Annexure- 4.01.52 (Revised)
AC-25.01.2023

Index
Department of Botany
SEMESTER -III

COURSES OFFERED BY DEPARTMENT OF BOTANY

Category-I

Botany (H) Courses for Undergraduate Programme of study with Botany as a Single Core Discipline

DISCIPLINE SPECIFIC CORE COURSE - 7: Phycology - The World of Algae

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Phycology - The World of Algae DSC-7	4	**2**	**0**	**2**	Class XII pass	Nil

Learning Objective:

To provide students with in-depth knowledge of the unique group of algae that are the primary photosynthetic organisms.

Learning Outcomes:

By studying this course students will gain basic knowledge on algae, with reference to:

- the diversity and general characteristics.
- distinguishing features of taxa belonging to different families.
- the various ecological and economic benefits.

Unit 1: Introduction to Algal World **6 hours**

Relevance of studying algae – Industrial (food, feed, fodder), Environmental (climate change, biofuel, acidification of oceans), Evolutionary (range of thallus organization); General characteristics; Ecology, diversity and distribution; Range of thallus organization; Cell structure; Criteria for classification (cell wall, pigment system, reserve food, flagella); Reproduction and life cycle patterns; Classification by Fritsch; Evolutionary classification of Lee (only up to groups); Significant contributions of eminent Phycologists.

Unit 2: Cyanophyceae (Blue-Green Algae) **3 hours**

General characteristics; Occurrence; Cell structure; Heterocyst (structure and function); Morphology, reproduction and life-cycle of *Nostoc*, economic importance.

Unit 3: Chlorophyceae (Green Algae) **6 hours**

General characteristics; Occurrence; Cell structure; Morphology, reproduction and life-cycle of *Chlamydomonas, Volvox, Chlorella, Ulva*, *Oedogonium*, *Coleochaete*; *Chara*; Structure and evolutionary significance of *Prochloron*, economic importance.

Unit 4: Xanthophyceae (Yellow-Green Algae) 2 hours
General characteristics; Occurrence; Morphology, reproduction, and life-cycle of *Vaucheria*, economic importance.

Unit 5: Bacillariophyceae (Diatoms) and Dinophyceae (Dinoflagellates) 3 hours

General characteristics, Occurrence, morphology, unique features**,** economic importance.

Unit 6: Phaeophyceae (Brown Algae) 4 hours
General characteristics; Occurrence; Morphology, reproduction, and life-cycle of *Ectocarpus* and *Sargassum*, economic importance.

Unit 7: Rhodophyceae (Red Algae) 4 hours
General characteristics; Occurrence; Morphology, reproduction, and life-cycle of *Gracilaria*, economic importance.

Unit 8: Recent advances in algal studies 2 hours
Model systems and their applications in genetic, molecular and evolutionary studies.

Practicals 60 hours

1. Study of algal diversity in different habitats through botanical excursion and submission of digital catalogue/report of various species observed.
2. ***Nostoc***: Study of vegetative, reproductive structures from temporary mounts and permanent slides; Ultrastructure of Heterocyst through Electron Micrographs.
3. ***Chlorella***: Study of vegetative, reproductive structures from temporary mounts. Study of ultrastructure through Electron Micrographs.
4. ***Volvox***: Study of vegetative, reproductive structures from temporary mounts and permanent slides.
5. ***Oedogonium***: Study of vegetative, reproductive structures from temporary mounts and permanent slides.
6. ***Coleochaete***: Study of vegetative, reproductive structures from temporary mounts and permanent slides.
7. ***Chara***: Study of vegetative, reproductive structures from temporary mounts, specimens and permanent slides.
8. ***Vaucheria***: Study of vegetative, reproductive structures from temporary mounts and permanent slides.
9. **Diatoms** and **Dinoflagellates**: Study vegetative, reproductive structures of at least two taxa from water bodies.
10. ***Ectocarpus***: Study of vegetative, reproductive structures from temporary mounts and permanent slides.
11. ***Sargassum***: Study of vegetative, reproductive structures from temporary mounts, specimens and permanent slides.

12. ***Polysiphonia/ Gracilaria***: Study of vegetative, reproductive structures from temporary mounts and permanent slides.

