Assessment	10 Marks

Syllabus Prescribed for M.Sc. Part-II

Semester-III (Bioinformatics)

- Paper: IX** - Data Structures and Programming Concepts
Paper: X - Physics and Chemistry for Biologists
Paper: XI - Bioethics and Intellectuals Property Rights and Java programming
Paper: XII- Relational Database Management System

Paper-IX

(Data Structures and Programming Concepts)

50 Marks

- Unit-I** : **Concepts in Computing** – Overview and functions of computer systems – History of Computers – Storage Devices – Memory – Type of Processing – Types of Computers – Operating System Concepts – Internet and its resources.
- Unit-II** : **Elementary Data Structures** – Arrays, Stacks, Queues, Dequeues, Order Lists, Generalized List, Linear List, Linked lists, Circular Linked Lists, Doubly-Linked Lists, Infinite Lists, Hash tables, Hash functions, Recursive functions
- Unit-III** : **Computing Algorithms** – Algorithms in Computing, Analyzing algorithms, Designing algorithms – Sorting and Searching techniques: Bubble Sort, Merge Sort and Insertion sort – Binary Search
- Unit-IV** : **C** – Algorithms, flow-charts, programming languages, compilation, linking and loading, testing and debugging, documentation – C programming – variables and identifiers, data types, Conditional statements and loops – if, if-else statements, while, do-while, for loop, switch case, Structured Programming, Library Functions
- Unit-V** : **Object Oriented Programming Concepts** – C++ – Abstract Data type, Encapsulation, Object, Message, Method, class, Inheritance, Polymorphism, Virtual Functions, Abstract Classes, Interface, Constructors & Destructors, Overloading & Overriding, Copy Instructor

Suggested readings:

- Lafore, R. (2002) “Object Oriented Programming using C++”, Fourth Edition, Sams Publishers.
- Ritchie, D.M. (1996) “ The C programming language”, Second Edition, Prentice Hall Publishers, USA.
- Balaguruswamy, E. (1985) “Computer Fundamentals and Applications”, Second Edition, Tata McGraw-Hill Publishing Co. Ltd., India.

4. Fundamentals of Data Structures, E. Horowitz and S. Sahani, Galgotia Books Pvt. Ltd., (1999)

Paper-X

(Physics and Chemistry for Biologists)

50 Marks

- Unit-I** : **Thermodynamics and energetics** – Thermodynamics systems; laws of thermodynamics; statement and applications; concepts of entropy and enthalpy; chemical potentials; free energy; Gibb and Helmholtz free energy; ATP as energy currency in biological systems; free energy of hydrolysis of ATP and other organophosphates.
- Unit-II** : **Current electricity and circuits** – Review of basic electrostatics – Current and current density – Ohm’s law – Conductivity in metals, insulators, semiconductors and ionic liquids – Electrical energy and dissipation – Combinations of resistors – Kirchoff’s rules – RC circuits – RL and LC circuits.
- Unit-III** : **Optics and Lasers** – Interference: single and multiple beam interference – Diffraction at single and multiple rectangular slits – Polarization – Optical instruments – Resolving power – Introduction to LASERS and their applications.
- Unit-IV** : **Chemistry** – Introduction to Organic Functional Groups and ionic reaction mechanisms: Functional Groups, Reactive intermediates - electrophiles nucleophiles, radicals, substitution reactions, addition reactions, elimination reactions, redox reactions. **Heterocyclic Chemistry** – Introduction to heterocyclic compounds: Nomenclature, Reactivity of five membered and six membered heterocycles
- Unit-V** : **Spectroscopy of organic molecules** – Spectroscopic identification of simple organic molecules - Infrared Spectroscopy, nuclear magnetic resonance Spectroscopy, mass spectrometry

Suggested reading:

1. Resnick, R., Halliday, D. and Walker (2001) “Fundamentals of Physics”, Sixth edition, John Wiley and Sons, USA.
2. Tipler, P.A. (1999) “Physics for Engineers and Scientists”; Fourth edition, W.H. Freeman and Company, USA.