Suggested Readings:

1. Bold, H.C. and Wynne, M.J. (1985). Introduction to the Algae: Structure and Reproduction, 2nd edition. Prentice-Hall International INC.
2. Kumar, H.D. (1999). Introductory Phycology, 2nd edition. Affiliated East-West Press, New Delhi.
3. Lee, R.E. (2018). Phycology, 4th edition: Cambridge University Press, Cambridge.
4. Sahoo, D. and Seckbach, J. (2015). The Algae World. Springer, Dordrecht.
5. Sahoo, D. (2000).Farming the Ocean: Seaweed Cultivation and Utilization. Aravali Book International, New Delhi.

Additional Resources:

1. Van den Hoek, C., Mann, D.G., Jahans H.M. (1995). Algae: An Introduction to Phycology. Cambridge University Press.
2. Sharma, O.P. (2011). Algae. Tata Mc Graw Hill Education Private Limited, New Delhi.
3. Smith, G.M. (1955). Cryptogamic Botany. Vol.1.Algae and Fungi. McGraw-Hill Book Company, New York.
4. Vashishta, B.R., Singh, V.P. and Sinha, A.K. (2012). Botany for Degree Students: Algae. S Chand Publishing, New Delhi.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 8: Bryophytes, Pteridophytes and Gymnosperms

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Bryophytes, Pteridophytes and Gymnosperms DSC – 8	**4**	**2**	**0**	**2**	Class XII pass	**Nil**

Learning Objectives:

- Provide a deep understanding of morphology, anatomy, reproduction and developmental biology of these unique groups of non-flowering plants.
- Enhance understanding of diversity, economic value, taxonomy in representative members of phylogenetically important groups.

Learning Outcomes:

At the end of this course students will be able to:

- identify and describe the group of plants that have given rise to land habit and the flowering plants.
- comprehend various phenological stages of the plants belonging to the sub-groups – bryophytes, pteridophytes and gymnosperms.

Unit 1: Bryophytes **9 hours**

Origin of bryophytes through green algal ancestor; Morphology and Reproduction of *Marchantia*, *Anthoceros* and *Funaria* with fertilization & spore dispersal mechanism (excluding developmental stages). Progressive sterilization of sporogenous tissue; Ecological and economic importance of bryophytes with special reference to *Sphagnum*.

Unit 2: Pteridophytes **9 hours**

Fossil pteridophytes (*Rhynia*). Morphology and Reproduction *of Selaginella*, *Equisetum* and *Pteris* (excluding developmental stages). Apogamy and apospory; Heterospory and seed habit; Stelar evolution. Economic importance.

Unit 3: Gymnosperms **9 hours**

Morphology, Sstem anatomy (significance of transfusion tissue) and Reproduction of *Cycas*, *Pinus* and *Gnetum*(excluding developmental stages and secondary growth). Economic importance.

Unit 4: Recent Advances **3 hours**

Model systems (*Physcomitrella*, *Ceratopteris*, *Ephedra*) and their applications in genetic, molecular and evolutionary studies.

Practicals: **60 hours**

1. *Riccia* – Morphology: Vegetative and reproductive structures (Specimen).

2. *Marchantia* - Morphology; V.S. of thallus through Gemma cup, whole mount of Gemmae (temporary slides); V.S. of Vegetative thallus, Antheridiophore, Archegoniophore, L.S. of Sporophyte (permanent slides).

3. *Pellia* - Morphological details through specimens/permanent slides; L.S. Sporophyte (permanent slide).

4. *Porella* - Vegetative Morphological details through specimens/permanent slides.

5. *Anthoceros* – Morphology; Dissection of sporophyte (to show stomata, spores, pseudoelaters, columella) (temporary slide), V.S. of thallus (permanent slide).

6. *Funaria* - Morphology; T.S. Stem (temporary and permanent slides both); Sporophyte: operculum, peristome, spores (temporary slides); Antheridial and archegonial heads, L.S. of capsule, W.M. of protonema (Permanent slides).

5. *Psilotum* – Morphology (specimen); T.S. of rhizome, stem and synangium (permanent slides).

6. *Selaginella* – Morphology (specimen); W.M. of leaf with ligule, T.S. of stem, L.S. of strobilus, W.M. of microsporophyll, megasporophyll (temporary slides); T.S. of rhizophore (permanent slide).

7. *Equisetum* – Morphology (specimen), T.S. of internode, L.S. of strobilus, T.S. of strobilus, W.M. of sporangiophore, W.M. of spores (wet and dry) (temporary slide).

8. *Pteris* - Morphology, T.S. of rachis, V.S. of sporophyll (temporary slides), T.S. of rhizome, W.M. of prothallus with sex organs and young sporophyte (permanent slide).

9. *Cycas* – Morphology, T.S. of coralloid root, T.S. of rachis, V.S. of leaflet, V.S. of microsporophyll, W.M. of spores (temporary slides); T.S. of stem, T.S. of root, L.S. of ovule (permanent slide).

10. *Pinus* - Morphology, T.S. of Needle, L.S. and T.S. of male cone, W.M. of microsporophyll (temporary slides); T.S. of stem, R.L.S. and T.L.S. of stem, L.S. of female cone (permanent slide).

11. *Gnetum* - Morphology (stem, male & female cones); T.S. of stem, L.S. of ovule (permanent slide).

12. Botanical Excursion and submission of digital catalogue/report of various species observed.

Suggested readings:

1. Bhatnagar, S.P., Moitra, A. (2023). Gymnosperms. 2nd edition, New Delhi, Delhi: New Age International (P) Ltd Publishers.
2. Kaur I.D., Uniyal P.L. (2019). Text Book of Gymnosperms. New Delhi, Delhi: Daya Publishing House.
3. Kaur I.D., Uniyal P.L. (2019). Text Book of Bryophytes. New Delhi, Delhi: Daya Publishing House.
4. Kaur I.D. (2023). Text Book of Pteridophytes. New Delhi, Delhi: Daya Publishing House.
5. Parihar, N.S. (2019). An Introduction to Embryophyta. Vol. II: Pteridophyta. Surjeet Publications.

Additional Resources:

1. Campbell, N.A., Reece J.B., Urry L.A., Cain M.L., Wasserman S.A., Minorsky P.V., Jackson, R.B. (2020). Biology. San Francisco, SF: Pearson Benjamin Cummings.
2. Raven, P.H., Johnson, G.B., Losos, J.B., Singer, S.R., (latest edition). Biology. New Delhi, Delhi: Tata McGraw Hill.
3. Singh, H. (1978). Embryology of Gymnosperms. Berlin, Germany. GebruderBorntraeger.
4. Vashishta, P.C., Sinha, A.K., Kumar, A. (2022). Botany For Degree Students Pteridophyta, New Delhi, Delhi: S. Chand Publication. Delhi, India.
5. Vashistha, B.R., Sinha, A.K., Kumar, A. (2010). Botany For Degree Students, Bryophyta. New Delhi, Delhi: S Chand Publication.
6. Parihar, N.S. (1965). An Introduction to Embryophyta. Vol. I: Bryophyta. Allahabad, UP: Central Book Depot.
7. Puri, P. (1973). Bryophytes. New Delhi, Delhi, Atma Ram and Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 9: Genetics and Plant Breeding

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Genetics & Plant Breeding **DSC-9**	**4**	**2**	**0**	**2**	Class XII pass	**Nil**

Learning Objectives:

- To apprise students with the basic principles of Genetics
- To enhance the applications of genetics in plant breeding and agriculture.

Learning Outcomes:

On completion of the course the students will be able to:

- understand the fundamentals of Mendelian inheritance and its deviation in gene interactions.
- describe the concepts of linkage and crossing over and their usage in constructing gene maps.
- become familiar with pedigree analysis.
- learn about principles of population genetics
- gain knowledge about gene mutations and inherited disorders
- learn about various plant breeding techniques / methods

Unit 1. Mendelian Genetics **6 hours**

Mendelism: History; Principles of inheritance, deviations (Incomplete dominance and co-dominance); Chromosome theory of inheritance; Multiple allelism; lethal alleles; Epistasis; Pleiotropy; Penetrance and expressivity; Polygenic inheritance; brief introduction to sex determination.

Unit 2. Extra-Nuclear Inheritance **4 hours**

Chloroplast and mitochondrial genomes; Chloroplast Inheritance: Variegation in Four O` clock plant; Mitochondrial inheritance in yeast; Maternal effect (Shell coiling in Snails).

Unit 3. Linkage, crossing over and chromosome mapping **5 hours**

Linkage and crossing over, Cytological basis of crossing over (Creighton and McClintock experiment in Maize); three factor crosses; interference and coincidence; Sex linkage (*Drosophila*)

Unit 4. Variation in Chromosome number and structure **4 hours**

Deletion; Duplication; Inversion; Translocation; Euploidy and aneuploidy (In Brief).