Paper-XI

(Bioethics and Intellectuals Property Rights and Java programming)

50 Marks

- Unit-I** : **(Bioethics and Intellectuals Property Rights)**
The legal and socioeconomic impacts of biotechnology; public education of the process of the processes of biotechnology involved in generating new forms of life for informed decision making. Biosafety regulation and national and international guidelines; rDNA guidelines; Experimental protocol approval; levels of containment
- Unit-II** : **(Bioethics and Intellectuals Property Rights)**
Environmental aspects of biotechnology applications; Use of genetically modified organisms and their release in environment; Special procedures for rDNA-based product production. General principles of Intellectual property rights (IPR); Patents and methods; application of patents; Legal implications; International treaties for protection of IP – Bern, Paris, TRIPS, WIPO treaties, Biodiversity convention, etc.
- Unit-III** : **(Bioethics and Intellectuals Property Rights)**
Biodiversity and farmers rights; Beneficial applications and development of research focus to the need of the poor; Identification of directions for yield effect in agriculture, aquaculture, etc; Bioremediation
- Unit-IV** : **(Java programming)**
Java Basics - Importance and features of java, Modifiers, Access Controls, Data types, Expressions, Declarations, Statements & Control Structures, Program Structures, String handling, Packages, Interfaces, Working with java util Package, Garbage Collection, Object Class
- Unit-V** : **(Java programming)**
BioJava - Installing BioJava, Symbols, Basic Sequence Manipulation (DNA to RNA, Reverse Complement, motif as regular expression), Translation (DNA to Protein, Codon to amino acid, Six frame translation), Proteomics (Calculate the mass and pI of a peptide), Sequence I/O (File Formats conversions), Locations and Features (PointLocation, RangeLocation, Feature modifications), BLAST and FASTA (Blast and FastA Parser, extract information from parsed results), Counts and Distributions, Weight Matrices and Dynamic Programming, User Interfaces.

Suggested reading:

1. Sasson, A. (1988) "Biotechnologies and Development", UNESCO Publications.
2. Sasson, A. (1993) "Biotechnologies in developing countries present and future"; UNESCO Publishers.
3. Singh, K. "Intellectual Property Rights on Biotechnology"; BCIL, New Delhi.
4. Naughton, P. and Schildt, H. (1999) "Java-2: The complete Reference"; Third Edition, McGraw Hill Publishers.
5. Benjamin, Cummings and Booch, G. (1994) "Object Oriented Design and Applications"; Second edition, Addison Wesley Publishers.
6. Horstmann, C.S. (2000) "Computing Concepts with Java 2 Essentials"; Second Edition, John Wiley Publishers.

Paper-XII**(Relational Database Management System)**

50 Marks

- Unit-I** : **Introduction** – Database & Database users, Characteristics of Database, Database System Applications, Database System Versus File Systems, Concepts and Architecture, Data Models, Schemas & Instances, DBMS architecture and Data Independence, Database Languages & Interfaces, View of Data, Data Models, Database Languages, Database Users and Administrators, Database System Structure
- Unit-II** : **Data models** – ER Model: Keys, Constraints, Design Issues, Extended ER features, Reductions of ER Schema to Tables. Relational Model: Structure, Relational Algebra; Hierarchical Model, Network Model, Object Oriented Model
- Unit-III** : **Structured Query Language** – Basic Structure, Set Operations, Aggregate Functions, Null Values, Nested Sub queries, Views, Integrity: Domain constraints, Joined Relations, Data-Definition Language, Embedded SQL, Dynamic SQL
- Unit-IV** : **Relational Database and Storage** – Pitfalls in Relational Design Database, Functional dependencies, Decomposition Normal Forms – 1NF, 2NF, 3NF & Boyce-Codd NF, Overall Database Design Process, Multivalued Dependencies, Data Storage – Ordered indices, Static Hashing, Dynamic Hashing - Transaction Management – Security and Authorization.