Unit 5. Mutations **4 hours**

Mutation types; Muller's CIB method, Molecular basis of mutations; Chemical mutagens (Base analogs, deaminating, hydroxylating, alkylating and intercalating agents) and Physical mutagens (Ionising and Non ionising radiations); Transposable genetic elements and their significance (Basic concept).

Unit 6. Population and evolutionary genetics **3 hours**

Hardy Weinberg law (Allele frequencies, genotype frequencies); speciation (modes of speciation and genetics of speciation).

Unit 7. Plant Breeding **4 hours**

Plant breeding- Principle and Practices, domestication and plant introduction (primary and secondary introduction), selection and its types: pure line selection, mass selection and clonal selection; hybridizations (inter-specific and intra-specific), heterosis and its significance.

Practicals: **60 hours**

1. To study meiosis in *Allium cepa* through squash preparation of anthers.
2. To study mitosis in *Allium cepa* through squash preparation of root tips.
3. To understand the deviations of Mendelian dihybrid ratios (12:3:1, 9:3:4, 9:7, 15:1, 13:3, 9:6:1) involved using the seed mixture given. Genetic ratio to be calculated using Chi square analysis.

4. Human Genetics:
   a) Study of autosomal & sex-linked dominant & recessive inheritance through pedigree analyses.
   b) ABO blood group testing using kits,
   c) To study the syndromes (Down's, Klinefelter's, Turner's, Edward's & Patau) through karyotypes
5. To calculate allelic and genotypic frequencies of human dominant and recessive traits using Hardy- Weinberg's principle.
6. To study Xeroderma pigmentosum, Sickle cell anaemia, albinism, haemophilia and colour blindness (Ishihara charts may be used to study colour blindness)
7. To study chromosomal aberrations:
   a) Quadrivalents, lagging chromosomes, dicentric/inversion bridge through photographs/permanent slides
   b) Reciprocal translocation through squash preparations of *Rhoeo* anthers.

8. Demonstration of basic methods of plant breeding (hybridizations): Emasculation, bagging and tagging using available plant material in pots/gardens/field.

Suggested Readings:

1. Gardner, E.J., Simmons, M.J., Snustad, D.P. (1991). Principles of Genetics, 8th edition. New Delhi, Delhi: John Wiley & sons.
2. Griffiths, A.J.F., Doebley,J., Peichel, C, Wassarman D (2020). Introduction to Genetic Analysis, 12th edition. New York, NY: W.H. Freeman and Co.
3. Klug, W.S., Cummings, M.R., Spencer, C.A. (2020). Concepts of Genetics, 12th edition. San Francisco, California: Benjamin Cummings.
4. Pierce, B. A. (2020). Genetics: A Conceptual Approach, 7th Edition, Macmillan

5. Campbell, N.A., Reece J.B., Urry L.A., Cain M.L., Wasserman S.A., Minorsky P.V., Jackson, R.B. (2020). Biology. San Francisco, SF: Pearson Benjamin Cummings.
6. Singh, B.D., (2022). Plant Breeding: Principles and Methods. New Delhi, Medtech Publishers

Additional Resources:

1. Russell, P. J. (2010). Genetics- A Molecular Approach. 3rd Edition. Benjamin Cummings
2. Snustad, D.P., Simmons, M.J. (2016). Principles of Genetics, 7th Edition. New Delhi, Delhi: John Wiley & sons
3. Hartl, D.L., Ruvolo, M. (2019). Genetics: Analysis of Genes and Genomes, 9th edition, Jones and Bartlett Learning.
4. Singh, B. D. (2023). Fundamentals of Genetics, 6th edition. MedTech.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE (DSE -1): Evolutionary Biology of Plants

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Evolutionary Biology of Plants **DSE-1**	**4**	**2**	**0**	**2**	Class XII pass	**Nil**

Learning Objectives:

- This course builds on the fundamental points introduced in the core course on Plant Diversity and Evolution and presents a synthesis of various theories, concepts, evidence and methods to study evolution.

Learning Outcomes:

At the end of this course the students will be able to:

- understand the essential theories in evolution
- differentiate between micro and macroevolution and the forces shaping evolution
- construct phylogenetic trees based on morphological and molecular data
- understand evolution of life.

Unit 1: Historical Perspective of Eevolutionary Cconcepts **4 hours**

Pre-Darwinian ideas, Lamarckism, Darwinism, Post-Darwinian era – Modern synthetic theory, Neo-Darwinism

Unit 2: Origin of Life **3 hours**

Chemogeny – An overview of pre-biotic conditions and events; experimental proofs to abiotic origin of micro- and macro-molecules. Current concept of chemogeny – RNA first hypothesis. Biogeny – Cellular evolution based on proto-cell models (coacervates and proteinoid micro-spheres). Evolution of eukaryotes from pprokaryotes

Unit 3: Evidences of Evolution **4 hours**

Paleobiological– Concept of Stratigraphy and geological timescale; fossil study
Anatomical & Embryological – Vestigial organs; homologous and analogous organs (concept of parallelism and convergence in evolution)
Taxonomic –Transitional forms/evolutionary intermediates, living fossils
Phylogenetic – morphology, protein (Cytochrome C) and gene (Globin gene family) based

Unit 4: Microevolution and Macroevolution **8 hours**

Hardy Weinberg equilibrium; Founder effect, Natural and artificial selection. Levels of selection.

Inferring phylogenies- Gene trees, species trees; Patterns of evolutionary change; Adaptive radiation, Evolution and development (evo-devo); Biodiversity- Estimating changes in biodiversity; Taxonomic diversity through the Phanerozoic era.

Unit 5. Forces of Evolution **3 hours**

Mutation, Geneflow, Selection, Genetic Drift, Co-adaptation and co-evolution, Anthropogenic activities, Extinction (in brief)- Periodic and Mass-scale – Causes and events.

Unit 6. Speciation **4 hours**

Species concept, Modes of speciation – Allopatric; sympatric; peripatric; Patterns of speciation – Anagenesis and Cladogenesis; Phyletic gradualism and Punctuated eequilibrium (Quantum evolution); Basis of speciation – Isolating mechanisms.

Unit 7. Evolution of Land Plants **4 hours**

Origin of land plants – Terrestrial algae and Bryophytes; alternation of generations. Early vascular plants – Stelar evolution; Sporangium evolution; seed habit and evolution of seed. Angiosperms – Phylogeny of major groups.

Practicals **60 hours**

1. Study of different types of fossils, connecting links/transitional forms and Living fossils (Specimens/slides/photographs)
2. Sampling of quantitative characters (continuous and discontinuous) in a population(height, weight, number of nodes etc)
3. Study of adaptive strategies (colouration, co-adaptation and co-evolution); (Specimens/photographs)
4. Calculations of genotypic, phenotypic and allelic frequencies from the data provided
5. Simulation experiments using coloured beads/playing cards to understand the effects of Selection and Genetic drift on gene frequencies
6. To study and interpret Phylogenetic trees (reading and using trees) - minimum of three examples.

Suggested Readings:

1. Campbell, N.A., Reece J.B., Urry L.A., Cain M.L., Wasserman S.A., Minorsky P.V., Jackson, R.B. (2020). Biology. San Francisco, SF: Pearson Benjamin Cummings.
2. Ridley, M. (2004). Evolution. III Edn. Blackwell Pub., Oxford.
3. Hall, B. K., Hallgrimson, B. (2008) Strickberger's Evolution. IV Edn. Jones and Barlett.
4. Zimmer, C., Emlen, D. J. (2013). Evolution: Making Sense of Life. Roberts & Co.
5. Futuyma, D. (1998). Evolutionary Biology. III Edn. Sinauer Assoc. Inc.
6. Barton, Briggs, Eisen, Goldstein and Patel. (2007). Evolution. Cold Spring Harbor Laboratory Press.
7. Nei, M., Kumar S. (2000). Molecular Evolution and Phylogenetics. Oxford University Press, New York.
8. Futuyma, J. D., Kirkpatrick, M. (2017). Evolution, 4th Ed. Sinauer, Sunderland, MA: Sinauer Associates.

DISCIPLINE SPECIFIC ELECTIVE COURSE (DSE -2): Biostatistics & Bioinformatics for Plant Sciences

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical / Practice		
Biostatistics & Bioinformatics for Plant Sciences **DSE-2**	**4**	**2**	**0**	**2**	Class XII pass	**Nil**

Learning Objective:

- To train students in using computational and mathematical tools to solve biological problems.