- Unit-V** : **Concurrency control techniques & Information retrieval** – Locking techniques, Granularity of Data Items – Database System Architecture and Information retrieval: Centralized and Client-Server Architecture, Distributed DBMS, Data Mining, Data Integration, Data Warehousing

Suggested reading:

1. Silberschatz, A., Korth, H.F. and Sudarshan, S. (2002) "Database system Concepts"; Fourth Edition, McGraw Hill Publishers.
2. Date, C.J. (2000) "An introduction to Database systems"; Seventh Edition, Addison Wesley Publishers.
3. Elmasri and Navathe (2004) "Fundamentals of Database systems"; Fourth Edition, Addison Wesley Publishers.
4. Ullman, J. D. (2001) "Principles of Database systems"; Second Edition, Galgotia Publications.

Practical V :

Practical based on paper IX and X

1. **C Programming:** Flowcharts, Algorithm, Keywords, Identifiers, variables, Constants, Scope of Life of variables- Local and Global variables. Data types, Expressions, Operators - Arithmetic operators, Logical operators, Relational, conditional, Bitwise operators - Input / Output Library functions.
Declaration statement, Conditional statement: If statement, If...Else statement, Nesting of If...Else statement, Switch statement – Iteration statements - Arrays: Concept of Single and Multi-dimensional arrays, Array declaration, and initialization of arrays. Functions: User defined and library functions - File Handling: Opening a file, Closing a file, Reading and Writing into a file, Appending to a file
2. **C++:** I/O statements- Escape sequences- Comment lines - Expressions and Statements-Standard libraries - Prototype of main() function - Data types – Conditional Statements - Functions and variables - Classes and objects – Constructors and Destructors – Inheritance.
3. Exercise in Structured Programming
Basic Operators and Control Flow, Basic Perl Data Types, References, Matrices, Complex/Nested Data Structures, Scope (my, local, our), Function/Subroutines, System and User Function, The local Operator, Variable-length Parameter Lists, Notes on Lexical Variable, File handle and File Tests, stat and lstat Functions, Formats, Directory Access & Manipulation, Process Management, Formatting Data, System Information.
4. Exercise in Regular Expressions

Syllabus Prescribed for M.Sc. Part-II

Semester-IV (Bioinformatics)

- Paper: XIII** - Applications of Bioinformatics
Paper: XIV - Genomics and Proteomics
Paper: XV - Bioinformatics-II
Paper: XVI - Molecular Modeling and Drug Design

Paper-XIII

(Applications of Bioinformatics)

50 Marks

- Unit-I** : **Profile analysis** – Expression profile analysis of cells, Mining data from Yeast. Microarray and genome wide expression analysis: transcriptomes, proteome: Genomics in medicine, disease monitoring, profile for therapeutic molecular targeting.
- Unit-II** : **Reconstruction of pathways and annotation** – Reconstructing metabolic pathways from sequence and function information in microbial species; statistical profiling and function annotation of genomes with a microbial genome as an example.
- Unit-III** : **Drug Designing Related Applications** – Finding new drug targets to treat diseases – Pharmacophore identification - Structure based drug design – Molecular Simulations.
- Unit-IV** : **Systems Biology** - Objectives of Systems Biology, Strategies relating to *In silico* Modeling of biological processes, Metabolic Networks, Signal Transduction Pathways, Gene Expression Patterns. E-cell and V-cell Simulations and Applications.
- Unit-V** : **Commercial Bioinformatics** - Definition of Bioinformatics company. Genome Technology: high throughput sequencing and assembly. Diagnostic drug discovery and genomics. Pharmacogenomics and its application. SNPs and their applications. Proteomics in medicine, Toxicology.

Suggested readings:

- Hunt, S.P. and Livesey, F.J. (2000) “Functional Genomics – a practical approach”, Oxford University Press, UK.
- Wilkins, M.R., Williams, K.L., Appel, R.D. and Hochstrasser, D.F. (1997) “Proteome Research: New frontiers in Functional Genomics”, Springer Verlag, New York, USA.
- Witten, I.H. and Frank, E. (2005) “Data mining: Practical Machine Learning Tools and Techniques”, Morgan Kaufman Publishers, USA.

Paper-XIV

(Genomics and Proteomics)

50 Marks

- Unit-I** : Organization of the prokaryotic and eukaryotic genomes; Genome maps and types; current sequencing technologies; partial sequencing; gene identification; gene prediction rules and softwares; Genome databases; Annotation of genome. Genome diversity: taxonomy and significance of genomes – bacteria, yeast, *Caenorhabditis*, *Homo sapiens*, *Arabidopsis*, etc.
- Unit-II** : **Microarray** - Gene Expression, methods for gene expression analysis; DNA array for global expression profile; Types of DNA array, Array databases; Applications of DNA microarray – analysis of gene expression, differential gene expression under different conditions and during development of organisms.
- Unit-III** : **Human Genome** - Mapping of Human Genome; Construction of physical maps; Basics of radiation hybrid maps; Sequencing of the entire human genome, annotation and analysis of genome sequences: sequence repeats, transposable elements, gene structure, pseudogenes; Gene analysis; gene order; chromosome rearrangement; compositional analysis; clustering of genes; composite genes. Implications of the Human Genome Project; Basics of Single Nucleotide Polymorphisms, detection and its implications.
- Unit-IV** : **The proteome and Proteome technology** – Introduction; Expression proteomics (express profile); Cell map proteomics; Protein separation technology - 2D-Gel Electrophoresis, liquid chromatography, affinity chromatography (for cell map proteomics); mass spectroscopy and its uses in protein identification; Forward and Reverse Proteomics
- Unit-V** : **Protein-Protein Interactions** – Yeast two hybrid, Co-Precipitation, Phage Display, Phylogenetic Profile, Domain fusion, Gene Neighborhood, Gene Cluster, Mirror Tree, Analysis of genome wide Protein-Protein Interactions in yeast, Genome wide yeast two hybrid analysis of other organisms, Protein fragment complementation assays.

Suggested readings:

- Primrose, S.B. and Twyman, R.M. (2003) “Principles of Genome Analysis and Genomics”; Third edition, Blackwell Publishing Company, Oxford, UK.

2. Liebler, D.C. (2002) "Introduction to proteomics – Tools for the new biology"; First edition, Human Press Inc., New Jersey, USA.
3. Pevsner, J. (2003) "Bioinformatics and Functional Genomics"; John Wiley and Sons, New Jersey, USA.
4. Mount, D. (2004) "Bioinformatics: Sequence and Genome Analysis"; Cold Spring Harbor Laboratory Press, New York.
5. Lesk, A.M. (2002) "Introduction to Bioinformatics", First edition, Oxford University Press, UK.
6. Sensen, C.W. (2002) "Essentials of Genomics and Bioinformatics"; Wiley-VCH Publishers, USA.

Paper-XV
(Bioinformatics-II)

50 Marks

- Unit-I** : **Sequence Analysis** – Methods of sequence alignment: graphic similarity comparison; Dot plots; Hash tables; Scoring matrices – identify matrix, genetic code matrices (GCM); Substitution matrices, Mutation Data Matrices (MDM), Percentage accepted Mutation (PAM). Block Substitution Matrices (BLOSUM), mutation probability matrices; Sequence similarity searches and alignment tools – dynamic programming algorithms; Needleman-Wunch and Smith Waterman; alignment scores and gap penalties; measurement of sequence similarity; percentage of identically aligned residues; Optimal global alignment and optimal local alignment.
- Unit-II** : **Pairwise Sequence Alignment** – Concept; Programmes (Dot matrix, Dot plot, Dynamic programming); Similarity Searches; Sequence repeats and inversion; Database searching (BLAST and FASTA).
- Unit-III** : **Multiple Sequence alignment (MSA)** – significance; softwares (PIMA, Clustal, Pileup, ClustalW, Meme, MACAW); Considerations while choosing a MSA software for analysis; sensitivity and specificity of each software.
- Unit-IV** : **Comparative Genome Analysis** – Relevance of comparative genomics; orthologs and paralogs; Comparative genomics of prokaryotes; Minimal genome; Vertical and horizontal gene transfer. Comparative genomics of organelles; Comparative genomics of eukaryotes. Differences and similarities in genomes of organisms; Evolution of protein families; Applications of comparative genomics in reconstruction of metabolic pathways.