Learning Outcomes:

At the end of this course students will be able to:

- use the various online databases and resources for accessing biological data.
- use the different methods of alignment of DNA, RNA and protein sequences and interpret the significance of the same.
- understand the descriptive and inferential statistical tests for interpretation of experimental data.

Unit 1- Introduction to Bioinformatics **3 hours**

Historical background; Aims and scope; Bioinformatics in Genomics, Transcriptomics, Proteomics, Metabolomics; Applications of bioinformatics in crop improvement

Unit 2- Biological databases **4 hours**

Introduction to biological databases - Primary, secondary and composite databases. Study of following databases: NCBI (GenBank, PubChem, PubMed and its tools (only BLAST)), introduction to UniProt, PDB, PlantPepDB.

Unit 3- Basic concepts of Sequence alignment **4 hours**

Similarity, identity and homology. Concepts of alignment (gaps and penalty); Alignment – pairwise and multiple sequence alignments

Unit 4- Molecular Phylogeny **4 hours**

Introduction, methods of construction of phylogenetic trees: maximum parsimony (MP), maximum likelihood (ML) and distance (Neighbour-joining) methods.

Unit 5- Introduction to Biostatistics **2 hours**

Definition, Basics of descriptive and inferential statistics; Limitations and applications.

Unit 6- Data and sampling methods **3 hours**

Primary and secondary data; Sampling methods (in brief); tabulation and presentation of data.

Unit 7- Measures and deviations of central tendencies 4 hours
Dispersion - range, standard deviation, mean deviation, standard error, skewness and kurtosis, quartile deviation –merits and demerits; Coefficient of variation.

Unit 8-Correlation and Regression 3 hours
Correlation - types and methods of correlation (I. E. Karl Pearson and Spearman Rank method), Introduction to simple regression equation; similarities and dissimilarities between correlation and regression.

Unit 9- Statistical tests 3 hours
Statistical inference - hypothesis – (simple hypothesis), student's t test, chi-square test.

(Note: Numerical based questions of unit 7, 8 and 9 should be covered only in practical)

Practicals 60 hours

1. Biological databases (NCBI, UniProt, PlantPepDB)
2. Literature retrieval from PubMed
3. Sequence retrieval (protein and gene) from NCBI (formats - FASTA, GenBank and GenPept formats)
4. Protein Structure retrieval from PDB (in pdb format) and visualization by viewing tools (Ras Mol/ J mol/Mol*/Swiss 3D Viewer/Pymol)
5. Multiple sequence alignment (MEGA/Clustal omega)
6. Construction of phylogenetic tree (PHYLIP/ MEGA/ Clustal omega).
7. Calculation of standard deviation and coefficient of variation through manual calculation and using Microsoft Excel, using only ungrouped data)
8. Calculation of correlation coefficient values by Karl Pearson's /Spearman Rank methods (through manual calculation and using Microsoft Excel)
9. Student's t-test (using Microsoft Excel), chi square test (Manual and using Microsoft Excel)

Suggested Readings:

1. Ghosh, Z., Mallick, B. (2008). Bioinformatics – *Principles and Applications*, 1st edition. New Delhi, Delhi: Oxford University Press.
2. Baxevanis, A.D., Ouellette, B.F., John (2005). Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins, 3rd edition. New Jersey, U.S.: Wiley & Sons, Inc.
3. Roy, D. (2009). Bioinformatics, 1st edition. New Delhi, Delhi: Narosa Publishing House.
4. Zar, J.H. (2012). Biostatistical Analysis, 4th edition. London, London: Pearson Publication.
5. Campbell, R.C. (1998). Statistics for Biologists. Cambridge, U.S.A.: Cambridge University Press

Additional Resources:

1. Pevsner J. (2009). Bioinformatics and Functional Genomics, 2nd edition. New Jersey, U.S.: Wiley Blackwell.

2. Xiong J. (2006). Essential Bioinformatics,1st edition. Cambridge, U.K.: Cambridge University Press.
3. Mount, D.W. (2004). Bioinformatics: Sequence and Genome analysis 2nd edition, Cold Spring Harbor Laboratory Press, USA.
4. Pandey, M. (2015). Biostatistics Basic and Advanced. New Delhi, Delhi: M V Learning.
5. Khan, I.A., Khanum, A., Khan S., (2020). Fundamentals of Biostatistics, 6th edition. Ukaaz Publications, Hyderabad, India.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.