- Unit-V** : **Phylogenetic analysis** – Phylogenetics, cladistics and ontology; Phylogenetic representations – graphs, trees and cladograms; Classification and ontologies; Steps in phylogenetic analysis; Methods of phylogenetic analysis – similarity and distance tables, distance matrix method; Method of calculation of distance matrix (UPGMA, WPGMA); The Neighbour Joining Method; The Fitch/Margoliash method; Character-based Methods – maximum parsimony, maximum likelihood; Reliability of Phylogenetic trees; Steps in constructing alignments and phylogenies; Limitations of phylogenetic algorithms; Phylogenetic softwares – PAUP, PHYLIP, MacClade.

Suggested readings:

1. Mount, D. (2004) "Bioinformatics: Sequence and Genome Analysis"; Cold Spring Harbor Laboratory Press, New York.
2. Baxevanis, A.D. and Francis Ouellette, B.F. (1998) "Bioinformatics – a practical guide to the analysis of Genes and Proteins"; John Wiley & Sons, UK.
3. Pevzner, P.A. (2004) "Computational Molecular Biology"; Prentice Hall of India Ltd, New Delhi.
4. Pevsner, J. (2003) "Bioinformatics and Functional Genomics"; John Wiley and Sons, New Jersey, USA.
5. Lesk, A.M. (2002) "Introduction to Bioinformatics", First edition, Oxford University Press, UK.
6. Sensen, C.W. (2002) "Essentials of Genomics and Bioinformatics"; Wiley-VCH Publishers, USA.

Paper-XVI
(Molecular Modeling and Drug Design)

50 Marks

- Unit-I** : **Concepts in Molecular Modeling** – Introduction; Coordinate System; potential energy surfaces molecular graphics; Computer hardware and software; Mathematical concepts – introduction of molecular mechanics & quantum mechanics.
- Unit-II** : **Molecular Mechanics** – Features of molecular mechanics, force fields; Bond structure and bending angles – electrostatic, van der Waals and non-bonded interactions, hydrogen bonding in molecular mechanics; Derivatives of molecular mechanics energy function; Calculating thermodynamic properties using force field; Transferability of force field parameters, treatment of delocalised π system; **Force field for metals and inorganic systems** – Application of energy minimization.

- Unit-III : Molecular Dynamics Simulation Methods** – Molecular Dynamics using simple models; Molecular Dynamics with continuous potentials and at constant temperature and pressure; Time-dependent properties; Solvent effects in Molecular Dynamics; Conformational changes from Molecular Dynamics simulation.
- Unit-IV : Molecular Modeling in Drug Discovery** – Deriving and using 3D pharmacophore; Molecular Docking; Structure-based methods to identify lead compounds; *de novo* ligand design; Applications of 3D Database Searching and Docking.
- Unit-V : Structure Activity Relationship** - QSARs and QSPRs, QSAR Methodology, Various Descriptors used in QSARs: Electronic; Topology; Quantum Chemical based Descriptors. Use of Genetic Algorithms, Neural Networks and Principle Components Analysis in the QSAR equations.

Suggested readings:

1. Andrew R. Leach (2001) “Molecular Modeling – Principles and Applications”; Second Edition, Prentice Hall, USA.
2. Fenniri, H. (2000) “Combinatorial Chemistry – A practical approach”, Oxford University Press, UK.
3. Lednicer, D. (1998) “Strategies for Organic Drug Discovery Synthesis and Design”; Wiley International Publishers.
4. Gordon, E.M. and Kerwin, J.F. (1998) “Combinatorial chemistry and molecular diversity in drug discovery”; Wiley-Liss Publishers.
5. Swatz, M.E. (2000) “Analytical techniques in Combinatorial Chemistry”; Marcel Dekker Publishers.

Practical VII :

1. Multiple sequence alignment
2. MEME/MAST, eMotif, InterproScan, ProSite, ProDom, Pfam
3. Phylogenetic analysis – PAUP, PHYLIP, MacClade
4. Genome annotation – Artemis.
5. Hypothetical Protein analysis
6. Genome Comparison
7. Binding Site Identification.
8. Pharmacophore Identification.
9. Rigid body Docking using AutoDock and ADT.
10. Molecular dynamics simulations using Gromacs.
11. Visual molecular Dynamics (VMD).
12. Docking with LigandFit (Discovery studio).
13. Receptor and Ligand Optimization.
14. Conformational Analysis.
15. BABEL, MOPAC.

Distribution of Marks :

Time 6 Hrs.	Marks : 50
(1) Exercise-I	15 Marks
(2) Exercise-II	15 Marks
(3) Record	05 Marks
(4) Viva-voce	05 Marks
(5) Internal Assessment	10 Marks

**M.Sc.Part-II
Semester-IV
Project Work**

Time : 3 Hrs./week

Marks : 50

The Students will develop the skill for designing the programmes related to Bio-informatics. For this, variety of small research project designed by the teacher based on the interest of the student and capabilities should be worked out.

The project will be evaluated by external and internal examiners.

Study Tour : Educational / Industrial tour is compulsory for M.Sc. Bioinformatics.

- (i) Semesters I/II : Visit to local research laboratory.
- (ii) Semester III/IV : Education tour to visit the industry / C.S.I.R. Research Laboratory.

Distribution of Marks :

	Marks : 50
(1) Viva based on the project.	40 Marks
(2) Internal Assessment	10 Marks

List of Equipments:

1. Microscopes
2. Laminar Airflow
3. High speed centrifuge
4. Horizontal gel electrophoresis apparatus
5. Vertical gel electrophoresis apparatus
6. Submarine gel electrophoresis apparatus
7. UV spectrophotometer
8. Sonicator
9. Chromatography Chamber
10. Calculator.
11. Computer systems.
12. LAN
13. Server

14. High speed internet connection
15. Telescope
16. Monochromator
17. Spectrophotometer
18. Babinet's compensator
19. Conductors.
20. Conductivity meter.
21. Printers.
22. CCD Camera.
23. Projector.
24. Online lecture hall.
25. Rosetta Server
26. Discovery Studio Server
27. MySQL Operator
28. Deep Freezer
29. PCR Machine
30. Lyophilizer
31. Spectrometer
32. Plane Transmission Grating (England Make – 15000 LPI)
33. Thermal Conductivity of Solid Kit
34. Wavelength of light by Newtons Ring Method – Complete Setup including travelling microscope, sodium lamp, and lenses.
35. Clement & de Serme's apparatus for specific Heat of gases.
36. Sodium lamp with leak transmitter (35 Watt, 65 Watt)
37. Variable slit
38. Apparatus for conductivity of a semiconductor by Four Probe method
39. Polaroids with circular scale.
40. Double dense flint glass prism.
41. LASER light source.
42. **List of Software :** Visualization software, Verify 3D, Whatif, Prosa, Modeller, PAUP, PHYLIP, MacClade, MEME/MAST, eMotif, interproScan, ProSite, ProDom, Pfam., VMD. BABL, MOPAC, Phylodraw, ClusterX, ClusterL.
43. **Databases :** PubMed, PubMed central, OMIM / OMIA, Citation matcher, Nucleotide/ Genome Databases, Protein Sequence Database, Structure databases, Protein Pattern Databases, FmtSeq, ReadSeq, Sequence manipulation Suite, Dot Plot, Pairwise alignment, Multiple Sequence Alignment, BioEdit, GeneDoc, ClustalW / X, MEGA, MEME, RasMol, Cn3D, MolMol, NCBI.

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